DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1973/75

THE GEOLOGICAL EVOLUTION OF PAPUA NEW GUINEA

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Until recently, the rugged interior of much of Papua New Guinea was so inaccessible that the geology of large areas remained unknown, and prevented all but the most superficial reconstructions of the geological history of the country. The situation has been transformed in the last few years by teams of geologists using modern means of transport to penetrate into the mountainous hinterland and fill in the blanks on the geological map.

These expeditions needed massive logistic support which only organizations such as the Commonwealth Bureau of Mineral Resources and the larger oil exploration companies could supply. One such expedition was the 1966 exploration of the mountains south of the Sepik River, for which I was the leader. This exceptionally rugged, jungle-covered, and virtually uninhabited area is approachable only by way of the Sepik swamps, which present a most formidable barrier even today. Shallow-draft boats driven by water jets were used for the first time in Papua New Guinea to carry men and equipment into the foothills (Figure 1), and helicopters to ferry light, mobile geological parties into the mountains (Figure 2). Once in the mountains, the usual difficulties of dense jungle, mountain torrents, waterfalls and gorges (Figure 3) were compounded by the almost complete lack of population, which meant that the parties did not have the benefit of even the most rudimentary jungle tracks. Small isolated pockets of nomadic peoples were contacted for the first time, but in the absence of any means of communication other than sign language, we were unable to enlist their help.

When one considers that these difficulties are found to greater or lesser degree in most parts of Papua New Guinea, it is little wonder that so much of the country remained unknown for so long; but geological knowledge has now reached the stage where at least the broad outline of the geological evolution of the country can be confidently reconstructed.

Unfortunately the farther one goes back in time, the less complete the geological record, because in an area so strongly affected by earth movements, the older rocks become transformed by heat and pressure, and the evidence of earlier events locked in the rocks becomes obliterated. This has happened to most of the Palaeozoic and older rocks (see Geological Time Scale, Figure 4), but knowledge of events since the beginning of the Mesozoic Era is fairly complete. During most of this time, Papua New Guinea has been the buffer zone between the northward-drifting Australian continent (Australian Platform in Figure 5) and fragments of oceanic crust, each many thousands of square kilometres in area, that acted as rigid plates to the north and east. The net result has been an intensely folded and faulted geologically complex zone, called the New Guinea Mobile Belt, which forms the spine of mainland Papua New Guinea. Thus the geology, from south to north, falls into three broad divisions: the Australian Platform, the New Guinea Mobile Belt, and the Melanesian Oceanic Province (Figure 5).

Australian Platform

During most of the Mesozoic and Tertiary, the Australian Platform was submerged beneath the sea, and received a thick cover of sedimentary rocks: because the underlying continental crust was strong and stable, the whole area was protected from the forces which were acting to such effect farther north. Changes in sedimentation were therefore gradual, affecting the whole of the Platform, and as a consequence the sediments are uniform over a wide area. As far as is known, sedimentation began in the early Mesozoic, and from then until the Tertiary, shale, siltstone, and sandstone, supplied by weathering and erosion of the Australian continent, were deposited over the whole of the Platform (Figure 5). Many of the sandstone beds are good reservoir rocks for the accumulation of petroleum, but so far exploratory drilling has located only sporadic gas flows.

During the earliest Tertiary, most of the Australian Platform was above sea level, and when the sea once more encroached in Oligocene time the supply of detritus from the Australian continent had virtually ceased, and the only sediment deposited over the whole of this large area was limestone. Great thicknesses accumulated in places, the maximum known being over 3000 metres penetrated in a petroleum exploration well.

Near the margin of the platform the limestone formed a barrier reef which can be traced southwards to the Great Barrier Reef of North Queensland. The Australian part of the reef has continued to grow to the present day, but the northern part was uplifted along with the spine of mainland Papua New Guinea several million years ago (in the Pliocene), and has subsequently been eroded to form the spectacular limestone cliffs of western Papua (Figure 6).

New Guinea Mobile Belt

An entirely different story is told by the rocks flanking the Australian Platform, which now form the mountainous backbone of the mainland. Here the rocks, almost without exception, have been crushed and highly deformed by the huge forces generated by the collision between the Australian continental block and the oceanic plates.

Knowledge of the rocks of the Mobile Belt is fairly complete because they have been uplifted and eroded, and so exposed to the geologists' hammer. Over most of the Australian Platform, on the other hand, the older rocks are covered by young sediments, and almost the only way of obtaining knowledge is from the few deep exploration wells put down by oil companies.

The oldest rocks in this Mobile Belt are thick sedimentary rocks deposited during late Mesozoic time in a deep ocean trough called the New Guinea Geosyncline which wrapped around the Australian Platform (Figure 7). Widespread volcanism occurred spasmodically in the geosyncline, probably as chains of island volcanoes, whose products are preserved as thick sequences of lava and other volcanic rocks interbedded with the sedimentary rocks. In view of the close proximity of these volcanoes to the Australian Platform it is perhaps surprising that volcanic detritus is absent from the Platform sediments. However, the deep trough probably acted as a sediment trap and prevented the volcanic detritus from being carried south to the Platform.

Early Tertiary (Oligocene) time was one of major earth movement during which the rocks of the New Guinea Geosyncline were crushed and deformed, and the whole of what is now mainland Papua New Guinea was raised above the sea. The effects of the earth movements were most severe along the outer (northern) margin of the geosyncline, where the sediments were recrystallized to form metamorphic rocks which are now exposed in a zone extending from the West Irian border to southeast Papua.

Geosynclinal sedimentation resumed in the Miocene (Figure 8), following closely the earlier pattern. There were two important differences, however: the outer margin of the geosyncline was occupied by a chain of mountainous islands composed of the metamorphic rocks formed during the earlier earth movements; and the supply of detritus from the Australian Continent had almost ceased, so allowing shallow-water limestone to accumulate on the Platform.

The simplified stratigraphic columns shown in Figure 9 are greatly generalized, but they illustrate the enormous contrast between the sediments laid down at the same time on the Platform and along the Mobile Belt. Thus from the early Jurassic until the upper Miocene, about 16,000 metres of sediments interspersed with marine volcanic rocks was laid down in parts of the Mobile Belt while no more than about 5,000 metres of monotonously uniform sediments was depsoited on the Australian Platform.

Several periods of igneous intrusion (large-scale injection of molten rock deep in the earth's crust) during the Mesozoic and Tertiary are recorded in the Mobile Belt; the most important of these took place about 15 million years ago. None, however, is known from the Australian Platform. The rocks are largely granitic, and they are of economic importance because almost without exception they were accompanied by sporadic gold mineralization and, in some places, by important copper mineralization. The copper deposit being tested at Frieda River in the South Sepik region was formed during this phase of intrusion.

One of the most spectacular features of the New Guinea Mobile Belt is the presence of ultramafic rocks derived from the earth's mantle; submarine lavas which overlie them are considered to be part of the deep ocean floor formed in Cretaceous and Eocene times. These rocks were thrust up from a depth of thousands of metres against the Australian Continental block, and it may have been this event which generated the huge compressive forces and great heat which metamorphosed the Mesozoic sediments of the New Guinea Geosyncline.

Melanesian Oceanic Province

The northern coastalarea of Papua New Guinea and the outlying islands belong to the Melanesian Oceanic Province, in which the land areas are made up almost entirely of the products of marine volcanism (Figure 10) and reef limestones. There is no evidence to suggest that the conditions differed significantly from those of the present day, in which chains of active volcanoes are located along fundamental breaks in the Earth's crust.

The volcanism was not continuous, and several breaks are recorded in the geological column, the main one being in the Miocene, when a thick blanket of limestone accumulated over most of the area (Figure 8).

By late Tertiary time the stage had been set for the earth movements which determined the present morphology of mainland Papua New Guinea. For reasons not yet understood, the rocks of the Mobile Belt were uplifted many thousands of metres to form the mountainous backbone of Papua New Guinea. Most of the movement took place along faults, most of which stand out as prominent scarps flanking the highlands.

Radar imagery (Figure 6) shows part of the Tertiary limestone on the edge of the Australian Platform, which was raised with the underlying basement rocks and formed an unstable cover over the actively rising mountains. Under the pull of gravity huge rafts of limestone slid off the flanks of the mountains, riding one over the other and crumpling, much like the snow crust in a slab avalanche - only in this case the sliding was inestimably slow, and may have taken hundreds of thousands of years before the movement ceased. The resulting contorted bed of limestone, repeated many times over, is well illustrated in the figure.

Volcanic activity has continued intermittently to the present day, but reached a climax in the Pliocene, when large volcanoes burst into eruption over much of mainland Papua New Guinea. Intrusive rocks which accompanied the Pliocene volcanism introduced gold and copper mineralization throughout the Mobile Belt and the Oceanic Province. The mine on Bougainville Island, one of the major copper mines in the world, occurs in an intrusive rock only about three million years old.

The earth movements which established the main landforms continue little abated to the present day, keeping pace with the rapid erosion caused by high rainfall and tropical weathering, and so maintaining the rugged mountainous character of Papua New Guinea.

Figure 1: Jet-boat negotiating a difficult rapid in the Yuat River, South Sepik region. These boats, which can travel in as little as four inches of water penetrated the southern tributaries of the Sepik River well beyond the limits of conventional craft into the southern mountains.

Figure 2: Helicopter pad constructed by a Bureau of Mineral Resources traverse party (one geologist and five carriers) at the end of a week-long traverse in the headwaters of the Salumei River, South Sepik region. It was not always possible to find clearings at the end of a traverse, and often a full day's work was required to clear a pad in virgin forest.

The hut belongs to the Bikalu people, who had not previously been visited by white men.

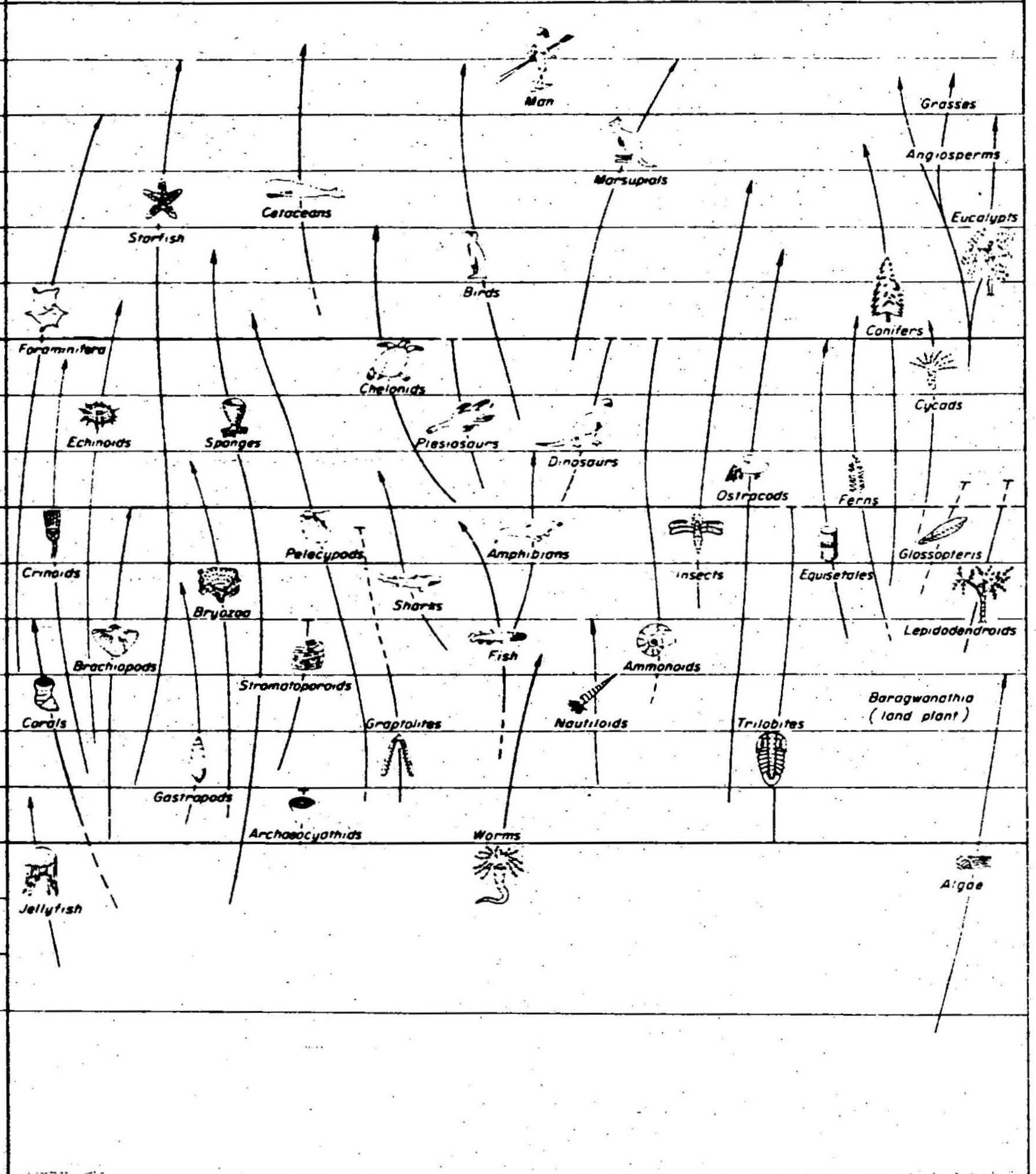
Figure 3: Typical traverse conditions in mountainous parts of Papua New Guinea. Rock outcrops are generally found only in rivers where the going is arduous and often dangerous.

GEOLOGICAL TIME-SCALE

Fig. 4

	Era	Period	Epoch	Age in years
PHANEROZOIC	CAINOZOIC	Quaternary	Recent	0 - 15,000
			Pleistocene	15,000 - 3,000,000
		Tertiary	Pliocene	3 - 7,000,000
			Miocene	7 - 22,500,000
			Oligocene	22·5 - 36,000,000
			Eocene & Paleocene	36 - 65,000,000
	MESOZOIC	Cretaceous		65 - 136,000,000
		Jurassic		136 - 195,000,000
		Triassic		195 - 225,000,000
	PALAEOZOIC	Permian		225 - 280,000,000
		Carboniferous		280 - 345,000,000
		Devonian		345 - 395,000,000
		Silurian		395 - 435,000,000
		Ordovician		435 - 500,000,000
		Cambrian		500 - 570,000,000
PRECAMBRIAN	PROTEROZOIC	Adelaidean		570 - 1,400,000,000
		Carpentarian		1,400 - 1,800,000,000
		Lower Proterozoic		1,800 - 2,300,000,000
	ARCHAEAN			2,300,000,000 +

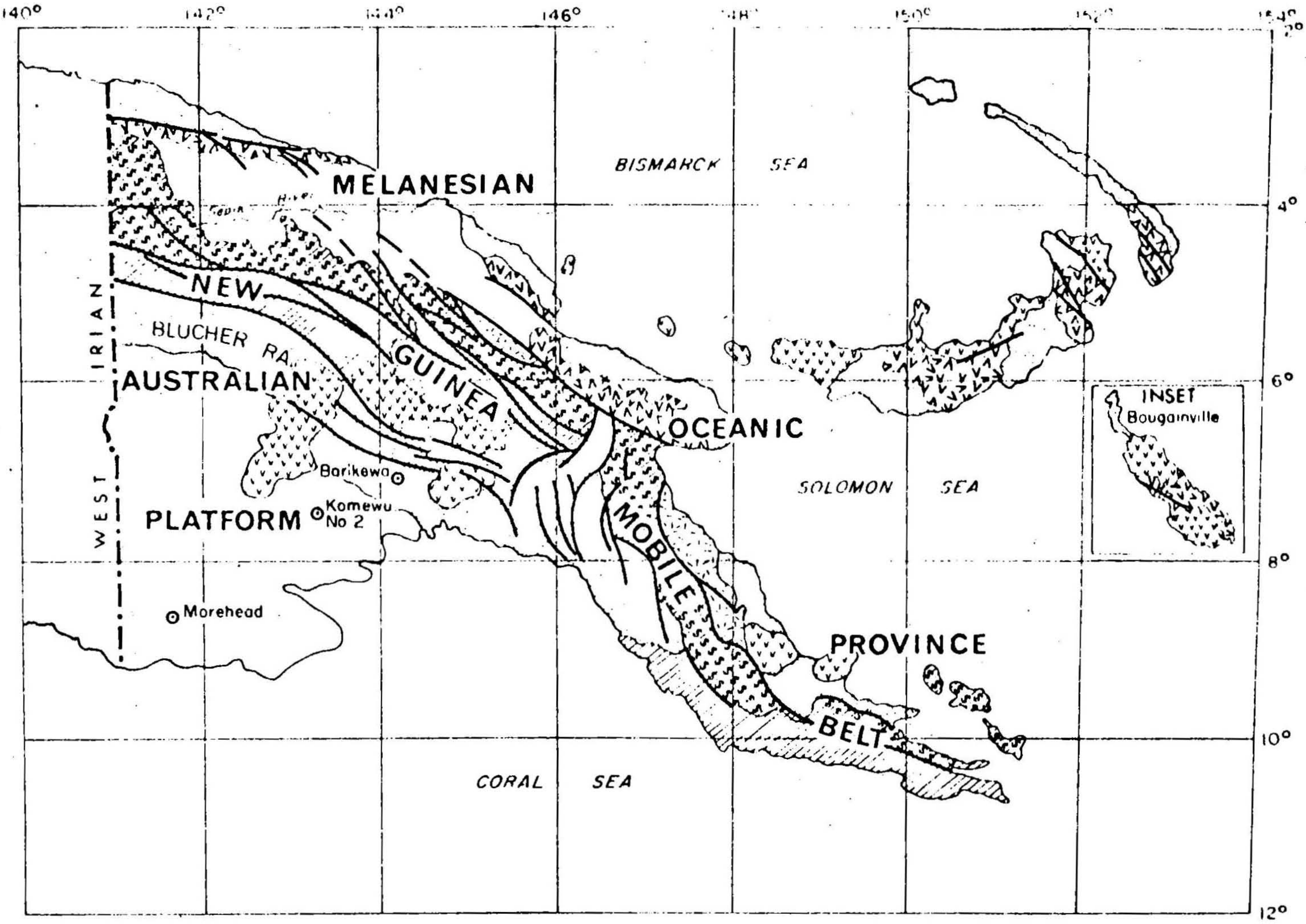
Record of Life



Bureau of Mineral Resources, Geology and Geophysics. March, 1972

Forms ranging up to the present — *Forms extinct*

F.J.R. M(S)20



UPPER TERTIARY TO RECENT
- *Alluvium*
- *Pleistocene to recent volcanoes, some still active*
- *Sedimentary cover includes thick limestone of western Papua*

MESOZOIC AND LOWER TERTIARY
- *Marine volcanics and derived sediments*
- *Sediments and volcanics deposited in troughs 'S' symbol denotes where metamorphosed to schist*
- *Ultramafic rocks derived from the earth's mantle; overlying marine volcanics*

Major fault — *Petroleum exploration wells*

0 100 200 300 400 km
0 100 200 300 M

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FIG 5 GEOLOGICAL MAP OF PAPUA NEW GUINEA

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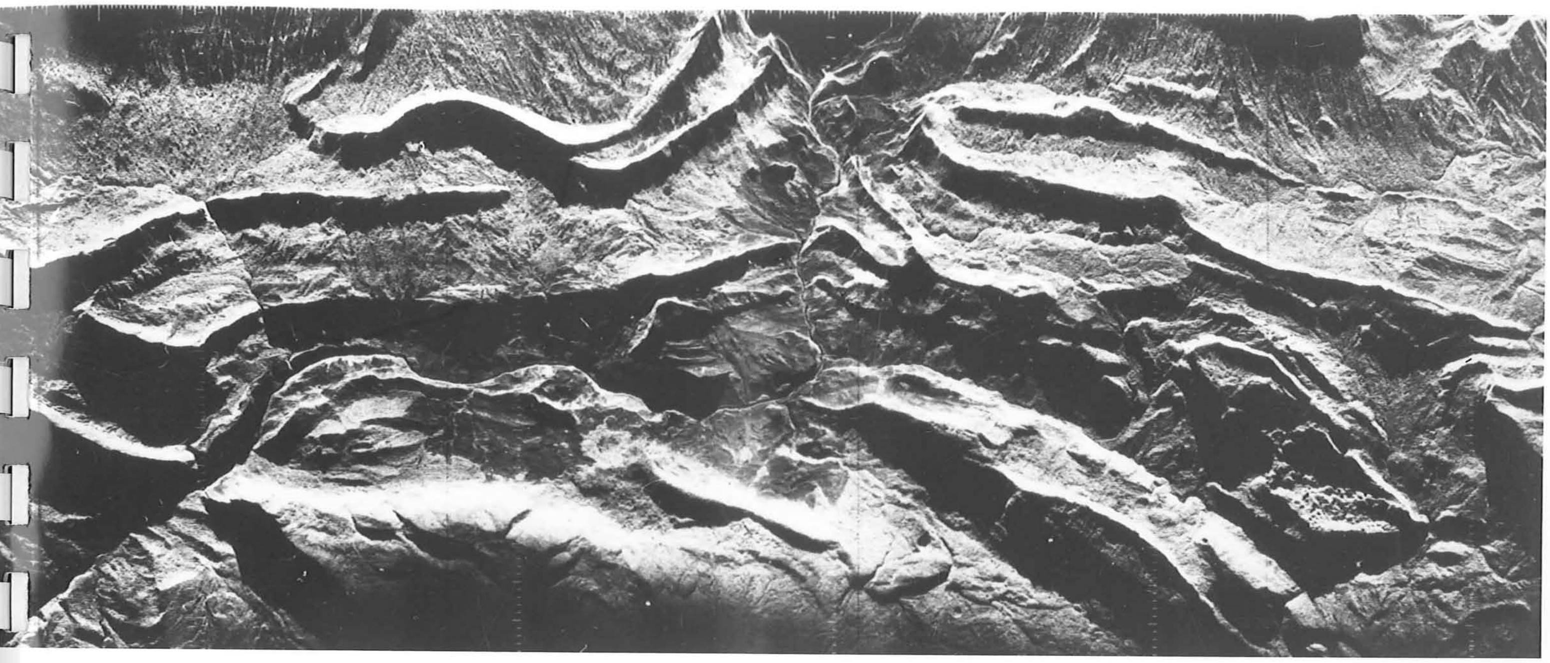

<u>Figure 6</u>: Radar image of the middle reaches of the Strickland River, western Papua. The sharp, sinuous ridges are the upturned edges of slabs of contorted Darai Limestone which are thought to have slumped down the flanks of the actively rising New Guinea mainland in Pliocene times.

Radar images can be obtained even through heavy cloud cover, and are the only source of topographic data for many areas of western Papua New Guinea.

Imagery by Westinghouse Raytheon for Department of Army.

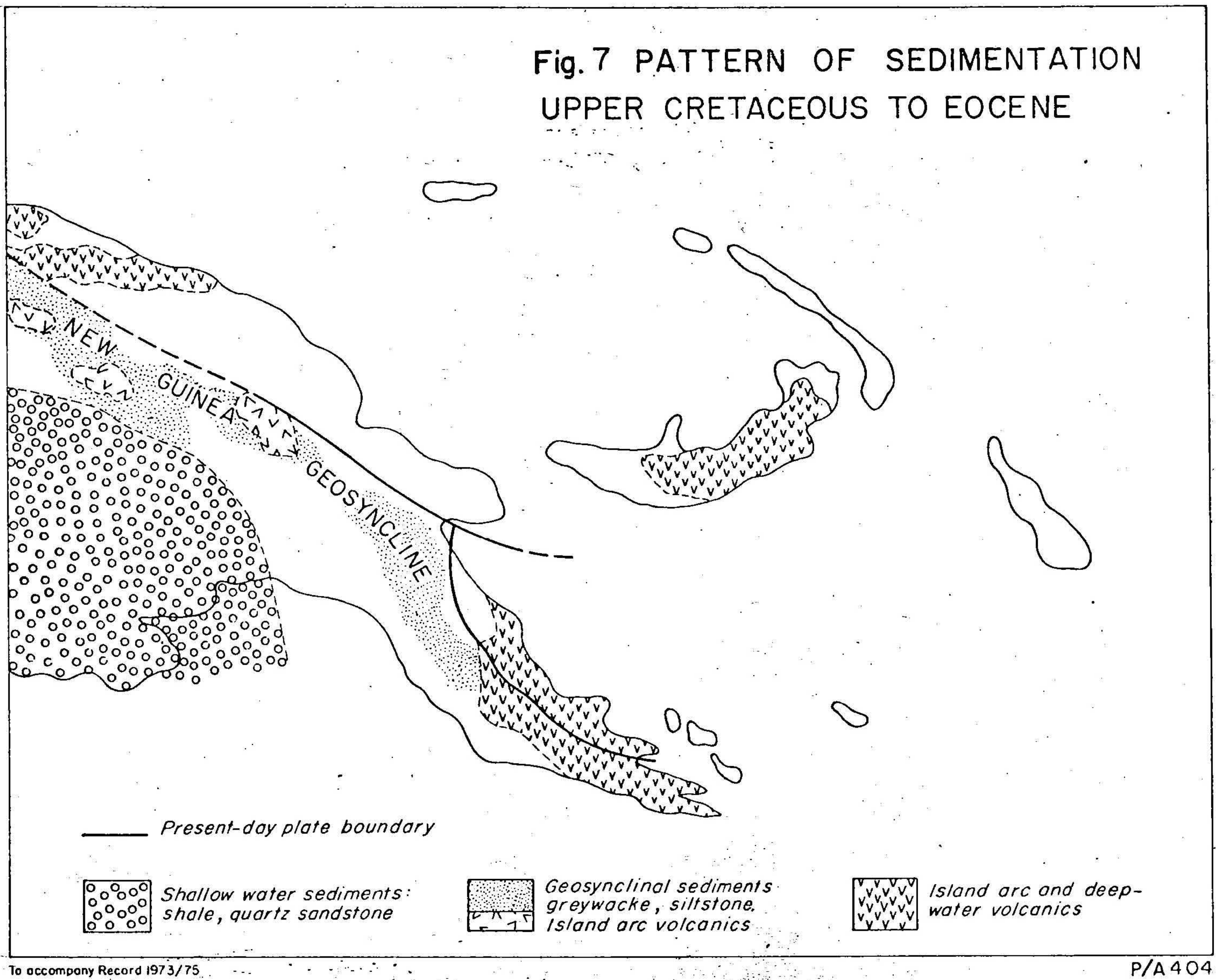
Fig. 7 PATTERN OF SEDIMENTATION
UPPER CRETACEOUS TO EOCENE
NEW GUINEA GEOSYNCLINE
Present-day plate boundary
Shallow water sediments: shale, quartz sandstone
Geosynclinal sediments greywacke, siltstone. Island arc volcanics
Island arc and deep-water volcanics
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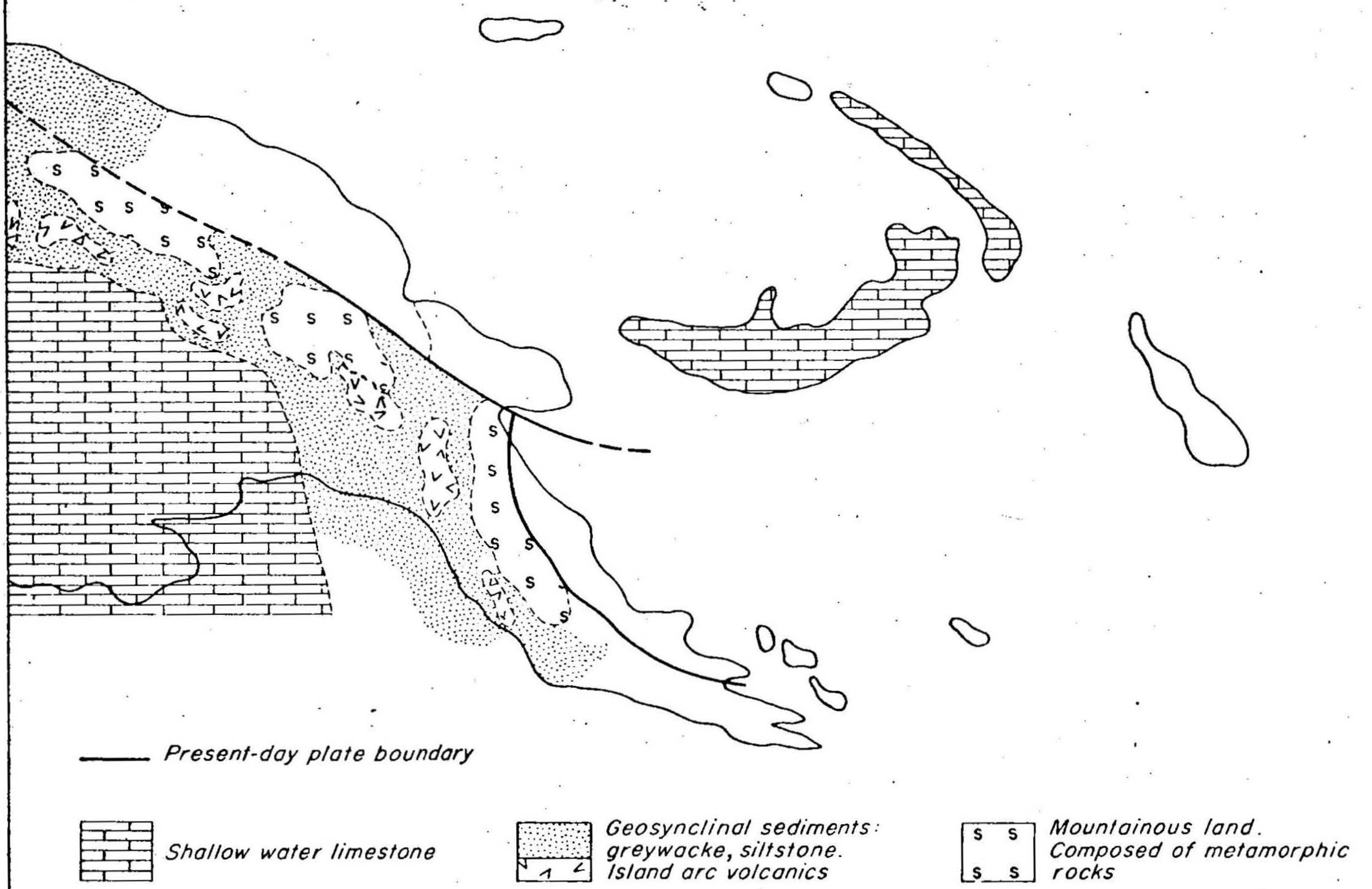
Fig.8 PATTERN OF SEDIMENTATION
MIDDLE MIOCENE



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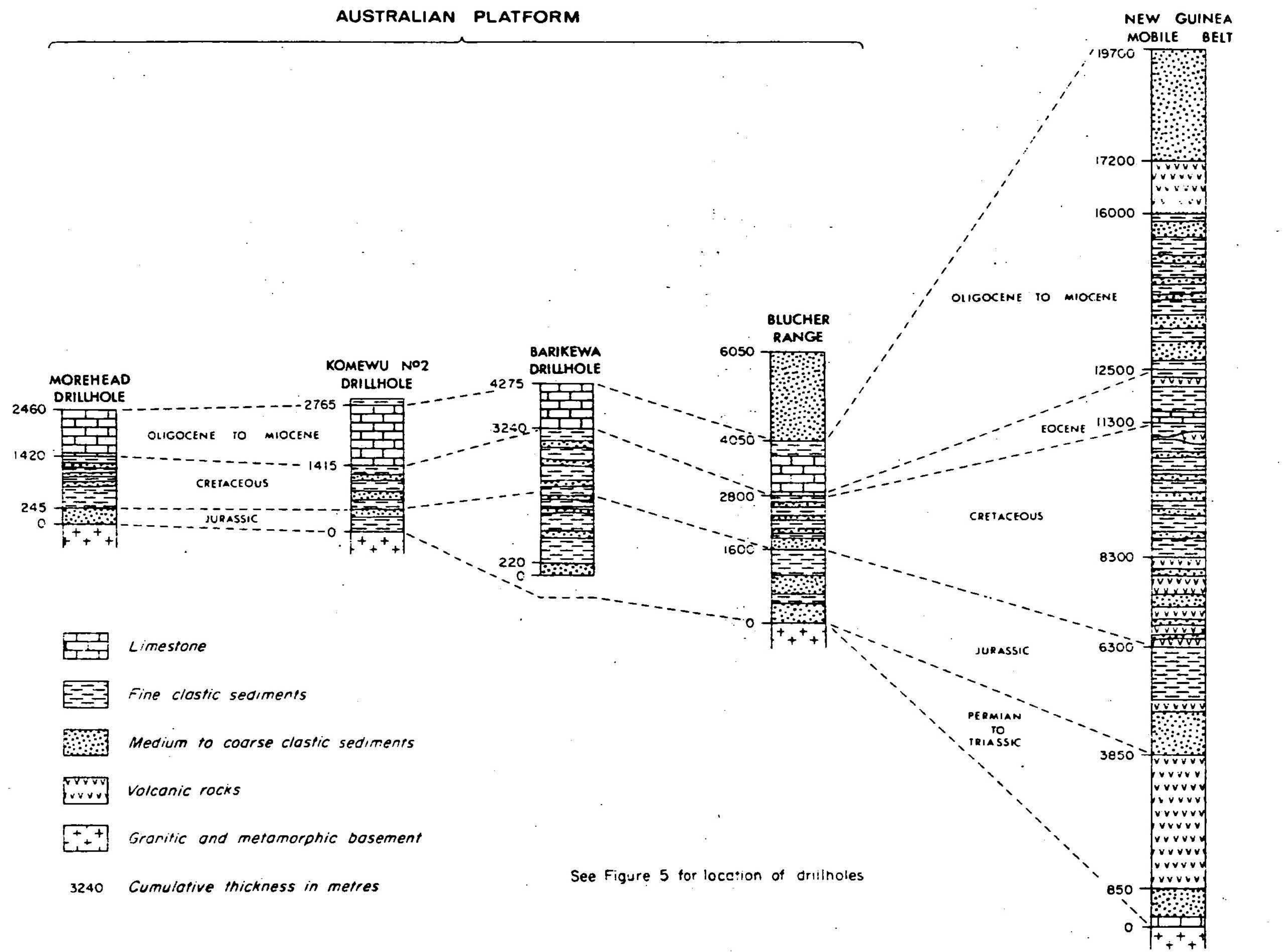

FIG. 9 GENERALISED STRATIGRAPHIC COLUMNS, PAPUA NEW GUINEA

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Figure 10: Rock outcrops such as this provide the clues to past geological events. Here, in a stream draining the Torricelli Mountains north of the Sepik River, pillow lavas of lower Tertiary age are exposed.

The rounded masses in the photograph were molten globes (pillows) of lava extruded on the sea floor. The white material in the interstices was a calcareous ooze on the sea floor caught up between the pillows. By fortunate chance the ooze contains microscopic fossil shells (Foraminifera) which date the lavas as lower Tertiary age.