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THE VOLCANOES AND ROCKS OF PANTELLERIA

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PART I

INTRODUCTION

Since the first half of the last century, when Pantelleria[1] figured in the controversy over von Buch's theory of craters of elevation, the geology of the island has been described only by H. Foerstner and A. Bergeat. Through Foerstner's researches the island has become classic in the annals of petrography, because of his discovery there of soda-microcline and the peculiar hornblende, cossyrite, as well as of the occurrence of the remarkable group of pantellerites.

In view of the interesting character of its rocks and the rather early date of Foerstner's descriptions and analyses, a re-examination of the island was considered to be desirable. Pantelleria was, therefore, visited in September, 1905, in the course of a trip to the western Mediterranean, undertaken for the Carnegie Institution of Washington.

During my stay I met with the utmost courtesy and hospitality, and it is a pleasure to record my thanks to friends on the island, among whom may be specially mentioned Captain G. Herrera, Captain A. Pocobelli, Lieutenant A. Innorta, and Doctor S. Granone. To Professor J. Volney Lewis I am indebted for making the photographs of the rock sections.

GENERAL DESCRIPTION

The island of Pantelleria lies about midway between Sicily and Tunis, rising steeply from depths of over 400 fathoms in the broad, deep channel which separates Sicily from Tunis, near the edge of the Adventure Bank. It is noteworthy that the volcanic Linosa to

[1] Attention may be called to the fact that this is the proper spelling of the name, being that used on all the official Italian maps. The chief accent is on the *i*, not the second *e*.

the southeast rises out of the same channel and is surrounded similarly by deep waters, while the neighboring limestone islands of Lampedusa and Malta are inside the hundred-fathom line, on the edges of the shallow banks which border, respectively, the east coast of Tunis and the south coast of Sicily.

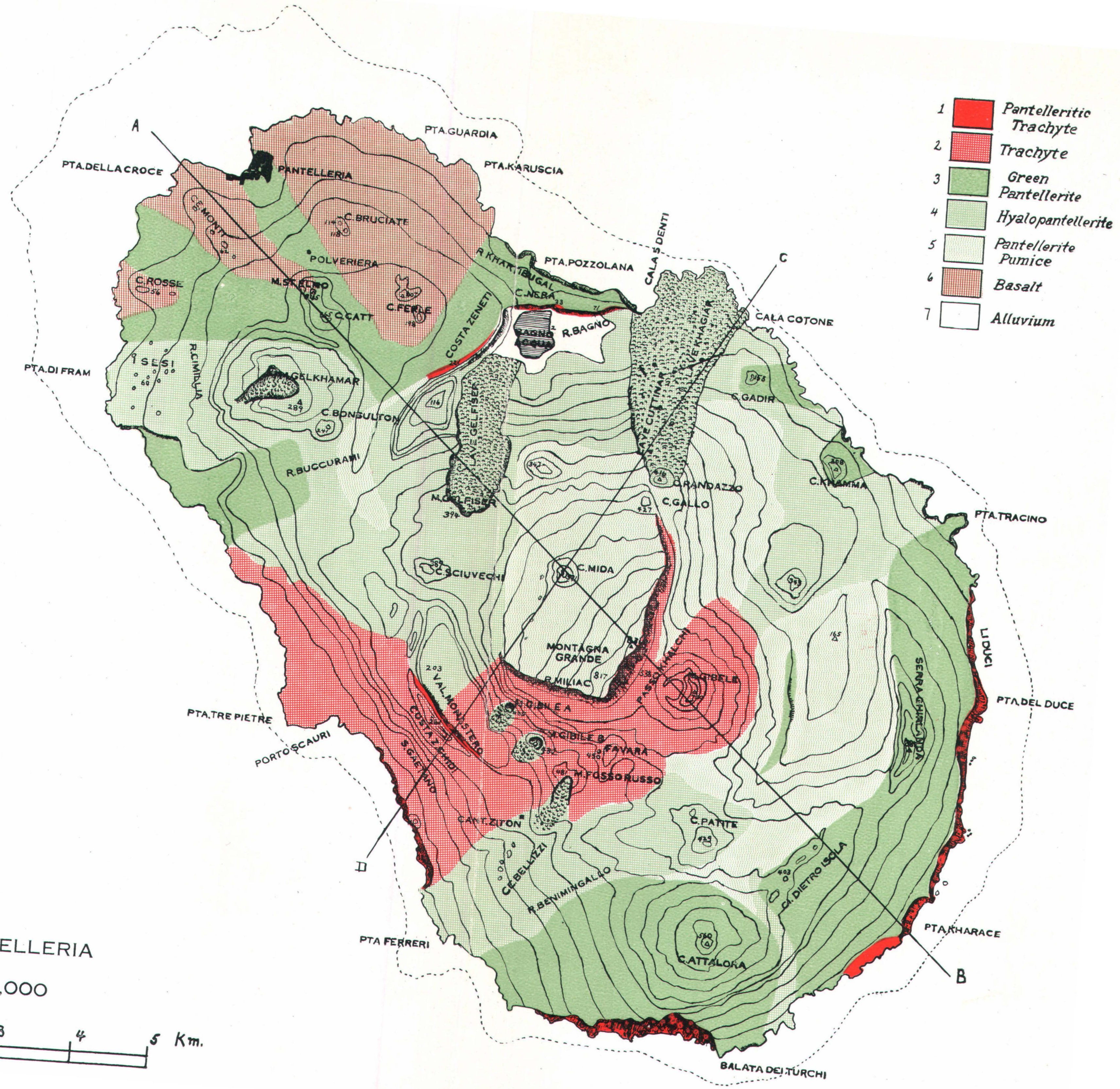
The island is elliptical in shape, with a length of about 13.5 kilometers from northwest to southeast, a breadth of about 8 kilometers from northeast to southwest, and an area of 33.3 square kilometers. Seen from the sea it presents a roughly mountainous and forbidding appearance, which is increased by the prevailing dark color of the rocks, so that it is often spoken of as "L'Isola Nera," the Black Island.

HISTORY

Pantelleria was inhabited in prehistoric times by a people of unknown race, who have left traces of their occupation in the peculiar constructions which are known as *sesi*, found only in the northwestern part of the island (Fig. 1). These are built of rough blocks of lava and are shaped like an elongated dome with a length of 40 to 50 feet, a width of about half this, and a height of from 15 to 25 feet. Each contains several small chambers, separate from each other, and entered by a rather small opening near the ground. In many respects they are almost unique, but they show some analogies with the *talajots* of the Balearic Islands and the *nuraghi* of Sardinia. These latter, however, are better constructed and far more elaborate, and evidently belong to a higher type of civilization than that of Pantelleria.

The island was known to the Greeks, who called it Κοσσοῦρα (Strabo), Κοσσύρα (Ptolemy), and other variants, while the Romans named it Cossyra (Ovid and Pliny), Cossyrus (Silius Italicus), Cosura (Seneca), etc. The origin of its present name, which dates from about the fourteenth century, is unknown, and its etymology uncertain. Its history has been briefly sketched by D'Avezac,[1] who, however, does not mention the *sesi*. According to him it was probably first inhabited by the Phoenicians or Carthaginians. Traces of this remote occupation are still to be found in the dialect

[1] D'Avezac, *Iles de l'Afrique*, Paris, 1885, p. 104.



MAP OF PANTELLERIA

SCALE 1 : 64,000

1 2 3 4 5 Km.

and in many of the topographic names. From this Semitic period dates a coinage which Head[1] refers to the second century B.C. Cossyra figured in several episodes of the Punic wars, but on the fall of Carthage became Roman, and another series of coins dates from this epoch.[1] It seems to have had a reputation for roughness and inhospitality and is mentioned by Seneca as one of the most undesirable places of exile.

FIG. 1.—Sese (prehistoric dwelling)

It was captured by the Moors in 835 A.D., who called it Qussra, a name by which it is still known in Arabic. After a stormy period, during which the island was the object of contention between the Moors and the Norman kings of Sicily, it became part of the kingdom of Sicily, and thence passed under the dominion of the present kingdom of Italy.

PRODUCTS AND POPULATION

The cultivable parts are mostly given over to vineyards, which produce large, white, and very sweet grapes, which are dried to

[1] Barclay V. Head, *Historia Numorum*, London, 1887, p. 743.

form raisins of a most excellent quality. These vineyards are terraced and surrounded by high stone walls, thus concealing the geology of the areas covered by them. Capers are also cultivated, growing abundantly over the stone walls, while excellent donkeys, noted for their strength and endurance, form the third principal object of export. Olives and figs are also raised.

The island is subject to violent winds, so that fig trees often grow with their trunks horizontal and close to the ground. Vegetable gardens and the small groups of fruit trees are usually protected by high, circular, surrounding walls, such inclosures forming a characteristic feature of the landscape in parts of the island.

Potable water is very scarce, though it is furnished by some of the volcanic springs, one of which forms a public fountain in the town. This is closed except for an hour every morning, when each household is allowed to draw its allotted supply. Some of the steam fumaroles are utilized by herdsmen by covering them with brushwood, which condenses the water and gives rise to small rivulets. The rains are the main source of supply, the water being gathered on the flat, cemented roofs and preserved in cisterns beneath the houses. But after a long dry spell, as at the time of my visit, this supply is likely to fail and the whole population goes on short water rations. Indeed, at times, water has to be imported from Sicily, and an earthquake is likely to cause great distress by cracking the cisterns, as happened prior to the submarine eruption of 1891.

The population numbered 8,619 in 1901, of which about 2,500 inhabit the sole town, also called Pantelleria, on the northwest coast. There is an evident infusion of Moorish blood, dating back to the Saracenic occupation, or even possibly to the original Phoenician settlement. This is specially manifest in the island dialect and in the place-names, many of which show distinctly non-Italian forms, and some of which can be positively identified with Semitic roots. Thus Gibelé is clearly the Arabic جبل (*gebel*) = "mountain,"[1] and Rione Ziton is from زيتون (*zitun*) = "olive," Khagiar is derived from the Arabic حجر (*hajar*) = "stone," Gelfiser probably from جبل فزر (*gebel fozir*) = "burst mountain," Gadir

[1] The same is seen in the name Mongibello for the peak of Etna, and an analogous case is the peak of Ὄρος Βοῦνο (Mountain Mountain) on Aegina, Greece.

possibly from غدير (*ghadir*) = "a pond," and Gelkhamar from جبل قمر (*gebel kamar*) = "moon mountain." The local term *cuddia*, applied to the small volcanoes and hills, may be derived from حاد (*hadd*) = "pointed," and if so, its etymology would be analogous to that of the French *puy* and the Catalan *puig*.

Pantelleria is now used by the Italian government as a penal station (as is Lampedusa), several hundred convicts being at liberty on the island, returning to their quarters at night, and being guarded by two companies of soldiers.

TOPOGRAPHY[1]

Montagna Grande.—The most prominent topographic feature of Pantelleria is the volcanic mass of Montagna Grande, which occupies the center of the island, its summit forming the culminating point with an elevation of 836 meters above sea-level. The mass has suffered extensively from erosion and shows few traces of the original crater. The top consists of a ridge on the east and south, from which the surface slopes rather gently downward toward the west and north. On this slope is the cone of Cuddia Mida, with a small summit crater, so called from being near the center of the island. The summit ridge of Montagna Grande is very precipitous outwardly on the east and south, the scarp varying from 50 to 150 meters in height, built up of massive sheets of trachyte, which sometimes show a rough columnar structure. These scarps do not form a continuous curve, but are roughly straight lines, meeting at an angle of about 110° at the southeast corner at Rione Miliac. From their foot the surface slopes sharply downward to the south and east, the general uniformity being interrupted by several small volcanic cones.

Of these Monte Gibelé, immediately east of the highest point of the summit ridge, is the largest and most important. It is fairly well preserved, its highest point being 700 meters above sea-level, and it shows an almost circular crater, about 100 meters deep and

[1] The accompanying map is based on that of the Instituto Geographico Militare (Firenze, 1877, 1:10000), the geology being based on the map of Foerstner (*Bull. Cour. Geol. Ital.*, 1881, Tav. XI.), and my own observations. The contour lines (interval 50 meters) are only roughly given, and the boundaries of the different geologic areas are only approximate.

200 meters across, which is breached on the southwest side. To the east and southeast of Montagna Grande and Monte Gibelé is the long crescentic ridge of Serra di Ghirlanda, which runs parallel to, and about one kilometer from, the coast, and presents toward the Montagna Grande, over much of its length, a very steep face from 50 to 90 meters high. This is continued to the southwest in the curving line of the Cuddioli dietro Isola, a series of low, isolated hills. At the southwest end of this ridge, and occupying the southern end of the island, is the wooded cone of Cuddia Attalora, 560 meters high, a well-formed, very symmetrical cone, with the remains of a breached crater near the summit The isolated Cuddia Khamma, northeast of Montagna Grande, appears to be a remnant of a continuation of the Serra di Ghirlanda to the north.

On the southwest and western flanks of Montagna Grande are several small, parasitic cones, namely Fosso del Russo, and two which are both called Monte Gibilé, and which may be designated as Gibilé *a* (north) and *b* (south), to distinguish them from the large cone of a similar name on the east flank. The southwest slopes of Montagna Grande run into the narrow, crescentic Valle del Monastero, which is about 2 kilometers long by half a kilometer wide. This is bounded on the west by the ridge of Costa Zichidi, which shuts in the valley with a precipitous scarp rising 30 to 75 meters above the valley floor. This ridge outwardly slopes rather gently down to the sea, the small harbor of Porto Scauri lying to the west of it and being used instead of the principal harbor when the wind is from the north.

The northwestern and northern slopes of Montagna Grande present a decidedly irregular topography, the original surface having been buried beneath the accumulations from several parasitic cones. Of these the most important are: Monte Gelfiser on the northwest, from which issued the flow called Lava Gelfiser, about 500 meters wide and 2,200 long, extending northwardly to near the Bagno dell' Acqua; and Cuddia Randazzo, on the north, with the large flow known as Lave Cuttinar in its upper portion and Lave Khagiar below. The total length of these is about 3 kilometers and they form a fan whose widest part stretches from Bagno dell' Acqua

on the west to Cala del Cotone on the east, a distance of 2 kilometers along the coast.

Rione di Bagno.—Close to the north coast is a small, irregularly elliptical plain, the Rione di Bagno (Fig. 2). The western part of this is occupied by an oval lake, the Bagno dell' Acqua, with dimensions of about 600 by 500 meters, the surface being only 2 meters above sea-level. The lake is shallow and is evidently the remnant of one which formerly covered the whole of the inclosed

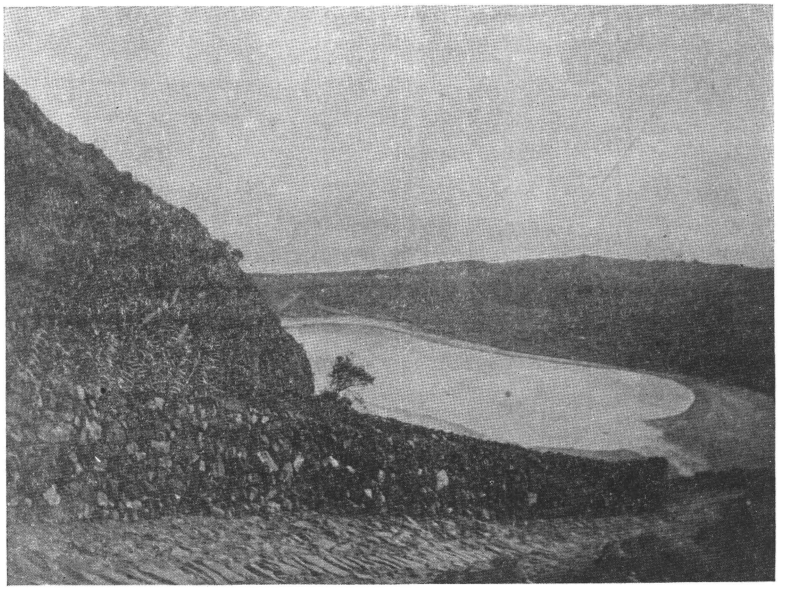


FIG. 2.—Bagno dell' Acqua, from west

area. The Rione di Bagno (including the lake) is bounded on the west by the precipitous east face of a scarp, the Costa Zeneti, which rises to about 200 meters above the lake surface. This ridge is continued to the south and southwest, parallel to the course of the Lava Gelfiser, inclosing the narrow Valle Silhoumen, which is flanked on the east by the towering mass of tumbled lava blocks which constitutes the flow (Fig. 3). To the north the Rione is bounded by a similar though lower (38 m.) precipice, known as Cuddia Nera, which is indubitably a continuation of the Costa

Zeneti, the direction of the scarp face changing from north to east at the northwest angle of the lake. On the east are the rough masses of the Khagiar flow, and on the southeast and south the steep slopes of Costa del Bagno, evidently part of the original north flank of Montagna Grande, while at the southwest corner is the extremity of the Gelfiser flow.

Basaltic area.—The northwestern end of the island offers peculiar features of its own. In general the surface shows a fairly

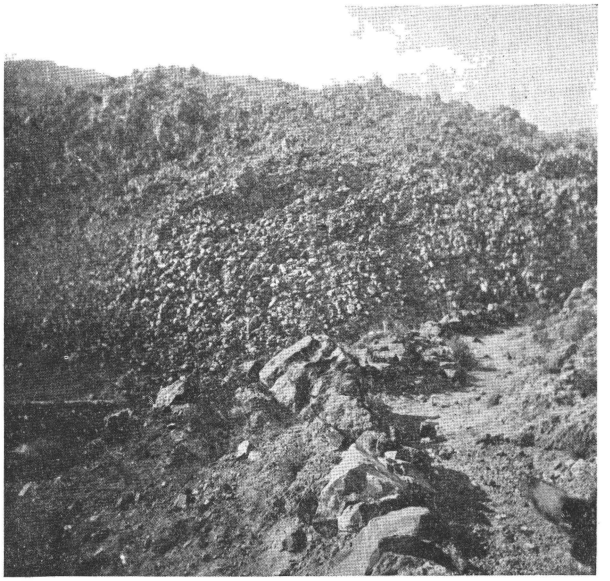


FIG. 3.—Lava Gelfiser, from Costa Zeneti

uniform, gentle slope away from the central mass of Montagna Grande, the contour lines being roughly concentric about this. On this broad, low, conical base, which has a radial extent of about 4 kilometers and a maximum altitude in the interior of about 200 meters, there are several volcanic cones. These are of two distinct types—a pantelleritic and a basaltic.

Of the former type is Monte Gelkhamar, whose summit, 289 meters above sea-level, rises not more than 100 meters above the general slope on the east, but about 200 meters on the west. In form it is roughly circular, though somewhat irregular, and is

notable for the large barranco which has breached the southwestern side, forming an impressive gulf 600 meters long and 300 wide, with precipitous sides. From this issued the lava flow of Rione Cimillia, on which are to be found the prehistoric buildings mentioned above. The second pantelleritic cone lies about one kilometer north-northeast of Gelkhamar and one and a half south-southeast of the town of Pantelleria. It is crescent-shaped, widely breached on the east, the ridge culminating in the northerly Monte Sant' Elmo (245 m.), on which is a semaphore, and the southerly Cuddia Catt (265 m.). The main mass of this is composed of pantellerite, but on the north flank of Sant' Elmo there has taken place a small, later eruption of basalt, the scorias and lavas of which cover the northern and western slopes, while a flow extends to the north.

The basaltic cones, which are entirely confined to this part of the island, are all small and are less important topographically than they are petrographically. The best preserved are the Cuddie Brucciate and the Cuddia delle Ferle, respectively one and two kilometers southeast of Pantelleria. The former consists of a twin pair of cinder cones, with summits 118 and 114 meters above sea-level, but only about 30 above the base, each with a deep, circular, well-preserved crater. Cuddia Ferle is somewhat higher (207 m.), but with a less well-marked summit crater and with a small subsidiary conelet with breached crater on the north. On the northwest coast are the Cuddie Rosse and Cuddie delli (*sic*) Monti, which are 50 to 60 meters high. Flows of basalt and beds of scoria, derived in part from these cones and probably in part from now hidden vents, cover much of the northwestern coastal part of the island.

The coast line of Pantelleria is, in general, irregular with many small indentations. On the east, southeast, south, and southwest it is mostly precipitous, up to heights of 275 and 200 meters, due to wave action; while on the northwest it is low and formed by the tongue-like ends of the basalt flows.

GEOLOGY[1]

The geological structure of Pantelleria is somewhat complex and has given rise to divergent views. With the exception of some

[1] A short account by me of the geology of Pantelleria was published in *Science* (N.S.), XXVIII (1908), 576. It is practically an abstract of this section.

insignificant beds of travertine and the lacustrine deposits of the Rione di Bagno, the rocks are wholly volcanic. Some fragments of granite found by Foerstner[1] and Soellner[2] in several places on the island indicate that the foundation is of this material. I was not fortunate enough to meet with any of these, but observed fragments of diorite in the lava of the island of Linosa,[3] so that a basement of plutonic rocks may be inferred for the bed of this part of the Mediterranean.

Of the earlier view as to the structure, only mention may be made that Pantelleria was cited as an illustration of von Buch's theory of craters of elevation, the circle of scarps surrounding Montagna Grande being supposed to be due to elevation incident to the formation of this volcano.

Foerstner's views.—Foerstner has discussed the geological structure at some length.[4] In the following summary his rock-names will be retained. According to Foerstner the first eruptions on the granite base were of "phonolite" and "liparite," which uniformly underlie the other lavas, and which issued from a now vanished vent. These were covered by the "andesites" of Monte Gibelé, which was also probably the volcanic center of the lavas of Montagna Grande, then not raised to its present height. From an unknown center of the same epoch are supposed to have issued the "andesites" which form the surface of Costa Zichidi, and which are probably the latest flows of this stage. The next period was that of the eruption of the first pantellerites, especially of the crystalline variety, which poured out of numerous vents all around the large andesitic volcano. The Bagno dell' Acqua is supposed to belong to this period and to have been an explosion crater, while the Cuddia Attalora is a well-preserved parasitic cone of the same period.

The ejection of this mass of lava caused profound dislocations and resulted in the upthrust of the mass of Montagna Grande, which was accompanied by the formation of many subsidiary cones on its flanks and the pouring-out of flows of vitreous pantellerite, as

[1] H. Foerstner, *Boll. Com. Geol. Ital.*, 1881, p. 550.

[2] J. Soellner, *Zeits. Kryst.*, XLVI (1909), 522.

[3] H. S. Washington, *Jour. Geol.*, XVI (1908), 6.

[4] H. Foerstner, *Boll. Com. Geol. Ital.*, 1881, pp. 550–53.

represented by Monte Fosso del Russo, Monti Gibilé *a* and *b*, Monte Gelfiser, Cuddia Randazzo, and others. The faults according to Foerstner, are the cause of, and are represented by, the various encircling scarps mentioned in describing the topography and certain coastal features.

At the close of this period of dislocation the last of the pantellerite cones was formed, that of Monte Sant' Elmo and Cuddia del Catt, after which the lava underwent a change in composition, "by subtraction of silicic acid." The last phase of basaltic eruptions began with an outburst on the northwest flank of Sant' Elmo, and was continued in the small cones of basaltic scoriae and flows of basalt.

Bergeat's views.—The geological structure has also recently been briefly discussed by Bergeat,[1] who cites the mass of Montagna Grande as an example of *Staukuppen* or plug domes, analogous to the spine of Mont Pelée. He adopts the views of Foerstner that the prominent scarps are due to faulting, and indicates on a map the traces of what he considers to be the chief fault-lines, as shown by volcanic cones, scarps, or other lineaments. He calls attention, however, to the fact that a depression would more naturally be supposed to follow the ejection of lavas on a large scale than the upheaval advocated by Foerstner, and would explain equally well the formation of Montagna Grande and the precipitous scarps. On his view the upthrust of Montagna Grande is supposed to be a differential one, due to subsidence of the encircling portion. Bergeat considers that Monte Gibelé was the volcanic center for the whole mass of Montagna Grande and that the two were separated by a fault which he noted in the Passo Khalchi, northwest of the Gibelé crater. With Foerstner, Bergeat apparently considers the Bagno dell' Acqua as a separate center of eruption, since it is indicated on the course of one of his fault-lines, though he does not mention it directly.

Objections to these views.—I am quite in accord with Foerstner as to the general succession of the lavas, especially the earlier date of his "phonolites," "liparites," and the "andesite" of Zichidi, the subsequent eruption of the pantellerites, and the final appearance of

[1] A. Bergeat, *Neues Jahrbuch*, Festband, 1907, pp. 315–17.

the basalts; as I am with Bergeat's conclusion as to the essential structural unity of Montagna Grande and Monte Gibelé, and his conclusion that the latter was the crater of the "andesite" mass. My observations, however, lead me to different conclusions as to the presence of fault-lines and other lineaments, and the origin of the volcano of Monte Gibelé and Montagna Grande, the ring of scarps, and the Bagno dell' Acqua.

The straightness and parallelism of the supposed fault-lines of Foerstner and Bergeat appear to me, after examination of the island and study of the large-scale chart, to be unduly emphasized. As a matter of fact, the inner scarp and ridge of Serra di Ghirlanda with its orogenic continuation in the Cuddioli dietro Isola is far from being a straight line, curving gently round from a north-north-westerly direction at the north end, through north-south, to northeast-southwest at the southern end. A similar curvature is shown by the Costa Zichidi ridge, and also at that of Costa di Zeneti, which latter turns sharply, but without any tectonic discontinuity, into the ridge and scarp of Cuddia Nera, with an east-west direction. The scarp of the summit of Montagna Grande, on the other hand, while in general following the lines of the Ghirlanda–Zichidi ridges and facing them, shows essentially straight lines: one on the east with a nearly north-south direction and the other east-west, the two meeting in a sharp angle at the southeast corner of the mountain, at the Rione Miliac. On the west, northwest, and north, however, the mass of Montagna Grande shows no scarps which correspond to those of Costa Zeneti and Cuddia Nera. Furthermore, the eastern slopes of Monte Gibelé slope gently down, with typical volcanic cone topography, to the Piano di Ghirlanda, whereas if the Ghirlanda scarp was due to faulting, and if Monte Gibelé is an originally integral part of the Montagna Grande mass, as there is good petrographic and orogenic reason to believe, we should expect Gibelé also to show fault scarps marking the line of separation from the surrounding region.

Again, it is difficult to conceive of the origin of the deep and narrow valleys surrounding Montagna Grande on the basis of either the fault or the upthrust theory. The one would explain them by the slipping down or differential movement of narrow

blocks, concentric about the central mass, a case which, so far as I know, is unparalleled elsewhere, especially on so small a scale; or the other as due to erosion along the fault zone, which is also difficult to accept in view of the relatively dry climate and the character of the surface-drainage topography.

Without desiring to be polemical, I may mention that the fault-lines mentioned by Foerstner, and indicated on the small map by Bergeat, seem to me to be somewhat arbitrary and subjective and their apparent parallelism rather forced by judicious choice. Thus, the most northeasterly connects the Bagno dell' Acqua (which can scarcely be regarded as a volcanic center) with a very minor part of the Montagna Grande scarp. That on the southwest connects the very minor Cuddia Sataria with a not very pronounced part of the coast line. That connecting Cuddia Sciuvechi and Monte Fosso del Russo might have been extended on the one side to Cuddia Gelkhamar and on the other to Cuddia Attalora with little deviation from a straight line. Also, they are arbitrary in their omissions. Thus, radiating lines might have been drawn from Cuddia Mida as a center toward the north, northwest, and west, each of which would have run through three or more volcanic cones, and such radiating lines would have been consonant with the radiating system of dikes observed about many volcanoes.

Author's views.—Accepting the hypothetical granitic basement, which is in harmony with observations on Linosa, I suppose that the first volcano (which presumably started in submarine eruptions like those in 1831 and 1891[1]) was a large one and covered the whole of the present area of the island, except possibly a small area at the northwest. The flows poured out by this volcano were of pantelleritic trachyte (Foerstner's "phonolite" and "later andesite") and of comendite (Foerstner's "liparite"), the now existent sheets of which formed the lower flanks of the old cone. On the west, at the Costa Zichidi and the Scauri district, they still show in places traces of the original lava surfaces. Later than these, but issuing from the same volcanic center, which may be supposed to have been probably between the Cuddia Mida and Monte Gibelé, were flows of green pantellerite (Foerstner's crystalline pantellerites), which

[1] Cf. H. S. Washington, *Am. Jour. Sci.*, XXVII (1909), 131.

covered most of the slopes of the old cone and are now seen in the southeast portion of the island and to the north and northwest of Montagna Grande. This original, large volcano was reduced to a large caldera with an encircling somma (about 6 kilometers in diameter), with gentle slopes toward the periphery but steep scarps on the inner side, either by an explosion or possibly by subsidence of the central portion, according to Stübel's theory. These are the scarps of Serra Ghirlanda, Costa Zichidi, Costa Zeneti, and Cuddia Nera. A similar history and a similar form at the end of the first stage of activity have been true of many well-known volcanoes, such as Santorini, Monte Vico near Viterbo, Somma-Vesuvius, Etna, Pico de Teyde, Taal, and many others. During this first phase and presumably before the formation of the caldera there were formed the parasitic cones of green pantellerite, notably those of Cuddia Attalora, Cuddia Gadir, Monte Sant' Elmo, and Cuddioli dietro Isola.

The eruptions of the second phase began within this caldera, the floor of which may have been below sea-level (as in the case of Santorini), and which was apparently breached to the north, between Cuddie Nera and Gadir. These consisted largely of trachyte (Foerstner's "older andesite"), which built up the great mass of Montagna Grande and Monte Gibelé. I follow Bergeat in thinking that the latter served as the vent for most of these eruptions, while Cuddia Mida may be regarded as a later parasitic cone near the summit of the volcano, which emitted mostly pantelleritic pumice. The trachytes of Monte Gibelé filled, or nearly filled, the large caldera, and are covered in many portions of the area with pumiceous lapilli derived from Cuddia Mida.

This pumiceous outburst may be regarded as the last of this phase, after which the northwestern part underwent a serious dislocation. The block which constitutes the present Montagna Grande was separated from the Gibelé portion by the Passo Khalchi fault, and tilted about an almost east-west axis. The southern end was raised some 250 meters or so, forming the prominent Miliac scarp and bringing the upper edge above the level of the former summit of Monte Gibilé. To the north the movement was downward, producing the depression of the Rione di Bagno now in part occupied by the lake.

That such a movement can have taken place on the island is shown by that preceding the submarine eruption of 1891 near the corner of the island, when a section of the northeast coast from Punta Karuscia to Punta Tracion was raised nearly one meter.[1] Such a tilting of a fault block explains reasonably the steep scarps, their presence only at one end of the mass, the revealed structure of sheets of columnar flows, and the general slope of the surface toward the north, while the simple set of two almost straight lines formed by the scarps is also in harmony with this interpretation.

Subsequent to this dislocation the second stage of the second phase took place in the formation of the small parasitic cones of Fosso del Russo, Monti Gibilé *a* and *b*, Cuddia Randazzo, Monte Gelfiser, and others, which poured out flows only of black pantellerite (Foerstner's vitreous pantellerite). It is noteworthy that all these small cones are found on the edges of the Montagna Grande block, just where the movement of the block would give exit to the magma along the fracture lines. None of them have broken through the main area of the mass, though it is uncertain whether Cuddia Sciuvechi, which also poured out black pantellerite, is along the western fracture line or on the slope of the original large volcano, and hence belonging to Phase I.

The southern cones of this period, Gibilé *a* and *b* and Russo, are of small size, and their flows are short and barely do more than reach the bottom of the old caldera flow, not getting as far as the opposite inner somma ring. The northern cones, on the contrary, Cuddie Randazzo and Gelfiser, are much larger, and their flows of much greater length and volume, Khagiar reaching the sea and Gelfiser coming up to the Zeneti scarp and apparently overflowing the northwest corner portion of the tilted block. It will be observed that this disposition is in harmony with the structural explanation here suggested.

According to this interpretation the Bagno dell' Acqua (with the alluvial Rione) is not a center of eruption, as supposed by Foerstner and Bergeat, but part of the old caldera floor, somewhat lowered by the block tilting, and left uncovered by the flows of Monte Gibelé and those following the Montagna Grande dislocation. This

[1] G. A. Butler, *Nature*, XLV (1891), 584.

explains its features better than does the view that it is due to an explosive eruption, surrounded as it is by the scarps of Costa Zeneti and Cuddia Nera on two sides, and the ends of the lava flows of Gelfiser and Khagiar and the slopes of the Montagna Grande mass on the others.

With the cessation of the outflows of black pantellerite, though after what interval we do not know, began the phase of basaltic eruptions, the earliest being apparently that which broke through the green pantellerite of Monte Sant' Elmo. These were comparatively small in volume and confined entirely to the northwest part of the island, though Foerstner mentions some basaltic dikes as occurring along the east coast. These eruptions formed the small,

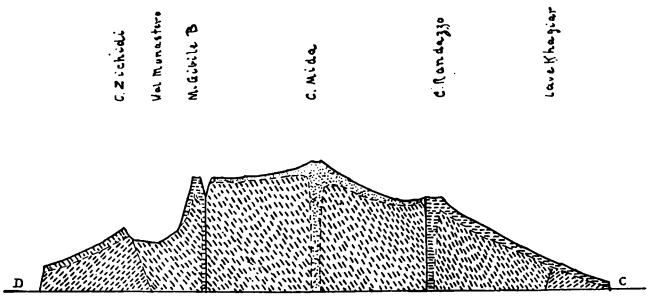


FIG. 4

scoriaceous cones already mentioned, and also gave rise to flows of basalt, which covered a large part of this portion of Pantelleria. The submarine eruption of 1891, four kilometers west of the harbor, is to be regarded as the last eruptive activity.[1]

Evidence of diminishing volcanicity is still manifest in fumaroles and hot springs. Of the former the most important are the Favara Grande and the Stufa di Khasen. The first is situated on the slope of Montagna Grande, northeast of Monte Fosso del Russo, at an altitude above sea-level of 410 meters. It consists of three openings in the rough lava, which emit scalding hot steam with a strong odor of sulphur dioxide, the rocks being deeply decomposed for some distance around. This fumarole is utilized by the goatherds for a

[1] H. S. Washington, *Am. Jour. Sci.*, XXVII (1909), 131.

supply of potable water by covering the openings with brushwood, which condenses the steam and gives rise to a variable trickle of water. The Stufa di Khasen is situated in the northwest corner of the island, near the Cuddie Rosse, and the vapors issue in a deep grotto, which was walled up and converted into a hot-vapor bath, apparently by the Arabs. There are other fumaroles below the Rione Miliac, at the summit of Montagna Grande, and in the crater of Cuddia Mida, as well as one, the Grotta di Bagno Asciutto, near Monte Gibilé *a*. The occurrence of these fumaroles around the Montagna Grande block is quite consonant with the presence

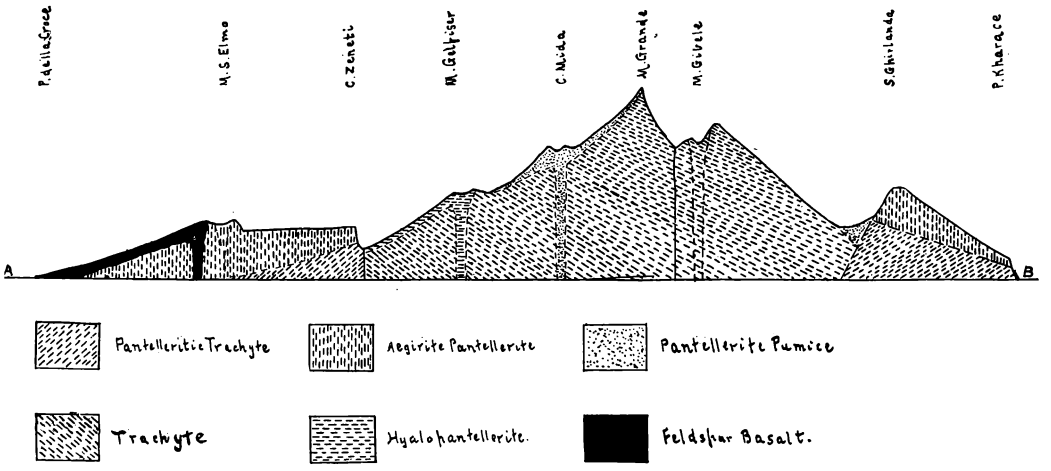


FIG. 5

of a line of fracture. The hot springs occur in various parts of the island, chiefly near the shore, while others are found at the southeast corner of the Bagno dell' Acqua. Foerstner gives two analyses, from which it appears that the waters of the lake are high in soda, with some potash, chiefly as chlorides, with less sulphates and carbonates.

To sum up, my idea of the volcanic succession may be briefly put thus:

Phase I: Building-up of a large cone, composed of flows of pantelleritic trachyte, comendite, and lastly green pantellerite. Attalora and Gadir and Monte Sant' Elmo are parasitic cones of this.

This phase was ended by an explosion, or possibly by a subsidence, blowing off the central and upper parts of the cone, forming a large caldera in the center, and leaving Serra di Ghirlanda, and Coste Zichidi, Monastero, Zeneti and Nera as a surrounding somma.

Phase II, Subphase 1: The building-up within the caldera of the Gibelé–Montagna Grande cone, with its crater probably that of Gibelé, the lavas being trachytes. Cuddia Mida was a parasitic vent, ejecting pantelleritic pumice, and the last eruptive crater of this subphase, which was concluded by the dislocation of the Montagna Grande block, which tilted up toward the south and down toward the north.

Subphase 2: The eruption of black pantellerite along the fracture line surrounding the tilted block, forming the Cuddie Randazzo, Gelfiser, Russo, and Gibilé *a* and *b*, with their flows.

Phase III: Eruption of basalts alone, formation of Cuddie Ferle, Brucciate, Foerstner Volcano (1891), etc. Fumaroles and hot springs.

These relations are shown in the accompanying sections (Figs. 4 and 5), in which the vertical scale is five times the horizontal.