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Autor: Brack, Peter / Rieber, Hans

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Stratigraphy and Ammonoids of the lower Buchenstein Beds of the Brescian Prealps and Giudicarie and their significance for the Anisian/Ladinian boundary

By PETER BRACK[1]) and HANS RIEBER[2])

ZUSAMMENFASSUNG

Ausgehend von dem vollständigen, fossilführenden Mitteltriasprofil von Bagolino (Romanterra), werden mehrere stratigraphische Profile der unteren Buchensteiner Schichten beschrieben. Charakteristische Abfolgen vulkanoklastischer Lagen und Fossilinhalt (Ammonoideen) ermöglichen eine Gliederung und Korrelation der untersuchten Profile und weisen auf ein gleichförmiges, pelagisches Ablagerungsmilieu hin.

Das in allen Profilen festgestellte *Trachyceras chiesense* MOJS., für das die Gattung *Chieseiceras* eingeführt wird, erlaubt deren Verbindung mit anderen Anis/Ladin-Grenzprofilen der Südalpen (Grenzbitumenzone des Monte San Giorgio; Val Gola).

Die wichtigsten Ammonoideen der untersuchten Profile werden beschrieben, darunter *Chieseiceras pèrticaense* n.sp. Aus der zeitlichen Verteilung der Ammonoideen geht hervor, dass das Einsetzen von *Eoprotrachyceras curionii* einen einschneidenden Faunenwechsel markiert. Deshalb wird vorgeschlagen, die Anis/Ladin-Grenze mit der Grenze zwischen der Reitzi- (Nevadites-Z.) und der Curionii-Zone gleichzusetzen.

Verfügbare absolute Altersdaten aus mitteltriassischen Vulkanoklastika der Südalpen lassen sich auf die untersuchten Profile im Anis/Ladin-Grenzbereich übertragen.

ABSTRACT

Following an illustration of the complete stratigraphic section of the Middle Triassic at Bagolino (Romanterra), several stratigraphic columns of the lower Buchenstein Beds (Livinallongo Formation) are described. The characteristic sequences of volcanoclastics and fossils (ammonoids) permit a subdivision and correlation of the investigated profiles, and indicate an extensive, uniform pelagic sedimentary environment.

A new genus, *Chieseiceras,* is defined on the basis of *Trachyceras chiesense* MOJS. This latter has been found in all stratigraphic sections of the Brescian Prealps and Giudicarie and enables a comparison with other Southern Alpine sequences ("Grenzbitumenzone" Monte San Giorgio; Val Gola) straddling the Anisian/Ladinian boundary.

A description of the most important ammonoid finds is given, including *Chieseiceras pèrticaense* n.sp. The temporal distribution of ammonoids suggests a notable faunal change corresponding to the appearance of *Eoprotrachyceras curionii* and therefore, a correlation of the Anisian/Ladinian boundary with that between the Reitzi (Nevadites) and the Curionii Zones is proposed.

Available absolute radiometric age determinations of the Middle Triassic volcanoclastic layers of the Southern Alps are correlated with the studied Anisian/Ladinian boundary sections.

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[1]) Istituto di Geologia, Paleontologia e Geologia applicata dell'Università, Via Giotto 1, I–35100 Padova.

[2]) Paläontologisches Institut und Museum der Universität, Künstlergasse 16, CH–8006 Zürich (Switzerland).

RIASSUNTO

Dopo un'illustrazione della sezione stratigrafica completa del Triassico medio di Bagolino (Romanterra) vengono descritte diverse colonne stratigrafiche della parte inferiore degli Strati di Buchenstein (Formazione di Livinallongo). La successione dei livelli vulcanoclastici ed il contenuto faunistico (ammonoidi) permettono una suddivisione e correlazione tra le sezioni studiate ed indicano un ambiente di deposizione pelagico uniforme.

Viene istituito il nuovo genere *Chieseiceras* (= *Trachyceras chiesense* MOJS.); la sua presenza in tutte sezioni delle Prealpi Bresciane e delle Giudicarie consente un confronto con altre successioni sudalpine al limite Anisico/Ladinico («Grenzbitumenzone» del M.te San Giorgio; Val Gola).

Dalla distribuzione temporale degli ammonoidi si può notare un notevole cambiamento faunistico in corrispondenza alla comparsa di *Eoprotrachycears curionii*. Si propone perciò la correlazione del limite Anisico/Ladinico con il limite tra la Zona a reitzi (o a Nevadites) e la Zona a curionii.

Vengono infine confrontate datazioni radiometriche eseguite su livelli vulcanoclastici mediotriassici del Sudalpino con le sezioni studiate.

1. Introduction

The base of the Ladinian Stage and therefore, the Anisian/Ladinian boundary has been correlated with the base of the Buchenstein Beds, or has at least been related to this formation since BITTNER (1892, p. 392) proposed the term "ladinisch" (Ladinian) for the Buchenstein and Wengen Beds and, if necessary, also for the St. Cassian Beds.

The Buchenstein Beds were originally considered as a lithostratigraphic unit. In contrast to the original definition of the Buchenstein Beds by RICHTHOFEN (1860, p. 45 and 64), MOJSISOVICS (1879, p. 52ff.) extended the term to include the associated so-called "Bänderkalke". MOJSISOVICS also correlated (p. 79) the Buchenstein Beds with the Zone of *Trachyceras Reitzi* and *Curionii* and included in his list of fossils of the above formation those which BÖCKH (1873, 1874) had described from the "beds with *Ceratites Reitzi*" at Bakony (Hungary). Following MOJSISOVICS (1879) the Buchenstein Beds were effectively treated as a chronostratigraphical unit and as an equivalent to the Zone of *Trachyceras Reitzi* and/or the Zone of *Trachyceras Curionii*[3]), though there was no agreement on the stratigraphic limits of the formation. Obviously BITTNER was of the same opinion when he introduced the term Ladinian in 1892.

Subsequent studies of the Buchenstein Beds led to different results. Based on fossil content and lithology HORN (1914) distinguished three major divisions within the Buchenstein Beds (his so called "ladinische Knollenkalke"). According to HORN the base of the Buchenstein Beds is not everywhere of the same age within the Dolomites, and the formation may be partly or fully replaced by carbonate platform sediments or, at higher levels, also by volcanics. The idea that the "Buchensteiner Knollenkalke" are not only a facies but also a chronological unit was restated by HUMMEL (1932), and he regarded the widespread volcanoclastic sediments (Pietra verde) as even better indicators of time than the ammonoids.

More recently ROSSI (1962) reviewed ideas on the Buchenstein Beds, and BACCELLE SCUDELER (1972) and VIEL (1979) proposed typesections (= Formazione di Livinallongo).

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[3]) In 1879 MOJSISOVICS stated that the Buchenstein Beds are the predominant formation characterising the Zone of *Trachyceras Reitzi* and *Curionii*. Later (1881, p. 313) he correlated, as earlier suggested in 1874 (p. 36), the Buchenstein Beds with the Zone of *Trachyceras Reitzi* alone. MOJSISOVICS, WAAGEN & DIENER (1895, p. 1279) no longer mention the Reitzi Zone and put the Buchenstein Beds in the Zone of *Protrachyceras curionii*.

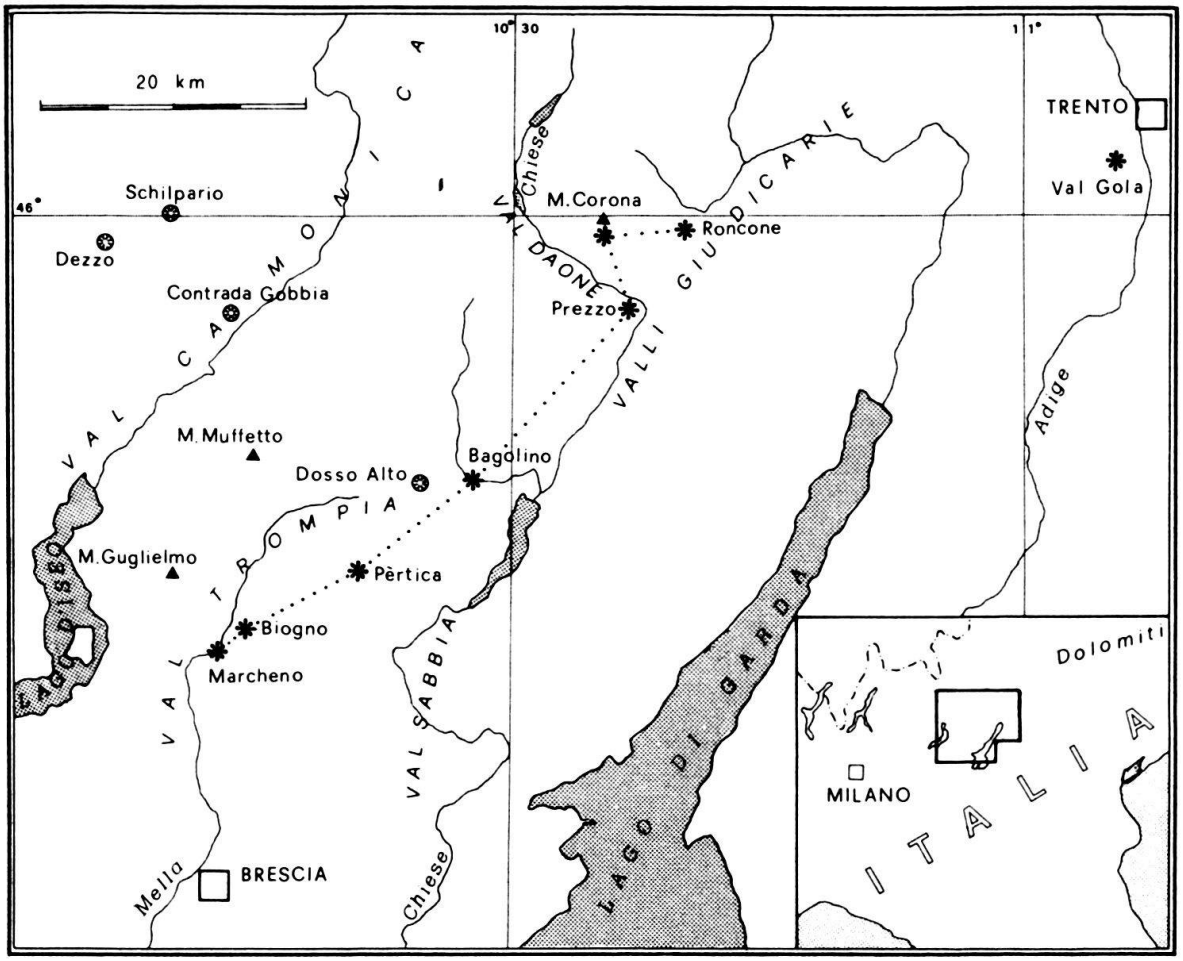

Fig. 1. Location of the area investigated showing the position of stratigraphic columns described in text (black asterisks), as well as classic Middle Triassic localities (white asterisks).

Until now the Anisian/Ladinian boundary could not be well defined in the Southern Alps, as neither the fauna of the Reitzi Zone nor the chronostratigraphic range of the Buchenstein Beds were sufficiently known. For this reason the fossiliferous sections of the Buchenstein Beds in the Brescian Prealps and Giudicarie are of special interest.

Within these sections the exact stratigraphic position of *Trachyceras chiesense* MOJS. has now been established. This species furthermore occurs in the well known, fossil-rich "Grenzbitumenzone" at Monte San Giorgio (Canton Ticino, Switzerland). After a discussion of the Buchenstein Beds in the area studied, this species is redescribed, and, in addition, a new genus *(Chieseiceras)* is introduced. On the basis of the rich fossil content of these sections the present scheme of ammonoid zonation and the position, within this scheme, of the Anisian/Ladinian boundary are reviewed.

2. The Buchenstein Beds of the Brescian Prealps and Giudicarie

2.1 Distribution and stratigraphic position

Since BITTNER (1881), the pelagic, cherty nodular limestones with volcanoclastic intercalations that are widespread throughout the eastern Lombardian Alps and Giudi-

carie, have been known as the "Buchensteiner Schichten" due to their lithologic similarity to equivalent beds in the Dolomites. Today, the same beds are also termed the "Calcare/ Formazione di Buchenstein".

The Buchenstein Beds outcrop from Giudicarie to the west along the southern margin of the Adamello Batholith, as well as in the area between Val Sabbia and Val Trompia, and further in Val Camonica and in Val di Scalve. Between Val Trompia and Giudicarie

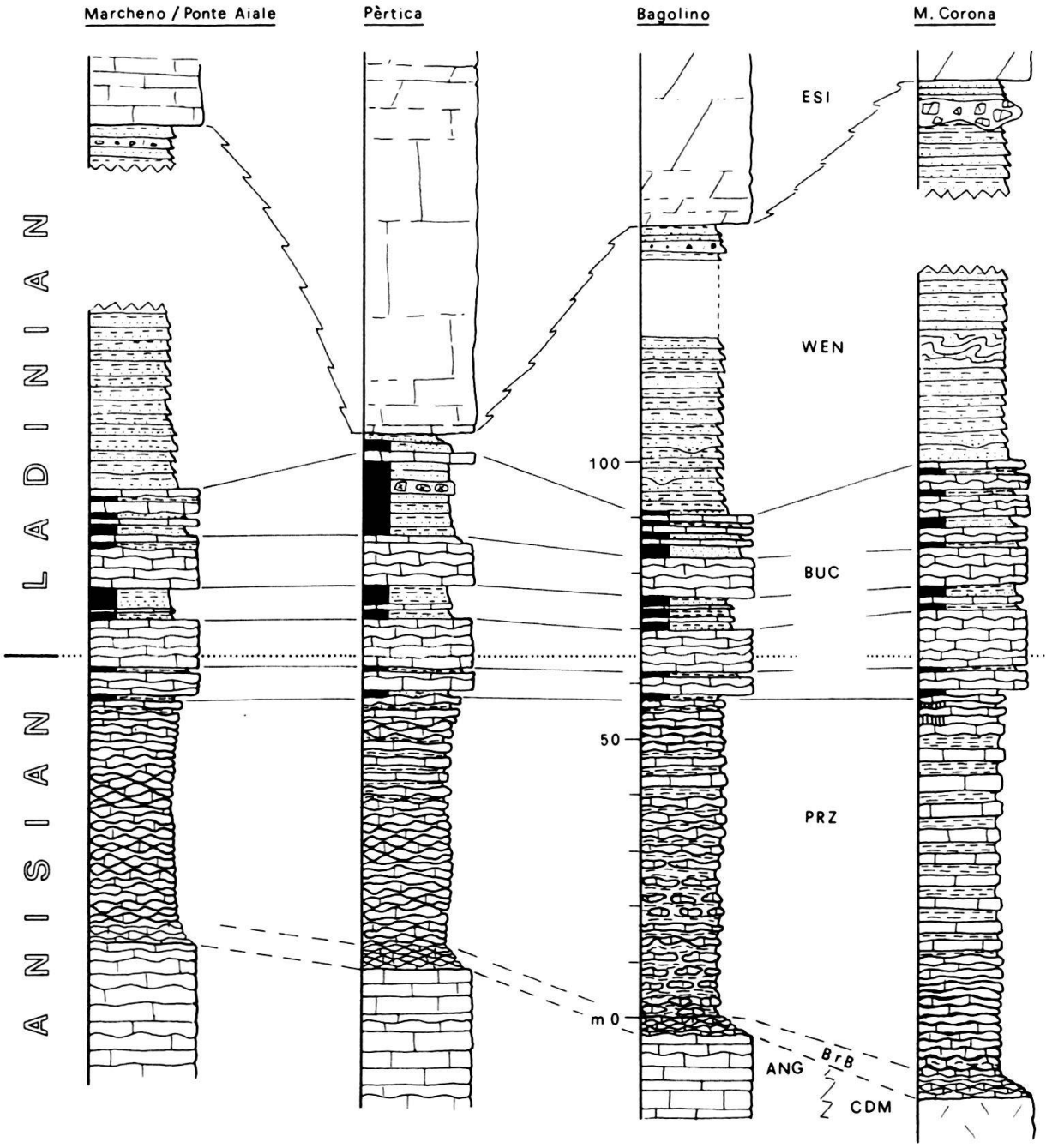

Fig. 2. Stratigraphic position of the Buchenstein Beds (BUC) and comparison of four representative columns of the Middle Triassic formations in the Brescian Prealps and Giudicarie. (Column locations are given in Fig. 1.) CDM: Dosso dei Morti limestone; ANG: Angolo limestone; BrB: Brachiopod Bed; PRZ: Prezzo limestone; WEN: Wengen Beds; ESI: Esino limestone. – Scale is indicated on the Bagolino column. Principal volcanoclastic successions are indicated by black bands.

they are exceptionally uniform and range from 35 to 45 m in thickness (Fig. 2). Only the volcanoclastic sediments show notable variation in their composition and bedding thickness. These so-called "Pietra verde" occur as a basal, middle and upper sequence, thereby dividing the nodular limestones into two main series. The uppermost Pietra verde sequence thickens rapidly from Bagolino towards the southwest and reaches a maximum between upper Val Trompia and Pèrtica where it contains coarse-grained tuffitic sandstones, conglomerates and breccias with dacitic porphyry components. Rocks comparable to these porphyries presently outcrop at Monte Muffetto to the north of Val Trompia as subvolcanic intrusives (laccoliths and stocks hosted by Permian and Lower Triassic sediments). Their radiometric data are discussed below. "Bänder- und Plattenkalke", typical of the Buchenstein Beds in the Dolomites, appear only as minor members within a thin series, that is transitional to the Prezzo Limestone.

Further afield the Buchenstein Beds are similarly developed in Val Camonica, whereas to the northwest, on Pizzo Camino (south of Schilpario) banded limestones and tuffs replace the entire upper nodular limestone series. In the middle Val Sabbia (south of Nozza; BITTNER 1883) the Buchenstein Beds abruptly disappear but for reasons as yet unknown. Northwest of Giudicarie they outcrop only as sporadic lenses, being replaced by Ladinian carbonates (EPTING et al. 1976; PELOSIO & VERCESI 1982).

Thick, evenly-bedded, pelagic limestone-shale intercalations of the Prezzo Limestone underlie the Buchenstein Beds at Giudicarie and Bagolino, and grade towards the southwest into coarsely-nodular limestones (Fig. 2). The overlying sediments comprise the siliciclastic turbidites and shales of the Wengen Beds, carbonate basin sediments and platform carbonates (Esino Limestone).

Detailed descriptions of the general paleogeographic evolution of the Brescian Alps during the Anisian and Ladinian stages have been presented by ASSERETO & CASATI (1965), EPTING et al. (1976), CASATI & GAETANI (1979).

2.2 Relative age of the Buchenstein Beds

The stratigraphic position of the Buchenstein Beds is bracketed below by the fossiliferous upper Anisian Prezzo Limestone (Trinodosus Zone, see ASSERETO 1963, 1971; GAETANI 1969) below, and by the middle to upper Ladinian Wengen Beds above. A relatively rich ammonoid fauna from the Buchenstein Beds themselves has been reported by MOJSISOVICS (1880, 1882), BITTNER (1881, 1883), ARTHABER (1896), HORN (1913, 1914) and BONI (1943). Most of this fauna comes from the classic localities near Prezzo and Marcheno but it lacks detailed stratigraphic control. Only HORN (1913, 1914) distinguished "three faunistically distinct stages" in the cherty nodular limestones of Val Trompia.

The unfavourable outcrop relations of the Buchenstein Beds at the above localities (folds and small thrusts at Marcheno and surroundings; faults and slips at Prezzo), however, necessitate a revision of HORN's stratigraphic conclusions, especially in view of his overestimated bed thicknesses (75–80 m versus 35–45 m in reality). Well-exposed, fossil-rich and continuous Buchenstein sections are unfortunately quite rare. The bedding sequences are often highly tectonized and the transition to the Prezzo Limestone is mostly hidden by detritus accumulated on the gentler slopes at the base of the Buchenstein cliffs. Clearly exposed sections are found on Monte Corona (Dosso dei Morti area; Fig. 3) but

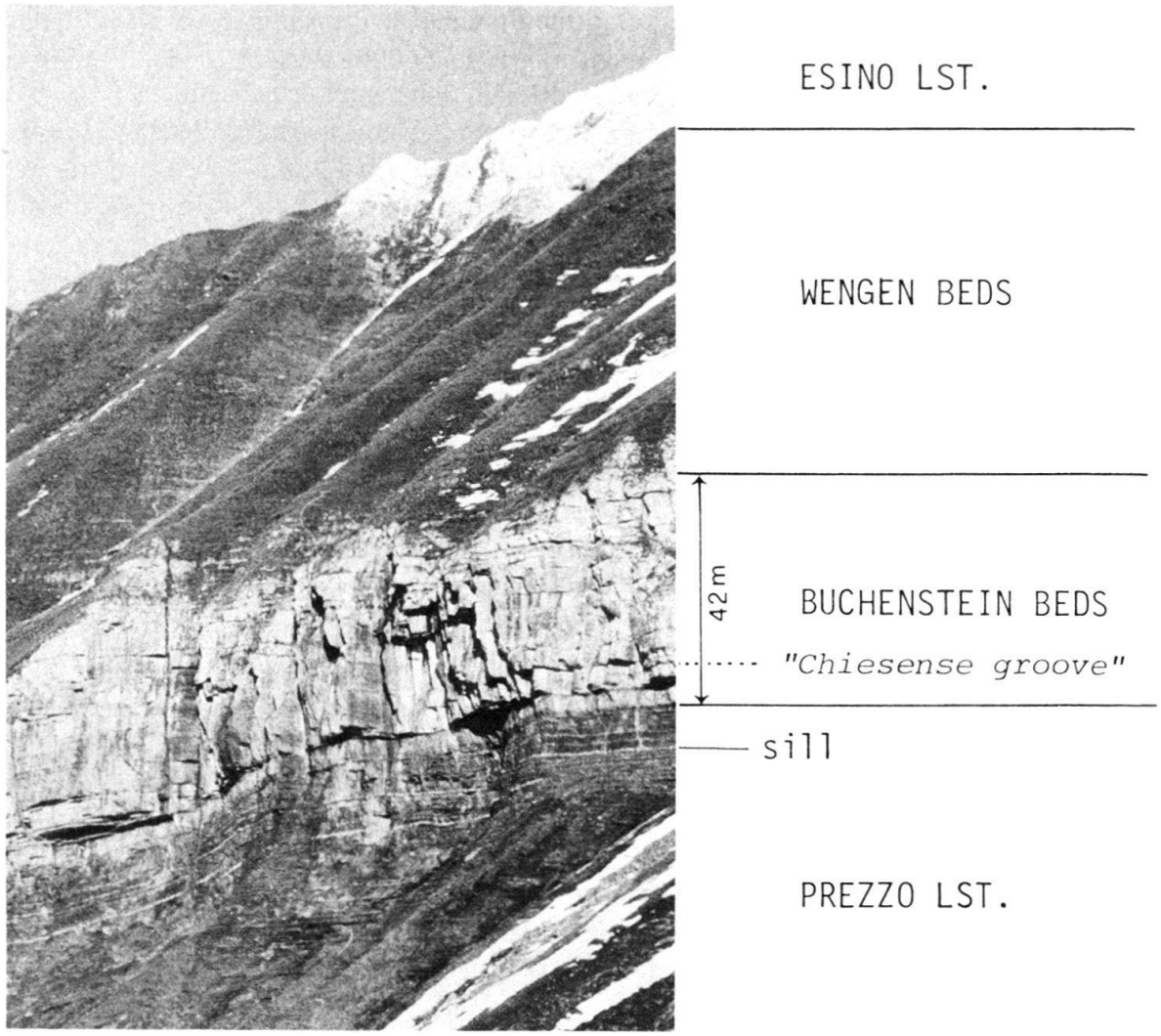

Fig. 3. View of the upper Anisian/Ladinian formations on the western flank of Monte Corona (Giudicarie) crosscut by subhorizontal porphyritic sills of possibly Triassic age. Figure 6 shows a detailed picture of the lower Buchenstein Beds at a nearby locality.

due to pronounced weathering of the carbonate nodules any ammonoids present are generally unrecognizable.

During recording of the Middle Triassic stratigraphic section at Bagolino (Fig. 4), BRACK (1984) collected several ammonoids directly out of their host beds. Since radiometric age determinations of Pietra verde horizons in the nearby Val Trompia are now available (CRISCI et al. 1984, see discussion below), and because HUMMEL (1933, p. 434) pointed out that such layers are moreover well-suited "to check the constancy of ammonoid distribution" (with respect to time), an attempt has been made here to correlate the Bagolino stratigraphic section with other Buchenstein sequences in the Brescian Alps and Giudicarie. At the same time it was possible to considerably expand the collection of fauna from the lowermost Buchenstein Beds close to the Anisian–Ladinian boundary, so that to date, over 200 stratigraphically significant ammonoid samples are available.

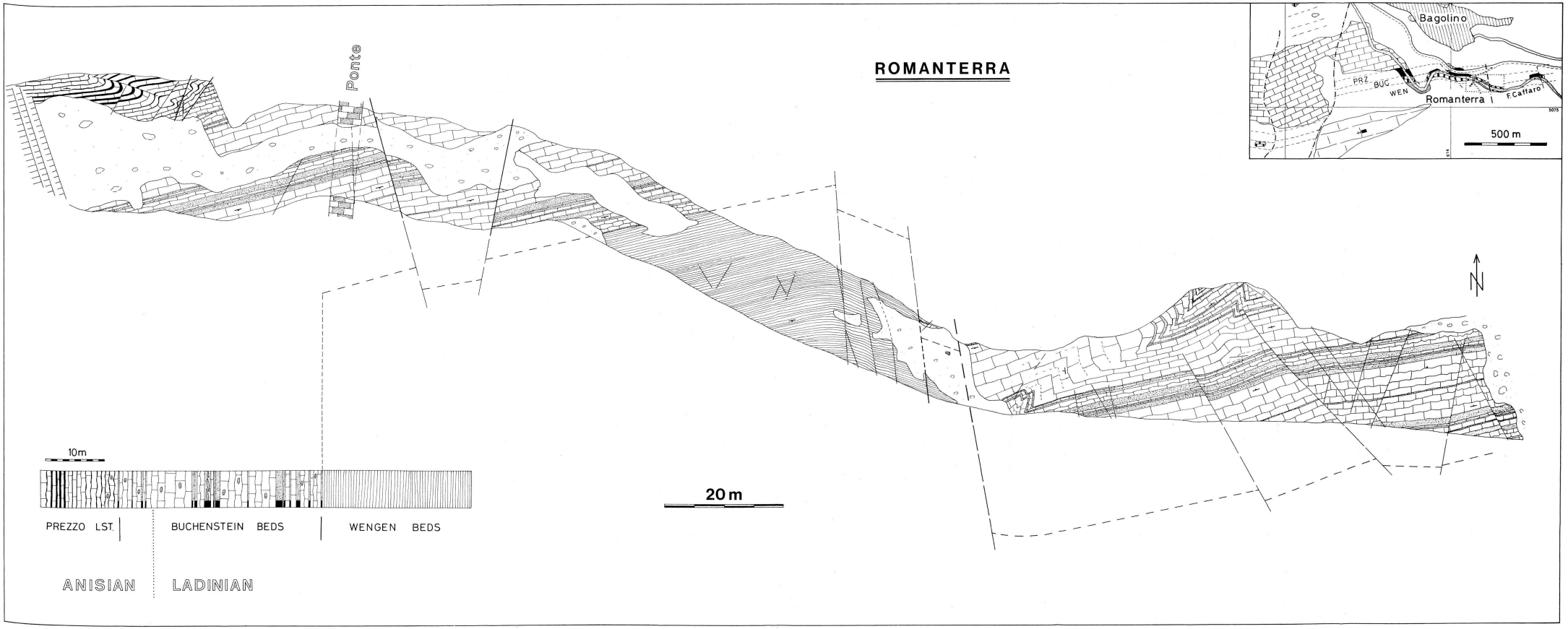

Fig. 4. Geological map of the steeply dipping strata in the Romanterra outcrop (Caffaro riverbed) south of Bagolino with a simplified reconstructed stratigraphy indicating the proposed Anisian/Ladinian boundary («Chiesense groove»).

3. The Middle Triassic section at Bagolino (Fig. 5)

The Buchenstein Beds below the Romanterra Bridge south of Bagolino (Fig. 4) were discovered by BITTNER (1881), but only MARIANI (1906) has documented an ammonoid find from this locality.

Characteristic volcanogenic sequences of the Pietra verde in the dry riverbed served as the necessary marker horizons to reconstruct a continuous stratigraphic section of the faulted, generally subvertical Buchenstein Beds (river water submerges the section between April and June). Further outcrops along the Caffaro River both to the east and west permitted expansion of the fossiliferous section to one of the most complete, well-exposed and accessible stratigraphic columns of the Middle Triassic in eastern Lombardy (Fig. 5). In contrast, the classic section on the north ridge of Dosso Alto (LEPSIUS 1878; MOJSISOVICS 1880; BITTNER 1881, 1883; SALOMON 1908–1910; ROSENBERG 1958) only 4 km to the west of Romanterra remains obscured in many places.

3.1 Short description of lithologies in the stratigraphic section

A detailed sedimentological description of the Buchenstein Beds will be the subject of a future paper.

The Angolo Limestone is an irregularly-bedded, often highly bioturbated and nodular light-grey limestone that is poor in fossils but contains intercalations up to several meters thick of Crinoidal sandstones (total thickness > 450 m). It is overlain by a bed 3.5 m thick that contains two major accumulations of brachiopods, both whole or fragmented and frequently showing geopetal filling. This "Banco a Brachiopodi" (earlier known as the Ponte di Cimego Level) or its immediately overlying beds also contain ammonoids at Monte Guglielmo, west of Val Trompia and at Giudicarie (e.g. GAETANI 1969).

Above the brachiopod bed (top = 0 m level on column) the clay fraction rapidly increases and coarsely-nodular, pelagic micrites pass into progressively more evenly-bedded, alternating mudstones and limestones (Calcare di Prezzo). These lithologies are occasionally rich in pyrite and contain several calcarenite and turbidite beds. In addition to vertebrate fragments (mainly fish scales and ichthyosaur bones) the Prezzo Limestone hosts a classic fauna of the Trinodosus Zone (from 35 to 47 m on the column). Above the 48-m level the beds become more nodular again and then from about 55 m silicification and radiolarians appear, together within beige-grey illite layers (Ta on the column in Fig. 7; ?ash tuffs) and the lowermost Pietra verde horizons.

The succeeding beds with their higher clay and fine-grained volcanoclastic components (Fig. 7, Monte Corona Section) are reminiscent of the lower "Bänderkalke" of the Buchenstein Beds in the Dolomites, although they never reach comparable regularity[4]).

[4]) The boundary between the Prezzo Limestone and the Buchenstein Beds has traditionally been taken as the first occurrence of chert nodules. With respect to the Bagolino section we prefer to draw the limit at the base of the compact nodular limestones, i.e. at the 58-m level (Fig. 2, 4, 5). Although the underlying cherty limestones and mixed clay/tuff layers may resemble the lower "Bänderkalke" of the Dolomites, these lithologies can still be considered as part of the Prezzo limestone facies. A distinct lithological change is visible only at the top of these transitional beds which may reach a few meters in thickness (Fig. 3; note that in GAETANI 1969, Fig. 13, the above-mentioned strata have been ascribed to the Buchenstein Formation). An alternative definition of the lower boundary of the Buchenstein Beds as the first occurrence of volcanoclastic layers is uncertain however, because possible volcanic derivates may already appear much lower in the stratigraphic column but in typical Prezzo Limestone.

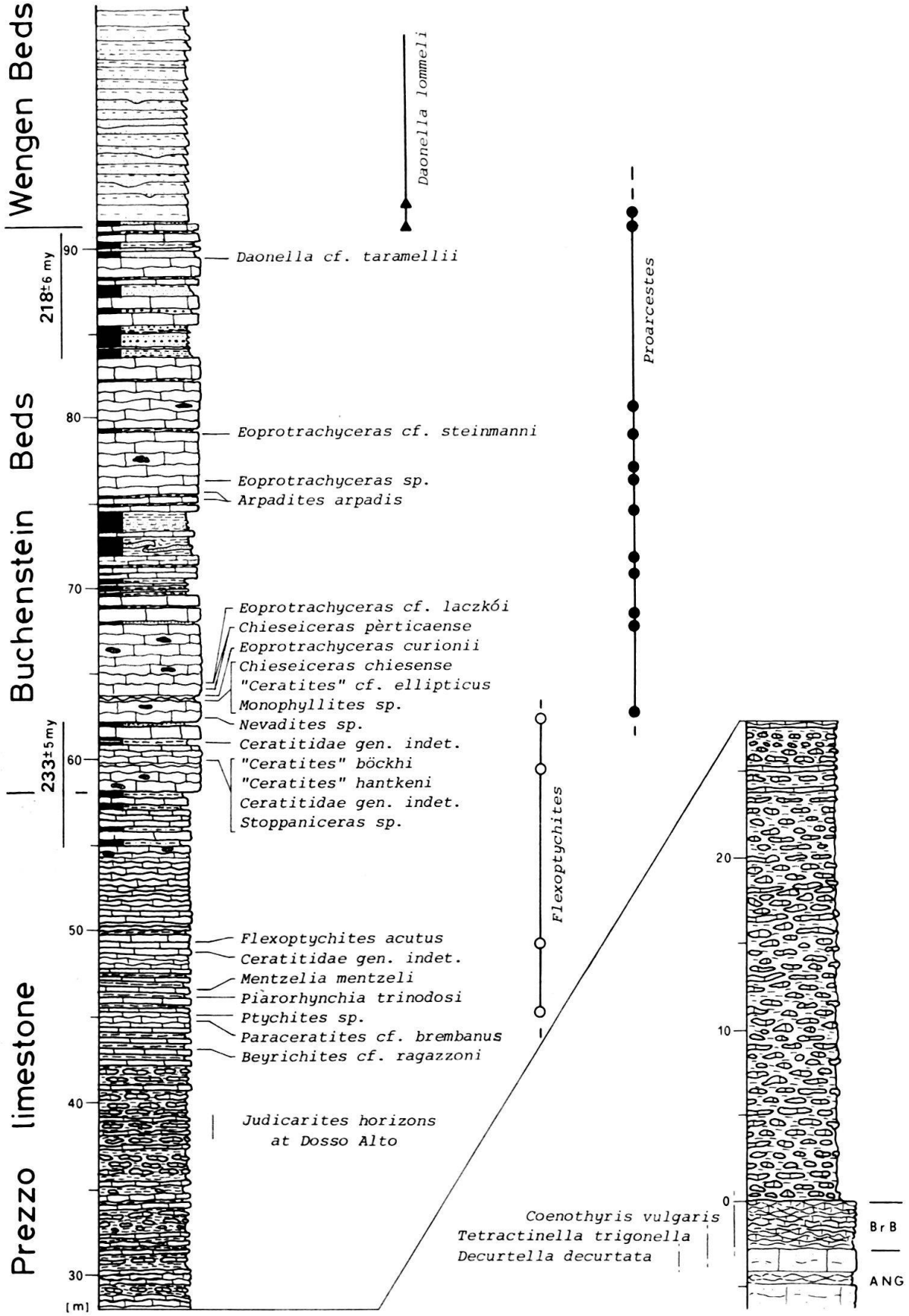

Fig. 5. Column and fossil content of the complete stratigraphic succession of the Middle Triassic strata long the Caffaro riverbed south of Bagolino (see also Fig. 4). See text for a brief lithologic description. 0-m level of the scale corresponds to the top of the Brachiopod Bed. Principal volcanoclastic layers are indicated by black bands.

Above the 58-m level the sediments are typical Buchenstein cherty nodular limestones (equivalent to the "Knollenkalke" of the Formazione di Livinallongo of VIEL 1979 in the Dolomites). The grey-weathering nodular limestone beds have characteristic undulating and knobbly surfaces spaced from cm to dm apart, and consist of mainly filament- and radiolarian-microsparites (mudstone–wackestone), often strongly bioturbated. Silicification may be diffuse or nodular. Individual limestone nodules occasionally consist of single ammonoids, that are enveloped by silicified shales often mixed with fine ash- and crystal-tuffs.

Green to reddish volcanoclastic sand- and siltstones, as well as dense ash layers (Pietra verde) form three sequences separated by limestones: from the base to the 62-m level, from 68 to 76 m, and from 83 m to the top. The most common components of the Pietra verde sand-fractions and crystal-tuffs are plagioclase, quartz, biotite, vitreous shards and subordinate sanidine crystals, while the green siltstones mainly consist of ash fragments.

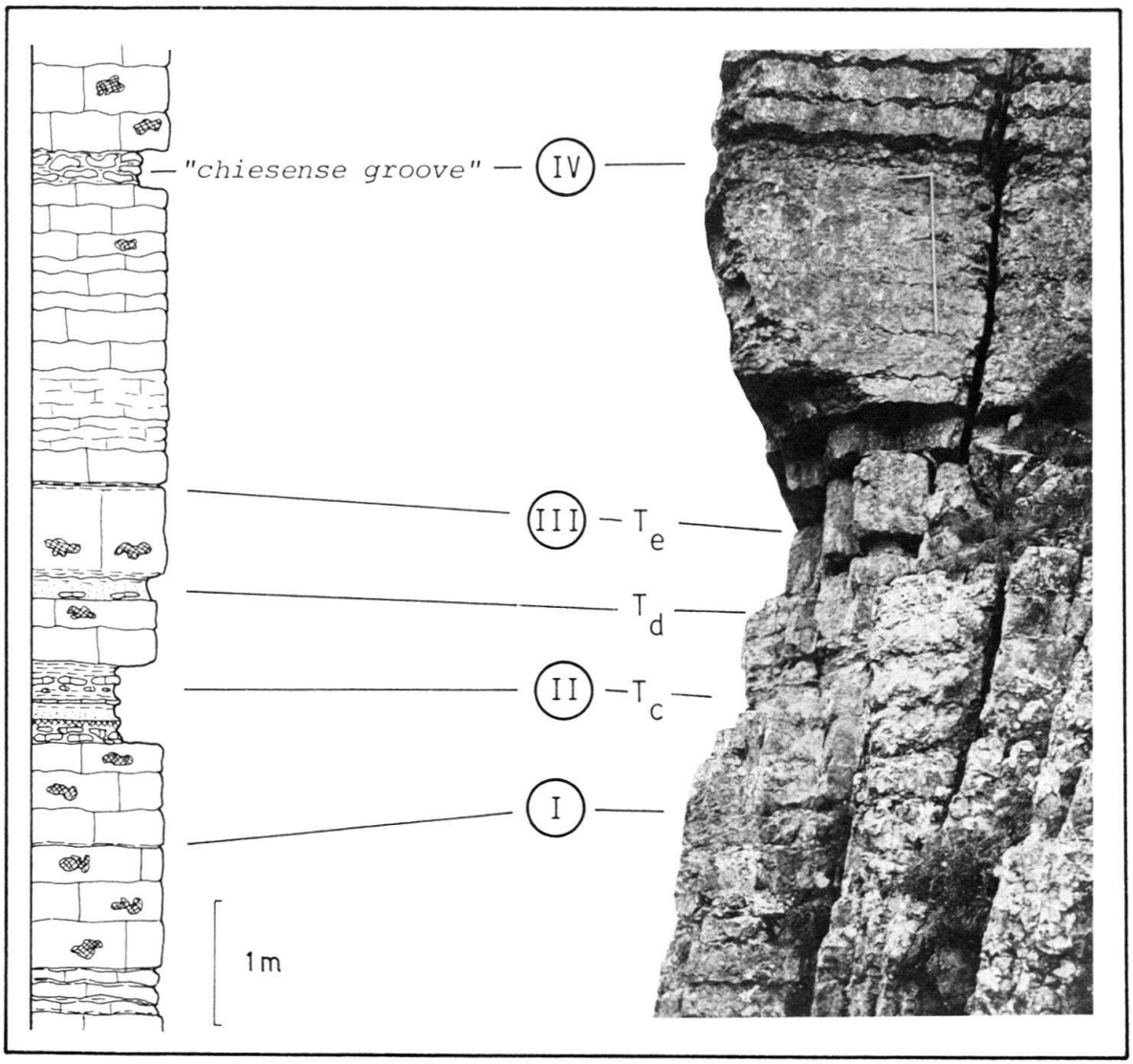

Fig. 6. Detail of the lowermost Buchenstein Beds with their principal volcanoclastic layers (T_c–T_e) and fossil horizons (I–IV), situated near the crest south of Malga Stabol Fresco (Monte Corona–Dosso dei Morti area, Giudicarie).

The mineralogical and chemical composition of this Pietra verde occurrence is quite similar to that described by CALLEGARI & MONESE (1964) from the Dolomites. These authors consider the Pietra verde to have a rhyolitic to rhyodacitic origin, whereas CROS & HOUEL (1983) favour a trachyandesitic origin for the lower Pietra verde horizons. Corresponding Pietra verde sequences in the Dosso dei Morti area also contain accretionary lapilli (DIENI & SPAGNULO 1964). Graded-bedding and penecontemporaneous slumping are commonly observed structures.

The presence of the above-mentioned accretionary lapilli and crystal tuffs indicate quiet sedimentation in the form of ash falls, while the coarse detrital Pietra verde horizons point to more vigorous transport mechanisms. CROS & HOUEL (1983) interpret similar sediments in the lower Pietra verde of the Dolomites as submarine pyroclastic flows.

Calcarenites and tuffitic sandstones above the 91-m level give way to the Wengen Beds which consist of a series of bioturbated, cm- to dm-thick amalgamated turbidites of siliciclastic detritus and Daonella-rich clayey horizons.

4. Stratigraphic correlation and ammonoids of the Lower Buchenstein Beds between Val Trompia and Giudicarie, and a comparison with the Val Gola column near Trento

4.1 Brief description and correlation of the studied sections (Fig. 7)

In the following paragraphs seven fossiliferous columns of the Lower Buchenstein Beds are compared. A section of the Middle Triassic column at Bagolino will be taken as a reference (Fig. 5, 55–65 m) because almost all the fossil horizons that also occur in the other localities are here found to contain ammonites.

The correlated fossil horizons (Fig. 7) are denoted by the encircled numerals I–IV and are schematically connected by dotted lines, while the bases of the most important volcanoclastic layers (Ta–Te) are marked by solid lines.

Finally, the fossiliferous Anisian/Ladinian boundary section at Val Gola (Fig. 8) that differs somewhat in its facies, will be compared with the lowermost Buchenstein Beds at Giudicarie.

Bagolino reference column (Romanterra; 55–65-m level in Fig. 5)

Several outcrops occur along the Caffaro river south of Bagolino (Fig. 4).

The first macroscopically visible silicification appears in the undulating limestones and mudstones just below a 20 cm thick, beige illite bed (Ta, 55-m level). Above these beds follow irregular tuffaceous mudstones and undulating limestone layers (showing ammonoid cross-sections) up to the base of a compact nodular limestone series (58-m level). Interlayered with thin tuff/mudstone layers, these latter continue to the marked tuffaceous groove at the 61-m level (Tc) and include the fossil horizon I. The tuffaceous groove (Tc) contains a nodular limestone layer with a cm-thick crystal-tuff at its base, some fine, partly silicified ash-tuffs as well as a distinct limestone bed in its uppermost part (fossil horizon II). It is overlain by a more compact nodular limestone series interrupted at the 61.5-m level by a pronounced dm-thick sandy tuff layer (Td), and at the 62-m level by a cm-thick fine tuff (Te, fossil horizon III: upper surface of the tuff layer). A 20 cm thick groove of nodular limestones with a muddy matrix (63.2-m level) is exceptionally rich in *Chieseiceras chiesense* (the "Chiesense groove", see also Fig. 6). Above this groove follows a series of irregular thick limestone beds with thin mudstone intercalations which persist up to the base of the middle tuff sequence (Fig. 5, 68-m level).

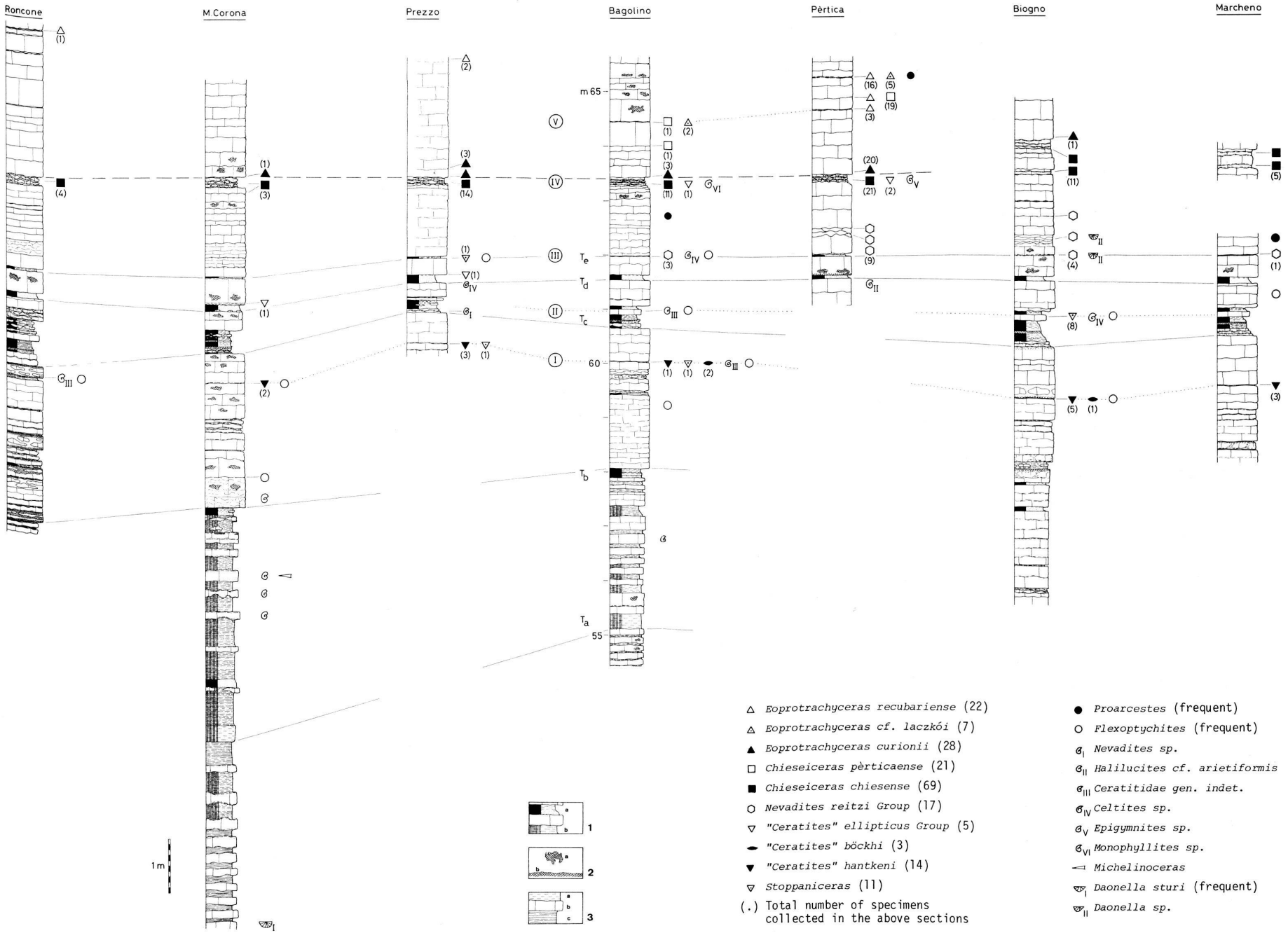

Fig. 7. Correlation and fossil content of selected sections of the lower Buchenstein Beds in the Brescian Prealps and Giudicarie (for location see Fig. 1). The actual distance between the Roncone and Marcheno columns is about 50 km; see text for a short description and location of the columns. 1a = volcanoclastic layers; 1b = mixed siliciclastic and volcanoclastic material; 2a = concentrations of chert nodules; 2b = strongly silicified shales; 3a = beige illite layers; 3b = undulating to nodular limestone beds; 3c = shales.

Pèrtica column

In the southwards-overthrust mid-Triassic units west and north of Forno d'Ono (Pèrtica Bassa) fossiliferous members of the Buchenstein Beds are present but they have not been previously described in detail.

A: Beds corresponding to the Bagolino column above the 61-m level are found on the southern slope of T. Glera, about 1 km along the walking track from Avenone–C.se Sar–La Cagna at an altitude of 1050–1150 m a.s.l. (coord. 605.325/5068.470 to 604.725/5069.300). The immediately underlying sediments here are hidden; only the deeper layers including the beige-grey illite bed (Ta) are visible. In contrast, the column upwards as far as the Esino Limestone is completely exposed (Fig. 2).

B: At the locality Nogne north of Forno d'Ono another section outcrops in a creek bed at 1000 m a.s.l. The column is continuous down to the level of the Prezzo Limestone. (coord. 606.800/5070.620).

C: Fossiliferous beds overlying the Chiesense groove occur approximately 200 m northwest of Odeno (Pèrtica Alta) above the road to Marmentino (coord. 603.820/5067.300).

In Figure 7 only the column at locality A is presented. Within it, the tuff horizons (Td, Te) of Bagolino and the Chiesense groove are easily recognizable. At Nogne the nodular limestone series between III/Te and IV is apparently 1 m thicker than elsewhere. In comparison to other columns the Chiesense groove and two horizons between 1.2 and 2 m above it are especially fossil-rich at all these localities near Pèrtica.

Biogno column

The Biogno column (named after the Biogno stream, an easterly tributary of the Mella near Brozzo) stretches from the Brozzo–Lodrino road (1 km east of Brozzo; coord. 596.925/5063.375) to about 50 m up the slope to the northwest. It corresponds to the "Val Biogno" locality of HORN (1913, 1914) who reported an unusual mixed fauna. This "mixture" is explained by the fact that the lower Buchenstein Beds in the stream show a tectonic contact with the strata, just below the Wengen Beds.

With respect to Bagolino (Fig. 7) the fossil horizons I to III as well as the Pietra verde horizons Tc to Te are clearly recognizable. Instead of the Chiesense groove a similar groove is present here, stratigraphically higher up. *Chieseiceras chiesense* are spread below this level over 0.5 m.

Marcheno column

The Marcheno column lies immediately north of the cemetery by the river Mella (coord. 594.990/5062.625) within folded Buchenstein Beds. It corresponds to the locality denoted by HORN (1913) as "close to the Marcheno Church", the classic locality of *"Protrachyceras Reitzi"* in Val Trompia.

The lithologic succession including fossil and tuff horizons is identical to the Biogno column only 2 km away, although the beds containing *Chieseiceras chiesense* may not be followed right to the bottom of the column.

Prezzo column

The column is exposed on the slope above the right bank of the river Chiese near Pieve di Bono (coord. 626.620/5088.525). Lower Buchenstein Beds outcrop to the east as part of a slip packet but to the west of a scree gully (north of a road curve near Prezzo) they are found in a topographically higher position. These relative outcrop heights explain BITTNER's (1881) assignment of *"Trachyceras chiesense"* to a stratigraphically higher level.

All fossil and tuff horizons (I–IV/Tc–Te) of Bagolino are recognisable in the Prezzo column. Relative to the Monte Corona column, however, the limestone layers between horizon Tc and IV (as yet undifferentiated) are about 0.5 m thinner.

Monte Corona column

The Monte Corona stratigraphic column is situated on the western slope of the ridge between the summit and Corno Vecchio, just west of spot height 2415, and approximately 200 m south of the section illustrated in Figure 3 (coord. 622.800/5094.680). The column may be followed further both upwards and downwards (Fig. 2). Other variously exposed sequences of the lower Buchenstein Beds (Fig. 6) stretch to the south on either side of the ridge as

far as Dosso dei Morti, as well as to the north of Malga Stabol Fresco, where likewise the transition to the underlying Prezzo limestone is exposed (see Fig. 13 in GAETANI 1969).

The section of column from Monte Corona (Tb-IV) corresponds perfectly to the lithological succession at Bagolino although here it is in part slightly thicker. Fossils are poorly preserved and quite rare. This is not due to a primary lack of fossils but rather to the pronounced weathering of the carbonate nodules above the tree-line. The strata below Tb consist of undulating limestone layers (rich in the ammonoids *Ptychites/Flexoptychites* and *Michelinoceras*) enveloped by chert and intercalated with silicified, rusty-brown mixed mudstones and tuffs. These latter are notably thicker than at Bagolino and thus result in an appearance similar to the lower banded limestones of the Dolomites.

Only 3 m below the beige illite horizon corresponding to Ta at Bagolino, limestone beds occur with abundant *Daonella sturi*, thus providing a continuous transition to the fossil-rich beds of the Trinodosus Zone described by GAETANI (1969, Fig. 4, 13).

Roncone column

At the curve in the road between the church and the cemetery at Roncone (coord. 629.820/5094.170) yet another section of the lowermost Buchenstein Beds is situated. In this small outcrop all the lithologies between Tc and IV are to be found, although the tuffaceous groove Tc is somewhat expanded.

Of interest is a sample from 1.25 m above the Chiesense groove in which P. Mietto (pers. comm.) identified a significant conodont assemblage including:

Gladigondolella tethydis
Gondolella excelsa
Gondolella constricta
Gondolella pseudolonga
Gondolella trammeri

Val Gola column

In Val Gola near Ravina (coord. 661.300/5099.950), southwest of Trento, a section of pelagic sediments was well exposed until recently on the northern bank of the river. It consisted of grey mudstones, marls and undulating limestone beds overlain by reddish to greenish, silicified nodular limestones. ARTHABER (1916) described several Daonellae and ammonoids from these strata (among others "*Protrachyceras Reitzi* BKH."), the lowermost of which he considered as "equivalents of the Trinodosus Zone", while the upper members were taken as part of the Ladinian stage.

Despite the partial coverage of this outcrop by a new stormwater wall, enough ammonoids were collected from still identifiable stratigraphic horizons during the summer of 1984 to permit a good correlation of the previously recorded complete column (Fig. 8) with the lowermost Buchenstein Beds at Giudicarie. The stratigraphic column here requires brief description because of its relevance to conodont studies (MIETTO 1982; MIETTO in prep.).

The stratigraphic level of the Chiesense groove at Bagolino may be identified in these strata by the presence of *Eoprotrachyceras curionii* and the immediately underlying *Chieseiceras* cf. *chiesense* and *Nevadites* (A in Fig. 8). Typical silicified Buchenstein nodular limestones are first found in Val Gola from this level on, that is, clearly higher than those in the Roncone column, today some 35 km away (Fig. 7).

The well-bedded, slightly silicified grey limestones and mudstones now exposed below A in Figure 8 thus correspond to the beds underlying the Chiesense groove (63-m level of Bagolino). The mudstones at the base of the Val Gola column contain Daonellae and Ceratitids as well as some yellow-brown-weathering tuff layers. They may be correlated with the basal compact nodular limestone beds at Bagolino (58–61 m level) and at Monte Corona although they are somewhat thicker due to increased siliciclastic content.

This correlation is significant in that fossils corresponding to those of the lower part in the Val Gola section have so far not been discovered in the Brescian Alps and Giudicarie. Such fossils which in Val Gola obviously lie above the Trinodosus Zone (RIEBER 1968) must therefore be either entirely lacking in the other areas, or present but unable to be extracted from the markedly silicified limestones.

Furthermore, this correlation clarifies the relationships of the lower banded limestones in the Buchenstein Beds of Val Gardena (Dolomites) and of the "Grenzbitumenzone" at Mt. S. Giorgio to our stratigraphic columns on the Anisian/Ladinian boundary.

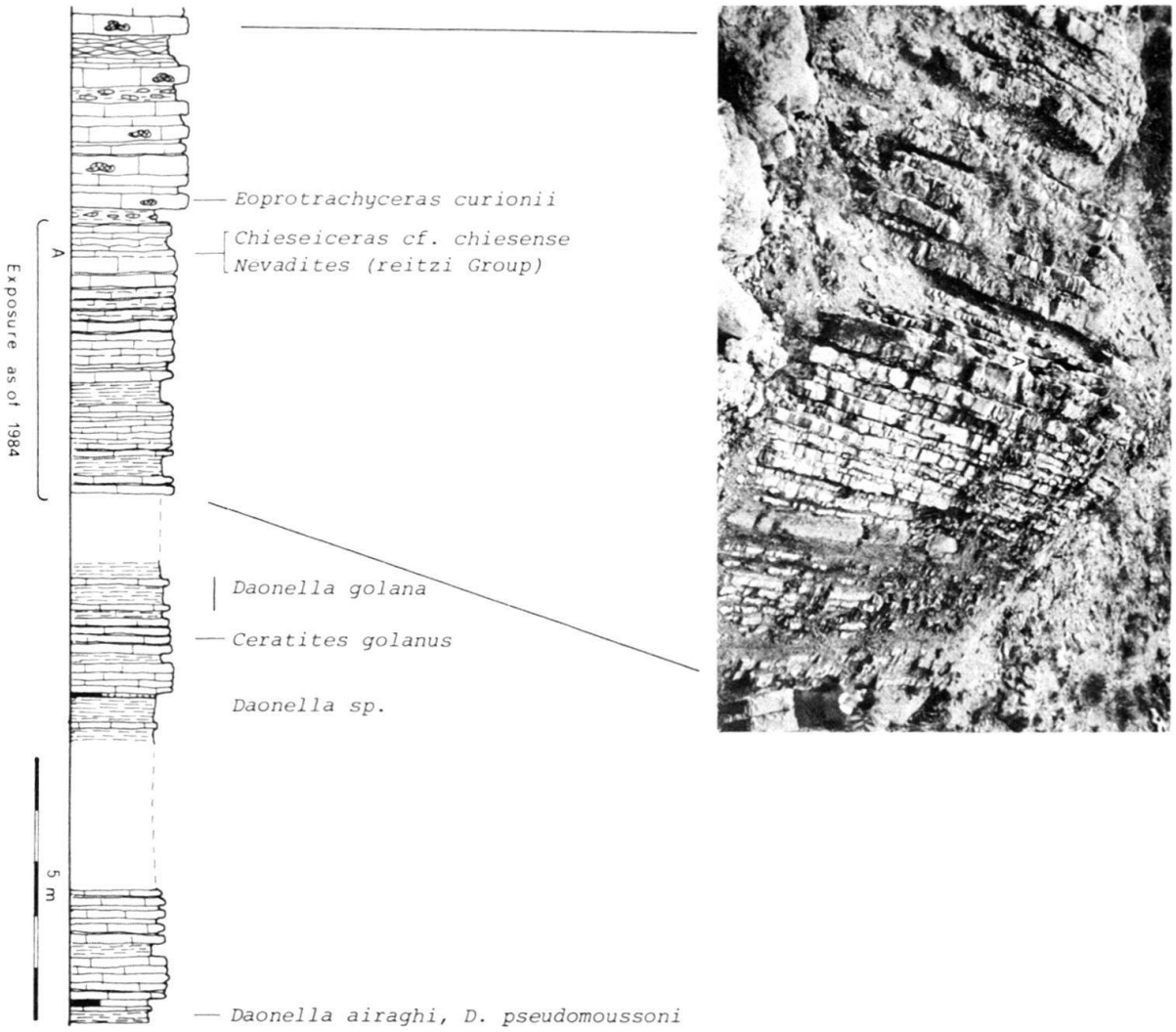

Fig. 8. Exposure of the strata close to the Anisian/Ladinian boundary along the riverbed in Val Gola (near Trento) as it appeared in 1966 and 1984.

Results of correlating the stratigraphic columns

Comparison of stratigraphic columns of the Buchenstein Beds between Val Trompia and Giudicarie (Fig. 7) reveals a surprisingly uniform sedimentation regime even across sections up to 50 km apart. Variations are to be seen only in the mudstone/tuff horizons between Ta and Tb. In higher sections of the column the tuff layers (Tc–Te) are the most important stratigraphic markers, while the nodular limestone beds are only occasionally useful, depending on their outcrop conditions and state of weathering. The only marker not associated with the tuffaceous layers is the fossil horizon IV (Chiesense groove). This limestone level can be followed in the stratigraphic columns from Roncone to Pèrtica and it possibly represents a longer period of sedimentation than the adjacent beds.

Sedimentation at the Anisian/Ladinian boundary between Val Trompia and Giudicarie was notably uniform, both in terms of carbonate production and influx of volcanic detritus. Even more remarkable is that the Buchenstein Beds in the near vicinity are either completely missing as in Val Sabbia (south of Nozza) or are partly replaced by other

lithologies; e.g. at Monte Guglielmo a carbonate-breccia occurs in place of the lower half of the Buchenstein Beds in Val Trompia.

In Val Gola the lithological sequence below the cherty nodular limestones differs from the equivalent strata at Giudicarie by its higher content of siliciclastics and smaller degree of replacement by chert. This indicates a continuation of sedimentation conditions at Val Gola, similar to those under which the Prezzo Limestone was deposited in Giudicarie.

4.2 Description of the main stratigraphically significant ammonoids

Position and preservation of the ammonoids

Most of the ammonoids of the Buchenstein Beds were found on exposed lower and upper surfaces of the nodular limestone beds. The extraction of ammonoids oblique to the surface of the cherty limestone was next to impossible. The ammonoids are preserved as internal moulds of parts of the body chamber and sometimes also of the phragmocone and/or as external moulds of part of the shell. Usually the ammonoids on the surfaces are only preserved where covered with shale or volcanogenic material. The opposite side of the internal mould may be attached to the cherty limestone and this makes complete preparation difficult or impossible. Only within the marly "Chiesense groove" are fragments of ammonoids preserved on both sides.

On the upper surface of the "Chiesense groove" fragments of internal moulds from the body chamber of *Eoprotrachyceras curionii* are arranged in such a manner that external sides may be well exposed. Complete specimens of the same species mostly lie parallel to the surface.

Genus *Chieseiceras* n. gen.

Type species: Chieseiceras chiesense (Mojs., 1882).

Name: Derived from the river Chiese, above which the village Prezzo, type locality of *Chieseiceras chiesense*, is situated.

Diagnosis: Representatives of the Ceratitids or Trachyceratids with smooth, nearly flat or faintly concave venter, highly trapezoidal to highly oval whorl section and steep umbilical wall. The ornamentation consists of numerous ribs, half of which originate at the umbilical margin with bulgy tubercles (umbilical tubercles). Somewhat outside of the umbilical margin, which is rounded between the umbilical tubercles, further ribs originate by intercalation or by branching off the primary ribs. On the outer part of the whorl side further ribs appear by branching off and/or intercalation. All the ribs of the outer part of the whorl side are low and broad and therefore relatively indistinct.

On the ventro-lateral shoulder all ribs end with weak to strong tubercles, which may be elongated in the direction of the spiral. Only in very large specimens the distinctly concave venter may be crossed by ribs which become weaker towards the middle of it. The suture line, which could only be observed to a certain degree in a few specimens, is ceratitic. Directly outside the middle of the whorl side is placed the distinct lateral lobe, flanked by rounded saddles. An evident umbilical lobe lies on the inner flank. The external lobe is short and confined to the venter.

Comparison: *Chieseiceras* n. gen. differs from *Nevadites* SMITH (sensu SILBERLING & NICHOLS 1982) and *Anolcites* MOJS. by the lack of lateral tubercles in adult as well as in juvenile specimens. Furthermore, *Nevadites* shows usually a broader whorl section than *Chieseiceras*. In *Anolcites* the venter is crossed by ribs, whereas in *Chieseiceras* no ribs appear on the venter up to a diameter of 10 cm. The representatives of *Eoprotrachyceras* TOZER, *Protrachyceras* MOJS. and Paratrachyceras ARTHABER differ from *Chieseiceras* by having a distinct ventral furrow. *Chieseiceras* shows in contrast to *Eoprotrachyceras* and *Protrachyceras* no spiral of lateral tubercles.

Discussion: Based on the ornamentation it can be judged that *Chieseiceras* may descend from *Nevadites*. However, there is also the possibility that *Chieseiceras* derives directly from Ceratitids which are close to *Paraceratites*.

Occurrence: Up to now, the oldest representative of *Chieseiceras* was found in the higher part of the Reitzi Zone (corresponding to the Nevadites Zone). Younger representatives come from the Curionii Zone.

Chieseiceras chiesense (MOJS., 1882)

Fig. 9a–f; Pl. 1, Fig. 1–11, Pl. 2, Fig. 1, 3, 4, 9, Pl. 4, Fig. 7.

Synonymy

?1854 *Ammonites Pemphix* n.sp. – MERIAN: Muschelkalkversteinerungen im Dolomite des Monte S. Salvatore bei Lugano, p. 88.

?1855 *Ammonites Pemphix* MERIAN. – HAUER: Über einige Fossilien aus dem Dolomite des Monte Salvatore bei Lugano, p. 410, Pl. Fig. 3–4.

1881 *Trachyceras (Ceratites) chiesense* MOJS. – BITTNER: Über die geologischen Aufnahmen in Judicarien und Val Sabbia, p. 255.

*1882 *Trachyceras chiesense* E. VON MOJSISOVICS. – MOJSISOVICS: Die Cephalopoden der mediterranen Triasprovinz, p. 95, Pl. 34, Fig. 4.

°1882 *Ceratites Zezianus* E. VON MOJSISOVICS. – Ibid., p. 44, Pl. 37, Fig. 3–4.

?1882 *Ceratites pemphix* (MERIAN) E. VON MOJSISOVICS. – Ibid., p. 41, Pl. 39, Fig. 9.

1898 *Protrachyceras chiesense* E. VON MOJSISOVICS. – GEYER: Cephalopoden der Buchensteiner Schichten bei Sappada, p. 134.

1905 *C. Zezianus* MOJSISOVICS. – DIENER: Entwurf einer Systematik der Cephalopoden des Muschelkalkes, p. 780.

1906 *Ceratites planus* G. VON ARTHABER. – MARIANI: Alcune osservazioni geologiche sui dintorni di Bagolino nella Valle del Caffaro, p. 652 and text-fig.

1913 *Anolcites doleriticus* MOJS. – TOMMASI: I fossili della lumachella triasica di Ghegna in Valsecca presso Roncobello, p. 66, Pl. IV, Fig. 25.

1914 *Protrachyceras chiesense* MOJS. – HORN: Über die ladinische Knollenkalkstufe der Südalpen, p. 22ff., 63, 67, 70.

1914 *Ceratites Zezianus* MOJS. – Ibid., p. 63.

1943 *Ceratites Zezianus* MOJS. – BONI: Geologia della regione fra il Sebino ..., p. 81.

1967 *Protrachyceras chiesense* (MOJSISOVICS). – JACOBSHAGEN: Cephalopoden-Stratigraphie der Hallställer Kalke..., p. 21.

Name: Referring to the river Chiese, on the steep bank of which the locus typicus is situated below the village Prezzo.

Remarks: The holotype of *Ammonites Pemphix* MERIAN, 1854 could be found neither in Lugano nor in Milano. Therefore, this form has only been judged by the illustrations of HAUER (1855) and MOJSISOVICS (1882). On the basis of these illustrations a synonymy of *Trachyceras chiesense* MOJS., 1882 and *Ammonites Pemphix* MERIAN, 1854 is probable but not certain. In this paper preference is given to the younger species named *chiesense*.

Holotype: The specimen illustrated by MOJSISOVICS 1882, Pl. 34, Fig. 4a–b (inventory number of the "Geologische Bundesanstalt Wien": 1882/03/113). It is a part of the internal mould of the body chamber, which is preserved in grey Buchenstein limestone.

Locus typicus: According to MOJSISOVICS 1882, p. 96, the holotype comes from the Buchenstein Beds, which are exposed on the steep bank of the river Chiese below the village Prezzo in Giudicarie. At the same locality, which was more exactly described by BITTNER 1881, p. 255, 14 specimens of *Chieseiceras chiesense* were collected in situ.

Stratum typicum: The indications of BITTNER (1881) and MOJSISOVICS (1882) that *Chieseiceras chiesense* should come from the higher part of the Buchenstein Beds could not be confirmed (see p. 191). All the collected specimens are from the lower part of the Buchenstein Beds.

Material: 71 determinable specimens were collected in the Buchenstein Beds (see Fig. 7). 33 of them are parts of the internal mould of the body chamber, whereas in 17 parts of the inner whorls are preserved as external moulds as well. From the Esino limestone facies of Ghegna (locality of TOMMASI 1913) come 16 specimens (preserved as internal mould with altered shell), from Buchenstein Beds of Frötschbach section (near Bad Ratzes, Dolomites) three, and from the upper part of the Grenzbitumenzone of the Monte San Giorgio (Canton Ticino, Switzerland) further three specimens (a completely compressed individual from layer 138 and two dolomitic internal moulds from layer 144 o).

Diagnosis: Moderately broad *Chieseiceras,* with trapezoidal whorl section. The whorl sides are slightly convex, and the umbilical wall is narrow and nearly perpendicular. Between the ribs the umbilical margin is rounded. The venter, which is flat on the inner whorls, becomes more or less concave in large specimens. The sculpture, which may change dinstinctly in the course of growth, consists of slightly sinuous primaries as well as of branched and intercalated ribs, which become less prominent towards the marginal shoulder. At the outer third of the flanks the ribs are inclined towards the aperture. They end at the marginal shoulder with ventral tubercles. Only in very large specimens the ribs may continue and cross the concave venter. The ribs may be swollen in the middle flank but there are no real tubercles.

Description: Development and strength of the ornamentation (Fig. 9a–f) vary considerably and change in a single specimen in the course of growth. In specimens of moderate size (diameter 3–6 cm) numerous slightly sinuous ribs originate with a blunt node at the umbilical margin. In most of the specimens these primaries are branching off in two secondaries. The latter are slightly inclined towards the aperture. Some ribs fail to split. Branched and unbranched ribs are intercalated between the primaries somewhat outside the umbilical margin and short ribs are developed on the outer part of the whorl side. The ribs, which are usually swollen at the middle of the whorl side, become broad and narrow and therefore indistinct on the outer third of the flank. All ribs end at the

marginal shoulder with a tubercle, which may be slightly elongated in the spiral plane. The venter lacks ribs and is even or somewhat concave.

In larger specimens (diameter about 7–12 cm) the straight primaries are slightly inclined adoradly on the flank. They originate near the umbilical seam and are somewhat inclined backwardly at the umbilical wall. On the whorl side they become broader outwardly. Frequently they are swollen at the middle flank. Somewhat outside the middle of the whorl side they are branching off into two or three secondaries, and in addition, they become low and broad and therefore indistinct. At the outer third of the flank few short intercalated ribs appear. All ribs end at the marginal shoulder with tubercles. At the anterior part of the body chamber of large specimens (corresponding to a diameter of 10–13 cm) the ribs are crossing the concave venter. In the middle of the venter they become weaker. Inside the umbilicus of larger specimens only unbranched ribs are visible, because the primaries of larger specimens are branching only in the outer part of the flank, which is covered by the following whorl. The ammonoid described by MOJSISOVICS 1882 (p. 44, Pl. 37, Fig. 3–4) as *Ceratites Zezianus* is nothing else than the not covered part of the inner whorl of a large specimen of *Chieseiceras chiesense*. A specimen and its silicon-rubber cast, illustrated in Plate 2, Figures 1–9, show this very impressively.

Based on the existing material it is not possible to determine exactly the width of the umbilicus and the whorl height. At a diameter of 5–6 cm the relative width of the umbilicus is ranging from 32–35% and the relative whorl height from 39–40%. In a specimen from Prezzo (L/1642 not figured) with a diameter of 8 cm the width of the umbilicus is 0.32 and the whorl height 0.38 of the diameter. The exact width of the whorls could not be measured in the collected material.

The suture is ceratitic (Pl. 1, Fig. 11). Two basically denticulate lobes (lateral lobe L and umbilical lobe U2) lie on the flank separated by an entire saddle. A further small and short lobe exists near the umbilical wall. The saddle between the lateral lobe and the short external lobe is broad and round. The external lobe has the same lenght as the umbilical lobe U2.

Comparison: Chieseiceras chiesense has a broader whorl section and more prominent ribs than the younger species *Chieseiceras pèrticaense* n.sp. The venter of larger specimens of *Chieseiceras pèrticaense* is slightly convex, and the tubercles on the marginal shoulder are faint or completely missing, whereas *Chieseiceras chiesense* has at the same diameter a slightly concave venter and prominent ventral tubercles.

Occurrence: Chieseiceras chiesense is known from Giudicarie (Prezzo, Monte Corona, Roncone), Brescian Prealps (Bagolino, Pèrtica, Marcheno, Val Biogno), Ghegna/Valle Brembana (undescribed material in the collection of the Paleontological Institute and Museum of the University of Zürich), Monte San Giorgio, Monte San Salvatore near Lugano (as *Ammonites Pemphix* MERIAN), Sappada (after GEYER 1898), and Felsö-Örs, Hungary (as *Ceratites Zezianus* in MOJSISOVICS 1882). An undescribed well preserved individual of *Chieseiceras chiesense* from Monte Savon (area of Monte Clapsavon) belongs to DE TONI's collection of the Geological Institute of Padova, Italy (number 26505, *Anolcites treneri* sp.n.).

Age: The level with *Chieseiceras chiesense* within the lower Buchenstein Beds of Giudicarie and Brescian Prealps is situated directly above the layers with representatives

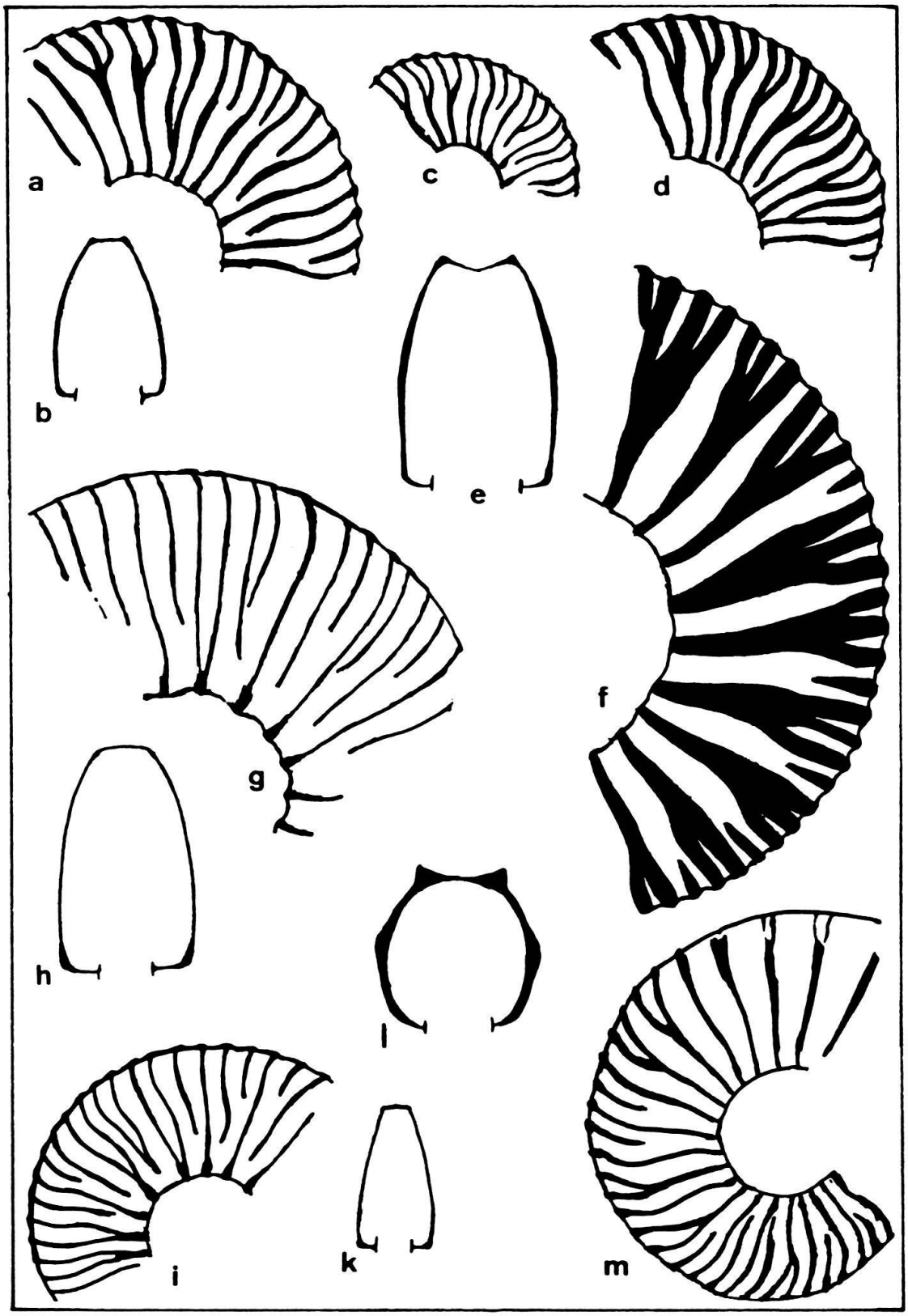

Fig. 9. Sculpture and whorl sections of some ammonoids of the Buchenstein Beds. a–f: *Chieseiceras chiesense* (Mojs.), fossil horizon IV, Reitzi Zone (a–b L/1611 Bagolino, c L/1610 as mirror-image, Bagolino, d L/1617, Pèrtica Bassa, e–f L/1612 Bagolino); g–k: *Chieseiceras pèrticaense* n.sp., Pèrtica Bassa, fossil horizon V, Curionii Zone (g–h holotype, L/1622, i–k L/1627); l: *Nevadites* sp., L/1628, Prezzo, lower part of fossil horizon II, Reitzi Zone, m: *Chieseiceras* cf. *chiesense*, L/1621, Val Gola, grey cherty limestone, Reitzi Zone. All figures natural size.

of the group of *Nevadites reitzi*. These layers belong to the uppermost part of the Reitzi Zone (= Nevadites Zone), which is considered as uppermost Anisian (see p. 209).

Chieseiceras cf. *chiesense* (MOJS.)

Fig. 9 m; Pl. 2, Fig. 7–8.

In the lowermost Buchenstein Beds in Val Gola (south of Trento, Italy) an individual of *Chieseiceras* was found, which is close to *Chieseiceras chiesense* (MOJS.). As in this specimen the ribs are more prominent and obviously more regular than in *Chieseiceras chiesense* of equal size from Prezzo and Bagolino, it should be described with open nomenclature. Though the ribs of *Chieseiceras* cf. *chiesense* are more prominent at the inner flank than in *Chieseiceras chiesense* itself, the characteristical blunt nodes at the umbilical margin do not exist. The intercalated ribs on the outer flank are shorter and more prominent in *Chieseiceras* cf. *chiesense*, and the whole section looks somewhat broader than in equivalent specimens of *Chieseiceras chiesense*. The individual of Val Gola seems to be a direct ancestor of *Chieseiceras chiesense*.

Chieseiceras pèrticaense n.sp.

Fig. 9g–k; Pl. 3, Fig. 1–9.

Name: Referring to Pèrtica Bassa (Prov. Brescia, Italy) where the holotype and paratypes come from (see p. 191).

Holotype: The individual figured in Plate 3, Figures 1 and 4. A part of the body chamber is preserved as internal mould, whereas parts of the inner whorls exist only as an external mould. The latter is somewhat distorted relatively to the body chamber.

Stratum typicum and locus typicus: Grey cherty limestone of the lower Buchenstein Beds of Pèrtica section (see Fig. 7 and p. 191). The holotype was found 1.45 m above the Chiesense groove.

Material: 19 specimens from Pèrtica and 2 from Bagolino section.

Diagnosis: Chieseiceras with a highly trapezoidal whorl section at diameters up to 5–6 cm and a highly oval periphery at diameters larger than about 6 cm. In juvenile specimens the ribs are slightly sinuous. In the course of growth they become nearly straight. The primaries originate near the umbilicus seam and form on the umbilical margin slightly curved radially elongated nodes. In smaller individuals (up to 5–6 cm diameter) the ribs are ending at the rounded venter shoulder with faint nodes. In larger specimens (diameter over 6 cm) these faint nodes diminish more and more and disappear finally. Besides the ribs, branching near the umbilical margin, some single ones of different length are intercalated.

Description: The holotype shows on the body chamber straight ribs of low relief. Some of these originate on the rounded umbilical shoulder with blunt elongated nodes. Further ribs are intercalated in the inner third of the flank or originate by indistinct splitting of primaries. Still inside the middle of the whorl side the number of ribs is increased especially by intercalation. Towards the marginal shoulder all ribs become very faint and are declined slightly adoradly. The venter is not crossed by ribs.

Especially smaller specimens show that the development of ribs varies considerably within this species. On the inner whorls the holotype possesses fairly dense and rather strong ribs (Pl. 3, Fig. 4). In the individual figured in Plate 3, Figures 7–8, the ribs are also strong but less dense, and in the specimen of Plate 3, Figure 6, the ribs are rather dense but of low relief.

Because of the incomplete preservation of the existing material an exact determination of the relative whorl height and width as well as of the umbilical width is not possible.

The suture is ceratitic (Pl. 3, Fig. 2, and especially Fig. 5). The lateral lobe showing five denticles lies directly outside the midflank. Within the inner third of the flank exists an umbilical lobe (U2) with four to five denticles, and immediately outside the umbilical margin is situated a further short lobe with two denticles. The external lobe is short, its length is equal to U2. It shows on both sides of the narrow external saddle three denticles.

Comparison: Chieseiceras pèrticaense n.sp. differs from *Chieseiceras chiesense* (MOJS.) by its less broad whorl section on the inner whorl as well as by at most faint ventral tubercles and further by its slightly concave venter. The elongated blunt nodes of the ribs at the umbilical margin are at most slightly inclined at the back in *Chieseiceras chiesense*, whereas in *Chieseiceras pèrticaense* they are distinctly curved.

Occurrence: Up to now *Chieseiceras pèrticaense* n.sp. is only known from the lower Buchenstein Beds of Pèrtica Bassa and Bagolino. At Pèrtica all specimens were found 1.45–1.60 cm above the Chiesense groove and therefore above the level, in which *Eoprotrachyceras curionii* is common, but below the horizon with *Eoprotrachyceras recubariense*.

Age: Curionii Zone, lower Ladinian.

The group of *Nevadites reitzi* (BÖCKH 1872)

Pl. 2, Fig. 2, Pl. 4, Fig. 4.

Within the lower Buchenstein Beds of the Brescian Prealps 17 representatives of the genus Nevadites were found. At Pèrtica section nine specimens were stated 1–1.3 m beneath the Chiesense groove. Two of these specimens (L/1629 and L/1630[5])) are very similar to *Nevadites humboldtensis* SMITH of Nevada (SILBERLING & NICHOLS 1982, Pl. 23, Fig. 18–19, resp. Pl. 24, Fig. 3–4). A small fragment (Pl. 2, Fig. 2) resembles *Protrachyceras dealessandri* (AIRAGHI) from the Grenzbitumenzone of Monte San Giorgio (RIEBER 1973, Pl. 15, Fig. 1). Within the corresponding horizon (Fig. 7, horizon III and above it) were found at Bagolino three, at Biogno four and at Marcheno one remain of a *Nevadites*, which are more or less equal to those of Pèrtica section. A further fragment of *Nevadites* comes from Val Gola near Trento from the same layer as *Chieseiceras* cf. *chiesense* (Pl. 2, Fig. 7–8).

The existing specimens of *Nevadites* show a similar whorl section and possess the same elements of ornamentation as *Trachyceras reitzi* (BÖCKH 1872) of Felsö-Örs in Bakony (Hungary). The elements of ornamentation are: irregularely arranged, rather straight ribs, most of which are ending with ventral nodes, possible existence of marginal, lateral

[5]) These specimens will be illustrated in a forthcoming paper on Nevadites of the Southern Alps.

and umbilical tubercles in larger individuals as well as a rather braod smooth venter between the external nodes. There is no doubt, that the representatives of *Nevadites* of the Brescian Prealps are closely related to *Trachyceras reitzi*. Therefore, the species *reitzi* BÖCKH is placed to the genus *Nevadites*, and the above mentioned forms of the Brescian Prealps are united in the "group of *Nevadites reitzi* (BÖCKH)". WANG (1983) established the genus *Xenoprotrachyceras* for a new species (*X. primus*) from Middle Triassic deposits of southwestern Guizhou, China. He included both "*Protrachyceras*" *reitzi* (BÖCKH) and "*Protrachyceras*" *recubariense* MOJS. in this new genus. Nevertheless, "*Protrachyceras*" *reitzi* is considered in this paper to be a representative of *Nevadites* and "*Protrachyceras*" *recubariense* to be a species of *Eoprotrachyceras*. The species names of the collected forms of *Nevadites* cannot be determined until a monographic study of the whole group of *Nevadites reitzi* (BÖCKH) is done.

Protrachyceras dealessandri (AIRAGHI 1912), *P. ambrosionii* (AIRAGHI 1912) and *P.* cf. *conspicuus* (DIENER) from the Grenzbitumenzone of Monte San Giorgio (RIEBER 1973 and 1974) belong to the group of *Nevadites reitzi* too. A juvenile individual of *Protrachyceras ambrosionii* (RIEBER 1973, Pl. 15, Fig. 5 and 10 and RIEBER 1974, Pl. 1, Fig. 8 and 10) shows very distinctly the ornamentation (umbilical, lateral, marginal and external tubercles) of the inner whorls of *Nevadites reitzi*, which MOJSISOVICS (1882, p. 114) indicated. To the group of *Nevadites reitzi* most likely belong besides the forms of *Ceratites* resp. *Trachyceras Reitzi*, which were described and illustrated by BÖCKH (1872/73), STÜRZENBAUM (1875) and MOJSISOVICS (1882), also *Balatonites conspicuus* (DIENER 1900, Pl. 2, Fig. 5a–d), *Ceratites conspicuus* (ARTHABER 1903, Pl. 1, Fig. 5a–d and 6), *Ceratites perauritus* DIENER (DIENER 1900, Pl. 2, Fig. 1), *Ceratites ecarinatus* HAUER (HAUER 1896, Pl. 8, Fig. 7–10, and ARTHABER 1903, Pl. 1, Fig. 4a–b), *Protrachyceras* sp. ind. (DIENER 1900, Pl. 2, Fig. 2), as well as *Trachyceras Fedaiae* SALOMON *Trachyceras symmetricum* SALOMON *Trachyceras Paronai* SALOMON (SALOMON 1895, Pl. VI, Fig. 13–15), and *Ceratites spiculifer* REIS (REIS 1907, Pl. 1, Fig. 19) and probably *Protrachyceras reitzi* (BÖCKH) in BANDO 1967 (p. 161, Pl. 1, Fig. 6).

Based on the figure and description, a specimen from the red limestones of Valdepena described by DE TONI (1914, Pl. XI, Fig. 2a–b) belongs to the group of *Nevadites reitzi* as well. Furthermore, a specimen (diameter 11.5 cm) of DE TONI's collection at Padova (number 26505 "Anolcites sp.n."), which comes from the red limestones of "Monte Savon, S. Osvaldo" (Monte Clapsavon, Italy) may also be ascribed to the group of *Nevadites reitzi*.

Nevadites sp.

Fig. 9l; Pl. 4, Fig. 1 and 2.

At Prezzo a Nevadites with very prominent ribs and a broad body whorl was extracted from a layer of cherty nodular limestone, which is situated considerably lower than the level (horizon III in Fig. 7) containing the group of *Nevadites reitzi*. Especially the development of the venter of this form differs from that of the stratigraphically younger group of *Nevadites reitzi*. The ventral nodes of the present specimen do so slowly decrease towards the middle of the venter, that the latter is undulated in direction of the spiral. The specimen resembles *Ceratites crassus* HAUER (HAUER 1896, p. 23, Pl. 8, Fig. 1–2).

Two individuals of *Nevadites* with broad whorl section and coarse ribs coming from Hallstatt limestone of Epidauros (Greece) particularly resemble the *Nevadites* sp. from Prezzo as well.

Group of *"Ceratites" ellipticus* HAUER 1887

Pl. 4, Fig. 3 and 6, Pl. 5, Fig. 2

At Prezzo, Bagolino und Pèrtica some Ceratitids were found in the lower Buchenstein Beds, mainly within the Chiesense groove and up to 2.3 m from this level downwards. These Ceratitids are closely related to *Ceratites ellipticus* HAUER 1887. Therefore, they are provisionally united in the group of *"Ceratites" ellipticus* HAUER 1887".

The representatives of this group show three spirals of tubercles (umbilical, lateral and marginal tubercles) and, excepting the body chamber, a strong external keel. The ribs being usually simple on the body whorl become broader outside the lateral tubercle. On the inner whorls some primaries are branching within the lateral tubercle and furthermore, there are some outer intercalated ribs. The most typical feature of these Ceratitids are the usually small and pointed lateral tubercles, which lie inside the middle of the flank, namely at the end of the inner third of the whorl side. Therefore, the lateral tubercles of the inner whorl are visible within the umbilicus. The marginal tubercles may be very prominent on the body chamber and nearly perpendicular to the spiral plane, or they may be of rather low relief. The keel which is acute and prominent on the phragmocone becomes increasingly low on the body chamber. Near the aperture of adult specimens is only an edge on the low roof-like venter. The holotype of *Ceratites ellipticus* (HAUER 1887, Pl. 6, Fig. 3a–b) shows impressively how the keel looses its relief on the body chamber.

Comprehensive, not yet described material of forms of the group of *"Ceratites" ellipticus* was collected in the Esino Limestone facies of Ghegna (locality of TOMMASI 1913). We intend to give a nomenclature of the few specimens from the lower Buchenstein Beds of Brescian Prealps only, when the material from Ghegna will be investigated in detail.

BUBNOFF'S *Ceratites ellipticus* (1921, Pl. 12, Fig. 8) from the Latemar limestone at Forno is considered to be a good example for our group of *"Ceratites" ellipticus*. The specimens which the latter described (1921, p. 456f., Pl. 12, Fig. 6–7) as *Hungarites Waageni* MOJSISOVICS sensu lato should probably also be associated to this group. *Hungarites Waageni* shows the same characteristics at the inner whorls of *Ceratites ellipticus* indicating a close relation between these two species. The species of *Balatonites* which SALOMON (1895) described from the Marmolata and the Latemar limestone should be treated in the same manner as BUBNOFF'S *Hungarites Waageni*. These species are: *Balatonites Waageni* MOJS. (p. 181, Pl. 6, Figs. 8 and 10a–b), *B. Waageni* MOJS., var. *angusteumbilicatus* m. (p. 181, Pl. 6, Fig. 9), *B. Rothpletzi* nov. sp. (p. 199, Pl. 6, Fig. 12a–b) and uncertainly *B. late-umbilicatus* nov. sp. (p. 182, Pl. 6, Fig. 11a–b).

For the present it is not possible to judge which of the numerous species of Ceratitids with prominent keel of the Wetterstein limestone of the Zugspitze massif (REIS 1901 and 1907) may be correlated with the group of *"Ceratites" ellipticus*.

The affiliation to a genus of the ammonoids united in the group of *"Ceratites" ellipticus* will be carried out within a monographical study of the whole group. However,

it is obvious that neither the genus *Ceratites* nor *Paraceratites* can be considered in this context, but based on the ornamentation and the whorl section rather close connections to *Stoppaniceras* RIEBER 1973, to *Repossia* RIEBER 1973, and to *Parakellnerites* RIEBER 1973 have to be assumed, whereas the relations to *Kellnerites* ARTHABER seem not to be as close as to the other genera.

Stoppaniceras

Pl. 5, Fig. 3

Eight Ceratitids with an elevated and acute external keel were discovered at the lower surface of a cherty nodular limestone layer within the lower Buchenstein Beds at Biogno. Beside simple ribs they show intercalated ones. The relief and the density of the ribs vary within a broad range. The ribs, which originate at the umbilical shoulder, develop a blunt umbilical node. At the end of the inner third of the flank, the ribs bear low but acute lateral tubercles, and at the ventro-lateral shoulder they end with obliquely elongated marginal tubercles. The Ceratitids resemble representatives of the genus *Stoppaniceras* RIEBER 1973, especially *Stoppaniceras artinii* (AIRAGHI) of the Grenzbitumenzone of the Monte San Giorgio, and they are therefore provisionally ascribed to *Stoppaniceras*. Some features, however, are common (the position of the lateral tubercles and the development of the keel) with the representatives of the group of *"Ceratites" ellipticus*.

Two poorly preserved remains of Ceratitids from Prezzo are provisionally put to the genus *Stoppaniceras*.

"Ceratites" böckhi ROTH 1871

Pl. 4, Fig. 5

Two internal moulds of the body chamber of a keeled Ceratitid from the lower Buchenstein Beds (fossil horizon II) of Bagolino most probably belong to *"Ceratites" böckhi* ROTH. At Biogno another sample was located 4.8 m below the Chiesense groove. Whereas BÖCKHS illustrations of the holotype (BÖCKH 1874, Pl. 4, Fig. 3a–b) do not fit at all, the associated description can be applied perfectly. Furthermore, the specimens from the lower Buchenstein Beds in the Brescian Prealps correspond to the refigured holotype (MOJSISOVICS, 1882, Pl. 9, Fig. 8). Though *"Ceratites" böckhi* does not represent at all a species of the genera *Ceratites* and *Paraceratites*, we refrain from an affiliation to a definite genus. A certain resemblance to the youngest representatives of *Parakellnerites* RIEBER, 1973 exists, but the keel of the former is more acute and the ribs not as regularely arranged as in *"Parakellernites" meriani* RIEBER.

"Ceratites" hantkeni MOJS. 1882

Pl. 5, Fig. 1

In the lower Buchenstein Beds at Marcheno, Biogno, Bagolino and Prezzo altogether 14 specimens of this evolute Ceratitid were found. The whorl section is subquadrate. At a diameter of 63.5 mm the specimen L/1641 (not pictured) shows a whorl height of 20 mm (31.5%), a whorl width between the coarse ribs of 19.8 mm (31.2%) and on ribs about 22 mm (34.6%) and an umbilical width of about 30,5 mm (48%). The venter is flat and shows only at the posterior end of the body chamber and on the phragmocone a very faint

median edge. The umbilical wall is narrow and nearly perpendicular, and the umbilical shoulder is rounded between the ribs. The simple ribs are supplemented with few intercalated ones. All ribs are thickened at the marginal shoulder to obliquely arranged marginal tubercles. From the marginal tubercles the ribs draw adoradly a little bit oblique to the spiral plane before they disappear on the venter. The ribs bear not far from the umbilical shoulder a small acute lateral node which marks in some specimens the branching point of the primaries. The existing specimens of *"Ceratites" hantkeni* from the lower Buchenstein Beds of the Brescian Prealps and Giudicarie will be studied in more detail together with similar specimens from the lowermost cherty nodular limestones at Seceda (Val Gardena, Dolomites).

Halilucites cf. *arietitiformis* (HAUER 1896)

Pl. 2, Fig. 5–6.

A small fragment of a keeled Ceratitid, which was found within the lower Buchenstein Beds of Pèrtica Bassa, can best be compared with *Halilucites arietitiformis* (HAUER 1896, p. 24, Pl. 10, Fig. 1–3). The elevated and acute keel is accompanied by ventral furrows. The simple ribs are broad and loosely arranged. The whorl section is lowly rectangular.

4.3 The range of ammonoids within the lower Buchenstein Beds of the Brescian Prealps and Giudicarie (Fig. 7, 10)

Chieseiceras chiesense (MOJS.) has been reported from all the studied sections of the lower Buchenstein Beds of the Brescian Prealps and Giudicarie. This characteristic species is most common within the Chiesense groove (Fig. 7, fossil horizon IV), and only at Prezzo it was also found some 15 cm lower.

Remains of *Eoprotrachyceras* are rather frequent at the upper surface of the Chiesense groove. Most specimens are preserved as internal moulds of the body chamber, and only in a few individual parts of the phragmocone are transmitted as external or/and internal mould. Though the strength of the sculpture and strongly varying whorl sections all specimens were determined as *Eoprotrachyceras curionii* (MOJS.). A larger specimen is figured (Pl. 5, Fig. 4). In all the sections studied nothing indicates the existence of remains of *Eoprotrachyceras* within or beneath the Chiesense groove, and the genus *Protrachyceras* resp. *Eoprotrachyceras* appears with *Eoprotrachyceras curionii* immediately above the level with *Chieseiceras chiesense*.

Several specimens of *Eoprotrachyceras recubariense* (MOJS.) sensu PISA 1966 were found above the level with *Eoprotrachyceras curionii*. A specimen of *Eoprotrachyceras recubariense* (MOJS.) is illustrated (Pl. 5, Fig. 5).

At Pèrtica and at Bagolino we got ammonoids which can be best compared with *Protrachyceras laczkói* (DIENER 1899). The horizon with *Protrachyceras* cf. *laczkói* (fossil horizon V in Fig. 7) is situated just beneath the level with *Eoprotrachyceras recubariense* and above the Chiesense groove.

Chieseiceras pèrticaense occurs at the type locality (Pèrtica) above the Chiesense groove, but somewhat beneath the main occurence of *Eoprotrachyceras recubariense*. At Bagolino only two poorly preserved specimens of this species have been detected.

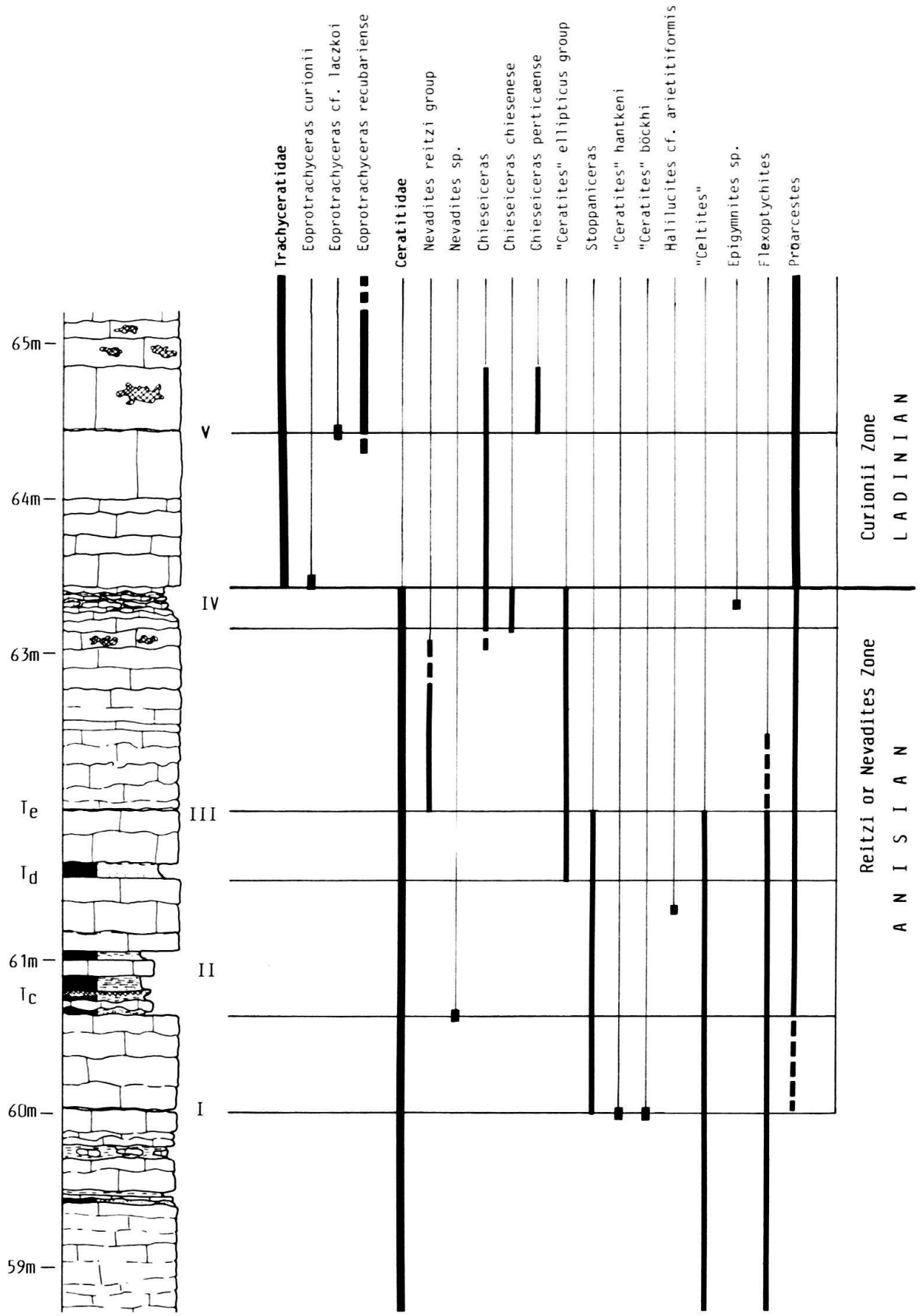

Fig. 10. Stratigraphic distribution of upper Anisian and lower Ladinian ammonoids in the lower Buchenstein Beds of the Brescian Prealps and Giudicarie related to the section of Bagolino with indication of the proposed placement of the Anisian/Ladinian boundary. I–V: fossil horizons, Tc–Te: tuffitic levels (see Fig. 7).

Representatives of the group of *Nevadites reitzi* have been found at Pèrtica, at Marcheno and at Biogno below the Chiesense groove. Therefore, in the area of the Brescian Prealps the group of *Nevadites reitzi* seems to be typical for the beds between horizon Td (Fig. 7) and the Chiesense groove. Up to now, we could not get any specimen of the group of *Nevadites reitzi* from Prezzo, Monte Corona and Roncone. A *Nevadites* sp., which is obviously not closely related to *Nevadites reitzi,* was found at Prezzo on the lower surface of the tuffite groove Tc (see Fig. 7).

The stratigraphically youngest Ceratitids come from the Chiesense groove (fossil horizon IV) and may be related to the group of *"Ceratites" ellipticus* (see page 202). The best preserved individual (Pl. 4, Fig. 6) is from the Chiesense groove at Bagolino, and two small fragments are from the same level (fossil horizon IV) at Pèrtica. A well preserved internal mould of a body whorl (Pl. 5, Fig. 2) of the same group was found at Prezzo 1.65 m below the Chiesense groove on the roof of the tuffite horizon Td. Another representative of the *ellipticus* group comes from a rather low level (2.6 m below the Chiesense groove) at Bagolino. Ceratitids, which were provisionally ascribed to the genus *Stoppaniceras* were found at Biogno about 2.2 m below the Chiesense groove as well as a similar fragment together with *"Ceratites" hantkeni* at Prezzo 2.9 m below the Chiesense groove.

Especially remarkable is the discovery of *"Ceratites" böckhi* ROTH within the lower Buchenstein Beds at Bagolino (two specimens) and at Biogno (one specimen). At both localities they occurred together with *"Ceratites" hantkeni* in the fossil horizon I.

The evolute *"Ceratites" hantkeni* MOJS. is restricted to the fossil horizon I, and a fragment of *Halilucites* cf. *arietitiformes* HAUER has been detected below the Chiesense groove at Pèrtica.

5. Biostratigraphical subdivision, absolute age and rate of sediment production of the lower Buchenstein Beds in the Brescian Prealps and Giudicarie and a comparison with the Grenzbitumenzone at Monte San Giorgio (Switzerland) and the Val Gola section

5.1 Biostratigraphical subdivision

The lower Buchenstein Beds of the Brescian Prealps and Giudicarie may be subdivided using the succession of ammonoids collected in situ. Since the studied sections are easily correlated by comparing their characteristic succession of tuffitic layers and fossil horizons, it is sufficient here to illustrate just one column in detail. The Bagolino section is the most complete and easily accessible locality where abundant fossils have been found and thus seems to be best suited for this purpose, even though more ammonoids were actually collected at Pèrtica.

As can be seen from Figure 10 the vertical distributions of the Ceratitids and Trachyceratids do not overlap. The former occur only below and within the Chiesense groove (Group of *"Ceratites" ellipticus*), whereas the Trachyceratids appear just at the top of this level. Representatives of the group of *Nevadites reitzi* have been found together with the youngest Ceratitids, but not with Trachyceratids.

Within the area studied, the base of the nodular limestone facies of the Buchenstein Beds is situated below the strata containing ammonoids of the genus *Nevadites* and *"Ceratites" hantkeni.* A comparison of the Buchenstein Beds in the Brescian Prealps with

the Grenzbitumenzone at Monte San Giorgio is now possible thanks to the finds of *Chieseiceras chiesense* and representatives of the group of *Nevadites reitzi* in both areas. In the Grenzbitumenzone *Chieseiceras chiesense* have been detected in layers 138 (1 specimen) and 144 (2 specimens) while representatives of the group of *Nevadites reitzi* are restricted to beds 98–112 in the middle part of the section. The Ceratitids reach the levels with *Chieseiceras chiesense*, but not further. The uppermost specimen of a Ceratitid derives from bed 142, and another fragment from layer 125 resembles *"Ceratites" ellipticus*. The few ammonoid finds from the upper Grenzbitumenzone are only poorly preserved and therefore not identifiable.

At Val Gola, a specimen of *Chieseiceras* cf. *chiesense* (Pl. 4, Fig. 7–8) was found together with a specimen of the *Nevadites reitzi* group. Some 0.9 m higher, greenish and reddish cherty nodular limestones contained a small, but typical fragment of *Eoprotrachyceras curionii*.

With the following list an attempt has been made to correlate the ammonoid horizons of the above mentioned three areas.

Grenzbitumenzone of the Monte San Giorgio		Lower Buchenstein Beds of Brescian Prealps/Giudicarie	Val Gola near Trento
Bed number			
200–230	*Protrachyceras* sp.	*Eoprotrachyceras curionii*	*Eoprotrachyceras curionii*
138–144	*Chieseiceras chiesense*	*Chieseiceras chiesense*	
125	group of *"Ceratites" ellipticus*	group of *"Ceratites" ellipticus*	*Chieseiceras* cf. *chiesense* group of *Nevadites reitzi*
98–112	group of *Nevadites reitzi*	group of *Nevadites reitzi*	
74–76	*Stoppaniceras artinii*	*Stoppaniceras* sp.	
	Daonella airaghii		*Daonella airaghii*
69	*Repossia acutenodosa*		
61	*Stoppaniceras variabilis*		
50	*Ticinites*		
41–49	*Parakellnerites*		

The sequence of ammonoid horizons in the Grenzbitumenzone indicates that the occurrence of the genus *Parakellnerites* lies considerably lower than that of the group of *Nevadites reitzi*. It should be emphasized, that representatives of the genus *Ticinites* and *Parakellnerites* have not yet been reported from the upper Prezzo Limestone, nor from the lower Buchenstein Beds. Furthermore, no equivalent to *"Ceratites" hantkeni* has so far been recorded from the Grenzbitumenzone. A detailed study of the uppermost Prezzo Limestone might furnish more information on the occurrence and range of *Parakellnerites* and other forms.

For the realm of the Brescian Prealps and Giudicarie the following sequence of horizons and zones can be stated:

Horizons	Zones
Eoprotrachyceras recubariense *Chieseiceras pèrticaense* *Eoprotrachyceras curionii*	Curionii Zone

Chieseiceras chiesense Group of *Nevadites reitzi* *"Ceratites" hantkeni*	Reitzi or Nevadites Zone

For the Grenzbitumenzone of the Monte San Giorgio the following sequence of horizons and local biostratigraphic zones were distinguished:

Horizons	Local zones
Protrachyceras sp.	Curionii Zone
Chieseiceras chiesense Group of *Nevadites reitzi* + *Serpianites serpianensis*	Reitzi or Nevadites Zone
Stoppaniceras artinii *Stoppaniceras variabilis* *Ticinites polymorphus* + *Serpianites curionii*	Polymorphus Zone
Parakellnerites	Parakellnerites Zone
	Trinodosus Zone (not proved)

5.2 Absolute age and net rate of sediment production of the Buchenstein Beds

The pronounced evolution of the ammonoids over such a narrow interval of the Buchenstein Beds (Fig. 5) suggests that these sediments represent a longer time span than the Prezzo Limestone below, or the turbiditic Wengen Beds above.

Radiometrically dated bentonite layers in the Grenzbitumenzone (232 + 5 m.y. average (K/Ar, Ar/Ar) ages on sanidines, obtained by HELLMANN & LIPPOLT 1981) lie clearly below the strata containing *Nevadites* of the *Reitzi* group. Their counterparts in the Bagolino column must therefore be situated below the 62-m level.

CRISCI et al. (1984) determined an older (Rb/Sr biotite–whole rock isochron: 225 ± 7 m.y.) and a younger set of ages (Rb/Sr biotite–whole rock isochron: 218 ± 6; K/Ar biotite: 212 ± 7/215 ± 8) for Pietra verde sequences in the Buchenstein Beds of Val Trompia and Val Camonica. Although a bed-by-bed comparison of the volcanoclastic sediments between Val Trompia and Bagolino would be possible (Fig. 2, 7), the insufficient stratigraphic documentation of the dated horizons permits only a tentative correlation. Because of their more certain radiometric basis and stratigraphic position, only the set of younger dates (most probably corresponding to the Pietra verde sequence above the 83-m level at Bagolino) will be used here.

On the basis of the above reported radiometric age determinations, the Buchenstein Beds at Bagolino must have been deposited between 232 and 218 m.y. The actual interval over which deposition took place was probably shorter than this quoted period, however. These dates are compatible with the age of the previously mentioned subvolcanic bodies at Monte Muffetto (Rb/Sr Biotite–whole rock: 231 ± 5, 226 ± 4 m.y.; in CASSINIS & ZEZZA 1982), equivalent lithologies of which are preserved as clasts within conglomerates and breccias of the uppermost Pietra verde.

The absence of clear hardgrounds in the Buchenstein Beds indicates continuous carbonate production except in the case of the Pietra verde deposits. Because individual Pietra verde beds generally contain only minor reworked carbonate material and because they represent short-lived events, almost the entire time span of the Buchenstein Beds is actually represented by the outcrop thickness of nodular limestones. At Bagolino these limestones constitute 70% of the entire formation. Accepting the average radiometric ages and assuming continuous carbonate sedimentation results in a mean net sediment production rate of the nodular limestone facies on the order of $2–4 \times 10^{-6}$ m/y, neglecting compaction.

A comparison of the ammonoid stratigraphies shows that the sedimentation rate in the Grenzbitumenzone (Monte San Giorgio) slightly exceeded that of the Buchenstein Beds at Bagolino, while in the Hallstatt-type limestone facies of Epidauros (KRYSTYN 1983) it was approximately an order of magnitude smaller.

6. The Anisian/Ladinian boundary

In 1892 BITTNER established the term "ladinisch" (Ladinian) for the Buchenstein and Wengen Beds. This expression should substitute what MOJSISOVICS in the same period called "norisch" (Norian). According to the interpretation then (e.g. MOJSISOVICS 1879, p. 79), the Buchenstein Beds themselves should include only the Zone of *Trachyceras reitzi* and *curionii*. In 1882 MOJSISOVICS used for the same beds the term "Zone of *Protrachyceras reitzi*" alone. In MOJSISOVICS et al. (1895, p. 1279) the lowermost Ladinian (called Norian by MOJSISOVICS until 1902) is known as the "Zone of *Protrachyceras curionii*".

The Anisian/Ladinian boundary was generally correlated with the limit between the "Zone of *Ceratites trinodosus*" and the succeeding "Zone of *Protrachyceras reitzi/curionii*". PISA (1966) avoided the latter expression and used the "Recubariense Zone" for the lowermost Ladinian. ASSERETO (1969) reintroduced the "Avisianus Zone" of MOJSISOVICS et al. (1895), with a modified position, i.e. between the Trinodosus and the Reitzi Zone. After his study of Daonella (1968, 1969) and ammonoids (1973) in the Southern Alps of Ticino, RIEBER introduced the local "Zone of *Ticinites polymorphus*", which corresponds more or less to the range of ASSERETO's "Avisianus Zone". Moreover, he placed the Anisian/Ladinian boundary just below the beds containing *Protrachyceras dealessandri* and *P. ambrosionii*, which were considered to be elements of the Reitzi Zone. Based on conodont studies KOVACS & KOZUR (1980) advocate an Anisian/Ladinian boundary between the Trinodosus and Avisianus Zones. Taking account of the results of RIEBER (1973) and KRYSTYN & MARIOLAKOS (1975), KRYSTYN (1983) proposed the new terms "Parakellnerites Zone" for the uppermost Anisian and "Nevadites Zone" for the basal Ladinian.

Considering the range of ammonoids within the lower Buchenstein Beds of the Brescian Prealps and Giudicarie (Fig. 10), the first appearance of Trachyceratids (*Eoprotrachyceras curionii*) is a particularly useful biostratigrafic subdivision. The striking faunal change, which immediately postdates the disappearance of the Ceratitids as well as the short-lived *Chieseiceras chiesense*, is best suited to fix the Anisian/Ladinian boundary. This position of the stage boundary, however, does not correspond to BITTNER's (1892) original definition; the lowermost part of the Buchenstein Beds becomes Anisian, at least

in the Brescian Prealps and Giudicarie. Alternative positions of this limit within the zonal scheme could only locally correspond to BITTNER's proposal as well, since preliminary comparative studies of the Buchenstein Beds in the Dolomites indicate that the base of the nodular limestone facies is in fact heterochronous. The Reitzi Zone itself is not suited to define the Anisian/Ladinian boundary because of its poorly documented faunistic content and chronostratigraphic range. Even the index fossil, the *Nevadites reitzi* (BÖCKH), has not yet been studied sufficiently.

The exact position of the proposed stage boundary can be pinpointed in all studied sections in the Brescian Prealps and Giudicarie, and corresponds to the top of the Chiesense groove (fossil horizon IV in Fig. 10).

At Val Gola (Fig. 8) the proposed Anisian/Ladinian boundary is situated between the occurrence of *Chieseiceras* cf. *chiesense* (together with a specimen of the *Nevadites reitzi* group; bed A) and of *Eoprotrachyceras curionii*.

In the Grenzbitumenzone at Monte San Giorgio the exact position of the base of the Curionii Zone cannot yet be specified, as only poorly preserved fragments of *Protrachyceras* sp. have been documented from the scree of beds 200–230. Consequently the Anisian/Ladinian boundary must be situated somewhere between bed 144 (latest occurrence of *Chieseiceras chiesense*) and the above mentioned strata.

In the ammonoid-rich Hallstatt-type limestones of Epidauros (see KRYSTYN 1983) the proposed stage boundary corresponds to the limit between the Nevadites and Curionii Zones (bed A5/6) and the base of the *"Epigondolella" hungarica* Zone.

The Occidentalis Zone in the recently reexamined Middle Triassic of the Humboldt Range (SILBERLING & NICHOLS 1982) can be correlated with the Reitzi Zone of the Brescian Prealps and Giudicarie because of the evident resemblance of *Nevadites* from both regions. Furthermore, the index fossil of the succeeding Subasperum Zone (*Protrachyceras subasperum*) is quite comparable to *Eoprotrachyceras curionii*. Assuming a synchronous appearance of the Trachyceratids both in Nevada and in the Southern Alps, the beginning of the Curionii Zone would then coincide with that of the Subasperum Zone.

The following table indicates the resulting correlation of the Anisian/Ladinian boundary between the Brescian Prealps and Nevada:

Brescian Prealps and Giudicarie (this paper)		Humboldt Range/Nevada (SILBERLING & NICHOLS 1982)
Ladinian	Curionii Zone	Subasperum Zone
Anisian	Chiesense Horizon	
	Reitzi Zone (= Nevadites Zone)	Occidentalis Zone
	equivalent to Polymorphus Zone	Meeki Zone
	Trinodosus Zone	Rotelliformis Zone

7. Final remarks

The main result of this study is the correlation and uniform subdivision of the lower Buchenstein Beds in the Brescian Prealps and Giudicarie. With regard to a comprehensive correlation of the Middle Triassic in the Alps, it would be of great interest to test whether these divisions can be applied to equivalent sequences in other Alpine areas (e.g. the Buchenstein Beds of the Dolomites, the Reifling Limestones of the Northern Calcareous Alps). Preliminary studies of the Buchenstein Beds in Val Gardena (northwestern Dolomites) indicate close relationships with the lithologic sequence and faunal content of the above described area. These results will be presented in a forthcoming publication by the authors.

In the context of this paper it was not possible to undertake a taxonomic study of all the collected ammonoids from the Buchenstein Beds. However, such studies would be of a notable importance with respect to the group of *"Ceratites" ellipticus, "Ceratites" böckhi* and *hantkeni,* the group of *Nevadites reitzi,* and the Trachyceratids. Further research will therefore be focused on these aspects, with special consideration of the classic fauna from Bakony (Hungary).

Acknowledgments

We would like to thank E. T. Tozer (Ottawa) for his critical review of this paper and for his many suggestions. Larryn Diamond (Zürich) was kindly forced to help with the English translation, and Dr. U. Formenti (Bagolino) provided a photographic documentation of previous ammonoid finds in the Romanterra outcrop. The description and identification of the ammonoids was greatly facilitated by the meticulous specimen preparation by A. Fassnacht and H. Lanz. H. Lanz also made the photographs. The first author's stay at the University of Padova was made possible by a postdoctoral "Nachwuchsstipendium" from the Swiss National Science Foundation. Financial support of the Georges and Antoine Claraz-Schenkung is acknowledged.

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Plate 1

Chieseiceras chiesense (MOJS.)

(Fig. 1–10 natural size, Fig. 11 two times natural size)

Fig. 1 L/1610, Steinkern of the body chamber and external mould of the inner whorls, Bagolino, Chiesense groove (= fossil horizon IV), upper Reitzi Zone, for ornamentation see text-figure 9c.

Fig. 2 L 1611, same preservation, locality and horizon as Figure 1, for ornamentation and whorl section see text-figures 9a–b.

Fig. 3 Cast of the silicon rubber of the external mould of the inner whorls of Figure 2.

Fig. 4 L/1612, Steinkern of the body whorl, same locality and horizon as Figure 1, for ornamentation and cross section see text-figures. 9e–f.

Fig. 5 L/1613, Steinkern of the body whorl, same locality and horizon as Figure 1.

Fig. 6 L/1614, same preservation as Figure 1, Prezzo, Chiesense groove (= fossil horizon IV).

Fig. 7 L/1615, Steinkern of the body whorl and of parts of the inner whorls, same locality and horizon as Figure 1.

Fig. 8 Ventral view of Figure 2.

Fig. 9 Ventral view of Figure 4.

Fig. 10 L/1616, ventral view of a fragment of the body whorl of a large specimen, same locality and horizon as Figure 1.

Fig. 11 Same specimen as Figure 1, enlarged twice, with traced suture.

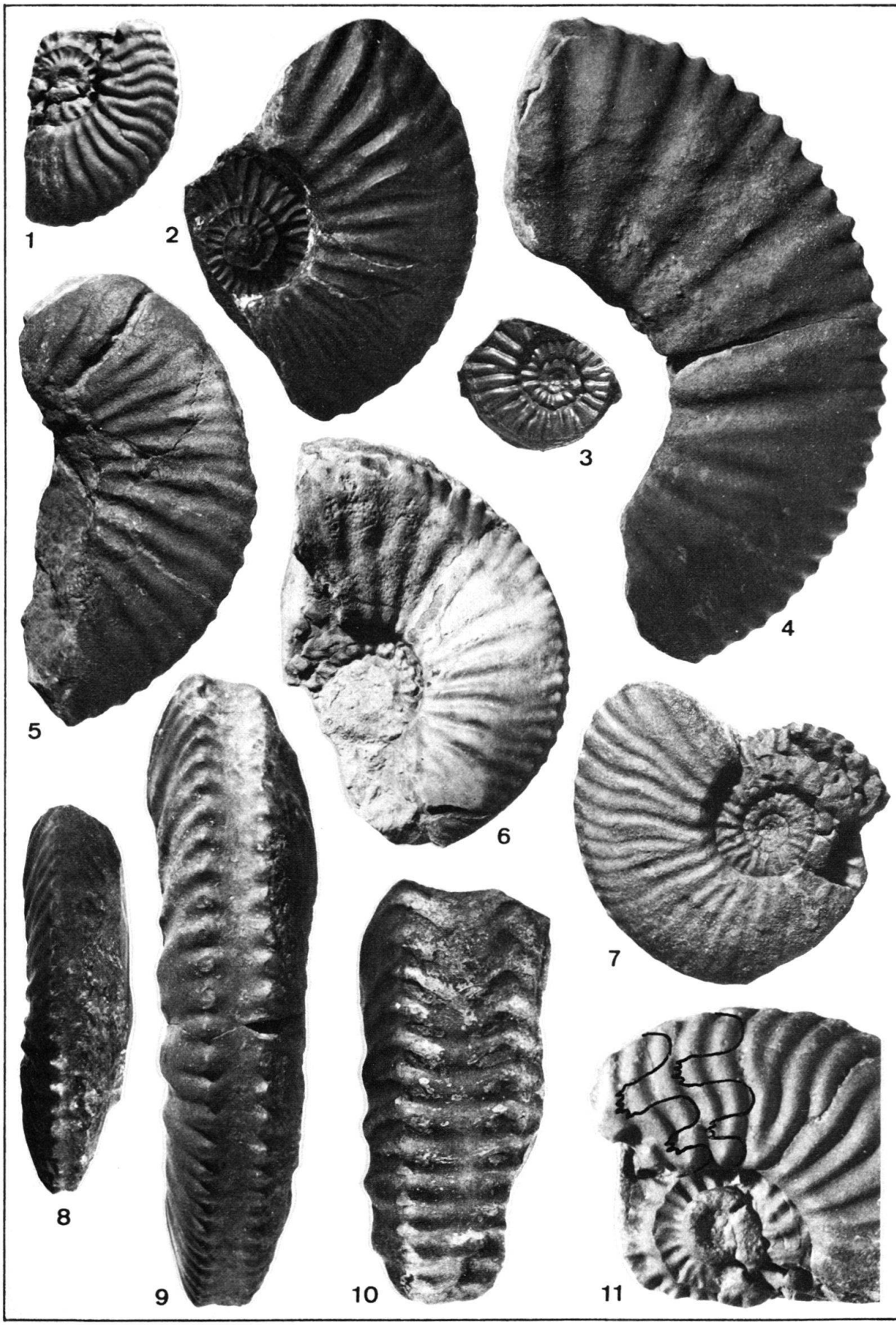
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Plate 2

(All figures natural size)

Fig. 1 *Chieseiceras chiesense* (MOJS.), Steinkern of the body whorl and external mould of the phragmocone, L/1618, Bagolino, Chiesense groove (= fossil horizon IV), uppermost Reitzi Zone.

Fig. 2 Group of *Nevadites reitzi*, Steinkern, L 1631, Pèrtica Bassa, 1.3 m below the Chiesense groove (= fossil horizon III), Reitzi Zone.

Fig. 3–4 *Chieseiceras chiesense* (MOJS.), Steinkern of the body whorl and silicon rubber cast of the inner whorls, L/1619, Valle Stelle/Monte San Giorgio, upper Grenzbitumenzone, bed 144 o, uppermost Reitzi Zone.

Fig. 5–6 *Halilucites* cf. *arietitiformis*, Steinkern of a part of the whorl, L/1643, Pèrtica Bassa, 1.9 m below the Chiesense groove, Reitzi Zone

Fig. 7–8 *Chieseiceras* cf. *chiesense*, Steinkern of the body whorl and of the anterior part of the phragmocone, L/1621, Val Gola, grey nodular limestone, Reitzi Zone; for ornamentation see text-figure 9m.

Fig. 9 Silicon rubber cast of the inner whorls of Figure 1.

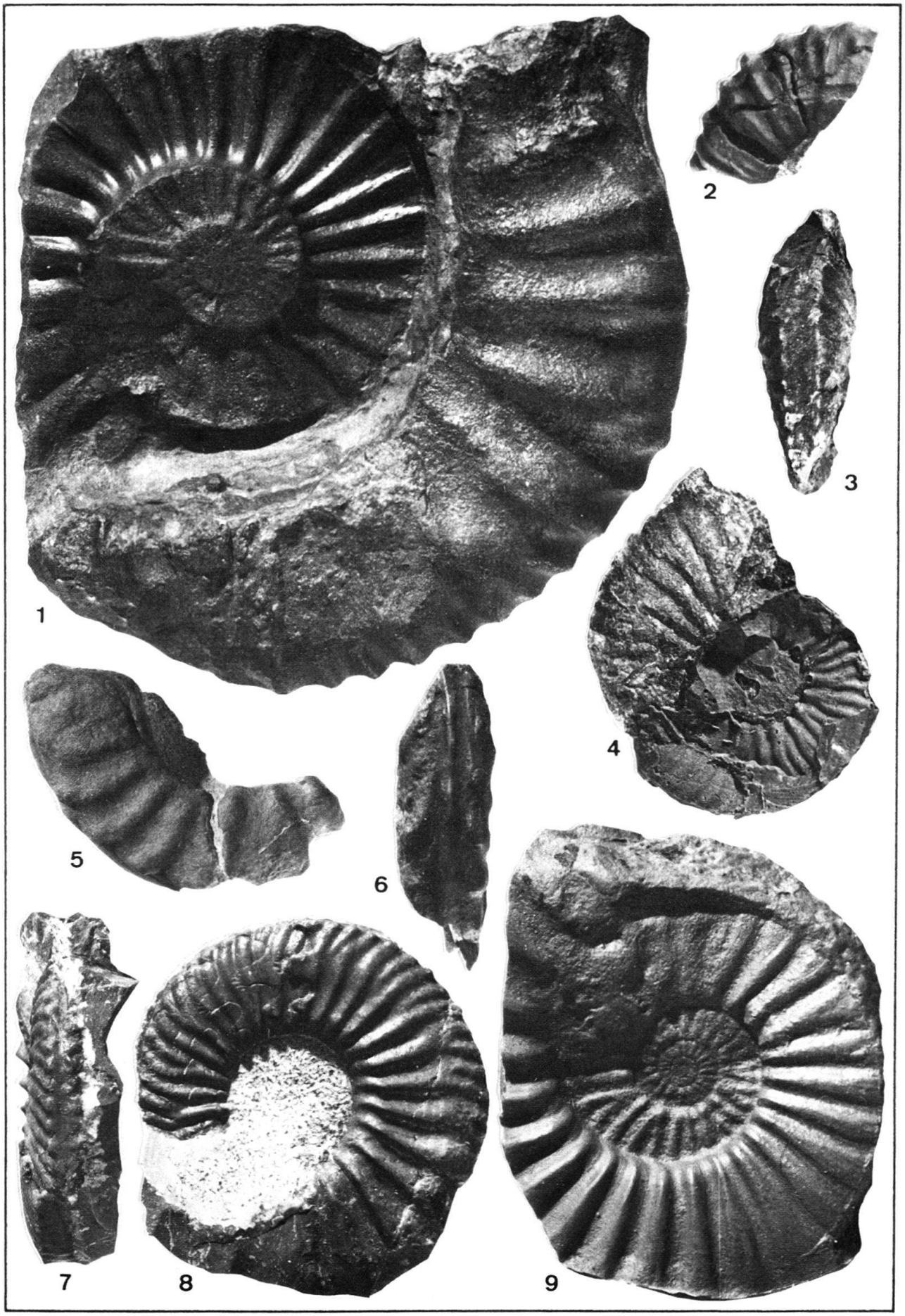
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Plate 3

Chieseiceras pèrticaense n.sp.

(All figures natural size)

Fig. 1 Holotype, L/1622, Steinkern of the body whorl and external mould of the inner whorls, Pèrtica Bassa, 1.45 m above the Chiesense groove (= fossil horizon V), Curionii Zone; for ornamentation and cross section see text-figures 9g–h.

Fig. 2 L 1623, Steinkern of the body whorl and a part of the phragmocone (suture partly visible), same locality and horizon as Figure 1.

Fig. 3 L/1624, Steinkern, Pèrtica Bassa, scree of lower Buchenstein Beds.

Fig. 4 Silicon rubber cast of the inner whorls of Figure 1 (holotype).

Fig. 5 L/1625, Steinkern of a part of the phragmocone with traced sutur, Pèrtica Bassa, 1.6 m above the Chiesense groove, Curionii Zone.

Fig. 6 L/1626, Steinkern of the body whorl, same locality and horizon as Figure 1.

Fig. 7–8 L/1627, same preservation as Figure 2 and same locality and horizon as Figure 1; for ornamentation and cross section see text-figures 9i–k.

Fig. 9 L/1628, Steinkern of a part of the body whorl, Pèrtica Bassa, 1.2 m above the Chiesense groove, Curionii Zone.

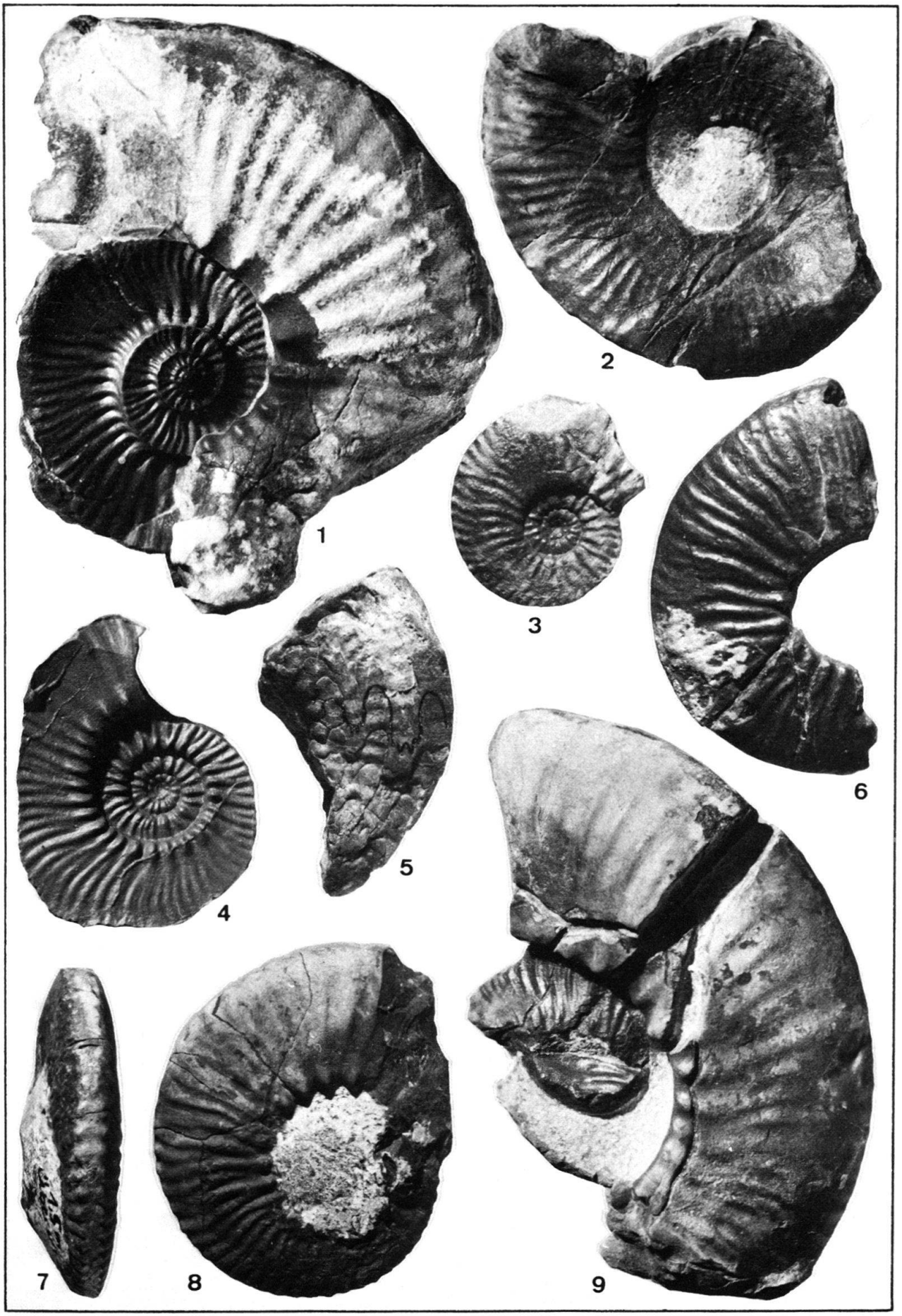
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Plate 4

(All figures natural size)

Fig. 1–2 *Nevadites* sp., L/1628, Steinkern of the body whorl, Prezzo (lower part of fossil horizon II), Reitzi Zone; for cross section see text-figure 9e.

Fig. 3 Silicon rubber cast of the inner whorls of Figure 6.

Fig. 4 Group of *Nevadites reitzi,* L/1632, Steinkern of a part of the body whorl, Biogno, 1.85 m below the Chiesense groove (= fossil horizon III), Reitzi Zone.

Fig. 5 *"Ceratites" böckhi* ROTH, L/1636, Steinkern of the body whorl, Bagolino, fossil horizon I.

Fig. 6 Group of *"Ceratites" ellipticus* HAUER, L/1633, Steinkern of the body whorl and external mould of the inner whorls, Bagolino, Chiesense groove (fossil horizon IV), uppermost Reitzi Zone.

Fig. 7 *Chieseiceras chiesense* (MOJS.), L/1620, Steinkern of a part of the body chamber of a large specimen, Valle Stelle/Monte San Giorgio, upper Grenzbitumenzone, bed 144 o, uppermost Reitzi Zone.

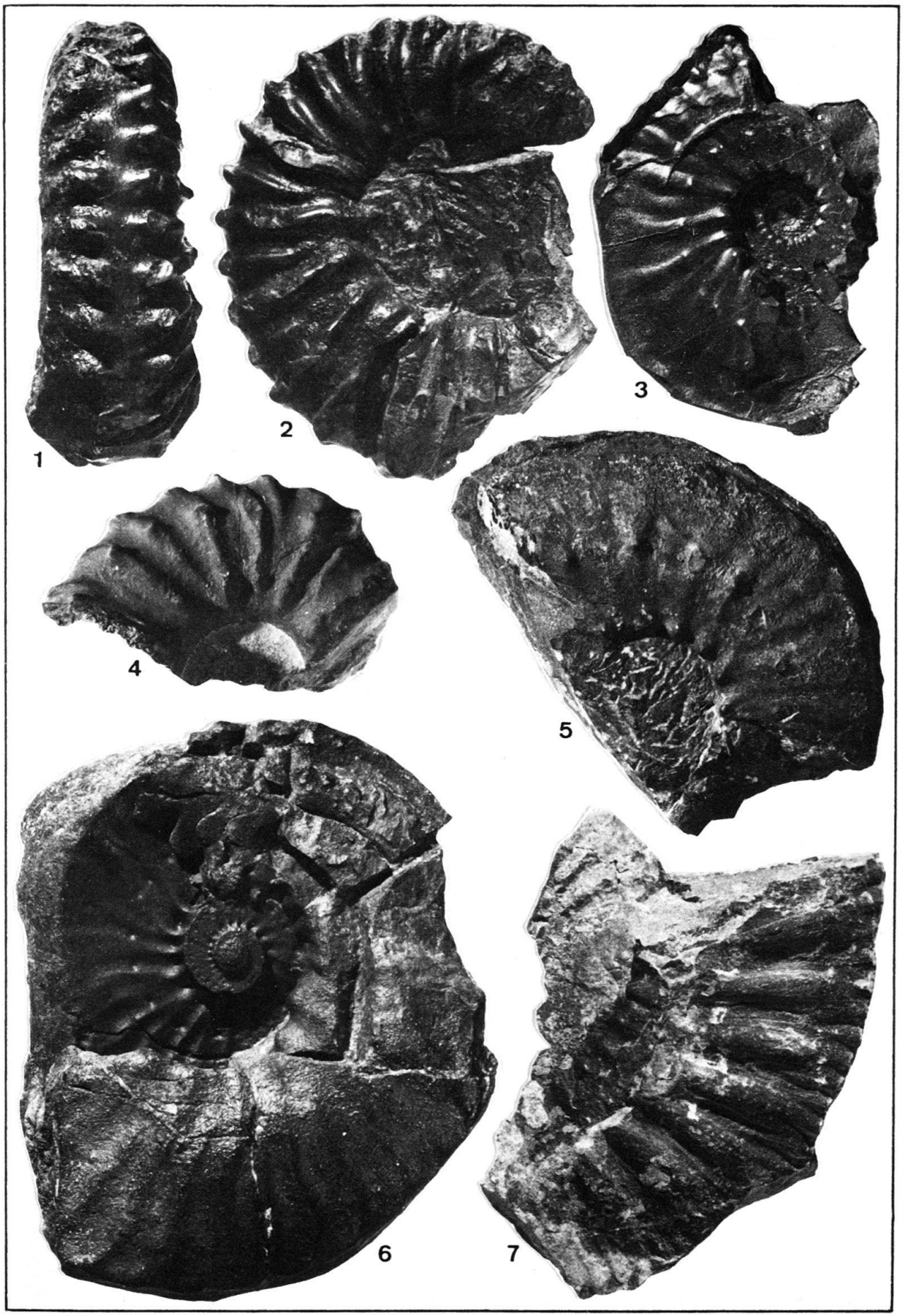
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Plate 5

(All figures natural size)

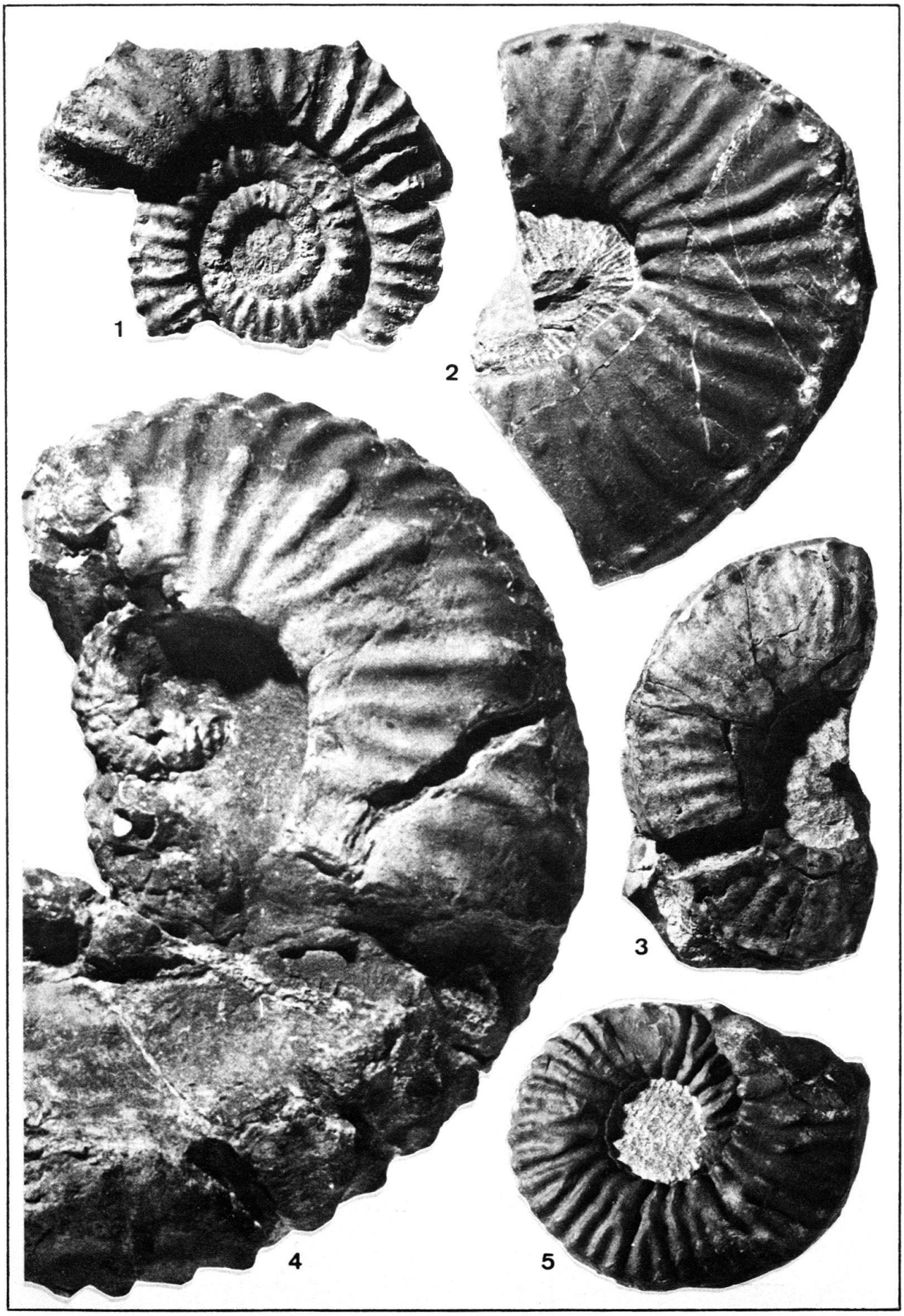
Fig. 1 *"Ceratites" hantkeni* MOJS., L/1637, Steinkern of a part of the body chamber and inner whorls (suture partly visible), Marcheno, fossil horizon I, Reitzi Zone.

Fig. 2 Group of *"Ceratites"* ellipticus HAUER, L/1635, Steinkern of the slightly distorted body chamber, Prezzo, lower surface of the nodular limestone forming the roof of the tuffitic level Td (see text-fig. 6), Reitzi Zone.

Fig. 3 *Stoppaniceras* sp., L/1638, Steinkern of the body chamber, Biogno, fossil horizon III, Reitzi Zone.

Fig. 4 *Eoprotrachyceras curionii* (MOJS.), L/1639, Steinkern of the body chamber and of parts of the inner whorls, Pèrtica Bassa, lower surface of the nodular limestone forming the roof of the Chiesense groove, Curionii Zone.

Fig. 5 *Eoprotrachyceras recubariense* (MOJS.), L/1640, Steinkern of the body chamber and of the anterior part of the phragmocone, Pèrtica Bassa, 1.8 m above the Chiesense groove, Curionii Zone.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