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NEW BIOSTRATIGRAPHIC DATA FROM THE LADINIAN PELAGIC LIMESTONES OF PIZZO DI SANT'OTIERO - MADONIE MOUNTAINS, SICILY

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Abstract. New biostratigraphic data, based on conodont investigations, were collected from the Ladinian limestones recently described at Sant'Otiero, a locality near the Village of Petralia Sottana in the Madonie Mountains (Central-Northern Sicily). At this locality a new calcareous succession lying at the base of a major tectonic unit of the Maghrebian chain is described. This succession consists of a lower massive part formed by a carbonate megabreccia, the elements of which are shallow water extraclasts with dasycladalean algae (*Diplopora annulatissima* Pia), benthic foraminifers, "*Tubiphytes*" and problematic organisms commonly described from Anisian carbonate platforms. Upward a well-bedded succession of dark-gray *Daonella*-bearing calcilutites follows. The presence of the bivalve *Daonella tyrolensis* Mojsisovics in a Lumachella bed from the upper part of the calcilutites can be related to the ammonoid Protrachyceras longobardicum Zone, upper Ladinian in age (lower Longobardian). Upward a sharp contact (decollement?) with the typical sediments of the Mufara Formation can be observed.

A re-sampling of the *Daonella*-bearing calcilutites for conodont investigation has been carried out in order to better constrain the age of this succession. The distribution of conodont species such as *Budurovignathus hungaricus* (Kozur & Végh), *B. mungoensis* (Diebel) and *Paragondolella trammeri* (Kozur) among other conodonts, permits the correlation of the succession to the P. gradleri and P. archelaus ammonoid Zones, extending downwards the age of the calcilutites at Sant'Otiero to the upper Fassanian. This confirms that the Sant'Otiero succession is a key section to document Ladinian pelagic carbonate sedimentation in the westernmost termination of the Ionian Tethys.

Introduction

Deep-water pelagic carbonates, Ladinian in age, were firstly described in Sicily from the Torrente San Calogero section near Palazzo Adriano Village, in the Sosio Valley (Catalano et al. 1988, 1990; Gullo e Kozur 1989, 1991). Cropping out in a tectonic "Sosio mélange" along with Permian sediments (Di Stefano & Gullo 1997), this succession consists of siliceous and/or condensed nodular limestones with a rich conodont association represented by *Budurovignathus truempy* (Hirsh), *Pseudofurnishius sosioensis* Gullo & Kozur, and *P. murcianus* group (Gullo & Kozur, 1989, 1991). Besides the small extension of the Torrente San Calogero outcrop and its complex tectonic setting, the exposed succession represents the first evidence of Middle Triassic pelagic sedimentation in the so-called Sicanian Basin.

More recently, the occurrence of a new Ladinian succession of dark-gray and well-bedded calcilutites has been reported from the Sant'Otiero peak (Di Stefano et al. 2012), near the village of Petralia Sottana in the Madonie Mountains (Fig. 1), yielding a rich bivalve *Daonella* assemblage and, in particular, *Daonella tyrolensis* Mojsisovics.

A re-sampling of this succession for biostratigraphic purposes has been performed in the frame of a national research project PRIN (2008) devoted to the Triassic stratigraphy and paleogeography of Sicily, with the aim to constrain the duration of the pelagic sedimentation represented by the Sant'Otiero strata.

The present paper summarizes the main biostratigraphic results and evaluations, based on the conodont biostratigraphy.

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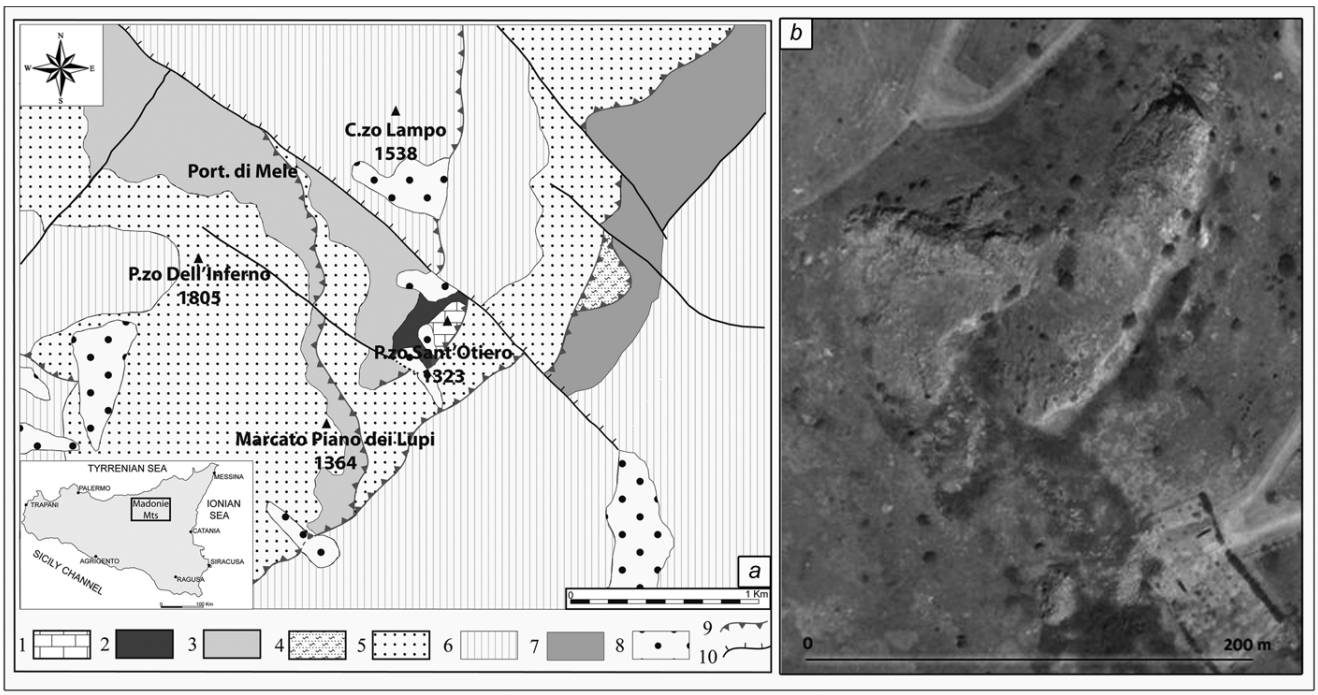


Fig. 1 - a) Simplified geological map of the Pizzo Sant'Otiero area (redrawn after the ISPRA 1:50.000 Sheet "Castelbuono", Grasso & Lentini *coord.*): 1) Calcilutites and megabreccias, calcare di Sant'Otiero, Middle Triassic; 2) marls and calcilutites, Mufara Fm., Carnian; 3) Dolostones, Quacella Fm., U. Triassic - L. Jurassic; 4) Clays and siltstones, Argille Variegate, U. Cretaceous- L. Oligocene; 5) Siliciclastic turbidites with carbonate megabreccias, Argille di Portella Mandarini, Upper Oligocene; 6) Numidian Flysch, Upper Oligocene - L. Miocene; 7) Marls, Marne di Castelbuono, L. Miocene; 8) Debris and landslides; 9) main thrust faults; 10) normal and transtensional faults.
b) Aerial view (Google Earth) of the Sant'Otiero peak. It is possible to observe a south-eastern limestone block that represents the lower and massive part of the succession and a northwestern one corresponding to the upper, well bedded, succession of pelagic calcilutites.

Geological setting

The studied area is located in northern-central Sicily, in the Madonie Mountains, near the village of Petralia Sottana, along the eastern slope of Monte San Salvatore (Fig. 1).

In this area a segment of the Apennine-Maghrebian fold and thrust belt crops out. It has been the subject of several stratigraphic and structural studies since the 1960s (Ogniben 1960; Broquet 1968, 1972; Grasso et al. 1978; Abate et al. 1982).

The structural setting of the area consists of a Neogene thrust pile that is derived from the deformation of a Meso-Cenozoic carbonate platform (known as Panormide), the related slope- to-basin fill (Imerese succession) and their Oligo-Miocene siliciclastic covers (i.e. Numidian Flysch) (Renda et al. 1999). Neo-Tethyan-derived thrust sheets, which are known as Sicilidi units (Ogniben 1960), are also involved in this collisional complex.

Among several Panormide and Imerese-derived tectonic units that have been recognized in the Madonie Mountains by previous authors, a large thrust sheet is well exposed at Monte San Salvatore (Carbone & Grasso 2012). In this thrust sheet, the lithostratigraphic units are typical of slope settings (i.e. the slope between the Panormide platform and the Imerese basin). They consist of Carnian calcilutites and marls (Mufara Fm. Schmidt di Friedberg 1962) transitional upward to slope dolostones (known as the Quacella Formation, Ceretti & Ciabatti 1965) and closed by the Numidian Flysch, deposited on a deep erosional surface. The Numidian Flysch occuring in this tectonic unit contains thick intercalations of platform-derived carbonate megabreccias. This particular flyschoid succession has been named as "Wildflysch di Monte San Salvatore" (Ogniben 1960), or "Argille di Portella Mandarini" (Grasso et al. 1978), or "Flysch a Megabrecce" (Abate et al. 1982). The abundant megabreccia intercalations in the Numidian Flysch appear related to large-scale slope failures from fault-controlled submarine escarpments between the Panormide Platform and the Imerese Basin during the late Oligocene (Renda et al. 1999).

The dark gray *Daonella*-bearing calcilutites, aim of the present paper, crop out at the base of the Monte San Salvatore tectonic unit (Fig. 1).

Fig. 2 - Outcrop view of the Sant'Otiero succession, showing the massive lower part and the well bedded upper part, well exposed along the western slope.

Fig. 3 - Panoramic view of the asymmetric syncline formed by the Ladinian calcilutites at Sant'Otiero outcrop. The crest (left) corresponds to the subvertical limb of the syncline. On the western escarpment (right) is instead illustrated the Sant'Otiero section (see Fig. 3).

The Sant'Otiero succession

The Sant'Otiero succession can be easily subdivided into a lower part consisting of a massive, coarse megabreccia and an upper part of well-bedded pelagic calcilutites (Fig. 2). About 2 m thick set of cuneiform pebbly mudstone beds marks the transition between the megabreccia and the overlying pelagic calcilutites.

According to Di Stefano et al. (2012) the lower part of the section consists of a clast-supported megabreccia containing boulders to fine grained extraclasts from an Anisian –?lowermost Ladinian carbonate platform.

The elements of this breccia are generally subangular and poorly sorted with a fine-grained matrix of either very fine peloidal-skeletal grainstone or a dark gray micrite with fragments of thin-shelled bivalves. Four main microfacies types have been described by Di Stefano et al. (2012):

- Dasycladalean grainstone with *Diplopora annulatissima* Pia;
- Peloidal grainstone with small benthic foraminifers and *Tubiphytes*;
- Algal boundstone with *Zornia obscura* Senowbari-Daryan & Di Stefano;
- Micritic limestones with calcispheres and filaments.

The upper part of the Sant'Otiero section consists of parallel-bedded limestones with mud-dominated microfacies types such as dark-gray mudstone

or wackestone with thin-shelled bivalves and rare calcispheres.

As shown in the ISPRA (2012) 1:50.000 geological sheet 610 "Castelbuono", the Sant'Otiero succession is thrust over Numidian Flysch sediments, which are grouped in the "Argille di Portella Mandarini" Formation. In this geological sheet, the Sant'Otiero outcrop is considered Carnian in age, and attributed to the Mufara Formation.

The well-bedded calcilutites from the upper part of the succession are folded in a large syncline with a 30° W plunging axis and a subvertical northern limb (Fig. 3).

Above the Sant'Otiero section, the Mufara Fm. that is characterized by alternation of brown marls and gray platy calcilutites, lays in sharp contact. Owing to the severe compressive deformation observed in this zone, a décollement of the Mufara sediments from the Sant'Otiero limestones is highly probable.

The sampled succession

Sampling for biostratigraphic investigation has been carried out along the western facing slope that corresponds to the southern limb of the syncline (Fig. 2). Here about 20 m of well-bedded gray calcilutites have been measured and sampled for conodont biostratigraphical studies. Five conodont samples have been collected from this section (SO1, SO9, SO11, SO14, SO15). The microfacies types in the samples are mudstones and wackestones containing conodonts, sponge spicules, thin-shelled bivalves, radiolarians and rare calcispheres. The topmost sample SO15 shows in addition a well-developed nodular structure.

The distribution of samples along section is irregular (large gap between SO1 and SO9) owing to the subvertical slope (Fig. 2). In addition the *Daonella tyrolensis* bed, already sampled (sample ST5) by Di Stefano et al. (2012) has been re-sampled for conodont biostratigraphy. This sample is located in the northern limb of the syncline and can be correlated to the sample SO11. The occurrences of conodont species and their stratigraphical ranges are illustrated in Fig. 4 and Tab. 1.

Biostratigraphic results and evaluations

All the studied conodont samples at Sant'Otiero section commonly record the occurrence of *Budurovignathus hungaricus* (Kozur & Vegh), which has a wide stratigraphic range through the Ladinian stage (Pl. 1, Figs 2, 3, 7).

According to Gullo & Kozur (1991), the appearance of the genus *Budurovignathus* occurs in the middle part of the lower Ladinian (middle Fassanian).

Samples SO9, SO11 and SO14 yielded *Paragondolella trammeri* (Kozur), which is a marker for the Fassanian and the lowermost zone of the Longobardian substages (Pl. 1, Figs. 4, 5).

In particular, in the sample SO9 *P. trammeri* is associated with *B. hungaricus* and *Gladigondolella* sp. but neither the conodont *Pseudofunishius* sp. nor the bivalve *D. tyrolensis* have been found.

This conodont association biochronostratigraphically corresponds to the P. gredleri Zone, Fassanian in age (Muttoni et al. 2004; Brack et al. 2005).

The sample SO11 corresponds to the *D. tyrolensis* lumachella that has already been correlated to the P. longobardicum Zone of lower Longobardian age.

Sample SO14, from the uppermost part of the section, records the first appearance of *Budurovignatus mungonensis* (Diebel), which occurs also in the topmost sample SO15 (Pl. 1, Fig 1, 6, 10). The appearance of *B. mungoensis* can be biochronostratigraphically correlated to the P. archelaus Zone of the middle Longobardian (Muttoni et al. 2004; Brack et al. 2005).

The conodont assemblages mostly characterized by the genera *Budurovignathus* and *Paragondolella*, confirm the previous biostratigraphic evaluations (Di Stefano et al. 2012) and allow extending to the lower Ladinian (Fassanian) the age of the lower portion of the calcilutite succession.

The conodont specimens are deposited in the Department of Geosciences at the Padova University.

Comparisons and correlations

The San Calogero section, Sosio Valley (Sicily)

The Ladinian conodont associations from Sant'Otiero are partly comparable to that described by Catalano et al. (1988, 1990) and Gullo & Kozur (1989, 1991) from the Torrente San Calogero Section in the Sosio Valley. Along this section several decameter scale "broken formations" are exposed and characterized by different lithologies and ages from Permian to Triassic (Catalano et al. 1991; Di Stefano & Gullo 1997). They are interpreted as tectonic slices of the original Permian-Triassic sedimentary fill of the Sicanian Basin, which have been detached either from the original substrate or from the overlying sedimentary succession as consequence of the Neogene accretion of the Maghrebian orogen.

In particular, as shown in Fig. 5, two different Middle Triassic units have been described and named respectively as the *argilliti e radiolariti del San Calogero*

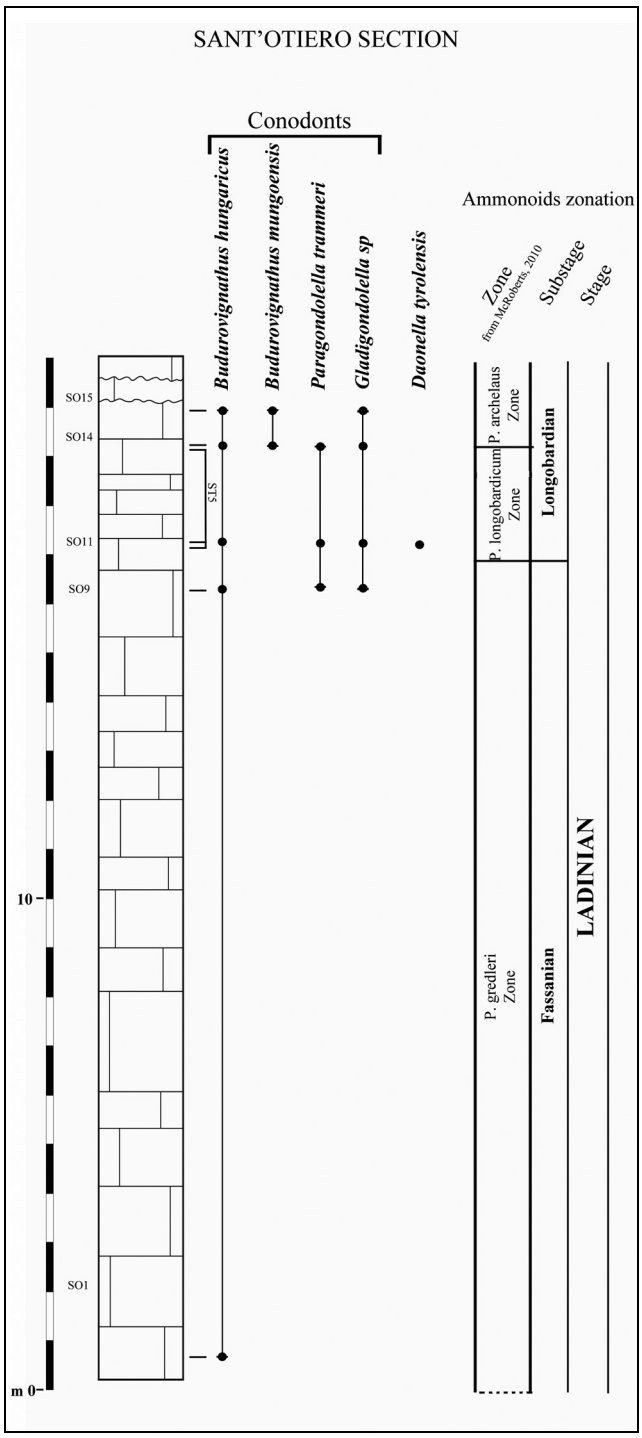


Fig. 4 - Distribution of the main conodont taxa along the upper part of the Sant'Otiero succession and bio-chronostratigraphic correlation with the ammonoid zonation (from McRoberts, 2010).

SAMPLES	*B. hungaricus*	*B. mungoensis*	*P. trammeri*	*G. tethydis*	*Gladigondolella* spp.
SO15	X	X			X
SO14	X	X	X	X	X
SO11≡ST5	X		X		X
SO9	X		X		X
SO1	X				

Tab. 1 - Conodont assemblages in the studied samples from the Sant'Otiero calcilutites.

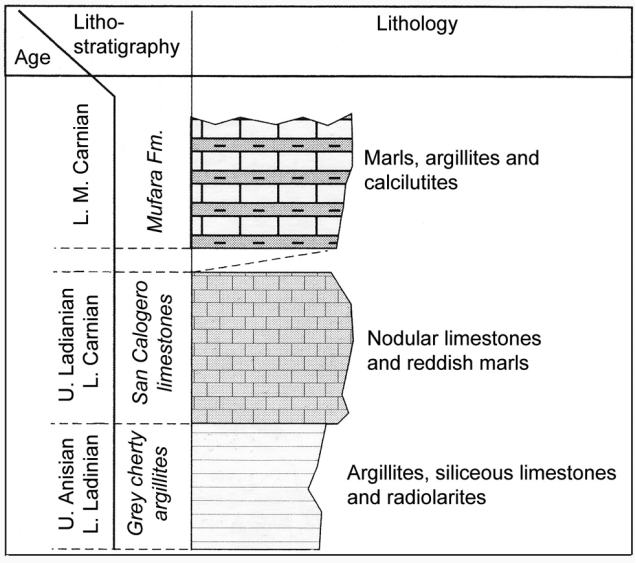


Fig. 5 - Composite section of the Middle Triassic to Carnian sediments from the Torrente San Calogero section, near Palazzo Adriano, in the Sosio Valley (mod. after Di Stefano & Gullo 1997).

and the *calcari nodulari del San Calogero* (Di Stefano & Gullo 1997).

The *argilliti e radiolariti del San Calogero* are greenish-gray siliceous limestones and marls with radiolarians, foraminifers and conodonts. The conodont assemblage is represented by four species among which conodont *Budurovignathus truempy* that dates these sediments to the lower Ladinian (Fassanian) (Gullo 1993).

The *calcari nodulari del San Calogero* consist of about 18 m of reddish nodular limestones with thin marly interbeds. The paleontological content mainly consists of conodonts, ammonoids and bivalve daonellids. The rich conodont assemblages collected from these beds allow to constrain these strata to the lower Longobardian (*Pseudofurnishius sosioensis*) up to the lower Carnian (*Ps. murcianus* group) (e.g. Gullo and Kozur 1991; Rigo et al. 2007; Mietto et al. 2012). Between the two Ladinian units a gap across the Fassanian/Longobardian boundary is indicated by Gullo (1993).

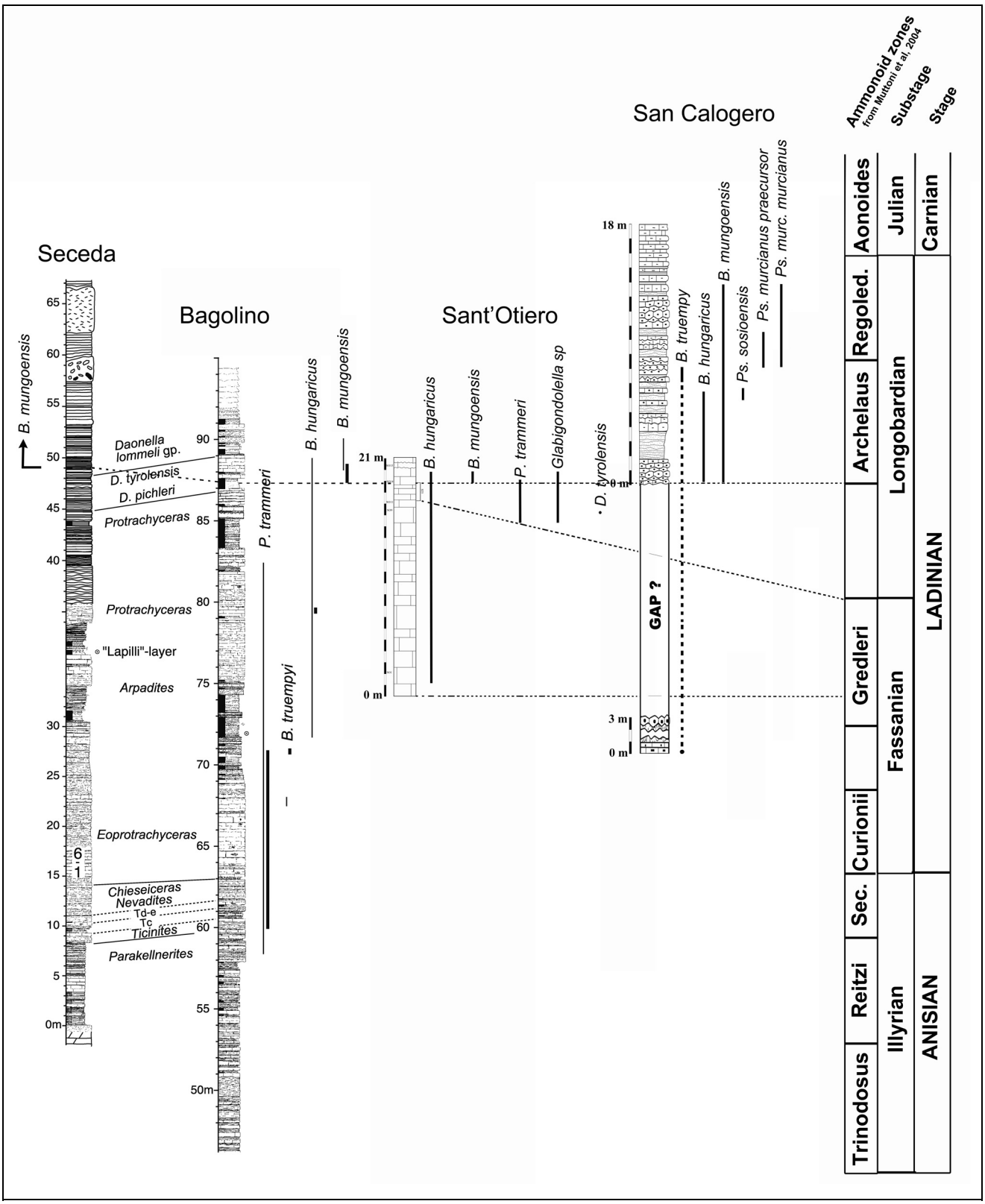


Fig. 6 - An attempt at bio-chronostratigraphic correlation of the Sant'Otiero calcilutites to the Seceda, Bagolino and San Calogero sections (Seceda and Bagolino mod. from Muttoni et al. 2004; San Calogero mod. from Gullo & Kozur 1991).

New biostratigrapic data collected from the Sant'Otiero section allow a correlation with the Ladinian beds of the Torrente San Calogero (Fig. 6). The presence of *Budurovignathus truempy* in the *argilliti e radiolariti del San Calogero* allows considering this unit older than the lowermost calcilutite beds at Sant'Otiero section.

The topmost beds in the Sant'Otiero section can be correlated with the lower part of the *calcari nodulari del San Calogero* on the base of the occurrence of *Budurovignathus mungoensis*. This correlation would indicate the presence in the Imerese basin (Sant'Otiero) and in the Sicanian basin (San Calogero) of two different upper Ladinian facies, which consist of thick parallel-bedded gray calcilutites and nodular to condensed limestone, respectively. The condensed facies in the Sicanian basin indicate a low-rated sedimentation in pelagic structural highs and/or a distal setting from the source areas of the carbonate mud.

The Bagolino and Seceda sections (northern Italy)

A comparison of the Sant'Otiero calcilutites with the well-known Tethyan successions of Ladinian age from Bagolino in the Lombardian Pre-Alps and from Seceda in the Belluno Dolomites (Brack et al. 2005; Muttoni et al. 2004) is also attempted. The Bagolino section is the GSSP of the Ladinian Stage, while Seceda represents an auxiliary sections (e.g. Brack et al. 2005).

The pelagic succession at Bagolino spans the lower/upper Anisian to the upper Ladinian. From the biostratigraphic point of view, this section has been studied in detail with ammoniods, daonellids and conodonts by Brack and co-authors (2005). The coeval Seceda section have been also investigated for magnetostratigraphy, the magnetozones of which are well calibrated with conodont and ammonoid biostratigraphic studies (Muttoni et al. 2004). The Sant'Otiero section shows some analogies with the two Alpine sections both in terms of the conodont assemblages and the presence of the bivalve *Daonella tyrolensis*.

The section of Seceda has been subdivided in five different biostratigraphic events by Muttoni et al. (2004). The last event is poor in conodonts but records the FO of *Paragondolella inclinata* Kovaks and *Budurovignathus mungoensis* in the transitional interval between the P. gredleri and P. archelaus zones, close to the FO of *Daonella pichleri* Mojsisovics. The Archelaus Zone is characterized by the presence of *Budurovignathus hungaricus, Paragondolella inclinata* and *Budurovignathus mungoensis*, in association with *Daonella tyrolensis*.

D. tyrolensis is also present in the upper part of the Bagolino section along with the conodont *P. trammeri*, *P. hungaricus* e *B. mungoensis* (Brack et al. 2005).

Based on conodont and daonellid distribution, a correlation between the Alpine sections and the Sant'Otiero calcilutites has been attempted in Fig. 6.

Conclusions

A well-preserved conodont assemblage has been collected from the calcilutites at the Sant'Otiero locality in the Madonie Mountains (Sicily). The most important biomarkers in this succession are the representatives of the genus *Budurovignathus* and *Paragondolella.*

The biostratigraphic evaluations based on the conodont assemblages confirm the Ladinian age of the Sant'Otiero calcilutites, previously based on the presence of *Daonella tyrolensis,* and extends the stratigraphic interval covered by this succession. In particular the association of *Paragondolella trammeri* with *Budurovignathus hungaricus* permits correlation of the lower part of this succession to the ammonoid Protrachyceras gredleri Zone of the upper Fassanian, while *Buduro-*

PLATE 1

Fig. 1 - *Budurovignathus mungoensis* (Diebel), sample SO15, calcare di Sant'Otiero, Sant'Otiero section. 2a) Upper view; 2b) lower view; 2c) lateral view.

Fig. 2 - *Budurovignathus hungaricus* (Kozur & Végh), sample SO1, calcare di Sant'Otiero, Sant'Otiero section. 1a) Upper view; 1b) lower view; 1c) lateral view.

Fig. 3 - *Budurovignathus hungaricus* (Kozur & Végh), sample SO15, calcare di Sant'Otiero, Sant'Otiero section. 1a) Upper view; 1b) lower view; 1c) lateral view.

Fig. 4 - *Paragondolella trammeri* (Kozur), sample SO14, calcare di Sant'Otiero, Sant'Otiero section. 6a) Upper view; 6b) lower view; 6c) lateral view.

Fig. 5 - *Paragondolella trammeri* (Kozur), sample SO9, calcare di Sant'Otiero, Sant'Otiero section. 6a) Upper view; 6b) lower view; 6c) lateral view.

Fig. 6 - *Budurovignathus mungoensis* (Diebel), sample SO14, calcare di Sant'Otiero, Sant'Otiero section. 4a) Lower view; 4b) upper view; 4c) lateral view.

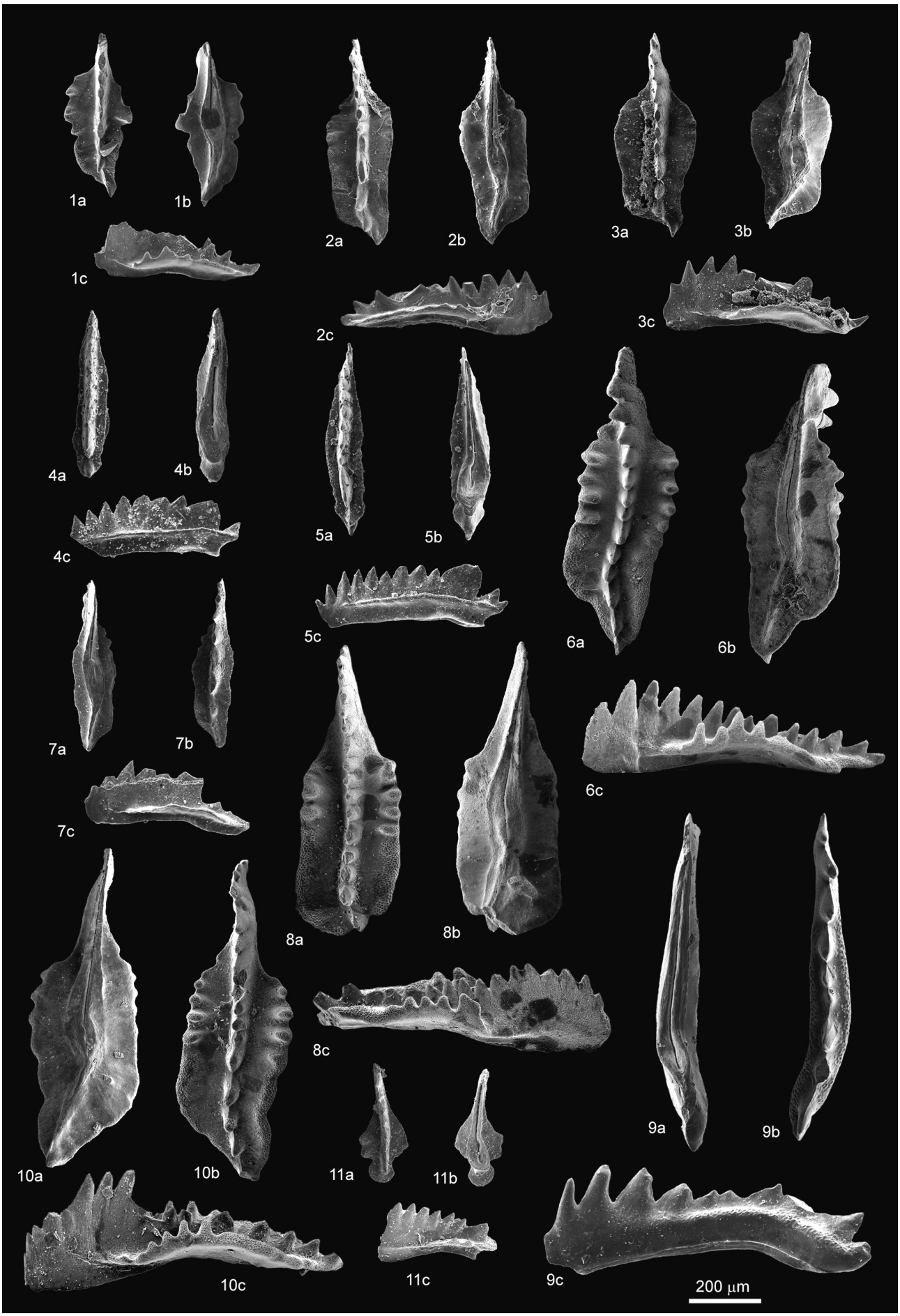
Fig. 7 - *Budurovignathus hungaricus* (Kozur & Végh), sample ST5, calcare di Sant'Otiero, Sant'Otiero section. 1a) Upper view; 1b) lower view; 1c) lateral view.

Fig. 8 - *Budurovignathus mungoensis/diebeli* transitional form, sample SO14, calcare di Sant'Otiero, Sant'Otiero section.5a) Upper view; 5b) lower view; 5c) lateral view.

Fig. 9 - *Gladigondolella tethydis* (Huckriede) transitional form, sample SO14, calcare di Sant'Otiero, Sant'Otiero section. 5a) Upper view; 5b) lower view; 5c) lateral view.

Fig. 10 - *Budurovignathus mungoensis* (Diebel), sample SO15, calcare di Sant'Otiero, Sant'Otiero section. 4a) Lower view; 4b) upper view; 4c) lateral view.

Fig. 11 - *Paragondolella* sp., juvanile form, sample SO1, calcare di Sant'Otiero, Sant'Otiero section. 6a) Upper view; 6b) lower view; 6c) lateral view.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vignathus mungoensis corresponds to the lower part of the Protrachyceras archelaus Zone of the lower/middle Longobardian (ca. equally to the ammonoid P. longobardicum Zone, sensu McRoberts 2010).

The new biostratigraphic studies of the Sant'Otiero section highlight the importance of this outcrop for the Triassic evolution of the sedimentary basins in the westernmost Ionian Tethys.

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