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# DEPARTMENT OF MINERALS AND ENERGY

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS



RECORD 1975/37

ABSTRACTS OF PAPERS PRESENTED AT THE SOUTHWEST PACIFIC SYMPOSIUM - TO BE PUBLISHED IN ASEG BULLETIN

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by

L.A. TILBURY

'Lineations in the Bismarck Sea'

by

L.A. Tilbury

The Bismarck Sea is a complex tectonic region lying in a zone of interaction between the Pacific and Australian plates. Several small crustal plates have been outlined in the region. Although the Bismarck Sea has a crustal thickness of about 20 km it appears to be oceanic in origin.

Data from some 10 000 n.ml of traversing in the Bismarck Sea has thrown some light on the understanding of the structure and evolution of the area. Oceanic basement occupies the northern two thirds of the Bismarck Sea region while the southern third appear to be primarily of andesitic composition. Minor northeast magnetic trends underlie major east-west trends associated with volcanic ridges. These minor trends appear to have arisen from sea floor spreading. Preliminary interpretation indicates the anomalies are possibly of Oligocene age.

The structure and sediment distribution of the West Melanesian Arc suggests that it is a sheared arc which formed as a feature continuous with the New Britain Arc.

A simple but speculative evolution consistent with most of the facts can be put forward.

a) The Bismarck Sea region formed during the Oligocene on the southern limb of a spreading centre. The extinct ridge is now possibly situated between Manus Island and the PNG margin.

Until this time the Northern New Guinea Arc, New Britain Arc and the West Melanesian Arc formed a continuous island arc to the south.

b) About lower Miocene the Northern New Guinea Arc collided with the Australian plate. Subduction ceased along the island arc and a shear zone was formed along the southern boundary of the West Melanesian Arc to release stress.

c) Between the lower Miocene to lower Pliocene the West Melanesian Arc moved 1000 km northwest along shear zone (rate about 7 cm/yr). Shearing could explain the absence of volcanism during this period, the formation of tensional features in the eastern Bismarck Sea, and the 'arc type' volcanics of Oligocene/Miocene age on the northeast of the West Melanesian Arc.

d) Post Pliocene saw the readjustment of plate boundaries and resumption of subduction under New Britain. The left-lateral Bismarck Sea fault was formed to accommodate movement originally along the West Melanesian Arc. A zone of andesitic volcanism from eastern New Britain to the Schouten Islands formed by subduction of the Australian plate to the north and northeast.

# DISTRIBUTION OF UNDERTHRUST LITHOSPHERIC SLABS AND FOCAL MECHANISMS- PAPUA NEW GUINEA AND SOLOMON ISLANDS REGION

by

David Denham

Bureau of Mineral Resources, Canberra.

Studies of the spatial distribution of shallow earthquakes define the present day plate boundaries. In the Papua New Guinea and Solomon Islands region (PNGS1) these are well determined and indicate a mozaic of several small plates each moving relatively to the other (see fig. 1). Some of the boundaries are zones of plate convergence where lithospheric material is being thrust (or sinks) deep into the mantle. These regions are revealed by earthquakes occurring at depths greater than 100 km.

In the PNGS1 region there appears to be three main zones where the lithosphere is being underthrust.

1. The Mainland of New Guinea. Here the situation is similar to a continent/continent collision zone where earthquakes do not take place deeper than 200 km. The absence of very deep earthquakes indicates that the rate of subduction is low, because the slabs are being assimilated into the mantle at comparatively shallow depths and also that a large part of the crustal compression results in mountain building. The stress directions from the focal mechanisms do not produce a recognizable pattern and are indicative of the complicated tectonic situation in this region.

2. The northern boundaries of the Solomon Sea. This region represents an island arc environment of rapid underthrusting ( ~10cm/yr) where earthquakes take place down to 600 km. The lithospheric slabs appear to be continuous except beneath Bougainville Island where the slab changes its strike below 400 km.

3. The Solomon Islands Arc, south of Bougainville Island. The situation here is very complex with current underthrusting of the Australian Plate beneath San Cristobal Island, deep remnants of lithospheric slabs beneath the central part of the island chain, and underthrusting of the Pacific Plate beneath Santa Ysabel Island.

The earthquake evidence supports significant recent changes in the zones of underthrusting beneath the Solomon Chain but suggests that the New Britain Arc has only changed its position slightly, if at all, in the last 6 m.y.

Fig. 2 shows the main zones of underthrusting.

PNG/B9-249A

## Figure Captions

Figure 1. Locations of plate boundaries in the Papua New Guinea/ Solomon Island region.

Figure 2. Location of underthrust lithosphere. F . . . F represent major discontinuities at depth. Section A . . . A portrays the complications beneath Bougainville Island.

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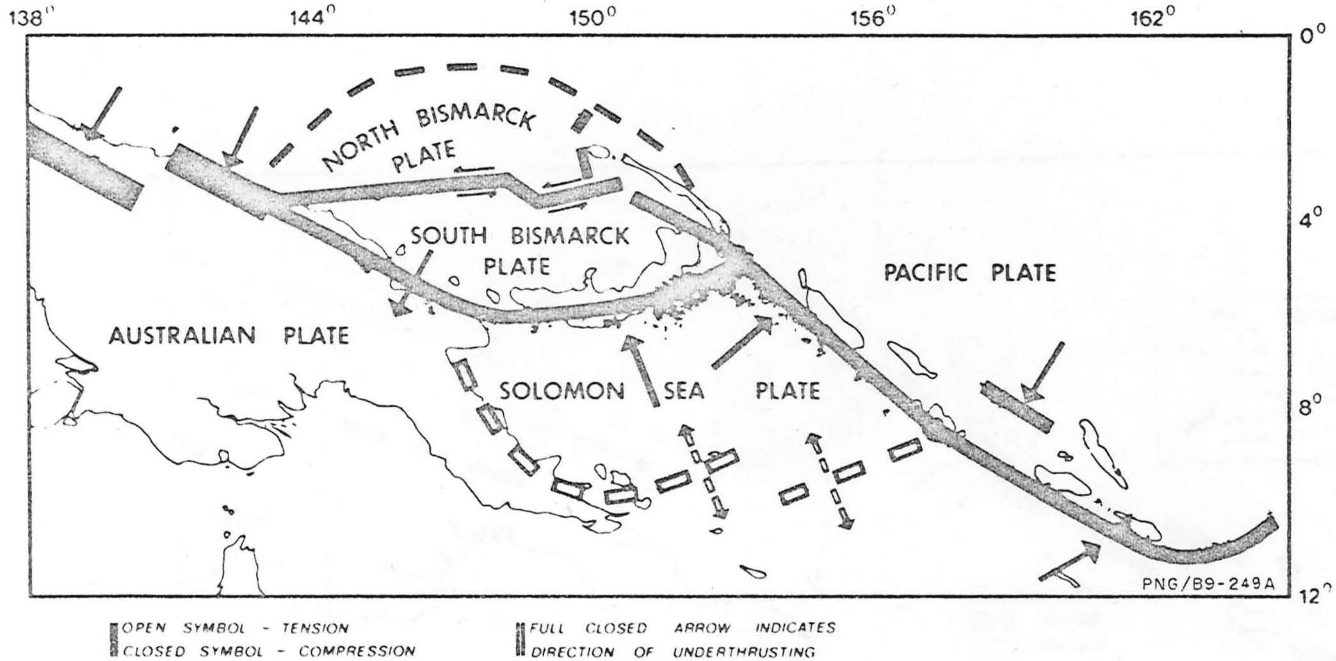
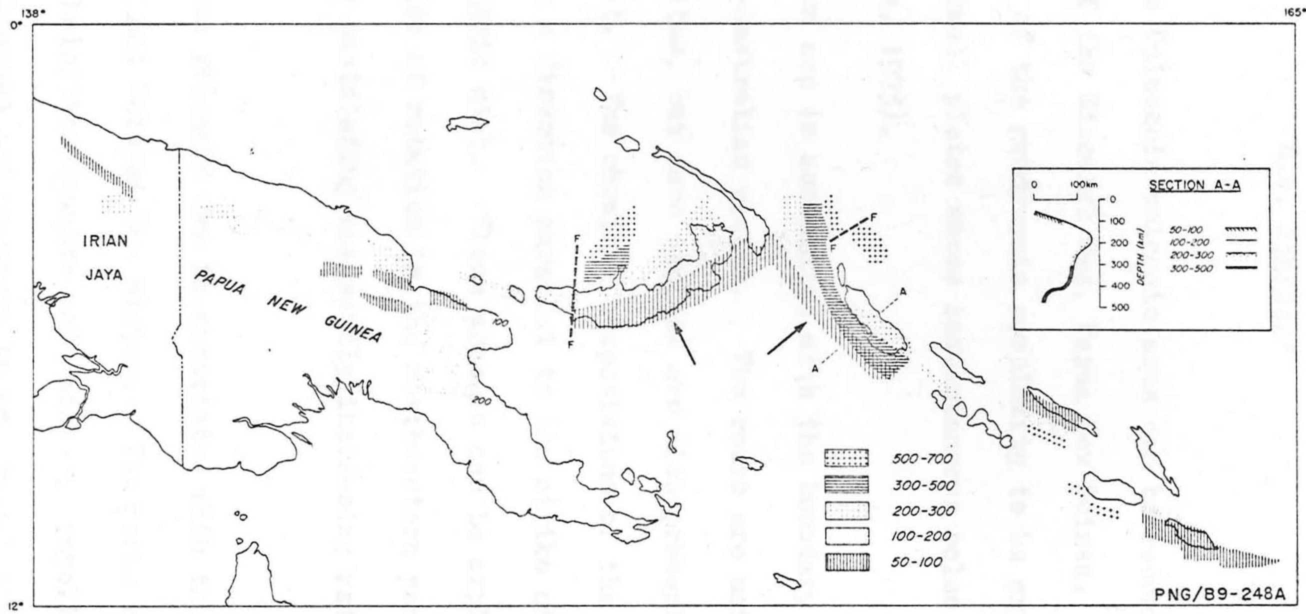


138°
144°
150°
156°
162°
0°
4°
8°
12°
NORTH BISMARCK PLATE
SOUTH BISMARCK PLATE
PACIFIC PLATE
AUSTRALIAN PLATE
SOLOMON SEA PLATE
PNG/B9-249A
OPEN SYMBOL - TENSION
CLOSED SYMBOL - COMPRESSION
FULL CLOSED ARROW INDICATES DIRECTION OF UNDERTHRUSTING


138°
0°
165°
12°
IRIAN
JAYA
PAPUA NEW GUINEA
F
F
A
A
100
200
SECTION A-A
0 100km
0
100
200
300
400
500
DEPTH (km)
50-100
100-200
200-300
300-500
500-700
300-500
200-300
100-200
50-100
PNG/B9-248A

# PLATE MODEL TO EXPLAIN LATE CAINOZOIC VOLCANISM AT THE SOUTHERN MARGIN OF THE BISMARCK SEA, PAPUA NEW GUINEA

by

R.W. Johnson*

Two Late Cainozoic volcanic arcs can be recognised at the southern margin of the Bismarck Sea, Papua New Guinea. Both arcs provide striking examples of the geodynamic complexity to be expected in regions characterised by small plates whose instantaneous poles of rotation are nearby (cf. Krause, 1973).

A western arc is associated with the boundary between the South Bismarck and Indo-Australian plates. The rocks are mainly tholeiitic basalts and andesites, but rare dacites are also present; rhyolites appear to be absent. The chemical compositions of the rocks change along the arc - i.e., in a direction parallel to the strike of a postulated subducted lithospheric slab. These changes can be explained by identifying Late Cainozoic poles of rotation in the northwestern part of mainland Papua New Guinea, and by postulating eastwardly increasing rates of plate convergence.

An eastern volcanic arc is associated with the boundary between the South Bismarck and Solomon Sea plates. The rocks are mainly andesites, but also include tholeiitic basalts and dacites; rhyolites are present, but rare. The volcanoes are arranged in an unusual zig-zag pattern, and the compositions of the volcanic rocks change with increasing depths to the northward dipping New Britain Benioff zone - i.e., in a direction at right angles to the strike of the Benioff zone, and to the axis of the New Britain

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submarine trench. The existence of a thrust slice in the northwestern corner of the Solomon Sea is postulated to account for the distribution pattern of the eastern-arc volcanoes.

Reference

KRAUSE, D.C., 1973 - Crustal plates of the Bismarck and Solomon Seas. In: Oceanography of the South Pacific 1972. Ed. R. Frazer, N.Z. Nat. Comm. UNESCO, Wellington, 1973, 271-280.

Other tectonic features are the ridge between New Ireland and Manus Island which appears to be of similar age to these islands and to have formed at least in part by compression. The area of deep sediments and thick continental crust east of Madang which must have affinities with the Adelbert and Finisterre Ranges and the broad rise parallel to the New Guinea Coast which appears to have been formed by diapiric action.

## CRUSTAL VARIATIONS ACROSS THE AUSTRALIAN/PACIFIC PLATE BOUNDARY IN THE PNG REGION BASED ON SEISMIC INVESTIGATIONS

by

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Explosion seismic investigations provide the definition required to enable the variations in gross crustal structure over quite small areas to be outlined. Typifying the crustal structure in any particular area may however be misleading. A number of seismic surveys have now been conducted which outline the variations in crustal structure between the Barkley Tablelands of northern Australia and the Ontong Java Plateau of the western Pacific. These surveys involved a number of different shooting/recording configurations; land shooting and recording, marine shooting/land recording and marine shooting and recording.

The upper mantle is usually taken to begin where the P wave velocity approaches 8 km/s but over the region this is shown to vary between 7.7 and 8.6 km/s and occur at depths ranging from less than 5 km to 43 km. Some crustal thicknesses in "continental" Australia (27 km) appear to be much thinner than those on the Ontong Java Plateau (43 km) with considerable variation throughout the region in between. The parameters controlling the stability or otherwise of a region would therefore appear not to be those of the crust but those of the deeper mantle.

## MAGNETIC AND GRAVITY MODELLING IN THE BISMARCK SEA

by

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A marine geophysical survey of the Bismarck Sea was made by the BMR in 1970 and magnetic gravity and seismic reflection records were made along north south traverses at a spacing of between 40 and 50 kms.

The geology of the land areas surrounding the Bismarck Sea indicates that they all originated as island arc type structures and that activity along these arcs ranges in age from Upper Cretaceous to Recent. Most of the arcs have been reactivated several times. Water depth in the sea is about 2000m but with two fairly extensive rises over which the water shallows to 1000m. Sediment distribution shows a general thickening towards land with a sediment free region in the centre and depths of up to 2 kms of sediment at the edges.

The sediment free area is an elongate east west zone of recent extrusion some 80 kms wide and the topography of this region is uniform in the east but more rugged and with some areas of sediment in the west. The Bismarck Sea Seismic Lineament a zone of shallow earthquakes coincides with the area of recent extrusion. Earthquake focal mechanism solutions along the lineament indicate that it is a major left lateral strike slip fault.

Magnetic trends in the Sea generally strike east west but are not pronounced except the eastern area of recent extrusions and along the coast of mainland New Guinea. Bouguer gravity values are very uniform except for lows over the two rises.

Two dimensional magnetic and gravity modelling was undertaken along five north south traverses comprising a total of 1800 kms. The models were used in combination with topographic and sedimentary features to delineate the main tectonic provinces.

The sea, while having a rather thicker crust than most other seas behind trenches, nonetheless appears to have originated by extension in a similar manner to them. The extension has occurred in a north south direction and is episodic rather than continuous. It is occurring at present across the centre of the sea but is most regular in the eastern half where an extension rate of 8 cms/year is indicated. The extension in the east is being accommodated along an extensive series of NW trending faults which extend from the Gazelle Peninsula to west of New Hanover.

# SEISMICITY AND EARTHQUAKE FOCAL MECHANISMS IN THE NEW GUINEA SOLOMON ISLANDS REGION

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There is general agreement between plate tectonic theory and seismicity for the New Guinea Solomon Islands region. Two minor plates, the Solomon Sea and South Bismarck plates, are sandwiched within the collision zone between the continental fronts of the Pacific and ~~Indo-~~Australian plates, and derive their relative motions from the collision. The azimuth of collision is approximately east-northeast.

Earthquake focal mechanism solutions support the theory that subduction of the Solomon Sea plate is occurring against the Pacific plate, although the dip of the seismic zone between Bougainville and the trench in the Solomon Sea is vertical. A cluster of deep focus earthquakes 100 km north of Bougainville, to the northeast of the seismic zone, may be evidence of a near dormant, earlier subduction of the Pacific plate. Subduction of the Solomon Sea plate is occurring beneath the New Britain margin of the South Bismarck plate. Although the sinistral shear between the Solomon Sea and ~~Indo-~~Australian plates in Southeast Papua required by Johnson nd Molnar's (1972) plate tectonic analysis is supported by two earthquake focal mechanism solutions, it is not supported by the low level of seismicity, unless the shear occurs largely by flow without the release of seismic energy. There appears to be a seismic zone dipping westward from the Huon Gulf, south of the Markham Valley, which suggests a compressional contact between the Solomon Sea and ~~Indo-~~Australian plates where the border curves onto a northwesterly trend.

Focal mechanism solutions have not clarified the tectonic processes currently occurring in northern New Guinea at the border of the South Bismarck and ~~Indo-~~Australian plates, because strike-slip, dip-slip over-thrust and dip-slip normal solutions have been obtained. The seismic zone dips steeply to the north from a depth of 100 km beneath the Huon Peninsula and Markham Valley, to a depth of 230 km beneath the volcanic arc, and appears to be a continuation of the New Britain inclined seismic zone. Solutions consistent with sinistral shear have been obtained for earthquakes of the Bismarck Sea seismic lineation, although the epicentres are scattered over too broad a band for a single transcurrent fault.

The Irian Jaya seismic zone is broad and diffuse. Most earthquakes occur above a depth of 70 km. The seismic zone does not indicate a simple subduction border between the ~~Indo-~~Australian and Pacific plates, but appears to indicate a buffer zone within the major triple junction of the Asian, Pacific and ~~Indo-~~Australian plates.

The paper was presented with the permission of the Director of the Bureau of Mineral Resources. The earthquake focal mechanism solutions shown on the seismicity maps are taken from Ripper (1975; in preparation)

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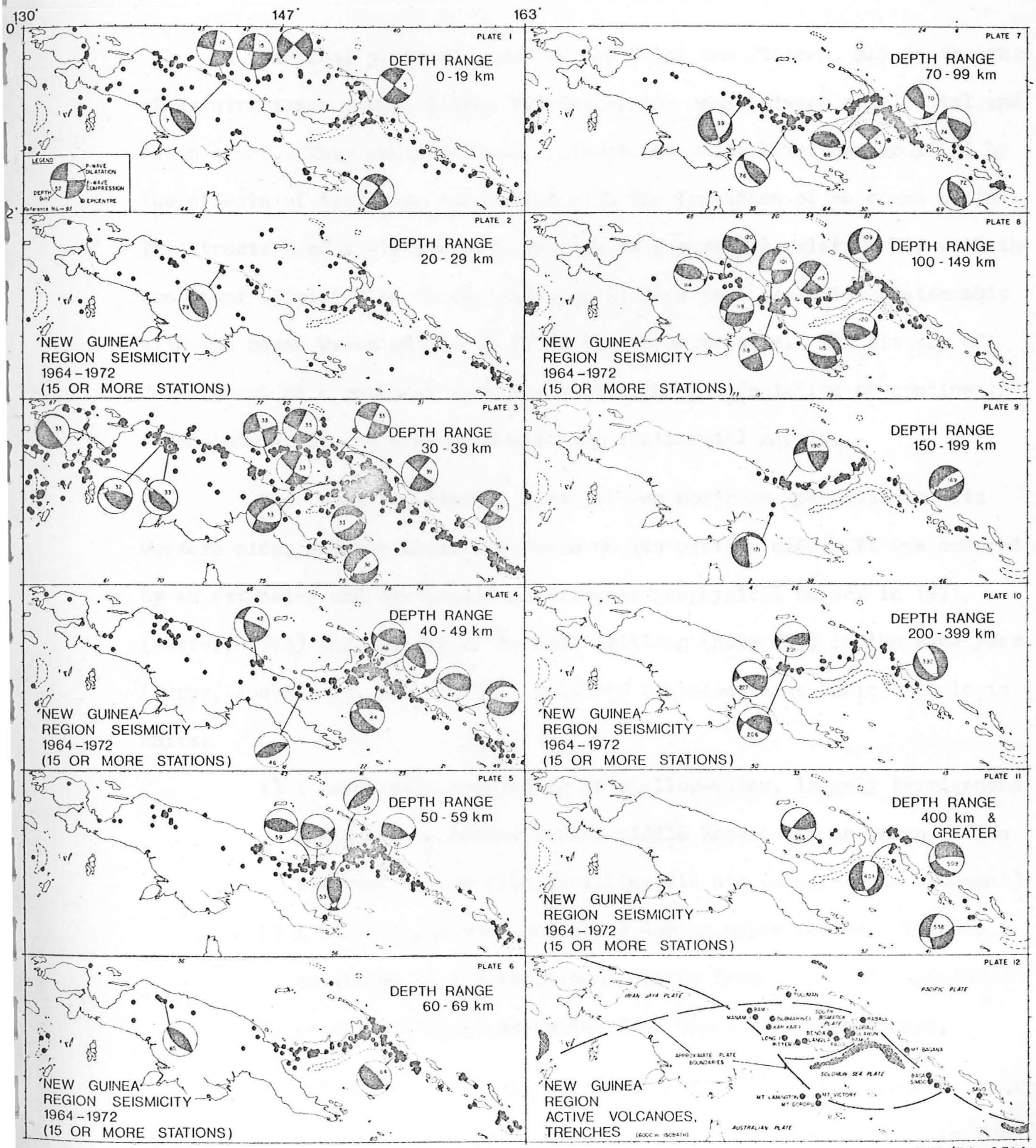
130°
147°
163°
0°
12°
PLATE 1
DEPTH RANGE 0-19 km
LEGEND
P-WAVE DILATATION
P-WAVE COMPRESSION
EPICENTRE
DEPTH
PLATE 2
DEPTH RANGE 20-29 km
NEW GUINEA REGION SEISMICITY 1964-1972 (15 OR MORE STATIONS)
PLATE 3
DEPTH RANGE 30-39 km
PLATE 4
DEPTH RANGE 40-49 km
NEW GUINEA REGION SEISMICITY 1964-1972 (15 OR MORE STATIONS)
PLATE 5
DEPTH RANGE 50-59 km
PLATE 6
DEPTH RANGE 60-69 km
NEW GUINEA REGION SEISMICITY 1964-1972 (15 OR MORE STATIONS)
PLATE 7
DEPTH RANGE 70-99 km
PLATE 8
DEPTH RANGE 100-149 km
NEW GUINEA REGION SEISMICITY 1964-1972 (15 OR MORE STATIONS)
PLATE 9
DEPTH RANGE 150-199 km
PLATE 10
DEPTH RANGE 200-399 km
NEW GUINEA REGION SEISMICITY 1964-1972 (15 OR MORE STATIONS)
PLATE 11
DEPTH RANGE 400 km & GREATER
NEW GUINEA REGION SEISMICITY 1964-1972 (15 OR MORE STATIONS)
PLATE 12
PACIFIC PLATE
SOLOMON SEA PLATE
AUSTRALIAN PLATE
APPROXIMATE PLATE BOUNDARIES
NEW GUINEA REGION ACTIVE VOLCANOES, TRENCHES

PNG/B9-251A

The relation between basin evolution and marginal plateau subsidence in the Coral Sea

by

John C. Mutter

Marginal plateaus, such as the Coral Sea Plateau, may be thought of as structures caught within the transition zone between continental and ocean crust. They are continental structures which have been modified by the effects of tectonism associated with the formation of an ocean basin. The structure of a plateau owes as much to a parental relationship with the continent adjoining it on one side, as it does to a tectonic relationship with the ocean basin adjoining it on the opposite side. The history of development of a marginal plateau is thus the manifestation of continent/ocean interaction at a newly developing continental margin.

The Coral Sea Plateau lies between northern Queensland on its western side, and the Coral Sea Basin on its eastern side. It was covered by an extensive and systematic multisensor geophysical survey in 1971 (Mutter, 1974) and was tested by DSDP drilling (hole 209) in the same year (Burns, Andrews et. al., 1973). Drilling revealed three basic lithologic units:

1) A basal unit consisting of shallow-water, largely terrigenous sediments deposited during middle Eocene and an unknown time interval before this (drilling did not penetrate to basement).
2) A hemipelagic rock deposited during upper Eocene. This is separated by a depositional hiatus from
3) pelagic sediment deposited from upper Oligocene onward.

This lithologic zonation has been matched with the acoustic zonation found on seismic reflection profiles. The Eocene/Oligocene hiatus in DSDP 209 corresponds well with a marked unconformity on the reflection profiles. The unconformity is often angular and is widespread on the Plateau. The lowest acoustic unit is a well stratified, structurally disturbed sequence which pinches out against basement highs, whose tops have been levelled by erosion. The lower unit represents the products of erosion of the basement highs and correlates with the basal rock unit in DSDP 209.

The geological history of the Coral Sea Plateau can be deduced from the distribution through time of the different litho-acoustic units. The history consists of three major episodes:

1) uplift of the basement, erosion of basement highs, and deposition of the erosion products in shallow water. Uplift probably occurred in Upper Cretaceous and erosion continued through to and including middle Eocene.

2) differential, orogenic subsidence in which the outer edge of the Plateau subsided with respect to the inner. The shallow-water sequence was faulted, and, as terrigenous source areas diminished, a hemipelagic sequence developed. This occurred during upper Eocene and Oligocene.

3) uniform, epeirogenic subsidence; source areas were lost and wholly pelagic sediment blanketed the Plateau. This occurred from Miocene onwards. The graben-troughs which form the western and southern margins of the Plateau probably formed between episodes 2 and 3.

With the stages in the evolution of the Coral Sea Plateau defined it is now possible to relate these to the evolution of the Coral Sea Basin. DSDP 210 drilled in the Basin gave the age of formation of oceanic crust as early Eocene. Thus a temporal relation between basin and plateau evolution can be defined and is shown schematically in Figure 1(a). The time scale is drawn zero at continental breakup. The inter-relation of tectonic events consists of plateau uplift and stabilization, followed by breakup and ocean basin genesis, followed by the two stages of plateau subsidence defined above. In Figure 1(b) this scheme is compared with the evolution of an Atlantic type continental margin as envisaged by Falvey (1974). The same time scale is employed so that a direct comparison can be made.

Major differences exist between the two models. The Atlantic model is characterized by a protracted rift valley stage which develops from about 40 m.y. before breakup, and the sequence of tectonic events progresses from uplift (arching), to subsidence (collapse), and then breakup. In the Coral Sea model the rift valley stage is absent and the sequence from subsidence to breakup is reversed compared with the Atlantic model. Although Falvey's model was not intended to define precisely the evolution of all Atlantic type margins, the significant differences observed may imply that the Coral Sea Basin is not of the Atlantic type.

Kargi (1971) classified the Coral Sea Basin as a Western Pacific 'marginal' basin. Such basins evolve by accretion of oceanic crust behind an island-arc trench system. If his model applied to the Coral Sea Basin, a south-dipping subduction zone should have been present in the position now occupied by eastern Papua and the Louisiade Archipelago at the time of basin formation in upper Paleocene and early Eocene. There is no geological evidence for such a subduction zone, and hence Karig's model can be discounted. The Coral Sea Basin must therefore be of a modified Atlantic type.

The absence of a rift valley stage may be explained by invoking rapid basin evolution; so rapid that the characteristic rift valley sediments did not have time to develop. Beforehand, a protracted uplift stage occurred. To explain this it is necessary to postulate a warm thermal anomaly, or more likely a hotter anomaly located some distance from the Coral Sea Basin. This thermal anomaly must have been capable of causing uplift of the crust without inducing metamorphism at its base. If the influence of this anomaly was later replaced by an intense but short-lived anomaly located in the Coral Sea Basin and associated with its opening, then the observed evolutionary scheme presents no difficulties. Subsidence of the Plateau will follow basin evolution as the intense anomaly would promote thermal metamorphism and crustal subsidence. Lithospheric cooling and contraction in the basin after spreading ceases would heighten this effect.

Thus the continental margin of northern Queensland appears to have formed by a modified type of Atlantic margin development, the key to which is rapid evolution following some time after the action of a remote thermal anomaly located outside the Coral Sea Basin.

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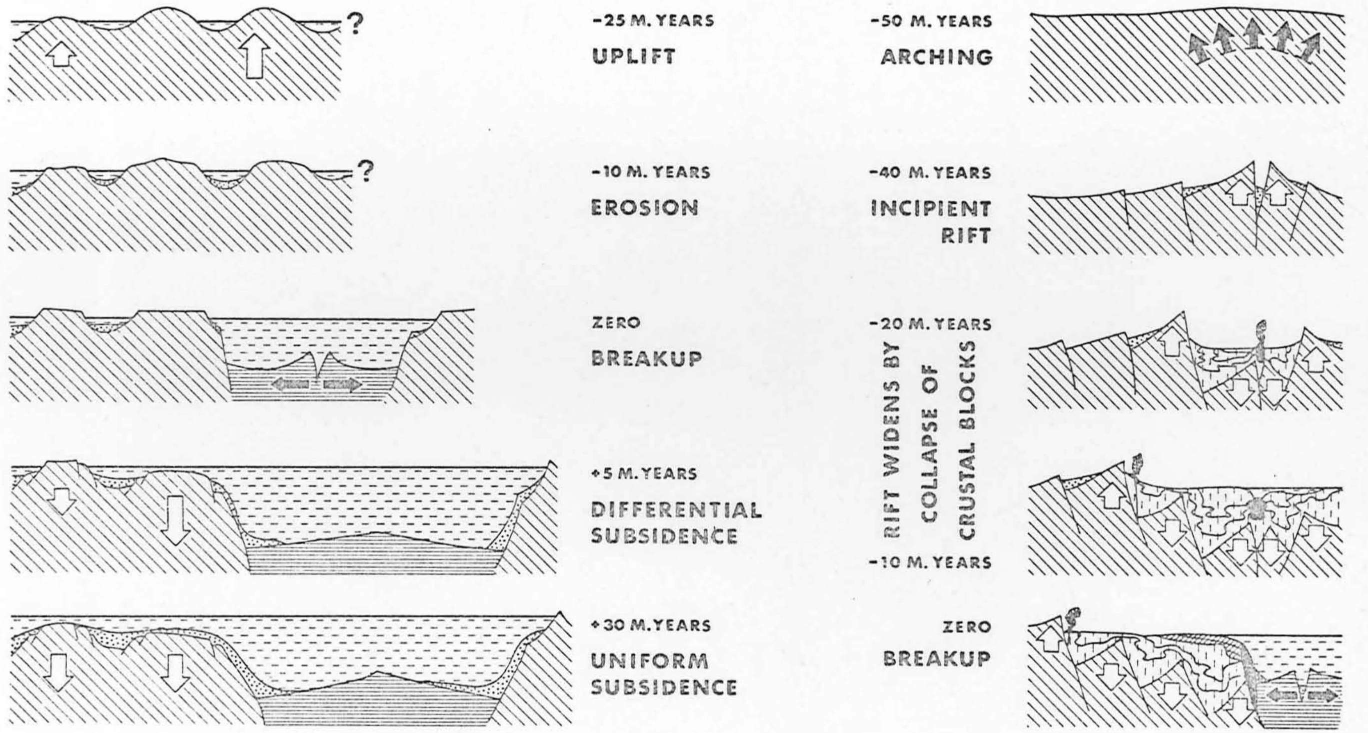


(a) CORAL SEA BASIN AND PLATEAU EVOLUTIONARY MODEL

(b) ATLANTIC TYPE CONTINENTAL MARGIN. AFTER : FALVEY, 1974

Fig. 1