THE CAPE VERDE ARCHIPELAGO AND AFRICAN AFFINITIES

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With 11 figures and 4 tables

RESUMO. A proximidade de Cabo Verde e outros Arquipélagos do NE do Atlântico dos continentes Europeu e Africano, levaram, desde há muito, os homens a pensar se no passado estes estiveram unidos a estes continentes e são agora meros fragmentos isolados.

No presente trabalho, são investigadas caracteristicas biológicas, estratigráficas, ígneas, estruturais, geológicas e batimétricas das ilhas de Cabo Verde e da parte oposta do Continente Africano com uma breve revisão da Geologia do arquipélago.

A estratigrafia do Mesozóico-Neogénico Superior das ilhas, bem como as litologias, quando comparadas às áreas continentais, assim como amostras da cresta na área oceânica entre o continente e o arquipélago, mostram semelhanças significantes. A petrografia, petroquímica e a petrogénese dos arquipélagos de Cabo Verde e de Los (o último ao largo de Guiné) mostram uma boa correlação relativa e a petrografia de Cabo Verde e da África Oriental mostram muitas semelhanças.

Estudos sísmicos e de gravidade, no oceano e em terra, nesta região geral, apontam para continuidades, nestas propriedades, do arquipélago para o Continente.

Não existe, no presente, nenhuma evidência, de qualquer origem, que permita postular que o arquipélago é uma parte destacada do continente Africano, que teve uma história geológica semelhante ao continente africano.

Propinquidade **per se** não é indicação de consanguinidade.

ABSTRACT. The closeness of the Cape Verde and other E. Atlantic archipelagos to the mainlands of Europe and Africa have long set men wondering if they might have been in the past united with the continents, and are now merely isolated fragments.

Here enquiry is made into biologic, stratigraphic, igneous, structural, geophysical and bathymetrical characteristics of the Cape Verde islands and the African mainland oppositte, with a brief review of the geology of the archipelago.

The Upper Mesozoic-Neogene stratigraphy of the islands, as well as the lithologies, when compared to mainland areas, as well as deep core sites in the intervening oceanic area, show significant similarities here and there. The petrography, petrochemistry and petrogenesis of the Cape Verde and Los archipelagos (latter offshore from Guinea) show relative good correlation, and the petrography of Cape Verde and Eastern Africa shows many similarities. Gravity and seismic studies of ocean and land in this general region point to continuities in such properties from archipelago to mainland.

There is no evidence available at present from any source which would allow one to postulate that the archipelago is a detached part of the African continent, that it has undergone a geological history similar to the neighbouring African mainland. Propinquity **per se**, is no indication of consanguinity.

INTRODUCTION

The Middle Atlantic Islands, W of the European-African mainlands, since the days of Antiquity have invited speculations as to whether or not they may be outposts of these continents, and even today, Plato's continent of «Atlantis» has some adherents.

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The Cape Verde Islands, southernmost of these archipelagos, has an intermediary position as regards distance from a mainland, lying between 830 and 460 km from Dakar, Sénégal, the Azores being most distant — between 1900 and 1480 km — whilst the Canaries are nearest — between 520 and 100 km.

The Cape Verde archipelago never has attracted buccaneer, traveller, tourist or scientist as have the other Macaronesian areas (the tiny, uninhabited Selvagens excepted), and hence the world at large knows less of these islands. Yet scientists of various disciplines, at one time or another, expressed opinions taking into account the African mainland, some pointing to affinities, others denying such.

We therefore propose to review and discuss this topic, treating rather of the major contributions from various scientific fields, in order to keep within convenient limits of text and references.

BRIEF REVIEW OF THE GEOLOGY OF THE CAPE VERDE ARCHIPELAGO

The initial geological report by Bebiano (1932) is largely devoted to igneous matters and gives little other information. To date, two monographs, those of Serralheiro on Maio (1970) and S. Tiago (1976) have appeared, and five of the ten chief islands have been mapped in more detail within the past few years, but still much of our geologic information is of reconnaissance nature, and some geological aspects have even yet scarce been touched upon.

These are volcanic islands, with consolidated pre-Quaternary sedimentaries, of which limestones comprise ca. 90% (Mitchell-Tomé, 1964) and constitute some 8% of rock exposures. Basanites, nephelinites and phonolites are the commonest volcanics, and essexites and syenites predominant intrusives. The notable undersaturated, highly alkaline nature of these rocks and the unique low isofalia values are features of interest. (Schmincke, 1982 however is critical of the oft-remarked very alkaline character of the rocks). True metamorphics are lacking, though some degree of marmorization and evidences of slight schistocity and foliation can be noted here and there. Under the dry climatic conditions prevailing, some islands, e. g. Boa Vista show wide and thick development of duricrusts. In this island, also in some others, dunes are well developed, the «active» dunes of Boa Vista and Sal interfering with transport facilities. Sedimentaries are usually but a few metres thick at most, have gentle dips and throughout the islands play a very minor role. The Mesozoics of Maio are exceptional as regards thicknesses and degree of disturbance. Lahar deposits are significant in S. Tiago.

The evolution of the archipelago is interspersed with vulcanism and sedimentation. For long, Maio has held prime geological interest of all the islands, more investigations (especially petrologic, petrogenetic and petrochemical) have been made here than elsewhere, and actually

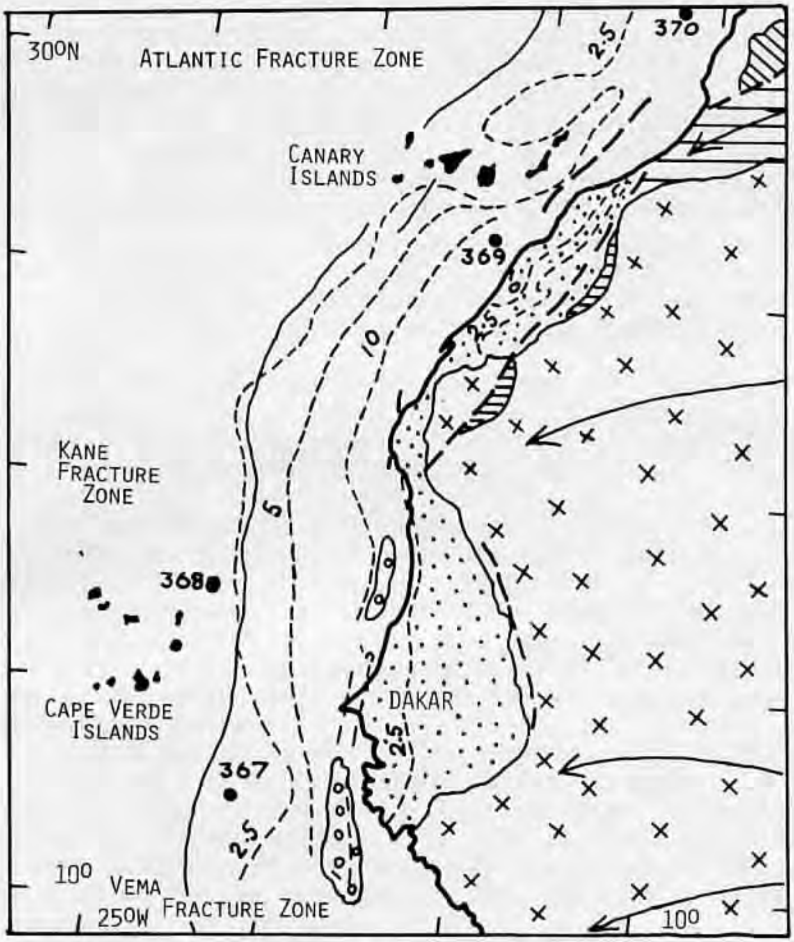
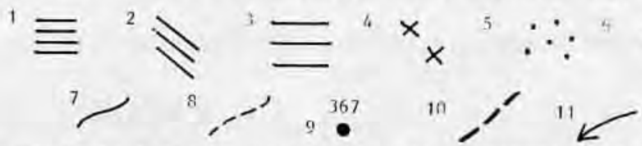


FIG.1 — WEST AFRICAN CONTINENTAL MARGIN AREA



1:- Variscan & Alpine Fold Belt 2:- Variscan Fold Belt 3:- Precambrian Massifs and Variscan Fold Belts 4:- Precambrian Crystalline Massifs 5:- Tertiary Basins 6:- Approximate Outline of Diapiric Structures of Evaporite Origin 7:- Approx. W border of Magnetic Quiet Zone 8:- Isopachs, sediments 2.5, 5 & 10km thick 9:- DSDP Sites mentioned in text 10:- Faults 11:- Major Areas of Uplift.

at the present time there is a Cape Verde Magmatism International Research Project carrying out intensive geological-geophysical studies of the island. (Stillman et al, 1982). As per De Paepe et al (1974), the pre-Kainozoic basement of Maio involves an eruptive complex of oceanic tholeiites, comprising pillow lavas, sills, breccias, cut by many dykes, and smaller essexitic intrusions. According to Stillman et al (op. cit.) the chain of events here involved: outpouring of pillow lavas on the ocean floor, strongly similar to mid-ocean pillow basalts; conformable

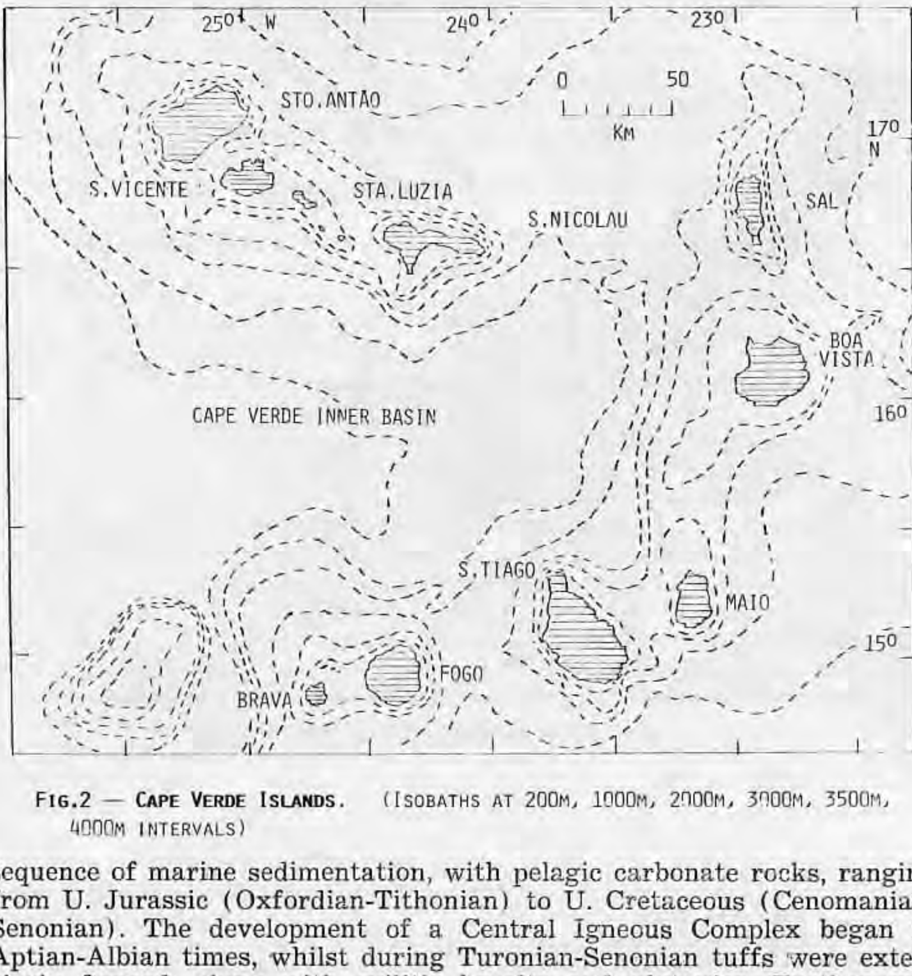


FIG. 2 — CAPE VERDE ISLANDS. (ISOBATHS AT 200M, 1000M, 2000M, 3000M, 3500M, 4000M INTERVALS)

sequence of marine sedimentation, with pelagic carbonate rocks, ranging from U. Jurassic (Oxfordian-Tithonian) to U. Cretaceous (Cenomanian-Senonian). The development of a Central Igneous Complex began in Aptian-Albian times, whilst during Turonian-Senonian tuffs were extensively formed, along with spilitic basalts and plutonics. Further vulcanism, emergence, exposure and erosion followed, the Neogene volcanic-sedimentary sequence resting with marked unconformable relations on prior rocks. The absence of the Palaeogene may have been due to either erosion or then non-deposition. In the Neogene there was renewed volcanism, ranging through the M. Miocene-Pliocene, with the formation of conglomerates, tuffs, hyaloclastics, ankaramites, ankaratrites. On all islands except Fogo, volcanism died out before the Quaternary, but during this period there were repeated vertical uplifts of many metres. The above evolution refers specifically to Maio, but how well this fits the other islands cannot be determined as of the present, and, e. g. Serralheiro's scheme for S. Tiago (1976) differs significantly from that proposed above for Maio. The eastern islands of Sal, Boa Vista and Maio have long been considered older — chiefly because of more advanced stages of erosion and evolution — but actual proof of this is lacking at present.

After long and heated debate, it can now be accepted that Jurassic occurs in Maio — Malm, including Tithonian and Portlandian, with Kimmeridgian-Oxfordian more doubtful. (Serralheiro, 1970, Cleintuar & Ealey, 1971, Rigassi, 1975, Robertson & Bernoulli, 1982, Stillman et al 1982).

For the site of the archipelago, various authors have visualized different numbers of volcanic phases. Part (1950) and Assunção (1968) supposed four phases of volcanism; Grunau et al (1975) for Maio suggested three phases; Serralheiro (1976) suggested six phases; Robertson & Bernoulli (1982) postulate four phases for Maio, and Stillman et al (1982) suggest also four phases for Maio or perhaps five if we include a Palaeogene phase of diapiric pluton emplacement, entirely unsubstantiated however.

Eustatic oscillations are evidenced by old marine shorelines, ranging from 2-6m (Flandrian) to 80-100m (Palaeo-Sicilian). The presence of Malm-Neocomian limestones as high as 265m in Maio, Neogene limestones up to 250m altitude in S. Nicolau (both highly inclined), along with raised marine terraces, testify to the role of vertical movements — primarily due to volcanic causes, lesser so to isostasy — in the evolution of the archipelago.

BIOLOGIC CONSIDERATIONS

Since the days of Darwin (1844) and Saint-Claire Deville (1848), biologic evidences, living and fossil, showing African affinities, have been commented upon. Chevalier (1935) gathered together earlier views regarding the flora, as well as giving his own opinions. However, since then no further botanical or palaeobotanical investigations have been made in the archipelago.

The Cape Verde Islands have received few introductions of seeds via currents, winds, birds, insects or floating organic rafts. Soils in general are of low nutritive value. The arid climate (all land bellow 500m is dry and barren, and Sal, the driest island, has only 95mm annual average rainfall) promotes saline, aeolian, desert-type soils often capped by duricrusts. In higher mountainous areas, rainfall is more plentiful (especially on windward sides) and here dark chestnut soils rich in humus can develope, but unfortunately these are just the localities where erosion is most drastic, resulting often in bare rock surfaces. Climate and geologic-soil conditions hinder plant growth.

The archipelago flora is of three types: Mediterranean-Insular Oceanic, Tropical African, and that introduced by Man. (Chevalier, 1935). The first, oldest and palaeo-endemic, shows species which emigrated from Africa during the Quaternary climatic fluctuations. Tropical African type shows considerable numbers of herbaceous species typical of Tropical Africa absent in W. Africa. It is common throughout Macaronesia, especially abundant in Cape Verde, though nowhere within the archipelago is there the riot of vegetation associated with tropical regions. 300 species of flowering plants have been recognized, about one-third limited to the archipelago, the majority of which show closer relations to the Mediterranean rather than the Atlantic coasts of Africa. Chevalier does mention African affinities of some plant species with those of the Sahara and Gambia-Sénégal, but refrains from speculating on such. The fossil flora is scant, and palaeobotanical studies no less. In one or two islands, e. g. Boa Vista, S. Vicente, Sal, Maio, *Tamarix* stalks and roots (*T. gallica* Linnaeus var.?) are plentiful, similar in structure to Monocotyledons such as *Palmae*, which latter are endemically spread throughout the islands.

The marine fauna, especially abyssal, is rich, but terrestrial specimens are few (Torres & Soares, 1946). When the islands were discovered in the mid-15th century, there were no terrestrial mammals. About 75 species of birds have been recorded of which 38 are indigenous, three of the former being introduced from Sénégal. Of Reptilia, terrestrial forms include tortoises and lizards, but the former died out some 100 years ago. The Green Turtle *(Chelonia mydas)* is the commonest marine turtle, and within the Pedra Lume crater in Sal, the bones of many specimens of tortoises *(Testudo calcarada* Schneider = *T. radicata senegalensis* Gray) have been found, this species now living along the Sénégal littoral. Lizards are mostly endemic, representing types native to neighbouring coastal Africa.

The entomology has been given more attention, e. g. Holdhaus (1928). Some 300 odd species of Coleoptera are endemic, these and spider species showing Mediterranean affinities. On the other hand, Berland (1935) and Jeannel (1942) proposed land connexion between the archipelago and W. Africa to account for Coleoptera similarities of these two areas. Most of the Lepidoptera also are found in neighbouring tropical W. African areas, whilst the Orthoptera show close links with those of the Sahara and N. Africa. Jeannel in particular, as regards not only the Coleoptera but biogeographic factors in general, believed that up to the end of L. Pontian times, the archipelago was united to Africa, but some of Jeannel's ideas are, to use the expression of Teixeira (1950), «les plus pures fantésies géologiques et paléogéographiques».

Freshwater native amphibians, turtles, snakes and fish are all but absent in Cape Verde, there being only two very short permanent streams in NE Sto. Antão. In these streams are found decapod Crustaceans, the species *Palaemon (Macrobrachium) chevalieri* J. Roux occurring as high as 800m in this island. These shrimps are eagerly fished by the islanders, and doubtless will soon disappear. Some shrimp species show close affinities to some found in far distant areas, e. g. *Palaemon chevalieri* in the Americas and Congo, *Atya scabra* Leach in Australia and New Caledonia. (What is rather disturbing in the statement of Torres & Soares is that they refer to permanent streams also in S. Nicolau and S. Tiago with specific freshwter shrimp species, whereas such streams are ONLY found in Sto. Antão.).

Germain (1926) wrote the outstanding work on terrestrial and fluviatile Mollusca of the archipelago, and indeed no comparable study has appeared since. Studies of Kainozoic, extinct and introduced species, led him to conclude that this was a somewhat impoverished fauna, suggesting relatively long isolation of the islands. Closest species analogies were found in the Antilles, and though Africa lies much nearer, not a single valid faunal relationship could be established with the latter area. He presumed that especially during the Oligocene — L. Miocene, all Macaronesian archipelagos were united to N. Africa and Europe on the one hand, to the Antilles and northern S. America on the other, with Cape Verde archipelago forming the southern border of this Tertiary «Atlantic» continent. The Molluscan fauna of Cape Verde showed terrestrial characters but no relationships with Equatorial Africa. Since the M. Miocene, the Cape Verde fauna especially, but also that of Macaronesia in general, evolved in its own fashion, the indigenous fauna being supplemented by faunas of African, American and European types.

Referring specifically to the Helicidiae, Joleaud (1941) remarked upon the Cape Verde affinities with Europe and N. Africa but not the rest of the continent. On the other hand, earlier Rochebrune (1881) had been much impressed with W. African littoral affinities of the Mollusca, though earlier still, Morelet (1873) had expressed views in keeping with Joleaud and Germain.

The fossil fauna relates largely to the Cretaceous, Neogene and Quaternary. As regards significant Malm-Neocomian fossils, there has been long debate revolving mostly around taxonometric and stratigraphic matters which need not detain us here. No specific W. African affinities of the Cape Verde fossils have been commented upon in the literature. It must be stressed that Mesozoic fossils have been given most attention, but it would appear that many Tertiary(?) and Quaternary species of marine Mollusca in the archipelago are also present in W. African regions. From Guinée to Morocco such is the case, being especially true of the genera *Ostrea*, *Arca*, *Strombus* and *Helix*. We recognize that the Vindobonian fauna of Europe reached the Atlantic area of Morocco by the Pliocene, and by the Quaternary as far as Sénégal. Most of the Cape Verde Neogene fauna has been essigned to the Vindobonian.

STRATIGRAPHIC CONSIDERATIONS

The sedimentaries and fossil contents have received relatively little attention within the archipelago, and hence the stratigraphy has

Age		Formations
Quat	Holocene	Sediments and volcanics
	Pleistocene	Limestones, calcarenites, conglomerates (Marine terraces)
		Pyroclastic cones, small basaltic outpourings
Pliocene		Important flows: post-Principal Eruptive Complex
		Principal Eruptive Complex, essentially basalts, phonolites and trachytes: Subaerial volcanics Phonolites, trachytes Limestones, calcarenites Subaerial and submarine volcanics Limestones and conglomerates Subaerial and submarine volcanics
Miocene	Upper	Post-Conglomerate/Breccia Formation Trachytes
		Conglomerate-Breccia Formation: Conglomerates and breccias Terrestrial facies with flows Marine facies
		Extensive and thick submarine flows
	Middle	Conglomerates and calcarenites
	Lower	Old Internal Eruptive Complex: Carbonatites, phonolites, trachytes and granular rocks Basaltic dyke complex
Palaeogene?		Marls and clays
L. Cretaceous		Clays, marls, limestones with flints, calcareous sandstones
U. Jurassic		Limestones, calcareous clays and sandstones, siltstones, marls, flints common

TABLE I Generalized Lithostratigraphy of the Cape Verde Islands.

(Modified after Serralheiro, 1976)

been much debated. Jurassic, post-Aptian Cretaceous and Palaeogene have all been recognized by some, denied by others, and, as remarked earlier, the U. Malm is accepted only in Maio. This Malm was taken to have lithologic correlatives in Oran Province, Algeria (Furon, 1968) and in the Tarfaya area of Morocco by Rothe (1968).

During Mesozoic and much of the Tertiary, a marginal trough lay between the African mainland and the site of the archipelago, with coastal basins and shelves forming from Morocco to Sénégal. Malm to Aptian sedimentation took place, with Jurassic salt-dome penetrations particularly off Morocco and the Sénégal Basin. In Morocco, during Late Jurassic, marine transgressions began (Ambroggi, 1963), spreading southward so that by Late Jurassic, transgressions had attained the Sénégal Basin. (Reyre, 1966). Jurassic outcrops in W. Morocco from the

Unit	Depth Range in m.	Lithology	Age
1	0-255	Foram.-nannofossil marl with quartz sand	Pleistocene-Miocene
2a	302.5-312	Diatom-bearing radiolarian clay	Late Eocene
2b	331-338	Zeolitic clay with chert and porcellanite	Eocene-Late Palaeocene
3	388-625.5	Multicoloured silty clay	Late Palaeocene/Early Eocene-Late Cret.
4a	636-787	Black shale	Early Turonian-Late Aptian/Early Albian
4b	834.5-844	Variegated claystone	Late Apt.-Early Alb.
5a	891.5-948.5	Light grey nannofossil limdstone, olive marlstone and black shale	Late Apt./Early Alb.-Hauterivian
5b	948.5-1089	Nannofossil limestone, marl and chert	Valangian/Hauterivian-Oxfordian/Kimmeridg.
6	1089-1144	Reddish-brown nannofossil-bearing argillaceous limestone, marl, clays and chert	Not older than Oxfordian-Kimmeridgian
7	1144-1153	Basalt	

TABLE II Lithostratigraphy of DSDP Leg 41, Site 367.

(Water depth, 4748m; Penetration, 1153m; Total core recovered, 174.3m. Position: 12°29.2'N, 20°02.8'W.)

(Modified after Shipboard Scientific Party, 1977)

Meseta sporadically as far S as the High Atlas, where strata ranging in age from Sinemurian to Kimmeridgian occur. Further S in the Aaiun Basin of ex-Spanish Sahara and in the Sénégal Basin of Mauritania-Sénégal Jurassic occurs at depth, where, e. g. just E of Dakar, U. Jurassic is found at depths between 3250-4010m. (Castelain, 1965). Table I shows the stratigraphy for the Cape Verde Islands as a whole, the Deep Sea Drilling Project (DSDP) Leg 41, Sites 367 and 368 drilling data (Shipboard Scientific Party, 1977) and the succession in the Sénégal Basin as per Wissmann (1982). The DSDP sites and Maio show very similar successions up to the Aptian, but thereafter there is divergence — in Maio carbonate sedimentation continued, with gradual shallowing until emergence in the Albian, whereas at Site 367, depth was maintained and likely even sank below the carbonate compensation depth. (Stillman et al, 1982). Gardner et al (1977) speak of «A surprisingly good correlation exists between the section at Site 367 and the L. Cretaceous-U. Jurassic section exposed in Maio.........».

It is scarce possible at this time to estimate with much precision the volcanic-sedimentary thicknesses for the islands, but it appears

Unit	Depth Range in m.	L i t h o l o g y	A g e
1a	0-132.5	Foram.-bearing nanno marl and ooze	Holocene-Early Pliocene
1b	161-265.5	Nanno ooze and marl, pelagic clay, 3 volcanic ash beds	Late Miocene-Early Miocene
2a	265.5-655	Cyclic interbeds of green silty clay and claystone	Early Miocene-Early Eocene?/Early Cret?
2b	702.5-731	Interbedded green and red shale	Palaeocene?-Late Cretaceous
2c	750-950	Cyclic interbeds of green and olive silty claystone, essentially same as 2a	Late Cretaceous
3	950-984.5	Black Shale, diabase sills	Late Cret-Turon/Albian

TABLE III.- Litho-stratigraphy of DSDP Leg 41, Site 368.

(Water depth, 3366m; Penetration, 984.5m; Total core recovered, 327.7m. Position: 17°30.4'N, 21°21.2'W.)

(Modified after Shipbord Scientific Party, 1977)

that as the mainland is approached, thicknesses increase — in the Cape Verde Basin they are ca. 870 m, on the Cape Verde Rise, 900 m, whilst on shore in Sénégal, the total is ca. 7900 m. The depth to the Paleozoic basement in Sénégal is taken to be between 6-8000 m below sea level. (Elouard, 1975). The base of coring in DSDP Site 367 lies 5900 m below sea level, in basalts underlying Jurassic sediments, not older than Oxfordian, and at DSDP Site 368 coring ends at 3690 m below sea level in black shales and diabasic sills of Late Cretaceous to Turonian-Albian age. (Shipboard Scientific Party, 1977). The geological section across the central Sénégal Basin of Spengler et al (1966) is duplicated with greater refinement by the various multichannel seismic reflection profiles, strata dipping westward from the mainland such that U. Jurassic occurring at depths between 3250-4010 m near Dakar is found at depths of ca. 5800 m below sea level at DSDP Site 367. Magmatic swellings in the Cape Verde archipelago area have caused the strata to rise from depth as they approach the archipelago, such that U. Jurassic is exposed in Maio, i. e. between the archipelago and the Sénégal mainland beds can be reasonably well deciphered in continuity forming a great trough-shaped structural feature. (Storetvedt & Lovlie, 1983, mention that by

AGE		LITHOLOGY
QUATERNARY		Volcanics, silty clays, limestones, dune deposits
PLIO	UPPER	Variegated clays, ferruginous sands, limestones, lignites "Continental Terminal"
	LOWER	Multicoloured clays and marls
MIOCENE	UPPER	
	MIDDLE	Chalks limestones chalky sands
	LOWER	
OLIGOCENE		Limestones, dolomitic limestones
EOCENE	UPPER	Marls, black clays, black silts, lignites
	MIDDLE	Chalky dolomites, limestones, clays, chert, phosphate and glauconite layers, sandy silts
	LOWER	Sandy chalky clays, marls, chert, phosphate and glauconite layers
PALAEOCENE		Marls, limestones, sandy-silty carbonate rocks
CRETACEOUS	UPPER	Clays, silts, conglomerates, gravels, shales, limestones
	MIDDLE	Claystones, shales, sandstones, quartzites, calcarenites, dolomites
	LOWER	Clays, dolomites, limestones, quartzites, sands, calcarenites
U. JURASSIC		Dolomitic-oolitic limestones, silty marls, dolomites

TABLE IV.- Litho-stratigraphy of the Sénégal Basin.
(Modified after Castelain (1965) and Wissmann (1982))

Albian-Senonian times, the crust in the Maio region had likely experienced an uplift of some 3-4 km.).

In the basins of NW Africa, the U. Cretaceous is surprisingly thin, and in the archipelago area, the concensus of opinion is inclined to doubt the presence of either U. Cretaceous or Palaeogene. Seibold (1982) has suggested for these NW African basins that during these periods, erosion was dominant and especially so during the Oligocene.

The general lithology of the W. African Mesozoics agree quite well with counterparts in Maio, and palaeontologically-determined ages for the African occurrences are also found in Cape Verde — at least Neocomian-Aptian. Malm-L. Cretaceous and Neogene lithological, palaeontological and stratigraphical affinities between the archipelago and the neighbouring African mainland from Morocco to Sénégal seems reasonably established via the DSDP Sites 367 and 368.

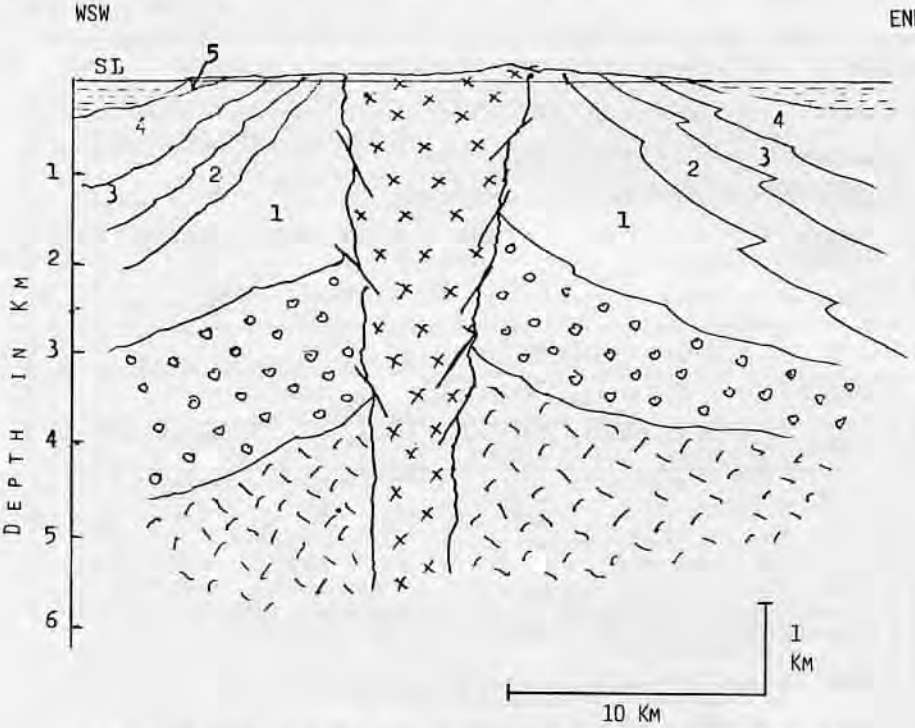


FIG.3 — STRATIGRAPHICAL PROFILE ACROSS MAIO, CAPE VERDE ISLANDS.

Ocean | 5 Quaternary | 4 Tertiary - largely Neogene
3 U.Cretaceous | 2 L.Cretaceous | 1 U.Jurassic
Central Igneous Complex | Volcanic Aprons | Basement

We would also note that as regards the Quaternary, Sicilian (I, II), Tyrrhenian (I, II, III) and Flandrian raised beaches seen in some Cape Verde Islands occur at comparable levels in Morocco and Mauritania. (Mitchell-Tomé, 1976).

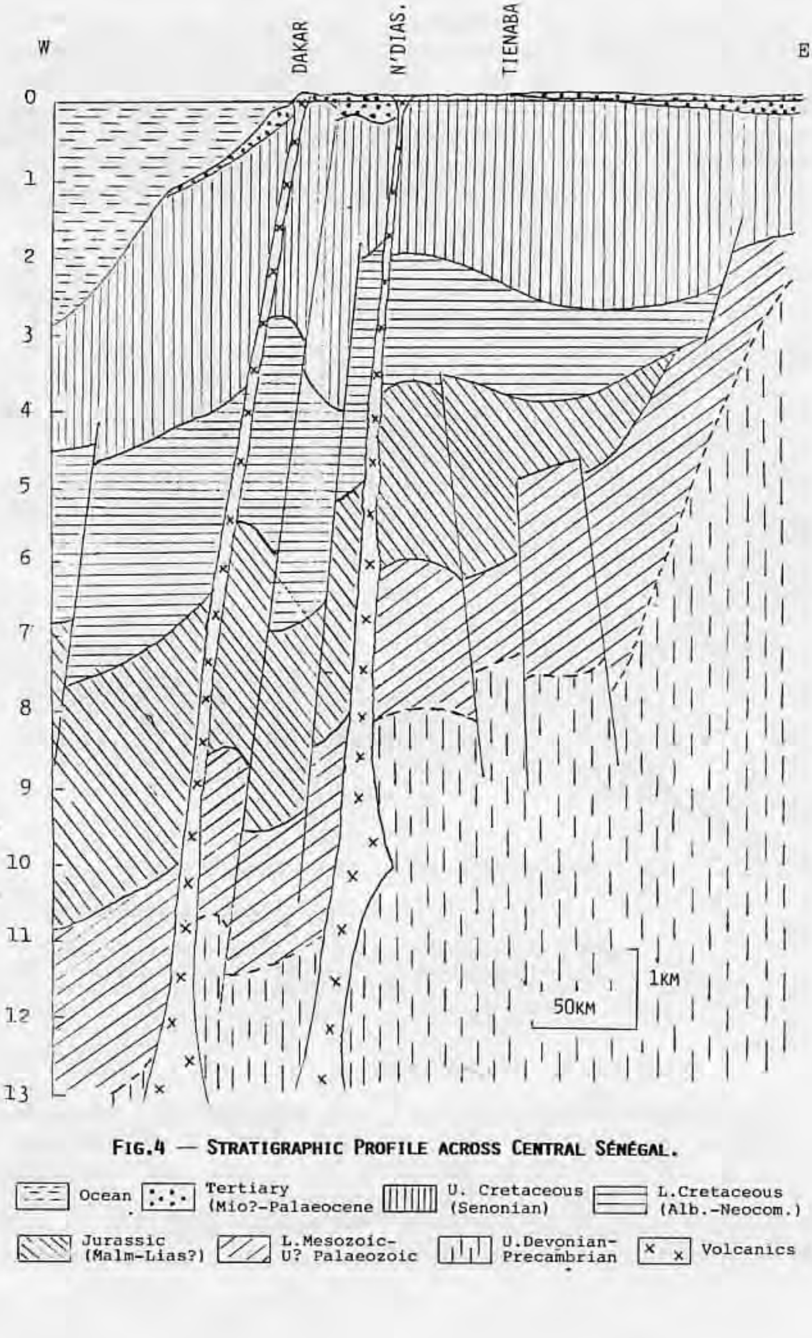


FIG.4 — STRATIGRAPHIC PROFILE ACROSS CENTRAL SÉNÉGAL.

IGNEOUS CONSIDERATIONS

In the archipelago, extrusives are vastly more important than plutonics, and pyroclastics constitute a large part of the former. The extreme scarcity of over-saturated rock types, the relative scarcity of intermediate types, tendency towards high alkalinity which shows overlap in composition, are all noteworthy features and taken to represent a primary mantle-derived magma, not contaminated by continental crust, with initially oceanic tholeiitic basalts, succeeded by strongly alkaline magmatism.

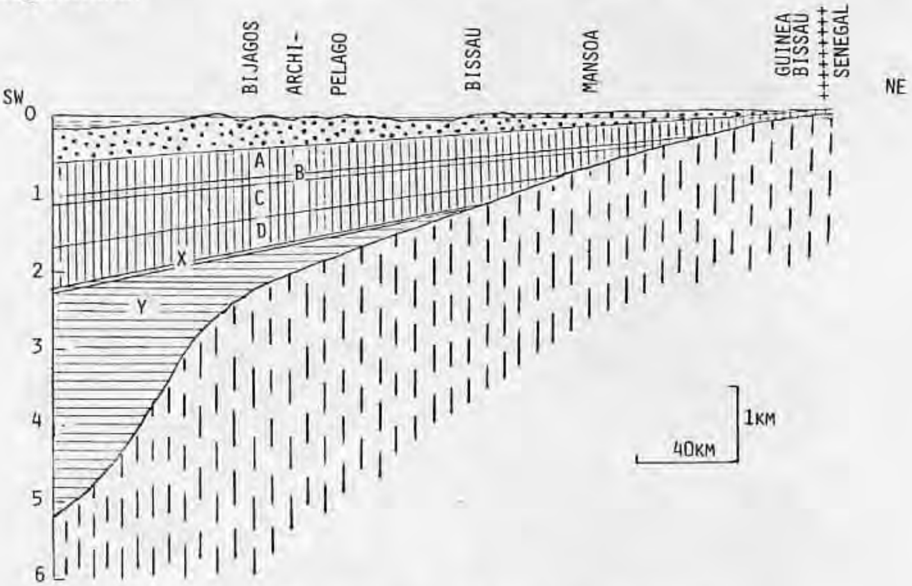


FIG.5 — STRATIGRAPHIC PROFILE ACROSS GUINEA BISSAU

Ocean

Tertiary (Plio?-Palaeocene)

U.Cretaceous (Danian-Cenom.)
A Danian-Maestricht.
B Campanian
C L.Senonian
D Turon.-Cenom.

L.Cretaceous (Alb-Apt.)
X Albian-Aptian
Y Undifferentiated

U.Devonian-Precambrian?

(Modified after Teixeira, 1968)

The presence of carbonatites in the archipelago (Assunção et al, 1965, Machado & Assunção, 1965, Machado, Leme & Monjardino, 1967, Alves et al, 1972) hitherto unknown in oceanic environments, and that of northern S. Tiago, the first example known of an oceanic carbonatitic volcanic pyroclastic structure (Silva et al, 1981) — all such may possibly represent an extreme differentiate of such alkaline magmas.

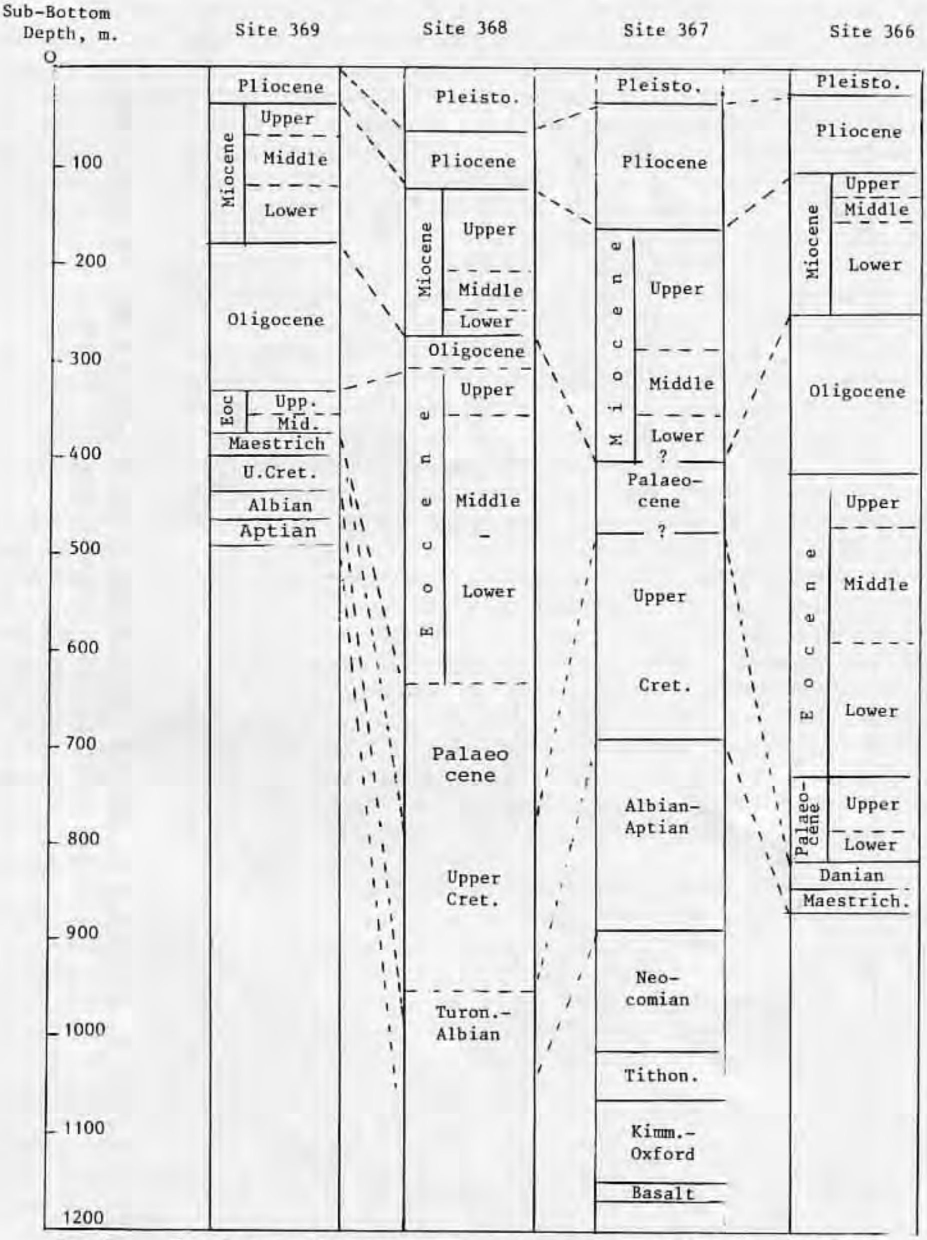


FIG.6 — SUB-BOTTOM STRATIGRAPHY AS REVEALED BY DSDP LEG 41 SITES. CORINGS IN OFF-SHORE W.AFRICAN REGION. (Modified after Shipboard Scientific Party, 1977 & Gardner et al, 1977)

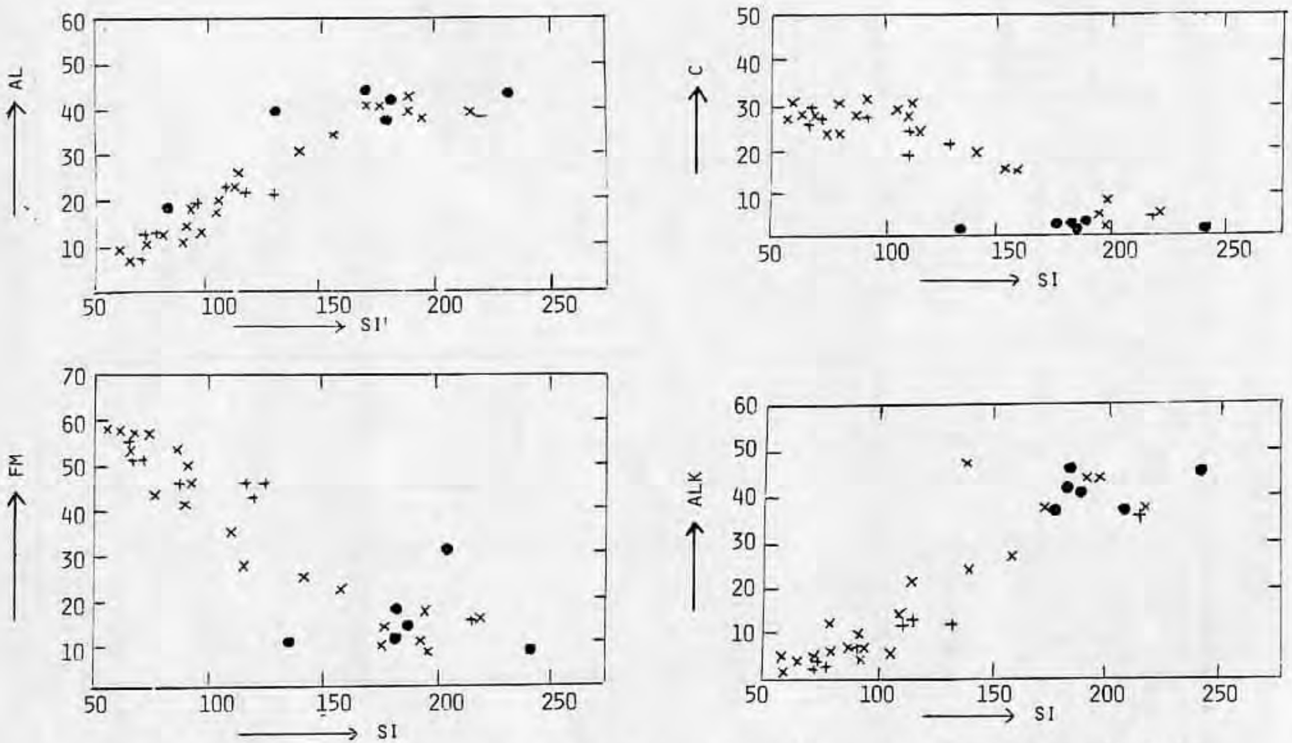


FIG.7 — SI-AL/FM/C/ALK DIAGRAMS OF 20 CAPE VERDE, 6 LOS ARCHIPELAGOS AND 8 W.SENEGAL ROCKS.
(x CAPE VERDE ISLANDS ● LOS ISLANDS + W.SENEGAL)

(Modified after Berthois, 1950, Burri, 1960)

African affinities of the Cape Verde rocks have, in general, referred to two regions: the small Los archipelago by Conakry, Guinée, and the Rift Valley environment of E. Africa. Berthois (1950) noted for the two archipelagos that such Niggli parameters as e. g. variations of *alk* and *fm* as functions of *si* show some magmatic values very similar, though others, e. g. variations of *c* as a function of *si*, very considerably. The two archipelagos show rocks with an excess, at times very notable, of Na over K; in neither areas are there rocks containing free silica, though exact saturation in silica is commoner in Los, where alkaline rocks are more abundant, but calc-alkalines occur about equally in both archipelagos. The magmas of these two regions show much more in common than is found in the neighbouring African littoral, referring specifically to Mauritania, Sénégal, Guinée and Ivory Coast, where oversaturated rocks do occur. In these latter regions, Na also predominates over K, but much less notable than in the two archipelagos. To Berthois «...malgré quelques différences, les roches de l'archipel de Los et de l'archipel du Cap-Vert présentent de nombreuses analogies.........».

Burri (1960) claimed that on petrochemical grounds, there were similarities between the Cape Verde rocks and those of Los, Sénégal, and Guinée, quoting pertinent data regarding Niggli, Rittmann and Jung parameters for the four areas, and noting that the magmatism of Los was older than that in the Cape Verde archipelago. (The Los magmatism can only be said to be older than the Neogene volcanism of Cape Verde, and is actually younger than the Malm-L. Cretaceous volcanism of Cape Verde). Burri was more impressed by rock analogies between the Cape Verde archipelago and the volcanic areas of the Rhine Valley, which latter area he knew well, as distinct from lack of field knowledge of the other areas mentioned. Assunção et al (1968) also noted similarities between the two archipelagos as regards alkaline syenitic rocks, but «For the ultrabasic plutonics and lavas it is more difficult to find the counterpart on the continent (Africa)».

In the Cape Verde islands of Sto. Antão, Fogo and S. Vicente (?), calderas show ring structures, that of Fogo the best preserved, being regarded as a caldera of Glen Coe-Suswa type, with the emission of pre-caldera nephelinites and kindred rocks, similar rocks occurring in the other two caldera areas. (Mitchell-Tomé, 1980) Petrochemically these rocks have their counterparts in the Los archipelago, where Millot & Dars (1959) also determined a ring structure origin for the circular shape of the archipelago, the rocks being nepheline-syenites.

Berthois (1950), Part (1950) and Assunção (1968) were no less aware of affinities between Cape Verde rocks and those of the Rift Valley region of E. Africa. Berthois referred to the Volcanic Series of Lake Kivu and Kilimanjaro as showing magmatic parameters similar to those of Cape Verde, where in the three regions, calc-alkalines are present, there is an excess of Na over K, and where there are close analogies in silica deficiency. He commented further that the region between the

Rift Valley and the Indian Ocean showed very close petrochemical analogies with Cape Verde, and concluded that in such a sense, this archipelago was distinctly different from other Macaronesian ones. He believed that profound dislocations in E. Africa and offshore from W. Africa (the Sénégal Basin, e. g. has been faulted, folded, intruded by volcanics, with Mesozoics dipping steeply seaward, Spengler et al, 1966, Wissmann, 1982) had activated a basaltic-type magma zone, suggesting to him a significant orogenic role in the emplacement of the eruptive structure. Assunção also was impressed by Cape Verde analogies in the Kivu-Kilimanjaro region. Part saw agreement in both rock types and eruptive phases between the archipelago and similar areas of the Rift Valley, volcano-tetctonism being comparable to the E and W of a stable central African block. Dillon & Sougy (1974) also stressed the time equivalence of the two main Tertiary-Quaternary volcanic periods in the archipelago and W. Africa. (The various periods of volcanism in the Cape Verde Islands, proposed by various authors, can broadly be placed into: Malm-L. Cretaceous, L. (?) Palaeogene, Early-Middle Miocene, Pliocene-Quaternary). As Friedländer (1913) had earlier proposed, Part (op. cit.) believed that geographically the Cape Verde Islands were an extension of the Tertiary orogeny which formed the Atlas system on NW Africa, and that African orogeny, tensional rift stress and isostatic adjustments characterized the tectonic history of both the archipelago and the E. African region. (More modern views do not even associate the Canary Islands — much closer to the mainland — with tectonic events in Africa; and it would be far-fetched indeed today to see evidences of African orogeny in the Cape Verde archipelago). Assunção et al (1968) remarked that the plutonic and volcanic rock suites of the Cape Verde archipelago and E. Africa seemed typical of the early history of rift valleys, that in the Cape Verde archipelago area we have a Mesozoic rift valley (Klerkx & De Paepe, 1971, spoke of a Mesozoic eruptive ridge, showing some analogies with mid-ocean ridges) formed when the African-S. American continental blocks started to drift apart, the more saturated, less alkaline rocks of the Mid-Atlantic Ridge being more advanced stages of such rift valley development.

STRUCTURE - TECTONIC CONSIDERATIONS

«Basement» material in the islands, the fundaments thereof, are better observed in the more profoundly eroded eastern islands, especially Boa Vista, Maio and S. Tiago. But nowhere here can one observe indications pointing to orogenic deformations which affected W. Africa from Late Eocene through Pliocene. Steeply dipping beds in S. Nicolau are in contact with a gravity fault, and the highly inclined Mesozoic strata of Maio result essentially from essexitic «diapir» intrusions which not only broke up and jostled the overlying Mesozoic blocks, but also resulted in significant thrusting in the E part of the island. Where strata within the archipelago display any salient degrees of deformation — with the above exceptions and several other very minor local occurrences in other islands — this is due to slumping and other surficial causes. Major folding in N-NW Africa (chief phases in Late Eocene, Late Oligocene and Miocene) and lava outpourings of the Miocene along the W. African coast (Dillon & Sougy, 1974) may find a distant echo in the Neogene-Quaternary volcanic episodes within the archipelago, but this is purely suppositional. Uplift via magmatic pulsations and isostatic adjustments took place during the Tertiary-Quaternary in these islands, but not orogeny.

As early as 1844 and 1848, Darwin and Saint-Claire Deville respectively, had drawn attention to island trends in the archipelago — the NW-SE alignment of Sto. Antão-S. Vicente-Sta. Luzia-S. Nicolau-Boa Vista, the N-S trend of Sal-Boa Vista-Maio, the W-E trend of Brava-Fogo-S. Tiago-Maio. The first-mentioned is more os less in line with the Guinée coastline, noted by Bebiano (1932), Moody & Hill (1956, 1966), Furon (1968), being elaborated into lineaments or what the writer prefers to call vincula. (Mitchell-Tomé, 1961). Bebiano claimed that island trends outlined fracture zones, island and coastal trends indicating to him diagonal and meridional patterns of fractures analogous to similar patterns in Africa. Within the islands themselves, faulting is present in NE Sto. Antão and central S. Nicolau, but in Maio (an island differing from the others in most geological aspects) faulting is much more significant, the Central Igneous Complex having severely disturbed older strata, with vertical displacements of up to 450 m as per Serralheiro (1970), and on the NE side of the Complex, both major and minor thrusting duplicate the stratigraphy. (Stillman et al, 1982). On the basis of seismic refraction studies, Dash et al (1976) postulated a fracture zone trending NW-SE to the W of Sal-Boa Vista with a throw of ca. 900-1000 m, and Ballard & Hemler (1969) had reported an E-facing fault scarp on the E side of the Sal-Boa Vista-Maio rise or ridge, and postulated boundary faults to the N, S and E of the archipelago. Dash et al claimed that, on the basis of gravity data, at this ridge area we have a wide faulted and fractured zone — indeed these authors claim the origin of the islands was due to intrusions and extrusions along N-NW, NW and W-SW trending fault systems. Evidence is lacking for the contention of Dash et al that «The position of the archipelago was apparently controlled by the convergence of fracture zones............». Only two of the better-known great transform fracture zones of the Atlantic, those of Kane and Vema, pass anywhere near the archipelago — ca. 500 km away to the N and S respectively — and one looks in vain for signs of «convergence» here. Those who would accept geographical disposition of islands and isobath trends, in the absence of other corroborative evidences to postulate great lineaments are not being objective, and faulting based on geophysical grounds in this area smacks too much of «Deus ex machina» techniques.

GEOPHYSICAL CONSIDERATIONS

The western boundary of the magnetic quiet or smooth zone, lying off the W. African coast, is not well defined. It appears to pass almost midway between the Cape Verde Islands and the mainland. Seaward of this zone, a 350 km wide strip occurs, extending to the eastern Cape Verde archipelago, which includes the Keathley sequence or J anomalies. Whether this band represents part of the Kane fracture zone is not known. The magnetic quiet zone boundary has been dated as ca. 155 MY by Pitman & Talwani (1972), and Vacquier (1972) placed the archipelago between the 140 MY and 120 MY isochrons, as per the magnetic structure of the oceanic crust. However, Hayes & Rabinowitz (1975) remarked that the quiet zone is not strictly an isochron, nor indeed do we know whether the zone represents any special time interval, (Pitman et al, 1971). The former authors confessed that the significance of this quiet zone still escapes us, and no less the origin. The preferred present explanation relates it to sea-floor spreading during a constant geomagnetic polarity epoch sometime in the Mesozoic, but others, e. g. van Bemmelen (1966), consider it related to continental crust conversion or oceanization, and as of the present, crustal studies are of little help in making decisions. We must also point out that Roeser (1982) has remarked that to a certain degree, the concept of a «magnetic quiet zone» is merely one of scale, for to plot the anomalies larger than normal vertical scale, would reduce appreciatively the width of the zone off W. Africa. It is thus apparent that little significance can be given at this time to this zone.

Geophysical work in the vicinal areas include magnetic studies by Rona et al (1970), seismic by Grunau et al (1975), Fritsch et al (1978) and Weigel et al (1982), and Dash et al (1976) conducted seismic, gravimetric and magnetic studies in the archipelago area. Within the islands, Watkins et al (1968) made palaeomagnetic studies, Mendes-Victor (1970) carried out magnetic and gravimetric investigations, and Storetvedt & Lovlie carried out remanent magnetization studies in Maio (1983). Dash et al claimed that the original crustal composition under the archipelago was probably of oceanic type, but the present crustal structure is transitional oceanic-continental. Fritsch et al (1978) took the trend of the zero milligal of Free-Air Anomaly as the approximate boundary of the oceanic-continental crust in this general NW African marine area. This contour is seen to be close to the 200 m isobath (seaward side) and hence well within the magnetic quiet zone, so that most of the area betwen the Cape Verde archipelago and the mainland represents oceanic crust — as per this argument.

Weigel et al (1982) also claim an original oceanic-type crust here, observing no crustal-type change in a refraction profile run across the magnetic quiet zone boundary some 250 km E of the archipelago, They also stated that oceanic-type crust occurs at least 200 km from the Mauri-

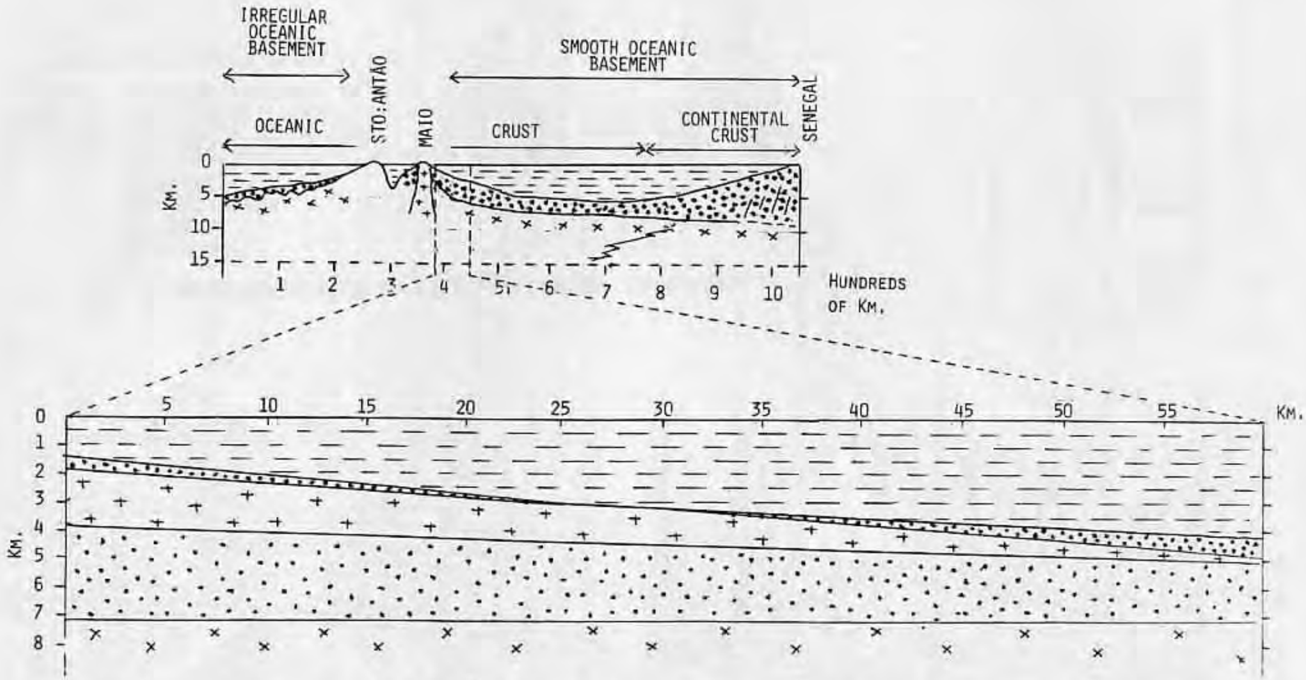
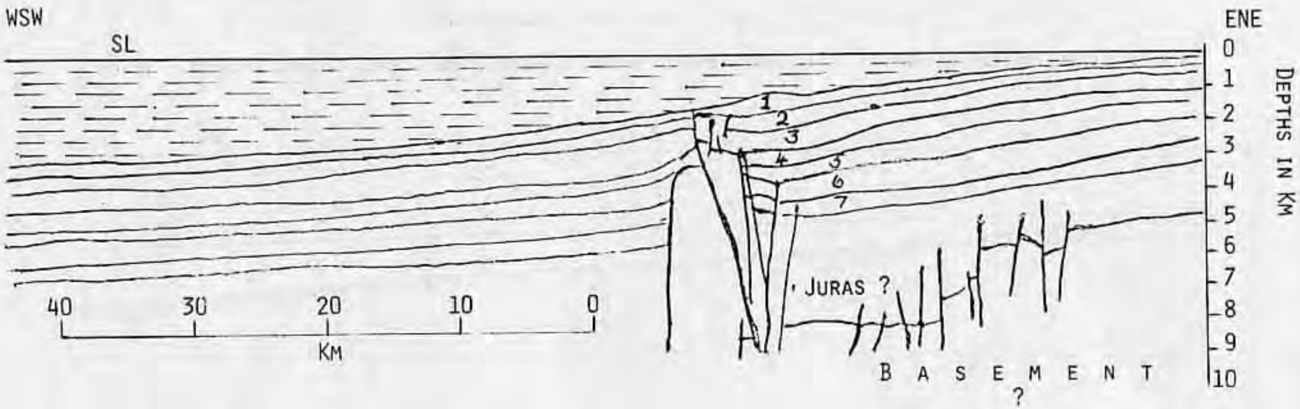


FIG.8 — REGIONAL PROFILE, CAPE VERDE ISLANDS TO SÉNÉGAL (UPPER) AND PART OF DIAGRAMIZED SEISMIC PROFILE (LOWER).

OCEAN | VOLCANICS AND VOLCANIC APRON (LOWER) | SEDIMENTS | BASEMENT

(Modified after Grunau et al, 1975)



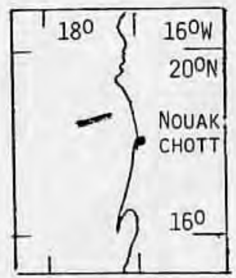


FIG.9 — SEISMIC REFLECTION PROFILE OFF CENTRAL MAURITANIA.

1	QUATERNARY	5	CONIACION
2	PLIOCENE	6	MIDDLE ALBIAN
3	EARLY MIOCENE	7	NEOCOMIAN
4	PALAEOCENE		

BASEMENT ONLY TENTATIVELY IDENTIFIED AS A DEEP, FAULTED, LOW FREQUENCY TWO PHASE REFLECTOR. STRATIGRAPHY CORRELATED FROM DSDP 367, 368 BECOMES UNCERTAIN TO EAST OF SALT OVERHANG ALONG A FAULT, OR MAYBE VOLCANIC PLUG.

(Modified after Wissmann, 1982)

tanian coast, refraction results indicating clear oceanic-type crust but not nearer than 100 km of this coast.

Mendes-Victor (1970) computed crustal thicknesses under each of the islands, which varied from 13 km for Sto. Antão to 22 km for Fogo and Sal. Dash et al (1976) believed that the western Cape Verde islands were underlain by crustal thicknesses varying between 16-17 km, that the MOHO rises eastwards towards the Sal-Boa Vista-Maio ridge. Mendes-Victor showed that regional gravity gradients in general converge towards the interior sea area — sometimes called the Inner Cape Verde Basin. This pattern led him to believe that for the archipelago, there was one common magmatic chamber. Dash et al postulated that the islands originated as igneous intrusions and extrusions along N-NW, NW and W-SW fault systems, and that at no time were the islands part of the African continent. Weigel et al (1982) comment upon a prominent seismic horizon (wave velocities of 7.1-7.3 km/sec at a depth of ca. 12 km under the Continental Rise, and dipping down to ca. 15 km under the Continental Slope), which, offshore from Mauritania, stretches uninterruptedly from the Shelf to the Cape Verde Rise over a distance exceeding 500 km, i. e. to the longitude of the archipelago. The same horizon is presumed to extend under the continent at a depth of some 25 km (it has also been detected under the Continental Slope off Morocco) and thus we have a seismic horizon linking the Cape Verde archipelago directly with the mainland.

The archipelago region has submarine sedimentary strata ca. 2 km thick (Grunau et al, 1975), increasing to 8-10 km at the continental margin. As per Dash et al, the sediments in the marine areas average 1.9-2.4 km thick, whereas in Seibold's map (1982), sediment thicknesses, as per isopachous lines, increase from 2.5 km some 20 km E of the islands, to more than 10 km thick some 15 km from the Sénégal coast, thereafter decreasing landward. Serralheiro (1976) mentioned 2-3 km of unconsolidated sediments lying on 3-6 km of limestones and basalts on the Cape Verde Platform. Dash et al envisaged for the Inner Cape Verde Basin, 2-3 km of semi-consolidated sediments overlying 3-6 km of basalts, overlying 6-8 km plutonics.

Of interest is the presence of shallow-water Globigerina-rich sediments in cores 0.8-4.6 m long, taken from depths of 1750-3750 m within the somewhat flat-floored deep-sea area of 3500-4000 m in the Inner Cape Verde Basin. (Rothe, 1973, Müller & Rothe, 1975) In these grab samples and piston cores, the absence or then rarity of terrigenous material is notable, probably explained by the geographic disposition of the islands in horse-shoe fashion, which shield the sampled area from continental influences, i. e. open marine sedimentation. It was also noted that volcanic material was scarce, which might have been eroded away or then might indicate little volcanic activity in the past 30,000 years. (In the period of recorded history for the archipelago, since 1445 or 1460, only Fogo has been actively erupting some 25 times. Mitchell-Thomé, 1981).

BATHYMETRIC CONSIDERATIONS

The bathymetry of the Cape Verde archipelago area show that the 4000 m isobath protrudes markedly westwards, the protuberance including the archipelago and the Cape Verde Rise. As per Weigel et al (1982) both archipelago and Rise are genetically related, having similar volcanotectonic histories, the Rise being uplifted some 1000 m, forming a local basement high, occurring contemporaneously with volcanism which built the islands. (It is of interest to note that the trend of Bouguer anomalies here show patterns similar to the isobaths, the 250 and 200 mgls especially. Bouvet, 1971). The westward protrusion of the 3500 m and 4000 m isobaths was thought by Bourcart (1946) as forming a great cape or headland of Africa which in time became gradually submerged. Grunau et al (1975) thought it represented a volcanic apron extending eastwards from the archipelago towards the mainland, whereas Serralheiro (1976) saw in it a seaward-extending apron of sedimentation from the mainland, to which were later added submarine flows. The islands rise from 5-7 km above the vicinal ocean floor, and the Rise forms part of the volcanic elements, the former being surrounded by volcanic aprons, admixed with sediments. DSDP Site 368, some 100 km NE of Sal, encountered diabasic sills at depths of 950-984 m below the ocean bed, in water ca. 4300 m deep. (Shipboard Scientific Party, 1977) A Miocene intrusion has been recorded under the Bafoulabe Rise, ca. 120 km SE of DSDP Site 368, at the SE border of the Rise. (Ruffman et al, 1977) and Miocene glass in Nanno marls and clays from depths of 161-265 m below the ocean bed (depth of 3366 m) at DSDP Site 368. (Rothe & Koch, 1977). The above promontory is bordered by Abyssal Plains to the NNW and S-SE. The Continental Shelf is narrowest off Dakar — ca. 20 km broad. The Continental Slope averages ca. 50 km breadth in these archipelago latitudes, rising steeply from depths of 2000-3000 m to the Shelf edge. This Slope was shaped by the growth of a Mesozoic carbonate platform, now lying under the Shelf edge. (Wissmann, 1982) The Continental Rise, within which lie the Cape Verde islands and plateau, ascends from average depths of 5000 m, with the Abyssal Plains having maximum depths between 5500 m and 6000 m.

Jacobi & Hayes (1982) have discussed the bathymetry of this general NW African marginal area, as also the micro-physiography, remarking on bathymetric-morprologic trends, which have general N-S and W-E orientations. To them, the Continental Rise has been developed by turbidity flows, sediment slides and geostrophic bottom currents. Turbidity flow pathways heading seaward are common on the Rise and Slope; sedimentary submarine slides are very common around isolated seamounts, islands and ridges on both the Slope and the Rise, one such slide extending from the Shelf break near Sénégal to SE of the Cape

Verde archipelago, a distance of over 570 km! Near the islands, several seamounts are present, some as shallow as 500 m, six fringing the eastern Cape Verde islands in roughly parallel fashion at distances of some 120 km and less, giving an impression of incipient islands. Significant features in these latitudes of the African offshore region are submarine canyons, the Mauritania, Cayar and Dakar canyons trending generally W-SW from the mainland towards the archipelago vicinity, and also the Cape Verde canyon, developed within the Inner Cape Verde Basin. The Cayar canyon, described by Dietz et al (1968), Egloff (1972) and Seibold & Hinz (1974), has a total length of some 900 km, beginning almost at the

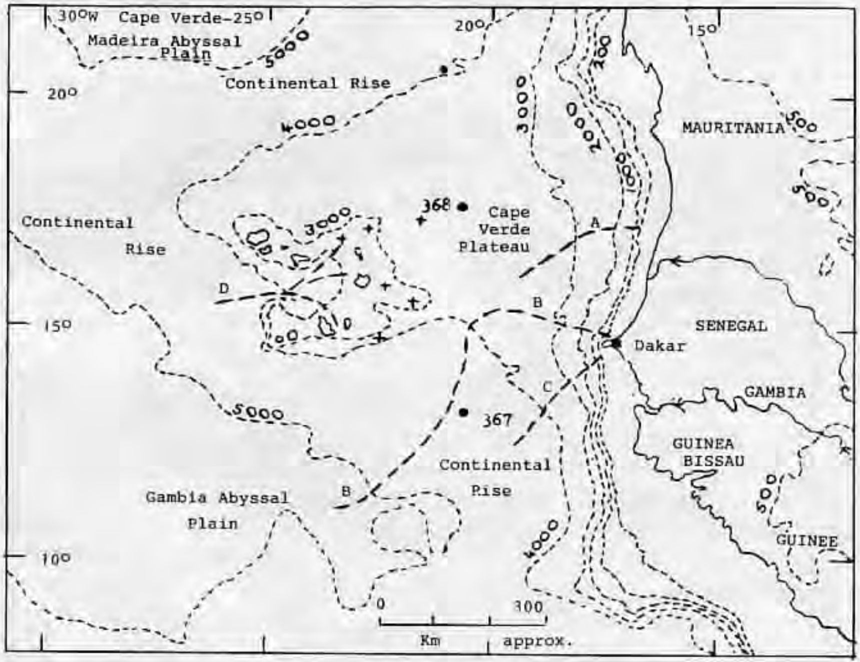


FIG.10 — BATHYMETRIC LOCATION OF THE CAPE VERDE ARCHIPELAGO.

ISOBATHS & CONTOURS IN METRES. ● DSDP SITES + SEAMOUNTS

SUBMARINE CANYONS: A MAURITANIAN B CAYAR C DAKAR D CAPE VERDE

(Modified after Carte Gén. Bathy. des Océans, Bur. Hydro. Intern., Monaco, 1968)

shore edge NE of Dakar. It first trends NW-W to ca. long. 21.° whereupon it turns abruptly to the SW towards the Gambia Abyssal Plain. The less pronounced Mauritania canyon has a W-SW trend from the coast towards the southern Cape Verde islands. The Dakar canyon commences some 45 km from Cape Verde and trends SW for ca. 220 km.

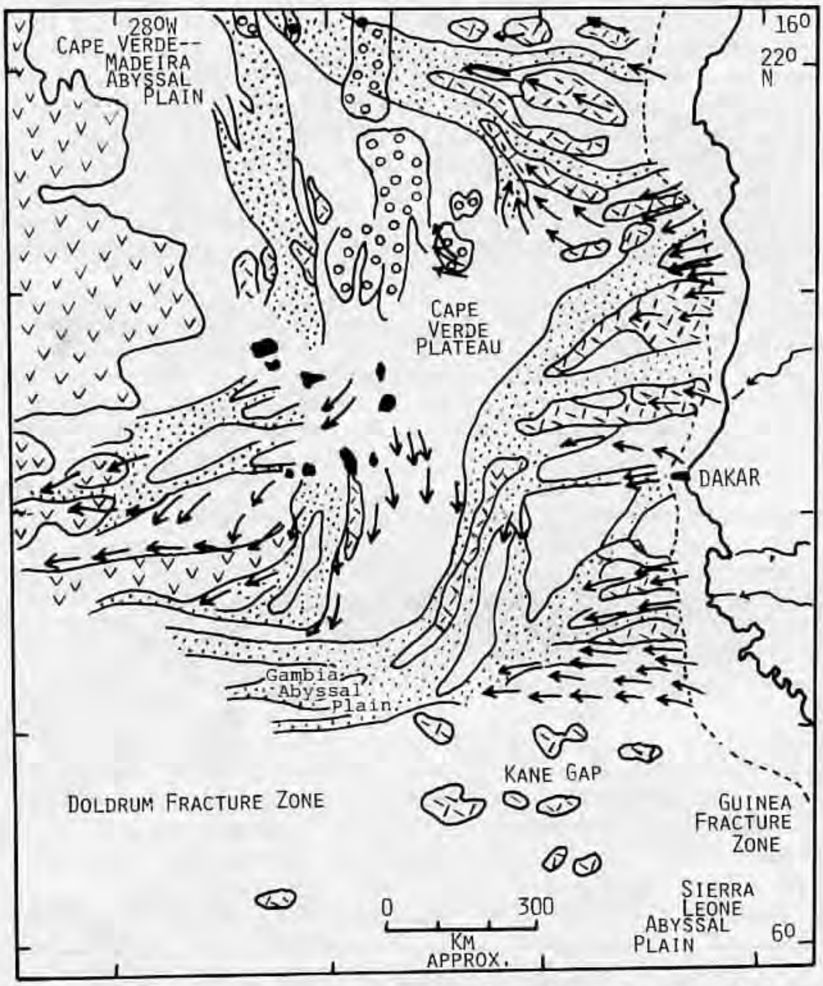


FIG. 11 — BATHYMETRIC FEATURES OF THE CAPE VERDE-AFRICAN AREA.

PIERCEMENT STRUCTURE PROVINCES

NARROW TUBIDITY FLOW PATHWAYS

BURIED AND EXPOSED SEDIMENT SLIDE COMPLEXES

ABYSSAL HILLS/MID-OCEAN RIDGD MORPHOLOGY

WIDE TURBIDITY FLOW PATHWAYS

CONTINENTAL SHELF BOUNDERY, AS PER BOTTOM REFLECTIVITY FEATURES

(Modified arter Jacobi & Haves, 1982)

The Cape Verde canyon forms within the horse-shoe disposition of the islands, originating tributaries in the S. Tiago-Maio, S. Nicolau-Sal and Sal-Boa Vista marine areas, the general course of the major canyon being SW-W into the Atlantic. All four canyons are characterized by similar W-SW trends. Jacobi & Hayes (1982) thought the first three canyons were formed by turbidity currents. Viewing the bathymetry, one might wonder if the Cape Verde Rise (which, as per Weigel et al (1982) was uplifted some 1000 m in M. Miocene times) interfered with an earlier submarine drainage of these canyons, particularly Mauritania and Cayar. These two canyon systems appear to have been deflected towards the SW by the Rise, either one of which (or both?) may have continued due westwards in line with the Cape Verde canyon.

CONCLUSION

Even in the case of the Canary Islands, as close as 100 km to the African mainland, the geological relationships of the two are not clearly evident, nor are we certain as to the nature of the crust beneath the islands. And in the light of present knowledge, it must be concluded that Cape Verde archipelago-African affinities are in general tenuous. Botanists and zoologists have been more forthright in postulating such than palaeobotanists and palaeontologists. Analagous biologic distributions encompass a relatively large area of Africa, from Algeria to Cameron, from the Atlantic seaboard to far within the Sahara. The many discussions amongst such scientists regarding such matters of affinity bear testimony to wide differences of opinion.

The petrography, petrochemistry and petrogenesis of some archipelago igneous rocks show close analogies with those of the Los archipelago, with neighbouring parts of Guinée and further afield in the Rift Valley region, with strikingly similar ring structures and rock types in the two archipelagos.

Stratigraphic and bathymetric affinities are better established. Especially for the Mesozoics, the lithologies, fossil contents and stratigraphic subdivisions do indeed find counterparts in western Africa. Mesozoic and Neogene marine sediments appear to continue at depth across the intervening oceanic gap.

As per Dillon & Sougy (1974) : «In general, the western continental margin of W. Africa has a simple structure formed by normal faulting of the basement, with subsequent subsidence. The slope and rise generally form a fan structure». This apron character noted for the Cape Verde «headland», displays basinal-type disposition of the sediments, dipping more steeply seaward off the continental margin and rising gently towards the archipelago. Volcanic upsurgings in the area of the islands during the Tertiary, gave the intervening oceanic region an eastward tilt to the flows and sediments, similar rocks dipping westward off the continent and so forming the basinal character in the Cape Verde Passage.

Kindred relations regarding tectonic and geophysical matters are too nebulous, too hypothetical, too subjective, to warrant serious considerations, for here one is impressed by the absence of the indispensable *aequo animo* approach by workers in these fields, the manipulation of facts to fit theory.

The imaginative, subjective approach characterizes the writing of History: the writing of Science requires a tightly-reined imagination and an objective approach. If the scientific imagination restrains itself within the limits of probability, we must never forget to ask ourselves: Who interprets the objective evidence?!

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