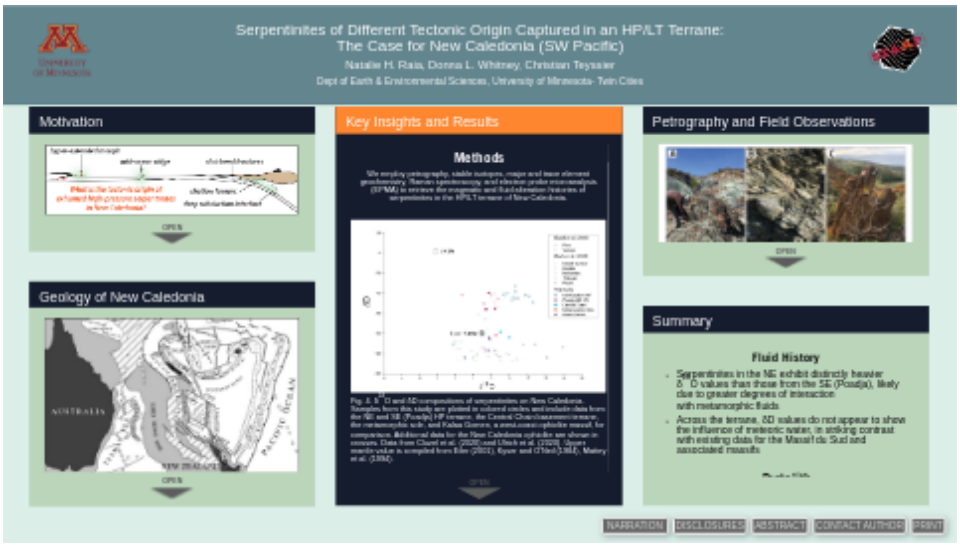
Serpentinites of Different Tectonic Origin Captured in an HP/LT Terrane: The Case for New Caledonia (SW Pacific)



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MOTIVATION

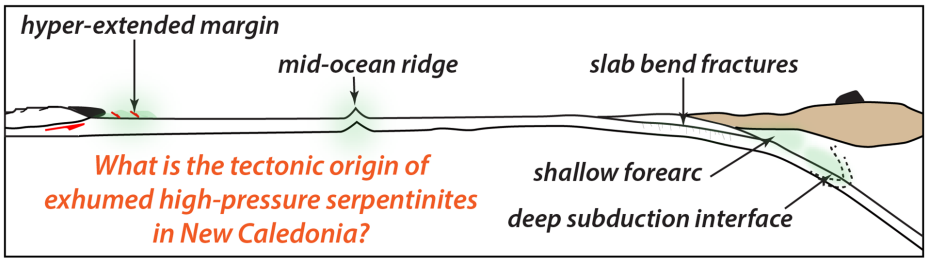

Fig. 1. Schematic diagram showing serpentinization environments in a subduction zone context.

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Serpentinites are hydrated and altered mantle rocks, and are common in exhumed subduction terranes worldwide. These rocks are one of the dominant carriers of water in downgoing oceanic slabs, and are critically important to a wide array of subduction-zone processes, including fluid-mobile element cycling and subduction zone seismicity. They may also provide buoyancy forces that aid in exhumation of subducted material. More recently, the oxidation state of serpentinites has been a focus of study, with relevance for the composition of arc magmas.

Serpentinites captured in exhumed subduction complexes may originate from downgoing oceanic lithosphere or from mantle overlying the slab. This provenance is not often discernable through field observations alone, and holds important clues about the mechanics of fossil subduction zones and possibly information about the former tectonics of the original slab.

GEOLOGY OF NEW CALEDONIA

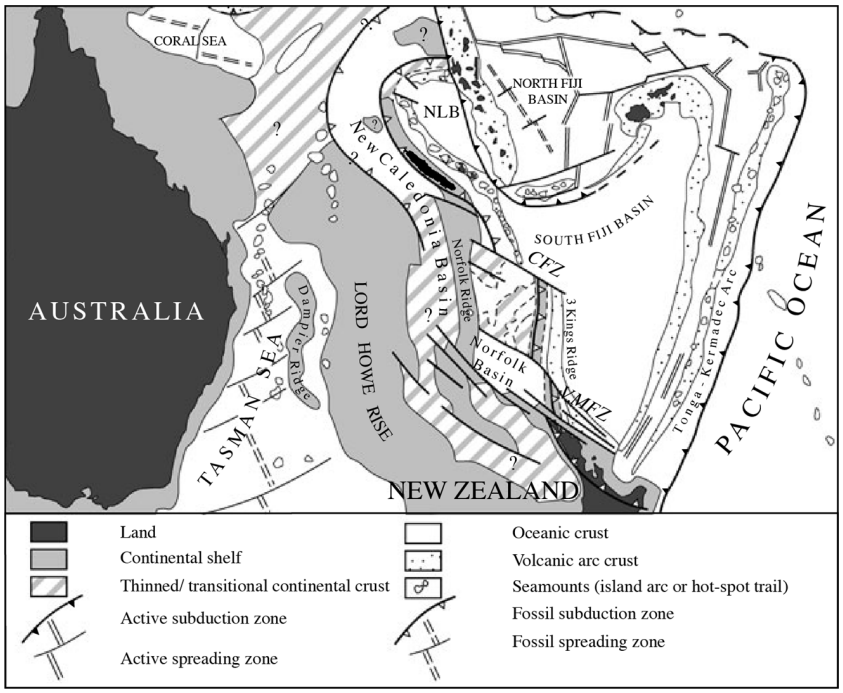

Fig. 2. Map of the southwest Pacific showing the array of continental slices (gray), marginal basins, and volcanic arcs. New Caledonia is shown in the northern portion of the Norfolk Ridge. Abbreviations:CFZ, Cook Fracture Zone; NLB, North Loyalty Basin; VMFZ, Vening-Meinesz Fracture Zone (Cluzel et al. (2005)).

The SW Pacific region consists of a complex set of submerged continental slices, volcanic arcs and marginal basins formed during and after the rifting and breakup of the eastern margin of Gondwana (Fig. 2). The island of New Caledonia preserves a dense assortment of geologic terranes. Amongst these are the world's second largest aerially-exposed ophiolite and one of the largest high-pressure, low-temperature (HP-LT) metamorphic terranes in the world (Fig. 3). Thus, this island hold important information about ophiolite obduction processes and subduction metamorphism.

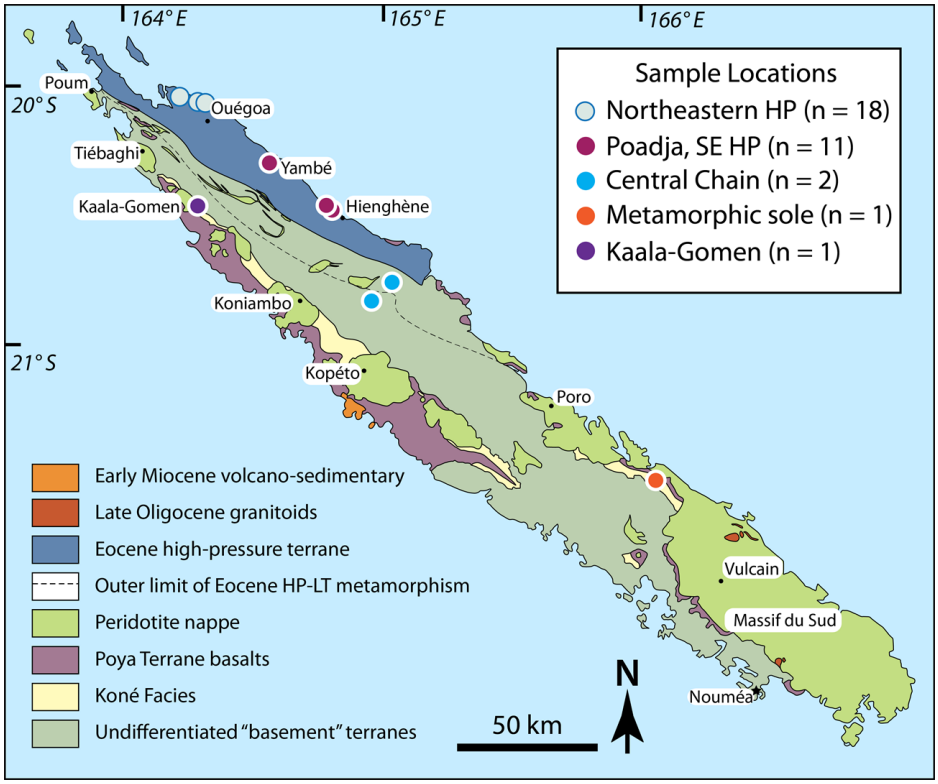

Fig. 3. Simplified geologic map of New Caledonia with sample localities for this study (colored circles). Location names for existing literature data referenced in this study are labeled. After Cluzel et al. (2020).

Ultramafic rocks occur in several distinct tectonic units on the island. Volumetrically most abundant, peridotites and serpentinites compose the Massif du Sud and other overlying peridotite nappes. Serpentinites can also be found in basement terranes that comprise material originally accreted to the eastern margin of Gondwana. Finally, serpentinites are found throughout the high-pressure, low-temperature metamorphic belt in the northeastern portion of the island.

The tectonic origin of the serpentinites in the metamorphic belt has been studied previously by Fitzherbert et al. (2004) and Spandler et al. (2008). We apply new methods with increased spatial coverage to further discern details about the magmatic and fluid histories recorded by these rocks.

KEY INSIGHTS AND RESULTS

Methods

We employ petrography, stable isotopes, major and trace element geochemistry to retrieve the magmatic and fluid alteration histories of serpentinites in the HP/LT terrane of New Caledonia.

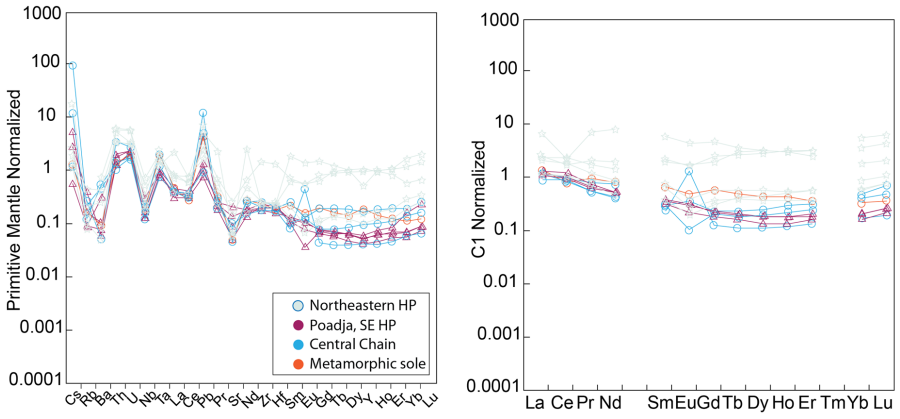

Fig. 4. Whole rock trace (left) and REE (right) data. Trace elements are normalized to primitive mantle and REE are normalized to C1 chondrite (McDonough and Sun, 1995).

Extensive compilation and analysis of geochemical data from drilled, dredged, obducted, and exhumed serpentinites has demonstrated that trace element contents can serve as "fingerprints" for their protolith origin and composition (e.g., Deschamps et al. (2013), Scambelluri et al. (2019)). This type of provenancing can be enhanced with analysis of major element and stable isotope (O, H) geochemistry, which can reveal information about the fluid interaction history of the serpentinite (Figs. 5, 6).

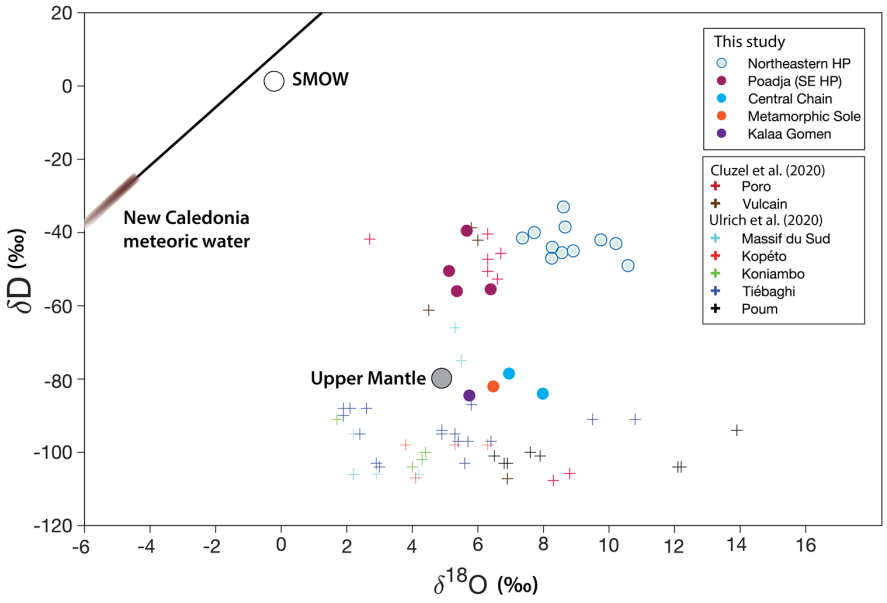

Fig. 5. $\delta^{18}O$ and δD compositions of serpentinites on New Caledonia. Samples from this study are plotted in colored circles and include data from the NE and SE (Poadja) HP terrane, the Central Chain basement terrane, the metamorphic sole, and Kalaa Gomen, a west-coast ophiolite massif, for comparison. Additional data for the New Caledonia ophiolite are shown in crosses. Data from Cluzel et al. (2020) and Ulrich et al. (2020). Upper mantle value is compiled from Eiler (2001), Kyser and O'Neil (1984), Mattey et al. (1994).

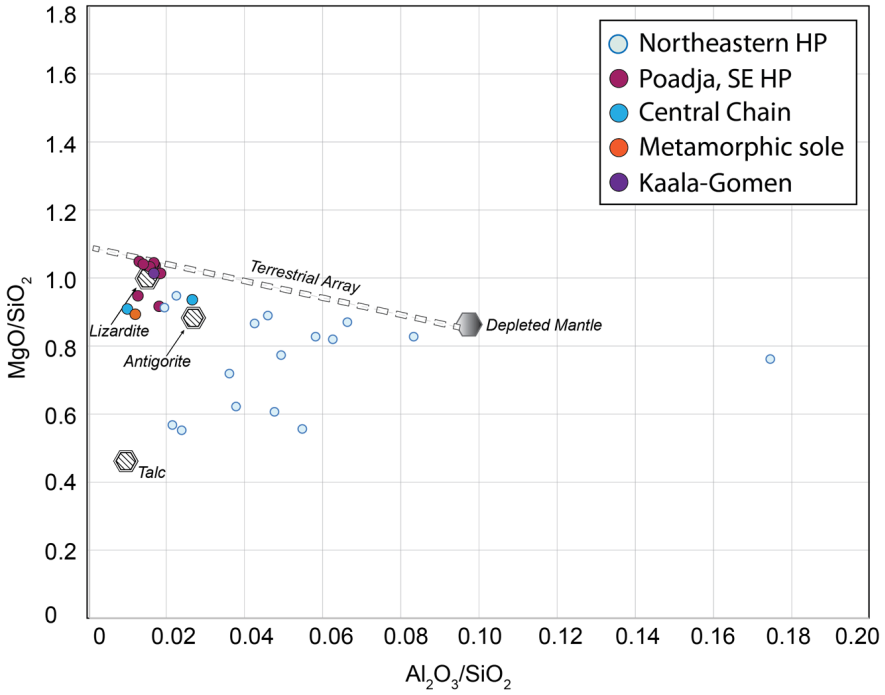

Fig. 6. Whole rock major element ratios of MgO/SiO2 versus Al2O3/SiO2. Dashed-outlinepolygons note deformed samples. Dashedwhite line is the "terrestrial array" (e.g., Jagoutz et al., 1979) in which partial melt extraction yields melt residues with higher MgO/SiO2 and lower Al2O3/SiO2 ratios than the melt. Depleted mantle value is from McDonough and Sun (1995). SerpentiniteAverage compositions for talc, lizardite, and antigorite are plotted as hatched polygons

FIELD OBSERVATIONS

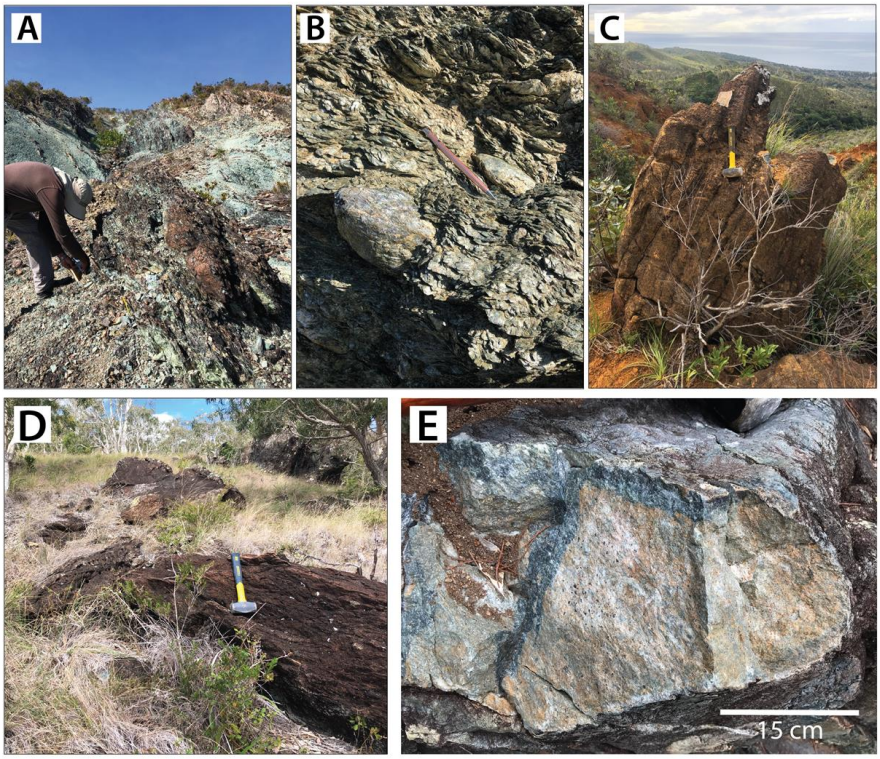

Fig. 7. Field photos dispalying the range of serpentinite outcropp styles. A) A sheared serpentinite zone in direct contact with metamorphosed sediments (visible in upper right); B) Highly-deformed serpentinite matrix encloses a recrystallized blueschist pod; C) Highly weathered outcrop at Poadja locality, with relict pyroxene magmatic foliation visible in some areas. Poadja is characterized by distinct oxidized weathered soils and surfaces, similar to obducted ophiolite massifs in the southern portion of the island; D) Resistant serpentinite blocks in the NE; E) Fresh serpentinite surface at Poadja. Dark green alteration rim is visible in upper portion of sample.

Serpentinites in the northernmost portion of the high-pressure terrane outcrop as highly sheared and deformed lenses and as more refractory, weathered boulders on hillslopes. In highly sheared areas, the serpentinites act as a matrix host for more refractory, rounded boulders of meta-mafic, meta-sedimentary, and ultramafic rocks.

SUMMARY

Summary

- Serpentinites in the HP/LT Terrane of New Caledonia can be group into two distinct groups based on geochemistry
- Samples in the far NE exhibit distinctly heavier $\delta^{18}O$ values and greater scatter in major element contents than those from the SE (Poadja), possibly due to greater degree of interaction with metamorphic fluids and increased degrees of metamorphism, respectively
- Trace element values are relatively homogenous amongst all analyzed samoles, though several samples from the far NE show enriched HREE
- Across the terrane, δD values do not appear to show the influence of or "resetting" by meteoric water; this is in striking contrast with existing data for the peridotite nappe, where light δD values (-80 to -100 per mille) have been interpreted to result from alteration by weathering

DISCLOSURES

We are grateful to Messieurs Guiart and Heiec, tribal chiefs of Yambé and Diahoué, respectively, for their authorization in accessing the Poadja Massif, and Mssr Hervé and family for their interest in our work and assistance in communicating our presence and purpose to the surrounding community. N. Raia is grateful to P. Maurizot and B. Robineau (DIMENC) for their warm welcome, thoughtful discussions, and generosity in use of DIMENC rock processing facilities. S. Lesimple (DIMENC) is additional thanked for spending several days in the field assisting in accessing different parts of the terrane. The UT-Austin High-Temperature Stable Isotope lab is thanked for assistance with analyses, particularly J. Barnes and J. Cullen. We thank A. von der Handt for assistance with EPMA analyses, B. Luo for assistance with Raman analyses, A. Steiner and C. Knaack (WSU) and S. and K. Mertzman (Franklin & Marshall) are thanked for their assistance in acquiring whole rock analyses.

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ABSTRACT

Serpentinites play a vital role in subduction zone processes: as one of the dominant carriers of water in downgoing plates, they are critical constituents in the global volatile cycle and add complexity to the bulk rheology and density of downgoing and overlying plates, with strong implications for seismicity and mechanical mixing. These rocks can form in a number of tectonic settings where water reacts with peridotite under certain conditions, including at or near mid-ocean ridges and in mantle overlying dehydrating subducted plates. In the HP/LT terrane preserved on the island of New Caledonia, serpentinites outcrop as meter-scale resistant blocks and as highly deformed "matrix" that hosts a range of metasedimentary, metamafic, and meta-ultramafic lenses. The origin of these HP serpentinites has been debated, with competing hypotheses linking protolith to nearby obducted ophiolite or to the subducted oceanic plate. We analyzed 30 serpentinites and associated hybrid rocks from across the HP terrane to discern the tectonic origin of their protoliths and to better understand their reaction history through subduction and exhumation. Whole rock major and trace element and stable isotope geochemistry reveal the existence of at least two distinct types of serpentinites in the HP terrane. Serpentinites in the far NE exhibit elevated HREE's, $\delta^{18}O$ values of 6-10‰, and scatter in major element concentrations. In the SE, a ~1 km^2 ultramafic massif contains serpentinites with relatively more depleted REE, $\delta^{18}O$ values of 5-7‰, and a more restricted range of major element concentrations, with distinctly higher MgO and lower Al_2O_3 than samples from the NE. We compare these data to a global geochemical compilation of serpentinites from various tectonic settings. Ongoing Raman spectroscopy work will determine serpentine polymorph(s) and electron probe microanalysis will target isolated relict pyroxene grains and oxide minerals to retrieve additional protolith information. The recognition of multiple types of serpentinites in this HP/LT terrane adds important information to debate about the origin of the ultramafic material, and may speak to complex interactions between the downgoing plate and overlying mantle or to systematic spatial differences in protolith composition or degree of metamorphism or deformation.

REFERENCES

Cluzel, Dominique, et al. "Late Oligocene post‐obduction granitoids of New Caledonia: A case for reactivated subduction and slab break‐off." Island Arc 14.3 (2005): 254-271.

Cluzel, Dominique, et al. "Slab-derived origin of tremolite–antigorite veins in a supra-subduction ophiolite: the Peridotite Nappe (New Caledonia) as a case study." International Journal of Earth Sciences 109.1 (2020): 171-196.

Deschamps, Fabien, et al. "Geochemistry of subduction zone serpentinites: A review." Lithos 178 (2013): 96-127.

Eiler, John M. "Oxygen isotope variations of basaltic lavas and upper mantle rocks." Reviews in mineralogy and geochemistry 43.1 (2001): 319-364.

Fitzherbert, J. A., et al. "The origin and P–T evolution of peridotites and serpentinites of NE New Caledonia: prograde interaction between continental margin and the mantle wedge." Journal of Metamorphic Geology 22.4 (2004): 327-344.

Jagoutz, Emile, et al. "The abundances of major, minor and trace elements in the earth's mantle as derived from primitive ultramafic nodules." Lunar and Planetary Science Conference Proceedings. Vol. 10. 1979.

Kyser, T. Kurtis, and James R. O'Neil. "Hydrogen isotope systematics of submarine basalts." Geochimica et Cosmochimica Acta 48.10 (1984): 2123-2133.

Mattey, David, David Lowry, and Colin Macpherson. "Oxygen isotope composition of mantle peridotite." Earth and Planetary Science Letters 128.3-4 (1994): 231-241.

McDonough, William F., and S-S. Sun. "The composition of the Earth." Chemical geology 120.3-4 (1995): 223-253.

Scambelluri, Marco, Enrico Cannaò, and Mattia Gilio. "The water and fluid-mobile element cycles during serpentinite subduction. A review." European Journal of Mineralogy 31.3 (2019): 405-428.

Spandler, Carl, et al. "The importance of talc and chlorite “hybrid” rocks for volatile recycling through subduction zones; evidence from the high-pressure subduction mélange of New Caledonia." Contributions to Mineralogy and Petrology 155.2 (2008): 181-198.

Ulrich, Marc, et al. "Serpentinization of New Caledonia peridotites: from depth to (sub-) surface." Contributions to Mineralogy and Petrology 175.9 (2020): 1-25.