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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD NO. 1972/81

GEOLOGY, VOLCANOES AND EARTHQUAKES OF PAPUA NEW GUINEA

by

D.B. Dow*, G.A.M. Taylor*, D. Denham*

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THE GEOLOGY OF PAPUA NEW GUINEA

STRATIGRAPHY AND STRUCTURE

by

D.B. Dow

The last ten years have seen remarkable advances in our knowledge of the geology of Papua New Guinea, mainly as a result of a systematic program of reconnaissance mapping undertaken by the Commonwealth Bureau of Mineral Resources in conjunction with the Geological Survey of Papua New Guinea. Other major contributors have been the oil exploration companies, which have mapped the major sedimentary basins covering about one-quarter of the land area. Thus the broad outline of the geology of the mainland and the outlying islands is known, the only important gap being the mountain ranges north of the Sepik plains, which it is planned to map in 1973.

Modern theories of crustal tectonics have been a major factor in explaining the geology of the Pacific margin, and Papua New Guinea is no exception. It is now well established that mainland New Guinea was formed as a result of interaction, over a long span of geological time, between the competent Australian continental platform in the south and fragments of oceanic crust that acted as rigid plates to the north and east (Fig. 1). The geology and limits of the continental block are well known, but because they are covered by the sea, the nature of the oceanic plates is much more conjectural.

The collision between the oceanic plates and the northward-moving Australian continent has resulted in the formation of an intensely folded and faulted zone of complex geology (called the New Guinea Mobile Belt (Dow et al 1972)) which forms the spine of mainland Papua New Guinea. Thus the geology falls into three broad divisions listed from south to north: the Australian Platform, the New Guinea Mobile Belt, and the Melanesian Oceanic Province.

STRATIGRAPHY

AUSTRALIAN PLATFORM

Southwest Papua is underlain by a stable Palaeozoic basement of granitic and metamorphic rocks which are exposed in only two places (in the Western Highlands), but which have been reached by several petroleum exploration wells in the southwest. The age of the granites has been determined by measurement of radio isotopes to be about 240 million years (Permian), similar to the younger granites of Cape York Peninsula.

During most of the Mesozoic and Tertiary the continental block was submerged beneath the sea and was covered by a thick sequence of sedimentary rocks: because the underlying continental block was strong and stable the whole area was protected from the forces which were operating to such effect farther north. Changes in sedimentation were therefore gradual across the whole of the Platform, and as a result a uniform sequence of sediments was laid down over a wide area. Sedimentation probably began in the early Jurassic and from then until the Tertiary, shale, siltstone, and interbedded quartz sandstone derived by weathering and erosion of the Australian continent were deposited over the whole of the Platform (Fig. 2). Many of the sandstones would be good reservoir rocks for accumulation of petroleum, but to date exploratory drilling has located only sporadic gas flows.

During the lower Tertiary most of the Australian Platform was a land area, 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 huge area was limestone and a little marl. Great thicknesses accumulated in places, the maximum recorded being at the Omati well where over 3 000 m were penetrated.

Near the margin of the platform the limestones formed a barrier reef that can now be traced southwards to the Great Barrier Reef in north Queensland, where the reef has grown continuously to the present day. The New Guinea part of the reef was uplifted along with the spine of mainland Papua New Guinea in the Pliocene, and has subsequently been eroded to form the imposing limestone cliffs of western Papua.

This uplift resulted in the formation of a spectacularly folded and overthrust belt of rocks along the southern flank of the main range. Huge plates of the limestone were thrust one upon the other, and at the same time they were complexly folded; it has been postulated that the effects are due mainly to gravity sliding of the semiconsolidated sediments immediately after uplift.

NEW GUINEA MOBILE BELT

The geology of the marginal zone of the Australian continental block is in complete contrast to that of the Platform because throughout the geological record it has borne the brunt of the collision with the oceanic plates. As expected of such a restless portion of the earth's crust, the sedimentary history was much more complex, and continuing earth movements caused periodic changes to the marine basins and troughs in which sediments accumulated, as well as to the mountain ranges and volcanoes which were supplying the sediments. The resulting great variety of sediments and interbedded volcanic rocks contrast strongly with those deposited on the stable Australian Platform.

The simplified stratigraphic columns shown in Figure 2 illustrate the contrast, both in thickness and rock type, between the sediments laid down in the two environments. Thus from the early Jurassic until the upper Miocene about 16 000 m of volcanically dervied sediments interbedded with thick sequences of marine volcanic rocks, were laid down in parts of the Mobile Belt, while a maximum of about 5 000 m of monotonously uniform shelf sediments were laid down on the Platform.

In addition, 4 000 m of Triassic volcanics and sediments are found at the base of the Mesozoic succession in the Mobile Belt. They have not been identified on the Platform, but are probably present under the younger sedimentary rocks, and may have been penetrated by Barikewa No. 1 well, which bottomed in dacite volcanics.

The middle Miocene sediments also exemplify the contrast between the two environments. At this time a chain of island volcanoes was active along the whole of the Mobile Belt and their products are preserved as isolated remnants of lava, agglomerate, volcanically dervied conglomerate, and lenses of reef limestone capping the mountains of the Highlands. Farther south, these rocks grade through sandy sediments, composed mainly of fine volcanic detritus, into the thick limestone laid down on the Australian Platform. It appears that the chain of island volcanoes was separated from the Australian Platform by a deep trough that trapped the volcanic detritus and prevented it from being deposited farther south.

Several periods of igneous intrusion are recorded in the Mobile Belt during the Mesozoic and Tertiary, the most important of which was associated with the middle Miocene volcanism about 15 million years ago. The intermediate to acid plutonic rocks (diorite, and granodiorite) are of economic importance because almost without exception they were accompanied by sporadic gold mineralization and in some cases by important copper mineralization. The copper deposit being tested at Frieda River was formed during this phase of intrusion.

Metamorphic rocks were produced by heat and pressure in zones of greatest stress within the New Guinea Mobile Belt; several ages of metamorphism are known, but one of the main ones was in the lower Tertiary (Oligocene), when much of the Owen Stanley Metamorphics, which make up the backbone of Papua, were formed.

One of the most spectacular features of the New Guinea Mobile Belt is the Papuan Ultramafic Belt, which consists of ultramafic rocks thought to have been originally part of the deep seated oceanic mantle. It is overlain by a great thickness of gabbro, dolerite, and submarine lavas which were probably part of an ancient sea floor formed in Cretaceous and Eocene times. These rocks were thrust up from a great depth against the Australian continental block. The huge compressive forces generated by the upthrusting of the Ultramafic Belt are thought to have metamorphosed Mesozoic sediments on the margin of the Australian Platform to form the Owen Stanley Metamorphics. Glaucophane schists, which are formed under high pressure, are widespread near the Ultramafic Belt, which lends support to this view.

Other rocks containing high-pressure minerals are found in association with ultramafic rocks, farther west along the northern front of the New Guinea Mobile Belt in the Lower Ramu and South Sepik regions; the presence of glaucophane schist and eclogite in the South Sepik region attests to extreme pressures suffered by the rocks. In all cases the age of emplacement was lower Tertiary.

The mountainous backbone of Papua New Guinea is cut near the middle by a northerly trending belt of broken country which is rarely over 2500 m high. The belt was formed by erosion of sediments laid down in the Aure Trough, a marine basin which cuts across the regional structure of Papua New Guinea. The trough was the site of almost continuous subsidence from the upper Oligocene to the end of the Pliocene, and it was filled with sediments derived from contemporaneous volcanism and the erosion of adjacent mountains. The sequence consists mainly greywacke, siltstone, conglomerate, reef limestone, and marine volcanics which in the deepest part of the trough exceed 10 000 m in thickness.

Sedimentation ceased over most of the New Guinea Mobile Belt in the upper Miocene with the start of the vertical uplift which blocked out the present physiography of mainland Papua New Guinea. Only around the margins of the mainland have upper Miocene and Pliocene marine sediments been laid down, and these are composed mainly of intermediate and acid volcanic detritus erupted from large sporadic stratovolcanoes during the uplift. Deep erosion of the older volcanoes has exposed the intrusive cores, some of which contain copper mineralization similar to that associated with the middle Miocene intrusives. The higher volcanoes were glaciated during the Ice Age, and at least two, Doma Peaks and Mount Yelia, show signs of recent solfataric activity which indicates that the cycle of volcanic activity in the New Guinea Mobile Belt is not yet finished.

MELANESIAN OCEANIC PROVINCE

The geological environment to the north of the New Guinea Mobile Belt is completely different. The land areas exposed are made up exclusively of the products of volcanoes, both subaerial and marine, and associated reef limestones: the only exception is the area north of the Sepik River where the cores of the mountain ranges consist of metamorphic rocks with possible affinities with continental crust.

The geology is best exemplified by the arc which includes the Huon Peninsula and the island of New Britain, where the oldest rocks are Eocene basic to intermediate volcanics and their sedimentary products. The rocks have been complexely faulted, folded and slightly metamorphosed in places; they are intruded by small upper Oligocene intermediate to acid plutons which gave rise to volcanically dervied sediments unconformably overlying the Eocene volcanics. Porphyry copper mineralization associated with some of the intrusions is now being tested in New Britain.

During the lower and middle Miocene, when there was an extended lull in volcanic activity, a thick blanket of limestone accumulated unconformably on the older rocks over most of the area, but acid to intermediate volcanic activity began once again the upper Miocene, and has continued to the present day.

The geological history of Manus, New Ireland, and Bougainville has followed a similar pattern, but on Bougainville the intrusive phases of Pliocene volcanism, one of which contains the large porphyry copper mine of Panguna, have been exposed by erosion.

The recent volcanicity and present seismicity of the Melanesian Oceanic Province is described later.

STRUCTURE

AUSTRALIAN PLATFORM

The stable basement of the Australian Platform has reacted competently to stress since the Palaeozoic, and during that time has suffered only minor adjustment by faulting and very gentle warping. The overlying sediments have reacted similarly, and over large areas are also generally flat-lying or very gently dipping. Only in the vicinity of the New Guinea Mobile Belt has the sedimentary cover been strongly deformed.

The deformation appears to be of two different origins. The first is exemplified by the Mueller and Kubor Anticlines, which are broad arches affecting the basement and overlying cover rocks alike. They are 150 km long and 60 km wide, and can be distinguished on the geological map as large inliers of older rocks within the Tertiary succession - the Mueller Anticline near the West Irian Border, and the Kubor Anticline south of the Waghi valley in the Central Highlands.

The second type of deformation has given rise to the Papuan Fold Belt, which extends south of the main range from the Gulf of Papua to the West Irian border. Here the Tertiary sediments form very long parallel folds with horizontal axes, most of which have been broken on their flanks by thrust faults; the limbs of the folds are generally steep, and in places overturned. It is generally accepted that the folds affect mainly the sedimentary cover and that the basement is not involved to any great extent. It is possible that most of the folding and thrusting is the result of gravity sliding of the thick incompetent sedimentary pile following uplift of the New Guinea Highlands in the Pliocene, but it is doubtful if all the features seen, such as subsequently folded thrust faults, can be explained in this way. There is ample evidence that the New Guinea Mobile Belt was subjected to strong compression after the middle Miocene, so it seems likely that the Papuan Fold Belt resulted from the combined effects of strong uplift of the Highlands accompanied by compression and gravity sliding of the sediments.

NEW GUINEA MOBILE BELT

The rocks of the Mobile Belt have been subjected to intense stress at least since early Mesozoic time. The manner in which they have reacted to this stress is infinitely variable, but several broad generalizations can be made.

Faulting

Where the Palaeozoic basement is involved, and where the younger rocks are made up of thick competent shelf-type sediments (the two are generally related), the whole region is broken into a mass of narrow fault wedges by anastomosing faults and fault zones, many of which are hundreds of kilometres long, and have histories of intermittent movement. Most of the New Guinea Highlands from the Markham River to the West Irian border is in this category.

The structure of the rocks in the fault wedges is rather simple and consists either of broad folds or tilted fault blocks. The faults are steeply dipping and commonly have vertical throws of hundreds or even thousands of metres, and in addition it is suspected that many have large horizontal displacements. Small lateral displacements are indicated by the offsetting of rivers, but the evidence is not unequivocal and nowhere have large horizontal displacements been proved.

Apart from the faults within the New Guinea Mobile Belt, there are two fundamental faults which define the northeastern boundary of the Belt for most of its length, the Owen Stanley Fault and the Markham-Ramu Fault Zone.

Owen Stanley Fault

The Owen Stanley Fault forms the northern flank of the Owen Stanley Range for over 400 km and is thought to represent the southwestern boundary of the Solomon Oceanic Plate (Thompson & Fisher, 1965, and Davies, 1971). Because there is little seismic activity along the fault at present, the main evidence for this hypothesis is the nature of the Papuan Ultramafic Belt, which consists of basal ultramafic rocks which are generally accepted as forming the upper parts of the earth's mantle. The overlying gabbro, dolerite, and thick marine basic lavas overlying the ultramafic rocks are thought to have once formed the oceanic crust.

If the hypothesis is accepted, the ultramafic rocks must have been uplifted at least 10 km along the Owen Stanley Fault to their present position, but there is evidence that the horizontal displacement is much larger. On the northern end of the fault near Salamaua the displacement of river courses indicates recent left lateral displacement of 4 km, while a total horizontal displacement of 100 km is indicated by the separation of the two northernmost ultramafic bodies along a major splay of the Owen Stanley Fault.

Markham-Ramu Fault Zone

One of the outstanding physiographic features of Papua New Guinea is the deep trench which extends from the Huon Gulf northwestward to near the Sepik River. It marks the site of a fault zone separating the Tertiary oceanic rocks of the Huon Peninsula from the Mesozoic and Tertiary rocks of the New Guinea Mobile Belt. The displacement on the fault zone is not known, but it could be predominantly horizontal.

It can be seen from the Geological Map that the Markham-Ramu Fault Zone is the northwestern extension of the New Britain Trench and there seems little doubt that it forms a major plate boundary, a conclusion supported by the intense seismicity displayed by the zone.

Folding

The deformation of the thick piles of less competent sediments laid down in marine troughs contrasts strongly with that of the more competent rocks - the less competent have reacted to stress mainly by tight folding and most have been converted to low-grade metamorphics. The widespread occurrence of glaucophane schist testifies to the high pressures prevailing during the folding.

These metamorphic rocks are confined to the mountains south of the Sepik River, the Bismarck and Schrader Ranges southwest of the Markham-Ramu Fault Zone, and the Owen Stanley Range, all of which lie along the outer periphery of the Mobile Belt, where they took much of the brunt of the interaction between the Australian continental block and the oceanic plates.

The nature of the folding of the metamorphic rocks is almost unknown. A combination of difficulty of access, poor exposure, lack of mappable marker beds, and ubiquitous strong cleavage which generally masks bedding, has prevented elucidation of the structure on the scale of mapping done to date, but in most places the rocks appear to be very tightly folded and have been affected by more than one period of folding.

The major structural trends in the New Guinea Mobile Belt follow the mountain spine, except in the middle where the Aure Trough cuts across nearly at right angles. The Miocene to Pliocene rocks of the trough have been tightly folded along axes which follow the regional trend in the southeast, but which swing abruptly at right angles north of Kerema. The major faults of the region swing in sympathy with the fold axes.

The trends in the Aure Trough are nearly parallel to the northern part of the Owen Stanley Fault and it seems likely that the Trough was formed by downbuckling of the Australian continental margin by pressure of the Solomon Plate (Figure 1). The folds are similar to those of the Papuan Fold Belt and have steep and commonly overturned limbs. The fold axes are horizontal over most of their length and many of the folds can be traced for over 80 km - the overturned western limbs and many of the anticlines have been broken by shallow easterly dipping thrust faults.

The extensive swamps and plains of the Sepik River have formed by very recent downwarping north of the Australian continental platform. The cause of the downwarping is not known, but it could be stress resulting from northward movement of the Australian Continent in direct analogy to the Aure Trough.

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ACTIVE VOLCANOES

by

G.A.M. Taylor

Papua New Guinea is part of the so called Pacific "girdle of fire". This colourful phrase draws attention to the fact that many of the unstable zones near Pacific margins are characterised by volcanic activity.

The incomplete and fragmentary recorded information on volcanic activity in the Papua New Guinea region indicates that eruptions have occurred at 17 volcanic centres in historical times. Another 12 centres are regarded as likely to erupt again because they retain active gas vents, or because their well preserved form suggests that only a short time, geologically speaking, has elapsed since they last erupted. As volcanoes may remain dormant over many centuries their designation as "active" or "extinct" presents difficulties in a country whose written records barely extend beyond a century.

The volcanic zones are generally arcuate, paralleling the geological structural trends of the region and the main tectonic earthquake zones. The three principal areas or volcanic zones include:

1) an arc on the southern margin of the Bismarck Sea extending 900 km from Bam, near Wewak, to Rabaul and paralleling the Markham-Sepik depression and the New Britain Trench.
2) an arc beginning in the Solomon Islands, parallel with Solomon Trench and extending 600 km northwest to include islands off the eastern coast of New Ireland. Tuluman, in the Admiralty Islands, may be the most westerly member of this chain.
3) a zone in eastern Papua which extends 300 km from Mount Lamington to Dobu in the D'Entrecastaux Islands.

Large volcanic cones and extensive areas covered with pyroclastics are also distributed through the highlands of Papua New Guinea. The centres are generally regarded as Pleistocene in age. However, two of them still show solfataric activity, and are placed in the "active" category.

Although the composition of the lavas in Papua New Guinea ranges from basalt to rhyolite, and includes peralkaline and shoshonitic suites, the most common lavas are basalt and low-silica andesite. Cone structures are almost invariably of the strato type, and calderas are a relatively common feature of the volcanoes of the Bismarck Sea area. Eight of them are present between Rabaul and Karkar. Some calderas are very young, having been formed within the last 3 000 years. The caldera in which Pago is situated is less than 3 000 years old. Blanche Bay caldera at Rabaul is about 1 100 years old, and Long Island's caldera may be even younger. The largest of these collapse structures is Blanche Bay, which measures 15 km by 10 km, and three of the others are only slightly smaller.

The types of eruptive activity recorded in the region range from a catastrophic eruption of the Krakatoan type to mildly explosive fountaining of incandescent lava. Probably the greatest historical eruption occurred in 1888, when a Krakatoan type explosion destroyed the 780 m cone of Ritter Island and generated tidal waves which caused widespread loss of life on neighbouring islands and on the mainland of New Guinea.

A better known and possibly more disastrous eruption occurred in 1951, when long-dormant Lamington produced a Pelean outburst which devastated an area of about 240 sq. km, and caused the deaths of about 3 000 people. The explosive phase of this eruption with its attendant glowing clouds lasted six months. It was replaced by an overlapping phase of dome building which continued for several years.

Bagana on Bougainville shares with Lamington the capacity to produce glowing clouds which have devastated the surrounding country from time to time. Its eruptive regime is quite different, however. Bagana is regarded as the most active centre in the region, as little time elapses between successive eruptions. Even during periods of apparent calm it is often pouring out slow-moving viscous lava flows.

The highly explosive dacitic lava expelled as pumice flows during the formation of the Blance Bay caldera, Rabaul, is still being produced by the centres of residual activity within the caldera. The explosive outburst of Vulcan in 1937 was of great intensity. In four days, an ash and pumice cone was built up on the sea floor to a height of 226 m above sea level. Some villages and gardens were destroyed, and 505 people were killed. Activity quickly subsided, and within eight years the new cone was entirely covered with vegetation.

A close study of Manam volcano since the eruptive cycle began in 1956 has brought to light the interesting fact that its basaltic lava is capable of producing a range of eruptive behaviour which covers a large proportion of the spectrum of known eruptive activity. The most common explosive activity may be protracted over periods of days, weeks, or months, and is of two main types:

(a) Strombolian - a rhythmical explosive jetting of incandescant lava;

(b) Vulcanian - spasmodic explosions of non-luminous ash and dust

When lava is high in the conduit effusive eruptions are common. Such events are often preceded by the discharge of "glowing clouds", devastating avalanches of incandescent fragmental material and gas which sweep down the slopes of the volcano at velocities which may exceed 100 km/hour. Similar avalanches were observed during the 1970 eruption of Ulawun, a volcano on New Britain, whose structure and lava composition are similar to those of Manam.

Surveillance of volcanoes in Papua New Guinea is maintained by a section of the Administration's Geological Survey, which is staffed professionally by scientists of the Australian Bureau of Mineral Resources, Geology and Geophysics. Operating from the Central Volcanological Observatory at Rabaul the section maintains five instrument stations in other volcanic areas and another five stations are being established. Centres which are not under direct instrument surveillance are kept under observation by airline pilots and a system of local observers who report regularly to Rabaul. Equipment and staff is available at Rabaul to carry out immediate field investigation of any volcanic centre which is reported to be showing signs of reactivation.

EARTHQUAKE ACTIVITY

by

D. Denham

Earthquakes are direct manifestations of the geodynamic activity currently taking place near the surface of the earth; their spatial distribution enables delineation of boundaries, along which crustal movement is taking place; and studies of the elastic radiation they produce provide clues pertinent to the source mechanisms. Apart from these tectonic aspects earthquakes pose a hazard to lives and property and can influence the development of any region where they occur frequently. Both these aspects of earthquakes are important in Papua New Guinea because it is one of the world's most seismically active regions: between five and ten percent of all earthquakes occur there.

Distribution of Earthquakes

In terms of the recent theory of plate tectonics, which divides the world into several large comparatively rigid plates, the situation in Papua New Guinea arises from the interaction between the northward moving Indian-Australian Plate and the westward moving Pacific Plate. These two large plates do not meet along a single boundary in Papua New Guinea and instead there are several small rigid plates all moving relatively to the others.

Most of the earthquakes take place along the plate boundaries and hence the zones of earthquakes define the margins of the plates. The distributions of earthquakes and plates are shown in figures (1 and 4). The epicentres plotted have been located by using recordings from at least fifteen seismographic stations in the period 1958-1970 (apart from the two large Solomon Sea earthquakes of July 1971) and are considered to be accurate to within 0.1 degree. At least six seismic zones can be recognised and these involve the interaction of five and possibly six rigid plates.

The most active boundary is that associated with the northern margin of the Solomon Sea Plate and is manifested by the New Britain and Solomon Island Arcs. The New Britain Arc contains a typical Benioff zone of earthquakes that dips to the north beneath New Britain. At the western end of the arc near 146°E, the zone dips almost vertically and it contains the "Long Island Nest", which is a small volume of intense earthquake activity situated at a depth of about 200 km, just south of Long Island. Beneath New Britain the dip of the seismic zone decreases from west to east along the arc and under East New Britain it dips at only about fifty degrees. Several deep earthquakes from the arc (at depths greater than 300 km) have been observed under the Bismarck Sea. They represent the underthrusting of the Solomon Sea Plate beneath the Bismarck Sea at a rate of about 9 cm/yr.

The New Britain Arc ends abruptly at the southern tip of New Ireland, where the strike of the seismic zone swings through ninety degrees and a new zone, striking parallel to the Solomon Islands chain, represents the boundary of the Solomon Sea Plate with the main Pacific Plate. Between New Ireland and Bougainville Island the seismic zone dips to the east and contains most of the very deep earthquakes (depth greater than 500 km) reported from Papua New Guinea. Near the northwest of Bougainville Island the dip of the zone changes abruptly and becomes vertical, and very few earthquakes are reported from beneath Bougainville Island. The rate of underthrusting of the Solomon Sea plate at this boundary is about 10 cm/yr.

The southern boundary of the Solomon Sea Plate is marked by a shallow zone of minor seismicity which extends from eastern Papua to New Georgia. This zone bifurcates east of Woodlark Island to contain the Woodlark Basin; the basin may be a spreading centre, but the level of seismicity is too low to reveal its tectonic significance.

Along the north coast of the main island of New Guinea the earthquakes represent a separate zone of thrusting. Instead of a well defined Benioff zone, there is a large shallow slab or wedge, dipping to the south, which is seismically active. The earthquakes observed here occur at depths less than 200 km and represent interaction between the Indian-Australian Plate and the Pacific Plate, west of 143°E, and the South Bismarck Sea Plate east of 144°E. In this region crustal compression is actively taking place at velocities between 3 and 10 cm/yr, and mountain building rather than underthrusting is taking place.

One of the most remarkable seismic features in Papua New Guinea is the zone of shallow earthquakes that extends E-W across the Bismarck Sea at about latitude 3°S. The maximum width of this zone is only about 40 km; it extends from the southern end of New Ireland to the New Guinea mainland, except for what appear to be two seismically inactive regions near the eastern end of the feature. Studies of the focal mechanisms of earthquakes suggest that it is a large left-lateral strike-slip fault with a slip rate of about 8 cm/yr.

This large fault marks the northern boundary of the South Bismarck Sea Plate. North of the fault zone there is the North Bismarck Sea Plate, whose northern boundary is the West Melanesian Arc. The level of earthquake activity associated with the West Melanesian Arc is very low, which suggests that the relative velocity between this plate and the main Pacific Plate is small (less than 2 cm/yr). Only nine earthquakes from this Arc are plotted in the figure.

Earthquake Risk

As well as representing the complicated tectonic activity currently taking place in the New Guinea region the large number of earthquakes pose a very considerable risk to buildings. The potentially damaging earthquakes are those which have magnitudes six or greater and which occur at shallow depths (usually less than 40 km). The design and construction of any structure in regions where these types of earthquakes occur regularly is most important if building collapse is to be avoided during large local shocks.

In general if a building is situated with its foundations resting directly on solid rock then it will not be structurally damaged during an earthquake unless it is of very poor design or construction or unless the earthquake hypocentre is extremely close (within 1 km). Most buildings damaged during earthquakes have been erected on unconsolidated material. Those situated on loose soils, infills, or recent alluvium are particularly vulnerable.

There are two reasons for this. Firstly the ground movement resulting from large local earthquakes can be as much as ten times as large on unconsolidated materials as on solid rock - this results from the acoustic properties of the two materials. Secondly loose alluvium may not behave as an elastic solid. When an earthquake shakes a competent rock, the rock will vibrate elastically and after the shaking has stopped it will return to its original position. However, unconsolidated materials have low rigidity and may be permanently deformed during the shaking. The ground then will not return to its original shape; uneven slumping and subsidence can occur; foundations can sink unevenly and buildings may collapse.

Despite the high level of earthquake activity and the poor geological conditions for building foundations in most of New Guinea the earthquake damage in the past has been comparatively light. This is mainly because before the mid 1960's there were very few buildings in New Guinea for earthquakes to attack. However, this situation is changing rapidly and since 1967 five large earthquakes have caused substantial damage. In August 1967 near the town of Kokopo in east New Britain an earthquake with a magnitude of about 6 caused considerable damage in a small, well defined area about 5 x 12 km, where Modified Mercalli intensities of VIII to IX were experienced. Most of the damage occurred at the Kabaleo Teachers' Training College, which was rendered uninhabitable, and the Vunapar Catholic Mission. It was estimated that the cost of the building damage was about $170 000.

The second significant recent earthquake to cause damage occurred in September 1968. It took place about 30 km south of the west New Britain coast near Kandrian, where two wharves were severly damaged and several water tanks destroyed. The largest financial loss resulting from this earthquake was caused when the SEACOM cable at the bottom of the Vitiaz Strait was broken by turbidity currents. Nearly 30 km of cable had to be replaced at a cost of $150 000.

During September and October 1968 three large earthquakes with magnitudes between 6 and 7 occurred near Wewak on the north coast of New Guinea. Damage amounted to about $100 000, mainly in the vicinity of Yangoru, Ulupu, and Dagua.

In October 1970 a magnitude 7 earthquake near Madang proved to be the most damaging shock ever to have occurred in Papua New Guinea to date. Fifteen people were killed and damage was estimated at $1.7 million of which repairs to the SEACOM cable amounted to $550 000. The remainder was made up of damage to roads, buildings, and bridges in the vicinity of Madang.

Two of the largest earthquakes ever recorded in Papua New Guinea took place in July 1971. They occurred beneath the Solomon Sea between Bougainville Island and New Ireland and both were of about magnitude 8. Damage was extensive in the islands near the northern margins of the Solomon Sea, but most was caused by the resulting tsunami (seismic tidal wave) which caused the only fatality and produced a 2-metre wave at Rabaul. The total cost of the damage was about $450 000, which is much less than that caused by the smaller Madang earthquake in October 1970.

Two important conclusions can be drawn from these recent damaging earthquakes. Firstly, all the earthquakes occurred in the well defined seismic zones: none of them occurred in unusual or unexpected places. Secondly, most of the resulting damage would not have taken place if the earthquakes had occurred ten years previously, because very few of the buildings damaged were in existence then. This indicates that earthquake risk is directly related to a country's development, and the more Papua New Guinea advances, the higher the potential earthquake risk will be.

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Figures Titles and Captions

Figure 1	Main tectonic feature of Papua New Guinea region. Plate nomenclature is as follows: (1) Pacific Plate; (2) North Bismarck Plate; (3) South Bismarck Plate; (4) Solomon Sea Plate; (5?) Possible Woodlark Basin Plate.	PNG/B9/141-3
Figure 2	Generalized stratigraphic columns	M(S)218
Figure 3	Geological map of Papua New Guinea	Not available in Record
Figure 4	Earthquakes and Volcanoes of Papua New Guinea	Not available in Record

Australian Platform		New Guinea Mobile Belt	
Aramia No. 1	Omati No. 1	Central Highlands	Aure Trough

Figure 2

Generalized stratigraphic columns

Limestone

Predominantly shale

Predominantly arenaceous sediments

Volcanics

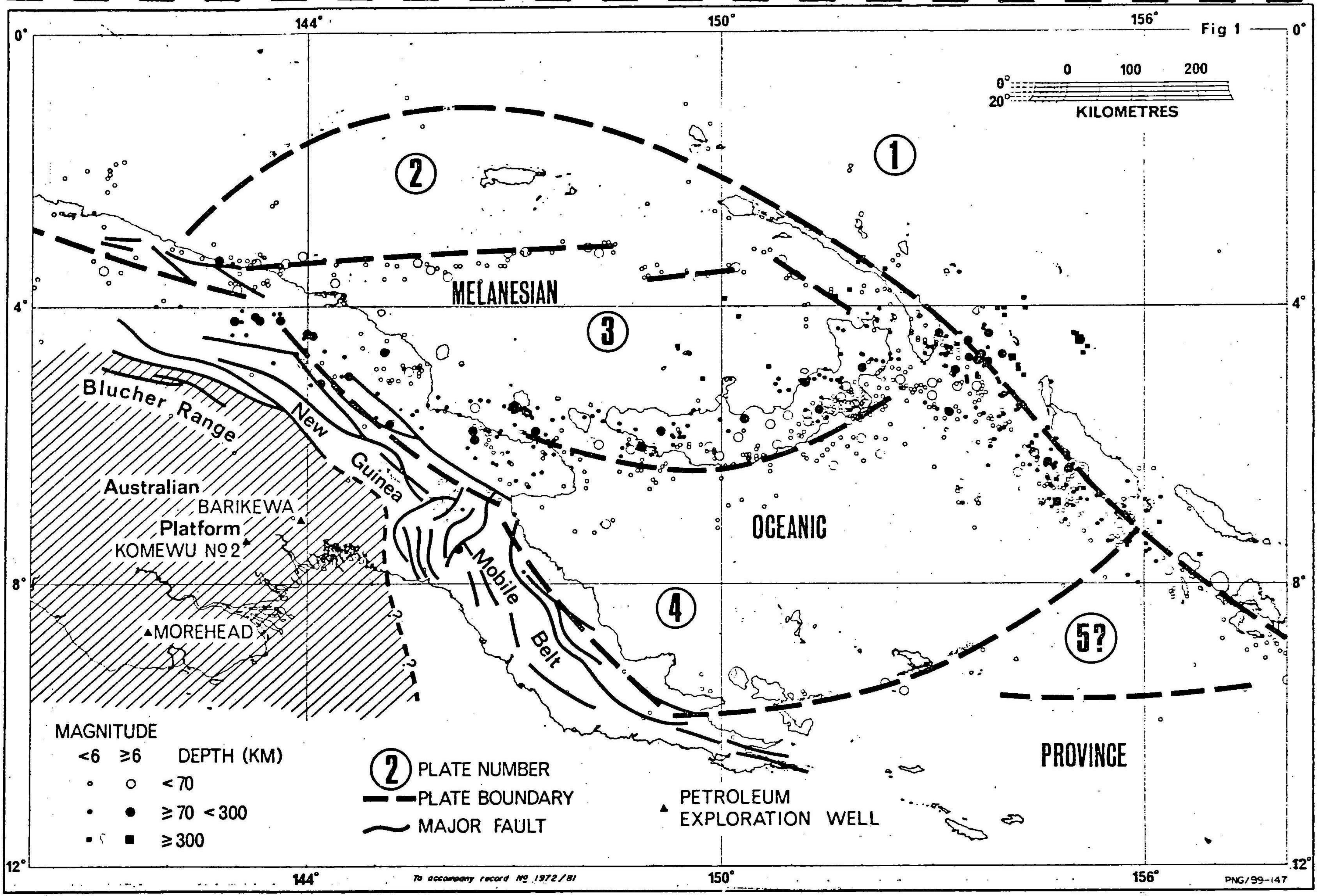

Fig 1
0°
144°
150°
156°
4°
8°
12°
0 100 200
KILOMETRES
1
2
3
4
5?
MELANESIAN
OCEANIC
PROVINCE
Blucher Range
New Guinea Mobile Belt
Australian Platform
BARIKEWA
KOMEWU Nº 2
MOREHEAD
MAGNITUDE
<6 ≥6 DEPTH (KM)
< 70
≥ 70 < 300
≥ 300
PLATE NUMBER
PLATE BOUNDARY
MAJOR FAULT
PETROLEUM EXPLORATION WELL
To accompany record Nº 1972/81
PNG/B9-147

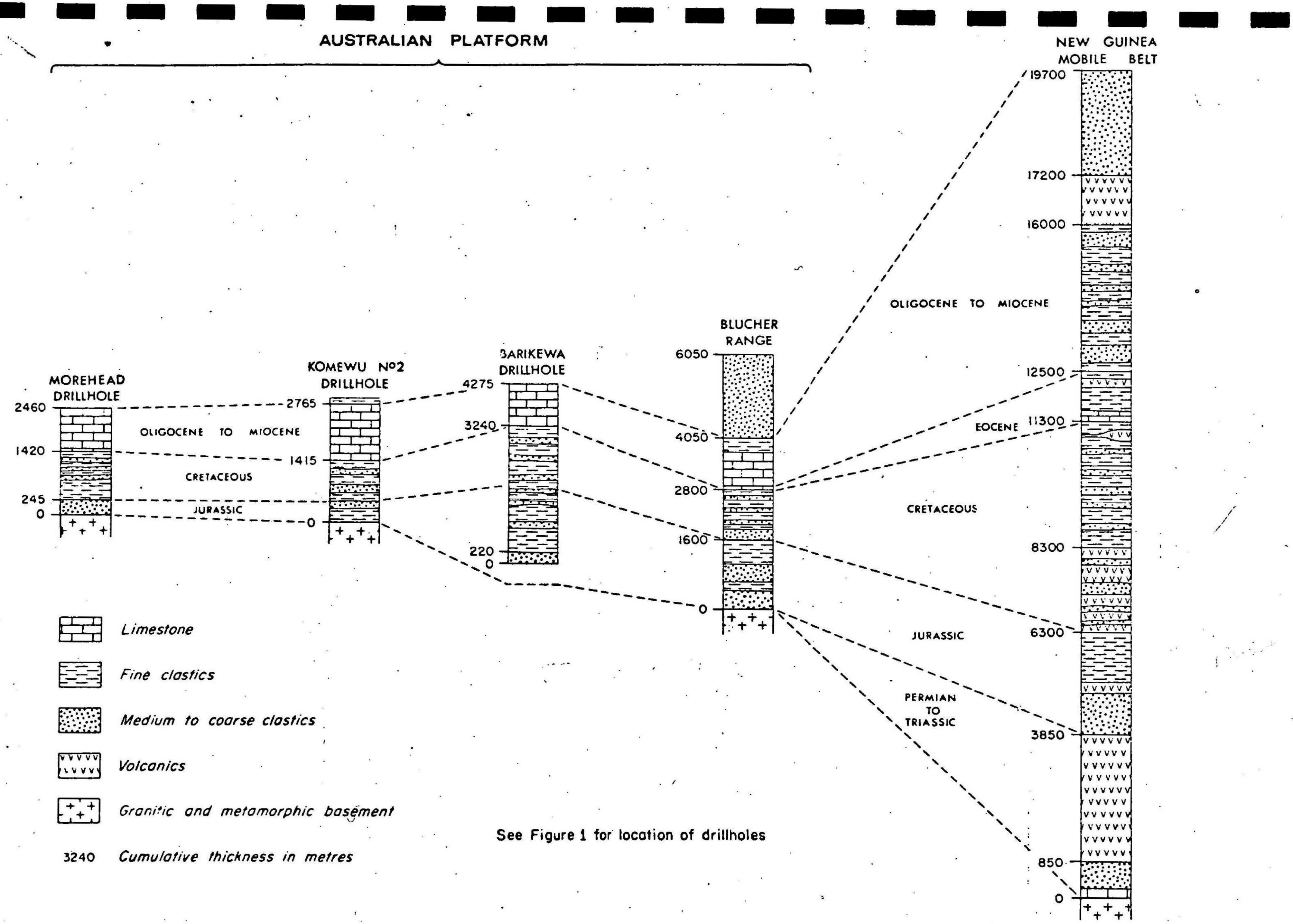

FIG 2 GENERALISED STRATIGRAPHIC COLUMNS, PAPUA NEW GUINEA 1:100 000

To accompany Record 1972/81

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