



HAL
open science

Subducted fragments of the Liguro-Piemont ocean, Western Alps: Spatial correlations and offscraping mechanisms during subduction

Clément Herviou, Philippe Agard, Alexis Plunder, Kevin Mendes, Anne Verlaguet, Damien Deldicque, Nadaya Cubas

► To cite this version:

Clément Herviou, Philippe Agard, Alexis Plunder, Kevin Mendes, Anne Verlaguet, et al.. Subducted fragments of the Liguro-Piemont ocean, Western Alps: Spatial correlations and offscraping mechanisms during subduction. *Tectonophysics*, 2022, 827, <10.1016/j.tecto.2022.229267>. <insu-03636647>

HAL Id: insu-03636647

<https://insu.hal.science/insu-03636647v1>

Submitted on 22 Jul 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY-NC 4.0 - Attribution - Non-commercial use - International License

1 **Subducted fragments of the Liguro-Piemont ocean, Western Alps: spatial**
2 **correlations and offscraping mechanisms during subduction**

3 Clément Herviou^{a*}, Philippe Agard^a, Alexis Plunder^b, Kevin Mendes^a, Anne
4 Verlaquet^a, Damien Deldicque^c, Nadaya Cubas^a

5 ^a Sorbonne Université, CNRS-INSU, Institut des Sciences de la Terre de Paris, ISTeP UMR
6 7193, F-75005 Paris, France

7 ^b BRGM, F-45060, Orléans, France

8 ^c Laboratoire de Géologie, Ecole Normale Supérieure PSL, F-75005 Paris, France

9 □ Corresponding author: clement.herviou@sorbonne-universite.fr (C. Herviou)

10

11 **Keywords:**

12 *Oceanic subduction, Liguro-Piemont, Schistes Lustrés, Western Alps, Tectonic slicing, HP-*
13 *LT metamorphism*

14 **Abstract**

15 Fragments of subducted slow-spreading oceanic lithosphere are exposed continuously in the
16 Liguro-Piemont domain of the Western Alps. By combining new and literature petrological
17 data, interpolated maps of maximum temperatures, maximum Si contents of phengite as a
18 proxy for peak pressure and thermodynamic modelling, we provide a detailed framework of
19 the peak metamorphic conditions experienced by the distinct subduction slices. High-
20 resolution mapping confirms the marked eastward increase in metamorphic grade throughout
21 the domain, as well as within some slices. The compilation of lithostratigraphic, structural and
22 radiochronological data and the estimation of sediment/mafic-ultramafic ratio for each slice
23 allow refining the origin of these tectonometamorphic units within the former oceanic domain.
24 The refined structural sketchmap allows to restore the geometries of the Alpine subduction at
25 peak burial conditions. Results point to a trimodal distribution of the units with an increase in
26 metamorphic conditions from the Upper (LPU; 320-400°C- 1.2-1.9 GPa) to the Middle (LPM;
27 415-475°C- 1.7-2.2 GPa) and to the Lower units (LPL; 500-580°C- 2.2-2.8 GPa). The
28 blueschist-facies LPU and LPM units are dominated by sediments (>90%), whereas the
29 eclogitic LPL units are far richer in mafic-ultramafic rocks (>40%). These characteristics,
30 along with lithostratigraphic differences, reflect major differences in their initial
31 paleogeography and/or in the mechanisms responsible for material offscraping from the
32 downgoing slab. The peak burial depths of the LPU, LPM and LPL units are similar to those
33 inferred for slicing and underplating in both modern and fossil subduction zones. Petrological
34 and lithostratigraphic data suggest that the offscraping of the LPU and LPM units was mostly

35 controlled by lithological contrasts, within pelagic shales or along contacts within the
36 uppermost serpentized mantle. In contrast, major dehydration reactions (such as lawsonite
37 breakdown in sediments) likely controlled the offscraping of the LPL units at eclogite-facies
38 conditions, possibly through high fluid pressure conditions and rocks embrittlement.

39

40 **1. Introduction**

41 Subduction zones trigger devastating earthquakes and volcanic eruptions (e.g. Ruff and
42 Kanamori, 1980; Tatsumi, 1986; Stern, 2002). Understanding mechanical coupling and mass
43 transfer occurring at the subduction plate boundary, and the complex interplay of short and
44 long-term processes, is therefore critical to decipher subduction dynamics and risk
45 assessment (Rüpke et al., 2004; Agard et al., 2018; Behr and Bürgmann, 2021). During
46 convergence, some material is removed from the downgoing plate (the 'slab') sporadically
47 and accreted, or 'underplated', to the upper one (Karig and Sharmann, 1975; Scholl et al.,
48 1980; Platt, 1986). At shallow depth, offscraping at the roof of the oceanic crust results in the
49 formation of accretionary wedges dominated by sediments (Platt, 1988). Deeper accretion
50 also takes place along the subduction plate interface (Willner, 2005; Agard et al., 2009) and
51 leads to the juxtaposition, and later exhumation, of deeply subducted slices with distinctive
52 subduction histories (Plunder et al., 2012, 2015; Angiboust et al., 2013, 2014, 2016, 2018;
53 Tewksbury-Christle et al., 2021). The removal of oceanic material from the slab, and
54 potential accretion to the upper plate, require the down-stepping of the plate interface
55 décollement into the slab (Kimura and Ludden, 1996; Kimura et al., 2007), hence an increase
56 in mechanical coupling (Agard et al., 2016, 2020) and strain localization into weakness zones
57 (Kimura and Ludden, 1996; Kimura et al., 2007; Angiboust et al., 2012c; Ruh et al., 2015).
58 The worldwide record of blueschist- and eclogite-facies subducted oceanic fragments shows
59 that this happens transiently (Agard et al., 2009; Monié and Agard, 2009; Bonnet et al., 2018)
60 and at non-random depths (Plunder et al., 2015; Agard et al., 2018).

61 The processes leading to coupling and slicing in the slab are still debated, despite
62 suggestions that large sediment inputs (Behr and Becker, 2018) and serpentization of the
63 slab (Ruh et al., 2015) or of the mantle wedge (Agard et al., 2009, 2016; Guillot et al., 2009,
64 2015), or fluid-mediated deformation mechanisms (Agard et al., 2020), may enhance the
65 lubrication of the plate interface, and thereby promote decoupling (Agard et al., 2018; Garber
66 et al., 2020b). More specifically, what are the mechanical processes driving deep slicing of
67 the downgoing plate and the recovery of slivers at the surface? Do rock recovery clusters
68 correspond to downdip changes of the mechanical behavior along the plate interface or to

69 lithological heterogeneities? How do dehydration reactions impact slab fragments, from the
70 base of the seismogenic zone down to sub-arc depths?

71 Since direct access through deep drilling is limited to the few first kilometers (e.g. Tobin et
72 al., 2019), the investigation of fossil subduction fragments with a diagnostic high pressure
73 low temperature (HP-LT) imprint is paramount. In the Western Alps, remnants of subducted
74 slow-spreading oceanic lithosphere (Lagabrielle and Cannat, 1990) are exposed along the
75 200 km-long and up to 50 km-wide Liguro-Piemont domain (L-P; or Piemonte-Liguria
76 domain; Deville et al., 1992; Agard, 2021; Agard and Handy, 2021). This nappe-stack is one
77 of the largest, better-preserved and most studied examples of fossil subduction complexes,
78 spanning a range from ~30 to 80 km depth (Berger and Bousquet, 2008; Agard et al., 2002,
79 2018; Agard, 2021), and providing an access to subduction processes along those depths
80 (Bebout et al., 2013; Herviou et al., 2021).

81 In the L-P domain, a major distinction can be made between the metamafic-ultramafic
82 dominated (MUM units of Agard, 2021) eclogite-facies units and the metasedimentary
83 dominated (S units of Agard, 2021) blueschist (BS)-facies units (Dal Piaz, 1974b; Caby et al.,
84 1978; Droop et al., 1990; Pognante, 1991; Agard et al., 2001a). Within these distinct zones,
85 several slices, generally three to four in total, were identified along different transects of the
86 L-P domain (Fudral, 1996; Agard et al., 2001a; Tricart and Schwartz, 2006; Lagabrielle et al.,
87 2015). However, tectonic contacts preserving the pristine, initial juxtaposition of the units
88 sliced during subduction are often obscured by later deformation and almost impossible to
89 follow over great distances. Consequently, very few studies (e.g. Deville et al., 1992) have
90 attempted to correlate these tectonic slices across the entire domain, and their extension and
91 distribution across the L-P domain remain poorly known. A detailed knowledge of this
92 tectonometamorphic set-up is nevertheless critical to reconstruct the 2D and 3D geometries
93 and to understand subduction-related processes along the L-P domain.

94 In the Liguro-Piemont domain, metamafic and ultramafic bodies are generally embedded in
95 volumetrically dominant sediments. These sediments, more sensitive to P-T changes (Goffé
96 and Chopin, 1986; Bousquet et al., 2008) are also cropping out continuously along the
97 complex and across the different slices. They provide the opportunity to follow in detail the
98 evolution of (i) the index mineralogy (Goffé et al., 2004; Bousquet et al., 2008), (ii) the
99 variation of their stratigraphic succession (Deville et al., 1992; Lemoine, 2003), (iii) the
100 maximum temperature experienced by these rocks during peak burial (Beyssac et al., 2002),
101 and (iv) the peak pressure, through adequate indicators (Agard et al., 2001a, 2001b).

102 This study tightly and systematically combines lithostratigraphic, structural and petrologic
103 data, both new and from the literature, across the entire L-P domain of the Western Alps, in

104 order to precise its tectonometamorphic set-up. A refined model of the distribution of
105 equivalent tectonic slices along the L-P complex is proposed. We then discuss the
106 mechanisms driving the recovery of the distinct rock types (MUM versus S units) from
107 selective depths and the insights gained on Alpine subduction dynamics, as well as on the
108 processes driving slab slicing and nappe stacking at depth.

109

110 **2. Geological setting**

111 **2.1 Fragments of subducted oceanic lithosphere in the Western Alps**

112 The Western Alps formed as a result of an east- to south-east-dipping and slow (~1 cm/yr)
113 subduction of the 100 to 1000 km wide Valais and Liguro-Piemont oceans below Adria/Apulia
114 (Le Pichon et al., 1988; Schmid et al., 1996, 2017; Lapen et al., 2003; Handy et al., 2010;
115 Agard and Handy, 2021). Subduction of these slow-spreading oceanic domains (Lagabrielle
116 and Cannat, 1990) started in the Late Cretaceous and was over by ~35 Ma (Stampfli et al.,
117 1998; Schmid et al., 2017). Subduction of oceanic material was followed by a phase of
118 continental subduction (Chopin, 1984; Rubatto and Hermann 2001; Bonnet et al., submitted)
119 before Eurasia-Adria/Apulia collision started (Simon-Labric et al., 2009; Bellahsen et al.,
120 2014).

121 Remnants of subducted Liguro-Piemont oceanic lithosphere are now exposed in the internal
122 domain of the Western Alps and form a nappe-stack known as the Liguro-Piemont (L-P)
123 domain (Agard, 2021; Agard and Handy, 2021; Fig. 1a) or Schistes Lustrés complex (Caron,
124 1977; Agard et al., 2001a, 2009), owing to their characteristic sedimentary features.
125 Metasediments (Schistes Lustrés s.s.) are volumetrically dominant in this complex and range
126 from the Late Jurassic (De Wever and Caby, 1981; Lagabrielle, 1987) to the Late Cretaceous
127 (Lemoine et al., 1984; Lagabrielle, 1987). They correspond to an initial ~200-400 m thick
128 sequence of pelagic and hemipelagic seafloor deposits (marls, shales and limestones
129 metamorphosed as calcschists, metapelites and marbles; Lemoine et al., 1984; Lemoine and
130 Tricart, 1986; Lemoine, 2003; Deville et al., 1992; Michard et al., 1996) embedding variable
131 amounts of mafic and ultramafic rocks (Fig. 1a). The serpentized mantle generally contains
132 sparse pockets of Jurassic mafic material (e.g. Decrausaz et al., 2021) highlighting the
133 discontinuous character of the oceanic crust (Lagabrielle, 1987; see Agard, 2021 and
134 references therein). Exposed fragments of L-P lithosphere often preserve pre-alpine oceanic
135 structures (Lagabrielle et al., 2015, Balestro et al., 2018, 2019; Decrausaz et al., 2021).

136 During subduction, these rocks were buried between ~30 and 80 km depth (Agard et al.,
137 2002, 2009) and were intensely folded, leading to significant thickening of the initial
138 sedimentary pile (Agard et al., 2002; Tricart and Schwartz, 2006). Agard et al. (2009) roughly

139 estimated that approximately 30% to 50% of the sedimentary deposits were scraped off
140 from the downgoing plate and exhumed, whereas only ~5% of the oceanic crust and
141 serpentinized mantle were.

142 After a peak burial between 60 and ~40 Ma (e.g. Agard et al., 2002; Rubatto and Hermann,
143 2003), these rocks were detached as slices from the subducting plate and were exhumed
144 from the Late Eocene to the Miocene (Agard et al., 2002, 2009; Schwartz et al., 2007, 2020;
145 Malusà et al., 2005; Angiboust and Glodny, 2020). This complex stack of slices formed a
146 deep accretionary complex, probably built by progressive underplating (Platt, 1986; Marthaler
147 and Stampfli, 1989; Agard et al., 2009, 2018; Agard, 2021), where structurally upper slices
148 may have been underplated earlier (Kimura et al., 2007; Dumitru et al., 2010; Plunder et al.,
149 2012; Agard and Vitale-Brovarone, 2013; Angiboust et al., 2016).

150 Rocks from the Western Alps L-P domain, metamorphosed under BS- to eclogite-facies
151 conditions, exhibit an almost continuous increase of metamorphic grade from west (~1.2
152 GPa-330°C) to east (~2.5 GPa-550°C), along a ~8°C metamorphic gradient characteristic of
153 subduction zones (Agard et al., 2001a; Gabalda, 2009; Plunder et al., 2012; Schwartz et al.,
154 2013; Agard, 2021). This gradient is recognizable by the evolution of metamorphic mineral
155 assemblages and notably by the subtle evolution of index minerals in metasediments (Goffé
156 and Chopin, 1986; Agard et al., 2001a; Goffé et al., 2004; Bousquet et al., 2008; Fig. 1b). For
157 example, in the western part of the Schistes Lustrés complex, and especially south of Ambin
158 massif, Fe-Mg carpholite is frequently present in pelitic layers (Fig. 1b; Goffé et Chopin,
159 1986; Agard et al., 2001a). Further east, Fe-Mg capholite gradually disappears at the
160 expense of chloritoid (Fig. 1b; Goffé et Chopin, 1986; Agard et al., 2001a). In both areas
161 lawsonite can be observed in the metasedimentary matrix as well as in metamorphic veins
162 (Caron, 1974; Bocquet, 1974; Saliot et al., 1978; Lefeuvre et al., 2020; Herviou et al., 2021).
163 Finally, the easternmost part of the L-P domain is characterized by the occurrence of garnet,
164 generally coexisting with chloritoid (Agard et al., 2001a; Plunder et al., 2012; Ghignone et al.,
165 2021a). In these metasediments, Fe-Mg carpholite is characteristic of low-temperature BS-
166 facies while chloritoid generally appears in high-temperature BS-facies (Goffé et Chopin,
167 1986; Goffé et al., 2004). Lawsonite is present over a wide range of P-T conditions in these
168 BS-facies rocks (Herviou et al., 2021), whereas the presence of garnet is indicative of
169 eclogite-facies metamorphism (Agard et al., 2001a; Plunder et al., 2012; Vitale-Brovarone et
170 al., 2014) except for rare spessartine and grossular-rich garnet in marbles (Ballèvre and
171 Lagabrielle, 1994; Manzotti et al., 2021).

172 Besides this metamorphic gradient, several units/slices were identified in the L-P domain of
173 the Western Alps based on lithostratigraphic and tectonometamorphic contrasts (Lagabrielle,

174 1987; Fudral, 1996; Agard, 2021). In particular, the metamafic-ultramafic dominated eclogite-
175 facies units crop out eastward of and tectonically below the BS-facies metasedimentary-
176 dominated units (Fig. 2c; Dal Piaz, 1974b; Caby et al., 1978; Droop et al., 1990; Pognante,
177 1991; respectively MUM and S units of Agard, 2021 and Agard and Handy, 2021). These
178 zones are separated by a major extensional tectonic contact (Philipot, 1990; Ballèvre et al.,
179 1990; Ballèvre and Merle, 1993). Inside these different zones, distinct slices, generally 3 to 4
180 were described in different transects of the L-P domain (Lagabrielle, 1987; Fudral, 1996;
181 Agard, 2021) and are described in the next section.

182

183 **3. Subduction slices across the Western Alps Liguro-Piemont domain**

184 **3.1 Valais-Aosta transect**

185 In this northern zone, the identification of a major sharp divide was first made in the Zermatt-
186 Saas area by Bearth (1959, 1962, 1967). Kienast (1973), Dal Piaz (1974a, 1974b) and Caby
187 et al. (1976, 1978) later described a similar divide in the Aosta Valley. These authors
188 identified a zone of “Lower Schistes Lustrés” rich in mafic and ultramafic rocks
189 metamorphosed in eclogite-facies that they distinguish from a zone of “Upper Schistes
190 Lustrés” only metamorphosed in blueschist- and greenschist-facies and almost devoid of
191 ophiolites. The eclogite-facies slices or Zermatt-Saas zone are cropping out eastward of the
192 Dent Blanche klippe and are tectonically overlain by the blueschist slices named Combin
193 zone (or Tsaté Nappe). These zones are separated by a Late Cretaceous-Early Tertiary
194 extensional fault, the Combin fault (Ballèvre et Merle, 1993, Fig. 1a-c).

195 Different tectonic slices were identified in the Zermatt-Saas zone: the Zermatt-Saas and Avic
196 slices found on both sides of the Aosta fault (ZS and AV in Fig. 1c; Dal Piaz et al., 2010;
197 Polino et al., 2015). Thermodynamic modelling, multi-equilibrium thermobarometry and
198 Raman Spectroscopy on Carbonaceous Material (RSCM) allowed to estimate peak P-T
199 conditions around $550 \pm 50^\circ\text{C}$ and 2.5 ± 0.5 GPa for the Zermatt-Saas unit (Bucher et al.,
200 2005; Bucher and Grapes, 2009; Angiboust et al., 2009; Angiboust and Agard 2010; Negro
201 et al., 2013; Zanoni et al., 2016) and around $550 \pm 50^\circ\text{C}$ and 2.1-2.3 GPa for the Avic unit
202 (Martin et al., 2008; Angiboust et al., 2009; Angiboust and Agard 2010; Dragovic et al.,
203 2020). While the homogeneity of the P-T conditions recorded in these two units may hint to
204 largely coherent slices (Angiboust et al., 2009), these two units show at smaller scale a
205 series of tectonic slices separated by serpentinite layers (Angiboust and Agard, 2010). Near
206 Lago di Cignana, a small 2 km^2 ZS slice contains diamond- and coesite-bearing
207 metasediments indicative of ultra-high pressure (UHP) conditions of 2.8-3.2 GPa and 600°C
208 (Reinecke, 1991, 1998; Compagnoni and Rolfo, 2003; Groppo et al., 2009; Frezzotti et al.,

209 2011). Finally, south of the Avic unit, an eclogite-facies slice is cropping out around the Gran
210 Paradiso massif, the Grivola-Urtier unit (GU in Fig. 1c; Bocchio et al., 2000; Dal Piaz et al.,
211 2010; Polino et al., 2015). P-T conditions of 550°C, 2.3-2.5 GPa are estimated for this slice
212 mostly made of calcschists enveloping mafic blocks (Bousquet, 2008; see also Reynard and
213 Ballèvre, 1988).

214 Based on multiple methods, most peak burial ages range between 40 and 50 Ma for the
215 Zermatt-Saas unit (Bowtell et al., 1994; De Meyer et al., 2014; Skora et al., 2015; Weber et
216 al., 2015; Rebay et al., 2018), between 42-46 Ma for the Avic unit (Dal Piaz et al., 2001;
217 Dragovic et al., 2020) and between 40 and 49 Ma for the Lago di Cignana slice (Rubatto et
218 al., 1998; Amato et al., 1999; Lapen et al., 2003; Gouzu et al., 2006, 2016; Skora et al.,
219 2015). For the Grivola-Urtier unit, peak burial ages were constrained between 42 and 48 Ma
220 by Rb-Sr and Ar-Ar on white mica in both metasediments and metamafics (Dal Piaz et al.,
221 2001; Villa et al., 2014) and between 55 and 60 Ma by Lu-Hf on bulk garnet-omphacite or
222 garnet-glaucophane assemblages (Villa et al., 2014). D1 syn-peak deformation stage is
223 dated at 48 Ma while D2 syn-BS facies exhumation is dated at 40 Ma (Villa et al., 2014). K-Ar
224 data on white-micas from two localities of the Grivola-Urtier unit gave 54-39 Ma ages
225 (Delaloye and Desmons, 1976).

226 In the BS-facies Combin zone, below the Dent Blanche klippe, the presence of a synformal
227 stack of slices was inferred from the distribution of RSCM temperatures (Negro et al., 2013;
228 Angiboust et al., 2014; Manzotti et al., 2021), possibly two or three slices (Angiboust et al.,
229 2014). Recently, Manzotti et al. (2021), based on petrological data and field observations,
230 suggested the presence of two slices, the Cornet unit separated from the underlying By unit
231 by a major tectonic discontinuity (respectively CO and BY in Fig. 1c). Based on this
232 distinction, peak temperatures range between 364 and 422°C in the Cornet unit and between
233 421 and 530°C in the By unit (Negro et al., 2013; Angiboust et al., 2014; Decrausaz et al.,
234 2021; Manzotti et al., 2021). The large By unit may comprise several slices (Broilliot and
235 Aouilletta slices; Ellero and Loprieno, 2018; Polino et al., 2015), but their extension is
236 unknown. Peak pressures are estimated at 1.6-1.7 GPa for the By unit and 0.8-0.9 GPa for
237 the Cornet unit (Manzotti et al., 2021). The D2 to D3 exhumation-related episodes of these
238 units were dated between 41 and 37 Ma (Reddy et al., 2003; Angiboust et al., 2014).
239 Potentially independent tectonic slices, rooted in the Briançonnais area and belonging to the
240 complex Valsavarenche mega-fold (Bucher et al., 2003), crop out around the Valgrisenche,
241 Val de Rhêmes and Valsavarenche valleys. These slices, grouped in the Avise-Tsaboc-
242 Feluma unit (ATF in Fig. 1c), seem to have recorded BS-facies conditions (Debelmas et al.,
243 1991; Caby, 1996; Polino et al., 2015). In the Avise area, D1 deformation was dated a 45.4
244 Ma and followed by a 39.5 Ma D2 deformation. Finally, a slice may be present in the eastern

245 side of Grand Paradiso between the Grivola-Urtier slice and the Sesia complex, featured as
246 a thin tongue of BS-facies L-P rocks in literature maps and cross-sections (Ballèvre et al.,
247 1986; Dal Piaz et al., 2001; West-Sesia, i.e. W-SS in Fig. 1c).

248 **3.2 Savoy-Susa transect**

249 A similar contrast between the BS-facies “Upper Schistes Lustrés” and eclogite-facies “Lower
250 Schistes Lustrés” was observed in the Savoy area by Bocquet (1974), Caby et al. (1976),
251 Chopin (1979) and Robert (1979), and in the Susa Valley by Pognante (1980, 1984). Chopin
252 (1979) first distinguished two sets of slices within the BS-facies zone, with the “Upper Unit”
253 characterized by low-grade BS-facies metamorphism atop the “Intermediate Unit” composed
254 by a thick series of calcschist metamorphosed in BS-facies. Based on lithostratigraphic and
255 structural arguments, Deville (1987), Fudral et al., (1987) and Fudral (1996) refined Chopin's
256 (1979) distinction by also suggesting the presence of three units in the Savoy region and by
257 mapping their distribution. These units are the eclogite-facies “Lower Oceanic Unit”, the BS-
258 facies “Middle Oceanic Unit” and the “Upper Oceanic Unit” also metamorphosed in BS-
259 facies.

260 The “Upper Oceanic Unit” (Savoy Upper Unit) crops out as rare klippen scattered across the
261 region (Lamet, Jovet, Sana, Grand Vallon; respectively LA, JO, SN-U and GV in Fig. 1c, see
262 also 2a). Their limited extent across the area precludes assessing whether they are
263 independent slices or instead correspond to a single one. Nevertheless, the Grand Vallon
264 klippe (Fig. 1c) contains a stratigraphic succession distinct from the other “Upper Oceanic
265 Unit” klippen (Deville, 1986, 1987; Fudral, 1996). Its detrital-rich sediments were dated as
266 Late Maastrichtian by the presence of foraminifera, as for the unmetamorphosed Helminthoid
267 Flysch (Deville, 1986). Such deposits are rarely encountered in the Schistes Lustrés,
268 suggesting that this klippe constitutes an independent slice (Deville, 1986; Deville et al.,
269 1992; Fudral, 1996). The “Upper Oceanic Unit” is characterized by a low-grade BS-facies,
270 marked by the presence of Fe-Mg carpholite or lawsonite and absence of chloritoid (Fig. 1b).
271 Peak burial temperatures range between 376 and 404°C in the Savoy region (Gabalda et al.,
272 2009; Plunder et al., 2012). No pressure or age constraints are available for these tectonic
273 slices.

274 The “Middle Oceanic Unit” (Savoy Middle Unit, i.e. SMU in Fig. 1c) predominates in this
275 region and seems to be made of several slices with uncertain boundaries (Fudral, 1996).
276 These slices mostly crop out across the Haute-Maurienne valley and have also been
277 identified in the Grande Sassièrè and Chardonney klippen and at the base of the Sana klippe
278 (Deville, 1987, Fudral, 1996; respectively GS, CH and SN-L in Fig. 1c). Near Susa, a distinct
279 Venaus slice was recognized (Polino et al., 2002; Cadoppi et al., 2002; VN in Fig. 1c) within

280 the previously defined Savoy slices (Fudral, 1996). The “Middle Oceanic Unit” is mostly
281 made of massive calcschist slices and characterized by the presence of chloritoid, lawsonite
282 and relics of Fe-Mg carpholite (Fig. 1b). Peak P-T are 384-503°C and 1.6-1.9 GPa (Rolland
283 et al., 2000; Gabalda et al., 2009; Plunder et al., 2012). Recent in situ Ar-Ar white-mica
284 dating of the “Middle Oceanic Unit” around Susa gave ages for an early foliation S1 between
285 49 and 40 Ma, while retrograde fabrics (S2 and mylonitic foliation) range between 40 and 37
286 Ma (Ghignone et al., 2021b). Previous Ar-Ar dating on white mica for this unit gave 42-37 Ma
287 ages (Chopin and Maluski, 1980).

288 The eclogite-facies “Lower Oceanic Unit” (Savoy Lower Unit, i.e. SLU in Fig. 1c) crops out in
289 the eastern part of the Haute-Maurienne area, immediately above the Gran Paradiso massif
290 (Fig. 2a; Chopin, 1979) and in the Susa, Viu and Ala Valleys (Fig. 1c). At least two slices
291 named Ciamarella-Gran Uia and Averole were recognized in this unit (Fudral, 1996), but
292 their exact distribution remains uncertain. A large slice of eclogitized mantle is also present in
293 the eastern part of this transect, the Lanzo massif (Lagabrielle et al., 1990; Debret et al.,
294 2013; Fig. 1a, b, c). Its ultramafic lithology contrasts with those of the “Lower Oceanic Unit”,
295 and whether it represents oceanic or sub-continental mantle is disputed (Bodinier et al.,
296 1991; Müntener et al., 2005; Pelletier and Müntener, 2006; Piccardo et al., 2007). The
297 “Lower Oceanic Unit” is characterized by the appearance of garnet coexisting with chloritoid,
298 suggesting the existence of a pressure gap with the “Middle Oceanic Unit” (Plunder et al.,
299 2012; Vitale-Brovarone et al., 2014). Estimated peak P-T are 460-570°C and 2.2-2.9 GPa
300 (Rolland et al., 2000; Gabalda et al., 2009; Plunder et al., 2012; Ghignone et al., 2021a).
301 Recent in-situ Ar-Ar dating on an early S1 foliation gave 47-42 Ma ages, while retrograde
302 fabrics (S2 and mylonitic foliation) range between 40 and 36 Ma (Ghignone et al., 2021b).
303 Previous Ar-Ar on white micas data for the HP stages of this unit yielded a wide range
304 between 68 and 39 Ma (Chopin and Maluski, 1980).

305 **3.3 Cottian Alps transect**

306 In this transect, the different L-P units are particularly well-exposed across a long ridge
307 between Susa and the Chisone valley, which constitutes a reference cross-section (Caron,
308 1977; Agard et al., 2001a, 2001b, 2009; Agard, 2021; Fig. 2b). A strong eastward
309 metamorphic gradient was identified by the progressive increase of the tschermak
310 substitution in white-mica (which serves as proxy for pressure; Velde, 1967; Massonne and
311 Schreyer, 1987) and by the evolution of index minerals in sediments (Agard et al., 2001a,
312 2001b; Fig. 1b). These trends are also reflected in the eastward increase of RSCM
313 temperatures (Beyssac et al., 2002). In this region, as well, a zone of BS-facies
314 metasedimentary-dominant slices stands out from an eclogite-facies zone containing more

315 metamafics and ultramafic rocks (Agard, 1999; Agard et al., 2001a; Fig.1a, c). These zones
316 are separated by a major tectonic contact, well exposed at the Finestre Pass (Fig. 2b;
317 Ballèvre et al., 1990; Agard et al., 2001a).

318 Several tectonic slices were described in the BS-facies zone. Structurally on top, the Lago
319 Nero unit (Polino et al., 2002; Barféty et al., 2006; LN in Fig. 1c, see also 2b) shows Fe-Mg
320 carpholite-bearing metasediments and the appearance of chloritoid in the eastern outcrops
321 (Agard et al., 2001a, 2001b). These rocks also contain massive amounts of lawsonite
322 (Lefeuvre et al., 2020). Peak P-T range from 300-350°C- 1.2-1.3 GPa at west to ~380°C- 1.8
323 GPa at east (Agard, 1999; Agard et al., 2001a, 2001b; Beyssac et al., 2002; Gabalda et al.,
324 2009). The Lago Nero unit was considered as analogous to the “Oceanic Upper Unit” of the
325 Savoy transect (Plunder et al., 2012; Agard, 2021). Below this slice, five BS-facies tectonic
326 slices were identified: (i) the Cerogne-Ciantiplagna unit (Polino et al., 2002; Cadoppi et al.,
327 2002; CC in Fig. 1c, see also 2b); (ii) the Albergian unit, separated from the Cerogne-
328 Ciantiplagna unit by a major tectonic contact nicely exposed in the Chisone valley (Polino et
329 al., 2002; ALB in Fig. 1c); (iii) the Puys unit, considered as an equivalent of the Venaus slice
330 from the Savoy-Susa transect (Polino et al., 2002; Barféty et al., 2006; PY in Fig. 1c); (iv) the
331 Aigle unit (Polino et al., 2002; Barféty et al., 2006; AG in Fig. 1c) and (v) the small Vin Vert
332 unit (Polino et al., 2002; Barféty et al., 2006; VV in Fig. 1c) immediately above the Ambin
333 massif. The Cerogne-Ciantiplagna and Albergian units are characterized by the presence of
334 chloritoid (Fig. 1b) and peak P-T conditions of 423-463°C- ~1.9 GPa (Agard et al., 2001a,
335 2001b, Beyssac et al., 2002). These slices were inferred to be equivalent to the “Middle
336 Oceanic Unit” of the Savoy-Susa transect (Plunder et al., 2012; Agard, 2021). The Puys,
337 Aigle and Vin Vert slices are essentially lacking P-T constraints, although a RSCM
338 temperature of 386°C was estimated in the Aigle unit (Gabalda et al., 2009). In
339 metasediments from the Lago Nero and Albergian units, several deformation stages were
340 identified and dated (Agard et al., 2001a, 2002; see also Ghignone et al., 2021a). D1
341 deformation relates to the development of early fabrics, km-scale folds and crystallization of
342 peak metamorphic assemblages at 61-55 Ma for the Lago Nero unit and 64-49 Ma for the
343 Albergian unit. A second phase (D2), dated at 51-43 Ma for the Lago Nero, corresponds to
344 the ductile east-vergent deformation accompanying early exhumation under BS-facies
345 conditions. The third fabric (D3), between ~38 and 36 Ma for the Lago Nero unit, is marked
346 by top-to-the-west ductile to brittle deformation associated with greenschist-facies
347 exhumation. Two K-Ar ages on white mica from the Lago Nero unit gave 67-62 Ma ages
348 (Delaloye and Desmons, 1976).

349 In the eclogite-facies zone, the presence of different slices is unclear. In the Orsiera-
350 Rocciavré unit (OR in Fig. 1c, Cadoppi et al., 2002), the Rocciavré massif is a large eclogitic

351 gabbroic and ultramafic body containing negligible amounts of metasediments (Pognante,
352 1985). In contrast, to the west, from Monte Orsiera to Finestre pass, mafic and ultramafic
353 rocks are embedded in metasediments that seem to be volumetrically equivalent to the
354 ophiolitic bodies (Fig. 1c). The existence of a tectonic contact between these two parts of the
355 unit was suggested by Cadoppi et al. (2002). Metasediments contain garnet and chloritoid
356 (Fig. 1b) and their estimated P-T conditions are 500-542°C and ~2-2.1 GPa (Agard, 1999;
357 Agard et al., 2001a, 2001b, Beyssac et al., 2002; Gabalda et al., 2009). No recent P-T
358 estimates are available for the mafic rocks. The Orsiera-Rocciavrè unit is interpreted as the
359 southern extension of the “Lower Oceanic Unit” of the Savoy-Susa transect (Plunder et al.,
360 2012). In metasediments from the Orsiera-Rocciavrè unit, the same D1 to D3 events of BS-
361 facies slices were described (Agard et al., 2001b). An early-HP stage, close to D1
362 deformation is dated at 61-53 Ma by in situ Ar-Ar in white mica, whereas D2 is dated at 46-42
363 Ma and D3 at 42-38 Ma (Agard et al., 2002). In Rocciavrè metagabbros, Rb-Sr on phengite
364 with high Si content gave a 46 Ma age (Angiboust and Glodny, 2020).

365 **3.4 Queyras-Monviso and Ubaye transects**

366 Along these southernmost transects, the BS-facies slices are separated from eclogite-facies
367 units by a major extensional contact (Philippot, 1990; Ballèvre et al., 1990; Fig. 2c).

368 Three BS-facies slices were identified in the Queyras region around the Guil valley, from
369 west to east (Lagabrielle, 1987; Lagabrielle et Polino, 1988; Lagabrielle et al., 2015): (i) the
370 Calcschist unit (CS in Fig. 1c, see also 2c), almost devoid of ophiolitic material, is
371 characterized by Fe-Mg carpholite and lawsonite occurrences (Herviou et al., 2021; Fig. 1b,
372 c); (ii) the Pelvas-Taillante unit (PT in Fig. 1c, see also 2c) also contains Fe-Mg carpholite
373 and lawsonite occurrences, and chloritoid appears in the eastern part (Fig. 1b); (iii) the
374 Mirabouc-Bouchet unit (MB in Fig. 1c, see also 2c), which is characterized by the presence
375 of lawsonite and chloritoid (Fig. 1b). Estimated P-T conditions are 320-340°C- ~1 GPa for the
376 Calcschist unit, 338-373°C- ~1.2 GPa for the Pelvas-Taillante Unit and 383-469°C- ~1.3 GPa
377 for the Mirabouc-Bouchet unit (Schwartz, 2000; Tricart and Schwartz, 2006; Schwartz et al.,
378 2013).

379 The eclogite-facies zone of this transect corresponds to the Monviso massif, a large mafic-
380 ultramafic body (Lombardo et al., 1978) comprising at least two tectonic slices (Schwartz et
381 al., 2000a; Angiboust et al., 2012b; Locatelli et al., 2018, 2019a). The Monviso Unit (MV in
382 Fig.1c, see also 2c), to the west, recorded 476-498°C- ~2.2 GPa P-T conditions (Angiboust
383 et al., 2012b; Schwartz et al., 2013) and the Lago Superiore unit to the east (LS in Fig. 1c,
384 see also 2c) recorded 514-580°C- 2.5-2.8 GPa (Groppo and Castelli, 2010; Angiboust et al.,

385 2012b, Schwartz et al., 2013; Locatelli et al., 2018). Metasediments from these two slices are
386 characterized by garnet-chloritoid-bearing assemblages (Fig. 1b).

387 The Lago Superiore unit peak-burial conditions were dated between 50 and 45 Ma by
388 multiple methods (Duchène et al., 1997; Rubatto and Hermann, 2003; Rubatto and
389 Angiboust, 2015; Garber et al. 2020a). The D2 and D3 exhumation-related deformation
390 episodes were dated at 38-37 Ma and 35 Ma in the Lago Superiore and Monviso slices
391 (Angiboust and Glodny, 2020; Rb-Sr on phengite). For the BS-facies slices, a 42-40 Ma Ar-
392 Ar age on white mica, supposedly close to peak P-T conditions, was obtained for the
393 Calcschist unit (Lanari, 2012). In the Pelvas-Taillante unit, two ages between 43 and 41 Ma
394 were obtained by bulk K-Ar on white mica (Delaloye and Desmons, 1976). Finally, Ar-Ar
395 dating on white mica on a sample from the Mirabouc-Bouchet unit gave 68-58 Ma for an
396 early S1 fabric (prograde to peak?), 45 Ma for a second fabric (S2) and a <30 Ma age for a
397 S3 foliation (Lanari, 2012). D3 deformation in the same slice was dated at ~35 Ma by Rb-Sr
398 on phengite (Angiboust and Glodny, 2020). All these BS- and eclogite-facies units were
399 stacked and exhumed from late Eocene to Miocene times (Angiboust and Glodny, 2020;
400 Schwartz et al., 2007, 2020). Along the Ubaye transect, an eastward metamorphic increase
401 was identified from the Briançonnais units to the Liguro-Piemont domain (Michard et al.,
402 2004), with no distinction of L-P slices. We will consider that the Queyras-Monviso slices
403 extend across this valley (Fig. 1c).

404

405 **4. Compilation of lithostratigraphic data and size of the recovered slices**

406 **4.1 Stratigraphic columns of the different slices**

407 In order to identify similarities between the tectonic slices of the different transects and gain
408 information on the paleogeography of the L-P slices (Fig. 3a), we compiled lithostratigraphic
409 columns across the Western Alps L-P domain (Fig. 3b).

410 In the Western Alps, the Chabrière series (stratigraphic column 1, Fig. 1a, 3b; Lemoine et al.,
411 1970; Tricart, 1974) is considered as the characteristic and idealized sequence of L-P
412 deposits. This stratigraphic column allowed to differentiate the L-P series deposited on an
413 oceanic basement from the Gondran-type series (Lemoine, 1959, 1971), which are made of
414 sediments deposited on the Piemont/Pre-Piemont continental margins (Fig. 1a-c; Lemoine,
415 1971; Elter, 1971; Bourbon et al., 1979; Lemoine et al., 1986). The Chabrière-type series
416 starts with radiolarian cherts or shales deposited on an oceanic basement. This formation,
417 dated between the Oxfordian and the Kimmeridgian (De wever and Caby, 1981; De Wever et
418 al., 1987a, 1987b; Lagabrielle, 1987) corresponds to the first argillite-dominated episode of

419 the series (A2; Fig. 3b; Lemoine, 2003), characterizing sediments deposited below the CCD.
420 These A2 deposits are often composed by manganese-rich quartzite layers instead of cherts
421 (Chopin, 1978, 1979). Overlying the cherts, there is a level of whitish to bluish marbles
422 attributed to the Late Jurassic (Tithonian and up to Berriasian?) by analogy with the
423 “Calpionelles Limestones” of the Ligurian Appenines (Decandia and Elter, 1969, 1972;
424 Lagabrielle, 1987). This formation corresponds to the first calcareous-dominated episode of
425 the series (C3; Fig. 3b; Lemoine, 2003), with deposition above the CCD. The above, younger
426 formation, made of shales with intercalations of calcareous beds with a characteristic reddish
427 patina, is named “Replatte formation” (Lemoine et al., 1970). This formation is attributed to
428 the Lower Cretaceous by analogy with the “Palombini shales” of the Ligurian Appenines
429 (Lemoine et al., 1970, Lemoine and Tricart, 1986; Lagabrielle, 1987). Just above, there is a
430 characteristic formation of black shales, often called the “Roche Noire formation” (Fig. 3b;
431 Tricart, 1974), assigned to the Mid-Cretaceous (Aptian-Albian?) given their similarity with the
432 “Val Lavagna Schists” of Ligurian Appenines (Decandia and Elter, 1972; Tricart, 1974;
433 Lagabrielle, 1987). These two Lower Cretaceous formations correspond to the second
434 argillite-dominated episode of the series (A3; Fig. 3b; Lemoine, 2003). For the sake of clarity,
435 we herein use A3a for the “Replatte formation” and A3b for the “Roche Noire formation” (Fig.
436 3b). Finally, these series end by a thick and fairly homogeneous formation of massive
437 calcschists dated as Late Cretaceous (Cenomanian-Turonian) by the presence of planktonic
438 foraminifera in various localities (Marthaler, 1984; Lemoine et al., 1984; Lagabrielle, 1987;
439 Deville, 1987). In scarce places the L-P series ends with a formation of Maastrichtian
440 calcareous flyschs considered as lateral equivalents of the unsubducted Helminthoid Flysch
441 (Deville, 1986; Deville et al., 1992). These Late Cretaceous formations correspond to the last
442 calcareous-dominated deposit of the series (C4; Fig. 3b; Lemoine, 2003; C4a is used below
443 for the Cenomanian-Turonian calcschists and C4b for the Maastrichtian flyschs). Some of
444 these C4 flyschs may correspond to trench-filling deposits (Marthaler, 1984). The different
445 formations of the Chabrière-type series generally contain detritic and breccia horizons made
446 of continental and/or oceanic material (e.g., Deville et al., 1992) not considered here.

447 The Chabrière series therefore consists of pelagic/hemipelagic and rarer clastic deposits
448 overlying mafic and ultramafic rocks. Changes of the stratigraphic record and/or tectonic
449 repetition of this succession may help reveal the distinct paleogeography and/or preferential
450 zones of detachment inside the sequences (Kimura et al., 1996).

451 In the Western Alps L-P domain, stratigraphic columns equivalent to the Chabrière series
452 were described in several of the blueschist-facies slices.

453 In the Queyras-Ubaye region, the complete Chabrière series was observed in the Pelvas-
454 Taillante slice (Fig. 1a, 3b, stratigraphic columns 1,2; Lemoine et al., 1970; Tricart, 1974;
455 Lemoine and Tricart, 1986; Lagabrielle, 1987). In the Calcschist unit, the deposits are mainly
456 made of a thick C4a calcschist formation overlying a thin A3b formation (Fig. 3b, stratigraphic
457 column 3; Lagabrielle, 1987; Deville et al., 1992). The lack of Jurassic deposits and
458 ophiolites led the authors to suggest that the Calcschist unit sediments may have been
459 deposited on continental margin rather than oceanic basement (Lagabrielle, 1987; Deville et
460 al., 1992). The lithostratigraphic column of the Mirabouc-Bouchet (Fig. 1a, 3b, stratigraphic
461 column 4; Lagabrielle, 1987) is close to the complete Chabrière series but differs by the
462 absence of A2 cherts and the presence of a thick C4a calcschist formation.

463 In the Cottian Alps region, a series close to the Chabrière one was described in the Lac des
464 Cordes (Fig. 1a, 3b, stratigraphic column 5; Dumont et al., 1984; Lemoine and Tricart, 1986).
465 This series is nevertheless lacking the Middle Jurassic cherts and contains a A3a calcschist
466 formation instead of the Replatte formation. In general, Chabrière-type series were identified
467 in the Lago Nero (Fig. 1a, 3b, stratigraphic columns 6 and 7; Caron, 1977; Polino and
468 Lemoine, 1984; Lemoine and Tricart, 1986) and Aigle slices (Fig. 1a, 3b, stratigraphic
469 column 9; Barfáty et al., 2006). C4a is characterized by a calcareous flysch rather than
470 calcschists in the Lago Nero locality (Fig. 3b, stratigraphic column 6; Polino and Lemoine,
471 1984). Deposits in the Puys slice consist of undifferentiated Cretaceous calcschists probably
472 corresponding to C4a (Fig. 1a, 3b; stratigraphic column 8; Barfáty et al., 2006), whereas the
473 Vin Vert slice contains massive C4a calcschists and C3 marbles (Fig. 1a, 3b; stratigraphic
474 column 10; Barfáty et al., 2006). Very few sedimentary descriptions are available for the
475 Cerogne-Ciantiplagna and Albergian slices. The Cerogne-Ciantiplagna sediments
476 nevertheless mostly comprise massive calcschists with very few pelitic alternations (Fig. 2b),
477 as for C4a calcschists. For the Albergian slice, where ophiolites are present in greater
478 amounts (Fig. 1a), the sedimentary sequence rather corresponds to a Chabrière-like series
479 analogous to that of the Mirabouc-Bouchet unit (Caron, 1977; Fig. 1a, 3b, stratigraphic
480 column 4).

481 Around the Savoy region, different series were identified in the Savoy Upper Unit klippen. In
482 most of them, such as for the Lamet klippe (Fig. 1a, 3b, stratigraphic column 11; Fudral,
483 1996), the metasediments correspond to C4a calcschists whereas the Grand Vallon klippe is
484 composed by the Maastrichtian C4b flysch (Fig. 1a, 3b, stratigraphic column 13; Deville,
485 1986, 1987; Deville et al., 1992). However, the Savoy Middle Unit stratigraphic column
486 seems to correspond to an incomplete Chabrière-type series (Fig. 1a, 3b, stratigraphic
487 column 12; Fudral, 1996; Deville et al., 1992): these C4 calcschists overly deposits markedly
488 from the A3 sediments, and this series may therefore lack Lower Cretaceous sediments.

489 Finally, around the Valais region, the Combin sediments resemble a Chabrière-like series
490 with C4 composed by a calcareous flysch (Fig. 1a, 3b, stratigraphic column 14; Marthaler,
491 1984; Sartori, 1987; Kunz, 1988; Marthaler and Stampfli, 1989; Stampfli and Marthaler, 1990;
492 Deville et al., 1992).

493 In the eclogite-facies slices, stratigraphic columns are always lacking Upper Cretaceous
494 formations (Fig. 1a, 3b, stratigraphic columns 15-18; Lagabrielle, 1987; Sartori, 1987;
495 Stampfli and Marthaler, 1990; Deville et al., 1992; Balestro et al., 2019; Tartarotti et al.,
496 2021). These sedimentary series are generally exposing A2 cherts and C3 marbles, overlain
497 by Lower Cretaceous A3a Replatte-like deposits or calcschists. In these slices, the thickness
498 variation of the sedimentary-series is interpreted as reflecting deposition on a rugged
499 seafloor (De Togni et al., 2021).

500 **4.2 Sediment/ophiolitic ratios and surface extension of the slices**

501 The ratio of sedimentary versus ophiolitic material (mafic and ultramafic rocks) cropping out
502 in each L-P slice was calculated using imagej©. This software was also used to compute the
503 approximate aerial exposure of each L-P slice using the geological outlines of the 1:250000
504 BRGM maps (Gap; Annecy and Thonons-les-Bains). For the different contours we used
505 1:50000 ISPRA maps (Aosta; Bardonecchia; Chatillon, Monte Cervino and Susa), 1:50000
506 BRGM maps (Lanslebourg-Mont d'Ambin; Névache-Bardonecchia-Modane; Tignes) and
507 some articles/PhD. theses (Lagabrielle, 1987; Fudral, 1996; Lagabrielle et al., 2015; Manzotti
508 et al., 2021). The Chenaillet and Lanzo massifs (Fig. 1a-c) were not considered in the
509 calculations.

510 The results highlight the predominance of sediments in the Western Alps L-P domain (71%;
511 Table 1). Almost all BS-facies slices surfaces have more than 90% (Table 1) of sediments
512 except for the Combin domain (By + Cornet slices) where numerous volcano-sedimentary
513 horizons (prasinities) are mapped, but where sediments still prevail (76%; Table 1). The
514 whole BS-facies zone surface only contains 9% of mafic and ultramafic rocks (Table 1). The
515 eclogite-facies slices surfaces drastically differ from the BS-facies slices (Table 1). Indeed,
516 four out of the six studied areas contain less than 40% of sediments, whereas the two
517 remaining areas contain around 60% of sediments (Table 1). The whole eclogite-facies zone
518 displays 62% of mafic and ultramafic rocks at the surface. Finally, in the two slices for which
519 few metamorphic informations are available (Avisé-Tsaboc-Feluma and West-Sesia; Fig. 1c)
520 sediments predominate (more than 90%; Table 1).

521 The outcropping surface of the L-P slices ranges from a few km² in the Savoy Upper Unit
522 klippen (less than 1 km² for the Lamet klippe; Table 1) to several hundred of km² (Table 1). In
523 the blueschist-facies zone, most of the slices (14 over 19) represent less than 100 km²,

524 whereas the Lago Nero and Calcschist units are respectively around 130 and 160 km² (Table
525 1). The three remaining zones correspond to greater surfaces but the poor knowledge of the
526 boundaries between the slices imposed some grouping (By+Cornet, Savoy Middle Unit,
527 Albergian+Mirabouc Bouchet; Table 1). In the eclogite-facies zone, most of the slices are
528 larger than 100 km² (5 over 6; Table 1), which may suggest the presence of several slices in
529 these areas.

530

531 **5. Evolution of temperature and pressure in the Western Alps Liguro-Piemont** 532 **slices**

533 **5.1 Raman Spectroscopy of Carbonaceous Material temperatures**

534 **Methodology**

535 The abundance of carbonaceous material in the almost continuously exposed L-P
536 metasediments allows quantifying the maximum temperature (T_{max}) experienced by these
537 metasediments during peak burial, using the Raman Spectra of Carbonaceous Material
538 technique (RSCM; Beyssac et al., 2002, 2003). Despite previous studies across the L-P
539 domain of the Western Alps, large gaps remain across the studied transects (Beyssac et al.,
540 2002; Gabalda et al., 2009; Angiboust et al., 2009, 2012b, 2014; Angiboust and Agard, 2010;
541 Plunder et al., 2012; Negro et al., 2013; Decrausaz et al., 2021; Manzotti et al., 2021; see
542 Fig. 4a). Complementary sampling (108 new samples added to the existing 289 ones) was
543 therefore conducted to constrain the maximum temperature of the entire domain (as for the
544 Central Alps; Wiederkehr et al., 2011), as well as to characterize the thermal imprint of
545 individual tectonic slices (Fig. 4a). Note that two samples, one from this study and another
546 from Schwartz et al. (2013), belong to the west-Chenaillet Gondran sediments, which may
547 rather correspond to Piemont margin deposits (Fig. 4a; Lemoine, 1971).

548 Raman spectra of carbonaceous material, were obtained using a Renishaw inVia
549 Spectrometer at ENS Paris. The excitation light was provided by a laser (Cobolt Fandango)
550 at 514.5 nm and at a power of 50 mW, focused on the sample using a x100 objective (Leica).
551 Thirteen to seventeen spectra per sample were acquired in the 1000-2000 cm⁻¹ range;
552 acquisition time was 30-90 seconds with 10% of laser power following the spectral
553 acquisition parameters of Beyssac et al. (2002). Peak position, baseline correction and band
554 width were determined using Peakfit© software and Matlab© codes. Temperatures were
555 determined using Beyssac et al. (2002) method for most of the samples (105 samples) and
556 using Lahfid et al. (2010) method for the very rare low-temperature samples (<330°C; 3
557 samples). The RSCM data from the literature and this study were then interpolated using the

558 inverse distance weighted interpolation method of QGis© software (Fig. 4b, c). Temperature
559 estimates, mineralogy and GPS coordinates of the samples can be found in Sup. mat. 1.

560 **Results**

561 RSCM temperatures and their interpolation illustrate the eastward increase of metamorphic
562 grade across the Western Alps L-P domain (Fig. 4a-c). This is particularly conspicuous south
563 of the Gran Paradiso massif, where western samples recorded 300-350°C peak
564 temperatures while eastward samples are generally greater than 500°C (Fig. 4a-c). The
565 distribution of the L-P tectonic contacts allows studying the specific maximum temperature of
566 each slice (Fig. 4c). It reveals the presence of both intra-slice metamorphic gradients, where
567 temperature overlaps rather smoothly across the slices, and temperature gaps matching
568 tectonic contacts (Fig. 4c). For example, some BS-facies slices (Fig. 1c; §3) are dominantly
569 in bluish-color in the interpolation maps, exposing temperatures below 400°C, while others
570 have greenish to yellowish colors outlining a temperatures range between 400°C and 500°C
571 (Fig. 4b-c). The eclogite-facies slices exhibit almost only orange to red colors suggesting
572 temperatures above 500°C (Fig. 4b-c). More irregular patterns in the temperature
573 interpolation, especially south of Gran Paradiso massif, result from the lack of data in these
574 areas (Fig. 4b).

575 The temperature distribution for each slice (mean, median, standard deviation, number of
576 samples and temperature range) is compiled in Table 2. While many slices show a wide
577 range of temperatures, reflecting their internal metamorphic gradient (Table 2; Fig. 4a-c), the
578 mean-median temperatures of slices appear clustered around three temperature ranges in
579 each of the four studied transect (Valais-Aosta, Savoy-Susa, Cottian Alps and Queyras-
580 Monviso; Table 2). These clusters are around 350-390°C (Cornet, Savoy Upper Unit, Lago
581 Nero, Puys, Aigle, Calcschist Unit and Pelvas-Taillante), 415-475°C (By, West-Sesia, Savoy
582 Middle Unit, Venaus, Vin Vert, Cerogne-Ciantiplagna, Albergian, Mirabouc-Bouchet) and
583 490-540°C (Zermatt-Saas, Avic, Grivola-Urtier, Avise-Tsaboc-Feluma, Savoy Lower Unit,
584 Orsiera-Rocciavrè, Monviso and Lago Superiore). Temperatures indeed follow a trimodal
585 distribution with Gaussian-like curves centered around 370-380°C, 460-470°C and 530-
586 550°C (Fig. 5a). Cumulative histograms of the RSCM temperatures for each transect, where
587 individual slices were grouped into the three distinct temperature clusters (Fig. 5b-e), show
588 that these groups have specific temperature distributions and only overlap around the
589 minimum and/or maximum values (Fig. 5b-e).

590 **5.2 Si^{max} values of phengite**

591 **Methodology**

592 Tschermak substitution ($Al^{IV} + Al^{VI} = Si^{IV} + Fe^{VI}, Mg^{VI}$) in phengite is known to be highly
593 sensitive to pressure variations in K-feldspar- or talc-bearing assemblages (Velde, 1967;
594 Massonne and Schreyer, 1987,1989; Massone, 1995) and in HP-LT metapelites (Saliot and
595 Velde, 1982; Massonne, 1992; Jolivet et al.,1996, 1998; Goffé and Bousquet, 1997;
596 Bousquet et al., 1998, 2002; Agard et al., 2001a, 2001b). The maximum Si values ($Si^{max}Ph$)
597 of highly substituted early phengite therefore provide an estimate of the peak pressure
598 experienced by the rocks during burial (Si values also depend on rock composition, see §6
599 below). This is a minimum value since phengite may have reequilibrated during the
600 retrograde path. In the Western Alps L-P domain, the map of $Si^{max}Ph$ isopleths revealed an
601 eastward increase in peak-pressure along the Cottian Alps transect (Agard, 1999; Agard et
602 al., 2001a). In the Savoy-Susa transect, the differences between the Savoy Lower Unit and
603 the Savoy Middle Unit are further supported by their contrasting $Si^{max}Ph$ values (Plunder et
604 al., 2012).

605 In order to map out the peak pressure distribution across the Western Alps L-P domain,
606 emphasis was placed on the southern half of the domain (Cottian Alps to Ubaye valley),
607 where a strong eastward metamorphic gradient was detected along several transects (Agard
608 et al., 2001a; Gabalda et al., 2009; Schwartz et al., 2013). This is also where numerous
609 slices were identified and very few P-T constraints are available for most of them (see § 3.3;
610 3.4). Thirty-two samples were selected (see Sup. mat. 1 for location and mineralogy). In each
611 sample, the different generations of white mica were carefully studied in order to locate early,
612 highly substituted phengite. In optimal samples, where up to three successive schistositities
613 (S1, S2 and S3) could be recognized, similar to those of Agard et al. (2001a; Fig. 6a-b),
614 phengite from the S1 generation was selected.

615 Electron Probe Microanalysis (EPMA) was performed at Camparis (Sorbonne Université,
616 Paris) using both Cameca SX-5 and SX-100 instruments. Point measurements were made in
617 classical analytical conditions (15 kV acceleration voltage, 10 nA beam current allowing ~2
618 μm beam size in wavelength-dispersive spectroscopy mode) using diopside (Ca, Mg, Si),
619 $MnTiO_3$ (Mn, Ti), orthoclase (K, Al), Fe_2O_3 (Fe), albite (Na) and Cr_2O_3 (Cr) as standards for
620 calibration of elements in parentheses. Representative electron microprobe compositions of
621 phengite are presented in Sup. mat. 2.

622 Phengite structural formulae were calculated on an 11 oxygen basis and the $Si^{max}Ph$ value of
623 each sample is considered as a proxy for the minimum peak-pressure recorded by the rocks.
624 In order to complete this dataset $Si^{max}Ph$ value from the same region were compiled from
625 literature (Bocquet, 1974; Liewig, 1981 and Agard et al., 2001a; Bonnet et al., submitted).
626 Selected $Si^{max}Ph$ values from this work and from the literature are given in Sup. mat. 3.

627 **Results**

628 Phengite microprobe data are shown in the muscovite-celadonite-pyrophyllite ternary
629 diagram (Fig. 7a). Most analyses plot close to the muscovite-celadonite axis, i.e. along the
630 tschermak substitution trend (Fig. 7a), and generally contain less than 20% of pyrophyllite.
631 We discard phengite containing more than 20% of pyrophyllite to avoid considering Si values
632 related to the pyrophyllitic substitution rather than to peak pressure (see Agard et al., 2001b).

633 $\text{Si}^{\text{max}}\text{Ph}$ values range between 3.25 and 3.67 atoms per formula units (a.p.f.u.) highlighting a
634 large range of tschermak substitution. Selected $\text{Si}^{\text{max}}\text{Ph}$ values from our data and the
635 literature were plotted against their corresponding RSCM temperatures (Fig. 7b). Most of the
636 points expose a relatively clear trend of $\text{Si}^{\text{max}}\text{Ph}$ increase with temperature, evidencing a
637 subduction-related HP-LT gradient in these rocks (Fig. 7b). Some points, especially for high
638 temperature (> to 440°C), are plotting away from the trend. These points may represent
639 samples where the most substituted phengite formed at peak burial was not preserved.

640 The selected $\text{Si}^{\text{max}}\text{Ph}$ are superimposed on the simplified structural sketch map of the
641 Cottian Alps-Queyras region in order to discern the evolution of peak-pressure across the L-
642 P domain (Fig. 8). Except for samples that may not have preserved peak Si values (Fig. 7b),
643 these data reveal an increase of $\text{Si}^{\text{max}}\text{Ph}$ values from west (generally lower than 3.35 a.p.f.u.)
644 to east (generally greater than 3.55 a.p.f.u.), consistent with previous findings on specific
645 sections (Agard et al., 2001a, 2001b) and with the strong eastward increase in metamorphic
646 grade. Our dense sample distribution allows to draw approximate $\text{Si}^{\text{max}}\text{Ph}$ isopleths for 0.10
647 a.p.f.u. steps and to map out the distribution of estimated peak pressure across the L-P
648 domain (Fig. 8). A finer resolution would nevertheless be necessary to scrutinize the
649 pressure evolution across individual tectonic contacts between the L-P slices (Fig. 1c),
650 except maybe for the contact between the BS and eclogite-facies slices, which appears close
651 to the Si 3.55 a.p.f.u. isopleth.

652

653 **6. Thermodynamic modelling for an average composition, peak pressure and** 654 **dehydration in the tectonic slices**

655 **Methodology**

656 In order to compare the peak pressure of the different slices, a reference P-T pseudosection
657 was calculated with the *Perple_X* software (version 6.9.1; Connolly, 1990, 2005, 2009; Fig.
658 9a). The updated thermodynamic database is that of Holland and Powell (1998), with the
659 corresponding solution models (for chloritoid, Fe-Mg carpholite, garnet, phengite) except for

660 chlorite (after Holland et al., 1998). For this pseudosection, we used the bulk composition
661 CBas912m of Henry et al. (1996; Fig. 9a) since that is considered as a representative L-P
662 calcschist (and was already used for the Schistes Lustrés by Bebout et al., 2013). The used
663 Na₂O-CaO-K₂O-FeO-MgO-Al₂O₃-SiO₂-H₂O (NaCaKFMASH) chemical system is assumed to
664 describe realistically most of the L-P metasediments. Manganese is largely restricted to
665 garnet cores and was thus neglected in the calculations. TiO₂ and BO₃ are only present in
666 accessory phases (rutile, titanite, tourmaline). Cr₂O₃ is minor and dominantly stored in
667 phengite (and/or lawsonite) and was therefore neglected. The pseudosection was calculated
668 with H₂O in excess in the P-T range of 0.9-2.5 GPa and 300-600°C encompassing most of
669 the peak P-T conditions in the Western Alps L-P domain. The Si-in-phengite isopleths
670 (a.p.f.u.), shown on the P-T grid (Fig. 9a), are relatively flat-lying, outlining the good
671 sensitivity of the phengitic tschermak substitution to pressure variations. The relative peak
672 pressure conditions were determined from the intersection of Si^{max}Ph values (along Si-in-
673 phengite isopleths) of this study and literature samples with their respective RSCM
674 temperatures. The estimated P-T ranges for the studied slices are given in Table 3 (see Sup.
675 mat. 3 for all P-T estimations). These pressure estimates must be considered with caution
676 since the Si content in phengite depends, to a minor extent, on each bulk rock composition.
677 Varying randomly the weight percent of each system component by a few percents results in
678 pressure variations of ± 0.1-0.15 GPa.

679 In order to track the evolution of metamorphic assemblages during burial, mineral proportions
680 were calculated along the 8°C/km gradient inferred for the Western Alps (Fig. 9b; Agard et
681 al., 2001a; Agard, 2021). We computed the evolution of water content bound in minerals
682 along the same gradient (Fig. 9c) to identify the major dehydration steps and assess their
683 potential impact on slicing mechanisms.

684 **Results**

685 The pseudosection reproduces mineral assemblages observed in L-P sediments (Fig. 1a, 9a,
686 b). Quartz and phengite are the dominant phases and are present in all fields (Fig. 9a, b). Fe-
687 Mg carpholite is present in low-grade sediments and progressively disappears at the
688 expense of chloritoid (Fig. 9a, b). Across a 8°C/km gradient, garnet appears around ~525°C
689 and ~2.2 GPa. This is in good agreement with the almost systematic lack of garnet in BS-
690 facies slices (Fig. 1a; §2.2, 3). Along the same gradient lawsonite is stable up to ~575°C and
691 ~2.4 GPa, fitting with the presence of lawsonite in the ~470°C peak P-T assemblages of the
692 L-P domain (Herviou et al., 2021). The major mismatch is the presence of Na-bearing
693 silicates (glaucophane, jadeite) and kyanite in minor proportions above 2 GPa (glaucophane
694 <6 vol%; jadeite ~1 vol%; kyanite 6-7 vol%), as already noticed by Bebout et al. (2013). The

695 amount of mineral-bound water first decreases significantly when crossing the chloritoid-in
696 reaction (Fig. 9b-c), and then progressively as Fe-Mg carpholite (~12% H₂O) is gradually
697 replaced by chloritoid (~7.5% H₂O; Fig. 9b). At higher grade two major steps of dehydration
698 are observed along this gradient (Fig. 9b, c): (i) the first one corresponds to chlorite
699 breakdown at ~500°C and 2 GPa (~3.5 to ~2.8 wt% H₂O in the system), followed by final
700 disappearance of carpholite (ii) the second one to lawsonite and chloritoid breakdown
701 reactions, at ~575°C and 2.4 GPa (~2.5 to ~1.2 wt% H₂O in the system).

702 Peak pressures estimated using the Si^{max}Ph and RSCM temperatures intersection range
703 between ~1.3 and 2.5 GPa (Table 3; Sup. mat. 3). Above 500°C, however, pressure
704 determination is limited by the steepening of the Si-in-phengite isopleths (Fig. 9a). The
705 obtained pressures are in good agreement with data available from literature, at least for
706 Cottian Alps (Agard et al., 2001a, 2001b). Indeed, for Lago Nero slice, the pressures
707 obtained range between ~1.3 GPa at west to ~1.9 GPa at east (Table 1) versus 1.2-1.3 and
708 1.8 GPa for Agard et al. (2001a) in the same samples. In Albergian slice, peak pressure
709 ranges between 1.8 and 2.3 GPa (Table 3) with most samples clustering around 2 GPa (Sup.
710 mat. 3) while Agard et al. (2001a) obtained ~1.9-2 GPa in the same slice. These pressures
711 are a bit higher than those of Agard et al. (2001a) but fit the 2-2.3 GPa peak pressure
712 recently estimated by Corno et al. (2021) for extensional allochthons embedded within the
713 Albergian slice (Corno et al., 2019; Fig. 1a-c). For the Orsiera-Rocciavère sediments, we
714 obtained slightly higher pressure (~2.2 to ~2.5 GPa; Table 3) than Agard et al. (2001a; 2-2.1
715 GPa). These values nevertheless fit better with the eclogitic sediments of the other L-P slices
716 (Bousquet, 2008; Angiboust et al., 2012b; Plunder et al., 2012), as well as the 8°C/km
717 gradient of the Western Alps. In the Puys, Vin Vert and Cerogne-Ciantiplagna units, where
718 no pressure estimates exist, the obtained ranges are respectively 1.7-1.8 GPa, 2.1 GPa and
719 1.7- ~2.2 GPa.

720 For the Queyras-Monviso BS-facies slices, the estimated pressures are higher than the
721 scarce literature values. Pressure is in the range 1.4-2 GPa for the Calcschist unit, 1.4-1.7
722 GPa for the Pelvas-Taillante unit and 1.9- ~2.4 GPa for the Mirabouc-Bouchet unit (with most
723 data around 1.9-2 GPa in the latter unit; Table 3; Sup. mat. 3). These pressure values
724 significantly contrast with those previously estimated for metamafic rocks of the same slices
725 (Schwartz, 2000; Tricart and Schwartz, 2006), i.e. respectively ~1 GPa (for ~300°C), ~1.2
726 GPa and ~1.3 GPa (for ~450°C). These older P-T estimates align along a ~16-17 °C/km
727 gradient, which seems inconsistent with the HP-LT gradient usually considered for Western
728 Alps (Agard, 2021), suggesting that peak pressure was strongly underestimated in these
729 previous works. Finally, the estimated peak pressure for the Lago-Superiore slice is >2.4

730 GPa (Table 3), in good agreement with literature data (see §3.4; Angiboust et al. 2012b;
731 Locatelli et al., 2018).

732 Individual slices were then plotted in a P-T space considering their mean RSCM temperature
733 and their approximate mean peak pressure (Fig. 10a). For the slices where no pressure was
734 determined by our study, the compiled P-T estimates from the literature of §3 were used. No
735 pressure data is available, however, for the Avise-Tsaboc-Feluma, West-Sesia, Savoy Upper
736 Unit, Venaus and Aigle slices, which are not shown in figure 10a. The slices were color-
737 coded on the basis of the trimodal temperature distribution (Fig. 5b-e; §5.1). The different
738 slices are also shown considering their peak pressure and age (see references in §3) in
739 figure 10b.

740 Figure 10a strengthens the existence of a trimodal distribution of tectonic slices with respect
741 to peak burial conditions. The first cluster is characterized by mean peak conditions of 350-
742 400°C and ~1.5-1.7 GPa. These slices (Calcschist unit, Lago Nero, Pelvas-Taillante and
743 Puys) mostly consist of sediments (>90%; Table 1; Fig. 1a, 10a, b). Cornet unit has the same
744 range of mean temperature (390°C; Table 2) but lower pressure (0.8-0.9 GPa; Manzotti et
745 al., 2021). Some pressure estimates for the lower grade rocks of Lago Nero and Calcschist
746 units (Agard et al., 2001a, 2001b; Tricart and Schwartz, 2006) are relatively close to those of
747 Cornet unit, then considered to belong to the same cluster. The second cluster shows mean
748 peak conditions of 415-475°C and ~1.7-2.1 GPa. These units (Albergian, By, Cerogne-
749 Ciantiplagna, Mirabouc-Bouchet, Savoy Middle Unit and Vin Vert) are also dominantly
750 composed by sediments (Table 1, Fig. 1a, 10a). The third cluster is characterized by mean
751 RSCM temperature of ~490-540°C and mean peak pressures of 2.2- ~2.6 GPa. These slices
752 (Avic, Lago Superiore, Monviso, Savoy Lower Unit, Zermatt-Saas) are mostly composed by
753 mafic and ultramafic rocks (~60%; Table 1; Fig. 1a, 10a) except for the Grivola-Urtier and
754 Orsiera-Rocciavrè, which nevertheless show a higher ophiolitic content than all BS-facies
755 slices.

756 **7. Discussion**

757 **7.1 Correlations between tectonic slices, distribution, and revised structural** 758 **sketchmap**

759 Using the peak P-T conditions, lithostratigraphy, zoneography of index minerals and
760 structural constraints, three groups of tectonic slices can be recognized in the L-P domain
761 (Figs. 11, 12a-d):

762 — *the Liguro-Piemont Upper units (LPU):*

763 These units, which make up ~18% of the Western Alps L-P surface (~440 km²; Table 1), crop
764 out in the west of the L-P domain (Figs. 11, 12a-d) and are dominated by metasediments
765 (>90%, Table 1; Fig. 1a). They are largely exposed in the southern L-P domain (Queyras-
766 Monviso and Cottian Alps, Fig. 11) while gradually disappearing from the Savoy-Susa to the
767 Valais-Aosta region, where they are relatively rare (except for the Cornet slice; Fig. 11). From
768 north to south, the LPU include the Cornet slice (Valais-Aosta), the Savoy Upper Unit with
769 the Jovet, Grand Vallon, Upper Sana and Lamet klippen (Savoy-Susa region), the Lago
770 Nero, Aigle and Puys slices (Cottian Alps) and the Calcschist and Pelvas-Taillante slices
771 (Queyras-Monviso). Some of these slices exhibit an almost complete Chabrière-type
772 stratigraphic succession (Lago Nero, Pelvas-Taillante, Cornet; Fig. 3b), whereas some only
773 contain C4a-b calcschists-flyschs (Calcschist unit, Puys, Savoy Upper Unit; Fig. 3b). The
774 lack of Lower-Cretaceous and Jurassic deposits in the latter units may indicate a more
775 proximal origin (Fig. 3a) or reflect differences in décollement depth (see §7.4). These LPU
776 units are characterized by low- to medium-temperature BS-facies peak metamorphism
777 highlighted, in metasediments, by the presence of Fe-Mg carpholite and lawsonite (Fig. 1b).
778 Chloritoid only appears in their higher-grade metasediments, in the eastern part of these
779 units (Fig. 1b). Peak P-T conditions range mostly between 320-400°C and 1.2 to 1.9 GPa
780 (Fig. 4a-c, 5b-e, 10a; Table 2, 3, see §3). Mean and median RSCM temperatures for these
781 units are ~373°C (86 samples; Fig. 13a), while mean/median values of Si^{max}Ph are 3.40/3.42
782 a.p.f.u. (30 samples; Fig. 13b).

783 Some uncertainties remain on the exact distribution of the LPU slices. In Savoy-Aosta, the
784 extent of the Cornet slice and the precise location of its contact with the underlying By slice
785 (Manzotti et al., 2021) still need to be investigated to the east of the Dent Blanche Nappe
786 (Fig. 11). In the Queyras-Monviso region, we have considered that Acceglio's half-window
787 separates the Pelvas-Taillante (LPU) to the west from the Mirabouc-Bouchet to the east of
788 Acceglio, the two samples closest to the contact nevertheless show temperatures <400°C,
789 which is significantly lower than most temperatures obtained for the Mirabouc-Bouchet slice
790 (Fig. 4a-c) and may indicate that the Pelvas-Taillante slice is cropping out over a short
791 distance to the east of Acceglio. Finally, only few temperature constraints are available for
792 the Savoy Upper Unit (4 samples), Puys (1 sample) and Aigle (3 samples) slices, and almost
793 no pressure constraints (only 1 sample for Puys). While their estimated RSCM temperatures
794 are similar to LPU units (Table 2, Fig. 5b-e, 10a), more P-T estimates are needed to confirm
795 this interpretation.

796 — *the Liguro-Piemont Middle units (LPM):*

797 These units make up ~42% of the L-P aeral exposure (~1050 km²; Fig. 11, Table 1) and are
798 also dominated by metasediments (generally >90%, Table 1; Fig. 1a). They crop out
799 eastward of the LPU units (Fig. 11, 12a-d), except in Savoy-Susa where the LPU is found as
800 klippen and in Valais-Aosta where the Cornet slice (LPU) forms a synformal stack atop the
801 By slice (LPM; Fig. 12a). The Liguro-Piemont Middle units comprise the By slice (Valais-
802 Aosta), the Savoy Middle Units (including Grande Sassièrè, Lower Sana and Chardonnet
803 klippen) and the Venaus slice (Savoy-Susa), the Albergian, Cerogne-Ciantiplagna and Vin
804 Vert slices (Cottian Alps) and the Mirabouc Bouchet slice (Queyras-Viso), and possibly the
805 West-Sesia and Avise-Tsaboc-Feluma slices (see below). These slices generally exhibit a
806 stratigraphic succession corresponding to an incomplete Chabrièrè-like series, commonly
807 with a thick sequence of – and in places restricted to – Upper-Cretaceous C4a deposits (Fig.
808 3b). The LPM are characterized by a high-temperature blueschist-facies and up to
809 transitional BS-eclogite-facies metamorphism highlighted in metasediments by the
810 appearance of chloritoid in peak assemblages, the disappearance of Fe-Mg carpholite, the
811 presence of lawsonite and the absence of garnet (Fig. 1b). Most P-T conditions range
812 between 415-475°C and 1.7-2.2 GPa (Fig.4a-c, 5b-e, 10a; Table 2, 3, see §3). Mean/median
813 RSCM temperatures for these units are 459°C/463°C (191 samples; Fig. 13a), while
814 mean/median values of Si^{max}Ph are 3.52/3.51 a.p.f.u. (23 samples; Fig. 13b).

815 Uncertainties on the spatial extent of the LPM concern slices with limited lithostratigraphic
816 and P-T data. While the Venaus slice was already considered as an equivalent of the Savoy
817 Middle Unit (Fudral, 1996) and shows a RSCM temperature of 485°C consistent with LPM,
818 the attribution is less clear for the West-Sesia and Avise-Tsaboc-Feluma slices. The RSCM
819 temperature for the West-Sesia slice (433°C; Fig. 4a-c; Table 2) fits LPM temperatures (no
820 such low value was found in the eclogite-facies units; Table 2, Fig. 5b-e, 10a). It is
821 furthermore largely dominated by metasediments (~93%; Table 1), in contrast with the LPL
822 lithology (Table 1, Fig. 1a), and would be the only BS-facies slice eastward of eclogite-facies
823 LPL (Fig. 11). We therefore suggest that this slice may be analogous to the other LPM units
824 and reflect the doming of Savoy Middle Unit-like slices above the Gran Paradiso massif (Fig.
825 11). For the Avise-Tsaboc-Feluma slice(s), while the RSCM temperature of 522°C fits in the
826 LPL temperature range (Table 2; Fig. 5b-e, 10a), its estimated sediment/mafic-ultramafic
827 ratio does not fit with the LPL units (~99% of sediments; Table 1), notwithstanding the fact
828 that a few temperatures are close to 500°C in the LPM Savoy Middle Unit, and even higher in
829 the LPM By and Mirabouc-Bouchet slices. Further P-T constraints are needed to confirm
830 these attributions.

831 — *the Liguro-Piemont Lower units (LPL)*

832 These units occupy ~40% of the L-P surface (~990 km²) and contain much more mafic and
833 ultramafic material than the LPU and LPM units (Table 1; Fig. 1a). Most LPL slices contain
834 >60% of ophiolitic material (Avic, Zermatt-Saas, Savoy Lower Unit, Monviso, Lago Superiore;
835 Table 1) and correspond to the MUM units of Agard (2021), while a few have ~40% of
836 ophiolites (Grivola-Urtier, Orsiera-Rocciavrè; Table 1). The Liguro-Piemont Lower units
837 comprise the Avic, Grivola-Urtier and Zermatt-Saas slices (Valais-Aosta), the Savoy Lower
838 Unit (Savoy-Susa), the Orsiera-Rocciavrè slice (Cottian Alps) and the Monviso and Lago
839 Superiore slices (Queyras-Monviso). The LPL units are characterized by a specific,
840 incomplete Chabrière-type series, devoid of Upper Cretaceous deposits (Fig. 3b), which may
841 reflect a distinct paleogeography and/or high topography on the seafloor or a tectonic
842 removal of its sedimentary cover during the subduction/exhumation processes. These LPL
843 slices were metamorphosed from BS-eclogite-facies to eclogite-facies as outlined by the
844 presence of chloritoid-garnet assemblages in metasediments (Fig. 1b). Most P-T conditions
845 range between 500 and 580°C and 2.2 to 2.8 GPa (Fig.4a-c, 5a-e, 10a; Table 2, 3, see §3).
846 Mean/median RSCM temperatures for these units are 529°C/534°C (118 samples; Fig. 13a),
847 while mean/median values of Si^{max}Ph are 3.55/3.54 a.p.f.u. (4 samples; Fig. 13b). Note that
848 some Alpine units fit the LPL in term of peak P-T conditions but appear slightly different in
849 terms of lithology, containing either almost only ophiolitic material for the Lanzo massif
850 (>90% of mafic and ultramafic rocks; Lagabrielle et al., 1990) or almost only metasediments
851 for the small Lago di Cignana UHP slice (e.g., Compagnoni and Rolfo, 2003).

852 The LPL units are exposed on the eastern side of the domain and appear separated from the
853 BS-facies LPM by a major extensional contact (Philippot, 1990; Ballèvre et al., 1990; Ballèvre
854 and Merle, 1993; Fig. 2a-c, 11, 12a-d). One might further sub-divide the LPL between mafic-
855 ultramafic-dominated (~60% mafic-ultramafic; Table 1) and sediment-dominated slices
856 (~60% sediments; Table 1), with the latter potentially representing the former cover of the
857 MUM units (Agard, 2021). Indeed, some of the described slices (Savoy Middle Unit, Orsiera-
858 Rocciavrè; §3) contain large amount of sediments embedding mafic-ultramafic rocks in their
859 western side and are almost devoid of sediments in their eastern side (Fig. 1a). This
860 distribution may either be explained by the west-dipping foliation of the slices (i.e., with the
861 oceanic basement at the base) or by the presence of tectonic contacts juxtaposing
862 sedimentary dominated eclogite-facies slices on top of mafic-ultramafic dominant slices. The
863 different peak burial age inferred for the Orsiera massif metasediments (61-53 Ma, Agard et
864 al., 2001a; Fig. 10b; §3, 7.3) and the Rocciavrè metagabbros (46 Ma, Angiboust and Glodny,
865 2020; Fig. 10b; §3, 6.3) rather supports this distinction. The Grivola-Urtier slice, which is
866 richer in metasediments than most LPL units, would be an analogous of these sediments-
867 dominated eclogite-facies slices.

869 **7.2 Diachronous burial and stacking, and possible paleogeographic origin**

870 The similar peak P-T conditions, structural position and lithological content among slices in
871 each of the three L-P groups (§7.1) suggest that they may have recorded similar subduction
872 histories and processes. The plot of RSCM temperatures versus longitude for each transect
873 highlights the similarity of slice-stacking of LPU, LPM and LPL units across the L-P domain
874 (Fig. 14a-e). The eastward-trend of temperature increase exposes the HP-LT subduction
875 gradient, less conspicuous for the Valais-Aosta transect where a stronger collisional imprint
876 on the nappe-stack (synformal-stack implying upper plate fragments) slightly erased this
877 trend (Fig. 14e). Subtle differences in lithostratigraphy nevertheless point out to differences in
878 their paleogeographic origin (Fig. 15a-c; see §7.3, 7.4), and all slices with similar P-T were
879 probably not buried, sliced and juxtaposed at the same time. While the formation of deeply
880 underplated nappe stacks suggests that the structurally lower units may have been buried,
881 detached and underplated later (Kimura et al., 2007; Bachmann et al., 2009; Dumitru et al.,
882 2010; Plunder et al., 2012), available metamorphic ages are here discussed to precise the
883 slicing and underplating sequence of the LPU, LPM and LPL units (Fig. 10b, 14a, 15b).

884 Very few robust ages are available for the BS-facies LPU and LPM units (Fig. 10b; §3). The
885 Lago Nero slice (LPU) was dated by in-situ Ar-Ar on phengite and gave 61-55 Ma, 51-43 Ma
886 and 38-36 Ma ages for D1 (peak P-T), D2 and D3 fabrics respectively (Agard et al., 2002).
887 Moreover, bulk Ar-Ar on separated generations of phengite from the Calcschist unit (LPU)
888 gave a 42-40 Ma age for a peak P-T foliation (Lanari, 2012; Fig. 10b). These ages suggest a
889 diachronous slicing of the LPU characterized by Chabrière-type series, which were buried
890 and underplated earlier than the LPU units lacking deposits older than the Upper Cretaceous
891 (Fig. 3b, 10b, 14a, 15a, b). The latter ones may have been originally located close to
892 Piemont margin and been underplated on top of the L-P stack at the very end of oceanic
893 subduction (Fig. 15b, 14a; see also Herviou et al., 2021, their Fig. 13 and §7.2.1).

894 In LPM (Albergian slice, Fig. 11), in situ Ar-Ar dating on phengite gave 64-49 Ma and ~50 Ma
895 ages for D1 (peak P-T) and D2 fabrics (Agard et al., 2002; Fig. 10b). This method also gave
896 47-42 Ma and 40-36 Ma for S1(peak) and S2 (potentially equivalent to D3 of Agard et al.,
897 2002; Fig. 10b) foliation in the Savoy Middle Unit (Ghignone et al., 2021b; Fig. 10b). Bulk Ar-
898 Ar on isolated generation of phengite from the Mirabouc-Bouchet slices (LPM) gave 68-58
899 Ma for an early foliation (prograde to peak?), 45 Ma for a S2 (peak or early retrograde?) and
900 an age younger than 30 Ma for a late S3 foliation (Lanari, 2012; Fig. 10b) while Rb-Sr on D3
901 phengite from the same slice gave ~35 Ma (Angiboust and Glodny, 2020; Fig. 10b). In the
902 Valais-Aosta region, D2 to D3 exhumation-related episodes of By (LPM) and Cornet (LPU)

903 slices were dated between 41 and 37 Ma (Reddy et al., 2003; Angiboust et al., 2014; Fig.
904 10b). These peak burial ages of the LPM units, either undistinguishable from or younger than
905 those for the Lago Nero unit, are broadly consistent with a slicing and underplating
906 somewhat later than the LPU Chabrière-serie slices (Fig. 10b, 14a, 15a, b) and with their
907 present structural position (Fig. 12a-d).

908 Finally, for LPL mafic-ultramafic-dominated units, most of the peak burial ages (from various
909 methods; see §3) range between 50 and 40 Ma (§3; Fig. 10b) and may represent the
910 sampling of a mafic-rich zone close to the Piemont margin units (Fig. 14a, 15a), as pointed
911 out by Agard (2021). Sediment-dominated units have older ages: 61-53 Ma, 46-42 Ma, 42-38
912 Ma in D1 (peak P-T), D2 and D3 fabrics of Orsiera massif sediments (in situ Ar-Ar in
913 phengite; Agard et al., 2002; Fig. 10b) and 60-48 Ma for Grivola-Urtier slice (bulk Lu-Hf and
914 Ar-Ar on phengite, Villa et al., 2014; Fig. 10b) suggesting that the few sediment-dominated
915 eclogite-facies units may have been stripped from and underplated before the ophiolitic-
916 dominated MUM LPL units (Fig. 14a, 15a). For each transect, the corresponding slices
917 successively detached from the Alpine slab during a short-lived period prior to continental
918 burial and were stacked together during exhumation around 40-35 Ma at ~20 km depth (Fig.
919 10b, 14a, 15a).

920

921 **7.3 Trimodal distribution of units: insights into subduction processes**

922 The three groups of L-P slices show peak P-T conditions comparable to those of subducted
923 oceanic fragments recovered worldwide, for which two major recovery depths were
924 recognized at 30-40 km and 80 ± 10 km, with a potential third cluster at 55-60 km (Fig. 16a-c;
925 Agard et al., 2018; see also Plunder et al., 2015). The same distinct recovery depths were
926 detected in continental-subduction slivers (Agard and Vitale-Brovarone, 2013; Soret et al.,
927 2021). These rock clusters are thought to reflect major changes in mechanical coupling along
928 the plate interface (Agard et al., 2018), which occur transiently (Monié and Agard, 2009) and
929 in places coevally across-dip (Bonnet et al., 2018). While offscraping from the downgoing
930 slab requires an increase in mechanical coupling (Agard et al., 2016, 2020), the stepping
931 down of the plate interface décollement into the slab and strain localization into zones of
932 weakness (Kimura and Ludden, 1996; Kimura et al., 2007; Angiboust et al., 2012c; Ruh et
933 al., 2015), mechanical processes controlling slicing are unknown. Similar depth clusters ($35 \pm$
934 10 km and 60 ± 5 km) for the locus of interplate deformation bounding earthquakes were also
935 recently identified by a mechanical analysis of the topography along the Chilean margin
936 (Cubas et al., submitted; Fig. 16a). These depths are interpreted as zones of distributed
937 deformation ultimately leading to slicing of the slab, underplating and topographic build-up

938 (Menant et al., 2019, 2020), which are responsible for stress build-up eventually leading to
939 the nucleation of earthquakes propagating across the domains B and C as defined by Lay et
940 al. (2012; Cubas et al., submitted; see Fig. 16c). The LPU, LPM and LPL units, with their
941 slicing depths of ~35-45 km, ~55-65 km and ~70-80 km, respectively, may therefore provide
942 insights into the mechanisms that control strain localization and slicing along the plate
943 interface (Fig. 16b).

944 — *Offscraping mechanisms in the LPU units*

945 The LPU ~35-45 km depth coincides with the downdip end of the seismogenic zone, where
946 the transition from upper plate continental crust to mantle wedge likely induces a strong
947 change in interplate coupling (Agard et al., 2018), and where ductile shear and dissolution-
948 precipitation creep (DPC) may be the dominant deformation mechanisms (Wassmann and
949 Stöckhert, 2013; Platt et al., 2018; Agard et al., 2018). Both geophysical and petrological data
950 suggest the presence of fluids and high pore fluid pressure (Audet et al., 2009; Saffer and
951 Tobin, 2011; Behr and Bürgmann, 2021), which reduces shear strength and enhances strain
952 localization in weak zones (Kimura and Ludden, 1995; Kimura et al., 2007; Saffer and Tobin,
953 2011; Kameda et al., 2017).

954 In the LPU units, the presence of fluids at peak burial conditions is attested by the large
955 amount of hydrated phases in sediments and metamorphic veins (Goffé and Chopin, 1986;
956 Lefeuvre et al., 2020; Herviou et al., 2021). The formation of lawsonite-bearing extensional
957 cracks in these rocks reflects near-lithostatic fluid-pressure (Lefeuvre et al., 2020; Herviou et
958 al., 2021). At these depths and for such a cold subduction gradient, however, no major
959 dehydration reaction is predicted (Peacock, 1993; Van Keken et al., 2011). Only the eastern
960 samples contain chloritoid (Fig. 1b), showing that the progressive carpholite-out reaction is
961 only crossed by the highest grade samples of LPU units, as predicted by our thermodynamic
962 modelling (Fig. 9a-c; see also Agard et al., 2001a; Bebout et al., 2013; Herviou et al., 2021).
963 Veins therefore likely formed by the local redistribution of material in the fluid through DPC-
964 controlled deformation (Herviou et al., 2021). Slicing of the LPU units may then be related to
965 inherited heterogeneities in the lithological succession and/or high fluid pressure rather than
966 to embrittlement by major fluid release (e.g., Hacker et al., 2003).

967 In the LPU slices limited to Upper Cretaceous deposits (Fig. 3b, §4.1, 7.1, 7.2), strain may
968 have localized between the Lower Cretaceous pelagic A3 and the more clastic Upper
969 Cretaceous C4 calcschists-flyschs (Fig. 15c; see also Fig. 3b; §4.1), as observed between
970 pelagic sediments and trench-filling turbidites in accretionary prisms (Karig and Sharman,
971 1975; Moore, 1975; Kimura et al., 2007). The Middle Cretaceous A3b shales would have
972 served as a zone of rheological weakness (weaker than more siliceous hemipelagic

973 sediments; Ikari et al., 2018) leading to deformation localization and slicing as in silty clays at
974 slow aseismic creep conditions (Vannucchi et al., 2017).

975 In the LPU Chabrière-series slices (3b, 14; §4.1, 7.1, 7.2), which contain a dismembered
976 ophiolitic basement (Table 1; Fig; 3b), slicing occurred deeper in the oceanic lithosphere
977 (Fig. 15a, c), possibly along the numerous pre-Alpine structures identified in the L-P domain
978 (e.g., oceanic-detachments; Manatschal et al., 2011; Lagabrielle et al., 2015; Balestro et al.,
979 2018; Decrausaz et al., 2021; Agard, 2021). Fluid infiltration along these structures, as
980 notably attested by the strong hydrothermal alteration of the L-P oceanic fragments
981 (Selvertson and Sharp, 2013; Busigny et al., 2011, 2018; see also Herviou et al., 2021),
982 promoted strain localization (Fig. 15c). Strain localization in serpentinized horizons, in
983 particular, is commonly considered for slicing in the slab (Angiboust et al., 2011; Agard et al.,
984 2018; Tewksbury-Christle et al., 2021) and supported by modeling (e.g., Ruh et al., 2015).

985 — *Offscraping mechanisms in the LPM units*

986 At ~55-65 km, the slab is juxtaposed against the partly serpentinized and decoupled mantle
987 wedge, explaining the lesser recovery of rocks for this range of subduction depths (Guillot et
988 al., 2015; Agard et al., 2018; Fig. 16c). In the LPM units, fresh lawsonite is found in both
989 metasediment matrix and veins (Fig. 1a; Herviou et al., 2021) and therefore considered to
990 have remained stable during burial, as predicted by our pseudosection (Fig. 9a-c; 10a). In
991 these slices, Fe-Mg carpholite is only found as micrometric needles in quartz crystals
992 preserved from recrystallization (Agard et al., 2000; 2001a), whereas chloritoid is widespread
993 in pelitic layers (Fig. 1a). The Fe-Mg carpholite (~12 wt% H₂O) to chloritoid (~7-8 wt% H₂O)
994 reaction is therefore well under way. The carpholite-out reaction along a 8°C/km gradient is
995 predicted at ~500°C-2 GPa (Fig. 9b, c, 10a), which fits the highest P-T conditions recorded
996 by the LPM units (Fig. 5b-e; table 2, 3). However, no other major dehydration reaction
997 releasing a large amount of water during a short P-T window is predicted for the LPM
998 metasediments (Fig. 9b-c) or mafic-ultramafic rocks (Angiboust and Agard, 2010). The slicing
999 of the LPM units may therefore be related to a combination of inherited lithological
1000 heterogeneities and fluid release (Fig. 15c, 16b). We therefore consider that strain localized
1001 in the Middle Cretaceous A3b shales for the Upper Cretaceous LPM slices (as for the LPU
1002 units; Fig. 3b, 15c) and around oceanic detachment faults for the Chabrière-like LPM (Fig.
1003 3b, 16c).

1004 — *Offscraping mechanisms in the LPL units*

1005 The third cluster at ~70-80 km coincides with the depth beyond which rocks are generally not
1006 recovered, due to density and slab pull changes as well as to viscous recoupling (Wada and
1007 Wang, 2009; Syracuse et al., 2010, see also Kerswell et al., 2021; Fig. 16c) dragging down

1008 irreversibly the slab into the mantle once serpentinite is fully dehydrated (Agard et al., 2009;
1009 2018; Duesterhoeft et al., 2014). A change in deformation mechanisms from fluid-assisted
1010 DPC to dislocation creep may drive this viscous coupling (Agard et al., 2020).

1011 The transition from BS- to eclogite-facies is considered as a major dehydration-step for the
1012 downgoing plate (Peacock, 1993; Angiboust and Agard, 2010; Van Keken et al., 2011;
1013 Paulatto et al., 2017). The boundary between these two facies coincides with the location of
1014 intermediate-depth earthquakes, suggesting that rocks undergo weakening and
1015 embrittlement during dehydration at eclogite-facies conditions (Hacker et al., 2003; Kita et al.,
1016 2006; Abers et al., 2006, 2013), especially for the coldest slabs (Abers et al., 2013).
1017 Dehydration reactions such as the lawsonite-out (~12 wt% H₂O) were suggested because
1018 crustal intermediate-depth seismicity coincide with the thermal stability of lawsonite (Abers et
1019 al., 2006), and because lawsonite dehydration may trigger brittle failure as unstable fault slip
1020 (Okazaki and Hirth, 2016; Incel et al., 2017). Brittle-deformation was furthermore evidenced
1021 in exhumed eclogites and may reflect an increase in fluid pressure induced by dehydration
1022 reactions (Angiboust et al., 2017; Hertgen et al., 2017; Behr et al., 2018).

1023 In LPL units, eclogitic breccias and veins reveal rupture events along rheological contrasts
1024 and during fluid ingression at ~80 km (Angiboust et al., 2011, 2012a; Locatelli et al., 2018,
1025 2019a, b; Broadwell et al., 2019). Furthermore, pseudotachylites formed in the same depth
1026 range were reported in Lanzo massif, adjacent to the LPL units (Scambelluri et al., 2017;
1027 Pennacchioni et al., 2020). At peak P-T conditions, in LPL units mafic crust, lawsonite is
1028 supposedly still stable (Angiboust and Agard, 2010; Angiboust et al., 2011, 2012b; Locatelli
1029 et al., 2018) whereas chlorite (~12 wt% H₂O) is predicted to breakdown at the BS- to
1030 eclogite-facies transition (Angiboust and Agard, 2010). In the LPL ultramafic rocks, antigorite
1031 (~12 wt% H₂O) is still stable at peak P-T conditions (Angiboust et Agard, 2010; Schwartz et
1032 al., 2013). In the LPL mafics and ultramafics, the only reaction that may contribute to high
1033 fluid pressure and affect rheology is therefore chlorite breakdown. Dehydration reactions
1034 occurring deeper, such as antigorite breakdown, may also affect rocks at LPL units peak-
1035 burial depths (Angiboust et al., 2012a).

1036 The P-T estimates for the LPL units lie close to predicted major dehydration reactions for
1037 metasediments (Fig. 9a-c; 10a), supporting the potential role of fluids in LPL slicing. While
1038 the chlorite and Fe-Mg carpholite breakdown in sediments is predicted at ~500°C-2 GPa
1039 (with a decrease in water content from ~3.5 wt% to ~2.8 wt% H₂O; Fig. 9b-c, 10a), another
1040 major step of dehydration (leading to a decrease from ~2.5 wt% to ~1.2 wt% H₂O) is
1041 predicted at ~575°C-2.4 GPa for chloritoid (~7-8 wt% H₂O) and lawsonite breakdown (Fig.
1042 9b-c, 10a). We note that this second step coincides with most of the maximum P-T

1043 conditions recorded in LPL units (Fig. 9c, 10a, see §3, 7.1), where lawsonite is no longer
1044 stable, and that large amounts of lawsonite, up to ~40 vol% of the host rocks, were present in
1045 metasediments (Lefeuvre et al., 2020). We therefore propose that the destabilization of these
1046 large amounts of lawsonite, accompanied by chloritoid-out reaction and/or chlorite
1047 breakdown (in mafic rocks), may have induced high fluid pressure and embrittlement able to
1048 slice LPL units from the downgoing slab (Fig. 15c, 16b; as supported by experiments;
1049 Okazaki and Hirth, 2016). These reactions would have helped localize strain deeper in the
1050 downgoing slab than for the LPU and LPM units, explaining the larger volume of mafic and
1051 ultramafic rocks in the present-day stack of LPL units (Fig. 1a, 10a, 15a, c; see §4, 7.1, 7.2).
1052 As for the LPU and LPM units, inherited detachment faults may have served as rheological
1053 weaknesses to localize the strain (Fig. 15a, 16c).

1054

1055

1056 **Conclusions**

1057 Through the compilation of petrological data (peak P-T estimations, zoneography of index
1058 minerals) and report of new RSCM temperatures, RSCM interpolation, maximum Si values of
1059 phengite (as a proxy for peak pressure) and thermodynamic modelling, this study provides a
1060 detailed framework of the peak P-T conditions recorded by the various Liguro-Piemont slices.
1061 A strong eastward increase in metamorphic grade through the Liguro-Piemont domain, as
1062 well as inside some slices, is notably highlighted by the distribution of RSCM temperatures
1063 and maximum Si values of phengite. In addition, the compilation of lithostratigraphic,
1064 structural and radiochronological data, together with the estimation of the sediment versus
1065 mafic-ultramafic content from aerial exposures, for each slice, allow refining the origin and
1066 evolution of these tectonometamorphic units/slices across the Liguro-Piemont domain. The
1067 revised structural organization of the various Liguro-Piemont units allows restoring the
1068 geometries of the Alpine subduction at peak burial conditions. Results point to a trimodal
1069 distribution of units with an almost continuous increase in metamorphic conditions from the
1070 Liguro-Piemont Upper units (LPU; 320-400°C- 1.2-1.9 GPa) to the Liguro-Piemont Middle
1071 units (LPM; 415-475°C- 1.7-2.2 GPa) and to the Liguro-Piemont Lower units (LPL; 500-
1072 580°C- 2.2-2.8 GPa). The LPU and LPM units, metamorphosed under blueschist-facies
1073 conditions at peak P-T conditions, are dominated by sediments (>90%) whereas the LPL
1074 units, metamorphosed at eclogite-facies conditions at peak burial, are much richer in mafic-
1075 ultramafic rocks (>40%). These two types exhibit major differences in terms of initial
1076 paleogeography and/or mechanisms responsible for material-offscraping from the downgoing
1077 slab. Peak burial depths of the LPU, LPM and LPL units are similar to those deduced for the
1078 slicing and underplating of rocks in modern and fossil subduction zones, pointing to specific

1079 mechanisms controlling transient changes in interplate coupling at these depths. Combined
1080 petrological and lithostratigraphic data suggest that strain localization leading to the
1081 offscraping of the LPU and LPM units was mostly controlled by lithological contrasts across
1082 sedimentary packages, within the shales or along the contacts within the uppermost
1083 serpentinized mantle (some of which may have been inherited from former oceanic
1084 detachment faults), which acted as rheological weaknesses, possibly under high fluid
1085 pressure conditions. In contrast, major dehydration reactions (such as lawsonite breakdown
1086 in sediments and chlorite breakdown in mafics) likely controlled the offscraping of the LPL
1087 units at eclogite facies conditions, possibly through high fluid pressure conditions and rock
1088 embrittlement. In these units too, strain localization may have been guided by preexisting
1089 heterogeneities such as inherited oceanic detachment faults.

1090

1091 **Acknowledgments**

1092 This study was funded by the BRGM in the frame of the RGF Alpes project. The authors
1093 thank S. Angiboust, O. Beyssac and T. Decrausaz for their help in locating samples of their
1094 articles. N. Rividi and M. Fialin are thanked for analytical support and E. Delairis for sample
1095 preparation. M. Ballèvre and an anonymous reviewer are thanked for their remarks and
1096 suggestions which have greatly helped to improve this work as Z.-X. Li for his editorial
1097 handling. We also thank G. Bonnet, B. Lefeuvre, S. Schwartz, L. Jolivet, H. Raimbourg, C.
1098 Chopin, B. Dubacq, T. Gyomlai and A. Lahfid for discussions.

1099

1100 **References**

1101 Abers, G.A., van Keken, P.E., Kneller, E.A., Ferris, A., Stachnik, J.C., 2006. The thermal
1102 structure of subduction zones constrained by seismic imaging: Implications for slab
1103 dehydration and wedge flow. *Earth and Planetary Science Letters* 241, 387–397.
1104 <https://doi.org/10.1016/j.epsl.2005.11.055>

1105 Abers, G.A., Nakajima, J., van Keken, P.E., Kita, S., Hacker, B.R., 2013. Thermal–
1106 petrological controls on the location of earthquakes within subducting plates. *Earth and
1107 Planetary Science Letters* 369–370, 178–187. <https://doi.org/10.1016/j.epsl.2013.03.022>

1108 Agard, P., 1999. Evolution métamorphique et structurale des métapélites océaniques dans
1109 l’orogène Alpin : l’exemple des Schistes Lustrés des Alpes occidentales (Alpes Cottiennes).
1110 PhD thesis Université de Paris 6.

1111 Agard, P., 2021. Subduction of oceanic lithosphere in the Alps: Selective and archetypal from
1112 (slow-spreading) oceans. *Earth-Science Reviews* 214, 103517.
1113 <https://doi.org/10.1016/j.earscirev.2021.103517>

- 1114 Agard, P., Vitale-Brovarone, A., 2013. Thermal regime of continental subduction: The record
1115 from exhumed HP–LT terranes (New Caledonia, Oman, Corsica). *Tectonophysics* 601, 206–
1116 215. <https://doi.org/10.1016/j.tecto.2013.05.011>
- 1117 Agard, P., Handy, M.R., 2021. Ocean Subduction Dynamics in the Alps. *Elements* 17, 9–16.
1118 <https://doi.org/10.2138/gselements.17.1.9>
- 1119 Agard, P., Goffé, B., Touret, J.L.R., Vidal, O., 2000. Retrograde mineral and fluid evolution in
1120 high-pressure metapelites (Schistes lustrés unit, Western Alps). *Contributions to Mineralogy
1121 and Petrology* 140, 296–315. <https://doi.org/10.1007/s004100000190>
- 1122 Agard, Philippe, Jolivet, L., Goffe, B., 2001a. Tectonometamorphic evolution of the Schistes
1123 Lustres Complex; implications for the exhumation of HP and UHP rocks in the Western Alps.
1124 *Bulletin de la Société Géologique de France* 172, 617–636. <https://doi.org/10.2113/172.5.617>
- 1125 Agard, P., Vidal, O., Goffé, B., 2001b. Interlayer and Si content of phengite in HP-LT
1126 carpholite-bearing metapelites. *Journal of Metamorphic Geology* 19, 479–495.
1127 <https://doi.org/10.1046/j.0263-4929.2001.00322.x>
- 1128 Agard, P., Monie, P., Jolivet, L., Goffe, B., 2002. Exhumation of the Schistes Lustres
1129 complex: in situ laser probe $^{40}\text{Ar}/^{39}\text{Ar}$ constraints and implications for the Western Alps. *J
1130 Metamorph Geol* 20, 599–618. <https://doi.org/10.1046/j.1525-1314.2002.00391.x>
- 1131 Agard, P., Yamato, P., Jolivet, L., Burov, E., 2009. Exhumation of oceanic blueschists and
1132 eclogites in subduction zones: Timing and mechanisms. *Earth-Science Reviews* 92, 53–79.
1133 <https://doi.org/10.1016/j.earscirev.2008.11.002>
- 1134 Agard, P., Yamato, P., Soret, M., Prigent, C., Guillot, S., Plunder, A., Dubacq, B., Chauvet,
1135 A., Monié, P., 2016. Plate interface rheological switches during subduction infancy: Control
1136 on slab penetration and metamorphic sole formation. *Earth and Planetary Science Letters*
1137 451, 208–220. <https://doi.org/10.1016/j.epsl.2016.06.054>
- 1138 Agard, P., Plunder, A., Angiboust, S., Bonnet, G., Ruh, J., 2018. The subduction plate
1139 interface: rock record and mechanical coupling (from long to short timescales). *Lithos* 320–
1140 321, 537–566. <https://doi.org/10.1016/j.lithos.2018.09.029>
- 1141 Agard, P., Prigent, C., Soret, M., Dubacq, B., Guillot, S., Deldicque, D., 2020. Slabitzation:
1142 Mechanisms controlling subduction development and viscous coupling. *Earth-Science
1143 Reviews* 208, 103259. <https://doi.org/10.1016/j.earscirev.2020.103259>
- 1144 Amato, J.M., Johnson, C.M., Baumgartner, L.P., Beard, B.L., 1999. Rapid exhumation of the
1145 Zermatt-Saas ophiolite deduced from high-precision SmNd and RbSr geochronology. *Earth
1146 and Planetary Science Letters* 171, 425–438. [https://doi.org/10.1016/S0012-821X\(99\)00161-
1147 2](https://doi.org/10.1016/S0012-821X(99)00161-2)
- 1148 Angiboust, S., Agard, P., 2010. Initial water budget: The key to detaching large volumes of
1149 eclogitized oceanic crust along the subduction channel? 22.
- 1150 Angiboust, S., Agard, P., Jolivet, L., Beyssac, O., 2009. The Zermatt-Saas ophiolite: the
1151 largest (60-km wide) and deepest (c. 70-80 km) continuous slice of oceanic lithosphere
1152 detached from a subduction zone? *Terra Nova* 21, 171–180. [https://doi.org/10.1111/j.1365-
1153 3121.2009.00870.x](https://doi.org/10.1111/j.1365-3121.2009.00870.x)
- 1154 Angiboust, S., Agard, P., Raimbourg, H., Yamato, P., Huet, B., 2011. Subduction interface
1155 processes recorded by eclogite-facies shear zones (Monviso, W. Alps). *Lithos* 127, 222–238.
1156 <https://doi.org/10.1016/j.lithos.2011.09.004>

- 1157 Angiboust, S., Agard, P., Yamato, P., Raimbourg, H., 2012a. Eclogite breccias in a
1158 subducted ophiolite: A record of intermediate-depth earthquakes? *Geology* 40, 707–710.
1159 <https://doi.org/10.1130/G32925.1>
- 1160 Angiboust, S., Langdon, R., Agard, P., Waters, D., Chopin, C., 2012b. Eclogitization of the
1161 Monviso ophiolite (W. Alps) and implications on subduction dynamics. *Journal of*
1162 *Metamorphic Geology* 30, 37–61. <https://doi.org/10.1111/j.1525-1314.2011.00951.x>
- 1163 Angiboust, S., Wolf, S., Burov, E., Agard, P., Yamato, P., 2012c. Effect of fluid circulation on
1164 subduction interface tectonic processes: Insights from thermo-mechanical numerical
1165 modelling. *Earth and Planetary Science Letters* 357–358, 238–248.
1166 <https://doi.org/10.1016/j.epsl.2012.09.012>
- 1167 Angiboust, S., Agard, P., De Hoog, J.C.M., Omrani, J., Plunder, A., 2013. Insights on deep,
1168 accretionary subduction processes from the Sistan ophiolitic “mélange” (Eastern Iran). *Lithos*
1169 156–159, 139–158. <https://doi.org/10.1016/j.lithos.2012.11.007>
- 1170 Angiboust, S., Glodny, J., Oncken, O., Chopin, C., 2014. In search of transient subduction
1171 interfaces in the Dent Blanche–Sesia Tectonic System (W. Alps). *Lithos* 205, 298–321.
1172 <https://doi.org/10.1016/j.lithos.2014.07.001>
- 1173 Angiboust, S., Kirsch, J., Oncken, O., Glodny, J., Monié, P., Rybacki, E., 2015. Probing the
1174 transition between seismically coupled and decoupled segments along an ancient subduction
1175 interface: CATACLASIS ON THE SUBDUCTION INTERFACE. *Geochem. Geophys.*
1176 *Geosyst.* 16, 1905–1922. <https://doi.org/10.1002/2015GC005776>
- 1177 Angiboust, S., Agard, P., Glodny, J., Omrani, J., Oncken, O., 2016. Zagros blueschists:
1178 Episodic underplating and long-lived cooling of a subduction zone. *Earth and Planetary*
1179 *Science Letters* 443, 48–58. <https://doi.org/10.1016/j.epsl.2016.03.017>
- 1180 Angiboust, S., Yamato, P., Hertgen, S., Hyppolito, T., Bebout, G.E., Morales, L., 2017. Fluid
1181 pathways and high- P metasomatism in a subducted continental slice (Mt. Emilius klippe, W.
1182 Alps). *J. Metamorph. Geol.* 35, 471–492. <https://doi.org/10.1111/jmg.12241>
- 1183 Angiboust, S., Cambeses, A., Hyppolito, T., Glodny, J., Monié, P., Calderón, M., Juliani, C.,
1184 2018. A 100-m.y.-long window onto mass-flow processes in the Patagonian Mesozoic
1185 subduction zone (Diego de Almagro Island, Chile). *GSA Bulletin* 130, 1439–1456.
1186 <https://doi.org/10.1130/B31891.1>
- 1187 Angiboust, S., Glodny, J., 2020. Exhumation of eclogitic ophiolitic nappes in the W. Alps:
1188 New age data and implications for crustal wedge dynamics. *Lithos* 356–357, 105374.
1189 <https://doi.org/10.1016/j.lithos.2020.105374>
- 1190 Bachmann, R., Glodny, J., Oncken, O., Seifert, W., 2009. Abandonment of the South
1191 Penninic–Austroalpine palaeosubduction zone, Central Alps, and shift from subduction
1192 erosion to accretion: constraints from Rb/Sr geochronology. *Journal of the Geological*
1193 *Society* 166, 217–231. <https://doi.org/10.1144/0016-76492008-024>
- 1194 Balestro, G., Festa, A., Borghi, A., Castelli, D., Gattiglio, M., Tartarotti, P., 2018. Role of Late
1195 Jurassic intra-oceanic structural inheritance in the Alpine tectonic evolution of the Monviso
1196 meta-ophiolite Complex (Western Alps). *Geol. Mag.* 155, 233–249.
1197 <https://doi.org/10.1017/S0016756817000553>
- 1198 Balestro, G., Festa, A., Dilek, Y., 2019. Structural architecture of the Western Alpine
1199 Ophiolites, and the Jurassic seafloor spreading tectonics of the Alpine Tethys. *Journal of the*
1200 *Geological Society* 176, 913–930. <https://doi.org/10.1144/jgs2018-099>

- 1201 Ballèvre, M., Merle, O., 1993. The Combin Fault: compressional reactivation of a Late
1202 Cretaceous-Early Tertiary detachment fault in the Western Alps. *Schweizerische*
1203 *Mineralogische Und Petrographische Mitteilungen* 73, 205–227.
1204 <https://doi.org/10.5169/SEALS-55570>
- 1205 Ballèvre, M., Lagabrielle, Y., 1994. Garnet in blueschist-facies marbles from the Queyras unit
1206 (Western Alps): its occurrence and its significance. *Schweizerische Mineralogische Und*
1207 *Petrographische Mitteilungen* 74, 203–212.
- 1208 Ballèvre, M., Kienast, J.-R., Vuichard, J.-P., 1986. La “nappe de la Dent-Blanche” (Alpes
1209 occidentales): deux unités austroalpines indépendantes. *Eclogae Geologicae Helvetiae* 79,
1210 57–74. <https://doi.org/10.5169/SEALS-165826>
- 1211 Ballèvre, M., Lagabrielle, Y., Merle, O., 1990. Tertiary ductile normal faulting as a
1212 consequence of lithospheric stacking in the western Alps. *Mémoires de la Société*
1213 *géologique de France* 156, 227–236.
- 1214 Barféty, J.-C., Polino, R., Mercier, D., 2006. Notice explicative de la feuille Névache-
1215 Bardonecchia-Modane à 1/50000 (799) - Orléans : BRGM.
- 1216 Bearth, P., 1959. Über Eklogite, Glaukophanschiefer und metamorphe Pillowlaven.
1217 *Schweizerische Mineralogische Und Petrographische Mitteilungen* 39, 267–286.
- 1218 Bearth, P., 1962. Versuch einer Gliederung alpinmetamorpher Serien der Westalpen.
1219 *Schweizerische Mineralogische Und Petrographische Mitteilungen* 42, 127–137.
- 1220 Bearth, P., 1967. Die Ophiolite der Zone von Zermatt – Saas Fee. *Beitr. Geol.Karte Schweiz*
1221 132.
- 1222 Bebout, G.E., Agard, P., Kobayashi, K., Moriguti, T., Nakamura, E., 2013. Devolatilization
1223 history and trace element mobility in deeply subducted sedimentary rocks: Evidence from
1224 Western Alps HP/UHP suites. *Chemical Geology* 342, 1–20.
1225 <https://doi.org/10.1016/j.chemgeo.2013.01.009>
- 1226 Behr, W.M., Becker, T.W., 2018. Sediment control on subduction plate speeds. *Earth and*
1227 *Planetary Science Letters* 502, 166–173. <https://doi.org/10.1016/j.epsl.2018.08.057>
- 1228 Behr, W.M., Bürgmann, R., 2021. What’s down there? The structures, materials and
1229 environment of deep-seated slow slip and tremor. *Phil. Trans. R. Soc. A.* 379, 20200218.
1230 <https://doi.org/10.1098/rsta.2020.0218>
- 1231 Behr, W.M., Kotowski, A.J., Ashley, K.T., 2018. Dehydration-induced rheological
1232 heterogeneity and the deep tremor source in warm subduction zones. *Geology* 46, 475–478.
1233 <https://doi.org/10.1130/G40105.1>
- 1234 Bellahsen, N., Mouthereau, F., Boutoux, A., Bellanger, M., Lacombe, O., Jolivet, L., Rolland,
1235 Y., 2014. Collision kinematics in the western external Alps: Kinematics of the Alpine collision.
1236 *Tectonics* 33, 1055–1088. <https://doi.org/10.1002/2013TC003453>
- 1237 Berger, A., Bousquet, R., 2008. Subduction-related metamorphism in the Alps: review of
1238 isotopic ages based on petrology and their geodynamic consequences. *Geological Society,*
1239 *London, Special Publications* 298, 117–144. <https://doi.org/10.1144/SP298.7>
- 1240 Beyssac, O., Goffé, B., Chopin, C., Rouzaud, J.N., 2002. Raman spectra of carbonaceous
1241 material in metasediments: a new geothermometer. *Journal of Metamorphic Geology* 20,
1242 859–871. <https://doi.org/10.1046/j.1525-1314.2002.00408.x>

- 1243 Beyssac, O., Goffé, B., Petitet, J.-P., Froigneux, E., Moreau, M., Rouzaud, J.-N., 2003. On
1244 the characterization of disordered and heterogeneous carbonaceous materials by Raman
1245 spectroscopy. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 59,
1246 2267–2276. [https://doi.org/10.1016/S1386-1425\(03\)00070-2](https://doi.org/10.1016/S1386-1425(03)00070-2)
- 1247 Bocchio, R., Benciolini, L., Martin, S., Tartarotti, P., 2000. Geochemistry of eclogitised Fe-Ti-
1248 gabbros from various lithological settings (Aosta Valley ophiolites, Italian western Alps).
1249 Protolith composition and eclogitic paragenesis. *Periodico di Mineralogia* 69, 217–237.
- 1250 Bocquet, J., 1974. Etudes minéralogiques et pétrologiques sur les métamorphismes d'âge
1251 alpin dans les Alpes françaises. PhD thesis Université de Grenoble.
- 1252 Bodinier, J.-L., Menzies, M.A., Thirlwall, M.F., 1991. Continental to Oceanic Mantle
1253 Transition--REE and Sr-Nd Isotopic Geochemistry of the Lanzo Lherzolite Massif. *Journal of*
1254 *Petrology Special_Volume*, 191–210.
1255 https://doi.org/10.1093/petrology/Special_Volume.2.191
- 1256 Bonnet, G., Agard, P., Angiboust, S., Monié, P., Jentzer, M., Omrani, J., Whitechurch, H.,
1257 Fournier, M., 2018. Tectonic slicing and mixing processes along the subduction interface:
1258 The Sistan example (Eastern Iran). *Lithos* 310–311, 269–287.
1259 <https://doi.org/10.1016/j.lithos.2018.04.016>
- 1260 Bonnet, G, Chopin, C, Locatelli, M, Kylander-Clark, A. R. C., Hacker, B. R., submitted.
1261 Protracted subduction of the European hyperextended margin exposed in the Dora-Maira
1262 massif (W. Alps).
- 1263 Bourbon, M, Caron, J.M., Lemoine, M, Tricart, P, 1979. Stratigraphie des schistes lustrés
1264 piémontais dans les Alpes cottiennes (Alpes occidentales franco-italiennes): nouvelle
1265 interprétation et conséquences géodynamiques. *Bulletin de la Societe Geologique de France*
1266 180–2182.
- 1267 Bousquet, R., 2008. Metamorphic heterogeneities within a single HP unit: Overprint effect or
1268 metamorphic mix? *Lithos* 103, 46–69. <https://doi.org/10.1016/j.lithos.2007.09.010>
- 1269 Bousquet, R., Oberhänsli, R., Goffe, B., Jolivet, L., Vidal, O., 1998. High-pressure-low-
1270 temperature metamorphism and deformation in the Bundnerschiefer of the Engadine
1271 window: implications for the regional evolution of the eastern Central Alps. *J Metamorph*
1272 *Geol* 16, 657–674. <https://doi.org/10.1111/j.1525-1314.1998.00161.x>
- 1273 Bousquet, R., Goffé, B., Vidal, O., Oberhänsli, R., Patriat, M., 2002. The tectono-
1274 metamorphic history of the Valaisan domain from the Western to the Central Alps: New
1275 constraints on the evolution of the Alps. *Geological Society of America Bulletin* 114, 207–
1276 225. [https://doi.org/10.1130/0016-7606\(2002\)114<0207:TTMHOT>2.0.CO;2](https://doi.org/10.1130/0016-7606(2002)114<0207:TTMHOT>2.0.CO;2)
- 1277 Bousquet, R., Oberhänsli, R., Goffé, B., Wiederkehr, M., Koller, F., Schmid, S.M., Schuster,
1278 R., Engi, M., Berger, A., Martinotti, G., 2008. Metamorphism of metasediments at the scale of
1279 an orogen: a key to the Tertiary geodynamic evolution of the Alps. *Geological Society,*
1280 *London, Special Publications* 298, 393–411. <https://doi.org/10.1144/SP298.18>
- 1281 Bowtell, S.A., Cliff, R.A., Barnicoat, A.C., 1994. Sm-Nd isotopic evidence on the age of
1282 eclogitization in the Zermatt-Saas ophiolite. *J Metamorph Geol* 12, 187–196.
1283 <https://doi.org/10.1111/j.1525-1314.1994.tb00013.x>
- 1284 Broadwell, K.S., Locatelli, M., Verlaguet, A., Agard, P., Caddick, M.J., 2019. Transient and
1285 periodic brittle deformation of eclogites during intermediate-depth subduction. *Earth and*
1286 *Planetary Science Letters* 521, 91–102. <https://doi.org/10.1016/j.epsl.2019.06.008>

- 1287 Bucher, K., Grapes, R., 2009. The Eclogite-facies Allalin Gabbro of the Zermatt-Saas
1288 Ophiolite, Western Alps: a Record of Subduction Zone Hydration. *Journal of Petrology* 50,
1289 1405–1442. <https://doi.org/10.1093/petrology/egp035>
- 1290 Bucher, S., Schmid, S.M., Bousquet, R., Fugenschuh, B., 2003. Late-stage deformation in a
1291 collisional orogen (Western Alps): nappe refolding, back-thrusting or normal faulting? *Terra*
1292 *Nova* 15, 109–117. <https://doi.org/10.1046/j.1365-3121.2003.00470.x>
- 1293 Bucher, K., Fazis, Y, De Capitani, C, Grapes, R, 2005. Blueschists, eclogites, and
1294 decompression assemblages of the Zermatt-Saas ophiolite: High-pressure metamorphism of
1295 subducted Tethys lithosphere. *American Mineralogist* 90, 821–835.
1296 <https://doi.org/10.2138/am.2005.1718>
- 1297 Busigny, V., Cartigny, P., Philippot, P., 2011. Nitrogen isotopes in ophiolitic metagabbros: A
1298 re-evaluation of modern nitrogen fluxes in subduction zones and implication for the early
1299 Earth atmosphere. *Geochimica et Cosmochimica Acta* 75, 7502–7521.
1300 <https://doi.org/10.1016/j.gca.2011.09.049>
- 1301 Busigny, V., Chen, J., Philippot, P., Borensztajn, S., Moynier, F., 2018. Insight into
1302 hydrothermal and subduction processes from copper and nitrogen isotopes in oceanic
1303 metagabbros. *Earth and Planetary Science Letters* 498, 54–64.
1304 <https://doi.org/10.1016/j.epsl.2018.06.030>
- 1305 Caby, R., 1996. Low-angle extrusion of high-pressure rocks and the balance between
1306 outward and inward displacements of Middle Penninic units in the western Alps. *Eclogae*
1307 *Geologicae Helvetiae* 89/1, 229–267. <https://doi.org/10.5169/SEALS-167901>
- 1308 Caby, R, Kienast, J. R., Saliot, P, 1976. Modèle d'évolution structurale des Alpes
1309 occidentales. *Colloque International CNRS, Ecologie et Géologie de l'Himalaya* 85–92.
- 1310 Caby, R., Kienast, J.-R., Saliot, P., 1978. Structure, métamorphisme et modèle d'évolution
1311 tectonique des Alpes occidentales. *Revue de géographie physique et de géologie*
1312 *dynamique Paris*, 20, 307–322.
- 1313 Cadoppi, P, Castelletto, M, Sacchi, R, Baggio, P, Carraro, F, Giraud, V, 2002. Note
1314 illustrative della carta geologica d'Italia alla scala 1:50000: foglio 154 Susa. ISPRA, Servizio
1315 Geologico d'Italia.
- 1316 Caron, J.-M., 1974. Rapports entre diverses "generations" de lawsonite et les deformations
1317 dans les Schistes lustrés des Alpes cottiennes septentrionales (France et Italie). *Bulletin de*
1318 *la Société Géologique de France* 7, 256–263.
- 1319 Caron, J.M., 1977. Lithostratigraphie et tectonique des Schistes Lustrés dans les Alpes
1320 Cottiennes septentrionales et en Corse orientale. PhD thesis, université de Strasbourg.
- 1321 Chopin, C, 1978. Les paragenèses réduites ou oxydées de concentrations manganésifères
1322 des «schistes lustrés» de Haute-Maurienne (Alpes françaises). *Bulletin de Minéralogie* 101,
1323 514–531.
- 1324 Chopin, C, 1979. De la Vanoise au massif du Grand Paradis, Une approche pétrographique
1325 et radiochronologique de la signification géodynamique du métamorphisme de haute
1326 pression. PhD thesis Université Pierre et Marie Curie, Paris 6.
- 1327 Chopin, C., 1984. Coesite and pure pyrope in high-grade blueschists of the Western Alps: a
1328 first record and some consequences. *Contr. Mineral. and Petrol.* 86, 107–118.
1329 <https://doi.org/10.1007/BF00381838>

- 1330 Chopin, C, Maluski, H, 1980. 40Ar-39Ar dating of high pressure metamorphic micas from the
1331 Gran Paradiso area (Western Alps): Evidence against the blocking temperature concept.
1332 *Contributions to Mineralogy and Petrology* 74, 109–122.
- 1333 Compagnoni, R., Rolfo, F., 2003. UHPM units in the Western Alps, in: Papp, G., Weiszburg,
1334 T.G., Carswell, D.A., Compagnoni, R., Rolfo, F. (Eds.), *Ultrahigh Pressure Metamorphism*.
1335 *Mineralogical Society of Great Britain and Ireland*, Budapest, pp. 13–49.
1336 <https://doi.org/10.1180/EMU-notes.5.2>
- 1337 Connolly, J. A. D., 1990. Multivariable phase diagrams: an algorithm based on generalized
1338 thermodynamics. *American Journal of Science* 290, 666–718.
- 1339 Connolly, J.A.D., 2005. Computation of phase equilibria by linear programming: A tool for
1340 geodynamic modeling and its application to subduction zone decarbonation. *Earth and*
1341 *Planetary Science Letters* 236, 524–541. <https://doi.org/10.1016/j.epsl.2005.04.033>
- 1342 Connolly, J.A.D., 2009. The geodynamic equation of state: What and how. *Geochem.*
1343 *Geophys. Geosyst.* 10, n/a-n/a. <https://doi.org/10.1029/2009GC002540>
- 1344 Corno, A., Mosca, P., Borghi, A., Gattiglio, M., 2019. Lithostratigraphy and petrography of
1345 the Monte Banchetta-Punta Rognosa oceanic succession (Tronca and Chisonetto Valleys,
1346 Western Alps). *Ofioliti* 44. <https://doi.org/10.4454/ofioliti.v44i2.526>
- 1347 Corno, A., Groppo, C., Mosca, P., Borghi, A., Gattiglio, M., 2021. Eclogitic metamorphism in
1348 the Alpine far-west: petrological constraints on the Banchetta-Rognosa tectonic unit (Val
1349 Tronca, Western Alps). *Swiss J Geosci* 114, 16. [https://doi.org/10.1186/s00015-021-00393-](https://doi.org/10.1186/s00015-021-00393-7)
1350 [7](https://doi.org/10.1186/s00015-021-00393-7)
- 1351 Cubas, N, Agard, P, Tissandier, R, submitted. Predicting earthquake ruptures from
1352 topography.
- 1353 Dal Piaz, G.V., 1974a. Le métamorphisme de haute pression et basse température dans
1354 l'évolution structurale du bassin ophiolitique alpino-apenninique. 1ère partie : Considérations
1355 paléogéographiques. *Bolletino della Societa Geologica Italiana* 93, 437–467.
- 1356 Dal Piaz, G.V., 1974b. Le métamorphisme de haute pression et basse température dans
1357 l'évolution structurale du bassin ophiolitique alpino-apenninique. *Schweizerische*
1358 *Mineralogische Und Petrographische Mitteilungen* 54, 399–424.
- 1359 Dal Piaz, G.V., Cortiana, G, Del Moro, A, Martin, S, Pennachioni, G, Tartarotti, P, 2001.
1360 Tertiary age and paleostructural inferences of the eclogitic imprint in the Austroalpine outliers
1361 and Zermatt-Saas ophiolite, western Alps. *International Journal of Earth Sciences (Geol*
1362 *Rundsch)* 90, 668–684.
- 1363 Dal Piaz, G.V., Gianotti, F, Monopoli, B, Pennachioni, G, Tartarotti, P, Schiavo, A, 2010.
1364 Note illustrative della carta geologica d'Italia alla scala 1:50000: foglio 091 Chatillon. ISPRA,
1365 Servizio Geologico d'Italia.
- 1366 de Meyer, C.M.C., Baumgartner, L.P., Beard, B.L., Johnson, C.M., 2014. Rb–Sr ages from
1367 phengite inclusions in garnets from high pressure rocks of the Swiss Western Alps. *Earth*
1368 *and Planetary Science Letters* 395, 205–216. <https://doi.org/10.1016/j.epsl.2014.03.050>
- 1369 De Togni, M., Gattiglio, M., Ghignone, S., Festa, A., 2021. Pre-Alpine Tectono-Stratigraphic
1370 Reconstruction of the Jurassic Tethys in the High-Pressure Internal Piedmont Zone (Stura di
1371 Viù Valley, Western Alps). *Minerals* 11, 361. <https://doi.org/10.3390/min11040361>

- 1372 De Wever, P., Caby, R., 1981. Datation de la base des schistes lustrés postophiolitiques par
1373 des radiolaires (Oxfordien-Kimmeridgien moyen) dans les Alpes Cottiennes (Saint Véran,
1374 France). *Comptes Rendus de l'Académie des Sciences de Paris* 292, 467–472.
- 1375 De Wever, P., Baumgartner, P.O., Polino, R., 1987a. Précision sur les datations de la base
1376 des Schistes Lustrés postophiolitiques dans les Alpes cottiennes. *Comptes Rendus de*
1377 *l'Académie des Sciences de Paris* 305, 487–491.
- 1378 De Wever, P., Danelian, T., Durand-Delga, M., Cordey, M., Kito, N., 1987b. Datations des
1379 radiolarites post-ophiolitiques de Corse alpine à l'aide des Radiolaires. *Comptes Rendus de*
1380 *l'Académie des Sciences de Paris* 305, 893–900.
- 1381 Debelmas, J, Caby, R, Desmons, J, 1991. Notice explicative de la feuille Sainte-Foy-
1382 Tarentaise à 1/50000 (728) - Orléans : BRGM.
- 1383 Debret, B., Nicollet, C., Andreani, M., Schwartz, S., Godard, M., 2013. Three steps of
1384 serpentization in an eclogitized oceanic serpentization front (Lanzo Massif - Western
1385 Alps). *Journal of Metamorphic Geology* 31, 165–186. <https://doi.org/10.1111/jmg.12008>
- 1386 Decandia, F.A., Elter, P, 1969. Riflessioni sul problema delle ofioliti nell'Appennino
1387 settentrionale (Nota preliminare). *Atti Societa Toscana delle Science Naturali : memorie Serie*
1388 *A*, 76, 1–9.
- 1389 Decandia, F.A., Elter, P, 1972. La " zona" ofiolitifera del Bracco nel settore compreso fra
1390 Levanto e la Val Gravena (Apennino ligure). *Bolletino della Societa Geologica Italiana* 11,
1391 37–64.
- 1392 Decrausaz, T., Müntener, O., Manzotti, P., Lafay, R., Spandler, C., 2021. Fossil oceanic core
1393 complexes in the Alps. New field, geochemical and isotopic constraints from the Tethyan
1394 Aiguilles Rouges Ophiolite (Val d'Hérens, Western Alps, Switzerland). *Swiss J Geosci* 114,
1395 3. <https://doi.org/10.1186/s00015-020-00380-4>
- 1396 Delaloye, M., Desmons, J., 1976. K-Ar Radiometric Age Determinations of White Micas from
1397 the Piemonte Zone, French-Italian Western Alps. *Contributions to Mineralogy and Petrology*
1398 *57*, 297–303. <https://doi.org/10.1007/BF03542939>
- 1399 Deville, E, 1986. La klippe de la Pointe du Grand Vallon (Vanoise-Alpes occidentales) : un
1400 lambeau de métasédiments à foraminifères du Maastrichtien supérieur couronnant les
1401 nappes de « schistes lustrés ». *Comptes rendus de l'Académie des sciences. Série 2,*
1402 *Mécanique, Physique, Chimie, Sciences de l'univers, Sciences de la Terre* 303, 1221–1226.
- 1403 Deville, E, 1987. Etude géologique en Vanoise orientale (Alpes occidentales, Savoie). De la
1404 naissance à la structuration d'un secteur de la paléo-marge européenne et de l'océan
1405 téthysien : aspects stratigraphiques, pétrographiques et tectoniques. PhD thesis Université
1406 de Savoie.
- 1407 Deville, E., Fudral, S., Lagabrielle, Y., Marthaler, M., Sartori, M., 1992. From oceanic closure
1408 to continental collision: A synthesis of the " Schistes lustrés" metamorphic complex of the
1409 Western Alps. *Geological Society of America Bulletin* 104, 127–139.
- 1410 Dragovic, B., Angiboust, S., Tappa, M.J., 2020. Petrochronological close-up on the thermal
1411 structure of a paleo-subduction zone (W. Alps). *Earth and Planetary Science Letters* 547,
1412 116446. <https://doi.org/10.1016/j.epsl.2020.116446>

- 1413 Droop, G.T.R., Lombardo, B, Pognante, U, 1990. Formation and distribution of eclogite
1414 facies rocks in the Alps. In: Carswell, D.A. (Ed.), *Eclogite Facies Rocks*: Glasgow. Blackie,
1415 United Kingdom, 225–259.
- 1416 Duchène, S., Blichert-Toft, J., Luais, B., Télouk, P., Lardeaux, J.-M., Albarède, F., 1997. The
1417 Lu–Hf dating of garnets and the ages of the Alpine high-pressure metamorphism. *Nature*
1418 387, 586–589. <https://doi.org/10.1038/42446>
- 1419 Duesterhoeft, E., Quinteros, J., Oberhänsli, R., Bousquet, R., de Capitani, C., 2014. Relative
1420 impact of mantle densification and eclogitization of slabs on subduction dynamics: A
1421 numerical thermodynamic/thermokinematic investigation of metamorphic density evolution.
1422 *Tectonophysics* 637, 20–29. <https://doi.org/10.1016/j.tecto.2014.09.009>
- 1423 Dumitru, T.A., Wakabayashi, J., Wright, J.E., Wooden, J.L., 2010. Early Cretaceous
1424 transition from nonaccretionary behavior to strongly accretionary behavior within the
1425 Franciscan subduction complex: ACCRETION IN THE FRANCISCAN COMPLEX. *Tectonics*
1426 29. <https://doi.org/10.1029/2009TC002542>
- 1427 Dumont, T, Lemoine, M, Tricart, P, 1984. Pérennité de la sédimentation pélagique du
1428 Jurassique supérieur jusque dans le crétacé supérieur au-dessus de la croûte océanique
1429 téthysienne ligure : la série supra-ophiolitique du lac des Cordes (zone piémontaise des
1430 Alpes occidentales au SE de Briançon). *Comptes rendus de l'Académie des sciences. Série*
1431 *2, Mécanique, Physique, Chimie, Sciences de l'univers, Sciences de la Terre* 7, 921–933.
- 1432 Ellero, A., Loprieno, A., 2018. Nappe stack of Piemonte–Ligurian units south of Aosta V
1433 alley: New evidence from Urtier Valley (Western Alps). *Geological Journal* 53, 1665–1684.
1434 <https://doi.org/10.1002/gj.2984>
- 1435 Elter, G, 1971. Schistes lustrés et ophiolites de la zone piémontaise entre Orco et Doire
1436 Baltée (Alpes Graies). *Hypothèses sur l'origine des ophiolites. Géologie Alpine* 47, 147–169.
- 1437 Tobin, H., Hirose, T., Ikari, M., Kanagawa, K., Kimura, G., Kinoshita, M., Kitajima, H., Saffer,
1438 D., Yamaguchi, A., Eguchi, N., Maeda, L., Toczko, S., 2019. Expedition 358 Preliminary
1439 Report: NanTroSEIZE Plate Boundary Deep Riser 4: Nankai Seismogenic/Slow Slip
1440 Megathrust, International Ocean Discovery Program Preliminary Report. International Ocean
1441 Discovery Program. <https://doi.org/10.14379/iodp.pr.358.2019>
- 1442 Frezzotti, M.L., Selverstone, J., Sharp, Z.D., Compagnoni, R., 2011. Carbonate dissolution
1443 during subduction revealed by diamond-bearing rocks from the Alps. *Nature Geosci* 4, 703–
1444 706. <https://doi.org/10.1038/ngeo1246>
- 1445 Fudral, S., 1996. Etude géologique de la suture téthysienne dans les Alpes franco-italiennes
1446 Nord-Occidentales de la Doire Ripaire (Italie) à la région de Bourg Saint-Maurice. PhD thesis
1447 Université de Savoie.
- 1448 Fudral, S., Deville, E., Marthaler, M., 1987. Distinction de trois ensembles d'unités dans les
1449 «Schistes lustrés» compris entre la Vanoise et le Val de Suse (Alpes franco-italiennes
1450 septentrionales): aspects lithostratigraphiques, paléogéographiques et géodynamiques.
1451 *Comptes rendus de l'Académie des sciences. Série 2, Mécanique, Physique, Chimie,*
1452 *Sciences de l'univers, Sciences de la Terre*, 305, 467–472.
- 1453 Gabalda, S., Beyssac, O., Jolivet, L., Agard, P., Chopin, C., 2009. Thermal structure of a
1454 fossil subduction wedge in the Western Alps. *Terra Nova* 21, 28–34.
1455 <https://doi.org/10.1111/j.1365-3121.2008.00849.x>

- 1456 Garber, J.M., Smye, A.J., Feineman, M.D., Kylander-Clark, A.R.C., Matthews, S., 2020a.
1457 Decoupling of zircon U–Pb and trace-element systematics driven by U diffusion in eclogite-
1458 facies zircon (Monviso meta-ophiolite, W. Alps). *Contrib Mineral Petrol* 175, 55.
1459 <https://doi.org/10.1007/s00410-020-01692-2>
- 1460 Garber, J.M., Rioux, M., Kylander-Clark, A.R.C., Hacker, B.R., Vervoort, J.D., Searle, M.P.,
1461 2020b. Petrochronology of Wadi Tayin Metamorphic Sole Metasediment, With Implications
1462 for the Thermal and Tectonic Evolution of the Samail Ophiolite (Oman/UAE). *Tectonics* 39.
1463 <https://doi.org/10.1029/2020TC006135>
- 1464 Ghignone, S., Borghi, A., Balestro, G., Castelli, D., Gattiglio, M., Groppo, C., 2021a. HP
1465 tectono-metamorphic evolution of the Internal Piedmont Zone in Susa Valley (Western Alps):
1466 New petrologic insight from garnet+chloritoid-bearing micaschists and Fe–Ti metagabbro.
1467 *Journal of Metamorphic Geology* 39, 391–416.
- 1468 Ghignone, S., Sudo, M., Balestro, G., Borghi, A., Gattiglio, M., Ferrero, S., van Schijndel, V.,
1469 2021b. Timing of exhumation of meta-ophiolite units in the Western Alps: New tectonic
1470 implications from ⁴⁰Ar/³⁹Ar white mica ages from Piedmont Zone (Susa Valley). *Lithos* 404–
1471 405, 106443. <https://doi.org/10.1016/j.lithos.2021.106443>
- 1472 Goffé, B., Chopin, C., 1986. High-pressure metamorphism in the Western Alps : zoneography
1473 of metapelites, chronology and consequences. *Schweizerische Mineralogische Und*
1474 *Petrographische Mitteilungen* 66, 41–52. <https://doi.org/10.5169/SEALS-50880>
- 1475 Goffé, B., Bousquet, R., 1997. Ferrocapholite, chloritoid and lawsonite in metapelites of the
1476 Versoyen and Petit St Bernard units (Valais zone, Western Alps). *Schweizerische*
1477 *Mineralogische und Petrographische Mitteilunge* 77, 137–147.
- 1478 Goffé, B., Schwartz, S., Lardeaux, J.-M., Bousquet, R., 2004. Explanatory notes of the map:
1479 metamorphic structure of the Alps Western and Ligurian Alps. *MITT.ÖSTERR.MINER.GES.*
1480 125–144.
- 1481 Gouzu, C., Itaya, T., Hyodo, H., Matsuda, T., 2006. Excess ⁴⁰Ar-free phengite in ultrahigh-
1482 pressure metamorphic rocks from the Lago di Cignana area, Western Alps. *Lithos* 92, 418–
1483 430. <https://doi.org/10.1016/j.lithos.2006.03.056>
- 1484 Gouzu, C., Yagi, K., Thanh, N.X., Itaya, T., Compagnoni, R., 2016. White mica K–Ar
1485 geochronology of HP–UHP units in the Lago di Cignana area, western Alps, Italy: Tectonic
1486 implications for exhumation. *Lithos* 248–251, 109–118.
1487 <https://doi.org/10.1016/j.lithos.2016.01.015>
- 1488 Groppo, C., Castelli, D., 2010. Prograde P–T Evolution of a Lawsonite Eclogite from the
1489 Monviso Meta-ophiolite (Western Alps): Dehydration and Redox Reactions during
1490 Subduction of Oceanic FeTi-oxide Gabbro. *Journal of Petrology* 51, 2489–2514.
1491 <https://doi.org/10.1093/petrology/egq065>
- 1492 Groppo, C., Beltrando, M., Compagnoni, R., 2009. The P-T path of the ultra-high pressure
1493 Lago Di Cignana and adjoining high-pressure meta-ophiolitic units: insights into the evolution
1494 of the subducting Tethyan slab. *Journal of Metamorphic Geology* 27, 207–231.
1495 <https://doi.org/10.1111/j.1525-1314.2009.00814>
- 1496 Guillot, S., Hattori, K., Agard, P., Schwartz, S., Vidal, O., 2009. Exhumation Processes in
1497 Oceanic and Continental Subduction Contexts: A Review, in: Lallemand, S., Funiciello, F.
1498 (Eds.), *Subduction Zone Geodynamics*, *Frontiers in Earth Sciences*. Springer Berlin
1499 Heidelberg, Berlin, Heidelberg, pp. 175–205. https://doi.org/10.1007/978-3-540-87974-9_10

- 1500 Guillot, S., Schwartz, S., Reynard, B., Agard, P., Prigent, C., 2015. Tectonic significance of
1501 serpentinites. *Tectonophysics* 646, 1–19. <https://doi.org/10.1016/j.tecto.2015.01.020>
- 1502 Hacker, B.R., Peacock, S.M., Abers, G.A., Holloway, S.D., 2003. Subduction factory 2. Are
1503 intermediate-depth earthquakes in subducting slabs linked to metamorphic dehydration
1504 reactions?: SUBDUCTION ZONE EARTHQUAKES AND DEHYDRATION. *J. Geophys. Res.*
1505 108. <https://doi.org/10.1029/2001JB001129>
- 1506 Handy, M.R., 2010. Reconciling plate-tectonic reconstructions of Alpine Tethys with the
1507 geological–geophysical record of spreading and subduction in the Alps 38.
- 1508 Henry, C., Burkhard, M., Goffé, B., 1996. Evolution of synmetamorphic veins and their
1509 wallrocks through a Western Alps transect: no evidence for large-scale fluid flow. Stable
1510 isotope, major- and trace-element systematics. *Chemical Geology* 127, 81–109.
1511 [https://doi.org/10.1016/0009-2541\(95\)00106-9](https://doi.org/10.1016/0009-2541(95)00106-9)
- 1512 Hertgen, S., Yamato, P., Morales, L.F.G., Angiboust, S., 2017. Evidence for brittle
1513 deformation events at eclogite-facies P-T conditions (example of the Mt. Emilius klippe,
1514 Western Alps). *Tectonophysics* 706–707, 1–13. <https://doi.org/10.1016/j.tecto.2017.03.028>
- 1515 Herviou, C., Verlaquet, A., Agard, P., Locatelli, M., Raimbourg, H., Lefeuvre, B., Dubacq, B.,
1516 2021. Along-dip variations of subduction fluids: The 30–80 km depth traverse of the Schistes
1517 Lustrés complex (Queyras-Monviso, W. Alps). *Lithos* 394–395, 106168.
1518 <https://doi.org/10.1016/j.lithos.2021.106168>
- 1519 Holland, T.J.B., Powell, R., 1998. An internally consistent thermodynamic data set for phases
1520 of petrological interest: AN INTERNALLY CONSISTENT THERMODYNAMIC DATA SET.
1521 *Journal of Metamorphic Geology* 16, 309–343. <https://doi.org/10.1111/j.1525-1314.1998.00140.x>
- 1523 Holland, T., Baker, J., Powell, R., 1998. Mixing properties and activity-composition
1524 relationships of chlorites in the system MgO-FeO-Al₂O₃-SiO₂-H₂O. *ejm* 10, 395–406.
1525 <https://doi.org/10.1127/ejm/10/3/0395>
- 1526 Ikari, M.J., Kopf, A.J., Hüpers, A., Vogt, C., 2018. Lithologic control of frictional strength
1527 variations in subduction zone sediment inputs. *Geosphere* 14, 604–625.
1528 <https://doi.org/10.1130/GES01546.1>
- 1529 Incel, S., Hilairet, N., Labrousse, L., John, T., Deldicque, D., Ferrand, T., Wang, Y., Renner,
1530 J., Morales, L., Schubnel, A., 2017. Laboratory earthquakes triggered during eclogitization of
1531 lawsonite-bearing blueschist. *Earth and Planetary Science Letters* 459, 320–331.
1532 <https://doi.org/10.1016/j.epsl.2016.11.047>
- 1533 Jolivet, L., Goffé, B., Monié, P., Truffert-Luxey, C., Patriat, M., Bonneau, M., 1996. Miocene
1534 detachment in Crete and exhumation P-T-t paths of high-pressure metamorphic rocks.
1535 *Tectonics* 15, 1129–1153. <https://doi.org/10.1029/96TC01417>
- 1536 Jolivet, L., Faccenna, C., Goffé, B., Mattei, M., Rossetti, F., Brunet, C., Storti, F., Funicello,
1537 R., Cadet, J.P., d'Agostino, N., Parra, T., 1998. Midcrustal shear zones in postorogenic
1538 extension: Example from the northern Tyrrhenian Sea. *J. Geophys. Res.* 103, 12123–12160.
1539 <https://doi.org/10.1029/97JB03616>
- 1540 Kameda, J., Inoue, S., Tanikawa, W., Yamaguchi, A., Hamada, Y., Hashimoto, Y., Kimura,
1541 G., 2017. Alteration and dehydration of subducting oceanic crust within subduction zones:
1542 implications for décollement step-down and plate-boundary seismogenesis. *Earth Planets
1543 Space* 69, 52. <https://doi.org/10.1186/s40623-017-0635-1>

- 1544 Karig, D.E., Sharman, G.F., 1975. Subduction and Accretion in Trenches. *Geol Soc America*
1545 *Bull* 86, 377–389. [https://doi.org/10.1130/0016-7606\(1975\)86<377:SAIT>2.0.CO;2](https://doi.org/10.1130/0016-7606(1975)86<377:SAIT>2.0.CO;2)
- 1546 Kerswell, B.C., Kohn, M.J., Gerya, T.V., 2021. Backarc Lithospheric Thickness and
1547 Serpentine Stability Control Slab-Mantle Coupling Depths in Subduction Zones. *Geochem*
1548 *Geophys Geosyst* 22. <https://doi.org/10.1029/2020GC009304>
- 1549 Kienast, J. R., 1973. Sur l'existence de deux séries différentes au sein de l'ensemble
1550 schistes lustrés-ophiolites du val d'Aoste ; quelques arguments fondés sur l'étude des roches
1551 métamorphiques. *Comptes Rendus de l'Académie des Sciences de Paris* 276, 2621–2624.
- 1552 Kimura, G., Ludden, J., 1995. Peeling oceanic crust in subduction zones. *Geol* 23, 217–220.
1553 [https://doi.org/10.1130/0091-7613\(1995\)023<0217:POCISZ>2.3.CO;2](https://doi.org/10.1130/0091-7613(1995)023<0217:POCISZ>2.3.CO;2)
- 1554 Kimura, G., Maruyama, S., Isozaki, Y., Terabayashi, M., 1996. Well-preserved underplating
1555 structure of the jadeitized Franciscan complex, Pacheco Pass, California. *Geol* 24, 75.
1556 [https://doi.org/10.1130/0091-7613\(1996\)024<0075:WPUSOT>2.3.CO;2](https://doi.org/10.1130/0091-7613(1996)024<0075:WPUSOT>2.3.CO;2)
- 1557 Kimura, G., Kitamura, Y., Hashimoto, Y., Yamaguchi, A., Shibata, T., Ujiie, K., Okamoto, S.,
1558 2007. Transition of accretionary wedge structures around the up-dip limit of the seismogenic
1559 subduction zone. *Earth and Planetary Science Letters* 255, 471–484.
1560 <https://doi.org/10.1016/j.epsl.2007.01.005>
- 1561 Kita, S., Okada, T., Nakajima, J., Matsuzawa, T., Hasegawa, A., 2006. Existence of a
1562 seismic belt in the upper plane of the double seismic zone extending in the along-arc
1563 direction at depths of 70–100 km beneath NE Japan. *Geophys. Res. Lett.* 33, L24310.
1564 <https://doi.org/10.1029/2006GL028239>
- 1565 Kunz, P., 1988. Ophiolites penniques et sédiments associés dans la région d'Arolla (val
1566 d'Hérens, Valais, Suisse). *Eclogae Geologicae Helvetiae* 81, 115–124.
1567 <https://doi.org/10.5169/SEALS-166172>
- 1568 Lagabrielle, Y., 1987. Les ophiolites : Marqueurs de l'histoire tectonique des domaines
1569 océaniques. PhD thesis Brest.
- 1570 Lagabrielle, Y, Polino, R, 1988. Un schéma structural du domaine des Schistes lustrés
1571 ophiolitifères au nord-ouest du massif du Mont Viso (Alpes Sud-Occidentales) et ses
1572 implications. *Comptes rendus de l'Académie des sciences. Série 2, Mécanique, Physique,*
1573 *Chimie, Sciences de l'univers, Sciences de la Terre,* 306, 921–928.
- 1574 Lagabrielle, Y., Cannat, M., 1990. Alpine Jurassic ophiolites resemble the modern central
1575 Atlantic basement. *Geology* 18, 319–322.
- 1576 Lagabrielle, Y., Fudral, S., Kienast, J.-R., 1990. La couverture océanique des ultrabasites de
1577 Lanzo (Alpes occidentales) : arguments lithostratigraphiques et pétrologiques. *Geodinamica*
1578 *Acta* 4, 43–55. <https://doi.org/10.1080/09853111.1990.11105199>
- 1579 Lagabrielle, Y., Vitale Brovarone, A., Ildefonse, B., 2015. Fossil oceanic core complexes
1580 recognized in the blueschist metaophiolites of Western Alps and Corsica. *Earth-Science*
1581 *Reviews* 141, 1–26. <https://doi.org/10.1016/j.earscirev.2014.11.004>
- 1582 Lahfid, A., Beyssac, O., Deville, E., Negro, F., Chopin, C., Goffé, B., 2010. Evolution of the
1583 Raman spectrum of carbonaceous material in low-grade metasediments of the Glarus Alps
1584 (Switzerland): RSCM in low-grade metasediments. *Terra Nova* 22, 354–360.
1585 <https://doi.org/10.1111/j.1365-3121.2010.00956.x>

- 1586 Lanari, P, 2012. Micro-cartographie P-T- ϵ dans les roches métamorphiques. Applications aux
1587 Alpes et à l'Himalaya. PhD thesis, Université de Grenoble.
- 1588 Lapen, T.J., Johnson, C.M., Baumgartner, L.P., Mahlen, N.J., Beard, B.L., Amato, J.M.,
1589 2003. Burial rates during prograde metamorphism of an ultra-high-pressure terrane: an
1590 example from Lago di Cignana, western Alps, Italy. *Earth and Planetary Science Letters* 215,
1591 57–72. [https://doi.org/10.1016/S0012-821X\(03\)00455-2](https://doi.org/10.1016/S0012-821X(03)00455-2)
- 1592 Lay, T., Kanamori, H., Ammon, C.J., Koper, K.D., Hutko, A.R., Ye, L., Yue, H., Rushing,
1593 T.M., 2012. Depth-varying rupture properties of subduction zone megathrust faults:
1594 MEGATHRUST RUPTURE DOMAINS. *J. Geophys. Res.* 117, n/a-n/a.
1595 <https://doi.org/10.1029/2011JB009133>
- 1596 Le Pichon, X., Bergerat, F., Roulet, M., 1988. Plate kinematics and tectonics leading to the
1597 Alpine belt formation: a new analysis. *Geological Society of America Special Issue* 218, 111–
1598 131.
- 1599 Lefeuvre, B., Agard, P., Verlaquet, A., Dubacq, B., Plunder, A., 2020. Massive formation of
1600 lawsonite in subducted sediments from the Schistes Lustrés (W. Alps): Implications for mass
1601 transfer and decarbonation in cold subduction zones. *Lithos* 370–371, 105629.
1602 <https://doi.org/10.1016/j.lithos.2020.105629>
- 1603 Lemoine, M, 1959. Remarques a propos de quelques faits et hypotheses concernant l'age
1604 des Schistes lustrés piemontais dans les Alpes cottiennes et briançonnaises. *Bulletin de la*
1605 *Société Géologique de France* 7, 90–92.
- 1606 Lemoine, M, 1971. Données nouvelles sur la série du Gondran près Briançon (Alpes
1607 Cottiennes). Réflexions sur les problèmes stratigraphique et paléogéographique de la zone
1608 piémontaise. *Géologie Alpine* 47, 181–201.
- 1609 Lemoine, M., 2003. Schistes lustrés from Corsica to Hungary : back to the original sediments
1610 and tentative dating of partly azoic metasediments. *Bulletin de la Société Géologique de*
1611 *France* 174, 197–209. <https://doi.org/10.2113/174.3.197>
- 1612 Lemoine, M., Tricart, P., 1986. Les Schistes lustrés piémontais des Alpes Occidentales :
1613 approche stratigraphique, structurales et sédimentologique. *Eclogae Geologicae Helvetiae*
1614 79, 271–294. <https://doi.org/10.5169/SEALS-165835>
- 1615 Lemoine, M, Steen, D.M., Vuagnat, M, 1970. Sur le problème stratigraphique des ophiolites
1616 piémontaises et des roches sédimentaires associées: observations dans le massif de
1617 Chabrière en Haute-Ubaye (Basses-Alpes, France). *Compte rendu des séances de la*
1618 *Société de physique et d'histoire naturelle de Genève* 5, 44–59.
- 1619 Lemoine, M., Marthaler, M., Caron, M., Sartori, M., Amaudric du Chaffaut, S., 1984.
1620 Découverte de foraminifères planctoniques du Crétacé supérieur dans les schistes lustrés du
1621 Queyras (Alpes occidentales). Conséquences paléogéographiques et tectoniques. *Comptes-*
1622 *rendus des séances de l'Académie des sciences. Série 2, Mécanique-physique, chimie,*
1623 *sciences de l'univers, sciences de la terre* 299, 727–732.
- 1624 Lemoine, M., Bas, T., Arnaud-Vanneau, A., Arnaud, H., Dumont, T., Gidon, M., Bourbon, M.,
1625 de Graciansky, P.-C., Rudkiewicz, J.-L., Megard-Galli, J., Tricart, P., 1986. The continental
1626 margin of the Mesozoic Tethys in the Western Alps. *Marine and Petroleum Geology* 3, 179-
1627 199.

- 1628 Liewig, N., 1981. Les phengites : marqueurs géométriques, chimiques et isotopiques de
1629 l'histoire des roches métamorphiques : application aux schistes lustres des Alpes cottiennes.
1630 PhD thesis, université de Strasbourg.
- 1631 Locatelli, M., Verlaquet, A., Agard, P., Federico, L., Angiboust, S., 2018. Intermediate-depth
1632 brecciation along the subduction plate interface (Monviso eclogite, W. Alps). *Lithos* 320–321,
1633 378–402. <https://doi.org/10.1016/j.lithos.2018.09.028>
- 1634 Locatelli, M., Federico, L., Agard, P., Verlaquet, A., 2019a. Geology of the southern Monviso
1635 metaophiolite complex (W-Alps, Italy). *Journal of Maps* 15, 283–297.
1636 <https://doi.org/10.1080/17445647.2019.1592030>
- 1637 Locatelli, M., Verlaquet, A., Agard, P., Pettke, T., Federico, L., 2019b. Fluid Pulses During
1638 Stepwise Brecciation at Intermediate Subduction Depths (Monviso Eclogites, W. Alps): First
1639 Internally Then Externally Sourced. *Geochem. Geophys. Geosyst.* 20, 5285–5318.
1640 <https://doi.org/10.1029/2019GC008549>
- 1641 Lombardo, B., Nervo, R., Compagnoni, R., Messiga, B., Kienast, J. R., Mevel, C., Fiora, L.,
1642 Piccardo, G. B., Lanza, R., 1978. Osservazioni preliminari sulle ofioliti metamorfiche del
1643 Monviso (Alpi Occidentali). *Rendiconti Della Soc. Ital. Mineral. E Petrol.* 34, 235–305.
- 1644 Malusà, M.G., Polino, R., Zattin, M., Bigazzi, G., Martin, S., Piana, F., 2005. Miocene to
1645 Present differential exhumation in the Western Alps: Insights from fission track
1646 thermochronology: EXHUMATION IN THE WESTERN ALPS. *Tectonics* 24, n/a-n/a.
1647 <https://doi.org/10.1029/2004TC001782>
- 1648 Manatschal, G., Sauter, D., Karpoff, A.M., Masini, E., Mohn, G., Lagabrielle, Y., 2011. The
1649 Chenaillet Ophiolite in the French/Italian Alps: An ancient analogue for an Oceanic Core
1650 Complex? *Lithos* 124, 169–184. <https://doi.org/10.1016/j.lithos.2010.10.017>
- 1651 Manzotti, P., Ballèvre, M., Pitra, P., Schiavi, F., 2021. Missing lawsonite and aragonite found:
1652 P–T and fluid composition in meta-marls from the Combin Zone (Western Alps). *Contrib*
1653 *Mineral Petrol* 176, 60. <https://doi.org/10.1007/s00410-021-01818-0>
- 1654 Marthaler, M., 1984. Géologie des unités penniques entre le val d'Anniviers et le val de
1655 Tourtemagne (Valais, Suisse). *Eclogae Geologicae Helvetiae* 77, 395–448.
1656 <https://doi.org/10.5169/SEALS-165516>
- 1657 Marthaler, M., Stampfli, G.M., 1989. Les Schistes lustrés à ophiolites de la nappe du Tsaté :
1658 un ancien prisme d'accrétion de la marge active apulienne? *Schweizerische Mineralogische*
1659 *und Petrographische Mitteilunge* 69, 211–216. <https://doi.org/10.5169/SEALS-52789>
- 1660 Martin, S., Rebay, G., Kienast, J.-R., Mével, C., 2008. AN ECLOGITISED OCEANIC
1661 PALAEO-HYDROTHERMAL FIELD FROM THE ST. MARCEL VALLEY (ITALIAN
1662 WESTERN ALPS) 33, 16.
- 1663 Massonne, H.J., 1992. Thermochemical determination of water activities relevant to eclogitic
1664 rocks. In: *Water-Rock Interaction* (eds Kharaka, Y. K., and Maest, A.S.). Balkema, Rotterdam
1665 1523–1526.
- 1666 Massonne, H.J., 1995. Experimental and petrogenetic study of UHPM. In: Coleman, R.G.
1667 and Wang, X., Eds., 1995. *Ultrahigh pressure metamorphism*. Cambridge University Press,
1668 Cambridge 33–95.

- 1669 Massonne, H.-J., Schreyer, W., 1987. Phengite geobarometry based on the limiting
1670 assemblage with K-feldspar, phlogopite, and quartz. *Contr. Mineral. and Petrol.* 96, 212–224.
1671 <https://doi.org/10.1007/BF00375235>
- 1672 Massonne, H.J., Schreyer, W, 1989. Stability field of the high-pressure assemblage, talc+
1673 phengite and two new phengite barometers. *European Journal of Mineralogy* 1, 391–410.
- 1674 Menant, A., Angiboust, S., Gerya, T., 2019. Stress-driven fluid flow controls long-term
1675 megathrust strength and deep accretionary dynamics. *Sci Rep* 9, 9714.
1676 <https://doi.org/10.1038/s41598-019-46191-y>
- 1677 Menant, A., Angiboust, S., Gerya, T., Lacassin, R., Simoes, M., Grandin, R., 2020. Transient
1678 stripping of subducting slabs controls periodic forearc uplift. *Nat Commun* 11, 1823.
1679 <https://doi.org/10.1038/s41467-020-15580-7>
- 1680 Michard, A., Goffé, B., Chopin, C., Henry, C., 1996. Did the Western Alps develop through an
1681 Oman-type stage? The geotectonic setting of high-pressure metamorphism in two
1682 contrasting Tethyan transects. *Eclogae Geologicae Helveticae* 89, 43–80.
- 1683 Michard, A., Avigad, D., Goffé, B., Chopin, C., 2004. The high-pressure metamorphic front of
1684 the south Western Alps (Ubaye-Maira transect, France, Italy). *Schweizerische*
1685 *Mineralogische Und Petrographische Mitteilungen* 84, 215–235.
- 1686 Monié, P., Agard, P., 2009. Coeval blueschist exhumation along thousands of kilometers:
1687 Implications for subduction channel processes. *Geochem. Geophys. Geosyst.* 10, n/a-n/a.
1688 <https://doi.org/10.1029/2009GC002428>
- 1689 Moore, J.C., 1975. Selective subduction. *Geol* 3, 530. [https://doi.org/10.1130/0091-7613\(1975\)3<530:SS>2.0.CO;2](https://doi.org/10.1130/0091-7613(1975)3<530:SS>2.0.CO;2)
- 1691 Müntener, O., Piccardo, G.B., Polino, R., Zanetti, A., 2005. REVISITING THE LANZO
1692 PERIDOTITE (NW-ITALY): 'ASTHENOSPHERIZATION' OF ANCIENT MANTLE
1693 LITHOSPHERE. *Ofioliti* 30, 111–124.
- 1694 Negro, F., Bousquet, R., Vils, F., Pellet, C.-M., Hänggi-Schaub, J., 2013. Thermal structure
1695 and metamorphic evolution of the Piedmont-Ligurian metasediments in the northern Western
1696 Alps. *Swiss J Geosci* 106, 63–78. <https://doi.org/10.1007/s00015-013-0119-7>
- 1697 Okazaki, K., Hirth, G., 2016. Dehydration of lawsonite could directly trigger earthquakes in
1698 subducting oceanic crust. *Nature* 530, 81–84. <https://doi.org/10.1038/nature16501>
- 1699 Paulatto, M., Laigle, M., Galve, A., Charvis, P., Sapin, M., Bayrakci, G., Evain, M., Kopp, H.,
1700 2017. Dehydration of subducting slow-spread oceanic lithosphere in the Lesser Antilles. *Nat*
1701 *Commun* 8, 15980. <https://doi.org/10.1038/ncomms15980>
- 1702 Peacock, S.M., 1993. The importance of blueschist → eclogite dehydration reactions in
1703 subducting oceanic crust. *Geological Society of America Bulletin* 105, 684–694.
1704 [https://doi.org/10.1130/0016-7606\(1993\)105<0684:TIOBED>2.3.CO;2](https://doi.org/10.1130/0016-7606(1993)105<0684:TIOBED>2.3.CO;2)
- 1705 Pelletier, L., Müntener, O., 2006. High-pressure metamorphism of the Lanzo peridotite and
1706 its oceanic cover, and some consequences for the Sesia–Lanzo zone (northwestern Italian
1707 Alps). *Lithos* 90, 111–130. <https://doi.org/10.1016/j.lithos.2006.01.006>
- 1708 Pennacchioni, G., Scambelluri, M., Bestmann, M., Notini, L., Nimis, P., Plümpner, O.,
1709 Faccenda, M., Nestola, F., 2020. Record of intermediate-depth subduction seismicity in a dry
1710 slab from an exhumed ophiolite. *Earth and Planetary Science Letters* 548, 116490.
1711 <https://doi.org/10.1016/j.epsl.2020.116490>

- 1712 Philippot, P., 1990. Opposite vergence of Nappes and crustal extension in the French-Italian
1713 western Alps. *Tectonics* 9, 1143–1164. <https://doi.org/10.1029/TC009i005p01143>
- 1714 Piccardo, G.B., Zanetti, A., Müntener, O., 2007. Melt/peridotite interaction in the Southern
1715 Lanzo peridotite: Field, textural and geochemical evidence. *Lithos* 94, 181–209.
1716 <https://doi.org/10.1016/j.lithos.2006.07.002>
- 1717 Platt, J.P., 1986. Dynamics of orogenic wedges and the uplift of high-pressure metamorphic
1718 rocks. *Geol Soc America Bull* 97, 1037–1053. [https://doi.org/10.1130/0016-7606\(1986\)97<1037:DOOWAT>2.0.CO;2](https://doi.org/10.1130/0016-7606(1986)97<1037:DOOWAT>2.0.CO;2)
- 1720 Platt, J.P., 1988. The mechanics of frontal imbrication: a first-order analysis. *Geol Rundsch*
1721 77, 577–589. <https://doi.org/10.1007/BF01832399>
- 1722 Platt, J.P., Xia, H., Schmidt, W.L., 2018. Rheology and stress in subduction zones around
1723 the aseismic/seismic transition. *Prog Earth Planet Sci* 5, 24. <https://doi.org/10.1186/s40645-018-0183-8>
- 1725 Plunder, A., Agard, P., Dubacq, B., Chopin, C., Bellanger, M., 2012. How continuous and
1726 precise is the record of P-T paths? Insights from combined thermobarometry and
1727 thermodynamic modelling into subduction dynamics (Schistes Lustrés, W. Alps): TOWARDS
1728 Continuous P-T PATHS? *Journal of Metamorphic Geology* 30, 323–346.
1729 <https://doi.org/10.1111/j.1525-1314.2011.00969.x>
- 1730 Plunder, A., Agard, P., Chopin, C., Pourteau, A., Okay, A.I., 2015. Accretion, underplating
1731 and exhumation along a subduction interface: From subduction initiation to continental
1732 subduction (Tavşanlı zone, W. Turkey). *Lithos* 226, 233–254.
1733 <https://doi.org/10.1016/j.lithos.2015.01.007>
- 1734 Pognante, U, 1980. Preliminary data on the Piemonte ophiolite nappe in the lower Val Susa
1735 – Val Chisone area, Italian western Alps. *Ophioliti* 2, 221–240.
- 1736 Pognante, U, 1984. Eclogitic versus blueschist metamorphism in the internal Western Alps
1737 along the Susa valley traverse. *Sciences Géologiques, bulletins et mémoires* 37, 29–36.
- 1738 Pognante, U., 1985. Coronitic reactions and ductile shear zones in eclogitised ophiolite
1739 metagabbro, Western Alps, North Italy. *Chemical Geology* 50, 99–109.
1740 [https://doi.org/10.1016/0009-2541\(85\)90114-7](https://doi.org/10.1016/0009-2541(85)90114-7)
- 1741 Pognante, U., 1991. Petrological constraints on the eclogite- and blueschistfacies
1742 metamorphism and P-T-t paths in the Western Alps. *J Metamorph Geol* 9, 5–17.
1743 <https://doi.org/10.1111/j.1525-1314.1991.tb00501.x>
- 1744 Polino, R, Lemoine, M, 1984. Détritisme mixte d'origine continentale et océanique dans les
1745 sédiments jurassico-crétacés supra-ophiolitiques de la Téthys ligure: la série du Lago Nero
1746 (Alpes Occidentales franco-italiennes). *Comptes rendus de l'Académie des sciences. Série*
1747 2, Mécanique, Physique, Chimie, Sciences de l'univers, Sciences de la Terre 298, 359–364.
- 1748 Polino, R, Dela Pierre, F, Borghi, A, Carraro, F, Fioraso, G, Giardino, M, 2002. Note
1749 illustrative della carta geologica d'Italia alla scala 1:50000: foglio 132-152-153 Bardonecchia.
1750 ISPRA, Servizio Geologico d'Italia.
- 1751 Polino, R, Malusà, M.G., Martin, S, Carraro, F, Gianotti, F, Bonetto, F, 2015. Note illustrative
1752 della carta geologica d'Italia alla scala 1:50000: foglio 090 Aosta. ISPRA, Servizio Geologico
1753 d'Italia.

- 1754 Rebay, G., Zanoni, D., Langone, A., Luoni, P., Tiepolo, M., Spalla, M.I., 2018. Dating of
1755 ultramafic rocks from the Western Alps ophiolites discloses Late Cretaceous subduction
1756 ages in the Zermatt-Saas Zone. *Geol. Mag.* 155, 298–315.
1757 <https://doi.org/10.1017/S0016756817000334>
- 1758 Reddy, S.M., Wheeler, J., Butler, R.W.H., Cliff, R.A., Freeman, S., Inger, S., Pickles, C.,
1759 Kelley, S.P., 2003. Kinematic reworking and exhumation within the convergent Alpine
1760 Orogen. *Tectonophysics* 365, 77–102. [https://doi.org/10.1016/S0040-1951\(03\)00017-9](https://doi.org/10.1016/S0040-1951(03)00017-9)
- 1761 Reinecke, T., 1991. Very-high-pressure metamorphism and uplift of coesite-bearing
1762 metasediments from the Zermatt-Saas zone, Western Alps. *ejm* 3, 7–18.
1763 <https://doi.org/10.1127/ejm/3/1/0007>
- 1764 Reinecke, T., 1998. Prograde high- to ultrahigh-pressure metamorphism and exhumation of
1765 oceanic sediments at Lago di Cignana, Zermatt-Saas Zone, western Alps. *Lithos* 42, 147–
1766 189. [https://doi.org/10.1016/S0024-4937\(97\)00041-8](https://doi.org/10.1016/S0024-4937(97)00041-8)
- 1767 Reynard, B., Ballèvre, M., 1988. Coexisting amphiboles in an eclogite from the Western Alps:
1768 new constraints on the miscibility gap between sodic and calcic amphiboles. *Journal of*
1769 *Metamorphic Geology* 6, 333–350.
- 1770 Robert, D., 1979. Contribution à l'étude géologique de la haute vallée de l'Arc-Région de
1771 Bonneval-Savoie. PhD thesis Université de Paris 6.
- 1772 Rolland, Y., Lardeaux, J.-M., Guillot, S., Nicollet, C., 2000. Extension syn-convergence,
1773 poinçonnement vertical et unités métamorphiques contrastées en bordure ouest du Grand
1774 Paradis (Alpes Franco-Italiennes). *Geodinamica Acta* 13, 133–148.
1775 <https://doi.org/10.1080/09853111.2000.11105369>
- 1776 Rubatto, D., Hermann, J., 2001. Exhumation as fast as subduction? *Geology* 29, 3–6.
- 1777 Rubatto, D., Hermann, J., 2003. Zircon formation during fluid circulation in eclogites
1778 (Monviso, Western Alps): implications for Zr and Hf budget in subduction zones. *Geochimica*
1779 *et Cosmochimica Acta* 67, 2173–2187.
- 1780 Rubatto, D., Angiboust, S., 2015. Oxygen isotope record of oceanic and high-pressure
1781 metasomatism: a P–T–time–fluid path for the Monviso eclogites (Italy). *Contrib Mineral Petrol*
1782 170, 44. <https://doi.org/10.1007/s00410-015-1198-4>
- 1783 Rubatto, D., Gebauer, D., Fanning, M., 1998. Jurassic formation and Eocene subduction of
1784 the Zermatt-Saas-Fee ophiolites: implications for the geodynamic evolution of the Central
1785 and Western Alps. *Contributions to Mineralogy and Petrology* 132, 269–287.
1786 <https://doi.org/10.1007/s004100050421>
- 1787 Ruff, L., Kanamori, H., 1980. Seismicity and the subduction process. *Physics of the Earth*
1788 *and Planetary Interiors* 23, 240–252. [https://doi.org/10.1016/0031-9201\(80\)90117-X](https://doi.org/10.1016/0031-9201(80)90117-X)
- 1789 Ruh, J.B., Le Pourhiet, L., Agard, Ph., Burov, E., Gerya, T., 2015. Tectonic slicing of
1790 subducting oceanic crust along plate interfaces: Numerical modeling. *Geochem. Geophys.*
1791 *Geosyst.* 16, 3505–3531. <https://doi.org/10.1002/2015GC005998>
- 1792 Rüpke, L., 2004. Serpentine and the subduction zone water cycle. *Earth and Planetary*
1793 *Science Letters* 223, 17–34. <https://doi.org/10.1016/j.epsl.2004.04.018>
- 1794 Saffer, D.M., Tobin, H.J., 2011. Hydrogeology and Mechanics of Subduction Zone Forearcs:
1795 Fluid Flow and Pore Pressure. *Annu. Rev. Earth Planet. Sci.* 39, 157–186.
1796 <https://doi.org/10.1146/annurev-earth-040610-133408>

- 1797 Saliot, Pierre, 1978. Le métamorphisme dans les Alpes françaises. PhD thesis Université
1798 Paris-Sud.
- 1799 Saliot, P., Velde, B., 1982. Phengite compositions and post-nappe high-pressure
1800 metamorphism in the pennine zone of the French Alps. *Earth and Planetary Science Letters*
1801 57, 133–138. [https://doi.org/10.1016/0012-821X\(82\)90179-0](https://doi.org/10.1016/0012-821X(82)90179-0)
- 1802 Sartori, M., 1987. Structure de la zone du Combin entre les Diablons et Zermatt (Valais).
1803 *Eclogae Geologicae Helvetiae* 80, 789–814. <https://doi.org/10.5169/SEALS-166026>
- 1804 Scambelluri, M., Pennacchioni, G., Gilio, M., Bestmann, M., Plümper, O., Nestola, F., 2017.
1805 Fossil intermediate-depth earthquakes in subducting slabs linked to differential stress
1806 release. *Nature Geoscience* 10, 960–966. <https://doi.org/10.1038/s41561-017-0010-7>
- 1807 Schmid, S.M., Pfiffner, O.A., Froitzheim, N., Schönborn, G., Kissling, E., 1996. Geophysical-
1808 geological transect and tectonic evolution of the Swiss-Italian Alps. *Tectonics* 15, 1036–
1809 1064. <https://doi.org/10.1029/96TC00433>
- 1810 Schmid, S.M., Kissling, E., Diehl, T., van Hinsbergen, D.J.J., Molli, G., 2017. Ivrea mantle
1811 wedge, arc of the Western Alps, and kinematic evolution of the Alps–Apennines orogenic
1812 system. *Swiss J Geosci* 110, 581–612. <https://doi.org/10.1007/s00015-016-0237-0>
- 1813 Scholl, D.W., von Huene, R., Vallier, T.L., Howell, D.G., 1980. Sedimentary masses and
1814 concepts about tectonic processes at underthrust ocean margins. *Geology* 8, 564–568.
1815 [https://doi.org/10.1130/0091-7613\(1980\)8<564:SMACAT>2.0.CO;2](https://doi.org/10.1130/0091-7613(1980)8<564:SMACAT>2.0.CO;2)
- 1816 Schwartz, Stéphane, 2000. La zone Piémontaise des Alpes occidentales: un paléo-
1817 complexe de subduction. Arguments métamorphiques, géochronologiques et structuraux.
1818 PhD thesis, Université Claude Bernard-Lyon I.
- 1819 Schwartz, S., Lardeaux, J.-M., Guillot, S., Tricart, P., 2000a. Diversité du métamorphisme
1820 éclogitique dans le massif ophiolitique du Monviso (Alpes occidentales, Italie). *Geodinamica*
1821 *Acta* 13, 169–188. <https://doi.org/10.1080/09853111.2000.11105371>
- 1822 Schwartz, S., Lardeaux, J.-M., Tricart, P., 2000b. La zone d’Acceglio (Alpes cottiennes): un
1823 nouvel exemple de croûte continentale éclogitisée dans les Alpes occidentales. *Comptes*
1824 *Rendus de l’Académie des Sciences - Series IIA - Earth and Planetary Science* 330, 859–
1825 866. [https://doi.org/10.1016/S1251-8050\(00\)00218-4](https://doi.org/10.1016/S1251-8050(00)00218-4)
- 1826 Schwartz, S., Lardeaux, J.M., Tricart, P., Guillot, S., Labrin, E., 2007. Diachronous
1827 exhumation of HP-LT metamorphic rocks from south-western Alps: evidence from fission-
1828 track analysis. *Terra Nova* 19, 133–140. <https://doi.org/10.1111/j.1365-3121.2006.00728.x>
- 1829 Schwartz, S., Guillot, S., Reynard, B., Lafay, R., Debret, B., Nicollet, C., Lanari, P., Auzende,
1830 A.L., 2013. Pressure–temperature estimates of the lizardite/antigorite transition in high
1831 pressure serpentinites. *Lithos* 178, 197–210. <https://doi.org/10.1016/j.lithos.2012.11.023>
- 1832 Schwartz, S., Gautheron, C., Ketcham, R.A., Brunet, F., Corre, M., Agranier, A., Pinna-
1833 Jamme, R., Haurine, F., Monvoïn, G., Riel, N., 2020. Unraveling the exhumation history of
1834 high-pressure ophiolites using magnetite (U-Th-Sm)/He thermochronometry. *Earth and*
1835 *Planetary Science Letters* 543, 116359. <https://doi.org/10.1016/j.epsl.2020.116359>
- 1836 Selverstone, J., Sharp, Z.D., 2013. Chlorine isotope constraints on fluid-rock interactions
1837 during subduction and exhumation of the Zermatt-Saas ophiolite: CHLORINE ISOTOPES IN
1838 SUBDUCTED OPHIOLITE. *Geochem. Geophys. Geosyst.* 14, 4370–4391.
1839 <https://doi.org/10.1002/ggge.20269>

1840 Simon-Labric, T., Rolland, Y., Dumont, T., Heymes, T., Authemayou, C., Corsini, M., Fornari,
1841 M., 2009. 40 Ar/ 39 Ar dating of Penninic Front tectonic displacement (W Alps) during the
1842 Lower Oligocene (31-34 Ma). *Terra Nova* 21, 127–136. <https://doi.org/10.1111/j.1365-3121.2009.00865.x>

1844 Skora, S., Mahlen, N.J., Johnson, C.M., Baumgartner, L.P., Lapen, T.J., Beard, B.L.,
1845 Szilvagy, E.T., 2015. Evidence for protracted prograde metamorphism followed by rapid
1846 exhumation of the Zermatt-Saas Fee ophiolite. *J. Metamorph. Geol.* 33, 711–734.
1847 <https://doi.org/10.1111/jmg.12148>

1848 Soret, M., Larson, K.P., Cottle, J., Ali, A., 2021. How Himalayan collision stems from
1849 subduction. *Geology* 49, 894–898. <https://doi.org/10.1130/G48803.1>

1850 Stampfli, G.M., Marthaler, M., 1990. Divergent and convergent margins in the North-Western
1851 alps confrontation to actualistic models. *Geodinamica Acta* 4, 159–184.
1852 <https://doi.org/10.1080/09853111.1990.11105208>

1853 Stampfli, G.M., Mosar, J., Marquer, D., Marchant, R., Baudin, T., Borel, G., 1998. Subduction
1854 and obduction processes in the Swiss Alps. *Tectonophysics* 296, 159–204.
1855 [https://doi.org/10.1016/S0040-1951\(98\)00142-5](https://doi.org/10.1016/S0040-1951(98)00142-5)

1856 Stern, R.J., 2002. SUBDUCTION ZONES. *Rev. Geophys.* 40, 3-1-3–38.
1857 <https://doi.org/10.1029/2001RG000108>

1858 Syracuse, E.M., van Keken, P.E., Abers, G.A., 2010. The global range of subduction zone
1859 thermal models. *Physics of the Earth and Planetary Interiors* 183, 73–90.
1860 <https://doi.org/10.1016/j.pepi.2010.02.004>

1861 Tartarotti, P., Martin, S., Festa, A., Balestro, G., 2021. Metasediments Covering Ophiolites in
1862 the HP Internal Belt of the Western Alps: Review of Tectono-Stratigraphic Successions and
1863 Constraints for the Alpine Evolution. *Minerals* 11, 411. <https://doi.org/10.3390/min11040411>

1864 Tatsumi, Y., 1986. Formation of the volcanic front in subduction zones. *Geophys. Res. Lett.*
1865 13, 717–720. <https://doi.org/10.1029/GL013i008p00717>

1866 Tewksbury-Christle, C.M., Behr, W.M., Helper, M.A., 2021. Tracking Deep Sediment
1867 Underplating in a Fossil Subduction Margin: Implications for Interface Rheology and Mass
1868 and Volatile Recycling. *Geochem Geophys Geosyst* 22.
1869 <https://doi.org/10.1029/2020GC009463>

1870 Tricart, P., 1974. Les Schistes lustrés du Haut-Cristillan (Alpes cottiennes, France):
1871 litostratigraphie, architecture et tectogenèse. *Géologie Alpine* 50, 131–152.

1872 Tricart, P., Schwartz, S., 2006. A north-south section across the Queyras Schistes lustrés
1873 (Piedmont zone, Western Alps): Syn-collision refolding of a subduction wedge. *Eclogae geol.*
1874 *Helv.* 99, 429–442. <https://doi.org/10.1007/s00015-006-1197-6>

1875 van Keken, P.E., Hacker, B.R., Syracuse, E.M., Abers, G.A., 2011. Subduction factory: 4.
1876 Depth-dependent flux of H₂O from subducting slabs worldwide. *J. Geophys. Res.* 116,
1877 B01401. <https://doi.org/10.1029/2010JB007922>

1878 Vannucchi, P., Spagnuolo, E., Aretusini, S., Di Toro, G., Ujiie, K., Tsutsumi, A., Nielsen, S.,
1879 2017. Past seismic slip-to-the-trench recorded in Central America megathrust. *Nature Geosci*
1880 10, 935–940. <https://doi.org/10.1038/s41561-017-0013-4>

1881 Velde, B., 1967. Si⁴⁺ content of natural phengites. *Contributions to Mineralogy and Petrology*
1882 14, 250–258.

- 1883 Villa, I.M., Bucher, S., Bousquet, R., Kleinhanns, I.C., Schmid, S.M., 2014. Dating
1884 Polygenetic Metamorphic Assemblages along a Transect across the Western Alps. *Journal*
1885 *of Petrology* 55, 803–830. <https://doi.org/10.1093/petrology/egu007>
- 1886 Vitale Brovarone, A., Picatto, M., Beyssac, O., Lagabrielle, Y., Castelli, D., 2014. The
1887 blueschist–eclogite transition in the Alpine chain: P–T paths and the role of slow-spreading
1888 extensional structures in the evolution of HP–LT mountain belts. *Tectonophysics* 615–616,
1889 96–121. <https://doi.org/10.1016/j.tecto.2014.01.001>
- 1890 von Huene, R., Scholl, D.W., 1991. Observations at convergent margins concerning
1891 sediment subduction, subduction erosion, and the growth of continental crust. *Rev. Geophys.*
1892 29, 279–316. <https://doi.org/10.1029/91RG00969>
- 1893 Wada, I., Wang, K., 2009. Common depth of slab-mantle decoupling: Reconciling diversity
1894 and uniformity of subduction zones. *Geochem. Geophys. Geosyst.* 10, n/a-n/a.
1895 <https://doi.org/10.1029/2009GC002570>
- 1896 Wassmann, S., Stöckhert, B., 2013. Rheology of the plate interface — Dissolution
1897 precipitation creep in high pressure metamorphic rocks. *Tectonophysics* 608, 1–29.
1898 <https://doi.org/10.1016/j.tecto.2013.09.030>
- 1899 Weber, S., Sandmann, S., Miladinova, I., Fonseca, R.O.C., Froitzheim, N., Münker, C.,
1900 Bucher, K., 2015. Dating the initiation of Piemonte-Liguria Ocean subduction: Lu–Hf garnet
1901 chronometry of eclogites from the Theodul Glacier Unit (Zermatt-Saas zone, Switzerland).
1902 *Swiss J Geosci* 108, 183–199. <https://doi.org/10.1007/s00015-015-0180-5>
- 1903 Willner, A.P., 2005. Pressure–Temperature Evolution of a Late Palaeozoic Paired
1904 Metamorphic Belt in North–Central Chile (34°–35°30'S). *Journal of Petrology* 46, 1805–1833.
1905 <https://doi.org/10.1093/petrology/egi035>
- 1906 Zanoni, D., Rebay, G., Spalla, M.I., 2016. Ocean floor and subduction record in the Zermatt-
1907 Saas rodingites, Valtournanche, Western Alps. *J. Metamorph. Geol.* 34, 941–961.
1908 <https://doi.org/10.1111/jmg.12215>

1909

1910

1911 **Table captions**

1912 **Table 1:** Lithological ratio (sediment versus mafic-ultramafic) and aerial exposure of the
1913 Liguro-Piemont slices. See text (§4.2) for details in the methodology.

1914 **Table 2:** RSCM temperatures of the Liguro-Piemont slices. All the compiled RSCM
1915 temperatures (from this study and literature) are presented in Sup. Mat 1.

1916 **Table 3:** Maximum Si a.p.f.u. values of phengite ($\text{Si}^{\text{max}}\text{Ph}$) and estimated peak pressure for
1917 Liguro-Piemont slices. Peak pressures were estimated by crossing RSCM temperatures (see
1918 Table 1; Fig. 4a-c, 5a-e) with the calculated isopleths of Si a.p.f.u. in phengite for a
1919 representative rock composition (Fig. 9a). Selected $\text{Si}^{\text{max}}\text{Ph}$, RSCM temperature for the
1920 same samples and all estimated pressure values are presented in Sup. mat. 3.

1921

1922 **Figure captions**

1923 **Figure 1:** Maps of the Western Alps focused on the Liguro-Piemont (L-P) domain. A)
1924 Distribution of sediments and mafic-ultramafic rocks across the L-P domain and location of
1925 the stratigraphic columns presented in figure 3b and the tectonic contacts separating L-P
1926 slices. B) Zoneography of index metamorphic minerals of L-P metasediments, both from field
1927 observations (this study) and compiled from literature (Bocquet, 1974; Agard et al., 2001a;
1928 Goffé et al., 2004; Bousquet et al., 2008; Manzotti et al., 2021). C) Distribution of blueschist-
1929 and eclogite-facies metamorphism across the L-P domain and location of the L-P tectonic
1930 slices described in literature. References for the different slices are in the text (see §3). Che:
1931 Chenaillet. Abbreviations for the tectonic slices: AG: Aigle; ALB: Albergian; ATF: Avise-
1932 Tsaboc-Feluma; AV: Avic; BY: By unit; CC: Cerogne-Ciantiplagna; CH: Chardonnet klippe;
1933 CO: Cornet; CS: Calcschist unit; GU: Grivola-Urtier; GS: Grande-Sassière klippe; GV: Grand
1934 Vallon klippe; JO: Jovet klippe; LA: Lamet klippe; LN: Lago Nero; LS: Lago Superiore; MB:
1935 Mirabouc-Bouchet; MV: Monviso unit; OR: Orsiera-Rocciavrè; PT: Pelvas-Taillante; PY:
1936 Puys; SLU: Savoy Lower Unit; SMU: Savoy Middle Unit; SN-L: Lower Sana klippe; SN-U:
1937 Upper Sana klippe; VN: Venaus; VV: Vin Vert; W-SS: West-Sesia unit; ZS: Zermatt-Saas.

1938 **Figure 2:** Panoramic pictures of the Liguro-Piemont domain exposing the present slice-
1939 stacking. A) Savoy-Susa transect from Rocciamelone summit. B) Cottian Alps transect. C)
1940 Queyras-Monviso transect from Bric-Froid summit. B) and C) are modified after Agard
1941 (2021).

1942 **Figure 3:** Stratigraphy and paleogeography of the Liguro-Piemont rocks. A) Schematic
1943 cross-section of the European margin and Liguro-Piemont ocean before subduction with
1944 emphasis on the paleogeographic unknowns. Grey sticks with question marks correspond to
1945 potential locations for the stratigraphic columns of figure 3b. B) Compilation of stratigraphic
1946 columns of the L-P domain. Description, references of the different stratigraphic columns,
1947 stratigraphic formations and events are in the text (§4.1). Location of the stratigraphic
1948 columns across the L-P complex are in figure 1a. Stratigraphic column 1 (Chabrière-series)
1949 corresponds to the reference complete succession of L-P deposits ranging from Middle-
1950 Upper Jurassic to Upper Cretaceous deposits. Most of the blueschist-facies slices have an
1951 almost similar stratigraphic succession with only few formations missing. Few blueschist-
1952 facies slices (column 3, 8, 10, 11, 13) (almost) only have Upper Cretaceous sediments. All
1953 stratigraphic columns from eclogite-facies slices are devoid of Upper Cretaceous.
1954 Abbreviations for the tectonic slices: AV: Avic; AG: Aigle; CS: Calcschist unit; CO: Cornet;
1955 GV: Grand Vallon klippe; LA: Lamet klippe; LN: Lago Nero; MB: Mirabouc-Bouchet; MV:
1956 Monviso unit; PT: Pelvas-Taillante; SLU: Savoy Lower Unit; SMU: Savoy Middle Unit; VV:
1957 Vin Vert; ZS: Zermatt-Saas.

1958 **Figure 4:** Distribution and interpolation of RSCM temperatures across the Liguro-Piemont
1959 domain. A) RSCM temperatures and L-P tectonic contacts across the domain notably
1960 highlighting the eastward metamorphic gradient. B) Interpolation of RSCM temperatures
1961 across the L-P domain with 25°C intervals. C) Smoothed interpolation of RSCM
1962 temperatures across the domain and tectonic contacts of the L-P slices. This map as C)
1963 highlights the burial temperature recorded by rocks across the whole L-P domain and the
1964 specific temperature range of each tectonic slice. Some slices have blue color corresponding
1965 to 300-400°C while other have green-to yellow colors highlighting ~400-500°C T_{max} . Finally,
1966 easternmost slices (eclogite-facies) have orange-to red colors corresponding to T_{max} above
1967 500°C. Most of the slices expose an internal eastward increase in T_{max} . For the three maps,
1968 square symbols correspond to our samples (108 samples) while round symbols correspond
1969 to RSCM temperatures compiled from literature (289 samples; Beyssac et al., 2002; Gabalda

1970 et al., 2009; Angiboust et al., 2009; 2012b, 2014; Angiboust and Agard, 2010; Plunder et al.,
1971 2012; Negro et al., 2013; Schwartz et al., 2013; Decrausaz et al., 2021; Manzotti et al.,
1972 2021). Samples description, temperature and mineral assemblages as well as compiled
1973 RSCM temperatures from literature are presented in Sup. mat. 1.

1974 **Figure 5:** Statistical distribution of RSCM temperatures in Liguro-Piemont domain. A) Bar
1975 chart of all RSCM temperatures showing a trimodal distribution with peaks at 370-380°C,
1976 460-470°C and ~540°C. B) to E) Cumulative bar charts of RSCM temperatures along Valais-
1977 Aosta, Savoy-Susa, Cottian Alps and Queyras-Monviso transects, all showing the same
1978 three temperature clusters of A). Slices were color-coded according to their specific
1979 temperature ranges (Table 1). For all charts, RSCM temperatures are both from this study
1980 and compiled from literature (see Fig. 4 caption)

1981 **Figure 6:** Microphotographs highlighting the successive deformation structures observed in
1982 our representative metasedimentary samples. A) to B) S1 and S2 foliation are marked by
1983 phengite (Ph) and chlorite crystals. D3 deformation corresponds to small shear bands cross-
1984 cutting S1 and S2. Index minerals, such as chloritoid (Cld), lawsonite, Fe-Mg carpholite or
1985 garnet often show textural equilibrium with S1 phengite.

1986 **Figure 7:** Phengite composition. A) Ternary diagram of point electron microprobe analyses
1987 of phengite. B) Maximum Si values of phengite ($Si^{max}Ph$; peak pressure indicator) versus
1988 RSCM temperatures of the same samples or samples from the same locality. Most samples
1989 plot on a linear trend, highlighting the increase of $Si^{max}Ph$ with temperature and the efficiency
1990 of Si value use as peak pressure indicator. Square/round symbols correspond to our
1991 samples/literature $Si^{max}Ph$ (Bocquet, 1974; Liewig, 1981; Agard et al., 2001a; Bonnet et al.,
1992 submitted). Light-blue symbols with dotted contours correspond to samples in which phengite
1993 with peak burial Si values was not preserved or not found. Representative compositions of
1994 analyzed phengite are presented in Sup. mat. 2 and selected $Si^{max}Ph$ values are presented
1995 in Sup. mat. 3.

1996 **Figure 8:** Distribution of maximum Si values of phengite ($Si^{max}Ph$) across the L-P domain, in
1997 Cottian Alps and Queyras-Monviso region. $Si^{max}Ph$ values progressively increase toward
1998 east, showing an eastward pressure gradient as highlighted for temperature in figure 4a-c.
1999 Square symbols correspond to our samples while round symbols correspond to literature
2000 data (see Fig. 7 caption). Symbols with dotted contours correspond to samples where peak
2001 burial Si values were not preserved or found. Selected $Si^{max}Ph$ values are presented in
2002 Sup. mat. 3.

2003 **Figure 9:** Thermodynamic modelling for a representative composition of Liguro-Piemont
2004 metasediments. A) Pseudosection (system NaCaKFMASH, with all assemblages containing
2005 quartz, phengite and H₂O) calculated using Perple_X software (Connolly, 1990, 2005, 2009)
2006 for the bulk composition of CBas912m sample of Henry et al. (1996) considered as
2007 representative of most Liguro-Piemont calcschists. Calculated isopleths of Si a.p.f.u. in
2008 phengite are represented. The red line corresponds to a 8°C/km gradient. Calculated B)
2009 evolution of mineral modes and C) H₂O content and major dehydration reactions, along a
2010 8°C/km gradient (from 300°C-1.25 GPa to 600°C-2.5GPa) for the pseudosection presented
2011 in A). Mineral abbreviations: Car: carpholite; Chl: Chlorite; Cld: chloritoid; Gln: glaucophane;
2012 Grt: grenat; Jd: jadeite; Ky: kyanite; Lws: lawsonite; Pg: paragonite; Ph: phengite; Qz: quartz;
2013 Zo: zoisite. Reaction abbreviations: Car-: carpholite-out; Chl-: chlorite-out; Cld+: chloritoid-in;
2014 Cld-: chloritoid-out; Lws-: lawsonite-out. Mineral assemblages in A) 1: Car Jd Lws Stp; 2: Car
2015 Chl Jd Lws Stp; 3: Car Jd Lws Pg Stp; 4: Car Chl Jd Lws Pg; 5: Chl Cld Lws Pg Zo; 6: Car
2016 Gln Jd Lws; 7: Car Chl Gln Jd Lws; 8: Car Gln Grt Jd Lws; 9: Car Cld Gln Jd Lws; 10: Car Grt

2017 Jd Lws; 11: Cld Car Gln Lws Pg; 12: Cld Gln Lws Pg; 13: Car Chl Cld Jd Lws; 14: Car Grt Jd
2018 Lws Pg; 15: Car Gln Grt Lws Pg; 16: Gln Grt Ky Lws Pg; 17: Car Cld Grt Lws Jd; 18: Cld Gln
2019 Jd Lws Pg; 19: Gln Grt Jd Ky; 20: Cld Gln Grt Ky Pg; 21: Cld Gln Grt Pg; 22: Chl Cld Grt Pg.

2020 **Figure 10:** A) Mean peak P-T conditions (circles) for the Liguro-Piemont slices. Slices were
2021 plotted in this P-T grid using their mean RSCM temperature and mean pressure retrieved
2022 from $Si^{max}Ph$ and the pseudosection (Fig. 9), or estimated in literature (§3). Increasing
2023 thickness of symbol contours represents increasing sediment/mafic-ultramafic ratio (table 1)
2024 in the slices: Sed.+ : $\geq 90\%$ of sediments; Maf.Umaf.+ : $\sim 60\%$ of sediments. Maf.Umaf.++ :
2025 $\sim 40\%$ of sediments (MUM units of Agard, 2021). The three major clusters of peak P-T
2026 conditions correspond to groups of slices with distinct sediment/mafic-ultramafic ratios. The
2027 major dehydration reactions of figure 9c are also reported. B) Subduction ages of Liguro-
2028 Piemont slices. Symbols correspond to the peak burial of the slices while dotted arrows
2029 depict their paths. This figure highlights the successive slicing of LPU, LPM, sediment-rich
2030 LPL and mafic-ultramafic-rich LPL from the downgoing slab and their stacking at $\sim 36-35$ Ma.
2031 Slices only composed by Upper Cretaceous deposits may be the last units sliced as
2032 highlighted by the peak burial age of CS. References for ages are in the text (§3; 7.2, 7.3).
2033 LPU: Liguro-piemont Upper units; LPM: Liguro-Piemont Middle units; LPL: Liguro-Piemont
2034 Lower units. Slice abbreviations: ALB: Albergian; ATF: Avise-Tsaboc-Feluma; AV: Avic; BY:
2035 By unit; CO: Cornet; CS: Calcschist unit; GU: Grivola-Urtier; LN: Lago Nero; LS: Lago
2036 Superiore; MB: Mirabouc-Bouchet; SLU: Savoy Lower Unit; SMU: Savoy Middle Unit; ZS:
2037 Zermatt-Saas. Abbreviations for continental units: DM: Dora-Maira; GP: Gran Paradiso; MR:
2038 Monte Rosa. Modified after Agard (2021).

2039 **Figure 11:** Simplified map showing the distribution of the three Liguro-Piemont units across
2040 the Western Alps. Location of cross-sections shown in figure 12 is indicated (A-A'; B-B'; C-C';
2041 D-D'). LPU: Liguro-Piemont Upper units; LPM: Liguro-Piemont Middle units; LPL: Liguro-
2042 Piemont Lower units.

2043 **Figure 12:** Cross-sections of the four major Liguro-Piemont transects described in this study
2044 exposing the actual stacking of the different slices and units. Cross-section locations are
2045 indicated in figure 11. A) to D) were respectively modified after Negro et al. (2013); Plunder et
2046 al. (2012); Agard (2021); Lagabrielle (1987). LPU: Liguro-Piemont Upper units; LPM: Liguro-
2047 Piemont Middle units; LPL: Liguro-Piemont Lower units. Slice abbreviations: BY: By unit; CC:
2048 Cerogne-Ciantiplagna; CO: Cornet; CS: Calcschist unit; GV: Grand Vallon klippe; LA: Lamet
2049 klippe; LN: Lago Nero; LS: Lago Superiore; MB: Mirabouc-Bouchet; MV: Monviso; OR:
2050 Orsiera-Rocciavrè; PT: Pelvas-Taillante; SLU: Savoy Lower Unit; SMU: Savoy Middle Unit;
2051 ZS: Zermatt-Saas.

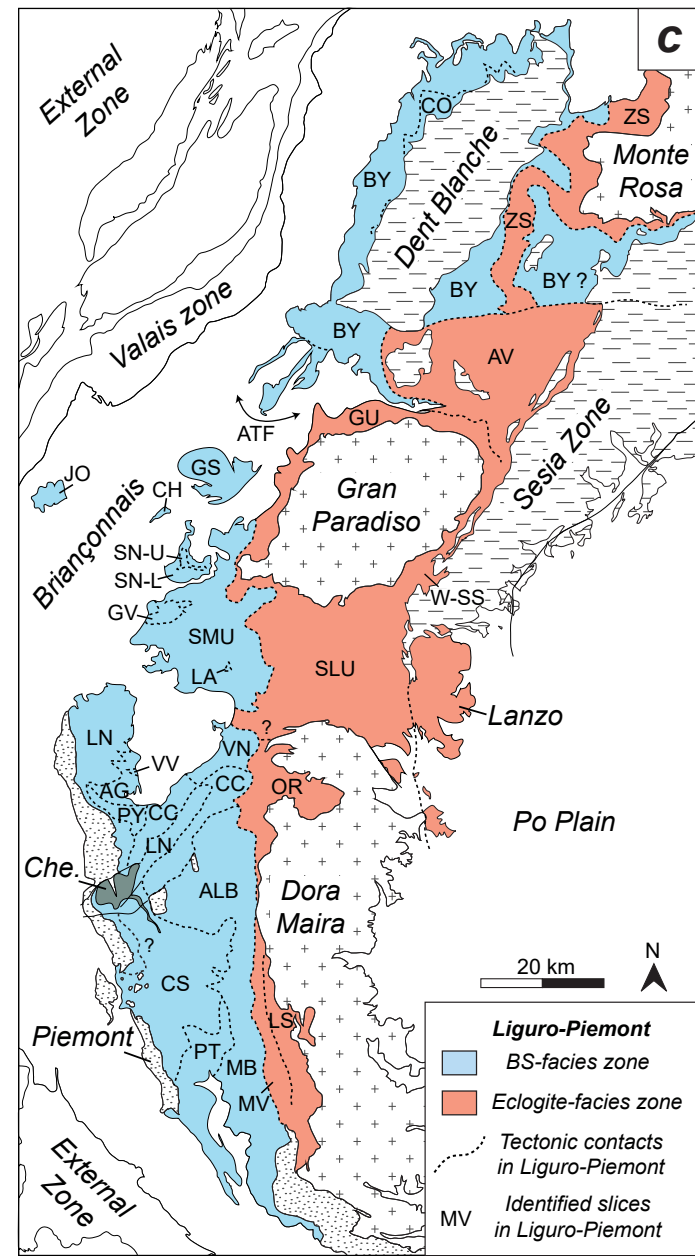
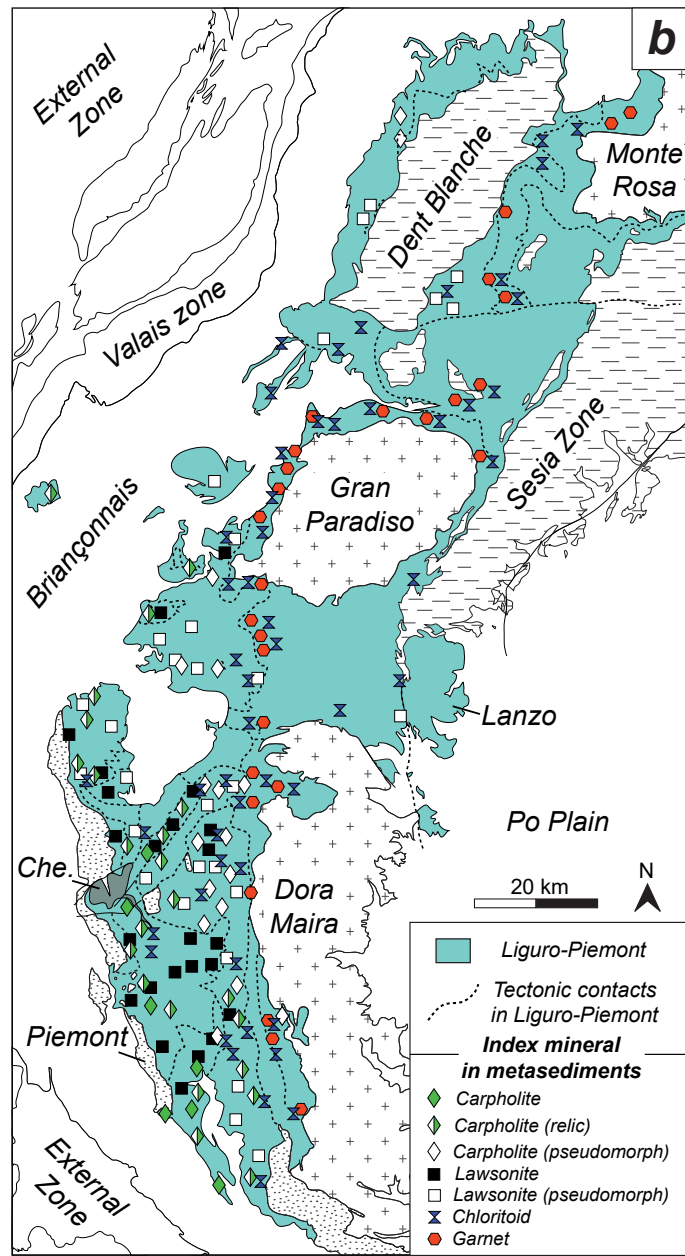
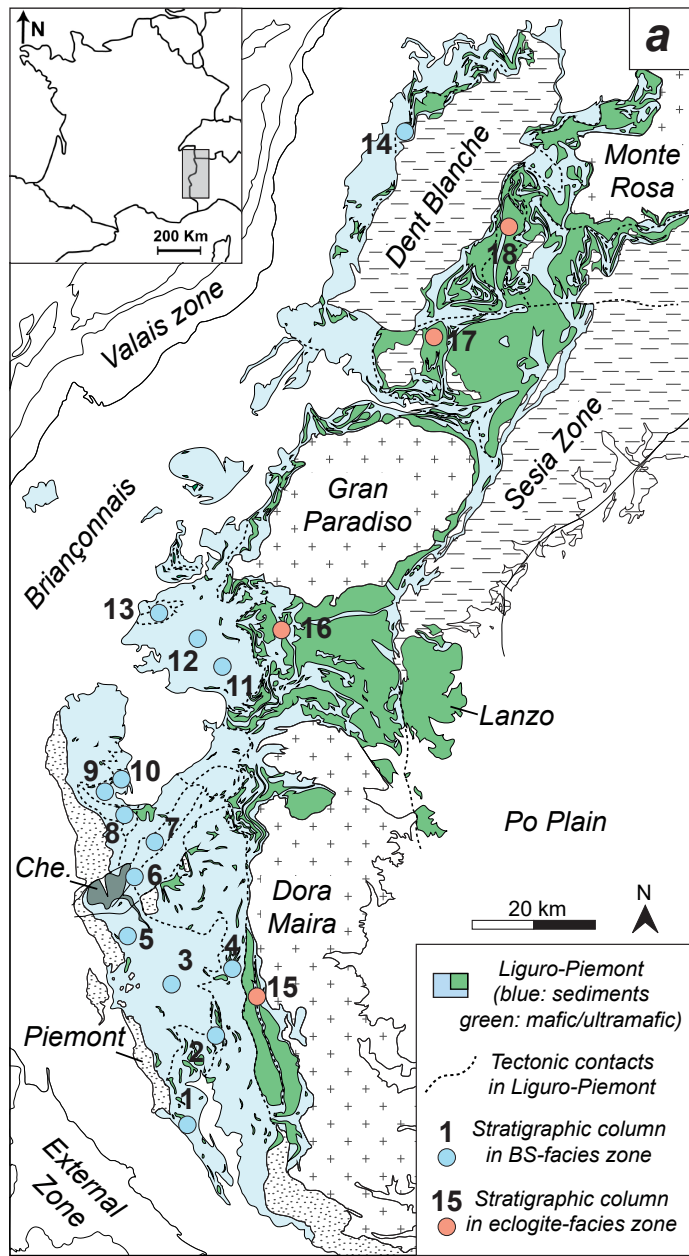
2052 **Figure 13:** Statistical distribution of RSCM temperatures in the Liguro-Piemont units. A)
2053 Boxplots of RSCM temperature for the three Liguro-Piemont units, both from this study and
2054 compiled from literature (see Fig. 4 caption). B) Boxplots of $Si^{max}Ph$ for the three Liguro-
2055 Piemont units, both from this study and compiled from literature (see Fig. 7 caption). Inside
2056 boxes, lines and crossed circles correspond to median and mean values of each boxplot,
2057 given in the text (§7.1). LPU: Liguro-Piemont Upper units; LPM: Liguro-Piemont Middle units;
2058 LPL: Liguro-Piemont Lower units.

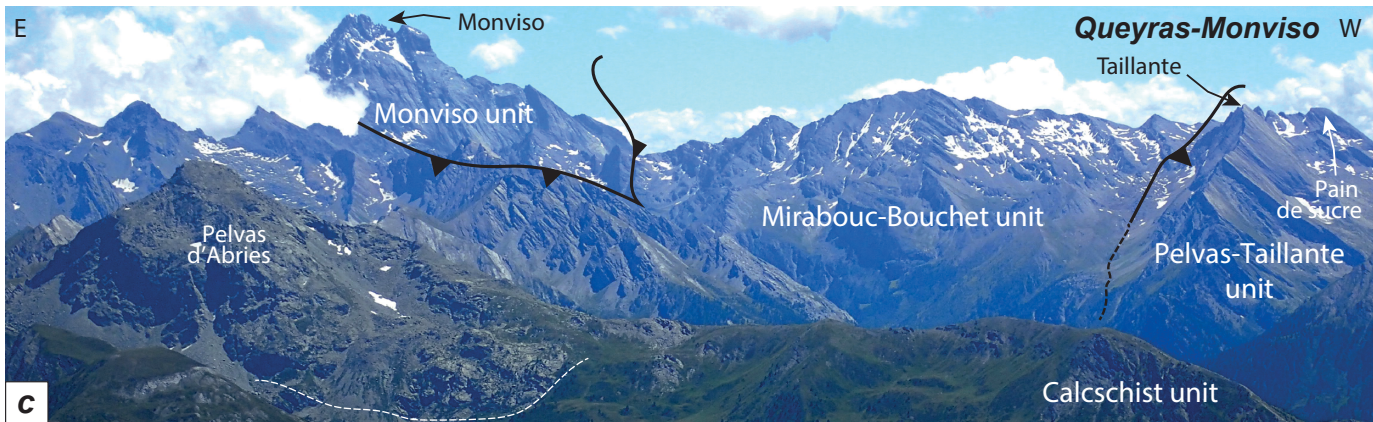
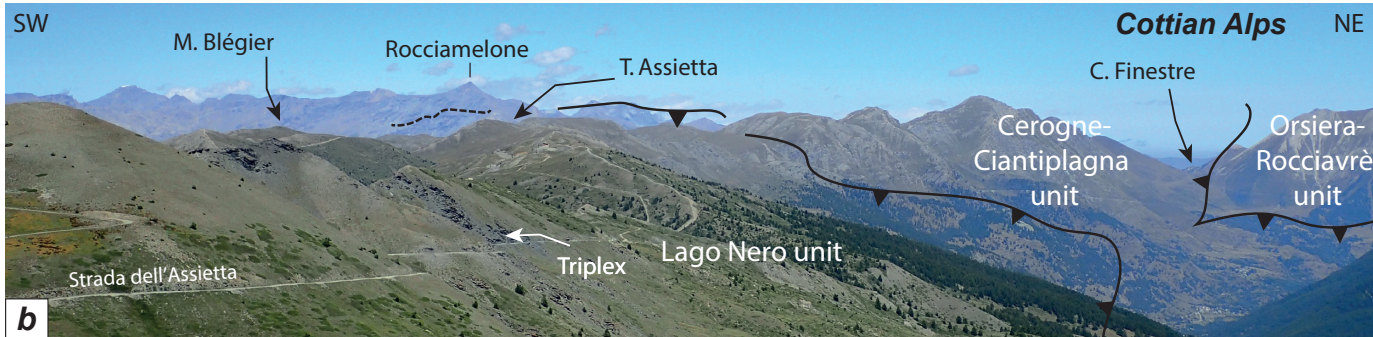
2059 **Figure 14:** Sketch of the slicing and stacking of Liguro-Piemont slices. A) Idealized view of
2060 the Alpine subduction zone at $\sim 50-45$ Ma, showing the relative location of the slices (for the
2061 four transects) discussed in the text. At this time, Chabrière-type LPU and LPM are already
2062 offscraped from the slab and are exhuming, as for the sedimentary-dominated LPL. Mafic-
2063 Ultramafic LPL, initially close to the continental margin are being sliced. Upper Cretaceous
2064 LPU and LPM will be the last to offscraped from the downgoing slab. Two different transects

2065 defined by Agard (2021) are represented (sectors A and B). Modified after Agard (2021). B)
2066 to E) RSCM temperature versus longitude for the four transects detailed in the text (see also
2067 Fig. 11, 12). These graphs show the increase of peak temperature from W to E and the
2068 current stacking of the L-P units, with LPU structurally at the top of LPM and LPL.
2069 Square/round symbols correspond to our samples/literature data respectively (see Fig. 4
2070 caption). Abbreviations: LPU: Liguro-Piemont Upper units; LPM: Liguro-Piemont Middle
2071 units; LPL: Liguro-Piemont Lower units. AG: Aigle; ALB: Albergian; ATF: Avise-Tsaboc-
2072 Feluma; AV: Avic; BY: By unit; CC: Cerogne-Ciantiplagna; CO: Cornet; CS: Calcschist unit;
2073 GU: Grivola-Urtier; LN: Lago Nero; LS: Lago Superiore; MB: Mirabouc-Bouchet; MV:
2074 Monviso; OR: Orsiera-Rocciavrè; PT: Pelvas-Taillante; PY: Puys; SLU: Savoy Lower Unit;
2075 SMU: Savoy Middle Unit; SUU: Savoy Upper Unit; VV: Vin Vert; W-SS: West-Sesia unit; ZS:
2076 Zermatt-Saas. U.K. slices: slices mostly made by Upper Cretaceous sediments such as the
2077 Savoy Upper Unit at Grand Vallon or Lamet klippe.

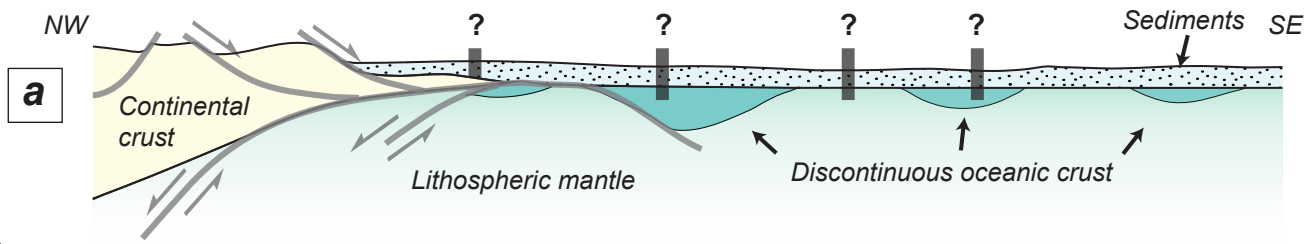
2078 **Figure 15:** A) Potential paleogeographic position of Liguro-Piemont units before subduction.
2079 B) Suggested slicing and stacking sequence of Liguro-Piemont units. C) Stratigraphic
2080 columns with recovered portion of the different Liguro-Piemont units and suggested
2081 decollement layers and offscraping mechanisms. For the Upper-Cretaceous LPU and LPM,
2082 the initial basement may either have been made of continental or oceanic rocks. We suggest
2083 that strain localization leading to LPU and LPM units' slicing mostly occurred due to major
2084 lithological contrasts in the pile, such as levels of pelagic sediments or serpentized mantle
2085 acting as rheological weaknesses, possibly under high fluid pressure conditions. On the
2086 other side, LPL units slicing at eclogite facies conditions may be linked to major dehydration
2087 reactions (as lawsonite breakdown in sediments), under high fluid pressure conditions,
2088 responsible for rocks embrittlement. LPU: Liguro-Piemont Upper units; LPM: Liguro-Piemont
2089 Middle units; LPL: Liguro-Piemont Lower units.

2090 **Figure 16:** Depth clusters and mechanisms of slicing in the Liguro-Piemont subduction zone.
2091 A) Bar chart of underplating depth (distributed deformation along the plate interface) along
2092 the Chilean margin (after Cubas et al., submitted). Mean peak burial depths estimated in this
2093 study for the Liguro-Piemont units LPU and LPM are in good agreement with the underplating
2094 depth clusters observed along the Chilean margin. The peak burial depth of the eclogite-
2095 facies LPL units is similar to the estimated peak burial depth for most of worldwide
2096 recovered eclogites (after Agard et al., 2018). B) Schematic peak P-T depth conditions for
2097 the Liguro-Piemont units, and suggested major slicing mechanisms, i.e. major lithological
2098 heterogeneities for LPU and LPM and fluid release combined with lithological heterogeneities
2099 for LPL. C) Schematic view of a subducting slab with discontinuous oceanic crust, subjected
2100 to three main depths of slicing at ~35-45 km, 55-65 km and 70-80 km. The heterogeneously
2101 distributed deformation leads to slicing of the slab, underplating and topographic build-up
2102 responsible for the nucleation of earthquakes propagating across the B and C domains.
2103 Modified after Cubas et al. (submitted). Abbreviations: LPU: Liguro-Piemont Upper units;
2104 LPM: Liguro-Piemont Middle units; LPL: Liguro-Piemont Lower units.



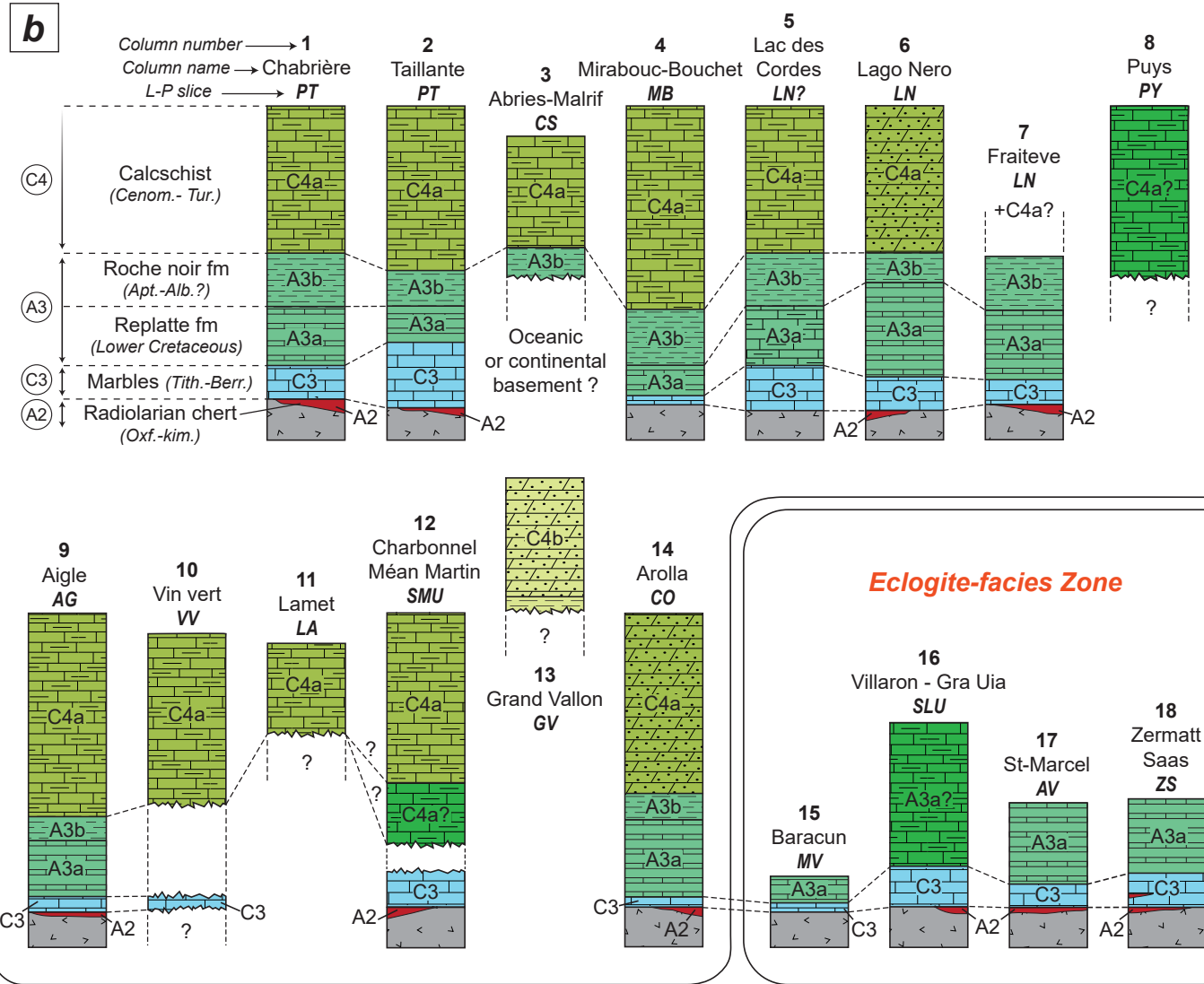


Briançonnais — **Piemont** — **Liguro-Piemont ocean** —

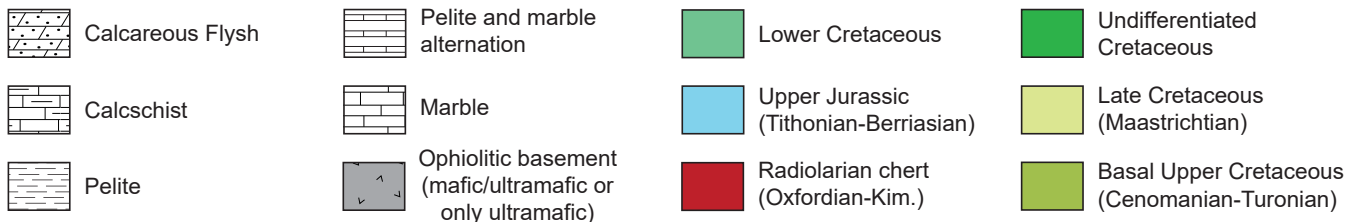


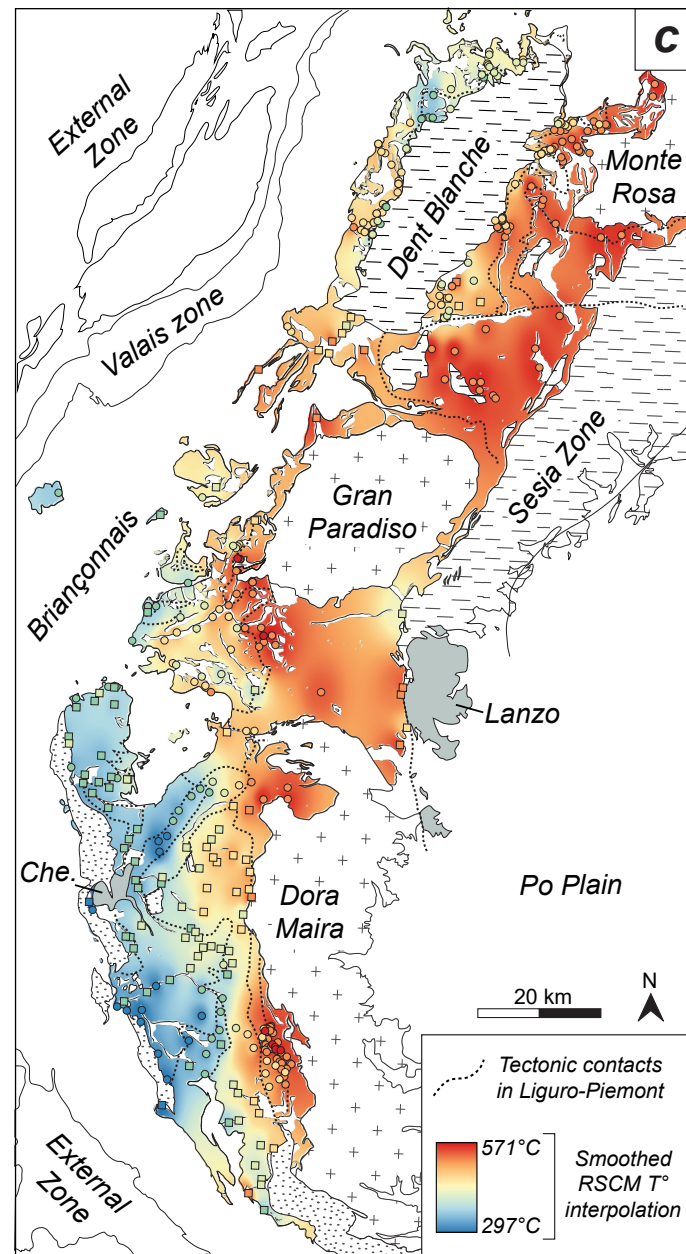
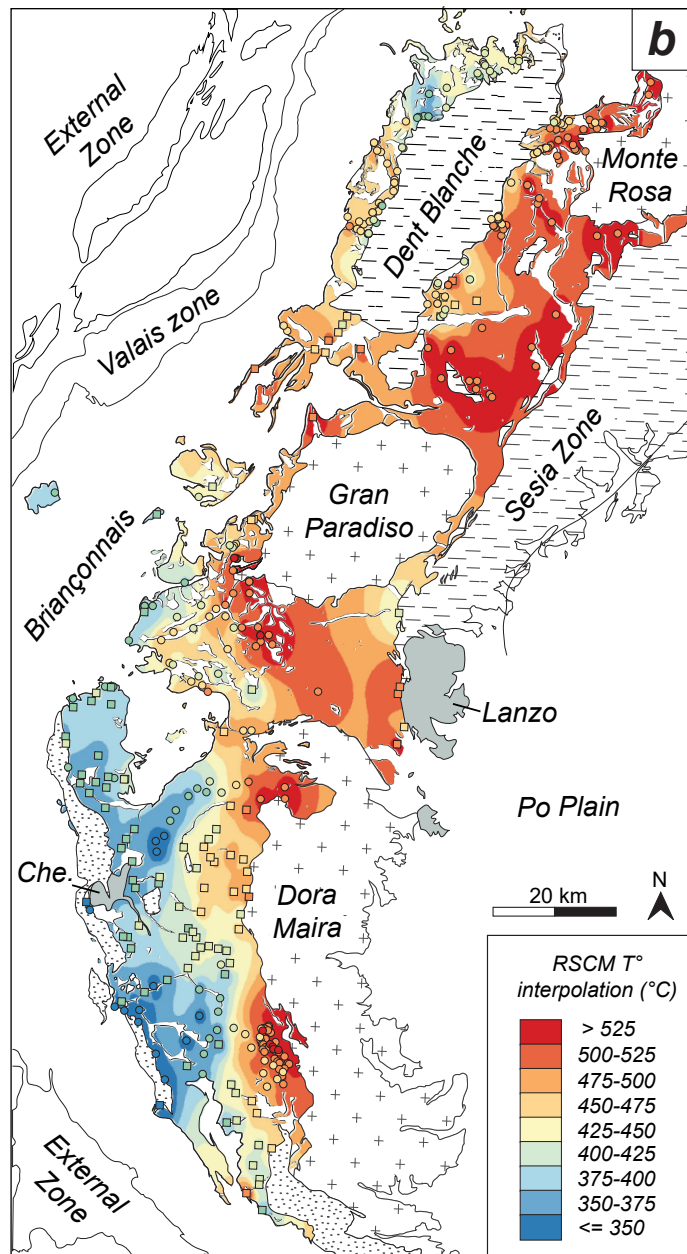
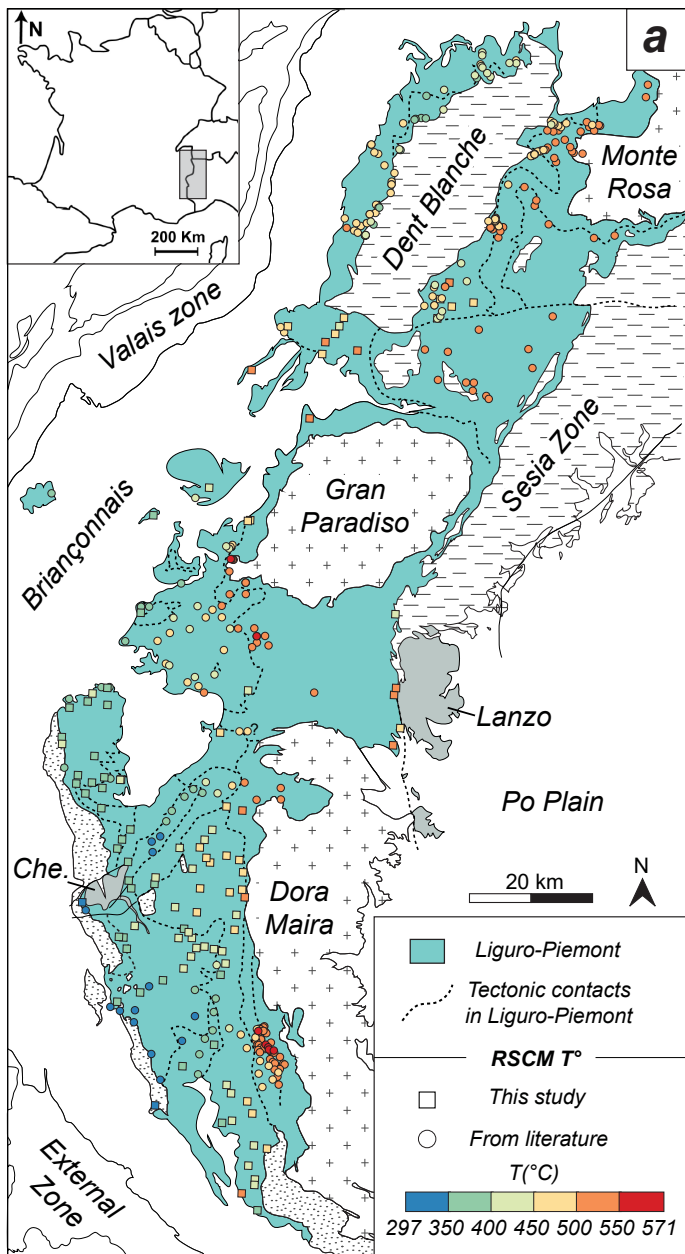
Blueschist-facies Zone

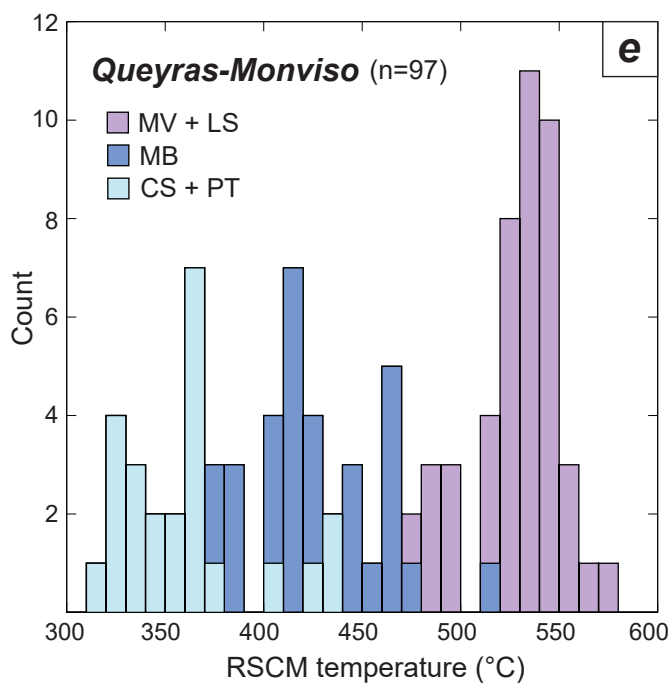
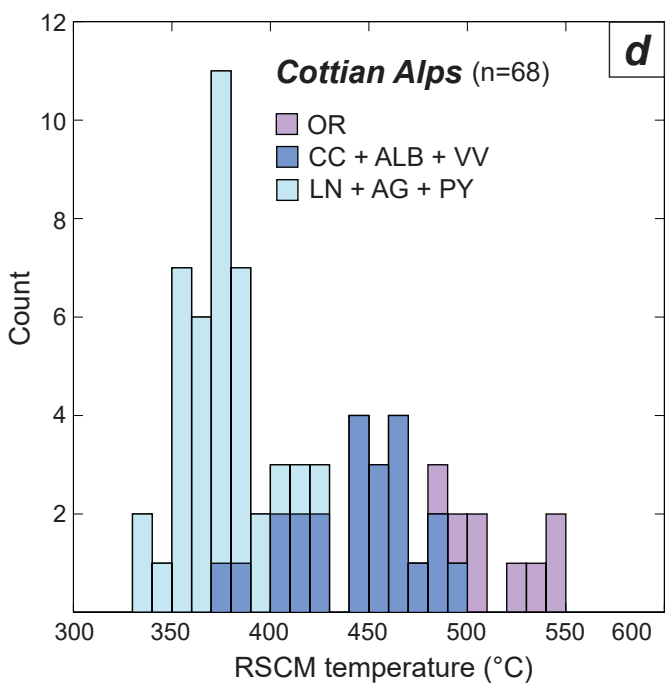
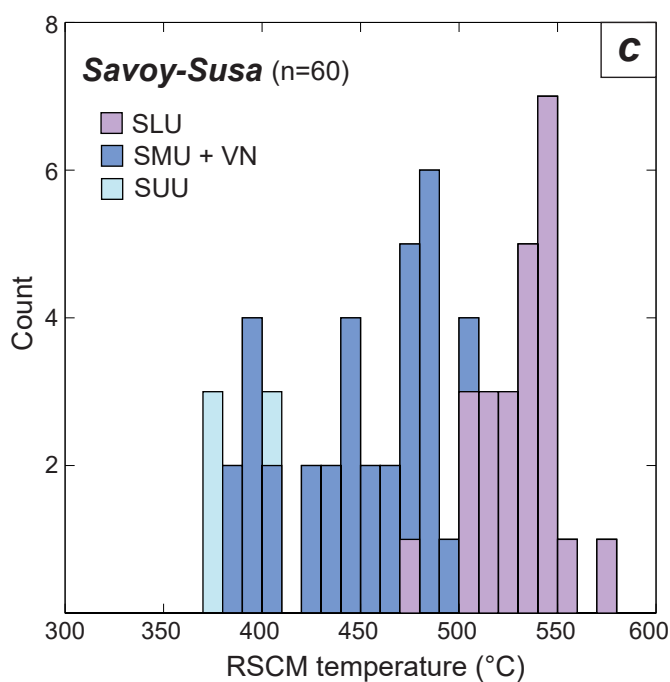
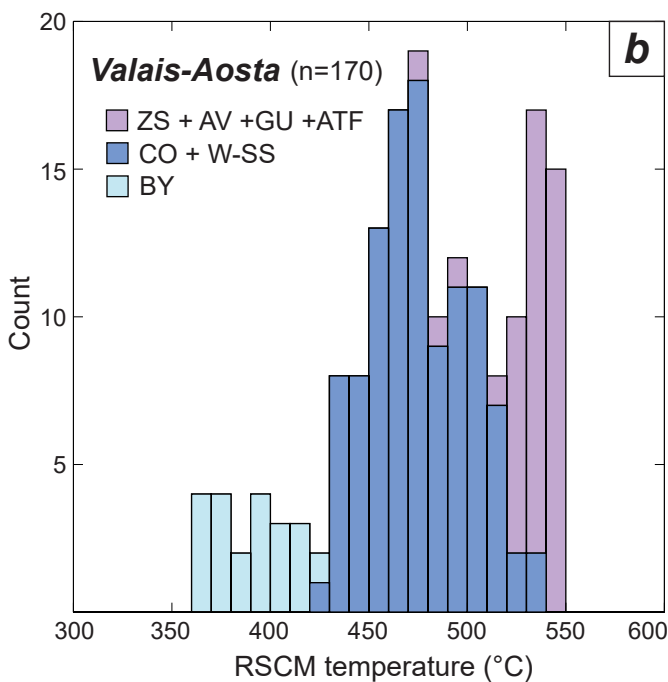
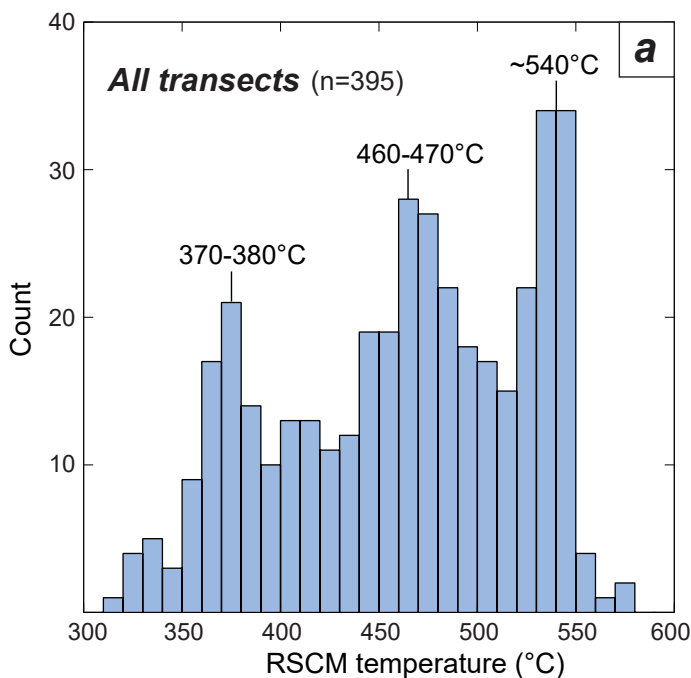
Not to scale

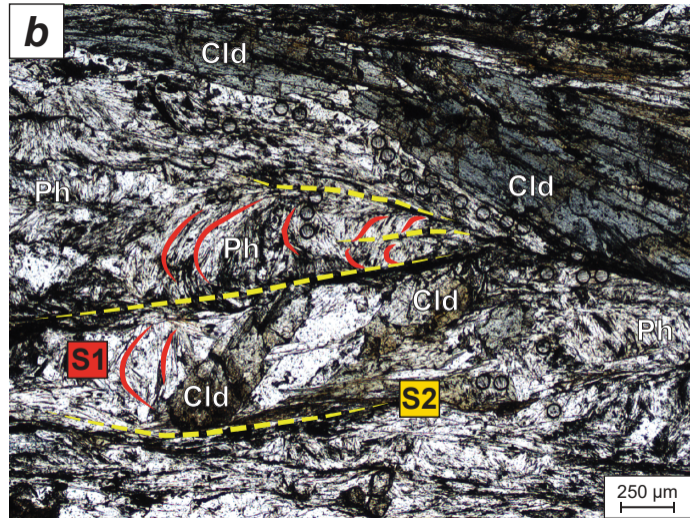
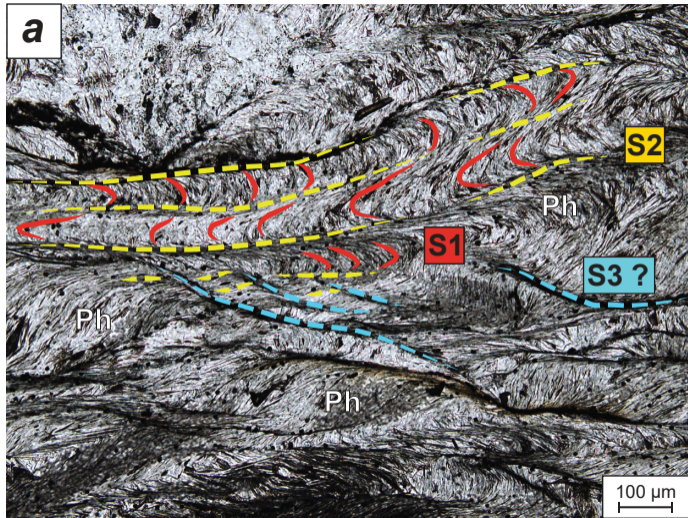


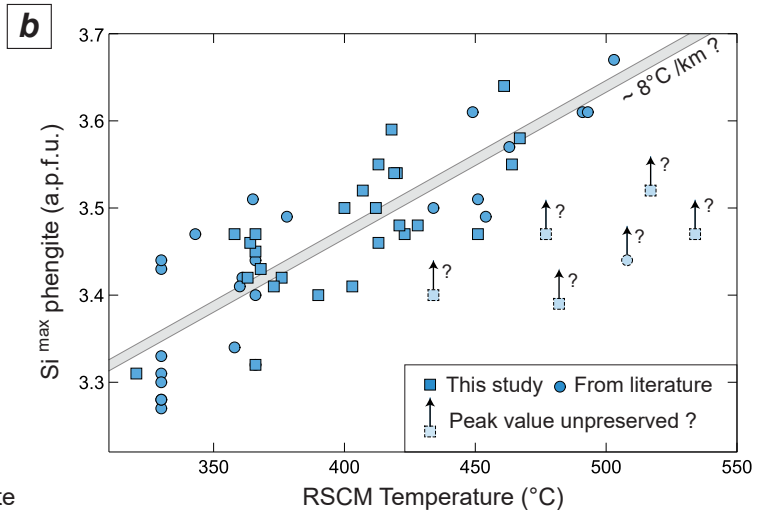
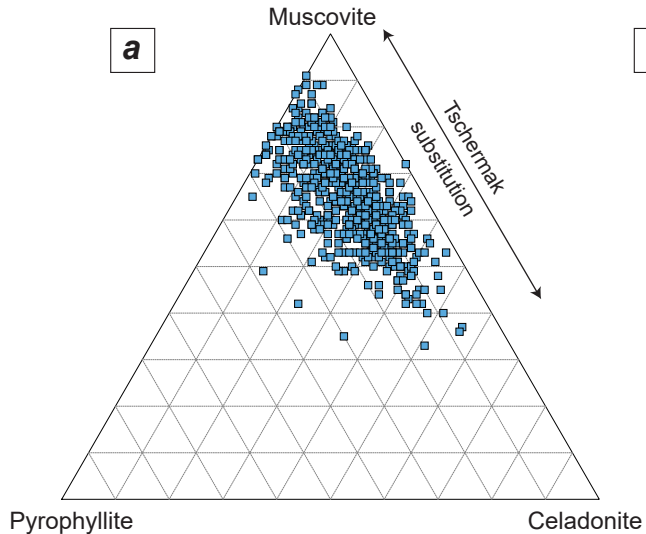
Eclogite-facies Zone

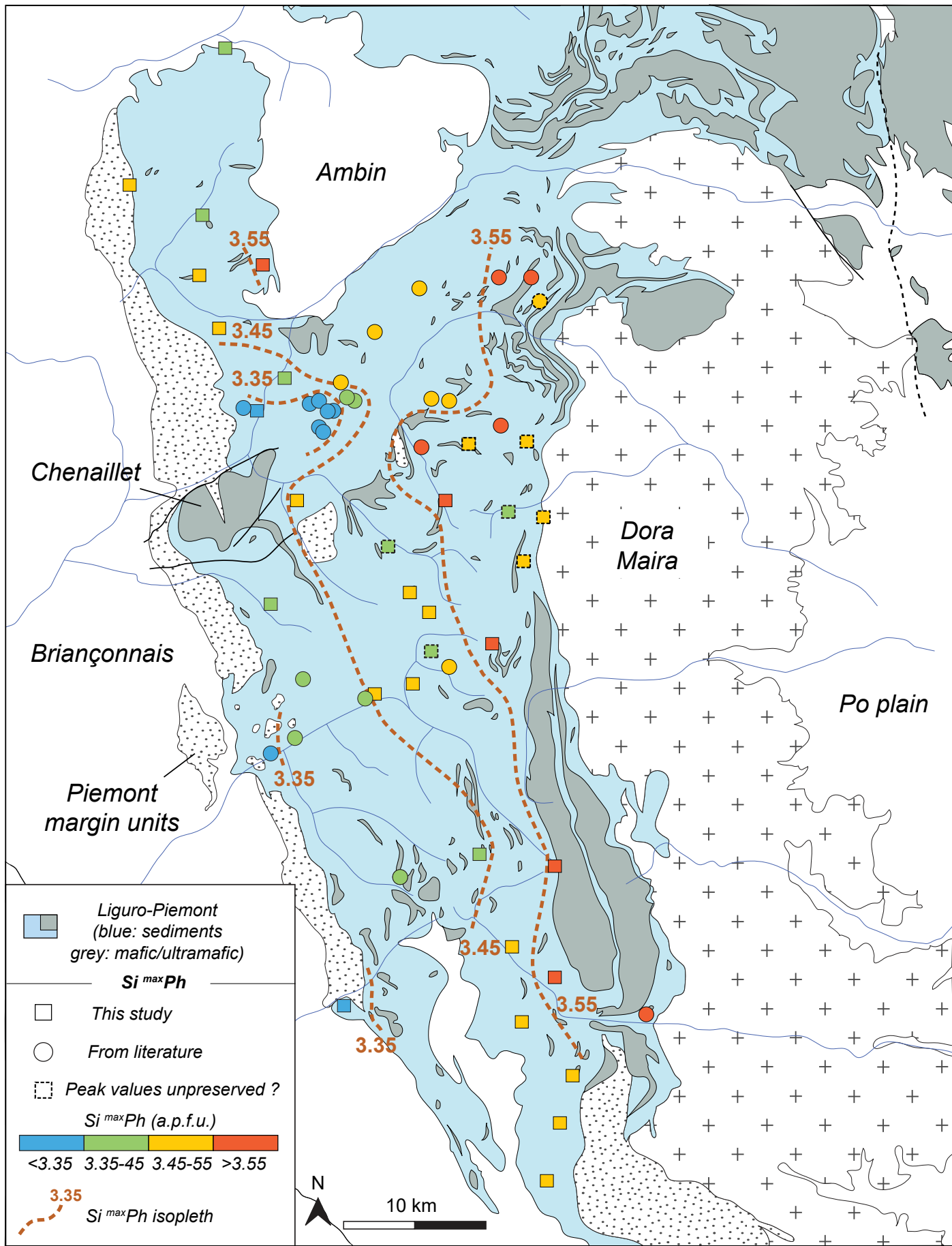


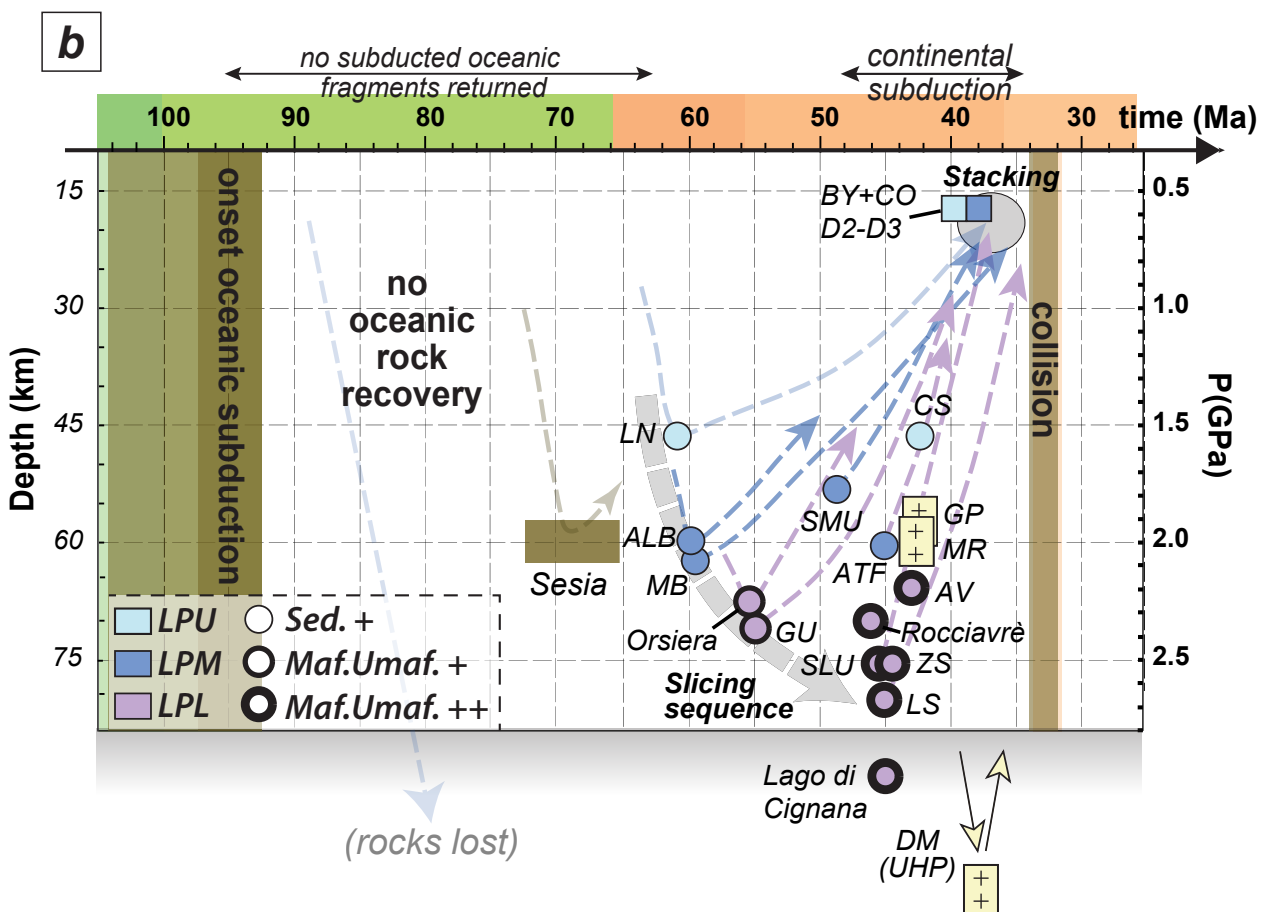
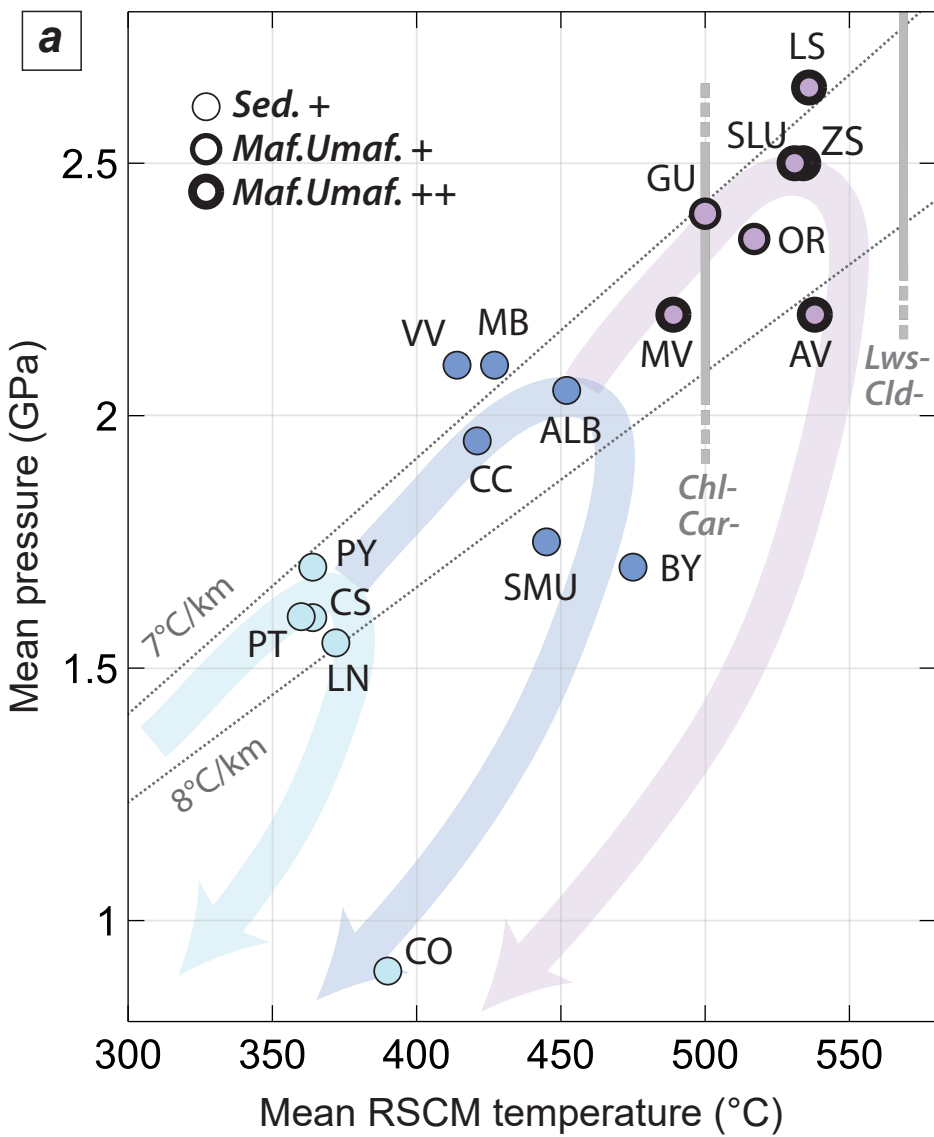




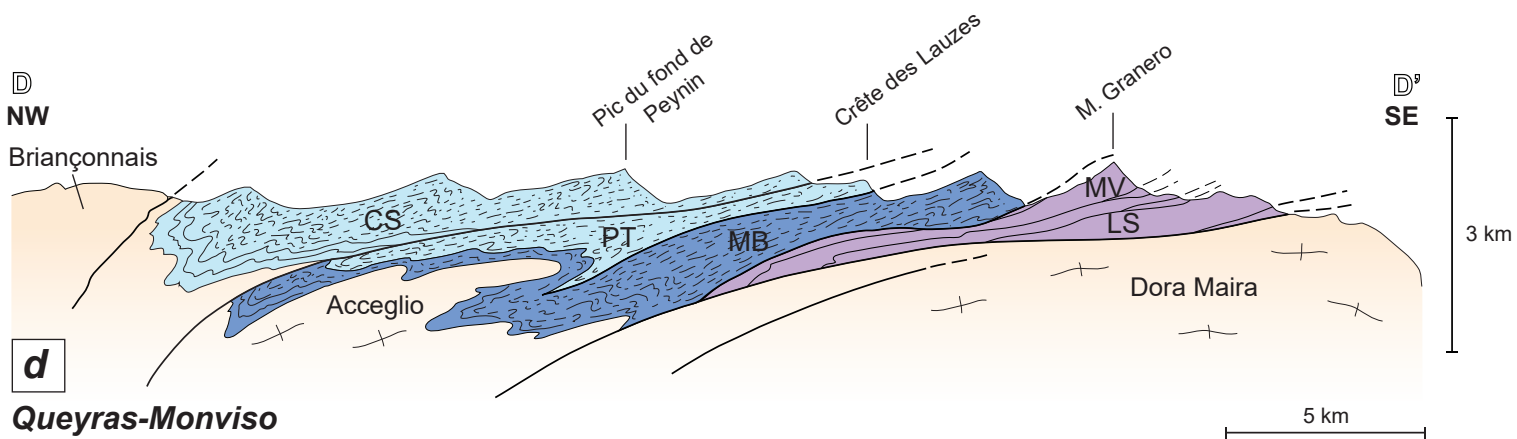
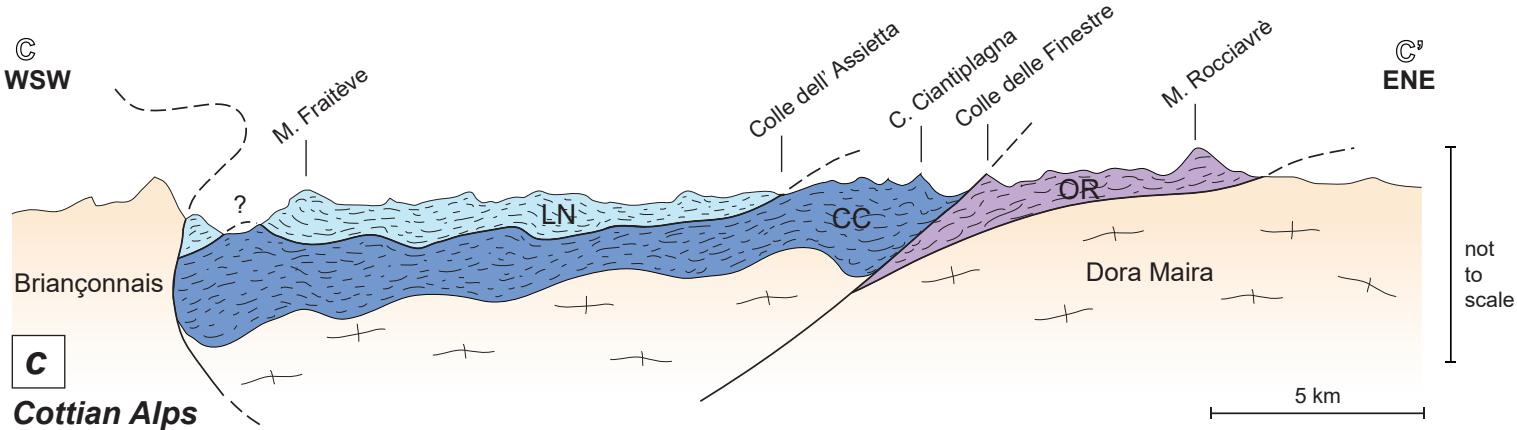
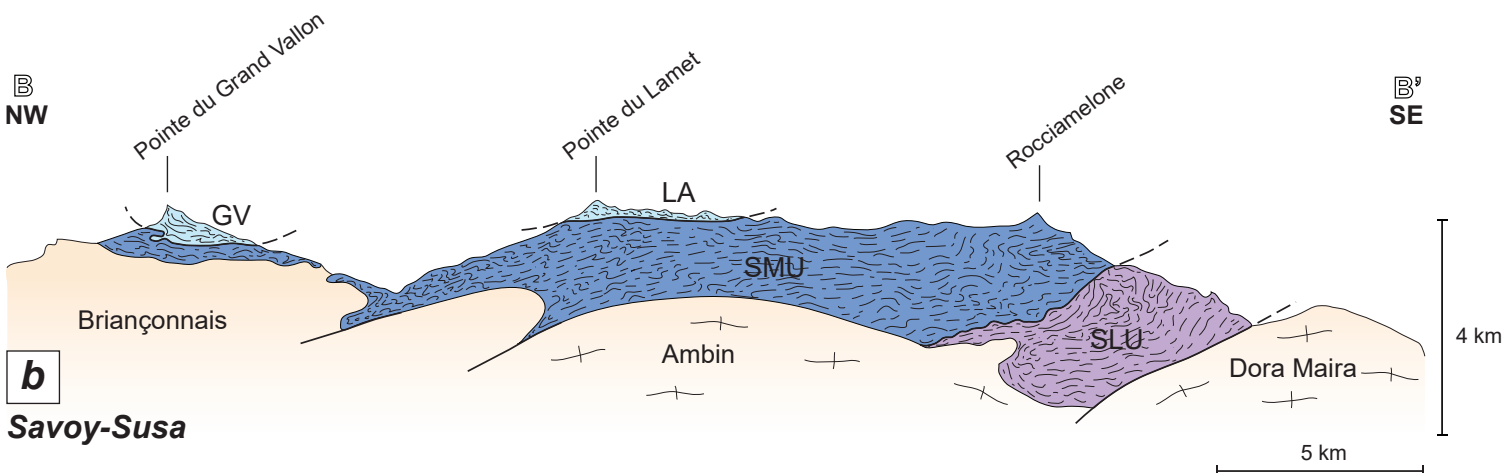
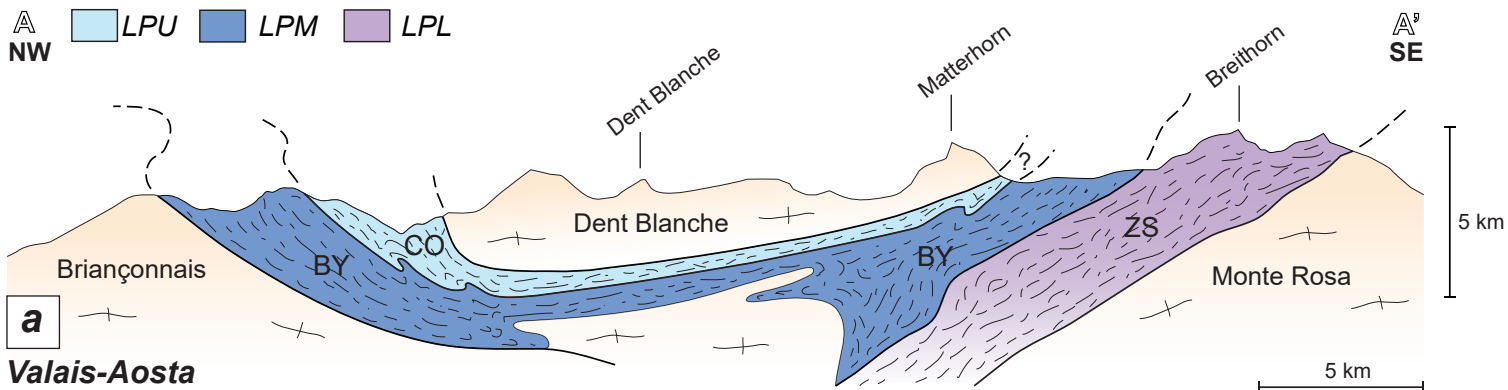


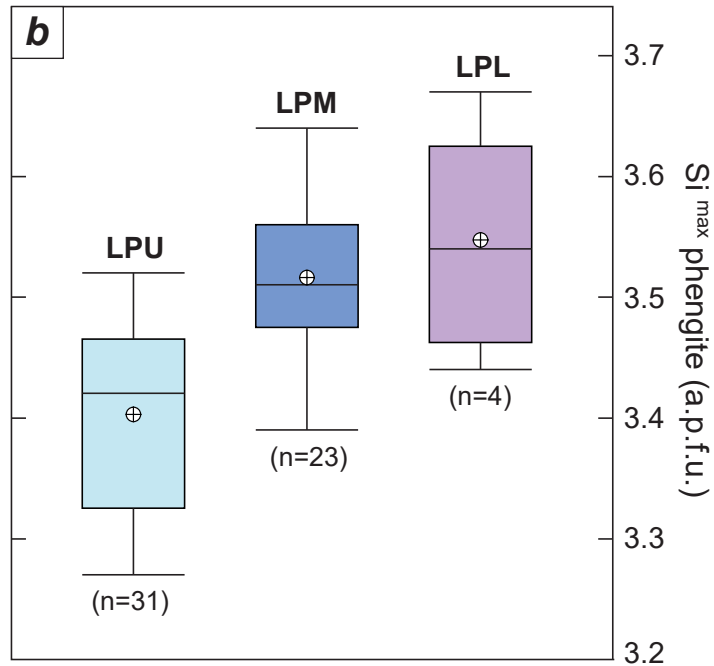
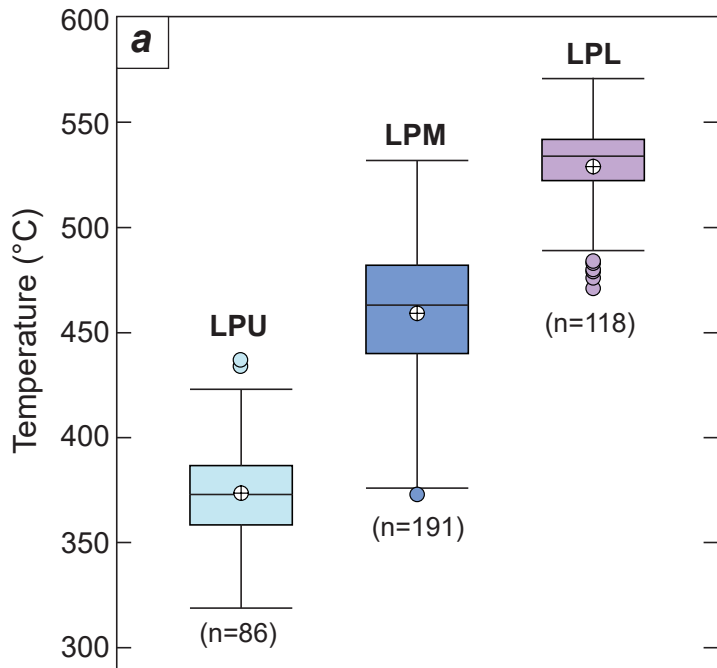


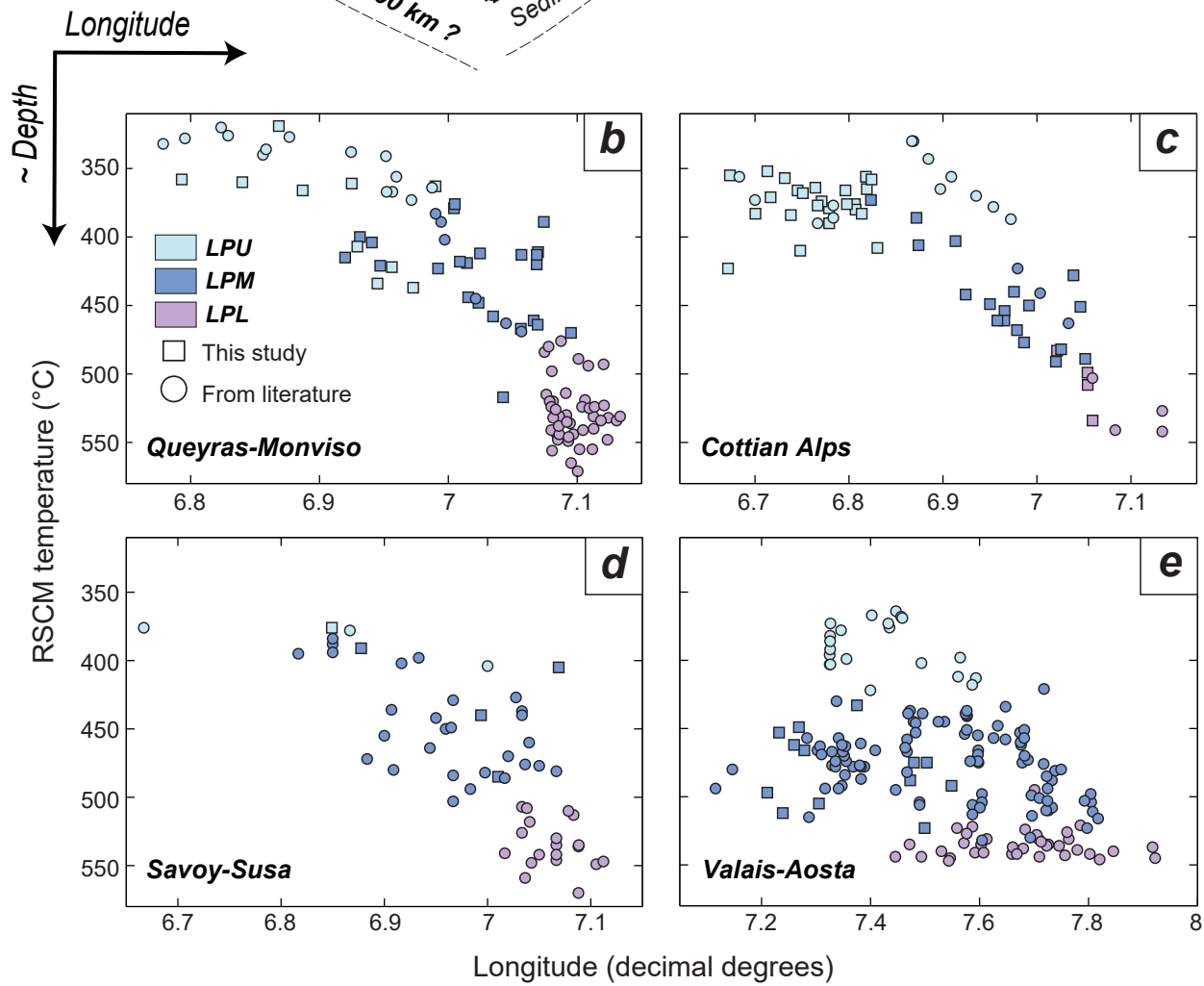
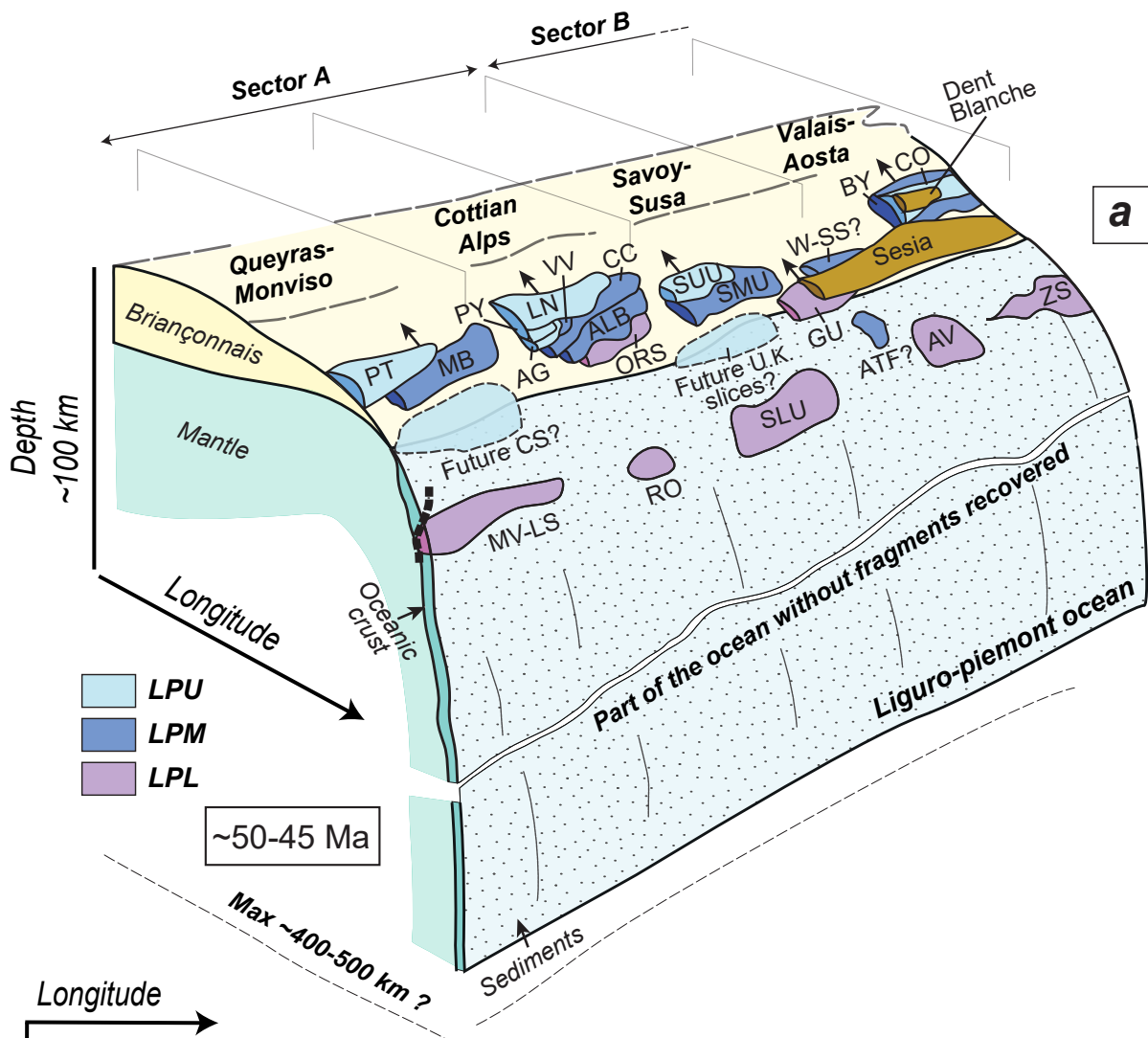




A NW LPU LPM LPL



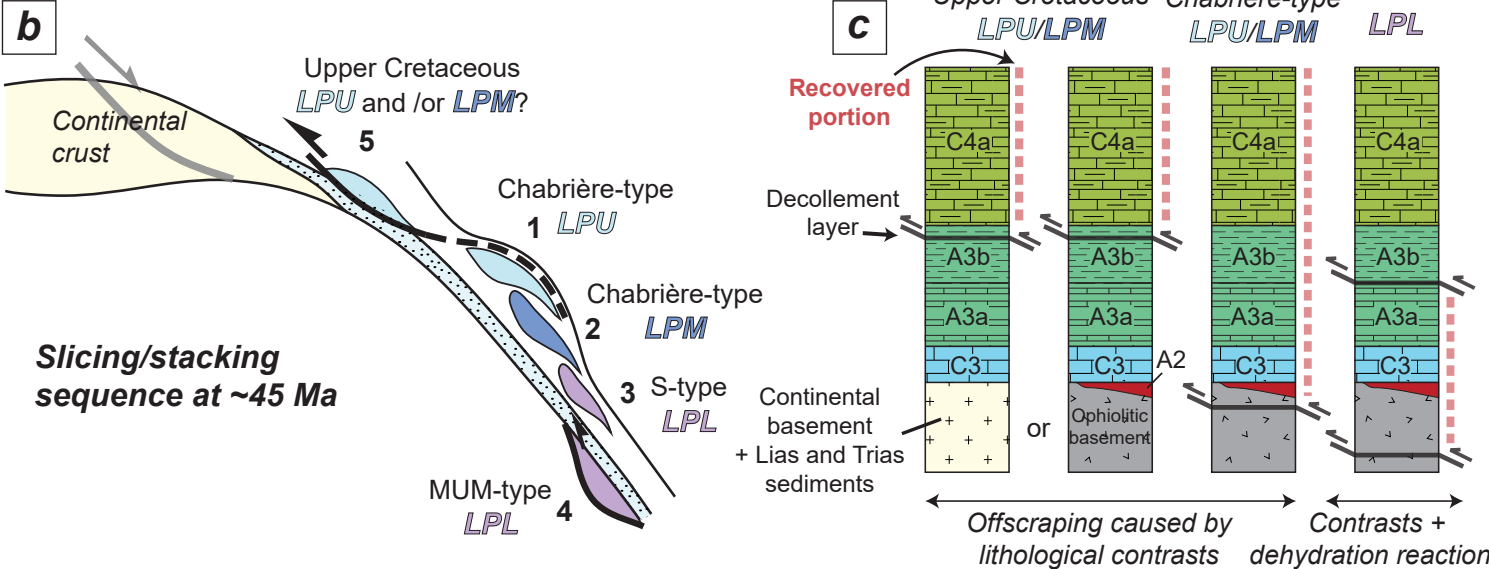
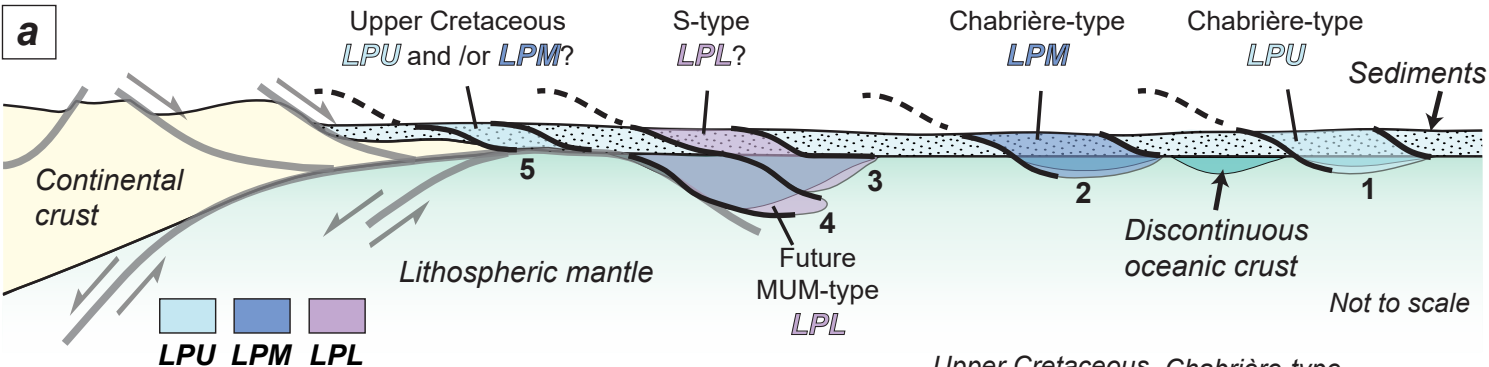


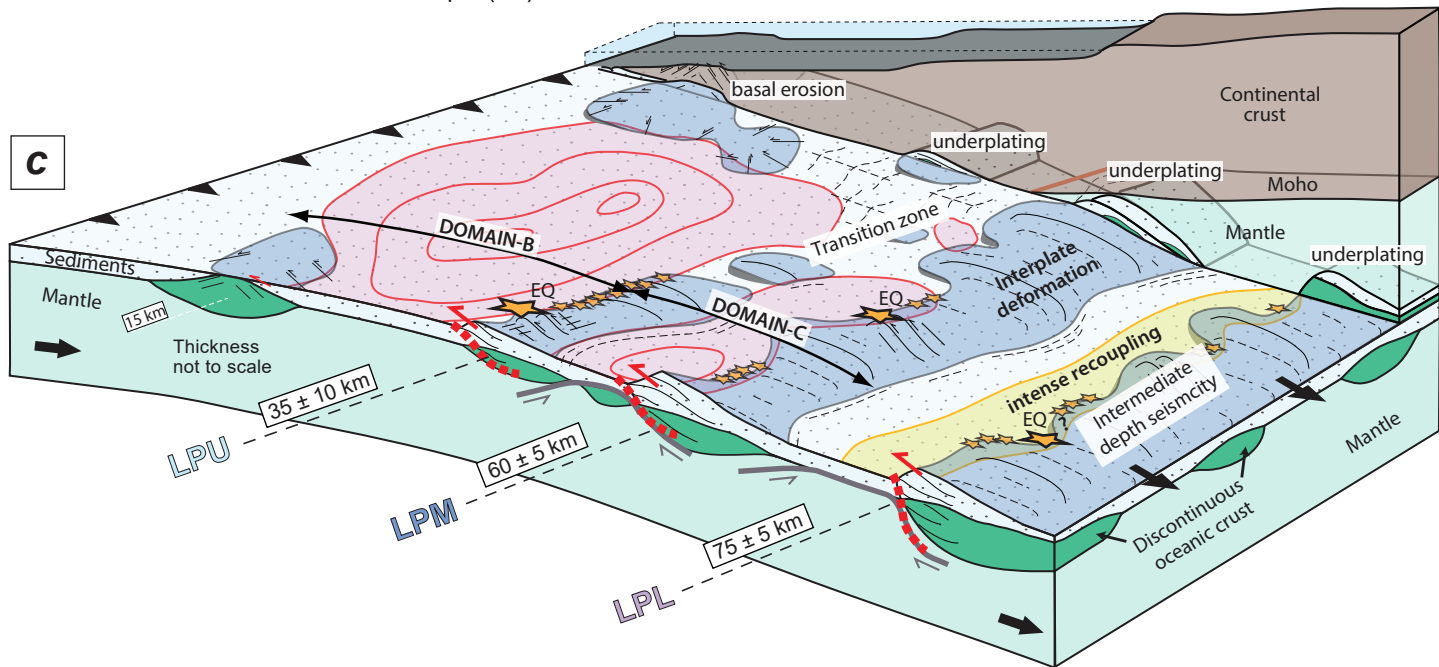
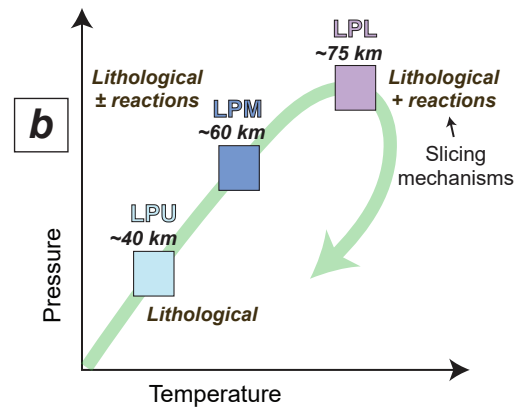
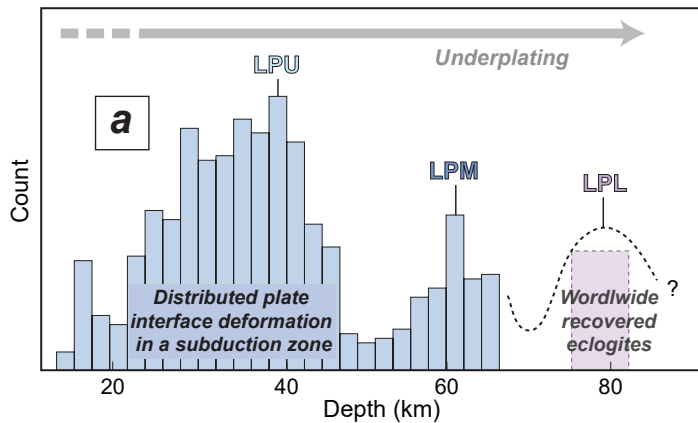


Briançonnais —||— **Piemont** —||— **Liguro-Piemont ocean** — - - -

NW

SE





<i>Slice</i>	<i>Metamorphic zone</i>	<i>Sediments %</i>	<i>Mafic-ultramafic %</i>	<i>~ outcropping surface (km²)</i>
All Liguro-Piemont domain	Blueschist and eclogite facies zones	71	29	2477
All Blueschist-facies slices	Blueschist-facies zone	91	9	1516
All Eclogite-facies slices	Eclogite-facies zone	38	62	961
Aigle + Vin vert	Blueschist-facies zone	98	2	20
Albergian + Mirabouc-Bouchet	"	96	4	258
Cerogne-Ciantiplagna	"	95	5	78
Chardonnet klippe (Savoy Middle Unit)	"	100	0	2
Combin (By + Cornet)	"	76	24	433
Calcschist unit	"	99	1	161
Grande-Sassière klippe (Savoy Middle Unit)	"	99	1	38
Grand Vallon klippe (Savoy Upper Unit)	"	100	0	9
Jovet klippe (Savoy Upper Unit)	"	100	0	9
Lamet klippe (Savoy Upper Unit)	"	100	0	<1
Lago Nero	"	99	1	134
Pelvas-Taillante	"	90	10	70
Puys	"	99	1	14
Savoy Middle Unit	"	98	2	181
Lower Sana klippe (Savoy Middle Unit)	"	96	4	14
Upper Sana klippe (Savoy Upper Unit)	"	91	9	3
Venaus	"	99	1	28
Avise-Tsaboc-Feluma	?	99	1	28
West-Sesia	?	93	7	34
Avic unit	Eclogite-facies zone	28	72	211
Grivola-Urtier	"	61	39	113
Monviso unit + Lago Superiore	"	40	60	101
Orsiera-Rocciavrè	"	59	41	70
Savoy Lower Unit	"	36	64	314
Zermatt-Saas	"	35	65	152

Table 1: Lithological ratio (sediment versus mafic-ultramafic) and aerial exposure of the Liguro-Piemont slices. See text (§4.2) for details in the methodology.

Transect	Slice	Mean T (°C)	Med. T (°C)	sd	n samples	T range (°C)	References
Valais-Aosta	Cornet (Combin)	390	392	18	21	364-422	Negro et al. (2013); Angiboust et al. (2014); Decrausaz et al. (2021); Manzotti et al. (2021)
"	By (Combin)	476	474	25	106	421-532	This study; Angiboust et Agard (2010); Negro et al. (2013); Angiboust et al. (2014); Decrausaz et al. (2021); Manzotti et al. (2021)
"	Zermatt-Saas	533	536	12	26	495-546	Angiboust et al. (2009); Angiboust et Agard (2010); Negro et al. (2013)
"	Avic	538	538	7	12	523-547	Angiboust et al. (2009); Angiboust et Agard (2010)
"	Grivola-Urtier	499	483	31	3	479-534	This study
"	Avise-Tsaboc-Feluma	/	/	/	1	522	This study
"	West-Sesia	/	/	/	1	433	This study
Savoy-Susa	Savoy Upper Unit	384	377	14	4	376-404	This study; Gabalda et al. (2009); Plunder et al. (2012)
"	Savoy Middle Unit	445	449	36	31	384-503	This study; Gabalda et al. (2009); Plunder et al. (2012)
"	Venaus	/	/	/	1	484	This study
"	Savoy Lower Unit	530	533	21	24	471-580	This study; Gabalda et al. (2009); Plunder et al. (2012)
Cottian Alps	Lago Nero	372	373	20	33	330-423	This study; Beyssac et al. (2002); Gabalda et al. (2009)
"	Puys	/	/	/	1	364	This study
"	Aigle	373	377	15	3	357-386	This study; Gabalda et al. (2009)
"	Vin Vert	414	414	3	2	413-416	This study
"	Cerogne-Ciantiplagna	421	423	34	5	373-463	This study; Beyssac et al. (2002)
"	Albergian	452	453	29	16	386-491	This study
"	Orsiera-Rocciavré	517	517	22	8	483-542	This study; Beyssac et al. (2002); Gabalda et al. (2009)
Queyras-Monviso	Calcschist unit	364	349	43	14	320-437	This study; Schwartz et al. (2013)
"	Pelvas-Taillante	355	362	17	10	319-363	This study; Schwartz et al. (2013)
"	Mirabouc-Bouchet	427	419	34	29	376-517	This study; Schwartz et al. (2013)
"	Monviso unit	488	489	8	7	476-498	Angiboust et al. (2011); Schwartz et al. (2013)
"	Lago Superiore	536	534	14	37	514-571	Angiboust et al. (2011); Schwartz et al. (2013)

Table 2: RSCM temperatures of the Liguro-Piemont slices. All the compiled RSCM temperatures (from this study and literature) are presented in Sup. Mat 1.

Slice	Si ^{max} Ph	Mean Si ^{max} Ph	Med. Si ^{max} Ph	sd	n samples	Relative pressure (GPa)	References for Si ^{max} Ph
Lago Nero	3.27-3.5	3.39	3.42	0.082	19	~1.3 - ~1.9	This study; Agard et al. (2001); Liewig (1981)
Puys	3.46	/	/	/	1	1.7-1.8	This study
Vin Vert	3.55	/	/	/	1	2.1	This study
Cerogne-Ciantiplagna	3.4-3.57	3.49	3.49	0.113	2	1.7- ~2.2	This study; Agard et al. (2001)
Albergian	3.39-3.64	3.5	3.48	0.082	11	1.8- ~2.3	This study; Agard et al. (2001)
Orsiera-Rocciavrè	3.47-3.67	3.53	3.47	0.125	3	2.2- ~2.5	This study; Agard et al. (2001)
Calcschist unit	3.34-3.5	3.43	3.42	0.059	8	1.4-2	This study; Liewig (1981)
Pelvas-Taillante	3.31-3.42	3.37	3.37	0.077	2	1.4-1.7	This study; Bocquet (1974)
Mirirabouc-Bouchet	3.48-3.59	3.53	3.54	0.037	9	1.9- ~2.4	This study
Lago Superiore	3.61	/	/	/	1	> 2.4	Bonnet et al. (submitted)

Table 3: Maximum Si a.p.f.u. values of phengite (Si^{max}Ph) and estimated peak pressure for Liguro-Piemont slices. Peak pressures were estimated by crossing RSCM temperatures (see Table 1; Fig. 4a-c, 5a-e) with the calculated isopleths of Si a.p.f.u. in phengite for a representative rock composition (Fig. 9a). Selected Si^{max}Ph, RSCM temperature for the same samples and all estimated pressure values are presented in Sup. mat. 3.