Int J Earth Sci (Geol Rundsch) (2018) 107:2635–2637
DOI 10.1007/s00531-018-1616-8

GEOSITES

Fossiliferous high-pressure metasediments from the Western Alps (Petit-Saint-Bernard Pass, Subbriançonnais Unit, Italy)

Fossils in high-pressure metasediments are rare, but contribute significantly to our understanding of subducted and deformed terranes. The stratigraphic age is indeed of primary importance for field geologists to derive information on the relative displacements between volumes of metamorphic rocks. Moreover, preserved fossils are ideal for studying the behavior of organic matter in subduction zones, and to investigate the partitioning of the deformation that permitted fossil preservation through a subduction–exhumation cycle.

In this contribution, I locate and describe one of the most famous outcrops of the Italian Western Alps. The "Calcschists" of this outcrop radically changed the interpretation of the Western Alps, because of their fossiliferous

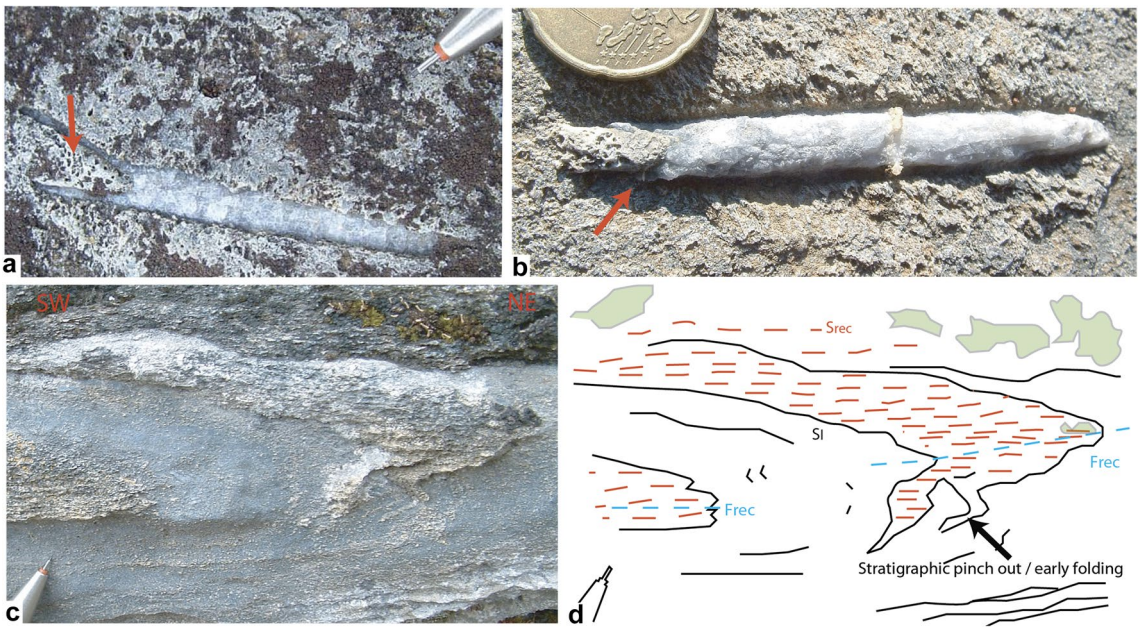

Fig. 1 **a, b** Belemnites in high-pressure metasediments. Phragmocones are shown by red arrows. **c, d** Isoclinal fold (F_{rec}, following Beltrando et al. 2012), main foliation (S_{rec}), and lithological beds (S_l) in the metasediments of the same outcrop

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00531-018-1616-8) contains supplementary material, which is available to authorized users.

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Received: 7 April 2018 / Accepted: 18 April 2018 / Published online: 28 July 2018

content with an undoubtedly Mesozoic age (Franchi 1899). In the nineteenth century, indeed, a strong debate emerged in the alpine geological community on the depositional age, Mesozoic or Paleozoic, of the "Calcschists" (also called "Schistes Lustrés"). Since 1857 and 1862, Lory and Favre, respectively, supported a Mesozoic age for the "Calcschists" in the internal and external part of the metamorphic Western Alps (see Dal Piaz 2010). Franchi (1898) documented Liassic fossils in the internal part of the Western Alps and extended a Mesozoic age to the entire ophiolite-bearing Piedmont "calcschist"-greenstone zone ("Calcescisti con Pietre Verdi", Lemoine 2003). With this "Geosite" outcrop at the Petit-Saint-Bernard Pass, Franchi (1899) also discovered vestiges of belemnites in the external part of the metamorphic domain of the Western Alps. After Franchi's discoveries, the majority of geologists at the time accepted the Mesozoic age of the "Calcschists" (Dal Piaz 2010). A more detailed Lower Jurassic age of the metasediments of the outcrop was sustained, often because of analogies between less/non-metamorphosed sediments in other sectors of the subbriançonnais (Schoeller 1929; Zulauf 1963; Elter and Elter 1965; Antoine 1971; Debelmas et al. 1991; Antoine et al. 1992).

Rocks at the outcrop consist of impure marbles alternated with carbonatic graphitic schists. In thin section, the schists are composed of fine-grained calcite, quartz, and white mica, with minor chlorite and tourmaline. In the impure marble layers, Belemnites are abundant and easily recognizable thanks to their bullet-like cylindrical shape that tapers out at one end and has conical cavities at the other end, i.e., the phragmocones (Fig. 1a, b). In the carbonatic schists, the main foliation (S_{rec}), underlined by phengitic micas and opaque minerals, is at low angles with the lithological contacts (S_0), and is characterized by a mm-sized spacing (Fig. 1c, d).

High-pressure minerals such as lawsonite, Mg–Fe carpholite, and chloritoid are described nearby, in the same Petit-Saint-Bernard tectonic unit. Peak-*P*, derived from this paragenesis, is approximately 17 kbar (estimates with Tschermak substitution in micas, Bousquet et al. 2002), slightly lower than what proposed in Goffé and Bousquet (1997). Alpine *T* ranges from 450 °C to 500 °C (chlorite–chloritoid geothermometer and Mg repartition in the association carpholite–chloritoid, Bousquet et al. 2002), and more precisely from 450 °C to 470 °C (Raman spectroscopy on carbonaceous material technique, Beltrando et al. 2012). These values are compatible with eclogite *P*–*T* conditions described in the French part of the Petit-Saint-Bernard unit (minimum *P*: 15 kbar and *T* between 425 and 470 °C; Cannic et al. 1996). All of these arguments indicate that the belemnites were preserved in these metasediments in spite of a blueschist/eclogitic-facies overprint.

This Geosite (45.7043N, 6.8822E; see .kml file in supplementary material) is located near the Plan Veyle Alp (La Thuile, Aosta, Italy) approximately 12 km from the Petit-Saint-Bernard Pass. Due to the relatively high altitude (about 2030 m), the outcrop can be reached only during the summer, using a dirt road that starts at a sharp bend on the National Road 26 at an altitude of 1861 m. Please note that a permit, which should be requested from the La Thuile municipality, is required to drive on this road.

The outcrop described in this GeoSite was crucial for the acceptance of the Mesozoic age of the "Calcschist" in the Western Alps in the alpine community. Fossil-bearing metapelites commonly occur also in the neighboring Valaisan Units, near the Petit-Saint-Bernard Pass (Beltrando et al. 2012; Frasca 2011; Frasca et al. 2015). This feature represents a distinctive characteristic of the area, in contrast with the fossil-free carbonatic schists of the "Calcescisti con Pietre Verdi" in the Aosta Valley. This calls for further investigation that could solve, by stratigraphic ages, the Valaisan oceanic age conundrum [see Masson et al. (2008); Loprieno et al. (2011) for the debate].

Acknowledgements I thank Roberto Compagnoni and Alberto Vitale Brovarone for discussions and encouragements. This work is dedicated to Marco Beltrando who first introduced me to the geology of the Petit-Saint-Bernard area.

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