Chapter 1

Introduction to New Caledonia: geology, geodynamic evolution and mineral resources

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New Caledonia is a French overseas territory in the SW Pacific, located in the southern tropical zone between 19 and 24° S. The country consists of several islands that are the emergent parts of two parallel submarine ridges: the Norfolk Ridge to the SW and the Loyalty Ridge to the NE (Fig. 1.1). The total area of the country is 18 350 km². Grande Terre, the largest and main island, is mountainous, c. 400 km long and c. 50 km wide. The highest points are Mont Panié (1628 m) in the north and Mont Humboldt (1618 m) in the south. Grande Terre is surrounded by a 1500 km long barrier reef complex, the second longest in the world, with parts listed as a UNESCO World Heritage site. By contrast, the Loyalty Islands have a low elevation (127 m maximum height on Maré). As well as Grand Terre and the Loyalty Islands, the New Caledonia archipelago includes the isolated and uninhabited Matthew and Hunter islands to the east and the sandy Chesterfield islets to the west. The New Caledonia Exclusive Economic Zone covers an area of 1 360 000 km².

The Norfolk and Loyalty ridges are part of a complex set of submarine continental and/or volcanic arcs and chains, mostly submerged, that developed between the Australian continent and the Pacific Ocean and usually referred to as Zealandia (Mortimer et al. 2017). Grande Terre is a complex mosaic of Phanerozoic geology, including ophiolitic units, monotonous volcaniclastic sedimentary rocks, and volcanic and metamorphic terranes. The oldest rocks are Carboniferous. The most distinctive and emblematic geological unit of Grande Terre is the 5400 km² Peridotite Nappe, which is one of the largest ultramafic terranes on Earth. Weathering of the peridotites in the Late Cenozoic resulted in the formation of a thick lateritic regolith with important supergene nickel deposits. The Loyalty Islands are composed largely of uplifted Neogene to Present carbonate platform deposits. The Matthew and Hunter islands are volcanoes located on the southern tip of the active Vanuatu island arc, whereas the Chesterfield islets are atolls built on subsided intra-oceanic volcanoes of the Lord Howe seamount chain.

This Memoir

This Memoir summarizes our current knowledge of New Caledonia geology, geodynamics and mineral resources based on published and unpublished information. Except for a short paper timed for the 34th International Geological Congress (Cluzel et al. 2012b), there has been no review of the geology of New Caledonia since Paris (1981) – that is, for more than 35 years. As such, it is timely that this Memoir is published.

This Memo comprises a collection of ten self-contained chapters written by 28 researchers from New Caledonia, France, New Zealand, Australia and Papua New Guinea. This work is not simply a summation of the factual material acquired since Paris (1981). The purpose of each chapter is to present: (1) a data synthesis from which the reader can make his or her own interpretations and (2) an interpretation by the authors incorporating contemporary datasets and geoscientific concepts. Onshore-offshore connections are emphasized, as are the geological relations with New Zealand, Australia and Papua New Guinea, although this Memoir certainly is not a synthesis of the geodynamics of the SW Pacific.

This introductory chapter is a starting point for understanding how the current state of geoscientific knowledge of New Caledonia was reached. It includes a small-scale geological map and proposes a general stratigraphic scheme for New Caledonia. It reviews the advances in knowledge of the geology of the country since the last synthesis of Paris (1981). It also summarizes current problems and issues and the analyses strengths and weaknesses in the state of knowledge of the country’s geology.

Chapter 2 reviews the geodynamics of the SW Pacific and its relations with New Caledonian geology (Collot et al. 2020). The onshore geology of New Caledonia cannot be separated from its regional and offshore context. This chapter identifies the major geological structures of the SW Pacific from the eastern Australian coast to the Tonga-Kermadec Trench. This mostly submerged system of basins, ridges and seamounts of various ages is interpreted as oceanic and thinned continental crust, continental ridges, volcanic arcs, intra-plate volcanic chains and oceanic plateaus. Part of this region, including New Caledonia, is a submerged continent referred to as Zealandia (Mortimer et al. 2017). This chapter presents and compares tectonic models that attempt to explain the formation and development of this complex area.

Chapter 3 considers the Pre-Late Cretaceous basement terranes of the Gondwana active margin (Maurizot et al. 2020a).
Grande Terre comprises three accreted terranes that span the Late Paleozoic to Early Cretaceous. They are all submarine, arc-related and developed offshore from the south Gondwana active margin during marginal basin development. This chapter describes the different terranes, compares them with possible correlative terranes in New Zealand and Australia, and proposes a model for the oceanwards evolution of proto-New Caledonia from the Phanerozoic subduction boundary that lay along south Gondwana.

Chapter 4 considers the Late Cretaceous to Eocene cover and the transition from rifting to convergence (Maurizot et al. 2020b). The Late Cretaceous to Paleogene cover of sedimentary rocks overlies the Late Paleozoic to Early Cretaceous basement above a pronounced unconformity and structurally underlie the allochthonous Eocene nappes. The first period of cover bed deposition (Late Cretaceous to Late Paleocene) was controlled by plate divergence and rifting, whereas the second period (latest Paleocene to Late Eocene) was dominated by plate convergence and contraction. This chapter describes the two-fold evolution and explains and integrates it into the wider framework of the tectonic evolution of the SW Pacific.

Chapter 5 discusses the Eocene subduction–obduction complex (Maurizot et al. 2020c). The subduction–obduction complex of Grande Terre is the result of a period of convergence of the northern part of the Norfolk Ridge and the obduction of an ophiolitic complex. This is the most extensively studied geological topic for New Caledonia and, as such, the scientific output has been prolific. The two main allochthonous and metamorphic units are the obducted Peridotite Nappe and the high-pressure–low-temperature metamorphic belt. The other two components of the subduction–obduction assemblage are the Poya Terrane and the Montagnes Blanches Nappe.

Chapter 6 describes the onshore geology of the Loyalty Islands and the current state of knowledge of the Loyalty Ridge (Maurizot et al. 2020d). The three main Loyalty Islands are the emergent part of the Loyalty Ridge. They are composed of thick Miocene to Present carbonate platform deposits. Minor basalts are exposed on the island of Maré. The geology of most of the submarine Loyalty Ridge remains unknown.

Chapter 7 considers the post-obduction evolution of New Caledonia (Sevin et al. 2020). The post-obduction formations in New Caledonia comprise a variety of disparate and areally restricted Neogene geological units. They include granitoid intrusions, regolith cover, and terrestrial and marine deposits. Neogene extensional tectonic collapse of the margins of Grande Terre explains the meagre geological record preserved onland and suggests that more extensive and informative marine successions may be present offshore. The onland terrestrial deposits are important, but are difficult to characterize and date. The regolith on the Peridotite Nappe is a distinctive feature of New Caledonian geology.

Chapter 8 describes New Caledonia’s geological and biological evolution afresh in an up-to-date, multi-disciplinary scheme (Maurizot and Campbell 2020). An isolated island today, New Caledonia was probably entirely submerged for significant periods of time following the break-up of Gondwana. As a result of its isolation and widespread ultramafic substrate, the archipelago has inherited and/or developed a...
unique and unusual biota with outstanding endemism. In the past, incorrect geological information has fed into biogeographical misinterpretations.

Mineral resources have always been important to the economy of New Caledonia. Chapter 9 (Maurizot et al. 2020b) and Chapter 10 (Maurizot et al. 2020a) provide an exhaustive review of the metallic, non-metallic, gemstone, hydrocarbon and thermal resources of the archipelago and its Exclusive Economic Zone (EEZ). Both chapters deal with nickel and cobalt, which are actively mined, as well as resources which are not currently exploited.

Previous work

Since the 1850s, our knowledge of the geology of New Caledonia has progressed in step with technological advances in the geosciences and the development of the country’s infrastructure. Grand Terre has restricted road and track access and, as in all tropical lands, the outcrops are often deeply weathered and masked by abundant vegetation. Unveiling New Caledonia’s complex geology is therefore not an easy task. From an historical perspective, three phases of data acquisition can be identified: (1) a pioneering exploration phase, which began shortly after the French settlement in the late nineteenth century and finished at the end of the Second World War; (2) a more systematic survey phase, extending from the post-war period to the 1980s; and (3) the current period, in which the correlation of onshore and offshore data and the integration of New Caledonia into the wider SW Pacific geodynamic context has been undertaken—and is still in progress.

Pioneering exploration phase

The first phase of geological investigation was closely linked to the assessment of the mineral resources of the then-new French colony (cf. Chapters 9 and 10). It was marked by the discovery of abundant and high-grade nickel deposits hosted by the regolith developed on the Peridotite Nappe (Garnier 1867a, b, c), as well as other resources such as chromium, coal, base metals and gold (Heurteau 1876; Pelatan 1891; Glasser 1904). The earliest formal scientific publication on New Caledonia’s geology was published shortly after the beginning of colonization by an artillery captain reporting on a geological excursion in the south of Grande Terre (Lombardeau 1860). The first geomorphological analysis of the country was made by Davis (1899). The first major monograph on the general geology of Grande Terre and the first synthetic geological map at the scale of 1:1 000 000 was published by Piroutet (1917). Most of the major geological features, notably the outlines of the ultramafic massifs, were described in this document. Throughout this early phase, the petrography and mineralogy of many metamorphic, volcanic and ultramafic rocks from the New Caledonia archipelago were described by Lacroix (1897, 1905, 1918, 1940, 1941, 1942), although he never visited the islands.

Systematic survey phase

This second phase of data acquisition led to two generations of geological maps. The first coverage, drawn on an incomplete topographic map at a scale of 1:100 000, was made during the 1950s. At that time, Grande Terre was subdivided into three study areas, from which arose three major monographs (all written in French): Avias (1953) for the central part; Routher (1953) for the NW part; and Arnould (1958) for the NE part. During this phase many important second-order features of New Caledonia geology were recognized. These included: the individual Boghen metamorphic units (Routher 1953), which were, however, mistakenly considered as a pre-Permian ‘sialic core’; the establishment of a first lithostratigraphic outline of Permian to Jurassic rocks (Avias 1953); the existence of tectonic events that predated the Late Cretaceous deposits (Routher 1953); the Paleogene age of the northern metamorphic belt (Arnould 1958); a description of the basaltic unit of the west coast (Routher 1953); the overthrust nature of the Peridotite Nappe (Avias 1967); and the assignment of the Népoui carbonate formations to the Miocene (Routher 1948).

The second generation of geological mapping took place between 1970 and 1990 and was directed by the Bureau de Recherches Géologiques et Minières (BRGM). New 1:50 000 scale topographic maps were now available and useful contributions by university researchers were incorporated into the maps. Among the many geologists who contributed advances were New Zealand geologists working on the Eocene high-pressure–low-temperature metamorphic belt of northeastern Grande Terre (e.g. Black 1977; Brothers and Black 1973) and the Paleoizoic–Mesoizoic Téremba Terrane stratigraphy (Campbell 1984; Campbell et al. 1985; Grant–Mackie 1985). There were also important contributions by Coudray (1977) on the stratigraphy of the Eocene to Neogene formations and the evolution of the Plio–Quaternary coastal reef complex and by Gonord (1977) on the Eocene syn- tectonic turbidities. Before the end of the BRGM geological mapping programme, the synthesis of Paris (1981) was published (again in French) and had an accompanying 1:200 000 scale geological map. Both the monograph and map are now out of print. Although Paris (1981) was an important task, it was published when the uptake of global plate tectonic principles by onshore geological map-makers was at an early stage.

From the early 1980s, new concepts in geoscience—including plate tectonics, terrane analysis and the recognition of ophiolites as former oceanic lithosphere—gave new perspectives to the geology of this region. Similarly, there were important technical advances in remote sensing and geophysical and analytical methods, notably isotope geochemistry and geochronology.

The systematic survey period involved programmes coordinated by the various geoscience institutions in New Caledonia. In the early 1980s, the BRGM initiated a systematic Mineral Resources Survey programme, which had several main outputs. Notably, it led to advances in the metallogeny of chromite deposits (Cassard et al. 1981), the platinum group elements (Augé and Maurizot 1995; Augé et al. 1998), base metals and gold deposits. During this programme, systematic sampling and geochemical analyses of stream sediments (about three samples per square kilometre) and alluvial concentrations (about one sample per square kilometre) were achieved across most of Grande Terre. Increasingly detailed geological mapping of the main units of the Peridotite Nappe took place in parallel with the BRGM Mineral Resources Survey. Much data on the mantle fabric, hypogene chromium mineralization and the kinematics of the ultramafic terrane were acquired during this period (Prinzhofer and Nicolas 1980; Prinzhofer et al. 1980; Prinzhofer 1981; Sécher 1981; Moutte 1982; Podvin 1983; Nicolas 1989).

The Office de la Recherche Scientifique et Technique Outre-Mer (Overseas Scientific and Technic Research Office, ORSTOM), now the Institut de Recherche pour le Développement (Research Institute for Development), focused efforts on the ultramafic regolith and associated nickel deposits (Trescases 1975, 1985; Latham 1986) and on the regional geodynamics of the offshore SW Pacific domain (Équipe
ORSTOM 1982). There were noteworthy publications on the rooting of the Peridotite Nappe in the Loyalty Basin (Collot et al. 1987), the lithospheric bulge of the Loyalty Islands in response to the east-dipping active Vanuatu subduction (Dubois et al. 1974) and the petrology of arc volcanics (Hildreth et al. 1984). Several offshore boreholes were drilled in the SW Pacific by the Deep Sea Drilling Project during this period (Burns et al. 1973).

The Université de Nouvelle-Calédonie (University of New Caledonia) was founded in 1987. It included a geoscience department from the start, which provided education, training and research on the onshore geology. The date of founding of the university also effectively marks the beginning of tectonostratigraphic terrane analysis of New Caledonia backed by the increasing use of geochronology and geochemistry (Aitchison et al. 1995, 1998; Cluzel et al. 1995, 2001, 2005, 2006; Melfire 1995; Melfire et al. 1996; Cluzel and Melfire 2002).

By the end of the 1990s, the terrane nomenclature of the country was effectively fixed and this nomenclature persists to the present day.

Current phase of work

It is impossible to precisely define a year that marks the change from the second to the current phase of geological investigation. However, attention to the offshore geology presented a new and valuable perspective that was lacking in earlier decades. Several research and exploration programmes of New Caledonia’s EEZ were launched from the 1970s to the 1990s to assess the offshore biological and mineral resources, notably the hydrocarbon potential. These had acronyms such as Zonécô, Extraplac, Noucaplac and Austradec (for a compilation, see Sutherland et al. 2012). These programmes produced essential contributions that led to the integration of the onshore and offshore geology of New Caledonia and a better appreciation of its context in the broader SW Pacific environment (Lafoy et al. 1998, 2005; Van De Beuque 1999; Auzende et al. 2000; Collot 2009). The Pleistocene–Holocene lagoon–reef complex of New Caledonia was thoroughly investigated from the early 1990s to the early 2000s (Cabiocq et al. 2008a, b).

One of the more recent institutional developments was the founding in 2006 of the Service Géologique de Nouvelle-Calédonie (New Caledonia Geological Survey, SGNC). The SGNC was set up as a government department to create and maintain the geological databases of New Caledonia and its EEZ. The SGNC has promoted and participated in several important international marine geoscience initiatives. There have been useful collaborations with the geological surveys of New Zealand (GNS Science) and Australia (Geoscience Australia) and Ifremer in France. Collaboration is ongoing. This joint work took the form of several research voyages with the R/V Tangaroa and N/O l’Atalante oceanographic ships and culminated in the International Ocean Discovery Programme Leg 371 of research drilling in North Zealandia’s Tasman Frontier. At the time of writing, international projects are still currently ongoing and planned to explore the ‘hidden continent’ of Zealandia in the areas between New Caledonia, New Zealand and Australia (Collot et al. 2015; Mortimer and Patent 2016; Sutherland et al. 2016, 2017). A synthesis map and explanatory note of the structural provinces of the SW Pacific is available at https://dimenc.gouv.nc//ressources/geologie (Collot et al. 2011).

Surprisingly, scientific research on New Caledonia’s nickel–cobalt deposits, which generate the main wealth of the country, was not active until the 2000s, or was not public. However, since then, the growing global demand for nickel, as well as depletion of the resource and environmental issues, have boosted scientific research. In 2007 the Centre National de Recherche et Technologie Nickel et son Environnement (National Centre for Research and Technology Nickel and its Environment, https://www.cnrt.nc) was created. This funding agency supports research projects (more than 50 from 2008 to 2019) devoted to the geology, natural environment and social sciences related to nickel. A selection of the many publications of this period includes Beauvais et al. (2007), Cathelineau et al. (2016), Chardon and Chevillotte (2006), Chevillotte et al. (2006), Dublet et al. (2012), Fritsch et al. (2016), Quesnel et al. (2017), Robinet et al. (2007) and Traoré et al. (2005).

Geological maps

At the time of writing, the geological map coverage of New Caledonia consists of 39 geological maps at 1:50 000 scale and their explanatory notes, written in French (Fig. 1.1). Coverage is of Grande Terre and the Loyalty Islands, but not the islands of Chesterfield, d’Entrecasteaux, Matthew or Hunter. The Grande Terre maps are of variable detail and were published at different times (Espirat and Millon 1965, 1967, 1971; Millon 1965; Carroué and Espirat 1967; Noesmoen 1970a, b, 1971; Carroué 1971a, b, c, 1972a, b, c; Espirat 1971a, b, c; Guillon and Trescases 1972, 1976; Lozes and Yerle 1976; Lozes and Guérangé 1977; Paris 1977; Trescases and Guillon 1977; Guy et al. 1979; Arène et al. 1980; Faure and Paris 1982; Paris and Guy 1982; Faure et al. 1983; Vogt and Podvin 1983; Maurizot et al. 1984, 1986, 1989; Guillon et al. 1986; Maurizot and Gasc 1986; Tessarlo et al. 1986).

The geological mapping of the three Loyalty Islands (https://dimenc.gouv.nc/ressources/geologie) was carried out more recently (Maurizot and Lafoy 2003, 2004a, b). All these 1:50 000 geological maps were digitized, edge-matched and merged in the early 2000s. The maps are still being improved and regularly updated, notably by regolith mapping on the ultramafic massifs. There is also a 1:25 000 urban geological map of the Nouméa Peninsula (Maurizot and Gasc 1986).

Figure 1.2 is a small-scale geological map synthesis based on this set of 1:50 000 scale sheets and based on the following stratigraphic scheme. This map is provided in geographical information system format in the Supplementary material (available online). It is an updated version of the 1:500 000 geological map (Maurizot and Vendé-Leclerc 2009) and its short explanatory note (https://dimenc.gouv.nc/ressources/la-géologie), which is available in both paper and digital form. An A3 size geological map of New Caledonia was also published in the 2012 Research Institute for Development Atlas (Maurizot and Vendé-Leclerc 2012).

A regularly updated multi-scale geological map, along with many other datasets, a catalogue, and metadata, can be viewed in online at the portal https://georep.nc. This online geographical information system includes a digitized version of the Paris (1981) 1:200 000 geological map. The availability of, and progress on, New Caledonia geological maps are summarized in Table 1.1.

High-level stratigraphic scheme for New Caledonia

Geological models and hypothesis are transient. However, if geological units are well defined in time and space and are arranged in a consistent scheme, that scheme may provide a stable and useful framework for the earth science community provide common terms when discussing a specific geological topic or place. The coherent classification of geological units
Fig. 1.2. Geological map of New Caledonia (1:1 300 000 scale). Numerical ages after the International Chronostratigraphic Chart v2018/08 (Cohen et al. 2013; updated). Units with an asterisk are undated.
Fig. 1.3. Formal nomenclature of geological units of New Caledonia. Excludes the Hunter-Matthew and Chesterfield island groups. Numerical ages after the International Chronostratigraphic Chart v2018/08 (Cohen et al. 2013; updated).
using consistently applied biostratigraphic, lithostratigraphic, chronostratigraphic or other criteria is not an easy task in a country where the geology is highly complex and where most stratigraphic names, to date, are informal. There is no specific committee to approve New Caledonian geological map units or stratotypes. By convention, the names of geological units are generated in published papers and a test of their usefulness is simply how well, or if, they are cited.

Here, we formalize a basic stratigraphic hierarchy of the New Caledonia geological units that are used in the different chapters of this Memoir, in the legend of the geological map (Fig. 1.2) and in the attribute table of the digital geological map provided in the Supplementary material for this chapter. The basis of the hierarchy is tectonostratigraphic because such schemes have remained stable and have been applied usefully in New Caledonia since the end of the 1990s (Aitchison and Meffre 1992; Cluzel et al. 1994), even if some issues still remain. A summary of the units is presented in Figure 1.3. The scheme is hierarchically organized into four high-level ‘Assemblages’ (which match the individual chapters of this Memoir) then, in increasing detail, ‘Terrane, Nappe or Sequence’, ‘Group’, ‘Formation’ and ‘Member’. The lower three ranks are only populated by coherent sedimentary successions. The general terms ‘unit’ and ‘complex’ are not included in this new formal hierarchy, but are still useful synonyms. So are the terms ‘basement’ and ‘cover’, which are in common use in New Zealand (Mortimer et al. 2014); these are also occasionally used in New Caledonia (instead of Basement Assemblage and Pre-Obduction Assemblage).

The four major tectonostratigraphic assemblages of New Caledonia are: (1) the Basement Assemblage (Chapter 3), which consists of three amalgamated terranes lying beneath the Late Cretaceous unconformity; (2) the Pre-Obduction Assemblage (Chapter 4), Late Cretaceous to Paleogene sedimentary successions that unconformably overlie the basement and structurally underlie the allochthonous terranes; (3) The Subduction–Obduction Assemblage (Chapter 5), consisting of mostly allochthonous units emplaced during the Eocene period of convergence, which involved subduction followed by obduction; and (4) The Post-Obduction Assemblage, which consists of a variety of Late Oligocene to Holocene geological units on both Grande Terre and the Loyalty Islands (Chapters 6 and 7).

Thirty-nine years of advances

A comparison of the last synthesis of New Caledonia geology by Paris (1981) with the present Memoir highlights several major advances in knowledge that have been made during the last 39 years.

Three terranes are now defined in the basement (Chapter 3) and constitute a stable and much-used scheme. The Boghen Terrane was formerly termed the ‘pre-Permian stiaic core’ of Grande Terre on the basis of its metamorphic nature and a putative unconformity below unmetamorphosed Permian rocks (Avias and Gonord 1973). The protolith of the unit was proven to be Mesozoic by U–Pb dating on zircons (Cluzel and Meffre 2002; Cluzel et al. 2010) and is now interpreted as a Mesozoic subduction complex. The two other terranes, the Téremba and Koh-Central terranes, are interpreted to be proximal and distal forearc basin deposits, respectively. They are related to an intra-oceanic volcanic arc located to the west, offshore from the eastern Gondwana margin, and probably separated from it by a marginal basin.

In what is now the Pre-Obduction Assemblage (Chapter 4), the Late Cretaceous basal unconformity was already recognized in the 1950s as a geological horizon of regional first-order importance, equivalent with that of New Zealand (Avias 1953; Routhier 1953; Laird 1981). Ubiquitous basement rift structures have been traced throughout Zealandia in seismic profiles (Bachet et al. 2012; Rouillard et al. 2014, 2015; Mortimer et al. 2017). Although the syn-tectonic nature of most of the Eocene deposits was recognized in the 1980s (Gonord 1977), a coherent interpretation for the whole Eocene flysch was still missing. The Bourail Group is now interpreted as having been deposited in a typical foreland basin, synchronous with the Eocene convergence and subduction (Cluzel et al. 1998; Maurizot 2011, 2013, 2014; Maurizot and Cluzel 2014). The Late Eocene Népoui–Koumac Flysch, formerly regarded as post-dating the obduction of the Peridotite Nappe (Paris et al. 1979; Paris 1981), is now interpreted as a pre-obduction syn-tectonic infill of piggy-back basins transported on the Poya Terrane during its forearc accretion (Cluzel 1998).

Three separate allochthonous units in the subduction–obduction complex (Chapter 5) are now clearly defined in their successive stacking order – namely, the Montagnes Blanches Nappe (Maurizot 2011), the Poya Terrane (Cluzel et al. 2001), including the Koné facies (Cluzel et al. 2017), and the Peridotite Nappe (Avias 1967). Numerous radiometric ages constrain the beginning of convergence at the Paleocene–Eocene boundary (Cluzel et al. 2006, 2012a, b, 2016; Maurizot 2013), (2) subduction spanning the whole Eocene (Ghent et al. 1994; Rawling 1998; Cluzel et al. 2001; Spandler et al. 2005; Baldwin et al. 2007; Pirard and Spandler 2017) and (3) the final obduction and exhumation at the end of the Eocene (Ghent et al. 1994; Rawling 1998; Baldwin et al. 2007). The Pouêbo Terrane has been recognized in the high-pressure–low-temperature metamorphic belt as the metamorphosed equivalent of the Poya Terrane (Cluzel et al. 2001). A number of radiometric ages and geothermobarometry on various mineral assemblages has constrained the P–T–t metamorphic path (Black 1974; Clarke et al. 1997; Carson et al. 1999; Fitzherbert 2002; Fitzherbert et al. 2003, 2004; Agard and Vitale-Brovarone 2013; Vitale Brovarone and Agard 2013, Taetz et al. 2016). The gabbronorite cumulates of the Massif du Sud, which were originally thought to be the products of a mid-oceanic spreading ridge (Prinzhofer et al. 1980; Prinzhofer and Allegre 1983), are now reassessed as a supra-subduction forearc crust (Marchesi et al. 2009; Pirard et al. 2013; Cluzel et al. 2016; Secchiari et al. 2018).

Many advances have also been made in the Post-Obduction Assemblage (Chapters 6 and 7). The Loyalty Islands were almost ignored in 1980s publications. Geological mapping of the islands was carried out in the 2000s (Maurizot and Lafoy 2003, 2004a, b, 2006) and the Loyalty Ridge is now integrated in the geology of New Caledonia (Chapter 6). The Koun and Saint Louis granitoids, which intrude the Peridotite Nappe and its substrate, have been dated at 27–24 Ma (Cluzel et al. 2005). Systematic mapping of the regolith is still in progress, while indirect dating of the main ferricrete of the Goro and Tiébaghi ultramafic massifs by palaeomagnetic methods has been interpreted at c. 25 Ma (Sevin et al. 2012). The discovery by drilling of a new c. 100 m thick reefal limestone underlying the so-called ‘basal conglomerate’ of the Miocene Népoui Formation led to the reinterpretation of the latter as a consequence of short-lived uplift due to post-obduction slab break-off (Sevin et al. 2014). The siliciclastic and carbonate-dominated Népoui Group is now dated as Aquitanian–Burdigalian by its foram content and strontium isotope stratigraphy (Maurizot et al. 2016). The older exposed sequence of the carbonate platform of the Loyalty Islands has been dated in Maré as Mid-Miocene (Maurizot and Lafoy 2003).
Table 1.1. Information on geological maps of New Caledonia

| Scale          | Date of publication | Map | Explanatory note | Paper* | Online digital† |
|----------------|---------------------|-----|------------------|--------|-----------------|
| 1:50 000       | 1967–86             | Yes | Yes              |        |                 |
| 1:200 000      | 1981                | Out of print | Out of print | Yes    | No              |
| 1:500 000 (A1) | 2009                | Yes | Yes              | Yes    | Yes             |
| 1:1 300 000 (A3)| 2019                | Yes | Yes              | Yes    | Yes             |

*Paper versions are available at Direction de l’Industrie, des Mines, et de l’Energie de Nouvelle-Calédonie, Geological Survey of New Caledonia, 1 ter rue Unger, Vallée du Tirs, B.P. M2, 98849 Nouméa CEDEX, New Caledonia.
†Online digital version downloadable at the portal https://georep.nc
‡Paris (1981).
§Maurizot and Vendé-Leclerc (2009).
¶This Memoir.

Remaining problems

Although many advances have been made in the last 39 years, there remain many shortcomings in our knowledge of New Caledonia geology.

- Refining the stratigraphy of all the Paleozoic–Early Mesozoic basement terranes of Grande Terre is hampered by the rarity of fossils and detrital zircons. Both are scarce because of the dominantly volcaniclastic provenance. The Koh-Central Terrane in particular lacks good lithostratigraphic subdivision and the protolith age of the areally extensive metamorphic Boghen Terrane relies only on a few samples (Cluzel and Meffre 2002; Cluzel et al. 2010). Knowledge of the Basement Assemblage could be greatly improved by more detailed cross-sections, geological mapping, systematic sampling and detrital zircon analysis.
- The P–T–t path of the Boghen Terrane is still poorly defined.
- Although progress has been made in establishing a general stratigraphy of the Eocene flysch (Maurizot 2011, 2013, 2014; Maurizot and Cluzel 2014), dating has been based only on benthic and planktonic forams. This needs to be refined in key sections by integrated nannofossil, radiolarian, forum and magnetostatigraphic work (e.g. Dallanave et al. 2018).
- A better knowledge of the Subduction–Oubduction Assemblage of New Caledonia is certainly desirable in terms of the scientific, economic and environmental benefits. Initiatives such as the New Caledonia Drilling Project to promote a proposal (NCDP 2019) to international drilling organizations (e.g. the International Ocean Discovery Program or the European Consortium for Ocean Research Drilling) should be encouraged.
- The subduction–obduction complex of New Caledonia is one of the major occurrences of high-pressure–low-temperature metamorphic rocks worldwide, but contradictory tectonic models exist (Cluzel et al. 2001; Rawling and Lister 2002; Lagabrielle et al. 2013; Gautier et al. 2016). The high-pressure–low-temperature metamorphic belt is under-investigated in the remote area of Mont Panié. As explained in this Chapter 5, the nature of the boundary between the Diahott Terrane and the Montagne Blanche Nappe is poorly characterized.
- The study of Peridotite Nappe petrofabrics performed by lattice preferred orientation analysis with the universal stage dates back to the 1980s (Prinzhofer et al. 1980). A more accurate and areally extensive appraisal of high-temperature mantle deformation could be obtained by systematic back-scattered electron diffraction or anisotropy of magnetic susceptibility methods.
- The crustal sequence of the Peridotite Nappe is still undated.
- Based on its morphology and geophysical anomalies, the deep part of the Loyalty Ridge near New Caledonia is regarded as an Eocene volcanic arc (e.g. Cluzel et al. 2001). However, no sample has ever been obtained and the age and nature of the Loyalty Ridge basement remains one of the main unknowns of SW Pacific tectonics. Deep dredging or drilling of this part of the ridge could test the Eocene arc hypothesis.
- Reconstituting the spatio-temporal development of the Post-Obduction Assemblage evolution of Grande Terre is complicated by the fact that many of its formations derive from the weathering of the Peridotite Nappe, which defy accurate and precise dating by any method tried so far. Direct dating by palynomorphs could be a solution in the Fluvio-lacustrine Formation and/or in the Népoui Group.
- The development of the Pleistocene–Holocene lagoon–reef complex is a potentially rich field of research that has been largely abandoned since the premature passing away of its leader G. Cabioch (e.g. Cabioch et al. 2008a, b). This research theme should be taken forward as a result of its importance regarding climate change baselines.

From a more general standpoint, the geoscientific data infrastructure of New Caledonia still have some weaknesses. The oldest geological maps (1:50 000) date back to the 1970s and are largely obsolete. A new generation of geological maps is desirable. Systematic geophysical surveys (e.g. airborne electromagnetic, gravimetric and radiometric coverage) are seriously lacking in a country that is dependent on its mineral resources and has many difficult to access remote areas. The deep structure and nature of the crust and upper mantle underlying the New Caledonia area remains to be investigated using seismic methods, including refraction, reflection and tomography. Such studies, combined with onshore and offshore investigations, will lead to a better understanding of the geology of New Caledonia in the context of the continent of Zealandia.

Acknowledgements The original idea of this Memoir was the initiative of the Geological Survey of New Caledonia in partnership with the Earth Science department of the University of New Caledonia. However, it could not have been realized without the long-term co-operation and collaboration of many geologists from the wider SW Pacific region, mainly from New Zealand and Australia. These joint efforts are both long-standing and valued. This Memoir is dedicated to all those involved. We gratefully acknowledge the Government of New Caledonia for their support of this work, and its appreciation that the importance of natural resources to the economy of the country was a major motivation of the project. We acknowledge the role played by editor Nick Mortimer in reviewing all the...


**Introduction**

submissions, co-ordinating referee comments and providing guidance on revisions.

**Funding** This research was funded by the Geological Survey of New Caledonia, Government of New Caledonia.

**Author contributions** PM: conceptualization (equal); BR: supervision (lead); MV-L: data curation (lead); DC: conceptualization (lead).

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