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Terranes and the accretion history of the New Guinea orogen

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The New Guinea orogen consists of a southern part that was formerly the northern edge of the Australia craton and a northern part that consists of at least thirty-two tectonostratigraphic terranes, many of them composite in nature. Many of these terranes are of oceanic affinity, but the western part of the orogen is dominated by terranes of continental affinity. An analysis of the accretion history of the orogen shows that the orogen was initiated in middle to late Oligocene time. Older Palaeogene deformation events, previously thought to mark the initial stages of orogenesis, occurred as amalgamation formed composite terranes at sites in ocean basins far removed from the edge of the Australian craton. The accretion that led to formation of the orogen took place because the northward-moving Australian craton entered subduction zones at which composite terranes had been assembled.

Introduction

The concept that the western part of the Cordillera of western North America constitutes a vast tectonic collage of tectonostratigraphic terranes (Coney & others, 1980) has greatly influenced recent thinking about the evolution of orogenic belts, particularly those of the circum-Pacific region.

Tectonostratigraphic terranes are internally homogeneous geological provinces, the stratigraphy, fauna, tectonic style, palaeomagnetic signature and history of which contrast with those of adjoining provinces. Boundaries between terranes are sharp structural junctions, which cannot be easily explained by normal changes in facies, gradation in structural style or unconformities. Individual terranes vary from small allochtons to major geological provinces. Most are of unknown palaeogeography with respect to the nearby craton margin, and it was for this reason that Coney & others (1980) referred to them as suspect terranes.

Once the craton margin within an orogen has been identified, the remainder of the orogen comprises terranes. By identifying the terranes and using the techniques of terrane analysis (Jones & others, 1983) it may be possible to establish a time frame for the juxtaposing of the terranes with the craton and each other.

In this paper we apply the terrane concept to the island of New Guinea (Fig. 1), drawing on the results of recently completed reconnaissance geological mapping in western Irian Jaya, and a comprehensive program of regional geological mapping in Papua New Guinea (PNG). We identify the Mesozoic margin of the Australian craton in New Guinea (Thompson, 1962; Pigram & Panggabean, 1984) (Fig. 2) and 32 tectonostratigraphic terranes that lie outboard of the craton margin.

The New Guinea orogen has long been recognised as a product of collisional processes along the northern edge of the Australian craton. Wegener (1920), who postulated that the Australian continent had forced its way between the island chain of southeast Indonesia and the Bismarck Archipelago, thought that the mountain building preceded this collision rather than being caused by it. Later workers, particularly those working in Papua New Guinea (PNG) who reviewed the over-all development of the orogen, recognised that the Australian craton formed the southern part of the orogen and that the northernmost part consisted of one or more island-arc complexes (Thompson & Fisher, 1967; Thompson, 1967, 1972; Dewey & Bird, 1970; Page 1971; Davies & Smith, 1971; Davies, 1977; Dow, 1977; Jaques & Robinson, 1977; Hamilton, 1979; Kroenke, 1984). It was argued that the collision of the craton with the island-arc complex or complexes led to the formation of the orogen by telescoping of the craton margin, the emplacement of forearc material (ophiolite, metamorphics) over it, and the accretion of the island arc or arcs. The collision generally was seen as a synchronous event along that part of the craton margin east of Sarera Bay, although Davies (1982b) and Kroenke (1984) have argued for multiple collisions. Evidence indicated that the timing of the collision ranged from Eocene in east PNG to late Oligocene — early Miocene in western PNG, and many other details of the history of the orogen were not easily reconciled with the model of a simple continent/island arc collision.

Two of the earlier workers, in particular, anticipated the terrane concept. They were J.J. Hermes and J.E. Thompson. Hermes postulated that western Irian Jaya consisted of a number of unrelated fragments that were not juxtaposed until the mid-Tertiary (Visser & Hermes, 1962, p. 206, figure IV-2). Similarly, Thompson (1967, Thompson & Fisher, 1967) suggested that much of the orogen north of the craton margin was made up of 'sialic segments that moved independently within the oceanic crust' (Thompson & Fisher, 1967, p. 144).

Former craton margin in New Guinea

The New Guinea orogen occupies a large part of the island of New Guinea and adjacent small islands. That part of the orogen occupied by the deformed craton margin is shown in Figure 2. The craton consists of a southern autochthonous portion and a northern para-autochthonous portion, which forms the southern part of the orogen. Studies of the para-autochthonous portion by Hobson (1986) suggest that parts of the craton have been thrust southward by as much as 100 km.

This former margin developed in the early Mesozoic (Pigram & Panggabean, 1984) and, during Jurassic to Palaeogene time, was a passive margin across which miogeoclinal sediments were draped (Thompson & Fisher, 1967; Dow, 1977; Brown & others, 1980). The correct eastern limits of the craton were not recognised until Symonds & others (1984) pointed out that the Coral Sea was surrounded by passive continental margins. Before the initiation of the orogen and after the opening of the Coral Sea the northern margin of the Australian craton probably had the configuration shown in Figure 4A.

Western Irian Jaya has also been regarded as part of the craton (see Hamilton, 1979; Dow & Sukamto, 1984) that has always occupied its present-day position relative to the craton. However, Pigram & others (1982) and Pigram & Panggabean (1984) have argued that it is allochthonous, and palaeomagnetic data (Giddings & others, 1985) support this suggestion. In this paper, western Irian Jaya is shown to consist of a number of terranes and its accretion history is examined.

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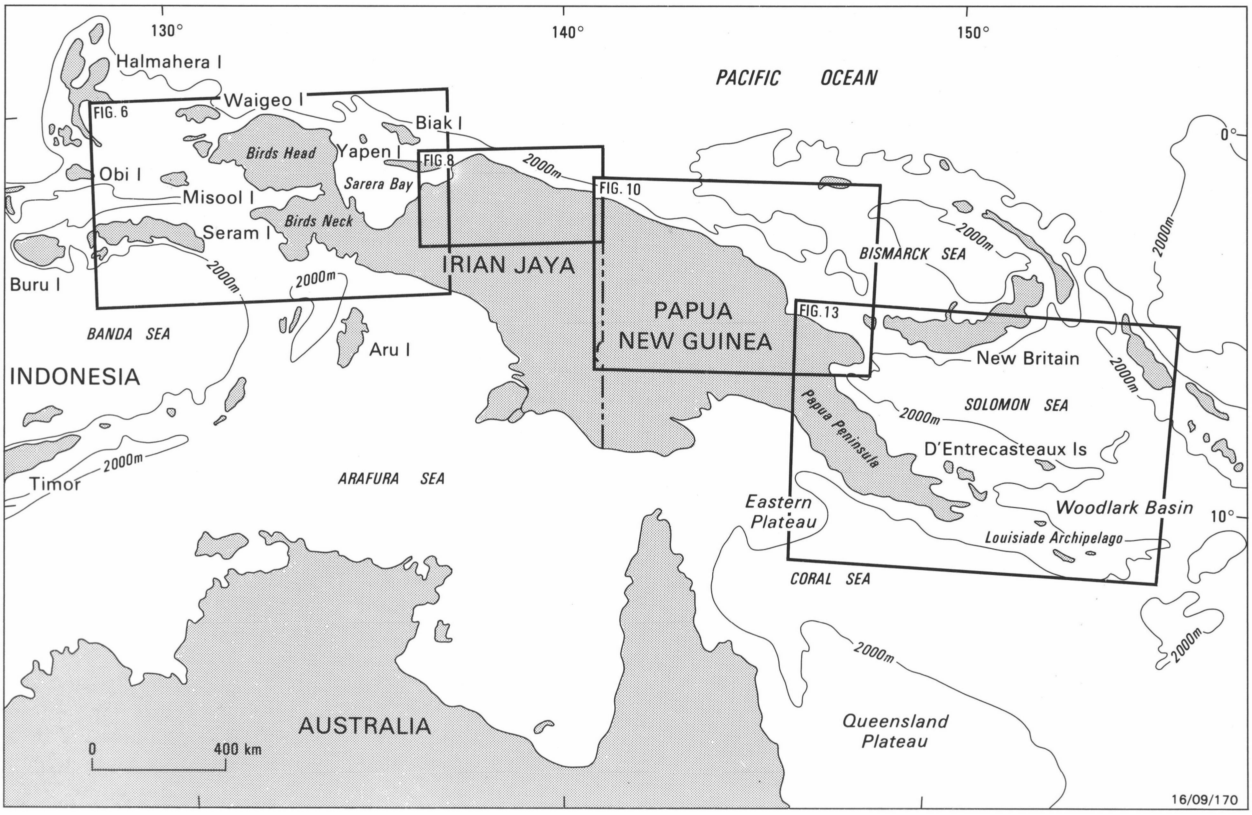

Figure 1. Locality map of New Guinea.
Boxes show the location of Figures 3, 5, 7, 10.

Terranes of the New Guinea orogen

Using comparative stratigraphy, we have identified thirty-two terranes in the New Guinea orogen (Figs 2, 6–14). Descriptions of each terrane are contained in Appendix 1. Below, we summarise the affinities of each terrane, discuss briefly the successor basins, and establish the accretion history of the orogen from a terrane analysis. The time frame developed for the evolution of the orogen reconciles many of the conflicts in previous interpretations.

Terrane affinities

The terranes of New Guinea each record unique stratigraphic histories, which reflect widely varying depositional environments, ranging from terranes with continental basement and well-layered inner shelf sedimentary strata, such as the Kemum terrane, to deep-water chert and carbonate-dominated terranes, formed far from sources of terrigenous detritus (Port Moresby terrane), to island-arc terranes with ophiolite basement such as the Waigeo terrane. The interpreted orgin of each terrane in terms of a continental or oceanic setting is shown in Table 1.

The Jimi, Bena Bena, and Lengguru terranes are considered to be part of the collision-deformed continental margin of the Australian craton. The Kemum and, possibly, the Misool terranes are former microcontinents rifted from Gondwana in the early Mesozoic (Pigram & Panggabean, 1984; J.W. Giddings, personal communication, 1984) and reunited by accretion in the late Tertiary. Ophiolitic and island-arc complexes such as the Bowutu and Finisterre terranes form a major part of the orogen, particularly along its northern or outer part.

The terranes typically are separated by faults or sedimentary basins. The nature of the faults is usually not clear. Some, such as the Sorong Fault Zone, are transcurrent; others, such as the Owen Stanley Fault, are thought to be thrusts. Many of the long linear faults that separate terranes have long been suspected of transcurrent movement (Thompson & Fisher, 1967; Bain, 1973), but unequivocal evidence is lacking. In the North American Cordillera many of the faults are thought to have caused displacements that led to dismembering and reorganisation of terranes after accretion (Coney & others, 1980). Such processes have probably occurred in New Guinea also, but have not been proven. The eastern end of the orogen is now being dismembered by the opening of the Woodlark Basin by seafloor spreading.

A feature of the New Guinea orogen is the large number of post-accretion basins that have formed across terrane boundaries, particularly those separating composite terranes. These include the Salawati, Bintuni, and North New Guinea Basins of Irian Jaya, and the Lumi, Aitape, Wewak, and Aure Troughs of Papua New Guinea. All these basins are of Miocene and younger age; they formed rapidly and typically contain 3–7 km of turbiditic sediments (Visser & Hermes, 1962; Brown & others, 1975; Pieters & others, 1983; Williams & Amiruddin, 1983; Hutchison & Norvick, 1980). Some of the basins were short lived: for example, the North New Guinea Basin of northern Irian Jaya formed in late Miocene or early Pliocene times, but has been deformed. The sequence has been faulted, folded, in part overturned, and intruded by extensive shale diapirs (Williams & Amiruddin, 1983; Williams & others, 1984). The basin existed for less than 10 Ma. The manner in which these basins formed and their relation to terrane accretion lies beyond the scope of this paper. However, some of the basins may be pull-apart

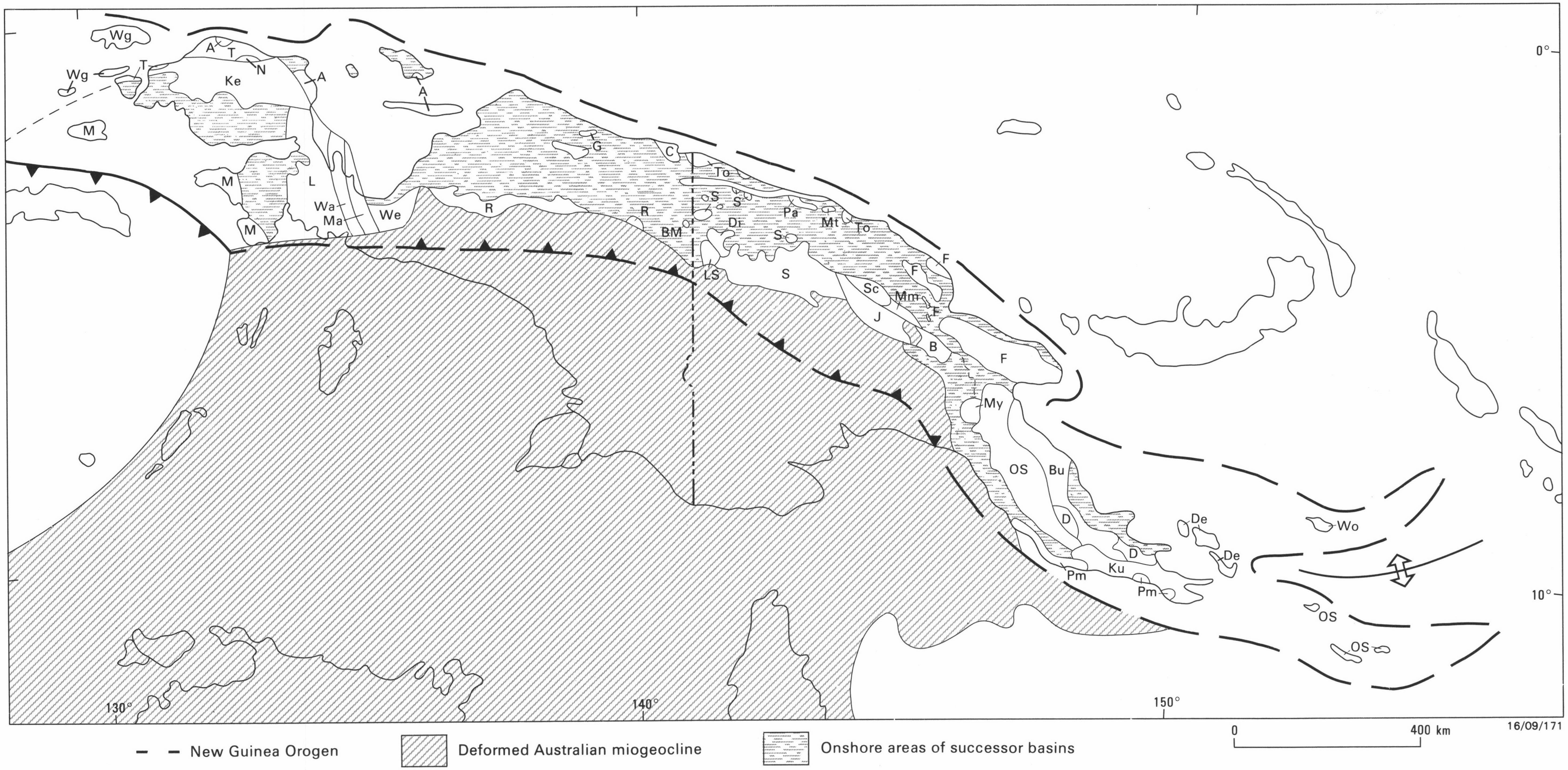

Figure 2. The New Guinea orogen and terranes described in this paper.
That part of the Australian craton which forms the southern part of the orogen is indicated. Only the onshore parts of various successor basins are shown. Wg, Waigeo; M, Misool; T, Tamrau; A, Arfak; Ke, Kemum; L, Lengguru; Wa, Wandamen; Ma, Maransabadi; We, Weyland; R, Rouffaer; G, Gauttier; C, Cyclops; BM, Border Mountains; To, Torricelli; S, Sepik; LS, Landslip; Di, Dimaie; Pa, Prince Alexander; Tu, Mount Turu; J, Jimi; Sc, Schrader; Mm, Marum; Bb, Bena Bena; F, Finisterre; My, Menyamya; OS, Owen Stanley; B, Bowutu; D, Dayman; PM, Port Moresby; Ku, Kutu; De, D'Entrecasteaux; Wo, Woodlark. Descriptions of each terrane are contained in Appendix 1.

Table 1. Affinities of the tectonostratigraphic terranes in the New Guinea orogen.

Ocean floor (Seamounts, Plateaus)	Volcanic arc	Margin (slope rise)	Platform
Bowutu	Finisterre	Tamrau	Prince Alexander
Marum	Torricelli		Bena Bena
Mt. Turu	Arfak		Jimi
Rouffaer	Dimaie		Netoni
Menyamya	Woodlark		Mangguar
Cyclops			Border Mountains
?Dayman			Wandamen
Kutu			Schrader
Port Moresby			Kemum
.... Waigeo.............			Landslip
.............?Gauttier.............			Misool
		Weyland	
		Owen Stanley	
		Lengguru	
		?D'Entrecasteaux	
..............................Sepik..............................			

structures (e.g. Waipoga Basin). Others, such as the Pliocene Aure Trough may be more akin to molasse basins formed by downwarp caused by loading due to the overthrust of terranes. Davies (1977) and Davies & others (1984) have suggested that the small basins at the eastern end of the Papuan Peninsula are related to the formation of the Woodlark spreading centre.

The great variety of basin-forming mechanisms in the New Guinea orogen shows the complexities of modern analogs for the basins in which the thick, now highly deformed Mesozoic flysch that separates some of the terranes in the North American Cordillera were deposited (Coney & others, 1980; Jones & others, 1982).

Accretion history

The accretion history of an orogen can be gleaned from the ages of cover sequences (successor basins or overlap assemblages of Jones & others, 1983), the depositional age of detritus shed from one terrane to another (provenance linking of Jones & others, 1983), the age of intrusive rocks that were emplaced across terrane boundaries (stitching plutons of Jones & others, 1983), and metamorphic, structural, palaeontological, and palaeomagnetic histories (Jones & others, 1983; Williams & Hatcher, 1982). Further indications for the timing of accretion events can be obtained from the time of and stages in the development of the foreland basin. Beaumont (1981) and Jordon (1981) have shown that foreland basins develop as a consequence of loading the craton and, as terrane accretion is a loading event on the craton margin, it will initiate the development of a foreland basin. In the absence of other constraints on the timing of accretion events, the history of the foreland may provide useful clues. An outline of the accretion history of the New Guinea orogen is presented below.

Western Irian Jaya

Western Irian Jaya is unique in the New Guinea orogen in that its accretion history involves mainly continental terranes, with only two of its ten terranes (Waigeo and Arfak terranes) being of oceanic origin. It was probably this preponderance of continental terranes that led many people to view western Irian Jaya as an integral part of the Australian craton that had always occupied its present-day position (Dow & Sukamto, 1984; Norvick, 1979) or had been rotated or faulted into its present position in the Neogene (Visser & Hermes, 1962; Hermes, 1968; Thompson, 1972; Audley-Charles & others, 1972; Carter & others 1976; Hamilton, 1979). However, palaeomagnetic data from the Kemum terrane (Giddings & others, 1985; personal communication, 1984) show that western Irian Jaya has not always occupied its present-day position relative to the Australian craton. The data show that the Kemum terrane and the Australian craton have the same polar wander path from the Late Carboniferous to Triassic, confirming the palaeontological evidence from the *Glossopteris* flora (Visser & Hermes, 1962; Pigram & Sukanta, 1982) and Permian brachiopods (Archbold & others, 1982) that the Kemum terrane originated as part of Gondwana. The Cretaceous and early Tertiary poles are off the main path, suggesting that some relative motion has occurred between the Kemum terrane and Australia. The data also show that no large-scale clockwise rotation of the Kemum terrane has taken place in the Neogene.

These data are important because they show that, although the Kemum terrane originated as part of Gondwana, it was detached by the Early Cretaceous and then had a history of movement independent of the Australian craton until at least the Miocene. The data have the further implication that, as the Kemum terrane forms the nucleus around which the other terranes of western Irian Jaya are clustered, these too may be allochthonous or, in the terminology of Coney & others (1980), suspect.

The development of western Irian Jaya was initiated by the amalgamation of the Kemum and Misool terranes in the latest Oligocene (by N4 time). The terranes are linked by an overlap assemblage of N4 and younger age (Salawati Basin) and a common deformation event (Pigram & others, 1982; N.R. Cameron, personal communication, 1983) that folded the Oligocene and other sediments before deposition of the overlap sequence. This composite Misool-Kemum terrane then amalgamated with the Lengguru terrane by late Miocene times, when all three terranes were contributing detritus to the overlapping Bintuni Basin. The amalgamation of the Misool-Kemum composite terrane with the Lengguru terrane may have involved the docking of the Misool-Kemum terrane with the Australian craton, as the Lengguru terrane is an Australian craton margin assemblage. However, it is not clear what the Lengguru terrane's relation to the craton was, and, if it is displaced, whether that displacement was a consequence of the docking of the Misool-Kemum composite terrane, or predated or postdated it.

To the north, the Tamrau terrane is linked to the Kemum terrane by an overlap assemblage of Pliocene sediments (Visser & Hermes, 1962; Pieters & others, 1983). Amalgamation of these two terranes may have occurred earlier, if the uplift of the northern edge of the Kemum terrane in the late Miocene was related to this event. The Tamrau and western Arfak terranes are linked by a Pliocene overlap assemblage (the Opmarai Formation of Pieters & others, 1983), while the Tamrau and Waigeo terranes are linked by the late Miocene and younger sediments of the Batanta Basin.

Eastern Irian Jaya

Too little is known of the geology of eastern Irian Jaya to document all the terranes and their accretion history. The Gauttier and Rouffaer terranes are linked by a middle Miocene and younger overlap sequence. A late Oligocene age for the oldest accretion event (perhaps the docking of the Rouffaer terrane) is indicated by initiation of sedimentation in the foreland Akimeugah Basin during the earliest Miocene.

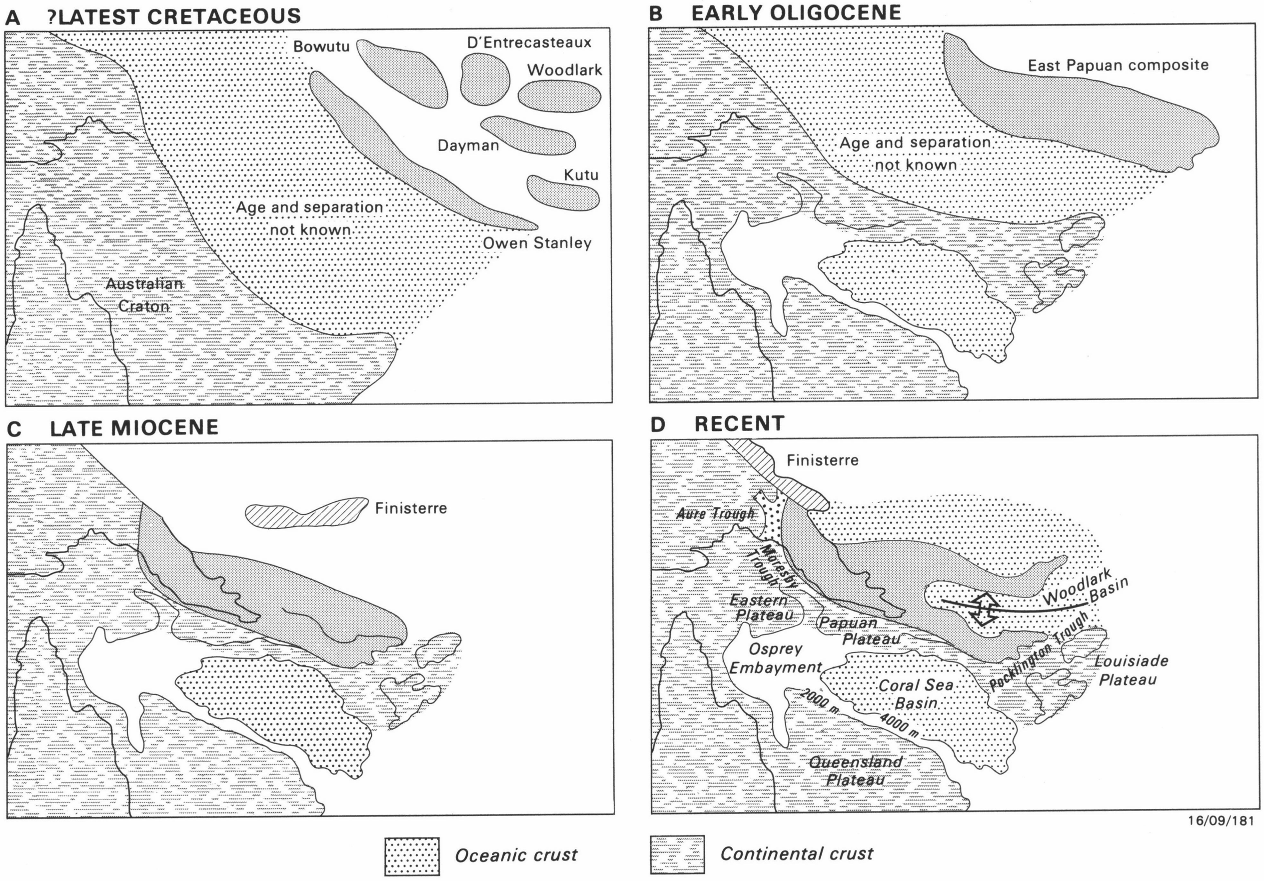

Figure 3. Schematic evolution of eastern Papua New Guinea, showing the formation of the east Papuan composite terrane by early Miocene time and its subsequent docking with a salient of the Australian craton by late Miocene time.
During the late Cretaceous the northeast edge of the Australian craton had the configuration shown in A. Outboard of it was an ocean basin of unknown age and dimension that contained or later developed features that were to become the terranes that amalgamated to form the East Papua composite terrane (EPCT). The shape of the terranes shown here has no significance. They are shown to indicate which terranes formed the EPCT by Oligocene time (B). By this time the Coral Sea Basin had opened and the Australian craton had the configuration shown in B. The EPCT had docked by late Miocene time (C), but was enlarged by the addition of the Port Moresby and Menyamya terranes during the Oligocene and early Miocene prior to dockings. The position of the Finisterre terrane in C has no palaeogeographic significance. It is shown as it is to indicate that the eastern part (at least) of the terrane must have docked after the EPCT. The western part of the Finisterre terrane may have docked just before or at about the same time as the EPCT. D shows the current position with the EPCT being dismembered by the opening of the Woodlark Basin. Diagrams not to scale.

Western Papua New Guinea

In the past, the development of the western PNG portion of the New Guinea orogen has been attributed to interaction between the Pacific and Australian plates, which culminated in a major orogeny in the Oligocene (Dow, 1977), and to continent and island arc collision (Davies, 1982a, b; Davies & Hutchison, 1982). The timing of the collision was thought to be late Eocene or early Oligocene by Davies & Hutchison (1982), latest Oligocene or end of early Miocene by Davies (1982a), while Davies (1982b) suggested that two arcs had collided, the first in the Oligocene and the second in the earliest Miocene.

Terrane analysis shows that the Sepik terrane is linked to the Australian craton by an overlap assemblage of late Oligocene to early Miocene (N3–N6) age (Kera Formation, Davies, 1983) and to the Landslip and Dimaie terranes by the middle Miocene and younger sediments of the Wogamush embayment. The northern terranes of Torricelli, Prince Alexander and Mount Turu are linked by an early Miocene overlap sequence. These early Miocene sediments, found along the north side of the Lumi Trough — the Puwani Limestone, Amogu conglomerate, and basal Senu Beds of Hutchison & Norvick (1980) — do not have equivalents on the south side of the basin. The overlap sequence that links the northern and southern terranes is the middle Miocene and younger strata of the Lumi Trough. This implies that the Sepik terrane docked with the Australian craton before the northern terranes docked with the Sepik terrane.

Further east, the Jimi terrane is stitched to the Sepik terrane by the late middle Miocene South Yuat Batholith (11.2–12.5 Ma; Page, 1976) and to the Bena Bena terrane by the middle Miocene Bismarck Intrusive Complex. The Schrader and Marum terranes amalgamated after the middle Eocene, and are linked to the western end of the Finisterre terrane by the Miocene and younger overlap assemblage of the Ramu Basin. The eastern part of the Finisterre terrane did not dock until after the middle Miocene (see discussion below on eastern PNG). This is in agreement with Jaques & Robinson (1977), who suggested that the western end of the Finisterre terrane docked before the eastern end, and with Johnson & Jaques (1980) and Falvey & Pritchard (1984), who suggested that the Finisterre terrane docked in the last 4 Ma. The relationship between the Sepik and Jimi terranes suggests they were juxtaposed by left-lateral movements on the Bismarck Fault Zone before emplacement of the South Yuat Batholith in the late middle Miocene. Also, parts of the Schrader terrane strongly resemble the northern part of the Owen Stanley terrane (Pigram, 1978). If the Schrader terrane should prove to be a dismembered portion of the Owen Stanley terrane it would imply a left-lateral offset of approximately 300 km along the Ramu-Markham and Bundi Fault Zones.

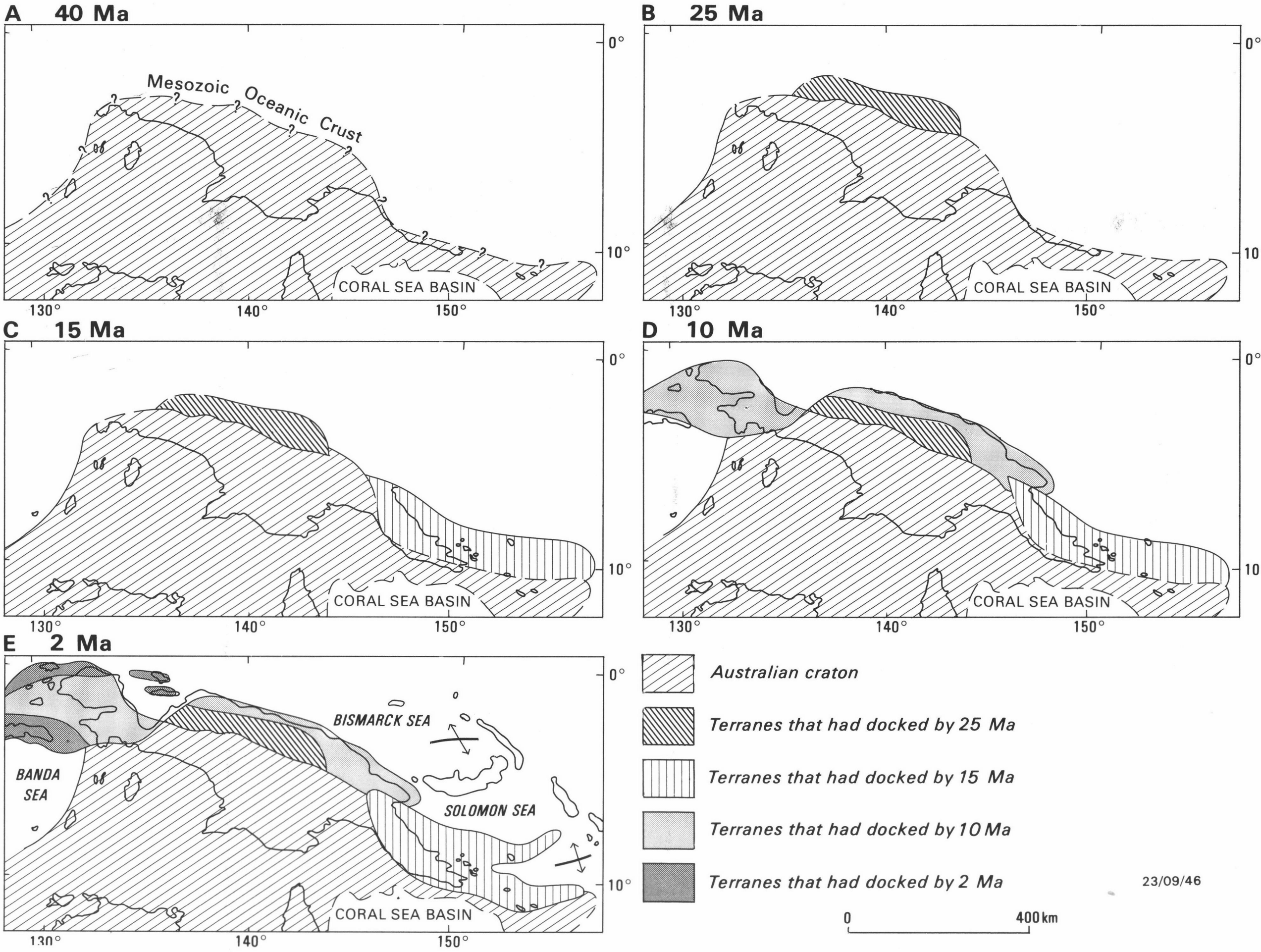

Figure 4. Simplified schematic accretion history of the New Guinea orogen.

The terranes are shaded according to their docking time. Successor basin sequences are not shown. The coastlines of southern New Guinea and northern Australia are shown in parts A-D for reference only. A: 40 Ma — Before the first docking event the northern edge of the Australian continent faced an ocean basin that had developed in Mesozoic time (Pigram & Panggabean, 1984). The Coral Sea Basin had formed in the Paleocene (Weissel & Watts, 1979) and was separated from the ocean basin to the north by a salient of continental crust. The Australian continent was moving northward. B: 25 Ma — by latest Oligocene the first composite terrane (the Sepik terrane) had docked. The Rouffaer terrane of eastern Irian Jaya is shown as having docked by this time also, but there is no age control for this assumption. C: 14 Ma — by latest middle Miocene, the northern part of the East Papua composite terrane had docked, but the eastern part of the terrane may not have docked with the Papuan and Louisade Plateau until a little later. D: 10 Ma — by early late Miocene time the Western Irian Jaya composite terrane and the northern island-arc terranes of central New Guinea had docked. The Jimi, Bena Bena, and Schrader terranes had reached their present-day position relative to the Sepik and Finisterre terrane. E: 2 Ma — by the Pliocene the northern terranes of western Irian Jaya (Tamrau, Arfak, and Waigeo terranes) had docked, while the Seram composite terrane docked about 2 Ma and completed what remains the present-day configuration of the orogen. No docking event has taken place along the orogen to the east of the Sarera Bay since the Pliocene, which is consistent with the establishment of a divergent regime leading to the opening of small ocean basins in the region. The opening of the Woodlark Basin is currently dismembering the eastern end of the East Papua composite terrane.

Eastern Papua New Guinea

The evolution of eastern PNG has been seen as the consequence of continent or microcontinent-island arc collision related to the opening of the Coral Sea. Davies & Smith (1971) suggested that the Australian craton collided with an island arc in the Eocene, causing obduction of the Papuan ultramafic belt and deformation of the leading edge of the craton. This deformed edge was subsequently detached and rotated away from the craton to form the Papuan Peninsula by the opening of the Coral Sea in the Eocene.

Pieters (1978) suggested a variation on this concept by proposing that a sliver of continent was rifted away from the craton by the opening of the Coral Sea and collided with the arc to produce the Papuan Peninsula. Hamilton (1979) suggested that eastern PNG was simply the eastern continuation of a continent-island arc collision that affected the entire margin of the Australian craton east of Sarera Bay.

Analysis of the accretion history of eastern PNG shows that it involves the amalgamation of several terranes of diverse origin in the Palaeogene to form a large composite terrane somewhere to the north or east of the Australian craton. This composite terrane then docked with the Australian craton in late Miocene times. A schematic history of the amalgamation and docking events of eastern PNG is shown in Figure 3.

The amalgamation of the Owen Stanley, Dayman, and Bowutu terranes may have begun as early as 52 Ma (early Eocene), if the metamorphism of the proto-Owen Stanley terrane was a consequence of this event. By late Oligocene time, the Menyamya terrane had amalgamated with this composite microcontinent (Fig. 3B).

By the end of the Oligocene, the Owen Stanley, Kutu, Dayman, Bowutu, and part of Port Moresby terranes had amalgamated to form a large composite terrane (East Papua composite terrane) that was separated from the Australian craton by an oceanic basin (Fig. 3B). The evidence for this basin is found in the deep-water sediments of the Port Moresby terrane and the Paleocene ophiolite complex of the Menyamya terrane. The submarine tholeiitic basalts of the Kutu terrane may also have floored the basin. The presence of an ocean basin separating the Owen Stanley terrane from the Australian craton was recognised by Thompson & Fisher (1965) and implied by Hamilton (1979). This basin was separated from the Coral Sea basin, which had opened in the Paleocene (Weissel & Watts, 1979) by a long salient of the Australian craton made up of the Eastern, Papuan and, possibly, the Louisiade Plateaus (Symonds & others, 1984) (Fig. 3B).

Docking of the East Papua composite terrane with this salient of the Australian craton occurred in the middle or late Miocene. The western end of the composite terrane is linked to the craton by Pliocene sediments of the Aure Trough. Further evidence comes from the time of deformation of sediments in the Aure Trough, Port Moresby, and east Papuan regions. Aure Trough sediments were deformed in early middle Miocene and early upper Miocene times (Dow & others, 1974; Brown & others, 1975; Tingey & Grainger, 1976). In the Port Moresby area deformation postdates N6/N7 (late early Miocene) bathyal sediments of the Fairfax Formation (Rogerson & others, 1981; G. Francis, personal communication, 1986), and in east Papua upper Te (early Miocene)

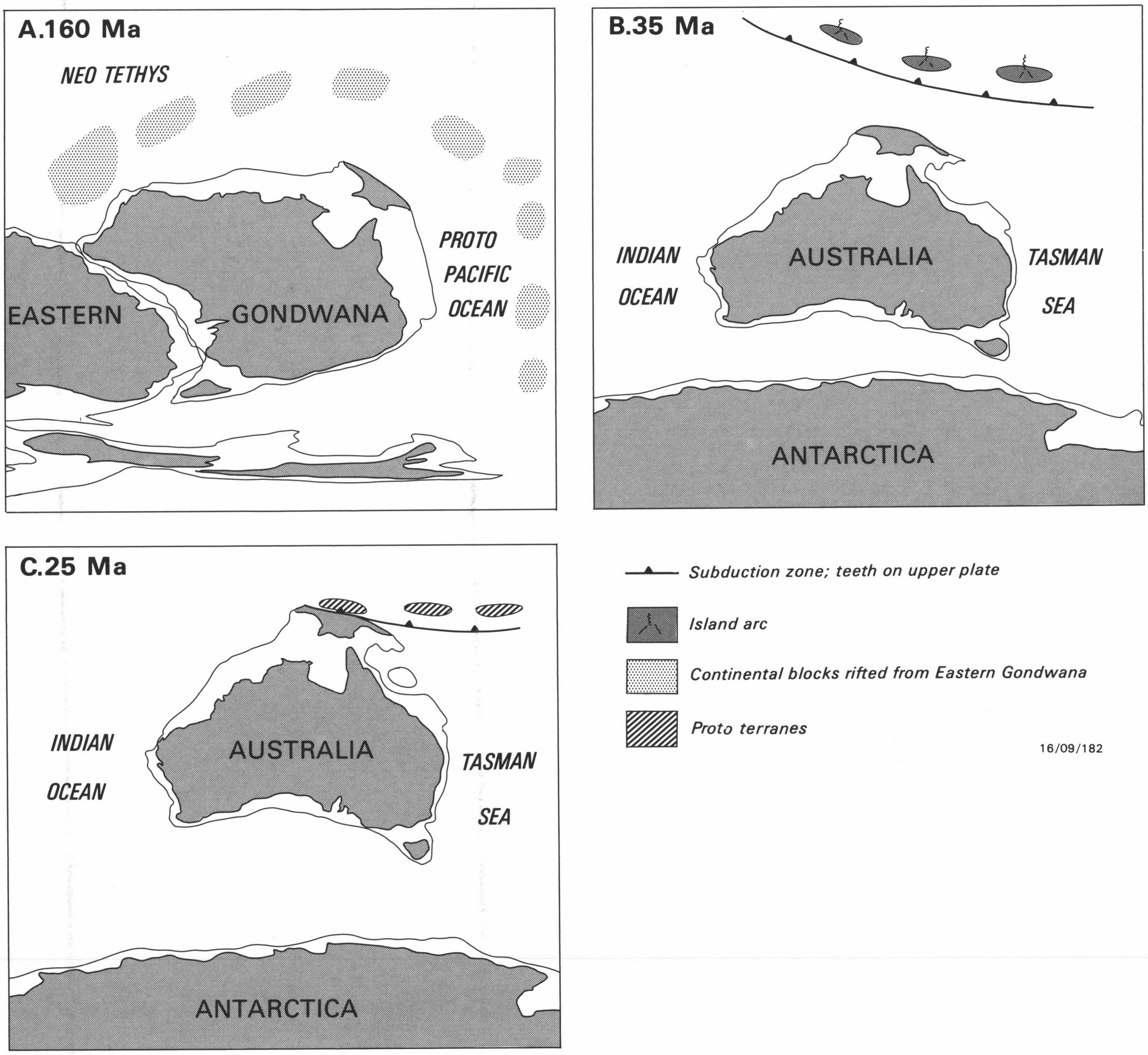

Figure 5. Schematic diagram of events that led to the formation of the northern margin of the Australian craton, its subsequent northward movement, and collision of the craton with a subduction zone (or zones), which led to the development of the New Guinea orogen. A. 160 Ma, Late Jurassic — Rifting of eastern Gondwana during the Late Triassic to Middle Jurassic formed what became the northern edge of the Australian craton (Pigram & Panggabean, 1984), and across which Jurassic to mid-Tertiary miogeoclinal sediments were draped. B. 35 Ma, Early Oligocene — The Australian continent had detached from Gondwana in the late Cretaceous and started travelling rapidly northward during the Eocene (Cande & Mutter, 1982). We speculate that this northward flight of Australia was accommodated by the development of a subduction zone or zones, over which island arcs developed, somewhere to the north of the continent. The island-arc complex is shown schematically because its configuration and location in relation to the Australian craton at this time is now known. C. 25 Ma, Latest Oligocene. The ocean basin that lay to the north of the Australian craton was consumed and, by 25 Ma, the leading edge of the craton entered a subduction zone, causing the accretion of the Sepik composite terrane and the initiation of the development of the New Guinea orogen. The subsequent evolution of the orogen probably involved the development of short-lived microplates with complex boundaries. Sorting out their complexities remains one of the long-term objectives of studies of the New Guinea orogen. Base maps are from Smith, Hurley & Briden (1981).

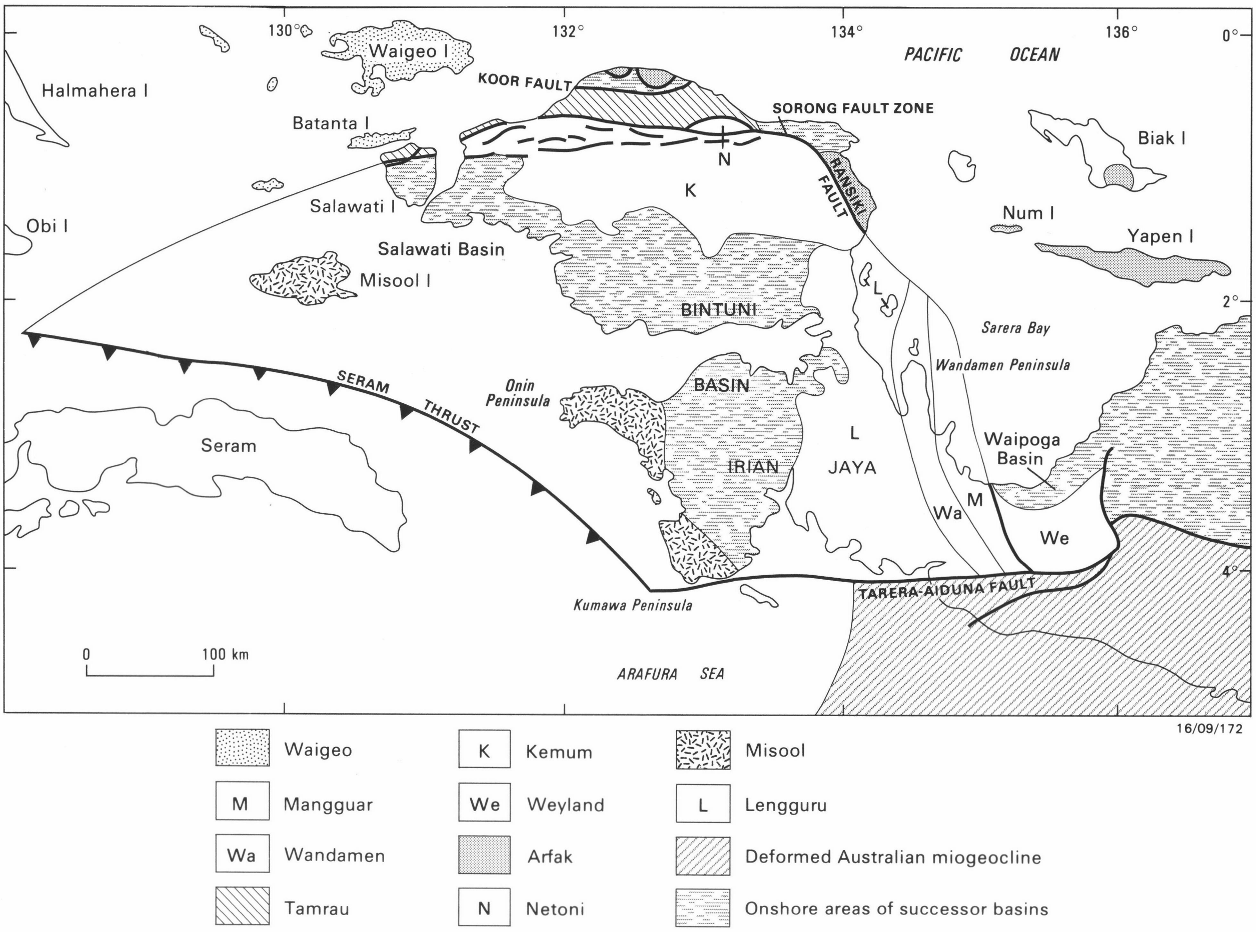

Figure 6. Map of the terranes of Western Irian Jaya.
Only the onshore areas of the successor basins are shown. Terranes on Seram Island that docked with the Misool terrane in late Pliocene to Pleistocene (Audley-Charles & others, 1979) are not discussed.

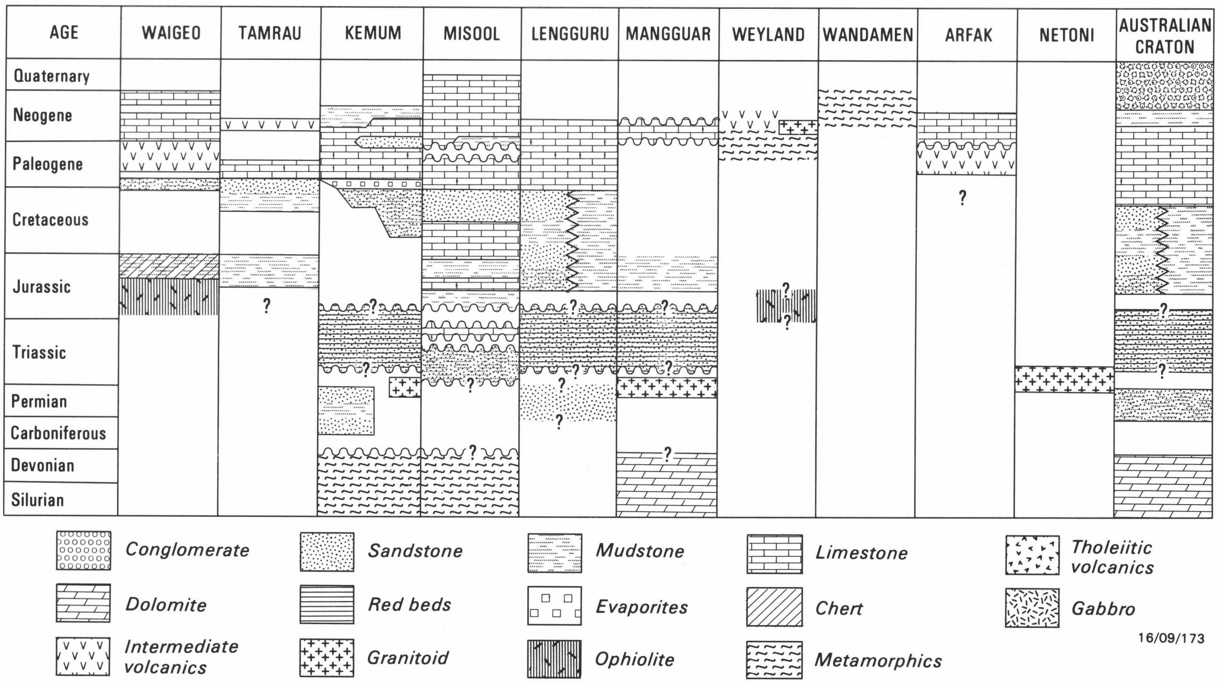

Figure 7. Stratigraphic columns for terranes of Western Irian Jaya.
See Figure 6 for location of terranes.

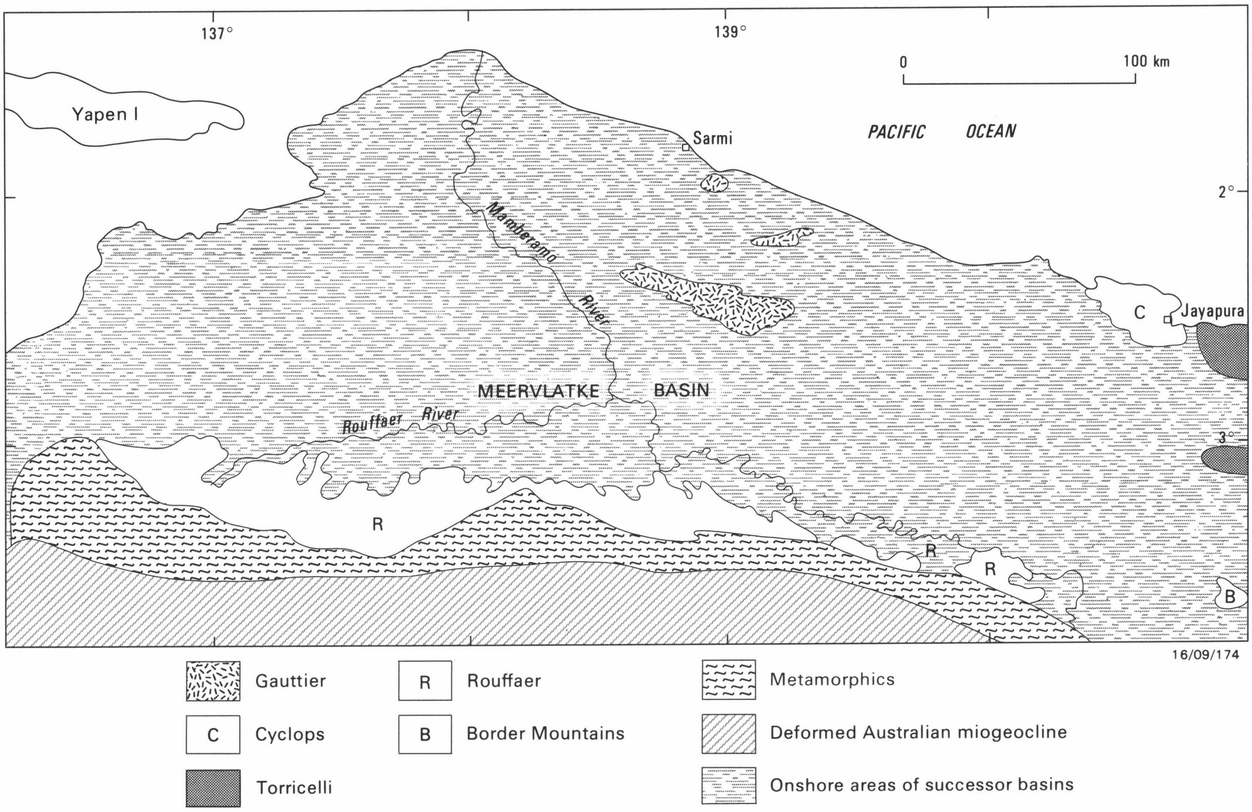

Figure 8. Map of terranes of eastern Irian Jaya.
The location of Rouffaer terrane is based on Landsat and airphoto interpretation. The narrow belt of metamorphics between the Rouffaer terrane and the Australian craton maybe a composite terrane.

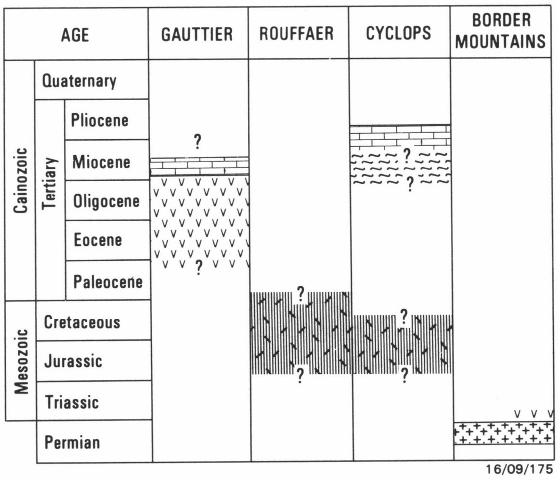

Figure 9. Stratigraphic columns for the terranes of eastern Irian Jaya.
See Figure 8 for terrane location.

sediments are the youngest involved in the deformation of the southern margin of the terrane. A mid-Miocene time for docking is also consistent with the uplift of the Papuan Ultramafic Belt (Smith & Davies, 1976) and the first appearance of siliciclastic turbidites in the Coral Sea Basin (Andrews & others, 1975).

The latest event in the accretion history of eastern PNG was the docking of the Finisterre terrane after the East Papua composite terrane had docked with the Australian craton, i.e. post middle Miocene. Rapid rates of uplift in the eastern Finisterre terrane (Chappell, 1974) may indicate that it is still being thrust southward over the Australian craton (Johnson & Jaques, 1980).

Post-docking lateral translation of terranes in the order of hundreds of kilometres would not affect the arguments presented above. Post docking translation of terranes by thousands of kilometres clearly would, but movements of that order seem unlikely.

Several implications for the palaeogeography of the east Papuan region arise out of the accretion history discussed above. The Menyamya, Port Moresby, and Kutu terranes are interpreted as remnants of an ocean basin that existed north-east of the Eastern and Papuan Plateaus (Fig. 3) before the opening of the Coral Sea. The pre-middle Miocene sediments of the Aure Trough may have been deposited in widely separated locations, the western assemblage (Darai Limestone) being deposited on the eastern edge of the Australian craton, and the eastern assemblage (Aure beds), on the western edge of the East Papuan composite terrane, while they were separated by an ocean basin. It follows that the Aure Trough may have an oceanic basement in part, a suggestion supported by anomalously high gravity values across the Aure Trough (St. John, 1967).

Overview of terrane accretion

The New Guinea orogen developed as the consequence of the docking of several terranes (many of which were large composite terranes) since the late Oligocene (Fig. 4). Eocene

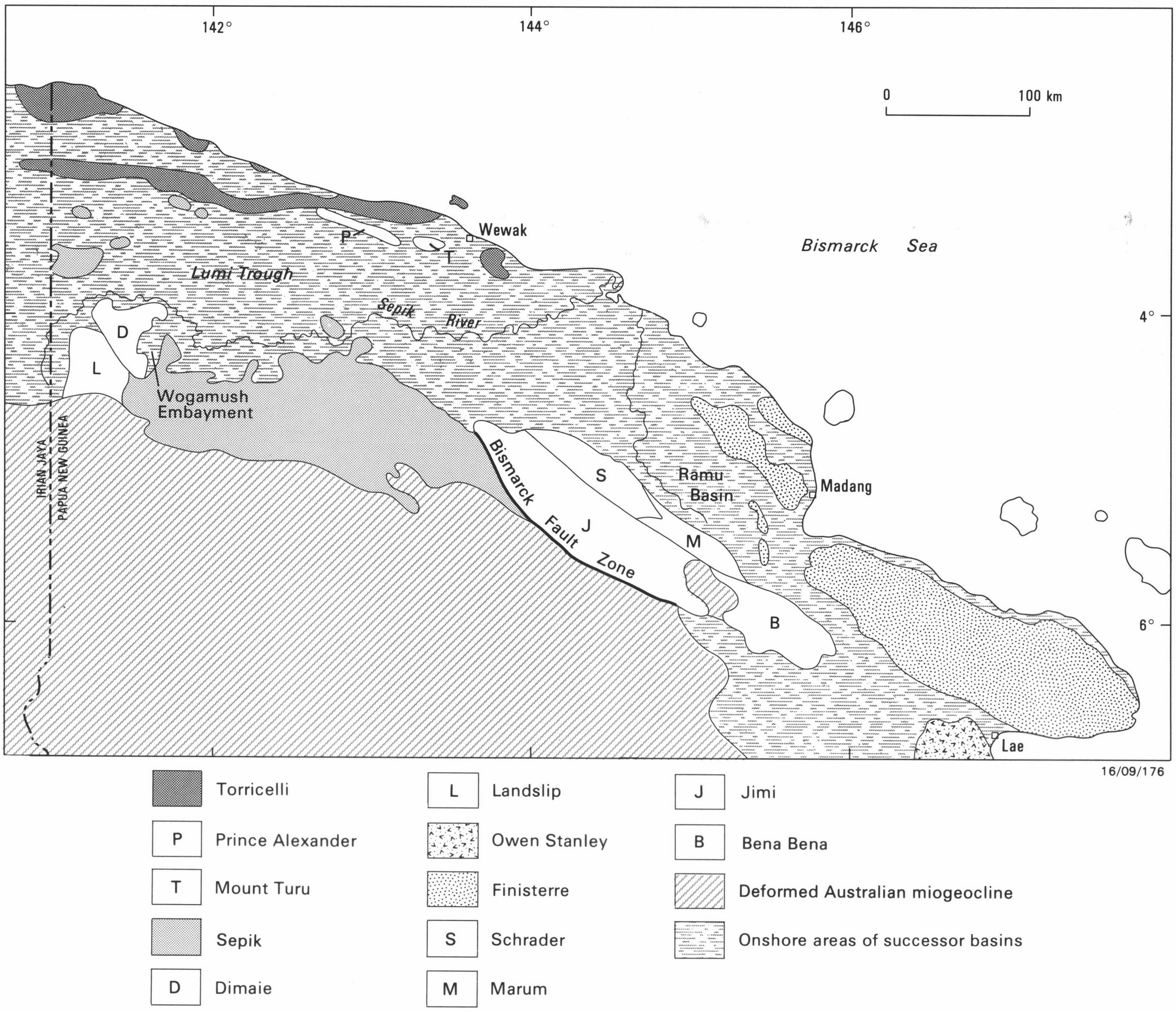

Figure 10. Map of the terranes of western Papua New Guinea.
Some of these terranes (e.g. Sepik terrane) are composite.

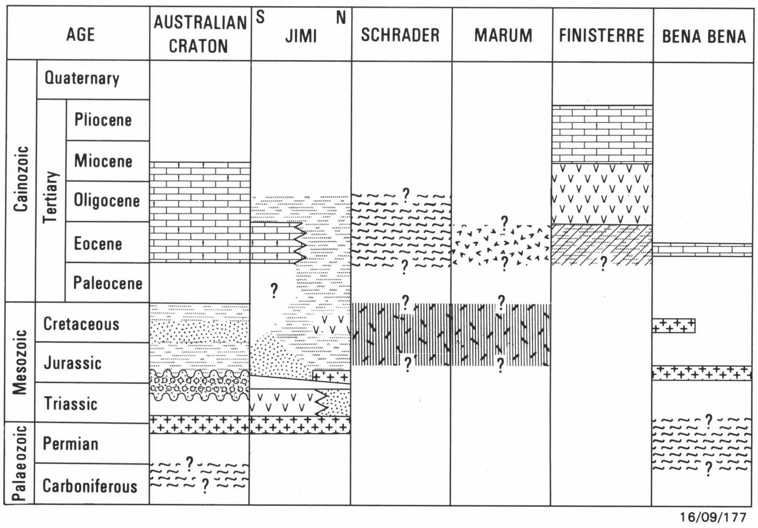

Figure 11. Stratigraphic columns for the terranes of the eastern part of western Papua New Guinea.
See Figure 10 for terrane location.

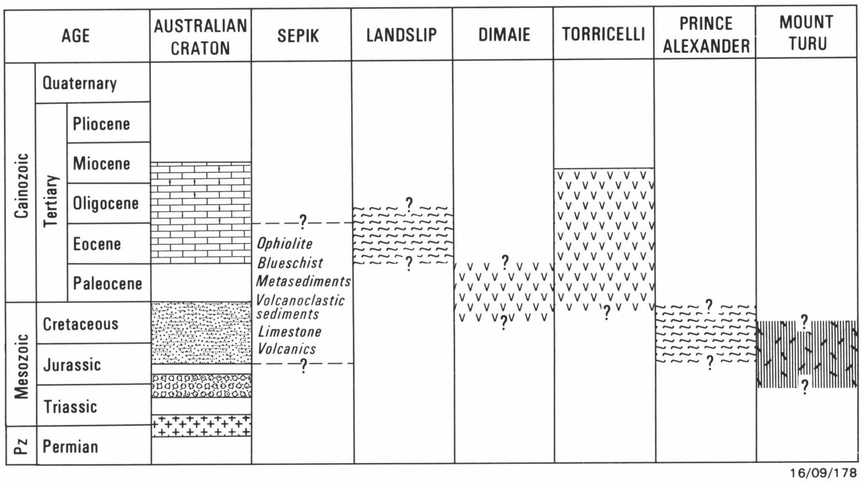

Figure 12. Stratigraphic columns for the terranes of the western part of western Papua New Guinea. See Figure 10 for terrane location.

deformation events that had previously been thought to mark the initial stages of orogenesis, took place as composite terranes were assembled at sites in ocean basins far removed from the craton edge. The first terrane to dock against the Australian craton was the Sepik composite terrane in the late Oligocene (prior to N3 time) (Fig. 4B). We have extended this docking event into Irian Jaya, based on the time of development of the foreland basin. This event was followed by the docking of the East Papua composite terrane along the eastern edge of the craton by middle Miocene time (Fig. 4C). By late Miocene time the Misool-Kemum composite terrane, the Torricelli-Prince Alexander-Mt Turu terranes, and the western end of the Finisterre terrane had all docked (Fig. 4D). By 2 Ma the eastern part of the Finisterre terrane had docked, as had several small terranes in western Irian Jaya and the terranes of Seram (Fig. 4E).

The apparent absence of docking events in eastern New Guinea since the Pliocene is consistent with the establishment of a number of young ocean basins (e.g. Woodlark and Bismark Basins) and, hence, the lack of a convergent regime along the northern edge of the orogen (see Johnson, 1979). The opening of the Woodlark Basin is currently dismembering the eastern end of the East Papua composite terrane.

Seafloor spreading is thought to be the major process by which terranes are transported across an ocean basin to a continental margin. In New Guinea, unlike North America, subduction beneath the craton was not taking place during the docking of terranes. There is no magmatic evidence for subduction beneath the craton during the Paleogene and early Miocene. Rather, docking occurred because the Australian continent, which was moving northward, entered a subduction zone at which the terranes had assembled during the Palaeogene. The northern edge of the craton had entered the subduction zone by late Oligocene time (Fig. 5).

Conclusions

The New Guinea orogen north of the collision-deformed Australian craton margin is made up of at least thirty-two tectonostratigraphic terranes of varying affinities. Unlike other orogens of the circum-Pacific region, where terranes are predominantly of oceanic affinity, the New Guinea orogen contains a large proportion (about 45%) of terranes with continental affinities. Many of these such as the Jimi and Bena Bena terranes, are probably displaced portions of the northern edge of craton. Others, however, such as the Kemum terrane, were formerly parts of Gondwana that were detached in early Mesozoic times and experienced a history independent of the craton before docking in the Miocene.

Many of the terranes now have their boundaries covered by successor or post-docking basins. These basins typically are Miocene and younger in age and contain from 3-7 km of turbidite fill. Some of these basins are probably pull-apart basins, while others may be molasse basins formed by loading due to the overthrust of terranes. These basins may be modern analogs of depositional environments of the now highly deformed Mesozoic flysch that separates some of the terranes in the North American Cordillera (Coney & others, 1980; Jones & others, 1982).

The analysis of the accretion history of the New Guinea Orogen shows that its development was initiated in the middle-late Oligocene. The Eocene deformation events that had previously been thought to mark the initial phase of development of the orogen are here related to amalgamation of terranes to form composite terranes at sites in ocean basins far removed from the craton. We suggest that the initial docking and accretion of the terranes took place without subduction beneath the craton, because the northward moving Australian continent began to enter, by late Oligocene time, a subduction zone at which composite terranes had been assembled during the Palaeogene.

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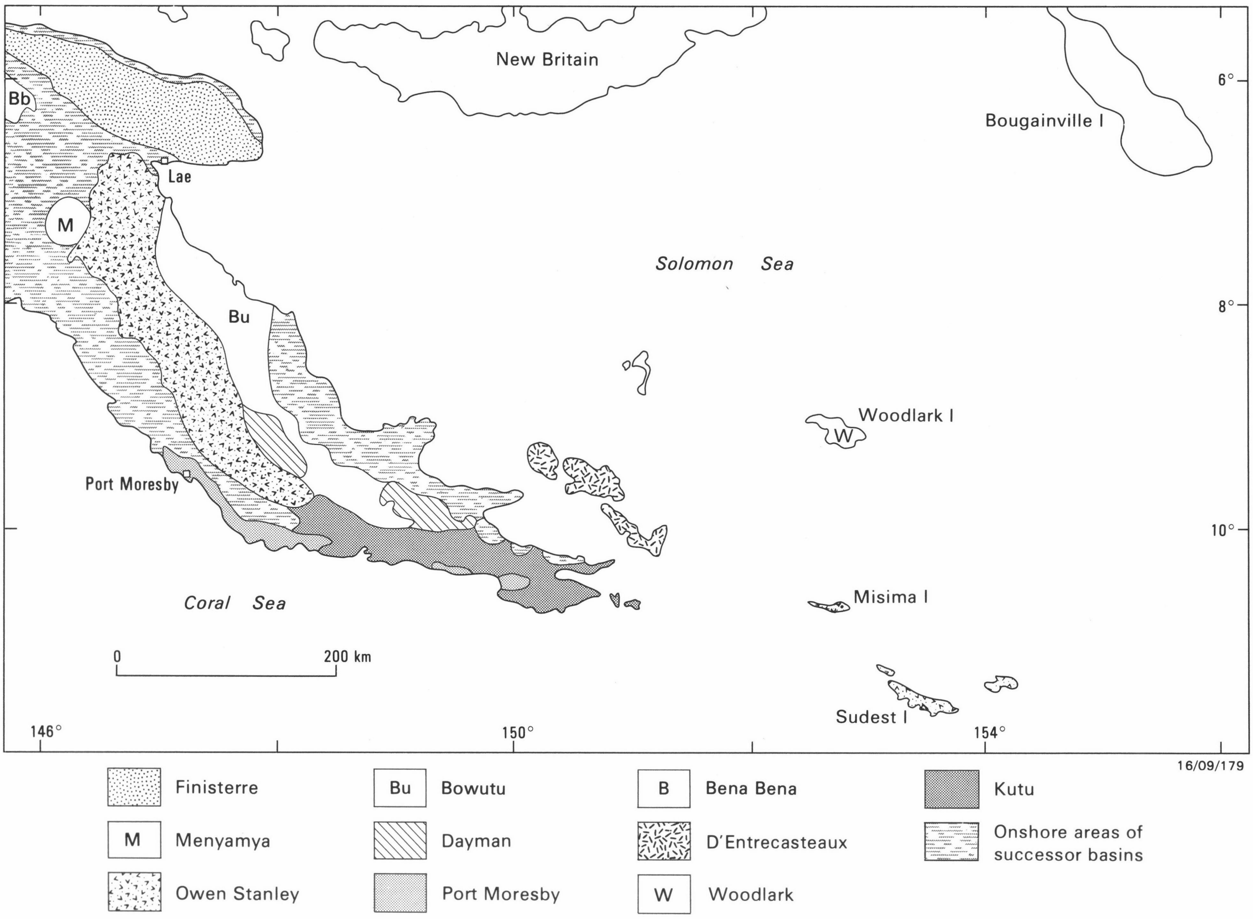

Figure 13. Map of the terranes of eastern Papua New Guinea.

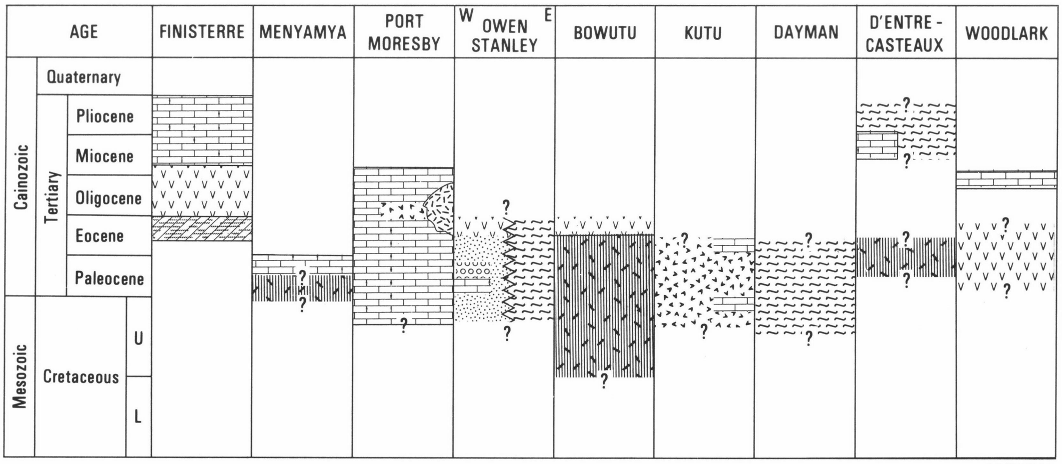

Figure 14. Stratigraphic columns for the terranes of eastern Papua New Guinea.
See Figure 13 for terrane location.

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Appendix 1. Terrane descriptions

The terranes described below occupy part of the orogen to the north of the craton margin. Only those terranes that occur on the island of New Guinea and adjacent small islands are described. We do not discuss terranes occuring on islands, such as Seram and Halmahera, that may form a western extension of the orogen. To simplify the description and discussion of the terranes, the New Guinea orogen has been divided into 4 regions; from west to east these are Western and Eastern Irian Jaya and Western and Eastern Papua New Guinea (Fig. 1).

Western Irian Jaya

A map of the ten terranes identified in western Irian Jaya is presented in Figure 6 and stratigraphic colums for each of the terranes along with that for the Australian craton are shown in Figure 7.

Kemum terrane

The Kemum terrane is a large continental terrane that occupies most of the Birds Head south of the Sorong Fault Zone. It is separated from the Arfak terrane to the east by the Ransiki Fault Zone. It is partly overthrust by the Lengguru terrane along its southeastern margin, and its southern margin is covered by Miocene sediments of the successor Bintuni and Salawati Basins. The Kemum terrane is the northern part of the western Irian Jaya microcontinent of Pigram & others (1982) and Pigram & Panggabean (1984).

The terrane consists of Siluro-Devonian turbidites, which were isoclinally folded and metamorphosed in the Late Devonian or Early Carboniferous and intruded by Early Carboniferous and Permo-Triassic granitoids. This basement is overlain by Middle Carboniferous to Late Permian shallow marine to paralic siliciclastic sediments. The Mesozoic section is thin, incomplete and locally absent. Jurassic to Triassic red beds overlie the Palaeozoic rocks and are in turn overlain by Cretaceous shallow marine sediments. The latest Cretaceous to early Eocene was marked by the local development of evaporitic sediment, and the Eocene section consists mainly of limestone (Visser & Hermes, 1962; Pigram & Sukanta, 1982; Pieters & others, 1983, 1985). This sequence was folded in the latest Oligocene, before N4 (N.R. Cameron, personal communication, 1984).

Misool terrane

The Misool terrane is a continental terrane that is largely submerged, but crops out on Misool Archipelago and the Kumawa and Onin Peninsulas of western Irian Jaya. The terrane is bounded to the southwest by the Seram Trough. The boundaries between the Misool and Kemum, and Misool and Lengguru terranes are covered by Miocene and younger sediments of the Salawati and Bintuni Basins. The Misool terrane is the southwesterly part of the western Irian Jaya microcontinent of Pigram & others (1982) and Pigram & Panggabean, (1984).

The Misool terrane consists of a Palaeozoic basement of an isoclinally folded and metamorphosed turbidite sequence overlain unconformably by an almost complete sequence of Mesozoic sediments. The sequence consists of Triassic turbidites, Late Triassic shallow-water limestone, Early Jurassic to early Late Cretaceous bathyal mudstone and limestone, which is tuffaceous near the top, and Late Cretaceous fluvio-deltaic clastics and nodular limestone. The Palaeogene section is dominated by shallow-water carbonates. The pre-Miocene section was folded in late Oligocene to early Miocene time (Pigram & others, 1982). The post-Palaeozoic section is highly fossiliferous and consequently well dated.

Tamrau terrane

The Tamrau terrane, named for the Tamrau Mountains, is found in the northern Birds Head and northern Salawati Island of Irian Jaya. In the northern Birds Head the terrane is separated from the Arfak terrane by the Koor Fault Zone, and from the Kemum terrane by the Sorong Fault Zone. The Tamrau terrane on Salawati Island is separated from the Waigeo terrane on Batanta Island by a narrow strait, which probably contains a strand of the Sorong Fault Zone. The Tamrau terrane partly corresponds to Pieters & others' (1982) Tamrau Block.

The terrane consists of Middle to Late Jurassic and (?)Late Cretaceous bathyal shale and minor quartz sandstone, (?)Late Cretaceous quartz sandstone, (?)Palaeogene calcilutite and middle Miocene intermediate volcanics and epiclastic sediments. The Jurassic and Neogene rocks are well dated, but there is no age control for the other sediments.

The Tamrau terrane is unlike any other of the terranes in western Irian Jaya. Similar associations of Mesozoic bathyal shale and mid-Miocene intermediate volcanics are known from the northern flank of the central ranges in east Irian Jaya and Papua New Guinea (Visser & Hermes, 1962; Dow, 1977).

Waigeo terrane

The Waigeo terrane is named after Waigeo Island in northwest Irian Jaya. The rocks of this terrane are exposed on Waigeo Island and on numerous small islands to the west, including Batanta and Kofiau. A small elongate sliver of the terrane occurs along the northern edge of the Birds Head east of Sorong. Waigeo Island is separated from the Birds Head by a shallow strait, which may coincide with a strand of the Sorong Fault Zone.

The terrane consists of an ophiolite complex overlain by Late Jurassic bathyal sediments. Both these units supplied detritus to the overlying Palaeocene to Eocene turbidites, which are overlain by late Eocene to Miocene basaltic to andesitic pillow lavas, lava breccia with intercalations of tuffaceous sandstone, mudstone, tuff, and minor conglomerate. The volcanic sequence is overlain by Miocene limestone (Supriatna & others, in press). The terrane is interpreted as a late Eocene to Miocene island-arc complex built on an oceanic basement. The pre-Late Jurassic age for the ophiolite makes it one of the oldest in the region and also suggests it is allochthonous, as the oceanic crust of the Philippine Plate to the north and the Caroline Basin to the west are both Paleogene or younger (Doutch, 1981).

Arfak terrane

The Arfak terrane is named for the Arfak Mountains in the northeastern Birds Head of Irian Jaya. The terrane has been dismembered and forms several subterranes, which are found on Biak, Yapen, and Num Islands at the head of Sarera Bay, and in the Arfak and Tosem Mountains of the northern Birds Head, The Arfak Mountains subterrane is separated from the Kemum terrane on its southwest side by the Ransiki Fault. The terrane extends offshore to the east and is covered by Late Cainozoic sediments. In the northern Birds Head, the terrane is separated from the Tamrau terrane to the south by the Koor Fault and Neogene sediments. The terrane consists of upper Eocene to middle Miocene basaltic to andesitic lava, breccia, and tuff, and is intruded by dykes and stocks of dolerite and gabbro. They are overlain by early to middle Miocene limestone (Pieters & others, 1982, 1983, 1985). Foraminifera are common in limestone lenses in the volcanics and four K-Ar isotope ages give a range of 10.5 Ma to 33.1 Ma. The terrane is interpreted as an island-arc complex.

Netoni terrane

The Netoni terrane, named for Mount Netoni, is a small terrane (60 km × 18 km) in the northwestern Birds Head, adjacent to the Sorong Fault Zone. It is faulted against the Tamrau terrane on the northern side, and the Kemum terrane on its southern side. The terrane consists of Late Permian to Early Triassic (245-225 Ma) granitoids, ranging in composition from quartz syenite to diorite and adamellite (Pieters & others, 1982).

Lengguru terrane

The Lengguru terrane occupies the eastern half of the Birds Neck in western Irian Jaya. It is named after, and largely corresponds to, the Lengguru fold belt of Visser & Hermes (1962). The Lengguru terrane is in fault contact with the Wandamen terrane to the east, forms part of the west side of Sarera Bay in the northeast, and is covered by sediments of the post middle Miocene Bintuni Basin along its western margin. Its southern margin is formed by the Tarera-Aiduna fault zone. The style of the contact between the Lengguru and Kemum terranes is not clear; possibly, the Lengguru terrane is thrust over the Kemum terrane. The terrane consists of middle Jurassic to Cretaceous siliciclastic littoral to bathyal sediments, overlain by Late Cretaceous to middle Miocene carbonates, which consist of a western shallow-water facies and an eastern deep-water facies (Visser & Hermes, 1962; Pieters & others, 1983). The nature of the basement to the Lengguru terrane is not known. This entire sequence was folded and thrust to the west during the late Cainozoic. The terrane has contributed detritus to the Bintuni Basin since the late Miocene.

The Middle Jurassic to mid Miocene sequence of the Lengguru terrane is very similar to that of the Australian craton to the southeast. The present-day distribution of shallow and deep-water facies of the Middle Jurassic and Cretaceous clastic sediments suggests that they were derived from a quartz-rich source to the west, but this implied source area is now occupied by the Misool terrane, which was the site of bathyal sedimentation during the Mesozoic. Clearly, the Lengguru terrane is no longer linked to its Mesozoic source areas.

Wandamen terrane

The Wandamen terrane occurs along the southwestern side of Sarera Bay, where it crops out on Roon Island, the Wandamen Peninsula, and the Wondiwoi Range. The northern end of the terrane forms a dissected elongate dome, which is thought to be a metamorphic core complex. The terrane is in fault contact with the Lengguru and Mangguar terranes.

The Wandamen terrane consists of northern high-grade and southern low-grade metamorphic portions. The high-grade portion consists mainly of amphibolite-grade gneiss and amphibolite. The gneiss is quartzo-feldspathic, formed from a protolith of granite, granodiorite, and quartz-monzonite. Metabasic rocks are much less common and appear to be metamorphosed basalts or gabbros. Some are retrogressively metamorphosed eclogite (Pieters & others, 1979, 1983). Minor pelitic schists and carbonate-bearing metasediments also occur (Pieters & others, 1979). The southern low-grade terrane is mostly dark slate, phyllite, metawacke, and quartzite of greenschist facies, with rare marble, chlorite schist, and metachert. The protoliths appear to be mainly turbidites in which no fossils are preserved and, hence, their age is not known. K-Ar isotope ages on biotite and hornblende give late Miocene to late Pliocene ages for the high-grade rocks (Pieters & others, 1979, 1983).

Mangguar terrane

The Mangguar terrane named for the Mangguar Peninsula, is a long narrow terrane (225 × 30 km) that occurs along the southwest side of Sarera Bay and extends south to the Tarera-Aiduna Fault Zone in the Birds Neck. In the south it is in fault contact with the

Wandamen and Weyland terranes, and to the north it is largely submerged.

The terrane consists of (?)Palaeozoic siliciclastics and dolomite, Permian and Triassic granitoids, Triassic to Jurassic red beds, Jurassic to Cretaceous mudstone, and Miocene shallow-water limestone (Pieters & others, 1983; Dow & others, 1985). The Mangguar terrane may be a composite terrane, consisting of elements of both the Australian craton and the Kemum terrane. The Palaeozoic sediments resemble those of the Australian craton to the south, but the Permian and Triassic granitoids are only known from the Kemum terrane, Netoni terrane, Sorong Fault Zone, Border Mountains terrane, and the Australian craton in Papua New Guinea. However, the position of the Mangguar terrane north of the Australian craton between the Wandamen and Weyland terranes suggests that it is entirely allochthonous.

Weyland terrane

The Weyland terrane lies south of Sarera Bay and is named after the Weyland Mountains; it corresponds to the Weyland overthrust of Dow & Sukamto (1984). The terrane is bounded by faults: the southern margin is faulted against the Australian craton along the Tarera-Aiduna Fault, the eastern margin is bounded by the Siriwo Fault; and the western margin, by an unnamed fault that separates it from the Mangguar terrane.

The terrane consists of slate, phyllite, and minor metavolcanics, calcsilicates, peridotite, and amphibolite, intruded by a large Miocene diorite and granodiorite batholith, and overlain by coeval andesitic volcanics (Pieters & others, 1983).

Mini-terranes in the Sorong and Ransiki fault ones

The Sorong and Ransiki Fault Zones range in width from a few hundred metres to 10 km and contain a wide range of 'mini' terranes ranging in size from a few metres of several kilometres across. Many of these blocks may by derived from adjacent terranes (Pieters & others, 1982).

Eastern Irian Jaya

The geology of eastern Irian Jaya is poorly known and has never been systematically mapped. Only four terranes are described below, but doubtless more will be identified in future. A map of the terranes is presented in Figure 8 and stratigraphic columns in Figure 9.

Gauttier terrane

The Gauttier terrane is named for the Gauttier Ranges in northern Irian Jaya. It consists of one large (75 km × 25 km) and two smaller (30 km × 5 km and 5 km × 25 km) fault-bounded blocks, which are completely surrounded by middle Miocene (N12) and younger sediments and mud volcano fields (Williams & Amiruddin, 1983). The geology of the terrane is poorly known. It appears to consist mainly of basaltic lavas and breccia, overlain by purple, reddish to pink calcilutite and tuffs of unknown age (Visser & Hermes, 1962). The Gauttier terrane is possibly a dismembered portion of the Torricelli terrane to the east.

Cyclops terrane

The Cyclops terrane is named after the Cyclops Mountains west of Jayapura in northeastern Irian Jaya. The terrane, which is separated from the Torricelli terrane by Late Cainozoic sediments, consists of early Miocene acid to intermediate schist, amphibolite gneiss, and marble, faulted against peridotite, gabbro, dolerite, basalt, and serpentinite of unknown age (Pieters & others, 1979). The latter are overlain unconformably by Miocene and younger biomicrite and biocalcarenite. Two K-Ar ages (20.6 ± 0.4 Ma and 21.4 ± 0.4 Ma) have been reported for the metamorphic rocks (Pieters & others, 1979). Little is known of its structural and metamorphic history or the timing of the juxtaposing of the metamorphic and mafic and ultramafic rocks of this terrane.

Rouffaer terrane

The Rouffaer terrane, named for the Rouffaer River, extends along the northern flank of the central ranges of Irian Jaya from the Derewo River at 136°15′E in the west to approximately 140°E. The terrane consists of a poorly known ophiolite complex called the Irian Jaya Ophiolite by Dow & Sukamto (1984). Only the western end of the terrane has been mapped (Dow & Hamonangan, 1981), but it can be traced eastward on airphotos and satellite images. The principal rock types at the western end are periodite, pyroxenite, metagabbro, and serpentinite.

Border Mountains terrane

The Border Mountains terrane is named for the Border Mountains, which straddle the Indonesia-Papua New Guinea border at about 3°45′S. The terrane is thought to consist of mainly Permian granitoids (257–242 Ma) and dacitic volcanics, but the rock types are known only from float (Norvick & Hutchison, 1980). The boundaries shown in Figure 5 are interpreted from aerial photographs and satellite images. Similar rocks are known from the Australian craton to the southeast and from the Kemum, Netoni, and Mangguar terranes of western Irian Jaya.

Western Papua New Guinea

Twelve terranes have been identified in western Papua New Guinea. Stratigraphic columns for each terrane and the Australia craton are shown in Figure 11 and 12 and the location of each terrane in Figure 10.

Sepik composite terrane

The terrane is named after the Sepik River. It is a large composite terrane that crops out along the north side of the central ranges south of the Sepik River and between the May River in the west and the Maramuni River in the east. The same rock types are common along the north side of the Sepik valley as far north as the axis of the northern ranges, suggesting that this terrane may also underlie the Lumi Trough. The Sepik composite terrane is in fault contact with the Landslip terrane to the west and the Jimi terrane to the east. To the south it has been thrust over Mesozoic platform, slope, and rise sediments of the Australian craton.

The Sepik composite terrane consists of at least 6 subterranes that are intimately mixed by thrusting and faulting. The terrane includes rocks of oceanic, island-arc, and continental origin. The predominant rock types are peridotite, blueschist, slate, phyllite, garnet—mica schist, quartzofeldspathic and calcic gneiss, volcanics, tuffaceous and volcaniclastic sediments, quartzose sediment, and limestone (Dow & others, 1972; Davies, 1982a, 1983; Davies & Hutchison, 1982).

The **April subterrane** consists of dismembered, thrust-bound sheets of peridotite with minor gabbro and pyroxenite, which are commonly serpentinised around their margins (Davies, 1982a, 1983; Davies & Hutchison, 1982;). The sheets are numerous and range in size from 25 × 8 km to blocks measured in tens of metres. They occur throughout the terrane and, in the northern Lagaip valley, directly overlie deformed Jurassic sediments (Davies, 1983) of the Australian craton margin.

The **Tau subterrane** consists of glaucophane—epidote and glaucophane— lawsonite mafic schist with chlorite, albite, white mica and quartz; some calcareous pelitic schist, rare ultramafic schist, and minor eclogite. This subterrane forms an overthrust sheet 55 km long with a maximum width of 12 km on the north side of the Schatteburg Mountains. It has overridden the Salumei and Sau subterranes. The age of the protolith is not known, but K-Ar glaucophane mineral ages of 38.7 Ma and 43.6 Ma suggest a late Eocene metamorphic event, while K-Ar ages on phengite (23–27 Ma) suggest a late Oligocene uplift age for this terrane (Davies, 1982a).

The **Ambunti subterrane** consists of garnet-mica schist, quartzofeldspathic, mafic and calcic gneiss with minor sericite schist, and phyllite. Protolith ages are not known, but five K-Ar and one Rb-Sr age determination suggest a late Oligocene (23–27 Ma) uplift age for this subterrane (Page, 1976; Davies, 1982a).

The **Salumei subterrane** consists of slate, phyllite, and sericitic schist derived from pelitic protoliths containing quartzose and lithic sandstones. A Cretaceous to early Tertiary age for these rocks is suggested by the presence of a Neocomian ammonite (Dow & others, 1972), Late Cretaceous-Tertiary bivalves and Cenomanian—Maastrichtian planktic foraminifera (Davies & Hutchison, 1982).

Blocks of Eocene shallow-water limestone (Davies, 1982a; Davies & Hutchison 1982) occur throughout this terrane. They may be either olistoliths, or dismembered parts of another terrane or the Australian craton.

The **Sau subterrane** consists of basalt and andesitic volcanics, red and green volcaniclastic sediment and limestone. Eocene planktic forams have been found in limestone and calcareous siltstone that form the matrix to volcanic breccia and agglomerate (Davies, 1983).

The **Sitipa subterrane** is confined to the Sitipa River area. It consists of dark-grey calcareous siltstone and shale with thin interbeds of fine quartz sandstone, and contains a characteristic Late Jurassic fauna (consisting of *Malayomaorica malayomaorica* and *Inoceramus* cf. *Haasti*) (Dow & others, 1972; Davies & Hutchison, 1982). This subterrane is identical to the Late Jurassic rocks of the Australian craton to the south and southeast. However, it is surrounded by other subterranes of the Sepik composite terrane, suggesting that it is either a window through the Sepik terrane or a displaced part of the Australian craton.

All the subterranes, except the Tau subterrane are intruded by Miocene granitoids and overlain by an overlap assemblage of middle Miocene and younger sediments and volcanics.

Landslip terrane

The Landslip terrane is named after the Landslip Ranges of western Papua New Guinea. The terrane occurs in the Landslip and West Ranges south of the Sepik River adjacent to the Irian Jaya border. The terrane is faulted against Middle and Late Jurassic black shale to the south (Trangiso Fault), the Sepik terrane to the southeast (Abi fault), and the Dimaie terrane to the northeast (Idam Fault). The western side of the terrane is buried beneath Late Cainozoic sediments of the upper Sepik Valley.

The Landslip terrane consists of mica schist, hornblende gneiss, minor marble, phyllite, and minor green mafic schist. The metamorphics are predominantly of amphibolite facies with some greenschist facies rocks. The protolith was pelitic sediment and mafic and minor calcareous rocks of unknown age. Limited isotope age dating of the metamorphism suggests that the most recent metamorphic event was completed by the late Oligocene (Davies, 1982a). It is possible that the Landslip terrane was formerly part of the Australian craton (like the Bena Bena terrane) that has been displaced and affected by a younger metamorphic overprint.

Dimaie terrane

The Dimaie terrane is named after the Dimaie River, a tributary of the Sepik River, and is located between the Sepik and May Rivers in western Papua New Guinea near the Irian Jaya border. The terrane is faulted against the Landslip terrane (Idam Fault), and surrounded on all other sides by Late Cainozoic sediments of the Lumi Trough. It consists of chloritised amygdaloidal and vesicular glassy basalt and andesite submarine lava, lava breccia, agglomerate and tuff, intruded by probably contemporaneous gabbro. There is little age control on these rocks. They are intruded by Eocene and Miocene stocks and overlain by late early Miocene sediments. They are regarded as Late Cretaceous to Eocene in age by Davies (1982a). The Sau subterrane of the Sepik composite terrane resembles the Dimaie terrane and may be dismembered parts of it.

Torricelli terrane

The Torricelli terrane is named for the Torricelli Mountains, which form part of the north coast ranges of Papua New Guinea. The terrane forms a linear east-west belt about 275 km long, extending from near Wewak to southeast of Jayapura in Irian Jaya. It is separated from the Prince Alexander and Mount Turu terranes by Late Cainozoic sediments, and, along its southern margin, is faulted against small outliers of metamorphic rock, which are referred to the Sepik terrane, but might belong to the Landslip terrane.

The Torricelli terrane consists of a basic to intermediate volcanic complex (Bliri Volcanics) and a coeval intrusive complex (Torricelli Intrusive Complex) (Hutchison & Norvick, 1980). The Bliri Volcanics are a mixed sequence of mainly basaltic and andesitic lavas and associated volcaniclastic rocks with minor argillite, small limestone lenses and, locally, thinly bedded radiolarian chert and tuffaceous limestone. Pillow lavas and pillow breccias are common. Foraminifera from calcareous rocks distributed throughout the section give ages ranging from Palaeocene to early Miocene. Possible Late Cretaceous faunas in volcanics, and reworked Late Cretaceous faunas in cover sediments suggest that the base of the sequence may be older (Hutchison & Norvick, 1980).

The intrusive rocks consist of medium-grained, non-porphyritic gabbro and diorite, dolerite, subordinate monzonite and granodiorite, and rare adamellite, harzburgite, and pyroxenite. The rocks are commonly highly deformed by fracturing, shearing, and brecciation. Twenty-one K-Ar isotopic age determinations indicate that the complex is partly Late Cretaceous (73.2–68.0 Ma), and partly late Eocene to early Miocene (41.3–17.3 Ma) (Hutchison & Norvick, 1980).

Prince Alexander terrane

The Prince Alexander terrane is named after the Prince Alexander Ranges of northern Papua New Guinea. It is a narrow southeasterly trending terrane separated from the Torricelli terrane by a complex fault system that is largely covered by Neogene sediments. The Mount Turu terrane occurs along strike from the Prince Alexander terrane, but the two are separated by Neogene sediments.

The terrane consists of deformed plutonic and metamorphic rocks, including granodiorite, diorite, dolerite, amphibolite, orthogneiss and quartz-mica- epidote schist, which are intruded by undeformed biotite adamellite stocks and andesite porphyry dykes. Shearing of the deformed rocks is accompanied by intense fracturing and mylonitisation; cataclastic rocks are common (Hutchison & Norvick, 1980). K-Ar isotope ages indicate that the high-grade metamorphic rocks are Early Cretaceous and the undeformed stocks and dykes are late Oligocene to early Miocene. A single K-Ar isotope age on a boulder of weathered granite indicates that part of the complex may be as old as Middle Jurassic (Hutchison & Norvick, 1980).

Mount Turu terrane

The Mount Turu terrane is a small terrane (27 km × 5 km) southwest of Wewak and centred on Mount Turu, a part of the north coast ranges of Papua New Guinea. It is separated from the Prince Alexander and Torricelli terranes by Late Cainozoic sediments. Its southern margin is faulted against low to medium-grade metamorphic rocks that are referred to the Sepik terrane. It consists of highly faulted and sheared ultramafic and basic rocks of unknown age and is intruded by Miocene adamellite and granodiorite. The terrane has a low gravity expression, suggesting that it is thin and possibly thrust over the Sepik composite terrane (Hutchison & Norvick, 1980).

Jimi terrane

The Jimi terrane is a large terrane (200 km long and 50 km wide) along the north side of the central ranges. It is named after the Jimi River, which drains a large part of the terrane. The terrane is separated from the Marum and Schrader terranes by the Bundi fault zone, and from the Sepik terrane by the Maramuni Fault. It is stitched to the Sepik terrane by the middle Miocene South Yuat batholith. The Bismarck Fault Zone separates the terrane from the Australian craton, and the large batholith of the middle Miocene Bismarck Intrusive Complex separates it from, and stitches it to, the Bena Bena terrane. The terrane consists of Permian to Triassic granitoids overlain by Middle Triassic black shale and a Middle to Late Triassic bimodal volcanic complex. The complex consists of acid and basic lavas, breccia tuffs, and basic dykes with an extensive non-marine and marine epiclastic apron. This complex is intruded by Early to Middle Jurassic granitoids and is overlain by a Jurassic sequence consisting of basal volcaniclastic sands which pass up into shaly facies. In the south of the terrane, the Jurassic shale gives way to Cretaceous shale with minor sandstone; to the northwest, the Jurassic shale passes up into Cretaceous basaltic and andesitic volcanics overlain by Late Cretaceous to Eocene shale (Bain & others, 1975; Pigram, 1978; Pigram & others, in press; Davies & Hutchison, 1982).

This sequence may have been part of the northern edge of the Australian continent (Brown & others, 1980; Pigram & Panggabean, 1984), but its present position, partly adjacent to the eastern end of the Sepik terrane, suggests that it has been displaced in a northwesterly direction. It should be considered a terrane, until the amount of movement between it and the Australian craton has been determined.

Schrader terrane

The Schrader terrane is named for the Schrader Range, which occurs between the Yuat and Ramu Rivers. It is separated from the Jimi terrane by the Bundi Fault Zone, and is overthrust by the Marum terrane. To the east and north it is covered by sediments of the late Cainozoic Sepik-Ramu Basin.

The Schrader terrane is a composite terrane consisting of a series of probable thrust slices made up to greenschist facies slate, phyllite, meta-volcanics, metasandstone and metaconglomerate, marble, marl, and a small ultramafic and mafic complex. The relationship between each slice unit is not known, but all exhibit the same structural history (Pigram, 1978). Rocks of the terrane are poorly dated. Deformed pelecypods of Late Cretaceous age have been collected from metasandstone, and Eocene foraminifera occur in float samples that may have been shed from the marble within the terrane. The terrane is intruded by middle Miocene granitoids. The southwestern edge of the terrane consists entirely of Late Cretaceous black calcareous slate with Late Cretaceous to Eocene limestone blocks scattered through it (Pigram, 1978).

Marum terrane

The Marum terrane is named after the Marum River, which cuts the terrane. It lies on the northern flank of the Bismarck Mountains, and is separated from the Bena Bena and Jimi terranes by the Bundi Fault Zone. The terrane is probably in thrust contact with the Schrader terrane; to the northeast, its contact with the Finisterre terrane is obscured by the Late Cainozoic Ramu Basin.

The Marum terrane consists of two allochthons; a large periodotite-gabbro massif and a smaller spilitic pillow basalt and argillite sheet that lies to the south and partly beneath the large massif. The peridotite-gabbro massif consists of a basal tectonite peridotite overlain by cumulate peridotite and gabbro. The two allochthons form northeasterly dipping thrust sheets. Windows through the peridotite-gabbro sheet and gravity data suggest that the terrane is thrust over the Schrader terrane (Jaques, 1981; Jaques & others, 1978). The age of formation of this ophiolite complex is uncertain. K-Ar isotope dating of cumulate gabbros indicates a maximum age of 173 Ma (Early Jurassic), but a granophyric diorite gave a much younger Paleocene date (59 ± 2.5 Ma). Probable Eocene fauna (radiolaria) occur in the argillite that overlies the pillow basalt (Jaques, 1981). The age of emplacement of the complex is not well constrained. It post-dates late Cretaceous to Eocene shales of the Schrader terrane found beneath the complex, and predates Quaternary alluvial deposits of the Ramu Valley.

Bena Bena terrane

The Bena Bena terrane, named after the Bena Bena River, is located in the eastern highlands of Papua New Guinea. It is separated from the Finisterre terrane by the Ramu-Markham Fault Zone and from the Marum terrane by the Bundi Fault Zone. The terrane is stitched to the Jimi terrane to the northwest by the large batholith of the middle Miocene Bismarck Intrusive Complex, and its southern boundary is covered by late Oligocene and younger sediments.

The Bena Bena terrane consists of slate, phyllite, and greenschist facies schists with minor amphibolite and marble intruded by Early Jurassic and early Late Cretaceous granitoids (McMillan & Malone, 1960; Dow & Plane, 1965; Tingey & Grainger, 1976; Page, 1976; Rogerson & others, 1982). The metamorphic rocks are unconformably overlain by Eocene limestone which contains schist clasts (Robinson & others, 1976). The metamorphics were formed from quartz-rich greywacke and sandstone, siltstone, and shale, the ages of which are unknown. Metamorphism occurred before the Jurassic.

Rogerson & others (1982) and Pigram & Panggabean (1984) considered the Bena Bena terrane to be part of the northern edge of the Australian craton. It is treated here as a distinct terrane because that relationship has not been proved.

Finisterre terrane

The Finisterre terrane is named after the Finisterre Range, which forms part of the north coast ranges of Papua New Guinea. It occurs in a discontinuous southeasterly trending belt, about 300 km long, that extends from south of Bogia to the Huon Peninsula and includes rocks of the Adelbert, Finisterre, and Saruwaged Ranges. The terrane is separated from the Owen Stanley and Bena Bena terranes by the Ramu-Markham Fault Zone and from the Marum, Schrader, and Torricelli terranes by the Late Cainozoic Sepik and Ramu Basins.

The terrane is an island-arc complex that consists of a thick sequence of middle and upper Eocene hemipelagic and pelagic sediments overlain by an Oligocene to early Miocene basaltic to andesitic volcanic complex with high-potash, high-alumina basaltic and shoshonitic affinities (Jaques, 1976). The volcanic complex is overlain by thick shallow-water limestone of middle Miocene to Pliocene age (Robinson, 1974; Robinson & others, 1976; Jaques & Robinson, 1980).

Preliminary palaeomagnetic data for the eastern end of the Finisterre terrane (Falvey & Pritchard, 1984) suggest that, during the Palaeogene, it was part of an extensive linear island arc formed by New Britain, New Ireland, Manus, and the Solomon Islands. This arc was subsequently broken up and Falvey & Pritchard (1984) suggested that the Finisterre terrane docked with the Australian craton some time after the early Pliocene.

Eastern Papua New Guinea

Eight terranes have been identified in eastern Papua New Guinea, and are described below. A map of the distribution of the terranes is shown in Figure 13 and stratigraphic columns for each terrane in Figure 14.

Owen Stanley terrane

The Owen Stanley terrane crops out over a large part of the East Papuan mainland and in the Louisiade Archipelago. It is named after the Owen Stanley Ranges, and in east Papua it forms a southeasterly trending terrane, 375 km long and up to 80 km wide, which extends from near Lae in the north to approximately 148°10′E. This part of the terrane is in fault contact with the Bowutu terrane for much of its eastern boundary. In the southeast it may be faulted against the Dayman terrane. The northwestern end of the terrane is separated from the Finisterre terrane by the Ramu-Markham Fault Zone. To the west, the Owen Stanley terrane is separated from the Menyamya terrane by an overlap assemblage of late Oligocene to early Miocene shallow marine sediments. Along its southern margin it is stitched to the Port Moresby terrane by the Oligocene Sadowa Gabbro.

The Owen Stanley terrane is made up of two belts. The eastern belt comprises low-grade greenschist facies metasediments of pelitic and psammitic derivation with subordinate metavolcanics, minor blueschists, and granulites adjacent to the Bowutu terrane. The western belt consists of argillite, shale, lithic and feldspathic sandstone, greywacke, minor limestone, pebble conglomerate, and spilitic volcanics (Dow & others, 1974; Davies & Smith, 1971; Brown, 1977; Pieters, 1978). The relationship between the belts is not clear. Davies & Smith (1971) suggested that the sediments rested unconformably on the metamorphics, but Brown (1977) and Pieters (1978) suggested the belts are lateral equivalents, and separated them at a chlorite isograd.

The age of the protoliths for the metamorphic rocks of the terrane is poorly known. Middle Cretaceous (Aptian-Cenomanian) molluscs (Glaessner, 1949) have been found in the northern part of the terrane, but, elsewhere, little control exists. Similarly, the age of the metamorphism is not well known. Eocene limestone containing schist clasts and strained quartz has been reported from near Tapini (Davies & Smith, 1971; Brown, 1977). A K-Ar age of 52 Ma for a hornblende granulite from near the Owen Stanley Fault is reported by Davies & Smith (1971) and Rb-Sr isotope age data (Page, 1976) on metasediments near Wau give an early Miocene age (21 Ma).

The belt of sediments is also largely unfossiliferous, but Late Cretaceous to Paleocene, early Eocene, and late Oligocene to early Miocene foraminifera are found in limestone lenses (Brown, 1977; Pieters, 1978; G. Francis, personal communication, February, 1986), which are generally sheared and may be fault bounded. The terrane is overlain by late Oligocene and younger sediments and volcanics, and intruded by Oligocene gabbro and Miocene granitoids.

Bowutu terrane

The Bowutu terrane forms an arcuate terrane, 400 km long and 25–40 km wide, along the northern side of the Owen Stanley Range in East Papua. Smaller areas of peridotite on Fergusson and Normanby Islands are also included in this terrane. It is separated from the Owen Stanley, Dayman, and Kutu terranes by the Owen Stanley fault zone (Davies, 1971; Smith & Davies, 1976; Davies, 1980b). The terrane on Fergusson and Normanby Islands is in fault contact with the D'Entrecastreaux terrane.

The Bowutu terrane consists of the Papuan Ultramafic Belt (PUB) (Davies, 1971), which is intruded by Eocene tonalite and unconformably overlain by middle Eocene andesitic volcanics (Davies, 1971, 1977). The PUB consists of 4–8 km of ultramafic rock overlain by about 4 km of gabbroic rocks, which are overlain by about 4 km of basaltic volcanics. The complex appears to be Cretaceous in age, based on several K-Ar isotope ages on rocks from the gabbroic and basaltic layers, and the occurrence of a poorly preserved foraminifera in sediments associated with the basalts (Davies, 1977).

Kutu terrane

The Kutu terrane, named after the Kutu River in east Papua, crops out over an extensive area of the southeast Papuan mainland and on Sideia and Basilaki Islands. It is in fault contact with the Dayman, Owen Stanley, and Bowutu terranes.

The Kutu terrane consists of submarine tholeitic basalt with minor dolerite, gabbro, and rare ultramafic rocks, interbedded volcanolithic sandstone, argillite, and calcilutite. The calcilutite lenses contain Maastrichtian and middle Eocene planktic foraminifera (Smith & Davies, 1973 a,b, 1976). The terrane is intruded by minor middle and late Miocene monzonite and syenite stocks and dykes.

Dayman terrane

The Dayman terrane is named for Mount Dayman in east Papua. Parts of the dismembered terrane occur in the Owen Stanley Ranges east of Port Moresby, around Mt Dayman and on Normanby Island. The terrane is thought to be thrust over the Owen Stanley terrane and is, in turn, overthrust by the Bowutu terrane. Near Mt Dayman, the southern margin of the terrane is in presumed fault contact with the Kutu terrane, and is covered along its northern edge by middle Miocene to Quaternary sediments of the Cape Vogel Basin. On Normanby Island, the terrane is in fault contact with the D'Entrecasteaux terrane.

The Dayman terrane consists of green mafic schist, with minor pelitic schist and marble. Metamorphic grade ranges from prehnite-pumpellyite to lawsonite—glaucophane and greenschist facies (Pieters, 1978; Davies, 1980a). The protolith was predominantly mafic volcanics with minor sediments. The age of the volcanic protoliths is not known, but the calcareous sedimentary protoliths of the Bonenau schist member in the Mt Dayman region contain late Cretaceous and Eocene faunas (Davies & Smith, 1974). A single K-Ar age on metamorphic amphibole from the western part of the terrane gives an Eocene age (42 ± 4 Ma) for the metamorphism (Davies, 1980b). The Dayman Dome has features in common with the metamorphic core complexes of western North America.

Woodlark terrane

The Woodlark terrane forms a largely submerged ridge that extends eastward from the Trobriand Islands. Woodlark Island, the only emergent part of the ridge, has a basement of lava, pillow lava, pyroclastics, and sediments of Eocene age (Williamson, 1984). These rocks are overlain by late Oligocene limestone, which contains reworked, probably Eocene, large benthonic foraminifera (Davies & others, 1984; Trail, 1967; Ashley & Flood, 1981).

The ridge was formerly next to that part of the Owen Stanley terrane found in the Louisiade Archipelago, but has been rifted from it by the formation of the Woodlark Basin by sea-floor spreading during Pliocene to Holocene time.

D'Entrecasteaux terrane

The D'Entrecasteaux terrane crops out on Fergusson, Goodenough, and Normanby Islands of the D'Entrecasteaux Islands in eastern Papua New Guinea. These islands form the southern part of a large shallow platform that extends to just north of the Trobriand Islands. The terrane consists of quartzo-feldspathic gneiss and layered amphibolite intruded by Pliocene granodiorite batholiths. The metamorphics are of amphibolite and pyroxene granulite and eclogite facies, and form domes with granodiorite cores, (Davies & Ives 1965; Davies & Smith, 1971; Davies, 1973). The age of the metamorphics is not known. The protoliths appear to have been predominantly of granodiorite composition with minor basic volcanics. This terrane may be an eastern extension of the Owen Stanley terrane.

Port Moresby terrane

The Port Moresby terrane is named for and occurs in the vicinity of Port Moresby and along the southern part of the Papuan peninsula to the east. The western part of the terrane is in fault contact with the Owen Stanley terrane. The nature of the contact of the eastern part of the terrane with the Kutu terrane is not known.

The Port Moresby terrane consists of ?Oligocene gabbroic rocks and a highly faulted and repeated sequence that contains a mixture of deep and shallow-water sediments. Neritic Campanian arenaceous limestone is juxatoposed with deep-water sediments, which include Maastrichtian-Paleocene middle to lower bathyal and Eocene abyssopelagic carbonate and siliceous rocks, as well as terrigenous turbidites. No upper Eocene or lower Oligocene units are known. Late Oligocene tuff and tuffaceous sediments, and bathyal turbidites and carbonates of late Oligocene to early Miocene and latest Miocene to earliest Pliocene age also occur (Pieters, 1978; Rogerson & others, 1981; Smith & Davies 1973a, b; Haig, 1982; D.W. Haig, personal communication, July 1985). The sediments generally contain abundant planktic foraminifera and are well dated.

Deformation of this terrane in the Port Moresby area occurred during the Oligocene to middle or late Miocene and, possibly, in the earliest Pliocene (Rogerson & others, 1981; D.W. Haig, personal communication, July, 1985).

Menyamya terrane

The Menyamya terrane, which is located west of Wau, is named after the town of Menyamya. It is a small elliptical terrane, measuring approximately 35 km × 25 km. The western edge of the terrane is in thrust fault contact with early middle Miocene sediments, which contain detritus derived from the terrane. To the east, its contact with the Owen Stanley terrane is covered by an overlap assemblage of late Oligocene to early Miocene marine sediments.

The terrane consists of sheared mafic and ultramafic rocks, basic volcanics, grey and red siltstone, chert and bathyal limestone (Uyaknji Complex) of probably Paleocene to Eocene age (T.J. Griffin, personal communication, December 1984). The terrane is interpreted as oceanic crust that formed close to an exposed landmass (T.J. Griffin, personal communication, December 1984) and was thrust westward in middle to late Miocene time.