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Towards a better definition of the Anisian/Ladinian boundary: New biostratigraphic data and correlations of boundary sections from the Southern Alps

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Abstract, Zusammenfassung, Riassunto

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ABSTRACT

Stratigraphic sections of basinal "Buchenstein Beds" in the northwestern Dolomites and eastern Lombardy are correlated on the basis of the distribution of macrofossils (ammonoids, Daonellas) and volcaniclastic layers. In Lombardy, these strata are bracketed by other Middle Triassic basinal sediments (Prezzo Lst., "Wengen Beds"), and the entire succession hosts a clear macrofossil (ammonoids, Daonellas) record ranging from the Late Anisian to the Late Ladinian. In the Anisian/Ladinian boundary interval this record appears to be relatively coherent when compared to equivalent standard sections in the western Tethys area. It allows the full integration of rich faunas from isolated localities in coeval platform carbonates (Latemar and Cernera) and intra-platform deposits (Monte San Giorgio). The combined series of fossils includes successive levels with key species of *Judicarites, Paraceratites, Kellnerites, Hungarites, Reitziites, Parakellnerites, Aplococeras, Ticinites, Halilucites, Stoppaniceras, Nevadites, Chieseiceras, Eoprotrachyceras, Arpadites* and *Protrachyceras* among other ammonoids and Daonellas. The non-condensed ammonoid succession is suitable for a partial revision of the Tethyan zonal subdivision. It also indicates a slightly, but distinctly diachronous base of the "Buchenstein Beds" or its single members. Thus the original location of the Anisian/Ladinian boundary at the base of the "Buchenstein Beds" (Bittner 1892) is ambiguous. The boundary between the Nevadites Zone and the Curionii Zone is at present the best constrained alternative. Not only can this marker be pinpointed in stratigraphic columns in the Southern Alps (i.e. the original "type-area" of the stage boundary) but it can also be traced to sections further afield in western Tethys and in North America.

Radiometric age data are available on volcaniclastic rocks within the studied sections but do not yet allow a conclusive correlation of the Ladinian Stage with the numerical time-scale. The best estimate at present is from 232 to 225 Ma. These values are in conflict, however, with other current estimates.

The recognition of corresponding levels in starved basinal sediments and carbonate platforms with clear large-scale architectures promises a detailed calibration and comparison of the individual platform to basin evolution histories. For the Upper Anisian to Ladinian platforms in the western Dolomites our data suggest a period of initially rapid but then decreasing up- and outbuilding at Latemar (Reitzi/Kellnerites Zone to Gredleri Zone) followed by a short phase of distinct lateral progradation (late stage at Rosengarten). Even higher rates of creation of accommodation space at Cernera in the central Dolomites prevented any significant progradation of this platform before its ultimate drowning close to the Anisian/Ladinian boundary.

Based on new fossil collections the generic and specific assignments of several ammonoids and Daonellas are revised in the paleontological part. This includes a description of the new genera *Reitziites* and *Latemarites* and of the new species *Kellnerites bagolinensis* n. sp., *Latemarites latemari* n. sp., *Parakellnerites zoniaensis* n. sp., *Ticinites brescianus* n. sp., *Ticinites dolomiticus* n. sp., *Stoppaniceras evolutum* n. sp., *Nevadites avenonensis* n. sp., *Nevadites bittneri* n. sp., *Nevadites secedensis* n. sp., *Nevadites crassiornatus* n. sp. and *Daonella cerneraensis* n. sp., *Daonella sotschiadensis* n. sp.

ZUSAMMENFASSUNG

Aufgrund der Verteilung von Makrofossilien (Ammonoideen, Daonellen) und vulkanoklastischer Lagen lassen sich stratigraphische Profile der pelagischen «Buchensteiner Schichten» in den nordwestlichen Dolomiten mit solchen in der Ostlombardei und Judikarien detailliert korrelieren. In den beiden letztgenannten Gebieten werden diese Schichten von fossilreichen Beckensedimenten unter- und überlagert (Prezzokalk, «Wengener Schichten»). Die gesamte pelagische Schichtfolge enthält eine Makrofossilsukzession, die vom späten Anis bis ins späte Ladin reicht. Überdies lassen sich Fossilien von isolierten Fundpunkten in gleichaltrigen Plattformkarbonaten (Latemar, Cernera) und in Ablagerungen plattforminterner Depressionen (Monte San Giorgio) integrieren. Gemessen an anderen Standardprofilen im westlichen Tethysgebiet ist die Fossilfolge insbesondere im Anis/Ladin-Grenzabschnitt recht kohärent.

Die nicht-kondensierte südalpine Ammonoideensukzession eignet sich für eine partielle Revision des Zonenschemas sowie der Anis/Ladin-Grenzziehung in der westlichen Tethys. Die Basis der «Buchensteiner Schichten» in den Dolomiten ist biostratigraphisch schlecht erfasst aber sicher leicht diachron und Bittner's (1892) ursprüngliche Auffassung der Anis/Ladin-Grenze deshalb zweideutig. Als Alternative für die Festlegung der Stufengrenze wird die Grenze zwischen der Nevadites- und der Curionii-Zone vorgeschlagen. Letztere lässt sich als Zeitmarke durch zahlreiche stratigraphische Profile der Südalpen sowie anderer Gebiete der westlichen Tethys und Nordamerikas verfolgen.

Radiometrische Altersdatierungen lassen noch keine abschliessende Beurteilung der Alterslimiten für das Ladin zu. Die Werte von 232 Ma und 225 Ma sind mit den meisten aus den Südalpen erhältlichen Daten vereinbar, weichen aber von anderen Abschätzungen für die Ladinische Stufe ab.

Die Funde entsprechender «pelagischer» Fossilien in Beckensedimenten und gleichaltrigen, zum Teil benachbarten Karbonatplattformen versprechen eine bessere Beurteilung und Eichung der Plattform-Becken-Entwicklung insbesondere in den Dolomiten. Unsere Daten weisen auf eine Phase raschen anfänglichen Vertikalwachstums der oberanisisch-ladinischen Plattformen hin. Plattformen in den östlichen Dolomiten konnten den hohen Raten des relativen Meeresspiegelanstiegs zum Teil nicht folgen und ertranken noch im Anis/Ladin-Grenzabschnitt (z. B. Cernera). Nach dem Abklingen der hohen Vertikalwachstumskomponente in den westlichen Dolomiten folgte eine Phase rascher Progradation (z. B. Rosengarten).

Aufgrund des neuen Materials an Makrofossilien wird die generische und spezifische Beurteilung einiger Ammonoideen und Daonellen im paläontologischen Teil revidiert. Neu beschriebene Genera und Spezies umfassen: *Reitziites* n. gen., *Latemarites* n. gen., *Kellnerites bagolinensis* n. sp., *Latemarites latemari* n. sp., *Parakellnerites zoniaensis* n. sp., *Ticinites brescianus* n. sp., *Ticinites dolomiticus* n. sp., *Stoppaniceras evolutum* n. sp., *Nevadites avenonensis* n. sp., *Nevadites bittneri* n. sp., *Nevadites secedensis* n. sp., *Nevadites crassiornatus* n. sp. und *Daonella cerneraensis* n. sp., *Daonella sotschiadensis* n. sp.

RIASSUNTO

Sezioni stratigrafiche degli «Strati di Buchenstein» nelle Dolomiti nord-occidentali e nella Lombardia occidentale vengono correlate in base alla distribuzione di macrofossili (ammonoidi, daonelle) e livelli vulcanoclastici.

In Lombardia gli «Strati di Buchenstein» sono posti tra altri strati bacinali Medio-triassici (Calcare di Prezzo, Formazione di Wengen). L'intera successione contiene una ricca fauna di ammonoidi e daonelle comprendente l'Anisico superiore fino al Ladinico superiore. L'intervallo comprendente il limite Anisico/Ladinico, se paragonato ad altri equivalenti sezioni di riferimento nella parte occidentale della Tetide, appare abbastanza coerente e permette di integrare le ricche faune di località isolate di piattaforme carbonatiche (Latemar e Cernera) e di depositi intra-piattaforma (Monte San Giorgio). Le serie di fossili includono livelli successivi ben definiti con varie specie di *Judicarites, Paraceratites, Kellnerites, Hungarites, Reitziites, Parakellnerites, Aplococeras, Ticinites, Halilucites, Stoppaniceras, Nevadites, Chieseiceras, Eoprotrachyceras, Arpadites e Protrachyceras.* La successione ad ammonoidi non condensata è adatta ad una parziale revisione della suddivisione delle zone nella Tetide e indica inoltre una leggera ma distinta diacroneità della base degli «Strati di Buchenstein». La definizione originale del limite Anisico/Ladinico alla base degli «Strati di Buchenstein» (Bittner 1892) è pertanto ambigua. Al momento la migliore alternativa è di localizzare il limite Anisico/Ladinico tra la Zona a Nevadites e quella a Curionii. Il limite basato su questa definizione può essere localizzato non solo nelle sezioni del Sudalpino (cioè nell' originale «area tipo») ma può essere anche riconosciuto in altre sezioni della Tetide occidentale come pure in Nordamerica.

Datazioni radiometriche di rocce vulcanoclastiche nelle sezioni studiate sono disponibili, ma non permettono tuttavia una correlazione definitiva del Ladinico con la scala numerica delle età. Al momento la stima migliore pone i limiti del Ladinico tra i 232 ed i 225 milioni di anni. Per ora questi valori sono in conflitto con le stime generalmente accettate.

Il ritrovamento di livelli corrispondenti in sedimenti bacinali e piattaforme carbonatiche con chiare strutture a larga scala promette una calibrazione e una correlazione dettagliata dell' evoluzione temporale delle piattaforme e dei bacini. Per le piattaforme dell' Anisico sommitale e del Ladinico nelle Dolomiti occidentali (p. es. al Latemar e al Catinaccio/Rosengarten) i nostri dati suggeriscono un periodo iniziale di rapida crescita verticale (dalla Zona a Reitzi/Kellnerites alla Zona a Gredleri). Alcune piattaforme nelle Dolomiti centrali ed orientali non riuscirono a seguire la rapida crescita del livello relativo del mare e furono annegate al limite Anisico/Ladinico (p. es. alla Cernera). Alla fine della crescita prevalentemente verticale fa seguito nelle Dolomiti occidentali una fase di veloce progradazione (p. es. al Rosengarten).

Sulla base dei nuovi ritrovamenti di fossili proponiamo una revisione delle designazioni di generi e specie di alcune forme di ammonoidi e di daonelle. Vengono inoltre descritti i seguenti nuovi generi e specie: *Reitziites* n. gen., *Latemarites* n. gen., *Kellnerites bagolinensis* n. sp., *Latemarites latemari* n. sp., *Parakellnerites zoniaensis* n. sp., *Ticinites brescianus* n. sp., *Ticinites dolomiticus* n. sp., *Stoppaniceras evolutum* n. sp., *Nevadites avenonensis* n. sp., *Nevadites bittneri* n. sp., *Nevadites secedensis* n. sp., *Nevadites crassiornatus* n. sp. e *Daonella cerneraensis* n. sp., *Daonella sotschiadensis* n. sp.

1. Introduction

The Middle Triassic sediments of the Southern Alps are classical representatives of a mediterranean "Tethyan" Triassic and have been the subject of intensive geological research for more than a century. The Ladinian Stage and names of various substages (Fassanian, Longobardian, Cordevolian, Julian) used in current time scales (e.g. Zapfe 1983; Tozer 1984) are derived from this area. However, due to complex stratigraphic patterns and the uneven occurrence of biostratigraphically relevant fossils, the original definitions of these time intervals are vague and in some cases inappropriate. Clearly outlined type sections exist neither for the single time units nor for the majority of their boundaries. As a consequence modern schemes of Middle Triassic ammonoid zones (e.g. Krystyn 1983; Tozer 1984) are based mainly on fossils from more straightforward sediment successions in other parts of the Triassic Tethys area and in North America.

Despite its stratigraphic complexity, the Middle Triassic of the Southern Alps will continue to be of biostratigraphical importance. This is especially true as numerous studies have already shed light on many former stratigraphical uncertainties and there is great potential for further discoveries. Reinvestigations were carried out over the last three decades mainly on classical sections and fossil localities (Fig. 1) and provided well documented data on macrofauna, in particular ammonoids and Daonellas. These studies

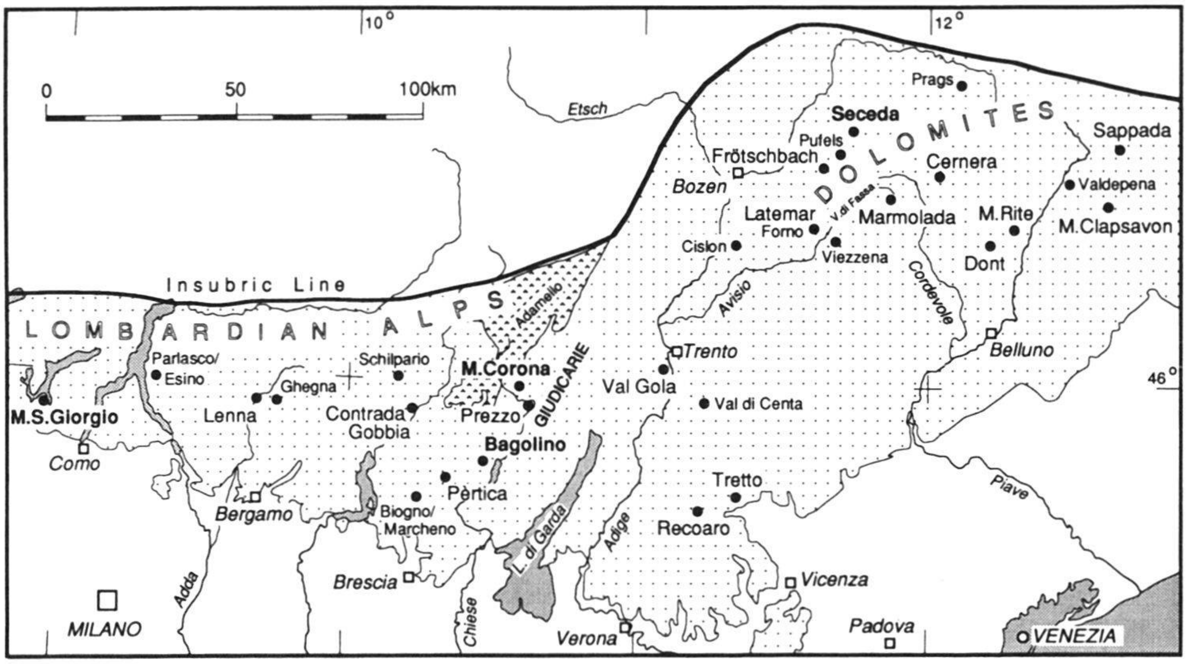


Fig. 1. Location map of the main South Alpine fossil localities mentioned in the text. Key sections for the Anisian/Ladinian boundary interval (i.e. Monte San Giorgio, Bagolino, M. Corona, Seceda) are highlighted. Exposed portions of the Southern Alps (dotted pattern) reach from a northern, tectonic boundary (Insubric Line) to the Neogene clastic basin fills of the Po and Venetian plains.

were initially focused on Upper Anisian pelagic sediments (e.g. Assereto 1963, 1971; Venzo & Pelosio 1968; Gaetani 1969; Farabegoli et al. 1984; Balini 1992) and on several isolated Anisian/Ladinian boundary intervals in shallow marine and platform carbonates (Pisa 1966, 1974; Rieber 1968a, 1969, 1973a, b, 1974; Assereto 1969). New ammonoid successions reaching higher up into the Ladinian were recently discovered in the "Buchenstein Beds" of eastern Lombardy and adjacent areas. Based on these finds we proposed a modified position for the Anisian/Ladinian boundary in the Tethys area (Brack & Rieber 1986).

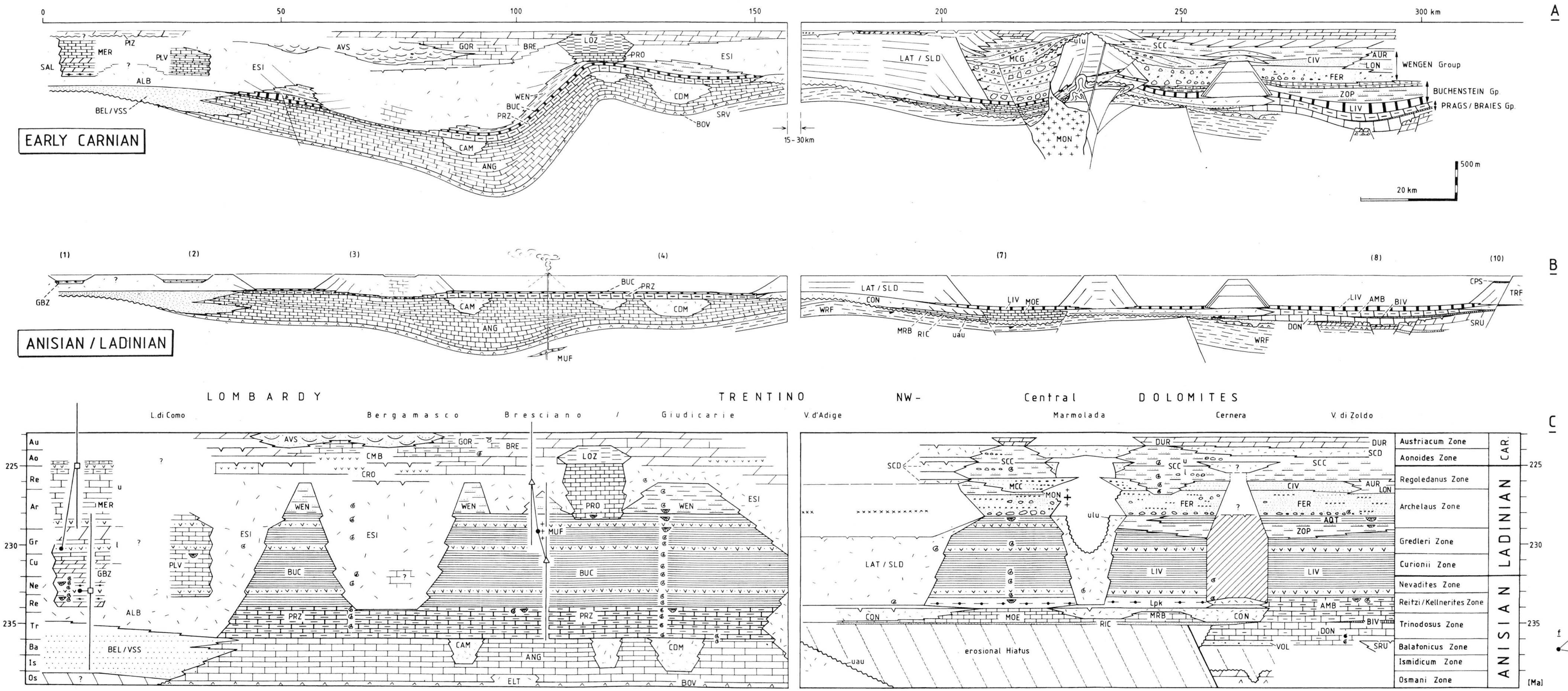
Follow-up studies have allowed us to significantly expand our fossil collection and further refine the correlations of key sections straddling the Anisian/Ladinian boundary. From a biostratigraphical point of view the main result of these investigations is an ammonoid record which now appears to be relatively coherent. On the basis of this South Alpine fossil record many stratigraphic sections can be better assessed including successions from the Dolomites, the original type area of the "Ladinian Stage" (Bittner 1892). Moreover we think that this provides an acceptable basis for a clear redefinition of boundaries between ammonoid zones as well as between the Anisian and the Ladinian Stages. The documentation of these findings is the main topic of this paper. A generalized picture is also sketched for the large-scale stratigraphic context of the studied sections within the Anisian to Ladinian evolution of the South Alpine realm. We hope that this approach might stimulate a better integration of various stratigraphic tools and further help assessing their consistency and chronostratigraphic value. Radiometric ages, micropaleontological and palynological data along with information on sea-level fluctuations at different scales and periods do already exist from rocks of the South Alpine Middle Triassic.

Details on new and revised ammonoid and Daonella genera and species are presented in the paleontological part.

2. Middle Triassic stratigraphy and fossiliferous Anisian/Ladinian boundary sections

The Middle to Upper Triassic rocks of the Southern and Eastern Alps formed prior to the Late Triassic-Jurassic breakup of the western Tethys in a tectonically mobile framework of repeatedly uplifted and subsiding blocks to the south of central Europe. Heterogenous Anisian to Carnian stratigraphic successions (Fig. 2) and Triassic tectonic structures indicate distinct periods of volcanism and tectonism, the latter with both, compressional and extensional components. Strike-slip movements were suggested in plate reconstructions for the Triassic western Tethyan area (e.g. Brandner 1984; Ziegler 1989) and wrench fault systems are indeed apparent in parts of the Southern Alps (Doglioni 1984a). Nevertheless, the large-scale geodynamic context of Triassic movements throughout the Southern Alps and formerly adjacent areas still remains largely obscure. Both rift-related and subduction-related models have been proposed (for discussions see e.g. Bechstädt et al. 1978, Brandner 1984, Castellarin et al. 1988, Sloman 1989).

Fig. 2. A, B) Simplified reconstructions of the cross sectional stratigraphy along the northern sector of the Southern Alps (see Fig. 3b for the trace of the section).
C) Chronostratigraphic chart for the South Alpine Middle Triassic.
The compilation is based on numerous references most of which are mentioned in the text. Unclear stratigraphic relationships are deliberately left vague. Scales are only approximate. In the Lombardian sector the depocenter of the Angolo Limestone lies in fact 30 km south of the section. Scheme of ammonoid zones modified after Krystyn (1983) (new Reitzi/Kellnerites Zone). See text for information on time-scale.
(1)–(10): Projected positions of sections in Fig. 14.
Special symbols: a: biostratigraphic calibration points (ammonoids, Daonellas); b: volcanic rocks, megabreccias/olistoliths; c: supposed stratigraphic position of shallow intrusives (M. Muffetto, Monzoni/Predazzo); d: typical successions of volcaniclastic layers; e: tectonically induced "diapirs" (Late Ladinian tectonism) of Upper Permian to Lower Triassic strata (central Dolomites); f: stratigraphic positions (full symbol) and age values (open symbol) with 2 sigma error bars of radiometrically dated rocks (see text for references).
Formal and informal stratigraphic units (in alphabetical order; abbreviations used in Figs. 2 and 14): ALB: Albiga Dol.; AMB: Ambata Fm.; ANG: Angolo Lst.; AQT: Aquatona Fm.; AUR: Auronzo Fm.; AVS: Val Sabbia Sst.; BEL: Bellano Fm.; BIV: Bivera Fm.; BOV: Bovegno "Cargneules"; BRE: Breno Fm.; BUC: Lombardian "Buchenstein Beds"; CAM: Camorelli Lst.; CDM: Dosso dei Morti Lst.; CIV: Civetta Sst.; CMB: Metallifero Bergamasco Lst.; CON: Contrin Fm. (= Upper Sarl Dol. auct.); CPS: Clapsavon Lst.; CRO: "Calcare Rosso"; DMR: "Daonella Marls"; DON: Dont Fm.; DUR: Dürrenstein Dol.; ELT: Elto Dol.; ESI: Esino Lst.; FER: Fernazza Hyaloclastites; GBZ: Grenzbitumenzone; GOR: Gorno Fm.; Knk: "Knollenkalke" (= "Buchenstein Beds" p.p.); LAT: Latemar Lst.; LIV: Livinallongo Fm. (= "Buchenstein Beds" of Dolomites); LON: Longiarin Sst.; LOZ: Lozio Shales; Lpk: "Lower Plattenkalke" Mb. (= "Buchenstein Beds" p.p.); MAR: Margon Lst.; MCG: Marmolada Cgl.; MER: Meride Lst.; MOE: Moena Fm.; MON: Monzoni & Predazzo intrusives; MRB: Morbiac Lst.; MUF: Muffetto subvolcanic rocks; PIZ: Pizella Marls; PLV: Perledo-Varenna Lst.; PRO: Pratotondo Lst.; PRZ: Prezzo Lst.; RIC: Richthofen Cgl.; SAL: Salvatore Dol.; SCC: basinal San Cassian Fm. (l: lower, u: upper); SCD: San Cassian Dol.; SLD: Schlern Dol.; SPZ: M. Spitz Lst.; TRF: Tiarfin Dol.; Ubk: "Upper Bänderkalke" (= "Buchenstein Beds" p.p.); VCM: Val di Centa Marls; VGL: Val Gola Lst.; VOL: Voltago Cgl.; VSS: Valsassina Clastics; WEN: Lombardian "Wengen Beds"; ZOP: Zoppè Sst. Main unconformities resulting from tectonic uplift and erosion: uau: "Upper Anisian Unconformity"; ulu: "Upper Ladinian Unconformity".



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The shoshonitic character of the igneous products is in conflict with a conventional rift model. No unambiguous reminders of Triassic oceanic crust or clearly subduction-related structural and sedimentological features have been reported from the Southern Alps or its original surroundings.

The South Alpine Anisian to Ladinian rocks originated during a long, overall transgression between a period of distinct sea-level lowstand in the basal Anisian and a period of multiple fluctuations in the Carnian. The overall transgressive trend was locally disturbed and overprinted by coeval volcanism and tectonic movements. As a result, a rapidly changing pattern of emergent areas, carbonate platforms, shallow marine shelves and pelagic basins evolved. This area lies to the north of an elongated "mobile belt", a site of repeated uplift and volcanism as documented from the subsurface of the Po plain (e.g. Brusca et al. 1981).

The area between Lombardy and the Dolomites includes the most important stratigraphic sections that will be discussed in this paper. The Anisian to Ladinian evolution of this sector shall therefore be rapidly outlined in a generalized and simplified way (Figs. 2, 3). No attempts have yet been made to restore the Alpine deformations although this would definitely improve the emerging picture of the Triassic paleogeography (for a rough sketch see Trümpy 1992). As a first approximation the strongly squeezed Lombardian sector has to be stretched and shifted by some 30–50 km (equivalent to the pre-43 Ma alpine shortening of the Lombardian Alps) in a northerly direction relative to the Dolomites. The transect of Fig. 2 was therefore approximately a straight line across the South Alpine realm during the Triassic.

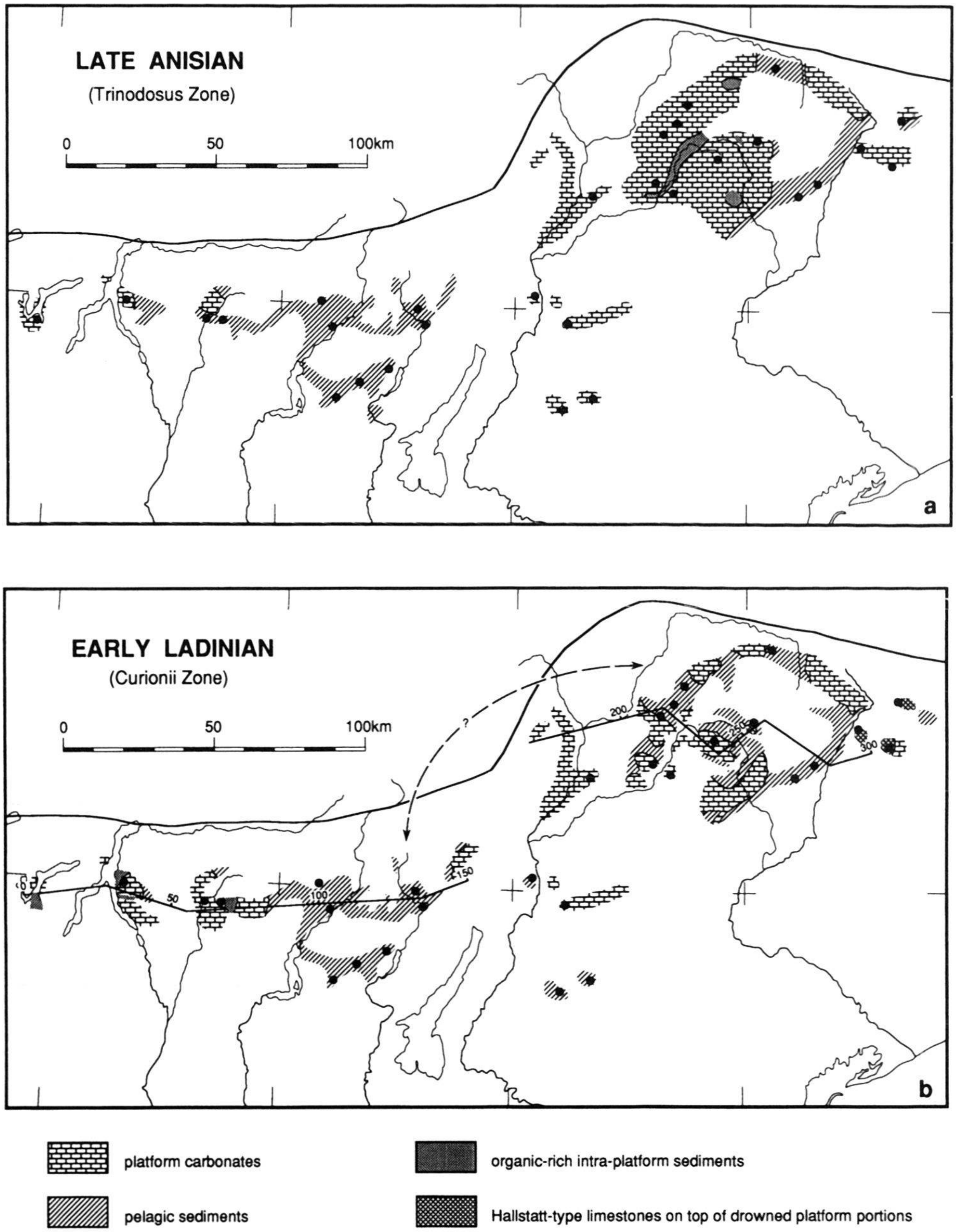
2.1. A few steps in the Anisian to Ladinian evolution

2.1.1. Early to Middle Anisian

Peritidal carbonates and mixed carbonate/evaporite deposits were laid down over most of the Southern Alps during a marked regression in the Early Anisian (Bovegno Cargneules, Lower Serla Fm.; e.g. De Zanche & Farabegoli 1982; Brandner 1984).

Monotonous successions of neritic and often nodular marly limestones (Angolo Lst.) interspersed with algal banks (Dosso dei Morti Lst. and equivalent shallow water carbonates) formed in the Middle Anisian in a shallow basin throughout eastern Lombardy. Pronounced thickness variations (50–700 m) in these shallow marine deposits clearly indicate tectonically controlled subsidence. Areas close to basin margins (Lake Como area, De Zanche & Farabegoli 1983; Gaetani et al. 1987; Recoaro/Tretto and Valsugana areas, De Zanche & Mietto 1981, 1989) still received clastic detritus with components from Permian and basement rocks.

In the eastern Dolomites carbonate platforms, flanked by shallow lagoons and tidal channels initially bordered a deepening, narrow basin (Pisa et al. 1978). In areas distant enough from the main clastic sources, basinal conditions persisted throughout most of the Anisian and Ladinian (Fig. 3a, b) as documented by a continuous pelagic succession of mixed siliciclastics and carbonates (Dont Fm., Bivera Fm., Ambata Fm., Daonella-Marls, Buchenstein Beds). Strata equivalent to the lower part of this succession might have extended into parts of the western Dolomites which were subject to erosion during Upper Anisian tectonic movements.



Figs. 3a, b. Actual distribution of basinal successions and platform carbonates in the Anisian/Ladinian boundary interval (area of Dolomites after Gaetani et al. 1981). The approximate trace of cross section Fig. 2 is indicated in Fig. 3b. Note that basinal conditions persisted throughout the Late Anisian into the Ladinian only in two areas: a wide basin in eastern Lombardy and a narrow N-S trending depression in the eastern Dolomites. A northern connection may have existed between these areas possibly via the Reifling and similar basins in the Northern Calcareous Alps or other areas inbetween (? Bakony).
Black dots mark the fossil localities indicated in Fig. 1.

2.1.2. Late Anisian to Early Ladinian

From late Middle Anisian time a large area of the western Dolomites was tilted (westward-dipping) and up to 400 m of strata, mainly of the Werfen Fm., were removed (Bosellini 1968; Brandner 1984). This erosional surface is unconformably covered by a thin sheet of fluviatile clastics (Peres Beds, Richthofen Cgl.). The resumption of subsidence allowed subtidal algal banks to build up and advance laterally over neritic limestones (Morbiac Lst.). The shallow water carbonates finally coalesced to a vast platform (Contrin Fm.) with some narrow basinal fingers or ponds (Moena Fm.; Masetti & Neri 1980). A more or less coherent platform may have ultimately reached to the south as far as the Recoaro/Tretto area (Monte Spitz Lst.; Fig. 3a).

The drowning of Anisian carbonate platforms in the Lombardian and eastern adjacent sector (Dosso dei Morti and equivalent carbonates) may have been related to the above mentioned westward tilting of the western Dolomites. Pelagic conditions persisted in this area throughout the rest of the Late Anisian and Early Ladinian (Prezzo Lst.; "Buchenstein Beds"). In western Lombardy basinal carbonates transgressed distal portions of a clastic succession. Further to the west these clastic deposits formed the substratum of Upper Anisian platform carbonates (Albiga and equivalent Dolomites; Farabegoli & De Zanche 1984, De Zanche & Farabegoli 1988).

In the Latest Anisian the large carbonate platform extending from the western Dolomites southwards was fragmented and portions of it collapsed (Figs. 2–5). Along its indented eastern margin platform carbonates continued to grow on (? fault bounded) topographic ridges (Dolomites area; Bosellini 1984). Bordering initially starved and silled but rapidly deepening basins, up to 800 m of small-cyclic platform carbonates and talus deposits (Marmolada- & Latemar Lst., Schlern Dol. p.p.) aggraded and eventually prograded (Bosellini & Rossi 1974; Bosellini 1984). In the intervening basins siliceous pelagic carbonates ("Buchenstein Beds") similar to coeval sediments in eastern Lombardy accumulated at low rates throughout the Latest Anisian and Early Ladinian. Basinal areas closer to carbonate platforms and volcanic sources received locally increased amounts of platform debris and reworked acidic volcanic detritus.

Red nodular limestones (Hallstatt-type limestones) were deposited on submerged platform portions especially in the eastern Dolomites and Cadore (Clapsavon Lst. p.p.; Pisa 1972; Marinelli 1980).

Anoxic conditions existed in bottom waters of depressions ("Grenzbitumenzone"; Perledo-Varenna Lst.; part of Meride Lst.) in the interior of larger carbonate platforms in western Lombardy (Salvatore Dol.; Esino Lst.). Organic-rich muds and reworked platform carbonates accumulated in these shallow basins but at rates that exceeded pelagic sedimentation in distal portions of the Buchenstein basins further to the east. Only subdued topographic relief thus existed in the intra-platform depressions and the carbonate platforms eventually migrated again across such areas.

2.1.3. Late Ladinian to Early Carnian

Vigorous tectonic and volcanic events affected the area of the Dolomites during the Late Ladinian (Bosellini et al. 1977, 1982; Doglioni 1982, 1984a, b; Blendinger 1985). Movements along a WSW-ENE-trending sinistral wrench-fault zone in the western and central Dolomites produced a high ridge thus triggering coarse gravity flows. Megabreccias and olistoliths accumulated in the adjacent basins. Carbonate platforms close to this ridge were exposed and suffered karstification and in places deep erosion (e.g. Blendinger 1985). During a short period of predominantly basic magmatism, the originally deep (600–800 m) interplatform-basins and collapsed areas around the main volcanic centers (Monzoni, Predazzo) were filled with volcanic rocks and their erosional products. Only after the volcanism had ceased did widespread subsidence resume. New generations of carbonate platforms (Cassian Dol.) then nucleated along the rims of remaining topographic highs and prograded rapidly across the depressions which were still being filled at high rates with reworked volcanic and increasingly with carbonate detritus (Bosellini 1984; Brandner 1984).

Between the basins of the western Dolomites and eastern Lombardy a wide carbonate platform persisted throughout most of the Ladinian. In the Late Ladinian the eastern Lombardian basins suddenly received increased amounts of siliciclastic material in the form of storm deposits and turbidites ("Wengen Beds"; ? southern source). However, volcanic rocks and tectonic structures comparable to those of the Dolomites are almost entirely absent. Small platforms (Esino Lst.) expanded rapidly and ultimately filled a significant portion of the former basins. The northernmost Lombardian platforms (e.g. the Concarena) reached locally exceptional thicknesses of up to 1300 m. Unlike the "Lower Ladinian" buildups and deep intervening basins in the Dolomites, some of the thick, younger platforms in Lombardy were confined to elongated (? pull-apart) zones of rapid subsidence and much smaller reliefs existed towards the adjacent basins (Pratotondo Lst.; "Wengen Beds"; Brack 1984). Similar geometries have been proposed for coeval platforms in the Northern Calcareous Alps (Sarnthein 1967; Brandner 1984). Indeed the latter may have been located close to the Lombardian sector in Triassic times.

Towards the end of the Ladinian and in the Early Carnian the Esino platform tops in Lombardy were subject to repeated emergences (Assereto et al. 1977a). Drowned or inactive platform portions were onlapped and covered by small cyclic sub- to peritidal carbonates (Gorno Fm.; Breno Fm.) and locally by fine-grained siliciclastic rocks (Lozio shales). Several Carnian delta systems, sourced by a new subaerial volcanic belt, advanced temporarily northward into the shallow lagoons and depressions of central and eastern Lombardy (e.g. Gnaccolini & Jadoul 1988, 1990; Garzanti & Jadoul 1985).

2.2. *Nature of fossiliferous Anisian/Ladinian boundary successions*

Fossiliferous pelagic successions spanning the entire Anisian and Ladinian time interval do not exist in the Southern Alps. Fossil bearing Anisian/Ladinian boundary sections are found mainly in the following settings: (a) continuous pelagic successions, (b) pelagic sediments overlying drowned platform carbonates and (c) internal and flank portions of carbonate platforms.

Sections straddling the complete stage boundary interval are restricted to those of type (a). They are found in two basinal zones (Figs. 2, 3), a narrow depression in the eastern Dolomites (Ambata Fm., Buchenstein and Wengen Groups of the respective type areas) and a wider basin in eastern Lombardy (Prezzo Lst., "Buchenstein Beds," "Wengen Beds"). The stratigraphy of the latter will be dealt with in some detail below.

Pelagic strata on top of drowned platform carbonates (Type b sections) are mainly the classical "Buchenstein Beds" which are present throughout the northwestern Dolomites and in the Trento and Recoaro/Tretto areas. Hallstatt-type limestones are also found locally (e.g. to the east of the Dolomites; Clapsavon Lst. of Cadore and Carnia). The base of these beds may not be isochronous in all settings, reflecting onlap relationships and/or different times of (tectonically induced) drowning of sometimes previously exposed platforms.

Fossil bearing intervals in carbonate platform areas (Type c sections) are usually of restricted vertical and lateral extent. Nevertheless they host some important and exceptionally rich faunas on flank and interior portions of small platforms (e.g. Latemar, Cernera) as well as in deposits of larger intra-platform depressions (e.g. "Grenzbitumenzone" at Monte San Giorgio).

In the following chapters we will present new stratigraphic and fossil data from representative successions in all these settings. The sections studied in detail are located in the Dolomites, in the eastern Lombardian Prealps and adjacent territories (Bergamask- and Brescian-Prealps, Giudicarie, Trento area) and in southern Switzerland (Fig. 1).

3. Anisian/Ladinian boundary intervals in basinal "Buchenstein Beds"

In 1892 Bittner proposed the Ladinian Stage with the "Buchenstein Beds" at its base. In the Southern Alps these are the most widespread fossiliferous pelagic sediments straddling or approaching the stage boundary. However, their fossil content is usually poor, they are lithologically variable and exhibit lateral facies changes with coeval platform carbonates. Opinions therefore diverged through time about the stratigraphic range of the "Buchenstein Beds." Some of the most important ideas are summarized in roughly chronological order before details are presented on the main lithologies, the depositional settings and the studied sections.

3.1. Opinions on the stratigraphy and range of the "Buchenstein Beds"

The "Buchenstein Beds" were defined by Richthofen (1860) in a section near Pufels[3]) in the northwestern Dolomites (Fig. 1) as a lithologically characteristic succession of evenly bedded and nodular siliceous limestones with greenish shaly intercalations. A few non-diagnostic fossils were mentioned from this unit at Pufels and Seceda by Richthofen (1860) and Stur (1868). Ammonoid finds from the Pufels section include "*T.* cf. *reitzi*" (Mojsisovics 1873), later referred to as "*T. reitzi*" and "*Trachyceras curionii*" (Mojsisovics 1882). This led the latter to correlate these beds with the "*Trachyceras reitzi*"-bearing limestones in the Balaton Highland of Hungary. Mojsisovics (1879) also extended and generalized the lithostratigraphical range to consist of two series of evenly bedded, dark limestones (the lower and upper "Bänderkalke", also called "Plattenkalke" by other authors) separated by a stack of nodular limestones with greenish volcaniclastic intercalations ("Pietra verde"). Similar nodular limestones associated with "Pietra verde" were recognized also in other parts of the Southern Alps, in the Eastern Alps and Bakony.

No relevant additional fossils were known from the "Buchenstein Beds" in the Dolomites when Bittner (1892) introduced the "Ladinian Stage[4])" (called "Norian" by Mojsisovics until 1902) and fixed its base with this lithologically defined unit. Thereafter the term "Buchenstein Beds" was frequently used in a chronostratigraphic

[3]) The name "Buchenstein" is derived from another locality near Andraz in the Livinallongo area of the central Dolomites where the homonymous beds are typically developed (e.g. Leonardi 1967).

[4]) After the Ladini people in the Dolomites.

sense i.e. as a synonym for the "*Zone of Protrachyceras reitzi*" and/or "*curionii*" (e.g. Arthaber 1906). However, doubts about the chronostratigraphic value of the "Buchenstein Beds" arose from apparently contradicting observations: Kittl (1894) listed a fauna with "*Trachyceras reitzi*" from platform carbonates at Marmolada, which according to Salomon (1895) were lying above typical "Buchenstein Beds". Philipp (1904) therefore recommended the use of this name in a strict lithological sense. Alternatively, new names were introduced for equivalent strata such as the "Nodosus Fm." in the Recoaro and Tretto areas (Tornquist 1901). Elsewhere in the Southern Alps pelagic Ladinian limestones were referred to as the "Reitzi-Schichten" or "Reitzi-Kalke" (Salomon 1908; Horn 1913, 1914) but the name "Buchenstein Beds" was not generally abandoned (e.g. Diener 1915, Klebelsberg 1935, Pia 1937).

New and substantial ammonoid finds were finally reported from "Buchenstein Bed" equivalents outside of the Dolomites by Geyer (1898), Tornquist (1898) and Horn (1913, 1914). The latter considered the cherty nodular limestones in the Brescian Prealps to be younger than the apparently Upper Anisian counterparts in the central Dolomites. This was subsequently disproved by an ammonoid find (*Arpadites arpadis*, Kieselinger 1927) in the "Pietra verde" near Buchenstein. Hummel (1928, 1932) finally recognized the correct lateral relationships between the thin Ladinian basin deposits ("Buchenstein Beds") and thick coeval carbonate platforms in the Dolomites. He also advocated an overall synchronous base of the nodular limestone facies and supposed a close relationship with the first "Pietra verde" occurrences.

Based on Diplopora finds Ogilvie Gordon (1927) suggested a Late Anisian age ("Oberer Muschelkalk" p.p.) for the "Lower Bänderkalke" in the Dolomites. Pia (1937) supposed the Anisian/Ladinian boundary to be situated within the lower part of the nodular limestones. As a consequence the "Lower Bänder- or Plattenkalke" were sometimes formally separated (Ogilvie Gordon 1927; Assereto et al. 1977a; Gaetani et al. 1981; Fois 1982) but in most cases still remained part of the "Buchenstein Beds" in the sense of Mojsisovics (e.g. Rossi 1962, 1964, 1967; Baccelle Scudeler 1971; Viel 1979; Bosellini & Ferri 1980). Few further macrofossils were found in the "Buchenstein Beds" between 1930 and 1980 (e.g. Ogilvie Gordon 1927, 1929; Leonardi & Panchieri 1949).

On the basis of Daonellas the "Lower Bänderkalke" could be correlated with other age equivalent strata at Val Gola and Monte San Giorgio (Rieber 1969). Ammonoid successions collected in the "Buchenstein Beds" of the Brescian Prealps and Giudicarie (Brack & Rieber 1986 and this paper) now clearly document the long time range of these strata. This is supported by studies on conodonts (e.g. Gasser 1978; Mietto & Petroni 1979, 1980; Mietto 1982; Kovacs et al. 1990) and by palynological investigations on samples from equivalent beds in the Southern Alps (van der Eem 1983; Brugman 1986).

Especially in the Italian literature after 1930 the name "Buchenstein" is often replaced by "Livinallongo." In the context of a detailed revision of the Ladinian lithostratigraphy in the eastern Dolomites Viel (1979) proposed a group rank for the German terms "Buchenstein" and "Wengen." In this scheme the "Buchenstein Group" comprises the "Livinallongo Fm." (i.e. the original "Buchenstein Beds" including the "Lower Plattenkalke") together with partly coeval basinal siliciclastic sediments, tuffs and pelagic carbonates (Zoppè Sst., Aquatona Fm.) which were traditionally considered as parts of the "Wengen Beds." Viel's (1979) "Wengen Group" is restricted mainly to volcanic rocks and their reworked products in the Dolomites and eastern adjacent areas.

Throughout this paper we maintain the informal expressions "Buchenstein"- and "Wengen Beds" because these names can be applied unambiguously in the Lombardian area and in the northwestern Dolomites. Moreover this facilitates comparisons with older publications especially on the Lombardian Triassic. Our term "Buchenstein Beds" thus corresponds largely to Viel's "Livinallongo Fm.". The mainly siliciclastic Lombardian "Wengen Beds" may be considered as partial equivalents of the Zoppè Sst., Aquatona Fm. and Longiarin Sst. of Viel's "Buchenstein-" and "Wengen" Groups (Fig. 2).

3.2. The main lithologies and depositional environments of the "Buchenstein Beds"

3.2.1. Standard subdivisions in the Dolomites

Complete sections of the "Buchenstein Beds" in the Dolomites are traditionally subdivided into three main lithological units (Mojsisovics 1879). These are from bottom to top the "Lower Plattenkalke" (instead of "Lower Bänderkalke" as in Mojsisovics 1879), the "Knollenkalke" and the "Upper Bänderkalke" (Viel 1979). Greenish volcaniclastic intercalations ("Pietra verde") occur as variably thick layers throughout the entire stratigraphic column. Locally, thin intervals of reddish nodular limestones are also present. Detailed descriptions of the various microfacies and mineralogical information on the volcaniclastic rocks can be found elsewhere (e.g. Baccelle & Sacerdoti 1965; Baccelle Scudeler 1972; Bosellini & Ferri 1980; Bosellini & Rossi 1974; Callegari 1964, 1965; Callegari & Monese 1964; Cros 1974; Rossi 1964, 1965, 1967; Viel 1979).

The **"Lower Plattenkalke"** are evenly bedded black calcareous to dolomitic mudstones. The beds are often strongly siliceous, laminated and rich in mainly amorphous organic matter with subordinate algae and palynomorph contents (C_{org} ranges between 1 and 3.5% by weight). Radiolarians and thin pelecypod shells (e.g. Daonellas, "*Posidonia*") are abundant. Fine-grained greenish to rusty weathering volcaniclastic detritus mixed with argillaceous material is intercalated at various levels. In the northwestern Dolomites this unit is up to 15 m thick in distal portions (with respect to coeval platform cores) and lies with a sharp contact on top of drowned Upper Anisian platform carbonates (Contrin Fm.; Figs. 4, 5). Larger amounts of volcaniclastic rocks and coarse breccias of platform carbonate boulders are intercalated in the "Lower Plattenkalke" in the central Dolomites (e.g. Bosellini & Ferri 1980; Cros & Houel 1983). In the northern and eastern Dolomites and in Cadore the "Plattenkalke" and their equivalents overlie pelagic Upper Anisian strata.

The **"Knollenkalke"** consist of irregularly spaced but generally dm-scale bedded (e.g. Seceda section, Figs. 4, 5), wavy to nodular, calcareous and sometimes pelletoidal mudstones surrounded by argillaceous material. Bioturbation is common and chert occurs in nodules or as diffuse patches. The rocks are also rich in thin shelled bivalve fragments and calcitized radiolaria.

Subtracting the volcaniclastic intercalations, the total thickness of the pelagic nodular limestone intervals in 30–40 m in settings at some distance from coeval carbonate platforms. Average net sediment accumulation rates range within 4.5–10 m/My (non decompacted) accepting the age calibration as discussed later. This reflects a uniform autochthonous (pelagic) carbonate production throughout the "Buchenstein" basins. In the central and eastern Dolomites parts or the entire unit may be replaced by siliciclastic turbidites (Zoppè Sst.; Viel 1979; Cros & Houel 1983).

The **"Upper Bänderkalke"** are similar in appearance to the "Lower Plattenkalke" and comprise lithologies such as siliceous, black, laminated micritic limestones. Well bedded, often dolomitized and presumably turbiditic calcarenites and megabreccias also occur throughout this unit, especially in settings close to the base of prograding carbonate platforms. The thickness and distribution of the "Upper Bänderkalke" are variable and portions of it may be replaced by or interbedded with siliciclastic turbidites (Zoppè Sst.; Viel 1979).

The **"Pietra verde"** layers are usually greenish to reddish coloured, but sometimes yellowish weathering volcaniclastic clay-, silt- and sandstones. They occur throughout the "Buchenstein Beds" as single strata or successions of layers, between a few millimeters up to several meters thick. Comparable tuffaceous intervals are also found at stratigraphically higher and less frequently at lower levels. Acidic (rhyodacitic; Callegari & Monese 1964; Carraro & Fiora 1974) magmas have been suggested for the origin of the pyroclastic deposits. In places the latter also contain accretionary lapilli. The proportion of volcaniclastic intercalations varies throughout the "Buchenstein Beds" in the Dolomites reflecting basin geometries and modes of distribution. Reduced cumulative

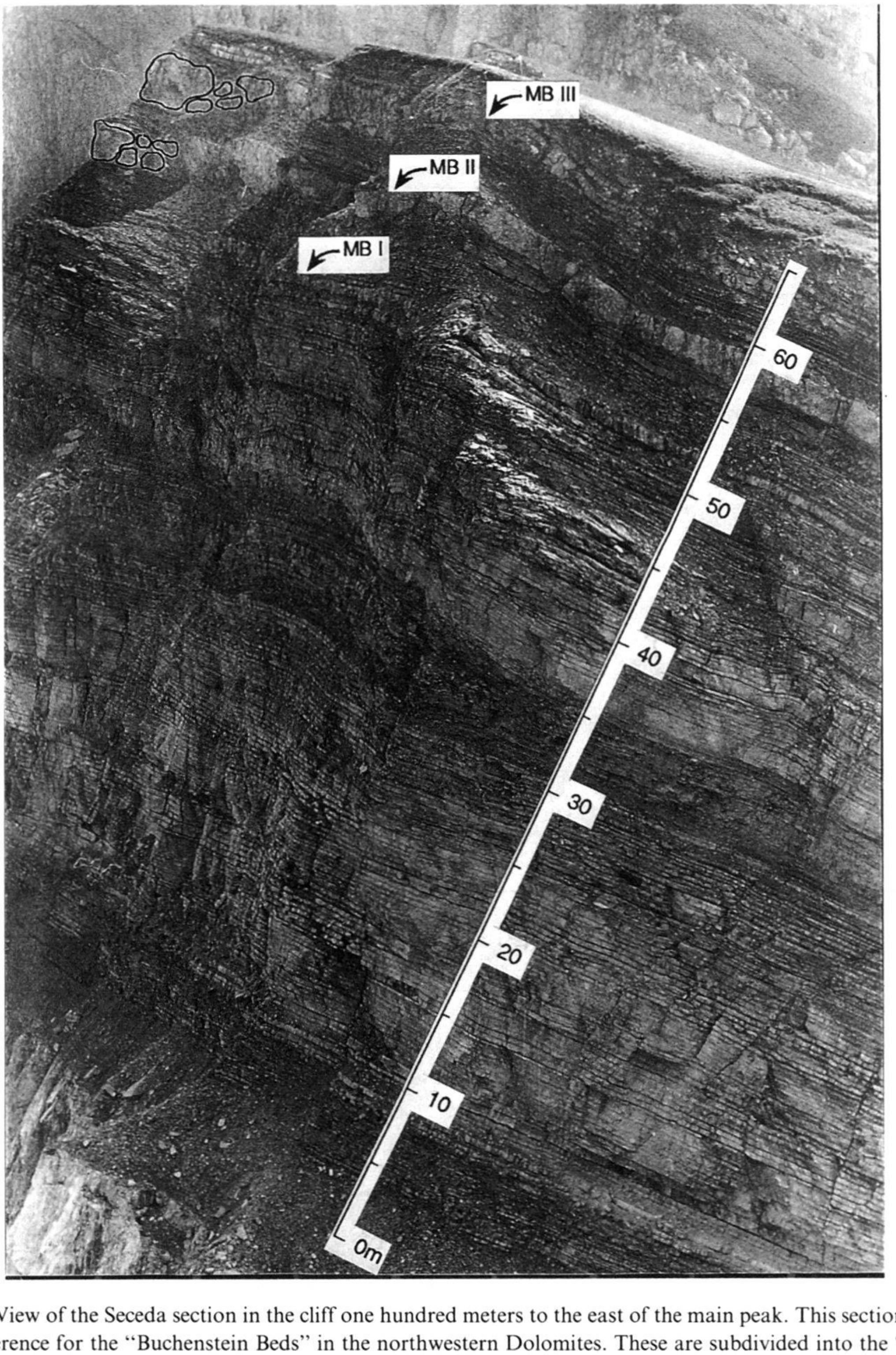


Fig. 4. View of the Seceda section in the cliff one hundred meters to the east of the main peak. This section serves as a reference for the "Buchenstein Beds" in the northwestern Dolomites. These are subdivided into the "Lower Plattenkalke" (0–8 m), the "Knollenkalke" (8–ca. 40 m), and the "Upper Bänderkalke" (ca. 40–55 m). The strata above the 50 m-level contain increasingly greater quantities of siliciclastic and reworked carbonate material as well as three major megabreccias (MB I–III) consisting of platform carbonate boulders and few volcanic clasts. Note the regular spacing of the limestone/marl alternations in the "Knollenkalke" below and above a wedge shaped "Plattenkalk-type" and "Pietra verde" bearing interval just above the 30 m-level. This interval thickens by several meters away from the observer (i.e. in a eastern direction; see text). Meter-scale is the same as in Figs. 5, 6, 7, 11.

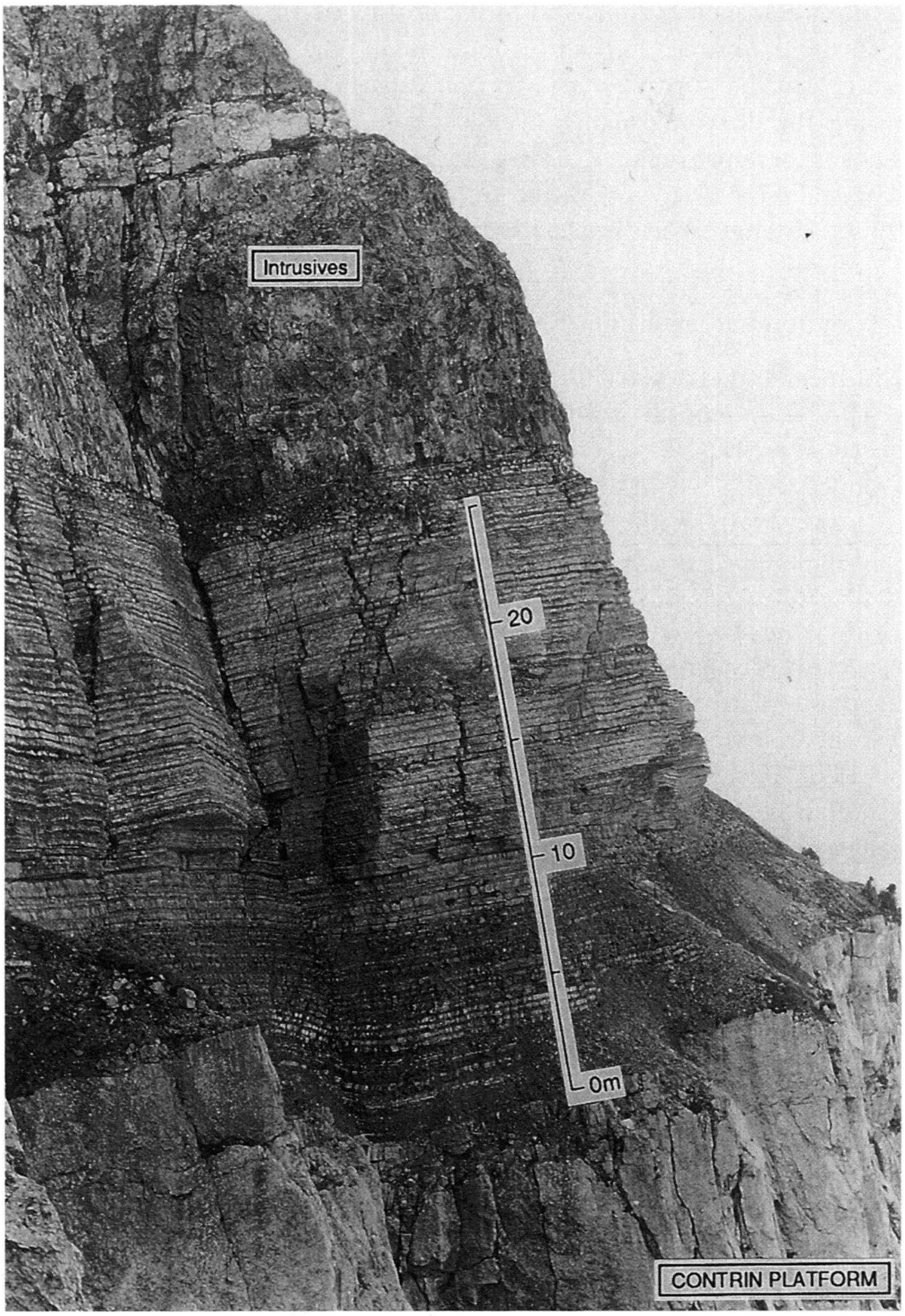


Fig. 5. The lower part of the "Buchenstein Beds" as exposed to the south of the Seceda cable car station (see Figs. 6, 7, 11 for fossil horizons). Drowned Upper Anisian platform carbonates (Contrin Fm.) are sharply overlain by the "Lower Plattenkalke" (0–8 m interval). The overlying "Knollenkalke" are crosscut by a laccolith-shaped intrusion of presumably Late Ladinian age.

thicknesses of a few meters are found in the northwestern Dolomites. Major accumulations exceed 100 m towards a possible source area in the southeast (Cros & Houel 1983). This suggests that the northwestern and central/eastern Dolomites were separated by a ridge limiting the distribution of at least the (turbiditic) submarine pyroclastic flow fractions of southern provenance. Along the flanks and in the interiors of coeval carbonate platforms similar layers are found only sporadically. The volcaniclastic fallout in these settings may have been washed out.

3.2.2. Distribution and environments of deposition of the "Buchenstein Beds"

The thickness and character of the "Buchenstein Beds" vary throughout the Southern Alps. The basin deposits in the **western** and **central Dolomites** represent deepening upward successions (Bosellini 1984). They document the transition from initially restricted, sill-bounded ponds where organic matter was preserved during rapid rise in relative sea-level ("Lower Plattenkalke") to interconnected, open marine areas, up to 800 m deep and with normal bottom water conditions. Single members vary in thickness or the entire pelagic succession may be replaced, depending on the position within the basins and relative to the sources of allochthonous material. This variability has been well documented especially along facies transitions between the basinal "Buchenstein Beds" and coeval carbonate platforms in the Dolomites (e.g. Hummel 1928, 1932; Cros & Lagny 1972; Bosellini & Rossi 1974; Cros 1974; Viel 1979; Bosellini & Ferri 1980; Gaetani et al. 1981; Fois 1982; Blendinger et al. 1982; Cros & Houel 1983; Bosellini 1984) but also in western Lombardy (Pasquarè & Rossi 1969; Gaetani et al. 1987).

In **Lombardy** and eastern adjacent areas, equivalent basinal strata (called "Buchenstein Fm." in Lombardy, "Nodosus Fm." near Recoaro/Tretto and "Margon Lst." near Trento) consist mainly of siliceous and sometimes reddish colored "Knollenkalk"-intervals and volcaniclastic intercalations. Where fully developed, as in eastern Lombardy and Giudicarie, the net thickness of the pelagic nodular limestones generally ranges between 30 and 40 m again reflecting a long lasting uniform deep marine environment (Fig. 7). Water depths may have been considerably shallower than the maximum values (i.e. around 800 m) reached in the Dolomites. This is indicated by the limited thickness of platform carbonates and coeval turbiditic and storm-generated siliciclastic deposits ("Wengen Beds") directly overlying the "Buchenstein Beds." Lithologies similar to the "Bänder-" and "Plattenkalke" of the Dolomites are not well developed. Siliceous and sometimes laminated dark limestone beds and shales frequently occur in a transitional zone, only a few meters thick, between typical Prezzo Limestone and distinct "Knollenkalk"-lithologies of the "Buchenstein Beds" (see below; Fig. 10). In the northeastern Bergamask Alps up to 40 m thick chert-rich, evenly-bedded dark limestones and volcaniclastic sandstones replace the middle/upper portion of the standard "Knollenkalk"-succession (e.g. in the tectonically higher Middle Triassic unit at Pizzo Camino south of Schilpario).

Sites of acidic to intermediate volcanic eruptions which are partly coeval with the "Buchenstein Beds" have been reported from the Recoaro area (De Zanche et al. 1979; Barbieri et al. 1980), the Julian Alps and Carnia (e.g. Spadea 1970; Cros 1979). Cros (1982) also mentions the occurrence of reworked ignimbrites as clasts in "Pietra verde" and megabreccia layers. In the Brescian Prealps evidence of volcanic activity is preserved as shallow intrusives in the "Buchenstein Beds" near Dezzo (e.g. Jadoul & Rossi 1982). Subvolcanic bodies also crosscut nearby Permian to Lower Triassic strata (M. Muffetto; Cassinis & Zezza 1982). Clasts of similar lithologies are contained in "Pietra verde" deposits in the uppermost "Buchenstein Beds" (Brack & Rieber 1986).

In an area adjacent to the Southern Alps, thick piles of volcanic rocks are interbedded with Upper Anisian to Ladinian carbonates on the slopes of the Dobratsch mountain in the Drauzug of Austria (Pilger & Schönenberg 1958; Colins & Nachtmann 1974). The igneous products consist of tuffs and agglomerates including volcanic bombs. Their original location may have been north of a central/western portion of the Southern Alps.

3.3. Fossiliferous sections and correlation of "Buchenstein Beds" in the northwestern Dolomites and the Brescian and adjacent Prealps

3.3.1. Northwestern Dolomites

Spectacular exposures of continuous successions of "Buchenstein Beds" are found around the **Seceda** peak (Figs. 4–6; see also figures in Ogilvie Gordon 1927) near Ortisei in Val Gardena. These outcrops [5]) are representative and suitable for a reference section of these beds in the northwestern Dolomites. The complete section (Figs. 4, 7) is 60–70 m thick, overlies Upper Anisian platform carbonates (Contrin Fm.) and is capped by strata with a higher siliciclastic content. The latter are preserved only sporadically. The "Plattenkalke" at the base of the Seceda section are 8 m thick and contain various levels of "Pietra verde" mixed with siliciclastic material. Sharply overlying are 35–40 m of "Knollenkalke" consisting of two units separated by a thin interval of "Pietra Verde" and "Plattenkalk"-type lithologies. Although not always evident in outcrop, the "Knollenkalke" show a distinct and fairly regular bedding (Fig. 4, 5). Nodular limestone beds with undulating surfaces are 0.1 to 0.5 m thick and separated by laterally continuous, thin siliceous clays and marls. In the uppermost part of the section the "Bänderkalke" are evenly bedded and more strongly dolomitized. They consist mainly of reworked platform carbonate debris. Intercalations of siliciclastic material thicken upwards (above 45 m-level) and three megabreccias with large platform carbonate boulders thin rapidly in a western direction along the Seceda north flank (Fig. 4). Volcaniclastic layers ("Pietra verde") are concentrated in three intervals throughout the section but their cumulative thickness amounts to only a few meters. The Seceda section appears to be largely undisturbed. Only the thin "Plattenkalk"-type interval approximately half way up the section (Figs. 4, 7) is not perfectly concordant and thickens slightly to the east of the main peak. Possible causes of this anomaly could be mechanical effects of laccolith-shaped intrusions which are found at approximately this stratigraphic level to the south of the cable-car station at Seceda (Fig. 5).

Along the steep north face of the Geisler Spitzen (Le Odle) to the east of Seceda, the "Buchenstein Beds" are progressively replaced by coeval and roughly southwestward

[5]) A complete section is accessible in a steep gully between the Seceda peak and the Pana Scharte. However, the access to this and other exposed outcrops immediately above the steep cliff of Upper Anisian platform carbonates requires caution!

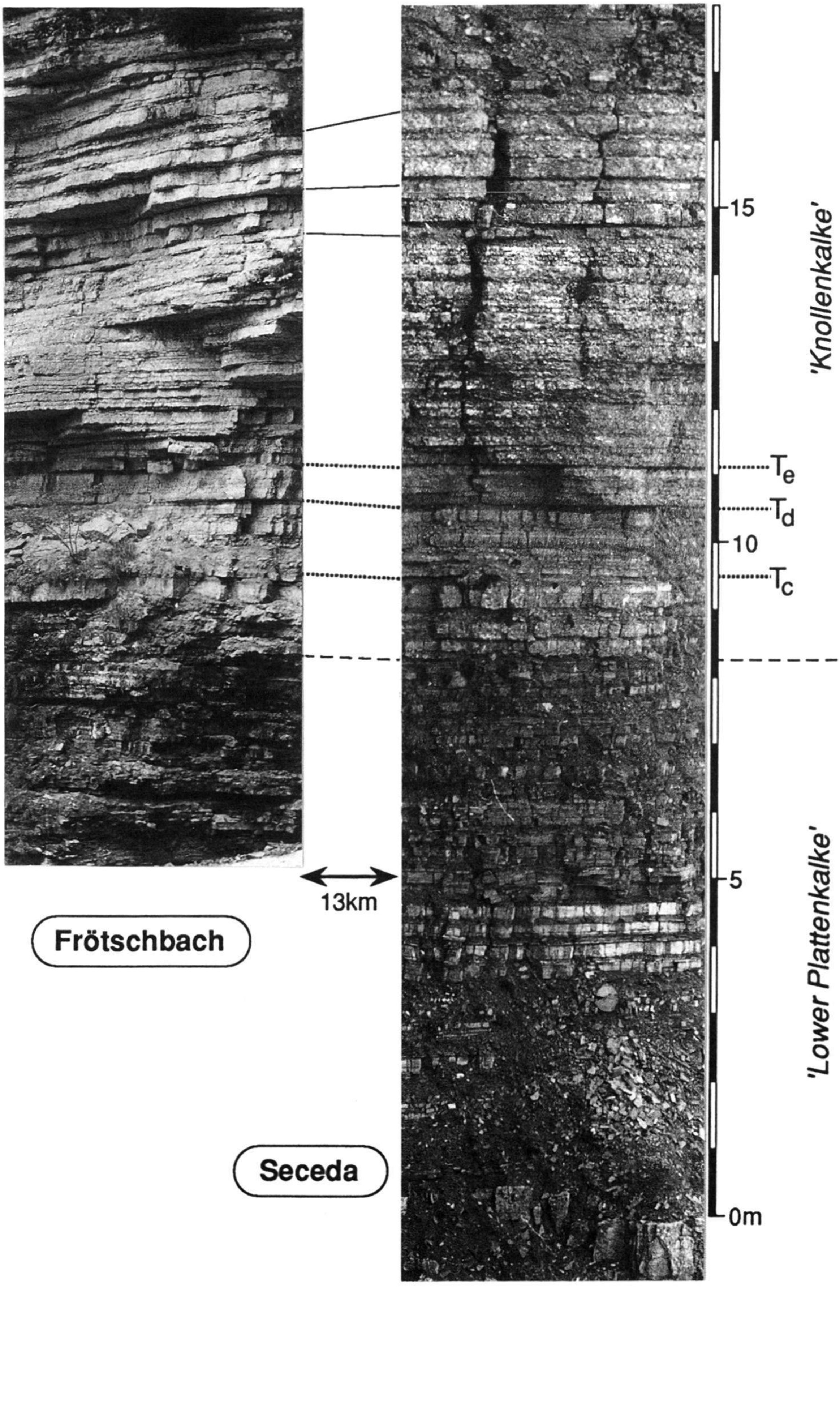
prograding clinoform deposits of a larger carbonate platform. Remains of the core of this platform are preserved in the cliffs between the Furchetta and Wasserkofel peaks of these mountains, but the main platform interior portion was presumably situated further to the north. The vertical size (800–900 m) and distances of clinoform progradation of this platform are comparable to the coeval Rosengarten (e.g. Bosellini & Stefani 1991) and Latemar platforms in the western Dolomites.

There are no similar interruptions in the outcrops of "Buchenstein Beds" across the Gröden valley and on the scarps around the Seiser Alm. These host classical sections of the "Buchenstein Beds" such as the original "type-section" in the **Pufels** gorge (Richthofen 1860; Mojsisovics 1873, 1879) and fossiliferous sections at Frommbach and **Frötschbach** (e.g. Horn 1913, 1914; Hummel 1932; Brandner 1982). Unfortunately the detailed stratigraphy of many sections in this area is partly obscured by shallow intrusives and tectonic structures. Moreover, the Pufels section is not sufficiently well exposed. However, individual beds can be correlated between Frötschbach and the Seceda section some 13 km distant, especially within the first 20–25 m of "Platten-" and "Knollenkalke" (Fig. 6). In particular, a typical succession of thin volcaniclastic layers about 1–4 m above the "Plattenkalk/Knollenkalk" boundary can easily be identified in both sections. This tuff sequence includes a characteristic 1 cm thick crystal-tuff at the base of a larger tuffaceous groove correlatable with the volcaniclastic T_c level in the Brescian Prealps (see below). The "Buchenstein Beds" at Seceda are a suitable replacement for the classical section at Pufels.

Another more easily accessible section of the lower part of the "Buchenstein Beds" is exposed along the main road in Val Badia 2 km north of **Pedraces** and around 15 km east of Seceda. Overlying Upper Anisian basinal limestones and marls are 15 m of "Plattenkalke." In common with the Seceda section, Daonellas occur throughout their uppermost layers. The "Knollenkalke" again include the above mentioned characteristic tuff interval close to their base and have thickness (23 m) and bedding characteristics not different from the lower "Knollenkalk"-unit at Seceda. These beds are overlain by an interval containing "Pietra verde" and "Plattenkalk"-type dark, siliceous limestones. Higher up the section is disturbed, and megabreccias and "Platten/Bänderkalk"-type lithologies possibly replace the upper "Knollenkalk"-unit of the reference section at Seceda.

Lithostratigraphic correlations of the Pedraces section with the "Buchenstein Beds" in the **central Dolomites** (Cros & Houel 1983; Fig. 5) indicate that the lower "Knollenkalk"-unit at Seceda corresponds to the main "Knollenkalk"-interval in the present type-sections of the Livinallongo Formation (i.e. our "Buchenstein Beds") near Caprile (Baccelle Scudeler 1972; Viel 1979). These are the "Median Knollenkalke" [MKK] of Cros & Houel (1983). Accordingly the thin "Pietra verde" layers close to the "Plattenkalk/Knollenkalk"-transition at Seceda most likely represent distal (? subaerially transported) fractions of the "Lower Pietra verde" [LPV] which are several meters thick in the central Dolomites and Cadore. The intermediate and upper "Pietra verde" intervals at Seceda are equivalents of the "Upper Pietra verde [UPV]."

Fig. 6. Lithological correlation of the lower "Buchenstein Beds" ("Lower Plattenkalke" and lowermost "Knollenkalke") between Frötschbach and Seceda (see also Figs. 4, 5 and Fig. 7 for the distribution of fossil horizons; T_c–T_e: tuff markers).


15
'Knollenkalke'
Te
Td
10
Tc
5
'Lower Plattenkalke'
13km
Frötschbach
Seceda
0m

The main "Pietra verde" bearing intervals of the Seceda section might also be correlated with three similar intervals in the **San Lucano Valley** section described by Bosellini & Ferri (1980). This section is strongly expanded (total thickness exceeds 250 m) due to increased amounts of reworked platform carbonates at the base and on lower slope portions of the S. Lucano-Civetta platform.

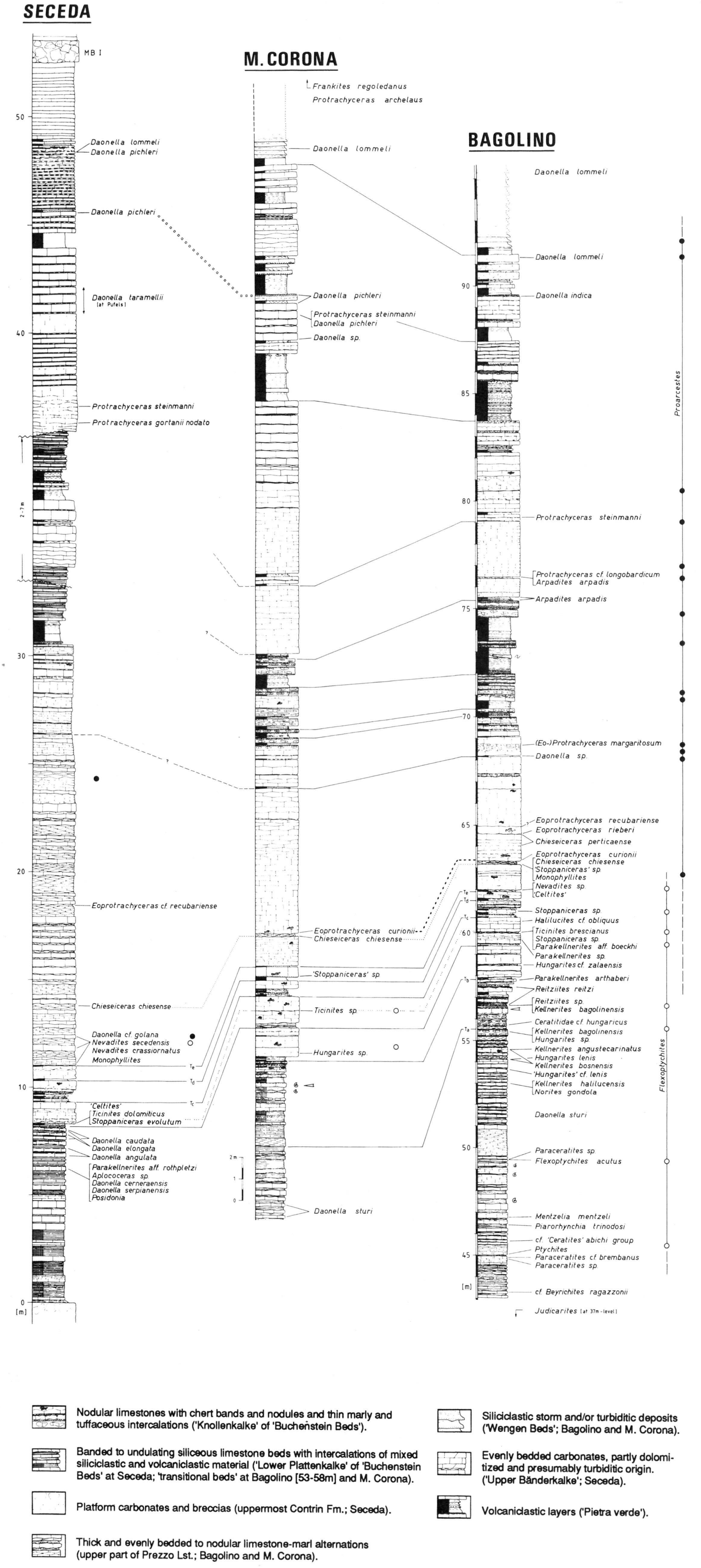
Well exposed "Buchenstein Beds" along a ski slope south of **Passo Feudo** between the Latemar and the Agnello platforms can also be compared with the Seceda section. The "Buchenstein Beds" with "Lower Plattenkalke" at their base follow on top of shallow basinal sediments known as the Moena Formation (Masetti & Neri 1980). In the "Plattenkalke" two levels with Daonellas (*D. elongata* in the upper, *D. serpianensis* in the lower horizon) were identified 0.7 and 1.8 m below the base of the "Knollenkalke". The latter are exposed over approximately 45 m and include frequent intercalations of thin "Pietra verde" layers in the lowermost 6 m and in the upper part of the outcrop.

(Macro-)Fossil levels (Figs. 4–7, 11):

The lowest stratigraphic level at which macrofossils in the "Buchenstein Beds" were found is about 6 m above the base of the "Lower Plattenkalke" at Seceda. The fossils include *Daonella cerneraensis* n. sp., *D. serpianensis, Parakellnerites* aff. *rothpletzi* and *Aplococeras* sp. which provide an important link to an isolated fauna at Cernera ("lower" fossil horizon with *Daonella cerneraensis* n. sp., *Aplococeras avisianum, Hungarites, Parakellnerites*; see below). This in turn shows close affinities with the "allochthonous" fauna of Forno and their in-situ equivalents at Latemar (*Aplococeras avisianum, Hungarites, Parakellnerites, Latemarites* among other ammonoids; see below). Daonellas of the *Daonella elongata* group occur in the uppermost "Plattenkalke" at Seceda, Frötschbach, Pufels, Pedraces and Passo Feudo. A comparatively rich fauna of ammonoids and more Daonellas could be collected from the "Knollenkalke" at Seceda and Frötschbach. Remarkable are the finds of well preserved specimens of (in ascending order) *Ticinites* (*Ticinites dolomiticus* n. sp.), *Stoppaniceras* (*Stoppaniceras evolutum* n. sp.), *Nevadites* (*Nevadites secedensis* n. sp., *N. crassiornatus* n. sp.), *Chieseiceras* (*Chieseiceras chiesense*) and *Eoprotrachyceras* (*Eoprotrachyceras* cf. *recubariense*) all from within the first 20 m of the "Buchenstein Beds." This fossil succession along with the above mentioned volcaniclastic layers permit unambiguous and detailed correlations of the Seceda section with other key sections such as Bagolino and Monte San Giorgio (Fig. 11; see discussions below). In particular, the Daonellas of the *Daonella elongata* group show the same detailed evolution pattern at Seceda and Monte San Giorgio. Higher up in the "Knollenkalke" various specimens of *Protrachyceras* (*Protrachyceras gortanii nodato, P. steinmanni*) were found at Seceda [6]). In the overlying evenly bedded limestones and dolomites, layers rich in Daonellas (*Daonella pichleri* and few *D. lommeli*)

Fig. 7. Correlation and fossil horizons of the "Buchenstein Beds" in the northwestern Dolomites (Seceda), Giudicarie (Monte Corona) and in the Brescian Prealps (Bagolino). Meter-scales are the same as in Figs. 4, 5, 10, 11 and Figs. 5, 7, 10 of Brack & Rieber (1986). For lithostratigraphic subdivisions see Fig. 12 and text.
MB-I: first megabreccia in Seceda sections (see also Fig. 4).
T_a–T_e: selected volcaniclastic markers.

[6]) Well preserved *Protrachyceras* from a stratigraphic interval equivalent to 30–40 m on the Seceda section (location of findspot: top station of the Seceda cable-car) belong to the fossil collections of the museum in St. Ulrich/Val Gardena.


SECEDA
M. CORONA
BAGOLINO
MB I
[m]
Daonella lommeli
Daonella pichleri
Daonella taramellii (at Pufels)
Protrachyceras steinmanni
Protrachyceras gortanii nodato
2-7 m
Eoprotrachyceras cf. recubariense
Chieseiceras chiesense
Daonella cf. golana
Nevadites secedensis
Nevadites crassiornatus
Monophyllites
'Celtites'
Ticinites dolomiticus
Stoppaniceras evolutum
Daonella caudata
Daonella elongata
Daonella angulata
Parakellnerites aff. rothpletzi
Aplococeras sp.
Daonella cerneraensis
Daonella serpianensis
Posidonia
Frankites regoledanus
Protrachyceras archelaus
Daonella sp.
Eoprotrachyceras curionii
'Stoppaniceras' sp.
Ticinites sp.
Hungarites sp.
Daonella sturi
Daonella indica
Protrachyceras cf. longobardicum
Arpadites arpadis
(Eo-)Protrachyceras margaritosum
Eoprotrachyceras recubariense
Eoprotrachyceras rieberi
Chieseiceras perticaense
Stoppaniceras sp.
Nevadites sp.
Halilucites cf. obliquus
Ticinites brescianus
Parakellnerites aff. boeckhi
Parakellnerites sp.
Hungarites cf. zalaensis
Parakellnerites arthaberi
Reitziites reitzi
Reitziites sp.
Kellnerites bagolinensis
Ceratitidae cf. hungaricus
Kellnerites angustecarinatus
Hungarites lenis
Kellnerites bosnensis
'Hungarites' cf. lenis
Kellnerites halilucensis
Norites gondola
Paraceratites sp.
Flexoptychites acutus
Mentzelia mentzeli
Piarorhynchia trinodosi
cf. 'Ceratites' abichi group
Ptychites
Paraceratites cf. brembanus
cf. Beyrichites ragazzonii
Judicarites (at 37m-level)
Proarcestes
Flexoptychites
Nodular limestones with chert bands and nodules and thin marly and tuffaceous intercalations ('Knollenkalke' of 'Buchenstein Beds').
Banded to undulating siliceous limestone beds with intercalations of mixed siliciclastic and volcaniclastic material ('Lower Plattenkalke' of 'Buchenstein Beds' at Seceda; 'transitional beds' at Bagolino [53-58m] and M. Corona).
Platform carbonates and breccias (uppermost Contrin Fm.; Seceda).
Thick and evenly bedded to nodular limestone-marl alternations (upper part of Prezzo Lst.; Bagolino and M. Corona).
Siliciclastic storm and/or turbiditic deposits ('Wengen Beds'; Bagolino and M. Corona).
Evenly bedded carbonates, partly dolomitized and presumably turbiditic origin. ('Upper Bänderkalke'; Seceda).
Volcaniclastic layers ('Pietra verde').

occur. Fois (1982) reported Daonellas from similar but possibly slightly younger beds at the base of the Sass di Putia (Peitlerkofel) platform 10 km northeast of Seceda.

The remains of a large Ichthyosaur from the scree of the "Buchenstein Beds" at Seceda were described by Kuhn-Schnyder (1980). Ichthyosaur bones were also recognized in "Knollenkalke" of the Pufels section.

Detailed correlations of our macrofossil levels in the "Buchenstein Beds" with previously described data on palynomorphs (van der Eem 1983) and conodonts (Gasser 1978) from the northwestern Dolomites are hampered by insufficient stratigraphic documentation. Nevertheless, the results are largely compatible. In particular the "Lower Plattenkalke" at Frötschbach have yielded palynomorphs of the "vicentinense-scheuringi Phase" (Brugman pers. comm.). This phase was identified in the "Reitzi tuffs" of the Balaton Highland in Hungary (Brugman 1986) and thus supports our correlation of this unit with the lowermost strata of the "Lower Plattenkalke" and with the "transitional beds" in the Brescian Prealps and Giudicarie (see further on). According to the conodont study by Gasser (1978) *Metapolygnathus mungoensis* is present in the upper part of the "Knollenkalke" at Pufels.

The Seceda and Frötschbach sections are prime candidates for precise calibrations of various biostratigraphic scales. Well preserved radiolaria can be obtained e.g. from samples of the "Lower Plattenkalke."

3.3.2. Brescian and adjacent Prealps (eastern Bergamask Alps, Giudicarie)

The Middle Triassic in this sector of the Southern Alps is particularly important for Anisian to Ladinian biostratigraphy because the "Buchenstein Beds" are bracketed by basinal sediments well known for their macrofossil content (Prezzo Lst., "Wengen Beds"). Moreover, the "Buchenstein Beds" are relatively rich in ammonoids and thin but characteristic successions of volcaniclastic layers allow unambiguous comparisons of various stratigraphic sections (Brack & Rieber 1986). Representative and complete sections are exposed at Monte Corona and Bagolino (Figs. 7, 8; Brack & Rieber 1986, Figs. 3–5).

The Prezzo Limestone has long been known to contain faunas of the Trinodosus Zone in its upper part. The interval of a classical fauna at Contrada Gobbia and nearby localities in Val Camonica (Völker 1931, Riedel 1949, Assereto 1963, Assereto & Casati 1965, Casati & Gaetani 1979, Balini 1992) lies within typical dm-bedded dark limestone-shale alternations. Similar beds are also found in the M. Corona/Dosso dei Morti area to the east (e.g. Bittner 1881, Gaetani 1969; Kovacs et al. 1990, Balini 1992) and in upper Val di Scalve to the west (Fig. 10 [7])). In a southeastern direction the proportion of shale

[7]) The "Contrada Gobbia" equivalent interval is well exposed e.g. around 1875 m on the western slope of the **Corna di S. Fermo** peak to the southwest of Pizzo Camino near Schilpario (Val di Scalve; coord. 589.800/5091.700). Fossils collected during a short inspection comprise *Reiflingites* sensu Assereto (1963), *Ptychites* and Daonellas.

Bulogites, *Semiornites* sensu Assereto (1963), *Longobardites* and Daonellas were also recovered from strata in a creek on the northeastern flank of **M. Lavanech**. This locality lies just across the Daone valley 5 km southwest of M. Corona (coord. 619.750/5090.650).

The **Pèrtica** column corresponds to locality **A** of Brack & Rieber (1986, p. 191) at Pèrtica. Another complete section (from T_a upwards) at Pèrtica Alta is exposed in a small creek approximately 1 km NNW of Navono (coord. 603.000/5067.600).

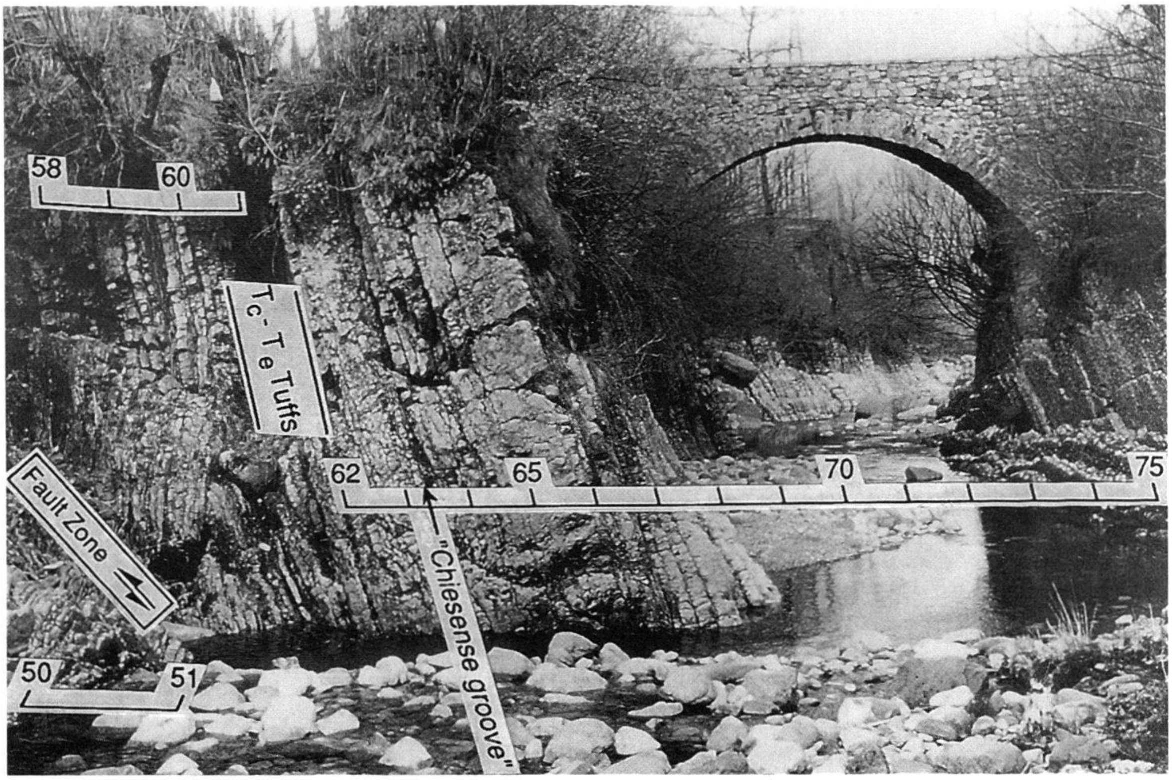


Fig. 8. The steeply dipping lower "Buchenstein Beds" below the Romanterra bridge (looking eastwards) at Bagolino. Meter scale as in Fig. 7; the top of the "Chiesense groove" corresponds to the proposed Anisian/Ladinian boundary; see Fig. 4 in Brack & Rieber (1986) for a map of the main outcrop at Romanterra. Note that the transition between the Prezzo Limestone (just visible on the left-hand foreground) and the "Buchenstein Beds" (58 m onward) is slightly disturbed in this exposure.

decreases and these strata become more thinly bedded and nodular. Nevertheless, the occurrence of three thin, rusty-weathering tuff layers still allows a positive identification of the corresponding intervals at Bagolino [8]) and Pèrtica. Cross-sections of cephalopods are common at this level in Pèrtica, but specimens are difficult to extract from the hard limestone beds.

Between the above mentioned strata of the Prezzo Limestone and the first typical nodular limestones of the "Buchenstein Beds" are "transitional beds" (53–58 m-interval on Bagolino section), 5–8 m thick with irregularly bedded to coarsely nodular, dark limestones and shales. These rocks sometimes resemble the "Plattenkalke"-lithologies of the Dolomites (see also Brack & Rieber 1986, p. 187). The first occurrence of siliceous

[8]) At Bagolino (Romanterra) these beds (between 50–53 m) are poorly exposed but they are stratigraphically distinctly higher than fossiliferous strata containing *Paraceratites*, "*Ceratites*" *abichi* (43–46 m on section) and *Judicarites* found recently around 37 m and also known from the Dosso Alto section a few kilometers to the west. This is in good agreement with the fossil succession near Malga Avalina at Dosso dei Morti (area of Monte Corona). There the lowermost "Contrada Gobbia"-equivalent layers which also contain frequent pavings of *Daonella sturi* were found 4–6 m above layers with "*Ceratites*" *abichi* (sensu Balini in Kovacs et al. 1990) which in turn lie 12-15 m above the *Judicarites* beds. The strata in between also yielded *Semiornites* (sensu Assereto 1963) and Nautilids. This fits well the ammonoid succession found by Balini (in Kovacs et al. 1990) in the nearby Stabol Fresco and Adana sections at M. Corona.

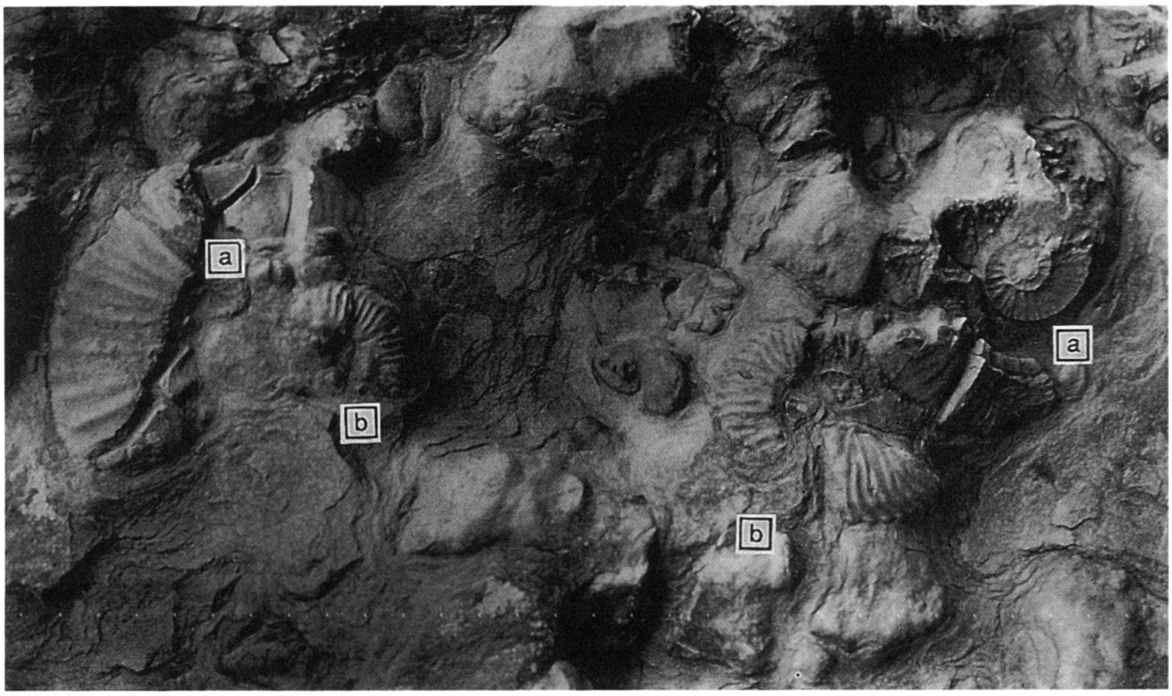


Fig. 9. Ammonoids (a: *Chieseiceras perticaense*, b: *Eoprotrachyceras rieberi* [see comments in section 3.3.2.], *Arcestes*) on the undulating lower surface of a nodular cherty limestone bed covered by a thin layer of fine-grained siliciclastic material (Pèrtica Bassa, Brescian Prealps). Field of view: 30 cm. Around 10 ammonoids were counted per square meter on this bed surface.

beds and chert nodules is just below a series of two to three remarkable beige weathering tuff beds (54.7–55.65 m on Bagolino section [T_a], Figs. 7, 10, 11). The uppermost of these tuffs is a 15–30 cm thick, banded compact stack of four thicker and several thin, graded layers rich in quartz, feldspars and illite. This characteristic bed was identified in localities as far away as Lenna/Piazza Brembana [9]) 50 km to the west of Bagolino. Greenish "Pietra verde" tuffs commonly occur above this layer.

Within the "transitional beds" several important fossil horizons were identified at Bagolino [10]), Pèrtica and Brozzo [11]). The fauna consists of *Lardaroceras* sp., *Kellnerites* (*Kellnerites halilucensis, K. bosnensis, K. bagolinensis* n. sp., *K. angustecarinatus, K. fissicostatus*), *Reitziites* (*Reitziites reitzi*), *Hungarites* (*Hungarites lenis*), *Parakellnerites* (*Parakellnerites arthaberi*), *Longobardites, Norites* together with *Ptychitidae* and *Michelinoceras* and shows closest affinities with the fauna of the "Reitzi tuffs" in the Balaton

[9]) At Lenna/Piazza Brembana the characteristic T_a tuffs are interbedded with thick carbonate layers at the transition between the Prezzo Limestone and the Esino Limestone. This succession is well exposed and easily accessible just behind the cemetery of Piazza Brembana. Fossiliferous nodular limestone beds with *Lardaroceras* and thin tuffaceous intercalations similar to the "Contrada Gobbia interval" occur 7–9 m below the uppermost T_a reference tuffs (Fig. 10). At Lenna the strata form the top of a 20–30 m thick Prezzo Limestone package. Fossil-rich layers including the *Paraceratites brembanus* fauna illustrated by Venzo & Pelosio (1968, see also for location of the sections) are found 10–20 m below the "Contrada Gobbia equivalent" interval.

[10]) At Romanterra and to the southwest in outcrops of steeply dipping, overturned beds along a new forest track on the southern slope of M. Pizza (1150–1250 a.s.l., approx. coord. 612.850/5074.750).

[11]) In the Mella riverbed at the southern end of the village Brozzo near Marcheno in Val Trompia.

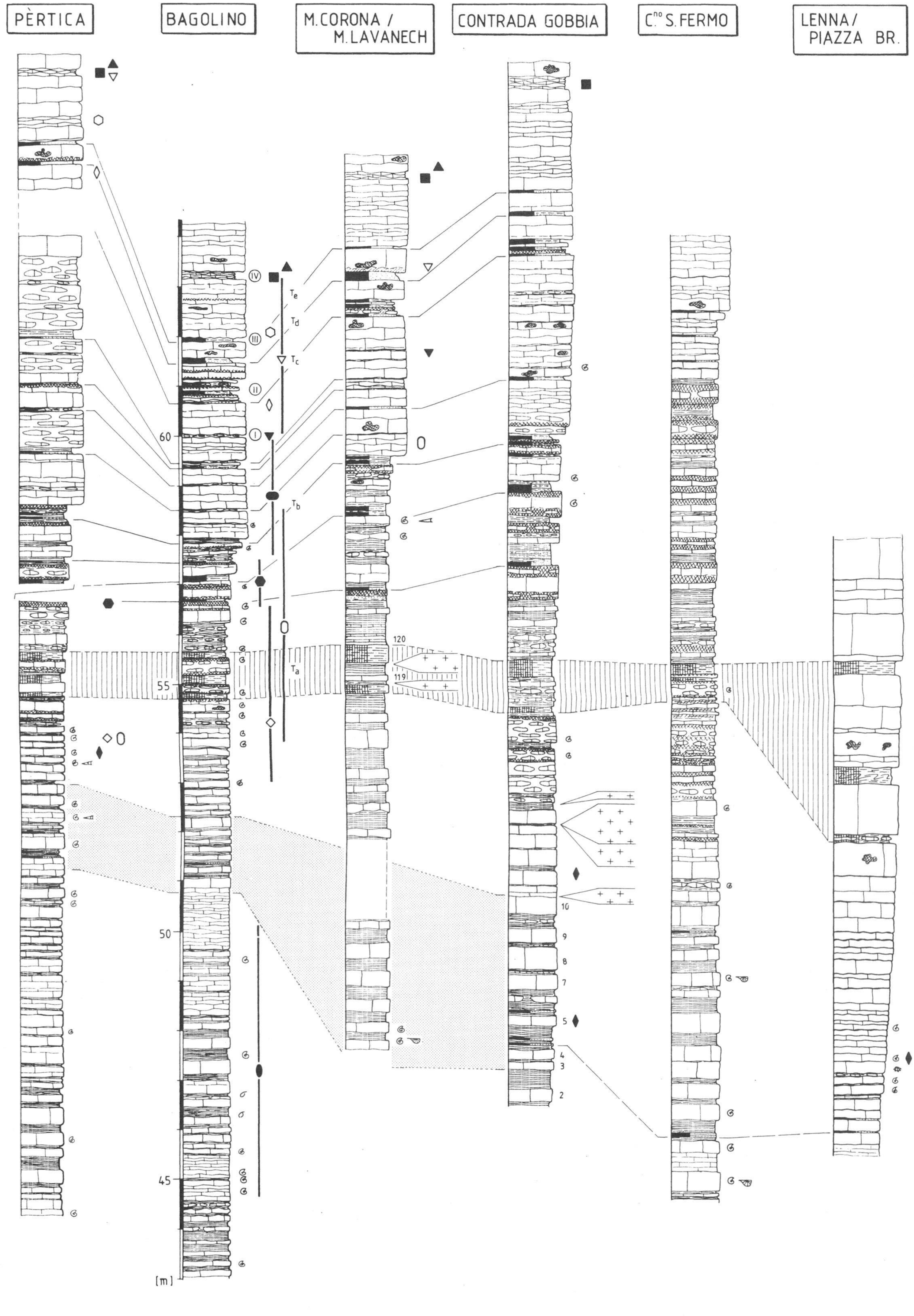
Highland of Hungary (e.g. Vörös & Palfy 1989; Kovacs et al. 1990). In particular the appearance of *Reitziites reitzi* is remarkable because this indicates that it is well established within a continuous fossil succession across an extended Anisian/Ladinian boundary interval. Moreover, *Reitziites* occurs at a distinctly deeper stratigraphic level (56.5–57.6 m at Bagolino) than the *Ticinites* horizon (61 m at Bagolino) and the *Nevadites* from above the tuff level T_e (i.e. 62 m at Bagolino). The *Nevadites* in the Brescian Prealps are related to the specimens from Seceda and presumably correspond to those ammonoids from the Southern Alps that were named "*Trachyceras reitzi*" by Mojsisovics (1882) and Horn (1913, 1914). The mis-identification remained also in our previous paper (Brack & Rieber 1986) is therefore revised here.

The lower "Knollenkalke" in the Brescian and adjacent Prealps contain *Hungarites* (*Hungarites* cf. *zalaensis*), *Ticinites* (*Ticinites brescianus* n. sp.), *Parakellnerites* (*Parakellnerites* aff. *boeckhi* instead of "*Ceratites*" *boeckhi* in Brack & Rieber 1986), *Halilucites* (*Halilucites* cf. *obliquus*), *Stoppaniceras*, "*Stoppaniceras*" (provisionally including the "*Ceratites*" *ellipticus* group of Brack & Rieber 1986), *Nevadites* (*Nevadites avenonensis* n. sp., *N. bittneri* n. sp.), *Chieseiceras* (*Chieseiceras chiesense*, *Ch. perticaense*), *Eoprotrachyceras* (*Eoprotrachyceras curionii*, *E. recubariense*, *E. rieberi*[12])) among other genera as discussed by Brack & Rieber (1986). At Bagolino and M. Corona new *Protrachyceras* ([*Eo*-]*Protrachyceras margaritosum*, *Protrachyceras* cf. *longobardicum*, *P. steinmanni*, *P. archelaus*), *Arpadites* (*Arpadites arpadis*) and Daonellas (*Daonella indica*, *D. pichleri*, *D. lommeli*) were collected at higher levels in the "Buchenstein Beds" and in the lowermost "Wengen Beds" (Fig. 7). Bittner (1881) and Mojsisovics (1869, 1880, 1882) described rich ammonoid faunas from the siliciclastic "Wengen Beds" at various localities in Giudicarie and eastern Lombardy[13]). These strata certainly deserve further attention but ammonoid specimens are often strongly flattened. Nevertheless, we confirm the occurrence

Fig. 10. Detailed correlation of stratigraphic sections in eastern Lombardy and Giudicarie including the "transitional beds" (53–58 m interval on Bagolino section) situated between the Prezzo Limestone (below) and "Knollenkalke" of the "Buchenstein Beds" (above). Characteristic successions of beige ash layers (T_a tuffs, vertical ruling) and up to ten thin "Pietra verde" layers between T_b and T_e are correlatable in detail. The T_a volcaniclastic layers are also identified in thickly bedded strata at the transition of the Prezzo Limestone and the Esino Limestone at Lenna/Piazza Brembana. The fossil-rich interval at "Contrada Gobbia" (main southern outcrop, bed numbers as in Casati & Gaetani 1979, Fig. 10, Kovacs et al. 1990, Fig. 13, and Balini 1992, Fig. 2) and corresponding strata as recognized by fossils and/or the occurrence of thin tuff layers are indicated (dotted pattern). Distributions of only the most important ammonoid genera are shown (symbols for fossils as in Fig. 11, bivalve signs indicate Daonellas close to *Daonella sturi*). See Kovacs et al. (1990) for distributions of conodonts in the Contrada Gobbia and Monte Corona (Stabol Fresco) sections. Magmatic dykes crosscutting the sections are omitted but their positions indicated. See text for the location of the sections and additional information on content and positions of faunas also at deeper levels in the Prezzo Limestone. The illustrated parts of the Lenna/Piazza Brembana and Contrada Gobbia sections correspond approximately to the photograph in Venzo & Pelosio (1968, Fig. 3) and to the lower two thirds of the section visible on Fig. 2 of Assereto (1963) respectively.

[12]) The name *Eoprotrachyceras rieberi* is anticipated here for convenience and replaces *Eoprotrachyceras* cf. *laczkoi* in Brack & Rieber 1986 (Figs. 7, 10). The new species *E. rieberi* will be figured and described formally in a forthcoming publication by Fantini Sestini (pers. comm.) on the basis of our material from Pèrtica (type locality; horizon 1.4–1.6 m above "Chiesense groove") and additional finds from the Bergamask Alps.

[13] The "Wengen Beds" at Prezzo only a few kilometers southeast of M. Corona are the type-strata of important ammonoids such as *Frankites regoledanus*, *Protrachyceras judicaricus*, *P. neumayri*, *Proarcestes tridentinus* (Moisisovics 1869). *Celtites epolensis* is named after a locality south of Schilpario.



PÈRTICA
BAGOLINO
M.CORONA / M.LAVANECH
CONTRADA GOBBIA
C.no S.FERMO
LENNA/ PIAZZA BR.
IV
III
II
I
Te
Td
Tc
Tb
Ta
60
55
50
45
[m]
120
119
10
9
8
7
5
4
3
2

of *Protrachyceras archelaus*. *Frankites regoledanus* was found in higher levels of the "Wengen Beds" at M. Corona. Ammonoids from roughly coeval platform carbonates at Dosso Alto (Malga Ciunela) [14]) near Bagolino have been identified as *Rimkinites nitiensis* and *Arcestes*.

A comparison of the sections in eastern Lombardy and Giudicarie with those of the northwestern Dolomites (Fig. 7) shows the same main "Pietra verde" bearing intervals in both areas. Of these, the thin tuff series T_c to T_e in the "Knollenkalke" can be correlated in detail (Fig. 11). This correlation is in agreement with the fossil distribution, in particular the succession of *Parakellnerites, Ticinites, Nevadites, Chieseiceras* and *Eoprotrachyceras*. Moreover it shows that the base of the "Knollenkalk" facies is indeed clearly diachronous. The "Plattenkalke" of the northwestern Dolomites (e.g. Seceda) therefore correspond to an interval that includes the basal "Knollenkalke" and probably parts of the "transitional beds" at Bagolino.

Information on the distribution of conodonts is available for densely sampled sections at M. Corona and Contrada Gobbia (Kovacs et al. 1990). The sections can be compared in detail with our own data (Fig. 10) although the unambiguous T_a tuff markers are not mentioned by these authors. The projection of the conodont data onto the Bagolino reference section indicates that *Gondolella* aff. *szaboi* occurs up to the 58 m-level and *G.* aff. *eotrammeri* up to the 61 m-level. *Gondolella trammeri* is present above the T_d tuffs and is accompanied by *G. pseudolonga* and *G. transita* above the "Chiesense groove," in agreement with a conodont sample from this level in Roncone (Brack & Rieber 1986). *Metapolygnathus hungaricus* was found in a layer that presumably corresponds to the 68–70 m-interval of Bagolino. Stratigraphically somewhat higher *Metapolygnathus mungoensis* appears in the upper part of the "Knollenkalke" (northwestern Dolomites; Gasser 1978). In strata above the "Knollenkalke" equivalent beds *Metapolygnathus mungoensis* was found together with *M. mostleri* and *M. diebeli* in Val Gola (Mietto 1982; De Zanche & Mietto 1986). The conodont data are thus in good agreement with fossil distributions in the Hallstatt-type limestones of Epidhavros (Krystyn 1983).

3.3.3. Val Gola (Trento)

The fossiliferous, pelagic sediments at Val Gola near Trento and in Valsugana (Arthaber 1916; Rieber 1968a, 1969, 1973a; Brack & Rieber 1986; De Zanche & Mietto 1986, 1989: the names of the lithological units are adapted from these two publications) overlie platform carbonates covered by a stack of sometimes bituminous and laminated limestones and marls with few thin tuffitic intercalations ("Margon Lst."). The successive marly interval with thin undulating limestone beds ("Val di Centa Marls") bears Daonellas (*Daonella elongata, D. airaghii, D. pseudomoussoni, D. golana* at Val Gola and *Daonella elongata, D. vaceki, D. airaghii* at Fricca/Val di Centa, see Rieber 1968a, 1969) and ammonoids (*Stoppaniceras golanum* at Val Gola and *S. friccensis, S. falcifer, "Ceratites" subnodosus* at Fricca/Val di Centa, see Rieber 1973a, p. 41). These beds are overlain by "Knollenkalke" ("Val Gola Lst."). Except for their lowermost few meters of transitional beds they are typically siliceous and contain thin and sometimes reddish

[14]) Fossils and information on this locality were kindly provided by Manfred Epting.

coloured "Pietra verde" layers. From the "Knollenkalke" in Val Gola we collected *Chieseiceras* cf. *chiesense, Nevadites, Eoprotrachyceras curionii* (see Brack & Rieber 1986), and somewhat higher up *Eoprotrachyceras margaritosum* and *Arpadites*. The fossil succession is thus in good agreement with the sequence at Bagolino. The pelagic faunas also point to the existence of at least temporary surface water connections between the intra-platform depressions of the "Val di Centa Marls" and "Val Gola Limestone" and the wider basins of eastern Lombardy and/or the eastern Dolomites.

A comparison of the faunal successions at Val Gola with the "Buchenstein Beds" (Seceda, Bagolino) and the "Grenzbitumenzone" at Monte San Giorgio (Fig. 12) suggests that the 15–25 m thick "Val di Centa Marls" are an expanded equivalent of a thin "Knollenkalk" interval at Bagolino (approximately 59–62.5 m; uppermost Reitzi/Kellnerites and Nevadites Zones). Moreover, the base of typical siliceous nodular limestones (i.e. the "Knollenkalke" of the Val Gola Lst./"Buchenstein Beds") is clearly diachronous between Bagolino, Seceda and Val Gola.

4. Anisian to Ladinian carbonate platforms

Some of the Upper Anisian/Ladinian platform and intra-platform carbonates of the Southern Alps are unusual in that they contain layers, lenses or fissure infills rich in macrofossils, in particular ammonoids and Daonellas. Fossil localities in the Esino Limestone have long been known in Lombardy (e.g. Esino, Ghegna; Stoppani 1860, Mojsisovics 1882, Tommasi 1911–13, Jadoul et al. 1992). They are also known in the Marmolada Limestone, in the Schlern Dolomite and related carbonates in the Dolomites and adjacent areas (e.g. Marmolada, Latemar, Viezzena, Cislon; Mojsisovics 1882, Kittl 1894, Salomon 1895, Polifka 1886, Koken 1911, Häberle 1908, Wilckens 1909, Bubnoff 1921 and others). Due to the isolated nature of the fossil localities and the absence of well documented pelagic reference sections, the stratigraphic positions of the "platform faunas" have in many cases remained unclear or could be assessed only through indirect evidence (e.g. Assereto 1969). The new fossil successions in the basinal "Buchenstein Beds" allow a more accurate positioning of such faunas.

The fossil finds from platforms with clear large-scale geometries provide unique opportunities for the calibration of the platform versus basin evolution. Fossiliferous intervals were discovered in flank portions of carbonate platforms (e.g. Cernera, Marmolada, Latemar) but also in platform interior lithologies (e.g. Latemar) and partly bituminous sediments deposited in wider intra-platform depressions (e.g. Monte San Giorgio, Perledo-Varenna Lst.).

Results from the most remarkable sections of biostratigraphical relevance in platform and intra-platform settings in Lombardy (Monte San Giorgio) and in the Dolomites (Latemar, Cernera) are briefly outlined below. Ammonoids, Daonellas and additional fossils were also collected from platform carbonates at other localities but in less clear physical stratigraphic positions such as Marmolada (platform interior beds, clinoform deposits and reddish limestones; outcrops on the Marmolada north slope), Viezzena (clinoform deposits), Monte Cislòn (platform interior beds around 300 m above the base of platform carbonates), Ghegna (see below) and Esino.

4.1. *Ammonoid bearing platform carbonates and intra-platform deposits*

4.1.1. Monte San Giorgio (Ticino; southern Switzerland)

At Monte San Giorgio in southern Switzerland a 20 m thick interval of dolomitized carbonate layers alternating with thin bituminous shales (called the "Grenzbitumenzone" [GBZ] or the "bituminous shales of Serpiano and/or Besano") is famous for its rich vertebrate and mollusk fauna. Most of the available fossils were collected during systematic excavations carried out between 1924 and 1968 (for data on ammonoids and Daonellas see Rieber 1968a, 1969, 1973a, b, 1974). Initially only few of the pelagic fossils found in the GBZ were known also from other areas. Nevertheless this interval was interpreted as representing a time-span close to the Anisian/Ladinian boundary (Frauenfelder 1916, Senn 1924, Rieber 1967, 1969).

The new fossil data on the "Buchenstein Beds" at Bagolino and Seceda allow for the first time an accurate integration of the GBZ (Figs. 11, 12). The correlations are based on the distribution of Daonellas (GBZ-Seceda: *Daonella elongata* group, *Daonella golana*) and ammonoids (GBZ-Seceda: *Aplococeras, Ticinites, Nevadites, Chieseiceras*; GBZ-Bagolino: *Ticinites, Nevadites, Chieseiceras*; Bagolino-Seceda: *Ticinites, Nevadites, Chieseiceras, Eoprotrachyceras*). This is supported by the occurrence of thin volcaniclastic layers some of which (T_c to T_e) can be traced in detail from Seceda to Bagolino and are again present as bentonites and crystal tuffs in the GBZ (Müller et al. 1964). Radiometric ages obtained on feldspars of the latter (Hellmann & Lippolt 1981) are thus finally pinpointed in a proper stratigraphic context. Although not all of the volcaniclastic layers in the GBZ can yet be linked with sufficient accuracy to the counterparts in the "Buchenstein Beds", their concentrated occurrence between beds 20 and 85 of the GBZ obviously reflects the frequency of "Pietra verde" intercalations at 56–62 m in the Bagolino section (Fig. 11).

According to our correlation (Fig. 11), the interval with *Kellnerites* and *Reitziites* at Bagolino (53–58 m on section) corresponds to strata below the deepest fossiliferous beds in the GBZ (i.e. below Bed 38). The "Lower Plattenkalke" at Seceda are equivalent to the deepest "Knollenkalke" and parts of the "transitional beds" at Bagolino and the GBZ-beds below the *Ticinites* horizon (Bed 58). The main bituminous intervals in the "Lower Plattenkalke" at Seceda and in the GBZ are therefore clearly not coeval. The organic content of the former is moderate ($C_{org.} < 3.5\%$ [by weight]) but their stratigraphic range lies below the *Ticinites* horizon. In the GBZ thin discrete beds rich in organic matter appear throughout a 10 m thick interval that extends well above the occurrences of *Nevadites* and *Chieseiceras*. In these bituminous mudstones total organic carbon contents of up to 35% are common and the immature (VR/E around 0.6 [15])) source rock material consists predominantly of laminated amorphous organic matter with subordinate contents of algae and sporomorphs (see also Bernasconi 1991).

In the stratigraphic succession above the GBZ, Wirz (1945) found ammonoids (*Arpadites arpadis, Protrachyceras*) and Daonellas (*Daonella* aff. *moussoni* according to Rieber,

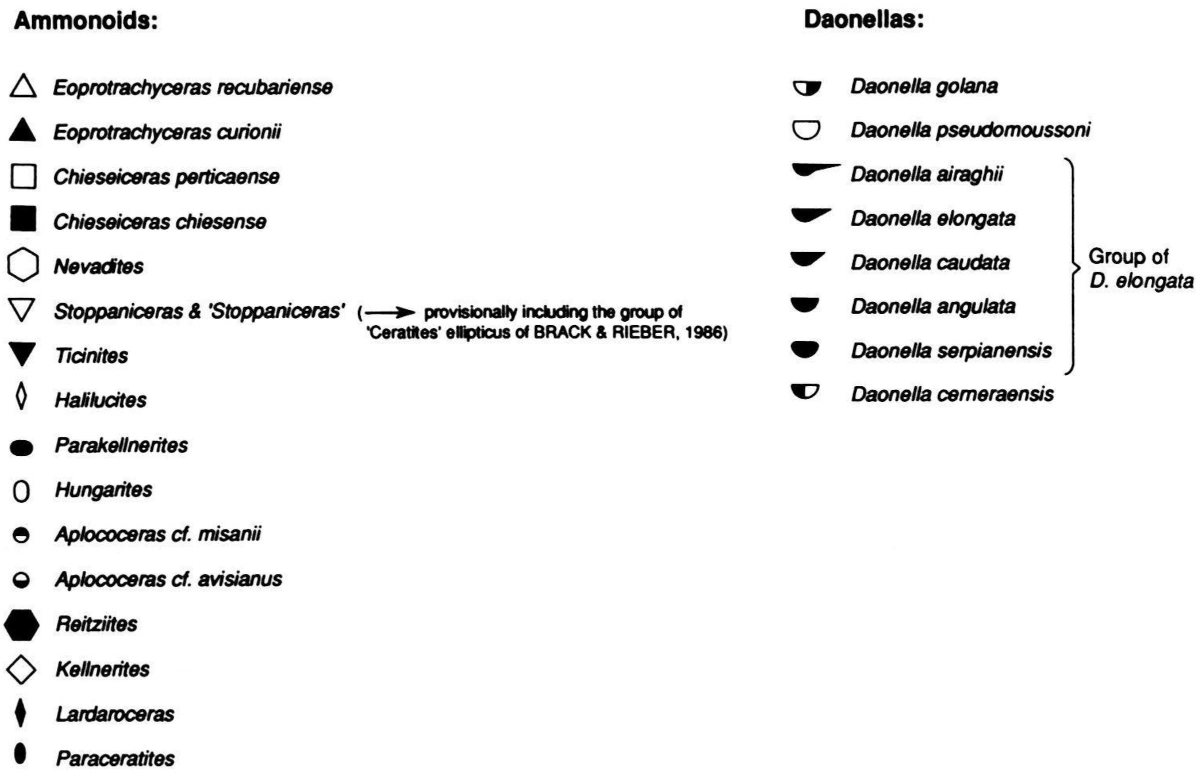
[15]) This value is based on Rock Eval pyrolysis data using a calibrated series of average Hydrogen Indices (HI) for extracted Type I/II source rock samples versus VR. An average HI of 615 [mg HC/g TOC] was derived from a S_2-TOC plot for extracted GBZ samples of a 3.8–33.3% TOC range. T_{max} for these samples varied between 412–426 [°C].

1969) within the 90 m thick "Lower Meride Limestone" some 25 m below a major volcaniclastic interval (the so-called "Val Serrata tuffs"; radiometric ages in Hellmann & Lippolt, 1981). At Bagolino, *Arpadites* occurs around the 75 m-level and the "Val Serrata tuffs" could therefore correspond to volcaniclastic beds in the upper part of the "Buchenstein Beds". Palynomorphs from the topmost section of the 450 m thick "Upper Meride Limestone" indicate a Late Ladinian age (Scheuring 1979).

The original areal extension of the basins of the GBZ and the Meride Limestone is unknown. It may have been linked at least temporarily to the larger intra-platform depression of the Perledo-Varenna Limestone (Gianotti & Tannoia 1987) and similar basins which appear to have reached further to the south (e.g. Riva et al. 1985). The rich "pelagic" faunas in the GBZ testify to the existence of surface water connections across the Esino Limestone barriers to the "Buchenstein" basins of central and eastern Lombardy.

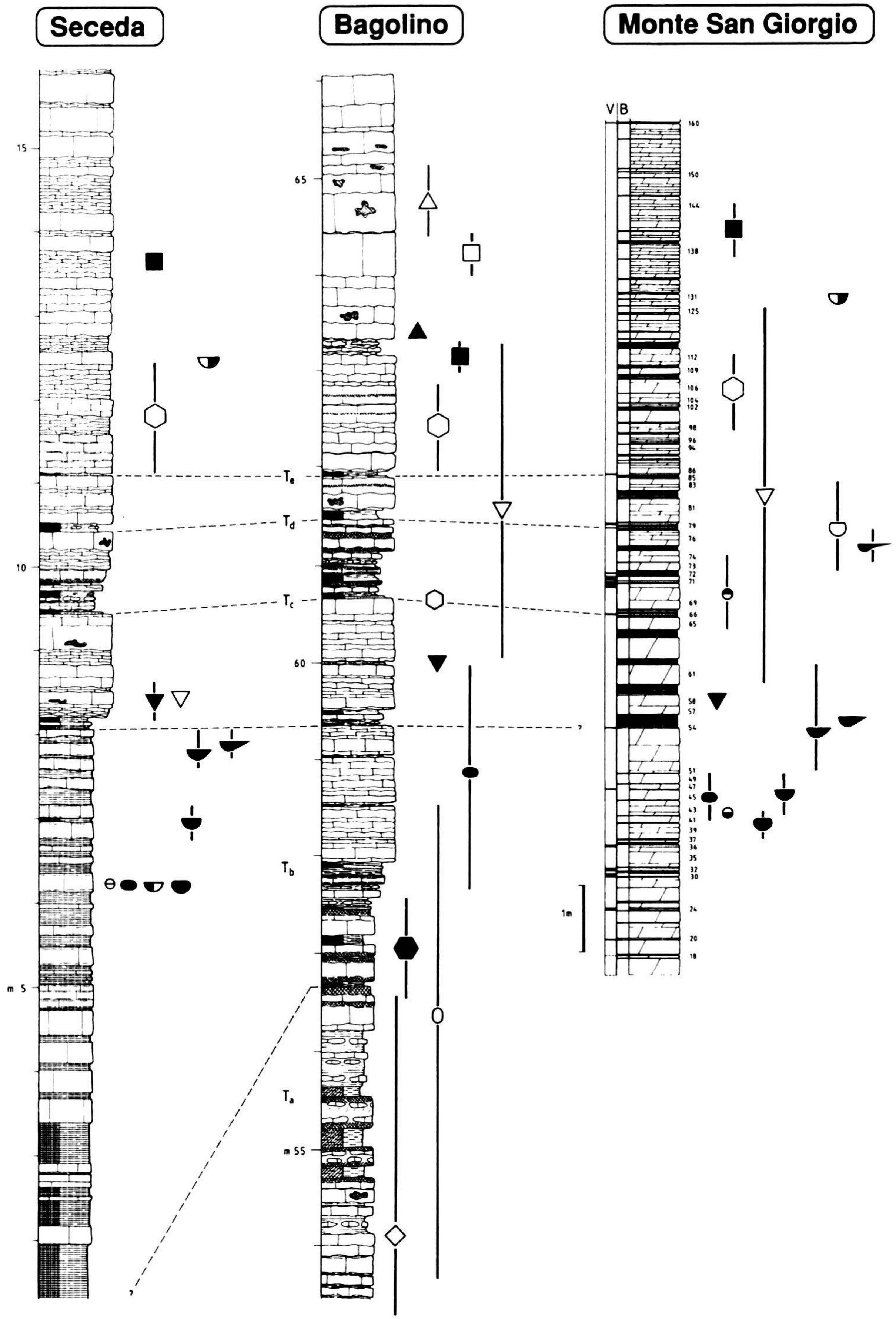
4.1.2. Latemar (western Dolomites)

Ammonoids including *Hungarites, Longobardites* and *Aplococeras avisianum* ("type locality") have long been known from isolated, allochthonous blocks in Quaternary



Legend to Figs. 10 and 11

Fig. 11. Succession and range of the most important fossil groups and detailed correlations of the key intervals at Seceda, Bagolino (fossil distribution projected for Brescian Prealps/Giudicarie) and Monte San Giorgio (see text for further information and Fig. 12 for lithostratigraphic subdivisions). Scales are linear but have been adjusted to fit a 1:1 correlation between the T_c–T_e tuff markers. Bituminous (B) and volcaniclastic (V) layers are highlighted in the Monte San Giorgio section.


Seceda
Bagolino
Monte San Giorgio
15
10
m 5
65
60
m 55
T_e
T_d
T_c
T_b
T_a
V
B
1m

moraines near Forno in the western Dolomites (for further indications and references see Assereto 1969). According to Häberle (1908) the blocks were transported by glaciers from the Val Sorda area in the Latemar massif but their exact provenance and stratigraphic position remained unkown [16]) (Assereto 1969). During a field-trip in 1989 across the Latemar we discovered a potential site for the origin of the Forno blocks or at least a stratigraphically equivalent level. The fossiliferous interval lies in the interior of the Latemar platform (in this paper the outcrop is called the "Lastei di Valsorda" locality) [17]) and more precisely in the uppermost part of the 250 m thick so-called "Lower Edifice"/ "Lower Platform Facies" (Gaetani et al. 1981, Goldhammer & Harris 1989). It is 20 m thick and consists of irregular m-scale bedded and light coloured limestones which are sometimes sucrosic and have thin reddish intercalations every 4–6 m. The reddish material also infills cavities and might have formed during sporadic subaerial exposure of this mainly subtidal unit (Goldhammer & Harris 1989). Within these 20 m of sediments twelve layers are rich in gastropods, bivalves and, above all, ammonoids. The layers are laterally continuous over tens of meters but no fossils could be spotted in approximately equivalent horizons further apart. We suppose that the pelagic fossils were living close to the platform margins and their shells were swept into the platform interior where they were concentrated by currents or accumulated in local depressions. Due to the high rate of platform aggradation in the "Lower Platform Facies" the entire fossiliferous interval presumably reflects a short time-span.

Few ammonoid species are always dominant in each layer. Among these *Aplococeras avisianum* is rare in the lower part but frequent in the upper part of the section. *Hungarites zalaensis* occurs throughout a larger interval and is associated with *Parakellnerites rothpletzi* in the top layer. *Latemarites latemarensis* n. sp., *Norites* and *Longobardites* appear in the deeper portion, *Proarcestes* and *Epigymnites* in the upper part and *(Flexo-) Ptychites noricus* and *Michelinoceras* are scattered throughout the interval.

The similarity of these fossils with those from the "allochthonous" blocks at Forno is obvious. Moreover this fauna is closely related to the lower fossil-level at Cernera (see later) which in turn can be linked to a horizon in the upper part of the "Lower Plattenkalke" at Seceda. The time-equivalence of the 6–8 m of starved, organic-rich "Lower Plattenkalke" of the "Buchenstein Beds" in the northwestern Dolomites with the 250 m thick "Lower Platform Facies" at Latemar is indeed compatible with their sequence stratigraphic interpretation as parts of the same "transgressive systems tract" (Goldhammer et al. 1990).

Following the indications of Koken (1911) we relocated another fossil locality within clinoform deposits of the southern platform slope (the "Isugadoi" locality [18]) of Koken 1911). Extrapolations along the dip of the clinoforms demonstrate that this level corresponds to a position in the upper part of the "Lower Cyclic Facies" of Goldhammer &

[16]) Häberle (1908, p. 526) mentions that Richthofen (1860) might have known a fossiliferous locality with ammonoids on the interior slopes of the Latemar mountains.

[17]) Due to the exceptional nature of the fossil locality we refrain from giving more information on its location. Further details can be obtained directly from the authors.

[18]) "Isugadoi" lies about 500 m southeast of point 2636 which is the peak on the southern rim of the Latemar group that was originally called Cima Feoda (e.g. Fig. 11 in Häberle 1908) in contrast to the indications on recent topographic maps.

Harris (1989). It is therefore stratigraphically higher than the former fossil locality. This is supported by the faunal elements mentioned by Koken (1911). Our own finds in the exploited locality confirm the presence of *Aplococeras misanii* and Daonella (a species with coarse bundled and another one with fine densely spaced ribs) among other ammonoid fragments, gastropods, frequent bivalves and crinoids. At Monte San Giorgio *Aplococeras* cf. *misanii* occurs in beds 65 to 74 corresponding to the tuffaceous groove in the lowermost "Knollenkalke" at Seceda and the T_c level at Bagolino (Fig. 11).

Daonellas and ammonoids including *Arpadites* are also known from the stratigraphically higher clinoform deposits at Col Cornon (i.e. the so-called "Latemar-Ostgipfel"; e.g. Wilckens 1909; Gaetani et al. 1981). In the "Buchenstein Beds" at Bagolino, *Arpadites* first occurs at around the 75 m-level. The youngest clinoforms at Latemar are therefore presumably coeval with the upper "Knollenkalk" unit at Seceda (Fig. 7).

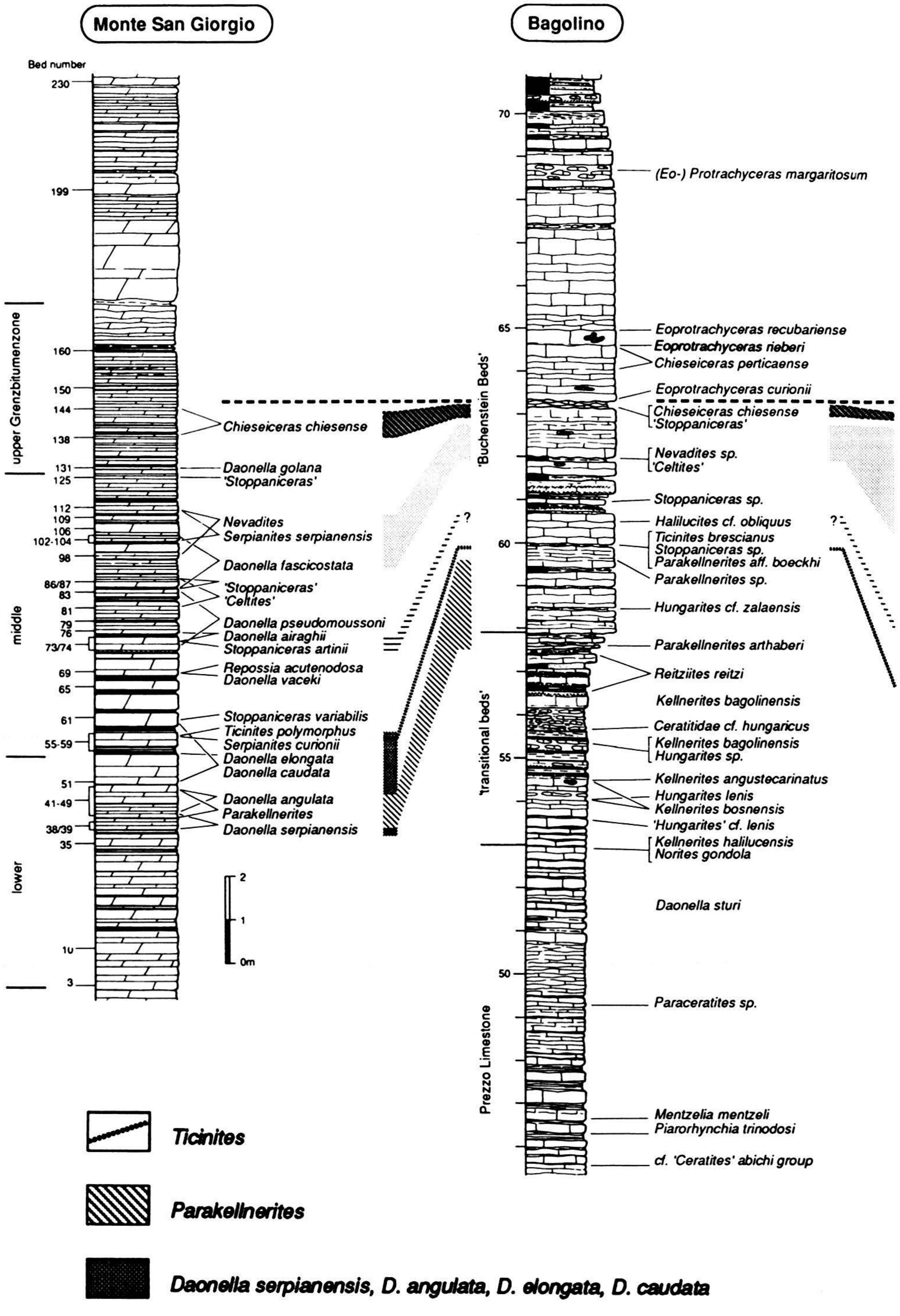
4.1.3. Cernera (Dolomites)

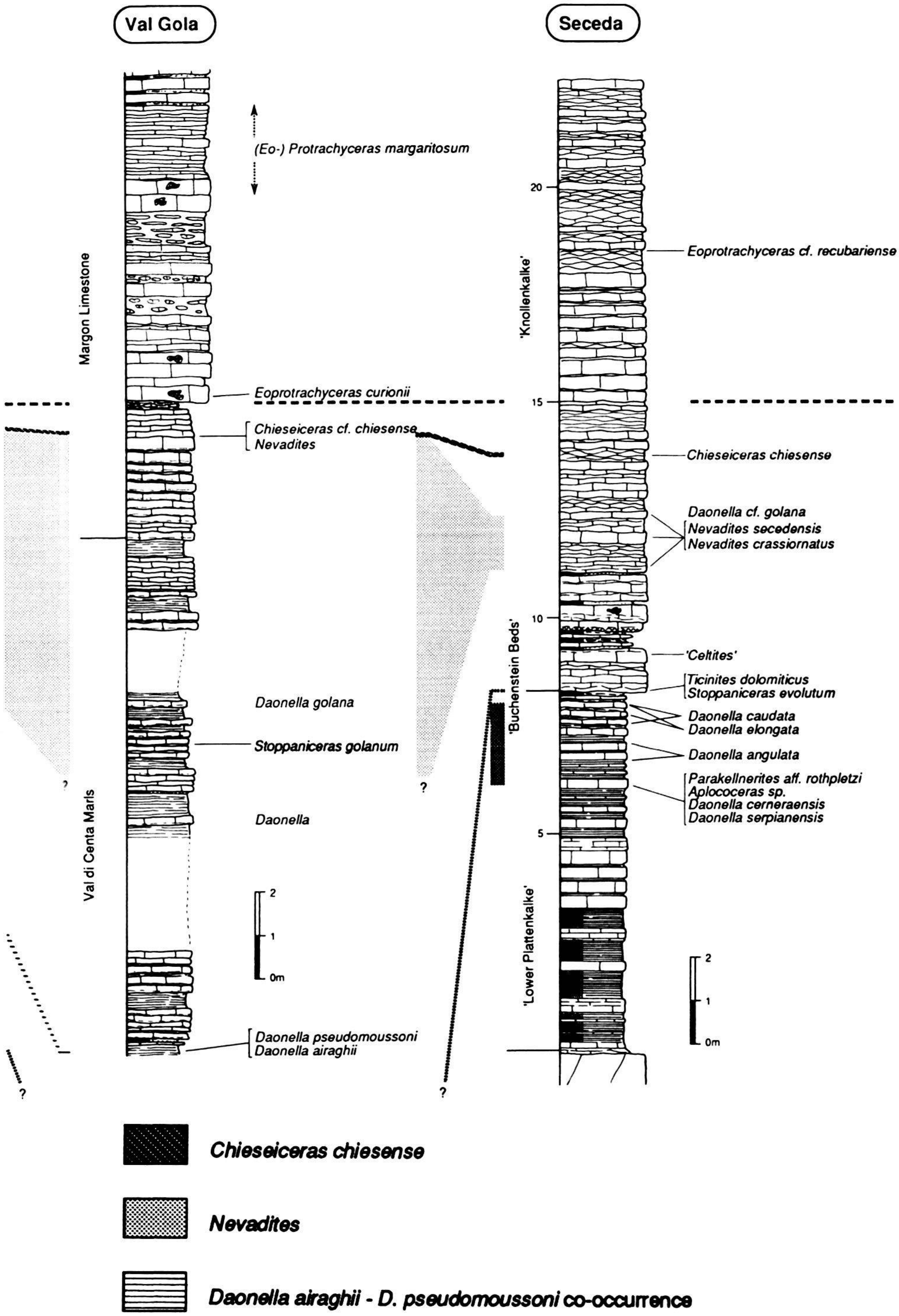
To the southeast of Punta di Zonia on the northern paleoslope of the Cernera platform, Cros & Houel (1983) reported a thin carbonate interval with two successive fossil levels containing ammonoids. A brief inspection of this locality indeed confirmed the presence of *Aplococeras avisianum* along with *Parakellnerites zoniaensis* n. sp., *Hungarites* cf. *plicatus* and *Daonella cerneraensis* n. sp. in the lower horizon. "*Ceratites*" *hungaricus*, mentioned by the above authors, was not found. This level shows clear affinities with the new Latemar fauna ("Lastei di Valsorda" locality). Based on the occurrence of *Daonella cerneraensis* n. sp. it can be linked to the upper portion of the "Lower Plattenkalke" at Seceda.

In a horizon only about 2 m above the former level, various species of *Eoprotrachyceras* occur together with *Chieseiceras chiesense, Sturia, Epigymnites.* A conodont fauna from this level includes *Gladigondolella tethydis, Gondolella excelsa, G. lindstroemi, G. pseudolonga, G. constricta, G. longa* (Vrielynck 1984). The comparison of the ammonoids with the fossil succession in the "Buchenstein Beds" clearly documents stratigraphic condensation.

The absence of thick clinoform packages and significant progradation distances at Cernera suggest that this platform was inbuilding and eventually drowned (Blendinger et al. 1982; Blendinger & Blendinger 1989). The ultimate platform flanks are onlapped by basinal sediments ranging from the "Knollenkalke" of the "Buchenstein Beds" (Cros & Vrielynck 1989) to Upper Ladinian volcaniclastic units. The ammonoid faunas found in the pelagic sediments draping the paleoslopes suggest that the drowning of the Cernera platform occurred in the latest Reitzi/Kellnerites or the Nevadites Zone i.e. corresponding to a stratigraphic interval in the lowermost "Buchenstein Beds" (between 6 and 14 m on the Seceda column). Assuming an initially smooth base of the platform, this shows that just prior to the drowning the core had aggraded to a thickness of 500–650 m

Fig. 12, a, b. Correlation and important faunas of Anisian/Ladinian boundary intervals. Note the diachronous base of the siliceous nodular limestones ("Knollenkalke") between the Bagolino, Val Gola and Seceda sections. All sections at equal scale.
Fossil groups used for correlation are highlighted. The heavy dashed line marks the proposed Anisian/Ladinian boundary.


Monte San Giorgio
Bagolino
Bed number
230
199
160
150
144
138
131
125
112
109
106
102-104
98
86/87
83
81
79
76
73/74
69
65
61
55-59
51
41-49
38/39
35
10
3
upper Grenzbitumenzone
middle
lower
Chieseiceras chiesense
Daonella golana
'Stoppaniceras'
Nevadites
Serpianites serpianensis
Daonella fascicostata
'Stoppaniceras'
'Celtites'
Daonella pseudomoussoni
Daonella airaghii
Stoppaniceras artinii
Repossia acutenodosa
Daonella vaceki
Stoppaniceras variabilis
Ticinites polymorphus
Serpianites curionii
Daonella elongata
Daonella caudata
Daonella angulata
Parakellnerites
Daonella serpianensis
2
1
0m
70
65
60
55
50
'Buchenstein Beds'
'transitional beds'
Prezzo Limestone
(Eo-) Protrachyceras margaritosum
Eoprotrachyceras recubariense
Eoprotrachyceras rieberi
Chieseiceras perticaense
Eoprotrachyceras curionii
Chieseiceras chiesense
'Stoppaniceras'
Nevadites sp.
'Celtites'
Stoppaniceras sp.
Halilucites cf. obliquus
Ticinites brescianus
Stoppaniceras sp.
Parakellnerites aff. boeckhi
Parakellnerites sp.
Hungarites cf. zalaensis
Parakellnerites arthaberi
Reitziites reitzi
Kellnerites bagolinensis
Ceratitidae cf. hungaricus
Kellnerites bagolinensis
Hungarites sp.
Kellnerites angustecarinatus
Hungarites lenis
Kellnerites bosnensis
'Hungarites' cf. lenis
Kellnerites halilucensis
Norites gondola
Daonella sturi
Paraceratites sp.
Mentzelia mentzeli
Piarorhynchia trinodosi
cf. 'Ceratites' abichi group
?
Ticinites
Parakellnerites
Daonella serpianensis, D. angulata, D. elongata, D. caudata


Val Gola
Seceda
(Eo-) Protrachyceras margaritosum
Margon Limestone
Eoprotrachyceras curionii
Chieseiceras cf. chiesense
Nevadites
Daonella golana
Stoppaniceras golanum
Daonella
Val di Centa Marls
Daonella pseudomoussoni
Daonella airaghii
2
1
0m
?
20
15
10
5
'Knollenkalke'
'Buchenstein Beds'
'Lower Plattenkalke'
Eoprotrachyceras cf. recubariense
Chieseiceras chiesense
Daonella cf. golana
Nevadites secedensis
Nevadites crassiornatus
'Celtites'
Ticinites dolomiticus
Stoppaniceras evolutum
Daonella caudata
Daonella elongata
Daonella angulata
Parakellnerites aff. rothpletzi
Aplococeras sp.
Daonella cerneraensis
Daonella serpianensis
Chieseiceras chiesense
Nevadites
Daonella airaghii - D. pseudomoussoni co-occurrence

compared to the 250–350 m of the Latemar time-equivalent. Provided the onset of platform growth was approximately coeval in both areas, the obviously higher rate of creation of accommodation space at Cernera explains the reduced proportion of clinoform deposits there, because little excess carbonate material was available from the platform top and rim. Acceleration of the relative sea-level rise may have induced the inbuilding geometry and drowning at Cernera.

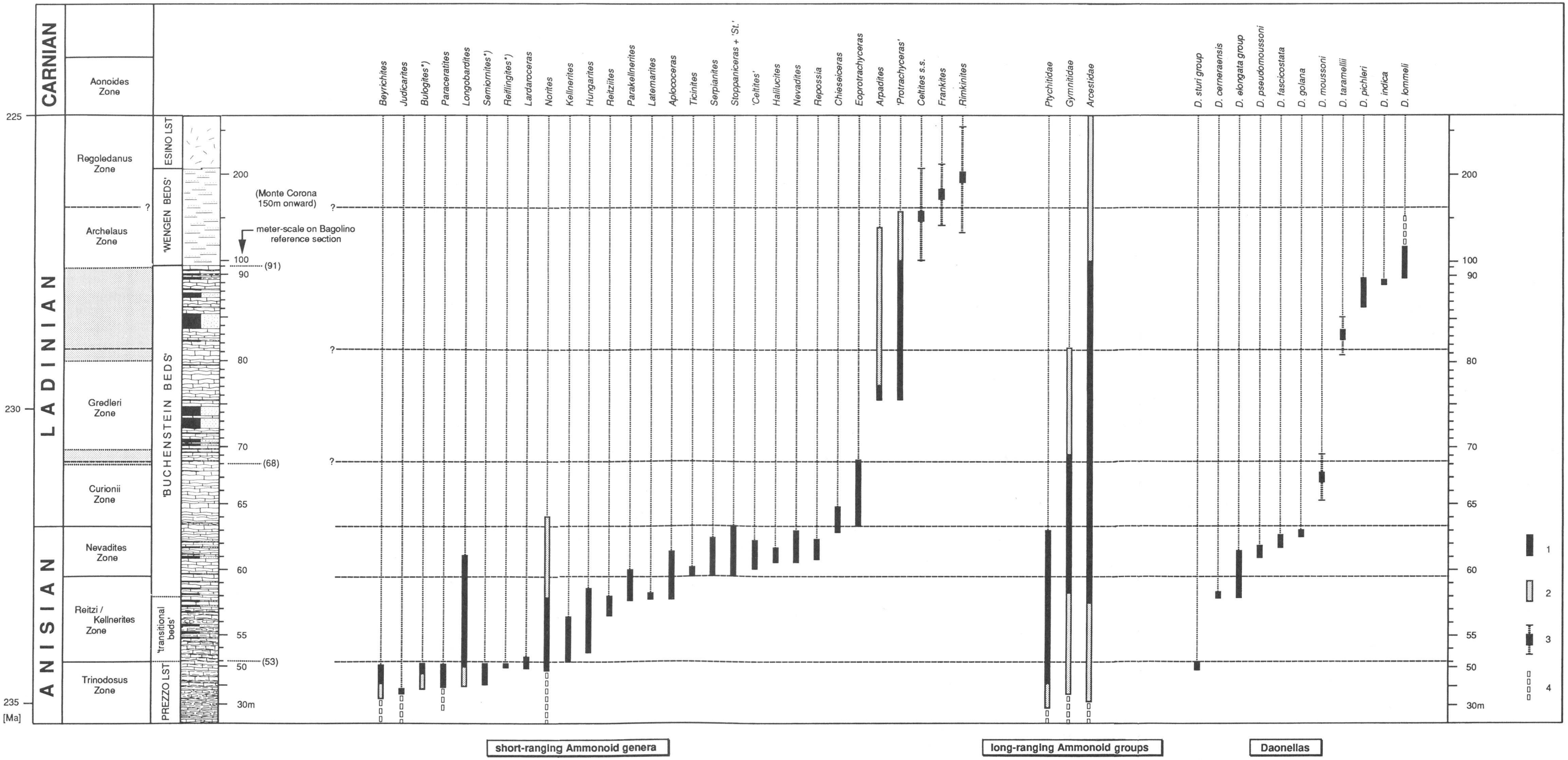
After its submergence the Cernera platform top may have been covered by Hallstatt-type red nodular limestones as suggested by ammonoid bearing reddish limestone clasts within nearby Upper Ladinian megabreccias (Blendinger et al. 1982). Karstification and erosion of parts of the Cernera platform (Assereto et al. 1977 a) probably occurred later, i.e. during uplift related to the Upper Ladinian tectonic episode but prior to the ultimate deposition of thick volcaniclastic units.

5. The South Alpine ammonoid record: Its zonal subdivision and the position of the Anisian/Ladinian boundary

5.1. The fossil succession and resulting scheme of ammonoid zones

The correlations of South Alpine stratigraphic sections ranging from the Upper Anisian to the Middle/Upper Ladinian are based on the occurrence of macrofossils and are supported by the distribution of volcaniclastic layers. Some of the layers (the supposedly subaerially transported tuff fractions) are excellent time markers in different parts of a irregularly shaped sedimentary basin (Fig. 2). The greatest number of fossil levels positively identified in a continuous succession is at Bagolino (Fig. 7). In this section more than 20 ammonoid and Daonella bearing intervals represent a time span between at least the Trinodosus Zone and the Archelaus Zone. Furthermore, the correlative positions are established for most of the important additional fossil horizons of other South Alpine localities. This site is therefore a suitable reference section for the projection of our own and other data available from the studied areas (Figs. 7, 10–12). Even though improvements are expected for certain intervals, the combined fossil record (Fig. 13) across the Anisian/Ladinian boundary is relatively coherent.

Fig. 13. Range and distribution of Late Anisian to Ladinian ammonoid genera and Daonellas from the studied area. The fossil data are projected on the Bagolino reference section where the greatest number of fossil levels was recognized in a single section (Fig. 7). In order to approximately compensate for highly variable sediment accumulation rates four sectors (20–53 m; 53–68 m; 68–91 m; 91–300 m) are shown at different scales but the meter-levels correspond to those of the other figures of the section. The thickness of the "Wengen Beds" represents the situation at Monte Corona; at Bagolino-Dosso Alto these beds are only 5–50 m thick and overlain by platform carbonates of the Esino Limestone (Brack & Rieber 1986, Fig. 2).
Dotted patterns mark stratigraphic intervals for the Curionii/Gredleri and the Gredleri/Archelaus zone-boundaries. Possible positions are indicated by dashed lines.
*Bulogites**), *Semiornites**) and *Reiflingites**) sensu Assereto (1963); generic and specific names for these and other forms from the Brescian Prealps (e.g. Contrada Gobbia) and Giudicarie are currently under revision (Balini 1992 and pers. comm.). "*St.*" for "*Stoppaniceras*" (including provisionally the group of "*Ceratites*" *ellipticus* of Brack & Rieber, 1986).
Symbols: 1: distribution of fossils as observed in this study; 2: range of fossils according to correlatable South Alpine sections reported in literature; 3: interval for probable position of fossils; 4: supposed range of fossils according to additional information from literature.


CARNIAN
LADINIAN
ANISIAN
Aonoides Zone
Regoledanus Zone
Archelaus Zone
Gredleri Zone
Curionii Zone
Nevadites Zone
Reitzi / Kellnerites Zone
Trinodosus Zone
225
230
235
[Ma]
ESINO LST
'WENGEN BEDS'
'BUCHENSTEIN BEDS'
'transitional beds'
PREZZO LST
200
100
90
80
70
65
60
55
50
30m
(91)
(68)
(53)
(Monte Corona 150m onward)
meter-scale on Bagolino reference section
Beyrichites
Judicarites
Bulogites*)
Paraceratites
Longobardites
Semiornites*)
Reiflingites*)
Lardaroceras
Norites
Kellnerites
Hungarites
Reitziites
Parakellnerites
Latemarites
Aplococeras
Ticinites
Serpianites
Stoppaniceras + 'St.'
'Celtites'
Halilucites
Nevadites
Repossia
Chieseiceras
Eoprotrachyceras
Arpadites
'Protrachyceras'
Celtites s.s.
Frankites
Rimkinites
Ptychitidae
Gymnitidae
Arcestidae
D. sturi group
D. cerneraensis
D. elongata group
D. pseudomoussoni
D. fascicostata
D. golana
D. moussoni
D. taramellii
D. pichleri
D. indica
D. lommeli
1
2
3
4
short-ranging Ammonoid genera
long-ranging Ammonoid groups
Daonellas

Similarly complete and uncondensed ammonoid successions straddling the Late Anisian – Ladinian time interval are rare in the western Tethys. The classical Hungarian sections of the Balaton Highland contain clearly superimposed faunas of the Balatonicus Zone, the Trinodosus Zone and parts of our Reitzi/Kellnerites Zone (Szabo et al. 1980; Balogh et al. 1983; Vörös 1987; Vörös & Palfy 1989; Kovacs et al. 1990). The well documented fossil-rich tuffaceous strata of the lowermost Buchenstein Formation (we shall call it the "Reitzi tuffs") at Felsöörs (Kovacs et al. 1990) and Vászoly (Vörös & Palfy 1989; Kovacs et al. 1990) correspond, however, to only a narrow interval at Bagolino. Neglecting the volcaniclastic beds in the 5 to 25 m thick Hungarian "Reitzi tuffs," the composite thickness of the limestone intercalations does not exceed three meters. This compares well with the pelagic carbonate fraction of the correlative 53–58 m interval at Bagolino. In Hungary the stratigraphical control and spectrum of ammonoids above this level are as yet unsatisfactory. The same probably holds true for the most important sections in the Eastern Alps of Austria (e.g. Gross-Reifling, Hallstatt and surroundings; for a compilation see Tollmann 1985). In the fossil-rich condensed Hallstatt-type limestones at Epidhavros in Greece (Krystyn & Mariolakos 1975; Krystyn 1983) the interval between the Trinodosus Zone and the Archelaus Zone is 2.15 m thick compared to approximately 30 m in the Bagolino section. Nevertheless both faunal successions are apparently in agreement. The number of fossil levels is somewhat higher at Bagolino whereas the condensed cephalopod limestones yielded presumably more specimens. The stratigraphic sections in the Humboldt Range of Nevada (Silberling & Nichols 1982) are thicker by up to a factor of two relative to corresponding intervals in the Bagolino and related stratigraphic sections.

The South Alpine macrofossil record shows an unambiguous sequence of key species of *Judicarites, Paraceratites, Kellnerites, Hungarites, Reitziites, Parakellnerites, Aplococeras, Ticinites, Halilucites, Stoppaniceras, Nevadites, Chieseiceras, Eoprotrachyceras, Arpadites* and *Protrachyceras* among other ammonoids as well as Daonellas. Based on this succession we suggest a redefinition of some ammonoid zones and zone boundaries. Particularly important in this context are the clarified relative positions of *Reitziites reitzi, Parakellnerites, Ticinites polymorphus, Aplococeras avisianum* and *Nevadites* which are index fossils of previously used zones.

Following the current schemes for the Tethyan area, we subdivide the interval between the Trinodosus Zone and the Curionii Zone into two parts. Both units include around four fossil horizons or intervals. More detailed subdivisions would produce much smaller units compared to adjacent zones and are therefore better made on a subzone level.

The South Alpine *Nevadites* which were originally thought to represent the *reitzi* group are indeed younger than *Reitziites reitzi* (Böckh 1872) after which the "Reitzi Zone" was named in Hungary. "Nevadites Zone" [19]) is hence an acceptable term for the zone below the Curionii Zone. At Bagolino its base is provisionally drawn at the 59.5 m-level [20]) corresponding to the appearance of *Ticinites*. Its upper limit and therefore the

[19]) Instead of "Reitzi or Nevadites Zone" as previously suggested (Brack & Rieber 1986).

[20]) The first *Nevadites* were found at Prezzo in strata equivalent to the 60.75 m-level in the Bagolino section (Brack & Rieber 1986, Fig. 7, Pl. 4). The inclusion of *Ticinites* is probably a slight downwards expansion of the Nevadites Zone as defined by Krystyn (1983) but it makes the zone boundary clearly recognisable at Monte San Giorgio, Bagolino and Seceda.

base of the Curionii Zone correspond to the top of the "Chiesense-groove" (Brack & Rieber 1986).

For the interval between the Trinodosus Zone and the Nevadites Zone we think that the name "Reitzi/Kellnerites Zone" is a more suitable term than "Parakellnerites Zone." The "Parakellnerites Zone" was introduced by Krystyn (1983) as a substitute for the "Avisianus-", the "Polymorphus-" and the "Ceratites reitzi Zones." In the Southern Alps the range of *Parakellnerites* is known within a full ammonoid succession at Monte San Giorgio and Bagolino, and falls there in the upper part of our Reitzi/Kellnerites Zone. This zone presumably corresponds to a larger part of the original "Reitzi Zone" in Hungary and the appearance of *Kellnerites* is a useful element for its distinction from the Trinodosus Zone. In the Bagolino reference section the base of the Reitzi/Kellnerites Zone lies at the 53 m-level. According to our correlation (Fig. 10) Balini's (1992) *Lardaroceras* beds at Contrada Gobbia and Monte Corona (Stabol Fresco and Adana sections) are therefore considered as the uppermost part of the Trinodosus Zone in this paper.

Vörös & Palfy (1989) advocate an "Avisianum Zone" followed by a "Reitzi Zone" with the first occurrence of *Reitziites* at its base. Because *Reitziites* (= *Xenoprotrachyceras* in Vörös & Palfy, 1989) is clearly older than *Ticinites* and *Nevadites* this would be a subdivision of our Reitzi/Kellnerites Zone. As mentioned earlier such a subdivision may be acceptable on a subzone level. The index "Avisianum" is unfortunate, however, because the faunas with *Aplococeras avisianum* from Latemar and Cernera appear to be slightly younger than the *Reitziites* horizons at Bagolino.

The definitions of the lower boundaries of the Gredleri- and the Archelaus Zones have to await more thorough documentations of fossils from the middle/upper part of the "Buchenstein Beds". In the Bagolino reference section the base of the Gredleri Zone can be located provisionally within the 68–70 m interval. Its top falls between the 80–91 m levels, depending on which ammonoid zone the Daonellas (*Daonella pichleri, D. indica*) of this and equivalent sections are assigned to.

The allocated positions of the above mentioned ammonoid zone boundaries in the South Alpine Upper Anisian – Ladinian sections closely correspond to the zone boundaries in the Hallstatt Limestone at Epidhavros in Greece (Krystyn 1983).

5.2. The positions of the Anisian/Ladinian and the substage boundaries

Much has been written on what might be the most suitable position for the Anisian/Ladinian boundary (for a compilation of various ideas see e.g. Brugman 1986). The location of a stage boundary is chiefly a matter of convention and practical arguments should therefore outweigh historical reasons. This is especially valid where the latter have become ambiguous and the documentation of the fossil record has improved. This is indeed the case for the stratigraphic interval which includes all proposed Anisian/Ladinian boundaries in western Tethys. Moreover, a widely accepted choice has been made for the stage boundary in North America (e.g. Silberling & Tozer 1968). This boundary also serves as a reference for the most recent sea-level curves (Haq et al. 1988).

Bittner's (1892) original proposal for the Ladinian Stage implies that its lower boundary should be located at the (lithological) base of the "Buchenstein Beds" in the Dolomites. These beds were originally interpreted as equivalents of the "*Protrachyceras reitzi*"-bearing limestones in Hungary. We have shown that what was probably thought to be "*reitzi*" in the Southern Alps (i.e. the *Nevadites*) is distinctly younger than *Reitziites reitzi*. Moreover the age of the lowermost "Buchenstein Beds" in the Dolomites is not sufficiently well constrained. To our knowledge no macrofossils have yet been identified in the first few meters of "Plattenkalke" on top of the barren (regarding ammonoids) Upper Anisian platform carbonates (Contrin Fm.). The frequent occurrence of "Pietra verde" intercalations from the base of the "Plattenkalke" onwards suggests only that they may be close to a level corresponding to the *Reitziites* horizons at Bagolino (Figs. 7, 11). A truly isochronous age for the base of the "Buchenstein Beds" is doubtful, however, even within the Dolomites. Bittner's (1892) implicit definition for the base of the Ladinian lacks a type-section and is therefore ambiguous.

Similarly unclear is the limit between the frequently quoted Anisian and Ladinian substages Illyrian and Fassanian. This is mainly due to the recognition of a significant time-span between the Trinodosus Zone and Curionii Zone after the introduction of these substages. The Illyrian (renamed by Pia, 1930 after the "Bosnian Substage" of Mojsisovics et al. 1895) is based in part on "Hallstatt-type" limestones in Bosnia. The stratigraphic range of these beds exceeds the Trinodosus Zone (Arthaber 1906; Krystyn & Mariolakos 1975) and may reach at least the deeper parts of the Nevadites Zone. According to its original concept the Fassanian is represented by the "Buchenstein Beds" and "Marmolada Limestone" of the Dolomites (Mojsisovics et al. 1895). It thus spans a time interval between the Reitzi/Kellnerites and the lowermost Archelaus Zones. The original Illyrian and Fassanian therefore overlap and the position of the Illyrian/Fassanian boundary at the base of the Nevadites Zone (e.g. Krystyn 1983) is a compromise. The equivalent level in the "Buchenstein Beds" of the northwestern Dolomites is the base of the "Knollenkalke" (e.g. Seceda section) and not of the "Buchenstein Beds" according to Mojsisovics' definition.

It is obvious that these historical concepts are not sufficiently clear to be implemented in a redefinition of the stage boundary. Nevertheless, in view of the newly discovered fossil successions (ammonoids, Daonellas, conodonts, palynomorphs), the Southern Alps may still be regarded as a type area for the Ladinian. It seems reasonable to opt for a biostratigraphical scale with high resolution and wide applicability for the first approximation of the stage boundary prior to the choice of a reference point in a stratigraphic succession. According to the available information the resolution of the ammonoids up to now clearly surpasses alternative scales in the studied interval.

There is general agreement that an ammonoid-based Anisian/Ladinian boundary in the western Tethys area should be drawn somewhere between the Trinodosus Zone and the Curionii Zone. Potentially suitable levels can be associated with the three zone boundaries in this interval (e.g. Krystyn 1983)[21]) all of which can be recognized and

[21]) At least three different Anisian/Ladinian boundary positions have been proposed to date in the Balaton Highland of Hungary. The traditional boundary at the base of the "Reitzi tuffs" at Felsöörs presumably lies close to the boundary between our Trinodosus and the Reitzi/Kellnerites Zones. The recent proposal for an alternative stage boundary just below a *Reitziites*-bearing layer at Vászoly (Vörös & Palfy, 1989) would fall within our Reitzi/Kellnerites Zone. However, as mentioned earlier we think that this zone should not be further subdivided on a zonal level. The first occurrence of *Gondolella trammeri* has also been suggested for the position of the stage boundary (Kovacs et al. 1990). In Hungary this event lacks full ammonoid control. If indeed *G. trammeri* appears at the base of the Nevadites Zone the comparison with the Bagolino section suggests that this boundary is significantly younger than the *Reitziites* horizons (Fig. 13).

assessed in at least one South Alpine section. The full range of the Reitzi/Kellnerites Zone is hitherto only documented at Bagolino. This is thus not a practical level for the stage boundary. The base of the Nevadites Zone is a more suitable alternative but the zone boundary is still insufficiently controlled by fossils. Hence the base of the Curionii Zone is at present the best marker for the Anisian/Ladinian boundary in the Southern Alps. In the stratigraphic successions of the Brescian Prealps and Giudicarie this is equivalent to the top of the "Chiesense groove" (63.3 m-level in the Bagolino reference section; Figs. 7, 8, 10, 11) as discussed in Brack & Rieber (1986). In Epidhavros (Greece) the equivalent boundary is clearly recognizable (Krystyn 1983). In the Balaton Highland of Hungary, however, it lies above the fossil rich "Reitzi tuffs." Certainly our stage boundary concept corresponds most closely to the American convention and thus helps avoiding unnecessary complications in global stratigraphic correlations.

If substages are to be maintained the Illyrian/Fassanian boundary should coincide with the base of the Ladinian Stage. The Fassanian should therefore comprise at least the Curionii Zone but would no longer include the Reitzi/Kellnerites and Nevadites Zones as represented by the lowermost "Buchenstein Beds". Many recent European time scales indicate the Fassanian/Longobardian boundary at the base of the Gredleri Zone (e.g. Krystyn 1983). Again the original concepts of the Fassanian ("Buchenstein Beds" and "Marmolada Lst.") and of the Longobardian ("Wengen Beds") provide no unambiguous definition of their boundaries. However, in the Southern Alps (including the northwestern Dolomites), typical "Wengen Beds" span mainly the Archelaus Zone and in many areas (e.g. eastern Lombardy, Giudicarie) parts of the Regoledanus Zone also (Fig. 2c). This supports an inclusion of the Gredleri Zone into the Fassanian thus restricting the Longobardian to the Archelaus and Regoledanus Zones. The upper limit of the Longobardian is defined by the base of the Cordevolian in the Dolomites (Urlichs 1974, 1977). The resulting homogeneous substage pattern for the Late Anisian and Ladinian is again in good agreement with North American conventions.

5.3. *Indications for the Anisian/Ladinian boundary in South Alpine sections*

The boundary between the Nevadites Zone and the Curionii Zone (i.e. our Anisian/Ladinian boundary) can be pinpointed or approximated in a number of South Alpine localities in addition to the formerly discussed key sections (Fig. 14).

Parts of the Perledo/Varenna Limestone in a section at **Parlasco**/Val Portone (area of Esino; Pasquarè & Rossi 1969) are here tentatively correlated with the "Grenzbitumenzone" (GBZ) and the "Buchenstein Beds." The lowermost volcaniclastic layers at Parlasco (the "Cestaglia horizon" of Pasquarè & Rossi 1969; Gianotti & Tannoia 1987) seem to correspond to the tuffs in the GBZ at Monte San Giorgio and the T_c–T_e levels at Bagolino. The upper volcaniclastic strata (i.e. the "Parlasco horizon") could represent a tuffaceous succession in the middle portion of the "Buchenstein Beds". The resulting Anisian/Ladinian boundary interval at Parlasco (Fig. 14) is compatible with fossil finds (Gaetani et al. 1987). Conodonts were reported from the lowermost Perledo-Varenna Limestone (*Gondolella constricta, G. trammeri, G.* cf. *longa*) and also occur higher up (*Metapolygnathus hungaricus*) in horizons containing *Daonella moussoni* (Fig. 14). In the same area ammonoids including *Protrachyceras longobardicum, P. steinmanni* and various *Arpadites* are known from lenses in platform carbonates of the Esino Limestone (e.g. Mojsisovics 1882; Rossi Ronchetti 1960 and our own finds). These levels are probably equivalent to the middle/upper portion of the "Buchenstein Beds" at Bagolino and possibly correspond to parts of the Lower Meride Limestone at Monte San Giorgio.

At **Ghegna** (Val Brembana) a rich fauna with ammonoids was found in the scree of the Esino platform carbonates (Tommasi 1913). Our collection from this locality includes representatives of "*Stoppaniceras*" besides *Aplococeras misanii, Chieseiceras chiesense* and other ammonoids, some of which occur close to the boundary between the Nevadites Zone and the Curionii Zone at Bagolino. According to Assereto et al. (1977b, Fig. 3) the lumachella rocks of Ghegna form lenses at the base of the Esino Limestone 15–20 m above typical but thin (< 30 m) Prezzo Limestone. This is in good agreement with the position of distinct tuff markers (corresponding to the T_a tuffs at the 55 m-level at Bagolino) which we identified in equivalent beds at Lenna and Piazza Brembana a few kilometers to the west (Fig. 10). Jadoul et al. (1992) locate the lumachella rocks somewhat higher up in the Esino Limestone (60–100 m from its base). Interestingly these authors also describe several fossil rich lenses in Esino platform carbonates in Val Parina only four kilometers to the southeast of Lenna. In these fossil lenses ammonoids are abundant and include species that are well known from time equivalent "Buchenstein Beds" (*Chieseiceras perticaense, Norites dieneri,* various *Eoprotrachyceras* (*E. rieberi, E. recubariense*) (Fantini Sestini pers. comm.), *Protrachyceras* (*P. longobardicum; P. steinmanni*) among other ammonoids).

In the **Recoaro/Tretto** area, early finds of ammonoids (Tornquist 1898, 1901) include specimens of *Hungarites, Eoprotrachyceras* (*E. curionii* (?), *E. recubariense, E. margaritosum*) and *Arpadites.* These fossils were presumably collected from the scree of nodular limestones, a few meters thick, on top of a prominent "Pietra verde" series (Mietto pers. comm.). Neighboring sections (including the "Pietra verde" interval) provided conodonts (Mietto & Petroni 1979, 1980) indicative of the Nevadites Zone (Krystyn 1983) or a somewhat deeper level for the lowermost samples. Our Anisian/Ladinian boundary falls most probably within the above mentioned nodular limestones. On the basis of the ammonoids these limestones could be a condensed equivalent of the 58–75 m interval of the Bagolino section. The locally thick "Pietra verde" successions at Tretto/Recoaro may thus be tentatively interpreted as equivalents of the T_b–T_e volcaniclastic layers at Bagolino.

At **M. Rite** and **Dont**, Middle/Upper Anisian pelagic successions (Assereto 1971; Farabegoli et al. 1984) continue upwards into typical "Buchenstein Beds." Even though the stage boundary cannot be fixed accurately it probably falls within the lowermost "Knollenkalke." These beds overlie a "Pietra verde" succession above a marlstone unit with Daonellas (known as the "*Daonella* marls"). Similar lithologies with Daonellas in the Prags area (Schadebach section; see Bechstädt & Brandner 1970 for location) are capped by "Plattenkalke" and "Knollenkalke" comparable to those of the Pedraces and Seceda sections. In the area between Prags and M. Rite ammonoids of our Reitzi/Kellnerites Zone were reported from strata just below typical "Knollenkalke" of the "Buchenstein Beds" (Casati et al. 1982; "Stabin" locality).

Further to the east in **Cadore** and **western Carnia**, ammonoids from red nodular limestones (Clapsavon Lst.) date the submergence of platform portions as slightly older than the Anisian/Ladinian boundary (possibly comparable to the drowning of the Cernera platform in the Dolomites). Geyer (1898) found *Chieseiceras chiesense* and *Eopro-*

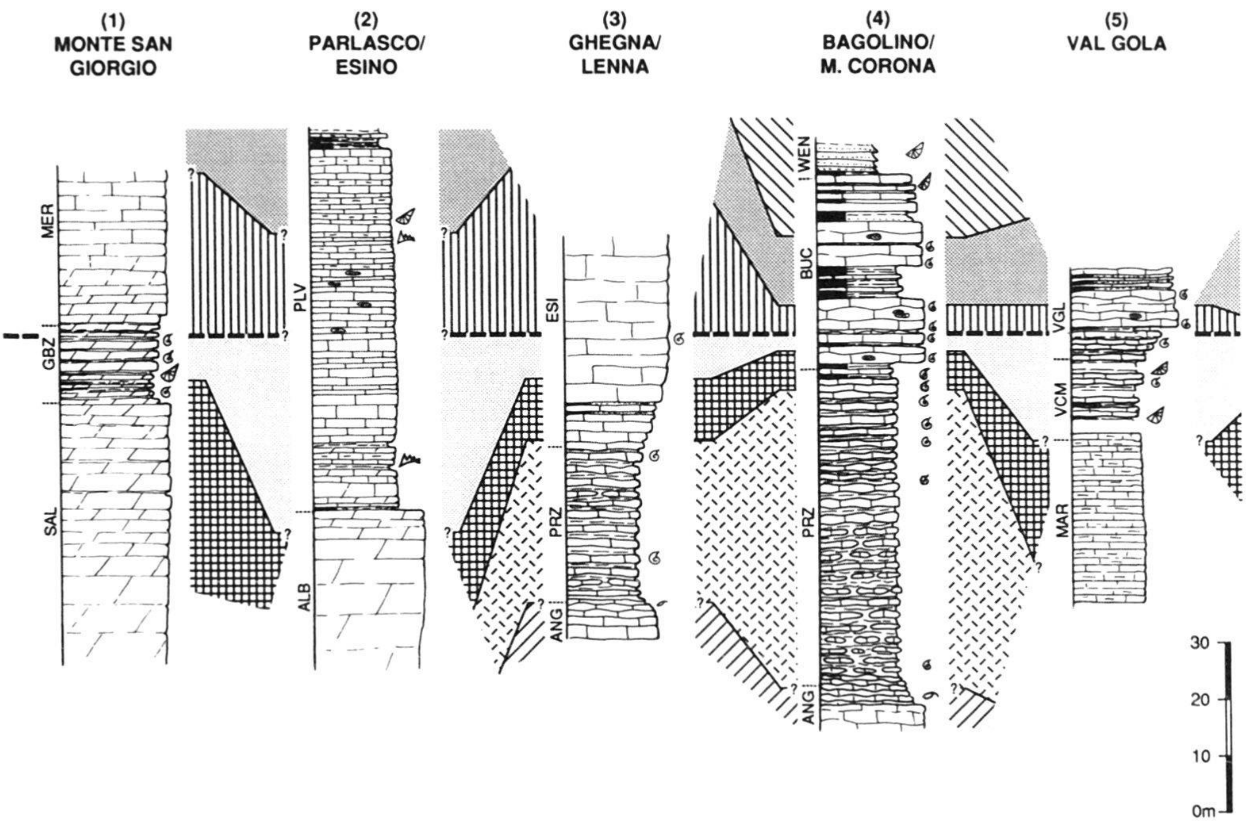
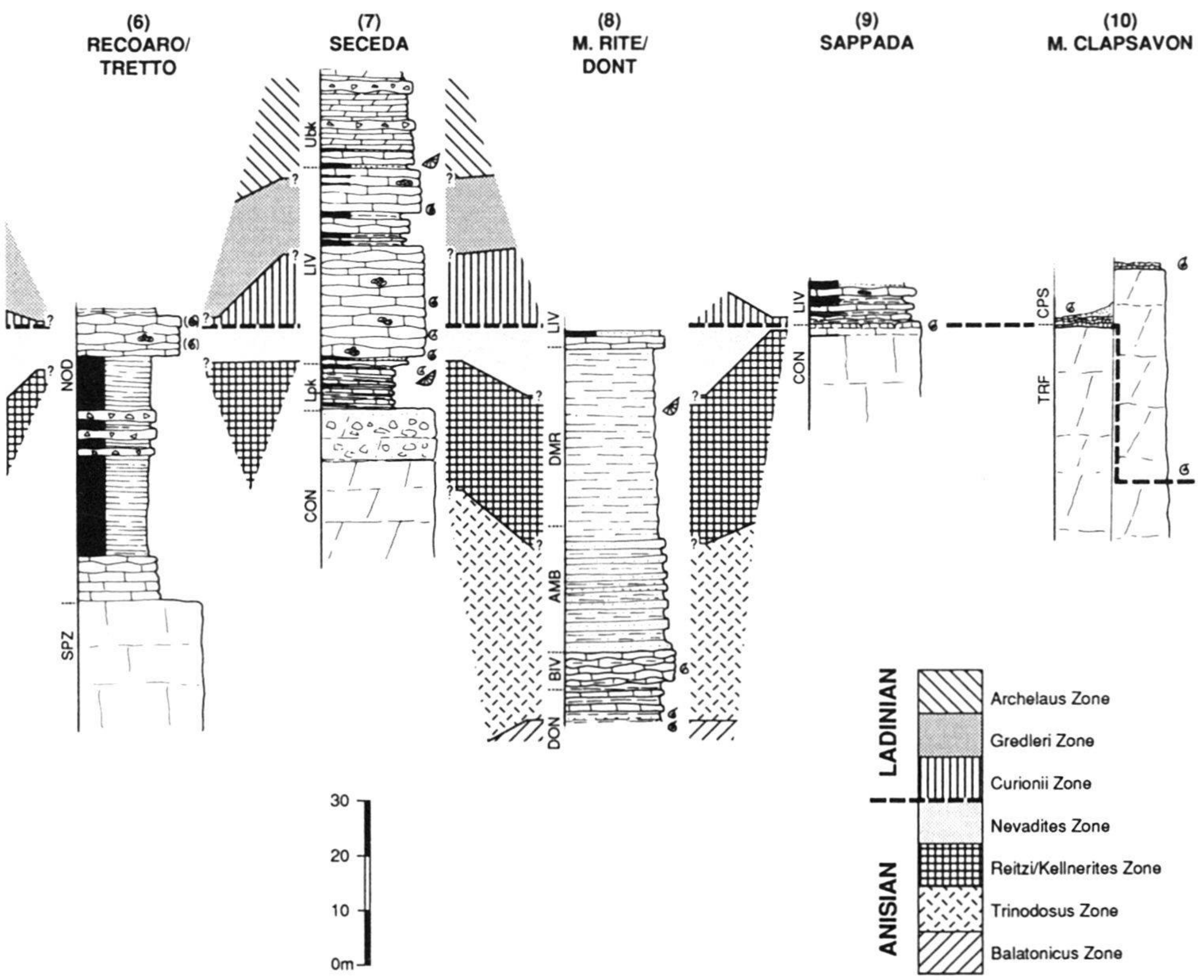


Fig. 14. A correlation of sections straddling the Anisian/Ladinian boundary in various settings along the Southern Alps (see text for discussion and Fig. 1 for locations). The suggested stage boundary (i.e. the limit between the Nevadites and the Curionii Zones) can be pinpointed or approximated in most sections. See Fig. 2b for the large-scale stratigraphic context of individual sections and Fig. 12 and text for details on sections (1), (4), (5) and (7). References for stratigraphic columns which are partly or fully adapted from literature: (2) after Pasquarè & Rossi (1969), bivalve symbol marks position of *Daonella moussoni*, conodonts are mentioned in the text; (3) after Assereto et al. (1977b), faunas indicated are those of the Prezzo Lst. (the *Paraceratites brembanus* fauna e.g. Venzo & Pelosio 1968; the Contrada Gobbia equivalent fauna) and of the lumachella rocks at Ghegna (see text); (5) partly after De Zanche & Mietto (1986, 1989); (6) after De Zanche et al. (1979), Val di Creme section, probable correlative position of the fauna from Tretto (Tornquist 1898, 1901) is indicated; (8) after Pisa et al. (1978) and Assereto (1971); (9) after Lagny (1974) "Casera Plotta" locality with fauna of Geyer (1898); (10) schematic after Pisa (1972, 1974).
Abbreviations of formal and informal stratigraphic units are the same as in Fig. 2.

trachyceras recubariense among other ammonoids in a thin condensed horizon near Sappada (the "Casera Plotta" locality; see also Lagny 1974; Assereto & Pisa 1978). Unpublished specimens of *Chieseiceras chiesense* and *Nevadites* have also been identified at Padova University in De Toni's collections from the Clapsavon Limestone at Valdepena (Lorenzago) and in the M. Clapsavon/M. Bivera area (Brack & Rieber 1986). Interestingly, in the same area, Pisa (1966, 1972) found ammonoids including *Eoprotrachyceras curionii* in platform carbonates 40 m below their top. Provided that the accumulation of fossils is not a fissure fill this would suggest a non-isochronous and presumably tectonically influenced drowning of different platform portions even within a small area. Based on the occurrence of *Protrachyceras gortanii nodato* in the "Buchenstein Beds" at Seceda, the main fauna from M. Clapsavon and Forni di Sotto (Pisa 1966) may correspond to the middle/upper portion of the "Knollenkalke" at Seceda.



6. Additional Information on chronostratigraphy and time-scales

6.1. The calibration of the stratigraphic scheme (Fig. 2)

The calibration of the (chrono-)stratigraphic scheme of the South Alpine Middle Triassic (Fig. 2c) is based on age indications from ammonoids and Daonellas. The data coverage is obviously better for the basinal lithologies. We feel, however, that a careful integration of other stratigraphic tools including palynomorphs, conodonts, radiolarians and calcareous algae could improve the resolution in poorly constrained units. A prerequisite for this is a coherent calibration of the different scales against a common standard (e.g. the zonal scheme based on ammonoids).

In addition to the fossil data already discussed in this paper, calibration points for the western sector (Lombardy, western Trentino) include mainly ammonoids and Daonellas from the Prezzo Limestone (Trinodosus Zone), the "Wengen Beds" (Archelaus- & Regoledanus Zones) and the Esino Limestone. Daonellas (*Daonella pichleri*) have been found in the lower part of the Pratotondo Limestone (Brack 1984) and a ammonoid fauna is known from Carnian platform carbonates (Aonoides Zone; Allasinaz 1968). The biostratigraphic control on Lower/Middle Anisian and Upper Ladinian – Lower Carnian units is as yet unsatisfactory. Particularly difficult to assess are the positions, correlations and durations of time gaps documented by prominent and widespread exposure surfaces in platform carbonates (e.g. Assereto et al. 1977b; Gnaccolini & Jadoul 1990).

The age of the Middle to Upper Anisian pelagic sediments in the eastern Dolomites (Dont Fm., Bivera Fm., Ambata Fm.) is constrained by ammonoids, conodonts and Daonellas (see Assereto 1971; Farabegoli et al. 1984). The calibration of Upper Ladinian to Lower Carnian units in the Dolomites is based on ammonoids and Daonellas from formations of the Wengen Group (mainly Archelaus to Lower Regoledanus Zone; e.g. Viel 1979; Blendinger et al. 1982) and the basinal San Cassian Fm. (uppermost Archelaus to Aonoides Zone; Urlichs 1974, 1977). The stratigraphic scheme (Fig. 2c) is compatible with palynostratigraphical results (mainly van der Eem 1983; see also data in Brugman 1986, Blendinger 1988).

Physical relationships between platform carbonates and basinal successions in this sector have largely been adapted from Bosellini (1984) and Doglioni et al. (1990). However some units have been repositioned with respect to the biostratigraphical scale.

At present it is difficult to judge how this affects the correlations of the stratigraphic pattern with eustatic-cycle charts for the Triassic as indicated by Sarg (1988) and Doglioni et al. (1990). According to Haq et al. (1988) this chart is partly based on the Dolomites for the Anisian to Carnian time interval but no details were released on a biostratigraphic calibration. Thus it is not clear whether our modifications imply equivalent shifts in the chart or, alternatively, they require new correlations between the stratigraphy and a fixed chart. The latter would apply if the cycle chart is demonstrably tied to biostratigraphic scales in areas independent of the Southern Alps (e.g. the Arctic Triassic). Moreover, the significance of tectonic noise is in our opinion not yet sufficiently well established in the analysis of South Alpine sequences and it is unclear to what degree it obscures their straightforward interpretation in eustatic terms.

In view of these unsolved problems we refrain from correlating our stratigraphic scheme with published cycle charts even though this may eventually improve the calibrations. Nevertheless, a few striking and apparently synchronous changes in the South Alpine stratigraphic patterns (Fig. 2) shall be briefly emphasized. Particularly evident are distinct drowning events of carbonate platforms, several of which have also been recognized in the Triassic of the Eastern Alps. In both areas drowning affected in some cases only parts of larger platforms while carbonate growth was unimpeded or could quickly enough resume in other platform portions.

The pelagic cover (Prezzo Lst.) on top of Anisian platforms in eastern Lombardy (Dosso dei Morti and equivalent Limestones) is analogous to similar basinal strata (Reifling Beds) above the Steinalm platform in the Eastern Alps (e.g. near Saalbach, Brandner 1984). A relationship between this sudden transition in eastern Lombardy and prominent tectonic events in the Middle/Late Anisian cannot be ruled out. These movements resulted in, amongst other effects, a prominent uplift and tilting of the realm of the western Dolomites. Near surface-water carbonate production may have dropped in adjacent areas due to a suddenly increased input of clastic fines. In western Lombardy a clastic succession was submerged at approximately the same time. Its eastern margin was transgressed by basinal strata (Prezzo Lst.) and a vast carbonate platform nucleated in adjacent areas. Portions of large platforms in western Lombardy (Albiga and equivalent dolomites) and in the Dolomites possibly drowned within a short time span in the

Late Anisian (Reitzi/Kellnerites Zone). Time-equivalent pelagic sediments ("Buchenstein Beds") in eastern Lombardy document a roughly coeval lowering in sedimentation rate (at 58 m-level on Bagolino section; Figs. 7, 10, 11) due mainly to a reduction in the supply of fine clastic detritus to the basin. In the easternmost portion of the Southern Alps this event could correlate with a stage in the drowning of a depply eroded ridge (the "Dorsale Palaeocarnica" of Farabegoli et al. 1985). In the Eastern Alps this same event may have submerged the "Zwischendolomit"-platform in the Drau range and at Dobratsch (Bechstädt et al. 1976; Tollmann 1977). This in turn presumably corresponds to the abrupt changes in the stratigraphical patterns which were termed the "Reiflinger Wende" by Schlager & Schöllnberger (1974). Even further afield in Hungary (Balaton Highland), the Megyehegy Dolomite platform drowned in places during the same time interval.

Slightly younger but apparently not synchronous (Nevadites to Curionii Zones) drowning events affected portions of carbonate platforms in Cadore/western Carnia and in the eastern Dolomites (e.g. Cemera).

The products of the prominent Late Ladinian transpressional tectonic movements and magmatism (peak activity in the Archelaus Zone) in the Dolomites have no obvious counterparts in Lombardy. We suspect, however, that the sudden influx of siliciclastic detritus into the previously starved Buchenstein basins (i.e. the Lombardian "Wengen Beds") was a result of the simultaneous reworking of clastic shelves or exposed (? basement) areas. Moreover, the rapid and apparently local subsidence of the northernmost Esino Limestone platforms in Lombardy could be related to transtensional zones within the same Late Ladinian tectonic system.

Uppermost Ladinian and Lower Carnian exposure surfaces in the Lombardian platforms document higher amplitude sea-level fluctuations similar to features observed in the Dolomites. The age of individual events is, however, not yet sufficiently well constrained for precise correlation.

6.2. The numerical time-scale and duration of the Ladinian

Assessments of the durations of intervals and the correlation of relative and numerical time-scales are still problematic for the Triassic.

In the Southern Alps radiometric age data exist for a number of stratigraphically constrained Middle Triassic intrusive and volcaniclastic rocks (Borsi & Ferrara 1967 [22]); Borsi et al. 1968; Hellmann & Lippolt 1981; Cassinis & Zezza 1982; Crisci et al. 1984).

The K/Ar and Ar/Ar ages of alkali feldspars from bentonite layers in the "Grenzbitumenzone" at Monte San Giorgio (Hellmann & Lippolt 1981) are the best documented tie between Triassic biostratigraphical and chronometric time-scales. Based on our correlations these data can finally be pinpointed in a wider stratigraphic context. Forster & Warrington (1985; p. 106) call it "the most precise data available for any level within the Triassic" and according to a recent database (Harland et al. 1989) no significant additional data have been published recently for levels within this period. New age values are available for magmatic products close to the upper and lower boundary of the Triassic Period (Dunning & Hodych 1990; Claoué-Long et al. 1991).

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[22]) See Forster & Warrington (1985) and Harland et al. (1989) for recalculated values.

The numerical scale in Fig. 2c is largely tied to the radiometric ages of the above mentioned bentonites as well as to selected data from shallow intrusives and "Pietra verde" deposits in eastern Lombardy (see Brack & Rieber 1986). The radiometric ages of the Upper Ladinian Monzoni and Predazzo intrusives and their metamorphosed host rocks were not considered here for reasons given in Forster & Warrington (1985).

Despite the disagreement with most other current scales our time-scale is largely compatible with an inferred age of 223 Ma for the Middle/Late Carnian boundary. This age can be estimated from the time span represented by Upper Carnian to top Triassic orbitally induced cycles in lacustrine sediments of the Newark Group in NE-America (around 23 My; Olsen 1986, Olsen et al. 1989) and high-quality U/Pb data (201 $\pm$ 1 Ma; Dunning & Hodych 1990) of igneous rocks that are probably correlative with the Triassic/Jurassic boundary.

Based on the presently available age information we assume a duration of 7 My for the Ladinian Stage. However, this is in conflict with other estimates. The application of Milankovitch frequencies to the stacking patterns of the allocyclic platform carbonates at Latemar (Goldhammer et al. 1990) suggests a minimum duration of 11 My for the Ladinian platform portion alone (i.e. 20 ky times 550 cycles). According to our ammonoid based calibration this portion includes the uppermost part of the "Lower Cyclic Facies," the "Tepee Facies" and the "Upper Cyclic Facies". Biostratigraphically this corresponds to the Curionii and parts of the Gredleri Zones i.e. the lower two out of four Tethyan ammonoid zones of the Ladinian. Assuming all four ammonoid zones to be of similar duration this would indicate a time span longer than 20 My for the Ladinian Stage. In the Southern Alps it is difficult to estimate the relative length of the Early and Late Ladinian. However, more homogeneous sedimentary successions in other areas suggest that the duration of the younger two Ladinian ammonoid zones is in the same order of magnitude as the older ones.

Accepting a Ladinian Stage of 7 My, net average sediment accumulation rates for the (non decompacted) pelagic carbonate fraction of the "Knollenkalke" ("Buchenstein Beds") range between 4.5 and 10 m/My. This compares well with average sediment accumulation rates of ancient pelagic sediments (e.g. Scholle et al. 1983). The rates of correlative Hallstatt-type limestone intervals at Epidhavros (Greece; Krystyn 1983) are approximately one order of magnitude smaller (i.e. around 0.5 m/My). Lower values (1–2.2 m/My for the "Knollenkalke" and 0.11 m/My for the Hallstatt facies) are obtained if the 20 ky-cycle based time span is applied, however, these values appear to be unrealistically small. This is especially true for the "Buchenstein Beds" which were deposited in narrow inter-platform depressions in the northwestern Dolomites.

Provided the above mentioned duration for the Late Triassic (Olsen 1986, Olsen et al. 1989) is correct, the sum of the cycle-based time spans from the base of the Ladinian to the end of the Triassic would approach or even exceed time-spans that are generally assumed for the entire Triassic Period (40–50 My on current time-scales). Some of the estimates based on the application of astronomical frequencies to sedimentary cycles are therefore either too high or the duration of the Triassic is seriously underestimated. In the Southern Alps the problem cannot be solved by simply shifting well dated Upper Ladinian units into the Carnian as suggested by Goldhammer et al. (1990, Fig. 8). Although the allocyclic interpretation of the Latemar cycles is plausible we suspect that the smallest recorded cycle generation has not a 20 ky period but one of hitherto unrecognized shorter duration (around 5000–8000 y).

Additional high-quality age determinations are clearly required to resolve the discrepancies. Stratigraphically controlled rocks which are potentially suitable for radiometric age dating occur at various levels throughout the Anisian to Carnian stratigraphy of the Southern Alps! Our future efforts shall therefore address these problems.

7. Conclusions

South Alpine Anisian/Ladinian boundary sections in basinal and platform settings are correlatable in detail by means of macrofossils and characteristic volcaniclastic layers. The projections are the basis for the following conclusions of bio- and chronostratigraphical interest:

(1) Clear relative positions are ascertained for ammonoids and Daonellas in the Anisian/Ladinian boundary interval. Key ammonoids include species of *Judicarites, Paraceratites, Kellnerites, Hungarites, Reitziites, Parakellnerites, Aplococeras, Ticinites, Halilucites, Stoppaniceras, Nevadites, Chieseiceras, Eoprotrachyceras, Arpadites* and *Protrachyceras*. In the Southern Alps most of the recognized ammonoid levels are documented in the Bagolino section.

(2) The ammonoid succession between the Trinodosus and the Curionii Zones is split into two zones of presumably similar duration. The terms "Reitzi/Kellnerites Zone" and "Nevadites Zone" are suggested for the older and younger interval respectively.

(3) Within this zonal scheme the Anisian/Ladinian boundary can be suitably located at the boundary between the Nevadites and Curionii Zones. This is equivalent to the top of the "Chiesense groove" in the continuous pelagic successions of the Brescian Prealps and Giudicarie. This time marker can be pinpointed or approximated in a number of sections in the Southern Alps and further afield. Moreover it corresponds most closely to the widely accepted position of the stage boundary in North America.

(4) Radiometric age data of stratigraphically controlled Middle Triassic magmatic rocks in the Southern Alps suggest an age of some 232 Ma for the base of the Ladinian Stage. However, this age and the duration of 7 My for this stage (Curionii to Regoledanus Zone) is in conflict with other recent estimates.

(5) The time scale and resulting rates of sedimentation suggest that the smallest recorded cycle generation of the Latemar platform interior facies has a period that is significantly shorter than 20 ky. A corroboration of this conclusion has to await more high quality radiometric age data, however.

Clear geometrical relationships and the positions of equivalent macrofossils (ammonoids and Daonellas) in basinal sediments and adjacent carbonate platforms in the Dolomites constrain the timing and reconstruction of the platform to basin evolution:

(6) In the western Dolomites, a long lasting phase (Reitzi/Kellnerites- to Gredleri Zone) of platform up- and equivalent outbuilding (Latemar, Rosengarten) was followed by a short period of rapid lateral accretion (Rosengarten). The latter stage corresponds to only a small stratigraphic interval of the uppermost "Buchenstein Beds."

(7) At Latemar and Cernera, platform aggradation was fastest during parts of the Reizi/Kellnerites- and Nevadites Zones. However, the net carbonate accumulation

rates were not uniform. The higher rate of creation of accommodation space at Cernera resulted in a inbuilding geometry with little clinoform progradation prior to the drowning of the platform.

(8) The fossil finds support the correlation of the rapid inital aggradation at Latemar with the deposition of starved, organic rich mudstones at the base of the "Buchenstein Beds" (i.e. the "Lower Plattenkalke"). On a larger scale, however, the origin and significance of strata rich in organic matter is less clear. The stratigraphic range of an interval with discrete bituminous layers at Monte San Giorgio overlaps only marginally with the range of the "Lower Plattenkalke" in the Dolomites.

(9) The drowning of carbonate platforms in the eastern Dolomites and Carnia started somewhat earlier than the Anisian/Ladinian boundary. The demonstrably variable ages of pelagic sediments on top of different platform portions suggest an important role of tectonic subsidence in these phases of drowning.

8. Systematic descriptions

Classification: Except for the genus *Nevadites* the sequence of the ammonoid genera followed in the description is based on the classification by Tozer (1981a, b). However, it is supposed that a detailed study of the suture line may better elucidate the relationships between genera than does the present classification which is based mainly on the ornamentation and the cross section as taxonomic characteristics. Because of its relatively simple suture line the new genus *Latemarites* is affiliated to the Danubitidae.
Numeration and keeping: The ammonoid and bivalve material dealt with in this paper is kept in the collection of the **P**alaeontological **I**nstitute and **M**useum of the **U**niversity of **Z**urich (PIMUZ). The specimens are labelled with the prefix "PIMUZ" followed by a number (e.g. PIMUZ 7102). In the text and in tables but not in their legends the prefix is omitted.

Standard abbreviations used in tables are: D: diameter, H: whorl height, Hr: relative whorl height (in % of the diameter), MN: number of marginal nodes per half turn, LN: number of lateral nodes per half turn, P: primary ribs per half turn, U: umbilical width, UN: umbilical nodes per half turn, Ur: relative umbilical width (in % of the diameter), W: whorl width, Wr: relative whorl width (in % of the diameter).

8.1. Class **Cephalopoda**

Order **Ceratitida** Hyatt, 1884
Superfamily **Ceratitaceae** Mojsisovics, 1879

8.1.1. Family **Hungaritidae** Waagen, 1895

***Hungarites* Mojsisovics, 1879**

Remarks on *Hungarites* and *Parakellnerites* sensu lato:
In several levels of the "Buchenstein Beds" as well as in Latemar Limestone and in a condensed interval on the northern paleoslope of the Cenera platform ceratitids occur which are characterized by a distinct external keel (at least on inner whorls) and prominent and sometimes elongated marginal tubercles. The umbilical wall of these ceratitids

is steep, perpendicular or even overhanging. The umbilical rim is sharply rounded and shows vague and radially elongated umbilical tubercles. On the flanks weak, slightly sinuous ribs with or without small lateral tubercles appear occasionally. Such ceratitids are provisionally referred to in this paper as *Parakellnerites* sensu lato.

The authors are convinced, that *Parakellnerites* in this very broad sense is no monophyletic unit. Additional well preserved bedrock material with suture lines is needed to elucidate the relationships in this group. Thereafter it may be possible to define several genera or at least subgenera. For the time being it is necessary to distinguish these *Parakellnerites* from *Hungarites* (type species: *Hungarites zalaensis* resp. *mojsisovicsi*, see remarks on *Hungarites zalaensis*). The latter genus is characterized by a promiment keel and a more or less sharp, uninterrupted acute marginal edge at least on the inner whorls. Marginal tubercles are usually absent. If present, they are weak and obliquely elongated. Lateral tubercles do commonly not occur.

The morphological gap between several representatives of *Parakellnerites* sensu lato and *Hungarites* is very small. *Ceratites lenis* HAUER, 1896 is considered to be a *Hungarites* because of its uninterrupted marginal edges with very weak marginal tubercles. However, similar forms such as *Ceratites boeckhi* ROTH, 1871 are referred to *Parakellnerites*. The generic separation of these two species seems to be arbitrary, likewise is the allocation to two families (Hungaritidae and Ceratitidae).

The problem of the origin of different species of the genus *Hungarites* cannot be dealt with in this paper. However, it appears that *Hungarites* and, in addition, the family Hungaritidae are no phylogenetic units, but a rather heterogeneous group, in which several descendants of the Ceratitidae are united. This was also indicated by Tozer (1981 a, b), who affiliated to Hungaritidae several genera established by Parnes (1975) for Ceratitidae of Israel (*Paraceratitoides* and *Gevanites*) and *Iberites* HYATT, 1900 (= *Israelites* PARNES, 1962).

***Hungarites zalaensis* (BÖCKH, 1872)**
Pl. 1, Figs. 1–8; Figs. 15a, 15b.

Synonymy:

? 1871 *Ceratites Mojsisovicsi* Böckh M. S. – ROTH: A Felsö-Örs melletti Forráshegy lejtöjének geologiai atmetszete, p. 213 (without Fig.).
* 1872 *Ceratites Zalaensis* – BÖCKH: A Bakony déli részének földtani viszonyai, p. 140, 145–146, Pl. 7, Figs. 1–2.
1873 *Ceratites Zalaenis* – BÖCKH: Die geologischen Verhältnisse des südlichen Theiles des Bakony (German translation of Böckh 1872), p. 150 + 155, Pl. 7, Figs. 1–2.
1874 *Cer. Zalaensis* Böckh – BÖCKH: Die geologischen Verhältnisse des südlichen Theiles des Bakony, II. Theil, p. 176.
1879 Trachyceras Zalaense Böckh – MOJSISOVICS: Die Dolomit-Riffe von Südtirol und von Venetien, p. 53.
1882 *Hungarites Mojsisovicsi* (Boeckh) E. v. M. – MOJSISOVICS: Die Cephalopoden der mediterranen Triasprovinz, p. 222, Pl. 7, Fig. 6 and Pl. 8, Fig. 3.
1882 *Hungarites emiliae* E. v. Mojsisovics – MOJSISOVICS: ibid., p. 223, Pl. 8, Fig. 8.
1989 *Hungarites* cf. *mojsisovicsi* (Roth) – VÖRÖS & PALFY: The Anisian/Ladinian boundary in the Vászoly section (Balaton Highland, Hungary), p. 23, Pl. 1, Fig. 4.
1989 *Hungarites mojsisovicsi* (Roth) – VÖRÖS & PALFY: ibid., p. 23–25, Pl. 2, Fig. 2.

Remarks on the nomenclature and synonymy of *Hungarites zalaensis*:
Roth (1871) mentioned a new species *Ceratites mojsisovicsi*. No figure was given for this ammonoid and therefore the name is not valid. In 1872 Böckh, referring to the paper of

Roth illustrated the specimen but explicitly called it *Ceratites zalaensis*. In 1879 Mojsisovics first cited *Trachyceras zalaense* but introduced three years later (1882), without giving any explanation, the name *Hungarites Mojsisovicsi* (Boeckh).

Representatives of *Hungarites* occur frequently at the "Lastei di Valsorda" locality in the Latemar platform. Small specimens from this outcrop are identical with *Hungarites emiliae* Mojs. from blocks in the scree of Latemar Limestone near Forno (type locality). Larger specimens from the same layers at "Lastei di Valsorda" correspond to *Hungarites zalaensis* from the Balaton Highland. Therefore *Hungarites emiliae* Mojs. is considered as a younger synonym of *Hungarites zalaensis* (Böckh).

Description: On the inner whorls *Hungarites zalaensis* shows a narrow umbilicus with perpendicular umbilical wall. On the last whorl the umbilical width increases by an obvious egression of the umbilical spiral. The ornamentation of the flanks consists of more or less irregularly arranged swellings. In small individuals this form has rounded tubercles at the umbilical shoulder. On the outer third of the flank the swellings disappear. Up to a diameter of 9 to 10 cm the uninterrupted marginal edge and the ventral keel are well developed and separated by a concave zone of the inclined external surface. On the adult body chamber the marginal edge and the keel disappear, and at its end the external side is rounded. It is noteworthy that neither lateral nor marginal nodes appear in these hungaritids.

The representatives of *Hungarites zalaensis* of the lower part of the fossiliferous interval at "Lastei di Valsorda" differ somewhat from those of the middle portion (3 m higher up). The latter show only weak or no umbilical tubercles. Their cross section is narrower and the umbilical wall is not as high as in the former specimens. Although these differences seem to have no exceptions an additional species or subspecies is not established here.

A corroded fragment of *Hungarites* (7011) from the 58.4 m-level at Bagolino is referred to *Hungarites zalaensis* too. Interestingly this fragment reveals a suture line, a feature which is usually not visible in specimens from the Latemar Limestone.

Hungarites cf. *plicatus* (Hauer, 1896)

Pl. 2, Figs. 1–4, 8–9; Figs. 15c, 16a–16c.

Seven hungaritids from layer 4 of the section "Punta di Zonia," described by Cros & Houel (1983, p. 441, Fig. 7B) are dealt with open nomenclature and compared with *Hungarites plicatus* (Hauer, 1896).

The whorl section of these forms is high-triangular with an acute, uninterrupted marginal edge and a distinct keel on the roof-shaped ventral side. The umbilicus is

Table 1:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur
7017	48.9	26.2	53.6	c13.	26.6	7.	14.3
7012 (Pl.2,Fig.1)	42.6	23.	54.0	11.	25.8	6.5	15.3
7015 (Pl.2,Fig.4)	30.	14.8	49.3	7.8	26.0	6.6	22.0
C. (H) plicatus *	48.	26.4	55.	14.9	31.	5.3	11.
C. (H.) semiplicatus *			50.		29.		20.

* Measurements reported by HAUER (1896)

narrow and its wall perpendicular to slightly overhanging. Up to a diameter of about 5 cm rectiradiat rib-like swellings are developed. These start at the umbilical edge with more or less distinct, rounded umbilical tubercles and become successively weaker somewhat outside the middle of the flank. The umbilical tubercles of the inner whorls are visible on the umbilicus. The suture line (Figs. 16a–16c) is ceratitic to subammonitic and shows 5 lobes on the flank.

The form can be distinguished from *Hungarites plicatus* by its narrower whorl section and its somewhat wider umbilicus.

Occurence and age: Known from Punta di Zonia, north of Cernera, central Dolomites, associated with *Parakellnerites zoniaensis* n. sp. and *Aplococeras avisianus*. Reitzi-Kellnerites Zone.

Hungarites lenis (HAUER, 1896)

Pl. 2, Figs. 5–7.

Five specimens of *Hungarites lenis* were found in the "transitional beds" of Bagolino (54.25 m). The largest complete but slightly deformed specimen (7019) with a diameter of 10.63 cm corresponds well to the holotype, figured by Hauer (1896; Pl. &, Figs. 1, 2).

At the onset of the last whorl the distinct marginal edge is slightly undulated by very weak, obliquely elongated, short marginal swellings. The external side is roof-shaped with a distinct keel. The umbilical wall is slightly overhanging. The umbilical rim is smooth and shows rounded, irregularly arranged umbilical swellings which lead to indistinct ribs on the inner part of the flanks. At the last quarter of the body chamber the shell shows slightly sinuous lines on the flanks. The external side becomes roof-shaped with a low, rounded medium swelling, instead of the keel on inner whorls. The umbilical spiral has a distinct egression on the last whorl.

Table 2:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur
7019 (Pl.2, Fig.5)	106.3	47.9	45.1	26.5	24.9	22.	20.7
ibid.	76.2	37.1	48.7	c21.	27.5	13.3	17.5
7022	70.	36.3	51.9	19.2	27.4	9.5	13.57
7020 (Pl.2, Figs.6-7)	46.6	23.5	50.5	11.9	25.5	8.6	18.5

A second, not complete specimen (7022) with a restored diameter of about 7.0 cm has a narrow keel on the external side. The marginal edge is undulated by weak, densely arranged, oblique marginal swellings. The section of the whorls is wedge-shaped with a largest width close to the umbilical rim. The umbilicus is very narrow.

A third specimen (7020, pl. 2, Figs. 6–7; with a maximum diameter of 4.8 cm) shows at a diameter of 4.0 cm a fundamental change in the ornamentation. In the inner part the ornamentation consists of distinct marginal tubercles and slightly sinuous ribs on the flanks. At a diameter larger than 4 cm the ribbing becomes weak and indistinct and the marginal tubercles are transformed to low, densely arranged marginal swellings.

"*Hungarites*" cf. *lenis* (Hauer, 1896)
Pl. 5, Figs. 1–2.

One specimen (7048) from the same interval (Bagolino 53.8 m) as *Hungarites lenis* differs from this species by having small lateral nodes. These nodes are easily visible on the last but one quarter of the outer whorl. They are also present at a diameter of about 4 cm as can be seen on the left side of the shell. The ornamentation of the inner whorls up to a diameter of about 5.5 cm consists of sinuous ribs which start as rounded umbilical tubercles, bear weak lateral nodes slightly inside the middle of the flank and terminate with distinct, obliquely elongated marginal tubercles. The ventral side is roof-shaped.

Table 3:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur
7048 (Pl.5, Figs.1-2)	98.0	50.4	51.4	c24	24.5	17.4	17.7
ibid.	50.7	26.7	52.7	-	-	8.7	17.2

Due to the coarser ornamentation of the inner whorls this form shows great similarity with a small specimen of *Hungarites lenis*, figured in Hauer (1896, Pl. 6, Figs. 3–6).

Hungaritidae gen. et sp. indet.
Pl. 5, Fig. 6.

Two involute ammonoids preserved as siliceous pseudomorphs in the "transitional beds" of Pèrtica can, for the time being, not be attributed to a genus or a species.

Considering the cross section the larger specimen (7055, Pl. 5, Fig. 6) shows some similarity with *Hungarites lenis* (Hauer) and *Parakellnerites arthaberi* (Diener). However, the ventral side is rounded and has no median keel. A distinct marginal edge is also missing. The umbilical wall is steep, but not completely perpendicular, and the umbilical shoulder is sharply rounded with no tubercles. On the inner whorls (up to a diameter of about 3 cm) feeble, slightly sinuous ribs (primaries branching somewhat outside the middle of the flanks, and intercalatories) are developed. On the innermost part of the flank the ribs are very weak or absent. The outer whorls show no ornamentation. The suture line preserved on one septum shows the lateral lobe and three lobes of decreasing length on the flank. In the small individual (7056), the saddles are weakly denticulated and therefore the suture line seems to be ammonitic.

The open nomenclature applied to these ammonoids may change after a thorough study of the Hungaritidae and the Ceratitidae (see also the remarks on *Hungarites* and *Parakellnerites* sensu lato).

Table 4:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur	H/W
7055 (Pl.5, Fig.6)	35.3	19.6	55.4	11.5	32.5	4.8	13.59	1.70
7056	22.8	12.4	54.3	8.0	34.9	4.8	21	1.55
H. lenis (7020, Pl.2, Figs.6-7)	46.6	23.5	50.5	11.9	25.5	8.6	18.5	1.97
P. arthaberi (7024, Pl.2, Figs.10-11)	44.0	21.6	49.0	11.7	26.5	10.0	27.7	1.85

8.1.2. Family **Ceratitidae** Mojsisovics, 1879

***Parakellnerites* Rieber, 1973**

***Parakellnerites arthaberi* (Diener, 1899)**

Pl. 2. Figs. 10–11, Pl. 12, Figs. 7; Fig. 16f.

Two relatively complete specimens and a fragment from the Bagolino section show great similarities with *Hungarites arthaberi* Diener with respect to their ornamentation, the whorl section, and the suture line. Because the type specimen of this species is not available these ammonoids are provisionally referred to as *Parakellnerites arthaberi*. The specimen 7025 (Pl. 12, Fig. 7) with a largest diameter of 7.58 cm consists of the phragmocone with a part (arc of 90°) of the body chamber. The ventral side is roof-shaped and separated from the flanks by an acute ventral shoulder. The latter is accentuated by spirally elongated marginal tubercles. On the flanks weak, slightly prosiradiate ribs are developed. These start at the umbilical rim with small swellings, bear the marginal tubercles and cross as very feeble, obliquely arranged ribs the external surface before reaching the keel. The suture line of this specimen (Fig. 16f) is consistent with the line figured by Diener (1899, Pl. 1, Fig. 3).

The second specimen (7024, Pl. 2, Figs. 10–11) with a diameter of 7.25 cm has a weaker ornamentation. The ribbing is slightly sinuous and considering its arrangement it corresponds well to that of the holotype. As a result of a slightly concave external surface the keel and the ventral shoulder are more distinct on the inner whorls.

Table 5:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur
7024 (Pl.2, Figs.10-11)	72.5	36.7	50.6	20.8	28.7	13.1	18.1
ibid.	44.0	21.6	49.0	11.7	26.5	10.0	27.7
7025 (Pl.12, Fig.7)	44.8	24.7	51.0	11.0	23.0	8.5	17.7

The fragment 7026 (Pl. 12, Fig. 10) shows low and broad ribs with very weak swellings on the internal mould of the body chamber. These swellings were also mentioned by Diener (1899, p. 9).

Parakellnerites arthaberi (Diener) occurs in the "Transitional beds" at Bagolino around the 57.8 m-level. Its age is Reitzi/Kellnerites Zone.

***Parakellnerites zoniaensis* n. sp.**

Pl. 3, Figs. 1–10; Figs. 15d–15g, 16d.

Synonymy:

?1982 Ceratites hungaricus Mojsisovics – Blendinger, Parow & Keppler, p. 223.
? 1983 Ceratites hungaricus (Mojs.) – Cros & Houel, p. 435.

Holotype: Specimen 7033, figured in Pl. 3, Fig. 10. It is a well preserved, nearly complete individual. On the right side the shell is partly removed and the internal mould with the suture line is visible.
Name: Referring to the Punta di Zonia type locality.

Locus typicus: Small hill on the southern slope of Punta di Zonia north of Cernera, central Dolomites, Prov. Belluno/Italy.
Stratum typicum: Layer 4 of the section described by CROS & HOUEL (1983, p. 441, Fig. 7 b) as "coquina – phosphatized biosparite with ammonites of the avisianus zone." The writers assign this level to the Reitzi/Kellnerites Zone.
Material: Seven nearly complete specimens and six fragments from the locus typicus.
Diagnosis: Involute representative of *Parakellnerites* with perpendicular to slightly overhanging umbilical wall. Whorl section rounded subtrapezoidal to rounded subrectangular. Ventral shoulder and umbilical edge are distinct.
Description: The ornamentation varies during ontogeny and from specimen to specimen. In adult individuals (diameter with mature body chamber 7.5 to 8.5 cm) it consists of faint ribs which start at the umbilical edge with somewhat bullate umbilical nodes. The ribbing fades towards the outer part of the flank. Somewhat inside the middle of the flanks weak to strong lateral nodes are developed. The ventral shoulder carries regularly arranged and acute marginal nodes. These latter send short and faint ribs towards the inclined external side. The obliquely foreward directed ribs accentuate the ventral shoulder. They vanish before reaching the ventral keel. In small individuals (7028, 7032; Pl. 3, Figs. 3 and 8) the ribs especially on the inner flank portions and the bullate umbilical nodes are elevated. The suture line (Fig. 16 d) is typically ceratitic with three large denticulated lobes on the flank.

Table 6:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur
7033 holotype (Pl.3, Fig.10)	7.24	3.16	43.6	2.11	29.1	1.55	21.4
ibid.	5.82	2.68	46.0	1.5	25.7	1.11	19.0
7027 (Pl.3, Figs.1-2)	7.59	3.7	48.7	2.14	28.2	1.5	19.8
ibid.	5.48	2.71	49.5	1.5	27.4	1.0	18.2
7031 (Pl.3, Figs.6-7)	6.12	2.8	45.75	1.6	26.1	1.36	22.2
ibid.	4.46	2.08	46.6	1.31	29.4	0.96	21.5

Discussion: *Parakellnerites hungaricus* (MOJS.) is similar to *Parakellnerites zoniaensis* but has no steep umbilical wall and its umbilicus is wider. On the basis of these characteristics the new species can be distinguished from the representatives of *Parakellnerites* from the "Grenzbitumenzone" at M. S. Giorgio (Rieber 1973 a). *Parakellnerites rothpletzi* shows a similar development of the umbilicus. It differs from *P. zoniaensis* by its more regular ribbing on the outer portion of the flank. The usually more numerous marginal nodes are arranged in a different way and the keel on the roof-shaped ventral side is less elevated than in *P. zoniaensis*.
Occurence and age: Known only from the type locality; Reitzi/Kellnerites Zone.

***Parakellnerites rothpletzi* (SALOMON, 1895)**
Pl. 4, Figs. 1–17; Fig. 15 h.

In the upper part of the fossiliferous interval at the "Lastei di Valsorda" locality (Latemar) ceratitids here referred to *Parakellnerites rothpletzi* (SALOMON) are abundant. The ornamentation of this species varies in wide ranges. The specimens are characterized by a moderately narrow umbilicus with a wall perpendicular on the inner whorls to slightly overhanging on the outer ones. Marginal tubercles are obliquely elongated and form an undulated marginal edge. A sharply rounded keel sits on the roof-shaped ventral side and ribs of various elevations run across the outer half of the flank. Many specimens have lateral nodes. These fade on the outer whorls as do the marginal tubercles and the ventral keel. Von Bubnoff (1921) assigned the species *rothpletzi* to *Hungarites waageni* (MOJS., 1882).

He also noticed differences between the type of *Hungarites waageni* from the Marmolada, and his forms from the Latemar Limestone blocks near Forno. For this reason the latter were figured under the name "*Hungarites waageni* var. form *Rothpletzi* Salomon" (v. BUBNOFF 1921, p. 456, Pl. 12). There is no doubt, that the species *P. rothpletzi* (SALOMON) has to be separated from *Hungarites waageni*, which shows an undulated external keel – a feature already described by Mojsisovics (1882, p. 82). Moreover *Hungarites waageni* appears to be younger than *P. rothpletzi.*

***Parakellnerites* aff. *rothpletzi* (SALOMON, 1895)**
Pl. 4, Fig. 18.

A ammonoid specimen (7046, Pl. 4, Fig. 18) from the "Lower Plattenkalke", 2,2 m below the base of the "Knollenkalke" at Seceda can be compared with *Parakellnerites rothpletzi.* The specimen shows large, rounded umbilical tubercles (5 per half turn) sticking out towards the umbilicus. The ribs start with the umbilical tubercles and are relatively strong. They bear weak lateral nodes at one third of the whorl height. All ribs, primaries and secondaries, terminate at the ventrolateral shoulder with obliquely elongated, densely arranged marginal tubercles of equal size. The ventral side is low roof-shaped with a narrow medikan keel. The umbilical wall seems to be perpendicular or even overhanging.

Because of its strong umbilical and marginal tubercles this form can be distinguished easily from *Parakellnerites rothpletzi* itself. A small *Aplococeras* sp. is preserved on the same specimen.

***Parakellnerites* ? *waageni* (MOJS., 1882)**
Pl. 4, Fig. 19.

Two specimens from the Marmolada north slope and now in the collection of the Museum of Predazzo, distinctly reveal the features of *Parakellnerites* ? *waageni* (Mojs.). The larger one, a cast of a mould, shows perfectly the undulated keel (pl. 4, Fig. 19). This feature led Mojsisovics to affiliate the species waageni to *Balatonites.* It is rather strange why v. Bubnoff (1921) assigned the species *rothpletzi* (SALOMON) with its uninterrupted median keel to the species *waageni* (MOJS.).

***Lardaroceras* BALINI, 1992**

Several fragments of large and some small ammonoids from the "transitional beds" at Pèrtica are attributed to the genus *Lardaroceras* BALINI. Most of these ammonoids are preserved as siliceous pseudomorphs and could therefore be partly isolated from the hard grey siliceous limestone using diluted hydrochlorid acid.

The main features of these ammonoids are in agreement with those of *Lardaroceras krystyni* and *L. pseudohungaricum* described by Balini (1992a). However, there are also some pronounced differences. In the forms from Pèrtica the umbilicus is considerably wider. The ornamentation is weaker and fades earlier than in Balini's species from the Prezzo Limestone.

For the time being we treat these forms with open nomenclature. Additional material and studies are needed to describe in detail the forms from Pèrtica and to judge if there is just one species with a great intraspecific variability or several species with correspondingly smaller variabilities.

***Lardaroceras* aff. *pseudohungaricum* Balini, 1992**
Pl. 5, Figs. 3, 11–12, 15.

Diagnosis: *Lardaroceras* with wide umbilicus and three rows of nodes. Ribs are weak or completely absent.
Description and discussion: The lateral nodes located somewhat outside the inner third of the whorl height can be distinct and pointed as in 7049 (Pl. 5, Figs. 11–12) or weak and low as in 7050 (Pl. 5, Fig. 3). As regards the whorl section and the number of rows of nodes these forms are similar to *L. pseudohungaricum*. However, they show nor ribs on the flanks, and their umbilicus is wider than in the latter species.
Occurrence and age: Known only from the "transitional beds" at Pèrtica; Reitzi/Kellnerites Zone.

***Lardaroceras* aff. *krystyni* Balini, 1992**
Pl. 5, Figs. 16–17.

Diagnosis: *Lardaroceras* with wide umbilicus, two rows of nodes (umbilical and marginal) and with low broad, slightly sinuous ribs.
Description and discussion: The single specimen differs from *L.* aff. *pseudohungaricum* by the absence of lateral nodes and the occurrence of ribs. Its umbilicus is relatively wide especially on the inner turns. The form is compared with *L. krystyni* because it has no lateral nodes. However, the ribbing differs considerably. The suture line which is preserved on one septum – perhaps the last one – shows three lobes on the flanks and is probably ammonitic. The saddles are apparently denticulated. However, because of the coarse grained silification of the septum it is difficult to distinguish between denticulation and a structure produced by diagenesis. Concerning the number of elements the suture line is in good agreement with that of *L. krystyni.*
Occurrence and age: As for *Lardaroceras* aff. *pseudohungaricum.*

***Lardaroceras* sp.**
Pl. 5, Figs. 4–5.

Two small specimens with features typical for the genus *Lardaroceras* cannot be attributed to or compared with a species. They show umbilical and marginal nodes, and weak, broad ribs.
Occurrence and age: The same as for *Lardaroceras* aff. *pseudohungaricum.*

Table 7:
Dimensions (in mm and %) of several illustrated representatives of *Lardaroceras*:

Specimen	D	H	Hr	W	Wr	U	Ur	H/W
7049 (Pl.5, Figs.11-12)	-	22.3	-	14.1	-	-	-	1.38
ibid.	16.0	6.8	42.3	5.1	31.7	5.1	31.6	1.33
7052 (Pl.5, Figs.16-17)	32.2	13.3	41.3	10.1	31.4	9.9	30.9	1.31
ibid.	22.1	8.7	39.4	-	-	7.8	35.4	-
7054 (Pl.5, Fig. 4)	20.6	8.6	41.7	6.1	29.4	6.1	29.6	1.42

Stoppaniceras **RIEBER, 1973**

Stoppaniceras evolutum **n. sp.**
Pl. 9, Figs. 6, 7, 10; Fig. 151.

Name: Referring to the evolute shell of this species of *Stoppaniceras*.
Holotype: Specimen 7095, figured in Pl. 9, Fig. 10.
Stratum typicum and locus typicus: "Buchenstein Beds", lowermost layer of the "Knollenkalke" on the western slope at Seceda east of Ortisei (St. Ulrich, Val Gardena, Italy).
Material: Four specimens of which two are very fragmentary.
Diagnosis: Small, evolute *Stoppaniceras* with low subrectangular whorl section and a low, distinct median keel on the flat ventral side. The suture line shows on the flank two ceratitic lobes with denticulated bases.
Description: The ornamentation consists of primaries and intercalatories. Both type of ribs are slightly prosiradiate, especially on the outer part of the flank. The primaries start with small, rounded umbilical tubercles. A distinct umbilical wall is not developed. All ribs end at the ventrolateral shoulder with distinct nodes some of which are obliquely elongated. These marginal nodes tower slightly over the flat and smooth ventral side. The median keel is narrow and truncated.

Table 8:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur	P	MN
7095, holotype (Pl.9, Fig.10)	38.3	12.1	31.6	-	-	17.4	45.4		
ibid.	33.9	10.7	31.7	c8.5	25.2	16.9	47.3	12	c20
7096, paratype (Pl.9, Figs.6-7)	29.4	9.0	29.4	c8.3	36.6	14.2	48.3	10	15

Comparison and discussion: *Stoppaniceras evolutum* n. sp. differs from *S. variabilis* by its wider umbilicus, its flat ventral side and the absence of lateral nodes and an umbilical wall.

The assignation of the genus *Stoppaniceras* to the Ceratitidae is not yet firmly established. It should be noticed that the suture line of *Stoppaniceras* shows only few elements.

Occurrence and age: *Stoppaniceras evolutum* n. sp. is known from the lower "Buchenstein Beds" at Seceda; oldest Nevadites Zone.

Kellnerites **ARTHABER, 1912**

Specimens of the genus *Kellnerites* ARTHABER 1912 were found in the "transitional beds" at Bagolino and Pèrtica. At Bagolino they are commonly preserved as internal moulds of the body chamber and as parts of the phragmocone. Removing these mechanically from the siliceous limestone beds is usually difficult or impossible. At Pèrtica the shells are partly silicified and could therefore be isolated using diluted hydrochlorid acid.

Most of the specimens are attributed to *Kellnerites bosnensis* and *K. halilucensis* and to forms, which Hauer (1896) called *K. fissicostatus, K. angustecarinatus* and *K. ecarinatus*. However the three latter species may be varieties of *K. halilucensis* or *K. bosnensis*, as Hauer (1896, p. 255) already mentioned.

In all specimens from Bagolino the whorl width seems to be smaller than in the type specimens from Han Bulog and Haliluci in Bosnia. The ornamentation varies in wide ranges and its development depends obviously on the ontogenetic stage. The median keel also changes its shape. It may be narrow or low and broad or missing (especially in smaller individuals). Because we dispose of no sufficiently well preserved material, we refrain from giving a thorough study of the genus *Kellnerites*. Nevertheless a new species is established here for an unknown form.

***Kellnerites bagolinensis* n. sp.**
Pl. 6, Figs. 1–3, 9; Figs. 15o, 16e.

Holotype: Specimen 7061, figured in Pl. 6, Figs. 1–2. It is an internal mould with body chamber (a half turn). The well preserved right flank and external side are exposed, whereas the left side is crushed and covered with rock.
Name: Referring to the type locality Bagolino, Prov. Brescia, Italy.
Locus typicus: Small outcrop of "transitional beds" along a forest road on the southern slope (about 1250 m a.s.l.) of M. Pizza 1 km southwest from Bagolino/Romanterra.
Stratum typicum: Middle part of "transitional beds" (55.5 m).
Material: Two nearly complete specimens, two well preserved larger and several small and compressed fragments.
Diagnosis: Involute *Kellnerites* with 4 rows of nodes (umbilical, inner and outer lateral as well as marginal nodes), situated on weak, low and partly broadened ribs. The whorl section is rounded subrectangular with a steep, nearly perpendicular umbilical wall. The low, roof-shaped ventral side bears a narrow, distinct median keel. The suture line is ceratitic with three denticulated lobes on the flank.
Description: The number and strength of the nodes and ribs vary in wide ranges. The holotype is the most coarsely ornamented specimen of the type series. The primaries start at the sharply rounded umbilical shoulder with nodes, which are somewhat elongated radially. In the holotype some of inner umbilical nodes are paired. The position of the two rows of lateral nodes varies from one specimen to another. The spiral of the inner lateral nodes is situated in the holotype close to the middle, in specimen 7063 (Pl. 6,

Table 9:
Dimensions (in mm and %):

Specimen	D	H	Hr	W	Wr	U	Ur	UN	LN1	LN2	MN
7061, holotype (Pl.6,Fig.1)	72.	31.6	43.9	c20.6	28.6	19.4	26.9	10	12	13	19
ibid.	68.2	30.4	44.6	c17.6	25.8	18.5	27.1	8	11	13	20
ibid.	49.5	21.1	42.6	c14.6	29.4	14.	28.2	9	-	-	18
7064	-	-	-	-	-	-	-	-	-	-	c32
H. liepoldti, holotype	63.	31.	49.2	17.	27.0	12.	19.0	6	6	7	c24

Fig. 9) however in the inner third of the flank. In specimen 7064 (not figured) even the spiral of the outer lateral nodes is situated in the inner half of the whorl height. The low ribs are rather broad, straight and rectiradiate in the holotype and thin, slightly sinuous and prosiradiate in specimen 7063 (Pl. 6, Fig. 9). Beside the primaries there are intercalatories of different length. All ribs bear more or less obliquely elongated marginal nodes.
Discussion: Especially the more densely ornamented specimens of the new species are similar to *Hyparpadites liepoldti* (Mojs., 1882) from Balaton area, Hungary. The narrow median groove indicated by Mojsisovics (1882, p. 53) for the type of *Hyparpadites liepoldti* is caused by preservation. In reality this species owns a median keel (pers. comm. by A. Vörös). The suture lines of *H. liepoldti* and of the new species from Bagolino are identical. *Kellnerites bagolinensis* shows a larger umbilicus than *H. liepoldti*.
The authors are convinced, that both species are closely related. Moreover there is no doubt that *K. bagolinensis* has to be assigned to the genus *Kellnerites*. Therefore the genus *Hyparpadites* Spath, 1951 appears to be unnecessary. If the genus *Hyparpadites* should not be abandoned, it would have to be integrated into the Ceratitidae.
Occurrence: Known only from the "transitional beds" at Bagolino. Closely related forms such as *Hyparpadites liepoldti* are known from the Balaton area, Hungary (Vörös et al., 1991, p. 44).
Age: Reitzi/Kellnerites Zone.

***Reitziites* n. gen.**

Type species: *Reitziites reitzi* (Böckh, 1972)
Diagnosis: Ceratitids with narrow and flattened venter, which is lined by obliquely elongated ventral tubercles. The rows on both sides of the latter are in nearly opposite to alternating positions. The inner whorls show distinct, slightly sinuous ribbing. On the outer whorls the ribbing becomes less sinuous. Marginal and, close to the umbilical edge, weak lateral tubercles appear. Between the marginal and ventral tubercles only low swellings are developed. The ribbing on the flanks shows some fibulations. On the inner whorls two ribs merge in a ventral node and on the outer whorls in a marginal node occasionally.

The suture line of *Reitziites* is ceratitic and shows two lobes on the flanks and a small third one on the umbilical edge.
Remarks and Discussion: The species *reitzi*, established by Böckh 1872, was first referred to the genus *Ceratites*, and later by Mojsisovics (1882) to *Trachyceras*. Frech (1903) and other authors called it *Trachyceras* (*Protrachyceras*) or *Protrachyceras*. Wang (1983) attributed it to *Xenoprotrachyceras* (genus introduced by him), and Brack & Rieber (1986) used *Nevadites* instead. During a reinvestigation of the specimens of the type series at the Hungarian Geological Institute and the study of new material from Bagolino we noted that especially the inner whorls of *reitzi* show no elements which are typical for the above mentioned genera. Therefore a new genus is established here.

The outer whorls of the most coarsely ornamented specimens from the Brescian Prealps resemble some representatives of *Nevadites*. It is therefore probable that the genus *Nevadites* has its origin in *Reitziites*. *Reitziites* in turn is very likely a descendant of *Kellnerites*.

Composition of the genus: *Reitziites reitzi* (Böckh), respectively *Ceratites reitzi* Böckh, *Trachyceras (Protrachyceras) cholnokyi* Frech, 1903, and *Ceratites perauritus* Diener, 1900.
Occurrence and age: Balaton Highland (Hungary) and Brescian Prealps (Bagolino, Pèrtica, Brozzo, Italy); upper part of the Reitzi-Kellnerites zone.

Reitziites reitzi **(Böckh, 1872)**
Pl. 7, Figs. 1, 4–7, Pl. 8, Figs. 1–14, Pl. 11, Figs. 1–3; Figs. 15r, 15s, 17e, 17f.

Synonymy:

* 1872 *Ceratites Reitzi* n. sp. – Böckh, A Bakony déli részének földtani viszonyai: p. 147–148, Pl. 7, Fig. 3a, Pl. 8, Figs. 3b, 4, 5.
1873 *Ceratites Reitzi* n. sp. – Böckh, Die geologischen Verhältnisse des südlichen Theiles des Bakony. (German translation of Böckh 1872): p. 157.
1875 *Ceratites Reitzi* Böckh – Stürzenbaum, Adatok a Bakony Ceratites Reitzi – sziul fannájanak ismeretéhez: p. 256, Pl. 5, Figs. 2a + b.
1882 *Trachyceras Reitzi* (Boeckh) – Mojsisovics, Die Cephalopoden der mediterranen Triasprovinz: p. 113, Pl. 7, Figs. 2–5.
1900 *Ceratites perauritus* nov. sp. – Diener, Neue Beobachtungen über Muschelkalk-Cephalopoden des südlichen Bakony: p. 26, Pl. 2, Fig. 1.
1903 *Trachyceras Cholnokyi* n. sp. (*Protrachyceras*) – Frech, Neue Cephalopoden aus den Buchensteiner...: p. 8–9, Pl. 2, Figs. 5a, b.
non 1986 Group of *Nevadites reitzi* (Böckh 1872) – Brack & Rieber, Stratigraphy and Ammonoids of the lower "Buchenstein Beds" of the Brescian Prealps and Giudicarie and their significance for the Anisian/Ladinian boundary: p. 200–201, Pl. 2, Fig. 2, Pl. 4, Fig. 4.
1989 *Xenoprotrachyceras cholnokyi* (Frech) – Vörös & Palfy, The Anisian/Ladinian Boundary: Pl. 3, Figs. 3a, b, 4a, b.
1989 *Xenoprotrachyceras reitzi* (Böckh) – ibid.: Pl. 3, Figs. 5a–c.
non 1900 "*Protrachyceras*" *reitzi* (Böckh) – Kovacs et al., Conodont Biostratigraphy of Anisian/Ladinian Boundary...: Pl. 3, Fig. 4.

Lectotype: Specimen figured by Böckh (1972), Pl. 7, Fig. 3a and Pl. 8, Fig. 3b, refigured by Mojsisovics 1882, Pl. 7, Figs. 2a, b. The type is kept in the Hungarian Geological Institute at Budapest.
Locus typicus and stratum typicum: According to Mojsisovics 1882 (p. 114 and Pl. 7): yellowish, cherty limestone at Felsö-Örs in the "Bakonyerwalde," Reitzi Zone.
Material: A total of 40 specimens (including 15 fragments) is available. 31 are from Bagolino, six from Avenone/Pèrtica and three from Brozzo.
Diagnosis: The same as for the genus *Reitziites*.
Description: The largest specimen (Pl. 7, Fig. 5) reaches at the end of the body chamber a diameter of 13.5 cm. The most typical feature of *Reitziites reitzi* is the alternation of the ornamentation during growth. Specimens with a diameter larger than 4 cm show usually ventral tubercles and more or less prominent marginal and umbilical tubercles which latter on the inner part of the flank are radially elongated. In specimens with a diameter less than 4 cm the marginal and lateral nodes are missing. Therefore the flanks bear ribs only. The ribs consist of primaries starting at the rounded umbilical rim in the vicinity of which most of them bifurcate.

The secondary, the few undivided primary and some intercalated ribs are slightly falcoid. They are all rectiradiate or weakly rursiradiate in the middle part of the flank. At the marginal region the ribs turn forward and terminate at or close to the elongated ventral tubercles. Frequently two ribs join with each other before they end marginally. This fibultion is a very typical feature for *Reitziites reitzi*. The density of ribbing varies in wide ranges. The venter of smaller growth stages is a narrow flattened ribbon lined by ventral tubercles, which tower only slightly. On specimens with a diameter smaller than 2.5 cm the venter is rounded and the weak, obliquely arranged ventral tubercles reach its midline.

On specimens with diameters exceeding 4 cm marginal tubercles appear and become increasingly prominent as do the ventral tubercles. The space between these two rows of tubercles looses its ornamentation progressively. The ventral tubercles of both sides show alternating to almost opposite positions. However, in no specimens opposite positions were observed over more than a quarter of a whorl. It seems that the ventral tubercles especially of large specimens are hollow. The tubercles are long, pointed spines on the outer side of the shell but shorter and rounded on the internal mould. The marginal nodes may have been hollow too in mature stages.

The umbilical wall is rounded and steep to perpendicular. The sutur is ceratitic and shows two lobes on the flank. A small third one is located at the rounded umbilical rim.

The inner whorls of *Reitziites reitzi* have the same ornamentation and whorl section as *Ceratites perauritus* DIENER and *Trachyceras cholnokyi* FRECH. This is observed also on a cast of the inner whorls of the lectotype. Therefore *Ceratites perauritus* and *Trachyceras cholnokyi* are considered to be synonyms of *Reitziites reitzi*.

Comparison: The ornamentation of the outer whorls of *Reitziites reitzi* is somewhat similar to some representatives of *Nevadites*. However, the whorl sections differ distinctly, being much broader in *Nevadites*. The inner whorls of *R. reitzi* and of *Nevadites* look quite differently. In contrast to *Nevadites, R. reitzi* has normal ribbing without tubercles on the flanks.

Superfamily **Danubitaceae** SPATH, 1951

8.1.3. Family **Danubitidae** SPATH 1951

***Ticinites* RIEBER, 1973**

***Ticinites brescianus* n. sp.**

Pl. 9, Figs. 1–3, 11; Fig. 15m.

Synonymy:

v 1986 "Ceratites" hantkeni MOJS. 1882 – BRACK & RIEBER: Stratigraphy and Ammonoids., p. 203, Pl. 5, Fig. 1.

Name: Referring to the Brescian Prealps, the origin of the type series.

Holotype: Specimen L/1637 described and figured in Brack & Rieber (1986) as "Ceratites" hantkeni. It is the left side of an internal mould with a portion of the body chamber. The suture line is partly visible.

Stratum typicum and locus typicus: Lower "Buchenstein Beds," fossil horizon I at Marcheno in Val Trompia/Prov. Brescia (see Brack & Rieber, 1986, p. 191 and Fig. 10, p. 205).

Material: 14 specimens from the lower "Buchenstein Beds" at Marcheno, Biogno, Bagolino and Prezzo. In most cases only the internal moulds of the body chamber are preserved.
Diagnosis: Evolute *Ticinites* with subquadrate whorl section, a flat venter with a very faint keel, distinct marginal nodes and small lateral nodes in the inner third of the flank.
Description: The whorl section is typically subquadrate (Fig. 15m) with a short steep, but not perpendicular umbilical wall. The venter is nearly flat. Up to a diameter of about 5 cm a very low, faint ventral keel is developed. The ornamentation consists of simple ribs, supplemented by few intercalatories. All ribs bear at the ventral shoulder distinct marginal tubercles. From the latter the ribs draw adorally continue for a short distance and finally disappear. These short, obliquely arranged parts of the ribs accentuate the ventral shoulder which appears to be acute. All ribs which start at the umbilical shoulder bear small, but pointed lateral nodes close to the end of the inner quarter of the flank. The spacing of ribs varies considerably in the available specimens.

The suture line is typically ceratitic with few elements. The denticulation of the lateral lobe is restricted to its basis. The second lobe on the flank shows only two short denticles.
Comparison: *Ticinites polymorphus* and *T. ticinensis* from the "Grenzbitumenzone" at M. S. Giorgio show a smaller width of the umbilicus and a different ribbing. In *Ticinites dolomiticus* the ribs are spaced less densely. Brack & Rieber (1986) provisionally assigned the forms named here *Ticinites brescianus* to "*Ceratites*" *hantkeni* Mojs. In the present view of the authors the species *Ceratites hantkeni* does probably not belong to the genus *Ticinites*. According to the figures in Mojsisovics (1882, Pl. 30, Figs. 16a–c) the umbilical width of *C. hantkeni* is smaller and the whorl considerably narrower than in *T. brescianus*. Unfortunately the type specimen could not be found in the collections of the Geological Institute at Budapest.
Occurrence: *T. brescianus* is known from the lower "Buchenstein Beds" of the Brescian Prealps.
Age: Lowermost Nevadites Zone.

***Ticinites dolomiticus* n. sp.**
Pl. 9, Figs. 4, 8, 9; Figs. 15n, 17a.

Name: Referring to the Dolomites, where the holotype was found.
Holotype: Specimen 7092, figured in Pl. 9, Fig. 4. It is the right-hand side of an internal mould of the phragmocone and about 100° of the body chamber. The left side is not preserved.
Stratum typicum and locus typicus: "Buchenstein Beds", lowermost layer of the "Knollenkalke" on the western slope at Seceda east of Ortisei (St. Ulrich, Val Gardena, Italy).
Material: Two specimens, 7092 (holotype) and 7093 (paratype).
Diagnosis: Evolute representative of *Ticinites* with distantly arranged ribs and a rounded subquadrate whorl section.
Description: Because of the incomplete preservation (with the exception of a small part of the phragmocone more than the left half of the shell is missing) the whorl section of the holotype cannot be figured. A reconstructed cross section of the somewhat twisted paratype is illustrated in Fig. 15n. The whorl width is largest in the inner third of the flank. The transition from the short umbilical wall to the flank is rounded and the ventral

Table 10:
Dimensions (in mm and %) of the studied *Ticinites* and of the type of *Ceratites hantkeni* (MOJSISOVICS, 1882):

Specimen	D	H	Hr	W	Wr	U	Ur	MN	LN
Ticinites brescianus n. sp.,									
holotype, L/1637	66.0	20.7	31.3	-	-	34.4	52.1	c19	c15
ibid.	36.4	9.5	26.1	-	-	20.0	54.9	c16	c14
L/1641 (Pl.9, Fig.1)	66.2	22.0	33.2	c23.5	35.4	30.2	45.6	16.5	
	10.5								
7090 (Pl. 9, Fig.3)	59.2	17.8	30.0	-	-	29.0	48.9	15	12.5
Type of "C." hantkeni*	31	10	32.2	35.5	11	14.0	45.2	14	11
Ticinites dolomiticus n. sp.,									
holotype, 7092 (Pl.9, Fig.4)	76.7	24.7	32	-	-	35.0	45.6	16	10
ibid.	60.0	18.9	31.6	-	-	28.8	47.9	17	-
7093 (Pl.9, Figs.8-9)	40.9	13.3	32.6	16.0	39.2	19.3	47.3	15	-
ibid. including ribs	*	*	*	17.4	42.6	*	*	*	*

* Measurements after MOJSISOVICS (1882).

side is flat and has no keel. In the holotype a low keel may have existed. The ornamentation consists of primaries and of few intercalatories. The primaries start close to the umbilical seam and obtain their largest elevation as more or less bullate tubercles somewhat outside the rounded umbilical shoulder. All ribs end with distinct marginal nodes at the ventrolateral shoulder. The suture line with few elements is typically ceratitic (Fig. 17a).
Comparison: see *Ticinites brescianus.*
Occurrence and age: *Ticinites dolomiticus* is known only from the lowermost "Buchenstein Beds" at Seceda. Its age is oldest Nevadites Zone.
Dimensions: see *Ticinites brescianus.*

***Ticinites* sp.**
Pl. 9, Fig. 5.

A fragment of a small and moderately evolute ammonoid (7049) is assigned with open nomenclature to *Ticinites*. The whorl is broad-ovate (H/W 0.68 to 0.79 without and with ribs respectively) with a nearly flat ventral side. Strong ribs (single and few branched) start close to the umbilical seam. On the ventral side they terminate abruptly and form small tubercles. In the middle third of the ventral side a broad, smooth zone is developed.

The fragment was found 80 cm above the lower boundary of the "Knollenkalke" on the western slope at Seceda. Its age is Nevadites Zone.

***Latemarites* n. gen.**

Type species: *Latemarites latemarensis* n. sp.
Name: From the Latemar carbonate platform (western Dolomites, Italy), where the new type species was found.
Diagnosis: Evolute ceratitids of medium size with rounded rectangular to subtrapezoidal whorl section and three rows of nodes in a mature stage. The umbilical wall is short and rather steep at the umbilical seam. The umbilical shoulder is rounded. The greatest whorl width is reached close to the end of the inner third of the whorl height. From there towards the "sharply rounded" ventral shoulder the flanks gently converge. The non-car-

inate venter is low-arched to even. The ornamentation changes during ontogeny. In juvenile stages (up to a diameter of about 2.5 cm) it consists of densely to loosely spaced simple, straight or slightly convex ribs which rise near the umbilical seam. They are well elevated in the inner third of the flank and weaken in the middle or outer third. Most of them do not reach the marginal nodes and an almost smooth stripe links the outer termination o the ribs to the marginal nodes. The number of ribs exceeds that of the marginal nodes. Obliquely arranged marginal nodes become distinct at a diameter of 1.5 to 2 cm and tower slightly over the middle of the venter. The rows on both sides are in opposite positions. In subadult to adult stages distinct umbilical and lateral nodes evolve on the ribs. The umbilical nodes are situated at the transition from the umbilical wall to the flank and mark the broadest part of the whorl section. The lateral nodes lie close to the onset of the outer third of the whorl height. There the ribs weaken slightly.

Sature line: In ammonoids from Latemar complete suture lines are usually not preserved because of the complete recrystallisation of shells and internal moulds. Nevertheless in few specimens parts of the suture lines could still be observed. They consists of only few elements and are typically ceratitic (Fig. 17b). Of the two lobes on the flanks the outer one is denticulate, whereas the smaller inner one shows no denticles.

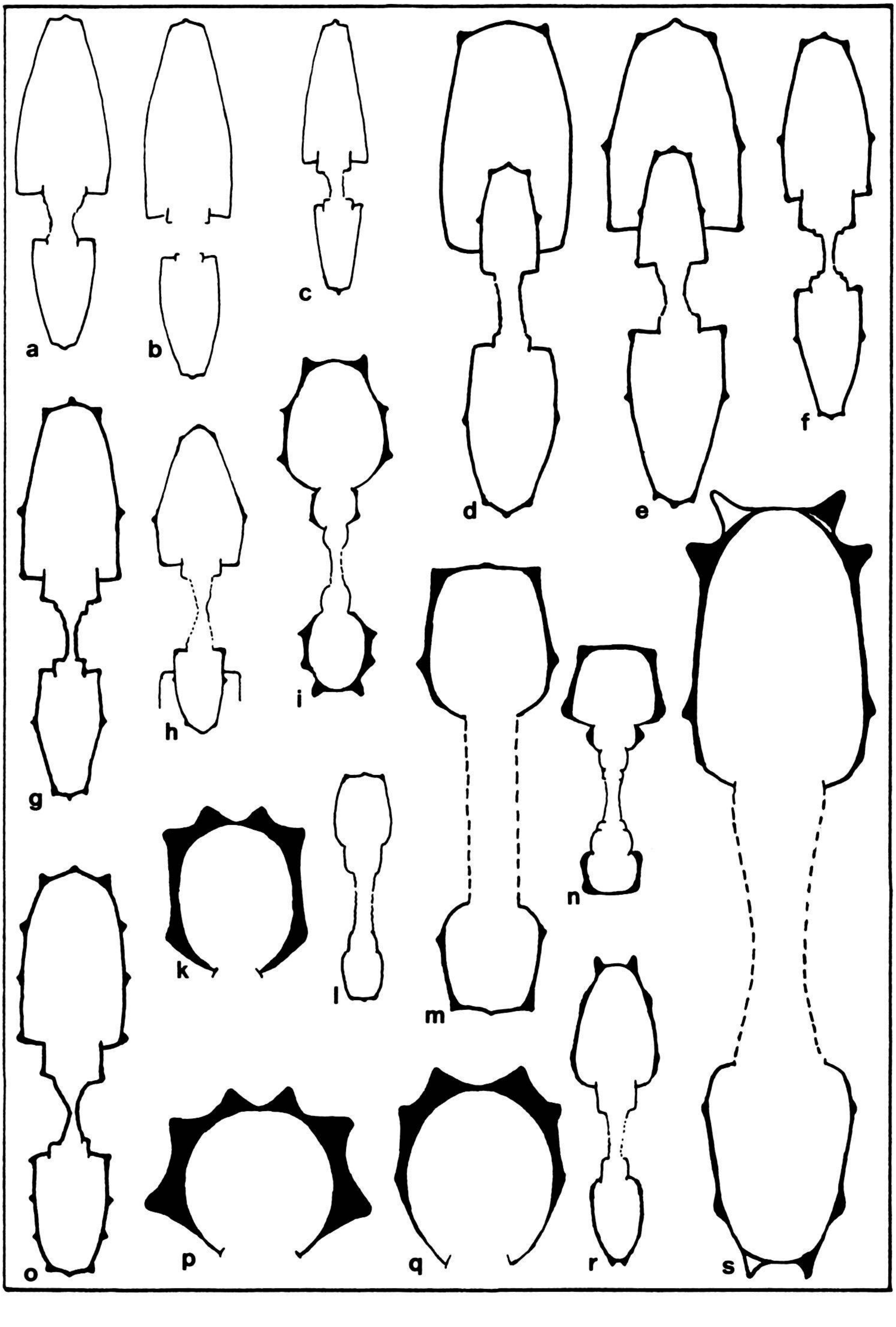
Remarks: Because of the small number of elements of the suture lines and the non-carinate venter the new genus *Latemarites* is provisionally assigned to the Danubitidae Spath, 1951.

Discussion: On the basis of its characteristic ornamentation and whorl section in adult stages (three rows of nodes, non-carinate venter, evolute shell) *Latemarites* can be easily distinguished from other Triassic ammonoid genera. Considering the ornamentation *Latemarites* slightly resembles *Kellnerites* (usually with a carinate venter), *Nevadites* (broader whorl section) and *Reitziites* gen. n. (shell moderately involute, juvenile stage with different ribbing, no marginal nodes).

Composition of the genus: *Latemarites latemarensis* n. sp.

Fig. 15. Cross and whorl sections of ammonoids dealt with in the text. See legends of plate figures for horizon and locality.

a *Hungarites zalaensis*, 7009, Pl. 1, Figs. 5–6.
b *Hungarites zalaensis*, 7007, Pl. 1, Fig. 3.
c *Hungarites* cf. *plicatus*, 7012, Pl. 2, Fig. 1.
d *Parakellnerites zoniaensis* n. sp., holotype, 7033, Pl. 3, Fig. 10.
e *Parakellnerites zoniaensis* n. sp., 7027, Pl. 3, Figs. 1–2.
f *Parakellnerites zoniaensis* n. sp., 7030, Pl. 3, Fig. 5.
g *Parakellnerites zoniaensis* n. sp., 7031, Pl. 3, Figs. 6–7.
h *Parakellnerites rothpletzi*, 7034, Pl. 4, Figs. 1–2.
i *Latemarites latemarensis* n. sp., holotype, 7069, Pl. 10, Figs. 1–2.
k *Nevadites secedensis* n. sp., holotype, 7116, Pl. 11, Fig. 8.
l *Stoppaniceras evolutum* n. sp., holotype, 7095, Pl. 9, Fig. 10.
m *Ticinites brescianus* n. sp., L/1641, Pl. 9, Figs. 1–2.
n *Ticinites dolomiticus* n. sp., 7093, Pl. 9, Figs. 8–9.
o *Kellnerites bagolinensis* n. sp., holotype, 7061, Pl. 6, Figs. 1–2.
p *Nevadites crassiornatus* n. sp., holotype, 7119, Pl. 12, Figs. 1–2.
q *Nevadites secedensis* n. sp., 7114, Pl. 11, Figs. 6–7.
r *Reitziites reitzii*, 7105, Pl. 8, Fig. 5.
s *Reitziites reitzii*, 7100, Pl. 7, Fig. 5.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Occurrence: Known only from Latemar, deeper part of the outcrop at the "Lastei di Valsorda" locality.
Age: Reitzi/Kellnerites Zone.

***Latemarites latemarensis* n. sp.**
Pl. 10, Figs. 1–24; Figs. 15i, 17b.

Holotype: Specimen 7069, figured in Pl. 10, Figs. 1–2. It is the largest of the available specimens.
Name: Referring to the type locality in the Latemar platform (western Dolomites, Italy).
Locus typicus: "Lastei di Valsorda" locality in the interior of the Latemar platform. Uppermost portion of the so-called "Lower Platform Facies."
Stratum typicum: Deeper portion of fossiliferous interval of the Latemar Limestone at the above mentioned type locality.
Material: The available material consists of more than 40 specimens from just one layer of about 30 cm thickness. The specimens are usually preserved with their shell and show therefore the outer morphology. The shell and their fill are recrystallized and only occasionally the septa are preserved. Moreover the shell cannot be removed from the inner mold in order to uncover the suture lines.
Diagnosis and description: In addition to the diagnosis of the genus it should be emphasized, that the strength of the ornamentation and the distances between the ribs vary in wide ranges. This intraspecific variability produced weakly ornamented forms as e.g. 7084 and 7085 (Pl. 10, Figs. 21–24), forms with moderately coarse ribs and nodes as e.g. the holotype and only rarely forms which are coarsely tuberculated (7070, 7071, 7075 (Pl. 10, Figs. 3, 4, 9)). Some specimens of the type series have elevated intercalated ribs. These ribs are restricted to the middle and outer part of the flank and usually do not bear nodes. The largest specimen is the holotype with a diameter of 5.3 cm. It appears to be nearly complete, because nodes and ribs become weaker and the latter are more densely and irregularly spaced on the outer third of the last whorl. On the inner whorls, up to a diameter of about 1.5 cm the ornamentation consists of loosely spaced primaries, which are confined to the inner third of the whorl height and form distinct umbilical bullae. Marginal nodes are absent at this ontogenetic stage.
Comparison, occurrence and age: As in *Latemarites* n. gen.

8.1.4. Family **Aplococeratidae** Spath, 1951

Aplococeras **Hyatt, 1900**

***Aplococeras avisianum* (Mojs., 1882)**
Pl. 12, Figs. 9, 11–12, Fig. 17c.

Aplococeras avisianum was found in several layers of the fossiliferous interval at the "Lastei di Valsorda" locality (Latemar) and in layer 4 (i.e. the lower horizon) of the Punta di Zonia section described by Cros & Houel (1983).

In the specimens from Latemar the suture line is not visible (due to the recrystallisation of the internal mould and the shell), but it can be easily observed in some individuals from Punta di Zonia. The suture line of specimen 7125 (Pl. 12, Fig. 12) consists of a distinctly denticulated lateral lobus and second lobus on the flank where the denticulation just starts (Fig. 17c). In specimen 7124 (Pl. 12, Fig. 11) both lobus are only weakly denticulated.

Asserto (1969) unified *Lecanites vogdesi* HYATT & SMITH from Nevada and *Aplococeras avisianum* from the Alps. Silberling & Nichols (1982, p. 53) separated the forms again (*Aplococeras vogdesi* (HYATT & SMITH), *Aplococeras avisianum* (MOJS.)). Our own observations on the material from the Dolomites support this view. Furthermore, it is possible that *Aplococeras* from Punta di Zonia is not conspecific with those from "Lastei di Valsorda". In cases where the suture line is not visible *Aplococeras* has no reliable taxonomic characteristics. The ornamentation of *Aplococeras avisianum* from Latemar and Forno (type locality) varies in wide ranges (from coarsely over densely spaced ribs to smooth). Several specimens from Punta di Zonia are larger than those from Latemar and have a slightly different ribbing and cross section. Further research on additional material may show, whether these differences are significant or caused by preservation.

Aplococeratids with no ornamentation and slightly different cross sections were collected from the Marmolada Limestone on the northern slope of Marmolada and at "Isugadoi" on the southern slope of the Latemar platform. These aplococeratids are considered as *Aplococeras misanii* (MOJS.). Several poorly preserved specimens of *Aplococeras* from the "Lower Plattenkalke" at Seceda cannot be specified. A small individual was found together with *Parakellnerites* aff. *rothpletzi* (7046, Pl. 4, Fig. 18).

8.1.5. Family **indet.**

***Nevadites* SMITH, 1914**

Remarks: The systematic position of the genus *Nevadites* is still uncertain. Considering the simple suture line the genus resembles *Ticinites*. It is therefore provisionally assigned to the Family Danubitidae. Further comparative studies on the suture line among other features may reveal whether this is justified.

From the lower "Buchenstein Beds" of the Brescian Prealps Brack & Rieber (1986) mentioned *Nevadites* and also regarded as such two species (*N. dealessandri* and *N. ambrosionii*) from the "Grenzbitumenzone" at Monte San Giorgio, which formerly had been referred to as *Protrachyceras* (Rieber, 1973a). These *Nevadites* were joined in the group of *Nevadites reitzi* (BÖCKH, 1872). However, our new fossil finds from Bagolino clearly demonstrate that the species *reitzi* cannot be linked to *Nevadites*.

When compared with the forms from Nevada all representatives of *Nevadites* from the Southern Alps show a different umbilical region. In juvenile and adult individuals from the Alps the transition from the flank to the umbilical wall is rounded and no umbilical edge is developed. The umbilical wall itself can be steep close to the umbilical seam, but in no case is it perpendicular or even overhanging as in juvenile specimens from Nevada. The ribbing and the widely varying tuberculation are also different. Nevertheless, the representatives from the Southern Alps are considered as *Nevadites*. Further finds and studies may show, if a new genus for these southalpine *Nevadites* would be more appropriate.

The inner whorls of *Nevadites* and, in particular, those of the "Grenzbitumenzone" have ornamentations similar to *Protrachyceras* as stated by Rieber (1973a, p. 65). It seems thus probable that *Nevadites* is a forerunner of the Trachyceratids.

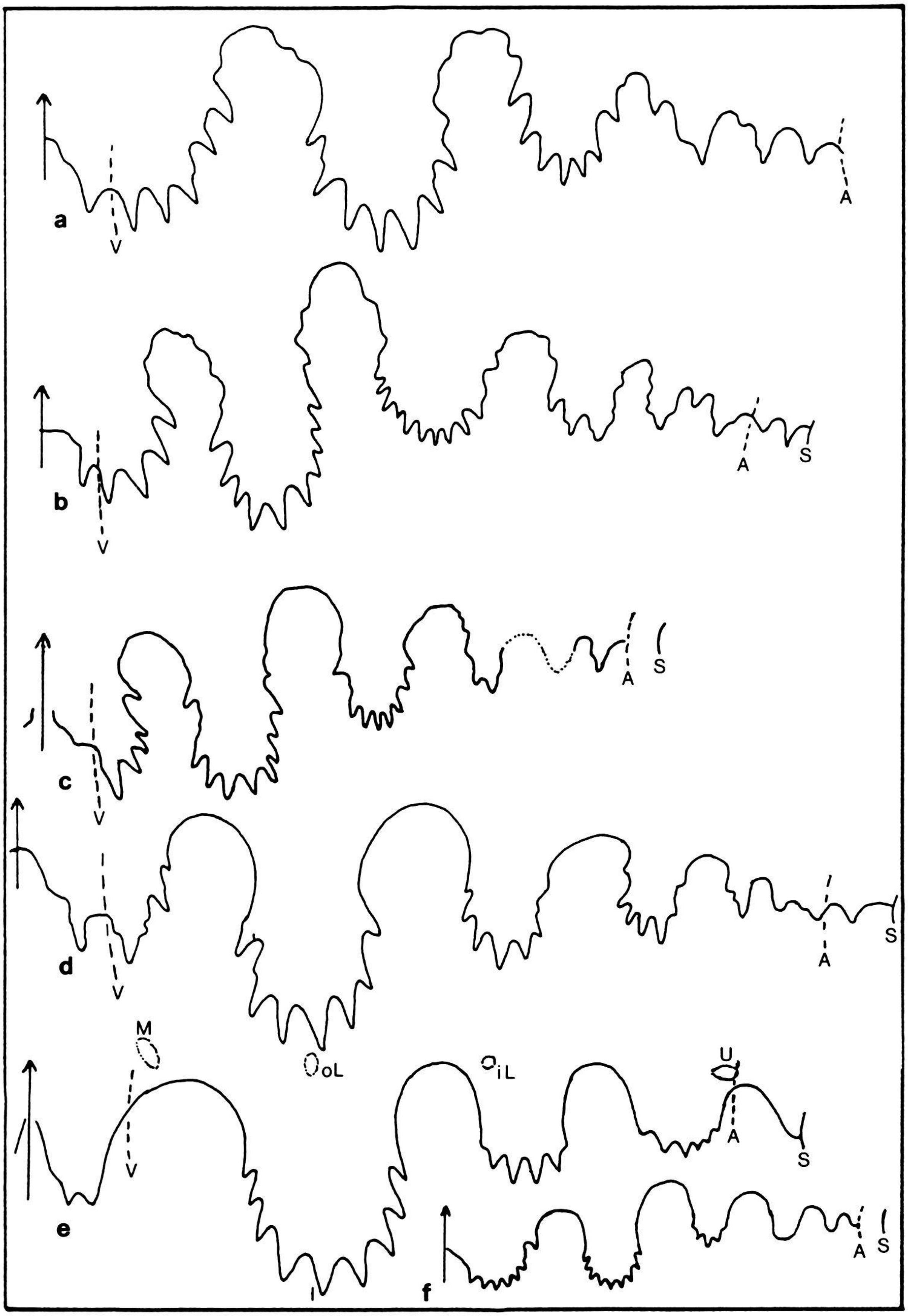
Nevadites avenonensis **n. sp.**
Pl. 11, Figs. 9–12, Pl. 12, Figs. 5–6.

Synonymy:

? 1913–14 *Trachyceras reitzi.* – HORN.
v 1986 Group of *Nevadites reitzi.* – BRACK & RIEBER, Pl. 2, Fig. 2, Pl. 4, Fig. 4.

Holotype: Specimen 7117, figured on Pl. 11, Figs. 11–12. It consists of the anterior part of a body chamber. The right flank and the venter are preserved.
Name: Referring to Avenone (Comune Pèrtica Bassa, Prov. Brescia, Italy), a small village two kilometers northwest of which the holotype was found.
Stratum typicum and locus typicus: Grey, cherty limestones of the lower "Buchenstein Beds" at Pèrtica (coord. 604900/5069100). The specimen was collected 1 m below the "Chiesense groove" (see Brack & Rieber 1986).
Material: Five specimens form the type locality and one from Biogno.
Diagnosis: *Nevadites* with rounded rectangular whorl section, irregular, weakly prosiradiate ribbing and three rows of tubercles (weak umbilical, distinct lateral and strong ventral ones). The lateral tubercles vary in size and are located at some distance above the midline of the flanks. The venter is rather flat, broad and weakly undulated in the direction of the spiral.
Description: In large specimens, as e.g. the holotype, the umbilical tubercles are only weak or even absent. In smaller specimens they are located outside the rounded umbilical rim. Their tips point away from the flanks. The umbilical wall is smooth and steep, but not perpendicular or even overhanging. The flanks bear simple ribs, which start with umbilical tubercles. Other specimens have intercalatories with no such tubercles. The holotype shows a primary rib which splits in two secondaries at the lateral tubercles. All ribs bear rather strong ventral tubercles of the same size, whereas some intercalatories have no lateral tubercles. The ventral tubercles extend only slightly beyond the flattened stripe of the venter, and the rows on both sides show alternating as well as opposite positions. In specimen (L 1632) from Biogno (Brack & Rieber 1986, Pl. 4, Fig. 4) small tubercles appear between the lateral and ventral ones. This specimen has therefore a similar ornamentation as *N. ambrosionii* (Airaghi) and *N. dealessandri* (Airaghi) from the "Grenzbitumenzone" at Monte San Giorgio, Ticino/Switzerland (Rieber 1973 a). The incomplete preservation of the available specimens impedes measurements of the whorl section and umbilical width. No suture line was observed.

Fig. 16. Suture lines of ammonoids. See legends of plate figures for horizon and locality; H: height of the whorl wherefrom the suture line was taken.
a *Hungarites* cf. *plicatus*, H = 30 mm, 7013, Pl. 2, Fig. 2.
b *Hungarites* cf. *plicatus*, H = 14 mm, 7012, Pl. 2, Fig. 1.
c *Hungarites* cf. *plicatus*, H = 16 mm, 7013, horizon and locality as in b.
d *Parakellnerites zoniaensis* n. sp., H = 25 mm, 7027, Pl. 3, Figs. 1–2.
e *Kellnerites bagolinensis* n. sp., H = 18 mm, holotype, 7061, the position of the nodes is indicated, Pl. 6, Figs. 1–2.
f *Parakellnerites arthaberi*, H = 20 mm, 7025, Pl. 12, Fig. 7.
A: umbilical angle or edge (dashed line), oL: outer lateral node, iL: inner lateral node, M: marginal nodes, S: umbilical seam, U: umbilical node, V: ventral shoulder (dashed line).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Discussion: Especially in small specimens of *Nevadites hyatti* (Smith) and *N. humboldtensis* Smith the umbilical wall is overhanging. The tips of the strong umbilical tubercles point towards the center of the umbilicus and the lateral tubercles are located near the midline of the flanks. Furthermore, the ribbing is more regular, and the intercalatories are shorter than in *N. avenonensis* n. sp. *Nevadites ambrosionii* and *N. dealessandri* have a fourth row of small tubercles between the lateral and the ventral tubercles. *Nevadites dealessandrii* has usually thinner and higher whorls than the new species.
Occurrence: *N. avenonensis* n. sp. was found in the lower "Buchenstein Beds" at the locus typicus and its surroundings as well as at Biogno (see Brack & Rieber 1986, p. 191).
Age: Nevadites Zone.

***Nevadites secedensis* n. sp.**
Pl. 11, Figs. 4–8, Pl. 12, Figs. 3–4, 8; Figs. 15k, 15q, 17d.

Synonymy:

? 1879 *Trachyceras Reitzi* Böckh–Mojsisovics: Die Dolomitriffe von Südtirol und Venetien, S. 53.
? 1879 *Trachyceras* cf. *Reitzi* Böckh–Mojsisovics: ibid. S. 150.
? 1882 p.p. *Trachyceras reitzi* (Boeckh, 1873). – Mojsisovics: Die Cephalopoden der mediterranen Triasprovinz, p. 114 (findings from "Pufelser Schlucht bei St. Ulrich in Gröden").

Remarks: Although no completely preserved specimen of this form was found and all available fragments differ in preservation, size, ornamentation and cross section, it is appropriate to establish at least one new species for this group.
Holotype: Specimen 7116 (Pl. 11, Fig. 8), an internal mould of the phragmocone and the body chambers. It is slightly twisted and corroded.
Name: Referring to the Seceda peak, a mountain 5 km northeast of Ortisei (St. Ulrich, Val Gardena, Italy), where the holotype and several other specimens were found.
Locus typicus: Western slope of the Seceda peak.
Stratum typicum: Lower "Buchenstein Beds," several layers around 3 m above the base of the "Knollenkalke".
Material: 17 specimens from the locus typicus, 14 of which are only small fragments of the body chamber. Five poorly preserved specimens come from several localities in the Brescian Prealps. All specimens are somewhat bent and corroded.
Diagnosis: Evolute *Nevadites* with strong lateral and ventral spines. Umbilical tubercles vary in size and are absent on the body chambers of several specimens. Whorl sections at the interspaces are subcircular with the height exceeding slightly the width. The umbilical wall is smooth, rounded, and steep. The ventral side is narrow and V-shaped. Ventral spines are in opposite positions. The ribbing is variable, with or without intercalatories. All ribs end at ventral nodes. The ceratitic suture consists of few elements.
Description: The holotype shows a largest diameter of 6.5 cm. The last half turn is a part of the body chamber and the diameter at the end of the phragmocone measures 41 cm. Specimen 7122 (Pl. 12, Fig. 8) has a phragmocone diameter of 5.8 cm. The diameter of the restored shell of the fragment 7114 (Pl. 11, Figs. 6–7) is 11.5 cm. The shape of another, small fragment 7162 (not figured) suggests that diameters of large individuals may have reached up to at least 15 cm. The lateral ornamentation of the holotype consists of strong simple ribs with wide interspaces. The ribs bear pronounced and radially somewhat elongated umbilical tubercles as well as strong pointed lateral and

ventral nodes of similar size. On the inner whorls the ribbing is denser and intercalatories are developed. All ventral nodes have the same size. The lateral nodes on the intercalatories are slightly weaker than those of the primaries. The slope between the flank and the umbilical seam is rounded (i.e. between the umbilical tubercles). The umbilical wall is steep, but not perpendicular. The marginal region is also curved at the interspaces. Specimen 7114 (Pl. 11, Figs. 6–7) is a fragment of the body chamber (about 60°) and a small part of the phragmocone and shows no umbilical tubercles. The ornamentation of the flanks consists of simple, prosiradiate ribs. The latter become increasingly stronger (higher) towards the outer part. Both, lateral and ventral nodes are strong. The ventral nodes are slightly larger than the lateral ones. The umbilical wall is smooth and rounded. Ribbing and tuberculation of this species thus vary in wide ranges.
Comparison: The shell of *N. secedensis* is more evolute than shells of all other alpine *Nevadites* (*N. crassiornatus* excluded). The positions of ventral nodes are opposite. Small tubercles between lateral and ventral nodes as observed in *N. ambrosionii* do not occur in *N. secedensis*.
Occurrence: In addition to the 17 specimens from the locus typicus several poorly preserved specimens were found in the lower "Buchenstein Beds" of the Brescian Prealps (Marcheno, Biogno, Pèrtica, Bagolino).
Age: Nevadites Zone.

***Nevadites crassiornatus* n. sp.**
Pl. 12, Figs. 1–2; Fig. 15p.

Remarks: A new species is established for a single specimen from the locus typicus and stratum typicum of *Nevadites secedensis* n. sp. which differs significantly from all other specimens of *Nevadites*.
Holotype: Specimen 7119 (Pl. 12, Figs. 1–2), the internal mould of the left side and venter of a body chamber.
Name: Referring to the coarse ribbing and tuberculation of the species.
Locus typicus: Western slope of the Seceda peak near Ortisei (St. Ulrich, Val Gardena, Italy).
Stratum typicum: Lower "Buchenstein Beds," upper surface of the T_e-tuff level, 3 m above the lower boundary of the "Knollenkalke."
Material: One single specimen (the holotype).
Diagnosis: Evolute *Nevadites* with strong and pointed umbilical, lateral and ventral tubercles on the body chamber. The cross section of the whorl is subcircular at the wide interspaces. The number of ventral spines exceeds the one of lateral spines by a factor of two. The additional ventral spines are located in the interspaces but closer to the anterior spines than to the posterior ones. The ventral side between the ventral spines is narrow and broadly V-shaped.
Description: Most remarkable features of this species are strong umbilical tubercles on the anterior part of the body chamber as well as additional ventral spines. It seems as if the additional ventral spines belong to intercalatories, which are not developed on the body chamber. The ventral spines on both sides occupy opposite positions.
Comparison: *Nevadites crassiornatus* differs from all other known species of *Nevadites* by its coarse tuberculation and ribbing with wide interspaces.
Occurrence and age: Known only from the locus typicus. Nevadites Zone.

Superfamily **Trachyceratacea** HAUG, 1894
8.1.6. Family **Arpaditidae** HYATT, 1900

Protrachyceratinae TOZER, **1971**
Pl. 13; Figs. 17g, 17h.

Several protrachyceratinids were found in situ in the "Knollenkalke" of the "Buchenstein Beds" in the Brescian Prealps/Giudicarie, Val Gola and in the Dolomites. Specimens of *Eoprotrachyceras curionii* (MOJS.) and *Eoprotrachyceras recubariense* MOJS. are illustrated in Brack & Rieber (1986, Pl. 5, Figs. 4–5).

(Eo-)Protrachyceras margaritosum **(MOJS., 1882)**
Pl. 13, Figs. 6–7; Fig. 17h.

Two trachyceratids are comparable with *Eoprotrachyceras margaritosum* (MOJS.). The specimen (7129, Pl. 13, Fig. 6) from the "Knollenkalke" at Bagolino is an internal mould of a part of the body chamber. It has nine rows of tubercles and a deep external sulcus. The strong clavate tubercles bordering the sulcus are arranged in an altering fashion.

A second specimen (7130, Pl. 13, Fig. 7), from the scree of the "Knollenkalke" at Val Gola consists of the body chamber and a part of the phragmocone with a suture line. The ornamentation has eight rows of distinct tubercles. A ninth spiral of very weak tubercles occupies the interspace between the umbilical and the first row of distinct lateral tubercles. The spirally elongated tubercles bordering the narrow and shallow median sulcus are in alternating positions. The suture line (Fig. 17h) shows denticulated saddles. However, this denticulation is less deep compared to the lobes. Furthermore, the denticulation of the saddles and flanks looks similarly irregular as do suture lines in other trachyceratids. The denticulated saddles suggest an affiliation of the species *margaritosum* to the genus *Protrachyceras* instead of *Eoprotrachyceras* as supposed by Tozer (1980, p. 107).

Protrachyceras steinmanni **(MOJS., 1882)**
Pl. 13, Figs. 1, 4–5; Fig. 17g.

Two specimens (7126, 7128) from the same layer in the upper "Knollenkalke" at M. Corona and a fragment (7127) from a somewhat older layer at Bagolino are assigned to

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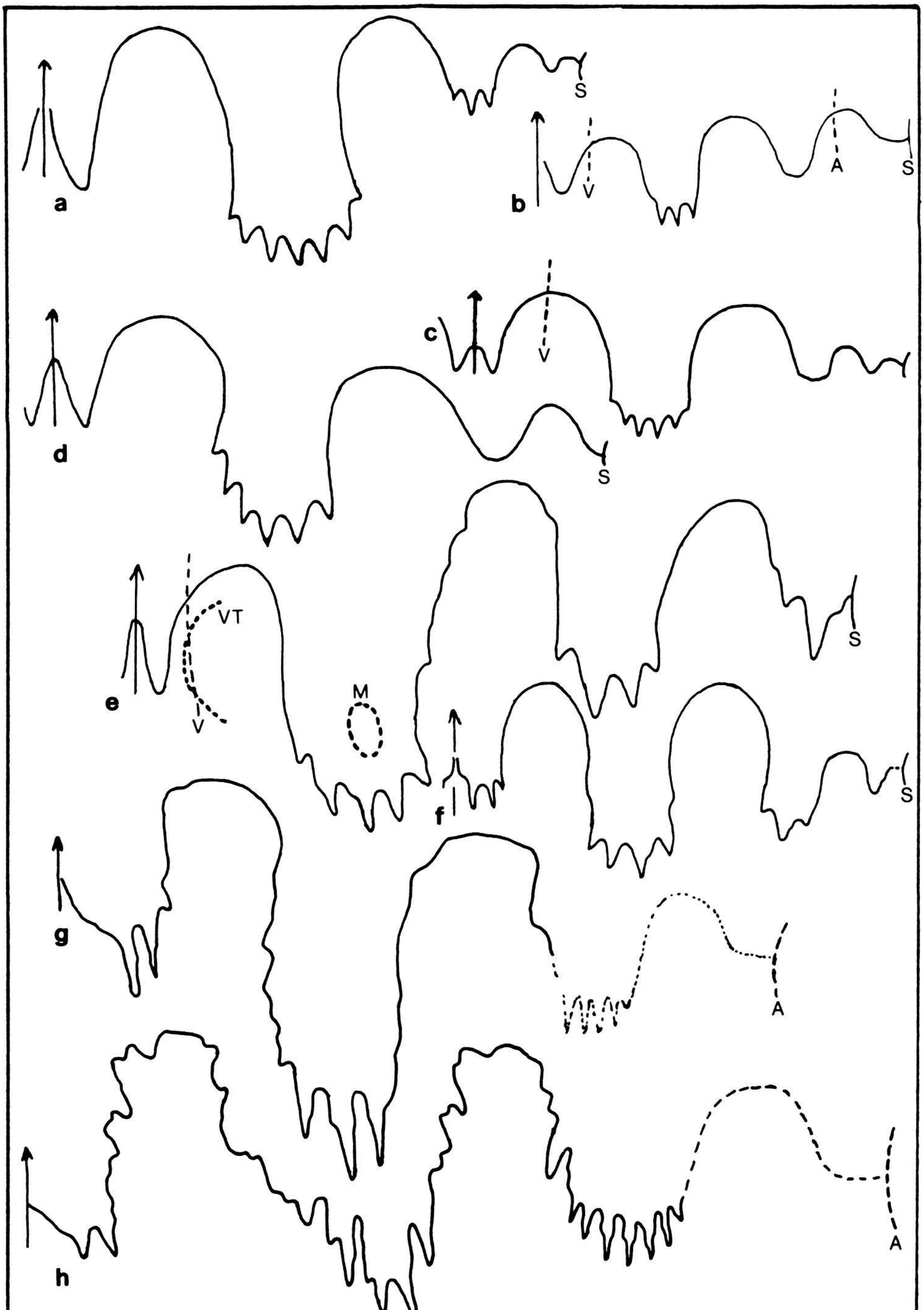
Fig. 17. Suture lines of ammonoids. See legends of plate figures for horizon and locality; H: height of the whorl wherefrom the suture line was taken.
a *Ticinites dolomiticus* n. sp., H = 15 mm, holotype, 7092, Pl. 9, Fig. 4.
b *Latemarites latemarensis* n. sp., H = 9 mm, 7089, Latemar Limestone, "Lastei di Valsorda" locality.
c *Aplococeras avisianum*, H = 7 mm, 7125, Pl. 12, Fig. 12.
d *Nevadites secedensis* n. sp., H = 18 mm, 7122, Pl. 12, Fig. 8.
e *Reitziites reitzi*, H = 33 mm, 7100, the position of the marginal and ventral tubercles is indicated, Pl. 7, Fig. 5.
f *Reitziites reitzi*, H = 11 mm, 7111, Pl. 8, Fig. 12.
g *Protrachyceras steinmanni*, H = 23 mm, 7127, Pl. 13, Fig. 5.
h *(Eo-)Protrachyceras margaritosum*, H = 25 mm, 7130, Pl. 13, Fig. 7.
A: umbilical angle or edge (dashed line), M: marginal node, S: umbilical seam, V: ventral shoulder (dashed line), VT: ventral tubercles (dotted line).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Protrachyceras steinmanni (MOJS.). The ornamentation and cross sections correspond to the figures and description of the type of this species in Mojsisovics (1882, Pl. 81, Figs. 8–10, p. 109).

Specimen 7127 from Bagolino shows parts of the suture lines (Fig. 17 g). The lateral lobus has long lobules, whereas the saddles are nearly smooth. Only weak deflections are developed on the flanks of the saddles. Therefore the species *steinmanni* might indeed be joined with the genus *Eoprotrachyceras* (Tozer 1980).

A large *Daonella pichleri* is preserved on the back side of the slab with specimen 7126.

***Protrachyceras gortanii* PISA, 1966**
Pl. 13, Figs. 8–9.

A specimen (7132) from the "Knollenkalke" on the northern slope at Seceda is considered as *Protrachyceras gortanii* Pisa morphotype *nodato*. It is the internal mould of the body chamber. The phragmocone is not present. The ornamentation consists of single, branched and intercalatory ribs with five rows of weak, radially elongated tubercles. In the center of the rounded external side the ribs are completely interrupted and a sharply bordered, shallow median sulcus is developed.

***Protrachyceras archelaus* (LAUBE, 1868)**
Pl. 13, Figs. 2–3.

A well preserved specimen (7133, Pl. 13, Figs. 2–3) of *Protrachyceras archelaus* (LAUBE) comes from the lowermost "Wengen Beds" at M. Corona only a few meters above the top of the "Buchenstein Beds." The small individual (diameter 2.8 cm) shows the typical ornamentation (six rows of tubercles and a distinct median sulcus) and cross section of *Protrachyceras archelaus*.

Remarks on the classification and ecology of ammonoids discussed in this chapter:

The systematic positions of middle/late Anisian to early Ladinian ammonoid genera from the Alps are based mainly on distinctive characteristics of the ornamentation and the cross section. The systematic positions of genera such as *Nevadites, Ticinites* and the new *Reitziites* and *Latemarites* are problematic. They cannot be affiliated to a family on the basis of their ornamentation and cross section alone. It seems, however, that the suture line although not always visible and usually not considered as an important taxonomic characteristic might provide useful addition information.

The number and shapes of lobes as well as the position of the umbilical angle and seam are compared in the following table. In order to facilitate the comparison the lateral and subsequent umbilical lobes are numbered consecutively.

Two groups may be distinguished in Table 11. Ammonoids of a first group with dominance of ceratitids have broad, denticulated external lobes and at least four additional lobes up to the umbilical angle. A second group including Danubitidae and Protrachyceratinae is characterized by a narrow external lobe and only two lobes (L and U2) up to the umbilical angle. *Kellnerites* and *Lardaroceras* have broad to moderately narrow external lobes and four lobes up to the umbilical angle and therefore occupy an intermediate position. Further studies are needed to clarify if these observations are of decisive importance for the taxonomy of these ammonoids.

Table 11:
Shapes of the suture lines and position of the umbilical angle (A) and umbilical seam (S) in selected ammonoids of this study.

Lobes on the flank	E		L	U_2	U	U	U	U	U
Development, number	Ebd	En	1	2	3	4	5	6	7
Genus or species									
Hungarites cf. *plicatus*	+	-	+	+	+	+	+ A	+	+ S
Parakellnerites zoniaensis	+	-	+	+	+	+	+	+ A	+ S
Parakellnerites arthaberi	+	-	+	+	+	+ A	-S	-	-
Lardaroceras	+	-	+	+	+ A	±	-	-	-
Kellnerites bagolinensis	-	+	+	+	+ A	+S	-	-	-
Ticinites dolomiticus	-	+	+	+ A	+ S	-	-	-	-
Latemarites latemarensis	-	+	+	+ A	+S	-	-	-	-
Aplococeras avisianus	-	+	+	+ A	+S	-	-	-	-
Nevadites secedensis	-	+	+	+ A	+S	-	-	-	-
Reitziites reitzii	-	+	+	+ A	+ S	-	-	-	-
Protrachyceras steinmanni	-	+	+	+ A	±	-	-	-	-

A: umbilical angle (umbilical edge), E: external lobe, Ebd: external lobe broad and denticulated, En: external lobe narrow not or weakly denticulated, L: lateral lobe, U: umbilical lobe; the lateral lobe and the following umbilical lobes are numbered consecutively.

Ammonoid faunas from platform interior portions and platform slopes (Latemar and Marmolada Limestones respectively) obviously differ from those in coeval basinal settings ("Buchenstein Beds" and "transitional beds"). The faunas from Latemar and Marmolada are characterized by the frequent occurrence of *Hungarites, Parakellnerites* and *Aplococeras*. In basinal equivalents *Kellnerites, Reitziites* and *Chieseiceras* are locally dominant but *Nevadites* and *Ticinites* also occur. In the "Lower Plattenkalke" ammonoids are rare. This may be partly due to diagenetic processes but other fossils such as Daonellas are locally abundant.

The fauna of the "Grenzbitumenzone" at M. S. Giorgio (Rieber 1973 a, b) occupies an intermediate position. However, if the fauna is considered on a layer by layer basis the composition varies remarkably strong from bed to bed. Surprisingly no *Hungarites* were found so far in this succession.

It seems as if *Hungarites, Parakellnerites* and *Aplococeras* lived preferentially in shallow waters in close vicinity of carbonate plaforms whereas other ammonoid genera and species prefered deeper and/or open sea waters.

8.2. Class **Bivalvia**

Order **Pterioida** Newell, 1965

8.2.1. Family **Posidoniidae** Frech, 1909

Daonella **Mojsisovics, 1874**

Daonellas are an important component of the faunas in the "Buchenstein Beds" of the Dolomites and in the "Grenzbitumenzone" at M. S. Giorgio (Rieber, 1969). In particular the group of *Daonella elongata* Mojs. are reliable guide fossils. Other species of *Daonella* proved also to be useful for stratigraphic correlations.

***Daonella (Longidaonella)* FARSAN, 1972**
Pl. 14, Figs. 4, 7, 10.

Several horizons in the uppermost "Lower Plattenkalke" at Seceda and Pufels yielded abundant and in several cases extraordinarily well preserved specimens of the group of *Daonella* (*Longidaonella*) *elongata*. Specimens of the three species *D.* (*L.*) *elongata* MOJS., *D.* (*L.*) *angulata* RIEBER, and *D.* (*L.*) *serpianensis* RIEBER are illustrated on Plate 14.

***Daonella cerneraensis* n. sp.**
Pl. 14, Figs. 8–9, 11–19.

Holotype: Specimen 7142 figured on Pl. 14, Figs. 11 and 13.
Name: Referring to the Cernera mountain in the central Dolomites just south of the type locality.
Locus typicus: Small hill southwest of Punta di Zonia on the northern slope of the Cernera platform.
Stratum typicum: Layer 4 of the section described by Cros & Houel (1983, p. 441, Fig. 7 B) as "coquina – phosphatized biosparite with ammonites of the avisianus zone". The writers assign this level to the Reitzi/Kellnerites Zone.
Material: Single valves on several slabs from the type locality and from the "Lower Plattenkalke" at Seceda.
Diagnosis: Small *Daonella* with elongate, oblique shape. Elevated beak somewhat anterior and greatest height considerably posterior to the middle of the valve. Ribs in the middle part of the valve are rather broad with narrow grooves in between. Towards the posterior and anterior dorsal margin the spacing of the ribs becomes abruptly narrower and the grooves wider. The ribs disappear in the narrow, vaulted sectors at the dorsal margin. Only few ribs in the middle of the posterior part of the valve have narrow second-order grooves.

Table 12:
Dimensions of Daonellas in mm (method of measurement after SILBERLING & NICHOLS, 1982, p. 67)

Specimen	L	H	H/L	AD	AV	AV/L
D. cerneraensis (holotype, 7142 ; Pl.14, Fig.11)	19	8.8	0.46	8.3	14	0.72
D. sotschiadensis (holotype, 7138 ; Pl.14, Fig.5-6)	21.5	13.6	0.63	9.2	13.5	0.62

L, length; H, height; AD, anterior dorsal length; AV, anterior ventral length.

Description: The ribbing of *Daonella cerneraensis* n. sp. varies from specimen to specimen. However, in the middle part of the valve the ribs are generally broad, flat-topped, and separated by narrow grooves. At the onset of the posterior part (a sector of about 40°) the grooves become considerably wider and in the last 20–10° of the posterior valve portion the ribs and grooves fade and finally disappear near (10–5°) the vaulted dorsal margin. On the anterior portion of the valve the variation of the ribbing is generally less pronounced. The smooth sector along the dorsal margin is also narrower. The strong beak is prosogyr and towers slightly across the dorsal margin. An elevation of the shell starts at the beak and takes its course to the ventral margin reaching (about 20°) behind the middle of the valve. The largest specimen (7145, Pl. 14, Figs. 16, 19) from Seceda has a length of 3.5 cm.

Discussion: *Daonella cerneraensis* resembles *Daonella serpianensis*. However, the latter has a weaker and less elevated beak. The ribbing, especially near the beak, is also weaker in *D. serpianensis*.

Very similar to *D. cerneraensis* with respect to the size, the outline of the valve, the development of the beak and the arrangement of the ribs are Daonellas from grey siltstone and marls at M. Rite. However, the ribbing of the latter seems to be generally finer than in *D. cerneraensis*. The Daonellas from M. Rite are compressed and preserved in a different way which hampers a detailed comparison. Studies on additional material from M. Rite may reveal whether these Daonellas have to be considered as *D. cerneraensis*. In any case they cannot be assigned to *D. fascicostata* RIEBER, as suggested by Farabegoli (1979, p. 52). *Daonella pauciforata* RIEBER as mentioned in Assereto (1971) is presumably a misprint.

Occurrence and age: Known from the type locality and the "Lower Plattenkalke" at Seceda. Very similar forms are known from M. Rite. Reitzi/Kellnerites Zone.

***Daonella sotschiadensis* n. sp.**
Pl. 14, Figs. 5-6.

Holotype: Specimen 7138, figured on Pl. 14, Figs. 5-6.

Name: Referring to Sotschiada, an old name for the Seceda mountain where the holotype and the paratypes were found.

Locus typicus: Western slope of Seceda, 5 km NE of Ortisei (St. Ulrich, Val Gardena, Italy).

Stratum typicum: "Buchenstein Beds", "Lower Plattenkalke", about 2.3 m below the base of the "Knollenkalke".

Material: The holotype and five fragments of single valves.

Diagnosis: Relatively small Daonellas with ovate shape, elevated beak slightly anterior to the middle of the valve. Ribs start near the beak and are broad and flat-topped, grooves are narrow. Some ribs have fine second-order grooves.

Description: *Daonella sotschiadensis* is characterized by its broad, top-flattened ribs. These are separated by narrow, rather deep first-order grooves starting at a distance of 0.25 to 0.3 cm from the elevated beak. Second-order grooves appear 0.7-1 cm from the beak and can be traced up to the margin of the valve. Comarginal folds are especially prominent near the beak.

Discussion: *Daonella sturi* BENECKE shows some similarity with *Daonella sotschiadensis* but has narrower and irregularly arranged ribs, broader first-order grooves and reaches larger sizes (length exceeding 8 cm). *Daonella paucicostata* TORNQUIST has narrower ribs and broader grooves. The valve is higher than in *D. sotschiadensis*. The second-order grooves of the relatively large *Daonella dubia* (GABB) from the Humboldt Range in Nevada (Silberling & Nichols 1982, p. 68) become broader and deeper than in *D. sotschiadensis*. The paucicostate Daonellas from the higher stratigraphic intervals of the Latemar and Marmolada Limestone have broader, top-rounded ribs.

Occurrence and age: Known from the "Lower Plattenkalke" at Seceda. Reitzi/Kellnerites Zone.

***Daonella pichleri* Mojs., 1874**
Pl. 14, Figs. 1–3.

In several levels of the "Upper Bänderkalke" at Seceda and of the upper "Knollenkalke" at M. Corona often well preserved specimens of *Daonella pichleri* Mojs. occur frequently. At M. Corona this species was found together with *Protrachyceras steinmanni* Mojs.

Most characteristic features of *D. pichleri* are the position of the beak in the anterior third of the valve, the straight dorsal margin and the ontogenetical growth of the height of the shell. This can be best demonstrated by the dimensions in the following table.

Table 13:
Dimensions (in mm) of specimens of *Daonella pichleri* (method of measurement after SILBERLING & NICHOLS, 1982, p. 67):

Specimen	L	H	H/L	Ad	AV	AV/L	AD/L
7136 (M. Corona ,Pl.14, Fig.3)	17.5	10.5	0.6	5.4	7.8	0.4	0.31
ibid.	25.6	15.9	0.61	7.6	11.2	0.43	0.29
ibid.	35.8	23.3	0.65	11.6	16.6	0.46	0.32
ibid.	c50.1	31.9	0.63	16.5	22.8	0.45	0.33
7126 (M. Corona)	24.4	16.6	0.68	5.8	12.7	0.52	0.23
ibid.	42.1	32.9	0.78	10.7	23.2	0.55	0.25
7134 (Seceda; Pl.14, Fig.1)	16.1	10.6	0.66	4.2	9.3	0.58	0.26
ibid.	28.1	20.2	0.72	8.1	14.4	0.51	0.29
7135 (Seceda; Pl.14, Fig.2)	21.7	13.6	0.63	5.4	13.4	0.62	0.25
ibid.	30.8	19.4	0.63	9.6	19.2	0.62	0.31

L, length; H, height; AD, anterior dorsal length; AV, anterior ventral length.

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Plate 1

(all figures natural size)

Figs. 1–8: *Hungarites zalaensis* (Böckh, 1872), Latemar Limestone, "Lastei di Valsorda" locality, Reitzi/Kellnerites Zone.

Fig. 1: PIMUZ 7005, lower part of outcrop.

Fig. 2: PIMUZ 7006, lower part of outcrop.

Fig. 3: PIMUZ 7007, middle part of outcrop; for cross section see Fig. 15b.

Fig. 4: PIMUZ 7008, adult, complete specimen, lower part of outcrop.

Figs. 5–6: PIMUZ 7009, lower part of outcrop; for cross section see Fig. 15a.

Figs. 7–8: PIMUZ 7010, middle part of outcrop.

Plate 1

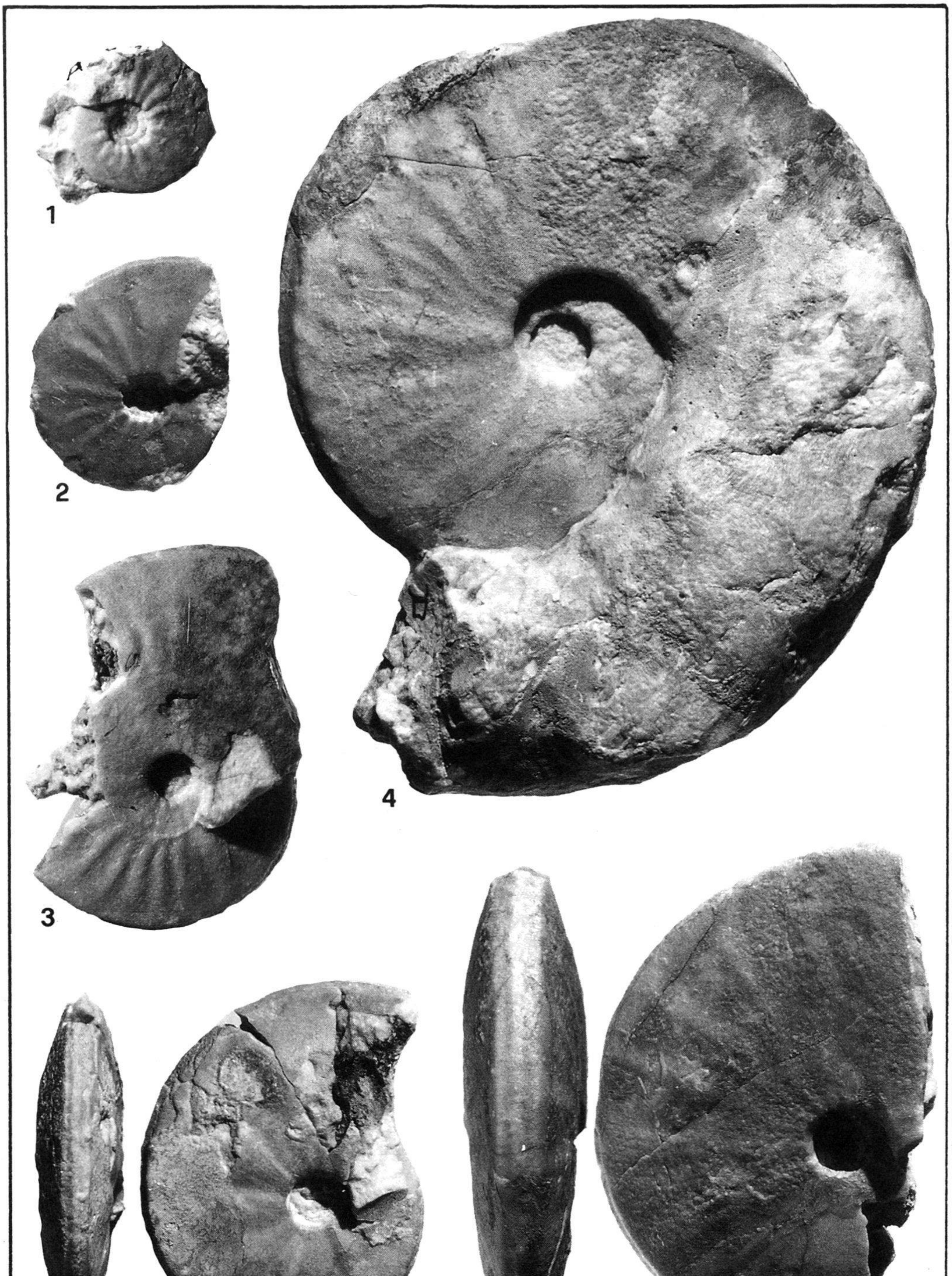

Plate 2

(all figures natural size)

Fig. 1: *Hungarites* cf. *plicatus* (Hauer, 1896), PIMUZ 7012, specimen with shell, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone; for cross section and suture line see Figs. 15c and 16b.

Fig. 2: *Hungarites* cf. *plicatus* (Hauer, 1896), PIMUZ 7013, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone; for suture line see Fig. 16a.

Fig. 3: *Hungarites* cf. *plicatus* (Hauer, 1896), PIMUZ 7014, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Fig. 4: *Hungarites* cf. *plicatus* (Hauer, 1896), PIMUZ 7015, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Fig. 5: *Hungarites lenis* (Hauer, 1896), PIMUZ 7019, adult, complete specimen with partly preserved shell, "transitional beds", 54.25 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 6–7: *Hungarites lenis* (Hauer, 1896), PIMUZ 7020, "transitional beds", 54.25 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 8–9: *Hungarites* cf. *plicatus* (Hauer, 1896), PIMUZ 7016, fragment of a small specimen with distinct ribs, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Figs. 10–11: *Parakellnerites arthaberi* (Diener, 1899), PIMUZ 7024, Fig. 10: anterior part of last turn removed to show the inner whorl, "transitional beds", 57.8 m, Bagolino, Reitzi/Kellnerites Zone.

Plate 2

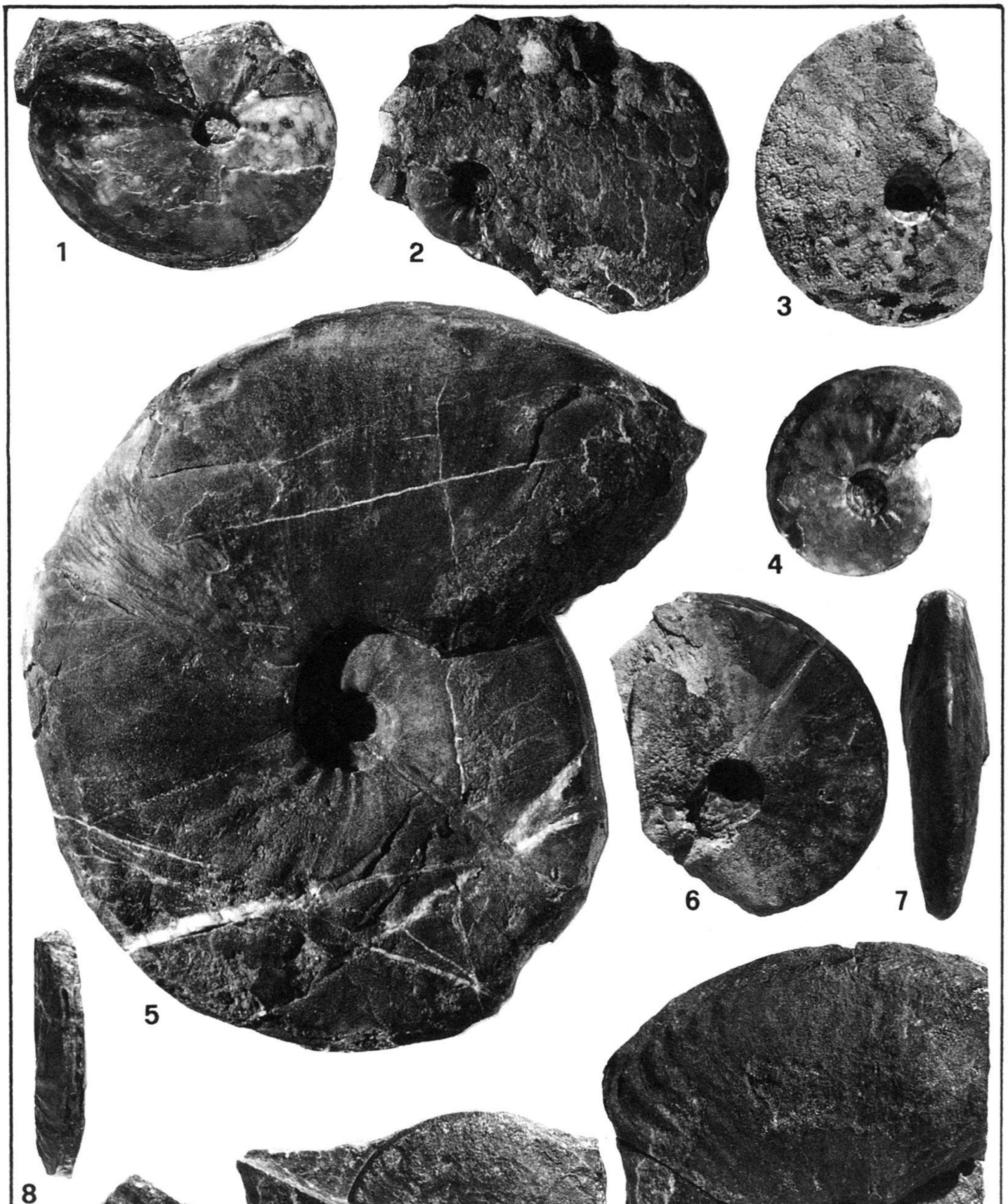

Plate 3

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Figs. 1–10:	*Parakellnerites zoniaensis* n. sp., Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/ Kellnerites Zone.
Figs. 1–2:	PIMUZ 7027, complete, adult specimen; for cross section and suture line see Figs. 15e and 16d.
Fig. 3:	PIMUZ 7028, small specimen, note the distinct ribs on the inner part of the flank.
Fig. 4:	PIMUZ 7029.
Fig. 5:	PIMUZ 7030, phragmocone; for cross section see Fig. 15f.
Figs. 6–7:	PIMUZ 7031, complete specimen; for cross section see Fig. 15g.
Figs. 8–9:	PIMUZ 7032.
Fig. 10:	Holotype, PIMUZ 7033, complete, adult specimen; for cross section see Fig. 15d.

Plate 3

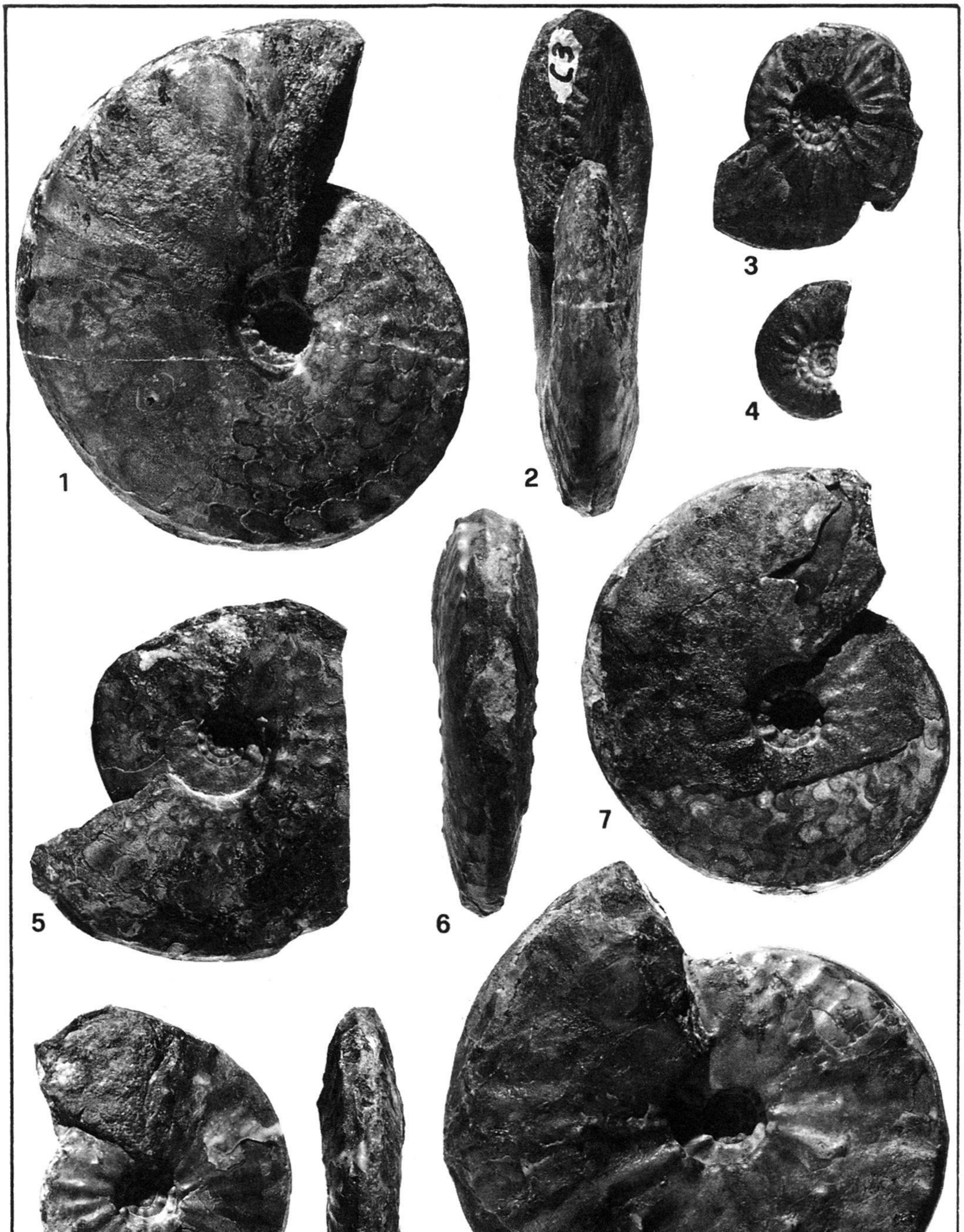

Plate 4

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Figs. 1–17: *Parakellnerites rothpletzi* (Salomon, 1895), Latemar Limestone, "Lastei di Valsorda" locality, upper part of outcrop, Reitzi/Kellnerites Zone.

Figs. 1–2: PIMUZ 7034; for cross section see Fig. 15h.

Figs. 3–4: PIMUZ 7035.

Fig. 5: PIMUZ 7036.

Fig. 6: PIMUZ 7037.

Figs. 7–8: PIMUZ 7038.

Fig. 9: PIMUZ 7039.

Fig. 10: PIMUZ 7040.

Fig. 11: PIMUZ 7041.

Figs. 12–13: PIMUZ 7042.

Fig. 14: PIMUZ 7043.

Fig. 15: PIMUZ 7044.

Figs. 16–17: PIMUZ 7045.

Fig. 18: *Parakellnerites* aff. *rothpletzi* (Salomon, 1895) and a very small *Aplococeras* sp., PIMUZ 7046, "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Fig. 19: *Parakellnerites ? waageni* (Mojs., 1882), PIMUZ 7047, cast of a mould from the Marmolada Limestone, Marmolada, note the undulated median keel.

Plate 4

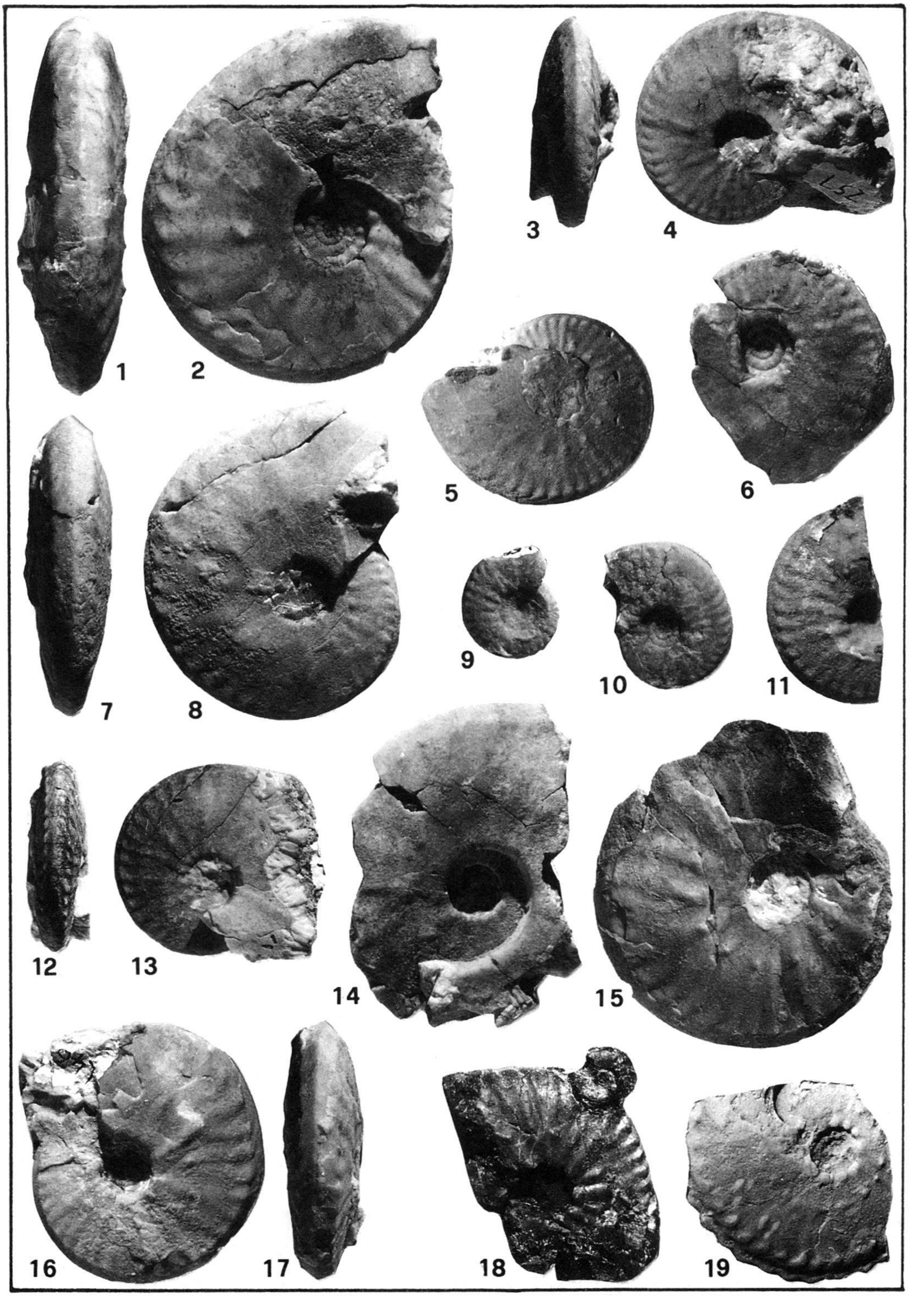

Plate 5

(all figures natural size)

Figs. 1–2: "*Hungarites*" cf. *lenis* (Hauer, 1896), PIMUZ 7048, complete specimen, Fig. 1: right side with body chamber, Fig. 2: left side anterior part of the body chamber removed, "transitional beds", 53.8 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 3–17: Ammonoids from the "transitional beds", Pèrtica, Reitzi/Kellnerites Zone; all figured specimens are preserved as siliceous pseudomorphs.

Fig. 3: *Lardaroceras* aff. *pseudohungaricum* Balini, 1992, PIMUZ 7050.

Fig. 4: *Lardaroceras* sp., PIMUZ 7054.

Fig. 5: *Lardaroceras* sp., PIMUZ 7053.

Fig. 6: Hungaritidae gen. et sp. indet., PIMUZ 7055.

Figs. 7–8: *Kellnerites bosnensis* (Hauer, 1887), PIMUZ 7059.

Fig. 9: *Kellnerites bosnensis* (Hauer, 1887), PIMUZ 7060.

Fig. 10: *Kellnerites bosnensis* (Hauer, 1887), PIMUZ 7058.

Figs. 11–12: *Lardaroceras* aff. *pseudohungaricum* Balini, 1992, PIMUZ 7049.

Figs. 13–14: *Kellnerites bosnensis* (Hauer, 1887), PIMUZ 7057.

Fig. 15: *Lardaroceras* aff. *pseudohungaricum* Balini, 1992, PIMUZ 7051.

Figs. 16–17: *Lardaroceras* aff. *krystyni* Balini, 1992, PIMUZ 7052.

Plate 5

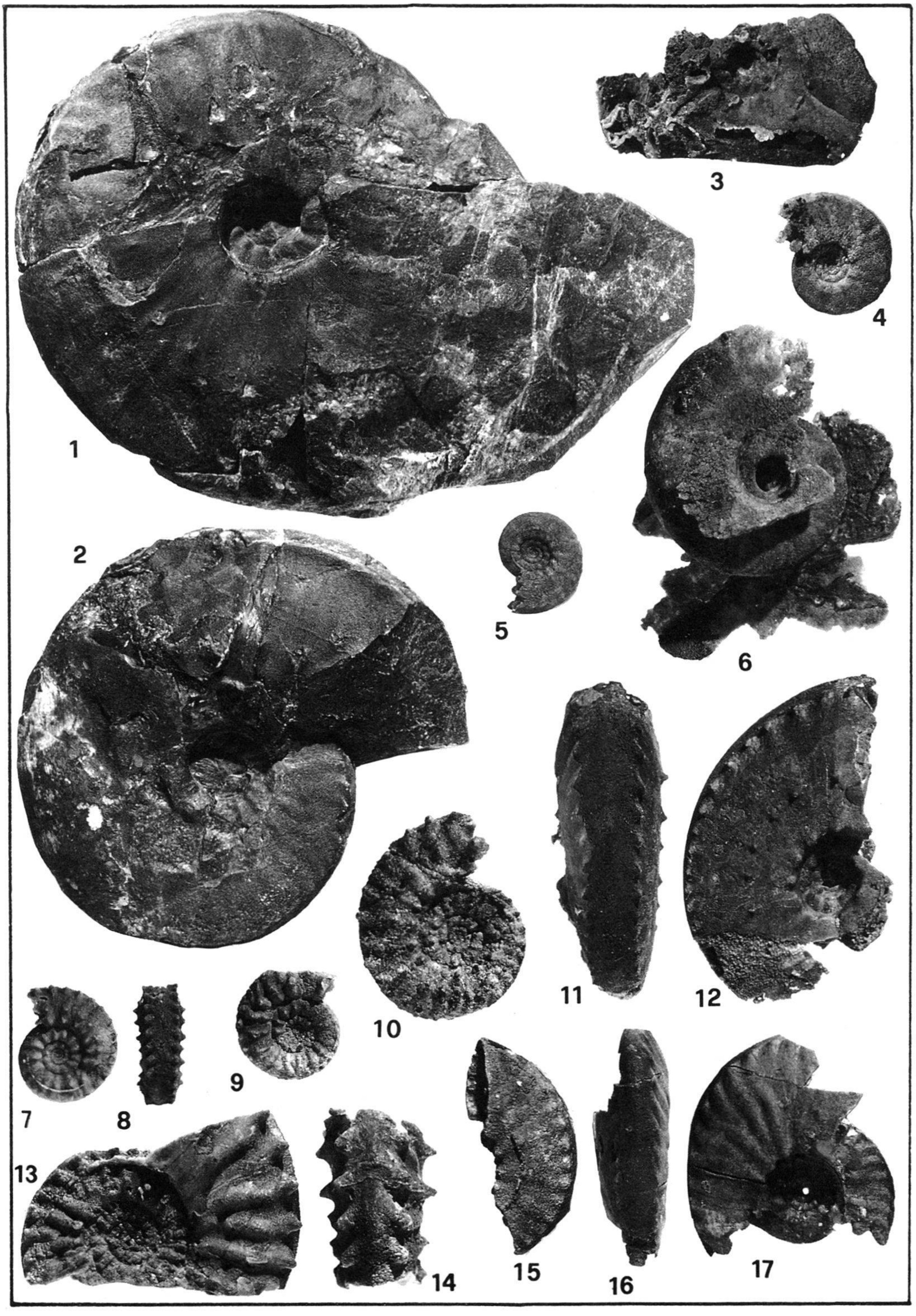

Plate 6

(all figures natural size)

Figs. 1–2: *Kellnerites bagolinensis* n. sp., holotype, PIMUZ 7061, internal mould with body chamber (180°), "transitional beds", 55.5 m, Bagolino, Reitzi/Kellnerites Zone; for cross section and suture line see Figs. 15o and 16e.

Fig. 3: *Kellnerites bagolinensis* n. sp., PIMUZ 7062, internal mould of a specimen with weak, densely arranged ribs and nodes, "transitional beds", 56.6 m, Bagolino, Reitzi/Kellnerites Zone.

Fig. 4: *Kellnerites angustecarinatus* (Hauer, 1896), PIMUZ 7065, "transitional beds", 54.25 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 5–6: *Kellnerites* cf. *ecarinatus* (Hauer, 1896), PIMUZ 7066, internal mould of the body chamber, external side without median keel, "transitional beds", 54.65 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 7–8: *Kellnerites halilucensis* (Hauer, 1896), PIMUZ 7067, internal mould, last half turn belonging to the body chamber, "transitional beds", 53.0 m, Bagolino, Reitzi/Kellnerites Zone.

Fig. 9: *Kellnerites bagolinensis* n. sp., PIMUZ 7063, internal mould of the body chamber with weak, densely arranged ribs and nodes, "transitional beds", 55.5 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 10–11: *Kellnerites bosnensis* (Hauer, 1896), PIMUZ 7068, internal mould of the body chamber and a small part of the phragmocone, "transitional beds", scree, Bagolino, Reitzi/Kellnerites Zone.

Plate 6

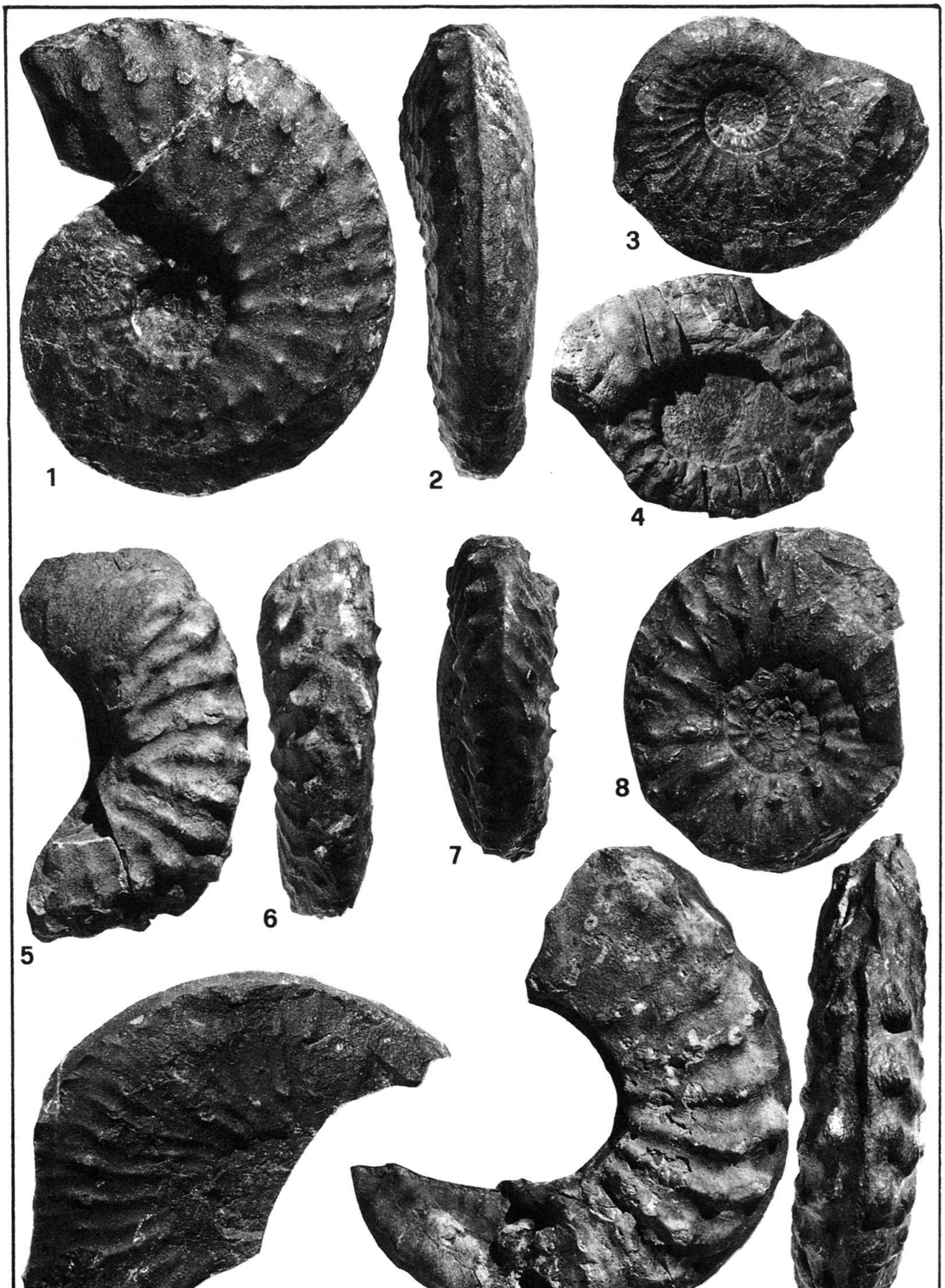

Plate 7

(all figures natural size)

Fig. 1: *Reitziites reitzi* (Böckh, 1872), PIMUZ 7097, internal mould with a part of the body chamber, "transitional beds", 56.6 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 2–3: *Kellnerites fissicostatus* (Hauer, 1896), PIMUZ 7098, "transitional beds", 54.25 m, Bagolino, Reitzi/Kellnerites Zone.

Fig. 4: *Reitziites reitzi* (Böckh, 1872), PIMUZ 7099, a little compressed internal mould, "transitional beds", Pèrtica, Reitzi/Kellnerites Zone.

Fig. 5: *Reitziites reitzi* (Böckh, 1872), PIMUZ 7100, internal mould with the body chamber, "transitional beds", 56.6 m, Bagolino, Reitzi/Kellnerites Zone; for cross section and suture line see Figs. 15s and 17e.

Figs. 6–7: *Reitziites reitzi* (Böckh, 1872), PIMUZ 7101, internal mould of the inner whorls of a finely ornamented specimen, "transitional beds", 56.6 m, Bagolino, Reitzi/Kellnerites Zone.

Plate 7

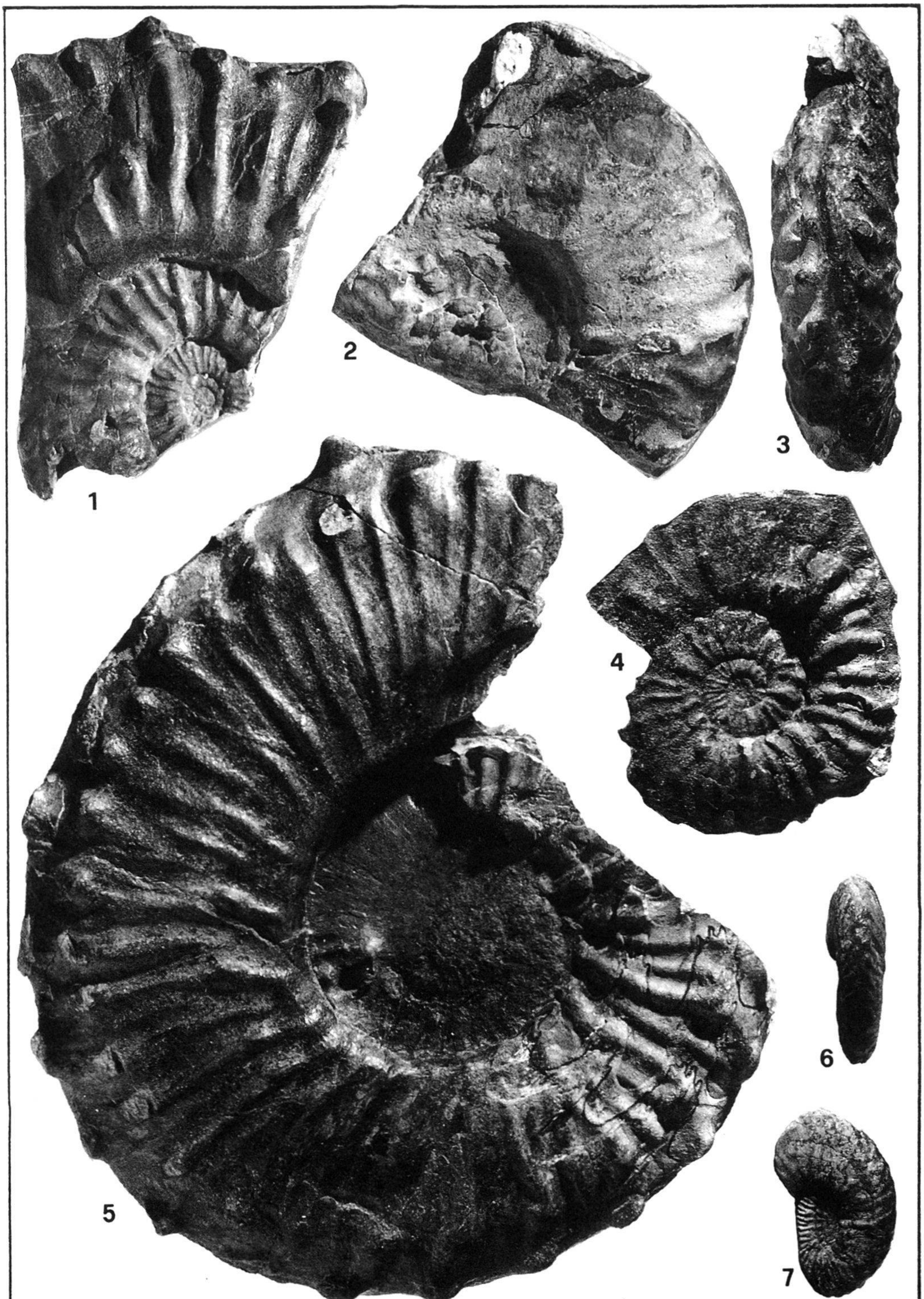

Plate 8

(all figures natural size)

Figs. 1–14: *Reitziites reitzi* (Böckh, 1872), all figured specimens are preserved as internal moulds and are from the "transitional beds" at Bagolino (Figs.: 1–5, 7–10, 13–14 from horizon, 56.6 m, and Fig. 11 from horizon 57.6 m) and Pèrtica (Figs.: 6, 12), Reitzi/Kellnerites Zone.

Fig. 1: PIMUZ 7102.

Fig. 2: PIMUZ 7104.

Figs. 3–4: PIMUZ 7103.

Fig. 5: PIMUZ 7105; for cross section see Fig. 15r.

Fig. 6: PIMUZ 7110.

Figs. 7–8: PIMUZ 7106.

Figs. 9–10: PIMUZ 7107.

Fig. 11: PIMUZ 7109.

Fig. 12: PIMUZ 7111; for suture line see Fig. 17f.

Figs. 13–14: PIMUZ 7108.

Plate 8

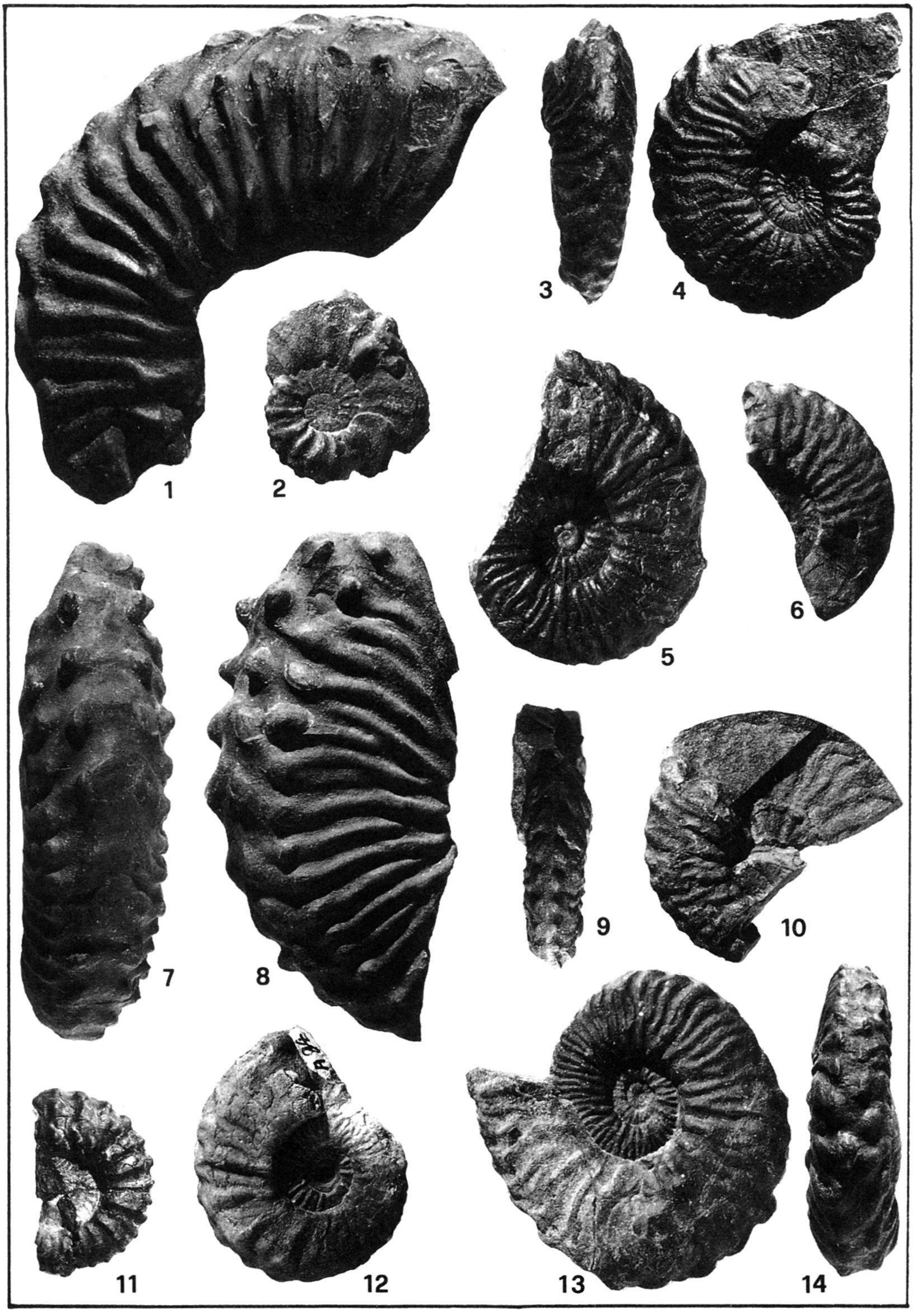

Plate 9

(all figures natural size)

Figs. 1–2: *Ticinites brescianus* n. sp., PIMUZ L/1641, internal mould of the body chamber and of a small part of the phragmocone, "Buchenstein Beds", lower "Knollenkalke", Biogno, Nevadites Zone; for cross section see Fig. 15 m.

Fig. 3: *Ticinites brescianus* n. sp., PIMUZ 7090, internal mould of the body chamber, "Buchenstein Beds", lower "Knollenkalke", Biogno, Nevadites Zone.

Fig. 4: *Ticinites dolomiticus* n. sp., holotype, PIMUZ 7092, internal mould of the right side (left side completely corroded), "Buchenstein Beds", lowermost "Knollenkalke", Seceda, Nevadites Zone; for suture line see Fig. 17 a.

Fig. 5: *Ticinites* sp., PIMUZ 7094, "Buchenstein Beds", lowermost "Knollenkalke", Seceda, Nevadites Zone.

Figs. 6–7: *Stoppaniceras evolutum* n. sp., PIMUZ 7096, internal mould of the body chamber and parts of the phragmocone, "Buchenstein Beds", lowermost "Knollenkalke", Seceda, Nevadites Zone.

Figs. 8–9: *Ticinites dolomiticus* n. sp., PIMUZ 7093, internal mould, "Buchenstein Beds", scree of the lowermost "Knollenkalke", Seceda, Nevadites Zone; for cross section see Fig. 15 n.

Fig. 10: *Stoppaniceras evolutum* n. sp., holotype, PIMUZ 7095, internal mould with body chamber, "Buchenstein Beds", lowermost "Knollenkalke", Seceda, Nevadites Zone; for cross section see Fig. 15 l.

Fig. 11: *Ticinites brescianus* n. sp., PIMUZ 7091, internal mould of a part of the body chamber, "Buchenstein Beds", lower "Knollenkalke", Prezzo, Nevadites Zone.

Plate 9

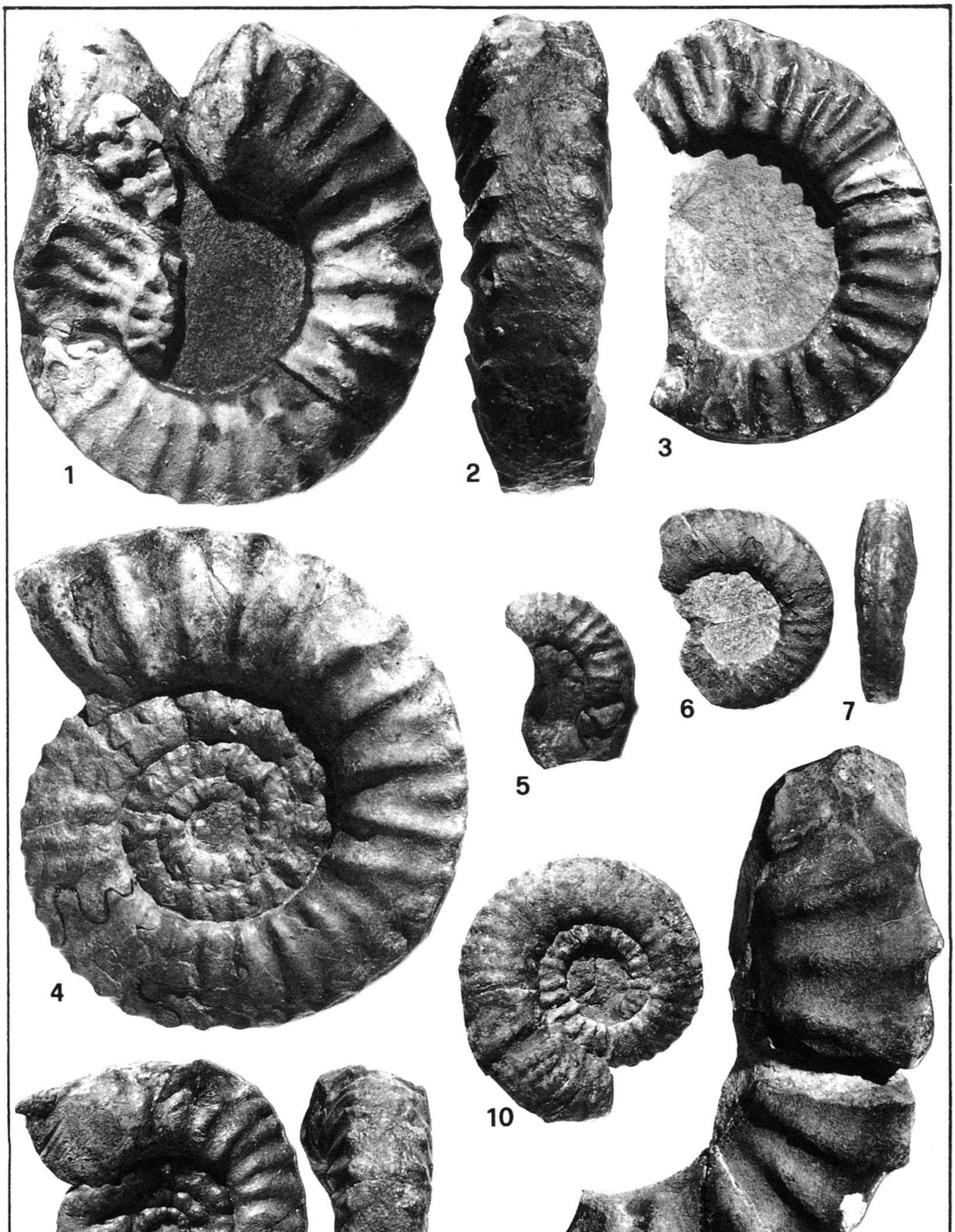

Plate 10

(all figures natural size)

Figs. 1–24: *Latemarites latemarensis* n. sp., Latemar Limestone, "Lastei di Valsorda" locality, lower part, Reitzi/Kellnerites Zone. All specimens are preserved with the shell. However, the internal mould and the shell are usually completely recrystallized. With the exception of Figs. 1–2 all figures are arranged in such a way, that the ornamentation of the specimens decreases from top to bottom.

Figs. 1–2: Holotype, PIMUZ 7069; for cross section see Fig. 15i.

Fig. 3: PIMUZ 7070.

Fig. 4: PIMUZ 7071.

Fig. 5: PIMUZ 7072.

Fig. 6: PIMUZ 7073.

Figs. 7–8: PIMUZ 7074.

Fig. 9: PIMUZ 7075.

Figs. 10–11: PIMUZ 7076.

Fig. 12: PIMUZ 7077.

Fig. 13: PIMUZ 7078.

Figs. 14–15: PIMUZ 7079.

Fig. 16: PIMUZ 7080.

Figs. 17–18: PIMUZ 7081.

Fig. 19: PIMUZ 7082.

Fig. 20: PIMUZ 7083.

Figs. 21–22: PIMUZ 7084.

Figs. 23–24: PIMUZ 7085.

Plate 10

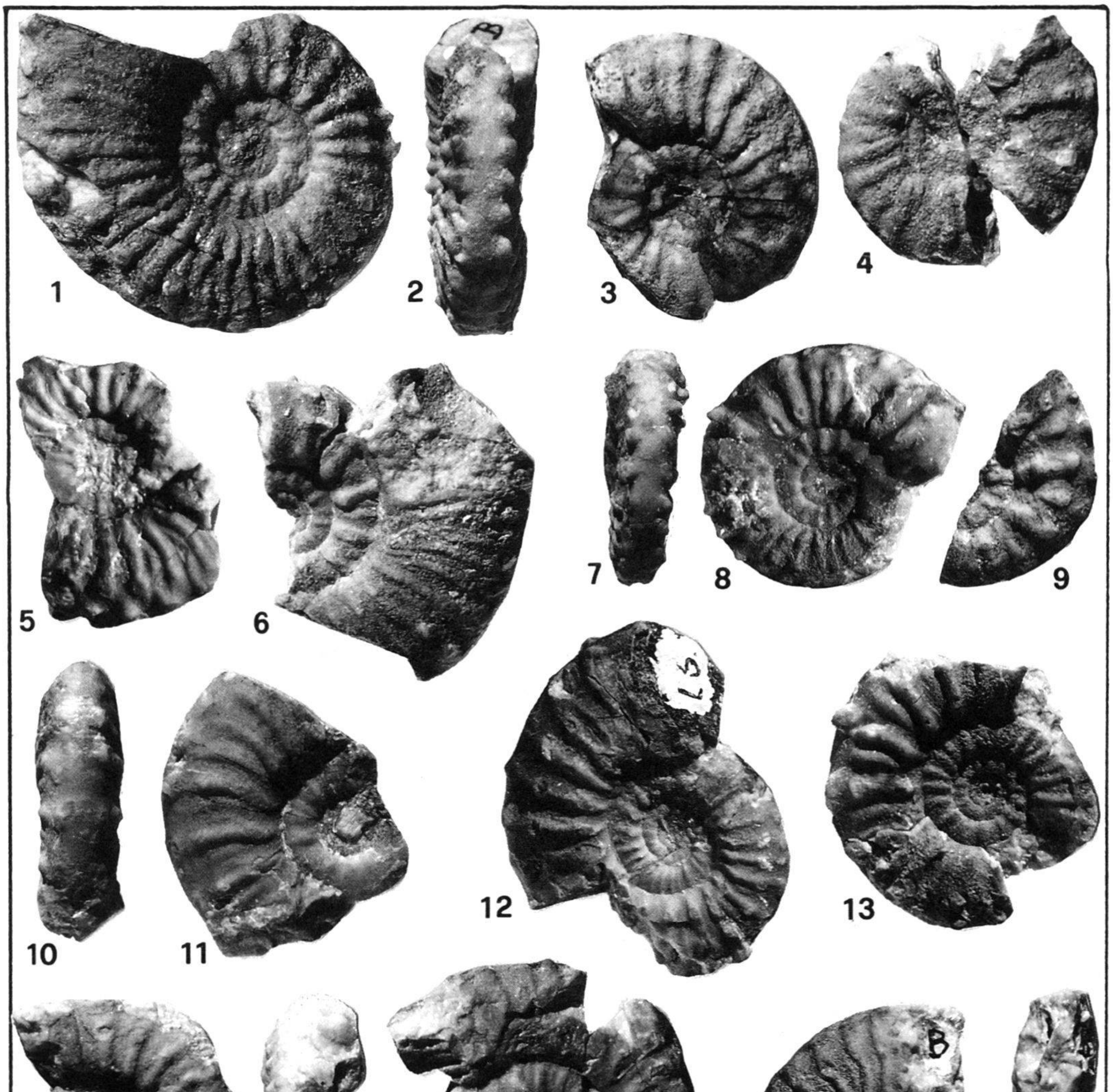

Plate 11

(all figures natural size)

Figs. 1–2: *Reitziites reitzi* (Böckh, 1872), PIMUZ 7112, very coarsely ornamented morphotype, "transitional beds", 56.6 m, Bagolino, Reitzi/Kellnerites Zone.

Fig. 3: *Reitziites reitzi* (Böckh, 1872), PIMUZ 7113, very finely ornamented morphotype, "transitional beds", 56.6 m, Bagolino, Reitzi/Kellnerites Zone.

Figs. 4–5: *Nevadites secedensis* n. sp., PIMUZ 7115, "Buchenstein Beds", lower "Knollenkalke", Seceda, Nevadites Zone.

Figs. 6–7: *Nevadites secedensis* n. sp., PIMUZ 7114, "Buchenstein Beds", lower "Knollenkalke", Seceda, Nevadites Zone; for cross section see Fig. 15q.

Fig. 8: *Nevadites secedensis* n. sp., holotype, PIMUZ 7116, internal mould of a complete specimen, "Buchenstein Beds", lower "Knollenkalke", Seceda, Nevadites Zone; for cross section see Fig. 15k.

Figs. 9–10: *Nevadites avenonensis* n. sp., PIMUZ 7118, "Buchenstein Beds", lower "Knollenkalke", Pèrtica, Nevadites Zone.

Figs. 11–12: *Nevadites avenonensis* n. sp., holotype, PIMUZ 7117, part of the body chamber, internal mould with some fragments of the shell, "Buchenstein Beds", lower "Knollenkalke", Pèrtica, Nevadites Zone.

Plate 11

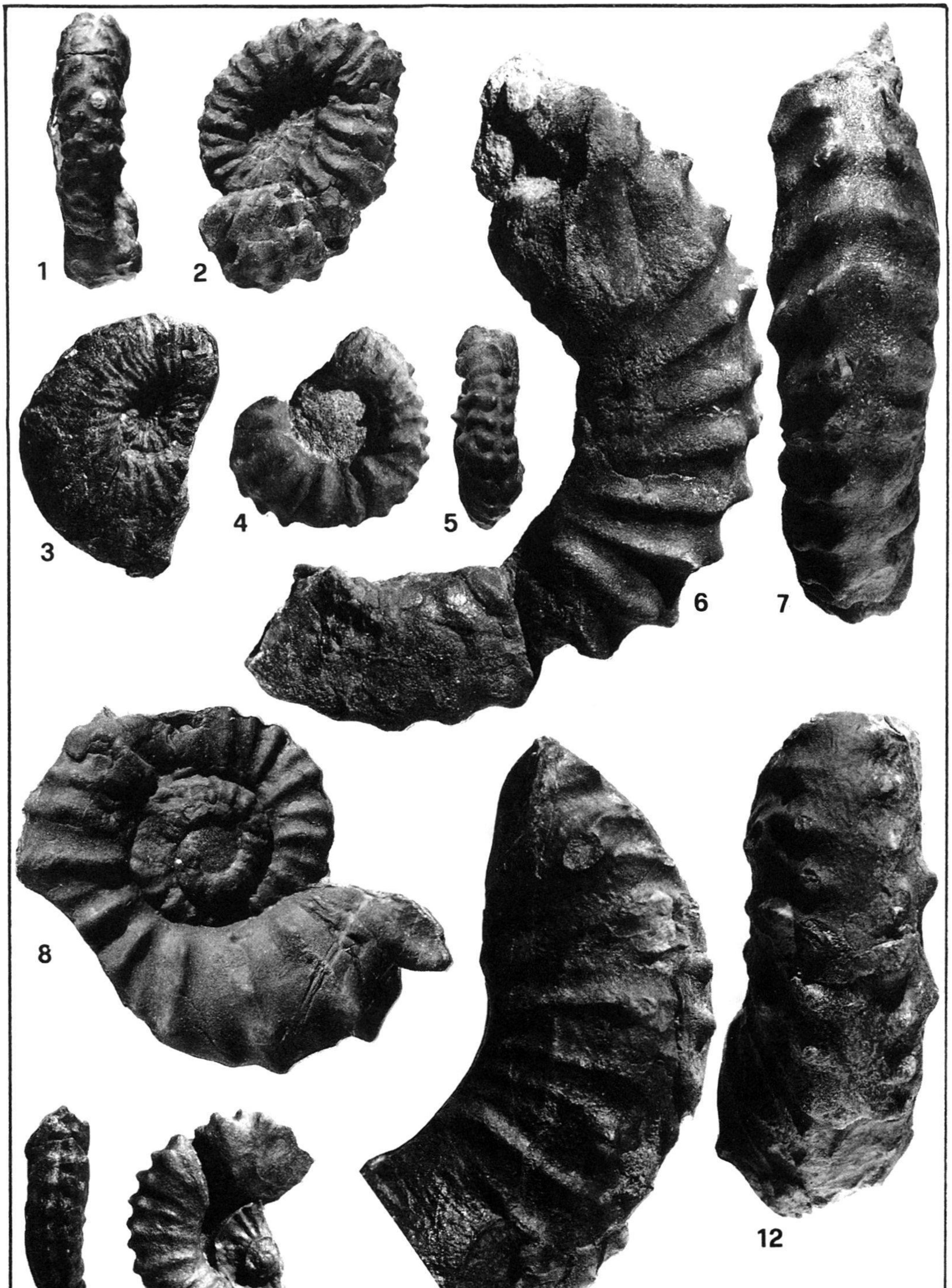

Plate 12

(all figures natural size)

Figs. 1–2: *Nevadites crassiornatus* n. sp., holotype, PIMUZ 7119, internal mould of the body chamber, "Buchenstein Beds", lower "Knollenkalke", Seceda, Nevadites Zone; for cross section see Fig. 15p.

Figs. 3–4: *Nevadites secedensis* n. sp., PIMUZ 7120, "Buchenstein Beds", lower "Knollenkalke", Seceda, Nevadites Zone.

Figs. 5–6: *Nevadites avenonensis* n. sp., PIMUZ 7121, "Buchenstein Beds", lower "Knollenkalke", Pèrtica, Nevadites Zone.

Fig. 7: *Parakellnerites arthaberi* (Diener, 1899), PIMUZ 7025, "transitional beds", 57.75 m, Bagolino, Reitzi/Kellnerites Zone; for suture line see Fig. 16f.

Fig. 8: *Nevadites secedensis* n. sp., PIMUZ 7122, "Buchenstein Beds", lower "Knollenkalke", Seceda, Nevadites Zone; for suture line see Fig. 17d.

Fig. 9: *Aplococeras avisianum* (Mojs., 1882), PIMUZ 7123, Latemar Limestone, "Lastei di Valsorda" locality, upper part, Reitzi/Kellnerites Zone.

Fig. 10: *Parakellnerites arthaberi* (Diener, 1899), PIMUZ 7026, "transitional beds", 57.75 m, Bagolino, Reitzi/Kellnerites Zone.

Fig. 11: *Aplococeras avisianum* (Mojs., 1882), PIMUZ 7124, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Fig. 12: *Aplococeras avisianum* (Mojs., 1882), PIMUZ 7125, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone; for suture line see Fig. 17c.

Plate 12

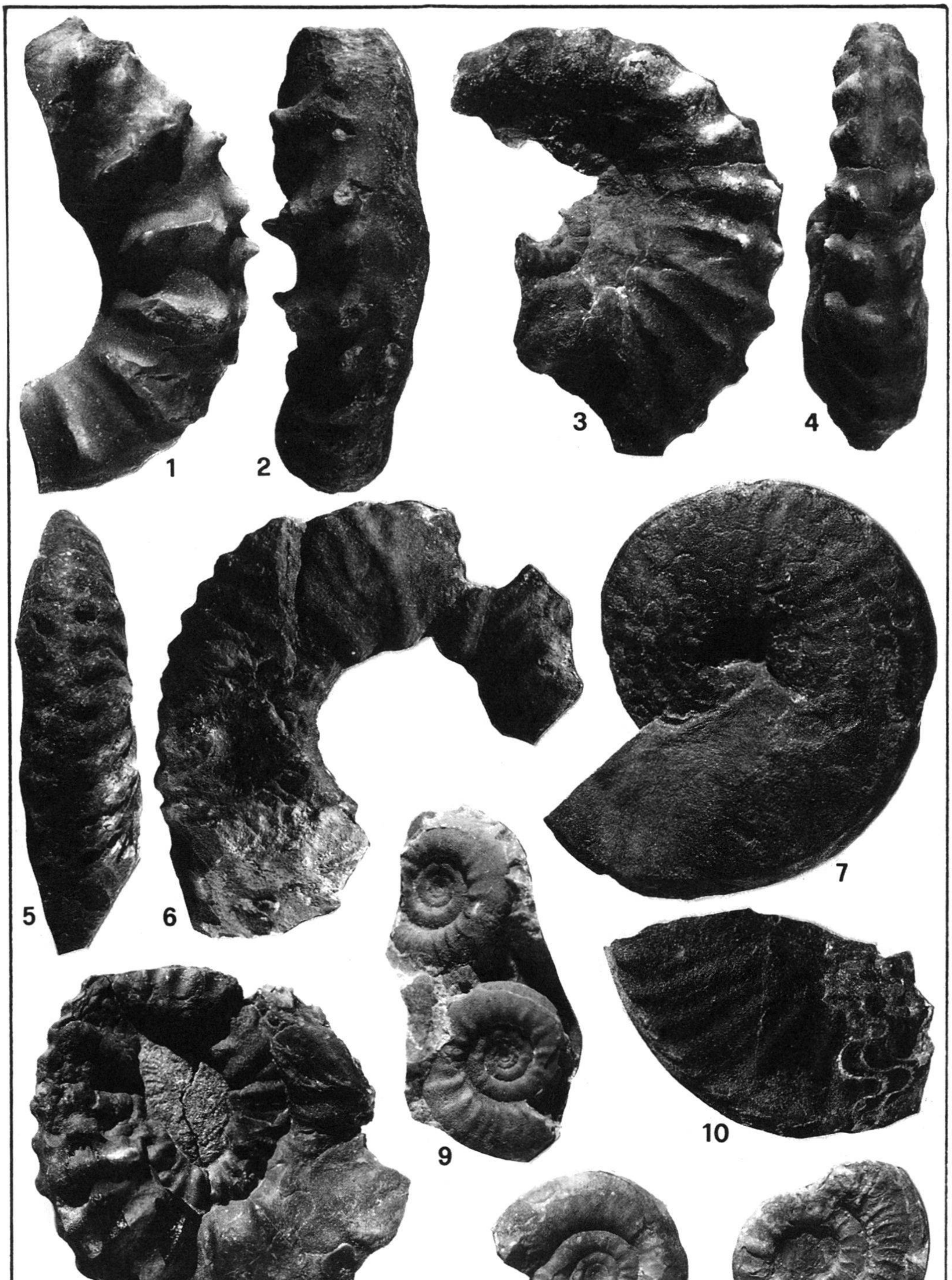

Plate 13

(all figures natural size)

Fig. 1: *Protrachyceras steinmanni* (Mojs., 1882), PIMUZ 7126, internal mould of the body chamber, "Buchenstein Beds", upper "Knollenkalke", Monte Corona, Gredleri or Archelaus Zone.

Figs. 2–3: *Protrachyceras archelaus* (Laube, 1869), PIMUZ 7133, "Wengen Beds", Monte Corona, Archelaus Zone.

Fig. 4: *Protrachyceras steinmanni* (Mojs., 1882), PIMUZ 7128, "Buchenstein Beds", upper "Knollenkalke", Monte Corona, Gredleri or Archelaus Zone.

Fig. 5: *Protrachyceras steinmanni* (Mojs., 1882), PIMUZ 7127, "Buchenstein Beds", upper "Knollenkalke", Bagolino, 79.25 m, Gredleri Zone; for suture line see Fig. 17g.

Fig. 6: *(Eo-)Protrachyceras margaritosum* (Mojs., 1882), PIMUZ 7129, internal mould of the body chamber, "Buchenstein Beds", "Knollenkalke", Bagolino, 68.75 m, Curionii or Gredleri Zone.

Fig. 7: *(Eo-)Protrachyceras margaritosum* (Mojs., 1882), PIMUZ 7130, "Buchenstein Beds", scree of "Knollenkalke", Val Gola, Curionii or Gredleri Zone; for suture line see Fig. 17h.

Figs. 8–9: *Protrachyceras gortanii* Pisa, 1966, morphotype *nodato*, PIMUZ 7132, internal mould of the body chamber, "Buchenstein Beds", "Knollenkalke", Seceda, Gredleri Zone.

Plate 13

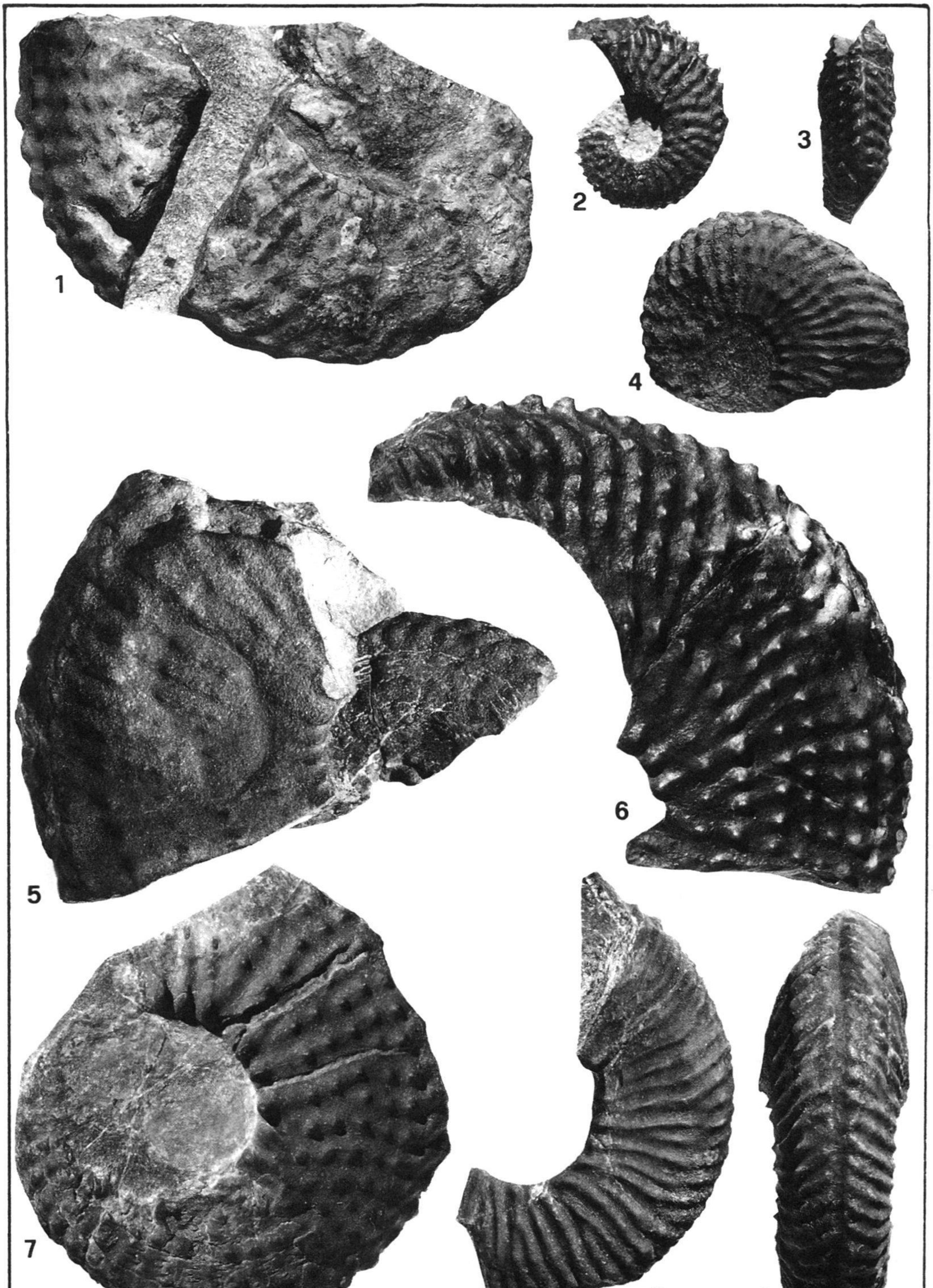

Plate 14

Figs.: 1–4, 6–7, 9–10, 13–14, 17, 19 natural size, and Figs.: 5, 8, 11–12, 15–16, 18 twice natural size.

Fig. 1: *Daonella pichleri* (Gümbel, 1861), PIMUZ 7134, "Buchenstein Beds", "Upper Bänderkalke", Seceda, Gredleri or Archelaus Zone.

Fig. 2: *Daonella pichleri* (Gümbel, 1861), PIMUZ 7135, "Buchenstein Beds", "Upper Bänderkalke", Seceda, Gredleri or Archelaus Zone.

Fig. 3: *Daonella pichleri* (Gümbel, 1861), PIMUZ 7136, "Buchenstein Beds", upper "Knollenkalke", Monte Corona, Gredleri or Archelaus Zone.

Fig. 4: *Daonella (Longidaonella) elongata* Mojs., 1874, PIMUZ 7137, "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Figs. 5–6: *Daonella sotschiadensis* n. sp., holotype, PIMUZ 7138, "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Fig. 7: *Daonella (Longidaonella) angulata* Rieber, 1968, PIMUZ 7139, "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Figs. 8–9: *Daonella cerneraensis* n. sp., PIMUZ 7140, cast of silicon rubber, "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Fig. 10: *Daonella (Longidaonella) serpianensis* Rieber, 1968, PIMUZ 7141, "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Fig. 11: *Daonella cerneraensis* n. sp., holotype, PIMUZ 7142, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Fig. 12: *Daonella cerneraensis* n. sp., PIMUZ 7143, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Fig. 13: Slab with *Daonella cerneraensis* n. sp., PIMUZ 7142 (Fig. 11, holotype) and 7143 (Fig. 12).

Figs. 14–15: *Daonella cerneraensis* n. sp., PIMUZ 7144, "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Fig. 16: *Daonella cerneraensis* n. sp., PIMUZ 7145 (Fig. 19), "Buchenstein Beds", "Lower Plattenkalke", Seceda, Reitzi/Kellnerites Zone.

Figs. 17–18: Slab with *Daonella cerneraensis* n. sp., PIMUZ 7146, Marmolada Limestone, Punta di Zonia, lower horizon, Reitzi/Kellnerites Zone.

Fig. 19: *Daonella cerneraensis* n. sp., PIMUZ 7145 (Fig. 16).

Plate 14