Societas Scientiarum Fennica
Commentationes Physico-Mathematicae XXVII 1

NEW CONTRIBUTIONS TO THE GEOLOGY OF GRAND CANARY

(Gran Canaria, Canary Islands)

BY

Hans Hausen

With 37 figures in the text, XVIII plates with photographies and a geological map of the island on the scale c. 1 : 200 000

Co- workers in the laboratory research:
A. Heikkinen M. A. (chemist), T. Mikkola M. A. (mineralogist), C. A. Nilsson B. A. (mineralogist), A. Tyrväinen M. A. (mineralogist) and C. A. Wessman M. A. (mineralogist)

Studies patronized by El Museo Canario, Las Palmas

HELSINKI — HELSINGFORS 1962

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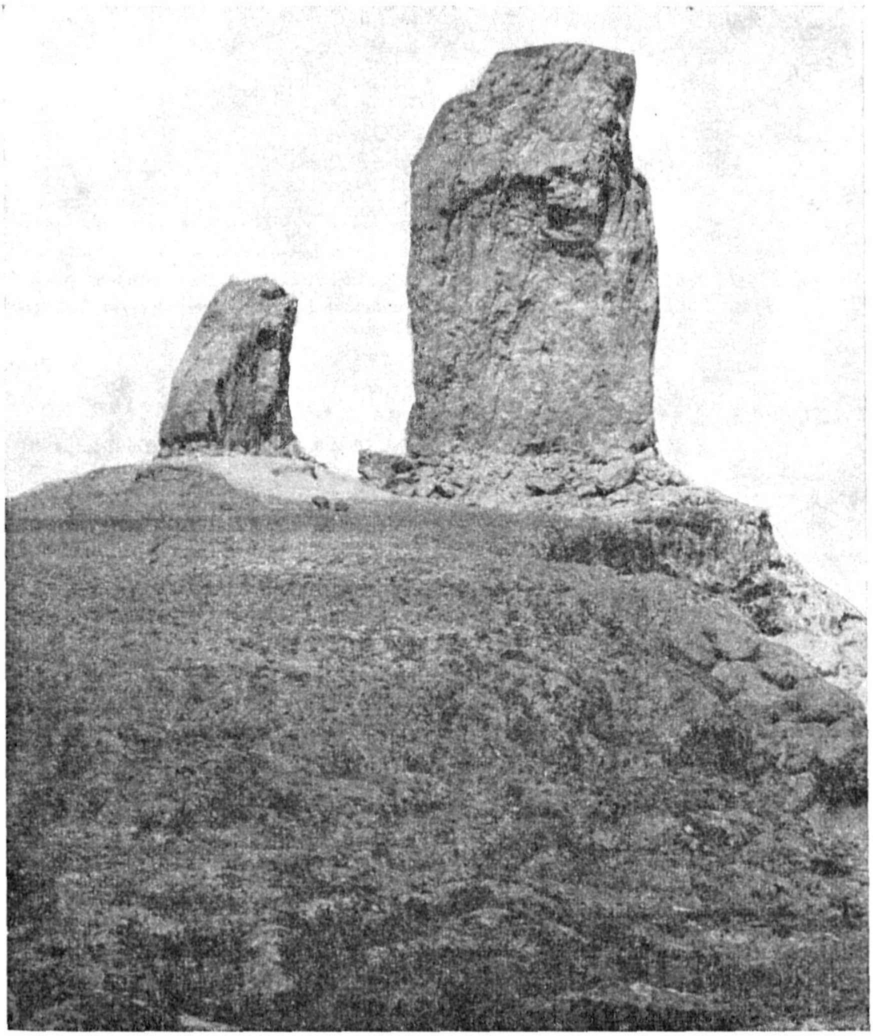
CENTRALTRYCKERIET
HELSINGFORS 1962

»A great deal of ingenuity has been expended in guessing at the meaning of these remarkable variations in the composition of the lavas emitted from a common vent, or within a limited region. It is a wise conclusion that until we know more about the causes of differentiation in deep seated rocks we cannot begin to understand the genesis of lava flows.»

S. JAMES SHAND, Eruptive Rocks (1949, p. 152).



Roque Nublo (80 m from the base) an erosion witness in a volcanic breccia formation once covering the major part of the island of Grand Canary. It is a monument to illustrate the exogene forces amidst a volcanic terrane.

Phot. T. BRAVO 1954

CONTENTS

List of quantitative chemical analyses of rocks from Grand Canary

A) Made for the present memoir by Aulis Heikkinen

Anal. No.	Sample	Rock name	Locality
1	12	Alk. trachyte	Mountain side S of Teror
2	22	Doleritic gabbro, olivine bearing	Barranco de la Mina, betw. Cruz de Tejeda and Las Lagunetas
3	76	Puzzolane	Quarry in the vicinity of San Lorenzo
4	172	Hauynophyre	Risco Blanco de Tirajana
5	169	Alk. trachyte	Barranco de Tirajana, at Puente de Rosiana
6	564	Nepheline phonolite	Western summit of Montaña del Horno (triang. vert.)
7	349	Olivine basalt	Barranco de Tasartico (region Aldea de S. Nicolás)
8	375	Rhyolite	Summit of Pico del Cedro (region Aldea de S. Nicolás)
9	401	Nepheline trachyte	Cuesta de la Cueva Nueva (region of Tirma)
10	411	Basalt	Montaña de Tirma. Sideroad to the coast road
11	440	Alk. trachyte	Summit of Montaña de Tamadaba (1 438 m)
12	523	Alk. trachyte	Profile Lance – La Costa (region of Moya)
13	25	Nepheline trachyphonolite	Head of Valle de los Portales, road Arucas — Teror
14	602	Picritic olivine basalt (dike)	Highland SE of Cruz de Tejeda (cumbre road)
15	9	Hauynophyre	La Caldereta, N of Altos de los Peñonallos
16	647	Alk. basalt (tephrite)	Northern wall of Caldera de Tejeda (25 m)
17	637	Alk. trachyte	Bottom of Barranco de Tejeda at La Solana
18	677	Trachyphonolite	Bottom of Barranco de Tejeda, vicinity of Los Parralillos.
19	693	Alk. syenite	Lower course of Barranco de Siberio, opposite Mesa de los Junquillos.

B) Made for memoirs by E. Jérémine and J. Bourcart — E. Jérémine (1933—1937)

E. Jérémine 1933

No. of anal.	Rock name	Locality
1	Pantellerite	Barranco de Don Zoilo (Las Palmas)
2	Pechstein	Aldea de San Nicolás de Tolentino
3	Metaphonolite	Barranco de Don Zoilo (L. P.)
4	Tahitite	El Saucillo
5	Mesocrate	El Saucillo
6	Limburgitic ankaramite	Cinder cone, Vega de San Mateo
7	Analcime basalt (basanite)	Tirajana

J. Bourcart & E. Jérémine 1937

1	Comendite breccia	Aldea de San Nicolás
2	Comendite	NW coast between El Risco and Aldea de S. Nicolás
3	Rhyolite—perlite	Mogán
4	Rhyolite pitchstone	Cercado de Espino (Barr. Arguineguín)
5	Silicified pitchstone	Cercado de Soria (Barr. Arguineguín)
6	Labradorite — sakalavite	Aldea de San Nicolás
7	Basanitoid andesine basalt	Barranco de la Dehesa (region de Arucas)
8	Andesine basalt	Between Teror and Tamaraceite
9	Basanitic ankaramite	Lava stream, volcano Montaña de Gáldar
10	Ordanchite	Lava stream, volcano Montaña de Arucas
11	Nepheline monzonite	Xenolith in the R. N. agglomerate, Roque Nublo.

C) 1 chemical analysis published in the paper by K. Smulikowski 1946

Aegirine phonolite Santa Brígida

The sum of all chemical analyses available up to the present time is = 38. This is not a great number regarding the complicated structure of the island and the great variations of its lavas, dikes etc. There is especially in the cases of dikes still a sensible shortage of analyses.

All the analyses listed above and referring to those earlier publications have been incorporated in the list of the new analyses (made for this memoir), page 375 in the chapter on petrology. This list gives the usual Niggli parameters and also the two proposed by A. Rittmann (1933): *Si°* and *Az°*.

PREFACE

Grand Canary (Gran Canaria) is the name of one of the larger islands in the Canarian Archipelago (Spain). Its geology and lithology have much to interest the volcanologist and the petrographer. Many are the investigators, both Spaniards and foreigners, who have devoted time, some of them years, to excursions and to detailed reconnaissances of the island. The start was made by the great German naturalist LEOPOLD VON BUCH in 1815. He was followed by a number of visitors up to the present time. Grand Canary is therefore by no means virgin territory in the field of geology, and there is a rather imposing list of papers and works which deal with the geology of the Canaries and with that of the island of Grand Canary.

Most of the publications, it is true, are from rather far back; they are more or less antiquated and appeared before the rise of the young science of volcanology and that of petrology. If we consider Grand Canary, there are, however, some very important past studies, which will be referred to in the following text, such as the one by the French geologist and oceanographer JACQUES BOURCART (Sorbonne), who was invited to the island by its government to carry out geological studies.

In the early fifties the present author had the opportunity of starting on a geological reconnaissance of Grand Canary, invited by El Museo Canario in Las Palmas. The work was carried out in 1953—1954 and later on in 1957. I had previously (1948 and 1950) had occasion to visit the island on short trips. I have spent about two years altogether in the study of the geology there.

Most of the collection of rocks and minerals was deposited and registered at the Museum mentioned above, since the field work had been financed by this institution. Duplicates were brought to Finland for closer examination.

In the laboratory treatment of the material I had the good fortune to receive help from various co-workers: Mr AULIS HEIKKINEN M.A.

(chemist), Mrs TOINI MIKKOLA M.A. (mineralogist), Mr C. A. NILSSON B.A. (of the University of Stockholm), Mr AIMO TYRVÄINEN M.A. (mineralogist) and Mr C. A. WESSMAN M.A. (mineralogist). Mr E. Halme, scient. assistant for the Geological Survey of Finland, has provided me with good microphotos of the rock slides. To all these persons I am much obliged for their kind assistance.

My warmest feelings of gratitude go to El Museo Canario of Las Palmas and to its Board and Staff. I have been entrusted with an extremely interesting mission, and I venture to hope that I have to some extent been able to live up to the expectations in bringing together new facts about the geology of this complicatedly composed island, about which many eminent scientists have written in the past, as was stated above.

Since the present treatise deals with so many aspects of geological science, one man's work over a relatively short period will produce incomplete results in several ways. I have had to pay attention to volcanologic, to tectonic and to exogenic geological records and to the interpretation of many phenomena which had already been met with in the field. — Later on, of course, there have arisen many questions of an intricate nature during the laboratory work. A meticulous treatment of all these problems in modern petrography and petrology including petrochemistry and also mineral chemistry, would have required far more means and time than the author had had at his disposal. Owing to this the present memoir is not to be considered an exhaustive monograph on the island geology, only a mere contribution to it. Thus the optic data presented here need to be completed in many ways for an exact diagnosis of all the minerals encountered; the mode of presentation of the petrochemical relations should have been more up -to -date. The author considers, however, that it is better to maintain the order introduced in his first (and following) memoir on Canarian geology for the sake of uniformity throughout.

With these contributions to the geology of Grand Canary the author considers his mission in the Canaries as ended, a very exciting task indeed in these charming islands in the lower Atlantic latitudes.

Brändö, Helsinki-Helsingfors, May 1961

The Author

INTRODUCTION

S i t u a t i o n. — The island of Grand Canary (Gran Canaria) is one of the larger members of the Canarian Archipelago forming two Spanish provinces far off the mother peninsula. Our island represents a central link in the chain of volcanic islands stretching in a southwards bowed arch off the northwest coast of Africa. The Canaries can be considered as belonging geophysically to the great continent, since they lie inside the 4 000 m isobath, and this limit may be identical with that of the continent block in contrast to the great depths in the Mid-Atlantic. But the Canaries are not true *shelf* islands, since they lie outside this platform or slope; they are of sub- continental nature. — Except for the shallow strait La Bocaína separating Lanzarote from Fuerteventura, all the sounds between the islands are deep, going down to 2 à 3 000 m, so that the archipelago is in the reality an assemblage of rather independent elevations (except the two easternmost islands, which lie on a common submarine platform).

The Canaries form a part of the so called Macaronesian insular world, which is spread over a vast surface of the Mid-Atlantic Ocean from the Azores in the north to the Cape Verde Islands in the south.

Although the Canaries are orographically a part of the great block of Africa, they belong to Europe in a political sense: the islands are grouped into two administrative areas: the province of Las Palmas and that of Santa Cruz de Tenerife. Our island belongs to the eastern province.

G r a n d   C a n a r y lies between the geographical coordinates 27° 44′ and 28° 09′ N. Lat., and 15° 21′ and 15° 44′ W. Long. of Greenwich. It has an area of c. 1 532 sq. km, and it is the third of the islands in order of size. Its western neighbour, Tenerife (Teneriffa), is the largest of the Canaries, with a surface of 2 058 sq. km. The total area of the archipelago is c. 7 545 sq. km, including 12 islands. Grand Canary corresponds to c. 1/5 of the total area. The cross-dimensions of the island are: 46 km from N. to S, 45 km from W. to E. The measurements in other directions are not very different, since the island has a rounded contour (with some irregularities of course). The shortest distance to Fuerteventura (Punta de Jandía) is c. 80 km, and to Tenerife (Punta de Anaga) c. 60 km. The distance from Maspalomas on the southern cape to Cape Bojador on the African coast is c. 190 km.

Physiographical features. — The island of Grand Canary is roughly the shape of a shield, with a maximum elevation of 1 950 m in the centre. From here a widely branching system of *barrancos* and valleys diverge in all directions to the sea. Gomera, one of the westerly islands, possesses a similar shape, but this island is much smaller in circumference. The remaining islands in the archipelago all have irregular contours (cf. with the key map fig. 1).

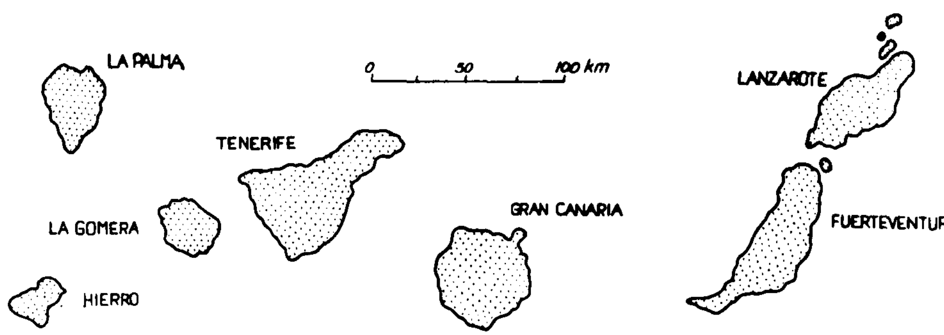


Fig. 1. Key map of the Canaries.

Grand Canary is a rather independent island in the archipelago in spite of the fact that it forms an inner link in the chain. It is surrounded by deep waters reaching down to more than 2 000 m, and there seem to be no submarine ridges connecting it with the neighbours.

When studying the topographic map of the island, one will find that the relief is not so regular as may appear at first glance. On the eastern side there is a lowland under the 200 m contour line, whereas in the west the declivities to the sea are high and steep.

The part of the island that lies above the 1 500 m contour line, is very restricted, having an irregular shape with a promontory in the northwest. It represents an old upland surface with a mature relief, dating apparently from a time when the island lay considerably lower than now, as will be explained in another connection.

The area lying above the 1 000 m contour line has a widely branching extension and approaches rather closely to the northwest coast where in parts great precipices occur. There are several valley-embayments dissecting the highland, the largest of them being Caldera de Tejeda advancing from the west almost to the heart of the island. It has a relatively narrow outlet. In the southeastern sector of the island there opens another large embayment, Caldera de Tirajana.

Achievements of erosion are generally very important, and most of the bottoms of the *barrancos* and the valleys have been lowered to a mature longitudinal profile. Steps or ledges (*caideros*) in the bottoms are very rare. No doubt many of these channels have their courses controlled by fault lines radiating from the central part of the island. The age of these erosion furrows may be different. Some are relatively young created by backward erosion, other are chiseled into an old valley bottom. Of more advanced age are certainly several of the long *barrancos* in the southern sector.

Amount of erosion is, however, not in accordance with the sedimentary masses of gravel, sand and silt. Only along the eastern coast do there extend alluvial plains right down to the sea shore, even further at the mouth of Barranco de Tirajana, Maspalomas, Barranco de Arguineguín and in the northwest sector at the mouth of Barranco de La Aldea. Most of the material transported has been dragged away to the shelf that surrounds the island, and the finer fractions have been brought to the open sea, — where they have been caught by the Canarian Current which heads towards the south.

But this more or less recent material of alluvial nature represents only a small fraction of those enormous masses of debris which have been transported to the coasts in former periods, i.e. during times of inactivity between the stages of outpourings of lavas. In these »calm» periods erosion was of course activated by emersions of the island. — The different volcanic formations composing Grand Canary are in reality only »ruins» of volcanic edifices superimposed upon each other.

In spite of the dominance of erosion forms in the landscape of Grand Canary, accumulative volcanic forms are by no means absent. These are represented chiefly by the younger volcanic cones, mostly by those of a parasitic nature. Many of them are strewn over the northern half of the island from rather high altitudes down to the coast, in one sector also forming a promontory (La Isleta). A central cone dominating the island, like Pico de Teide in Tenerife, is not present here. — Many of the lava streams which issued from relatively recent volcanic vents have already partly filled existing *barrancos*, thus to some degree softening the roughness in the ancient landscape.

The island as a whole is a shield, and this would be a rather well formed one if there did not exist two deep irregularities: the »calderas» of Tejeda and Tirajana. They were formerly known as typical examples of volcanic destructive forms; i.e. explosion calderas in the true sense of this word. But now they are considered as formed by tectonic displacements and powerful erosion. Such amphitheatre-formed valley heads are typical of volcanic oceanic islands, such as in the Hawaii Islands and elsewhere in islands chiefly of basaltic nature.

We will later on devote some pages to a discussion of the special mode of origin of these two spectacular embayments in the core of Grand Canary.

The coasts of Grand Canary are relatively smooth, and most of the embayments are of a shallow nature. Promontories are few in number, the most important being La Isleta in the northeast and Punta de Arinaga in the east. In the extreme south we have the broad headland of Maspalomas. Sheltering harbours are lacking, except inside La Isleta — the Port of La Luz. Here a mole has been constructed, and one of the best harbours on the whole transatlantic routes to the southern continents has been created.

Since rainfall is relatively small except in the mountains on the windward side (of the northerly trade wind), vegetation is sparse, and the aspect of the landscape is that of a desert in most parts. This barrenness, however, is in the higher mountains due to de-forestation during centuries of Spanish occupation; the primeval *Pinus*-forests are gone except for limited areas of forest reservations being under the vigilance of the government.

The runoff of the atmospheric water is now caught by dams constructed in the *barrancos* in the windward side, lately also in some of the *barrancos* of the south. Ground water on the other hand is caught by an elaborate system of tunnels (*galerías*) on different levels; also shafts (*pozos*) have (in the coastal lowlands) been dug. These systems of water explotations have made possible extensive cultures of bananas and tomatoes, the well known Canarian produces. The chief area of these cultures is, however, confined to the northern half of the island, receiving the humidity of the trade wind. Here the most important centres of population are situated: except the capital Las Palmas, Telde, Arucas, Teror, Santa Brígida, Guía, Gáldar and Agaete.

The entire population of Grand Canary amounts to c. 400 000 (according to the census available).

PREVIOUS WORKS

Grand Canary is an attractive field of study for the geologist and especially for the volcanologist. Its many *barrancos* radiating from a central nucleus have disclosed the inner structure of the island along the many excellent geologic profiles. With the aid of these the geological development of this volcanic edifice can be followed. The island offers more advantages than its big neighbour Tenerife which is far more confined into one mountainous bulk. Caldera de las Cañadas in the centre of Tenerife, lies c. 2.000 m above sea. Hence this one discloses only the uppermost part of the island. In Grand Canary the two »calderas» of Tejeda and Tirajana, represent deep embayments reaching into the very heart of the island.

In spite of these opportunities for a geological investigation Grand Canary until rather recently has been little known as far as both lithology and dynamic history are concerned. I shall give a brief summary here of the contributions to be found in geological literature.

The pioneer investigator in Canarian geology, in 1815, the German Leopold von Buch in his voluminous work (1825) also gives a summary of the conditions in Grand Canary. In this relatively short chapter he deals with several geologic details of great interest, and these will be related in this memoir. His conceptions of volcanology — which reflect the ideas of his time — may appear somewhat strange (he states among other things that Grand Canary has no volcanoes, i.e. »an orifice leading to the interior from where eruptions find their way out»). Caldera de Tirajana was considered by him as a good proof of his »elevation hypothesis» (the formation of tumors in the earth's crust owing to pushes by subterranean forces). von Buch divides his descriptions concerning Grand Canary into the following chapters: »Las Palmas» (and its terrace), »Telde» (and surroundings), »Bandama» (and surroundings), »The central highland», »La Isleta», »The northwestern part of the island», »Caldera de Tirajana», »Tejeda valley», »Mogán», »Teror and Moya». — von Buch was the first to encounter a fossil marine shell fauna in rather elevated positions in the vicinity of Tamaraceite (NE. part of the island), forming a bed 300 feet above the sea. He correctly concluded that the island had formerly been depressed into the ocean to that amount.

In the thirties of the last century (c. 20 years after VON BUCH's visit to the islands) F. BARKER WEBB and SABINE BERTHELOT (1839) undertook a very comprehensive survey of the nature of the Canaries. One volume of the great work issued is devoted to geology, and in this Grand Canary is also treated (called by them »Canaria»).

The geological ideas expressed in the book seem in the main to follow those of VON BUCH. A large collection of rock samples was brought home by BARKER WEBB. This material was never closely studied in those days (antedating the rise of the science of petrography). Fortunately a hundred years later on it was possible to submit this same collection to laboratory treatment in the University of Sorbonne, as we will see later on.

In the fifties of the last century the German naturalist GEORG HARTUNG investigated the Canaries anew, exactly to what extent is not known except in the special case of Fuerteventura and Lanzarote. He published a work on these two islands dealing with their geology (1857). In a later publication by C. GAGEL (1910) there are, however, some quotations (page 18) from HARTUNG's paper on Grand Canary, a literary source which is not indicated in GAGEL's bibliographical list. According to that report HARTUNG says on a certain occasion that on the way from Las Palmas to Maspalomas there are exposed curious slaty, greenish to grayish — green rocks that give the impression of being of more advanced age. Perhaps these correspond to a group of old basalts in Barranco de Balo(?) (decomposed, chlorite-bearing lavas).

The results of investigations carried out by KARL VON FRITSCH and W. REISS in the Canaries in the Sixties also included Grand Canary. But the material collected on this island was never studied (?) at least not published. The results are only shortly mentioned by C. GAGEL (l.c.), who quotes a list of the rock formations found in the manuscript by VON FRITSCH, as follows:

1. Oldest basalts in the NW. part of the island.
2. Main formation of volcanics at Agaete, Aldea, Mogán consisting of trachytes, phonolites, tuffs and trasses resting directly on the old basalts. Conglomerates of the Miocene Las Palmas'-terrace.
3. Basaltic and phonolitic lavas as fills in the barrancos.
4. Young basaltic lavas, lapillis, ashes and cinder cones of late- prehistoric age.

At the same time (1876) A. SAUER published a small petrographical study of phonolitic rocks in the Canaries. He used the material collected by VON FRITSCH and REISS. Only a few of the samples were, however, from Grand Canary.

S. CALDERÓN Y ARANA, a *catedratico* and naturalist resident in Las Palmas and also attached to service in the Canarian Museum, published in the same year (1876) a paper entitled: »Rocas de la Isla de Gran Canaria», and some years later on (1880) an additional description of the lithology of both Grand Canary and Tenerife. The collection studied was put at his disposal by DIEGO RIPOCHE. This rather comprehensive study is the first carried out in the Canaries in a more modern way. The author in question used the newly appeared textbook by F. ZIRKEL (1878) in giving names to the rocks. The »Classification metodica» by CALDERÓN Y ARANA is as follows:

I. Rocks with	Sanidinite	
sanidine	with quartz	liparites
as dominating	without quartz	trachyites
feldspar	with nepheline	
	or hauyne............	phonolites
II. Rocks with	some sanidine	
plagioclase as	with hbl. or	
dominating	augite	andesites
feldspar	with plag.	
	exclusively +	
	dark min.	feldspar basalts, dolerites, »lava feldespatico»
	with nepheline	
	and olivine	basanites
	without olivine	tephrites
III. Rocks without feldspar	nepheline +	
	dark min.	nepheline basalts
	with olivine	limburgites
	without olivine	pyroxenites

We will return later on to some of the descriptions given by CALDERÓN Y ARANA.

In 1890 a very important paper appeared about the geology of Grand Canary: on the marine littoral deposits in the so-called Las Palmas' terrace by A. ROTHPLETZ and V. SIMONELLI. They described not only the stratigraphy but also the marine shell faunaof the Miocene age found there. With the use of this stratigraphical horizon it was now possible to divide into two parts at least the volcanics of the island (pre- and post-Miocene lavas, etc.).

L. FERNÁNDEZ NAVARRO has (1925, 1926) treated the volcanic events in the island in two publications. We may return to some of his statements later on.

F. VON WOLFF (1931) has also devoted some pages to Grand Canary in his compilatory work »Der Vulkanismus». In his brief account of the characteristics several statements are made, some of which have been proved incorrect, as it will be shown later on. Not a chemical analysis of a rock from the island is included in the text, a somewhat regrettable circumstance considering the petrological approach into the matter. This non-existence of petrochemical data showed an apparent contrast to the state of things in the neighbour island of Tenerife provided with numerous analytical facts.

M:me ELIZABETH JÉRÉMINE, a participant in the Canarian Excursion of the XIVth International Geological Congress in Madrid 1926, has somewhat later on (1933) published an interesting petrographical study of volcanic rocks from Tenerife, La Palma and Grand Canary. This study is based on the collections made by P. BARKER WEBB (at the beginning of the preceding century), by D. RIPOCHE and also by herself (during the excursions). — We may briefly summarize the results concerning Grand Canary.

In her introduction she states that there is no evidence of a plutonic rock in the island except in the shape of enclaves in tuffs. — The deficit in silice may be a common feature of most of the lavas. She has nevertheless found some types of rhyolite (in scattered places) and they are hyperalkaline. Two chemical analyses illustrate the rhyolitic nature of these magmas (with SiO_2 = 65,86% and 66,78% resp.); in the mode quartz is present as small grains in the paste. — An occurrence of rhyolite at Agüimes (on the east coast) which is stated by JÉRÉMINE is somewhat surprising since as far as is known this coast has a rock ground of basalts. Perhaps the sample is from a loose boulder (?). — A rhyolite sample »from Tejeda» containing modal quartz is of interest; one does not know, however, its position in the stratigraphic column of this region. JÉRÉMINE (l.c.) has distinguished two groups among the phonolites: the hauyne — and the nepheline-bearing types. They are the most pale-coloured of the undersaturated salic lavas (in a weathered state almost white). A fair number of the former group is from Caldera de Tirajana (SE sector of the island). The chief mineral is feldspar (anorthoclase and sanidine); hauyne crystals are rimmed with a corona of aegirine. Nepheline is also present. Aegirine is the leading mafic mineral in all the phonolites. The tahitites are also to be placed among the phonolites, likewise the ordanchites. A chemical analysis of a sample from El Saucillo is published. — The authoress then gives an account of the basaltic lavas with their leading minerals: olivine, augite, plagioclase, nepheline, analcite, magnetite and (seldom) hauyne. There are the following types: basanites, tephrites (with or without modal nepheline), ankaramites, limburgites and ankaratrites. There are two chemical analyses referring to this group, one of a limburgite, another of a basanite. In what follows there are data about volcanic glasses, tuffs and enclaves. A concluding chapter is devoted to a magmatic history of the island (the sequence of magmas).

In the same year (1933) as JÉRÉMINE published her paper referred to, JACQUES BOURCART (Sorbonne) was invited to Grand Canary by Cabildo Insular of Las Palmas to make a geological reconnaissance of the island with the main purpose of studying the ground water resources. On his many excursions in the island, he was also able to carry out a fairly detailed study of the volcanic formations and to bring together a collection of rocks from nearly all parts of the island. The journeys were continued in the following year (1934). The material was then handed over to E. JÉRÉMINE for a closer study. The field observations, the petrographical data and the deductions were then published in a joint memoir by BOURCART and JÉRÉMINE (1937), and this was accompanied by a coloured geological map on the scale 1: 100 000. I will briefly recapitulate the contents of this memoir here, leaving all the details to my later descriptive chapters.

The first part of the mentioned memoir on Grand Canary deals with t h e g e o l o g y. It is a study of the volcanic formations of all ages encountered and of their stratigraphical positions. The divisions in the column (expressed also in the map) are 6, viz.:

I. »Série basaltique ancienne» (on the west coast), II. »Série rhyolitique rouge». III. »Série trachyto-phonolitique», IV. »Série de coulées boueuses vindoboniennes», V. »Basaltes post- Miocenes» and finally: VI. »Éruptions basaltiques quaternaires». A concluding chapter of the memoir deals with the Quaternary (mostly sedimentary) formation of the island.

The second part, t h e p e t r o g r a p h y (by JÉRÉMINE) deals with the microscopic descriptions of the rocks accompanied by a number of chemical analyses. In this part there are the following headings:

A. »Rhyolites
Rhyolites anciennes (série II). Rhyolites avec et sin quartz
Rhyolites récentes (parte sup., série III)
B. Phonolites
Phonolites anciennes (série II)
Phonolites supérieures (série III)
C. Trachytes et microsyenites (série II et III)
D. Roches à facies basaltique
Basaltes anciens (série IV)
Basaltes des plateaux (série V)
Basaltes récents (série VI)
E. Roches grenues
Syenites, sanidinites, gabbros, pyroxenolites amphibolitiques monzonites nepheliniques.»

To these descriptions is added a geological map in colours, mentioned above.

The paper by E. JÉRÉMINE (1933) and that by J. BOURCART and JÉRÉMINE (1937) provide a firm basis for further investigations of the island and of the Canaries in common. The present author has of course made much use of the data to be found in these works, as may be seen from the many references in the following text. Nevertheless I have met with some difficulties in the attempt to make these earlier data agree with mine. Rock samples described by JÉRÉMINE have not been exactly fixed as to their stratigraphic position, and localities are vaguely indicated. I shall illustrate this with an example: a »pechstein» of pantellerite has been described, the sample taken from »Aldea de San Nicolás». In this region there are in fact plenty of geological profiles in the shape of high bluffs in the south, in the east and in the north of the settlement. In all these slopes there are salic types of lavas to be found, also at different levels. — On the other hand samples have been described that apparently have been collected from loose boulders in the slopes and in the valley bottoms. Many of such boulders may have belonged to the Roque Nublo agglomerate, others are derived from lava banks somewhere.

In the time to follow S. BENÍTEZ PADILLA (1945), a Canarian geologist, very well acquainted with the geologic structure of the island, produced a kind of synopsis, read before members of the Society of the Canarian Museum. I shall deal with some of his ideas of a general nature on a later occasion. It may be sufficient to mention here the important part he placed to the marine abrasion along the windward or *barlovento* coast, not only in Grand Canary but also in the other islands. The steep western and north-western coasts may according to him, be the result of this incessant work. Moreover he gives information about the stand of the ocean in the Miocene time reaching no less than 400 m above present mean water level.

Later on an important paper on Canarian geology was published by K. SMULIKOWSKI and co-workers (1946). This work deals chiefly with the petrography and petrology of the three islands: Tenerife, La Palma and Grand Canary. As far as the last named island is concerned many petrographic details and also a chemical analysis of a lava rock (phonolite, Santa Brígida) were published. This publication also contains a fairly short petrochemical review referring to the Canarian petrographic province based on facts available to the authors at that time. The statistical treatment, however, is only backed by 8 chemical analyses in all, those of the papers by BOURCART and JÉRÉMINE being unknown to the Polish authors owing to the circumstances following World War II.

In 1951 M. MARTEL SANGIL, a young Spanish geologist well acquainted with the Canaries, presented a synthesis of the archipelago. After briefly quoting earlier conceptions about the islands, the author gives his own opinions based on considerations at isostasy and at currents in the Sima. These undercurrents caused the Sial crust to be broken up with faults and folds, in their turn giving origin to volcanic eruptions. The latter formed with the time a kind of superstructure to each of the islands.

The same author has made a new contribution to Canarian geology 1952, this time considering only Grand Canary. After a short introduction on the volcanic formations, he deals chiefly with the marine shell fauna of the Las Palmas' terrace and includes a revision of families and specimens. His data are to some extent quoted in the descriptive chapters of this memoir.

In the following years a Spanish road engineer, F. MACAU VILAR, at that time engaged in the construction of new roads in Grand Canary, also made many useful observations on the island geology.

His studies were facilitated by the aid of deep borings and exact measurements in connection with the roads. — He has published a number of bulletins (1956—1959), partly in an engineering journal, partly in the scientific series »*Anuario de Estudios Atlánticos*«. The first (1956) of these communications deals with the land-slides in Caldera de Tirajana which damaged a highroad and a bridge; two other publications concern hydrologic studies in the island (1957); one following (1958) gives an example of practical geological methods in road construction. A last paper (1959), written after the author's departure from the island (to other work on the Spanish mainland) treats the intricate question of the »calderas» in Grand Canary. Later on I shall in connection with the descriptive chapters return to these papers.

Finally it remains to be mentioned that the Canarian geologist TELESFORO BRAVO (of Puerto de la Cruz, Tenerife) has devoted considerable time to field studies in the island of Grand Canary (together with his explorations in the other islands). He has also accompanied the present author in his excursions in Grand Canary and given him much assistance. Afterward he has completed my collection with new material (samples, profiles, photos, partly on request). It is to be expected that BRAVO will continue with his comprehensive »Geografía general de Canarias», of which the first volume has appeared (1954).

THE GEOLOGICAL STRUCTURE OF GRAND CANARY

Before we begin the chapters of a descriptive character, we shall orientate ourselves by glancing at the general geological features of this remarkable island which looms before us: a broad shield-formed mass rising from deep ocean waters to a height of 1950 m, the summits wrapped in the mantle of the trade wind clouds. The inner structure of the island can, of course, be studied only in the part lying above sea level, and we can only guess at what kind of material forms the real submarine fundament, which represents by far the greater share of the whole island mass.

If we now follow the different formations — all in the main of volcanic nature — from the most ancient to the most recent, we have first to look at the »basal» complex (in the relative sense). In the cliffs at the western and northwestern shore, there are numerous banks of basaltic lavas and tuffs and agglomerates, considered by earlier investigators as the most ancient rocks of the island. It is evident, however, that there must be a basement upon which this series has been piled. When one follows the deep erosion channels that open the way to the more central parts of the island, one will find that the basalts disappear and are replaced by s a l i c, t r a c h y t i c l a v a r o c k s, now in a tilted position. This complex is penetrated by eruptive bosses and dikes of a l k. s y e n i t e s. The upper limit (the surface) of the tilted trachyte lavas rises to rather considerable heights in the centre of the island, and here to my mind is the topmost part of an old nucleus of the island. No traces of the western basalt formation are disclosed here.

It seems most likely that these western basalts with their generally easterly dip form the remaining eastern flank of a great shield volcano of basaltic nature belonging to the oldest volcanic period in the Canarian area. These things will be more closely dealt with in Part II.

The formation next in age is a concordant pile of salic volcanics superimposed with a perceptible unconformity upon the old basalts in the western mountains. This formation comprises rhyolitic and trachytic lavas, tuffs and ignimbrites, all in thick banks and in nearly flat position. Thickness is c. 800 m (formerly more). — This formation was followed by a nepheline phonolite lava formation, also a mighty series in a large southern sector of the island. It originally covered the entire island; it was a somewhat flattened volcanic cone. In this there were numerous concordant layers of pale-coloured or reddish (calcined) tuff banks, separating the thick lava sheets (with their columnar jointings) from each other.

After the completion of this great volcanic edifice of the central type, ruptures occurred in the island and some greater displacements followed. A master fault runs NW—SE across the whole island and the north-eastern half- the so-called *Neo-Canaria* subsided in relation to the south-western half, or *Palaeo-Canaria*.

After these crustal disturbances, a new volcanic phase began, this time also of the central type — but the eruptions were highly explosive, and it was most likely an activity of the Peléean type. The island was covered by a thick mantle of a chaotic agglomerate, called the Roque Nublo agglomerate (after a pinnacle in the central highland, Roque Nublo, which is a last erosion remnant). The mantle of agglomerate has greatly suffered from the *barranco*-erosion so that most of it has disappeared. The composition of the agglomerate is shared by a pale-coloured pumice matrix and inclusions of variously-sized boulders and stones of eruptive rocks from the deep interior.

These Peléean eruptions alternated with quietly flowing basic lava streams issued from vents somewhere in the center of the island (probably from the area of the present Caldera de Tejeda), as may be found from the intercalations of such lavas between the thick banks of the R.N. agglomerate. These lavas have generally the composition of tephrites.

After the cessation of the Peléean activity eruptions occurred in the central highland anew, this time from scattered vents (numbering 6 to 7); lava sheets covered the R.N. agglomerates in this part of the island. These new lavas are strongly Na: enriched, they are chiefly h a u y n o p h y r e s (tahitites and ordanchites, LACROIX). Such lavas, mostly of high viscosity, did not reach far down the slopes of the island. The vents have now the shape of towering necks, the most prominent of them are seen in the upland behind Tenteniguada.

After the termination of these lava emissions in the central highland a long period of denudation started seemingly under more humid climatic conditions, and great masses of rock debris were carried down the *barrancos*. The island then lay more depressed than now is the case, it is in the Miocene period (Vindobonian); and a m a r i n e s h e l l f a u n a was then accumulated as fossils in the littoral calcareous sediments.

There then followed an important volcanic phase, manifested by outpourings of great masses of very fluid o l i v i n e b a s a l t i c l a v a s and a spreading of their pyroclastic materials. These lavas covered a great deal of the island, mostly in the northern and in the eastern sectors, and their streams filled many of the pre-existing valleys leading down to the coasts. It seems the lavas issued mostly from some central vents in the highland, almost from great fissures. Subsequently there grew up a great number of a d v e n t i v e c o n e s also consisting of basaltic materials; most of them were spread over the northern and the eastern declivities. The age of these cones ranges as it seems from the Quaternary to the recent period.

It is a remarkable fact that almost the whole of the great southern sector of the island is devoid of such cones, also older basalt streams are of restricted occurrences. Instead salic lavas dominate here.

The latest mainfestations of volcanism belong certainly to the time of the Guanches, and several of the basalt volcanoes may have had outbursts just before the Spanish occupation of the islands. Now the activity has closed down entirely.

The formation of the two great »c a l d e r a s» in the central part of the island has certainly required a rather long period, beginning before, but concluding long after the deposition of the R.N. agglomerate mantle over the island. Several geologic forces have been in co-operation to create these deep hollows in the island structure, such as faults (at repeated occasions) accompanied by collapses, vigorous erosion assisted by weathering, and also by great land slides.

The geologic history of Grand Canary is of course not to be understood as a continuous upbuilding process with volcanic materials of various composition. There have been many breaks in the chain of outpourings of lavas and in the spreading of pyroclastics. These breaks consisted in tectonic disturbances but also in *barranco* — erosion. The latter filled up the »calm» interludes between periods of volcanic activity. These exogene processes were influenced by changes of level of the island so that during upheavals the erosion was invigorated. Also changes of climate have had their effects on the exogenic forces.

Part I

Descriptive Chapters. Field and Laboratory Data

1.

The northeastern Sector of the Island between Barranco de Teror — Tenoya and Barranco Guiniguada

including the Las Palmas' terrace and La Isleta

Barranco de Teror — Tenoya with adjacent ridges

This valley train reaches from Lomo La Solana (above Teror) down to the north coast. The general trend of the valley is SSW—NNE. Tributary *barrancos* are few and insignificant. In the upper course the region is rather mountainous (to 1 200 m); the lower course passes across a flat landscape, where the valley is confined by rather steep sides.

The region of Teror

This region is limited to the west by the Balcón de Zamora ridge and the volcano of Osorio (925 m), in the east by the long Lomo de los Tilos' ridge. Between the two head *barrancos* to Barr. de Teror, there rises Lomo La Solana, ending in the north with a rather steep cape (1 000 m).

The rock ground can be studied most conveniently along the high-road leading from San Mateo to Teror, passing the watershed at Barranco de la Mina at an altitude of 900 m, in Lomo Gallego.

At the pass itself there are exposures of dark basaltic lavas with tuff layers. Samples from here and from the vicinity (13, 16, 17, 31, 32) are all augite — and hornblende bearing tephrites or trachytephrites. No. 13 from the divide shows micr. stray euhedral pyroxene phenocrysts, and to a lesser amount brown hornblende and plagioclase. There are also grains of sphene and magnetite. The matrix consists of pyroxene, magnetite and tiny rods of feldspar. Apatite is accessory. — No. 17 from the vicinity is micr. rather similar, with pyroxene and hornblende in the I gen. of components. The plagioclase is confined to the matrix. The optic data are:

Pyroxene : $2V\gamma = 74°$, $c \wedge \gamma = 34°$ (augite with some % aeg. mol.)

Nos. 31 and 32 are of the tephritic group of lavas. They contain some sodalite or nepheline.

To the west from the *degollada* (Lomo Gallego) the divide rises to greater heights. Following this, one soon reaches a hilltop (with a wooden cross). Here a basalt lava is exposed (16) which contains plagioclase instead of the mafics as a component of the I gen. It is a plagioclase basalt. The optics of the plagioclase are:

$2V\gamma = 78°$ Comp.: An/55 (polysynthetic twinning)

All these basaltic lavas seem to belong to the R. N. agglomerate formation that appears in the vicinity (to the east).

Following the highroad further down to Villa de Teror one passes lower strata of lavas and tuffs. At the same time the lavas become more salic in composition. No. 29, for example, taken from a small quarry some hundred metres above Teror, is a lava of trachytic nature containing alk. feldspar as the chief mineral, partly as phenocrysts, partly as small rods filling the groundmass. There are also corroded crystals of a sodalite mineral. Mafics are very sparsely present (greenish pyroxene prisms and sphene and magnetite). Apatite is an accessory constituent. In the phenocrysts the alk. feldspar shows opt. char.+(albite). These are surrounded by a shell of orthoclase(?). The lava may be a phonolite.

Lower down the hillside facing Villa de Teror, there appears a pale — grayish, thick lava bank with columnar jointings (12). It forms a steep cliff reaching down to the bottom of Barranco Madre de Agua on the southern outskirts of the Villa. This rock shows micr. a trachytoid texture of minute feldspar laths and with sparsely larger grains of alk. feldspar. There are prisms of a pale-greenish clinopyroxene and also sphene (the latter in typical cross-sections elongated acc. to the b-axis). The pyroxene has ext. angle on (010) $c \wedge = 60°$ (aeg. aug.). Iron ore powder is seen in the paste. The optics of the larger feldspar grains could not be determined (anorthoclase or Na:sanidine?). The mafics form less than 1/8 of the composition. Besides there are very sparse grains of a sodalite mineral powdered with hematite. The lava may be classified as a trachyte or a trachy-phonolite.

A chemical analysis was made of this lava with the following results:

Analysis no. 1.

Sample no. 12 (Hausen 1953) of a light-grayish trachyte or trachy-phonolite in the slopes south of Villa de Teror. (c. 750 m above the sea level).

		Mol. prop.
SiO_2	59.60%	9884
TiO_2	0.78 »	97
Al_2O_3	19.97 »	1954
Fe_2O_3	2.75 »	172
FeO	0.35 »	49
MnO	0.10 »	14
MgO	0.62 »	154
CaO	1.85 »	330
BaO	0.30 »	20
Na_2O	5.30 »	855
K_2O	5.46 »	580
P_2O_5	0.11 »	8
V_2O_5	0.01 »	1
Cl_2	0.08 »	11
F_2	0.03 »	8
H_2O +	1.39 »	771
H_2O −	1.22 »	
	99.92%	
−0	0.01 »	
Sum:	99.89%	

Norm:		
Q	3.3	
or	32.3	85,3
ab	44.2	
an	8.8	
hl	0.1	
C	2.2	
Σ Sal:		90.9
en	1.5	
hm	2.8	
il	1.0	
ru	0.3	
ap	0.3	
fr	0.04	
Σ Fem		5.9
H_2O		2.6
	Sum:	99.4

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.52
(+23.5 °C)

NIGGLI values:
si = 230½, ti = 2.3, p = 0.2, cl_2 = 0.2, f_2 = 0.2, h+ = 17.9, al = 45½, fm = 13, c = 8, alk = 33½, k = 0.40, mg = 0.27, qz = −3½, al−fm' = 32½, al−alk = +12.

C. I. P. W. Classif. — I. 5. 2. 3.
Pulaskose
Magma type: pulaskitic
Mol. prop. % normative feldspars
Ab:An:Or = 49:18:33
MgO:FeO = 100:1

RITTMANN parameters (1952) for nomenclature:
Al−17.97, FM−4.49, Alk−13.41, k−0.41, an−0.15, ca"−−0.89.
Light latite.

The name *latite* implies, as has been defined, a trachytic lava that shows transitions to the andesites — a trachy-andesite-containing besides the *K*:feldspar also a plagioclase (or a soda-orthoclase). In this particular case it was not possible to carry out optic diagnosis. The few phenocrysts of feldspar in the slide do not show any kind of twins, and the minute rods in the paste have ind. of refr. < balsam.

It seems this salic lava type belongs to the upper series of the volcanic beds, which consist of only light-coloured feldspar-rich rocks. A corresponding latite type has not been found so far, only a puzzolane (see below, page 46) which approximately shares that composition.

Further down the slopes in the direction of Teror, one meets with more of the salic volcanics at lower levels, right down to the bottom of Barranco Madre de Agua. First there is a thick bank of a whitish tuff, of very soft consistency, then an agglomerate (no samples), then a sheet of dark lava (no sample) and finally tuffs, a brick-red one and a yellowish one in the bed of the *barranco*. One is now at a level of 550 m above the sea.

At a still lower level (500 m) lies the well-known spring of mineral water, Fuente Agria, east of Villa de Teror. Here a shaft has been dug, and a sample was kept of the lumps of rocks hoisted up from the interior (depth not known). Micr. it is (6) a trachytic type with phenocrysts of alk. feldspar and smaller crystals of a hornblende in a paste consisting of tiny rods of sanidine (?) and a gray, isotropic substance. (ind. of refr. <1.54). Cavities in the rock are filled with a grayish brown subst. (analcime?).

Summary of the volcanic stratigraphy on the mountain slopes from Cumbre de Lomo La Solana to Fuente Agria (Teror):

Altitude	Number of sample	Rock type	Locality
Top 1200 m	16	Plagioclase basalt (hbl-bearing)	Cumbre del Lomo La Solana
1100 »	31	Hornblende-augite tephrite	*Cuesta* above San Isidro
950 »	17	Hornblende-augite tephrite	E of the pass on the road Teror — S. Mateo
900 »	32	Hornblende-augite tephrite	Pass in the divide, road Teror — S. Mateo
900 »	46	Hornblende-augite tephrite	*Barranco* S of the pass road Teror — S. Mateo
800 »	29	Sodalite-trachyte	Small quarry by the road. Slope S of Teror
700 »	12	Trachyte (light-gray)	10 m thickness, slope S of Teror
650 »	—	Agglomerate	Below trachyte bank, at Madre de Agua, Teror
550 »	—	Variegated tuffs	Barranco Madre de Agua, Teror
500 »	6	Trachyte (porphyry), vesicular	Water shaft in Fuente Agria

At still lower levels many salic lava beds certainly occur, judging from what the shafts in the surroundings have revealed.

The basic lavas in the upper part of the profile without doubt belong to the series that accompanied the outbursts of the R. N. agglomerate materials. Alkaline basaltic lavas probably issued from the central part of the island.

Ridge east of Teror

If we again turn to higher stratigraphic levels, we may glance at the long ridge following the right side of the Teror valley Lomo de los Tilos — Lomo Blanco — Altos de San José del Álamo. I have followed the entire range, beginning from the watershed in the southwest. The ridge represents the divide between the Teror valley and Barranco de San Lorenzo. In this southwestern, higher-lying part, the ridge consists of the R. N. agglomerate in thick banks, in some parts capped by basalt lava sheets forming flat topped summits. A sample of this lava was kept (30), consisting of augite phenocrysts (plenty) and stray grains of somewhat altered olivine. The paste is basaltic with plagioclase laths, augite and ore. Cavities in the paste are filled with a colourless isotropic substance (ind. of refr. $\sim$1.54). Vol. % of the augite appr. 30. The lava may belong to the tephrite-basanite lavas that accompany the agglomerate deposits of the Peléean outbursts.

Proceeding along the ridge in a northeasterly direction, one finds again exposures of basalt lavas in Lomo Blanco disclosed in a side-*barranco* leading to the Teror valley. One sample from here is also a tephritic lava with euhedral phenocrysts of augite (abundantly) and of brown hornblende with an opaque fringe (ext. angle on (010) $c \wedge \gamma = 24°$). The paste is basaltic. — Lomo Blanco seems to consist in its main (basal) parts of the phonolite lavas, covered on the surface with a lime crust (hence the name of the hill).

Further northeast one arrives at Altos de San José del Álamo, terminating in Cuesta de las Palmas. Still further northeast appears the gravel ground of the so-called Las Palmas' terrace which reaches to the sea shore.

During a climb to the top of Altos de San José del Álamo, one will find the following succession of beds, starting from the side of the Teror valley (highroad): by the road there is basalt (300 m above the sea), then there follow dark phonolite lavas, the same as are seen in Lomo Blanco.

Uphill there is a bank of a porphyry (sample 74). Micr. it shows plenty of clear alk. feldspar phenocrysts (rectangular), brown hornblende and mica in a glassy, pilotaxitic paste also containing rods of feldspar and magnetite grains. The lava is a vitrophyre. The texture is beautifully fluidal. — Further up the slope there lies a bank of the R. N. agglomerate formation forming steep cliffs bordering the valley. One will then find another lava bank (73) with relatively large plagioclase laths in a fine grained groundmass of a basaltic texture. There are small crystals of a clinopyroxene and also scattered grains of a red-brown mineral (sec.). The plagioclase of the second gen. is abundantly present, mingled with pyroxene, apatite and ors. Optics:

Plagioclase: $2V\gamma = 82°$. Ext. angle $\perp$ PM$=26°$. Comp. An/47 (I gen.).

Pyroxene: ext. angle on $(010) c \wedge \gamma = 45°$ (diopside).

This lava may be a plagioclase basalt approaching andesite.

The top lava sheet in the hill of San José del Álamo is a porphyrite (75) of much the same aspect as no. 73. There are plenty of laths of plagioclase (opt char. $+$ =labradorite) and also much feldspar in the groundmass, mostly as stout rectangular grains. They leave a matrix turbid-gray and isotropic (glass?), in which are small crystals of magnetite. Stray phenocrysts of a pale-coloured clinopyroxene are present. Ext. angle on (010) $c \wedge \gamma = 51°$. Moreover, one will find crystals of a red-brown mineral without perceptible cleavage, with strong refr. and birefr. (c. 0.020). The mineral shows no pleochroic changes. It encloses grains of magnetite and apatite. There are also patches of a colourless subst. without birefr. (analcime?). The lava may be called a plagioclase basalt approaching an andesite. The lava bank lies 550 m above the sea, and it has formerly had a much wider extension.

If we go down the northwestern slope of Altos de San José del Álamo, we enter an extensive terrain underlaid by the R. N. agglomerate reaching northward to the road from Tamaraceite to Teror. Basalts are met with at the foot of the slope, and they seem to lie immediately above the R. N. agglomerate, which appears in the right side of Barranco de Teror nearby. — This basalt seems to correspond to a type described by E. Jérémine (1937) as an amphibole-bearing andesine basalt (»Route de Teror á Tamaraceite»), of which a chemical analysis also was made (see list of Niggli-values page 375, no. IX).

Along the left side of Barranco de Teror is a lava tongue of basalt, the origin of which may be sought in the volcano O s o r i o. The end of this tongue lies in the vicinity of La Santidad. It is, however, already much eroded. No sample was guarded of this lava.

The course of Barranco de Teror (Tenoya) from Lomo Blanco to the village Tenoya is incised into a ground consisting at the base of phonolites overlaid by basalts, then of banks of agglomerate, then again of basalts. The latter form the right edge of the *barranco* for some distance to the north. In the left side of the same *barranco* there is first the lava tongue from Osorio that ends opposite Cuesta de las Palmas. This tongue is separated from the ridge of Riquiánez by Barranco del Pino. The latter runs to the north of La Santidad, where it suddenly broadens and forms a plateau.

The eastern flank of Lomo Riquiánez shows banks of the R. N. aggomerate in westward-tilted position. Behind these outcrops lie dark trachyphonolites on higher levels. These platy lavas also dip to the west. The disturbances may be due to fault movements along the valley side. A fault line seems to run between the agglomerate and the phonolite lavas.

The agglomerate underlies the flat ground to the north of La Santidad. At the base of the agglomerate one will find basaltic lava banks. A sample of such a rock a little below La Santidad (28) consists micr. of a plagioclase-rich rock also containing crystals of a pyroxene and a red-brown sec. mineral (altered olivine?). The matrix consists of plagioclase laths, pyroxene grains and ore and also a zeolite subst. The optics of the minerals in the I gen. are:

Plagioclase: ($2V$ not det.) twins acc. to the Karlsbad and albite laws. Comp.: An/45.

Pyroxene: $2\ V\gamma = 46°$, $c \wedge \gamma = 38°$ (augite)

This lava may be of the tephrite group that accompanies the R. N. agglomerate.

The lower course of the valley (from Tenoya to the coast)

On the stretch down to the coast from a point where the Las Palmas —Arucas highroad crosses the valley, there are some things of geological interest.

Tenoya lies at the end of a long ridge which begins at Cuesta de Las Palmas and fringes the Las Palmas' terrace to the west. The ridge consists of basalt lavas (no sample) and lies on tuffs. On the opposite side of the valley — at the road branch running to Cardones — basalt is also to be seen (51). It is an olivine basalt, perhaps of the post-Miocene effusions. It contains plagioclase, augite and olivine in a paste of plagioclase, clinopyroxene and abundantly of magnetite. Plagioclase has the comp. An / 55 (according to the max. angle of ext. in the symmetrical zone). The olivine grains are partly altered. — When following this lava bank along the road that leads to Cardones, one will find the lava covering a mighty mass of brownish tuffs disclosed in a large gravel pit. This tuff seems to continue to the north to the vicinity of the cinder cone Cabeza de la Rosa (175 m) rising near to the coast (Fig. 2). Proceeding northwards along the *barranco* bottom from the village Tenoya, we will find it relatively deeply incised into the flat coastal volcanic ground, and not far from the mouth it narrows to a chasm-like canyon. Banks of a dark trachytic lava (64) are exposed in the vertical walls on both sides. Micr. this rock shows phenocrysts of an alk. feldspar in Karlsbad twins lying in a trachytoid paste with feldspar rods and aegirine prisms arranged in the common flow direction of the texture, in places also in arborescent bundles. Iron ore grains are sparse. No nepheline or sodalite is to be seen.

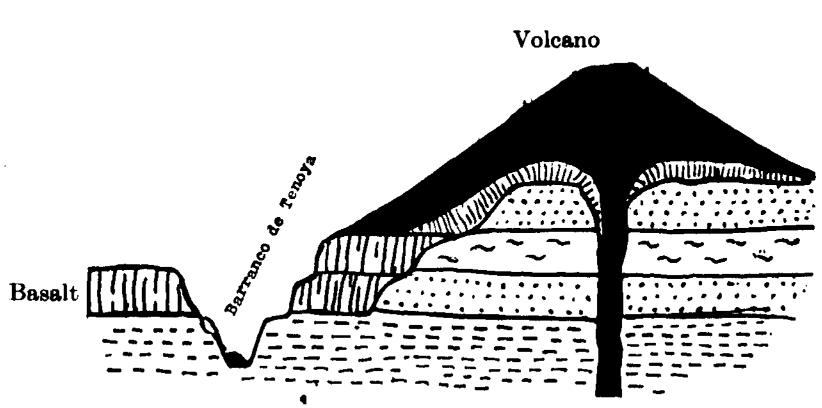


Fig. 2. Cross section in the Recent volcano Cabeza de la Rosa (basalt) resting on a basement of sediments and salic lavas (acc. to F. MACAU VILAR 1954).

This trachyte lava is capped by thick banks of a basalt lava (no sample), forming a kind of terrace on both sides (edges of the canyon). This basalt seems to belong to an ancient lava stream which used the old valley of Tenoya before the rejuvenation of the erosion which incised the canyon into the fill.

There is a recent basalt lava stream in the narrow bottom of this young canyon; the point of issue is, however, not clear. A sample of the lava (62) is an olivine basalt with phenocrysts of olivine (clear) in a paste consisting of augite, magnetite and a colourless isotropic substance (maybe analcime). Plagioclase microlites are not to be seen in the paste. Hence the lava may be designed as a picrite or ankaramite.

The *meseta* on the right side of Barranco de Tenoya is capped by a basalt lava sheet (described later on page 66). The mentioned *meseta* forms part of the Las Palmas' terrace, to which we will turn our attention later on.

Barranco de Teror—Tenoya is apparently a relatively old river valley that has several times been used to varying extent by lava streams coming from adjacent regions. An ancient fill of basalts was cut across by later erosion and a new valley bottom was incised. This in its turn was used by a long lava tongue coming from the Osorio volcano. Finally still younger streams filled the lower course.

The basement in which the primary valley erosion started consists of the R. N. agglomerate formation with its tephrites underlaid, as can be seen in the profiles along the north coast, by banks of phonolite.

Barranco de San Lorenzo with the puzzolane quarries

This *barranco* begins in the vicinity of Caldera de Pino Santo a small explosion crater (*maar*) located in the R.N. agglomerate ground. The valley runs northeast, roughly parallel to the Teror valley, on its right side. The *barranco* ends at the village of San Lorenzo, in the vicinity of which are situated the largest quarries of puzzolane to be found in the island.

There are no rock samples at my disposal from the upper course of Barranco de San Lorenzo. I noticed the geologic features of the rock ground in the area during a traverse from Teror to Santa Brígida. Several *barrancos* and intervening ridges are traversed on this route. The start was made from Lomo Blanco. Most parts are underlaid by the R. N. agglomerate covered with basalts in the ridges. The last ridge, opposite the Guiniguada valley, Lomo de Andújar consists of mighty tuffs resting on phonolites.

Lower down Barranco de San Lorenzo (to the northeast) one arrives at a hill, Altos de San Gregorio (450 m), rising on the left side of the Barranco (to the east of Cuesta de las Palmas). It likewise consists of the R. N. agglomerate, here and there covered with basalts (tephrite?).

After passing Altos de San Gregorio Barr. de San Lorenzo ends in a plain in which the village of S. L. is situated. On the fringes of this plain (i.e. in the surrounding hillsides) there are many quarries in a pale-yellowish puzzolane, the most important occurrences of that material in the island. The largest of the quarries lie at the northern end of the Andújar ridge.

By examining the vertical (and smooth) walls of these quarries (see fig. 1 plate I), one is impressed by the homogeneous appearance of the tuff: very few xenoliths and a scarcely perceptible stratification. The maximum thickness of the deposit is not visible, as the excavations do not reach to the bottom. The walls are no less than 20 m high in places. The rock is cut into rectangular pieces for building material. It can easily be transported by lorries, since there is a road to the northern highway at Tamaraceite.

A sample of the puzzolane (76) has been examined under the micr. and also submitted to a chemical analysis. — Micr. there are fragments of alk. feldspar, grains of a red-brown subst., also small fragments of a phonolite lava (with hex. crystals of nepheline, but no mafic minerals.). The matrix seems to consist of glass shreds and pumice powder. The texture is clearly tuffitic. Pores in the mass seem to be relatively sparse, at least in the sample available. In this sense it is differing from the Tenerifan puzzolane (Hausen 1956), in which the vesicles are filled with a canary-yellow zeolitic substance.

The results of a chemical analysis carried out of the puzzolane sample are given below:

Analysis no. 2

Sample no. 76 (Hausen 1953) of a pale-yellowish puzzolane from one of the quarries in San Lorenzo (NE sector of the island).

		Mol. prop.	Norm:		
SiO_2	59.06%	9794	Q	20.4	
TiO_2	0.69 »	86	or	30.8	
Al_2O_3	19.52 »	1910	ab	25.8	57.7
Fe_2O_3	3.70 »	232	an	1.1	
FeO	0.05 »	7	C	8.4	
MnO	0.23 »	32			
MgO	0.19 »	47	Σ Sal:		86.5

CaO	....	0.28%	50			
Na_2O	....	3.05 »	492	en	....	0.5
K_2O	....	5.21 »	553	hm	....	3.7
P_2O_5	....	0.04 »	3	il	....	0.6
H_2O+	....	4.84 »	2686	ru	....	0.4
H_2O-	....	3.50 »		ap	....	0.1
	Sum:	100.36%			Σ Fem:	5.3
					H_2O	8.3
					Sum:	100.1

Analyst: AULIS HEIKKINEN

Sp. gr. not det. (porous and inhomogeneous)

NIGGLI-values:

si = 276, ti = 2.5, p = 0.1, h+ = 75.8, al = 54, fm = 15½, c = 1½, alk = 29, k = 0.53, mg = 0.09, qz = +60, al − fm' = +38½, al − alk = +25.

C.I.P.W. Classif. — I. 4. 1. 3.
Liparose

RITTMANN — parameters for nomenclature: Al — 17.57, FM — 4 39, Alk — 9.79, k — 0.53, an — 0.28, ca" — —4.39. Light latite.

The type in question shares its extremely salic composition with lava No. 12 (anal. 1) from Teror. It seems that the two rocks also lie stratigraphically close to each other. (Cf. also the anal. of a puzzolane in Tenerife, HAUSEN 1956, page 131!). — There seems to be much zeolite in the puzzolane (content of H_2O+!). The silica surplus is here extremely elevated: this may depend on sec. silicification.

In spite of the considerable thickness of the puzzolane deposit at San Lorenzo, it would be difficult to follow the formation into the surroundings. It appears in the west at San Gregorio, in the east for some distance along the Guiniguada valley (esp. in the left side opposite Tafira Alta), i.e. in places where erosion has gone deep enough. It is fairly certain that the puzzolane goes down the sides of the valley of Guiniguada to the city of Las Palmas, where it appears at the base of the Miocene terrace. Here it is also called *canto blanco* and underlies the well-stratified littoral deposits (see next chapter!). — I do not know of the depth of the puzzolane, since there are no immediately underlying volcanics at the base. The thickness of the formation may vary, however, since it has been spread over a very uneven eroded surface, and, as in similar cases of volcanic mud streams, it has naturally followed existing valleys or *barrancos.* In short, it has never had the shape of a sheet flood.

The absence of stratification in the huge puzzolane walls in the quarries, or at least a very undecided one, has led to the assumption that the mass has moved on as a thick mud (*lahar*), in which there were turbulent streams. The sparseness of stone inclusions of alien lavas in the puzzolane is remarkable. One would have expected admixture of such material on the long way from the *cumbre*-region to the coast. The puzzolane differs on this scarceness of xenoliths from the Roque Nublo agglomerate, which was deposited later on and is very wide spread, although the major part of these xenoliths was certainly dragged from the core of the island (by explosions).

The stratigraphic position of the San Lorenzo puzzolane is of some interest. The profile demonstrates that it underlies salic tuffs and lavas which in turn are capped by the R. N. agglomerate. The latter forms the whole crest of the ridge of L o m o d e A n d ú j a r. — What kind of rocks lie under the puzzolane here? one may ask. The author thinks that we will meet with the dark, platy phonolites on deeper levels, the same formation that appears at La Laja on the east coast south of Las Palmas.

The highroad from San Lorenzo to T a m a r a c e i t e runs due north along the broad valley of San Lorenzo (lower course). To the right there is a slope, forming the western limit of the so-called Las Palmas' terrace (here gravel-covered); to the left there runs a *cuesta* belonging to the eastern part of A l t o s d e S a n G r e g o r i o, terminating in a rocky cape not far from the suburb of Tamaraceite. The edge of this *cuesta* lies c. 400 m above the sea.

At the south end of the *cuesta* there is puzzolane to a great thickness, capped by a brown tuff which is covered with a thick sheet of the R. N. agglomerate. The tuff (68) seems to be an explosion breccia with micr. a mixture of different minerals and fragments of lavas in an iron stained matrix. — Going north along the *cuesta*, one reaches a cape in which there is the following sequence: at the foot of the slope is a (talus-covered) basalt (tephrite?), farther up-hill there is a huge bank of a pale-coloured lava (no sample). It is capped by an agglomerate (R. N. type), and the top sheet consists of a scoriaceous basalt lava (65). Micr. this rock is tephritic and shows phenocrysts of euhedral clinopyroxene (gray-lilac) associated with magnetite grains; further one finds turbid crystals of a sodalite mineral. The paste consists of plagioclase laths, pyroxene and ore, the texture is basaltic. No olivine can be seen in the slide. The share of the plagioclase in the paste equals the mafic components. This lava undoubtedly belongs to the R. N. agglomerate formation, of which there is much in Altos de San Gregorio.

From this prominent erosion cape onwards to the north, one first passes T a m a r a c e i t e, then the lower course of the *barranco* leading down to the sea, begins. On the way the course meanders between the limits of the Las Palmas' terrace to the right and a basalt table land to the left. The lowest stretch of the *barranco*, however, runs across a part of the basalt *meseta* (see map fig. 41).

The Guiniguada valley train

This valley begins with a head-*barranco* at D e g o l l a d a C r u z d e T e j e d a, 1 500 m above the sea. It runs fairly straight to the north-east reaching the coast in the city of L a s P a l m a s. The upper course of this train is called Barranco de la Mina as far down as to the vicinity of S a n M a t e o. From here onwards the valley goes by the name of Barranco de Alonso, receiving a tributary, Barranco de Angostura from the left. After this junction at Santa Brígida the stretch of the valley is called Guiniguada as far as the mouth in the sea. There are few tributaries, the most important (except Barr. de la Angostura) being Barranco de Mireles from the right side.

Barranco de la Mina.

At high levels around the head-*barranco* highland-basalts and their tuffs are met with. Lower down along the highway to L a s L a g u n e t a s there the R. N. agglomerate is exposed, rather decomposed on the surface. It is crossed by several dikes with steep inclination. I have only one sample (6) of these dikes, which was taken from the road fork Las Lagunetas—Valleseco (altitude 1 460 m). This dike (weathered on the surface) shows micr. a typical lamprophyre with phenocrysts of brown hornblende (rimmed with opacite) and pale-coloured clinopyroxene but also with stray crystals of a sodalite mineral. Magnetite is accessory. The ground-mass is very fine-grained with tiny laths of feldspar. It looks rather dark between + nic. (altered). There are colourless patches of an isotropic subst., perhaps analcime. But there are also fibrous aggregates of a yellowish colour with ind. of refr. <1.54 and weak birefr. Ext. is

// along the *c*-axis (length slow). Cavities in the paste are filled in places with a zeolite mineral, in other with calcite (center). Optics of the leading minerals are:

Clinopyroxene:	$2V\gamma = 60°$	(average of 5 meas.)
	$c \wedge \gamma = 41°$	(augite)
Brown hornblende:	$2V\alpha = 74°$	(average of 5 meas.)
	$c \wedge \gamma = 9°$.	(pleochr.: α-yellow, γ-brown, barkevikite)

This dike rock may most conveniently be called a vogesite-lamprophyre.

Going down along the highway with its many turns in the mountainsides, one passes somewhat below the above-mentioned fork an exposure of a gabbro rock (sample 22): apparently an instrusive mass in the agglomerates. This occurrence was first mentioned by J. Bourcart (1937). I myself was conducted to the exposure by my Canarian colleague S. Benítez Padilla. The rock has been dismantled, thanks to the deep erosion of Rio de la Mina, and cut clean through the road construction.

This gabbro, the only one so far known on the island of a basic plutonic boss, is rather doleritic under the micr. It shows plenty of broad laths of plagioclase in random arrangement, augite, olivine and magnetite. The olivine is partly decomposed into an opaque substance penetrating into the host mineral along cracks. E. Jérémine has earlier (1937) examined the same rock (if I am not in error) called by her »filon á La Laguna» and found that the plagioclase has the comp. An/44, rimmed with a shell of oligoclase (An/20) and with twins acc. to the Karlsbad and albite laws.

In a slide of sample no. 22 the chief constituents have been examined with the following results:

Plagioclase:	($2V$ not det.), max. angle of ext. in the zone ⊥ (010): 25°. Comp. An/45
Pyroxene:	$2V\gamma = 53° - 53.5°$, $c \wedge \gamma = 45{,}5°$ (augite)
Olivine:	$2V\alpha = 80°$ (Fa $= 35\%$, hyalosiderite)

Apatite is an accessory constituent. Magnetite grains are mostly enclosed in the augite. — The exposure may be considered the topmost part of an intrusive mass which would certainly widen downwards.

My sample was submitted to a chemical analysis, the results of which are given below:

Analysis no. 3.

Sample no. 22 (Hausen 1950) of a doleritic gabbro intrusive rock, slightly altered. Roadside cut between Las Lagunetas and Cruz de Tejeda, Barranco de la Mina.

		Mol. prop.
SiO_2	46.45%	7703
TiO_2	2.91%	363
Al_2O_3	13.51%	1322
Cr_2O_3	0.01 »	1
Fe_2O_3	3.74 »	234
FeO	7.29 »	1015
MnO	0.18 »	25
NiO	0.03 »	4
MgO	7.70 »	1910
CaO	10.07 »	1795
Na_2O	2.97 »	479
K_2O	1.32 »	140
P_2O_5	0.51 »	36
F_2	0.05 »	13
CO_2	1.11 »	252
V_2O_5	0.05 »	3
H_2O+	1.31 »	727
H_2O-	1.16 »	
	100.37%	
−0	0.02	
Sum:	100.35%	

Norm:

or	7.8	52.4
ab	25.1	
an	19.5	
Σ Sal:		52.4
di	15.9	
hy	6.9	
ol	7.5	
mt	5.4	
cm	(0.02)	
il	5.5	
ap	1.2	
fr	(0.01)	
Σ Fem:		42.4
Sec. Ca CO_3		2.5
V_2O_5		0.1
H_2O		2.5
Sum:		47.5

Analyst: Aulis Heikkinen

Spec. gr. = 3.01 (+23.5°C)

Niggli values:
si = 107½, ti = 5.0, p = 0.6, f_2 = 0.1, co_2 = 3.5, h+ = 10.2, al = 18½, fm = 48, c = 25, alk = 8½, k = 0.23, mg = 0.56, qz = −26½, al−fm' = −29½, al−alk = +10.

C. I. P. W. Classif. — III. 5. 3. 4.
Camptonose
Magma type: essexitic gabbroid
Mol. prop. % of normative feldspars;
Ab:An:Or = 36:53:11
MgO:FeO = 81:19

Rittmann- parameters for nomenclature: Al — 12.16, FM — 27.36, Alk — 5.78, k — 0.23, an — 0.36, ca″ — 6.24. — »Olivine andesine trachy-basalt», i.e. a plutonic counterpart

This doleritic gabbro has been considered a kind of subvolcanic intrusive mass connected with the post-Miocene olivine bearing picritic basalt lavas in the highland nearby. This assumption can scarcely be correct, however, on account of the difference in petrochemical sense. The author is inclined to think of a magmatic connection with the tephritic and basanitic lavas which accompany the R.N. agglomerate formation in many parts of the island.

I do not have enough observations, however, from this region (Barranco de la Mina) to express any definite opinion. When examining the list of the NIGGLI-values (page 375), one will find a rather close resemblance to the basanitoid basalt from Barranco de la Dehesa (anal. no. VIII), from the north coast in the region of Arucas. This magma type is gabbrotheralitic, and I suppose as already mentioned, it belongs to a group of alkaline basalts associated with the R. N. agglomerates.

At Las Lagunetas there is the table-formed ridge Lomo de Enmedio, consisting of a concordant series of flat lying basalt lavas. This flat promontory perhaps only represents an erosion remnant of lavas which were formerly more extended in this upper part of Valle de Guiniguada. — At El Portillo (on the highroad), where Lomo de Enmedio is connected with the nearby central highland by way of a narrow spine (or crest), one can see how the basalts follow uphill in the same flat position forming a series of »*escalones*». No doubt all these basic lavas have been emitted from fissures in the central highland.

If we go down the highroad to the small town of San Mateo (800 m), we first pass across a landscape of many cinder cones of reddish colour. A rather imposing cone, Montaña Cabrera (1 000 m) rises close to San Mateo and seems to belong to this group of cones. They are all as it seems of Quaternary age. The lava emitted from Mont. Cabrera is according to E. JÉRÉMINE (1933) an ankaramite-limburgite, the NIGGLI-values of which are to be found in the list page 375, no. 2 o.

When following the highroad from San Mateo to Teror, one passes close to the east of the volcano mentioned above, and several cuts in basalt lavas, emitted from this volcano, are seen. These lavas did flow down the valley in broad streams. — A sample of a basaltic lava (10) in Barranco de la Mina was taken. Micr. this rock consists of laths of plagioclase, grains of clinopyroxene, of brown hornblende, of sodalite and magnetite, all lying in a trachytoid paste. Optics are:

Plagioclase: ($2V$ not det.) Comp. An/55 (acc. to max. angle of ext. 30°, in the zone $\perp$ M). Opt. char.+
Clinopyroxene: ($2V$ not det.) $c \wedge \gamma = 72°$ (aeg. aug.)

There are also colourless, isotropic patches in the mesostasis between the feldspar laths. The lava may be a tephrite and seems to be older than the basalt streams filling the bottom of the valley.

In the left side of Barranco de la Mina along the highroad to Degollada Lomo El Gallego (and Teror) there are many cuts through dark lava banks in a great succession. One sample (46) from a rather high level above the bottom of the *barranco* shows micr. the composition of a tephrite of the rather current type which accompanies the R. N. agglomerate. Similar lavas were already described from occurrences in the mentioned *degollada*.

Turning back to Barranco de la Mina and following its course downstream one soon arrives to an *angostura* caused by the presence of a cinder cone grown up in the valley. No sample of this cone was taken, there seems, however, to be an olivine basalt of the younger series.

Lower down the valley widens rather suddenly and is now called Barranco de Alonso, receiving Barr. de la Angostura from the left. The whole valley floor is here occupied by basalt lavas forming a kind of plateau dissected by the named *barrancos* in rather deep gorges. This plateau lying between the two canyons is called Lomo del Espino. It is not clear from where these lavas have issued, if from the cone above mentioned, or from more distant vents (in the region of San Mateo?).

On the left side of this lava filled valley stretch there lies a smaller explosion *maar* called Caldera de Pino Santo. It has perforated the R. N. agglomerate formation which composes the ridge known by the name of Lomo de la Humbría.

On the way from Caldera del Pino Santo down to the town Santa Brígida (lying at a high level on the right side of the Guiniguada valley) one crosses the basalt lava fill of the same valley —. When approaching Santa Brígida the valley is getting narrower. Barranco Alonso and Barr. de la Angostura join one another, and from now on the valley has the character of an erosion gorge. There are, however, remnants of the basalts on both sides in the shape of narrow erosion terraces. They rest on a basement of light coloured, trachytic lavas (see later on!).

Before we continue our journey down the valley, we may turn back to San Mateo (800 m) and from here follow the right hand ridge of the valley which plays the role of a watershed to the drainage area of Barranco de Telde and its tributaries in the south.

From San Mateo one has first to follow the highroad which leads to

Tenteniguada and after reaching a pass one has to stroll along the water shed down to the vicinity of Santa Brígida. This ridge consists in the main of the R. N. agglomerate formation with intercalated tephrite lavas (107) resting on old salic lavas.

From the *degollada* Divisoria Bermejal was followed to Santa Brígida. A volcano, Cabeza de Las Palmas (825 m), was passed on the way. No doubt it is contemporaneous with Montaña Cabrera at San Mateo. — The agglomerate masses continue forming the crest of the ridge in a northeasterly direction until one arrives at the Government pump station (for the transfer of the water to the northern plantations). Here there is a break in the R. N. agglomerate and beneath the same a basalt lava bank (no sample) has been exposed. The agglomerate lies immediately above the lava and this may be of tephritic nature.

Divisoria del Bermejal — the long ridge — increases in height towards the vicinity of Santa Brígida, where some high profiles can be studied.

In the precipices facing the *finca* El Vinco not far from the sharp turn of the highroad above S. Brígida there is a sequence as follows.

Starting from the base one finds at first agglomerate banks without basement in sight (nepheline phonolites). Then there are two sheets of basalt (tephrites?) with an intervening tuff layer. Further uphill there is again the R. N. agglomerate in vertical precipices with an intercalated sheet of alk. trachyte. The top sheet is a basalt. The total height of the profile is c. 100 m.

The alk. trachyte (94) is a porphyry with phenocrysts of alk. feldspar in a very fine grained paste of feldspar microlites, pyroxene grains and ore powder. The pyroxene is green and prismatic (aegirine), mostly altered to opacite. Sphene is an accessory constituent.

The top sheet of basalt lava (100) is an olivine basalt. The summit sheet in Morro de la Concepción farther northeast, a hill connected with Divisoria Bermejal is of a similar nature. The sample from here (91) is also an olivine basalt, containing phenocrysts of olivine, largely altered to a yellowish substance, seemingly serpentine. Augite also belongs to the first generation. The groundmass contains plagioclase laths, augite prisms and plenty of magnetite powder. The lava has a composition approaching picrites (or ankaramites). We may suppose that it is the last remnant of an once wide-spread sheet of lavas of the post-Miocene age. The hill in question is a typical erosion 'witness'.

The lower course of the Guiniguada valley from Santa Brígida to Las Palmas

Compared with the upper course this stretch of the valley is considerably narrower; it has changed to a canyon which continues all the way down to the capital. Depth of this canyon is not however, very great.

If we now start our stroll down the valley from the vicinity of Santa Brígida we soon enter L a A n g o s t u r a that reaches to the vicinity of M o n t e L e n t i s c a l. As we have found already, the walls of the canyon expose basalts (ancient fill) forming terraces on both sides. The erosion of the river has, however, reached to a depth below the basalts, and a subjacent pale-coloured trachyte lava has come to show (=the basement rock). One sample of the terrace basalt (13) from the vicinity of Santa Brígida is micr. a rather ordinary olivine basalt with plenty of olivine phenocrysts and smaller crystals of a clinopyroxene and ore grains in a fine- grained groundmass of plagioclase, pyroxene and ore.

The underlying pale-coloured trachytic rock (11) contains micr. clear alk. feldspar phenocrysts (anorthoclase) and prisms of brown hornblende in which are minute grains of zircon with a dark halo. The paste is microgranular, streaky and may be devitrified glass. This lava is certainly not of the old series but it lies above the puzzolane formation (not exposed in this profile). Above the trachyte there follows the R. N. agglomerate formation (in Cuesta de Andújar).

In the right side of the valley, at Monte Lentiscal there are basalts to be seen (opposite the English Hotel), and a sample was taken from here (80). It is of the same ancient fill of the valley. Micr. this rock is likewise a rather ordinary olivine basalt. Optics of the chief mineral are:

$$\text{Olivine (phenocrysts):}\quad 2V\gamma = 85° - 88° \quad (\text{Fa} \sim 10\%)$$

This is the only mineral of the I gen. The groundmass is composed of plagioclase laths, pyroxene and ore. The plagioclase is very sparsely present, augite is on the other hand abundant. Consequently the colour index is high (about 80). Remarkable is the high iron content of this rock; the magnetite grains being in some cases clustered to the olivine phenocrysts. The aspect of this rock is rather fresh. There are no signs of alterations in the olivine crystals.[1] In examining the groundmass under the micr. one will find a rather high frequency of cavities which

[1]) Except a narrow rim of iddingsite.

are filled with fibrous aragonite aggregates or with bundles of zeolites. The rock is picritic in composition as is the case with the basalts farther up the valley bottom. Evidently they all belong to one and the same train of lava floods.

In La Angostura passing the west foot of the cone Morro Cruz del Inglés (which has a crater open to the north) there are vertical walls through the basalt lavas. The left hand wall was climbed and a stroll was made to the ridge in the west, Divisoria de Andújar. On the way up to this ridge (of a middle height) a ground was crossed consisting of dark phonolites (no sample). The ridge itself consists of the R. N. agglomerate formation in rather hard banks which form the flat topped crest line. This was followed to its northern end in the vicinity of San Lorenzo, where it suddenly ends with a steep slope, leading down the puzzolane quarries at this place.

The succession of strata in this northern end is of some interest. One will find here at the base the puzzolane formation which is capped by a trachyte and by a brownish-yellowish tuff layer. This supports a brownish tuff, and the latter forms the basement of huge masses of the R. N. agglomerate.

The trachyte lava (71) shows micr. phenocrysts of alk. feldspar in a glassy matrix of a streamlined texture. There are also flakes of brown mica and scattered grains of a pale-coloured clino-pyroxene forming also clusters; magnetite and apatite are the accessories.

The brownish-yellowish tuff (70) resting on the trachyte bank shows micr. fragments of feldspar and pyroxene and angular pieces of a trachyte lava, all lying in a glassy substance dotted with ore grains. The tuff belongs evidently to the underlying lava.

The topmost tuff layer (69) has been quarried for obtaining building materials. Micr. it has (like the former tuff) a typical pyroclastic texture; the rock is soft and well suitable for the shaping of building stones.

A notable circumstance about this profile is that salic lavas lie between the puzzolane and the R. N. agglomerate. Evidently these salic volcanics belong to a period which followed the great outbursts of the phonolite lavas of the island. These salic products are to be kept aside from the old salic series of lavas and tuffs in other sectors of the island. As was mentioned earlier (page 48), the puzzolane is probably underlaid by phonolitic lavas.

Turning back to the Guiniguada valley, we may examine its sides downwards from La Angostura. At the small village of La Calz a d a, lying in the valley bottom opposite Monte Lentiscal, there is a basalt lava stream (somewhat eroded), perhaps having issued from the subrecent cone of C r u z d e l I n g l é s. The lava can be followed down the valley to the big bend at L a F l o r i d a in the vicinity of Tafira Baja.

The lava that fills the entire bottom of the valley here, has a somewhat weathered surface, and along the flanks there have been incised narrow canyons down to the basement. Although the surface of the lava is smoothed, there are still a number of huge lava blocks, rootless masses that were floated with the lava stream in the surface (»lava ships»). The reader is referred to fig. 1, plate II.

If we examine the nearly vertical profile in the right side of the valley (below Tafira Alta) we will find, from the base upwards the following strata: at first there is a bed of a coarse conglomerate (disclosed by the young canyon at the wall) carrying huge boulders. This is capped by a series of basalt lava beds and intervening tuff layers (to be studied along a path in the Botanical Garden of Tafira (located in the steep slope itself). Samples from here are three (from the base uphill: 108, 111, 90). They are all olivine bearing, picritic basalts. Occasionally the phenocrysts of olivine are much corroded. In the groundmass between the olivine grains we will find plagioclase laths, augite and ore grains (only a trifling amount of the first named component). No doubt these lavas belong to the post-Miocene effusions.

The uppermost of the lava sheets is capped with pyroclastics, by weathering converted into a fertile soil. These ejecta may have been strewn into the surroundings from the crater of a solitary cone in Tafira (of Quaternary age). This cone has grown up on the base formed by the above mentioned basalt lava sheet that seems to have a wide extension.

On the left side of the Guiniguada valley, opposite Monte Lentiscal there rises C u e s t a d e A n d ú j a r (the north end). The top sheet of this ridge consists of the R. N. agglomerate resting on salic lavas and these on puzzolane. This last named deposit is of great thickness and may correspond to the puzzolane at S a n L o r e n z o not far to the west.

From the northern end of Andújar the Las Palmas' gravel covered terrace begins, forming the left side of the valley right down to the city. The right side is on the other hand formed by four basalt lava sheets resting on the stratified conglomerate with heavy boulders. This conglomerate cannot be identical with the R. N. agglomerate but must correspond to the superficial terrace conglomerate of a post-Miocene age — i.e.

to the conglomerate lying at higher levels in the opposite side of the valley. The basalt lava beds belong to the post-Miocene effusions.

The lowest course of the valley will be described in the next chapter dealing with the Las Palmas' terrace.

* *
*

Some general aspects of the Guiniguada valley. — This more than 20 km long valley train offers many interesting geological details for a closer study. It can be stated that the original valley was eroded in a thick sheet of the R. N. agglomerate formation which perhaps covered the major part of this northeastern sector of the island. The river erosion also worked down into the basement of this formation, consisting of the nepheline phonolitic lava and tuff series, — in places also into the underlying rhyolitic — trachytic formation. This river erosion was going on at a time when the heavy masses of coarse gravel material was deposited over the Miocene Las Palmas' terrace, at that time (in Pliocene) being a coastal flat. The material carried down the valley train consisted of an astonishingly coarse material, and the composition of all the boulders and stones was phonolitic, demonstrated already by L. von Buch (1825). Consequently, the Guiniguada valley was an important highway for the transport of incredible masses of boulder material traced from the central highland of the island. But such a gigantic transport demanded a steeper gradient than what is now the case, and one has to imagine a sudden rise of the island in that period.

Then the emissions of the very fluid basaltic lavas started, — forming vast sheets in the slopes. These lavas are all of picrite basaltic kind, and their floods filled the bottoms of many of the *barrancos* belonging to the drainage pattern of this sector. The Guiniguada valley was also used by these currents, as we have seen. Later on erosion has incised a canyon in this bottom fill, and in this way lava terraces have been formed. Ultimately young basalt lavas ran down the new canyon from some cinder cones on the right side of the valley.

The region of Bandama, La Atalaya and Barranco de San Roque

This rather limited area, crowned with a number of more modern volcanic cones and with a spectacular explosion hollow, is an attraction of the first order for the visiting geologist as well as for the ordinary tourist. The area lies only about 10 km distant from Las Palmas and can easily be reached by car, even up to the summit of the Bandama cinder cone, from where there is a strange outlook in all directions.

Caldera de Bandama, the Bandama volcano and La Atalaya

Caldera de Bandama is not really a *caldera* in the strict sense of the word; it is far too small to be called that kind of volcanic depression. The diameter NW—SE is only c. 870 m, its depth is 180 m. The rim of the hollow lies c. 400 m above the sea level. Immediately to the NW of the hollow there rises the Bandama volcano (660 m above the sea), a coke black cone without any crater in its top.

The author has arrived to the conclusion the Bandama depression may be called an explosion crater or more precisely a *maar*. The reason for this opinion will become clear from the characteristics told in the following.

The Bandama depression was first studied by L. von Buch (1825), and this explorer found it to be a very well rounded hollow lowered into the rock ground consisting of conglomerate, trachyte, tuff and a basalt sheet intercalated. The rim is crowned with stratified masses of small stones, i.e. lapillis (cf. with the fig. 3). He found the formation to have a great resemblance to the Mid-Italian craters of Nemi and Lago di Albano in Latium. This seems to have been a very reasonable comparison.

Several geologists have later on visited this curious deep hollow, such as S. Calderón y Arana (1880), L. Fernández Navarro (1925)

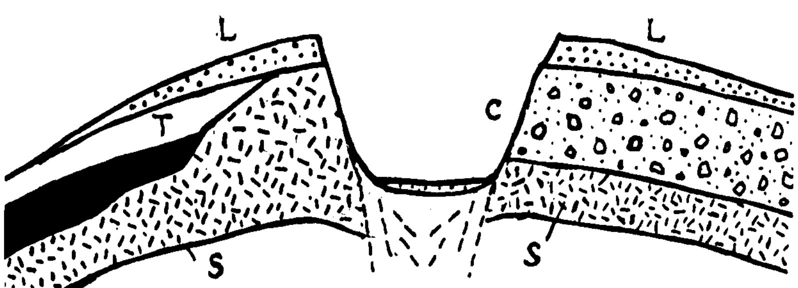


Fig. 3. Caldera de Bandama (region of Atalaya) according to L. von Buch (1825). L — explosion ejecta of salic material. T — white tuff. C — conglomerate. Black — intervening basalt lava. S — salic lavas (rhyolite (?)). Unsigned basement — phonolites (?)

and J. BOURCART (1937) and ultimately F. MACAU VILAR (1959). The former three have expressed one and the same opinion: Bandama is an explosion crater. MACAU VILAR, on the other hand, has related the origin of the hollow to the outbursts of the near lying Bandama volcano: the hollow is the immediate result of a withdrawal of lava from the basement of the present depression, and this is in the reality a small 'collapse caldera'.

In examining the rims of the hollow, I have found them covered with layers of a small-stone conglomerate of chiefly salic lava types. The outward inclination of c. 10° is well perceptible. It is evident that these deposits settled around, when the hollow was opened by the explosion blasts (in fact there were several blasts judging from the stratification of the conglomerate). We may suppose a rock ground consisting of salic lavas and the R. N. agglomerate was during these acts perforated. These rocks may correspond to VON BUCH's »conglomerate» and »trachyte». The cause of the explosions may be sought in the levels, where the island's basal ground water is situated (c. 220 m below the present caldera-bottom). It is possible that molten basalt lavas have at some times brought about a vaporization of the ground water, and pressure has cleared an escape of the steam. These lavas in the underground did not have any relation to the lavas and slags which piled up the cone of Bandama nearby, but to the older Quaternary volcanoes in the surroundings. When the Bandama cone was in activity, the Bandama »caldera» already existed, as it can be seen very clearly: the walls of the »caldera» are weathered, whereas the cone is fresh, with glassy, coke-black slags and lapilli that have slided down right to the bottom of the »caldera». The cone is of the same age as those on the side of Jinámar.

In times preceding the outbursts of the Bandama volcano there was much volcanic activity in the surroundings, as is manifested by the rather imposing cones Montaña de Atalaya, Montaña de Tafira, Montaña Pelada and Lomo del Viento etc. — The Bandama cone has ejected masses of slags and lapillis also over the ridges in the south of the site, as one may find when following the road from Atalaya to San Roque. — All the volcanoes enumerated (older and more recent) have been piled up on a basement consisting of the R. N. agglomerate, well exposed in the sides of the canyon of Las Goteras.

We may now look at some geological details in the region and briefly describe samples collected (25, 60a, 87, 89, 91, 98, 99, 110, 117, 153).

The lowest members in the series of the subjacent ground apparently consist of phonolites (cf. with La Laja). Exposures of such rocks are seen in Monte Lentiscal. From this level (300 m) they drop rather suddenly to the coast in the east. Above the phonolite there are banks of the R. N. agglomerate. This formation is here of a great thickness. The sample from Los Toscones (60a) is micr. a vitrophyre with a rather pyroclastic texture. It contains fragments of alk. feldspar, of plagioclase and grains of a pyroxene, all mingled with fragments of alien lava rocks. They lie in a glassy matrix containing microlites of feldspar. There are also numerous small sphaerolites, a colourless isotropic substance surrounded by a dark shell. Sphene is an accessory constituent. The lava bank which appears as steep cliffs by the road is apparently capped by the R. N. agglomerate.

Barranco de las Goteras, which limits the Bandama-caldera encircling wall in the south, shows great exposures of the yellowish puzzolane in its bottom. This is overlaid by the R. N. agglomerate, and this in its turn by basalts lavas and lapillis extending over the ridge of El Palmital (right side of the mentioned *barranco*).

Along the highroad which runs from La Atalaya down to this *barranco* and then turns up along the right side of it there are first enormous exposures of the R. N. agglomerate formation into which this stretch of the *barranco* has been incised. The formation is covered by a series of basaltic lavas and tuffs appearing in long cuts at the side of the highroad. A sample of the basalt (99) is a tephrite containing phenocrysts of plagioclase, augite and sparingly olivine (rather altered to a brownish subst.). The groundmass consists chiefly of augite, ore and a colourless subst. with weak birefr. (zeolite).

These basic lavas belong no doubt to the agglomerate formation, an association very common in the island.

These tephritic lavas are in the crest, in the right side of the gorge of Las Goteras capped by a lava of a different nature, being more salic in composition (89). Micr. one will find phenocrysts of augite and brown hornblende (with a dark corrosion rim), feldspar laths (clear) and magneite crystals. They all lie in a paste with feldspar, aegirine and ore powder. Sodalite grains are also present. Texture is porphyritic, not fluidal. The optics of the phenocrysts are:

Plagioclase: $2V\gamma = 73°$, Ext. angle $\alpha' \wedge (010) = 33°$ (max.) Comp.: An/55 ± 2

Clinopyroxene: $2V\gamma = 55°$, $c \wedge \gamma = 56°$ (Ti: augite)
Hornblende: $c \wedge \gamma = 19°$. Pleochr.: α-yellow, γ-brown

This may be a transition type between tephrite and phonolite. The rock is quarried on a small scale.

A lava bank by the road to San Roque near Monte Lentiscal (altitude c. 300 m) is dark, fine-grained (98). Micr. it is a rather light type, sparingly containing phenocrysts of clinopyroxene and brown hornblende, sodalite and laths of a plagioclase. Sphene also occurs. These components lie embedded in a very fine-grained matrix of short feldspar laths mingled with a dark mineral (cryptocrystalline) and iron ore powder. Stray magnetite crystals are also to be seen. Apatite is an accessory constituent. The colour ratio of the rock is appr. 20 —. The optics of the chief minerals are:

Plagioclase:	$2V\gamma = 79°$, $\gamma \wedge (010) = 35°$. (det. on 3 ind.) Comp.: An/60
Clinopyroxene:	$2V\gamma = 69°$, $c \wedge \gamma = 45°$ (det. on 2 ind.) — (augite with an amount of aeg. mol.)
Brown hornblende:	($2V$ not det.), $c \wedge \gamma = 8°$. (α-yellow, γ-brown, rimmed with sec. min.)

This lava may belong to the family of *tephritic nepheline* (sodalite) *phonolites*, class V (nomenclature by RITTMANN). The comp. of the feldspar microlites in the paste may be more alkaline. — The lava bank lies under a thick sheet of the R. N. agglomerate which in turn is capped by olivine basalt.

Degollada Bermejal — Barranco de San Roque — Telde

In the upper region above 600 m there seems to be mostly basaltic lavas (no sample), covered on the surface by a red lateritic soil. Lower down there is the tephritic lava described above, and we then reach extensive fields covered with brown and black lapilli (from a volcano nearby). Under this cover there are rock surfaces of a basalt lava (153). It is an olivine basalt containing phenocrysts of augite (plenty) and of olivine, the latter surrounded by a brown fringe. Magnetite crystals are associated with these minerals. The paste is very fine-grained and rich in augite and also magnetite, whereas microlites of feldspar are restricted. The composition is that of a picritic basalt, a common type met with among the post-Miocene lavas in the eastern declivities of the island.

Barranco de San Roque was not sufficiently investigated. There is a cinder cone half way up the *barranco* called El Morro. The outbursts from this vent have strewn the surroundings with much lapilli and ashmaterial, i.e. over the slopes in the vicinity of La Solana.

The lower course of Barranco de San Roque widens considerably with the approach to Telde, and the bottom is filled with gravels. There are many dry, braided water courses in this train. The valley seems to have been eroded into the weak substratum of the puzzolane (*canto blanco*) formation. This rock appears just outside the city of Telde forming the core of the ridge El Espolón. In a great cut at Hoya de las Canteras there are numerous caves dug by the aborigines in pre-Spanish time.

J. BOURCART (1937) mentions the occurrence of a »rhyolite» (belonging to the older series) in the middle course of Barranco de San Roque. According to his geological map, this place is somewhat to the east of the village of San Roque, visible as an eminence in the ground which is generally covered here by younger basalt lavas.

The Las Palmas' terrace

The northeastern part of the island, with the exception of La Isleta (the peninsula), consists of a relatively low and smooth ground which has the shape of a broad, flattened cone of accumulation material i.e. a kind of elevated »delta». It suddenly ends at the sea shore with a steep cliff of c. 80—100 m height, and this is fringed by a low sandy beach or a shore platform with a gentle inclination to the sea. The inner limit of this platform lies c. 15 m above the sea. On this flat the city of Las Palmas extends for several km along the shore. — The great cone (the »delta») is furrowed by a number of *barrancos* roughly arranged into a radiating pattern. The main erosion channel is that of Barranco Guiniguada which has been dealt with in more detail in a preceding chapter. Marine abrasion in Quaternary time has worked the above mentioned escarpment, and it is evident that the terrace has formerly had a much wider extension seawards. The apex of the great cone lies in the region of Tafira Alta (Monte Lentiscal) c. 300 m above the sea level. The limits of the flanks of the »delta»-fan are difficult to fix, but fig. 4 may give an approximate idea of the extension. The total area of the terrace comproses 25—30 sq. km. It represents a somewhat monotonous and

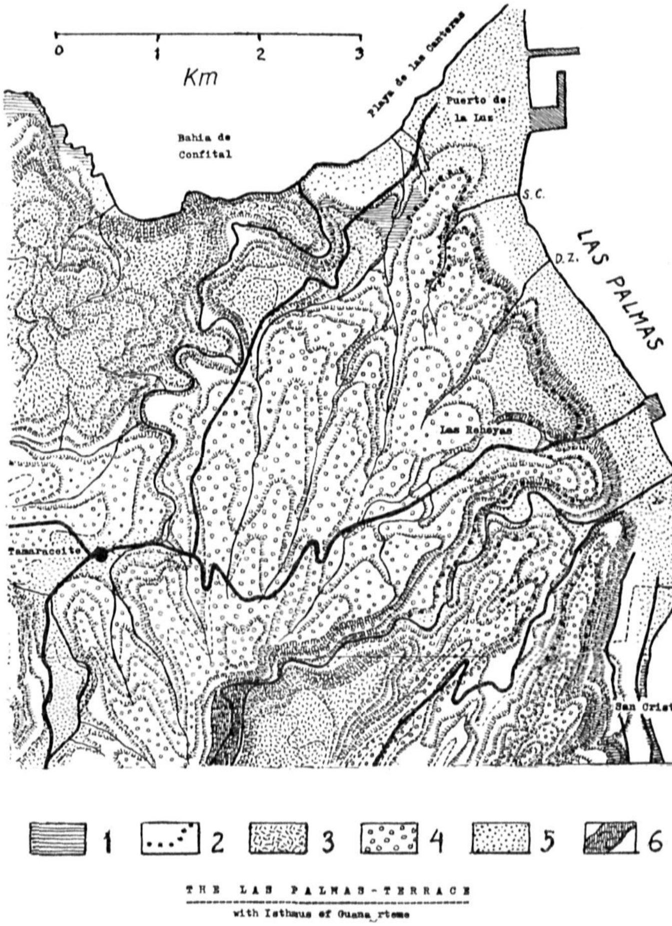


Fig. 4. 1 — phonolite lavas (S. Cristóbal), 2 — fossil-bearing horizon, 3 — olivine basalt lavas, 4 — boulder top-conglomerate, 5 — Quaternary beach sand, 6 — young olivine basalt lava stream (in the Guiniguada valley).

desert — like landscape, in spite of the fact that it forms the immediate surroundings to a big and flourishing city.

The Las Palmas' terrace is well known among the geologists chiefly by its content of a fossil marine shell fauna in some of its calcareous layers. This fauna is from the Miocene (Vindobonian) age. It is one of the very rare occurrences of fossil bearing beds in the Canaries, allowing one to some extent to determine the age of the volcanic products related to the terrace.

Among earlier investigators who have examined the terrace (or more properly: the stratigraphy of the same) including the marine fossil fauna found here we should mention at first L. von Buch, then P. Barker Webb and Sabin Berthelot, Charles Lyell, S. Calderón y Arana, A. Rothpletz and V. Simonelli, L. Fernández Navarro, J. Bourcart and finally M. Martel Sangil. The present author has made no further study of the matters involved in the stratigraphy. In later time T. Bravo has kindly given me many details and also profile sketches to complete earlier observations. These profiles will be dealt with in the following.

To get an idea of the stratigraphy in a more comprehensive way I shall describe the succession of the strata in various sectors of the escarpment, starting from the northwestern corner and then following the escarpment of the terrace all the way to the region south of Las Palmas.

Description of localities

If we start at the mouth of Barranco de Tenoya (see the small topographical-geological map of the terrace area, fig. 4!), we will find the edge of the terrace already well formed. Here its upper parts, however, are not of sedimentary material but of basalt lavas. They are remnants of an once vast basalt lava flow (or flows). The lavas are of olivine basalt. These lavas rest on agglomerates apparently of Miocene age. At the sea shore there are again banks of lavas, this time of phonolites.

In the cape of El Rincón jutting out into the sea at the extreme western end of Bahía del Confital, there is the following profile (Fig. 5): At

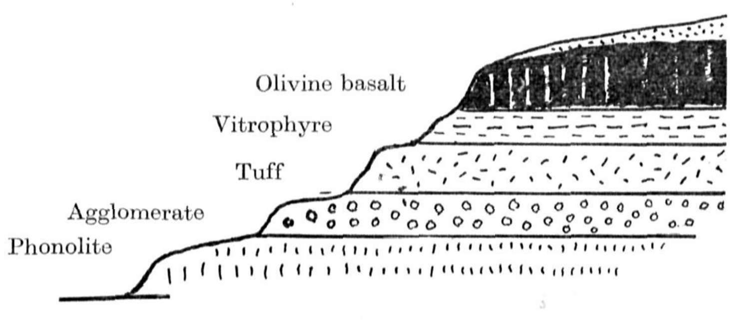


Fig. 5. Coast profile W of Bahía del Confital, at El Rincón. The tuff is quarried.

the sea shore there is a dark platy phonolite lava (quarried) of unknown thickness. This lava is capped by a thick layer of agglomerate, and this in turn by a brown tuff (59). This has micr. a typical pyroclastic texture containing also lithophyses. — The agglomerate including the tuff is in turn capped by a lava bank of a trachyphonolite (63), dark in hand specimen. Micr. it displays a trachytoid texture with fragments of a clear alk. feldspar and also crystals of clinopyroxene that seems to be diopside (with an ext. angle on (010) $c \wedge \gamma = 45°$). There are abundant pores in the groundmass, in which the interstices between the feldspar laths are of a glassy substance.

This decidedly salic lava is covered by sheets of the large basalt *meseta* mentioned above (60, 61). Micr. one finds phenocrysts of olivine, in no. 60 almost completely altered to iddingsite, whereas in no. 61 the same mineral is rather clear. Euhedral crystals of augite also occur in the I generation of components. The groundmass shows a basaltic texture with laths of plagioclase, grains of augite and magnetite. The optics of the phenocrysts (in 61) are:

Olivine: $2V\gamma = 86°$ (corroded forms, Fa = 10%)
Augite: $2V\gamma = 69°$, $c \wedge \gamma = 41°$ (in some grains zonal)

The lava may be designated a picritic olivine basalt.

If we proceed along the coast, i.e. along the south shore of Bahía del Confital, using the road that leads to Puerto de La Luz, we approach the steep cliff of Cabeza del Morro (175 m) facing the sea. The geological profile has been studied earlier by F. MACAU VILAR (1958), later on by myself in company with T. BRAVO. The succession of strata is as follows:

At the water's edge one finds a kind of *canto blanco* of a thickness that cannot be discovered without borings. The road runs along the same bed. The next bank in the profile is a reddish porphyry of type 63 (described above). The bank is slightly inclined to the east (owing to fault movements?). This lava is capped by a sedimentary complex composed of conglomerate and sandstone with a puzzolane layer at the base. All these strata obviously belong to the Miocene terrace formation (kinds of beach sediments?). The series is overlaid by a scoriaceous lava of a basalt composition (no sample from here) which seems to have moved from west to east (?). If one climbs the escarpment higher up, other basalt lava banks in a flat position (nearer the top, intercalated with a conglomerate layer) will be found.

Farther along the road there is much scree covering the strata on the slopes. The upper edge, however, always consists of basalt, whereas down at the base *canto blanco* is seen for a while.

The ascent of the road to Tamaraceite. — Leaving the outskirts of Puerto de la Luz and heading for Tamaraceite, one has to climb a *cuesta* where exposures are to be found. At the base there is a lava bank of a hauyne phonolite (88 d) showing micr. phenocrysts of alk. feldspar and crystals of hauyne with a brownish marginal zone. The feldspar is in Karlsbad twins (opt. char. —. ind. of refr. $< 1.54 =$ sanidine). The paste consists of feldspar laths. pyroxene and iron ore grains —. This lava is capped by a basalt bed (88 c) showing micr. laths of albite-twinned plagioclase, augite and ilmenite flakes and also grains of olivine. The augite also appears as large euhedral crystals. It shows ext. angle on (010) $c \wedge \gamma = 45°$. The olivine is marginally altered to iddingsite (the small grains completely changed). This lava is capped by a tuff of considerable thickness. Real sedimentary strata seem to be absent from this profile; they may be met at deeper levels than in the *cuesta*. It seems that the lower ground at the foot of the *cuesta*, stretching northward into the city of Puerto de La Luz consists of the sedimentary members of the terrace formation, covered on the surface with drifting, calcareous sand, the same sand that lies in the Isthmus of Guanarteme (see below!).

After climbing the *cuesta* and advancing along the road to Tamaraceite one has to follow the left side of Barranco del Cardón, where a basalt lava appears in the side profiles (88 a), consisting of olivine basalt with olivine (altered), augite, plagioclase and flaky ilmenite. The texture is doleritic, of a coarser grain than in the preceding basalt. The amount of augite seems to exceed that of olivine. On the other hand, plagioclase is an important component, the type is richer in that mineral than is usual among the post-Miocene lavas in general. — The basalt is capped by a grayish tuff and this in turn by a superficial sheet of lime-cemented gravels. The basalt is quarried. Perhaps the *barranco* discloses Miocene sedimentary strata in its deeper parts.

E. Jérémine (1933) has described the occurrence of a hauyne bearing phonolite from Barranco de Don Zoilo (vicinity of Barrio Schamann). The present author has been unable to locate this occurrence. According to her this lava is an ordanchite with plagioclase as the dominating feldspar (An/40—50). The paste on the other hand, contains an oligoclase (An/20). Of mafic constituents, there are brown hornblende (corroded), augite and sphene, with apatite and ore as accessories. This rock may belong to the same group as the phonolites exposed in the *cuesta* farther northwest towards the bay of Confital (sample 88 d).

Since there are no data about the stratigraphy exposed in Barranco de Don Zoilo, the position of the lava sheet is unknown.

Barranco de Santa Catalina. — At the mouth of this rather short *barranco* cut into the edge of the Las Palmas' terrace there is the geological profile earlier described by L. FERNÁNDEZ NAVARRO (1925) and illustrated by a diagram. According to him the sequence of beds is as follows: at the base is a kind of basalt lava of unknown thickness; it is capped by a littoral sandstone. Then there follows a thick layer of *canto blanco* and a fine-grained sandstone, the latter containing a fossil littoral fauna. It is surmounted by a reddish earth which contains fossil wood fragments and also shells of land snails. At the top there is a layer of calcareous, fine-grained drifting sand which has migrated over the ground from the north.

Road cuts have recently been opened along the new autostrada which ascends from the city to Barrio Schamann, situated at the upper edge of the terrace. Here strata are disclosed. At my request T. BRAVO has sent me a profile sketch of this sector of the terrace. (Fig. 6). The plane of the profile is oriented c. northeast—southwest. If we start with our scrutiny at the base there appears at first a massive puzzolane, layer, the bottom of which is invisible. Uphill in the escarpment it becomes somewhat stratified. Then there follows a layer which encloses heavy, angular boulders of phonolite lavas. In the hanging beds there is an alternation between sand and gravels of varying kinds up to the fossiliferous littoral beds: a marine shell fauna in layers which alternate with layers of *Litothamnium* (of Miocene age). Further up in the profile we find stratified, coarse gravels with boulders that were embedded in the Roque Nublo agglomerate. These layers are topped with superficial limestone *costra*. The total height of the profile from the foot (Quaternary marine limit) is 55 m.

This interesting profile reveals a changing history involving migrations of the shore line and other events. The lowest layer, the puzzolane or *canto blanco*, was deposited from mud-streams when the island lay much higher than now. Then a subsidence occurred, and the sea invaded this coastal sector, first depositing littoral sands and gravels. Then, with the deepening of the shore waters, fossils were accumulated; then regression commenced again with a general rise of the island (in the Pliocene

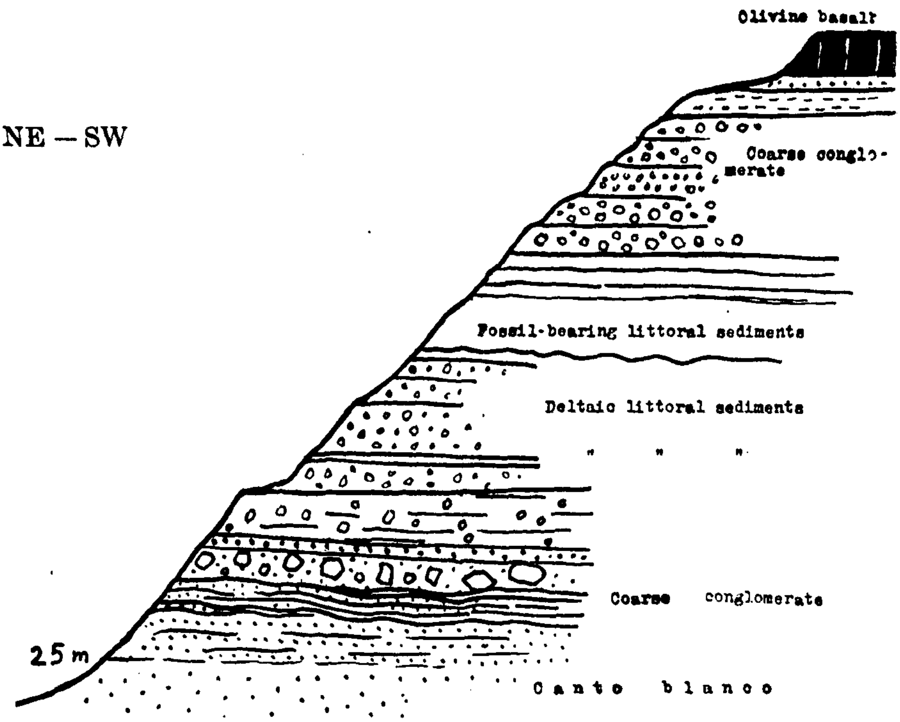


Fig. 6. A section across the strata of the Las Palmas' terrace in the city of L. P. according to T. Bravo.

age?) and much coarse material was deposited in the shape of gravel sheets. — These layers were extended much farther seawards than now, of course; later marine abrasion has destroyed much of the deposists and pushed back the escarpment (in the Quaternary period).

If we go round the cape from where the profile above has been drawn, we enter

B a r r a n c o d e L a s M a t a s. — This ends with a rather open cross-profile in the escarpment. Bravo has sent to me a stratigr.-profile of this *barranco*-mouth at L a s R e h o y a s. From the same locality (left side of the *barranco*) Rothpletz and Simonelli (1890) have gathered their richest harvest of the Miocene marine shell fauna. I myself have easily found beautiful specimens of *Ostraea* etc. — Bravo's stratigraphic sequence is here communicated (from base to top):

Lowest sheet is of a gravel conglomerate without any 'Roque Nublo material' among the pebbles. It is a pre-Miocene gravel deposit. In the middle part of the profile there appears the fossil bearing limestone (Miocene) capped by a bank of »phonolite» lava (no sample available).

The list of fossils found in this limestone of Las Rehoyas will not be quoted here; the reader is referred to the paper by ROTHPLETZ & SIMONELLI. A bank of *Litothamnium* limestone that lies above the fossil fauna beds, can be followed along the escarpment for a considerable distance. The fossil horizon lies according to BRAVO c. 65 m above sea leval.

The uppermost bank in the Las Rehoyas-profile consists of basalt (88) of considerable thickness. Micr. this rock is a typical olivine basalt with phenocrysts of olivine and augite and also plagioclase laths in a paste of augite and ore and a colourless, isotropic subst. The optics of the chief minerals are:

Plagioclase:	$2V\gamma = 80°$ (average of 5 det.)
	$\alpha' \wedge (010) = 34°$. Comp.; An/60$\pm$2%
Pyroxene:	$2V\gamma = 59°$, $c \wedge \gamma = 52°$ (Ti-augite)
Olivine:	$2V\alpha = \sim 89°$ (Fa = 23$\pm$2%)

The type differs somewhat from the basalt in the *cuesta* to the south of Puerto de La Luz, being of a more picritic kind.

L. FERNÁNDEZ NAVARRO (1925) described the same profile and in his sequence of strata the lowest bed is a puzzolane or *canto blanco* (of unknown thickness). This is overlaid by a conglomerate bed (the same mentioned by BRAVO). Above it there lie the fossil bearing littoral beds, the *Litothamnium* limestone and so on.

At a short distance to the south we arrive to the mouth of Barranco Guiniguada. — This is the main erosion valley crossing the terrace. Just before its mouth (in the city) it receives Barranco Seco from the right. I myself have to some extent examined the lowest stretch of this *barranco*; later on I have received complementary data from T. BRAVO (including a cross-profile drawing).

In the *barranco*-bottom theie lies puzzolane, cream-coloured of unknown thickness. No stratification in the mass is perceptible. The covering layer is a conglomerate separated from the former by an erosion surface. The conglomerate is not homogeneous, but alternates with layers of a platy sandstone. No doubt they are littoral sediments. At a level of c. 90 m above the sea there is a limestone bank containing a fossil marine shell fauna corresponding to that of the fossil bearing bed in

Barranco de Las Matas. A layer of calcareous algae (*Litothamnium*) follows next and this is topped by huge masses of very coarse gravel material containing boulders derived from the R. N. agglomerate formation.

The puzzolane or *canto blanco* can be seen in clean vertical (artificial) exposures at the side of the highroad which climbs Barranco Seco on the way to Tafira Baja (a locality not far from the city's water works).

When following the highroad up to Tafira in southwesterly direction one soon arrives to the upper, plain surface of the terrace. This is covered with lime-*tosca* which has cemented the underlying gravels. The aspect of the landscape in this upland region is desert-like.

Farther uphill in Tafira Alta one approaches the volcanic cone of Taffra. The plain ground is here underlaid by basalt lavas which have been described earlier (page 57). When entering this lava plain with its superimposed volcano one has left the terrace in proper sense. From now on the ground continually rises in southwesterly direction towards Santa Brígida.

Coast profiles from La Vegueta (L.P.) to Jinámar. — On this stretch along the east coast there are plenty of opportunities to study the stratigraphy of the terrace, exposed as it is in the sea cliffs as well as in some *barranco* mouths. One soon finds that the geological conditions have changed considerably.

Along the highway to Jinámar (and Telde) we have always the coast escarpment to the right. It is here fringed by a shore platform tilted seawards and ending in a rocky shore; (vicinity of San Cristóbal). — Here the rocks consist of a phonolite (45). It is of the rather common type, nepheline and aegirine bearing and with the trachytoid texture.

This lava exposed at the water's edge is inland covered by a reddish earth. In the background there rises a ledge with almost vertical walls. It is an outcrop of a mighty lava bank with columnar jointings, in a flat position, although it is rising somewhat to the north (and it finally disappears in this direction). The lava rests on red tuff layers. These have been calcined by the heat of the hanging lava. It is evident that the same lava bank formerly continued far to the east, where now the ocean rollers attack the shoals, a result of a powerful marine abrasion.

Some samples of this lava rock (149, 150) were examined under the micr. They show a typical trachytoid texture like that of the rock at San Cristóbal nearby. The rock contains phenocrysts of alk. feldspar and of a clinopyroxene, greenish, euhedral. Nepheline prisms and aegirine are strewn in the groundmass, also magnetite. Optics of the chief minerals are:

Alk. feldspar: $2V\alpha = 60°$ (Karlsbad twins, anorthoclase)
Clinopyroxene: $2V\gamma = 72,°$ $c \wedge \gamma = 46°$ (aegirine augite)

Of sec. substances there are patches of calcite and also epidote in the paste.

The phonolite bank is capped by a layer of *canto blanco*. This is in turn overlaid by a bed of well worn pebbles consolidated to a conglomerate by lime infiltration. It is evidently a beach gravel now lying c. 50 m above the sea. This layer is covered by a basalt lava sheet, an olivine basalt, containing megascop. visible phenocrysts of olivine and augite. Uphill along the escarpment there follow conglomerate masses of large pebbles, apparently of the same kind appearing farther north in the upper parts of the terrace. The conglomerate seems to continue with growing altitude above the sea far to the west, it can be followed to the vicinity of Tafira Alta.

Farther south along the highway which leads to Jinámar this passes through a tunnel across the above mentioned thick phonolite bank. At the southern entrance to the tunnel there are exposures of *canto blanco* of great thickness, lying above the phonolite. The latter dips under a low angle to the south, and finally it disappears under the sea level. — The *canto blanco* is covered by the top conglomerate roughly stratified. This can be followed all the way to the open ground of Jinámar, where the slopes are furrowed into a veritable 'bad land'. In Jinámar we have a kind of depression partly filled with young lavas.

In Lomo del Capón a ridge belonging to the terrace to the north of Jinámar there is a small *barranco* disclosing a yellowish-white, soft limestone, or more exactly a calcareous silt, hardened to a rock. Judging from its cross-bedding and its fine grain, this deposit must be of eolic origin (and of Miocene age). It is quarried for a kiln in the vicinity. The deposit is covered by the usual coarse top-conglomerate.

On the inner side of the broad embayment, in which Jinámar is situated, rocks of nepheline phonolite appear on the road from Marzagán to Tafira Alta. These lava banks may correspond to the phonolites seen at the highway on the east coast at La Laja.

After passing the young volcanoes at Jinámar and heading south along the coast highway into the direction of Telde one soon reaches the spine of a long ridge crossed by the road in a cut. Here old basalts[1]) are exposed. Then to the right there are long exposures of a *canto blanco* all the way to the edge of Barranco de San Roque opposite Telde. Here the Las Palmas' terrace can be considered to terminate in southerly direction.

When examining the upper surface of the terrace from the coast to the vicinity of Tafira Alta—El Monte, one will almost everywhere find the coarse conglomerate, lime-cemented or covered with a crust of *tosca*. The general inclination is towards the sea (some degrees only). The radiating pattern of the *barrancos* which dissect the plain indicates its flattened conical shape. Whereas the edge at the coast is no more than about 100 m (and lower), the surface rises to about 300 m in the vicinity of El Monte. It can be considered to have its apex here.

* *
*

General features of the stratigraphy. — If we now take a look at the inner composition of the terrace, the areal extension of which is at least 30 sq. km, we will find (as regards the many *barranco* cuts in the peripherical parts) that there will be the following sequence:

At the base there lies a phonolite formation which is mostly invisible, but which in the SE. rises to a considerable height. It is the same when going west along the northern escarpment. At Puerto de la Luz there is also an exposure of phonolite at the foot of the *cuesta*.

The salic lava in question is overlaid by a thick sheet of *canto blanco*, the material of which belongs to the phonolite eruptions. Upward in the profile this *canto blanco* is followed by a conglomerate and sandstone of a littoral nature (delta sediments!) —. There then follow the interesting fossiliferous strata with marine shell fauna and an agglomeration of calcareous algal concretions of Miocene age. These are capped by littoral sandstone.

Higher up in the profile there appear the very coarse conglomerate masses which cover the entire area of the terrace. The limit towards underlying soft — in parts fine grained — littoral deposits is a surface of erosion. In the steep cuts of the escarpment one can see how the top gravel sheet masses have completely buried the old *barrancos*

[1]) i. e. of post-Miocene age.

and depressions. We have here a hiatus in the sedimentation process. Whereas the underlying beds are well stratified and mostly of finer grain — sometimes alternating with conglomerate beds of well rounded single — the top-conglomerate is a veritable jumble of sub-angular blocks and stones, some of the former of spectacular sizes. These boulders consist exclusively of phonolitic material, not of basalts.

The conditions point to the existence of four different stages of terrace formation: 1) a period of positive shore migration (in Miocene time) with a gradual delta-sedimentation, the material having been carried to the shore by rivers. This period of slow sinking was followed by 2) emersion of the sediments above the sea, and they were eroded in *barrancos*; 3) then there occurred (in the Pliocene period?) avalanches of coarse volcanic material born somewhere in the highland behind the terrace. This stony jumble was spread as a thick sheet out over the (furrowed) delta deposits. This spreading reached far beyound the present shore line; 4) later on, in the Quaternary period, the shore line was worked back, and a shore platform was formed in front of the escarpment. With the emersion in late-Quaternary and sub-Recent time the sandy beach was left dry and this shore platform — with a gentle grade to the sea — has been used in the planning of the city of Las Palmas. At the same time also the Isthmus of Guanarteme was left dry, giving room for the building of the port city of La Luz.

In the process of accumulations there was also a participation of lava inundations, first before the deposition of the puzzolane (i.e. in the pre-terrace period) and later on after the puzzolane and beach gravels had been laid down. Still later on lavas flooded the terrace again, chiefly in its border parts in the south and in the northwest. The first mentioned lavas are phonolites, whereas all the later outpourings consist of olivine basalt lavas. Finally there are the Quaternary to sub-Recent emissions of olivine basalt lavas along the cross-going *barrancos* and in the depression of Jinámar. Most potent are the lava streams in the Guiniguada valley.

The reader is referred to the small topographic-geologic map of the terrace area, fig. 4.

More recently the coarse angular gravels of the top sheet of the terrace has been impregnated with lime (*tosca blanca*), the result of semidesert climatic conditions. The lime solutions have risen from below (as bicarbonate), and with the escape of the carbon dioxide at the surface lime carbonate has precipitated, partly as cement between the lava fragments, partly as coherent sheets (in the surface). This whitish cover gives the surroundings of the city an almost desolate aspect. The superficial *tosca blanca* can be followed inland for many kilometres, i.e. until we meet with the reddish soil of the higher lying volcanic ground. The efflorescence of the lime carbonate in the terrace surface may be due to the presence of the *litothamnium*-layers in the interior parts of the terrace and on the shell beds close to them.

The phenomenon of *tosca blanca* is in Grand Canary not so common as in the eastern islands, but in them the primary source of lime is far more abundantly present — in the basalts that constitute the major part of the underlying rock ground.

The Las Palmas' terrace is in fact a remarkable feature in the geologic structure of the island. In no other sectors there are any such mighty accumulations of detrital products as here (cf. with the geological map!) Only in the far south — arround the lower course of Barranco de Arguineguín we may find another accumulation, chiefly consisting of gravel material (resting on puzzolane). This also is in an uplifted position. — We may in a later chapter (in Part II) devote some attention to this problem of limited coastal accumulations.

Istmo de Guanarteme

As has been mentioned, the peninsula of La Isleta, in Quaternary time an island, has been connected to the mainland by a low isthmus of sand — called Istmo de Guanarteme. Its narrowest part lies close to La Isleta, measuring only c. 400 m here. Southwards, the isthmus widens rather suddenly and rises to join the *cuesta* of the Las Palmas' terrace. Here an area of drifting sand — a fine-grained, whitish calcareous sand — is met with; — most of the other parts of the isthmus is covered by the blocks of the city of Puerto de la Luz.

It was stated already by VON BUCH (1825) that the sand here is oolithic in nature. Every one of the rounded grains has a core of a fragment of a calcareous shell of marine organisms, and it has consequently nothing to do with volcanic »ashes».

The composition of the basement of the isthmus is not visible, except to a small extent in some beach profiles in the west — at Playa de Las Canteras. — Here, at the end of Calle de Nicolás Estébanez there is a low abrasion escarpment, attacked by the surf at high tide. It consists of a dark calcareous sandstone, reaching some distance into the sea as a platform. This layer rests on a conglomerate. Upon the sandstone there lies the mentioned fine calcareous sand. — When following the beach in the southerly direction to the vicinity of the cannery factories, one will find that the shore profile grows higher. Here is the edge of a low plateau showing alternating layers of small-pebble conglomerate and a reddish earth. These deposits are apparently of a later date than the calcareous sandstone. Further in a southwesterly direction, the deposits come to an end in front of a boulder mass, consisting of basalt lava scree derived from a high edge of the Las Palmas' terrace (a short distance to the south). — As has been mentioned earlier this terrace (of Miocene sediments) is here capped by sheets of lavas of basalts forming the sharp edge.

Some hundred m off the sandy beach of Guanarteme or Las Canteras (the well known bathing *playa* of Las Palmas), there extends a row of low rocks or *arrecifes*, seen only at low tide. They are called Los Rompientes, and they consist of relatively hard lime-cemented sandstone and conglomerate which occur along the shore, as we have seen.

The geological age of these sandstones and conglomerates is not precisely fixed, it may, however, be contemporaneous with the Miocene littoral sediments in the Las Palmas' terrace (upper part).

We have lately been informed of the composition of the deeper lying ground of the isthmus thanks to the many deep drillings executed inside the area of the harbour of La Luz (the port of Las Palmas). It is due to the courtesy of the Head of *Obras de Puertos* in the city and of the executive officer in *El Museo Canario* in Las Palmas that the author has received reports, plans and profiles based on the records obtained. The operations were carried out in order to gain a necessary insight into the geologic conditions of the harbour bottom between La Isleta and El Parque de San Telmo (in the south) with the aim of planning a new dry dock.

The plans accompanying the reports are on the scale of 1:5 000 and give a picture of the bottom relief (in 1 m isobaths) as well as the location of the deep borings.

If we at first look at the bottom relief, we can discover a submarine ridge which indicates the presence of a lava tongue stretching southeast from La Isleta for a considerable distance. This lava may have been emitted from the vent of Montaña del Vigía which rises close to the north of the harbour. The mole of Generalisimo Franco has been laid (2 km) along this submarine edge. The lava may be of Quaternary age and have issued when the sea was considerably lower than now.

On examining the geologic profiles from the drill holes, we will find that a great deal of the harbour area is underlaid by the puzzolane (or the *canto blanco*). This formation meets at various depths inside this area. It emerges at the sea bottom near the shore, where the old 'Hotel Atlantico' is situated. Here the puzzolane has a thickness of 5.5—7.5 m It is underlaid by a »basalt» drilled to a max. depth of 17 m. I have not a sample of this »basalt» at my disposal, but perhaps it is a dark phonolite? For some distance offshore the thickness of the puzzolane attains a max. of 10.0 m. Here it is covered by a sheet of a young basalt. — Other drillings closer to the north shore of the harbour bay have proved the existence of basalts and »conglomerate» (volcanic slags?), but no puzzolane.

We will find from these records obtained by drillings that the harbour is underlaid by puzzolane (*canto blanco*) in parts covered by basalt lavas connected with the volcanoes of La Isleta. The maximum depth to which the puzzolane has been drilled is 10 m (perhaps more). This fact means that, when the puzzolane was deposited here, the ocean level was considerably lower than at present (c. 25 m below zero minimum). This state of affairs may have occurred in the earlier Miocene period, before the commencement of the positive shore migration which led to the successive deposition of the shell-bearing Miocene littoral sediments exposed in the terrace cuts above the city and described in the preceding pages.

At my request, *El Museo Canario* in Las Palmas has sent me three samples of puzzolane taken from three different sites in the terrace basement. These localites and samples are as follows:

1. 'Barranco Guiniguada, lado de San Roque' (sample 45)
2. 'Subida de la carretera de Las Palmas al Barrio Schamann' (sample 46)
3. 'Carretera de El Rincón a Casa Ayala' (sample 47)

The two first samples are of a rather firmly consolidated puzzolane (*canto blanco*), and of them slides have been made. Sample 47 is very much softer and was subjected to a chemical determination of the percentage of SiO_2.

Sample 45: an isotropic, light-brownish, non-crystalline mass, porous with fragments of a nepheline phonolite lava.

Sample 46: an isotropic detrital mass (pumice) containing stray laths of alk. feldspar (albite).

Sample 47: det. of SiO_2=56.42% (Mineral-Chem. laboratory of the University of Helsinki—Helsingfors). The value corresponds to that of the nepheline phonolites. It is slightly less silica-rich than the puzzolane from San Lorenzo (SiO_2=59.06%, anal. no. 2, sample 79).

The puzzolane or *canto blanco* undoubtedly belongs to the period of outbursts of the phonolite lavas of the activity of the central type with its *lahars* (mudstreams) consolidated later on. In La Laja at the east coast there is a close association as we have already seen, between the nepheline phonolite lava banks and the deposits of puzzolane, the latter lying above the lavas (and at the top covered with the coarse terrace gravels).

La Isleta

The strange appendix on the northeastern corner of Grand Canary would be an island itself, if the ocean level were to rise for about ten metres. It has, of course, previously really been an island, during the time of the Quaternary eustatic transgression. Now it is firmly united with the mainland by the low, sandy Isthmus of Guanarteme. The Isleta offers a shelter from the (mostly strong) northerly trade winds, and in that shelter has been constructed the important port of La Luz.

La Isleta has an area of only 12 sq. km and it consists entirely of volcanic products, if we disregard some sand accumulations on the coasts and in a shallow basin in the centre. La Isleta comprises not less than 8 cinder cones of different ages (Quatern.- Recent), roughly arranged in a ring around a basin filled with alluvium. The volcanoes standing at the west coast are relatively old (Quaternary), whereas in the north and east there are fresh-looking cones with their craters and lava streams. The chief cones are called as follows: Montaña Atalaya (or Mont. del Faro) (250 m), Mont. La Esfinge (125 m), Mont. Vigía (200 m), Lomos Colorados (250 m) and Altos del Confital (120 m). This last named is a ruin of a caldera.

Montaña del Faro consists of ashes, lapillis and slags. In the top there is a crater open to the northeast. A lighthouse stands on the southern rim. From the east side lava has been sent down to the plain to the east. The lava soon embraced, however, almost the whole circumference of the cone and sent a stream to the southwest in the direction of Bahía del Confital. On the way a hill of older lava was surrounded like an island. The end of the stream then plunged into the sea, At a later date this end has been vigorously attacked by the breakers, and pinnacles and grottos have been formed, the place being known by the name Baja de los Sargos (Cf. microphoto fig. 1, plate X).

On the east side of the central basin (100 m above sea), there is a row of rather fresh volcanic cones lying in a NE—SW direction. From the southernmost of them, Mont. del Vigía, a stream has been sent down to the (present) commercial port, and this rock is quarried. Mont. Vigía has a rounded kettle-like crater. To the east of the row there lies the solitary cone of Mont. de la Esfinge. From here to the east the coast has a rocky cape jutting into the ocean and this, together with some small *islotes*, may be remnants of an ancient platform upon which the new volcanoes have been accumulated.

The northwest coast of La Isleta shows abrasion cliffs exposed to the incessant attack of the trade wind surf. A platform has been cut in earlier times — a wide '*strandflat*' of c. 30 m altitude, and the cliff exposes basalt lavas and tuffs. The bank of basalt forming the platform itself shows beautiful columnar jointings, giving in the plain a network, a joint pattern, according to L. von Buch (1825), reminding one of the well known »Giants Causeway» in Antrim (N Ireland). The relatively old volcano nearby, Las Lomas Coloradas, consisting of lavas, slags and tuffs, seems to have formerly extended far into the sea, and consequently it is of a relatively old age.

The westernmost promontory of La Isleta is formed by the volcano Altos del Confital (120 m), also of relatively old age. It is a half destroyed cone with its precipices facing Bahía del Confital. Here a downfaulting seems to have occurred: the half of the cone has been cut away, and the northern part stands with a high bluff against the shore. At the foot of the precipice there extends a low shore platform consisting of brown stratified tuffs with a slight inclination towards the fault line (inwards). The tuff contains a great number of lava inclusions, it may be better called an agglomerate. It seems here has formerly existed an explosion crater some distance off the shore line. The agglomerate and the tuff layers are (with unconformity) capped by a horizontal sheet of light yellowish, calcareous sandstone containing snail shells, — a consolidated beach sand.

There is not much to be seen of the substratum of the Isleta volcanoes. L. von Buch (l.c.) mentions the occurrence of a »Conglomerat von Trachytstückchen» appearing on the both ends of the row of small cones arranged in a line NE—SW across the Isleta. One occurrence is at Bahía del Confital, where a lava (emitted from Montaña del Faro) has embraced it with two arms. von Buch means that this conglomerate formed a kind of plateau (surface cover) in time before the eruptions of the Isleta volcanoes followed.

The central part of La Isleta is a closed basin with even ground (alluvium) deposited here by rain wash of tuffs and lavas in the surrounding slopes. These sediments contain sometimes remains of animals (lizards), maybe of late-Quaternary age.

I have only a few samples of the basaltic lavas (2, 3, 68) from La Isleta and one of an ejectum of a coarse-grained eruptive rock (4). Two of the basalts are of the lavas from Montaña del Faro, a fresh looking lava, micr. consisting of clear, corroded olivine crystals and also augite crystals (euhedral), lying in a glassy, dark matrix. One sample was taken of a sea cliff northeast of the volcano, the other from a large lava stream that ends at Bahía del Confital (from a point situated a short distance NE of the Headquarters of the Artillery). The third sample (68) is from a thick lava bank at the sea shore in the western promontory at Bahía del Confital, where a small fortress is situated. This last named lava rests in a flat position on brown tuffs, well stratified.

It is not clear at first sight if this last named lava belongs to the near lying (relatively old) volcano Altos del Confital. Further investigations have, however, shown that it can be traced to this volcano.

The volcanic bomb (4) was found at the rim of a relatively large explosion crater appearing in the north side of Montaña del Vigía (N of the commercial harbour's Muelle del Generalísimo). Here in the slopes a great number of bombs and stones of ejecta lie around. This one is an anorthosite, coarse grained and rather fresh looking. An examination on the U:stage gave the following results:

Plagioclase: $2V\gamma=78°$ (2 det.), $\alpha' \wedge (010)=33°$. Comp.: An/60 (low temp. form) (Cf. microphoto fig. 2, plate X)

The slides do not contain other constituents. — Similar anorthosite bombs are also known from the island of Lanzarote (Hausen 1959).

J. Bourcart (1937) has published a cross-profile of the steep abrasion coast in the north side of La Isleta (page 48), and this figure shows no less than 4 sheets of basalt lavas with interstratified littoral sediments, the lowest already petrified (lying below the zero level). On the surface of the plateau (edge) there lie scoriae dating from the latest eruptions of the volcano (del Faro) which seems to have been of a 'Strombolian' nature. Judging from the stratigraphy in the profile there seems to have been emersion of La Isleta before a new lava emission from the volcano occurred, then the island was subjected to subsidence (following an outburst of the near lying volcano).

2.

The Eastern Declivities of the Island

(Between Barranco de San Roque and Barranco de Tirajana)

General conditions

This large sector of the island has not been very thoroughly investigated by the author. Its geological appearance seems to be somewhat monotonous. There are large expanses of basaltic lavas and tuffs sloping gently toward the coast. These originally relatively smooth declivities have been furrowed by many rivers, now generally dry, with a system of *barrancos* dividing the slopes into a number of broad ridges. They do not reach down to the sea, but in front of them is an alluvial lowland forming an open sandy coast — with some promontories.

The basalt lavas, a rather thick series well displayed, for instance, in the vertical walls of the important Barranco de Guayadeque, have been crowned with a number of volcanic cinder cones in more recent times (see the geol. map!), the most important of them being Montaña de Las Palmas between Valsequillo and Telde. These volcanoes have also contributed to the lava floods, in places filling old *barrancos*.

The basement is mostly hidden under these basalt lavas, but there are some *barrancos* and valley heads, where the basement is displayed and where it can be studied. The best exposures are to be found in the amphitheatre-like head of Tenteniguada, a kind of »semi-caldera». The large and deeply-incised Barranco de Guayadeque further south does not, remarkably enough, expose any rock formations older than the post-Miocene basalts. We have to go further south, to the vicinity of Temisas, to get a view of the older rocks of the basement (following the highroad of Agüimes—Temisas).

In our geological descriptions of the eastern sector of the island we must follow along the erosion channels of the slopes, chiefly along Barranco de Telde and Barranco de Guayadeque, to get an insight into the interior on the mountains. The former route is the more interesting one, where we will find many profiles, principally around Tenteniguada (in the head region). Barranco de Guayadeque on the other hand has in spite of its walls several hundred metres high, only exposures of basalt lava beds. But the *barranco* represents a problem in itself, as we will find later on.

The stretch of Barranco de Telde, including its head region, the semi-caldera of Tenteniguada, can most conveniently be investigated along the highroad from San Mateo to Tenteniguada and further along the road that descends from this village to Valsequillo and to Telde.

South of this sector the slopes can be investigated along a road that ascends from Barrio de Ingenio to an altitude of 800 m.

An examination of the profiles along Barranco de Guayadeque must be made on foot up along the boulder-filled bottom of the canyon, a somewhat tiresome walk.

The southernmost part of the sector in question can be studied along the highroad from Agüimes to Temisas and further to Santa Lucía de Tirajana.

San Mateo—Tenteniguada

If we begin our study from the north, we must first follow a highroad from Vega de San Mateo (800 m above sea level) over the pass Degollada de Chiginique (1 000 m) to Valle de Tenteniguada (700—800 m above sea level) with the highland border as a background in the west. The road makes several curves, and there are plenty of opportunities for a study of the rock ground in the *barranco* exposures and along the road cuts. Several samples were collected on this route, mostly comprising lavas of a basaltic nature (42, 49, 50, 106, 107, 122, 133, 134, 138).

Leaving San Mateo with its large cinder cone (200 m) which has already been mentioned (Montaña Cabrera), we first ascend slopes covered with ashes and lapillis, mostly decomposed into arable soil. This loose material is chiefly derived from the cinder cones higher up the mountains southwest of Lomo de los Aljorraderos. After passing Barranco de la Higuera, one reaches the watershed at Chiginique and here there are huge banks of the R. N. agglomerate capped by basic lavas. A precipice of the latter, facing the San Mateo valley, consists of a kind of basanite (107) Micr. it contains phenocrysts of olivine (partly altered), augite and brown hornblende, all lying in a paste of a basaltic texture with plagioclase laths, augite and ore. Apatite is accessory. The optics of the chief minerals are:

Olivine: $2V\gamma=93°$ (average) (Fa=5%)
Augite: $2V\gamma=54°$ (average)
$c\wedge\gamma=52°$ (average) (Ti-augite)
Hornblende: $2V\alpha=71°$, $c\wedge\gamma=8°$ (averages) Pleochr. weak.

The paste looks rather dark between + nic. owing to the presence of a zeolite mineral (analcime?). The feldspar laths are clear, however (ext. angle in the zone ⊥ (010) small).

Some distance from the divide, on the way to Tenteniguada, there appears by the road a lava bank of greater thickness, consisting of a basalt (138). Micr. this is olivine-free, showing phenocrysts of augite and brown hornblende and also laths of plagioclase, a sodalite mineral and magnetite, all enclosed in a very fine-grained paste, almost dark between + nic. Feldspar microlites are relatively sparse. The sodalite crystals have an altered core. Apatite (enclosed in hornblende) is accessory. The plagioclase (of the I gen.) is labradorite. The lava may be classified as a tephrite. No doubt it belongs to the effusions which have accompanied the deposition of the R. N. agglomerate in this region. — No. 19 taken from a rock exposure at the bottom of Barranco de Barbuzanos (the upper course, where the highroad crosses the *barranco* by a bridge) is likewise a tephrite with rel. large phenocrysts of augite (euhedral) in a groundmass consisting of plagioclase, augite and ore (partly as larger grains).

A short distance to the south of Degollada de Chiginique there is a great dike by the road, which stands vertically with a N—S trend and a breadth of 8 m. The rock (106) is macr. dense. Micr. one will find a trachytoid texture of tiny feldspar rods (sanidine) mingled with a greenish-brown pyroxene and ore. Stray phenocrysts of sanidine (clear) are to be seen and also scattered crystals of a bluish sodalite (partly altered) and brown hornblende. The rock may be designated as a sodalite tinguaite, connected with the foid-bearing salic, intrusive bosses in the surroundings (see later on!).

Proceeding along the highroad in the direction of Tenteniguada, one passes along several cuts at the road, exposing dark-coloured lavas and also brownish (or reddish) tuffs. Lava samples were taken (42, 50, 133). No. 42 shows micr. plenty of euhedral augite, gray-lilac, associated with magnetite and lying in a groundmass of plagioclase laths, augite and ore. The plagioclase is relatively abundant and is arranged into the ophitic texture. No olivine is to be seen in the slide. The rock is of the same type as no. 49. No. 50 and 133 are of rather similar comp, the former occurring as a lava bank in the base of a huge R. N. agglomerate mass. The other lava type forms a rocky cape called Lomo del Picacho (to the north of Tenteniguada). It carries some sodalite in addition to the minerals enumerated above.

The 'semi-caldera' of Tenteniguada. — The head of the large valley used by Rio de Telde (now mostly dry) has a broad amphitheatre — like shape, with bold precipices encircling the romantic village of Tenteniguada. The total height of these precipices attains c. 600 m. The stratigraphy is as follows: the basal beds are tephrites, they are capped by brownish agglomerate masses (with an aquifer-layer at the base). This is in turn capped by lava banks of a phonolitic appearance. The upper edge consists of massive outcrops of the R. N. agglomerate, forming vertical cliffs and showing a rather wide extension on the border of the highland. Further up the central highland the agglomerate is (as we will find in Chapter 10) covered with lavas of hauynophyre and also crowned with necks of the same eruptive rock.

The brownish tuff agglomerates in the precipices are crossed by several steeply dipping dikes of salic composition. Samples are not available.

The valley of Valsequillo down to Telde and the coast

If we now leave the highland border of Tenteniguada and turn east down the long slopes towards the coast, we can most conveniently follow the highroad that runs along Barranco de Telde and passes the small town of Valsequillo (550 m). At first the ground drops rather suddenly, so that the road makes several turns, then it slopes more gently down to the old city of Telde (125 m).

There are not many geological profiles to be studied on the way. The general impression is that the valley of Tenteniguada is of tectonic origin, but it has later on been filled with lavas and then eroded to a young canyon. The lavas on the way are chiefly basalts (no samples from the upper regions) leading down from the cone of El Espigón (1 250 m), and lower down from the cone of Valsequillo. These lava streams have later on been eroded by Barranco de Barbuzanos and Barr. de la Plata which join one another in the vicinity of Valsequillo. Further down there is a rather deep canyon, Barranco de Telde, which has been incised into lavas derived from the great basalt volcano of Montaña de Las Palmas (550 m), the cone of which dominates the whole scenery on the lower slopes towards Telde. The middle stretch of Barranco de Telde is called Barranco de los Nueve.

The volcano of Las Palmas stands on a ridge separating Barr. de Telde from Barr. de San Roque in the north. The ridge seems to consist of the R. N. agglomerate which has been covered by the great cone and its products mentioned above.

Some samples have been kept from the stretch of Montaña de Las Palmas—Telde (141, 142): olivine bearing basalts of Quaternary (?) age.

No. 141 is micr. a picritic olivine basalt with olivine as the only component of the first gen. The crystals are mostly rounded, due to magmatic corrosion, and the rims consist of iddingsite. The pyroxene is chiefly restricted to the groundmass, in which it is abundantly present mingled with grains of magnetite. Stray larger crystals also appear. Laths of plagioclase cannot be seen in the slide. There are colourless, isotropic patches perhaps consisting of analcime. The vesicles are filled with a zeolite mineral showing birefr. The optics of the chief minerals are:

Olivine: $2V\gamma=91°$ (average of 7 det.) (Fa=18%)
Pyroxene: $2V\gamma=54°$ (» » 7 ») ,$c\wedge\gamma=41°$ (augite)

This lava may be a representative of the Las Palmas' volcano and its age may be Quaternary. Its ultrabasic composition is rather typical of the Quaternary and the Recent lavas of the island.

No. 142 is a sample from the outskirts of Telde, a basalt lava (aphanite) belonging to the older flows in which the river channel has been eroded.

When following a road that leads from Telde to Playa de Melenara on the coast, one passes a small solitary cone called La Montañeta. On the coast there are outcrops of the basalts which underlie the gravel-covered coastal flat. At Punta de Melenara there is a half-destroyed cinder cone, providing shelter for a small fishermens' harbour.

Barranco de los Cernícalos

This *barranco* in the highland border region was not visited by me. T. Bravo has brought some samples from here and given a profile sketch. Barr. de los Cernícalos begins at an altitude of 1 300 m in the vicinity of Caldera de los Marteles. Its bottom drops rather suddenly in the direction ENE, and its sides disclose a succession of lavas which compose the highland border here. It is of interest to note the preponderance of hauyne phonolites in these cuts, altogether of a considerable thickness. Only the top sheets consist of the olivine basalts of the more picritic types. The phonolite lavas below are certainly all of the same kind and relative age, like those which compose the many necks on the highland nearby, forming the rim of the great semi-caldera above Tenteniguada, and also reaching into the upland ground behind. This cover seems generally to have no great thickness, whereas in Barranco de los Cernícalos it is relatively important. Samples from here of foid-bearing phonolites are: 797, 798, 800, 801.

These types are all rather indentical under the micr. with phenocrysts of a dark rimmed hauyne (perfect crystal faces), prisms of greenish aegirine augite rimmed with a shell of green aegirine, of alk feldspar, sphene and magnetite. All these components lie in a matrix consisting of feldspar rods, aegirine prisms and ore powder. Stray prisms of brown hornblende are also present (rimmed with opacite). Nepheline is likewise to be seen in the slide. This mineral is surrounded by a corona of aegirine.

The bottom of the *barranco* is filled, according to BRAVO with a young basalt lava stream (799), an olivine basalt of the more picritic kind. Its site of emission is not indicated.

The head region of Tenteniguada has in the course of time been the stage of several lava outbursts (mostly apparently belonging to the Quaternary period), flooding the courses of the waterways down towards Valsequillo and Telde. The volcanoes of El Espigón and Valsequillo seem to have been especially productive.

The eastern basalt slopes of the island

If we are heading south from Barranco de los Cernícalos, we must cross a broad slope furrowed by many *barrancos*, a rather uncomfortable route. The lavas here are always of the basalts of the post-Miocene age, and the different beds are interfoliated with tuff layers of a brownish colour.

The slopes above Ingenio

There is a rather convenient ascent to higher levels from Ingenio by following a newly built road which after many windings climbs to an altitude of c. 800 m (Ingenio lies 350 m above the sea). At first here are several cultivated fields in the weathering soil changing upwards to gravels; then the road reaches lava ground. The inclination to the east of the many lava banks is steeper than that of the slope itself. Between the black lava banks there are tuff and agglomerate layers. One sample of a lava rock from the termination point of the road (800 m above the sea) is an olivine basalt (66). Micr. it consists of clear grains of olivine lying as phenocrysts in a paste of densely packed augite prisms and magnetite grains, and very sparsely of plagioclase. The pyroxene appears in aggregates, associated with magnetite. The rock is of a type approaching ankaramite.

Barranco de Guayadeque

This is the name of one of the most spectacular canyons in the island, measuring in length c. 10 km from the head at Caldera de los Marteles (1 500 m elevation) down to Barrio de Ingenio. In its continuation, the *barranco* runs across a more open coastal land to the east coast. The upper part of the course has an easterly trend, then it turns southeast, then east again to the coast.

Barranco de Guayadeque is renowned for its many cave dwellings in its side walls, and they all date from the pre-Spanish period. A great number of implements and human skulls have been collected in the caves, and much of that collection is exhibited in monters of the Canarian Museum in Las Palmas.

In our day the canyon is dry most of the year, only during showers in winter time may there be occasional »*crecientes*». In earlier times, with other climatic conditions, there was certainly a perennial river, judging from the great masses of blocks and stones that clog the bottom of the canyon.

Geologically, however, there is not very much to study if we disregard the achievements of erosion — the formation of the canyon and its coarse boulders already mentioned filling the bottom for a considerable distance. I myself have inspected the whole stretch of the canyon from Barrio de Ingenio up to its head in the central high land. The walls on both sides are generally inaccessible, owing not only to their steepness, but also to the lack of field paths. In my sample collection from here are nos. 59, 60, 114, 151, of which 114 was taken at Los Cazadores, a farm on the left side of the canyon at a high level.

On studying the walls of the canyon of Guayadeque in an upstream direction, one finds a large succession of concordant banks of dark lavas with interstratified tuffs, all sloping towards the east. The upper beds of lavas are apparently very thick, they have columnar jointings. Judging from the stones in the gravel train of the bottom most of these lavas are basalts (olivine bearing), no doubt all of the post-Miocene series. In the boulder jumble one will find scattered stones of pale-grayish-green rocks, no doubt of some foid-bearing dikes in the highland.

In the upper course opposite Mesa de los Pinos, there is a cinder cone located in the midst of the canyon and called La Hoya de Arriba. This relatively well preserved cone seems to be of a later date than the canyon itself. Remarkably enough, the left head arm of Barranco de Guayadeque is occupied by another volcanic orifice, Caldera de los Marteles, walled in from the *barranco* (downwards) by a broad slag-lapilli ridge.

If we look at the few samples of rocks collected from the area along the canyon, no. 151 is from the vicinity of Barrio de Ingenio, a rather common picritic olivine basalt. Micr. the olivines are euhedral, but showing corroded embayments. It represents the I generation and lies in a groundmass of plagioclase, augite and ore (abundantly). There are also colourless isotropic patches which may be analcime.

Sample no. 66 (previously described) may represent the left side of the series exposed, corresponding to its upper part. — No. 114 from a point close to Los Cazadores (a farm), from a still higher level on the same side of the canyon, is micr. fresh-looking with clear olivine crystals in well developed forms (abundantly); there are also phenocrysts of euhedral augite, both lying in a paste of augite and ore closely packed together. There is rather scanty of feldspar microlites. We see also colourless cavity fills and patches of analcime (?). Olivine has opt. char. + and $2V \sim 90°$. The lava is of the current type in these slopes. — No. 59 is from a table-formed hill on the left side of the left head arm (where Caldera de los Marteles is situated). It is an erosion witness of a more wide-spread lava cover of a fine grained olivine basalt, resting on a thick layer of brown tuff. It can be considered as representing one of the last effusions of post-Miocene basalts in this sector of the island. Micr. it consists of plenty of olivine phenocrysts, mostly rounded-off by corrosion and lying in a groundmass of chiefly augite prisms and ore grains, the latter irregularly distributed and of varying size. The olivine has no iddingsite fringe, instead there are cracks filled with serpentine. The slender augite prisms form a web in which the interstices are of an isotropic turbid substance. The lava can be classified as an ankaramite.

In spite of its great depth, Barranco de Guayadeque has not reached down to the basement rocks below the basaltic series. It is probable, however, that the heavy overburden of boulders in the bottom has concealed outcrops of older rocks.

Finally, we must consider the possible formation of this remarkable *barranco*. Perhaps it has been controlled by fault lines, dissecting the whole pile of basalt volcanics, thus making it easy for erosion to work on this very energetic mode. Since the catchment area — the highland seems to be rather small, one must suppose that most of the erosion work was performed during a pluvial time, perhaps during the Quaternary period, or most likely somewhat earlier — in the Pliocene period. At that time the island was in the course of elevation after the Miocene submersion. The Pliocene uplift seems to coincide with the formation of many deep *barrancos* in the island (after the cessation of the wide spread basalt effusions). — Finally the coastal region below Agüimes ought to be more closely investigated and particularly the old delta deposits belonging to this great *barranco*. Perhaps in this way some idea of the approximate age of the same may be obtained.

The coastal stretch from Bahía de Gando to Punta de Arinaga

This stretch represents a low and sandy terrain largely covered by tomato plantations. The detrital material has been carried down the slopes by various waterways, perhaps mostly during times of more rain. The coastal zone is confined inland by the 200 m contour level and this may coincide with the position of the Miocene sea level.

There are, however, some eminences in the coast lowland which represent older cinder cones of basalts. To these belong the Peninsula of Gando, a half-eroded cone, Montaña Malfú (250 m), and further on Montaña de los Vélez (175 m). At Punta de Arinaga another volcano is situated, Montaña de Arinaga (175 m). It has also suffered from attack by the surf.

There is a promontory southeast of Agüimes called Montaña de Agüimes (350 m max.) which according to J. Bourcart (1937), consists of basalts. I did not visit this mountain; its shape suggests an old crater open to the east: a small 'semi-caldera'. This has not been created by erosion, not even by marine abrasion. — To the south of the promontory a vast plain begins which is traversed by the gravel train of Barranco de Balo. The whole region between the coast and the foothills in the northwest is called Llanos de Arinaga, one of the most extensive sediment plains in the island. It is limited inland by the 100 m contour level. This vast accumulation area has been created after the eruptions which occurred in the volcano Montaña de Arinaga, apparently chiefly in the Quaternary epoch.

Agüimes—Temisas—Santa Lucía (de Tirajana)

The sector of the island extending from Barranco de Guayadeque to Caldera and Barranco de Tirajana is in the main a very mountainous landscape, only in the lowest part does the slope change to the wide coastal plain of Llanos de Arinaga.

There are numerous *barrancos* which dissect the upper slopes, the most important being Barranco de Balo (in its upper course called Barr. de la Angostura). The region has been studied rather cursorily by the author, chiefly along the highroad through Temisas to Barranco de Tirajana. Additional data and also rock samples have been obtained from T. Bravo later on.

The stretch of the road from Agüimes to Temisas passes across a basaltic landscape with rock exposures in a rather weathered state. Banks of lavas alternate with tuff layers, all in a slightly inclined posi-

Fig. 7. Dislocated trachytic lavas in the bottom of Barranco de Temisas (road Agüimes—Santa Lucía) with the post-Miocene olivine basalt lavas and tuffs in the background. Looking east.

Phot. H. H—n 1957

tion grading into the coast. There are no samples from this stretch. When approaching Temisas, one enters an open valley in which there suddenly appears another rock ground: light-grayish, well-banked lavas of a trachytic aspect (no sample from here). They are not in the gentle coastwards-inclined position but have a much steeper eastern dip (cf. fig. 7). — Further along the way between Temisas and the border of the Tirajana valley, the rock ground is first of the R. N. agglomerate. Then the road crosses an eroded terrain of the highland basalts. These latter again lie in a flat position, like the lavas on the side of Agüimes.

I have not examined the conditions in the surroundings of Temisas, and I have no idea of the causes of the disturbances in the salic lavas occurring there. T. Bravo suggests sliding phenomena in the rock ground, old basalts being the 'lubricated' basement of the movements. Recently F. Macau Vilar (1960), on the other hand, has found a solution in the formation of a small 'collapse caldera', a minor replica of Caldera de Tirajana, according to him a gigantic phenomenon of the same kinds of movements. It seems that more investigations are needed to settle this question of the appearance of dislocated salic lavas in the midst of the post-Miocene basalt formation.

The conditions met with in the border of the Tirajana valley will be treated in more detail in the following chapter. It may only be stated here that the R.N. agglomerate nearer to the valley is covered with the post-Miocene basalt lavas.

Another route for investigating the sector in question is to use the highroad from Agüimes in a northwesterly direction to the road fork NW of Sardina. One can then turn down to that little town or into the direction of Barranco de Tirajana at Lomo de las Carboneras. The most remarkable occurrence on this stretch from a geological point of view is the appearance of a series of basalts of greater age than those of the post-Miocene eruptions. I have been provided with samples of these rocks thanks to the courtesy of Mr T. Bravo (samples 1—5, 72, 861).

Some km after leaving Barrio de Ingenio, one suddenly enters the terrain of these old basalts. They can be observed in the road cuts all the way to the Sardina road fork. They can also be followed up the *barrancos* which lie in the way. They are likewise seen down the slopes towards the coastal plains, where they dissolve into smaller ridges which are soon submerged under the alluvium.

The foothill of Roque Acuario (580 m) is of some interest in this connection. It lies east of the road and has a remarkable asymmetric shape: the north end is highest, the spine slopes down southwards into the lowland. The top of the ridge is of pale-coloured salic lavas, whereas the basal part consists of the old basalts. This hill is a curious erosion witness from a time when the old basalts were covered (to an unknown extent) by the salic lavas. Similar conditions may exist in Lomo de los Perros (375 m) nearer to Sardina. More to the east, Montaña Majada Ciega (275 m) is another isolated foothill consisting of the old basalts (?).

It is not possible to say at what time these scattered outliers have been formed. This kind of landscape does not occur in the other sectors of the island. The only explanation at present may be that the hills owe their existence to the old basalts which have offered little but unequal resistance to denudation in later times. Plates of phonolite at the summit of a hill may have protected it from complete destruction for some time. That a great amount of denudation has gone on here can be seen from the enormous masses of detrital products which lie spread over the coastal plain of Llanos de Arinaga. A closer study of the evolution of this stretch of landscape may be of some interest.

If we now turn our attention to the petrography of the rocks in this region, we may first look at the old basalts. They are nearly all from the vicinity of Roque Acuario (N of it) from a stretch of the highroad of 1 km in length. One sample (861) is from a water-shaft, at a depth of c. 170 m below the bottom of Barranco de Balo.

If we begin with the latter rock type, it is an olivine basalt in a rather altered state. The olivine phenocrysts are completely altered (to antigorite); the plagioclase laths in the paste are also altered to some extent. With these laths are mingled pyroxene grains and ore. But crystals of pyroxene may rather frequently appear in the I generation of comp. This mineral is clear with good prism. cleavage. Ext. angle on (010) $c \wedge \gamma = 45°$. The ore may at least in places be ilmenite, judging from the elongated forms of the grains. The paste contains plenty of rounded vesicles, either empty or filled with calcite. The lava represents the relatively oldest bank in the basalt series of the region.

Samples 1, 2 and 3 are all rather similar. Micr. there are many olivine pseudomorphs stained with iron oxide, and we will also find pale-yellowish clinopyroxene. The paste also consists of pyroxene mingled with ore grains and tiny laths of feldspar. It looks rather dark between + nic., and there may be alteration products in it. In nos. 1 and 2 there are rounded vesicles filled with sphaerolithic aggregates of chalcedony, so that one vesicle contains a great number of them densely packed together; the walls of the vesicle are lined with short fibres perpendicular to them. — According to BRAVO, no. 4 is an intrusive body (dike?), also a typical olivine basalt of the more picritic kind. The olivine phenocrysts are here better preserved, alterations have chiefly occurred from the sides and along cracks. The originally euhedral forms are mostly corroded. Clinopyroxene also occurs in the I gen., often in aggregates. The paste is fine-grained, basaltic with tiny feldspar laths, pyroxene and ore (abundantly). — No. 5 is from the uppermost bank of lava in the series investigated along the highroad (opposite Roque Acuario). It differs micr. from the other types in having no phenocrysts; it is a an aphanite with plagioclase, pyroxene and ore and scattered prisms of a red-brown mineral (with high ind. of refr. and strong birefr., iddingsite?). The share of plagioclase is greater in this type, the composition approaches that of plagioclase basalts.

The idea that these basalts may belong to the old series (the first period of basaltic volcanism) may be confirmed by the fact that at the top of Roque Acuario there is a »hat» of phonolite lava (72) of the current type which dominates in the southern sector (nepheline-aegirine phonolite). This phonolite lies on a basement of the old basalts.

3.

Caldera and Barranco de Tirajana

General features

This great depression in the southeastern sector of the island provides much of geologic interest. There are many excellent exposures of the rock ground in the steep precipices surrounding the Caldera, and also in the outlet canyon that leads to the SE from the depression. — This canyon is Barranco de Tirajana. Moreover, the area seems to offer many intricate problems concerning the processes that ended in the present shape of the depression. In fact many investigators have tried to find a plausible explanation for this special kind of a caldera-problem. The first geologist who visited the region was L. VON BUCH (in 1815), and he thought the Caldera must be a good example (or an illustration) of his now so famous »elevation hypothesis».[1])

Caldera de Tirajana is not really a caldera in the original sense of the word. It lacks the circular limitation and it is wide open in the southeasterly direction. Moreover, it is not well separated from the neighbouring valley of Fataga. The Caldera gives the impression of an erosion valley (see the map fig. 8), but initial displacements of the ground in this sector seem very probable. The northern end — the semicircular or amphitheatre-like valley-head is, however, chiefly the result of great land slides, as we will find later on, when we devote some pages to the discussion of the genesis of the Caldera.

Here are at first some topographic remarks (see the fig. 8). In the map I have drawn the course of the enclosing watershed. Inside this line there lies the great depression comprising c. 50 sq. km (if we include also the valley of Tirajana as far down as to the small village Aldea Blanca). — At the edge of the northern precipices there stands the highest summit of the island, Pozo de las Nieves (1 950 m). This wall is at the same time the southern rim of the relatively flat highland ground above the 1 500 m contour line. This part of the island is

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[1]) This hypothesis suggests the formation of a geotumor and subsequently of a top caldera or a crater, due to collapse.

called *La Cumbre*. Hence the highest central elevation is not a Pico like that in Tenerife, but a plateau-like surface. Pozo de las Nieves looks from the north side rather insignificant. On the southern side is a tremendous precipice.

The author has made many excursions inside the Tirajana area using as headquarters the small mountain village of San Bartolomé. — We may start our descriptions with the northern precipices. Generally these do not allow a climb up to the border, consequently a closer examination of all the strata is not possible. In some cases boulders dropped to the foot have been picked up for examination.

The northern wall of Caldera de Tirajana

Now we will follow the highroad that leads from San Bartolomé (900 m above the sea) northwards to the precipices. Reaching the foot of them we are c. 100 m higher up. Further on the road ascends to 1 200 m in Degollada de Tirajana, lying on the watershed towards the Chira valley. From the road one gets opportunity to study the slopes at least in their lower parts for 'several km along. In the precipices the beds lie in their original position, below the road, however; the ground is apparently allochtonous: land slides have occurred here, consequently debris conceal most of the underground. Judging from the stones in the debris here, the formation that underlies the great pile of the precipices consists of platy phonolites.

Los Caideros Altos
(Upper edge 1 700 m above the sea)

From the road level (1 000 m) I climbed the slope of the cape so named and I reached some hundred m higher up to the foot of the vertical precipices (consisting of the R. N. agglomerate). Samples were collected from several beds traversed (188, 192, 193, 194, 195, 196, 198, 199). Later on I got complementary samples from the top sheets of the precipice (181, 182, 183, 184, 186) during a stroll along the edge (border of the adjoined highland).

The description of the first series above of the lava types will follow in reverse order, i.e. from the base at the road to the topmost sheets.

The general aspect of this geologic profile is remarkable: there is a striking alternation between dark, basic lavas and pale-coloured banks

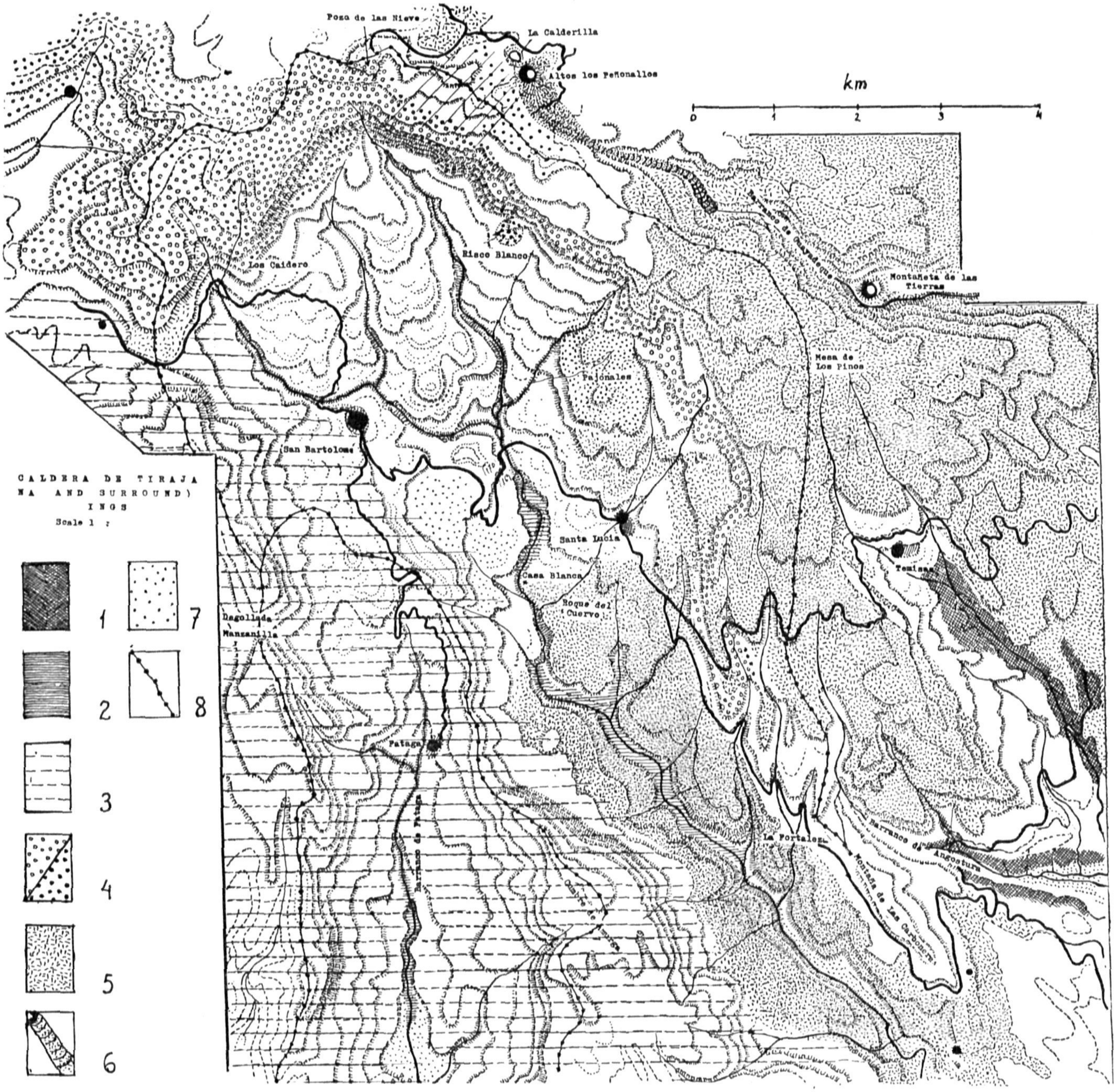

Fig. 8. Topogr. — geol. map of Caldera de Tirajana with contour intervals of 100 m . 1 — *old basalts (in barranco-bottoms to the right)* , 2 — *trachytic — rhyolitic* volcanics (in the bottoms of Barr. de Tirajana and B. de Fataga), 3 — nepheline phonolite formation 4 — circles: the Roque Nublo formation (including alk. basalts) and points: high level gravel delta N. of Santa Lucía. 5—olivine basalt lavas of late-Tertiary—Quaternary age, 6 — younger olivine basalt lava stream (upper edge), 7 — alluvium, 8 — watershed.

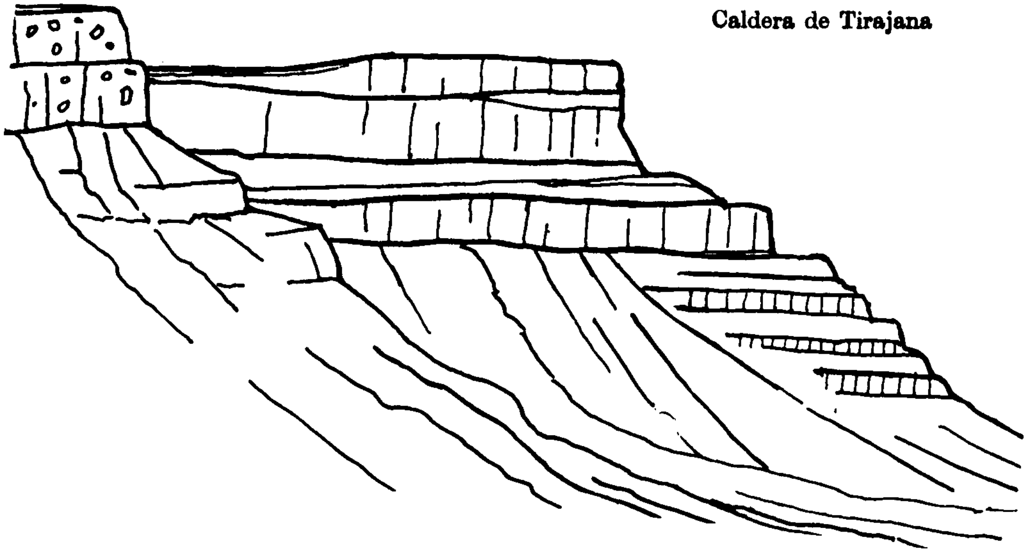

Fig. 9. Los Caideros Altos, part of the northern wall of Caldera de Tirajana seen from the vicinity of Degollada de Tirajana. Banks of agglomerate alternate with tephrite lava sheets and tuff layers.

Field sketch by H. H—n

of the R. N. agglomerate formation. The lavas are of relatively insignificant thicknesses, whereas the agglomerate assumes in parts considerable dimensions. The steepness of the profile owes the appearance of vertical diaclases that dissect the rock.

This alternation indicates that the volcanic outbursts piling up the entire series were of twofold nature: Peléean eruptions with the spreading of the agglomerates were at least 7 times interrupted by emissions of basic (basaltic) lavas issued (like the agglomerates) from some source in the central highland nearby.

Here some characteristics of the lavas inserted in the series will be communicated.

By the road there are exposures of a brown tuff overlaid by a black lava bank (199). Micr. this rock is richly augite-bearing, showing euhedral crystals of the I gen., but also small prisms in the groundmass. The mineral is associated with magnetite grains (plenty). There are also grains of a completely altered mineral (olivine ?). The groundmass consists of augite, plagioclase, altered, and ore in a basaltic texture. Apatite is an accessory. The paste also contains colourless isotropic patches, perhaps analcime. The rock is a tephrite.

Further up the slope there follow layers of dark-coloured tuffs in huge banks (with caves). They are capped with a lava bank of salic aspect (198), perhaps a flat-lying intrusive body (sill). Micr. the texture is trachytoid with tiny feldspar laths (altered) as the chief mineral. There are phenocrysts of a pale-greenish clinopyroxene and stray prisms of a brown hornblende (rimmed with opacite). There are also crystals of a sodalite mineral (turbid). The feldspar is mingled in the paste with slender prisms of alk. pyroxene. Magnetite and apatite are accessories. The rock is a phonolite, somewhat amydaloidal (with zeolite-filled pores).

Further up in the sequence there follows a dark lava (196). This is inserted between the phonolite just described and a hanging bank of the R. N. agglomerate. It is rather identical with 199 (tephrite). There lies another dark lava bank (195), amygdaloidal, in the hanging agglomerate mass. Micr. it contains phenocrysts of augite and brown hornblende (longprismatic) in a groundmass of plagioclase (altered), minute pyroxene prisms and ore powder. Apatite is an accessory constituent. The rock is altered and the paste looks rather dark between + nic. Vesicles are filled with zeolite (aggregate-polarization). The rock is also a tephrite. Sample no. 194 is very similar with phenocrysts of euhedral augite and rich in magnetite. It is intercalated in the agglomerate mass. — No. 193, another lava bank higher up in the profile, is also of tephritic composition, amygdaloidal. It contains augite in the I gen., and also pseudomorphs of a prismatic mineral, zeolite-altered. The augite has ext. on (010) $c\wedge\gamma=56°$. This mineral also fills a great deal of the groundmass. Grains of magnetite are richly present. The feldspar is altered, texture is basaltic. Vesicles are filled with carbonate.

Finally, we may examine the uppermost part of the profile in question. This is accessible only from the highland side (elevations 1 650—1 700 m). Of the samples 182 and 184 will be described, whereas no. 183 will be dealt with in Chapter 10, comprising the central highland proper. This rock is of a dike crossing the R. N. agglomerate.

No. 182 is a tephritic lava. Micr. there are phenocrysts of euhedral prisms of clinopyroxene and also prisms of brown hornblende rimmed with opacite. They lie in a paste that consists of tiny feldspar rods, pyroxene and ore, and an isotropic substance (analcime?). The pores appearing in the paste are in parts empty, in parts filled with a zeolite mineral. Optics of the chief minerals are:

Clinopyroxene: $2V\gamma = 60°$ (average of 6 det.), $c\wedge\gamma = 45°$ (augite)
Hornblende: $2V\alpha = 73°$, $c\wedge\gamma = 3°$ (oxy-hornblende)

This lava is inserted into the R. N. agglomerate formation, dominating in this upper part of the great profile.

No. 184 is likewise a tephrite lava referring to another sheet intercalated in the agglomerate of this upper part. The lava is amygdaloidal Micr. we again have euhedral phenocrysts of clinopyroxene (augite), small grains of brown hornblende, an altered sodalite mineral (with an opaque rim) and stray laths of plagioclase with indistinct polysynthetic twinning. Magnetite appears in relatively large crystals. Vesicles are filled with fine-grained chalcedony. The paste looks rather dark between + nic. (analcime?).

We have in a preceding page already pointed out the interesting fact that the R. N. agglomerate alternates with tephrite lavas in this profile, the lavas being repeated no less than 7 times. Originally they were certainly more numerous if we take into consideration the fact that a part of the top of the profile has been worn away by denudation.

Similar conditions (alternation between tephrite lavas and R. N. agglomerate) will be met with in the great profiles of the northern wall in Caldera de Tejeda (Chapter 11). — This complex of lavas and agglomerate represents a special phase in the evolution of the island. — Since the emissions of both lavas and the volcanic agglomerates took place in the central highland, it is clear that the hugest masses of both kinds of material are to be found in this central part of the island. Lower down the slopes the same rocks continue with their expansion, but here they are getting thinner (and much dissected by erosion).

From the mountain cape mentioned the author followed the northern rim of the Caldera in easterly direction until he reached the head of Barranco del Risco Blanco, in its turn the head of Barranco de Tirajana. The passage is difficult. Great rock slides have occurred all along the escarpment, apparently chiefly in a phonolite ground. These phonolites which have platy partings, seem to be especially suited to such gliding movements. The phonolite formation constitutes, as I have found, the chief basement of the huge sequence of the R. N. agglomerate formation in the precipices.

But there are not only these sliding phenomena with the characteristic topography in the lower slopes. Side by side with them erosion has been vigorously at work, and the two agents in combination produce (and have produced) in some parts a rather strange relief.

Barranco del Risco Blanco is, however, a fresh cut reaching deeply into the border of the Caldera and into the allochtonous lower ground. In the head of the *barranco* there are almost vertical walls which are difficult to climb. I noticed thick layers of brownish tuffs (or agglomerates?), in which numerous caves, old dwelling places of the Guanches, can be seen.

Risco Blanco (de Tirajana)

When one follows this *barranco* downstream for some distance, one passes on the left a very remarkable standing rock with columnar, vertical jointings, known as Risco Blanco de T. This name owes its origin to a whitish weathering crust covering the surface of the phonolitic rock or neck which we find in this *risco*, half disclosed by the river erosion.

Risco Blanco has almost vertical contacts with the enclosing formation which mostly consists of reddish or brown tuffs. The rock mass may represent a lava filled volcanic conduit and, as we will find later on (Chapter 10), may be considered one of the many vents in this region of the adjoined upland, from where large masses of phonolitic (strongly Na:alkaline) lavas were spread over the upland surface.

Here a short description of the Risco Blanco phonolite will follow based on samples collected from the basal part of this gigantic monolith.[1])

Most of the samples are of blocks lying at the foot of the precipice.

The current type (172) is dark-gray with glistering tabular feldspar phenocrysts. Micr. the rock consists of feldspar, also in the groundmass, here mingled with aegirine prisms in the trachytoid texture. Of other phenocrysts, there are a sodalite mineral (hauyne), zonal and partly altered of nepheline (in hex. crystals) and a pale-greenish clinopyroxene with a dark-greenish border zone. The optics of the feldspar phenocrysts are:

Alk. feldspar: $2V\alpha = 57.5°$, ind. of refr. < 1.54, opt. char. $-$
(anorthoclase)

The magnetite has a skeletal appearance. The pores are filled with a zeolite mineral. Mafics play a very subordinate role in the composition. The rock may be called a hauynophyre of the tahitite group (A. LACROIX).

[1]) Nos. 172–176.

A chemical analysis of this rock has been carried out with the results quoted below:

Analysis no. 4

Sample no. 172 (HAUSEN 1953) of a hauyne phonolite, Risco Blanco de Tirajana. Loose boulder at the base of the rock.

		Mol. prop.
SiO_2	55.00%	9121
TiO_2	0.12 »	15
Al_2O_3	23.30 »	2280
Fe_2O_3	1.57 »	98
FeO	0.57 »	79
MnO	0.13 »	18
MgO	0.14 »	35
CaO	1.19 »	212
BaO	0.00 »	
Na_2O	10.20 »	1645
K_2O	5.76 »	611
P_2O_5	0.03 »	2
SO_3	0.15 »	19
CO_2	0.00 »	
H_2O+	2.08 »	1154
H_2O-	0.16 »	
Sum:	100.40%	

Norm:		
or	34.0	60.4
ab	25.2	
an	1.2	
ne	32.6	
th	0.3	
Σ Sal:		93.3
di	0.8	
wo	1.5	
mt	1.9	
hm	0.3	
il	0.2	
ap	0.1	
Σ Fem:		4.8
H_2O		2.2
Sum:		100.3

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.55 (+23.5°C)

NIGGLI — values:
si=179, ti=0.4, p=0.04, so_3= 0.4, h+=22.6, al=45, fm=6½, c=4, alk= =44½, k=0.27, mg=0.12, qz=−99, al−fm' =38½, al−alk=+½

C. I. P. W. Classif. — I. 6. 1. 4.
Miaskose
Magma type: normal foyaitic/urtitic
Mol. prop. % of normative feldspars Ab:An:Or=42:4:54
MgO:FeO=100:1

RITTMANN parameters for nomenclature: Al−20.97, FM−2.62, Alk−21.06, k−0.27, an− −0.002, ca″−1.24. — Nepheline (hauyne) phonolite.

Here is an example of a group of lavas — foid-bearing phonolites, extremely rich in natron, rich in aluminium and rather undersaturated in silica. As we will find later on, this type and a number of other foid-phonolites, form a group of lavas corresponding to a certain volcanic phase in the geological evolution (see the chapter on petrology!).

The border of the Caldera, i.e. the left side of Barranco de Risco Blanco consisting of tuffs and the R. N. agglomerate, is capped with a basaltic lava bank of a tephritic nature (177).

This rock is a porphyrite with micr. clear phenocrysts of plagioclase, of clinopyroxene and of brown hornblende, sodalite and sphene with apatite and ore as accessories. The optics of the chief minerals are:

Plagioclase: $2V\alpha = 100°$, albite & Karlsbad twins. Ext. angle $\alpha' \wedge (010) = 24°$. Comp.: An/40—50.
Pyroxene: $2V\gamma = 62°$, $c \wedge \gamma = 40°$ (augite)
Hornblende: $2V\alpha = 56°$, $c \wedge \gamma = 17°$. Pleochr.: α-yellow, γ—brownish black (barkevikite)

This lava without doubt belongs to the R. N. agglomerate formation, and it is capped with the hauyne-bearing phonolites which are connected with the half-dismantled conduit of Risco Blanco. But these in turn are capped with olivine basalt of the post-Miocene effusions.

No. 178 is of the top sheet of basalt (covering the tephrite). It is an olivine-bearing basalt, evidently the youngest rock in the sequence. Micr. it is a rather ordinary type with phenocrysts of olivine (clear) rimmed with iddingsite. The paste is filled with fine-grained augite prisms and magnetite and a trifling amount of plagioclase. Hence the rock may be of a more picritic composition.

The eastern side of Caldera de Tirajana

This marked eastern border of the great abyss is in reality not a bowed limit (an emabyment fitting a giant rounded caldera) but a straight edge, most probably a fault scarp. It runs southeast, with continually decreasing height in that direction, until it disappears some distance from the coast. Only its upper part can be considered a »caldera border», the continuation is the left wall of the wide valley of Tirajana.

This long profile has in some parts been investigated by the author. Many details are still to be cleared up.

In the north, I used Santa Lucía as a basis for excursions. This village lies c. 700 m above sea level, rather close to the foot of the *cuesta*. From here I climbed the slopes to the north, reaching a height of c. 1 050 m. At first basalts are met with (connected with the basalt lava fill further down in the Tirajana valley?). Going uphill, one enters a *barranquillo* leading down from the highland border. Here phonolites are exposed, showing the typical platy partings. Higher up in the profile, there are huge banks of the R. N. agglomerate, forming a series of precipices ('staircases') with interstratified dark lava beds (tephrites?, no samples). Following the foot of the highest lying *escalón* to the north, one soon reaches flatter ground extending off the same. It is gently inclined towards the abyss of the Caldera; in that direction it is confined by a sharp edge. This flat, inclined ground is called Los Pajonales. It lies 1 000 m—900 m above sea level. To my surprise I found this ledge to be composed of a very coarse detrital material of late geological age. It is a delta fan[1]) accumulated by some wildwater streams coming from the highland. That occurred at a time, when the floor of the Caldera lay considerably higher than now!

The gravel fan is backed by the steep border of the R. N. agglomerate, covered with the olivine basalt lavas of the highland. It proved impossible to climb this wall in search of the apex of the gravel fan mentioned. The coarseness of the material bears witness to very powerful transport by running water, certainly from a time with a completely different climate from that of today, (or was there a *lahar*?.)

From the edge of this elevated platform a narrow gorge cut into the gravel mass was followed downhill. The coarseness of the material is astonishing, and huge blocks have dropped to the bottom of the gorge, thus clogging the passage. This gorge — the result of young erosion divides the delta into two parts. — At the mouth of the gorge is the small mountain village El Morisco, and the ground here consists as it seems chiefly of phonolites in a flat position. On the way down to La Rosiana the path drops c. 175 m.

The village of Santa Lucía lies not far from the foot of the eastern wall of the Caldera. This steep slope was examined during an excursion from the village to the edge. Somewhat to the east of the dwellings there are rocks of phonolite, forming the basement of later basalt lavas which have issued from some vents (fissures?) at the foot of the *cuesta*. The mountainside itself consists of a series of basalt lavas and tuffs, apparently underlaid by the R. N. agglomerate formation (mostly concealed by talus masses). The top basalt lavas have a wide extension in the highland behind the edge, a *barranco*-furrowed ground

[1]) A piedmont fan.

sloping to the south. The lavas are here rather decomposed and covered with weathering products (and to some extent cultivated). A sample of one of the basalt types (162) is micr. a typical olivine basalt of the more picritic kind, with the olivine as the only phenocrysts. The groundmass chiefly consists of augite and ore and laths of plagioclase. The olivines are clear, but rimmed with iddingsite. The plagioclase is altered, apparently chiefly to zeolite. The lava no doubt belongs to the post-Miocene effusions of wide-spread occurrence in the highland (cfr. with no. 178).

An excursion from Santa Lucía to the south followed the new high-road which leads to Temísas and Agüimes. This road first crosses a lava field of basalts (belonging to the lava fill of the Tirajana valley), then it climbs obliquely up the steep slope on the left side of the valley to a pass. Several volcanic beds are crossed on the way, all slightly tilted to the south.

The lowest beds in the profile here consist of basalts, which seem to be free of olivine, i.e. lavas of a more tephritic aspect. They are capped with lavas of a salic composition, and on these there lies the R. N. agglomerate formation, here forming vertical precipices. This seems to continue farther south along the side of the valley.

This rock is in turn capped with a top-series of basalt lavas and tuffs in a harmonious sequence. They are sculptured into a fantastic ridge with pinnacles. The road crosses this ridge in a sharp turn and then it continues on a winding course in the direction of Temisas (and further on to Agüimes). We refer the reader to descriptions of this route in Chapter 2. It is of interest to note the presence of the R. N. agglomerate at the bottom of the next *barranco* to the east of the Tirajana valley — border. This suggests a wider extension of the agglomerate to the east (under the lavas of post-Miocene basalts).

Some samples have been collected from this route (9, 156, 158, 160). No. 9 is a black lava, an augite basalt appearing as the lowest bed in the series. It is of a similar composition as the many tephrites described from the profile of Los Caideros Altos and no doubt belongs to the R. N. agglomerate association. There are sparse phenocrysts of augite and brown hornblende in a basaltic groundmass with plag. laths, pyroxene and ore. The augite appears in radial aggregates as well. Olivine is not seen in the slide.

The next banks of lavas in the profile are salic types of phonolitic aspect (158, 160). These lavas lie under a thick bank of the R. N. agglomerate which forms a vertical wall. Micr. the former shows pale-coloured clinopyroxene in the first gen., further a blue sodalite min., but no feldspar phenocrysts. The paste consists of feldspar rods (altered?) with birefr. very weak, mingled with tiny prisms of a pyroxene and ore powder. There are also stray crystals of olivine with a brown fringe and small flakes of brown mica. — No. 160 shows micr. the same (greenish) pyroxene, besides a sodalite mineral and also phenocrysts of alk.feldspar (wandering ext.). Moreover there are prisms of brown hornblende and sphene. The paste consists of feldspar rods, aegirine prisms and ore powder. Apatite is an accessory. We have here sheets of foid-bearing phonolites.

Above these salic lavas there rests the R. N. agglomerate in huge banks and this can be seen continuing far to the north in the same profile. It also seems to continue in a southerly direction. The formation is capped by basalts (mentioned already). A sample of these basalts (156) shows micr. a comp. of the common olivine basalts belonging to the post-Miocene lavas of the highland nearby. In fact these basalts form the very edge of the *cuesta* in this sector, and the top sheets are already much attacked by erosion and weathering.

In the continuation to the south-southeast, the slope can be easily explored along the highway that runs along it right to the southern end of Mont. de las Carboneras. In the steep rocky walls that follow the road to the left there lies the R. N. agglomerate formation, at least down to a site opposite Las Fortalezas, always capped with the highland basalts which seem to continue further southeast.

By the road and below it, on the slopes towards the valley, there are glimpses of the red, rhyolitic (?) volcanics underlying the agglomerate banks (seen chiefly in small ravines leading down to the valley).

After passing Las Fortalezas, one will find the *cuesta* as disappeared and instead smooth ground is passed, covered with basalt tuffs (decomp.). The road runs along the southwest flank of Montaña de las Carboneras (650 m). This ridge was somewhat studied along its northeastern side (along an old path from Sardina). It is composed of a series of flat-lying phonolite lava banks of great thickness, separated from each other by tuff layers. (This ridge is not capped with basalts). It must be considered part of the great sector of the phonolite formation following to the west of the Tirajana valley. The steep east side of the ridge may be a fault scarp.

On the stretch between Santa Lucía and Montaña de las Carboneras, two samples were taken of d i k e s crossing the R. N. agglomerate banks (164, 168). No. 164 is a foid-bearing type, with plenty of euhedral phenocrysts of a clinopyroxene. There are also phenocrysts of brown hornblende (with an outer zone of decomp. prod.), and sparsely feldspar crystals, magnetite and a sodalite mineral (grayish brown) which seems to have been altered to analcime. Apatite is an accessory enclosed in the pyroxene. The microlites of feldspar in the paste have a very weak birefr. They are mingled with short, small prisms of the clinopyroxene and with ore grains. The colour index of the rock is c. 35. It may be a phonolite approaching a sodalite tephrite (analcime tephrite?).

No. 168 is likewise of a dike crossing the R. N. agglomerate. The locality is at L o m o G a l l e g o. Micr. the rock is distinctly porphyric, with clear phenocrysts of alk. feldspar without polysynthetic twinning (opt. char. +, ind. of refr. ~1.54, albite). No mafic components are seen in the I gen. The paste consists of a cryptocrystalline feldspar web and grains of a pyroxene (?) and ore. The birefr. of the feldspar is weak (sanidine?). The paste may have undergone devitrification. The rock is a trachy-andesite.

The western side of Caldera de Tirajana

In the west, the Caldera has a remarkable boundary in the mountain wall which rises at its northern end to 1 500 m, then continues southward as a very long chain with slightly decreasing heights. The chain in question also forms the eastern divide of a well-separated drainage area, the master *barranco* being that of A y a g a u r e s, ending at Maspalomas. Northwards, the chain is separated from the central highland by a saddle pass — D e g o l l a d a d e T i r a j a n a (1 200 m). The southern continuation of the chain does not belong to the Caldera, since it forms the right side of the deep B a r r a n c o d e F a t a g a. This valley, which will be described later on, is not connected with Caldera de Tirajana but is an independent erosion channel.

The mountain chain in question has no general name; in the north we have the fortress-like summit of B a r r a n q u i l l o s (1 500 m), then M o r r o P e l a d o, then M o r r o M a n z a n i l l a, and so on. The eminences are separated from each other by rather high-lying passes, difficult to reach. The most comfortable route goes through Degollada de Tirajana.

The author has made some excursions along these western mountains, starting from Casa forestal de Tirajana which lies a short distance to the south of the *degollada*. Although the topography is extremely varying, wild and romantic, the rock ground is monotonous throughout as far as I could prove. Few samples of rocks were collected (224, 225, 230). There are mighty banks of platy phonolite lavas, dark-coloured with vertical columns. The banks together form a kind of gigantic staircase, as the lava banks are interstratified with thick layers of soft tuffs. These tuffs are mostly of bright-yellowish colours and are also stratified. Sometimes they display an astonishing thickness, as in the vicinity of the Tirajana Forest Inn lying south of the *degollada*. Here the lavas and tuffs have been given an eastward tilted position.

It is striking that these phonolite lavas and tuff layers do not continue to the north beyound the *degollada* just mentioned. This circumstance will be dealt with in some detail further on in the text.

It is likewise remarkable that the phonolite formation does not appear again in the same high position, neither in the northern nor in the eastern side of the Tirajana depression. All this is evidence of great displacements, problems which are connected with interpretation of Caldera de Tirajana.

A phonolite lava (224) from a high lying bed in Montaña de Manzanilla (Degollada de Manzanilla) to the west of San Bartolomé is a thick bank with columnar jointings resting on brown tuffs. Micr. it is devoid of phenocrysts of any kind, the mass is of trachytoid texture: feldspar rods mingled with minute aegirine prisms, the latter in arborescent aggregates enclosing small crystals of nepheline. The colour index is 20—30. The share of nepheline is next to that of the feldspar and the aegirine. Magnetite grains are sparse. The lava is almost identical with a type (220) from the vicinity of Maspalomas, 17 km distant. This fact indicates a wide extension of such a lava type.

On the path from San Bartolomé to Degollada de Tirajana there are large screes of phonolite, masses of slabs which have moved down from the *cumbre* of Montaña Barranquillos. No. 230 is also a phonolite with nepheline, but it differs from the former one by its very beautiful development of plumes of aegirine needles: bundles and radiating groups without any common orientation. These aggregates enclose crystals of nepheline. The mesostasis is a very fine-grained, devitrified mass charged with feldspar grains. The lava was evidently an obsidian. It reminds one of the glassy lavas of Arran, Scotland, having similar arborescent aegirine aggregates in a glass basis.

No. 225 is a somewhat different lava type. It was taken from a bank in a slope to the south of Casa Forestal de Tirajana (in the western slope of Montaña de Barranquillos). The lava rests on a very thick layer of a pale-brownish tuff, well stratified. Micr. the lava shows plenty of clear alk. feldspar phenocrysts, also fragments of the same mineral, all enclosed in a paste of glassy nature. No pyroxene is seen in the slide, small fragments of a brown hornblende instead. The feldspar crystals have corrosion embayments in some cases. There are in the paste also angular grains (fragments) of a colourless substance, surrounded by a dark shell (glass drops?). The lava is a somewhat altered vitrophyre, and it is possible that it belongs to the older salic series which underlies the nepheline bearing phonolites. In this case it should be a top sheet of this series (of rhyolites and trachytes). More detailed investigations are needed here.

We shall now leave the Caldera in its proper sense and go down along Barranco de Tirajana, following it in its entire length in south-easterly direction to the vicinity of the coast, where it ends in a lowland 7 km from the coast line.

Barranco de Tirajana

Barranco de Tirajana has two head branches: Barr. de los Lomillos (from the right) and Barr. de Risco Blanco. These two meet one another at an altitude of 650 m somewhat above La Rosiana (where a stone bridge leads over the bottom). From now on the *barranco* becomes more and more deeply incised into the ground of lavas which constitute the ancient bottom of a wide valley which may be of tectonic origin. — Still farther down the valley, the gorge in the bottom grows deeper, and we enter a long stretch where a basalt lava fill in the valley has been cut by the river (at an earlier time). This relatively young canyon can be followed down to the vicinity of Aldea Blanca.

I have to some extent studied the profiles met with in several parts of this valley train, and a small collection of rocks comes from here (4, 163, 164, 166, 167, 168, 169, 170, 179, 180). Most of them will be briefly characterized in the following.

Going down the *barranco* from Rosiana, we pass through relatively open ground on both sides of the *barranco* (which grows continually deeper). To the right there is at some distance a *cuesta*, the foot of which lies c. 700 m above sea. This *cuesta* runs SSE from the vicinity of San

Bartolomé and continues further south in the much higher east flank of Cumbre de Amurga. In the profiles of this *cuesta* there are phonolitic lavas exposed, alternating with tuff layers. The total height of the profile is c. 300 m. The lowest bank of the series is a bright coloured tuff-agglomerate. From here there is a gentle slope down to the edge of the *barranco*. There are great masses of scree (phonolite material) on the surface, and this covers a reddish lava which comes into sight in the *barranco* walls. We see here a superposition of the phonolites on rhyolitic (-trachyic) volcanics. Good exposures are to be found at Angostura del Ingenio de Abajo.

Further down along the Tirajana valley, the above-mentioned right hand *cuesta* suddenly rises to the spectacular north cape of Cumbre de Amurga (1 100 m). At the same time it forms the divide of the Fataga valley. From now on, the east flank of this imposing ridge forms the right wall of the Tirajana valley. It consists all the way of the phonolite formation with huge banks of columnar jointings.

Before we proceed further along the valley, we may look at some lavas exposed in the *barranco* itself, incised into the old valley bottom. At Puente de Rosiana there are banks of lavas on the right with a steep ledge facing the *barranco*. The lower lava bank is of a reddish colour and of rhyolitic aspect. The upper bank is larger and of a gray colour. It has columnar jointings. They seem to continue up and down the stretch of the *barranco* for a great distance, especially the lower red one.

The reddish lava (169) shows micr. phenocrysts of alk. feldspar (clear) surrounded by a dark fringe, lying in a glassy, iron-stained paste with a fluidal texture in which there are litophyses: small feldspar rods in dark patches. Mafic minerals are not present. Optics of the clear feldspar phenocrysts are:

$2V\alpha = 42°$, ind. of refr. $<$ balsam. Ax. pl. $\sim \perp(010)$ (anorthoclase)

Then there are colourless grains, somewhat altered, with small axial angle (sanidine?). The glassy, streaky texture and the angular fragments of a lava of the same kind in the paste speak in favour of an ignimbrite. The rock belongs apparently to the old rhyolite-trachyte series.

Since this type seems to be representative of these red volcanics that lie under the phonolite formation in the western wall (above described), it has been submitted to a chemical analysis, the results of which are given below:

Analysis no. 5

Sample no. 169 (HAUSEN 1953) of a reddish trachyte lava, right side of Barranco de Tirajana at Puente de Rosiana.

		Mol. prop.	Norm:		
SiO_2	59.87%	9929	Q	5.1	
TiO_2	1.23 »	154	or	29.1	
Al_2O_3	15.60 »	1526	ab	48.8	79.8
Fe_2O_3	6.64 »	416	an	1.9	
FeO	0.05 »	7	C	0.03	
MnO	0.32 »	45	Σ Sal:		84.9
MgO	0.82 »	203			
CaO	0.49 »	87			
Na_2O	5.78 »	932	en	2.0	
K_2O	4.94 »	524	hm	6.7	
P_2O_5	0.08 »	6	il	0.8	
CO_2	0.00 »	—	ru	0.8	
H_2O+	1.40 »	777	ap	0.2	
H_2O-	2.53 »		Σ Fem:		10.5
Sum:	99.75%		H_2O		3.9
				Sum:	99.3

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.44 (+23.5°C)

NIGGLI values:
si = 238½, ti = 3.6, p = 0.1, h+ = 18.8, al = 37, fm = 26, c = 2, alk = 35, k = 0.36, mg = 0.18, qz − 1½, al − fm′ = +11, al − alk = +2.

C. I. P. W. Classif.: — I. 5. 1. 4.
Nordmarkose
Magma type: *si*—natron syenitic/umptekitic
Mol. prop. % of normative feldspars Ab:An:Or = 61:4:35
MgO:FeO = 100:0

RITTMANN parameters for nomenclature: Al — 14.04, FM — 8.69, Alk — 13.61, k — 0.36, an — 0.02, ca″ — 0.23. — Soda trachyte.

This lava, slightly silica-oversaturated, may be the uppermost of the trachytic-rhyolitic series which underlies the phonolite formation (seen in the *cuesta* to the west).

The grayish columnar lava, which likewise has a flat position and has apparently not been disturbed later on (contrary to the volcanics on the opposite side of the *barranco*), is a phonolite (170). Micr. it shows slender, clear laths of alk. feldspar lying in a fine-grained paste of cryptocrystalline feldspar, nepheline and aegirine aggregates. The lava seems to have been a vitrophyre, somewhat altered later on. It shows a great similarity to the phonolite from the Manzanilla mountain in the west (high level).

If we now proceed down the *barranco*, we arrive at Angostura Ingenio de Abajo. Here there are good exposures in the reddish lavas on both sides of the gorge. One sample (166) shows clear phenocrysts of anorthoclase in a very fine-grained paste consisting of brownish microlites of mica (?) and a colourless substance (feldspar mixed with sec. calcite?). Ore powder also occurs. The lava may be a soda-trachyte, and it forms rather massive banks a long way along the gorge.

At Ingenio one will already find that basalt lavas cover the red ones on the left side of the *barranco*. I crossed these basalts on the way up to Santa Lucía. The lavas are rather decomposed and in places tilled fields. Risco del Cuervo, just below Santa Lucía, is a basalt knob that has perhaps functioned as a small orifice during the lava eruptions.

From here to the southeast a broad terrace covered with basalts extends on the left side of the master *barranco*. These can be followed all the way down to the vicinity of the coastal lowland. The same basalt cover reappears on the right side of the *barranco*, here forming a similar terrace of equal height. It is evident that these terraces once formed a single fill of lavas covering the bottom of the old valley. The height of the right-hand terrace in the vicinity of the farm of La Barrera is at least 200 m above the gravel floor of the gorge. The basalts do not form a single mass; there are several sheets of lavas with interstratified tuff layers.

Of the left-hand terrace the basalts have been carved out to the erosion witnesses of Las Fortalezas (F. GRANDE and F. CHICA), almost isolated pinnacles rising more than 200 m above the bottom of the *barranco*. They seem to rest on red layers.

We will return to these basalts later on.

The higher right side of the Tirajana valley is identical with the flank of Cumbre de Amurga: a continuous exposure of concordant phonolite banks and tuffs. The samples from here are few. One (167) is of a lower lying bank betw. Aldea Blanca and El Gallego. It shows micr. clear, euhedral alk. feldspar phenocrysts in a fine-grained paste of feldspar, aegirine and also a brown mica (?), of nepheline and appearently sec. zeolite. Optics are:

Alk. feldspar: $2Va = 40° - 50°$ (meas. in twin crystals acc. to the Karlsbad law. Ax. pl. $\sim \perp$ (010) (anorthoclase)

In front of the phonolite *cuesta* lies the basalt lava terrace. Its limit, however, has been obscured in places by scree.

Down in the bottom of the *barranco* one will here and there find small rock exposures of salic lavas. — A sample from here (179) shows micr. phenocrysts of alk. feldspar (anorthoclase) in a fine-grained groundmass consisting of feldspar rods mingled with dark, minute flakes of mica (?) The type bears a certain similarity to the porphyry lava from La Angostura (opposite Casa Blanca) which has been described. — Still further down the canyon we will find on the right side a pale-coloured trachyte-looking rock exposure lying at the base of the basalt lavas of the valley. Perhaps this salic rock belongs to the trachyte in the neighbouring ridge of Montaña de las Carboneras.

As far as the higher left side of the Tirajana valley is concerned, it has already been briefly characterized (page 111). A remarkable circumstance is that the geological structure in this wall is different from that of the right hand one: in the former the phonolites are absent; instead we have the R. N. agglomerate formation crowned by olivine basalts. At the base there are tephrites, and still lower down reddish lavas and tuffs. Some dikes crossing the sequence have already been dealt with; they are of phonolitic composition (164, 168).

If we now turn our attention to the basalts which fill the valley, these consist, as was mentioned, of a number of lava sheets with interstratified tuff layers. The infilling process has consequently been repeated several times. In Pliocene (?) time there began rather remarkable flows rushing down the valley from a source somewhere above the present Santa Lucía. The path of these incandescent streams was the broad bottom of the tectonical outlet valley of the Caldera, an almost 3 km wide train with a consequent (low) gradient to the sea. When reaching the end of the valley some km distant from the shore, the lavas inundated a broad area, they expanded like a delta fan, forming a flattened cone. One can still recognize this cone of lavas, which is covered in the surface, with gravels and also lime-*tosca*, but lava exposures are seen in the steep cuts along the lowest course of Barranco de Tirajana.

When these lavas flooded down the Tirajana valley, the Caldera already existed as a wide depression; the bottom lay, however, considerably higher.

The author has tried to locate the orifices of these copious masses of basalt lavas. One can follow then along the valley upstream as far as Santa Lucía and from here up a long slope (behind the church) to the foot of the eastern caldera wall. It seems fissures opened along the eastern *cuesta* of the Caldera had given way for the lavas to rush down the valley.

During a later period when the island lay higher than now (the Great Ice Age?), a new erosion cycle started. A deep canyon was then incised into the lava fill.

Samples of these lavas (154, 163, 180) are rather ordinary olivine basalts. Some characteristics will follow, and we will begin our description of localities and rocks at Santa Lucía.

South of the village there is already a vast cover of basalts decomposed in the surface (no samples from here) and they seem to cover a substratum of salic lavas (rhyolites etc.) visible in the young canyon of Tirajana. The rocks in Las Fortalezas, the two spectacular erosion witnesses carved out of the lava fill (F. Grande 525 m) were studied more closely. In Fortaleza Grande there seems to be in the basal part a red lava (?) or tuff; then thin sheets of basalt lavas forming a kind of socle follow; on this there rests a »butte» of brown tuffs like a top hat. Numerous caves have in pre-Spanish time been dug into the soft rock mass. This brown tuff seems to correspond to the tuff of great extension that is met with in the flat topped watershed in the west at Barranco de La Angostura (or Barr. de Balo).

A sample (180) was taken from the right hand lava terrace of the valley at a locality called Paso de La Cruz (N of El Gallego). It is of the top lava bank. Micr. the lava contains phenocrysts of olivine and augite lying in a groundmass of plagioclase, pyroxene and ore. The pyroxene is zonal. Optics of the chief minerals are:

Olivine: $2V\gamma = 80°$ (Fa=0%)

Pyroxene: $2V\gamma = 76°$ (core — aug. 20% aeg. mol.) / $2V\gamma = 62°$ (shell — diopside aug.) } $c \wedge \gamma = \sim 45°$.

No. 163 is from a site in the vicinity of a settlement called El Gallego and belongs to the right-hand basalt terrace of the valley. Micr. the rock shows olivine as the only mineral of the I gen. The groundmass consists of plagioclase laths, augite and ore. There is also a colourless isotropic substance in patches (analcime?). The lava does not look very fresh. The olivine grains are iddingsite-rimmed.

No. 154 is of a lava bank belonging to the broad flattened lava cone spread before the mouth of the Tirajana gorge (locality is Aldea Blanca). Micr. this lava rock is also olivine bearing basalt, the olivine forming phenocrysts, whereas the groundmass consists of plagioclase, pyroxene and ore. The pyroxene appears as slender prisms, forming a kind of web with ore in the interstices. The lava looks rather fresh. No iddingsite rims are seen in the olivines.[1])

Geological summary of the area

Finally, the details may be summed up here in a short review of the lithological sequence and regional distribution of the rock types. Some words will also be devoted to the question of the probable formation of this so-called »caldera».

Regarding the volcanic stratigraphy, we will find the lowest exposed member at the bottom of the Tirajana valley to be red porphyric lavas of a rhyolitic aspect. According to the (few) samples, they are not really rhyolites, but soda trachytes, perhaps the topbeds of underlying rhyolites. — Upwards, there follows a rich complex of nepheline-bearing phonolites. These in their turn support the R. N. agglomerate formation with its alk. basaltic lavas intercalated. Still higher up in the geological column, there are foid-bearing, highly Na-alkaline phonolites (extending over the highland nearby), and at the top we have the vast expanses of olivine-basalt lavas of the post-Miocene age. — Of somewhat later age are the basalt lavas, olivine-bearing, that fill the bottom of the old Tirajana valley.

The repartition of all these lithological complexes in the area is rather confusing. There is, as we have found, no correspondance in the composition of the northern and the eastern walls of the depression on the one side and of the western wall on the other. Whereas in the former the R. N. agglomerate with its alk. basalts and the covering olivine basalts are chiefly exposed, the western wall offers a huge profile across the platy nepheline-bearing phonolite formation without any covering basalts. This discrepancy is repeated along the sides of the outlet of the Caldera—the Tirajana valley. Such a marked break may be due to great

[1]) E. Jérémine (1933) has described a »basanitoide feldspathique» among the rocks from the same region. Her type may belong to the basanites-tephrites (of the R. N. agglomerate formation), hence it has nothing to do with the valley basalt lavas. A chemical analysis of Jérémine's rock is presented in the list of the Niggli-values on page 375, no. 2°.

displacements along a fault line (or zone) which runs across the area in the direction NW-SE(—SSE).

Of a later age than the complexes in the surrounding walls are the olivine basalt lavas that fill the bottom of the Tirajana valley for a distance of at least 13 km. That this fill is not very young, however, is demonstrated by the fact that it has been cut through by a channel, probably in Quaternary times. This erosion has reached down to the basement, i.e. the bottom of the old valley, which consists of salic lavas apparently belonging to the first sequence of such volcanics in the island.

No young volcanic manifestations, in the shape of cinder cones, are to be found inside the Caldera area.

The origin of Caldera de Tirajana has been much disputed in the course of time. The first to express his opinion was L. von Buch (1825), who found the great depression a good example of his »elevation hypothesis», one of a really gigantic scale. In more modern times L. Fernández Navarro (1925) declared its real nature to be a purely (negative) volcanic form, a giant explosion crater. Later on J. Bourcart (1937) only found evidences of exogene geological work- weathering and erosion. More recently S. Benítez Padilla (1947) who is well acquainted with the island geology, recognized a new factor, formerly overlooked: great land slides due to seasonal rains. These have been helping the enlargement of the depression, originally created by subsidence movements. The great importance of these sliding movements was fully well illustrated by F. Macau Vilar (1956), until recently a road engineer in the island. As to the origin of the depression this author shares the opinion held by Benítez Padilla: the Caldera is an example of a true collapse-caldera of volcanic kind, the result of withdrawal of magma from below in connection with great lava outbursts in the surroundings (see also F. Macau Vilar 1960).

The present author must confess he cannot agree with the idea of a collapse caldera of true volcanic origin. There are no evidence of a circular depression to justify the expression 'collapse caldera': the depression is not a closed basin, only the rounded end of a deep mountain valley (Valle de Tirajana) is to be seen. This amphitheatre-head is caused by sliding phenomena in combination with weathering. Finally: where are the enormous masses of lavas withdrawn from the basement of the depression bringing the ground to collapse?

The region is traversed it is true, by great lines of displacements connected with the dissection of the whole island into the two segments, as has been pointed out already by J. BOURCART (1937). The river erosion may assisted by weathering have made use of these lines of weakness in its excavation work.

Hence: the main factors which have helped to create this spectacular depression are: ruptures and displacements crossing this sector of the island; vigorous headwater erosion and weathering; finally landslides on a grand scale.

4.

The Southern Declivities of the Island

General features of the great southern sector

Bandas del Sur is the usual name of the remote southern declivities of the island in which the population is sparse and the roads are few. The slopes of the ridges to the south coast are generally gentle, it is true, but the region is nevertheless much dissected by *barrancos*. These all head south, although with some deviations. They are separated from each other by flat-topped watersheds, real table mountains — a strange type of landscape. — The upper part of the sector, however, is lofty, with outstanding mountain summits and very deep gorges. On the other hand the coast is low, forming a rocky abrasion cliff of low heights alternating with sandy embayments.

This broad sector of the island has been sculptured into the southern flank of an old phonolite volcano which probably occupied the whole island. This part alone has been relatively well preserved and rarely covered with younger volcanic beds. The dominating volcanics are here dark, platy phonolite lavas alternating with brownish tuffs.The flatness of the ridges between the *barrancos* owes its existence to the platy phonolite banks. There are also lavas of other kinds, rhyolites and trachytes and their tuffs in some of the *barrancos* at deeper levels (here exposed by later erosion). Also along the coast cliffs there are exposures of similar rocks.

As we will find from the descriptions to follow there is a general rise of the salic (rhyolitic- trachytic) volcanic complex in westerly direction. At the same pace the old basalts are more and more exposed on lower levels (in the western *barrancos*).

Younger constructive volcanic forms are practically absent in this part of the island. In this sense the South differs considerably from the northern declivities.

There are in the South some long *barrancos* which can be followed and studied. The sides are generally steep and display good geological profiles. The master canyon of all is that of Soria-Arguineguín, dividing the sector into two parts. Total length of this *barranco* is c. 22 km. — There are also good opportunities for studying the sequence of volcanics, — i.e. the relative age of the different outbursts.

In the following pages we will visit all the more important *barrancos*, starting from the most easterly one — B a r r a n c o d e F a t a g a. As we proceed in westerly direction, we will find occasion to look at the geological details exposed in the long sea cliffs — from J u a n G r a n d e to the mouth of B a r r a n c o d e V e n e g u e r a.

Barranco de Fataga

This rather straight valley of c. 16 km in length runs from north to south and is a very marked mountain trench confined by steep and lofty sides. Its head, however, is surprisingly low, at 900 m above sea level — and it is here separated from Caldera de Tirajana by a broad, plateau-like ridge. The Fataga valley has evidently no topographic connection with the caldera itself, although the right side of the valley is the immediate southern continuation of the western wall of the greatd epression.

The geological conditions along the Fataga valley are rather simple. On both sides we will find a great succession of the nepheline phonolite formation, lavas and tuffs. Only in the bottom canyon along the upper course do there appear some red lavas and tuffs belonging to a rhyolite formation underlying the phonolites. Similar older salic volcanics reappear also in the south, in the vicinity of M a s p a l o m a s. — One gets the impression that the Fataga valley is of tectonic origin, afterwards enlarged and deepened by the running water (finally by bottom erosion forming a narrow canyon). — A number of rock samples has been taken along the valley in question (200, 202, 206, 207, 210, 213). They will briefly be characterized below.

It has already been mentioned that the valley sides are very steep (following dislocation lines) and few tributaries are seen. Owing to the steepness, a great rock slide has taken place in pre-Spanish times where the settlement A r t e d a r a is now situated (half way from Fataga to Maspalomas). One half of an entire mountain has collapsed and filled the valley bottom with a chaotic jumble of angular blocks. Owing to this dam, an alluival flat has been created on the upper side of it.

If we now look at the main rock types found along the valley, we can start at the head, at the divide by the Caldera. Here only nepheline phonolites and their tuffs are exposed. In the steep slope of Montaña de la Guardia opposite the village Fataga, there are thick banks with columnar phonolite lavas (200, 202) showing micr. the typical trachytoid texture with alk. feldspar phenocrysts, nepheline grains and aegirine in tiny prisms (rather abundantly).

To the east of the village, there are also phonolites and their tuffs in the very steep sides of Montaña de Amurga, slopes which are difficult of access. The lavas here have also columnar jointings and are separated by thick layers of brown tuffs, in which caves have been dug. I followed the slopes southward to Paso de los Puercos, then turned down the talus slopes to the bottom of the valley.

The young canyon that has been incised into the upper course of the valley has laid bare some reddish volcanics that are older than the phonolites just mentioned. At least two banks of red lavas are here seen, separated by a reddish tuff layer. A red tuff also covers the upper of these lava banks. The lavas display columnar jointing and are somewhat brittle. They have a rhyolitic aspect (samples 206, 207, 210). The first is a distinct porphyry with clear phenocrysts of alk. feldspar in Karlsbad twins (anorthoclase). They lie in a groundmass consisting of fragments of feldspar in streaks, in which the pores have been filled with an isotropic substance (glass?). There are also elongated streaks filled with a network of tiny laths of sanidine (lithophyses). The interstices between the rods are filled with an isotropic subst. (glass?). No mafic minerals are present. Optics are:

Alk. feldspar: $2V\alpha = 44.5°$ (det. on 2 indiv.). Ax. pl. $\sim \perp(010)$
(anorthoclase)

The rock may be a rhyolitic ignimbrite or vitreous trachyte.

No. 207 is of a rather similar nature, showing micr. quartz in the pores of the paste, apparently of sec. origin. Between + nic. the paste looks nearly isotropic (glassy?). The alk. feldspar phenocrysts are clear (opt. char. —, ind. of refr. < 1.54). No mafic components are seen in the slide, instead, fragments of alien lavas with a basaltic texture. — No. 210 is likewise a porphyry with alk. feldspar crystals, besides brown hornblende in an almost isotropic, turbid paste containing stray grains of magnetite. No quartz is visible.

Although no more accurate diagnosis of these lavas has been made, we may assume that they belong to the rhyolite series that underlies the nepheline-bearing phonolites in the profiles uphill on the slopes on both sides.

From this upper course, Barranco de Fataga can be followed down to Maspalomas by using the military road which has been built along the left side of the valley. Here one has an opportunity to examine many details in the volcanic sequence. Few samples however, were collected from this route.

At the village of Artedara, I turned west up the gigantic scree of the above-mentioned mountain avalanches which occurred a long time ago. I entered a small side-*barranco* eroded into the phonolite formation and ascended to a divide in the west, called Degollada del Gigante. From here there is a good view in westerly direction over a wild and strange erosion landscape in the table — land formation: the phonolites and their tuffs slightly inclined to the south. All the ridges are flat topped, a type of landscape not found in other sectors of the island. These land forms are certainly not very young: they apparently date from the Tertiary period. — All the lava banks have columnar jointings despite their flat-lying, platy cleavage. Between the lavas there are thick layers of brownish or reddish tuffs. These last-named allow the digging of stables and barns used by the scanty population of the region.

If we turn back to Barranco de Fataga and follow the military road downwards to the settlement Maspalomas (along the left side of the canyon), we can prove the existence of this phonolite formation right down to the named village. Just before entering this village, I took a sample of a dark lava rock (213). It is a phonolite very similar to the types higher up along the canyon. Micr. one will find phenocrysts of alk. feldspar in a groundmass consisting of rods of feldspar and minute prisms of green pyroxene (aegirine), the latter in clusters. There are also small stout prisms of nepheline. Optics of the feldspar phenocrysts are:

$2V\alpha = 40° - 48°$, ind. of refr. $<$ balsam, opt. char. —, Karlsbad twins. Ax. pl. $\sim \perp (010)$ (anorthoclase)

In this region the above mentioned dissected table-land ends with a kind of escarpment (an old shore cliff?). Further down to the coast there is only a relatively flat ground slightly inclined to the sea. The whole gravel covered plain seems to be a very much flattened cone, divided by a broad erosion channel created by Río de Fataga (i.e. in former times of more humid climate). The bottom of this waterway is gravel covered and full of braided (dry) water courses.

This gravel train receives some tributary valleys from the right side: Barranco Negro (with its head Barrancos de Ayagaures and Chomotiscón. — This coastal region will be desciibed in more detail in later pages.

To sum up: Barranco de Fataga is tectonically prescribed and was already eroded (deepened) in Tertiary time, later on rejuvenated. The valley bottom now reaches down into the salic (rhyolitic-trachytic) lava formation.

The coastal stretch from Juan Grande to Maspalomas

This part of the south coast can be studied by using the highroad that iuns close to the shore, where many outcrops of rocks are also to be seen. This coastal, relatively flat land lies outside the mountains that rise to the north as a background to a rather desolate landscape, where here and there tomato fields have been tilled

The oasis of Juan Grande lies a short distance from the sea shore in a plain (Llanos de J. G.), consisting of gravel fans spread out by rivers which have descended from the mountain valleys. When going west from the oasis, one reaches a number of parallel ridges of gravel material resting on a basement of phonolites. All the pebbles in the gravels consist of phonolites. The gravel ridges (which were traversed in a westerly direction) are only remnants of an elevated gravel delta fan, stripped by later erosion. The region is called La Guancha.

More to the west, one reaches the lower course of a deep canyon, Barranco Hondo, eroded in a table-formed ground consisting of the phonolites. This coastal mountain area is called Mesa de Toledo. Northwards, the slopes rise continuously.

Barranco Hondo ends some distance before the coast is reached, and here a gravel delta accumulation in an elevated position is met with. Its distal border lies c. 100 m above the sea, and the apex of the flattened cone 50 m higher. This delta may have been accumulated in post-Miocene time, when the island was already in the course of elevation.

To the west of Barranco Hondo, there rises a solitary cinder cone called Morro Tabaibas (400 m) from a platform of 300 m in altitude. I did not visit it, and no lavas which might have emanated from this orifice could (from distance) be detected.

Barranco Hondo is one of the long and deeply incised canyons which split the triangular mountain block that ends in the north with the narrow cape of Cumbre de Amurga. It seems that the entire area lying between Barranco de Tirajana and Barranco de Fataga is built of phonolites and their tuffs. The gravel train along the bottom of Barranco Hondo consists entirely of the same phonolitic material, as I could see.

In the long slopes of the mountains there are many *barranquillos*, all heading southwards to the coast. They were not visited, however. It should be worth while examining the mouths of all these small gorges to see if some kind of old marine beach line (or lines) in elevated position occur. These gorges may have existed in Tertiary times.

There are outcrops of lavas on the coast opposite the mouth of Barranco Hondo, Playa del Cardón. A sample from here (73) is micr. a typical nepheline phonolite, containing slender laths of alk. feldspar and short prisms of nepheline lying in a trachytoid paste of feldspar and aegirine. The latter surrounds the small nepheline crystals in the shape of coronas. This type seems to be common in the *hinterland* to the north.

Further westward, the highroad crosses a ridge, Morete de Tarajadillo, where outcrops are seen. Then one follows the coast for a short distance until one reaches a promontory, Punta Morro Besudo. It ends suddenly at the sea with a cliff. In the road cuts lava rocks are seen, trachyte-looking (74). Micr. one type is a trachyte containing alk. feldspar laths (opt. char. — ind. of refr. <1.54) showing twins according to the Karlsbad law. These lie in a trachytoid paste of feldspar mingled with aegirine microlites and iron ore grains. Moreover, one will find angular xenoliths. Mafic minerals of the first generation are not present.

In the same Morro Besudo there are also outcrops of a greenish-gray agglomerate of a rather massive aspect, forming thick banks. It contains stones and boulders of various kinds. It seems to form the basement of the salic lava above described. Such an agglomerate is rather different from the R. N. agglomerate with its cream-coloured pumiceous matrix, and it is (as we will find later on) confined to the southernmost part of the island. Here it always underlies the puzzolane.

After passing Morro Besudo, one again enters a coastal plain, flat and undulating, with the rugged mountain edge to be seen in the north, and this is forelaid by a rock terrace consisting of basalt (?).

The village of Maspalomas extends along a wide gravel plain with a gentle gradient to the sea, where a cordon of sand and dunes appears. The gravel plain is bounded in the west by a terrain edge following the lowest course of Barranco de Fataga.

Faro de Maspalomas (the lighthouse) lies at the termination of the broad headland which is confined in the east by the large Bahía del Inglés. The mentioned headland is covered by gravels in the surface (and by the dunes at the shore), but below the gravels there is a bank of a hard conglomerate. This bank can be seen in the vicinity of the lighthouse, here jutting out into the surf.

The drainage area between Barranco de Fataga and Barranco de Chira — — Arguineguín

This region is a rather closed mountain landscape of a lenticular shape, dominated by the system of four *barrancos* all heading south to join Barranco de Fataga in the gravel field above Maspalomas. The most important of the *barrancos* is that of Las Hatas, the head of which is semi-circular in shape. This is embraced by the mountain nucleus of Montaña de Barranquillos (1 500 m) with its two side arms: the eastern one consisting of the phonolite ridge separating the area from Caldera de Tirajana; the western one forming the divide at Barranco de Chira.

The high nucleus in the north — Mont. de Barranquillos — is separated from the central highland by the pass of Cruz Grande or Tirajana.

The author disposes only of few samples of rocks from this extensive region, and my excursions in it do not cover more than some relatively short stretches. Consequently, there is not much to be said here about the geological conditions of the area.

The high mountains in the north are composed in their upper parts by phonolites in banks accumulating to a great thickness and showing columnar jointing. These lavas rest on tuffs with bright colours and these are, as far as I have been able to discover, of astonishing thickness and wide extension. This fact seems to have facilitated a very energetic *barranco*-erosion in the mountain sides. Great screes are also common in many parts, slabs of phonolites cover the slopes, which in several places consist of the soft tuffs. These tuffs reach to heights of more than 1 000 m above the sea (Casa forestal de Tirajana).

Some types of the lavas have already been described in connection with Caldera de Tirajana. Other samples were taken from the western ridge, Llanos de las Mesas (252, 253), consisting of nepheline phonolites and their tuffs.

The absence of the R. N. agglomerate formation in the summits and crests of the ridges is noticeable. I have found only one place with a small remnant of this formation: in Degollada de Majadilla Blanca.

Some sub-Recent volcanic cones occur in this southern part, they will be mentioned later on. In the interior they are entirely absent as far as I have been able to prove.

To the west of Barranco de los Vicentes, there follows Barranco de Ayagaures (or Barr. de las Hatas) in which a surface water dam has been built; then follows Barranco de Chamariscas (which joins Barranco de la Negra lower down). I have no rock samples available from the former valley. Barr. de la Negra has been visited by T. BRAVO, and he has sent me some samples from its upper course, called Barr. de la Mosca. Further samples were collected by him from the upper course of Barr. de Tabaqueros, the head arm of Barr. El Negro which joins Barr. de Fataga in the region of Maspalomas. As far as this low lying region is concerned there are in my collection some samples of lava rocks.

Barranco de la Mosca and B. de los Tabaqueros

No. 843 is of a salic lava bank underlying a remnant of the R. N. agglomerate formation (the southernmost one encountered in the island) Micr. it is a glassy lava with a streaky-pigmented texture, enclosing stray crystals of alk. feldspar, brown mica (nearly uniaxial) and brown hornblende and magnetite. The rock may belong to the old salic series. — No. 826 is from Montañeta de la Mosca, a ridge on the right side of Barranco de la Negra. According to BRAVO, the sample is of an intrusive rock. It is micr. a porphyry with phenocrysts of alk. feldspar of a greenish-gray clinopyroxene, brown hornblende, sphene and a sodalite mineral. Ore and apatite are accessories. The fine-grained feldspar-rich paste seems to be altered. It also contains greenish aegirine prisms. The rock may be a phonolite of the strongly alkaline type (of a later age than the R. N. agglomerate?).

To the west of Lomo de la Mosca (divide), there is the head of Barranco de los Tabaqueros (running south a short distance to the east of the lower course of Barranco de Arguineguín). BRAVO has given an interesting cross-profile from here, showing a sequence of 6 beds of concordant lavas (samples 846, 847, 848, 849, 850, 851). This sequence is of some importance, since it illustrates the conditions in a border zone between the nepheline phonolites in the east and the trachytes-rhyolites in the west.

If we begin from the base (*barranco*-bottom), we have here a salic vitrophyre (851) showing micr. a beautiful flow texture with elongated pores and fragments of a trachyte lava, filled with feldspar laths and an opaque substance. There are crystals and fragments of alk. feldspar (sparsely in the glass basis), a pale coloured pyroxene and magnetite, also lithophyses (rather frequently) consisting of tiny feldspar rods in random orientations. The pores are filled with an isotropic substance (opal?). The lava without doubt belongs to the trachytic-rhyolitic series and it may be rhyolitic in composition.

Above this vitrophyre there follows a trachyte-looking lava (850) although it is rather dark-coloured. Micr. it is very fine-grained, consisting of a mixture of feldspar rods, an elongated clinopyroxene and ore grains, and also colourless, isotropic patches. The paste encloses smaller crystals of a clinopyroxene associated with magnetite. The texture is trachytoid. The colour index is somewhat higher than in the common trachytes, owing to the frequent pyroxene prisms in the groundmass. Nepheline is not seen in the slide. The lava may be called a trachyte-phrite.

The next bank of lava uphill is of a dark colour (849), consisting micr. of a fine-grained feldspar mass mingled with aggregates of aegirine needles, enclosing small, stout crystals of nepheline. Appr. comp.: Feldspar — 50%, aegirine — 30%, nepheline — 20%. The texture is not trachytoid. The rock may be classified as a nepheline trachyphonolite. — Higher up the slope (on the right side of Barr. de los Tabaqueros), there are two banks of salic- vitrophyric lavas (848, 847) both with trifling amounts of mafic components (brown mica or brown hornblende). In the streaky, glassy paste there are lithophyses, consisting of tiny feldspar rods in random orientations. Clear alk. feldspar phenocrysts are also present. They show Karlsbad twins and may be sanidine (no striation.). — Finally, we must look at the top sheet in the profile, a rather broad bank of nepheline phonolite (846). Micr. this rock offers the characteristic sight of the platy, dark-coloured phonolites (prevailing in the large sector of the slopes further to the east). The chief constituents are alk. feldspar laths, aegirine needles and nepheline prisms, the latter surrounded by a corona of aegirine microlites. The texture is trachytoid. — This top sheet undoubtedly belongs to the period of the great nepheline phonolite lava emissions of the central type which followed after the deposition of the old trachytes and rhyolites, now displayed in a huge pile in the western mountains.

The region of El Tablero

If we now go south, following Barranco de la Negra, we arrive to a region, where it joins Barranco de Chamariscas not far from the small settlement of El Tablero (to the north of Faro de Maspalomas). The author has collected a lot of samples of lava rocks from here (11, 214, 215, 217, 219, 220, 221).

In the region of El Tablero, the *barrancos* that have their mouth in the gravel train of Barranco de Fataga are rather shallow and their bottoms are likewise filled with gravels (the consequence of a later rise of the ocean level). The sides of the *barrancos* are steep, however, and the lavas and tuffs in them well exposed.

In the corner where Barranco de Ayagaures and Barranco de la Negra join one another, there are two lava banks with a tuff layer between. A sample of the upper lava (215) is dark-coloured, micr. it is glassy with a streaky texture. It carries phenocrysts of alk. feldspar and also fragments of these and of a trachytic lava which contains nepheline. No sample is available of the underlying lava bank. It may likewise be of a salic composition (trachyte). The former lava looks more like a welded tuff or ignimbrite.

At a short distance from this corner down the *barranco* gravel train (towards Maspalomas), a water shaft has been opened north of El Tablero. The lumps of rock fragments lying around the opening consist of a rhyolite-looking lava (214). Micr. this consists of a vitrophyre with the streaky texture of a glass basis (iron-stained) in which there are phenocrysts of alk. feldspar in Karlsbad twins; no mafic components are seen in the slide; elongated pores in the paste are filled with sec. feldspar aggregates (lithophyses), or they are empty. The lava may be a rhyolite (or trachyte). According to information obtained, the lumps are from a depth of c. 100 m. From the bottom of Barranco de la Negra, I headed for the nearest elevated ground on the right side of the *barranco* in the direction of

Pozo Salobre in the SW. The escarpment facing the *barranco* consists of the greenish tuff agglomerate in huge banks (the stone has been quarried to some extent). This agglomerate disappears some distance up the valley and is replaced by dark platy phonolites. These are capped by a sheet of basalt which seems to form a kind of *meseta* farther south (in the direction of Montaña Blanca). Going down to Pozo Salobre (which is situated in a *barranco*) one will again find the phonolites. One sample (220) shows micr. the texture typical of the phonolites (alk. feldspar, aegirine but no nepheline?). There are colourless, isotropic patches in the paste which seem to be analcime.

The lumps (»*escombros*») in the vicinity of Pozo Salobre consist of the dark, platy phonolites (no sample from here).

In the direction northwest of Pozo Salobre, the ground rises continuously and it is rather plain, but furrowed by *barrancos*. The rock ground on the surface consists of weathered basalts, an extensive lava sheet (— or sheets), originally an unbroken cover which seems to have issued as flows from a vent somewhere in the northwest. Looking in that direction, one will notice a dark-coloured eminence. This could be a cinder cone, from where the lavas erupted. It seems to have been a rather productive volcano; it is called Lomo de Arguineguín (375 m). Lavas were spread over the whole of the coastal land between the lower course of Barranco de Arguineguín and Barranco de Fataga. Now the lava cover has been much eroded, partly abolished (see fig. 11). — The author has no sample of the lavas which seem to have undergone alterations on the surface. This volcano may be one of the very rare adventive cones found in the whole southern sector of the island.

There are some other samples from the vicinity of Pozo Salobre which illustrate the composition of the basement of the young basalts (217, 219, 221).

The road that runs southeast from Pozo Salobre joining the coastal highroad in the vicinity of Faro de Maspalomas passes a flat — undulating ground which exposes salic volcanics in a shallow *degollada*. A rock from here (217) has micr. relatively large phenocrysts of alk. feldspar, whereas the mafic components of the I gen. are sparse and consist of an altered pyroxene (?) and flakes of brown mica. The texture of the groundmass is trachytoid with altered feldspar laths mingled with iron ore powder. Optics of the feldspar are:

$$2V\alpha = 44°,\ \beta' \sim \perp (001) \text{ (anorthoclase)}$$

The lava may be a trachyte or trachyrhyolite (?).

In the higher hills in the vicinity the salic volcanics are capped by a dark lava sheet which is apparently a basalt (no sample). Further along the country road to the southeast there are low exposures of a greenish agglomerate (earlier mentioned) and also here is a cap of the dull coloured basaltic lava.

In a westerly direction from Pozo Salobre, there is a hill devoid of a basalt cover and which consists of a salic lava (221). It is a fine-grained porphyry (altered) in which the alk. feldspar phenocrysts have mostly been transformed into aggregates of a carbonate. Other phenocrysts are of brownish hornblende (opacite-rimmed) and stray crystals of a pale-coloured clinopyroxene; of accessories there are apatite and magnetite. The paste, consisting in the main of feldspar rods, contains vesicles filled with calcite. The lava may be a trachyte.

M o n t a ñ a B l a n c a is a hill to the south of Pozo Salobre. It consists, as the name suggests, of a pale-coloured rock mass, a puzzolane. On a more close examination one will find that the rock is more like a breccia: it contains plenty of angular fragments of alien lavas, and the rims of these pieces are dark coloured (reaction zone?). Further to the west this puzzolane agglomerate (or breccia) is replaced by a salic lava (see above no 221!). Both are capped by a dull coloured lava of a basalt (216, no slide available). A sample was also kept of a salic lava (219) from a place to the south of Montaña Blanca. Micr. this contains clear phenocrysts of alk. feldspar, also fragments in a microbreccia of trachytic material. There are crystals of clinopyroxene (euhedral) of a grass-green colour; plechr. is scarcely perceptible. Ext. angle on (010) $c \wedge \gamma = 50°$. (aeg. augite). There is also a very finely crystallized carbonate, playing the role of a matrix between the angular trachyte fragments. It is a trachytic breccia, somewhat altered (impregn. with carbonate!).

To summarize the stratigraphy of the volcanic beds in the region northwest of Maspalomas (the drainage area of Barranco de la Negra—Barr. del Negro), we can state that most of the ground is occupied by the old salic lavas (commonly with vitrophyres) capped with the dark platy phonolites (with aegirine, nepheline). Puzzolane does not appear in the region; it is met with more to the west (Montaña Blanca is the farthest outlier in the east). In the region south of Barranco de la Negra the whole complex of salic lavas is capped with a basalt lava which may have issued from a cone in the vicinity (Lomo de Arguineguín).

The coastal stretch from Maspalomas to Arguineguín

There is not much to be studied on this route (10 km) except for some profiles nearer Arguineguín (coastal cliffs). After passing the gravel train of the Fataga 'river' mouth, the highroad enters low, undulating coastal ground which rises inland to the 100 m contour line. Further westwards the road crosses several shallow *barrancos*. In some parts dunes have also been formed of a fine calcareous sand.

Some km from the fork of the road which leads to the lighthouse of Maspalomas, there is an outcrop of a dark lava (11), a flat-lying bank. Micr. it is a porphyry with clear phenocrysts of alk. feldspar with twins acc. to the Karlsbad law. In addition there are crystals of brown hornblende and brown mica. The paste is trachytoid. Nepheline is also present. Apatite is an accessory. The lava may be a trachyphonolite. Further west the basement seems to consist of a coarse conglomerate with flattened pebbles of the dark phonolites. It is possible that puzzolane is met with lower down.

After passing Mesa de la Arena (SW of Montaña Blanca), the road approaches the coast which it follows to Arguineguín. In the same direction, the coastal cliffs grow higher and are generally steep. All along the shore of Bahía de Santa Agueda is a bank of greenish-gray agglomerate with boulders and stones embedded in a homogeneous matrix. This agglomerate is constantly attacked by the surf, so that smooth rocky capes have been formed. The bank is capped by a pale-yellowish puzzolane showing a surprising thickness, nearer Arguineguín attaining at least 50 m. It has a cream-coloured matrix with many small lava fragments enclosed, but there are also plenty of vesicles filled witht a canary-yellow powder. — This puzzolane no doubt extends far inland, and obviously it had formerly a wide extension also to the south, before marine abrasion had worked back the shore line. The puzzolane is capped by the coarse phonolite conglomerate, the stratigraphic limit being an erosion surface. In cuts along the existing *barrancos* in the region, as in Barranco del Corral Blanco and along Cañada del Galeón, does the bright colour in the sides of the valleys indicate the presence of the puzzolane under the cover of the conglomerate.

This remarkable occurrence of puzzolane has not been noticed by earlier travellers; at least there are no remarks about it to be found in the literature. The formation is still to be more closely investigated as regards its extension and thickness and its chemical composition. Externally the dominating rock seems to me to be very similar to the puzzolane in San Lorenzo (cf. chapter I) and to the same formation occurring in Tenerife (Hausen 1956). In the latter island it is quarried ultimately for the making of hydraulic cement (at Puerto Cristianos). It is doubtful, however, if the occurrence in the far south of Grand Canary will be exploited, owing to its situation and to the fact that a similar rock is met with in San Lorenzo at a short distance from the capital Las Palmas.

The puzzolane is of soft consistency, and it would certainly have been destroyed long ago, if there did not exist the thick cover of the lime-cemented, hard conglomerate (of phonolitic material). Nevertheless the marine abrasion has already cut off a great deal of the formation.

The Chira valley with Cuesta de La Plata

Barranco de Chira is a left hand tributary to Barranco de Soria—Arguineguín. Remarkably enough, the longitudinal profile of the former has not been adjusted to that of the master — *barranco*; it is a 'hanging valley', like those encountered in formerly glaciated mountain landscapes. In more recent times an adjustment is going on: the formation of a gorge leading down to the bottom of the main valley. — Obviously the Chira valley is relatively much older than the latter, it belongs, as it seems, to the pre-*barranco* period (the pre-*barranco* relief), whereas Barranco de Soria—Arguineguín is younger, dating probably from late — Tertiary time, characterized by a pluvial climate and vigorous erosion.

The Chira valley — a flat bottomed, open highland valley — has its head at the very border of the central highland, not far from Roque Nublo. The head is a somewhat semi-circular embayment (»semi-caldera») in this highland bulk. Here three head arms join one another to form Barranco de Ahogaderos, which lower down is called Barranco de Chira. This valley head provides an impressive mountain panorama with the almost vertical precipices of the R. N. agglomerate formation in the background (see fig. 10!). To the right and to the left of the valley are ridges, the latter belonging to the mountains described earlier.

At the lower end of the open Chira valley (above the beginning of the young canyon), the Island Government has constructed a water reservoir — Presa de Chira. A lake has been dammed up here, measuring c. 2 km in length.

The broad-bottomed Chira valley has been eroded into a series of chiefly salic lavas and tuffs, in the east capped with platy nepheline

Fig. 10. The Roque Nublo formation of agglomerates in the region of Ayacata, central elevation of the island. Looking north-east.
Phot. T. BRAVO 1958

phonolites. Moreover, there are also outliers in the region of the (once widespread) R. N. agglomerate formation. Remnants of this flat-lying cover are to be found in both the lateral ridges, but also at the bottom of the valley itself. It seems that this valley of advanced maturity was formed in a time antedating the deposition of the agglomerate, and the valley has been used as a runway for the (glowing?) avalanches of the Peléean eruptions.

We may begin with our descriptions of the rock ground in the highland border itself, here called Cuesta de La Plata after a small settlement in the region — Caseríos de La Plata. We will then proceed down the valley and into the outlet gorge.

Cuesta de La Plata (head of the Chira valley)

Precipices of c. 200 m altitude form the border of the highland in this sector of the island and they can most conveniently be investigated if one uses the military road of S. Bartolomé—Ayacata as a basis. The stretch dealt with here is between Degollada de Tirajana and the mountain corner of Las Candelillas, where the road suddenly bends to the small village of Ayacata, situated in the innermost head of Barranco de Soria. At Las Candelillas we will find a road fork: here a field road turns south and descends to the village of Cercado de Araña and further to the new water storage dam of Chira.

The cliffs of the highland border in the north are almost vertical and difficult of access. At one point, however, there is a path used by the islanders to cross the highland (down to Barranco de La Mina and Las Lagunetas). An ascend may be started at Degollada de Tirajana, then the foot of the precipices may be followed to a point opposite Caseríos de La Plata where the path turns uphill.

At the *degollada* a promontory juts out from underneath the foot of the precipices, showing flat lying banks of a basaltic aspect. They rest on pale-coloured tuffs belonging to the phonolite formation (topmost layers). There are two lava beds, which seem to continue under the sequence of strata building the precipices. The former ones are apparently basal beds to that series. Micr. the two lava rocks (226, 228) contain phenocrysts of pyroxene and brown hornblende, and a sodalite mineral in euhedral crystals is also to be seen. The groundmass is fine grained with plagioclase laths, pyroxene and magnetite grains. Vesicles are filled with a zeolite and calcite. Optic data (in 226) are:

Pyroxene: $2V\gamma = 58°$, $c \wedge \gamma = 53°$ (augite with aeg. mol.)
Hornblende: $2V\alpha = 70°$, pleochr.: α-yellow, γ-brown
$c \wedge \gamma = 10°$ (oxy-hornblende)
Plagioclase: (in the paste). Comp.: An/30

These lavas may be classified as tephrites and they seem to belong to the period of (repeated) activity of Peléean outbursts which did spread the R. N. agglomerates over the island.

The lavas in question are capped by a dark, platy lava (241) which can be followed along the foot of the precipices to the west. Of this rock, apparently a kind of phonolite, no thin section is available. This is overlaid by a lava of pale-grayish colour and of a trachytic aspect (235). It seems to have been intruded into the pile of beds at a somewhat later time. Micr. it shows phenocrysts of a clinopyroxene and of brown hornblende and also of a sodalite mineral, all lying in a trachytoid paste filled with feldspar laths (altered). There are also scattered phenocrysts of feldspar completely changed into kaolin (?). Magnetite is an accessory. The rock may be a phonolite. — Climbing the profile further uphill, one meets a series of tephritic lavas separated by tuff layers (231, 232, 234, 239, 240). An intercalation of a blistery, pale-grayish lava bank is seen in the upper part of this series (238). This latter rock is fine-grained, trachytoid with feldspar laths and aegirine needles. Sphene is an accessory. Iron ore powder is seen, mingled with rods of feldspar and a secondary substance (analcime?). This type may also possibly be an intrusive body. The uppermost tephrite bank (240) forms the basement of the top member of the profile: the R. N. agglomerate of some ten m in thickness. It has vertical walls, due to the presence of large diaclases. The upper surface of this potent cake is flat and undulating (part of the central highland).

In the descriptions above we started with some tephrite lava sheets in Degollada de Tirajana, forming the basal part of the whole series. These lavas no doubt belong to the R. N. agglomerate formation, the lowest thick bank of which is displayed here. But the basement of the tephrites is not seen in firm rock[1]) instead I saw that we have here only allochtonous masses of phonolites which have moved down the valley in the direction of Cercado de Araña. It is clear that this valley head has not only been formed by erosion but with the cooperation of land-slides (as in Caldera de Tirajana). Perhaps these allochtonous masses hide underlying autochtonous phonolites in the lower slopes (down to 1 000 m).

The huge bank of the R.N. agglomerate exposed in Cuesta de La Plata (height appr. 100 m) may represent the first phase of several Peléean outbursts, and this act was preceded by the emission of alk. basaltic lavas, now to be seen at the foot of the *cuesta* to the north of Degollada de Tirajana (Cruz Grande). If we go farther east, to the north-wall of Caldera de Tirajana, we will find the Peléean deposits complete (6 sheets) intercalated by the alk. basalts, as has already been described (page 102, 103).

Cuesta de La Plata, being only the southwesterly continuation of the north-wall of Caldera de Tirajana, can be followed further west and then north around the central 'fortress' of Roque Nublo. We will later on (Part II) more closely consider these remarkable achievemets of weathering and erosion.

The Chira valley (and Canyon)

This highland valley is approximately enclosed by the 1 000 contour line and its length is — as far down as the ledge, where the canyon begins —

[1]) excepting a soft tuff layer.

c. 3.5 km. The sides reach to 300 m and more above the valley bottom. The outlet gorge in the south falls c. 500 m to the bottom of the Soria canyon. This gorge is very narrow — only some hundred m wide. We shall briefly describe the rock complexes inside the valley and the gorge and also what is to be seen in the ridges in the sides. A more detailed survey of the area is still needed, chiefly in combination with a scrutiny of the great profiles along the Soria canyon in the west.

As has already been pointed out, the Chira valley and its gorge have been eroded into a series of salic lavas, capped on the summits on both sides by the R. N. agglomerate formation. These salic volcanics can be followed down the course of the gorge to the bottom of the master *barranco*. The series has a total thickness of c. 800—900 m, disregarding the highest-lying R. N. agglomerate banks.

No basement (of basalts or possibly of salic lavas) is to be seen at the bottom of the master canyon at the place of junction.

The left side of the Chira valley has already been described (page 132). This long ridge chiefly consists of platy phonolites and their tuffs. On the slopes towards Presa de Chira, however, there are some remnants of the R. N. agglomerate to be seen. They may perhaps represent vanishing parts of an ancient fill of the valley.

In the north of Cercado de Araña there are (as it was stated above) allochtonous phonolite masses on the upper slopes.

On the ridge to the right of the valley, called Lomo de la Ermita de Santiago — Lomo de La Palma, there is a thick cover of the R. N. agglomerate that can be followed right down to the rocky cape of El Salvear. I have some samples of the underlying lavas obtained with some difficulties owing to the large screes in the slopes (12, 13, 243). The upper sheet (243) is near the road fork to Chira (elevation 1 375 m). Micr. the rock consists of clear tabular feldspar phenocrysts, clinopyroxene crystals (small elongated prisms), brown hornblende, a sodalite mineral and sphene. The optics of the feldspar phenocrysts are:

$2V\alpha = 51°$. Karlsbad twins, ext. angle $a \wedge \alpha' = 6°$ (anorthoclase)

The paste is a trachytoid mixture of feldspar rods, aegirine prisms, nepheline grains and ore powder. The cavities in the paste are filled with opal. The texture is porphyritic. The rock may be designated a phonolite (somewhat altered).

No. 12 is of a lava bank lying under the thick top sheet of the R. N.

agglomerate in Lomo de Ermita de Santiago—Lomo La Palma. Micr. the rock contains relatively large laths of alk. feldspar (altered), showing Karlsbad twins in a turbid paste of fine grain and almost isotropic with microlites of feldspar and tiny prisms of aegirine and ore powder. There are no phenocrysts of mafic minerals. The lava may be called a trachyte (meta-trachyte).

No. 13 from somewhat lower down on the slope towards Cercado de Araña, has also micr. relatively large laths of alk. feldspar in crystals, of a greenish-gray clinopyroxene, brown hornblende, sphene a sodalite mineral and also magnetite in a turbid paste with feldspar microlites and ore powder. This paste looks rather dark between + nic. The lava is a kind of trachyte (or trachyphonolite).

Passing the small village Cercado de Araña, we finally arrive at the bottom of the Chira valley (alt. 900 m) and here other kinds of volcanics are met. On the east side of the dammed-up lake (close to the dam), there is a quarry for building-stone in the bedrock. It is a brownish-red, soft lava (251), easy to handle with a miner's hammer. Micr. it shows a distinct porphyry texture with clear phenocrysts of alk. feldspar in a brown, streaky, glassy paste, also with fragments of feldspar. The elongated pores are filled with a web of small sanidine rods; the filling-in substance between them is opaque (lithophyses). In fact, the rock is very porous and well suited to building material. No mafic minerals are seen. It may be a kind of tuffaceous rhyolite or an ignimbrite.

In a southerly direction from Presa de Chira, along the path that leads to the small forest reserve of Escusabarajas (a promontory facing south at the Arguineguín valley), one passes along a gentle slope which ends in the Chira canyon. There are outcrops of a reddish soft lava of rhyolitic aspect (255) in this slope. Micr. it is distinctly porphyric with clear phenocrysts of alk. feldspar, also fragments of it in an iron-stained paste which has originally been very porous, but post-magmatically (?) filled with a web of sanidine rods in an acicular texture (lithophyses). Small flakes of brown mica are present. Grains of magnetite are seen (sparsely). Optics of the feldspar are:

$2V\alpha = 48°$, opt. char. —, ind. of refr. < 1.54. Ax. pl. $\sim \perp (010)$ (anorthoclase)

The lava may be designated as a rhyolitic (?) vitrophyre.

It is evident that these vitrophyres-rhyolites or trachyrhyolites-stratigraphically precede the nepheline bearing phonolites and trachyphonolites in the bordering mountains. The former salic lavas apparently belong to the same sequence as that met with in the great profiles of lavas and tuffs in the Montaña del Horno complex (as we will find later on).

The salic (vitrophyric) lavas are also seen in the gorge below Presa de Chira, where they are topped by the R. N. agglomerate formation in a thick sheet. This can be very well seen in the head of the canyon. These facts indicate that the Chira valley already existed at a time before the spreading of the agglomerates, i.e. before the great Peléean outbursts ravaged the island.

The prominent mountain corner of El Salvear above Cercado del Espino has been sculptured in the salic series and in the overlying banks of the R.N. agglomerate. The monstrous cape marks the junction between the master *barranco* and the young canyon of Chira.

It is evident that the great avalanches of chaotic material which consolidated to agglomerate, later on did not stop here in El Salvear but continued far down the slopes to the south. This happened at a time when Barranco de Arguineguín did not exist, but instead there was a mature valley, the bottom of which lay much higher than that of the present *barranco*. Pontón de Gavilanes (right side of Barr. de Arguineguín) was then a hill on the right side of the old valley. Erosion has later on abolished the agglomerate from the stretch south of El Salvear, except for what is left on the summit of the tongue-shaped Escusabarajas (left side of the *barranco*).

Barranco de Soria—Arguineguín

This is a surprisingly large *barranco* in the island — c. 22 km — running north—south, and dividing the southern part into two subsectors. This *barranco* begins at an altitude of 1 000 m with a very steep gradient at the border of the central highland. The uppermost stretch is a wild gorge, lower down its cross-profile is more open, although the sides are steep all the way down to the vicinity of the coast at Arguineguín. — There are few tributaries on the way, the most important being Barranco de la Jarra from the left. From the same side, Barranco de Chira also joins the master valley, as we have seen, but its bottom has not been adjusted to the profile of Barranco de Arguineguín.

I have made several trips along the valley in question and up its sides in some places, and a few samples of the rocks have been collected.

Additional notes and also samples have later on been obtained from my colleague T. Bravo.

Barranco de Soria—Arguineguín runs for almost its entire length across a landscape of table mountains, i.e. between flat topped ridges —, consisting of rather flat lying banks of lavas and tuffs, a huge and apparently concordant pile. There are many stately cross-profiles to be studied on the way, and sometimes they attain a total height of many 100 m. The best exposures are to be found in the surroundings of Soria (settlement at the bottom of the valley above the junction of the Chira canyon) at the mountain cape of El Salvear. Further down the *barranco* the sides gradually get lower, at the same time the valley bottom widens and is being filled with gravels.

Much loose material has apparently been transported down this deep and long valley and most has found its resting place in the sea. The delta accumulations are not important. Nevertheless, erosion has been very vigorous all along the *barranco*. It seems to have been accomplished in an earlier geologic period, when the island stood higher than now (Pliocene?). The gravel fill in the lower course is the result of a Quaternary (?) depression (before the sub-Recent uplift began).

Barranco de Soria—Arguineguín crosses an extensive complex of salic lavas mostly apparently of a rhyolitic, trachytic and to some degree also of a phonolitic composition. As was already mentioned there are excellent geological profiles in many parts. These show an astonishing number of concordant lavas and tuffs, and the total height of the sequence is not less than 700 m (in one place). The position of the beds is almost flat, a slight inclination to the south is perceptible. Dikes are seldom to be seen, and faults have not been observed so far. The whole complex gives the impression of an undisturbed pile.

In what follows we will look at the geological conditions along the entire course of the valley by using the field data and the results of microscopic examinations. A meticulous study of all the problems met with here will be left to future investigators.

If we first look at the environments of the Soria valley head near the small settlement of Ayacata (1 250 m above the sea level), we see a very interesting landscape before our eyes, owing to the presence of a top formation of the R. N. agglomerate in enormously thick banks. These banks form almost vertical walls facing the deeply incised valley head, a site of great avalanches in bygone times. There is a great difference of level down to the bottom of the canyon of Soria (400—500 m).

— The geological details have here not been worked out, since I did not visit the canyon on this stretch. Samples of the rocks are few from Ayacata (246, 247, 258). There are, however, additional samples from the canyon somewhat lower down collected by T. Bravo (869, 873).

The mass of the R. N. agglomerate rests on a dark lava bank of basaltic aspect (246) in the vicinity of Ayacata. Micr. one will find well formed phenocrysts of clinopyroxene as the dominating mineral, crystals of magnetite and stray laths of plagioclase, all lying in a groundmass with a basaltic texture. The cavities in the groundmass are in parts filled with calcite, in parts with a colourless, fibrous mineral with a low ind. of refr. (chalcedony). The lava may belong to the tephrites, since there is no olivine present except sparse small grains of iddingsite-altered olivine. This lava bank lies in a horizontal position.

To the south of Ayacata at a level somewhat lower than the former place, there is a lava of another aspect (247). It shows micr. laths of alk. feldspar, prisms of brown hornblende and stray crystals of sphene, all lying in a very fine-grained paste with feldspar microlites, ore powder and an isotropic mass (analcime?). The vesicles are filled with opal. The rock is a kind of bostonite or alk. trachyte with a low colour index. It seems to belong to the salic series which underlies the phonolites.

When following the narrow road to Presa de Majada Alta for some km (from Ayacata), one meets high-road cuts in a black felsitic lava (258). The position of the lava was not clear, perhaps it is of the dislocated series (the basement rocks). The fracture is conchoidal and knife-sharp edges have been formed (like those of flint). Micr. there are larger laths of alk. feldspar in a very fine-grained (devitrified) paste, containing aggregates of minute hex. nepheline crystals and needles of aegirine in a matrix of isotropic substance. Brown mica is seen enclosed in the feldspar. The rock may be a devitrified trachyphonolite. It is not known if this type is common in the walls of the canyon here. The deeply-incised gorge may indicate a certain stage of decomposition of the rock ground in the depths, otherwise it is difficult to explain the vigorous attack by the (once existing) wildwater in this head region.

The samples sent to me by Bravo are from places lower down the course of the canyon. No. 869 is of a great dike with a trend ENE—WSW, crossing the *barranco* somewhat above Soria. Micr. we will find a distinct porphyric texture with relatively large phenocrysts of alk. feldspar, a mineral of the sodalite group and prisms of brown hornblende (corroded).

In additon there are crystals of a clinopyroxene[1]) and magnetite. The paste consists of feldspar aegirine and an isotropic product. It is a phonolite dike. — No. 873 is from the vicinity of Presa de Majada Alta (elevation c. 900 m) on the right side of the Soria canyon. Micr. there are no phenocrysts at all. The mass consists of a trachytoid texture with feldspar microlites, aegirine prisms and ore powder and also minute prisms of altered nepheline together with isotropic products (analcime?) giving to the paste an almost dark aspect between nic. +. It is a phonolite.[2])

If we proceed down the canyon and pass the village of Soria, we enter the interesting passage between Montaña de Tauro and El Salvear —Escusabárajas, with their high profiles in the volcanic sequence.

The cape of El Salvear (left side) is, as has been mentioned, capped with the R. N. agglomerate in a huge sheet. The basement consists of a multitude of concordant volcanics. There are only two samples (260, 312), of them, both from the upper slope. No. 260 consists of a nepheline phonolite containing phenocrysts of alk. feldspar laths in a paste of feldspar rods, nepheline, aegirine and ore powder. Aegirine aggregates have surrounded both feldspar and nepheline. Optics are:

Alk. feldspar $2V\alpha = 52°$. Ax. pl. $\sim \perp$ (010) (anorthoclase)

No. 312 is a grayish-brown porphyry lava taken from La Puntilla, somewhat below Soria on the left hand side of the valley (close to El Salvear). Micr. it is a vitrophyre with a fluidal texture of feldspar rods and aegirine and with phenocrysts of alk. feldspar (rectangular crystals) and brown hornblende. Magnetite is sparse. A microphoto of the rock is seen in fig. 1, plate VI.

No. 268 is an aphanitic lava. Micr. it shows a basaltic texture with plenty of plagioclase laths in two generations. Phenocrysts of clinopyroxene also occur associated with magnetite. The paste consists of plag. + pyr. + ore and plenty of colourless, isotropic patches (analcime). (Comp. of the plagioclase not det.; ind. of refr. > balsam, opt. char. —). The lava may be an andesitic basalt. — No. 273 is micr. a plagioclase — rich basalt with clear laths, albite twinned, clinopyroxene and some olivine (partly altered to iddingsite). The paste is basaltic.

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[1]) Aegirine augite acc. to ext. angle $c \wedge \gamma = 66°$.

[2]) In the highland to the northwest of Soria (right side of the valley), Bravo has seen a zone of the old dislocated trachytes, according to a sketch map sent to me (cf. fig. 37). There are no samples from this area. It is a complex that appears in an unexpectedly solitary position. Further surveys are needed here.

Plagioclase: $2V\alpha = 94°$. Comp. = An/60. (phenocrysts)

The amount of olivine is relatively insignificant.

No. 266 (no slide avail.) is a dark, platy lava of a phonolitic aspect. It is the highest-lying bank in the profile.

The basalt lavas in question may represent the basement of the salic series and correspond to those basalts appearing in the bottom of Barranco de Arguineguín, somewhat below Cercado del Espino.

After passing Mesa de las Pardelas and its southern lower prolongation — Lomo de la Jarra, — one enters the broadened lowermost course of the great valley. The sides are now getting considerably lower and the (mostly dry) watercourses are braided over the gravel field at the bottom. — It seems that this heavy accumulation mass of gravels may be the result of a higher level of the ocean in Quaternary times.

Nos. 302 and 303 are of the lowest sheets of salic lavas exposed in the left side of the canyon some distance to the south of Soria. The first of these rocks is a typical porphyry, the latter is devoid of phenocrysts of feldspar or other components of the I gen. In the former type the feldspar crystals show a fine striation and may be anorthoclase. The paste in both is streaky and vitreous with tiny feldspar rods. They are vitrophyres or obsidian, most likely belonging to the rhyolites in the lowest part of the series.

Montaña de Tauro (1 200 m)

On the western side of the great valley train — on the watershed towards Barranco de Mogán rises the eminence of Tauro, one of the highest summits in the southern sector of the island. This eminence is connected in the north with Cordillera del Horno by way of a broad saddle pass (900 m), where the reservoir Majada Alta has been erected. Tauro's summit forms a kind if escarpment towards the flat ground of the pass. To the south the mountain drops gradually to the coast, forming a broad slope furrowed by *barrancos*. In the east and in the west there are great precipices of c. 700 m in height down to the bottom of the confining valleys. We are here concerned only with the eastern side of the mountain.

The profile exposed here ought to be investigated more in detail — from the bottom of the valley up to the summit lava sheet. The author is in the possession of a rather meagre collection of data and samples to illustrate the volcanic sequence here (cf. with the list, page 150). BRAVO has later on provided with some additional samples from different levels.

For stratigraphic reasons we will start from the bottom of the valley in the vicinity of the settlement Soria (lying somewhat below the rocky cape El Salvear, junction of Barranco de Chira).

Lowest exposures found in the *barranco* bed close to Cercado del Espino consist of basic lavas (269, 288, 299). Of them the uppermost bed is of andesitic character, finegrained, but downward there follow lavas of olivine basalts. No doubt these basic lavas represent the ancient series of basalts appearing at the west coast. — These lavas are capped by red rhyolitic lavas (292). Such a type has already been described by E. JÉRÉMINE from Cercado del Espino (1937). It is called by her a pitchstone containing large anorthoclase phenocrysts, also crystals of hornblende. Besides there are fragments of glassy lavas in the paste. A chemical analysis of this pitchstone is published by JÉRÉMINE (see the list of NIGGLI — values page 375, no. IV).

Some of the succeding types of rocks (upwards in the profile) (302, 303, 312) have already been described. They are all vitrophyres. No samples are available in order to know more about the sequence of the beds exposed in the uppermost part of the profile (right side of the valley). Instead we have to rely on samples from an excursion to the summit region of Montaña de Tauro. Here in the upper course of Barranco de Jaboneros (500 m elevation) there is a lava of a vitrophyre (289), micr. with clear phenocrysts of alk. feldspar and crystals of a brownish sodalite mineral, prisms of brown hornblende and ore. They all lie in a glassy paste with streaks of varying shades, containing microlites of green pyroxene (aegirine), laths of feldspar and ore grains. Also fragments of feldspar are to be seen. There is another vitrophyre (295) some distance higher up along the course of Barranco de Tauro (550 m elevation) forming a bank of considerable thickness. Micr. it is of a similar nature, with clear alk. feldspar crystals (and fragments) in the glassy paste. (Cf. microphoto 2, plate IV).

A tunnel has been opened from this *barranco*-head to the water storage dam Majada Alta at levels of c. 800—900 m. This tunnel runs across a lava bank of dark phonolite (observed by BRAVO). I took a sample of a lava from about the same level (700 m) — somewhat to the south of the summit. It is a place called Degollada de Cortadores. Here also a phonolite occurs (41). Micr. it shows phenocrysts of alk. feldspar (turbid), prisms of brown hornblende and a sodalite mineral, all enclosed in a fine-grained paste filled with feldspar and aegirine microlites.

Higher uphill towards the summit of Montaña de Tauro (1 200 m) there are apparently only phonolite lavas (293, 294, 297), but also some vitrophyres.—No. 293 is of the summit lava bed. It is a distinct porphyry with clear alk. feldspar phenocrysts, clinopyroxene and brown hornblende prisms in a streaky, glassy paste, in which there are feldspar laths and tiny nepheline crystals. Optics of the chief minerals are:

Alk. feldspar: $2V\alpha = 48° - 50°$ (anorthoclase)
Clinopyroxene: $2V\gamma = 50°$, $c \wedge \gamma = 42°$ (Ti:augite)

No estimation has been made of the relative amount of pyroclastic beds in the series of Tauro. In an excursion up to the southside of the summit, I noticed the presence of a layer of cream-coloured tuff supporting the top lava sheets and measuring at least 5 m in thickness. Lower down the slopes many tuff layers can also be seen.

Sequence of lavas in the east side of Montaña de Tauro

Level	No. of sample	Type of lava	Locality, etc.
1200 m	293	Nepheline phonolite	Summit lava sheet
1100 »	297	Hbl-mica vitrophyre	3:d lava bed below summit
1000 »	294	Vitrophyre vesicular	S. side of summit
900 »	301	Dark phonolite	Tunnel from Majada Alta
700 »	—	» »	Head region of Barr. de Mogán
700 »	41	Hbl sodalite phonolite	Degollada de Cortadores
550 »	295	Vitrophyre	Cabecera Barr. Tauro
500 »	289	Sodalite vitrophyre	Barr. de Jaboneros upper c.
450 »	303	Vitrophyre	Lowest bank S. of Soria
150 »	292	Redbrown porphyry	Cercado del Espino
Bottom of the salic series			
150 »	299	Andesite basalt	Vicinity of Cercado de Espino.
100 »	269	Olivine basalt	Bottom of Barr. de Arguineguín, Cercado del Espino
100 » pozo	288	Basalt, decomp.	Below bottom of Barranco de A.

In the list above, we will find a total thickness of c. 1 100 m, the major part belonging to the salic series. Below, there are basalts to an unknown depth. Of the former group, the upper part down to c. 600 m consist of phonolites; lower down, mostly rhyolitic vitrophyres are met with until the basalts at the base. In all, there are at least 30 different beds in the great profile, apparently lying in perfect conformity. Detailed observations are needed here, however, to find out the stratigraphy.

The Tauro mountain has a long slope to the south furrowed by *barrancos*, broadening in that direction like a fan, the borders of which represent the sides of Barranco de Arguineguín and Mogán. On the eastern wing rises the cupola-shaped eminence of Pontón de los Gavilanes (775 m), close to the former valley. Here it forms a precipice of c. 650 m in altitude, cutting the cupola-shaped summit to half the size. Here great rock slides have occurred in Quaternary (?) times. — Pontón de los Gavilanes is the remains of an ancient highland relief of advanced maturity extending over this part of the island in times before the cutting down of the present stately valley of Arguineguín. As we have already seen, the Chira valley is also from the pre-*barranco* period of erosion.

Escusabarajas

Turning again down the Arguineguín valley bottom and up the left hand slopes opposite the giant wall of Montaña de Tauro, we have the strangely looking ridge of Escusabarajas (a smaller forest reserve protected by the Island Government). This ridge has a height of 925 m and is connected with the neighbour table-land of Llanos de las Mesas (mentioned earlier). Escusabarajas consists of a great pile of salic lavas, obviously the interrupted continuation to the east of the sequence in Montaña de Tauro. Unlike however, the conditions in Tauro there is a capping sheet of the R. N. agglomerate. This bank was formerly connected with a similar bank of agglomerate in El Salvear, lying on the opposite side of the Chira canyon.

The author did not have time enough to examine the volcanics in Escusabarajas more closely. Later on, BRAVO sent me 3 samples from the western side (784, 832, 838). Of these, no. 838 is a porphyry (position 660 m above sea). Micr. it consists of clear phenocrysts of alk. feldspar with Karlsbad twins and a narrow outer zone of later growth (anorthoclase+sanidine?). There are also sodalite crystals, all lying in a fine-grained paste of feldspar, nepheline, aegirine, apatite and ore. Stray individuals of brown hornblende also occur. The lava may be a trachyphonolite.

No. 832 is of a dike crossing the lava beds. It is micr. of a lamprophyric composition with euhedral phenocrysts of clinopyroxene, and altered olivine. The former mineral also fills the main part of the groundmass, together with magnetite and a coloured, isotropic substance (?). There are plenty of vesicles filled with (or coated with) zeolite in radial aggregates. The dike rock is apparently of a much later date than the (dissected) salic series and may belong to the effusive period of tephrites which accompany the R. N. agglomerate (at the top). The dike may be a kind of monchiquite.

Hoyas del Naranjo

On the same (left) side of Barranco de Arguineguín, NE of Cercado del Espino there is a rather deep embayment in the side of the valley produced by some short *barranquillos*, of which Hoyas del Naranjo is one. BRAVO, who visited the site has sent me some samples from here (815, 819, 821, 822, 824). Information about the stratigraphy is not available.

There is not much to say about the samples. No. 821 is a porphyry with clear alk. feldspar phenocrysts (rel. small opt. angle: sanidine?) and stray prisms of a pale-yellowish clinopyroxene and magnetite (sparsely) in a very fine-grained (devitrified?) paste, rather dark between + nic. The lava is a trachyte (rhyolite?). — No. 824 is extremely fine-grained, with sparsely alk. feldspar phenocrysts lying in a paste of a mottled appearance with cryptocrystalline, isometric grains, which may be nepheline, embedded in a dark substance. There may be analcime in the paste, together with tiny microlites of feldspar. The rock may be a devitrified phonolite-felsite.

No. 815 is of a dike rock (or of a small intrusive body) in the lava series. It contains alk. feldspar almost exclusively, partly as phenocrysts, partly as tiny rods in the paste showing an acicular texture. Mafic minerals are not present. The rock may be a bostonite.

Farther south along the valley, the left side has not been examined at all, including the plateau in the south called Mesa de Marzagán. This part belongs to the area which comes next to the east and comprises the drainages of Barranco de Tabaqueros and Barranco de la Negra. The localities here visited by BRAVO have already been briefly described (page 132).

The right side of the master valley — from Montaña Tauro in the north to Lomo de Las Toscas in the south likewise has not been more closely examined (with some exceptions).

There are reasons for assuming that the higher ground on the right side of the valley consists of the platy, dark phonolites. A conglomerate covering the lower ground more to the south down to the sea shore consists of pebbles of these phonolites, a material perhaps transported in pre-Quaternary times from the upper ground south of Tauro towards the coast.

In the precipices forming the right side of the master valley are, on the other hand, lavas of a more 'rhyolitic' aspect. Most of these banks are grayish to reddish and the lowest bank — at Los Peñones — — is red-coloured. — The gravel masses filling the bottom of the valley are chiefly not of the dark, platy phonolites, but of a more rhyolitic aspect: a rather striking contrast to the above-mentioned conglomerate (of a greater geological age).

We may now deal with some particular occurrences of rocks on the stretch from near Cercado del Espino down to the last *angostura* before the valley enters its coastal gravel-accumulation train (at Lomo de Las Toscas).

The bottom of the master canyon some km down from Cercado del Espino (150 m above sea) has not been filled with gravels. Rocks are seen in many places. They consist, remarkably enough, of basaltic lavas (269, 288, 299), already mentioned in connection with the volcanic profile of Montaña de Tauro. Nos. 269 and 299 are directly capped with red rhyolite banks. The former is an olivine basalt in which clinopyroxene forms the I gen.; the paste consists of plagioclase laths, pyroxene, altered olivine and ore. The texture is basaltic (or somewhat streamlined); — the latter type is olivine-free, with phenocrysts of clinopyroxene. The paste contains rich amounts of ore grains.

These old basalts disappear lower down the course of the valley bottom. But they reappear in the left side to the south of Llano de Marzagán, as we will see later on.

A boulder dropped from the summit of Los Peñones (right side) to the valley bottom is of a basaltic aspect (271). Micr. there are plenty of phenocrysts of a clinopyroxene, euhedral, sometimes long-prismatic, zonal. It is associated with magnetite grains. The paste consists of tiny plagioclase laths, of pyroxene and ore powder and an isotropic coloured matrix (glass?). Apatite crystals are enclosed in the pyroxene. There are also stray hex. nepheline crystals in the paste (sparsely). The texture is more like that of a lamprophyric dike rock; perhaps this is really a dike.

From the right side of the valley a sample was taken of a lava bank (lower down in the profile) somewhat down from the site opposite Los Peñones. The lava is of the salic kind (262). Micr. it contains euhedral phenocrysts of a clinopyroxene, pale-yellowish, and clear relatively large crystals of alk. feldspar. Magnetite grains are associated with the pyroxene. The paste is glassy, dotted with fragments of feldspar. Apatite is an accessory constituent. There are small lithophyses, densely crowded. The rock may be a vitrophyre.

In the left side of the master *barranco*, in the ridge called Mesa de las Pardelas, are some lava banks in a flat position lying one upon the other (from the base: 267, 268, 273, 266). At the base is the limit of the bottom gravel fill of the valley.

No. 267 is a plagioclase basalt. Optics are:

Plagioclase: $2V\alpha = 102°$. Opt. char. —, ext. angle $\perp(010)$ (phenocrysts) $= 35° - 38°$. Comp.: An/60.

The mafics are clinopyroxene and altered olivine. The groundmass is rich in plagioclase microlites pyroxene and ore.

No. 268. is an aphanitic basalt. Micr. it shows laths of plagioclase and crystals of augite and ore in a fine grained (basaltic) groundmass with tiny laths of oligoclase (// ext., ind. of refr. ~balsam), pyroxene and ore powder (abundantly). The lava may be designated a tephrite — containing colourless patches of analcime (?).

Next lava uphill (273) is a dark porphyrite. Micr. there are clear laths of plagioclase in a dark coloured groundmass. There are also stray grains of clinopyroxene, (altered) olivine and ore. Texture is basaltic. Optics of the feldspar laths are:

$2V\gamma = 94°$. Angle of ext. in the plane $\perp$ PM $= 36°$. Comp. = An/60

The topmost lava (266) is dark, platy (no slide avail.).

Stratigraphic position of these lavas is uncertain. Further surveys are needed.

After passing Mesa de las Pardelas and its southerly continuation Lomo de la Jarra one enters the widened gravel bottom fill of the lowest course of the valley. The valley sides are from now on relatively low *cuestas*.

Lomo de las Toscas

The right side of the lowest stretch of the valley is called Lomo de las Toscas: it is covered on the surface with a whitish lime-crust. In its northern part, the ridge attains a height of 300 m, becoming constantly lower to the south and ending in the village of Arguineguín. On examining the ridge more closely, we will find in the upper parts a gravel — conglomerate sheet with stones and boulders of phonolites. This deposit lies on salic lavas (275, 277, 280, 285), these lavas on a basement of puzzolane and this in its turn on a greenish agglomerate, which is the lowest visible member in the profile. This can be followed right down to the sea shore. — The salic lavas in the upper part of the profile are vitrophyric, containing phenocrysts of alk. feldspar and also fragments of it in a streaky, glassy paste, in which there are tiny rods of feldspar and needles of aegirine. Perhaps the lavas are rhyolites. — Sample 285 taken from a rock edge 20 m above the bottom gravel-fill of the valley (right side) also shows micr. alk. feldspar phenocrysts (clear) lying in a paste of a glassy nature, filled with feldspar rods and aegirine, all in a fluidal arrangement. The optics of the alk. feldspar are:

$2V\alpha = 42°$, opt. char. —, ind. of refr. < 1.54. Ax. pl. $\sim \perp$ (010) (anorthoclase)

The succession of beds in Lomo de las Toscas is as follows:

Top — Gravel conglomerate (lime-cemented)
Rhyolitic vitrophyre (thick banks)
Puzzolane (cream-coloured)
Agglomerate with a greenish matrix (hard)
Base — Phonolite formation (not exposed here)

Lomo de las Toscas grows constantly lower in the direction to the coast while the underlying volcanics drop below sea level and disappear out of sight.

Lomo del Galeón

If we now turn our attention to the left side of the lowest course of Barranco de Arguineguín — the wide gravel train some km before its end at the coast — we will meet a long *cuesta*, stretching with decreasing height to the coast and ending here with a perpendicular cliff. This ridge is called Lomo del Galeón. — On the way to this left side we cross the mentioned gravel train with its many dry, braided water courses. In the midst of the train we will stop at a water shaft reaching down to the ground water level. The lumps of rocks lying around the shaft consist of salic lavas (274, 279). They have been hoisted up from a depth of c. 125 m. Both samples are of porphyries with micr. clear phenocrysts of alk. feldspar lying in a glassy matrix which also contains small prisms of brown hornblende and a brown mica (almost uniaxial), and also small crystals of a pale-coloured clinopyroxene. Some of the feldspar crystals are corroded, and fragments of them are rather common in the glassy paste. Apatite and ore are accessories. Texture is eutaxitic. The lava may be a rhyolite, although quartz is not visible in the slide.

After crossing the train and approaching the *cuesta* of Lomo del Galeón, one will find the outcrops of flat lying lava banks of dark colours. The lowest of the banks is a kind of basalt (284), and it seems to extend over wide stretches, sloping gently to the coast. The lava is amygdaloid and shows micr. phenocrysts of augite of grayish-lilac colour. Its prisms are in clusters and associated with magnetite grains. There are also prisms of brown hornblende. The paste consists of feldspar microlites and a colourless substance (analcime?). There is also iron ore powder. Apatite is an accessory const. Vesicles are filled with calcite and with a brownish concretionary mineral in radial bundles. The rock may be a tephrite (belonging to the R. N. agglomerate formation?). — A capping lava sheet seems to be of the same kind. The top layer is a conglomerate (the same that occurs in Lomo de las Toscas) and it continues down to the coast covering here the puzzolane formation, as it has been mentioned in a preceding chapter.

The coastal stretch from Arguineguín to Puerto Mogán

Where the coast highroad leaves the village Arguineguín, there is a low promontory jutting out into the sea in southeasterly direction. It consists of the greenish agglomerate at the base, overlaid by light coloured puzzolane. This in its turn is capped by a mantle of a coarse conglomerate. It is apparent that this small headland is only the remaining part of a former widely extended mantle of gravel, the same one which appears in Lomo de las Toscas and in the surface of other ridges in the vicinity. Marine abrasion and river erosion has destroyed the continuity.

Advancing north-westwards along the road, one will first find several cuts in the same conglomerate layer. Still farther west other profiles can be seen which expose the greenish agglomerate at the base, overlaid by puzzolane, bright-yellowish in colour, and this is capped by the coarse conglomerate with gravels in the surface.

Going further in the same direction the conglomerate disappears from the coast abrasion profiles and instead one finds that there are banks of dark lavas. No. 76 is of a salic lava, a vitrophyre. Going up the coast escarpment, however, one will again meet the conglomerate formation as a mighty top sheet covering wide areas in the upper slopes.

The author undertook an excursion which crossed this gravel terrain on the way up to the summit region of M o n t a ñ a d e T a u r o. The gravel masses are furrowed by many *barranquillos* in the long slopes

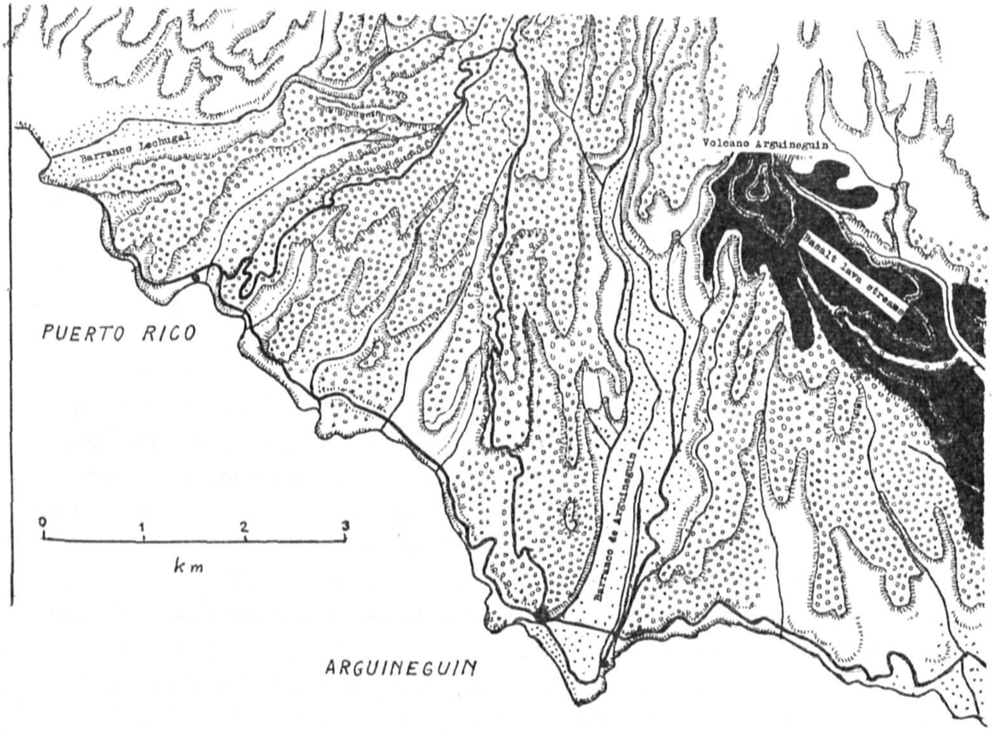


Fig. 11. Main part of a large gravel delta covering puzzolane and salic lavas at the south coast. The gravel is hardened to conglomerate. The sheets have been much dissected by later barranco erosion. The deposits may be contemporaneous with the covering gravel conglomerate on the Las Palmas' terrace (-Pliocene?). Black: basalt lavas covering the conglomerate.

towards the sea forming a kind of »bad lands», displaying an astonishing thickness of the conglomerate (lime cemented). Northwards this conglomerate reaches to the vicinity of Tauro, and in this region an apex of the fan-shaped wide sheet may be placed. This gravel fan was laid down at a time succeding the deposition of the R. N. agglomerate mantles. Erosion that followed the agglomerate deposition not only abolished this formation, it attacked to a great extent also the underlying phonolite, as may be seen from the abundance of phonolite material in the stones and boulders of the conglomerate.

East of the mouth of Cañada del Conejo (E of Puerto Rico) there are rather high profiles on the coast showing at their base the greenish agglomerate capped by puzzolane, then there are salic lavas in slaggy condition, and a top sheet of conglomerate. Samples of the lavas are of salic nature (308, 309, 310). Two of these are typical vitrophyres; no. 310 is a trachyte with feldspar phenocrysts. There are in the paste plenty of cryptocrystalline aegirine needles; ore powder occurs sparingly. Nepheline seems to be absent; if present it is altered.

The *hinterland* of this coastal stretch (nearer Puerto Rico) consists of a plateau-like ground gently sloping down to the sea. On the surface it is always covered with a coarse conglomerate of phonolite slabs (transported from Tauro). This conglomerate entirely covers the salic volcanics, except at the coast, where some *barranquillos* have cut their beds into the edge of the plateau. — A sharp *cuesta* is also seen along the left side of Barranco de Puerto Rico. One will find in the profiles here the same succession of salic volcanics with the top-conglomerate.

In the opposite (right) side of the mentioned *barranco*, in Montaña de Llamaderos, we will find the same beds as before. But here the puzzolane layer seems to lie on a higher level. The road from Puerto Rico to Barranco de Lechugal (its mouth) follows this layer in the coastcliffs all the way to Punta del Tablero, situated at the mouth of the *barranco*. The latter — oriented E—W — forms the extreme limit of the wide gravel — conglomerate terrace that we have traversed from Arguineguín (see fig. 11).

Along the road from Puerto Rico to Playa del Tauro (at the mouth of Barr. Lechugal) the puzzolane layer is capped by a lava bank of a salic nature (75). Micr. it is like the earlier ones: a vitrophyre with a streaky paste, containing clear, slender laths of alk. feldspar, brown hornblende and magnetite. There are also streaks and lenses of granulated feldspar substance. The lava seems to correspond to a rhyolite. — At

Lomo del Taurito (before Mogán) there is a salic lava exposed in a sea cliff with a thickness of 10 m and lying c. 75 m above high tide level. The rock is a trachyte (311) with clear phenocrysts of alk. feldspar and crystals of clinopyroxene and brown hornblende in a very fine-grained paste containing aegirine and ore and tiny feldspar rods. The texture is fluidal (streaky). Since the paste is largely isotropic, there is certainly much of analcime.

These salic lavas do not belong to the ancient series, the emission of which preceded the production of nepheline bearing phonolites. The latter kind of lavas is not represented along the coast here. Instead it is met higher up the slopes in the direction of Tauro. Only detrital products of the same lavas are present — consisting of the top-conglomerate mentioned in the descriptions above.

Barranco de Mogán

This very impressive mountain valley of c. 15 km in length is one of the most remotely situated in the island. The valley head lies in Cordillera del Horno, or more exactly expressed, in Montaña Sándara (1 550 m), the loftiest point in this mountain range. The valley runs SE to SSE to the south coast following the west flank of the Tauro mountain complex (described earlier). This valley has a rather smooth longitudinal profile, except in the upper course, where it descends from the mountains. The cross-profile of the valley is surprisingly open, in spite of the steepness of the sides, all the way down to the coast at Playa de Mogán. At the foot of the precipices, however, are great masses of scree forming cones. The bottom of the valley shows signs of a rejuvenation in its upper course, lower down it is filled with gravel in which there are several braided (dry) water courses. The main settlement in the valley, Mogán, is situated at a point, where the valley leaves its upper course (with the young canyon).

The author has followed the valley for most of its length, the sides have also been visited in some parts. The left side provides a very high profile in a series of concordant salic lavas and tuffs, — the same series which we have seen along Barranco de Arguineguín. Somewhat above Mogán, there is a high cape, called Los Alares, belonging to the Montaña del Horno complex. Many volcanic beds are exposed here. — Samples have been collected along the valley, but they are not very numerous and a continuous series of them has not been kept (316, 317, 318, 319, 321, 322, 325, 326).

Briefly the geological conditions along the valley are as follows: along the upper course there is a basal series of basalts and tuffs belonging to the same ancient formation that appears on the west coast. They are capped by salic lavas and a very variegated series of tuffs. The dominating lavas are rhyolites, trachytes and phonolites the latter chiefly in the precipices of the left side of the valley. In the upper part (Los Alares) an interesting plane of unconformity is to be seen, where the salic lavas lie on the old basalts. These latter continue for a while to the south along the watershed towards the Veneguera valley. but they are soon (in Montaña de Tristan) capped by salic lavas which continue down to the coast with a gentle dip. The basalts disappear in the same direction under the overburden of the salic volcanics.

If we begin our study of the geology in the head region, we may use the path which ascends from the *barranco* bottom to the neighbouring highland, where the water storage dam of Majada Alta has been constructed (altitude c. 900 m). There are several banks of slaggy basalt lavas to be traversed at the base of the profile (no samples of these rocks). — Then there follow thick layers of brown tuffs capped by a bank of a trachyte lava. This bank supports a huge mass of soft, brick-red tuffs, the individual layers of them being separated by thin sheets of a grayish cinerite. This one shows platy partings. The outcrops of the red tuffs are rounded off by mechanical weathering. — Further uphill these tuffs are covered by a thick porphyry bank (319, 325). There then follows a reddish tuff again, also in potent layers. Finally there is a typical phonolite lava at the top, most probably of the nepheline-rich variety, characterized by dark colour and platy partings. — After entering the highland plateau that extends north of the foot of Cumbre de Tauro, we will find the dominating formation being the R. N. agglomerate. In this rock ground the dam of Majada Alta has been located. The agglomerate formation extends further northwards to the foot of Cordillera del Horno.

Nos. 319 and 325 are of the usual salic type of rhyolitic vitrophyre. Optics are (in 319):

Alk. feldspar: $2V\alpha = 50°$. Karlsbad twins. Ax. pl. $\sim \perp$ (010) (anorthoclase)

The feldspar phenocrysts lie in an iron stained, glassy matrix containing empty vesicles. No mafics are to be seen in the slide. Lithophyses are present in the paste, elongated in the flow direction. No. 325 is of a similar aspect.

The salic volcanics resting on the old basalts in this mountain corner may belong to the ancient salic series that was deposited before emission of the phonolite lavas, which as we have seen, top the series here (in its turn capped by the R. N. agglomerate). The rhyolites and their tuffs (and ignimbrites) are as it seems only the continuation of the Montaña del Horno series in the west.

Turning back to the Mogán valley we will find on its right side the prominent cape Los Alares jutting out from the mountain of Juanito Ojeda. Here is a high profile displaying a very well marked unconformity between the old basalts (at the base) and the overlying salic series. It seems, however, the unconformity is due to later gliding movements, it is not a real stratigraphic break.

There is an uphill- sample of a phonolite-like type (322) of the same mountain mass (Juanito Ojeda). Micr. it has no phenocrysts, but a fine grained paste of feldspar laths, aegirine and nepheline arranged in a trachytoid texture. It may perhaps represent a transition type to the richly nepheline-bearing hanging, phonolites (here abolished by erosion).

The divide between Barranco de Mogán and Barranco de Veneguera varies in aspect down to the coast. In the upper part it consists of olivine basalts; lower towards the coast rhyolitic lavas dominate, covering the basalts, and the latter disappear completely in the same southerly direction.

A basalt from Cruz de Mogán (the pass between Mogán and Veneguera), a surface bank of lava (321), is a typical olivine basalt. The optics are:

Olivine: $2V\gamma=88°$, (2 det. Fa=8%)
Augite: $2V\gamma=58°$, $c\wedge\gamma=44°$

Apatite is an accessory; there is plenty of magnetite grains. The rock is of a more picritic composition owing to the small quantity of feldspar.

The dividing ridge rises to a greater height in southerly direction and culminates in Cumbre de Tristan (650 m). This summit consists entirely of salic lavas and tuffs, judging from the reddish colour of the concordant beds. A sample of a boulder dropped from this *cumbre* (326) is distinctly porphyric, with clear phenocrysts of alk. feldspar in an iron stained paste of glassy nature. Crystals of brown hornblende are also present, and apatite and magnetite form the accessories. The optics of the chief minerals are:

Alk. feldspar: $2V\alpha = 50°$ (anorthoclase)
Hornblende: $2V\alpha = 64°$ (average), $c \wedge \gamma = 14°$ (barkevikite)

On the left (opposite) side of the Mogán valley rises the huge mountain complex of Tauro, displaying large exposures of concordant lavas and tuffs, the former with beautiful columnar jointings in some of the banks. It is the same succession that we have already dealt with on the other side of this mountain. Great talus slopes cover the lower parts of the mountain wall. In the vicinity of Mogán the stone material in the scree consists of phonolites, derived obviously from the uppermost banks in Tauro.

The cross-profile of the valley has much in common with that of the Fataga valley.

If we now proceed to the lower part of the valley, we have on the left side Lomo del Taurito, from where one sample has already been described (311). It is a porphyry reminding one of that from the summit of Tristan. — To the right runs a *cuesta* down to the sea at Playa de Mogán. Before reaching the shore, one will find a side road climbing the steep slope up to the crest and then going down on the other side to Barranco de Veneguera. — The lava beds in this slope all lie conformably. There are two samples of them (316, 318). These types are vitrophyres with phenocrysts of alk. feldspar in a streaky paste somewhat devitrified, containing rows of nepheline grains and prisms of aegirine. Stray grains of brown hornblende and brown mica are to be seen.

A sample of a boulder which has dropped from the same right-hand *cuesta* (317) is vitreous with fragments of alk. feldspar and also euhedral-grains of the same mineral, in which there is a kind of zoning. Stray crystals of a pale-coloured clinopyroxene are to be seen. The paste is glassy and iron-stained, rather rich in ore grains. — All these lavas belong to the old trachytic-rhyolitic series that succeded the eruption of the west-coast basalts.

The whole triangular sector to the west of Barranco de Mogán—Lomo de Veneguera — may be an isolated part of the salic formation which composes Montaña del Horno, etc., in the north. It is separated from the latter by the stretch of olivine basalts that lies between Los Aláres and the north end of Montaña de Tristan. The latter forms the apex, so to speak, of the fan-shaped Lomo de Veneguera.

Barranco de Veneguera

This *barranco* is somewhat shorter than Barranco de Mogán and runs 5 km due southwest to the sea, starting at the foot of the great Acantilado del Horno. The author only visited its upper course. Additional information and samples have been obtained from F. UNTERBERGER (a Viennese student) and from T. BRAVO. The former collected a series of samples from the right slope 3.5 km from the coast. BRAVO has taken some from Playa de Veneguera (*acantilado*, right side) (samples 321, 328, 330, 331, 332, 333, 871, 874).

To these samples of lava rocks may be added one of a great dike (329) occurring in the uppermost course of Barranco de Veneguera, close to the foot of Acantilado del Horno.

Acantilado del Horno (Fig. 12), will be described in another connection (Chapter 5).

Barranco de Veneguera like its eastern neighbour, is a rather open valley with a heavy gravel bottom-fill in its lower course, ending in the sea with a stony beach — Playa de Veneguera. The valley has been eroded into a basaltic basement complex which is exposed at

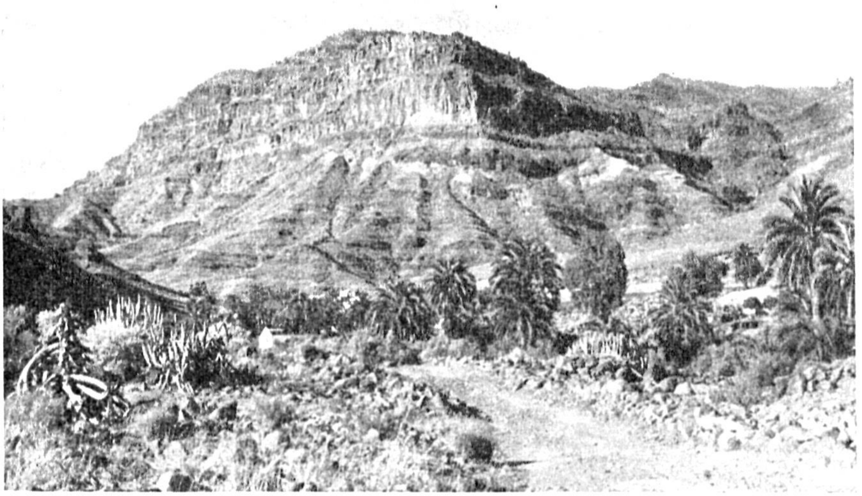


Fig. 12. The high erosion bluff of Montaña del Horno facing Barranco de Veneguera, consists of the salic series of lavas, tuffs and ignimbrites. Basalts in the lower slopes and in the foreground (under the valley bottom).
Phot. T. BRAVO 1958

the bottom in the upper course. These basalts are like those in the Mogán valley capped by a salic series of lavas. Since all the volcanic beds have a slight inclination towards the sea shore, the underlying basalts eventually become submerged into the ground—disappearing in that direction. Only salic lavas and tuffs are met with in the cliffs at the sea. — In the divide between Barranco de Mogán and Barr. de Veneguera, there is (as we have seen earlier) no communication between the salic beds in Los Alares in the north and those in Cumbre de Tristan farther south along the ridge. Erosion has abolished this link completely.

We may now examine the geologic conditions met with in Barranco de Veneguera. They are illustrated by a meagre collection of rock specimens.

If we begin with the basement basalts, we have some rather fine-grained olivine-free types occurring at the valley bottom (328, 330, 874). Micr. these types are composed of tiny feldspar laths arranged in the basaltic texture with grains and small prisms of a pale-coloured clinopyroxene and magnetite. Stray phenocrysts of clinopyroxene are also present (not very abundantly). Appr. comp. (in vol. %): plag.=60%, pyr.=30%, magn.=10%. In one case there are vesicles filled with calcite, in other types the cavities are empty. Apatite is an accessory constituent. These lavas are aphanitic plagioclase basalts grading into andesites. They no doubt belong to the upper part of the old basalt series.

A dike in a vertical position with an E—W trend crossing the old basalts is exposed at the foot of A c a n t i l a d o d e l H o r n o (the valley head). One sample (329) is a somewhat altered porphyry, consisting chiefly of feldspar laths in random orientations mingled with clinopyroxene grains and also ore powder. There are also stray phenocrysts of a pale-coloured clinopyroxene. Apatite is an accessory. The dike rock may be a kind of lamprophyre of the more feldspar-rich kind.

There are 3 successive samples of the salic lavas that follow higher up on the right side of the valley (331, 332, 333); they are taken from a part of the valley 3.5 km from the mouth. — Above the underlying plagioclase basalt follows a vitrophyre (331) containing clear phenocrysts of alk. feldspar, crystals of brown hornblende (pleochr.: α-yellow, γ-pale-brown, $c \wedge \gamma = 30°$). There are also scattered grains of magnetite and apatite. The paste shows a beautiful flow texture, most of it is glassy (isotropic). The feldspar may be anorthoclase (fine striation). The rock is perhaps a kind of 'welded tuff'. The bank lies 120 m above sea. —

Next lava bank (332) (the right side of the valley) is a distinct porphyry with clear euhedral alk. feldspar phenocrysts, also crystals of a clinopyroxene, pale-coloured, and magnetite lying in a very fine-grained paste of tiny feldspar rods and minute dots of a brownish-gray colour (mica?). Apatite is an accessory. The optics are:

Alk. feldspar: $2V\alpha = 50°$. Ax. pl. $\sim \perp$ (010) (anorthoclase)
Clinopyroxene: $2V\gamma = 48°$, $c \wedge \gamma = 47° - 48°$ (Ti:augite)

The lava may be a trachyte. It lies c. 300 m above sea.

The next lava bank (333), 200 m higher up the right slope, is a very fine-grained, pale-coloured rock. Micr. it chiefly shows a web of feldspar rods with some larger laths interstrewn. Other components are grains of a clinopyroxene, in places as phenocrysts ($c \wedge \gamma = 45°$) and magnetite. There are also stray crystals of hex. contours — pseudomorphs of a thick prismatic mineral. They consist of an opaque border and a kernel of fine aggregates of carbonate (?). The lava may be a trachyte.

On the right side of the valley, to the west of the mouth BRAVO found a series of lavas and tuffs, of which only a sample of the lowest bank is available (871). In a hand specimen it is a dark-brownish obsidian-like, dense rock with small whitish phenocrysts of feldspar. Micr. it is almost completely vitreous, in the glass mesostasis tiny rods of feldspar are strewn. In addition there are corroded grains of alk. feldspar phenocrysts (fine striation) and sparse crystals of a pale-coloured clinopyroxene. It is associated with magnetite grains. This lava is one of the relatively rare ones of a glassy character in this part of the island. Whether it is rhyolitic can only be decided by a chemical analysis. — According to a profile sketch sent by BRAVO, this locality shows at least 5 different volcanic beds in conformity. No. 871 is of the lowest one appearing in the valley-floor itself. It seems to be capped with a tuff layer (according to a photo of BRAVO's). If we add this latter to the other, the number of volcanic sheets in this profile is 6.

Summary of the volcanic stratigraphy in the southern sector. — The relatively oldest visible members are basalts, in places olivine basalts, in places also olivine-free plagioclase basalts. They occur chiefly in the westernmost sub-sector, in Barranco de Veneguera and Mogán (in the upper course of these valleys). They reappear also further east at the bottom of Barranco de Arguineguín (below Cercado del Espino). There are no basalts visible on the coast.

Above these ancient basalts follow salic volcanics which are largely vitrophyres of a trachytic or rhyolitic composition. This series is well displayed in the sides of the great *barrancos*. There is an astonishing number of lava and tuff sheets in the great profiles, in Barranco de Arguineguín for inst. Similar younger volcanics are met with along the coast between Maspalomas and Playa de Veneguera. At the coast we will find the intercalation of puzzolane forming a very continuous layer, attaining several metres in thickness. It seems that this puzzolane occupies a position in the upper part of this salic series. From Maspalomas westwards, the puzzolane alternates with thick banks of a greenish agglomerate of a greater consistency. In some places this agglomerate forms the shore rocks, immediately covered by the puzzolane. This agglomerate is not to be confounded with the R. N. agglomerate formation further up the slopes in this sector.

Above the salic lavas and tuffs of the older series follows the nepheline phonolite formation with its platy lavas and tuffs. This formation dominates a considerable area between Caldera de Tirajana and Barranco de Arguineguín. To the west of this *barranco*, the formations thins out, and is only preserved in isolated patches in the higher lying mountain ridges (Tauro etc.). Consequently it seems that the phonolites have previously extended much farther; later on they have been almost abolished by erosion owing to the rise of the land in the southwest.

The nepheline phonolites are in the N. capped by the R. N. agglomerate formation. This was originally deposited over a vast area in the south — reaching down to the vicinity of the coast. Later upheaval of the land and subsequent erosion, however, have greatly reduced the formation so that only patches have been left behind. — Nothing has been conserved of the basaltic lavas which accompany the R.N. agglomerate banks inside the area in question as far as I have been able to prove, if we except the uppermost part — Cuesta de La Plata. It seems that these lavas originally had a relatively restricted expansion in this southern sector.

As far as I have been able to find, there are no traces in the southern sector of the foid-bearing, highly Na:alkaline phonolite lavas, which followed the great Peléean outbursts in the highland. Not even dikes of this kind have been found.

There are very few occurrences of post-Miocene olivine balsalt lavas. The only basalt volcanoes of an adventive nature are Montaña Tabaibo and Montaña de Arguineguín. The latter has sent rather far reaching lava streams in the direction of the coast.

The relative youngest formation of the area (except for the gravel and sand masses in the bottoms of the valleys and the white dune sand on the coast) is a conglomerate deposit consisting of slabs of phonolite, lime — cemented, covering vast surfaces over the southern part of this sector. Its material is derived from the platy nepheline phonolite lavas, and the gravel was probably dragged along in Pliocene time. In some places this conglomerate lies immediately on the puzzolane, and one can see that the stratigraphic limit is represented by an erosion surface. The deposit has had the shape of a great gravel fan — a flattened cone, with its apex lying somewhere to the south of the eminence of Tauro. Originally this conglomerate fan extended much farther to the south, but marine abrasion has later — during a higher stand of the sea level — pushed the distal edge back, aided in this work by the underlying, very soft puzzolane formation.

This southern gravel formation (or conglomerate cover) has a certain similarity to the gravel conglomerate deposits of chaotic nature topping the Las Palmas' terrace of Miocene strata in the northeast corner of the island.

In short: the great southern sector of the island has thanks to the deep reaching *barranco* — erosion, been a rather well disclosed field of geologic study; here there are plenty of vertical profiles of several hundred metres in height, all along the canyons. Chiefly salic lavas are to be seen in these profiles, whereas the basement basalts rarely appear. No traces of the oldest formation are exposed in the south. This trachyte complex is met with chiefly in the bottom of Caldera de Tejeda.[1]

Finally we may give the general stratigraphical scheme of the southern sector (overleaf):

[1]) Bravo has reported to the author some occurrences of old trachytes found in the upper region of Barranco de Arguineguín and in Barranco de Juncal (La Ronda).

Top	Conglomerates (with phonolite slabs)
	The R. N. agglomerate formation
	Upper salic series (at the coast)
	Puzzolane (canto blanco) (at the coast)
	Greenish agglomerate (at the coast)
	Platy nepheline phonolites (in the highland)
	Lower salic series
	Old basalts (chiefly in the west)
Base	Old (dislocated) trachytes (?)

5.

Cordillera del Horno
(Ayacata — Aldea de San Nicolás)

General aspect

One of the most important topographic features in the island is the lofty chain of ridges and summits that runs in westerly direction from the central highland at Aserrador to the vicinity of Aldea de San Nicolás de Tolentino. The course is somewhat winding, however, and the summits are of very unequal heights attaining max. of 1 400—1 550 m above the sea level. The chain has no special name, and therefore we may accept that in the title above, since Montaña del Horno is the most prominent of all the eminences here. The chain represents the divide between the drainage area of Barranco de Tejeda in the north and Barranco de Mogán and Barr. de Venguera in the south. The crest line is not straight, and there are several ramifications on both sides.

Cordillera del Horno has no volcanic cones of constructive nature; its surface forms have been created entirely by erosion. The bulk of the chain consists of the trachyte-rhyolite formation that antedates the emission of the phonolitic lavas in the island (of the great phonolite volcano). On the other hand there are several necks of phonolites representing no doubt volcanic throats filled with lavas. They are now isolated by the denudation in the shape of necks. In the steep northern declivities facing Caldera de Tejeda (i.e. the side of Barranco de Siberio), a subjacent formation is revealed by erosion: the real fundament of this chain — consisting of dislocated old trachytes.

The author has investigated Cordillera del Horno along its entire length, from Aserrador—Ayacata to the western summit of Montaña del Horno, going chiefly along the crest line. On the way a fair number of samples was collected, chiefly, however, from Montaña del Horno.

In the northeast where the chain begins in the vicinity of the central highland, it forms the watershed between Barranco de Juncal and Barranco de Soria. The heights are here rather considerable: in Lomo de

A l m a c e n e s 1 475 m. The socle of this part consists of the oldest formation in the island — the dislocated trachytes (of Tejeda). They are capped by a mighty bank of the R. N. agglomerate formation in a flat position. Consequently this agglomerate rests of the trachyte series with an unconformity. — There is a curious erosion witness standing alone on the crest consisting of this agglomerate, formerly coherent with the Roque Nublo platform, now separated from it by a narrow gate. — The old trachytes dip west.

Here are s o m e p e t r o g r a p h i c d a t a about the chain.

The old dislocated trachytic lavas appear on both sides of B a r r a n c o d e J u n c a l (the head of Barr. de Siberio). Samples were collected from this region (534, 537). One is a light-grayish, weathered type, micr. with the trachytoid texture well displayed. The mass of feldspar rods encloses stray phenocrysts of the same mineral (alk. feldspar). Mafic minerals are not seen, only iron ore powder. The vesicles are partly empty, partly filled with an isotropic, colourless subst. (opal). No. 537 is a rather similar trachyte lava. There is in both an isotropic subst. in the paste (sec.). The rocks are weathered. — Their softness in general has caused vigorous erosion in this head-region, like that in the head of the Soria canyon. A consequence has been that the overlying thick banks of the R. N. agglomerate formation (on both sides) have in places become loosened and dropped to the bottom in huge, rectangular blocks. The loosening of the blocks has been aided by the vertical diaclases, which dissect the R. N. agglomerate banks.

When following the sharp divide from the Ayacata pass in the direction of P a j o n a l e s (the left side of Barr. de Juncal), one meets with a remnant of a basalt lava in the crest (sample 530). Micr. it is a kind of tephrite: phenocrysts of clinopyroxene (augite), brown hornblende and a blue-green sodalite mineral. They lie in a paste which consists of feldspar microlites, pyroxene and ore. The texture is trachytoid. Apatite is an accessory. The pyroxene is somewhat zonal. There are crystals of hornblende which enclose a kernel of pyroxene. It seems that this type belongs to the lavas accompanying the R. N. agglomerate formation; in this place the latter, however, has been abolished by erosion.

Roque de Pajonales (1 400 m)

This prominent neck of phonolite stands on the divide between the gorges of Juncal and Soria, and it displays a beautiful steep columnar jointing. At the western foot of the neck lies the forest inn of Pajonales. — Some samples were collected from the rock during a climb to its summit (531, 532, 535, 536). They all belong to one and the same type: a dark-coloured porphyry rock with glistening feldspar of a tabular shape. Micr. there are clear phenocrysts of alk. feldspar with Karlsbad twins, a sodalite mineral, clinopyroxene and brown hornblende, sphene and magnetite. The paste is filled with feldspar rods in a trachytoid texture mingled with aegirine and ore grains. Colourless isotropic patches are also present, perhaps analcime.

The optics are (in 536):

Alk. feldspar $2V\alpha = 51.5° - 52°$ (anorthoclase).

The rock may be designated as a phonolite, the geological position remains undecided. It seems, however, that the neck is of a greater geological age than the R. N. agglomerate formation (which lies in a flat position somewhat to the west of the neck). In that case the rock may not belong to the highly Na-alkaline phonolite lavas of the central highland (hauynophyres, etc.). No contact relations have so far been closely studied.

Morro de la Negra (1 489 m)

If we go west from Pajonales, we first pass along the crest an intensely weathered ground consisting of old (?) trachytes. Then we arrive at another neck-eminence with the name above and of a very similar aspect as the one at Pajonales. Here the columnar jointing is also apparent. The rock is a dark porphyry (539) with glistening tabular feldspars, clear, with Karlsbad twins, lying in a paste which consists of nepheline microlites, zeolite aggregates (nearly isotropic) and arborescent aggregates of aegirine needles. There are clusters of nepheline grains entangled in the aegirine »bushes». Magnetite is sparse. The rock may be a phonolite (altered). It has superficially a platy parting perpendicular to the columnar pattern of the neck.

Some distance to the south of Morro de la Negra, in the direction of M a j a d a A l t a (1 000 m above sea level), is a dominating pale-grayish lava rock (544) of a porphyric habit. Micr. it contains phenocrysts of alk. feldspar crystals, of pale-greenish clinopyroxene, brown hornblende and sphene in a very finely crystalline paste of feldspar rods and ore powder. The share of the mafics is insignificant. There are no foid minerals to be seen. The rock may be a trachyte.

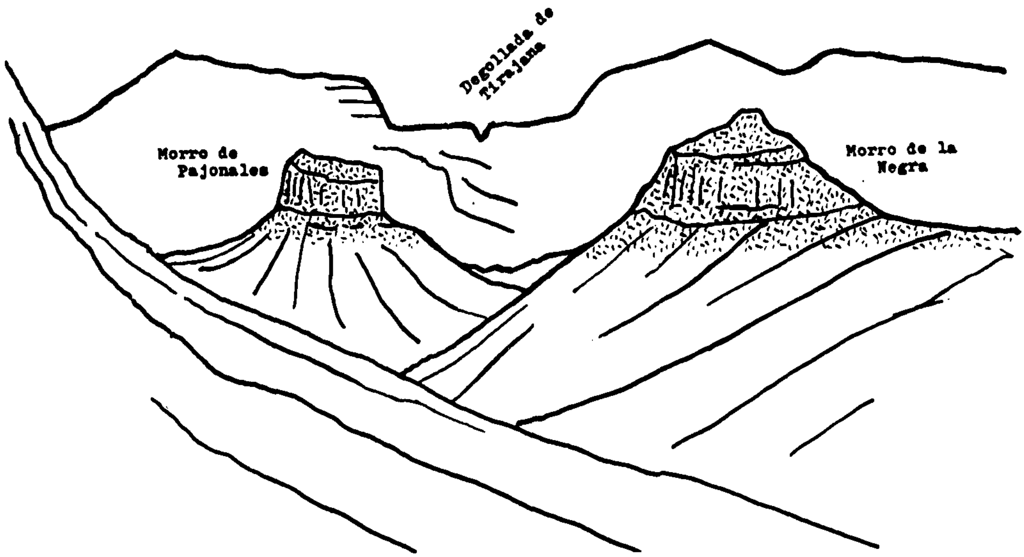


Fig. 13. Mountain landscape in Cordillera del Horno as seen from the S slope of Sándara to the east. In the middle distance two phonolite necks (M. de Pajonales and M. de la Negra).

Field sketch by H. H—n

The reader is referred to the field sketch, fig. 13, which shows the position of the two necks (Pajonales and Negra) in the landscape.

Passing Degollada del Gigante on the way to the west, one arrives at the eastern part of the lofty ridge of Montaña de las Yescas. The eastern culmination is called:

Montaña de Sándara (1 550 m)

This eminence was traversed along its steep northern side which reaches down to the bottom of Barranco de Siberio, a drop of c. 1 000 m. Only one sample (541) was taken from this mountain summit — a phonolitic lava. Micr. it is distinct porphyric with broad laths of alk. feldspar rather sparingly, a greenish clinopyroxene, sphene and also magnetite in a groundmass consisting of decomposed feldspar rods and minute stout prisms of nepheline in clusters (as in sample 539). This lava may be a phonolite, but it differs from the current type (the nepheline—aegirine phonolite) which dominates in the southern sector.

Optic data are:

Clinopyroxene: $2V\gamma=79°$ (average of 5 det.), ext. angle on (010) $c\wedge\gamma=55°$. Pleochr.: α-yellowish, γ-green (aegirine augite)

This lava bank lies at an altitude of c. 1 350 m. It seems to constitute a member of a series lying with unconformity on the old dislocated trachytes. A closer investigation of Montaña de Sándara, however, may reveal the existence of a neck forming the highest summit.

In a westerly direction, the ridge (Cordillera del Horno) continues with varying heights to Paso de Palo, a prominent *cumbre*. A sample taken at the summit is a trachyte (549). Micr. it is a porous mass of feldspar laths with the typical trachytoid arrangement and with mafics in a very reduced quantity. Ore grains are more apparent.

To the south of the crest line (1 500 m altitude) is a long slope down to the valleys of Mogán and Veneguera. The head of the former valley forms two deep embayments in the mountain range, where the salic lavas and tuffs are always exposed. They seem to lie in a rather flat position (no samples). A long ridge extends to the south with steadily diminishing height ending in the prominent mountain cape Los Alares (600 m), still consisting of the salic series. But the underlying basalts have been exposed in the precipices here. — Erosion has carved out a very impressive mountain landscape in the crests adorned with the growth of a pine forest.

The ridge of Montaña de las Yescas has still to be more closely investigated. It seems that Montaña Sándara and Montaña Paso de Palo may in reality be remains of necks like the two described earlier and not simply parts of the flat lying salic series (resting with unconformity on the old dislocated trachytes). In the two summits above mentioned there are the same large-scale columnar jointings, typical of the volcanic necks in the island. If this is so, we should have a file of necks in this range, vents from where phonolite lavas issued.

West of Paso de Palo we arrive at Degollada del Aguajero (1 325 m), a ridge with steep slopes on both sides and connecting Paso de Palo with Montaña de las Monjas (farther west). To the north of the pass there is a drop of at least 800 m down to the bottom of Barranco de Siberio (Tejeda drainage). In the middle height of the slope there is the bottom of our salic series: a plane of unconformity with the underlying dislocated old trachytes of Caldera de Tejeda (see the map fig. 37, p. 389).

A kind of porphyry appears in the above mentioned *degollada* (546) with micr. clear phenocrysts of alk. feldspar in a very finely crystalline groundmass consisting of feldspar- and aegirine microlites with a streaky arrangement alternating with isotropic streaks and lenses of glassy nature. Elongated rooms in the paste are filled with tiny rods of feldspar in an opaque mesostasis (lithophyses). Perhaps this rock represents a kind of 'welded tuff' or an ignimbrite.

Montaña de las Monjas (1 475 m)

This important summit of our mountain range forms a kind of gigantic fortress, extending north as a promontory towards the cross-going gorge of Tejeda, with very steep slopes in that direction. These slopes are called El Roque. I did not examine the conditions in this promontory.

Montaña de las Monjas is built of a very great number of flat lying beds of lavas and tuffs is almost perfect conformity. It is in the reality an erosion mountain modeled from a more coherent mass of the salic series. — The author has only one sample of a lava rock from this mountain (550). Micr. we find alk. feldspar phenocrysts, somewhat turbid, but with a clear outer shell. No mafic components are to be seen in the slide, only some opaque patches in the very fine-grained paste. This contains plenty of lithophyses. The type may perhaps be called an ignimbrite too.

From a lookout point in the north slope of Montaña del Horno, one may recognize the whole sequence of series of lavas and tuffs in Mont. de las Monjas, reaching a total thickness of c. 1 000 m. There are several harder banks of lavas (?) standing out as shelves and showing columnar jointings. They are separated by softer layers of tuffs. The profile is one of the most impressive in this part of the island, — it reaches to the bottom of the cross-going canyon of Tejeda (from where the author has some data to tell).

Montaña de las Monjas is separated from Montaña del Horno by a broad pass called Degollada de las Brujas (or Llano de las Brujas). It is in the reality an even plateau with a surface layer of a hard platy lava resting on a reddish massive tuff mass, this again on a hard greenish lava. Samples of these rocks are not available to the author. These layers do continue sidewards into the sequence of the mountains on both sides of the pass.

Montaña del Horno — Montaña del Viso

Finally we have to deal with the westernmost part of the mountain range, which was followed from its beginning at the vicinity of Roque Nublo. Montaña del Horno is a formidable pile of volcanics which has steep precipices towards the southwest and west. These escarpments no doubt represent some fault lines separating the block from the lower ground in the coastal regions which are mostly composed of basalts of the ancient series. Montaña del Horno is continued in the northwest to north by a somewhat lower ridge — Montaña del Viso.

Geologically, Montaña del Horno, with its appendix in the northwest, is of much interest, and it should deserve a more detailed study than I have been able to devote to it. Here we find a series of volcanic beds exposed to a total height of c. 800 m seemingly in perfect conformity. The series is of salic nature and it rests on a basement of old basalts. Among the salic beds are lavas, tuffs and mighty sheets of rhyolitic aspect with columnar jointings. As we will find later on these — of

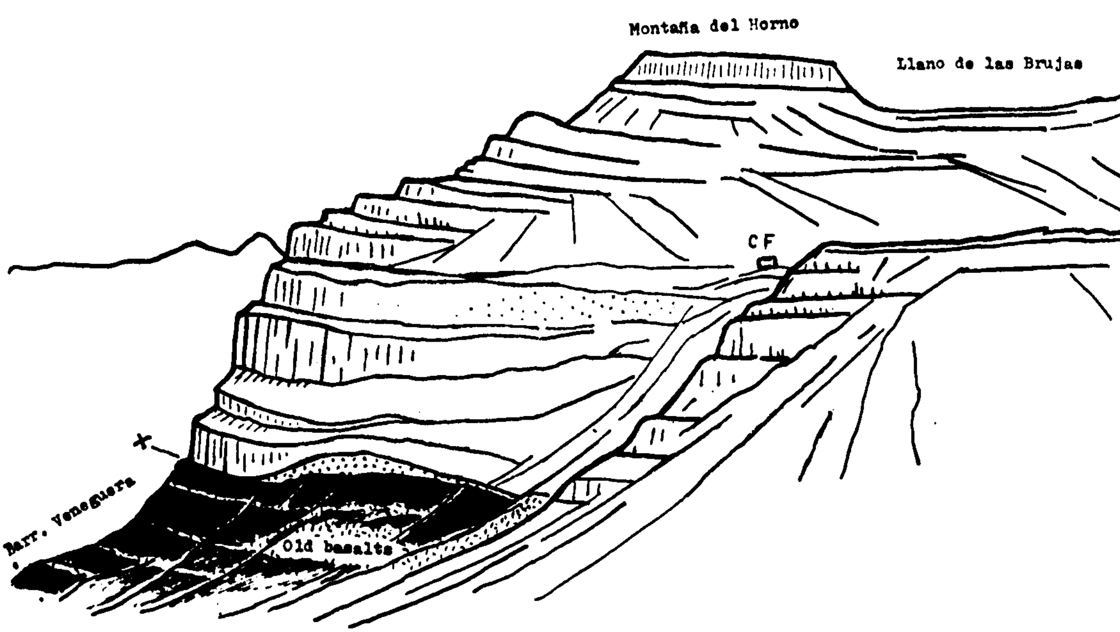


Fig. 14. Montaña del Horno, eastern side showing a concordant succession of salic lavas, tuffs and ignimbrites resting on a basement of old basalts with a tectonic limit (X). C F—Casa forestal de Linagua.

Field sketch by H. H—n.

astonishing regularity and wide lateral extension seem to be ignimbrites or 'welded tuffs' of rhyolitic nature. The pile of these volcanics bears witness of a very persistent activity, apparently of the fissural type, with centres of eruption in the highland of the island (the *cumbre* region).

Since the basis and the foreland of this salic pile of volcanics consist of basalts, these must belong to the ancient series appearing at the west coast. It seems that the Montaña del Horno complex has subsided *in relation to the basalt terrane outside it: the latter lies much higher* than the basal basalts under the salic pile. Planes of such subsidence movements can still be seen along the foot of the wall of Mont. del Horno in the shape of greenish mylonite zones.

The salic series undoubtedly formerly continued far to the southwest and west. That can be seen from the many erosion remnants in the hilltops consisting of salic lavas and lying on the old basalts. The reader is referred to the geological map.

There are at least 13 different sheets of lavas, tuffs and ignimbrites in the great profile above Veneguera (see fig. 14). The share of the pyroclastics is important and many of the individual sheets are of great thickness. — A great deal of my collection of samples from this profile has been examined covering, however, only a fraction of all the types met with. Altogether there are 14 slides made of the rocks (328, 329, 339, 554, 559, 560, 564, 569, 570, 572, 574, 575, 576, 584). Of them, the first 3 are of loose boulders at the foot of the great escarpment.

The microstructures are rather varying. The dominating features are a streaky groundmass, mostly of glass (or devitrified) and crystals of alk. feldspar (or fragments of them) floating in it. Mafic minerals are relatively sparse, the most common constituent seems to be aegirine in minute prisms, or biotite or brown hornblende. Quartz has so far not been seen in the slides available; this does not mean so much. however, since the glassy paste may in many cases contain free silica. — In some types, especially in the highest part of the series, the lavas contain many rather small nepheline crystals, indicating a certain amount of undersaturation in silica.

Most of the samples enumerated above are from the upper part of the great pile of salic volcanics, and the brief microscopic data in the following cannot give a full picture of the variations.

No. 329 shows micr. a very pronounced flow texture of a glassy material (pigmented), containing streaks of alk. feldspar, but also crystals of a larger size. Minute feldspar rods and aegirine needles of a green colour are to be seen in the paste, arranged in the flow direction. Fragment of alien trachyte types are also present. No. 339 has no such flow texture; it is more porphyric, with larger phenocrysts of alk. feldspar and prisms of green aegirine (length fast, pleochr. α-green, γ-yellow). The paste is glassy and brown-pigmented. — 554 is from a lava bed on a high level above *Casa forestal*. It shows micr. extremely corroded alk. feldspar phenocrysts lying in a brown, glassy paste, somewhat porous. There are scattered prisms of brown hornblende (ext. angle on (010) $c \wedge \gamma$ very small). — 559 is of one of the topmost beds in the eastern *cumbre* (above *Casa forestal*). Micr. it is trachytoid, with streaks of aegirine prisms and laths of feldspar and also short prismatic nepheline crystals scattered rather densely. The latter are surrounded by a corona of aegirine microlites. Some of the pyroxenes are of a larger size and aggregated. The lava may be designated as a trachyphonolite.—560 is from the top-bed in the eastern *cumbre*. It shows micr. a feldspar-rich groundmass in which lie aegirine prisms in random orientations. The mass encloses alk. feldspar phenocrysts, somewhat zonal. There are streaks with cellular aggregates of feldspar (sec?). Nepheline is also present. The rock may be a trachyphonolite.

In the highest summit of Montaña del Horno (1 450 m), where a triangulation vertex has been erected, there appears a somewhat different type of the salic series, and it can be classified as a nepheline phonolite (564). It forms rather massive rocks, with steep sides rising above the plain of the surrounding highland plateau. — The rock in the top contains micr. a fine crystalline mass of alk. feldspar rods and aegirine prisms and small, stout prisms of nepheline, the latter surrounded by clusters of the aegirine, like a corona. The nature of the feldspar cannot be determined more exactly. The texture is not trachytoid; the needles of the aegirine lie in random orientations. (Micr. photo 2, plate VI).

A sample of this summit rock was submitted to a chemical analysis, the results being given below:

Analysis no. 6 — **Sample no. 564 (HAUSEN 1953) of a nepheline phonolite from the summit of Montaña del Horno, in the western part of the island.**

		Mol. prop.	Norm:		
SiO_2	59.69%	9899	or	30.6	77.6
TiO_2	0.84 »	105	ab	47.0	
Al_2O_3	18.15 »	1776	ne	9.4	
Fe_2O_3	3.74 »	234	Σ Sal:		87.0

FeO	0.82%	114			
MnO	0.18 »	25	ac	3.3	
MgO	0.64 »	159	di	2.8	
CaO	0.79 »	141	fo	0.2	
Na_2O	8.05 »	1298	mt	0.8	
K_2O	5.18 »	550	hm	2.1	
P_2O_5	0.05 »	3	il	1.6	
H_2O+	1.00 »	555	ap	0.1	
H_2O-	0.80 »		Σ Fem:		10.9
Sum:	99.93%		H_2O		1.8
				Sum:	99.7

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.64 (+23.5°C)

NIGGLI values:

si = 218½, ti = 2.4, p = 0.1, h+ = 12.4, al = 39½, fm = 16½, c = 3, alk = 41. k = 0.30, mg = 0.21, qz = −41, al−fm′ = +24½, al−alk = −1½.

C. I. P. W. Classif. —I. 5. 1. 4.
Nordmarkose
Magma type: normal foyaitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 62:0:38
MgO:FeO = 100:0

RITTMANN parameters for nomenclature: Al − 16.34, FM − 6.12, Alk − 17.26, k − 0.30, an − −0.03, ca″ − 1.34. Nepheline phonolite.

The lava is of a certain interest in the salic sequence, since it occupies the stratigraphically highest position in the Montaña del Horno complex. This circumstance seems to indicate a type of transition to the stratigr. younger, huge phonolite formation of the southern sector.

Of the remaining samples taken from this mountain complex, no. 569 is a light grayish-brown tuff, or rather an ignimbrite, occupying a relatively high level. Micr. it shows phenocrysts and fragments of alk. feldspar, also flakes of brown mica and crystals of brown hornblende and magnetite in a streaky paste with zones of granulated feldspar. — 570 is from a bank of brownish lava on the north slope of Cumbre de la montaña towards Llano de las Brujas. Micr. this rock contains alk. feldspar phenocrysts in a paste consisting of a streaky mass with flakes of brown mica and lithophyses of tiny feldspar rods in an opaque fill. The optics are:

Alk. feldspar $2V\alpha=42°$ (2 det., anorthoclase).

Nepheline cannot be seen in the slide. — No. 575 is a porous lava in the eastern *cumbre* (one of the highest beds). Micr. it is likewise a feldspar porphyry with a groundmass of feldspar rods and aegirine prisms in random orientations. The optics are:

Alk. feldspar $2V\alpha=45°$ (2 det., anorthoclase).

Montaña del Horno continues in a northwesterly direction with a broad table-mountain called Montaña del Viso (see map, fig. 32). In the west it faces the lowland of Aldea de San Nicolás de Tolentino with a high *cuesta* showing a succession of salic volcanics. I did not climb this slope. At the base are old basalts, half hidden beneath the talus masses.

In Degollada de la Aldea one can study the immediate contact between the basalts of the basement complex and the overlying salic series. The limit is undoubtedly a sliding plane, along which the salic volcanics have subsided in relation to the basalts. At the foot of the high *cuesta* are 3 narrow zones of greenish colour consisting of a fine grained mylonite which can be followed from the slope above Veneguera to the vicinity of Aldea de San Nicolás (slope of Montaña del Viso). These sheets are inclined towards the interior of the mountain block. — Montaña del Lechugal (975 m), standing at Degollada de la Aldea opposite the high *cuesta* of Mont. del Horno, consists of the old basalts, but it has a cap of the salic series, as may be seen already from difference in colours (cf. fig. 15).

Montaña del Viso was studied only along the profiles in the crossgoing gorge of Barranco de Tejeda (see chapter III).

Summary of the geological conditions in the Cordillera del Horno.

If we now try to characterize in short terms this mountain range, which constitutes the divide between the Tejeda drainage area in the north and that of systems of southwards heading *barrancos* in the south (Soria—Mogán—Veneguera), we can first state that the range consists of the salic volcanics that followed the deposition of the lavas and tuffs of the western basalt formation. In the west and southwest the salic series rests on these basalts. Farther east the basalts have disappeared, and here the salic volcanics lie on the upturned edges of the most ancient formation in the island — the Tejeda trachytes. — The total thickness of the pile of the Mont. del Horno series amounts c. 1000 m; originally it was certainly much more before a period of erosion altered the land forms.

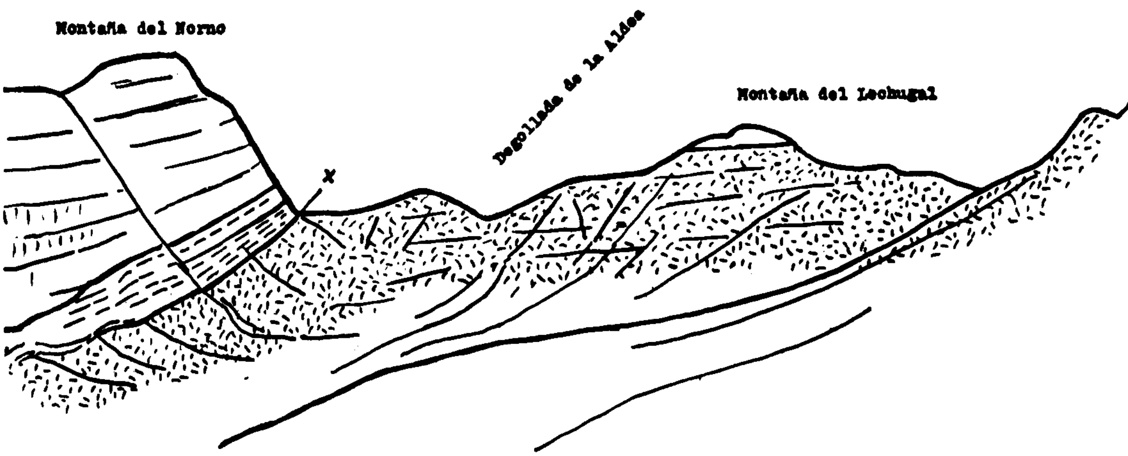


Fig. 15. Degollada de la Aldea seen from northwest. To the right Montaña Lechugal (basalt with a cap of rhyolite). In the center the pass with basalts, to the left Montaña del Horno with ignimbrites etc.
X -outcrop of dislocation-line (with mylonites)
Field sketch by H H—n.

We have to assume that the salic formation in question covered a vast surface of the island in its western part even reaching beyound the western coast line. Owing to subsidences occurred in the mountain block (M. del Horno) the western border region of the formation came into a higher position and was attacked by erosion more than the subsided part.

In fact the erosion has been strong enough, also in the remaining parts of the formation, so that all the land forms here are those due to erosion. There are the deep valley heads of Mogán and Veneguera dissecting the south flank. On the northern side there is the very deeply incised train of Barranco de Siberio-Barranco del Juncal, creating differences in height to not less than 1 000 m. Of the erosion forms in the crest line there are the many sharp summits of which Montaña de Sándara is the loftiest in the whole range. The most remarkable, however, are the still well conserved throat fills or n e c k s which follow one another along the main divide: Pajonales, La Negra, Sándara, Paso de Palo and the western summit of Montaña del Horno(?). The two first *morros* are the most typical, although their heights are relatively insignificant. Since these necks chiefly consist of nepheline phonolites, it seems that they represent some of the ancient conduits that brought to the surface the corresponding lava masses flooding parts of the island. But from the nearer surroundings these lavas have been abolished by erosion.

It seems if the mountain range in question never had a cover of the R. N. agglomerate masses, if we make an exception for the eastern — most sector —· Pajonales. Perhaps the range had in time of the Peléean eruptions a strong relief already, so that it did escape the avalanches.

As far as the petrographic data are concerned, the pile of volcanics is mainly very salic in composition. There are feldspar-rocks throughout the series, either porphyries, vitrophyres, ignimbrites or tuffs and agglomerates. The dominating feldspar is anorthoclase, appearing as clear, broad laths with Karlsbad twins. Foid minerals are, as far as I have seen, very sparse; they seem to appear only in the necks. Quartz has not been detected in the collection available. This does not mean very much, since the paste is generally glassy. The colour index is almost very low — 10—20. The chief mineral of the mafic group is brown mica and (or) hornblende. On the other hand, the aegirine is the leading mafic in the neck-phonolites.

Since lavas of such an eccessive salic composition are almost viscous in nature, it is difficult to understand how such a great number of volcanic sheets has been piled up in perfect conformity and of so wide extension in case these have been fluid rhyolitic lavas. Taking into consideration the microstructures of these volcanics (hitherto available in slides) and what has been found in similar cases in other regions of rhyolite volcanism in the world one is inclined to think of these beds as of welded tuffs or ignimbrites — at least to their greater part.

We may discuss the matter somewhat more particularly in Part II of this memoir (the concluding chapter on Systematic geology).

6.

The South-western Coastal Mountains

This very remote corner of the island comprises a stretch of the coast extending from the mouth of Barranco de Veneguera to the mouth of Barranco de la Aldea and to the lowland which is crossed by the latter water course. Inland the sector is limited by the great fault scarp of Montaña del Horno (previously described).

The mountainous corner now to be characterized has a rough relief with a number of short *barrancos* ending at the coast after a steep gradient from a divide on which the highest eminence of the region Pico del Cedro (1 025 m) is to be found.

The rock ground in the region chiefly consists of basaltic volcanics belonging to the so-called 'ancient basalt formation', mostly rather decomposed in its superficial parts and often amygdaloidal. This formation is capped with a variegated series of lavas and tuffs of sometimes bright colours. They have a varying composition but with some topmost beds of rhyolites. It is quite apparent that these latter volcanics once covered the old basalts extensively, but later on they have been much reduced by erosion, so that only remains are seen crowning the higher ridges and summits.

The volcanic beds in this region do not lie in a flat position but are somewhat inclined to the south and southwest, i.e. towards the coast.

The geological conditions along Barranco de Veneguera have already been described (page 163), so we do not need to start with them. The following *barranco* in northwesterly direction, separated from Barranco de Veneguera by a rather broad divide, is Barranco Seco. It was never visited by the author, and samples from here are not available. According to J. Bourcart's geological map (1937), the rock ground in the *barranco* consists of the old basalts (probably olivine basalts), but they are separated from the next valley to the northwest-(Barr, de Tasarte) by a divide, where the salic volcanics are exposed.

We may now shortly characterize the geological conditions in this mountain region taking the *barrancos* as they follow one another in northwesterly direction. — It may be pointed out that there is still very scanty of data and samples of rocks, so that a comprehensive picture cannot be given. The shortcomings are chiefly to be found in the salic, variegated series of volcanics surmounting the old basalt-formation. There should also be more informations about the fracture tectonics that have affected the region.

Barranco de Tasarte

This mountain valley runs south-southwest from an altitude of 600 m down to Playa de Tasarte at the coast, exposing the old basalt formation in its sides. In the divides on both sides there are, however, remains of the salic superimposed lava formation. The author has only visited the upper course of this valley (above 500 m) and the samples from here are few in number (18, 335, 336, 347).

This *barranco* has a relatively open cross-profile. In the lower course, however, a young bottom canyon appears accompanied by rock terraces. To the right opens a deep *cañada* reaching down from the divide.

I have only two samples of the old basalts (18, 347). The former is a typical olivine basalt with the olivine phenocrysts completely changed to iddingsite. The vesicles in the paste are lined with zeolite in radial bundles. Phenocrysts of a plagioclase are clear, albite twinned (labradorite). Magnetite is present in abundance, in places in skeletal forms.

No. 347 is taken from the vicinity of Degollada de Tasarte, the head of the *barranco*. This lava is very fine-grained showing a basaltic texture. There are phenocrysts of augite (euhedral), slightly zonal. Olivine has been completely altered to iddingsite. Magnetite grains are abundant. Some samples of the salic lavas (335, 336) were collected in Degollada de Corrales, on the divide between Barranco de Tasarte and Barranco de Tasartico. There are peculiar fortress — like rocks standing on the divide and immediately on basaltic basement. Between the basic and the salic rocks there is no visible unconformity. The salic lavas continue to the north along the crest line to its northern end which is Montaña del Lechugal (975 m) a conical summit. This summit is also built of the salic lavas.

Of the two samples mentioned, no. 335 corresponds to a basal bed of lava. It shows micr. phenocrysts of alk. feldspar, prisms of brown hornblende and pale-coloured clinopyroxene. Accessories are apatite and ore. The paste is very fine-grained, glassy in parts. The optics of the chief minerals are:

Alk. feldspar: $2V\alpha=48°$. Ax. pl. $\sim \perp(010)$ (anorthoclase)
Hornblende: $2V\alpha=88°$, $c \wedge \gamma = 10°$

The lava should be classified as a vitrophyre, perhaps of rhyolitic kind, although quartz does not appear in the slides.

No. 336, also from the *degollada*, is another vitrophyre with clear alk. feldspar phenocrysts and prisms of brown hornblende in a paste with a beautiful flow texture. The optics of the phenocrysts are:

Alk. feldspar: $2V\alpha=48°$ (anorthoclase)
Hornblende: $2V\alpha=90°$, $c \wedge \gamma = 17°$

This lava may also be trachyte or a trachyrhyolite, corresponding to one of the earlier flows of lava in the long period of effusions of salic magma which followed the interlude of basaltic effusions.

Barranco de Tasartico

This rather short mountain valley has its head in Degollada de Tasartico (600 m above sea level), and from here it runs with a rather steep gradient down to the coast at Playa del Asno. This mouth is guarded on both sides by high sea cliffs. The valley obviously represents only the remaining part of a larger ancient valley which has been cut off by displacements and (or) by marine abrasion. The valley has chiefly been eroded in basalts of the ancient series, but in the high crests on both sides there are remains of a superimposed series of salic lavas and tuffs. This fact has already been demonstrated as far as the left side of the valley is concerned.

The visitor to this remote, extremely rough landscape is aware of the peculiar erosion forms of the mountains around him, and he gets the impression that these sharp edges are the result of a shortening of the gradient of the *barranco* that seems to have invigorated the erosion, in combination with weathering. Much gravel material has accumulated in the bottom of the valley, but also from the sides of the valley stones have been carried down by torrents. — A small collection has been made of samples of rocks met with in the *degollada* and inside the valley (partly of boulders): 339, 340, 342, 345, 347, 349. The lavas are always basalts in the slopes, but there are also lamprophyric dikes standing in relief. Salic types were taken of boulders dropped from the side crests. — The basalt series is gently inclined to the coast, and so is the case with the superimposed salic lavas. The latter may have issued from sources rather far away (in the interior of the island). These remains are mere outliers isolated by erosion.

Here are some petrographic data:

No. 342 is micr. porphyritic with broad laths of plagioclase in random orientations. In addition, there are relatively large crystals of a grayish pyroxene and also scattered grains of a red-brown mineral, obviously of sec. nature (birefr., iddingsite ?). Magnetite grains are present in abundance. The cavities in the paste are empty. Olivine in the rock may have been completely altered. The paste chiefly consists of feldspar laths, of pyroxene and ore (plenty). The lava may be an olivine basalt of a more feldspar-rich variety.

No. 345 is of a rather similar aspect: micr. broad laths of plagioclase and euhedral crystals of augite in a fine-grained paste with red grains of (olivine (?) altered to) iddingsite. A brownish mesostasis is isotropic and may be glass. The ore grains are flaky and may correspond to ilmenite. The optics are:

Plagioclase: $2V\alpha = 94°$ (ext. angle in plane $\perp$ PM$=37°$. Comp.: An/62.
Pyroxene: $2V\gamma = 50°$, $c \wedge \gamma = 45°$ (Ti:augite)

The two types mentioned are from lava banks found in the vicinity of the pass, Degollada de Tasartico (elevation 600 m above sea level).

Lower down along the right side of the *barranco*, the basalts continue in banks with a gentle dip towards the coast. They are crossed by numerous dikes of an aphanitic aspect, resistant to denudation. Two samples of the basalt lavas were kept (349 a and b). They both show micr. plenty of plagioclase laths of the I gen. with crystals of augite and (the iddingsite-altered) olivine. The groundmass is fine-grained with a basaltic texture consisting of feldspar rods, pyroxene and ore grains. There are some grains of iddingsite in which a kernel of olivine has been preserved. The optics are[1]):

349 a Plagioclase: ($2V$ not ind.) — meas. on twins acc. to the Karlsbad law (001). Comp.$=$An/58 (high-temp. form)
349 b Pyroxene: $2V\gamma = 54° - 54{,}5°$ (det. on two grains), $c \wedge \gamma = 46°$ (Ti:augite)

A chemical analysis was carried out of basalt no. 349 a exposed in the upper right side of Barranco de Tasartico. The results are given here:

[1]) Cf. microphoto fig 1, plate III.

Analysis no. 7

Sample no. 349 (HAUSEN 1953) of a plagioclase basalt, Barranco de Tasartico.

		Mol. prop.
SiO_2	48.90%	8109
TiO_2	2.98 »	372
Al_2O_3	10.58 »	1035
Cr_2O_3	0.01 »	1
Fe_2O_3	4.86 »	304
FeO	6.62 »	921
MnO	0.18 »	25
NiO	0.03 »	4
MgO	9.44 »	2341
CaO	11.26 »	2007
BaO	0.02 »	1
Na_2O	2.01 »	324
K_2O	0.99 »	105
P_2O_5	0.34 »	24
F_2	0.04 »	11
V_2O_5	0.07 »	4
H_2O+	1.03 »	572
H_2O-	0.65 »	
	100.01%	
−0	0.02	
Sum:	99.99%	

Norm:

Q	2.3	
or	5.8	39.7
ab	17.0	
an	16.9	
Σ Sal:		42.0
di	28.9	
hy	13.4	
mt	7.1	
cm	(0.02)	
il	5.7	
ap	0.8	
fr	(0.02)	
Σ Fem:		55.9
V_2O_5		0.1
H_2O		1.7
Sum:		99.7

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.87 (+23.5°C)

NIGGLI values:

si = 110, ti = 5.0, p = 0.3, f_2 = 0.1, h+ = 7.7, al = 14, fm = 53, c = 27, alk = 6, k = 0.26, mg = 0.60, qz = −14, al−fm' = −39, al−alk = +8.

C.I.P.W. Classif. — III. 5. 3. 4.
Camptonose
Magma type: essexitic gabbroid/gabbroid
Mol. prop. % of normative feldspars:
Ab:An:Or = 31:59:10
MgO:FeO = 90:10

RITTMANN parameters for nomenclature:
Al−9.52, FM−31.22, Alk−4.01, k−0.25, an−0.41, ca″−7.95. Andesine basalt.

Since the plagioclase in the phenocrysts (optically determined) is a basic labradorite, the feldspar in the groundmass must be considerably more Na — enriched. This lava which shows a close correspondance to no. 411 (anal. no. 10) and which is from the Tirma region (described later on) seems to be rather extensive along this coast of the island. It may represent t h e u p p e r p a r t of the old basalt complex, the underlying beds being olivine bearing, rather picritic basalts.

In the vicinity of D e g o l l a d a d e T a s a r t i c o there are also amygdaloid types to be seen, likewise along the *barranco* down to T a-s a r t i c o, crossed by lamprophyric dikes (samples are not available). These things have already been mentioned.

When examining the loose boulders in the gravel train of Barranco de Tasartico, my attention was drawn to the great number of salic lava types of grayish-greenish colours. They belong to some beds of this nature in the crests of the mountains on both sides of the valley. A couple of them have already been described (from the left-hand divide, samples taken from firm rocks). Other samples, of boulders in the village of T. derived from M o n t a ñ a d e l a s V a c a s, the right hand divide, (339, 340) show a trachytic or rhyolitic aspect. The first is a porphyry with phenocrysts of alk. feldspar bordered by clusters of aegirine and an almost isotropic paste with minute aegirine prisms and ore powder; stray grains of an altered sodalite mineral are also present. Apatite is an accessory. — No. 340 has micr. non-porphyritic texture, only fragments of alk. feldspar with a fine striation (anorthoclase) and small prisms of aegirine. The paste is eutaxitic. No foid mineral is to be seen in the slide. It may be a rhyolite (ignimbrite?).

*　*
*

We may now turn our attention to the geological conditions in the mountain region between the lowland of Aldea de S. Nicolás in the north and the coast in the southwest. It is a very rough landscape difficult of access.

To the south of the basin of Aldea de San Nicolás is a continuous mountain barrier reaching from D e g o l l a d a d e l a A l d e a in the SE. to P l a y a d e l a A l d e a (on the coast) in the NW, with heights attaining up to 1 000 m (Pico del Cedro). This wall suggests the presence of an old dislocation line. This is difficult to follow, however, since the foot of the mountains is here covered with heavy masses of gravels (talus cones).

The escarpment in question has been studied by the author to some extent. A stretch of this wall can be followed by using the recently built highroad which runs from Aldea de S. Nicolás to Mogán, passing through Degollada de la Aldea. Further west, I have visited the north side of Pico del Cedro, and, nearer to the coast, a profile along Barranco de las Vacas was studied.

The volcanic beds composing this mountain wall are of different composition, but seem to be fairly concordant. They have a slight dip towards the south, perhaps due to displacements.

If we now begin our descriptions in the east, we may start from the village of Aldea de S.N. and proceed along the highroad to Degollada de la Aldea. The lower slopes are here composed of basalts of the old series, much weathered on the surface (if they are not covered by gravels). The same basalts also appear in Degollada de Tasartico (600 m above sea level), the divide between the basin of Aldea and the mountain valley of Tasartico. Types from here have already been described. To the W, at an altitude of c. 500 m there are salic lava banks resting on the basalts, and at still higher levels other such lavas appear, judging from boulders which have dropped down the slopes.

I have some samples of these salic types (351c, 353, 360). They are all porphyries with feldspar phenocrysts. Micr. the feldspar is anorthoclase (with a fine striation but with deep corrosion embayments). Of mafics, there are grains of pale-coloured clinopyroxene, in some cases a green aegirine and a brown hornblende (rimmed with opacite). Apatite is an accessory constituent. Grains of iron ore are scattered in the paste, and this seems to have been originally of a glassy nature, i.e. the porphyries in question may have been vitrophyres (in places also ignimbrites) of the trachy-rhyolitic assemblage.

These salic lavas which follow the old basalts apparently lie in a fairly concordant position on these basic lavas. There has of course been a considerable break in the piling-up of the volcanics. The basic lavas have advanced from the west, the salic ones from the northeast, hence we have to consider two widely separated centres of activity producing these very different materials. There is no doubt that the salic lavas belong to the same series which forms the great pile in Montaña del Horno in the vicinity.

The basaltic terrane from Degollada de la Aldea to Tocodomán

Only a few samples were collected by the author from this stretch. The ground traversed belongs to the old basalts. At my request T. BRAVO has later on (1960) kindly made a complementary collection of the types met with along the road that leads to Tocodomán and to Aldea de San Nicolás (9, 10, 12, 14, 15, 17, 18). — Most of them are olivine basalts, but with the olivine grains completely altered. One type is a plagioclase basalt (18) and a top lava (17) is a porphyry of salic composition.

No. 9 from Degollada de Tasarte (de la Aldea) contains phenocrysts of ex-olivine (pseudomorphs) and augite crystals (ext. angle on (010) $c \wedge \gamma = 57°$) both lying in a fine-grained groundmass of basaltic texture. This is rather dark between + nic. Fine laths of plagioclase and augite grains are seen in it, and also plenty of magnetite. There are no remains of the olivine substance in the pseudomorphs, all has been changed to serpentine (in fine aggregates). The original contours of the olivine crystals and the cracks dissecting the same are now marked by sec. opacite. This basalt lava may have been of the more picritic kind.

No. 10 is an iron-rich type, the paste being filled with slender laths of feldspar in the trachytoidal arrangement. Of phenocrysts there are augite crystals and olivine pseudomorphs. Between + nic. the paste looks rather dark. — No. 12 contains phenocrysts of augite, altered olivine and plagioclase laths (in corroded state). Prisms of brown hornblende are also present. The vesicles are filled with calcite. — No. 14 is a similar type; olivine is also completely changed here. — No. 15 is not very different in composition, an olivine basalt with the olivine pseudomorphs reminding one of the altered basalts in Barranco de Balo (SE sector of the island).

No. 18 is a lava which seems to occupy a relatively higher altitude than the olivine basalts above enumerated. Its stratigraphic position seems to be at the base of the salic series of Pico del Cedro (see next chapter!). — Micr. the dominating mineral seems to be a plagioclase in clear laths with random orientations. The laths are twinned according to the albite law. Opt. char. — (andesine). Of mafic phenocrysts there are only scattered grains of an altered mineral. The lava is a plagioclase basalt.

Pico del Cedro

This is a prominent conical mountain peak dominating the scenery to the south of the plain of Aldea de San Nicolás. It reaches to 1 025 m above the sea level, and has a rather steep northern side which lower down, however, changes to a gentle slope untill this terminates at the fringe of the gravel filled plain on which the mentioned village has been built. In the lower slopes the rock ground is mostly hidden beneath arable soil, but higher up basalts appear and can be followed up to an altitude of at least 700 m. These basalts belong to the old complex above dealt with, and the same continue all the way along the *cuesta* to the sea border.

Upon the basalts there lies a brown tuff layer, where there is a spring. It is covered by a sheet of brown porphyry (362). Micr. this lava consists of clinopyroxene and magnetite in a fine grained paste (devitrified glass?) with a streaky texture. The paste looks almost dark between + nic. No quartz is visible. It is a vitrophyre. — The next lava bank uphill (365) is of great thickness. Micr. it contains plenty of pores. Of phenocrysts, there are only small crystals of a clinopyroxene in prisms, partly clustered into groups and associated with magnetite grains. The pyroxene is somewhat zonal and has a relatively small optical angle (pigeonite?). The paste is filled with feldspar microlites (basaltic texture), ore powder and minute grains of pyroxene(?), and perhaps also plenty of analcime (dark patches betw. + nic.). Some of the pores in the paste are filled with opal.
The optics are:

Clinopyroxene: $2V\gamma=49°$, $c\wedge\gamma=45°$ (Ti-augite)

Since the nature of the feldspar microlites remains uncertain, a proper classification is not possible without a chemical analysis. The lava may be a kind of trachybasalt of the more salic types. There are rather few mafic components in the rock. In hand specimen it looks like an aphanite. The lava bank shows columnar jointings. It is separated from the underlying bank (362) by a layer of a green tuff. The lava seems to extend very far sideways in the long escarpment facing the lowland in the north. We are now at a level of c. 750 m above the sea.

We will find in a profile exposed farther to the west lava types of similar nature embedded with conformity in the salic series of volcanics (lavas and tuffs etc.).

Higher up the slope is another lava bank (366) of a dark colour. Micr.

it is a distinct porphyry with clear phenocrysts of alk. feldspar and also of mafic components represented by brown hornblende, in places almost completely resorbed and replaced by opacite, whereas other individuals are only rimmed with the same substance. The paste is chiefly vitreous, sprinkled with ore grains and elongated microlites of hornblende (?). Small crystals of a clinopyroxene are also to be seen.

The summit of Pico del Cedro likewise consists of porphyry (369). Micr. it is of a rather similar nature, with phenocrysts of alk. feldspar (anorthoclase) and with rimmed hornblende in elongated prisms. Magnetite is an accessory. The paste contains feldspar microlites in a streamlined arrangement and also a glass substance.

These salic types on high levels show a certain resemblance to salic lava types in Montaña del Horno, described earlier, and I think those in Pico del Cedro represent the lower part of the whole formation of salic volcanics. They may be, at least in places, of an ignimbritic nature. It is notable that there is no nepheline among the constituents of the Pico del Cedro-lavas, whereas at least the top sheet in Montaña del Horno is of a transitional type leading to the nepheline phonolites.

Since the samples taken in the north slope of Pico del Cedro are rather too few to illustrate the salic series in this region, I turned west and climbed the easily accessible profile of Barranco de las Vacas, leading up to Degollada Peñón Bermejo. This profile runs only c. 750 m from the sea shore at Playa de la Aldea. For stratigraphical reasons we may follow the series exposed here from base to top (the watershed).

Profile along Barranco de Las Vacas[1])
(Region of Aldea de San Nicolás)

This *barranco* can be reached from the highroad that runs from the village S.N. to the coast following the foot of the long *cuesta*. Before reaching the shore (Playa de la Aldea) one may turn to the left to a small settlement which lies at the foot of the mountains. The ground is here much eroded and covered with gravels on the lower slopes, and no exposures of the rock ground are to be seen. It may be possible that a fault line (or a zone of faults) runs here, confining the basin of La Aldea to the south.

From this point one can follow Barranco de las Vacas uphill to the

[1]) Called also Cañada de las Vacas.

degollada (a rather steep ascent). One traverses a great number of lava and tuff banks, as we will find in the following.

At the foot of the long profile are weathered rock exposures — kinds of foothills, consisting of a dark porphyrite (376). Micr. the rock shows tabular phenocrysts of plagioclase lying in a dark-coloured paste filled with tiny feldspar microlites and iron ore powder. There are also stray phenocrysts of clinopyroxene of a pale-yellowish colour (in the slide). The texture is streamlined. There are many empty pores in the paste. The optic data are:

Plagioclase: $2V\gamma = 75°$ (average of 6 det.)
$\alpha' \wedge (010) = 32°$. Comp. An/54$\pm$2
Pyroxene: ($2V$ could not be det.) $c \wedge \gamma = 47°$

The lava is a kind of plagioclase basalt. There are exposures of lava banks of the same kind in the vicinity, all lying in a flat position.

Going uphill along the *barranco*, one soon meets a bank of a brown porphyry (377) of considerable thickness. In hand sp. it is very distinctly porphyric with glistering feldspar phenocrysts in a dense, grayish-brown groundmass. Micr. one will find the feldspar (clear) in twins according to the Karlsbad law and also to the Manebach law. Of mafic components, there are prisms of brown hornblende, surrounded by an opaque fringe. The paste is almost isotropic, mostly glass, in which feldspar and iron ore are disseminated. The optic data are:

Alk. feldspar: $2V\alpha = 42.5°$, $44.5° - 45°$ Manebach twins (anorthoclase)
Brown hornblende: ($2V\alpha$=not det.) $c \wedge \gamma = 10°$
Pleochr. α-yellow, γ-brown.

Some of the hornblende individuals are completely changed to an opaque subst. — This lava, a rhyolite (?) is the lowest of the salic lavas which will follow higher up in the profile.

Climbing uphill from this bed, we meet a dark lava (378). It consists micr. of large laths of a plagioclase and also of crystals of a clinopyroxene, the latter with wandering extinction. The groundmass is trachytoid with plenty of feldspar laths mingled with pyroxene grains, a red-brown sec. subst., also iron ore (rather abundantly). This lava may be designated a plagioclase basalt approaching an andesite.

Optics of the chief minerals are:

Plagioclase: meas. on twins acc. to the Karlsbad law (001).
Comp.: An=52% (high temp. form)

Pyroxene: ext. angle on (010) $c \wedge \gamma = 45°$
Brown hornblende: ext. angle on (010) $c \wedge \gamma = 16°$

The next bank in the series is a dark, fine-grained type (379) showing micr. a basaltic texture. It contains stray crystals of a clinopyroxene and of magnetite. There are also occasional grains of a feldspar without albitic twinning. The paste consists of feldspar, pyroxene and ore grains. The rock may be designated as aphanite.

This lava is in the turn capped by a red-brown porphyry rock that is similar to no. 377. No sample is available, however.

Further uphill in the profile follows a blistery, dark lava (380) accompanied by reddish tuff layers. Micr. the rock contains scattered feldspar grains (clear) in a very fine-grained paste charged with iron ore dust and also bigger ore grains of a skeletal aspect. No mafic crystals are present in the slide. The rock seems to be an altered vitrophyre (?).

The next bank following upwards is a kind of fine-grained rock (no sample). — Then there is a thick bank of a dark lava showing beautiful columnar partings (381). Micr. it is fine-grained, partly with a trachytoid texture, containing feldspar rods, pyroxene and ore. The feldspar component is very abundantly present. It may be a kind of trachyandesite.

Further uphill, we arrive at an extensive, thick bank of a gray, salic lava (382), c. 500 m above the sea. Micr. it contains phenocrysts of alk. feldspar with fine striation and with opt. char. — (anorthoclase), lying in a nearly isotropic paste, rather dark between + nic.; it contains small feldspar rods and aegirine prisms. No mafic phenocrysts are present. The lava may be a trachytic vitrophyre.

This lava is capped with an extensive sheet of a gray tuff (383), almost isotropic under the micr. except for scattered clear feldspar fragments. It is a vitrophyric tuff, probably of the rhyolitic kind. — This pyroclastic member is capped with a yellowish tuff (no slide).

The top sheet in the profile of Barr. de las Vacas in Degollada del Peñón Bermejo (800 m) is again a reddish lava bank (384) resting on the yellow tuff layer. Micr. it contains phenocrysts of alk. feldspar with a fine striation (anorthoclase) and crystals of a brown hornblende. Ore and apatite are accessories. The paste is glassy and streaky. The lava seems to be a rhyolite. No. 375 is of a very similar nature, taken from the summit region of Pico del Cedro, a bank in a stratigraphically more elevated position than the series already described. It is also eutaxitic, with clear alk. feldspar phenocrysts and brown hornblende in a streaky matrix which also contains microlites of feldspar[1]). The optics are:

Alk. feldspar: $2V\alpha = 35.5°$, opt. char. —, ind. of refr. < 1.54 (anorthoclase)

Hornblende (corroded): $c \wedge \gamma = 20°$, pleochr.: α-yellow, γ-brown

A chemical analysis of sample 375 was carried out with the following results:

Analysis no. 8

Sample no. 375 (F. UNTERBERGER 1953) of a grayish rhyolite lava forming the summit of Pico del Cedro, in the region of Aldea de San Nicolás, western coast.

		Mol. prop.
SiO_2	71.03%	11779
TiO_2	0.62 »	77
Al_2O_3	12.95 »	1267
Fe_2O_3	3.98 »	249
FeO	0.23 »	32
MnO	0.24 »	34
MgO	0.37 »	92
CaO	0.27 »	48
BaO	0.00 »	
Na_2O	5.72 »	923
K_2O	4.38 »	465
P_2O_5	0.05 »	3
Cl_2	0.08 »	11
SO_3	0.00 »	
CO_2	0.00 »	
H_2O+	0.16 »	89
H_2O-	0.17 »	
	100.25	
−0 ..	0.02	
Sum:	100.23%	

Norm:

Q	21.6	
or	25.9	67.9
ab	42.0	
hl	0.1	
Σ Sal:		89.6
ac	5.1	
di	0.6	
en	0.7	
hm	2.2	
il	1.0	
tn	0.2	
ap	0.1	
Σ Fem:		9.9
H_2O		0.3
	Sum:	99.8

Analyst: AULIS HEIKKINEN

Spec. gr. = 2. 48 (+23.5°C)

NIGGLI values:

si = 350½, ti = p = 0.1. cl_2 = 0.3, h+ = 2.7, al = 37½, fm = 19½, c = 1½, alk = 41½, k = 0.34, mg = 0.14, qz = +96½, al−fm′ = +21½, al−alk = −4.

[1]) (Cf. with microphoto fig. 1, pl. V.).

C.I.P.W. Classif. — I. 4. 1. 4.
Kallerudose
Magma type: normal alkali-granitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 63:O; 37
MgO:FeO = 100:0

RITTMANN parameters for the nomenclature:
Al — 11.66, FM — 5.24, Alk — 12.96, k — 0.34, an — 0.05, ca" — 1.05. Soda rhyolite.

This topmost lava bed in the high profile of Montaña del Cedro (1 000 m above sea level) is one of the few rhyolitic types collected by me (the silica-oversaturated types). It may be comparable with another rhyolite described by E. JÉRÉMINE (1937) from the same region (»Aldea de San Nicolás») and called by her »*brèche ignée de comendite*». The authoress does not mention, however the point in the sequence from where the sample was taken. I am inclined to assume that the two samples are from about the same locality: south of the village of Aldea de S. Nicolás.

The same authoress mentions (1937) several other occurrences of rhyolites in the southern region and she also gives analytical data of them (see the list of NIGGLI-values Part II, page 375, I, II, III).

A summary of the stratigraphy in the profile of Barranco de las Vacas:

1000 m	(top of Mont. del Cedro)
	375 soda rhyolite (chem. anal.).
800 »	384 reddish rhyolite, Degollada del Peñón Bermejo
	385 yellowish tuff bank, Degollada del Peñón Bermejo
	383 grayish tuff bank (extensive)
500 »	382 pale-grayish trachyte bank
	381 aphanite lava bank, great thickness (trachy-andesite)
	380 blistery, dark lava bank (meta-vitrophyre)
	— red-brown porphyry lava sheet (no sample)
	379 aphanitic lava bank
	378 porphyrite, dark
	377 red porphyry lava
	376 plagioclase basalt (basal bed)
	gravel covered slopes
Base 150 m	above sea level

As it will be found from this column the limit between the basalts and the hanging salic series has dropped to a much lower level than in Degollada de Tasartico and in Pico del Cedro.

The mountains on the west coast between Barranco de Tasartico and Playa de la Aldea de San Nicolás

This remote corner is difficult to traverse, the only »road» being a mule path leading from Barranco de Tasartico over some rough *barranquillos* to Degollada del Peñon Bermejo and to the coast of La Aldea. The rock ground consists chiefly of old basalts, mostly as it seems of the olivine bearing types, much decomposed in the surface. These lavas are in the summits and in the higher crests capped with salic volcanics resting conformably on the old basement. These uppermost beds — remains of erosion — are clearly visible owing to their bright colours which contrast with the dull colours of the underlying basalts. — The latter are of about the same kind which was seen in Barranco de Tasartico, and dikes of lamprophyres are common. A huge bank of a brown tuff was seen in the upper course of Barranco de Gugui Grande (above the small cattle farm).

It seems that the coast-line owes its steepness to faultings and abrasion. This shortening has caused vigorous erosion into the mountains, although water is now seldom to be seen. Instead, mechanical weathering goes on in the slopes. The crests dividing the two *barrancos* Guigui Grande and Guigui Chico and the latter from Barranco Bermejo (the northernmost gorge) have, owing to strong erosion, been formed into wedge-like spines, reaching the sea in almost vertical cliffs. In altitudes of c. 600 m and still higher up there are no more basalts but the salic volcanics. The bulk of the ridges consist of the old basalts (no samples) chiefly as it seems of the olivine-bearing types. In the upper part of Guigui Grande there is the above mentioned brown tuff. Boulders from the high *cuesta* around the gorge consist of pale-grayish, trachyte-looking rock types, stones of which lie along the bottom of the *barranco*. The divide at Barranco de Tasartico is extremely rough and it ends at the sea with a cliff of 700 m altitude, called Montaña de Agua Sabina.

The N. mountainside continues to the west to Barranco de las Vacas and further on to the sea border, where it ends in a steep cliff. This cape confines Playa de la Aldea to the south. Here, in a gate that opens the basin of Aldea de San Nicolás to the sea is the mouth of Rio de la Aldea (or de Tejeda)

The rocks by the sea in this sector were not studied in greater detail. *There is only one sample in my collection (386) taken just to the south* of Playa de la Aldea. It is of the lowest bank of lavas exposed in a high profile. The rock is a porphyrite with relatively large laths of plagioclase. Other crystals of the I gen. are a pale-coloured clinopyroxene and grains of a completely altered olivine. Optics are:

Plagioclase: ($2V$ not det.). Twins according to the albite-, pericline- and the Karlsbad laws. Comp. An/50 (high temp. form)
Pyroxene: ($2V$ not det.) $c \wedge \gamma = 48°$.

The groundmass is composed of plagioclase, pyroxene and flakes of ilmenite. The lava may be a plagioclase basalt. Higher up in the sequence of volcanics there are salic lavas and tuffs.

To summarize the geological conditions in this sector of the island, we can state that it is a basalt terrane capped in the crests by remnants of a rhyolitic- trachytic lava formation. No unconformity is to be seen between the two complexes. The basalts are olivine bearing, at the top they are more plagioclase-rich. The salic series may be connected with that of the Montaña del Horno complex, this latter, however is in a relatively depressed position owing to later faultings.

The whole mountain landscape to the south of the basin of Aldea de San Nicolás has been modelled into a fault block tilted to the south.

7.

The Tamadaba complex

(with the coastal stretch from San Nicolás to Villa de Agaete)

The Tamadaba mountain complex, general features

By the expression »Tamadaba» we mean an orographic unit on the northwestern coast, rising to a maximum height of 1 438 m (Cumbre de Tamadaba). The mountain has steep slopes towards the sea of nearly 1 000 m altitude (see fig. 2, plate IV). The area is confined on almost all sides by escarpments: in the northwest we have the sea cliffs; in the north there is the long precipice facing the Agaete valley. In the east there is the deep scar of Barranco de la Hoya, and in the south we will find the tectonic depression of Aldea de San Nicolás. But in the east there is a narrow ridge — a watershed connecting Tamadana with the central highland.

This mountain block is not very much dissected by erosion; Barranco del Risco with its tributary *barranquillos* is the most noticeable. In the central part the ground is more plateau-like, the sides forming, however, broad 'staircases'.

There are many interesting geological problems to be studied in all directions where erosion has disclosed the volcanic strata. The headquarters of the author were the forest inn of Tamadaba and La Marquesa in Tirma.

As has been proved by earlier investigators, a large series of basalt lavas, tuffs and intersecting dikes appears at the coast, magnificiently exposed in the high cliffs. This complex is capped with a salic series of trachytes and rhyolites (with their tuffs), the limit between the two unities being expressed by a plane of unconformity. The angle of unconformity, however, is not large, although perceptible from a certain distance. There is at the shore no basement on which the basic lavas may have been deposited; the lavas reach down to the sea. It is evident, however, that there must exist a basement, but of what kind? The author is of the opinion that there lies hidden under the sea level a part of some salic lava series, the same that appears in the bottom of Caldera de Tejeda. The basalts so impressively displayed in the coast cliffs may be the remaining parts of some large basalt effusions in a region farther off to the west. They do not really belong to the proper island of Grand Canary-structure. The matter will be more closely discussed in Part II.

Route Aldea de San Nicolás de Tolentino—La Marquesa

We may now start in the direction of Tirma and look at the geological conditions on this stretch.

The lowland on which the village of S.N. is situated is a rather remarkable topographical feature in this mountainous part of the island. It is a kind of basin walled in on all sides by mountains, except on the coastal side, where only a low ridge separates it from the ocean. There is a wide gap in this ridge: the mouth of Rio de la Aldea (now dried up). — It seems reasonable to suppose that this basin is a subsidence area confined by fault lines.

We may be able to reconstruct the formation of this tectonic *graben* by examining a terrace, filling a part of the bottom of the depression.

On the way to La Marquesa I devoted some time to the study of this terrace which rises with a sharp edge some distance to the north of the village — on the right side of the wide (and braided) gravel train that marks the course of Rio de la Aldea.

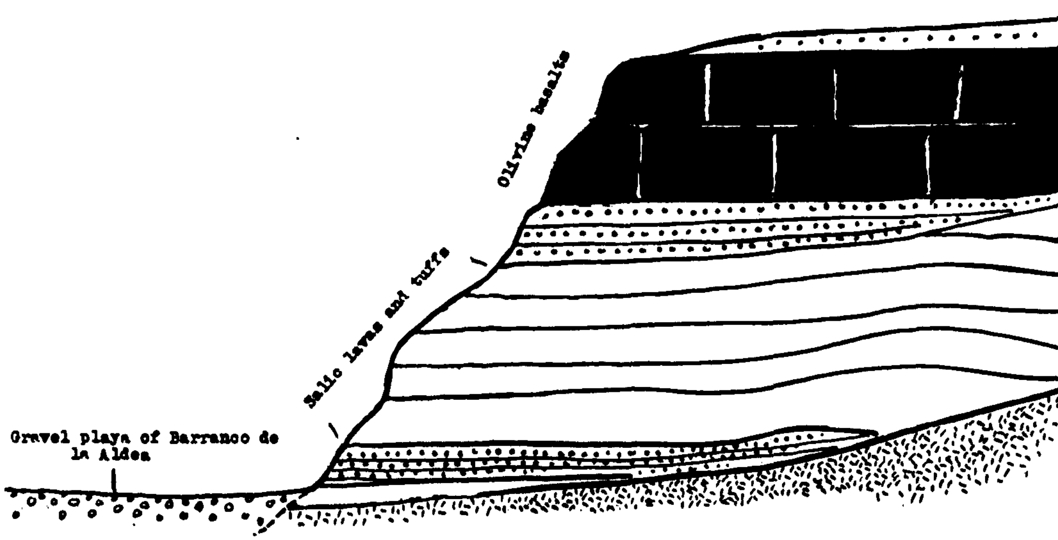


Fig. 16. The terrace-like erosion remnant of a basin fill in the lowland of Aldea de San Nicolás. Acc. to HAUSEN—BRAVO. Looking west.

In a study of this natural section (see fig. 16) we will find outcrops of old basalts at the base (at the western foot). These basalts support a series of reddish, salic lavas and tuffs being in a somewhat disturbed position. The series is capped by a gravel sheet and this in its turn by two fairly mighty banks of olivine basalt, forming the top of the terrace with a sharp edge. The upper basalt sheet is capped only by sand and gravels. — This terrace extends to the east rising slowly to the foot of Montaña de la Fuente Blanca; in the north it is separated from the Tirma mountains by a system of creeks. It is evident that later erosion has to a great extent destroyed the terrace which maybe once filled up the entire basin.

What can the terrace tell us about the history of the basin of San Nicolás? Here are some suggestions:

1. The basin was formed by subsidence, probably in connection with great displacements along the west coast of the island.

2. The subsidence movements gave to a series of salic lavas inside the area a relatively lower position in relation to the surroundings.

3. The sea became access to the depression at a time (Miocene?), when the ocean level stood at least some hundred m higher than now. Abrasion in the soft tuffaceous series followed inside the bay thus formed and a smooth coastal ground (a shelf) was worked out.

4. Somewhat later on during a regression (?) the plain was flooded with basalt lavas coming down from the interior of the island, apparently following the course of the ancient outlet gorge of the Tejeda basin (the primeval caldera).

5. In Quaternary times (the Ice Age) the eustatic lowering of the ocean level brought about a revival of erosion and a great deal of the fill of the basin was destroyed. Only the terrace was left standing — thanks to the sheltering sheets of the top basalt lavas. The amount of erosion reached down to the old basalts in the basin floor.

6. With the rising ocean level in late-Quaternary times there began inside the basin an accumulation of river gravels, thus covering its entire bottom. Only the terrace stands above this flood plain.

Thus the upper surface of the terrace (i.e. what lies under the top-basalts) marks the ancient stand of the ocean level.

The point of issue of the covering basalts is not known. The author thinks it must be sought for inside the Tejeda area in the east, from where the lavas passed down along the ancient valley of Rio de Tejeda (Rio

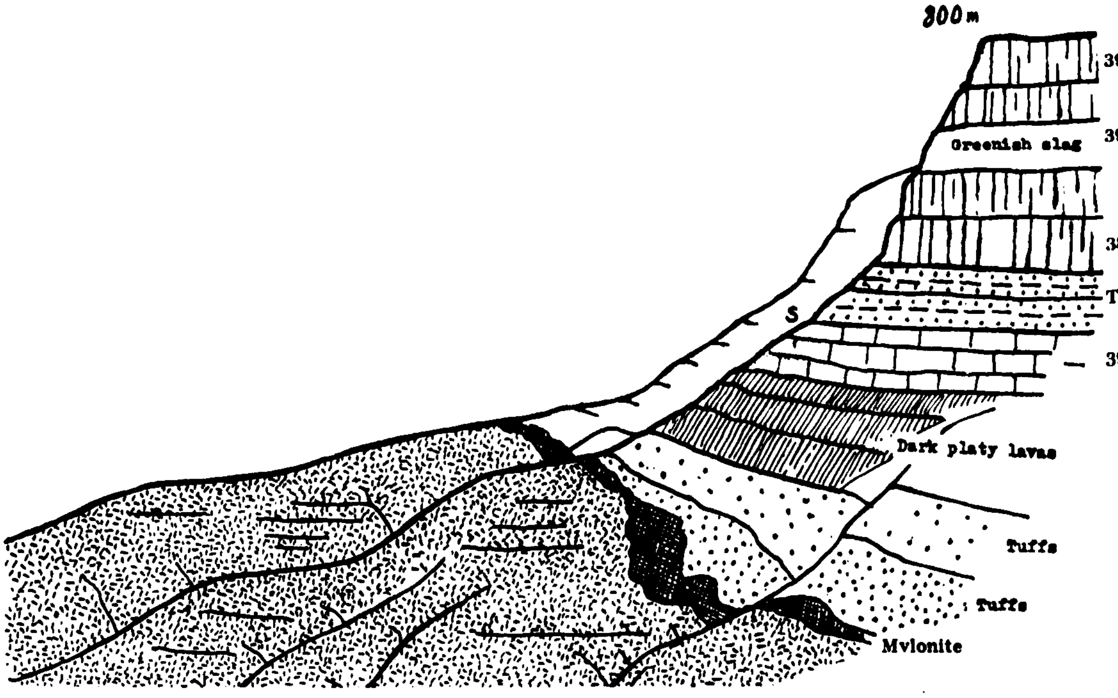


Fig. 17. Cuesta de la Fuente Blanca, NE from Aldea de San Nicolás, showing a concordant series of salic lavas and tuffs resting with a tectonical unconformity on a basement of the old basalts. Looking north. T—tuff, S—spring. Field sketch by H. H — .n

de la Aldea) before its later adjustment to a deep canyon, hence before a rise of the island after the Miocene transgression.

From the terrace I made my way to the northeast, towards *a cuesta*, which is called Montaña de la Fuente Blanca. Its edge attains 800 m in elevation. Wandering up the piedmont slopes, one first meets the salic, reddish lavas in an inclined position. Then there is a sudden limit (fault?), beyond which the old basalts appear in flat-lying lava banks (see the profile, fig. 17). At the foot of the precipice is a zone of greenish mylonite, then there are some layers of tuffs of pale colours. They are capped with a brownish lava (no sample). The next lava uphill is reddish (395) and has micr. a banded texture; it is glassy, with fragments of alk. feldspar (ignimbrite?)[1]) It is followed by a trachyte lava (389), greenish and showing micr. phenocrysts of alk. feldspar (with strangely corroded forms) lying in a trachytoid paste rich in aegirine

[1]) Cf. microphoto 2, plate VI

arranged in parallel streaks. No mafic minerals of the I gen. are to be seen. Xenoliths of alien lavas occur. — A sample of the top sheet in the profile (392) is fine-grained, with clear phenocrysts of alk. feldspar (opt. negative) in a paste rich in minute grains of nepheline mingled with the feldspar rods together with prisms of aegirine, and some turbid isotropic substance in a trachytoid texture. Stray grains of a clinopyroxene and brown mica are present. The nepheline crystals are surrounded by aggregates of aegirine. The rock is evidently a transition type to the nepheline-bearing phonolites.

In the middle of the profile (between the base and top) is a thick bank of grass-green tuff (T). At the base of this tuff is a spring used by the shepherds for their flocks (S). This green tuff can be followed for some distance along the trail to the north. The lava that lies close to this tuff is also greenish.

The series has a total thickness of c. 400 m.

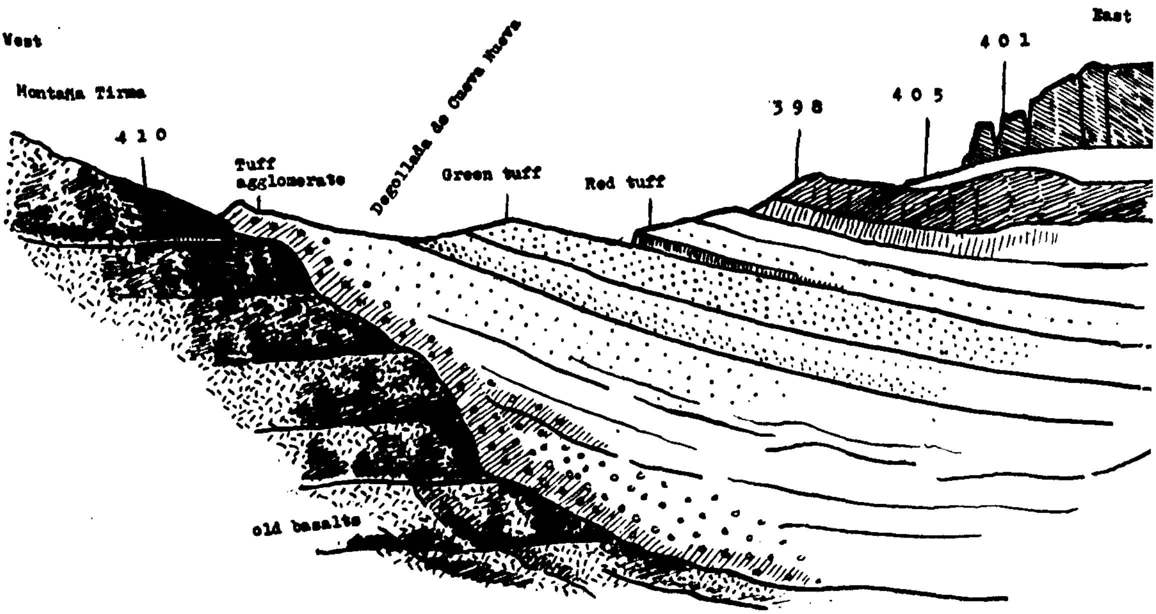


Fig. 18. Tectonic contact between the old basalts (left) and a thick series of agglomerates, tuffs and lavas of salic composition and of various colours. Degollada de la Cueva Nueva (750 m) east of Tirma.

Field sketch by H. H—n

The old trail leading from Aldea de S. Nicolás to La Marquesa (and to El Risco) was followed further northeast and north along the *cuesta* (see map, fig. 32 p. 335), and finally the pass of Degollada de la Cueva Nueva was reached. It is a rather interesting geological locality, as may be seen from the cross-profile, fig. 18.

In Deg. de la Cueva Nueva we have the old basalts in a rather flat position on the left, composing the lower part of Montaña de Tirma (860 m). Its summit consists of salic lavas. Going east, we meet a tectonic limit and beyond it a succession of variegated tuffs and lavas ending in a *cuesta* of 900 m in altitude. All these beds have a gradient to the east: they have been downfaulted in relation to the basalts in the west.

The basalts (410) are rather decomposed, partly fine-grained, partly porphyritic (plag. basalts). — The lowest member of the salic series (close to the tectonic contact line) is a pale grayish-brown agglomerate carrying fragments of pumice. Then to the east follows a sequence of tuffs, of green-brown and cinnabar-red colours of a soft consistency. They are all perfectly concordant. This series is capped with a grayish-green, platy porphyry, forming a kind of *cuesta*. It is overlaid by a cream-coloured porphyry which in the surface has a whitish film. It forms a bank of c. 20 m thickness and has a rather wide extension. This lava rock forms the substratum of a very mighty castellated top lava bank, a dark coloured trachyte with platy partings and columnar pillars. This same bank extends far to the southeast and to the east into the direction of Alta Vista. In hand specimen the rock shows large tabular, glistening feldspar phenocrysts in a dense groundmass. We called it the »star stone», and it occurs also elsewhere in the island.

As may be found from the fig. 32, the sequence in the great profile of Degollada de la Cueva Nueva is in the reality in the northwestern corner of an extensive flat topped ridge which stretches westwards from the mountain nucleus of Alta Vista with a general elevation of 1 000 m. This same ridge forms the watershed between Barranco de Tejeda and Barranco del Risco drainage areas. It is one of the remains of a vanishing table land of salic volcanics in this part of the island.

If we now look more closely at the petrography of the lava rocks found in the profile of Degollada de la Cueva Nueva (of which there are samples and slides at our disposal), we may start with the lowest one (398), which rests on the variegated tuff beds. Micr. it shows phenocrysts of alk. feldspar of a tabular shape lying in a trachytoid groundmass of feldspar rods and tiny aegirine prisms, and also minute nepheline crystals. It represents a rather current type among the foid-bearing phonolite lavas in the island.

The next lava bank uphill in the profile is a cream-coloured porphyry, whitish on the surface (405), forming the immediate basement to a top lava sheet. Micr. the former has clear phenocrysts of alk. feldspar in Karlsbad twins. Its optics are:

$2V\alpha = 49°$, ind. of refr. < 1.54, opt. char. — (anorthoclase)

In the groundmass there are chiefly feldspar rods and aegirine prisms, forming the typical trachytoid texture. Nepheline was not observed in the slide. The rock may be designated as a trachyte.

The top lava sheet is very thick and displays columnar jointing. It has castellated erosion forms. The rock is of a dark colour and has glistening tabular feldspar phenocrysts (»star stone», sample 401). Micr. the large feldspar phenocrysts have the optics:

$2V\alpha = 46° - 47°$, ind. of refr. < 1.54, opt. char. — (anorthoclase).

These tabular feldspars lie in a groundmass consisting of feldspar laths and aegirine prisms; interstrewn are small crystals of nepheline. This latter mineral is always surrounded by a corona of aegirine microlites. The lava may be designated as a nepheline trachyte (or trachyphonolite).

This rock has been submitted to a chemical analysis with the following results:

Analysis no. 9

Sample. no. 401 (HAUSEN 1953) of a trachy-phonolite top lava sheet in the profile at Degollada de la Cueva Nueva (Tirma).

		Mol. prop.	Norm:		
SiO_2	60.18%	9980	or	29.9	85.3
TiO_2	1.15 »	144	ab	55.4	
Al_2O_3	16.91 »	1655	an	—	
Fe_2O_3	4.53 »	284	ne	1.7	
FeO	0.61 »	85	hl	0.2	
MnO	0.29 »	41	th	0.1	
MgO	0.65 »	161	Σ Sal:		87.3
CaO	0.80 »	143			

Na_2O	7.17 »	1156	ac	0.7
K_2O	5.06 »	537	di	2.1
P_2O_5	0.11 »	8	fo	0.5
Cl_2	0.09 »	13	hm	4.3
SO_3	0.08 »	10	il	1.9
H_2O+	1.47 »	81	pf	0-2
H_2O-	0.80 »		ap	0.3
	99.90%	537	Σ Fem:	10.0
−0 ..	0.02		H_2O	2.3
Sum:	99.88%		Sum:	99.6

Analyst: Aulis Heikkinen

Spec. gr. = 2.60 (+23.5°C)

Niggli values:

si = 229½, ti = 3.2, p = 0.2, cl_2 = = 0.2, so_3 = 0.2, h+ = 18.9, al = 38, fm = 19½, c = 3½, alk = 39, k = 0.32, mg = 0.19, qz = −23½, al−fm′ = +19, al−alk = −1.

C. I. P. W. Classif.- I. 5. 1. 4.
Nordmarkose
Magma type: normal foyaitic/umptekitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 66:0:34
Mg:OFeO = 100:0

Rittmann-parameters for the nomenclature:
Al − 15.22, Fm − 6.82, Alk − 15.82, k − 0.32, an − −0.02, ca″ −1.16.
Soda trachyte.

This lava is the topmost one of a rather thick series of tuffs and lavas, all of a salic composition. It is more saturated than no. 564 (in the top of Montaña del Horno) and we may suppose that it lies in a somewhat lower position than the latter. No doubt it marks a transition type to the nepheline phonolites higher up in the geological column of the island. It seems to extend rather far, forming the roof of the long table-formed promontory which extends to the west from Alta Vista. It is at the same time one of the higher banks in the salic series of Tamadaba in general (cf. no. 440, page 225).

The coastal stretch between Aldea de San Nicolás and El Risco

The lofty northwestern coast of the island forms, as may be seen from the map, a broad embayment, disfiguring the generally rounded contour of the island. Such an irregularity suggests the occurrence of great displacements along the coast line in some remote period. Thanks to the cliffs, which rise to more than 1 000 m in height, great profiles have been formed in the succession of volcanic strata. The rocks exposed can most conveniently be studied along the highroad from Aldea de S.N. to El Risco (and further on to Agaete), built along the precipices and passing at various levels. There are, however, few opportunities to examine the ground above and below the road in a determined sector, since the steepness is often too difficult to overcome. The author, however, made use of a side road which leads up to the estate of La Marquesa in the Tirma region, so that at least in one sector complementary samples could be collected.

Most of these large natural cuts expose basalt lavas, tuffs and intersecting dikes. At the upper edge (c. 1 000 m) there also appear salic volcanics resting with a slight unconformity on the basalts, conditions which have already been described by J. BOURCART (1937).

The highroad that is now followed leaves the basin of Aldea de S.N. at sea level, then it runs up along the low coast ridge earlier mentioned, and which separates the basin from the sea. The height of the ridge increases slowly to the region of Tirma, and it consists of the old basalts. These are much decomposed on the surface. Seawards they have been exposed in vertical cliffs. At the rocky cape of Los Herreros at an altitude of c. 400 m, a sample was taken (408) of an aphanatic basalt. Micr. one will find the basaltic texture with tiny plagioclase laths, grains of a clinopyroxene and magnetite powder, the latter fairly abundantly. No phenocrysts have been formed. A turbid isotropic substance appears, perhaps consisting of analcime. — Amygdaloid types are met with at the cape of Punta del Marinero, not very far from the former place.

These aphanitic basalt types can be followed along the highroad to the vicinity of Montaña Blanca. This eminence consists of salic lavas which may represent an outlier of the salic volcanics of the Tirma region later on to be described.

Going along the highroad further on to the northeast one comes close to the coast, and here red and brownish salic lavas appear, in places of a glassy character, mostly very fine grained or porphyritic. These salic volcanics seem to be connected with the volcanics in Montaña Blanca (somewhat to the east). It seems as if a fault plane separates the basalts from the salic series here exposed.

The coastal road runs further on along a basaltic terrain, but suddenly there are salic lavas again, facing the sea in high, almost vertical profiles (position 700 m altitude). These beds rest on a basement of basalts. We are now passing the western spurs of Tirma. A sample of a salic lava (393) resting on a tuff bank shows micr. euhedral phenocrysts of alk. feldspar (clear) with albitic polysynthetic twinning. (opt. char. — max. angle of ext. in the zone ⊥ (010)=30°:An/32). There are also grains of a pale-coloured clinopyroxene (diopside) and magnetite. The groundmass is very fine-grained, almost of an isotropic nature. The lava may be a trachyandesite of a vitrophyric kind. This type shows a strong resemblance to a type found in the Tirma mountain (the upper part).

* *
*

It may be appropriately to insert here some data obtained by studying a series of samples from the same region. They were collected by T. BRAVO after my departure from the island and kindly put at my disposal. The samples are from a profile at a locality called A n d é n V e r d e in the vicinity of Tirma. Most of these samples are of a basic composition except for two (these at the top of the series).

The numbers to be described (19—26) will follow in ascending order.

No. 19 is a rather ordinary olivine basalt of a more picritic kind. Micr. it shows larger phenocrysts of euhedral olivine with a narrow iddingsite rim and crystals of augite, the latter partly in aggregates. They lie in a groundmass of a basaltic tecture with plagioclase laths, augite and ore. There are also small grains of a mineral completely altered to antigorite. The vesicles in the rock are filled with calcite; hence the lava is amygdaloid. — No. 20 is more fine-grained, with sparsely distributed crystals of a pale-coloured clinopyroxene associated with a red-brown mineral and also with laths of plagioclase (sparsely). They all lie in a very fine-grained groundmass with a basaltic texture: plag., augite and ore powder. The cavities in the paste are filled with chalcedony (zonal). — No. 21 is from a dike rock rich in plagioclase (comp. An/60), twinned acc. to the Karlsbad, albite and pericline laws. Other components are augite and sparsely altered olivine (?) and ore. The rock may be a lamprophyre crossing the basalt lavas.

Higher up in the series are more of the plagioclase basalts w i t h o u t olivine (22, 23, 24). The feldspar occupies c. 60% of the mass; next there is granular augite and flaky ilmenite. Scattered grains of a red-brown mineral also occur (birefr. weak), a secondary product. No. 24 is distinctly porphyritic with tabular phenocrysts of plagioclase in a trachytoid groundmass filled with rods of feldspar. Grains of a clinopyroxene and magnetite are also present as components of the I. gen. The same minerals are also in the groundmass together with a red-brown (sec.) mineral. The rock may be more andesitic in composition.

With this type we have reached the top of the old basic series, and there are now only salic volcanics uphill. I have in my collection two samples (25, 26). The former is a vitrophyre with a streaky glassy paste in which there are crystals of a clinopyroxene, very much crowded with magnetite grains. In addition there are laths of a plagioclase (oligoclase). No. 26 is another vitrophyre, containing broader laths of plagioclase (opt. char. —, ind. of refr. >1.54 Karlsbad, albitic twinning). No mafic components are to be seen. The paste shows trachytoid texture and is powdered with magnetite.

When following the coast further in the direction of El Risco, the reddish vitrophyre lavas disappear, and only basalts are seen in the roadside cuts. We now pass the highest point of the road (700 m), and from now on it descends in wide bends towards El Risco.

But before we proceed further in the direction of this small settlement (lying some few metres above the sea), we reach the fork of a right hand side-road, climbing straight up the slopes in the east to the Tirma region. Along this branch are several outcrops of lavas, apparently chiefly basalts. On reaching the top of the road (a pass), there suddenly appear lavas of salic nature. My samples collected in ascending order along this branch, are as follows:

	Plagioclase basalt, fine grained	411	(chem. anal.)
	Amydaloid basalt, fine grained	413	
	Rhyolite, dark	414	
	Tuff bank	—	
Top	Porphyrite lava	423	

Of these no. 411 is a feldspar-rich type showing micr. a trachytoid texture and bearing phenocrysts of plagioclase feldspar, also grains of a clinopyroxene. The paste is filled with feldspar rods and plenty of ore powder. Vesicles in the paste are often elongated and lined with chalcedony enclosing aragonite bundles in the interior. My co-worker A. C. Nilsson, found the feldspar phenocrysts difficult to determine, since it has an anomalous extinction, but seems to be an intermediary plagioclase. This lava may be an andesitic basalt. A chemical analysis of this rock was carried out with the results communicated below:

Analysis no 10

Sample 411 (HAUSEN 1953) of a basalt lava from the side road off the coastal highway of S. Nicolás; ascent to Tirma—La Marquesa. Altitude above the sea, 600 m.

		Mol. prop.
SiO_2	46.60%	7728
TiO_2	4.11 »	513
Al_2O_3	14.73 »	1441
Cr_2O_3	0.00 »	—
Fe_2O_3	6.04 »	378
FeO	6.58 »	916
MnO	0.21 »	30
NiO	0.01 »	1
MgO	5.19 »	1287
CaO	9.32 »	1662
BaO	0.00 »	—
Na_2O	3.10 »	500
K_2O	1.20 »	127
P_2O_5	0.50 »	35
F_2	0.08 »	21
CO_2	1.22 »	277
V_2O_5	0.08 »	4
H_2O+	0.75 »	416
H_2O-	0.60 »	
Sum:	100.32%	
−0 ..	0.03 »	
Sum:	100.29%	

Norm:

Q	3.3	
or	7.1	
ab	26.2	55.9
an	22.6	
Σ Sal:		59.2
di	9.8	
hy	9.1	
mt	8.8	
il	7.8	
ap	1.2	
fr	0.1	
Σ Fem:		36.8
Sec. $CaCO_3$		2.8
V_2O_5		0.1
H_2O		1.4
Sum:		100.3

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.95 (+23.5°C)

NIGGLI values:
si = 115, ti = 7.6, p = 0.6, f_2 = 0.3, co_2 = 4.2, h+ = 6.2, al = 21½, fm = 44½, c = 24½, alk = 9½, k = 0.21, mg = 0.43, qz = −23, al−fm′ = −23, al−alk = +12.

C. I. P. W. Classif. — III. 5. 3. 4.
Camptonose
Magma type: essexitic—gabbrodioritic
Mol. prop. % of normative feldspars:
Ab:An:Or = 35:56:9
MgO:FeO = 96:4.

RITTMANN-parameters for nomenclature:
Al—13.26, FM—23.89, Alk—5.85, k—0.21, an—0.39, ca″—4.87.
Andesine basalt.

This type may be a representative of the upper part of the old basalt sequence resting on the olivine-bearing (decomposed) basalts. In fact, this lava bed does not lie far beneath the salic series that follows in the higher ground of Tirma.

Another basaltic lava from the upper part of the profile along the side road is fine-grained (aphanitic) and amygdaloidal (413). Micr. its shows a basaltic texture, with tiny laths of plagioclase and grains of augite and ore powder, the latter in abundance. In the slide there also appears a solitary crystal of olivine, iddingsite-rimmed, perhaps occasionally present. The vesicles are filled with radial bundles of aragonite. The lava may be of about the same kind as no 411 (in spite of the olivine). — The lava bank next in order uphill on the slope consists of a salic type (414), and it belongs to the covering series of the Tirma region. Micr. it shows phenocrysts of alk. feldspar (clear) with polysynthetic twinning and opt. char. neg. (— oligoclase?), a pale-coloured clinopyroxene and a brown mica (almost uniaxial). The groundmass has a trachytoid texture with scattered ore grains. The small feldspar rods in the paste may be sanidine (judging from the ind. of refr.).

Further uphill is a thick, brownish tuff bank, and on this there lies a lava bank, the topmost in the series, which is of a salic composition (423). It forms the crest of a ridge stretching from the mountain of Tirma nearby. Micr. one will find phenocrysts of alk. feldspar (clear) with polysynthetic (albite-)twinning and opt. char.+. It may be albite. In addition there are crystals of a clinopyroxene with $c \wedge \gamma = 60°$. The colour of the mineral is pale-yellowish, and it seems to correspond to aegirine augite. The paste is cryptocrystalline (devitr. glass?). There are also stray grains of a red-brown secondary mineral. The rock may be a tiachy-andesite.

The conical mountain of T i r m a (860 m) which rises in the vicinity, consists, as has previously been mentioned, of the old basalt formation topped by salic volcanics. It is a typical erosion mountain sculptured into the once table-formed mountain complex of this region. There are two samples from the top lavas in my collection (412, 426). No. 412 is a kind of vitric tuff carrying fragments of clear alk. feldspar, also crystals, lying in an almost isotropic mass with dark patches. The paste also contains fragments of alien lavas giving to the rock an aspect of detritus-tuff. The alk. feldspar crystals are almost turbid, but have a clear border of later growth. — No. 426 is a vitrophyre with clear alk. feldspar phenocrysts in a dark-coloured paste containing black patches and grains of magnetite. In addition there is a red-brown mineral of secondary origin. The glassy substance of the paste has partly changed to microlites of feldspar and aegirine.

After passing the northern foot of the Tirma mountain cone, one will find that the salic series of tuffs and lavas rests with a certain unconformity on the old basalts, the latter being slightly tilted to the east.

The geological conditions in the Degollada de la Cueva Nueva have already been described. In order to study the volcanics more to the east of the *degollada*, I followed a small road leading up to the ridge (flat-topped), which extends as a large promontory from the mountain nucleus of Alta Vista (cf. the map, fig. 32). Here one reaches an altitude of c. 1 000 m. The high-lying crest consists chiefly of a rock-like no. 401 (already described; see also anal. no 9). The lava banks here lie in a flat position. — On going down the south slope of the ridge, I could see that the beds lie all in the same flat position, lavas alternating with tuffs. Judging from a sample (431), the lavas are here greenish nepheline-bearing phonolites (or trachyphonolites) showing micr. a rather fine grain with small feldspar laths, aegirine, nepheline and also small flakes of brown mica. The pores in the lava are empty.

This flat-lying complex can be followed further down the south slopes of the ridge, probably right down to the canyon of Barranco de la Aldea (de Tejeda) as well as eastwards to the summit region of the Alta Vista mountain.

On the way from Tirma to La Marquesa there are many exposures of lavas and tuffs of a salic composition, all lying in a flat position. The share of tuffs is relatively large, however. These are capped with salic lavas. The tuffs are of very different colours, like those exposed in the east side of Degollada de la Cueva Nueva.

La Marquesa

The cattle farm of La Marquesa lies in the midst of the Tamadaba mountains, called Tirma here, and wild gorges dissect the slopes in many parts. The farm lies c. 500 m above sea level and the lodge has been built on a small platform consisting of salic lavas and tuffs in a flat position. Down the slopes in the direction of El Risco basalts will soon be met reaching down to the sea. A short distance to the north of the lodge Barranco del Risco descends with a steep gradient to the sea. On the opposite side of this gorge rises the forest-clad promontory R i s c o F a n e q u e (1 085 m).

During my stay on the farm I made some excursions in different directions — one along a road under construction up the slopes to the east. Some samples were collected of the salic volcanics which form the mountainsides here (417, 419, 429).

No. 417 is from the bottom of the small B a r r. d e E s c o b a r in the vicinity of the lodge. It is a fine-grained lava showing micr. a trachytoid texture with phenocrysts of alk. feldspar lying in a groundmass filled with tiny feldspar rods. No mafic components are present in the slide. The rock is somewhat altered, and a diagnosis of the feldspar is difficult (opt. char. —, ind. of refr. <1.54). The lava may be a trachyte. — No. 419 is from the same *barranquillo*, a lava bank lying horizontally between layers of tuffs. It is likewise practically a feldspar rock with rather densely packed rectangular feldspar crystals (altered) in a paste apparently consisting chiefly of feldspar, but turbid. It may likewise be a trachyte. The presence of nepheline could not be proved. It has perhaps been completely altered (?).

Barranco del Risco was followed uphill for a while, with a start at the 600 m level. Here a great succession of volcanic beds is met with. They lie in a flat position and are of a brownish or reddish colour, externally rather rhyolitic. Sample no. 429 shows micr. a slaggy texture with fragments of alk. feldspar in an iron-stained, porous paste, also containing opaque patches. The feldspar seems to be sanidine.

This series of salic volcanics continues uphill for a considerable distance, but before reaching the crest, i.e. the summit called C r u z d e M a r í a, we will observe a change in the position of the beds: instead of the horizontal series hitherto passed there appears a tilted series with a dip to the southeast (cf. page 316, Chapter 11). It seems we have crossed a dislocation line separating two complexes from each other.

The coastal stretch from El Risco to Agaete

If we continue from the Tirma fork over El Risco to the town of Agaete (and to Puerto de las Nieves), we will have several opportunities to study the volcanic rocks i.e. the old basalts and their tuffs etc. in the sea cliffs. Samples were collected from this route (El Risco—Agaete), first by myself (in 1948), later on by T. BRAVO (in 1960), so there is a fairly good assortment of types of both lavas and dike rocks.

The old basalts in these profiles are capped by the salic volcanics well to be discerned from a distance (from Gáldar) in the prominent cape El Faneque. The basalts have a slight inclination inland; the capping salic beds lie in flat position forming a slight unconformity.

We may here look in some detail at the rock types collected, comprising almost exclusively the basic lavas and dikes, the topping salic volcanics being treated in another connection (page 226). — We may start here with Bravo's collection, since it refers to a profile at El Risco. The collection made by myself is from the stretch between El Risco and Agaete.

Bravo's collection shows the following sequence:

Profile of El Risco

	Sample		
Top	27	Vitrophyre (devitrified)	Unconformity
	28	Plagioclase basalt	
	29	Aphanite	
	30	Plagioclase basalt	
	31	» »	
	32	Phonolite (dike rock)	
	33	Vitreous amygdaloid lava	
	34	Olivine basalt	(with the olivines altered)
	35	» »	(with the olivines altered)
Base	(unknown)		

We will at first notice that the olivine bearing types lie at the base, followed upward by several olivine-free types untill we reach the lower limit of the capping salic series (27).

In nos. 35 and 34 the olivines are completely altered (pseudomorphs) consisting of either talc or antigorite + chlorite. Minerals of the I gen. are olivine and augite; plagioclase is in the paste with augite and ore grains (rather abundantly). Hence, the lavas are of a more picritic composition. — The altered state of the olivines is remarkable; no other types of olivine-bearing basalts in the island display these kinds of alteration products, instead, we have found chiefly iddingsite. This latter product seems to be absent from the lavas at El Risco.

No. 33 is a slaggy and glassy lava of a blistery nature. Micr. one will find crystals of augite and feldspar laths, whereas the vesicles are filled with chalcedony. The paste is almost opaque. — No. 32 seems to be a dike of a later age inserted into the basic series. Micr. it has a trachytoid texture and chiefly consists of small feldspar laths and aegirine and scattered grains of nepheline. The cavities are filled with a gray, isotropic substance. It may be a tinguaite dike rock.

Nos. 31 and 30 are plagioclase basalts (free of olivine) and containing plenty of plagioclase. This min. occurs both in the I gen. and in the groundmass. *Mafics* are a pyroxene (with hourglass str.) and a red-brown mineral (scanty) and magnetite, the latter (plenty) in the paste. The pyroxene (augite) also belongs to the I gen. The vesicles are filled with calcite. Of the topmost lavas, 29 and 28, are plagioclase basalts of varying grain (28 is aphanite). Plagioclase is the chief mineral in all, followed by augite and then magnetite. The texture is basaltic.

Type 27 (the topmost of all) is a rhyolite, i.e. a vitrophyre (like 26 from Anden Verde), in which the feldspar phenocrysts are albite (opt. char. +, ind. of refr. $\sim$1.54). The paste is a glass substance, in which there are microlites of feldspar and ore powder. There is no mafic mineral to be seen. The texture is porphyric and the paste without any flow phenomena. Quartz cannot be detected, but the comp. may correspond to a rhyolite as well.

If we now proceed from El Risco in the direction of Agaete, we always have to do with similar basalts (as may be seen from the author's 1948-collection 2, 3, 5, 6, 7, 8, 10, 13, 20, 24, 29, 32).

P e t r o g r a p h i c d e t a i l s: — One sample (3) from the roadside in the cliff has micr. a basaltic texture with plagioclase laths in random orientations. Pyroxene appears as small grains together with magnetite, the latter also in larger crystals. Other phenocrysts are not present in the slide. — Another lava (5) is amygdaloid with the vesicles filled with calcite. Micr. one will find plenty of plagioclase laths in a fine-grained basaltic paste. There are also euhedral grains of augite and magnetite (abundantly). The lava is a plagioclase basalt. — The optics of the chief minerals are:

Plagioclase: $2V\gamma=80°$, $\alpha' \wedge (010)=36°$. Comp. : An/61$\pm$2.
Augite: $2V\gamma=56°$, $c\wedge\gamma$ not det.

Near this locality another type appears (6), an amygdaloidal one with the vesicles occupied by opal. The rock is somewhat altered. It consists of laths of plagioclase and grains of a pyroxene, the latter also as relatively large crystals. The ore mineral is represented by ilmenite (in flakes). The optics of the chief minerals are:

Plagioclase: $2V\alpha = 80°$ (slightly varying). Ext. angle in cuts ⊥ (010) and (001) $\alpha' \wedge (010) = 10°$. Comp.: An/25—28.
Pyroxene: $2V\gamma = 53°$ (average of 6 det.), $c \wedge \gamma = 47°$ (augite)

This type is also a plagioclase basalt or, referring to the nature of the feldspar (an oligoclase) — a type approaching the andesites.

Another sample (10) of a basalt (c. 49 km from Las Palmas) on the highroad to San Nicolás is likewise a plagioclase basalt with plenty of laths of plagioclase of the I gen. lying in a groundmass of feldspar, pyroxene and ore. There are also stray phenocrysts of euhedral pyroxene and further pseudomorphs of another mineral now consisting of calcite in aggregates. The vesicles are either empty, or lined with a veneer of chalcedony. The optics of the chief minerals are:

Plagioclase: $2V\gamma = 76°$ (average of 6 det.), $\alpha' \wedge (010) = 30°$. Comp.: An/$53 \pm 1$
Pyroxene: $2V\gamma = 51°$ (average of 6 det.), $c \wedge \gamma = 45°$ (augite)

This rock is a plagioclase basalt, rather typical and less alkaline than the preceding one.

There is still one more type of plagioclase basaltic composition in my collection (29) which has been more closely examined. The sample is from the same coastal cliff by the road. Micr. the texture is distinctly porphyritic with large laths of plagioclase in random orientations and also phenocrysts of augite lying in a groundmass of a basaltic texture. This consists of plagioclase rods, augite and ore grains. The optics of the chief minerals are:

Plagioclase: $2V\gamma = 82°$ (average of 6 det.), $\alpha' \wedge (010) = 37°$. Comp.: An/$63 \pm 1$
Augite: $2V\gamma = 50°$ (average of 5 det.), $c \wedge \gamma = 46°$ (Ti:augite)

The groundmass has plenty of magnetite grains. The share of the feldspar in the rock may be c. 50 vol. %.

Several other samples from the same stretch of the road are of similar types, some amygdaloid, other dense. No olivine was found in any of these: apparently we have here a complex distinct from the olivine bearing basalts.

As far as dikes are concerned, they seem to be rather numerous in the formation, in places dipping steeply, in places in a flat position. They are either basic (lamprophyres) or phonolites in composition.

No. 2 is a representative of the basic dikes. Micr. it contains phenocrysts of augite (euhedral). The mineral is zonal and shows ext. angle $c \wedge \gamma = 45°$. It is twinned according to (100). In addition there are crystals of magnetite. The paste is basaltic with plenty of ore powder mingled with feldspar rods and augite grains. There are also pseudomorphs consisting of calcite or aragonite (after olivine?) —. The rock is a typical lamprophyre, and the dike cuts the lava series at a place some km SW. of Agaete. (Cf. microphoto 2, plate III).

Dikes of salic composition are also present. Two samples illustrate the types (8, 32). The former was from the vicinity of Barranco Guayera at the sea shore, where it crosses the old basalts in a steep position. Micr. it shows phenocrysts of alk. feldspar in Karlsbad twins (sanidine), sodalite, greenish clinopyroxene and sphene, all lying in a fine-grained paste filled with rods of feldspar mingled with minute pyroxenes and iron ore powder. The pyroxene has ext. angle on (010) $c \wedge \gamma = 60°$ (aegirine augite). There are also stray crystals of brown hornblende rimmed with opacite. The rock is a sodalite phonolite. It contains alien olivine crystals partly altered.

The other sample (32) is of a somewhat different nature. Micr. it shows a perfect trachytoid texture with feldspar rods, nepheline grains and aegirine needles. The latter surround the nepheline like a corona. Phenocrysts are absent. The paste contains cavities filled with an aniso-tropic, colourless subst. with a low ind. of refr. (chalcedony).

In the same region (near Barranco Guayera) a curious erosion witness was found: a seawards inclined bank of a reddish lava resting unconformably on the old basalts (see fig. 19). A sample of the reddish lava (428) shows micr. an eutaxitic texture with angular fragments of alk. feldspar, lying in a streaky — somewhat devitrified paste stained with iron oxide pigment. No mafic minerals can be seen in the slide. The rock belongs obviously to the top beds in Tamadaba.

One gets the impression that this solitary outlier of the salic series, which has been displaced several hundred metres down the slopes, was broken off from its original connection with the top beds by great fault movements which occurred along the northwest coast.

When approaching the valley of Agaete, the sea cliffs have changed to more gentle slopes, and finally one reaches a kind of platform only

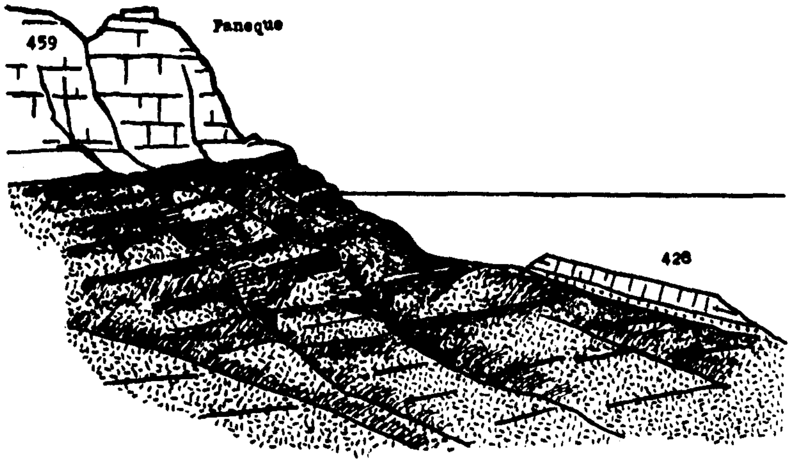


Fig. 19. Part of the northwest coast between Agaete and El Risco showing large exposures of the old basalts capped with the salic (trachytic rhyolitic) series. To the right a displaced chunk of the salic lavas.
Field sketch by H. H—n

some ten metres above the sea. At the northwest corner of this ground there rises a tower-like rock, called Roque Partido (75 m) an abrasion witness craved out in the basalts and reminding one of a higher stand of the ocean level in Miocene (?) time.

The Tamadaba summit region, the promontory of Faneque and the great N. escarpment at the Agaete valley

In its northern part the highland of Tamadaba is a kind of undulating plateau with a cupola-shaped summit — Cumbre de Tamadaba (1 438 m). This massif is rather well separated from its surroundings by several *barrancos* following as it seems old fracture lines.

This highland area is easily reached by using a forest road which leads from the mountain village Artenara (at the northern edge of Caldera de Tejeda) to the Government forest inn of Tamadaba lying c. 1 200 m above the sea in the northern part of the mountain massif.

The geological structure of this region is rather simple. We will find chiefly salic lavas and tuffs and ignimbrites, all lying in flat position. The series rests, as has been told before, on the old basalts, separated from them by a slight unconformity. The salic volcanics form a huge pile of several hundred m in their total thickness, well exposed in the steep cliffs on nearly all sides. The lavas and tuffs are chiefly of reddish or brownish, sometimes of grayish colours. Dikes intersecting the series are almost few, as far as I have seen.

We may start our examination of the geology in this highland at the culminating point — Cumbre de Tamadaba. The rock at the top is a flat lying lava bank of grayish colour (440). In hand specimen there are well visible tabular feldspars. Micr. one will find chiefly alk. feldspar, partly as larger grains, partly as small rods filling the groundmass. Nepheline also appears in small crystals. The texture is trachytoid. Of mafic components we will find small aegirine prisms, also powder of iron ore. The large feldspar grains are twinned according to the Karlsbad law. On examination the following data were obtained:

Alk. feldspar: $2V\alpha = 52.5° - 53°$. Opt. char. —. Ind. of refr. $<$ balsam (anorthoclase)

This lava bank is the topmost one of the whole series in Tamadaba. But it is obvious that the series did not terminate with this bank. Much has been destroyed by erosion. — One may suppose, however, the massif has not been covered neither by the platy phonolites nor by the R.N. agglomerate formation. The eminence of Tamadaba seems to be a rather ancient mountain block in the island structure.

A chemical analysis of this culminating lava bank has been carried out with the results given below:

Analysis no. 11

Sample no. 440 (Hausen 1953) of an alk. trachyte taken of a flat lying lava bank in Cumbre de Tamadaba, 1 438 m above the sea level.

		Mol. prop.	Norm:		
SiO_2	61.51%	10201	Q	0.6	
TiO_2	0.68 »	85	or	32.3	91.0
Al_2O_3	18.10 »	1771	ab	55.8	
Fe_2O_3	3.63 »	227	an	2.9	
FeO	0.43 »	60	C	0.2	
MnO	0.44 »	62	Σ Sal:		91.8
MgO	0.13 »	32			

15

CaO	0.62 »	110
Na_2O	6.60 »	1064
K_2O	5.47 »	581
P_2O_5	0.03 »	2
H_2O+	1.61 »	894
H_2O-	1.02 »	
Sum:	100.27%	

en	0.3
mt	0.9
hm	3.0
il	1.3
ap	0.1
Σ Fem:	5.6
H_2O	2.6
Sum:	100.0

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.55 (+23.5°C)

NIGGLI values:
si = 247, ti = 2.2, p = 0.1, h+ = 21.6, al = 43, fm = 15, c = 2½, alk = 39½, k = 0.35, mg = 0.05, qz = −11, al−fm′ = +28, al−alk = +3½.

C. I. P. W. Classif. — I. 5. 1. 4.
Nordmarkose
Magma type: nordmarkitic/bostonitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 61:6:33
MgO:FeO = 100:0

This lava consequently represents the top sheet of the whole pile of effusions in this sector (i.e. of what has escaped denudation). Type 440 is silica-saturated and is to be classified as a trachyte, not a rhyolite. It perhaps forms a transition type to the nepheline — bearing phonolites next in age. — According to the proposals by A. RITTMANN (1952) concerning the nomenclature of volcanic rocks, and applying key no. 3 of his procedure by calculation from the analytic data, the rock would be a *soda trachyte* (Al = 16.29, FM = 4.85, Alk = 15, 37, k = 0.36, an = 0.03, ca" — 0.07).

If we go down the upper slopes in a northwesterly direction, we finally arrive at the promontory Risco Faneque (1 085 m). This cape plunges directly into the sea at Cruz del Dionisio.

All the way down to this spectacular cape only salic lavas and tuffs are to be seem in a concordant succession. No samples were kept from this stretch.

Risco Faneque is divided by notches into three summits which can be seen from afar. These summits are plateau-shaped and sculptured in the flat-lying lava beds. One sample (459) of a bank in the middle summit consists of a reddish type of a rhyolitic aspect. Micr. it is rather decomposed and contains phenocrysts of alk. feldspar of a rectangular shape and also crystals of brown hornblende, clinopyroxene and sphene, all lying in a paste filled with small feldspar laths with a trachytoid arrangement. Magnetite grains are associated with the pyroxene crystals. The lava may be classified as a trachyphonolite (or trachyte). It lies not very far above the basal complex of basalt lavas and tuffs which constitute the whole lower part of the great precipices here. These basalts are separated from the overlying salic series by a plane of unconformity (as has already been pointed out in an earlier chapter).

The westerly notch which separates the outermost summit of Faneque from the ridge (see fig. 20) shows a multitude of steeply dipping dislocation planes, forming a zone with a northwesterly trend. The notch has been excavated in this shattered zone, thanks to its lesser resistance to erosion. That zone no doubt belongs to the great lines of displacements which have caused the steepness of the present northwest coast. A missing part lies under the sea.

If we follow the slopes of Cumbre de Tamadaba to the east, south, southwest or to the north, we will find that the formation always lies in a flat position, forming broad 'staircases'. The banks are either of pale-coloured lavas or tuffs, all of the salic series, probably mostly of a trachytic or rhyotrachytic composition to judge from the samples col-

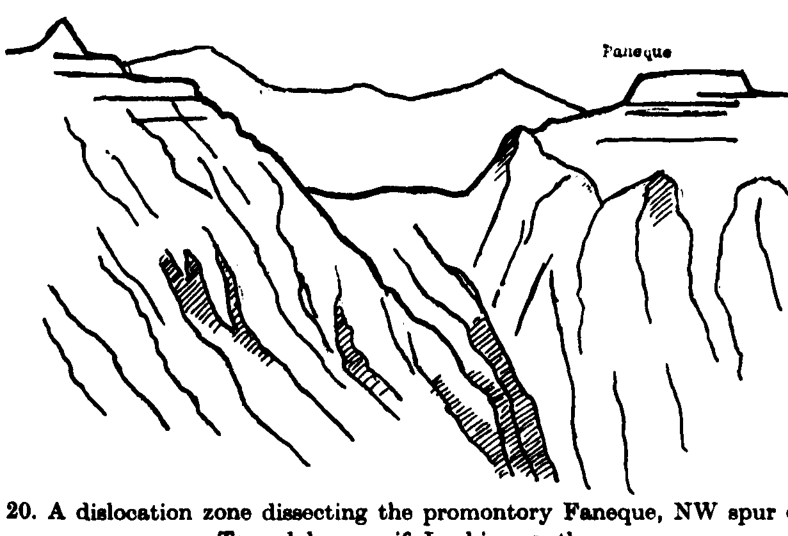


Fig. 20. A dislocation zone dissecting the promontory Faneque, NW spur of the Tamadaba massif. Looking south.

Field sketch by H. H—n

lected in this upper region. — No. 436 was taken from the east side above the reservoir of Presa de los Pérez half-way below *la Cumbre.* It is micr. a typical trachyte with broad laths of alk. feldspar lying in a trachytoid paste with slender feldspar laths. No mafic components are to be seen in the slide, only a pigment. The vesicles in the paste are filled with an isotropic, colourless substance, probably analcime. The optics of the feldspar phenocrysts are:

$2V\alpha$=44.5°—46.5°, opt. char. —, ind. of refr. ~ 1.54, Karlsbad twins (001). Contains 15% An(?). High temp. form (?)

No. 439. is of a bank on the southern upper slope of *La Cumbre.* It is micr. a porphyry, or rather a vitrophyre with a streaky paste. There are phenocrysts of alk. feldspar and tiny rods of feldspar in the paste, also aegirine microlites. The texture gives the impression of an ignimbrite.

At Casa Forestal de Tamadaba (1 260 m) there is a long succession of outcrops of lava and tuff banks. The most remarkable type is a dark-brown lava sprinkled with white spots of feldspar, called by the geologists »*roca de salchichón*» (i.e. »sausage rock»). This (457) shows micr. a beautiful porphyric texture with phenocrysts of alk. feldspar (turbid) and a brown mica in flakes lying in a vitreous, pigmented paste. In this there are also stray magnetite grains. The optics of the feldspar are:

$2V\alpha$=41°—42°. Opt. char. —. Ind. of refr. <balsam (anorthoclase)

Some of the crystals are corroded. The lava may be a rhyolitic vitrophyre.

No. 450, which is also from the vicinity of Casa Forestal de Tamadaba, is micr. of a sphaerulitic texture. The lithophyses consist of glass in pigmented zones, sometimes empty in the centre. These lithophyses lie rather densely packed together in a glassy matrix, iron-stained. There are also fragments of feldspar in the paste. The rock could be designated as a vitreous lithic tuff or ignimbrite.

Proceeding in a northerly direction from Casa Forestal, one soon reaches the edge of the table mountain of Tamadaba facing the Agaete valley. This edge — with height above the valley bottom of 800—900 m consists of a smoke-gray, fine grained rock (448), micr. of an apparently streaky texture. There are no primary mineral components to be determined in the slide, only glassy bands of various shades alternating with opaque streaks. Besides there are lens-shaped pores occupied by tiny rods of sanidine (?) and an opaque substance — flattened lithophyses, I suppose. The texture suggests a 'welded tuff' or an ignimbrite. Empty pores in the rock have been filled in parts with chalcedony. The composition may be that of a rhyolite, although grains of quartz have not been seen.

At the estate belonging to Sr SANSON there is a wide terrace just inside the mountain edge at the Agaete valley. It is Los Siete Pinos, 1 100 m above the sea. A path leads from the forest inn down the escarpment to the village San Pedro in the Agaete valley. I followed this path down to the middle of the precipices (altitude 600 m).

At the point where the path leaves the edge of the platform there is a hill consisting of a brittle, reddish lava bank (444). Micr. this rock is a tuff of a brecciated nature containing clear fragments of alk. feldspar and also of alien lava rocks.

Going down the precipice from the edge, we first have a thick lava bank with columnar jointings, a gray, fine-grained rock (458). Micr. this contains phenocrysts of orthoclase (?) (clear), brown hornblende and magnetite. They lie in a dark, pigmented, isotropic paste, apparently of a glass substance with a pilotaxitic texture. — A lower bank along the same path consists of a trachyte (449), somewhat altered. Micr. there are turbid feldspar phenocrysts (sparsely) in a trachytoid paste, where the feldspar rods are mingled with iron ore powder. The lava is devoid of mafic constituents. This sample represents the bank no. 3 in a descending order. It was not possible this time to examine all the banks appearing lower down the precipice. On a later occasion I made a stroll along the lower parts of the escarpment, where in a ledge the basalts are met with. We will here give some data referring to this route.

The excursion started at a point, where the highroad from Agaete to El Risco climbs the left hand slopes of the Agaete valley (not far from the sea shore). At first the path goes over a weathered ground consisting of inward inclined basalt lavas. They are all strongly lime-impregnated, the lime having filled all the cracks near the surface.

One sample of a basalt (465) is micr. a typical olivine basalt with crystals of olivine and augite in the I gen. The olivines, which surpass the augites in relative amount and also in the size of the phenocrysts, is iddingsite-rimmed. The augite is in the slide colourless. The groundmass is basaltic, and vesicles are filled with calcite.

The basalt series is considered by J. BOURCART (1937) as »*facies basaltique des plateaux*», it is a formation which belongs to the post-Miocene lavas. They may be separated from the old coast-basalts by a zone of faults, which runs along the northern escarpment of the Tamadaba massif. I myself did not follow this tectonic line more closely, but already a study of the samples of basalts taken from both sides of the line of separation is sufficient to prove the difference. I have followed the idea expressed by BOURCART in my map appended to this paper.

The path that runs along the escarpment in easterly direction soon reaches higher levels. At 450 m there is an interesting superposition of a younger basalt series upon an older one of the coast. The younger beds form a northward-inclined thick plate, resting with great unconformity on its basement rocks. A sample of a lava lying between tuff layers in the younger complex (473) is an olivine basalt with corroded olivine crystals rimmed with iddingsite lying in a paste of augite prisms and magnetite grains and microlites of feldspar. The texture of the paste is extremely fine-grained. Augite seems to dominate here. The lava is picritic in composition.

At the foot of the great precipices, as the lowest bed directly upon the olivine basalt series (the older inclined one), lies a dark coloured lava (466) which is amygdaloid and porphyritic. Micr. there are plenty of large laths of plagioclase in random orientations and a paste of a basaltic texture with plenty of small laths of feldspar. The interstices between the small laths are filled with an opaque substance. Mafic minerals are not visible. Amygdules are filled with zonal calcite. Comp. of the plagioclase is acc. to max. angle of ext. in the zone ⊥ (010)=An/10 (appr.). This lava may be classified as an andesite, considerably differing from the underlying basalts, and it obviously represents some kind of transitional effusion to the great salic lava outpourings (higher up in the profile).

The overlying salic lavas were not investigated from this level, owing to the inaccessibility of the precipices.

Further to the east, one can follow a mountain ledge accompanying the great escarpment along the Agaete valley. This ledge consists of the old basalts tilted inward i.e. to the south.

This ledge was followed to the proximity of Berrazales (hotel Guayarmina), and it seems to be confined at the salic lavas in the precipices by a zone of faults, which has already been shown in the geological map of the island by J. BOURCART (1937). It seems that the salic series has subsided in relation to the old basalts.

Last year (1960) T. BRAVO, in company with J. NARANJO SUÁREZ of the Canarian Museum have studied the tectonics in the vicinity of Berrazales (opposite the hotel), this visit being made at my request. A very instructive profile and a photo of the fault zone in question were then sent to me (together with some rock samples).

The demarcation zone, running along the foot of the high escarpment from Agaete to Berrazales, cannot be followed further to the east owing to a sudden change in the geological conditions, as will be explained in more detail in the following.

Turning again to the high levels of the Tamadaba mountains, we will find a great succession of salic lavas, tuffs and ignimbrites in the east side of the mountain too, at Angostura de Berrazales and from it also southwards to the head of the Agaete valley, here called Barranco de la Hoya. These volcanics reach to Degollada de Acusa. On the other hand, there is no continuation of the same volcanic beds in the right side of Barr. de La Hoya, but instead we will find here a pile of sandstones and conglomerates (from Berrazales southwards).

My headquarters in this region, the Hotel Guayarmina (Berrazales), lies 400 m above sea level in a *barranquillo* which joins the Agaete valley just below the narrow passage (*angostura*) of the river. The bottom of the *barranquillo* is occupied by a sub-recent, blocky basalt lava stream which has spilled down from the highland in the east. Rough cliffs surround the hotel on three sides, exposing a great succession of volcanics. These mountainsides are too steep to climb, except in the south, where a path leads up with many windings.

A strange topographical feature is that of Angostura de Berrazales close to the west of the hotel, one of the most spectacular gorges in the island. Later on we will try to explain its formation, i.e. the cutting down of a bar which formerly existed here.

The path leading from the Hotel Guayarmina southwards up the course of the Agaete valley (here called Barranco de La Hoya), at first climbs a cliff which forms the right spur of the *angostura* nearby. Several lava banks are exposed in this profile; a dike with a steep inclination is also seen. The lowermost bank is a grayish-green porphyry (17) with micr. clear phenocrysts of alk. feldspar (with Karlsbad twins) lying in a paste of feldspar laths, aegirine prisms and scattered crystals of nepheline. The latter are enclosed in aggregates of the aegirine. The rock is somewhat altered, a nepheline phonolite (or trachyphonolite).

Upon this lava bank follows another of a brownish colour (486).

Like the former, it has micr. a trachytoid texture with plenty of feldspar microlites and a brownish pigment. There are also aegirine needles in the paste, and laths of sanidine (?), likewise grains of a completely altered mineral (hornblende?). We will find elongated lenses in the paste (pores) filled with sec. subst. consisting of sanidine laths in an opaque mesostasis (lithophyses). These pores are arranged conformably with the orientation of the texture. The lava may be an ignimbrite of a very low colour index.

Higher up in the sequence of volcanics there follows a greenish tuff, then a lava bank of a grayish colour (487) at a level of c. 500 m. Micr. it is a trachyte without any visible mafic minerals, only opaque needles (altered aegirine?) in the feldspar-rich trachytoid paste. The dark needles are clustered into aggregates. Feldspar fragments are disseminated in the paste which may partly be of glassy nature. The rock suggests properties of an ignimbrite.

All these salic lavas and tuffs and ignimbrites may correspond to those which compose the neighbouring great profiles in the Tamadaba mountain block.

Some km to the south of Berrazales (Hotel Guayarmina), on the right side of B a r r a n c o d e l a H o y a, these volcanics are capped by a pile of sandstone and conglomerate layers attaining a total thickness of c. 150 m. This sedimentary series -- a noteworthy thing in this volcanic island — is capped by banks of basalt lavas (26) showing a composition of tephritic nature with pyroxene, plagioclase and magnetite, all as phenocrysts but also composing the groundmass, in which isotropic patches occur, maybe analcime.

In a northerly direction from Berrazales are steep mountain sides exposing salic lavas and tuffs like those in the south just described; one sample from here (481) is a kind of trachyte lava.

From the descriptions above, we have found that the upper course of the Agaete valley — Barranco de La Hoya — exposes along its right side a great pile of sedimentary strata comprising both sandstones and conglomerates. These strata may represent the R.N. agglomerate formation i n a r e w o r k e d c o n d i t i o n: the chaotic material of the agglomerate has been assorted by running water. In other words, these sediments, the largest in the island, apparently represent some kind of delta or basin deposits. These were laid down in a closed basin which was later on opened up by Angostura de Berrazales.

The disclosing of this mountain basin which may be of a tectonic origin, has caused vigorous erosion in the sediments deposited here, and these would have been destroyed completely, if there did not exist a protecting cover of basalt lavas of a tephritic composition (26), the edges of which are still to be seen in the upper part of the great profiles along Barranco de la Hoya. These tephrites are met in many parts of the island, where the R.N. agglomerate formation has been conserved from erosion. — In later times the tephrite lavas in this *barranco*, or rather in its right-hand highland ground, have been overridden by olivine-bearing lavas of the post-Miocene series and later on by recent lavas of the same kind (including cinder cones).

The fact that the R.N. agglomerate formation in the region of Berrazales has been subjected to reassortment and redeposition by running water (in a basin) may be explained by the simple fact that this region lies at a considerable distance from the vents which produced the material of the great Peléean eruptions. — The author has followed the R.N. formation uphill all the way to the region of Caldera de Tejeda, and he has seen how the sediments gradually change into the chaotic mixture of the typical R.N. agglomerate formation.

On the other hand, we may conclude that the lofty massif of Tamadaba already existed in the period when the Peléean outbursts occurred in the center of the island. The east flank of the massif was at that time separated from the central highland by the tectonic graben. This was then gradually filled up with the reassorted agglomerate masses.

If we now s u m m a r i z e t h e s t r a t i g r a p h y displayed in the great escarpment of Tamadaba facing the Agaete valley, we will find the following succession:

Alt. above sealevel	Number of sample	Rock type	Locality
1 438 m	440	Nepheline trachyphonolite	Cumbre de Tamadaba
1 400 »	439	Trachyte-tuffite	S. slope of *La Cumbre*
1 200 »	434	Vitreous trachyte	Degollada de Tamadaba
1 150 »	436	Trachyte	E. slope of Tamadaba
1 100 »	450	Vitrophyre	Vicinity of Casa Forestal de Tamadaba
	453	Vitrophyre	
	456	Vitrophyre	
	457	Vitrophyre	
1 100 »	459	Trachyte	Faneque, middle hill
1 000 »	448	Eutaxite	Border of the great escarpment facing the Agaete valley
1 000 »	444	Trachytic tuff	Border of the escarpment above San Pedro.

Alt. Above sea level	Number of sample	Rock type	Locality
1 000 m	458	Trachyte	The same locality
900 »	449	Trachyte	Above San Pedro
900 »	445	Hyalopilitic trachyte	The northwestern corner of the great escarpment
800 »	472	Trachyte	Opposite Berrazales
600 »	38	Tuff	» »
500 »	37	Agglomerate	» »
500 »	466	Porphyrite amygdaloid	Base of the salic series above the unconformity
Unconformity			Opposite Agaete
400 »	465	Olivine basalt series	Lower slope, left side of the Agaete valley

This sequence is by no means a complete one, as may be understood (when examining the heights of the strata from where the samples have been taken). Nevertheless, there are some vell recognizable characteristics of these lavas of the salic series which indicate their slight variations.

A sequence of salic lavas, tuffs and ignimbrites which constitutes the Tamadaba massif, a series of c. 1 000 m, which has no visible break in the shape of unconformities or erosion hiatus, is a rather remarkable feature in this restricted island area. Its extension in horizontal directions is no less remarkable: the Tamadaba formation comprises c. 30 sq. km. The limits on all sides, caused by faults and erosion, clearly point to a former, much wider expansion. It seems that the El Viso—El Horno complex is to be interpreted as forming such a continuation (now separated by the Tejeda gorge and erosion embayments, see the geological map).

Nevertheless, however imposing these accumulations of salic volcanics may be, they represent only a fraction of the total bulk of the island structure of similar salic products. Later displacements and their escape from the olivine basalt-lava inundations in post-Miocene times have put the Tamadaba series in a more visible position than in the remaining parts of the island structure.

An important question is: from where have all these lavas and pyroclastics been emitted? (This problem will be discussed further in Part II, chapter on Systematic Geology). It may here be sufficient to point out that a common source may be sought for in a southeasterly direction, i.e. in an area now occupied by Caldera de Tejeda. There was certainly not one single vent producing these enormous masses of viscous material, but a set of fissures, as is commonly assumed in similar cases elsewhere in the world.

*

The tectonic conditions all along the Agaete valley should deserve a closer investigation. A smaller basaltic cinder cone standing at the left border of the valley seems to be connected with the faults of the great escarpment. From this volcano a blocky lava stream had found its way down to the coast at Puerto de las Nieves. The eruptions may belong to the late— Quaternary. The lava is a typical picritic olivine basalt (4) (Cf. fig. 2, plate IX).

8.

Northwestern Sector

We have now to scrutinize geological conditions in the northwestern corner of the island confined by the Agaete valley in the south and the border of the highland in the east, where Montaña del Viento forms a conspicuous land-mark. The ground in the relatively low area in this way confined, has some eminences, however, and a rather rocky coast. The extreme cape in northwest is Punta de Sardina.

The right side of the Agaete valley

If we begin in the south, we have a long and relatively low escarpment at the Agaete valley. This edge is much lower than the opposite side of the valley with the Tamadaba escarpment. Hence the cross-profile of the valley is here (i.e. in its middle course) highly asymmetrical. This circumstance alone speaks in favour of a tectonic origin of the valley in question.

The right hand *ladera* is composed of a series of basaltic lavas and tuffs without any unconformities. There are some samples of the lavas (474, 475, 476). The first of these is of a low lying bank and is an olivine basalt, rather fresh-looking. Micr. one will find well developed phenocrysts of olivine and augite in a groundmass of augite and ore and very little of plagioclase. The augite in the I gen. is slightly zonal. The groundmass augite has the shape of elongated prisms densely packed together. — The rock is a picrite with colour index > 80. No. 475 is amygdaloidal, but of similar (picritic) composition. The amygdules consist of aragonite in radical bundles and of zeolite. — No. 476 is of a lava bank still higher up in the cliff, and the bank displays columnar jointing. Micr. the rock shows corroded phenocrysts of olivine rimmed with iddingsite. There are also smaller phenocrysts of augite and ore and very subordinately of plagioclase. Patches in the paste are isotropic (analcime?).

All these lavas including the interlayered tuffs are apparently of the post-Miocene series, and they have all a picrite-basaltic composition.

After reaching the upper edge of this escarpment, one enters a relatively flat ground with a gentle grade to the sea in the west. It forms a kind of piedmont to a high *cuesta* in the east with Montaña Aceville and other eminences. The piedmont plain is furrowed by *barrancos*. — The higher ground in the east seems to consist of salic lavas, but the uppermost parts of them may be younger basalts. I did not have occasion to climb the slope, which is rather asperous, but at least in the lower parts there are ignimbrites (?) of the Tamadaba type judging from the composition of rock lumps dragged from a water gallery opened up here. One sample (481) is micr. a streaky mass of a glassy nature (isotropic) with stripes of ore and scattered fragments of alk. feldspar; this type may be classified as an ignimbrite. No doubt it belongs to the types found in the Tamadaba series behind the valley of Agaete. No mafic components are seen in the slide. The lava rock is of a complex which builds the basalt covered highland nearby in the east.

The lapilli-covered ground between Agaete and Gáldar

From the edge of the Agaete valley we take a northerly course and are heading for San Isidro and Gáldar and traverse a rather desolate ground consisting of pyroclastic sediments. These seem to be of greater thickness on the side of Villa de Agaete, and they are here dissected by *barranquillos* with a westerly orientation, ending at the sea. Nearer to San Isidro, opposite Montaña Almagro, the cover becomes thinner. In some small ravines one sees the bedrock, consisting of basalt. Further north, the ground slopes to the north in the direction of the Gáldar volcano, and the pyroclastic cover grows more potent on that side.

From where were these pyroclastic masses spread out over the plain? It seems to the author that there were two vents: one in a smaller cone just to the south of Montaña Almagro, and another in the Gáldar volcano which has ejected all the material deposited between Gáldar and Montaña Almagro.

Montaña Almagro (500 m)

This rather solitary hill (cf. fig. 21) is not a volcanic cone but an erosion hill consisting of salic lavas. I ascended to the summit of the mountain. A sample of the chief rock (502) is very fine-grained, with small

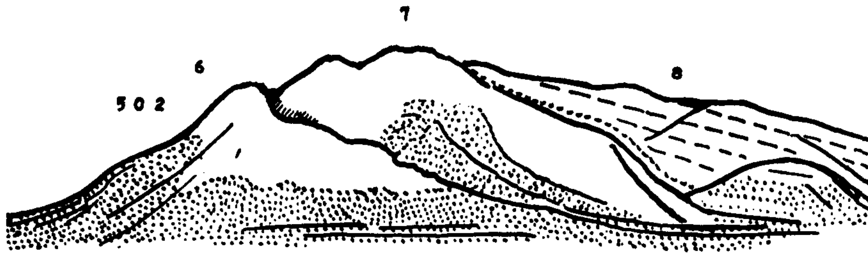


Fig. 21. Montaña Almagro seen from the N. After a photo by J. NARANJO SUÁREZ. Numbers refer to samples described in the text.

phenocrysts of a clinopyroxene (euhedral) and sparse laths of an alk. feldspar. The paste is filled with tiny rods of feldspar and a brownish-green aegirine; also nepheline grains occur, the latter embedded in aggregates of aegirine. Texture is not trachytoid. The lava may be a phonolite.

Recently (1960) I have received additional samples (6. 7. 8) from the same mountain sent by T. BRAVO. One of these (6) was taken from the south slope. It is more coarse grained, also nepheline bearing, the latter surrounded by a corona of aegirine microlites. The colour index is somewhat higher than in the former case.

No. 7 is a sample from the summit of the mountain (see fig. 21 sketched from a photo). Micr. this type is also a feldspar-rich aegirine-bearing one with small euhedral crystals of nepheline and also grains of a sodalite mineral. They lie embedded in aegirine aggregates. The texture is trachytoid.

No. 8 is from the northwestern slope of the mountain and is of a somewhat coarser grain but similar to the other varieties. — The general impression is that Montaña Almagro is the remaining basal part of an ancient neck of the salic series, perhaps somewhat deformed by later fault movements. During the activity of the Gáldar volcano the mountain was entirely covered by lapillis and slags and ashes, but rain wash has in later times cleaned the slopes, except for some remnants at the foot of the mountain.

The slopes of Montaña del Viento

The *cuesta* rising to the east of the plain of San Isidro has been studied by the author in some places, and samples have been collected.

An ascent was made at the farm of La Costa, half way between Agaete and Guía. One first climbs a blocky lava stream no doubt belonging to the volcano in the upland, Montaña del Viento. Higher up the slope are barren rock surfaces of a pale-coloured trachytic rock rising like a *contrafuerte* on the slope. A sample of the rock (506) shows micr. a beautiful trachytoid texture with clear phenocrysts of alk. feldspar (twins to the Karlsbad law, opt. char. — , ind. of refr. < 1.54). The paste consists of feldspar laths, aegirine needles and grains of nepheline. One is inclined to relate this rock to that exposed in near by Montaña Almagro. — It has the shape of a standing neck isolated from its surroundings. The latter consist of dark platy phonolites forming the escarpment here, and the same rock continues to the north to Montaña de Guía.

The upper edge of the phonolite escarpment lies 700 m above sealevel. This upper surface consists not of phonolites but of basalt lavas and pyroclastics. The surface-layer is a red lateritic soil and it forms a plain called Llano de la Casa.

The basalt lavas all belong to the nearby volcano Montaña del Viento (825 m), which rises above the plain. A sample of this lava (505) is a typical olivine basalt of the more picritic kind, showing corroded olivine crystals lying in a paste which consists of augite, plagioclase and ore. Augite also appears in somewhat larger grains. The olivines are surrounded by a rim of iddingsite. The share of plagioclase is insignificant (c. 20%). Magnetite is richly present in the shape of a fine powder and as stray larger grains associated with the olivine. The very deep corrosion embayments in the olivine are noticeable.

Copious masses of lavas have been sent down from the volcano of Montaña del Viento into the surroundings; they have partly spilled down to the lowland in the west. — This volcano is decidedly older than the Gáldar volcano in the vicinity. It may date from the late-Tertiary period like the other cinder cones more to the east which will be treated later on. The great masses of pyroclastic material which were spread over the surroundings were transformed in later times into red lateritic soil, i.e. what has remained in place, not carried away by erosion.

Montaña de Guía

Farther northeast is the rather isolated ridge called Montaña de Guía, part of the escarpment carved out by two *barrancos*. It stretches north-south and has a max. elevation of 500 m. It consists entirely of dark-coloured, platy phonolites in thick banks intercalated with tuff layers. There are at least three such lava banks, all showing beautiful columnar jointing. These columns of lavas are the best developed visible in the phonolite formation, although the banks of basalt lavas may also display similar strong partings (for instance the lavas in the walls of Barranco de la Virgen).

There are some samples of phonolites in Montaña de Guía of which no. 512 shows micr. a typical trachytoid texture with feldspar laths and slender aegirine prisms. There are also phenocrysts of alk. feldspar with Karlsbad twins. One will find in the paste disseminated grains of nepheline surrounded by a corona of aegirine. It seems that the ridge in question has been limited by faults along which erosion has worked, so that the ridge has been isolated from its surroundings (consisting of phonolites), in the east covered with the R.N. agglomerate. Perhaps these faults are parts of a set of fractures, which have created the *cuesta* described above.

The volcano of Montaña de Gáldar (425 m)

Not far from the north coast and a short distance to the east of Punta de Sardina, the northwestern cape of the island, there rises in a very isolated position, the historic Montaña de Gáldar, a pre-Recent cinder cone. At its southwestern foot lies V i l l a d e G á l d a r, close to an ancient stronghold of the aborigines, the Guanches. Seen at a distance from the east, the cone has a certain similarity to Pico de Teide in Tenerife. — From the summit of the cone there is a magnificent panorama in all directions, especially to the south over the fertile fields extending to San Isidro and to the distant contour of the Tamadaba mountains. The author ascended to the summit, which has a truncated shape. No crater is to be seen here. The flanks consist of lapilli, well stratified at an angle of 33°. Several gravel pits have been dug in the mantle. The outbursts of this volcano have evidently been of a 'Strombolian' nature: both lavas and pyrolastics have been produced. — J. BOURCART (1937) found two lava tongues reaching from the N foot of the cone to the coast. In a southerly direction masses of lapillis have been strewn over the fields, especially to the southwest, where they attain a thickness of many metres. Lime incrustations have changed the masses into a relatively hard rock which is quarried. — E. JÉRÉMINE (l.c.) has examined the lavas found by BOURCART and identified them as a 'basanitic ankaramite'. Micr. this rock shows no traces of a feldspar. The I gen. of components is olivine, and the paste is filled with augite prisms, magnetite and also some nepheline. A chemical analysis was also published of the basanite rock, the NIGGLI values of which are found in the list page 375, X (Part II). The lavas of Montaña de Gáldar belong to the group of ultrabasic lavas which characterise the latest volcanic phase in the island, — epigones to the olivine basalt lava outpourings of the post-Miocene age.

The lapilli-covered ground to the south of the volcano called Llano de las Quintanas is the widest plain in this northern part of the island, also one of the most fertile, since the finer pyroclastics have undergone a weathering process which has converted them into soil. No wonder this region is one of the earlier settlement areas in the island, provided as it was with many springs on the bordering mountain slopes in the east.

The Gáldar volcano is the most northerly of all the young volcanoes in the island, if we disregard those confined to the Isleta-appendix in the extreme northeast.

The coast to the north of Villa de Guía

This part of the coast was never visited by the author. Data and samples have been forwarded to him by T. BRAVO later on, together with a geological profile and an instructive photo. The conditions are briefly described here (cf. fig. 22).

East of Montaña de Gáldar, the coast is accompanied by a terrace of c. 100—150 m elevation ending in a cliff at the sea. At El Marmol this cliff is almost perpendicular, getting less steep towards the east. — In short it is a *meseta* extending between the shore and the volcano of Guía (375 m). The *meseta* consists superficially of basalts, and these seem to have been sent to the coast from some vent in the volcano mentioned above. BRAVO has found that the superficial basalts cover a rather thick series of (50 m) of gravels and sand. In the terrace Llanos de la Perra they rest upon older basalt lava sheets exposed at the shore. Farther east at El Marmol (Punta del Perro), there is a thick deposit of volcanic agglomerate including angular stones (not the R.N. agglomerate!) between two basalt lava sheets. There is a distance of c. 600 m between the two points of observation.

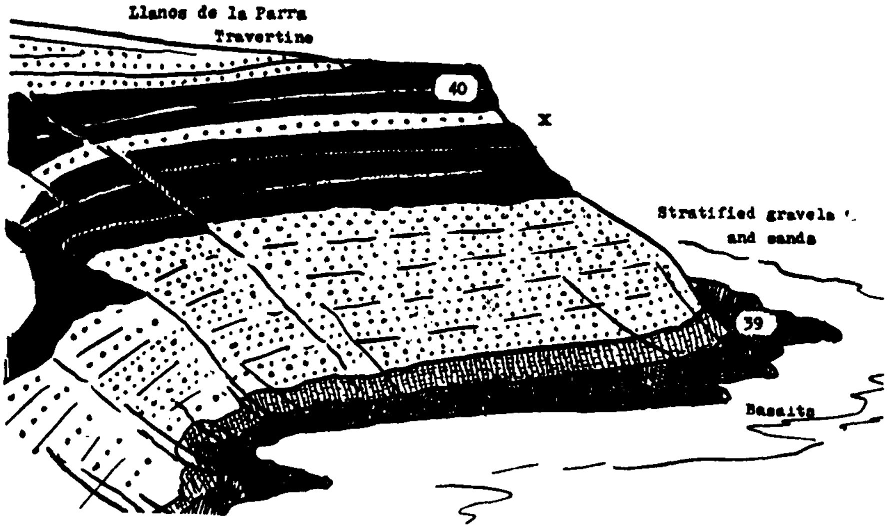


Fig. 22. Geologic profile from the north coast, NE of Guía, west of El Marmol, showing basalt lavas (39, 40) of different ages with interstratified accumulations of fine- and coarse-grained deltaic sediments. Interpretation and samples communicated by T. BRAVO. Drawn from a photogr. by J. NARANJO SUÁREZ.

The interbasaltic detrital deposits may be considered delta sediments probably from late-Tertiary times, whereas the capping basalt lavas may belong to the Quaternary period (like the Guía volcano).

There are two basalt samples (39, 40) of the same profile (see fig. 22). The former is from the water's edge and is a typical limburgite. Micr. it contains plenty of slender pyroxene prisms in random orientations; in addition, there are euhedral olivine crystals with a rim of iddingsite. The paste seems to consist of a brownish-gray glass filled with isometric grains of magnetite and flakes of ilmenite, the latter are often skeletal aggregates. Moreover, the paste encloses irregular cavities filled with beautifully zoned fibrous aragonite. The lava should be called an amygdaloidal basalt (limburgite) a type devoid of feldspar. The lava may be of late Tertiary age.

The other sample (40) is of an upper lava sheet capping the stratified gravels and sands. There are in reality *two* sheets of lava separated from each other by a layer of a yellowish clay (x) containing nests of *Antophora* and branches of wood. The clay is overlaid by a thin layer of reddish lapilli, and the latter in its turn by a lime layer in a marmorized state. This recrystallization is due to the overlying basalt lava. This lava is designated by BRAVO (in his profile) as of sub-Recent age. I think it is older.

The basalt (40) shows micr. a picritic olivine basalt with well-developed olivine crystals lying in a fine-grained paste consisting of augite and ore grains and (altered) plagioclase microlites. There are no augite crystals of the first generation, only scattered magnetite grains. The rock is very rich in iron ore. The olivines are surrounded by a rim of iddingsite.

As we have seen, there are only basalt lavas (older and younger) to be seen in these profiles on the coast N of Guía. Going further east along the coast and passing the precipices E of El Marmol, there appears E of Punta Ancha a basement to the basalts: the phonolite formation. This forms the shore (the low coastal land) from San Felipe onwards to Bañaderos. Consequently, the phonolite formation has been depressed under the ocean level in the stretch of coast at Gáldar and Guía. A dislocation line seems to run from the northern side of Montaña de Almagro to the north end of Montaña de Guía. Perhaps the outbursts of the Gáldar and Guía volcanoes are connected in some way with these displacements?

9.

Northern Declivities and the North Coast

(Guía—Tenoya)

The upland around Montaña Alta (a late-Tertiary volcano)

This part of the northern declivities is in general a rather smooth ground , although it is to some degree furrowed by *barrancos* with a north to northeast trend. In the midst of the area rises the large volcano of Montaña Alta, lying on a straight line between Montaña del Viento in WNE and Montaña Doramas (a volcano) in ESE. To the northwest of Mont. Alta we will find a smaller cone, Montaña Vargara. Going up the slopes in a southerly direction, we arrive at the cone La Montañeta and some other cinder cones, but these may be counted as the volcanic assembly of the central highland.

Most of these northern declivities are covered with basalt lavas undoubtedly belonging to the post-Miocene series. They are, however, mostly hidden beneath a surface layer of reddish (lateritic) soil — decomposed volcanic ashes. The latter have apparently been ejected chiefly from Montaña Alta. — Under the basalts and their pyroclastics we may find a basement consisting of the R.N. agglomerate formation, and under this cover the phonolites. Exposures are rare, it is true, except along the deeper *barrancos*, especially along Barranco de los Propios, Moya and los Tilos, and more to the east along Barranco de la Virgen.

Montaña Alta (985 m), climbed by the author, is an imposing extinct volcano, covered with reddish soil and furrowed by erosion. It has a wide crater open to the north. Lava streams which were sent from its orifice cannot immediately be recognized owing to the superficial earth cover. It seems (judging from the topographical map) as if most of the lavas from here flowed north and northeast.

A sample of the lava belonging to this volcano was taken in its immediate vicinity (510). Micr. it shows great similarity to the type from Mont. del Viento (505). There are large phenocrysts of olivine with a narrow border of iddingsite and also crystals of augite. The matrix consists of plagioclase laths arranged in a basaltic texture and mingled with pyroxene and ore grains. The comp. of the rock approaches that of a picritic basalt. The optics of the chief minerals are:

Olivine: $2V\alpha = 91°$ (average of 6 meas.) Fa $= 18 \pm 4\%$
Pyroxene: $2V\gamma = 54°$, $c \wedge \gamma = 46°$ (augite)

The volcano seems to be of pre-Quaternary age, most probably from the Pliocene period like its neighbours in the west and in the east.

Barranco de Moya with Barr. de los Propios and adjacent mountain slopes

When following the highroad from Guía to Moya, one has to traverse a rather monotonous landscape: a highland ground sloping to the north coast. But when approaching Moya a deep canyon suddenly appears, Barranco de Moya, on the right side of which Villa de Moya is situated at an altitude of c. 475 m.

Barranco de Moya is not very long — about 3.5 km, but instead its depth reaches (opposite Moya) to 100 m, and the walls are here almost vertical. Following the canyon up the course one soon meets a sudden end, where two head *barrancos* join one another. The right hand *barranco* is called Barr. de los Propios. In the stretch from Moya to the coast the *barranco* gets shallower, but just before the mouth there is a narrow passage across a coastal terrace.

We may now look at the geological conditions along the route from Guía to Moya.

Not far to the east of Guía rises a broad cinder cone, El Volcán de Guía (375 m) (or San Juan y Gallego), covered with reddish (weathered) loose gravels (lapillis). It is a volcano of somewhat advanced age, of the Quaternary period (?). When going up the slopes to the south (along the road), one will find the R.N. agglomerate exposed, except where it is covered with reddish soil. The latter seems to cover wide stretches further up the slopes to the south of the road to Guía. — Lower down towards the coast, basalts are met with, exposed in the deep embayment at Cuesta de Silva (the mouth of Barr. Calabozo).

The highroad running southeast of Los Paredones (on levels somewhat above 500 m) goes along smooth ground, consisting chiefly of phonolites capped with red soils, sometimes of a considerable thickness. Just before Barr. de Moya there is a sharply modeled edge of the phonolites, facing north. Behind it is the highland of Hoya de la Cruz, a flat undulating landscape covered with red soil and headed in the south by the volcano of Montaña Alta.

The head region of Barranco de Moya was not studied in detail by the author. There is red soil all the way up to Montaña Doramas and along Lomo de Moya and Lomo de las Vacas. The underground apparently consists of basalts from the post-Miocene age, but at deeper levels we may meet the R.N. agglomerate formation.

The superficial red soil seems to be of considerable thickness, at least in places, judging from the deep gullies furrowed into it. This material may originally have been sheets of pyroclastics ejected from the old volcanoes in the region. Soil destruction is a severe menace to the agriculture on the whole stretch of land in this sector, and the vegetative cover is very sparse indeed.

Barranco de Moya has been cut down across the basalt lava cover and also into the underlying R.N. agglomerate formation. Opposite Moya, one will find in the bottom of the canyon a bedrock of phonolites, underlying the agglomerate.

Barranco de Moya is of some interest as a topographical feature. One may ask how this relatively deep canyon has got a short course with a sudden upper end (at the junction of the two head *barrancos*). — No doubt the canyon is the result of energetic river erosion which has worked backwards (with a water-fall). It is the result of a pluvial climate in the past, perhaps in the Quaternary period. The backward erosion started from the coast.

The geological profile of El Pagador — El Lance

To the east of Barranco de Moya a rather smooth ground extends for some km until the great Barranco de la Virgen is met. These inter-*barranco* declivities end at the coast in a *cuesta* c. 100 m in height (from 400 to 300 m above sea level). Still lower down are some coast terraces of this sector.

The slopes from the 400 m contour line down to the coast expose many interesting details in the volcanic sequence. Good opportunities to study them will be found along the road leading down to the coast from Moya and also from El Lance. We may here describe in some de-

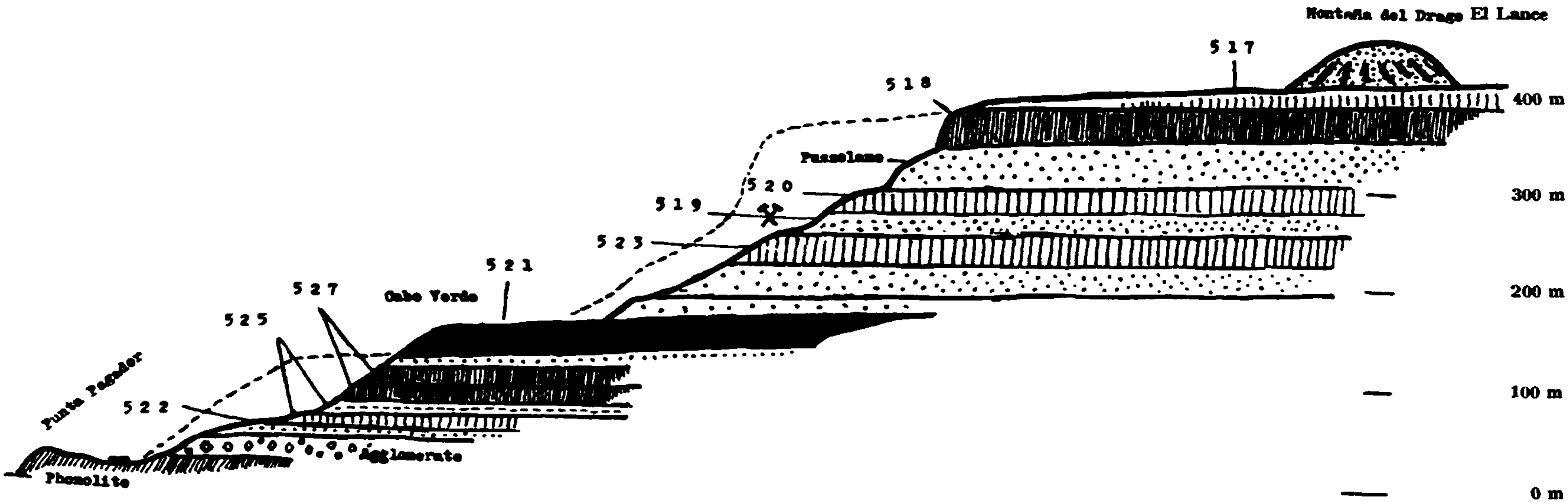


Fig. 23. A somewhat idealized cross-section of the seaward slope from Punta Pagador to Lance, E of Moya. The concordant series comprises salic volcanics except the lavas of basalts composing the Cabo Verde terrace (repr. younger flows).

tails the outcrops and rocks met with along the latter road El Lance-Pagador. For stratigraphical reasons, we will start from below, i.e. from El Pagador (see profile, fig. 23).

Punta del Pagador is a rocky cape jutting into the sea and occupied by a fishermen's settlement. It consists of a dark-grayish platy lava rock, apparently a phonolite. Behind the cape runs the coastal cliff, and at its foot we will meet the highroad which unites Guía with Bañaderos and Arucas.

If we now go uphill in the direction of El Anco, we first pass through an opening in the coastal cliff at El Pagador. It is a *barranquillo* which limits the Cabo Verde-terrace to the east. Along it runs a carriage-road which we have to follow. The first exposures in the sides of the small gorge are coarse agglomerates which seem to rest immediately upon the coastal phonolites (?). Next there are hanging banks of salic lavas and tuffs, capped in turn by basaltic lavas and some intercalated tuff layers. The Cabo Verde-terrace mainly shows basalt beds in a horizontal position. They do not belong, however, to the sequence to be followed in our climb: they have been sent down from the volcanoes in the upland in later times.

In the Cabo Verde-terrace we have reached the middle height of the profile (200 m). From now on the ground rises continually along a *cuesta*, nearly 400 m above sea level. Then there is rather flat ground up to the small village of El Lance. — There are many banks exposed in the slopes, partly of tuffs, partly of lavas. They all seem to belong to the salic series. The profile is of interest owing to the fact that it is one of the best exposed of the salic sequence in the northern part of the island, where most of the ground happens to be covered with the post-Miocene and the younger basaltic lavas.

Petrographic details. — Sample no. 522, corresponding to the lowermost member of the salic beds on the coast (covering the agglomerates there) at El Pagador (left side of the *barranquillo*), seems to be of an ignimbritic nature. Micr. there are laths of alk. feldspar lying conformably in a streaky paste of a glassy nature. Mafic minerals of the first gen. are not seen in the slide. The optics of the feldspar are:

$2Va = 47° - 47.7°$, ind. of refr. < 1.54, opt. char. — (anorthoclase)

The next lava bank in the same *barranquillo* (left side) is a grayish-green trachytic rock (525) lying c. 60 m above sea level. Micr. it shows a trachytic texture without any minerals of the I gen. Instead, there are tiny, clear feldspar rods mingled with aegirine prisms in streaks and bundles. No foid minerals could be seen. The paste is glassy and colourless. The lava is a trachyte (or rhyolite?).

Between 522 and 525 there are stratified tuffs to be seen.

Further up the *barranquillo* (left side), we will meet banks of basalt lavas separated from the underlying trachyte by tuff layers. These dark lavas (527 a and 527 b) seem to be a basanite and a tephrite respectively. I doubt whether they really belong to our sequence. Most likely, they are somewhat younger having reached the coast at a time when the Peléean outbursts held sway and deposited (elsewhere) the R.N. agglomerate. Some particulars of these basalts may, however, be given here:

No. 527 a is a plagioclase basalt with pyroxene and remnants of olivine (if not completely altered to a brown subst.). The ore is ilmenite. The optics are:

Plagioclase: $2V\gamma=74°$, $\alpha' \wedge (010)=33°$ (average of 5 det.) Comp.: An/$55\pm1\%$
Pyroxene: $2V\gamma=60°$, $c\wedge\gamma=50°$ (augite)

No. 527 b contains phenocrysts of pyroxene and hornblende, but no plagioclase is to be seen in the I gen. Grains of magnetite are associated with the pyroxene. The groundmass consists of plagioclase, pyroxene, magnetite and apatite (access.). The paste looks rather dark between + nic. The optics of the mafic minerals are:

Pyroxene: $2V\gamma=52°$, $c\wedge\gamma=50°$ (augite)
Brown hornblende: $2V\alpha=71°$, $c\wedge\gamma=4°$

Covering this basaltic (tephritic) lava of a blistery nature is a huge burden of stratified tuffs of a brownish colour, forming the immediate basement of the Cabo Verde olivine basalts (521). The latter appear in two separate banks with a tuff intercalation. This basalt will be described later on.

Going up the slopes from the plain of Cabo Verde (with its banana plantations) to the southeast, one will first meet large exposures of variegated tuffs (no samples). They are capped by a lava bank, a salic porphyry (523). Micr. this shows clear phenocrysts of alk. feldspar of a broad, tabular shape, lying conformably in a glassy paste of a streaky texture. There are also small flakes of brown mica (nearly uniaxial).

Alk. feldspar :2 $V\alpha=44°$. Axial plane nearly $\perp$ (010) (anorthoclase)

This lava corresponds to a vitrophyre or an ignimbrite of a trachytic or trachyrhyolitic composition. The bank is covered with a brownish agglomerate (519).

A chemical analysis of the salic ignimbrite (or lava) was carried out with the results published below:

Analysis no. 12

Sample no. 523 (HAUSEN (1953) Alk. trachyte (ignimbrite). Middle of the profile of El Pagador-Lance (Vicinity of Moya). Northern side of the island.

		Mol. prop.
SiO_2	62.33%	10337
TiO_2	0.67 »	84
Al_2O_3	18.92 »	1851
Fe_2O_3	2.98 »	187
FeO	0.21 »	29
MnO	0.14 »	20
MgO	0.26 »	64
CaO	0.47 »	84
Na_2O	6.15 »	992
K_2O	5.50 »	584
BaO	0.05 »	3
P_2O_5	0.07 »	5
H_2O+	1.24 »	688
H_2O-	0.78 »	
Sum:	99.77%	

Norm:

Q	4.1	
or	32.5	86.5
ab	52.0	
an	2.0	
C	2.1	
Σ Sal:		92.7
en	0.6	
hm	3.0	
il	0.7	
ru	0.3	
ap	0.2	
Σ Fem:		4.8
H_2O		2.0
Sum:		99.5

Analyst: AULIS HEIKKINEN

Spec. gr. = 2, 33 (+23.5°C)

NIGGLI values:

si = 259, ti = 2.0, p = 0.1, h+ = 17.3, al = 46½, fm = 12, c = 2, alk = 39½, k = 0.37, mg = 0.12, qz = +1, al−fm′ = +34½, al−alk = +7.

C. I. P. W. Classif. — I. 5. 1. 4.
Nordmarkose
Magma type: bostonitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 60:4:36
MgO:FeO = 100:0

RITTMANN-parameters for nomenclature:
Al−17.03, FM−3.89, Alk−14.73, k−0.37, an−0.07, ca″− −0.91. Soda trachyte.

This lava no doubt belongs to the old sequence of salic volcanics (rhyolites and soda trachytes, etc.) which have such a wide extension in the western mountains, and it may be connected with the same central eruptions which deposited this formation in the western sector.

Further up the slope, we have the brown tuff layer already mentioned (519). It is rather soft, and it is easy to shape into appropriate sizes for building materials. Relatively large quarries have at the road that winds up this slope been opened. Micr. the rock shows an abundance of crystals and fragments of alk. feldspar (clear) lying in a paste with a brownish pigment and fragments of a brown hornblende, partly altered to opacite. There are also small laths of feldspar and cavities to some degree filled with sec. feldspar aggregates.

The hanging bank to this tuff rock is made of a dark, somewhat platy lava (520), micr. rather fine-grained and with a trachytoid texture. There are no phenocrysts in the slide; the chief minerals are laths of alk. feldspar and aegirine needles and small grains of nepheline (euhedral). Ore grains are sparse. The lava is a phonolite, or rather a trachyphonolite.

This platy lava is covered with a pale-brownish to yellow tuff of great thickness, in some parts much like the common puzzolane. It occupies the greater part of the uppermost section of the profile. — The top of the series in this *cuesta*, however, is again a lava bank of the dark-coloured »star stone» with glistening tabular feldspar phenocrysts (518). Owing to its firm consistency, the rock forms the very edge of the *cuesta*. Micr. there are large laths of alk. feldspar but also phenocrysts of a greenish pyroxene with euhedral forms. Plenty of small nepheline crystals are in the paste that is filled with tiny feldspar rods and aegirine prisms. The latter surround the nephelines like a corona. Ore powder is rather sparsely present.

This phonolite lava lies c. 380 m above sea. It bears a great similarity to the phonolite (no. 401) in Cuesta de la Cueva Nueva in the western part of the island, a sheet which likewise crowns a series of salic lavas and tuffs.

From the edge of the *cuesta* (with no. 518) a plain extends southwards rising slowly in that direction (cultivated). Following the road to El Lance, one does not observe any outcrops, but probably there are tuffs in the ground (judging from excavations made for water storage tanks). Just before reaching El Lance (and the highway of Moya—Arucas), one has to traverse a shallow *barranco*. In its sides a pale-greenish lava of a soft consistency (517) is exposed. One is now at the 400 m level above the sea. Micr. the rock is a porphyry with clear phenocrysts of alk. feldspar in a groundmass consisting of feldspar rods, aegirine and powder of iron ore but also of small crystals of nepheline. The rock contains stray phenocrysts of a clinopyroxene, partly associated with grains of magnetite. The texture of the paste is trachytoid. The light-greenish colour of the lava is due to the presence of aegirine. The optics of the chief minerals (I gen.) are:

Alk. feldspar: $2V\alpha = 46°$ (average of 4 det.) $a \wedge \alpha = 10°$.
Axial plane $\sim \perp$ (010) (anorthoclase)
Clinopyroxene: $2V\gamma = 100°$, $c \wedge \gamma = 26°$ (aeg. augite)

This phonolite lava, the thickness of which cannot be very great forms the immediate base of a cinder cone nearby, Montaña del Drago (450 m) already somewhat eroded and provided with numerous caves dug in the pre-Spanish period.

Looking at the sequence of volcanic beds just described in detail, we must consider its position in the general scheme of the island structure. — Since the top beds in the profile consist of nepheline phonolite much like that of Cuesta de Cueva Nueva (in the region of Tirma), it is conceivable that the series is contemporaneous with that of the Tirma region as well as with the Montaña del Horno-series. The volcanics exposed in Pagador—Lance would be older than the nepheline phonolite formation. We have now seen that there are phonolites at the sea shore in the north. More of such lavas will follow to the east along the shore (in Quintanillos, Bañaderos, etc.). We shall leave the question open until we have surveyed the conditions further to the east.

We have still to add some remarks about the alien rock members exposed in the profile El Pagador—El Lance. I refer to the basalt lava beds underlying the so-called 'Cabo Verde terrace' at altitudes of 150—200 m above the sea.

As we already have pointed out, there are at least two top lava banks separated by tuff layers. They are olivine basalts (521) and most probably from the post-Miocene age; they do not belong to the sequence in the profile described. — Micr. one sample of the lava shows clear phenocrysts of olivine (not very well developed) belonging to the I generation, lying in a very iron-rich paste with augite but scarcely any plagioclase. The small augite prisms lie densely packed together. The lava may also contain some analcime, judging from the darkness of some interstices when crossed nic. are used. The rock may be a limburgite (or picrite).

Such a basic composition seems to be characteristical of many post-Miocene and recent lavas.

As we have found already, these lavas rest on brownish, stratified tuffs presumably belonging to the underlying alk. basalts above characterized. These do not fit well in with the sequence either, their stratigraphic position is too low.

Barranco de La Virgen and surroundings

This is one of the most important drainage systems in the northern declivities of the island. It measures c. 15 km from the head region in the vicinity of the volcano Montañón Negro (1 650 m altitude) down to the coast. The course of the canyon is only slightly winding, and the longitudinal profile is comparatively smooth, i.e. there are scarcely any sudden drops in the whole train of the bottom. Tributaries are few and short. The *barranco* gives the impression of having a relatively young age (in spite of the absence of ledges). It is evident that the *barranco* has been eroded in times of more rains than now, although this part of the island is still of relatively high humidity owing to the tradewinds: there is much accumulation of clouds in the mountains. But more condensation occurred in times past.

The geological conditions along the master *barranco* and in its immediate surroundings are rather varying. In the head region there are great cliffs of the R.N. agglomerate formation covered by the post-Miocene basalt lavas. Lower down in the valley sides we will find lava banks of hauyne phonolites resting on the agglomerate, the latter appearing in precipices reaching almost down to the bottom. Still lower down the course, the *barranco*-sides expose a great number of basalt lava beds and tuffs, all slightly inclined towards the coast. It seems that the canyon has been cut down across the whole pile of these basic volcanics, once filling the valley (in late-Tertiary time).

A final infilling process occurred in sub-recent times, when basalt lavas were sent down the *barranco* from the volcano of Montañón Negro. This lava reached to the vicinity of the present mineral-water factory of Firgas. Another stream of basalt lava ran down a right-hand tributary from a volcano lying above the village of Lanzarote.

We may now look at the exposures of some rocks along Barranco de la Virgen, beginning from the head region at an altitude of c. 1 400 m. The author has not examined the entire stretch of the valley, but the chief complexes of rocks have been determined.

The highland slopes to the east of Montañón Negro, where the *barranco* has its main head, consist of a series of basalt lava banks and intervening tuff layers. One sample from Montaña Pajarito (17) is a typical olivine basalt of the more picritic kind, phenocrysts of olivine and augite in a paste which between + nic. looks rather dark, consisting of pyroxene, magnetite and feldspar microlites and also colourless, isotropic patches, probably analcime. No doubt this butte belongs to vast post-Miocene lava effusions covering the major part of the highland surface. — In the vicinity of Montañón Negro there are other such erosion remains of the once coherent lava formation.

These basic highland lavas rest on the R.N. agglomerate formation which comes into sight below the lava banks in the steep slopes — at the head of Barranco del Andén and Cuevas de la Corona, i.e. around the heads of Barranco de La Virgen. The R.N. agglomerates here attain an altitude above the sea of max. 1 400 m, exposed partly in overhanging cliffs along the highroad to Artenara. They also reach down the slope many hundred m. I have no proofs of the hanging lavas in this sector; it is uncertain if there are tephrite-basanite lavas or perhaps olivine basalts of post-Miocene age. I think the lowest ones may be of the former kinds, associated with the R.N. agglomerate banks.

Downward along the highroad on the right side of the *barranco* in the direction of Lanzarote, one will find large cuts in a dark grayish, somewhat weathered lava. One sample (38) shows micr. that the rock is a phonolite, containing plenty of corroded phenocrysts of hauyne, turbid but with a clear rim, and also prisms of a greenish pyroxene with ext. angle $c \wedge \gamma = 45°$, hornblende, sphene and magnetite, the latter associated with the pyroxene. The paste mostly consists of feldspar laths and is poor in coloured minerals (pyroxene). The lava may be called a hauynophyre and no doubt belongs to the group of *Na*:rich lavas and intrusives which appeared after the cessation of the Peléean outbursts in the island with their deposition of the R.N. agglomerate mantles.

From a point in the same valley side not far from the Lanzarote cinder volcano, one looks across the master-*barranco* (de la Virgen) which here is already of an imposing breadth. The huge cliffs on the opposite (i.c. the left) side expose a conspicuous terrace of considerable elevation, apparently consisting of the R.N. agglomerate formation dissected by many vertical fissures (diaclases) forming thick columns in the precipices. Above the terrace there is a kind of ancient lava fill and further off are higher ridges apparently consisting of olivine basalts of the post-Miocene series. They form the northern part of Montaña del Pajarito.

The young lava of basalt filling the bottom of Barranco de la Virgen was emitted from the volcano Montañón Negro. This cone, probably of sub-Recent age, attains c. 1 650 m above the sea. It has a crater open to the north.

The lava from here is a glassy basalt which will be desciibed in more detail in the next chapter (10!).

The long lava tongue which found its way from Mont. Negro along Barranco de la Virgen came to a standstill a short distance from the present mineral-water factory of Firgas, situated in the *barranco*-bottom. A sample of this lava (48) from a site somewhat above the factory is an olivine basalt of a fresh aspect, with clear olivine phenocrysts and crystals of a pyroxene lying in a paste composed of pyroxene grains, magnetite and small rods of plagioclase. The optics of the minerals in the I gen. are:

Olivine: $2V\alpha = 86°$ (average of 6 det.). Comp.: Fa=30%.
Pyroxene: $2V\gamma = 53°$ (average of 6 det.)
$c \wedge \gamma = 49°$ (augite) — The mineral is zonal:
in the kernel $2V\gamma = 78°$,
$c \wedge \gamma = 55°$ (aegirine augite)

The lava is of a more picritic (ankaramitic) composition owing to its insignificant feldspar content. It plays the role of an important aquifer with its many cracks and tunnels (F. MACAU VILAR 1957).

If we turn back to the head of the master valley and follow the highroad which runs from Artenara to Lanzarote, we will pass a volcano (that rises to the south of the village) on its western side, then to the north side, where a large crater is exposed. This volcano, of a more advanced age (Quaternary?), has sent a stream of basalt lava down the *barranco* which joins Barr. de la Virgen somewhat above Firgas. The cone itself rests on a platform consisting of a phonolite lava which is exposed along the highroad at several localities. According to sample no. 12 it is a hauynophyre (like that of no. 38) which was taken from the northern foot of the volcano above the village Lanzarote. Micr. the dominating mineral of the I gen. is a strongly corroded hauyne. Other phenocrysts are a greenish pyroxene and magnetite. The groundmass consists of feldspar rods arranged according to the trachytoid texture. The lavas in question are of some northern outliers of the phonolites of similar kind in the central highland.

The Lanzarote volcano is surrounded by masses of the R.N. agglomerate, forming its deeper basement.

The author made an excursion from the mountain town Valleseco (1 000 m), lying on the highroad Teror—Artenara, straight to the west and reached Barranco de la Virgen at a point somewhat above Firgas. It is an undulating highland which rises to the south. (it will be described later on). — Reaching the rim of the great *barranco*, I descended to its bottom, passing a number of flat-lying lava and tuff banks. At the top of the profile are lavas of a phonolite? aspect (no sample). There then follow several basalt lava sheets and tuffs until one reaches the bottom. Some samples from this profile (514, 515, 516) are of basalts. No. 514 shows micr. a more picritic comp., with euhedral phenocrysts of olivine (clear but with a narrow brown fringe; (opt. char. —). There are also, sparingly, pyroxene phenocrysts, somewhat zonal. The groundmass consists of plagioclase laths, pyroxene and ore, the latter in abundance. This lava may belong to the post-Miocene effusions which filled the ancient valley now occupied by Barr. de la Virgen. The optics of the chief components are:

Olivine: $2V\alpha = 88°$ (average of 6 det.). Comp.: Fa$=23 \pm 3\%$
Pyroxene: $2V\gamma = 62°$, $c \wedge \gamma = 47°$ (augite)

If we follow Barranco de la Virgen downward, and after passing along the young basalt lava tongue (filling the bottom to the vicinity of the factory of Firgas), we use a carriage-road that leads to Pueblo de Firgas, climbing to rather high levels above the bottom. On this route we will find only the basalt formation in a concordant sequence (lavas and tuffs). The same is seen in the opposite (left) side of the *barranco*.

These volcanics in the high *barranco* walls are, as we have found, an ancient fill of a Tertiary valley that has been reopened by later erosion. Most likely the original valley was eroded into the R.N. agglomerate formation (with underlying phonolites).

Just to the south of Firgas (Pueblo) there are outcrops of a phonolite, the basement of the basalts and of the volcano of Firgas, an old cinder cone. There is no sample of the salic rock.

Pueblo de Firgas lies at the northern foot of the volcano of F., 650 m abs. height which is relatively old (Quaternary?). It rises at the end of a long ridge which accompanies Barranco de la Virgen on its right side. The cone is capped completely on the surface with decomposed pyroclastic material — a reddish soil. A large crater appears in the north side of the cone. The west flank has been damaged by erosion in the nearby *barranco*. At the foot of the steep cliff phonolites are seen underlying the basaltic material belonging in parts to the volcano. — Great quantities of lava seem to have been emitted from the Firgas volcano, flooding the slopes to the north and northeast. This lava is now covered with weathering soil; the ground is called Llano del Reparto. *Barrancos* have furrowed it to some extent in later times. — A sample of the Firgas-lava (54) is a typical olivine basalt. Micr. it shows euhedral olivine phenocrysts with a brown iddingsite fringe. Small grains of the same mineral are completely altered to a reddish substance. The groundmass is composed of plagioclase, clinopyroxene and magnetite grains. The amount of the latter is remarkable; the rock is of a more basic nature (picritic).

The lowest course of Barranco de la Virgen is eroded in a rather thick formation of basalt lavas and tuffs. High profiles are seen, for instance, where the highroad from Arucas to Moya crosses the canyon. Here thick banks of lavas appear, showing beautiful columnar jointings. Of samples 32, 69, the former is a typical picrite with plenty of olivine and augite phenocrysts in a paste filled with pyroxene and magnetite and sparsely of plagioclase. The big olivines are corroded and rimmed with iddingsite (cf. with microphoto fig. 1, plate IX). The other sample (69), a similar lava from the right side (lower bank) is micr. rich in olivine and augite but only the former appears as phenocrysts. The olivines are euhedral in places and always iddingsite — rimmed. The mineral is much dissected by cracks filled with serpentine. The dominating mineral in the groundmass is clinopyroxene appearing as elongated prisms in random orientations. It is a Ti-augite (ext. angle $c \wedge \gamma = 45°$). In the interstices is a colourless substance with a very weak birefr. (zeolite). Plagioclase is not seen in the slide. There are equal quantities of olivine and augite. Magnetite is rather abundant in the paste often aggregated around the olivines. Apatite is an accessory constituent. The lava may be designated as an ankaramite.

Nearer to the coast, on both sides of the mouth of the *barranco* there are terraces consisting of basalt lavas resting on older rocks. The surface of these terraces lies c. 100—150 m above the sea level. According to one sample (521), these lavas are likewise ankaramites. Perhaps the lavas have been laid down on an old marine terrace formed in Miocene time. The effusions occurred in the post-Miocene period of the extensive floodings of basalt lavas, when the sea level already had been lowered considerably.

The northern declivities between Barranco de la Virgen and Barranco de Teror (Tenoya)

Geologically, this sub-sector is dominated by two complexes of volcanic rocks: the salic lavas and tuffs of the underground and the more superficial basalt lavas, cinder cones and pyroclastic masses. To these may also be added remains of the ancient cover of the R.N. agglomerates, although many of them are capped with the younger volcanics.

If we start with our descriptions on the highest levels, in the region of Valleseco (1 000 m), we have already briefly characterized the ground that lies south of the little town (the Lanzarote volcano, etc.).

The ground traversed by the author to the west of Valleseco seems to be covered with the R.N. agglomerate and tephritic lavas of about the same age. There is a small quarry in an escarpment facing north a short distance from Valleseco. Here a kind of dark gray tephrite (7) occurs. The rock shows micr. phenocrysts of a pyroxene, pale-coloured, a brown hornblende and also plagioclase laths. They lie in a paste of plagioclase microlites, pyroxene ore and (accessory) apatite. Grains of sphene also occur. The optics of the chief minerals are:

Plagioclase:	$2V\gamma = 77°$. Comp.: An/60
Pyroxene:	$2V\gamma = 59°$, $c\wedge\gamma = 56°$ (aeg. augite)
Brown hornblende:	$2V\alpha = 68°$, $c\wedge\gamma = \sim 10°$

Olivine is not visible. The lava may be classified as a tephrite. Most probably it belongs to the R.N. agglomerate formation which occurs in the same region. The name tephrite is justified because in the paste there are small grains of hex. contours, isotropic, which may be a sodalite mineral.

If we follow the highroad from Valleseco northwards to Lomo de la Rosa and further on to Villa de Teror, we will pass along a ridge called Lomos — and Balcón de Zamora (the watershed between the drainage system of Barr. de la Virgen and that of Barr. de Teror). The upper parts of this ridge consist of olivine basalt lavas (57) of a not very fresh aspect. The lava is picritic in composition: euhedral olivine phenocrysts with a brownish fringe in a groundmass of augite and magnetite and trifling amounts of feldspar. It is a lava of the post-Miocene series, already much eroded.

The Osorio volcano and its surroundings

To the north of Degollada de La Rosa there extends a ridge rising to a max. height of 900 m above the sea. It consists of a large basaltic volcano, in the surface almost covered with lapillis, ashes and their decomposition products. It is a relatively old volcano, perhaps from the late-Tertiary time (or from the end of the same). There is a number of craters in the crest of this ridge, the largest one in the centre, being wide open to the east. From this crater great masses of basalt lavas have been emitted, flowing down the valley of Teror into the direction of the coast. Other streams headed northwest, moving along the relatively short Valle de los Portales, other advanced to the west. In short, Osorio was a very productive volcano in its time, displaying a kind of 'Strombolian' outbursts. It is in fact the most important of the adventive volcanoes in the northern declivities of the island.

Some samples have been kept from the Osorio volcano (26, 41). The former is of a stream of lava in Valle de los Portales. The lava is blocky on the surface and somewhat decomposed. Micr. it contains phenocrysts of olivine (rounded contours), pyroxene and brown hornblende enclosed in a groundmass consisting of pyroxene, feldspar laths and magnetite grains. Apatite is an accessory. The olivine is surrounded by a zone of yellowish-brown serpentine. The pyroxene is zonal, pale-coloured. The hornblende shows α-yellow, γ-brownish-yellow; $c \wedge \gamma = 0°$. The mineral is surrounded by a fringe of secondary products. There may be zeolite in the paste (analcime?). The lava is a basanite.

No. 41 is from another place in the same valley, a lava connected with the former. Micr. the picture is somewhat different. Only olivine phenocrysts are seen in a fine-grained paste of feldspar, pyroxene and ore powder. The cavities are filled with zeolite in radial bundles.

Olivine $2V\gamma = 84°$ (Comp.: Fa 0%, — forsterite)

This lava is of a more fresh aspect and may belong to a later outburst of the volcano. — These lava streams ran down to the basin of Arucas

(250 m above sea level), where they accumulated to a thick fill covering a bottom deposit of gravels. Perhaps parts of these lavas continued along a spillway to the north coast.

* * *

The basement of the Osorio volcano is not immediately to be seen owing to the surrounding cover of lavas, pyroclastics and later gravel deposits. One has to study the many water-shafts dug deeply into the underground. I had no opportunity to carry out a more detailed survey or to collect specimens of lavas perforated by the digging of shafts, from the lumps which had accumulated in the vicinity. In some cases when such a study was attempted, I found it impossible to get exact information about the depth to which the rock type belonged. We therefore have to be content with only scattered data.

The following samples were collected from the surroundings of the Osorio volcano, where they form the basement rocks: 23, 24, 25, 35, 36, 37, 38, 42, 44, 47, 49, 52, 56. Some of them will here be briefly characterized. In one case (25) a chemical analysis will also be presented.

Nearly all these lavas are of a salic composition: they belong to the alk. trachytes or the trachyphonolites and perhaps to some extent also to the phonolites. As to their geological age (position in the geological column of the island), they are all from the mid-Tertiary period (Miocene?), lavas which all have been emitted from the central conduits of the highland.

Sample no. 25 is from a small quarry at the south-end of ridge of Cerro Riquiánez, which stretches along the left side of Barranco de Teror. This ridge consists mainly of salic lavas, capped with a basalt sheet. Micr. no. 25 is practically a feldspar rock with small laths of alk. feldspar (anorthoclase) mingled with prisms of aegirine and also grains of nepheline, this latter being surrounded by a corona of aegirine needles. There are also colourless aggregates of a zeolite with weak refr. and birefr. The aegirine prisms are opt. length fast. Ore grains are sparsely present. The lava may be a soda trachyte or a trachyphonolite, nepheline bearing.

The rock in question has been quarried for the obtaining of slabs, since it has good partings on one direction. In the weathered surface it is almost grayish-white.

A chemical analysis of the rock has been carried out with the following results:

Analysis no. 13

Sample no. 25 (HAUSEN 1953) from a small quarry at the southern end of Cerro Riquiánez Deg. de los Portales, region of Teror.

		Mol. prop.
SiO_2	60.54%	10040
TiO_2	0.70 »	87
Al_2O_3	17.52 »	1714
Fe_2O_3	3.83 »	240
FeO	0.53 »	74
MnO	0.34 »	48
MgO	0.72 »	179
CaO	0.56 »	100
Na_2O	7.20 »	1161
K_2O	5.35 »	568
P_2O_5	0.06 »	4
H_2O+	1.70 »	944
H_2O-	1.18 »	
Sum:	100.23%	

Norm:

or	31.6	84.8
ab	53.2	
an	—	
ne	3.7	
Σ Sal:		88.5
ac	0.7	
di	1.9	
fo	0.6	
mt	0.8	
hm	3.0	
il	1.3	
ap	0.1	
Σ Fem:		8.4
H_2O		2.9
Sum:		99.8

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.66 (+23.5°C)

NIGGLI values:

si = 232½, ti = 2.1, p = 0.1, h+ = 21.8, al = 39½, fm = 18, c = 2½, alk = 40, k = 0.33, mg = 0.23, qz = −26. al − fm′ = +22, al − alk = −½.

C. I. P. W. Classif. — I. 5. 1. 4.
Nordmarkose
Magma type: nordmarkitic/normal foyaitic/umptekitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 64:0:36
MgO:FeO = 100:0

RITTMANN-parameters for nomenclature:
Al − 15.77, FM − 6.23, Alk − 16.15, k − 0.33, an − 0.01, ca″ − 0.79. Soda trachyte.

This lava rock corresponds fairly well to some types in the series of the southwestern mountains (for inst. to 401 and 440). The rock in this northern slope may belong to the upper part of the salic series which antedates the emission of the nepheline phonolites (in the south). It is, as we have seen, slightly undersaturated: trachyphonolite would be an appropriate name.

There are some other samples of nepheline bearing salic lavas from the ridge of Mont. Riquiánez (38, 49). The former is of a higher-lying bank and consists micr. of a trachytoid feldspar mass with intermingled nepheline crystals and aegirine prisms. There are also phenocrysts of alk. feldspar. The nephelines are surrounded by a fringe of aegirine aggregates. The groundmass seems to be somewhat altered (dark between + nic.). — No. 49 is from a water-tunnel at the northern foot of the mountain ridge, 250 m above sea level (SE of Arucas, *finca* Las Fuentitas). It has rather the same composition — it is a nepheline trachyphonolite. The texture of the groundmass here is also trachytoid. It seems that the bulk of the ridge consists of these lavas which lie in a rather flat position, with a slight synclinal bend.

In the southern part of the crest of the same ridge there is a culminating hill consisting of a basalt lava (35), the last remains of an once wide-spread, probably post-Miocene lava sheet. Micr. it contains phenocrysts of olivine (dark-rimmed) as the only component of the first gen. The groundmass contains plenty of pale-coloured pyroxene prisms, feldspar rods and ore powder. The lava has a rather basic composition. Colourless patches in the paste may be analcime. The optics are:

Olivine: $2V\gamma = 85°$. (Fa $= < 10\%$)

In the left side of the head of Valle de los Portales which leads down to the basin of Arucas (250 m above sea level), there is a water-shaft from which some samples were kept. The mouth of the shaft lies c. 450 m above sea level. The types are light trachytes. A sample was taken from another shaft to the west, Casa Herrera, 400 m above sea level.

This lava (42) is light coloured and distinctly porphyric with clear alk. feldspar phenocrysts (sanidine) and brown mica in a very fine-grained groundmass of feldspar rods. There are also stray crystals of a sodalite mineral (colourless). Iron ore powder fills the interstices together with an isotropic substance (zeolite?). The rock may be a soda-trachyte.

From the same shaft (at a depth of 173 m, 225 m above sea level) another sample (52) is of a mica porphyry with clear alk. feldspar phenocrysts (Karlsbad twins) and mica flakes in a fine-grained groundmass of feldspar rods, mica and ore powder. There are also larger crystals of magnetite. The optics are:

Alk. feldspar: 2 $V\alpha = 8°$ (sanidine)

Brown mica-nearly uniaxial.

Zeolite fills the interstices in the paste. — The lava is a trachyte.

The ridge of the west side of Valle de los Portales is of a similar aspect as that to the right. It seems to consist of trachytes or trachyphonolites and it ends suddenly in the north with a cape facing the basin (the plain) of Arucas. The foot of the slope here lies 250 m above the sea level, and this is considered by BRAVO as an old sea cliff (comm. to the author). In the midst of the ridge there rises a cinder cone apparently of sub-Recent age, and from here lavas of basalt have spilled down the west flank to Barranco de Arucas.

Some samples have been collected from shafts dug for recovery of ground water in the northwestern outskirts of the Osorio volcano. One is of a tephrite lava (34) taken of lumps hoisted up from a level of c. 370 m. Micr. the rock shows phenocrysts of augite and hornblende, the latter with corroded contours. The magnetite has skeletal forms in some of the grains and it is associated with the augite. Apatite is an accessory constituent. The groundmass is fine-grained and rich in iron ore grains mingled with augite prisms and rods of plagioclase. Vesicles are filled with aggregates of aragonite and zeolite. — No doubt this lava is older than the great volcano in the vicinity and belongs to the R.N. agglomerate formation instead which may lie concealed in the underground of the volcano.

The region of Arucas—Cardones

If we first follow the course of Barranco de Arucas which begins in the higher ground with some narrow *barranquillos* not far from Casa Herrera and runs northeast to the plain of Arucas (a basin, filled with alluvium) we will find basalt lava banks fringing the *barranco* on both sides. These lavas belong to the Firgas volcano, a Quaternary cinder cone. The lavas rest on a basement of salic volcanics exposed in the *barranco* lower down. In the left side of the same there is a quarry in these latter, a place called Lomo de San Pedro. Here a soft, pale-coloured trachytic lava is exposed (56), it is porous and easy to handle with the hammer. Micr. there are phenocrysts of alk. feldspar, brown mica enclosed in an inhomogeneous paste with rods of feldspar and aegirine and also minute nepheline crystals, surrounded by a corona of the aegirine. Magnetite is also present. In the paste there are lithophyses, elongated in a flow direction. The type may correspond to a trachyphonolite. It belongs maybe to the old series of salic lavas in the island (cf. with the profile El Pagador—El Lance).

If we follow Barranco de Arucas further down to the plain (250 m above the sea level), we pass along a ridge occupied by Arucas' suburban settlements (La Gotela, Cerrillos). The whole ridge seems to consist of similar salic, porous lava and tuff rocks (as no. 56). Drainage grooves (small channels) have been carved in the rock ground along which runs the main throughfare. In La Gotela a small quarry has also been opened. The dominating lava is a pale-brownish, soft rock (19), showing micr. laths of alk. feldspar somewhat corroded, lying in a groundmass of feldspar laths with the trachytoid texture. There are also flakes of brown mica and grains of ore, moreover grains of a colourless isotropic substance (analcime?). Elongated pores are filled with sec. feldspar microlites (sanidine?). The type is rather identical with no. 56 farther up the *barranco*, in Lomo de San Pedro.

The pale-coloured trachyte lava of a soft consistency was followed along the road through the village of Barrio Cerrillos into the city of Arucas, situated at the southern foot of the volcanic cone of Montaña de Arucas. To the west of the city there is a sudden drop of the ground to the north towards the coast, a real escarpment, perhaps an old marine abrasion cliff worked out in the salic volcanics. This escarpment is the north side of the ridge followed from La Gotela—Los Cerrillos. Here the trachyte seems to have been changed into a kind of tuff of a dark-brownish colour. It is magnificently disclosed in a large quarry inside the city itself, in a *cantera municipal*. This rock (54) is of a soft consistency and is easy to handle with the hammer and other tools. This pyroclastic type no doubt belongs to the same salic series which is quarried higher up the slopes in Lomo de San Pedro. The microstructure is typical of a porous tuff containing a great deal of a glassy substance, in which there are fragments of alien lavas, but also fragments of alk. feldspar (opt. char. —, ind. of refr. $<$ balsam) and also flakes of brown mica (pleochr.: α-yellow, β, γ-brown). Grains of magnetite are also present. In the finer-grained groundmass there are plenty of pores filled with fine aggregates of feldspar which have grown from the walls of the cavity towards the centre (lithophyses). Scattered grains of quartz are also seen (colourless, ind. of refr. > balsam, opt. +. uniaxial).

The quarried blocks of this rock have a rough surface and are of a dull brownish colour. The material has been used for building purposes, and the cathedral of Arucas is built of this kind of stone.

The declivities to the west of Arucas, in the course of Barranco de Bañaderos have only been inspected along the highroad that leads to Firgas. They seem to consist of salic lavas; further to the west we have (superficially at least) only basalts derived from the Firgas' volcano. — I have only a few samples of the salic lavas. No. 44 from a point where the road crosses Barr. de Bañaderos is a nepheline phonolite or trachyphonolite with micr. clear phenocrysts of alk. feldspar embedded in a trachytoid paste with feldspar microlites, aegirine, ore powder and nepheline in stout crystals with hexagonal cross-cuts. The share of the latter mineral is remarkable. The aegirine surrounds the nepheline like a corona. There is some zeolitic subst. in the paste, judging from the weak birefr. The type corresponds almost perfectly to no. 25 from Degollada de los Portales, of which a chemical analysis (No. 13) has been carried out.

If we follow the highroad that descends from Arucas to the coast at Bañaderos, we will pass along a ground of salic lavas and tuffs limited to the east by the phonolite lavas emitted from Montaña de Arucas (see later on). At Bañaderos, lying close to the sea shore is a terrace of some interest, bordering the low coastal strip. In the profiles there are basalt lavas at the top, no doubt of the post-Miocene effusions. They rest on a basement of salic lavas and tuffs. A sample of the latter series is a grayish lava (58) containing phenocrysts of alk. feldspar in a trachytoid paste filled with feldspar rods, aegirine in streaks, nepheline and ore powder. No mafic phenocrysts are visible. This lava also reaches down to the shore-rocks (on the highway). A short distance to the west from Bañaderos there is a rocky cape, Lomo Quintanillos, covered with basalt. These lavas rest on a basement of a salic lava much like the one just described — it is a nepheline phonolite (526). The same rock forms the shore at the village of Quintanillos. Micr. it has phenocrysts of alk. feldspar (opt. char.+, ind. of refr. ~1.54 =albite) in a trachytoid paste with feldspar and bundles of aegirine prisms arranged in beautiful aggregates (like ice »flowers» on the windowpane) also surrounding small nepheline crystals. The latter have been completely altered to a turbid, isotropic substance.

According to the stratigraphical scheme, these phonolites should be younger than the more trachytic lavas and tuffs in the higher slopes SW. of Arucas. The relatively low position of the phonolites (by the shore) may be due either to primary declination of the banks or to later displacements. The latter alternative appears more conceivable.

Montaña de Arucas and Montaña de Cardones, two cumulo-volcanoes

Prominent topographical forms in the region dealt with here are the two cumulo-volcanoes mentioned above, consisting of phonolitic material. They lie rather close to each other, the distance being only c. 2 000 m. The summit of the former cone reaches 400 m above the sea, the latter c. 275 m.

Montaña de Arucas is a broad cone with a truncated top without any signs of a crater and entirely covered by clasmatics. in the surface decomposed by weathering. Lavas are seen in the shape of a broad blocky stream leading down to the coast. According to a profile sketch communicated by T. BRAVO this lava has overridden a R.N. agglomerate bank, a fact which proves that the outbursts in Arucas were of later date than the great Peléean eruptions which deposited the agglomerate. There is no way of fixing the upper limit of the age of the Arucas' volcano. It seems, however, that the cone (and its neighbour) may be of an earlier period than the many adventive cinder cones of basalts strewn over the slopes of the island in this sector. — On the other hand the cones may be younger than the Miocene sea transgression which gave origin to the sea cliffs of more than 200 m altitude just to the south of Arucas.

E. JÉRÉMINE (1937) has already studied the lavas of these two volcanoes. In Montaña de Arucas the lavas are hauyne phonolites, of dark gray colour. According to the French nomenclature (A. LACROIX) they correspond to tahitites and ordanchites. — The present author has a sample of one of these lavas from Trasmontaña lying on the way from Arucas to Cardones. This sample (5) is micr. rather fine-grained but contains phenocrysts of a clinopyraxene, hornblende, hauyne and sphene all lying in a trachytoid groundmass of tiny feldspar laths mingled with microlites of a pyroxene and hauyne and ore powder. The lava may be a tahitite with colour index of c. 20—30.

The lava taken from the north foot of Montaña Cardones (6) seems to be rather similar in composition. Micr. there are phenocrysts of a blue hauyne in well formed crystals, a clinopyroxene, a brown hornblende and sphene. The paste is trachytoid with feldspar laths, hauyne and ore grains. E. JÉRÉMINE (l.c.) has published a chemical analysis of this lava. The NIGGLI data corresponding to the analysis have been quoted in the list, Part II, page 375, XI.

Turning from Bañaderos along the coast to the east and passing Punta del Camello to Punta Caletón, we will find a rock ground consisting of a somewhat different kind of salic lava (865). Micr. it shows phenocrysts of alk. feldspar with Karlsbad twins, an altered sodalite mineral and crystals of aegirine-augite, all lying in a paste of feldspar laths, aegirine and nepheline. Calcite appears as a secondary product. E. JÉRÉMINE (l.c.) calls the rock »hauyne-bearing metaphonolite». — According to a general profile along the coast from Bañaderos in the west to the mouth of Barranco de Tenoya in the east (F. MACAU VILAR 1958), this hauyne-meta-phonolite forms a rather extensive cover resting on a trachyte (as can be seen in the coastal cliffs). This metaphonolite may be related in some way to the cumulo-volcanoes in the vicinity, being perhaps effusions of a somewhat earlier date. The deep basement of all these effusions is, according to MACAU VILAR, a trachyte resting on an unknown (submarine) rock formation.

The profile just mentioned, founded on data obtained from a number of drill-holes along the coast, demonstrates the presence of an old buried valley mouth underlying the mouth of the present Barranco de Tenoya. This old (now invisible) valley seems to have been filled with puzzolane (*canto blanco*) and this in turn covered by trachyte — and a topmost stream of basalt lava, belonging to the post-Miocene series (?). The old valley was eroded in the salic basement series.

The many remains of the R. N. agglomerate formation appearing at several points along the coast, according to the coastal long-profile given by F. MACAU VILAR (l.c.), are also of interest. Here are some stratigraphical facts which will be discussed in the following Part II. — Since the author who published the profile does not give any petrographic details of the lavas found on the stretch, a later detailed investigation may to some extent have changed the nomenclature of these lavas.

10.

The Central Highland

(confined by the 1 500 m contour line)

General aspects

The central elevation of the shield-formed island — confined by the 1 500 m contour line — occupies a relatively restricted area. It has the aspect of an undulating upland surface with a number of cupola-shaped hills — all giving the impression of a long lasting denudation. The very sinuous course of this contour line indicates that the upland — the old ground — has lately been attacked by erosion from the sides, and that it has formerly had a much wider extension. There are in fact many deep embayments on all sides of the upland, the most important being of course Caldera de Tejeda and Caldera de Tirajana. The latest phase of erosion has reached a stage, when the upland is on the way being split into two parts. — Only a narrow ridge forms a connecting link — that is Degollada de Cruz de Tejeda.

It is a relatively simple task for the geologist to investigate the upland area in question starting from an operation base at Cruz de Tejeda that is from Parador nacional de C. de T. situated 1 500 m above the sea. One can comfortably stroll in several directions over the smooth ground right to the borders. But it is a different task to examine what is to be seen in the steep slopes behind the limits in order to get an insight into the basement structure. In the present chapter we will no more deal with the profiles of the precipices, since these have already been mustered in the descriptions of all the sectors of the island (with the exception of Caldera de Tejeda which will be treated later on).

When starting a scrutiny of the central highland, we may divide the object into two parts: the central highland in its proper sense, and the northern promontory attached to the former only by way on the narrow Degollada de Cruz de Tejeda.

The Central Highland
N of Caldera de Tirajana

This area which is rather monotonous, lies at elevations above the 1 500 m contour line. The highest point is Pozo de las Nieves

(1950 m), a rounded hill except in the south where it drops into Caldera de Tirajana. In the eastern part of the area there are several *roques* breaking the monotony. The ground is mostly covered with rock waste and clayish decomposition products, and the shallow creeks have a gravel filled bottom. Erosion is at a relative standstill, the decomposing agencies seem to prevail.

This central highland shows a ground of basalt lavas and their tuffs, at least in the surface. They are frequently crossed by great dikes with a straight or a curved course and a vertical position. Owing to the intense weathering of the lavas exceeding that of the dikes the latter are standing in high relief. These walls indicate the location of ancient fissures through which the basalt magmas have once (in post-Miocene time?) found their channels of escape to the surface and expanded on it. Many of the lava sheets formed have, however, long ago disappeared through denudation.

Samples of the *Cumbre* lavas and dikes have been collected by the author (596, 602, 604, 607, 610, 614, 622). They are all olivine-bearing basalts of the more picritic kinds with olivine and augite phenocrysts (sometimes only the former) in a paste of plagioclase laths, augite and magnetite. The content of plagioclase is mostly rather restricted (ankaramites, picritic basalts). Instead, there are small patches of an isotropic, colourless substance in the paste, probably analcime (ex-nepheline?).

Some brief petrographical characteristics may be added here.

No. 596 is from a low erosion *cuesta* in Llano de la Paz, the highland ground extending between Pozo de las Nieves and Roque Nublo. Micr. it shows a decidedly picritic composition with the leading minerals being olivine, augite and ore, whereas plagioclase laths are tiny and sparsely intermingled in the matrix. The olivines are clear, euhedral; the augites are mostly long-prismatic, especially in the groundmass. Magnetite is evenly scattered in the paste. — No. 602 is of a great dike known among Canarian geologists as »Stegosaurus» — a cyclopic wall with a jagged spine rising by the Cumbre road above the lavas and the tuffs. The composition of this type is rather similar to that of 596, with well-developed olivine phenocrysts and also prisms of augite in an iron-rich groundmass containing augite and zeolite (analcime?). The optics of the chief minerals are:

Olivine: $2V\gamma = 88°$ (Fa$=8\%$)
Augite: $2V\gamma = 58°$, $c \wedge \gamma = 39°$

A chemical analysis was made of the sample with the results given below:

Analysis no. 14

Sample no. 602 (Hausen 1953) of a picrite basalt from a great dike cutting the basalt formation in the upland on the way from Cruz de Tejeda to Cuevas Blancas.

		Mol. prop.
SiO_2	37.88%	6282
TiO_2	3.82 »	477
Al_2O_3	9.92 »	971
Cr_2O_3	0.01 »	1
Fe_2O_3	5.50 »	344
FeO	7.30 »	1016
MnO	0.22 »	31
NiO	0.05 »	7
MgO	14.38 »	3566
CaO	13.70 »	2442
Na_2O	2.69 »	434
K_2O	1.05 »	111
P_2O_5	1.49 »	105
CO_2	0.00 »	
V_2O	0.05 »	(3)
H_2O+	0.99 »	549
H_2O	0.88 »	
Sum:	99.93%	

Norm:

an	11.8	
lc	4.8	
ne	12.3	
Σ Sal:		28.9
di	30.2	
ol	17.4	
cs	2.4	
mt	8.0	
cm	(0.02)	
il	7.3	
ap	3.5	
Σ Fem:		68.8
H_2O		1.9
Sum:		99.6

Analyst: Aulis Heikkinen

Spec. gr. = 3.22 (+23.5°C)

Niggli values:

si = 68, ti = 5.2, p = 1.2, h+ = 5.9, al = 10½, fm = 57½, c = 26½, alk = 5½, k = 0.20, mg = 0.67, qz = −54, al−fm′ = −47, al−alk = +5.

C. I. P. W. Classif. – IV. 2. 3. 2. 2.
Uvaldose
Magma type: pyroxenitic/vesecit-polzenitic
Mol. prop. % of the normative feldspars:
Ab:An:Or = 0:100:0
MgO:FeO = 94:6

Rittmann-parameters for nomenclature:
Al−8.93, FM−42.53, Alk−5.09, k−0.21, an−0.27, ca″−11.40.
Mafitic nephelinite.

This dike rock is the most basic of all the types of basalts submitted to chemical analysis. I have designated it a 'picrite basalt', since its feldspar content is rather restricted (acc. to P. D. QUENSEL: picrite basalt has ol.=45, aug.=27, plag.=23, and ore+ap.=5 vol.%). In the NIGGLI variation diagram (page 376) its place is on the extreme left. The dike, like many of its neighbours in the highland, may be considered as a »feeding channel» for lava sheets of picritic basalts which expanded over this elevated part of the centre. Of these dikes, no. 604 and 607 are rather similar in composition, the former carries some scattered grains of a sodalite mineral.

This olivine basalt formation in *La Cumbre* can be followed (as we have already found) for long distances down the slopes in the north and in the east, to some extent also in the northwest (see the geological map). The sheets are numerous, as may be found, for example in the steep right side of Barranco de La Culata (left head arm of Barr. de Tejeda). The greatest thickness of the series is to be seen in the walls of Barranco de Guayadeque on the eastern side of the island. — There were principally eruptions from fissures which lasted for a long time span in the post-Miocene period. But this production of basic volcanics also continued in later time, only with the difference that the eruptions were confined to definite centres.

Highly Na:alkaline phonolites in the *Cumbre*-region. — Leaving aside the superficial basalts and their swarms of dikes — all of very basic composition — we will find plenty of hauyne bearing phonolites in the same highland, covered, however, in most parts by the basalts. I have collected a number of such rocks (1, 9, 14, 35, 122, 127, 134, 137, 183, 185, 190, 191). Some of these were taken either from necks or from lavas which can be traced from them. — Most of these rocks are dark-grayish green (in a fresh state) with glistening tabular feldspar phenocrysts, but evengrained types also occur. In weathered surface the rocks are whitish (cf. *Risco Blanco*=»The White Rock»). Micr. they are all rather identical in composition. Only the texture differs somewhat.

We have to limit our descriptions to a few samples only. No. 9 for instance taken from the north side of the small La Caldereta (1 500 m above the sea level), is of a horizontal lava sheet. Micr. there are strongly corroded hauyne phenocrysts, a greenish pyroxene ($2V\gamma=70°$, $c\wedge\gamma=60°$ — aegirine augite) euhedral sphene and magnetite, the latter associated with the pyroxene. The groundmass is trachytoid.

A chemical analysis of the rock was carried out with the following results:

Analysis no. 15

Sample no. 9 (Hausen 1953) of a hauyne phonolite taken from the northern wall of the small explosion (or collapse-) caldera of La Caldereta, N. of the Quaternary volcano Altos de los Peñonallos.

		Mol. prop.
SiO_2	51.11%	8476
TiO_2	1.64 »	205
Al_2O_3	18.82 »	1841
Fe_2O_3	2.68 »	168
FeO	2.69 »	374
MnO	0.23 »	32
MgO	1.64 »	407
CaO	4.44 »	792
BaO	0.12 »	8
Na_2O	8.72 »	1406
K_2O	4.60 »	488
P_2O_5	0.33 »	23
CO_2	0.00 »	—
SO_3	1.64 »	205
Cl_2	0.37 »	52
H_2O+	1.07 »	594
H_2O-	0.30 »	
	100.40%	
−0 ..	0.08	
Sum:	100.32%	

Norm:

or	27.1	57.5
ab	24.7	
an	5.7	
ne	19.3	
hl	0.6	
th	2.9	
Σ Sal:		80.3
di	9.6	
wo	0.9	
mt	3.9	
il	3.1	
ap	0.8	
Σ Fem:		18.3
H_2O		1
	Sum:	100.0

Analyst: Aulis Heikkinen

Spec. gr. = 2.75 (+23.5°C)

Niggli values:

si = 149, ti = 3.7, p = 0.4, cl_2 = 0.9, so_3 = 3.7, h+ = 10.4, al = 32½, fm = 20, c = 14, alk = 33½, k = 0.26, mg = 0.36, qz = −82, al−fm′ = +12½, al−alk = −1.

C. I. P. W. Classif. — II. 6. 1. 4.
Lardalose
Magma type: lardalitic/tahititic
Mol. prop. % of normative feldspars:
Ab:An:Or = 40:18:42
MgO:FeO = 93:7

Rittmann-parameters for nomenclature:
Al − 16.94, FM − 91 9.17, Alk − 17.68, k − 0.26, an − 0.02, ca″ − 4.88. - Hauyne phonolite.

This lava may be a good representative of the strongly Na-alkaline highland phonolites, to which group El Saucillo and Risco Blanco also belong. (Cf. microphot. 1 and 2, plate VIII).

The lava in question is capped with stratified lapillis and ashes ejected from the nearby Quaternary volcano of Altos de los Peñonallos (cf., fig. 25!) The subjacent rock, which may be the R.N. agglomerate, does not appear in the bottom of La Caldereta.

Los Roques de Tenteniguada

Los Roques de Tenteniguada are most typical necks rising above the general upland surface and attaining c. 1 500 m in height. They all consist of hauyne-bearing phonolites. The rock in the northernmost of the *roques*, El Saucillo, (fig.24) has been studied by E. JÉRÉMINE (1933). A chemical analysis has also been published (for NIGGLI data, see the list p. 375, 3 ○). The feldspar phenocrysts in this rock are sanidine, whereas oligoclase appears in the groundmass.

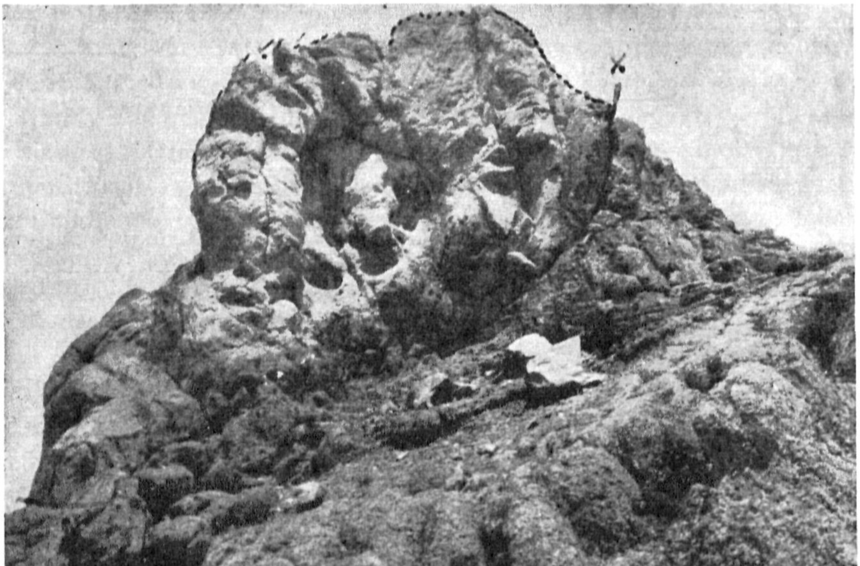


Fig. 24. Roque del Saucillo (1 000 m) standing on the northeastern corner of the central highland facing San Mateo, erosion remnant of a neck of hauynophyre leaning on a basement of the R. N. agglomerate. Looking north.
Phot. H. H—n 1953

Risco Grande de Tenteniguada (fig. 2, plate I), the most outstanding of the *roques* in the mountain panorama here, is largely dismantled by erosion. It is united with the highland border only by way of a narrow crest. The whole neck shows a stately columnar jointing. The rock in this natural tower is either fine-grained or porphyric, with glistening tabular feldspars; the colour is dark gray, but there is a pale-coloured weathering film in the surface. A sample of the former type (127) shows micr. phenocrysts of aegirine augite ($c \wedge \gamma =$ 65°, twins acc. to (100), pleochr. weak), of sphene and a sodalite mineral with a dark border. They lie in a groundmass of feldspar laths (trachytoid texture), aegirine and ore powder. The feldspar is sanidine. The rock may be a tahitite.

These *roques* in the region are 6 in all, if Risco Grande de Tirajana is added. They were probably originally all cumulo-volcanoes, but they have since then been eroded to necks. The lava sheets which issued from them still cover a certain area in the highland, hiding the underlying R.N. agglomerate formation.

Going west from the highland border of Tenteniguada and passing the great cinder cone of Altos de los Peñonallos, we arrive at the northeastern corner of Caldera de Tirajana, near Risco Blanco. The latter is in reality also an ancient throat fill, containing the foid-bearing types just described (cf. page 106, and analysis no. 4!). The border erosion has partly dismantled the fill from its enclosing formations in this place as well.

There are even further occurrences of foid-bearing phonolites in this part of the highland, although these do not appear in the shape of necks. They are simply exposures in the highland ground revealed by weathering and erosion.

There are some of them in the surroundings of Pozo de las Nieves, the highest point of the island (1 950 m). The summit itself is made up of the R.N. agglomerate; this disappears, however, to the north under the cover of younger basalt lavas. The occurrences of the foid-bearing phonolites are outcrops of smaller intrusive masses which have penetrated the agglomerate banks in the underground.

At the end of the road which reaches Pozo de las Nieves (i.e. the *Cumbre* road) is such an exposure of a salic rock of a greenish-gray colour (190). Micr. it shows phenocrysts of alk. feldspar, greenish pyroxene, a sodalite mineral (strongly corroded) and also crystals of sphene, all lying in a trachytoid groundmass. Stray grains of hornblende have been altered. Apatite is an accessory. Ext. angle of the pyroxene $c\wedge\gamma=63°$. Twins acc. to (100) are seen. There is a tendency to a zonal structure. The sodalite mineral has a blue border zone but the kernel is grayish. The alk. feldspar is clear (sanidine). The lava may be designated a tahitite.

A similar rock type is met with somewhat to the east of Pozo de las Nieves, exposed in a flat ground. It seems to be a similar intrusive mass in the R.N. agglomerate which forms the immediate ground here. The sample available is grayish-green (191) and has relatively large glistening alk. feldspar phenocrysts, sodalite crystals (corroded), aegirine augite ($c\wedge\gamma=60°$) and sphene in a trachytoid paste.

This occurrence lies rather close to the border of Caldera de Tirajana, and the cover of basalts does not reach this point.

If we go west from Pozo de las Nievas and follow the border of Caldera de Tirajana, we will find another intrusive mass of the foid phonolites intercalated in the R.N. agglomerate banks. This rock (183) is micr. an ordanchite with phenocrysts of *Na-Ca*-plagioclase, a sodalite mineral, pyroxene, brown hornblende, sphene and magnetite in a groundmass filled with feldspar rods. The optics of the chief minerals are:

Plagioclase:	Opt. char.+, ind. of refr. >1.54, twins acc. to the Karlsbad law. Comp.: An/35–40%
Pyroxene:	$2V\gamma=70°$, $c\wedge\gamma=44°$ (augite)
Brown hornblende:	$2V\alpha=63°$, $c\wedge\gamma=9°$ (basaltic hornblende)

Finally we must mention a great dike of a rock of lamprophyric nature (185), occurring with N–S trend in the highland somewhat to the east of the path that leads straight across the highland from Caserio de la Plata to Las Lagunetas. The dike crosses the R.N. agglomerate. Micr. there are well-developed laths of plagioclase, crystals of a greenish pyroxene, of brown hornblende, sphene and magnetite and also small crystals of a sodalite mineral. All these lie in a paste consisting of feldspar rods, pyroxene grains and ore powder. Apatite appears as an accessory. The paste looks rather dark between +nic. (analcime?). The plagioclase laths are twinned acc. to the Karlsbad and the albite laws. Opt. char.+, ind. of refr. >1.54. It may be an andesine. The greenish-gray pyroxene is euhedral with ext. angle on (010) $c\wedge\gamma=47°$ It is associated with magnetite grains. The sodalite mineral is yellowish at the borders of the crystals, the kernel is colourless. The rock may be designated a camptonite, certainly associated with the tephritic lavas which alternate with the banks of the R.N. agglomerate.

To the east of Degollada de los Hornos, not far from the northern edge of Caldera de Tirajana (the path to Las Lagunetas over the highland), there is a sheet of a grayish lava embedded in the R.N. agglomerate (186). Micr. it has very sparse phenocrysts, some hornblende prisms and sodalite grains (small) in a fine-grained paste of feldspar laths, pyroxene prisms, sphene, ore and zeolite. The texture is not trachytoid. The brown hornblende is pleochroic (α-yellow, γ-brown). Ext. angle on (010) $c\wedge\gamma=20°$. The small prisms of hornblende occurring in the groundmass are completely altered to opacite. The lava is a trachytephrite.

Later volcanic manifestations in the central highland (eastern part)

Altos de los Peñonallos (1 850 m abs. height).- On the stretch between the 'semi-caldera' of Tenteniguada and Caldera de Tirajana, there rises the relatively large cone with the name above, consisting of slags and lapillis. The cone has to some degree been eroded, chiefly on its western flank, and the basement has here been disclosed (hauynophyre, no. 14). The volcano has sent a lava stream down the right headarm of Barranco de Guayadeque (see fig. 26, page 285). This lava (to some degree already decomposed by weathering) is an olivine basalt (60). Micr. it shows clear, euhedral phenocrysts of olivine, representing the first gen. of components. Next there are prisms of augite, partly in the I gen., but chiefly in the groundmass, in which it is mingled with plagioclase (very restricted) and magnetite (as smaller isometric grains). The lava is a picritic basalt. The cone may be from the Quaternary age, superimposed on the hauynophyre lava beds (in their turn lying on R.N. agglomerate).

La Caldereta — Only 1 km to the north of the volcano just described is the small collapse-caldera of La Caldereta, of c. 250 m in diameter and having a depth of c. 50 m. It lies in the hauynophyre (9) lava which is exposed in the north vertical wall (see fig. 25). The bottom of the caldera is covered with sand and gravels; at the foot of the steep sides there are blocky talus masses. — Covering the hauynophyre lava are layers of volcanic sand and lapillis, apparently ejecta from the volcano nearby. It seems that La Caldereta is a collapse-hollow due to the withdrawal of magma from below to the neighbouring volcano (?).

Caldera de los Marteles. — This is one of the more spectacular negative volcanic forms in the island. It is relatively seldom

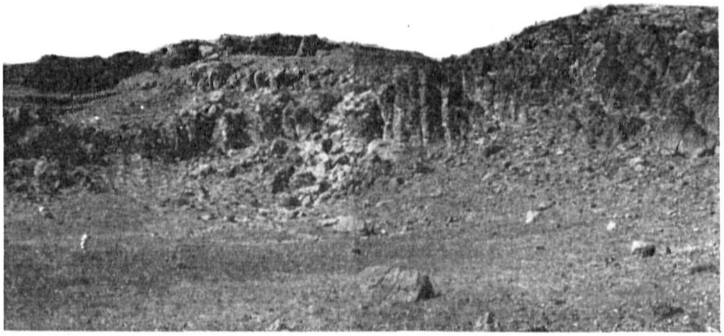


Fig. 25. Central part of the small collapse caldera La Caldereta, situated c. 1 500 m above sea in the central part of the island north of the Quaternary cinder cone Los Peñonallos. Looking west. The walls consist of hauynophyre capped with layers of olivine basaltic scoriae and lapilli.

Phot. H. H—n 1957

visited by foreigners or even by Spanish travellers, owing to its remote and elevated situation (1 500 m). A photograph of the caldera is partially seen in fig. 26. The caldera can be reached by following the *Cumbre*-road to its last bend (toward Pozo de las Nieves) and then by taking a field path leading to C u e v a s B l a n c a s.

Caldera de los Marteles is situated in the left head-arm of Barranco de Guayadeque, and consequently it is of a later period than the erosion of the valley. The bead-*barranquillo* can be followed uphill for a long distance in the highland ground, but it has almost the shape of a rather shallow gorge with an open cross-profile. Here a water storage dam has been constructed which crosses the gorge somewhat north of the caldera. The caldera is limited to the south by a bar or ridge of black lapilli and slags; in the west there is a steep wall of slaggy volcanic material representing the cross-section of a cinder cone. In the north and in the east there are cliffs of older volcanics.

The dimensions of the caldera are: diam.: 600 m, depth 50—200 m (the heights of the walls are very varying). The bottom is plain, alluvium-covered.

I think the only explanation of the origin of this hollow is to assume an explosion of the cinder cone which once occupied the place of the caldera, and which then collapsed: the caldera is the negative remains of an once existing cone, of which the south flank is seen, and of which the western half has also been preserved.

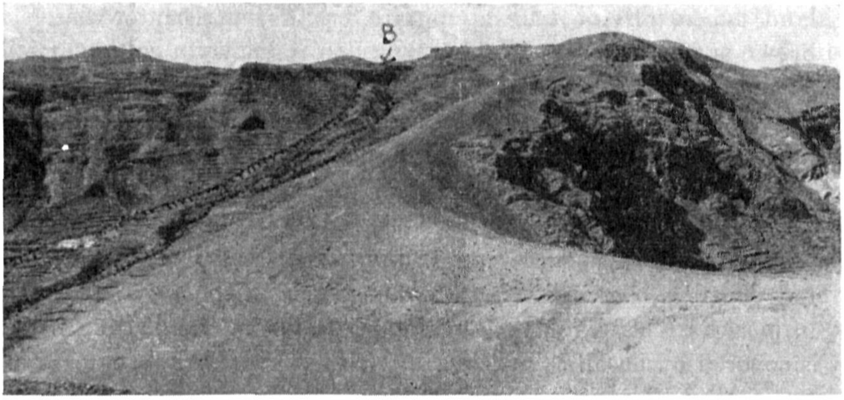


Fig. 26. Southern rim of Caldera de los Marteles, eastern side of the Cumbre region (c. 1 500 m above sea). This ridge consists of lapillis. To the left, the right head of Barranco de Guayadeque. Looking west. B: olivine basalt lava tongue.
Phot. T. BRAVO

Except for the volcanic manifestations characterized above, there are no other vents of a more recent age in the central highland. The extensive basalt lavas in Llano de la Paz have been emitted from vents no longer preserved in the topography. These lavas are, as we have already supposed, of an older age (they are fissure eruptions, judging from the presence of great dikes). But the lava sheets connected with these dikes have long ago been abolished by erosion.

As we have found the geology of this elevated central part of the island has a rather complicated structure, best exposed in the escarpments confining the highland on almost all sides. These good geological profiles have already been described in the preceding chapters dealing with the different sectors of the island. Inside the highland there are only insignificant scars or ledges showing little of the underlying rocks, owing to the fact that the young gorges have not reached far enough into the area, except in two cases: Barranco de Guayadeque and Barranco de la Culata. The former canyon despite its length, has not gone deeply enough below the basalt series of the highland 'armour plate'. Barranco de la Culata on the other hand, gives a somewhat better insight into the pre-basaltic rocks.

Between Llano de la Paz and the pass of Cruz de Tejeda runs the highland border, at the same time the dividing line between the Tejeda and the Guiniguada drainage areas. This ridge consists of basalts of the highland types (olivine basalts, picrite basalts) with intercalated red and brown tuffs. Many of the thick lava banks display a columnar jointing. Several dikes intersect the series standing almost vertically. A relatively young cinder cone has grown up on the watershed and it has sent a lava stream down to the canyon of Rio de Tejeda (see map fig. 8).

Degollada Cruz de Tejeda ((elevation 1 500 m) is a narrow saddle formed ridge, on which the tourist inn of C. de T. is situated. It is evident that this saddle-pass in the nearer geological future will be lowered progressively owing to head water erosion that is going on from two opposite sides. The R.N. agglomerate forms the basement here, but is covered by basalts.

The northern promontory of the central highland

The geological conditions inside this relatively restricted area do not vary much. On the surface there are mostly olivine basalts belonging to the post-Miocene effusions with their tuff layers and intersecting dikes. But under this cover there are other lava rocks appearing in some of the (radiating) *barranco* cuts, and especially in the gigantic precipices facing Caldera de Tejeda. Such rocks are foid-bearing phonolites. These — forming flat lying sheets — lie on a basement of the R.N. agglomerate (as the Caldera wall demonstrates).

Some cinder cones of a more recent age have also been found in this area.

In the hills rising to the north of the Tejeda pass there are basalts which, judging from samples, do not belong to the olivine bearing basalts. No. 605 is of a tephritic composition without olivine but containing euhedral phenocrysts of augite and also plagioclase lying in a groundmass of plagioclase laths, augite and ore (plenty). Optic data are as follows:

Plagioclase: $2V\gamma = 77°$ (average of 5 det.). $\alpha' \wedge (010) =$ $33°$ (average of 6 det.) Comp.: An/56.
Pyroxene: $2V\gamma = 51°$ (average of 6 det.). Zonal, $c\wedge\gamma = 60° - 45°$ (augite)
Apatite is an accessory constituent.

This lava belongs to a series of volcanics which compose an entire hill, and numerous brown tuff layers are interstratified here. The hill may be a protruding part of the basal complex underlying the post-Miocene basalt lavas.

To the west of this hill rises a higher ground, the highest in the whole promontory, culminating in Morro de los Moriscos (1 750 m). The rocks here apparently consist of the post-Miocene basalts, olivine bearing and picritic in composition. They are crossed by several dikes of lamprophyres. — In Morro de los Moriscos there appears in the culminating part a great dike of basalt standing vertically. Its trend is NW—SE. Its presence indicates the former expansion on levels above the present surface of lava sheets now removed by erosion. One sample of the dike (500) is a picritic basalt, with olivine and augite in the first generation of components. In the groundmass there is plenty of augite with magnetite and very sparsely of feldspar.

The superficial basalts in Morro de los Moriscos do form a kind of carapace to the underlying formations, which consist of phonolites, R.N. agglomerates and tephritic lava intercalations in the latter. These under-complexes come to sight in the great precipices of the Caldera nearby. But also in other sides of Morro de los Moriscos erosion scars have brought exposures of the basement (chiefly W and N slopes).

There are several samples of foid-bearing phonolites in the author's collection (499, 548, 649, 650, 657, 658, 659, 662). Most of them represent outcrops near the border on the Caldera along a stretch from Artenara to opposite Roque Bentaiga (which stands on the S side of the Caldera). Some samples are from the west flank of Morro de los M. The types differ in many respects from the hauynophyres of the central highland (N of Caldera de Tirajana) with their necks. The former will here be briefly characterized.

A common feature under the micr. is the poverty of phenocrysts in relation to the groundmass, which is very fine-grained and seldom with a trachytoid texture displayed. Moreover the dominating phenocrysts are of the mafic kinds, — being brown hornblende and a clinopyroxene, whereas feldspars in laths are relatively sparse — they are confined to the groundmass. A sodalite mineral occurs also, sparsely, however, but belongs to the I gen. of components. Sphene is commonly present in crystals associated with the mafics. — Most of the types may belong to the phonolites — or to the hornblende phonolites.

No chemical analysis has been carried out of this material.

We may limit our descriptions to only two samples (649, 650). No. 649 is from the northern edge of the Caldera, and it is associated as a lava bank with an underlying R.N. agglomerate. Micr. it shows plagioclase, crystals of aegirine augite, of brown hornblende, of a sodalite mineral, and also of sphene. They lie with magnetite grains in a groundmass of feldspar microlites and tiny prisms of a pyroxene (aegirine) and powder of iron ore. Optics of the chief minerals are:

Plagioclase:	$2V$ (not det.) max. angle of ext. in the zone $\perp$ (010)=22°, opt. char.+(andesine)
Pyroxene:	$2V$ (not det.), $c\wedge\gamma=54°$ (aeg. aug.)
Brown hornblende:	($2V$ not det.), $c\wedge\gamma=10°$

The other sample (650) is also from the proximity of the northern edge of the Caldera. (N 30° E fr. Roque Bentaiga). Micr. it has phenocrysts of alk. feldspar, a sodalite mineral, a pyroxene and a brown hornblende and also sphene. They lie in a fine-grained trachytoid groundmass, powdered with ore. The feldspar rods in the paste are in an altered state. Ext. angle of the hornblende $c\wedge\gamma=15°$, pleochr.: α-yellow, γ-dark brown. Cavities in the paste are filled with an isotropic substance (opal). The rock may be a rather ordinary trachy-phonolite.

About the extension of these salic lava in the highland N of Caldera de Tejeda there are few data available. They may be contemporaneous with the foid-bearing phonolites in the central highland and belong to a period of volcanic activity which succeeded the great Peléean eruptions which deposited the R.N. agglomerates.

Later volcanic activity

In this part of the highlands (above the 1 500 m contour line) there are some volcanic manifestations of relatively recent age to be briefly mentioned. Montañón Negro, a coke-black cone, stands on a basement at c. 1 500 m altitude, overlooking the head region of Barranco de la Virgen. It has a crater open to the northeast. From here,blocky, glassy lavas have poured to the north, finding their way down into a head-*barranco* to Barranco de la Virgen, as we already have found (page 260). Bombs and lapillis have been scattered over the slopes of the highland in the south, demonstrating the existence of northerly winds during the eruptions. A sample of the glassy lava (496) contains micr. olivine, augite and plagioclase in clusters. The lava may correspond to a picritic basalt.

Considering the fresh appearance of the cone and of its lavas, bombs and lapillis, we may assume that it belongs to the late-Quaternary or sub-Recent period of activity. It is a rather solitary cone standing wide apart from the assembly of adventive cones in the northern declivities of the island, and it differs also considerably in elevation above the sea level.

P i n o s d e G á l d a r is the name of a relatively small explosion crater-caldera surrounded by walls of slaggy material. Inside these walls are almost vertical. It lies not far from Montañón Negro at an elevation of 1 460 m. The highroad to Artenara passes nearby. No samples of the slags were taken. A stream has gone down a *barranco* to the north for a longer distance. E. JÉRÉMINE (1937) mentions this lava. It is a limburgite with micr. plenty of olivine and augite crystals in a glass basis dotted with opaque powder. The authoress compares this lava to a lava issued from the volcano Montaña Cabrera in the vicinity of San Mateo.

* *
*

T o s u m m a r i z e the geologic conditions in the main area and in the promontory of the highland, we can state that the most extensive formation met in these regions is that of the olivine basalt lavas of presumably post-Miocene age. The thickness varies, however, and in places the basalts are completely lacking. In such cases the underlying rocks come to show in the shape of phonolites. The origin of basic effusions may have been in the area now occupied by the Caldera, but undoubtedly many fissures have also contributed with effusions of lavas (Morro de los Moriscos, great dikes on the stretch between Cruz de Tejeda and Pozo de las Nieves).

The foid-bearing phonolites under the basalt cover also appear as necks (region of Tenteniguada). The phonolites lie above the R.N. agglomerate formation with its interfingering tephritic and basanitic lavas. About the situation of the vents of all these eruptions there is much uncertainty. The formation of Caldera de Tejeda has to a high degree disturbed the original relations. We will discuss these questions in Part II (Systematic geology).

Latest manifestations of endogenic nature in the area are the picrite basalt lava eruptions in some restricted areas.

11.

Caldera and Barranco de Tejeda

Caldera de Tejeda
as a topographical manifestation
(see the map fig. 27)

This so called »Caldera de Tejeda» which is in fact no *caldera* in the sense used by the volcanologists, is without doubt the most remarkable landscape feature is the island, surpassing with its wild gorges and mountain walls that of the other great depression — Caldera de Tirajana. It can without exaggeration be called one of the wonders of Nature. It has attracted innumerable visitors, not only mountaineers and common tourists, but also scores of naturalists, among them geologists. The first among the explorers of the last named category was L. VON. BUCH in the year 1815. Since then a great number of geologists with fame have seen it and expressed their opinions about the processes which have contributed to the formation of this enigmatic hollow. We will not recapitulate here the various opinions; they are quoted in a summary on »*Canarian Calderas*» recently published by the author (1961).

I have spent a considerable time to the study of the »*caldera*» and of its environments, and as a base of operations I did have the advantage to use the tourist inn Parador nacional Cruz de Tejeda, run by the Island Government (altitude 1 500 m). A great number of samples of the rocks exposed in the sides of all the gorges and in the crests were collected. Nevertheless the results have not been made complete owing to the roughness of the area, the lack of detailed maps and the time to my disposal. The field work has to be continued, also the laboratory experiences need to be considerably augmented.

»Caldera de Tejeda» is in general used to designate a broad valley with steep sides stretching — a gigantic abyss — 16 km due west from the divide at Cruz de Tejeda. Its bottom is occupied by the gorge of Rio de Tejeda which begins in the head arm of Rio de la Culata. The valley is confined on all sides by mountain walls. Only in the west there is a narrow gate which leads the river further on to the sea — crossing a mountain barrier that lies in the way. The Tejeda valley is consequently not an ordinary mountain valley — it is a depression disclosed in the west by the mentioned water gap. It is evident

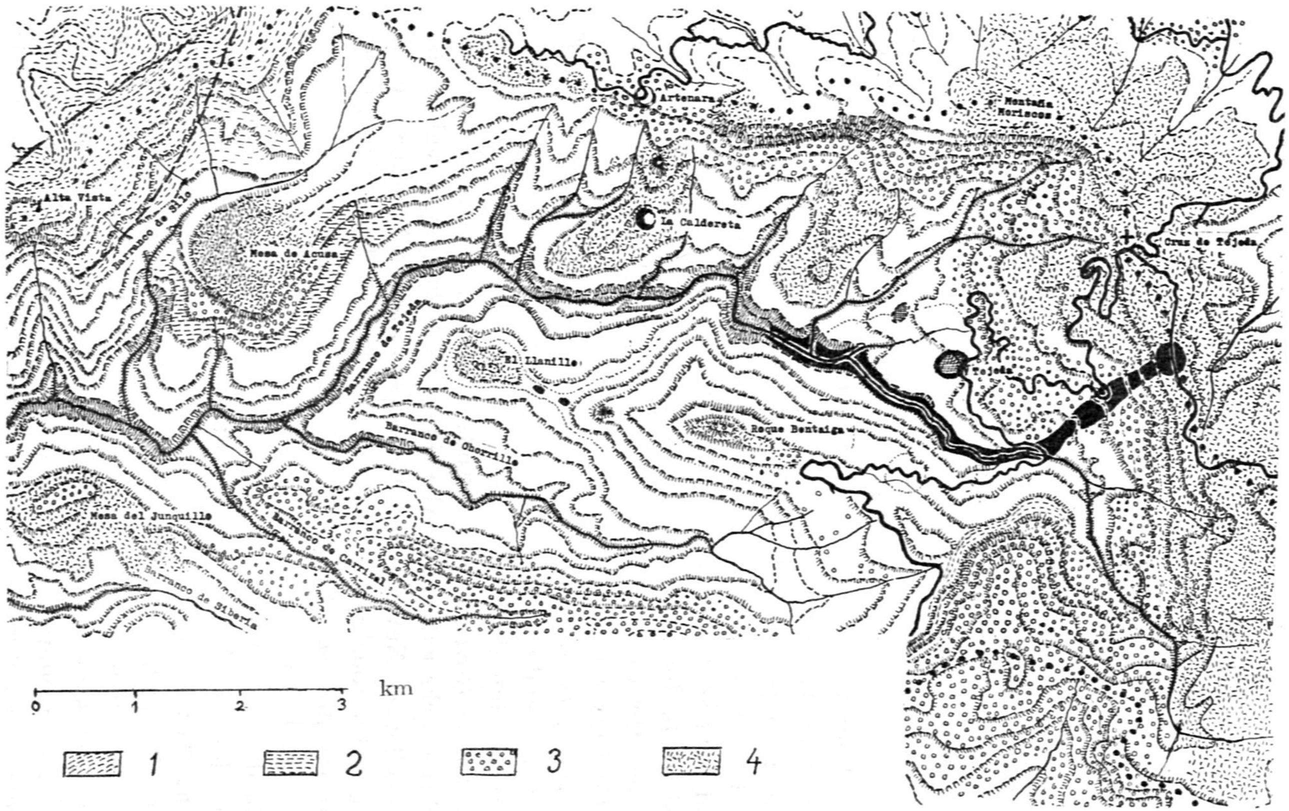


Fig. 27. Topogr.-geol. map of Caldera de Tejeda with contour lines of 100 m. White areas: exposures of the oldest dislocated trachytes. 1 — rhyolites/trachytes of Alta Vista (upper corner, left), 2 — phonolites of the Roque Nublo platform and Mesa de Acusa, 3 — The Roque Nublo agglomerate formation (including alk. basalts), 4 — olivine basalt lavas. Black train to the right: young basalt lava stream.

that the river erosion cannot be the real cause to the excavations in the island structure here. Other factors must have been involved too.

The Tejeda valley is not, however, a single gorge: it receives from the left some tributary gorges: Barranco de Chorrillo, Barranco de Carrizal and Barranco de Siberio, whereas from the right side there are only some insignificant *barranquillos:* Barr. del Rincón and Barr. de los Silos. We will find from these circumstances — also from a study of the topographic map — that the expression »Caldera de Tejeda» does not cover the area comprised by the Tejeda drainage area which is much wider in circumference. The southern divide of the latter runs along the crest line of Cordillera del Horno (as we already have seen).

The land forms which dominate in the Caldera are due to vigorous erosion aided by the weathering effects. This deeply reaching incision has created differences in altitude of c. 1 000 (on short distances). The development of the whole gorge system in the Tejeda drainage area has been made possible by the opening of the cross-going canyon in the west. We will later on to some extent discuss this rather peculiar hydrographical anomaly.

The great excavations brought about by the river system in the Tejeda depression with transport of enormous masses of stone material and sands along the gorge to the coast in the west must as it seems belong to a sub-Recent and also to a somewhat earlier period. In our days there is scarcely any running water in the bottoms of the gorges (except during occasional cloud bursts in winter time). Instead mechanical and also chemical weathering in the mountain sides, are going on. There are great masses of scree in the slopes originated in the decaying rock precipices.

In the following pages we will try to examine the geology inside the depression drained by Rio de Tejeda and that of the tributaries. We will begin with the »caldera» in the proper sense, i.e. with the sides of the Tejeda valley: the east, the south and the north sides of it. Then we will loak at the conditions along the gorge itself (the deeper lying parts down to the western limit of the depression. Further we will treat the rock exposures found along the cross-going gorge which ends in the gravel plain of Aldea de San Nicolás de Tolentino (not far from the coast). — Finally we will devote some words to the genesis of Caldera de Tejeda, in the same short terms as has been done with Caldera de Tirajana.

We will start with the east slope and with the adjoined gorge of La Culata — the head of the master canyon of Tejeda.

The eastern slopes of the Caldera, reaching from Barranco de la Culata to Barranco del Rincón

According to the (relatively few) rock samples from this sector of the great circumvallation, the upper slopes mostly consist of basalt lava beds and intercalated red and brown tuff layers. To those may be added many intersecting dikes of basaltic or lamprophyric nature. Lower down the slopes, great masses of the R.N. agglomerates dominate; these are also crossed by sets of dikes. Still lower down, near Villa de Tejeda, one meets dikes and also smaller intrusive bosses of pale-greenish porphyric phonolite rocks. In short there are many variations to be seen, on the stretch for example between Cruz de Tejeda (1 500 m) and Villa de Tejeda (c. 800 m).

If we first look at the covering basalts of the crest and hills in the region of Degollada Cruz de Tejeda we will find a succession of basalt lava banks with intervening brown tuff layers, in parts of great thickness. NE. and N. of the pass there are types represented by nos. 605, 624. The former consists of an olivine-free basalt lava with well developed crystals of augite and also laths of plagioclase and grains of magnetite. They lie in a fine-grained paste rich in augite and ore. It may belong to the tephrites — associated with the R.N. agglomerate in the basement.

There are long exposures of basalts along the highroad to Villa de Tejeda (c. 1 km in southerly direction). They seem to be tephrites also. One sample (67) consists micr. of augite and hornblende phenocrysts in a paste of plagioclase, augite and ore with apatite as an accessory. The optics of the chief minerals are:

Pyroxene: $2V\gamma = 51°$, $c \wedge \gamma = 45° - 58°$ (zonal) (average of 6 det.)

Brown hornblende: $2V\alpha - 70°$, $c \wedge \gamma = 10°$ „ „

Another sample of a basalt lava from a higher level in the same slope is an olivine basalt (56) belonging no doubt to the post-Miocene effusions of the highland. It contains phenocrysts of olivine (clear) and augite in a rather dark groundmass of a basaltic texture, in which the share of plagioclase is very small. Hence the composition of the rock is more picritic like that of the basalts, lavas and dikes in the Central highland.

To the south of the first bend of the Tejeda highroad towards Barranco de la Culata is a black lava stream which has flowed down from the crest to the Tejeda canyon. It is a typical olivine basalt (36) of the more picritic kind, but it belongs to a younger generation than the highland basalts.

From Degollada Cruz de Tejeda an old trail runs straight down to Villa de Tejeda (used in times before the winding highway was built) and it follows a ridge which becomes lower in that direction. Here is a drop of c. 500 m along the broad promontory jutting out into the Caldera from the east side. The upper parts of this ridge consist of basalts. One sample (28) from an altitude of c. 1 300 m consists micr. of olivine and augite in a dark groundmass, in which augite and magnetite dominate, whereas feldspar is present only in trifling amounts. The composition is picritic (or ankaramitic). The lava shows likeness to the highland basalts, and it seems to the author these lavas in the superficial parts of the ridge may be flows of the post-Miocene series, already rather eroded. It is not impossible that later subsidences have brought the basalt banks of the ridge into a lower position in relation to the highland basalts. — When following the trail further down towards Villa de Tejeda, one will find that these basalts come into contact with the R.N. agglomerates. These dominate in the lower parts of the ridge (the end of the promontory).

* * *

An interesting phenomenon in these slopes of the Caldera is the swarm of l a m p r o p h y r i c d i k e s, traversing the basalt series but also the underlying R.N. agglomerates. Some of them were mentioned by J. Bourcart (1937) and schematically indicated in the geological map accompanying his paper.

The best opportunity to study these dikes is along the above mentioned trail down to Villa de T., or along another very steeply lowering path from the *degollada* to the small settlement E l R i n c ó n. The dominating types seem to be composed, according to a rather sparse material (samples nos 10, 14, 17) of olivine-free rocks containing augite and brown hornblende as phenocrysts and (in one case) plagioclase laths and crystals of magnetite, lying in an iron-rich groundmass filled with pyroxene and magnetite powder and microlites of feldspar. The pyroxene crystals are pale-lilac, well developed, the hornblendes are rounded by corrosion. If present as phenocrysts, the feldspar is labradorite. A mesostasis consists of a colourless, isotropic substance. The augite has ext. angle on

(010) $c \wedge \gamma = 52° - 62°$ (augite with some of the aeg. mol.). The composition of these dikes seems to be chiefly pyroxenitic.

The exact geological position of these lamprophyric dikes is somewhat uncertain. It seems that they must have something to do with the tephritic magmas which erupted in the time span of the R.N. agglomerate depositions and formed the numerous sheets interfingering with the agglomerate banks. The lamprophyres are without doubt older than the post-Miocene olivine bearing (picritic) basalts in the highland nearby.

The lamprophyric dikes run in different direction —, in much cases N—S, and their position is steep or vertical. They offer a stronger resistance to the erosion than the surrounding ground, hence they appear as walls or small crests showing a beautiful prismatic jointing with axis lying perpendicularly to the sides of the dike.

In the same eastern part of the Caldera there appear also s a l i c d i k e s, and the author has a few samples of them (616, 639). — The former will be described later on under the heading Barranco de la Culata. Sample no. 639 is of a dike of larger dimensions, — it belongs more closely to the southern side of the Caldera, and will be mentioned in this connection. — These dikes may be of a later geological-age than the lamprophyres. They are as it seems to the author, contemporaneous with a number of smaller s a l i c i n t r u s i v e b o s s e s met in the R.N. agglomerate formation in the surroundings of Villa de Tejeda. These rocks are phonolites, distinctly porphyric and of a pale-greenish colour. In them feldspar phenocrysts (almost white) give a spotted aspect.

These small intrusive masses are obviously the roots of smaller feeding channels of phonolite magmas once rising to the island surface and spreading on it in the shape of sheets. The conduit filled with lava has in several cases been left standing as a neck. Such phenomena have already been described from the eastern part of the highland. Here, in the depression of Tejeda, erosion has laid bare the roots of these conduits, and it is shown how they have forced their way up across the mighty masses of the R.N. agglomerates.

As it was mentioned the most common type of these hypabyssal rocks is of a pale-greenish to gray colour and with a distinctly porphyric aspect thanks to the presence of the white spots of feldspar of broad rectangular shape, enclosed in a fine-grained paste. The mafic components are macroscopically visible as dark-greenish spots in the paste. The types are rather fresh thanks to the energetic erosion which is going on in the slopes — accompanied by screes.

The author has a few samples of these intrusive rocks (21, 619, 620, 623). No. 21 is from a slope immediately above T e j e d a. Micr. it contains euhedral (clear) phenocrysts of an alk. feldspar, a greenish clinopyroxene, sphene and a completely altered euhedral mineral of the sodalite group. They all lie in a matrix consisting of tiny (clear) feldspar laths, greenish aegirine and a grayish-brown isotropic mineral which may be altered nepheline (?). The alk. feldspar of the I gen. has not been investigated in more detail (ind. of refr. <1.54, opt. char. —); it may be sanidine. The pyroxene has ext. angle on (010) $c\wedge\gamma=56°$ (aeg. augite). It is bordered by a green shell of aegirine and encloses small prisms of apatite. The sodalite mineral has well-preserved crystal outlines; the mineral however, is, completely replaced by a colourless, fibrous mineral in bundles (natrolite?). The rock is a phonolite, rather altered. The pores in the matrix are filled with a colourless, isotropic substance (analcine?).

No. 619, from l a C r u c i t a (N of Tejeda), is a rather similar phonolite type with altered sodalite min. — No. 620 is from a loose boulder transported from the upper region in the southeast (see below). No. 623 is from a big scree by the side of the highroad between Tejeda and the bridge at L a C u l a t a. A rather large exposure of a pale-grayish-green phonolite has been formed here. Micr. the rock shows a beautiful porphyric texture with phenocrysts of an alk. feldspar (plagioclase), a sodalite mineral, a clinopyroxene, brown hornblende and sphene. Apatite and ore are accessories. The matrix shows a trachytoid texture with small feldspar laths, nepheline (?) grains and aegirine prisms, the latter corona-like surrounding grains of (altered) nepheline (?). The sodalite mineral is zonal with a kernel filled with a brownish grid. The feldspar of the I gen. is a plagioclase with polysynthetic twinning, but surrounded by a shell of orthoclase. The matrix is filled with small feldspar laths in random orientations, sometimes trachytoid. The rock is a phonolite, or (if we accept the nomenclature of A. LACROIX) an ordanchité.

These rocks belong to a distinct phase in the volcanologic development of the island, and we will get opportunity to discuss the matter in Part II of this memoir.

Barranco de La Culata

By this name we understand the upper course of Barranco de Tejeda from its sources in L l a n o d e L a P a z to a point where the *barranco* joins a right tributary canyon — Barr. del Rincón. The junction is somewhat below Villa de Tejeda at an altitude of c. 700 m.

Barranco de La Culata is of some interest since it discloses to a great depth the inner structure of the socle of the highland to some extent. The author has devoted some days to investigate the conditions here and collected samples of rocks. Since the topographic obstacles are in parts rather difficult to overcome further studies are needed here.

Barranco de La Culata begins at an altitude of 1 750 m at the rim of Llano de La Paz. Here, at a point where the gorge begins to drop, a dam for recovery of water has been constructed. Below this the bottom lowers rather suddenly, and wild erosion forms have been created representing a new erosion cycle penetrating into the old highland ground which is, as we have seen, a part of an old surface of maturity.

The lower course of the gorge has been incised into an old fundament of pale — almost whitish colours representing a complex of weathered salic lavas and tuffs, and these seem to have been tilted into a vertical or strongly inclined position. They form the basement to a thick series of flat lying agglomerates, conglomerates and sandstones well displayed in the sides of the gorge. To the left the precipices lead up to the Roque Nublo platform also consisting of the R.N. agglomerate, here, however, lying in a higher position. In the right side of the *barranco* there are great profiles of (from the bottom): dislocated trachytes, agglomerates,

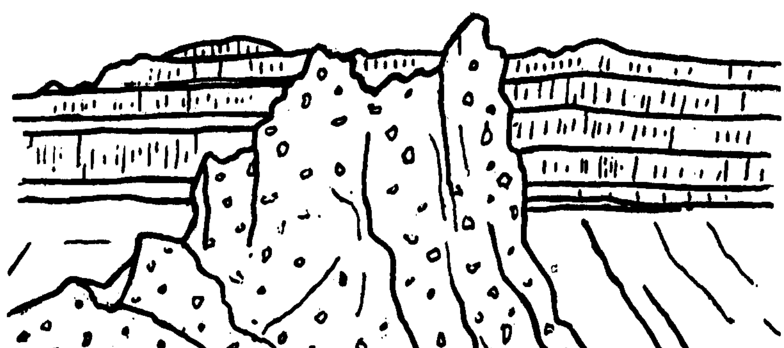


Fig. 28. Erosion pinnacles formed in strongly dislocated R. N. agglomerate banks in Barranco de la Culata (Tejeda area) standing against the post-Miocene basalt lavas of the central highland. Looking east.

Field sketch by H. H—n

conglomerates and sandstones, and (at the top) a mighty series of flat lying basalt lavas and tuff layers. One can discern here at least 7 different sheets of lavas, and they represent the western border (or ledge) of the basalt covered highland. A former continuation into the present area of Caldera de Tejeda seems obvious.

In the middle course of Barranco de La Culata there are some peculiar rock masses (see fig. 28) being in an almost vertical position and consisting of banks of an agglomerate crossed by lamprophyric dikes (comm. by BRAVO). I have seen it only from a distance but I have wondered about what has caused this tilting. Maybe that we here have one of the points of issue of the Peléean eruptions (and explosions) which has spread the agglomerate deposits over the island?

An important geologic feature is the plane of unconformity that separates the basal trachytes from the capping series of sediments and basalts lavas. In Part II we will discuss the significance of this structural feature.

If we now look somewhat closer at the large exposures of the R.N. agglomerates and the accompanying layers of conglomerates and sandstones seen along the right side of the gorge, the conditions are rather interesting indeed (cf. with fig. 1, 2, plate VII). The total thickness of the series has not been measured, but a rough estimation gives c. 100 m.

The outcrops of the flat lying series of the mentioned rock members indicate the former continuation to the west of them; but this continuation has been destroyed by vigorous erosion. More of the sediment series would have disappeared without the presence of the protecting cover of the tough basalt in the top. — It is evident that the deposition of the detrital material was going on in a time antedating the formation of Caldera de Tejeda.

The presence of the conglomerates and the sandstones in concordant layers is also a remarkable fact. According to the author they represent fluviatile deposits, — assorted (reworked) R.N. agglomerate material.

Petrographical characteristics

Nos. 598, 607 and 622 of samples from Barranco de La Culata belong to the covering post-Miocene basalt sheets which top the agglomerate and conglomerate deposits. These lavas are all olivine-bearing, picritic basalts with olivine and augite as constituents of the I gen. Plagioclase is sparingly present and is confined to the groundmass, here mingled with augite grains and magnetite, the latter in abundance. — The intervening tuff layers are brick-red or brownish and stratified. Springs of clear water are to be seen in connection with these intercalations. The banks of lavas are of varying thickness, and in some of them a columnar jointing is well perceptible.

In addition to the basalt lavas there are also l a m p r o p h y r i c d i k e s in a more or less vertical position. Many of them seem to emerge from within the basement of the decomposed trachytes. Of samples corresponding to these lamprophyres (16, 615, 621) all are olivine bearing types, showing micr. phenocrysts of olivine and augite lying in a groundmass of augite and magnetite, whereas feldspar seems to be present in trifling amount. Instead there is an isotropic substance, maybe glass. This type shows a similarity to no. 602, also a dike rock, which occurs in the highland to the east.

No. 615 is of a dike with N—S trend and vertical position crossing the agglomerates. The dike has a *flat lying parting into prisms* which lie perpendicularly to the walls. Micr. the rock shows euhedral phenocrysts of olivine and augite, the latter partly in clusters. The olivine crystals have deep embayments owing to corrosion. There are also relatively large magnetite octahedrons. The groundmass consists of augite and ore and some dark isotropic substance (glass?); plagioclase cannot be seen in the slide. The dike rock may be limburgitic, rich in iron ore. — No. 621 is likewise of an ultrabasic type with olivine and augite and ore as the essential minerals, but here grains of a sodalite mineral are seen (sparsely). Feldspar is not present. Vesicles are filled with calcite, the walls being lined with chalcedony, however (»pepper and salt« str.).

No. 16 was taken of a tholoid which has been left standing in the slope rising above a ground of agglomerate. It is also an olivine bearing lamprophyre with olivine and augite in the I gen. of components the groundmass being filled with augite together with magnetite. No feldspar is visible. Instead there are isotropic, turbid patches, maybe of glass subst.

There are certainly much more of similar basic dikes in the region crossed by the canyon.

Apart from these mafites there are also many d i k e s o f a s a l i c c o m p o s i t i o n. Few samples are available, however. No. 616 is of a relatively large dike in the left side of Barranco de La Culata. It crosses a bank of the R.N. agglomerate. The trend of the dike is here NE—SW, and its position is vertical. Micr. there are broad laths of an alk. feldspar showing Karlsbad twins and opt. char. —, clinopyroxene, brown hornblende in elongated prisms, sodalite and sphene. These minerals of the I gen. lie in a paste filled with feldspar laths in the trachytoid arrangement. There are also small grains of iron ore. The pores are filled with a colourless, isotropic substance, except in the centre which is occupied by carbonate. The dike may be a phonolite.

Southern rim of Caldera de Tejeda with Roque Nublo

If we now leave Barranco de La Culata, going downstream we enter the master *barranco* of Tejeda. The steep left side of it is at the same time the southern side of Caldera de Tejeda in a proper sense. The Tejeda *drainage area* is on the other hand much wider comprising the left hand tributaries of the Chorrillo, Carrizal and Siberio.

This time we may limit ourselves to the left wall of the canyon of Tejeda leaving the more southerly region to another occasion. —

This southern wall can most conveniently be studied along a military road which runs from Villa de Tejeda to Ayacata, climbing the slope obliquely. The author has collected some samples on this way. They will be shortly described in the following (samples nos. 586, 588, 590, 591, 594, 626, 627, 634, 635, 636, 639). They refer to the stretch of the road between the gorge of La Culata (bridge) up to the divide at Barranco de Chorrillo, where the road makes a sudden bend and then runs east to the foot of Roque Nublo, then turning south to Aserrador.

The author followed also the slope more to the west on high levels. Few samples were taken on this stretch (cf. farther on!).

Finally also the great monolith of Roque Nublo was examined and its immediate surroundings. The total height of the geologic profile offered by the left side of Barranco de Tejeda is c. 1 000 m.

In the profiles there are the following rocks to be seen: lavas of salic composition (trachytes, phonolites), salic dikes, basalt lavas and dikes, coarse — and middle-grained alk. syenites, puzzolane and R.N. agglomerate, the last named lying on the top.

The stretch of Villa de Tejeda — Aserrador

The highroad turns, after leaving Tejeda into the bottom of Barr. de La Culata (where it passes a bridge) to the south side. On the way there are chiefly R.N. agglomerates to be seen (levels c. 800 m). Here an intrusive mass of a pale-greenish phonolite has been well exposed thanks to a rock avalanche. The rock will be described in connection with other similar occurrences in the Tejeda region.

Leaving the bridge one ascends the slope obliquely into the direction of R o q u e B e n t a i g a. At first there are old, weathered trachytes in disturbed positions (the basement). One sample (586) is micr. distinctly porphyric with clear rectangular alk. feldspar phenocrysts in a feldspar-rich, trachytoid paste. The small rods lie in a mesostasis of a grayish-brown, isotropic substance. No quartz is to be seen, neither any mafics, except some ore. The feldspar is albite, showing Karlsbad- and albite twins. The type may be a pantellerite. — When climbing the road to higher levels one passes a rather large basaltic volcano, or more exactly expressed the ruined remains of the same. It had been accumulated here in the higher part of the slope. — Still higher up one meets a thick bank of a grayish-green lava, fine-grained with columnar jointings (626). It seems to have a rather wide extension and forms a ledge towards the abyss of the Caldera. Micr. this lava is provided with euhedral phenocrysts of alk. feldspar (altered), of a greenish clinopyroxene, a sodalite mineral and brown hornblende. Smaller crystals of sphene also occur. Apatite and magnetite are accessories. Optics of the mafics are:

Pyroxene: ($2V$ not. det.), $c \wedge \gamma = 44° - 53°$ (zonal)

Hornblende: ($2V$ not. det.), $c \wedge \gamma = 10°$ (oxy-hbl?)

The groundmass is filled with tiny feldspar laths (sanidine), small prisms of aegirine and a colourless mineral with weak birefr. (zeolite?). The texture is trachytoid. The lava may be classified as a kind of trachy-phonolite.

Still further uphill but before one reaches the sharp bend of the road in the divide itself, one observes some large dikes of basalt (635, 636) with an east-west trend. They cross the R.N. agglomerate that dominates on these levels. Micr. one will find phenocrysts of pyroxene associated with grains of magnetite. They lie in a groundmass with pyroxene, magnetite and tiny plagioclase laths. Apatite is an accessory.

Pyroxene: ($2V$ not. det.) $c \wedge \gamma$ $52° - 62°$ (core and shell, aegirine augite). Calcite is also present in the paste together with an isotropic, colourless substance (analcime?). The dikes may be classified as belonging to the lamprophyres. They seem to be magmatically connected with the tephritic lavas which accompany the R.N. agglomerate.

This agglomerate can be followed up to the divide, and here steeply sided blocks of the same have remained standing as erosion witnesses just outside the sharp bend of the road.

From this bend the road follows the divide along its south flank into the direction of the 'great corner' of the Roque Nublo platform. There first appears to my surprise a long cut in a puzzolane bank, pale-yellowish and containing layered inclusions of dark lavas (xenoliths). This »stratification» has a perceptible inclination to the north. — Farther on in the divide there are basaltic lavas forming a hill (no sample) maybe the remains of the above mentioned adventive volcano. These basalts lie on a basement consisting of pale-coloured trachytes, somewhat rusty (weathered) not unlike those trachytes which occur on lower levels in the canyon. These lavas (634) are crossed by a dike of salic composition. Micr. the trachyte rock is very rich in alk. feldspar in laths showing the trachytoid texture. They are mingled with aegirine needles, and the latter also surround grains of nepheline (altered). The lava may be a trachyphonolite. — As far as the dikes crossing the former rock are concerned (639) we have here a kind of bostonite with phenocrysts of albite, some pyroxene, brown hornblende, sodalite and sphene. Magnetite grains are also seen. The groundmass is of the trachytoid texture.

Finally one approaches the mentioned great corner in the northwestern part of the Roque Nublo platform (see fig. 29) which rises considerably higher than the divide that has been followed. Here a succession of volcanics is exposed. If we examine the steep slope from below (1 275 m above the sea) we have first a weathered sheet of phonolite lava, dissected by a lamprophyre dike. The phonolite is capped by a basic, blistery lava (629) showing micr. phenocrysts of pyroxene and brown hornblende, the latter dominating. No phenocrysts of feldspar are seen. Magnetite is associated with the pyroxene, and apatite is an accessory. The groundmass is dark-gray with plenty of pyroxene prisms, plagioclase microlites and ore powder. Some of the vesicles are filled with a zeolite. The lava no doubt belongs to the tephrites which accompany the R.N. agglomerates. — Above this basic lava follows a pale coloured tuff, then again phonolite (588) of a blistery aspect. It forms the immediate base to the great agglomerate banks which constitute the Roque Nublo platform. This latter stands out at the abyss of the Caldera as a sharp edge.

When following the military road further in the direction of Aserrador, passing close by the foot of the great platform one will find a dark

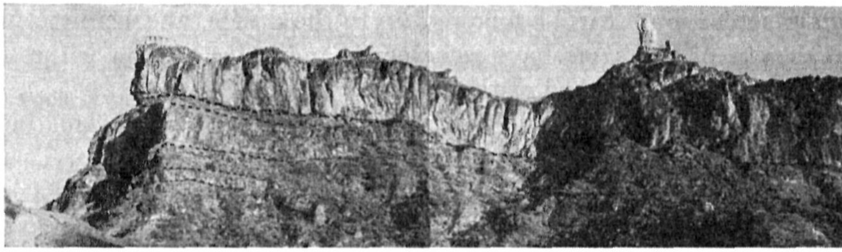


Fig. 29. A panorama view of the western escarpment of the Roque Nublo platform (central part of the island). Looking east. The top sheet consists of the R. N. agglomerate, resting here on a series of salic lavas and tuffs.
Phot. T. BRAVO

lava bed at the base of the agglomerate masses. The sample of the lava (590) is micr. a typical tephrite with augite and brown hornblende as components of the I gen. Vesicles in the paste are filled with chalcedony.

To sum up the volcanic stratigraphy in the southern wall of Caldera de Tejeda we can fix the following succession of beds:

Base — dislocated (weathered) trachytes
— plane of unconformity —
puzzolane
phonolites
tephrites
R. N. agglomerates
young basalt lavas (adventive cone)

We may get occasion to complete this scheme later on taking into consideration data from localities farther to the west along the ridge.

Roque Nublo (1 700 m)[1])

This »Monolith in the Clouds» is an isolated stack of the R.N. agglomerate, an erosion remnant of the uppermost sheet of the formation standing on the plain base of the underlying (next) sheet of the same kind. The height of the monolith is 80 m, and the sides are almost ver-

[1]) Sr JUAN PÉREZ NAVARRO, secretary of the Society El Museo Canario, has kindly informed me about the etymology of the name Roque Nublo. According to his opinion it is the hispanized form of the old name Nuro used by the Guanches and still surviving among the people in some remote sities of the island.

tical. In the vicinity there is another stack of lesser dimensions. — The agglomerate consists here (as in other places) of the pale-coloured pumice material with embedded xenoliths of alien lava rocks: samples 591, 594. The former is a tephrite lava with micr. well-developed crystals of clinopyroxene, brown hornblende, laths of a plagioclase, also sphene and magnetite. The paste is almost isotropic, with tiny feldspar rods in a vitreous matrix. — No. 594 is a type richer in the feldspar component both as phenocrysts and in the groundmass; in addition there are crystals of nepheline. Mafics are clinopyroxene and brown hornblende. Apatite is an accessory. Besides the feldspar the paste also contains pyroxene and ore powder. The lava is a trachytephrite.

The platform on which the monolith stands (c. 1 600 m above sea level) is very sinuous in its circumference. In the north, there is a cape jutting towards the abyss of the Caldera — a precipice of c. 500 m in altitude. On the northwestern flank, there is a long profile which can be examined from the road running along its foot. In the southwest, there is a big corner (Lomo del Aserrador). On the south flank, great precipices again appear: Roque de San José, facing Ayacata. — In the east, there is a narrow ridge which attaches the platform to the highland in the east. — On the northeast flank, steep slopes reach down to the canyon of La Culata.

The R.N. agglomerate is exposed on all sides in vertical or very steep walls determined by great diaclases. Huge blocks have from time to time become dropped to lower levels. The agglomerate is underlaid by sheets of lavas and tuffs, parts of which have already been described in preceding pages.

The entire mountain is of a spectacular shape, one of the most impressive land forms met with in the Canaries. The reader is referred to the frontispiece, to fig. 1, plate VIII, and to the fig. 29.

Roque Bentaiga (1 300 m)

This holy mountain of the natives of Grand Canary is another remarkable erosion witness worked out in the R.N. agglomerate formation. It dominates the southern part of the Caldera (see fig. 2 plate XVI). The monolith stands on a platform like that of Roque Nublo, sloping however, on a slight angle to the west. This platform does not consist of the same agglomerate but of other kinds of volcanics which will be described here. First we may mention that the socle consists of old dislocated trachytes and intrusive bosses of alk. syenites rather coarse grained. They are capped by a sheet of dark lava consisting of a tephrite, apparently related to the R.N. agglomerate which forms the monolith. This has a height from the base of c. 50 m. The sides of the monolith are almost vertical, their presence being determined by diaclases.

Roque Bentaiga represents obviously the remains of an extensive sheet of the R.N. agglomerate formation which once was connected with the Roque Nublo agglomerate banks. The sheet in question extended also far to the west, in this direction continuously dropping to lower levels. The solitary position of Roque Bentaiga on the divide between the Tejeda and the Chorrillo canyons is a result of intense weathering and erosion acting from all sides.

The tephrite lava at the base of the monolith (sample 643 a) shows micr. phenocrysts of augite and brown hornblende, the latter fringed by opacite. Grains of magnetite are associated with these minerals. The paste is composed of minute feldspar laths arranged according to the trachytoid texture. The laths are mingled with tiny prisms of pyroxene and grains of iron ore. It seems some zeolites occur in the groundmass.

In the north slope of Roque Bentaiga, or more exactly at the socle of it there are loose boulders dropped from above and consisting of a lava of dark colour (638). These boulders may belong to a lava bed underlying the above described tephrite. Micr. the rock shows a porphyric texture with phenocrysts of alk. feldspar (altered) with corroded contours. They lie in a groundmass of streaky aspect with winding zones of lighter and darker colours, the type being a somewhat devitrified vitrophyre of the salic kind. The paste also contains flakes of brown mica and stray prisms of a pale coloured clinopyroxene. Apatite is an accessory. The lava may correspond to some basal bed of the old rhyolite-trachyte formation once covering this region, and still conserved to the south, in the Montaña del Horno formation.

If we follow the divide from Roque Bentaiga further to the west we arrive to lower and lower levels. On the way we pass some curious erosion witnesses standing on the divide as something like ruins of fortresses. The first stack of these is of a basalt (644). Micr. it is a tephrite lava with pyroxene, brown hornblende and magnetite, in a groundmass rich in plagioclase laths (An/35) mingled with pyroxene and ore grains. Apatite is an accessory. There may be also zeolite in the paste judging from the very weak birefr. The lava corresponds to a tephrite, the same type that was mentioned of the socle of Roque Bentaiga.

Proceeding in a westerly direction along the divide, we will pass two volcano-ruins standing on the crest line itself. They are dark-coloured, strange pinnacles and they represent the last remains of some basaltic cones, contrasting with the pale-coloured basement in the divide itself. — A short distance further along, we arrive to El Llanillo, a butte of erosion sculptured into a vanishing basalt lava sheet. It has a »hat» of the R.N. agglomerate. It marks the end of the divide at Barranco de Chorrillo. The socle of El Llanillo consists of the pale-coloured trachytes.

These erosion witnesses enumerated, together with some others (Mesa de Acusa and Mesa de los Junquillos to be described later on), clearly indicate the presence of a former higher-lying bottom to the Caldera at a time when the gorges did not exist. The old bottom was flooded with basaltic lavas, and some volcanoes also grew upon this floor.

The watershed between Barranco de Chorrillo and Barranco de Carrizal consists of a broad ridge capped with a thick mantle of the R.N. agglomerate formation. I did not visit it, nor the *barranco* itself. The ridge is a ramification of a large mountain block which is confined by Barranco de Siberio and its head, Barranco de Juncal (or Pajonales), in the south. This broad divide is also covered with the agglomerate formation. The agglomerate apparently always rests on a fundament of old trachytes and intermingled bosses and dikes of alk. syenites and nepheline syenites, as will be explained in more details later on.

The southern limit of the Tejeda drainage area is consequently not the divide on which Roque Bentaiga is located, but the mountain chain to the south of Barranco de Siberio, the last left-hand tributary of the master canyon. This mountain range has been described under the name of »Cordillera del Horno».

Consequently, the small topographical map, fig. 27, does not comprise the entire »Caldera de Tejeda», but only its northern part, if by the expression »caldera» we understand the entire drainage area. This does not however, coincide with the popular idea of the Caldera: by it is meant only the abyss which reveals its panorama when one is standing on the pass of Degollada de Cruz de Tejeda and looking west.

Northern wall of Caldera de Tejeda (between El Rincón and Artenara)

This sector of the circumvallation is topographically a rather straight east-west escarpment, one of the grander geological profiles in the island. It can be studied principally along a path (»*camino real*») running from El Rincón (Villa de Tejeda) to Artenara, passing the slope at somewhat changing heights. Uphill from the path, the precipices are mostly too steep and dangerous for a closer study, and one has to be satisfied with samples taken of boulders which have dropped from above. Lower down, there are somewhat more passable slopes.

The author has tried to compile the entire geological profile (pag. 313-314) of this northern wall, partly with the assistance of T. BRAVO. The strata mainly belong to the R.N. formation and its accompanying basic (and salic) lavas. Lower down towards the gorge of Tejeda, we will meet with a basement complex of trachytes and alk. syenites, described later on in connection with the gorge itself.

Barranco del Rincón (or Barr. de Guardaya) is a rather deep gorge (a left hand tributary of Barr. de Tejeda). It seems to indicate the trend of a dislocation line, since the sides of the gorge are of a contrasted nature: the left one consists of the R.N. agglomerate formation, the right one of weathered trachytes crossed by dikes, apparently a part of the basement (see above). Following the slopes further westward, one arrives at Cuesta de la Cruz, a kind of promontory jutting out from the northern precipice of the Caldera. It consists of a series of flat-lying basalt lavas, and one gets the impression that it is not stratigraphically related to the beds in the great wall towering nearby. The basalts may have been part of a bottom fill of the Caldera during an earlier stage of its development.

A sample (656) from the vicinity of *finca* Juan Fernández (Guardaja Arriba) is an olivine basalt with euhedral phenocrysts of olivine enclosed in a fine-grained, iron-rich paste with pyroxene grains and very sparse by feldspar (altered). The crystals of olivine are surrounded by a thin shell of iddingsite. The lava may be classified as a picritic basalt and has a close resemblance to the olivine-rich lavas in the central highland.

After passing these basalts and the small farm, one follows the main slope of the Caldera in a westerly direction. The path steadily gains in height in that direction.

The slopes are rather steep, especially upwards from the path, where outcrops are difficult to examine. I did not climb the slopes, but made a sketch of it in an easterly direction. Sr T. Bravo was kind enough to put at my disposal a corrected profile of the slope, comprising a total height of 800 m. Resting on the basement of the weathered trachytes is a series of basalt lavas alternating with banks of the R.N. agglomerate (of changing thicknesses). Bravo has established no less than 6 banks of the agglomerate, the biggest being in the upper part of the profile. The basalt lavas are apparently all olivine-free — tephritic in composition.

Interfoliated in this series are a few sheets of a grayish trachyte lava, and these seen to be flat-lying dikes of a later date.

On another occasion I followed the upper rim of the great profile, i.e. the northern rim of the Caldera starting from A r t e n a r a. Here one will find salic lavas crowning the basalts-agglomerates, but also, resting on the former, banks of younger basalts of the olivine-rich kind. The immediate basement of the salic lavas are the uppermost banks of the R.N. agglomerate.

The author has collected a small number of samples of the rocks appearing in the great profile, chiefly of the basalts but also of salic types: both those appearing intercalated in the main series. A certain number of the salic beds also in the upper rim of the precipices was checked with samples (647, 651, 652, 653, 654, 655).

A sample was taken from the vicinity of the farm of Juan Fernández (653), where a small quarry is situated. Micr. the rock contains phenocrysts of alk. feldspar, phenocrysts of pyroxene and brown hornblende, the two latter with well-developed crystal forms, and sphene. The groundmass is trachytoid with small feldspar laths and sparse grains of sodalite (with hex. contours). Iron ore and apatite are accessories. The optics are:

Alk. feldspar:	($2V$ not det.) Karlsbad twins. Opt. char. +, ind. of refr. $>$ 1.54. Comp.: $\sim$ An/10
Pyroxene:	ext. angle on (010) $c \wedge \gamma = 53°$ (aeg. aug.)
Brown hornblende:	ext. angle on (010) $c \wedge \gamma = 12°$ .Pleochr.: α-yellow, γ-rusty brown

This lava rock may be designated a phonolite belonging to the decidedly alkaline group of an age somewhat later than that of the R.N. agglomerate. The occurrence has the shape of a flat-lying dike (sill).

No. 647 is of a basaltic lava bank associated with the R.N. agglomerate high in the profile on the north side of the Caldera. It appears as a bank of at least 25 m thickness. Micr. the rock is a basanite with well-developed pinkish-gray augite phenocrysts (euhedral). In addition, there are pseudomorphs of olivine. Magnetite is associated with the augite. The optics of the augite are:

$2V\gamma = 52°$, $c \wedge \gamma = 42° \pm 5$ (average of 4 det.)

The groundmass contains plenty of pyroxene prisms, plagioclase laths and ore powder. Moreover, there are colourless, isotropic patches of analcime (?). The vesicles are filled with fibrous aggregates of aragonite.

A chemical analysis of this rock was carried out with the following results:

Analysis no. 16

Sample no. 647 (HAUSEN 1953), bank of 25 m in thickness, N. side of Caldera de Tejeda (ass. with the R. N. agglomerate).

		Mol. prop.
SiO_2	43.51%	7216
TiO_2	3.60 »	449
Al_2O_3	14.16 »	1385
Cr_2O_3	0.05 »	3
Fe_2O_3	5.63 »	352
FeO	6.09 »	848
MnO	0.18 »	25
MgO	7.40 »	1835
CaO	10.44 »	1861
BaO	0.00 »	
Na_2O	3.44 »	555
K_2O	1.06 »	112
P_2O_5	1.02 »	72
SO_3	0.00 »	
CO_2	0.42 »	95
H_2O+	2.06 »	1143
H_2O-	1.04 »	
Sum:	100.10%	

Norm:

or	6.2	50.2
ab	24.0	
an	20.0	
ne	2.8	
Σ Sal:		53
di	17.6	
ol	7.8	
mt	8.2	
cm	0.1	
il	6.8	
ap	2.4	
Σ Fem:		42.9
Sec. $CaCO_3$		1.0
H_2O		3.1
Sum:		100.0

Analyst: AULIS HEIKKINEN

Spec. gr. = 3.03 (+23.5°C)

NIGGLI values:

si = 98 ½, ti = 6.1, p = 1.0, co2 – 1.4, h+ = 15.5, al = 19, fm = 46 ½, c = 25 ½, alk = 9, k = 0.16, mg = 0.54, qz = – 37 ½, al – fm' = – 27 ½, al – alk = + 10.

C. I. P. W. Classif. — III. 5. 3. 4.
Camptonose
Magma type: essexitic-gabbroid/normal gabbro-theralitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 35:56:9
MgO:FeO = 96:4

RITTMANN-parameters for nomenclature:
Al — 12.74, FM — 27.33, Alk — 6.22, k — 0.17, an — 0.34, ca″ — 6.53.
Dark nepheline basanite.

This type of alk. basaltic lava may be a rather good representative of the group closely associated with the R.N. agglomerate formation (group of tephrites and basanites). It may be a difficult task to trace these lavas to their points of departure, considering the deep erosion which has destroyed much of the central part of the island. The author thinks, however, several of the dikes of lamprophyres found inside the Caldera may have been the feeding channels of these lavas.

Another sample of a basic lava from the north wall of the Caldera (655) is of a rather similar composition as 647. It contains phenocrysts of augite and brown hornblende. They lie in a groundmass of a basaltic texture, consisting of plagioclase laths, augite and plenty of magnetite. (Optics: augite ext. angle on (010) $c \wedge \gamma = 60°$, hornblende $c \wedge \gamma = 20°$).

The whole series — the agglomerates and the intercalated basalt lavas — are capped with foid-bearing phonolites appearing at the upper edge of the great precipices. These alkaline lavas have been briefly described in Chapter 10 (p. 287).

S u m m a r y of the volcanic stratigraphy in the northern precipices of Caldera de Tejeda:

Altitude	Sample	Rock type	Site of exposure
1 750 m	500	Olivine basalt	Great dike crossing flat-lying olivine basalt lavas
1 600—		Phonolites	
1 500 »	—	R.N. agglomerate	Upper edge of the Caldera precipice
1 400 »	647	Basanite basalt	bank 25 m of lavas lying between two banks of the R.N. agglomerate
1 300 »	—	R.N. agglomerate	Upper part of the precipice
1 250 »	651	Tephrite basalt	Sheet between two banks of the R.N. agglomerate

Altitude	Sample	Rock type	Site of exposure
1 200 »	—	Thick bank of the R.N. agglomerate	Middle of the profile. The bank rises eastwards.
1 150 »	654	Tephrite basalt lava banks	Lower part of the profile between two banks of the R.N. agglomerate
900 »	—	R.N. agglomerate bank	The path from Tejeda to Artenara runs along its foot.
850 »	655	Tephrite basalt	Basement of the R.N. agglomerate bank.
800 »	653	Trachyphonolite (gray)	Immediately under the preceding bank.
800 »	—	Tephrite basalt	Several banks in conformity.
750 »	—	Basalts with intercalation of trachyte and R.N. agglomerate	Lowest banks in the whole sequence. They rest on a denudation surface.
Unconformity			
700 m	637	Dislocated series of trachytes, in which Barranco de Tejeda has been eroded.	Walls and bottom of the Tejeda canyon.

Artenara—Cruz de María—Alta Vista Mountain

We must now investigate the western (lower) continuation of the northern wall of Caldera de Tejeda, it is, the divide between the head of the Agaete valley (Barr. de la Hoya) and the Tejeda drainage area. Arriving at Degollada de Acusa we will follow the eastern edge of the Tamadaba mountains which limits the Caldera in the west as an imposing mountain wall.

In order to examine the rocks along this stretch, it is best to follow the Forest Department's carriage road leading from Artenara to the forest inn of Tamadaba. The road follows the divide until its end at the limit of the Tamadaba forest reserve. Heading for Alta Vista, one has to use a path leading off to the south just before the hill Cruz de María is reached.

Artenara (1 250 m above the sea) is an ancient dwelling place at the rim of the Caldera. Here many caves have been dug into the R.N. agglomerate banks which form the mountain edge. Going to the west one will find that the agglomerate disappears and is replaced by basalt lava banks (with tuffs) in a flat lying position. They have been formed into erosion

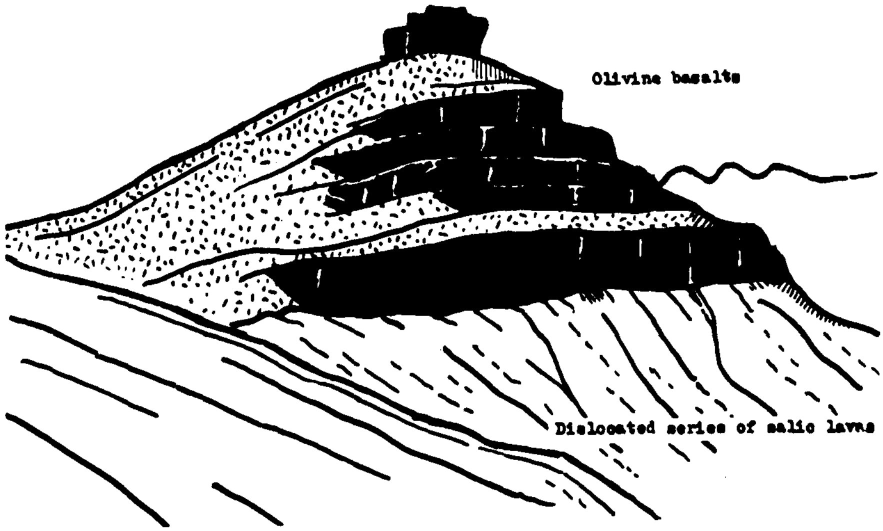


Fig. 30. Morro de los Cuervos, an erosion hill of post-Miocene basalt lavas at the northern edge of Caldera de Tejeda, W of Artenara. The basalt series rests on dislocated trachytes. Looking north.

Field sketch by H. H—n

buttes resting on a ground consisting of pale-coloured trachytes (showing a weathered state). These salic lavas are in inclined position. In the erosion mountain Morro de los Cuervos (see fig. 30) the basalt formation rests with an unconformity on the old trachytes. Sample no. 663 from the *morro* is an olivine basalt forming one of the lower banks in the series. Micr. the rock type shows phenocrysts of olivine, augite and magnetite all lying in a paste of plagioclase laths, augite and ore grains. The olivines are clear, but rimmed with iron oxide; augite is unaffected, but the feldspar is somewhat altered. Cavities in the paste are filled with a colourless, isotropic substance (analcime?). The lava has a more basic composition than the ordinary olivine basalts, it may approach the ankaramites. No doubt this lava belongs to the post-Miocene period, during which vast outpourings of similar lavas took place in the northern declivities of the island. Morro de los Cuervos is the last remain of a former cover of basalt lavas which expanded over the western sector finally reaching Tamadaba (but leaving this mountain un-flooded).

After passing Morro de los Cuervos, the road winds along many recent cuts in the decomposed salic lavas, here and there crowned with small remains of the basalts. The divide seems to consist entirely of these salic lava and tuff banks, always very decomposed. One sample taken of a rock in the south side of the ridge (on the path leading down to Mesa de Acusa) (670) is micr. extremely fine-grained without any phenocrysts of feldspar or of mafic minerals. The rock consists of aggregates of tiny aegirine prisms and of feldspar rods in random orientations, together with a fine, opaque powder. Any foid mineral could not be seen in the slide. The paste, however, contains colourless, isotropic patches that may be analcime. The rock can be classified as a kind of tinguaite. The dike character, however, could not be definitely proved.

On the way down the slope from the road to Mesa de Acusa (described page 330), the salic lavas are well exposed in *barranquillos* constituting the head of Barranco del Silo. The rocks are all in such an altered condition that it seemed impracticable to take a sample. On the surface they are light cherry-coloured, probably owing to the presence of sec. hematite. Thanks to the softness the ground that composes the whole ridge (the watershed), erosion has been able to work out a rather sharp-crested morphology in this divide separating the Tejeda drainage area from that of Valle de Agaete.

The Alta Vista Mountain

This is a very outstanding eminence in the ring of mountains which embrace Caldera de Tejeda. It forms the western marker of the depression, rising to a height of 1 375 m, and it is at the southern end of the skyline which stretches in that direction from the Tamadaba massif. The south side of Alta Vista is almost vertical, a plunge of c. 300 m in height.

One reaches the Alta Vista Mountain by using the forest road from Artenara to Tamadaba. After passing Degollada de Acusa, one enters the slope of Cruz de María (1 275 m), an eminence consisting of salic lavas in a weathered state, at least on the east side. One sample from here is (728) an alk. trachyte with feldspar laths, aegirine and nepheline and iron ore powder. — Another sample (729) is a porphyry with broad laths of alk. feldspar in random orientations. They lie in a paste of a trachytoid texture with feldspar rods and aegirine prisms and also brown hornblende. There are occasional crystals of a sodalite mineral (altered, but with a clear border zone). This lava may be designated a trachyphonolite.

When following the rough divide in the direction of Alta Vista, one can see all the way a monoclinal structure of the salic volcanic beds. They are tilted to the southeast, forming a slope of c. 500 m in height. The angle of inclination is c. 40°.

When approaching Alta Vista, one will find that the summit consists of flat-lying huge banks of lavas, whereas on the slopes lower down the inclination towards the Caldera persists. There is obviously a plane of unconformity here. The presence itself of this plane is not so interesting as its high position (c. 1 200 above the sea). In Alta Vista we find preserved an old eminence of the basement formation and this is the case, as we already have seen, with the unconformity in Cordillera del Horno (Sándara Mountain).

There are only three samples of lava rocks composing the mountain according to the author's collection (730, 731, 733). The first is a phonolite or a trachyphonolite with clear phenocrysts of euhedral alk. feldspar with Karlsbad twins (ind. of refr. < balsam, opt. char. —) in a paste filled with feldspar rods containing scattered nepheline crystals and also dark streaks of aegirine microlites and ore. Texture is trachytoid. [1]

No. 731 is from a somewhat lower level in the east side of the mountain; it is fine-grained, dark-gray. Micr. it shows no phenocrysts either of feldspar or mafic minerals. The former appears in the paste as tiny laths mingled with aegirine prisms and ore powder (no foid mineral).

No. 733 is a lava from the western edge of the mountain (high level) and consists micr. of clear phenocrysts of alk. feldspar with Karlsbad twins lying in a paste filled with tiny laths of feldspar in a trachytoid texture. They are mingled with streaks of altered aegirine (?), dark (iron-stained) surrounding crystals of nepheline (turbid). Stray prisms of brown hornblende are also seen. They show pleochroic changes from yellow to dark brown. The alk. feldspar has the properties of sanidine. The lava belongs to the table mountain (the capping) series of Tamadaba.

The crest of this mountain range from Cruz de María to the northern foot of Alta Vista is, as we have found, composed of the inclined trachytic — trachyphonolitic series. To the west of this divide, the slopes are likewise steep but not smoothed by any structural planes. They are formed into »staircases». Here the lava and tuff beds lie in a flat position. They continue to the north into the Tamadaba table mountain, — and in the opposite direction they reappear in the summit of Alta Vista.

[1]) Cf. microphoto 2, plate 1.

Barranco de Tejeda
with its left hand tributary *barrancos*

Barranco de Tejeda, with its continuation down to the north-western sea shore — »Barranco de la Aldea« —, is the most important drainage way in the island, having its begin in the very heart of the central highland. From the head arm — Barr. de la Culata — to the mouth of the (mostly dried up) river at Playa de la Aldea, it measures c. 25 km. Its canyon has in its upper course a steep gradient, lower down it is getting more gentle, and the last distance to the sea is passed in a braided course. — Tributary canyons are relatively few in number, the most important being Barr. de Chorrillo, Barr. de Carrizal and Barr. de Siberio — all from the left side (cf. the map fig. 27). From the right there are but insignificant *barrancos* as Barr. del Rincón and Barr. del Silo. In its lower course the river crosses a mountain barrier before reaching the lowland of Aldea de San Nicolás (Cf. with the map fig. 32).

All the mentioned *barrancos* represent very deep scars in the island structure, and for this reason they are of the outmost importance to the geologist. Such great profiles are not to be expected in the neighbouring island of Tenerife, in which erosion has only furrowed the slopes and left the island nucleus intact. There the only informations about the constitution of the hidden interior can be won from volcanic ejecta strewn into the surroundings of the central volcano Pico de Teide.

In Grand Canary the Tejeda drainage courses were studied by the author in many parts, chiefly along the master canyon, to a lesser extent along Barranco de Siberio. The remaining *barrancos* were visited only in their upper courses in connection with a study of the so called *laderas*, i.e. the sides of what is known as Caldera de Tejeda (above described). — A certain number of samples was brought together representing many of the rock types met with along the gorges. In this respect much material is still needed to illustrate the intricate conditions revealed in these depths of the island. Lack of time and lack of an appropriate topographical map have prevented the author from carrying out a detailed rock-survey. — But there are also other questions to clear up; chiefly connected with the fracture tectonics of the area and with the different stages of erosion.

If we now look at the geological complexes revealed in the deep cuts of the canyon, we have first to examine a series of dislocated salic lavas of a pale-grayish colour. They are apparently all trachytic rocks but to some degree decomposed, at least on the surface. The rock ground is soft or brittle and shows rusty patches, and it seems these sprinkles are due to decomposed iron sulphides. — Such lavas can be followed for long distances down the course of the canyon, and they can be seen also on rather high levels above the bottom of the same.

These trachytes are to some extent replaced by bosses and great dikes of salic, granular plutonic rocks (syenites etc.). A multitude of narrow dikes intersect the ground.

The oldest salic lavas the Tejeda sodatrachytes and trachyphonolites

When speaking about the geological conditions in Barranco de la Culata (Chapter 10) we have already found that the deepest part of this gorge exposes a complex of pale-coloured trachytic lavas showing a weathered state. This complex is with unconformity capped by a series of R.N. agglomerate, sandstone and conglomerate layers all lying in a flat position. Their top is crowned with basalt lava beds. The salic basement is — like the overlying formations — crossed by innumerable dikes of lamprophyric and salic composition.

If we now go down from this gorge along the bottom of the master canyon which begins in the vicinity of Villa de Tejeda (level 730 m above the sea) we will pass good outcrops of the dislocated trachytes at La Solana. River erosion has cut deeply into this rather soft ground. In late-Quaternary time (?) the gorge had been filled with a basalt lava stream, but this is now cut across, and of the fill only terraces on both sides have been left behind.

The trachyte banks are here tilted to a southeasterly dip. The rocks are decomposed in spite of the young erosion forms, and it is not easy to obtain a fresh hand specimen. The sample that I took (637) is relatively fresh, however, and it shows micr. a trachytic texture with tiny feldspar rods and without any phenocrysts of feldspar. The ind. of refr. is below balsam. Mafics are not present except minute flakes of brown mica. Opaque patches are disseminated in the paste. They may correspond to secondary products (of ferrihydrate?) produced by oxidation of primary iron sulphides. (Cf. microphoto 1, plate I).

The rock may be called an alk. trachyte or a pantellerite.

A chemical analysis of this rock has been carried out with the results given below:

Analysis no. 17

Sample no. 637 (HAUSEN 1953) of an alk. trachyte exposed in the bottom of Barranco de Tejeda, vicinity of La Solana, c. 730 m above the sea.

		Mol. prop.
SiO_2	63.75%	10572
TiO_2	0.61 »	76
Al_2O_3	16.71 »	1635
Fe_2O_3	3.29 »	206
FeO	1.10 »	153
MnO	0.36 »	51
MgO	0.28 »	69
CaO	0.23 »	41
Na_2O	6.09 »	982
K_2O	5.40 »	573
BaO	0.20 »	13
P_2O_5	0.04 »	3
SO_3	0.05 »	3
CO_2	1.27 »	289
H_2O+	0.79 »	438
H_2O-	0.22 »	
Sum:	100.39%	

Norm:		
Q	7.0	
or	31.9	83.4
ab	51.5	
C	0.8	
Σ Sal:		91.2%
en	0.7	
mt	2.9	
hm	1.3	
il	1.2	
ap	0.1	
pr	0.04	
Σ Fem:		6.2
$CaCO_3$		0.4
CO_2		1.1
H_2O		1.0
Sum:		99.9%

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.56 (+23.5°C)

NIGGLI values:
si = 269, ti = 2.0, p = 0.1, so_3 = 0.1, co_2 = 7.4, h+ = 11.2, al = 41½, fm = 17½, c = 1½, alk = 39½, k = 0.37, mg = 0.10, qz = +11, al−fm′ = +24, al−alk = +2.

C. I. P. W. Classif. — I. 5. 1. 4.
Nordmarkose
Magma type: nordmarkitic
Mol. prop. % of normative feldspars
Ab:An:Or = 63:0:37
MgO:FeO = 100:0

RITTMANN-parameters for nomenclature:
Al — 15.04, FM — 5.46, Alk — 14.54, k — 0.37, an — 0.02, ca″ — —0.07. Soda trachyte.

Although the rock is slightly slica-oversaturated, no quartz appears in the slide. The content of potash is remarkable; this points to anorthoclase as the dominating feldspar. The unfresh state of the rock is shown by the presence of carbon dioxide. The alteration may be due to sulphuric acid of primary iron sulphide (which has been axidised). In fact I have found impregnations of pyrite in the trachytes below Artenara.

In the following pages we shall mention rather similar lava types of a pale-grayish or a pale-brownish tinge. They have all been tilted to an angle of c. 45° SE. The same unfresh state can be noted all the way along the canyon.

At somewhat higher levels in the south side of the master *barranco*, along the military road to Ayacata similar types of trachytes are unexpectedly met with, as we already have mentioned (page 305).

If we now proceed further in westerly direction along the canyon, though not always along its bottom, since there are no roads, we will again and again meet the pale-coloured, tilted salic lavas intermingled with bosses of the middle-to coarse-grained syenitic rocks. The aspect of the plutonics is always rather fresh; this is unlike the case with the penetrated trachytes themselves.

Turning again to petrographic details we may at first look at some types of lavas (665, 667), collected from a locality below Artenara. Here a small 'water gallery' has been opened and the blasted rocks lie around (in the right side of the canyon). The rocks are porphyric and they consist mainly of alk. feldspar as phenocrysts and as small rods in the groundmass. Mafic components are confined to minute prisms of aegirine. In no. 665 there are also grains of nepheline, somewhat altered. These rocks may be trachytes or trachyphonolites and in one sample hexaeders of pyrite appear. If they really are of lava sheets or if they may represent some kinds of dikes could not be made clear.

Still lower down the course of Barranco de Tejeda, one passes the foot of the impressive, fortress-like Mesa de Acusa, rising to the right. In the very steep slopes (partly covered by scree) dislocated trachytic lavas seem to dominate. They are inclined to the southeast. Farther up the slope they are capped with the flat lying beds composing Mesa de Acusa (see page 330).

We now approach a passage in the canyon where a small farm — Los Parralillos is situated. A salic lava type (677) was taken from here. Micr. it is, like the former one, a feldspar rock with small feldspar laths in a trachytoid paste, here mingled with small flakes of brown mica and opaque powder. Minute prisms of a clinopyroxene are also present. Phenocrysts have not been formed. The paste contains vesicles filled with a colourless, isotropic substance (ind. of refr. $<$ balsam, analcime?). Between + nic. the slide looks rather dark, so there must be some isotropic substance in the mesotasis too. The absence of nepheline is to be observed, and quartz is likewise not present. The lava may be designated as a trachyte or a pantellerite.

A chemical analysis of this rock was also carried out with the results given below:

Analysis no. 18

Sample no. 677 (HAUSEN 1953) of an alk. trachyte from the bottom of Barranco de Tejeda near the farm Los Parralillos (not far from Mesa de los Junquillos).

		Mol. prop.
SiO_2	59.62%	9887
TiO_2	0.51 »	64
Al_2O_3	18.22 »	1783
Fe_2O_3	2.11 »	132
FeO	1.39 »	193
MnO	0.44 »	62
MgO	0.19 »	47
CaO	0.31 »	55
Na_2O	7.82 »	1261
K_2O	5.03 »	534
P_2O_5	0.03 »	2
CO_2	0.81 »	184
H_2O+	3.04 »	1687
H_2O-	0.61 »	
Sum:	100.13%	

Norm:		
or	29.7	87.1
ab	57.4	
ne	0.9	
nc	1.4	
C	1.3	
Σ Sal:		90.7
ol	0.9	
mt	3.1	
il	1.0	
ap	0.1	
Σ Fem:		5.1
Sec. $CaCO_3$		0.5
H_2O		3.7
Sum:		100.0

Analyst: AULIS HEIKKINEN

Spec. gr. = 2.38 (+23.5°C)

NIGGLI values:
si = 236, ti = 1.4, p = 0.1, co_2 = 4.3, h+ = 40.3, al = 42½, fm = 13½, c = 1½, alk = 42½, k = 0.30, mg = 0.09, qz = −34, al − fm′ = +29, al − alk = ±0.

C. I. P. W. Classif. — I. 5. 1. 4.
Nordmarkose
Magma type: normal foyaitic

Mol. prop. % of normative feldspars
Ab:An:Or = 66:0:34
MgO:FeO = 40:60

RITTMANN-parameters for nomenclature:
Al — 16.40, FM — 4.50, Alk — 16.76, k — 0.30, an — 0.01, ca″ — 0.53. Soda trachyte.

Compared with salic lava no. 637 (anal. no. 17), this is rather similar in composition, showing, however, a slight tendency to undersaturation and at the same time a reduced sodium content. This type is also characterized by a remarkable scarcity of coloured minerals and they are both practically feldspar rocks. — A certain water content (of + water) indicates a somewhat advanced stage of decomposition which may correspond to the kaolinization of the feldspars.

Going further down the master canyon the trachyte lavas can be followed in long exposures. At Paso de las Vacas, not far from the north side of Mesa de los Junquillos, a sample was taken (646) of a grayish trachyte lava. Micr. it is rather fine-grained with a web of slender feldspar laths in the trachytoid arrangement. These laths are mingled with an opaque substance of mostly irregular forms, apparently of secondary origin. Here and there a pseudomorph filled with opacite can be seen, the outlines suggesting a hornblende. Compared with other types of the Tejeda trachytes, this is strikingly rich in the opaque substance. The feldspar laths are sanidine (ind. of refr. < 1.54, opt. char. —). No quartz could be seen in the slide, and there are no signs of mafic components either, except for the pseudomorphs mentioned.

If we proceed further along the master canyon, we approach the steep northern side of Mesa de los Junquillos, the strange fortress-like erosion remnant in this part of the area. The rocky precipices expose a salic lava of a trachytic aspect (694), very like the types found in the upper parts of the course. Micr. we will find a fine trachytoid texture with feldspar rods, also with some bigger laths of (altered) feldspar (Karlsbad twins). No mafic components are seen. There are plenty of rusty patches of secondary origin in the paste. The rock is altered and the feldspars turbid. No foid minerals can be found. The rock may be a trachyte (pantellerite). The lavas here are inclined to the southeast. They are crowned on higher levels by the flat-lying sediments and basalt banks of Mesa de los Junquillos (see page 332).

Intrusive bodies of alk. syenites and nepheline syenites in the dislocated trachyte series

The presence of alk. syenites in the Tejeda area was first proved by J. BOURCART (1937), not in firm rock, however, but in the shape of scattered boulders near Aldea de San Nicolás de Tolentino. — I myself have encountered these syenites, not only as boulders but also in large exposures in Barranco de Tejeda and Barr. de Siberio.

The largest and the most interesting of these exposures was found in the steep northern side of the eminence on the left-hand side of the canyon, where Roque Bentaiga crowns the top. Here we will find a feldspar-rich, brownish-red, coarse-grained, plutonic rock without quartz — a syenite. It is easily decomposed on the surface. There are no distinct boundaries of the host rock — the dislocated trachyte lavas. Both types seem to be intimately connected, and one gets the impression here that a kind of anatexis has occurred between the trachytes and the penetrating syenite.

Petrographic data. — The author is in possession of 20 samples of the plutonics including some more basic types (22, 77, 78, 79, 80, 81, 82, 83, 643, 645, 664, 667, 686, 691, 693, 695, 696, 703, 723). There is only one chemical analysis (693) to be presented. This is not, I think, a very severe handicap, since most of these rocks display a certain monotony, as will be apparent in the descriptions that follow.

It is still not possible, to fix the areal extent of these plutonics, owing to lack of sufficient observations and to the many transitions to the host rocks — the trachytes. Only the main stretches have of course been established in the geological map, in which the plutonics seem to dominate (in the deepest parts of the canyons).

In hand specimens, most of these salic plutonics are rather fresh-looking with glistening feldspar grains of an equigranular size. Dark patches of mafic minerals are seen, the colour index being fairly low. Micr. the texture is miarolitic: the feldspar grains appear as thick plates of a rectangular shape, leaving triangular interstices between them. These pores are either empty or filled with an opaque substance or they are occupied by greenish pyroxenes and/or nepheline, also fluorite. — The feldspar is orthoclase or perthite, sometimes albite appears. E. JÉRÉMINE (1937) has also found sanidine. The mafics are of two generations: aegirine augite in larger individuals and aegirine in slender prisms, the latter being the last product to crystallize (often in radial bundles, of fig. 2, plate II). Some brown mica can be seen and also brown hornblende. Sphene sometimes occurs in relatively large crystals.

A typical sample (693) from the lower course of Barranco de Siberio (to the south of Mesa de los Junquillos) has alk. feldspar as its chief mineral; in addition, there is aegirine augite, aegirine (radially arranged aggregates), brown mica (almost uniaxial) and sphene. Apatite and magnetite are accessories. In the interstices an isotropic, colourless substance can be seen (analcime?). The optics are:

Sample 643, Tejeda canyon, below Roque Bentaiga:

Alk. feldspar: $2V\alpha = 77°$ (low-temp. var., orthoclase microperthite)

Sample 645, Tejeda canyon, north of Mesa de los Junquillos:

Alk. feldspar: perthite (orthoclase + albitic plagioclase with An/35%)

Clinopyroxene: $c \wedge \gamma = 60°$(kernel)
$c \wedge \alpha = 14°$ (border zone)

Sample 693, Barranco de Siberio:

Sphene: $2V\gamma = 20° - 33°$

Sample no. 693 was submitted to a chemical analysis with the results communicated below:

Analysis no. 19.

Sample no. 693 (HAUSEN 1953) of an alk. syenite from the lower course of Barranco de Siberio on the south side of Mesa de los Junquillos.

		Mol. prop.
SiO_2	59.75%	9909
TiO_2	0.86 »	107
Al_2O_3	19.00 »	1859
Fe_2O_3	2.46 »	154
FeO	1.16 »	161
MnO	0.23 »	32
MgO	0.42 »	104
CaO	1.09 »	194
BaO	0.23 »	15
Na_2O	7.00 »	1129
K_2O	4.73 »	502
P_2O_5	0.15 »	11
CO_2	0.50 »	114
H_2O+	1.76 »	977
H_2O-	0.49 »	
Sum:	99.83%	

Norm:

or	27.9	88.1
ab	58.6	
an	1.6	
ne	0.3	
C	1.7	
Σ Sal:		90.1
fo	0.7	
mt	2.0	
hm	1.1	
il	1.6	
ap	0.4	
Σ Fem:		5.8
$CaCO_3$		1.1
H_2O		2.3
Sum:		99.3

Analyst: AULIS HEIKKINEN

Sp. gr. = 2.57 (+23.5° C)

NIGGLI values:
si = 231, ti = 2.6, p = 0.2, h+ = 22.8, co_2 = 2.6, al = 43½, fm = 13½, c = 5, alk = 38, k = 0.31, mg = 0.17, qz = −21, al−fm′ = +30, al − alk = +5½.

C. I. P. W. Classif. — I. 5. 1. 4.
Nordmarkose
Magma type: bostonitic
Mol. prop. % of normative feldspars:
Ab:An:Or = 67:3:30
MgO:FeO = 100:0

RITTMANN-parameters for nomenclature:
Al−17.10, FM−4.83, 15.23, k−0.31, an−0.06, ca″ − −0.03. Soda trachyte (i.e. a plutonic counterpart).

If we compare these data with those of the trachytes from the Tejeda canyon, we will find rather close affinities. One is inclined to accept the idea that the syenite is the anatectic product of the trachytes (cf. anal. 17 and 18). Taking into consideration the partly undecided limits between the trachytes and these granular rocks, we may suppose that the exposures along this deep canyon have reached levels of the 'anatectic front'.

No.	Texture	Feldsp.	Neph.	Pyr. I	Pyr. II	Hbl.	Mica	Sphene	Ap.	Ore
22	agpait.	or	×	×	×		×	×	×	×
78	»	or	×	×	×				×	×
79	»	perth.	×	×	×					×
80	»	or	×	×	×		×		×	
81	»	or	×	×	×					
62	»	or	×	×	×			×		
83	»	or	×	×	×	×	×	×	×	×
643	»	perth.							×	×
645	»	or		×						×
664	»	or								×
667	»	or			×		×			
686	»	or	×				×		×	×
691	»	or				×		×	×	×
693	»	or	×	×	×		×	×	×	×
703	»	perth.								×
723	»	»	×	×	×		×		×	×

In this case a large amount of the overlying rock masses must have been carried away in earlier times.

As far as I have been able to prove, the syenites in the Caldera area never seem to reach a stage of silica-oversaturation, — quartz-bearing types (quartz syenites, granites) have not been observed.

Finally, we may here give in tabulated form the mineral composition of the granular plutonics found inside the Caldera (page 326).

Of the types enumerated, the first seven listed are from Barranco de Siberio, the others except for 693 (B.Sib.) are from Barranco de Tejeda (middle course). The types from the former region seem to be mainly richer in nepheline; they can be designated nepheline syenites. They also contain rather much pyroxene of the two generations (pyr. I is aegirine-augite and pyr. II is aegirine needles) associated with ore grains and apatite. In 9 of the types listed above an isotropic substance was found filling the miarolitic spaces between the broad feldspar laths (analcime?). The purest syenites are of a rather coarse and agpaitic texture, and with a pale-brownish colour, and they are to be found in Barranco de Tejeda.

Except the many large exposures of these feldspar-rich syenites there are further basic types to be encountered, I think. Boulders of the same have so far not been picked up in the gravel material filling the bottom of the master *barranco* (lower course). A closer scrutiny of the canyons will certainly reveal exposures of gabbros and other types; one gabbro was indeed found by myself (no sample). In the depth there must be many bosses since E. JÉRÉMINE had been able to demonstrate (l.c.), that the R.N. agglomerate formation frequently carries xenoliths of monzonites, essexites and also of more basic types. They may have been dragged by explosions from somewhat lower levels than those of the present erosion surface.

Dikes inside the Caldera

In the *barranco* walls inside the Caldera there are many dike intrusions traversing the basement trachytic rocks and also the plutonic masses. They also reach higher up in the profiles, into the hanging formation of the R.N. agglomerates and their intervening basic lavas. These dikes can most conveniently be divided into two groups: the salic (trachytic-phonolitic) and the basic dikes, chiefly lamprophyres. The dike swarms appearing in the head region of Barranco de Tejeda have already been briefly characterized, and they are in the main lamprophyres. This time we may look at dikes farther down the master canyon and along the left hand tributaries, chiefly Barranco de Siberio. The material at our disposal is far from adequate (the number of samples is only 10), and they comprise chiefly dikes of salic composition. We will briefly describe the samples collected (40, 77, 84, 85, 674, 704). Concerning the age of all these dikes nothing can at present be stated with certainty; they are, however, all younger than the old dislocated trachytes and the syenitic bosses which penetrate the latter. Some are also younger than the R.N. agglomerates (both salic and basic dikes).

Salic dikes—. A special group of dikes can be designated as sheet-like intrusions of the syenitic magma branching off the bosses of these same syenites (and nepheline syenites).

Several dikes of porphyries were found in the middle course of the Tejeda canyon. One sample (704) shows micr. phenocrysts of an altered alk. feldspar in a paste filled with feldspar rods in the trachytoid texture. It also contains streaks of an opaque substance and powder of ore. No mafic components are seen, only pseudomorphs consisting of iron oxide and also calcite. Apatite is an accessory. The rock may be a kind of bostonite, supposing the feldspar to be of an alkaline nature. Other dikes found in the right side of the canyon below A r t e n a r a (lumps of rock obtained at the mouth of a water galley) seem to be of a similar nature. But there are also different types. In one sample (666) there are micr. elongated prisms of a pale-coloured clinopyroxene and of brown hornblende (opacite-rimmed), but no feldspar phenocrysts are seen. The paste is very fine-grained, containing not only feldspar but also minute crystals of a sodalite mineral. Zeolite is also present. The dike rock may be classified as a kind of phonolite; a diagnosis is difficult owing to the alterations.

Further down the master canyon is a dike oriented E—W near the farm L o s P a r r a l i l l o s (not far from Mesa de los Junquillos) intersecting the trachytes dominating here. The sample (674) is micr. a porphyry with large phenocrysts of alk. feldspar (somewhat altered) lying in a paste of feldspar laths and aegirine needles in a trachytoid texture. The aegirine also appears in coronas surrounding small crystals of nepheline. There is also anisotropic, colourless mineral in the paste showing opt. char. + and a small opt. angle. The rock is a phonolite.

If we now pass over to the left-hand tributary of B a r r a n c o d e S i b e r i o (which was followed for some km upstream) several dikes were observed crossing the great bodies of alk. syenites exposed in the canyon walls. They are all micr. of the trachytoid phonolite type of salic dikes (77, 84, 85). They contain nepheline crystals together with the leading alk. feldspar, the latter appearing in the two generations of components. Aegirine is the mafic mineral, confined to the paste, where it surrounds the nepheline crystals. Brown hornblende was also observed in one case. In no. 85 the nepheline plays the role of phenocrysts around which the stream-lined paste forms graceful curves.[1])

There are other dikes and intrusive masses of fine-grained salic rocks along the lowest course of the Tejeda canyon, crossing the series of salic lavas in the mountain barrier traversed by the canyon. They will be described later on (Barr. de la Aldea).

*

The general impression from an examination of the salic lavas exposed in the canyon of Tejeda is that of a rather decomposed state of the rocks, and this aspect can be noticed all the way from Barranco de la Culata down to the vicinity of Mesa de los Junquillos. These lavas have a whitish-grayish colour and they are dotted with rusty patches or streaks. The consistency is soft. On the other hand, the penetrating coarse-grained syenites are fresh looking with their glistening feldspar crystals. If we were faced with a regional weathering of this part of the island structure, such a contrast would be difficult to explain. It seems more probable that the trachytes have been affected by post-magmatic gases emitted from the plutonics in the depth.

This softness of the old, dislocated trachytes seems to be of great importance as regards the origin of the deep gorges in this area.

We still have to deal with two erosion witnesses closely associated with the Tejeda canyon, the one on its right, the other on its left side: M e s a d e A c u s a and M e s a d e l o s J u n q u i l l o s. I have to some extent examined these two peculiar land forms; they seem to provide a clue (at least to some degree) to the explanation of the origin of the so called Caldera de Tejeda.

[1]) Dikes of basic composition (lamprophyres etc.) will not be treated here owing to lack of material. They do occur, however, rather frequently along the canyons.

Mesa de Acusa (1 000 m)

Mesa de Acusa lies as a kind of terrace on the right side of the master canyon, at a point where the latter curves to the south and where two left hand tributaries are received: B a r r a n c o d e C h o r r i l l o and B a r r a n c o d e C a r r i z a l. The upper edge of the *mesa* lies c. 900 m above sea level and there is a very pronounced escarpment facing the canyon in which the different formations composing the *mesa* are displayed. The reader is referred to the profile in fig. 31.

We may briefly examine the various lithologic complexes starting from the bottom of the canyon.

The rock ground in these deep cuts consists of the old dislocated trachytes which have an inclination to the southeast (c. 45°). In this series there are some coarse-grained plutonic bodies without any distinct borders at the host rock. Great boulders of these plutonics — mostly alk. syenites — have clogged the bottom of the canyon.

If we climb the steep slope to the edge of the *mesa*, we will meet with a distinct p l a n e o f u n c o n f o r m i t y (at c. 700 m in height), a geological limit: over the truncated edges of the inclined trachyte banks

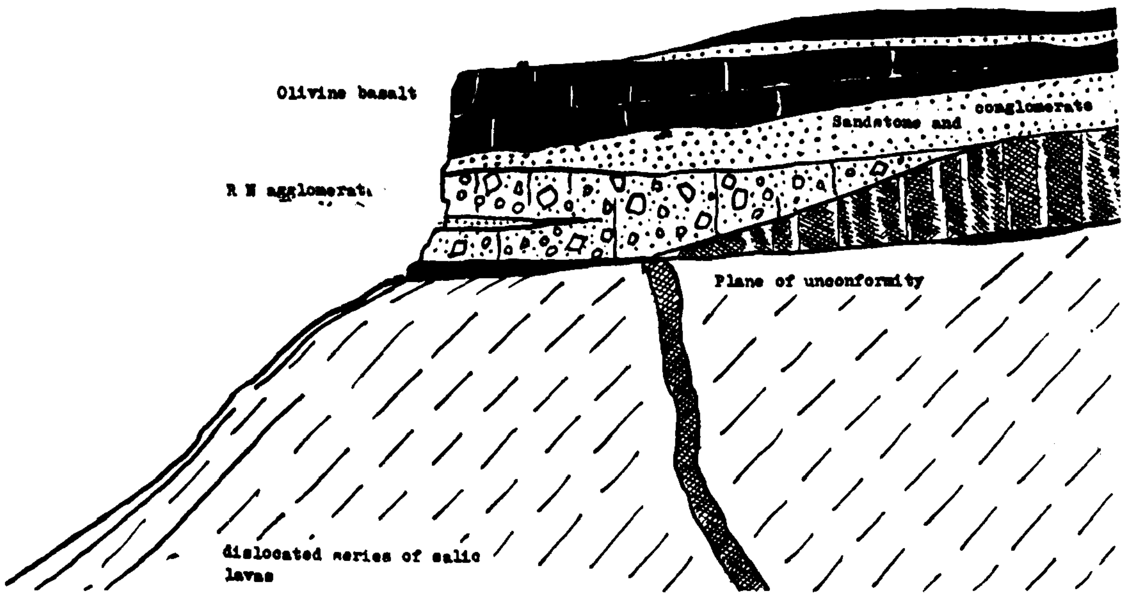


Fig. 31. Mesa de Acusa, Caldera de Tejeda seen from the canyon (fr. ENE).

rests a thick bank of a gray phonolite (or trachyphonolite) lava with vertical columnar jointings in a flat position. The plane of unconformity is also marked by the presence of decomposition (kaolinite?), a whitish, crumbled rock, in which ground water also appears. The vertical wall of this lava cake measures at least 50 m in height. A sample of the lava (65) has a fine-grained trachytoid texture, in which there are big crystals of a clinopyroxene and alk. feldspar (altered). The paste chiefly consists of tiny feldspar laths mingled with prisms of pyroxene and scattered resorbed grains of brown hornblende. Iron ore grains are sparse. The lava may be called a trachyphonolite (altered), rather distinct from the types met with further down in the canyon (the dislocated series).

This lava bank seems to be of great extent and reaches far to the northeast (in the direction of Artenara), always forming a marked escarpment towards the Tejeda canyon.

Continuing our climb up the steep slope above the plane of unconformity and crossing the mighty trachyphonolite lava cake to its upper edge, we will find it capped with a basalt lava sheet. Uphill there follows first a large mass of the R.N. agglomerate with vertical precipices. A great number of cave dwellings, hewed out by aborigenes in pre-Spanish times, are still occupied by the islanders. The thickness of this agglomerate bank was estimated to c. 50 m. Upward in the profile this chaotic agglomerate is replaced by stratified conglomerates and sandstones, apparently fluviatile deposits in the Caldera basin, when its floor lay much higher than the bottoms of the present gorges. — These strata form the basis of basalt lava sheets (671, 672). Micr. it is an olivine basalt. The olivine phenocrysts are mostly transformed into red-brown iddingsite. There are also euhedral crystals of augite (Ti-augite) lying in a groundmass of plagioclase laths (sparsely), augite and magnetite. There are also isotropic turbid patches, perhaps analcime. The types may be designated picritic basalts and differ from those in Mesa de los Junquillos. — The Acusa basalt forms two beds with sandstone layers between. The upper sheet is capped with loose material (lapillis).

These olivine basalts have no connection with the olivine-bearing basalts in the highland border above Artenara. The break may, however, be due to later erosion.

Mesa de los Junquillos (850 m)

This is the other remarkable erosion witness inside the Caldera, at a level which also antedates the excavation of the present gorges. It is a narrow eminence extending eastwest, not unlike the hull of a steamship, at the western termination of a long divide which separates Barranco de Carrizal from Barranco de Siberio (two left-hand tributaries to the master canyon). The maximum height of this *mesa* above the bottom of the latter is c. 500 m. The top is flat, the sides almost vertical down to a socle, the sides of which are also steep reaching down to the gravel-filled bottoms of the confining *barrancos*.

The socle of Mesa de los Junquillos consists, as we have already mentioned, of the old trachyte formation in a dislocated position. The banks of these lava sheets have a dip to the southeast of c. 45°. They are in places penetrated by dikes and small stocks of a fine-grained trachyte; rocks that are described later on.

The top sheets of Mesa de los Junquillos consist of basalts with interstratified sandstones and conglomerates. The uppermost lava bank is crowned with a thick cake of the R.N. agglomerate.

It is evident that Mesa de los Junquillos represents the remains of an ancient floor of the Caldera-depression like Mesa de Acusa. The eminence was carved out after the spreading (and the lithification) of the R.N. agglomerate masses.

The basalt lava banks were examined during a stroll along the north side of the *mesa*. There are 3 samples available (678, 680, 683) from lower lava sheets. Micr. the first is a typical olivine basalt of the more picritic kind with phenocrysts of olivine and augite. The groundmass consists of plagioclase, augite and ore and patches of a colourless, isotropic substance, perhaps analcime. Olivine is rimmed with iddingsite and augite is zonal. The texture of the paste is basaltic. — No. 680 is more tephritic in composition. Micr. it contains phenocrysts of augite and of brown hornblende, the latter opacite-rimmed. No olivine is seen in the slide. Magnetite is abundant, partly in larger grains. The paste chiefly consists of augite prisms and magnetite, feldspar is very sparingly seen. An isotropic substance also fills the interstices (analcime?) here. This lava appears in a very thick bank at the eastern termination of the *mesa* — ridge. There is no more basalt to the east (along the divide). — No. 681, also from the eastern end of the *mesa*, is amygdaloidal. Micr. it shows only augite (no olivine, no hornblende) in a paste of plagioclase (comp. An/40), augite and ore. The vesicles are filled with fibrous zeolite.

The topmost sheet in the *mesa* is, as was mentioned, not basalt but a thick bed of the R.N. agglomerate with a flat top and vertical sides. It shows vertical jointings in huge rectangular blocks. Some of them have dropped down the sides to the *barrancos*. This strange, completely isolated remain of a formerly certainly extensive formation (covering the whole of the ancient, higher-lying bottom of the Caldera) may be connected with part of the same formation still to be seen in the broad ridge that lies between Barranco de Chorrillo and Barranco de Siberio.

Mesa de los Junquillos was isolated from its surroundings at a time when the cross-going gorge of Barranco de la Aldea was gradually incised into the mountain barrier in the west. It is an integrating part of the young relief inside the Caldera created in connection with the lowering of the outflow-bottom.

If we try to compare the stratigraphy in Mesa de los Junquillos with that of Mesa de Acusa, we will find some discrepancies. It is evident that the basalt lavas crowning the latter are not contemporaneous with those of Junquillos, since they lie a b o v e the R.N. agglomerate, whereas the lavas in Mesa de J. lie u n d e r the same formation. Such facts speak in favour of lava emissions in the Caldera at different times in relation to the great Peléean activity. — It seems the Acusa lavas belong to the post-Miocene effusions of olivine basalt lavas which flooded such vast surfaces in the northern half of the island and also in the central highland. The part of the same lava inundations (i.e. the lava sheets then deposited) that did reach Junquillos may later on have been abolished by erosion.

* *
*

Inside the area of Caldera de Tejeda, there also rises the third erosion witness called E l L l a n i l l o, lying on the divide-ridge which forms the western continuation of the eminence of Roque Bentaiga. The small butte is situated in the fork between Barranco de Tejeda and Barranco de Chorrillo. The elevation above the sea is c. 850 m. I had no opportunity to visit this eminence. Seen from a certain distance, it has a dark-coloured flat-lying cap, most probably of basalts resting on a light-coloured socle (the old trachytes).

Later volcanic activity inside the Caldera and along its borders

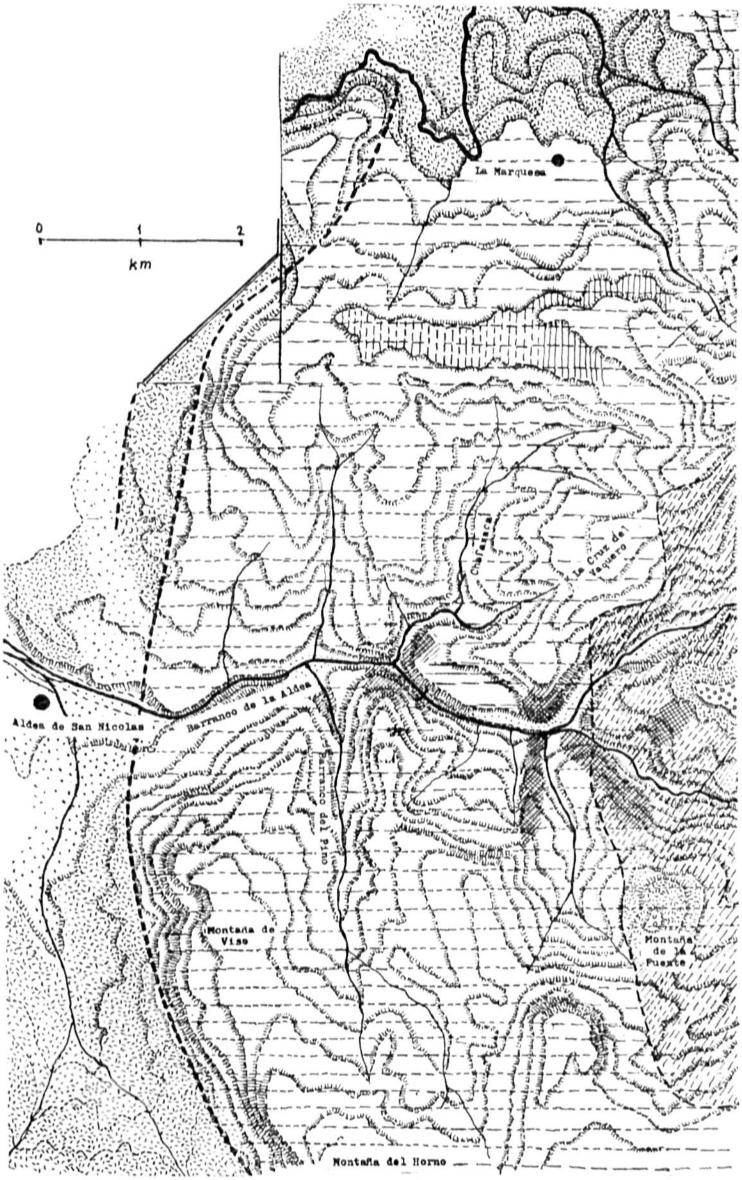
In the preceding chapters we have found that the area comprised by the Tejeda drainage area has been the site of many volcanic outbursts of the central type in the island. The latest of these apparently occurred in post-Miocene times. But all these successive orifices of great volcanoes have been abolished by later erosion. In the area in question, however, there are several volcanoes of an adventive character, partly inside the divide, partly upon it. Most of them seem to be relatively young, from Quaternary or from sub-Recent times.

A rather well-preserved cinder cone stands on the divide to the east of La Culata by the *cumbre* road some km from Cruz de Tejeda. It has sent a lava stream down the long slope to the Tejeda canyon, which has been filled to a certain height. But later on a narrow canyon has been incised into it. The lava walls in this young canyon display columnar jointing. One sample (641) is micr. a rather common olivine basalt with phenocrysts of olivine (clear) and augite. The groundmass consists of plagioclase, augite and ore. The composition approaches that of a picritic basalt and it shows an affinity to the highland basalts of a greater age. Since the cone is somewhat eroded and since its lava which has filled the bottom of the canyon has been eroded already in a pluvial period, the volcano cannot be very young, perhaps Quaternary.

Another cone stands on the divide between the Tejeda canyon and the head of Barr. de Chorrillo, and a lava has gone down to the north. This cone is considerably eroded.

In the north side of the caldera, not far from Artenara, there are other cones, such as La Caldereta with lavas down the slope. — Then we have the two ruins of cones on the divide to the west of Roque Bentaiga, on the stretch between it and El Llanillo.

Perhaps there are also other cones which have escaped attention. —



Symbols:

1. Obliquely hatched area (right) — oldest trachytes.
2. Densely dotted marginal zones (left and uppermost part) — old basalts.
3. Horiz. stripped main area — the salic series.
4. Vert. stripped: phonolite mesa west of Alta Vista.
5. Shaded patches in the Tejeda canyon — salic intrusive bodies.
6. Heavy, dashed lines (left) — dislocation zone.

Fig. 32. Topogr. geol. map of the mountain barrier of salic volcanics, region of Aldea de S. Nicolás, with the antecedent river gorge of Barr. de Tejeda (de la Aldea). Contour intervals 100 m. N—S vertically.

The lower course of Barranco de Tejeda (the cross-going canyon, cf. the topogr. geol. map fig. 32)

This stretch of the *barranco*, walled in by very steep and high mountain sides, is of c. 4 km in length and reaches from the mouth of Barranco de Siberio to the plain of Aldea de San Nicolás. The gorge offers an interesting geological cross-section through the western formidable barrier, and several tributary *barrancos* have contributed to the dissection of this mountain block. The gorge has a clearly antecedent character: the erosion started at higher levels, having the function as an outlet spillway of a pre-caldera basin filled with water (?). The bottom of this basin lay considerably higher than the present one. Hence the canyon is here a real water gap (to use an expression referring to the Appalachian morphology, in U.S.A.). At the present time no water is running along the bottom, however, (except in times of torrential rains). In bygone days, under a more pluvial climate, there certainly existed a perennial river. This can be seen for example from the fact that no ledges along the gravel filled bottom are visible. The longitudinal profile is smooth!

The downcutting of the canyon has gone on at the same pace as the erosion inside the Tejeda basin behind it: all the gorges there have adjusted their bottoms to this gorge.

On both sides of the canyon there are geologic exposures to great heights, attaining 1 300—1 400 m. Only the steepness of the slopes is difficult to overcome in many sectors. But on the other hand there are insights into the side canyons too, elucidating the inner structure. The author must confess, however, he did not have time enough to his disposal to investigate the conditions in detail. Much is to be left for future work.

The formation traversed by this cross-going gorge belongs to the salic series of volcanics succeding the west coast basalts. High bluffs of those rocks are exposed in the west side of Montaña del Viso and in Montaña de la Fuente Blanca. Here also the underlying old basalts are visible. — On the other hand no exposures of the oldest Tejeda trachytes are to be seen in the gorge W of the junction of Barranco de Siberio.

Petrographical characteristics. — We may first describe the layered series of lavas and tuffs, then we will deal with some small intrusive bodies.

Lavas, tuffs and ignimbrites in a flat-lying position

As we have found from the descriptions in the preceding pages, the lavas inside the so-called Caldera de Tejeda are in an inclined position as far as their basement is concerned. These inclined beds reach west to the vicinity of the junction with Barranco de Siberio and here the cross-going gorge also begins. When following this latter to its end in the low-land of Aldea de S. Nicolás, one will pass an enormous pile of flat-lying volcanic sheets: tuffs and lavas. In fact, the mountain barrier here (dissected by the gorge) is part of the western formation of salic volcanics which we have already treated in some preceding chapters. The reader is referred to the topographical and geological map, fig. 32.

The author has to some extent studied the geological profiles in this impressive gorge or »water gap». The roughness of the mountain sides here, however, have prevented him from a more detailed study of the outcrops. The following samples have been collected: 675, 692, 705, 706, 712, 719, 720, 723.

A basement to the flat-lying series is not visible in the canyon. One has to follow it for its entire length and leave its mouth to find outcrops of old basalts at the foot of Montaña del Viso (opposite the village of S. Nicolás). This does not mean, however, that there really is a basalt lying under the salic beds further east.

The first horizontal volcanic beds to be found when one comes along the canyon from the east (and approaches the mouth of Barr. de Siberio) lies at the western termination of Mesa de los Junquillos. A sample of the lava lying at the bottom level of the canyon (692) is a fine-grained grayish lava of a felsitic texture without any phenocrysts. There are chiefly tiny rods of feldspar in random orientations mingled with opaque grains and aggregates and also with a colourless substance of isotropy which may be analcime. The pores are filled with carbonate. It is a rock type corresponding to a pantellerite (or trachyte).

Further down, we approach the reservoir of Caidero de las Niñas. But before we are there we pass a very narrow rock gap (*angostura*) with walls of a fine-grained massive rock (described later on). Then we enter Barranquillo de Bigaroy on the left side of the canyon and follow its steep gradient. Along this there are large exposures of salic lavas (706, 716). The first is a fine-grained feldspar lava also containing nepheline and ore (it seems to be ilmenite). Microlites of aegirine also occur surrounding the small nepheline crystals. The slide

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looks rather dark between + nic., indicating a certain stage of alteration. The lava is a metatrachyte. — No. 716 is likewise in an altered state but it is distinctly porphyric with relatively large laths of feldspar phenocrysts in a fine-grained paste of feldspar rods mingled with aegirine (?) and ore powder. This lava may be of about the same composition as the preceding one.

From the cattle post of B i g a r o y, I climbed the steep slope in a southwesterly direction, first crossing an intrusive body in the lavas — a greenish porphyry (see later on). On higher levels appears a series of variegated tuffs and finally a huge lava bank (no sample). Reaching the foot of an escarpment at an altitude of c. 400 m above the bottom of the canyon, I found it to consist of a columnar lava bank of a trachytic aspect (705). The rock is fine-grained, grayish-green and tough. Micr. there is a distinct porphyric texture with well discernible euhedral phenocrysts of alk. feldspar (altered) in Karlsbad twins. They lie in a paste of feldspar rods, aegirine needles in random orientations and tiny stout prisms of nepheline surrounded by aegirine clusters. The rest of the paste looks rather dark between + nic. There are also radial bundles of a zeolite. The rock may be a phonolite or trachyphonolite.

Above this bank of lava of many tens of m thickness, with columnar jointing, there follow other lava banks of a great extension sideways, all belonging to the northern promontory of M o n t a ñ a d e l a s M o n j a s. As has been pointed out earlier, the mountain consists in its entirety of flat-lying lavas and tuff layers, a veritable table-mountain. The thickness of the salic series can be estimated as c. 1 000 m.

The slope right down to the bottom of the Tejeda (Aldea) canyon exposes several banks of lavas and tuffs; the lowest part consists of finely stratified tuffs in a horizontal position. They are here crossed by a bostonite dike.

All the way from C a i d e r o d e l a s N i ñ a s to Aldea de San Nicolás there are flat-lying banks of lavas to be seen. Samples 712 and 719 illustrate the nature of these lavas: they are trachytic, rather decomposed and the components are difficult to determine, especially the feldspar in phenocrysts and in the paste. The lava banks are large, with columnar jointings and of a dull, brownish-gray colour. They are penetrated in some places by dikes and bosses which will be treated below.

Intrusive bosses and dikes of trachytic rocks in the horizontal-lying salic series in the western mountain barrier

Thanks to the presence of the cross-going gorge of Aldea (or Tejeda), before reaching the lowland of Aldea de San Nicolás a number of intrusive rocks of an extremely salic composition have been disclosed. They have found an emplacement through the flat-lying lavas and their tuff layers to varying heights above the bottom of the canyon. They may in reality be very numerous, I have studied only a few of them and collected some samples (684, 688, 707, 709, 711, 713, 713a, 714).

If we proceed from east to west, we first notice a smaller intrusive mass in the steep south slope of Mesa de los Junquillos (socle, below the covering basalts). This rock (684, 688) is partly trachytoid, partly of a texture without a determined orientation. The chief mineral is alk. feldspar in tiny laths mingled with irregular small patches of an opaque substance. No phenocrysts are present of feldspar or of mafic minerals. In the fluidal type minute crystals of nepheline are present, also needles of aegirine (strongly pleochr.). The pores in the rock are empty. The composition points to a bostonite. Owing to the somewhat altered state of the feldspar and its small size, no closer diagnosis is possible (// ext., length fast);

If we proceed down the master canyon from the mouth of the left tributary, Barranco de Siberio, we arrive at the narrow passage with vertical walls of a felsitic rock (711, 713, 713a). The canyon has here cut its way across an intrusive body of a very fine-grained mass, which is micr. of the bostonite type. In one slide (713a) there are also relatively large phenocrysts of alk. feldspar with a fine, polysynthetic twinning (opt. char. +, albite). Mafic minerals are not seen in the slides; instead there are irregular dark and opaque grains and patches intermingled with the feldspar rods. The intrusive body in the *angostura* here seems to be of the same kind as that in Mesa de los Junquillos (the socle) — a bostonite, tough and with a conchoidal fracture.

Since the walls of the *angostura* are only some ten m. high, it could not be proved how far up this body has found its way in the series of lavas. — Going up a left hand *barranquillo* in the vicinity to Bigaroy (mentioned earlier), a great dike with a steep inclination was met crossing the flat-lying lavas there (sample 714). It is a bostonite porphyry, rather altered. There are euhedral phonocrysts of alk. feldspar (turbid) in a fine-grained paste of feldspar rods and magnetite grains and — aggregates (also skeletal forms); in addition some pseudomorphs appear (after hornblende?). Fluorite is seen in the cavities. It is possible that this great dike is related to the felsite below in the *angostura*.

On the way between the previously mentioned *angostura* and the reservoir Caidero de las Niñas, the horizontal layers of reddish tuffs in the canyon (left side) are crossed obliquely by a narrow dike (707). Micr. this is a porphyry, rather altered, with crystals of feldspar (turbid) lying in a paste of a trachytoid texture, chiefly consisting of feldspar rods (slender laths) mingled with opaque grains and pseudomorphs consisting of some opaque substance. The contours suggest a former hornblende (alk. ferri-hornblende?). In the latter there are small crystals of apatite. In addition the paste contains gray patches of an isotropic nature; they may be a glass residuum. The rock may be a bostonite porphyry, without doubt connected with the previously mentioned intrusive bosses.

At the new dam (Caid. de las Niñas) the canyon passes a very narrow *angostura*, the walls of which do not display any flat-lying lava banks, but a massive rock of a dull colour. I did not visit this place but it seems evident that we have here another felsitic intrusive boss like that above the water dam. The left wall is the end of a large northern promontory belonging to Montaña de las Monjas, the right wall corresponds to the end of the long ridge of La Cruz del Vaquero.

Downwards from this *angostura*, the canyon has a more open profile, although the walls are still steep, almost vertical. The road to Aldea de San Nicolás follows a terrace on the right side down to the mouth. Here huge banks of lavas are exposed (mentioned earlier). A small intrusive body was observed not far from the *angostura*, a light grayish-greenish trachyte-looking type (the sample has been lost).

* *
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The cross-going gorge of Aldea (Tejeda), which we have followed from the junction of Barranco de Siberio to the mouth above La Aldea de S. N., is geomorphologically of great interest — an antecedent water gap, to which we will return later on. The reader was referred to the topographical map, fig. 32.

Summary

of the geology inside the Tejeda drainage area. After the reader has been in the chapter above informed with a multitude of field and laboratory data about the area in question it may be necessary to have a certain conception of the geological structure as well as of the development of the great depression.

According to the stratigraphic principle, we may start our review with the relatively oldest lithological complex, then proceed to succeeding formations which have left their traces inside the area.

On going down to the bottoms of the deep gorges, we will find here the formation of salic lavas — trachytes and trachyphonolites, mostly in a weathered state. These lavas have been tilted into isoclinal positions, mostly to the east or southeast. According to two chemical analyses, these lavas are of the normal foyaitic to nordmarkitic magma types.

These salic lavas are intimately associated with alk. syenitic and nepheline syenitic plutonic granular rocks. The behaviour of these is such that one may suppose their origin to have been due to anatexis of the old trachytes. It seems that erosion has laid bare the subvolcanic levels of the eruptions of a later formation of salic lavas tuffs and ignimrites which constitute the embracing mountain barrier in the west of the area. The plutonics are of the bostonitic magma type (according to one analysis only). Inside the Tejeda area, this salic volcanic formation has mostly been abolished by erosion: we will find it only on the outskirts (the divides) in the south and west, where the formation lies with unconformity on the tilted trachytes.

With the beginning of a new volcanic phase, the area was first covered with some trachytic lavas and tuffs, then with the R. N. agglomerate masses, apparently forming a continuous cover over the area. Alternating with the Peléean eruptions that brought the agglomerates to the surface, there appeared lavas of alk. basaltic composition, spreading sheets which alternate with the agglomerate banks. These basic lavas are of the essexitic gabbroidal magma type.

Both kinds of material were emitted from central vents, most probably fissures in the highland.

The agglomerate formation is in turn covered with olivine basaltic lavas which have also been emitted from fissures (certainly reaching deeply into the island structure). The material is simatic — of the pyroxenitic magma type.

All these covering formations have afterwards been greatly damaged by erosion, so that only traces have been left behind inside the Caldera area.

Besides these lavas, agglomerates and tuffs which have been successively laid down upon each other there is a multitude of dikes inside the caldera area occurring at all levels. Generally they may be considered as feeding channels for the molten material brought to the surface. In some cases also emplacements in the shape of smaller bosses have taken place. There are many kinds of dikes here: ultrabasic basic, intermediary and salic are encountered. It seems the ultrabasic ones must be alloted to the latest generations.

Of young surface manifestations of protruding magas are the cinder cones and their lava streams, occurring partly in the surrounding crests, partly inside the Caldera itself. Their composition seems to be predominantly ultrabasic.

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Considering the genesis of Caldera de Tejeda drainage area, we will here speak only in generalized terms. The author has discussed the matter in another place (1961) in more details. We may here only try to check the events which have in the course of time led to the formation of this astonishingly deep scar in the island bulk.

1. The area was the place of many fissural eruptions of salic gas- (and water) containing magmas. The eruptions consisted in the emission of rhyolitic lavas, pyroclastic streams (hot avalanches) and the deposition of ashes. Owing to exhaustion in the deeper ground of these materials by withdrawal, a subsidence occurred following a set of fault lines.

2. The same area (now a depression) was anew the place of emission of salic lavas, this time of phonolites in great quantity. The material covered as it seems the entire island. A collapse followed also this time with the concluding eruptions. The depression was opened anew.

3. After a period of erosion volcanic activity of the Peléean type started somewhat to the east of the region. Great

avalanches flooded the depression and filled it up to certain heights with the chaotic masses of the R.N. agglomerates. Alk. basaltic lavas were added to these agglomerates as alternating sheets.

4. The central highland including the Tejeda area was the stage of great fissure eruptions of olivine basaltic magmas, and masses of lavas flooded the ground finding their way also down the island slopes in several sectors. The Tejeda area was covered by these basalts and they ran over the previously deposited R.N. agglomerate masses (already hardened). In this way the depression was to a considerable part filled up anew.

5. New displacements occurred in the Tejeda area and the depression deepened. A closed basin took shape.

6. This basin was gradually filled with atmosphaeric water — a lake was formed — and a spillway of the lake found its course to the west over the mountain barrier, previously formed.

7. The outflow channel was continually deepened and a crossgoing — antecedent gorge came into existence. This was more and more incised into the barrier, and at the same pace erosion was going on inside the Tejeda depression. Much of the material previously deposited was carried away. The lake was drained off completely.

8. In Quaternary and sub-Recent time volcanic activity started again, this time on a very reduced scale. Only a small number of cones grew up in the immediate surroundings and inside the Caldera.

Now we have reached the end of our descriptions on the geology of Grand Canary, and practically all the field data and also the laboratory experiences have been related. The author regrets that he does not have an appropriate topographical map provided with a sufficient number of locality names, to put to the reader's disposal when faced with the many *barrancos*, settlements and towns which appear in the text. The appended geological map of the island is a meagre substitute: owing to the very reduced scale only few names have found room in it. To those of my readers who intend to visit the island and on such an occasion will make use of this memoir, I wish to recommend a topographical map on the scale 1:50 000 with contour intervals of every 50 m (projection LAMBERT, »Canarias«).

Part II

Petrology and Systematic Geology

PETROLOGY

1. Rock types
2. Minerals in the rocks
3. Petrochemical conditions
4. Sequence of magmas and causes of diversification

1. Rock types

Some attempts have been made at times to classify the igneous rock types of Grand Canary, chiefly by S. CALDERÓN Y ARANA (1880) and more recently by E. JÉRÉMINE (1933, 1937). Brief quotations from the outlines of these authors have already been given in the Historic summary, so we do not need to recapitulate them here. The present author wishes, however, to stress the importance of the contributions of the latter authoress, which have been of great use to him in the preparations of this work. There is only one regrettable fact concerning JÉRÉMINE's data: the indications of the localities, from which the samples were taken and of their stratigraphical position are often rather vague. JÉRÉMINE has not made the collections herself (except during her trip in 1926). the material is mainly, as we already have mentioned, collected by J. BOURCART.

The total number of rock types and varieties recorded in Grand Canary is astonishingly large, although there is, of course, only a limited number of leading types. These can be divided into the two headcategories: the salic and the basic (and ultrabasic) types. Intermediary rock types are not very frequently present. In order to make divisions one has to recognize the colour ratio (index), the textural variations, the relative frequency of amygdules in the matrix, the degree of glass substance, properties besides the mineral paragenesis. Except magmatic rock types (volcanic and plutonic) there are of course also pyroclastic varieties, including ignimbrites, redeposited tuffs (*canto blanco*) and finally various types of altered rocks (there are in fact all stages of rock alterations to be found).

Rocks of sedimentary origin are in the island of rather restricted occurrence. There are the two main groups: the *in situ* soils derived mostly from pyroclastic material and the re-deposited rock waste and pyroclastics.

A special feature in the composition of the igneous rock ground of Grand Canary is t h e h i g h f r e q u e n c y o f s a l i c t y p e s in relation to the basic ones. In this respect the island stands alone in the whole archipelago, although Tenerife also has much of the salic types besides the basic ones. This conspicuous abundance of salic rocks in Grand Canary not only concerns the more superficial formations, but also the deeper lying parts of the island, a fact already recognized by J. BOURCART (1937).

T h e n o m e n c l a t u r e of the rocks in Grand Canary will provide considerable difficulties in all cases when chemical analyses are not available. This is because most of the lavas are of a fine grain in their paste and owing to the frequent admixture of glass substance or of the deuteric alterations of the components in the II generation. Zeolithisation is a common feature.

A. RITTMANN has in 1952 and in his book on Volcanism (1960) proposed to divide the lava rocks into several »classes» and »fields» within a double triangle of the same kind that was used by P. NIGGLI (1923) for the plutonic rocks. This division takes into account only the salic mineral components and the colour ratio (vol. % of mafics). Referring to the double triangle of RITTMANN we may enumerate all the »classes» and the »fields» having representatives among the rocks in Grand Canary (leading types):

Class I. Rhyolitic volcanites

Field 1 a. alk. rhyolites *sensu stricto* (with sanidine etc.)

Field 1 b. *Na:* rhyolites (with anorthoclase, aegirine etc.)

Class III. Trachytic volcanites

Field 6 a. alk. trachytes *sensu stricto* (with sanidine etc.)

Field 6 b. *Na:* trachytes (with anorthoclase, etc.)

Class IV. Basaltic volcanites

Field 10 b. basalts (40—75% mafics)

Class V. Phonolitic volcanites
Field 11 a. nepheline and sodalite phonolites

Class VI. Tephritic volcanites
Field 13 a. phonolitic nepheline tephrites
Field 14 a. nepheline tephrites (or analcime tephrites)

Class VIII. Ultrafemic volcanites
Field 18 a. picrites (olivine dominating)
Field 18 b. mafites (augite dominating)

There are of course several transition types within and between these groups (classes and fields), but the grouping may hold good for the majority of the types encountered. At is found in the descriptive Part I there are in fact many dubious cases quantitatively of lesser importance.

In trying to find a suitable nomenclature to our rocks we ought to make use of the proposals given by A. RITTMANN (1952). He has elaborated graphic keys for:

1. determinations of volcanic rocks whose mode is exactly known;
2. determination of volcanic rocks whose mode has been estimated;
3. determination of volcanic rocks the chemical analyses of which are available.

Exact mode of the rocks by using the Integration stage has only exceptionally been calculated. In the case of key no. 2, i.e. when the groundmass is very fine grained, partially or completely glassy, or when some of its minerals have been subjected to alterations, the estimation has been rather approximative. NIGGLI had proposed to use the prefix »pheno-» to the name chosen for the rock, thus leaving the composition of the groundmass somewhat uncertain. This prefix has not been used in this paper.

Key no. 3 referring to all the rocks which have been chemically analysed, has been used in 19 cases; the RITTMANN diagrams have given a graphical solution of the name question. For the use of the diagrams weight percentages of the analyses have been partly transformed and arranged into a number of groups with the following symbols: (SiO_2), Al, Alk, (CaO), FM, k, an, and ca''. These values have been added to every analysis in the descriptive Part I, and the name of the rock found with the aid of the diagrams has been added.

E. JÉRÉMINE (1933, 1937) has used rock names according to the nomenclature of A. LACROIX. The present author has in his quotations made use of these too. Analyses published by this authoress have not been calculated according to the RITTMANN-procedure.

Classification of the leading types of igneous rocks in Grand Canary

Plutonic rocks: alkali syenites, nepheline syenites, monzonites, essexites, olivine gabbros, anorthosites, theralites, pyroxenolites.

Volcanic rocks:

Lava rocks:

pitchstones, vitrophyres, rhyolites, light latites, pantellerites, comendites, rhyotrachytes, sodatrachytes, trachyphonolites, nepheline phonolites, hauyne (nosean) phonolites, tahitites, ordanchites.

sakalavites, trachybasalts, olivine-andesine-trachybasalts, plagioclase basalts, tephrites, basanites, olivine basalts, dark nepheline basalts, picritic basalts (with limburgites, ankaramites), ankaratrites.

Pyroclastic rocks: puzzolane (*trass*), ignimbrites, phonolite tuffs, Roque Nublo agglomerates, basalt tuffs and agglomerates, decomposed tuffs (mostly basaltic).

Dike rocks: bostonites, tinguaites, phonolitic dike rocks, monchiquites, camptonites, a.o. lamprophyres, ankaramitic dike rocks, madeirites.

A number of the names above has been obtained by using the key no. 3 of RITTMANN.

In the general petrographic characteristics to follow the orden in the scheme above will be maintained excepting (in parts) the pyroclastic rocks and the plutonics, the latter forming a concluding chapter.

Finally, we may insert here the double triangle according to NIGGLI (1931) and TRÖGER (1938) referring to the salic modal composition of volcanic rocks. Colour index (vol. % of mafics) could also be indicated.

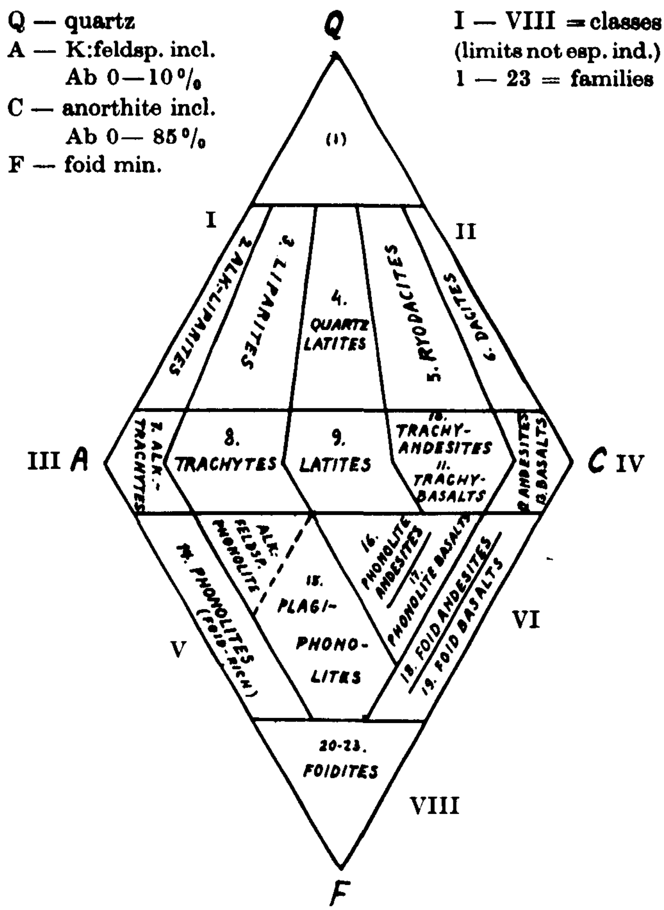

Fig. 33.

Rhyolites, trachytes and their pyroclastics

A great many kinds of these volcanics have been mustered microscopically, most of them from the western mountains (Montaña del Horno, Mont. del Viso and Mont. de Tamadaba), a certain number from the deeper parts of Caldera de Tejeda, some also from the north coast.

It is difficult to characterize these rocks in general terms, since they show a great variety — not so much in their mineralogical composition as in the their textures and their external aspect. — Most of them are porphyric, they contain feldspar phenocrysts of euhedral shape (or there are only fragments of feldspar) enclosed in a fine grained paste. The feldspar seems mostly to be anorthoclase. Quartz has only occasionally been seen in the slides, even the rhyolites are poor in this mineral. Mafics are rare, there are small flakes of brown mica or small prisms of a clino-pyroxene and scattered grains of iron ore. Small grains of nepheline can occasionally be seen in the uppermost sheets of lavas, representing a kind of transition to the phonolites. — The texture is in parts without any lamination, but often laminated with beautiful flow traces: streaks of fine grained groundmass alternating with glassy zones or elongated vesicles filled with tiny tablets of sanidine and powder of iron ore. Trachytoid arrangement of the small feldspar laths is a common feature.

There are plenty of streaky textures to be seen. In some cases — especially when feldspar phenocrysts have been crushed and the fragments strewn in long rows in the flow direction — one is struck by a resemblance with the ignimbrites described from many parts of the world, where rhyolite volcanics have been found in greater thicknesses. Here is not the place to enter into discussion about these pyroclastics — the material at hand is not comprehensive enough. — We may only refer to some papers of later date (S. Hjelmqvist 1956 and F. R. Boyd 1961). The ignimbrites do appear generally as very thick banks of wide extension showing columnar jointings (C. A. Cotton 1952, A. Rittmann 1960). The same is the case with the series of rhyolites-trachytes exposed in the western mountains of Grand Canary. These things will be briefly mentioned in the chapter on Systematic geology.

In the deep erosion channels of Barranco de Tejeda and its tributaries we will find plenty of fine grained trachyte lavas and also of varieties with the aspect of ignimbrites. Micr. the trachytes have phenocrysts of anorthoclase, lying in a trachytoid groundmass of small feldspar laths and microlites of a pyroxene. The lavas have undergone alterations (kaolinization?), the rocks are of soft consistency. This circumstance has facilitated the work of erosion in the canyons. These often intense alterations are due to an original impregnation of the rocks with iron sulphide which has been oxydished to rusty patches, and sulphuric acid has been generated soaking the rocks.

The whole complex inside Caldera de Tejeda represents an old volcanic formation in dislocated positions. We will later on return to this formation.

2. Nepheline phonolites

This formation, next in age after the rhyolite-trachyte formation in the western mountains is a characteristic lithologic unit. Externally the rocks are dark-brown to nearly black or dark-grayish and they are laminated (platy). On the cleavage planes one will se glistening feldspar phenocrysts of dark colour. The lamination has been caused by the fabric: micr. one will find a distinct parallel texture of the feldspar laths both the phenocrysts and the small rods in the groundmass. The rocks also contain plenty of aegirine needles arranged in the same direction. Besides there are always nepheline crystals interstrewn, chiefly of smaller dimensions, however. The feldspar phenocrysts seem to be anorthoclase. An average composition of these phonolites is as follows (in vol. %): alk. feldspars — 60, nepheline — 10, aegirine — 20, ore — 10.

These phonolites belonged to a great volcano of the central type covering with its lavas most of the island. Now only the southern sector is to be seen, and the original grade of the slope is here conserved.

These phonolites are exceedingly typical in their appearance chiefly due to the distinct lamination that produces a debris consisting of slabs. The lava sheets are of great thickness, and they generally alternate with tuff banks of brownish or reddish colours. In the surface these dark phonolites are nearly white, they are covered with a film of kaolinized rock.

The presence in the surface of the freshly broken rock slabs of glistening, large feldspar phenocrysts has justified the name »star stone» (*»roca de estrellas»*).

The puzzolane (*canto blanco*)

This pyroclastic deposit represents an important member in the volcanic sequence of the island. It is also of practical use (construction material). The deposit is not unique in the archipelago, it occurs also in Tenerife, here in major quantities.

The puzzolane is an unstratified cream-coloured, rather fine grained pumiceous mass, either homogenous, or it contains more or less of xenoliths of dark lava rocks, sometimes arranged in horizontal »rows» (in vertical profile). In the pumice there are frequently vesicles, either empty or filled with a canary-yellow powdery substance (a kind of zeolite). The mass is divided by great vertical diaclases, and these are of some use in the quarrying work.

Microscopically the texture is that of a glassy pumice powder with plenty of feldspar fragments, mostly sanidine, occurring also as tiny plates. Mafic minerals seem to be absent. In the pumice there is also free silica, judging from a chemical analysis of a puzzolane from the quarries at San Lorenzo. It cannot be stated, however, if the silica surplus is of primary or of secondary origin. There are micr. minute grains of iron oxide, disseminated. The puzzolane must have been swept down the slopes mingled with hot water, an avalanche of a paste, a mudstream of low viscosity. It ran down where appropriate runways existed and filled up lower grounds, sometimes to an astonishing thickness. These mudstreams did consolidate chiefly by zeolitisation in the intergranular spaces. — The hot streams were of course devastating to the plants and animals that happened to exist in the way. In Tenerife there have been found remains of *Testudo Burchardii* AHL and also empty cylindrical hollows that may be casts of tree trunks (so called *cañones*).

This peculiar tuff mass seems to correspond to the German *Trass* of the Laacher See region, described by K. VOLZING (1909—1910).

The puzzolane has since long time been quarried. Chief locality of puzzolane in Grand Canary is in San Lorenzo, at a relatively short distance from Las Palmas. Another important occurrence is in the far south at Arguineguín. Here explotation has still not commenced.[1]) Chief uses of the rock is for building purposes, also for the fabrication of pieces composing the irrigation canals. In Tenerife the puzzolane has been used as a raw material for production of hydraulic cement (at Puerto de Cristianos).

The Roque Nublo-agglomerates

This name refers to a lithologic unit in the island and has been lent from a well known land-mark in the mountains — consisting of the same material — an erosion witness Roque Nublo (frontispiece) — 'The Rock in The Clouds" as it may be called in English. The agglomerate consists of a chaotic mass of a brownish pumice matrix with plenty of intermingled stones and boulders of angular forms. The mass is rather firmly lithified, but it is dissected by huge vertical joints or diaclases. Thickness is varying, but attains in the more central parts c. 100 m; sometimes more. A rough horizontal sheeting is perceptible.

[1]) According to recent information a cement factory has started in Argnineguín, based on the same puzzolane

There is no chemical analysis of the matrix at hand, but it seems to be of salic composition. On the other hand we have the xenoliths consisting partly of deep seated rock types, according to E. JÉRÉMINE (1937) nepheline monzonites, essexites, theralites, pyroxenolites and hornblendites. These types are considered by JÉRÉMINE the intrusive facies of lavas. They are proofs dragged to the surface by the eruptions of the pumice masses. On the way also some effusive rock types were caught, judging from some samples collected by the present author; they are of tephritic composition.

The Roque Nublo agglomerate has originated by Peléean eruptions from some orifices in the central highland, there is no doubt about that. The great thicknesses met with in the still remaining sheets of agglomerate covering most of the central highland strengthens such an assumption. Down the slopes the thickness diminishes steadily.

The true agglomerate has no stratification as we already have pointed out. There is only a rough parting into thick horizontal sheets in parts interfoliated with tephrite lava banks (see further on!). In some places the agglomerate has been, however, transformed into a stratified sequence of conglomerates and sandstones, representing no doubt water transported and from water deposited materials, derived from the (still not consolidated) agglomerate masses. These true sedimentary deposits will be dealt with in a following chapter.

There were consequently two different phases of deposition: a Peléean explosion period with glowing avalanches covering most of the island, and a succeeding phase of water transport of the already deposited (but not solidified) material down the slopes and deposition into occasional basins lying in the way.

Na: rich sodalite-hauyne bearing phonolites

This is an interesting group of phonolites differing from the phonolites in the southern sector. Externally they are not dark and platy, but of greenish tint, massive and dotted with white feldspar phenocrysts. Micr. they reveal a rather different composition, chiefly by the presence of a sodalite mineral as one of the essential constituents.

These greenish phonolites are the result of multiple vents eruptions and the vents are easily located thanks to the necks which the eruptions have left standing. But there are also lava fields in the surroundings. Chief area of the exposures is in the central highland c. 1 500 m above the sea. The eruptions are of later age than the deposition of the R.N. agglomerates (see later on, chapter on endogenic events!).

Micr. these lava rocks are distinctly porphyric. There are alk. feldspars in broad laths, they are anorthoclase. Besides there are the well developed crystals of a sodalite mineral, chiefly as it seems hauyne. The crystal forms are often corroded as it was mentioned already. Mafic phenocrysts are greenish clinopyroxene, euhedral and with good cleavages. It may correspond to aegirine augite. In the groundmass there is a second generation of pyroxene, small green prisms of aegirine. Sphene is a rather common constituent. Tiny laths of feldspar fill the groundmass, they seem to be oligoclase. Accessories are magnetite (or ilmeno-magnetite) and apatite.

There are hauynophyres, tahitites and ordanchites to be mentioned. The lavas seem to have been of high viscosity, since they have accumulated above their vents (forming necks). Also the cumulo-volcanoes at Arucas and Cardones on the north coast demonstrate the same viscosity. These two volcanoes consist as it was proved already by E. JÉRÉMINE (1937) of tahitite and ordanchite respectively (the latter carrying a basic plagioclase instead of anorthoclase).

These (according to two chemical analyses) strongly *Na*-enriched lava rocks, at the same time silica-undersaturated, represent the last eruptions of salic magmas of alkaline character in the island, as it will be pointed out more closely in a succeeding chapter. This group of volcanics is not very common in the Canarian petrographic province, and even in Grand Canary their relative quantity is of no great importance.

Lava rocks of basic and ultrabasic composition

We may have a three-fold division of this large group (disregarding here the relative age of the formations).

1. Plagioclase basalts.
2. Alkali basalts (tephrites and basanites).
3. Olivine basalts ranging from ordinary olivine basalts to ultrabasic types (ankaramites, limburgites etc.).

The first mentioned group is not very wide spread, it appears chiefly along the west coast but in stratigraphically higher positions. The second group of lavas has expanded chiefly in the central highland, but also somewhat down the slopes of the island in certain sectors. The third group is very wide-spread: it covers a great deal of the central highland, the northern and the eastern declivities. Moreover it is exposed in the sea cliffs along the west coast (under the lavas of the first group), and finally these olivine bearing lavas build the many adventive cones strewn over the island.

1. Plagioclase basalts

These lavas are characterized chiefly by their porphyritic development with clearly visible plagioclase phenocrysts. Composition of these plagioclase is c. An/60. Besides there are phenocrysts of augite and magnetite (rather plenty present). Vesicles are filled with calcite but lined with a film of chlorite, or there is only chlorite in the fill. The groundmass has basaltic texture and is rich in magnetite. According to E. JÉRÉMINE (1937) the composition is as follows: plagioclase — 30%, augite — 25%, accessories — 8% and a glassy matrix — 37% (or, if crystallized it contains plag. + aug. + ore). A chemical analysis communicated by her reveals saturation with silica. An analysis of mine of a similar rock is slightly more alkaline, and the texture of the groundmass in the same rock is trachytoidal (instead of basaltic). The plagioclase is confined to the groundmass, only augite forms the phenocrysts.

JÉRÉMINE (l.c.) mentions also the occurrence of a sakalavite (in the west).

2. Tephrites and basanites

This group of alkaline basalts is rather typical of the Canarian magmatic province. The names themselves are old, it is true, the first geologists to use them were A. CORDIER and AL. BRONGNIART, the latter applying the name basanite to olivine bearing tephrites. Later, these names seem to have been forgotten until KARL VON FRITSCH and his countryman W. REISS in their now classical monograph on the geology of Tenerife definitely introduced these names into the descriptive petrography. They recognized the common occurrences of these lava types in the Canaries. Later investigations have only confirmed this experience.

BOURCART—JÉRÉMINE's often quoted researches in Grand Canary, proved, like mine, the wide spread occurrence of such alkaline basic rocks and their dike swarms, as the reader may have found from the descriptive Part I. More common among the two types are the tephrites, however. We will find these of a rather uniform composition. The leading minerals of the I gen. are Ti-augite, a brown barkevikitic hornblende and sometimes also laths of a plagioclase (An/40—60) all lying in a groundmass consisting of plagioclase, analcime (sec.), pyroxene and magnetite (or ilmeno-magnetite). In the case of the basanites the olivine appears as phenocrysts, but it seldom occurs in the groundmass. A primary foid mineral (nepheline or hauyne) is rare, instead we will find analcime or an isotropic colourless substance in the paste. The relative abundance of brown hornblende in these rocks is remarkable; it is never found in the olivine basalts of common types. The mineral shows mostly signs of magmatic corrosion, it was to some degree unstable during the further crystallization of the magma. The prisms of hornblende are then surrounded by a fringe of opaque substance. In the groundmass hornblende does not appear, instead there is augite as the only mafic mineral.

The tephrite (and basanite) lavas are seldom blistery, they are dark grayish and they appear in thick lava banks, mostly intercalated in the R.N. agglomerate formation, to which they are genetically allied.

Dikes related to the tephrites are as it seems, the lamprophyres occurring in abundance in the Tejeda area. They will be more closely characterized in a succeeding chapter.

In the work by J. Bourcart & E. Jérémine (1937) there are no details about the basanites in the island (called by Jérémine »basanitoides»). In the earlier paper by the latter author (1933) we have however, several notices (occurrences: Barr. Don Zoilo, Tejeda, Arucas and Tirajana). The rocks are in parts basanites, in parts basanitoides. The reader is missing indications about the stratigraphic position of the lava in every particular case. These rocks contain olivine, augite, nepheline, analcime, plagioclase and magnetite. The An: content of the plagioclase changes from sample to sample (An/38—60).

3. Olivine basalts
(basic to ultrabasic types)

This large group of basic lavas ranging from plagioclase-rich olivine basalts to feldspar-poor ankaramites and limburgites and their pyroclastic products occupy a very extensive part of the island surface. The chief basa'tic terranes are the northern and the eastern declivities, but also in the central highland and along the west coast there are plenty of these basalts. The geologic age is different, however, reaching from one of the oldest formations (of Eocene age?) down to the Recent lavas (La Isleta, Jinámar).

These olivine bearing basalts are as it was told varying in their mineral composition and in colour index. Their texture is also not always identical. Then there is plenty of glassy substance in the young lavas. Finally the state of preservation may be very different in the different formations, although this behaviour also depends on the exposition of the lava.

The olivine bearing basalts can of course be arranged according to their colour index as well as to their content (in weight %) of the olivine. The nomenclature found in the litterature on the subject is, however, not always the same. According to E. TRÖGER (1935) and other authors, the following range may be established as far as the olivine content is concerned: masafuerite — 45%, oceanite — 34%, picrite — 31%, ankaramite — 17%, picritic basalt — 15%, ordinary olivine basalt — 14—8%. We can state that none of the types studied in our collection shows the same abundance of olivine, as is found in the three first mentioned basaltic rocks. In the descriptive Part I, I have mostly used the name picritic basalt and this seems to be appropriate for most of the lavas of this basic group. Then there are several occurrences of olivine bearing basalts with a much lower colour index, in which the plagioclase is the most essential mineral, both in the phenocrysts and in the groundmass. In this kind of lavas the olivine occurs in smaller quantity than the pyroxene but it is almost altered to a redbrown iddingsite. The composition of the plagioclase is rather constant through the whole range of types (An/60—55), being a high-temperature form. The plagioclase of the paste seems to have been transformed to a zeolite substance. Augite and ore are anhedral. The augite may always be a Ti-augite.

Dike rocks

As is true of every more complicated volcanic structure in a somewhat advanced stage or erosion, there is a high frequency of dikes of different ages, trend and also composition. Such a state of affairs is seen in Grand Canary, especially of course in those sectors of the island where erosion has reached a great depth. If one enters the Caldera of Tejeda or Tirajana, a multitude of dikes will appear. The frequency is not evenly distributed, however. Also along the west coast there are exposures (cliffs) with dikes crossing the basalt formation in this part. — It seems however, the general frequency of the dikes in our island does not match the astonishing number and variety of dikes to be seen in the famous

Caldera de Taburiente in La Palma, admirably described long ago by C. GAGEL, (1910 lit.).

A closer examination of the dikes in Grand Canary has up to the present time not been carried out, and no detailed mapping of the most important areas has been made. — Only a fragmentary summary of the dikes can therefore be made here. Nevertheless we may gain some insight into the essential features of the matter.

A rough division of the dikes is into the two groups- salic and basic. Intermediary types are not of common occurrence.

1. S a l i c d i k e s. — These seem to be of a relatively advanced age, because the salic magma eruptions have ceased long ago. We have in this group bostonites and tinguaites. The bostonites are fine grained, trachytoid, but in some cases also with a random arrangement of the feldspar laths. They are either porphyric or aphyric. In the former case anorthoclase seems to be the mineral of the I gen. Mafics are almost absent, only tiny flakes of brown mica or elongated microlites of aegirine can be seen in the paste. — The tinguaites are trachytoid, with laths of alk. feldspar (anorthoclase or sanidine) in a groundmass of fine feldspar laths and aegirine prisms, the latter in aggregates. Nepheline in stout small prisms, also appears. Such dikes often relatively rich in aegirine and of greenish colour, are met with in Barranco de Siberio, for instance. The rocks are fine-grained, occasionally also of coarser grain, and they seem to have a magmatic connection with the nepheline phonolites, lavas that occupy vast areas to the south of the Caldera. It looks if at least some of the larger dikes may have played the role of passageways for phonolitic magmas.

Along the lower course of Barranco de Tejeda (the cross-going canyon) there are plenty of salic, felsitic dikes and also smaller bosses of bostonitic kind. They cross the flat-lying series of rhyolite and trachyte lavas and tuffs. These felsites are in a rather altered state. The composition is feldspathic, both the porphyric and the paste feldspars are turbid and difficult to recognize. Mafics seem to be absent, except for small flakes of mica or small aggregates or iron ore.

A somewhat different group of the salic dikes can be found in the environments of Villa de Tejeda crossing the R.N. agglomerate formation, but also in some other parts of the central highland. These dikes are of a higher colour index and they contain always a foid mineral. They may be considered transition types to the lamprophyres (described later on). These rocks have phenocrysts of brown hornblende and an alk. pyroxene (aegirine augite), sphene and sometimes an alk. feldspar (with Karlsbad twins), generally decomposed. Besides there are euhedral grains of a bluish sodalite mineral. The groundmass is trachytoid, filled with feldspar laths. Apatite is accessory, also magnetite. These dikes are without doubt connected with the above characterized hauynophyres etc., forming the necks in the highland. Such dikes are rather wide spread, they have been found also outside Caldera de Tejeda.

J. BOURCART (l.c.) has indicated in his geological map several »syenites et microsyenites en filons couches» in the Tejeda area. I have noticed one such dike in the Tejeda canyon below Artenara.

2. Basic dikes. — There are several types belonging to this group. We have the two major categories: the lamprophyres and the basaltic dikes (mostly olivine bearing). The differences in age are also wide. In general the basalts in the mountains of the *Cumbre* belong to the post-Miocene volcanism, whereas the lamprophyres are older. Still older are basaltic dikes crossing the old basalts at the west coast.

Lamprophyric dikes have been found principally in the Tejeda area, more exactly in the slopes of the eastern half of the depression. But they reappear also on the other side of the divide of Cruz de Tejeda and in some other places.

My collection refers principally to the dikes inside the Caldera of Tejeda. Here they are well to be seen standing as walls above the ground owing to their greater resistance to weathering and erosion. The dikes are almost in vertical position and their extension seems to be rather large. Their trend is almost N—S or NW—SE. Micr. these rocks are distinctly porphyric, with phenocrysts of a *Ti*-augite with well developed crystal faces. There is also a brown pleochroic hornblende, always to a smaller amount. Plagioclase of the I gen. is restricted in quantity, — in one case it has been proved to be labradorite. On the other hand magnetite appears in big crystals, and it is mostly associated with the augite. The groundmass is a mixture of plagioclase microlites, augite prisms and magnetite (abundantly). Besides there is generally a colourless, isotropic substance, perhaps analcime (secondary?). One may suppose this substance represents an altered nepheline (also a plagioclase?)

The author has come to the conclusion the lamprophyric dikes are magmatically connected with the tephrite lavas which appear as intercalated sheets in the R.N. agglomerate formation, although conclusive proofs cannot be presented. These dikes are mostly of insignificant breadth, and they have a very characteristic prismatic jointing perpendicularly to the walls of the dike.

Basaltic dikes are rather common. As it was told before they are of different ages, the oldest are seen in the basaltic coast cliffs in the west. They are olivine-bearing, and they may be closely connected with the basalt lavas themselves. — A younger group are the large dikes in the central highland, many hundred of metres in length and several metres in breadth. Since they offer more resistance to erosion than the surrounding ground, they stand in relief. These dike rocks are all olivine-rich (picritic) basalts grading into ultrabasic types. Here the feldspar component is scarcely to be seen. Instead we will find an isotropic, colourless substance forming a mesostasis between the augite prisms and the magnetite grains in the groundmass. The phenocrysts are augite and olivine and bigger crystals of magnetite. In one case a mineral of the sodalite group occurs in this category of rocks.

Dikes of the last kind may be designated as madeirites or the like. Madeirite is described by A. HOLMES (1920) as follows: »a porphyritic variety of alkali picrite containing abundant phenocrysts of titaniferous augite with a (somewhat serpentinized) olivine in a groundmass consisting of mainly augite and magnetite with a little plagioclase». It corresponds also with the ankaramites or the limburgites (according to the nomenclature of A. LACROIX).

Plutonic rocks

The occurrences of salic plutonic rock bodies in the central part of the island (Caldera de Tejeda) have already been described in some detail and we may here limit ourselves to a short summary.

Alkaline syenitic granular rocks are known from Fuerteventura (J. BOURCART & E. JÉRÉMINE 1938, HAUSEN 1958) and now similar bodies have been detected in Grand Canary. Their presence was at first supposed by J. BOURCART (l.c.) after the finding of loose boulders in Aldea de San Nicolás. The present author has seen several massifs of the same rocks in the canyons of Tejeda and Siberio.

The alk. syenites are rather coarse-grained rocks of a reddish-brownish colour, consisting almost of a feldspar that is orthoclase of the low temp. form ($2V\alpha = 77°$). This mineral has crystallized in thick tabular forms in random orientations. In the pores between the feldspars there has been formed an opaque substance or aegirine. Stray flakes of mica are also seen, besides sphene in anhedral crystals. Some of the pores are occupied by a colourless, isotropic substance (turbid), probably analcime. Apatite and magnetite are accessories. The rock is in an unaltered state, as may be seen from the glistening cleavage surfaces of the feldspar grains. This well conserved condition stands in a striking contrast to the decomposed state of the trachytes which the syenite has penetrated. We can therefore conclude that the syenites are relatively younger.

Aside from these syenites we will find n e p h e l i n e s y e n i t e s of a somewhat similar aspect. They differ from the syenites by their higher colour index, mafics are present rather abundantly in the shape of aegirine crystals. Another typical mineral is nepheline (anhedral aeleolite). The feldspar, here also in thick laths in random orientations — is perthite, the host mineral being orthoclase, the other feldspar andesine. There are two generations of aegirine, an anhedral one sometimes filling the pores, and a slender aegirine in beautiful bundles. (Aegirine I$-2V\alpha = 68°$, $c\wedge\alpha = 11°$), aegirine II$-c\wedge\alpha$ — almost 0°). Sphene and fluorite are also present, the latter as fills in the pores. Flakes of a brown mica can be found. Colour index has been estimated to c. 25.

The order of crystallization in the nepheline syenite magma has evidently been as follows:

At first the feldspar was formed growing into random orientations in thick tabular crystals. The miarolitic cavities left between these crystals were subsequently filled with aegirine which did not have space to develop euhedral forms. Other pores were filled with an isotropic substance or with nepheline. Later on the aegirine needles crystallized in their beautiful suns. There are consequently two generations of alk. pyroxenes.

A solitary occurrence of an olivine gabbro was found in Barranco de la Mina above Las Lagunetas. Micr. it displays an unfresh state. The plagioclase is an andesine (An/45), besides it contains augite and olivine, the latter with signs of alteration. Composition of the olivine is more Fa-rich than in the common olivine basalts.

It was mentioned already that the R.N. agglomerate carries plenty of xenoliths of plutonic rocks which according to E. JÉRÉMINE are ranging in composition from monzonites to gabbros and pyroxenolites. It is obvious that in the substratum of the island there are occurrences of such plutonic rock types.

Other proofs of the composition of the deep-level materials of the island are bombs ejected during eruptions of certain volcanoes. Bombs of anorthosite have been found in La Isleta. One sample of these contains only a plagioclase of the composition An/60 ($2V\gamma=78°$). It represents a low temperature form.

2. Minerals in the rocks of Grand Canary

1. *Salic minerals*

We have the two groups of feldspars: the alk. feldspars and the plagioclases. The former are $K-Na$ feldspars either sanidine or (more commonly) anorthoclase, the latter are intermediary plagioclase of the andesine - labradorite composition. Finally we have the perthitic feldspars appearing in the alk. syenites and the nepheline-syenites. In many cases the feldspars, especially the alk. feldspars have undergone alterations, so that their exact nature is difficult to establish.

The feldspars of the Grand Canarian rocks have hitherto been examined chiefly by E. JÉRÉMINE (1933, 1937). In the most salic group of lavas she found predominantly anorthoclase (as phenocrysts), sometimes also an oligoclase. In certain trachytes and phonolites orthoclase was recognized, often in small laths in the groundmass (together with oligoclase). Tahitites seem to contain chiefly orthoclase, ordanchites a basic plagioclase. As far as the basaltic lavas are concerned they contain always the usual intermediary plagioclase (An/45—60%, sometimes reaching 70%).

Alk. feldspars. Below a list of optics of the feldspars of this group may be presented, referring to the salic lavas examined. Most of these feldspars are anorthoclase (phenocrysts), sanidine seems to be more subordinate. As far as the small laths in the groundmass are concerned a closer determination has not been carried out. They may be sanidine in some cases, judging from JÉRÉMINE's results (ind. of refr. and ext. angle). Many of the salic lavas and dikes are exceedingly rich in alk. feldspars, they are practically feldspar rocks (rhyotrachytes, ignimbrites, trachytes, bostonites, tinguaites).

Orthoclase has been found in the plutonic rocks of syenitic composition. According to the value of $2V\alpha=77°$, it may be a low-temperature form. This feldspar is frequently associated with a plagioclase forming perthite. Also in these rock types the feldspar is the far dominating member.

Note: Samples of all the rock types described above are exposed in the Geological Department of «El Museo Canario», Las Palmas.

List of alkali feldspars occurring in the salic (rhyolitic, trachytic and phonolitis) lavas

No.	2Vα	Particulars	Feldspar	Rock
1	47°—47.7°	euhedral, clear	anorthoclase	ignimbrite
52	8°	Karlsbad twins	sanidine	mica trachyte
149	60°	» »	microperthite	nepheline phonolite
167	40°—50°	» » ∼⊥(010)	anorthoclase	nepheline phonolite
169	26°—42°	monoclinic	high-temp. sanidine (?)	ignimbrite (or vitroph.)
206	44°—44.5°	Karlsbad twins	anorthoclase	rhyolite
213	40°—48°	» »	»	nepheline phonolite
217	44°	β⊥(001)	»	trachyte
255	48°	euhedral, clear	»	vitrophyre
260	52°	» »	»	nepheline phonolite
285	42°	» »	»	trachyte
293	48°—50°	» »	»	nepheline phonolite
319	50°	Karlsbad twins	»	vitrophyre
326	50°	fine striation	»	red porphyry
332	50°	rectang., clear	»	trachyte
335	48°	» »	»	brown porphyry
336	48°	» »	»	» »
375	35.5°	» »	»	rhyolite
377	42.5°	fine striation	»	red porphyry
377	44.5°—45°	twins acc. to (001) Manebach	»	» »
401	46°—47°	—	»	nepheline phonolite
405	49°	Karlsbad twins	»	white porphyry
436	44.5°—46.5	» — »	»	gray rhyolite
440	52.5°—53°	» »	»	alk. trachyte (trachy-phonolite)
457	41°—42°	euhedral, clear	»	red rhyolite (»*roca de salchichon*«)
517	46°	a∧α′=10°, ⊥ AP (010) appr.	»	nepheline phonolite
523	44°	large laths, clear	»	brown rhyolite (porous)
536	51.5°—52°	» » »	»	nepheline phonolite
570	42°	» » »	»	rhyolite
575	45°	clear-rimmed	»	trachyte

The plagioclases are judging from the list presented below, fairly uniform in composition throughout the whole series of basic lavas, the composition ranging from An 35% to An 62% — , the majority gathering around labradorite. On the other hand the share of plagioclase in the rock composition varies considerably, as may be found from the characteristics in the descriptive Part I. In the extreme cases we have nearly 100% of plagioclase (volcanic bomb, La Isleta), another extreme is a dike of a picrite basalt with only a trifling amount of plagioclase (11,8% according to the norm). — In many types the feldspar of the groundmass has been altered to an indeterminable substance or to analcime. The list here refers only to the phenocrysts.

List of plagioclase feldspars in basic lavas

No.	2V	Ext. angle	Twin law	Comp.	Rock type
5	+ 80°	$a' \wedge (010) = 36°$	albite	An 61 ± 2%	plagioclase basalt
6	— 80°	$a' \wedge (010) = 10°$	»	» 25-28 »	amygdal. basalt
7	+ 77°		»	» 60 »	hornblende tephrite
10	+ 76°	$a' \wedge (010) = 30°$	»	» 53 ±1 »	basalt
16	+ 78°		»	» 55 »	porphyrite
28	—	—	Karlsbad-albite	» 45 »	porphyrite
29	+ 82°	$a' \wedge (010) = 37°$	albite	» 63 ± 1 »	plagioclase basalt
73	+ 82°	⊥ PM = 26°	»	» 47 »	plagioclase basalt
88	+ 80°	$a' \wedge (010) = 34°$	»	» 60 ±2 »	olivine basalt
89	+ 73°	$a' \wedge (010) = 33°$	»	» 55 ±2 »	plagioclase basalt
98	+ 79°	$\gamma' \wedge (010) = 35°$	»	» 60 »	» »
177	— 100°	⊥(010) = 24°	Karlsbad	» 40— ± 50	tephrite
183	—	—	»	» 35— 40	sodalite tephrite
267	— 102°	⊥(010) = 35° — 38°	albite	» 60 »	plagioclase basalt
273	— 94°	—	»	» 60 »	porphyrite
345	— 94°	⊥ PM = 37°	»	» 62 »	plagioclase basalt
349	—	high temp.	Karlsbad	» 58 »	olivine basalt
376	+ 75°	$a' \wedge (010) = 32°$	albite	» 54 »	plagioclase basalt
378	—	high temp.	Karlsbad	» 52 »	» »
386	—	» »	albite	» 50 »	porphyrite
527	+ 74°	$a' \wedge (010) = 33°$	»	» 55 ±1 »	plagioclase basalt
605	+ 77°	$a' \wedge (010) = 33°$	»	» 56 ±1 »	» »

F e l d s p a t h o i d s. — These do occur nearly exclusively in the phonolite lavas and dikes, and since they have a rather wide extension, the minerals in question are of importance. N e p h e l i n e is the most common, it is the typical mineral of the dark, platy phonolites covering the whole southern sector of the island and certain areas in other sectors

The typical appearance of nepheline in the phonolites is that of stout, hexagonal prisms, mostly slightly altered. The individuals are surrounded by a corona of green aegirine microlites, so that the grains of the host mineral are easily to recognize in the slide. The share of nepheline is varying, however, sometimes it is a very conspicuous component, sometimes it drops to a trifling amount (scattered grains).

In the nepheline syenites the mineral fills pores in the rock between the feldspar individuals, and then it is of anhedral shape (elaeolite). It can also have been transferred to analcime.

The sodalite minerals are typical of a certain group of phonolites as it has been explained in a previous chapter. In these rocks the mineral appears in large euhedral crystals (see microphotos 1 and 2, plate VIII) of the I gen. of components. In such cases the mineral has a dark, opaque border. Often the mineral is strongly magmatically corroded. This corrosion antedates the alteration of the outer zone to the dark substance. — It is difficult to determine which of these foids (sodalite, nosean or hauyne) may be present in every case examined. If a chemical analysis of the rock is available the content of SO_3 may indicate the presence of hauyne. A blue colour as a criterion is very seldom available.

A joint occurrence of nepheline and sodalite min. is rare in the phonolites.

Quartz is as a rock-forming mineral in the orthomagmatic paragenesis, apparently rather rare. I myself have only occasionally been able to detect the same, although JÉRÉMINE (l.c.) has reported some quartz-bearing porphyries. Quartz is present in some rhyolites as small grains in the groundmass and also in some of the lithophyses not uncommonly present in the paste (together with feldspar rods). In most rhyolites quartz has not been expressed mineralogically although it is potentially present. That is indicated by the positive value of qz in the analyses.

Tridymite has been reported by JÉRÉMINE from a rhyolite. Chalcedony is a common substance in vesicles of many lavas.

2. *Mafic minerals*

Of these we may first consider the pyroxenes. They are very wide spread, except in the most salic types of lavas, where they are lacking. Only the monoclinic pyroxenes will be dealt with here, since the rhombic pyroxenes have so far not been detected in the rocks. There are on the one hand the alk. pyroxenes of the salic lavas, on the other hand the augites and the Ti-augites (and diopside) in the more or less basic lavas. The syenites do carry only alk. pyroxenes.

The list below presented of the pyroxenes contains the $2V$-data and the value of the ext. angle on (010) $c \wedge \gamma$. Refractive indices would be necessary for more accurate diagnosis, not to speak of chemical analyses.

Looking now at the values of $2V$ we can state that pigeonitic pyroxene has been found rather sparingly, or more exactly, there are cases with $2V\gamma - 40° - 50°$ that may approach to that of the pigeonite.

As is the case with the previously enlisted minerals the determinations to follow refer to the phenocrysts, whereas the composition of pyroxenes occurring in the groundmass of the rock in question remains somewhat vague. When the small pyroxenes there are of a green colour and show the appropriate extinction angles, pleochroism etc. one may suppose about presence of aegirine. This is escpecially the case with the groundmass of the phonolites (both the nepheline phonolites and the sodalite-bearing ones).

The augites (and Ti-augites) in the basic lavas are of two generations: phenocrysts in well developed crystals and small prisms in the groundmass (densely crowded together). Magnetite is always closely allied with the pyroxenes in these rocks; in the phenocrysts this is enclosed in the pyroxene, in the paste it is mingled with the small grains of the pyroxene. It seems the two minerals have crystallized almost simultaneously.

The pyroxenes are seldom zoned, neither the alk. pyroxenes nor the augites may have tendencies of that kind. Nevertheless in the alk. pyroxenes of the I gen. in some phonolites there is a narrow green outer aegirine rim enclosing a paler coloured kernel (aeg. augite).

Pleochroism is met with only in the more intensely greenish coloured alk. pyroxenes.

Of the data enlisted here the extinction angle on (010) $c \wedge \gamma$ seems to be rather uniform throughout (max. 56°. min. 34°). On the other hand the value of $2V$ shows some deviations from the common values 45°—60°. These exceptions are 11. Such pyroxenes refer to phonolites, in one case to an olivine basalt (basanitic?) and to a tephrite. All the other pyroxenes measured are of basalt lavas.

Among the mafic minerals, h o r n b l e n d e is not as common in the lavas and in the dikes as are the pyroxenes. It is of a chestnut brown colour, pleochroic almost throughout. It is most often in a corroded state, contrasting with the well preserved pyroxenes. The crystal faces

List of pyroxene phenocrysts in the salic, intermediary and basic lavas and dike rocks

No.	2V	Ext. angle on (010)	Colours, etc.	Species	Rock type
5	+56°	$c \wedge \gamma$ = —	—	augite	Plag. basalt
6	+53°	» =47°	—	»	» »
6a	+60°	» =41°	pale col.	diopside	lamprophyre
7	+59°	» =56°	pale yellow	aeg. aug.	porphyrite
9	+70°	» =43°	green, pleochr.	» »	hauynophyre
10	+51°	» =45°	gray lilac	Ti-aug.	plag. basalt
17	+74°	» =34°	» »	aeg. aug.	tephrite
28	+46°	» =38°	pale yellow	pigeonite	porphyrite
29	+50°	» =46°	gray lilac	augite	plag. basalt
48	+53°	» =49°	gray	»	olivine basalt
48	+78°	» =55°	green core	aeg.aug.	» »
61	+69°	» =41°	grayish	»	» »
67	+51	» 45° - 58°	zonal	augite	tephrite
88	+59°	» =52°	gray lilac	augite	olivine »
89	+55°	» =56°	» »	»	phonolite
98	+69°	» =45°	» »	»	tephrite
107	+54°	» =52°	zonal	»	basanite
141	+54°	» =41°	gray	»	olivine basalt
149	+72°	» =46°	green, pleochr.	aeg. aug.	phonolite
180	+62°— 76°	» =45°	lilac »	core aeg. augite	olivine basalt
182	+60°	» =45°	gray lilac	augite	basalt
183	+70°	» =44°	pale yellow	aeg. aug.	phonolite
226	+58°	» =53°	gray lilac	augite	andesite
293	+50°	» =42°		diopside	trachyphonolite
321	+58°	» =44°	pale yellow	»	olivine basalt
332	+48°	» =47°—48°	» »	pigeonite	trachyte
333	+53°	» =39°	» »	pigeon. aug.	»
345	+50°	» =45°	grayish	» »	basalt
349	+54°—	» =46°	»	» »	olivine basalt
349	+54.5°	» =46°	»	» »	» »
365	+49°	» =45°	»	pigeon. aug.	basalt
386	+—	» =47.5°	»	augite	plag. basalt
510	+54°	» =46°	»	»	olivine basalt
514	+62°	» =47°	zonal	Ti-augite	olivine basalt
517	+100°	» =26°	greenish	aeg. aug.	trachyte
527a	+60°	» =50°	grayish	augite	basalt
527b	+52°	» =50°	zonal	»	basalt
541	+79°	» =55°	greenish	aeg. aug.	phonolite
602	+58°— 59°	» =39°	hour glass-str.	diopside	ankaramite
605	+51°	» =45°-60°	grayish	augite	plag. basalt
647	+52°	» =42°	gray lilac	Ti-augite	olivine basalt
653	—	» =53°	pale-col.	augite (?)	phonolite
869	+75°	» =52°	greenish	aeg. aug.	»

have entirely disappeared (although the length-axis has persisted) and instead the contours are rounded off or they have deep embayments. The mineral is surrounded by a narrow zone of minute pyroxene crystals and magnetite. Cleavage cracks are distinct. — I have a list below of hornblendes examined on the U:stage; 2 V and ext. angle $c \wedge \gamma$ have been measured. There seem to be some varieties of the hornblende. Exact diagnosis would require more optical data and also chemical analyses. The cases examined are all phenocrysts, and in fact hornblende always belongs to the I generation.

List of hornblendes occurring in the intermediary and basic lava and dike rocks

No.	$2V$	Ext. angle on (010)	Colours $//\alpha$	$//\gamma$	Specimen	Rock type
6	$-74°$	$c \wedge \gamma = 9°$	yellowbrown		hbl (common)	lamprophyre
7	$-68°$	» $= 0°$	»	»	hbl (basaltic)	tephrite
67	$-70°$	» $= 10°$	»	»	hbl (common)	»
107	$-71°$	» $= 8°$	»	»	hbl. (common)	basanite
177	$-56°$	» $= 17°$	»	dark br.	hbl (barkev.)	tephrite
182	$-73°$	» $= 3°$	»	brown	hbl (basaltic)	basalt
183	$-63°$	» $= 9°$	»	»	hbl (common)	phonolite
226	$-70°$	» $=$	»	dark br.	hbl (common)	trachyte
326	$-64°$	» $= 14°$	»	brown	hbl (common)	porphyry
335	$-88°$	» $= 10°$	»	»	hbl (common)	vitrophyre
336	$-90°$	» $= 17°$	»	»	hbl (common)	»
527b	$-71°$	» $= 4°$	»	»	hbl (basaltic)	tephrite
653	(not det.)	» $= 12°$	»	rusty br.	barkevik.	phonolite

The data above do not give more than an approximate idea of the composition of the hornblendes. E. Jérémine (1937) has found barkevikite in the rhyolites and alk. hornblende (perhaps also katophorite) in the phonolites.

O l i v i n e is the outstanding mafic component in the nonalkaline basic lavas. (Basanites seem to be of more restricted occurrence). The mineral is common also in most of the basic dike rocks and especially in the ultrabasic ones. In the geologic formations the repartition of the olivines reflects the basicity. It abounds in the old basalts in the west and in the southeast, here it is mostly decomposed to pseudomorphs. The mineral disappears with the long interlude of salic eruptions. It returns in the post-Miocene basalts in which it persists as an essential component into the most recent lavas. — Here follows the list of examined olivines:

List of olivines in the picritic olivine basalts and in the connected dike rocks

No.	$2V\alpha$	Particulars	% Fayalite	Rock type
35	94°–95°	β-1.658	<10	Picritic olivine basalt
41	82°–96°	β-1.658	0–30	lava stream of ol. basalt
48	86°–96°	euhedral, clear	0–30	picritic ol. basalt
61	94°	» »	<10	» » »
80	92°–94°	» »	< 8	» » »
88	72°–102°	iddingsite rimmed	(2 gen.)	
			0–20	» » »
107	93°	» »	<10	» » »
141	89°	» »	18	» » »
180	100°	» »	0	» » »
321	92°	clear, euhedral	8	» » »
510	91°	clear, corroded	10	» » »
514	88°–96°	» euhedral	0–20	» » »
521	90°	β-1.690 euhedral	20	» » »
602	92°	large, clear, euhedral	8	ankaramite (dike)

Of olivines occurring in basanites I have no data. Instead an olivine in an olivine gabbro at Las Lagunetas was examined, showing $2V\alpha=$ 80° (Fa=35%). This rock may be magmatically connected with the basanites (of the R.N. agglomerate formation).

The list above does not reveal any great variations throughout the basaltic lavas, as far as one may rely on the $2V$ value alone. Refractive indices would, of course, be of some use in defining the composition, and better than these physical values, the chemical analyses which are still missing. I think the variations would, however, not be of greater importance; perhaps one could be able to make distinction between olivines belonging to the post-Miocene basalts and those of the more recent basalt lavas.

The instability of the olivines in most of the pre-Quaternary lavas is apparent, although the products of alterations differ to some extent. In the post-Miocene (pre-Quaternary) lavas there are mostly the iddingsite-rimmed olivines, the alterations having been formed after the magmatic corrosion of the host mineral had taken place. — In the older lavas on the west coast and in the lower southeastern sector the olivines are often completely changed to talc, to chlorite, to iron oxide, serpentine, and also to calcite, so that only the pseudomorphs may have been left behind. Contrarily the pyroxenes have remained intact.

In some of the more plagioclase-rich types of basalts of post-Miocene age the olivines have been changed into a reddish-brown substance, which in parts may be iddingsite.

Since the degree of alterations of the olivines appears to increase with the age of the lava, it seems most likely that the degree of alteration stands in relation to it. In the young lavas the olivines are always fresh. P. D. QURNSEL (1952) is of the opinion that they cannot be attributed to atmosphaeric influences in the course of time but to post-magmatic, juvenile agencies. Wether this is true or not in the case of the basalts in Grand Canary cannot be stated for the lack of more comprehensive informations.

Of the olivine-bearing lavas those belonging to the basanites seem to be sparingly present (i.e. those associated with the R.N. agglomerate formation). Instead the tephrites dominate as we have found, in the formation mentioned.

Another of the coloured mineral components is s p h e n e, chiefly distributed in the highland phonolites and in dike rocks of the same group, i.e. in the types carrying minerals of the sodalite group. Here the sphene appears in well developed crystals with the typical contours. Twins according to (100) are common. It belongs to the first generation of components and matches the pyroxene in size, not in quantity. The sphene has obviously crystallized in a gas-enriched magma. — It is also an essential constituent in the alk- syenites and in the nepheline syenites appearing mostly in anhedral forms. The mineral can easily be confounded with monazite, but its optical angle is larger ($2V\gamma=33°$, one determ., whereas monazite shows $2V\gamma=6°-19°$). Although monazite does not appear in the slides available to the author, the mineral is almost certainly present, judging from samples of alluvial sands (see below!). In the only chemical analysis made of an alk. syenite the content of TiO_2 happens to be rather low (0.86%).

Of accessory minerals m a g n e t i t e is the most wide spread in the lavas and in the dike rocks, attaining the highest frequency of course in the ultrabasic types (ankaramites etc. in which the normative magnetite reaches 8.0%). In such types it appears partly as larger grains, partly as a fine powder disseminated in the paste. The larger grains are mostly associated with the pyroxene crystals. Skeletal forms are rare. — I l m e n i t e seems to be rather common in the basalt lavas and dikes of a more plagioclase-rich composition. It is recognizable because of its flaky appearance. In a basalt lava type from Tasartico the content of normative $il = 5.7\%$, and in the ankaramites even higher $= 7.6\%$. Some of *Ti* is of course to be alloted to the pyroxenes. — A p a t i t e is very commonly distributed in many rock types both of basic and of salic (phonolitic) nature. It is generally enclosed in the larger pyroxene grains or in the brown hornblende of the I generation of components. It always appears as stout hexagonal prisms, never in the needle form. The highest frequency of this accessory mineral is in the ankaramites (norm. $ap = 3.5\%$ and also in the tephrites $= 2.4\%$). Z i r c o n has been reported by E. JÉRÉMINE (1937) from an alk. syenite dike in the Tejeda area. M e l a n i t e was found in a slide of a syenite in the same region.

A list of the relative quantities of h e a v y m i n e r a l s obtained from mechanical analysis of an average sample of sands (beach sands) from various sectors of the island, so called *arenas titaníferas* is given below. Localities from where the sands were collected are: Bahía Confital, Bahía Lata, Bahía Gando, and Lago de Arinaga (Laboratory: Parreña, Santa Lucía, Cartagena, Spain)[1].

Titanomagnetite	30.000%
Ilmenite	21.000 »
Magnetite	12.456 »
M o n a z i t e	5.582 »
»Mangan oxide»	1.747 »
Cassiterite	0.343 »
»Bismuth oxide»	0.165 »
»Copper oxide»	0.112 »
Arsenopyrite	0.114 »
Gold	0.0002%
Z i r c o n	presence indicated but not quantity.
Pyroxene	20.555%

Most interesting is the content of monazite, which seems to be rather considerable in this island. If we compare with beach sands from Travancore, India, the content of monazite is here reported to be 0.5—1% (ilmenite may attain 65—80% in the same sands). (Data quoted from S. J. JOHNSTONE. Minerals for chemical and allied industries, London 1954). Travancore is one of the most important deposits of its kind in the world. Concentrates of monazite (95% at least) are obtained there by

[1]) These data have been obtained from Mr H. GERLACH, Madrid, who has kindly permitted to publish them here.

Unfortunately no samples from the alluvium of Barranco de la Aldea are included; a special mechanical analysis of sand derived from the Tejeda area would be of the highest interest.

way of powerful electromagnets. Brazilian concentrates of beach sands containing not only monazite 1.20 % but also other heavy minerals (chiefly ilmenite and zircon) have been sold in the United States.

The figure for Canarian monazite is merely an indication. The sectors with the highest concentration must still be located and the resources calculated in tons. There is no information on the most probable source of the monazite or of the routes it was carried by river transport to the shores. The common parental rock of this rare earth-mineral may be (as it is well known) granites or its aplitic or pegmatitic derivatives. Syenites are also a conceivable source. The latter kind of rock is, as we have seen, present in large exposures in the gorges of the central area of the island. The chief way of transport from this region is along Barranco de Tejeda—de la Aldea. Consequently a mechanical analysis of the transported sands in the vicinity of Aldea de San Nicolás, ought to be carried out either of the bottom beds of the alluvial fill there, or of the beach sands. Ilmenite natural concentrates in the sands are good indicators.

In short the question about the occurrence of monazite concentrates in the beach sands or in the river accumulations of the lower courses ought to be more closely investigated. In this connection it may be appropriate to recommend a similar scrutiny also of the sands (the river sands, not the dune sands) in the island of Fuerteventura. Here are, as is well known, large exposures of alkaline plutonic bodies which also may carry monazite. Erosion has here progressed farther than in Grand Canary, a circumstance of importance when considering the duration of river transport and the volume of the weathered products.

3. Petrochemical conditions

We have had a sparse knowledge of the geochemical conditions in Grand Canary until rather recently. Most of the works dealing with the geology and lithology of the island antedate the rise of geochemistry in modern sense, and this drawback has persisted until the thirties. F. von Wolff published a part of his great compilatory work on Volcanism dealing with the volcanic islands in the Atlantic region as late as in 1931. Although he devoted much attention to the petrochemistry in the work, not one chemical analysis is here given from Grand Canary. Some years later the things improved, however. E. Jérémine published in 1933 some analyses of rocks from this island, and in 1937 she presented more of them, so that the total amount was 19. One further analysis more referring to the island could be found in the paper by K. SMULIKOWSKI in 1947.

When preparing this report, the author submitted 19 samples for chemical analyses, so that the total number of analyses now available referring to Grand Canary amounts 39.

This figure does not mean, however, we have gained a sufficient knowledge of the petrochemistry of this complicated island. There is certainly room for considerably more data before we have a full picture of all the variations and also of the chronological side of the matter. Such a time order is, in fact, of the outmost importance if we wish to follow the magmatic evolution in Grand Canary since the time when the first volcanic products reached the level of the ocean.

My predecessor in studying the geology in Grand Canary, J. BOURCART (1937), has already tried to establish such a chronologic scheme of the magmas (cf. with the colour scheme in his geological map and also with the quotations in our Historical review).

Turning now to our petrochemical data I will first give a list of the NIGGLI-values:[1]) (page 375).

The values in the list below have not been arranged according to the different age groups of the rock formations and to the genetic associations between them (as it was done with the groupings in a similar list of the Tenerifan rocks (HAUSEN 1956). There are among the types in Grand Canary several ones of which the stratigraphic position is somewhat uncertain (especially in those referring to the data of JÉRÉMINE), The principle of order is the increasing value of *si*.

Variation diagrams

The modern petrochemistry uses a number of ways to express the petrochemical relations according to different kinds of calculations (C. BURRI 1960). In the present treatment of the material, we shall limit ourselves to only a few of the most commonly used expressions in spite of the fact that already fairly extensive analytical data have been brought together. This restriction has been held partly because earlier

[1]) *Explanatory note* to the list, page 375. — To the common NIGGLI-values the RITTMANN-parameters $Si°$ and $Az°$ (1933): have been added. — Column I contains: 1) three small circles referring to anal. in the paper by JÉRÉMINE of 1933; 2) Roman figures referring to anal. in the paper by BOURCART & JÉRÉMINE of 1937; 3) Arabic figures referring to the anal. in this memior (sample-nos.) 4) S — one anal. in the paper by K. SMULIKOWSKI of 1946.

No.	si	ti	al	fm	c	alk	al—alk	k	mg	qz	Si°	Az°	Magma type
602	68	5	10½	57½	26½	5½	+ 5	.20	.67	— 54	0.56	0.40	vesecit-polzenitic/pyroxenitic
X	74	7	11	58	25½	5½	+ 5½	.18	.73	— 48	0.61	0.43	hornblenditic
1o	74½	1	12	59½	24½	4	+ 8	.33	.66	— 44	0.64	0.43	hornblenditic
2o	86	9	16½	43½	32	7½	+ 9	.32	.46	— 44	0.66	0.46	c-gabbro theralitic
647	98½	6	19	46½	25½	9	+10	.16	.54	— 37½	0.72	0.50	essexitic gabbroid
VIII	104	10	18	42	25½	10	+ 8	.17	.47	— 36	0.74	0.51	gabbro theralitic
22	107½	5	18½	48	25	8½	+10	.23	.56	— 26½	0.80	0.52	essexitic gabbroid
349	110	5	14	53	27	6	+ 8	.26	.60	— 14	0.89	0.52	*si*-pyroxenitic
IX	113½	$8^1/_2$	20	41	30	9	+11	.23	.45	— $22^1/_2$	0.83	0.53	essexitic gabbro dioritic
411	115	7½	21½	44½	24½	9½	+12	.21	.43	— 23	0.83	0.53	essexitic gabbro dioritic
VII	131	9	19½	47	28	5½	+14	.30	.53	+ 9	1.07	0.57	*c*-gabbroid
XII	135		27	32	23	18	+ 9	.30	.40	— 37	0.78	0.57	essexitic
9	149	3½	32½	20	14	33½	— 1	.26	.36	— 82	0.65	0.60	lardalitic
XI	162½	3½	35½	19	19	26½	+ 9	.15	.37	— 43½	0.79	0.62	tahititic
3o	166½	3	37	18	15½	29½	+ 7½	.33	.22	— 51½	0.76	0.63	foyaitic
172	179	½	45	6½	4	44½	+ ½	.27	.12	— 99	0.64	0.64	normal foyaitic
564	218½	2½	39½	16½	3	41	— 1½	.30	.21	— 41	0.84	0.68	normal foyaitic
S	222		38	18½	3½	40	— 2	.33	.24	— 32	0.90	0.70	foyaitic/umptekitic
401	229½	3	38	19½	3½	39	— 1	.32	.19	— 23½	0.91	0.70	normal foyaitic/umptekitic
12	230½	2½	45½	13	8	33½	+12	.40	.27	— 3½	0.99	0.70	pulaskitic
693	231	2½	43½	13½	5	38	+ 5½	.31	.17	— 21	0.92	0.70	bostonitic
25	232½	2	39½	18	2½	40	½	.33	.23	— 26	0.90	0.70	nordmarkitic/umptekitic
677	236	1½	42½	13½	1½	42½	0	.30	.09	— 34	0.87	0.70	normal foyaitic
169	238½	3½	37	26	2	35	+ 2	.36	.18	— 1½	0.99	0.70	*si*-natron syenitic/umptekitic
440	247		43	15	2½	39½	+ 3½	.35	.05	— 11	0.96	0.71	nordmarkitic/bostonitic
523	259		46½	12	2	35½	+ 7	.37	.12	+ 1	1.00	0.72	bostonitic
637	269		41½	17½	1½	39½	+ 2	.37	.10	+ 11	1.04	0.73	nordmarkitic
76	276	2½	54	15½	1½	29	+25	.53	.09	+ 60	1.22	0.73	peralic
III	303½	4½	36	23½	3½	37½	— 1½	.33	.01	+ 58	1.24	0.75	essexitic/grorudıtic
V	311	3½	41	16½	7½	35	+ 6	.33	.22	+ 71	1.30	0.71	nordmarkitic
I	327½	2½	31½	28½	3	37	— 5½	.34	.09	+ 96	1.41	0.77	evisitic pantelleritic
375	350½	2½	37½	19½	1½	41½	— 4	.34	.14	+ 96½	1.38	0.78	normal alkali granitic
II	354	4	33½	26	4½	36	— 2½	.32	.02	+117½	1.50	0.78	*si*-natron syenitic
IV	354	3	43	16	6	35½	+ 7½	.22	.04	+112	1.46	0.78	trondheimitic

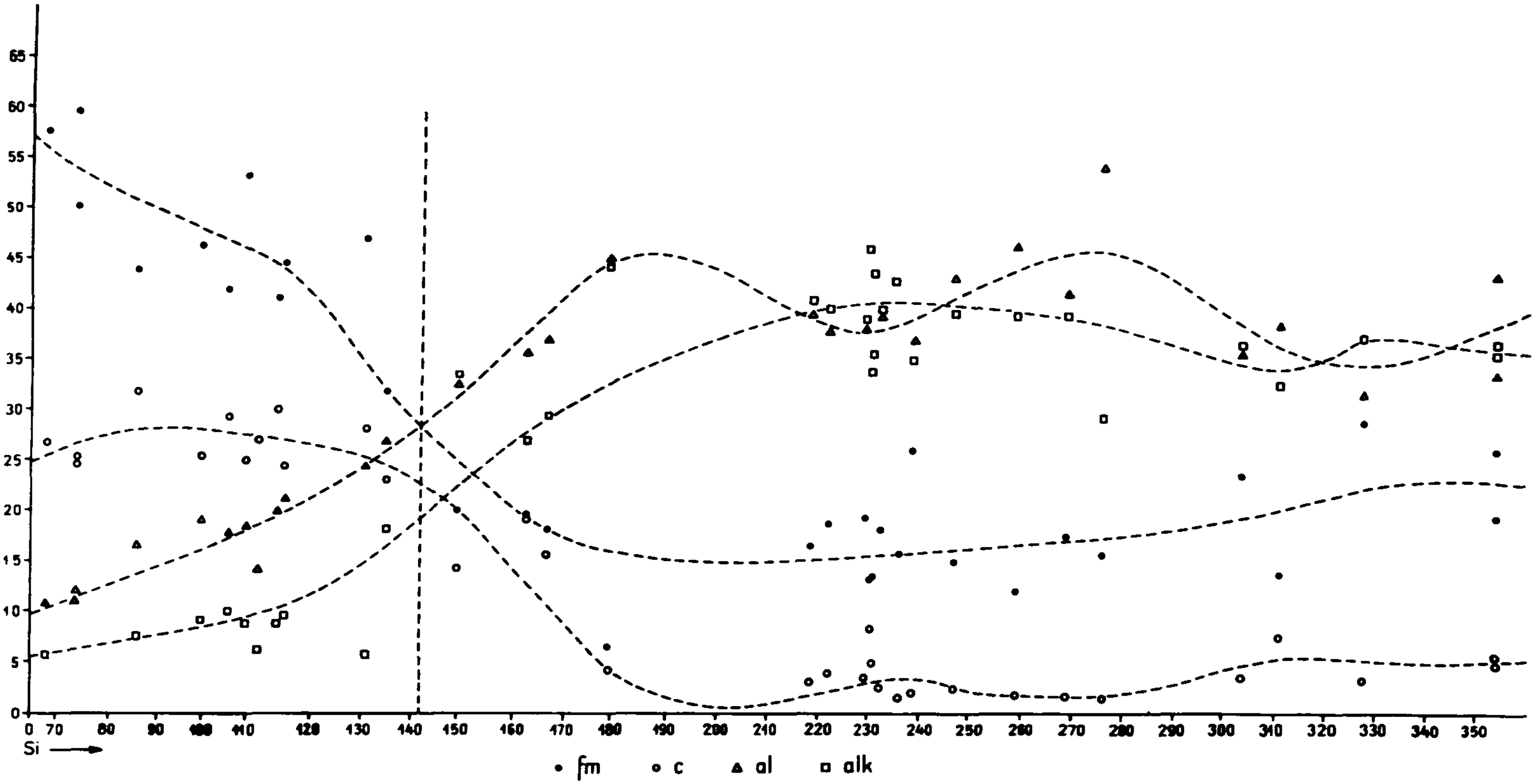

Fig. 34.

reports on Canarian geology (HAUSEN 1956, 1958 and 1959) appear with the same simplicity, partly because a general treatment of the Canarian petrochemical province has been planned. This one is intended to be carried out with the cooperation of the Canarian geologist T. BRAVO. New chemical analyses of rocks from three islands are planned: from Gomera, La Palma and Hierro, islands from where up to this date petrochemical informations are very scanty.

Now we may look at the NIGGLI-variation diagram, with the relation *si:* al, *fm, c* and *alk.* (see fig. 34). The repartition of the *si* values will show several groups (from left to right): 1) a basic group between *si* 68 and 135 comprising magma types from hornblenditic to essexitic types; 2) an intermediary undersaturated group with *si* between 149 and 179 in which there are the tahititic and related magmas; 3) a group with *si* values between 179 and 218.5 is not represented in the diagram (i.e. of the intermediary magma types); 4) further to the right there is a rather crowded space between the *si* values 218.5 and 240, comprising the foyaitic magma types; 5) the right wing of the diagram to the ultimate *si* value 354 contains all the saturated and supersaturated types including the normal alk. granitic magma. The last named represents the most salic type of the whole assemblage found in Grand Canary.

Of the four curves in the diagram the *fm*-curve drops rather suddenly from its maximum value of 57 to about 15 (if we disregard the extremely low value related to *si* 179), then the curve runs rather smoothly with a slight increase in value to the end. The values on this latter stretch are principally due to the presence of mafics with the ferri-ion (aegirine etc.); the *c*-curve, which starts at about the value 30 drops finally to the abscissa and this line is followed rather closely almost to the end. The salic lavas are extremely poor in lime; the *al*-curve starting at about the value of 10, rises suddenly to appr. 45 crossing the *fm*-curve at the ordinata 142, the isofalic point; further to the right the curve runs without major fluctuations to the end. There is no room for the anorthite mol. except in the left wing. The *alk*-curve rises from the value 5. following fairly parallel to the curve *al* until the maximum value — appr. 40 — is reached at the ordinata 230, then it almost coincides with the *al*-curve in a common, rather narrow zone to the end.

If we compare this variation diagram with that corresponding to the Tenerifan magmas, we shall see that there is a great deal of similarity. There is, however, one important difference: The Tenerifan abscissa stops at *si* 260 (nordmarkitic magma type), no supersaturated rocks have so far been found in that island (if we except an »obsidian» in Pico de Teide, according to A. LAGORIO; see HAUSEN 1956).

In this behaviour there lies the most important difference in the petrochemistry of the two central islands.

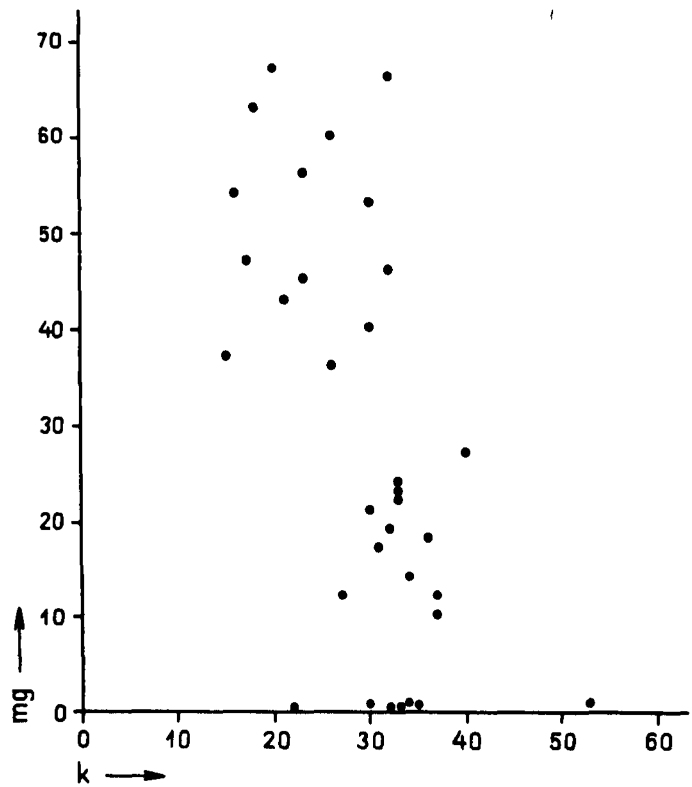

Fig. 35.

The NIGGLI-variation diagram *k:mg* (cf. fig. 35) has the usual appearance of 'Atlantic' magmas. Three groups of points can be recognized: an uppermost group (rather dispersed), a middle group, and a basal group rather closely attached to the abscissa. Some errant points are also present.

The RITTMANN variation diagram $Si°:Az°$, founded on the relation between degree of silicification and that of acidity, according to the formulae:

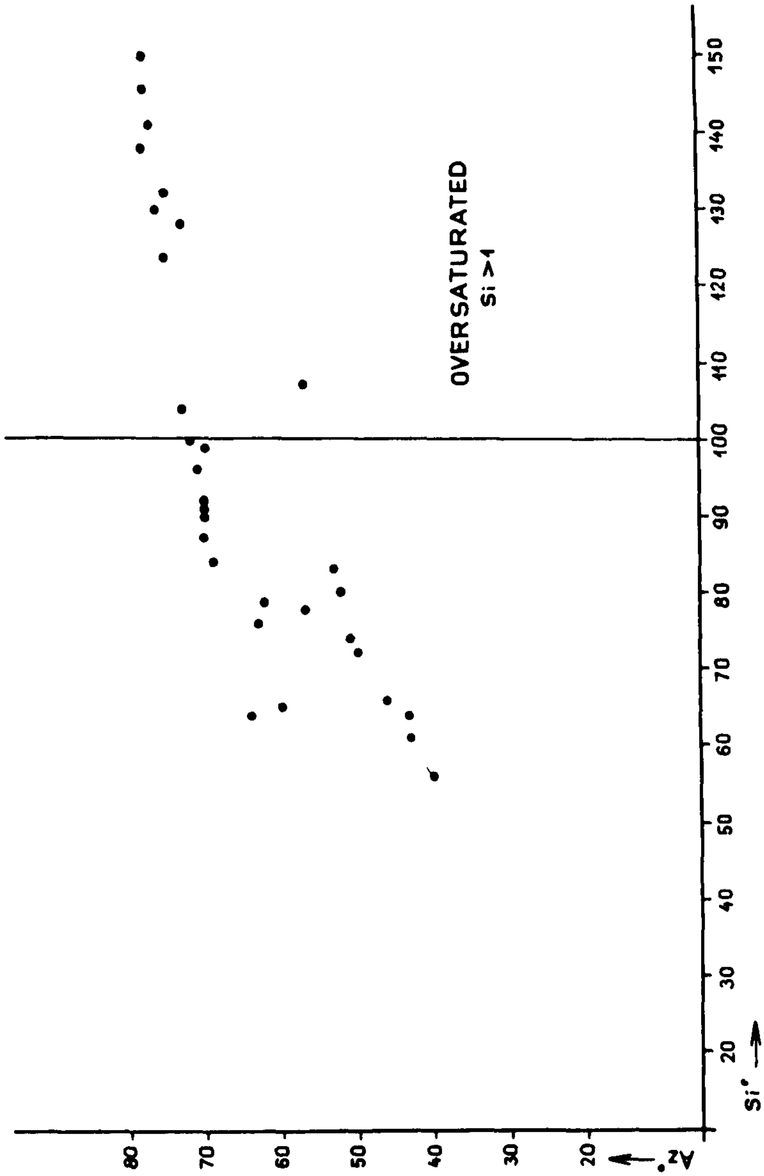

Fig. 36.

$$Si^\circ = \frac{si}{si - qz} \text{ and } Az^\circ = \frac{si}{si + 100}$$

The diagram demonstrates silicification of the rock in a very clear way.

If this graphical expression is applied to the Grand Canarian material the diagram has the aspect shown in fig. 36. Here we will find in the main two smoothly running curves: an upper one of higher acidity reaching to the right deeply into the field of silica-supersaturation, and a lower curve chiefly extending to the left of the ordinata $Si^\circ - 1$. Both curves have about the same trend dropping to the left, i.e. the undersaturation decreases in both cases rather simultaneously. There are some projection points, however, in an intermediary position between the two curves, and these correspond to the foid bearing phonolites.

The relatively large amount of supersaturated types is of interest, but most of them do not belong to the author's material. They have been taken from E. JÉRÉMINE's data (1933, 1937). On the other hand, the undersaturated types of rocks do not attain extreme values ($Si^\circ - 55$, $Az^\circ - 40$).

It may be of some interest to compare our diagram with that recently constructed by C. BURRI (1960) who took advantage of already published analytical material of rocks from the Cape Verde Islands and from the continent border nearby. These islands have much in common with the Canaries in petrological sense, also as regards the geotectonic position. With the aid of the RITTMANN-diagram BURRI has recognized four groups of igneous rocks there: they correspond to different degree of undersaturation with silica, saturated and supersaturated types seem to be almost lacking.

The following groups of that rocks in the archipelago have been established by BURRI:

Ia — basaltic-trachytic rocks
Ib — basaltic phonolitic rocks
II — foid-rich rocks
III — low silicified rocks

These groups follow one another from right to left in the diagram, i.e. in the order of increasing undersaturation. If we now apply the Grand Canary-diagram on that of the Cape Verde Islands, we will note certain differences. Except the complete absence of the supersaturated group in the latter, there are no representatives of groups II and III in the

Grand Canarian diagram if we make an exception for some stray types in II. The Cape Verde islands' rocks are far more undersaturated, owing, according to BURRI, to syntexis of carbonate rocks.

4. Sequence of magmas and causes of diversification

I have tried to fix the relative age of the different volcanic complexes in the field. This outline does not comprise, of course, more than a small fraction of the bulk of the island — it deals with the supramarine part only. What lies under the ocean level of the island we shall never know with certainty.

The lowest complex exposed in the surface is that of the somewhat altered and dislocated trachytes and trachyphonolites which appear principally in the Tejeda gorge. According to microscopic data and to two chemical analyses, these lavas are decidedly *Na*-alkaline, of the nordmarkitic magma type of NIGGLI. This salic complex is to be considered the relatively oldest lithologic element in the island, and the author sees in them the remnants of the pre-Canarian basement.

The salic *Na*-alkaline plutonic bodies which have intruded into this complex are of a later geologic age, they may be of anatectic origin of deeper levels. According to one chemical analysis, they are of the bostonitic magma type, but other types are certainly present (nordmarkitic, umptekitic etc.) judging from reported occurrences of nepheline syenites.

After the deposition and the later tiltings (sub-continental tectonics) of the old trachyte series, the pre-Canarian relief was flooded by basalt lavas, chiefly from the west. They surrounded an eminence of the old lavas, where Grand Canary now exists. The basalts are of the pyroxenitic and essexite gabbrodioritic magma types (acc. to two chemical analyses). These basic lavas (with their tuffs etc.) do not really belong to the products of a central volcanic apparatus of Grand Canary — they are »extra insular» so to say.

Next there appeared immense quantities of salic lavas, tuffs and ignimbrites, covering as it seems the major part of the (already individualized) island. This formation is conserved chiefly in the west and northwest. The rocks are (according to 6 chemical analyses) of the normal alk. granitic, the bostonitic, the nordmarkitic and the u m p t e k i t i c m a g m a t y p e s. The source of all these eruptions is to be sought for in the Tejeda depression, and the author considers the plutonic bosses exposed here as the visible parts of the subvolcanic forges. The magmas were rich in volatiles and their eruptions were violent. Hence much of this material was spread in the form of tuffs, agglomerates and ignimbrites.

Superimposed on the latter group of salic volcanics there lies a huge complex of the dark, platy nepheline phonolites, dominating in the southern sector of the island. These lavas and their tuffs have been emitted from vents of the central type — and like the preceding group of volcanics they have covered the major part of the island. There is no chemical analysis at hand of the phonolites. But in the summit of Montaña del Horno (SW:sector) there is a small remnant of the same formation superimposed on a mighty pile of the rhyolite-trachytic series, already mentioned. According to 1 chemical analysis of this »outlier» lava bank t h e m a g m a t y p e is n o r m a l f o y a i t i c.

The phonolite volcanic phase (with outbursts of the central type) was certainly of long duration and was succeded by a revival of b o s t o n i t i c a n d p u l a s k i t i c m a g m a emissions (according to 2 chemical analyses). This phase was apparently combined with the spreading of *canto blanco* (abnormally salic according to one chemical analysis), representing large-scale mud streams.

Following this, there was a long period of explosive outbursts depositing the Roque Nublo agglomerate formation. In a salic matrix larger and smaller fragments of lavas and plutonics are enclosed. Interfingering with the agglomerate banks we have the tephritic lavas. The latter correspond to the n o r m a l g a b b r o-t h e r a l i t i c m a g m a t y p e (according to one chemical analysis). These tephrites were the first basic lavas again to appear after a long time span of salic volcanism.

After the deposition and lithification of the mentioned agglomerates there were outbursts of highly *Na*-alkaline lavas of high viscosity emitted from various foci, chiefly in the highland. The vents can be recognized in the shape of necks. According to two chemical analyses, the m a g m a t y p e s are t a h i t i t i c - u r t i t i c. The vents have perforated the cover of the R.N. agglomerate in the shape of diatremes and smaller massifs, also as dikes.

After a long period of denudation the production of basaltic and also of ultrabasic lava material began on a grand scale. That occurred in post-Miocene time. A thick cover of lavas and tuffs and agglomerates was spread over the northern and the eastern slopes of the island. The magma types are (according to some chemical analyses) hornblenditic to pyroxenitic, i.e. more or less unaltered *Sima*-material from deeply lying sources. The lavas were very fluid; volatiles also appeared, impetus being given in deeply lying ground water levels?

In the Quaternary and the Recent periods the basic and the ultrabasic lava emissions continued; as may be seen from the petrographic data, magma types are chiefly pyroxenitic and hornblenditic, maybe also alk. issitic.

Here a tabulated chronological sequence of the lavas will follow:

Geological age	Lithological unit	Magma type
Oldest: Pre-Tertiary	Dislocated alk. trachytes, trachyphonolites........	nordmarkitic to normal foyaitic
Eocene (?)	Olivine basalts, plagioclase basalts	si-pyraxenitic to essexite gabbro dioritic, c-gabbroid
Eocene (?)	Alk. syenites to nepheline syenites	bostonitic to umptekitic (?)
Oligocene (?)	Rhyolites, trachytes, trachyphonolites (lavas and pyrocl.)	si-natronsyenitic to trondheimitic and normal foyaitic
»	Platy nepheline aegirine phonolites	normal foyaitic
	Rhyolites, trachytes	bostonitic
Miocene	Puzzolane deposits (*Canto blanco*)	peralic (anomalous)
»	Roque Nublo agglomerates	no analysis of the salic pumice matrix
	Interfingering tephrite lavas	essexitic gabbroidal to normal gabbrotheralitic
»	Hauynophyres, tahitites, ordanchites	normal foyaitic to lardalitic and tahititic
Post-Miocene	Olivine-rich basalts (basic to ultrabasic lavas)	hornblenditic to pyroxenitic-
Quaternary-Recent	Cinder cones with lavas	hornblenditic, alk. issitic (?)

The age division is of course rather tentative. More reliable is the threefold division into a pre-Miocene, group of rocks, a Miocene and a post-Miocene complex of rocks, although there is no sharp limit between the first two sequences. As we have found the *canto blanco* or the puzzolane contains trachyphonolitic and trachytic material. The foid-bearing phonolites appearing after the cessation of the Peléean eruptions (of the Roque Nublo breccias) seem to be separated from the latter by period of volcanic inactivity and weathering and erosion.

Diversification of the insular magmas

The causes of the major changes in the composition of the magmas brought to the surface by the various eruptions ought to be explained, likewise the geophysical conditions governing each of the volcanic phases. These fundamental problems are precarious to scrutinize and probably they never will be solved satisfactorily. Consequently the ideas here presented obtained through field- and laboratory studies, are mere suggestions, as the reader may understand.

It may be safe to say that the old Tejeda trachytes are not »Canarian». They belonged originally to the Sahara block of the ancient headland here existing. Their origin may be considered anatectic. — *Sial* material mobilized in the depth rose to the surface charged with volatiles and erupted from fissures, chiefly perhaps as ignimbrites.

There are in the basement of Fuerteventura (HAUSEN 1958) also lavas of 'pre-Canarian' age, now strongly dislocated, their composition is, however, not trachytic but spilitic (in parts rather leukocratic).

The following volcanic formation — the old basalts — originated in the *Sima* sphere. A great deal of them reached the surface rather unaltered (picritic olivine basalts), in parts they were transformed to plagioclase basalts (tholeiites) and to trachybasalts. The first phase represented fissure outbursts from great depths.

In the next phase of volcanism masses of salic materials rose to the surface. The author considers them as produced by anatexis of the old trachytes. The syenite and nepheline syenite bosses in the depths of the Tejeda canyon are, as has been told, the volcanic forge itself. No basaltic materials of the first phase of that kind were intermingled. The chemical composition of the old trachytes is, as we have seen, rather similar to that of the plutonics.

As time went on the rhyolitic-trachytic magma changed into undersaturated — phonolitic magma. The undersaturation with the formation of nepheline as a leading mineral, was probably brought about by a gaseous transfer (A. RITTMANN, 1960) an internal differentiation (without any kind of syntexis with silica adsorbing rocks). These phonolite lavas are about of the same kind as those in Tenerife (HAUSEN 1956).

But in later times there was a revival of saturated and supersaturated volcanic outbursts (the younger rhyolites according to J. BOURCART 1937). In connection with this emission of volcanics parts of them were transformed to a pumiceous powdered mass, a puzzolane, that was spread in the shape of *lahars*.

The following epoch brought again salic material but this was intermingled with masses of xenoliths of various kinds (the R.N. agglomerate). The production of these agglomerates was enormous: the island was covered by them in all directions. Between these outbursts of Peléean nature tephrite lavas interfered as we have seen. It was a vivid alternation. How can that be explained? — The author thinks it was the rising basalt magmas that heated the overlying *Sial* material, so that salic magma (charged with gases) was generated. This heating occurred many times, it was a peculiar r h y t h m i c a c t i v i t y of salic and basic products. Every time an outburst started, the rising salic magma catched fragments of solidified rocks on the way, among them also plutonics. In this way the pumiceous mass became charged with xenoliths. After the salic (Peléean) eruptions were exhausted, the (tephritic) basalts reached the surface quietly expanding as sheets of lavas covering the previously deposited (and lithified) R.N. agglomerate banks.

The tephrite lavas may be considered *Sima* material adsorbing alkalies on the way upwards in the crust.

The end of this period of rhythmic activity is characterized by the multiple vents outbursts of viscous, phonolite lavas, silica undersaturated types carrying foids of the sodalite group. The total quantity of these outbursts was not great, they occurred chiefly in the central highland where they had to make their way to the surface across the thick cover of the R.N. formation. These tahitites, ordanchites, hauynophyres and the like may be considered differentiates from the mentioned tephrite magmas. They mark the end of this whole alkali-basaltic activity. The desilicification of the end products and the enrichment in Na-content have as it seems been brought about by a gaseous transfer with the formation in the rock of minerals such as sphene, ilmenite, alk. ferripyroxenes and -amphiboles besides the dominant alk. feldspar and the foid minerals.

With the last mentioned magmatic phase the production of salic and alkaline magmas had come to an end. In post-Miocene time a new phase started, that of the olivine-bearing basalt lavas and dikes. Their production was voluminous, as we already have seen, and they concealed the salic basement extensively.

These lava emissions have continued from the late-Tertiary period to the Recent time, and the composition of the lavas has remained practically unchanged (in chemical sense). The picrite basalt magmas have risen rather straight from the *Sima* sphere across the whole island structure. The main eruptions appeared in the central highland, but as time went on more and more adventive craters were opened lower down in the slopes, reaching the sea in some sectors.

This volcanism of basaltic nature has now faded away. A great volcanic cycle has been completed — a cycle that started in Eocene time (?) with the old basalts at the west side of the island.

This cycle includes as we have seen immense quantities of salic lavas and pyroclastics. We can speak of a 'contrasted differentiation' in this island. Somewhat similar conditions are met with in Tenerife, to some degree also in Fuerteventura, whereas in the western islands the splitting up of the magmas is less accentuated (here the basic lavas dominate).

The Canarian petrographic province may consequently be characterized by this magmatic behaviour, and especially that is true with Grand Canary. The proximity to the African *Sial* block seems to offer an explanation to these special conditions in the Canaries. They are no real 'oceanic islands', but are sub-continental.

The author is of the same opinion as that expressed already by T. BRAVO (1954) that changes in the crustal levels were the main causes of these sudden changes in the composition of the erupted magmas. When the *Sial* crust was elevated in the Canarian area and fissures were opened to great depths (i.e. tension cracks), basaltic magma from *Sima* found its way straight up to the island surface; again when the uplifted *Sial* block (i.e. the island mass) was tectonically depressed, the lower parts of it were subjected to anatexis. Here gas-rich, salic magmas were generated, and these were forced up to the surface. Violent eruptions followed. After a certain time these manifestations were fading out, and the *Sial* block rose anew. Tension cracks were opened, and *Sima* magma reached the surface sending out basalt lavas. These profound changes in the magmatic conditions may be considered typical of the border zone between Africa and the Atlantic.

True magmatic splitting due to fractional crystallization seems to have occurred in Grand Canary only to a limited extent. In Fuerteventura the conditions may have been different (J. BOURCART and E. JÉRÉMINE 1938, HAUSEN 1958).

SYSTEMATIC GEOLOGY

Summary of the geologic history of the island

1. Endogenic events

Introduction

Since Grand Canary is a volcanic island, the main forces in operation here have been of a volcanic constructive kind. The island represents a huge pile of volcanic strata accumulated on a basement which is also chiefly of volcanic nature. This basement is much older, however, its strata being in a tilted position. The surface covering the series in question is a plane of unconformity.

There are, however, several stratigraphic breaks also in the succeeding pile of volcanics, as we will find from the pages to follow. These breaks consisted in periods of weathering and erosion, also of tectonic displacements. It is difficult to understand the evolution of the island structure without taking into account these intervening non-volcanic periods.

Referring to the basement we may at first speculate a little about the geographical conditions in the area before the Canary islands came into existence. The author considers the present archipelago as the scattered remains of a broad continental headland jutting out into the ocean. These conditions already existed, I think, in the Mesozoic, and they persisted into the beginning of the Tertiary period. This pre-Canarian headland representing a marginal part of the Sial block of Africa, was of course subjected to displacements at many times. It is therefore not surprising to find that this headland consists of downwarped strata (marginal tectonics) towards the abyss of the Atlantic. In fact we will find in the island the relatively oldest formation showing such marginal tectonics.

Before we enter into a scrutiny of this old complex of strata in Grand Canary we may look around if we find some traces of a supposed basement also in the other Canaries. In Lanzarote it is invisible owing to covering younger basalt lavas, but these lavas have of course had their basement. In Fuerteventura there are exposures of a strongly tilted spilite formation covered with angular unconformity by the younger basalt formation. Turning to Tenerife we have to observe only younger formations, but ejecta of plutonic rocks speak of a hidden interior. Erosion has here not reached a sufficient depth to disclose a basement.

In Gomera there are old and decomposed lava rocks of a salic nature disclosed by marine abrasion and river erosion. — In La Palma we will note the presence of old, dislocated spilites and granular intrusive rocks in the bottom of Caldera de Taburiente in the core of the island overlaid by a heavy formation of basalt lavas. — Hierro exposes only a basalt formation; the basement does not appear here.

Turning back to Grand Canary, we have first to consider the oldest formation, consisting of salic lavas in tilted positions appearing inside the Tejeda drainage area.

The core (the nucleus) of the island
Dislocated trachyte lavas

The small sketch map, fig. 37, will demonstrate the extension of the area inside which these old trachytes have been laid bare by erosion. It has an extension of c. 10 × 10 km and occupies about 1/15 of the island surface. Outside this area, there are some smaller places in which similar rocks occur, as in the region of Majada Alta west of the middle course of Barranco de Arguineguín (T. Bravo). It is clear that these salic lavas in a tilted position must really be the relatively oldest formation from the fact that the surrounding formation rests with angular unconformity on these lavas. This important stratigraphic surface lies, as was mentioned on varying heights above sea level, as in the Sándara and Alta Vista mountains where it reaches c. 1 400 m in height. In other parts inside the area it is deeply depressed.

We have to distinguish the old dislocated lavas from the relatively younger formation of salic lavas, ignimbrites and tuffs that compose the high mountains in the west and northwest, in spite of the fact that they do not differ much in composition compared with the old complex. In the geological map appended, the two complexes have been given the

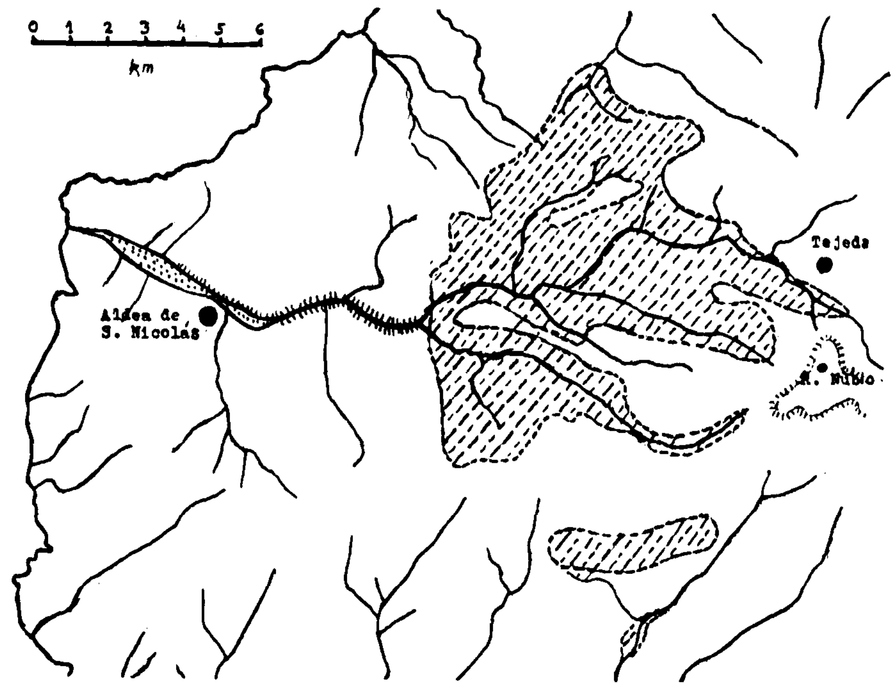

Fig. 37. Sketch map showing the extent of the old dislocated trachytes (the island nucleus) in the Tejeda area.

same colour (6a); there is, however, a line indicating the limit between the two.

J. BOURCART (1937) has not distinguished between the two salic complexes in his geological map or in the accompanying descriptions. This is reasonable from a petrographic point of view. As it was mentioned in the Historic review, this author considers the west coast basalts to be the relatively oldest formation in the island. — If that were the case one would expect to find inclusions of basalts in the trachytes of the Tejeda area, also in the syenites there. Instead such proofs do not exist, however.

These bosses and dikes of granular plutonic rocks, chiefly alk. syenites and nepheline syenites (appearing only in the deepest parts of the Tejeda area), do not belong to the old trachyte formation but have been generated from them and risen to higher levels. These circumstances will be considered later on when we are dealing with the rhyolite—trachyte formation of the western mountains.

An Eocene (?) volcanic phase in the pre-Canarian area (the table-land formation)

The now dominating volcanic complexes in the Canarian archipelago are basalts of somewhat changing ages and composition. The oldest lavas expanded over the surface of the pre-Canarian land were basalts (and their tuffs): vast lava fields and shield volcanoes, also cinder cones. The two easternmost islands were completely covered with these lavas i.e. the land, of which these islands now are remaining parts. In Grand Canary these basic effusions have left their masses chiefly in the west coast-basalts, here forming huge cliffs. Further traces are to be found in the bottom of Barranco de Arguineguín and in the southeastern sector (Barranco de Balo). The central nucleus (the trachytes), however, has remained free of these basaltic inundations. It seems that this part was an eminence already at that (pre-Canarian) time.

The best place to study these old basalts is along the coast profiles in the west, northwest and southwest. Here the lower part of the concordant series is olivine bearing, whereas the upper part consists of plagioclase basalts, also trachybasalts. Generally these rocks are much altered, and the vesicles in the blistery lavas have been filled with secondary minerals (calcite, chalcedony, chlorite).

In the southeastern sector (Barr. de Balo) the old lavas are likewise much altered, and here as is the case in the west, the olivines have changed completely into aggregates of sec. minerals.

One may ask where the orifices which emitted these basic lavas were situated. As far as the west coast basalts are concerned, they seem to have belonged to some great shield volcano (or volcanoes) lying off the present coast line. The orifices themselves have disappeared into the ocean. They did not really belong to the volcanic apparatus of Grand Canary in a proper sense. Consequently they ought to be excluded from the volcano-stratigraphic column of the island.

The same old basalt formation appears as it was pointed out already, in the other Canaries. They have been much dissected by fractures of later ages, and erosion and marine abrasion have attacked them. The 'best conserved' table-land of basalts is in the eastern islands — »the Purpuraries» — where they lie in flat position over wide areas interstratified with tuff layers. In Tenerife they are best exposed in the Anaga peninsula in the northeast and in Teno in the northwest. They form probably the basement of the great central Cañadas-Pico apparatus.

Gomera, La Palma and Hierro are typical basalt islands.

The pre-Canarian »Atlantis» (if we may use such an expression) was consequently mainly a basaltic table-land with several shield volcanoes and cinder cones. But there were apparently also some eminences of the basement rising above the lava fields. One of them was in the present Grand Canary (the Tejeda area).

The emission of the table-land basalts took place from a set of large fissures reaching to great depths, allowing *Sima* material to reach the surface. Most of these feeding channels of the lavas have already disappeared into the sea, but the position of many of them can approximately be located. The basalts of Fuerteventura came from the west. As far as Grand Canary is concerned the important source of lava emission lay also in the west, but there were certainly also other vents in the surroundings of the island.

Fracturation of the pre-Canarian marginal area

The splitting into different bodies (islands) separated by deep sounds

The continental border zone towards the Atlantic has always been a very unstable one. It has through the ages had the character of a zone of strains. Tensional fractures have from time to time opened and given passage-ways for magmas from the depths. In other cases no magmas have risen to the surface, only displacements have occurred.

Thanks to such fault-fractures of which there seems to have been at least two principal sets, the pre-Canarian, basalt-covered headland of the *Sial* block of Africa, was torn asunder, parts were left standing, other were depressed under the ocean level.

A number of angular blocks or »chunks» appeared, separated one from another by deep channels, reaching down to 2 à 3 000 m (except between the Purpuraries). The number of the »chunks» was originally probably lesser than that of the present islands, scarcely more than 5. The eastern islands: Alegranza, Montaña Clara, Graciosa, Lanzarote, Lobos and Fuerteventura formed one single land area of greater extension. Tenerife was probably connected with Gomera. Most of these ancient islands did have a greater circumference than now; faultings and abrasion have largely reduced their size.

The principal sets of fissures which dissected the area were at first recognized by T. BRAVO (1954). These run NNW—SSE and NE—SW, conformably with the two main trends of the near lying coast of Africa. Later faultings have to a great extent followed the old directions.

The individualization of Grand Canary was in this way completed, and from now on it started with its own geological evolution: volcanic, tectonic and exogenetic phases, all having left their records in the island structure. The relations between the endogenetic (chiefly volcanic) events and the exogenetic processes were rather varying. In some periods the volcanic manifestations dominated, in other or »calm» periods the erosion took over. One can, however, make the general statement that with the time the volcanic outbursts gradually lost their energy, and finally they completely faded away.

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We may now follow the geological evolution of Grand Canary, look at the different phases that followed one another, both the endogenetic and the exogenetic ones. The former comprise the volcanism in its various aspects, also the volcano-tectonic displacements of changing magnitude. The exogenetic events, in many ways counteracting the achievements of the eruptions will be shortly elucidated, although this side of the geological study has not been accomplished to the same extent.

A long period of volcanic activity of an explosive nature. Production of salic material

There is a sharp turn in the character of volcanism from the oldest basalt effusions to the first volcanic phase of the island proper: the highly explosive and salic magmas now found their way to the surface of the island.

From where came these new and salic silica- supersaturated lavas? The author is of the opinion already expressed that they are simply the result of anatexis in the depths. The old trachytes of the nucleus offered the original material.

The immediate products of this anatexis were the syenitic plutonic bosses now exposed in Barranco de Tejeda. They represented the subvolcanic parts rising through the complex of dislocated old trachytes.

These magmas were rich in volatiles and — with the aid of fissures as passageways — they reached the surface under explosive activity. The masses were ejected over the island as tuffs, agglomerates and ignimbrites, to a lesser degree as rhyolite and trachyte lavas.

These products were spread over vast surfaces, chiefly as it seems to the west. The island was then of greater circumference than now, and the total volumen of the materials must have been important. Thick banks to a number of 12—13 were accumulated, the one upon another forming a concordant pile. Later erosion has since then greatly reduced their extension (cf. with the geological map appended).

This formation is rather unique in the Canaries. Its importance was recognized already by J. BOURCART (1937). There are interesting profiles of the formation to be studied, as the reader already may have found form the descriptive Part I.

In the later decades many occurrences of ignimbrites have been described, but is is not necessary to quote them here. All of the occurrences — comprising only salic volcanics, mainly rhyolites — refer to greater land areas, whereas ignimbrites in oceanic islands have not hitherto been mentioned. Now we may say Grand Canary is no real oceanic island, it is a sub-continental island. Hence it has a special position that may explain the occurrence of ignimbrites.

Nevertheless, of all the Canaries Grand Canary is the only one provided with this kind of material. Not even Tenerife, magmatically of similar composition has any formations like those of Grand Canary just characterized.

Revival of the volcanic production of salic magmas

The formation of the great phonolite volcano

Most of the products of the preceding phase are silica-saturated or-supersaturated. As time went on these magmas gradually changed, so that amount of silica diminished and content of natron increased. Lavas of phonolites were the result together with huge masses of tuffs. A very voluminous production of these volcanics followed for a long period: they built up a giant volcano of the central type. The crater of this volcano was certainly situated in the culminating part of the island, although traces of the same are not more conserved. — The phonolite volcano represented apparently a broad cone with relatively smooth slopes judging from the still remaining southern sector of the cone. It was a strato-volcano with alternating banks of platy, dark lavas and brownish tuffs between them. The size of the volcano can well be compared with that of the central part of Tenerife in times before the formation of the great Caldera de las Cañadas replacing the summit.

What is missing in the phonolite volcano of Grand Canary is a similar top-caldera (collapse-caldera) and likewise a central Pico. Instead the phonolite cone of Grand Canary has been badly dissected by ruptures; the northern and the eastern parts have almost disappeared out of sight due to great displacements in later time. These sunken flanks of the cone have been overridden by younger basalt lava floods.

In the western sector the slopes seem also to have been dissected but here uplifted. The relatively higher positions have caused erosion so that nearly all of the phonolite lavas have been abolished, leaving the under-lying rhyolites-trachytes free. But in other parts of the island one can still find some remnants of the phonolites exposed under the younger formations. A good exposure stretches along the east coast to the south of Las Palmas (region of La Laja). Another well visible remnant is re-presented by Montaña de Guía in the northwest, a horst consisting entire-ly of the phonolite formation.

The large southern sector of the volcano reaching from Barranco de Tirajana in the east to Barranco de Mogán in the west offers good geologic profiles thanks to the many deep *barrancos* dissecting the flank, really a strange landscape of so called *tableros*.

It was mentioned that the crater has been destroyed. There are how-ever, in the deep erosion channels of the Tejeda area many phonolite dikes to be seen crossing the old trachytes or the plutonic bodies. They can be considered a kind of feeding channels of the lavas.

About the geologic age of this phonolite volcano nothing can be stated with greater exactitude. We can see that the lavas are younger than the rhyolite-trachyte formation in the west — there are in some places im-mediate superpositions to be observed. In the region of Las Palmas the phonolite banks are covered with the fossil bearing Miocene littoral strata — consequently the volcano may be of pre-Miocene age. The phonolites are likewise covered by the puzzolane formation, and it seems the de-position of this wide-spread pyroclastic sediment represented the final act of the rather long period of volcanism that built up the cone. A similar age relation is met with also in Tenerife.

It is conceivable that the mudflows were emitted from a bursting crater that contained hot water. The bursting may have been accompanied by the eruption of fine ashes, which were mingled with the water during its escape down the slopes (see next chapter!)

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*

The phonolite volcano was accumulated on a basis consisting of the rhyolite-trachyte formation of lavas, ignimbrites and tuffs. n o t, however, on the old basalts except in the southeastern corner; here we have in fact an immediate superposition of the phonolites of on the old weathered basalts (Montaña de Acuario).

We will find in these relatively old volcanic formations strong evidences of erosion. An impressive witness of this process are the huge masses of phonolite gravel conglomerates covering the Miocene littoral strata in the vicinity of Las Palmas and also in the far south (region of Arguineguín). Most of the debris has of course been transported to the sea and deposited in the surroundings.

The original height of the phonolite strato-volcano may have attained more than 2 000 metres above the sea. It is conceivable that the cone did have a top-collapse caldera like that in Tenerife, and it may have been situated above the present area of the Tejeda depression. Extension seawards was certainly far greater than now, especially in the east side. Such a statement can be confirmed by the conditions in La Laja (S of Las Palmas). where a huge phonolite bank has been abruptly cut off from the sea. Also along the northern coast there was a former continuation northwards judging from the abrasion cliffs there.

The spreading of the puzzolane (canto blanco)

This pale-cream-coloured, rather fine grained and unstratified pumice material of phonolitic composition occupies a far more restricted area in Grand Canary than in Tenerife (Hausen 1956). This is sometimes due to later erosion, sometimes to its being covered by younger formations, but chiefly to the fact that this deposit was originally of much lesser quantity than in Tenerife. In the latter, the puzzolane was emitted from the great central caldera in times before its final enlargement (by subsidences). The southern declivities of the island in particular were flooded with the puzzolane. The sources of the emissions are not definitely clear, but it is beyound doubt that the orifices lay somewhere in the central highland, since all the remaining parts of the formation can be followed up the slopes to this part.

In Grand Canary much puzzolane has been destroyed. There were however at least t w o m a i n s t r e a m s: one directed to the south, another to the northeast, both right down to the sea. The western mountains in the region of San Nicolás and Tamadaba were never flooded by the puzzolane.

The puzzolane may be considered a consolidated watery mudstream like the *lahars* in the East Indian Archipelago, and it belonged no doubt to the h o t *lahars*. The water had a temperature of some hundred degrees Celsius. Occasionally stones of lavas were intermingled now embedded in the fine-grained pumice mass.

The puzzolane was expanded in a time when the relief of the island was different from the present one. That can be well seen in the sector around Barranco de Arguineguín. Since then erosion has made a great progress and much of the relatively brittle puzzolane has been abolished.

The stratigraphic position of the puzzolane is seen from its relation to the R.N. agglomerate on the one hand and to the phonolite formation on the other. It appears between these two, or more exactly above the rhyolites of the younger group that covers the phonolites. The puzzolane is of a time antedating the deposition of the fossil bearing littoral sediments of the Las Palmas' terrace, since the puzzolane forms the basement of the whole littoral series of strata.

If we turn to the sea front of the southerly puzzolane avalanches, we will miss the Miocene strata in this sector entirely. Instead the puzzolane is overlaid by a coarse conglomerate, separated from it by a surface of erosion. Nevertheless the two occurrences — in the northeast and in the far south are contemporaneous in origin.

The period of erosion that followed certainly destroyed much of the puzzolane cover, also marine abrasion participated — in the reduction of the extension seawards.

Displacements in the salic volcanic formations

The irregular distribution of the salic volcanics in the surface of the island (cf. with the geological map!) is to a great deal due to later faultings in the ground, and many of these disturbances were obviously of large scale. J. Bourcart (l.c.) has recognized a number of them (indicated in his geological map) the most important being the Agaete—Tirajana line (or zone) dissecting the island in the direction NW—SE into two parts: a northwestern and a southwestern one. The former was called by him *Neo-Canaria*, the latter *Palaeo-Canaria*. This great fracture was accompanied by a displacement that brought Neo-Canaria in a relatively lower position than Palaeo-Canaria. The old phonolite volcano of the central type was cut across. — But there were also other lines of rupture. Bourcart supposes the Guiniguada valley has been controlled by a fault line along its whole course (direction SW—NE). Moreover the east coastal land has been depressed along a N—S line from Las Palmas over Telde to the vicinity of Juan Grande.

But there were certainly many other fault lines that have dissected the island at about the same time. The present author has found fault lines along the western escarpments of the Montaña del Horno—Tamadaba mountains, further along the *cuesta* to the south of Aldea de San Nicolás. Another line runs obviously along the steep coast in the extreme west, where the original *barrancos* have been cut short.

Of smaller faults there are some confining the Guía horst block in the northwest. This horst is a small visible remnant of the old phonolite volcano (in its NW: flank), etc.

All these fractures with accompanying block movements have greatly damaged the old phonolite cone, simultaneously also the underlying rhyolite-trachyte formation. Later erosion and the emissions of new volcanic products (the R.N. agglomerate, then the basaltic lavas of post-Miocene to Recent age) have contributed to the irregular geologic picture of the salic formations in the surface.

To these displacements ought to be added all the later faultings connected with the younger volcanics, to which we will return later on.

A Peléean volcanic activity of the central type. The deposition of the R.N. agglomerates.

The most interesting volcanic formation met with in Grand Canary, and the most »endemic» of them all, is the so called Roque Nublo formation of unstratified agglomerates, intercalated with sheets of tephritic lavas. Its repartition is seen from the accompanying geological map. We realize that the material was issued from the central highland, and these masses appeared as great avalanches.

In the other Canaries there are no similar kinds of pyroclastic deposits, not even in Tenerife, as far as the author knows. The agglomerates deposited during a series of outbursts mark the climax of explosive activity in the whole history of the island. — The genesis of the formation was first recognized by J. BOURCART (1937) who placed the eruptions in the same category as the Peléean type of ALFRED LACROIX. The agglomerates are the remains of glowing avalanches, pumiceous sands and stones deposited in the slopes in a chaotic mixture. The appearance of the avalanches s i g n i f i e d a h a v o c t o t h e o r g a n i c l i f e i n t h e i s l a n d, and these catastrophes occurred (as we have pointed out already) at least six or seven times.

An intricate question is where to locate the vent (or the vents) from which these tremendous avalanches departed. There have been some speculations about the matter, but no decisive solution has as yet appeared. According to the author's experiences it seems most likely that the places of eruptions were situated in the chasm of Barranco de la Culata (cf. with page 299, Part I).

The extension of the Roque Nublo agglomerate has been followed through many sectors of the island, from the central highland down to the vicinity of the coasts. The original cover was apparently rather continous except in the west (the Tamadaba and del Horno Mts). As to the thickness of the cover, it is evident that the maximum amount is reached in the region of Roque Nublo (the platform). It is therefore natural to suppose that the principal outbursts occurred in the vicinity, i.e. in the chasm of La Culata, as it was mentioned above. A similar idea has been expressed by T. BRAVO (in a letter to the author). The blasts escaped from fissures, and it seems as if these coincided with the formation of the great dislocation line above mentioned.

These avalanches consisted of chiefly pumiceous material as it has been stated in the petrologic part. The matrix contains plenty of xenoliths, in parts of basic lavas, in parts of different plutonic types already mentioned. The latter bear witness of a deep origin within the crust.

The texture of the agglomerate is wholly chaotic. No stratification is perceptible in most of the profiles studied, except in cases when the material has been re-worked and re-deposited by running water. A series of sandstones and conglomerates has resulted. That was the case in at least two localities: Barranco de la Culata and Barranco de la Hoya (Berrazales).

Morphologically the R.N. agglomerate banks play an important role in the landscape: the erosion remnants of them stand as mighty witnesses confined by vertical walls (due to diaclases) in most of the watersheds, where they have been left behind by erosion. From time to time gigantic rectangular blocks have dropped down the mountain sides, as may well be seen in the sides of the central Roque Noblo platform itself.

The interfingering tephritic lava effusions

In the huge nearly vertical profiles of Caldera de Tirajana and Caldera de Tejeda, we will find, as it has already been described, several interstratified tephrite lava banks in the R.N. formation exposed. But these basic lavas are met with also in many other parts lower down the island slopes, here either intercalated in the agglomerates or covering them. These alternating banks of wholly different composition reflect a r h y t h m i c a c t i v i t y of explosive outbursts and of quiet lava effusions. This kind of events has not left any records in the other Canaries, as far as I have seen.

These changes lasted a considerable time, and it looks as if the lavas were expanded over an already lithified agglomerate. The lavas departed from the highland like the avalanches, most probably from fissures, the remains of which are still seen in the shape of dikes.

In the chapter on causes of diversification of magmas in Grand Canary we have already discussed these rhythmic eruptions of such a special character. The tephrite lava emissions stand rather alone representing a kind of interlude activity between the old olivine bearing basalt volcanism in the west and the later on following likewise olivine basalt effusions in the post-Miocene and younger periods. It is important to distinguish between these alkaline basalts and the other and not to throw them all into one and the same group (»more or less alkaline») as it has sometimes been made. The tephritic effusions were quantitatively important: together with the alternating R.N. agglomerate deposits they have considerably enlarged the island structure, the heights have increased. And with them the erosion has been invigorated.

There seems to have been a rather long time span between the piling up of the R.N. agglomerate formation with the tephrites and the later on beginning activity which produced the olivine bearing basalts. This time was an interlude of erosion. But before the exogene work had advanced too far, there followed a period of volcanism — with the production of the undersaturated and highly *Na*-alkaline lavas.

Eruptions of highly Na-alkaline phonolitic lavas

Multiple vents eruptions in the central highland

It was a somewhat restricted production of salic lavas and there were many smaller vents lying rather closely grouped. Since the lavas were highly viscous, plugs were formed, but also shorter lava streams followed spreading over the now already consolidated R.N. agglomerates of the central highland and its nearer surroundings. This phase was not of greater importance in the development of our island and it lasted a comparatively short time. The domes and the monolith-like necks left standing in the highland by the subsequent erosion have, however, added to the landscape a strange accent, especially in the mountainous background of Tenteniguada.

The lavas of these hauynophyres etc. have covered the R.N. agglomerates, in parts also the tephrites, they are, however, rather restricted in the surface, this being due to later emission of (the post-Miocene) olivine bearing basalts. In the borders of the caldera-precipices and other borders of the highland they are well exposed, however, as it has been described in Part I.

I have already discussed the probable origin of these phonolites and considered them as derivatives of the tephrite magmas. They indicate the climax of alkalinity of the volcanic products in the island, they are the record of a final act in the long lasting process of Miocene (?) accumution of materials belonging to the R.N. formation. There are in the other Canaries, as far as I have been able to prove, no such strongly undersaturated and *Na*-alkaline lavas, one can say they are of a rather exceptional nature.

Similar lavas at the north coast
The two cumulo-volcanoes of Arucas and Cardones

Two volcanoes close to the north coast seem to belong to the same period of volcanism as all the multiple vents in the central highland. The lavas emitted from the two volcanoes are of a rather similar nature, tahitites and ordanchites according to E. Jérémine, also to experiences won by myself. The two cones are of an aspect different from all the other adventive cones strewn over the island slopes in the north and in the east. They have contrarily to the last named no crater, lavas have been sent down to the coast from the base of the cones.

J. BOURCART (l.c.) considers the two cumulo-volcanoes as geologically young. No doubt they have no advanced age, seen already from the small amount of erosion in the cones. But they may be older than the near lying basaltic cinder cones such as Cabeza de la Rosa, Bandama etc.

T. BRAVO has (according to a geological profile sent to the author) observed that the two cones lie on R.N. agglomerate. Hence they are younger than these. A short distance to the south from Arucas there is a Miocene shore line (c. 200 m above the sea), and this cliff was worked out in time before the accumulation of the Arucas volcano. The author is inclined to think the two cones may belong to a period antedating the post-Miocene basalt effusions — and they are most likely of the same age as the multiple vents in the highland, from where the foid bearing phonolite lavas emanated. — All these lavas were highly viscous, and the formation of necks or of cumulo-volcanoes was only the natural expression of the magma-character.

The two volcanoes at the coast form, however, a separate eruption-field rather distant from that of the central highland. Contemporaneous with the cumulo-volcanoes are sheets of foid-bearing phonolites on a stretch of the north coast from Bañaderos to Puerto de la Luz, where they crop out in sea cliffs. These lavas may have been sent down the slopes from higher lying vents, scarcely, however, from the central highland. They all antedate the basalt lava effusions, since the latter form the top sheets in escarpments facing the sea.

The author has not been able to locate these vents or to follow the phonolite lavas in question from the coast farther up the slopes.

The later basalt volcanism in the centre and on the northern and eastern slopes

We now have to deal with the latest volcanic phase in the island which began in the post-Miocene period and continued to the present one (in geological sense). For the sake of convenience, we will treat the matter under two headings: the late-Tertiary (the post-Miocene) volcanism and the Quaternary-Recent volcanism, although these phases have much in common, not the least as regards the composition of the erupted material.

The late-Tertiary volcanism

We shall begin with the manifestations in the central highland (c. 1 500 m above the sea level), where the cover of these lavas is rather thick. The chief vents (probably fissures) from where all these lavas have started are not known with certainty. It seems that an important centre was situated in the area now occupied by Caldera de Tejeda, but no traces of a crater are to be found here. Later displacements have in cooperation with erosion destroyed the orifice (or orifices). But in the margins of the deep hollow, especially in the north and in the east there are many basalt lava banks having tuff intercalations and crossed by steeply dipping dikes of basalt. The same lavas can be followed also farther down the declivities in the north and in the east and southeast flooding vast surfaces. It is consequently obvious that there was a very important centre in Tejeda. J. BOURCART (1937) expressed the same idea and he used the designation »le grand volcan (basaltique) de Tejeda».

These eruptions were consequently of the central type, although effusions seem to have avoided the south and the west sides of the island.

One is impressed by the great quantities of the basalt lavas which inundated practically the whole *Neo-Canaria*. The many *barrancos* afterwards dissecting the series expose good geologic profiles for long distances.

A great deal of these lavas reached the surface along many fissures in the highland and inundated the previously formed R.N. formation and spilled over the borders in the eastern sectors. These lava filled fissures are still to be seen standing above the highland ground as cyclopic walls.

If we leave the highland and go down the declivities in the north or in the east, we will meet numerous adventive cinder cones, many of which are obviously not very recent not even of Quaternary age, judging from their state of preservation. They are also of relatively greater sizes than the younger cones in the same areas.

We have already dealt with these cones and with their erupted material, so we will limit ourselves to some short characteristics of more typical cones. — One of the foremost of them is Montaña de Osorio (900 m) rising to the west of Teror. It is entirely covered with a mantle of lapillis and ashes already oxydished in the surface. From the large crater open to the east lava streams have found their way down the train of Barranco de Teror to the vicinity of the coast. This stately cone (or more exactly: this complex cone) rests on a basement of salic lavas and tuffs.

Of other similar cones belonging to this age group is Montaña de Firgas, further Montaña Doramas, Montaña Alta and Montaña del Viento. Turning to the eastern declivities of the island we have here several of relatively large cones. A rather impressive cone is Montaña de Las Palmas above Telde. From this cone a long lava stream was sent down Valle de los Nueve (later on cut across by a canyon). On the coast we have also some old cones, of which Montaña de Arinaga forms a peninsula.

Aside from the cones enumerated, all furrowed by erosion and weathered in the surface, we have to observe the presence of lava floods inside Caldera de Tirajana and Caldera de Tejeda, the age of which is somewhat uncertain. One such stream has filled the bottom of Barranco de Tirajana (later on cut by a new gorge). It is not definitely proved from where the lava was issued (in the highland border to the east of the valley). In Caldera de Tejeda there are several erosion remains of basalt lavas formerly flowing down the bottom of the great valley in time before the working out of the present gorges (cf. with Mesa de Acusa and Mesa de los Junquillos).

Great masses of pyroclastic materials have been strewn over the surroundings of the larger cones, especially in the northern declivities. These have been subjected to intense weathering processes, and a reddish lateritic soil has been produced. It has not been possible to fix in the geological map the true extension of these covers. The occurrence of the soils owes the effect of moisture laden trade winds in this *barlovento* side of the island.

The Quaternary and the Recent volcanism
(Adventive cones, their lavas and ashes)

As may be seen from the geological map, the northern and the eastern slopes of the island are rather densely dotted with volcanic cones of varying sizes; some of them lie close to the coasts, other are strewn higher up the slopes to the Cumbre region. — These adventive cones appear in the same areas as the above described older ones. They represent the continuation of the basalt volcanism of the former periods — only the intensity of eruption has considerably diminished.

Like the older cones these of the younger group may be closely connected with fracture lines in the island. Where there is a straight row of cones, a controlling volcano-tectonic line may be suggested. In other cases the reconstruction remains conjectural; strict evidenses of such fractures are scarce. Some of them are revealed during road engineering works and the like (opening of water tunnels).

It is a striking fact that in the whole southern part of the island there are not, with a few exceptions, adventive cones. The long geologic profiles exposed in many *barrancos* there do not reveal any fractures either. These profiles give the impression of an unbroken table-land of old volcanic strata dissected by erosion only.

It is also difficult to determine the exact geologic age of all these cones. Some are without doubt from the Quaternary time, other are Recent in age. There may also be difficulties to decide wether a cone is from the latest Tertiary or from the early Quaternary time. The state of conservation may decide in such cases: are the materials in the surface oxydished or not, and how far has the erosion been able to destroy the flanks and the surrounding materials.

We may, however, as a rather reliable criterion of young age consider the coke black slaggy and glassy lavas and their cones. The activity of these adventive volcanoes was of a mixed nature: explosions with plenty of pyroclastics, and lava emissions. The lava-tongues followed many of the existing *barrancos*, filling them to a certain degree or nearly completely.

It is not necessary to enumerate here all the cones, they are described in Part I. We may, however, look at some more illustrative examples. — In the central mountains we have the large cone Altos de los Peñonallos (1 850 m), a Quaternary cone which sent a lava down the right head arm of Barranco de Guayadeque. A short distance to the north from this cone there is a smaller collapse caldera sunk into the hauynophyre rock ground a f t e r the lapillis and ashes from the volcano were settled into the surroundings.

Of cones situated on lower levels there are some small ones in the vicinity of Jinámar, to the south of Las Palmas. They have sent lavas down to the near lying coast. The highroad to Telde crosses two of these lava tongues, all being basalts, olivine bearing.

A most interesting group of volcanoes is found in the peninsula of La Isleta, giving shelter to the commercial port of Las Palmas. The cones here are 8 in number, but they are of somewhat different age (as it has been pointed out in Part I). The one of them with the latest activity is Montaña del Faro in the north of the area. This has sent a broad stream of basalt across the peninsula to Bahía del Confital.

The two volcanoes of the Arucas-region on the north coast are considered by J. BOURCART (1937) as of recent age. They consist as we have found of phonolites, making an exception to the whole assemblage of younger basaltic cones in the surroundings. The present author is of the opinion the two cones in question are older, maybe late- Tertiary in age (Part I,, page 271).

Further west along the north coast there stands the conspicuous cone of Montaña de Gáldar, at the ancient stronghold of the Guanches. It may be a Quaternary cone, its aspect is not very fresh. A crater is open to the north. The flanks are covered with lapillis and ashes. A lava stream of basalt (limburgite) was sent to the coast, according to J. BOURCART (l.c.). When in activity the volcano ejected masses of lapillis into the air drifting southwards and covering a great part of the plain stretching towards Agaete likewise the phonolite erosion mountain Almagro.

More famous among the later volcanic mainfestations is the so called Caldera de Bandama, situated a short distance to the south of Las Palmas. It is flanked by a cone of rather recent aspect — Montaña de Bandama. The author is of the opinion that the cone is of later age than the caldera, the latter being a kind of *maar* (explosion crater, HAUSEN 1961).

Other young cones are strewn in the surroundings, being apparently epigones to some larger, older cones more to the south. Of the more easily accessible small volcanoes is Morro del Inglés in the vicinity of Santa Brìgida. It has sent a lava stream down Barranco de Guiniguada to the bend of the valley at La Florida. The eruptions are not very young, since the river of Guiniguada has cut across the west flank of the cone (at La Angostura).

It has been pointed out already (Chapter on Petrology) that the lavas of these young cones are olivine bearing rather picritic basalts. They are consequently of low viscosity, the lava streams have run with great speed down the *barrancos* and the slopes. The occurrence of large quantities of ejecta (Gáldar etc.) speaks, however, in favour of violent explosions, and these may (at least in parts) have been caused by ground water (the basal ground water body of the island).

The volcanic activity of the island has now come to an end. No outbursts are known from times after the first arrival of Europeans. The freshness of the lavas in some places (Jinámar etc.) indicates, however, a rather recent time of outbursts, maybe from some centuries before the *Conquista* of the island (1404—1494).

The only signs of the fading volcanism are some mineral springs (Firgas, Berrazales).

2. Exogenic processes

River (*barranco*-) erosion

The physiography of Grand Canary is largely dominated by the results of erosion. A glance at the topographical map of the island reveals a fairly regularly formed drainage pattern arranged like the spokes in a wheel. It is evident that erosion has worked very intensely and reached an advanced stage judging from the smoothened, longitudinal profiles of the water courses.

On closer study, many irregularities are of course to be found in the drainage pattern, and it will also be clear that the progress of erosion must have passed many phases, calm times interrupted by volcanic outbursts. In fact, a full geological history of the island cannot be deciphered without due attention to the marked alternation between endogenic and exogenic events. But not only volcanic manifestations in proper sense have interfered with weathering and erosion, also fracturation and displacements have occurred from time to time causing still more complications in the island structure.

If we now look at the radiating *barranco* systems, we will find some greater irregularities: there are at least two large embayments penetrating into the core of the island: the Calderas of Tejeda and Tirajana. They have their drainage systems of their own, to which we will return later on. Then there is the rather independent system of deep *barrancos* in the southwestern coast mountains and the gorges connected with the rather isolated Tamadaba mountain block.

Note: State of volcanism in the Canaries. *Recent outbursts* have been recorded in Lanzarote (1824), Tenerife (1909) and La Palma (1949).

Volcanism has faded out in Alegranza, Montaña Clara, Los Lobos, Fuerteventura, Grand Canary, Gomera and Hierro. No outbursts in 'historic time' have been observed in these islands, of which Gomera as the first one seems to have turned into inactivity.

It is obvious that the *barrancos* are of different ages. In the southwestern half — in *Palaeo-Canaria* — most of them are relatively old stately mountain valleys — like Barr. de Fataga, Barr. de Arguineguín, Barr. de Mogán and Barr. de Veneguera. They all widen along their course and have a broad mouth. The longitudinal profile is rather smooth without *saltos*. The head-parts have, however, the shape of gorges with a steep grade.

In the northeastern half of the island -- in *Neo-Canaria* — there are also many long *barrancos*, they are, however, rather young, since the rivers have cut down their courses into the post-Miocene cover of basalt lavas and tuffs. The longitudinal profiles are not of the mature stage — there are irregularities in the way. Either there are tresholds that have been cut across (Barr. de Agaete at Berrazales) or there is a sudden break as in Barr. de Moya, or the grade of the profile is rather steep — as in Barr. de Guayadeque. Other irregularities have been caused by young basalt lava streams that have used the water course for some distance. The *barrancos* in *Neo-Canaria* bear the sign of rapid erosion under rather humid climatic conditions (windward side of the island), contrasting against the erosion landscape in the south (especially inside the phonolite-sector) with its semi-arid land forms (*tableros* and steep *barranco* walls).

The west coast has the physiognomy of its own: short gorges with a steep gradient dissecting the coast cliffs and the steep slopes surrounding the Tamadaba complex.

Remains of an old pre-*barranco* relief in *Palaeo-Canaria*

As has already been mentioned in the descriptive Part I (Chapter 4,5) there are in the southern sector certain surface forms which look rather ancient, created by weathering and erosion: the whole ridge of the so called 'Cordillera del Horno', the eminence of Tauro to the south of it and the Chira valley, a left tributary to Barranco de Arguineguín. This relief has a rather advanced maturity: open valleys and rounded hills between them and a low grade to the sea. These forms were probably connected with the undulating relief still to be seen in the central highland, although younger basalt lavas have to some extent concealed the same.

The relief features in question are apparently of pre-*barranco* age; they antedate an uplift of the island when erosion was invigorated.

We may now look at some special features of the old relief.

'Cordillera del Horno' shows a rather advanced erosion, as may be found from the very undulating crest line with more resistant rock masses carved out into *haute relief*. Most illustrative are the necks of phonolites (see the field sketch, fig. 13). These necks are the old throat fills of once existing volcanoes. Passes between the eminences are saddle-formed, and sharp forms are rare. These begin down in the flanks, where young erosion has reached from the north and from the south. — Interesting is the Chira valley, the bottom of which lies c. 900 m above the sea. It represents a hanging valley to Barranco de Arguineguín. There has occurred, however, a later adjustment in the shape of a short and steep canyon above the junction. On the right side of Barranco de Arguineguín (middle course) there is the conspicuous rounded eminence Pontón de Gavilanes, a half-dome separated from the still higher Tauro eminence by a broad saddle pass. Pontón de Gavilanes has in the east been attacked by erosion (in Barranco de Arguineguín), and a tremendous precipice has been formed (with land slides).

The Tauro mountain in its turn is separated from 'Cordillera del Horno' by a broad saddle — where the water reservoir Majada Alta is situated.

In the west, in the summit region of the Tamadaba Mountain there is also a remnant of an old relief of limited extension with a number of eminences carved out in more resistant rocks. Cumbre de Tamadaba is the greatest monadnock here.

It is of interest to note that the old erosion surface mentioned to a great deal has been covered by the R.N. agglomerate formation. This deposit has been conserved partly in saddle passes (Majada Alta) partly in valley bottoms (Chira valley) and partly in the old divides themselves (divide between the Chira valley and Barr. de Arguineguín). Also in the central highland (above the 1 500 m contour line) there are the masses of the R.N. agglomerate lying on the old ground (later on capped by olivine basalt lavas).

Erosion in the two Calderas (de Tejeda and de Tirajana)

Finally we must mention the special conditions governing the erosion inside these two large depressions. The conditions are rather briefly mentioned here, since we have already dealt with them in the descriptive chapters 3 and 11 (see also HAUSEN 1961).

C a l d e r a d e T e j e d a represents a typical erosion landscape (cf. with fig. 27). It is apparent, however, that erosion alone cannot have worked out this great abyss. The author supposes that various kinds of displacements have from time to time opened ways for attack by running water. But a later phase in the caldera- forming process consisted in erosion alone, i.e. when the gorge in the west was opened. This gorge was originally a spillway for stagnant water in the Caldera. With the downcutting of the same across the mountain barrier erosion proceded at the same pace in the Caldera. The final stage of erosion coincided with the upheaval of the island in post-Miocene time.

Barranco de Tejeda has as we know, several left-hand tributaries, all deep gorges like the master canyon. Their head erosion is attacking the highland ground especially in Barranco de la Culata.

C a l d e r a d e T i r a j a n a (cf. with fig. 8) has a rather similar history, except that there was no stagnant water in the basin. Erosion has worked vigorously, and the outlet valley has existed from the beginning — Barranco de Tirajana. Stages of erosion are indicated by terrace remnants — one of them lying c. 900 m in the eastern side; the latest terrace accompanies the upper course of the main *barranco*. After the downcutting of the *barranco* had reached a mature stage the bottom was filled with basalt lava streams. — This lava fill was afterwards cut by a canyon. — The enlargement of the Caldera was due not only to erosion (and head water erosion), but also to great land slides which have worked repeatedly until our days.

Coastal abrasion work

The Canary Islands have since Quaternary time (?) been exposed to the northern and northeastern trade winds. Owing to the impact of the breakers in the windward side the coasts here have been forced to retire, and shore cliffs have been formed. Further there are terraces open to the sea. They bear witness of positive and negative migrations of the shore. In the northwest and in the west there are as we have found the highest and the steepest cliffs (see fig. 1 and 2, plate IV). These are considered by S. BENÍTEZ PADILLA (1945) as true marine cliffs. I am inclined however, to see in them the results of displacements, not excluding the effect of the breakers.

If we now turn to the east and the south coasts, we will find the things rather different. A great deal of the stretches is occupied by flat coastal lands covered with gravels, carried down by the rivers. There is, however, on the stretch between Arguineguín and Playa de Veneguera a true abrasion coast with steep cliffs although of only some ten metres in height. The steepness here has its special causes. In the descriptive Part I we have already mentioned the long exposures of the soft stratum of puzzolane supporting layers of gravel-conglomerates. In this weak formation the waves have had good opportunity to excavate — undercutting the hanging conglomerates.

In short: Grand Canary has suffered considerably from the abrasion at least in Quaternary and Recent time, maybe also earlier (in Pliocene and Miocene time), then, however, on other levels than at present. There have not been any closer studies of raised beaches in this island so far, except what is mentioned in the older literature.

Sub-aquatic sedimentation

River sediments and lacustrine deposits older than the post-Miocene volcanics

In the course of my excursions I have encountered rather thick series of sandstones and conglomerates in alternation, lying in an almost horizontal position, but mostly on high levels. It is evident that these sediments are not marine, but they have been deposited in closed basins, now long ago opened by erosion. — One occurrence of that kind is exposed in the right wall of Barranco de La Culata (head of Barr. de Tejeda), as has been more closely described in Chapter 11. The base of the series lies c. 1 400 m above sea level. I have regarded the series as re-worked R.N. agglomerate material from a time when this agglomerate still was in an unconsolidated state. The sediments were carried by running water to a closed basin antedating the present Caldera de Tejeda. This basin, the bottom of which lay much higher than that of the present Caldera, was filled with water. It had a spillway or outlet river in the west. The total thickness of the series of La Culata is estimated to c. 100 m. — After the sedimentation of these layers they were covered by a thick series of post-Miocene basalt lavas and tuffs.

Inside Caldera de Tejeda there are other consolidated sediments lying on much lower levels, in Mesa de Acusa and in Mesa de los Junquillos, there also capped by basalts. Perhaps these layers belong to a somewhat later period than that of the sediments of La Culata — when the outlet canyon already had been cut down into the mountain barrier in the west.

Another very interesting occurrence of sandstones and conglomerates is met in the vicinity of Berrazales, along Barranco de la Hoya (head of Valle de Agaete). Here lies a concordant series of detrital sediments exposed in huge vertical profiles along the right side of Barranco de la Hoya. The total thickness amounts to c. 150 m. The basement lies at a level of c. 800 m. This series is also capped by basalt lava sheets —. It seems clear that these sediments were laid down in a closed basin, the barrier of which has later on been cut across by the river in a narrow gorge. The basin was probably a lake, filled up with the detrital products. After the draining of the lake the fill was attacked by erosion, so that it is now much dissected by gorges. It is clear that the whole pile of sediments would have been carried away a long time ago, if there did not exist a protecting cover of basalt. — On the opposite side of the *barranco*, in the high flank of the Tamadaba Mountain no sediments of the kinds described are to be seen, — only the series of salic lavas and tuffs in a huge succession. The sediments have completely been wiped away from here. — The detracted material now lies at the bottom of Valle de Agaete (Barranco de la Hoya), filling it with a train of gravels. It has, however, been covered by a sub-Recent lava stream of basalt. — The great pile of sandstone and conglomerate strata, i.e. the ancient basin fill, must once have been carried downhill by running water from the central highland to the east, where there are still great masses of the R.N. agglomerate formation left behind.

A formation of coarse conglomerates of chiefly phonolitic material corresponding to a post-Miocene erosion period

We must now mention a rather strange kind of coarse detrital accumulations, the origin of which is to some degree of 'enigmatic' nature I mean the wide gravel fans (hardened to conglomerates) at lower levels in the northeastern and the southern sectors of the island. In the former sector — immediately above the city of Las Palmas, these conglomerates rest directly on the fossil bearing Miocene littoral sediments with a surface of erosion. The conglomerates form a huge top sheet containing sub-angular boulders up to several tons mingled with smaller stones. The conglomerate has a fan-like extension (see the map fig. 4!) with its apex somewhere in the vicinity of El Monte. It is evident that these coarse deposits were laid down during a regression of the sea shore and after a period of erosion in the Miocene strata. This marine regression corresponds to a rise of the island. Since the stones all consist of phonolites, we have to conclude that a vigorous erosion of the old phonolite volcano (the great central volcano) took over. The material seems to have been carried down by running water along the Guiniguada valley train.

The conglomerate in the southern sector (fig.11) has in the same way conserved its fan-like repartition, although the thickness of the deposit is much greater. It rests on a surface of erosion in the soft puzzolane layer in this region, no Miocene littoral sediments being seen here. Later erosion has carved out a system of gullies in this conglomerate deposit, the apex of which seems to lie some km south of the Tauro mountain.

The material in this southern occurrence is not so rich in heavy boulders as that of the Las Palmas' terrace.

A common feature of both deposits is the intense cementation with lime carbonate (*tosca*), especially at the surface.

What kind of water has been able to carry down to the coasts these immense masses of coarse material ? one may ask.

The location of the deposits and their fan-like shape indicate the former presence of two different streams of water: the one leading north-east — presumably along the Guiniguada valley, the other directed to the south following the slopes approximately along the course of the present Barranco de Arguineguín. The streams that carried the material down the slopes must have had a tremendous transporting power. The sub-angular and platy forms (slabs) of the boulders speak in favour of a rapid transport too.

In short, there is something mysterious about the transport problem involved here. Ordinary river transport (also under conditions of rather abundant rains) being excluded, we have to imagine the appearance of some kinds of avalanches: stones mingled with water floods rushing down the slopes. The streams were fed in the summit region of the old phonolite volcano, in times when the slopes of the same were freely exposed, i.e. before the beginning of the basalt lava effusions.

There remains only one source of water of this magnitude to be able to carry on the heavy stony burden: a water filled crater or caldera in the top of the volcano. This crater-lake may have been subjected to explosive outbursts, which emptied the lake, maybe several times, in the two directions above mentioned: it was water- borne stony avalanches occurring in time before the basalt volcanic phase, maybe in the Pliocene period.

Littoral sediments with delta accumulations

The most remarkable of all the littoral deposits in the island is the so called 'Miocene terrace' of Las Palmas, the edge of which lies c. 80 m above the sea level. We do not need to recapitulate the details concerning the stratigraphy here (cf. page 65, Part I). The only point to be considered is, how has such a vast delta-accumulation been formed in this corner of the island?

The position of the apex of the fan-shaped delta indicates that the material must have been transported to the coast by way of the Guiniguada valley, and this one is indeed a rather ancient drainage way (afterwards filled to some extent with basalt lava streams). There are in the island few comparable valleys of the same magnitude as Guiniguada. — The brittle sediments composing the terrace have resisted erosion and abrasion thanks to the top conglomerate, in parts also thanks to some basalt lava sheets of post-Miocene age.

There are few other littoral sediments in the island — a rather remarkable fact when considering the erosion that has gone on for such a long time. It is chiefly on the east coast and in some stretches along the south coast that we find gravel and sand accumulation flats with pebble beaches fringing the shore line. Also dune sand appears in some places (Arinaga, Maspalomas, Istmo de Guanarteme). All this material (except the calcareous dune sands) has in the course of times been dragged down to the coasts along the *barrancos*. The major part of such detracted material has disappeared, however, into the sea and been deposited in shoals; There is a conspicuous sparseness of delta plains in elevated positions (now cut across by the rivers) indicating the former stand of the ocean level in Quaternary or in earlier time. I have observed only some such ancient deltas, one situated at the mouth of Barranco Hondo in the south (west of Barranco de Tirajana). Its surface lies c. 100 m above the sea level. Other similar deposits are seen to the south of Agaete, c. 300 m above sea level. This may be from the Miocene time.

The geological map
Explanatory note

The basic map used for construction of the geological map reproduced here on the approximate scale 1:200 000, was on a scale 1:50 000 with contour intervals at 50 m. In my geological map the contours have been reduced to half the number (with intervals at 100 m).

A reader familiar with the geological map of Grand Canary published by J. BOURCART (1937) will at once recognize some rather identical features in the map here presented. Likewise he will soon find out that our geological formations as indicated in the colour scheme are rather similar. There are, however, some differences concerning some fundamental facts but also details.

During my excursions in the island I made use of the section sheets of the topographic map of the island on the scale 1 : 25 000. These sheets which are provided with contour intervals at 25 m were put to my disposal by the authorities of the Society El Museo Canario. All the details could be located in this good map.

The reproduction of my map has been made with great skill in the lithographic printing house »Åbo Stentryckeri/Turun Kivipaino» Company in Turku (Åbo), Finland.

Bibliography

Literature concerning the Canaries

1825 — LEOPOLD VON BUCH, Physikalische Beschreibung der Canarischen Inseln. Berlin. (With Atlas).

1838 — 50 — P. BARKER WEBB et SABIN BERTHELOT, Histoire naturelle des Iles Canaries. Paris.

1867 — KARL VON FRITSCH, Reisebilder von den Canarischen Inseln. Petermanns geogr. Mitteilungen. 122. Gotha.

1876 — G. A. SAUER, Untersuchungen über phonolitische Gesteine der Canarischen Inseln. Zeitschrift für die gesammten Naturwissenschaften. Neue Folge. Band XIII. Berlin.

1876 — S. CALDERÓN Y ARANA, Reseña de las Rocas de la Isla volcánica de Gran Canaria. Madrid.

1880 — —»— Nuevas observaciones sobre la litología de Tenerife y Gran Canaria. Anales de la Sociedad Española de Historia Natural. Tomo IX. Cuad. 2. Madrid.

1890 — A. ROTHPLETZ u. V. SIMONELLI, Die marinen Ablagerungen auf Gran Canaria. Zeitschrift der Deutschen geologischen Gesellschaft. Band 42. Berlin.

1907 — W. VON KNEBEL, Der vulkanische Aufbau der Insel Gran Canaria. Globus XCII. N:o 21 und 22.

1910 — C. GAGEL, Die Mittelatlantischen Vulkaninseln. Handbuch der regionalen Geologie. VII Band. Abt. 10. Heidelberg.

1925 — L. FERNÁNDEZ NAVARRO, Datos sobre el volcanismo Canario. Bulletin volcanologique. N:o 2. Naples.

1926 — —»— Iles Canaries, Excursion A 7. XIV Congrès géol. International. Madrid.

1931 — F. VON WOLFF, Der Vulkanismus. Band II. 2 Teil. Die Alte Welt. 1 Lieferung: Der Atlantischen Ozean. Stuttgart.

1933 — E. JÉRÉMINE, Contribution a l'étude petrographique des trois iles de l'Archipel Canarien: Tenerife, La Palma et Gran Canaria. Bulletin de la Société Francaise de Minéralogie. Tome 56. 4—5. Paris.

1936 — M. SAN MIGUEL DE LA CAMARA, Estudio de las rocas eruptivas de España. Tomo VI de la Serie de Ciencias Exactas. Memorias. Madrid.

1837 — J. BOURCART et E. JÉRÉMINE, La Grande Canarie. Bulletin volcanologique. Série II. Tome 2. Napoli. (with a geological map).

1938 — —»— Fuerteventura. Bull. volcanologique, Série II. Tome 4. Napoli.

1945 — SIMON BENÍTES PADILLA, Sintesis geológica del Archipiélago Canario. Estudios Geológicos n:o 5. Instituto de Estudios Geológicos »Lucas Mallada». Madrid.

1946 — K. SMULIKOWSKI, A. POLANSKI et M. TOMKIEWICZ, Contribution a la petrographie des Iles Canaries. Archives de Minéralogie de la Société des Sciences et des Lettres de Varsovie. Volume XV. Warszawa.

1947 — EXC:MO CABILDO INSULAR DE GRAN CANARIA, Obras hidráulicas. M e m o r i a, Las Palmas de Gran Canaria.

1951 — M. MARTEL SANGIL, Genesis del Archipiélago Canario. Estudios Geológi-. cos. N:o 13. Instituto de Est. Geol. »Lucas Mallada». Madrid.

1952 — —»— Contribución al estudio geológico y paleontológico de Gran Canaria. Est. Geol. N:o 15. Inst. de Est. Geol. »Lucas Mallada». Madrid.

1952 — SIMON BENÍTEZ PADILLA, La erupción de »Las Manchas» en la isla de La Palma y el volcanismo canario. Publicaciones de »El Museo Canario», Las Palmas.

1953 — LEONCIO AFONSO, Esquema de geografía física de las Canarias. La Laguna de Tenerife.

1954 — TELESFORO BRAVO, Geografía general de las Islas Canarias. Tomo I. Santa Cruz de Tenerife.

1956 — FEDERICO MACAU VILAR, La muerte de un joven enfermo. Análisis de las causas de la destrucción del puente de Rosiana en la carretera de Las Palmas a San Bartolomé de Tirajana (Gran Canaria). Revista de Obras Públicas. Madrid.

1956 — HANS HAUSEN, Contributions to the Geology of Tenerife. (Canary Islands). Soc. Scient. Fennica. Comment. Phys. Math. Vol. 18. N:o 1; Helsingfors.

1957 — FEDERICO MACAU VILAR, Estudio hidrológico de Gran Canaria. Patronato de la Casa de Colón. Anuario de Estudios Atlánticos. Madrid — Las Palmas.

1958 — —»— Aplicación de la geología al estudio de presupuesto para la construcción de una carretera (along the north coast of Grand Canary). Revista de Obras Públicas. Madrid.

1958 — HANS HAUSEN, On the Geology of Fuerteventura. (Canary Islands). Soc. Scient. Fennica. Comm. Phys. Math. Vol. XXII. N:o 1. Helsingfors.

1959 — FEDERICO MACAU VILAR, »Las Calderas» de Gran Canaria. Patronato de la Casa del Colón. Anuario de Estudios Atlánticos. N:o 5. Madrid — Las Palmas.

1961 — HANS HAUSEN, Canarian Calderas. A short review based on personal impressions 1947—1957. Suomen Geologinen Seura. 75-vuotis-Juhlajulkaisu. (Jubilee Publ. of the 75th Anniversary of the Geological Society of Finland). N:o 196. Helsinki.

Works and papers consulted

BOYD FRANCIS R., Welded Tuffs and Flows in the Rhyolite Plateau in Yellowstone Park, Wyoming. Geol. Society of America. Bulletin 7. Geophysical Laboratory. Carnegie Institution. 1961.

BURRI C., Petrochemische Berechnungsmethoden auf aequivalenter Grundlage. Mineralogische und Technische Reihe. Birkhäuser Verlag. Basel—Stuttgart. 1959.

—»— Petrochemie der Kapverden und Vergleich des kapverdischen Vulkanismus mit demjenigen des Rheinlandes. Schweizerische Mineralogische und Petrographische Mitteilungen. Band 40. Heft 1. 1960.

BURRI C. und NIGGLI P., Die jungen Eruptivgesteine des mediterranen Orogens. Erster Hauptteil. Vulk. Inst. Imm. Friedlaender Zürich 1945.

CLOOS HANS, Bau und Tätigkeit von Tuffschloten. Geol. Rundschau. Band XXXII. Heft 6—8. Stuttgart 1941.

COTTON C. A., Volcanoes as landscape forms. New York 1952.

DALY R. A., The Geology of Ascension Island. Proceedings of the American Academy of Sciences. Volume LX. Boston 1925.

—»— The Geology of Saint Helena. Shaler Memorial Series. Ibidem. Vol. LXII. N:o 2. Boston 1927.

ESCHER, B. G., Gloedwolken en lahar's. Vulkanische Katastrophes in Nederlandsch Indie. »Tropisch Nederland». III Jaargang. 19—20. Amsterdam 1931.

—»— On the classification of central eruptions according to the gas pressure of the magma and viscosity of the lava. — On the character of the Merapi eruption in central Java. Leidsche geol. Mededeelingen. VI. 1. Leiden 1933.

—»— Vesuvius, the Tengger mountains and the problem of calderas. Ibidem. Vol. II. 2. Leiden 1927.

FRIEDLAENDER IMM., Ueber vulkanische Verwerfungstäler. Zeitschr. für Vulkanologie. Band II. Berlin 1915—16.

—»— Die Azoren. Ibidem. Band XII. Berlin 1929—30.

GAGEL CURT, Über den Aufbau und die Gesteine Madeiras. Zeitschr. d. Deutsch. Geol. Ges. Band 64—66. Berlin 1912—14.

HARTUNG GEORG, Die Azoren in ihrer äusseren Erscheinung und nach ihrer geognostischen Natur. Text and Atlas. Leipzig 1860.

HJELMQVIST S., On the occurrence of ignimbrites in the Pre-Cambrian. Sveriges geol. Undersökn. Ser. C. N:o 542. Årsbok 49. (1955). Stockholm 1956. (See bibliography!).

HOLMES ARTHUR, The Nomenclature of Petrology. London 1920.

IDDINGS J. P., Geology of Yellowstone National Park. U.S. Geol. Survey Monogr. 32. 2. 1899.

KERR PAUL, Optical Minerology. New-York—Toronto—London, 1959.

KREJCI—GRAF KARL, Vulkanologische Beobachtungen auf den Azoren. Frankfurter geogr. Hefte. 30 Jahrg. Einziges Heft — Frankfurt am Main 1956.

—»— and others, Gesteine und Fossilien von den Azoren. Senckenbergiana Lethea; Band 39. Frankfurt am Main 1958.

LACROIX ALFRED, Le Montagne Pelée et ses éruptions. Paris 1904.

—»— Les roches alcalines de Tahiti. Bull. de la Société géol. de France. 4: Série. Tome X. Paris 1910.

—»— Les syénites nepheliniques de l'Archipel de Los. Bull. Soc. Min. de France. 35. Paris 1912.

LYELL CHARLES, Manual of Elementary Geology. London 1855.

—»— The Principles of Geology. Vol. II. London 1868.

MARSHALL P., Notes on some volcanic rocks of the North Island of New Zealand. The N. Z. Journ. of Sc. and Techn. N:o 13. 1932.

NIGGLI PAUL, Gesteins- und Mineralprovinzen. I. Berlin. 1923.

—»— Die kvantitative mineralogische Klassification der Eruptivgesteine. Schweiz. min u. petrogr. Mitt. II Zürich 1931.

PART G. M., (see bibliography in BURRI 1960). The papers concern rock from the Cape Verde Islands.

QUENSEL P. D., Die Geologie der Juan Fernández Inseln. Bull. geol. Inst. of the Univ. of Upsala. Vol. XI. Upsala 1912.

—»— Additional Comments on the Geology of the Juan Fernández Islands. The Natural History of Juan Fernández and Easter Island. Ed. by Dr CARL SKOTTSBERG. Vol. 1. Uppsala 1952.

RITTMANN ALFRED, Die geologisch bedingte Evolution und Differentiation des Somma-Vesuvmagmas. Zeitschr. f. Vulk. Bd XV. Berlin 1933

—»— Nomenclature of volcanic rocks. Bulletin volcanologique. Série II. Tome XII. Napoli 1952.

—»— Cenni sulle colate di ignimbrite. Instituto di Volcanologia dell'Universitá di Catania. Catania 1958.

—»— Vulkane und ihre Tätigkeit. Stuttgart 1960.

SHAND S. J., Eruptive Rocks. 3rd Edition. London and New York 1948.

TRÖGER E., Spezielle Petrographie der Eruptivgesteine. Berlin 1935. — Eruptivgesteinsnamen. Fortschritte der Mineralogie, Kristallographie und Petrographie. Vol. 23.Berlin 1938.

—»— Optische Bestimmung der gesteinsbildenden Minerale. Teil I. Bestimmungstabellen. Stuttgart 1956.

VOLZING K., Der Trass der Brohltales. Jahrbuch der Preussischen Geologischen Landesanstalt. Band 28. 1907. Berlin 1909—1910.

WINCHELL ALEXANDER N. and WINCHELL HORACE, Elements of optical Mineralogy. Part II. Descriptions of Minerals. Fourth edition. New York—London 1951.

Printed September 1962.

PLATES

with

LANDSCAPE PICTURES

Plate I

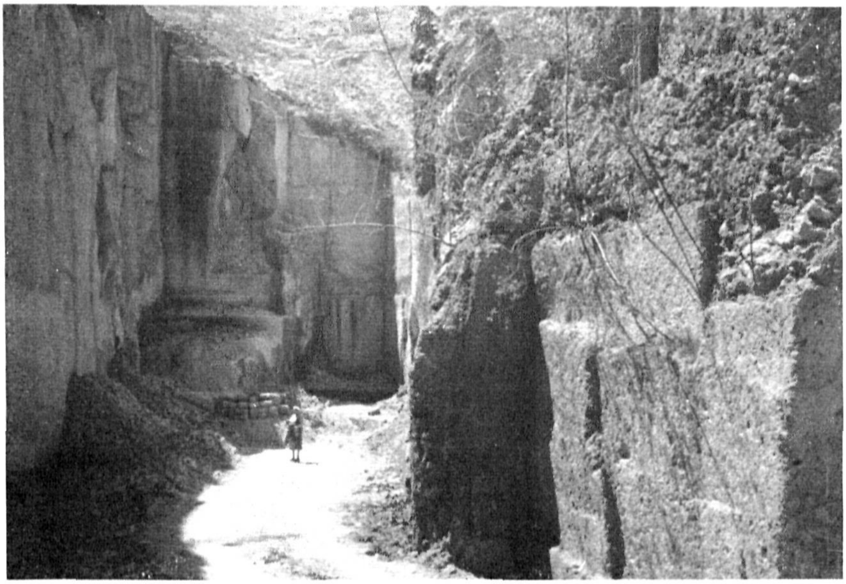

Fig. 1. Entrance to a large puzzolane quarry in the vicinity of San Lorenzo, northeastern part of the island. — Phot. H. H—n 1957

Fig. 2. Risco Grande de Tenteniguada, one of the necks of hauynophyres standing at the eastern border of the central highland that consists of the R. N. agglomerate formation. Looking south. — Phot. H. H—n 1950

Plate II

Fig. 1. A 'lava ship' carried some distance and left standing in the midst of a basalt lava stream filling the bottom of Valle de Guiniguada at Tafira Alta. Looking west across the lava tongue that moved to the right. — Phot. H. H—n 1954

Fig. 2. The same lava stream filling Valle de Guiniguada in its lower course. The lava is of sub-Recent age. Cliff in the (right) background consists of older basalt lavas, farther to the left a bit of the Miocene sedimentary terrace. Looking in the direction of Las Palmas (NE). — Phot. H. H—n 1954

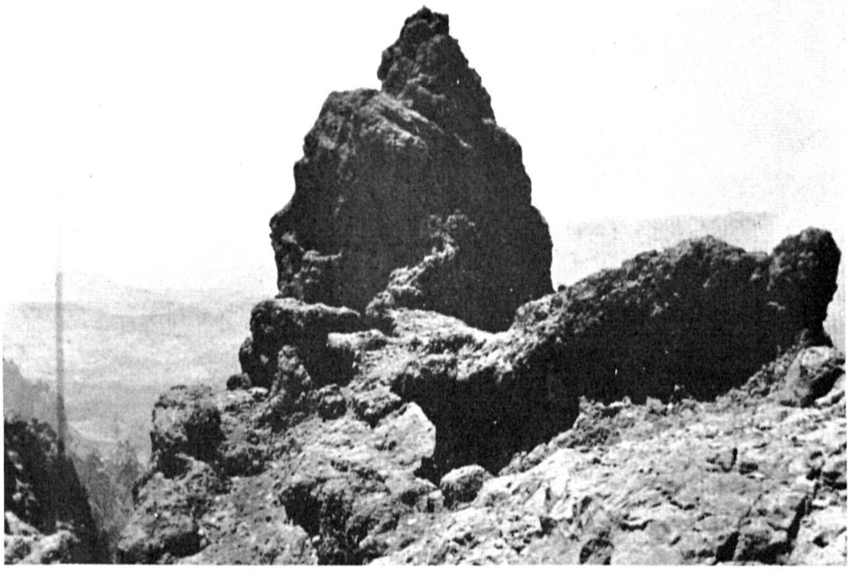

Fig. 1. A standing rock of erosion in the post- Miocene olivine basalt series at the eastern margin of the Tirajana valley, vicinity of Las Fortalezas. Looking SW across the valley. — Phot. H. H—n 1953

Fig. 2. The same basalt formation north of the former place showing the lava banks of basalt tilted towards the valley. Looking northwest with the lofty summits on the west side of Caldera de Tirajana in the distance. — Phot. H. H—n 1953

Plate IV

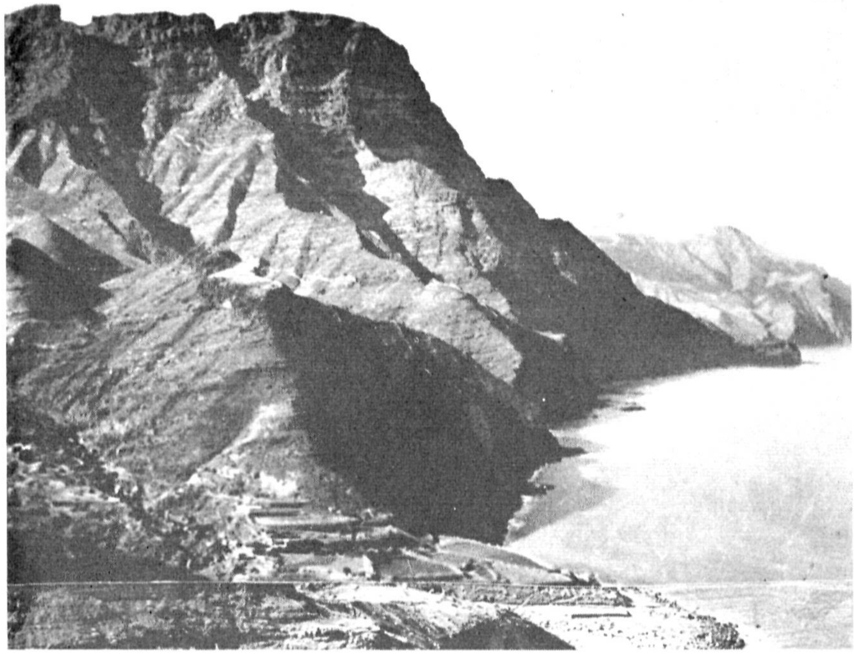

Fig. 1. The great precipices of Roque Faneque, the western border of the Tamadaba massif, northwest coast of the island. This geologic profile exposes at the top the salic volcanic formation in mighty banks resting on a basement of basalts with a certain unconformity. Looking southwest from a point between Agaete and El Risco. — Phot. H. H—n 1948

Fig. 2. A near view of the same basalt coast showing the concordant succession of the lava banks (partly covered with talus gravels). — Phot. H. H—n 1948

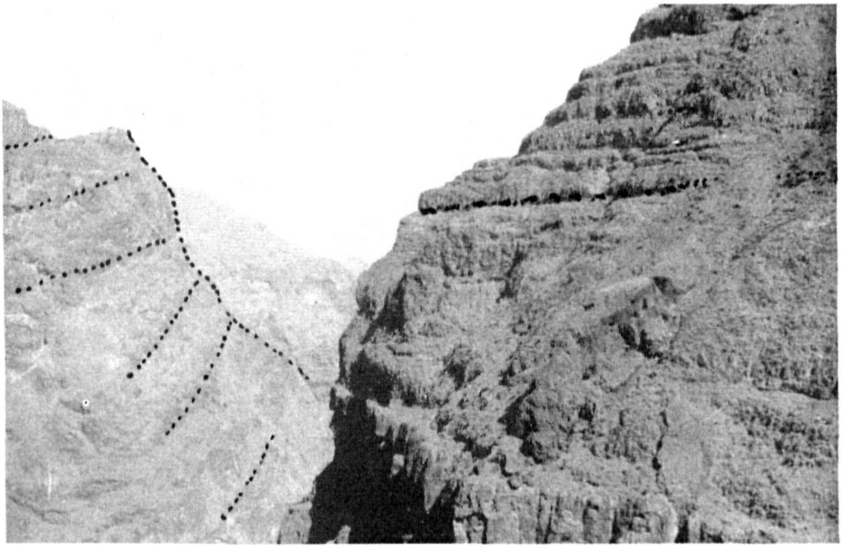

Fig. 1. Part of the great escarpment toward the Agaete valley in the vicinity of Berrazales (Baños de Agaete). To the right: edge of the R. N. agglomerate formation (here more conglomerate and sandstone), capped with a series of thin basalt lava sheets. Tamadaba massif in the left background. Looking west.

Phot. H. H—n 1957

Fig. 2. Part of the R. N. formation in its sedimentary facies (conglomerates and sandstones) forming an escarpment in the right side of Valle de Agaete, upper course. Looking south. T — the Tamadaba massif of salic lavas.

Phot. H. H—n 1957

Plate VI

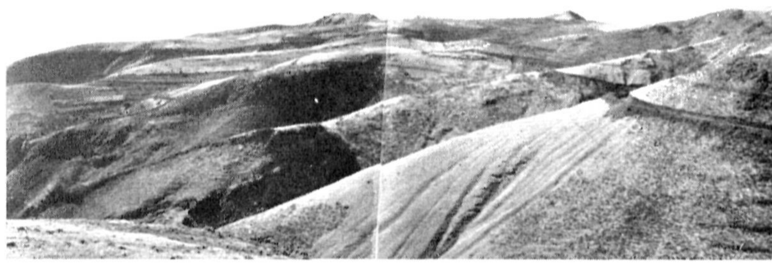

Fig. 1. A panorama view over the northern declivities of the highland ground to the north of Caldera de Tejeda. The rocks here are olivine basalts and their tuffs, both crossed by dikes of basalt.

Phot. H. H—n 1953

Fig. 2. Roque de Bentaiga, an erosion witness of the R. N. agglomerate formation standing on a platform of porphyritic lavas, in their turn resting on a basement of coarse grained alk. syenites (S). Looking southwest across Caldera de Tejeda.

Phot. H. H—n 1957

Fig. 1. A view across the upper course of Barranco de la Culata, left head arm of Barranco de Tejeda, with an escarpment of the post-Miocene olivine basalt lavas in the background. Looking northeast. — Phot. H. H—n 1950

Fig. 2. Part of the right side of the same Barranco showing (from the base) weathered trachytes, unconformity, stratified detrital masses in horizontal position, crowned with olivine basalt beds. — Phot. H. H—n 1954

Plate VIII

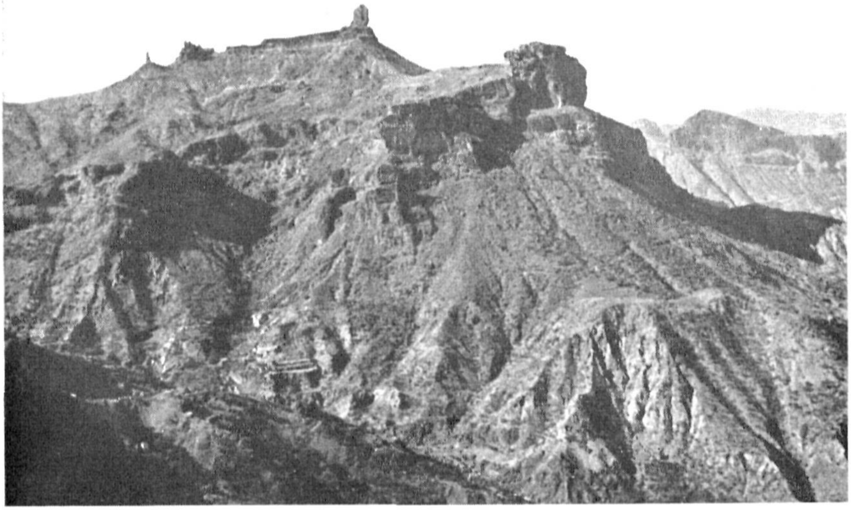

Fig. 1. Roque Nublo with its platform of the R. N. agglomerate formation. The precipices in the lower foreground consist of the old trachytic basement rocks. Looking southwest across Barranco de la Culata. — Phot. H. H—n 1957

Fig. 2. Northern wall of Caldera de Tejeda seen from the opposite side with Villa de Tejeda to the extreme right in the middle slope. At the foot of the picture the Tejeda canyon with a terrace consisting of basalt lava fill of Quaternary? age.
Phot. H. H—n 1953

PLATES

with

Microphotos

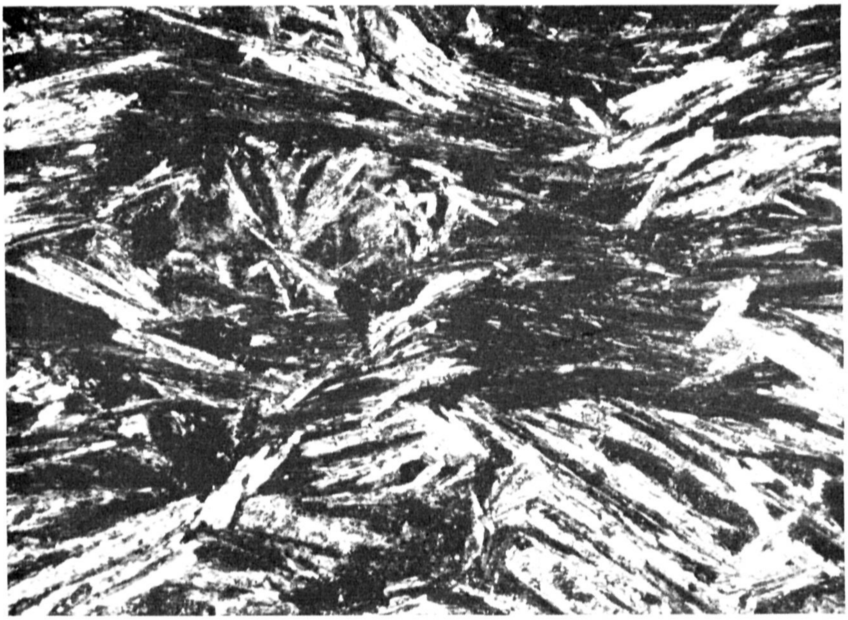

Fig. 1. Trachyrhyolite, slightly altered. Bottom of Barranco de Tejeda, below Villa de Tejeda.

Magn. 12 ×. Nic. +

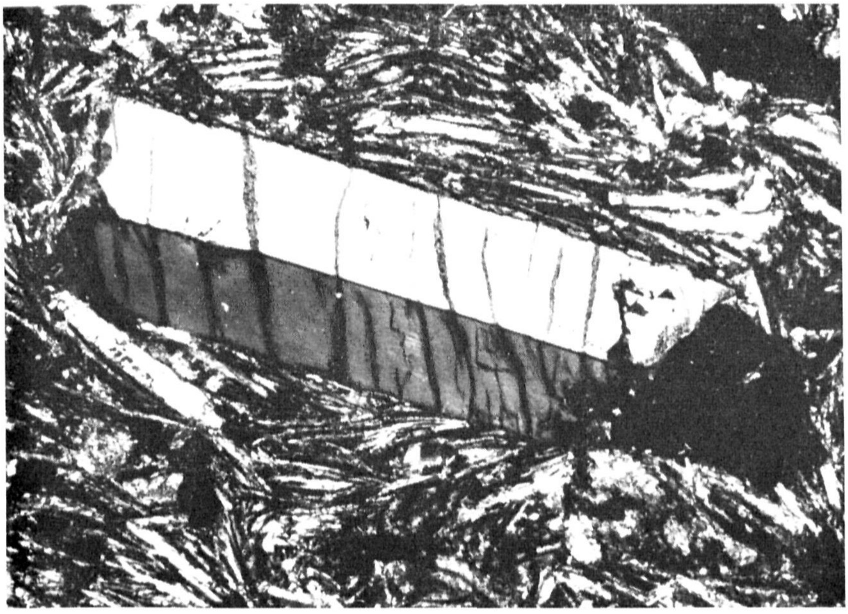

Fig. 2. Trachyphonolite, nepheline bearing, with phenocrysts of anorthoclase (Karlsbad twins). E side of Alta Vista.

Magn. 10 ×. Nic. +

Plate II

Fig. 1. Alk. syenite showing large crystals of anorthoclase with a fine striation Interstices filled with opaque subst. Fluorite bearing. Barranco de Tejeda, below Mesa de Acusa.

Magn. 6 ×. Nic. +

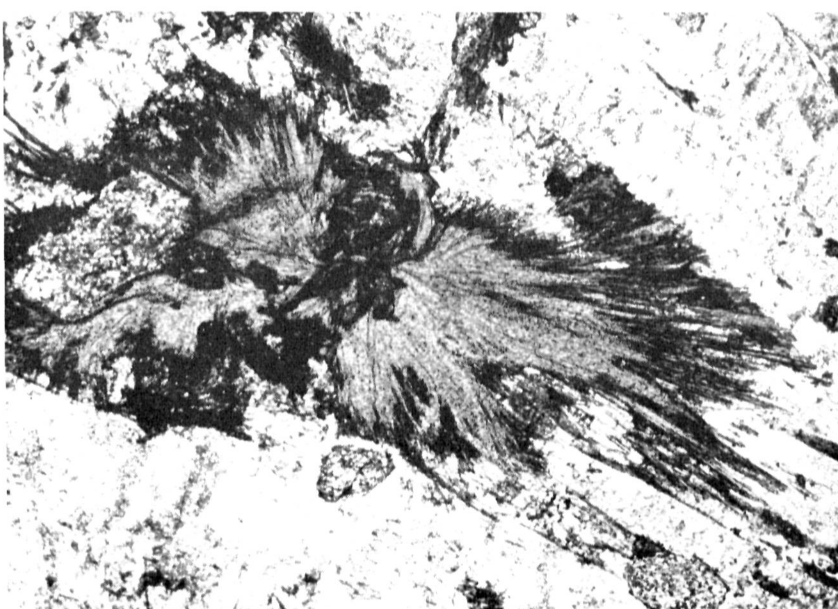

Fig. 2. Aggregate of aegirine needles in a nepheline syenite. Barranco de Siberio, Tejeda drainage.

Magn. 8 ×. Nic. //

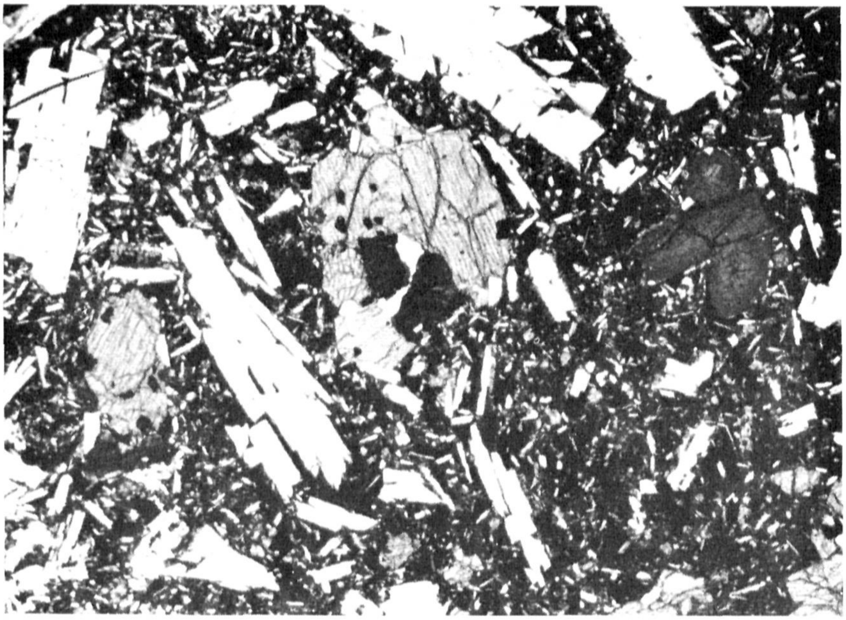

Fig. 1. Plagioclase basalt with phenocrysts of plag. (labradorite) and augite in an iron rich paste with amygdules. Degollada Tasartico.

Magn. 20 ×. Nic. //

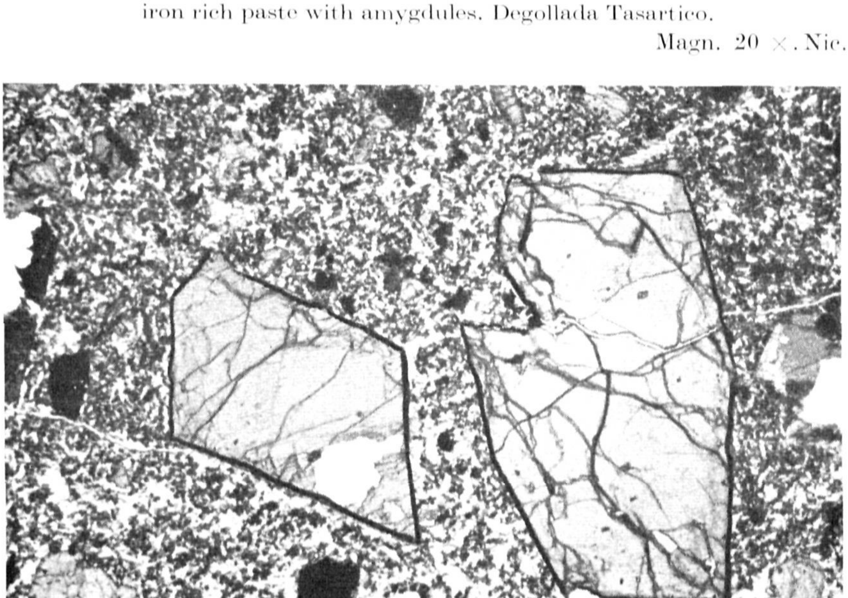

Fig. 2. Dike of lamprophyre cutting across the old basalt series in the coast cliffs between Agaete and Risco. Phenocrysts of augite (zonal).

Magn. 20 × .Nic. //

Plate IV

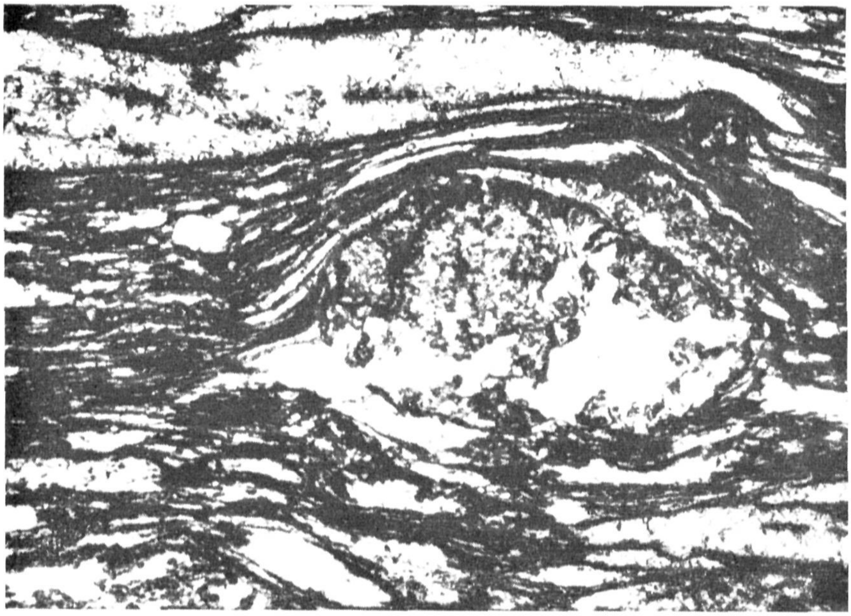

Fig. 1. Typical ignimbrite (vitrophyre) with elongated shreds and elliptical nodules of acicular sanidine in a glassy paste. Upper part of the S escarpment of Mont. del Horno.

Magn. 8 ×. Nic. //

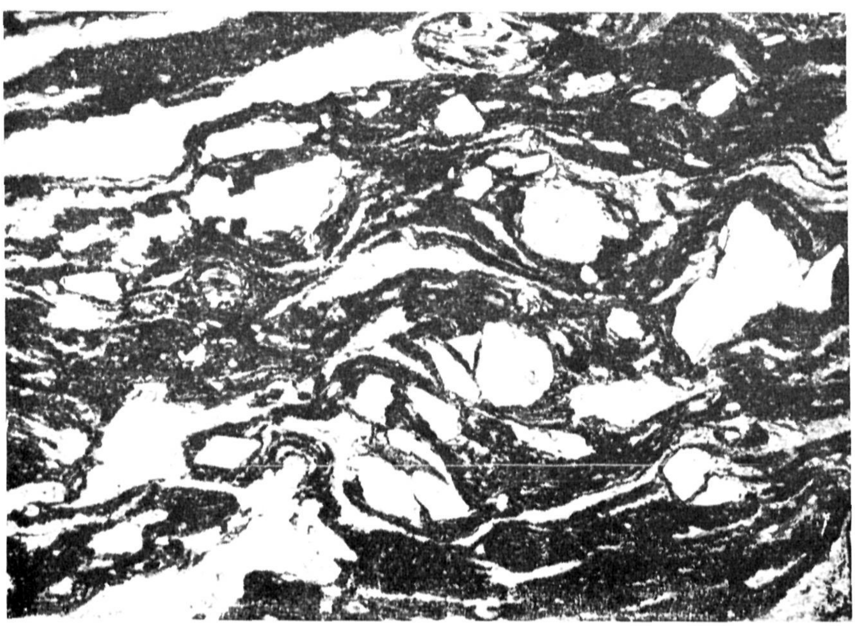

Fig. 2. Glassy ignimbrite from the culminating part of Montaña de Tauro. Fragments and shreds of alk. feldspar in a sharply twisted paste.

Magn. 6 ×, Nic. //

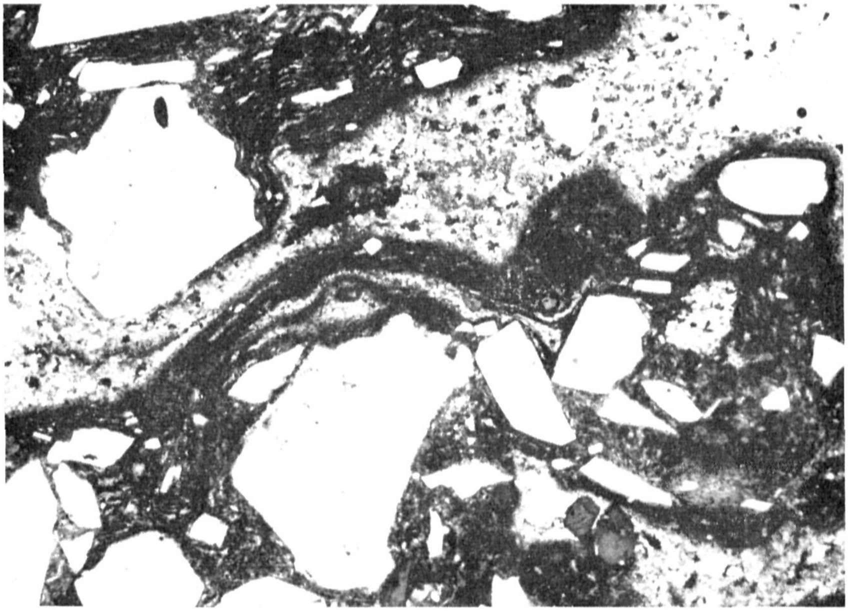

Fig. 1. Rhyolitic ignimbrite with fragments of alk. feldspar and (sparsely) prisms of brown hornblende in a glassy paste with flow texture. Summit of Pico del Cedro, region of Aldea de S. Nicolás.

Magn. 20 ×. Nic. ×

Fig. 2. Streaky rhyolitic vitrophyre (ignimbrite) from the middle part of the natural profile Cuesta de la Fuente Blanca to the north of Aldea de S. Nicolás.

Magn. 6 ×. Nic. //

Plate VI

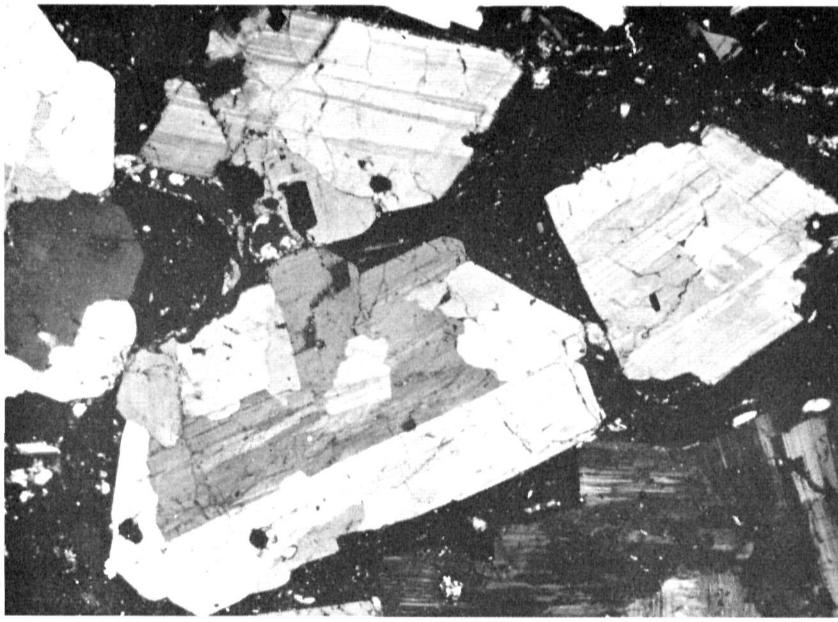

Fig. 1. Feldspar porphyry (vitrophyre) showing large phenocrysts of anorthoclase (+ twins acc. to Karlsbad and Pericline laws) in a glassy paste. Barranco de Arguineguín, betw. Soria and Cercado del Espino.

Magn. 12 ×. Nic. +

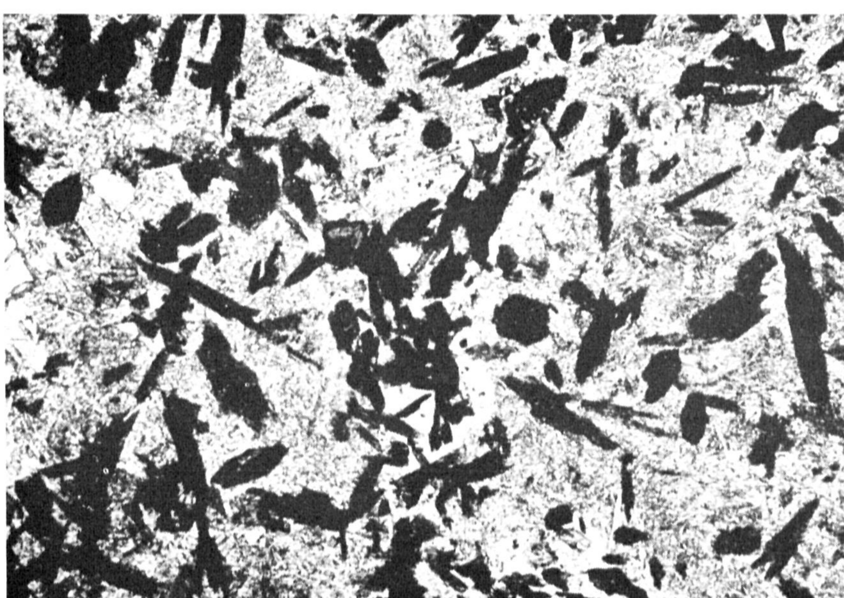

Fig. 2. Nepheline phonolite comp. of anorthoclase, nepheline and aegirine (black prisms in random orient.). Cumbre de la Montaña del Horno.

Magn. 15 ×. Nic. //

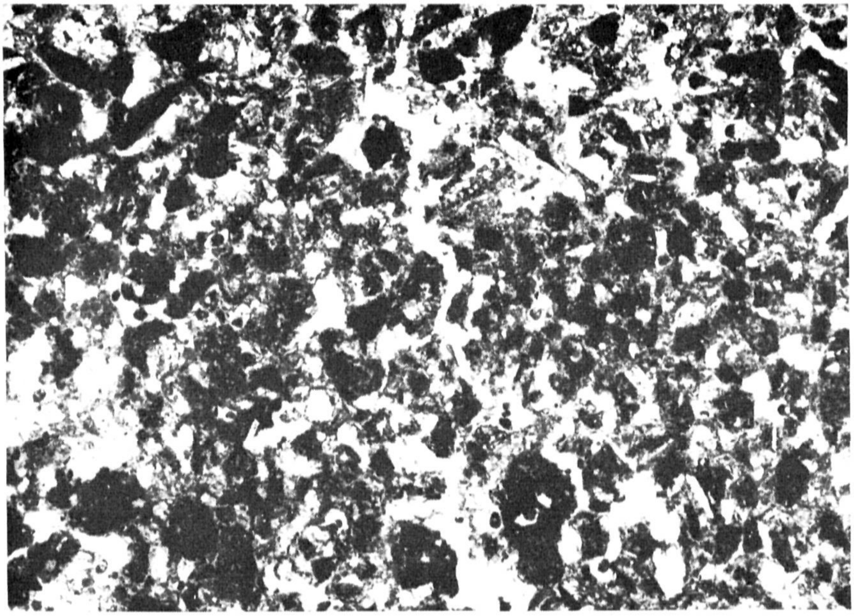

Fig. 1. Tuffite (sandstone) alternating with conglomerates. Right side of Valle de Agaete, upper course.

Magn. 15 ×. Nic. //

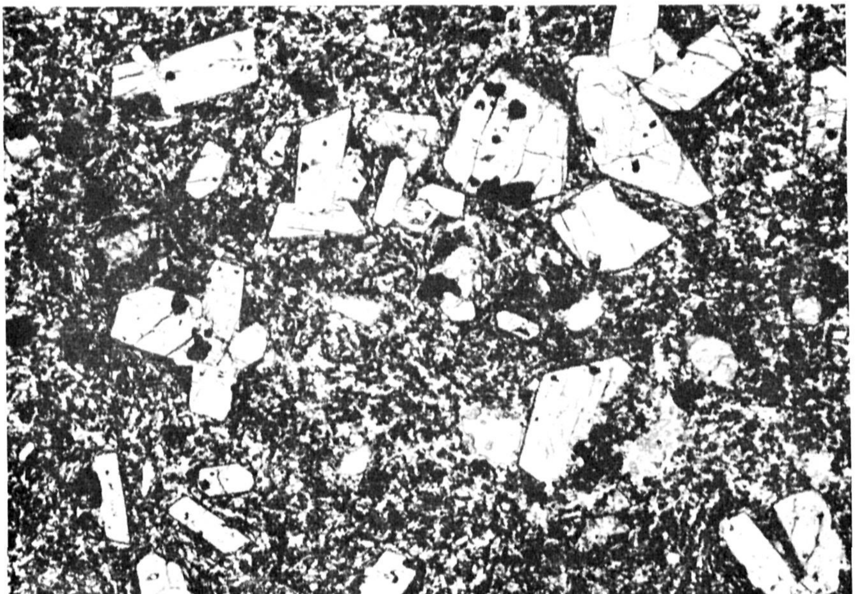

Fig. 2. Tephrite. Lava bed intercalated in the Roque Nublo *nuée-ard.*- formation North wall of Caldera de Tejeda. Augite phenocrysts. ass. with magnetite.

Magn. 9 ×. Nic. //.

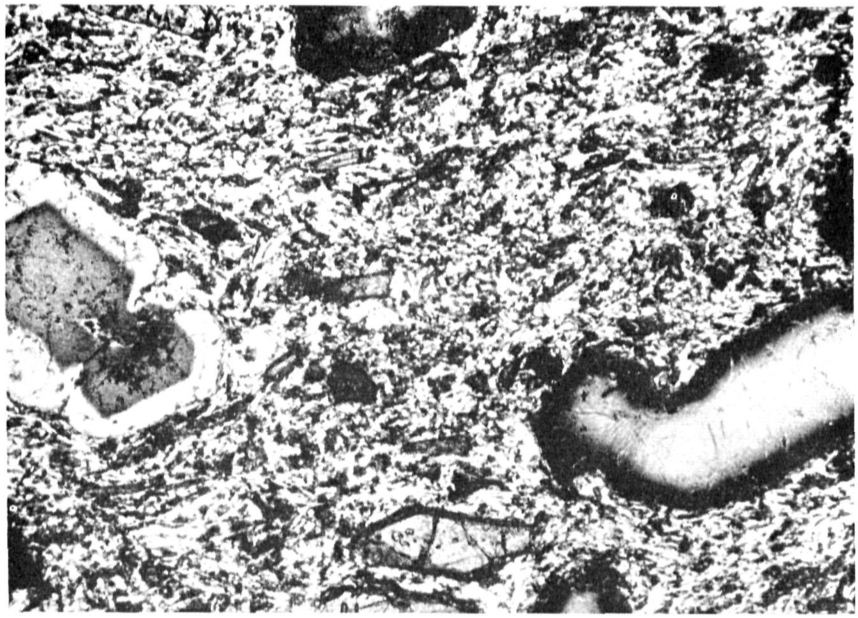

Fig. 1. Hauynophyre from Montaña de la Cruz Santa, Cumbre de Tenteniguada. To the r. a corroded hauyne, to the l. a zoned ind., euhedral.

Magn. 12 ×. Nic. //

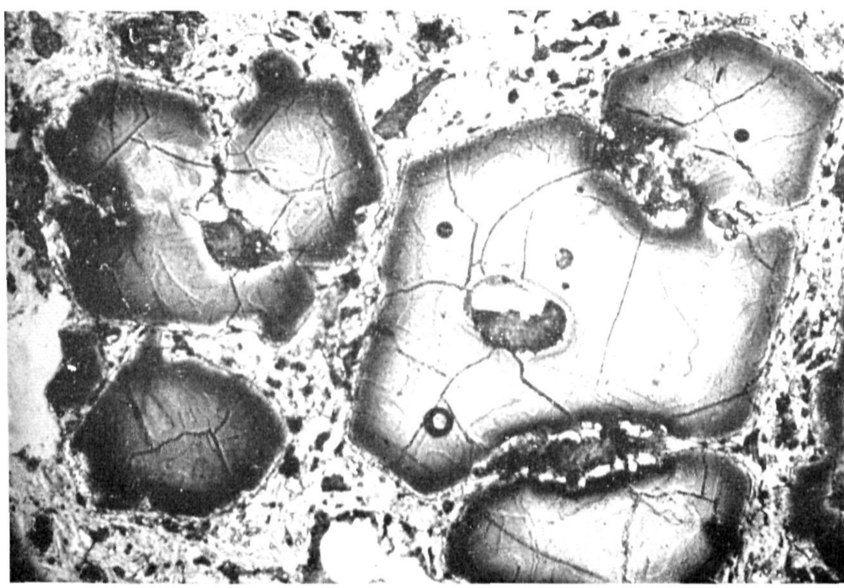

Fig. 2. Hauynophyre phonolite from the vicinity of Los Peñonallos, La Cumbre, W of Tenteniguada.

Magn. 12 ×. Nic. //.

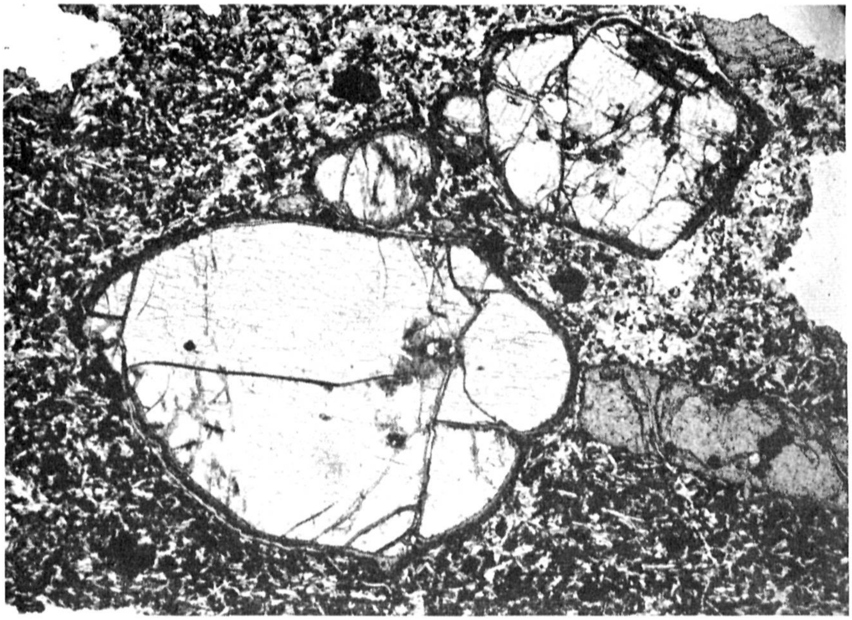

Fig. 1. Olivine basalt with euhedral olivine phenocrysts, rimmed with iddingsite. Left side of Barranco de la Virgen, at the Moya highroad.
Magn. 10 ×. Nic. //

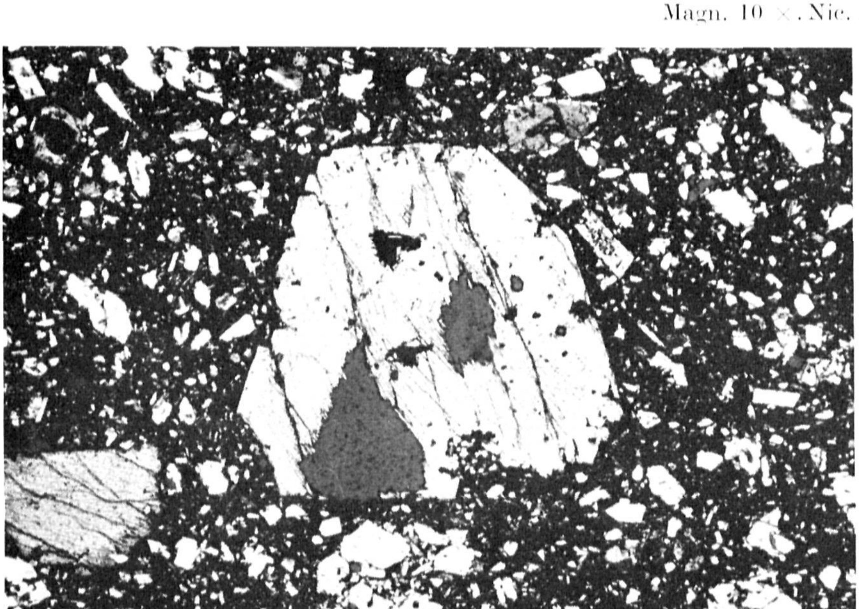

Fig. 2. Picritic basalt with a large olivine individuum in a matrix consist. of plag., augite and magnetite. Young lava (Quaternary-Recent?) in the Agaete valley.
Magn. 9 ×. Nic. +

Plate X

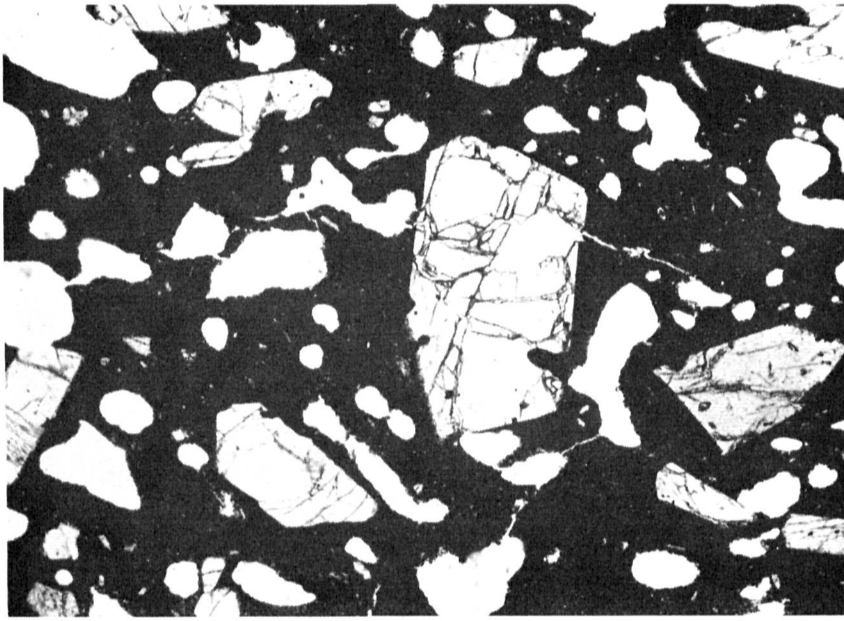

Fig. 1. Glassy, vesicular olivine basalt lava emitted from the volcano Montaña del Faro, La Isleta.

Magn. 8 ×, Nic. //

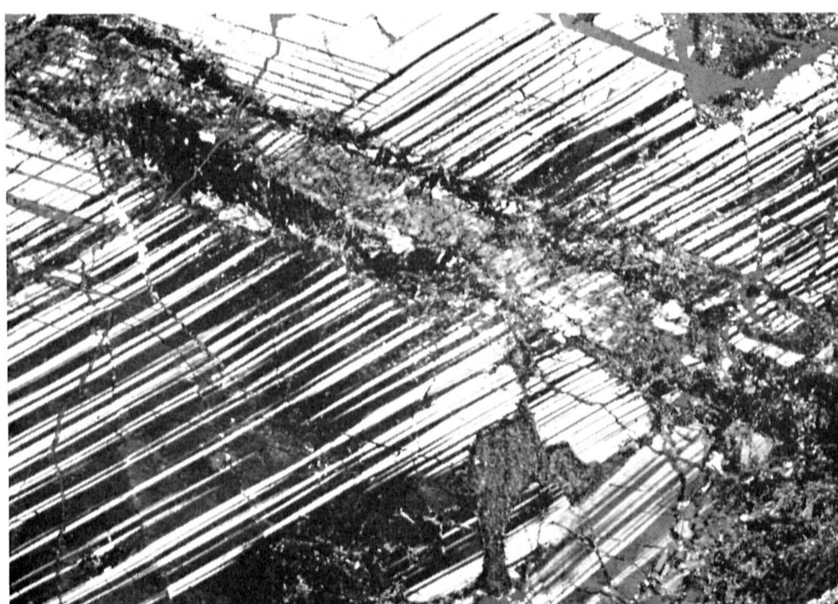

Fig. 2. Volcanic bomb of gabbro- anorthosite ejected from one of the craters in La Isleta.

Magn. 8 ×, Nic. +

GEOLOGICAL MAP OF
GRAND CANARY
(GRAN CANARIA, CANARY ISLANDS)

COMPILED BY USING THE TOPOGRAPHIC MAP
1 : 50,000 WITH CONTOUR INTERVALS 100 m.
BY

DR. HANS HAUSEN

1960

0 1 2 3 4 5 6 7 8 9 10
km.

COLOUR SCHEME
according to decreasing age of formations

1. a. A dislocated series of altered trachytes and trachyphonolites. With limit. Nucleus of the island.
   b. Intrusive alkali syenites and nepheline syenites.
2. Amygdaloidal olivine basalts with tuffs, agglomerates and dikes, mostly weathered. Position generally flat or slightly tilted.
3. Plagioclase basalts with tuffs, agglomerates and dikes. Series superimposed on the olivine bearing basalts.
4. Rhyolites and trachytes with tuffs, ignimbrites and dikes, also smaller intrusive bodies of trachytes.
5. Nepheline bearing phonolites with platy partings, tuffs, agglomerates and dikes. Sometimes distinctly porphyric varieties of lavas ("star stones").
6. Pumiceous rock complexes:
   a. Pale yellowish puzzolane deposits.
   b. Deposits of Peléean eruptions: the Roque Nublo agglomerates (carrying xenoliths of different composition). – Interfingering tephritic lavas.
7. Strongly Na-alkaline lavas of the central highland: tahitites, ordanchites, hauynophyres, lava sheets and necks. Two cumulo-volcanoes of similar kind at the north coast.
8. Terrace gravels and conglomerates, mostly of phonolitic material.
9. a. Post-Miocene olivine basaltic lavas.
   b. Post-Miocene pyroclastic deposits (mostly weathered).
10. Late-Tertiary to Recent volcanoes with lava tongues (aa-lava) and surrounding ash fields. Lavas are of the olivine basaltic kinds: limburgites, ankaramites, picrites,
11. Alluvial deposits: barranco- and delta gravel and sand, beach sand, dune sand.
12. Highroad and village or town.