## Table of Contents

Executive Summary ........................................................................................................ 3  

1.0. Overview of New Caledonia .................................................................................. 4  
   1.1. Geography ........................................................................................................ 4  
   1.2. Climate and Ecology ....................................................................................... 5  
   1.3. History, demography and politics ................................................................... 6  
   1.4. Economy .......................................................................................................... 7  

2.0. Geology ................................................................................................................ 9  
   2.1. Regional geological settings .......................................................................... 9  
   2.2. General tectonics ........................................................................................... 10  
   2.3. Terranes of New Caledonia ............................................................................ 11  
      2.3.1. Ante-Senonian basement ....................................................................... 12  
      2.3.2. High pressure rocks ............................................................................. 17  
      2.3.3. Obduction nappes ............................................................................... 23  
      2.3.4. Post-obduction rocks ......................................................................... 29  

3.0. Mining in New Caledonia ................................................................................... 33  
   3.1. Major Past and current extracted products ................................................. 35  
   3.2. Minor exploitations ..................................................................................... 46  
   3.3. Subeconomic enrichments ......................................................................... 49  
   3.4. Non-metal resources .................................................................................. 52  

4.0. References .......................................................................................................... 53
Executive Summary

New Caledonia is an island of the south-western Pacific Ocean which belongs to France. This island has a long geological history which goes back to the break up of Gondwana during the Mesozoic. The succession of large scale events including accretion, subduction and obduction has formed 4 main groups of rocks in New Caledonia. The Ante-Senonian basement is the accretion of oceanic terrane on the eastern margin of Gondwana from Permian to Late Jurassic. Subduction processes are the main feature of the northern terranes which show high pressure metamorphism from shallow zone to blueschists and eclogite facies. In the same time, obduction of oceanic crust on New Caledonia continent has created the main feature of the island’s geology with large ultramafic massifs underlying nearly half of New Caledonia surface area. The last group of rock occurring after the subduction and obduction events is mainly characterized by sedimentary rocks and important tropical alteration processes of the older rocks.

This complex geological history provides the basis for the formation of ore deposits. The most remarkable feature of New Caledonia mining landscape is nickel laterite. These ores cover most of the ultramafic terranes and have been exploited for decades. New projects are underway in Goro and Koniambo areas which will re-establish New Caledonia as one of the biggest producers of nickel in the world. Cobalt and chromium are also by-products of the ultramafic terrane exploitation. Other deposits are more limited in size such as Cu-Zn-Pb-Ag mineralization in the Diahot area and occurrences of platinoids and gold appear to be uneconomic. Minor occurrences of iron ores, coal and manganese are known.

The institutional arrangements in New Caledonia, particularly the Geological Survey, provide basic information on the geology and mineral resources of the island.
1.0. Overview of New Caledonia

1.1. Geography

New Caledonia is an archipelago composed of several islands (Loyalty Islands, Belep Islands, Ile des Pins, Grande Terre), reefs and lagoons located in the western Pacific Ocean. It lies approximately 1500km east of Australia, 2000km north of New Zealand and just south of Vanuatu (Fig. 1).

Grande Terre (translation: large land), the main island, forms more than 80% of the New Caledonia surface area and is an elongated island nearly 400km long and over 40km wide. The name New Caledonia is often considered as a synonym of Grande Terre and the minor islands are only significant at a local scale. Grande Terre is the only mountainous island in the area with Mount Panié (1628m) and Mount Humboldt (1610m) the highest points. Mountains form a continuous chain across the island, steep on the east coast and forming numerous rias, whereas the west has low and swampy coastal plains between hilly massifs (Paris, 1981). Most of the rivers are transversal to the central ridge and run down in those lowlands and mangrove finally entering in the lagoon which rims the entire island.

Fig.1. New Caledonia in the south western Pacific Ocean (Cluzel et al., 2001).
The lagoon is one of the largest and most diverse in the world. The barrier reef lies 10 to 50km offshore, with several passes between the lagoon and the open-sea. The whole archipelago is part of a submerged continental mass called Zealandia which has the shape of a long ridge orientated NE-SW, connecting New Caledonia to New Zealand. This ridge (Norfolk Ridge), with an average depth of 1000 to 1500m, is evident from the presence of other small islands such as Belep Island, Ile des Pins or Norfolk Island. The Loyalty Ridge runs parallel to New Caledonia on the eastern side and is also evident from a series of small islands. In the vicinity of Grande Terre, the edge of the reef marks the limit of Zealandia and seafloor dives down to more than 3000m into the New Caledonian and Loyalty Basins (Paris, 1981; Wood et al., 2003; Keith et al., 2007) (Fig. 1).

1.2. Climate and Ecology

New Caledonia lies astride the Tropic of Capricorn, between 19° and 23° south latitude. The climate of the islands is tropical, and rainfall is highly seasonal, brought by trade winds that usually come from the east. Rainfall averages about 1500mm annually on the Loyalty Islands, 2000mm at low elevations on eastern Grande Terre and 2000 to 4000mm at higher altitude. The western side is drier, lying in the rain shadow of the central range and an average rainfall averages of 1200mm per year.

Because of the particular geology of New Caledonia compared to other oceanic and volcanic islands, the ecology is extraordinary and unique, endemic and extremely primitive, with plants and animals of Gondwanan origin. Zealandia separated from Australia 85 million years ago and New Caledonia has been isolated from any other island for the past 55 millions years (Keith et al., 2007). This remoteness has allowed conservation of a prehistoric gondwanan biodiversity with no mammals (except for flying foxes). The main emblematic species of this endemism are Araucariaceae, Niaoulis (Melaleuca quinquenervia), Kagu (Rhynochetos jubatus) or Amborella trichopoda (Jaffré et al., 2004; CBNC, 2007; Richer de Forges, 2007).

The main island contains two floral zones: Higher-rainfall areas (eastern side of Grande Terre and small islands) which support rain forests and a more arid region with shrinking dry forests caused by extensive European-style farming. In addition to
those precipitation zones, soil type, altitude and geographic location have a major effect on the ecological provinces (CBNC, 2007).

Endemism is not only visible in terrestrial environments but also in the freshwater ecosystem which has evolved as a result of long isolation. Offshore, the New Caledonia barrier reef is the world’s second largest coral reef reaching a length of 1500km. It has developed a great diversity and is home to endangered species such as dugongs (*Dugong dugong*), the green sea turtle (*Chelonia mydas*) and the *Nautilus* (Richer de Forges, 2007).

1.3. **History, demography and politics**

According to Lapita pottery fragment, the first human settlement on New Caledonia started approximately 3000 years ago. The Lapita culture was replaced in 200BC by the Naia Oundjo period and the domination of the Kanak people (Galipaud, 1992, 1995).

In 1774, James Cook discovered a land which he named New Caledonia because of its supposed resemblance to Scotland. Several French navigators then sailed to New Caledonia area, with the first European settlement occurring 1841. In 1853, New Caledonia was proclaimed a French colony, with Nouméa founded in 1854. Initially like Australia, the French republic used New Caledonia as a detention island. Apartheid-like laws were used against the native people and these lasted until the end of the Second World War. In the same time, New Caledonia showed rapid and important economic growth due to nickel mining, becoming the world’s third largest producer. In the eighties, confrontation between independence fighters and French partisans degenerated into civil war and ethnic conflict culminating in the Ouvéa Cave hostage-taking in 1988. This last event caused both groups to negotiate; they signed the Matignon Accords for a 10-year transitional status with a self-governing referendum at the end of this period. In 1998, the Nouméa Accord was accepted by 72% of the voters. This allowed a strong autonomy for New Caledonia. The final referendum about the institutional future of New Caledonia (independency or part of the French Republic) will be voted on between 2014 and 2018.

The population of New Caledonia is currently 240400 but is growing rapidly due to the natural birth rate and immigration (ISEE, 2007). The total area covered by land in New Caledonia is 18575km² and the population density is 13h/km². However,
in 2004, the population of Nouméa was 146000 inhabitants which represent \(\frac{2}{3}\) of the total population. As mentioned before, different ethnic groups are present in New Caledonia.

- Kanak (Melanesians): 44.1%, which are the native people of New Caledonia.
- Caldoches (Europeans): 34.1%, often mixed blood, offspring of the first Europeans.
- Wallisians & Futunians (Polynesians): 9% who arrived in New Caledonia during the 60’s and 70’s.
- Tahitians (Polynesians): 2.6%
- French, Indonesian, Vietnamese, Japanese, Chinese, Kabyles, Ni-Vanuatu (10%)

The official language is French; however, there are more than 28 Austronesians local languages and additional languages spoken by immigrants (ISEE, 2007).

1.4. Economy

The New Caledonian gross domestic product (GDP) is estimated to be 3.158 billion US dollars in 2003 which is approximately US$14800 GDP per habitant (ISEE, 2007). This economy is supported by three main pillars: the nickel industry, tourism and financial transfers from continental France.

The nickel mining industry represents more than 10% of the GDP and has increased considerably since 1998, which was the low point (3% of GDP) for the nickel mining industry in New Caledonia in the last 50 years (Fig. 2). Nickel products represent 90% of the value of exports from New Caledonia (ISEE, 2007).
New Caledonia is self-sufficient in livestock but crops are scanty due to unsuitable soils for farming. The main products are fruits, tropical roots and potatoes. Most other foods have to be imported. Fishing is mainly based on various species of tuna and holothurians which are partly exported to Asia. Recently, shrimp aquaculture has started and is likely to increase in importance (ISEE, 2007).

Tourism represents 4% of the GDP and employs 6% of the total working population. Tourists mainly comes from Japan (31%), France (28%), Australia (16%) and New Zealand (6%) (ISEE, 2007).

Finally, large scale financial transfers with continental France are the source of substantial income, making up 25% of the GDP in 1998 (ISEE, 2007).

The balance of payments is still in deficit, with the value of exports of nickel ore and ferronickel more than counterbalanced by imports of consumer goods, food and transport. The recent expansion of in the nickel industry will have lot of importance to the balance of exports and imports in the future.
2.0. Geology

2.1. Regional Geological Settings

New Caledonia is an unusual oceanic island for the southern Pacific. Most islands of the Pacific are relatively young and formed by recent volcanic activity; Grande Terre in contrast has a complex Palaeozoic and Mesozoic geology (Fig. 4).

The island is an emerged part of the Norfolk Ridge. This latter structure is, with the Lord Howe Rise and the Fairway Ridge, part of a large continental plate called Zealandia which drifted away from the Australian continent as a result of the Late Cretaceous Gondwana break-up (Dubois et al., 1976; Crawford et al., 2003; Lafoy et al., 2005). Norfolk Ridge has been studied through the Deep Sea Drilling Program and through seismic studies. These have revealed a 32km thick sialic crust (Dubois, 1969) covered by Oligocene to Recent sedimentary rocks (Dupont et al., 1975; Dubois et al., 1976; Daniel et al., 1976).

The New Caledonia geological history can be divided into three parts which represent major changes in the geodynamical status of Grande Terre. During the Palaeozoic and most of the Mesozoic, New Caledonia was attached to the eastern coast of Australia, somewhere near Brisbane (Glympie Terrane; Cluzel & Meffre, 2002). The primary basement of Grande Terre was covered by several accreting terranes making a complex mosaic of volcanic, sedimentary and metamorphic units (Aitchison et al., 1992). This tectonic collage occurred from the Late Jurassic to Early Cretaceous and is related to the New Zealand Rangitata orogeny (Bradshaw, 1979; Paris, 1981). These Pre-Rangitata terranes form the central part of Grande Terre and are often regarded as the basement of New Caledonia.

At the end of the Cretaceous, the Tasman Sea started to open and the various ridges forming Zealandia also drifted apart forming narrow basins (Davies & Smith, 1971). The New Caledonia basin lies on the west side of Grande Terre. It is a 3000m deep basin, filled with 200-300m to 4000m of sediments where the thickness is a function of the proximity to faults which bound the basin (Dubois et al., 1974; Launay et al., 1979). These sediments are dated as Palaeocene to Recent (Goslin et al., 1972.).

The Loyalty ridge is interpreted to be an Eocene island arc with a back-arc basin (Cluzel et al., 1999, 2001). The Loyalty basin, a remnant of the fore-arc basin
formed during subduction, lies between the Norfolk and Loyalty ridges. It is 2000m deep and covered by major Oligocene to Recent terrigenous deposits, covering important extension faults on the edge of the basin (Weissel & Watts, 1975). The Mohorovičić discontinuity of this area occurs at 17km under the basin and 24km under the volcanic arc (Collot & Misègue, 1977a,b; Weissel et al., 1977).

At the end of the Eocene, a part of the Loyalty basin was obducted on to Grande Terre. This supra-subduction event is characterized by different metamorphic rocks with high-pressure facies or ophiolitic features. These latter ophiolites extend discontinuously from Papua New Guinea to the South Island of New Zealand. This is a widespread but diachronic phenomenon which occurred on the Australian plate margin in the south western pacific during Cenozoic (Aitchison et al., 1995; Auboin et al., 1977).

Since at least the middle Miocene, the whole Zealandia continent has been carried along by the Australian plate; its eastern margin is being subducted beneath the Pacific plate along the Vanuatu trench (Auzende et al., 1995).

2.2. General tectonics

With the exception of the main transcurrent zone, there is no major tectonic feature in New Caledonia. However, most of the terranes have faulted boundaries and faults related to different events that are still visible throughout these units.

Thrust faulting is mainly associated with the two obducted terranes of the Poya and Ultramafic nappes (Fig. 3). These faults are easily visible by their low dipping angle and the intense serpentinization and mylonitization at the contact between these terranes and the basement. Serpentinization is also widespread throughout these terranes on the margins of dip-slip faults.

On the western side of the South Massif, a dextral transcurrent fault is described by Brothers (1974). This faulting offsets the western margin of the obducted mafic sheet, spreading ophiolites massifs along the western coast.

The present day New Caledonia is mainly affected by extension faulting with a NW-NNW trending direction. This faulting has been occurring since early Miocene as recorded by fluvial Neogene formations (Lagabrielle et al., 2005; Chardon & Chevillotte, 2006). These recent tectonic movements are responsible for drowned valleys in the western lagoon and the occurrence of uplifted reefs on the east coast.
(Lagabrielle et al., 2005). These extension processes seems to be controlled by post-obduction isostatic readjustments and more recently by the possible flexure of the oceanic lithosphere currently subducting under the Vanuatu trench at a rate of 12cm/yr (Lagabrielle et al., 2005).

![Diagram of New Caledonia](image)

Fig. 3. Simplified tectonic map of New Caledonia (modified from Chardon & Chevillotte, 2006).

2.3. Terranes of New Caledonia

Four geological groups can be distinguished in New Caledonia and represent the main phases of the island geological history.

- Ante-Senonian terranes [Koh, Tèreomba, Central Chain, Boghen]
- High-Pressure metamorphic terranes [Koumac, Diahot, Pouébo]
- Obducted terranes [Poya, Ultramafic nappe]
- Post-obduction rocks of intrusive and sedimentary origins.
2.3.1. Ante-Senonian terranes

**Koh Ophiolite**

**Age**: Late Carboniferous to Permian  
**Lithology**: Gabbro, dolerite, boninite, tholeiite, plagiogranite, chert, sandstone, siltstone  
**Thickness**: 3000m at Koh, thinner in the northern and southern units  
**Context**: Convergent margin settings; Supra-subduction from a back-arc basin  

The Koh terrane is a part of the Central Chain volcanics. It occurs in several small units in the middle of Grande Terre and is considered to form the oldest rocks in New Caledonia. In the type locality of Koh, where the ophiolite is the thickest, three main units are described (Meffre *et al.*, 1996) (Fig. 5).
- Upper tholeiite basalts and intrusions: This upper unit is 100 to 300m thick and is the least altered rock of the Koh terrane. Intrusive rocks are common with small dikes and or small bodies of altered gabbros and diorite.

- Boninite pillows and felsic volcanics: This member is restricted to the Koh area and separates the lower from the upper tholeiites. It is made of long pillow lava tubes associated with cherts, hyaloclastites and breccias in a 250m thick sequence. The lithology changes upwards to more dacitic compositions with prominent quartz, clinopyroxene and tuffs.

- Cumulate rocks and lower tholeiite: This is the lowermost part of the Koh ophiolite. Plutonic rocks forming the base of this unit are cumulate gabbros with minor gabbronorite and pyroxenite. These lithologies evolve progressively upwards into isotropic gabbros cut by dikes of plagiogranite and dolerite which feed tholeiitic pillow-lavas. On the basis of geochemical pattern, all these rocks form one magmatic sequence. Peridotites and ultramafics cumulates, common at the base of many ophiolites, are absent in Koh, probably removed during obduction or subsequent strike-slip faulting.

![Stratigraphical column of the Central Chain terrane and Koh ophiolites](image)

**Fig. 5**: Stratigraphical column of the Central Chain terrane and Koh ophiolites. Diagonal lines are faults and arrows show that Central Chain sedimentary sequence continues conformably upward (modified from Meffre *et al.*, 1996).

Subseafloor alteration is widespread in the basaltic lavas and characterized by a greenschist facies with numerous secondary paragenese (chlorite, actinolite, pumpellyite, prehnite, serpentine) affecting petrological observations. Moreover,
northern ophiolites (Cantaloupai, Sphinx & Tarouimba) are affected by blueschist metamorphism (Ali & Aitchison, 2002).

Lateral variations are mainly noticeable by the absence of boninitic units in other ophiolites outcrops. Although the sequence remains fairly thick in Sphinx and Tarouimba, in other units, only the shallower magmatic rocks are preserved (Fig. 5).

On the basis of plagiogranite zircons, U-Pb dating gives an age from 302±7 to 290±5Ma for the formation of the ophiolites (Aitchison et al., 1998). These ages are similar to Dun Mountain Ophiolite Belt in New Zealand and geochemical similarities are also to be found with that terrane. The occurrence of N-MORB tholeiite at this time has some importance to geodynamic reconstruction of the eastern margins of Gondwana during Late Palaeozoic and early Mesozoic.

**Central Chain Terrane**

*Age:* Permian to Upper Jurassic

*Lithology:* Volcanoclastic sandstone; tuffaceous and black siltstone; conglomerate

*Thickness:* >7000m

*Context:* Convergent margin settings; SSZ from a back-arc basin

*Resources:* Au

*References:* Guérangé et al., 1975; Maurizot et al., 1985; Meffre et al., 1996; Potel et al., 2006; Potel, 2007

The Central Chain Terrane is in a continuity of mafic ophiolites of the Koh terrane. It crops out in the mountains and on the east coast, covering approximately 15% of the island (Guérangé et al., 1975).

This terrane is relatively monotonous, starting with the pelagic green and red chert overlying pillow basalts of Koh Terrane in a sequence 130m thick. This unit is succeeded by tuffaceous siltstones, volcanoclastic sandstones and conglomerates for approximately 1150m. Volcanoclastics are then interbedded with black siltstones which provide a paleontological dating based on ammonoid fauna of mid-Triassic (H.J. Campbell, IGNS, New Zealand, written communication, 1990) contemporaneous with the New Zealand Maitai terrane. Black siltstones approximately 1000m thick are overlain by other volcanoclastic sandstones and
conglomerates which continue up section and form a Middle Triassic to Upper Jurassic sedimentary sequence a few thousands meters thick.

North of the Cantaloupai Koh Ophiolite, rocks are affected by the same metamorphic event that affected the Diahot and Pouébo Terrane. TA lawsonite-facies in the volcanoclastic sequence is apparent as well as some fine grained blue amphiboles. The lowest metamorphic grade is reached west of Ponérihouen where stilpnomelane-chlorite metapelites were investigated by Potel et al. (2006) and Potel (2007). The latter also shows an increasing metamorphism towards the southwest, reaching glaucophane isograde close to the contact with the Poya Terrane (Cluzel & Meffre, 2002; Potel, 2007).

**Téremba-Moindou Terrane**

**Age:** Mid-Permian to Late Jurassic

**Lithology:** Calc-alkaline volcanoclastic sedimentary rocks

**Context:** Convergent margin settings; Proximal arc-related terrane

**References:** Paris, 1981; Campbell, 1984; Campbell et al., 1985; Aitchison et al., 1998

The Téremba block is the smallest unit of the ante-Senonian terranes. It occurs only on the south-western coast of New Caledonia where it is largely covered by Quaternary alluvium.

The base of the terrane is composed of calc-alkaline volcanic rocks, which become more terrigenous with calc-alkaline volcanoclastic lithology in the upper section. The eastern part of the terrane is dominated by shallow to deep volcanoclastic sedimentary rocks; volcanic rocks are absent. Further east, a poorly understood fine-grained volcanoclastic sedimentary rock is sometimes described as the Moindou Terrane (Aitchison et al., 1998).

The terrane was affected by a low-grade high-pressure metamorphic event which brought the Téremba province in the pumpellyite-chlorite range (Paris, 1981; Campbell et al., 1985; Cluzel & Meffre, 2002).

Many comparisons have been made between the Téremba terrane and the Murihuku Group in New Zealand. Similarities includes the fauna (Campbell & Grant-Mackie, 1984; Ballance & Campbell, 1993), palynomorphs (de Jersey & Grant-
Mackie, 1989), volcanoclastic sources (Roser & Korschand, 1988) and age (Campbell & Grant-Mackie, 1984; Aitchison et al., 1998).

**Fig. 6.** Reconstruction of Eastern Gondwana margin during Jurassic. Ante-Senonian terranes are represented in their more likely geodynamical position (modified from Cluzel & Meffre, 2002).

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**Boghen Terrane**

**Age:** Lias and older  
**Lithology:** Schist, metagreywacke  
**Thickness:** Several thousands of meters  
**Context:** Derived volcanic-arc rocks  
**References:** Avias & Gonord, 1973; Paris, 1981; Campbell et al., 1985; Cluzel, 1996; Cluzel & Meffre, 2002

This terrane is formed by three main massifs (Boghen, Ouango, Netchaot) and many smaller tectonic units (Karaka, Dothio,…). All boundaries are faulted and no stratigraphic correlations are possible.

The base is formed of 500m of alternating tholeiitic pillow lavas, hyaloclastites and radiolarites. A few breccia horizons and spartic limestone are also present. The upper part of the terrane consists of a thick monotonous schist and greywacke sequence. The schist composition varies between pelitic, carbonaceous and mafic volcanic ‘greenschist-blueschist’ end-members. Psammitic layers contain volcanogenic plagioclase and clasts of angular quartz and pelagic chert. These sediments are interpreted as having been deposited within a deep sea fan and derived from mixed terrigenous and volcanic-arc sources. These sediments were probably
accumulated on the oceanic crust and were subsequently reworked in an accretionary complex.

Boghen terrane seems related to Torlesse rocks in New Zealand, sharing same zircons age. The Torlesse Group is more proximal than Boghen but both show detrital Precambrian zircons from Gondwana. However, their histories diverge during the Jurassic when the Boghen terrane is partially subducted to 20-25km depth into a blueschist facies (Fig. 6) and then exhumed through the Central Chain terrane during late Mesozoic (Cluzel & Meffre, 2002).

2.3.2. High pressure rocks

**Formation à Charbons**

*Age*: Cenomanian to Santonian (Upper Cretaceous)

*Lithology*: Coal, conglomerate, arkose, sandstone, siltstone

*Thickness*: 200 to 1000m

*Context*: Transgressive sedimentary sequence


The “formation à charbons” unit (translation: coal-bearing formation) is the first formation to overlay the eroded Rangitata basement and is regarded as the clear limit to the end of the Carboniferous to Lower Cretaceous accretion process.

The formation is characterized by deltaic deposits from the Australian continent which alternate some mangrove facies, rare limestone and coarse sandstone and volcanics (Black, 1995; Picard, 1995) (Fig. 7). In the Koh area, sedimentation starts above the basal unconformity with 20 to 30 meters of sandy matrix-supported conglomerate where pebble-sized clasts are formed of rocks largely derived from the pre-Cretaceous basement. This conglomerate evolves in quartz-rich sandstone with a thickness of 50 to 180m (Aitchison *et al.*, 1998). Clastic sedimentation is less and less pronounced and the upper part is dominated by organic-rich layers of siltite and argillite (Cluzel *et al.*, 1999). Large variations of thickness and the presence of marginal outcrops with breccias and olistostromes features underline the existence of active faults and a tilted block system.
Zircon dating has been done out on Senonian arkosic sandstone layers of the formation à charbons. Ages show two main populations of 90-140 Ma and 170-220 Ma as well as some rare detrital Precambrian zircons from 670±30 to 1055±40 Ma. Jurassic zircons are similar to those found in Torlesse rocks and could be related to an Australian (New England) orogen source but this remains problematic (Aitchison et al., 1998; Aronson & Tilton, 1971).

Fig. 7. Post-Jurassic sedimentary sequence in Nouméa area with terrigenous, volcanoclastics and hemipelagic rocks (modified from Cluzel et al., 2001).

**Koumac Terrane**

**Age**: Upper Cretaceous to basal Eocene  
**Lithology**: Chert, limestone, marl, flysch  
**Thickness**: >200m  
**Context**: Transgressive deep (meta-)sedimentary sequence  
**References**: Cluzel et al., 1999; Potel et al., 2006

This unit is concordant with the upper part of the Formation à Charbon. It occurs throughout New Caledonia but is especially abundant in the north western part of the island where most of the terrane shows a low-grade high pressure – low temperature metamorphism.
The lower part of this formation starts with sandstones which show an increasing content of carbonate along with stratigraphy. Planktonic foraminifera-bearing marls are the main basal lithology, overlain by 100-170m of fine-grained black chert (phalanites) containing diverse siliceous organisms of Campanian to Late Paleocene age (Bodorkos 1994; Paul, 1994). In many areas, this black chert is interbedded with pelagic micrite which is sometimes the dominating lithology (Fig. 8). However the trend of this terrane is to be more siliceous in the upper part, with age ranging up to middle Eocene (Gonord, 1977; Maurizot & Feigner, 1986). In the northwestern area, Koumac terrane boundaries are not well defined to the east. Using the lawsonite metamorphic isograde as the boundary between Koumac and Diahot terrane, Potel et al. (2006) placed the limit of the Koumac terrane on the edge of Bwaluyu Fault.

The evolution from the Formation à Charbons to these cherts and micrites is clearly seen as a progressive decrease of terrigenous material. This observation is related to the opening of New Caledonian basin and the separation between Lord Howe Rise and Norfolk Ridge (Cluzel et al., 1994). The increasing siliceous content in those rocks represents gradual deepening marine conditions related to post-rift thermal cooling and associated subsidence (Aitchison et al., 1995).

Metamorphism in the Koumac Terrane is discreet as is the case when it occurs in siliceous rocks. However, a prehnite-pumpellyite facies is described in basic igneous rocks (Brothers, 1974; Black 1977). Clay minerals provide more information on the basis of their Kübler and Árkai index and vitrinite reflectivity is of some help in this low-grade metamorphism (Potel et al., 2006).

**Diahot Terrane**

**Age**: Upper Cretaceous to Middle Eocene  
**Lithology**: Blueschists  
**Context**: subducted sedimentary and volcanic rocks  
**Resources**: Cu, Pb, Zn, Ag, Au, Bi, Sn  
**References**: Black & Brothers, 1977; Clarke et al., 1997; Fitzherbert et al., 2003
The Diahot terrane is a metamorphic unit in the northern part of New Caledonia. It lies between the Koumac and Pouébo terranes as the middle part of the HP-LT metamorphic belt.

The Diahot terrane ranges from lawsonite to epidote—omphacite facies and/or ferro-glaucophane—lawsonite to albite—epidote—omphacite zone (Black & Brothers, 1977) (Fig. 9). Rocks forming this terrane are similar to the Koumac unit, with meta-sedimentary and meta-volcanic rocks. This heterogeneity leads to several different metamorphic zones (Clarke et al., 1997; Fitzherbert et al., 2003).

- Basaltic protolith
  - Zone 1 : Lawsonite blueschist (Lawsonite-Omphacite-Glaucophane)
    Fine-grained metabasalts which retained their igneous textures and remains of the basaltic mineralogy (augite, plagioclase).
  - Zone 2 : Epidote blueschist (Lawsonite-Clinozoisite-Garnet)
    The metabasites are coarse-grained and two lithological subfacies are distinguished with a spessartine-bearing assemblage which sometimes sees the disappearance of lawsonite and the formation of almandine in coarser areas.
  - Zone 3 : Epidote-Hornblende blueschist (Clinozoisite-Almandine-Hornblende)
    Even if the protolith seems slightly different, this zone is still referred as a metabasite. Barroisitic hornblende defines the zone and makes, along with almandine and clinozoisite, the main component of these rocks.
  - Zone 4 : Hornblende-paragonite eclogite (Clinozoisite-Almandine-Omphacite)
    This zone is the highest grade in Diahot terrane and is referred as eclogite type-II in Clarke et al. (1997). It is characterized by the reappearance of omphacite-forming layers between hornblende-clinozoisite rich zones.

- Metasedimentary rocks
  - Ferro-glaucophane-Lawsonite
    In the southwest part of Pam peninsula, Fe-glaucophane-albite phengite fine-grained meta-sedimentary rocks are described (Yokohama et al., 1986) and sometimes contain some lawsonite, chlorite and titanite.
  - Glaucophane-Albite-Garnet schist
    These schists, who occur in the central part of Pam peninsula, are carbonaceous and fine-grained.
- Albite-Epidote-Omphacite

Because of the large variety of metasedimentary protoliths, several assemblages occur in that zone, containing phengite, garnet, glaucophane, chloritoid

- Felsic eclogites

- Felsic eclogites were described by Black et al. (1988) in the vicinity of the peak Bouehndep and mapped as meta-rhyolite by Maurizot et al. (1989). These rocks are feldspar-rich variations of Albite-Epidote-Omphacite facies. Jadeite, phengite, chloritoid and chlorite are also present.

According to metabasites assemblage, Pressure-Temperature conditions range from 350°C/8-10kbar for zone 1 to 620°C/17kbar in zone 4.

Pouébo Terrane

**Age:** Upper Cretaceous to Middle Eocene

**Lithology:** Eclogite

**Context:** subducted volcanic rocks

**References:** Clarke et al., 1997; Carson et al., 1999, 2000; Spandler et al., 2005

The Pouébo rocks are a high-pressure metamorphic terrane which lies along the northernmost eastern coast of New Caledonia. It stands as the continuity of Diazhot terrane through higher metamorphic conditions.

The Pouébo terrane is a well known area of New Caledonia showing eclogite-facies for metabasic and metasedimentary rocks. These eclogites occur in a glaucophane matrix made by rehydration of eclogite (Maurizot et al., 1989) (Fig. 9).

- Eclogite Type I

  This metamorphic rock forms the main part of the Pouébo terrane even if most of the time, rehydration modified the mineralogy to garnet glaucophanite. Eclogite contains large grains of garnet enveloped in a granoblastic foliation of barroisitic hornblende, quartz, epidote, phengite and rutile, with or without omphacite, apatite and titanite.

- Eclogite Type II
Also described as the Hornblende-Paragonite eclogite (Zone 4) in Diahot terrane (Fitzherbert et al., 2003).

- **Eclogite Type III**
  
  This type is inferred as metamorphosed chert, occurring in rare meta-quartzite lens of the metabasic eclogite. Quartz is dominant (>70%) with andradite, epidote, glaucophane and titanite.

- **Garnet Glauconiphane**
  
  Garnet glauconiphane represents the hydrated and variably recrystallized equivalent of metabasite eclogite type I. These rocks are almost everywhere dominated by crossite and clinozoisite with garnet. Different sub-types are distinguished according to their content in barroisitic hornblende, omphacite and phengite (Carson et al., 2000).

- **Shear Zone**
  
  Discrete shear zones of 1 to 100m wide cut type I eclogites. They are not related to shallow exhumation shear zones or to the distribution of metamorphic grade in the Pouébo terrane. These shear zones are characterized by a greenschist facies assemblage of crossite, chlorite, clinozoisite, barroisite, actinolite and phengite. Garnet is partially pseudomorphed by albite and chlorite (Clarke et al., 1997; Carson et al., 2000).

Based on relic mineral assemblage, the highest metamorphic conditions reached by Pouébo eclogite are 24 kbar at 600°C. Hydration of Pouébo eclogite in glauconiphane occurs during decompression at P=14 kbar. The peak eclogitic metamorphism took place 44Ma ago (Spandler et al., 2005) and the unroofing and cooling of the terrane lasted until 34Ma (Cluzel et al., 2001).

![Fig. 9. Simplified geological map of metamorphic isograd in Northern New Caledonia. (modified from Black & Brothers, 1977; Spandler et al., 2003).](image-url)
Poya Terrane

**Age**: Senonian (Upper Cretaceous) to Paleogene

**Lithology**: Basalts, hyaloclasites, diverse sediments

**Thickness**: <2000m

**Context**: obducted marginal basin oceanic crust

**Resources**: Mn, Co, Cu, Au


Poya terrane is a regionally extensive unit of New Caledonia which occurs mainly on the western coast between Bourail to Koumac and in several smaller outcrops on the east coast and Nouméa area.

Called “Formation des Basaltes” (Translation: Basalts Formation) by previous authors (Routhier, 1953), the Poya terrane is the upper section of an oceanic crust. Therefore, it is mainly composed of pillow basalts which alternate with bathyal black, red or green argillite and chert. Some massive basalts occur as well along with rare outcrops of dolerite and fine-grained gabbro. Magmatic rocks are also associated with minor oceanic floor mineralization.

The MORB geochemical signature of the Poya tholeiite clearly shows it to be allochthonous feature and the Poya terrane is now confirmed as an obducted oceanic crust. Radiolarian fauna found in the chert shows Campanian to basal Eocene ages. The nearly complete absence of continental sediments would indicate that the Poya terrane was formed in an intra-oceanic environment (Cluzel *et al.*, 2001).

The Poya terrane has been affected to various degrees by low-temperature and low-pressure metamorphism. The resultant paragenese are greenschist facies or lower grade. Another metamorphic event occurred during the Eocene and is evident from now by the presence of infra-subduction blueschist facies (crossite-glaucophane) in the northeast outcrops of the Poya basalts.

Numerous dykes cross the Poya terrane but all of them are younger than the terrane itself, crossing also the ultramafic nappe. Ca-rich boninite dykes have been studied and revealed to be of a Miocene age and not directly related to the subduction events (Black *et al.*, 1994; Eissen *et al.*, 1998). However in some places (Pinjen and
Foué peninsula), older alkaline basalts have been found and are interpreted as remnants of an oceanic island formed on the Poya oceanic floor (Fig. 10).

Due to complex folding, faulting and disruption, the Poya terrane seems to be emplaced as a duplex of tectonic slices pinched beneath the ultramafic terrane. The asymmetric folding observed was probably formed during or immediately after eclogite exhumation.

![Fig. 10. A geodynamic model for the evolution of the Eocene accretion/subduction complex of New Caledonia (modified from Cluzel et al., 2001).](image)
The ultramafic nappe is the main feature of New Caledonia geology. It covers 8000km² of Grande Terre but is thought to have once overlain the whole island (Dupuy et al., 1981a)(Fig. 10). The main outcrops include several massifs on the west coast, some small nappes in the central chain area and the ‘Grand Massif du Sud’ which dominates the whole southern part of the island. Peridotites also occur on islands of the Norfolk Ridge in altered outcrops (Belep Is., Pine Is., Ouen Is.).

Most of the ophiolitic massifs have similar properties. The main exception is the Tiébaghi massif which shows some lherzolite outcrops and important chromitite bodies. The large Southern massif is also much more diverse than other nappes and show upper terms of the ultramafic series whereas other massifs are only part of the depleted mantle. However, only 20% of the southern massif is above the paleo-Moho (Dupuy et al., 1981a) and the absence of upper and middle oceanic crust is probably due to deep erosion or tectonic detachment (Cluzel et al., 2001)(Fig. 11). In addition to this, most of the rocks from the ultramafic terrane are deeply serpentinized and lateritization affect important surface of the nappe, making fresh outcrops relatively rare compared to the extension of this terrane.

From bottom to top, the ultramafic sequence in the southern massif is mainly divided in harzburgitic mantle, dunitic transition zone and gabbroic crustal rocks (Fig. 11). This ultramafic nappe lies on Poya basalts and occasionally on the Central Chain terrane. Rare high-Ca boninites are also described as sandwiched within a fault zone between Poya and the ultramafic nappe. These last rocks remain enigmatic and might represent manifestations of near-trench fore-arc volcanism (Aitchison et al., 1995).
The lower part is magnesian harzburgite (Mg# = 0.93) composed of forsterite and enstatite and minor chromian spinel. Sulphides and alloys (pentlandite, heazlewoodite, awaruite, copper) are also present in this lower zone, associated with orthopyroxene rich layers. The main variations in the harzburgite zone are a decrease of the Mg-number from 0.93 at the base to 0.90 in the transition zone, a decrease of nickel content in silicates and an increase of MgO, Al₂O₃ and TiO₂ in spinel phase along with stratigraphy. Foliation is clearly visible, underlined by porphyroblastic orthopyroxene and layering is sometimes well developed with centimetric segregated olivine and orthopyroxene layers (Guillon et al., 1974; Guillon & Trescases, 1976; Trescases & Guillon, 1977).

The dunite zone is discordant with regard to the harzburgite. The contact is progressive over a few tens of meters with the disappearance of orthopyroxene. These dunitic bodies have complex relationship with harzburgite with many cross-cutting apophyses. The main minerals are forsterite and chromian spinel and rare plagioclase (melatroctolite) in dunite bodies of Prony area.
The transition zone between dunite and gabbro is gradual and shows the successive appearance of orthopyroxene, calcic plagioclase (An75-90) and clinopyroxene in the cumulative dunite. This leads to the formation of numerous rock types such as orthopyroxene-dunite and harzburgite, troctolite, wehrlite and noritic and anorthositic rocks. These rocks are emplaced with a cumulative structure and are reminiscent of stratiform complexes. This fractionated crystallization which leads to the formation of the oceanic basaltic crust, has a strong geochemical evolution with a decrease of iron, magnesium and nickel and enrichment in aluminium, calcium and titanium (Guillon & Trescases, 1976).

Gabbros crop out at the top of the sequence, just above the dunite and transition zone. Mineralogy is mainly calcic plagioclase, chromian diopside, pigeonite and hypersthene but alteration is frequent and uralitisation and saussuritisation form tremolite, nephrite, epidote, smaragdite, etc. Layering is still visible, mainly as alternation of pyroxenitic and anorthositic decimetric layers. The general composition is gabbro-noritic.

Many dikes occur through the ultramafic terrane. These are related to different processes and show different compositions and geochemical affinities.

Dunite dykes and pods can be concordant or discordant. Their formation is related to the isothermal and peritectical reaction which leads to the consumption of
orthopyroxene out of harzburgite and forms dunite channels (Kelemen, 1990). This reaction also helps in the precipitation of chromite and chromitite bodies in small magmatic chambers.

Concordant pyroxenitic dykes are related to segregation processes in harzburgite giving alternation between dunite and orthopyroxenite. Discordant dikes are related to a silica enrichment of the mantle rocks in confined zone. Some of these dikes could be related to a pre-obduction subduction process and show a modal composition of orthopyroxene, clinopyroxene and amphiboles.

Tholeiitic basaltic dikes occur in the peridotite of the gabbro. These feeding dikes have an intermediate olivine fractionation which contrasts with the gabbro itself which show limited fractionation. The theoretical source of these dykes is the anatexis of pyrolite (strongly depleted mantle) to partial melting ratio of 11 to 13% (Dupuy et al., 1981a).

In the higher part of the mantle section, felsic dykes and small intrusions are present with composition ranging from diorite to granite. Geochemical features, age and field relationship do not fit with plagiogranites described in other ophiolites. However, by comparison to the post-obduction granitoids, these rocks do not show a strong contact metamorphism with the ultramafic rocks. Their age based on zircons is around 50Ma (Prinzhofer et al., 1980; Cluzel et al., 2006).

The whole ultramafic sequence is 4000m thick (Harzburgite: 3000m; Dunite: 500m; Transition zone: ±100m; Gabbro: >300m) and is still attached in places, to the Loyalty basin seafloor (Paris, 1981; Prinzhofer, 1981). By comparison with other ophiolites and oceanic crust, it seems that 8km of rocks are missing over the gabbros (Prinzhofer et al., 1980), removed by tectonic processes or erosion. High temperature stretching lineation and wrench shear zones visible in peridotites are interpreted as transform faults (Prinzhofer et al., 1980) and provide evidence that the obduction which occurred in the Eocene was a north over south overthrusting direction as a result of the synchronous opening of the Loyalty basin (Collot et al., 1987).

The age of the ultramafic and events which affected these rocks are difficult to determine. On the basis of K-Ar geochronology, crosscutting dikes displays two age groups of 77-100Ma and 48Ma (Prinzhofer, 1981). This would mean that the oceanic crust was probably formed at the beginning of the Late Cretaceous and the 50Ma event, which is also dated on zircon (Aitchison et al., 1995; Cluzel et al., 2006), is
probably related to a pre-obduction subduction process which has also formed the blueschists and eclogite terranes of Diahot and Pouébo.

2.3.4. Post obduction rocks

Post-obduction granitoids

Age: Late Oligocene

Lithology: Granodiorite, adamellite

Context: subduction related magmatism and slab break-off

Resources: W, Mo, Au, Sb

References: Cluzel et al., 2005

These intrusive rocks are observed in two areas, Koum-Borindi on the east coast, just south of Thio and St Louis area near Nouméa. Host rocks are peridotites from the ultramafic terrane.

The St Louis intrusion is a relatively homogeneous hornblende-biotite granodiorite with numerous subvolcanic dykes and comagmatic enclaves. The typical composition is plagioclase (40-50%), K-feldspar, quartz, biotite and hornblende with pyroxene relics. Accessories are apatite, zircon, rutile, magnetite and ilmenite which crystallized early and epidote, muscovite and chlorite formed during postmagmatic alteration. Dikes are mainly microgranodiorite intruded in the hot host rock whereas enclaves are darker hornblende-rich fine-grained rocks (Cluzel et al., 2005). The St Louis stage which resulted from the obduction event (32Ma) related to this intrusion (27Ma), is interpreted as the result of the new subduction zone forming along the west coast in response of the opening of the North Loyalty basin (Cluzel et al., 1999, 2002; Paquette & Cluzel, 2007).

The Koum-Borindi intrusive complex is more heterogeneous and differentiated. Two main facies are present: a leucocratic tonalite (plagioclase, K-feldspar, quartz and biotite) mainly found in dykes and intrusive stocks and an amphibole-biotite-bearing granodiorite apparently restricted to the main Koum massif. The tonalite facies varies in quartz (15-40%), plagioclase and K-feldspar where plagioclase is zoned and K-feldspar show perthite and/or granophyre subsolidus textures. In the granodiorite, amphibole frequently displays Mg-rich biotite (Mg#≈0.59) pseudomorphs. Corroded quartz grains also occur in the subvolcanic
dykes. These observations of chemical instability are probably created by intraplutonic magma mixing processes (Cluzel et al., 2005). The Koum-Borindi Stage (24Ma) is related to the shrinking of the New Caledonia basin, the break-off of the older slab and the exhumation of the HP/LT terrane complex (Cluzel et al., 2002; Paquette & Cluzel, 2007).

**Post-obduction Fluvial and Lacustral Formations**

**Age**: Late Oligocene to Lower Miocene  
**Lithology**: Conglomerate, breccia to sandstone, calcarenite  
**Context**: Fluvial erosion of ultramafic terrane  
**Resources**: Ni, Co, Mn, Au, PGE, Limestone  

After the obduction of the oceanic crust, erosion affected the ultramafic terrane and produced some onshore sedimentary deposits which have not received much attention until recently. Three phases are known and called Goa N’Doro formation, Népoui formation and unspecified lateritic planations which have formed up to the present day.

The Goa N’Doro Formation is a Miocene fluvial complex of sandstone overlain by conglomerate. It occurs mainly as a cover on the ultramafic terrane and on some parts of the Koumac and Poya terrane on the west coast (Orloff & Gonord, 1968; Orloff, 1968; Carroué, 1972; Guillon & Trescases, 1975; Trescases, 1975; Paris, 1981; Vogt et al., 1984).

The lower sequence (Goa N’Doro s.s.) comprises conglomerates and breccias of a reworked bedrock and material derived from weathering profiles. It is then overlain by microconglomerates and sandstones passing into siltstones with traces of paleosols, indicative of a flood plain environment. The younger conglomeratic unit (Goa N’Doro s.l.) is almost exclusively made up of peridotite pebbles, rests on a channelling erosion surface truncating both the Goa N’Doro s.s. and peridotite substrate. This formation has a strong lateral variability related to the geomorphic environment but most of the stepped lateritic surfaces from 1600 to 400m elevation are recognized as part of these rocks (Chevillotte, 2005; Chardon & Chevillotte, 2006)(Fig. 13).
Rocks described as the Népoui Formation (Coudray, 1976) are a deltaic sequence of Aquitanian to Langhian age showing a gradation from prominent coarse conglomeratic fluvial deposits to biocalcarenitic deposits (Coudray, 1976; Paris, 1981). Further studies and the description of other post-obduction fluvial deposits seem to indicate that the upper conglomerate of the Goa N’Doro Fm. is correlated to the early Miocene Népoui Fm. (Chardon & Chevillotte, 2006).

Fig. 13. Stratigraphical columns of Goa N’Doro and Népoui formations with correlation lines. Elevation thicknesses are in meters (modified from Chardon & Chevillotte, 2006).
The complex assemblage of these sedimentary bodies is mainly due to an equilibration profile with a fluctuating sea level creating erosional unconformities. Two regional river aggradation cycles are distinguished, each of which is preceded by a deep river incision phase. Moreover, Neogene extension tectonics have deeply affected the deposition of these rocks with the disruption and collapse of the aggraded sedimentary sequences (Chardon & Chevillotte, 2006).

**Quaternary Alluvial and Recifal deposits**

*Age*: Quaternary  
*Lithology*: Sand, Silt, Limestone  
*Context*: Recent deposits  
*Resources*: Limestone  
*References*: Lagabrielle *et al.*, 2005

The Neogene and Quaternary epochs are characterized by the erosion of Grande Terre and the development of the lagoon. Due to extensional tectonic movements, fault blocks have moved on both side of the island. In consequence, some coral reefs have been uplifted on the east coast tilted blocks and drowned valleys and sediment-filled graben occur beneath the lagoon floor of the west coast (Lagabrielle *et al.*, 2005).
3.0. Mining in New Caledonia

Interest in the mineral deposits of New Caledonia started in 1864 with the discovery of garnierite (Dana, 1873) by the French geologist and explorer, Jules Garnier. Industrial mining started in 1876 in New Caledonia and has not stopped since. At the present time, New Caledonia is the world’s second ranked producer of ferronickel just after Japan and the fourth ranked source of nickel ore (laterite and sulphides) after Russia, Canada and Australia (Mining Journal Ltd., 2003; Jorgenson et al., 2004; Kuck, 2006, 2007) (Fig. 14).

This industry has a major impact on the New Caledonian economy and politics, accounting for more than 12% of the gross domestic product (GDP), employing more than 3200 workers and contributing an estimated 90% of foreign exchange earnings in 2007 (Lyday, 2003, Australian Trade Commission, 2007). Politically, regarding to the Kanak indigenous community and relationships with France, the nickel industry has strong interactions and could play a definitive part in the forthcoming independence referendum.

The mineral industry of New Caledonia is dominated by the mining of nickeliferous laterite-saprolite-limonite-garnierite and the production of ferronickel and nickel-cobalt matte of various commercial grades. 7Mt of nickel ore are extracted each year (4.5Mt of garnierite, 2.6Mt of laterite). 4Mt are exported to Asia and
Australia and the remaining 3Mt are processed locally by Société Le Nickel (SLN) (Australian Trade Commission, 2007) (Fig. 15).

![Fig. 15. Nickel mineral production of New Caledonia from 1900 to 2004 (ISEE, 2007).](image)

Since 2000, the New Caledonia territory has been free to make its own decision concerning hydrocarbon, nickel, cobalt and chromium resources. The three provinces have their own mining policy (mining, environment, work) and two groups are working to maintain coherency between institutions and legal procedures (Fig. 16).

**Conseil des Mines (CM)**: Mining Council is where the French state, New Caledonia and the provinces try to reach an accord concerning mining issues. Council members are executive of government and provinces councils.

**Comité Consultatif des Mines (CCM)** (Consultative Mining Council) has State representatives, New Caledonian representatives, congress, senate, professional and syndical organizations and environment protection associations. This group is consulted for any mining regulations that are proposed by the Congress or the New Caledonian Assembly.

**Service de Géologie et des Mines (Geological Survey)**: The main objective of this institution is to regulate and facilitate the mining activity in a variety of ways. This service is a subdivision of DIMENC and works in parallel with the French Geological Survey (BRGM).
Direction de l'Industrie, des Mines et de l'Énergie de Nouvelle Calédonie (DIMENC) has as its objective to control and promote the New Caledonian industry abroad.

![Application procedure for acceptance of mining issues.](image)

3.1. Main past and current extracted products

**Nickel**

**Geological Control**: Ultramafic Terrane alteration

**Rocks**: Laterite, saprolite, limonite, garnierite

**Minerals**: Ni-bearing phyllosilicates (nontronite, népouite, pimelite, willemseit, pecoraite), uvarovite, pentlandite, heazlewoodite, violarite, millerite, nickel, awaruite, orcelite, vaesite, Ni-bearing forsterite

**Companies**: Société Le Nickel; Société Minière du Sud Pacifique; Société des Mines de la Tontouta; Société Minière Georges Montagnat; JS Berton Mines; *Inco*; Falconbridge

**Quantity**: 7Mt of Nickel Ore

40% are processed in New Caledonia with 75000t/yr of ferronickel (80%) and nickel matte (20%).

**Geology**

Nickel ores are formed by the alteration of the peridotite massif. This geological process is mainly based on the mobility of silicon and magnesium compared to nickel and cobalt during leaching of the serpentinized peridotite.

The primary mineral in this process is fosterite \([\text{Mg,Fe}]\text{SiO}_4\). This magnesian olivine which is also composed of small amounts of iron, contains approximately 0.3% of nickel and 0.01% of cobalt. Under wet tropical conditions, this olivine is not stable and decomposes into clays and other phyllosilicates (serpentines, chlorites) which cover most of ultramafic massifs. During these hydration reactions,
some silica and magnesium are leached by the water and the newly formed minerals are enriched in non-mobile element such as nickel.

The development of a Ni-enriched laterite profile needs the right conditions. The climate must be warm and wet, such as tropical and equatorial areas covered by rainforest or humid savannah. The other main factors controlling laterite formation are well developed topography and drainage to avoid stagnant water and to provide an efficient process to remove soluble elements. Additionally, the development of important silicate laterite is promoted by tectonic uplift and the composition and structure of the parent rock (Elias, 2002). All these conditions occur together in New Caledonia, facilitating the formation of extensive nickel-bearing laterite.

The first facies to appear during laterization is a nickel-bearing limonitic layer overlying the serpentinized peridotite. As the alteration continues, a part of the nickel contained in this zone, is transported further down the weathering profile and reacts with silica in solution to form the nickel-rich saprolite. During this same process, the iron crust forms at the surface by a complete leaching of all the major elements except iron. In some places, the saprolite is so enriched that green garnieritic pockets and veins are found. Garnierite is a mix of true nickel silicates and has a very high grade in nickel, from 10 to 30% Ni (Fig. 17). However, since its intense exploitation in the beginning of the last century, this replacive rock has become rare.

![Fig. 17. Laterite accumulation processes and nickel enrichment (inspired from McFarlane, 1976).](image)
The enrichment in nickel of the lower horizons of the lateritic profile is confirmed until the alteration front of the basement reaches the groundwater table level. All elements are then dissolved in the water and no further precipitation of metals occurs.

**Mining**

Mining activities are confined to lateritic deposits overlying ultramafic massifs. 17 mines are currently active and the Goro Project should be starting in a few months (Fig. 18).

At present, there are 6 large companies involved in New Caledonian Mining industry

- Société Le Nickel (SLN) owned by Eramet and processing 45% of the ore to Doniambo
- Société Minière du Sud Pacifique S.A. (SMSP) owned by the Northern Province and accounts for 70% of the export.
- Société des Mines de Tontouta (SMT) owned by Groupe Ballande
- Société Minière Georges Montagnat (privately owned)
- New Inco (merging of Inco and Falconbridge)
- Queensland Nickel Inc. owned by BHP Billiton but not carrying out any mining operations yet.

![Fig. 18. Distribution of active and inactive nickel mine in Grande Terre of New Caledonia.](image-url)
Société Le Nickel (SLN)

SLN is mining limonite-saprolite nickel ore from the following open-cut operations: Koumac, Kouaoua, Népoui-Kopéto, Thio and Tiébaghi. SLN is a consortium of the Eramet Group of France (60%), Société Territoriale Calédonienne de Participation Industrielle (30%) and Nisshin Steel Co. of Japan (10%) (Resource Information Unit, 2004).

- Etoile du Nord (Koumac) produces 18% of the total SLN production. Limonite is also exploited and exported to Australia. This site is operated by Société Minière Georges Montagnat for SLN.

- Kouaoua is mined by SLN for a saprolitic ore which averaged 2 to 3% nickel. The ore is conveyed to coastal stockpiles by a single 11km long conveyor. It is loaded onto carriers at the offshore terminal at a rate of 1200 t/h, the saprolite is then shipped to the Doniambo smelter. The main site in Kouaoua, called the Méa deposit, has been exploited since 1977 with an output of 1Mt/yr of sorted ore (Resource Information Unit, 2004; Mbendi, 2005).

- Népoui-Kopéto Mine reopened in 1994 after more than a decade of closure. The orebody is a saprolite extracted at a rate of 4Mt/yr then sent to a sorting plant where the ore is screened, scrubbed and sized onsite and then hydraulically transported via a 7km long pipeline to the washing plant at the foot of Népoui massif. The washed ore is stored, blended and shipped to the Doniambo smelter which has an input of 830 kt/yr (Resource Information unit, 2004).

- Thio is one of the first mines opened in New Caledonia. Mining started in 1880 and by 1999, the mine had produced 900000 tons of nickel from 40Mt of saprolite. Several sites were operated simultaneously in the past but only Camp des Sapins and the Plateau des Mines are in operation now. Plateau des Mines itself has produced 25Mt of ore assaying 3% nickel, making it one of the largest nickel deposit in the world (Mbendi, 2005). Ore is trucked and then transported by a 7.5km long cable way to coastal piles. The output is 750 kt/yr with a portion exported to Japan and the remainder processed at Doniambo.

- Tiébaghi was first mined for chromium-cobalt ores and nickel enrichments have been discovered relatively recently (around 1970) (Mbendi, 2005). Tiébaghi was recently acquired by SLN and proved difficult to mine as the iron crust was too hard for direct extraction and explosives had to be used. Tiébaghi Mine opens directly onto the Port of Paagoumene. First ore deliveries from Tiébaghi mine to the Doniambo
smelter began in September 1998. From 2003 to 2006, plans to extend the Tiébaghi mine were in place and production was brought from 250 kt/yr in 2003 to 1Mt/yr in 2006 (Resource Information Unit, 2004, Australian Trade Commission, 2007).

**JC Berton Mines (JCBM)**

Bienvenue opencut mine is owned by JCBM. It is a small scale mining operation of high-grade saprolitic nickel ore (3.15% Ni) which has been carried out intermittently for more than 70 years. In 1990, JCBM began mining limonite ore for exportation to BHP Billiton Ltd.’s Yabulu nickel refinery in Townsville, Australia. Ore reserves of this deposit should allow the mine to maintain deliveries of 450 kt/yr wet ore for the next several years (Resource Information Unit, 2004).

**Société Minière du sud Pacifique S.A. (SMSP)**

This company is mining small size deposits of saprolitic nickel ore at Boakaine, Kouaoua, Nakéty, Poum, Poya and Ouaco mining centers.

**Société des Mines de la Tontouta (SMT)**

Mining operations are underway at Karembe, Monéo and Nakéty mining centers. Gemini S.A. is operating the Nakéty-Bogota Mine for SMT. All the outputs from these deposits are exported to Townsville smelter in Queensland.

**Goro Nickel Project**

Inco discovered the Goro deposit in 1969 and acquired the mining rights in 1992. It is an extensive low-grade laterite deposit with the potential to have one of the lowest cost sources of nickel in the world. In 2001, Inco began discussions with a number of companies. The French Geological Survey, Bureau de Recherches Géologiques et Minières (BRGM) obtained a 15% interest (Lyday, 2003).

In May 2005, the shareholding were revised and Goro Nickel is now owned by Inco (69%), Sumic Netherlands Nickel (a joint venture of Sumitomo Metal Mining Co. Ltd. and Mitsui & Co.) (21%) and Société de Participation Minière du Sud Calédonien which are the provincial authorities of New Caledonia, holds 10% (Fig. 19).
The main features of the Goro deposit are its size and its consistent geometry and mineralogy. Moreover, its localization in a humid area, fractured and drained by underground water, has created basin morphologies with high metal contents. The total thickness of the alteration sequence of the Goro Plateau is important and can reach 60 meters with an average of 40m (Fig. 20). The laterite exploited has a high content of free water, (up to 50%) and nickel grades higher than Australian deposits but lower than New Caledonian saprolite. It is mainly for this last reason that the Goro deposit wasn’t previously exploited.

Hydrometallurgical process (Fig. 22) developed by Inco is likely to make this deposit highly profitable. The mine which should open in late 2007, is designed to produce 60000 t/yr of nickel and 5000 t/yr of cobalt at full capacity. In a few years, Goro Nickel could become the world’s biggest producer of low-cost nickel and the
lifespan of the Goro Plateau Mine is estimated to be at least 30 years. 57Mt of proven probable reserves makes it the best undeveloped laterite orebody (Mbendi, 2005) but it is likely that more than 120Mt of ore is present and exploitable with an average nickel content of 1.48% and cobalt of 0.11% (Goro Nickel 2006).

**Koniambo Project**

The Koniambo project is the other major new project. It is being undertaken by Inco-Falconbridge in a joint venture with SMSP. 49% of the project will be owned by Falconbridge and 51% by Société Minière du Sud Pacifique (Falconbridge, 2006; Australian Trade Commission, 2007). A feasibility study for the nickel laterite has been completed. Nickel is contained in both saprolite and limonite with good grades. The saprolite orebody contains 142Mt of measured and indicated resources grading 2.12% nickel and 156Mt of inferred resources grading 2.2% Ni. The expected annual production would be 60000 tons of nickel as ferronickel.

Nickel will be extracted using a new smelting process to produce ferronickel from the saprolite. In a future extension, 100Mt of nickeliferous limonite with 1.6% Ni could be exploited by hydrometallurgical processes (Falconbridge, 2006; Australian Trade Commission, 2007) (Fig. 22).

The capital cost of Koniambo project was US$2.2 billion in September 2004 and the earliest possible start-up is expected in 2009 (Falconbridge, 2006).
Most of the ore coming from the SLN mines of New Caledonia is transported to the Doniambo smelter located on the harbour of Nouméa. The current output of this smelter is 75000 metric tons per year due to an extension in June 2004 which increased the production by 13000 t/yr. 3Mt of nickel ore are processed every year by the smelter to produce 80% of ferronickel with an average nickel content of 26 to 32% and the remaining 20% are nickel-cobalt matte carrying 75% nickel (Fig. 22). Ferronickel is used directly to make stainless steel whereas the matte is shipped to Eramet’s Le Havre – Sandouville refinery in France. The nickel-cobalt matte is converted into high-purity nickel metal and salts of nickel and cobalt (Eramet Group, 2005).

As a part of the Koniambo project, Falconbridge Ltd. and its joint venture partners are planning to build a ferronickel smelter at Koniambo. This smelter would have a capacity of 54000 t/yr nickel and ferronickel and would use lateritic ores from the Koniambo massif as a feedstock. Commissioning of the Koniambo smelter is scheduled for 2009 or 2010 (Jorgenson et al., 2004).

Because of the low-grade laterite exploited by the Goro Project, pyrometallurgical processes are not suitable. A hydrometallurgical plant with Pressure Acid Leaching (PAL) process is constructed in Prony area and should start progressively in 2008 (Goro Nickel, 2006).

Fig. 22. Main processes for the extraction of nickel out of lateritic rocks.
**Cobalt**

*Location*: Ultramafic Terrane alteration, Poya  
*Rocks*: Laterite, pods, chromitite  
*Minerals*: Co-bearing phyllosilicates, asbolane, *pentlandite*  
*Companies*: Inco; Société Le Nickel  
*Quantity*: by-product of Nickel ore; 300 t/yr in nickel matte mainly  

**Geology**

Cobalt is enriched in a similar way to nickel. Cobalt is released by alteration of forsterite in the laterite but geochemical and crystallochemical conditions make it less enriched than nickel in the saprolite and the transition zone where those metals occur in phyllosilicates. However, in the lower part of the laterite, just above the transition zone, precipitations of manganese oxides retain large quantities of cobalt in dark blue-grey pods of asbolane.  

**Mining**

Asbolane has been extracted since 1890 by underground mining. New Caledonia was the only producer of cobalt in the world until 1909 when Canadian mines opened. Asbolane extraction operations slowly declined in the first half of the 20th century, but cobalt was still produced as a by-product of garnierite and saprolite and follow nickel in the matte during pyrometallurgy processing. At Goro, however, cobalt will be extracted directly out of the laterite and separated from nickel during hydrometallurgical processes. The production of this mine should be around 5000 t/yr of cobalt as a cobalt carbonate.  

**Chromium**

*Location*: Ultramafic Terrane, transition zone  
*Rocks*: Chromitite, dunito-chromitite, laterite  
*Minerals*: Magnesiochromite, chromite, *Cr-bearing spinel*  
*Quantity*: 3.85Mt of chromite  

**Geology**

Chromite-bearing pods and layers are common in the ultramafics. They are especially related with the dunites of the transition zone. Those bodies are interpreted as accumulative features of basaltic conduits feeding the main magma chamber in an ocean ridge system (Fig. 24). The two main features which play a major role in
chromite concentration are an active upward magma flow in narrow dykes and an active convection inside the cavities (Lago et al., 1981)(Fig. 23).

These two processes concentrate chromite in elongated pods or layers depending where the cumulating reaction takes place. Chromitite bodies are surrounded by a dunitic rim, the result of a reaction between the harzburgite and the olivine-saturated melt which migrated through these mantle rocks. As harzburgite is a pyroxene-bearing rocks, these are assimilated in the basaltic melt, following the peritectical and isothermal reaction: \( \text{Opx} + \text{Liq} \leftrightarrow \text{Olv} + \text{SiO}_2(\text{liq}) \) which form dunite and a more silicic melt (Kelemen, 1990).

The chromite deposits of the Tiébaghi area are different from the rest of New Caledonia. In the southern massif, chromite pods are small and scattered around the transition zone whereas in the Tiébaghi area, these rocks show large scale alternations of dunite, chromitite, harzburgites and lherzolites. This is interpreted as the result of strong fractional crystallization processes forming bodies analogous to large layered igneous complexes (Moutte, 1979).

![Fig. 23. Model of chromitite pods formation in a cavity along magma dykes in ophiolites (modified from Lago et al., 1981)](image1)

![Fig. 24. Model of the genesis and evolution of chromitite deposits morphology in ophiolites (modified from Lago et al., 1981)](image2)
Above the transition zone, cumulus chromitite occurs in layers and dykes which were only locally exploited (Fig. 24). This chromite is poorer in chromium oxide (40 wt.%) and richer in iron whereas Tiébaghi chromite can reach 63.5 wt.% Cr₂O₃. The Southern massif podiform chromite has a lower chromium content with a slight Cr-Al substitution (Augé, 1988; Augé & Maurizot, 1995).

**Mining**

Chromitite bodies were first mined in 1878 at Lucky Hill near Plum and subsequently at Mont Dore and Nakéty. The Tiébaghi deposit was discovered in 1877 and mining started in 1902, first as an opencut (until 1926) and then as an underground mining operation until 1963. Chromite exploitation restarted in 1980 and ended in 1990 when the deposit was mined out. 3.3 Mt of massive rich-chromite (54 wt.% of Cr₂O₃) has been extracted at Tiébaghi. Smaller deposits are known in the Tiébaghi massif such as at Chagrin, Fantoche, Vieille Montagne and Bellacoscia (Moutte, 1979)(Fig. 25).

In the southern massif, many small chromitite bodies have been worked such as at Marais Kiki, Georges Pile, Alice-Louise and La Madeleine. In the Pirogues River valley, chromian laterite were studied by the BRGM between 1962 and 1975. These studies have shown that some of the chromium deposits are as big as Tiébaghi but the chromium contents are lower and the deposits are not economically viable (CroixduSud.info, 2007).

**Fig. 25. Important historic mining centres of Grande Terre.**
3.2. Minor deposits

Iron

**Location**: Ultramafic Terrane alteration; Dunite-transition zone

**Rocks**: Laterite, pisolithic horizon, ferricrete, magnetitite

**Minerals**: Hematite, goethite, alumomaghemite, *magnetite*, *valleriite*, *chromite*, *awaruite*, *pyrite*, *chalcopyrite*, *pentlandite*, *bornite*, *cubanite*, *pyrrhotite*, *mackinawite*

**Companies**: Société Le Nickel; *Inco*

**Quantity**: 75000 t/yr of ferronickel

**Geology**

High iron contents mainly occur as iron crust on the top of lateritic profiles (Figs. 17, 20). The iron crusts form a residual rock by the leaching out of other elements. Phases which are left are hematite, goethite and maghemite. In a few places, magnetitite bodies have also been described from dunites of the southern massif (Guillon & Trescases, 1976) but economic exploitation is not feasible because of their small size.

**Mining**

Iron is a major impurity in nickel ores and nickel products. Although it is strongly reduced by various metallurgical processes, the final product remains ferronickel and iron forms nearly three quarter of the alloy. The use of nickel by the steel industry is however fully compatible with high iron contents.

Iron as a metal was only exploited out of the lateritic crust from 1938 to 1941 in Goro and the entire production (450 kilotons of ore) was exported to Japan. From 1955 to 1960, mining was undertaken at Prony Bay and the output (3 Mt) was sent to BHP smelters in Australia. The New Caledonia iron ores are of little interest to the mining industry.

Manganese

**Location**: Ultramafic Terrane alteration, Poya

**Rocks**: Laterite, pods

**Minerals**: Asbolane, manganite

**Quantity**: 60000 tons
Mining

Small pods of manganese were exploited from the Poya basalts between 1918 and 1922 and from 1949 to 1953. A few thousands tonnes have been produced mainly from Bourail and Koumac areas (Gineste, 2007) (Fig. 25). Manganese is an important impurity in nickel and cobalt ores. The main cobalt bearing phase, asbolane, is a wad-like mineral species which contains up to 45% manganese and a few percents of cobalt and nickel. This manganese is efficiently extracted during pyro- and hydrometallurgical processes.

Copper-Zinc-Lead-Silver

Location: Diahot, Ultramafic Terrane
Rocks: Mica schists, magnetitite
Minerals: Chalcopyrite, chalcocite, covellite, digenite, bornite, cubanite, copper, tenorite, cuprite, valleriite, azurite, malachite, chrysocolla, chalcantite
Galena, cerusite, anglesite, pyromorphite, wulfenite, aikinite
Sphalerite, Smithsonite
Silver, argentite, jalpaite
Companies: Caledonian Pacific, Base Metals Exploration
Quantity: 7000 tons of Cu extracted from 1872 to 1949
Geology

Copper mineralization mainly occurs in Diahot Terrane as stratiform sulphide deposits (Fig. 25). These deposits are restricted to defined stratigraphical horizons of diahot terrane. However, they didn’t reach the same metamorphic conditions and are therefore hosted in different grade rock. The sulphide ores are usually well laminated with compositional banding of sulphides, show relict of sedimentary textures and occur as layers and lenses which are conformable with the host rock. Two kinds of deposits are distinguished with copper-enriched ore with small amounts of Pb, Zn (Balade, Murat, Ao, Pilou) and lead-zinc deposits with minor cupriferous minerals (Mérétrice, Fern-hill) (Fig. 26). In Mérétrice Mine, a secondary enrichment in silver bearing minerals is observed but silver is also present in solution in galena and tetraedrite in the main ore. Some gold and tin enrichment are also noticed in this mine (Gineste, 2007). In Ao mine, strong enrichments in bismuth (bismuthinite, aikinite) also occur in the copper ore (Briggs et al., 1977).
The host rock protolith is mainly acidic rhyolitic tuff. However, black carbonaceous phyllites seem necessary for the formation of the deposits. These latter rocks are rich in pyrite and show sulphide concentrations in layers of a few centimetres thick. In Balade Mine, an iron-rich non-sulphide metasediments zone is described and show many similarities with kuroko-type deposits. However, the high pressure metamorphism of the Diahot terrane makes assumptions difficult to make regarding the metallogeny of these deposits. The presence of black shales relates these more to Rio Tinto-type deposits whereas some features are more sedimentary-exhalative (Briggs et al., 1977).

Fig. 26. Map of the Diahot region with the location of Cu-Pb-Zn mines with respect to regional structures and the progressive metamorphic sequence modified from Briggs et al., 1977)

Mining

Copper was found in the northeastern part of Grande Terre, in Diahot valley, near Ouégoa in 1872 and many small mines opened such as Balade, Bruat and Murat and later Pilou-Nemou, Méretrice and Ao mine, famous for its azurite deposit.

Copper exploitation started in 1873. Production from Balade, Bruat, Pilou-Nemou and Méretrice was sent to smelting plants in Pam, Dilah and Tao. The copper-lead-silver mining activity ended in 1931 when the Société Minière du Diahot was declared bankrupt. In 1949, some mining activities were resumed to exploit 9000
tonnes of ore still available but only 1750 additional tonnes have been extracted. The metal grade of Méretrice mine is 15-20% Pb and 25-30% Zn with important amounts of copper and silver (100g/t) in the sulphurised zone. In the oxidation zone, the ore is richer in lead (25-30%) and lower in copper (15-25%) with 400 g/t of silver and up to 3.7g/t of gold (Briggs et al., 1977; Gineste, 2007). Other deposits are richer in copper and iron sulphides (Briggs et al., 1977).

At the end of the nineties, an intensive program of ground geophysics was started for the Méretrice Zinc Project. The purpose of survey was to identify drilling targets along a 4km belt of potential stratabound, sediment hosted massive sulphide Cu-Zn-Pb-Ag mineralisation (Mining Exploration News, 1997). Intense anomalies have been detected as bodies of 4500 meters long and 1500 meters wide near the Méretrice Mine (Mining Exploration News, 1998). According to BRGM studies, 25000 to 30000 tonnes of ore (25%Zn, 15%Pb) is still available.

3.3. Subeconomic enrichments

**Gold**

**Location**: Pouébo, Diahot, Poya, Ultramafic Terrane, Central Chain

**Rocks**: Quartz veins

**Minerals**: Gold, awaruite, pyrite, arsenopyrite

**Companies**: Base Metals Exploration

**Quantity**: 300kg

**Mining**

Gold was first discovered in 1863 in Pouébo but the most important discovery was at Fern Hill in 1870 where the site produced 212kg of gold from 1873 to 1900. Other localities also produced gold such as Grosses Gouttes near St Louis, Queyras (La Foa), Edison (Pouembout), Honfleur (Poya) and at Nakéty (Fig. 25). However not all these localities show economic grade (Croixdusud.info, 2007). Nonetheless, in many quartz veins throughout New Caledonia, small particles of gold can be found as inclusions (Noesmoen, 1971).

In the late nineties, a drilling campaign has identified 16Mt of ore average 6.1g/t Au and 12Mt of ore average 3.57g/t Au in Fern hill Mine and 5Mt at 5.86 g/t Au in Nundle (Mining Exploration News, 1997). In November 2000, six large gold and base metals prospects (Méretrice, Nakéty, Fern Hill, Edison, Devaux, Azema and
St Louis) were purchased by Base Metals Exploration NL of Australia from Quadtel Ltd for $12.5 million (Mining Exploration News, 1998). However, by year end 2003, Base Metals Exploration was no longer active in drilling and the sites were idle (Resource Information Unit, 2004).

In the ultramafic terrane, a geochemical study has investigated the enrichment processes of gold and copper. Cu and Au decrease with the increasing residual character of the mantle rocks. In the cumulative zone, Cu is strongly enriched in basaltic rocks whereas early cumulates (dunites and pyroxenites) have high Au contents (Dupuy et al., 1981b). However, concentrations in those rocks and chromitites are significantly lower than those in layered intrusions such as Bushveld and are unlikely to be exploitable (Fig. 27).

![Fig. 27. Average abundances of some metals in ultramafics rocks (Dupuy et al., 1981b)](image)

**Platinoids**

Location: Ultramafic Terrane, Quaternary placers

Rocks: harzburgite; chromitite; alluvial placers

Minerals: Numerous alloys, sulphides and oxides of Pt, Ru, Rh, Ir, Os

Geology
PGE mineralization was studied and investigated in the 1980’s and 1990’s in the southern massif and Tiébaghi area. Some sulphide-rich zone of the harzburgites with anomalous concentrations of PGE and heavy-mineral concentrates have high concentrations of platinoids (1835ppb Ir, 1527ppb Rh, 9718ppb Pt, 11494ppb Pd and 988ppb Au) (Augé et al., 1999). Awaruite seems to be a preferential host for PGE in this system but some Ir-Ru-Os alloys are identified in the Southern Massif and laurite and erlichmanite have been described from the Tiébaghi chromitite (Augé & Maurizot, 1995).

Pirogues River mineralization shows two types of enrichment in PGE. The main enrichment in PGE occurs in the ultramafic transition zone, with a strong correlation with chromitite layers and dykes. Average concentrations found for these chromium-bearing rocks are 3882ppb Pt, 269ppb Pd, 350ppb Rh, 192ppb Ru and 248ppb Ir with higher concentrations in massive chromitite dykes (Augé & Maurizot, 1995). Elsewhere in the Pirogues River area, there are no PGE concentrations in the mantle chromitite pods but in placers derived from these chromitite layers, PGE-bearing minerals are freed from their chromite matrix. Therefore, this alluvial deposit is mainly composed of alloys and sulphides of PGE whereas chromitite ultramafic layers are more characterized by PGE oxides and PGE-bearing base metal sulphide inclusions (Augé & Legendre, 1994). In placers of the Pirogues River, average concentrations of bulk sediments are 500ppb Pt but obtaining concentrates is a process of screening, density and magnetic separation (Augé & Maurizot, 1995).

Molybdenum & Tungsten

Location: “Ultramafic Terrane”

Rocks: Granitic and pegmatitic intrusions

Minerals: Molybdenite, wulfenite, scheelite

Geology

In the granodiorite batholith north of La Coulée, molybdenite occurs in association with chalcopyrite in quartz veins. Tungsten ore is also present as scheelite in quartz breccias of the Thy valley where the granodiorite is in contact with Cretaceous sedimentary rocks. Small amounts of scheelite have been described by Guillon & Trescases (1976) from many small granitic and pegmatitic intrusions crossing the ultramafic terrane.
Antimony

Location: Central Chain
Rocks: Quartz veins
Minerals: Stibnite, valentinite, senarmontite

Mining

Between 1883 and 1884, 1600 tonnes of ore (34% Sb) have been extracted out of the Nakéty Mine. Sibnite occurs with some amounts of gold and sphalerite in quartz veins (Gineste, 2007) (Fig. 25).

3.4. Non metal resources

Coal

Coal measures occur in New Caledonia but the coals are thin, discontinuous folded, and low quality. Small scale mining activities were undertaken in the last century at Nondoué (Dumbéa valley) and Moindou (croixdusud.info, 2007).

Oil

Oil exploration was undertaken between 1907 and 1911 at Ouen Toro near Nouméa (750m deep borehole) and in Koumac area between 1913 and 1921. Two 600m deep boreholes were also drilled at Gouaro (Bourail) in 1951 but these too were unsuccessful. In 1999-2000, a 1600m deep borehole was drilled in Gouaro by Victoria Petroleum N.P. and Sun Resources N.L. but was dry (Mining Exploration News, 1998). A new phase of oil exploration is underway offshore and recent work has indicated favourable structures in the Fairway Basin (North-eastern part of New Caledonia basin), in 2000m of water.

Limestone and other rocks

Limestone is extracted for local purposes in some places and processed at the cement plant of Société des Ciments de Numbo in Nouméa. This industry has an average growth of 4% (Holderbank, 1999; Lyday, 2003). Construction materials are also exploited locally from several small quarries (Lyday, 2003).
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