Voltzia recubariensis from the uppermost Angolo Limestone of the Bagolino succession (Southern Alps of Eastern Lombardy, Italy)

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Abstract

Bagolino is the Global Stratotype Section and point for the base of the Ladinian Stage, well known for its ammonoids, bivalves and conodonts, while plant remains have so far not been described. Recently a conifer shoot of *Voltzia recubariensis* was found in the Anisian Angolo Limestone of the Rio Riccomassimo section east of Bagolino. This discovery opened a taxonomic discussion. A detailed literature research confirmed the validity of the name *Voltzia recubariensis* against *V. agordica*. The plant remain confirms also the presence of emerged land near Bagolino during the Anisian, probably to the south. It confirms also that *V. recubariensis* was one of the most common taxa of the Anisian of the Southern Alps and suggests that the flora of the western border area of the Tethys ocean must have been quite uniform.

1. Introduction

The Anisian stratigraphic successions of eastern Lombardy and Giudicarie rank among the classic localities since the early research on the Alpine Middle Triassic (Lepsius, 1878; Bittner, 1881; Mojsisovics, 1882). Additional stratigraphical and paleontological results were gained during subsequent studies, especially in the last 50 years (e.g., Assereto, 1963, 1971; Assereto & Casati, 1965; Gaetani 1969, 1993; Balini, 1998; Balini et al., 1993; Brack & Rieber, 1986, 1993; Brack et al., 1999; Mietto et al, 2003). As a result of this research, the Global Stratotype Section and point for the base of the Ladinian Stage has been established in the stratigraphic succession at Bagolino (Brack et al., 2005). The main fossil taxa described from the upper Anisian to upper Ladinian units (Prezzo Limestone, Buchenstein Formation, Wengen Formation) include ammonoids, thin-shelled "pelagic" bivalves (e.g., *Daonella*) and conodonts (Brack et al., 2005). Only few ammonoid-bearing horizons are known also from older Anisian strata, i.e. from the uppermost part of the Angolo Limestone (Monnet et al., 2008). Hitherto even less frequent in the Anisian successions of this area are findings of sufficiently well preserved plant remains. So far only Bittner (1881, p. 247) mentions "*Voltzia recubariensis* Massal. spec." from nodular limestones with brachiopods below the village of Prezzo. Unfortunately no drawing or figure exists of Bittner's specimen, thus the attribution could not be verified.

In this paper we describe a *Voltzia recubariensis* shoot from the Anisian (uppermost Angolo Limestone) of the Rio Riccomassimo section east of Bagolino. This is the first unequivocal report of this species also from the western Southern Alps, but its distribution hitherto remains restricted to the Anisian of the Southern Alps.

2. Geological setting

The Middle Triassic sediments of eastern Lombardy and Giudicarie (Fig. 1) are part of the S- and SE-directed fold and thrust belt of the Southern Alps. Internal deformation varies strongly in these rocks but largely undeformed stratigraphic successions are exposed along the western flank of lower Val Camonica and also around Dosso dei Morti in Giudicarie. The Triassic successions between and northwest of these areas are thrusted and folded. Along the borders of the Adamello batholith they were cut and metamorphosed during the emplacement of the Eocene-Oligocene magmas. Another array of Triassic rocks is preserved south of a prominent thrust-related structural high between Val Camonica and Giudicarie. The uplifted portion north of the Val Trompia Line

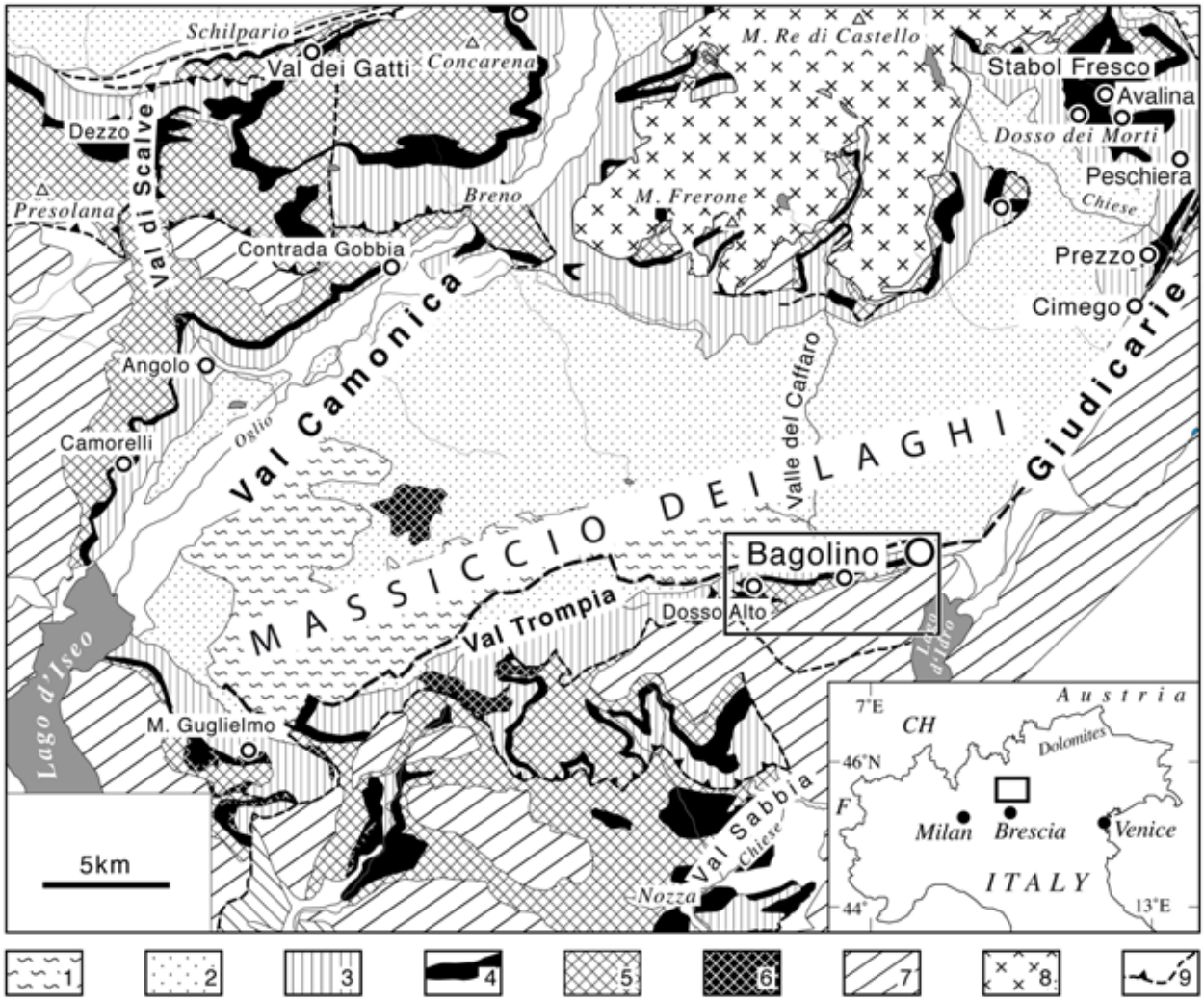

Figure 1: Geological overview map of the Brescian Prealps and adjacent areas with classical localities for the middle/upper Anisian (Middle Triassic) stratigraphy in eastern Lombardy-Giudicarie (modified after Brack et al., 2005). The black frame marks the Bagolino area as shown in Fig. 2 (big circle: Rio Riccomassimo section). 1) pre-Permian basement; 2) Permian to Lower Triassic including lowermost Anisian units; 3) mainly lower/middle Anisian units (Angolo Lst., Camorelli-Dosso dei Morti–M. Guglielmo Lst.); 4) upper Anisian–Ladinian pelagic successions (Prezzo Lst., Buchenstein and Wengen Fms.); 5) Ladinian/Carnian platform carbonates (Esino Lst., Breno Fm., Gorno Fm.) and age equivalent intra-platform deposits (Pratotondo Lst., Lozio Shales); 6) Ladinian/Carnian shallow intrusive rocks; 7) Norian–Rhaetian shallow water carbonates and basinal equivalents; 8) Tertiary Adamello plutonics; 9) major tectonic lines (faults and thrusts).

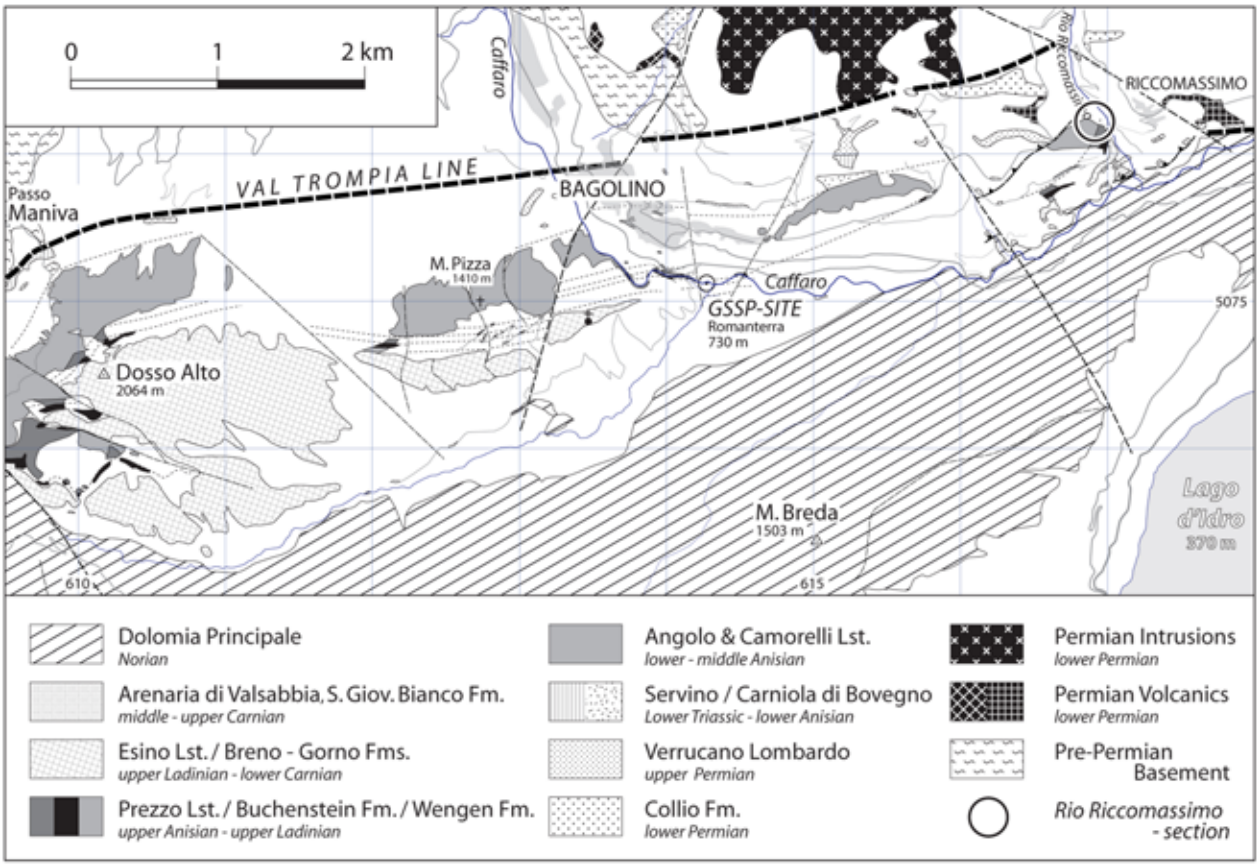

Figure 2 : Geological sketch map of the vertical to slightly overturned Middle Triassic succession in the surroundings of Bagolino (see Fig. 1 for location of map). The GSSP site marking the base of the Ladinian Stage is indicated. The Rio Riccomassimo section (circle) represents the easternmost outcrops of Middle Triassic rocks south of the Val Trompia Line.

is called the "Massiccio dei Laghi". Immediately south of this fault follow generally south-dipping Permian to Triassic sediments.

The Triassic sediments of Bagolino are located south of the Val Trompia Line and belong to a ca. 3 km thick and WSW-ENE trending prism of steeply dipping to slightly overturned strata. The stratigraphic succession ranges from Upper Permian redbeds (Verrucano Lombardo) in the north to a thick portion of upper Triassic Dolomia Principale in the south (Fig. 2).

In the western part of this prism, the Middle Triassic units dip around 60° towards SE and host the classical Dosso Alto section, known since Lepsius (1878). Further east the upright to overturned succession is dissected by a system of steeply dipping conjugate faults. Displacements along these faults range between several hundred metres and a few centimetres (visible, e.g., in the GSSP-outcrop in the Caffaro riverbed at Romanterra). Close to the hamlet of Riccomassimo the easternmost preserved Middle Triassic sediments are truncated by a fault. A possibly original continuation of these strata is found northeast of Ponte di Cimego, in a position displaced by more than ten kilometres along the Giudicarie Line s.s. (Fig. 1).

3. The Riccomassimo section east of Bagolino

Along the Rio Riccomassimo creek, between its junction with the Caffaro River (at ca. 500 m asl) and the road connecting Riccomassimo with Bagolino (at 870 m asl), the easternmost Middle Triassic sediments south of the Val Trompia Line are exposed (Fig. 3). The section is overturned and dips ca. 60° towards northwest. Stratigraphically it ranges from the Anisian *Angolo Limestone* to the Upper Triassic *Dolomia Principale*. Steeply dipping Permian sediments and volcanic rocks occur north of a reverse fault limiting the Triassic succession at the level of the Bagolino – Riccomassimo road. The sediments at the transition of the Carnian Val Sabbia Sandstone / San Giovanni Bianco Fm. and the basal Dolomia Principale are also cut by a supposedly northward dipping reverse fault. The stratigraphic succession between these faults has remained relatively intact. Because of the dense vegetation the exposures on the forested slopes as well as along Rio Riccomassimo are best visible during winter or in early spring.

The Middle Triassic units of the Rio Riccomassimo section are comparable with the well exposed successions at Romanterra and Dosso Alto, a few kilometres further west (Fig. 2).

The visible portion of the Angolo Limestone at Rio Riccomassimo reaches around 300 m and corresponds to the upper two thirds of the complete succession at Dosso Alto. There the formation is ca. 500 metres thick and follows on top of lowermost Anisian evaporates (Carniola di Bovegno). West of Rio Riccomassimo the Angolo Limestone can be examined along a trail following a water pipe at ca. 750 m level north of "Paradisi" (Fig. 3). It consists of irregularly thick bedded and partly nodular, strongly bioturbated limestone layers. Marly intercalations are usually thin but there are also intervals with up to 5 cm thick marls. The carbonate – marl alternations of the Angolo Limestone were most likely formed in a shallow and possibly restricted basin. Age diagnostic pelagic fossils (ammonoids) are known from the uppermost portion of Angolo Limestone sections in Valle Camonica / Val di Scalve and in Giudicarie (Monnet et al., 2008). At Dosso Alto a badly preserved internal mold (Steinkern) of a nautilid has been observed recently in debris from the lower part of the formation.

In the sections around Bagolino a prominent brachiopod lumachella occurs at the top of the Angolo Limestone (at Rio Riccomassimo this layer can be identified in the topographically deepest outcrops west of the creek). The fauna of the ca. 2–4 metres thick "brachiopod bed" is dominated by articulated and broken valves of *Coenothyris vulgaris*. In the area including Val Trompia, Val Sabbia and Giudicarie, this conspicuous interval can be traced over a few tens of kilometres. This level seems to coincide with a rapid deepening of the originally rather shallow depositional environment (e.g., Monnet et al., 2008).

Above the "brachiopod bed" a succession of pelagic strata comprises the Prezzo Limestone and the Buchenstein Formation. The limestone and shale layers of the Prezzo Lst. are nodular in the lower part and more evenly bedded in the upper section. Siliceous nodular limestone layers with only thin marly partings are characteristic for the Buchenstein Formation. As in Romanterra the Buchenstein Fm. hosts the same conspicuous greenish volcanoclastic layers known as "Pietra verde". In eastern Lombardy and Giudicarie the Anisian-Ladinian pelagic succession (Prezzo Lst., Buchenstein Fm.) is known for its ammonoid faunas. The base of the Ladinian Stage is located in the lower part of the Buchenstein Formation. (for further information see Brack et al., 2005).

Siliciclastic layers of the Wengen Formation are more than 40 m thick at Romanterra. In the Rio Riccomassimo section, as well as at Dosso Alto only a few of these layers occur. In both sections the Wengen Formation is largely replaced by slope deposits of a carbonate platform (Esino Limestone) and the Romanterra setting likely corresponds to a sort of channel between prograding carbonate platforms.

The succession above the partly dolomitic Esino Limestone at Rio Riccomassimo comprises carbonate layers with several prominent metre-thick intercalations of shale. This interval is tentatively referred to the Carnian Gorno Formation with intercalated reddish sandstones and siltstones of the Val Sabbia Sandstone in its upper part.

The shoot fragment of *Voltzia* discussed here is from a block of Angolo Limestone from the uppermost 50 metres of the formation, stratigraphically beneath the "brachiopod bed" (Figs. 3, 4). Based on the ammonoid faunas from sections in eastern Lombardy and Giudicarie this interval is Pelsonian in age and most likely corresponds to the *Balatonites ottonis* Zone or a slightly older level (Monnet et al., 2008).

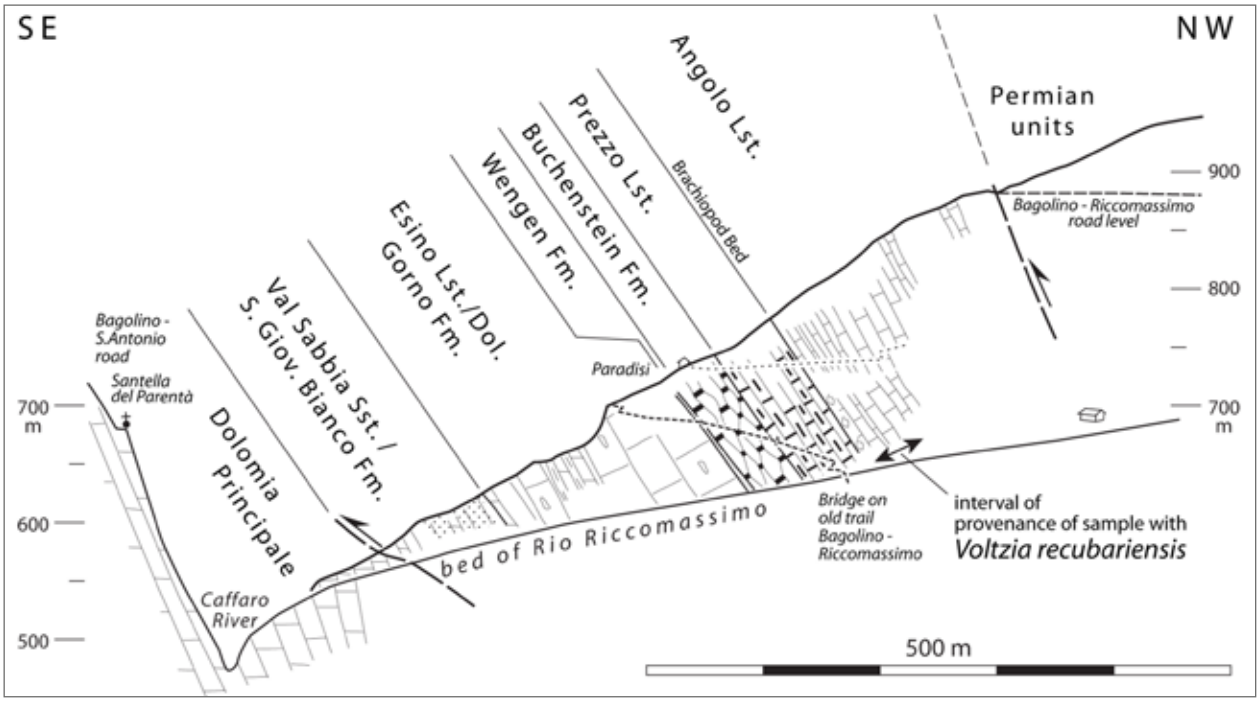

Figure 3: The overturned succession of Middle Triassic strata west of Rio Riccomassimo spans the upper part of the Angolo Lst. (middle Anisian) to the basal Dolomia Principale (Norian). The specimen with *Voltzia recubariensis* derives from the scree of the uppermost 50 metres of Angolo Lst., i.e. stratigraphicallybelow the "brachiopod bed".

4. Systematic palaeontology

Voltzia recubariensis (Massalongo ex De Zigno) Schenk, 1868
Figure 5

Selected synonymy:

1844 *Lycopodiolithes arboreus* Fuchs, p. 6. (*nomen nudum*)
1846 *Voltzia brevifolia* Catullo, p. 11-12, pl. 2, figs. 6a, b.
1850 *Araucarites agordicus* Unger, p. 382.
1850 *Araucarites agordicus* Unger, Hauer, p. 5, pl. 3, fig. 16.
1862 *Araucarites recubariensis* Massalongo ex De Zigno, p. 19-20, pl. 5, figs. 1, 2A-C, 3, 4.
1868 *Voltzia recubariensis* (Massalongo ex De Zigno) Schenk, p. 82-87, pls. 7-12.

The shoot fragment is 74 mm long and about 80 mm broad. From the main axis of 50 mm length and 2.5 mm width arise the falcate to triangular leaves with a wide helix. The single leaves are very leathery with a distinct abaxial costa. The proximal margin is inclined at an angle of ca. 45° while the distal margin arises almost perpendicularly from the axis. The leaves are 4–5 mm long and 2–3 mm wide. The lateral shoot fragments arise at an angle of 45–60° and at a distance of 25 mm alternately of the main rachis. The lateral shoots are 50–60 mm long with an about 1 mm broad rachis on which the leaves are inserted in a loose helix. The leaves are only slightly smaller (3–4 mm long and 2 mm wide) than those of the main axis.

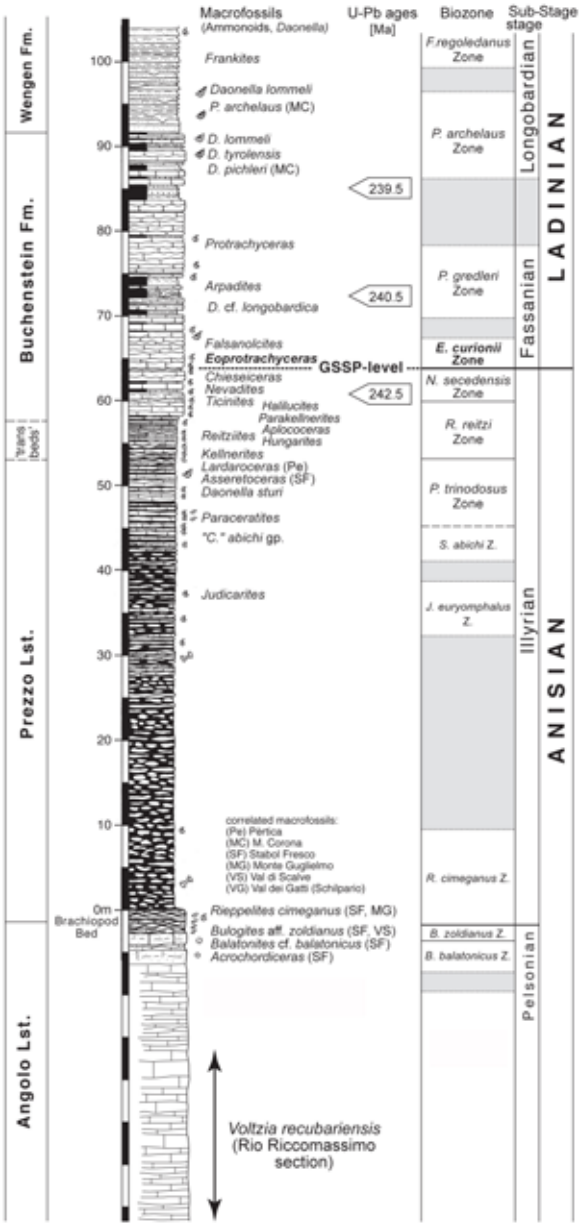

Figure 4: Summary log of the Middle Triassic pelagic succession at Romanterra (Bagolino). The main macrofossil horizons and the scheme of ammonoid zones are indicated. Radio-isotopic age data are from volcanoclastic layers at Bagolino and Seceda (modified after Brack et al., 2005). Range of late Anisian (Illyrian) after Monnet et al. (2008).

Material. PIMUZ A/VI 67 (Paläontologisches Institut und Museum der Universität Zürich, Switzerland).

Discussion. *Voltzia recubariensis* is a very characteristic conifer with its stout main shoot from which the lateral, widely spaced shoots arise at an acute angle. The lateral shoots are very similar to the main shoot, no heterophylly has been observed. The leaves are coarse triangular with a distinct costa and inserted in a loose spiral. This particular and distinctive general feature makes the taxon easily recognisable even if the remains are badly preserved. The robust structure of the shoots and the leathery leaves give them a high potential for fossilisation, even if they have been transported over a long distance (see also below).

Taxonomic considerations. Hauer (1850, p. 5) described and figured conifer shoots as *Araucarites agordicus* Unger that look very much like *Voltzia recubariensis*; this would make the previous species a prior homonym of *V. recubariensis*. However, there are some nomenclatural problems with *Araucarites agordicus*. According to Hauer (1850, p. 5) *Araucarites agordicus* is a synonym to *Lycopodiolithes arboreus* Fuchs and *Voltzia brevifolia* Catullo but *Lycopodiolithes arboreus* is a *nomen nudum* without description, figure and diagnosis. *Araucarites agordicus* was described by Unger (1850, p. 382) based on the material of *Voltzia brevifolia* Catullo, which makes *Araucarites agordicus* a junior synonymy of *Voltzia brevifolia* Catullo. Additionally, Unger attributed the conifer to the Liassic of Val Imperina, while Catullo (1846, p. 10) and Mojsisovics (1879, p. 47, 437) stated that the material comes from the "Muschelkalk" (=Anisian). However, *Voltzia brevifolia* Catullo is a junior synonym of *Voltzia brevifolia* Brongniart, 1828. Although the leaf shape of *Voltzia brevifolia* Brongniart, 1828 (p. 449–51, pls. 1, 2, Fig. 1–2) slightly resembles that of *Voltzia recubariensis*, the lateral shoots are more densely and probably only laterally inserted on the main shoot and the structure of *Voltzia brevifolia* Brongniart is less coarse than *Voltzia recubariensis*. Thus the correct name for this specimen is *Voltzia recubariensis*.

Schenk (1868, p. 83) suggested to unify both the former *Araucarites recubariensis* and *Araucarites massalongii* of De Zigno; the original material is however not available for cuticular analyses and also no intermediate specimens are available, thus it is still unclear if both conifer type of shoots belong to the same species. It can also not be ascertained if the cone described as *Echinostachys*

massalongii by De Zigno (p. 16, pl. 2, fig. 4) belongs to the sphenophytes or also to *Voltzia recubariensis* as suggested by Schenk (1868, p. 87).

Distribution. *Voltzia recubariensis* is a typical Anisian element and has so far not been described outside of the Southern Alps. Originally it has been described from the "Strati di Voltzia" of Recoaro (e.g., Schenk, 1868), that are Pelsonian in age. More recently this species has been described also from the Dolomites, where it has been found in the Agordo Formation of the San Lucano Valley (Bithynian-Pelsonian; Kustatscher et al., 2011), in the Dont Formation of Kühwiesenkopf/Monte Prà della Vacca (middle–late Pelsonian, late Anisian; e.g., Broglio Loriga et al., 2002; Kustatscher, 2004), in the Richthofen Conglomerate of Piz da Peres (Illyrian; Todesco et al., 2008) and from general Anisian sediments of the Vallarsa Valley (Selli, 1938) and the Non Valley (Kustatscher et al., 2012).

Figure 5: Photo of *Voltzia recubariensis* from Rio Riccomassimo section (specimen PIMUZ A/VI 67).

5. Final remarks

In this paper we report the first unequivocal finding of *Voltzia recubariensis* in the western Southern Alps since Bittner (1881, p. 247) mentioned the species without providing any figure or description. Additionally, no comparable sample has been found, neither in the Geologische Bundesanstalt Vienna nor in the Naturhistorisches Museum Vienna, which would be the most likely repository place for Bittners material. The bad preservation of the conifer shoot from the Bagolino section suggests that the shoot was transported over a long distance from its source area. So far there are no clear signs for emerged land in Anisian successions near Bagolino. However, in a southern direction, i.e. towards the present Po plain, the thickness of Anisian successions tends to be reduced and more lagoonal ambients possibly bordered an emerged area, from which the shoot fragments could have been washed in (Fig. 6). This situation may have resembled the subsequent Ladinian–Carnian paleogeography with terrestrial domains in the present subsurface of the Po plain (e.g., Brusca et al., 1981). More plant material also from other Angolo Limestone successions would be required for a better location of potential source areas.
Voltzia recubariensis is one of the most common taxa of the Anisian of the Southern Alps. This conifer is characteristic for all Pelsonian and Illyrian plant localities known so far (e.g., Kühwiesenkopf/Monte Prà della Vacca, Piz da Peres, Val di Non, Recoaro). This could point to a rather uniform flora during the Anisian even if the vegetation grew on different islands throughout the western border area of the Tethys ocean.

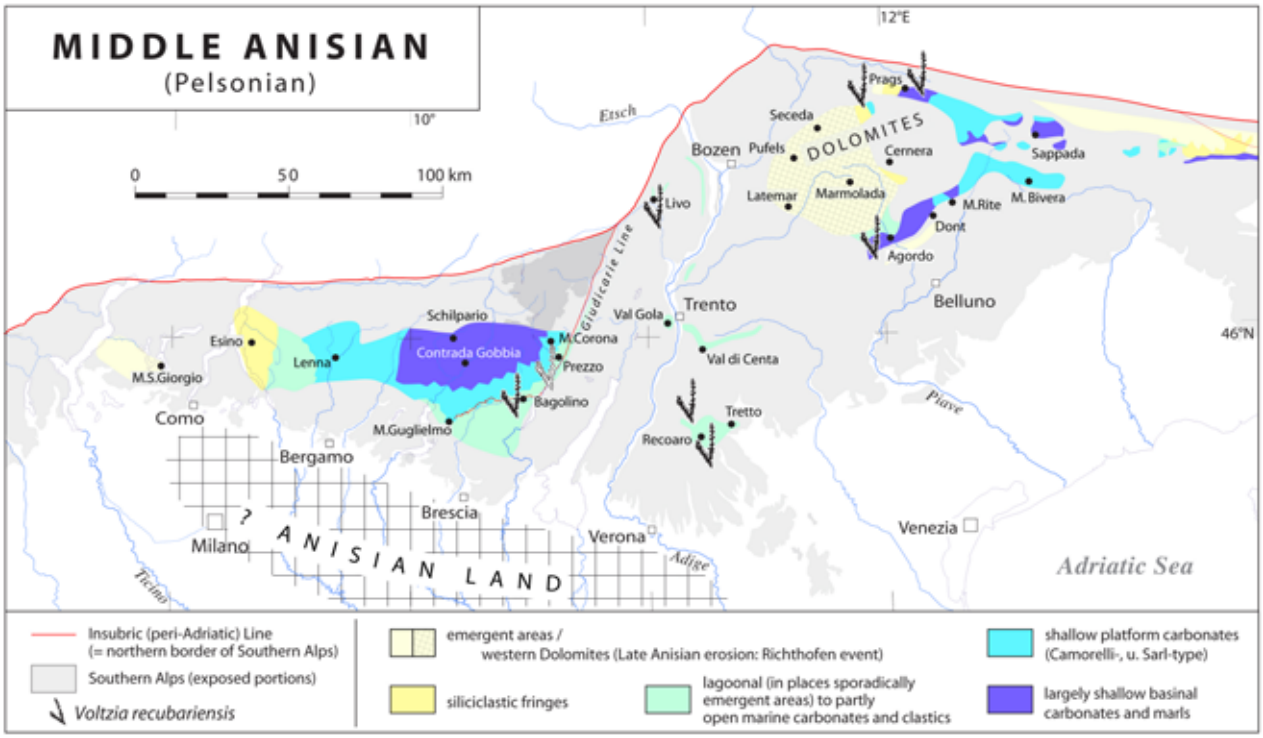

Figure 6: Sketch of the distribution of Middle Anisian sedimentary units in the Southern Alps. A paleogeographic reconstruction would require an extension and northward displacement by a few tens of kilometres of the South Alpine units west of the Giudicarie Line. The compilation is based on maps in De Zanche & Farabegoli (1988), Berra et al. (2005), Assereto et al. (1977), Farabegoli et al. (1985) and own observations..

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