Swiss J Geosci (2016) 109:69–81
DOI 10.1007/s00015-016-0207-6

Facies and Late Triassic fossils in the Roisan zone, Austroalpine Dent Blanche and Mt Mary-Cervino nappe system, NW Alps

Gloria Ciarapica[1] · Leonsevero Passeri[1] · Franco Bonetto[2] · Giorgio Vittorio Dal Piaz[3]

Received: 11 August 2015 / Accepted: 7 January 2016 / Published online: 12 February 2016

Abstract The Roisan zone is a metamorphic cover unit exposed along the ductile shear zone between the Dent Blanche s.s. and Mont Mary-Cervino Upper Austroalpine outliers, Aosta Valley, north-western Italian Alps. It is characterized by the occurrence of dolostones, pure marbles, marbles with quartz, calcirudites and ophiolite-free calcschists. Locally, dolostones preserve alternances of thick massive beds and thinner levels of planar stromatolites and other sedimentary structures and textures typical of a carbonate platform. In Mt Grand Pays they contain Dasycladales and foraminifers referable to the Norian. Pure marbles and marbles with quartz grains are tentatively referred to the end of Triassic–Early Jurassic, thin-bedded marbles and calcirudites to the Early and Middle Jurassic, calcschists from Middle Jurassic to Late Cretaceous. This Roisan succession is quite similar to the one of Mt Dolin, in the Swiss part of the Dent Blanche nappe, where the same Triassic foraminifer association has been reported. There, the fossils were found only in reworked pebbles, contained in calcirudites of presumed Jurassic age. Some differences exist between the two successions: calcirudites are abundant in the Mt Dolin and sporadic in the Roisan zone, whereas calcschists are very thick in the Roisan zone. As consequence the Mt Dolin succession can be considered settled down in the proximity of the faults related to the pre-oceanic rifting of the Piedmont basin, whereas the Roisan zone could have been deposited in a more distal area.

Keywords Austroalpine covers · Sedimentology · Stratigraphy · Foraminifers · Dasycladales

Editorial handling: W. Winkler.

✉ Gloria Ciarapica
gloria.ciarapica@gmail.com

[1] Università di Perugia, Piazza Università, 06100 Perugia, Italy

[2] Regione Autonoma Valle d'Aosta, Aosta, Italy

[3] Accademia delle Scienze, via Maria Vittoria 6, Torino, Italy

1 Introduction

The Roisan zone is the most extended sedimentary cover unit associated to the Austroalpine Dent Blanche and Sesia–Lanzo nappe system, the upper part of the subduction-related collisional wedge in the northwestern Alps. As shown in Fig. 1, classic Argand's (1908, 1909) Dent Blanche fold-nappe is currently replaced by a lot of Austroalpine outliers derived from the distal part of the Adria passive continental margin, ribbon continents or extensional allochthons (Ballèvre et al. 1986; Dal Piaz 1999; Dal Piaz et al. 2001, 2003, 2015; De Giusti et al. 2004; Manzotti et al. 2012, 2014; Beltrando et al. 2014). Among them, two main groups of second order nappes–also known as tectonic units, klippen or subnappes–can be recognized, based on contrasting metamorphic features and structural location within the nappe stack: (1) Upper Austroalpine outliers, represented by the blueschist and greenschist facies Dent Blanche s.s., Mt Mary-Cervino and Pillonet thrust system, including the Roisan zone; (2) Lower Austroalpine outliers, represented by the Mt Emilius, Glacier-Rafray, Etirol-Levaz and other eclogitic basement slices, all free of cover units. The former group is thrusted over the entire ophiolithic Piedmont zone, the latter is sandwiched inside it (Ballèvre et al. 1986; Ballèvre and Merle 1993; Dal Piaz 1999).

Sedimentary covers, where present, are usually devoid of preserved sedimentary structures and fossils. Foraminifers were found only in some reworked pebbles in the

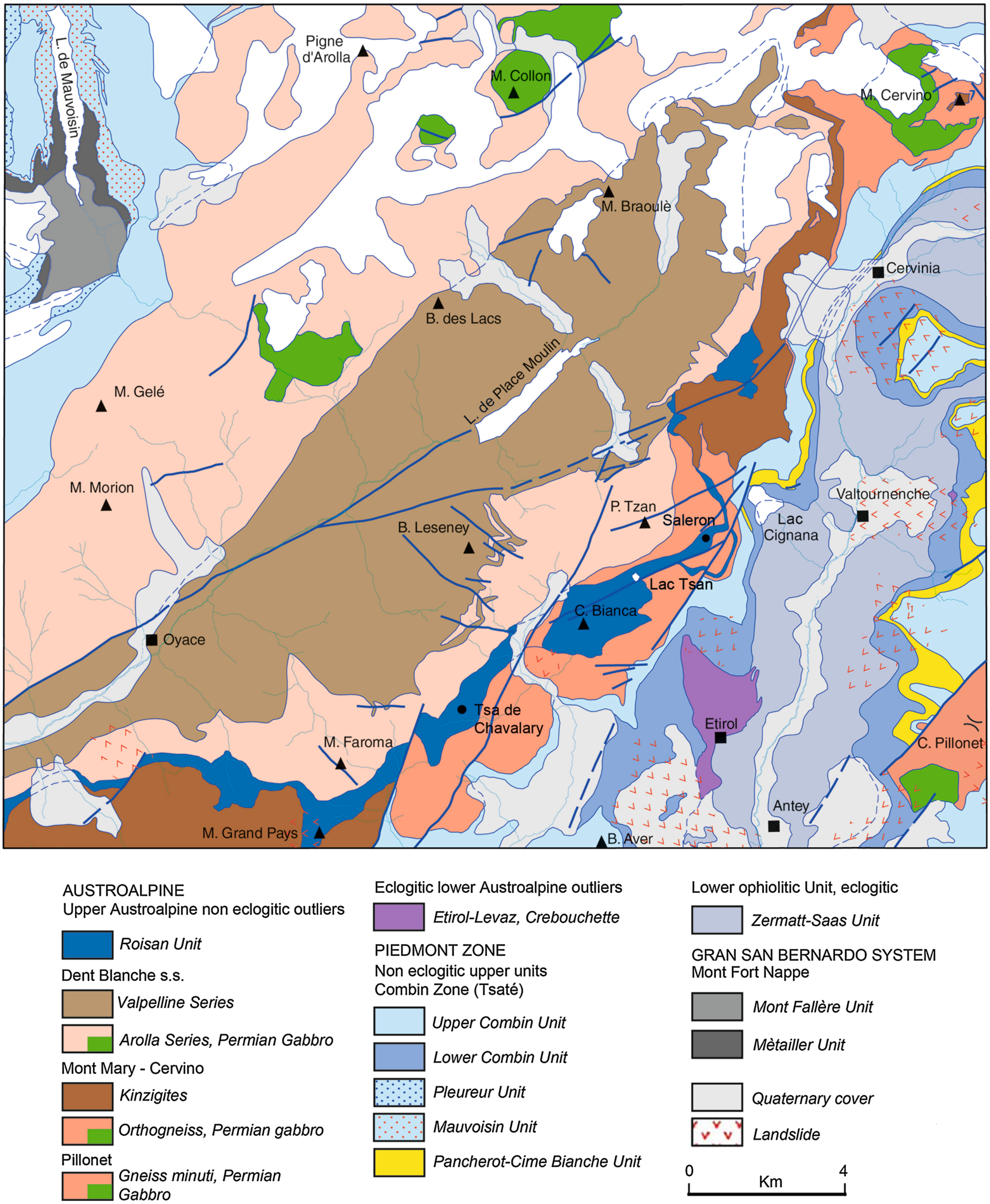


Fig. 1 Tectonic map of the Dent Blanche and Mt Mary-Cervino nappe system and surrounding units (modified from Dal Piaz et al. 2015)

Swiss part of the Dent Blanche Nappe system (Mt Dolin, Weidmann and Zaninetti 1974). Diplopores (Dasycladales) were also found in an unspecified zone of Valtournenche by Kienast as reported by Ballèvre et al. (1986).

During the 85th National Congress of the Italian Geological Society we presented an extended abstract on the first discovery of Late Triassic microfossils in the Roisan zone (Ciarapica et al. 2010). Now we intend: (a) to give a full description of all the lithofacies recognised in the Roisan zone, (b) to define the succession of these lithofacies, (c) to compare the Roisan succession with that of Mt Dolin (Valais) where the same species of microfossils were found (Weidmann and Zaninetti 1974). These researches were carried out during field and laboratory refinements of the Foglio Monte Cervino (070) of the Carta Geologica d'Italia at 1:50.000 scale (CARG Project; Dal Piaz et al. 2015), printed during the assessment of this note.

2 Roisan zone and related basement units

The Roisan zone is a metamorphic, strongly transposed and fragmented sedimentary unit of supposed Mesozoic age. This meta-sedimentary unit is discontinuously exposed along the kilometric ductile shear zone between the Upper Austroalpine Dent Blanche s.s. and Mont Mary-Cervino outliers (Figs. 1, 2-1; Dal Piaz 1999; Bucher et al. 2003–2004; Manzotti et al. 2014), and extends from the Roisan village, north of Aosta, to the Mont Blanc du Creton (Valtournenche), through the Col de l'Arpeyssaou, Col de St. Barthélemy, Grand Pays, Col Salvé-Tsa de Chavalary, Cima Bianca-Tsan Lake and Col de Saleron area (Stutz and Masson 1938; Diehl et al. 1952; Elter 1960; Dal Piaz 1976, 1992a, b; Canepa et al. 1990; Manzotti 2011; Manzotti et al. 2014; Dal Piaz et al. 2015). The Roisan zone is generally interpreted as the former sedimentary cover of the pre-Triassic lower-to-upper crust Mont Mary basement units (Elter 1960; Canepa et al. 1990), but its primary substratum cannot be precisely established due to the pervasive tectonic contact between them. Isolated minor slices reappear in the Point des Cors eastern spur (Gosso and Martinotti in Dal Piaz 1976), Hörnli ridge of the Matterhorn, and left slope of Zmutt valley, within the NE extension of the Mont Mary-Cervino nappe (Bucher et al. 2003–2004; Dal Piaz et al. 2015). Similar successions of supposed Mesozoic age are also recorded in the Pillonet klippe (Dal Piaz 1976).

The Dent Blanche s.s. and Mont Mary-Cervino nappes share two main pre-Triassic basement units, separated by a mylonitic contact (Stutz and Masson 1938; Pennacchioni and Guermani 1993): (1) the Valpelline Series, that is a fragment of Variscan lower crust consisting of granulite to amphibolite facies felsic and mafic rocks; (2) the underlying Arolla Series, a larger tectonic unit mainly consisting of the Alpine derivatives from Permian granitoids and gabbros (Diehl et al. 1952; Dal Piaz et al. 1977, 2015; Dal Piaz 1992a, b, 1993, 1999; Pennacchioni and Guermani 1993; Gardien et al. 1994; Burri et al. 1998; Bussy et al. 1998; Bucher et al. 2003–2004; Baletti et al. 2012; Manzotti et al. 2012, 2014; Manzotti and Zucali 2013). These basement units are poorly to pervasively reworked by the polyphase Alpine metamorphism which is documented by relics of a relative high-P imprint, intermediate between epidote-blueschist and glaucophane-bearing greenschist facies conditions (Ayrton et al. 1982; Ballèvre et al. 1986; Dal Piaz and Martin 1988; Pennacchioni and Guermani 1993; Höpfer 1997; Oberhänsli et al. 2004; Manzotti 2011; Baletti et al. 2012; Manzotti et al. 2014) of Upper Cretaceous age (75–73 Ma in the Pillonet klippe, Rb–Sr and $^{40}Ar/^{39}Ar$ dating: Cortiana et al. 1998), and by a greenschist facies regional overprint at decreasing pressure. Eocene (48–43 Ma) Rb–Sr ages have been recently provided by Angiboust et al. (2014) for the Dent Blanche frontal thrust over the ophiolitic Combin (Tsaté) zone. The polydeformed mylonitic basement rocks intimately associated to the Roisan metasediments and figured in the map Monte Cervino are mainly derived from igneous protoliths of the Arolla Series and minor paraschists.

Other remnants of the Mesozoic cover are preserved in the north-western edge of the Dent Blanche nappe (Mt Dolin area), over the frontal part of the Arolla unit (Hagen 1948; Ayrton et al. 1982; Burri et al. 1998; Angiboust et al. 2014; Manzotti et al. 2014). These remnants consist of Triassic dolostones, marbles and a thick sequence of sedimentary breccias of supposed Jurassic age. Late Triassic foraminifera were found in some dolomitic pebbles (Weidmann and Zaninetti 1974).

No traces of Mesozoic metasediments are reported from the eclogitic Lower Austroalpine outliers, derived from a Variscan or older metamorphic basement and Permian intrusives. Conversely, debated scattered remnants of cover units occur within the Eclogitic Micaschist Complex of the Sesia–Lanzo zone (Fig. 1), including quartzites, dolostones, marbles and metapelites (Scalaro unit, Venturini 1995; Rubatto and Gebauer 1997). Comparison with these Permian and/or Mesozoic cover slices is beyond the aim of this note and sent to future developments, as well as the classic Lower Austroalpine successions in the Central-Eastern Alps and related palaeostructural restoration (e.g., Roesli 1946; Masini et al. 2011).

3 Roisan lithofacies

The Roisan zone is characterized by the occurrence of various types of dolostones, marbles and ophiolite-free calcschists, which are intimately associated with grey-

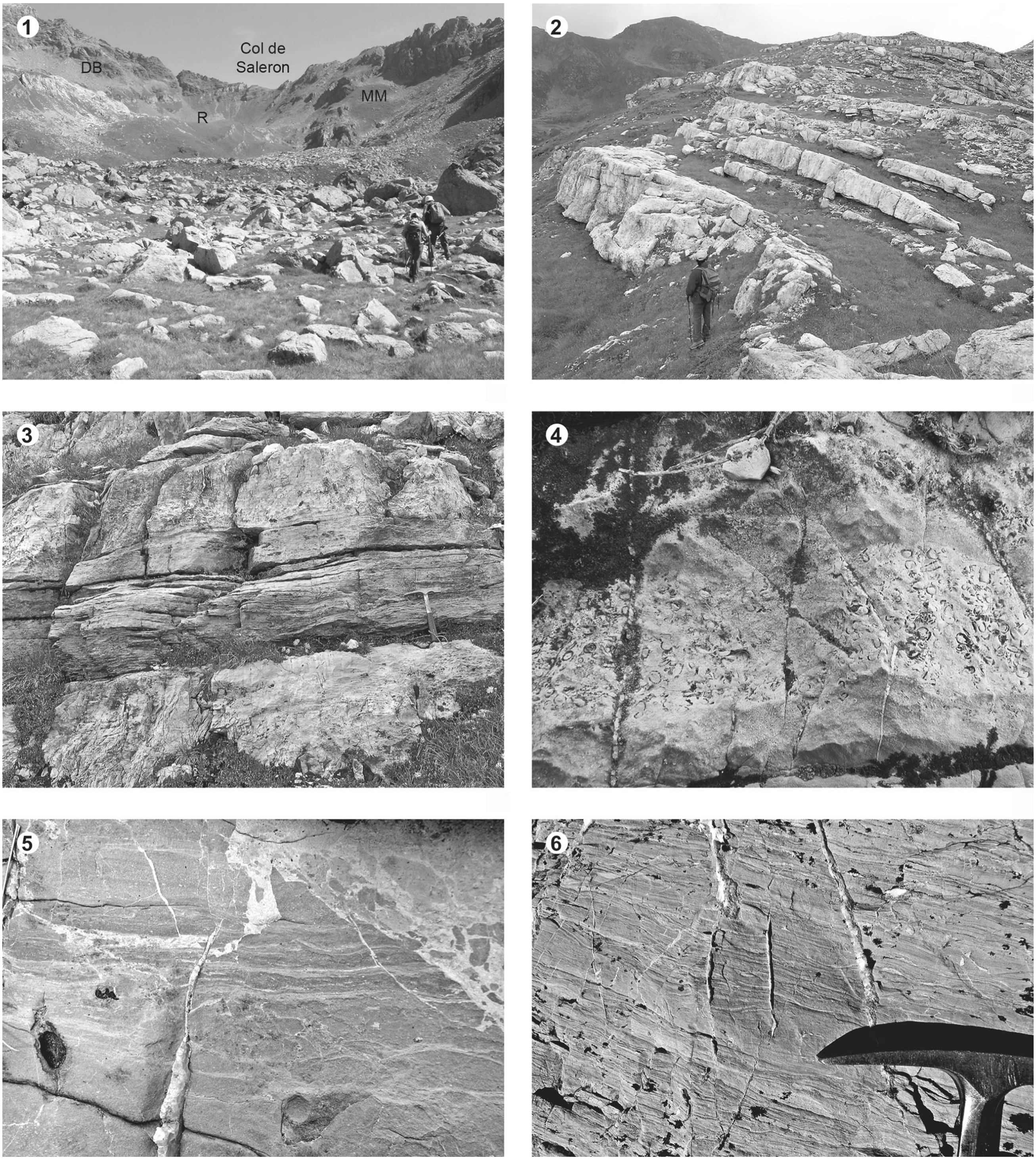


Fig. 2 Dolostones of the Roisan zone. **1** The Roisan zone (R), with dolostones, marbles and calcschists, is interposed between the Mont Mary-Cervino nappe (MM) and the Dent Blanche nappe (DB) as is clearly visible in the Col de Saleron area. **2** Thick-bedded dolostones nearby the road to Tsa de Chavalary (below Cunéy Sanctuary). This succession shows repeated cycles with thick massive banks separated by thin laminated levels that are very similar to the well-known lagoon-tidal flat cycles. **3** Detail of a laminated level situated between thick massive banks nearby the road to Tsa de Chavalary. **4** Massive bank with green algae (Dasicladales) on the eastern side of Grand Pays, above Alpe Léché. **5** Laminas very similar to planar stromatolites on the eastern side of the Grand Pays above Alpe Léché. **6** Dolostone with planar stromatolites on the top of the Grand Pays

greenish and dark mylonites coming from cover and basement protoliths. The primary features of these metasediments are generally effaced by the tectono-metamorphic overprint, with the exception of a few occurrences where the depositional environment can be recognized with good confidence.

3.1 Thick-bedded dolostones

Thick-bedded dolostones and dolomitic limestones are the most common and typical rocks of the Roisan zone. Usually they do not preserve clear traces of their sedimentary environment, but almost in few cases they can be surely referred to a shallow-water carbonate platform.

The best outcrops are on the right side of the high St Barhélemy valley below Col de Saleron (Saleron Combe) and nearby the road to Tsa de Chavalary (below the Cunéy Sanctuary). Special mention for fossils content and for preserved sedimentary structures is given to the dolostones of the Mont Grand Pays area.

(a) Near Tsa de Chavalary and in the Saleron Combe, these dolostones are regularly stratified and show repeated couples of massive beds and thin levels with planar lamination (Fig. 2-2, -3). These features are roughly similar to those of the classic sequences of carbonate platform with lagoon-tidal flat cycles, but no clear sedimentary structures are preserved, with the exception of some ghosts of stromatolites.

(b) The best outcrops of the Grand Pays area are on the divide between Comba Dèche and Comba di Chaleby and on its eastern slope, above the new Alpe Léché. The dolostones of Grand Pays show massive banks (1 m thick) sometimes with green algae (Fig. 2-4), beds with crenulated laminas very similar to planar stromatolites (Fig. 2-5, -6) and erosion surfaces followed by dolomitic breccias showing a very low sorting with angular to sub-rounded pebbles in fine matrix.

These features allow to refer the Grand Pays dolostones to a shallow-water carbonate platform, subjected to temporary erosional phases due to storms or small sea level fluctuations. Similar facies are well known in the Main Dolomite formation of the Southern Alps (Bosellini 1967) and also in the coeval Grezzoni formation of the Metamorphic Core of the Apuane Alps (Ciarapica and Passeri 1978).

3.1.1 Fossils in the Grand Pays dolostones

At the field observation the textures of the Grand Pays dolostones appear mainly as grainstone-packstone or mudstone-wakestone, but in thin section they are mostly a mosaic of fine-crystalline dolomite with ghosts of fossils. Fortunately, a well-preserved sample (GP 30, near the Grand Pays summit, coordinates UTM ED 50, 32°N: 378838/5073562) provided a rich association of foraminifers. The best-preserved forms are *Aulotortus friedli* (Kristan-Tollmann), *Aulotortus sinuosus* Weynschenk, *Aulotortus tenuis* (Kristan), *A. communis* (Kristan), *Gandinella falsofriedli* (Salaj, Borza and Samuel), *Glomospirella expansa* (Kristan-Tollmann) and *Glomospirella* spp. (Fig. 3).

This association can be referred to a generic Late Triassic age, but the presence of *A. friedli* and the absence of *A. praegaschei* (Koehn-Zaninetti) and other typical foraminifers let us to exclude a Carnian age; on the other hand, the small size of the foraminifers and the absence of *Triasina hantkeni* and *Auloconus permodiscoides* exclude the Rhaetian (intended as the uppermost part of the Late Triassic, waiting for the Norian-Rhaetian boundary definition) (Tunaboylu et al. 2014). It is important to point out that the foraminifers mentioned above come from a single sample and we do not know the stratigraphic extension of the whole outcropping succession.

Dasycladalean algae were also found, well observed only on the weathered surfaces (Fig. 4). They are present in two outcrops, near the top of Mt Grand Pays and along the eastern slope down to Léché hut. Those coming from the latter outcrop, better preserved, are comparable to both *Griphoporella curvata* and *Gyroporella vesiculifera* (Barattolo pers. com.) that are very common in Late Triassic dolostones of the Alps and Apennines. Their diameter ranges from 2 to 5 mm.

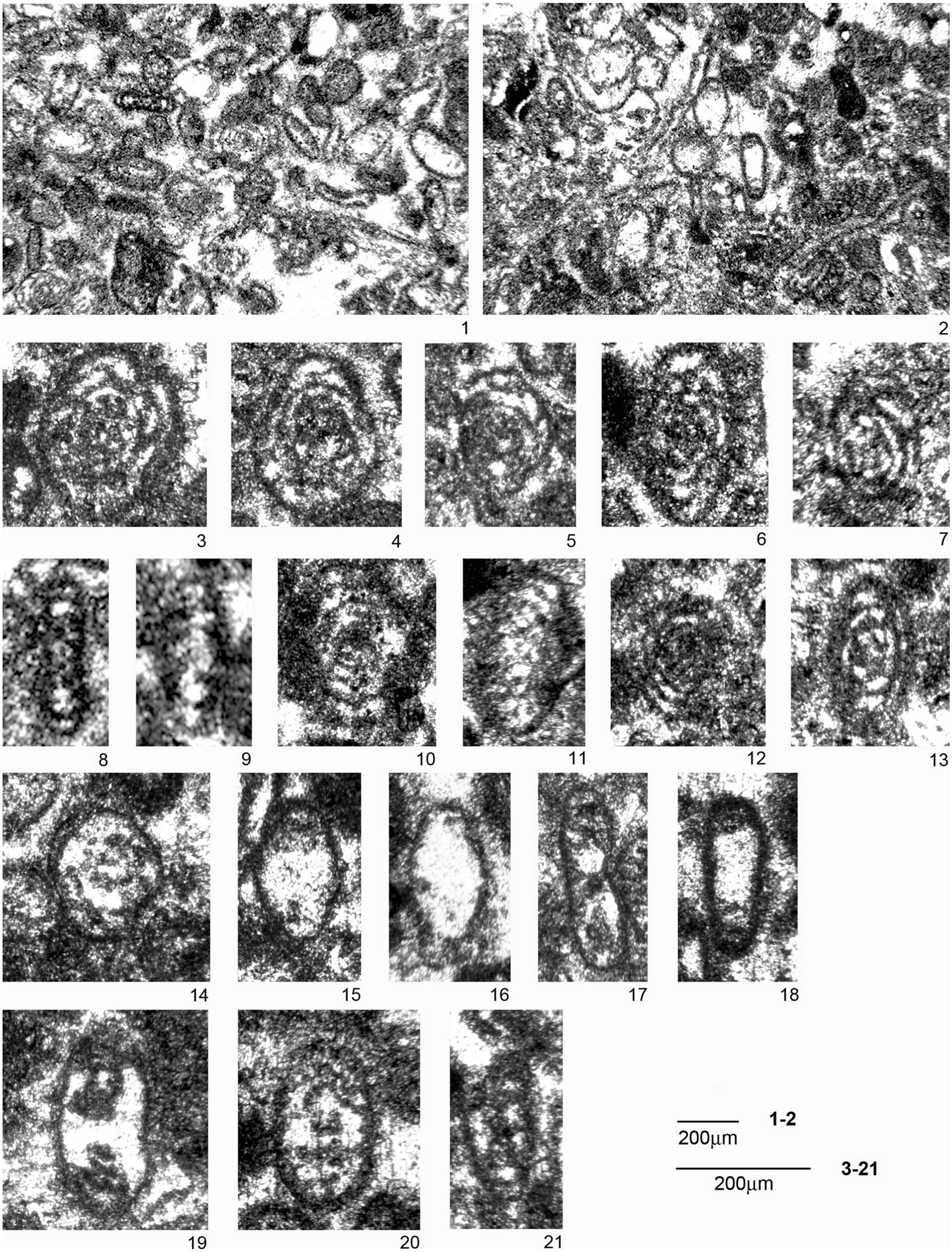
In conclusion, the fossil content is representative of the middle part of the Late Triassic (Norian), the same age inferred from the fossils found in the reworked pebbles of the Mt Dolin breccia (Weidmann and Zaninetti 1974).

3.2 Marbles

They are tabular grey, or more rarely white, pure marbles with coarse crystalline texture. No fossils or sedimentary structures are preserved. They outcrop in the Tsa de Chavalary area, on the top of Cima Bianca (Fig. 5-1), on the Comba de Chavacour and below the Col de Saleron. They can derive from massive limestones. Near Tsa de Chavalary and in the Col de Saleron area, these marbles are interposed between the thick-bedded dolostones and the marbles with quartz.

3.3 Marbles with quartz

They are a peculiar facies of the Roisan zone, always associated to the previous ones with a gradual transition. Alternated beds of pure marble, marble with quartz grains and thin quartzite without carbonates characterize them (Fig. 5-2, -3). They are well exposed along the road to Tsa de Chavalary, on the top of Cima Bianca, on the top of the carbonate succession in the Saleron Combe and in the


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
200μm 1-2
200μm 3-21

◀**Fig. 3** Foraminifers in the Grand Pays dolostones. **1**, **2** Microfacies of the sample GP 30 (2.1-thin section GP 30A and 2.2-thin section GP 30B). **3–7** *Gandinella falsofriedli* (Salaj, Borza and Samuel), thin section GP 30A. **8**, **9** ?*Glomospirella expansa* (Kristan-Tollmann), thin section GP 30A. **10–13** *Glomospirella* spp. (2.10–2.12 thin section GP 30A, 2.13 thin section GP 30C). **14** *Aulotortus friedli* (Kristan-Tollmann), thin section GP 30C. **15**, **16** *Aulotortus communis* (Kristan), thin section GP 30B. **17**, **18** *Aulotortus tenuis* (Kristan), thin section GP 30B. **19–21** *A. sinuosus* Weynschenk, thin section GP 30B

southern side of Chateau des Dames. They are few meters thick and are often pervasively folded.

Grains of quartz are floating in coarse crystalline calcite or are densely packed in repeated beds suggesting that they derive by quartzarenites and not by chert.

3.4 Thin-bedded white marbles with calcirudites

Thin-bedded white marbles and dolomitic limestones are easily visible along and nearby the path above the western side of Tsan Lake. Beds are 30–40 cm thick (Fig. 6-1) and thin levels of schist or quartzite separate them. Bands of quartzite appear to be derived by metamorphism of chert. Conglomerates are present only in few places; the best outcrops are on the right side of Comba de Chavacour to the west of Tsan Lake. They contain sub-rounded to sub-angular pebbles and can be monogenic, with only marble pebbles (Fig. 6-2), or polygenic, with a mix of dolostone and marble pebbles (Fig. 6-3). Pebbles derived by quartzite or by basement rocks have not been found. These conglomerates can be grain-supported or matrix-supported (Fig. 6-2, -3); in the last case, pebbles are sometimes floating in fine-grained schists (Fig. 6-3). Fine-grained calcirudites are also present in the upper part of the eastern ridge of Mont Blanc du Creton in tectonic contact above the Arolla Gneiss.

Thin-bedded marbles with quartzite bands, probably derived by chert, and banks of reworked pebbles suggest that this lithofacies is referable to a basin environment. The strong deformations of the Roisan zone prevent to define the field relations with the other lithofacies, but the presence of conglomerates, containing marble and dolomitic pebbles, evidences that these thin-bedded marbles with calcirudites are younger of the previously described lithofacies.

3.5 Calcschists

They are ophiolite-free calcschists, containing carbonates, white mica, quartz, chlorite and epidote in variable amount from place to place. They are often associated to grey schists and show a rusty patina. Some calcschists are very rich in carbonate and they appear as "dirty" marbles (Fig. 7-1); others contain abundant terrigenous grains, mainly recrystallized quartz and mica (Fig. 7-2). Their sedimentary environment can be referred to a basin with shales, marls and a variable amount of terrigenous grains. The unspecified presence of rare Belemnites in the lower part of calcschists (Ballèvre et al. 1986) cannot be confirmed.

3.6 Other kinds of rocks

(a) Quartz-mylonites. White and greenish quartz-mylonites are quite common (ridge E–W of Cima Bianca, Mt Morion). The lithofacies rich in albite can derive from basement rocks, but we cannot exclude that some quartz-mylonites can derive from the siliciclastic lower part of the sedimentary cover.

(b) Fe–Mn quartzite. To the Roisan zone was originally referred also the single occurrence of very finely banded Fe–Mn quartzite discovered by Ballèvre and Kienast (1987) inside the folded Arolla gneiss NW of Cignana Lake, although some doubts existed about the pertinence of this lithofacies to the Roisan zone rather than to the Piedmont. Recent dating of allanite grains provided Permian (around 280 Ma) and Early to Middle Jurassic ages (190–160 Ma) (Manzotti et al. 2012). Due to the presence of pre-Alpine amphibolite-facies relics in some associated marble succession, this facies of the Cignana Lake is thought to be representative of the pre-Triassic basement (Manzotti 2011).

Everywhere else, the Fe–Mn quartzite are generally considered as the metamorphic equivalent of the radiolarian-bearing beds with Mn, that are known in oceanic and in epicontinental Jurassic sequences of the Southern Alps and Northern Apennines. As these, they are referable to a deep-water environment.

4 The problematic stratigraphy of the Roisan zone

Contacts among the various lithofacies of Roisan are transposed by polyphase ductile shear and rootless folding. Although the general concordance could often simulate a primary succession, the internal structural setting of the Roisan zone prevents a clear and complete reconstruction of the whole stratigraphic sequence. For this reason we cannot describe a stratigraphic section, but we can only discuss some hypotheses in order to understand the possible relations that had existed among the previously described lithofacies before the orogenesis.

1. As pointed out by Ballèvre et al. (1986), no traces of tabular quartzite, like the classic occurrences of generally accepted Permian to eo-Triassic age from the Briançonnais

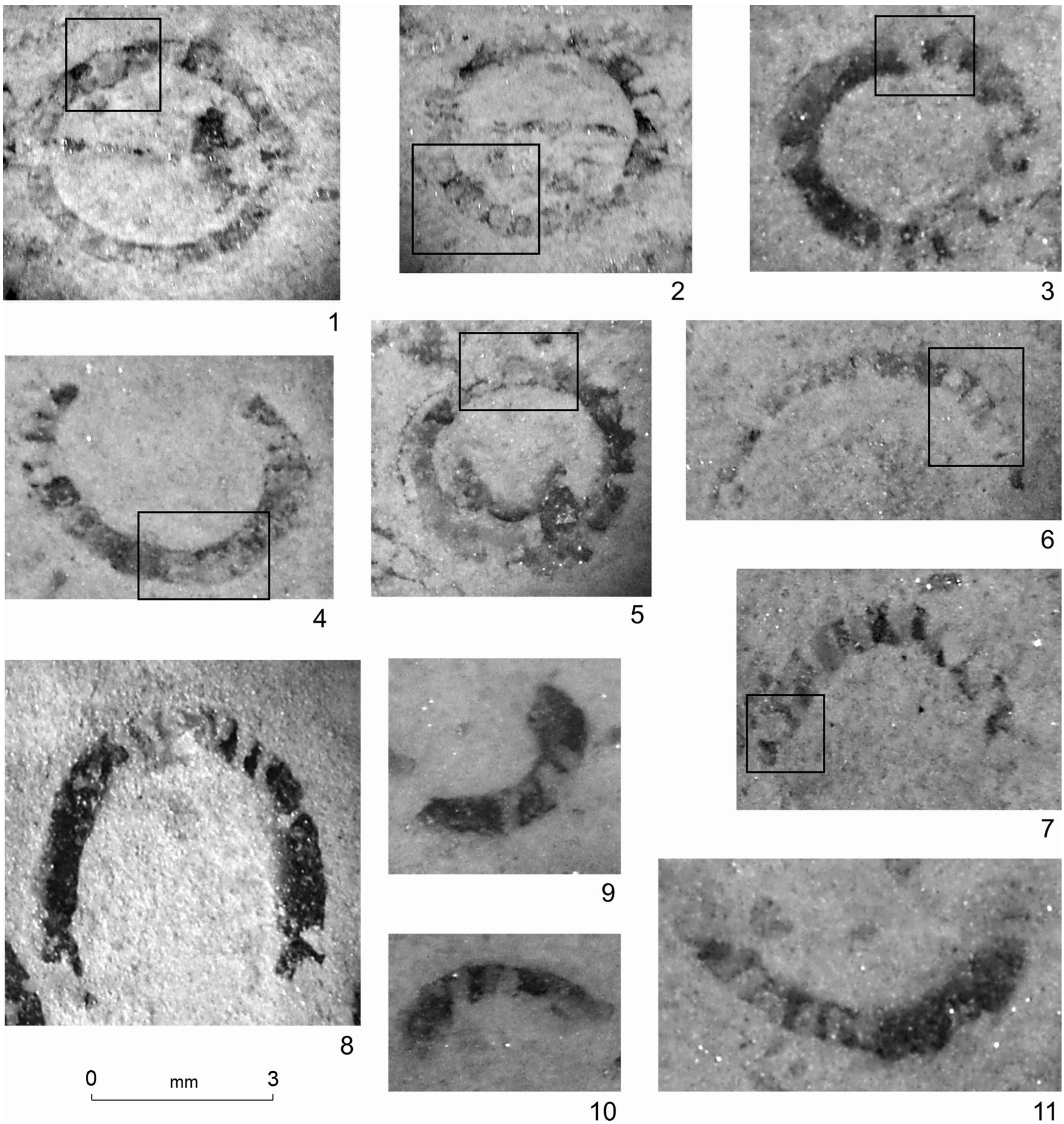


Fig. 4 Various sections of green algae (Dasycladales) in the Gran Pays dolostones. In the *boxes*, the ampolliform branches are evidenced

and Pancherot-Cime Bianche (PCB) cover units (Dal Piaz et al. 2015 and refs. therein), have been found in the entire Roisan zone (the "metamorphic conglomerates" mapped by Höpfer 1997, in the central Roisan zone are actually cataclastic to mylonitic augengneiss of the Arolla unit). Therefore, the outcrops of Roisan zone cannot be older than the Middle Triassic.

2. In some relatively less deformed zones, two very similar geometric successions were found: one on the right side of the valley below the Col de Saleron, the other nearby the road to Tsa de Chavalary (St. Barthélemy valley).

(a) Combe of the Col de Saleron. On the right side of this valley the following succession, from bottom to top, is

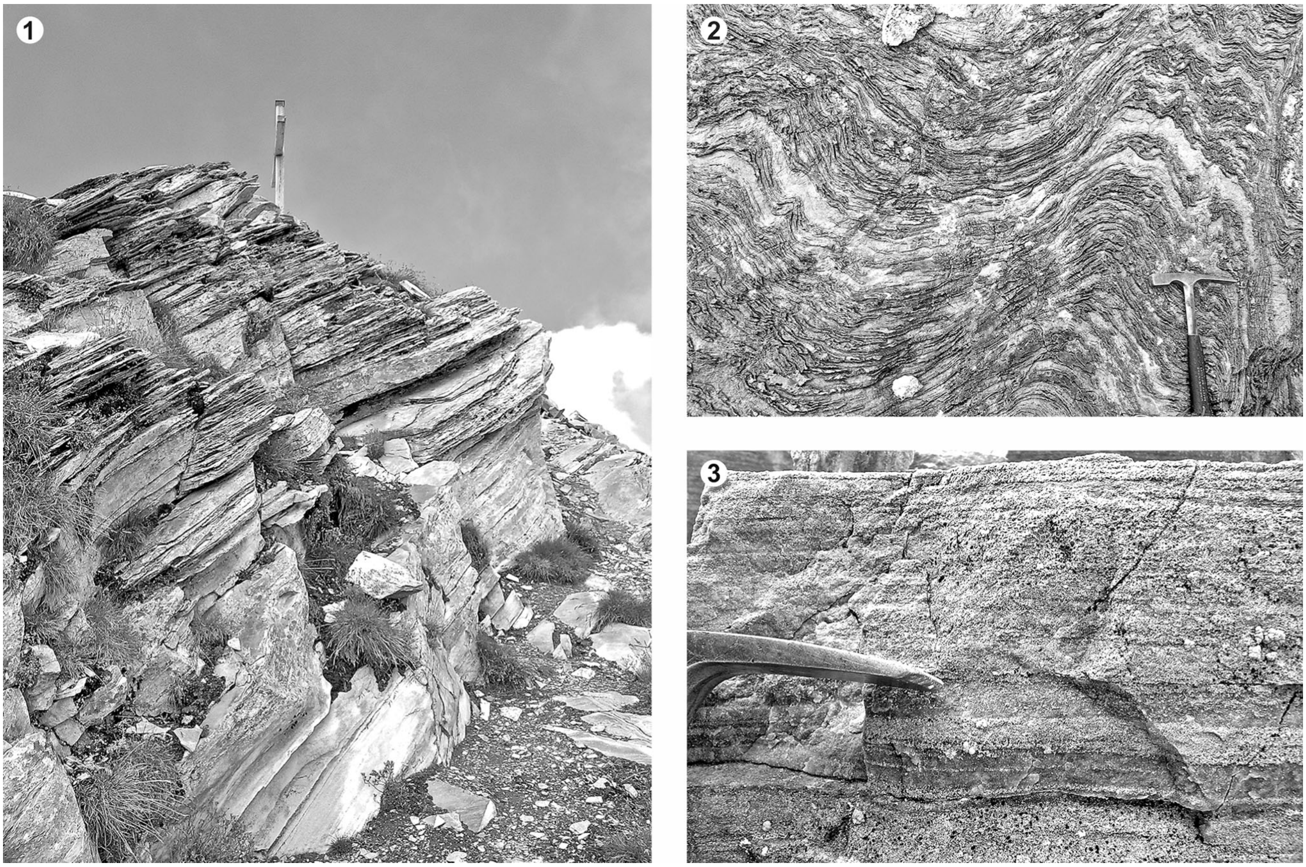


Fig. 5 Marbles and marbles with quartz in the Roisan zone. **1** Tabular *grey* marbles on the top of Cima Bianca. **2** Marble with quartz along the road to Tsa de Chavalary. **3** Beds of quartzite alternated with thin bands of marble on the top of Cima Bianca

cropping out: (a) regularly bedded dolostones and dolomitic limestones, with 1-1.5 m thick beds (50–60 m ca); (b) dolomitic limestones and massive dolostones, with disharmonic basal contact (50 m ca); (c) tabular grey marbles with two horizons of green chlorite schists (10–15 m); (d) marbles with thin bands of pervasively folded quartzarenites (4–5 m). Basement rocks of the Dent Blanche nappe cut off this Roisan succession.

(b) Tsa de Chavalary. Also in this area a quite similar succession is cropping out along and nearby the road to Tsa de Chavalary. From bottom: (a) thick-bedded dolostones with couples of massive banks and thin laminated levels rhythmically repeated. In some case laminas look like planar stromatolites; (b) a thin level of grey marble; (c) grey marbles with quartzarenites. Thick-bedded dolostones lie above calcschists, but the contact is not exposed.

The original stratigraphic order of these sequences is undefined due to the absence of clear sedimentary indicators. A Norian age has been recognized for the thick-bedded dolostones, the overlying marbles can be referred to the Rhaetian—Hettangian interval in the case of direct successions or to the Ladinian—Carnian if they are reversed.

Early Jurassic massive limestones and pure marbles are typical of the Northern Apennines and of the Apuane Metamorphic Core Complex; moreover, Early Jurassic limestones overlie the Triassic dolostones along the entire Southalpine area. This observation favours the hypothesis of a Rhaetian—Early Jurassic age rather than a Ladinian—Carnian age for the Roisan marbles. Some doubts still remain because the presence of quartz grains induces further considerations: quartzarenites need a source from a continental area subject to prolonged weathering. In the Adriatic margin quartzitic facies were quite common during the Early Triassic and Carnian rather than during the Raetian and Jurassic, but quartzarenites are also known in some Rhaetian and Hettangian sequences of southern Tuscany (Gandin 2012).

3. The thin-bedded marbles with calcirudites ought to be younger than the thick-bedded dolostones and marbles and they are older than the main body of calcschists.

4. The ophiolite-free calcschists mark the transition from a pre-orogenic, drifting situation (impure marbles and carbonate-rich calcschists) to early syn-orogenic conditions (terrigenous calcschists, sometime like a flysch): their age may be bracketed between the Middle Jurassic and the

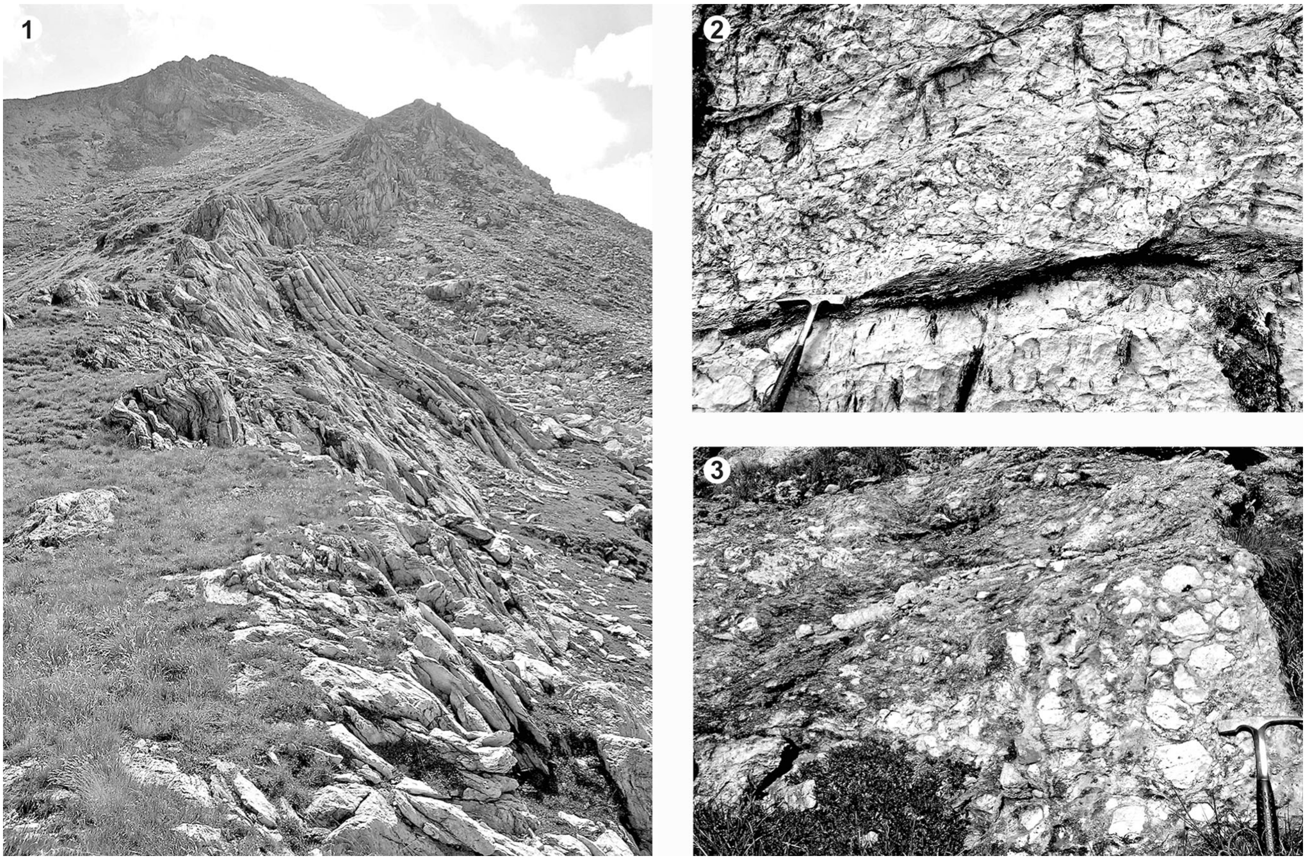


Fig. 6 Thin-bedded marbles and calcirudites in the Roisan zone. **1** Thin-bedded marbles and dolomitic limestones in the eastern part of the Comba di Chavacour, to the west of Tsan Lake. **2** Grain-supported calcirudites, inside the thin-bedded marbles to the west of Tsan Lake. Pebbles are made of calcite. **3** Calcirudites to the west of Tsan Lake. The grain-supported lower part contains pebbles of marble and dolostone. Pebbles in the upper part are floating in phyllitic matrix

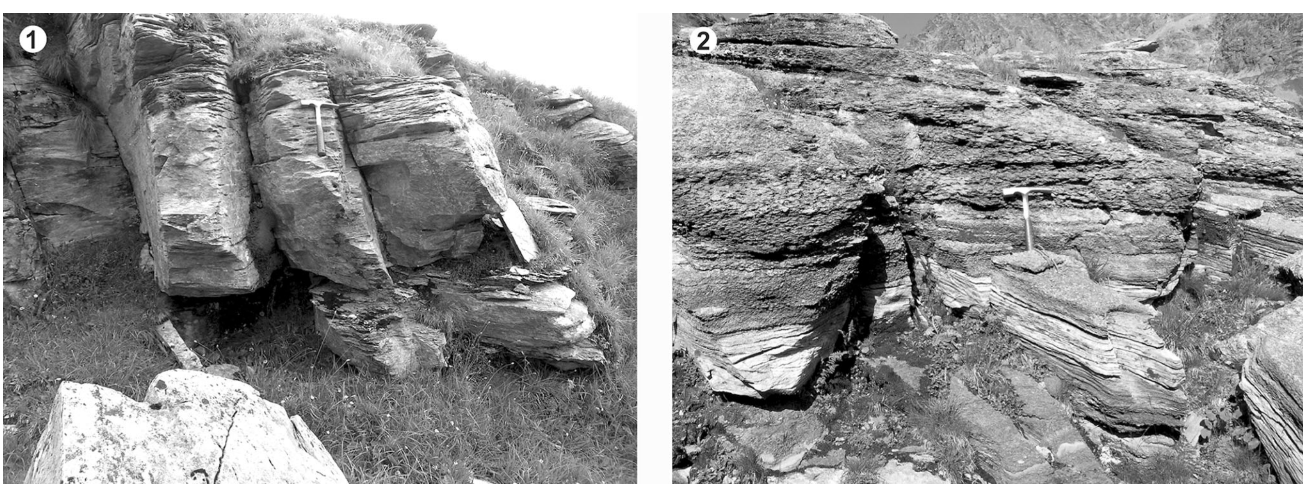


Fig. 7 Calcschists of the Roisan zone. **1** Calcschists very rich in carbonate (Combe de Saleron). **2** Terrigenous calcschists near Erbion

early Late Cretaceous by comparison with the Piedmont zone and considering the constraint provided by the relatively high-P imprint in the Pillonet basement (75–73 Ma; Cortiana et al. 1998) closely associated to Roisan-type impure marbles.

In conclusion, these observations allow to rough out the following (probably incomplete) sedimentary succession: (a) thick-bedded dolostones (Norian), (b) tabular marbles and marbles with quartz (Rhaetian—Lower Jurassic?), (c) thin-bedded marbles with calcirudites (Lower and

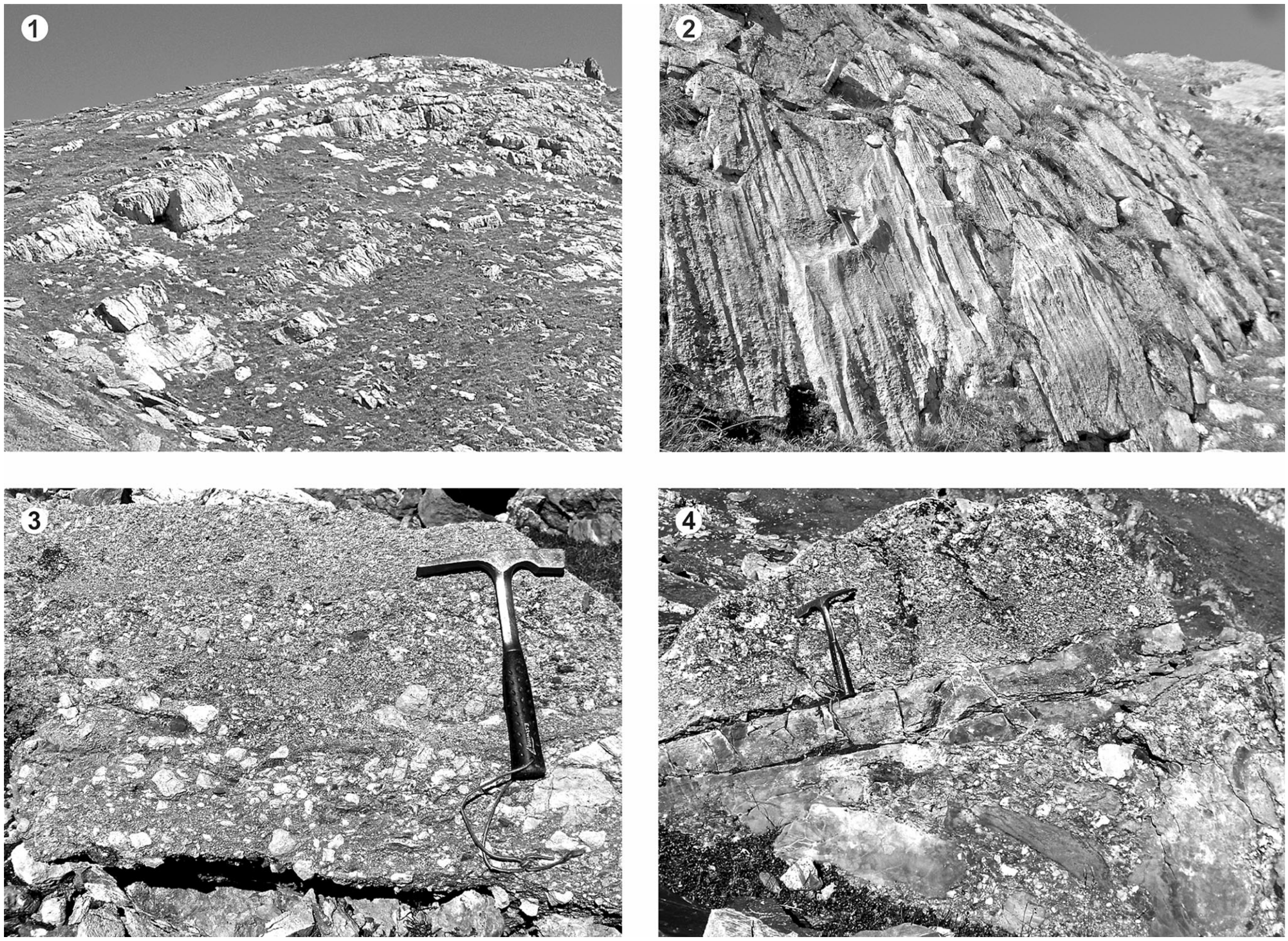


Fig. 8 Lithofacies of Mt Dolin (Swiss part of the Dent Blanche nappe). **1** Thick-bedded dolostones along the southern side of Petit Mt Rouge (Mt Dolin). **2** *Dark-grey* marbles laying over the thick-bedded dolostones (Mt Dolin). **3** Monogenic graded breccias of *dark-grey* marbles along the southern side of Petit Mt Rouge (Mt Dolin). **4** Polygenic breccias on the northern side of Mt Dolin

Middle Jurassic?), (d) pre-orogenic impure marbles and calcschists (Middle Jurassic to Lower Cretaceous?), (e) syn-orogenic calcschists with abundant terrigenous grains (probably from the Upper Cretaceous).

5 Comparison with the Mt Dolin succession

The Mt Dolin succession was fully described by Hagen (1948), Weidmann and Zaninetti (1974) and Burri et al. (1998). It belongs to the Swiss part of the Dent Blanche nappe (Fig. 1). The meta-sedimentary rocks of Mt Dolin and Petit Mt Rouge lay on the Arolla orthogneiss by means of a discontinuous sheet of grey-greenish mylonites from granitoids and gabbro protoliths. They are fragmented in various tectonic elements to which the following stratigraphic succession can be inferred.

1. Quartz conglomerates and fine quarzites, described by Burri et al. (1998).
2. Massive and thick-bedded dolostones, referable to a Late Triassic age (Fig. 8-1).
3. Dark grey, coarse crystalline marbles, lying above the dolostones (Fig. 8-2) (Early Jurassic?).
4. Dark grey marbles with calcarenites, fine calcirudites and monogenic breccias of dark grey marble (Fig. 8-3).
5. Polygenic breccias (Middle Jurassic?) that are the more typical and thick lithofacies of the Mt Dolin succession; their thickness probably exceeds 60 m. The size of the clasts is variable from few mm to many dm and sorting is very low. Pebbles are dark grey marbles and dolostones (Fig. 8-4). Late Triassic fossils described by Weidmann and Zaninetti (1974) come from dolomitic pebbles found in these polygenic breccias.

The succession of Mt Dolin shows a transition from shallow-water environments (thick-bedded dolostones and marbles) to a slope where angular pebbles of Jurassic marbles and Triassic dolostones were carried down by gravity flows. These polygenic breccias have to be related to normal faults that dissected the preexisting environment, at least from the Early-Middle Jurassic (Beltrando et al. 2014; Manzotti et al. 2014).

The Mt Dolin succession supports our reconstruction of the sedimentary evolution occurred in the Roisan zone, but if some lithofacies are similar, others are very different. Late Triassic thick-bedded dolostones followed by tabular marbles are present in both the successions, but in the Roisan zone marbles contain quartzarenites that seem to be lacking in the Mt Dolin succession. Moreover rudites are very polygenic and thick in the Mt Dolin whereas they are sporadic with only carbonate pebbles in the Roisan outcrops.

6 Conclusions

Although the Roisan zone was strongly deformed, the following succession of lithofacies has been recognised: (a) Late Triassic thick-bedded dolostones, (b) tabular marbles and marbles with quartzarenites, (c) thin-bedded white marbles with calcirudites, (d) calcareous schists and terrigenous calcschists. This succession is in part similar and in part different from that of the Mt Dolin. Both contain the same Late Triassic dolostones and the same Early Jurassic (?) marbles, but the Mt Dolin succession is characterized by large amount of monogenic and polygenic rudites that are very rare in the Roisan outcrops. Conversely, calcschists are more abundant in the Roisan zone.

Both the successions belong to the Jurassic northwestern margin of Adria Plate that from the Late Triassic were dissected by normal faults anticipating the spreading of the Alpine Ocean. The differences in rudites and calcschists content suggest that the Mt Dolin succession was settled down in the inner, proximal part of a slope, whereas the Roisan was in a more distal area, or even in a different sub-basin (half-graben?) as proposed by Manzotti et al. (2014). Obviously, no direct relationships can be established between these successions that belong to two different nappes.

Despite many still unsolved problems, this analysis of the Roisan litostratigraphy and sedimentology, the comparison with Mt Dolin, the description of Dasycladales and the first finding of foraminifers in the Italian part of the Dent Blanche nappe s.l. represent a new important step in the knowledge of the Western Alps history.

References

Angiboust, S., Glodny, J., Oncken, O., & Chopin, C. (2014). In search of transient subduction interfaces in the Dent Blanche-Sesia tectonic system (W. Alps). *Lithos, 205*, 298–321.

Argand, E. (1908). Carte géologique du massif de la Dent Blanche, 1:50.000. *Matériaux pour la Carte géologique de la Suisse, N.S., 23, carte spécial n. 52, Berne*.

Argand, E. (1909). L'exploration géologique des Alpes pennines centrales. *Bulletin de la Société Vaudoise des Sciences naturelle, 45*, 217–276.

Ayrton, A., Bugnon, C., Haarpainther, T., Weidmann, M., & Frank, E. (1982). Géologie du front de la Nappe de la Dent-Blanche dans la région des Mont-Dolins, Valais. *Eclogae Geologicae Helvetiae, 75*(2), 269–286.

Baletti, L., Zanoni, D., Spalla, M. I., & Gosso, G. (2012). Structural and petrographic map of the Sassa gabbro complex (Dent Blanche nappe, Austroalpine tectonic system, Western Alps, Italy). *Journal of Maps, 8*(4), 413–430.

Ballèvre, M., & Kienast, J. R. (1987). Découverte et signification de paragenèses à grenat-amphiboles bleues dans la couverture mésozoïque de la nappe de la Dent- Blanche (Alpes occidentales). *Compte Rendus de l'Académie des Sciences de Paris, 305*, 43–47.

Ballèvre, M., Kienast, J. R., & Vuichard, J. P. (1986). La "nappe de la Dent Blanche" (Alpes occidentales): deux unités austroalpines indépéndantes. *Eclogae Geologicae Helvetiae, 79*, 57–74.

Ballèvre, M., & Merle, O. (1993). The Combin Fault: reactivation of a detachment fault. *Schweizerische Mineralogische und Petrographische Mitteilungen, 73*, 205–227.

Beltrando, M., Manatschal, G., Mohn, G., Dal Piaz, G. V., Brovarone, A. V., & Masini, E. (2014). Recognizing remnants of magma-poor rifted margins in high-pressure orogenic belts: the Alpine case study. *Earth-Science Reviews, 131*, 88–115.

Bosellini, A. (1967). La tematica deposizionale della Dolomia Principale. *Bollettino della Società Geologica Italiana, 86*, 133–169.

Bucher, K., Dal Piaz, G.V., Oberhänsli, R., Gouffon, Y., Martinotti, G., & Polino, R. (2003–2004). Blatt 1347-Matterhorn, Erleuterungen. *Atlas géologique de la Suisse 1:25.000, Service hydrologique et géologique national, Berne, 107*, p. 73.

Burri, M., Alliman, M., Chessex, R., Dal Piaz, G.V., Della Valle, G., Du Bois, L., Gouffon, Y., Guermani, A., Hagen, T., Krummenacher, D., & Looser, M.O. (1998). Feuille 1346 Chanrion, avec partie nord de la feuille 1366 Mont Vélan. *Atlas géologique de la Suisse 1:25.000, Service hydrologique et géologique national, Berne.*

Bussy, F., Venturini, G., Hunziker, J. C., & Martinotti, G. (1998). U-Pb ages of magmatic rocks of the western Austroalpine Dent-Blanche-Sesia Unit. *Schweizerische Mineralogische und Petrografische Mitteilungen, 78*, 163–168.

Canepa, M., Castelletto, M., Cesare, B., Martin, S., & Zaggia, L. (1990). The Austroalpine Mont Mary nappe (Italian Western Alps). *Memorie di Scienze Geologiche, 42*, 1–17.

Ciarapica, G., Dal Piaz, G. V., & Passeri, L. (2010). Late Triassic microfossils in the Roisan zone, Austroalpine Dent Blanche-Mont Mary nappe system, NW-Alps. *Rendiconti Online della Società Geologica Italiana, 11*, 261–262.

Ciarapica, G., & Passeri, L. (1978). I Grezzoni del nucleo Apuano: nascita, sviluppo e morte di una piattaforma carbonatica iperalina. *Bollettino della Società Geologica Italiana, 97*(4), 527–564.

Cortiana, G., Dal Piaz, G. V., Del Moro, A., Hunziker, J. C., & Martin, S. (1998). ^{40}Ar-^{39}Ar and Rb-Sr dating on the Pillonet klippe and frontal Sesia-Lanzo zone in the Ayas valley and evolution of the western Austroalpine nappe stack. *Memorie di Scienze Geologiche, 50*, 177–194.

Dal Piaz, G.V. (1976). Il lembo di ricoprimento del Pillonet, falda della Dent Blanche nelle Alpi occidentali. *Memorie degli Istituti di Geologia e Mineralogia dell'Università di Padova, 31*, p. 60.

Dal Piaz, G.V. (1992a). Le Alpi dal M. Bianco al Lago Maggiore. I Volume: 13 itinerari. *Guide Geologiche Regionali, Società Geologica Italiana, BE-MA Milano, 3/1,* p. 311.

Dal Piaz, G.V. (1992b). Le Alpi dal M. Bianco al Lago Maggiore. II Volume: 97 escursioni a piedi. *Guide Geologiche Regionali, Società Geologica Italiana, BE-MA Milano, 3/2,* p. 209.

Dal Piaz, G.V. (1993). Evolution of Austro-Alpine and Upper Penninic basement in the northwestern Alps from Variscan convergence to post-Variscan extension. In J. Von Raumer & F. Neubauer (Eds.) *Pre-Mesozoic geology in the Alps* (pp. 327–344). New York: Springer.

Dal Piaz, G.V. (1999). The Austroalpine-Piedmont nappe stack and the puzzle of Alpine Tethys. In G. Gosso et al. (Eds.) *3rd Workshop on Alpine Geological Studies, Memorie di Scienze Geologiche, Biella-Oropa, September 29th-October 1st 1997* (pp 155–176), vol. 51.

Dal Piaz, G.V., Bistacchi, A., Gianotti, F., Monopoli, B., Passeri, L., et al. (2015). Foglio 070 Monte Cervino e Note Illustrative. *Carta Geologica d'Italia alla scala 1:50.000, ISPRA, Servizio Geologico d'Italia.*

Dal Piaz, G.V., Bistacchi, A., & Massironi, M. (2003). Geological outline of the Alps. *Episodes, 26/3 September 2003,* 174–179.

Dal Piaz, G. V., Cortiana, G., Del Moro, A., Martin, S., Pennacchioni, G., & Tartarotti, P. (2001). Tertiary age and paleostructural inferences of the eclogitic imprint in the Austroalpine outliers and Zermatt-Saas ophiolite, Western Alps. *International Journal of Earth Sciences, 90*, 668–684.

Dal Piaz, G. V., De Vecchi, G. P., & Hunziker, J. C. (1977). The Austroalpine layered gabbros of the Matterhorn and Mt Collon-Dents de Bertol. *Schweizerische Mineralogische und Petrografische Mitteilungen, 57*, 59–88.

Dal Piaz, G. V., & Martin, S. (1988). Dati microchimici sul metamorfismo alpino nei lembi Austroalpini del Pillonet e di Chatillon (Valle d'Aosta). *Rendiconti della Società Geologica Italiana, 9*(1986), 15–16.

De Giusti, F., Dal Piaz, G. V., Massironi, M., & Schiavo, A. (2004). Carta geotettonica della Valle d'Aosta. *Memorie di Scienze Geologiche, 55*(2003), 129–149.

Diehl, E.A., Masson, R., Stutz, A.H. (1952). Contributi alla conoscenza del ricoprimento Dent Blanche. *Memorie degli Istituti di Geologia e Mineralogia dell' Università di Padova, 17,* p. 53.

Elter, G. (1960). La Zona Pennidica dell'alta e media Valle d'Aosta e le unità limitrofe. *Memorie Istituto di Geologia e Mineralogia dell' Università di Padova, 22,* p. 113.

Gandin, A. (2012). Tectonic control on the sedimentary architecture of Early Mesozoic mixed siliciclastic-carbonate Pseudoverrucano successions (southern Tuscany, Italy). *Italian Journal of Geosciences, 131*(1), 77–94.

Gardien, V., Reusser, E., & Marquer, D. (1994). Pre-Alpine metamorphioc evolution of the gneisses from the Valpelline series (Western Alps, Italy). *Schweizerische Mineralogische und Petrographische Mitteilungen, 74*, 489–502.

Hagen, T. (1948). Geologie des Mont Dolin und des Nordrandes der Dent Blanche-Decke zwischen Mont Blanc de Cheillon und Ferpècle (Wallis). *Matériaux pour la Carte géologique de la Suisse (n.s.) 90.*

Höpfer, N. (1997). Sedimentäre Abfolge und Alpine Ueberprägung der Permotriassischen Roisan Zone (Südliche Austroalpine Dent Blanche Decke, Italienische Westalpen). *Bonner Geowissenschaftliche Schriften, 25,* p. 154.

Manzotti, P. (2011). Petro-structural map of the Dent Blanche tectonic system between Valpelline and Valtournenche valleys, Western Italian Alps. *Journal of Maps, 2011*, 340–352.

Manzotti, P., Ballèvre, M., Zucali, M., Robyr, M., & Engi, M. (2014). The tectonometamorphic evolution of the Sesia-Dent Blanche nappes (internal Western Alps): review and synthesis. *Swiss Journal of Geosciences, 107*(2), 309–332.

Manzotti, P., Rubatto, D., Darling, J., Zucali, M., Cenki-Tok, B., & Engi, M. (2012). From Permo-Triassic lithospheric thinning to Jurassic rifting at the Adriatic margin: petrological and geochronological record in Valtournenche (Western Italian Alps). *Lithos, 146–147*, 276–292.

Manzotti, P., & Zucali, M. (2013). The pre-Alpine tectonic history of the Austroalpine continental basement in the Valpelline unit (Western Italian Alps). *Geological Magazine, 150*, 153–172.

Masini, E., Manatschal, G., Mohn, G., Ghienne, J. F., & Lafont, F. (2011). The tectono-sedimentary evolution of a supra-detachment rift basin at a deep-water magma-poor rifted margin: the example of the Samedan Basin preserved in the Err nappe in the SE Switzerland. *Basin Research, 23*, 652–677.

Oberhänsli, R., Bousquet, R., Engi, M., Goffé, B., Gosso, G., Handy, M., Höck, V., et al. (2004). Metamorphic structure of the Alps 1:1.000.000. *Commission for the Geological Map of the World, Paris.*

Pennacchioni, G., & Guermani, A. (1993). The mylonites of the Austroalpine Dent Blanche nappe along the northwestern side of the Valpelline valley (Italian Western Alps). *Memorie di Scienze Geologiche, 45*, 37–55.

Roesli, F. (1946). Sedimentäre Zone von Samaden (Kt. Graubünden). *Eclogae Geologicae Helvetiae, 38*, 329–336.

Rubatto, D., & Gebauer, D. (1997). The Bonze Unit (Sesia-lanzo Zone, Western Alps): a gabbroid Early Carboniferous intrusion that recorded Hercynian and Alpine metamorphism. *Quaderni Geodinamica Alpina Quaternaria, 4*, 106–107.

Stutz, A.H., & Masson, R. (1938). Zur Tektonik der Dent Blanche Decke. *Schwezerische Mineralogisches und Petrographisches Mitteilungen, 18*, 40–53.

Tunaboylu, B. C., Altiner, D., Isintek, I., & Demirci, D. (2014). Foraminiferal biostratigraphy and sequence stratigraphy of peritidal carbonates at the Triassic-Jurassic boundary (Karaburun Peninsula, Western Turkey). *Journal of Asian Earth Sciences, 90*, 61–76.

Venturini, G. (1995). Geology, geochemistry and geochronology of the inner central Sesia zone (western Alps, Italy). *Mémoires de Géologie (Lausanne), 25*, 148.

Weidmann, M., & Zaninetti, L. (1974). Quelques données nouvelles sur la série du Mont-Dolin (par Wiedman) et Description des Foraminifères triasique (par Zaninetti). *Eclogae Geologicae Helvetiae, 67*(3), 597–603.