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**Subduction erosion: contributions of footwall and hangingwall to serpentinite melange; field, geochemical and radiochronological evidence from the Eocene HP-LT belt of New Caledonia.**

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**Abstract**

Slivers of mixed and metamorphosed ultramafic, mafic and sedimentary rocks crop out within the Eocene HP-LT metamorphic complex of northern New Caledonia. These units are: (1) pinched slices of the serpentinite sole of Peridotite Nappe (upper plate), which characteristically contain boudinaged supra-subduction dykes; (2) Intermediate Melange units composed of elements of the serpentinite sole mixed with basalt and red chert clasts, which represent the interface of Peridotite Nappe and Poya Terrane (lower plate); (3) the Pouebo Terrane, an eclogite-blueschist facies melange, which crops out over 150 km along the NE coast of the island. Intermediate Melange units are transitional between shallowly accreted oceanic crust rocks of the Poya Terrane and the deeply subducted Pouebo Terrane. Their metamorphic grade is similar to that of the enclosing metasedimentary units of the Diahot Terrane and steeply increases northeastward.

The composition of blocks in the Pouebo mélange suggests that they come from: (1) subducted oceanic material (Poya Terrane Basalts, abyssal argillite/chert, passive margin sedimentary and magmatic components (terrigenous turbidites, limestone and dolerites), and (2) supra-subduction components (mantle wedge serpentinite, 55-52 Ma supra-subduction dykes, fore-arc basin, which characteristically refer to the lower plate and upper plate of the subduction/obduction system respectively).

*Key for abbreviations:* NMORB: normal mid-oceanic ridge basalt; EMORB: enriched (or undepleted) MORB; OIB: oceanic island basalt; BABB: back-arc basin basalt; IAT: island-arc tholeiite; IAB: Island-arc basalt; HT-LP high temperature -low pressure (metamorphic rocks/gradients).

**Keywords:** melange, serpentinite, subduction erosion, fore-arc accretion, fore-arc basin

1  
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3 **1. Introduction**  
4

5 Subduction erosion is a major process of active margins (Andes, Japan), which was mainly evidenced  
6 indirectly to account margin subsidence through swath bathymetry (e.g., Cloos and Shreve, 1988), reflection  
7 seismology (for a review see Von Huene et al, 2004, Stern 2011 and references therein), or some peculiar  
8 geochemical features of supra-subduction zone magmatism (Stern, 2011). Prominent surface roughness (e.g.,  
9 horst-graben structure, seamounts) of the lower plate, high frictional forces and fluid overpressure are  
10 generally advocated to explain enhanced rock fragmentation and abrasion at converging plate boundaries.  
11 Analogic modelling mainly aimed at exploring the behavior of the sedimentary tegument transported by the  
12 lower plate of the subduction systems (Lallemand et al, 1994; Gutscher et al, 1998); in contrast, the oceanic  
13 crust itself, judged out of reach or too strong, was rarely considered in spite of some prominent occurrences  
14 (e.g., Cluzel et al, 2001). Conversely, a few authors explored the possibility of subtraction of large parts of the  
15 upper plate dragged into subduction zones (e.g., Boutelier et al, 2003; Lallemand, 1995; Shemenda, 1993).

16  
17 The occurrence of chaotic associations of various high-strength blocks (crust) enclosed in a soft serpentine  
18 matrix (mantle) is a rather sound evidence for a prominent mixing process termed melange (from the French  
19 word for mixture). Melange-like units may form from sedimentary, tectonic or diapiric mixing (Festa et al.,  
20 2010; Wakabayashi, 2015). In the case of tectonic mixing, the source for serpentinite matrix may be the  
21 serpentinized mantle wedge of the subduction zone and previously exhumed serpentinites from the lower  
22 plate as well. In most cases, deciphering whether serpentinites come from the hangingwall or the footwall of  
23 the subduction zone is problematical because these rocks are almost impossible to distinguish. It is therefore  
24 necessary to identify the markers of upper vs. lower plate provenance.

25  
26 The type locality for models of subduction inception is the Izu-Bonin-Mariana (IBM) subduction system in  
27 the western Pacific Ocean (Bloomer et al., 1995; Ishizuka et al., 2006; Reagan et al., 2013; Stern & Bloomer,  
28 1992), which probably extended southward into Vitiav-Tonga-Kermadec (VTK) zone (Stern et al, 2012) through  
29 Solomon (Tapster et al, 2014), Vanuatu (Buys et al, 2014) and Fiji (Cluzel and Meffre, 2018), giving birth to one  
30 of the largest subduction system on Earth. In this area, west-dipping intra-oceanic subduction started in the  
31 Early Eocene (~50 Ma), involved cold and dense western Pacific lithosphere, thus giving birth to a steeply-  
32 dipping non-accretionary wedge. In contrast to IBM(VTK), the almost coeval New Caledonia subduction started  
33 at ~56 Ma (i.e. ~6 Ma earlier), was east- or northeast-dipping, involved young and buoyant lithosphere and  
34 therefore was shallow-dipping and strongly accretionary (Cluzel et al 2001, 2012a). As a consequence, the  
35 Eocene New Caledonia wedge gave birth to fore-arc accretion and deep subduction of oceanic crust fragments  
36 (Cluzel et al, 2001, 2017). In this article, the timing of subduction erosion will be addressed through the age of  
37 melange rocks exhumed along the subduction channel. Direct evidence for subduction erosion and mélange  
38 derivation from both the hangingwall and the footwall of a subduction zone comes from the Peridotite Nappe,  
39 which represents the exposed roof of the Eocene paleo-subduction, and from melange units pinched in the HP-  
40 LT belt. Block provenance in the metamorphosed melanges was assessed geochemically and through U-Pb  
41 zircon geochronology only because primary features of the protolith were erased by metamorphic  
42 recrystallization while specifically “immobile” trace elements ratios remained unchanged.  
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## 2. Geological setting

New Caledonia is an elongate (400km x 45km) island forming the emerged northern part of the Norfolk Ridge, a narrow submarine ribbon of continental nature bound to the southwest by the New Caledonia Basin and to the northeast by the Loyalty Basin. The Norfolk/New Caledonia Ridge is connected southward to New Zealand and forms the northern part of a continent-size largely submarine area of thinned continental crust termed Zealandia (Luyendik, 1995; Mortimer et al, 2017), originally connected to Southeast Gondwana and rifted during the Late Cretaceous.

The geology of New Caledonia is characterized by: (1) a pre-Late Cretaceous basement formed of amalgamated arc-derived terranes (Meffre, 1995; Maurizot et al, 2019a), which relate to the Southeast Gondwana margin; (2) Late Cretaceous to Late Eocene sedimentary cover (Maurizot et al, 2019b); (3) Eocene high-pressure metamorphic belt exposed in the northern part of the island (Maurizot et al, 2019c); and, (4) two large allochthonous terranes emplaced during the Eocene, the Poya Terrane and Peridotite Nappe, which together represent almost one half of island's surface (Fig. 1a) (Cluzel et al 2012a; Maurizot et al, 2019c).

In northern New Caledonia where the HP-LT belt is exposed, five litho-tectonic units are recognized from the top downwards: (1) Peridotite Nappe, (2) Pouébo Melange, (3) Intermediate Melange, (4) Poya Terrane, (5) Parautochthonous substrate.

The Peridotite Nappe of New Caledonia (Avias, 1967), resulted from obduction of the Loyalty Basin lithosphere upon the continental Norfolk/New Caledonia Ridge (Collot et al, 1987) when the latter obliquely entered the subduction zone (Cluzel et al 2001, 2017). It originally covered most of the island and further south, part of the submarine Norfolk Ridge (Patriat et al, 2018); however, several phases of erosion on the island only let tectonic klippe spread along the west coast, a larger unit termed "Massif du Sud" in the south of the island, and insular extensions in Belep Islands (north) and Isle of Pines (south).

Inception of the intra-oceanic subduction that eventually led to obduction is time-constrained by the granulite-facies metamorphic sole, dated at ~56 Ma ( $^{40}\text{Ar}/^{39}\text{Ar}$  on hornblende and U-Pb on zircon overgrowths) (Cluzel et al 2012b). From the thermal gradient recorded by the metamorphic sole ( $60^\circ\text{C km}^{-1}$ ) it may be inferred that subduction started near the ridge and that the lower plate (the South Loyalty Basin), which was young and buoyant at subduction inception, was shallow dipping. Such a thermo-mechanical regime likely resulted for a while in strong frictional forces at the plates interface (for a review, see Dmowska & Eckström Eds, 1993) until older and colder parts of the lower plate were involved into the subduction. Cooling of the subduction zone is documented in New Caledonia by the change of latest Paleocene HT-LP gradient of the metamorphic sole ( $\sim 60^\circ\text{C/km}$ ) (Cluzel et al, 2012a) into mid-Eocene HP-LT gradient ( $\sim 10^\circ\text{C/km}$ ) recorded by eclogites of the HP-LT belt (Clarke et al, 1997; Carson et al, 1999; Fitzhebert et al, 2003; Vitale-Brovarone et al, 2017).

The Poya Terrane (or Poya Nappe) (Cluzel et al 1997; 2001) consists of a main unit 10 to 20 km wide, which extends over about 160 km along the west coast of the island and km-sized lenses pinched beneath the Peridotite Nappe of the Massif du Sud, the northernmost massifs and along the east coast. It is composed of oceanic basalts associated with abyssal argillite (2/3 of the unit) and passive margin turbidites intruded by prominent dolerite sills (1/3).

The Eocene HP-LT metamorphic belt comprises two terranes: a dominantly metasedimentary unit referred to as the Diahot-Panié Terrane and a mafic-ultramafic melange termed Pouebo Terrane. The Diahot-Panié Terrane is principally composed of terrigenous metasediments and meta-volcanic rocks of the Late Cretaceous-Eocene cover and volumetrically minor meta-volcaniclastic rocks representing the pre-Late Cretaceous basement terranes. It is worth noting that little is known on the pre-Late Cretaceous part of this terrane, which is principally exposed in the poorly explored Mt Panié Massif. The Pouebo Terrane is formed of cm- to km-size blocks enclosed in a sheared meta-serpentinite matrix.

The post-Early Cretaceous geological evolution may be summarized as follows:

- The rifting period (Coniacian to Santonian) is recorded on the Norfolk Ridge by terrigenous coal-bearing shallow water marine sedimentation and moderate volcanic activity (Formation a charbon). Coeval coarse- to medium grain turbidites and black shales of the Diahot-Panié Terrane may be attributed to deeper water half-graben deposits, while more distal passive margin turbidites are found in the Kone Facies (Poya Terrane). Marginal rifting is generally attributed to the eastward retreat of the Pacific subduction, although no trace of a Late Cretaceous volcanic arc has been hitherto discovered (e.g. Cluzel and Meffre 2018);
- The post-rift (oceanization) period is represented by Maastrichtian to Lower Eocene fining upward sequence of siltstone, argillaceous black cherts, siliceous micrite and finally micrite, which recorded thermal subsidence and Eocene global warming, meanwhile, marginal basins opened on both sides of the Norfolk Ridge;
- At the end of the Paleocene, a new NE-dipping subduction started to the NE of New Caledonia and consumed the basin located to the east of Norfolk Ridge, termed South Loyalty Basin (Cluzel et al, 2001). When the northern part of the Norfolk Ridge reached the trench, the fore-arc bulge of the Australian Plate provoked local southward propagating emersion and tectonic instability, and thus a change of sedimentary regime from pelagic platform into upward coarsening Middle to Upper Eocene turbiditic foreland. The latter witness the syn-sedimentary thrusting of approaching parautochthonous (Montages Blanches Nappe) and allochthonous (Poya Terrane) units (Maurizot and Cluzel, 2014);
- Finally, the Loyalty Basin was in turn underthrust by the Norfolk Ridge and obducted at the end-Eocene-Early Oligocene without known sedimentary record.

### 3. Analytical procedures

Gathering a representative sampling of ophiolitic melanges is an uncertain task and a large number of samples is needed to prevent omission of minor but significant elements. The data presented in this article is based upon 108 samples from Pouebo Terrane and Intermediate Melange coming from already published data (Cluzel et al 2001, Spandler et al 2005, 2006) and newly sampled material. Correlation was based upon a data base of 113 samples of Lower Eocene dykes from the Peridotite Nappe (Cluzel et al 2006 and unpublished data) and 171 samples from the Poya Terrane (Cluzel et al 2001, 2017; Eissen et al 1998).

The new samples have been analyzed for whole-rock geochemistry at the SARM (CRPG Nancy, France) by ICP-AES for major elements and ICP-MS for trace elements and rare earth elements (REE). For details about

analytical procedures, see Carignan et al. (2001), accuracy and detection limits are provided at:

<http://helium.crgp.cnrs-nancy.fr/SARM/pages/roches.html>.

U–Pb zircon analyses were performed on an Agilent 7500cs quadrupole ICPMS with a 193 nm Coherent Ar–F gas laser and the Resonetics S155 ablation cell at the School of Earth Sciences, University of Tasmania. Each analysis was pre-ablated with 5 laser pulses to remove the surface contamination then the blank gas was analysed for 30 s followed by 30 s of zircon ablation at 5 Hz and  $\sim 2 \text{ J/cm}^2$  using a spot size of 13  $\mu\text{m}$ ; keeping U and Th in the pulse counting mode of detection on the electron multiplier. A flow of He carrier gas at a rate of 0.35 l/min carried particles ablated by the laser out of the sample chamber to be mixed with Ar gas before transfer to the plasma. Elements measured include  $^{49}\text{Ti}$ ,  $^{56}\text{Fe}$ ,  $^{90}\text{Zr}$ ,  $^{178}\text{Hf}$ ,  $^{202}\text{Hg}$ ,  $^{204}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ ,  $^{208}\text{Pb}$ ,  $^{232}\text{Th}$  and  $^{238}\text{U}$  with each element being measured sequentially every 0.16 s with longer counting time on the Pb isotopes compared to the other elements. The down hole fractionation, instrument drift and mass bias correction factors for Pb/U and Pb/Th ratios on zircons were two analyses on the primary standard (91500 of Wiedenbeck et al., 1995) and one analysis on each of the secondary standard zircons (TEMORA 1 of Black et al., 2003; GJ-1 of Jackson et al., 2004) analysed at the beginning of the session and every 16 unknowns using the same spot size and conditions as used on the samples to provide an independent control to assess accuracy and precision. Additional secondary zircon standards (Mud Tank of Black and Gulson, 1978; Plšovice of Sláma et al., 2008) were also analysed. The correction factor for the  $^{207}\text{Pb}/^{206}\text{Pb}$  ratio was calculated using six analyses of the international glass standard NIST610 analysed throughout analytical session and corrected using the values recommended by Baker et al. (2004) to provide an independent control to assess accuracy and precision.

Incompatible trace element ratios, which are considered to reflect source compositions and melting processes, are widely used to discriminate the various magmatic rock series. In contrast, mobile elements (Ba, Rb, K, P, Sr), which display erratic variations under metamorphic conditions cannot be considered. In this study chondrite-normalized REE patterns (Evensen et al, 1978), NMORB-normalized expanded REE and trace-elements patterns (Sun & McDonough 1989), Zr/TiO<sub>2</sub> vs. Nb/Y binary diagram (Winchester & Floyd 1977) and Hf/3-Th-Ta ternary diagram (Wood, 1980; Vermeesch, 2006) were used for geochemical discrimination.

#### 4. Geological features of allochthonous terranes

##### 4.1. Peridotite Nappe

The Peridotite Nappe is dominantly composed of harzburgite (>80%), dunite and minor lherzolite (in northern massifs only) that represent a prominently depleted supra-subduction mantle lithosphere (Marchesi et al 2009; Pirard et al 2013; Prinzhofer, 1981). Owing to their depletion in incompatible elements compared to primitive mantle composition, highly depleted residual harzburgites probably underwent about 20–25 % bulk partial melting (Prinzhofer 1981), while Nd-Sr and Pb Isotope signatures and trace-elements petrological modelling suggest that prominent depletion was due to one episode of dry melting followed by supra-subduction re-melting assisted by fluids influenced by subducted sediments (Secchiari et al 2019).

The harzburgites-dunite association is overlain by dunite, pyroxenite, websterite and gabbro-norite cumulates (Prinzhofer 1981). Cumulate websterite and gabbro-norite probably crystallized in equilibrium with



depleted melts intermediate between boninite and island-arc tholeiite (Marchesi et al 2009; Pirard et al 2013; Cluzel et al 2016; Secchiari et al 2018), which at present are not preserved. Whole rock and mineral chemical constraints on lherzolites allow a polyphase evolution to be drawn, from oceanic accretion to mantle metasomatism during subduction (Marchesi et al 2009; Secchiari et al 2016, 2019; Spandler et al 2004a; Ulrich et al 2010).

A highly sheared, porphyroclastic serpentinite sole, 20-300 m thick, generally indicates top-to-the-southwest emplacement kinematics (Quesnel et al 2013, 2016). Thrust-related deformation rapidly vanishes upward; in contrast serpentinitization persists up to 2,000 m above the base of the ultramafic allochthon with an upward decreasing amount though.

The Peridotite Nappe is crosscut by a wide variety of dykes and sills emplaced between 55Ma and 47Ma (Early Eocene; Cluzel et al 2006, 2016), which are absent in the underlying Poya Terrane. These intrusive rocks comprise medium to coarse grain rocks (sills and dykes), the compositions of which vary from ultramafic (pyroxenite and hornblendite) to mafic (hornblende-gabbro, diorite), and felsic (leucogabbro, leucodiorite and granite) and minor dolerite dykes. Dolerite dykes crosscut all levels of the Peridotite Nappe, including the gabbro-norite cumulates, while the other dykes and sills are apparently restricted to the ultramafic part of the allochthon. Boudinaged dykes are present in the serpentinite sole as well. Some dykes are strongly foliated, isoclinally folded or mylonitized as a consequence of syntectonic intrusion in shear fractures. With only a few exceptions, the original composition of the dykes (geochemical and mineralogical) is surprisingly well preserved in spite of widespread serpentinitization of the host rock; however, some of them display secondary parageneses due to post-magmatic recrystallization. In the latter, amphibolitization is common with hornblende or tremolite depending upon initial composition, temperature and fluid/rock ratio. A few metasomatized dykes display high Ca-Sr and low SiO<sub>2</sub> contents and can be termed rodingites (e.g., Python et al., 2007, 2011) they contain secondary hydro-grossular, pink zoisite, prehnite, and clinocllore.

#### 4.2. Poya Terrane

The Poya Terrane (or Poya Nappe) (Cluzel et al 1997, 2001, 2017) is a composite litho-tectonic unit made of two contrasting sub-units: i) Poya Terrane Basalts (PTB), which consist of massive and pillow basalts associated with Campanian to Lower Eocene red, green, gray or whitish abyssal argillite and minor pink micrite (Aitchison et al 1995, Cluzel et al 2001), the PTB comprise N-MORB, E-MORB, BABB and OIB-type basalts (Cluzel et al 2001, Eissen et al 1998), and ii) Coniacian-Santonian yellowish sandstone, turbidites with minor dark red or dark gray argillite on top, termed Kone Facies (KF, Carroué 1972) intruded by 10m to 100m thick Early Eocene (~55 Ma) E-MORB sills, referred to as Kone Facies Dolerites (KFD) (Cluzel et al, 2017) (Fig. 1).

The structure of PTB consists of upright slices a few 10 ms thick and a few 100 ms long, getting shallower southwestward. This unit is limited on top by the almost horizontal basal thrust of the Peridotite Nappe. At the base, the PTB rest upon parautochthonous basement units through a shallow dipping thrust, which sharply truncates the basalt slices, giving the unit a broad synform structure. The PTB was scrapped off the uppermost oceanic crust of the lower plate during the subduction of the South Loyalty Basin. The tectonic slices were first accreted to the fore-arc region of the Loyalty Arc then pushed upon the margin of the New Caledonia Ridge.

When it reached the margin, the PTB dragged large parts of the passive margin turbidites of the Kone Facies and the whole set was thrust upon autochthonous/parautochthonous rocks of the New Caledonia Ridge. Meanwhile, some parts of the Poya Terrane (PTB and KF) were dragged down into the subduction and recrystallized into the blueschist facies; as a consequence, discontinuous slivers of metamorphosed Poya Terrane rocks crop out along the east coast of New Caledonia (Hienghène region) on the northern side of the Mt. Panié anticlinorium, cored by Pouebo Eclogite Melange (or Pouebo Terrane, see below).

#### 4.3. Pinched serpentinite bodies (“fils serpentineux” of Routhier 1951)

Upright serpentinite slices are widespread; they are randomly distributed within the substrate of the Peridotite Nappe, while not always clearly connected with the serpentinite sole so far. These serpentinite bodies, a few 100s m to a few kms long and a few 10s to a few 100s m wide, are dominantly composed of strongly sheared serpentinite and contain rare blocks (porphyroclasts) of serpentinitized peridotite and boudinaged lower Eocene dykes (Cluzel et al 2006, 2016). Such serpentinite slices are scarce in Poya Terrane Basalts except in the northern part of the terrane between Kaala and Tiebaghi massifs where they pass northeastward into the sedimentary substrate. These serpentinites are difficult to distinguish from the similar serpentinite lenses widespread in the pre-Late Cretaceous basement, especially in the Boghen Terrane, a blueschist-greenschist facies subduction complex composed of about 25% serpentinites (Cluzel and Meffre 2002; Maurizot et al 2019a). However, pre-Late Cretaceous serpentinites apparently never contain supra-subduction dykes and may be distinguished on this basis.

Some deeply rooted serpentinite lenses are overlain by gently synformal peridotite bodies (Peak Ougne, Ouehat summit) (Fig. 2 & 3). This geometry may be interpreted in two ways: (1) serpentinite and peridotite may represent the result of one-step km-scale “folding” of one single ultramafic unit, the shear strength contrast resulting in tight serpentinite lenses, while peridotite makes large boudins; alternatively, (2) these serpentinites may represent lenses of the serpentinite sole disconnected from the main peridotite body, which simply overthrust them after they were pinched in their basement.

### 5. The Eocene HP-LT belt of northern New Caledonia

The metamorphic belt which extends over more than 225 km along the northeastern coast of New Caledonia from the Boat Pass to Houailou (Fig. 1) has been extensively studied in its northern part along the Koumac-Ouegoa-Amos transect; in contrast, the remote and rugged mountainous area between Amos Pass and Mt Panié remains largely underexplored. Four main lithotectonic units may be distinguished on the basis of lithology and metamorphic grade: (1) Montagnes Blanches Nappe, (2) Diahot-Mt Panié Terrane, (3) Pouebo Terrane (or Melange) and (4) Intermediate Melange units. The metamorphic grade increases along a SW-NE section from anchizone (250°C; 0.3 GPa) (Potel et al, 2006) to eclogite facies (620°C; 2.4 GPa) (Clarke et al, 1997; Fitzhebert et al 2003; Vitale-Brovarone & Agard, 2013) over a distance of about 20 km. Such a steep increase implies that “isograds” across strike are actually fault/thrust boundaries between sliced units of different yet NE-ward increasing metamorphic grade (Vitale Brovarone & Agard 2013). Abrupt changes in strain facies (style and intensity of ductile deformation) are generally associated with these boundaries, which may be

or not, underlined by serpentinite or *mélange* slices. In contrast, the metamorphic grade gently decreases southeastward (along strike), a fact that suggests that exhumation of the high grade parts of the HP-LT belt occurred in a scissors-like fashion.

#### 5.1. Parautochthonous low grade unit : Montagnes Blanches Nappe

This collective term (Maurizot 2011) refers to a complex set of tectonic sub-units several km in size, and smaller tectonic slices of Late Cretaceous to Eocene sedimentary rocks forming the parautochthonous substrate of the Poya Terrane. This unit has no known basement and was possibly detached from the underlying (autochthonous ?) sequence at the boundary between Maastrichtian siltstones and Paleocene black cherts (Maurizot, 2011); however, this scheme does not fully fit with the observed complexity of this unit, which locally (Bourail region) contains tectonic slices scrapped from the “basement” terranes (Permian greywackes, Boghen metabasalts, serpentinite, etc). Due to facies similarity, it is difficult to precisely locate the boundary between this unit and the Diahot-Panié Terrane (see below); in addition, the metamorphic grade is difficult to establish in the absence of index lithology. Based upon illite crystallinity, reflectance and Raman spectrometry of organic material, a maximum temperature of 250°C at a pressure of 0.3 GPa was estimated (Potel et al, 2006).

#### 5.2. Diahot-Panié Terrane

This metamorphic unit has about the same content as the autochthonous/parautochthonous sedimentary cover except for the Late Cretaceous part, which displays distinctive features. Compared to the proximal Fm. a charbon, it displays more distal and deep water characteristics, and is composed of two members that record the Late Cretaceous rifting of the Gondwana margin. The Tendo Fm. is formed of sandy and silty turbidites and minor poorly sorted conglomerates with cobbles up to 1.5m of probable mass-flow origin. The Pilou Fm. is formed of monotonous black shales (slates) associated with volcanic and volcanoclastic rocks and polymetallic sulfide ores. Due to ductile thrusting, isoclinal folding and the lack of marker horizons, the original thickness of this unit remains unknown. Near Colnet Peak, Albion blueschist facies metagreywackes closely associated with Late Cretaceous metasediments (Cluzel et al, 2010) represent the pre-Late Cretaceous basement terranes; the poorly studied rest of the Diahot-Panié Terrane remains uncorrelated. In spite of the apparently low grade metamorphism of carbonaceous schists due to complete retrogression during exhumation, it appears that the Diahot-Panié Terrane reached eclogite facies peak conditions (1.7 GPa; 500°C) recorded in some Late Cretaceous mafic metavolcanic rocks (Fitzhebert et al, 2003; 2005). The tectonic structure of the terrane is composed of two parts: to the west, along the western bank of Diahot Valley, isoclinal folds associated with upright foliation define narrow linear ribbons of various lithologies; in contrast, the Pam Peninsula and in a general fashion the Mt Panié-Colnet Massif delineates a broad foliation anticlinorium cored by the Pouebo Terrane and limited to the NE by the linear boundary of the Loyalty Basin. The stretching lineation born by the regional foliation has an average N70E trend (Cluzel et al, 1995) oblique to the average N130E strike of the HP-LT belt.

### 5.3. Intermediate Melange units

Spaced melange lenses, a few 100 ms to a few kms wide and several kms long, occur within metamorphosed metasedimentary units, while they are apparently absent in the low-grade westernmost units (Montagnes Blanches Nappe). Blocks in these melange slices are basalt, red chert, dolerite, leucogabbro/diorite, and granite with the same metamorphic grade as the neighbouring rocks. The serpentinite matrix of the melange clearly differs from the serpentinite sole of the Peridotite Nappe and underwent metamorphic recrystallization marked by the northeast-ward increasing development of talc. These melange slices are referred to as “intermediate” because they display features transitional between that of serpentinite slices issued from the Peridotite Nappe and that of the Pouebo Terrane.

### 5.4. Pouebo Terrane

The Pouebo Terrane (Cluzel et al, 1994, 2001) is a typical tectonic melange (e.g. Festa et al, 2010 and references therein) composed of cm- to km-size lensoids (Plate 1a & 1c) enclosed in a (meta)serpentinite matrix. The best outcrops of the terrane are exposed along the provincial road on the northern slope of Amoss Pass. Most blocks are mafic and dominantly display blueschist facies associations (garnet, lawsonite, glaucophane) with rare eclogite remnants and retrograde/reaction rims a few cm to 1m thick, composed of actinolite, chlorite, magnetite and talc. Contorted blocks of well-foliated retrograde albite schist/gneiss and incompletely retrograded mafic rocks (Plate 1b) enclosed in the serpentinite suggest that incorporation of these blocks in the serpentinite matrix occurred at least partly during the exhumation of eclogite-facies rocks. Locally (e.g., Balade Beach), a metamorphosed (although weakly deformed) polygenic cobble conglomerate is composed of mafic elements and a few felsic rocks up to 1m in size (Plate 1b). Outcrop conditions do not allow the observation of relationship between this peculiar facies and the rest of the unit; however, it most probably represents one single block embedded in the melange.

Although a large part of the Pouebo Terrane is only exposed in remote and rugged areas of the Mt Panié, and thus is poorly known, it seems that the amount of serpentinite matrix decreases along strike from NW to SE, while that of metasedimentary elements increases up to 50% in the Hienghène region where elements of Maastrichtian black cherts are mixed with mafic blocks. In the south-easternmost known exposure of the Pouebo Melange, at Anse Ponandu (4.5km to the SSE of Touho village), the melange contains mafic (E-MORB) and metasedimentary rocks, which include meta-conglomerate blocks identical to those of Late Cretaceous Tendo Fm. (see 5.2 above) apparently without serpentinite matrix.

## 6. Nature and origin of blocks in intermediate mélange units

Elongated melange lenses crop out discontinuously within the meta-sedimentary rocks of the HP-LT belt (Fig. 2); in the following paragraph they will be described from SW to NE, i.e. at increasing metamorphic grade across strike.

### 6.1. Mamelons Verts Unit

A 6 km long - 1km wide lens of serpentinite-rich mélange crops out immediately to the north of the main road from Koumac to Poum (Fig. 2, loc. 1). Overall, this unit forms a tightly pinched synform, which thins out

NW-ward and SE-ward and rests against isoclinally folded and steeply dipping (70° on av.) Maastrichtian-Paleocene chert and micrite. The mélange is composed of strongly foliated porphyroclastic serpentinite without naked-eye evidence for metamorphic recrystallization. Serpentinite foliation is parallel to that of the surrounding rocks and does not show F2 folding. Various dm- to 10 m blocks represent about ¼ of the mélange volume. Undeformed serpentinitized harzburgite blocks/porphyroclasts are found throughout the unit. The other blocks are gabbro, dolerite, basalt and red chert, which most probably represent elements of oceanic crust, and occasionally blue-black schist. Some mafic rocks have a negative slope on multi-elements spiderdiagrams, display strong Nb and Ta and to a lesser extent, Ti negative anomalies. They are intermediate between IAT and IAB and thus similar to the subduction-related rocks of the Haute Néhoué Unit (see below) and display the same positive anomaly in Zr and Hf (Fig. 5a). Others are more depleted and display a positive slope with almost unnoticeable Zr-Hf anomalies and may be related to IAT series. Blocks of leucogabbro, which very much resemble the Lower Eocene dykes of the Peridotite Nappe are found throughout the unit. Blue-black schist clasts have not been formally correlated but they very much resemble Late Cretaceous low grade metasediments of the Pilou Fm.

#### 6.2. Ougne-Ouehat Unit

The Ougne (Uny) and Ouehat (Mwaida) peaks are located in a poorly populated area at about 11 km to the NW of the main road from Koumac to Ouegoa (Fig. 2, loc. 2). They are the highest of a series of hills, at 200 to 300m elevation, which belong to a double belt of mélange capped by peridotite. The base of the peridotite lenses and the serpentinite sole 10-20m thick, which underlines it, are folded (dip < 45°) and define a series of gentle synclines. Beneath the peridotites, the serpentinites interleaved with melange lenses, are deeply rooted within tightly folded Late Cretaceous to Eocene metasediments and extend laterally over more than 15 km. The composition of blocks in melange lenses displays the same usual diversity (granite, leucogabbro, diorite, red chert, basalt, dolerite). Dolerites display EMORB geochemical features (Fig. 6), while felsic rocks (granite and leucodiorite) are typically subduction-related (IAB) (Fig. 5f & 6) and similar to rocks of the Haute Nehoue Unit (see below).

Despite their diversity, the felsic blocks sampled in the mélange yielded very similar U-Pb zircon ages (leucodiorite #POugn 1: 54.02±0.46 Ma; granite #Ouehat 1: 54.12±0.47 ; diorite #Ouehat 5 : 53.4±0.9Ma) (Fig. 8), and are coeval with the Lower Eocene dykes of the Peridotite Nappe.

#### 6.3. Haute Nehoue Unit

This small unit about 1km-wide is located at the northwestern end of an 11 km-long NW-SE trending serpentinite sliver (Fig. 2, loc. 3). It is mainly composed of a coherent set of mafic and intermediate rocks discontinuously surrounded by serpentinites. The melange lens is in faulted contact in the south with isoclinally folded Late Cretaceous black cherts and Paleocene micrite, and to the north with Late Cretaceous black cherts. It is composed of remarkably fresh although metamorphosed greenish pillow lavas and parallel fine to medium-grain felsic dykes (Plate 1a) without obvious tectonic deformation. Geochemical discrimination based upon “immobile” trace elements ratios (Zr/TiO<sub>2</sub>, Nb/Y) (Winchester & Floyd 1977) delineate one single fractionation

1  
2  
3 trend from basalt-andesite to dacite (diorite) composition (Fig. 4). Chondrite-normalized REE patterns display  
4 prominent LREE fractionation and flat HREE patterns (not shown). Rare earths and incompatible trace elements  
5 extended patterns indicate compositions intermediate between island-arc tholeiites (IAT) and island-arc basalts  
6 (IAB) (Fig. 5a). The most evolved dyke (medium-grain diorite) has yielded a U-Pb zircon age of  $54.7 \pm 0.8$  Ma  
7 (Fig. 8a), which owing to the geochemical similarity, most probably represents the age of the whole sequence.

8  
9  
10 This subduction-related unit is bounded to the southwest by dolerite of E-MORB affinity; however, the  
11 boundary is masked by river alluvium. To the northeast, the sequence has a (block/faulted ?) boundary with  
12 pillow lavas of BABB composition.

13  
14  
15 At about 2.5 km to the southeast along strike, upright foliated serpentinites contain boudinaged blocks of  
16 serpentinitized harzburgite, basalt and leucogabbro. Foliation and stretching lineation in serpentinites (S1:  
17 N130E-70NE; L1: N70E) are similar to the regional structural features and likely result from the same tectonic  
18 event.

#### 21 22 23 6.4. Arama Unit

24 The main road from Koumac to Arama village crosscuts at Arama Pass a melange lens 500m wide and 2.5  
25 km long with a NNE-SSW strike (Fig. 2, loc. 4). The melange contains blocks of metamorphosed pillow basalt,  
26 red chert, metadolerite and granitoid in a matrix of talc-bearing meta-serpentine. The local occurrence of  
27 glaucophane-garnet-bearing mafic blocks (Routhier 1953; this study) and the widespread development of talc  
28 in the serpentinite matrix would suggest that the metamorphic grade in mélangé is higher than that of the  
29 surrounding schists. However, retrograde recrystallization in the presence of excess water has erased all traces  
30 of high-grade parageneses (blueschist or eclogite) in metasediments, while in contrast they are well preserved  
31 in metamorphosed mafic rocks (Fitzhebert et al, 2005). The nearby meta-basalts and meta-andesites of the  
32 Diahot schists (Pilou Fm.) display the same blueschist facies assemblages and therefore have the same  
33 metamorphic grade. The occurrence of oceanic basalt features (pillows, red cherts) as well as NMORB and  
34 EMORB geochemical composition of mafic blocks allow correlation with Poya Terrane rocks. The granitoid  
35 boudin enclosed in meta-serpentine (sample # ARM 9) (Plate 1b) has geochemical affinities intermediate  
36 between IAT and IAB-series and resemble felsic rocks of the Haute Nehoue unit.

37  
38  
39 At the northwest entry of Arama Village, a talc-rich lens of serpentinite mélangé, 2 km long, crops out with  
40 a N-S strike. It looks very similar to the Pouebo eclogitic mélangé and contains blocks of glaucophane-bearing  
41 metabasalt a few cm to several m wide enclosed in the talc-rich metaserpentine matrix. In addition to mafic  
42 blocks of EMORB and OIB affinity, one light blue medium grain rock of IAT/IAB affinity (sample #ARM 8  
43 geochemically similar to #ARM 9). Along the border of one large mafic block, a streak of breccia is composed of  
44 angular cm- to dm-size clasts of various lithologies, which include metabasalt identical to that of the large  
45 block, (Late Cretaceous ?) grey schist and white fine-grain limestone similar to the Paleocene-Lower Eocene  
46 micrite (Plate 1c & 1d); however, this is the only known occurrence of such facies in this unit. The rock features  
47 of this outcrop means that the polygenic breccia and the basalt block were associated before being enclosed in  
48 the serpentinite matrix.



6.5. Baviolet Unit

A large serpentinite slice 3km x 11km oriented WNW-ESE is located half-way between Kaala-Gomen and the Mt Panié (Fig. 2, loc. 5). The main serpentinite unit contains tectonic lenses of schistose Late Cretaceous microconglomerate (Tondo Fm.) and rare melange lenses. The unit rests at shallow angles (<30°) upon moderately metamorphosed Late Cretaceous schists. It is overlain by several shallow-dipping non-foliated (but serpentinitized) peridotite lenses 50m to 500m wide. Downwards and laterally, it extends over about 40 km into several narrower (ca. 50m thick) and steeper slices of foliated serpentinite. Due to the difficult access and tropical weathering, melange lenses were not sampled; however, a deformed felsic dyke, 20m thick, which crops out along the main track crossing the Central Range from Hienghene to Gomen at 3.8 km to the ENE of Baviolet Summit could be sampled (sample #HCLN 8). It contains rare pegmatoid pockets, hornblende lenses, and ultramylonite bands orthogonally crosscut by tension cracks filled with quartz-albite, albite-tremolite or tremolite only, denoting ductile deformation at about the same metamorphic grade as the enclosing metasediments. Its extreme depletion in incompatible elements (Fig. 5f) makes it an unusual magmatic rock, while its modal composition of Ca-plagioclase (~45 wt%) and diopside (~25 wt%) makes it similar to some Ca-rich rodingites. The Zr content is too low for crystallizing zircons large enough to be extracted; however, REE pattern shows a positive Eu anomaly, which also characteristically appears in some Lower Eocene dykes of the Peridotite Nappe (Cluzel et al, 2006) (Fig. 7).

7. Nature and origin of blocks in the Pouebo Terrane

Due to tropical weathering and rugged topography, outcrops of the Pouebo Melange are restricted to the shoreline, creek valleys (mostly waterfalls) and a few road sides; as a consequence mafic boulders, which are resistant to weathering and erosion were probably oversampled compared to other lithologies (e.g., felsic rocks, serpentinitized peridotite, ...).

7.1 Sedimentary rocks

The volumetrically minor metasedimentary blocks are metamorphosed abyssal argillites similar to that of the Poya Terrane and rocks from the Late Cretaceous to Paleocene sedimentary cover (siltstone, chert, limestone) (Maurizot et al, 2020c). Detrital zircon populations from metasandstones and siltstones show features similar to Late Cretaceous sediments. The occurrence of a prominent Santonian-Campanian detrital zircon population (88-77Ma) (Pirard & Spandler, 2017), suggests that the protolith of these rocks was likely derived from the distal Diahot Terrane or merely from passive margin turbidites of the Kone Facies (Poya Terrane) rather than from the proximal Fm. a charbon, in which this population is minor (Cluzel et al, 2011, 2017).

7.1 Ultramafic rocks.

In addition to the well-foliated serpentinite matrix, a few blocks of ultramafic rocks a few ms wide have partly or totally escaped shearing deformation (Plate 2b & 2d), most of them are composed of massive talc- and chlorite-bearing meta-serpentinite (Spandler et al 2008). Almost pure steatite with minor tremolite

(soapstone) appears in foliated and unfoliated bodies that are commonly used for local art works. However, larger ultramafic blocks such as the Pwa Radèn Block (Yambé) about 1 km x 1 km, have preserved their original composition except at their limits, which are surrounded by serpentinite and melange lenses that record the same metamorphic grade as the host rocks of the Pouébo Terrane. Although no direct correlation exists with the Peridotite Nappe, this small unit has been interpreted as a preserved slab /mantle-wedge boundary dragged into the subduction at 50-60 km depth before its exhumation with Pouébo Terrane (Fitzherbert et al. 2004). It is worth noting that serpentinization in these rocks predates the eclogite-facies peak metamorphism recorded by zircon overgrowths at 44 Ma; and thus, has been developed more than 10 Ma before obduction.

## 7.2 Mafic rocks.

Despite apparent similitude, mafic blocks a few cm to one km in size (Plate 2a, 2b & 2c), mostly of basalt or basalt-andesite composition, display multiple magmatic affinities as suggested by incompatible trace element ratios. Four groups may be defined (numbers into brackets refer to Fig. 5 & 6):

- (1) LREE-depleted rocks with almost flat patterns, with a weak Nb negative anomaly, no Ta anomaly, they plot in the MORB field of Wood's ternary plot and thus can be termed BABB (Fig. 5b)
- (2) LREE undepleted rocks with a moderate negative slope, a very weak negative Eu anomaly and no Ta anomaly (Fig. 5c), they plot in the low Hf/Th and low Hf/Ta part of the MORB field of Wood's ternary plot (Fig. 6) and can be qualified of enriched (or undepleted) MORB (EMORB)
- (3) Alkaline rocks, which display strong negative slope on REE and trace-elements expanded patterns, no Nb-Ta anomalies (Fig. 5d) and plot in the field of OIB-series on Wood's ternary plot (Fig. 6)
- (4) Subduction-related rocks showing a continuous range of composition with variable negative slope on expanded patterns, well defined Nb and Ta negative anomalies (Fig. 5e). These rocks plot within the IAB/IAT domain on Wood's diagram (Fig. 6)

It is worth noting that the types 1, 2 and 3 are closely similar to Poya Terrane Basalts and for the type 2, EMORB dolerites of the Kone Facies; in contrast, the type 4; i.e., clearly subduction-related, was never found in the Poya Terrane.

## 7.3 Uncorrelated rocks

A few depleted to ultra-depleted rocks with supra-subduction signatures (Fig. 5f) escape the typology mentioned above, they are generally termed felsic in the field; however, their white color may also be due to abundant light-colored amphibole and the most depleted rocks are close to "rodingite" composition. Some occurrences of tremolitite may also be signaled. Some rocks of this type yielded magmatic zircons dated at 55.7 ± 0.4 Ma (Spandler 2006) (Fig. 8).

## 8. Discussion

The samples with BABB, EMORB and OIB affinities (types 1, 2 and 3) are geochemically similar to the basalts and dolerites of the Poya Terrane (Cluzel et al 2001, 2017; Spandler et al 2006) (Fig. 6); in addition, the few available U-Pb radiochronological data from inherited zircon cores (Spandler et al 2006, Pirard & Spandler



2017) suggest that these mafic blocks have the same Late Cretaceous-Paleocene age as Poya Terrane rocks and that the latter are the most probable protoliths of the melange. Especially, EMORB dolerite sills of the Kone Facies, which yielded U-Pb zircon ages of ~55 Ma (Cluzel et al 2017), are the best candidates for the largest mafic blocks of the melange.

The occurrence of low-temperature mineral exsolution at the boundary of the inherited core and the metamorphic zircon rims of some eclogites (sample #3007) allowed Spandler et al (2004b) to suggest the occurrence of seafloor alteration before eclogite-facies metamorphism and thus origin in the lower plate of the subduction system. However, magmatic zircons cores at 55 Ma (Spandler et al, 2004a) and above all, unusual whole-rock composition compared with PTB (oceanic crust of the lower plate), i.e. negative Nb-Ta anomalies (Fig. 5f) slightly U-shaped REE patterns with prominent positive Eu anomaly (Fig. 7), suggest a different interpretation. Supra-subduction dykes with a similar positive Eu anomaly are not unusual in the Peridotite Nappe, they have been emplaced at ~55-53 Ma (Fig. 7) and were interpreted as slab melts coming from the melting of gabbro cumulates (Cluzel et al 2006). These dykes occasionally display evidence for (hydrothermal) alteration (see above), which could account for the low temperature alteration of magmatic zircon cores. Thus, at variance with the interpretation of Spandler et al (2004b), these rocks could belong to the upper plate as well.

In contrast with mafic rocks of tholeiitic or alkaline composition, which closely fit with the composition of PTB, felsic rocks, which are extremely rare in the Poya Terrane and mafic blocks with supra-subduction zone geochemical features (type 4) had not been correlated yet. In addition, the available U-Pb ages for these rocks (55-54 Ma) (Spandler et al 2006, Pirard & Spandler 2017; this study) (Fig. 7) are younger than that of PTB (Campanian-Eocene; i.e., 84-56 Ma), slightly postdate subduction inception (~56 Ma) and fit with the age range of the dykes of Peridotite Nappe.

The basalt-andesite pillow lavas and diorite dykes of the Haute Nehoue Unit and Ouehat-Ougne Peaks occur within the Intermediate Melange and are (tectonically) associated with EMORB and BABB likely derived from PTB. They have no equivalent in the Poya Terrane (lower plate) and clearly differ from IAT dolerites of the Peridotite Nappe (upper plate), which are much more depleted (Fig. 5a). They are also older (55-54 Ma vs. 50-47 Ma). It is suggested that they represent a small supra-subduction basin formed immediately after subduction inception and most likely resulting from incipient fore-arc extension.

The occurrence in the melange of Lower Eocene mafic rocks with IAB/IAT (supra-subduction) affinity and thus derived from the upper plate is worth noting because they contrast with EMORB sills of the Kone Facies Dolerites (Poya Terrane), which come from the lower plate and have exactly the same U-Pb zircon age of ~55Ma.

A comparison of IAB/IAT rocks of the Pouebo Terrane and EMORBs of the Poya Terrane shows some similarity. Their incompatible elements contents are similar and except Nb-Ta and to some extent Zr-Hf, the extended patterns are similar with the same negative slope (Fig. 5c & 5d). Negative Nb and Ta anomalies and positive Zr and Hf anomalies are apparently overprinted on geochemical features coming from the melting of an undepleted MORB-type source (EMORB). Lower Eocene EMORB dolerite sills (KFD) were interpreted to form a laccolith associated with the transcurrent reactivation of the ancient Late Cretaceous passive margin due to

the obliquity of the new trench with respect to the northern Norfolk Ridge (Cluzel et al, 2017). Thus, as a working hypothesis, some of the rocks with supra-subduction affinity, especially those found in the Intermediate Melange, were possibly issued from a fertile mantle source of similar nature, which was pinched on top of the subduction zone and variably metasomatized by fluids released by the subducted slab. It is worth noting that strongly depleted IAT dolerites similar to those of the Peridotite Nappe (50-47 Ma) (Fig. 5a) are absent in Pouebo Terrane and Intermediate Melange as well. This undepleted supra-subduction melt source was very short-lived because no rock of this type younger than 55 Ma was found. Some of the felsic dykes of the Peridotite Nappe (54-52 Ma) share some features with the IAB-IAT of the Pouebo Terrane; however, they are more fractionated and depleted in HFSE (Fig. 5e). Compared to Peridotite Nappe, Pouebo Terrane contains "normal" supra-subduction rocks, while the latter is dominantly crosscut by younger slab melts and ultra-depleted supra-subduction melts.

A better characterization of melt sources through isotope geochemistry is obviously needed; however, it is beyond the scope of this article. Melt sources seem to be increasingly depleted through time and a tentative chronology of these short-lived events may be established: (1) undepleted IAB from Haute Nehoue Unit (55 Ma); (2) IAB-IAT Pouebo Terrane (54 Ma); (3) depleted IAB-IAT from Peridotite Nappe (54-52 Ma); and (4) ultra-depleted IAT from Peridotite Nappe (50-47 Ma)

9. Conclusion

The components of melanges involved in the Eocene HP-LT metamorphic belt of New Caledonia not only come from the lower plate as previously established, but also involve major elements from the upper plate. Lower plate elements are dominantly derived from the Poya Terrane; i.e., basalts and red cherts. Scarce metasediments were also derived from the ancient passive margin (Late Cretaceous turbidites) and the sedimentary cover of the Norfolk Ridge (e.g., micritic limestone, black chert). The occurrence of polygenic breccia blocks in the melange suggests that lower plate components, which include collapse breccia, have been scrapped off from the base of the accreted material in front of the fore-arc region (Fig. 9).

Upper plate elements come from the serpentinized mantle rocks of the hanging wall characterized by various supra-subduction rocks, all emplaced within a very short time interval (55 Ma to 54 Ma). Among the multiple magmatic events recorded in melange units some were coeval to basin formation in the upper plate, as suggested by the occurrence of andesite pillow lavas. These lavas erupted very shortly (<1 Ma) after subduction inception, and the coeval magmatic activity ceased immediately, a fact which suggests that parts of the fore-arc region were dragged very early into the subduction zone and tectonically mixed with other components (Fig. 9). In spite of major similitudes (e.g., meta-serpentinite matrix, occurrence of oceanic rocks derived from the Poya Terrane), there are significant differences between Intermediate Melange and Pouebo Terrane; especially, un-depleted supra-subduction rocks (andesite-dacite series) such as Haute Nehoué rocks, and strongly fractionated supra-subduction rocks similar to the dykes of the Peridotite Nappe are apparently lacking in the Pouebo Terrane. In contrast, “normal” suprasubduction rocks, which are widespread in the Pouebo Terrane do not appear in Intermediate Melange and in the Peridotite Nappe as well. This and a slightly different timing suggest that supra-subduction components come from different places/depths of the fore-arc region.

Incidentally, the evidence discussed above suggests that:

- mélange units of the HP-LT metamorphic complex of northern New Caledonia represents exhumed and sliced elements of the Eocene subduction zone
- formation of these units resulted from subduction erosion of the footwall/lower plate (oceanic crust of the South Loyalty Basin) and the hangingwall/upper plate (fore-arc mantle of the Loyalty Basin)
- the lower plate components were probably accreted first in the fore-arc region and thereafter eroded from the base of the accretion complex
- the melange process occurred at least partly during exhumation
- except the development of porphyroclastic mylonites, which occurred during peridotite overthrusting, the bulk of the serpentinite sole was formed largely (>10My) before end-Eocene obduction and owing to its upward decrease in the Peridotite Nappe was mostly related to subduction

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### Figure captions

Figure 1: Simplified tectonic map of New Caledonia

Figure 2: Geological sketch map of melange units of northern New Caledonia. ABCD: location of the cross section line of Figure 3. Circled numbers refer to the locations cited in the text.

Figure 3: Simplified cross section (for location see Fig. 2). Vertical magnification x2.2; values in GPa indicate the maximum pressure (depth) attained during prograde HP-LT metamorphism. The double bar shows the attitude of the regional foliation S1.

Figure 4: Trace-elements geochemical determination of rocks of the Haute Nehoue Unit (Winchester & Floyd 1977).

Figure 5: Expanded rare earths and incompatible trace elements spiderdiagrammes normalized to the N-MORB (Pearce 1982) of rocks from Pouebo and Intermediate Melange units.

Figure 6: Discrimination diagram of Wood (1980) modified by Vermeesch (2006) to show the four main groups of melange rocks and their correlation with Poya Terrane Basalts and supra-subduction dykes of the Peridotite Nappe.

Figure 7: Chondrite-normalized REE diagram (Evensen 1978) of Lower Eocene dykes (slab melts) with positive Eu anomalies of the Peridotite Nappe and coeval rocks found in Pouebo Melange.

Figure 8: Terra-Wasserburg concordia plot for U-Pb dating of zircons extracted from Haute Nehoue diorite and boudinaged dykes of the Intermediate Melange (diagrams elaborated with Isoplot 3 software; Ludwig, 2012).

Plate 1: Field pictures of Intermediate Melange units. 1a: andesite-basalt crosscut by parallel diorite dykes. 1b: boudinaged granite enclosed in foliated serpentinite, Arama Pass. 1c: large mafic block associated with breccia composed of angular mafic clasts of the same composition and white micrite, seaside track north of Arama Village. 1d: detailed view of polygenic breccia.

Plate 2: Outcrop pictures of the Pouebo Terrane. 2a: large mafic boulder near the top of Pouebo Terrane, Ouaième Mouth, 10 km northwest of Hienghène Village. 2b: roadside on the northern slope of Amoss Pass, serpentinous melange composed of blocks of weakly or non-foliated talc-rich serpentinite (underlined in green), mafic eclogites (underlined in blue) and contorted retrograde albite schist/gneiss (underlined in white) enclosed in well foliated serpentinite. 2c: lensoids of mafic rocks (same outcrop as 2b). 2d: moderately foliated talc-rich serpentinite (same outcrop as 2b). 2d and 2c: conglomerate-like polygenic breccia, Balade Beach.

Unit	age	Rock typology	provenance
Intermediate Melange	90 - 55 Ma	BABB/NMORB EMORB OIB	Poya Terrane (lower plate)
	> 84 – 56 Ma	Cretaceous Paleocene sediments	Norfolk/New Caledonia Ridge (lower plate)
	55 - 54 Ma	“enriched” IAB	Fore-arc region (upper plate)
Pouebo Melange	90 – 55 Ma	BABB/NMORB EMORB OIB	Poya Terrane (lower plate)
	> 84 – 56 Ma	Cretaceous Paleocene sediments	Norfolk/New Caledonia Ridge (lower plate)
	55 - 54 Ma	IAB/IAT	Fore-arc region (upper plate)
	<44 Ma (?)	Retrograde shear zones	

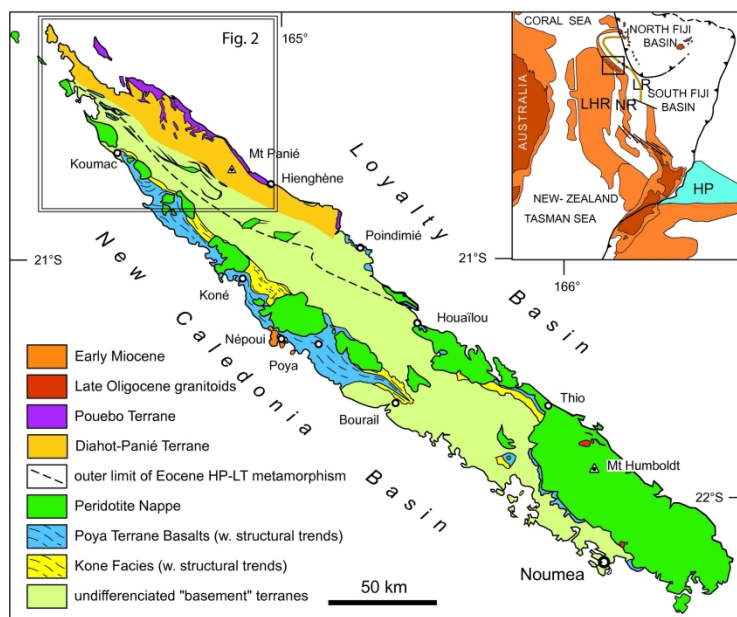


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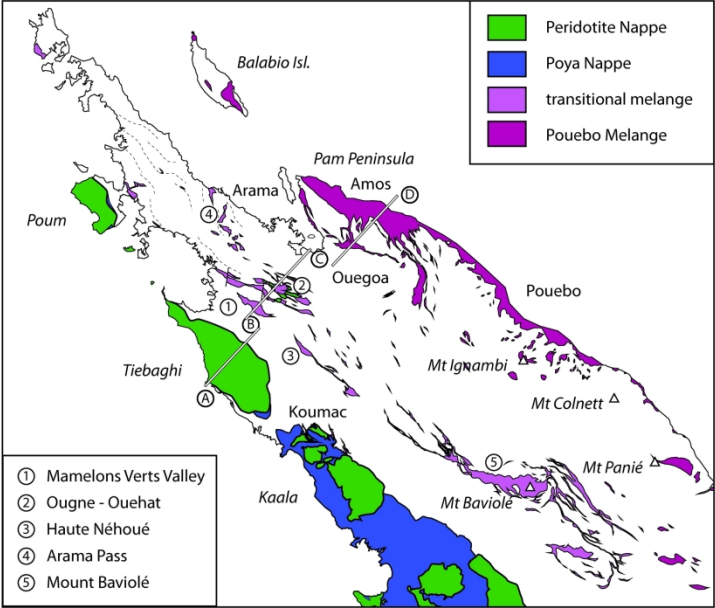


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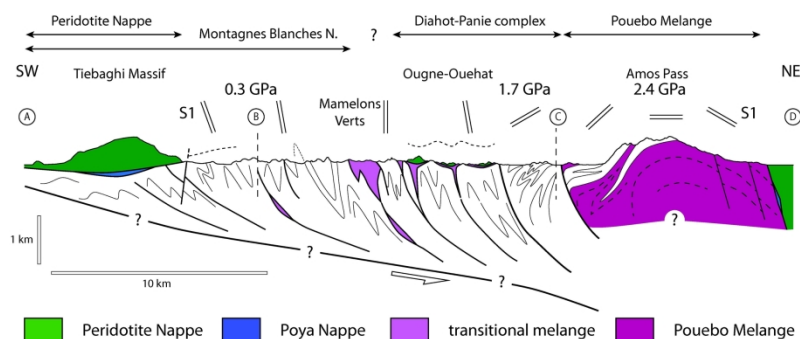


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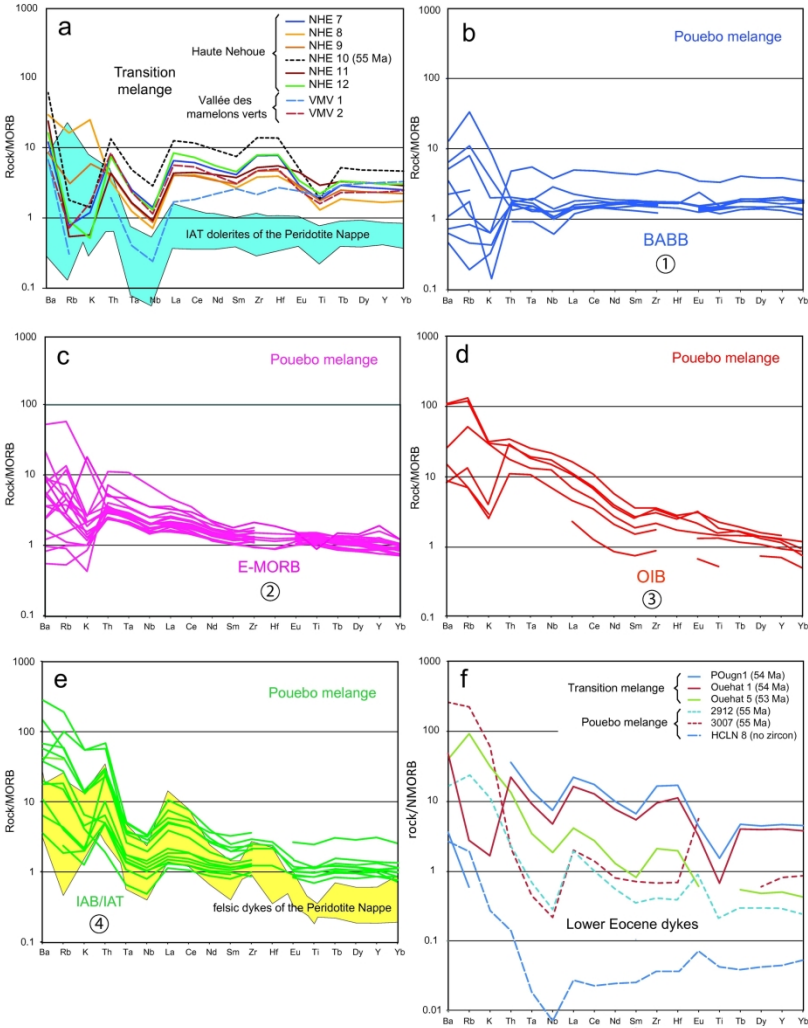


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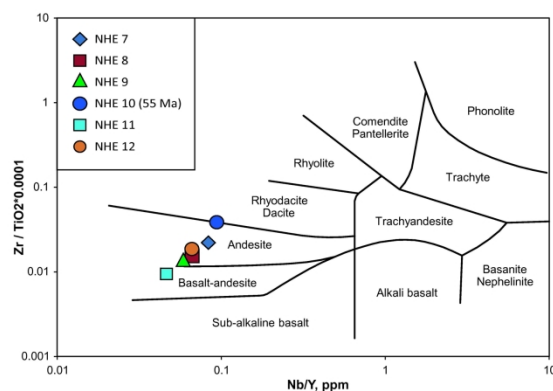


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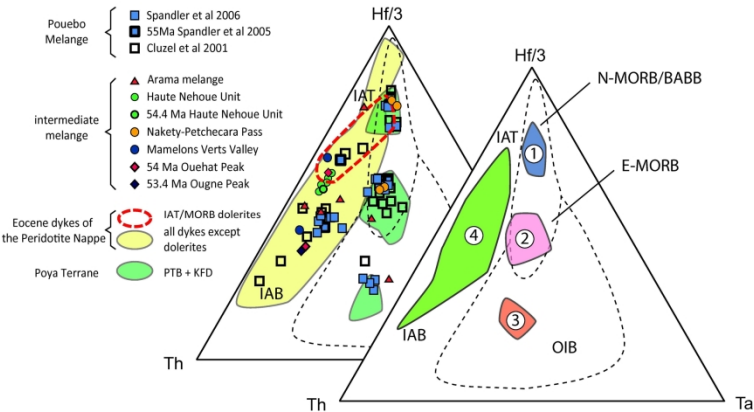


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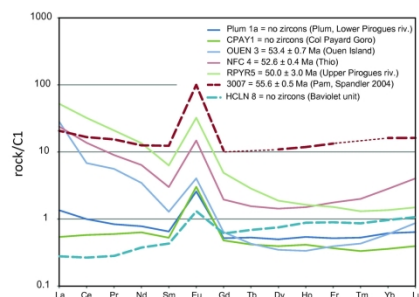


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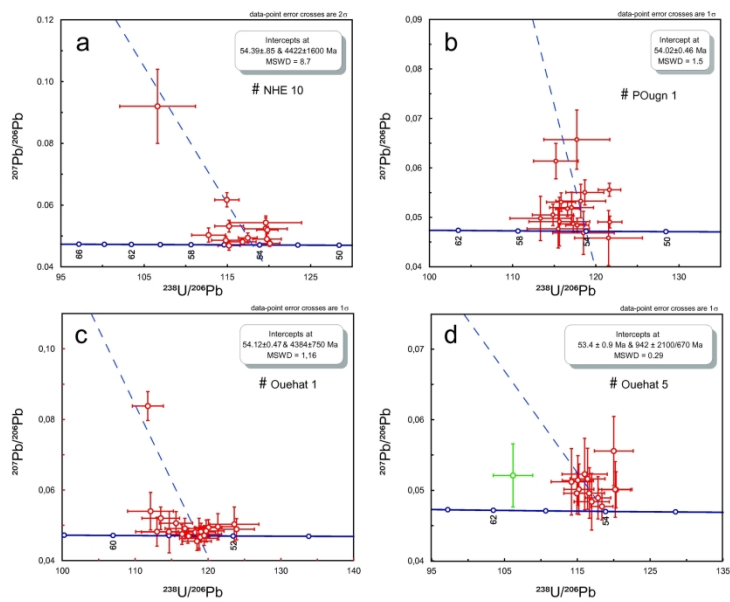


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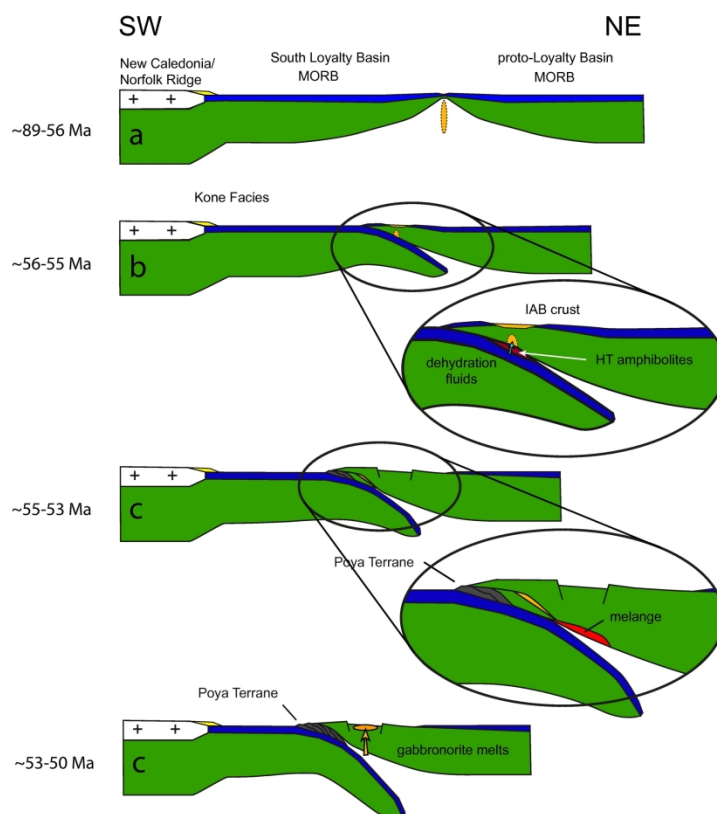


Figure 9: tentative model of accretion and subduction erosion during the period immediately following subduction inception.

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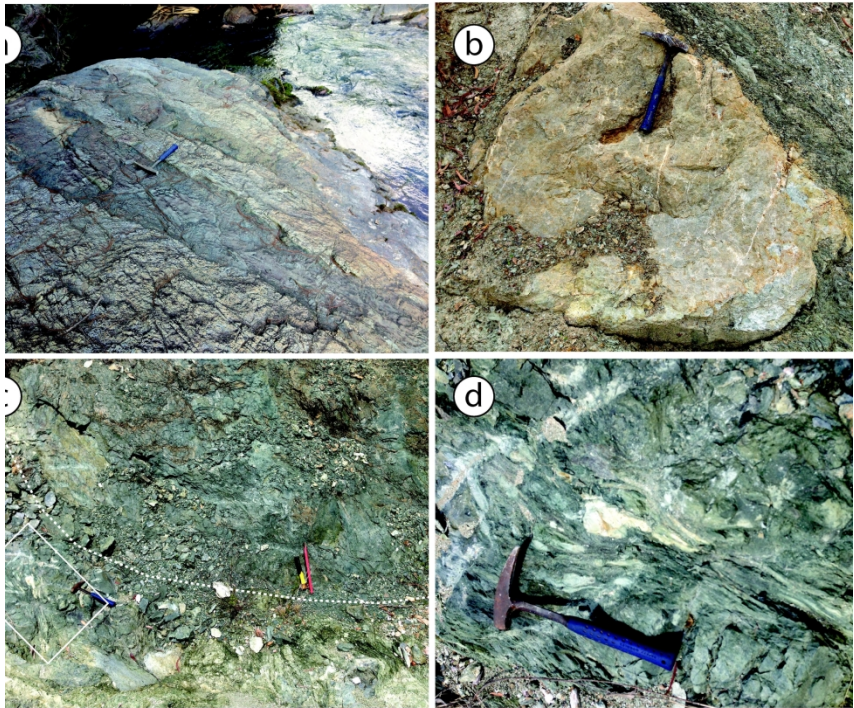


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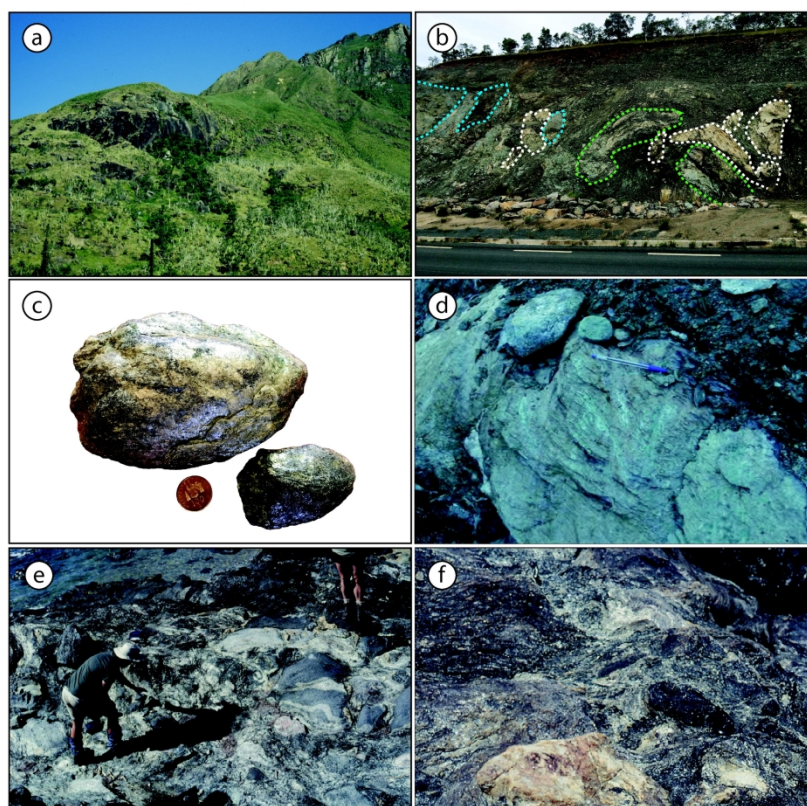


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