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SOME GEOMORPHOLOGIC ASPECTS OF THE CAPE VERDE ARCHIPELAGO

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With 8 figures and 3 tables

INTRODUCTION

The uninhabited Selvagens Archipelago excepted, the Cape Verde Islands are the least well known of the Macaronesian archipelagos to visitors and scholars alike.

Like all the Middle Atlantic archipelagos, that of Cape Verde is of volcanic constitution, like the others, sedimentary rocks occur, but in the Cape Verde island of Maio are significant thicknesses of Mesozoic sediments, indeed the oldest dated in Macaronesia.

Southernmost of the various archipelagos here, extending as far S as 15° latitude and 460 km W of the Saharan mainland, here also desert climatic conditions prevail which have resulted in catastrophic agricultural crises in the past. There has been a chronic increase in population especially during the past 35 odd years, and the present Republic suffers grievous economic, financial, agricultural and demopraghic problems.

Scenically the archipelago cannot compete with the grandeurs and charms of the Azores, Madeira, the Canaries, yet geologically Cape Verde can hold its own in interest, and the geomorphologist can find ample interests. We propose then to comment upon some landforms worthy of note, even although detailed geomorphological studies, by the writer or others, are all but non-existent.

CLIMATE, TOPOGRAPHY, RELIEF

The archipelago measures 4033 km^2, and lies within Köppen's "BWh" climatic zone, i.e. experiencing a dry, hot, desert regime, with potential evaporation exceeding precipitation throughout the year, and is thus linked to the desert areas of Northern Africa and the Middle East. Arid conditions and appearances characterize all regions below some 500 m, with mean

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annual temperatures over 18°C. Above this altitude, and particularly in areas exposed to rain-bearing winds, the aspect is less harsh, there is some greenness, in places even lush forests. Sal is the most barren, rainfall-deficient island, with an average annual of only 95 mm, yet in some areas,

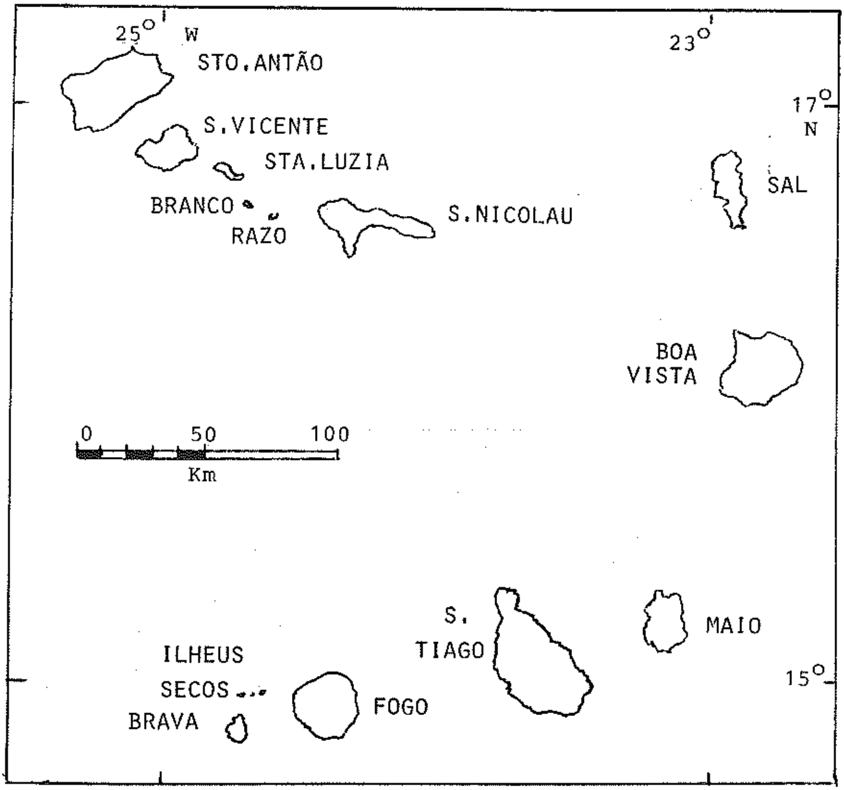


Fig. 1. — The Cape Verde Archipelago.

e.g. the NE sector of Sto. Antão, the average may total over 2500 mm — and in leeward localities only 20 km away, may be less than 200 mm the same year. Table I gives some average annual climatic data, and from this we see that, for the archipelago as a whole, average annual temperatures, rainfall and evaporation are 22.9°C, 348 mm and 1451 mm. There are many conflicting statements regarding permanent streams in the archipelago, a matter carefully considered by the author during his hydrogeological investigations of the islands (Mitchell-Thomé, 1960), and it can be confidently stated that in NE Sto. Antão are the ONLY two permanent streams — all

ISLAND		AREA Km^2	MAX ALT.m.	MAX.EXTENTS E-W,N-S,Km.		AV.ANN. TEMP.°C	AV.ANN. RAIN,mm	AV.ANN. EVAP.mm
St.Antão	§	779	1979	42.7	23.9	22.6	475	1580
S.Vicente	§	227	774	24.2	16.2	23.6	175	1614
Sta.Luzia		35	395	12.4	5.3	?	?	?
S.Nicolau	§	343	1304	44.4	22.0	23.9	200	1750
Sal	§	216	406	11.8	29.7	23.5	95	2180
Boa Vista	§	620	390	30.8	28.9	24.0	275	1150
Maio	§	269	436	16.3	24.1	23.6	373	?
S.Tiago	§	991	1392	28.8	54.9	21.6	455	1070
Fogo	§	476	1829	23.9	26.3	22.1	665	1770
Brava	§	64	976	9.3	10.5	21.5	400	500
Il.Razo		7	164	3.6	2.8	?	?	?
Il.Branco		3	327	4.0	1.3	?	?	?
Il.Grande		2	96	1.9	2.4	?	?	?
Il.Cima		1	77	2.4	0.7	?	?	?
Il.L.Carneiro		0.22	32	1.6	0.3	?	?	?

§ Inhabited Islands.

TABLE I.–Pertinent Geographic Data regarding Cape Verde Archipelago.

others are ephemeral. The NE Trade Winds dominate throughout the year, and the rainy period occurs between July and December, but at lower elevations one, two or more years might pass with no measurable rain at all. On the other hand, higher locations with NE exposures are invariably assured of rains annually.

On a topographic basis, there are two distinct groupings: (i) those islands which are mountainous, strong relief, fluvial erosion active, relatively little low and/or level land — Sto. Antão, S. Nicolau, S. Tiago, Fogo, Brava: those having a mild relief, smaller, lower, rounded hills, deposition is dominant, relatively wide extents of low and/or level land — Sal, Sta. Luzia, Boa Vista, Maio. S. Vicente occupies a somewhat intermediate position, here and there strong relief, elevations up to 774 m, but also wide extents of low, level land. In the first group, slopes can be extraordinarily steep, both inland- and coastwise. The gradient from Pico (2829 m, Fogo) down to the E coast measures 25°; slopes down to the SW coast of Brava average 27°; the NE aspect of Serra Pico do António (S. Tiago) has an average gradient of 29°; slopes on the N side of the Rib. Grande (Sto. Antão) average 41°, etc. By contrast, in the less robust islands interior slopes can be as low as 0°30' in Boa Vista; 0°35' in Sal; in S. Vicente slopes down to coasts of 0°45', and in Maio, 1°. In lower islands, prominent elevations — almost invariably scoria cones — ascend from the generally slightly rolling, barren landscapes. These differences within the archipelago in topography and relief, are less a reflexion of rock constitution and climatic regimes experienced, than in stage of development, i.e. age, the more subdued eastern islands being considerably older, where, e.g. Jurassic outcrops in Maio, whereas in the western, more rugged islands, it is questionable if rocks older than Younger Palaeogene occur.

CALDERAS

These large, (diameter at least 1.6 km = 1 mile) basin-shaped, oval or circular shaped volcanic depressions, no matter where found are impressive landforms. In Fogo is the outstanding, text-book example of such, Chã Caldera. The perimeter measures 30 km, maximum width 9.4 km, height of caldera rim (Bordeira), 2700 m, lowest elevation in caldera floor, 1625 m. (Mitchell-Thomé, 1980). This, unquestionably the premier scenic feature of the archipelago, presents a massive, unbroken scarp on the N, W and S sides, with outward slopes of 12°-18°, but on the E side, lava outpourings have over-brimmed and coursed right down to the sea during at least the eruptions of the 18 th., 19 th. and 20 th. centuries. (We have reasonably well-substantiated records of 25 major eruptions in Fogo since the year 1500.) (Mitchell-Thomé, 1981). The last eruption, during July-August 1951, has been admirably documented by Ribeiro (1960), along with magnificent photographs. The inner floor undulates slightly, and somewhat E-of-centre, slopes rise steeply upward to Pico, 2829 m, second highest mountain in all Atlantic islands, with a 500 m diameter crater at the sum-

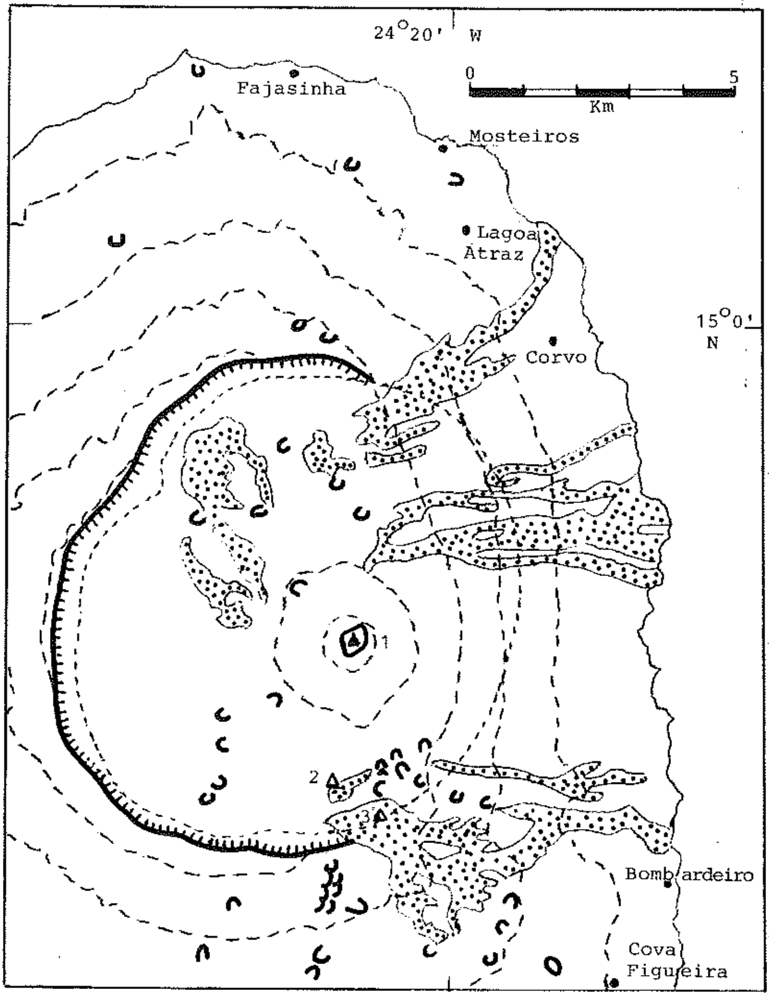
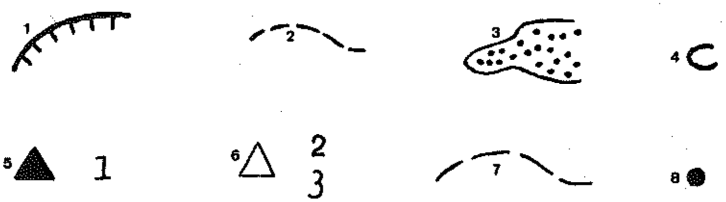


Fig. 2. — NE Sector of Fogo showing the Caldera da Chã and vicinity. (Modified after Machado & Assunção, 1965, Assunção et al., 1967). 1: — Caldera Rim (=Bordeira). 2: — Caldera Floor. 3: — Lava Flows of the 18th. and 20th. centuries. 4: — Craters. 5: — 1 Pico, 2829 m. 6: — 2 Mte. Orlando, 1930 m; 3 Mte. Rendall, 1815 m. 7: — Contours, equidistant 500 m. 8: — Villages.



mit and some 180 m deep, and final slopes up to 35°. (Mitchell-Thomé, 1976). The last volcanic outbursts sent lava flows streaming down the E sides to the sea, disrupting the circular island road, and leaving a black, chaotic mass of blocky lavas down the mountain side, devoid of all vegetation. This eruptive event also created two new summits, Montes Orlando and Randall, in the SE sector of the caldera floor, rising to elevations of 1930 m and 1815 m respectively. Pico entirely dominates the landscape of Fogo — indeed the entire island is naught else but steep slopes of a great volcano.

On the southern slopes in the W part of Sto. Antão lies a great depression, Chã da Morte, 6.6 km in diameter, caldera perimeter 20 km, height of caldera rim, 1750 m, lowest elevation in the floor, 525 m. Only the N and W walls are prominent, though land as high as 984 m and 1284 m on the E and S sides respectively, clearly outline the basin character, and, in fact, there is only a narrow exit in the SE side where the Rib. Patas manages to escape towards the southern coast. In spite of the sinister name (said to refer to the wiping out of the inhabitants during one of the many agriculture disasters affecting the archipelago) there are several hamlets and scattered dwellings within the caldera, for normally rainfall is adequate, the site is well sheltered, sunny, there are many springs and agriculture is relatively prosperous. There is a well developed network of centripetal drainage, which coalesces at the exit into the Rib. Patas, likely the longest valley in the island.

NE of Chã da Morte is another deep depression, rather similar in form, through which the Rib. da Garcia is directed towards the N coast. Here the walls are not precipitous though steep, at the S extremity elevations rise to 1660 m, to 1020 m on the E and to 1064 m on the W. In the southern half of the depression is a distinct centripetal drainage network, but northwards, the lateral walls approach each other, with one major valley carrying water towards the sea, and even within 500 m of the coast, land rises abruptly to 285 m, the valley here being some 500 m broad, valley walls much steeper on the E side.

True calderas are of volcanic origin, typically (in earlier stages at least) with precipitous walls, commonly forming pronounced scarps, but wall and floor forms and characteristics are of secondary importance. The older the caldera the more it has undergone trenchant erosion and mass gravitational movements, which obviously can greatly modify the original volcanic form. Whether then this Rib. da Garcia basin is a true caldera or then a depression developed via exogenic processes — perhaps an "Exogenic" Caldera — is not clear, but genesis apart, the feature is impressive and worthy of note.

In S. Vicente almost half of the island takes the shape of a large basin, open towards the N. This Porto Grande caldera measures 15.5 km from rim-to-rim, the perimeter totals 41 km, highest elevation thereof, 774 m (highest summit on the island), and the landform continues below sea level in the moon-shaped bay where Mindelo, the capital and chief port of the archipelago, is located. Bebiano (1932) spoke of a main central eruptive locus just S of the port, where a 2 km radius would outline a crater rim — presumably represented by Montes Pedra Rolada, Passarão and Socego, average elevations of ca. 126 m. He also mentioned a "large crater", presumably the present much greater basin which has the dimensions of a caldera. The writer Mitchell-Thomé (1960), Machado (1965), Serralheiro (1966), Assunção (1968) and Mendes-Victor (1970) have all contended that this extensive basinal form is a caldera. Agreed some of the above authors seem to prefer a subsidence origin, others emphasizing rather exogenic processes, chiefly marine and fluvial erosion. To the N, marine erosion has broken through the caldera rim and formed the sandy embayment of Porto Grande. Isobaths, especially the 50 m one, suggest a former extension of the rim seawards, the tiny Ilhéu dos Pássaros being an emerged fragment of the submerged N rim. It is only in the field that one can appreciate this large depression, for aerial photographs and large contour-interval topographic maps fail to impress the image of a landform of caldera type.

CRATERS

Also volcanic but of smaller overall dimensions, though equally imposing, are several well-preserved craters.

In eastern Sto. Antão, close beside the route which crosses the island from N to S, at a general altitude of ca. 1350 m, is a superb crater, Cova, 800 m in diameter, level grassy floor where cattle graze peacefully, lying some 225 m below the scarp-like encircling walls clothed in vegetation.

In NE Sal occurs a more unusual crater, Pedra Lume. This feature measures some 800 m in diameter and is in subterranean communication with the sea a kilometre distant, the crater surface having an altitude of ca. 30 m. Oceanic tides flush sea water into the base of the crater along a subterranean channel, this continuously replenished water being pumped to the surface and spread out into pans, and upon evaporation salt deposits are formed. The almost circular boundary of the pans marks the crater borders. Hence the unusual phenomenon of a crater being outlined by salt pans! Near the N coast of eastern S. Nicolau lies Chão de Marcel, a marked depression. This measures 700 m in diameter, floor lies at elevation of ca. 390 m, the rims to the N, S and W rising as high as 440 m, whereas to the E-SE, there is a gradual slope upward to Alto Joaquina, 619 m. Aerial photographs rather then the large contour interval topographic maps show this feature to perfection, and in the ground, it is indeed a marked landform. Further W in the island, Assunção (1968) spoke of "Uma cratera localizada no sítio onde se ergue presentemente o Monte Gordo.................", and indeed aerial photographs of the region do suggest a crater landform, but as the writer has not visited here he is unable to comment further.

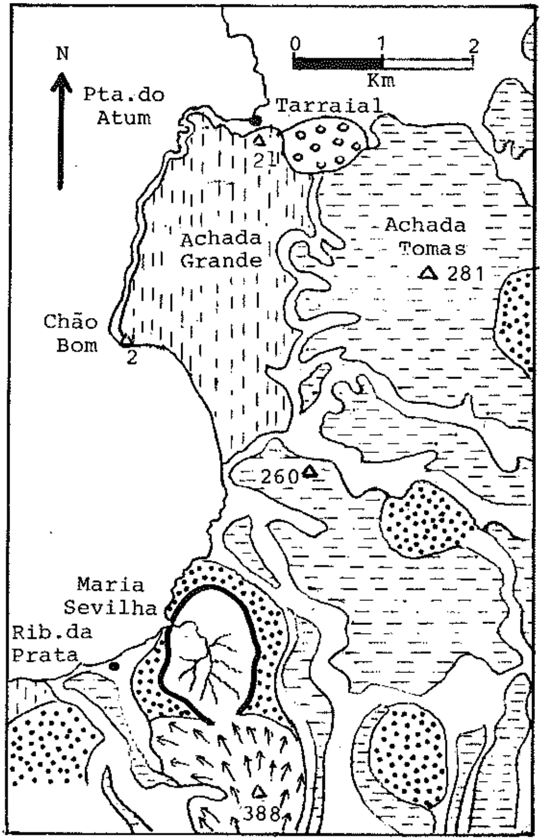
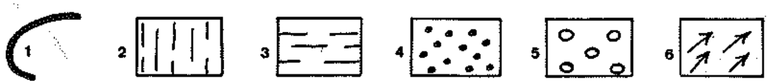


Fig. 3. — Morphology of the Maria Sevilha - Tarafal area, NW S. Tiago. (Modified after Amaral, 1964). 1: — Maria Sevilha Crater. 2: — Marine Abrasion Platform. 3: — Achadas. 4: — Eroded Volcanic Cones. 5: — Volcanic Cupola. 6: — Basaltic flows — 'tongue' of highly fluidal flows.



A truly magnificent crater is Maria Sevilha in NW S. Tiago. This measures ca. 1100 m by 1400 m from rim-to-rim, a dendritic drainage pattern of small valleys exiting eventually at the NW rim to the near-by coast. Viewed from the heights to the SE, this is a most imposing feature, with basaltic flows dipping seaward, intercalated with calcareous-cemented breccioidal tufa, also many limestone veins and stringers and lenses of sands-sandstones. On occasion the tuffs have a distinctly calcareous, limestone-like appearance. The relatively regular stratification suggests a submarine origin, the interior drainage having broken through the NW wall and allowing the sea to penetrate inwards a short distance.

Almost in the centre of Brava lies Fundo Grande, the flat, circular floor of which lies at ca. 875 m altitude, the crater measuring 750 m in diameter. The northern rim rises steeply to Fontainhas, 976 m, highest elevation in the island, and peaks rising to 900 m occur on the S and SW borders. Whether from the ground or the air, this striking depression high up in the central plateau ("Campos"), bordered by superb canyons and very steep slopes down to peripheral seas, makes one think of a gigantic bomb crater.

In the Cape Verde archipelago, neither calderas nor craters are as plentiful and/or as spectacular as those of the Azores, lesser so Madeira, and nowhere do these possess lakes — indeed, nowhere in the archipelago are there standing bodies of water, natural or artificial.

AEOLIAN ACTIVITY

Wind, like other agencies, erodes, transports and deposits. Erosion may be via deflation, the removal of loose particles by lifting or rolling; or then abrasion may be effective, where particles act as cutting tools and wear away rocks by friction — the 'sand blast' effect. We have said that in the archipelago at levels lower than ca. 500 m, a desert-type climate prevails, where aridity is the hallmark. The de Martonne Aridity Indices vary from 85.9 (NE exposed coast of Fogo at 1300 m) to 2.0 (Sea level, SW coast of Sto. Antão), with an archipelago average of 13.4. Wandering over the level or slightly undulating terrains at lower elevations, the barrenness, aridity is comparable to many Saharan areas, and all that is lacking are camels and bedouins.

In all islands, the NE Trade Winds dominate the year through, followed by those from the E, SE and N in that order, i.e. Saharan influences are significant. Calm days are few and far between, with average estimated wind velocities of ca. 40 km/hour. The usual aggitated state of the surrounding seas, and in more littoral areas of the islands the commonness of blurred visibility through dust-sand particles in rapid motions, testify to far from quiet circumstances. Naturally island location and the topographic-relief character influence wind strength, southern areas invariably being somewhat more sheltered, NE regions most exposed.

Areas where vegetation is scant or non-existent and also beaches provide ideal places for deflation to operate. Here, rock material is blown away, perhaps to far distances out to sea (aeolian sands originating in the Sahara can be proven in the archipelago), but the principal result is to create deflation basins or depression of deflation armour. It is likely

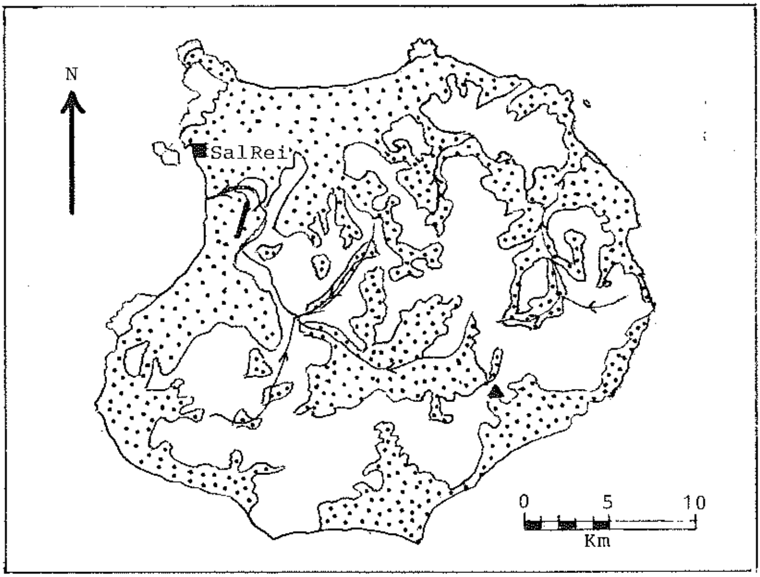
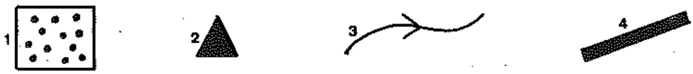


Fig. 4. — Boa Vista, showing areas where sand sheets, fossil and active dunes, and lesser so, valley alluvial sands, outcrop. 1: — Areas where arenaceous sediments outcrop. 2: — Highest elevation, 390 m. 3: — Major streams. 4: — Landing field.



that the majority of basinal or hollow areas in the islands are so developed by this lifting and removing action, e.g. the region of Porto Grande, S. Vicent, in NW and NE Sta. Luzia, in NW Maio (Terras Salgadas), the basinal valley of the Rib. Rabil in Boa Vista, the large, S-sloping basinal area of southern Sto. Antão, etc. That the deflating process can develope immense basins is witnessed by the Qattara Depression of Egypt, some 300 km long and 140 km broad, scalloped out to a maximum depth of 134 m below sea level.

The removal of finer particles (fine sands, silts, clays) leaves coarser material in place (gravels, pebbles, cobbles, boulders) which have been so concentrated due to this winnowing process chiefly by deflation, so creating a deflation armour or desert pavement. This is analogous to the formation of hammadas in true deserts, but in the Cape Verde Islands, such pavements never have the extremely coarse, chaotic appearance of hammadas. In no sense can deflation armoured surface be confused with duricrusts, case-hardened crusts of soil formed by the precipitation of salts at the ground surface via evaporation, and which may, on occasion in these islands, e.g. Sal, Boa Vista, Maio, reach thicknesses of more than a metre, though more generally are only ca. 5 cm thick, forming hard, impermeable surfaces, prohibiting the infiltration of water and thus robbing the groundwater of its quota.

Abrasional effects of wind are best observed in the archipelago where cliffs or steep slopes of bedded sediments, pyroclastics, flows are exposed to constant winds charged with sand particles. In many parts of Maio, in the Tarrafal Bay area of S. Tiago, by Monte Verde in S. Vicente, along the N coast of eastern S. Nicolau, etc. abrasional attacks can be clearly noted. On the other hand, the author has seen relatively few examples of well-formed ventifacts, most being noted in the N-NE coastal areas of Sal. As abrasional erosion is more constant within the archipelago than sporadic fluvial erosion, the role of the former is manifest in the many "orgãos" — almost perpendicular topmost parts of prominent peaks, the weathered remnants of volcanic necks. Excellent examples occur at Pico de João Teves and Monte Bedela, S. Tiago; Pico do Vento, S. Vicente; Monte Penoso, Maio; valley of the Rib. Paul, Sto. Antão; plentiful in the mountainous western part of S. Nicolau, etc. Pedestals and perched boulders seem relatively rare, but in eastern Boa Vista several imperfect ones occur, rising ca. 10 m above the surrounding terrain and with "waists" ca. 5 m in diameter, e.g. in the Lomba do Baluarte and Chão de Calheta regions. Pedestals require almost equal development of winds from all directions in order that the form be moulded with a narrow "waist" and spreading outwards further up beyond the reach of sand-blast action, the most violent abrasive effects being felt in the lowermost 50-100 cm up from the ground surface.

Both fossil and active dunes are common in the archipelago. The former are well expressed in SW, NW and E Maio, Palha Carga of the S coastal region of S. Vicente and around Salamanza in the NE of the same island; near Palmeira, Serra Negra and Palha Verde, Sal; scattered areas throughout Boa Vista, etc. A fine example of fossil dunes is in Maio. At Montinho de Lume, N of the capital Vila do Maio, calcareous sands form a small hill rising to 45 m, upper exposures showing excellent cross-bedding of paper-thin beds wrapping round the upper heights. A similar fine example is near Lomba da Vigia, where again cross-bedding is found at elevations of some 75-110 m.

Of greater significance are the living dunes, well represented in Sal, Boa Vista, Maio, lesser so in Sto. Antão, S. Nicolau and S. Tiago. In Boa Vista these have their maximum development, and are most obviously "on the march". In the general area of the capital Sal-Rei, active dunes seriously interfere with communications — trails, routes and former landing field, tend to smother the pitiful attempts at gardening and crop growing, no less hinder the exiting to the sea of the Rib. Rabil. Years ago when the landing field was on the edge of town, several times the writer could not take-off or then land by plane because of moving dunes covering the airstrip up to sand thicknesses of 50 cm, and vicious gusts of wind reduced visibility to almost zero. (The more modern landing field at Rabil, some 6 km to the SE, is only slightly better in this respect, but still drifting sands are a common problem.)

Dunes comprise sands, and sands are noted for their good porosity and permeability, hence repositories of groundwater. At Boa Esperança and in the valley of the Rib. Talho, Boa Vista, constructions were made to improve the seriously inadequate water supplies of the capital and nearby villages. At the former locality, a gallery was built, 32 m long, 0.5 m broad, 0.75 m high, gallery roof 3 m below ground surface, in order to tap and concentrate waters infiltrating the dunes. Even after a 9-month dry spell, as much as 480 m^3 water daily, drawing upon a radius of 500 m, was dispatched along concealed pipes and thus led, by gravity flow, to the capital. Some 90 km^2 of Boa Vista comprises dunes and sand sheets. The author (Mitchell-Thomé, 1960) estimated some 3 million m^3 water could be obtained annually from dune areas, and considering that by 1985, 4700 m^3 water is needed daily on the island for the estimated 4400 inhabitants, thus representing an ample supply of water needs, even on this dry island whose average annual rainfall is only 275 mm.

Nowhere within the archipelago are dunes as impressive as in many continental desert regions, either as regards heights, lengths or volumes — here these seem to average ca. 10 m in height, 75 m in length. But finding one's self in the midst of dune country does indeed give the impression of being in a true desert environment.

Much more extensive in area, especially in Boa Vista, are sand sheets, defined by Bagnold (1941) as "wide extents of sands, may be flat or undulating or then diversified with more or less crude examples of dunes...........", composed of sand below a critical grade of size which can withstand erosion by wind, forming somewhat powdery sheets which behave as if they were smooth. Within the archipelago are tens of square kilometres of loose sands usually but a few centimetres thick, on occasion thicker accumulations forming dunes, and projecting above the sand surface are boulders, cobbles, pebbles, here and there stunted plant growths, giving a tawny, barren, so often empty landscape. Sheets invariably are thicker in hollows, thinner on more prominent rises, their distribution and disposition being governed by winds. They can be most uncomfortable to traverse when strong or gusty winds are blowing, creat-

ISLANDS		LEVELS (m)	STRATIGRAPHIC CLASSIFICATION
Sto.Antão		3-6	
S.Vicente	§	2-6	
Sal	§	2-6	
Boa Vista		3-4	Flandiran
Maio	§	2-6	
S.Tiago	§	2-6	
S.Nicolau		3-4	
Sal	§	7-12	
Sal		13	
Boa Vista		10?	
Maio	§	7-12	Neo-Tyrrhenian
S.Tiago	§	7-12	
Brava		8-10	
Ils.Secos		Ca.10	
Sto.Antão		Ca.17	
S.Vicente		15-20	
Maio	§	15-25	Eu-Tyrrhenian
S.Tiago	§	15-25	
Sal	§	30-40	
S.Vicente		28-35	
Maio	§	30-40	Palaeo-Tyrrhenian
S.Tiago	§	30-40	
Brava		35-37	
Sal		55	
Maio	§	50-60	
S.Tiago	§	50-60	Sicilian II
Fogo		50-54	
S.Nicolau		70-90	
Maio	§	80-100	
Fogo		Ca.100	Sicilian I
Brava		Ca.95	

TABLE II.-Raised Marine Benches in Cape Verde Archipelago.

(§ = those reported by Lecointre & Serralheiro) ing whirling duststorms, sandstorms, and so often very rough and awkward to walk over. And here we might mention the notorious Harmattan winds blowing out of the Sahara. These dust- and/or sand-laden, searing, hot, dry winds, mercifully infrequent and of relatively short duration, but liable at any time of the year, though commonest during July-September. Such winds have a devastating effect upon all agricultural pursuits, wilting and withering plant life with catastrophic economic consequences. Humans and animals no lesse become extremely nervous, restless, bad-tempered.

RAISED BENCHES AND MARINE ABRASION PLATFORMS

Regarding the former, we define a beach "as a deposit of sand, gravel or cobbles, formed inshore from the zone of breaking waves by the action of swash and backwash". (Strahler, 1967). But it is very rare indeed to find anywhere contemporary loose material of this type resting on exposed surfaces, and we agree with Cresswell (1967) that raised 'beach' is a misnomer and should rather be referred to as a raised bench.

As per Lecointre (1963) and Serralheiro (1966, 1967, 1968), raised benches in the archipelago occur as per Table II, to which are added further examples recognized by the author.

One might raise some questions as to the validity of such in some instances, but it is well established that raised benches up to 100 m above present sea level can be found in some islands, that the youngest and lowest bench, the Flandrian, is better substantiated and more prevalent. Though when viewed in profile from greater distances, some have the appearance of partial "achadas" and conform to "fajãs" (see below) in location and altitude, the more uniform surface and lesser slopes of benches serve as distinction, whilst closer inspection of the lithology, stratification, etc. of the two latter forms confirm dissimilarities. It was the belief of Serralheiro (1968) that most benches in southern Maio and S. Tiago could be explained by the constancy of the dominant NE winds. This would explain the absence of higher benches in the northern sectors of these islands, whilst central higher regions sheltered benches in southern areas from marine attack, being more subject to fluvial erosion effects.

Fluvial benches or terraces are noteworthy in some islands. In Sto. Antão, Bebiano (1932) drew attention to such near the mouth of, the Rib. Grande, in the NE, lying between 10 m and 20 m above present sea level. Further up this same valley, the writer has noted benches 28 m higher than sea level and 8 km from the coast. It is worth recalling that the only two permanent streams in the archipelago, the Ribeiras Paul and Janela, also in NE Sto. Antão, have benches trending upstream for some 2 km from the coast and at ca. 2 m above high flood mark. In general, benches along valleys are better preserved in islands where the relief is more subdued, valleys broader and not deeply incised. Hence they are best exemplified in Sal, Boa Vista, Maio, varying in elevation above sea level from ca. 30 m to 12 m, and in the case of the Rabil valley in Boa Vista,

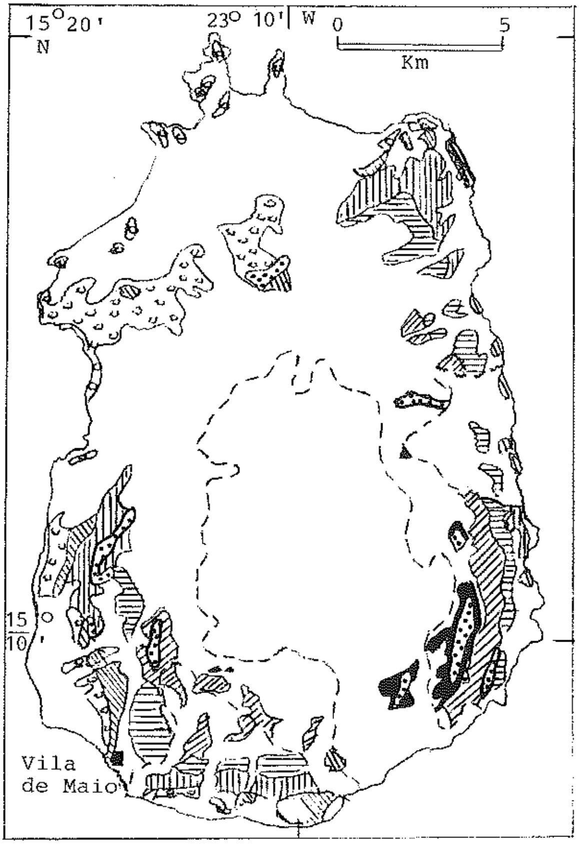
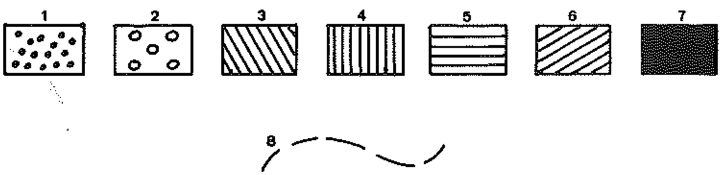


Fig. 5. — Map showing extent of Old Marine Benches, Maio. (Modified after Serralheiro, 1967). 1: — Fossil Dunes. 2: — 2-6 m Bench. 3: — 8-12 m Bench. 4: — 15-20 m Bench. 5: — 30-40 m Bench. 6: — 50-60 m Bench. 7: — 80-100m Bench. 8: — Approximate extent of exposed igneous rocks.



can be found as far from the mouth as 25 km. Generally fluvial benches are not broad, but frequently show stepped developments, e.g. those valleys trending NE towards Terras Salgadas in Maio, where three levels between ca. 3 m and 10 m display stepped profiles.

ISLANDS	ELEVATIONS (m)
Sto.Antão	2 3 3.5-4
S.Vicente	2-2.5
Sta.Luzia	2 2.5 3
S.Nicolau	3.5 4?
Sal	2.5 3
Boa Vista	2-4
Maio	2 3.5
S.Tiago	3-4.5 3.5 4
Fogo	3.5-4
Brava	2.5 4 4.5?
Ilheus Secos	2

TABLE III.-Marine Abrasion Platforms in the Cape Verde Archipelago.

Bebiano (1932) described the first-known marine abrasion platform in the archipelago, that at Ponta do Sol, NE Sto. Antão. Here a small level surface, 3 m above high tide, comprises a calcareously-cemented conglomerate composed of marine Gastropoda and Bivalvia shells. The very exposed location of the platform means that much of the time, high or rough seas hurl spray on to the platform, seas always washing over it, in other words, marine attack is vigorous.

Table III indicates where marine abrasion platforms have been noted in the archipelago, and doubtless this is not a complete compilation. It is seen that all these have elevations consistent with those of Flandrian raised benches, that nowhere seemingly are higher platforms present. If indeed such were formed, then active erosion leading to the blanketing of such by-débris, plus the effects of vulcanism with lava flows and pyroclastics, have concealed their presence. This is in contrast to the Azores, where in the older islands of Sta. Maria and S. Miguel, Sicilian-Calabrian marine abrasion platforms occur at elevations of 50 m to 200 m above present sea level. (Mitchell-Thomé, 1980). It is well known that the Azores is a highly seismic, unstable archipelago, positive and negative vertical movements pronounced, whilst on the other hand, vulcanism apart, the Cape Verde archipelago has shown relative stability. The highest occurrence of marine sediments in the latter is 265 m in Maio (Mesozoic limestones), whereas Miocene marine limestones outcrop at 400 m in Sta. Maria (Azores) and in Madeira, perhaps ca. 275 m for Neogene sediments in Fuerteventura and 500 m (?) for Pliocene deposits in Hierro, both in the Canaries. If indeed uplift by isostatic recoil is thought to have been the major cause of uplifts in the Macaronesian archipelagos, as several authors proclaim, then such has been much less powerful in Cape Verde than in other archipelagos. (See also Achadas below.)

ACHADAS

As distinct from other Macaronesian archipelagos, achadas (sometimes abbreviated to chas) or, if of smaller dimensions, achadinhas, are very common in Cape Verde. This Portuguese word has been given various interpretations: "elevated plains", "plateaux", "structural surfaces", "structurally-raised more level areas", "tablelands", "upland planated surfaces", "scarp-bordered uplands", but all combine to render a common concept of the forms in question. It is indeed strange to find Agostinho (1938) remarking that such are rare in the Azores "por causa de vulcanismo" for igneous rocks and volcanic forms and products overwhelmingly predominate in all Macaronesia, the Azores no less than other archipelagos. But only in Cape Verde do achadas-achadinhas assume unusual importance — in some islands at least. Characteristic of achada-achadinha terrains are the quasi-horizontality of the rocks or then with coincident slopes-dips and cross-profiles tending to be slightly convex — in other words, structure is not only significant but controlling. Serralheiro (1976) speaking specifically of such landforms in S. Tiago, stated that such resulted from very fluid lava flows, with slopes varying between 2° and 10°, though in coastal achadas the aspect is quasi-horizontal, being originally "planuras". Canyon development can dissect these tabular surfaces to dimensions comparable to mesas, even buttes. There are many more achadas and achadinhas, no less more clearly distinguishable, in S. Tiago and Sto. Antão than in other islands, which sets one wondering if sheer area may have some influence in development, for these are the two largest islands in the archipelago.

The excellent volume by Amaral (1964), with copious maps and photographs of S. Tiago, plus the many pages devoted to geomorphologic descriptions, represents by far the longest, most detailed account of landscapes on any of the islands. Some 70% of the island is formed of achadas-achadinhas, usually restricted to regions less than 500 m altitude, such landforms commonly ranging in elevation from ca. 75 m to ca. 500 m. Only the higher W-E trending Serra Malagueta and the NW-SE oriented higher topographic axis from Malagueta for some 30 km to the SE, are devoid of achadas-achadinhas. Thus we have ca. 700 km² of the island formed by such features, an unusually large proportion for the archipelago, though in Sto. Antão the percentage may perhaps reach ca. 50%. The peripheral arrangement of achadas-achadinhas in S. Tiago commonly extends very close to shorelines, with cliffs fronting the sea. But here and there, e.g. in the Tarrafal region, N of Porto Rincão, between Cidade Velha and Praia, between Porto de S. Francisco and Na. Sha. da Luz, in the vicinities of Pedra Badejo and Calheta, etc., instead we find marine abrasion platforms and raised benches intervening between achadas and shorelines. Figs. 6 & 7, adopted from Amaral, give good impressions of these landforms, and Fig. 8, taken from Serralheiro (1971), illustratetes his conception how the achadinha of Praia evolved, whereby an inversion of volcanic relief has taken place. Trenchant fluvial erosion from infrequent but severe rains result in canyons, vigorous vertical corrasion cutting down through more resistant lava flows and more rapidly eroding into the softer pyroclastics below. No less, strong wave attacks by almost incessant aggitated seas cause profound cliffing to yield further very abrupt terminal slopes. In higher areas, where canyon-development is less pronounced because of reduced erosive ability due to lesser water volumes, the mantle of pyroclastics is thicker, so that in general achadas-achadinhas gently merge into higher slopes — in other words, these tablelands are commonly bounded on three sides, lower and lateral, by prominent breaks in slope, though many four-sided forms also occur where subsequent drainage into the main consequents developes a fourth very abrupt slope.

In S. Nicolau, various maps presented by Nunes (1962) are an extra aid in determining these tablelands, but often the use of the term "Chã" on the topographic map of the island refers more usually to gentle slopes upward from coasts to ca. 100 m, and tabular character is less well repre-

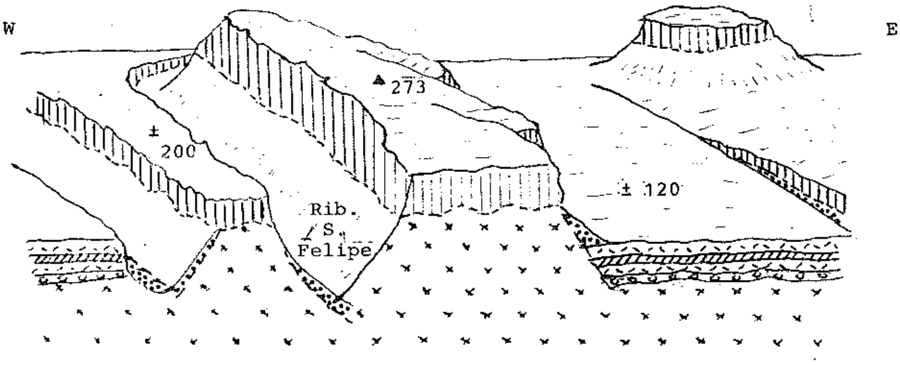
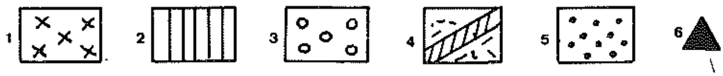


Fig. 6. — Panorama and schematic geological profile of the area around Monte S. Filipe, southern S. Tiago, showing development of Achadas. (Modified after Amaral, 1964). 1: — Pico do António Eruptive Complex. (Mio-Pliocene). 2: — Basaltic Scarps. 3: — Fossilized Soils. 4: — Basaltic Flows and Pyroclastics. 5: — Scree Depostis. 6: — Monte S. Filipe.



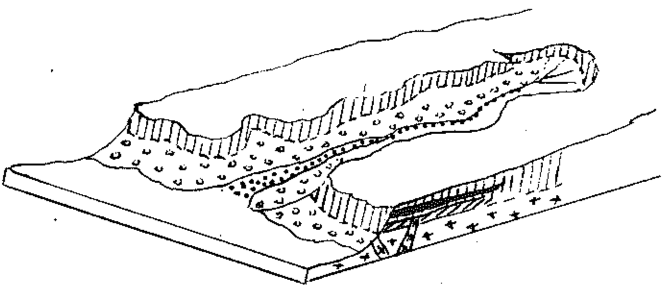
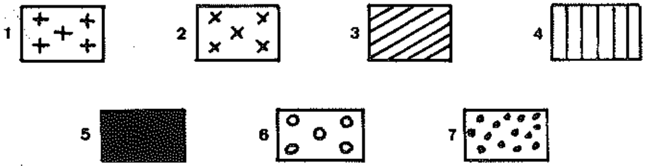


Fig. 7. — Block Diagram and schematic geologic cross sections showing a valley in Achada terrain. (Modified after Amaral, 1964). 1: — "Basal Series". 2: — Dykes. 3: — Pyroclastics. 4: — Basalte Scarps. 5: — Sedimentaries. 6: — Scree Deposits. 7: — River Alluvium.



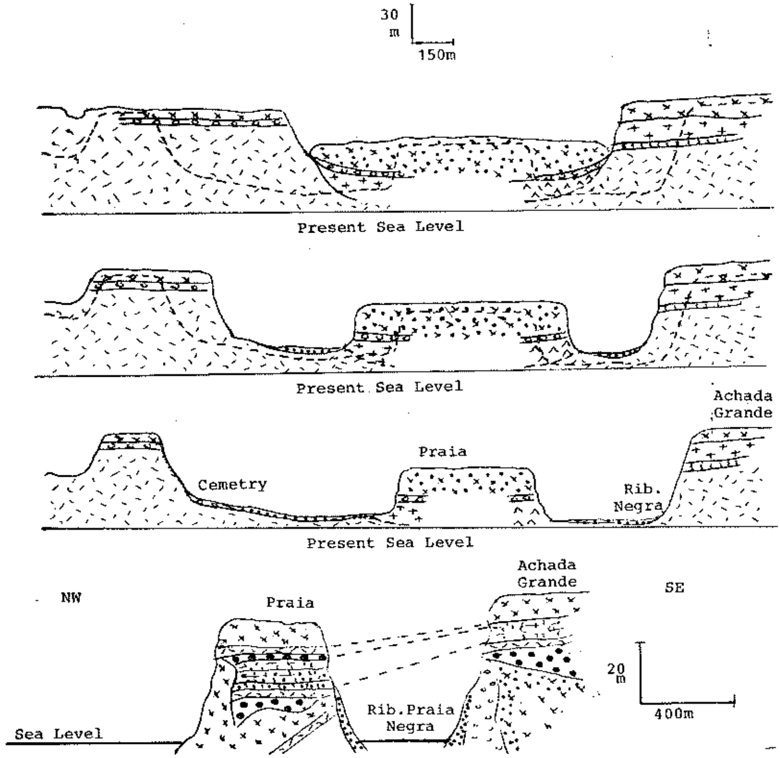
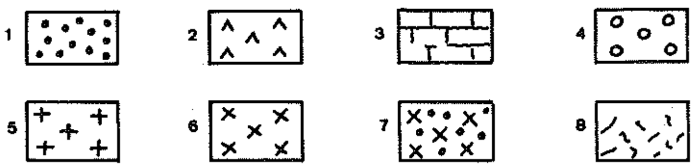
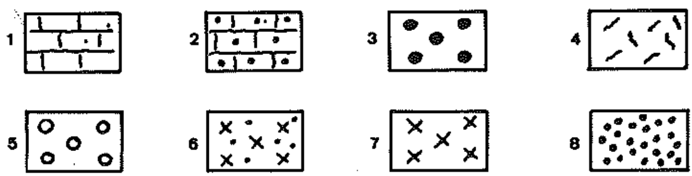


Fig. 8. — Evolution of Achadas in area of Praia town, S. Tiago, (1, A. B. C.) (Modified after Serralheiro, 1971), and Geological Interpretation of Praia-Grande Achada, as per the author (Mitchell-Thomé 1976). (1) 1: — River Alluvium. 2: — Calcarenites. 3: — Limestones. 4: — Conglomerates. 5: — Pillow Lavas. 6: — Lavas of Pico do António Eruptive Complex (Mio-Plio). 7: — Younger Lavas, same complex. 8: — Old Internal Eruptive Complex (Pre-Miocene). (2) 1: — Limestones. 2: — Sandy Limestones. 3: — Tufa. 4: — Agglomerates. 5: — Volcanic Conglomerates. 6: — Basalts and Pyroclastics. 7: — Basalts. 8: — Scree Deposits.





sentend — they might be termed "pseudo-achadas". Campo de Preguiça, where the landing field occurs, is of achada form, bounded on the W by a prominent fault-scarp, the fault-block to the W being upraised to heights of 250 m whilst the Campo has an average elevation of 200 m. Another good example on the island lies in the extreme E, where Terra Chã, rising to some 130 m and terminated by a strongly cliffed coastline, is a pronounced landform when seen from land, sea or air. Achada Cegueirinha on the NE coast is also a good example.

The topographic map of Sto. Antão refers to many "Chãs", both peripheral and in the interior, the majority of which conform to the concept of tablelands or plateaux, though as regards quite a few coastal occurrences, these are rather coastal plains sloping quite strongly seaward. The best example is Chã de Lagoa, a relatively even surface, average elevation 1200 m, 2.5 km broad and 9 km long, forming the drainage divide in this part of the island. Only northern slopes are abrupt, much less so to W and E, whilst southwards the gentle declevity averages ca. 7°30'.

The NE and SE sectors of S. Vicente have quite extensive tableland areas fronting the coasts, but in this older, more extensively eroded island, achadas are less than 100 m in altitude. In the Salamanza area, covering some 12 km^2, the boulder-cobble strewn land is remarkably flat, imperceptibly sloping down to sandy beaches to the SE and rocky coasts to the NW, devoid of all drainage channels. Only on the SW border of this area represents rather a pediment, a very gently inclined planate erosion surface carved in bedrock with a veneer of coarse erosion products originating in the higher terrain to the SW.

In Sal, the central-eastern Lagedos of Espargos (where the international airport is located), Rib. de Tarafo and Socorro all have a tabular appearance, average elevations between 50 m and 60 m, in all cases serving as drainage divides, though Lecointre (1963), speaking of the small island in general, spoke of "un plateau d'altitude variant de 30 m à 50 m", with lower platforms ca. 10 m in altitude, above which rose volcanic eminences.

On the smaller island of Sta. Luzia, tabular platforms lie in both the NW and SE coastal regions, but here, as in the islet of Razo, though the topographic map refers to several "Chãs", these have more the appearance of normal coastal plains.

In Brava, smallest of the inhabited islands, are several distinctive tabular landscapes — Achadas Favatal, Figueiral, Figueirinha, Burras Brancas, usually lying between 200 m and 350 m elevation, the first-named, near the N coast, being used as a landing field — one of the very, very few low, level areas occurring in this precipitous island.

Fogo shows morphologic features of achada-achadinha characteristics, especially well observed along the N and E coastal sectors. Inland from shores here for distances up to ca. one kilometre, the more typical steeper-sloping achadas rise abruptly, composed entirely of lava flows. Between this abrupt inland rise and the shore are level, even surfaces, only a few metres above sea level, locally known as "Fajãs". These are of two types: (i) erosional features involving pyroclastic-talus materials, and (ii), low, step-arrangement of lava flows. Assunção (1968) defined a fajã as a level tract of land close to sea level, wedged between the shore and steeper rises inland, whereas Agostinho (1938), referring in particular to the Azores, defined such as planated areas below cliffs, formed of materials which detach themselves from said cliffs — i.e. talus material. In the volcanically young island of Fogo, the entire slopes outward from the central locus of eruptivity are formed of lava flows dissected into longitudinal 'blocks' by the quite dense radial network of valleys. But as a general rule, the degree of land slope or then dip of these flows is much greater than what is more commonly considered achadas, and perhaps it were safer to use the term "achadas" in inverted commas. In Fogo excellent examples of fajãs, backed by achadas, are to be seen as Fajãsinha, Mosteiros, Lagoa Atraz and Bombardeiro, all have N and E coast locations.

Serralheiro (1976), writing specifically of S. Tiago, claimed that littoral achadas-achadinhas are due to fossilization of lava flows, that such in fact are Quaternary marine abrasion platforms, covered by sediments, having more regular, even surfaces than the more corrugated achadas at higher levels. The writer would stress this difference in surface expression between inland, higher achadas, and lower, littoral ones. Further, coastal achadas have steeper slopes than marine abrasion platforms, where slopes of ca. 0°30' typify the latter, and from ca. 2° to 8° for the former. Also, marine abrasion platforms are bounded landward by notches and/or sea cliffs, the height of the latter depending upon the stage of cliff formation. Marine abrasion platforms result from wave action, hydraulic mechanisms rolling rock débris back and forth, so that eroded products are well-rounded, tend to be coarse with little winnowing effects, and perhaps covered with later sediments. The mode of origin, lithology, granulometry, structure and geometric character of such platforms differ from achadas, and thus the writer would disagree with Serralheiro that littoral achadas are actually Quaternary marine abrasion platforms.

The relatively short, sporadic wet season in the archipelago has rains of great intensity, whereby longitudinal deep furrows are carved, vertical erosion ever dominant over lateral. Hence canyon-type valleys are characteristic in the more mountainous islands with strong relief. Most achadas-achadinhas are laterally bordered by gorge-like valleys, and tributary valleys, and tributary valleys impose a third-side. Successive erosion along these directions can carve-up the planated surfaces into smaller and smaller areas. Throughout the history of these landforms, the upper surfaces maintain their near-vertical slopes effected largely by mass gravitational movements (landslides, rockfalls, slumping, etc.), with gentler scree slopes below, thus areally reducing achadas to achadinhas, to mesas, even buttes — mere flat-topped, near-vertical sided pinnacles. Characteristically, planated achada surfaces comprise lava flows, almost invariably surface rocks involve thicker, more resistant extensive flows overlying a complex of pyroclastics and older flows. Thus these landforms are in reality the results of erosion acting upon flows surficially exposed resting on other volcanics. Lava flows being volcanic structures, it is thus permissible to refer these landforms as erosional effects upon volcanic structures. Seaward slopes of flows provide initial smoother surfaces into which streams have excavated deep, narrow valleys, thus splitting-up said surfaces into tablelands of varying dimensions. Such landforms commonly rise in elevation inland to dovetail into higher, non-tabular slopes, and coastwise are bordered either by more gently-sloping littoral plains or then by sea cliffs. The relatively younger, high, more rugged islands display these landforms more clearly than lower, more subdued islands. Sheer area as well as extremely strong relief appear to be factors favouring achada-achadinha formation, surface expressions of lava flows occurring throughout.

CONCLUSION

Volcanic landforms set in a desert environment have a fascination all their own. Commonly, in temporal geological terms, their evolution is interrupted by renewed volcanic activity, violent or then more quiescent, so that new showers of pyroclastics, new outpourings of lava, new volcanic structures, edifices, depressions are formed. Hence the cycles of erosion produce particular characteristics, so often the landforms are unique — indeed, many "are a bit larger than life", fantastic in shape, awesome in dimensions.

The marine milieu of the Cape Verde archipelago must obviously ameliorate somewhat arid conditions, yet lower terrain in these islands, both scientifically and scenically acquires landscape features synonymous with deserts. In a sense, islands experiencing desert climatic regimes, are anachronisms, certainly in the popular mind, where the more humid oceanic ambience might be thought to counteract barrenness. It is indeed true that in this archipelago, the arid morphology is less clearly expressed, not quite so harsh or impressive as in the neighbouring Sahara with its breathtaking volcanic forms in such areas as Adrar des Iforas, Ahaggar, Air, Tibesti, etc. Yet volcanic islands experiencing a desert-type climate are indeed infrequent, are more "off the beaten track", more lonely less developed, less known to the public at large. The Cape Verde archipelago therefore, located in the world's busiest ocean, where shipping and aerial routes pass close by, where ships and planes call, is conveniently placed geographically for the visitor, whatever his interests. Fortunately to date these islands are not swamped by tourists, one will find none of the garish, gaudy attractions to lure the "package tour" travellers. Life here is cruder, far from ostentatious, is led at a slower, more dreamy pace, inconveniences are perhaps more apparant, but as a worthwhile compensation, there is the undeniable charms of both the peoples and the landscapes. Most assuredly the scientist, whatever his field, can find infinite pleasure in probing further into the mysteries of Nature, and if Geology is his interest, there are ample opportunities for study, for all aspects of such are known only in reconnaissance fashion.

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