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The sediments of the Cape Verde Archipelago

by

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ABSTRACT

In the Cape Verde archipelago occurs the most extensive development of sedimentary rocks in Macaronesia. These comprise almost exclusively limestones which in general are thin and have slight inclinations towards the peripheries of the islands. In Maio, thick, steep-dipping limestones outcrop, constituting the oldest dated rocks in Macaronesia, of Malm-Neocomian age. These igneous islands, formed essentially of subaerial lave outpourings, had their origins in epicontinental seas, the sediments suggesting deposition in neritic, littoral and terrestrial environments.

Careful investigations of these sediments offer a promising field of endeavour in elucidating the geology of Macaronesia and the evolution of the Atlantic islands in general.

INTRODUCTION

In the Eastern North Atlantic, lying W of the coasts of Iberia and Africa, are the five archipelagos of the Azores, Madeira, Selvagens, Canaries and Cape Verde islands, constituting what is known as Macaronesia, having a combined area of 14,688 km² (Fig. 1). The relative closeness of Macaronesia to the Old World has meant that some islands have been known since ANCIENT times, and it is interesting to note that skulls discovered in old burial grounds in the Canaries indicate a Cro-Magnon affinity.

Relative propinquity to Europe has stimulated an interest amongst scientists and much has been written by investigators in various fields, including geology. Throughout the five archipelagos, extrusive rocks predominate to an overwhelming extent. Many phases of vulcanism can be studied here and we would note that present-day eruptivity draws the interest of scientist and traveller alike. The abundance of extrusives and pyroclastics, the magnificient varieties of igneous forms, studies on the mechanism of vulcanism, enquiries into the structures, tectures, genesis, petrology of the igneous rocks, etc. all have tended to demote sedimentary rocks to a very minor position. Whilst the archipelagos have attracted many of the world's great students of vulcanology and igneous petrology, the stratigrapher and palaeontologist have shown much less interest.

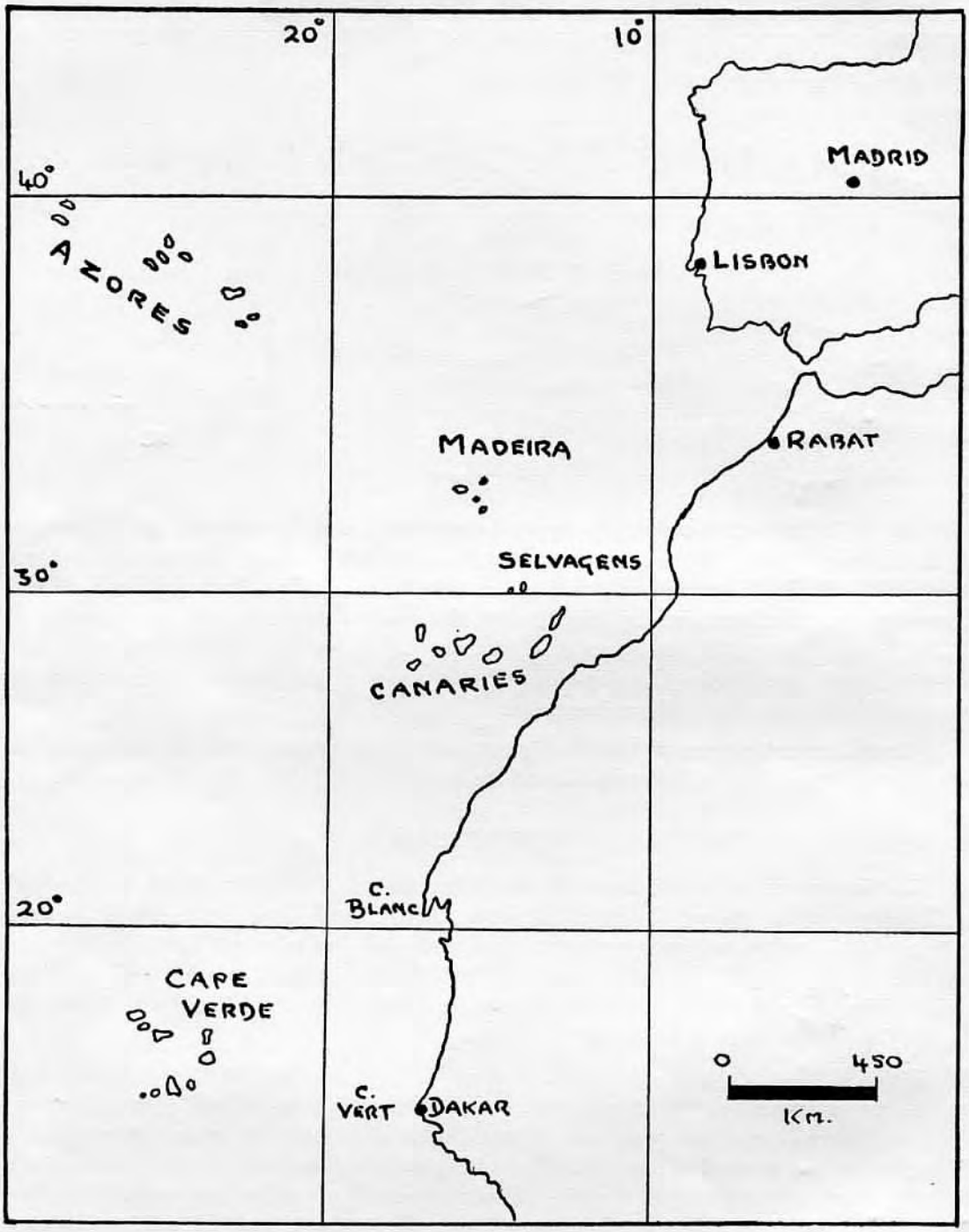

Fig. 1. Macaronesia

Although sedimentary rocks are not lacking in the other archipelagos, in the Cape Verde islands such rocks assume greatest importance, cover the greatest areal extents, acquire greater thickness and comprise a longer time range than elsewhere in Macaronesia. Because of these features and beacuse the sediments of Macaronesia are given relatively little attention in the literature ,it may be of interest to present here pertinent and current information regarding the sedimentary rocks of the Cape Verde archipelago.

During a stay of some four mounths, the writer had the opportunity of visiting all the inhabited island and three others, examined the sedimentary occurrences mentioned in the literature and discovered many hitherto unrecorded outcrops. The pressure of other duties, difficulties of travel within the islands and inter-island communication combined to prevent the prosecution of detailed, systematic studies and mapping.

PREVIOUS LITERATURE

The two standard references concerning the sedimentary rocks of the archipelago are those of *BEBIANO* (1932) and *TORRES* and *SOARES* (1946), both of which, however, are unsatisfactory from several points of view. The former is a reconnaissance study, and up to now is the only generalized account of the geology to be written, all subsequent publications by others making very heavy reliance on this work. *BEBIANO* gives only brief lithological descriptions of the sediments, seldom quotes thicknesses, makes no reference to stratigraphical matters and merely lists the names of a few fossils collected.

The work by *TORRES* and *SOARES* is a strange compilation, full of typographical and other errors, a confused bibliography, copious mis-spellings of fossil names and essentially quite lacking in all originality, except for fossil determinations. The writers never visited the islands and for all information regarding the sediments depend entirely upon *BEBIANO*, even copying *BEBIANO'S* typographical errors ! Lengthy verbatim quotations are taken from *BEBIANO* and such other writers as *FURON, CHEVALIER, JEANNEL* etc. etc. The merit of the publication is that in one volume it brings together scattered opinions in the literature regarding stratigraphical, palaeontological, palaeogeographical and tectonic interpretations.

The publication by *BERTHOIS* (1950) is chiefly concerned with a study of igneous rock samples collected by the Prince of Monaco (Berthois, 1946) from some of the islands. A few beach and dune sands were studied from the point of view of their granulometry and some 10 samples of consolidated sediments from three islands were investigated. Other than the above, no publication is available containing pertinent data regarding the sedimentary rocks, although there are a few papers dealing with the stratigraphy and/or palaeontology of some islands, and passing reference to sediments is contained in most articles dealing with the geology.

GEOGRAPHIC DISTRIBUTION

It is necessary to indicate that none of the islands are large ,and because of their configurations, no place within any island is far (maximum 14 km in Sto. Antao) from the sea. (Fig. 2, Table I). Except in Maio and Boa Vista, where sedimentary rocks have a large areal extent, such rocks are limited in general to localities within about 2 km of the sea. Sediments are usually to be found along coastal stretches where they may form cliffs or, more com-

monly occur interbedded with lava flows and/or pyroclastics forming more pronounced cliffs, as for example at Porto da Praia, S. Tiago, where 40 m high cliffs occur. In the lower sections of valleys, usually along the valley sides, sediments likewise are to be found interstratified with igneous material. Maio and Boa Vista excepted, only in Sal and S. Nicolau are thin, small, sedimentary outcrops present away from valley locations.

Because of the marked topography and strong relief so typical of many islands, sediments may occur at considerable altitudes in coastal and valley localities. In S. Tiago thin limestones in the Ribeira Barca valley are found as high as 150 m yet only a few hundred metres from the shore. On the other hand, the extensive exposures in Boa Vista may be found at altitudes of only 30 m yet some 7 km from the sea, as for example in the valley of the Ribeira de Sto. Antonio.

Highest known sedimentary exposures are found in Maio, S. Nicolau and Brava, at elevations of 235 m to 265 m.

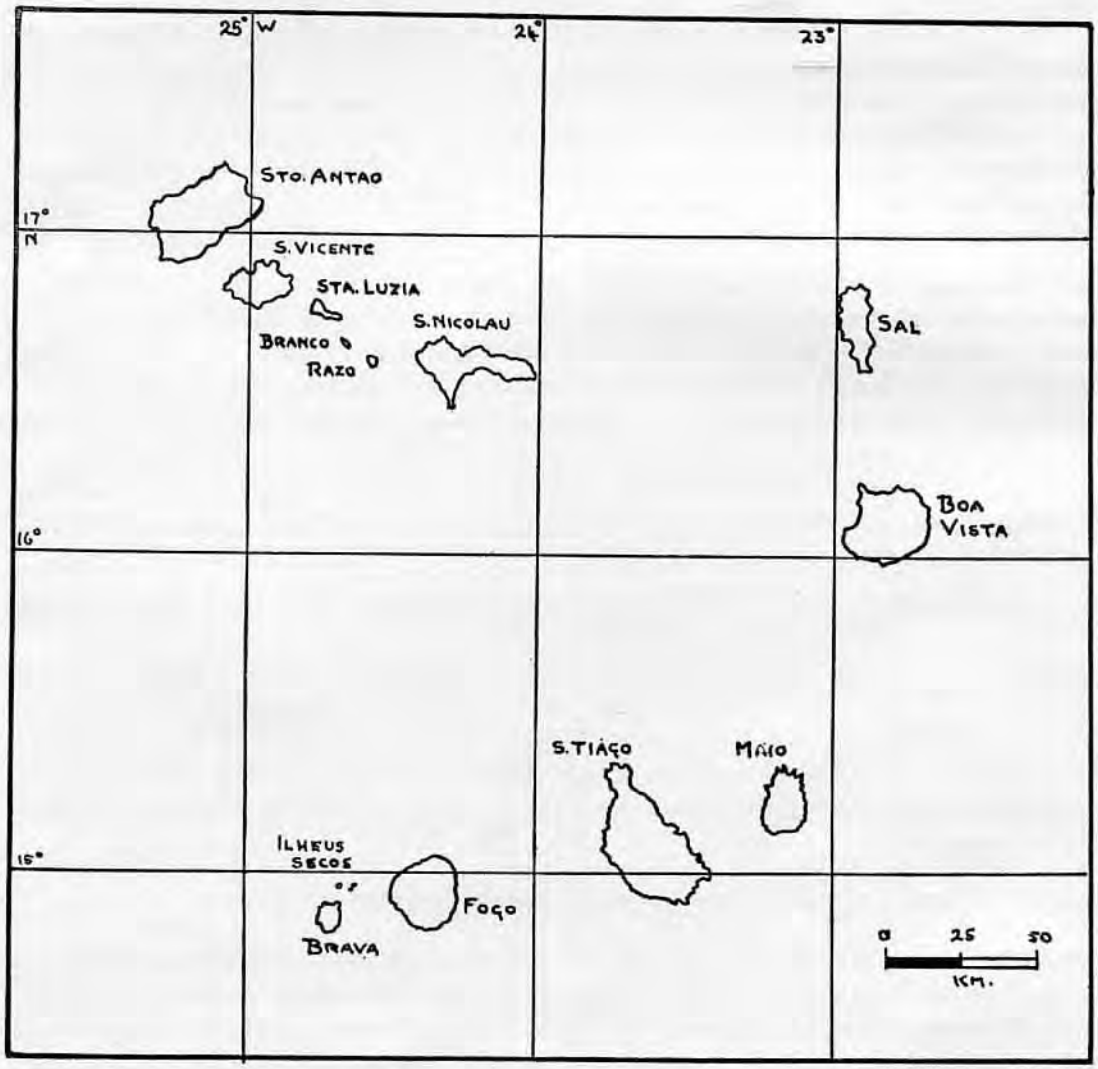

Fig. 2. The Cape Verde Archipelago

Sediments have their greatest areal extent in Boa Vista where they occupy about one-third of the island. However much of this terrain represents merely a duricrust a centimetre or so in thickness. In Maio sediments attain their greatest thickness, the Mesozoic rocks totalling at least 435 m thick.

Consolidated sedimentary rocks occur on every island except Branco, where only calcareous sand dunes are present. The consolidated sediments occupy about 9 % of the archipelago, or some 363 km².

LITHOLOGY

Dunes and extensive areas with an extremely thin covering of sand occupy the terrain in some islands — in Boa Vista, where such attain a maximum, some 90 km² of dunes and sand plains are to be found. Here, however, we shall only consider the consolidated varieties of sediments. Of these, limestones have overwhelming importance and probably account for something like 90 % of the sedimentary rocks present. Rudaceous and arenaceous sediments occur but argillaceous rocks are rare.

LIMESTONES

Calcitic limestones are the commonest types, and in large measure are of fossil-fragmental variety. These shelly-detrital or clastic biochemical limestones underwent transportation and deposition as a final stage in their development. Fossil fragments, generally of coarse size, rock fragments and various mineral crystals, mainly calcite, constitute the ensemble. The detrital character of these rocks links them closely with the clastic sediments and they are to be considered as allochthonous. Particle sizes of rock fragments and minerals show a range from about 0.2 to 3 mm in diameter and thus indicate features akin to arenaceous and rudaceous clastics. Fossil fragments, on the other hand, are very much larger — up to diameters of several centimetres — and frequently whole shells are present. Included constituents show a relatively high degree of rounding ,and, in fact, only quartz grains and compact dense igneous fragments such as basalt, phonolite, diorite, etc. have subangular to angular shapes. Characteristically these limestones include foraminifera, radiolaria, gastropods, lamellibranchs and echinoid shells, igneous rock fragments — mostly extrusive rocks — and of heavy minerals, augite and olivine predominate. Most often the cementing material is carbonate and in general the degree of bonding is somewhat weak, surficial friability being very common.

Only occasionally are calcitic limestones autochthonous, in which case they show a clayey matrix, are poorly sorted, branchiopod shells are often encrusted with bryozoa, there is a greater development of laminae, pockets and micro-lenses of marly material.

After the above types of limestones, those calcitic limestones containing much sandy-silty material are most common. Again these are of allochthonous biochemical type, showing amongst other features ripple marking and cross-lamination. The carbonate cement is sparingly developed and the rocks in general are much more friable than those mentioned above. Typically the carbonate cement comprises a coarsely crystalline lying between the detrital grains and thus when viewed microscopically gives a somewhat poikiloblastic texture. These arenaceous limestones are notable for their much greater proportion of tuf-

faceous residues, which give to the rocks a darker hue and also a more speckled appearance. In contrast to the limestones referred to above, these usually occur as thinner beds, are less massive, less compact, less durable.

Micro-brecciated limestones represent another type common in some islands. Under the microscope these are seen to comprise subangular shell fragments, angular fragments of extrusive rocks and euhedral grains of augite, olivine, magnetite, calcite and feldspars. The groundmass is composed of siliceous material in parts and also carbonate in crystallographic continuity. The close-packed arrangement of the included angular fragments leads one to suppose that in the process of lithification, considerable stresses must have been imposed to cause this compaction. The prevalence of angularity in all the constituents suggests a cataclastic origin — a grinding and crushing involving little movement. Noticeable in these limestones is the combination of both stable minerals — sphene and zircon, for example — and metastable-unstable minerals — such as augite, biotite, plagioclase.

The type of limestone which we may call, for want of current better term, normal marine limestone, is not abundant, though in S. Nicolau it acquires greater importance. In colour and purity such limestones are clearly distinguishable from other types. The texture is usually finely crystalline, of equigranular grains of saccharaidal appearance. Laminae of shaly and silty material are common, both of which have a quartzose character. Occasonally small nodules of chert show varying degrees of replacement of the fossils. These limestones are well bedded, tend to have a massive appearance, may be frequently jointed and show calcite veining.

The above varieties of limestone constitute a group in which no pronounced changes have occured so as to obliterate or confuse the inherent composition and origin. In the archipelago there are present, however, limestones which have undergone alteration and replacement and may be termed metasomatic limestones. Of these, dolomitic limestones are the most plentiful. Due to variation in the proportion of carbonates here, in more strict terminology we have magnesian limestones, dolomitic limestones and calcareous limestones. Where the Ca/Mg carbonate ratio is 90 : 10, the limestones are called magnesian ; where the above ratio varies from 50 : 90 to 50 : 10, we have dolomitic limestones ; where this ratio varies from 10 : 50 to 90 : 50, the rocks are termed calcareous limestones. The above three types of limestone can be found on several islands, but on the other hand, true dolomites, comprising more than 90 % Ca Mg $(CO_3)_2$ have not been recognized in the archipelago. As calcareous limestones are rare, these metasomatic rocks tend towards the limestone rather than the dolomite end of the scale.

The texture of the limestones is usually from fine — to medium-grain, but textural characteristics are far less clearly developed than in the non-metasomatic varieties. This is a consequence of the dolomitization which results in a pseudo-porphyroblastic texture. Small cavities within the rocks are common and appear to be due to solution which has removed fossil and/or calcite fragments. Occasionally dolomitic limestones may acquire a brecciated appearance. The matrix is of argillaceous nature in which the more angular limestone fragments are embedded. The argillaceous constituents are possibly derived from the decomposition of feldspars and micas in the vicinal extrusives, crystallizing centres extracting carbonates from the vicinity, at the same time that expulsion of argillaceous matter takes place, the latter thus forming the groundmass for the former.

Amongst evidences pointing to the secondary origin of such rocks by the replacement of $CaCO_3$ by $MgCO_3$, presumably by addition rather than leaching, we note the dolomitization of the fossils, sharp contacts and interlocking character of dolomite and calcite crystals, presence of subhedral quartz grains in euhedral dolomite. Siliceous limestones are most frequent in Maio and Boa Vista. The rock are dense, compact and hard ,and often show chert nodules and chert veining as well as silicification of the contained fossils. Styolitic contacts of the cherts with the limestones suggest a replacement origin for the siliceous material. This epigenetic silica deposition has taken place in the zone of weathering, where denudation over a long period of time has allowed waters to dissolve silica and enter into replacement of soluble rocks.

A few occurrences of ferruginous and bituminous limestones are to be found, the latter chiefly in Maio. The former show calcite replaced by siderite and occasionally the rocks are pyritic. The bituminous limestones have a typical dark colour and fetid odour when freshly broken. Invariable these limestones are associated with marly claystones which likewise have acquired a bituminous character. Both limestones and claystones contain some sulphur compounds.

CONGLOMERATES

After limestones, conglomerates are the most abundant sediments. These, of boulder and pebble size ,are of two types — those with igneous ingredients and those comprising limestone fragments, though in both types some admixing is always present. These epiclastic conglomerates comprise usually basaltic and phonolitic boulders, though other igneous rocks may occur but never so prolific. The limestone ingredients include only those more dense and compact varieties of limestone, and in general the size of these fragments are smaller than igneous ingredients. Quite common in places are conglomerates with ignous ingredients of boulder and cobble size along with limestone ingredients of pebble and gravel size. Commonly the cementing material is sil'ceous rather than calcareous, but ferruginous-cemented rocks are common in Fogo. It is believed that some of the limestone conglomerates are self-cementing. Siliceous-cemented conglomerates invariably are more compact, consolidated, whereas calcareous-cemented varieties are very much more friable. The cementing substances are all believed to be authigenic.

The occurrence of limestone conglomerate must obviously call for ~~somewath~~ SOMEWHAT special conditions, involving rapid erosion of limestone beds with no long interval of weathering, and also rapid burial after transport.

Igneous conglomerates show both horizontal and cross bedding and may attain individual thicknesses of several metres. Limestone conglomerates present no clear indications of any bedding and always are much thinner.

As a generalization, the conglomerates tend to be wellsorted and lithologically quite homogeneous, they are present as relatively thin beds and suggest basal deposition of transgressive seas. Less frequent are poorly-sorted, lithologically homogeneous conglomerates, such as intraformational limestone conglomerates. The Cap Verde conglomerates are essentially of oligomictic type, synonymous with conditions of epicontinental sedimentation.

SANDSTONES

Of arenaceous rocks, calcarenites and tuffaceous sandstones predominate.

As used here, calcarenites refer to slightly indurated rocks where the detrital constituents, calcite and quartz, comprise more than 50 %, of which calcite averages 25 %, the grain size lying within the range 0.07 to 2 mm. and possessing a texture and structure akin to detrital rather than chemical sediments. These rocks can be regarded in general as medium-grained calcareous sandstones, chiefly of clastic texture — minerals plus fossil debris — in ~~with~~ the cementing material — most commonly $CaCO_3$ — is a chemically authigenic product. Occasionally silica, in the form of overgrowths on quartz grains, or then limonitic material acts as the bonding medium. The calcarenites all tend to be very friable and invariably have light colours. Stratification is good and cross-lamination often is well developed. Calcarenites grade into calcareous siltstones on the one hand and into sandy and silty limestones on the other but as distinct from the sandy-silty limestones mentioned above a matrix is less well defined and the mineral composition more varied.

Tuffaceous sandstones are all of darker colour and grade imperceptibly into tuffs. The grains are usually coarse and angular, weakly bonded by ferruginous cement.

Graywackes are sparingly developed. Sorting is poor, the cement is siliceous, small-scale cross-bedding may be present and frequently the rocks have a characteristic red coloration.

Nowhere are arenaceous rocks of commanding aspect. Invariably they are thin and highly irregular in external morphology. Weathering, whether by running water, the waves or wind readily attacks the rocks, resulting in slumping and formation of thin sand veneers.

ARGILLACEOUS ROCKS

Marls and calcareous clays are the chief representatives. The hybrid rock marl shows a higher clay than carbonate content and hence here is considered argillaceous. The soft, white, powdery marls are nearly always associated with calcitic autochthonous limestones and occur as lenses and stringers.

Calcareous clays are very thin and highly sporadic in occurrence. They are of reddish colour and all occurrences noted were in valleys some distance removed from the coast. The clays at Rabil in Boa Vista are used for the manufacture of tile and crude pottery.

BERTHOIS (1950) described a siliceous shale (phtanite) from Sal, and because the sample was entirely devoid of organisms he preferred the above term rather than jasper, though the specimen had the common red aspect of jasper. In S. Nicolau, S. Tiago, Maio and Brava the writer has noted small outcrops of reddish siliceous claystone containing radiolarian tests.

Terrigenous deposits of size dimensions commensurate with clay and silt formed as a result of aeolian agencies were noted in some islands, e.g. NE Boa Vista. This material present certain features — such as lack of stratification, ability to maintain vertical walls which suggest loess.

In general the argillaceous sediments of the archipelago are characterized by lack of induration and fissility and stratification is weak. The exposures are all small and thin, sporadic in occurence. However thin partings and laminae within the limestones and sandstones of argillaceous material are to be found almost anywhere such rocks occur.

DURICRUSTS

It has been remarked that duricrusts occupy large extents in Boa Vista and also are prominent in Sal and Maio. The duricrust or hardpan represents a layer of indurated soil, a lime-rich deposit, resulting from the evaporation of mineralized groundwater, where capillary action draws the lime-bearing waters to the surface. Limestone deposits were slowly dissolved by infiltrating waters of the infrequent rains, lime being deposited in a deeper layer. This redeposited lime accumulated as an indurated hardpan, and actually constitutes the first evidence of soil development in the areas in question. These duricrusts therefore represent pedological rather than sedimentary deposits.

They are invariably thin — less than 3 cms. — are very hard and brittle and have broken into sharp, angular tabuar bodies, difficult to traverse by any means.

As duricrust is a pedological product, the extent of true sedimentary deposits within the archipelago is somewhat less than indicated in Table I — probably an area of some 40 km^2 represents duricrusts.

Low-grade metamorphism of sediments can be seen in some islands, e.g. Sal, S. Vicente, S. Nicolau, Brava, Boa Vista, Maio. The metamorphism is of thermal optalic type, resulting from the injetion of thin dykes and sills and also lavas emitted at the surface. Because of the predominance of limestones. their susceptibility to change due to the solubility of their minerals and the ease with which recrystallization takes place, these rocks display more clearly changes resulting from increased temperatures.

Incipient marmorization, induration, baking and fritting has been accomplished, forming crystalloblastic aggregates, but true marbles are nowhere present. Where the original silica impurity was high, the result is lime silicate ; where there was a considerable magnesian content, calc-silicate hornfels has formed.

Occasional examples of granoblastic graywackes and porcellanite have been noted, but it appears that sediments other than limestones have, in their totality, been unaffected by metamorphism.

THICKNESS, ATTITUDE, STRUCTURES

With the exception of Maio, Boa Vista and Sal, sedimentary occurrences are all small and localized. Sediments may have surficial exposures or then occur interbedded with extrusives and/or pyroclastics. Older sediments are interstratified with igneous material but limestones of Pleistocene and even Holocene age may be interbedded.

With one outstanding exception, exposures, whether surficial or interbedded, are thin. In the Tarrafal region of S. Tiago, limestones, conglomerates and sandstones total 34 m in some sections, but an average thickness for the sedimentary rocks is rather of the order of 2-3 m. Although sediments have the greatests areal extent in Boa Vista, yet here the thickness nowhere exceeds some 7 m, and for the most part are only a metre or so or a fraction thereof. In Maio thicknesses attain relatively great proportions. In the vicinity of the stream and village both called Morro, some 4 km N of the capital Porto Inglez, *STAHLECKER* (1935) reported 400-500 m of limestones, marls and clays which he assigned to the Neocomian. At this locality, the writer has measured 435 m of sediments. Nowhere else in the archipelago, nor for that matter in all Macaronesia, is such a thickness of sediments to be found.

As a generalization it can be said that the sediments lie horizontally or then show very small inclinations. Almost invariably surficial exposures show these attitudes. Interbedded sedimentary rocks display a greater variety in attitude, but seldom is the dip in excess of 25-30°. The regional dip is always towards the peripheries of the islands.

As with the thickness, so too with the dips, the exception is Maio. At Morro and Barreiro, for example, rocks dipping at extremely high angles and even vertical, are present. In the valley of the Barreiro, in the 20 m high steep valley sides, excellent exposures of limestones, lamprophyric dykes and oceanites are all dipping at 70° to the NE.

One searches in vain for examples of tectonic disturbances in the sediments, and it is extremely doubtful if any of the small folds and faults noted are of true tectonic origin. Such disturbances as are seen are the result of pseudo-tectonics — slumping and gliding — or then volcano-tectonic features imposed upon the rocks as a result of igneous emplacements. Minor puckerings, slippage, facturing is indeed however quite common — jointing in the limestones is typical — but all such features are of small dimensions.

On the other hand, structures acquired during processes of sedimentation and/or lithification and diagenesis are well represented. Of syngenetic structures, cross-bedding, wave- and rill-marks are prominent in the arenaceous rocks. Accretionary epigenetic structures such as nodules, concretions, septaria in the calcareous sediments and clastic dykes in the rudaceous-arenaceous rocks are to be noted. Probably the most common sedimentary structure is the current bedding associated with the clastics. Water, either as waves or streams, has been the chief agent causing this. Occasionally examples are met of torrential bedding affecting gravels and conglomerates. Cross-bedding of aeolian origin seems scarce, even in dune formations. This would presuppose a relative constancy in wind directions throughout much of the geological time represented stratigraphically by the islands. (At present the NE Trade Winds predominate throughout the year in all islands, and where dunes and sand plains are plentiful, the direction of movement is and has been from NE to SW). A good example however of cross-bedding of aeolian origin occurs in the compact, consolidated old dunes at Montinho de Lume, Maio.

The commonest syngenetic structures in calcareous rocks are concretions. These include chert, calcite and iron oxide concretions. Most are of ellipsoidal or disc shapes and tend to show amorphous internal structures. It is believed that these concretions formed contemporaneously (or penecontemporaneously) on account of the frequent presence of fossil nuclei and the abrupt termination or then abrupt bending of stratification planes where concretions occur. Concretions in arenaceous and argillaceous beds seem mostly to be of epigenetic origin, as the bedding planes of the host rock pass through the concretions.

Styolites occur in the metasomatized limestones. Generally the styolitic surface shows minute irregularities, governed by the textural variation between cherts and limestones. These surfaces can be traced for distances of several metres and die-out where the rock acquires a greater impurity.

Intraformational limestone conglomerates are always thin, contain much sandy material, and as they are associated with mudcracked clays, we presume that they have resulted from desiccation and hardening of calcareous muds and clays and redeposited in a similar milieu.

The only pronounced unconformity observed is the angular one in Maio separating Mesozoic and Tertiary beds. Innumerable interruptions in sedimentation of the order of diastems suggest a slow rate of deposition for the sequence as a whole.

At Monte Focinho, S. Nicolau, 7.5 m of marly and dolomitic limestones are dipping at 47° to the SW. The acquisition of such a relatively high dip is here associated with a prominent N-S curving fault running some 12 km just to the W of the sedimentary exposures. The limestones and the block E of the fault were upraised and tilted to the W, this old fracture being reactivated in possibly late Neogene time.

The very steep-to-vertical sediments of Maio are intimately associated with lamprophyre dykes and various types of basaltic flows. In strong angular unconformable relationship to these are soft, silty and sandy limestones. The former sediments are taken to be Mesozoic and the latter, Neogene-Holocene. This feature, therefore represents a structural stratigraphic hiatus. The high inclination of the Mesozoic sediments is assumed to have resulted from a pushing aside by viscous lavas. In seeking an outlet to the surface, the lavas had to thrust up the older superincumbent sediments and in so doing gradually caused them to bend more and more until even a vertical position was attained. Though at Barreiro these steeply-dipping sediments total only some 20 m in thickness, at Morro we have more than 435 m of stepply-inclined rocks dipping westward, of which more than three-quarters comprise compact limestones underlying marls, marly and clayey limestones with stringers and lenses of arenaceous rocks. Limestones in general are considered to be competent rocks and the limestones here at Morro certainly are. To explain the up-ending of thick beds of competent strata by means of upthrusting magma would seem to call for eruptivity relatively soon after the deposition of the sediments, before they had acquired lithification, i.e. magma upwelling took place before diagenesis had time to effect any radical lithic changes. Some confirmation of this is forthcoming from structures observed at Morro. These high-dipping beds here and there show strata of pure limestones folded asymmetrically, the axial planes of the folds dipping at a smaller angle in the direction of the general dip. These folds seem to have developed as a result of gliding on non-lithified deposits which occurred when the strata were upended, the slope thus created causing instability for the recently formed, non-lithified beds, which folded in this manner under the influence of gravity. It is to be noted that nowhere in Sal or Boa Vista, where presumed Lower Cretaceous-Malm rocks occur, are high dips to be noted and no angular unconformable contacts can be seen with younger sediments.

STRATIGRAPHY

No formational or other stratigraphical units, whether time, time-rock or rock, have been proposed by any workers for the sediments of the Cape Verde islands. Indeed, however, this is a fortuitous event, for too often terminology is hastily devised before any sound knowledge of the rocks in question have been obtained.

The first fossil interest in the archipelago dates back to the voyage of *CHARLES DARWIN* in the "Beagle" (1844). Since then various scientists visited the islands and made and/or studied fossil collections, but the sum total of either the fossil collections or palaeontological-stratigraphical writings is small indeed.

PRE-MESOZOIC

Several workers have claimed a Palaeozoic and even Pre-Cambrian age for rocks present in the archipelago. Apparently *DOELTER* (1882) was the first to suggest a pre-Mesozoic age for gneissic boulders found on the beach at Porto Inglez, Maio. Later in 1913, *FRIEDLANDER* corrected this statement by noting that these boulders had been transported as ballast in ships coming from Brazil, and this also applied to gneiss, granite and quartzite boulders found at Sal-Rei, Boa Vista. *DOELTER* also considered that the marmorized and dolomitic limestones in Maio, S. Vincente and S. Tiago were intimately associated with schists and plutonic rocks, all of which represented vestiges of an ancient continent. The limestones he thought were Mesozoic and even Palaeozoic.

GAGEL (1910) claimed that the basement volcanics and interbedded sediments of the islands were the isolated remains of an ancient continent, these rocks being of Palaeozoic/Pre-Cambrian age. *BERGT* (1917) in his notes to accompany *FRIEDLANDER'S* map of the archipelago, referred to granites in Sal, S. Tiago, Brava and Ilheu Grande, biotite-gneisses and green-mica-gneisses in Boa Vista, but stated that these all represented ship-ballast material. Though he refrained from actually assigning an age to the metamorphosed limestones of the archipelago, he considered such to be the oldest sediments and by inference allots them to the pre-Mesozoic.

CHEVALIER (1935) claimed that in several islands (he does not specify) are to be seen traces of ancient socle in the form of gneisses, diorites, diabases, syenites and gabbros. *FURON* (1935) stated a Pre-Cambrian socle was represented by granites, ortho — and paragneisses and also various metamorphic rocks in the islands of S. Tiago, Sal, Fogo and Boa Vista. Though claiming that, strictly speaking, we know nothing of the Palaeozoic, he believed that some crystalline limestones containing mica and amphibole outcropping in Fogo could probably be assigned such an age. *D'ORCHYMONT* (1936) believed that in Fogo, Sal, Maio, Boa Vista, S. Vincente and S. Tiago there were traces of ancient volcanics and Archaean sediments, constituting the foundation material of these islands.

It is thus seen that *GAGEL, BERGT, FURON* and *D'ORCHYMONT* made claim for a Pre-Cambrian and/or Palaeozoic age for sediments occurring in the Cape Verde islands. However in the second edition of two of his books, *FURON* (1959, 1960) corrects himself, and in personal correspondence with the writer has remarked : „Je suis entièrement de votre avis sur l'absence de socle cristallin aux Iles du Cap Vert."

It is made abundantly clear from the literature that all the above statements regarding a socle, ancient rocks, gneisses and granites, etc. are extremely vague in context and completety lacking in substantial evidence. We would further remark that *BEBIANO*, who, to date, has spent more time in the archipelago than any other geologist, made no reference to possible pre-Mesozoic rocks, and from personal contacts, his opinion is still the same. The writer agrees entirely with *BEBIANO* on this point, and nowhere within the archipelago are gneisses present, granites are totally lacking, oversaturated rocks, whether intrusive or extrusive, are essentially non-existent.

In the light of our presente knowledge, therefore, it is idle to speculate upon pre-Mesozoic times, for nowhere within any of the islands has any evidence of any type for such old rocks been substantiated. Too frequently such statements have had a foundation

solely in a 'certain feeling' on the part of the worker. It must also be emphasized that too many geological articles were compiled by those who never visited the archipelago, a feature most characteristic of palaeontological papers.

MESOZOIC

FRIEDLANDER (1912) collected near Morro, Maio, some specimens of *Aptychus*, all more or less fractured and broken, which ware reported by *HENNIG* (1913). These specimens and those collected by *STAHLECKER* (1935) were later studied by *TRAUTH* (1936, 1938) and *SOARES* (1944-47), and further comments were made by *SOARES* in 1952. *HENNIG* specifically only determined one specimen, *Aptychus atlanticus Hennig sp. nov.*, but this, along with other fragmented specimens, allowed him to make comparisons with the Solenhofen fauna of Germany, from which he deducted an Upper Jurassic age. *TRAUTH* (op. cit.) however recognized the following species in the *FRIEDLANDER* collection : *Lamellaptychus angulocostatus (Pet.) var. atlantica, Aptychus of euglyptus, Ammonites euglyptus OPPEL and Aptychus sp.(= Laevilamellaptychus Hennigi TRAUTH).* He attributed *L. angulocostatus (Pet.) var. atlantica* to the Neocomian, which likewise was placed in the Neocomian by *STAHLECKER*. *SOARES* (op. cit.) however argued that *L. Hennigi TRAUTH* was indicative of the Malm (Portlandian ?), and further, that all the other form of *Laevilamellaptychus* studied by *TRAUTH* are to be referred to the Dogger and Malm of Europe and the Tithonian of Argentina. From a further collection made at Morro by *SALDANHA* in 1945, *SOARES* (1952) determined the following : *Laevilamellaptychus aff. xestus TRAUTH var. Sousa-Torresi, Lamellaptychus Saldanhai var. Assuncaoi.* He claimed that these determinations, plus the facies characteristics of the rocks-limestones with flint nodules and showing styolites — indicated a Portlandian age. It was *SOARES'* opinion that *STAHLECKER'S* Lower Neocomian was really Upper Malm. *SOARES* (op. cit.) quotes a letter received from *TRAUTH* in 1948 in which the latter says : "In stratigraphic regard, I cannot contradict you and *E. HENNIG'S* meaning that many of the Maio *Aptychi* are originated from U. Jurassic strata (Portland-Tithon) ; but the *Lamellaptychus angulocostatus var. atlantica.* I think indicates already transition from Upper Jurassic to Neocom (ev. Berrias ?) or Neocom, and *STAHLECKER'S L. angulocostatus and L. seranonis* certainly, as also demonstrate the *Ammonites.* L. Cretaceous (Neocom)". In the same publication of *SOARES*, however, later on we are led to understand that in subsequent correspondence with *TRAUTH*, the latter was prepared to accept a Malm age. For the present, therefore, the beds at Morro, Maio, *may* belong to the Malm, which would make these not only the oldest dated sediments in the archipelago, but the oldest dated rocks in all Macaronesia.

In Maio, *STAHLECKER* (1935) recognized the Neocomian (Valangian, Hauterivian, Barremian), and as alrealy remarked, *TRAUTH* (1956, 1938) originally placed *FRIEDLANDER'S* specimens also in the Neocomian. However, as a result of *SOARES'* publications 1944-47, 1952) and his correspondence with *TRAUTH*, we are now not certain as to the rock proportions to be assigned to the Malm on the one hand and the Neocomian on the other. *SOARES* seems to prefer to place all the lower Neocomian of *STAHLECKER* in the upper Malm. *HEINZ* (1935) however recognized species of *Inoceramus* in material collected from Maio which, according to him, proved the presence of the Lower Cretaceous. *STAHLECKER* likewise recognized at Morro, Maio, the presence of Aptian and post-Aptian was

absent within the archipelago. *FURON* (1935), on the other hand, claimed that marine beds younger than the Aptian were present but had not yet been dated. However later, *SOARES* (1948) mentions the likely presence of the Senonian at Monte Focinho, S. Nicolau and believed that the azoic and/or metarmorphosed limestones of S. Vincente, Sal, Maio and Ileheus Secos were also of this age.

During the time the writer was in Cabo Verde, Dr. Karl *STAESCHE* of the Geological Museum, Stuttgart University was also there engaging in palaeontological studies, chiefly in Maio. Recent correspondence with *STAESCHE* indicates that so far he has not completed his fossil studies, nor has he published. However in a personal letter dated September 19, 1962 he states : "Concerning the Mesozoic rocks of Maio, my collections are in accord with the results obtained by *STAHLECKER* in 1929. Where fossils could be found, they belong to the Lower Cretaceous, but, like *STAHLECKER*, I did not find anything in the lowermost beds of the sequence, in spite of the special attention given to them. Therefore the Upper Jurassic age of these lowermost beds cannot be excluded, but there is no proof of fossil evidence."

The presumed presence of the Malm and Neocomian in Boa Vista and the Cretaceous in Sal is, at this stage of our knowledge, based solely upon speculation, and the presence of Senonian in the above islands has not been proven.

TERTIARY

(1) Palaeogene

The literature, especially that of *TORRES* and *SOARES* (1946) gives brief indications of the presence of Eocene and/or Oligocene in some islands. At Monte Focinho, S. Nicolau ; Montes Cabouco and Verde, S. Vicente ; Morro Branco, Sal ; Monte Miranda, Brava ; Vale da Custa, S. Tiago ; Portela Esteves and Ribeira Gombezinha, Boa Vista ; Porto Inglez, Barreiro, Ribeira Casas Velhas, Na. Sa. da Luz and other localities in Maio, rocks of supposedly Palaeogene age have been mentioned. Oligocene is suspected in S. Nicolau, Maio and Bao Vista and Eocene in S. Nicolau, S. Vicente, Sal, Brava and S. Tiago. To date, the very small sedimentary occurrence at Monte Focinho, S. Nicolau has created most interest in this respect. *TORRES* and *SOARES* (op. cit.), on the basis of fossil determinations of the limestones collected at this locality by *BEBIANO,* stated that these indicated a time-interval beginning in the Nummulitic and ending in the Vindobonian. However in 1948, *SOARES* claimed the likely presence of the Lutetian at this locality.

Some authors, e. g. *FURON* (1935), *BOURCART* (1946) believed that during the Palaeogene — or part thereof — the entire archipelago was emergent, thus accounting for the absence of such strata. For the present, no dogmatic statements can be made regarding the Palaeogene of the Cap Verde islands, but in all likelihood future study will prove the presence of such.

(2) Neogene

TORRES and *SOARES,* writing in 1946, stated that up to that time (and the statement still holds true) the most numerous species of Neogene fossils had been obtained from S. Nicolau, and whilst the actual number of fossil specimes collected in some other islands

— S. Tiago and Maio, for example — was of almost equal quantity, the disparity in numbers of species collected from the various islands created a serious disproportion when attempting to engage in palaeontological-stratigraphical analyses. It follows therefore that the Neogene stratigraphy is better determined in S. Nicolau than elsewhere in the archipelago.

The question of the presence of the Lower Miocene in S. Nicolau can not be settled at this time. The above authors prefer to regard the oldest Neogene beds of this island as being Vindobonian, sensu lato, by which they mean Middle Neogene. They regard the Lower Miocene as comprising the Burdigalian and Aquitanian, but their Vindobonian, sensu lato, equals the Middle Miocene (Tortonian and Helvetian). Although the Burdigalian in general is taken as marking the beginning of the Miocene transgression, the above authors contend that in the Cape islands at least this occurred in the Helvetian.

The Vindobonian (Helvetian and/or Tortonian) was believed by the above authors to be represented in all islands where sediments occur, but writing in 1948 *SOARES* omits Brava from the list.

As sedimentary rocks were hitherto almost unknown in Fogo, it might be of interest to remark that in the micaceous and siliceous limestones in the Ribeira Sanha, the whriter obtained some poorly preserved fossils, kindly identified by Dr. *A. SAYYAB* as : *Oliva flammulata LAMARCK, Arca (Senilia) senilis LINNAEUS, Chama gryphina LAMARCK and Certithium oemulum SOWERBY*. These species have been recognized as Vindobonian in S. Nikolau, S. Tiago and Boa Vista. The first-two named fossils were considered as probably lower Helvetian in Boa Vista by *TORRES* and *SOARES* (op. cit.). Nowhere has the Pontian been proven but it is suspected in most islands.

LECOINTRE (1962) remarks that as regards Sal (and by inference, the archipelago as a whole) many beds which previously have been determined as Miocene should be classed as Quaternary. In a personal communication dated July 30, 1962 he further comments : „I believe that perhaps all the predecessors believed to be Miocene are Quaternary."

The contention of *LECOINTRE* perhaps receives some support from *STAESCHE'S* studies. The latter is of the opinion (letter quoted above) that in Maio on the summit of Monte Esgrovere (99 m) the shore/near-shore limestone deposits, measuring up to 40 cms in thickness (constituing the 'Schill' of the Germans) contain very badly preserved fossils which render difficulty in determination but *STAESCHE* thinks they are younger than the generally assumed Middle Miocene and may be Upper Miocene or even Pliocene. In Sal, he believed also that younger fossil deposits occurring as high as 50 m above sea level might also be Holocene and Recent ,and in S. Tiago, he states : "I doubt whether even the intravolcanic sediments at Praia are as old as Middle Miocene, and I am more inclined to consider them as of later age."

The Lower and Middle Pliocene (Plaisancian and Astian) are believed present in the archipelago, but only in S. Nicolau are we reasonably sure of this. In the other islands, recourse is made solety to facies correlations. *SOARES* (1948) remarks that the molluscs show partly a Vindobonian character and partly a Plaisancian-Astian character.

QUATERNARY

Pleistocene and Holocene can be established in nearly all islands. Only in Branco and Ilheus Secos is palaeontological evidence so far lacking, though we have little reason to think Quaternary is absent here.

The Pleistocene clastics are believed to be Tyrrehenian by *BERTHOIS* (1950), and stated as Tyrrehenian by *FURON* (1950, 1960).

It is obvious from what has been said above that in spite of some 120 years of stratigraphical-palaeontological interest shown in the archipelago, careful studies, wether in the field or in the laboratory ,and precise knowledge concerning the ages of the sedimentary strata and the chronological evolution of the islands are lacking. Fossil collections have never — with the possible exception of the *Aptychi* or Morro, Maio, and the present studies of *STAESCHE* — been submitted to rigorous and exhaustive study. The greater part of all palaeontological-stratigraphical investigations have been made by those unacquaint with the islands. General geological mapping and geological knowledge is only at a reconnaissance stage of development. There is no substitute for personal field acquaintance, and therein lies much of the problem as this affects the Cape Verde islands.

GEOLOGIC EVOLUTION

As far as is known, intrusives occur on all islands except Branco and Razo, but as our geological acquaintance here is extremely sketchy in nature, doubtless plutonics are present. However plutonics do not constitute the fundament of the islands, though in general they do represent older phases of igneous activity. The basement material of the archipelago is represented by extrusives of basaltic type, and from what can be ascertained, the building of the islands began with subaerial outpourings of basalts, most of which contain olivine in varying proportion. There is a possibility that in Brava the origins began with saturated intrusives of dioritic and syenitic type, now found as small exposures deep within valleys.

The prevailing view of an intrusive basement (the Tiefengestein of *BERGT)*, presuming that plutonism represented the initial igneous phase, gives the impression that the archipelago construction resulted from a sequence of lava extrusions and pyroclastic deposition built on top of an intrusive foundation. Such a view finds little if any substantiation from field evidence. It is preferrable to regard the vast bulk of the intrusive rocks rather as hypabyssals, by which we mean that 'floors' are visible, they did not consolidate in a deep-seated environment under a thick cover, they do not represent intrusion of major status. Though quite agreeing with *HATCH, WELLS* and *WELLS* (1952) that too much emphasis has been placed hithertofore on the mode of occurence of igneous rocks, in the Cape Verde islands it seems desirable to point out the 'intermediary' character of the hypabyssals in order essentially to distinguish these occurences from plutonic fundaments.

As to the age of these earliest manifestations of igneous activity, all we can say, with any degree of certitude, is that in some islands — Maio, for example — they date from pre-Malm times and at the oldest are possibly to be assigned to the Jurassic.

The oldest dated sediments of the archipelago — the Portlandian (?), Valangian and Hauterivian of Morro, Maio — are claimed by *TORRES* and *SOARES* (1946) to have formed at great depths, and *TEIXEIRA* (1950) refers to an environment of formation at the depth of 2000 m.

TORRES and *SOARES* seem to base their contention upon microscopic study of *BEBIANO'S* samples, of which they quote only one such analysis as follows : "Cryptocrystalline limestone, containing Radiolaria (presumably of the genera *Cornutella sp., Bathopyramis sp., Conosphoera sp., Staurosphoera sp.* and *Theococys sp.)*, crystals of dolomite and veined with pure calcite." From this solitary evidence there is no compelling reason to invoke great depth of formation. Radiolaria do not, *per se*, testify to great depth, and may indeed even indicate shallow lagoonal deposition. *TWENHOFEL* (1939) claimed there was little supporting positive evidence for a deep-sea origin for radiolarites. Isolated rhombs of dolomite may occur in deepsea deposits but also may occur at depths of 500 m. *FAIRBRIDGE*, (1957).

TEIXEIRA (op. cit.) gives no reasons nor presents any evidence for claiming depths of 2000 m as the locus of formation of Malm-Valangian-Hauterivian sediments. He further claimed that the Barremian-Aptian strata indicated a greater variety in environment of deposition, but the absence of sands suggested distance from the littoral zone, and he proposed a geosynclinal site of deposition.

As vulcanism is associated with these sediments we would therefore presume that the geosyncline was of eugeosynclinal type. However, such features as absence of graywacke conglomerates and sandstones, also shales, plus the great abundance of limestones do not accord with typical geosyclinal features. Further, the eruptives, which, we have assumed, took place relatively soon after the deposition of these sediments, certainly do not suggest a submarine environment. The chert nodules and, here and there, the extremely thin bedded cherts which occur in these sediments at Morro no less can be accepted as indicating an abyssal environment of deposition. Neither the question of the origin of chert nor the depth of water in which chert is formed can be satisfactorily answered at this time.

Field study and investigations of the rocks in question show no incontrovertible evidence of great depth of formation for these Jurassic-Lower Cretaceous sediments in Maio, and as regards the Barremian-Aptian sediments, the writer fails to note characteristics synonymous with (eu) geosynclinal deposition.

The Malm-Neocomian rocks of Maio are considered to represent neritic sedimentation in epicontinental seas. Rise of sea level may have caused the outer part of the infraneritic environment to become part of the epibathyal zone where greater depths pertained. We base this contention chiefly on the following : somewhat provincial faunal content ; lack of fragmental fossil limenstonesdetritals and greater development of dolomitized normal limestones; lack of mechanical energy and consequent structures ; presence of ferruginous and bituminous limestones. The environment is presumed to have been epicontinental with volcanic islands formed and forming, probably intermediate in character between the infraneritic and the epibathyal.

We would stress that the well-known geographic oceanographic classification of environments agrees rather well with the habitat of organic life but considerably less so with the actual loci of application of sedimentary processes, particulary in the case of mixed marine environments. The 'functional' classification of environments proposed by *PETTIJOHN* (1949) agrees much better with actual lithologies. Indeed, the well-known environments are *not* the controlling factors in sedimentation, but rather the net balance of the different forces which act within each locus of application.

The initiation of the Atlantic Ocean in the Lower Cretaceous is succeeded by the beginnings of marked transgression in the Albian which continued through the Senonian and reached a maxium in the Maestrichtian, regression setting-in during the Danian. Jurassic and/or Cretaceous strata are either known or presumed in Maio, Boa Vista, Sal, S. Tiago, S. Vicente, S. Nicolau and the Ilheus Secos and thus these islands at least may be presumed to date from Mesozoic.

During the late Senonian (early Aturian), due perhaps to localized magmatic pulsation in the region of the archipelago, emergence took place. The above-mentioned 'Mesozoic' islands underwent drastic denudation, stripping off much of the sedimentary covering from these islands. The emergence of these islands may, as *FURON* (1935) and *BOURCART* (1946) stated, during part of the whole of the Palaeogene account for the absence of strata of this age. (The supposed Lutetian of S. Nicolau is far from proven.) On the other hand the remaining islands are believed to have been intiated during this period by subaerial outpourings of extrusives. The Vindobonian is considered to be present on these other islands where to date no pre-Maestrichtian strata have been recorded. Thus by Middle Miocene it is presumed that all the islands had been formed, and according to *TEIXEIRA* (1950), almost all the Atlantic islands were in existence in the Miocene.

For the Cape Verde region, the Miocene transgression, according to *TORRES* and *SOARES* (1946) began in the Helvetian. The Tertiary — and Holocene — sediments lying unconformably on the Mesozoic sediments at Barreiro, Maio, were claimed by *BEBIANO* (1932) to have been formed in 'more or less deep water'. Fossilized eggs of *Testudo calcarata SCHNEIDER* were discovered by him in similar rocks (conglomerates — cf. basal conglomerates at the unconformity at Barreiro) lying on basalts at approximately the same elevation and some 2 km distant. At both these localities the writer could see no reason why *BEBIANO* should consider considerable depth of formation necessary for the sediments in question, and indeed, a littoral milieu seems more in order.

The above transgression is believed to have contained until Astian times. During this period, vulcanism was in abeyance.

Regression followed in the Quaternary, with littoral, estuarine and aeolian influences dominant. Fresh vulcanism occurred and in fact has not ended yet — Pico in Fogo erupted strongly in July 1951. Holocene uplift is evident in several islands, witnessed by marine and river terraces, old abandoned caves, etc. (*KREJCI-GRAF*, 1961). As some of these features lie as high as 35 m above present sea level, it is believed that marine withdrawal took place contemporaneously.

BEBIANO (op. cit.) has invoked — unquestioningly copied by *TORRES* and *SOARES* (op. cit.) — vertical uplift of the islands in response to efforts to restore isostatic equilibrium. The writer feels that *BEBIANO* has made far too free and loose usage of the isostatic principale without the due regard to all the geological, geophysical and physical factors involved. In our joys emanating form the panacea offered by the concept of isostasy, we should not overlook the bothersome but very real anachronisms of Peninsula India with its large negative gravity anomalies yet shows no signs of rising or subsidence, or Cyprus with its large positive gravity anomalies but no evidences of subsidence — indeed uplift has taken place. ("Very few things happen at the right time, and the rest do not happen at all", as *MARK TWAIN* has cogently reminded us !). That uplift of the islands has occurred in the past and

in recent geological times we do not question but to assume, as *BEBIANO* does, that such is invariably due to isostatic readjustments is stretching the concept too far. On the other hand, it is very doubtful wether orogenesis has had anything to do with such uplift and we feel more inclined to call upon vertical block movements of epeirogenic origin.

CONCLUSIONS

The relative wide-spread development of fossiliferous sediments in the Cape Verde islands have so far yielded only scant information and tentative opinions. Yet because of a greater abundance of preserved sediments here than elsewhere in Macaronesia — or for that matter, the entire Atlantic, Bermuda-Bahamas excepted — systematic and detailed investigations of these rocks would prove of great value in enabling us to unraval the geological history of this ocean and its scattered specks of land. The chronological sequence of geological events in the Atlantic islands is but imperfectly known, due essentially to impoverishment in sediments and fossils and lack of detailed studies. The Cape Verde islands hence hold an unusual interest in offering possible clues to the volcanic, sedimentary, palaeontologic and tectonic evolution not only of this archipelago but also Macaronesia and the Atlantic islands in general.

Fom what has been said here it is evident that all phases of our knowledge concerning the sedimentary rocks of the Cape Verde archipelago are most fragmentary, rudimentary and tenuous. Because of such limitations, it is quite impossible at this time to pontificate upon matters geological as these affect the archipelago, for the sum total of all our geological knowledge here is based only on rapid reconnaissance surveys. Much work remains to be done before facts can substitute for speculations.

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	ISLAND	AREA (KM²)	MAX. ALT. (M)	SEDIMENTARY ROCKS				
				AREA (KM²)	MAX. THICK (M)	MAX. DISTANCE FROM COAST (KM)	MAX. ALT. (M)	STRATIGRAPHY
BARLOVENTO	STO. ANTAO *	779	1979	0.003	2.0	0.5	4	HOLOCENE, PLEISTOCENE, NEOGENE (VINDOBONIAN ?)
	S. VICENTE *	227	774	0.008	2.5	1.8	70	HOLOCENE, PLEISTOCENE, PLIOCENE (?) MIOCENE (VINDOBONIAN ?) PALAEOGENE (?) SENONIAN (?)
	STA. LUZIA	35	395	0.09	2.0	1.2	50	HOLOCENE, PLEISTOCENE, NEOGENE (VINDOBONIAN ?)
	I. BRANCO	3	327	—	—	—	—	
	I. RAZO	7	164	0.04	1.0	0.5	18	HOLOCENE, PLEISTOCENE, NEOGENE (VINDOBONIAN ?)
	S. NICOLAU *	343	1304	0.5	7.5	4.0	250	HOLOCENE, PLEISTOCENE, PLIOCENE (ASTIAN, PLAISANCIAN), MIOCENE (VINDOBONIAN, BURDIGALIAN), PALAEOGENE (?) (AQUITANIAN ? BARTONIAN ? LUTETIAN ?), SENONIAN (?)
	SAL *	216	406	70	2.5	3.2	105	HOLOCENE, PLEISTOCENE, NEOGENE (VINDOBONIAN ?), PALAEOGENE (?), CRETACEOUS (?), (SENONIAN ? VALANGIAN ?)
	BOA VISTA *	620	390	185	6.5	8.4	175	HOLOCENE, PLEISTOCENE, PLIOCENE (?), MIOCENE (VINDOBONIAN ?), OLIGOCENE (?), CRETACEOUS (?) (VALANGIAN ?), JURASSIC (?) (MALM ? PORTLANDIAN ?)

	ISLAND	AREA (KM²)	MAX. ALT. (M)	SEDIMENTARY ROCKS				
				AREA (KM²)	MAX. THICK (M)	MAX. DISTANCE FROM COAST (KM)	MAX. ALT. (M)	STRATIGRAPHY
SOTOVENTO	MAIO *	269	436	104	435 +	6.3	265	HOLO., PLEIST., PLIO (?) MIO. (VINDO) PALAEOGENE (?) CRET. (POST-APTIAN ? APTIAN, BARREMIAN, HAUTERIVIAN, VALANGIAN), JURASSIC (MALM, PORTLANDIAN ?)
	S. TIAGO *	991	1392	3	34.0	1.2	163	HOLOCENE, PLEISTOCENE, PLIOCENE(?) MIOCENE (VINDOBONIAN) PALAEOGENE(?) CRETACEOUS (SENONIAN ? NEOCOMIAN ?)
	FOGO *	476	2829	0.05	1.3	2.3	114	QUATERNARY, MIOCENE (VINDOBONIAN)
	BRAVA *	64	976	0.03	3.6	1.1	235	HOLOCENE, PLEISTOCENE(?), PLIOCENE(?) MIOCENE(?) (VINDOBONIAN ?), PALAEOGENE(?)
	ILHEUS SECOS I. GRANDE	2	96	0.005	0.9?	0.4	52	QUATERNARY(?), NEOGENE (MIOCENE ? VINDOBONIAN ?) SENONIAN (?)
	ILHEUS SECOS I. LUIS CARNEIRO	0.22	32	0.21	24.0?	0.2	32	QUATERNARY(?), NEOGENE (MIOCENE ? VINDOBONIAN ?) SENONIAN (?)
	ILHEUS SECOS I. CIMA	1.15	77	0.002	3.0?	0.2	47	QUATERNARY (?), NEOGENE (MIOCENE ? VINDOBONIAN ?) SENONIAN (?)
	CABO VERDE	4033.37	2829	362.938	435 +	8.4	265	HOLOCENE TO JURASSIC (MALM - PORTLANDIAN ?)

* INHABITED

TABLE I

DATA REGARDING THE ISLANDS AND SEDIMENTARY ROCKS.

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