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MIDDLE TRIASSIC FORAMINIFERA FROM THE SECEDA CORE (DOLOMITES, NORTHERN ITALY)

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Riassunto. Nel presente lavoro viene esaminata l'associazione a foraminiferi rinvenuti in 224 sezioni sottili effettuate in sedimenti torbiditici di una successione bacinale al limite Anisico/Ladinico. La microfauna é costituita da forme di acqua bassa associate a foraminiferi calcareo-ialini (*Lagenina*) riferibili ad un ambiente di mare aperto. La definizione biostratigrafica dell'intervallo mediotriassico studiato permette la datazione di comparse e scomparse di alcuni foraminiferi bentonici di mare basso. In particolare le specie *Meandrospira dinarica* Kochansky-Devidè & Pantic e *Arenovidalina chialingchiangensis* Ho sono limitate alla zona a *Reitzi*, mentre le specie *Variostoma alta* Kristan e *Hoyenella* gr. *sinensis* nella successione studiata non superano la zona a *Curionii*. L'evento biostratigrafico piú significativo si rinviene alla base della zona a *Gredleri* dove si registra la comparsa della famiglia Involutinidae Bütschli, rappresentata dai generi *Lamelliconus* e *Aulotortus*. La composizione microfaunistica é simile a quella conosciuta in aree paleogeograficamente circostanti, ma in generale si nota una diversificazione generica e specifica minore in confronto con le associazioni a foraminiferi dell'Anisico o del Carnico.

Abstract. The assemblage of foraminifera in turbidite beds in Middle Triassic basinal deposits straddling the Anisian/Ladinian boundary interval was studied in 224 thin sections. The fauna consists mainly of shallow-water inhabitants, associated with calcareous hyaline foraminifera (*Lagenina*) of open-marine environment. Due to a well established biostratigraphy in the studied interval, the first and last appearance of some shallow-water, benthic foraminifera can be assigned to the Mid Triassic ammonoid stratigraphy. The species *Meandrospira dinarica* Kochansky-Devidè & Pantic and *Arenovidalina chialingchiangensis* Ho are limited to the *Reitzi* ammonoid zone. The species *Variostoma alta* Kristan and *Hoyenella* gr. *sinensis* both do not superate the *Curionii* zone in age in the studied succession. The biostratigraphic most important event occurs at the base of the *Gredleri* Zone with the appearance of the family Involutinidae Bütschli, represented by the genera *Lamelliconus* and *Aulotortus*. The faunal composition is similar to those of neighbouring paleoprovinces, but generally a lower faunistical diversification compared to foraminiferal assemblages in the Anisian or Carnian is observed.

Introduction

Middle Triassic foraminifera are well studied within the Tethyan domain (Salaj et al. 1983; Zaninetti 1976; Oravecz-Scheffer 1987; Trifonova 1992, 1993, 1994; Rettori 1995). However, several case studies describe species of shallow-water habitats that lack age-diagnostic macrofaunas and thus in several cases the stratigraphic range of these forms is not very well defined.

In this paper we describe foraminifera derived from a biostratigraphically well constrained interval straddling the Anisian/Ladinian boundary interval (Brack & Rieber 1993). Since the stratigraphic position of this stage boundary is still under discussion, only the names of the ammonoid zones are used in the text. The majority of the samples are taken from turbidite beds in a core drilled for scientific purposes at Seceda in the western Dolomites (Fig. 1; Brack et al. 2000). In this respect, the here presented results are part of the scientific investigations on the core.

Geological setting.

The Buchenstein beds, from which the samples were taken, are an up to 70 m thick succession of basinal limestones and marls with intercalations of debris from adjacent carbonate platforms and volcaniclastics (Viel 1979; Bosellini & Ferri 1980). They were deposited in small interplatform basins, which reached depths of up to 1000 m (Fig. 1; Bosellini 1984). During the deposition of the Buchenstein beds oxygenation on the sea-bottom varied, leading to both laminated and bioturbated facies types (Brack & Muttoni 2000). The biostratigraphic range of this succession is well constrained by age-diagnostic macrofossils and encompasses five ammonoid zones (*Reitzi, Secedensis, Curionii, Gredleri* and *Archelaus* zones; Brack & Rieber 1993).

All 224 studied samples are thin sections from turbidite beds, which mainly contain debris from the plat-

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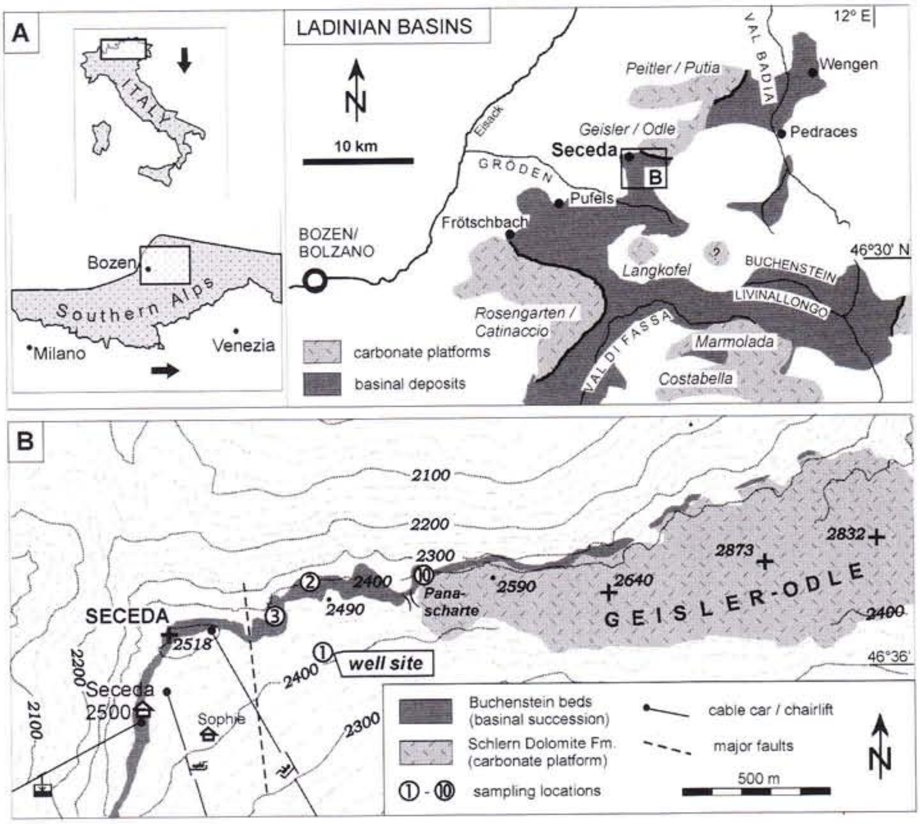


Fig. 1 - A) Distribution of carbonate platforms and basinal sediments in the Dolomites during the early Ladinian. Names of platforms are written in italics, bold dark lines mark approximate position of platform/basin transition. B) Study area around Seceda indicating major outcrops of the Buchenstein beds, the well site (1) and additional sampling locations (2, 3, 10).

form top and slopes, and which are present throughout the studied succession (Maurer et al. 2002). Most samples derive from the Seceda core, which was recovered in proximity to an age-equivalent carbonate platform (Fig. 1B). Additional samples were taken from outcrop sections around the well site that cover a short stratigraphic interval missing in the core.

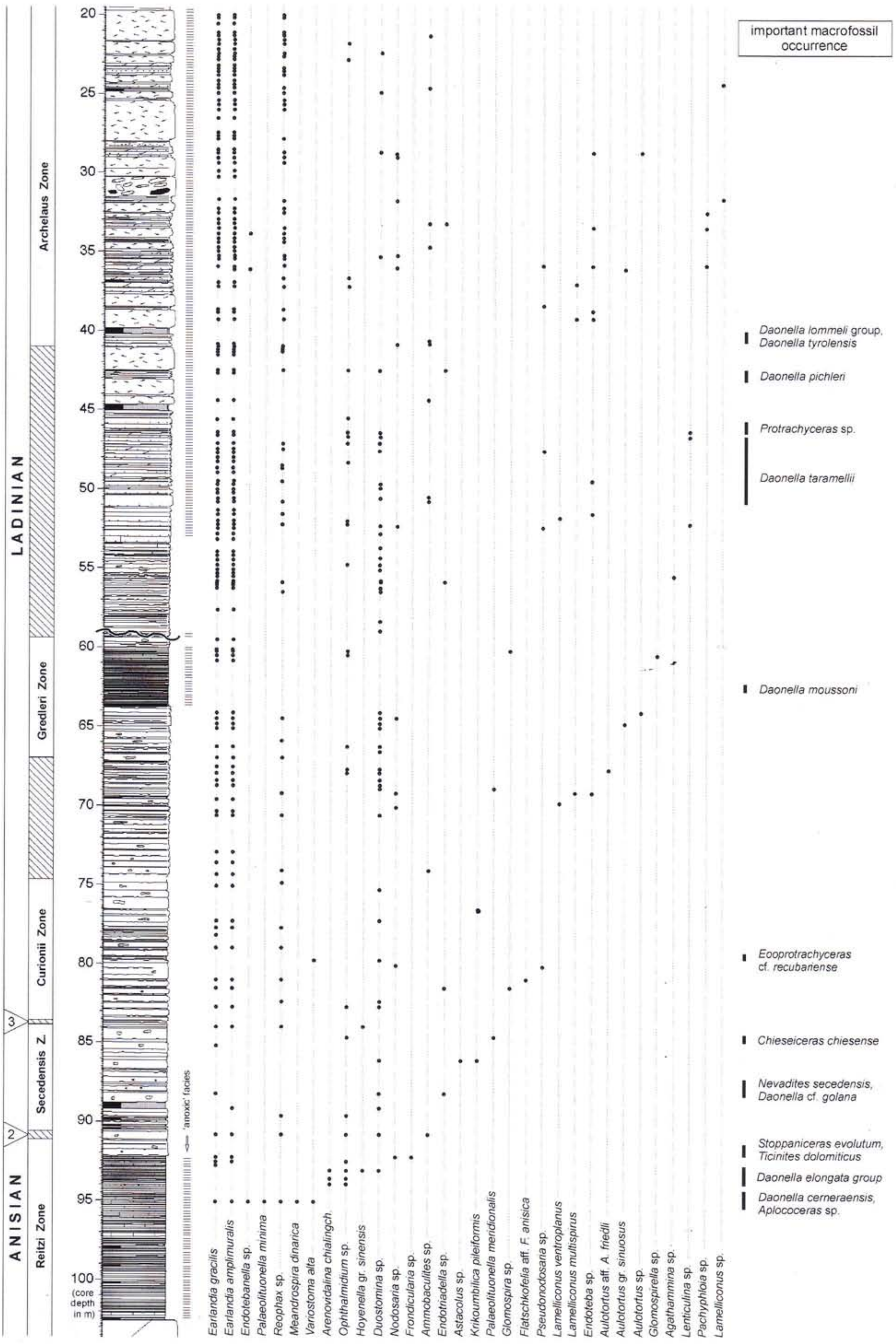
Foraminiferal assemblage and diversification.

In the analyzed thin sections foraminifera are present as part of the debris shed from the adjoining carbonate platforms and slopes by turbidity currents (Maurer et al. 2002). Throughout the core we encountered platform-derived benthonic foraminifera in association with calcareous hyaline (*Lagenina*) foraminifera of open-marine environment (Fig. 2). The assemblages attributed to a shallow-water environment are characterized by the constant presence of unilocular, tubular foraminifera referable to the genus *Earlandia* Plummer, in association with microgranular multilocular foraminifera with elongated morphology belonging to the genera *Endotebanella* Vachard et al. *Endotriadella* Vachard et al., and agglutinated foraminifera such as *Ammobaculites* Cushman, *Reophax* de Montfort and *Palaeolituonella* Bèrczi-Makk. Less frequent there occur trochospiral and streptospiral types of the genera *Endoteba* and *Glomospira*. Furthermore porcelaneous foraminifera are represented by *Ophthalmidium* sp., *Arenovidalina chialingchiangensis* Ho, *Hoyenella* gr. *sinensis* (Ho) and *Agathammina* sp.

Throughout the whole succession we noticed the presence of originally aragonitic foraminifera of the family Duostominidae Brotzen with the genera *Variostoma* Kristan-Tollmann, *Duostomina* Kristan-Tollmann and *Krikoumbilica* He. The sample 69.90 marks the appearance of the originally aragonitic family Involutinidae; upsection there follows a diversification of these types, represented by the lenticular genus *Aulotortus* Weynschenk and the cone-shaped genus *Lamelliconus* Piller (Fig. 2, 3, 4). Elongated calcareous hyaline foraminifera include the genera *Nodosaria* Lamarck, *Pseudonodosaria* Boomgaart, *Frondicularia* Defrance, *Astacolus* de Montfort and *Lenticulina* Lamarck.

The distribution of foraminifera along the studied section (Fig. 2) shows phases of increase and decrease in the diversity (= richness) of the microfauna both at generic and specific levels. A general increase is given from the base of the section until sample 81.00. In the upper part of the *Curionii* zone follows a decrease in the

Fig. 2 - Distribution of foraminifera found in 224 thin sections in the Seceda core along with a lithological log of the 20-103 m core interval. The range of ammonoid zones and current candidates 2 (*sensu* Krystyn 1983) and 3 (*sensu* Brack & Rieber 1993) for the definition of the Anisian/Ladinian boundary are indicated on the left. Important macrofossils found in surrounding outcrop sections are indicated on the right (after Brack & Rieber 1993, Brack et al. 2000, Brack et al. 2001). The lithology of the core is explained in inset on Fig. 3.


ANISIAN
LADINIAN
Reitzi Zone
Secedensis Z.
Curionii Zone
Gredleri Zone
Archelaus Zone
2
3
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
(core depth in m)
'anoxic' facies
Earlandia gracilis
Earlandia amplimuralis
Endotebanella sp.
Palaeolituonella minima
Reophax sp.
Meandrospira dinarica
Variostoma alta
Arenovidalina chialingch.
Ophthalmidium sp.
Hoyenella gr. sinensis
Duostomina sp.
Nodosaria sp.
Frondicularia sp.
Ammobaculites sp.
Endotriadella sp.
Astacolus sp.
Krikoumbilica pileiformis
Palaeolituonella meridionalis
Glomospira sp.
Flatschkofelia aff. F. anisica
Pseudonodosaria sp.
Lamelliconus ventroplanus
Lamelliconus multispirus
Endoteba sp.
Aulotortus aff. A. friedli
Aulotortus gr. sinuosus
Aulotortus sp.
Glomospirella sp.
Agathammina sp.
Lenticulina sp.
Pachyphloia sp.
Lamelliconus sp.
important macrofossil occurrence
Daonella lommeli group, Daonella tyrolensis
Daonella pichleri
Protrachyceras sp.
Daonella taramellii
Daonella moussoni
Eoprotrachyceras cf. recubariense
Chieseiceras chiesense
Nevadites secedensis, Daonella cf. golana
Stoppaniceras evolutum, Ticinites dolomiticus
Daonella elongata group
Daonella cerneraensis, Aplococeras sp.

presence of foraminifera and a total absence in the interval between samples 72.94 and 70.64. Above this level a new increase in diversification is present, dominated by the first appearance of the representatives of the family Involutinidae Bütschli from sample 69.90 upwards.

In the *Gredleri* and *Archelaus* zones the microfauna does not show any major decrease in diversification. Only the interval 64-61m, which is characterized by very fine-grained (<177 micron) turbidite beds, lacks foraminifera (Fig. 2). Correlation of this interval with outcrop-equivalents revealed the presence of foraminifera in coarser grained portions of turbidites closer to the platform (Fig. 3). In the outcrop we also sampled the interval of section 10, illustrated in Fig. 3, and missing in the core due to local tectonic unconformities. The outcrop samples show the same assemblages as the surrounding samples in the core close to this interval. In general we noticed a low faunistical diversification compared to the foraminiferal assemblages in the Anisian or Carnian, although there is a good state of preservation in the analyzed samples.

Stratigraphic implications.

The well constrained biostratigraphic age of the section allows a more precise calibration of the first and last appearence of some of the described species. Due to an accurate core-to-outcrop correlation a direct comparison of the microfauna with the occurrence of age-diagnostic macrofossils in the outcrop is possible (Fig. 2).

The sample 95.06 shows the presence of *Meandrospira dinarica* Kochansky-Devidè & Pantic (Fig. 4), a well known species in the Anisian of the Tethyan domain (Rettori 1995, cum bibl.). This species occurs in the *Reitzi* zone, but does not show up anymore further up in the section; it is therefore likely to have died out in the *Reitzi* zone. The species *Arenovidalina chialingchiangensis* Ho, so far known as Middle Triassic in age (Rettori 1995, *cum bibl.*) is limited to the *Reitzi* zone as well and disappears above the sample 93.09. The species *Variostoma alta* Kristan and *Hoyenella* gr. *sinensis* are present in the *Reitzi* zone and both do not superate the Curionii zone in age in the studied succession. *Palaeolituonella meridionalis* Bèrczi-Makk disappears at the base of the *Gredleri* Zone.

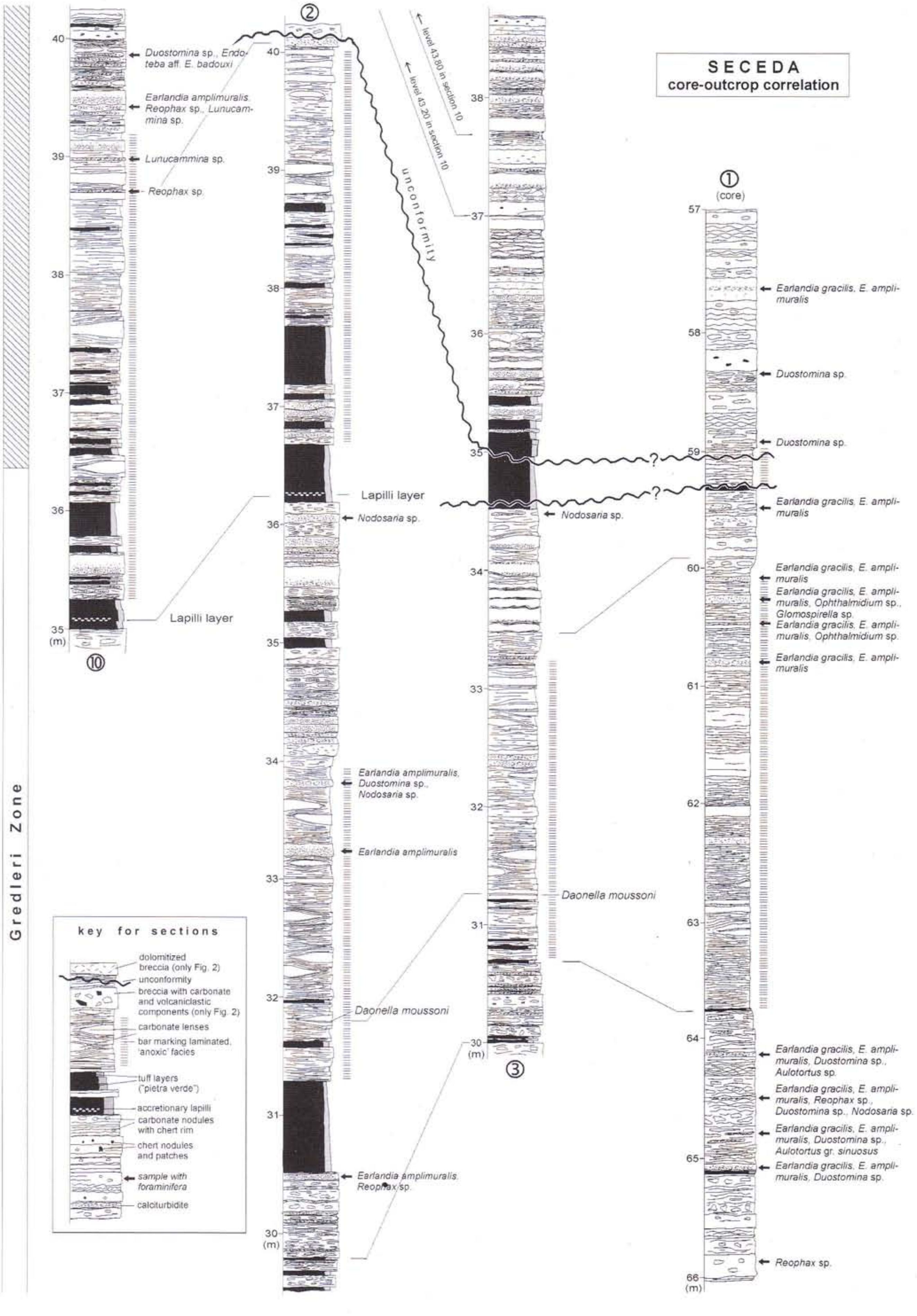
The biostratigraphic most important event occurs from level 69.90 m upwards with the appearance of the genera *Lamelliconus* and *Aulotortus* (Fig. 2, 4). These Involutinidae are represented by the species *L. ventroplanus* (Oberhauser), *L. multispirus* (Oberhauser), *A.* aff. *A. friedli* (Kristan-Tollmann) and *A.* gr. *sinuosus* Weynschenk. Based on ammonoid data their appearence can be pinpointed at a level slightly older than the base of the *Gredleri* zone (base late Ladinian *sensu* Krystyn 1983). In the Buchenstein beds in the Dolomites this level approximately matches the first occurrence of *Budurovignathus hungaricus* (Kozur & Vegh), a conodont marker (Maurer 1999).

Paleoecology

From an ecological point of view some considerations can be made on the calcareous hyaline foraminifera (*Lagenina*) of open-sea environment. In particular we noticed that the elongated, cylindrical morphotypes (*Nodosaria, Frondicularia* and *Pseudonodosaria*) are most frequent at the beginning or at the end of the anoxic intervals (e.g. levels 92.22 m and 64.49 m in Fig. 2, level 36 m in section 2 on Fig. 3). This is in agreement with the fact that these morphotypes are adapted to disaerobic and low-energy environments (Murray 1991; Tyszca 1993). The planispiral and biconvex strictly coiled forms such as biconvex *Lenticulina*, are in contrast more typical for better oxigenated substrates (Murray 1991; Tyszca 1993).

The fauna typical for restricted, low-energy shallow-marine habitats (i.e. backreef and lagoon) is characterized by porcelaneous miliolid foraminifera (Haunold et al. 1997; Davaud & Septfontaine 1995; Travè et al. 1996; Fornos & Ahr 1997) and include the genera *Ophthalmidium* Kubler & Zwingli, *Arenovidalina* Ho, *Hoyenella* Rettori and *Agathammina* Neumayr. In the studied section these types are more frequent than in older Anisian formations in the Dolomites, where only the genus *Ophthalmidium* is present (Senowbari-Daryan et al. 1993). In recent environments miliolid foraminifera are not limited to restricted shallow-marine areas, but occur also in forereef and slope settings (in the Bahamas, e.g. Rose & Lidz 1977; in the Gulf of Aqaba, Reiss & Hottinger 1984). The here described genera may therefore have colonized the same range of environments in the Triassic.

Fig. 3 - Correlation of the 57-66 m core interval (section 1) with equivalent portions in outcrop sections 2, 3 and 10, where 10 is the most proximal and 1 the most distal section relative to the nearby carbonate platform. The foraminifera found in the outcrop samples are indicated. Note the occurrence of *Nodosaria* at the beginning and end of the anoxic facies intervals (e.g. 33.8 and 36 m in section 3). The stratigraphic column in the core and the sections 2 and 3 is disturbed by local tectonic unconformities. The 35-40 m interval shown in section 10 most probably represents the interval missing in the core. The occurrence of the macrofossil *Daonella moussoni* Mérian, collected during this study, is indicated. The layer with accretionary lapilli represents a unique marker horizon that can be correlated over the entire Buchenstein basin within the Dolomites (Gianolla 1991, Maurer 1999). Due to the local unconformity at Seceda, the lapilli-layer disappears in section 3 and in the core. For general correlation of core and outcrop see Brack et al. (2000).


SECEDA
core-outcrop correlation
Gredleri Zone
⑩
40
Duostomina sp., Endoteba aff. E. badouxi
Earlandia amplimuralis, Reophax sp., Lunucammina sp.
39
Lunucammina sp.
Reophax sp.
38
37
36
Lapilli layer
35
(m)
②
40
39
38
37
unconformity
Lapilli layer
36
Nodosaria sp.
35
34
Earlandia amplimuralis, Duostomina sp., Nodosaria sp.
Earlandia amplimuralis
33
32
Daonella moussoni
31
Earlandia amplimuralis, Reophax sp.
30
(m)
← level 43.80 in section 10
← level 43.20 in section 10
③
38
37
36
35
?
?
Nodosaria sp.
34
33
32
Daonella moussoni
31
30
(m)
①
(core)
57
Earlandia gracilis, E. amplimuralis
58
Duostomina sp.
Duostomina sp.
59
Earlandia gracilis, E. amplimuralis
60
Earlandia gracilis, E. amplimuralis
Earlandia gracilis, E. amplimuralis, Ophthalmidium sp., Glomospirella sp.
Earlandia gracilis, E. amplimuralis, Ophthalmidium sp.
Earlandia gracilis, E. amplimuralis
61
62
63
64
Earlandia gracilis, E. amplimuralis, Duostomina sp., Aulotortus sp.
Earlandia gracilis, E. amplimuralis, Reophax sp., Duostomina sp., Nodosaria sp.
Earlandia gracilis, E. amplimuralis, Duostomina sp., Aulotortus gr. sinuosus
65
Earlandia gracilis, E. amplimuralis, Duostomina sp.
Reophax sp.
66
(m)
key for sections
dolomitized breccia (only Fig. 2)
unconformity
breccia with carbonate and volcaniclastic components (only Fig. 2)
carbonate lenses
bar marking laminated, 'anoxic' facies
tuff layers ("pietra verde")
accretionary lapilli
carbonate nodules with chert rim
chert nodules and patches
sample with foraminifera
calciturbidite

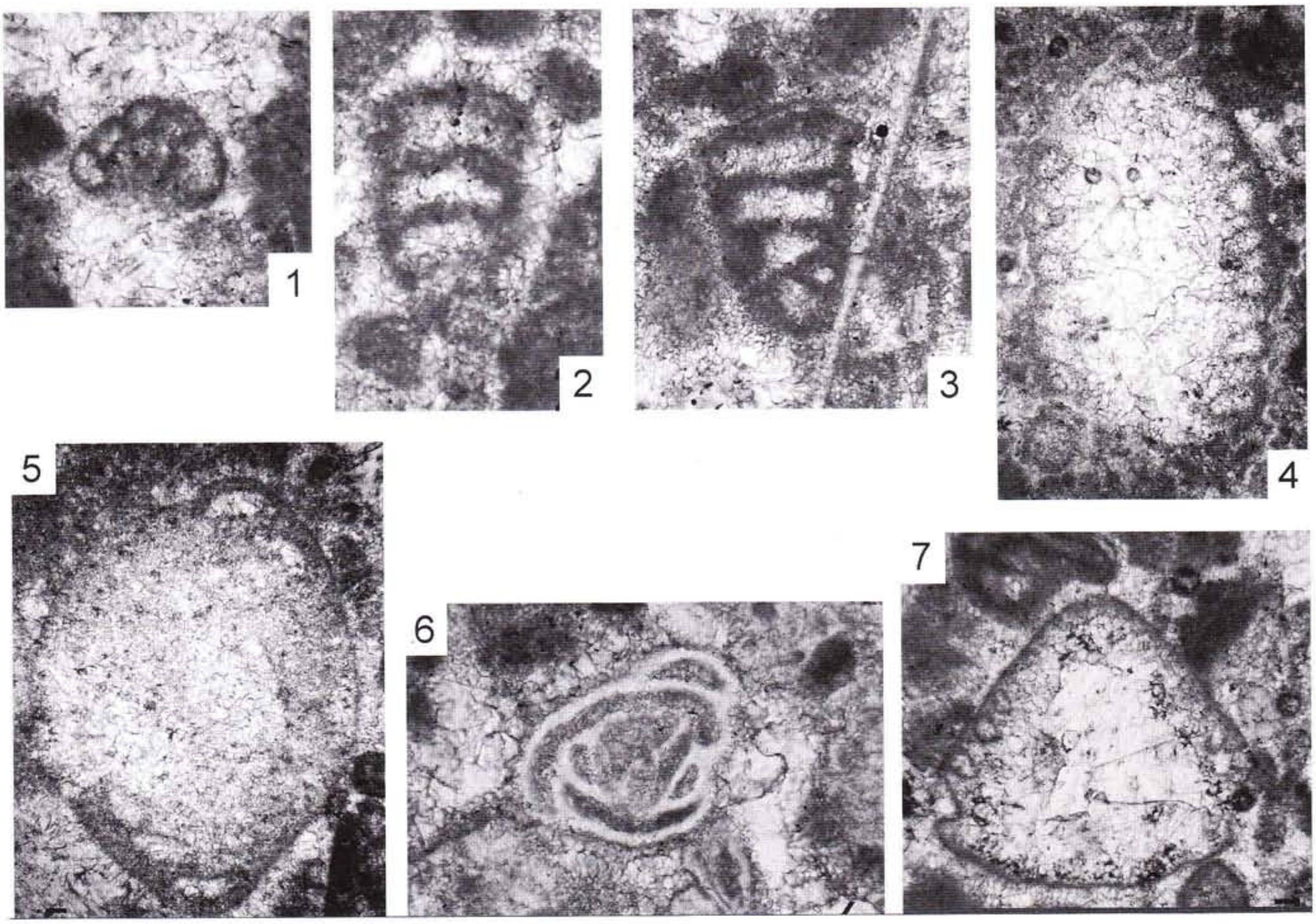


Fig. 4 - Illustration of some species of foraminifera found in the Seceda core. 1 - *Meandrospira dinarica* Kochansky-Devidè & Pantic, level 95.06 m, magnification x66. 2 - *Palaeolituonella minima* He, level 95.06 m, magnification x106. 3 - *Palaeolituonella meridionalis* Bèrczi-Makk, level 68.92 m, magnification x80. 4 - *Lamelliconus multispirus* (Oberhauser), level 69.22 m, magnification x50. 5 - *Aulotortus* ex gr. *sinuosus* Weynschenk, level 64.83 m, magnification x45. 6 - *Aulotortus* aff. *A. friedli* (Kristan-Tollmann), level 67.70 m, magnification x55. 7 - *Lamelliconus ventroplanus* (Oberhauser), level 69.90 m, magnification x58.

The agglutinated and microgranular elongated genera *Reophax, Endotriadella, Endotebanella* and *Ammobaculites* are also part of shallow-marine environments; they are suggested to live infaunal with detrital-scavenger feeding habit (Jones & Charnock 1985). The elongated, unilocular genus *Earlandia*, which is quantitative the most abundant in the samples, and the originally aragonitic genera *Duostomina, Variostoma* and *Krikoumbilica* of the family Duostominidae are generally common in Triassic carbonate platforms.

In the *Gredleri* and *Archelaus* zones the lamellar, aragonitic foraminifera of the family Involutinidae appear as additional shallow-water inhabitants. These types, represented by the genera *Lamelliconus* and *Aulotortus*, live in various shallow-marine environments ranging from the reef to restricted lagoon (Piller 1978).

Discussion and conclusions.

A significant event in the faunal evolution of foraminifera recorded in the Buchenstein beds is the appearance of the family Involutinidae Bütschli at the base of the *Gredleri* Zone (base late Ladinian *sensu* Krystyn 1983). Lenticular morphotypes are considered the ancestral forms of this family at the base of its evolution, followed by conical types (Salaj et al. 1983; Gazdzicki 1983; di Bari & Laghi 1994). For instance, Oravecz-Scheffer (1987) describes the appearance of lenticular Involutinidae, assigned to the genera *Aulotortus* Weynschenk and *Triadodiscus* Piller, followed by the conical genus *Lamelliconus* Piller, in the Carnian of the Transdanubian Central range. In contrast, we encountered first the conical genus *Lamelliconus* (first appearance at level 69.90m) and then the lenticular morphotype, represented by *Aulotortus* (first appearance at level 67.70m; Fig. 2). We attribute this phenomenon to a lack of lenticular morphotypes due to the general poor percentage of foraminifera in the samples, rather than to a different evolutionary trend of the family Involutinidae in the Buchenstein basin. The appearance of Involutinidae at the base of the late Ladinian as recorded here is in agreement with the general description of the evolution of this family in the late Ladinian/early Carnian (e.g. Salaj et al. 1983). Note, however, that the conical morphotype *Lamelliconus* has been described already in the Anisian Eros Limestone of Hydra (Greece; Rettori et al. 1994), which has been dated as Pelsonian in age based on conodonts (Angiolini et al. 1992).

It is not clear what favourized the appearance of Involutinidae in the *Gredleri* Zone. In view of Márquez & Trifonova (2000), their occurrence depends on the relative percentage of aragonite solved in the sea water. In this respect, a rise in aragonite in the sea water could have favoured the evolution of Involutinidae in this part of the Tethys. In addition, it could have contributed to the rise in carbonate production on the adjoining platforms (e.g. Maurer 1999).

The repeated alternation of oxic (=bioturbated) and anoxic (=laminated) facies in the Buchenstein beds of the Seceda core is a feature that is restricted to the area of the Dolomites and may have been caused by episodic closure of the seaways of the Buchenstein basin bordering the open ocean and related variations in oxygenation of the sea floor. Equivalent basinal limestones in the Lombardian Alps (Bagolino, e.g. Brack & Rieber 1993) and Hungary (Oravecz-Scheffer 1987) show bioturbated facies throughout their deposition. A comparison of the foraminifera found in the laminated facies of the *Reitzi* zone in the Seceda core with the equivalent bioturbated interval in the Transdanubian Central Range (Oravecz-Scheffer 1987) reveals no major differences in faunal composition. Lagenina are represented by similar genera in both areas, indicating that these foraminifera were probably not affected by oxygenation-variations on the sea bottom. The fauna described by Oravecz-Scheffer (1987) is poor in shallow-water foraminifera, probably related to a lack of turbidites in that succession. The dataset presented here is limited to the source area of the turbidite sediments, which may not cover the whole shallow-water habitat of the foraminifera.

The Middle Triassic Buchenstein beds show a continuous record of foraminifera in the late Anisian and early Ladinian over a time interval of five ammonoid zones. The presence of shallow-water, benthic foraminifera in turbidite deposits in this biostratigraphically well defined succession gives the opportunity to narrow down the biostratigraphic range of some species. This is a goal that can almost not be achieved when these species are found in place in their shallow-marine habitats, which normally lack age-diagnostic macrofossils. Overall, the fauna is characterized by a lower diversification compared to older Anisian or Carnian foraminiferal assemblages. However, it has to be mentioned that the presented dataset is limited to the turbidite source area, which might not have covered the whole foraminiferal habitat.

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