NEW CALEDONIA

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CONTENTS

A. INTRODUCTION

New Caledonia with the adjacent islands, situated some 1200 km north-east of Australia, is an exposed section of a highly complex orogenic belt flanked on both sides by deep ocean. The geology is dominated by 'gliding nappes'; phases of metamorphism occurred in late Jurassic and again in late Eocene.

Knowledge of the geology is insufficiently detailed for a full quantitative analysis, and this chapter is partly in essay form.

B. GEOLOGICAL HISTORY

The known geological history of New Caledonia started in the Permian with the deposition of multicoloured tuffs. Between the Permian and the Trias there was an orogenic phase, indications of which are present in certain islands of the Bay of St. Vincent (Fig. 1); this phase corresponds to the 'Hunter-Bowen orogeny' of eastern Australia. A thick monotonous series of greywackes demonstrates continuous sedimentation from the Triassic to the Oxfordian. The first phase of metamorphism to affect these series occurred during an emergence (Cimmerian phase), which most likely took place in the upper Jurassic. Sedimentation did not resume until the upper Cretaceous, with the formation of a conglomeratic bed, followed generally by the deposition of pelites. In the Nouméa basin, several levels of interbedded rhyolitic tuffs and coarse sandstones in the pelitic series indicate a more obviously continental sedimentation.

The Cretaceous formations are conformably overlain by cherts and globigerinal limestones (Eocene I of the 1:100,000 maps), themselves covered by a series of flysch-type (M. Eocene?). The first phases of the Alpine folding appear to have taken place after deposition of the flysch. They were complex and caused the emplacement of gliding nappes especially on the western side of the island. The exposure of reliefs at this time was the source for breccias and a suite of greywackes. These greywackes (corresponding to Eocene II of earlier writers) lie with angular unconformity on the Eocene I formations and on the flysch (particularly in the basins of Nouméa and Bourail).

At approximately the Eocene-Oligocene limit the paroxysmal phase of the Alpine orogenesis took place. The sedimentary formations were folded. Thrust slices developed and the Cretaceous formations, the cherts and limestones (Eocene I) and the flysch, came locally—as in the Nouméa peninsula—to overlie tectonically the Eocene greywackes. The amount of the displacements cannot be precisely established yet. The main direction of the folds is parallel to the alignment of the island (N. 110° E.) and their movement is always in a south or south-westerly direction.

Vast discharges of tholeiitic basalts, accompanied by pillow-lava, cover a large part of the western slope (Fig. 1). They were thought to be of Montian (basal Palaeocene) age. Then sedimentary intercalations containing *Inoceramus* were found, but it seems very unlikely that these are autochthonous. Recently H. Gonord has observed that these volcanics are discordantly overlain by Eocene greywackes. The fact that they were emplaced on the west coast of the island at the same time as the M. Eocene gliding nappes, leads this author to believe they are allochthonous. The relationship between the basalt outcrops of the east and west coasts cannot yet be determined exactly, but it is possible that the former represent the zone of origin of the overthrust units. With this hypothesis one can explain why at various points on the west coast the basalts are in direct contact with Cretaceous formations and the intervening siliceous and calcareous Eocene I is absent.

The basalts are very often overlain by the great allochthonous, peridotitic massifs, whose derived fragments only appear in the L. Miocene of the Nepoui region (Fig. 1) but the peridotites also lie on sedimentary and metamorphic rocks. The emplacement of the peridotites occurred late compared with the major phases of orogenesis. The basal surface of the large massifs is never affected by intense or tight folds; the angular discordance between this superstructure and the infrastructure is therefore very noticeable.

Metamorphism affected the sedimentary rocks older than Eocene II over large areas. A first phase of metamorphism occurred during the Cimmerian emergence in the central region of the island and a second (lawsonite, pumpellyite, epidote, glaucophane) occurred in the late Eocene in the northern regions. Among the major questions concerning the geology of New Caledonia, the analysis of metamorphic zones, their structure and the ages of the different phases must be looked at afresh.

The structure of New Caledonia remains little understood; mapping

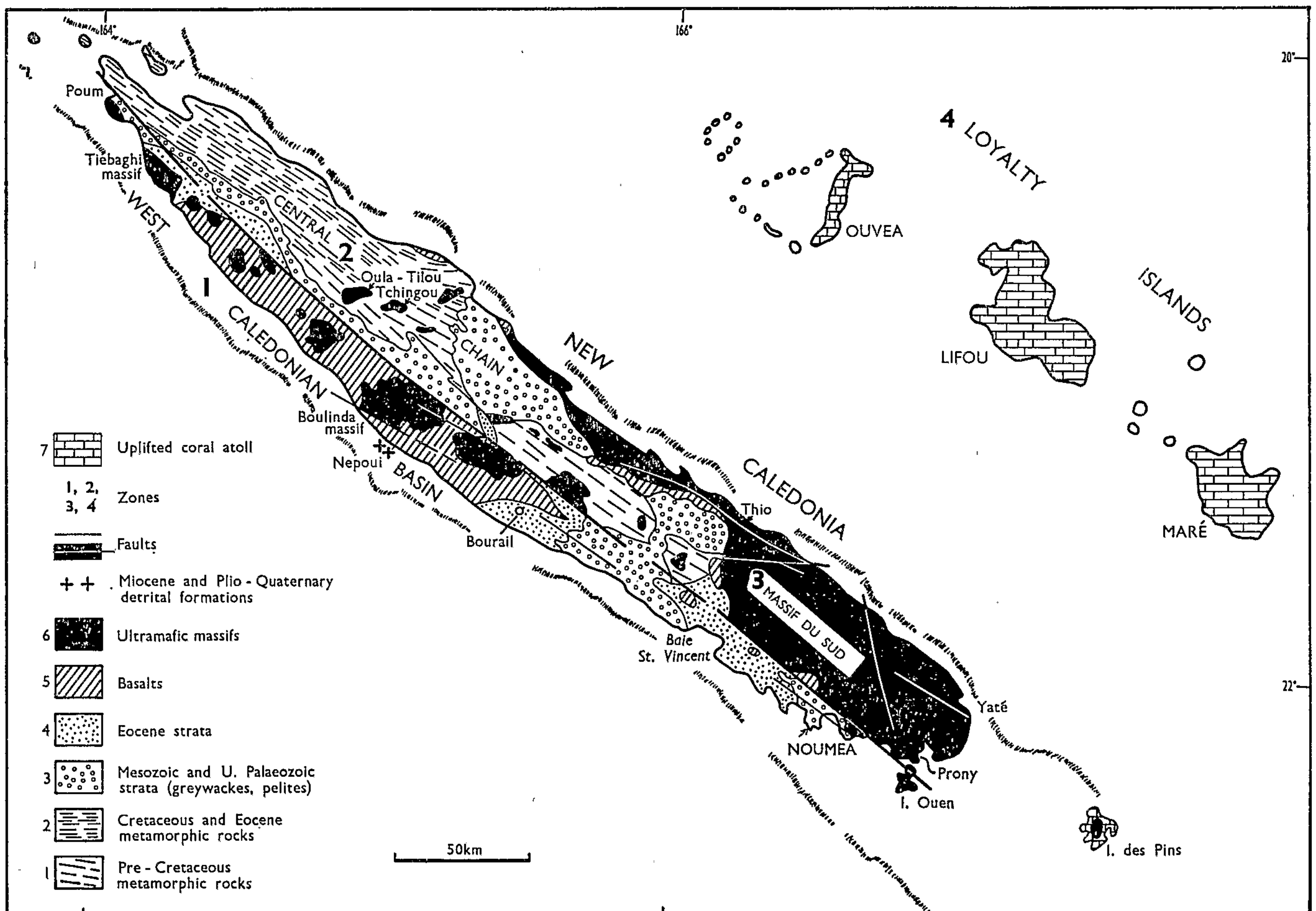

Figure 1. Outline geology of New Caledonia and the Loyalty Islands.

in the east side is not advanced, since the area is thickly forested. Attention should be drawn, however, to an important aspect of the structure not emphasized in previous publications. A line parallel to the axis of the island separates zones 1 and 2. To the south-west occur great amounts of basalt, from Poum to near Bourail, covered by large peridotitic massifs whose basal surface is slightly inclined towards the south-west (Fig. 2). This is the zone which Routhier (1953) called 'sillon' (furrow) because the most recent formations occur there. In the central chain (Figs. 1 and 2), north-east of the division line, the rocks are everywhere older, often metamorphic and overfolded towards the south-west or the south; serpentinites and ultramafic masses occur, notably the Oua-Tilou and Tchingou massifs (Fig. 1). The division line is certainly an old structural feature. It is effectively on this line that the most definite indications of Cimmerian emergence lie (Senonian conglomerates of the Congo and of the Mecougna). In this same region, and over a distance of more than 50 km, the basalts directly overlie the Cretaceous. The south-eastward continuation of the line coincides with the south-west edge of the large south-eastern ultramafic massif (Fig. 1) discussed below. The line corresponds with a large, NE-dipping, reversed fault, which formed before the deposition of the Senonian and moved several times afterwards: firstly in the late Cretaceous, then in Eocene times (it is at the very place of this fault that the origin of the gliding nappes of the M. Eocene took place) and even during a late post-Miocene phase. This great feature may, for lack of a better term, be called the 'great longitudinal fold-fault'.

After the Miocene whose outcrops are very localized, continental, fluvial-lacustrine and lagoonal deposits, representing the Plio-Quaternary, were deposited on a surface cut in all the previous formations. Their outliers (*e.g.* at Goa N'Doro) are situated at altitudes between 200 and 800 m on the east coast; they have just been discovered on the west coast (*e.g.* at Kopeto and on the Mueo peninsula). The change of level of these different outcrops shows definitely that important fault activity occurred during the Plio-Quaternary, forming the imposing mountains which today are the backbone of the island.

C. DETAILS OF THE GEOLOGY OF THE ZONES

New Caledonia is described in terms of three zones. The West Caledonian Basin (zone 1) is characterized by ultramafic massifs and basalts resting on Mesozoic greywackes and Eocene rocks (see Table 1). In the Central Chain (zone 2) basalts are absent and the Cretaceous is non-metamorphic (see Table 2). The south-eastern belt (zone 3) is characterized by a very large ultramafic massif resting on sediments broadly similar to those of zone 1 (see Table 3).

The Loyalty Islands (zone 4) are a group of raised atolls which mark the position of a submarine, volcanic ridge. This NW.–SE. ridge lies 100 km north-east of New Caledonia and extends parallel to the latter for at least 800 km. The outline stratigraphical column of the Loyalty Islands is shown in Table 4.

Table 1

STRATIGRAPHY IN ZONE 1

Rock unit	*Age and evidence for age*	*Lithology*	*Thickness m*	*Comments*	
Mueo Fm	Plioc-Quaternary	Clay, conglomerate; littoral	50		
				?Unconformity	
Nepoui Fm	Mioc, fossils	Limestone, sand, conglomerates; marine	50		
				Unconformity	
Ultramafic massifs	Olig or U. Eoc	Harzburgite, dunite, pyroxenite	1500		
				Unconformity: phase of thrusting (isoclinal folds, thrust and overfolded towards the SSW.)	'Alpine orogeny'
Eocene II	Olig or U. Eoc	Greywacke, breccia	Unknown		
				Unconformity	
	?M. Eoc, *Asterocyclina*	Flysch, tholeiitic basalt lavas (pillow lavas)	>300		
				Unconformity	
Eocene I	L. Eoc, *Globigerina* and *Globorotalia*	Limestone, dolomite, chert			

Rock unit	*Age and evidence for age*	*Lithology*	*Thickness m*	*Comments*
'Formation à charbon'	U. Cret, perhaps Senon;	Rhyolitic tuff; carbonaceous beds; sandstones and arkoses with *Inoceramus*; conglomerate	200	
				Unconformity: *Cimmerian phase* (Hokonui orogeny of New Zealand)
	?Portland	Sandstone with gastropods		
				Possible non-sequence during Kimm
'Formation des grauwackes' (unmetamorphosed or little metamorphosed greywackes) (equivalent to the Hokonui System of New Zealand	Call to Oxf, belemnites	Diorite and microgabbro; sandy greywacke; black shale		
				Possible non-sequence during Bajoc to Bath
	Sinem to Toarc; *Pseudocella marshalli*	Coarse greywacke rich in clastics		
	Hett, ammonoids	Sandstone and calcareous greywacke; breccia	>1600	
	Rhaet; *Arcestes rhaeticus* and Spiriferids	Greywacke		
	Ladin to Nor; Monotidae and *Halobia*	Fine-grained greywacke		
				Possible non-sequence during Virglorien
Moindou Fm	Werf?, *Meekoceras*	Greywacke, shale		
				Unconformity: *Hercynian orogeny* (Hunter-Bowen orogeny of New Zealand)
Multicoloured tuff Fm (equivalent to Te Anau Fm of New Zealand)	Perm (*Maitaia trechmanni*)	Dacite and rhyolite beds; calcareous greywacke		
	Base not seen			

Table 2

STRATIGRAPHY IN ZONE 2

Rock unit	*Age and evidence for age*	*Lithology*	*Thickness m*	*Comments*
Ultramafic massifs	U. Eoc or Olig	Harzburgite, serpentinite	50–500	
Cretaceous strata	Cret, certainly Senon, fossils	Limestone, clay, sand; conglomerate	>100	Flat lying, unfolded and unmetamorphosed*
				Unconformity: Cimmerian orogeny
	?Portland	Sandstone with gastropods		
'Formation des grauwackes'	Sinem to Oxf?	Fine-grained greywacke; black, chloritic shale; prasinites	>1000	Much folded and metamorphosed (chlorite, pumpellyite); intruded by diorites; many non-sequences may exist
	Nor, fossils	Fine-grained greywacke		
	Base not seen			

* At the northern extremity of the Central Chain, Eocene strata are present and both the Eocene and Cretaceous rocks are folded and metamorphosed (sericite schists with epidote, lawsonite, glaucophane and glaucophanites). Thus a second phase of metamorphism has occurred in this northernmost area of the zone. Brothers (1969) found that the P/T ratio decreases from south to north in this region.

Table 3

STRATIGRAPHY IN ZONE 3

Rock unit	*Age and evidence for age*	*Lithology*	*Thickness m*	*Comments*
Recent alluvium	Recent Quaternary	Sands, pebbles, mangroves, corals		
				Flandrian transgression (5 ft terraces)
				Tilting of massif: coral reefs of Yaté (in north-east) are more uplifted than south-west area (Prony)
Older alluvium	Older Quaternary?	Peridotite conglomerate (on high terraces)	30	

Rock unit	*Age and evidence for age*	*Lithology*	*Thickness m*	*Comments*
		Ferruginous silt deposits	60–90	
		Coral reefs	30	
				Two phases of uplift and transverse faulting (Plioc to Quaternary); uplift greater in north-west of massif than in south-east
				Peneplanation
				Lateritization (Olig and Mioc) and development of Karst morphology
				Faulting and tilting of massif to south-west
Calc-alkaline rocks	?Olig; intrude ultramafic massifs and Eoc-Cret strata	Dykes and veins of: feldspathic hornblendite, quartz diorite, granodiorite, adamellite, pegmatite		
				Faulting
Discordant ultramafic unit	Unknown	Huge dunitic bodies; gradational passage from dunites to noritic gabbros in upper part of bodies		
				Folding and faulting
Main ultramafic mass	Emplaced in pre-Mioc times (U. Eoc or Olig); age of crystallization may be given by Rb/Sr date of 730 m.y. (Roe 1964)	Saxonites (Mg olivine and orthopyroxene) with primary layers of dunites and pyroxenites; no mineralogical variations; contemporaneous feldspathic rocks absent	3000	
				Unconformity: recent Alpine orogenic phase
Eocene	Eoc, fossils	Basalts and sedimentary rocks		
	Sequence below here is similar to that in West Caledonian Basin			

Table 4

STRATIGRAPHY IN THE LOYALTY ISLANDS

Rock unit	*Age and evidence for age*	*Lithology*	*Thickness m*	*Comments*
Raised terraces	Quaternary, madreporarians	Coral limestone terrace	0 to many metres	Discontinuous uplift of the southern part of the submarine volcanic arc is marked on the ancient uplifted atolls by a sequence of belts of coral platforms or erosion levels; there is no evidence of uplift in the north
				Unconformity: uplift
Fossil coral atolls on Maré, Lifou, Ouvéa	Neogene, madreporarians	Dolomitized coral atoll with madreporarians and Lithothamnions	Many hundreds of metres towards the margins of the atoll; 0 to 200 m in the centre	
				Unconformity and subsidence
Volcaniclastic breccias (on Maré only)	Unknown	Lenticular, submarine volcaniclastic formations with reworked limestone concretions	Unknown	
Volcanic substratum (exposed on Maré)	29 ± 4 m.y. (K/Ar, Chevalier 1968)	Oceanic olivine basalt	Probably 1000 m	
	Base not seen			

D. DETAILS OF THE ULTRAMAFIC ROCKS

The ultramafic material occurs as serpentinite bodies and as large thrust ('recouvrant') massifs along the whole length of the island over nearly 30% of the total area of the island.

(i) *Serpentinite bodies*: these occur in formations of varying age and type (Cretaceous and Eocene strata, metamorphic rocks, basalts) or at the fault contact between two formations. Generally these serpentinite bodies are conformable with the structure of the surrounding rocks (Routhier 1953, p. 187) and are similarly affected by folds and faults. They are not, any more than the peridotites of the massifs, present as detrital fragments in pre-Miocene formations and probably formed, therefore, towards the end of the Eocene or in the Oligocene. The geometrical and chronological relations between the serpentinite bodies and the overlying massifs are not yet well understood. It is likely that several of these bodies represent remains of a more extensive peridotitic sheet, in some places squeezed along faults and in tight folds.

(ii) *Ultramafic massifs of the west coast* (see Routhier 1953, pp. 176–220): these massifs occur in a chain parallel to the west coast and situated along the axis of a furrow, that is a synclinal basin determined by the sedimentary rocks and basalts (Figs. 1 and 2). They lie directly either on the basalts or, much more rarely, on the sedimentary rocks which over the whole zone are affected by very tight folds and thrusts, directed towards the south-west. There is therefore a distinct disharmony between the structures of the substratum and the base of the massifs; the latter approaches the horizontal or is slightly inclined towards the south-west, and is affected by broad folds of SW–NE trend (a direction found again in the southern massif), *i.e.* transverse to the dominant structural direction of the island. These folds have certainly played a role in the separation of the massifs; the ultrabasic sheet must once have been much more extensive than now, as the numerous peridotitic nappe-outliers scattered over the whole of the island show. Its fragmentation is obviously due largely to erosion, which has itself been influenced by the buckling and fracturing of the base of the sheet.

The massifs are made of harzburgites, dunites and of pyroxenites arranged in thin layers. At the base of the massifs, serpentinites form a continuous sheet often several hundred metres thick. Serpentinites represent an important part of the constituent materials of the massifs of the west coast, whilst the serpentine 'sole' of the southern massif is thin and negligible in volume compared to its total volume.

Layering is usually visible in the unserpentinized part of the massifs. There seems to be no general rule concerning the arrangement of the banding in relation to the basal contact; sometimes it is parallel to it. In contrast, in the northern massifs of the island (for example in the Tiebaghi massif) the banding is oblique, or even perpendicular to the contact.

The peridotites are accompanied by very small amounts of feldspathic rocks: gabbros, hornblende-quartz diorites, granites, and alkaline rocks with stilpnomelane (see explanation books of sheets 1–6 of the 1:100,000 geological map; Routhier 1953, pp. 195–9). These feldspathic rocks are never found, as far as the wiiter knows, in the substratum of massifs; they are therefore an integral part of the ultramafic suite.

The trough of western New Caledonia is more faulted than any other structural zone of the island. The faults, orientated N. 10° and N. 110° E., suffered late movements and affected the Miocene and Plio-Quaternary detrital formations, as well as the peridotitic massifs. The faults truncate the latter and produce tilting or even collapsing of them, thus the contact between the basalts and the thick peridotites

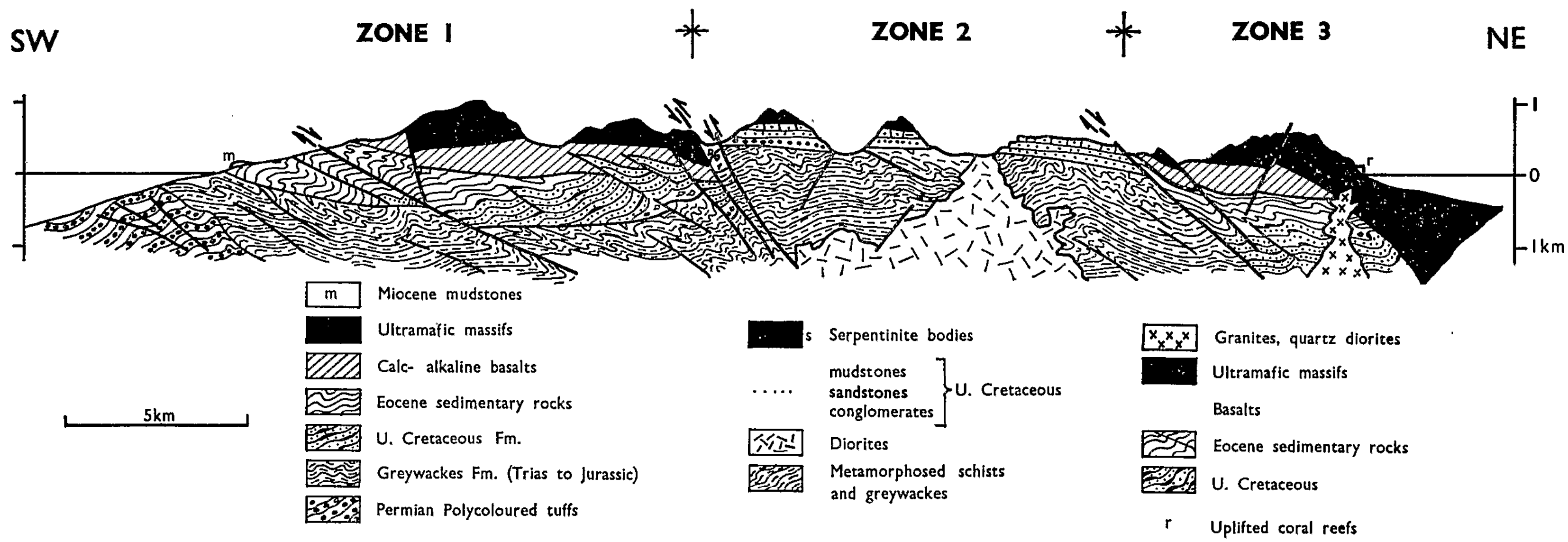

Figure 2. Outline geological profile of New Caledonia.

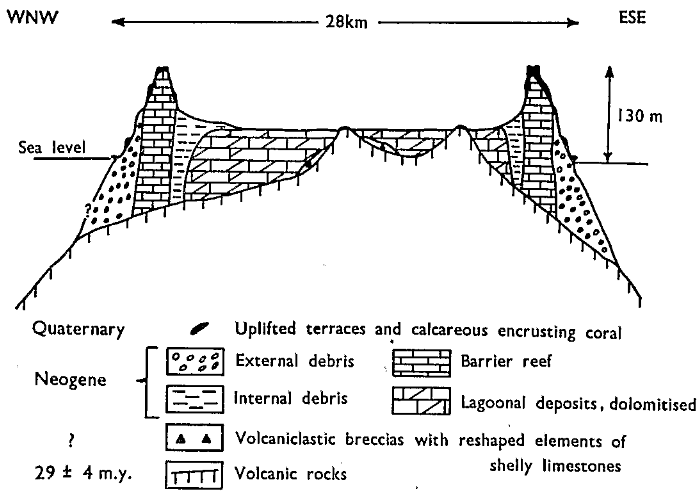

Figure 3. Hypothetical cross-section of Maré Island in the Loyalty Islands (by J. Launay & J. Recy).

can be locally very tilted (as on the southern border of the Boulinda massif). The positive gravity anomalies shown by Crenn (1953) in certain of the massifs in the north of the island can be explained in the same way.

(iii) *The large ultramafic massif in the south-east*: this massif covers about 4000 km^2 and rests upon Cretaceous formations or basalts and sedimentary rocks of Eocene age with either horizontal or gently dipping contact towards the north-east. Within it two lithologic units can be distinguished (Guillon 1969). *The main ultramafic mass* is more than 2·5 km thick and is composed throughout of forsteritic olivine (Fo 88–92), enstatite (En 90) and chromium spinel. It is little differentiated: there are very few variations in mineral composition and plagioclase and clinopyroxene do not appear. It is composed of rocks rich in Mg and poor in Ca and Al: *i.e.* saxonites, dunites and pyroxenites in a vertical rhythmic pattern. Primary layering, generally discordant with the floor of the massif, is very well developed. This layering has been folded and the folds are slightly overtilted towards the south-west.

The discordant ultramafic unit. Several huge dunitic pipes occur in the main ultramafic mass and cut orthogonally its layering, with gradational contact. In these dunites cryptic layering is parallel to the attitude of banding in the main ultramafic mass. In the highest part of the pipes, dunites change progressively to noritic gabbros, due to appearance and increase of plagioclase, ortho- and clinopyroxene. At the same time a lime enrichment and a gradual increase of the ratio Fe/Mg of olivine, pyroxenes and chromium spinel can be observed.

The ultramafic rocks are irregularly cut by dykes of hornblende-quartz diorites, adamellites and calc-alkaline granites; similarly granites and diorites intrude into the sedimentary formations of the substratum but they are never remote from the floor contact of the massif. The occurrence of these rocks can be explained by injection of granitic material, originating from the sialic crust, later than the setting of the ultramafic massif. Late granites and quartz diorites are known in other islands of the Melanesian arc, especially in Neogene sedimentary rocks of the New Hebrides and in New Zealand Miocene formations.

After intrusion of the granitic rocks, the part of the massif located south-west of the big western fault was overthrust on the sedimentary substratum (*e.g.* in île Ouen). A late motion of this fault brings about a purely mechanical displacement of a part of the massif towards south or south-west. This could be the origin of the separation of the ultramafic bodies of the West Caledonian basin.

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