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

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Kapitel: 4: Anisian to Ladinian carbonate platforms

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

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

4. Anisian to Ladinian carbonate platforms

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

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

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

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

4.1.1. Monte San Giorgio (Ticino; southern Switzerland)

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

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

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

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

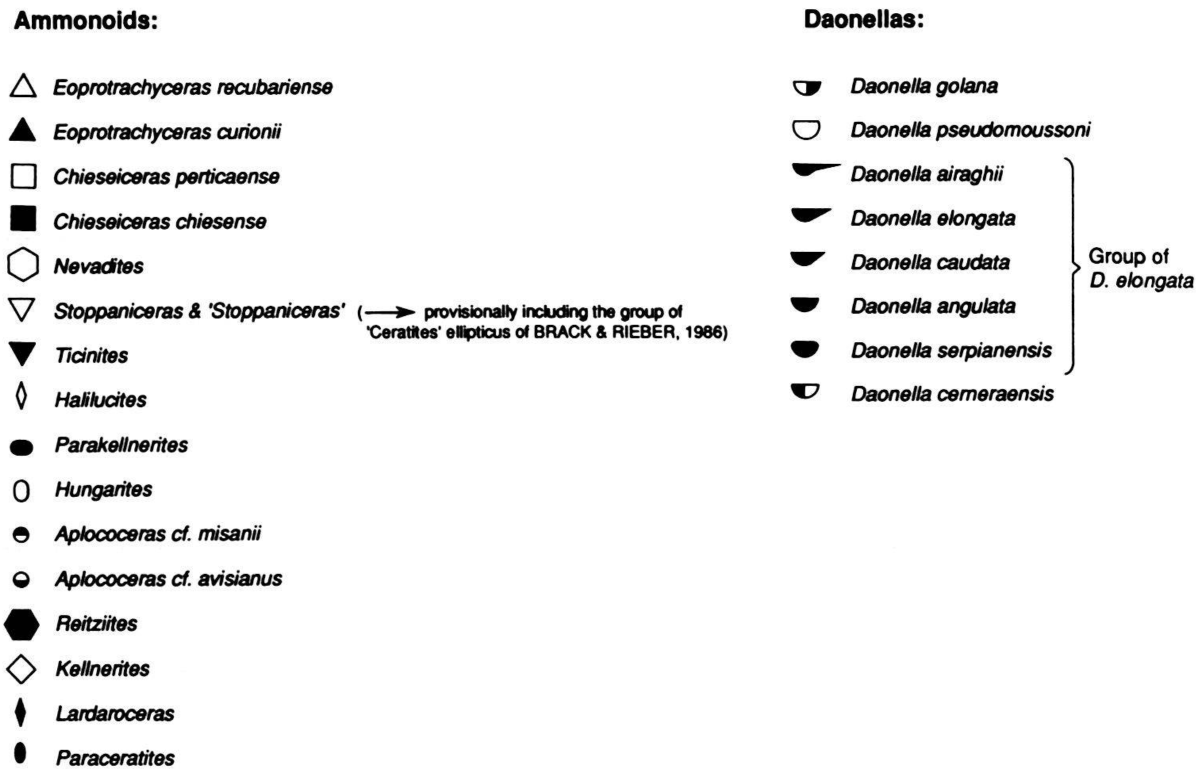
[15]) This value is based on Rock Eval pyrolysis data using a calibrated series of average Hydrogen Indices (HI) for extracted Type I/II source rock samples versus VR. An average HI of 615 [mg HC/g TOC] was derived from a S_2-TOC plot for extracted GBZ samples of a 3.8–33.3% TOC range. T_{max} for these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

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

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

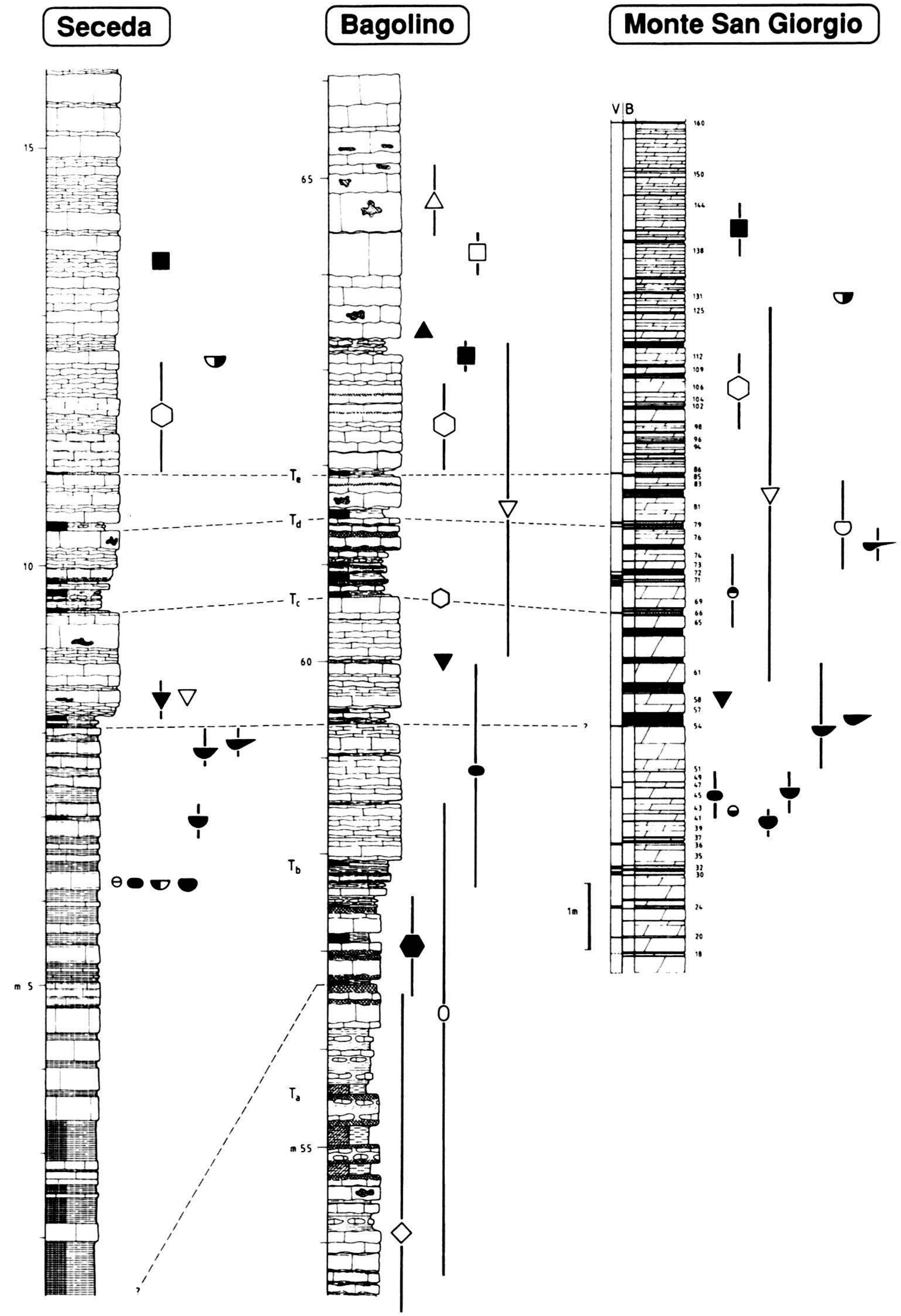
4.1.2. Latemar (western Dolomites)

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



Legend to Figs. 10 and 11

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


Seceda
Bagolino
Monte San Giorgio
15
10
m 5
65
60
m 55
Te
Td
Tc
Tb
Ta
V
B
1m
160
150
144
138
131
125
112
109
106
104
102
98
96
94
86
85
83
81
79
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moraines near Forno in the western Dolomites (for further indications and references see Assereto 1969). According to Häberle (1908) the blocks were transported by glaciers from the Val Sorda area in the Latemar massif but their exact provenance and stratigraphic position remained unkown [16]) (Assereto 1969). During a field-trip in 1989 across the Latemar we discovered a potential site for the origin of the Forno blocks or at least a stratigraphically equivalent level. The fossiliferous interval lies in the interior of the Latemar platform (in this paper the outcrop is called the "Lastei di Valsorda" locality) [17]) and more precisely in the uppermost part of the 250 m thick so-called "Lower Edifice"/ "Lower Platform Facies" (Gaetani et al. 1981, Goldhammer & Harris 1989). It is 20 m thick and consists of irregular m-scale bedded and light coloured limestones which are sometimes sucrosic and have thin reddish intercalations every 4–6 m. The reddish material also infills cavities and might have formed during sporadic subaerial exposure of this mainly subtidal unit (Goldhammer & Harris 1989). Within these 20 m of sediments twelve layers are rich in gastropods, bivalves and, above all, ammonoids. The layers are laterally continuous over tens of meters but no fossils could be spotted in approximately equivalent horizons further apart. We suppose that the pelagic fossils were living close to the platform margins and their shells were swept into the platform interior where they were concentrated by currents or accumulated in local depressions. Due to the high rate of platform aggradation in the "Lower Platform Facies" the entire fossiliferous interval presumably reflects a short time-span.

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

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

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

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

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

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

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

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

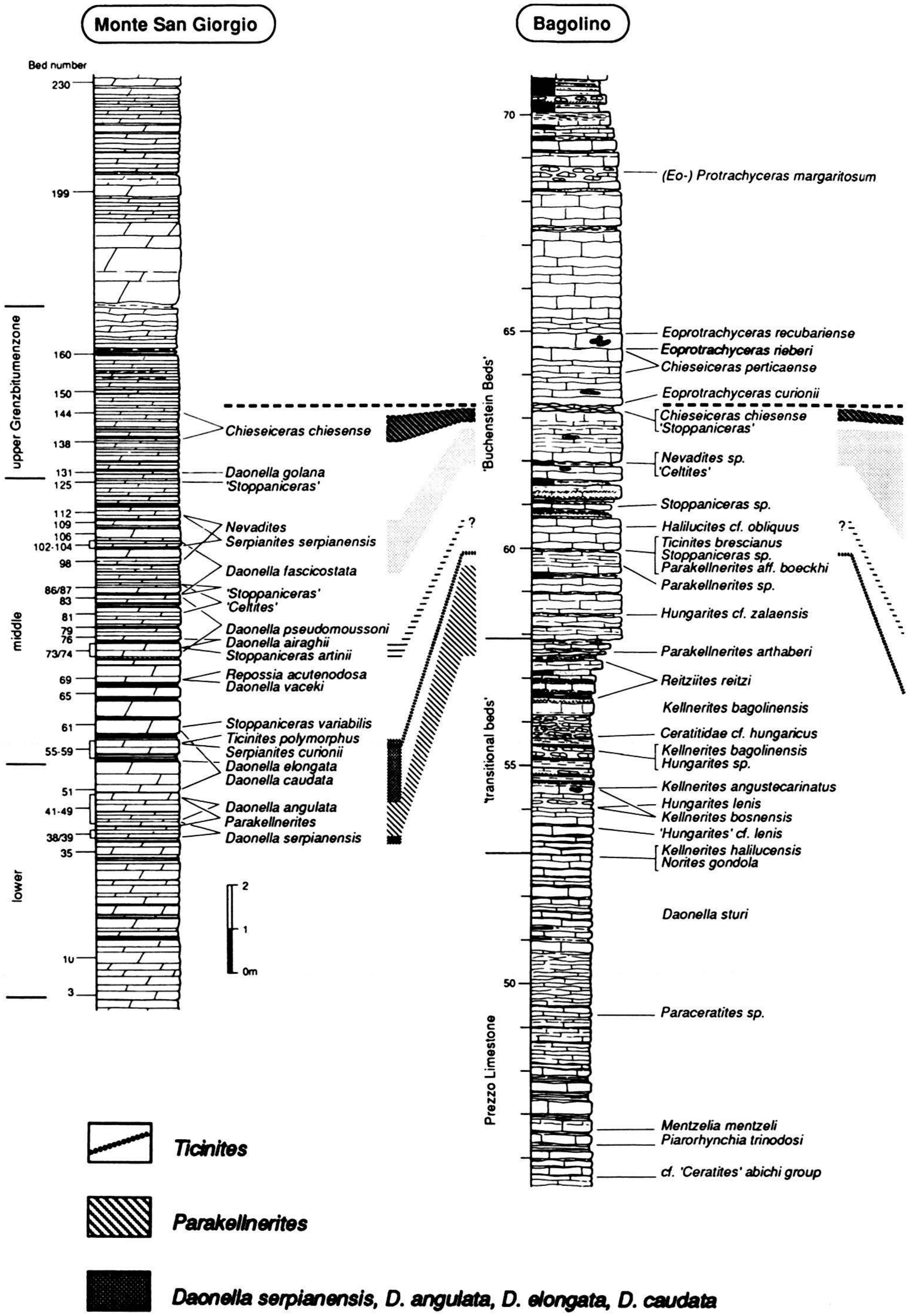
4.1.3. Cernera (Dolomites)

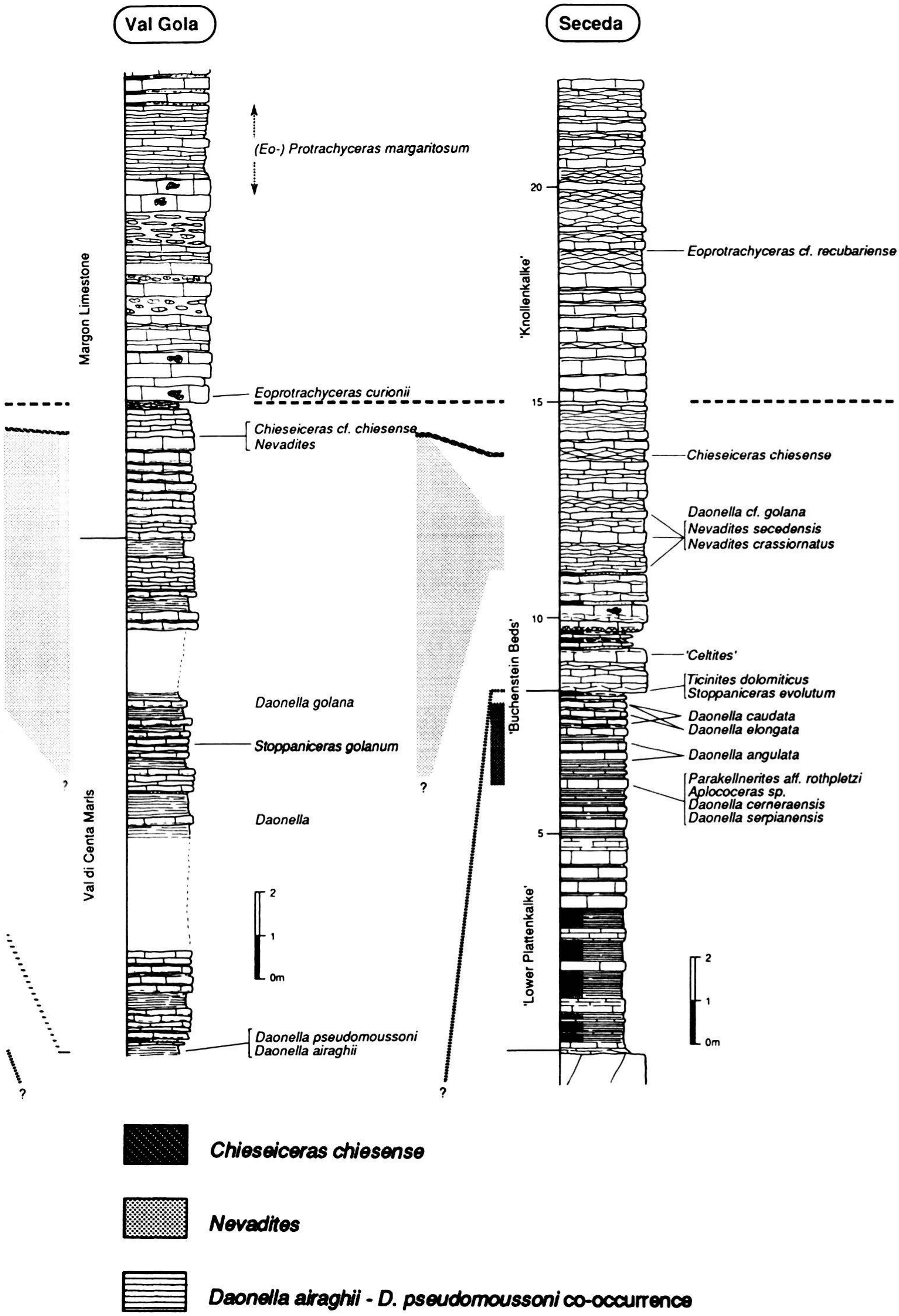
To the southeast of Punta di Zonia on the northern paleoslope of the Cernera platform, Cros & Houel (1983) reported a thin carbonate interval with two successive fossil levels containing ammonoids. A brief inspection of this locality indeed confirmed the presence of *Aplococeras avisianum* along with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

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

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

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


Monte San Giorgio
Bagolino
Bed number
upper Grenzbitumenzone
middle
lower
Chieseiceras chiesense
Daonella golana
'Stoppaniceras'
Nevadites
Serpianites serpianensis
Daonella fascicostata
'Stoppaniceras'
'Celtites'
Daonella pseudomoussoni
Daonella airaghii
Stoppaniceras artinii
Repossia acutenodosa
Daonella vaceki
Stoppaniceras variabilis
Ticinites polymorphus
Serpianites curionii
Daonella elongata
Daonella caudata
Daonella angulata
Parakellnerites
Daonella serpianensis
'Buchenstein Beds'
'transitional beds'
Prezzo Limestone
(Eo-) Protrachyceras margaritosum
Eoprotrachyceras recubariense
Eoprotrachyceras rieberi
Chieseiceras perticaense
Eoprotrachyceras curionii
Chieseiceras chiesense
'Stoppaniceras'
Nevadites sp.
'Celtites'
Stoppaniceras sp.
Halilucites cf. obliquus
Ticinites brescianus
Stoppaniceras sp.
Parakellnerites aff. boeckhi
Parakellnerites sp.
Hungarites cf. zalaensis
Parakellnerites arthaberi
Reitziites reitzi
Kellnerites bagolinensis
Ceratitidae cf. hungaricus
Kellnerites bagolinensis
Hungarites sp.
Kellnerites angustecarinatus
Hungarites lenis
Kellnerites bosnensis
'Hungarites' cf. lenis
Kellnerites halilucensis
Norites gondola
Daonella sturi
Paraceratites sp.
Mentzelia mentzeli
Piarorhynchia trinodosi
cf. 'Ceratites' abichi group
Ticinites
Parakellnerites
Daonella serpianensis, D. angulata, D. elongata, D. caudata



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

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

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

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

5.1. The fossil succession and resulting scheme of ammonoid zones

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

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