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SOME ASPECTS OF THE GEOMORPHOLOGY OF THE CANARY ISLANDS

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With 9 figures & 6 tables

INTRODUCTION

The Canary Islands have received more geological attention than any other Macaronesian archipelago during the past 160 odd years, attracting a wide international range of scholars. Yet, in common with all these archipelagos, very little attention has been given to geomorphology, and we have only two monographs, those of Klug (1968) and Pomel (1986) devoted to landform matters, though others, e. g. Hausen, the only scholar to have done geological work in all the Canary Islands, have given scattered remarks on this topic.

Scholar and tourist are invariably charmed by these lovely islands, and those of scientific bent have viewed here Nature's wonders with awe and curiosity, whilst visiting laymen have their minds stimulated as they look up to a towering pinnacle such as Roque del Nubo in Gran Canaria, or down into that impressive, immense hollow of the Taburiente Caldera in La Palma.

Herewith, within the confines of a modest contribution, we shall examine some geomorphological features of these islands, the only Atlantic islands to have possessed an aboriginal population dating back some 2500 years B. C..

THE SETTING

A few basic geographic data will aid in appreciating the salient features of the islands, seven major ones. (Table I)

The two Falkland Islands and Iceland excepted, Tenerife is the largest Atlantic island, and as regards altitude, none can compete with Pico Teide, 3718 m on the same island.

The Canaries, as other Macaronesian archipelagos, comprise essentially two topographic-relief types — high, rugged, strong relief (Tene-

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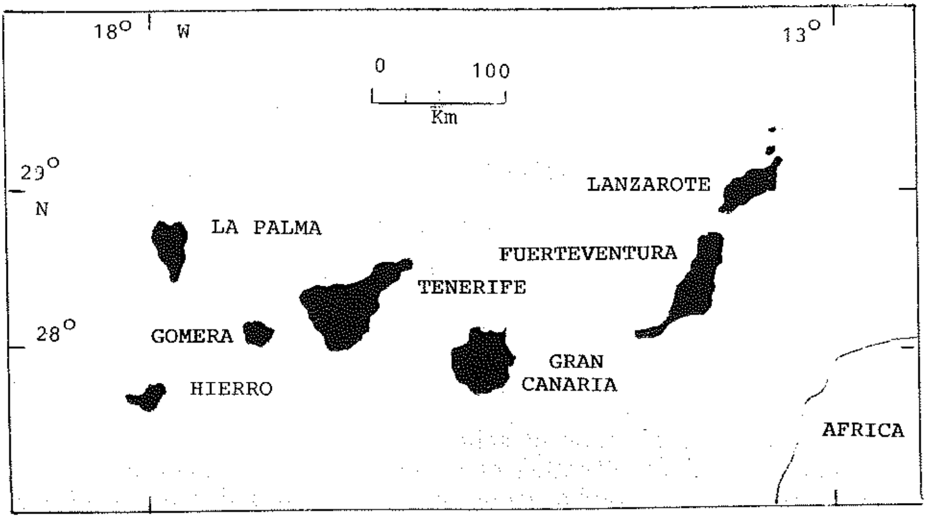

Fig. 1. — The Canary Archipelago.

rife, Gran Canaria, La Palma, Hierro), and lower, more subdued relief, (Lanzarote, Fuerteventura). Gomera, though slightly higher than Hierro, is more shaped like an inverted bowl, with more gentle upper tableland slopes and steeper descents everywhre down to the coasts. However throughout there is strong coastal cliffing, and in all islands, many valleys are canyon-like — at least in part of their courses. In this manner therefore, areas of very steep slopes can be found on all islands. Level land is very scarce in the central highlands of Gran Canaria whilst on higher slopes of Pico are distinctly localized. "Hilly" and "mountainous" are adbjectives that come to mind in succinctly categorizing the islands.

Average annual temperatures range from 9.5°C (Icod, elev. 656 m, NW Tenerife) to 20.4°C (Arrecife, SL, Lanzarote), but at higher elevations lacking meteorological stations, snow during winter is quite common, e. g. in the central highlands of Gran Canaria whilst on higher slopes of Pico Teide, snow may lie on the ground four-five months per year. On the other hand, temperatures as high as 45°C are not unknown, especially in low, sheltered locations of the eastern islands, closer to Saharan influences. Average annual[1] rainfalls vary between ca. 118 mm (Playa de la Rasca, Tenerife) to 1100 mm at Valleseco, 996 m, Gran Canaria, and presumed to be in excess of 2000 mm at Pico de la Cruz, 2350 m, La Palma. The average monthly rainfall for the archipelago as a whole is 35.6 mm. Some 43% of the winds come from the N, 20% from the SE, and for some 300 days annually northern winds predominate. On an average, the islands have 285 clear, sunny days, 54 days with rain, 7 cloudy days annually — obvious reasons why tourism is so popular. The closer the islands are to

1 author's correction made by printer

Island	Area (km²)	Max. elev. (m)	Name of peak	Approx. pop.	Chief town
Lanzarote	796	671	Penas Chache	48,000	Arrecife
Fuerteventura	1725	807	Pico Zarsa	25,000	Puerto Rosario
Gran Canaria	1532	1950	Pozo Nieves	600,000	Las Palmas
Tenerife	2058	3718	Pico Teide	570,000	Santa Cruz
Gomera	378	1482	Garajonay	24,000	San Sebastian
La Palma	729	2426	Roq. Muchachos	80,000	Santa Cruz
Hierro	278	1501	Malpaso	7,000	Valverde
Graciosa	27	266	Pedra Barba		
Alegranza	12	289	La Caldera		
Lobos	6	122	La Caldera		
Montana Clara	1	25	La Mariana		
Roque Este	0.07	84			
Roque Oeste	0,06	41			

Tab. I. — Pertinent Geographic Data, Canary Islands.

Africa, the warmer they are, rainfall less, and on all it is southern exposures which have greater heat, less rainfall.

As with the climate, there is a pronounced vertical zonation of vegetation, no less with respect to orientation to winds, rains. Bravo (1954) recognized the following vegetation zones : coastal, up to 200 m, xerophytic vegetation ; low zones, 200 - 600 m ; middle zones, 600 - 1500 m with lauri-silva and fayal heaths ('monte verde') up to ca. 800 m and from here to 1500 m (occasionally 2500 m), pines and brooms, of which *Pinus canariensis* is one of the most majestic of trees, at times reaching heights of 65 m ; high zones, 1500 - 2700 m, with dyeweeds prevalent between 1700 - 2000 m, but up to 3000 m on Teide-Viejo in Tenerife. The delightful pale blue, fragrant-scented Teide violet (*Viola cheirantifolia*) occurs a mere 20 m below the summit of Teide, a rare plant species that can withstand for months under a snow cover the rigours of cold and strong winds at such elevations. The sub-Alpine zone lies between 2700 m and 3000 m.

CALDERAS

These large depressions, diameters of at least 1.6 km (1 mile), of general round or oval shape, initially of volcanic origin, can be the most impressive of all volcanic landforms. The Canaries have their share of

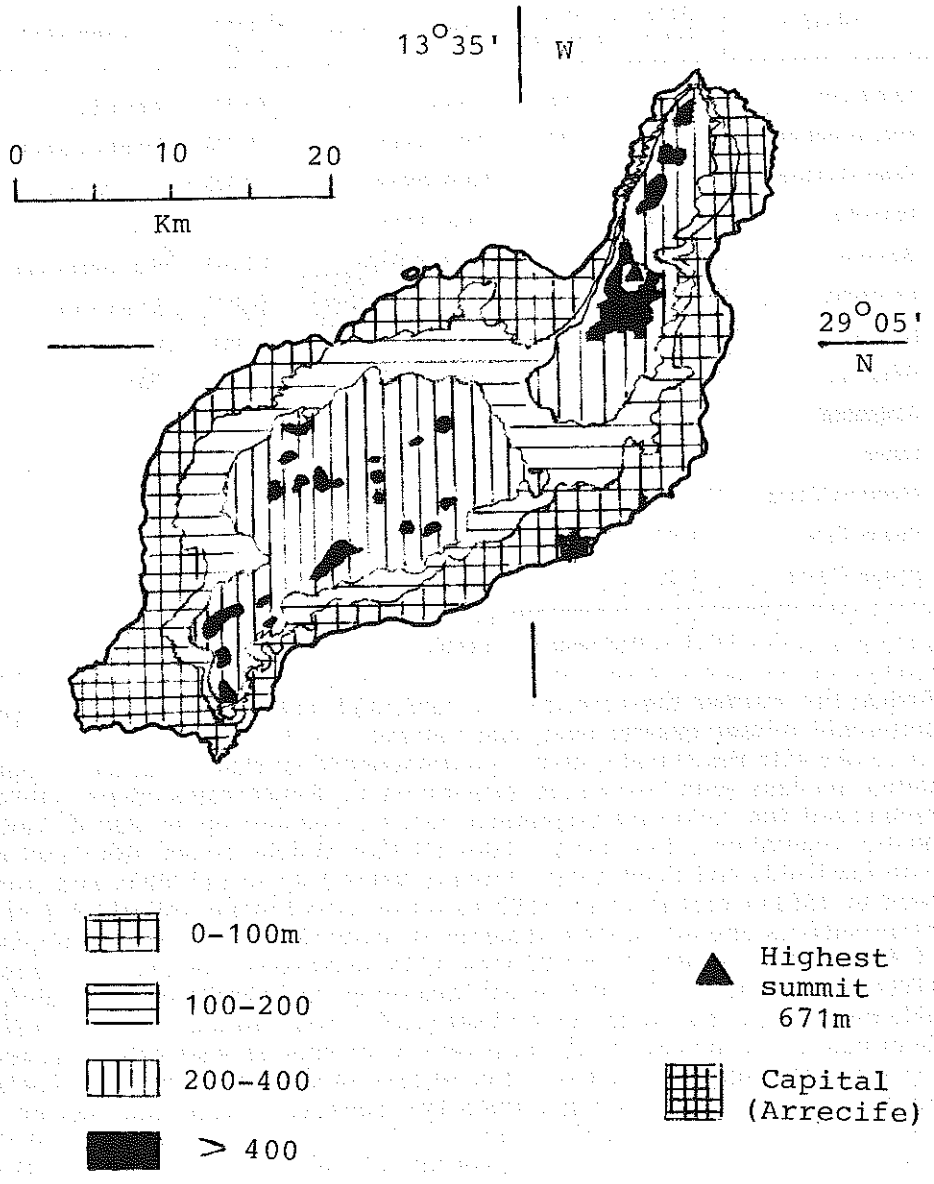

Fig. 2. — Hypsometric Map of Lanzarote.

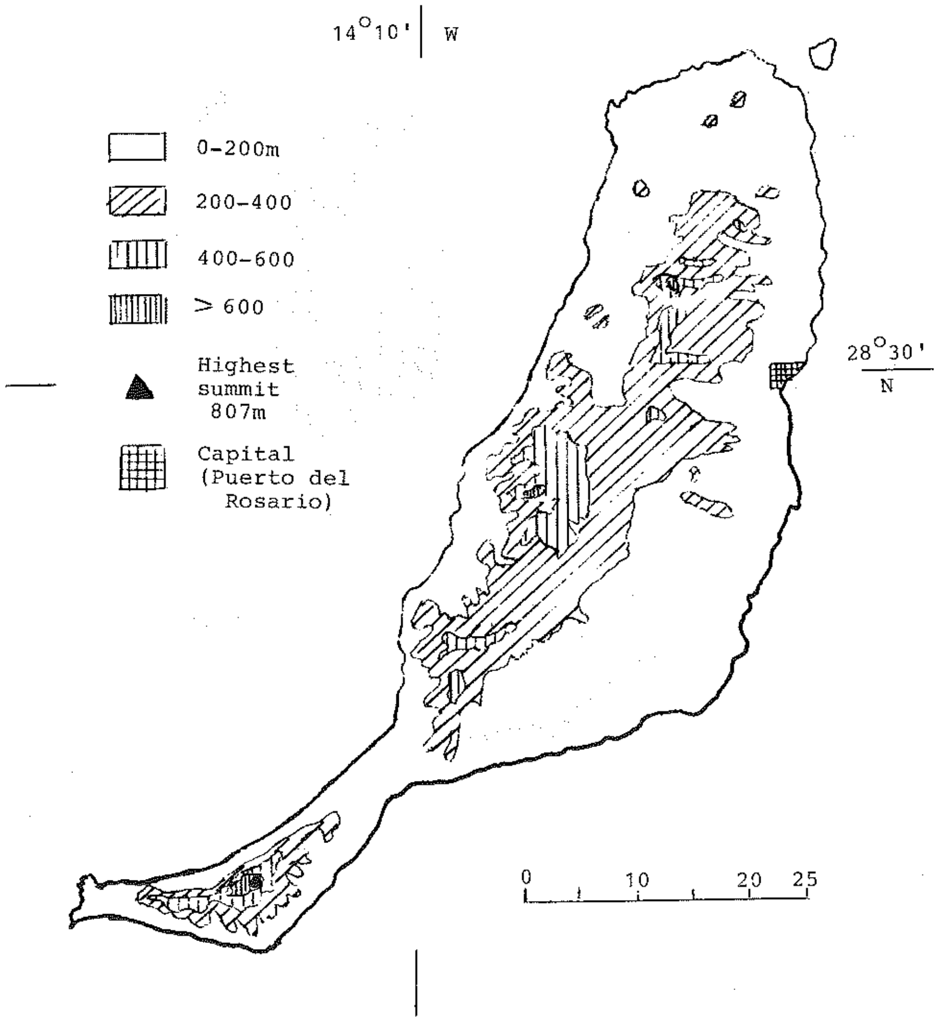

Fig. 3. — Hypsometric Map of Fuerteventura.

calderas (Hausen, 1961 ; Mitchell-Thomé, 1980), and of them all none can compare with that of Taburiente in La Palma. (Fig. 9) This gigantic amphitheatre, measuring some 14 x 7 kms, is open towards the SW, is drained by the Barranco de las Angustias and tributaries, and is only a kilometre wide at the exit. The N-NW rims (latter known as the El Time escarpment) forms a truly abrupt descent down from over 2300 m to 600 m in the valley floor, and here is Roque de los Muchachos, 2426 m ; highest summit in the island. The lowest point within the caldera is 50 m. From any aspect

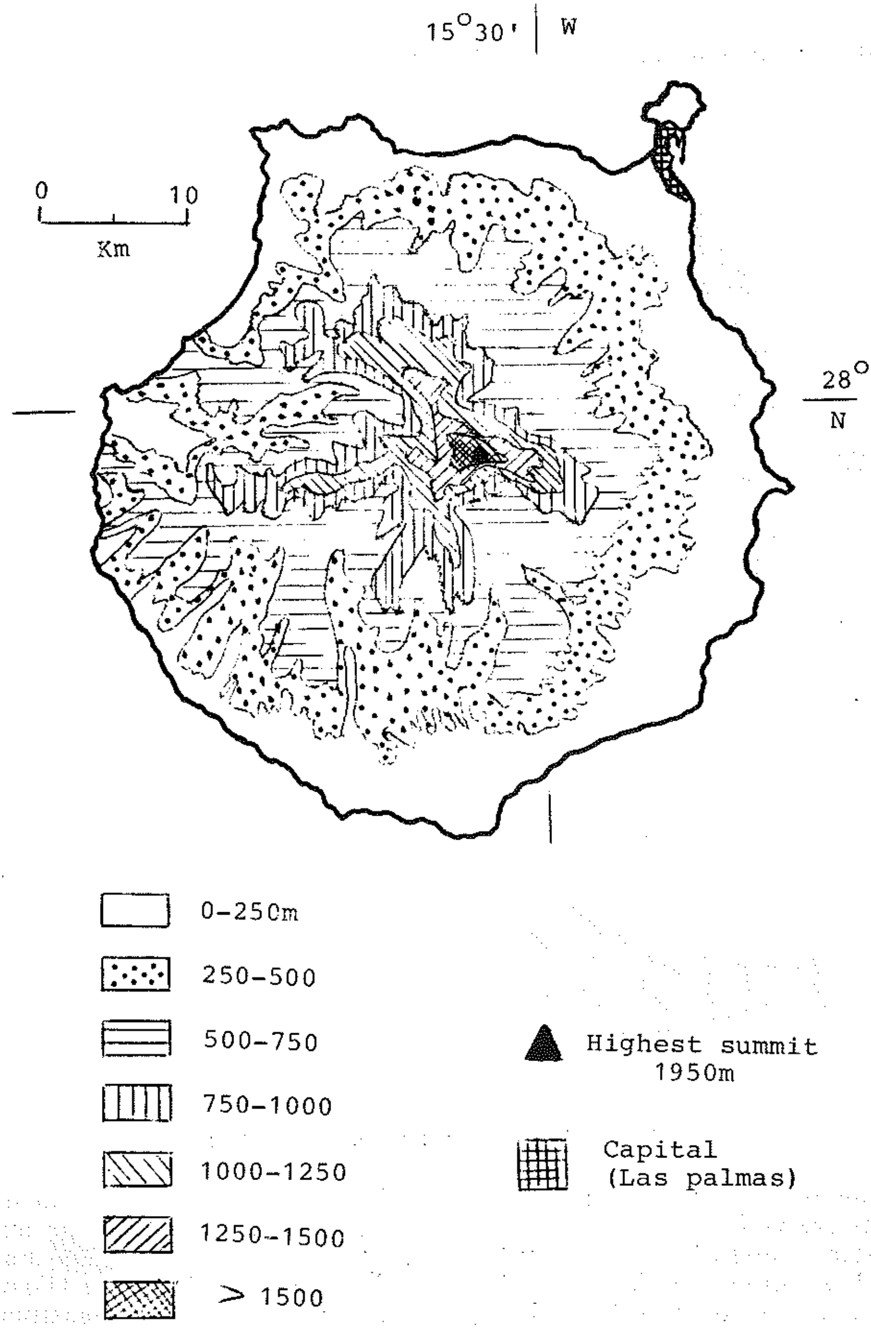

Fig. 4. — Hypsometric Map of Gran Canaria.

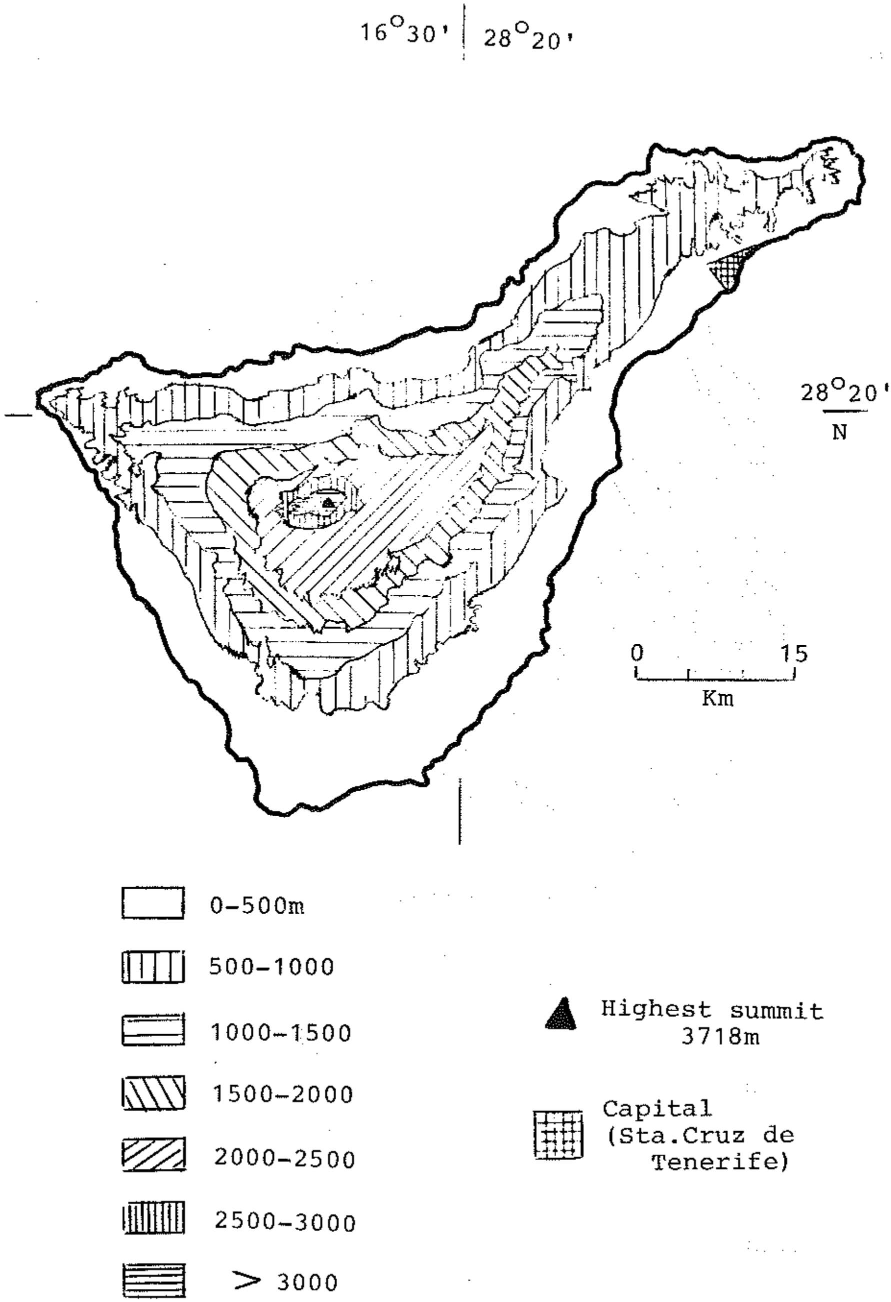

Fig. 5. — Hypsometric Map of Tenerife.

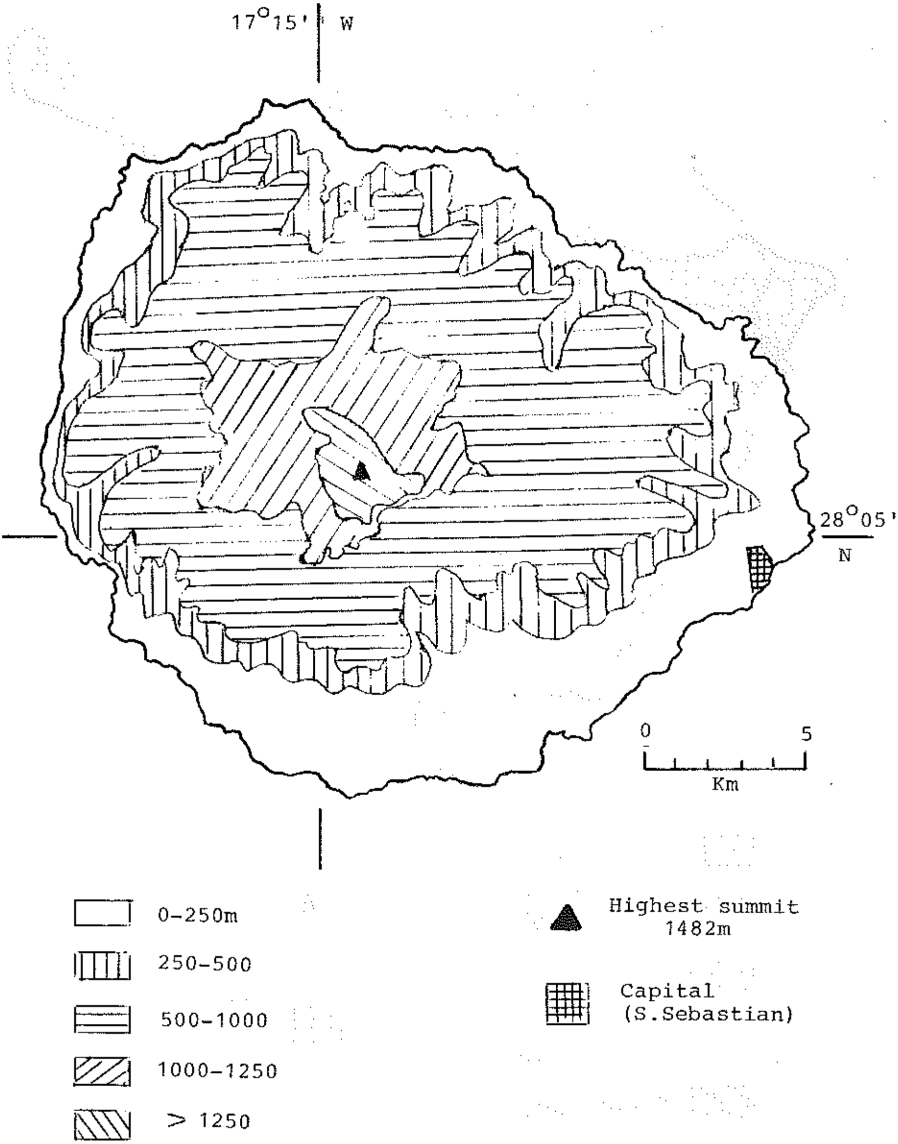

Fig. 6. — Hypsometric Map of Gomera.

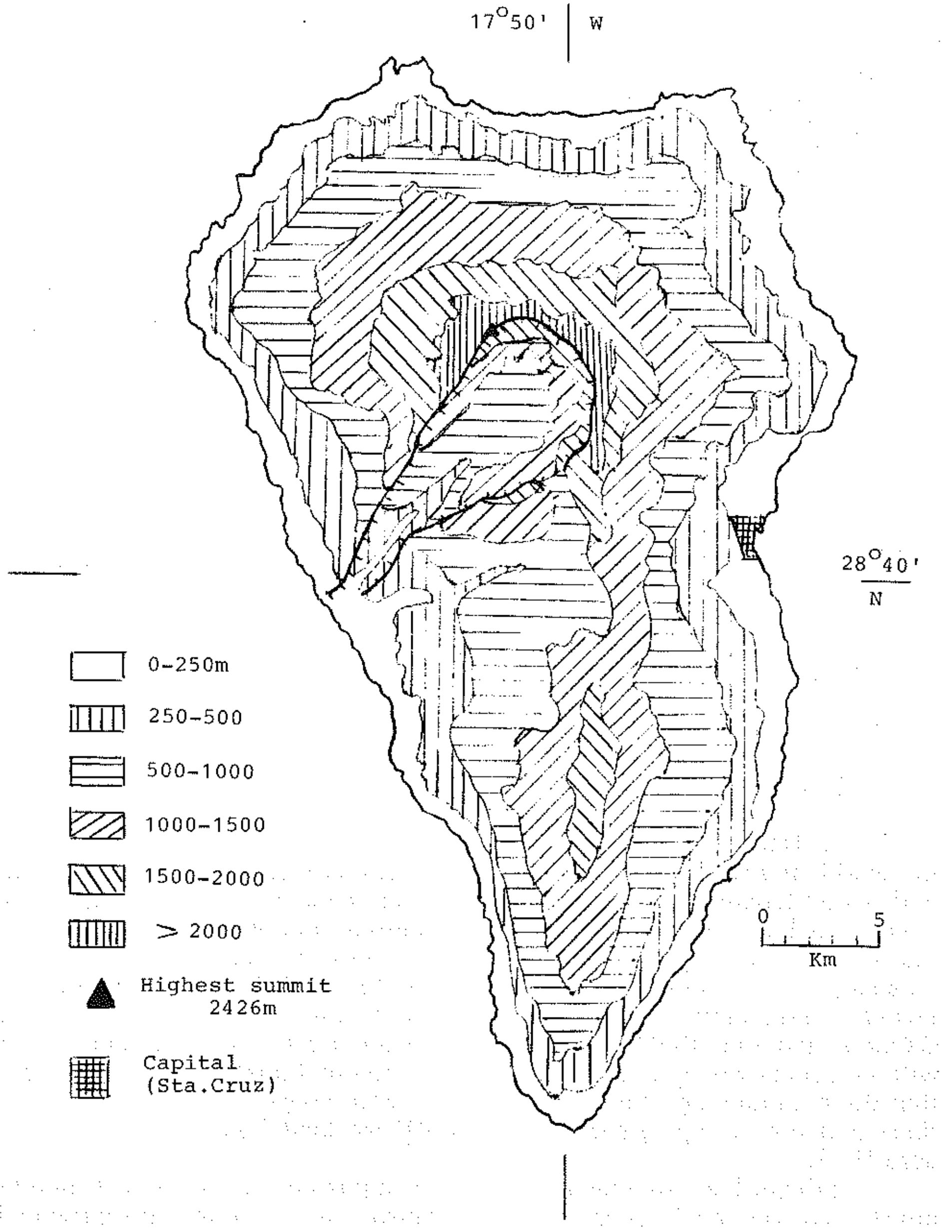

Fig. 7. — Hypsometric Map of La Palma.

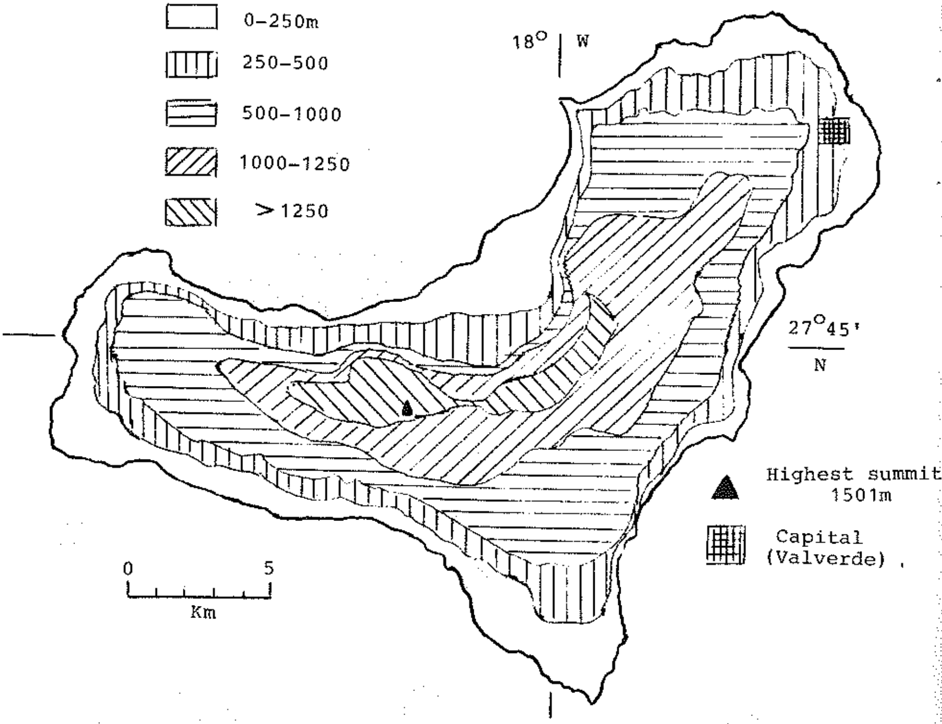

Fig. 8. — Hypsometric Map of Hierro.

or viewed from the air, this is surely one of the great natural wonders of the world, and remind the author of an American visitor's comment as they both stood looking down into this awesome abyss : "Wow, the bulldozers have sure been busy here"! Martin, Pelletier and Pomel (1984) claimed that in the lower and central part of the caldera, terraces are to be distinguished, dating from the Lower Pliocene to 200,000 - 100,000 years ago, giving a systematic arrangement similar to those of Las Palmas, Gran Canaria, and that the finding of *Rothpletzia rudista* in a marine horizon with volcanics would invalidate the contention of Abdel-Monem *et al* (1972) that the minimum age for La Palma dates from some 1.6 MY ago, as fossil finds indicate an age greater than 1.8 MY for landslide blocks in the caldera floor.

Perhaps less spectacular, but still imposing, is the large scalloped embayment on the N coast of Hierro known as El Golfo. The curving N wall, concave in same direction, extends for some 25 km, precipitous slopes from heights of 1500 m down to the shore, with one or two small villages lower down near the coast. Some, e. g. Ridley (1971), would argue

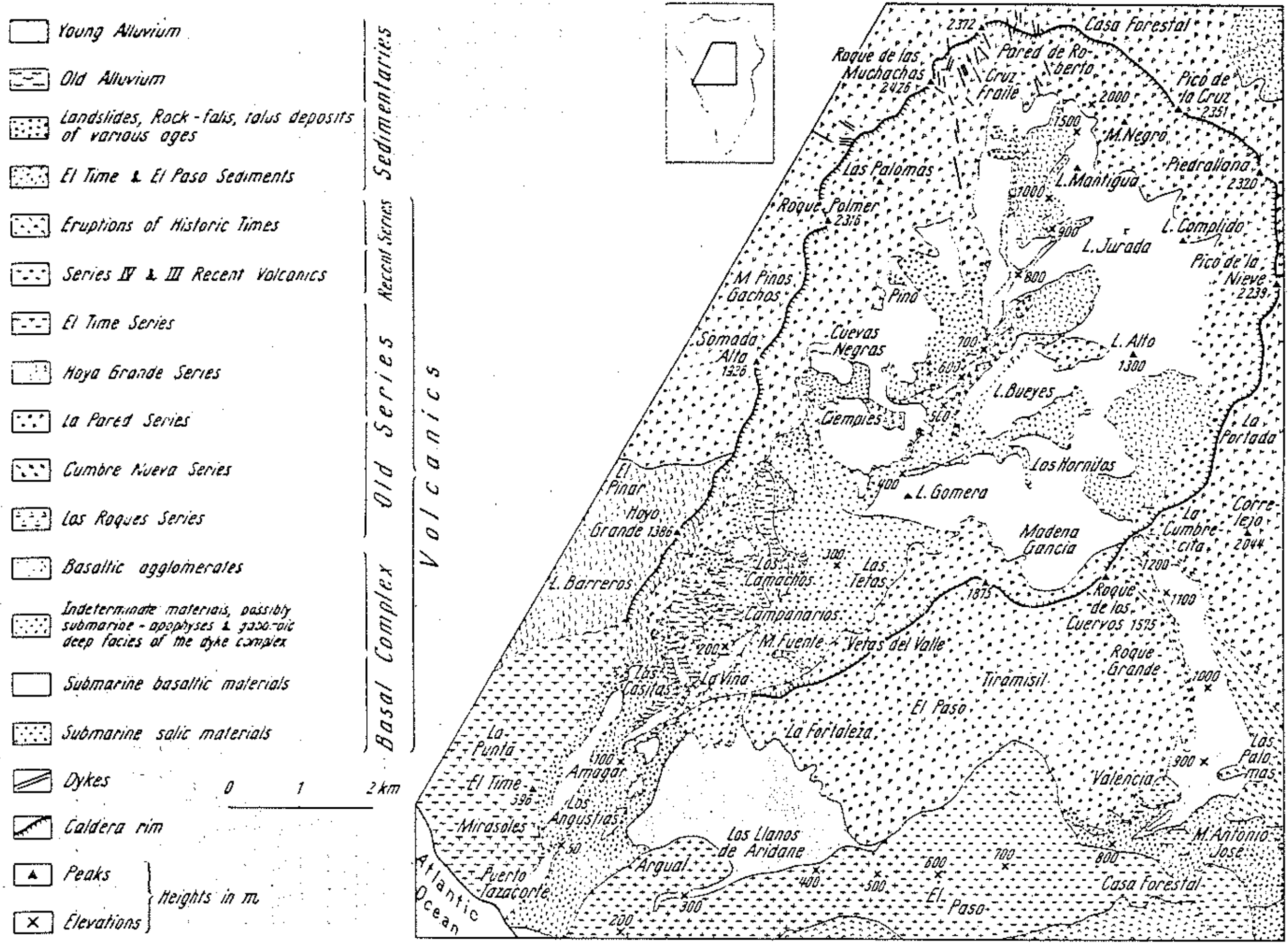

Fig. 9. Geological map of Caldera de Taburiente, La Palma. (Modified after HERNANDEZ-PACHECO & AFONSO, Direcc. Gen. de Obras Hidraulicas Map, 1974).

that El Golfo is the remains of a central caldera, half of which subsided into the sea, whilst others, e. g. Pellicer (1977) prefer rather an exogenic origin, whereby subsidence along a curvilinear fault took place, followed by drastic erosion, rockfalls, etc.. This depression is thought to be ca. 200,000 years old, Hierro being the youngest of the Canary Islands, probably dating from Upper Pliocene.

In Gran Canaria are two long-recognized calderas, those of Tirajana and Tejeda. The former, opening towards the SE and drained by the Barranco Tirajana and tributaries, has a maximum measurement of 11.3 km across, narrowing towards the coast, with 520 m and 1950 m being lowest and highest elevations. Tejeda, facing westwards and drained by several more significant streams, has a 36 km perimeter, maximum dimension 13.8 km, with 250 m and 1750 m being lowest and highest points respectively. It was Hausen's opinion (1962) that both these features were not calderas in a strict geological sense, but rather immense valleys, generally quite broad but also canyon sections, that of Tejeda having a water gap at its western extremity, and that both depressions resulted from erosion plus mass gravitational movements, i. e. of exogenic, NOT volcanic[2] origin, hence not true calderas. The majority of opinions published as to the origins of these two features conform to Hausen's ideas, though purely explosion and collapse origins have also been promulgated.

In 1966, Schminke & Swanson first proposed "Eine alte Caldera" in the central part of Gran Canaria, of semi-circular shape, a feature of "synvolcanic" origin, which abruptly separates basalts outside this curve from trachytic welded ash flows within. The length of the partial caldera wall is ca. 55 km, measures 28 km from rim-to-rim and encloses both the Tirajana and Tejeda depressions. McDougall (McDougall & Schmincke, 1976 - 77) and Hernan (1976) also support the concept of one very large central caldera on the island, and if further work should substantiate this view, then this caldera would be not only the largest in the Canaries but no less in Macaronesian. It is perhaps worth noting that Hausen (1962), in considering the development of wide gravel fans, consolidated into conglomerates, occurring behind the Las Palmas area in the NE of Gran Canaria and in the Puerto Rico - Juan Grande region on the S, with very coarse accumulations of conglomeratic material — and strong lime carbonate cementation, — was led to conclude that such could not be the result of normal river transport. He rather surmised that powerful avalanches of rubble and water roaring down steep slopes were responsible, that the only source of water of this magnitude, with their heavy burdens of rubble, were from a crater or caldera lake which was subjected to explosive outbursts which emptied the lake, maybe several times, causing wild, torrential, flood-like overflows of water-rubble — "waterborne stony avalanches" to use his term — downwards towards Las Palmas and the Puerto Rico - Juan Grande areas at opposite sides of the island. If the lake which formed here was of caldera proportions, this might be some kind of proof for the

2. Author's correction made by printer

"alte caldera" of Schmincke & Swanson (*op. cit.*).

Every visitor to Tenerife has seen, from a distance at least, the conical summit of Pico Teide, frequently draped in lingering snow. This peak, and its less high neighbour, Pico Viejo, 3103 m, rise up within a vast depression known as Las Palmas. The caldera has well-developed walls only on the SW, S and E sides, rising some 700 m above the floor of the basin, the perimeter of the structure being 26+ km, maximum diameter 16 km. Both Teide and Viejo comprise products of their own volcanism which occurred posterior to the formation of the Las Cañadas Series, this last being associated with the caldera formation. There are actually two depressions within the basin, the higher eastern one being composed of Teide lavas only, the lower, smaller western one by Viejo products. No less there are two distinct escarpments along the southern sector, Portillo to the E being strongly scalloped but well-defined, whereas the[3] Sauce one to the W presents a more uniform but less striking appearance. As with Taburiente in La Palma, various hypotheses have been put forward to account for this great caldera, with the majority favouring a collapse origin — probably two collapses following the Las Canadas volcanic phase.

In the extreme SW of Fuerteventura there is a strong suggestion of a breached caldera. The curving[4] N shore of the peninsula is backed by the Jandia Mountains, rising to 807 m, with very steep slopes northwards, much gentler to the S. Hartung (1857), von Fritsch (1867) and Benitez (1946) thought that here we have a collapse structure, major part of the caldera being below SL. On the other hand, Bourcart & Jérémine (1938), Hausen (1956, 1958, 1961, 1971), and, by inference, Fuster *et al.* (1968a) and Lopez (1969) favoured downfaulting parallel to the present N coast, eruptive centres here being now below SL. The roles of caldera collapse, downfaulting and exogenic agencies — especially marine erosion — can all be invoked as landform causes here, but certainly to view this large embayment from off-shore, with its narrow strand, very steep slopes up to the heights of the range, does indeed give the impression of a large caldera, with a landward perimeter of some 30 km.

The El Golfo, Tirajana, Tejeda, Canada depressions, as seen today, owe their essential characteristics likely to exogenic agencies, the consequences of faulting, mass gravitational movements and fluvial erosion. Yet initially, such large hollows within volcanic terrain are no doubt due to explosion and/or collapse mechanisms. Fault-line scarps are much commoner than fault scarps, the latter being, as it were, more pristine effects of faulting whereas the former clearly indicate modifications due to erosion, etc.. In the same way, it is probably true to say that all calderas are modified landforms resulting from the play of exogenic agencies, irrespective of the initial means whereby such depressions were formed. Thus the author would claim that as long as the area can prove its volcanic constitution, great depressions formed initially via explosive or collapse mechanisms, then whatever later modifications have taken place, such fea-

3 Author's correction made by printer

4 " " " " "

tures should be considered calderas, or if of smaller dimensions, then craters. Only where generally rounded depressions occur in non-volcanic environments can we rightly use another term than caldera (crater). World-famous Meteor Crater in Arizona, U. S. A. has all the outward appearances of a volcanic crater, but as the environment is non-volcanic, it is rather an imposing circular depression, ca. 800 m in diameter and 300 m deep, formed by the impact of a giant meteorite, hence NOT a true crater.

The Spanish term "caldera" was introduced into the geological vocabulary by von Buch (1825), taking as his type Bandama in NE Gran Canaria. However this feature is much too small to be a caldera, and is properly a crater. It is unfortunate that even many scientists confuse the two names, Spanish geologists no less, but always, calderas are much larger, deeper features than craters.

CRATERS

These have all the geologic, topographic and geomorphologic features of calderas, differing only in dimensions and being of more diminutive size, they can be more readily appreciated at a glance, for the eye can encompass the form from a single viewpoint. Craters are well scattered throughout the archipelago. The best-known and longest-known to the outside world is that of Bandama, 10 km by road from the Gran Canarian capital, so that countless thousands of visitors have looked down on this textbook example. This well-preserved feature, of almost perfect round shape, breached towards the NW side, has the steep inner slopes spotted in garish vegetation, flowers such as broom, gorse, lavender, thyme, etc. when in bloom producing a delightful vista and a fragrant scent in the air. The level floor, dry an[5] sandy, has one or two small habitations located here. (Interesting enough, the name "Bandama" is a corruption of Van Damme, a former Flemish entrepreneur in sugar and wine who once owned the site.)

In these islands, the more impressive and/or larger craters are shown in Table II. Statistics given here are mostly approximations, and as earlier remarked, Spaniards make no distinction between craters and calderas, and indeed Fuster *et al.* (1968d) clearly state : "La denomenacion "caldera" se usa en Canarias para nombrar crateras o depressiones circulares qualquiere que sea su tamano". Yet to confuse the issue even more, Blumenthal (1961) speaks of "crateras en forma des calderas"!! Seldom do craters show completely enclosed forms, and in these islands most usually they are open towards the northern sector, facing the dominant winds. Worthy of note is the relative profusion of craters in Lanzarote and Fuerteventura, contrasting with scant development in La Palma, Gomera and Hierro, i. e. crater development decreases from E to W. Speaking only of Gomera, Hausen (1971) was inclined to assign the cause of crater paucity to the greater age of the island. Radiometric datings (Mitchell-

5 overlooked (should have been "and")

Island	Name	Locality	Dimensions, Elevations (m) of Rims
Lanzarote	La Corona	SW of Orzola	500 diam., 130 deep, 610 elev.
	M. Quemado	Nr. Maguez	550 diam., 100 deep, 560 elev.
	M. Medio	N, Los Ajaches	700 diam., 125 deep, 510 elev.
	C. Riscada	Nr. Femés	550 diam., 160 deep, 450 elev.
	M. Roja	Extreme SW	450 diam., 65 deep, 195 elev.
	C. Blanca	Nr. Tinguaton	1100 diam., 130 deep, 270 elev.
	C. Guanapay	Nr. Teguise	600 diam., 100 deep, 430 elev.
	La Caldera	Is. Alegranza	1100 diam., 200 deep, 290 elev.
Fuerte-ventura	C. Gairia	S of Antigua	850 diam., 140 deep, 460 elev.
	C. San Rafael	SW of Corralej	600 diam., 150 deep, 300 elev.
	C. Lirla	S of Cacilla de Morales	375 diam., 50 deep, 250 elev.
	C. La Laguna	N of C. Lirla	350 diam., 50 deep, 300 elev.
	C. Arrabales	S of Liria	250 diam., 45 deep, 200 elev.
	La Caldera	Isla Lobos	450 diam., 35 deep, 125 elev.
Gran Canaria	Bandama	SW Las Palmas	1000 diam., 200 deep, 400 elev.
	La Caldereta	Cent. Highlands	250 diam., 55 deep, 1250 elev.
	Los Marteles	Cent. Highlands	600 diam., 50-200 deep, 1500 elev.
	Pinos Galdar	Betw. Valleseco & Artenara	450 diam., 45 deep, 1400 elev.
	Tenteniguada	Cent. Highlands	1400 diam., 350 deep, 1300 elev.
Tenerife	C. Rey	SW, 1 km from sea	1450 diam., 110 deep, 150 elev.
	'Arafo'	N of Arafo	350 diam., 120 deep, 1300 elev.
	Buenavista	Nr. Buenavista	600 diam., 60 deep, 250 elev.
	Pico Viejo	Nr. P. Teide	1350 diam., 175 deep, 3050 elev.
Gomera	La Caldera	E of Cantera	290 elev.
La Palma	S. Antonio	Nr. Fuencaliente	350 diam., 55 deep, 660 elev.
Hierro		Nr. Valverde	1100 diam., 65 deep, 1050 elev.
		Nr. Jinama	600 diam., 50 deep, 1350 elev.

Tab. II. — Data regarding some Craters in Canary Islands.

Thomé, 1985a) indicate that Gomera dates from the Upper L. Miocene (Burdigalian), Hierro from the L. Pliocene and La Palma certainly much older than Pleistocene datings obtained so far, whilst Lanzarote is probably as old as Gomera and Fuerteventura dates from the U. Eocene (Bartonian). The Basal Complexes of La Palma, Gomera and Fuerteventura show certain petrological similarities and are considered of pre-Vindobonian age, perhaps even Late Mesozoic. The geomorphic characteristics of calderas and craters — deep hollows, steep inner sides, looser, more friable rock constituents obviously means that both are clearer expressed where vulcanism is not old, to be translated as Pleistocene-Recent in age. Hence the younger the last episodes of colvanity,[6] we would expect calderas and craters to be better preserved. The ravages of Time work ceaselessly to modify initial configurations, the spread of vegetation can not only conceal original appearances but no less slow-down erosion, the nature of the climatic

6 overlooked (should have been "volcanicity")

regime acts to promote change, so that considering many well-preserved craters may be 50,000, 100,000, 200,000 years old, it is indeed remarkable that preservation can be so obvious.

An interesting aspect of many cratered areas (lesser so in calderas) is their groundwater potentialities, exploitation being via galleries or wells. Considerable water development has occurred in northern Lanzarote, where craters are very numerous. (Mitchell-Thomé, 1974, Custódio, 1978). On both geohydrologic and geomorphic grounds, craters are to be distinguished into those having flat floors and usually with extrusive rocks at or almost at the surface and more often of collapse origin, from those having floors sloping towards the centre, more commonly associated with looser pyroclastics forming talus-scree slopes towards the centre, and more usually associated with adventitious cones.

VALLEYS

As would be expected with islands of Canary dimensions, the general drainage pattern is radial, specially so in Gran Canaria, Tenerife and Gomera, where the central regions are highest. Referring to the Canary islands in general, Klug (1968) divided valley types and generations into three kinds : Oldest (M. Miocene - L. Pliocene), wide, enclosed or residual valleys, usually basin-shaped, termed Kehltäler ; Shallow, very gentle-sloping outer parts, the stream itself with a narrow, deeper inner valley, the whole of general basin-shape, termed Muldentâler ; Steep-walled, deeply eroded valleys, being youngest in age (Pliocene-Quaternary), termed Kerbtäler. As examples of such in Gran Canaria, the writer (Mitchell-Thomé, 1985b) quoted for the first Temova and Tirajana ; for the second, Tenoya and Chira ; for the third, Tazarte and Tavrito. In other islands, these three types are perhaps less prolific, and, for example, Gomera shows mostly Kerbtäler valley types.

The most astonishing valley in the archipelago is that of the Barranco de las Angustias within the Taburiente caldera in La Palma. Flows from innumerable springs are so abundant that this is a perennial stream, the only one in the Canaries. (Hausen, 1951). The maximum breadth of this valley-caldera is 6.5 km, narrowing to ca. 1 km at its exit, the main stream being some 16 km in length. Some headwaters begin at elevations as high as 2300 m, a distinct centripetal drainage network having developed. With an average gradient of ca. 1 in 7, this is indeed a remarkable valley, gorge sections typical throughout, deeply-incised meanders being common, the entire course of the main stream being extremely tortuous. Doubtless faulting, no less collapse, has been at least partially responsible in the creation of this awesome depression, but the roles of fluvial erosion and especially mass gravitational movements impress the viewer more so, and indeed the majority opinion of those who have studied in the field this feature assign a principal role to exogenic agencies.

In Gran Canaria, the valley of the Barranco de Tejeda has aroused much interest and was studied in detail by Hausen (1962), though chiefly from the standpoint of rock constitution, and was termed by him as "the most remarkable landscape feature in the island". A water gap occurs at the western outlet, where a 4 km long gorge is bordered by unscalable heights up to 1400 m. In this major valley of the island, some tributaries begin as high as 1750 m, the main stream being some 25 km in length, the depression itself measuring 16 km long and up to 6 km broad. Hausen (*op. cit.*, also 1970) claimed that this huge hollow was NOT a caldera in the accepted volcanological sense, but rather the consequence of exogenic agencies, with the likely accompaniment of collapse mechanisms, in 1971 favouring more the latter explanation. (Admittedly this is rather confusing, and in correspondence with Hausen — he died in 1979, aged 95 — this author could still not determin just exactly what Hausen had in mind, for collapse is an accepted volcanological-structural explanation, hence a true caldera) Be this as it may, the Tejeda depression-valley is an awe-inspiring sight, an enormous E-W gash extending halfway across the island.

The above comments made re. Tejeda can likewise be made of another great gash in Gran Canaria, that of the Tirajana depression-valley, trending SE towards the coast. Headwater tributaries rise as high as 1550 m (near Pozo de las Nieves, 1950 m, highest peak on the island), the total length of the main stream being ca. 24 km. The N wall is remarkably steep, all but unscalable, and so also with much of the E wall in the northern part — this perimeter could be interpreted as a fault scarp or faultline scarp. This amphitheatre extends down to ca. 500 m. The N part of the western rim is much more sinuous in form, generally lower — except in the extreme NW. From an elevation of 550 - 600 m the main stream exits from the basin, becomes deeply incised and a gorge section continues down to near Alda Blanca, thereafter the stream flowing over Recent sedimentary infill for ca. 8 km before entering the sea.

It is thus seen that both Tejeda and Tirajana have clearly defined topographic restrictions (= caldera rims) at their western and southern extremities respectively, succeeded by canyon sections before levaing mountainous terrain, to continue over more gently sloping land to the coast. As with Tejeda, much discussion has arisen as to the origin of Tirajana, with explosion, collapse, tectonism and fluvial erosion-mass gravitational movements all being invoked, at least to varying degrees. But there is no question that these huge, profound depressions associated with the valleys of the Barrancos Angustias, Tejeda and Tirajana are as spectacular as found anywhere on earth, though all valleys are relatively short.

Another feature of small areas and relatively high altitudes of such islands as La Palma, Gomera, Tenerife, Gran Canaria, is the very pronounced talwegs — the line joining the lowest points along the valley from source to mouth. Not only are stream gradients very steep but transverse profiles no less, with canyon sections common. This is particularly well seen in Gomera and Gran Canaria, where the radial drainage patterns are well developed. As examples, the highest elevation in Gran Canaria is 1950 m, almost centrally located, coasts being ca. 20 km distant. In all directions an abundance of valleys strike outwards and downwards to the shores, so that talwegs are ca. 1 in 14 in general. (1 in 10 for the Guayadeque stream, 1 in 12 for the Virgen, 1 in 14 for the Agaete, 1 in 18 for the Soria, etc.) In smaller Gomera, ca. one-quarter the area of Gran Canaria, with maximum elevation only ca. 450 m less, the general configuration of the island differs in that here we have a high central tableland reaching downwards to ca. 500 m altitude, at the edge of which streams have their sources. Where the tableland or platform edge is closer to the coast, e. g. the SW corner, the many short valleys have frequently talwegs of 1 in 10 to 1 in 13. Especially the western Gran Canaria and the S-SW sectors of Gomera display strong coastal cliffing, such that in the latter island almost the entire lengths of the short streams have carved out gorges below the tableland rims.

Three valleys in Tenerife, though scarce of unusual scenic interest, have caused considerable discussions as to their origins. The Valle de Orotava, open to the N coast, a large basin-shaped hollow, descends from elevations of 2300 m, is some 12 km long by 9 km broad. It is bordered for much of its length to W and E by very steep scarps, resulting in an arcuate headwater area. From the coast the rise is gentle up to ca. 1500 m, then steep gradients up to 2000+m. The main ephemeral stream rises at ca. 1750 m with an average gradient of 1 in 6. Some, e. g. Ridley (1971) have favoured a volcano-tectonic origin ; Arana & Carracedo (1978) considered it an example of a "valle intercolonaire", where the margins are formed of many lava flows issuing from the dorsal of the chain (Pedro Gil), thus building up "walls", i. e. the valley does NOT result from erosion but by the piling[7] of flows at the rear and sides giving a depression shape ; Pelletier & Pomel (1984) remark on the dense concentration of dykes in the high axial part of the range, this "breaking up" of the volcanic terrain favouring landslides, before or after an important explosive phase ; Hausen (1955) preferred a tectonic-exogenic origin ; Blumenthal (1961) argued for a caldera-collapse origin whilst Fuster *et al.* (1968b) inclined rather to the role of great landslides in the excavation of the valley. As the Valle is a densely populated area, with the garish tourist resort of Puerto de la Cruz on the coast and rich agricultural land, the location is well known to many peoples.

The Valle de Guimar descends[8] SE from the Pedro Gil spine, being 10 km long, 6 km broad at SL but broadening to 8 km at the valley head. As with Orotava, abrupt scarps enclose the valley on the NE and SW sides, attaining heights of 600 m, and similarly the headwaters area shows an arcuate trend, concave to the SE. The main valley floor descends steeply from a height of 2200 m in a great series of giant steps over a length of 4.5 km down to ca. 750 m, with a gradient[9] of 1 in 3 (!), where a pronounced

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break in slope takes place, the succeeding gradient being ca.1 in 11. Again we are uncertain as to the cause(s) of this depression. For both Orotava and Guimar, Bravo (1952, 1954) thought that perhaps large inroads of the sea — ria-type development — were the major causes in either case, and Klug (1968) was quite sympathetic to this idea, actually a concept which dated back to Rothpletz (1889).

The third valley in Tenerife is the least impressive but certainly seen by more tourists than any other, for here lies the international airport Los Rodeos. To the NW of the capital of Santa Cruz lies the La Laguna valley, lying between the rugged mountainous Anaga peninsula to the N and to the S, the NE end of the Pedro Gil dorsal. Throughout this linear depression are sinuous steep slopes leading up to the mountains on the N side, whilst the southern border rises more gently to lesser summits, hence a distinct asymmetric transverse profile. The highest part of the valley is ca. 10 km in length and up to 4 km broad, the through valley sloping both towards the SE and NW, and where the flatter terrain of soft, friable arenaceous sediments are found the airport has been constructed. In spite of an all-but total lack of geomorphologic studies here, there is a possibility that faulting is the major cause of this through-way, Mingarro (1963) believed that a large fracture — a faultline scarp — marked the N border between valley and mountains. On the other hand, Blumenthal (1961) thought the valley was bounded by faults on both N and S sides, extending from the SE to the NW coasts. Structurally and geomorphologically this region deserves study, for the entire setting is somewhat unusual.

MALPAISES

The literal translation of this term is "bad lands", but in the Canaries the meaning differs from American bad lands, where the name was coined. In the latter, these are all-but devoid of vegetation where erosion has etched the terrain into an intricate maze of narrow ravines, sharp crests and pinnacles, travel across such being extremely difficult, comparable to hammadas as regards this last feature. In these islands, however, the term is restricted to terrain of volcanic origin only, to lava fields of highly chaotic surficial appearance — slabs, irregular blocks, boulders, rounded and linear depressions, hummocky jagged land of sharp edges and corners, and again most difficult to traverse. Where humans make the effort to clear, break-up, level-off such terrain, then because of its initial nourishing mineral content they can be successfully converted into agricultural land. In essence, malpaises are areas of lava flows similar in appearance to the Hawaiian "aa" terrain. Where Man has effected clearance and planted crops, it is not possible to determine the original features, and hence there are younger and older malpaises showing varying degrees of natural and artificial alteration. Obviously it is the non-cleared malpaises which attract the eye, for the less cleared, the more obvious its initial state.

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Malpais country is found in all islands, to varying extents and stages of transformation, and is best displayed where volcanism is of younger age. In Lanzarote the entire area around Montana del Fuego in the S is one vast field of malpaises, where an area of some 200 km^2 is lava erupted from the twenty five centres of volcanism during the years 1730 - 1736, also later in 1824. The landscape here is dishevelled, chaotic, of blocky lava appearance, devoid of human life (except at Yaiza at the southern border), only one real short road enters the region, vegetation is all but lacking — a classic example of malpais country.

In Fuerteventura extensive malpaises are in the extreme N, also in the central-eastern part where the Malpais Chico and Malpais Grande are found, totalling some 120 km^2.

In both Grand Canaria and Gomera, with high central domal shapes and radially very steep slopes to the coasts and especially the relative scarcity of more Recent volcanism, malpaises are much reduced. In the former island" the most extensive area is Bandama-Teldein in the NE. As for long this island has had the densest population, it can be expected that original malpais country has been cleared and planted, thus concealing the primitive chaotic lava aspect.

In Tenerife, scattered localities occur in the NE, NW, SW, S and central areas (Picos Teide-Viejo).

In La Palma and Hierro, malpais country is associated with younger volcanic manifestations, e. g. the flanks of Cumbre Nueva in the former island and the SW slopes in Hierro.

Thus as we go from E to W, malpais terrain decreases in area and importance, but we must never forget that human labours can transform such inhospitable land into prosperous agricultural properties. Such transformations are no less remarkable than making desert areas "blossom as the rose".

It is indeed unfortunate that "malpaises" is so readily translated into "badlands", for the latter term, as used in its geological sense, refers to ANY type of rock constitution — more usually of argillaceous type — which has undergone intense erosion, the normal precipitation being insufficient to support an adequate plant covering, hence such regions are usually higher, arid to semi-arid such as e. g. South Dakota or then Kansu Province in China. In the Canaries, malpaises result from the disintegration of lava flows, whereby chaotic, rubbly, blocky extents mantle the terrain. Elevation has a slight influence but climate exerts little influence to the extent that windward and leeward exposures may both be similarly effected. In their younger, less transformed conditions, malpaises cannot fail to impress by the sheer barren awesomeness, wild disorder of broken rock fragments, devoid of human, animal or plant life. Yet in Lanzarote, e. g. it is surprising to see large extents of land where lava cinders have been scooped out into miniature craters within which vines are planted, the

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"crater" sides, perhaps 1.5 m in height, providing protection for the plants against the constant Trade Winds that whip the island.

MARINE and FLUVIAL BENCHES

These islands are essentially products not older than Palaeogene, with the exception of Fuerteventura, likely Lanzarote, maybe also Gomera and La Palma. Further, it was in Late Neogene-Recent times that volcanism played such a fundamental role in island construction. It follows then that the landscapes here we view today are the results of relatively recent events. Where land is upraised, or then sea level falls, the consequent changes brought about by exogenic agents — and in these islands, no less repeated lava outpourings and showers of pyroclastics — can relatively rapidly alter newly-created terrain, so that everywhere youth is the dominant leit-motiv. This is well exemplified where marine-fluvial depositional activities and erosion effects have resulted in terraces and platforms, here collectively referred to a benches, a more appropriate term than beaches-terraces, as Gresswell (1967) pointed out. These result where the level of the sea-river, with respect to the land, takes up a new position so that either land becomes submerged or then emerges. In one instance, new terra firma becomes exposed to the atmosphere, in the other, it becomes protected from the atmosphere, i. e. exogenic agencies may become operative or then obliterated. Throughout these islands such changes are evident in many localities, and Zeuner (1958) and Klug (1968) give useful summaries of marine-fluvial benches, lesser so of abrasion platforms. Benches are more plentiful, better preserved, easier to identify in the four easternmost islands, which obviously argues for independent island movements. Table III, doubtless an incomplete listing, gives details of marine benches in the seven major islands ; Table IV summarizes period-elevation data ; Table V attempts to correlate marine benches in Macaronesia with neighbouring mainlands.

In Lanzarote, benches and abrasion platforms are well displayed in the southern extremity. Here, for some 10 km, is an uninterrupted abrupt rise of 5-6 m from, Playa de Janubio to Punta Pechiguera. At the latter locality is a marked abrasion platform, 2 km long and up to 1.5 km broad, ranging in elevation above SL from 6-23 m. In the area of Caleta Larga and at Playa Quemada, on the S coast of this region, benches 55-60 m above SL can clearly be seen, fronted by terrace deposits.

In Fuerteventura benches are well displayed in the Jandia peninsula and the landward extension thereof. Inland from the Playa Ugan area, benches occur from 60-65 m on the lower slopes of Clilegua peak. The N coast of the Pared isthmus is flanked by a 3 m high cliff for some 10 km. This unusual isthmus region, rising to heights of ca. 200 m, is almost completely covered by aeolian sands, with here and there patches of volcanics outcropping in a "sea of sands", thus testifying to the subsurface conti-

		Holo-cene	Neo-Tyrr.	Eu-Tyrr.	Paleo-Tyrr.	Pre-Tyrr.	Sicil-ian	Old Quat? Plio?	Mio-cene
LANZAROTE	Playa Caleta	3.9							
	Cast. Don Carlos	3.6							
	Playa Blanca	3.6	4.9						
	S of Tias						60		
	Playa Quemada		6						
	SE Los Ajaches		6	15 - 18	25 - 35		55 - 60		
	Rubicon	3 - 4	6 - 7	15 - 18	40 - 45		55 - 60		
	Salinas Janubio		6 - 7						
FUERTE-VENTURA	Gran Tarajal		Ca. 7	18					
	Playa Blanca	4		17					
	W Coast		7	15	25 - 35		55		
	Chilegua						65		
	Jandia	3 - 15	15 - 55						
CANARIA	Las Palmas	4	7 - 8	18					
	Rincon		13	22					
	Ayala		6	15	35				
	Pta. Arucas			15	35	55			
	Pta. Cebolla			15	35				
	Banad. Salinas		7.1						
	Banaderos		8.2	15.4	35 - 40				
	Banad. Friedhof					65			
	Quintanillo					90			
	La Puntilla	3.75							
	San Andres		6 - 7	16	40				
	Pagador	4.5							
	Agaete N					78 - 85			
	Agaete E					78 - 85			140 - 150
	Agaete S					78 - 85			
	Guayera				55				
	Pta. Gondora				Ca. 100				
	Arguineguin	4 - 4.8							
	Maspalomas W	2	6						
	Juan Grande					60 - 70 ? 90 - 100 ?			

GRAN	Arenaga	4		18					↓
	Gando			16					
	Gando Penin.	4							
	La Laja	3.5	8		45	85			
	Agua Dulce	4	7						
	Mont. Colorado	4.5			23 - 27				
	Mont. Confital			12					
TENERIFE	S. Juan Rambla		8.2						
	La Roqueta	4.8		Ca. 15					
	Pta. Hidalgo	3.5	7.6						
	Bajamar	3.6							
	Martianez		8						
	Tegina							60	
	Teno		8 ?						
GOMERA	Pta. Llana	Ca. 4		18					
	Arguamul	4							
	Pta. Delgada	4 ?							
	Gran Rey	3.5		18	35				
LA PALMA	Pta. Salinas	4							↕ 200 - 250 ?
	Puntallana			Ca. 25					
	Lomo Machin			Ca. 25					
	Charco Verde		6 - 13						
HIERRO	Arenas Blancas	Ca. 4							
	Playas Cardones	Ca. 4							
	Hoya Tamaduste			Ca. 18					
	Playas Largas	4			30 ?				

Tab. III. — Data regarding Raised Marine Benches in the Canary Islands.
(Heights in m;) (Klug. 1968)

Period \ Islands	Lanzarote	Fuerteventura	Gran Canaria	Tenerife	Gomera	La Palma	Hierro
Flandrian	1 - 2 3 - 4	1 - 2 3 - 4	1 - 2 3.5 - 4.8	1 - 2 4 - 5	3.5 - 4	4	4
Neo-Tyrrhenian	4.9 - 7	7	6 - 13	7.6 - 8.2		6 - 13	
Eu-Tyrrhenian	15 - 18	15 - 18	15 - 22	Ca. 15	18	Ca. 25	Ca. 18
Paleo-Tyrrhenian	25 - 45	25 - 35	35 - 100 ?		35		30 ?
Milazzian	55	55	55,65				
Paleo-Sicilian	60	60	100 ?				
Calabrian				60			
Pliocene ?			75 - 85 90 - 100	60 100			
Miocene			140 - 150			200 - 250	

Tab. IV. — Marine Benches (heigths in m) in the Canary Islands.
(Modified after Mitchell-Thomé, 1976)

nuation of rock constitution to either side of the isthmus. On the sotavente or leeward coast of Jandia, to the W of here, benches occur at 15 m and 55 m for ca. 12 km on the southern slopes. In Gran Canaria marine benches are conspicuous at several sites along the coastlines, especially well-developed in the Punta de los Rios-Ayala area of the NE coast, the Agaete area, NW coast, and the Gando area, E coast. Both marine terraces and abrasion platforms occur, from elevations of ca. 6 m to 85 m, the 45 m benches at Gando curving parallel to the general contour trends of the highest summit here, 104 m, the 85 m bench also being found S of this same eminence. On the Isleta (peninsula N of Las Palmas) benches occur from 4 m to 28 m on the W side thereof where the slope is steeper. Probably fluvial terraces are better preserved in this island than others. In the Barranco de Villaver just SW of Las Palmas, this "Kerbtal" valley shows an excellent series of five benches, elevations of 1-2 m, 5-6 m, 15-20 m, 35-40 m and 50-55 m, extending as far as 8 km upstream from the coast, some of which are 500 m in length and 260 m broad.

Though benches are not very numerous in Tenerife, most are along the northern coastal area. In the Anaga peninsula, 40-60 m benches lie some 100-160 m above SL, smaller, lower ones from 3.5 - 15 m. In the Teno peninsula, Klug only reports one at 8m? at Punta Teno, but NE of here less clear platforms occur at heights of ca. 12-18 m. It is only in these two peninsula regions that coasts are more strongly indented, cliffing more prominent, all told presenting a more wild, irregular coastline.

In Gomera marine benches are found at Punta Llana (E coast), an abrasion platform 15 m high above 3-4 m high cliffs. At Arguamul on the

	MACARONESIA				AFRICA		EUROPE	
	Canaries	Azores	Madeira	Cabo Verde	Mauri-tania	Morocco	Gibral-tar	Portu-gal
Flandrian	1 - 4	0.5 - 5	1.5 - 6	2 - 6		2	5	± 2
Neo-Tyrrhenian	6 - 13	5 - 15	8 - 10	7 - 12	2 - 7	6 - 8	8.5	5 - 8
Eu-Tyrrhenian	15 - 25	12 - 20	12 - 15	13 - 20	12 - 20	15 - 20	15	12 - 20
Paleo-Tyrrhenian	25 - 45	30	25 - 30 ?	30 - 55	30 - 40	25 - 30	33	30 - 45
Milazzian	55 - 65	50 - 60	50	50 - 60	55	55 - 60	62	50 - 60
Paleo-Sicilian	60 - 100 ?	80 - 100	100	80 - 100		100	99	80 - 90 ?
Calabrian	60	150				+ 100	180 - 210	150 - 160 ?
Pliocene ?								180 - 190
Miocene	140 - 250							

Tab. V. — Correlations of Marine Benches in Macaronesia and Neighbouring Mainlands.
(Modified after Mitchell-Thomé, 1976)

N coast lies a 4 m high bench and at Playa de Valle Gran Rey, W coast, where a significant deep valley penetrates some 6 km inland, marine and fluvial benches are seen at 4 m, 18 m and 35 m above SL.

In La Palma, von Fritsch (1867), in the Caldera de Taburiente, within fissures at a cliff basement, referred to "Reste von Korallen und Balanen ... bis in Höhen von 200 bis 250 Meter über der See". Here is a wide, ancient gravel-fan extending down to the coast, "obviously a torrential mountain stream gravel mass well consolidated ... that there have been several phases of deposition as the island rose in Quaternary time". (Hausen, 1969). Whilst the stream eroded deeper, forming a gorge across the gravels, "these were re-worked and deposited as terraces at different levels". This old fanglomerate, first remarked upon by von Buch (1825), later by Lyell (1855), Hartung (1862), Gagel (1908) etc., has been considered as a type of marine gravel deposition, von Fritsch assigning a Miocene age to the fossils collected here, later amended to Helvetian by von Wolff (1931). (But see earlier under "Calderas" the finding of marine fossils in the "premières terraces" in the Angustias valley, though no other workers other than Martin *et al.* (1984) have ever found fossils here substantiating a Neogene age, these authors failing to state precisely where they located the fossils which they argued indicated a Pliocene age.)

The 140-150 m high platform in Gran Canaria referred to by Klug (1968) occurs S of Arucas within ca. 5 km of the present N coast. ("Südlich Arucas liegt ein miozänes Kliff mit einer alten Talmündung ca. 200 m NN, also wenigstens 60 m höher als die errechnete maximal Spiegelhöhe des Meeres bei Las Palmas. Der Differenzbetrag von 60 m muss nicht unbedingt einen örtlichen Hebungsantrag darstellen ... Lavastrom ... zusammen mit ihm aufliegenden terrestrischen Sediment zu einer Aufhöhung der marinen Plattform geführt hat. Sie könnte in etwa 140-150 m NN liegen"). At the base of the cliff "aparece la arena fina de una formacion de playa" (Benitez, 1958) — presumably the same reference as given by Klug, who, however, gives the Benitez date as 1959. Klug was unsure of both the age of the "Hochterrassen"-Schotter and also the time of transport of this "Geröll". Hausen (1962) does indeed state that the Tenoay valley (ca. 2 km E of here) "is apparently a relatively old river valley", and Fuster *et al.* (1968c) mapped Miocene sediments between Arucas and this valley, so that the bench might be of Miocene age, but could equally well be Pliocene.

In the El Golfo embayment of Hierro are traces of benches at ca. 20 m above SL. At the NW corner of the island (Arenas Blancas), pyroclastics lie on a 4 m high bench, and at Tamaduste (NE) benches occur at heights of 2 m, 4 m, 20 m and 30 m ?

As marine-fluvial benches in the islands are related to the waxing and waning of Quaternary glaciations, they have been correlated with accepted Pleistocene-Holocene stratigraphy. (It is to be noted that Gignoux (1950) pointed out that these stratigraphic terms, devised mostly by French scholars, is, in essence, an incorrect interpretation in that it was assumed

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that various benches resulted solely from eustatic movements and NOT movements of the land). Calbrian is in general considered to be Pleistocene. The succeeding Sicilian transgression is associated with the Cromer interglacial episode, where oceanic waters increased in height up to 90 m, maybe 100 m, followed by regression in Elster times. In the Palaeo-Tyrrhenian, the Holstein interglacial, oceanic waters flooded up to 55 m, followed by regression — the Saale glaciation. In the Eu-Tyrrhenian, the important Eem interglacial event took place, with seas rising to ca. 25 m, followed by a lesser warming of the climate — the Brorup interstadial — resulting in a positive sea level change of some 6-8 m. The Flandrian transgression of the Holocene again caused positive ocean movements of 3-4 m and 1-2 m. This last event is naturally the best recorded and most commonly detected, having begun some 6000 years ago.

Finally, it should be noted that in these islands, where lava flows have repeatedly coursed downwards towards coasts, many such flows have the appearance, notably in profile views, of marine-fluvial benches. Pomel (1986) speaks of " 'rasas' construites par les coulées, caractérisées par les plans de coulées, de fausses platformes étagées, la prismation des laves, ce qui n'exclut pas les formes de corrosion". Hausen, no less, in his many publications on these islands, often refers to lava platforms and terraces.

AEOLIAN ACTIVITY

Islands throughout the world are characterized by quite powerful, constant winds. In Macaronesia, the NE Trade Winds are remarkably constant and dominant, the Canaries included. Winds affecting terrain experiencing relatively low rainfalls, high evaporation, sparse vegetation, must naturally make their effects felt as agents of erosion, transportation and deposition. In the Canary archipelago it is the deflationary aspect rather than the abrasional which is distinctly more obvious. Travel brochures wearily trot out their photographs of tourists riding camels over dark dunes, lurid skies, a palm tree or two to add to the exotic flavour, yet in nearly all examples of such, the pictures do not refer to the popular concept of sand sunes but rather to black volcanic ejectamenta.

The greater prevalence of sand accumulations in Lanzarote and Fuerteventura (collectively known as Purpurarias) results from a combination of three factors : closer to the immense desert areas of the Sahara ; more open, rolling topography ; in the case of Lanzarote, more extensive, long-continued volcanism within historic times. (Mitchell-Thomé, 1981). (It must be remembered that though we tend to think in genetic terms of "sand" as sedimentary detrital siliceous products containing chiefly quartz particles, yet the definition of such refers only to specific sizes of particles, that mineral-rock constitution is irrelevant, and hence sedidmentary, volcanic and metamorphic sands are equally validly named, provided they subscribe to appropriate grain sizes).

The Purpurarias have slightly higher average annual temperatures (21°C), considerably less average annual rainfalls (152 mm) and here desert influences are more keenly felt, more apparent, the natural landscapes more tawny, more barren, vegetation scarce. Summers here can be considered rainless, with very strong sunlight, cloudless skies, high evapotranspiration, dominant winds from the N and NE, so that S and SE aspects experience more extreme climatic conditions. In both islands, high land trends NE-SW, so that again S-SE aspects are usually referred to as desertic.

Drifting sands, either in the form of dunes (low hills, banks, mounds of wind-blown or aeolian sands), or then sand sheets, often termed "arenales" in Spanish, with flat, undulating thin mass accumulations of sand, quite often below a critical grade size (ca. 0.03 mm diameter), always thin but can have very large areal extents. Sand sheets comprise ca. one-quarter the area of Lanzarote and ca. one-tenth that of Fuerteventura. In the former island the most extensive occurrence stretches from the N coast (Bahia de Penedo) across the island to the S coast (Bahia de Guasimete) where the international airport is located, as also in the extreme SW. In Fuerteventura, the chief areas are in the NE (Jable del Moro — "jable" being the Spanish transliteration of the French "sable"), in the E (Playa Blanca) and the Jandia peninsula (Jable del Istmo) and in the W (Jable de las Salinas).

Along the S-SE sectors of Gran Canaria extend gravelly-sandy areas, on occasion reaching some 7 km inland. Sand sheets principally (lesser so smaller dunes) cover gravels-conglomerates-agglomerates. The extreme southern tip, around Maspalomas, probably best known to tourists, shows these coarse aeolian deposits, as well as semi-marsh conditions with heath and palms developed.

The southern slopes of Hierro were reported by Hausen (1973) to show an area of some 25 km² where black sands, rich in magnetite, are exposed such pyroclastic deposits having been blown southwards from eruptive centres in the El Golfo area. These lapilli and ashes constitute a thick covering over lavas considered to be of Recent age, and form valuable land for viticulture on the more sunny, sheltered slopes. As distinct from Purpurarias, these deposits occur only as sand sheets. Islands W of Gran Canaria show much less development of aeolian depositional features, other than Hierro.

In the Purpurarias, winds have certainly been responsible in moving ashes, lapilli, etc. thus creating quite impressive dune landscapes, Saharan in appearance, only here the colours are black, brown, not the light colours of siliceous sands.

SALIENT EMINENCES

Throughout most of the archipelago we find commanding peaks, prominent summits, vertical standing rock masses, pronounced smaller hillocks, etc. which, whatever their origin, attract attention. Such features have been modelled by Nature, but no less, age and rock constitution have exercised a profound role.

Pico Teide, the supreme summit, as with many great peaks throughout the world, though visible from far out at sea, has its true dimensions concealed by notable "shoulders" — arcuate Cañadas wall, peaks along the Pedro Gil axis, yet on the other hand, on the island itself, its dominance is supreme. Teide, and its near-by satellite, Pico Viejo, are stratovolcanoes of trachytic-trachybasaltic lavas and pumice composition, products of three principal effusions. The first phase constructed this enormous volcanic edifice, the second involved peripherally located adventive cones, and the third witnessed re-activation of acidic emissions to form the present Teide summit, with outpourings of black phonolite flows, the entire structure being of Recent age — post-Sicilian. (Fuster *et al.*, 1968b). Two distinct parts can be recognized : (i) a topographic and stratigraphic lower part of truncated cone shape — Old Teide ; (ii) draped black flows lying above and forming the highest terrain — Pico Teide. The aa[13] lava flows of Old Teide have an explosive crater at the summit, with residual fumarolic activity of sulphurous nature, giving an alternation of rocks of yellowish to white colour, gases exiting[14] here at temperatures of ca. 80°C. The Teide-Viejo structure "punctured" the older Las Cañadas volcanics, the immense Las Cañadas depression forming presumably by collapse, thus the pronounced caldera wall to the W, S and E, the Teide-Viejo volcanism being built within this depression.

In the rugged NE peninsula of Tenerife, Pico de Limante, 953 m, some 2 km from the N coast, crowns a prominent mountain mass of basaltic lavas and lapilli, and no less in the NW Teno peninsula, Pico de Baracan, 1003 m is prominently displayed, where lavas are more conspicuous than pyroclastics. In both these peninsulas, volcanism is relatively old, as per a few radiometric datings, between ca. 7 and 16 MY, i. e. M-U. Miocene. (Mitchell-Thomé, 1985a).

In SW Gran Canaria rises prominently the peak Inagua, 1426 m, which, when viewed from either the NW or SE has a distinctly asymmetric profile, steeper to the SW although the phonolitic and trachytic lavas and pyroclastics have a general horizontal disposition, and rising ca. 800 m above the Hoya (depression) de la Higuerita. Equally impressive are the mesas on either side of the Tejeda stream, e. g. Mesa de Acusa (N bank), ca. 2 km in length, ca. 800 m elevation, formed of basaltic lavas and agglomerates overlying unconformably trachytes, whilst on the S bank of the stream is Junquillo mesa, ca. 1.6 km long, ca. 800 m elevation, where agglomerates pass downwards into basalts.

In Fuerteventura prominent summits include Cerro Melindraga between Fayagua and Chilegua in the SW, a basalt-capped 530 m high remnant of Hausen's (1958) Basaltic Tableland Formation (= Basaltic Series I of Fuster *et al.* (1968a) with flat-lying basalts resting on highly-inclined Trapp rocks. Pico del Fraile, 683 m, is a pyramid-shaped peak, one of the summits

13 Should ~~probably~~ possibly have been "AA" and not "aa". (?)
14 Correction made by printer.

overlooking the N coast of Jandia, where thin, compact flows are intercalated with lapilli, scoriae, tuffs and ashes.

In Lanzarote, Montana La Corona, 609 m and Pico Partido, ca. 520 m, in the N and N-Central areas respectively, are imposing edifices, the former a young volcano of mixed pyroclastics, slaggy lavas and baked "caliche" whereas the latter comprises pyroclastics formed during the 18th. century eruptions.

The western islands lack any outstanding, massive summits, unless perhaps one stands on shores or, in the case of La Palma, deep within the Taburiente caldera, where, casting one's eyes upward, some peaks are more prominent. Even Roque de los Muchachos, 2436 m, forming part of the El Time escarpment in La Palma, when viewed from high neighbouring land, is scarce a dominating feature, and the same can be said of Acantilado de Tivataje forming the steep eastern escarpment of El Golfo in Hierro.

All the above remarks are generally concerned with older, prominent, eroded peaks, more in the nature[15] of massifs, but if we change the scale to include adventive cones and younger volcanoes, then indeed a great many more prominences can be recognized. Such summits usually comprise scoria, looser, more friable material, the ejectamenta of major volcanic outbursts. Yet there is no denying that the superb symmetrical shapes of many such cones, with or without craters, rising from lower terrain can rivet the eye. To list all such examples would be tedious, but we might mention the El Volcan area of NW Lanzarote, extreme N of Fuerteventura, the San Lorenzo-Galletas area in Tenerife, the NE part of Hierro, etc.

Of smaller dimensions than the towering summits and aesthetic cones are a group of eminences of divers origin, still spectacular in their own ways. For example volcanic necks and plugs, lava-filled conduits of extinct volcanoes now exposed by erosion and landslide activity. Probably the outstanding and best known example in the archipelago is Roque Nublo, Gran Canaria, formed of agglomerates, actually two remarkable larger monoliths rising sheer for 80 m to attain elevations of 1700 m, which can be seen from far. The platform from which these rise comprises salic lavas and tuffs and when viewed from the E, the relation of agglomerates to rocks below is magnificently displayed as vast sheets to form striking precipices, some almost 500 m in altitude. Of almost equal striking appearance is Roque Bentaiga, a central spine ca. 60 m high, formed of agglomerates resting on basaltic and tephritic porphyritic lavas, in turn underlain by syenites.[16] Risco Grande de Tenteniguada, ca. 1500 m elevation and Roque del Saucillo, ca. 1430 m, both on the eastern side of the central highlands, are conspicuous hauynophyres necks in an agglomeratic milieu. Just N of 'Caldera' de los Marteles in the same general area, is a prominent plug (similar in origin and form to necks but comprising compact rocks, necks having broken-up rock fragments) composed of ordanchite, perhaps 40 m in height

15 correction made by printer

16 " " " "

and partially covered on one side by basaltic lavas. It is to be noted that in this central highlands region, where the Roque Nublo Series or Group outcrops—comprising thick sheets of polygenic welded rocks—lava flows, tuffites and breccias overlying strongly-eroded principally of trachytic and phonolitic composition rocks — there are quite numerous necks and plugs protruding through agglomerates. As instances elsewhere of these volcanic forms, we could mention : Roque de la Tierra, Roque de las Animas and Roque del Agua, N coastal area of Anaga, Tenerife ; in Gomera, the more rounded neck of Roque del Cano in the central Montana Quemada general region, and some lesser ones by the coast at San Sebastian ; in Hierro, in the region of Tamaduste (NE coast) ; in La Palma the Roques de Salmor (N coast), also within the Taburiente caldera, especially on the western side thereof. In the Purpurarias, where the topography is more subdued, relief less strong, necks and plugs are far fewer, having been subjected for longer time to erosion and the "flooding" of landscapes by Recent lava flows and sprinkled with pyroclastics.

Lastly we would mention even smaller volcanic structures, yet no less impressive. Spatter cories or hornitos (for some considered as synonymous terms, for others, hornitos are associated with pahoehoe lavas, of beehive shape and smaller than spatter cones) are seldom higher than 30-35 m, steepsided hillocks of welded scoria or spatter built by lava fountains, typical of basaltic eruptions. (Driblet spires are smaller still, shaped like thin columns or spires.) Though not large, spatter cones can command attention, being conical shaped dumps of chaotic volcanic ejectamenta. In the Montana del Fuego and the extreme N of Lanzarote, in the Tirajana valley of Gran Canaria, within the Las Cañadas depression in Tenerife, inside the Taburiente caldera of La Palma, to mention but a few places, many examples are to be seen of these volcanic forms, scarce grandiose or imposing, yet do catch the eye.

Dykes are extremely common in the Canary Islands, and indeed in parts of Fuerteventura, host rocks may total only some 5-10% of the ensemble the area,[17] of dense dyke swarms here being "... que puede ser considerada como una de las mas espectaculares del mundo ...". (Fuester *et al.*, 1968a.) Dykes are common almost anywhere, here and there have been weathered-out to become spectacular vertical or near-vertical veritable walls. A superb example to the NE of Frontera on the steep northern slope of El Golfo in Hierro involves a crumbling pinnacle some 60 m in height. Within the Las Cañadas caldera in Tenerife, several upstanding dykes occur, some of which are unstable and lean dangerously over. In the Betancuria region of Fuerteventura many weathered-out dykes dot the landscape. N of the Vallehermoso area in Gomera many dykes can be seen in coastal sections, some etched-out to form prominent walls.

From soaring summits such as Pico Teide to weathered-out dykes, a few metres thick, maybe up to 60 m in height, these volcanic eminences lend impressive variety to the landforms of these islands, all encompassed

17 correction made by author printer

within a total area of some 7500 km^2, and indeed are challenging analogues to the great volcanic Saharan terrains of an Ahaggar or Tibesti.

For general reviews of the geology of the Canary Islands, the writer would refer to Mitchell-Thomé (1976) and Rothe (1986).

CONCLUSION

Of the five archipelagos forming Macaronesia, that enchanted, fabled region W of the shores of Europe and Africa, the Canaries are the largest in area (7500 km^2), have the densest population (probably today ca. 1,400,000), the highest summit (3718 m) and lie closest to a continent, Africa being some 100 km E of Fuerteventura. Possibility propinquity to Europe-Africa caused them to first settled, long, long before Europeans set out to effect colonization, and thus, from what we can glean, peoples have dwelt longer in the Canaries than the other archipelagos. There is

ISLAND	PRESUMED AGES
Lanzarote	Early Miocene Pre-Miocene Eocene
Fuerteventura	Helvetian-Burdigalian Jurassic or Older Palaeozoic (pre-Hercynian)
Gran Canaria	Pre-Vindobonian Miocene Eocene Jurassic or Older
Tenerife	Between 2 - 12 MY Eocene Pre-Palaeogene
Gomera	Early Tertiary Pre-Cretaceous Jurassic or Older
La Palma	Pre-Miocene Jurassic or Older
Hierro	Less than 3 MY Pre-Vindobonian

Tab. VI. — Presumed Ages of Earliest Volcanism in Canary Archipelago. (As per Blumenthal (1961), Cendrero (1971), Fuster *et al.* (1968), Hausen (1955-73), Hernandez-Pacheco (1971) an echo of this attraction of peoples at the present day, for nowhere else within Macaronesia is tourism so popular.

Probably inhabited by aboriginals some 2500-2000 years B. C. ago, visited and inhabited by Europeans for ca. 600 years, these islands have been known and appreciated for a long time. Ever since the Italian poet, Torquato Tasso composed his pastorale "Liberated Jerusalem" in the 16th. century, one sees that glimpses of these islands have made lasting impressions. And even today, the hurried visitor with but perhaps two weeks to enjoy the islands, he or she never fails to be attracted by some aspect of the natural scenery.

A long history of repeated volcanism, the never-ceasing activities of Nature's modelling agencies, have moulded the islands into a kaleidoscopic pattern of landforms which in many instances imbue the onlooker, whether scientist or layman, with a sense of awe and wonderment. In the construction of towering summits and pinnacles and the carving of tremendous calderas and gorges, Nature displays both her constructive and destructive abilities, the sum total through the long geological years resulting in the wondrous and fascinating varieties of landscapes to be found in these islands, the Garden of Hesperides, the Blessed Islands of bygone days.

"Pour saisir les principales articulations du paysage, le morphologue doits sans cesse le confronter avec les explications possibles".

M. Derruau, 1958.

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