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Ammonoids of the middle/late Anisian boundary (Middle Triassic) and the transgression of the Prezzo Limestone in eastern Lombardy-Giudicarie (Italy)

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Key words: ammonoids, Anisian, Triassic, Southern Alps, correlation, palaeogeography

ABSTRACT

This study documents ammonoids with a precise stratigraphic control at the middle/late Anisian (Pelsonian/Illyrian) boundary from a new locality in eastern Lombardy-Giudicarie (Monte Guglielmo) and from classical sections in Giudicarie. These ammonoid faunas allow revising the taxonomic interpretation of *Ceratites cimeganus* MOJSISOVICS 1882 and of the genus *Paraceratites* HYATT 1900. *Ceratites cimeganus* is here assigned to the North American genus *Rieppelites* MONNET & BUCHER 2005. In eastern Lombardy-Giudicarie, *R. cimeganus* is diagnostic of a distinct biochronological unit (*cimeganus* Zone) bracketed between the older *Bulogites zoldianus* Zone and the younger *Judicarites euryomphalus–Paraceratites trinodosus* zones. The recognition of this *cimeganus* Zone significantly improves worldwide correlation since it is recognized in several other Tethyan basins (Dolomites, Northern Calcareous Alps) as well as in North America (Nevada). These new data allow a redefinition of the middle/late Anisian boundary in the western Tethys, which is here intercalated between the *zoldianus* and *cimeganus* zones. This limit is marked by a clear ammonoid turnover (e.g. disappearance of *Acrochordiceras* and *Balatonites*, appearance of *Rieppelites*). Finally, the presence of sections including the *cimeganus* Zone in eastern Lombardy-Giudicarie allow the establishment of local gaps in sedimentation, which may reflect the regional and important transgression of the pelagic Prezzo Limestone over the shallow water platform carbonates of a "Camorelli-Dosso dei Morti barrier", as also underlined by the spatial distribution of brachiopod lumachellas.

RESUME

Cette étude décrit les faunes d'ammonites de la nouvelle coupe de Monte Guglielmo (Lombardie-Giudicarie, Italie) et les coupes plus classiques de la région couvrant la limite moyen/supérieur de l'Anisien (Pelsonien/Illyrien). Ces faunes d'ammonites permettent de réviser l'interprétation taxinomique de l'espèce *Ceratites cimeganus* MOJSISOVICS 1882, ainsi que le genre *Paraceratites* HYATT 1900. *Ceratites cimeganus* est attribué au genre nord-américain *Rieppelites* MONNET & BUCHER 2005. En Lombardie-Giudicarie, *R. cimeganus* est caractéristique de la nouvelle zone éponyme qui se situe entre les zones à *Bulogites zoldianus* et *Judicarites euryomphalus–Paraceratites trinodosus*. Cette nouvelle zone affine les corrélations à l'échelle mondiale car elle est connue dans plusieurs bassins téthysiens et au Nevada. Les faunes d'ammonites décrites dans cette étude permettent aussi de mieux définir la limite Anisien moyen/supérieur qui se situe donc entre les zones à *zoldianus* et *cimeganus*. Cette limite se caractérise par un important renouvellement des faunes d'ammonites avec notamment la disparition des genres *Acrochordiceras* et *Balatonites*, ainsi que l'apparition du genre *Rieppelites*. Enfin, la répartition de la zone à *cimeganus* dans les diverses coupes étudiées de Lombardie et Giudicarie, couplée à la répartition des facies sédimentaires et des faunes de brachiopodes, permet de mettre en évidence des lacunes sédimentaires. Celles-ci résultent probablement de l'ennoyage généralisé de la région, avec le dépôt des calcaires pélagiques du Prezzo surmontant les barres peu profondes des formations carbonatées de Camorelli et Dosso dei Morti.

Introduction

Pelagic sediments following with sharp contacts on top of shallow water carbonates are quite common features in Middle Triassic successions of the Southern and Eastern Alps (e.g. Assereto 1971, Schlager & Schöllnberger 1974, Epting et al. 1976, Brandner 1984) and suggest distinct episodes of platform drowning. In most cases, the nature and reasons for these abrupt stratigraphic breaks are still poorly known, however. Prerequisites for the assessment of the significance of such events in a larger context are their precise timing and correlation. In this paper, we present new constraints on the age of one such prominent change in the Anisian stratigraphy of the central and western Southern Alps. In eastern Lombardy-Giudicarie, heterogeneous successions of neritic and shallow water carbonates are capped by pelagic limestone-marl alternations of the Prezzo Limestone, documenting a distinct phase of basin deepening and platform drowning known for a long time (e.g. Bittner 1881, Salomon 1908, Assereto & Casati 1965, Gaetani 1969). Ammonoids from basinal carbonates and underlying

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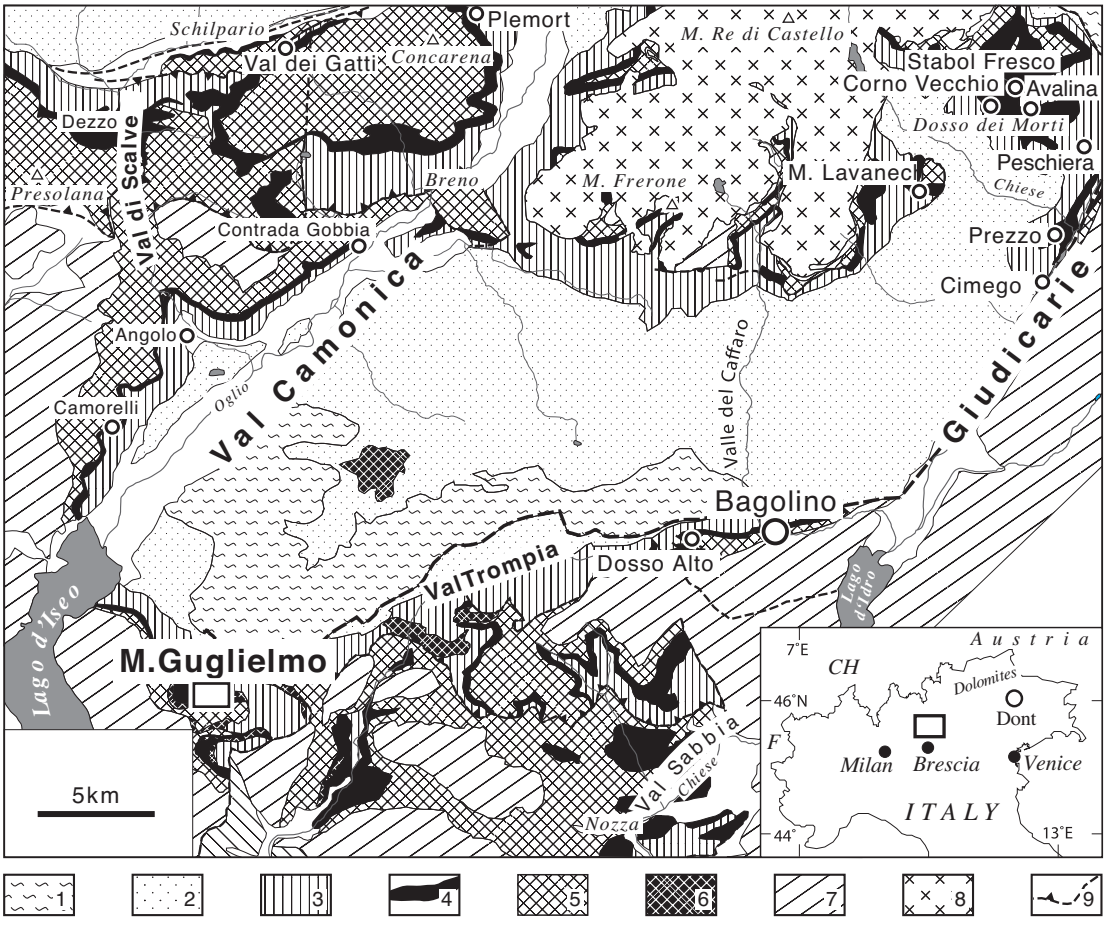


Fig. 1. Geological overview map of the Brescian Prealps and adjacent areas with classical localities for the middle/late Anisian (Middle Triassic) stratigraphy in eastern Lombardy-Giudicarie (Trentino, Italy). The location of the Monte Guglielmo area (Fig. 2) is indicated. 1) pre-Permian basement; 2) Permian to Early Triassic including earliest Anisian units; 3) mainly early/middle Anisian units (Angolo Lst., Camorelli-Dosso dei Morti–M. Guglielmo Lst.); 4) late 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).

platform beds suggest that in a restricted area around Dosso dei Morti in Giudicarie this event occurred around the "Pelsonian/Illyrian" (middle/late Anisian) boundary (Gaetani 1969, 1993; Pisa 1974). However, because of the patchy occurrence of age diagnostic fossils and due to the absence of a generally accepted and unambiguous Tethyan ammonoid reference for this time interval, the age assignment remained indicative at best. Only recently, ammonoid data have also become available for the uppermost shallow basinal Angolo Limestone immediately below the Prezzo Limestone (Brack et al. 1999).

The aim of this paper is to document ammonoids with precise stratigraphic control from the basal Prezzo Limestone and the immediately underlying beds at a new locality in eastern Lombardy (Monte Guglielmo) as well as from classical sections in Giudicarie. An improved age calibration of the regional transition from shallow to deep water environments is then obtained through the assessment of the new fossil finds and literature data. This refined ammonoid succession is then compared with the recently revised Anisian ammonoid record from Nevada (Monnet & Bucher 2006). On the basis of new collections from this area, Monnet & Bucher (2005) established two new ammonoid zones at the base of the late Anisian, namely the *Gymnotoceras weitschati* and *Gymnotoceras mimetus* zones, intercalated between the *Balatonites shoshonensis* and *Gymnotoceras rotelliformis* zones, and a new subzone (*Bulogites mojsvari* subzone) in the latest middle Anisian *shoshonensis* Zone, as well as a revision of the *rotelliformis* Zone in Nevada.

Geological setting

The Middle Triassic sediments of eastern Lombardy-Giudicarie (Fig. 1) belong to the S- and SE-directed South Alpine fold and thrust belt. Internal deformation varies strongly in these rocks but successions along the western flank of the lower Val Camonica and around Dosso dei Morti in Giudicarie re-

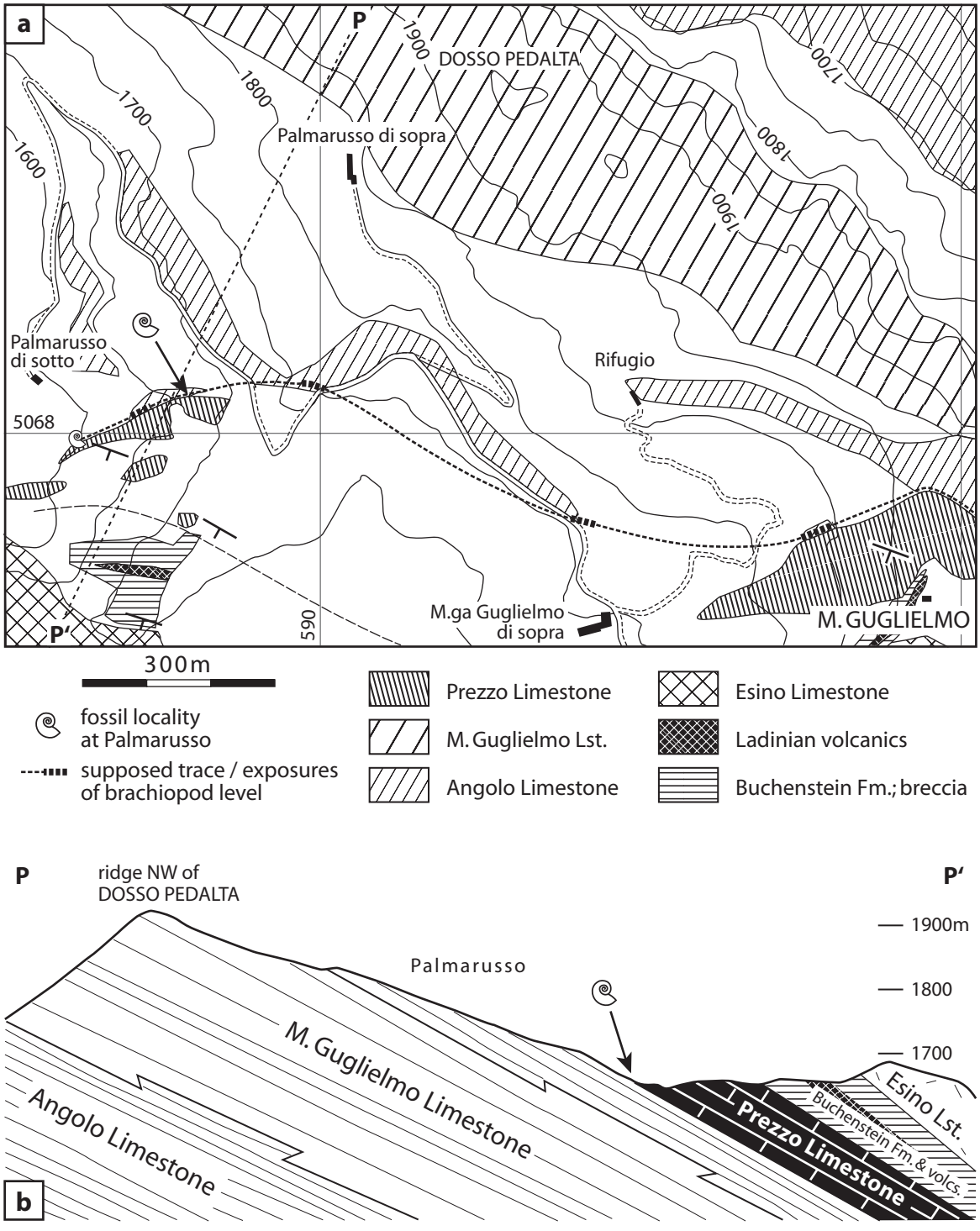


Fig. 2. a) Geological sketch map of the Monte Guglielmo area with indication of the new ammonoid locality above Malga Palmarusso di sotto. Also shown are outcrops and the supposed trace of a layer with frequent brachiopods (mainly *Tetractinella trigonella*) in the uppermost Angolo Limestone. b) Cross section (see A for trace) showing the early/middle Anisian to late Ladinian stratigraphic interval at Monte Gugliemo.

mained largely undeformed. Restoration of alpine shortening requires a roughly NWN–SES directed expansion of the area of Figure 1. In particular, the upper unit of the repeated Middle Triassic sediments between Val di Scalve and Val Camonica was located originally around 15 km further north, relative to their substrate (e.g. Brack 1984, Balini et al. 2000).

The Middle Triassic formations of the studied area overlie a fairly regular interval of early Triassic shelf deposits (Servino Formation) with a tectonized evaporate-rich detachment horizon (Carniola di Bovegno) of early Anisian (?) age in between. A prominent succession of predominantly middle Anisian neritic and shallow water carbonates (Angolo Limestone, Camorelli Limestone and equivalent platform carbonates) shows marked thickness variation, between values of 150–300 m in the northern and southeastern border areas of Figure 1 and maximum values greater than 650 m around Angolo north of Lago d'Iseo. The shallow marine lithologies are sharply overlain by more uniform pelagic sediments of largely late Anisian to late Ladinian age (Prezzo Limestone, Buchenstein Formation). While the lithological characters and thickness of the pelagic carbonate portion of the Buchenstein Formation persist throughout wide areas of Figure 1, the appearance of the Prezzo Limestone changes remarkably, mainly due to variable silt and clay content. The thickness of the Prezzo Limestone is maximal in upper Val di Scalve (100–120 m) and gradually decreases in a southeastern direction to values around 55–70 m between Val Trompia and Bagolino. With the reduction of the clay fraction the limestone-marl alternations of the Prezzo Limestone become progressively more lenticular and nodular. Further southeast, nodular limestones predominate and the Prezzo Limestone is not always easily distinguished from nodular examples of the underlying Angolo Limestone. The strong thickness variations of the middle and late Anisian formations and the significant offset of the respective depocenters indicate a locally variable tectonic component of basin subsidence. The Buchenstein Formation is followed by another heterogeneous stratigraphic interval comprising the siliciclastic Wengen Formation and platform carbonates of the Esino Limestone as well as subordinate basinal carbonate equivalents (Pratotondo Limestone). The age of these partly heteropic units reaches the earliest Carnian and their thickness changes even more dramatically than that of the middle/late Anisian intervals. The Esino Limestone is only a few tens of meters thick in the southeast whereas its maximum values exceed 1000 m at Concarena in Val Camonica (Fig. 1).

Along the upper Chiese Valley (Giudicarie), in Val di Scalve and Val Camonica and between Lago d'Iseo and Lago d'Idro (eastern Lombardy), the Middle Triassic successions host numerous classical sections with Anisian and Ladinian ammonoid faunas, some of which have been known since the onset of stratigraphic research on Triassic rocks in the Alps (e.g. Lepsius 1878; Bittner 1881, 1883). In particular, the ammonoids from the upper part of the Prezzo Limestone were of fundamental importance for the establishment of Mojsisovics' (1882) late Anisian *Paraceratites trinodosus* Zone.

Substrate of the Prezzo Limestone

The Anisian successions below the pelagic Prezzo Limestone in eastern Lombardy-Giudicarie comprise shallow basinal to lagoonal strata (Angolo Limestone) as well as banks of mainly subtidal shallow water carbonates (Camorelli Limestone, Dosso dei Morti Limestone). Traditionally the Angolo Limestone has been divided into an irregularly and generally coarsely bedded "lower" and a more finely, regularly bedded and muddier "upper" member (Salomon 1908, Assereto & Casati 1965). The normal superposition of the upper and lower members of Angolo Limestone is restricted to the region north and west of the area between Camorelli (Val Camonica) and Dosso dei Morti (Giudicarie). South and east of this area the lower member of the Angolo Limestone (i.e. the "judikarische Facies" of Salomon 1908) reaches the top of the formation. There the upper meters of the Angolo Limestone usually comprise crinoid sands and layers with abundant brachiopods. In numerous places, the accumulations of brachiopods form distinct meter-thick lumachellas (e.g. Bittner 1881, Speciale 1967, Gaetani 1969). Around Camorelli in Val Camonica and in the area of Dosso dei Morti, parts of the Angolo Limestone are replaced by the Camorelli- and Dosso dei Morti Limestone respectively (Salomon 1908, Assereto & Casati 1965, Gaetani 1969). These largely equivalent formations form irregular bodies of compact bioclastic packstones and bindstones, dominated by blue-green algae and *Tubiphytes* (e.g. Gaetani & Gorza 1989). Only at Dosso dei Morti signs of local emersion have been mentioned for such carbonates (Unland 1975). The absence of significant breccias in the adjacent muddier and somewhat deeper water Angolo Limestone suggests that the Camorelli-Dosso dei Morti-type platforms were minor topographic features, which grew in a predominantly subtidal environment. This is in agreement with the rapid transition to and the smooth base of the overlying pelagic Prezzo Limestone.

The facies change between the Dosso dei Morti and the upper Angolo Limestone is spectacularly exposed on the flanks of Monte Corona in Giudicarie (e.g. Salomon 1908: pl. 4, fig. 2; Epting et al. 1976: figs. 3–4; Brack et al. 1999: fig. 3). Beyond Camorelli and Dosso dei Morti, similar platform carbonates form a lenticular body in the middle/upper portion of the Angolo Limestone also at Monte Guglielmo (Falleti & Ivanova 2003) and remnants of comparable carbonates are preserved in a few places along the southern border of the Adamello igneous body (e.g. Monte Lavanech, Cima Bondolo, Gaver; Brack 1984).

For the assessment of the timing of the Prezzo-transgression in eastern Lombardy-Giudicarie, we studied in detail stratigraphic intervals straddling the base of the Prezzo Limestone overlying different stratigraphic units in three areas, namely: (i) the upper Angolo Limestone in Val di Scalve (Schilpario), (ii) neritic to shallow water carbonates at Monte Guglielmo, and (iii) platform carbonates (Camorelli/Dosso dei Morti Limestone) and the lower member of the Angolo Limestone in Giudicarie (Dosso dei Morti area: Malga Avalina, Stabol Fresco, Corno Vecchio).

Studied sections

Val di Scalve – Val Clegna (Val dei Gatti, Plemort)

Ammonoids from the terminal layers of the upper Angolo Limestone are reported in Brack et al. (1999) from the upper

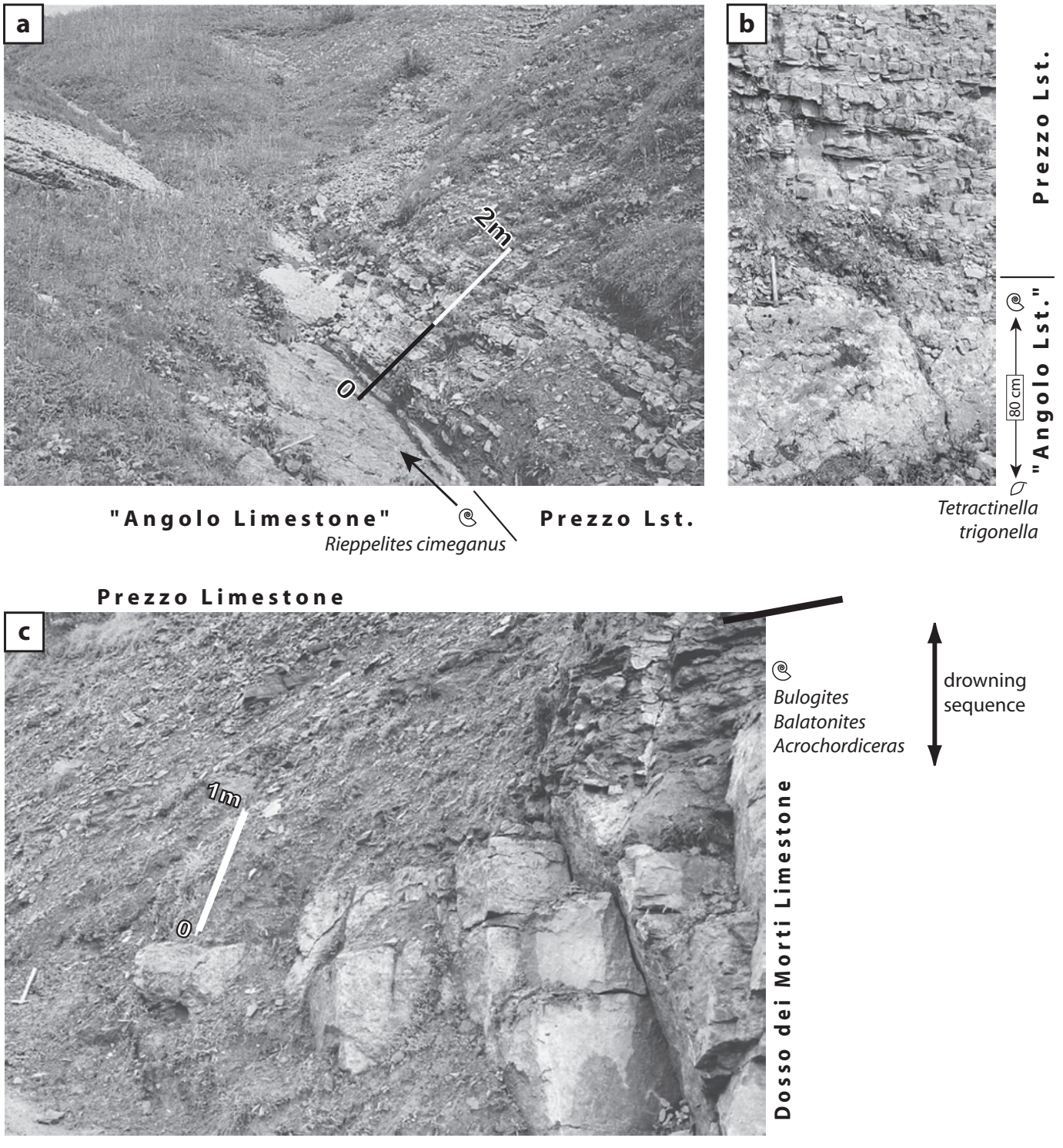


Fig. 3. a) Exposure of the contact between the uppermost layers of the "Angolo Limestone" and the basal part of the Prezzo Limestone above Malga Palmarusso di Sotto (Monte Guglielmo area; see Fig. 2 for location). The arrow indicates the ammonoid level (HB 911) beneath the base of the Prezzo Limestone. b) Detail of the boundary interval between the "Angolo Limestone" and Prezzo Limestone a few tens of meters west of the area shown in A (at 1620 m altitude). c) Contact between the Dosso dei Morti Limestone and Prezzo Limestone with indication of the ammonoid bearing layers along the trail west of Malga Avalina in the Dosso dei Morti area (Giudicarie).

of two tectonically superimposed Middle Triassic successions southeast of Schilpario (Fig. 1). The fossiliferous interval is exposed on both flanks of the steep gully of the uppermost Val dei Gatti, at an altitude of 1650–1700 m around 700 m east-northeast of Baita Ezendola. Ammonoids from this section include *Balatonites* sp., *B.* gr. *B. ottonis*, *Acrochordiceras*, *Ptychites* and *Ismidites*. Similar ammonoids were also found in another exposure of the corresponding strata around 8.5 km to the east-northeast of Val dei Gatti. At this locality (here referred to as Plemort), the Angolo-Prezzo transition is spectacularly exposed, at an altitude of ca. 1400 m in two steep gullies southwest of Baite Plemort northwest of the village of Ono San Pietro in Val Camonica. At Plemort, specimens of *Balatonites* gr. *B. ottonis* were found 5–6 m below the transition between the upper Angolo and Prezzo Limestones. Finally, some specimens referred to *Bulogites* cf. *B. zoldianus* have been very recently discovered in the uppermost part of the Angolo Limestone at the lower Val di Scalve (section near Angolo Terme), thus complementing the ammonoid sequence from the Angolo Limestone.

Monte Guglielmo

To the west of the Guglielmo peak (Fig. 2), the Prezzo Limestone follows on top of a early to middle Anisian succession comprising the neritic Angolo Limestone and intercalated bodies of shallow water carbonates (Monte Guglielmo Limestone, Falleti & Ivanova 2003), with an estimated cumulative thickness of 650 m. In the topmost part of this interval, a bed with frequent brachiopods (here mainly *Tetractinella trigonella*) can be recognized in scattered outcrops over several hundred meters from the western flank of Monte Guglielmo to the area of Malga Palmarusso di Sotto. The best exposures of the mainly grass-covered Prezzo Limestone lie to the southeast of Palmarusso di Sotto. On the western slope, close to the ridge crest southeast of Palmarusso di Sotto, a characteristic light-grey tuff bed (T_{ac}, Brack & Rieber 1993) is visible along hiking trail nr. 227. In eastern Lombardy-Giudicarie, this bed belongs to the transitional beds between the Prezzo Limestone and the Buchenstein Formation. This constrains the constructed thickness of the Prezzo Limestone west of Guglielmo to a value around 80 m. The Buchenstein Formation comprises a heterogeneous interval of unusual massive carbonate breccias and more typical siliceous nodular limestone and tuff layers. Shallow intrusive rocks associated with this succession are exposed at Monte Guglielmo and along the ridge south of Malga Palmarusso. A few *Daonella*-bearing layers of reworked siliciclastic and carbonate material finally lead to the compact interval of late Ladinian (? to early Carnian) Esino Limestone.

In this fairly regularly southwest-dipping Anisian–Ladinian succession, brachiopods and badly preserved ammonoids were mentioned previously (e.g. Salomon 1908) but only recently a hitherto unknown fossil-rich interval was discovered by one of the authors (P.B.), at the base of a 15 m thick continuous interval of lowermost Prezzo Limestone. This outcrop is here referred to as "Monte Guglielmo" and lies around 1 km west-northwest of the Guglielmo peak, at an altitude of ca. 1680 m in a gully above Malga Palmarusso di Sotto (UTM coordinates 5068.060/589.800). The locality can be reached either from Malga Guglielmo di Sopra (road and trail from the village of Zone – Croce di Marone) or following trail nr. 227 from Zone to Monte Guglielmo. The fossils were mainly collected from the uppermost bed of the "Angolo Limestone", which is well exposed along the gully (Figs. 3a, b). What here is referred to as "Angolo Limestone" could turn out to be a drowning succession on top of the Camorelli-type shallow water carbonates (M. Guglielmo Limestone of Falletti & Ivanova 2003) and might eventually be merged with this unit. This bed contains nautiloids, ammonoids, brachiopods, bivalves, and vertebrate remains. Ammonoids are preserved as external casts, the phragmocone being usually crushed and recrystallized. The same fauna has also been sampled from several beds at the base of the Prezzo Limestone (Fig. 4a), but the material from these levels is poorly preserved and fragmentary.

Giudicarie: area of Dosso dei Morti (Malga Avalina, Stabol Fresco, Corno Vecchio) and Cimego

Several fossil localities have been known for a long time in the basal Prezzo Limestone and underlying strata in Giudicarie (e.g. Lepsius 1878; Bittner 1881, 1883). Most of these localities are situated in the surroundings of Dosso dei Morti (southeast of Stabol Fresco; Fig. 1) and their stratigraphic context was mapped and studied systematically by Gaetani (1969) to whom reference is made for further details. The sections reported here (Fig. 5) straddle the base of the Prezzo Limestone and are named as follows: 1) Malga Avalina (loc. G29 in Gaetani 1969; probably corresponding to the "Anstiege südöstlich von der Malga la Valino" in Bittner 1883; base of Prezzo Limestone along the trail at 1945 m altitude, ca. 200 m west of the present Malga Avalina: good exposure of the Prezzo Limestone from its base up to the *abichi*-bed at the Malga itself and straddling layers with *Judicarites* and *Semiornites* in the upper 10 m west of the hut, Fig. 3c); 2) Stabol Fresco (= "Stabol Fresco"-section of Gaetani 1969; "Stabol Fresco UNO" of Balini et al. 1993); and 3) Corno Vecchio (section on the western slope of the ridge between Dosso dei Morti and Monte Corona with its base at 2200 m, 200 m southwest of Corno Vecchio; loc. G31 in Gaetani 1969).

The Cimego locality was originally a small quarry (Lepsius 1878) close to the old bridge across the river Chiese (Ponte di Cimego). After the quarry had been abandoned, only few and poorly preserved fossils including *"Ceratites" cimeganus* were collected from the screes in the surroundings of the Cimego bridge (Bittner 1881) but a detailed stratigraphy was never established for this locality. In 2005–2006, a steeply northeast-dipping stratigraphic succession of uppermost Angolo Limestone and ca. 20 m of the basal nodular Prezzo Limestone ("Cimego Limestone" auct.) was visible temporarily during construction works for the foundation of a new bridge. This interval presumably exceeds the range of strata from which ammonoids were originally collected at Cimego. To the north the Prezzo layers

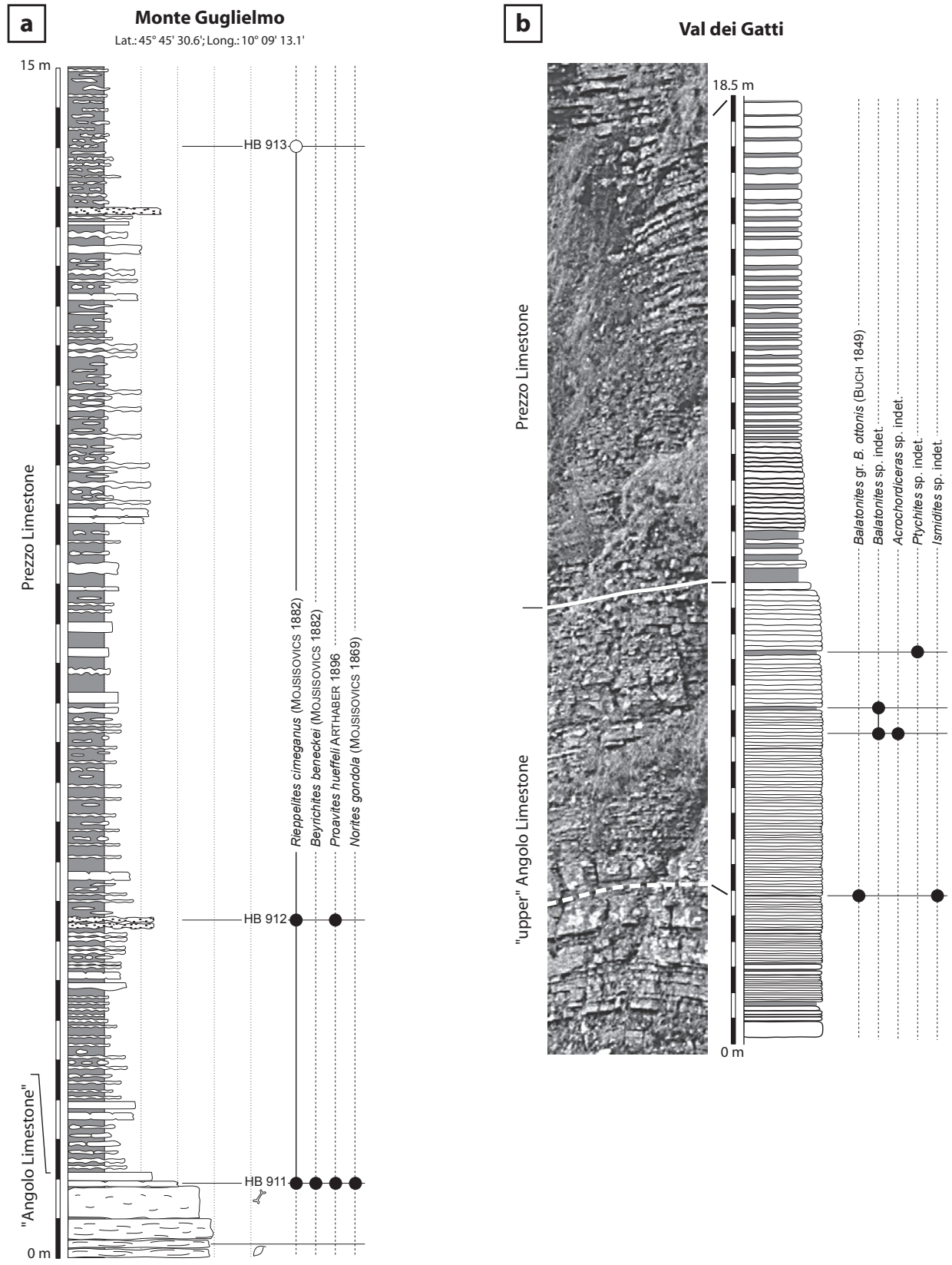


Fig. 4. Distribution of ammonoid taxa in eastern Lombardy. a) Monte Guglielmo section. b) Val dei Gatti section. Open circles indicate occurrences based only on fragementary or poorly preserved material.

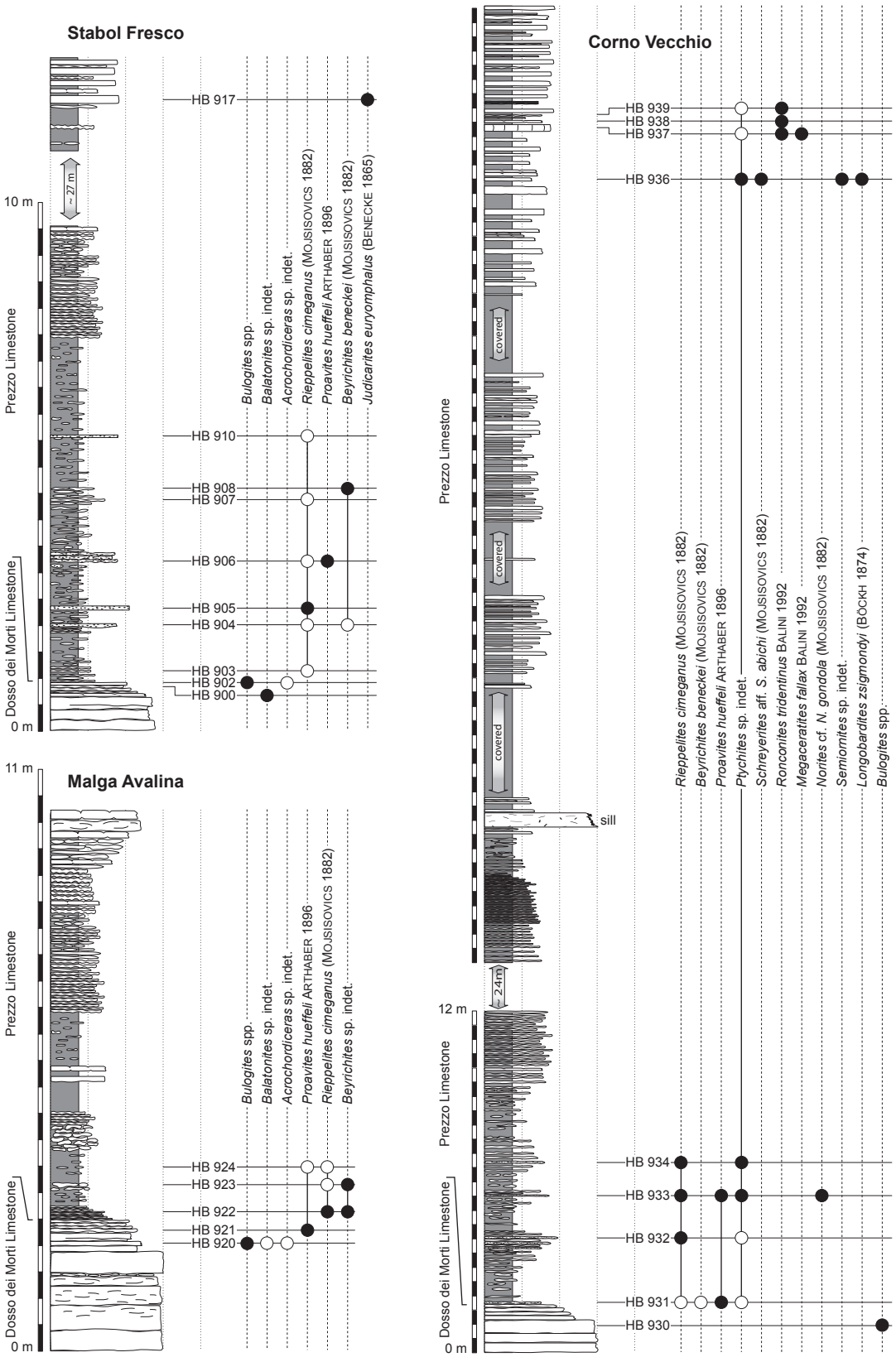


Fig. 5. Distribution of ammonoid taxa in the Stabol Fresco, Malga Avalina, and Corno Vecchio sections (Dosso dei Morti area, Giudicarie). Open circles indicate occurrences based only on fragmentary or poorly preserved material.

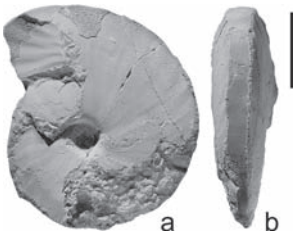


Fig. 6. *Norites gondola* (Mojsisovics 1869), PIMUZ 26500, Loc. HB 911, Monte Guglielmo (eastern Lombardy), *Rieppelites cimeganus* Zone (early late Anisian). Scale bar: 10 mm.

are again in tectonic contact with beds of Angolo Limestone. The distinct 2–3 m thick brachiopod lumachella at the top of the Angolo Limestone is dominated by the brachiopod *Coenothyris vulgaris* and shows striking similarities with the corresponding interval at Bagolino. Poorly preserved ammonoids (including specimens of possible *"Ceratites" cimeganus*) were observed in both the brachiopod lumachella and the nodular first few meters of Prezzo Limestone. These observations constrain the origin of *"Ceratites" cimeganus* to a relatively narrow stratigraphic interval at its type locality.

Systematic palaeontology

The taxonomic descriptions follow the terminology of Arkell et al. (1957) and the classification of Tozer (1981). The material is deposited in the collection of the Palaeontological Institute and Museum of Zürich (PIMUZ). Occurrences of taxa described here include the number of specimens obtained from each locality. For example, HB 911 (12) means that twelve specimens were identified from bed HB 911. Locality numbers are reported on the measured profiles (Figs. 4, 5). Measurements in millimetres of diameter (D), followed by whorl height (H), whorl width (W), and umbilical diameter (U) are plotted on bivariate diagrams. Conventional abbreviations used in front of the year in the synonymy lists have briefly the following meanings (see Matthews 1973 for details): * → the work validating the species; . → the authors agree on the identification and endorse it; ? → the allocation of this reference is subject to some doubt; *non* → the reference actually does not belong to the species under discussion; p → the reference applies only in part to the species under discussion; no sign → the authors were unable to check the validity of this reference; v → the authors have seen the original material of the reference. Year in italics indicates a work without description or illustration.

Class Cephalopoda Cuvier 1797
Subclass Ammonoidea Agassiz 1847
Order Ceratitida Hyatt 1884
Superfamily Noritaceae Karpinsky 1889
Family Noritidae Karpinsky 1889
Genus *Norites* Mojsisovics 1879
Type species. – *Ammonites gondola* Mojsisovics 1869; SD Diener 1915: 228.

Remarks. – In the absence of the suture line, the genus *Norites* (ceratitic suture line) is morphologically close to *Proavites* (goniatitic suture line) with a tabulate venter and a subtrapezoidal whorl section. Nevertheless, a significantly more compressed shell shape easily distinguishes *Norites* from *Proavites*.

Norites gondola (Mojsisovics 1869)
(Figs. 6, 7)

* 1869 *Ammonites Gondola* – Mojsisovics: 584, pl. 15, figs. 3a–b.
1872 *Ammonites* cf. *Gondola* – Böckh: 75.

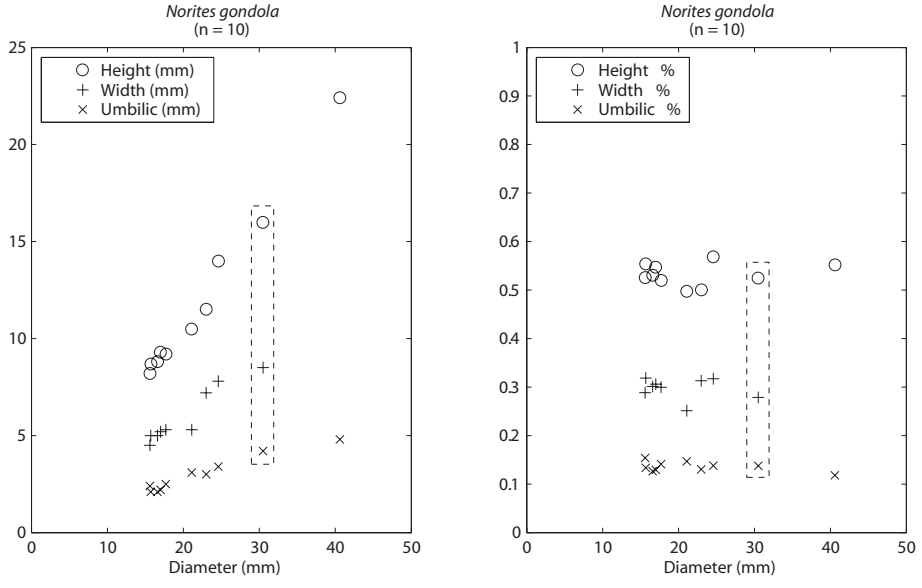


Fig. 7. Scatter diagrams of H, W, and U (left), and of H/D, W/D, and U/D (right) for *Norites gondola* (Mojsisovics 1869). All points from Balaton Highland (after Vörös 2003) except for those within the dashed frame, which come from Monte Guglielmo (eastern Lombardy; *Rieppelites cimeganus* Zone, early late Anisian). Abbreviations: D, diameter; H, whorl height; U, umbilical diameter; W, whorl width.

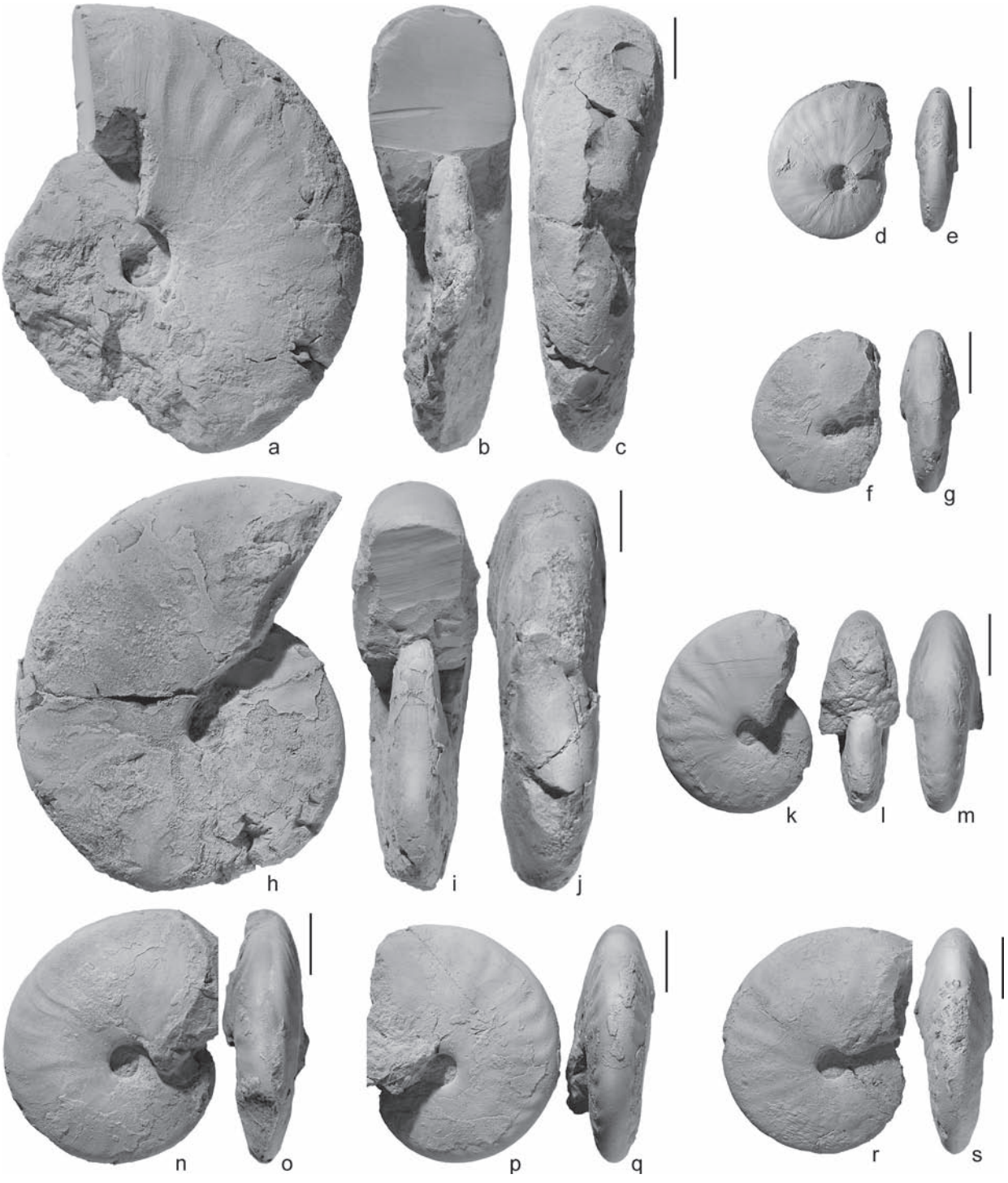


Fig. 8. *Beyrichites beneckei* (Mojsisovics 1882); Monte Guglielmo (eastern Lombardy), *Rieppelites cimeganus* Zone (early late Anisian). a–c) PIMUZ 26501, Loc. HB 911. d, e) PIMUZ 26502, Loc. HB 911. f, g) PIMUZ 26503, Loc. HB 911. H-J) PIMUZ 26504, Loc. HB 911. k–m) PIMUZ 26505, Loc. HB 911. n, o) PIMUZ 26506, Loc. HB 911. p, q) PIMUZ 26507, Loc. HB 911. r, s) PIMUZ 26508, Loc. HB 911. Scale bars: 10 mm.

. 1882 *Norites gondola* – Mojsisovics: 202, pl. 52, figs. 5–8.
1896a *Norites* cf. *gondola* – Arthaber: 89, pl. 7, figs. 12a–b.
?. 1896a *Norites apioïdes* – Arthaber: 91, pl. 8, figs. 3a–c.
?. 1896a *Norites psilodiscus* – Arthaber: 92, pl. 8, figs. 4a–c.
? 1901 *Norites gondola* var. nov. – Reis: 90, pl. 4, figs. 24–25.
? 1904 *Norites gondola* – Martelli: 97, pl. 8, figs. 1a–b.
? 1912 *Norites* sp. indet. cf. *Norites gondola* – Arthaber: 355, pl. 17, figs. 10–11.

non. 1914 *Norites gondola* – Arthaber: 157, pl. 17, fig. 2.
1915 *Norites gondola* – Diener: 210.
1934 *Norites gondola* – Spath: 281.
non. 1969 *Norites gondola* – Gaetani: 514, pl. 36, figs. 1–2 [= *Proavites hueffeli*].
. 1987 *Norites* cf. *gondola* – Vörös: 55, pl. 2, figs. 2a–b.
non 1987 *Norites psilodiscus* – Vörös: 55.
1991 *Norites gondola* – Tatzreiter & Vörös: 253.
. 1992a *Norites* aff. *Gondola* – Balini: 97, text-fig. 6.1, pl. 4, figs. 1–2.
1993 *Norites gondola* – Brack & Rieber: fig. 7.
. 2002 *Norites* cf. *gondola* – Vörös & Pálfy: 55, pl. 1, figs. 2a–b.
. 2003 *Norites gondola* – Vörös: 79, text-fig. 9, pl. 1, figs. 5–7.

Description. – Involute, finely ribbed, and compressed shell with a tabulate venter (Fig. 6). Shell with an involute coiling, a compressed, subtrapezoidal whorl section, a flat, tabulate and smooth venter, angular marginal shoulders, slightly convex flanks (maximal flank curvature being low on flanks), slightly convergent flanks toward the venter, shallow umbilicus, abrupt and rounded umbilical shoulder. Ornamentation composed of thin, prorsiradiate, irregular, slightly sinuous growth lines. Signs of faint, keel-like ridges along marginal shoulders are visible. Suture line not available from our material.
Measurements. – See Figure 7.
Remarks. – *Norites gondola* is the type species of the genus *Norites*. Arthaber (1896a, b) described four additional species (*N. falcatus*, *N. apioïdes*, *N. psilodiscus*, *N. arcuatus*). Vörös (2003) examined the types, which appeared poorly preserved and crushed. Vörös (2003) tentatively assigned *N. psilodiscus* and *N. apioïdes* to *N. gondola* and kept *N. falcatus* as an independent species based on its different ornamentation (flexuous, falcate rather than convex, slightly sinuous growth lines). Vörös (2003) also synonymized *N. arcuatus* with *N. falcatus*. Note that the drawings of Arthaber suggest that specimens of *Norites* range from subrectangular to subtrapezoidal whorl section and from convex to flexuous growth lines. Thus, Vörös (2003) implicitly assumed that the differences of whorl section correspond to intraspecific variation. Although our material cannot contribute to test Vörös' hypothesis, we endorse the synonymy because it matches well classical intraspecific variation observed in other ammonoid species (e.g. Westermann 1966, Silberling & Nichols 1982, Dagys & Weitschat 1993, Dagys et al. 1999, Monnet & Bucher 2005, Hammer & Bucher 2005). Hence, compressed specimens of *Norites* tend to have a more subrectangular whorl section and a slightly smaller umbilical diameter.
Occurrence. – Monte Guglielmo (eastern Lombardy): HB 911 (1); *cimeganus* Zone (early late Anisian). Corno Vecchio (Giudicarie): HB 933 (1); *cimeganus* Zone (early late Anisian). In eastern Lombardy-Giudicarie, *Norites gondola* was documented in the *trinodosus* Zone (Balini 1992a, Balini et al. 1993, Brack & Rieber 1993) and in the *cimeganus* Zone (this work). The species was also described from the Balaton Highland (Hungary) and Northern Calcareous Alps (Austria).

Fig. 9. Suture line (×2, reversed) of *Beyrichites beneckei* (Mojsisovics 1882), PIMUZ 26504, Loc. HB 911, Monte Guglielmo (eastern Lombardy); *Rieppelites cimeganus* Zone (early late Anisian). Scale bar: 10 mm.

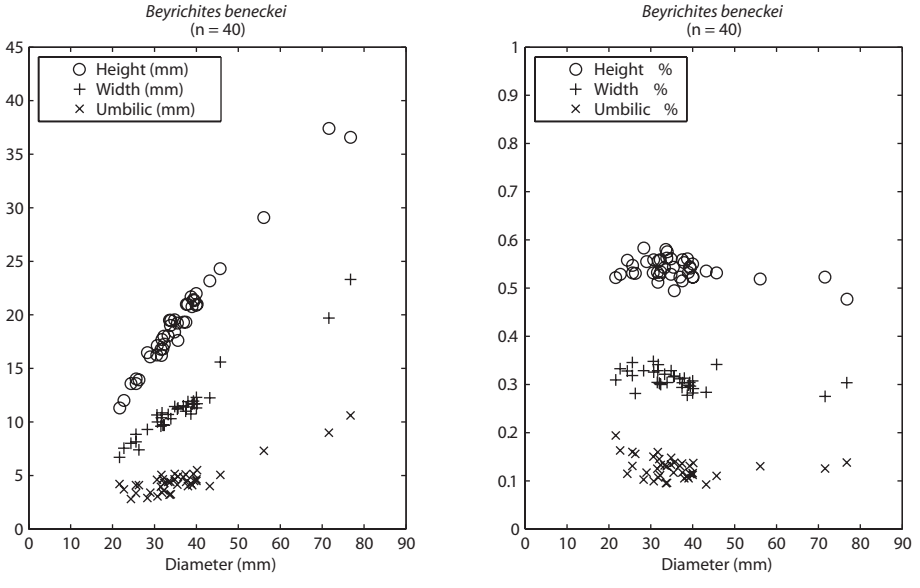


Fig. 10. Scatter diagrams of H, W, and U (left), and of H/D, W/D, and U/D (right) for *Beyrichites beneckei* (Mojsisovics 1882) (Monte Guglielmo, eastern Lombardy; *Rieppelites cimeganus* Zone, early late Anisian). Abbreviations: D, diameter; H, whorl height; U, umbilical diameter; W, whorl width.

Superfamily Ceratitaceae MOJSISOVICS 1879
Family Ceratitidae MOJSISOVICS 1879
Subfamily Beyrichitinae SPATH 1934
Genus *Beyrichites* WAAGEN 1895
Type species. – *Ammonites reuttensis* BEYRICH 1867; SD Smith 1904: 379.

***Beyrichites* beneckei (MOJSISOVICS 1882)**
(Figs. 8–10)

* 1882 *Meekoceras Beneckei* – Mojsisovics: 216, pl. 38, fig. 1, pl. 39, fig. 6, pl. 61, figs. 2, 3, 4?.
1898 *Ceratites Beneckei* – Tornquist: 643, pl. 20, fig. 2.
? 1901 *Beyrichites* cf. *Beneckei* – Reis: 99, pl. 7, fig. 34.
1911 *Beyrichites beneckei* – Salopek: 35.
? 1963 *Beyrichites (Beyrichites)* cf. *beneckei* – Assereto: 29, text-fig. 7, pl. 1, fig. 8.
p? 1963 *Beyrichites (Beyrichites) reuttensis* – Assereto: 31, text-fig. 8, pl. 2, fig. 2.
p? 1968 *Beyrichites (Beyrichites) beneckei* – Venzo & Pelosio: 93, pl. 7, fig. 2; pl. 7, figs. 3–5?, 12?
? 1976 *Beyrichites* cf. *beneckei* – Wang & He: 299, text-fig. 18b, pl. 8, figs. 8–10.
1987 *Beyrichites beneckei* – Vörös: 55.
. 1992a *Beyrichites beneckei* – Balini: 100, pl. 3, fig. 3 [cop. Mojsisovics 1882: pl. 61, fig. 2].
. 1992a *Beyrichites beneckei* – Balini: 100, text-fig. 6.2, pl. 4, figs. 3–13.
. 2002 *Beyrichites beneckei* – Vörös & Pálfy: 55, pl. 1, fig. 6.
. 2003 *Beyrichites beneckei* – Vörös: 94, text-fig. 23, pl. 7, figs. 4–5.

Description. – Involute, compressed shell with a rounded venter and sinuous ribs strengthening on upper flanks (Fig. 8). Shell with an involute coiling, a narrow umbilicus, and with slight egression of outer whorls. Whorl section high oval and compressed with a rounded venter, rounded ventral shoulders, abrupt umbilical shoulders, slightly convex flanks converging to the narrow venter on inner whorls (flank curvature on lower flanks imparts a subtriangular outline of the whorl section), and flat and subparallel flanks on outer whorls. Ornamentation consisting of fine sinuous to flexuous, slightly prorsiradiate ribs fading on lower flanks and strengthening on upper flanks. Suture line subammonitic with a deep first lateral saddle (E/L) and slightly crenulated saddles (Fig. 9).
Measurements. – See Figure 10.
Remarks. – Three species of *Beyrichites* are already known from eastern Lombardy-Giudicarie: *B. beneckei* (MOJSISOVICS 1882), *B. cadoricus* (MOJSISOVICS 1869), and *B. reuttensis* (BEYRICH 1867). *Beyrichites beneckei* differs from other species by its sinuous, strengthened ribs on upper flanks. It is noteworthy that the drawing of Mojsisovics (1882: pl. 38, fig. 1) does not show this diagnostic pattern, but Balini (1992a: pl. 3, fig. 3) illustrated a syntype where this trait is clearly expressed.
Our material shows that the shell geometry of *B. beneckei* changes on outer whorls from high oval to slightly subrectangular. Although this pattern has not yet been described for *B. beneckei* in the literature, inner whorls of these specimens clearly show the diagnostic ornamentation and shell geometry of *B. beneckei*. Balini (1992a) figured a series of *B. beneckei* from Stabol Fresco (Giudicarie), which matches well our material with some specimens (Balini, 1992a: pl. 4, figs. 11–12) showing this change in shell geometry, although Balini's material comes from a younger horizon (*trinodosus* Zone).
Beyrichites beneckei shows superficial similarities with *Gymnotoceras weitschati* MONNET & BUCHER 2005 and *G. mimetus* MONNET & BUCHER 2005 from Nevada. *G. weitschati* shares the strengthened ribs on upper flanks and *G. mimetus* shares the changing whorl section from high oval to subrectangular. However, robust variants of *G. weitschati* and *G. mimetus* clearly bear a keel on inner whorls compared to *B. beneckei*.
Occurrence. – Monte Guglielmo (eastern Lombardy): HB 911 (67); *cimeganus* Zone (early late Anisian). Stabol Fresco (Giudicarie): HB 904 (2?), HB 908 (3); *cimeganus* Zone (early late Anisian). This species has also been described from the Balaton Highland (Hungary).

Subfamily Paraceratitinae SILBERLING 1962
Genus *Rieppelites* MONNET & BUCHER 2005
Type species. – *Rieppelites boletzkyi* MONNET & BUCHER 2005.

Remarks. – *Rieppelites* was created for a group of trituberculate paraceratitins from northwestern Nevada with a subrectangular whorl section and a low arched venter. This genus presents some affinities with several Alpine genera such as *Lardaroceras* BALINI 1992b, *Ronconites* BALINI 1992c, *Pisaites* BALINI 1992c, and *Paraceratites* HYATT 1900. *Lardaroceras* differs from *Rieppelites* by having a more compressed whorl shape, a more involute coiling, higher whorls, a distinct keel on the venter, denser ribbing, and ornamentation persisting on adult whorls. *Pisaites* differs from *Rieppelites* by having a clearly keeled venter, a more compressed and subrectangular whorl section, denser and thinner ribs, weaker tubercles, and higher whorls. *Paraceratites* differs from *Rieppelites* by having a distinct ventral keel, persisting ornamentation on outer whorls, and straighter ribs. *Rieppelites* is closer to *Ronconites*, from which it differs by a smaller adult size, a more depressed whorl section of outer whorls, sharper and more sinuous ribs, sharper umbilical tubercles, and lateral tubercles below midflanks on inner whorls.

***Rieppelites cimeganus* (MOJSISOVICS 1882)**
(Figs. 11–13)

1881 *Ceratites cimeganus* – Bittner: 247 [nomen nudum].
* 1882 *Ceratites cimeganus* – Mojsisovics: 28, pl. 39, fig. 5.
v. 1896a *Ceratites Waageni* – Arthaber: 49, pl. 4, fig. 5.
. 1969 *Paraceratites cimeganus* – Gaetani: 515, text-fig. 11a, pl. 36, fig. 7 [cop. Mojsisovics 1882: pl. 39, fig. 5].
v. 1969 *Paraceratites cimeganus* – Gaetani: 515, text-fig. 11b, pl. 36, figs. 3–6.
. *1971* *Ceratites waageni* – Assereto: 44.
?. 1995 *Paraceratites cimeganus* – Mietto & Manfrin: pl. 1, fig. 10.
pv. 2005 *Rieppelites shevyrevi* – Monnet & Bucher: pl. 20, fig. 3 [only].

Description. – Moderately involute, compressed, subrectangular to subtrapezoidal shell with trituberculate ribs (Fig. 11). Shell with a moderately involute coiling and a wide umbilicus.

Fig. 11. *Rieppelites cimeganus* (Mojsisovics 1882); Monte Guglielmo (eastern Lombardy), *Rieppelites cimeganus* Zone (early late Anisian). a–c) PIMUZ 26509, Loc. HB 911, mature specimen showing final egression and approximation of suture lines. d, e) PIMUZ 26510, Loc. HB 911. f, g) PIMUZ 26511, Loc. HB 911. h, i) PIMUZ 26512, Loc. HB 911. j, k) PIMUZ 26513, Loc. HB 911. l, m) PIMUZ 26514, Loc. HB 911. n, o) PIMUZ 26515, Loc. HB 911. p, q) PIMUZ 26517, Loc. HB 912. Scale bars: 10 mm.

Subrectangular, compressed whorl section with a low arched venter, angular ventral and umbilical shoulders, convex flanks slightly converging to the venter. Ornamentation consisting of fine, prorsiradiate, straight to slightly sinuous ribs. Shell trituberculate, with a umbilical row of tiny tubercles, a lateral row of coarse to small tubercles very low on flanks, and a marginal

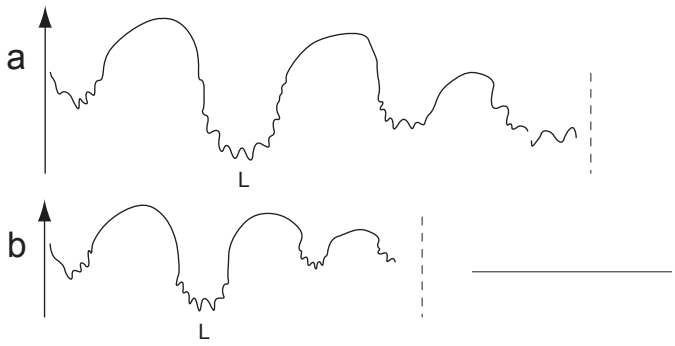


Fig. 12. Suture lines (×2) of *Rieppelites cimeganus* (MOJSISOVICS 1882); Monte Guglielmo (eastern Lombardy), *Rieppelites cimeganus* Zone (early late Anisian). a) PIMUZ 26509, Loc. HB 911. b) PIMUZ 26516, Loc. HB 911. Scale bar: 10 mm.

row of slightly clavate tubercles. On inner whorls, umbilical and lateral tubercles are very close and become clearly separated at a diameter larger than ca. 25 mm. On outer whorls and mature body chamber, ribs and tubercles fade. Ribs may branch from the lateral tubercles and sometimes loop between the lateral and marginal tubercles. Suture line ceratitic (Fig. 12) with three broad smooth saddles and narrowly denticulated lobes; first lateral lobe deep (L).

Measurements. – See Figure 13.

Remarks. – *"Ceratites" cimeganus* has usually been placed within the genus *Paraceratites* HYATT 1900. However, as discussed above, *"C." cimeganus* has several distinctive features (e.g. fading ornamentation on mature whorls and a low arched venter without a keel) and intraspecific variations, which are not typical of *Paraceratites* HYATT 1900 but are characteristic of the recently described genus *Rieppelites* MONNET & BUCHER 2005 from northwestern Nevada.

Monnet & Bucher (2005) described two species of *Rieppelites* (*R. boletzkyi* and *R. shevyrevi*). *Rieppelites cimeganus* differs from *R. boletzkyi* by having lateral tubercles always low on flanks. *R. cimeganus* differs from *R. shevyrevi* by having lateral tubercles still low on flanks at mature stages and by lacking parabolic tubercles on inner whorls.

As already discussed by Gaetani (1969), *"Ceratites" cimeganus* can be confused with *"Paraceratites" binodosus* (HAUER 1851) and *Paraceratites trinodosus* (MOJSISOVICS 1882). However, *"Ceratites" cimeganus* significantly differs from *P. trinodosus* by having a low arched venter without a keel, fewer marginal tubercles, and a fading ornamentation on the body chamber, as well as lateral tubercles low on flanks on outer whorls. *"Ceratites" cimeganus* also significantly differs from *"P." binodosus* by having a low arched venter, a ceratitic suture line, thinner ribs, lateral tubercles well below mid-flanks, marked marginal shoulders, and ornamentation fading on outer whorls.

It is noteworthy that Mojsisovics (1882: 28) clearly defined *cimeganus* as being binodose without umbilical nodes. According to Gaetani (1969: 515), of the four specimens attributed by Mojsisovics to *cimeganus*, only the figured specimen from Ponte di Cimego remains in the Geologische Bundesanstalt in Vienna, which Gaetani re-illustrated (1969: pl. 36, fig. 7) and designated as lectotype. Although we here describe *cimeganus* as being trinodose, our material clearly includes and does not differ from those of Mojsisovics and Gaetani. Indeed, while the outer whorls of our specimens are clearly trinodose with umbilical tubercles (e.g. Figs. 11j–m), their inner whorls do not have umbilical tubercles and are clearly identical to the lectotype of *cimeganus* (e.g. Figs. 11f, g). The ontogenetic transition from a binodose to a trinodose tuberculation can be seen on specimens at a diameter of ca. 25 mm (e.g. Figs. 11f, g, n, o), thus clearly relating all these specimens to the species *cimeganus*.

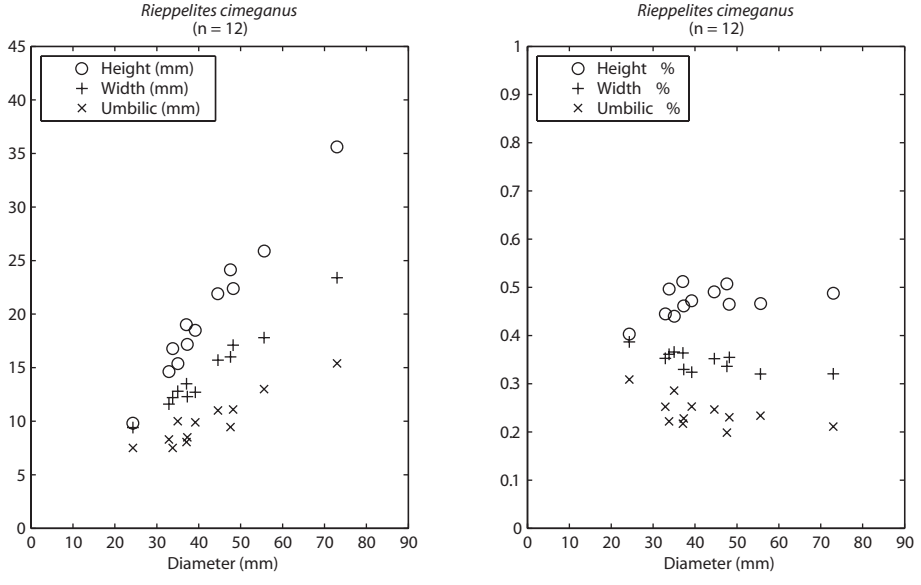


Fig. 13. Scatter diagrams of H, W, and U (left), and of H/D, W/D, and U/D (right) for *Rieppelites cimeganus* (MOJSISOVICS 1882) (Monte Guglielmo, eastern Lombardy; *Rieppelites cimeganus* Zone, early late Anisian). Abbreviations: D, diameter; H, whorl height; U, umbilical diameter; W, whorl width.

Therefore, our data complete the material of Gaetani and document all the ontogenetic changes of *cimeganus,* which were unknown to Mojsisovics.

Occurrence. – Monte Guglielmo (eastern Lombardy): HB 911 (53), HB 912 (17), HB 913 (2?); *cimeganus* Zone (early late Anisian). Stabol Fresco (Giudicarie): HB 903 (1?), HB 905 (3), HB 906 (4?), HB 907 (2?), HB 910 (2?); *cimeganus* Zone (early late Anisian). Malga Avalina (Giudicarie): HB 922 (4), HB 923 (2?), HB 924 (3?); *cimeganus* Zone (early late Anisian). Corno Vecchio (Giudicarie): HB 931 (1?), HB 932 (6), HB 933 (12), HB 934 (17); *cimeganus* Zone (early late Anisian). This species has also been documented in the Dolomites (Italy), Northern Calcareous Alps (Austria), and Nevada (USA).

Remarks on the genus Paraceratites. – The genus *Paraceratites* HYATT 1900 (type species *Ceratites elegans* MOJSISOVICS 1882: 31) has been used differently in the literature since its creation leading to a puzzling 'melting pot'. Since several studies (Balini 1992a, b, c; this study) described and partly revised species of "*Paraceratites*" s.l., it is necessary to clearly define what we here consider as *Paraceratites*.

In the Tethys, the genus *Paraceratites* was usually represented by seven species: *Ceratites elegans* MOJSISOVICS 1882, *C. trinodosus* MOJSISOVICS 1882, *C. brembanus* MOJSISOVICS 1882, and *Paraceratites donadonii* VENZO & PELOSIO 1968, and more questionably *C. rothi* MOJSISOVICS 1882, *C. cimeganus* MOJSISOVICS 1882, and *C. binodosus* HAUER 1851.

Species defined by Mojsisovics (1882) are now hardly applicable because they are based on a typological concept and illustrated by drawings. Consequently, the genus *Paraceratites* received a too broad definition and several species are commonly cited as questionably belonging to the genus.

The type species *Ceratites elegans* MOJSISOVICS 1882 (pl. 9, fig. 5) has a subtrapezoidal and compressed whorl section, a slightly involute coiling with a wide umbilicus, a clear median elevation on the venter (keel), three rows of tubercles (umbilical, lateral just below mid-flanks, and marginal), and straight, thin ribs bifurcating from lateral tubercles.

Ceratites trinodosus MOJSISOVICS 1882 (pl. 8, figs. 5–7, 9; pl. 37, figs. 6–7) is similar to *C. elegans* but differs by having a less marked keel and lateral tubercles low on flanks on inner whorls.

Ceratites brembanus MOJSISOVICS 1882 (pl. 10, figs. 1–3) is similar to *C. elegans* but differs by having stronger and fewer ribs, a slightly more evolute coiling, a more quadrangular whorl section and lower whorls, and the lateral tubercles placed well below mid-flanks. Note that this species is defined on smaller specimens than *C. elegans*.

Paraceratites donadonii VENZO & PELOSIO 1968 (pl. 10, fig. 5) is defined on a single specimen, which is nevertheless clearly keeled, with a subrectangular whorl section, a moderately involute coiling, dense and strong trituberculate ribs (lateral tubercles being at mid-flanks) fading on outer whorls.

Ceratites cimeganus MOJSISOVICS 1882, *C. rothi* MOJSISOVICS 1882 (pl. 9, fig. 7), and *C. binodosus* HAUER 1851 are clearly different from the group of *C. elegans*, *C. trinodosus*, and *C. brembanus*. *Ceratites cimeganus* differs from the *elegans* group by having a low arched venter without a keel, more sinuous ribs, lateral tubercles very low on flanks, fewer marginal tubercles, and ornamentation fading on outer whorls. The geometry, ornamentation and intraspecific variability of *C. cimeganus* are characteristic of the recently introduced genus *Rieppelites* from Nevada (USA); *Ceratites cimeganus* is therefore included within *Rieppelites*.

Ceratites binodosus HAUER 1851 (pl. 19, fig. 2) differs from the *elegans* group by having a rounded venter without a keel, moderately marked marginal shoulders, lateral tubercles below mid-flanks, more sinuous ribs, and a rather subammonitic suture line. These characters are close to the genus *Schreyerites* – type species *S. abichi* (MOJSISOVICS 1882) – to which it probably belongs even if the suture line does not match the very restrictive definition of *Schreyerites* given by Tatzreiter & Balini (1993).

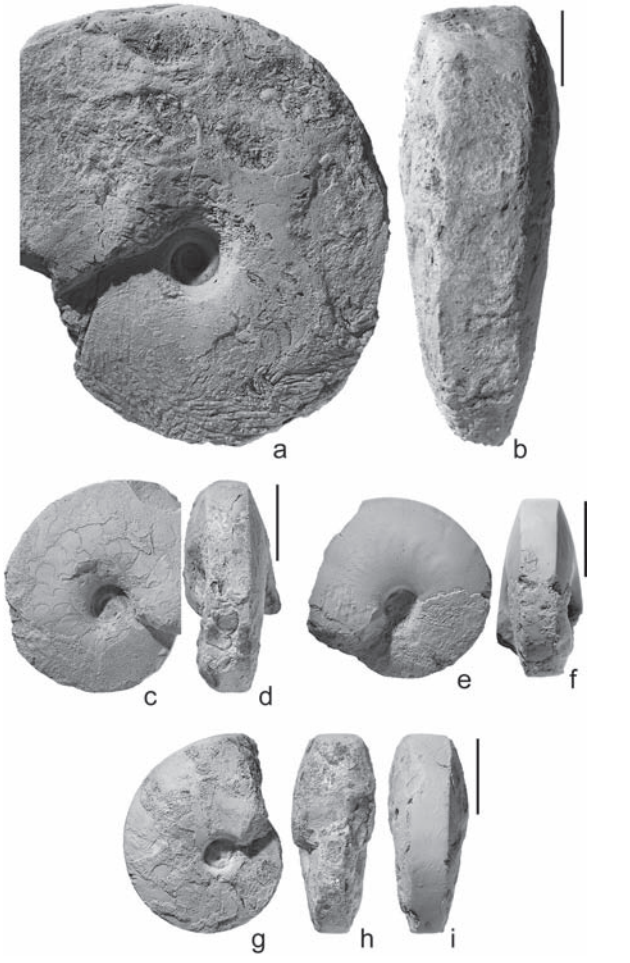


Fig. 14. *Proavites hueffeli* ARTHABER 1896; Monte Guglielmo (eastern Lombardy), *Rieppelites cimeganus* Zone (early late Anisian). a, b) PIMUZ 26499, Loc. HB 912, Mature specimen showing final approximation of suture lines. c, d) PIMUZ 26495, Loc. HB 911. e, f) PIMUZ 26496, Loc. HB 911. g–i) PIMUZ 26497, Loc. HB 911. Scale bars: 10 mm.

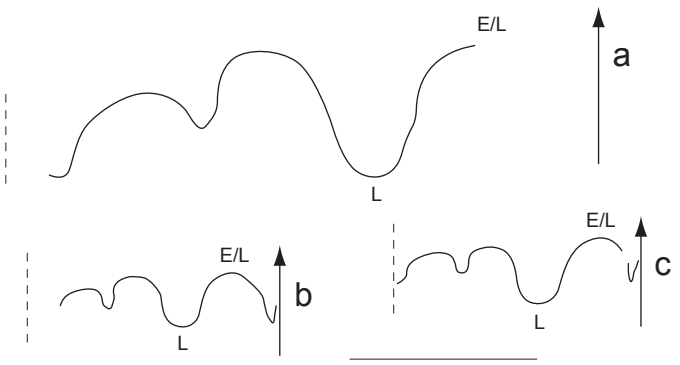


Fig. 15. Suture lines (×2) of *Proavites hueffeli* ARTHABER 1896; Monte Guglielmo (eastern Lombardy), *Rieppelites cimeganus* Zone (early late Anisian). a) PIMUZ 26499, Loc. HB 912. b) PIMUZ 26497, Loc. HB 911. c) PIMUZ 26498, Loc. HB 911. Scale bar: 10 mm.

Ceratites rothi MOJSISOVICS 1882 (pl. 9, fig. 7) differs from the *elegans* group by having a more subrectangular and depressed whorl section, a tabulate venter without a keel, weak umbilical tubercles, sinuous ribs and ornamentation fading on outer whorls. These characters suggest affinities with *Ronconites* and *Rieppelites*. As discussed by Balini (1992c), *C. rothi* is defined on a single, probably deformed specimen. Hence, in the absence of new material and a taxonomic revision, the position of this species remains open.

Superfamily *incertae sedis*
Family *incertae sedis*
Genus *Proavites* ARTHABER 1896
Type species. – *Proavites Hüffeli* ARTHABER 1896; SD Diener 1915: 228.

Remarks. – The genus *Proavites* is a well-defined and easily recognizable genus with its smooth, tabulate shell and a goniatitic suture line. However, its assignment to a precise family remains difficult because of its unusual goniatitic suture line.

***Proavites hueffeli* ARTHABER 1896**
(Figs. 14–16)

* 1896a *Proavites Hüffeli* – Arthaber: 104, pl. 10, figs. 2a–d.
. 1896a *Proavites marginatus* – Arthaber: 105, pl. 10, figs. 4a–c.
. 1896a *Proavites avitus* – Arthaber: 105, pl. 10, figs. 3a–c.
. 1896b *Proavites avitus* – Arthaber: 239, pl. 26, figs. 12a–c.
1934 *Proavites hueffeli* – Spath: 273.
. 1969 *Norites gondola* – Gaetani: 514, pl. 36, figs. 1–2.
1980 *Proavites hueffeli* – Gu et al.: 346, pl. 1, figs. 1–5.
? 1986 *Proavites* cf. *proavitus* – Rakús: 80, text-figs. 6–7, pl. 1, fig. 2.
. 1987 *Proavites hueffeli* – Vörös: 55, pl. 2, figs. 4a–b.
. 1987 *Proavites marginatus* – Vörös: 55, pl. 2, figs. 5a–b.
. 1991 *Proavites hueffeli* – Tatzreiter & Vörös: pl. 2, fig. 4.
. 1991 *Proavites margaritatus* – Tatzreiter & Vörös: pl. 2, figs. 10a–b [cop. Arthaber 1896a: pl. 10, fig. 4].
. 2003 *Proavites hueffeli* – Vörös: 77, text-figs. 2–8, pl. 1, figs. 1–4.

Description. – Involute, thick-whorled, and smooth shell with a broad tabulate venter (Fig. 14). Relatively depressed, subtrapezoidal whorl section with a broad, flat, tabulate to slightly concave and smooth venter, angular marginal shoulders, slightly convex flanks (flank maximal curvature being low on flanks), slightly convergent flanks toward the venter, moderately deep umbilicus, and narrowly rounded umbilical shoulder. Shell smooth except for thin, prorsiradiate, sinuous to flexuous growth lines. On outer whorls, the umbilical shoulder becomes wider and less angular. Suture line goniatitic with wide saddles and narrow lobes, characterized by a large first lateral saddle (E/L) and a deep first lateral lobe (L) (Fig. 15).
Measurements. – See Figure 16.

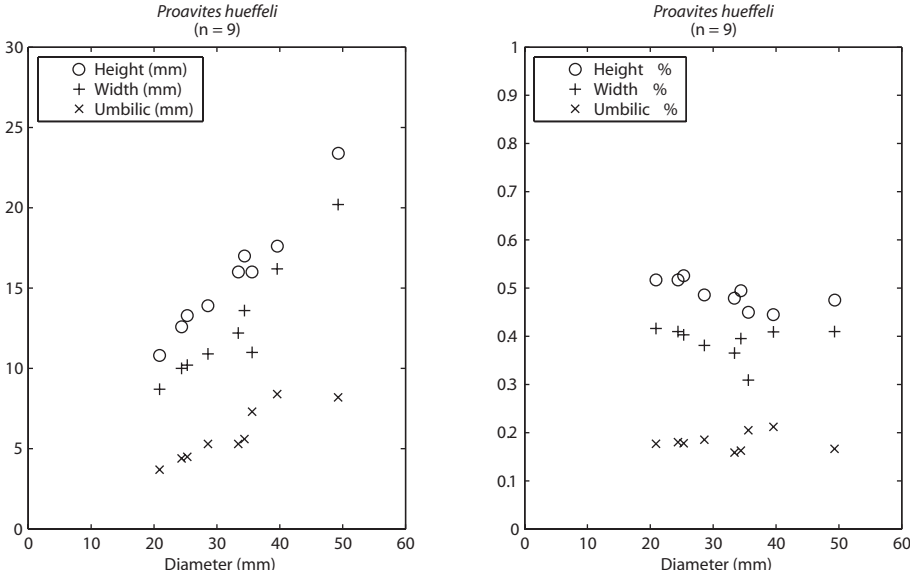
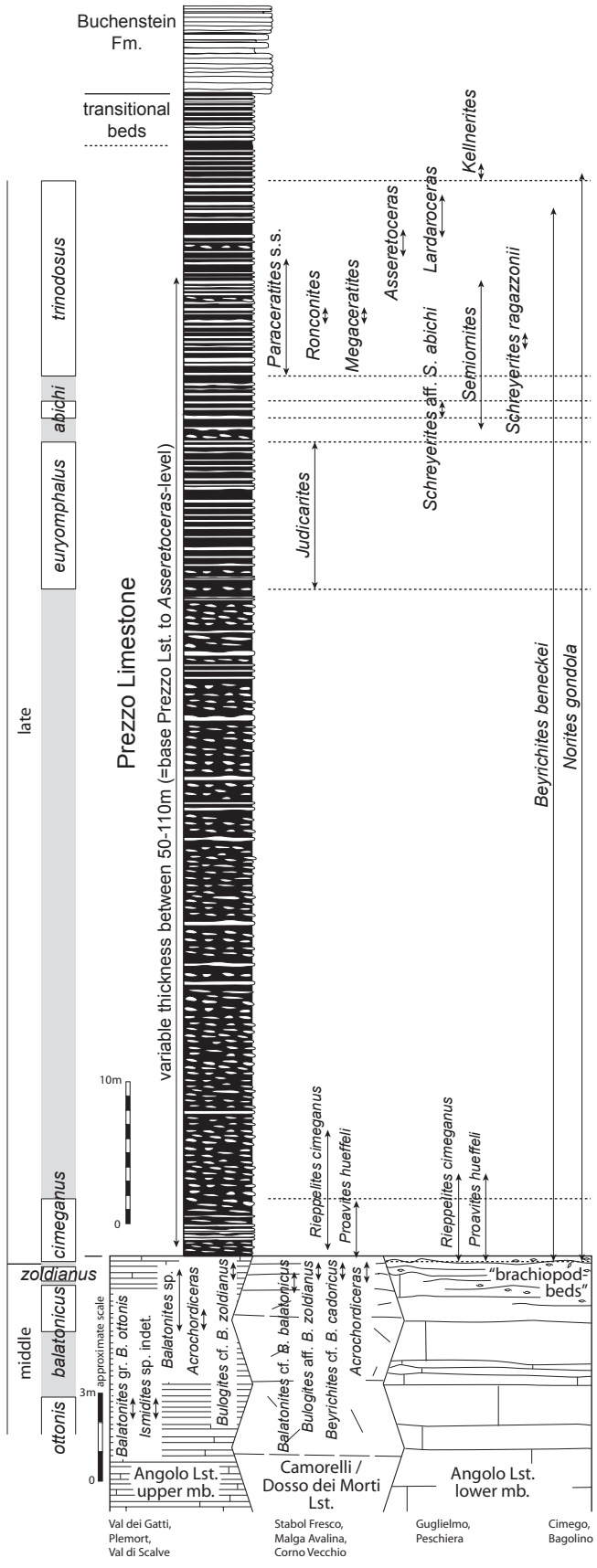


Fig. 16. Scatter diagrams of H, W, and U (left), and of H/D, W/D, and U/D (right) for *Proavites hueffeli* ARTHABER 1896a (Monte Guglielmo, eastern Lombardy; *Rieppelites cimeganus* Zone, early late Anisian). Abbreviations: D, diameter; H, whorl height; U, umbilical diameter; W, whorl width.



Remarks. – Arthaber (1896a) initially described three species of *Proavites* (*P. hueffeli*, *P. marginatus*, *and P. avitus*) on the basis of slight differences in their shape and suture lines. However, Vörös (2003) examined the material of Arthaber and stressed the poorly preserved and fragmentary state of these specimens. Vörös (2003) also observed a wide variation of these supposed differences in his collections and concluded that the three species are synonyms. The intraspecific variation observed within our own material matches that documented by Vörös (2003). Hence, we endorse the opinion of Vörös and assign our specimens to *P. hueffeli*. It is noteworthy that the variation observed in this material falls typically in the classical Buckman's laws of covariation (Westermann 1966, Hammer & Bucher 2005).
Occurence. – Monte Guglielmo (eastern Lombardy): HB 911 (18), HB 912 (2); *cimeganus* Zone (early late Anisian). Stabol Fresco (Giudicarie): HB 906 (2); *cimeganus* Zone (early late Anisian). Malga Avalina (Giudicarie): HB 921 (2); *cimeganus* Zone (early late Anisian). Corno Vecchio (Giudicarie): HB 931 (1), HB 933 (1); *cimeganus* Zone (early late Anisian). The species *Proavites hueffeli* was also described from the middle Anisian of the Balaton Highland (Hungary), the Northern Calcareous Alps (Austria), and Tibet.

Biostratigraphy and correlation

Zonation of eastern Lombardy-Giudicarie

Figure 17 summarizes the distribution of major ammonoid taxa in eastern Lombardy-Giudicarie after data compiled from the literature (whose taxonomy has been recently revised) and this study. The Camorelli/Dosso dei Morti Limestone and Angolo Limestone, which record the Pelsonian substage (middle Anisian), contain very few ammonoids. Nevertheless, the following assemblages are identified in ascending order: 1) *Balatonites* gr. *B. ottonis* with *Ismidites* sp. indet.; 2) *Balatonites* cf. *B. balatonicus*; 3) *Bulogites* aff. *B. zoldianus* with *Acrochordiceras* cf. *A. carolinae*, *P. hueffeli*, and *Beyrichites* cf. *B. cadoricus*; and 4) *Rieppelites cimeganus* with *P. hueffeli*, *Norites gondola* and *Beyrichites beneckei*.

The overlying Prezzo Limestone contains the following assemblages in ascending order: 1) the same *cimeganus* assemblage found in the uppermost part of the Dosso dei Morti/lower Angolo Limestones; 2) *Judicarites* spp. 3) *Schreyerites* aff. *S. abichi* with *Semiornites* spp. and 4) the classical *trinodosus* Zone with the true *Paraceratites* (e.g. *P. brembanus* and *P. trinodosus*), as well as *Ronconites tridentinus*, *Megaceratites fallax*, *Semiornites* spp. *Asseretoceras*, *Lardaroceras*, *Schreyerites ragazzonii*, *Beyrichites beneckei*, and *Norites gondola*.

Fig. 17. Schematic summary distribution of major ammonoids around the middle/late Anisian boundary in eastern Lombardy-Giudicarie (compiled and modified after Gaetani 1969; Balini 1992c; Balini et al. 1993; Brack et al. 1999, 2005; this study).

It is noteworthy that Tatzreiter & Balini (1993) rejected the taxonomic position of specimens from Giudicarie considered as *"Ceratites" abichi* by several authors (e.g. Venzo & Pelosio, 1968; Gaetani, 1969; Balini in Kovacs et al. 1990). According to these authors, Giudicarian specimens differ from *S. abichi* by having a suture line with four saddles instead of five, lateral tubercles appearing 10 mm earlier during ontogeny, and the presence of a temporary second series of lateral nodes in inner whorls. Because Tatzreiter & Balini (1993) may have set extremely narrow limits to the definition of *Schreyerites* and *S. abichi*, we refer these Giudicarian specimens to *Schreyerites* aff. *S. abichi*, pending the taxonomic revision of this material.

The fauna described in this study characterizes the *Rieppelites cimeganus* Zone. From a biochronological viewpoint, only *R. cimeganus* is diagnostic of a distinct ammonoid horizon. *Proavites hueffeli* and *N. gondola* are long-ranging species, which are already known in the middle Anisian of Balaton Highland for example (see Vörös 2003). *Beyrichites beneckei* is known from the middle Anisian of Balaton Highland (see Vörös 2003) and the *trinodosus* Zone (late Anisian) of Giudicarie (see Venzo & Pelosio 1968, Balini 1992c).

Correlation

Balaton Highland (Hungary)

The Balaton Highland is one of the most important reference areas of the Alpine Triassic stratigraphy. Important and recent studies (e.g. Vörös 1987, 1993, 2003; Tatzreiter & Vörös 1991; Vörös et al. 1996) allow relatively detailed correlations with eastern Lombardy-Giudicarie. The specimens of *Balatonites* gr. *B. ottonis* and *Acrochordiceras* collected by Brack et al. (1999) at Val dei Gatti and Schilpario (Lombardy) in the Angolo Limestone may correlate with the *ottonis* subzone of Balaton Highland as defined by Vörös (2003).

The rare occurrence of *Balatonites balatonicus* may correlate with the *balatonicus* and/or *cadoricus* subzones of Balaton Highland (Fig. 18). The level of *Bulogites zoldianus* in eastern Lombardy-Giudicarie probably belongs to the *zoldianus* subzone of Balaton Highland. This level is widespread since it is also recognized in Nevada with finds of *Bulogites mojsvari* (Bucher 1992, Monnet & Bucher 2005), which also characterizes the *zoldianus* subzone in Balaton Highland. Gaetani (1969) and Balini et al. (1993) indicated the co-occurrence of *Beyrichites* cf. *B. cadoricus* and *Bulogites* aff. *B. zoldianus* in Stabol Fresco (Giudicarie), whereas in Balaton Highland, *Beyrichites cadoricus* constitutes a distinct level (Fig. 18b) older than *Bulogites zoldianus* (Vörös 2003). Since Balini et al. (1993) did not figure this *Beyrichites* cf. *B. cadoricus* and specimens figured by Gaetani (1969) are poorly preserved and too small for a precise determination, the co-occurrence of *B.* cf. *B. cadoricus* with *B. zoldianus* may result from either a taxonomic misidentification or from diachronism.

The correlation of the Hungarian *binodosus* subzone with the eastern Lombardy-Giudicarie sequence is more problematic. *Rieppelites cimeganus* is unknown from Hungary and *Beyrichites beneckei*, *Proavites hueffeli* and *Norites gondola* are found in older and younger levels. Since the *binodosus* subzone is defined by *Schreyerites binodosus*, *Beyrichites reuttensis* and *Judicarites* at Balaton Highland, it may correlate with the *Judicarites* beds of eastern Lombardy-Giudicarie. The stratigraphic position of *S. binodosus* is contradictory with the one from Dont (Southern Alps) where it is older (see below). Finally, above the *Judicarites* level in the Köveskál section Vörös & Pálfy (2002) documented (although in loose blocks) the classical *trinodosus* Zone with *Paraceratites* cf. *P. trinodosus* and *Lardaroceras* spp.

Dolomites (Italy)

The Dont Formation in the Dolomites (Italy) records several ammonoid faunas around the middle/late Anisian boundary. Balini (1993), Tatzreiter & Balini (1993), Muttoni et al. (1998), and Kustatscher et al. (2006) discussed the ammonoid faunas and sequence relevant to this formation. Four major successive levels cover the middle/late Anisian boundary (Fig. 18a): a *Balatonites* gr. *B. balatonicus* and *Acrochordiceras* gr. *A. carolinae* assemblage (by correlation), a *Schreyerites binodosus*, *Balatonites gemmatus*, and *Bulogites zoldianus* assemblage ("level R"), a "*Paraceratites" cimeganus*, *Schreyerites abichi*, *Schreyerites binodosus*, and *Judicarites* spp. assemblage ("level β"), and a *Paraceratites trinodosus* assemblage containing *Megaceratites*.

These faunas show several discrepancies with other discussed areas. In Dont, *R. cimeganus* and *S. abichi* co-occur with *Judicarites*, whereas in eastern Lombardy-Giudicarie these three taxa characterize distinct biochronological levels. However, the *Judicarites* of Dont and eastern Lombardy-Giudicarie belong to different species (Brack et al. 1999) and Giudicarian *Schreyerites* aff. *S. abichi* remain to be revised. *Schreyerites binodosus* has also a different stratigraphic occurrence between Dont and Balaton Highland. Assessing if these discrepancies result from diachronous taxa or misidentification is hampered by absence of the illustration of the bed-by-bed collections of Dont.

Northern Calcareous Alps (Austria)

The Grossreifling area is well known for its middle–late Anisian faunas since the first descriptions of Arthaber (1896a, b). Tatzreiter & Vörös (1991) documented a fauna with *Bulogites* cf. *B. mojsvari* and *B.* cf. *B. gosaviensis* in the upper part of the Tiefengraben section (above an assemblage with *Balatonites* and *Acrochordiceras*), which possibly correlates with the *Bulogites* level of eastern Lombardy-Giudicarie and Balaton Highland. It is noteworthy that *R. cimeganus* has been described from the Reiflinger Kalke by Arthaber (1896a) with the description of *Ceratites Waageni*. In agreement with Assereto (1971: 44) who also checked the original material, this species is here considered to be a junior synonym of *R. cimeganus*. This strongly suggests that the *cimeganus* Zone occurs at Grossreifling, but information about its local stratigraphic position is still wanting.

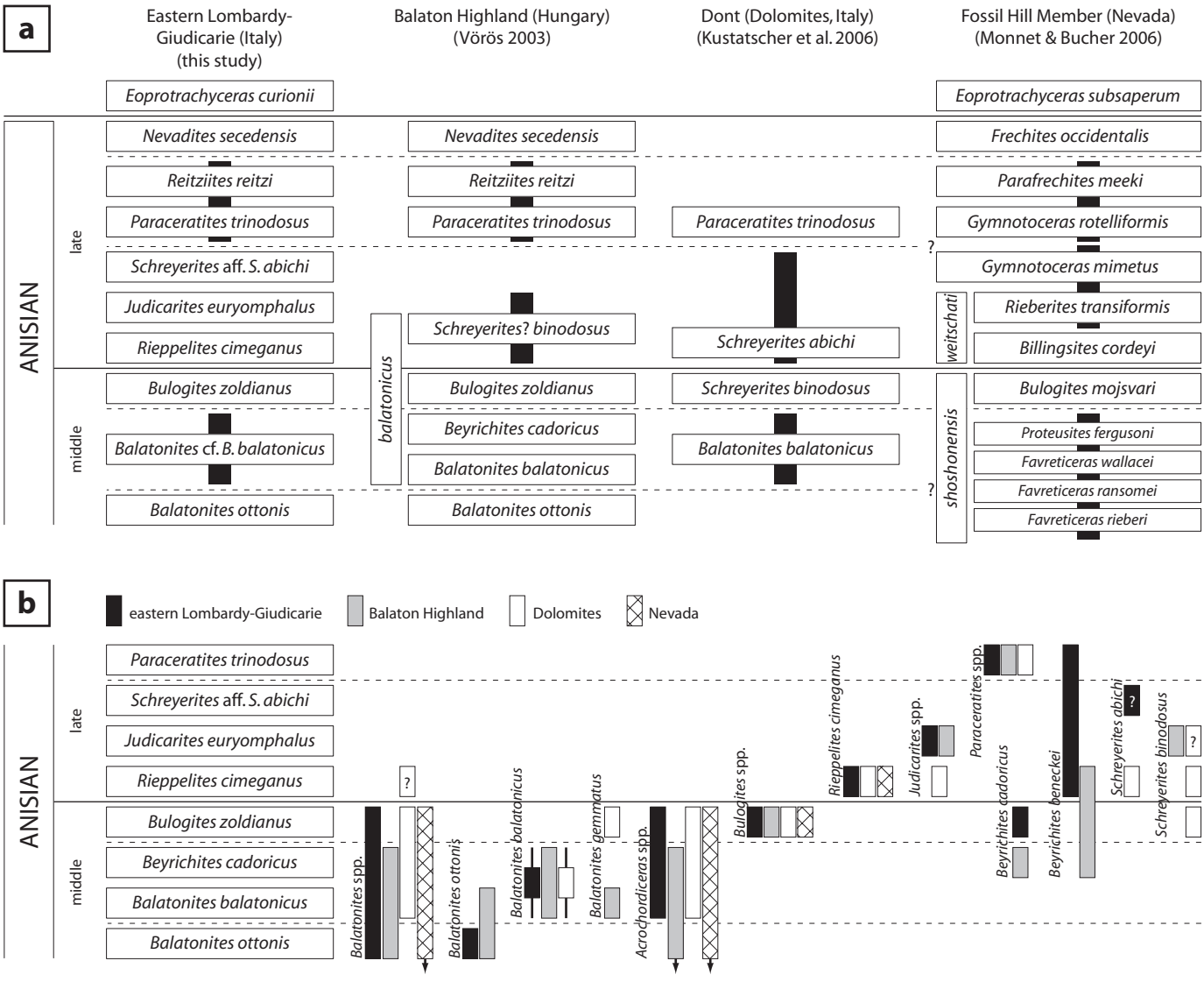


Fig. 18. a) Correlation zones and subzones of the middle/late Anisian boundary (Pelsonian/Illyrian) between major Tethyan basins and Nevada (USA). Vertical black bars indicate amount of uncertain correlation. b) Stratigraphic distribution of major ammonoid taxa between these areas.

Arthaber's collection therefore includes several distinct ammonoid faunas among which the *zoldianus* and *cimeganus* zones can be recognized. Hence, we suspect the *cimeganus* Zone to occur stratigraphically above the re-excavated supposed "Arthaber section" in the topmost Gutenstein Fm. at Tiefengraben as reported by Tatzreiter & Vörös (1991). Based on new field investigations, Tatzreiter (2001) sampled additional ammonoid-bearing levels which enable to revise the stratigraphic position of the classical ammonoid localities of the Grossreifling area. The upper part of the Tiefengraben section (Tatzreiter 2001: fig. 8, part C, levels TG 3–4 and TG 1) records *Bulogites mojsvari*, *B. gosaviensis* and *Acrochordiceras* cf. *A. carolinae* among other ammonoids, which clearly correspond to the *zoldianus* Zone. The underlying assemblage (Tatzreiter 2001: fig. 8, part C, levels TG 7–8 and lower) contain *Balatonites* cf. *B. balatonicus* and other ammonoids suggesting the presence of the *balatonicus* Zone.

Gebze (Turkey)

The Gebze region contains rich Anisian macrofaunas described by Toula (1896), Arthaber (1914) and Fantini Sestini (1988). Two faunas may concern this study: (i) fauna D, which contains *Balatonites* spp. and (ii) fauna E, which includes two groups of "*Paraceratites*" (*Ceratites himalayanus–C. cimeganus* and *C. binodosus*) according to Assereto (1972). However, illustrations of these bed-by-bed collections are lacking. The few figured specimens (see Arthaber 1914 and Fantini

Sestini 1988) neither belong to *R. cimeganus* nor to *Paraceratites*; thus the presence of the *cimeganus* Zone at Gebze remains open.

Nevada (USA)

North-western Nevada provides a very detailed ammonoid zonation, which has been recently completed and revised by Monnet & Bucher (2005, 2006). The Anisian contains rich faunas (~174 species) distributed into 13 zones and 31 subzones. However, western Tethys and Nevada have very few ammonoid species in common. This hampers precise correlation with the exception of few intervals.

The common occurrence of *Balatonites* and *Acrochordiceras* suggests that the *Balatonites shoshonensis* and *B. balatonicus* zones roughly correlate (Fig. 18a). See Bucher (1992) for a complete revision and description of the *shoshonensis* Zone in Nevada. The common occurrence of *Bulogites mojsvari* even indicates that the *mojsvari* subzone of Nevada correlates with the *zoldianus* subzone of eastern Lombardy-Giudicarie and Balaton Highland. Monnet & Bucher (2005) illustrated a specimen of *R. cimeganus* from Nevada within the *Billingsites cordeyi* subzone of the *Gymnotoceras weitschati* Zone, which allows correlation of this level with the *cimeganus* Zone of eastern Lombardy-Giudicarie. The next common ammonoid genera (*Aplococeras* and *Nevadites*) range in the latest Anisian (see Silberling & Nichols 1982, Brack et al. 2005, Monnet & Bucher 2006). In between, the *Gymnotoceras rotelliformis* Zone may correlate with the *trinodosus* Zone, even though species of *Paraceratites* described by Silberling & Nichols (1982) do not belong to this genus (Monnet & Bucher 2005). Consequently, no common age-diagnostic ammonoid species are currently known between Nevada and eastern Lombardy-Giudicarie during the *rotelliformis*/*trinodosus* intervals. Nevertheless, this description of the *mojsvari* and *cordeyi* subzones in Nevada (Monnet & Bucher 2005) and of the *zoldianus* and *cimeganus* zones in eastern Lombardy-Giudicarie (this study) significantly improve the correlation of the middle/late Anisian boundary within and outside Tethys.

Middle/late Anisian boundary

The middle/late Anisian boundary, which in the Tethys corresponds to the boundary between the Pelsonian and Illyrian substages, is usually placed above the *Bulogites* level and at the First Appearance Datum of *Paraceratites*. However, the position of this boundary in the literature fluctuates according to the taxonomic interpretation of *Paraceratites*. Moreover, this study and the works of Monnet & Bucher (2005, 2006) show several distinct ammonoid zones between the *Bulogites* and the true *Paraceratites*. We propose here to draw the middle/late Anisian boundary between the *zoldianus* and *cimeganus* zones. The boundary is thus placed between the disappearance of *Bulogites*, *Balatonites* and *Acrochordiceras* and the appearance of *Rieppelites*. This limit is recognizable within and outside Tethys in several basins and marks an important turnover in ammonoid faunas. This boundary is followed by the diversification of Paraceratitinae during several successive zones and consists essentially of more endemic genera (e.g. *Rieppelites*, *Paraceratites*, *Ronconites*, *Lardaroceras, Asseretoceras, Jenksites, Rieberites, Silberlingitoides*).

Palaeogeography and age of the transgression of the Prezzo Limestone

The regional pre-Prezzo Limestone sedimentation pattern throughout Lombardy and Giudicarie indicates the existence of an up to 100 km wide shallow basin where neritic and shallow water carbonates accumulated (e.g. De Zanche & Farabegoli 1988). With the exception of the topmost layers, the thick and predominantly middle Anisian sediment successions in eastern Lombardy-Giudicarie are almost devoid of planktonic fauna remains. A basin margin is located west of Lake Como and more emergent land areas may be hidden beneath the Neogene clastic fill of the Po plain. Other source areas for siliciclastic detritus include the western Dolomites where thick piles of Early Triassic were eroded during middle/late Anisian times. Comparable sediment successions in distant Alpine tectonic units (e.g. Drauzug, western Northern Calcareous Alps) may originally have been located close to the western Southern Alps (Brack et al. 1999) and represent similar basins and possible northern extensions of the Anisian Lombardian basin. Inside the shallow basin of Lombardy and Giudicarie a slightly deeper and probably tectonically controlled embayment or pond, about 30 km wide, formed in rough correspondence with the maximal accumulation of the thinly and evenly bedded dark upper Angolo Limestone in lower Val Camonica (see also fig. 1b in Berra et al. 2005). This upper Angolo embayment was likely bordered by shallow subtidal banks and barriers. The distribution of shallow water carbonates (Camorelli-, Dosso dei Morti-, Guglielmo and equivalent limestones) between Val Camonica and Giudicarie and the contrasting Angolo stratigraphies on either side indeed suggests that this area was originally a major stratigraphic divide in correspondence with an irregular and mainly subtidal barrier (Fig. 19a). To the west of Val Camonica, similar lithologies are preserved in allochtonous Triassic units of the central Bergamask Alps (Berra et al. 2005). Relative to the Middle Triassic successions in Val Camonica the latter units were originally situated further north and bordered a westerly adjacent area with reduced thickness of Anisian sediments (including the Prezzo Limestone). Similar to Val Trompia and Val Sabbia the layers underlying the Prezzo Limestone in Val Brembana and Valsassina (central/western Bergamask Alps) bear local accumulations of brachiopods. Further to the west, these middle Anisian successions are replaced by land-locked clastic delta deposits (e.g. fig. 1 in Berra et al. 2005).

At the onset of the late Anisian, large portions of the shallow basinal areas throughout Lombardy and Giudicarie were submerged and turned into a pelagic realm with the formation of the pelagic carbonate-shale-couplets of the Prezzo Lime-

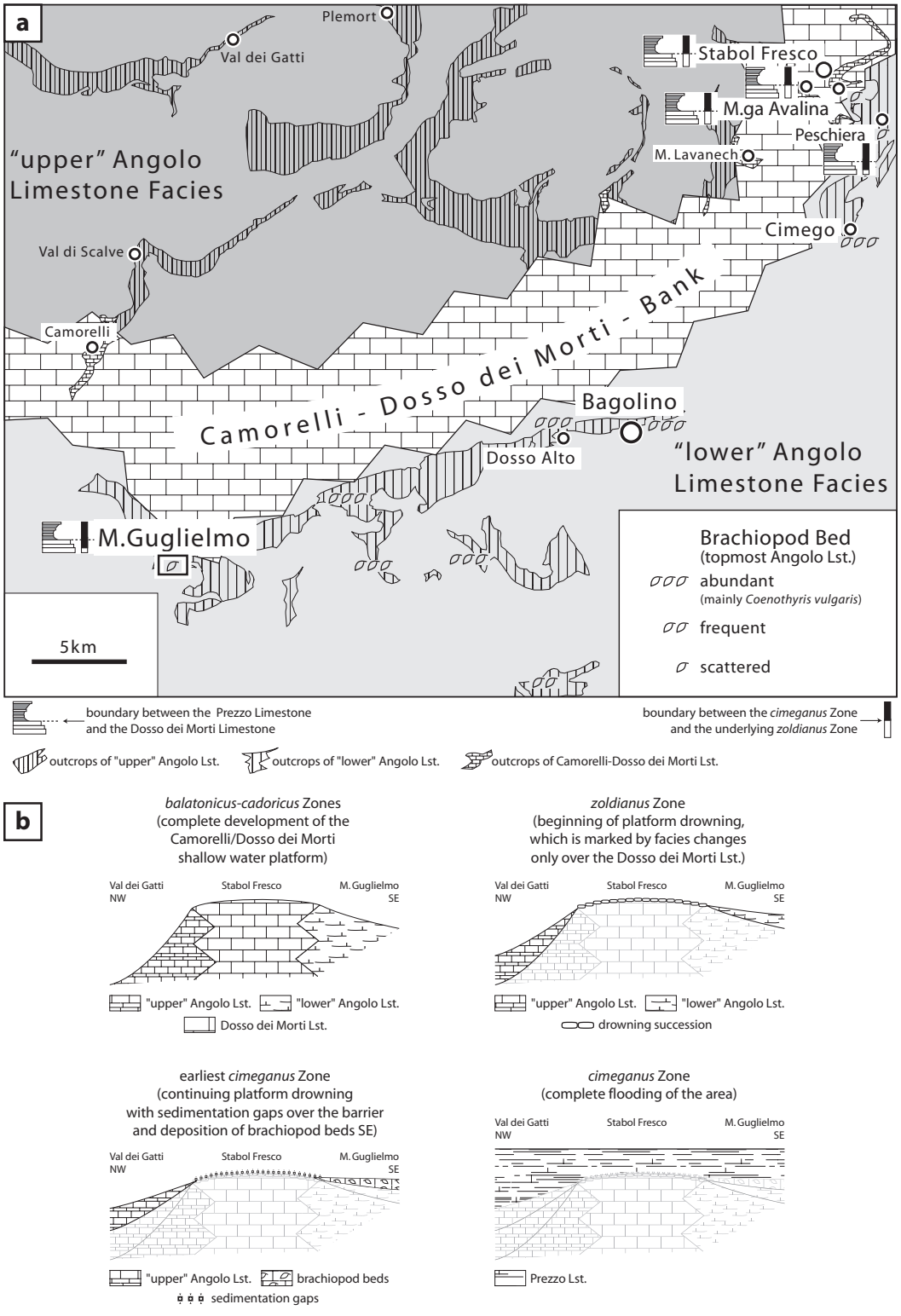


Fig. 19. a) Geological sketch of eastern Lombardy-Giudicarie during the *zoldianus* Zone (latest middle Anisian; not corrected for Alpine shortening). In this model, shallow water carbonates of the Camorelli-Dosso dei Morti limestones are assumed to have formed a continuous bank along a W–NE axis. It is noteworthy that the distinct brachiopod lumachellas (topmost Angolo Lst.) are observed only southeast of this area. b) These data allow suggesting the presence of a shallow carbonate platform, which forms a "barrier" during the late middle Anisian and which is drowned by the regional transgression of the Prezzo Limestone (relief in cartoons is exaggerated). The age calibration of the different facies suggests that the drowning started during the *zoldianus* Zone and was complete during the *cimeganus* Zone.

stone. Minimum basin depth was such as to allow the invasion of (pseudo)planktonic organisms (mainly ammonoids and thin shelled bivalves). In areas of reduced thickness of the Prezzo Limestone (5–25 m in the central/western Bergamask Alps), it is as yet unclear if submergence occurred simultaneously or if the base of the Prezzo Limestone becomes diachronous. The fossils discussed in this report constrain the age of the base of the Prezzo Limestone throughout eastern Lombardy-Giudicarie where the unit follows with significant variation in thickness and bedding characteristics on top of a heterogeneous substrate. In the northern and western sector of the area of Figure 1, the transition between the upper Angolo Limestone and Prezzo Limestone occurs within a narrow stratigraphic interval of 1–2 meters (Fig. 4b) or less. The basal Prezzo Limestone is rich in marl and shale and exhibits relatively even bedding planes. In the areas of the Camorelli-Dosso dei Morti Limestone, a shale-rich and coarsely nodular basal Prezzo Limestone overlies a "drowning succession" consisting of a few meters of nodular bioclastic limestone. The absence of significant karst fissures or other signs of emersion point to a gradual but rapid downwrapping of the carbonate bank. Gaetani & Gorza (1989) mention foraminiferal sands at the top of the Camorelli Limestone and invoke a possible reworking of the topmost platform sediments. This could have resulted in minor stratigraphic gaps between the platform top and its pelagic cover.

The timing of the Prezzo-transgression across the area of Figure 1 is constrained by ammonoid information, which can be summarized as follows for the different substrates:

i) *Prezzo Limestone overlying the upper Angolo Limestone (e.g. Val dei Gatti)*. Specimens of *Balatonites* gr. *B. ottonis*, followed by other forms of *Balatonites* as well as *Acrochordiceras* and ptychitids document the *ottonis* to the *balatonicus* zones for the uppermost (but not the terminal) layers of upper Angolo Limestone at Val dei Gatti. Terminal layers of the Angolo Limestone yield *Bulogites* cf. *B. zoldianus* at lower Val di Scalve and thus record the *zoldianus* Zone. No ammonoids have been found yet in the basal Prezzo Limestone of this area.

ii) *Prezzo Limestone above shallow water carbonates capped by a thin drowning succession (e.g. Stabol Fresco)*. Specimens of *Balatonites* are associated with *Bulogites* and *Acrochordiceras* immediately below the first shale-rich layers of Prezzo Limestone with *Rieppelites cimeganus* and *Beyrichites beneckei*. The thin drowning succession in the Dosso dei Morti area thus likely starts in the *zoldianus* Zone whereas the beds above the lithological break belong to the *cimeganus* Zone.

iii) *Prezzo Limestone above Angolo Limestone (lower member) with brachiopod-bearing layers at the top (e.g. Monte Guglielmo)*. The occurrence of *Rieppelites cimeganus* and *Beyrichites beneckei* in the last layers of the shallow water succession at Monte Guglielmo is comparable with the fossils from the terminal lower Angolo Limestone at Peschiera in Giudicarie (Gaetani 1969). This demonstrates that in such places the *cimeganus* Zone also comprises the uppermost Angolo layers. With the exception of Cimego, only a few additional ammonoids have been mentioned from the uppermost part of the lower Angolo Limestone and from the basal Prezzo Limestone elsewhere throughout eastern Lombardy-Giudicarie. Bittner (1881) reports *Balatonites balatonicus*, *Acrochordiceras* and *Ptychites dontianus* from the uppermost Angolo Limestone (presumably below the brachiopod level) south of Nozza in Val Sabbia. A specimen of *Acrochordiceras* is also mentioned from an unclear level in or at the top of the brachiopod level at Dosso Alto. As stated earlier, the occurrence of *Rieppelites cimeganus* at Cimego cannot be excluded for the brachiopod lumachella itself. All these data suggest a largely *balatonicus* to *zoldianus* Zone age for the upper part of the lower Angolo Limestone. At least locally, terminal Angolo layers and possibly parts of the brachiopod lumachellas indeed range into the *cimeganus* Zone. Contrary to the foraminifera-based conclusions by Falletti & Ivanova (2003) this indicates that the stratigraphic succession including the Angolo and Guglielmo Limestones at Monte Guglielmo is pre-late Anisian and does not go well beyond the middle/late Anisian boundary.

The age constraints for the strata straddling the base of the Prezzo Limestone are compatible with a rapid regional basin deepening and flooding during the Prezzo transgression, most likely in a short time-interval at the base of the *cimeganus* Zone. At Guglielmo and Peschiera *Rieppelites cimeganus* first occurs in the topmost Angolo layers below the base of the Prezzo Limestone whereas above the Dosso dei Morti platform it starts in the basal Prezzo beds. This points to the existence of local small hiatuses corresponding to the top of the drowning successions capping the Camorelli-Dosso-dei-Morti-type carbonates and could indeed be due to reworking or non deposition during the submergence of the slight positive topographic features (Fig. 19b).

Conclusions

This study describes the ammonoid fauna of a new section recording the transgression of the Prezzo Limestone over the "Angolo Limestone" near Monte Guglielmo (eastern Lombardy-Giudicarie, Italy). The ammonoid fauna includes *Rieppelites cimeganus*, *Beyrichites beneckei*, *Proavites hueffeli*, and *Norites gondola*. It allows re-describing *Ceratites cimeganus* Mojsisovics 1882 and discussing the taxonomy of the genus *Paraceratites* Hyatt 1900.

The synthesis of ammonoid faunas in the literature and our sampled sections in eastern Lombardy-Giudicarie show that this ammonoid fauna characterizes a distinct biochronological level, here referred to as the *cimeganus* Zone. This zone significantly improves Anisian worldwide correlation since it is recognized in several Tethyan basins, as well as in Nevada (USA).

The recognition of the *zoldianus* and its overlying *cimeganus* zones allows a precise definition of the middle/late Anisian boundary (Pelsonian/Illyrian substage boundary). This boundary is characterized by the disappearance of *Acrochordiceras*, *Balatonites* and *Bulogites* and the appearance of *Rieppelites*.

Finally, our precisely sampled ammonoid faunas and compiled data from the literature from eastern Lombardy-Giudicarie

provide an improved age calibration of the regional transgression of the Prezzo Limestone over the shallow water carbonates of the Dosso dei Morti Limestone and its equivalents. Hence, the drowning succession formed during the *zoldianus* Zone and complete flooding was achieved during the *cimeganus* Zone.

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