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GEOLOGY OF PAPUA NEW GUINEA

by

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INTRODUCTION

Until recently it was not possible to make a soundly based interpretation of the geological history of Papua New Guinea because a large part of the country remained unexplored; these areas were mostly rugged, jungle-covered, unpopulated, and accessible only to parties using modern means of transport and supported by substantial logistics. However, the systematic geological mapping begun by the Bureau of Mineral Resources is 1956 is now all but completed and, combined with the results of mapping by oil exploration companies, provides a detailed geological framework upon which the following outline of the geology is based.

REGIONAL FRAMEWORK

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. As a result of the recent mapping it is now well established that mainland Papua New Guinea was formed by interaction, over a long span of geological time, between the Australian continent 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 the nature of the oceanic plates, which are mostly covered by sea, is much more conjectural.

The collision between these two crustal elements has resulted in the formation of an intensely faulted and folded zone (New Guinea Mobile Belt) which forms

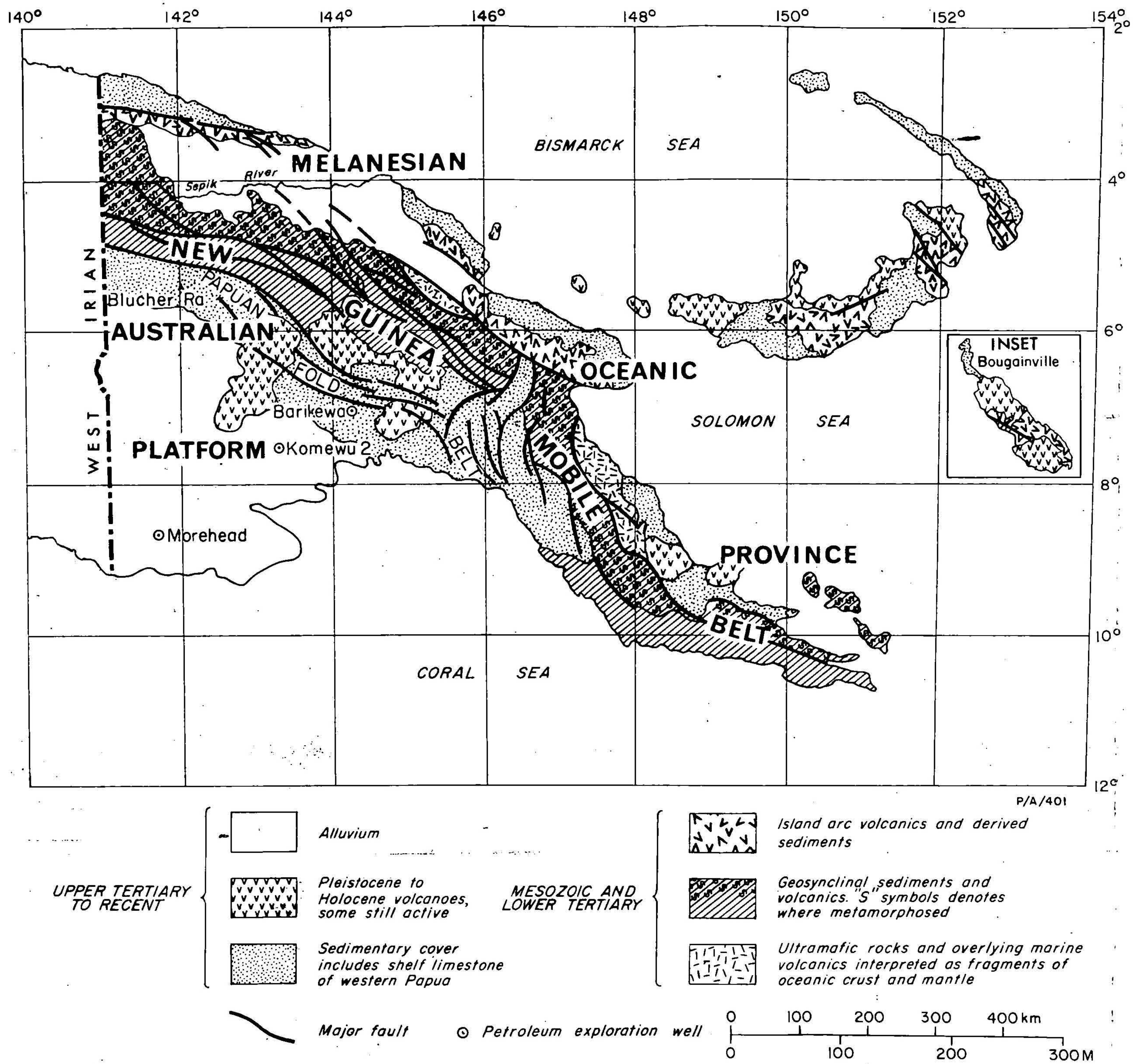

FIG. 1. GEOLOGICAL PROVINCES OF PAPUA NEW GUINEA.

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the spine of mainland Papua New Guinea. Thus the geology falls into three broad divisions: the Australian Platform (that part of Papua New Guinea underlain by the Australian continent); the New Guinea Mobile Belt; and the Melanesian Oceanic Province (Fig. 1).

AUSTRALIAN PLATFORM

(Reference: A.P.C. 1961)

Southwest Papua is underlain by a stable Palaeozoic, and probably Precambrian, basement of granitic and metamorphic rocks which is exposed in only two places (in the Western Highlands), but which has been reached by several petroleum exploration wells in the southwest. Isotopic dating indicates that the granites are Permian (about 240 m.y.), similar to the younger granites of Cape York Peninsula (Page, in prep.).

Stratigraphy

The Australian Platform was the site of almost continuous shallow marine or lacustrine sedimentation from early Jurassic to Holocene. The sedimentary environment was stable for long periods, and as a consequence the sediments are uniform over large areas: the Mesozoic sequence consists mainly of shale and siltstone with prominent interbeds of quartz sandstone, and the Tertiary rocks are notable for a thick (up to 3000 m) shelf limestone which extends over most of the Platform (Fig. 2). The sediment was derived almost entirely from the Australian continent, which was low-lying for most of the time.

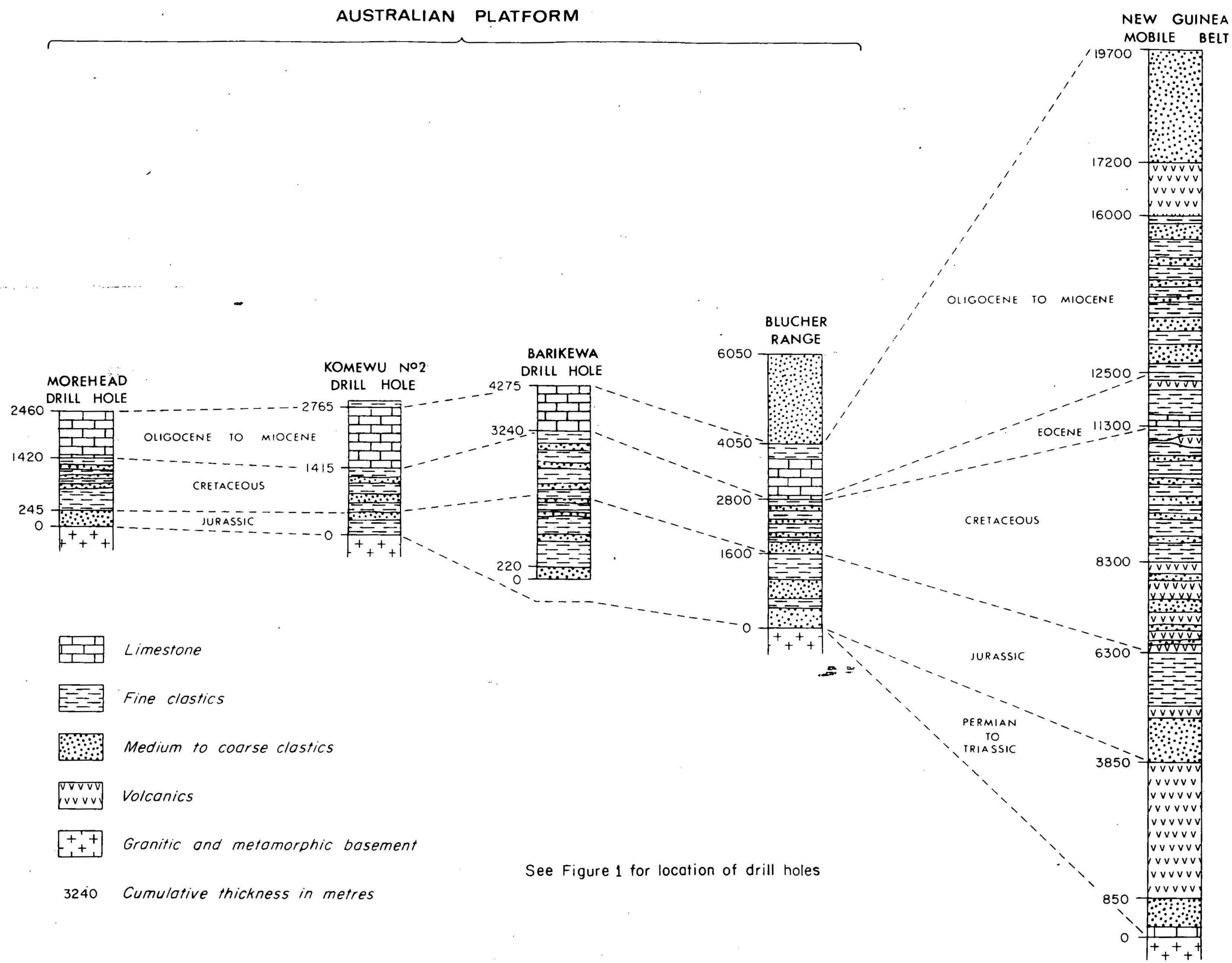

FIG. 2. GENERALIZED STRATIGRAPHIC COLUMNS, PAPUA NEW GUINEA.

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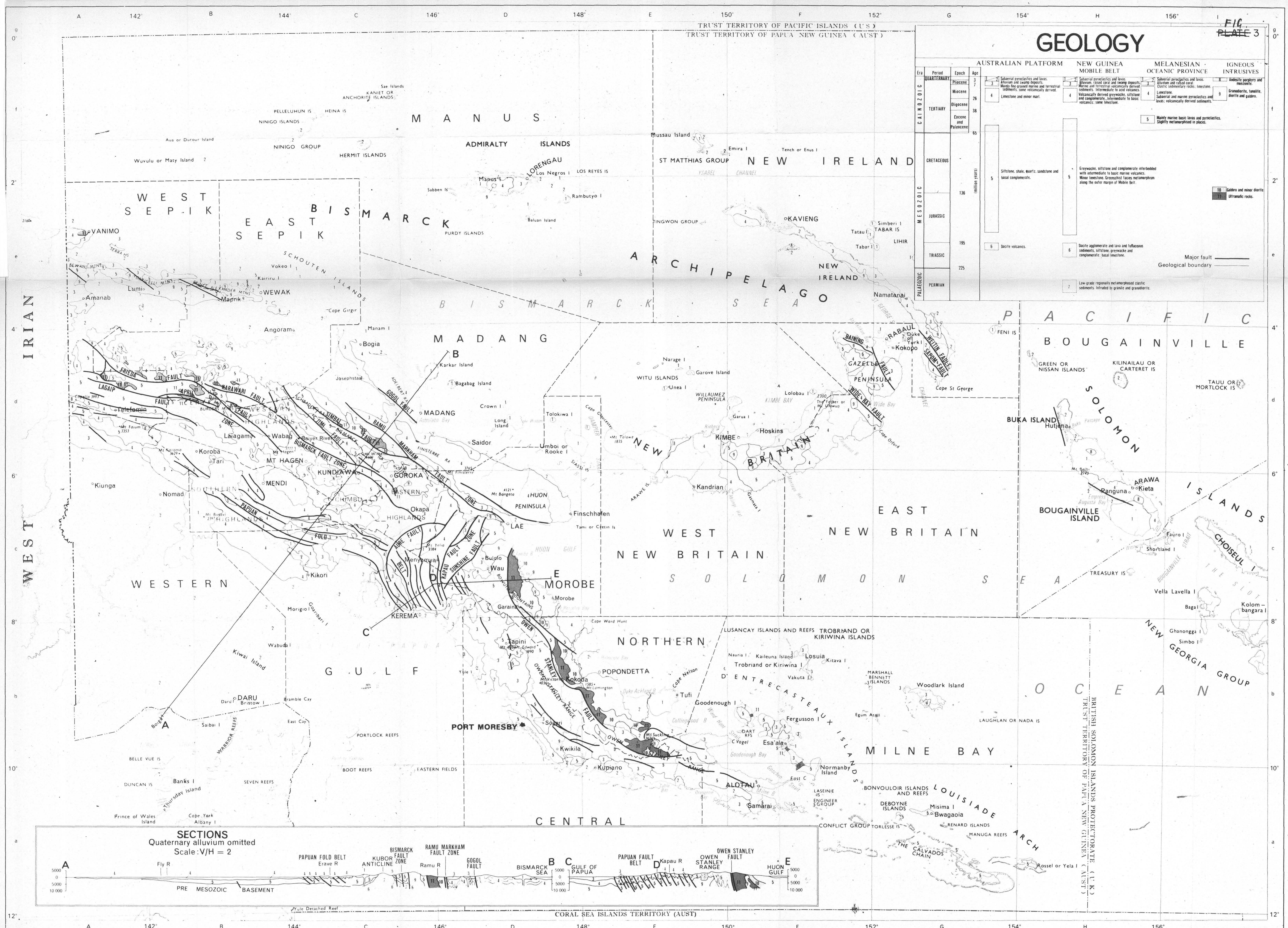

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The limits of the continental block are well defined to the north and northeast, but can only be guessed at to the east, where the continental margin is obscured by sediments of the Tertiary Aure Trough. In the north the boundary of the continental block is marked by a fault zone which separates the Mesozoic shelf sediments to the south from the deeper-water sediments to the north. This fault zone also marks the northern limit of the Tertiary shelf limestone.

In the northeast the Lagaip Fault Zone marks the continental edge, and also separates shelf and trough sediments of Mesozoic and Tertiary age (Fig. 3). It is not known whether the faults controlled the depositional environment or whether large transcurrent displacements on the faults have brought into juxtaposition contrasting sedimentary environments, although present knowledge suggests that the former is more likely.

In the east the boundary of the continent is taken at the eastern limit of the Tertiary shelf limestone as indicated by geological mapping and seismic surveys by oil exploration companies.

Igneous activity

A striking feature of the geology is the virtual absence of igneous rocks younger than Permian: no intrusive igneous rocks other than basement granite are known from any petroleum exploration wells, and the only volcanic rocks are thin dacitic lavas penetrated in two wells at the base of the sedimentary succession.

These could be equivalent to the Traissic Kana Volcanics which are a major unit in the New Guinea Mobile Belt.

Even in the peripheral 50 km of the Australian Platform, which has been mildly deformed, there was no igneous activity until the Pliocene. Thin discontinuous lava flows have been mapped in Upper Jurassic sediments in the Kubor Anticline to the north of the peripheral zone, and may be present on the continental block, but the only extensive volcanics were erupted from large stratovolcanoes of Pliocene to Holocene age.

Structure

The sediments over most of the Platform, having been protected by the underlying competent continental block, are almost completely undeformed. Minor faults have been detected by oil exploration surveys, but the sediments have essentially the same attitude as when they were laid down.

In the peripheral 50 km, however, the basement and the overlying sedimentary blanket were broadly arched along axes parallel to the continental margin, probably in the Pliocene. The Mueller Anticline in western Papua exemplifies the deformation, and is a broad anticline 100 km long and 50 km wide with limbs 40° to 50° at their steepest.

Faulting was dominant to the north in the New Guinea Mobile Belt where large fault blocks were uplifted thousands of metres in the Pliocene to form the present-day highlands. The Papuan Fold Belt (Fig. 1) which affects the uppermost Mesozoic and Tertiary sedimentary cover along the northern margin of the Australian Platform is thought, at least in the west, to have resulted largely from the effects of this uplift. The folds within the belt are long (60 km not uncommon) and narrow (3 to 5 km) with subhorizontal axes; they are markedly asymmetrical with steeper southwestern limbs which are commonly overturned and broken by northeasterly-dipping thrust-faults.

In the western half of the Papuan Fold Belt the direction of overfolding and overthrusting shows conclusively that the sedimentary cover over the whole of the fold belt has been subject to southerly or southwesterly movement, which could be largely the result of gravity sliding off the southern flank of the actively rising New Guinea Nighlands. The folding and thrust-faulting are probably confined to the upper part of the succession, decollement having taken place in the thick Cretaceous siltstone underlying the Tertiary limestone.

Upper Miocene and Pliocene sediments are involved in the folding which therefore was probably of middle or late Pliocene age.

Pliocene and Quaternary intrusions and volcanoes

The uplift of the continental margin in the Pliocene was accompanied by volcanic eruptions from scattered centres from the West Irian border to the Gulf of Papua. The earlier volcanoes, most of which lie in the west, have been almost completely eroded away, and are now represented mainly by stocks and plugs of intermediate and acid hypabyssal rocks. The Pliocene sediments to the south contain a high proportion of detritus derived from these volcanoes, showing that igenous activity began in early Pliocene time.

The high-level intrusions associated with the earlier volcanism (isotopically dated as between 1 and 5 m.y.) are of considerable economic importance because some are host to porphyry copper mineralisation, and one, the Mount Fubilan (Ok Tedi) Prospect, could be economic despite its remoteness.

The large stratovolcanoes which dominate the skyline southwest of the Wahgi valley, Mount Hagen (3775 m) and Giluwe (4370 m), are members of a group of volcanoes in the northeastern extremity of the Australian Platform (Fig. 3). They are made up of subaerial pyroclastics, lava flows, lahars, and outwash deposits (Mackenzie 1973). The volcanics range from basic to intermediate and rarely acid, and are mostly shoshonitic. In most, the original volcanic morphology is well preserved, and the oldest isotopic date so far obtained is 850 000 y. from lava from Mount Kerewa. Cold solfataric activity is known from two of the volcanoes and mention of eruptions in local legends shows that some of the volcanoes have been active in recent times.

Though no chemical analyses are available for the intrusive rocks, they were probably derived from the same high-potash magma as the volcanics. Any theory of the origin of this magma must take into account the following factors:

(a) The volcanics are confined to areas underlain by continental crust, and located near the margin of the continental block where it has borne the brunt of the collision with the oceanic plates.

(b) The Sr^{87}/Sr^{86} ratios of the volcanic rocks (Page & Johnson, in prep.) are consistently higher than those of the oceanic province. They indicate a mantle origin, but with some contamination by sialic crust.

NEW GUINEA MOBILE BELT

(References: Dow et.al., 1973; Bain et.al., in. press)

The New Guinea Mobile Belt is defined as the tectonically unstable zone between the Australian continental block to the southwest and the oceanic crustal plates of the Melanesian Oceanic Province to the north and northeast. It has been the site of intense deformation since at least the Eocene, and is characterized by major anastamosing faults which are thought to be predominantly strike-slip.

The geology of the New Guinea Mobile Belt offers a complete contrast to that of the Australian Platform, and three main features stand out. Firstly, throughout its history the Mobile Belt has been an unsettled sedimentary environment, and is the repository of a great variety of sediments several times as thick as those of the Platform (Fig. 2): most of the sediments were deposited in geosynclines, and the great majority are composed of volcanic detritus derived mainly from contemporaneous volcanoes within the Mobile Belt.

Numbers refer to localities of stratigraphic columns shown in Figures 5,7, and 9

Fig. 4. PATTERN OF SEDIMENTATION UPPER CRETACEOUS TO EOCENE.

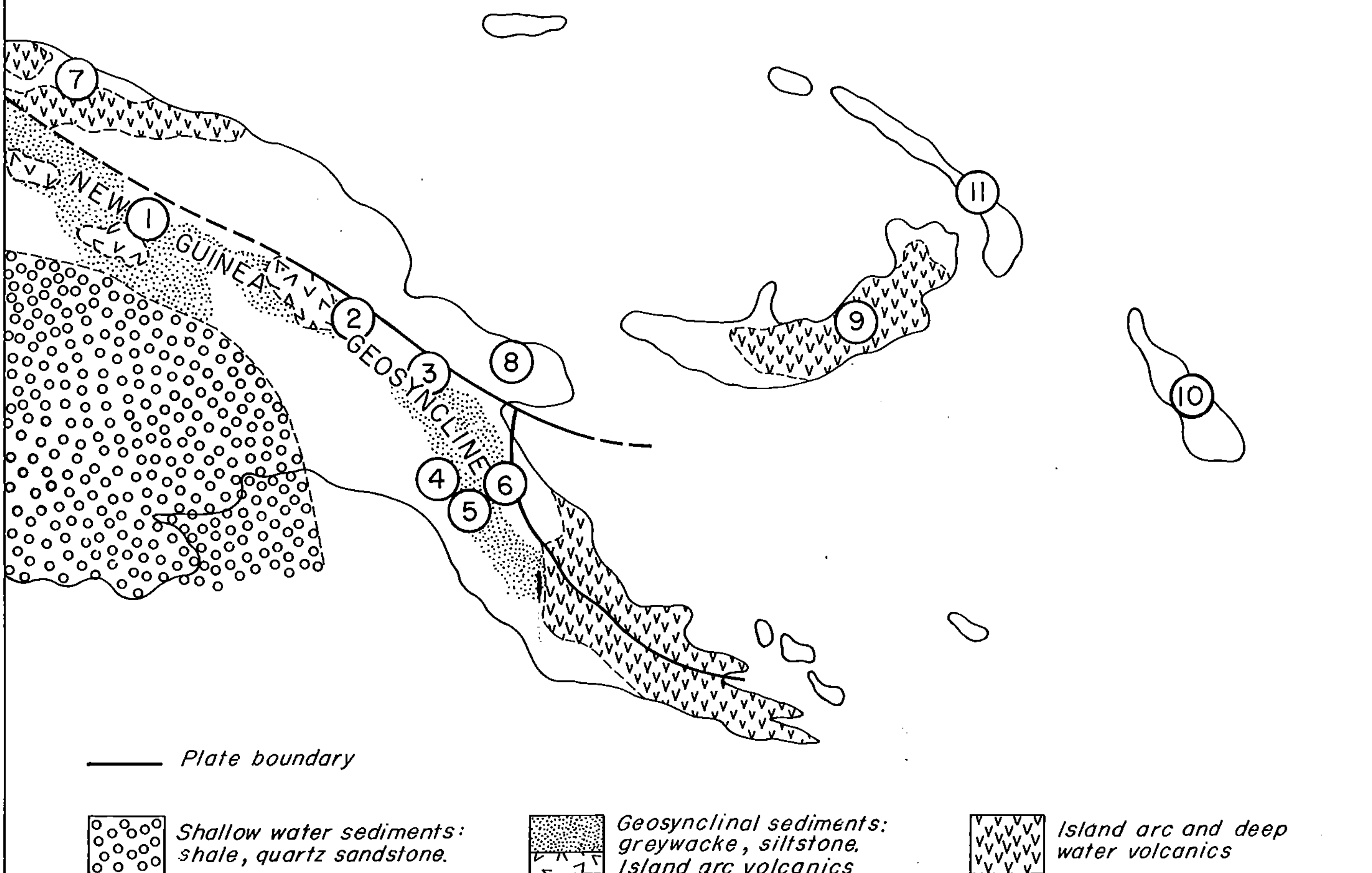

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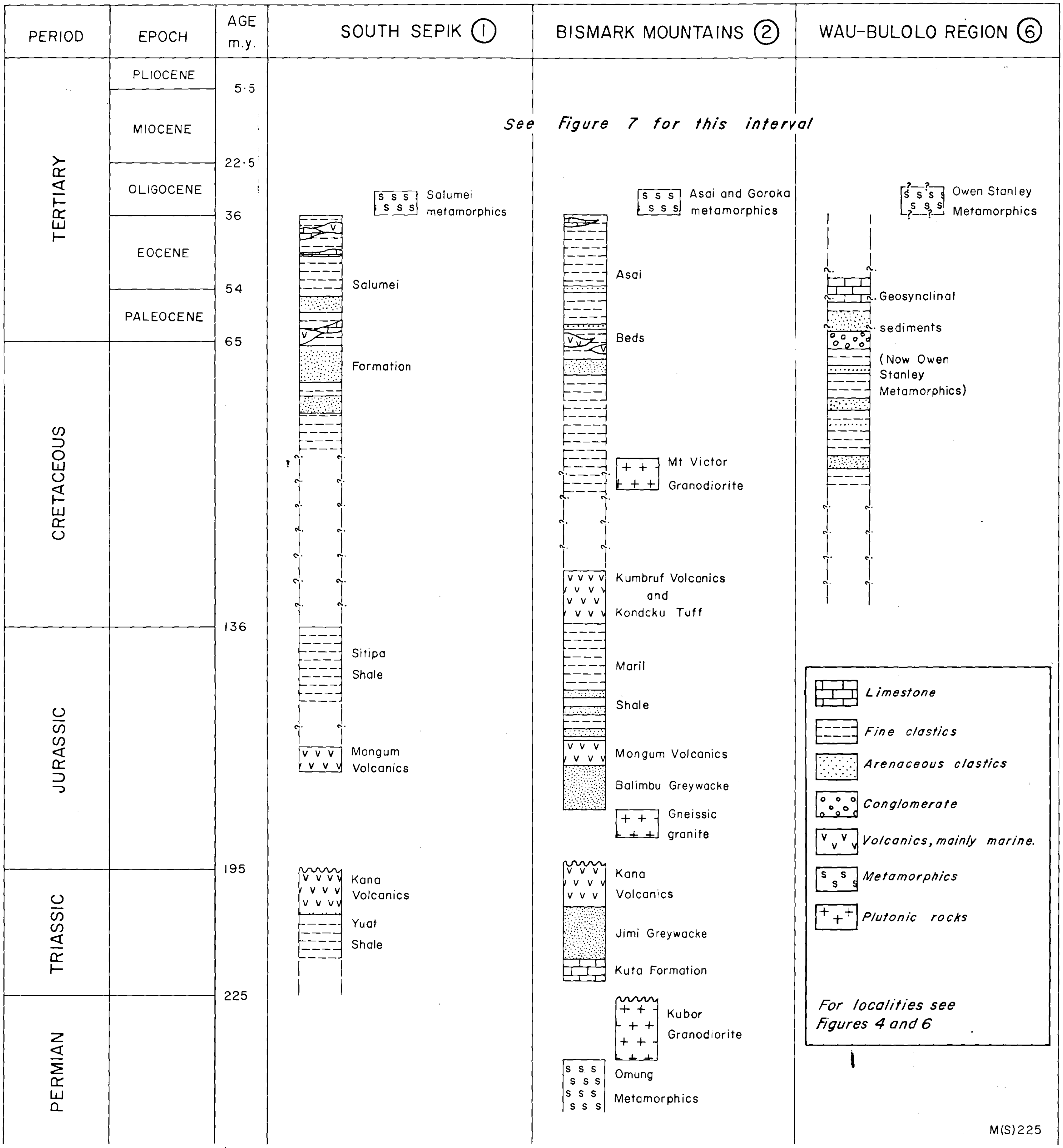
Fig. 5. GENERALIZED STRATIGRAPHIC COLUMNS NEW GUINEA MOBILE BELT, TRIASSIC TO EOCENE.



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The prevalence of igneous activity provides the second main contrast with the Australian Platform. Major volcanic units occur throughout the stratigraphic column and most are associated with acid to basic plutonic rocks.

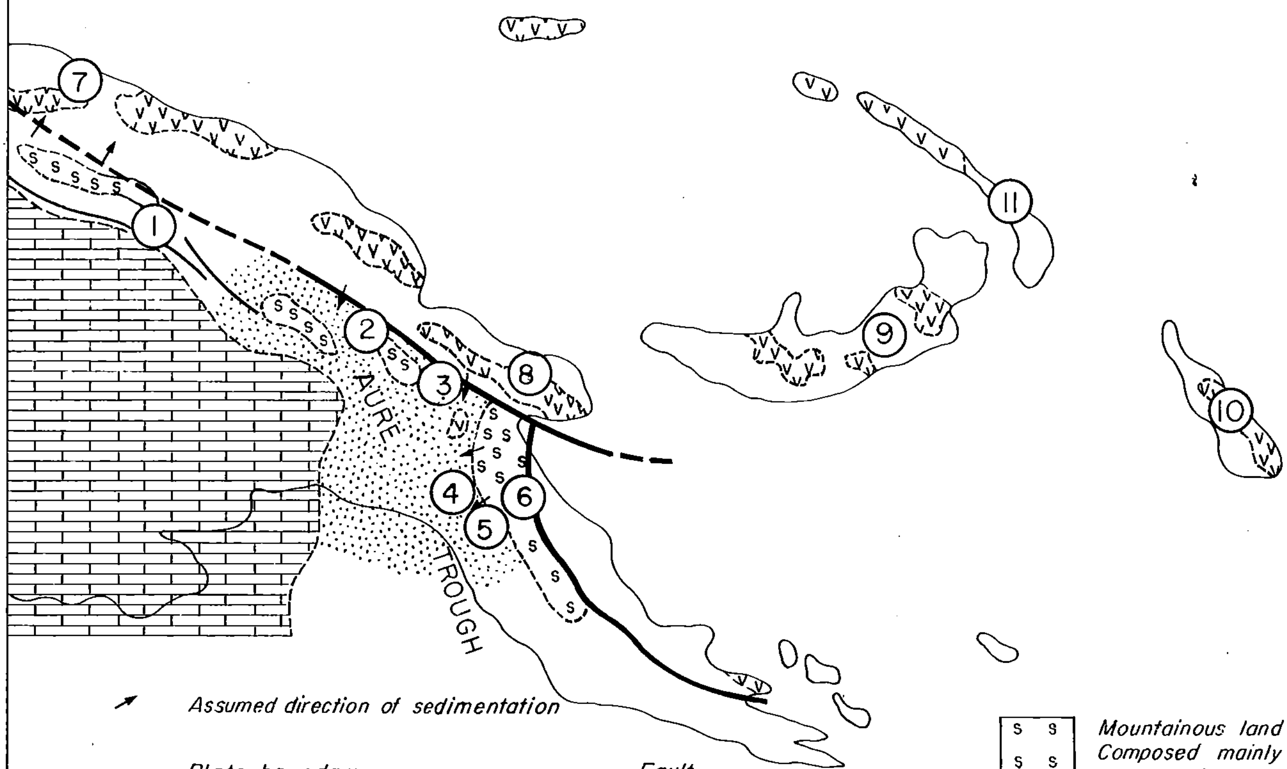
The third and most obvious difference between the two geological provinces in the intense deformation of the rocks in the Mobile Belt. Faulting over most of the Belt is extraordinarily intense - so much so that the whole Belt could be described as a fault zone. In some areas folding is dominant, particularly on the periphery of the Belt where the rocks have been metamorphosed.

The nature of the basement rocks underlying the Mobile Belt is unknown. Metamorphic rocks intruded by Permian granite form the core of the Kubor Anticline, which is interpreted as a detached fragement of continental crust, but elsewhere the oldest rocks are uppermost Permian, Traissic, and Jurassic sediments, most of which could have accumulated on oceanic rather than continental crust.

There were three main periods of sedimentation in the New Guinea Mobile Belt: (1) Triassic to Eocene; (2) upper Oligocene to middle Miocene; and (3) upper Miocene to Pliocene. The three periods form the basis of the divisions shown on the geological map (Fig. 3). Regional unconformities demarcate the main divisions, but in addition there are many unconformities and disconformities throughout the stratigraphic column; of these, an unconformity at the base of the Jurassic succession, and another at the base of the middle

Numbers refer to localities of stratigraphic columns shown in Figures 5,7, and 9

Fig. 6. PATTERN OF SEDIMENTATION OLIGOCENE TO LOWER MIOCENE.



Assumed direction of sedimentation

Plate boundary

Fault

Mountainous land Composed mainly of metamorphic rocks

Shallow water limestone

Geosynclinal sediments greywacke, siltstone

Island arc and deep water volcanics

Miocene sequence (Fig. 7), are of regional importance.

TRIASSIC TO EOCENE

Stratigraphy

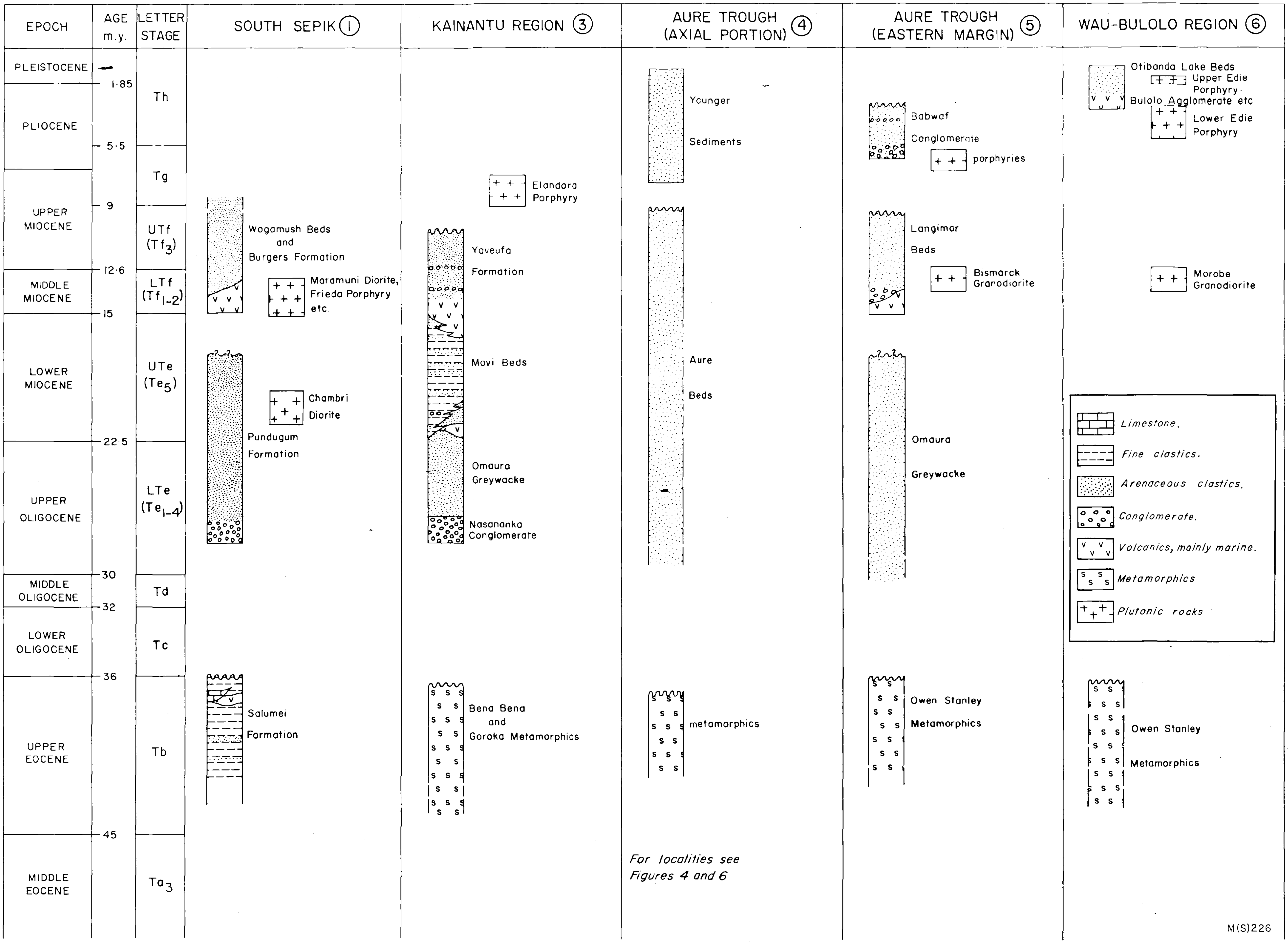
The oldest sediments, known only from the central part of the Belt to the east and north of Mount Hagen, are reef limestone and clastics of uppermost Permian age (Kuta Formation), and shelf-type clastics (Jimi Greywacke) and daoitic volcanics (Kana Volcanics) of Upper Triassic age (Fig. 5). These rocks, with a total thickness of about 3500 m, are preserved as relatively undeformed fault wedges in a short sector of the Belt between Mount Hagen and the Wahgi valley. They could be underlain by fragments of the Australian continental block detached by left lateral movement of the oceanic plates.

The Triassic rocks in the fault wedges are unconformably overlain by over 1500 m of Lower Jurassic marine volcanics, greywacke, and siltstone, which are not known elsewhere.

The first record of extensive sedimentation in the New Guinea Mobile Belt is given by the Middle Jurassic to Eocene shelf-type sediments, which crop out along the southern margin of the Belt between Goroka and the West Irian border. They are mainly shale, siltstone, and interbedded quartz sandstone similar to the sediments laid down at the same time on the Australian Platform, but are much thicker (Fig. 2) and more deformed.

In the late Jurassic or early Cretaceous a geo-syncline, here called the New Guinea Geosyncline, was

Fig. 7. GENERALIZED STRATIGRAPHIC COLUMNS NEW GUINEA MOBILE BELT, OLIGOCENE TO PLIOCENE.



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formed along the northern margin of the Belt. It extended from southeast Papua to the West Irian border and beyond (Fig. 4), and was filled with flysch-type sediments interspersed with submarine volcanics (Fig. 5). The geosyncline persisted until the Eocene in the west, and probably in the southeast also, though the youngest fossils found there in the metamorphics are Cretaceous.

The source of the geosynclinal sediments is not known, but the rock types suggest that they were derived from contemporaneous volcanism. There is ample evidence of extensive basic to intermediate volcanism within the geosyncline in the Lower Cretaceous (Kumbruf Volcanics and Kondaku Tuff), and basic marine volcanics occur sporadically in the Upper Cretaceous and Eocene. Thus although a considerable proportion of the detritus was apparently derived from submarine volcanism within the geosyncline, the bulk probably came from contemporaneous volcanism to the north.

Structure

The most severe and most widespread orogeny recorded in Papua New Guinea affected all the rocks of the Mobile Belt in uppermost Eocene or early Oligocene time. The sediments on the inner (southwestern) margin of the belt were faulted and moderately folded, but the most intense effects were confined to the outer margin where the rocks were tightly folded and metamorphosed. As a result, low-grade metamorphics now form an almost unbroken belt from the West Irian border to southeast

Papua (Salumei, Goroka, and Bena Bena Formations, Asai Beds, and Owen Stanley Metamorphics).

At least some of the major faults in the New Guinea Mobile Belt were probably active at this time, and there is evidence that the Lagaip Fault was active even earlier and controlled the sedimentary environment. However, it can be equally well argued that the juxtaposition of contrasting sedimentary environments is a result of later transcurrent faulting.

The metamorphic fringe is bounded to the north and northeast by fundamental faults which delineate the boundary with the Melanesian Oceanic Province: the Owen Stanley Fault to the northeast, the Ramu-Markham Fault Zone to the north, and a complex zone of faults in the northwest, which are covered over most of their lengths by the recent swamp deposits of the Sepik River.

This association of the metamorphics with the boundary between the provinces strongly suggests that the orogeny and consequent metamorphism were directly attributable to the interaction of the Australian continent and the oceanic plates to the north and northeast. If this is correct, it follows that the continental/oceanic plate boundary must have been more or less coincident with the present-day boundary (Fig. 1).

The metamorphics form some of the most rugged, inaccessible country in Papua New Guinea, and even in the more accessible areas, such as the Wau region near the northern end of the Owen Stanley Range, good exposures are rare, and structural interpretation is of necessity largely speculative. However, mapping in this area shows that the main foliation is parallel to the axial plane of small-scale isoclinal folds (Dow & Davies, 1964). The foliation has since been folded, but away from the Owen Stanley Fault it is only gently dipping over large areas. The gentle dip of the foliation is difficult to explain unless the original attitude was also nearly horizontal. The few known facts therefore do not conflict with a picture of large recumbent folds being formed in the Owen Stanley Metamorphics by the impact of the Papuan Ultramafic Belt in late Eocene or early Oligocene time. Glaucophane schist is widespread in the metamorphics and as it indicates highpressure/low temperature metamorphism its presence is consistent with the interpretation given above.

Igneous intrusives and mineralization

There was little plutonic igneous activity from the Triassic to Eocene in the New Guinea Mobile Belt. Several small diorite and granodiorite plutons in the Goroka-Kainantu region are unconformably overlain by upper Oligocene sediments, and have isotopic ages ranging from early Jurassic to mid-Cretaceous. Small gneissic granite bodies in the same region have no stratigraphic control, but give an early Jurassic isotopic age.

As stated above, a tectonic event in early Jurassic times is indicated by the unconformity at the base of the Jurassic succession, and it seems likely that the plutonic activity accompanied this event. No mineralization is known to be associated with these intrusives.

UPPER OLIGOCENE TO LOWER MIOCENE

Stratigraphy

Geosynclinal sedimentation resumed in the upper Oligocene with the formation of the Aure Trough to the north of what is now the Gulf of Papua (Fig. 6); the trough also extended to the northwest roughly along the site of the earlier New Guinea Geosyncline. While shelf limestone was being deposited on the Australian Platform, a thick sequence of greywacke and siltstone was being laid down in the geosyncline.

The palaeogeography is relatively well known for this period, and it has been established that a land-mass of pre-Oligocene metamorphics existed in the region of the Central Highlands between Kainantu and Mount Hagen. Much of the Owen Stanley Metamorphics in the southeast were also emergent, as shown by the prevalence of metamorphic components in the coarse clastics which were deposited on the eastern margin of the Aure Trough.

Thus we can make a well substantiated reconstruct-ion of the palaeogeography (Fig. 6) showing a shallow sea covering the Australian Platform upon which shelf limestone was being laid down, bounded in the north by a narrow geosyncline which widened markedly in the Gulf of Papua region into the Aure Trough. Mountainous land, probably in the form of an archipelago, constituted the northern margin of the geosyncline. The major rock units laid down during the period are shown in Figure 7.

Although some of the detritus was derived from metamorphic source rocks, the bulk of the sediment laid down in the geosyncline consisted of fresh volcanic material. This high proportion of volcanic material is surprising because the only volcanic rocks known within the geosyncline are thin discontinuous basic lava and agglomerate found near the eastern margin of the Aure Trough. As no volcanic detritus was being deposited on the Australian Platform, the provenance must have been to the north, and could possibly have been the island volcanics known to have been active in the Melanesian Oceanic Province (see later).

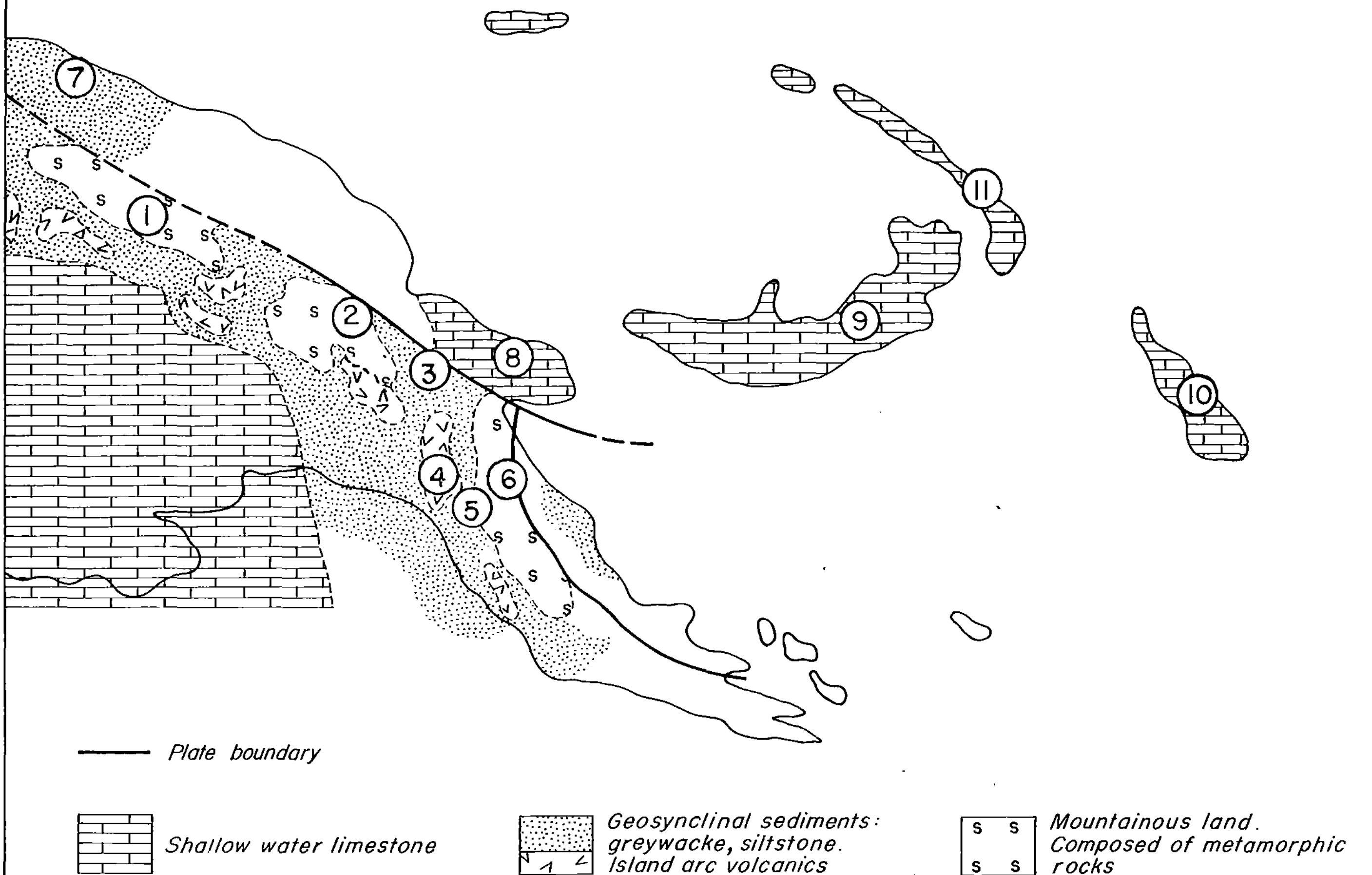
Structure

A mild orogeny interrupted sedimentation in the lower Miocene, and the resulting unconformity can be mapped over much of the Mobile Belt (Fig. 7). It cannot be distinguished in the central part of the Aure Trough, possibly because it has been obscured by late folding and faulting, but more probably because sedimentation was continuous in the deeper part of the trough.

The deformation was especially intense along the eastern margin of the Aure Trough where shelf-type sediments were laid down on the flanks of the Owen Stanley Metamorphics. The rocks have a well developed axial-plane cleavage, and in places are weakly metamorphosed; there is some evidence that some of the less metamorphosed rocks mapped as Owen Stanley Metamorphics are in fact these highly cleaved Oligocene/Miocene sediments (Dow et.al., in press).

Numbers refer to localities of stratigraphic columns shown in Figures 5, 7, and 9

Fig. 8. PATTERN OF SEDIMENTATION MIDDLE MIOCENE.



Igneous intrusives and mineralization

There was insignificant igneous activity within the New Guinea Mobile Belt during sedimentation and deformation in the lower Miocene. The only volcanics in the sequence are thin sporadic submarine basalts on the western margin of the Aure Trough, and the only intrusives known are small granodiorite/diorite batholiths along the northern part of the Mobile Belt south of the Sepik River. The intrusives have been isotopically dated as lower Miocene (20-22 m.u.) (Page, in prep.). No economic mineral deposits are associated with any of the rocks formed during this period.

As with the earlier orogeny, it is postulated that the lower Miocene deformation was the result of accelerated interaction between the two crustal elements.

MIDDLE MIOCENE

Middle Miocene rocks are well exposed throughout most of the New Guinea Mobile Belt, and it is possible to reconstruct the palaeogeography in some detail.

Stratigraphy

Sedimentation followed the Oligocene/lower Miocene pattern with a marine trough extending along the full length of the Mobile Belt (Fig. 8); the trough was flanked by shelf limestone of the Australian Platform in the south and an archipelago of metamorphic rocks to the north. There was, however, one extreme contrast with the earlier geosynclines because intense island arc volcanism was active throughout its length. The products are preserved along the axis of the trough, and consist of lavas and agglomerate of basic to intermediate composition and a great variety of coarse clastics composed almost entirely of volcanic detritus. Lenses of coralline limestone containing a variety of volcanic pebbles and cobbles are common, and were coral reefs fringing the volcanic islands. Away from the volcanic arc, feldspathic sandstone and greywacke grade into marly siltstone near the southern margin of the trough.

Sedimentation continued until the upper Miocene, and as most of the Mobile Belt was tectonically active for most of the time, the sediments are mainly coarse clastics which commonly show great lateral and vertical variation.

Structure

The middle Miocene was a period of strong faulting when most of the faults shown on the geological map (Fig. 3) were active, especially south of the Sepik River where the Maramuni Diorite was upfaulted and eroded shortly after it was emplaced.

Other faults had a marked effect on the sedimentary environment - for example, the Lagaip Fault Zone in the Wabag area, which separated the shelf environment to the south (in which shallow-water limestone was being laid down) from the trough in which the volcanics and volcanolithic sediments of the Burgers Formation were being deposited.

Folding which accompanied the faulting was generally mild, and the competent rocks, such as the volcanics and coarse clastics, occur as broad shallow synclines. The less competent beds, such as the sediments in the Aure Trough, are tightly folded, but it is not known how much of the folding is attributable to later Pliocene tectonism.

Igneous intrusives and mineralization

The middle Miocene was a period of intense plutonic activity during which batholiths and stocks, ranging from granodiorite and adamellite to gabbro, invaded the rocks of the Mobile Belt from the West Irian border to the Wau-Bulolo region at the northern end of the Owen Stanley Range.

Few plutonic events have been so exhaustively dated (Page, in prep.), and it has been shown conclusively that the bulk of the plutons were emplaced between 12 and 15 m.y. ago.

Apart from ubiquitous but sparse gold mineralization associated with the acid and intermediate intrusives, the only promising metalliferous prospect formed during this intrusive episode in the New Guinea Mobile Zone is the Frieda Copper Prospect in the south Sepik region. This is a porphyry copper deposit in highly altered intermediate porphyry which has been dated as middle Miocene (15-16 m.y.) (Page & McDougall, 1972). Many other occurrences of disseminated copper mineralization are known in these intrusives, but none has proved worthy of more than preliminary exploration.

UPPER MIOCENE TO PLIOCENE

Stratigraphy

After a period of widespread erosion in the upper Miocene, sediments of late upper Miocene and Pliocene age were laid down unconformably on the older sediments in restricted shallow basins.

The sediments consist of a variety of coarse clastics derived from terrestrial volcanoes active in the highlands.

Structure

The great uplift which shaped the present-day morphology began late in the Pliocene. Vertical displacements of the order of thousands of metres occurred on faults flanking the highlands, most of which had been active in the Miocene.

Uplift has continued unabated to the present day, keeping pace with the rapid erosion caused by high rainfall and tropical weathering, and so maintained the rugged mountainous character of Papua New Guinea.

PLIOCENE METALLOGENIC EPOCH

The important period of Pliocene volcanic and plutonic activity on the Australian Platform has its counterpart in the New Guinea Mobile Belt. Porphyry stocks, mainly of intermediate composition, were intruded sporadically along the Mobile Belt throughout the period of uplift (Page & McDougall, 1972).

These igneous rocks, along with those of the same age in the Australian Platform and the Melanesian Oceanic Province, have introduced by far the greatest proportion of metals mined in Papua New Guinea, both from primary lodes and alluvial deposits.

All the primary gold mined, with the possible exception of the lodes on Woodlark Island, owes its origin to these young intrusives. The important porphyry copper deposits of Panguna and Mount Fubilan also belong to this metallogenic epoch.

The principal deposits of alluvial gold, which constitute most of the mineral wealth so far won in Papua New Guinea, derive from this epoch, and are located at Porgera, Mount Hagen, Jimi River, Simbai River, Kainantu, Wau-Bulolo, and Waria River.

The reason for this concentration of metallic mineralization is not known, but part of the answer probably lies in the fact that in such a tectonically active region the chances of the upper, more mineralized, parts of igneous intrusions being preserved are much greater for such young rocks.

MELANESIAN OCEANIC PROVINCE

The rocks of the Melanesian Oceanic Province are quite different from those of the Australian Platform or the New Guinea Mobile Belt, and consist entirely of the products of oceanic volcanism. They comprise lavas extruded on the deep ocean floor, and island arc submarine lavas and agglomerates, tuffs, volcanolithic sediments, and some reef limestones.

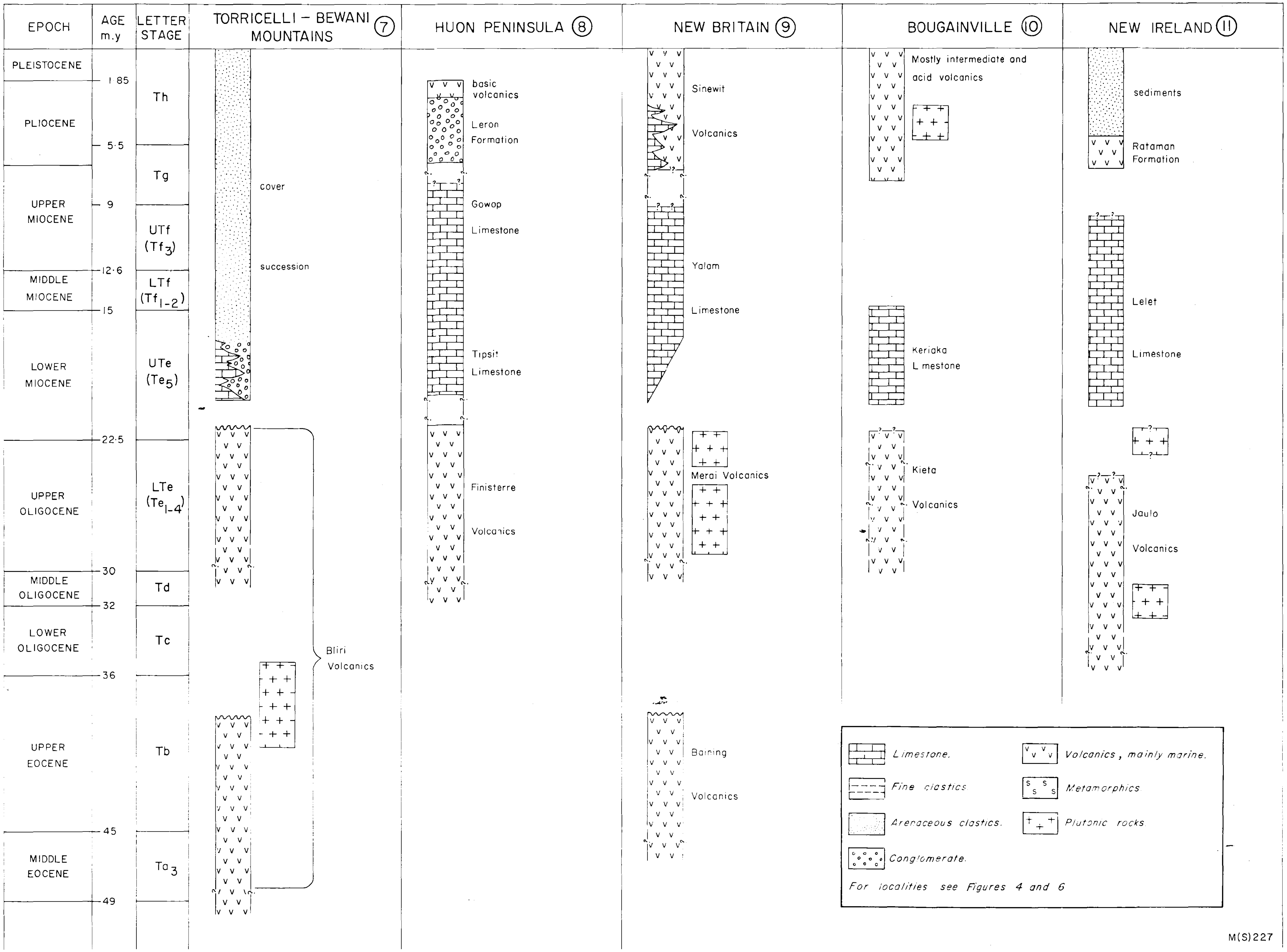
The boundary between the New Guinea Mobile Belt and the Melanesian Oceanic Province is well defined, except in the northwest where it is concealed by the swamps of the Sepik River.

From the Huon Gulf to near the southeastern extremity of the mainland, the Owen Stanley Fault Zone has brought the Papuan Ultramafic Belt into contact with Owen Stanley Metamorphics. The ultramafic rocks and layered gabbro of the Ultramafic Belt, and overlying deep ocean basalts of Eocene age, are thought to represent a section of mantle and oceanic crust that has been upfaulted along the Owen Stanley Fault Zone (Thompson & Fisher, 1965; Davies, 1971).

Northwest of the Huon Gulf the Ramu-Markham Fault Zone forms the boundary between the Oligocene and Miocene volcanics and volcanolithic sediments of the Oceanic Province, and the metamorphics along the northern fringe of the Mobile Belt. The Marum Basic Belt, a large wedge of layered gabbro and ultramafics north of the Simbai Fault, by analogy with the Papua Ultramafic Belt, is probably an unfaulted segment of mantle material.

The northwestern continuation of the Ramu-Markham Fault Zone is obscured by the swamps of the Sepik River, and there is some uncertainty as to the location of the boundary between the provinces. The mountain ranges north of the Sepik River consist of Eocene to lower Miocene oceanic volcanics and volcanolithic sedi-

Fig. 9. GENERALIZED STRATIGRAPHIC COLUMNS MELANESIAN OCEANIC PROVINCE, EOCENE TO HOLOCENE.



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ments of the Melanesian Oceanic Province, whereas the mountains to the south of the Sepik River are made up in part of metamorphic rocks of the Mobile Belt, so the boundary must lie somewhere between. Mapping by the Bureau of Mineral Resources in 1972 has shown that Cretaceous to Eocene metamorphics of the Salumei formation extend northwestwards across the Sepik River to the West Irian border, and it is therefore likely that the boundary between the provinces trends diagonally across the Sepik plains to the north of Ambunti as shown in Figure 4.

Large masses of fresh peridotite, with a total outcrop area of about 800 km^2, intrude the Salumei Formation in the very highly faulted region south of the Sepik River; they are associated with glaucophane schists and eclogitic rocks. The faulted region is not far from the postulated boundary of the province under the Sepik plains, and it is thought that the peridotite bodies originated in the mantle of the Melanesian Oceanic Province, and were upfaulted into their present positions.

The oldest rocks exposed in the Oceanic Province are marine volcanics of Eocene age (Fig. 9). In the overlying volcanic and sedimentary successions there are the same breaks in sedimentation as found in the New Guinea Mobile Belt - that is, in the Oligocene, lower Miocene, and Upper Miocene. The igneous and tectonic event which took place in the Mobile Belt in the middle Miocene is not seen in the Melanesian

Oceanic Province, where limestone deposition was apparently continuous throughout the lower and middle Miocene.

EOCENE

Stratigraphy and structure

Eocene rocks are found in the ranges north of the Sepik River and in New Britain; they consist of submarine volcanics and subordinate volcanolithic sediments. They are predominantly calcalkaline basaltic andesite and basalt. The sequences consist of pillow lavas, agglomerate, and tuffaceous sediments with numerous lenses of coralline reef limestone containing abundant volcanic clasts. The lavas and semiments were derived from island volcanoes fringed by coral reefs.

The evidence for a hiatus in Oligocene time is not as conclusive as in the Mobile Belt, mainly because the structure of the overlying and underlying rocks is virtually unknown (New Britain) or so complex (north of the Sepik River) that no structural discontinuity can be proved. However, three factors point to a major break in sedimentation in the lower and middle Oligocene:

(a) In New Britain the Eocene Baining Volcanics are much more highly altered than the overlying rocks, and in places are metamorphosed to the greenschist facies.

(b) Batholiths of granodiorite and diorite north of the Sepik River have been reliably dated by the K-Ar method as 35 to 40 m.y. old (recent determinations by AMDEL for BMR), and tonalite in east Papua is 50-55 m.y. old (Davies 1971).

(c) Although Foraminifera are common, there is a conspicuous lack of fossils of lower and middle Oligocene age (Tertiary c and d Stages) throughout most of the Oceanic Province.

Igneous intrusives and mineralization

The Eocene intrusives north of the Sepik River are complex batholiths ranging in composition from granodiorite to gabbro; no economic mineralization is associated with them, but the alluvial gold mined north of the Sepik River has been shed from lower Miocene conglomerates, and may have been derived from the granodioritic intrusives.

UPPER OLIGOCENE TO LOWER MIOCENE

Upper Oligocene to lower Miocene volcanics and volcanolithic sediments are known throughout the Oceanic Province. They are generally less indurated than the Eocene beds, but in many areas where there is no palaeontological control it is not possible to map them separately.

In New Ireland, the presence of Tertiary c-Stage limestone in the succession indicates that deposition continued over a longer period, possibly spanning the postulated Oligocene hiatus.

Igneous intrusives and mineralization

The age of the granodiorites and diorites, which are widely distributed in New Britain, ranges from 22 to 29 m.y. (R.W. Page, pers. comm.). Disseminated copper mineralization is associated with several of the stocks, and the island appears to be a promising porphyry copper province.

Similar intrusives are common in New Ireland; their precise age is uncertain, but they are overlain by middle Miocene limestone and an andesite intrusion in the Jaulo Volcanics has an isotoptic age of 31 m.y. The available evidence does suggest that the New Ireland intrusives are about the same age as the New Britain ones. They are also hosts for disseminated copper mineralization.

LOWER TO UPPER MIOCENE

Early in the lower Miocene, volcanism ceased in the Melanesian Oceanic Province. Throughout the islands and in the Huon Peninsula, only limestone and subordinate fine-grained calcareous sediments were deposited until the resumption of volcanic activity in the uppermost Miocene (Fig. 9).

Only north of the Sepik and Ramu Rivers was abundant terrigenous material deposited; it was eroded from mountains along the New Guinea Mobile Belt to the south. The sediments consist mainly of lithic arenite with massive polymict conglomerate at the base.

UPPERMOST MIOCENE TO HOLOCENE

In common with the Australian Platform and the New Guinea Mobile Zone, the late Cainozoic was a period of accelerated igneous activity which has continued to the present day. In the Melanesian Oceanic Province an influx of volcanic detritus in the uppermost Miocene or lower Pliocene sediments marks the beginning of volcanic activity throughout most of the province.

Four main volcanic zones (Johnson et. al., in press) have been recognized: the Bismarck and New Ireland volcanic arcs, Bougainville Island, and south-eastern Papua.

The Bismarck volcanic arc is related to a well defined Benioff Zone which dips northwards beneath New Britain. Active or dormant volcanoes extend along the length of the arc from Rabaul in the east near Wewak in the west, and it remains the most active volcanic region in Papua New Guinea.

In the Bismarck arc, andesite predominates, but basalt and dacite are common and rhyolite is rare. The volcanics show affinities with both the tholeiitic and calcalkaline suites.

The New Ireland volcanic arc extends from the Admiralty Islands in the west to the volcanic islands along the northeast ooast of New Ireland. Seismic activity along the arc is much less intense than in the Bismarck arc and there is only one active volcano, although several volcanoes still show solfataric activity.

The small number of analyses available indicates that the lavas are shoshonitic.

Bougainville Island has only one active volcano, but others still show solfataric activity. Intense seismic activity defines a vertical Benioff Zone beneath the island. The rocks are mainly calcalkaline andesite and dacite, and some of which have a moderately high potash content.

Southeast Papua has several active volcanoes, including Mount Lamington which erupted devastatingly in 1951. The lavas are similar to those of the Highlands and are shoshonitic and calcalkaline: the shoshonitic lavas are mainly basaltic, and the calcalkaline rocks mainly andesitic.

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