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Tectonism, magmatism and sedimentary basin development, Paleozoic to Paleogene, New Caledonia

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Abstract: Three pre-Cretaceous basement terranes are recognised in New Caledonia: 1. Karagreu–Boghen Terrane — an old accretionary complex, metamorphosed to greenschist facies, of uncertain age but probably Early Permian or older and tentatively correlated with Mid-Late Paleozoic complexes of New England Fold Belt. 2. Mt. Canala-Téremba Terrane — arc type volcanics and volcaniclastics of Upper Permian to Early Jurassic age and correlated with the Brook Street Terrane of New Zealand. 3. Ponérihouen-Baie St. Vincent Terrane — volcaniclastic and terrigenous sandstones and argillites of Mid Triassic to Jurassic age and correlated with the Murihiku and Waipapa Terranes of New Zealand. The Karagreu-Boghen and Mt. Canala-Téremba Terranes were probably juxtaposed by the Late Triassic. The three basement terranes were stitched together by late Mesozoic intrusives and Rangitata (Early Cretaceous) metamorphism and deformation. Late Cretaceous-Paleocene extensional sedimentary basins with bimodal volcanism were developed to the N (Diahot Basin) and S (Nouméa Basin). The Cretaceous basalts of the Diahot basin are ocean floor type while those of the Nouméa Basin are arc type and represent the final extensional stage of Mesozoic subduction. The allochthonous Cretaceous-Eocene West Coast basalts, believed to be New Caledonia Basin ocean floor, are normal MORB-type tholeiites with some arc affinities. The West Caledonian Fault post dates Early Oligocene obduction of the New Caledonian ultramafic sheet and has 55 km of right lateral transcurrent movement. Vertical movement on this fault has also played a major role in Miocene uplift particularly in the north of the island.

INTRODUCTION

New Caledonia is the only substantial emergent portion of the Norfolk Ridge north of New Zealand (Fig. 1) and as much provides a unique opportunity for studying the nature of the rocks forming that ridge system and understanding the crustal evolution of the North Tasman-Coral Sea part of the SW Pacific.

The geology of New Caledonia is well known, and described most recently in the synthesis of Paris (1981). There also exists a modern set of geological maps on the scale of 1:50,000 published over the past 15 years by the Bureau de Recherches Géologiques et Minières. The marine geology of the ridge and basin systems surrounding New Caledonia are also now well known through the work of Dubois *et al.* (1974), Kroenke (1984) and Eade (1988). Because of the strong geological similarities between New Caledonia and New Zealand, many New Zealand geologists (Campbell *et al.*, 1985; Brothers, 1985) have been interested, particularly in stratigraphic and petrologic aspect of New Caledonian geology. This study draws on previous work, supplemented with personal field and petrologic observations, to attempt a new terrane concept oriented model for the tectonic evolution of New Caledonia.

Major lithostratigraphic units of New Caledonian geology are shown in Figure 2. There are four main structural units (Paris, 1981; Brothers and Lillie, 1988) — the Central Chain "core" of pre-Cretaceous rocks; the northern belt of Late Cretaceous to Eocene sediments high pressure metamorphosed by a Late Eocene event; the "formation of basalts" and Eocene sediments which extend along the west coast; and an obducted sheet of ultramafic rocks which covers a major portion of the southern part of the main island.

The present-day relationships of these geological units are dominated by two mid-Tertiary tectonic features (Fig. 2):

1) an E-W trending "mélange zone" which separates the high pressure metamorphic belt from rocks of the Central Chain. The mélange zone has been interpreted as the site of a subduction zone (Brothers and Blake, 1973) and a transform suture system (Brothers and Lillie, 1988).
2) the NW-SE trending West Caledonian Fault (Paris, 1981) which is believed to have had a major dextral transcurrent movement and to dislocate the ultramafic sheet (Brothers and Blake, 1973).

In order to understand the tectonic development of New Caledonia and the relationship between the pre-Tertiary tectono-stratigraphic terranes, it is necessary to reconstruct the geology of New Caledonia restoring lithostratigraphic units to their relative positions before their mid-Tertiary disruption by the West Caledonian fault.

DISPLACEMENT AND TIMING OF WEST CALEDONIAN FAULT

The West Caledonian fault extends as a linear feature along the western margin of New Caledonia from east of Poum in the North to immediately west of Nouméa, marked along its length by a clear topographic depression and shearing of adjacent rocks. Some authors (Paris, 1981) have, near Moindou, swung the fault to the east to parallel a pre-Tertiary fracture zone with the apparent purpose of explaining a facies change in the Mesozoic sediments. However, the topographic and structural features which mark the West Caledonians Fault trace to the north continue with the SE trend to the south of Moindou along the eastern side of Baie St. Vincent and into the sea on Magenta Bay near Nouméa.

The sense of movement is considered to be right lateral but the amount of transcurrent movement on the fault has not previously been defined, although it has been suggested to be of the order of 200 km (Brothers and Blake, 1973). In order to achieve an estimate of movement, the fault movement was reversed. Slipping the western side of the fault approximately 55 km to the south achieves simultaneous juxtaposition of the following five geologic features on the western and eastern side of the fault respectively (Fig. 3):

1) Fossiliferous Late Jurassic sediments of Temala with a similar horizon at Goipin.
2) Cretaceous-Paleocene and Eocene sequences in the Bourail Basin with similar rocks in the Boulouparis-Nassirah area.
3) The Permian beds of the Téremba Group on the western side of the Baie de St. Vincent align with Permian rocks which extend from Mt. Canala into the Karaogue River basin the Central Chain.
4) The Mesozoic sediments of Baie de St. Vincent with those on the eastern side of Baie de Dumbea.

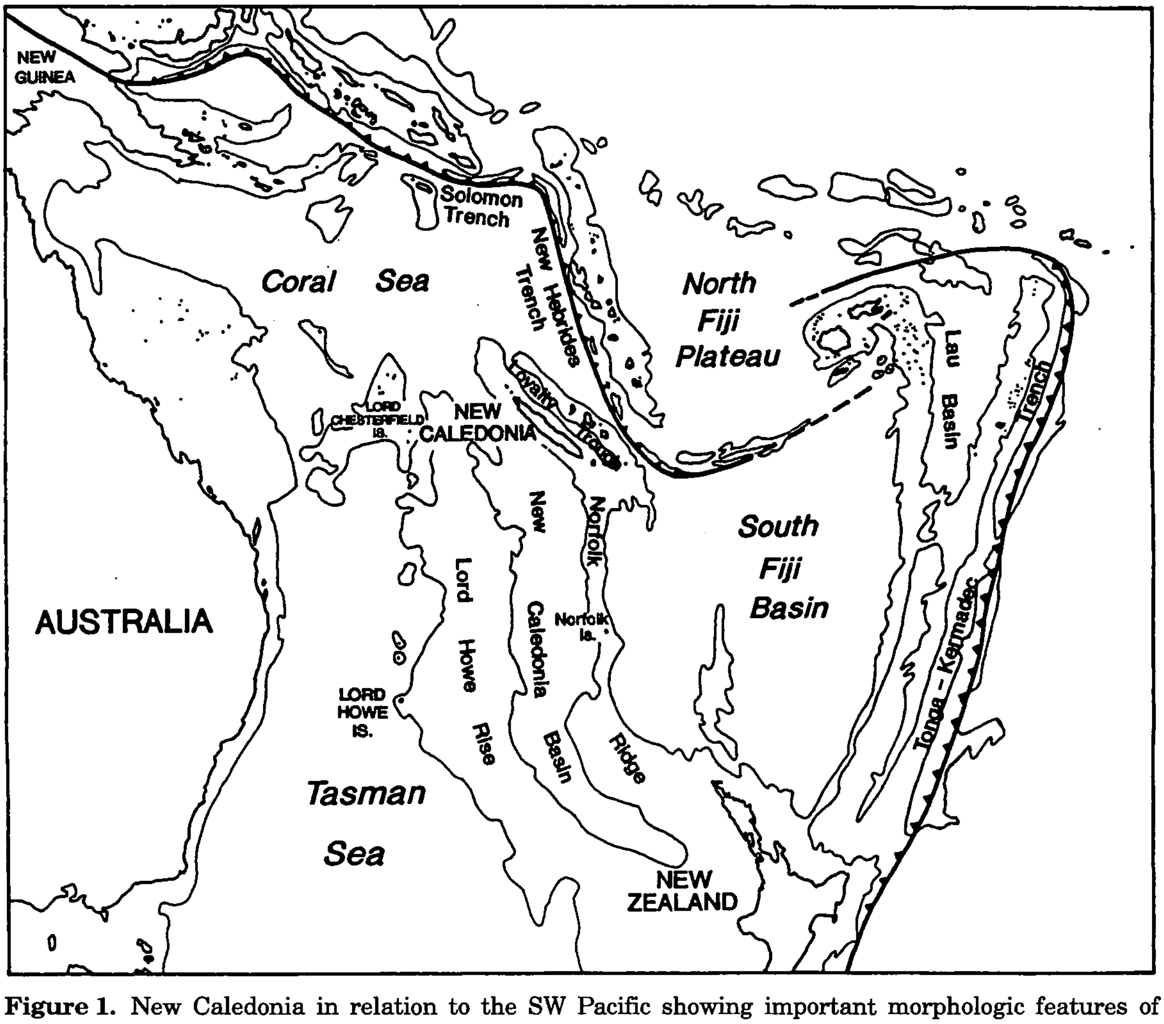

Figure 1. New Caledonia in relation to the SW Pacific showing important morphologic features of adjacent ocean areas.

5) The Kopeto-Boulinda and Téné ultramafic massifs.

The geological reconstruction of Figure 3 provides the basis for a new interpretation of the geology of New Caledonia and definition of pre-Tertiary tectonostratigraphic terranes. In the light of the close similarity between the Permian and Mesozoic strata of New Caledonia and New Zealand (Paris, 1981; Grant-Mackie, 1985) the New Caledonian terranes will, where appropriate, be compared with the recognised sequence of pre-Cretaceous terranes of New Zealand (Bradshaw, 1989).

PRE-CRETACEOUS TERRANES

There are three distinct pre-Cretaceous lithostratigraphic units in New Caledonia (Paris, 1981) which are here recognised as discrete tectonostratigraphic terranes.

Karagreu-Boghen Terrane (?late Paleozoic)

This terrane, which forms the massifs of Karagreu-Boghen and Ouango-Netchaot, is named from the Karagreu-Boghen formation of Paris and Lille (1977). Its age is uncertain but Paris (1981) maps it as ?pre-Permian. Efforts to extract microbiota so far have been unsuccessful and no fossils other than vague radiolarian remnants are known. It is a slice of an accretionary wedge composed in part of ocean floor material — with thick sequences of dolerites and basalts, sometimes with pillow form, interbedded cherts and calcareous sediments — together with quartzofeldspathic and calcareous schists and a more greywacke-type succession of tuffaceous and argillaceous sediments. The tuffaceous sequences, particularly in the northern Ouango-Netchaot massif have been metamorphosed to greenschist facies, are strongly foliated and have experienced several stages of intense deformation. Elsewhere they are typically polydeformed, often polymetamorphosed but always with at least pumpellyite-actinolite grades of metamorphism. The little published information available on the petrology and geochemistry of basaltic volcanics (Black and Brothers, 1975) indicate typical MORB (ocean floor) composition but andesitic-rhyolitic debris also occurs (Paris, 1981). This terrane has no counterparts with New Zealand basement terranes although it shows some

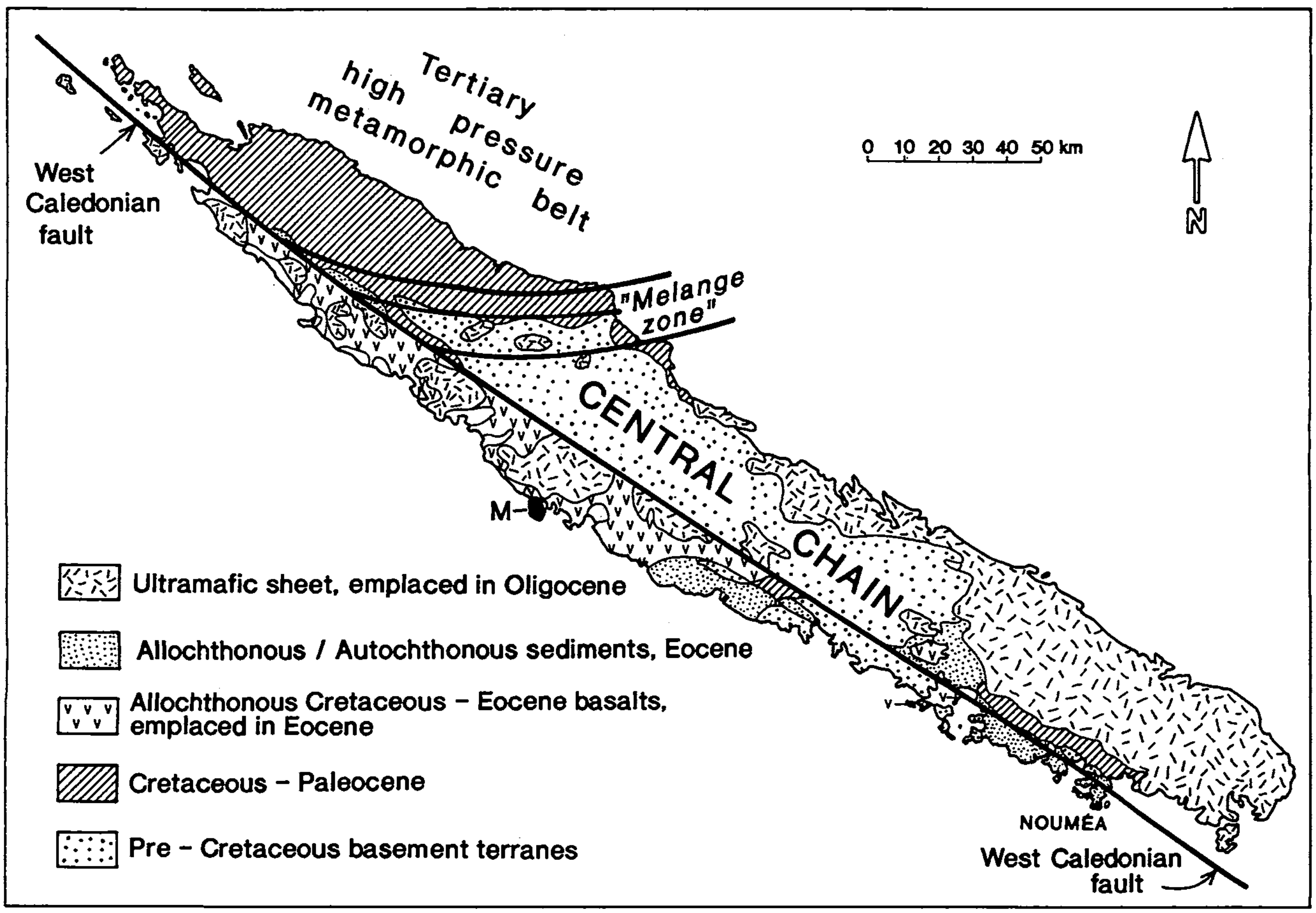

Figure 2. Major lithostratigraphic and tectonic features of New Caledonian geology (M = Miocene coral reefs).

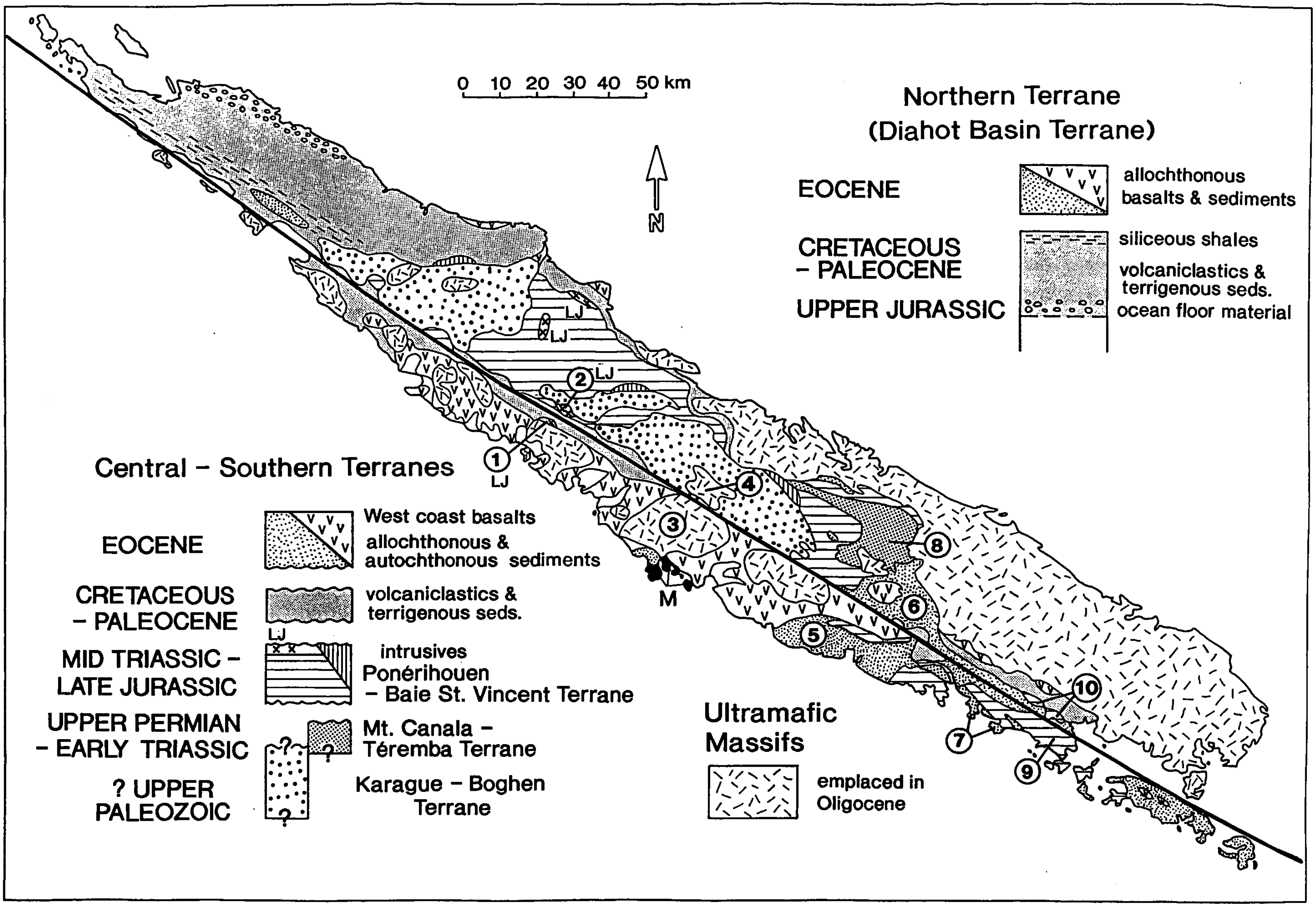

Figure 3. Simplified geological terrane map of New Caledonia (after Paris, 1981) after removing 55 km of displacement along the West Caledonian Fault. M = Miocene coral reefs. LJ = late Jurassic marine sediments. Numbers show geological features which were used to determine amount of displacement along West Caledonian Fault. (1) Late Jurassic sediments at Temala; (2) Late Jurassic sediments at Goipin; (3) Kopeto-Boulinda ultramafic massif; (4) Téné ultramafic massif; Cretaceous-Paleocene and Eocene sedimentary sequences of Bourail Basin (5) and Bouloupari area (6) Late Permian strata of Téremba (7) and Mt Canala (8) areas; Mesozoic sequence of St Vincent (9) and Dukbea Bays (10).

similarities with higher sections of the Dun Mt.-Maitai terrane (Coombs *et al.*, 1976).

Mt. Canala-Téremba Terrane (Upper Permian-Early Triassic)

This terrane lies to the east of the Karagreu-Boghen terrane and now survives as a sinuous elongate belt of volcanics and volcaniclastic sediments extending from Mt. Canala into the Karaogue Basin west of Thio and its continuation is exposed as the Téremba Group along the western side of Baie St. Vincent. Sediment in the northern section (Central Chain) are finer grained and less fossiliferous than those of the southern section (Paris, 1981; Campbell *et al.*, 1985). The volcanics, intrusives and lithic debris are all arc type (andesite, dacite, rhyodacites) and represent the remnants of a late Permian volcanic arc. The Mt. Canala-Téremba terrane has its closest similarities with the Brook Street Volcanic terrane of South Island of New Zealand in terms of its age, lithologies, faunal content and association with the Mesozoic Murihiku succession.

Ponérihouen-Baie St. Vincent Terrane (Mid Triassic to Upper Jurassic)

Much has already been written about the strong similarities between the Baie St. Vincent Group and the New Zealand Murihiku (Paris, 1981; Grant-Mackie, 1985) but the less fossiliferous, finer grained and more deformed greywackes of the Central Chain have never found an obvious counterpart among the Mesozoic terranes of New Zealand except for the Morrinsville facies of the Waipapa Terrane. Indeed the relationship between the North Island Murihiku and Morrinsville facies seems analogous to the Baie de St. Vincent-Central Chain greywackes of New Caledonia in that they appear to have shared the same provenance area and be part of the same paleobiogeographic (Maorian) province (Grant-Mackie, 1985). For this reason the Mid Triassic to upper Jurassic succession of New Caledonia are placed in a single terrane and the lithologic and faunal variations are considered simply to represent facies variations related to different positions in a 200 km long depositional belt. The rocks are volcaniclastic sandstones and argillites which become finer from south to north. Paris and Bradshaw (1977) note two sources of detrital material — volcanic debris from the east and terrestrial from the west. All rocks of this terrane (including those with similarities to the New Zealand Murihiku) have been metamorphosed to at least prehnite-pumpellyite facies.

PALEOTECTONIC CONSTRUCTION OF THE PRE-RANGITATA EVENTS

The age of the Karagreu-Boghen terrane is uncertain. On structural grounds (summarised in Paris, 1981) it is considered to be older than the Late Permian rocks. The paleotectonic reconstruction shown in Figures 4 and 5 adds support to this conclusion and the interpretation of the Karagreu-Boghen terrane as a fragment of an old arc system. Presumably it is a slice of late Paleozoic Gondwana margin dispersed by Early Permian rifting and fragmentation. If this is the case, then the Karagreu-Boghen terrane should be correlated with one of the mid-late Paleozoic complexes of the New England Fold Belt recognised by Cawood and Leitch (1980).

The Upper Permian volcanic arc (Mt. Canala-Téremba terrane), which may extend to the NW under the Mesozoic sediments, lies to the east curving slightly to the SW around the older arc core, with the Triassic-Jurassic volcanic arc further to the east feeding volcanic debris into the back arc basin (Figs. 4 and 5a). Boninites and tholeiites found in the Permo-Triassic igneous complex on the edge of the Boghen massif are considered to be evidence of a back arc environment during the early stage of development of the new Late Permian-Mesozoic arc system (Cameron, 1989).

Although the broad map relationship (Figs. 2-4) suggests both the Karagreu-Boghen and Mt. Canala-Téremba terranes are covered by the younger Mesozoic sediments, the three terranes are never seen in normal sedimentary contact. Everywhere contacts are thrusted and faulted and lenses of serpentine are sometimes strung out along terrane boundaries. When the two Paleozoic terranes were juxtaposed is uncertain, but the youngest rocks in the Mt. Canala-Téremba terrane, the carbonaceous terrigenous Momea Formation of Mid Triassic age contains abundant detrital quartz and white mica (Paris, 1981) which suggests they were in close proximity by the mid Triassic. The Karagreu-Boghen terrane is probably the source of the terrestrial debris, including detrital chlorite and epidote in Upper Triassic and Jurassic sandstones (Paris, 1977), and the Precambrian zircons recorded in Cretaceous sediments of the Moindou-Nouméa area (Aronson and Tilton, 1970).

The three pre-Cretaceous terranes were together in the early Cretaceous by Rangitata deformation, and metamorphism to at least prehnite-pumpellyite facies (Guerange *et al.*, 1977), and "sutured" by intrusion of basic and acidic magmas (Paris, 1981 see Fig. 36).

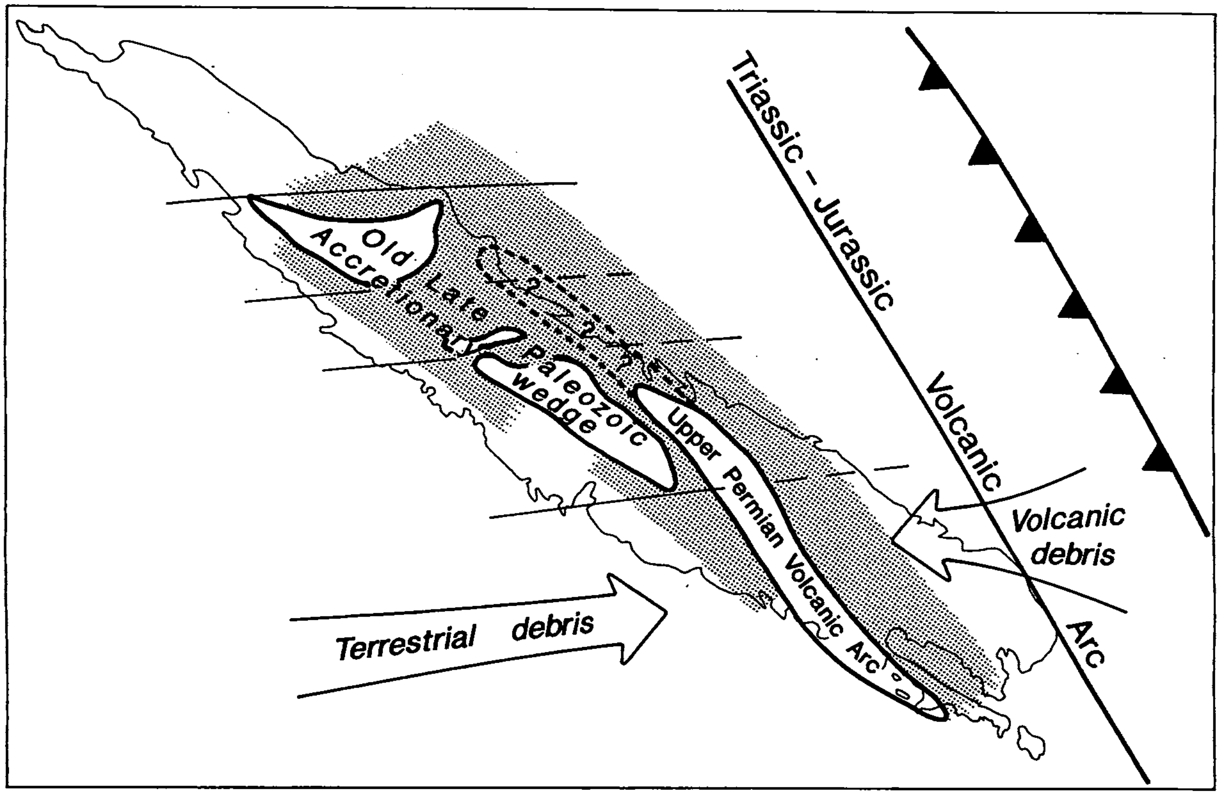

Figure 4. Cartoon showing paleogeographic interpretation of pre-Cretaceous Terranes. Stippled area represents mid Triassic to late Jurassic depositional basin.

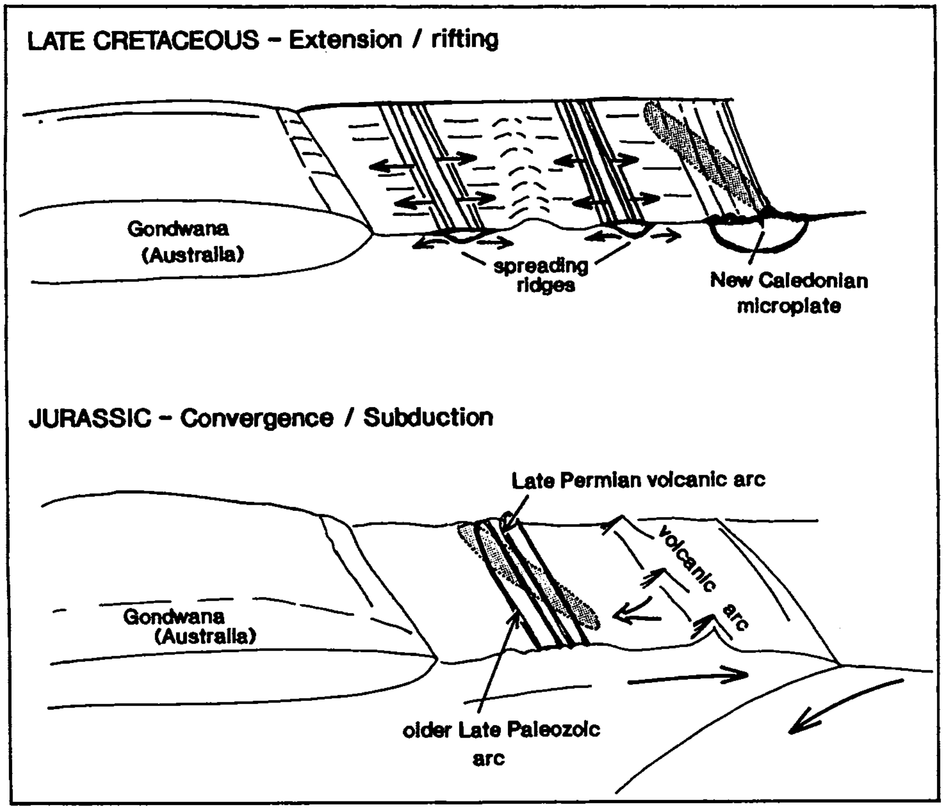

Figure 5. Cartoon showing tectonic setting of New Caledonia in the Jurassic and Late Cretaceous.

EVOLUTION OF CRETACEOUS SEDIMENTARY BASINS

The breakup of the eastern margin of Gondwana began in the late Cretaceous as part of a phase of extensional tectonics which also saw the opening up of the Tasman Sea. Spreading began about 80 Ma on two ridge systems one developing into the Tasman and the other into the New Caledonia Basin but spreading in the New Caledonia Basin was short-lived and had ceased by about 53 Ma at which time New Caledonia had reached its maximum distance from Australia (Eade, 1988).

During the late Cretaceous to early Tertiary period a number of extensional basins opened in the Tasman and Coral Seas. The main tectonic features which affected New Caledonia itself were the development of several major WE trending extensional fracture zones along which uplift occurred. These faults appear to have controlled sedimentational patterns through the late Cretaceous and early Tertiary. The central chain core of New Caledonia, which appears to have been emergent from the late Cretaceous, is margined by late Cretaceous transgressive carbonaceous sequences and locally also by thick conglomerate fans of the same age. The major sites of late Cretaceous sedimentation occur only to the north of the Central Chain in the Diahot Basin and in the south in a structurally controlled depression in the Bourail-Boulouparis-Nouméa area. Both of these basins are characterised by carbonaceous sedimentary sequences, which pass up into siliceous shales of Paleocene age, and by the occurrence in the late Cretaceous of horizons of rhyolitic and basaltic volcanism.

Nouméa-Bourail Basin

Upper Cretaceous sediments are transgressive shallow-water coarse sandstones and shales often containing plant material and local thin coal seams. Rhyolite flows which can be followed for several km and basaltic-andesitic tuffs and debris flows occur in a NW trending zone in the Nouméa basin. The volcanics are augite-olivine basalts, augite-hornblende andesites and aphyric rhyolites with medium to high K affinities and isotope, REE and trace element geochemistry which show strong orogenic affinities and evidence of crustal contamination. Such volcanic suites are typical of the final extensional stage of subduction and volcanics of similar age and type have been reported from islands off the Eastern Queensland coast (Ewart *et al.*, 1991).

Diahot Basin (Diahot Basin Terrane)

According to Maurizot (1987) the sedimentary succession of the Diahot basin was almost continuous from upper Jurassic through to the Paleocene and consists of Mesozoic fine grained greywacke-type successions and carbonaceous pelites of upper Cretaceous age passing into a Paleocene siliceous shale facies. The sequence appears to have been deposited directly on Mesozoic ocean floor which is exposed as eclogites on the eastern side of the basin (Maurizot, 1987). A horizon of rhyolitic tuffs and basalts flows is enclosed within the Upper Cretaceous. The basalts are typical oceanic tholeiites showing no evidence of subduction or crustal contamination and associated rhyolites also appear oceanic (Black *et al.*, 1992). The rocks of the Diahot basin are regarded as a distinct tectonostratigraphic terrane (Diahot Basin Terrane). Their contact with the Central Chain terranes is by a series of high angle southward dipping thrust zones. All rocks of the Diahot Basin Terrane and adjacent rocks in the Central Chain terranes have been subjected to mid Tertiary high pressure metamorphism.

PALEOGENE TECTONIC EVOLUTION

Seismic profiles taken in the New Caledonia region show a wedge of early Tertiary sediments dipping from a position to the west of New Caledonia eastwards under the island and this has been interpreted as an Eocene subduction zone (Dubois *et al.*, 1974). Plate boundary motion during the Eocene was oblique convergent with rotation of the Australian plate to the North with respect to the Pacific Plate. The plate boundary at that time was immediately to the west of New Caledonia, sited in the New Caledonia Basin and marked by several "jogs", one of which was positioned immediately to the west of the southern end of New Caledonia where the trend of the Norfolk Ridge system changes from NS to NW (Eade, 1988). Buckling and bulging of the New Caledonia Basin floor as the Australian plate rotated north past the flexure is believed to have caused ocean-floor material to slide NE onto New Caledonia (Kroenke, 1984; Eade, 1988). Flake tectonic theory predicts that the youngest material will be shed first. Eocene pelagic sediments are believed to have been shed first and slid onto the southern tectonically depressed part of New Caledonia, the Bourail-Nouméa basin, where allochthonous Eocene sequences are interleaved with the autochthonous clastic sequences derived from erosion of the adjacent basement highs. Following the removal of their covering sediments, the exposed and up-buckled Cretaceous-Eocene igneous ocean floor also became unstable and slid NE but since the plates are also rotating the olistostrome of basaltic material would have been projected to the north of the allochthon of pelagic sediments, where they banked up against the emergent Central Chain block (Fig. 6a). Black and Brothers (1989) have shown that basalts of Cretaceous-Eocene age on the western and eastern coasts are geochemically distinct so the Central Chain must have been effective in confining the allochthonous basalt sheet to the west coast.

The timing of the northward movement of the Australian plate against the Pacific plate is coincident with the high pressure metamorphic event in the Diahot Basin Terrane (Blake *et al.*, 1977). The resultant thrusting of the Central Chain to the N over the sediments of the Diahot Basin is believed by this writer to be the cause of the mid-Tertiary high pressure metamorphism in the northern part of New Caledonia (Fig. 6a).

By the Oligocene, the active plate boundary had jumped to the east into the South Loyalty basin. According to Kroenke (1984), convergence along the new plate boundary resulted in obduction of Loyalty basin ocean floor ultramafics onto New Caledonia (Fig. 6b) before the Miocene active plate margin jumped further east and the New Hebrides trench was developed.

CRETACEOUS – EOCENE MAGMATISM

The Cretaceous-Eocene period is probably the most important as far as magmatic activity in New Caledonia is concerned since it includes four petrogenetically distinct igneous groups: the extensive West Coast Basalts, the bimodal volcanism in the two Cretaceous sedimentary basins and boninites.

There is a considerable amount of information available on the West Coast Basalts (Paris, 1981) including some trace element and isotope data (Dupuy *et al.*, 1981; Cameron, 1989) and also good geochemical information of the volumetrically very minor boninites which are believed to be younger than the associated tholeiitic basalts and possibly represent the products of Eocene subduction processes (Cameron, 1989; Crawford *et al.*, 1989). However there is little published information about he late Cretaceous basalt-rhyolite volcanism. It is not the purpose of this paper to present geochemical and petrographic data or to discuss the magmatism in any detail. Unpublished trace element data for 75 basalts from *in situ* flows in the Diahot and Nouméa Basins and the tectonically emplaced West Coast Basalts, sourced in the New Caledonia Basin, are shown in discriminant diagrams to illustrate differences in their origin (Figs. 7 and 8).

The three sets of basalts are geochemically distinct. Basalts of the Nouméa basin are clearly arc type basalts while the Diahot and West Coast basalts are MORB type ocean floor basalts with some arc signature.

NEOGENE TECTONIC AND MAGMATIC EVENTS

According to Kroenke (1984) reorganisation of the Australia/Pacific plate boundary in the Early Miocene briefly reactivated the old eastwardly dipping Eocene subduction zone in the New Caledonian area leading to the intrusion, through the ultramafics of small granodioritic stocks (Guillon, 1975), and presumably also initiating the transcurrent movement along the West Caledonian Fault. From the evidence of the matching of the 5 pairs of geological features on opposite sides of the fault, it is concluded that there has been 55 km of dextral transcurrent movement along the West Caledonian Fault, all of which must have occurred after the obduction of the ultramafic sheet.

Black *et al.* (1992) have concluded that the preservation and exposure of the Tertiary high pressure metamorphic rocks in the Diahot Basin terrane is the result of rapid uplift on the West Caledonian Fault. Evidence of the importance of both transcurrent and vertical movement on this

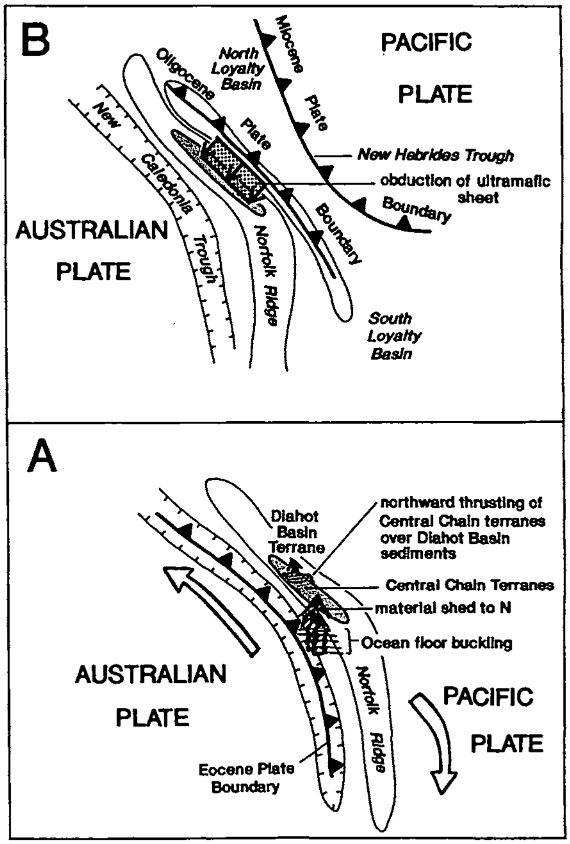

Figure 6. Cartoon showing tectonic setting of New Caledonia in Eocene (A) and Oligocene-Miocene (B).

fault comes from the pattern of metamorphism exhibited by the rocks on the east side of the fault in the Central Chain which show an increase in metamorphic grade towards the fault with preservation of high pressure facies in the pre-Cretaceous rocks adjacent to the fault trace (Guerange *et al.*, 1977; Paris, 1981).

A particularly important feature of the Miocene was rapid uplift of the Northern and Central parts of New Caledonia and the subsequent erosion and development of nickeliferous laterites (summarised in Brothers and Lillie, 1988). If the ultramafic sheet covered the whole of the island, as the present distribution of massifs along the West Coast suggests, then the general absence of ultramafics in the north and in the Central Chain is evidence of differential vertical movement along the fault and further emphasises the importance of the West Caledonian Fault on both the physiography and geology of New Caledonia.

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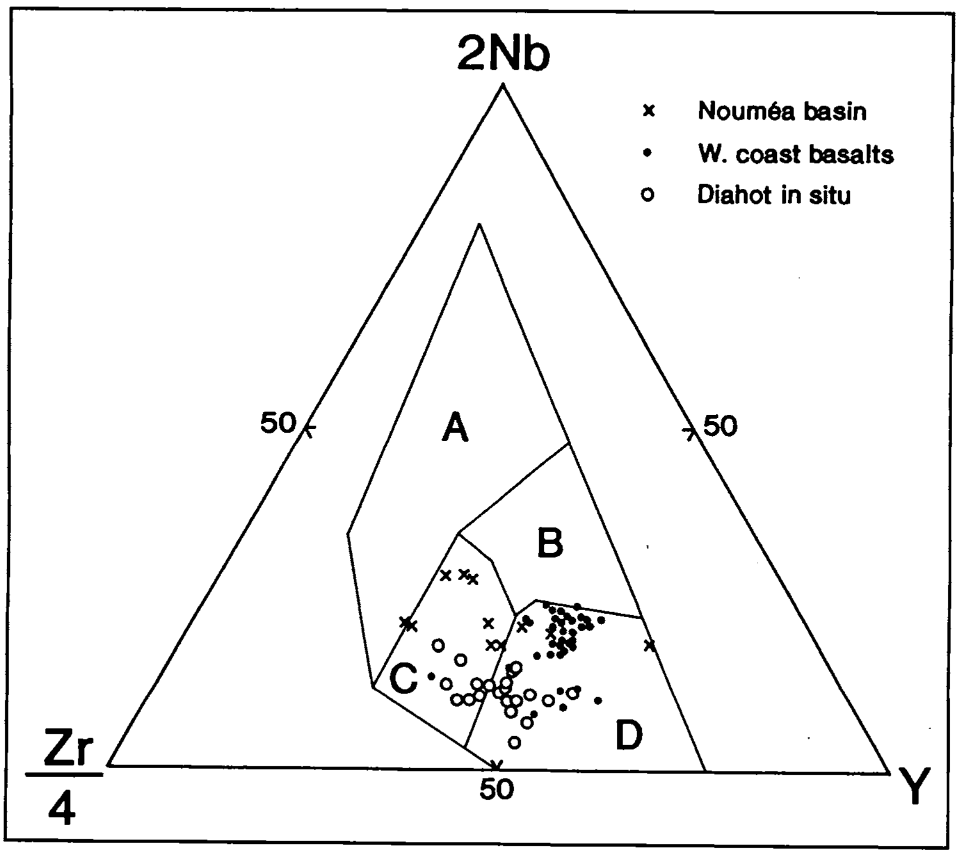

Figure 7. Trace element discriminant plot for basalts after Meschede (1986). A = within-plate alkalic basalts; C = within-plate tholeiites; B = primitive MORB; D = normal MORB; CD = arc basalts.

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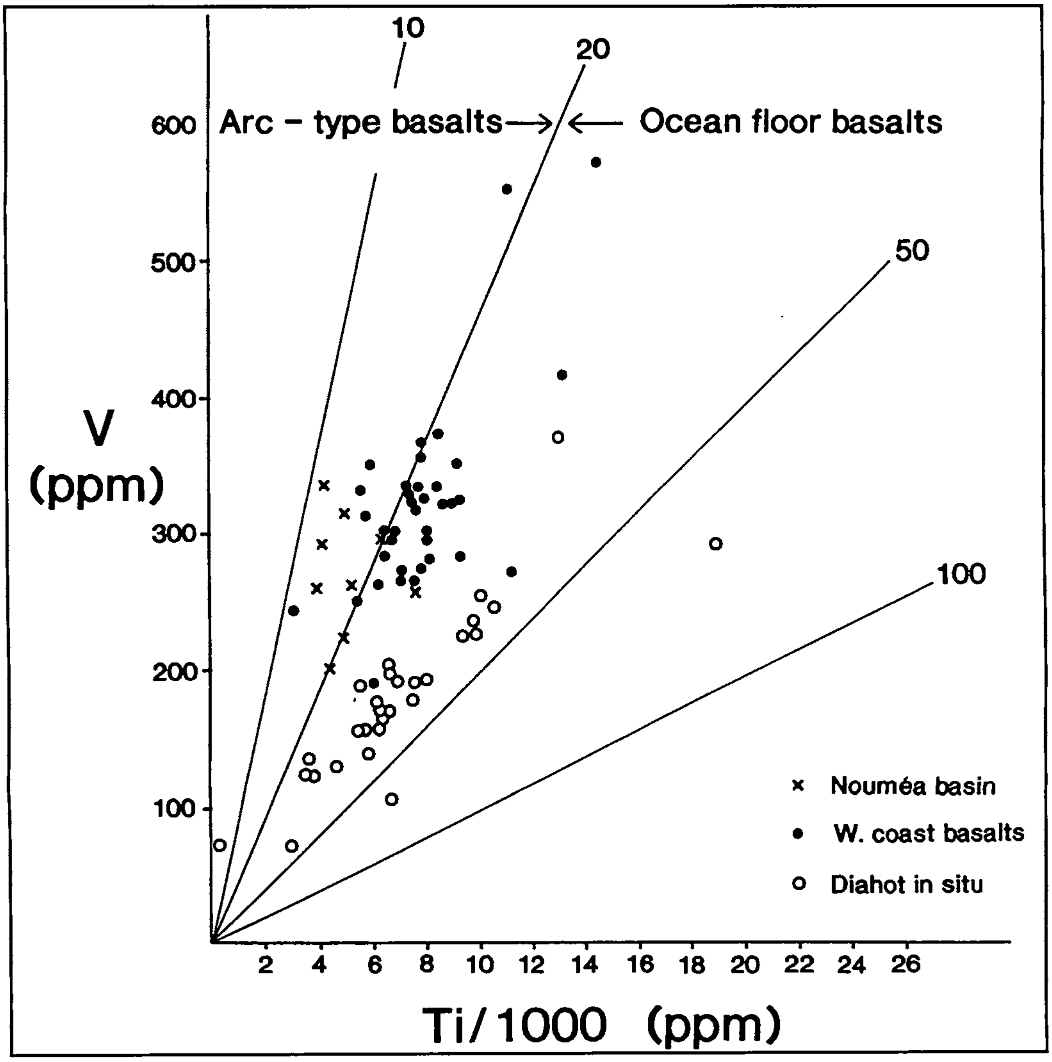

Figure 8. V/Ti plot for basalts after Shervais (1982).

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