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A SUMMARY OF THE MAIN STRUCTURAL ELEMENTS OF PAPUA NEW GUINEA *

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ABSTRACT

The new Bureau of Mineral Resources 1:1,000,000 scale geological map of Papua New Guinea has aided the recognition and definition of fourteen main structural and geological elements of Papua New Guinea:

The Fly Platform, a crystalline Palaeozoic basement veneered with shelf type Mesozoic and Cainozoic sediments;

The Papuan Fold Belt, a 50 by 600 km Tertiary fold belt on the uplifted margin of the Palaeozoic basement;

The Kubor Anticline, uplifted Palaeozoic basement north of the Papuan Fold Belt;

The New Guinea Mobile Belt, a 100 by 1600 km mountainous belt north of the Kubor Anticline which contains most of the intrusive, metamorphic, and ultramafic rocks and major faults in mainland Papua New Guinea;

The Papuan Ultramafic Belt, a 40 by 400 km peridotite-gabbro-basalt complex on the northeastern side of the Papuan Peninsula;

Two Palaeogene Volcanic Arcs, in the New Ireland-Solomons, and New Britain-Finisterre Range areas;

The Torricelli Mountains, Neogene sediments overlying metamorphic and intrusive rocks of unknown age north of the Sepik River;

The Tertiary Aure Trough, the Neogene Cape Vogel Basin, and the Quaternary Sepik-Ramu Basin;

The Southeast Papua Tertiary Volcanic Province, a submarine basalt and chert province;

The Ramu-Markham Fault Zone, a 10 by 250 km Neogene fault zone;

The Quaternary Volcanoes, arcuate belts in the Bismarck Archipelago and large irregular fields in eastern Papua and the Papua New Guinea Highlands.

Mainland Papua New Guina developed from a Palaeozoic nucleus by accretion and subsequent deformation of the products of north and east migrating marginal volcanism and sedimentation from the continent. During the Tertiary, a mobile belt consisting mostly of intrusive, metamorphic, ultramafic, and deformed but unmetamorphosed sedimentary rocks, and deep faults, formed along the outer limit of Palaeozoic basement. A decollement fold and thrust belt formed to the south of the upturned margin of the basement. Northwards movement of Papua New Guinea (which was part of the Australian continent) probably resulted in collision with part of the Palaeogene New Britain-Finisterre island arc and its attachment to the mainland as the Finisterre block. The Papuan Ultramafic Belt is similarly believed to have resulted from interaction between colliding crustal plates.

ACKNOWLEDGMENTS

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INTRODUCTION

During the last six years more than 1500 000 km^2 of Papua New Guinea have been mapped at 1:250 000 scale by the Bureau of Mineral Resources, and gravity, magnetic, and seismic surveys have covered large areas of land and sea. The mapping has progressed so rapidly that most of the information has not yet been published, although it is freely available from the Bureau.

This paper is intended as a summary of the geology to be read in conjunction with the 1:1 000 000 scale geological map of Papua New Guinea, which will be published during 1972.

STRUCTURAL ELEMENTS (Fig. 1)

From the present state of mapping a number of major structural and geological elements in Papua New Guinea can be delineated.

The Fly Platform consists of that part of the rigid, block-faulted, crystalline basement of pre-Mesozoic age (APC, 1961) that is overlain by essentially flat-lying Mesozoic sandstone, Neogene shelf limestone, and Quaternary sediments (including molasse) and volcanics. The granitic basement is exposed only at Mabaduan on the southwest coast of Papua (9°40'S, 142°40'E), although several petroleum exploration bores in western Papua have bottomed in granite (APC, 1961). The basement extends south beneath Torres Strait and is continuous with the Palaeozoic rocks of north Queensland (Willmott et al., 1969). It also extends north and east beneath the Papuan Fold Belt as far as the New Guinea Mobile Belt. The Fly Platform has clearly been part of the Australian continent since at least early Jurassic, and probably late Palaeozoic, time.

The Papuan Fold Belt is a belt of subparallel folds and faults (50-70 km wide, 600 km long) which bounds the northern and eastern limits of the Fly Platform and overlies the folded and upturned marginal areas of the crystalline basement (Smith, 1965; Jenkins & Martin, 1969). The sedimentary succession in the Fold Belt is: 100-5000 m of Mesozoic marine clastic sediments, thin Palaeogene siltstone, limestone and calcareous sandstone, 200-1500 m of early Neogene Shelf limestone and 100-600 m of late Neogene fine grained marine and terristrial clastic sediments. In two places (the Aure Trough and Mendi Basin) the Neogene limestone grades eastwards into flysch type clastic sediments. The style and state of preservation of the folds varies across the belt: from broad synclines and tight, commonly faulted anticlines in the outer parts (i.e. away from the Fly Platform), to overthrust anticlines and monoclines in the inner parts (Fig. 2). The Tertiary limestone has been considerably shortened within the belt by both folding and overthrusting from the north, or, in the Aure Trough, shortening from the east (Pitt, 1966). The outcrop pattern and degree of disturbance of the Mesozoic shales in the anticlinal cores in the outer zone of the belt are suggestive of diapiric folding (Jenkins & Martin, 1969). Thrust faults commonly mark a decollement surface between the Tertiary limestone and Mesozoic shales, although some faults clearly extend to considerable depth in the Mesozoic sequence and possibly into the Palaeozoic basement (e.g. Strickland Gorge, R.J. Ryburn, pers. comm. 1971). The foreshortening of the sedimentary rocks in the Papuan Fold Belt, therefore, may be due either to diapirism and associated gravity sliding or to north-south compression (east-west in the Aure Trough), or, more likely, to a combination of both.

The Kubor Anticline, a 60 by 125 km arch on the northeastern margin of the Palaeozoic basement, is the largest and easternmost exposure of basement in eastern New Guinea. The core of the anticline consists of low grade meta-sediments and minor metavolcanics intruded by late Permian composite plutons of acid to basic compositions. These are overlain by small remnants of Upper Permian to Lower Triassic coralline reef limestone, which are the oldest known fossiliferous rocks in eastern New Guinea (Bain et al., 1970). Except for a marine transgression during the Upper Triassic, the crystalline core of the anticline was a landmass from late Permian time onwards and had a profound influence on sedimentation in the surrounding area. The anticline separates and deflects the two parallel belts of intense deformation - the Papuan Fold Belt and the New Guinea Mobile Belt.

The New Guinea Mobile Belt (Dow et al., in press; Page, 1971) is 50-100 km wide and 1600 km long, and contains most of the major high angle faults, and more than 90 percent of the intrusive, ultramafic and metamorphic rocks of Mesozoic or younger age in Papua New Guinea (excluding Bougainville and the Bismarck Archipelago) (Fig. 3). Deformed but unmetamorphosed volcanic and sedimentary rocks of Mesozoic and Cainozoic age are also present.

The metamorphic rocks are mostly of the greenschist facies, but blueschist, eclogite, and amphibolite are locally present. They were formed during the late Mesozoic to early Neogene by metamorphism of Mesozoic and Palaeogene sedimentary and volcanic rocks.

The intrusive rocks are acid to basic, post-orogenic plutons of Mesozoic to Quaternary age; most are middle Miocene (12-15 m.y.). They have sharp cross-cutting boundaries, and the larger bodies have deflected major faults. The ultramafic rocks consist of fault-bounded blocks of peridotite, serpentinite, and gabbro emplaced during Palaeogene or early Neogene time.

The faults of the Mobile Belt are anastomosing systems of vertical or steeply dipping major shear zones with long sinuous traces. West of 146°E they have a general west-northwest trend but to the east they trend north and north-northwest. Some of these faults have been active since at least Cretaceous time with vertical movements up to 3000 m; large lateral movements are indicated but not measurable (Bain et al., 1970).

The New Guinea Mobile Belt is situated between the Palaeozoic crystalline basement block to the south and west, and the Torricelli Mountains, Palaeogene Volcanic Arc, and oceanic crust (part of which is the Papuan Ultramafic Belt), to the north and east; it has gradational or obscured contacts to the north and south. The New Guinea Mobile Belt is interpreted as a zone of interaction between opposing plates to the northeast and southwest. By this definition it contains the Papuan Ultramafic Belt which Davies (1971) suggests is the exposed southwestern margin of the Solomon Sea Oceanic plate. The relationship of the pre-Neogene igneous and metamorphic rocks of the Torricelli Mountains to those of the New Guinea Mobile Belt is not known.

The Papuan Ultramafic Belt is a peridotite-gabbro-basalt complex, 40 km by 400 km, dipping oceanwards from the northeastern side of the Owen Stanley Range in eastern Papua. It consists of an upper zone of 4-6 km of massive and pillow basalt and splitite and minor dacite; a middle zone of gabbro about 4 km thick and a lowermost zone of ultramafic rocks 4-8 km thick (Davies, 1971). Over 90 percent of the ultramafic zone consists of homogeneous harzburgite, dunite, and enstatite pyroxenite with metamorphic textures; cumulus-textured ultramafics make up the remainder. The complex is bounded by faults, and is intruded by Eocene tonalite at the gabbro-basalt interface. Thompson & Fisher (1965) and Davies (1971) believe the complex may be part of an overthrust sheet of Jurassic-Cretaceous oceanic crust (gabbro and basalt) and upper mantle (ultramafics) which was emplaced during Palaeogene time. If so, the Papuan Ultramafic Belt is the exposed margin of the oceanic crustal plate which underlies part of the Solomon Sea; in any case, it is part of the buffer zone (New Guinea Mobile Belt) between the oceanic and continental plates.

There are two Palaeogene Volcanic Arcs. The New Britain Finisterre arc is an ancient island arc 50-100 km wide and 1000 km long composed of andesitic and basaltic marine and terrestrial agglomerate, tuff, and lava, and minor interbedded sediments. The volcanics are mostly altered, incipiently metamorphosed, moderately to strongly folded, and intruded by small acid to basic plutonic and hypabyssal stocks (Mackenzie, 1971). Sedimentary rocks are more common in the upper part of the sequence and in the extreme western part of the arc. The arc is extensively overlain by Neogene shoal and reef limestone and minor interbedded sediments. Late Neogene-Quaternary subparallel northwest-trending major faults cut the Gazelle Peninsula and southern New Ireland (Macnab, 1970). Elsewhere, the island of New Britain has been gently warped about an axis parallel to the length of the island, but not strongly faulted (R.J. Ryburn, pers. comm., 1971). Structural trends in the Finisterre Range are also parallel to the longitudinal axis of the arc. The Bougainville-New Ireland arc is a similar but narrower arc, which extends from Manus Island southeastwards through New Ireland to Bougainville and the Solomon Islands (Blake & Miezitis, 1967; Hohnen, 1971). The deep structure of New Britain and southern New Ireland is described by Wiebenga et al (this volume).

Although commonly believed to be the northwestern extension of the New Britain-Finisterre volcanic arc, the Torricelli Mountains are discussed separately because they are not well enough known to be certain of this. The Neogene sediments have been mapped by oil exploration companies, but the igneous and metamorphic rocks are only now being mapped. The main difference between the two areas is that whereas Neogene rocks are underlain by Mesozoic? plutonic and metamorphic rocks in the Torricelli Mountains, they are underlain by Palaeogene volcanics in the New Britian-Finisterre arc. The absence of Quaternary volcanism from the Torricelli region is another significant difference. Relationships between the Torricelli Mountains and the New Guinea Mobile Belt are masked by the Quaternary sediments of the Sepik-Ramu Basin.

The Quaternary Sepik-Ramu Basin consists of low, flat-lying parts of the Sepik and lower Ramu River basins (75 by 450 km). The basin contains up to 1500-2000 m of unconsolidated marine and terrestrial clastic sediments derived from the high mountains that almost completely surround it. Metamorphic rocks, in part overlain by Neogene sediments, underlie most of the basin. Geomorphological evidence suggests that the northern margin of the basin is being elevated and the southern margin depressed; the low-lying parts of the basin are largely covered by swamp.

The Tertiary Aure Trough, a 150 by 400 km flysch basin extending from the central highlands to near Port Moresby (APC, 1961) is the largest and deepest clastic basin in Papua New Guinea, and as a structural element includes also the Mendi Basin, for which it is separated by the Kubor Anticline. It adjoins and partly overlaps the New Guinea Mobile Belt to the north and east and overlaps unmetamorphosed Mesozoic rocks to the west, where it thins markedly and grades into shelf limestone and subordinate siltstone. The greater part of the sequence, which has a maximum thickness of 10 000 m, is of Miocene age and contains a large proportion of volcanic detritus (Edwards, 1950) derived from the volcanic rocks which crop out along the northern and eastern margins of the basin. Although the axis of the Aure Trough is north-south, most of the post-depositional structural trends are north-northwest and northwest; in the northeast corner the trends are northeast. Most of the folds and faults (including the part of the Papuan Fold Belt that has been superimposed on the western part of the basin) are believed to be due to east-west compression (Pitt, 1966) and uplift along the New Guinea Mobile Belt. The northern embayment of the basin is strongly faulted as a result of vertical and strike slip movements in that part of the New Guinea Mobile Belt. Deformation occurred throughout the history of the basin and culminated in the late Neogene.

The Neogene Cape Vogel Basin (50-100 km by 400 km) overlies the Papuan Ultramafic Belt on the northeast side of the eastern Papuan peninsula and contains up to 4000 m of fine to coarse-grained sedimentary rocks of continental derivation, and subordinate tuff. These are mostly of middle Miocene to Pliocene age (Davies & Smith, 1970). A considerable thickness of Quaternary sedimentary and volcanic rocks covers the Neogene deposits.

The Southeast Papua Tertiary Volcanic Province (50 km by 400 km) overlies the Owen Stanley Metamorphics between Port Moresby and the tip of the Papuan peninsula. It consists mainly of submarine basaltic lavas at least 3000m thick, with subordinate lenses of Eocene limestone. West of 148°E the volcanics grade into clastic sediments and then into chert and calcilutite (Yates & de Ferranti, 1967). Pliocene shoshonite lavas and agglomerate overlie the Eocene basalts (Davies & Smith, 1970).

The Ramu-Markham Fault Zone comprises the graben-like southeasterly Ramu and Markham valleys, 10-15 km wide and 250 km long, which separate the Finisterre part of the Palaeogene Finisterre-New Britain Volcanic Arc from the New Guinea Mobile Belt. The true nature of the zone has not been determined because it is completely covered by Pliocene to Recent fanglomerate and alluvium. However, it is apparent that vertical movements of more than 1 km and possibly considerable horizontal movements have occurred along the fault zone.

Quaternary Volcanoes, many of them active (Fisher 1957), are found in areas of pronounced seismic activity in the Bismarck Archipelago, the Solomon Islands, the central highlands of New Guinea, and eastern Papua (Figs 1 & 7). Rocks of the calcalkaline association predominate, although those of the shoshonite association are common in the central highlands, eastern Papua, and the islands northeast of New Ireland. The distribution and chemistry of the volcanoes is discussed by Johnson et al. (this volume).

GEOLOGICAL HISTORY

The Palaeozoic basement (Australia-New Guinea continental crust) of the Fly Platform formed the nucleus for the development of the present landmass of Papua New Guinea. In the Jurassic, Cretaceous, and upper Palaeocene sediments of continental derivation were deposited on this basement. These were overlain by bioclastic shelf limestone in the Palaeogene and lower Neogene, and marine and lacustrine sediments (including molasse) in the upper Neogene and Quaternary (Fig. 7). The Platform was epeirogenically uplifted in the Holocene.

This sedimentary sequence extended and thickened oceanwards, and up to 5 km of Mesozoic sediments (Fig. 4) accumulated in the vicinity of the Papuan Fold Belt. These sediments were overlain partly by Palaeogene (Fig. 5) and lower Neogene (Fig. 8) shelf limestone, 500-1500 m thick, and partly by up to 10 km of Tertiary volcanolithic flysch-type sediments and volcanics in the Aure Trough and Mendi Basin (Figs 1, 5, 6). Marine and lacustrine sediments covered most of the limestone and flysch during the upper Neogene and Pleistocene (Fig. 6).

The Papuan Fold Belt was deformed during the Neogene: in the east probably by east-west compression, and in the west by southerly gravity sliding and diapirism induced by uplift of the northern margin of the Palaeozoic basement, as exemplified by the Kubor Anticline, and by north-south compression consequent on the northward movement of the continental crust.

From late Permian time onwards the Kubor Anticline was a basement high with a strong influence on the nature of the adjacent Mesozoic and Tertiary sedimentation. The anticline was further arched and elevated to its present position in the late Neogene.

Acid to basic volcanism began on the northeastern margin of the Palaeozoic basement (Australia-New Guinea continent) in late Triassic time. Thereafter a great thickness of volcanics and volcanically and continetally derived sediments accumulated on and around the continental margin, and the continent grew oceanwards during the Mesozoic and Palaeogene. The formation of most of the metamorphics and major faults (Figs 3 & 7), and the emplacement of most of the ultramafic and intrusive rocks of Mesozoic or younger age, which characterize the New Guinea Mobile Belt, took place in this marginal zone during the Tertiary. Orogenic uplift occurred in the late Neogene.

The Southeast Papua Tertiary Volcanic Province formed in the Eocene when a large volume of basaltic lava was extruded onto the sea floor in eastern Papua immediately south of the New Guinea Mobile Belt. Eocene chert and calcareous clastic sediments were also deposited in this submarine volcanic province. The volcanism may have been connected with opening of the Coral Sea (Davies & Smith, 1970). After a period of uplift and erosion in the late Palaeogene and early Neogene, parts of the region were covered by subaerial basic volcanics during the Pliocene.

Rocks of the Papuan Ultramafic Belt formed in the Jurassic and Cretaceous, probably as a part of the oceanic crust of the Solomon Sea. In the Palaeogene or early Neogene they were thrust over the metamorphic rocks of the New Guinea Mobile Belt. Both belts were uplifted during the late Neogene and Quaternary.

The Cape Vogel Basin developed during the Neogene and Quaternary on the northeast flank of the emergent New Guinea Mobile Belt (specificially the Papuan Ultramafic Belt), and was filled with material shed from the belt. The southern margin of the basin was uplifted during the Holocene by continued emergence of the New Guinea Mobile Belt.

Volcanic island arcs developed in the Bougainville-New Ireland-Manus and New Britain-Finisterre areas during the Palaeogene. Fluctuations in the intensity of volcanic activity, and periodic uplift of parts of the arcs, resulted in alternate episodes of essentially reef limestone growth and volcanic and volcaniclastic sediment growth which have continued to the present day. Opposing movements of the New Britain-Finisterre arc and mainland Papua New Guinea probably resulted in attachment of the Finisterre part of the arc to the mainland during the late Neogene. The New Britain arc probably moved southwards with respect to the Bougainville-New Ireland arc, resulting in attenuation of the Gazelle Peninsula and southern New Ireland.

In the Neogene marine clastics were deposited on the presumably late Mesozoic to Palaeogene metamorphic and igneous basement of the Torricelli Mountains. The probable source of the sediments was the emergent New Guinea Mobile Belt and subordinate local volcanism. The region was folded, faulted, and uplifted in the late Neogene or Quaternary, or both.

At that time a large basin opened between the Torricelli Mountains and New Guinea Mobile Belt (Speik-Ramu Basin) and was partly filled with Pliocene and Quaternary marine and lacustrine sediments.

Interaction between the Finisterre area and the New Guinea Mobile Belt during the Neogene gave rise to the Ramu-Markham Fault Zone, which is now represented by a pronounced graben-like valley along most of its length. The valley floor was covered by fanglomerates and aluvium in the Pliocene and Quaternary.

Numerous volcanoes, many still active, formed on the mainland and islands, and in the seas off the northeast coasts of the mainland and New Ireland during the Quaternary.

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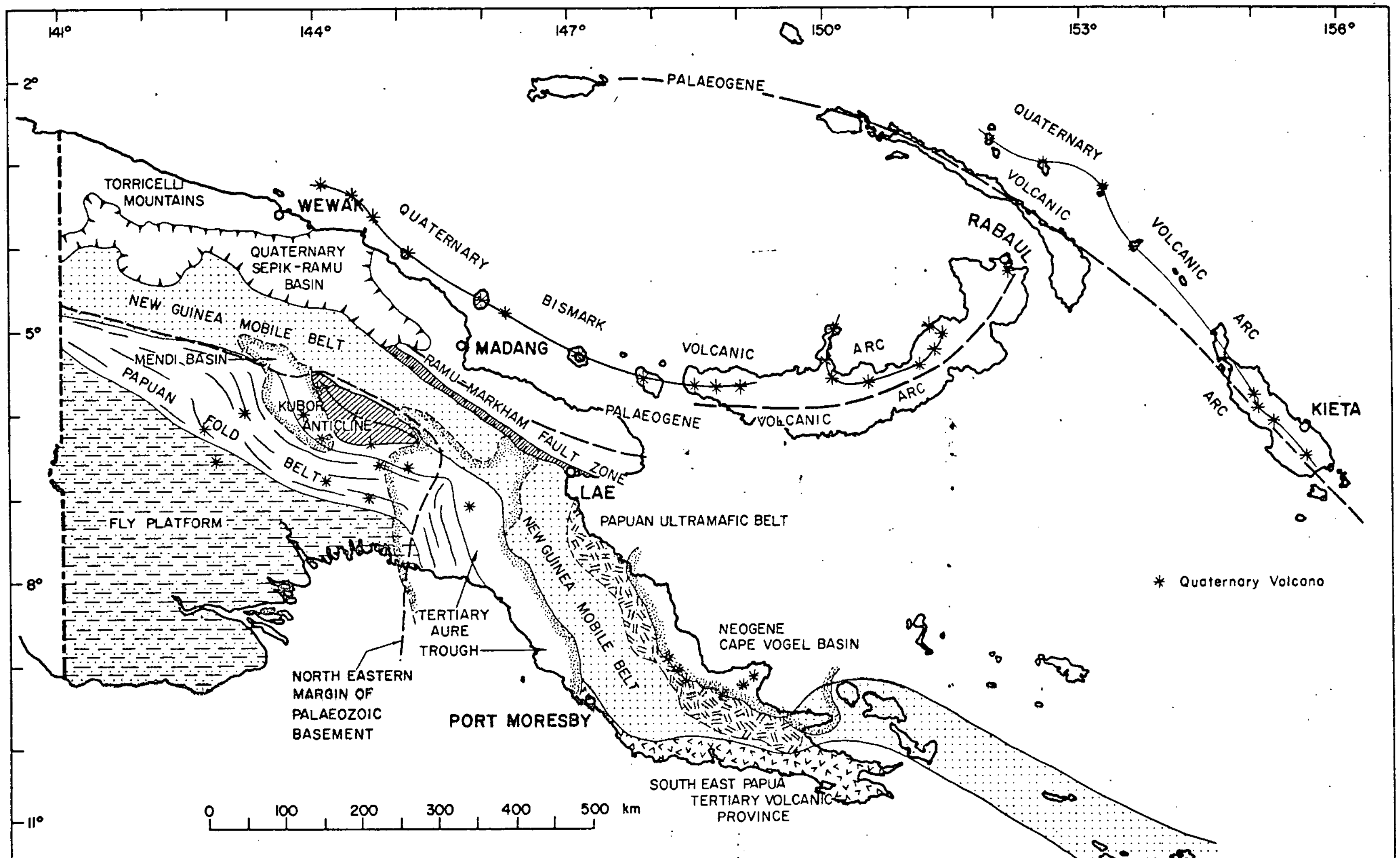
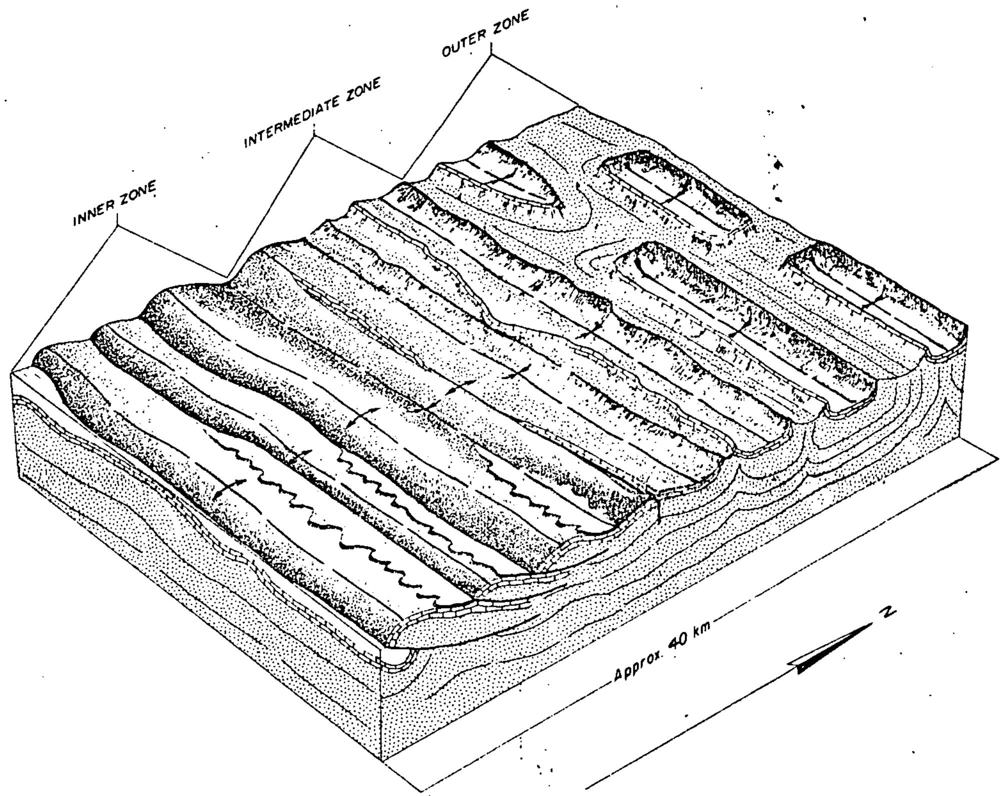


FIGURE I. MAIN STRUCTURAL ELEMENTS

STYLE OF FOLDING IN THE PAPUAN FOLD BELT

FIGURE 2

GENERALISED MODEL



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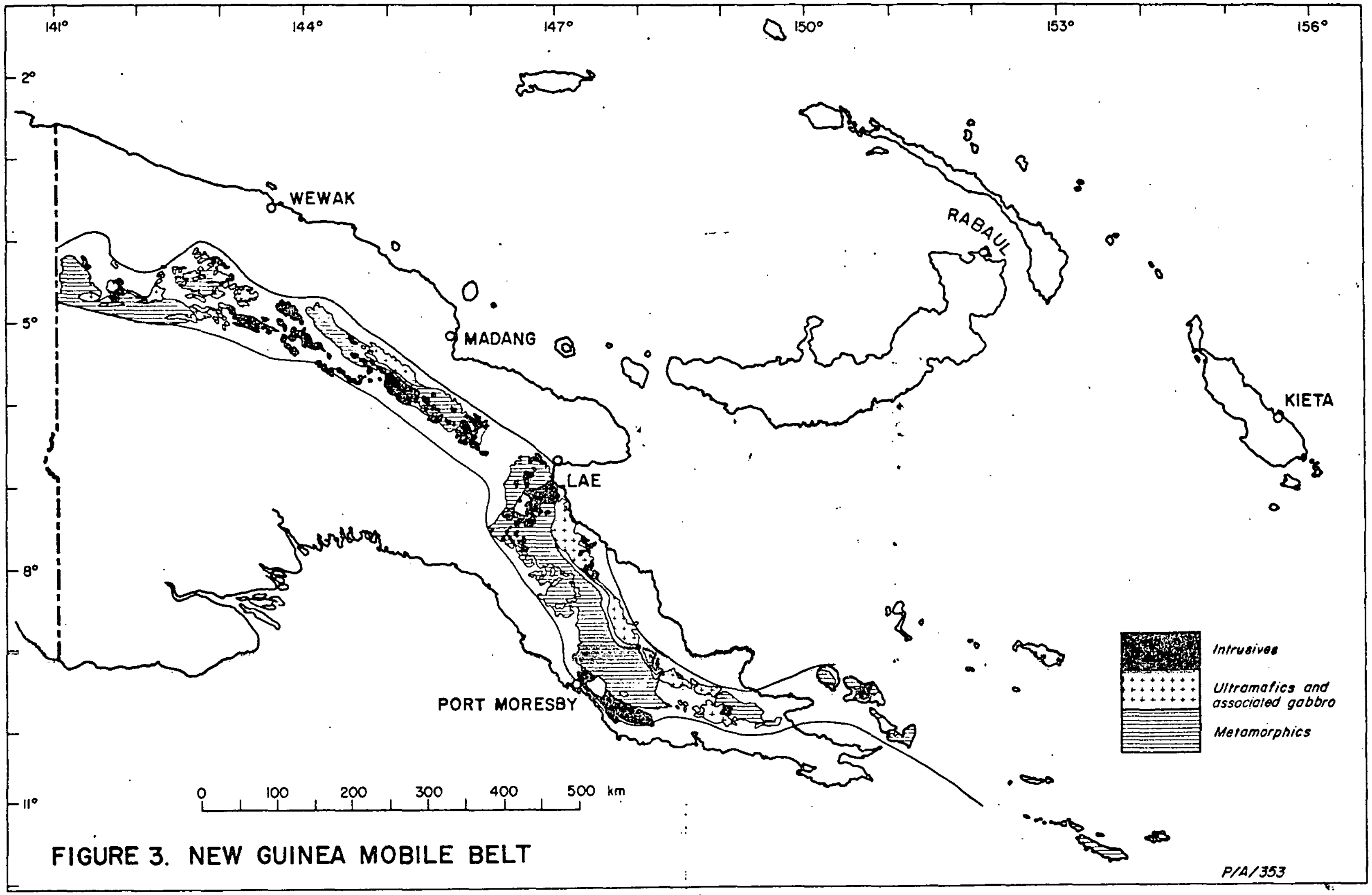

FIGURE 3. NEW GUINEA MOBILE BELT

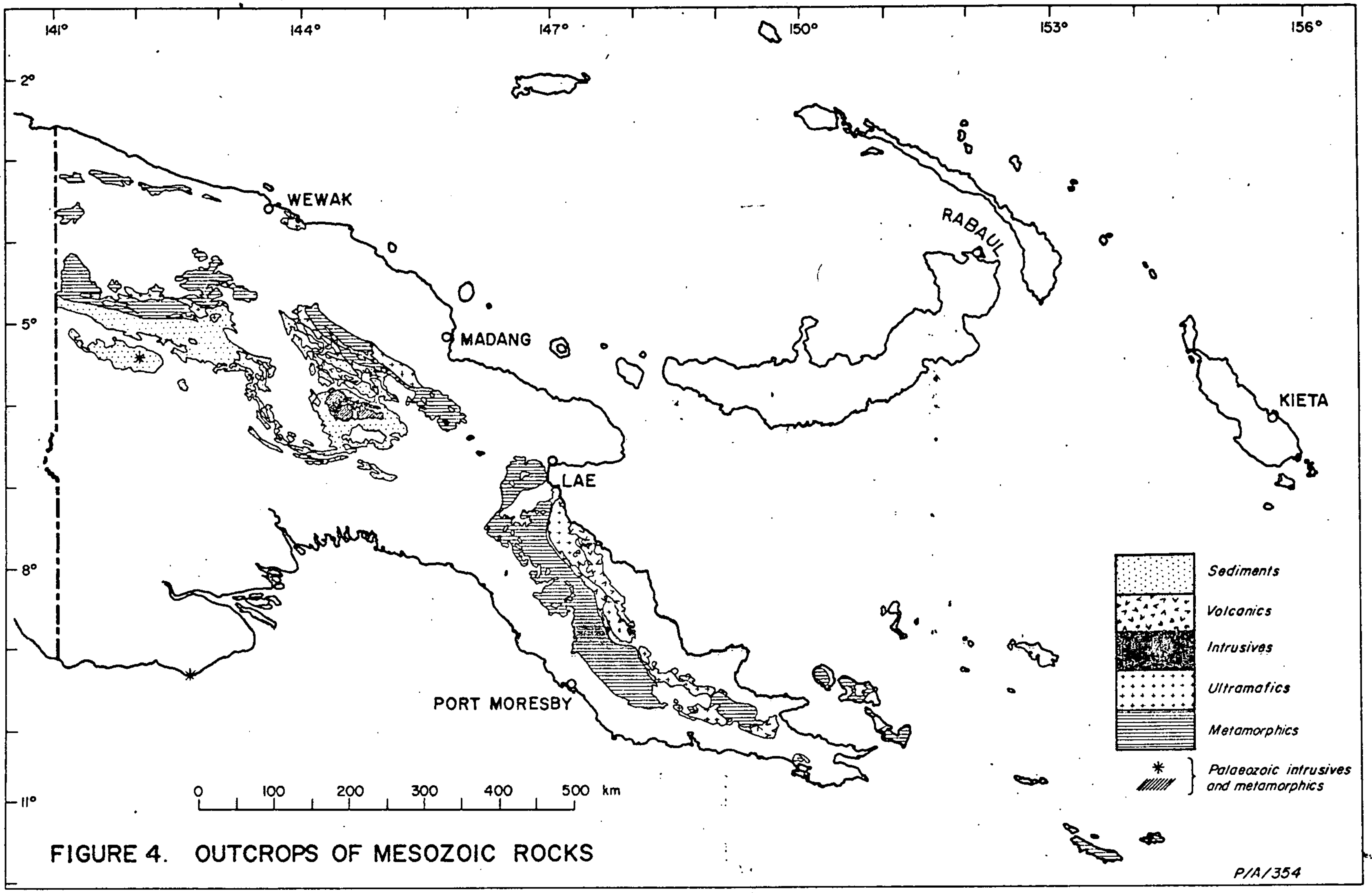

FIGURE 4. OUTCROPS OF MESOZOIC ROCKS

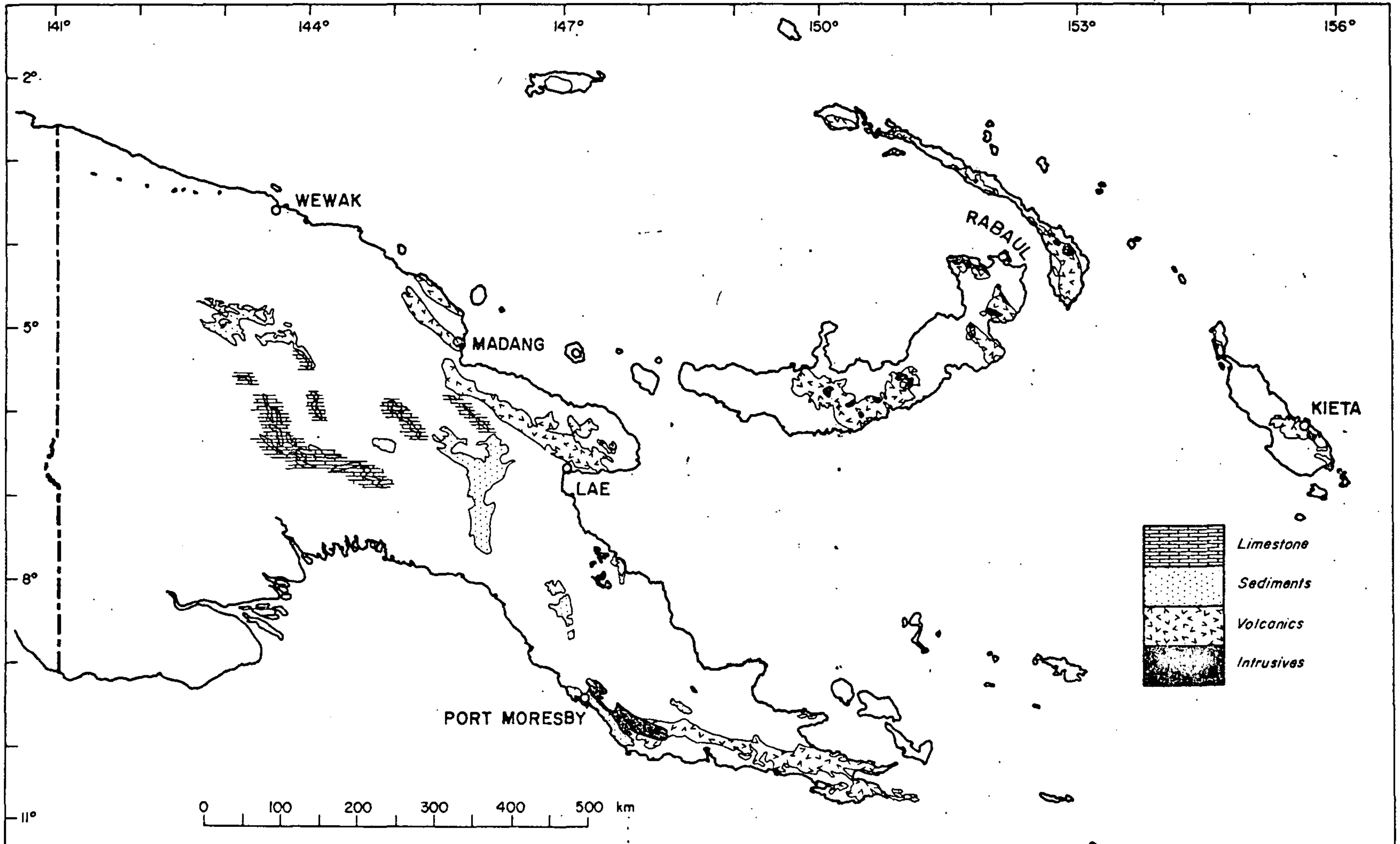

FIGURE 5. OUTCROPS OF PALAEOGENE ROCKS

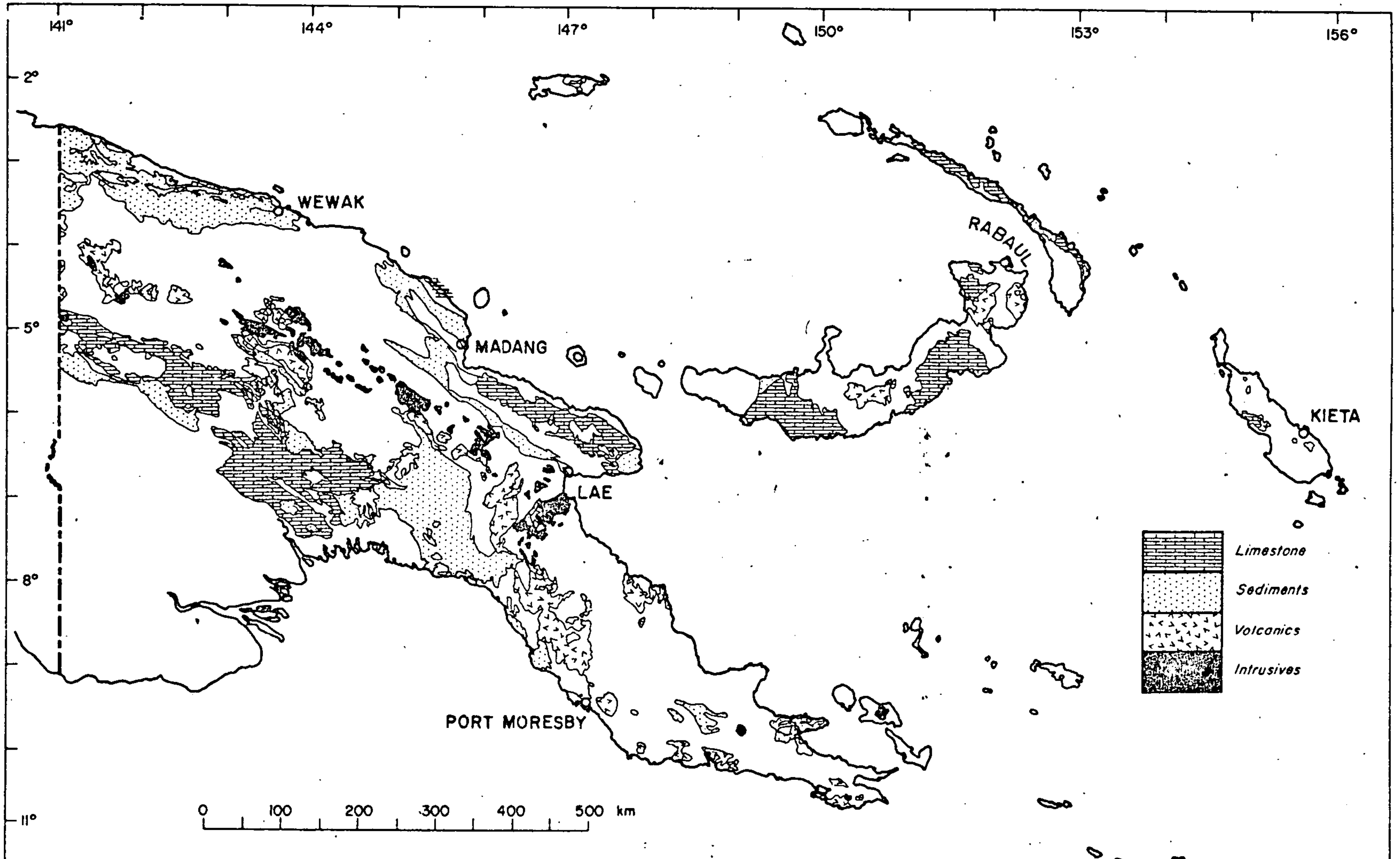

FIGURE 6. OUTCROPS OF NEOGENE ROCKS

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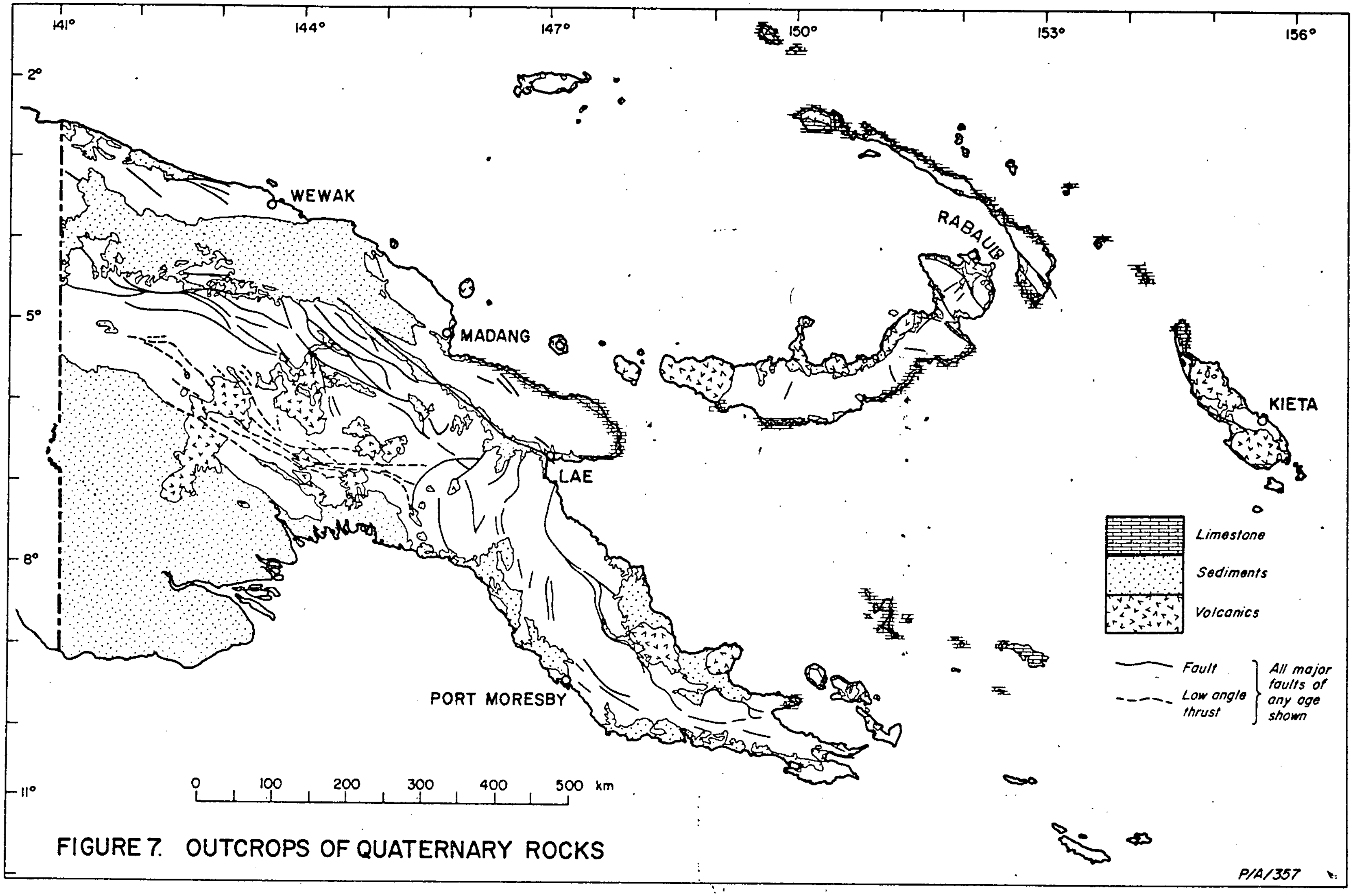

FIGURE 7. OUTCROPS OF QUATERNARY ROCKS