Serpentinites of Different Tectonic Origin in an Exhumed Subduction Complex (New Caledonia, SW Pacific)

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Abstract

Owing to the importance of serpentinites for planetary geochemical and geodynamic processes, there has been much work discerning the origins of their parent rocks, including distinguishing between serpentinites derived from a subducting plate vs. overlying mantle in exhumed subduction complexes. The island of New Caledonia (SW Pacific Ocean) provides a rare window into Cenozoic Pacific subduction processes. The island is unique in exposing both an exceptionally-preserved high-pressure, low-temperature subduction complex and one of the largest supra-subduction zone ophiolites in the world. Previous studies disagree on the origin of serpentinites in the subduction complex. In this study, we analyze twenty-three serpentinites from this subduction complex for whole-rock major and trace element geochemistry and stable isotope (δD , $\delta^{18}O$) compositions. Our data reveal two distinct groups of serpentinites: Group I samples in the northern portion of the complex are pervasively serpentinized, and exhibit enriched heavy rare earth element (REE) compositions and $\delta^{18}O$ between +6.7preserve relict orthopyroxene and olivine, and show depleted trace element compositions and comparatively lower $\delta^{18}O$ values between +5.1derive from downgoing plate mantle, whereas Group II serpentinites derive from overlying mantle wedge, exhibiting remarkable similarity to the REE geochemistry of the structurally-overlying New Caledonia ophiolite. Our results establish the subduction complex in New Caledonia as an unusual natural record of the entrainment and exhumation of mantle from both the overlying mantle wedge and the downgoing plate in an oceanic subduction zone.

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13	Key Points:
14 15	• Two compositionally-distinct types of serpentinites identified in the New Caledonia subduction complex
16 17	• Some serpentinites derive from the subducting plate; others from the overlying mantle wedge
18 19 20 21	• New Caledonia preserves evidence for incorporation and exhumation of mantle hangingwall via the subduction channel

22 Abstract

23 Owing to the importance of serpentinites for planetary geochemical and geodynamic 24 processes, there has been much work discerning the origins of their parent rocks, including 25 distinguishing between serpentinites derived from a subducting plate vs. overlying mantle in 26 exhumed subduction complexes. The island of New Caledonia (SW Pacific Ocean) provides a 27 rare window into Cenozoic Pacific subduction processes. The island is unique in exposing both an exceptionally-preserved high-pressure, low-temperature subduction complex and one of the 28 29 largest supra-subduction zone ophiolites in the world. Previous studies disagree on the origin of 30 serpentinites in the subduction complex. In this study, we analyze twenty-three serpentinites 31 from this subduction complex for whole-rock major and trace element geochemistry and stable 32 isotope (δD , $\delta^{18}O$) compositions. Our data reveal two distinct groups of serpentinites: Group I 33 samples in the northern portion of the complex are pervasively serpentinized, and exhibit enriched heavy rare earth element (REE) compositions and δ^{18} O between +6.7‰ and 10.2‰. In 34 35 contrast, Group II serpentinites in the south preserve relict orthopyroxene and olivine, and show depleted trace element compositions and comparatively lower δ^{18} O values between +5.1‰ and 36 37 +8.0‰. We interpret Group I serpentinites to derive from downgoing plate mantle, whereas 38 Group II serpentinities derive from overlying mantle wedge, exhibiting remarkable similarity to 39 the REE geochemistry of the structurally-overlying New Caledonia ophiolite. Our results 40 establish the subduction complex in New Caledonia as an unusual natural record of the 41 entrainment and exhumation of mantle from both the overlying mantle wedge and the 42 downgoing plate in an oceanic subduction zone.

43 Plain Language Summary

44 The hydration of Earth's mantle produces rocks called serpentinites that are important to chemical cycling within the Earth system. This process, a form of metamorphism, occurs in 45 46 several types of tectonic settings on Earth. Serpentinites formed in these different settings are 47 imparted with unique geochemical "fingerprints" due to different types of fluids and varied 48 compositions of the original mantle material. In metamorphic complexes that preserve remnants 49 of subduction zones, serpentinites can offer clues to the original tectonic setting and subsequent 50 mechanics of subduction. We analyze stable isotope and whole-rock compositions to determine 51 the origin of the mantle that produced serpentinites found in the metamorphic complex preserved in New Caledonia (SW Pacific). We discover two distinct groups of serpentinites: one group in the northern portion of the complex likely formed on the ocean floor prior to subduction, and experienced high degrees of fluid alteration as it was metamorphosed. In contrast, a second group of serpentinites in the southern portion of the complex resembles material from the mantle overlying the subducting plate and is less altered. This locality represents an uncommon example, globally, where material from this overlying mantle is entrained and preserved at the surface in an exhumed subduction complex.

59 **1 Introduction**

60 Serpentinities are hydrated fragments of Earth's mantle and commonly occur in exhumed subduction complexes. They are important vehicles in the global cycling of water, carbon, 61 62 nitrogen, fluid-mobile elements (FME), and halogens, releasing these elements by prograde dehydration at forearc to subarc depths during subduction (e.g., Alt et al., 2013; Barnes et al., 63 64 2018; Collins et al., 2015; Deschamps et al., 2011; Halama et al., 2014; Hattori & Guillot, 2003; 65 John et al., 2011; Kerrick & Connolly, 1998; Kodolanyi et al., 2012; Scambelluri et al. 2004, 2019; Tenthorey & Hermann, 2004; van Keken et al., 2011). Serpentinites and their hybridized, 66 67 metasomatized derivatives formed at depth in subduction zones are critical in producing the 68 distinct chemical composition of arc magmas (e.g., Codillo et al. 2018; Hattori & Guillot, 2003; 69 Marschall & Schumacher, 2012; Nielsen & Marschall, 2017; Shimoda & Kogiso, 2019; Tatsumi, 70 1986) and contribute significantly to the net redox budget of subducted oceanic plates and the 71 oxidation state of dehydration fluids infiltrating the overlying mantle (Debret & Sverjensky, 72 2017; Evans, 2012; Evans & Frost, 2021; Evans et al., 2017). The wide stability field of the 73 serpentine mineral antigorite also makes possible the transport of these chemical components 74 deeper into the mantle, past subarc depths (e.g., Hacker, 2008; Hattori & Guillot, 2003; Kendrick 75 et al., 2011, 2017; Scambelluri & Tonarini, 2012; Schmidt & Poli, 1998; Ulmer & Tromsdorff, 76 1995; Wunder & Schreyer, 1997).

Serpentinites are also critical to the rheology of the subducting zone, and in particular the
plate interface (Gerya et al., 2002; Hermann et al., 2000; Rüpke et al., 2004; van Keken et al.,
2011). Their high water contents and low density facilitate the exhumation of denser blueschist
and eclogite (Guillot et al., 2000; Magott et al., 2020; Schwartz et al., 2001), and serpentinization
of the cold "nose" of the mantle wedge carries implications for mantle wedge flow and the

82 minimum depth of decoupling of the subducting plate and overlying mantle (Hilairet & Reynard, 83 2009; Kerswell et al., 2021; Reynard, 2013; Wada et al., 2008). Furthermore, serpentinites have 84 been correlated with zones of slow slip and intermediate-depth seismicity in subduction zones, 85 possibly associated with dehydration embrittlement resulting from the breakdown of antigorite (Behr & Bürgmann, 2021; Ferrand, 2019; Hacker et al., 2003; Hilairet et al., 2006, 2007; Hirth & 86 87 Guillot, 2013; Jung & Green, 2004; Peacock, 2001; Proctor & Hirth, 2015; Toffol et al., 2022). 88 In short, the occurrence, composition, and spatial distribution of serpentinites and associated 89 metasomatic rocks in paleo-subduction complexes reveals information about first-order 90 subduction processes, including the transport and chemical evolution of fluids during subduction 91 and exhumation.

92 In exhumed subduction complexes, mantle material may originate from the downgoing 93 plate or the overriding plate (Figure 1). Prior to subduction, serpentinites form in the (eventual) 94 downgoing plate via hydrothermal circulation at ridge-transform systems where lithospheric 95 mantle underlying the igneous oceanic crust or exposed at/near the seafloor by extension is 96 hydrated by heated seawater (Barnes & O'Neil, 1969; Bonatti, 1976; Cannat, 1993; Cannat et al., 97 2010; Mével, 2003; Rouméjon et al., 2015). Hydration may also occur as the plate approaches 98 the trench, if water circulates through slab-bend faults (Ranero et al., 2003). In the overriding 99 plate, the mantle wedge experiences hydration from fluid fluxing off the dehydrating downgoing 100 plate (e.g., Bostock et al., 2002; Fyfe & McBirney, 1975; Hyndman & Peacock, 2003).

101 Serpentinites formed in each of these distinct tectonic settings are geochemically distinct 102 owing to differences in (1) mantle protolith composition (i.e., melt depletion and refertilization 103 histories and degrees of fractional crystallization) and (2) the chemistry and nature of fluid 104 alteration, such as fluid-rock ratio and temperature of serpentinization (Figure 1) (e.g., 105 Deschamps et al., 2010, 2013; Peters et al., 2017). These distinctions are evident in bulk-rock 106 major and trace element geochemistry, stable isotopes (e.g., O, H, Cl, B), and the composition of 107 relict primary minerals (e.g., spinel, pyroxene, and/or olivine) and have been proposed to be 108 diagnostic of the tectonic setting of serpentinization. This has unlocked opportunities to discern 109 the tectonic setting of mantle material exhumed in subduction complexes (Deschamps et al., 110 2010, 2013; Peters et al., 2017).

Studies aiming to determine the tectonic source of formerly subducted serpentinites must grapple with a nuanced, multi-staged history of serpentinization associated with pre-subduction processes and the prograde and retrograde paths of subduction and exhumation (Figure 1). Quantitatively determining the pressure (P), temperature (T), and time (t) conditions experienced by exhumed serpentinites is challenging owing to high-variance phase assemblages, though promising new approaches expand options for unlocking both temperature and time in these rocks (Cooperdock & Stockli, 2016; Schwartz et al., 2020).

118 Complexities notwithstanding, there is a growing body of literature with examples of 119 provenance interpretations of serpentinites in exhumed subduction complexes, such as studies 120 assigning serpentinite associated with blueschist and eclogite to the downgoing plate (e.g., 121 Cooperdock et al., 2018; Katzir et al., 2000; Li et al., 2004; Scambelluri et al., 1991; Shen et al., 122 2015). Some studies have further resolved detail within the oceanic realm of the protolith, 123 interpreting exhumed serpentinites to derive from passive margin settings (e.g., Barnes et al., 124 2014) or from abyssal transform faults (e.g., Cárdenas-Párraga et al., 2017). In many cases, 125 however, non-distinctive geochemical signatures, lack of relict phases, and heterogeneity of the 126 analyzed samples makes this level of resolution untenable. In other regions, the capturing of 127 hanging wall mantle via subduction erosion and other mass transfer mechanisms has been 128 identified (e.g., Bhat et al., 2019; Guice et al., 2021; Hattori et al., 2010; Lazar et al., 2021; Li et 129 al., 2018; Tewksbury-Christle et al., 2021; Wu et al., 2018). In yet other localities, serpentinites 130 from both the downgoing slab and the overlying mantle wedge are interpreted to be present, 131 implying complex slab-mantle interactions at a range of depths (e.g., Barnes et al., 2013; Blanco-132 Quintero et al., 2011). These results generate discussion of deep tectonic slicing of slabs at depth, 133 degrees of mechanical mixing and styles of deformation (e.g., coherent nappe stacking, block-134 and-matrix shear zones), and the processes of underplating and interaction with the mantle 135 material of the overriding plate.

In this contribution, we discern the tectonic origin and alteration histories of serpentinites entrained in an Eocene high-pressure / low-temperature (HP/LT) subduction complex on the island of New Caledonia (SW Pacific) and explore implications for the subduction and exhumation history of the complex. The island of New Caledonia exposes an extraordinarily complete Eocene subduction-obduction complex, including a high-temperature metamorphic sole representing incipient stages of subduction initiation, an HP/LT subduction complex, and an

142 obducted supra-subduction zone ophiolite sequence (Maurizot et al., 2020a). These entities are 143 well-studied and world-class sites: the ophiolite comprises one of the world's largest continuous 144 mantle exposures and has provided invaluable insights into upper mantle processes and melt 145 transfer in the lower crust (e.g., Cluzel et al., 2016; Dupuy et al., 1981; Marchesi et al., 2009; 146 Pirard et al., 2013; Secchiari et al., 2016, 2018; Ulrich et al., 2010). The subduction complex 147 exposes slivers of oceanic and thinned continental lithosphere that experienced blueschist and 148 eclogite-facies metamorphism and has served as a location for investigation of subduction zone 149 fluid-rock interaction, volatile recycling, and slab-mantle interactions (e.g., Cluzel, 2021; 150 Spandler et al., 2008; Taetz et al., 2016, 2018). Despite the geodynamic importance of mantle 151 rocks throughout the subduction-obduction complex, studies addressing the distribution, 152 structure, texture, or geochemistry of meta-ultramafic rocks in the HP/LT complex are few 153 (Cluzel, 2021; Fitzherbert et al., 2004; Rawling & Lister, 2002; Spandler et al., 2008). These 154 studies arrive at differing conclusions regarding the source of the ultramafic material entrained in 155 the complex. To evaluate these differences and determine the tectonic provenance and 156 petrogenesis of ultramafic rocks in this subduction complex, our approach integrates field 157 observations, petrographic characterization, whole rock major and trace element geochemistry, 158 and stable isotope (O and H) geochemistry. Our results reveal the existence of two distinct 159 groups of serpentinites, which we interpret to indicate differing tectonic settings for their 160 protoliths.

161 2 Geologic History of New Caledonia

162 Located in the SW Pacific Ocean, the main island of New Caledonia exposes a dense 163 array of geologic terranes that record Paleozoic and Mesozoic histories through to present day: a 164 material archive that stands in contrast to many other islands in the Pacific, which are mostly 165 entirely Cenozoic in age and volcanic in origin (Cluzel et al., 2012; Maurizot et al., 2020a; Paris, 166 1981). The island (~16,000 km²) is a rare emergent portion of the NW-SE trending submarine 167 Norfolk Ridge, a continental sliver located ~200-400 km southwest of active subduction at the 168 New Hebrides trench and comprising part of the largely submerged Zealandia microcontinent 169 (Figure 2a) (Crawford et al., 2003; Dubois et al., 1974; Lafoy et al., 2005; Mortimer et al., 2017). 170 New Caledonia exposes Late Carboniferous to Early Cretaceous basement rocks deriving 171 from the last accretionary stages of the active southern Gondwana margin (Figure 2b,

172 'undifferentiated "basement" terranes') (Aitchison & Meffre, 1992; Campbell et al., 1985; 173 Maurizot et al., 2020b); unless otherwise noted, we adopt the naming conventions of Maurizot et 174 al. (2020c) for New Caledonian rock units. In the Late Cretaceous, regional tectonic stresses 175 shifted, prompting divergence and rifting associated with the breakup of the Gondwanan 176 supercontintent. In the SW Pacific, the Tasman Sea and additional small ocean basins opened, 177 rifting ribbons of continental crust away from the eastern margin of Gondwana (Figure 2a) (e.g., 178 the submarine Dampier Ridge and Lord Howe Rise, for instance; e.g., Bache et al., 2014; Davies 179 & Smith, 1971; Mortimer et al., 2018).

180 Plate convergence in the SW Pacific began in the Late Paleocene, with an intra-oceanic 181 NE-dipping subduction zone initiating at ~56 Ma, as recorded by the recrystallization age of 182 high-temperature amphibolite in the basal sole of the ophiolite, and further corroborated by 183 boninite and adakite series dikes that range from 55-50 Ma (Cluzel et al., 2006, 2012). Two 184 distinct packages of differing protolith types and P-T-t paths are recognized to have been 185 subducted and exhumed. The Pouébo Terrane (Figure 2c, d), which subducted first, consists of 186 fragments of oceanic lithosphere, and was followed by the Diahot-Panié Complex (Figure 2c, d), 187 which consists dominantly of metasediments and metavolcanic rocks (Cluzel et al., 1994; Clarke 188 et al., 1997; Maurizot et al., 2020b). The Pouébo Terrane reached peak eclogite facies 189 metamorphic conditions of ~2.2-2.4 GPa and ~550-600°C, equating to ~70-80 km burial depth, 190 by ~44 Myr (Pirard & Spandler, 2017; Spandler et al., 2005; Vitale-Brovarone et al., 2013). The 191 Diahot-Panié Complex ranges in grade from lawsonite-blueschist facies (~0.5 GPa, ~250°C) to 192 eclogite facies (~1.8-2.2 GPa, ~500-550°C) and likely reached peak conditions at ~38 Ma 193 (Cluzel et al., 2010; Pirard and Spandler, 2017; Potel et al., 2006; Vitale-Brovarone et al., 2018). 194 Exhumation is interpreted to have occurred in two stages: the first stage brought the Pouébo 195 Terrane rocks up to ~40-50 km, where they were juxtaposed with the Diahot-Panié Complex. In 196 the second stage, the two terranes exhumed together between 38-36 Myr, with the last gasps of 197 rapid exhumation taking place at ~34 Ma (Baldwin et al., 2007; Vitale-Brovarone et al., 2018). 198 The arrival and partial subduction of the buoyant continental-affinity Diahot-Panié Complex 199 effectively halted subduction and triggered the obduction of a large fragment of overlying fore-200 arc mantle and oceanic crust from the modern-day Loyalty Basin onto Grande Terre (referred to 201 as the Peridotite Nappe and Poya Terrane, respectively; Brothers, 1974; Coleman, 1967).

202 2.1 Ultramafic rocks in New Caledonia

203 Ultramafic rocks occur in several discrete tectonic terranes on the island. We briefly
 204 summarize the state of knowledge with respect to the provenance of these mantle rocks,
 205 organized into tectonic groups.

206 2.1.1. The Peridotite Nappe: Massif du Sud and isolated ophiolitic klippen

207 The southern end of New Caledonia is dominated by the Massif du Sud, one of the 208 largest coherent exposures of mantle in the world (Figure 2b). This body is notably free of 209 significant tectonic overprint and remains attached to non-obducted lithospheric mantle in some 210 areas (Collot et al., 1987; Patriat et al., 2018; Prinzhofer & Nicolas, 1980). Additional remnants 211 of the large overthrust ophiolite dot the west coast of the island as small klippen. Most of the 212 mantle portion of the Nappe consists of harzburgite and dunite, with lherzolite being found in the 213 north (Belep, Poum, and Tiébaghi massifs; Moutte, 1982; Prinzhofer, 1981; Sécher, 1981; Ulrich 214 et al., 2010). The transition to the crustal sequence (pyroxenite, wehrlite, and gabbro) is 215 preserved on the southern portion of the island; the ophiolite lacks an uppermost dike complex 216 and pillow basalts (Maurizot et al., 2020c). The ophiolite is highly geochemically depleted 217 (Marchesi et al., 2009; Prinzhofer & Allègre, 1985), implying high degrees of melt production, 218 and this has made this body, and in particular, the continuous exposures in the Massif du Sud, a 219 globally-important site for studying melt transfer within the mantle and into the lower crust 220 (Marchesi et al., 2009; Pirard et al., 2013; Pirard & Hermann, 2015; Ulrich et al., 2010).

221

2.1.2. "Basement" ultramafic bodies of Gondwanan affinity

222 Serpentinites are reported in several Gondwanan basement terranes on the island. 223 Portions of these units experienced local low-grade (greenschist and/or lawsonite blueschist 224 facies) overprinting by Eocene HP/LT metamorphism. In some cases, serpentinites occur 225 amongst swaths of schist and contain tectonically-entrained oceanic crustal components (e.g., 226 metamorphosed pyroxenite, gabbro, basalt, chert). This ultramafic material is proposed to derive 227 from an incoming oceanic plate that reached maximum depths of ~30-35 km beneath the 228 overriding Gondwanan plate ('Boghen Terrane'; Black, 1993; Cluzel & Meffre, 2002; Guérangé 229 et al., 1977; Maurizot et al., 2020b). In other localities within the basement, serpentinites appear 230 at faulted boundaries between coherent volcanic and abyssal sedimentary units (e.g., chert,

siltstones) (Maurizot et al., 2020b; Meffre et al., 1996). Published geochemical data on these
rocks are lacking and a protolith origin for these serpentinites is not known.

233 2.1.3. Foreland accretionary units

234 Ultramafic rocks are reported to cross-cut the Montagnes Blanches Nappe, a remnant 235 foreland fold-thrust belt preserved immediately west of the HP/LT complex (Koumac Terrane of 236 Cluzel et al., 1994). Early interpretations link these rocks to the underlying oceanic lithosphere 237 of the folded abyssal Montagnes Blanche Nappe sedimentary units (Brothers, 1974; Maurizot et 238 al., 1989). These rocks have alternatively been interpreted as overthrust remnants of the 239 Peridotite Nappe (Cluzel et al., 1995; Gautier et al., 2016; Maurizot, 2011), though a recent 240 systematic field description of serpentinite occurences in these units by Cluzel (2021) has 241 pointed out inconsistencies with this hypothesis, instead positing that they are part of the upper 242 plate. We emphasize that these hypotheses are based on field context, and published geochemical 243 studies of the serpentinites are lacking.

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2.1.4. Ultramafic and hybrid "blackwall" rocks of the HP/LT complex

Serpentinites occur throughout the HP/LT metamorphic belt in the NE portion of the 245 246 island (Figure 2b-d). The exposed subduction complex is sprawling, spanning ~ 200 km long and 247 \sim 20 km wide. The far northern area of the complex is most often referred to as the Pam 248 Peninsula and exposes some of the best-preserved blueschists and eclogites in the complex 249 (Figure 2c). Though observations and descriptions of serpentinite outcrops exist (e.g., Black & 250 Brothers, 1977; Brothers & Blake, 1973; Cluzel, 2021; Lillie, 1975; Maurizot et al., 1989), 251 geochemical and textural studies of these ultramafic rocks are sparse (Fitzherbert et al., 2004; 252 Spandler et al., 2008), and the tectonic origin of this ultramafic material is debated. Spandler et 253 al. (2008) interpret a seafloor origin based on major and trace element geochemistry, stable 254 isotope measurements, and calculated temperatures of serpentinization for four serpentinite 255 samples in the far NE portion of the complex (Figure 2c). In contrast, Fitzherbert et al. (2004) 256 note the similarity of P-T paths and the existence of serpentinites across mapped terrane 257 boundaries (the Diahot Terrane and Pouébo Terrane of Cluzel et al. (1995) and Fitzherbert et al. 258 (2003)), interpreting this distribution as inconsistent with a downgoing slab origin, and instead 259 indicating interaction with the overlying mantle. This idea can be traced to earlier interpretations 260 that the ultramafic rocks exposed in the metamorphic complex today were part of a larger, now

261 extensively eroded overthrust "serpentinite sheet" that was incorporated from the hangingwall, 262 based on their consistent existence at the structurally highest levels of the complex (Rawling & 263 Lister, 2002). At a small, weathered massif outcropping in the SE portion of the complex, near 264 the town of Yambé (Figure 2d), Fitzherbert et al. (2004) interpret the ultramafic rocks to derive 265 from hanging wall mantle that was incorporated with the downgoing plate, subducting with it to 266 P-T conditions past the stability of antigorite. Critically, a geochemical link between the 267 serpentinites in the HP/LT complex and the interpretation of an overriding plate or supra-268 subduction mantle origin is lacking.

269 **3 Sample Localities and Description**

Twenty-three serpentinites, one chlorite schist, and one talc schist were collected in the HP/LT complex for the purposes of discerning their tectonic origin and fluid histories (Table S1; Figure 2c, d). For comparison, four serpentinites were collected from outside the HP/LT complex: two from the Boghen Terrane basement unit, one from the serpentinite sole at the base of the Peridotite Nappe, and one from Kalaa-Gomen, a small klippe of the ophiolite on the northwest coast (Figure 2b). Representative thin section photomicrographs are presented in Figures S1-S4.

277 3.1 Field Context

278 Serpentinites in the northernmost portion of the HP/LT complex - defined here as an area 279 encompassed by the Pam Peninsula and extending south along the eastern coastal road (RPN7) to 280 the town of Balade - outcrop both as highly sheared and deformed lenses and as weathered 281 boulders on hillslopes (Figure 2c). In highly sheared areas, the serpentinities act as a matrix for 282 rounded pods of metamorphosed mafic, sedimentary, and other ultramafic rocks. With the 283 exception of a small quarry south of Col d'Amos (NC19-14) and a locality in the foothills north 284 of Ouégoa (NC18-26), all samples group spatially within the "Pouébo-Tiari" unit of Vitale-285 Brovarone et al. (2018). These samples are entirely encompassed within the "mélange 286 ophiolitique glaucophanite" unit of Maurizot et al. (1989) and fall variably within the "Pouébo 287 metabasite dominates" and "Diahot metabasite dominates" units of Fitzherbert et al. (2004).

Nine samples in the HP/LT complex are located SE of the northern domain samples. A
 small (~ 0.5 km²) ultramafic body crops out within blueschist and eclogite facies metamafic

rocks near the town of Yambé (Figure 2d). Prior studies reference this ultramafic body as
"Yambé" or "Yambé massif" (Fitzherbert et al., 2004; Spandler et al., 2008) and "Pwa Radèn"
(e.g., Cluzel, 2021). With permission from Kanak tribal leadership, we adopt the local name
given to this ultramafic body, "Poadja." In some areas of the Poadja Massif, relict magmatic
foliation is discernable at outcrop scale. Further south along the coast, two minor serpentinite
outcrops (within 1 km of each other) are exposed in shear zones in beach outcrops, juxtaposed
with meta-mafic blocks.

297 3.2 Petrographic Context

298 Serpentinites in the NE region are characterized by a dominant mineral assemblage of 299 antigorite + talc + magnetite (Table S1; Figures 3a, b and S1) and are > 90% serpentinized, with 300 rare relict chromian spinel (NC19-54), olivine (NC18-26B), and clinopyroxene (NC19-54). 301 Antigorite most commonly occurs as the dominant matrix phase, forming interlocking crystals 302 with variably preserved evidence for mesh texture. Some samples exhibit anhedral fine-grained 303 $(<10 \,\mu\text{m})$, recrystallized antigorite intergrown with talc and less commonly, tremolite (e.g., 304 NC18-15C, NC18-15D, NC18-22A). In some cases, well-developed bastite pseudomorph 305 textures are evidenced by clumped aggregates of coarser-grained (~100-200 µm) euhedral 306 antigorite crystals accompanied by euhedral magnetite (~ 10 's of μ m) (e.g., NC19-86). Magnetite 307 additionally occurs as a matrix phase as single subhedral grains (~10's of μ m up to ~1 mm) or as 308 polymineralic aggregates of smaller euhedral grains ($\sim 10^{\circ}$ s of um). In deformed samples these 309 aggregates lie within the foliation (e.g., NC19-54, NC18-22A). In rare cases, relict chromite is 310 preserved in the core of grains mantled by ferritchromite and rimmed by magnetite (Figure 3a). 311 Two types of veins assemblages are present as cross-cutting networks: antigorite-magnetite 312 (NC19-86; Figures S1e, j) and antigorite-tremolite (NC19-94; Figure 3b).

Serpentinites in the SE region are characterized by the presence of relict phases (orthopyroxene and olivine) and range between ~50 to ~90% serpentinized (Table S1; Figures 3c-f and S2). Samples from this locality notably lack talc (with the exception of NC19-158), and four samples contain the Fe-Ni alloy awaruite as an accessory phase (Figure 3d). Oxide textures show varying degrees of retrogression from skeletal chromite with magnetite rims (Figure 3c) to chromian magnetite cores complexly replaced by magnetite (Figure 3e). Texturally-late brucite veins are observed in one sample (NC18-39A). Mesh textures are less developed compared tothe complete pseudomorphing observed in the NE (Figure 3f).

321 **4 Methods**

322 4.1 Whole-rock major and trace element geochemistry (XRF, ICP-MS) 323 Twenty-three serpentinites, one talc schist, and one chlorite schist were analyzed for 324 whole-rock major and trace element compositions. Major element analyses were acquired by 325 lithium tetraborate fusion X-ray fluorescence methods at the GeoAnalytical Laboratory 326 (Washington State University, USA; WSU) and Franklin & Marshall College (Pennsylvania, 327 USA; F&M). Hand-picked fresh chips of each sample were powdered and fused on-site. 328 Additional details on preparation and fusion are reported in supporting information S1. At WSU, 329 major elements were analyzed on a ThermoARL Advant'XP+sequential X-ray fluorescence 330 (XRF) spectrometer using the preparation and analytical procedure described in detail by 331 Johnson et al. (1999) and Kelly (2018). At F&M, major elements were analyzed on a Malvern 332 PANalytical Zetium X-ray fluorescence spectrometer. Trace element concentrations were 333 acquired at WSU and the University of Rhode Island (USA). Digestions and dilution were 334 performed on-site. At WSU, trace elements were analyzed on an Agilent quadrupole ICP-MS 335 using the method of Knaack et al. (1994). Analytical precision is <5% for REE's and <10% for 336 the remaining elements. At University of Rhode Island, trace elements were analyzed on a 337 Thermo X-Series 2 quadrupole ICP-MS following the method of Savov et al. (2005). 338 Interference corrections were applied for TiO on Zn, Ba++ on Ga, and CrO on Nb. Analytical 339 precision is <5% for most elements, and precision for Cr and Ni was <2%. Two samples (NC18-340 15D, NC18-49) were analyzed by all three labs (Table S2, S3).

341

4.2 Oxygen and hydrogen stable isotope geochemistry

Oxygen and hydrogen isotope compositions of serpentine, talc, and magnetite mineral separates were measured at the University of Texas at Austin using a ThermoElectron MAT 253 mass spectrometer. Serpentinite samples were coarsely crushed and handpicked under a binocular microscope to ensure purity of mineral separates. Handpicked serpentine and talc grains were washed with dilute HCl to remove any trace carbonate material. Approximately 2.0 mg of each mineral separate were analyzed using the laser fluorination method of Sharp (1990) 348 in which samples were heated by a CO₂ laser in the presence of a BrF₅ atmosphere to liberate 349 oxygen. Liberated oxygen was cryogenically purified and analyzed as O₂. Precision and accuracy 350 of oxygen analyses were verified through garnet standard UWG-2 ($\delta^{18}O = +5.8\%$) (Valley et al., 351 1995), in-house olivine standard San Carlos ($\delta^{18}O = +5.2\%$), and in-house quartz standard Lausanne-1 ($\delta^{18}O = +18.1\%$). All $\delta^{18}O$ values are reported relative to SMOW, where the $\delta^{18}O$ 352 value of NBS-28 is +9.7‰. The error on each δ^{18} O analysis is ±0.1‰, based on the long-term 353 354 average of standard analyses. Seven samples were run in duplicate to ensure reproducibility and 355 consistency over four analytical runs.

356 Hydrogen isotope ratios were measured using the method of Sharp et al. (2001). Samples 357 were hand-powdered using an agate mortar and pestle. Approximately 1 mg of each sample were 358 loaded into silver foil capsules, dried under vacuum at 70° C for 24 h, transferred to a Costech 359 zero-blank autosampler, and flushed with He gas. Samples were measured by continuous-flow 360 mass spectrometry using a ThermoElectron TC/EA (high-temperature conversion elemental 361 analyzer) coupled to the ThermoElectron MAT 253 mass spectrometer. Four internationally 362 referenced and certified standard materials (IAEA-CH7, NBS-22, USGS-57, USGS-58) and one 363 in-house working glass standard were analyzed with the samples throughout the run. Raw δD 364 values were corrected for instrumental drift and normalized to SMOW using a calibration curve 365 generated from the measurements of the standard reference materials. Error based on the 366 reproducibility of standards measured in the analytical runs is $\pm 2\%$. δD values referenced in the 367 text and plotted are the mean of two individual replicate analyses.

368 4.3 Raman spectroscopy

369 Raman spectra were acquired on eight serpentinite samples (two samples from Group I, 370 four samples from Group II, one from the Boghen Terrane, and the sample from Kalaa-Gomen). 371 In situ spot analyses on $30 \,\mu\text{m}$ polished thin sections were acquired on a Witec Alpha 300R 372 confocal Raman microscope at the Characterization Facility, University of Minnesota. The 373 confocal Raman microscope is equipped with a UHTS300 spectrometer and DV401 CCD 374 detector. Spectra were acquired with a frequency doubled Nd:YAG 532 nm laser, a 1,800 g/mm 375 grating, and a 100x objective. Spot size was $\sim 1 \,\mu m$ in diameter. Each spectra resulted from the 376 average of two 20 s acquisitions to optimize the signal/noise ratio. Two spectral intervals were 377 measured: a low-wavenumber region (100-1200 cm⁻¹) for structural bonding characterization and a high-wavenumber region (3300- 4050 cm⁻¹) for characterization of hydroxyl groups. A range

379 of relevant textural settings were targeted in each thin section (e.g., serpentine matrix, veins, and

380 pseudomorphs). Data were processed using the WITec Project Five+ software. Raw spectra

381 underwent background subtraction followed by smoothing using a third-order polynomial

382 Savitzsky-Golay filter. Serpentine species were identified by comparison to previously published

data (Auzende et al., 2004; Groppo et al., 2006, Petriglieri et al., 2015; Tarling et al. 2018).

384 **5 Results**

385 5.1 Whole rock major elements

386 Serpentinites from the HP/LT complex display differences in SiO₂, Al₂O₃, MgO, and 387 CaO contents and cluster in two distinct geochemical groupings (Table 1; Figure 4). One group 388 of serpentinities (n = 15; herein referred to as Group I) is depleted in MgO compared to other 389 serpentinites (herein referred to as Group II, n = 9): 34.05 \pm 3.34 wt% in Group I versus 40.19 \pm 390 3.20 wt% in Group II. Group I serpentinites contain higher Al₂O₃ contents than Group II (2.34 \pm 391 1.47 versus 0.75 ± 0.34 average wt%, respectively). Group I samples are generally elevated in 392 SiO₂ compared to Group II, though they overlap within uncertainty, with averages of $44.96 \pm$ 393 5.23 wt% and 41.13 ± 2.13 wt%, respectively. Fe₂O_{3(T)} contents do not vary significantly 394 between the two groups, though samples in Group I display a broader range of variation (7.92 \pm 395 1.85 wt % versus 7.38 ± 0.68 wt% for Group II). CaO concentrations in the HP/LT serpentinites 396 overall are <0.5 wt%, with the exception of the three least serpentinized samples (Table 1 and 397 Figure S2); all Group II samples located in the SE portion of the complex (0.53, 0.57, and 1.08 398 wt%). The ophiolitic reference sample from Kalaa-Gomen (NC19-178) has 0.66 wt% CaO. 399 Samples have a range of loss-on-ignition (LOI) values, from 5.25 to 12.64%, indicating varying 400 degrees of hydration, with an overall average of 10.43% \pm 2.77%. Na₂O, K₂O, and P₂O₅ are 401 close to or below detection limits.

402 The chlorite schist (NC19-85) is elevated with respect to the talc schist (NC19-169) in 403 Al₂O₃, Fe₂O_{3(T)}, and TiO₂, whereas the talc schist is elevated in SiO₂ and MgO (Table 1). The 404 chlorite schist (NC19-85) has CaO and P₂O₅ contents of 2.47 and 1.88 wt%, respectively, due to 405 the presence of ~5% modal abundance apatite.

406 5.2 Whole-rock trace elements

407	Group I and II samples are overall depleted in trace elements with respect to primitive
408	mantle (Figure 5a, b). Both groups show enrichments in Cs and Pb and negative Rb and Nb
409	anomalies. Group I samples show marked Th and U enrichments and a strong negative Sr
410	anomaly compared to Group II. Group I samples show greater overall enrichment enrichment in
411	middle to heavy rare-earth elements (M-HREE; Sm, Eu, Gd, Tb, Dy, Y, Ho, Er, Yb, Lu)
412	compared to Group II (Figure 5c-f). Differences in the pattern of light-rare earth elements
413	(LREE; La, Ce, Pr, Nd, Pm) to HREE most clearly distinguish the two groups (La _N /Ho _N = $1.66 \pm$
414	1.33 for Group I and 6.59 \pm 1.92 for Group II; normalized to primitive mantle).
415	The chlorite schist (NC19-85) and talc schist (NC19-169) samples display distinct
416	enrichments in trace elements. The chlorite schist is enriched in Li, Sc, V, Cu, Zn, Sr, Y, Zr, Nb,
417	Ba, La, Ce, Pr, Nd, Sm, Eu, Tb, Gd, and Dy relative to the talc schist. Conversely, the talc schist
418	is enriched in Cr and Ni relative to the chlorite schist.

- 419 5.3 Stable isotope geochemistry
- 420 5.3.1 Oxygen isotopes

421 Serpentine from the high-pressure complex displays a wide range of oxygen isotope 422 values: from +5.1 to +10.2‰ (Table 2 and Figure 6a, b). Group I samples are between +6.7 and 423 +10.2‰, whereas Group II samples are between +5.1 to +8.0‰. The mean serpentine δ^{18} O value 424 for Group I is $+8.7 \pm 0.9\%$ (n = 15) and $+5.5 \pm 0.4\%$ (n = 9) for Group II. A Group II sample (NC18-39A) shows a 1‰ increase in δ^{18} O between serpentine extracted from the sample interior 425 (+5.4‰) and serpentine from an outer altered rind (+6.4‰). δ^{18} O sample replicates reproduced 426 427 within 0.2‰, with the exception of two samples, NC18-15D and NC18-22A, which show 428 variability of 1.8‰ and 0.9‰, respectively. Comparative samples from the Boghen Terrane, 429 Kalaa-Gomen Massif, and the Peridotite Nappe serpentinite sole have δ^{18} O values of +7.5‰ 430 (average of two samples), +5.7‰, and +6.5‰, respectively.

431 Oxygen isotopes in magnetite were measured in three samples from the NE part of the 432 complex: a serpentinite (NC19-86), a chlorite schist (NC19-85), and a talc schist (NC19-169). 433 The δ^{18} O value of magnetite is +1.5‰ in the serpentinite and +2.4‰ in the chlorite schist. In the 434 talc schist, two separate grain size fractions were measured, 125-250 µm and >710 µm. The 125435 250 μ m grain size fraction has a δ^{18} O value of +4.3‰, whereas the >710 μ m has a value of +4.6

436 µm. Oxygen isotopes in talc from two samples (one from the SE and one from the NE), were

- 437 +9.0 and +10.5‰, respectively.
- 438 5.3.2. Hydrogen isotopes

 δD values of serpentine in the high-pressure complex range from -79 to -29% (Figure 439 440 6a). Group I sample range between -76 and -29‰ and Group II samples range between -79 and -441 39‰. The mean serpentine δD value is -44 ± 10‰ (n = 30) for Group I and -52 ± 14‰ (n = 18) 442 for Group II. The relatively large standard deviation in both groups derives from three samples 443 (one in Group I and two in Group II) that have δD values between -79 and -70‰. Without these 444 values, the remaining samples from Group I exhibit a more restricted range of δD values from -445 49 to -32, with an average of $-41\pm 5\%$ (n = 28). Group II ranges from -59 to -39‰, with an 446 average of $-46 \pm 8\%$ (n = 14). Comparative samples from the Boghen Terrane, Kalaa-Gomen 447 Massif, and the Peridotite Nappe serpentinite sole have δD values of -81‰ (average of two 448 samples), -85%, and -82%, respectively. Across all samples, δD sample replicates reproduced 449 within 2‰, on average.

450 5.4 Raman spectroscopy

451 Serpentine has three primary structural polymorphs that vary over *P-T* space: the low-T 452 form is chrysotile, followed by lizardite and antigorite. Diagnosing the polymorph in exhumed 453 serpentinites can aid in retrieving information about its prograde and/or retrograde path and 454 alteration. Serpentine in two samples from Group I and four samples from Group II was found to 455 be antigorite (only) in contrast to lizardite identified in comparative samples from the Boghen 456 Terrane basement unit and Kalaa-Gomen massif in the Peridotite Nappe (Figure 7 and S5-6).

457

5.5 Categorization of New Caledonia HP/LT serpentinites

458 As presented above, serpentinites in the high-pressure metamorphic complex cluster in 459 two distinct groups, revealed by petrography, major and trace element, and stable isotope 460 geochemistry. The significance of these groups and their composition will be discussed in the 461 next section. The results are summarized as follows:

462 Group I: >90% serpentinized, common assemblage of antigorite + talc + magnetite,

- 463 lower, more homogeneous MgO contents (relative to Group II), δ^{18} O values between
- 464 +6.7‰ and 10.2‰, flat M-HREE patterns;
- 465 Group II: ~50-90% serpentinized, notable preservation of orthopyroxene and olivine and
- 466 distinct presence of awaruite, higher MgO contents (relative to Group I), δ^{18} O between
- 467 +5.1‰ and +8.0‰, distinct curved LREE to HREE pattern compared to Group I.

468 **6 Discussion**

469 Prior studies of serpentinites in the HP/LT terrane of New Caledonia have disagreed on 470 the tectonic origin of the mantle protolith (Fitzherbert et al., 2004; Spandler et al., 2008). Our 471 results indicate the existence of two geochemically-distinct groups of serpentinites in the 472 blueschist- to eclogite-facies portions of the complex. This heterogeneity may derive from (1) 473 geochemical differences in the original mantle source material, (2) processes occurring 474 throughout serpentinization, (3) subsequent metamorphism during subduction and exhumation, 475 or (4) a combination of the above.

476 6.1 Assessing major and trace element mobility

477 The major and trace element compositions of exhumed serpentinites result from (a) the 478 original composition and melt history of the parent peridotite, (b) fluid-rock reactions occurring 479 at the source location for serpentinization (e.g., seafloor, mantle wedge), and (c) fluid-rock 480 reactions occurring during subduction and exhumation. Extensive study of variably serpentinized 481 abyssal and mantle wedge peridotites and serpentinites in exhumed subduction complexes has 482 demonstrated high-field strength elements (HFSE; Nb, Ta, Zr, Hf) and REE are generally (but 483 not wholly) immobile during serpentinization and aqueous fluid alteration and can be used to 484 discern information about protolith composition and pre-serpentinization magmatic processes 485 (e.g., Deschamps et al., 2013; Kodolányi et al., 2012; Niu, 2004; Parkinson & Pearce, 1998; 486 Savov et al., 2005; Scambelluri et al., 2004). By contrast, major elements and FME (e.g., Li, Pb, 487 U, Cs, Sr, Ba) must be interpreted with additional caution, as serpentinization is not isochemical 488 with respect to some of these elements and/or they are more readily mobilized during fluid 489 interaction over the course of subduction and exhumation (e.g., Cannao et al., 2016; Malvoisin, 490 2015; Peters et al., 2017). With this in mind, we first assess the degree to which major and trace

491 elements in the New Caledonia HP/LT serpentinites may have been mobilized, or whether they492 otherwise retain faithful geochemical signatures of their initial mantle protolith.

493 Ratios of immobile trace elements (e.g., LREE, HFSE vs HREE; La/Yb, Zr/Yb, Hf/Yb, 494 Nd/Yb) are observed to vary independently of LOI for both groups of HP/LT serpentinites 495 (Figure 8). This result, combined with the observed similarity of intra-group REE patterns for 496 Groups I and II (Figure 5), provides initial confidence in the retention of protolith mantle 497 geochemical signatures for these elements (c.f. Savov et al., 2005). For further assessment, plots 498 of LREE (La, Ce, Pr, Nd) versus HFSE (Nb, Ta, Zr, Hf) elucidate whether a common process or 499 processes were responsible for the enrichment or depletion of these groups of elements (c.f. Niu, 500 2004). It is worth noting that LREE are more readily mobilized by aqueous fluids than MREE 501 and HREE, so this test is a conservative indicator of trace element and REE immobility.

502 Group I LREE's are almost entirely decoupled from HFSE (Figure 9). Indications of a 503 once-coupled relationship between the LREE and HFSE are partially retained in a few samples, 504 as indicated by consistent low abundances that correlate somewhat more linearly (but to a degree 505 no longer statistically significant). More often, however, these samples have been overprinted by 506 a process or processes that added LREE (Figure 9). In contrast, statistically significant 507 correlations are observed for Group II serpentinites between the LREE and Zr and Nb (RLREE-Zr 508 $(avg) = 0.942 \pm 0.027$, $R_{LREE-Nb}(avg) = 0.678 \pm 0.024$) (Figure 9). Notably, LREE appear decoupled 509 from Ta and Hf (R_{LREE-Ta (avg)} = -0.267 ± 0.037 , R_{LREE-Hf (avg)} = 0.308 ± 0.106). Of the HFSE, Zr 510 and Nb (here coupled with LREE) are lighter in mass than Ta and Hf. Niu (2004) addresses the 511 potential importance of mass-dependent effects on the observed magmatic fractionation of Nb/Ta 512 and Zr/Hf ratios in global abyssal peridotite datasets, proposing that elevated LREE abundances 513 could be produced or enhanced by mass-dependent transfer rates, but notes that observational 514 tests of this hypothesis are necessary. These data possibly corroborate this hypothesis, 515 particularly given that none of the four elements correlate with LOI. However, the possibility 516 that this decoupling reflect later aqueous alteration processes cannot be ruled out, though it is 517 unclear whether subduction zone temperatures would be sufficiently high enough to mobilize 518 these HFSE.

519 In summary, both groups show variations in trace and REE independent of LOI - a 520 valuable first indicator for retained magmatic trace element signatures. Strong correlation

521 between LREE and HFSE in Group II samples bolsters this argument. Observed mobility in

522 Group I LREE does not preclude us from utilizing the REE data to ascertain a tectonic setting for

523 the mantle protolith, as there is no demonstrated correlation between the M-HREE with LOI;

though care must be taken in interpreting the significance of LREE abundances and their

- 525 contribution to the overall shape of L-HREE trends.
- 526 6.2 Serpentinization processes and fluid interactions

527 Within the ultramafic rock system, oxygen and hydrogen isotopes have been widely 528 utilized to discern the source of serpentinizing fluids and subsequent post-serpentinization fluid 529 histories (e.g., Alt and Shanks, 2006; Burkhard and O'Neil, 1988; Früh-Green et al., 1990, 2001; 530 Kyser et al., 1999). Ultimately, stable isotope values are the amalgamated product of several 531 important variables – the stable isotope composition of the interacting fluid, the fluid-rock ratio, 532 the composition of the reactive solid phase(s) in the system, and the fractionation factors 533 between these components and the fluid. Stable isotope data for the HP/LT serpentinites indicate 534 differing serpentinizing fluid compositions and/or T conditions for serpentinization between the 535 two groups of samples. Group II δ^{18} O values (+5.5 ± 0.4‰) cluster tightly around the typical 536 upper mantle value (+5.4‰), indicating little to no additional alteration of the primary mantle 537 signature during serpentinization, subduction, or exhumation (Figure 6). This assessment is 538 supported by recent stable isotope modeling of the ophiolite that indicates limited interaction of 539 slab sediment-derived fluids within New Caledonia's mantle wedge during the initial phases of 540 subduction (Ulrich et al., 2020). Moreover, these authors discern, on the basis of Sr isotopes and 541 low abundances of sediment-derived elements such as As and Sb (Deschamps et al., 2013), that 542 the input of subducted sediments was low at the time of serpentinization of the mantle wedge, 543 and instead the dehydration of altered oceanic crust comprised the dominant fluid source. 544 Though our data do not include measurements of As and Sb, we observe similarly low degrees of 545 elements typically regarded as classic markers of serpentinization in the mantle wedge via 546 shallow dewatering fluids released from slab sediments and lower-T metamorphic dehydration reactions (e.g., Cs, Sr, Rb, Li) (Figure 1). The narrow range of δ^{18} O values across all degrees of 547 548 hydration (as indicated by LOI %) supports a consistent temperature of serpentinization and/or a consistent fluid composition (Figure 6). The close relation between the δ^{18} O values of Group II 549

serpentinites and antigorite within slab-derived tremolite-antigorite veins in the Peridotite Nappealso supports a similar source for serpentinizing fluids.

552 By contrast, Group I samples show increased and variable δ^{18} O, which may be interpreted to reflect: (1) interaction with metamorphic fluids with a sedimentary component, (2) 553 554 differing temperatures of serpentinization in a seafloor environment, or (3) a mix of these two 555 influences. Both end-member explanations are plausible - all but two Group I samples are 556 located within 2 km of interpreted boundaries between the Pouébo Terrane and the sediment-557 dominated Diahot-Panié Complex. Moreover, significant fluid fluxing is evident for these 558 samples given major element concentrations, which show a clear deviation from the terrestrial 559 array as a function of increasing modal abundances of talc (Figure 6). The development of talc-560 rich serpentinite and hybrid rock assemblages in the NE portion of this HP/LT complex has been 561 attributed to high fluid flux-driven metasomatism at depth and is the source of a separate study 562 by Spandler et al. (2008).

563 A suite of discriminant fluid-mobile trace element diagrams complements our 564 interpretation of significantly different fluid and tectonic histories for Groups I and II. FME's in 565 serpentinities are an sensitive recorder of fluid interactions, in part because peridotite protoliths 566 are depleted in these elements, so increases in their concentration are attributable to fluid 567 interactions (e.g., Peters et al., 2017; Scambelluri et al., 2019). Recent re-analysis and refinement 568 of compiled serpentinite data has also demonstrated that these elements are sensitive tracers of 569 the tectonic environments of serpentinization (Peters et al., 2017). For the New Caledonia HP/LT 570 serpentinites, plots of fluid-mobile element enrichments (e.g., Ba, Cs) relative to fluid-immobile 571 elements such as Yb show compelling trends (Figure 10). Ba in Groups I and II (Figure 10a) 572 indicates a mantle wedge origin for Group II samples, which are relatively enriched compared to 573 Group I samples, which fall squarely within the field for mid-ocean ridge serpentinites. This 574 trend is not observed for Cs, which we interpret as becoming enriched in Group I samples during 575 intense fluid flow and deformation, and possible interaction with neighboring sediments from the 576 Diahot-Panié Complex. Cs in Group II falls lower than compiled forearc data, commensurate 577 with our interpretations for limited influence of sedimentary-derived fluids based on stable 578 isotope data. This Cs depletion is apparent in a plot of Cs vs fluid-immobile Yb, though the data 579 in this context better overlap with the range of observed values for drilled or dredged forearc 580 samples, and the Group I samples correlate well with the compiled mid-ocean ridge dataset.

581 Trends between U and Th enrichments show that Group I samples lack the seafloor U 582 enrichment that defines some (but not all) of the mid-ocean ridge dataset (Figure 10c).

583

6.3 Tectonic origin of New Caledonia HP/LT-complex serpentinites

584 Given evidence presented above, we interpret differing tectonic origins for serpentinites 585 in the NE and SE portions of the terrane:

586 Group I: Found dominantly in the NE part of the complex, these serpentinities are 587 remnants of lithospheric mantle from the downgoing plate (Figure 11a). They experienced 588 progressive serpentinization on or near the ocean floor prior to subduction and then faced high-589 fluid-rock ratios, metasomatism leading to the development of talc-bearing assemblages, and 590 deformation in the subduction channel. The formation of these rocks was possibly associated 591 with the development of several major shear zones, which facilitated slicing of the complex at 592 depth and have given parts of the Pouébo Terrane the appearance of a mélange. This geodynamic 593 interpretation is supported by recent reevaluations of the architecture of the belt (Maurizot et al., 594 2020c; Vitale-Brovarone et al., 2018) and consistent with our observation of the proximity of 595 serpentinites to major unit boundaries and faults (e.g., NC18-22A, NC18-26B, NC19-63) and 596 their prevalence as matrix hosts for dismembered blocks in km-scale shear zones. It is plausible 597 that the pre-subduction abyssal environment for the future Pouébo Terrane ultramafic rocks was 598 characterized by lower-T conditions, consistent with stable isotope data presented here (Figure 599 6b). Seismic imaging of the New Caledonia Basin to the west of the island has revealed thinned 600 continental crust interpreted to consist of a significant volume of serpentinized upper mantle and 601 resembling the structure of crust formed during slow, low-T amagmatic seafloor spreading 602 (Klingelhoefer et al., 2007).

603 Group II: These samples cluster in the southern portion of the complex, comprising the 604 Poadja Massif. Incorporated onto the top of the slab prior to the onshore obduction of the 605 Peridotite Nappe, this slice of mantle wedge was subducted and exhumed intact, with striking 606 preservation of relict minerals and comparatively minor degrees of fluid alteration, as evidenced 607 by δ^{18} O isotope values that remain near the pristine upper mantle average and lower degrees of 608 LREE and FME (Cs, U, Pb, and Sr) enrichment relative to other global forearc mantle settings 609 (Figure 11b). We interpret these data to reflect the lack of a strong sedimentary-derived fluid flux 610 during serpentinization of these rocks in their mantle wedge setting, and this is supported by

611 independent evidence from analyses of slab-derived tremolite vein assemblages at the base of the 612 obducted Peridotite Nappe (Cluzel et al., 2020). This muted enrichment of LREE and FME also 613 indicates that later overprinting by meta-sedimentary derived fluids during transport within the 614 subduction channel was limited. The samples display characteristic REE patterns that remarkably

615 resemble the harzburgitic mantle of New Caledonia's Peridotite Nappe (Figure 11b).

616

6.4 Relevance for the architecture of the New Caledonia HP/LT complex

617 In the NE portion of the complex, our combined field observations and geochemical data 618 suggest that Group I (downgoing-slab) serpentinites: (a) overwhelmingly appear in the highest-619 grade portions of the complex, within the oceanic affinity Pouébo Terrane, and (b) show distinct 620 geochemical markers for high degrees of fluid interaction and deformation during subduction 621 and/or exhumation (i.e., elevated δ^{18} O values, decoupled LREE's, enriched FME's such as Cs). 622 These observations are broadly consistent with recent re-interpretations of this subduction 623 complex by Vitale-Brovarone et al. (2018), which posits the existence of two accretionary 624 domains preserved in a nappe-type belt formed by progressive underplating and stacking. The SE 625 portion of the complex is far less studied: the existence of Group II mantle wedge serpentinites 626 carries implications for the structural level of the subduction zone sampled by rocks in the 627 immediate vicinity of the Poadja Massif. The existence of mantle wedge serpentinites adds to 628 independent observations made by Cluzel (2021) of the presence of hangingwall mafic rocks in 629 lower-grade portions of the Diahot-Panié Complex further north. Integrating these observations 630 into a unified subduction complex-scale picture of preserved lithostratigraphy requires further 631 studies. Nevertheless, these observations provide compounding evidence for greater structural 632 coherence within the New Caledonia subduction "mélange" than has previously been posited.

633

6.5 Implications for slab-mantle wedge interactions

Our finding of mantle wedge material within the exhumed HP/LT complex on New Caledonia provides direct evidence for interaction with the hangingwall mantle in this Eocene subduction zone. Geochemical modeling has demonstrated the importance of the mantle wedge as a reservoir for water and fluid-mobile elements that contribute to arc magma isotope and elemental budgets (e.g., Debret et al., 2019, 2020; Ribeiro & Lee, 2017; Savov et al., 2005, 2007), and there are strong conceptual bases, observational evidence, and modeled predictions 640 for the incorporation and downward dragging of mantle wedge material in some subduction 641 zones (e.g., Bebout & Barton, 2002; Bebout, 2007; Cloos & Shreve, 1988; Malatesta et al., 2012; 642 Peacock & Hyndman, 1999; Savov et al., 2005). New Caledonia provides an important natural 643 rock record comparison for geodynamic modeling: particuarly for outcomes in which 644 exhumation of downgoing plate mantle and overlying mantle wedge material is predicted (e.g., 645 Gerya & Stockert, 2006; Gerya et al., 2002; Malatesta et al., 2012). In these cases, the rheology 646 of serpentine and evolving hydration state of the ultramafic material are critical to the locus of 647 the weak, low-viscosity subduction channel and eventual migration of the plate interface 648 upwards into the mantle wedge. The development of talc in the overlying mantle assemblage 649 provides a possible physiochemical mechanism for this migration, and its stability in the 650 ultramafic chemical system may even control the depth of plate decoupling (Peacock & Wang, 651 2021).

652 This hypothesis is interesting to consider in light of our observations of relatively 653 undeformed, nearly talc-absent mantle wedge assemblages observed in the SE and deformed, 654 talc-bearing downgoing mantle assemblages in the NE. A local bulk assemblage-induced 655 rheological switch in the mantle wedge and consequent avulsion of the slab-mantle interface 656 could be broadly consistent with the results presented here. In this scenario, deformation rapidly 657 re-localizes in the new region of weakness and a stranded slice of mantle wedge material is 658 incorporated atop the downgoing slab. This mantle may feasibly have already experienced partial 659 high-T serpentinization from fluxed aqueous dehydration fluids (consistent with stable isotope 660 data presented here) and might largely escape prolonged intense deformation, because the 661 subduction interface was localized first below, and then above the mantle wedge slice in 662 rheologically weaker assemblages (consistent with observed petrographic textures and field 663 observations).

Tectonic erosion of the mantle wedge, and the type of HP/LT ultramafic material it
produces, contrasts markedly with the processes that retrieve lithospheric mantle under
subducted oceanic crust. Slicing and nappe development along lithologic (rheologic)
heterogeneities in the slab are commonly invoked as ways by which downgoing mantle may be
incorporated into the subduction channel (e.g., Angiboust & Agard, 2010; Guillot et al., 2009;
Hermann et al., 2000; Wakabayashi, 1992). During these processes, the mantle is juxtaposed and
reacts with sedimentary and mafic components of the slab, as reflected by stable isotope

671 compositions and Si and trace element enrichments. The data presented here for New

672 Caledonia's NE serpentinites reflect this type of metamorphic history, including their spatial

673 concentration within the oceanic Pouébo Terrane and proximity to inferred boundaries with the

674 Diahot-Panié Complex.

675 **7 Summary**

676 In this study, we resolve two petrographically, geochemically, and spatially distinct 677 groups of serpentinites within New Caledonia's HP/LT subduction complex. Our work 678 reconciles existing disparate interpretations of the tectonic origin of these rocks, with 679 implications for slab-mantle interaction during subduction. In the NE portion of the complex 680 serpentinite geochemistry and field relations indicate a downgoing slab origin. By contrast, the 681 chemistry of serpentinities in the SE points to a mantle wedge origin, indicating incorporation and 682 subduction of upper plate material. The exhumation of serpentinites from these two different 683 geodynamic settings within a single HP/LT complex is not common in the natural rock record, 684 but predicted for certain modeled scenarios as a function of serpentine rheology and hydration 685 state, among other subduction parameters. The mineralogy, chemistry, and spatial distribution of 686 New Caledonia's HP/LT serpentinites hold clues for understanding the architecture of this 687 subduction complex, and more broadly, for the modeled dynamics of deep tectonic slicing of 688 subducted oceanic plates and mass transfer between the upper and lower plates.

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707 9 Open Research

708 Data Availability Statement

To ensure the accessibility and discoverability of the samples used in this research, and to align with the National Science Foundation's guidelines of effective data practices, all samples used in this study have been registered with IGSN Global Sample Numbers through the System for Earth Sample Registration (SESAR). SESAR is maintained by the GeoInformatics Research Group of the Lamont-Doherty Earth Observatory. <u>https://www.geosamples.org/</u> Accessed 17 February 2022. Whole rock and stable isotope data presented in this paper will be submitted for archival in EarthChem data repository prior to paper acceptance.

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Figure 1. Schematic subduction zone cross-section showing relevant locations of
serpentinization and enrichments and loss of fluid-mobile elements during subduction and
exhumation (after Deschamps et al., 2013; Peters et al., 2017). Large semi-transparent arrow
indicates subduction and exhumation path of serpentinites, emphasizing that these rocks can
encounter chemical changes on both the prograde and retrograde paths. Subduction zone after
Guillot et al. (2015).

Figure 2. (a) Regional map highlighting significant tectonic features of the SW Pacific region after Maurizot & Collot (2009) and Sutherland et al. (2019). (b) Simplified geologic map of the main island of New Caledonia showing sample locations and additional localities referenced in text. Map and units after Maurizot et al. (2020c). (c) Simplified map of Pam Peninsula showing locations of Group I serpentinites samples (this study) and prior studied samples. Unit names after Maurizot et al. (2020c) and boundaries modified after Vitale-Brovarone et al. (2018). (d) Simplified map showing sampled locations at Poadja Massif. Estimated uncertainty for

Fitzherbert et al. (2004) georeferenced raster map locations (c, d) is ~500-700 m and ~200-400
m, respectively. Solid black lines denote roads, solid blue lines denote streams, and dashed black

1336 line denotes high-angle normal fault.

1337 Figure 3. Backscatter electron images from select high-pressure serpentinites. (a) A relict 1338 chromite core surrounded by a mantle of ferritchromite and rim of chromian magnetite 1339 containing inclusions of antigorite (NC19-48). (b) Delicate veins of tremolite and antigorite cross 1340 cut a pervasively serpentinized matrix (NC19-94). (c) Skeletal chromite replaced by magnetite 1341 and antigorite (NC18-39B). (d) Inclusions of Fe-Ni alloy awaruite and antigorite in magnetite 1342 (NC18-39A). (e) Brightness-contrast enhanced image highlighting complex curvilinear 1343 retrogression of chromian magnetite to magnetite (NC19-154A). (f) Representative texture of 1344 typical replacement of olivine by antigorite and magnetite via growth from fractures (NC18-

1345 39A).

Figure 4. Whole rock major element ratios of MgO/SiO₂ vs. Al₂O₃/SiO₂ for serpentinites and
hybrid rocks in New Caledonia's HP/LT terrane. Samples are plotted with compiled data for
harzburgites in the New Caledonia ophiolite (gray circles) (Liu et al., 2018; Mothersole, 2014;
Mothersole et al., 2017; Ulrich et al., 2010). Also shown is the field for abyssal serpentinites
from Niu (2004). Depleted mantle value from McDonough and Sun (1995), primitive mantle
value from Salters and Stracke (2004). "Terrestrial array" line after Hart and Zindler (1986),
Jagoutz et al. (1979), and Niu (2004).

Figure 5. Whole rock trace and REE compositions for New Caledonia HP/LT serpentinites.
Samples are plotted together (a, b) and separately into respective categories: Group I (c, d) and
Group II (e, f). Trace element concentrations are normalized to primitive mantle values of Sun
and McDonough (1989) (a,c,e). REE concentrations are normalized to C1 chondrite
(McDonough & Sun, 1995) (b,d,f).

Figure 6. (a) Hydrogen (δD) and oxygen ($\delta^{18}O$) stable isotope compositions of New Caledonia HP/LT serpentinites compared with existing data for serpentine in the overlying Peridotite Nappe (ophiolite groups after Cluzel et al., 2020; Ulrich et al., 2020). Weathered samples and samples for which antigorite was not specified in Cluzel et al. (2020) were excluded. Upper mantle values 1362 from Eiler (2001), Kyser and O'Neil (1984), and Mattey et al. (1994). (b) δ^{18} O versus loss on

1363 ignition (LOI) for HP/LT serpentinites. Group I serpentinites show decreasing δ^{18} O with

1364 progressive hydration whereas Group II serpentinites exhibit a narrow range of δ^{18} O values

1365 irrespective of degree of hydration. An arrow denotes the direction of δ^{18} O change when

1366 serpentine is formed at increasing temperatures in equilbirium with seawater (e.g., Saccocia et

1367 al., 2009).

1368 Figure 7. Representative cross-polarized photomicrographs and correlated Raman spectra for (a)

1369 two separate matrix sites in Group I sample NC18-09B and (b) one pseudomorph (red) and one

1370 vein (blue) in Group II sample NC19-152. Diagnostic Raman peaks for antigorite are highlighted

tan vertical bars. All serpentine polymorphs in Group I and II were identified as antigorite

1372 (Figures S5, S6).

1373 **Figure 8.** Variations in ratios of HFSE/HREE (i.e., Yb) with increasing LOI (%) for New

1374 Caledonia HP/LT serpentinites. Variations in trace element ratios are independent of LOI value.

1375 Figure 9. Plots of LREE (La, Ce, Pr, and Nd) versus HFSE (e.g., Zr) for all HP/LT serpentinites,

1376 with zoomed insets in upper right of graphs to highlight trace element depleted Group II samples.

1377 Groups I and II symbols are the same as Figure 8. One sample, NC19-158 (open orange circle),

1378 has been excluded from the trendline and computed R values.

1379 **Figure 10.** Plots for investigation of FME trends among New Caledonia HP/LT serpentinites.

1380 Data are plotted against compilations for mid-ocean ridge (MOR) serpentinites (teal circles) and

1381 forearc (FA) serpentinites (tan circles) from Peters et al. (2017). (a) Ba/Yb vs. Ba, (b) Cs/Yb vs.

1382 Cs, (c) U vs. Th, and (d) Cs vs. Yb.

Figure 11. REE compositions for New Caledonia HP/LT serpentinites. (a) Group I serpentinites

1384 plotted versus a global dataset of mid-ocean ridge serpentinites (Peters et al., 2017); (b) Group II

1385 serpentinites plotted versus harzburgite compositions from the New Caledonia ophiolite

1386 (Marchesi et al., 2009; Secchiari et al., 2020; Ulrich et al., 2010).

Figure 1.



Figure 2.



Figure 3.



Figure 4.



Figure 5.



Figure 6.



Figure 7.



Figure 7. Representative cross-polarized photomicrographs and correlated Raman spectra for (a) two separate matrix sites in Group I sample NC18-09B and (b) one pseudomorph (red) and one vein (blue) in Group II sample NC19-152. Diagnostic Raman peaks for antigorite are highlighted tan vertical bars. All serpentine polymorphs in Group I and II were identified as antigorite (Figure S5).

Figure 8.



Figure 9.



Figure 10.


Figure 11.



Table 1					
Whole rock major and tra	ce element con	npositions			
Lithology	Serpentinite				
Sample name	NC18-07C	NC18-09B	NC18-15C	NC18-15D	NC18-22A
IGSN	IENHR0002	IENHR0003	IENHR0004	IENHR0005	IENHR0006
Group/Locality	I	I	I	Ι	Ι
Maior elements (wt%)					
SiO ₂	53.95	43,78	41.90	42.25	41.32
TiO ₂	0.02	0.02	0.02	0.02	0.02
Al ₂ O ₂	1.31	2.18	2 46	1 73	3 46
Fe ₂ O _{2/T}	6.30	2.10	2.70	7.50	0.40
MpO	0.39	0.00	0.03	7.30	9.03
MaO	0.04	0.11	0.10	0.10	0.14
MigO CaO	29.00	0.02	0.01	<0.22	0.01
Na ₂ O	0.09	0.02	0.01	<0.01	<0.01
K₂O	0.00	0.00	0.00	<0.01	<0.01
P ₂ O ₂	0.01	0.00	0.00	<0.01	<0.01
$1 \cap 1^a$	7.50	11 20	12.06	11.67	11 21
	7.59	11.30	12.00	11.07	11.21
Total	98.98	99.69	99.68	99.50	99.76
Mg#	0.82	0.80	0.80	0.83	0.78
Lab	WSU	WSU	WSU	WSU	WSU
Trace elements (ppm)					
Li	n.d.	n.d.	n.d.	0.0464	n.d.
Ве	n.d.	n.d.	n.d.	0.110	n.d.
Sc	7.12	10.4	8.33	7.97	11.5
V	n.d.	n.d.	n.d.	37.3	n.d.
Cr	n.d.	n.d.	n.d.	2252	n.d.
Со	n.d.	n.d.	n.d.	94.8	n.d.
Ni	n.d.	n.d.	n.d.	2384	n.d.
Cu	n.d.	n.d.	n.d.	1.89	n.d.
Zn	n.d.	n.d.	n.d.	29.4	n.d.
Ga	n.d.	n.d.	n.d.	2.73	n.d.
Rb	0.293	0.0691	0.0525	bdl	0.0992
Sr	3.27	1.34	1.43	0.274	1.29
Y	2.36	0.720	4.99	0.637	0.478
Zr	2.95	2.93	2.68	0.938	2.40
Nb	0.180	0.251	0.136	0.0356	0.519

0.0111

3.04

0.0211

0.359

0.00898

5.33

0.00551

0.168

Cs

Ba

0.0156

0.636

La	0.554	0.267	1.58	0.131	0.506
Ce	1.40	0.653	1.36	0.285	1.12
Pr	0.165	0.0655	0.659	0.0526	0.116
Nd	0.677	0.228	3.57	0.253	0.410
Sm	0.283	0.0592	0.845	0.0761	0.0970
Eu	0.0977	0.0117	0.238	0.0144	0.0165
Tb	0.108	0.0163	0.133	0.0168	0.0151
Gd	0.388	0.0638	0.906	0.101	0.0755
Dy	0.765	0.113	0.765	0.100	0.0943
Но	0.166	0.0281	0.159	0.0244	0.0208
Er	0.515	0.0925	0.411	0.0742	0.0614
Tm	0.102	0.0169	0.0533	0.0122	0.0117
Yb	0.852	0.146	0.291	0.0843	0.0986
Lu	0.151	0.0262	0.0509	0.0152	0.0199
Hf	0.0733	0.0808	0.0779	0.0538	0.0705
Та	0.0605	0.0998	0.0528	0.0443	0.0864
Pb	0.121	0.512	0.371	0.00955	0.173
Th	0.292	0.495	0.458	0.163	0.534
U	0.0667	0.120	0.0717	0.0180	0.123
Lab	WSU	WSU	WSU	URI	WSU

Note . n.d. = not determined; bdl = below detection limits; F&M = Franklin & Marshall College; URI = aLOI measured by combustion

NC18-26B	NC18-43	NC19-14	NC19-48	NC19-54	NC19-63	NC19-81
IENHR0008	IENHR000C	IENHR000G	IENHR000I	IENHR000J	IENHR000K	IENHR000L
I	I	I	I	I	I	I
38.46	46.20	42.45	54.34	42.52	42.48	51.51
0.22	0.01	0.01	0.01	0.01	0.01	<0.01
6.73	1.68	1.96	1.18	0.84	2.68	2.48
13.39	7.00	6.50	6.30	7.09	8.29	6.83
0.14	0.07	0.10	0.07	0.09	0.12	0.07
29.19	32.94	37.65	30.61	38.67	34.64	30.92
0.44	0.11	0.01	0.02	0.01	0.02	0.14
<0.01	0.18	0.03	0.01	0.03	0.02	0.02
<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
11.78	12.33	11.83	7.25	11.36	12.49	8.16
100.35	100.54	100.54	99.79	100.62	100.75	100.13
0.69	0.82	0.85	0.83	0.85	0.81	0.82
WSU	F&M	F&M	F&M	F&M	F&M	F&M
n d	5 72	0 0154	0 907	1 75	2.08	0 820
n d	0.846	0.0985	0 155	0 126	0 236	0.0904
13.8	10.5	6.72	4.03	6.71	11.5	7.75
n.d.	43.0	27.8	25.2	33.7	41.2	45.4
n.d.	2400	2500	2193	2861	2280	2103
n.d.	88.8	91.9	88.0	169	69.6	82.1
n.d.	2209	2299	2368	5877	1942	2288
n.d.	4.09	4.61	2.98	17.1	24.6	2.12
n.d.	39.4	35.9	40.9	106	34.0	34.7
n.d.	4.51	2.00	1.98	1.83	3.18	3.31
0.139	0.122	bdl	0.00760	0.0662	0.0250	bdl
5.54	5.40	0.135	0.0957	0.602	1.39	0.558
4.41	5.59	0.374	0.507	0.595	1.69	1.26
16.6	0.543	1.22	0.196	5.11	0.609	0.409
0.384	0.661	0.134	0.0100	3.07	0.331	0.296
0.139	0.0591	0.00267	0.0187	0.00863	0.0313	0.00140
1.80	1.65	0.135	0.522	0.537	4.47	0.292

0.587	0.903	0.0988	0.0619	0.266	0.194	0.185
1.07	3.21	0.339	0.0607	0.827	0.317	0.124
0.195	0.468	0.0355	0.0146	0.0857	0.0896	0.0798
0.902	2.26	0.165	0.0770	0.336	0.455	0.457
0.323	0.744	0.0489	0.0274	0.0878	0.155	0.181
0.0947	0.172	0.0129	0.00537	0.0211	0.0475	0.0375
0.0975	0.158	0.0177	0.00776	0.0216	0.0390	0.0472
0.489	0.881	0.0646	0.0530	0.105	0.228	0.246
0.702	0.994	0.0680	0.0477	0.141	0.260	0.308
0.169	0.211	0.0164	0.0142	0.0307	0.0586	0.0614
0.520	0.604	0.0482	0.0485	0.0921	0.173	0.182
0.0849	0.0911	0.00814	0.00799	0.0169	0.0268	0.0323
0.589	0.579	0.0532	0.0581	0.124	0.189	0.249
0.107	0.0837	0.00963	0.0124	0.0191	0.0306	0.0374
0.411	0.0786	0.0645	0.0436	0.182	0.0570	0.0382
0.0639	0.0939	0.0745	0.0362	0.0744	0.0322	0.0434
0.204	0.114	0.0482	0.0606	0.169	0.278	0.0475
0.304	0.547	0.101	0.155	0.0946	0.161	0.149
0.0646	0.158	0.0107	0.0163	0.126	0.0140	0.0210
WSU	URI	URI	URI	URI	URI	URI

= University of Rhode Island; WSU = Washington State University.

NC19-86	NC19-89	NC19-94	NC18-39A (core)	NC18-39A (rxn)	NC18-39B
	IENHRUUUU	IENHRUUUP	IENARUUU9	IENHKUUU9	IENHRUUUA
I	I	I	11	11	11
41.69	50.75	42.12	38.57	40.64	40.05
0.02	0.01	0.01	0.01	0.01	0.01
0.95	1.93	2.81	0.51	0.52	0.57
7.15	7.10	7.50	7.49	7.29	7.59
0.05	0.09	0.13	0.11	0.12	0.11
39.25	31.28	36.47	40.34	38.42	41.55
0.03	0.02	0.06	<0.01	0.17	0.57
0.03	<0.01	0.03	<0.01	<0.01	<0.01
<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
0.01	<0.01	<0.01	<0.01	<0.01	<0.01
11.23	9.10	11.71	12.62	12.64	9.01
100.41	100.28	100.84	99.66	99.81	99.46
0.85	0.82	0.83	0.84	0.84	0.85
F&M	F&M	F&M	WSU	WSU	WSU
0.0470	0.602	1.60	n.d.	n.d.	n.d.
0.0267	0.124	0.326	n.d.	n.d.	n.d.
8.03	10.7	9.49	6.68	7.12	7.12
30.4	45.2	58.0	n.d.	n.d.	n.d.
2454	2747	2796	n.d.	n.d.	n.d.
52.5	93.9	110	n.d.	n.d.	n.d.
1601	2386	2678	n.d.	n.d.	n.d.
3.68	11.9	0.604	n.d.	n.d.	n.d.
30.0	42.3	40.8	n.d.	n.d.	n.d.
1.33	3.64	4.44	n.d.	n.d.	n.d.
bdl	0.0364	0.0736	0.264	0.0577	0.108
bdl	1.13	1.07	1.99	4.47	2.92
0.183	6.48	4.13	0.238	0.254	0.198
1.35	0.302	0.799	2.09	2.69	2.26
0.0397	0.194	0.0574	0.0947	0.122	0.0900
bdl	0.0184	0.0819	0.0227	0.0222	0.0423
0.339	5.59	1.47	0.431	2.23	0.741

0.0649	1.91	0.165	0.265	0.325	0.271
0.154	0.242	0.652	0.620	0.760	0.654
0.0124	0.637	0.101	0.0616	0.0723	0.0646
0.0643	2.72	0.507	0.242	0.256	0.250
0.00798	0.903	0.262	0.0605	0.0550	0.0503
0.00181	0.249	0.0545	0.0190	0.0183	0.0134
0.00341	0.198	0.0909	0.00773	0.00814	0.00639
0.0230	1.13	0.444	0.0464	0.0485	0.0396
0.0239	1.13	0.655	0.0491	0.0493	0.0355
0.00747	0.215	0.158	0.0109	0.0104	0.00772
0.0192	0.563	0.507	0.0320	0.0347	0.0272
0.00424	0.0848	0.0867	0.00475	0.00558	0.00478
0.0315	0.587	0.627	0.0350	0.0362	0.0285
0.00637	0.0891	0.110	0.00679	0.00687	0.00567
0.0592	0.0325	0.0544	0.0505	0.0669	0.0624
0.0377	0.0546	0.0257	0.0356	0.0416	0.0308
0.0841	0.0793	0.340	0.0981	0.0745	0.320
0.0245	0.0820	0.454	0.112	0.152	0.108
0.00827	0.0145	0.142	0.0424	0.0510	0.0453
URI	URI	URI	WSU	WSU	WSU

NC18-39C	NC19-42	NC19-152	NC19-154A	NC19-157	NC19-158	NC18-45
IENHR000B	IENHR000H	IENHR000Q	IENHR000R	IENHR000S	IENHR000T	IENHR000D
II	II	II	II	II	II	Boghen Terrane
41.61	41.96	40.80	38.86	40.64	41.98	40.26
0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
0.75	0.72	0.69	0.72	0.68	0.67	0.41
7.21	7.75	8.28	5.75	7.55	7.91	9.41
0.09	0.11	0.12	0.09	0.11	0.11	0.15
38.01	43.46	42.29	39.31	42.35	43.24	36.43
0.01	0.50	1.08	0.02	0.42	0.53	0.01
<0.01	0.06	0.05	0.04	0.05	0.08	<0.01
<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01
<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
12.00	5.33	6.90	17.28	8.32	5.25	13.19
99.70	99.90	100.21	102.07	100.12	99.78	99.86
0.84	0.85	0.84	0.87	0.85	0.85	0.79
WSU	F&M	F&M	F&M	F&M	F&M	WSU
n.d.	0.717	0.481	0.0560	0.180	0.630	n.d.
n.d.	bdl	bdl	0.0160	bdl	bdl	n.d.
7.20	8.75	7.01	6.74	6.01	5.39	9.79
n.d.	21.4	12.1	17.8	19.2	17.6	n.d.
n.d.	2672	1773	2285	2117	1819	n.d.
n.d.	104	97.8	98.4	103	112	n.d.
n.d.	2331	2184	2461	2278	2555	n.d.
n.d.	10.2	2.16	2.36	3.21	2.04	n.d.
n.d.	30.1	33.2	29.3	23.3	29.7	n.d.
n.d.	0.977	1.76	0.933	0.878	0.463	n.d.
0.0598	0.254	0.0568	0.00982	0.0229	0.276	0.0814
1.13	0.670	2.20	0.724	0.788	0.934	2.19
0.289	0.0115	0.0454	0.108	0.0895	0.126	0.197
2.43	0.929	0.334	0.388	0.264	2.82	2.06
0.219	0.00648	bdl	0.0284	0.0109	0.185	0.0892
0.00464	0.0112	0.00517	0.00189	0.00512	0.0169	0.0921
0.562	0.911	1.82	0.772	0.661	0.706	3.88

0.220	0.131	0.0586	0.121	0.0682	0.0437	0.281
0.559	0.282	0.135	0.266	0.189	0.0916	0.556
0.0520	0.0214	0.0141	0.0326	0.0224	0.0102	0.0546
0.194	0.0674	0.0442	0.121	0.0844	0.0231	0.212
0.0477	0.00564	0.00616	0.0227	0.0151	0.00348	0.0367
0.00634	bdl	0.00495	0.00752	0.00277	0.00163	0.0772
0.00705	0.000708	0.000971	0.00312	0.00225	0.00161	0.00446
0.0444	0.00616	0.00608	0.0195	0.0141	0.00625	0.0273
0.0517	bdl	0.00629	0.0176	0.0139	0.00989	0.0308
0.0130	0.00117	0.00154	0.00355	0.00294	0.00239	0.00704
0.0423	0.00451	0.00627	0.0114	0.00971	0.0115	0.0230
0.00821	0.00128	0.00118	0.00187	0.00176	0.00219	0.00417
0.0813	0.0115	0.0138	0.0166	0.0176	0.0239	0.0300
0.0181	0.00363	0.00315	0.00319	0.00357	0.00449	0.00509
0.0705	0.109	0.0290	0.0224	0.0257	0.0607	0.0558
0.0403	0.105	0.0240	0.123	0.0259	0.0952	0.0311
0.0555	0.0684	0.0932	0.0369	0.0576	0.0191	0.860
0.175	0.0176	0.00867	0.0372	0.0134	0.0186	0.123
0.0488	0.00653	0.00626	0.0782	0.00465	0.0119	0.0374
WSU	URI	URI	URI	URI	URI	WSU

NC18-46 IENHR000E Boghen Terrane	NC18-49 IENHR000F Serpentinite Sole	Peridotite NC19-178 IENHR000V Kalaa-Gomen	Chlorite schist NC19-85 IENHR000M	Talc schist NC19-169 IENHR000U
			•	·
39.00	42.04	40.51	22.35	54.16
0.02	<0.01	<0.01	3 54	0.02
1.05	0.51	0.69	13 / 3	2.00
10.00	6.01	0.09	10. 1 0 20.21	2.99
0.15	0.91	1.13	29.21	0.02
0.10	0.00	0.11	0.24	0.02
<0.01	0.04	40.91	2 47	29.93
<0.01	0.03	0.00	0.01	<0.00
<0.01	<0.00	<0.00	0.01	<0.01
-0.01	<0.01	<0.01	<0.01	<0.01
0.01	<0.01	<0.01	1.88	0.01
12.90	13.67	9.77	7.88	6.25
99.72	100.77	100.43	100.24	100.03
0.78	0.84	0.84	0.40	0.82
WSU	WSU	F&M	F&M	F&M
n d	1 91	1 27	7 12	0 162
n.d.	0.0109	bdl	0.252	0.0814
11.8	5.60	7.30	35.9	8.51
n.d.	19.7	26.6	448	49.0
n.d.	2314	2307	284	2336
n.d.	95.5	95.7	140	93.1
n.d.	2563	2069	247	1985
n.d.	2.55	1.82	59.7	7.40
n.d.	25.3	82.9	128	43.3
n.d.	0.645	0.879	8.47	4.28
0.144	0.00673	0.0809	0.0242	0.167
1.74	0.677	0.428	36.0	2.27
0.453	1.08	0.0220	54.8	0.327
3.12	0.497	0.353	25.0	0.256
0.155	0.00694	bdl	12.7	0.0267
0.787	0.00578	0.00336	0.00499	0.0109
3.50	0.709	0.168	12.9	0.341

0.296	0.202	0.0183	13.1	0.0523
0.600	0.170	0.0501	35.7	0.192
0.0760	0.0701	0.00444	4.29	0.0302
0.350	0.330	0.0101	20.5	0.156
0.0475	0.100	0.00109	6.42	0.0523
0.0220	0.0264	bdl	1.82	0.00663
0.00897	0.0199	0.000194	1.76	0.0118
0.0493	0.143	0.00120	9.71	0.0693
0.0652	0.110	0.000929	11.4	0.0706
0.0175	0.0273	0.000413	2.30	0.0141
0.0556	0.0752	0.00259	5.50	0.0355
0.00961	0.00983	0.000758	0.662	0.00444
0.0711	0.0544	0.00955	3.44	0.0237
0.0128	0.0109	0.00254	0.453	0.00355
0.0668	0.0437	0.0224	0.738	0.0105
0.0891	0.0525	0.0217	0.641	0.0135
0.362	0.260	0.00374	0.984	0.0827
0.0939	0.0165	0.00392	3.08	0.0223
0.0368	0.00565	0.00129	0.133	0.00457
WSU	URI	URI	URI	URI

Table 2Oxygen and hydrogen stable isotope data.

Sample	Rock type	Group/Locality	δD _{srp} (‰)	$\delta^{18}O_{srp}~(\text{\rm})$
NC18-07C	serpentinite	Ι	-45, -41	10.2
NC18-09B	serpentinite	Ι	-35, -36	8.0
NC18-15C	serpentinite	Ι	-34, -32	8.6
NC18-15D	serpentinite	Ι	-33, -29	8.5, 6.7
NC18-22A	serpentinite	I	-40, -40	7.7, 6.8
NC18-26B	serpentinite	I	-44, -46	8.9
NC18-43	serpentinite	Ι	-75, -77	7.5
NC19-14	serpentinite	Ι	-38, -39	8.7, 8.8
NC19-48	serpentinite	Ι	-42, -42	9.8
NC19-54	serpentinite	Ι	-42, -41	7.4, 7.2
NC19-63	serpentinite	Ι	-49, -49	10.6
NC19-81	serpentinite	Ι	-47, -44	8.6
NC19-86	serpentinite	Ι	-47, -47	8.3
NC19-89	serpentinite	Ι	-45, -45	8.9, 8.8
NC19-94	serpentinite	I	-44, -44	8.3
NC18-39A (core)	serpentinite	II	-59, -53	5.4
NC18-39A (rxn)	serpentinite	II	-56, -55	6.4
NC18-39B	serpentinite	II	-52, -49	5.1, 5.5
NC18-39C	serpentinite	II	-39, -40	5.7
NC19-42	serpentinite	II	-73, -79	5.7
NC19-152	serpentinite	II	-43, -44	5.2
NC19-154A	serpentinite	II	-40, -37	5.6
NC19-157	serpentinite	II	-42, -39	5.2
NC19-158	serpentinite	II	-70, -72	5.5
NC19-85	chlorite schist	I		
NC19-169	talc schist	I		
NC18-45	serpentinite	Boghen Terrane	-82, -86	8.0
NC18-46	serpentinite	Boghen Terrane	-78, -79	7.0
NC18-49	serpentinite	Serpentinite Sole	-82, -82	6.5
NC19-178	serpentinite	Kalaa-Gomen Massif	-84, -85	5.7

Note. Mineral abbreviations after Whitney and Evans (2010): Srp serpentine, Mag mag

 1 >710 µm grain size fraction

 2 125-250 μm grain size fraction

O _{tic} (‰)
;

9.0

1.5

2.3, 2.5 4.3¹, 4.6² 10.5

jnetite, *Tlc* talc



Geochemistry, Geophysics, and Geosystems

Supporting Information for

Serpentinites of Different Tectonic Origin in an Exhumed Subduction Complex (New Caledonia, SW Pacific)

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Contents of this file

Text S1 Figures S1 to S6 Tables S1 to S3

Introduction

The supporting information includes detailed descriptions of whole rock geochemistry analytical methods and inter-lab comparisons of measured major and trace compositions for two samples. This file also contains representative thin section scans, additional Raman spectra, and a table containing additional mineralogical descriptions and field context.

Text S1. Major element preparation methods for Washington State University and Franklin & Marshall College

<u>Franklin & Marshall College</u>: Fifty to sixty grams of representative, clean (exterior weathered surfaces removed) whole rock chips for each sample were sent to Franklin & Marshall College for analysis. Samples were further ground in a mullite grinder and then powdered via shatterbox in a ceramic container (to eliminate the possibility of tungsten carbide contamination). Approximately 1 gram of rock powder is weighed into a clean and dry porcelain crucible for each sample, and placed in a muffle furnace for 90 minutes at 950° C. The crucibles are removed and placed immediately in a desiccator. After reaching room temperature, samples are weighed again. Powders are placed in a small vial and stored in the desiccator- this is the starting material for XRF analysis.

To prepare the XRF disc ("bead"), 3.6000 ± 0.0002 g of lithium tetraborate is weighed into a clean glass bottle. Next, 0.4000 ± 0.0001 g of anhydrous rock powder are added. The bottle is gently mixed by hand for 20-30 seconds and then the bottle is mixed for an additional 10 minutes in a Spex Mixer Mill. The homogenized powder is transferred to a 25 cc. 95% Pt-5% Au crucible and 3-4 drops of a 2% solution of Lithium Iodide are added. The crucible is mounted on a standard ring stand and covered with a 95% Pt-5% Au lid with a flat and polished bottom. The crucible is heated over a Meeker burner for 12-15 minutes (sample is vigorously stirred at the 5-minute and 10-minute marks, and once again before pouring). Once the sample is fully convecting, the Pt lid is removed and heated over a second Meeker burner until it is red hot. The crucible is removed from the ring stand and rapidly emptied onto the hot Pt lid. Immediately after, the crucible is dropped into a warm beaker containing 4N HCI (enough to cover the crucible). The Pt lid is set on a flat slab of polished granite, left to cool (3-5 min), labeled on the side of the disc that is exposed to air, and stored in a dessicator to await analysis.

<u>Washington State University</u>: The following description summarizes preparation details most relevant for this paper. The full method is outlined in Johnson et al. (1999). Approximately 50 grams of representative, clean (exterior weathered surfaces removed) whole rock chips for each sample were transported to Washington State University. A standard volume of chips (enough to fit in a 2 oz Solo clear plastic soufflé cup; ~30 g) was ground in a swing mill with tungsten carbide surfaces for 2 minutes. The contamination of W and Co in the Rock Labs WC ring mills is well-documented, and these elements were not measured. Contamination of Nb and Ta, which is typically of the same order of magnitude as the precision of the method, is discussed in the procedures of Johnson et al. (1999). Next, 3.5 g of sample powder was weighted into a plastic mixing jar with 7.0 g of pure dilithium tetraborate and mixed using a vortex mixer until homogenized. For serpentinites, a high-purity silica powder was added at the weighing stage to prevent crystallization of the bead and to bring the Mg concentration within the lab's calibration range. The result is back calculated to remove the known amount of silica.

Homogenized sample-flux mixtures are placed into graphite crucibles placed on a silica tray and loaded into a muffle furnace (the furnace is just large enough to contain the tray). After the preheated furnace returns to 1000° C after loading, fusion takes five minutes. The silica plate with graphite crucibles is removed from the oven and allowed to

cool. Each beach is reground in the swing mill for 35 seconds. This glass powder is put back into the crucibles and refused for five minutes. After the second fusion, the beads are labeled with an engraver, and the lower flat surface is ground on 600 silicon carbide grit and finished briefly on a glass plate with 600 grit and alcohol (to remove any metal from the grinding wheel). The bead is then washed in an ultrasonic cleaner, rinsed in alcohol and wiped dry.



Figure S1. Representative plane-polarized (A-E) and cross-polarized (F-J) thin section scans of serpentinites from the northeastern portion of the HP terrane. NC18-09B (A, F). NC18-22A (B, G). NC19-54 (C, H). NC19-63 (D, I). NC19-86 (E, J).



Figure S2. Representative plane-polarized (A-F) and cross-polarized (G-L) thin section scans of serpentinites from the southeastern portion of the HP terrane. NC18-39A (A, G); NC18-39C (B, H); NC19-152 (C, I); NC19-154A (D, J); NC19-157 (E, K); NC19-158 (F, L).



Figure S3. Representative plane-polarized (A-C) and cross-polarized (D-F) thin section scans of serpentinites from the Boghen Terrane and Kalaa-Gomen. NC18-45 (A, D); NC18-46 (B, E); NC19-178 (C, F).



Figure S4. Plane-polarized (A, B) and cross-polarized (C, D) thin section scans of hybrid rocks. NC19-85 (A, B) is a chlorite schist consisting of chlorite, ilmenite, titanomagnetite, and inclusion-rich apatite. NC19-169 (C, D) is a foliated talc-magnetite schist consisting of talc and magnetite with minor serpentine and ilmenite.



Figure S5. Raman spectra acquired on a representative suite of Group I samples (NC19-54, NC18-09B), a Boghen Terrane sample (NC18-46), and the Kalaa-Gomen sample (NC19-178).



Figure S6. Raman spectra acquired on a representative suite of Group II samples (NC19-154A, NC19-152, NC19-158, NC19-157).

	NC18-15D			NC18-49		
Major	WSU XRF	F&M XRF	URI ICP-	WSU XRF	F&M XRF	URI ICP-
elements			MS			MS
(wt%)						
SiO ₂	42.25	42.74		41.03	42.04	
TiO ₂	0.02	0.01	0.0115	< 0.01	< 0.01	0.00211
Al ₂ O ₃	1.73	1.84		0.39	0.51	
Fe ₂ O _{3(T)}	7.50	7.36		7.09	7.86	
MnO	0.10	0.10		0.06	0.06	
MgO	36.22	36.89		36.51	37.51	
CaO	< 0.01	0.02		< 0.01	0.04	
Na ₂ O	< 0.01	0.03		< 0.01	0.03	
K ₂ O	< 0.01	< 0.01	bdl	< 0.01	< 0.01	bdl
P ₂ O ₅	< 0.01	< 0.01	bdl	< 0.01	< 0.01	0.00246
LOI	11.67	11.72		14.49	13.67	
Total	99.50	100.72		99.57	100.77	

Table S1. Raia-ds02.xlsx: Sample localities and descriptions.

Table S2. Duplicate major element analyses of NC18-15D and NC18-49 acquired at Washington State University and Franklin & Marshall College. These analyses incorporate all analytical variations and errors (from preparation through data acquisition and reduction) and sample heterogeneity, as separate aliquots of hand-picked chips from each sample were sent to each lab.

	NC18-15D		NC18-49			
Trace	WSU	URI	F&M	WSU	URI ICP-MS	F&M
elements	ICP-MS	ICP-MS	XRF	ICP-MS		XRF
(ppm)						
Li		0.0464			1.91	
Ве		0.110			0.0109	
Sc	8.03	7.97		5.68	5.60	
V		37.3			19.7	
Cr		2252	2312		2314	2933
Со		94.8			95.5	
Ni		2384			2563	
Cu		1.89			2.55	
Zn		29.4			25.3	
Ga		2.73			0.645	
Rb	0.176	bdl		0.110	0.0067	
Sr	0.990	0.274		1.09	0.677	
Υ	0.781	0.637		0.906	1.08	
Zr	2.30	0.938		2.76	0.497	
Nb	0.124	0.0356		0.137	0.00694	
Cs	0.00965	0.00551		0.0105	0.00578	
Ва	0.378	0.168		0.688	0.709	
La	0.281	0.131		0.335	0.202	
Ce	0.680	0.285		0.502	0.170	
Pr	0.0855	0.0526		0.0933	0.0701	
Nd	0.377	0.253		0.388	0.330	
Sm	0.115	0.0761		0.103	0.100	
Eu	0.0228	0.0144		0.0283	0.0264	
Tb	0.0216	0.0168		0.0183	0.0199	
Gd	0.119	0.101		0.121	0.143	
Dy	0.144	0.100		0.109	0.110	
Но	0.0310	0.0244		0.0244	0.0273	
Er	0.0953	0.0742		0.0626	0.0752	
Tm	0.0154	0.0122		0.00801	0.00983	
Yb	0.0968	0.0843		0.0577	0.0544	
Lu	0.0195	0.0152		0.00949	0.0109	
Hf	0.0622	0.0538		0.0588	0.0437	
Та	0.0512	0.0443		0.0828	0.0525	
Pb	0.0702	0.00955		0.313	0.260	
Th	0.299	0.163		0.121	0.0165	
U	0.0582	0.0180		0.0420	0.00565	

Table S3. Duplicate trace element analyses of NC18-15D and NC18-49 acquired at Washington State University and University of Rhode Island. These analyses incorporate

all analytical variations and errors (from preparation through data acquisition and reduction) and sample heterogeneity, as separate aliquots of hand-picked chips from each sample were sent to each lab.

Table S1Sample descriptions and localities

Sample	IGSN ^a	Latitude (S)	Longitude (E)	Location
NC18-07C	IENHR0002	-20.26346	164.38982	NE HP
		20 20216	164 41701	
NC18-09B	IENHR0003	-20.29310	104.41791	
NC18-15C	IENHR0004	-20.29555	164.42465	NE HP
NC18-15D	IENHR0005	-20.29555	164.42465	NE HP
NC18-22A	IENHR0006	-20.25241	164.33636	NE HP
NC18-26B	IENHR0008	-20.34202	164.44055	NE HP
NC19-14	IENHR000G	-20.30642	164.42471	NE HP
NC19-48	IENHR000I	-20.28663	164.41519	NE HP
NC19-54	IENHR000J	-20.30266	164.44181	NE HP
NC19-63	IENHR000K	-20.29904	164.42134	NE HP
NC19-81	IENHR000L	-20.28055	164.43731	NE HP
NC19-86	IENHR000N	-20.28569	164.43714	NE HP
NC19-89	IENHR0000	-20.27831	164.42915	NE HP
NC19-94	IENHR000P	-20.28916	164.42836	NE HP
NC18-39A	IENHR0009	-20.45731	164.65489	SE HP
NC18-39B	IENHR000A	-20.45731	164.65489	SE HP
NC18-39C	IENHR000B	-20.45731	164.65489	SE HP
NC18-43	IENHR000C	-20.65633	164.92468	SE HP
NC19-42	IENHR000H	-20.45807	164.65467	SE HP
NC19-152	IENHR000Q	-20.46006	164.65543	SE HP
NC19-154A	IENHR000R	-20.46192	164.65336	SE HP
NC19-157	IENHR000S	-20.45856	164.65565	SE HP
NC19-158	IENHR000T	-20.45738	164.65575	SE HP
NC18-45	IENHR000D	-20.90704	165.11151	Boghen Terrane
NC18-46	IENHR000E	-20.94518	165.03639	Boghen Terrane
NC18-49	IENHR000F	-21.56731	166.08440	Serpentinite Sole
NC19-178	IENHR000V	-20.63114	164.41613	Kalaa-Gomen
NC19-85	IENHR000M	-20.28749	164.43612	NE HP
NC19-169	IENHR000U	-20.26362	164.38982	NE HP

Note. Datum: WGS84. Mineral abbreviations after Whitney and Evans (2010): Ap apatite a International Geo Sample Number, www.geosamples.org

Description serpentinite peridotite chlorite schist talc schist

e, Atg antigorite, Awr awaruite, Chl ch

Mineralogy Atg + Tlc + Mag Atg + Chl + Ol Atg + Tlc + Mag Atg + Tlc + Mag + Fe-Chr + Chr Atg + Cpx + Mag + Cr-Spl Atg + Fe-Ni oxide Atg + Mag + Chr + Tr Atg + Mag Atg + Tlc Atg + Tr Atg + Mag + Brc + Awr Atg + OI + Mag + Chr + Cpx + Awr Atg + Mag + Chl Atg + Tr Atg + Opx + Mag Atg + Opx + OI + MagAtg + Mag + Opx + Ol + Awr Atg + Mag + Opx + Ol Atg + Opx + Ol + Tlc + AwrLz + Spl + Mag Lz + Spl + Mag Atg + Mag Atg + Ol + Cpx + Spl

> Chl + Ilm + Mag + Ap + Zrn Tlc + Mag + Atg + Ilm

ılorite, Chr chromite, Cpx clinopyroxene, Cr-Spl Chromium spinel, Fe-Chr ferritchromite, Ilm ilmenite, Lz li

Field context

sheared serpentinite in gradational contact with talc-mg schist reaction zone and metasediments at sheared serpentinite in meters-scale block-bearing shear zone exposed in roadcut along east side of RN7; blocks contained in serpentinite matrix include garnet blueschist and epidote-dominated rocks foliated serpentinite body exposed at quarry along dirt road NE of Col d'Amos foliated serpentinite body exposed at quarry along dirt road NE of Col d'Amos serpentinite in meters-scale outcrop along dirt road on NE Pam Peninsula meter-long serpentinite outcrop exposed in ditch at northern outer limits of Ouégoa small serpentinite guarry south of Col d'Amos on E side of RN7 within mafic-dominated hillside serpentinite in large road exposure along RN7 numerous resistant serpentinite blocks (<10 m in length) on north-facing hillslope past antenna, surrounded by variably retrogressed eclogite blocks steeply-dipping serpentinite shear zone in direct contact with well-exposed, highly foliated metasediments; at top of hill directly across road from Col d'Amos sheared serpentinite in direct contact with metasediments along dirt road resistant serpentinite blocks on N-dipping ridge meter-long serpentinite outcrop exposed within mafic-dominated area elongate, resistant serpentinite blocks with anastamosing foliation and singular elongation trend on mafic-dominated hillslope streambed at Poadja Massif consisting of fresh serpentinite, cross-cutting serp veins and alteration rinds visible in some places streambed at Poadja Massif consisting of fresh serpentinite, cross-cutting serp veins and alteration rinds visible in some places streambed at Poadja Massif consisting of fresh serpentinite, cross-cutting serp veins and alteration rinds visible in some places weathered serpentinite exposure with abundant white veins exposed at water's edge along beach ~400 m north of Tilougne coarser-grained serpentinite in streambed outcrop at Poadja Massif oxidized and weathered serpentinite outcrop on top of southern segment of Poadja Massif serpentinite in streambed outcrop at Poadja Massif, near inferred contact with mafic rocks oxidized and weathered serpentinite outcrop in natural drainageon southern segment of Poadja Massif serpentinite with visible pseudomorphs in float on top of southern segment of Poadja Massif serpentinite roadcut in Boghen Terrane containing volumetrically-minor sedimentary lenses and blocks serpentinite roadcut in Boghen Terrane containing volumetrically-minor sedimentary lenses and blocks sheared serpentinite exposed in roadcut exposing metamorphic sole highly weathered serpentinite in float in drainage on SE slopes of Kalaa-Gomen massif single chlorite schist block ($\sim 1 \text{ m}^3$) in float along recently exposed rural roadcut sheared talc-magnetite schist reaction zone between serpentinite and metasediments at Abwala

zardite, Mag magnetite, Opx orthopyroxene, Spl spinel, Tlc talc, Tr tremolite, Zrn zircon