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A Geological History of Eastern New Guinea

by

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A GEOLOGICAL HISTORY OF EASTERN NEW GUINEA

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GENERAL STATEMENT

This paper is presented in two parts. The first is a narrative of an interpreted sequence of geological, tectonic, magmatic and depositional processes which have together built up the present-day geological structure of New Guinea. In this part, the interpreted geological history is outlined with little reference to the evidence on which the interpretations are based.

The second part of the paper deals more specifically with stratigraphic aspects of geological history and is supported by text references to sources of information. The same illustrations are applicable to both parts of the paper and for convenience have been included in the first part.

The palaeogeographic maps (Figs. 3 - 9) are very generalized, and the following qualifications and comments should be applied when interpreting them:-

1. The present-day New Guinea outline is shown as a faint line on each map for reference only. It has no palaeogeographic significance.

2. Palaeoland areas are indicated by light hachuring: sea areas are blank.

3. The thick lines represent migratory shorelines of an arbitrary time within the geological interval specified. They do not necessarily correspond to the limits of marine transgression or regression within the interval specified.

4. The arrows against the shorelines show the predominant direction of shoreline migration during the specified intervals and at the places indicated.

5. The use of "early", "late", "Upper", "Middle" and "Lower" as time prefixes may seem confused, but the usage has been deliberate in each case. "Early" and "late" have been used where age controls are loose and where the more formal European time and time-rock subdivisions do not fit significant geological events in this region. "Upper", "Middle" and "Lower" have been used advisedly where palaeontological control is adequate.

6. Local Miocene stage names (Kereruan, Taurian, Muruan and Ivorian) and the Dutch letter classification of the Tertiary, although most useful for a thorough stratigraphic study, have been purposely avoided because they do not have wide application or usage on the Australian mainland.

PART 1

GEOLOGICAL HISTORY

INTRODUCTION

In formulating the geological history presented here, I have drawn on stratigraphic information from all known published sources. The compilation of "The geological results of petroleum exploration in western Papua, 1937-61" by Australasian Petroleum Company geologists, which was published as Volume 8, Part 1 of the Journal of the Geological Society of Australia, has been the principal reference for Papuan Basin stratigraphy. A broad understanding of the stratigraphy of both the Papuan Basin and the Northern New Guinea Basin was obtained while employed by Australasian Petroleum Company from 1946 to 1951. Since 1951, I have been able to follow the progress of oil exploration in both Basins through discussion with many of the geologists and geophysicists of companies operating in Papua and New Guinea and also through the reports of oil exploration surveys carried out with Commonwealth subsidy.

Much basic stratigraphic and structural information on the interbasinal areas has been culled from published and unpublished accounts of systematic mapping and reconnaissance surveys by Bureau of Mineral Resources geological field parties and individual geologists. Many observations made by the writer in these areas in the course of minor investigations and reconnaissance traverses, particularly in eastern Papua, have been incorporated.

The structural interpretation is not strongly based on confirmed geological facts, but leans heavily on many scattered field observations made during the past 20 years. These observations and the observations of others have been interpreted liberally in terms of the major structural, geomorphological and stratigraphic features considered to be significant in the geological history.

In a regional study such as this, it has been necessary to make broad generalizations and somewhat reckless extrapolations and correlations. I apologize to those geologists who may consider that their detailed observations in particular areas have been overlooked or misinterpreted. Most of them already know that I hold the view that, whereas a geological map can only be pieced together by careful recording of observations, some details could be more confusing than helpful in a regional appraisal of this kind. In particular, it may be difficult to relate superficial gravitational effects to the more deep-seated primary tectonic deformation.

I have endeavoured to construct a model, in both section and plan, which will fit many, but probably not all the observations. The schematic sections (Figures 12-15) have been designed only to support the text description of the concept; the concept did not derive from the figures, nor, regrettably, did the figures derive directly from geological facts.

They have been drawn at grossly exaggerated vertical scales, but some attempt has been made to maintain roughly correct proportions between continental crust, oceanic crust and sedimentary pile thicknesses.

In a summarized geological history such as this in which considerable licence has been used in the interpretation and extrapolation of evidence, text references to specific information have not been included. However, references have been cited in Part I in which the stratigraphy of the region is discussed in greater detail.

CONTINENTAL VERSUS OCEANIC CRUST

A distinction must be made between the continental basement, which underlies the south-western stable flank of the Papuan Basin and extends north into the central highlands, and the oceanic basement which underlies the north-eastern unstable flank of the Papuan Basin. The Australian geological continent has extended to the central highlands of eastern New Guinea, at least since the Permian.

The dividing zone which, I claim, separates continental from oceanic basements (Figure 2) is not a revision of the "Andesite Line" which is still a very useful and valid concept. The "Andesite Line" was recognised and traced (with some minor differences of opinion) by petrologists as the boundary between basaltic and andesitic vulcanism around the Pacific margin. They nominated this "Line" as the edge of the Pacific basaltic province which is interpreted, at least by me, as the boundary of oceanic crust uncontaminated by igneous or sedimentary derivatives from the continental provinces. It is odd, to say the least, that no concerted worldwide effort has been, or is being made to define the present and past margins of the continents. There are many features, both igneous and sedimentary, which are readily identifiable with continental crust.

In many places, such as New Guinea, it may be seen that between true continental basement and true oceanic basement there is an intermediate zone, dominantly of oceanic crust, but on which there are, literally, floating islands of detached continental crust. These "sialets (!)" are not only conspicuous because their lower density (2.85 approx.) causes them to protrude above oceanic crust and preferentially form islands, but also because they possess a characteristic capacity to generate, in their roots, highly volatile andesitic magma which is released at the surface explosively to form prominent, subaerial volcanic complexes.

In contrast, oceanic basement of slightly higher density (2.9 approx.), is only rarely elevated above sea-level and normally generates basaltic lava which is extruded and spread unobtrusively over the sea floor.

The distinction between oceanic basement, continental basement and the intermediate zone, is of importance because each has different magmatic and depositional habits which may permit or preclude hydrocarbon generation and accumulation. This distinction is also important to the understanding and definition of provinces of both sedimentary and magmatic mineralisation.

GEOLOGICAL HISTORY

Significant stages in the postulated geological history are diagrammatically represented in Figures 3 to 9.

Granodiorite basement formed low islands in the central highlands area in Permian time (Figure 3). Tectonics accompanying emplacement of the Bismarck Granodiorite in the Upper Triassic caused high, fault-bounded islands to emerge. The composition and facies of the clastic sediments preserved in down-faulted segments indicates nearby sub-aerial dacitic vulcanism and vigorous erosion. Some of the granodioritic islands persisted as land or shoal areas through subsequent marine transgressions and tectonic episodes.

Tectonic and isostatic stability was re-established in the central highlands region in the Lower Jurassic, and then the sea spread southwards across a low stable continental platform area on which Jurassic continental sandstone, with coal measures, lay unconformably on older terrestrial acid volcanic rocks and granite. This transgression culminated in the Lower Cretaceous, by which time at least one-third of the present-day Australian continent was covered by a shallow epeiric sea in which was deposited a blanket of fine-grained, dominantly clastic sediment derived from pre-existing superficial sand, soil and clay. Fresh angular feldspars in these sediments were probably derived from contemporaneous vulcanism associated with granodiorite emplacement in eastern Queensland.

There is ample record of Lower Cretaceous marine blanket deposition of clastic sediments on the broad continental platform area of western Papua (Figure 4). At the northern continental front, a thick marine shale sequence and some submarine basalt was deposited. There is no stratigraphic record of Lower Cretaceous or older sedimentation, either deep marine, littoral or continental, in the * Morobe Arc - eastern Papua region. It is assumed that Lower Cretaceous and older terrigenous sediments are incorporated in the undivided metasediments in the * Owen Stanley Range.

In the late Cretaceous, the epeiric sea receded from the continent and a large platform area was again exposed in western Papua, and marine clastic sediments were deposited on a continental slope in the Purari hinterland, in the central and western highlands, and in the Snake River area near Bulolo (Figure 5). Foliated red limestone of Upper Cretaceous age in the Port Moresby region, and farther east in the Mullins Harbour area, are oceanic sediments with very little terrigenous clastic contamination. On the western platform there was normal faulting (the Komewu Fault) and erosion before the next transgression in the Lower Miocene. On the eastern front of the platform and on the continental slope, block faulting is suggested by facies changes in Cretaceous sediments, but details are obscured by late Tertiary and Quaternary folding and faulting.

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* Geographic localities and principal geological provinces are indicated on Figure 1.

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During Mesozoic time, the western platform area did not support reef limestone-forming organisms, although water depth and tectonic stability were probably within tolerable limits. It is assumed that low water temperature inhibited reef formation. This may have been due to relative latitude change by pole or land shift, or to cold marine currents. A drastic environmental change took place from late Cretaceous to early Tertiary time, and by the Lower Miocene this platform and probably also its continuation south, fronting the Queensland coast, was extremely favourable for algal and bryozoal reef-forming communities. The Great Barrier Reef was initiated at this time. The northern part of the Miocene reef was involved in late Tertiary tectonics and it is now elevated over 10,000 ft. above sea level in West Irian. To the south on the Queensland coast, it subsided and is now concealed beneath younger reef limestone. Until Lower Tertiary time, marine deposition was on a simple open continental shelf and slope, and clastic sediments were derived predominantly from the continental land mass. There was no north-east flank to the Papuan Basin as we know it to-day, and there were no non-volcanic clastic sediments derived from that direction until the Lower Miocene when a landmass with a basement of oceanic crust emerged, first epeirogenically then later orogenically. By late Tertiary time, this new landmass occupied roughly the area and position of the present-day mountainous part of eastern Papua.

At the scale of this discussion, Upper Cretaceous to Lower Miocene time can be considered essentially a period of marine regression (Fig. 6). In detail, the situation is complex. The major regression initiated in the Upper Cretaceous probably continued into the Paleocene. This was followed by slight transgression in the Oligocene. In Lower Miocene, a major transgression commenced. The early Tertiary, short-lived, short-distance reversals may be attributed to either eustatic sea-level changes or to tectonic causes.

A thick sequence of Eocene dark marine shale and limestone on the northern flank of the central highlands represents a continental slope deposit of sediment derived from poorly consolidated muddy Cretaceous sediments exposed behind the retreating sea. The Eocene coast in this area was probably protected from the open sea by high basement islands, composed of the Kubor and Bismarck Granodiorites, and by volcanic islands. Both types of islands may have supported narrow fringing reefs.

On the eastern front of the late Cretaceous platform in western Papua, there were no plutonic or volcanic complexes and consequently no high islands. However, there may have been fault blocks of soft Cretaceous sediments which would soon have been eroded to wave base. Such eroded fault blocks served as foundations for Eocene or Lower Miocene outlying reefs. At this time, there was no landmass corresponding to present-day eastern Papua and the eastern platform of soft Cretaceous sediments was exposed to the full impact of wave action from the Pacific. At the onset of Eocene transgression, these waves probably reworked muddy Cretaceous sediments of the platform edge and produced strand deposits, or fan deposits, of quartzose sand. This process was soon arrested, for, when the transgression got under way, reef growth sealed the Cretaceous sediments from further erosion. Eocene quartzose sands, presumably derived from unconsolidated sediments, are represented in A.P.C. wells, WANA and IVIRI. They could be important hydrocarbon reservoirs for they occupy a critical stratigraphic position adjacent to thick marine shale sequences on the east. They are the only sandstones in the entire Tertiary clastic sedimentary pile in the Papuan Basin in which good permeability might be expected.

A thick, slumped and tightly folded Eocene chert sequence on the north-east flank of the Papua Basin represents sea-floor chemical and biogenic deposits accumulated beyond the reach of terrigenous clastic sediments before the orogenic emergence of eastern Papua. The slumping of this sequence is attributed to gravity sliding following arching of the sea floor. Larger-scale folding, progressing to full-scale orogeny by faulting and rapid isostatic uplift was initiated in the Miocene.

Scattered, thin, Eocene limestone patches are the first stratigraphic record of deposition in the Northern New Guinea Basin. They occur on or near basic igneous basement rocks, particularly in the western part of the Basin. These limestones indicate either uplift of parts of the ocean floor or lowering of sea-level. It was not until Middle Miocene time that the Northern New Guinea Basin started to receive a flood of ill-sorted clastic tuffaceous sediment from the south, where the northern continental front was being elevated along the Markham - Ramu Fault and associated faults. It is likely that this faulting had a strong transcurrent component, but evidence of the direction of such transcurrent movements has been concealed by subsequent vulcanism and thick clastic deposition.

The Lower Miocene was a distinct turning-point in the history of the Papuan Basin. In fact, it is difficult to justify the retention of the name "Papuan Basin: for the packet of sediment deposited from Lower Miocene to Recent time, because the pre-Tertiary depositional regime differed so vastly from the Lower Miocene and younger depositional regime. At this time eastern Papua emerged orogenically, the Aure Trough formed and copious quantities of tuffaceous sediments were derived from the north-east (Fig.10).

In the Lower Miocene (Fig. 8), the sea advanced across the continental platform to the spur of basement which extends north from Cape York, across Torres Strait to the south coast of western Papua. In this sea, algal and bryosoal reefs flourished and, by the Middle Miocene, reef and reef detritus, from a few hundred feet thick on the landward side to about 2,000 ft. thick on the outer part of the platform,had been built up. Within the platform the northwesterly aligned, deep and narrow Omati Trough was formed. It was isolated from clastic sedimentation, except in its very early history, and accumulated some 10,000 ft. of Lower Miocene deep-water calcareous mud and ooze. In Middle Miocene time, there was probably both regression and transgression, but the former Lower Miocene limit of transgression was not reached. The Omati Trough was filled at the time of the Middle Miocene transgression and it was then blanketed with reef and shoal limestone. The Miocene limestone blanket on the western platform cut off any further supply of terrigenous sediment from the continent to the Papuan Basin and the thick Lower-Miocene and younger clastic succession in the Aure Trough (40,000 to 50,000 ft.) came almost entirely from a new orogenic landmass corresponding to the present-day Owen Stanley Range. Clastic sediments from orogenic land at the northern front of the continent in the New Guinea highlands were shed northwards into the Northern New Guinea Basin and a minor amount of sediment from this source was shed into the Aure Trough.

Until Upper Miocene time, a narrow seaway existed between the Owen Stanley metamorphic block and the eastern highlands of New Guinea. This was closed in the late Miocene or early Pliocene when magmatic activity in the Wau - Bulolo area, on the east, and in the Kainantu area, on the west, caused elevation. This magmatic activity resulted in acid vulcanism and high-level emplacement of plugs, sills and dykes of quartz-feldspar porphyry, possibly from the same magma source as the granodiorite batholiths emplaced in the same areas in pre-Lower Miocene time. At the same time, transcurrent movement, in a right-lateral sense, on the Markham-Ramu Fault caused northerly deflection and further uplift of the Owen Stanley metamorphic block. Unconformity between Miocene and Pliocene sediments in the Tauri River area may be a reflection of these magmatic and tectonic events.

Gravitational folding and diapirism of the sedimentary pile in the Aure Trough has been proceeding since Upper Miocene time and many of the stratigraphic complications there are attributable to concomitant folding, faulting and deposition. Small fringing reefs grew along parts of the north-eastern margin of the Papuan Basin. They flourished for short periods, during lulls in sedimentation, and on headlands distant from prograding deltas at the mouths of major rivers, just as Pleistocene and recent reefs have grown at the Bluff between the deltas of the Vailala River and Kerema Bay. Andesitic and basaltic vulcanism was prevalent from Miocene to Pleistocene time on the south flank of the Owen Stanley Range, mainly in the foothill region between Yule Island and Moresby.

Early in the Pliocene (Fig. 9), the newly-emerged eastern Papuan Island was linked to the central highland orogenic island area, which was, in turn, linked to the Australian mainland through West Irian. As Pliocene time progressed, there was vigorous prograding, particularly in the area corresponding to the present-day middle reaches of the Fly - Strickland Rivers, in response to uplift in central New Guinea. In the Pliocene, this southward prograding probably linked western Papua to the Australian mainland across a large expanse of swampy, alluvial lowland. New Guinea was assuming roughly its present shape.

In late Pliocene and Pleistocene time, the Northern New Guinea Basin sediments were being folded, faulted and uplifted, particularly at the eastern end of the Basin where the rugged Finisterre and Saruwaged Ranges emerged. Clastic sedimentation into the Papuan

Basin from the Owen Stanley Range continued and deltas spread beyond their present-day limit. The world-wide marine Pleistocene transgressions and regressions modified the south Papuan coastline by inundating deltas and redistributing deltaic sediments. At this time, Torres Strait was formed and the sea encroached across the lowland area between the northern orogenic front of the continent and the stable craton to produce the Arafura Sea and the Gulf of Carpentaria.

Continuing uplift in the Owen Stanley Range provided sediment for reclamation of the south Papuan coastline by prograding and the successions of abandoned strand lines along much of that coast testify to very recent emergence.

Strong tides in the Pleistocene and Recent Arafura Sea and Gulf of Carpentaria flushed out much Pliocene and Pleistocene deltaic sediment deposited there from the north. The Arafura Sea is now being reclaimed again by delta encroachment from the north.

STRUCTURAL EVOLUTION

The concept of Miocene emergence of a new eastern Papuan landmass relies largely on the interpretation of gross changes in stratigraphy in the Eocene and Miocene sedimentary sequences on the north-eastern flank of the Papuan Basin. If this interpretation is correct, then some radical explanation is required for the difference in metamorphic grade between Eocene/Upper Cretaceous sediments in the Port Moresby area and the nearby metasediments of probable Mesozoic age in the Owen Stanley Range. In explanation of this apparent anomaly, the following sequence of events in late Cretaceous to Miocene orogenic evolution is proposed:

1. Late Cretaceous to Upper Miocene - deposition of oceanic sediments, principally red shale, fine-grained pink limestone and chert on the ocean floor beyond the reach of terrigenous clastic sediment from the continent. Submarine vulcanism, accompanied by deposition of basaltic pillow lavas and increase in silica concentration in the sea water. (Fig. 12).

2. Upper Eocene/Oligocene - low arching of the ocean floor beyond the limit of terrigenous clastic sedimentation; mass slumping of oceanic sediments and possibly also of pillow lavas, dolerite and gabbro of the upper part of the oceanic crust.

3. Oligocene - crestal rupturing of arched oceanic crust and thrusting of the north-eastern limb of the arch towards the Australian continent and over Mesozoic and older sediments accumulated at the base of the continental slope.

(Items 2 and 3: Fig. 13.)

4. Oligocene to Lower Miocene - metamorphism of Mesozoic and older continental slope sediments accelerated by the weight of the thrust slice of oceanic crust, compression and both frictional and magmatic heat.

5. Lower Miocene - metasediments now welded into a homogeneous crystalline block arose isostatically using the incline of original thrust plane as a glide plane. Rapid emergence of the metamorphic block turned back the leading edge of the thrust plate of oceanic crust to expose deep crust or upper mantle material in the form of ultramafic rocks (the Papuan Ultramafic Belt). Fig. 14

6. Lower Miocene onwards -continued emergence of the metamorphic block and tight tectonic folding and faulting of Eocene and Upper Cretaceous sediments (e.g. in the Port Moresby area). Complementary north-easterly downward sliding of the oceanic thrust plate as part of regional isostatic adjustment. Generation of granodioritic magma from anatexis of metamorphosed pre-Tertiary sediments and rise of magma (e.g. in Wau - Bulolo and Waria Valley areas).

Whereas the tectonic and depositional sequence portrayed in Figs. 12-14 may explain the present-day geological situation along a north-easterly line of section from Cape York, it is not directly applicable to a northerly line of section from Cape York, through the central highlands of New Guinea to the Northern New Guinea Basin. As discussed earlier in this paper, the Australian geological continent is considered to extend to the New Guinea highlands. Here it appears to be in compressional contact along the Markham-Ramu Fault and other parallel major faults, with basic igneous rocks of oceanic crustal affinity on which the thick Mio-Pliocene eugeosynclinal sedimentary pile of the Northern New Guinea Basin was deposited. It is notable that pre-Tertiary continental slope sediments, corresponding to the metasediments of the Owen Stanley Range in the north-easterly cross-sections (Figs. 12 to 14), do not form conspicuous outcrop north of the New Guinea highlands. They may have been uplifted and removed by erosion, or they may have been overridden by a thrust-slice of oceanic crust in late Mesozoic/early Tertiary time on which the Mio-Pliocene Northern New Guinea Basin sediments were deposited.

The former explanation does not seem feasible because the Northern New Guinea Basin, a structurally low region, adjoins the central highlands; and quite obviously, it received sediments rather than shed them throughout the Miocene, while the Owen Stanley Range was being elevated.

The latter explanation, although considerably more complex than the former, is preferred. The geological situation envisaged on the northern continental front is briefly this:-

Fig. 15a

1. Deposition of a thick pile of continental slope sediments largely on oceanic crust, off the northern continental front, from at least Permian to late Cretaceous time.

2. Downwarping and possible downfaulting of oceanic crust during, and in response to, the abovementioned deposition.

3. Low-angled thrusting of oceanic crust from the north or north-east over pre-Tertiary continental slope sediments during late Cretaceous to Lower Miocene time.

4. Compressional contact between thrust plate of oceanic crust and northern continental front causing large-scale, east-west aligned, reverse faulting and tectonic elevation of a large part of the New Guinea highlands.

5. Metamorphism of the entombed pile of the pre-Tertiary sediments during overthrusting of the plate of oceanic crust and, possibly, continuing to the present time. This metamorphism would be accompanied by the vaporisation of water and organic material contained in the entombed sedimentary pile and the consequent generation of very large vapour pressures. Increase in pressure by this means beneath the thrust plate may be an important contributing factor to hydrothermal alteration at the base of the plate, and possibly also to its tectonic instability. Hydrothermal alteration at the base of the thrust plate might have facilitated low-angled thrusting by alteration of peridotite at base of oceanic crust to serpentinite.

6. Deposition of Miocene and Pliocene sediments from the uplifted central highlands onto the thrust plate (see 4, above). During this deposition the thrust plate was tectonically unstable because of:-

   (a) compressional contact with the continental front and

   (b) redistribution and release of pressures generated during metamorphism of the entombed pre-Tertiary continental slope sediments.

   Once these sediments had been welded into large homogeneous blocks of metasediments, then rapid isostatic rise of such blocks, as in the Owen Stanley Range, might be expected. It is suggested that this stage has not yet been reached in northern New Guinea, except possibly beneath the Finisterre and Saruwaged Ranges which have been elevated rapidly in Pleistocene and Recent times.

7. Pliocene to Recent right-lateral rotational displacement of the thrust plate along the Sepik-Ramu-Markham-New Britain Trench fault line. The pre-Miocene andesitic volcanics and diorites in the core of New Britain may have been derived by

anatexis of pre-Tertiary continental slope sediments trapped between downwarped oceanic crust and the overthrust slice of oceanic crust and subsequently displaced some 400 miles to the north-east (from the northern front of the continent). To be converted to andesitic magma, such sediments would need to have been structurally depressed into the appropriate temperature region. A scheme such as this evades the controversial issue of whether or not andesitic magma can be generated in large quantities from oceanic crust or mantle ingredients.

Whereas this scheme of events is proposed to explain the northern New Guinea situation, it could also represent an earlier stage of the eastern Papuan evolution; possibly between the stages portrayed in Figures 13 and 14.

Late Tertiary and Quaternary deformation of clastic sediments in the Aure Trough and south of the central highlands is confined to distinctly linear zones in a three-pronged array centred in the Pio-Purari area (Fig. 11). The geometry of this array was determined by two independently active orogenic regions, namely, the Owen Stanley block to the east and the central highlands block to the north, causing compressional and gravitational folding of the incompetent clastic sediments against a buttress of thick competent Miocene limestone on a relatively stable platform of continental crust.

The first effects of the postulated arching and thrusting of the oceanic crust beyond the north-eastern and northern front of the Australian geological continent are evident in the late Cretaceous to early Tertiary geological record. It is tempting to suggest a correlation of the onset of these tectonic events with

1. Pacific-wide Cretaceous marine transgressions onto continental areas, and
2. the climatic changes, due to pole shift or land shift, which are reflected by the first appearance in the Paleocene of algal and bryozoal reefs on the north-eastern Australian continental shelf. (These reefs flourished until the Upper Miocene and persist, farther south, to-day.)

POSTSCRIPT

Definition of continental margins is as much the concern of the oil explorer as it is of academic. For I believe that the continental shelf is the optimum environment for both lithogenic and biogenic sediments in hydrocarbon reservoir facies, yet it is much less favourable from oil-source aspects. Furthermore, the intermediate zone, with its deep marine trenches in which terrigenous clastic sediments accumulate rapidly, is a good environment for oil source materials, but only rarely does it contain good reservoir rocks.

It follows that the narrow zone where continental shelf sediments are laterally in contact with, and up-dip from, thick accumulations of terrigenous clastic sediment in trenches on oceanic crust, is a very favourable environment for major oil accumulations. Further bonus features in this potent environment would be:-

1. a major tectonic event either on the continental or oceanic side to cause the spread of impermeable sediment over the clean, permeable shelf sediment to ensure capping.

2. robust folding or tilting to promote hydrocarbon migration, and

3. faulting, preferably low-angled thrust-faulting to bring reservoir rocks from the continental side into direct close contact with the oil source rocks of the oceanic side.

The Papuan Basin has many of the ingredients of this suggested recipe for a large oil field environment.

It is of interest to speculate on the ultimate fate of any hydrocarbons in sediments entombed beneath an almost flat-lying thrust plate of oceanic crust, such as that envisaged at the base of Northern New Guinea Basin sediments. Could the oil seepages in the Matapau area, anomalously issuing from faults in diorite, be an expression of an accumulation of pre-Tertiary oil below an intensively faulted thrust plate of basic igneous rocks of the oceanic crust?

PART II

STRATIGRAPHIC HISTORY

For convenience in presentation, the interpreted stratigraphic history is discussed briefly for the periods portrayed in each palaeogeographic map accompanying the main text, namely:-

1. Permian/Triassic/Early Jurassic - Regression (Fig. 3)
2. Late Jurassic to Early Cretaceous - Transgression (Fig. 4)
3. Early Cretaceous - Transgression on Australian continent (Fig. 5)
4. Late Cretaceous - Regression (Fig. 6)
5. Early Tertiary - Paleocene Regression, Eocene Transgression (Fig. 7)
6. Miocene - Continental Transgression, Island Regression (Fig. 8)
7. Pliocene - Regression (Fig. 9)

Permian/Triassic/Early Jurassic - Regression (Fig. 3)

The exposed sediments representing this interval are confined to a relatively small area in the central highlands. The oldest sediments recorded in Australian New Guinea are a thin Permian sequence of arkose, fossiliferous limestone and shale deposited on granodiorite and meta-sediments in the Kubor Range (Rickwood, 1955).

A K/r age of 236 million years (Permian) has been obtained from granite from 6,628 ft. in A.P.C. ARAMIA No. 1 well in south-western Papua (Harding, R.R., 1966). Weathered acid volcanic rocks below Jurassic continental sediments at the bottom of A.P.C. wells KOMEWU No. 1, IAMARA No. 1 and WUROI No. 1, also in south-western Papua, may be of Triassic or Permian age.

Triassic sediments were first recorded by Dow and Dekker (1964) from the central highlands; they described fossiliferous calcareous greywacke, feldspathic arenite and dacitic conglomerate of Upper Triassic age from north of the Permian sediments of the Kubor Range. From the same region, they also described Lower Jurassic calcareous greywacke with diagnostic marine fossils (Skwarko, 1967).

A large mass of granodiorite, the Bismarck Granodiorite, was emplaced in the Central Highlands, near the continental edge in late Triassic or early Jurassic time (Dow & Dekker, 1964).

The Permian, Triassic and Jurassic sediments are near-shore marine deposits. From this rather flimsy evidence and equally flimsy evidence of non-deposition elsewhere, it is tenuously deduced that the north-eastern continental margin was in the region of the central highlands of New Guinea in Permian time and that slight marine regression was proceeding until the Lower Jurassic about which time the Bismarck Granodiorite was emplaced. Emplacement of the Bismarck Granodiorite was preceded in the Triassic by sub-aerial acid vulcanism, the erosion products from which were deposited in a marine environment. In the central highlands region, volcanic islands probably existed in Triassic and Jurassic time. Subsequent faulting exposed the deep roots of this vulcanism in the form of the Bismarck Granodiorite.

Late Jurassic to Early Cretaceous - Transgression (Fig. 4)

Thick marine clastic sedimentation in the western highlands near Telefomin (A.P.C., 1961) in the Jimi River area (Dow & Dekker, 1964) and Waghi Valley (Edwards and Glaessner, 1953; Rickwood, 1955) in the central and eastern highlands respectively, indicate a deep marine continental slope environment near the north-eastern continental margin. Limestone and conglomerate deposits nearby suggest shoreline deposits around high islands corresponding to the Kubor and Bismarck Granodiorites. Jurassic marine clastic sediments have also been recorded in the upper reaches of the Fly and Strickland Rivers and also in the Kereru Range inland from the Purari Delta (A.P.C., 1961). In A.P.C. wells IEHI, BARIKEWA and OMATI, marine Jurassic sediments were intersected; but in wells farther south-west, the Jurassic sediments are continental; probably alluvial deposits on a very extensive coastal plain. By the late Jurassic, the north-eastern margin of the continent was depressed or down-faulted and the sea advanced some 50 to 80 miles on to the continent. Thick sequences of marine shale, possibly derived from the erosion of pre-Jurassic soil profiles, were deposited along the depressed margin of the continent.

This transgressive trend, which probably started after emplacement of the Bismarck Granodiorite, continued into the Lower Cretaceous when continental Australia was invaded by the sea from the north and possibly also from other directions (Fig. 6). The full extent of the early Cretaceous transgression cannot be determined because of obliteration of evidence of shorelines by late Cretaceous and younger regressions. However, in the Oriomo area, south of the lower Fly River, Miocene limestone overlies weathered granite and it is assumed that early Cretaceous transgression did not inundate the northerly trending low spur of granite between Cape York and the south coast of Papua.

Early Cretaceous - Transgression on Australian Continent (Fig. 5)

There is ample evidence that early Cretaceous sea spread across all low-lying ground within the Australian continent and isolated the tectonised zones of the Tasman Geosyncline, the Adelaide Geosyncline and the Amadeus Basin as large elongate islands. It also seems that the large areas of unmetamorphosed pre-Cambrian and Cambrian continental and near-shore marine sediments west and south-west of the Gulf of Carpentaria formed a low land area in the Lower Cretaceous. The wide extent of the Lower Cretaceous transgression, the apparent absence of major Cretaceous orogeny in New Guinea, and the evidence for similar Cretaceous transgressions on the North American and European continents, suggest some very wide-ranging, possibly global, cause which either raised sea-level or lowered continental land masses.

During this transgression, a blanket of glauconitic sediment having an average thickness of several hundreds of feet, but locally much thicker, was spread over about one-third of the Australian continent. The source of this sediment, which contains much angular fresh plagioclase (Whitehouse, 1954), is not readily apparent. Much of the sediment must be redistributed pre-existing soil, sand and clay, from which the glauconite was formed. The plagioclase was probably derived from vulcanism associated with the emplacement of Cretaceous granodiorite batholiths in eastern Queensland. The Cretaceous volcanics and volcanic detritus in the Maryborough Basin also record this period of vulcanism.

Late Cretaceous - Regression (Fig. 6)

Albian, and possibly younger Cretaceous, non-marine sediments throughout the Great Artesian Basin testify the rapid withdrawal of the sea from the continent.

In western Papua, the record of this regression is less clear. No post-Albian sediments, terrestrial or marine, are recorded in either wells or outcrop in south-western Papua, but considerable thicknesses of marine Upper Cretaceous sediments are known in the headwaters of the Fly and Strickland Rivers, near Telefomin in the western highlands (A.P.C., 1961), in the Jimi River area (Dow & Dekker, 1964) and in the Waghi Valley (Rickwood, 1955) of the central highlands. In the central highlands, volcanics comprise a large part of the Upper Cretaceous sequences. Post-Albian glauconitic sandstones and shales in the southern highlands are thought to be locally reworked older Cretaceous sediments derived from low emergences to the east (A.P.C. 1961). No attempt has been made to show this detail on the palaeogeographic map (Fig. 6).

Evidence of tectonic movement and erosion between the early Cretaceous marine transgression and the next significant transgression, which is marked by Lower Miocene algal and bryozoal reefs, is afforded by normal faulting and erosion of Cretaceous sediments at Komewu (A.P.C. 1961). Here, wells were drilled on both sides of a north-westerly striking normal fault. KOMEWU No. 1 on the southern, upthrown side passed out of Lower Miocene limestone into Jurassic sandstone. Whereas KOMEWU No. 2, less than 2 miles to the north, on the downthrown side of the fault, penetrated about 3,000 feet of early Cretaceous sediments below Lower Miocene limestone and above the Jurassic sediments. Although angular discordance between the Lower Miocene and Mesozoic sediments cannot be convincingly demonstrated in the Komewu wells or elsewhere in western Papua, the Komewu situation demonstrates regional unconformity at the base of the Lower Miocene sediments. Further, it would be reasonable to expect that pre-Lower Miocene folding and faulting in the Mesozoic sequence was more intense basinwards, and that discordance across the unconformity would also increase in that direction.

In south-westernmost Papua, the Morehead Basin was formed by Cretaceous subsidence. The Cretaceous sequence, which was intersected in A.P.C. MOREHEAD No. 1, comprises a lower section of marine mudstone about 1500 feet thick and an upper 2300-foot sandy section with carbonaceous material. It is tentatively suggested that the lower muddy sequence was deposited after the early Cretaceous transgression and the upper sandy section was deposited after the subsequent regression.

Upper Cretaceous calcareous greywacke from the Snake River near Bulolo, reported by Glaessner (1949) and discussed by Dow (1961) and Smit (1964) has been subjected to low-grade metamorphism. Smit (op. cit.) considers that these sediments are the lateral equivalents of finer-grained sediments which have been metamorphosed to schists and phyllites of the Kaindi Metamorphics; a vast thickness of undivided metasediments, the age limits of which have not been established.

It thus seems likely that in late Cretaceous time, unconsolidated younger Cretaceous sediments were derived from the south-western platform area which was exposed during regression and redeposited on the continental slope. Some of these sediments were later metamorphosed together with older sediments, and became part of the crystalline metamorphic block which emerged in the Lower Miocene to become the Owen Stanley Range.

Upper Cretaceous foliated red limestone in the Moresby area (Glaessner, 1952) and farther east in the Mullins Harbour area are regarded as oceanic sediments, deposited beyond the limit of terrigenous sedimentation.

Early Tertiary - Paleocene Regression, Eocene Transgression (Fig. 7)

There is scant record of pre-Eocene Tertiary sedimentation. A sandstone-shale-limestone sequence in the western highlands, south of Laiagam (Dekker and Faulks, 1964) contains Paleocene planktonic foraminifera (Belford, in press). Limestone from Cape Vogel in north-eastern Papua also contains Paleocene foraminifera (op. cit.). Eames and Dilley (in A.P.C., 1961) identified Paleocene algae and foraminifera in limestone at the base of thick Eocene chert sequence near Port Moresby.

The Paleocene sediments of the western highlands are in shallow marine facies and were probably deposited on the northern continental shelf during the late Cretaceous to early Tertiary regression.

The Paleocene limestone at Cape Vogel and the limestone at the base of the Eocene succession near Port Moresby probably represent reef and shoal deposits on oceanic crust brought close to the ocean surface by arching initiated in late Cretaceous or early Tertiary time. Faulting of the oceanic crust and extrusion of submarine basaltic lava accompanied this arching and produced localized shoals and low emergent areas on or around which reef and shoal limestone accreted.

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Eocene, reef and shoal limestone up to a few hundred feet thick, is distributed widely in the southern highlands and in the Purari River headwater drainage area. A.P.C. wells IEHI, BARIKEWA and OMATI, in the south-western region, intersected Eocene shoal limestone. In KURU and PURI wells, the Eocene limestone contains fine clastic material and glauconite. In WANA and IVIRI wells (A.P.C., 1961), the Eocene sequence is about 1,000 ft. thick and sandy, having much quartz and glauconite. These quartzose sandstones are probably the product of "cleaning up" of unconsolidated Cretaceous muddy clastic sediments exposed on the adjoining large platform area by the late Cretaceous regression.

They may occur as strand or fan deposits along the eastern front of the platform. Such sandstones could be important hydrocarbon reservoirs, for they occupy a critical position adjacent to thick marine shale sequences to the east, and they could be the only quartzose, permeable clastic sediments in the entire Mesozoic and Tertiary clastic sedimentary pile. The location of Eocene limestone landward of the inferred Paleocene limit of regression and in the Omati Trough, suggests further slight transgression on to the continental platform in the Eocene. Greater transgression locally in the Purari Delta region could account for the presence of the thick sandy deposits in front of the late Cretaceous platform in that area. At this time there was no landmass where eastern Papua now is, and the platform front must have been subjected to heavy surf action, for it was open to the great expanse of the Pacific Ocean. This surf action was undoubtedly an important agency in the formation of the Eocene sand deposits. It is unlikely that such deposits were formed on the northern front of the platform area, because high islands and their fringing reefs would have protected the platform front from vigorous surf action.

A thick sequence of black shale and slate exposed on the northern fall of the Bismarck Range in the eastern highlands has been considered partly Eocene (McMillan and Malone, 1960). They also recorded conglomerate and limestone in the same region. It is suggested that the marked change from shore-line facies to deep-water facies is due to the presence of high islands, corresponding to the Bismarck Granodiorite and the Kubor Granodiorite, fringing reefs and adjacent fault-bounded troughs. Farther west, between the Simbai and Ramu Rivers, Dow and Dekker (1964) encountered a similar Eocene succession overlying Cretaceous submarine volcanics.

The tightly folded and intricately slumped Eocene cherts which crop out in a coastal belt, which includes Port Moresby, are oceanic deposits in an environment uncontaminated by terrigenous clastic material. It is likely that nearly submarine vulcanism produced, in the sea, a high silica content which was deposited through a colloidal phase by physicochemical processes and through silica-secreting radiolaria. The localisation of this chert sequence in a narrow north-westerly belt, its small-scale slumping and its larger-scale tectonic folding and faulting, are attributed to gravitational sliding off a north-westerly aligned arch in the sea floor which was initiated in the Eocene, emerged above sea-level in the Lower Miocene, and has risen spasmodically ever since. This arching brought oceanic crust and oceanic sediments above sea-level. The arch then ruptured axially and its north-east flank overrode the south-western flank and a thick pile of pre-Tertiary terrigenous clastic continental slope sediments. The weight of this south-westerly riding thrust slice contributed to the metamorphism of the overridden sedimentary pile. Once metamorphosed, the overridden sediments then arose isostatically as a fault-bounded block. It was this isostatic rebound throughout the remainder of Tertiary time which caused the rapid emergence of the metasediments of the Owen Stanley Range, the copious supply of clastic sediment into the Aure Trough and the upturning of the front of the thrust slice of the oceanic crust to expose, in the Papuan Ultramafic Belt, dunite and pyroxenite of the upper mantle. (Thompson & Fisher, 1965).

After miogeosynclinal-type sedimentation on the wide continental shelf and slope throughout the Jurassic and Cretaceous, the pattern of sedimentation changed drastically in the Lower Tertiary. During the Paleocene to Upper Miocene transgression, algal and bryozoal reefs prevailed on the shelf area, and a broad barrier reef, comparable to, and probably contiguous with, the Great Barrier Reef, was built up. This change to limestone deposition may reflect either a change towards higher latitudes by pole shift or by shifting of the Australian continent, or it could be accounted for by the advent of a warm oceanic current stream. Whatever the cause, the reef growth very effectively arrested the movement of terrigenous clastic material across the continental shelf. At this time, it seems that the north-eastern part of the continent must have had very low relief, because at no time since the post-Miocene has reef growth been inhibited by clastic sedimentation from the south or west.

Complementary with this transgression, a new large island mass rapidly emerged in the north-east. It ultimately occupied that part of present-day New Guinea south-east of the Huon Gulf and north-east of the Papuan Delta. Initially, and throughout a large part of its history, this emerging land mass was bordered by andesitic and basaltic volcanoes and discontinuous, short-lived, fringing reefs and patch reefs on volcanic deposits.

The stratigraphic record of the Oligocene is very fragmentary. The absence of Oligocene sediments in almost all the continental part of the region can most readily be interpreted as indicative of a further short-lived regression, but this assumption must be accepted with reserve because of the negative nature of the evidence. A thick sequence of Oligocene limestone in the central highlands (Rickwood, 1955) indicates that the inferred regression did not completely expose the northern front of the continental shield. A boulder of Oligocene limestone found in the Purari River region (A.P.C. 1961) indicates minor marine deposition in that area. In Port Moresby area, a thick sequence of marine and terrestrial volcanics have been assigned an Oligocene age by Glaessner (1952). These are considered to mark volcanic activity which preceded the rapid emergence of the block of metamorphic rocks which were to form the Owen Stanley Range.

<u>Miocene</u> - <u>Continental Transgression, Island Regression. (Fig. 8)</u>.

With the emergence of eastern Papua as an orogenic land mass, the Papuan Basin received, from the north and north-east, a flood of ill-sorted clastic sediment including much volcanic detritus. The Papuan Basin, or more particularly, the Aure Trough, must have flexed or faulted downwards as the metasediments of the Owen Stanley Range emerged, because an aggregate thickness of 40,000 to 50,000 feet of Miocene ill-sorted, non-quartzose arenites and claystones accumulated there. Some of the

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Lower and Middle Miocene arenites in the Aure Trough have bedding features suggestive of turbidites. Turbidite "dumping" could account in part for the abnormally thick Miocene sedimentary pile.

The sediments of the Aure Trough are now tightly folded and faulted to produce a close structural grain which parallels the north-western end of the Owen Stanley Range which Glaessner (1950) referred to as the "Morobe Arc". This parallelism suggests that the folding is of either compressive or gravitational origin and related to orogenic emergence of the block of metasediments forming the core of the new island mass.

In the Lower Miocene, the sea transgressed rapidly across the continental shelf area which had been bared by the late Cretaceous regression. Vigorous growth of algal and bryozoal communities rapidly sealed the platform from erosion and prevented the encroachment of clastic sediments from the orogeny to the north and north-east. Lower Miocene reefs also formed on shoal areas in front of the main reef platform at the eastern side of the Purari delta. (Tallis, in press). These shoal areas are probably localised on fault or fold structural highs of Cretaceous sediments. Where covered by later Tertiary clastic sediments, they have good hydrocarbon entrapment potential.

Lower Miocene limestone in reef and calcarenite facies extends north and north-west to the Kikori-Fly-Strickland headwaters and beyond into West Irian, where it forms peaks above 10,000 feet a.s.l. in the Star Mountains. (Bär, Cortel & Escher, 1961). In the western highlands, south and west of Laiagam, the Lower and Middle Miocene sediments are fine-grained pelagic limestone, well-sorted fine-grained sandstone and foraminiferal claystone (Dekker & Faulks, 1964). Still farther north in the headwaters of the Maramuni River on the Sepik fall, the Miocene sediments are tuffaceous clastics, in places conglomeratic and containing small limestone lenses. It seems likely that Lower Miocene faulting and magmatic activity associated with emplacement of the Marum Basic Belt in the Bismarck Ranges (Dow and Dekker, 1964), caused emergence in the central highland region. The land area so formed extended westward in Upper Miocene time, because of uplift associated with movements on the Markham-Ramu Fault and parallel faults. It became the principal source area for clastic sediments deposited rapidly in the eugeosynclinal environment of the Northern New Guinea Basin in the Miocene and Pliocene.

Terrestrial volcanic activity was prevalent along the flanks of the newly emergent Papuan landmass, particularly on the southern flank, in the foothills between Port Moresby and the Lakekamu River. On the northern flank, terrestrial volcanics of probable Lower Miocene age have been recorded from the northern slopes of the Ajura Kujara Range and at Robinson Bay (Paterson and Kicinski, 1956).

In the Upper Miocene, eugeosynclinal clastic sedimentation was particularly vigorous in the Northern New Guinea Basin and in the Cape Vogel Basin (A.P.O.C. 1930).

A Middle Miocene to Upper Miocene reef and shoal limestone sequence deposited on andesitic volcanic agglomerate in New Britain (Noakes, 1942) marks the emergence of another large island. So little is known of the pre-Miocene geology of this island that any attempt to explain its origin must be highly speculative. It is isolated from the Papuan mainland by the New Britain Trench (approx. 25,000 feet deep) and, because of the Miocene limestone cover, cannot be regarded as a source area for any Miocene or younger sediments on the New Guinea mainland.

Pliocene - Regression (Fig. 9)

The small amount of information available (A.P.C. 1961) on the distribution of Upper Miocene limestone on the Papuan part of the continental shelf suggests that regression had already commenced in Upper Miocene time.

The Pliocene sedimentary record indicates widespread regression, probably in response to orogenic movements in the eastern Papuan crystalline block and in the central highlands tectonic zone, and sympathetic folding and faulting of the incompetent clastic sedimentary succession between the more rigid orogenic units and thick Miocene limestone blanket on the western Papuan shelf area. The zones of maximum deformation (Fig.11) form a three-pronged array centred on the middle reaches of the Purari River. This array can be readily explained by differential movement of the two orogenic blocks and the common buttressing effect of the single thick plate of Miocene shelf limestone firmly based on Mesozoic clastic shelf sediments overlying relatively stable continental basement.

During Upper Miocene and Lower Pliocene, orogenic movements were accompanied by andesitic to acid vulcanism and intrusion of quartz-feldspar porphyries in the Wau-Bulolo area at the north-western end of the eastern Papuan orogenic unit, and also in the Kainantu area at the south-eastern end of the central highlands orogenic block. This magmatic activity introduced important gold and some base-metal mineralization; it also caused a land bridge to form between the two orogenic blocks by uplift and by sedimentary filling. Later, but still within the Upper Miocene to Lower Pliocene interval, uplift of the central highlands block extended the land area north-westwards and eastern New Guinea became the eastern half of a continuous mountainous island at least 2,000 miles long (with West Irian included). A narrow and shallow seaway separated the central part of this island from the rest of the Australian continent to the south. This was rapidly filled with coarse detritus from the rising mountains to the north and a land connection to the continent was re-established. The sea separating eastern Papua from the Australian continental shelf was deep throughout Tertiary and Cainozoic time and, although it received much terrigenous and volcanic detritus from the north, this basin (the Coral Sea Basin) was not filled.

In the Papuan Basin, Pliocene, marine, fine-grained, clastic sediments are exposed in robust folds inland from the Purari delta in the axial portion of the Aure Trough. It seems that they have been deposited in structurally and topographically depressed areas during deformation of the underlying thick Miocene sedimentary pile. Thicker marine Pliocene sequences probably occur offshore, down the axial plunge of the Aure Trough. Marine Pliocene sediments are also present in the Lakekamu Embayment. In both the Purari delta hinterland, and in the Lakekamu Embayment, the marine Pliocene sediments are subsidiary to thick terrestrial sequences of coarser sediments which, in places, contain coal measures.

There are many small patch reefs of Pliocene age on the eastern flank of the Papuan Basin but, paradoxically, none are known on the western shelf area. Rapid Pliocene marine regression seems to have stranded much of the Miocene reef platform and only clastic reef detritus accumulated at the front of the platform. It is reasonable to surmise that Pliocene reefs flourished and are preserved at the outermost edge of the platform, but these have not yet been located in Papua. On the Great Barrier Reef at approximate latitude 23°20'S, about 400 feet of Pliocene reef detritus was recorded in the H.B.R. WRECK ISLAND No. 1 well (H.B.R., 1960).

A thick marine Pliocene clastic succession was deposited over the greater part of the Northern New Guinea Basin on Miocene sediments of similar facies which were being folded and faulted. Upwards in the Pliocene sequence, terrestrial sediments are increasingly more abundant and, as in the Papuan basin, there was a transitional zone where paralic conditions prevailed. This zone must have moved seawards and become younger as the rapid regression proceeded. Pliocene limestone in the far west, near the Australian/West Irian border, indicates uplift at the western end of the Basin, while the central part was still receiving sediment. It is not possible to correlate the dominantly terrestrial volcanic Mio/Pliocene succession of the Finisterre and Saruwaged Ranges with the sediments of the central part of the Basin. This is probably because the eastern end emerged more rapidly than other parts of the basin and terrestrial vulcanism and faulting have confused the stratigraphic record. Pleistocene marine limestone recorded from above 10,000 feet a.s.l. in the Saruwaged Ranges (Crespin and Stanley, 1965) testifies to the very rapid emergence of this mountain block.

In the Cape Vogel Basin, a thick Mio/Pliocene clastic succession was deposited (A.P.O.C., 1930). This succession is marine towards the base, then grades through a thick paralic arenaceous phase into continental, poorly sorted, lithic sandstone and polymict conglomerate. Volcanics within this succession and the poorly sorted sediments are typically eugosynclinal. The Cape Vogel Basin has many environmental features in common with the Northern New Guinea Basin, but it has not been as complexly folded and it is exposed over a much smaller area.

Within the central mountainous part of the Pliocene New Guinea, intermontane basins, many fault-controlled, were formed. These accumulated piedmont and lacustrine sediments and the products of vulcanism. Erosional remnants of these occur high in the Owen Stanley Range, and in the central and western highlands.

Post-Pliocene - Regression

In Pleistocene to Recent time, New Guinea grew laterally, locally by tectonic emergence, and regionally by the spread of sediments in deltas and along strand lines. These sediments were derived from vigorous erosion of the median cordillera such as is proceeding to-day. The exception to this situation is in the far south-west, where stable continental basement was unaffected by orogenic movements in New Guinea. Here the world-wide Pleistocene transgressions formed the Torres Straits. Elsewhere, the effects of the Pleistocene sea-level rises were largely negated by the overriding influence of orogeny and shoreline outgrowth by prograding.

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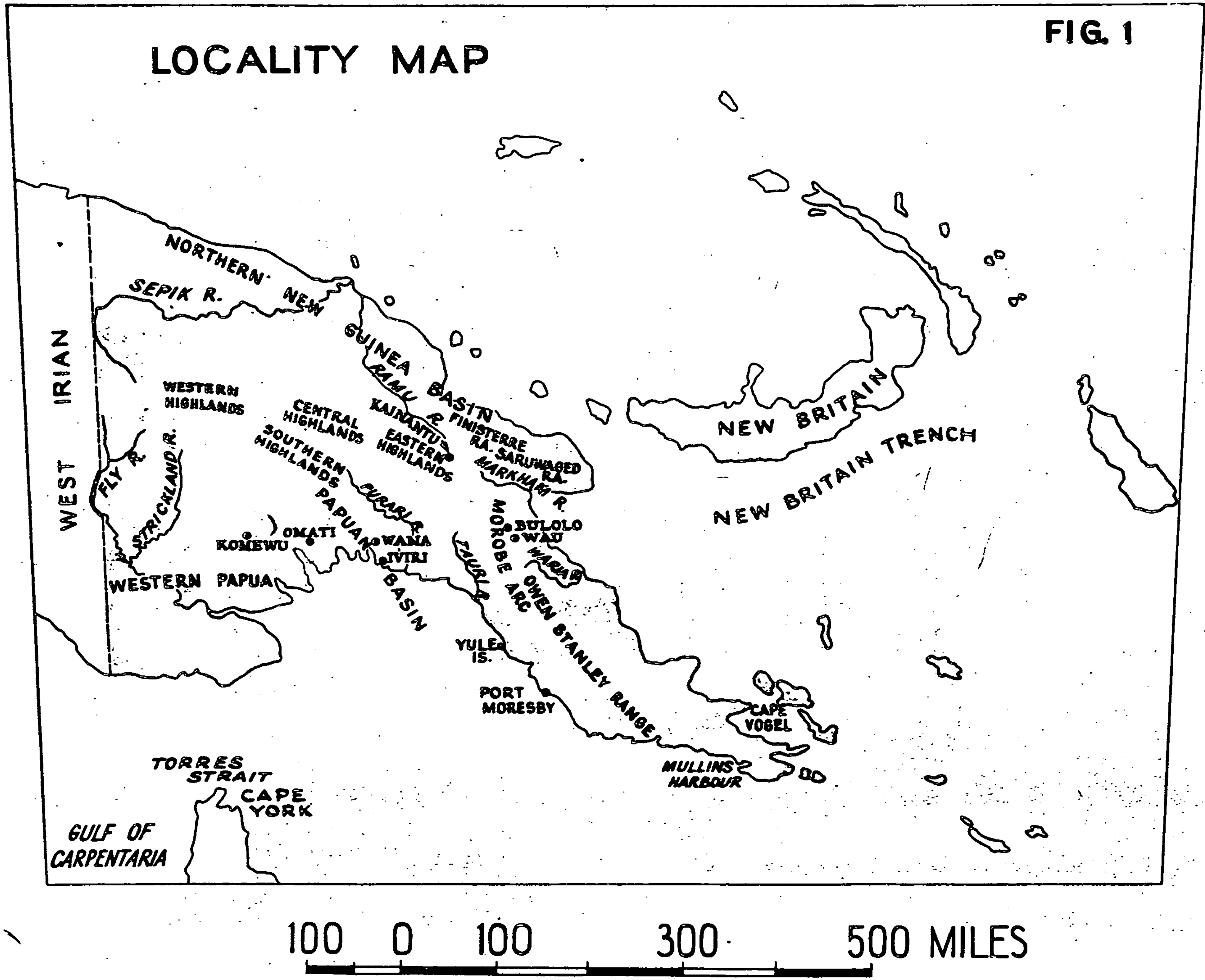


FIG. 1
LOCALITY MAP
WEST IRIAN
NORTHERN NEW GUINEA BASIN
SEPIK R.
RAMU R.
WESTERN HIGHLANDS
CENTRAL HIGHLANDS
SOUTHERN HIGHLANDS
KAINANTU
EASTERN HIGHLANDS
FINISTERRE RA.
SARUWAGED RA.
MARKHAM R.
FLY R.
STRICKLAND R.
PURARI R.
PAPUAN BASIN
OMATI
KOMEWU
WANA
IVIRI
BULOLO
WAU
WARIA R.
MOROBE ARC
OWEN STANLEY RANGE
TAURI R.
WESTERN PAPUA
YULE IS.
PORT MORESBY
CAPE VOGEL
MULLINS HARBOUR
NEW BRITAIN
NEW BRITAIN TRENCH
TORRES STRAIT
CAPE YORK
GULF OF CARPENTARIA
100 0 100 300 500 MILES

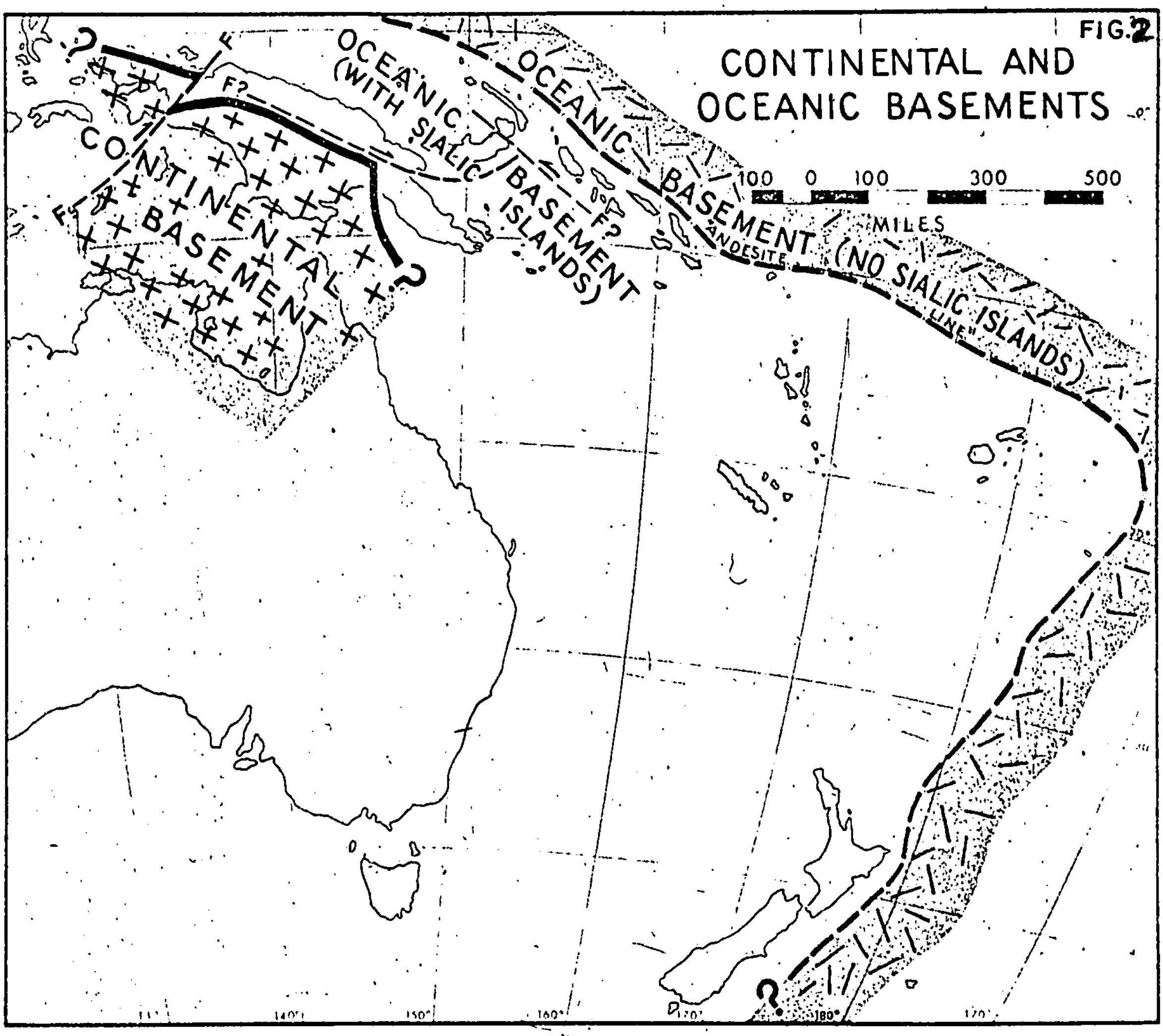
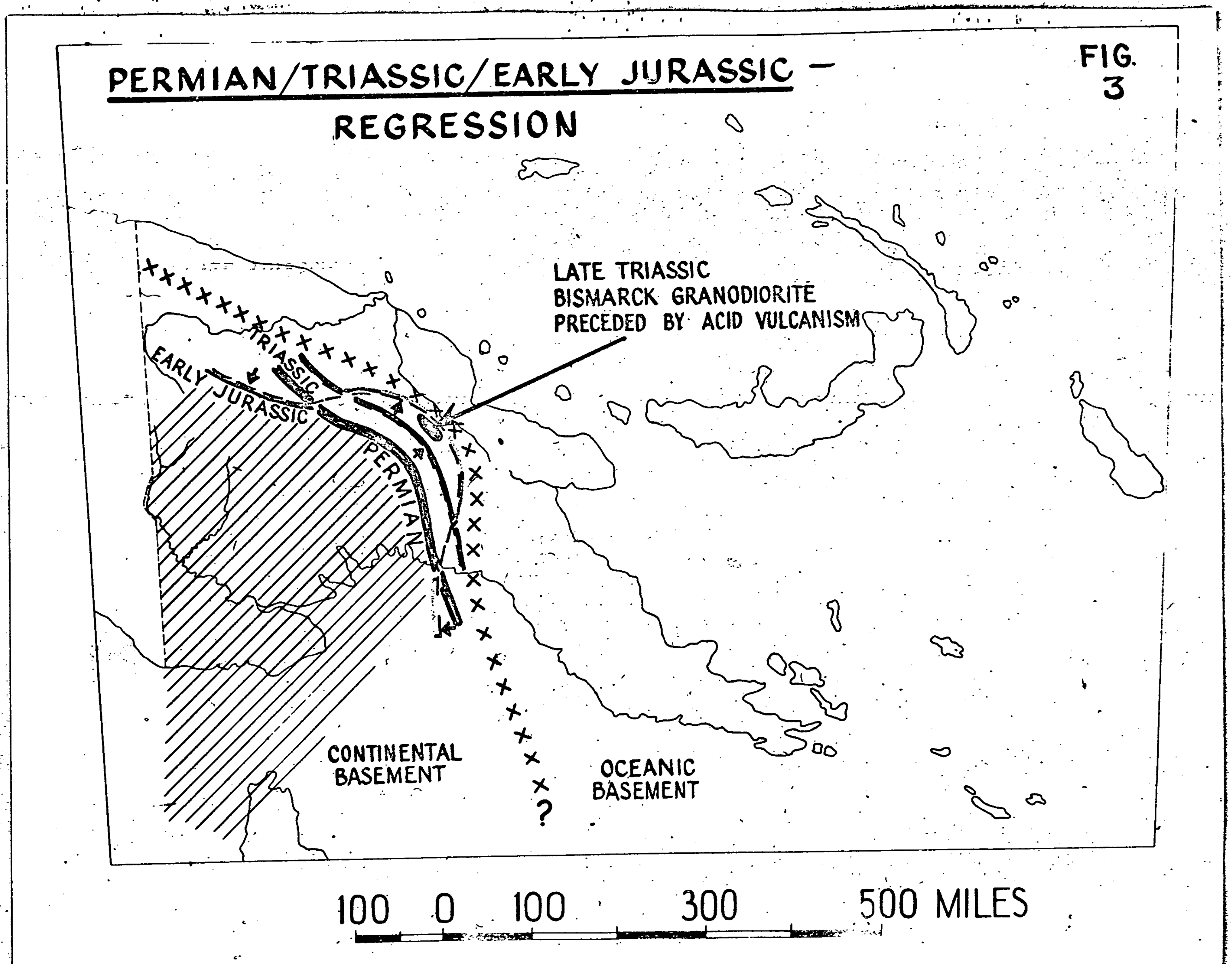
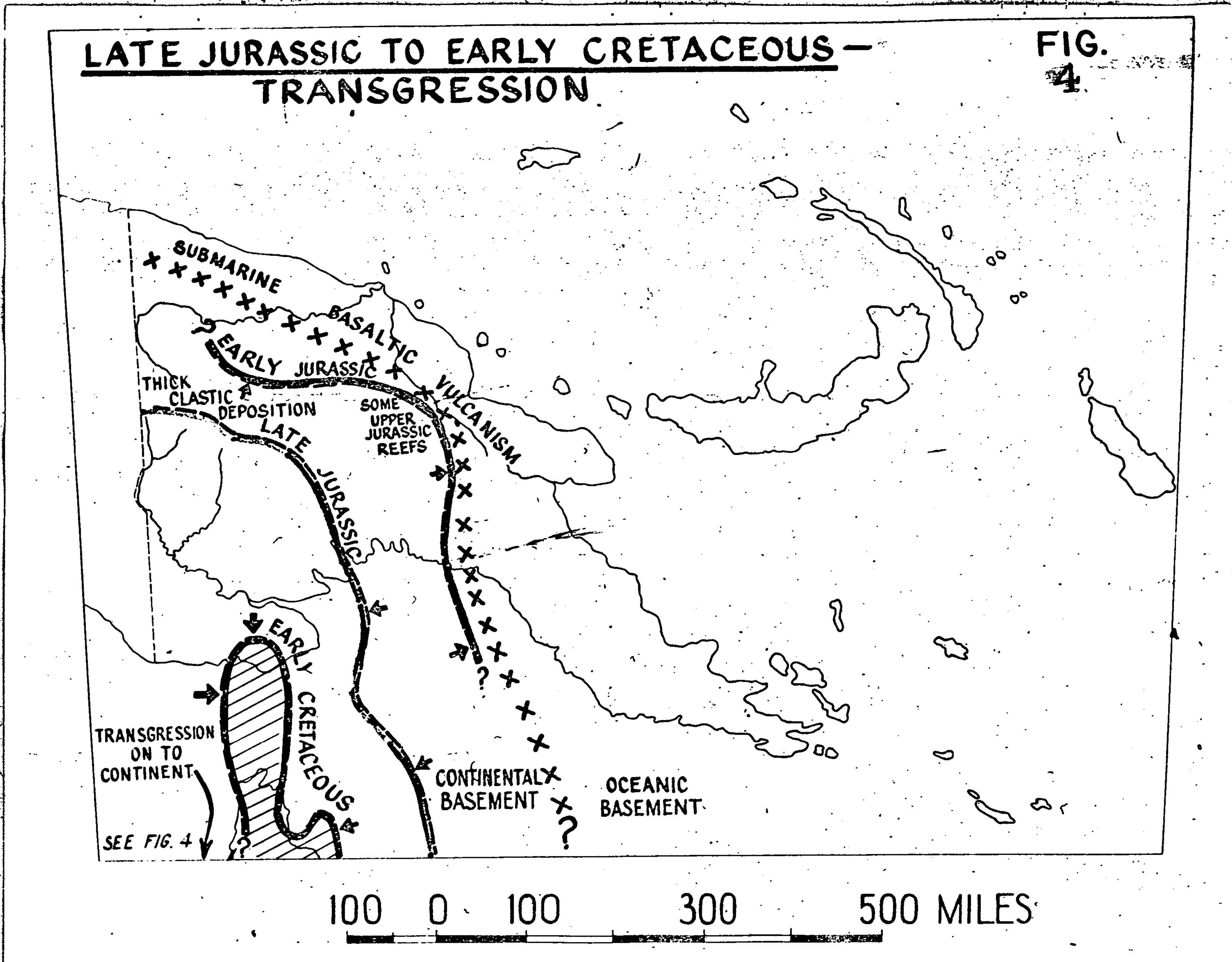


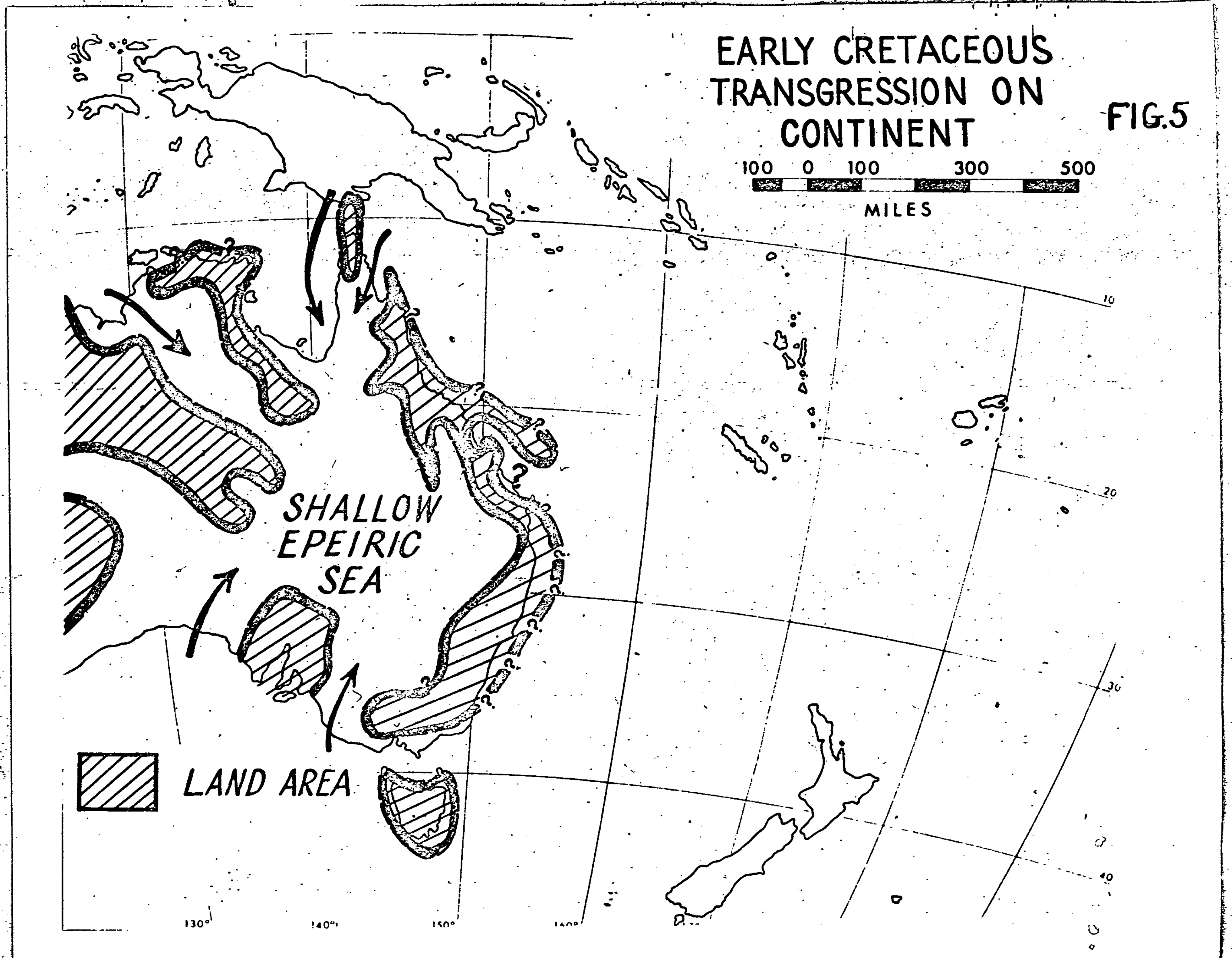
FIG. 2
CONTINENTAL AND OCEANIC BASEMENTS
100 0 100 300 500
MILES
CONTINENTAL BASEMENT
OCEANIC (WITH SIALIC ISLANDS) BASEMENT
OCEANIC BASEMENT (NO SIALIC ISLANDS)
"ANDESITE LINE"
F?
140°
150°
160°
170°
180°
170°


PERMIAN/TRIASSIC/EARLY JURASSIC —
REGRESSION
FIG. 3
LATE TRIASSIC
BISMARCK GRANODIORITE
PRECEDED BY ACID VULCANISM
TRIASSIC
EARLY JURASSIC
PERMIAN
CONTINENTAL BASEMENT
OCEANIC BASEMENT
?
100 0 100 300 500 MILES

30

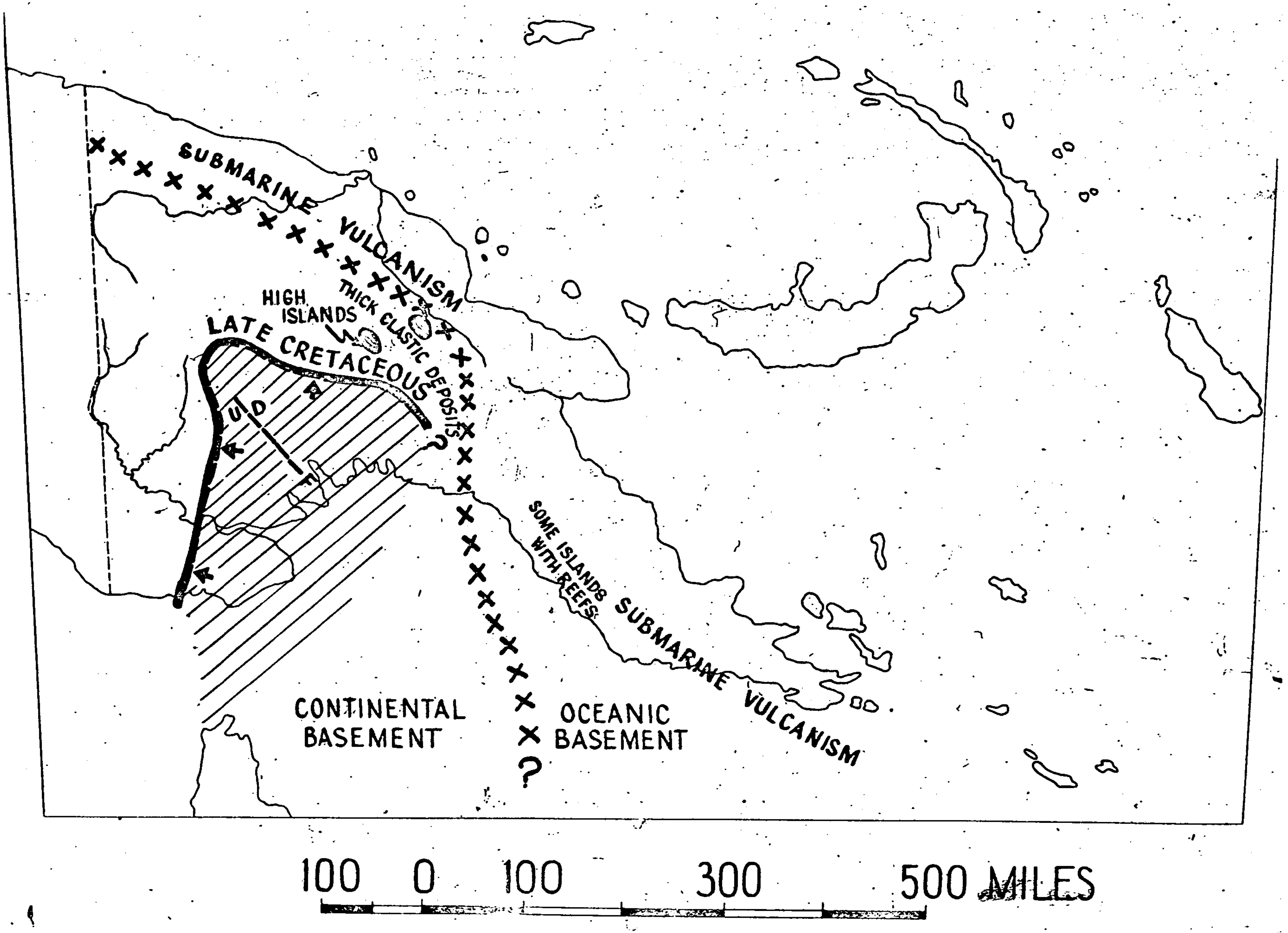

LATE JURASSIC TO EARLY CRETACEOUS — TRANSGRESSION
FIG. 4
SUBMARINE BASALTIC VULCANISM
EARLY JURASSIC
THICK CLASTIC DEPOSITION
LATE JURASSIC
SOME UPPER JURASSIC REEFS
EARLY CRETACEOUS
TRANSGRESSION ON TO CONTINENT
SEE FIG. 4
CONTINENTAL BASEMENT
OCEANIC BASEMENT
100 0 100 300 500 MILES

31


EARLY CRETACEOUS
TRANSGRESSION ON
CONTINENT
FIG.5
100 0 100 300 500
MILES
SHALLOW
EPEIRIC
SEA
LAND AREA
10
20
30
40
130°
140°
150°

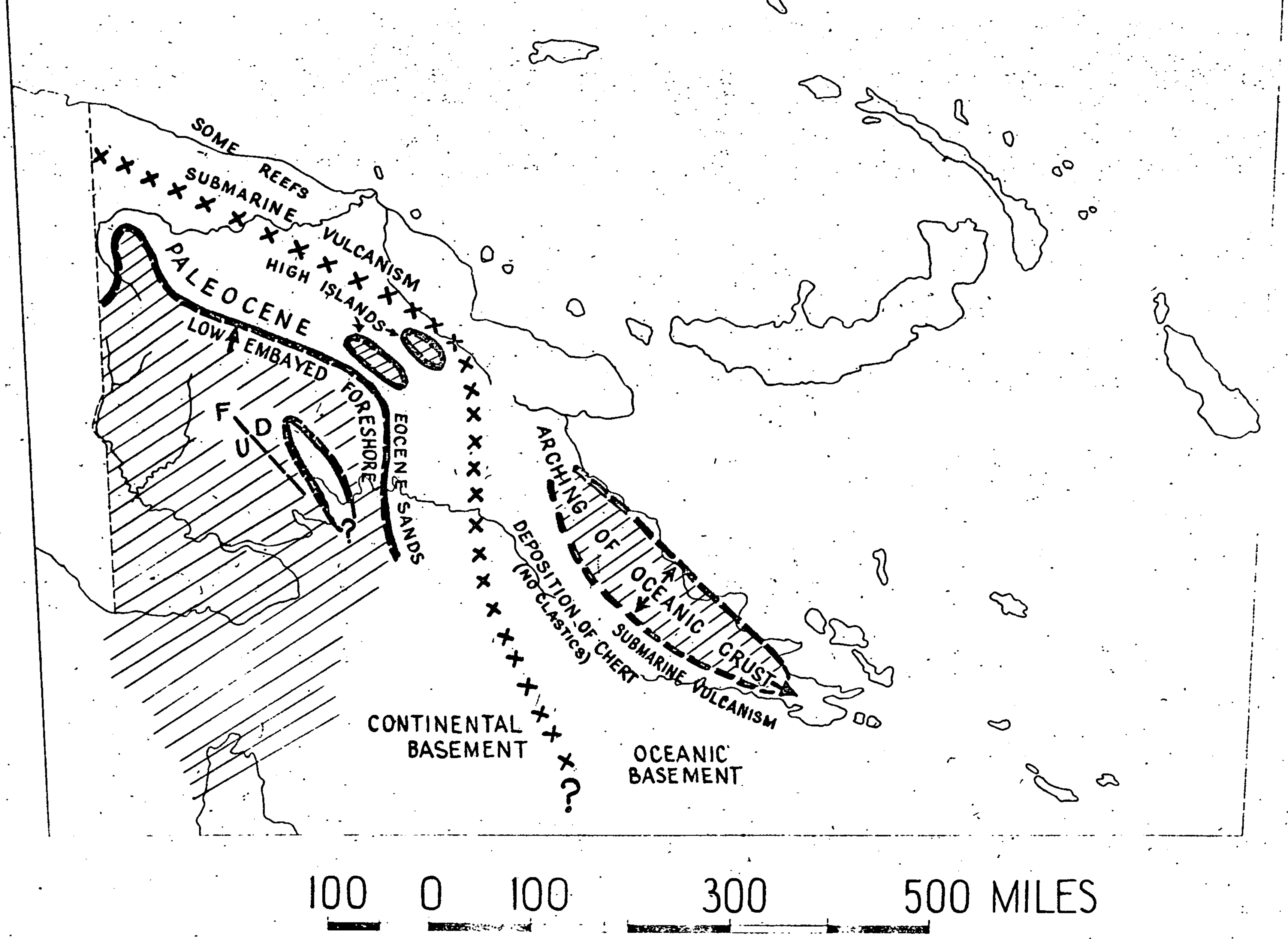
LATE CRETACEOUS — REGRESSION

FIG. 6



EARLY TERTIARY — PALEOCENE REGRESSION, EOCENE TRANSGRESSION

FIG. 7



MIOCENE —CONTINENTAL TRANSGRESSION, ISLAND REGRESSION

FIG. 8

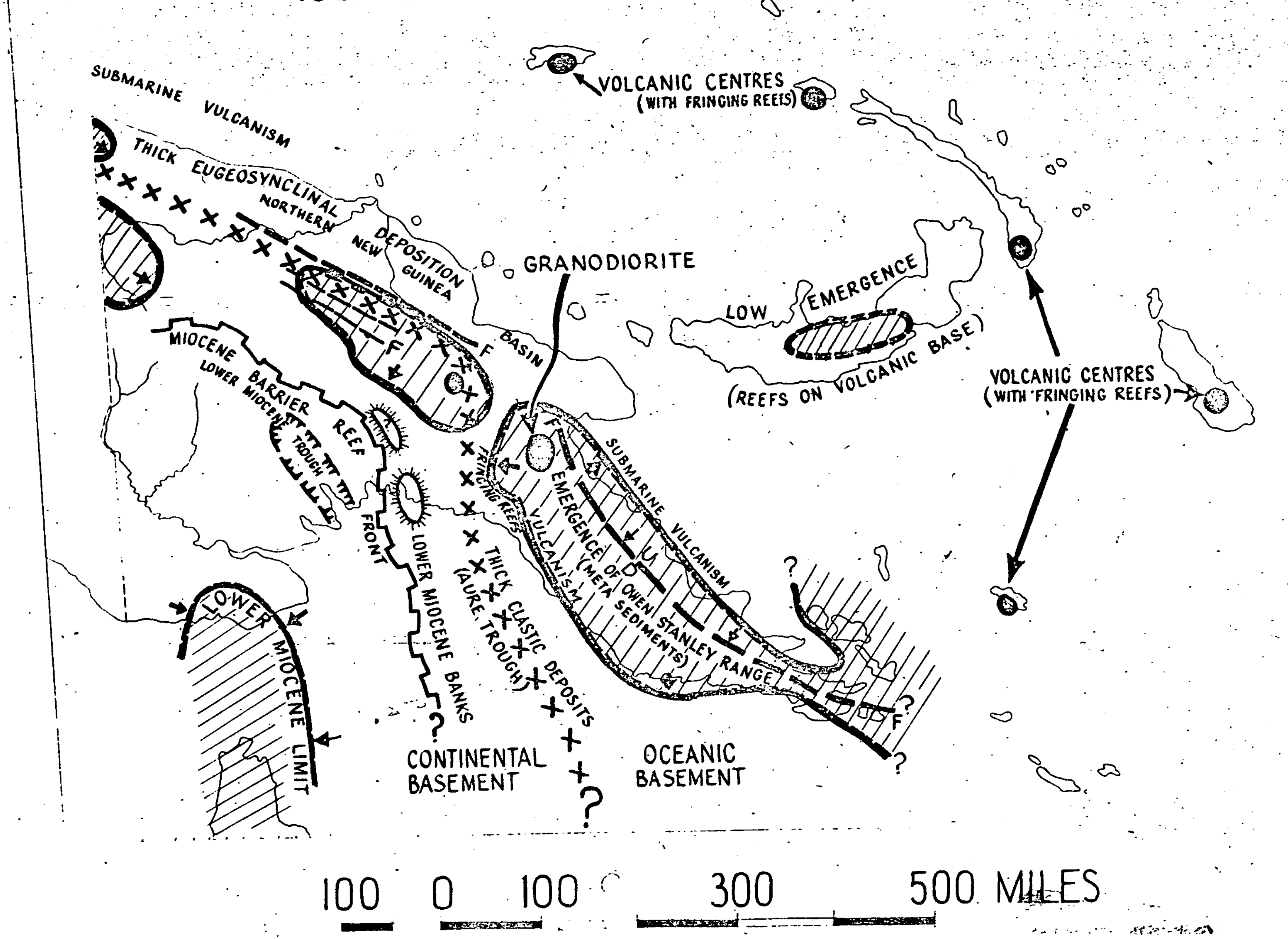
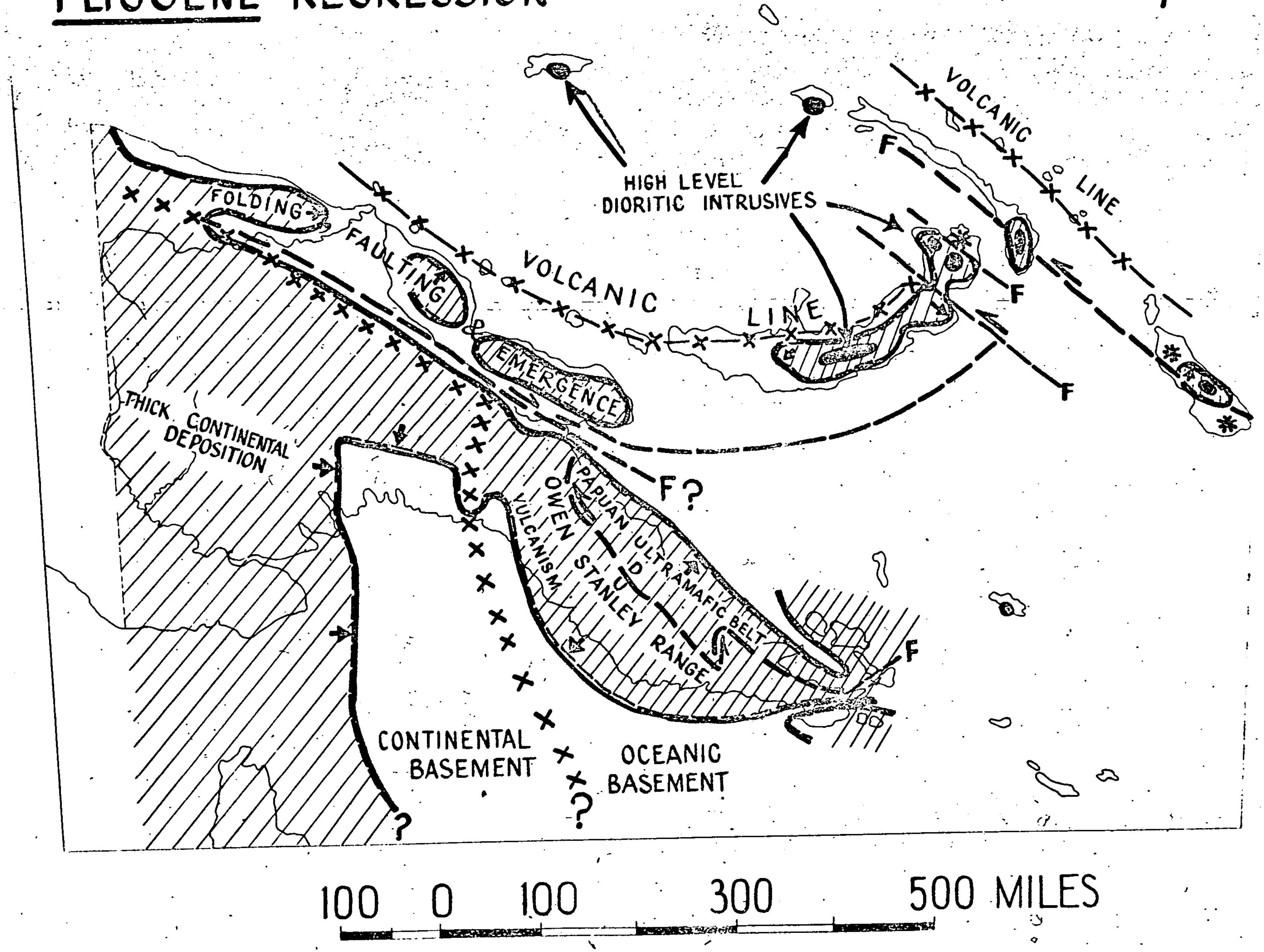


FIG. 9

PLIOCENE—REGRESSION

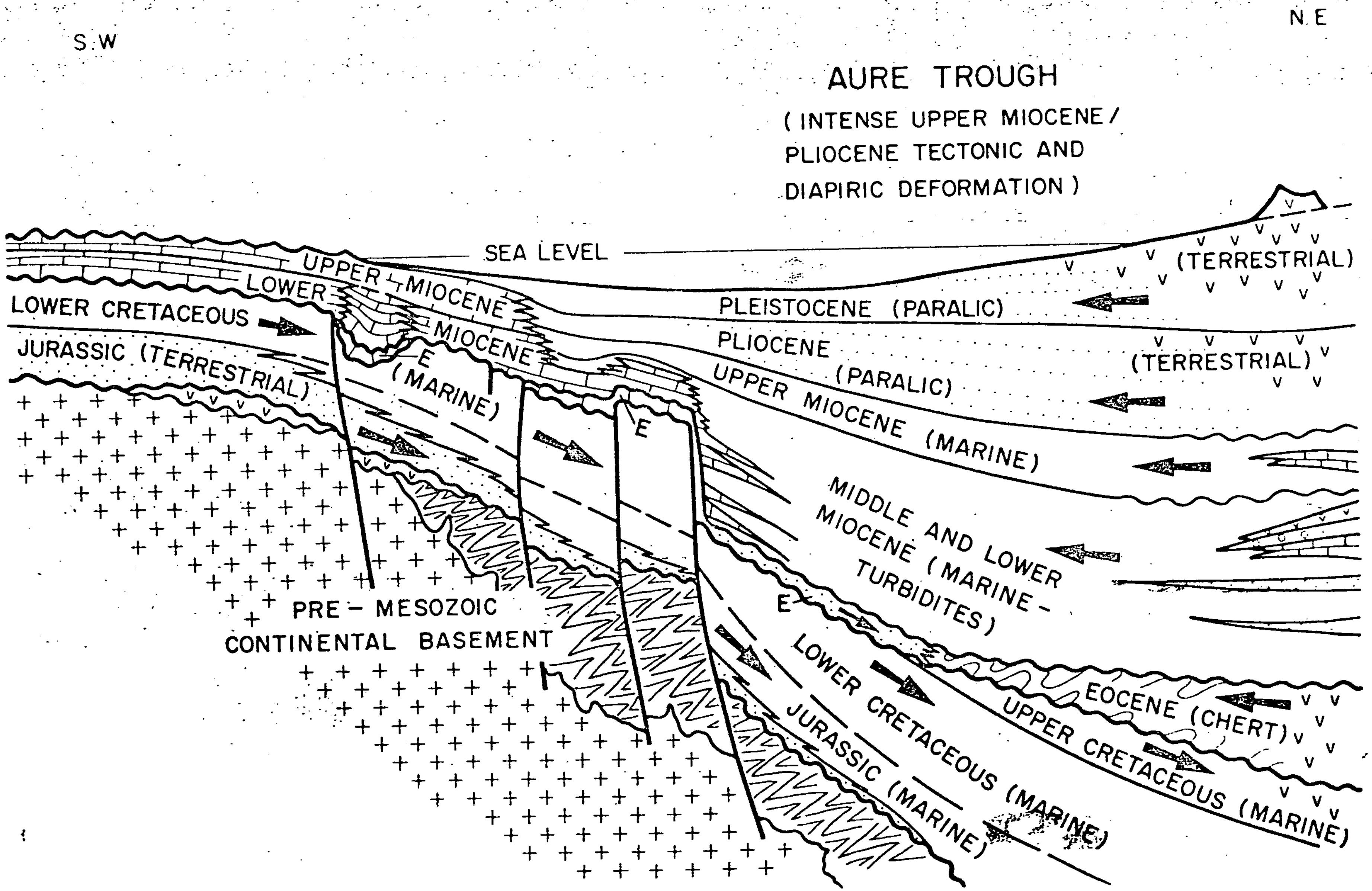


SCHEMATIC SECTION ACROSS S-W FLANK OF PAPUAN BASIN

FIG. 10

NOT TO SCALE

(DIRECTION OF SEDIMENT TRANSPORT ➡)



QUATERNARY STRUCTURAL MAP WITH VOLCANIC CENTRES

FIG. 11

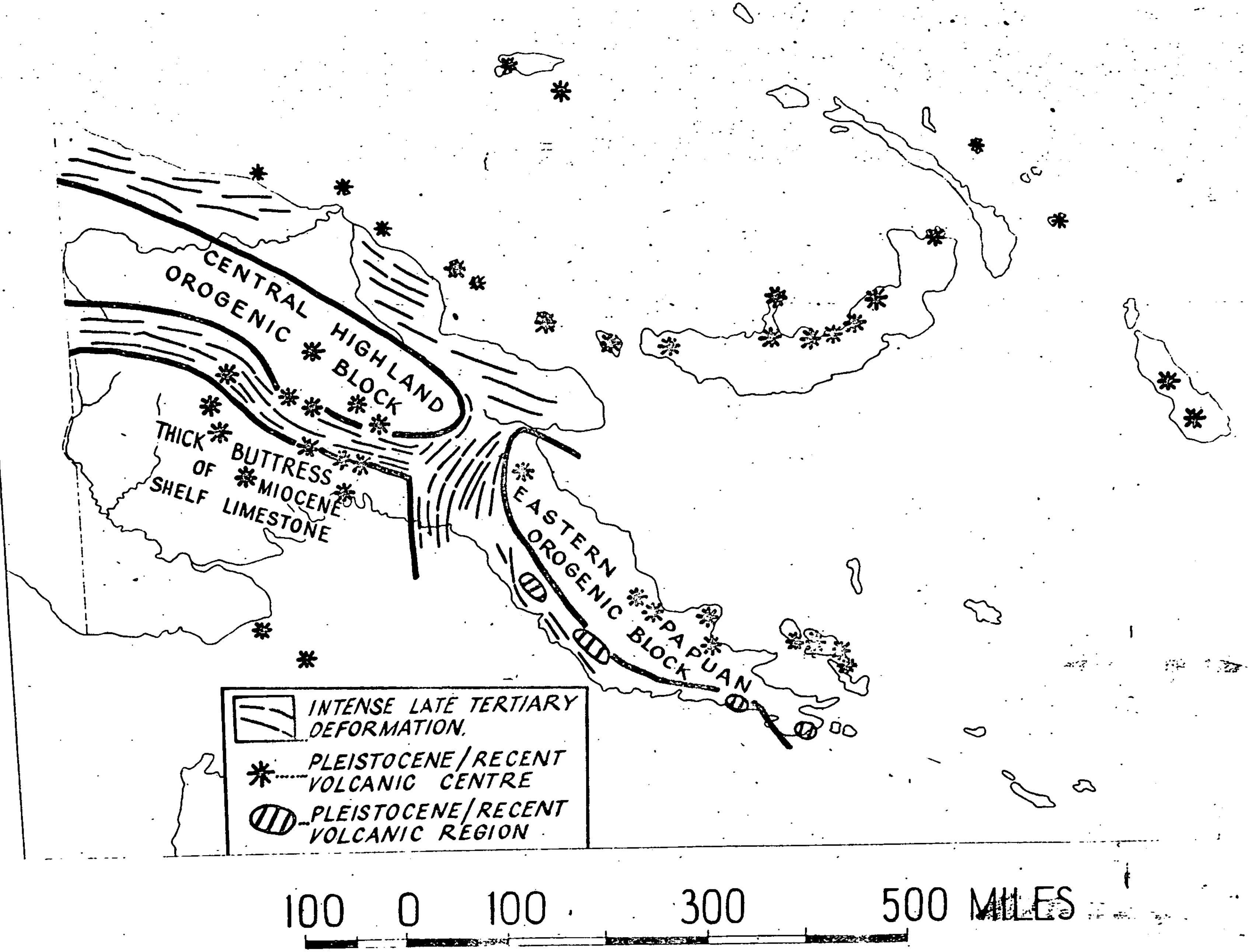


FIG. 12

EVOLUTION OF PAPUAN BASIN AND EASTERN PAPUA

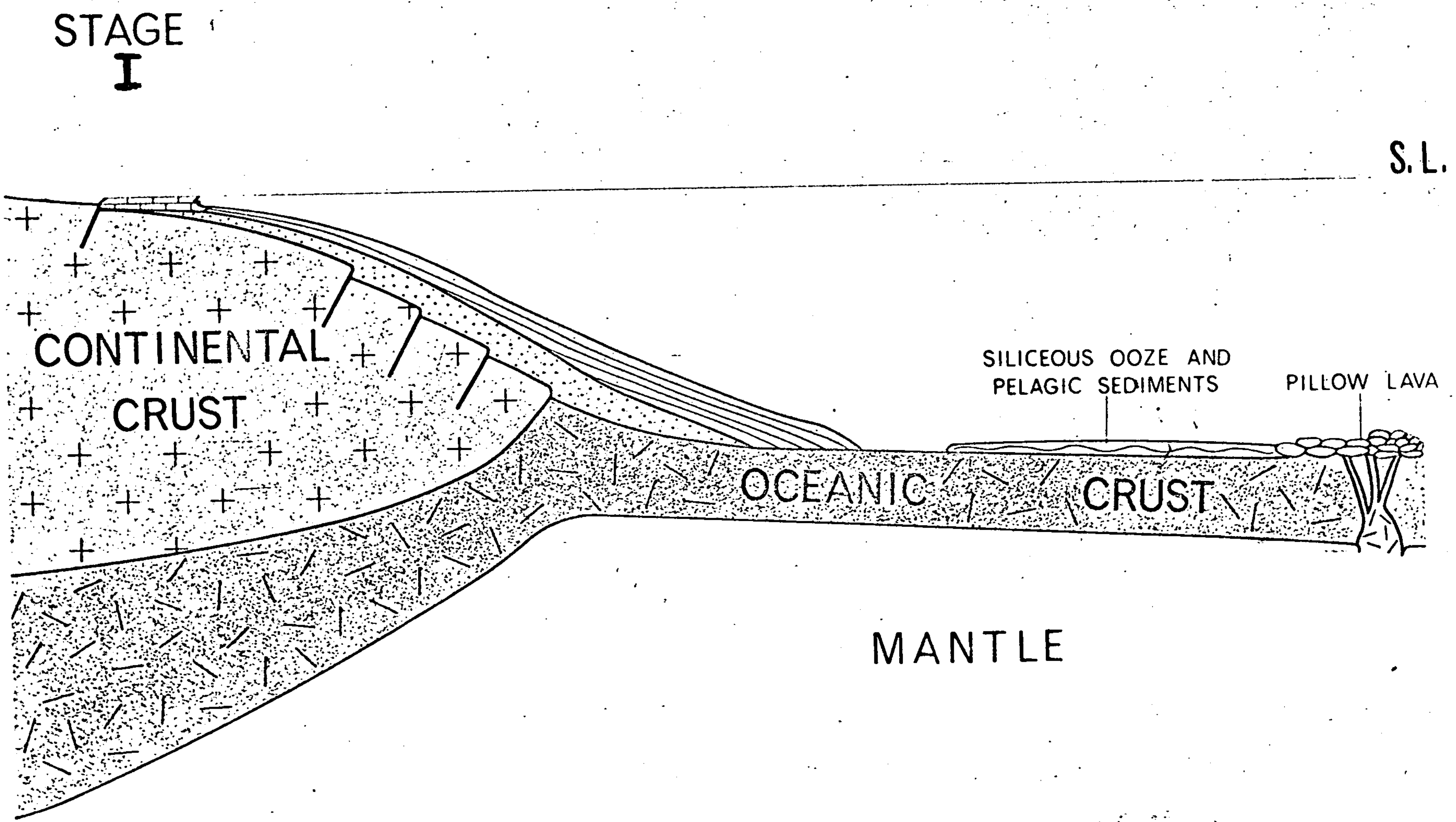
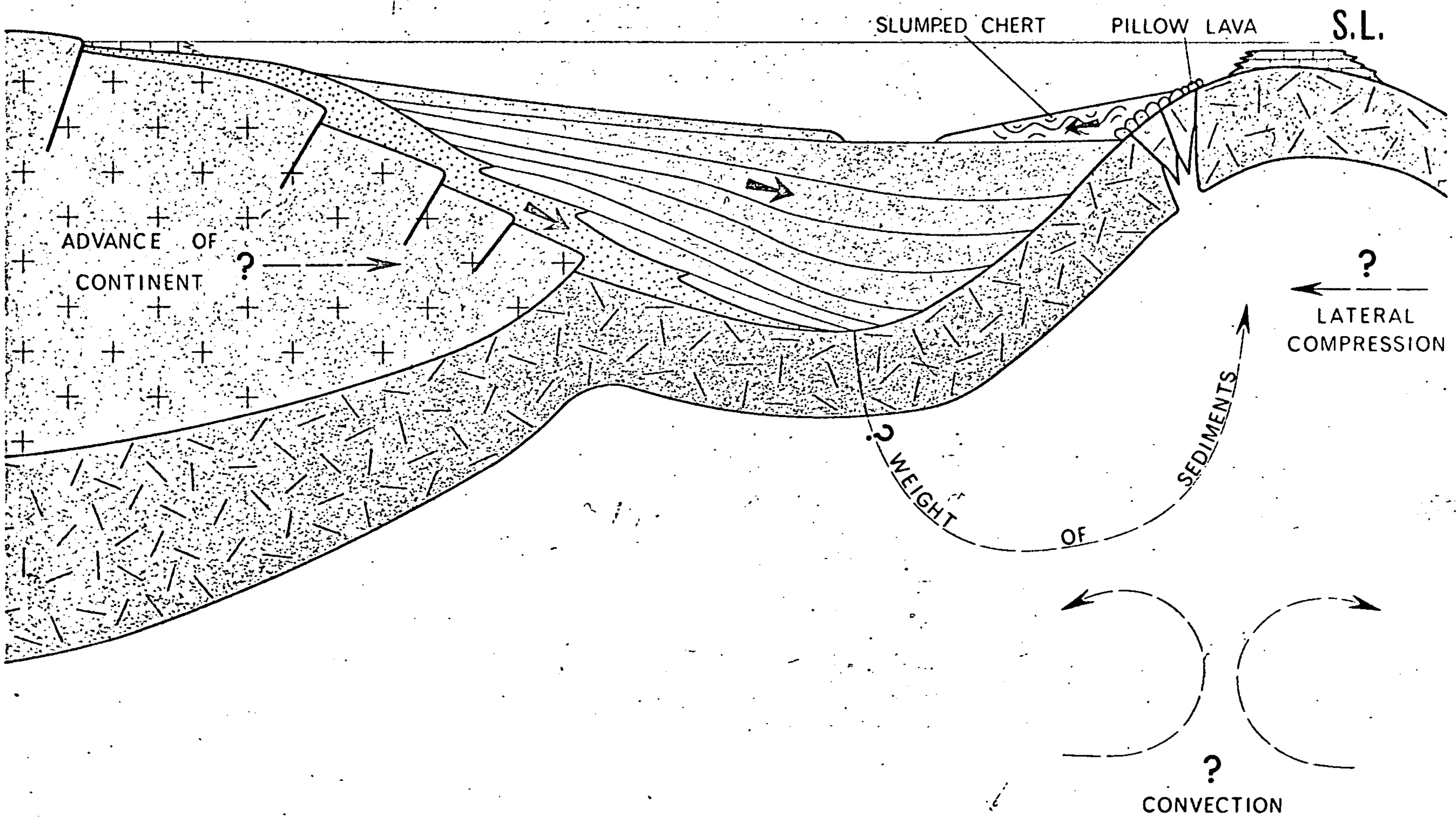


FIG. 13

EVOLUTION OF PAPUAN BASIN AND EASTERN PAPUA

STAGE II



EVOLUTION OF PAPUAN BASIN AND EASTERN PAPUA

FIG. 14

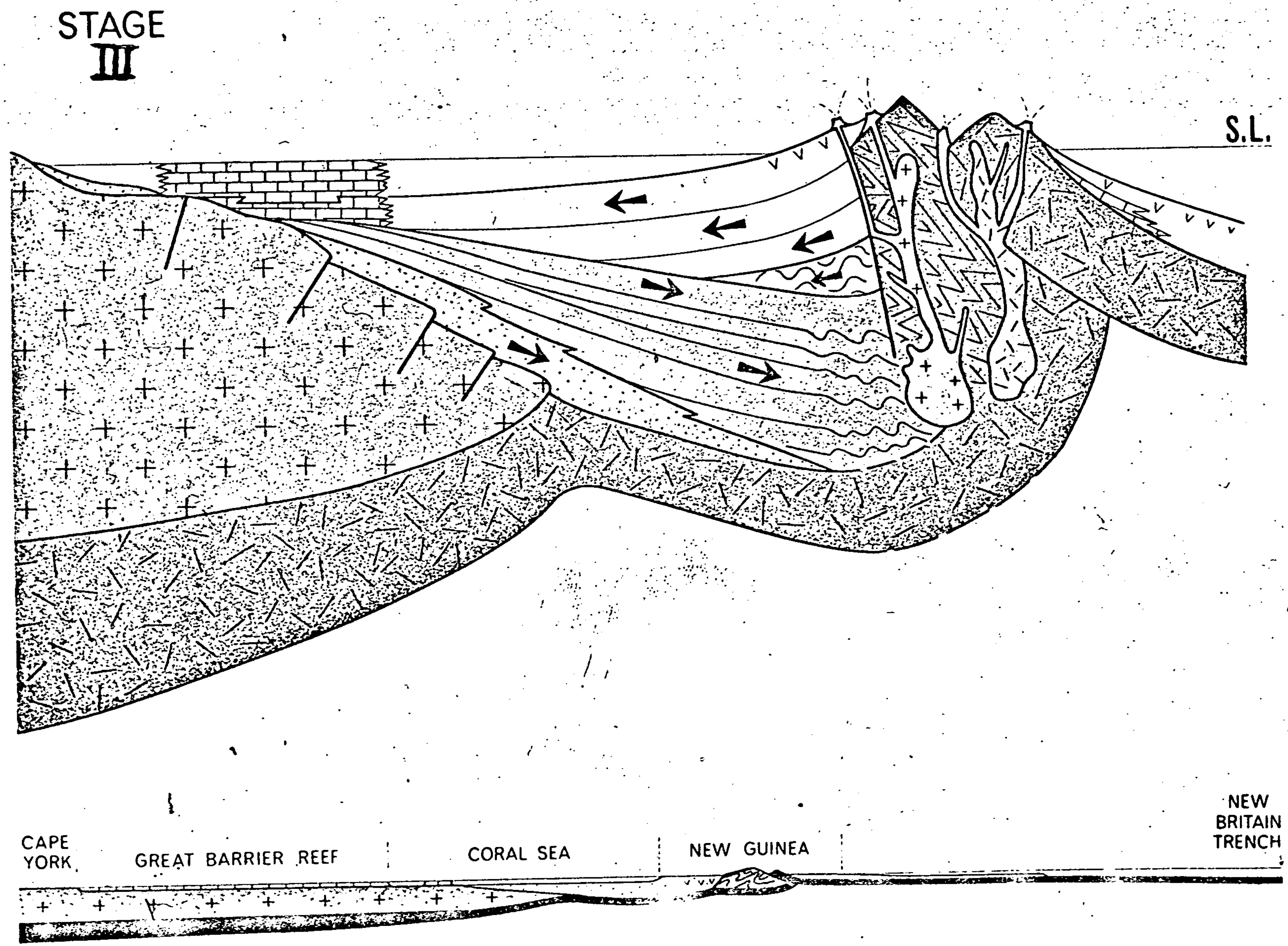


FIG. 15

SCHEMATIC SECTION
CAPE YORK TO NORTH NEW GUINEA

(NOT TO SCALE)