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LATE CARNIAN-EARLY NORIAN AMMONOIDS FROM THE GSSP CANDIDATE SECTION PIZZO MONDELLO (SICANI MOUNTAINS, SICILY)

MARCO BALINI [1], LEOPOLD KRYSTYN [2], MARCO LEVERA [1] & ANGELO TRIPODO [3]

This paper is dedicated to the memory of Paola De Capoa, the first paleontologist since the time of G.G.Gemmellaro to understand the great paleontologic potential of the "calcari con selce" of western Sicily.

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Abstract. A small collection of ammonoids from the Upper Triassic Scillato Formation at Pizzo Mondello (Agrigento, Sicily) is studied. These specimens were collected within the framework of a project intended to provide integrated high-resolution bio-chronostratigraphic support for the Upper Carnian-Norian magnetostratigraphic scale defined at this site, which is located in an historical area from which G.G. Gemmellaro collected and monographed Upper Triassic ammonoids at the beginning of the 20th century. The specimens, which were collected utilizing the bed-by-bed sampling method, represent the first collection of Upper Triassic ammonoids described from western Sicily since Gemmellaro's time. Several levels of the Pizzo Mondello section yielded ammonoids, but very few beds have provided more than one specimen. This scarcity of specimens has resulted in a complex taxonomic analysis because Gemmellaro, who described 166 new species, did not explain the variability of many of his taxa. Sixteen taxa belonging to eleven genera are described. They include *Placites* sp. ind., *Discotropites plinii* (Mojsisovics), *Anatropites* sp. ind., *Microtropites* cf. *paronai*, *Metathisbites* cf. *affinis*, *Hyattites* cf. *praefloridus*, *Projuvavites boehmi* (Gemmellaro), *Projuvavites inflatus* (Gemmellaro), *Gonionotites* cf. *italicus*, *Gonionotites* aff. *recuperoi*, *Pregriesbachites* n. gen., *P. bukowskii* (Gemmellaro), *Dimorphites noricus* n. sp., *Dimorphites selectus* Mojsisovics, *Dimorphites* sp. and *Discophyllites insignis*. Among the new taxa, *Dimorphites noricus* n. sp. formalizes the *nomen nudum* "*Dimorphites* n. sp. 1", which has been quoted in the literature for several years as the index ammonoid for the lowest subzone of the Norian stage.

The small collection documents the *Discotropites plinii* and *Gonionotites italicus* subzones of the uppermost Carnian Spinosus Zone as well as the *Dimorphites noricus* and *D. selectus* subzones of the Jandianus Zone, the first zone of the Lower Norian. This chronostratigraphic classification not only confidently ties the Pizzo Mondello succession to the Tethyan chronostratigraphic scale, but it is also crucial for the calibration of the *Halobia* and conodont bioevents identified in the section. Also discussed is the chronostratigraphic ammonoid-based correlation of the Pizzo Mondello section with Feuerkogel (Austria), Jomsom (Nepal), West Union Canyon (Nevada, USA), Black Bear Ridge (British Columbia, Canada) and the Yana Okhotskaya River (Siberia, Russia). These are the most complete ammonoid-bearing sections in the world that span the Carnian/Norian boundary, and they exhibit a discrete distribution of ammonoid-bearing beds across the boundary. Ammonoids will not provide the primary marker event for the definition of the GSSP of the Norian, but they are crucial for the selection of the most significant events based on other groups.

Riassunto. In questo lavoro viene studiata una piccola collezione di ammonoidi proveniente dalla Formazione Scillato (Triassico superiore) di Pizzo Mondello (Agrigento, Sicilia). Gli esemplari sono stati raccolti nel quadro di un progetto finalizzato alla taratura bio-cronostratigrafica integrata e ad alta risoluzione della scala magnetostratigrafica del Carnico superiore e Norico riconosciuta in questa località. Pizzo Mondello è una località fossilifera nuova, ubicata in un'area storica della Sicilia da cui G.G. Gemmellaro raccolse gli ammonoidi del Triassico superiore che descrisse in un'importante monografia all'inizio del XX secolo. Gli esemplari di Pizzo Mondello sono stati raccolti strato-per-strato e rappresentano la prima raccolta di ammonoidi del Triassico superiore della Sicilia occidentale descritta in oltre un secolo dalla monografia di Gemmellaro. Gli esemplari provengono da numerosi livelli della sezione, all'interno dei quali però spesso gli ammonoidi sono molto rari. La classificazione dei nuovi esemplari è risultata complessa in quanto Gemmellaro, che nella sua monografia descrisse 166 specie nuove, non fornì indicazioni chiare sulla variabilità dei suoi taxa.

Vengono descritti 16 taxa, appartenenti a 11 generi: *Placites* sp. ind., *Discotropites plinii* (Mojsisovics), *Anatropites* sp. ind., *Microtropites* cf. *paronai*, *Metathisbites* cf. *affinis*, *Hyattites* cf. *praefloridus*, *Projuvavites boehmi* (Gemmellaro), *Projuvavites inflatus* (Gemmellaro), *Gonionotites* cf. *italicus*, *Gonionotites* aff. *recuperoi*, *Pregriesbachites*

1 Dipartimento di Scienze della Terra "Ardito Desio", Via Mangiagalli 34, 20133 Milano, Italy. E-mail: Marco.balini@unimi.it
2 Department of Palaeontology, Vienna University, Althanstraße 14, 1090 Wien, Austria.
3 Dipartimento di Scienze della Terra e del Mare, Università di Palermo, Via Archirafi 22, 90123 Palermo, Italy.

n. gen., *P. bukowskii* (Gemmellaro), *Dimorphites noricus* n. sp., *Dimorphites selectus* Mojsisovics, *Dimorphites* sp. e *Discophyllites insignis*. *Dimorphites noricus* n. sp. è il più importante tra i nuovi taxa e rappresenta la descrizione di un *nomen nudum* riportato nella letteratura recente come "*Dimorphites* n. sp. 1". Questa specie è indice della prima sottozona del Norico.

La collezione studiata permette di riconoscere le sottozone a *Discotropites plinii* e a *Gonionotites italicus* della Zona a Spinosus del Carnico sommitale, e le sottozone a *Dimorphites noricus* e *D. selectus* della Zona a Jandianus, la prima zona del Norico inferiore. Questa classificazione cronostratigrafica data in modo chiaro la successione di Pizzo Mondello con la scala cronostratigrafica della Tetide, ed è fondamentale per la taratura dei bioeventi ad *Halobia* ed a conodonti individuati nella stessa sezione.

Vengono discusse le correlazioni cronostratigrafiche ad ammonoidi con le migliori sezioni stratigrafiche del mondo, per quanto riguarda il limite Carnico/Norico. Queste sono Feuerkogel (Austria), Jomsom (Nepal), West Union Canyon (Nevada, USA), Black Bear Ridge (British Columbia, Canada) e del fiume Yana Okhotskaya (Siberia, Russia). Tutte queste sezioni sono caratterizzate da una distribuzione discontinua di ammonoidi, soprattutto in corrispondenza del limite Carnico/Norico. Di conseguenza, molto probabilmente gli ammonoidi non forniranno l'evento primario per la definizione del GSSP del Norico, ma sono fondamentali nel processo di ricerca e valutazione dei bioeventi riconosciuti in altri gruppi sistematici.

Introduction

The "cherty limestone" ("Calcari con selce" or *Halobia* Limestone *auct.*, Scillato Formation: Schmidt di Friedberg et al. 1960) of western Sicily are been well known since the second half of the 19th century for its rich macrofossil record of Upper Triassic pelagic bivalves (halobiids) and ammonoids, first described by G.G. Gemmellaro (1882 and 1904). Following Gemmellaro's pioneering works, the investigation of halobiids continued and a few authors (Montanari & Renda 1976; De Wever et al. 1979; Cafiero & De Capoa Bonardi 1982; De Capoa Bonardi 1984) provided the first picture of the stratigraphic distribution of the various species within the "cherty limestone" as well as the refinement of their taxonomy (see especially Cafiero & De Capoa Bonardi 1982 and De Capoa Bonardi 1984).

Curiously, not even one specialist has chosen to follow in the "footprints" of Gemmellaro and continue the study of Triassic ammonoids from western Sicily, and since Gemmellaro's 1904 monograph, the literature regarding this fossil group is restricted to just the report of a single specimen of *Hoplotropites* from the Monte Cammarata section by Cafiero & De Capoa Bonardi (1982: fig. 2 and pl. 6, fig 4-5). Such a lack of literature is surprising because on the one hand, the collection from western Sicily described by Gemmellaro consisted of several hundreds of specimens from several localities scattered over six different areas (Gemmellaro 1904; Tripodo 2011). On the other hand, a few new but very small collections have been made during the 20th century from localities in Sicily that did not provide near as much material as found during Gemmellaro's time (e.g., Mufara Formation [Ladinian-Carnian] from Palermo area: Zia 1956; "cherty limestone" from Monte Judica, eastern Sicily: Lentini 1974).

In this paper we describe and illustrate ammonoids collected during a four-year long research program, whose purpose was to provide a high-resolution integrated bio-chronostratigraphy for the Upper Triassic magnetostratigraphic scale and stable isotope curve by Muttoni et al. (2001 and 2004) in the Pizzo Mondello section (Sicani Mountains, Agrigento). In just a very few years, this section has become known worldwide for its unusually thick and uniform Late Carnian to Rhaetian pelagic record as well as for the good preservation of its primary magnetization. Such a rare combination of features lead Hounslow & Muttoni (2010) to propose this section as a standard reference for the calibration of the Upper Triassic GPTS (Geomagnetic Polarity Time Scale).

This extensive bio-chronostratigraphic investigation, based on a very thorough bed-by-bed sampling program for ammonoids, halobiids, conodonts and radiolarians was carried out by specialists from five Italian universities in cooperation with foreign specialists within the framework of the activities of the Carnian-Norian boundary Task group of the Subcommission on Triassic Stratigraphy. Due to the importance of the Pizzo Mondello section for the definition of the GSSP (Global Stratotype Section and Point) of the Norian Stage, the investigation focused on the lower part of the Scillato Formation, which is the formal name for the "cherty limestone" *auct.*, straddling the Carnian/Norian boundary. We herein provide taxonomic descriptions for the ammonoids collected during the project, which complement the taxonomic descriptions for the halobiids (Levera 2012) and the conodonts (Mazza et al. 2012).

Lithostratigraphy and stratigraphic section

As shown in Fig. 1, the Sicani Mountains of Western Sicily are characterized by a typical Permian to Cenozoic pelagic succession (Mascle 1979) of the Sicanian domain, which is divided into several tectonic units (Sicanian structural units: Catalano et al. 1995) that are overthrust onto a thick allochthonous complex of Neogene mudstones and evaporites of the Gela Nappe (Bellanca et al. 1993; Bellanca et al. 1995; Guaiumi et al. 2007 and references therein).

The Pizzo Mondello section, located in the lowermost Sicanian thrust sheet (Pizzo Mondello tectonic unit) that overthursts upper Tortonian-Messinian clays, consists of three Triassic units, the Mufara Formation, the Scillato Formation and the Portella Gebbia Limestone (Di Stefano 1990; Gullo 1996; Di Stefano & Gullo

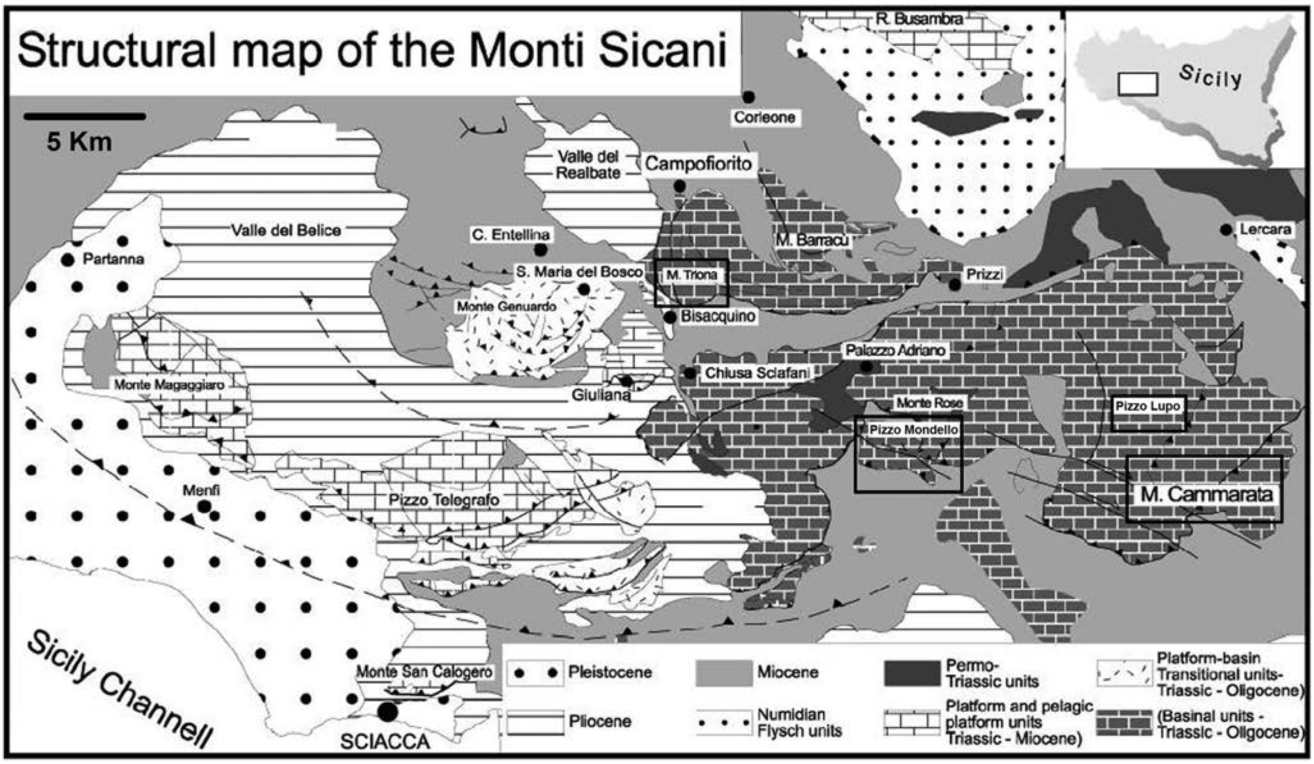


Fig. 1 - Geological and Structural map of the Monti Sicani (Sicani Mountains) showing the distribution of the Sicanian Triassic to Oligocene pelagic successions, as well as the position of Pizzo Mondello with respect to Monte Triona and Monte Cammarata (from Cacciatore et al. 2010).

1997; Guaiumi et al. 2007). The Scillato Formation (Schmidt di Friedberg et al. 1960) is the formal name accepted and codified by the ISPRA (Italian Geological Survey) for the unit known as "cherty limestone" or "Calcari con selce" or *Halobia* Limestone in Sicily.

Relatively new, the Pizzo Mondello locality was first described in the mid 1990s (Bellanca et al. 1995 and Gullo 1996), but it is located within Gemmellaro's "Regione ex-feudo Votano", one of the source areas for a large part of his collection of *Halobia* and ammonoids. Within this wide area (Fig. 1) the two best known localities for the Scillato Formation are Monte Triona and Monte Cammarata, both of which were studied in the 1970s and early 1980s (Montanari & Renda 1976; Mascle 1979; De Wever et al. 1979; Cafiero & De Capoa Bonardi 1982; De Capoa Bonardi 1984). Monte Triona is located about 14 km northwest of Pizzo Mondello, and Monte Cammarata is about 19 km to the east.

Outcrops at Pizzo Mondello are of much better quality than at Monte Triona and Monte Cammarata, and the locality is much better suited for a high resolution bed-by-bed sampling study. This observation applies especially to the lower part of the 430 m thick Scillato Formation, which straddles the Carnian/Norian boundary. This part is easy accessible at Pizzo Mondello because it is exposed in an abandoned quarry that was active in the 1970s ("La Cava" on some topographic maps). This 143 m thick interval (Fig 2), equivalent to Interval II of Muttoni et al. (2001, 2004), has been extensively sampled for ammonoids along two segments A and B, which in part overlap (Fig. 3). The distance between the two segments is about 200 m, and correlation is achieved simply by following the beds along strike. Bed thickness does not change between the segments and the thicker beds serve as excellent marker levels. Lithologically, the succession consists mostly of evenly bedded to nodular *Halobia*-bearing cherty calcilutites. This particular sequence was recently described by Guaiumi et al. (2007), Nicora et al. (2007), Balini et al. (2008) and Balini et al. (2010).

Sampling

During the past 10 year period, the Pizzo Mondello section has been sampled several times by specialists from a wide spectrum of fields including magnetostratigraphy, sedimentology, micro- and macropaleontology. During this time, sampling has become more and more thorough and several types of labels and numbering schemes have been used (for details see Balini et al. 2010). Beginning in 2006, the basis for all samplings has been an extremely detailed stratigraphic log measured by Preto and Guaiumi in the lower 143 m of the section underlying the *Slump breccia* (interval III of Muttoni et

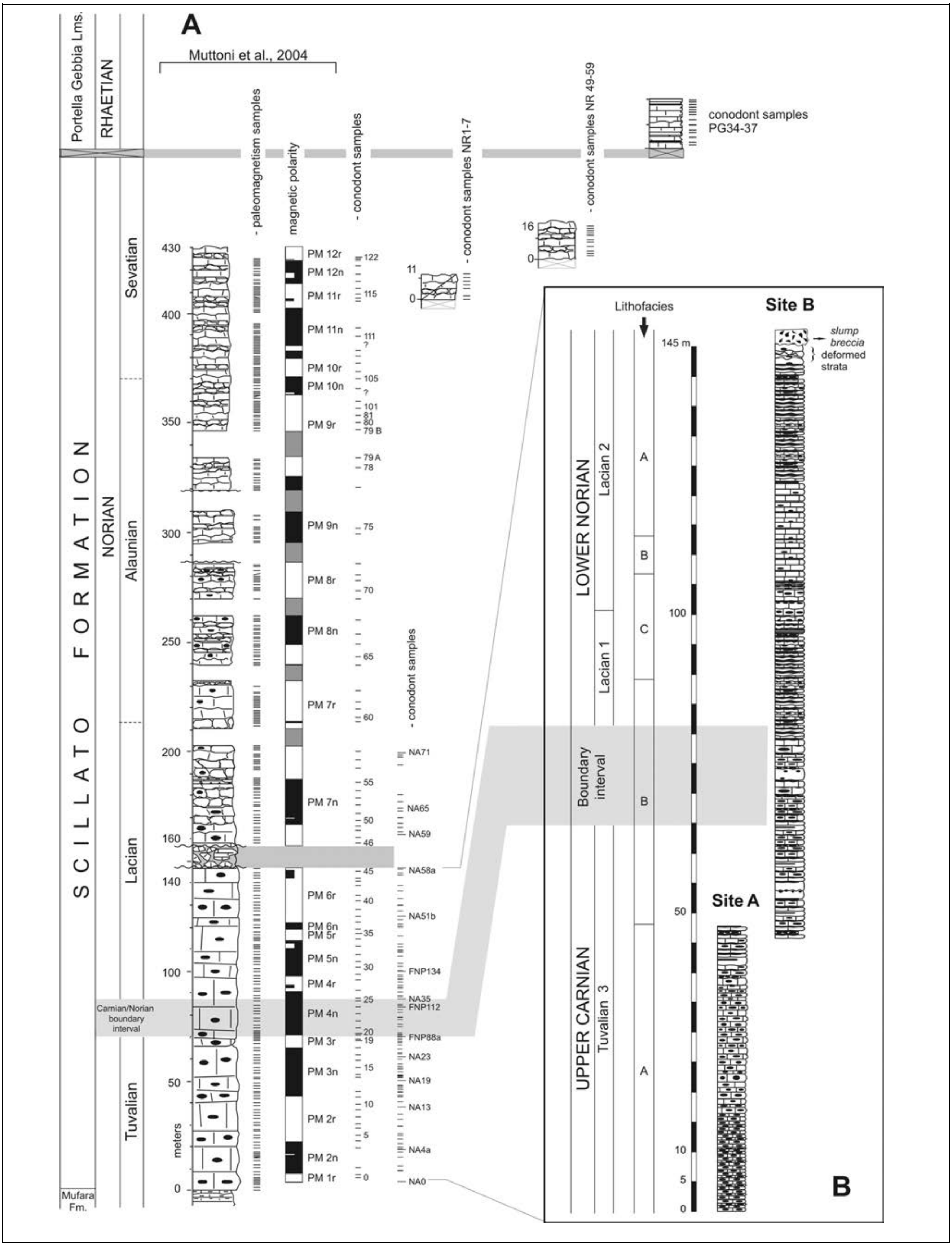


Fig. 2 - Stratigraphic log of the Pizzo Mondello section. A) The complete development of the section, from the base of the Scillato Formation to the Portella Gebbia Limestone, with magnetostratigraphy (Muttoni et al. 2001, 2004) and position of the conodont samples studied by Nicora et al. (2007), Mazza et al. (2010), Mazza et al. (2011) and Mazza et al. (2012). The log is from Balini et al. (2010) and is partly modified from Muttoni et al. (2004). B) detail of the lower part of the Scillato Formation (143 m) sampled for ammonoids.

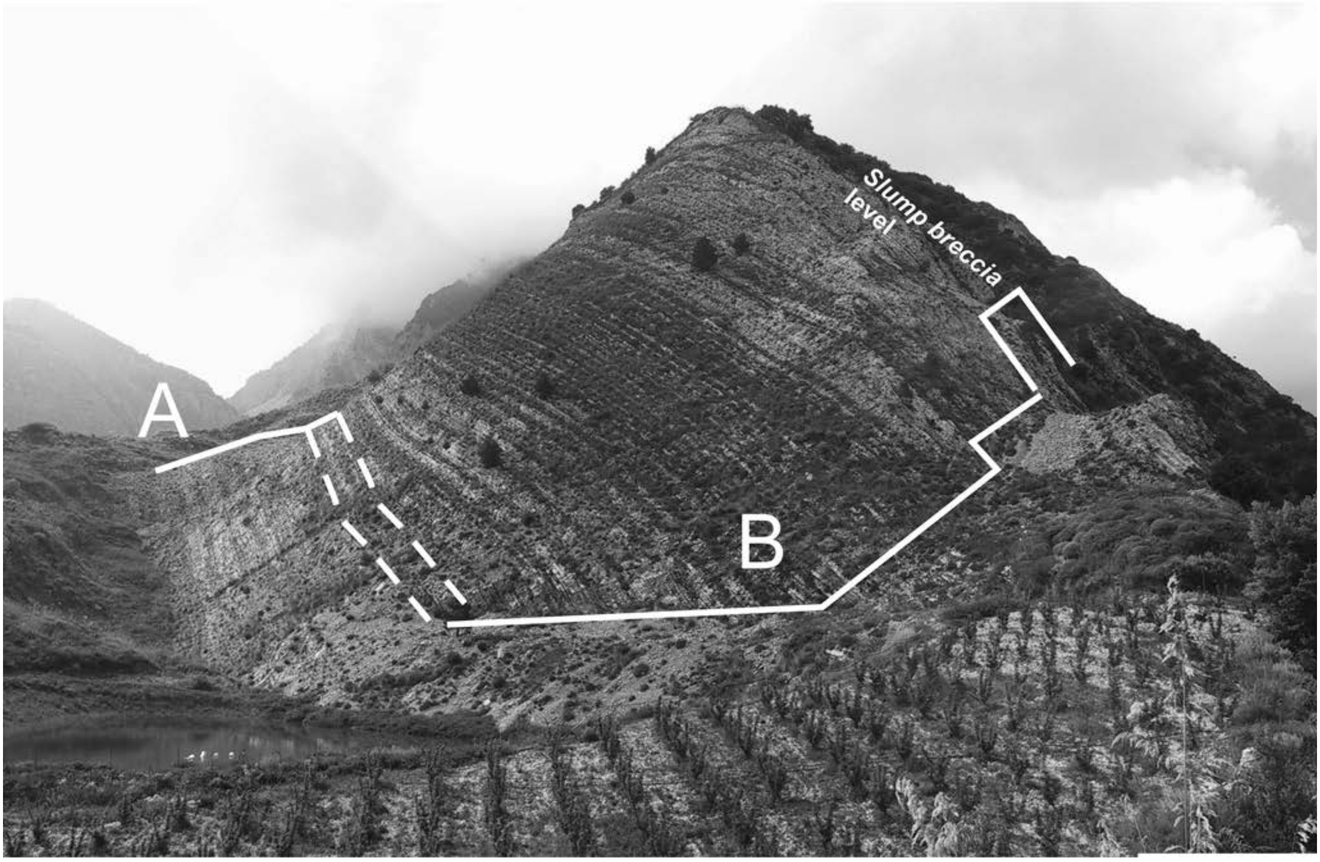


Fig. 3 - General view of the lower part of the Scillato Formation at "La cava", showing the position of the two segments of the composite section. The beds of the upper part of the segment A can be followed along strike to the lower part of the segment B (see also Fig. 2).

al. 2001, 2004). All previous samples taken by Muttoni et al., (2001 and 2004) that could be correlated with numbers painted on the beds, were also plotted on the log. When possible, ammonoids were labelled with the bed number from which they were collected, provided the bed had been previously sampled. Ammonoids from beds with no label have been numbered as PMAMxx. The sequence of these samples is merely chronologic and has no relation to the stratigraphic succession.

The ammonoid record

Six field trips to Pizzo Mondello, each averaging about one week duration, were carried out between spring 2007 and fall 2010. From the beginning, ammonoids were found throughout the succession, but their occurrence was found to be quite rare (Fig. 4). Because of this scarcity, it was necessary to follow the beds along strike for tens of meters searching for ammonoid cross-sections on the outcrop. The resulting collection was combined with ammonoid specimens found during the thorough bed-by-bed search for *Halobia* that even included beds without visible macrofossils on the surface. A total number of 166 beds were sampled utilizing this approach (see Levera 2012).

Overall, the final collection consists of 130 ammonoids collected from a stratigraphic interval of about 100 m. On rare occasions, two or more specimens were collected from the same bed (Fig. 4B), and even though the resulting collection is representative of the ammonoid record of the section, it does not allow for a population analysis. Most of the ammonoids are about 1 or 2 cm in diameter (Fig. 4A) and the frequency of larger specimens decreases with increasing size. The largest specimen (Fig. 4D) is a *Gonionotites* of about 10 cm in diameter. Quite often, specimens are preserved with a strongly recrystallized test, but some are also preserved as internal molds (Fig. 4C). The latter are usually very easy to extract from the rock matrix.

Ammonoid taxonomy: the complex heritage of G.G. Gemmellaro

As mentioned in the Introduction, our knowledge of Triassic ammonoids from western Sicily is based entirely on the monograph by Gaetano Giorgio Gemmellaro (1832-1904) that was published just after his death by his collaborators G. Di Stefano, L. Schopen and A. Carapezza (Gemmellaro 1904: p. III). This monograph is based on a large collection of ammonoids from the

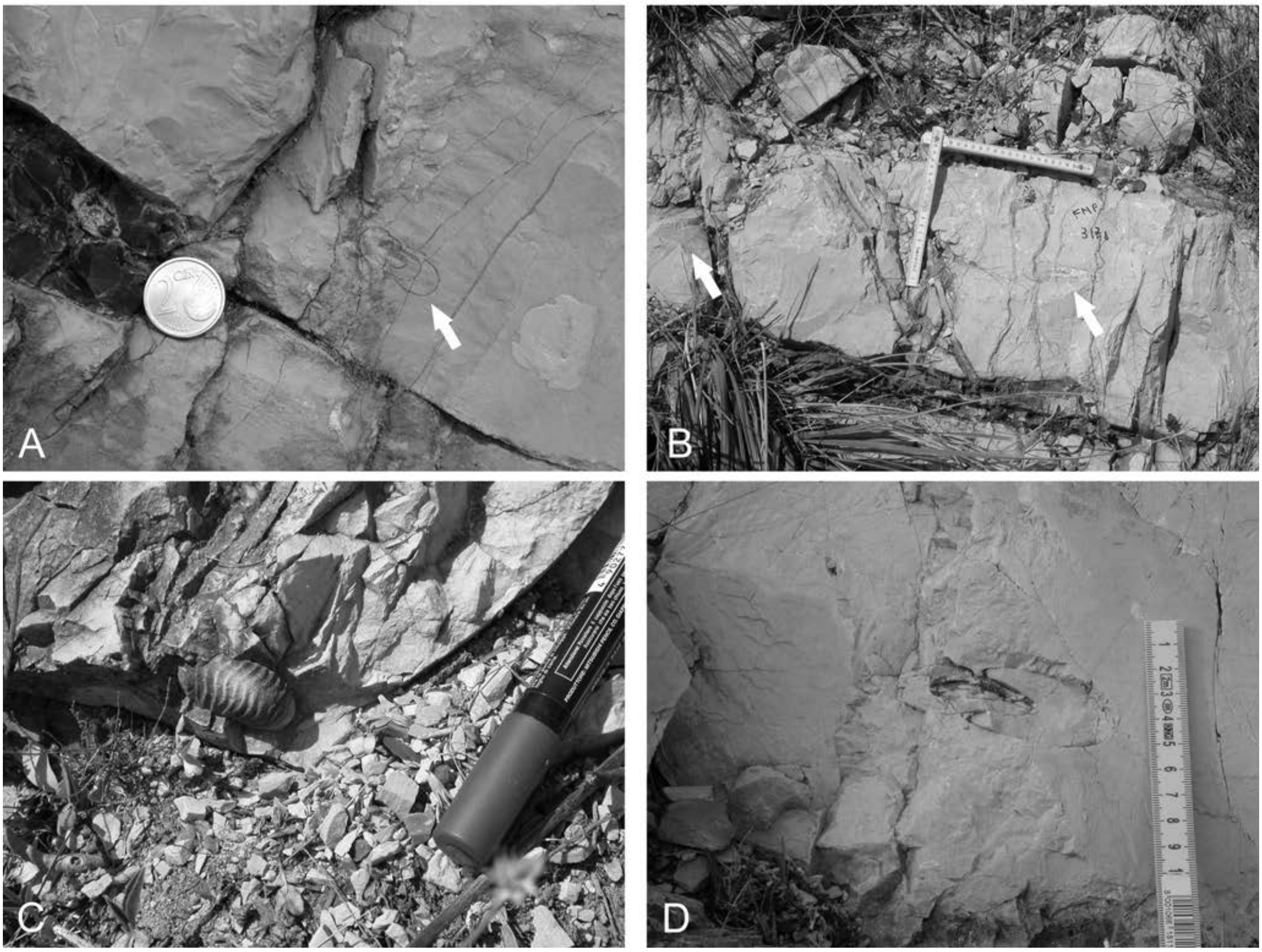


Fig. 4 - Field pictures of ammonoids. A) Cross section of a small specimen from level PMAM12. B) Rare occurrence of two specimens from the same level, FNP317b. C) Rarely the specimens are exposed in 3D and easy to be extracted: *Projuvavites inflatus* MPUM 10974, level PMAM49. D) Sometimes the specimens identified on the basis of the cross section are also easy to be collected, here *Gonionotites* cf. *italicus* MPUM 10975 from level PMAM7 (Pl. 2, fig. 1a-b).

following areas: Palermo ("Regione Giacalone", "Cave di Billiemi"), Trapani ("Castellammare del Golfo"), Bisacquino ("Regione Madonna del Balzo"= Monte Triona), S. Stefano Quisquina s.l. ("Regione ex-feudo Votano") and Castronuovo ("Regione Modanesi"), of which the major part is preserved in the Museo Geologico G.G. Gemmellaro of the University of Palermo. Gemmellaro did not always provide the total number of specimens attributed to each of his taxa, but the agreement between the number of specimens mentioned by him and the specimens stored in the Museo is generally quite good. The registered collection includes 780 specimens.

Gemmellaro's monograph is devoted entirely to taxonomy, with the description of 166 new species (and 84 taxa in open nomenclature), attributed to 49 genera and subgenera. The genera *Siculites*, *Palicites*, *Mojsisovicsites* and *Gonionotites* were also erected in this monograph. However, even with this impressive and well illustrated taxonomy (30 high quality plates), two main weak points are immediately obvious. The first is the lack of detailed geographic and geological information regarding the successions from which the fossils were collected and the number and position of the fossil-bearing levels. The second major problem is the lack of a biostratigraphic analysis of the faunas. This second point is somewhat surprising because by the end of the 19th century the knowledge of ammonoid biochronostratigrahic scales was well developed (i.e., Mojsisovics et al. 1895), and the common practice followed by all authors of that time was to include in every ammonoid monograph a chapter on faunal subdivision and correlation. This absence of critical information is difficult to understand; it is possible that Gemmellaro did not collect the major portion of the material by himself, or maybe he was unable to complete his monograph. No matter the reason, this information was not reported, and this may well be one of the reasons for the relatively low scientific impact of Gemmellaro's monograph.

New genera described by Gemmellaro have generally been accepted (e.g., Arkell et al. 1957; Tozer 1981a), but very few workers have tried to improve his taxonomy at the species level. Spath (1951) described the new genus *Euisculites* with *Isculites bittneri* Gemmellaro as type species and Tozer (1994) included *Styrites disciformis* Gemmellaro in his new genus *Discostyrites*. Some authors have not even mentioned Gemmellaro's monograph Diener's (1906: 6) criticism was in some respects "extreme", when he wrote that Gemmellaro's monograph could not be used because "the types are represented in a manner which defies every attempt to realize their true shape".

Surprisingly, for taxa with no stratigraphic position, a few of Gemmellaro's taxa have recently been recognized as having stratigraphic significance. *Gonionotites italicus* Gemmellaro was proposed by Krystyn in 1980 as an index ammonoid for the latest subzone of the Carnian Stage. Since then, the *Gonionotites italicus* subzone of the Spinosus Zone has became part of the Upper Triassic Tethyan scale (Krystyn et al. 2002; Balini et al. 2010). The genus *Mojsisovicsites* Gemmellaro, which is not found elsewhere in the Tethys realm, was recognized in North America by Silberling (1959), who attributed *Stikinoceras kerri* McLearn, 1930 to Gemmellaro's genus as the index taxon for the first zone of the Norian Stage. Tozer (1994) later rejected this attribution, but *Mojsisovicsites* and *Stikinoceras* are still considered to be very closely related forms.

The lack of new discoveries and taxonomic revisions, especially at the species level, implies that the state of the taxonomy of ammonoids from the Scillato Formation/"cherty limestone" remains the same as it was in 1904. This suggests that species are defined with a typologic approach, sometimes based on single specimens or even juveniles, or based on specimens grouped together on the basis of assumptions and not on ontogeny and population variability analyses. Last but not least, there is a lack of information about the stratigraphic position of the specimens. As so ably summarized by Tozer (1971), such a wide range of problems were rather normal for monographs published in the second half of the 19th century, but in the case of Gemmellaro's work the problem is much more severe because of the much greater uncertainty about the stratigraphic position of his taxa. The interval from which his taxa were collected is not restricted to just one or two substages, but rather it encompasses much of the Upper Carnian through the entire Norian stage.

Taxonomic results

The classification of the present collection from Pizzo Mondello and its comparison with the type specimens of the Gemmellaro collection, recently re-described by Tripodo (2011), provides the opportunity to test Gemmellaro's taxonomy with all its flaws as well as to evaluate the significance of his collection. A few points must be stressed:

a) Twelve genera have been identified in the new collection: *Placites*, *Discotropites*, *Anatropites*, *Microtropites*, *Metathisbites*, *Hyattites*, *Projuvavites*, *Gonionotites*, *Dimorphites*, *Discophyllites*, *Rhacophyllites* and *Pinacoceras*. In addition, we describe the new genus *Pregriesbachites* in the Systematic paleontology. Small ammonoids are also referred to the families Sandlingitidae and Arcestidae. All genera identified herein are documented in the list of taxa described by Gemmellaro. The genus *Discotropites* Hyatt & Smith, 1905 includes almost all species described by Gemmellaro as *Eutomoceras*. Another Tropitidae well represented in the Gemmellaro collection is *Hoplotropites* Spath, 1929, which is the new name for *Margarites* Mojsisovics, 1889. This genus, typical of the *Discotropites plinii* subzone, has not yet been found at Pizzo Mondello. A group of Juvavitidae that is well documented in the Gemmellaro collection (37 species) is *Anatomites* Mojsisovics, 1893. However, several species originally attributed to this genus would be better included in *Projuvavites* Tozer, 1971.

b) The taxonomic study of ammonoids from Pizzo Mondello provided an opportunity to describe two new taxa already outlined by Krystyn (1980, 1982) during an investigation of classic localities in the Salzkammergut area (Northern Alps) and a new site in the Nepalese Himalaya. *Dimorphites noricus* n sp. is a new species quoted in several previous papers as *Dimorphites* n. sp. 1, and the new genus *Pregriesbachites* is erected for the "*Projuvavites* n. gen. with nodes on the body chamber" mentioned by Krystyn (1982). Both new taxa are also documented in the Scillato Formation at Pizzo Mondello.

c) Classification of our specimens to a species rank has often revealed the limits of Gemmellaro's typologic approach to taxonomy. Ammonoids are rare in the sedimentary successions, and thus far it has proven very difficult to collect more than one specimen per bed. Comparison of these newly collected single specimens to Gemmellaro's species, which are often illustrated by only one or two types, is usually quite frustrating. Information regarding species variability is not available, and often the new specimens do not correspond well with one particular type specimen, but rather, they more commonly are similar to two or more type specimens of different species. For instance, this is the case for the single *Microtropites* specimen from level PMAM52A that in some respects resembles *M. paronai* (Gemmellaro), while for others it is more similar to *M. brancoi* (Gemmellaro). Similarly, the best preserved *Go-*

nionotites from level PMAM7 does not correspond well with any of the 11 species of *Gonionotites* described by Gemmellaro.

d) For a modern taxonomic revision of many of Gemmellaro's groups, it would be absolutely necessary to require a definition of their variability. However, very few beds of the Scillato Formation would provide enough specimens for even a simplified population analysis. A group that may potentially benefit from this approach is *Gonionotites*, which is relatively common in the succession. However, the main difficulty with this group is the large size of its type specimens, which contrasts with the extreme scarcity of these larger specimens and the high frequency occurrence of small- or medium-sized specimens in the succession. Several of the eleven species attributed to this genus by Gemmellaro seem to be distinguished only by the adult body chamber.

e) Overall, Gemmellaro's studied collection is clearly representative of the ammonoid record of the Scillato Formation. A few of his genera have not been found in the field (e.g., *Jovites*) but it is worth noting that a number of very rare, small forms were actually collected by him or by his collaborators. *Dimorphites*, for instance, belongs to this group. Thus far it has been found only in five beds at Pizzo Mondello, and the specimens are of rather small size. This scarcity, notwithstanding that *Dimorphites* is documented by several specimens in Gemmellaro's collection.

In the next chapter, we provide descriptions for the most significant and representative taxa, but a few specimens are left in open nomenclature. This approach strictly follows the recommendations of Salvador (1994: 91) and Remane et al. (1996) concerning the publication and illustration of the fossil record documented in GSSP sections. In addition to this formal reasoning, the description of the ammonoid record is useful for calibration of the *Halobia* and conodont bioevents (Levera 2012; Mazza et al. 2012).

Repository of specimens. Specimens described in this contribution are housed in three institutions in Italy and Austria as follows:

MPUM: Museo di Paleontologia, Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Via Mangiagalli 34, 20133 Milano, Italy.

MGUP: Museo Geologico G.G. Gemmellaro, Università degli Studi di Palermo, Corso Tukory 131, Palermo, Italy.

GBA: Sammlungen der Geologischen Bundesanstalt, Neulinggasse 38, A-1030 Wien, Österreich.

Numbering of the specimens. Every specimen mentioned in the text is identified by both registration number (e.g., MPUM....) and collection number. The latter, in parenthesis, indicates the bed of collection and the individual number of the specimen (e.g., FNP144-2: 2nd specimen from bed FNP144).

Dimensions. D= diameter; H= max. whorl height in D; h= min. whorl height in D; U= umbilical width in D; W= whorl width in H; SGR= (H-h)/h x 100. All measurements are in mm. SGR is in percent. Measurements in italics represent partly damaged specimens.

Occurrence. In the Systematic paleontology and Chronostratigraphy sections, the nomenclature for chronozones follows Hedberg (1976). This nomenclature is more synthetic than the one required by Salvador (1994): Jandianus Zone, instead of *Guembelites jandianus* chronozone. For subzones, biostratigraphic nomenclature is used because there is no chronostratigraphic counterpart for such a short subunit.

Systematic paleontology

Family-group taxonomy follows that of Tozer (1981a and 1994).

Order **Ceratitida** Hyatt, 1884
Superfamily Pinacocerataceae Mojsisovics, 1879
Family Gymnitidae Waagen, 1895
Subfamily Gymnitinae Waagen, 1895
Genus *Placites* Mojsisovics, 1896
Type species: *Pinacoceras platyphyllum* Mojsisovics, 1873

Placites sp. ind.
Pl. 1, fig. 1; Fig. 5

Material: One specimen MPUM 10966 (NA49.1-1).

Description. Small specimen (D= 15.3mm) preserved as a three dimensional internal mold. Specimen is a juvenile, last 70° of coiling belongs to the body chamber. Involute platycone with nearly closed umbilicus, compressed elliptical whorl section and very narrow venter. Suture line (Fig. 5) is typical of *Placites.*

Discussion. Species of *Placites* may reach a diameter of 100 mm and are distinguished (cf. Mojsisovics 1873) mainly on the basis of their whorl section and suture line at medium to large size, i.e., adult stage of growth. The specimen from Pizzo Mondello (level NA49.1) is clearly a juvenile and therefore is left in open nomenclature.

Occurrence. As with most of Gymnitidae, *Placites* is a long-ranging form; its range spans the entire Norian to Rhaetian stages. The specimen described here was collected from a bed yielding *Halobia mediterranea* (see Levera 2012), a species usually referred to the Paulckei Zone (Krystyn et al. 2002; Levera 2012).

Fig. 5 - Suture line of *Placites* sp. ind., specimen MPUM 10966 (NA 49.1.-1). Bar scale 2 mm.

Superfamily Tropitaceae Mojsisovics, 1875

Family Tropitidae Mojsisovics, 1875

Genus *Discotropites* Hyatt & Smith, 1905

Type species: *Ammonites sandlingensis* Hauer, 1850

Discotropites plinii (Mojsisovics, 1893)

Pl. 1, fig. 2a-b

1893 *Eutomoceras plinii* Mojsisovics, p. 289, pl. 130, fig. 4, 5, 6.

1982 *Discotropites plinii* – Krystyn, p. 34, pl. 7, fig. 3-4. [*Cum syn.*]

2000 *Discotropites plinii* - De Zanche et al., pl. 1, fig. 1a-b.

Stratum typicum: Hällstatter Kalk, at Feuerkogel (Salzkammergut, Austria).

Lectotype: Original of Mojsisovics 1893, pl. 130, fig. 5, GBA1893/01/264, selected by Krystyn (1982: 34).

Material: One specimen MPUM 10967 (PMAM17-1).

Description. Slightly elliptical, extremely crushed internal mold of large-sized specimen with diameter of about 90 mm. About 130° of the body chamber are preserved. Despite the extreme crushing, the keel is clearly visible. Ribbing consists of slightly prorsiradiate, gently sinuous-falcoid ribs. Organization of ribs is visible only on the last quarter of the preserved body chamber. Ribs are organized in bundles, each consisting of three primary ribs (Pl. 1, Fig. 2b). Usually one intercalatory/bifurcate rib appears a few mm from the umbilical margin. Additional branching at a little less than ¼ of whorl height, and very rarely (once in the last half whorl) intercalatory ribs appears at 1/3 of whorl height. Near the ventral shoulder, flat ribs are 3 to 4 times wider than the narrow inter-rib intervals.

Suture lines are strongly serrated, but not well preserved.

Remarks. This species was revised by Krystyn (1982), who discussed the synonymy and its relationship with *Discotropites theron* (Dittmar, 1866), the most similar species. In *D. theron* the primary ribs start from node-like periumbilical swellings (Mojsisovics 1893: 288; Krystyn 1982: 34), that are not developed in *D. plinii*. The difference between *D. plinii* and *D. theron* is even greater, if we follow the interpretation of *D. theron* by Tozer (1994), who extended its diagnosis to forms with several spiral rows of nodes.

Occurrence. The distribution of *Discotropites plinii* is widespread in the Tethys realm, from the Northern Alps to Japan, through Sicily, Turkey, Himalaya and Timor. Its stratigraphic position is so well constrained that this species has been selected by Krystyn (1980, 1982) as the index ammonoid for the first subzone of the uppermost Carnian Spinosus Zone (see also Krystyn et al. 2002).

Genus *Anatropites* Mojsisovics, 1893

Type species: *Tropites* (*Anatropites*) *spinosus* Mojsisovics, 1893

Anatropites sp. ind.

Pl. 1, fig. 3, 4a-b

Material: Two specimens, MPUM 10968 (FNP112-1) and MPUM 10969 (PMAM22bis).

Remarks. The two specimens attributed to *Anatropites* were collected from two different levels and most probably are not conspecific.

Following the stratigraphic succession, the first specimen (MPUM 10968 [FNP112-1]: Pl. 1, Fig. 4a-b) is preserved in three dimensions for one quarter of a whorl. The original diameter is about 20 mm, and the whorl cross section is typically semielliptical with lateral sides converging towards the rounded venter and the prominent keel. Ornamentation is also typical of the genus, consisting of prorsiradiate concave primary ribs strongly elevated/subspiny at the periumbilical border and fading towards the shoulder.

The second specimen, from level PMAM22bis (Pl. 1, Fig. 3), is preserved only as a whorl cross-section that is unextractable from the rock matix. Despite its very incomplete preservation, the specimen fits perfectly with *Anatropites* because of its peculiar whorl section with lateral sides converging to a rounded venter, its maximum width at the umbilical margin, its elevated keel without side furrows and its weak but distinct small projections at the umbilical margin, suggesting the umbilical spines typical of *Anatropites*.

Both specimens are left in open nomenclature, the first because of its rather small size and the second because details of its ornamentation are not visible.

Occurrence. The genus *Anatropites* occurs in the Tethys realm and North America. In both areas it is restricted to the last zone of the Carnian stage, namely the Spinosus Zone in the Tethys (Krystyn 1973, 1980; Krystyn & Gallet 2002; Krystyn et al. 2002) and the Macrolobatus Zone of central Nevada (Silberling 1959) and British Columbia (Tozer 1994).

Genus *Microtropites* Mojsisovics, 1893

Type species: *Ammonites galeolus* Hauer, 1860

Preliminary remarks. The genus *Microtropites* Mojsisovics, 1893 includes small-sized (dwarf) Tropitidae that exhibit a change in coiling during growth, a weak to very weak ornamentation and an ammonitic suture line (e.g., Mojsisovics 1893: 188; Arkell et al. 1957: L169). Species attributed to this genus show some differences in their whorl section, which varies from slightly compressed with a nearly semi-elliptical outline (e.g., the type *M. galeolus* [Hauer, 1860], *M. lepsiusi* Mojsisovics, 1893 and *M. tubercularis* Mojsisovics, 1893) to slightly depressed with a broadly rounded venter (e.g., *Microtropites* sp. ind. in Krystyn 1982). Taking into consideration the rarity of specimens from this group and the lack of pertinent literature plus the fact that their distribution is restricted to the latest Carnian (Krystyn 1980, 1982), we for now consider these differences in whorl section to be part of the variability of the genus.

Microtropites cf. **paronai** (Gemmellaro, 1904)

Pl. 1, fig. 5a-c

Remarks on the type series. Gemmellaro described the new species *Tropites paronai* based on only three specimens (Gemmellaro 1904: 96), but in the collection stored at Museo Gemmellaro, two groups of specimens are labelled as "*Tropites paronai*". The first group (MGUP 002.96.1-4) consists of four specimens and includes the two figured types (MGUP 002.96.1= pl. 7, fig. 27-28; MGUP 002.96.3= pl. 7, fig. 25-26). The second group includes six specimens that are referred to a different catalogue number (MGUP 002.95.1-6) than the first group. We consider the types of the species to be only the specimens of the first group (MGUP 002.96.1-4).

Material: One specimen MPUM 10970 (PMAM52A-1).

Description. Specimen preserved with strongly recrystallized test, but internal mold is occasionally visible because test was lost in a few places during preparation. Body chamber consists of 170° of the last whorl. Coiling is involute, but from approximately 4-5 mm of H it becomes evolute due to umbilical egression. Whorl cross-section is depressed with wide, rounded venter giving specimen a near cadicone shape. Ventral keel without significant bordering furrows.

Specimen appears to be nearly smooth except for strong forward-projected, concave, extremely weak and fading ribs that are visible under certain light conditions on last 90° of preserved body chamber.

Suture line not visible.

Dimensions (mm)

Specimen	D	U	H	h	W	U/D	H/U	H/W	SGR
MPUM 10970 PMAM52A	21.7	10.0	6.0	5.7		0.46	0.6		5.26

Discussion. The genus *Microtropites* was recognized in Sicily by Gemmellaro (1904), who classified a few specimens from his collection as *M. lepsiusi* Mojsisovics, 1893. However, certain other taxa included by Gemmallaro in *Tropites* may well be better referred to *Microtropites*; these are *Tropites paronai* Gemmellaro, *T. brancoi* Gemmallaro, *T. carapezzai* Gemmellaro and *Tropites* n.f. indet. ex aff. *T. brancoi*. According to the original descriptions and plates, these taxa are very similar with only slight differences in the degree of whorl compression, type of ribbing and whether or not umbilical nodes and weak furrows bordering the keel are present. An examination of Gemmellaro's type material reveals that he emphasized these differences in his descriptions and also that some details of the drawings were slightly exaggerated. A revision of the whole group is beyond the scope of this paper and would require much new material to test the population variability of these very small, poorly known Tropitiidae.

The Pizzo Mondello specimen is closer to *Microtropites paronai* (Gemmellaro, 1904) than to *M. brancoi* (Gemmellaro, 1904), which is characterized by ribs (visible on Gemmellaro's plate 25, fig. 1-4) and by a slightly more compressed whorl section. Its similarity with *M. paronai* includes the depressed whorl section (Gemmellaro's plate 7 fig. 27-28) and faded ribs. The specific attribution of the Pizzo Mondello specimen is challenged by certain differences from the syntype shown in pl. 7, fig. 25-26 (MGUP 002.95.3), which shows a narrowing of the whorl section that apparently is related to umbilical egression. Our specimen is slightly smaller than this particular syntype and it exhibits umbilical egression, but its venter does not become narrower. The same syntype has weak umbilical nodes (weaker than shown in Gemmellaro's figure) that are neither visible on the other figured syntype (pl. 7, fig. 27-28; MGUP 002.96.1), nor on the Pizzo Mondello specimen. Our specimen does not have furrows along side the keel, but this feature is often visible on Gemmellaro's types. We prefer not to over-emphasize this difference since it may simply be related to different types of preservation. The test of our specimen is nearly complete, whereas Gemmellaro's types are preserved as internal molds.

Occurrence. The genus *Microtropites* is known only from the Tethys realm, where it is regarded as a marker for the *Gonionotites italicus* subzone, upper part of the Spinosus Zone, uppermost Carnian (Krystyn, 1980, 1982). The stratigraphic positions of the taxa described by Gemmellaro (1904) from Sicily are unknown, but the new Pizzo Mondello specimen from level PMAM52A is herein used to mark the lower boundary of the *Gonionotites italicus* subzone (Fig. 6).

Family Thisbitidae Spath, 1951

Genus *Metathisbites* Tozer, 1994

Type species: *Buchites hilaris* var. *dawsoni* McLearn, 1940

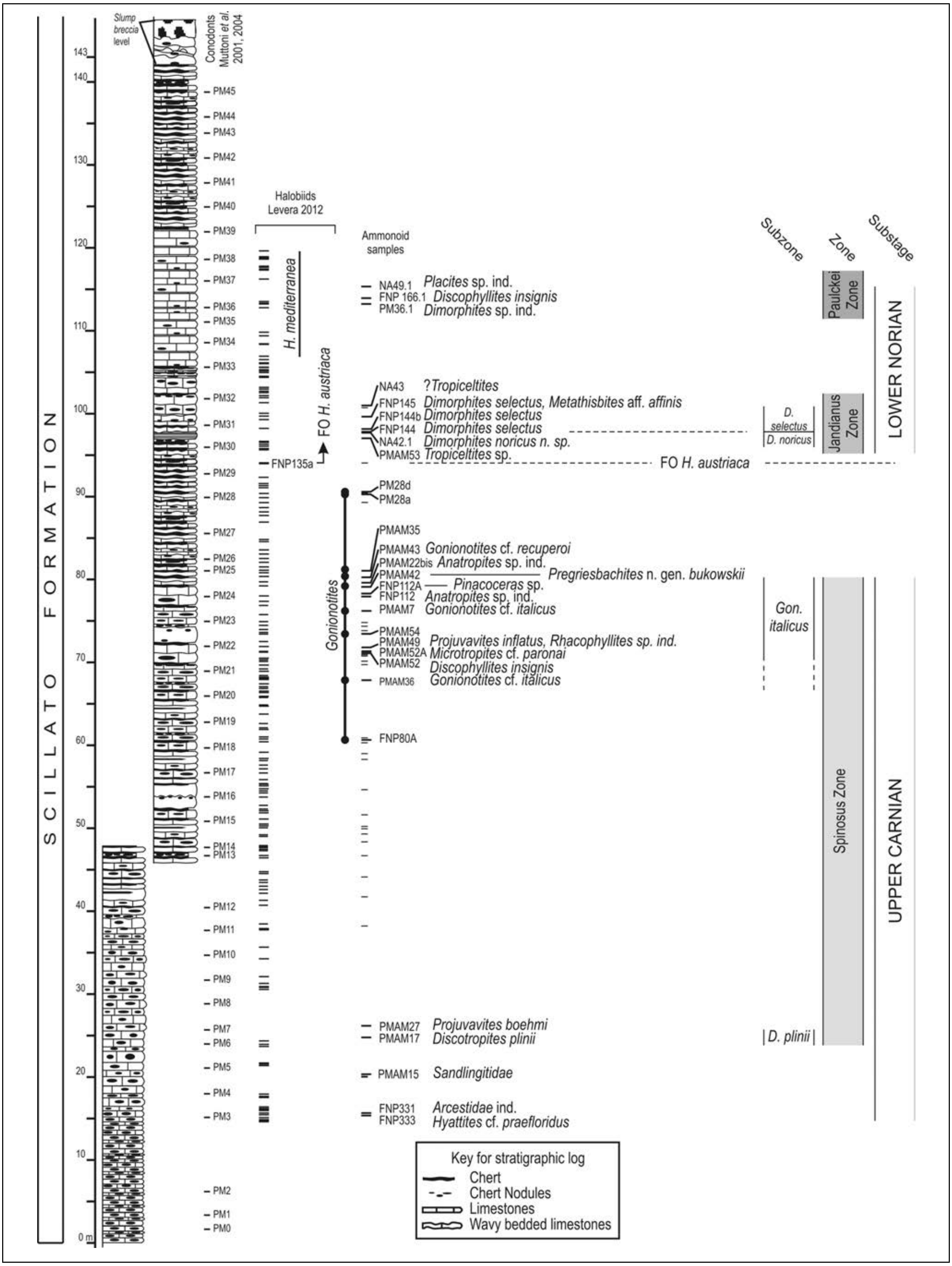


Fig. 6 - Distribution of the Upper Carnian-Lower Norian ammonoids in the studied interval of Pizzo Mondello section. The position of all the ammonoid samples is shown, but the occurrence of small sized specimens not classified in this work is differentiated with a short dash. For the sake of completeness the position of the conodont samples of Muttoni et al. (2001 and 2004) and of the halobiids described by Levera (2012) is also shown.

Metathisbites cf. **affinis** (Gemmellaro, 1904)
Pl. 1, fig. 6a-b

Material: One specimen MPUM 10971 (FNP145-1).

Description. Rather small specimen (diameter about 18.5 mm) that consists of an internal mold of a body chamber and preserved only on one side with a small part of the venter exposed.

Rate of coiling very low with H~U. Flank slightly convex suggesting a compressed whorl section with well developed shoulder. No keel visible on exposed part of venter.

Ornamentation consists of gentle, wavy-like, prorsiradiate, slightly sinuous primary ribs. Only one bifurcate rib occurs in about one half whorl. All ribs end on ventral shoulder with small but distinct rounded node (see Pl. 1, Fig. 6b).

Suture line not visible.

Discussion. The specimen is very close to *Thisbites* Mojsisovics, 1893 and *Metathisbites* Tozer, 1994. *Metathisbites* is characterized (Tozer 1994: 232) by an ovoid whorl section, a weak keel that sometimes is lacking, mostly simple ribs and nodes that are weaker than in *Thisbites*. The available specimen does not show an ovoid section, but its cross-section seems to be more subrectangular/subquadrate. Apart from this feature, the other characters suggest attribution to *Metathisbites.* Ribbing is rather simple and most of the ribs are primary. The ventrolateral nodes are very weak and for what is visible on the small part of the ventral side, there is no prominent keel.

Thisbites includes species with more dense ribbing, a much higher frequency of secondary ribs and usually a distinct and strong keel.

As regard the species, the specimen is referred by cf. to *Ceratites* (*Buchites*) *affinis* Gemmellaro on the basis of ribbing and nodes. This species is characterized by weak ventrolateral nodes and a very weak keel, both features not consistent with *Buchites* Mojsisovics, 1893. The attribution by cf. is due to the incomplete preservation of the ventral side of the specimen from Pizzo Mondello.

Occurrence. According to Tozer (1994) *Metathisbites* is documented in both the Tethys realm and North America. Its range is calibrated only in North America where it is restricted to the Lower Norian Kerri Zone, more precisely to the *Stikinoceras kerri* subzone II. The specimen from Pizzo Mondello, in open nomenclature, has been found together with *Dimorphites selectus*, index of the 2nd subzone of the Lower Norian Jandianus Zone. This finding is consistent with the stratigraphic position of the genus in North America.

Family Juvavitidae Tozer, 1971

Subfamily Juvavitinae Tozer, 1971

Genus *Hyattites* Mojsisovics, 1902

Type species: *Pinacoceras praefloridum* Mojsisovics, 1873

Preliminary remarks. *Hyattites* Mojsisovics, 1902, one of the poorest known ammonoid genera from the Upper Triassic of the Tethys, was established by Mojsisovics (1902) to accommodate three species with quite different stratigraphic positions that were previously referred to *Beyrichites* Waagen, 1895 by Philippi (1901:110). *Pinacoceras praefloridum* Mojsisovics, 1873, *Meekoceras maturum* Mojsisovics, 1882 and *Meekoceras emmerichi* Mojsisovics, 1882 are of relatively medium size and they exhibit involute coiling and a lack of ornamentation, but Mojsisovics (1902: 306) emphasized the suture line of *Hyattites* with its phylloid habitus and broad median hump in the external lobe (litt. "Medianhöckers im Externlobus") that was said to suggest a family connection with *Sturia* Mojsisovics, 1882. In his description of the genus, Mojsisovics selected *Pinacoceras praefloridum* Mojsisovics, 1873 (of Carnian age) to be representative of the development of the suture line of *Hyattites*, and this is probably the reason this taxon has long been considered to be the type species of the genus (Diener 1915: 154; Spath 1951: 154; Arkell et al. 1957: L182). Krystyn 1982 (p. 43) closely examined the type specimen of the species and recognized that the suture line drawing in Mojsisovics 1893 was incorrect due to excessive grinding of the test. In reality the external suture is actually juvavitid and *Hyattites* is closely related to *Gonionotites* from which it differs by the early fading of its sculpture.

Spath (1951) pointed out the relatively large age differences of the three species grouped together by Mojsisovics and therefore, reduced the composition of *Hyattites*. He confirmed the attribution of Anisian aged *M. maturum* to *Beyrichites*, as already suggested by Philippi (1901), and he selected Ladinian aged *M. emmerichi* as type species for the new genus *Parasturia*. Thus, Spath left only the type species in *Hyattites*, and until now it has remained the composition of the genus, because the only two taxa referred to this genus, *Hyattites salomoni* Gemmellaro, 1904 and *Hyattites* (?) *nepalensis* Jeannet, 1959 apparently are not conspecific with *H. praefloridum*.

Gemmellaro described the new species *Hyattites salomoni* on the basis of two specimens from "feudo Modanesi," western Sicily. However, his figured suture line (1904: pl. 27, fig. 29) contains simpler indentations than *H. praefloridus*. *Hyattites* (?) *nepalensis* Jeannet, 1959 from the Carnian of Nepal is referred with question to *Hyattites*, but apparently it is not conspecific with *H. praefloridus* because of its ribbed ornamentation. *Gonionotites rarus* McLearn, 1940, as figured in Tozer (1994, pl. 119), lacks ornamentation and could well be included in the genus *Hyattites*.

Occurrence and age. Neither the occurrence nor the age of *Hyattites* is well defined in literature. Arkell et al. (1957), probably following Spath's lead (1951), reported *Hyattites* from the Carnian of Sicily and the Northern Alps, whereas Tozer (1981a and b) provided an Early Norian age and a much wider paleogeographic distribution, from the Tethys to the East Pacific. Evidence in support of Tozer's conclusions is not clear because he does not cite the genus from North America, although it may very well occur there (e.g., *Gonionotites rarus*). The Tethys occurrence may be supported by the distribution of *Hyattites praefloridus* (Mojsisovics) and *H. salomoni* (Gemmellaro), but there have been no reports of *Hyattites* from North America, neither before Tozer 1981a nor after (e.g., Tozer 1994). *H. praefloridus* is known from "Schichten mit Lobites ellipticus" of Röthelstein (Mojsisovics 1873: 58), a fossil site containing a condensed fauna ranging in age from Carnian to Early Norian, according to Krystyn (1980).

Hyattites cf. **praefloridus** (Mojsisovics, 1873)

Pl. 1, fig. 7a-b; Fig. 7

Material: One specimen, MPUM 10972 (FNP333).

Description. Specimen is preserved as an internal mold, but retains small areas of recrystallized test. Last 240° of whorl belong to the body chamber. Involute conch with very narrow umbilicus and compressed whorl section, with nearly flat flanks and rounded venter. Surface of specimen is smooth on both the body chamber and portion of the last whorl that is phragmocone.

Suture lines are strongly serrated, specimen appears to be an adult. Suture is ammonitic with a gonionotitic pattern of indentitions (Fig. 7). External lobe has a wide internal saddle.

Discussion. One peculiar feature of the Pizzo Mondello specimen is the lack of ornamentation on the inner part of the last whorl at relatively small values of H. At this size, nearly all Juvavitidae have ribs and/or constrictions.

The attribution of the specimen to *Hyattites* relies mainly on these features and on the gonionotitic-like suture line that is consistent with the general pattern of the type specimen's suture line, re-described by Krystyn (1982: 42). However, the suture line of the type specimen of *H. praefloridus* is more indented, but this magnitude of difference is not fully justified by the slightly larger size of the type specimen (D about 50 mm) with respect to specimen MPUM 10972 (D about 39 mm). Because of this difference the specimen from Pizzo Mondello is attributed to this species, with cf.

Hyattites salomoni Gemmellaro from "feudo Modanesi" differs from *Hyattites* cf. *praefloridus* by its suture line with seven saddles on the lateral sides, very simple indentitions, and ribs developed on the external part of the lateral side.

Occurrence. *Hyattites* cf. *praefloridus* is the oldest ammonoid collected to date from the Scillato Formation at Pizzo Mondello. It was collected from the Upper Carnian part of the section, about 9 m below the single occurrence of *Discotropites plinii*.

Genus *Projuvavites* Tozer, 1971

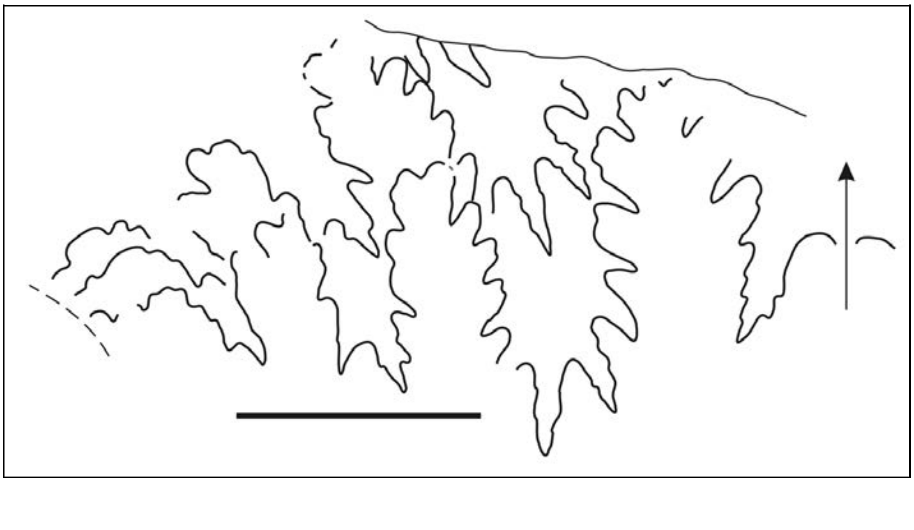
Type species: *Juvavites* (*Anatomites*) *brockensis* Smith, 1927

Projuvavites boehmi (Gemmellaro, 1904)

Pl. 1, fig. 8a-b; Fig. 8

v 1904 *Juvavites* (*Anatomites*) *böhmi* Gemmellaro, p. 207, pl. 27, fig. 9. *partim*

Fig. 7 - Suture line of *Hyattites* cf. *praefloridus*, specimen MPUM 10972 (FNP333). Bar scale 5 mm.



?v 1904 *Juvavites* (*Anatomites*) *böhmi* Gemmellaro, p. 207, pl. 27, fig. 10.

Stratum typicum and locus typicus: Light gray limestone with cherty nodules, "feudo Modanesi" near Castronuovo (Gemmellaro 1904:208).

Type series: Gemmellaro based his description of the species on two specimens, both of which are figured. Their repository is the Museo Gemmellaro under registration number MGUP 002.183.1 and.2. Specimen MGUP 002.183.1 (Gemmellaro 1904: pl. 27, fig. 9) is here designated as the lectotype.

Material: One specimen MPUM 10973 (PMAM27-1).

Description. Specimen consists of slightly more than half whorl, representing last part of phragmocone and beginning of body chamber (about 100°). Test on phragmocone lost during extraction.

Juvavitid with involute coiling and slightly compressed whorl section. Whorl section of inner whorls is semioval, but then apparently becomes almost subtriangular on body chamber. However, since body chamber is slightly crushed, this feature may be partly secondary. Two concave, projected constrictions are visible, one on phragmocone and the second located just after last visible suture line, at about 80° from first.

Ornamentation consists of slightly prorsiradiate, concave ribs with *Projuvavites*-like organization on the phragmocone (see Krystyn 1982). At the shoulder, about 13 ribs are visible between the two constrictions. Ribbing on body chamber is much weaker, consisting of widely-spaced primary ribs and intercalatory ribs visible only at the shoulder. Three intercalatory ribs are usually present between two primary ribs.

Suture line ammonitic (Fig. 8) with *Projuvavites*-like pattern of intentations.

Discussion. Relatively few species of the large group attributed by Gemmellaro to the subgenus *Juvavites* (*Anatomites*) have a large size and relatively thick whorl section. Within this small group, the species most similar to the Pizzo Mondello specimen is *J.* (*A.*) *boehmi* Gemmellaro, which exhibits a fading of the ribs on the body chamber, especially on the inner part of the lateral side. This feature is well visible on Gemmellaro's syntype figured in pl. 27, fig. 9 (MGUP 002-182.1),

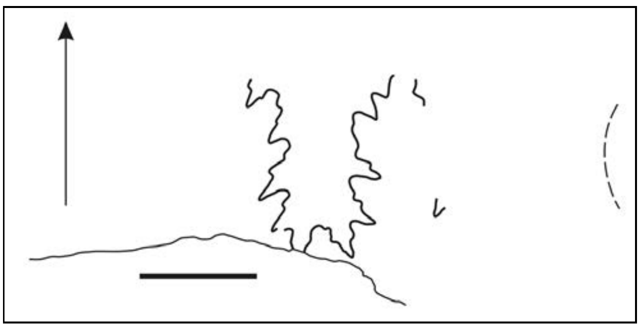


Fig. 8 - Suture line of *Projuvavites boehmi* (Gemmellaro, 1904), specimen MPUM 10973 (PMAM 27-1). Bar scale 5 mm.

which is designated as lectotype. The second specimen, now a paralectotype (pl. 27, fig. 10, MGUP 002-183.2), is a juvenile that does not show the typical features of *J.*(*A.*) *boehmi*.

An examination of the lectotype of *J.*(*A.*) *boehmi* reveals that Gemmellaro's figure of the whorl section is not correct. The specimen is more compressed than shown in the illustration in pl. 27, fig. 9, and in this feature the lectotype is more similar to the new specimen from Pizzo Mondello.

The only difference between MPUM 10973 and the lectotype is the width of the venter, which seems to be wider on the lectotype of *P. boehmi*. Information regarding population variability of *P. boehmi* is not available, but it is well known from tens of papers on Triassic ammonoids that population variability is rather wide for several groups, and thus, the shape and width of the venter may also be affected. Given that the difference in the width of the venter is rather small, and that the relatively narrow venter of MPUM 10973 may be due to a slight crushing of the body chamber, we have decided to include the new specimen in *P. boehmi* (Gemmellaro).

Occurrence. No literature is available for *Projuvavites boehmi* (Gemmellaro). This species is apparently restricted to Sicily, where its stratigraphic position is unknown. The new specimen from Pizzo Mondello comes from level PMAM27, just slightly above PMAM17, which yielded *Discotropites plinii*. *P. boehmi* could probably be referred to this subzone.

Projuvavites inflatus (Gemmellaro, 1904)

Pl. 1, fig. 9a-d

v 1904 *Juvavites* (*Anatomites*) *inflatus* Gemmellaro, p. 211, pl. 5, fig. 19-20.

?v 1904 *Juvavites* (*Anatomites*) *gelonis* Gemmellaro, p. 213, pl. 17, fig. 3-4, pl. 21, fig. 10.

Stratum typicum: Light gray limestone with chert nodules from "feudo Modanesi" near Castronuovo (Palermo) (Gemmellaro 1904:212).

Type series: The description of this species is based on two specimens, both registered in the Museo Gemmellaro under number MGUP 002.185.1-2. The only figured specimen (MGUP 002.185.1) is here designated as the lectotype.

Material: One specimen MPUM 10974 (PMAM49-1).

Description. The specimen consists of an internal mold of phragmocone and at least 270° of body chamber. Juvavitid with very involute coiling (U= 9% of D) and slightly depressed whorl section (H/W from 0.86 to 0.94) with semielliptical outline that becomes subtriangular on last whorl. Rounded venter is crossed by constrictions, but not by ribs, at least on phragmocone.

Constrictions spaced about 80°-90° apart. Ribs nearly straight, but bend forward at ventrolateral shoulder and then usually fade without crossing venter. Organization of ribs between constrictions follows the typical pattern of *Projuvavites* without trifurcation of ribs and about four primary ribs between constrictions. Ribbing also developed on beginning of body chamber.

Suture line ammonitic, not well enough preserved for drawing.

Dimensions

Specimen	D	H	U	h	W	w	U/D	H/W	h/w	SGR
MPUM 10974 (PMAM49-1)	50.0	27.4	4.65	17.95	28.9	20.75	0.09	0.94	0.86	52.64

Discussion. The Pizzo Mondello specimen is attributed to *Juvavites* (*Anatomites*) *inflatus* Gemmellaro, 1904 in part because of its involute coiling and slightly depressed whorl section, but especially for the change in its whorl section, which becomes nearly subtriangular on the outer whorl and also for the development of ribs on the body chamber. The constrictions are not well-represented on Gemmellaro's drawings, but they are clearly mentioned in the text (p. 211) and also quite visible on the lectotype.

Juvavites (Anatomites) gelonis Gemmellaro, 1904 is cogeneric with *Projuvavites inflatus*, and probably could be synonymized with this species. The size of the largest types (Gemmellaro 1904, pl. 17, fig. 3-4) is nearly equivalent to the inner whorl of the type specimen of *P. inflatus*, and their coiling and whorl sections are also very similar. Ribbing is slightly different, but this may not be of great significance at the species level. Gemmellaro's drawing (1904, pl. 17, fig 5) of *P. gelonis* appears to show a few trifurcations, but this feature is not very obvious on the original.

Among the large group of "*Anatomites*" described by Gemmellaro, *Projuvavites inflatus* is also similar to *J.* (*A.*) *archimedis* Gemmellaro, 1904, *J.* (*A.*) *mariani* Gemmellaro, 1904 and *J. (A.) boehmi* Gemmellaro, 1904, but all three species can be attributed to *Projuvavites* Tozer, 1971. *Juvavites* (*A.*) *archimedis* (Gemmellaro 1904: pl. 9, fig. 1-2) differs by the reduction of ribbing on its body chamber and its nearly semi-elliptical whorl section. *Juvavites* (*A.*) *mariani* has a totally different body chamber (Gemmellaro 1904: pl. 16, fig. 1-2). Its venter becomes wider (this feature is more developed on the syntype than shown on the plate), and its ribs are much reduced and wavy-like, but they persist in strength and cross the venter. *Juvavites* (*A.*) *boehmi* (Gemmellaro 1904: pl. 27, fig. 9-10) also exhibits a reduction of ribbing on the body chamber, especially on the inner part of the lateral side.

Occurrence. No information is available regarding the age and stratigraphic position of *Juvavites* (*Anatomites*) *inflatus* as described by Gemmellaro from western Sicily. In this respect, the discovery of the single specimen from Pizzo Mondello provides at least a partial solution to its age. The new specimen was found in a level just slightly above the base of the *Gonionotites italicus* subzone (Spinosus Zone, Tuvalian 3, Upper Carnian) that is marked by the occurrence of *Microtropites* in level PMAM52A.

Genus *Gonionotites* Gemmellaro, 1904

Type species: *Gonionotites italicus* Gemmellaro, 1904

Preliminary remarks. *Gonionotites* Gemmellaro, 1904 has been recognized in several Tethyan localities and North America, but despite a relative abundance of literature, the taxonomy of this genus at the species level is still complex. Gemmellaro described eleven new species of *Gonionotites* and two indeterminate taxa from the "cherty limestone" of Sicily. Since then, the genus has been recognized in the Tethys Himalaya (Diener 1906 and 1908; Wang & He 1976; Krystyn 1982), Northern Alps (Diener 1921; Krystyn 1973 and 1980), Iran (Besse et al. 1998) and Turkey (Krystyn & Gallet 2002), but it is worth noting that most of the species identified from these areas are different than those from Sicily.

The first report of *Gonionotites* from North America was by Smith (1927). Afterwards a number of species, most of which are different from the Tethyan faunas, were described from Canada by McLearn (1940, 1947 and 1960) and Tozer (1962). Then, in 1994 Tozer provided a comprehensive revision of the Canadian *Gonionotites* species. No recent literature is available from the United States apart from the illustration of two specimens by Kristan-Tollmann & Tollmann (1983).

Tethyan *Gonionotites* are not as well known as the North American faunas. Krystyn (1982) described *G. haugi* Gemmellaro, 1904, *G. gemmellaroi* Diener, 1906, and *G. noricus* Diener, 1921 from Nepal. He also revised *G. tingriensis* Wang & He, 1976 and transferred this species to *Malayites* Welter, 1914, based on its spiral strigations (Krystyn 1982). However, no updates are available for most of the eleven species erected by Gemmellaro, including the index species *G. italicus*.

An examination of Gemmellaro's species and their comparison with other species from the Tethys and North America suggests the following brief comments.

a) As already mentioned for other ammonoid groups of Gemmellaro's collection, several of his species appear to be morphologically very close. Surprisingly, a syntype of a given species is often more similar to a syntype of another species than to the other members of the same type-series. This is the case for *Gonionotites* *mojsisovicsi* in Gemmellaro's pl. 21, fig. 1-3, which is more similar to the compressed inner whorls of the syntype of *G. italicus* in pl. 21 (fig. 4-6) than to the syntype of *G. mojsisovicsi* figured in pl. 13, fig. 1-2.

b) Many of Gemmellaro's species exhibit compressed to very compressed inner whorls with a subtriangular whorl section followed by a widening venter and a thickening of the whorl width on the body chamber. This modification of the whorl section on the mature body chamber is much less common in other Tethyan and North American species.

c) Few Sicilian species of *Gonionotites* exhibits a thickening of the ribs on the widest part of the flank before the shoulder, which resembles radially elongated and forward concave nodes. These bulges are shown in *G. recuperoi* Gemmellaro (pl. 7, fig. 43-44), *G. diblasii* Gemmellaro (pl. 5, fig. 1-2) and possibly *G. dubius* Gemmellaro (pl. 6, fig. 9-10), but they also occur in a few very compressed species that Gemmellaro attributed to the subgenus *Anatomites*, such as *Juvavites* (*Anatomites*) *pulcher* Gemmellaro (pl. 5, fig. 3-4) and *J.* (*A.*) *formosus* Gemmellaro (pl. 20, fig. 6-7).

A clarification of these problems would require a population analysis of many bed-by-bed collected specimens, but thus far the scarcity of specimens from Pizzo Mondello does not allow such a revision. Pending a thorough revision of the group, we can only compare our new specimens with Gemmellaro's taxonomy.

Gonionotites cf. **italicus** Gemmellaro, 1904

Pl. 2, fig. 1a-c

v 2007 *Gonionotites maurolicoi* - Nicora et al., pl. 2, fig. 6a-b.

Remark on the Type series: Gemmellaro (1904: 159) clearly stated that the new species was based on five well preserved specimens plus several fragments. Seven specimens are housed in the Museo Gemmellaro collections, under registration number MGUP 002. 147.1-4 and MGUP 002.148.1-3.

Material: Two specimens, MPUM 10975 (PMAM7-1) and MPUM 10976 (PMAM36-1).

Description. The two specimens attributed to *Gonionotites* cf. *italicus* are of rather large size. One is slightly less than half one whorl (about 170°) of body chamber (estimated diameter of about 100 mm) with inner whorls visible in cross section, while the second is an incomplete fragment of less than 45° of body chamber. Both specimens have a compressed, slender subtriangular whorl section with very narrowly rounded venter and a smooth surface. The most complete specimen (Pl. 2, Fig. 1) exhibits a gradual thickening of the whorl section that is not accompanied by a widening of the venter. At the end of the preserved part of the body chamber (Pl. 2, Fig. 1b-c), the venter is still relatively narrow, and the maximum width of the whorl section is located just slightly above one- half of the whorl height.

Dimensions

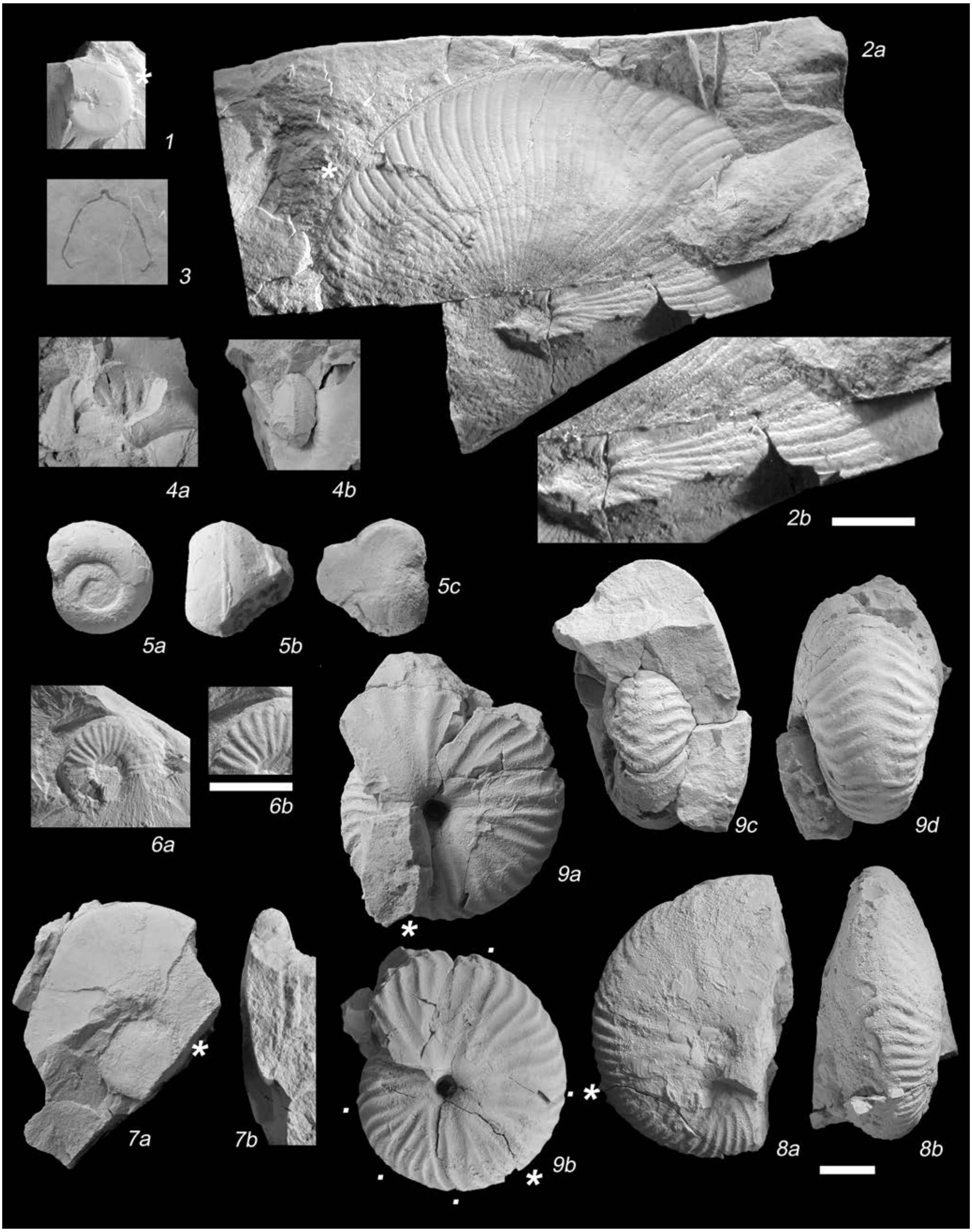
Specimen	D	H	U	h	W	w	U/D	H/W	h/w	SGR
MPUM 10975 (PMAM7-1)		42 54.8			22.4 29.7			1.87 1.84		

Discussion. As emphasized in the Preliminary remarks, the difference between some of Gemmellaro's species is rather obscure. We do not doubt that *G. italicus*, the first species described by Gemmellaro, is a valid species, and accordingly, we place slightly more emphasis on this taxon than to the other species.

Specimen MPUM 10976 is too incomplete for a fully accurate identification, while the attribution of the figured specimen (MPUM 10975; Pl. 2, Fig. 1) requires additional discussion. Comparison of this specimen with the *Gonionotites* of Gemmellaro's collection leads us to conclude that only part of the body chamber of the new specimen is preserved, with about 70-90° missing. A second observation resulting from the examination of *Gonionotites* of Gemmellaro's collection is that the thicknening of the whorl and widening of the venter usually take place on the last quarter of the whorl of the mature body chamber. Apparently, this particular part of the whorl is not preserved in specimen MPUM 10975. This specimen definitely exhibits a thickening of the whorl, but apparently its growth was not yet sufficient for the venter to become wider. Instead its venter is still rather narrow at the end of the preserved part of the body chamber (Pl. 2, Fig. 1c). In this aspect,

PLATE 1

Upper Carnian and Lower Norian ammonoids from Pizzo Mondello. 1) *Placites* sp. ind., specimen MPUM 10966 (NA49.1-1). 2) *Discotropites plinii* (Mojsisovics, 1893), specimen MPUM 10967 (PMAM17-1): a, lateral view, b enlargement showing branching of the ribs at the umbilical margin. 3) *Anatropites* sp. ind., specimen MPUM 10969 (PMAM22bis). 4) *Anatropites* sp. ind., specimen MPUM 10968 (FNP112-1): a, lateral view, b) ventral view. 5) *Microtropites* cf. *paronai*, specimen MPUM 10970 (PMAM52A-1): a, lateravl view; b, ventral view; c, apertural view. 6) *Metathisbites* cf. *affinis*, specimen MPUM 10971 (FNP145-1), a, lateral view; b, detail of the weak ventrolateral nodes. 7) *Hyattites* cf. *praefloridus*, specimen MPUM 10972 (FNP333), a) lateral view; b, view of the cross section. 8) *Projuvavites boehmi* (Gemmellaro), specimen MPUM 10973 (PMAM22-1), a, lateral view; b, ventral view. 9) *Projuvavites inflatus* (Gemmellaro), specimen MPUM 10974 (PMAM49-1), a, lateral view; b, lateral view after removal of the last part of body chamber; c, apertural view; d, ventral view; dots mark the constrictions. All specimens whitened with ammonium chloride except Fig. 3. Bar scale is 1 cm, that in lower right corner is for all the figures except for 2b and 6b. Asterisk marks the last septum.


1
2a
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9c
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7b
8a
8b

the specimen seems to differ from *G. italicus*, but on the other hand, none of Gemmellaro's other type specimens appear to be close to specimen MPUM 10975. The type specimen of *G. discus* (see 1904: pl. 13, fig. 3-6) has a body chamber that exhibits a flattening of the venter, a trend that is opposite with respect to the venter of MPUM 10975. The type specimen of *G. maurolicoi* also has a narrow venter, but it is characterized by much thicker whorls, whose maximum width is very close to the umbilical margin (e.g., 1904: pl. 14, fig. 5); therefore, the previous attribution of specimen MPUM 10975 to this species (Nicora et al. 2007) is here emended. One of the syntypes of *G. mojsisovicsi* shows some similarity with the new specimen, with respect for its narrow venter, but unfortunately this feature is accompanied by a maximum whorl width very close to the umbilical margin, instead of at about 50 % of the whorl height. This syntype (MGUP 002.153.2) was not figured by Gemmellaro, and thus it cannot be considered to be especially representative of *G. mojsisovicsi*. According to Gemmellaro (1904), the characteristic syntypes of this species include the large, much thicker specimen figured in pl. 13, fig. 1-2 with a more rounded venter than the present specimen, and the syntype in pl. 21, fig. 1-3, with a broad venter and maximum whorl width located at about ½ of whorl height.

Occurrence. Both specimens were collected from levels PMAM36 and PMAM7. The first level is located about 3 m below the occurrence of *Microtropites* cf. *paronai*, which presently marks the lower boundary of the *Gonionotites italicus* subzone. The second specimen was collected from the middle part of the *G. italicus* subzone.

Gonionoites aff. **recuperoi** Gemmellaro, 1904

Pl. 2, fig. 2a-b; Fig. 9

Material: One specimen MPUM 10977 (PMAM43-1).

Description. Specimen, which is preserved as an internal mold partly covered by recystallized test, consists of a phragmocone with about 270° of body chamber. Whorl section is compressed and slender for first 160° of body chamber, but then venter rapidly widens and maximum width of whorl section moves from the umbilical margin to 1/3 of whorl height. A weak constriction is visible at beginning of the body chamber.

Ribbing follows pattern typical of *Gonionotites*. On visible part of the phragmocone, ribbing consists of extremely weak prorsiradiate, primary ribs on the flank, and three to four secondary ribs are visible very close to the shoulder. On body chamber, ribs are barely visible and noticeable only on the outer half of the whorl. These ribs are widely spaced (about 4-5 ribs in 90°) and develop node-like elongated thickenings very close to the shoulder, which tend to follow the course of the ribs, first radially, but then bending forward and fading on the venter.

Suture line is ammonitic (Fig. 9), with well-developed *Gonionotites*-like indentations. Three sutures are visible and show a serration.

Dimensions

Specimen	D	H	U	W	h	w	U/D	H/W	h/w	SGR
10977 PMAM43-1	59.9	32.4	5.5	18.65	22	6.3	0,08	1.73	3.49	47.27
same specimen		29.95		7.35				4.07		
same specimen		35.4		22.5				1.57		

Discussion. The specimen, attributed to *Gonionotites*, agrees well with Gemmellaro's interpretation of the genus. An analysis of the taxonomic significance of the thicknening of the ribs on the outer part of the flank may be important, but would require a much larger collection of specimens.

At the species level, the specimen from level PMAM43 is referred by aff. to *G. recuperoi* Gemmellaro, 1904 because this particular species exhibits the

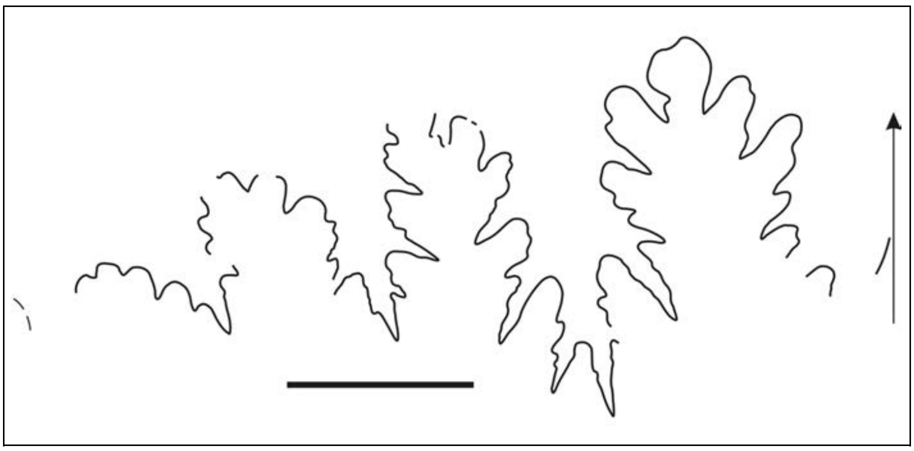


Fig. 9 - Suture line of *Gonionotites* aff. *recuperoi*, specimen MPUM 10977 (PMAM 43-1). Bar scale 5 mm.

thickening whorl section and widening of the venter at a size that is comparable to the size of the Pizzo Mondello specimen. The new specimen from Pizzo Mondello, however, shows the thickening of ribs on the outer part of the flank at a larger size with respect to the only figured syntype of *G. recuperoi*, after the weak ventral ribs have disappeared. *G. diblasii* Gemmellaro, 1904 reveals a ventral thickening of the whorl section that occurs at much larger size, while the "nodes" of *G. dubius* Gemmellaro, 1904 are only barely visible on the figured syntype.

Occurrence. *Gonionotites recuperoi* Gemmellaro has not been found since Gemmellaro's (1904) time and it is unknown outside of western Sicily, where its age might span from Late Carnian to Early Norian. The herein described specimen was collected from a level slightly above the younger of the two *Anatropites* sp. ind. collected thus far from the Pizzo Mondello section. The co-occurrence of *Halobia radiata* (cf. Levera 2012) suggests a Late Carnian age.

Pregriesbachites gen. n.

Type species: *Juvavites* (*Anatomites*) *Bukowskii* Gemmellaro, 1904

Etymology: from the suffix "pre" and *Griesbachites*. The compound name emphasizes the evolutionary link with the genus *Griesbachites* Mojsisovics, 1896.

Diagnosis: Small to middle-sized, relatively slim juvavitids with highly differing sculpture from juvenile to adult stage. Phragmocone bears prorsiradiate, paulostome constrictions and multi-branching, externally alternating or interrupted ribs. Body chamber is characterized by fading ribs and development of numerous pointed ventrolateral nodes. Suture line projuvavitid with low and medium indented saddles similar to *Griesbachites*.

Composition of the genus: *Juvavites* (*Anatomites*) *bukowskii* Gemellaro, 1904 (Type), *Juvavites timaei* Gemmellaro, 1904, *Griesbachites auctoris* Tozer, 1994, *G. pinensis* Tozer, 1994, *G. laevis* Tozer, 1994, *G. humi* (McLearn, 1937) and *G. selwyni* (McLearn, 1940).

Remarks. The new genus *Pregriesbachites* formalizes a taxonomic entity that was outlined as "nov. gen. (= *Projuvavites* mit Wohnkammerknoten)" (=*Projuvavites* with nodes on body chamber) by Krystyn (1982: 46, 59-60). The previous interpretation of this taxon as a descendent of *Projuvavites* and forerunner of *Griesbachites* is here confirmed.

Comparisons. *Pregriesbachites* has inner whorls similar to *Projuvavites* Tozer, 1971, but is distinguished from that genus by the presence of ventrolateral nodes on its body chamber. The shape and size of the nodes permits separation from the slightly younger but timely overlapping genus *Griesbachites* Mojsisovics, 1896. These nodes are rounded and pointed in *Pregriesbachites* n. gen., whereas in *Griesbachites*, they are larger and clavate. *Guembelites* Mojsisovics, 1896 lacks constrictions and bears nodes in a more external position on the phragmocone as well as on the body chamber. The inner whorls of *Pregriesbachites* may show similiarity with those of *Anatomites*. However, the type species, *A. rotundus* Mojsisovics, 1893, brings to mind the morphology of the inner whorls of *Griesbachites* and thereby, is suspected of representing the phragmocone stage of the latter genus (Krystyn 1982: 46).

Occurrence. The new genus is documented in the Tethys realm and North America. In Canada the species herein included in *Pregriesbachites* n. gen. document a latest Carnian, late Tuvalian 3 Macrolobatus Zone to Early Norian Kerri Zone range. An equivalent stratigraphic distribution (*G. italicus* Subzone of late Tuvalian 3 to Jandianus Zone of Lacian 1 is known for the Tethys (Krystyn 1982: 58). At Feuerkogel *Pregriesbachites* n. gen. was collected from level IV of F4 section (Fig. 10). The Pizzo Mondello occurrence (see description of species) most likely is from the *Gonionotites italicus* subzone, Spinosus Zone.

Pregriesbachites bukowskii (Gemmellaro, 1904)

Pl. 2, fig. 3a-b, 4a-b

v 1904 *Juvavites* (*Anatomites*) *bukowskii* Gemmellaro, p. 224, pl. 11, fig. 7-8.

?v 1904 *Juvavites* (*Anatomites*) *bukowskii* Gemmellaro, p. 224, *partim.*

Stratum typicum and locus typicus: Whitish limestone with cherty nodules, "feudo Modanesi" near Castronuovo (Gemmellaro 1904: 225).

Type series: Gemmellaro (1904: 225) cited seven specimens, but eight specimens are deposited in the Museo Geologico Gemmellaro, under registration number MGUP 002.193.1-8. Gemmellaro figured only one of the type specimens (pl. 11, fig. 7-8). This specimen, which is much better preserved than the other four large sized types, is here designated as lectotype.

Material: One specimen MPUM 10986 (PMAM42-1).

Description. Specimen is preserved as an internal mold that retains small patches of recrystallized test. Body chamber appears to occupy about 260° of whorl from last visible suture line.

Very involute coiling platicone (U/D~0.06). Whorl section, with maximum width very close to umbilical margin, exhibits a gradual change in the degree of compression combined with a very slight modification in the outline. Whorl section at end of phragmocone is semielliptical, with convex lateral sides and H/W ratio = 1.50. Just slightly past beginning of body chamber, the H/W ratio increases to 1.59, flanks become more flatter and shoulders become much more distinct. Towards the end of the body chamber, whorl section becomes more inflated and H/W decreases to 1.48. This variation is even more evident when viewing the specimen because the appearance of two more distinctive shoulders on the body chamber makes the venter appear to be even wider.

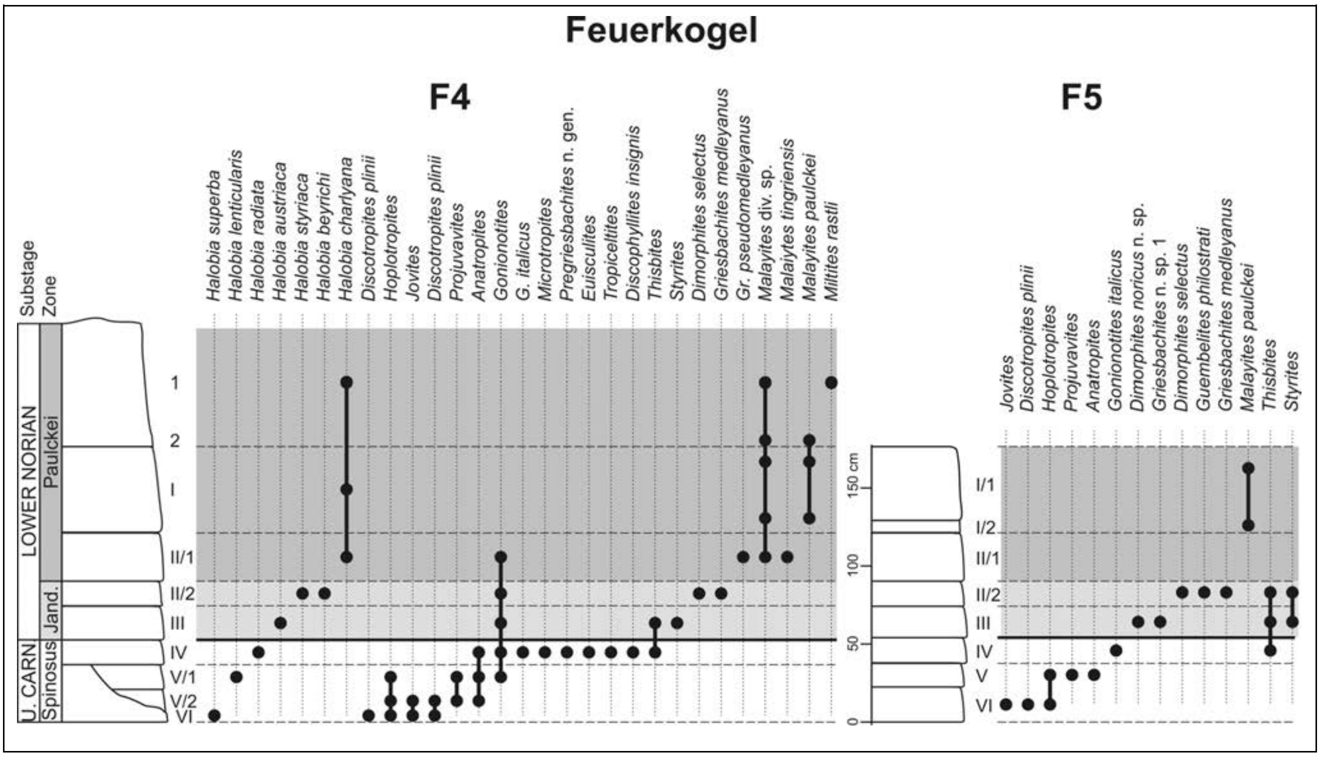


Fig. 10 - Ammonoid and *Halobia* record at Feuerkogel sections F4 and F5 (determination by LK). Preliminary data for these sections were previously reported by Krystyn (1973 and 1980).

Two constrictions are visible, one about 35° before the end of the phragmocone and the other on the body chamber about 100° after the first. Ornamentation consists of slightly concave primary and secondary ribs with a general *Projuvavites*-like organization between the constrictions. Ribs are developed between the umbilical margin and the shoulder on the first part of the last whorl before the first constriction. First branching of ribs occurs very close to the umbilical margin, while the second subdivision is located near the middle of the flank. Between the two constrictions, there are four widely-spaced weak primary ribs, each followed by four to five secondary ribs that are developed only ventrolaterally. Ventral ribs also continue on the body chamber and all ribs cross the venter.

Ventrolateral rounded nodes, which appear on the body chamber at whorl height of about 28 mm are located on flank, very close to the ventral shoulder.

Suture line ammonitic.

Dimensions

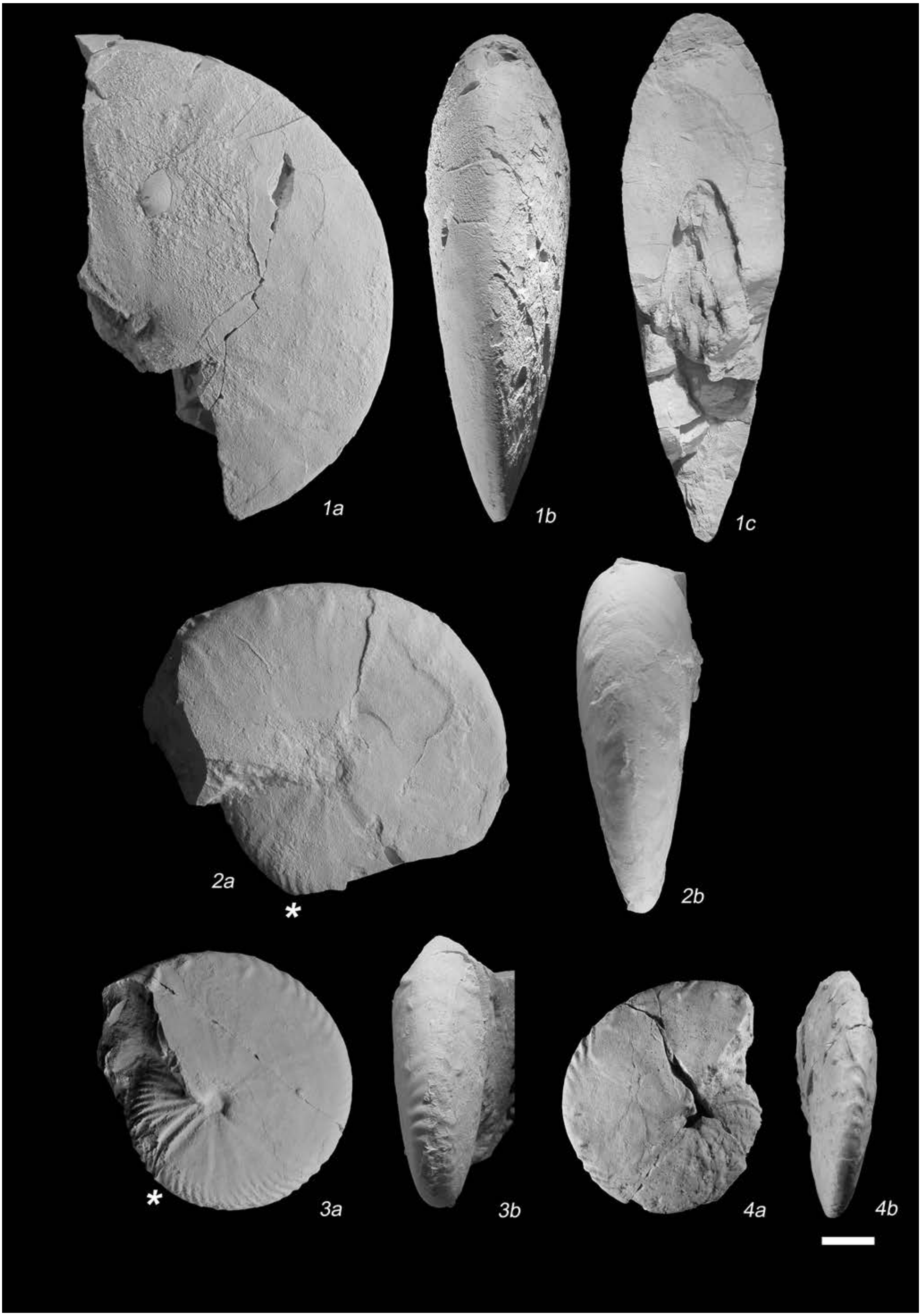
Specimen	D	H	U	h	W	w	U/D	H/W	SGR
PMAM42-1	51.65	28.0	3.35	20.3	18.8		0.064	1.48	37.9
same sp.				20.3		13.5		1.50	
same sp.	45.3	25.5			16			1.59	
002. 193.1	43.66	23.96	3.6		13.51		0.082	1.773	
002. 193.2	51.93	28.56	4.02		13.55		0.077	2.10	
002. 193.3	40.97	23.75	2.7		9.64		0.065	2.48	

Discussion. The type series consists of eight specimens (MGUP002.193.1-8) of different size. Four of them are very small, and their size does not exceed the innermost part of the last whorl of the four medium to large sized individuals (MGUP002.193.1-4). Since we have no evidence that the four small-sized specimens truly represent the juvenile growth stage of the larger individuals, these specimens are separated in the Synonymy.

The single specimen figured by Gemmellaro, designated as lectotype, is much better preserved and fits quite well with the original figure. Compared to the new specimen from Pizzo Mondello, the lectotype is

PLATE 2

Upper Carnian ammonoids from Pizzo Mondello. 1) *Gonionotites* cf. *italicus*, specimen MPUM 10975 (PMAM7-1), a, lateral view; b, ventral view; c, apertural view. 2) *Gonionotites* aff. *recuperoi*, specimen MPUM 10977 (PMAM43-1), a, lateral view; b, ventral view. 3) *Pregriesbachites bukowskii* (Gemmellaro), specimen MPUM 10986 (PMAM42-1), a lateral view; b, ventral view. 4) *Pregriesbachites bukowskii* (Gemmellaro), lectotype MGUP 002.193.1, a lateral view; b, ventral view. All specimens whitened with ammonium chloride except Fig. 4. Bar scale is 1 cm for all specimens. Asterisk marks the last septum.


1a
1b
1c
2a
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2b
3a
*
3b
4a
4b

slightly more compressed, but exhibits the same variation in the whorl section, especially on the body chamber, with nearly flat flanks meeting the shoulder on each side of the rounded venter. The ribbing pattern is also the same, but the nodes are already obvious at the beginning of the body chamber.

Occurrence. This is the first report of this species since Gemmellaro's 100 plus year old description. Therefore, the stratigraphic position of *Pregriesbachites bukowskii* (Gemmellaro) must rely on the present specimen from Pizzo Mondello. This specimen is from level PMAM42, which also yields *Halobia radiata* and rare *H. lenticularis* (Levera 2012). Since it was found slightly below the second level with *Anatropites* (PMAM22bis), *P. bukowskii* is thus referred to the Upper Carnian *Gonionotites italicus* subzone, Spinosus Zone.

Genus *Dimorphites* Mojsisovics, 1893

Type species: *Juvavites* (*Dimorphites*) *selectus* Mojsisovics, 1893

Dimorphites noricus n. sp.

Pl. 3, fig. 1-5

v 1980 *Dimorphites* n. sp. 1 Krystyn, p. 73.

v 2002 *Dimorphites* n. sp. 1 Krystyn et al., p. 344, fig. 1.

Derivatio nominis: From *noricus, -a, -um*. The name emphasizes the stratigraphic position of the species as a marker for the basal part of the Norian Stage.

Stratum typicum and locus typicus: Hallstatt Limestone, Feuerkogel (Northern Alps, Austria), section F5, bed III (Krystyn 1980, fig. 12; Fig. 10).

Material: Type series composed of four specimens. Holotype GBA 2011/055/0001; paratypes GBA 2011/055/0002-0004. One additional specimen from Pizzo Mondello is attributed to the new species MPUM 10978 (NA42.1).

Diagnosis: Relatively compressed *Dimorphites* with subdiscoidal inner whorls and semi-circular venter on the mature body chamber. Ornamentation consists of wide, flat ribs separated by narrow, furrow-like inter-spaces.

Description. Since all available specimens are preserved with the test, the description is based on features visible on outer surface of shell. Specimen from Pizzo Mondello compares well with paratype GBA 2011/055/0002 that is most similar.

Coiling very involute (U/D decreases with growth from 7.85 to 5.4) with medium SGR. Whorl section compressed (H/W increases during the growth from 1.47 to 2.29) with maximum width very close to the umbilical margin. Flanks slightly convex, slowly converging to narrow venter. General shape of shell is subdiscoidal until first half of adult body chamber, at which point venter begins to widen.

Ornamentation consists of rather wide, flat ribs separated by narrow, furrow-like inter-spaces. At all stages of growth, ribs begin slightly above umbilical margin, which is rounded and smooth. Innermost whorls differ from medium to large sized individuals by wavy-like ribbing. At whorl height less than 7-7.5 mm (specimens GBA 2011/055/0002 and 0003; MPUM 10978: Pl. 3, Fig. 1,2 and 5), ribs are slightly round rather than flat and about 1.5 times wider than the inter-rib spaces. At whorl height greater than 7.5 mm, ribsgradually become flat and wider than the inter-space furrows. Ribs are sinuous (falcoid sensu Arkell et al. 1957), with a rather peculiar course. Flat primary ribs begin just above the umbilical margin and gradually become wider. Bifurcation of primary ribs occurs at the beginning of a narrow furrow in the middle of rib, which is often very weak, but after a few millimeters gradually reaches depth and width of furrows delimitating primary rib. In such case, it is more common for the subdivisions to occur at the middle of the flank, the branching point of the secondary rib can be located only with some approximation. Subdivision of ribs mainly occurs at two positions on the flank. The first is between the starting point of the primary rib and about 10% of whorl height. The second position is about 40 to 60% of whorl height, but may change from one rib to the next. Occasionally, additional branching may also occur on the external part of the flank, at about 70-75% of whorl height. All ribs are projected forward slightly at the ventral shoulder, but then fade higher on the shoulder in an alternating manner such that an undulating effect is imparted to the course of the relatively narrow subtabulate venter. This feature is typical of the genus *Dimorphites*. For medium to large-sized specimens the frequency of ribs per half whorl is rather constant at about 33-35 ribs at the ventral shoulder.

Suture line not exposed on the type specimens, except for one single ammonitic 1st lateral saddle visible on one side of paratype GBA 2011/055/0002.

Dimensions

Specimen	D	H	U	h	W	U/D	H/W	SGR	Ribs in half whorl
0001 (Holotype)	44.3	26.2	2.8	15.3	11.4	6.32	2.29	71.24	33
Same sp.	34.9	20.3	2.7	11.6	9.8	7.73	2.07	75	34
0004	51.8	30	2.8	19		5.40		57.89	35
0003	~26								32
0002	14	8.1	1.1	4.8	5.5	7.85	1.47	68.75	24/25

Remarks. The description of *Dimorphites noricus* n. sp. formalizes a species previously mentioned in the literature (Krystyn 1980) as *Dimorphites* n. sp. 1, and designated as an index ammonoid for the first Norian ammonoid subzone (cf. Krystyn et al. 2002).

Discussion. With respect to its coiling and pattern of rib subdivision, *Dimorphites noricus* n. sp. is morphologically so close to the stratigraphically younger *D. selectus* Mojsisovics, 1893 that the two species may represent an evolutionary lineage. Despite *D. selectus* being slightly more compressed than *D. noricus*, the main difference between the two species is their ribs, which at all growth stages are much wider and flatter in *D. noricus* n. sp. than in *D. selectus*. Accordingly, the frequency of ribs per half whorl is distinctly lower in *D. noricus* than in *D. selectus.* The rib frequency on the type specimens of *D. noricus* n. sp. compared to that of the ype specimens of *D. selectus* is as follows:

a) Small-sized specimens: 24/25 ribs (GBA 2011/055/0002: Pl. 3, Fig. 1) *versus* 35 (Mojsisovics 1893, pl. 127, fig. 2a, D= 14mm),

b) small medium-sized specimens: 32 ribs (GBA 2011/055/0003: Pl. 3, Fig. 2) *versus* 53 (Mojsisovics 1893, pl. 127, fig. 5a, D= 27mm),

c) medium to large-sized specimens: 33-35 ribs (GBA 2011/055/0001 and 0004: Pl. 3, Fig. 3 and 4) *versus* 41-54 (Mojsisovics 1893, pl. 127, fig. 3a [Lectotype]: 41 at D= 30mm; fig. 4a: 46 at D= 41mm, 54 at D= 50mm).

Occurrence. The species has been recognized at Feuerkogel (Hallstatt, Northern Alps), section F5, level III, and at Pizzo Mondello (Sicani Mountains, western Sicily) level NA42. With regard to its chronostratigraphic position at Feuerkogel, this species was selected as the index ammonoid for the first subzone of the Jandianus Zone (Lacian 1: Krystyn 1980, 1982), which is the first Norian ammonoid zone of the Tethyan chronostratigraphic scale. The occurrence at Pizzo Mondello is also of earliest Norian age.

Dimorphites selectus Mojsisovics, 1893

Pl. 3, fig. 6-7

1893 *Juvavites* (*Dimorphites*) *selectus* Mojsisovics, p. 145, pl. 127, fig. 1-9.

v 1904 *Juvavites* (*Dimorphites*) *mariae* Gemmellaro, p. 243, pl. 17, fig. 19-20.

1921 *Dimorphites selectus* – Diener, p. 487.

1925 *Dimorphites selectus* - Diener, p. 65, pl. 16, fig. 9.

? 1940 *Juvavites* (*Dimorphites*?) *pardonetiensis* McLearn, p. 48, pl. 1, fig. 13.

? 1960 *Dimorphites pardonetiensis* – McLearn, p. 92, pl. 16, fig. 1-2.

v 1982 *Dimorphites selectus* – Krystyn, p. 45, pl. 11, fig. 6.

? 1994 *Dimorphites pardonetiensis* McLearn, Tozer, p. 240, pl. 114, fig. 1-3, text-fig. 91c.

v 2007 *Dimorphites* sp. ind. – Nicora et al., pl. 2, fig. 7.

Stratum typicum: Hällstatter Kalk, at Feuerkogel (Salzkammergut, Austria).

Lectotype: Original of Mojsisovics 1893, pl. 127, fig. 3, GBA1893/01/131, designated by Diener 1925:65).

Material: Ten specimens. Three are relatively complete: MPUM 10979 (FNP145-19), MPUM 10980 (FNP145-20) and MPUM 10981 (Det-1). Seven are fragmentary: MPUM 10982 (FNP144-2); MPUM 10983 (FNP144b-1); MPUM 10984 (FNP145-2, -7, -8, -14, -21).

Description. The three best preserved specimens are of medium size (~30<D<~45 mm) and exhibit very involute coiling. Venter, which is visible on specimens MPUM 10981 (Det-1) and MPUM 10980 (FNP145-20), is narrow and sub-tabulate. Whorl section appears to be compressed, but the opposite sides of the three best specimens are not preserved. Ornamentation is typical of *D. selectus*. Ribs are sinuous (falcoid sensu Arkell et al. 1957) and very closely spaced, with tops rounded. At the very end of the last preserved whorl on the larger specimen (Pl. 3, fig. 6), the ribs become slightly larger and flattened. Ribs begin slightly above umbilical margin and bifurcate at two positions; the first, at about 15% of H (all three specimens) and the second at about 35% of H (MPUM 10979 [FNP145-19] and MPUM 10980 [FNP145-20]) or 40% (MPUM 10981 [Det-1]).

Rib frequency is high. About 35 ribs per half whorl can be counted at about 30-32 mm of diameter on specimen MPUM 10980 (FNP145-20), while the slightly larger specimen MPUM 10981 (Det-1) shows about 42 ribs at 45 mm of diameter. All ribs are projected forward slightly at the ventral shoulder, but then fade higher on the shoulder in an alternating manner such that an undulating effect is imparted to the course of the relatively narrow subtabulate venter.

Suture line is not exposed.

Discussion. The ribbing frequency for the three best preserved specimens falls within the lower part of the range of variability of the type specimens of *Dimorphites selectus*, but it is definitely higher than the frequency of *D. noricus* n. sp. The three specimens are similar in size to the lectotype, which bears 41 ribs per half whorl for D~31 mm. The specimen from Jomsom, Nepal, described by Krystyn (1982) has about 42 ribs at D~36 mm.

Remarks on synonymy. The position of *D. pardonetiensis* McLearn, 1940 with respect to *D. selectus* is doubtful. According to McLearn (1960) *D. pardonetiensis* lacks certain features of *D. selectus*, such as constrictions on its inner whorls, flat ribs and distinct ventral shoulders. McLearn's type series consists of two specimens of which the larger, fragmented specimen is the holotype (pl. 16, fig. 2). This specimen is an adult body chamber fragment that develops distinct ventral shoulders and rounded venter as in *D. selectus*. The large (25 mm) paratype (pl. 16, fig. 1) otherwise shows the same narrow sub-tabulate venter and dense ribbing as in *D. selectus* and may well be synonymous. The lack of constrictions is due to the small size of the last whorl, which begins at H~10mm. At that small diameter *D. selectus* does not yet have constrictions (see Mojsisovics 1893, pl. 127, fig. 1 and 2). Tozer (1994, pl. 114) figures three specimens under *D. pardonetiensis,* a small poorly preserved specimen (fig. 3) of uncertain taxonomic affinity, a middle-sized specimen (fig. 2) very close to or conspecific with *D. selectus* and a large form (fig. 1) with well preserved test. The latter is of specific interest because it combines the dense ribbing of *D. selectus* with the robust cross-section of *D. noricus* n. sp. to which it may be more closely related.

Occurrence. In addition to Sicily, *Dimorphites selectus* is known from Austria, Turkey (Taurus, Antalya Nappes, Deliktas Fm. together with *H. styriaca;* Krystyn, unpubl. data) and the Tethys Himalaya (Nepal). In the Northern Alps, and especially at Feuerkogel, its stratigraphic range is calibrated by ammonoids, the bivalve *Halobia styriaca* and conodonts (Krystyn 1973, 1980; Krystyn et al. 2002; Fig. 10) and it has been served for 30 years as the index ammonoid for the upper subzone of the earliest Norian Jandianus Zone (Lacian 1, Krystyn 1980). In North America the closely related and possibly synonymous specimens of *Dimorphites pardonetiensis* McLearn occur in subzone 2 of the lowermost Norian Kerri Zone (Tozer 1994).

Dimorphites sp. ind.
Pl. 3, fig. 8

Material: One specimen, MPUM 10985 (PM36.1).

Remarks.The specimen is preserved only on one side for slightly less than one half whorl. The pattern of the dense ribbing is reminiscent of *D. selectus*, but the ribs and intervals between ribs seem to be less sculptured. The venter and suture line are not visible.

The specimen is attributed to *Dimorphites*, but left in open nomenclature because of its poor preservation.

Occurrence. The specimen from level PM36.1 may be the youngest representative of the genus because this particular level, which is located about 10 m above the last finding *Dimorphites selectus*, also yielded *Halobia mediterranea* (see Levera 2012). Thus far (Krystyn 1980, 1982; Krystyn & Gallet 2002; Krystyn et al. 2002) *Dimorphites* has been reported only from the Jandianus Zone (Lacian 1), while *H. mediterranea* is restricted to the Paulckei Zone (Lacian 2).

Order **Phylloceratida** Arkell, 1950
Superfamily Ussuritaceae Hyatt, 1900
Family Discophyllitidae Spath, 1927
Genus *Discophyllites* Hyatt, 1900
Type species: *Lytoceras patens* Mojsisovics, 1873

Remarks on the distribution of the genus. The genus is relatively common in the Tethys realm and North America, but it now appears to be restricted to low and middle paleolatitudes. Popow (1961) recognized it in the Boreal realm, but then Konstantinov (1995) assigned Popow's taxon *Discophyllites taimyrensis* Popow, 1961 to his new genus *Arctophyllites*.

Its range is now much better defined on the basis of bed-by-bed stratigraphically controlled sampling and it has been found to be not as long-lasting as reported in the Treatise (Arkell et al. 1957: Carnian-Norian) and by Tozer (1981a: Carnian-Early Norian). Krystyn (1973) included *Discophyllites* in faunas from the Subbullatus Zone (Tuvalian 2, Late Carnian) to the Magnus Zone (Lacian 3; Early Norian) of the Northern Alps. He also reported the genus from the *Discotropites plinii* Subzone (Tuvalian 3) of the Nepalese Himalaya (Krystyn 1982).

In North America, the distribution of the genus is consistent with the Tethyan record. Silberling (1959) reported *Discophyllites* from the Schucherti Zone, 2nd to the last zone of the Upper Carnian, of central Nevada and Tozer (1994) described the genus from the Kerri Zone of northeastern British Columbia.

Fig. 11 - Suture line of *Discophyllites insignis* Gemmellaro, 1904, specimen MPUM 10987 (PMAM52-1). Bar scale 5 mm.

Discophyllites insignis Gemmellaro, 1904

Pl. 3, fig. 9; Fig. 11

v 1904 *Rhacophyllites* (*Discophyllites*) *insignis* Gemmellaro, p. 298, pl. 1, fig. 21-22, pl. 9, fig. 13-16.

?non 1959 *Discophyllites* cf. *insignis* - Jeannet, p. 148, pl. 10, fig. 4; text-fig. 154, 155.

1973 *Discophyllites insignis* - Krystyn, p. 120. *Nn*

Stratum typicum and locus typicus: White limestone passing to dolomite, with cherty nodules, "feudo Modanesi" near Castronuovo (Gemmellaro 1904: 299).

Type series: Gemmellaro (1904:299) did not specify the exact number of specimens attributed to his new species, but he did mention several specimens ("vari esemplari"). Of these, he figured three specimens, a large individual (pl. 1, fig. 21-22) and two smaller-sized specimens (pl. 9, fig. 13, 14-16). Four specimens are reposited in the Museo Geologico Gemmellaro, MGUP002.261.1-4. The large specimen in plate 1, fig. 21-22 is here selected as lectotype (002.261.1).

Material: Two specimens: MPUM 10987 (PMAM52-1) and MPUM 10988 (FNP166.1).

Revised description of the type specimens. Lectotype is about 90 mm in diameter, but lacks the body chamber. Subtriangular whorl section, well drawn by Gemmellaro (1904, pl. 1, fig. 22), is developed only on the last quarter of the whorl. Whorl section of remaining part of the specimen is slightly less subtriangular with slightly more convex flanks, than on last one quarter of whorl. Paralectotypes appear to agree with this development. In particular, the subtriangular section of the small figured specimen (Gemmellaro 1904, pl 1, fig. 15) is noticeably restored, because the original specimen (paralectotype MGUP 002.261.4) has an almost semi-elliptical whorl section.

Description. The two Pizzo Mondello specimens are preserved as internal molds. Larger specimen consists of phragmocone and about 190° of body chamber. Coiling is slightly involute (H/U= 1.28; U= 32% of D) with relatively rapid increase in whorl height (SGR= 63%). Whorl section is clearly subtriangular, but only on the second half of the preserved part of the body chamber. On the first half (adapical) flanks appear slightly more convex and they converge at a slower rate towards the venter. As a result, the section outline is semi-oval to subtriangular.

Suture line (Fig. 11) is well preserved and agrees with that of the lectotype.

Dimensions

Specimen	D	H	U	h	W	w	U/D	H/W	SGR
PMAM42-1	92.3	38,55	30.1	23.65			0.32		63.0

Discussion.

Attribution to *D. insignis*. Both specimens from Pizzo Mondello agree perfectly with the type specimens, not only because of the matching suture lines, but more importantly because of the whorl section, which becomes subtriangular at a rather large size. One new Pizzo Mondello specimen is nearly equivalent in size (D= 92 mm) to the lectotype (D=90 mm), even though the lectotype lacks the body chamber. Both specimens have the typical subtriangular whorl section beginning at a diameter of 70-72 mm. A comparison of the suture lines of the type specimens and the new individuals from Pizzo Mondello shows no significant differences in the relative size of the element and the type of terminations of the saddles.

Remarks on Synonymy. We regard the attribution of a specimen described by Jeannet (1959) as *Discophyllites* cf. *insignis* to be doubtful because it shows a few differences with respect to *D. insignis*. Its whorl section, an important feature for this species, is subtriangular and would agree with *D. insignis*, even though it is slightly more compressed than the type specimens. Its coiling is slightly more involute (U/D about 0.30: Jeannet 1959: 148) but, more importantly, there are differences in the suture line that are not easy to explain in terms of intraspecific variability, unless they are pathologic. The external lobe (E) is very deep and the 3rd saddle is rather large in size ("massif" according to Jeannet).

Relationships with other species of the genus. *Discophyllites insignis* Gemmellaro, 1904 is a relatively rare species, at least with respect to its citations in literature, but it clearly differs from the type species of the genus, *Discophyllites patens* (Mojsisovics, 1873), by its coiling and whorl section. In *D. patens* the coiling is distinctly more evolute and the whorl section is oval, but the two species share a very similar suture line with a small external lobe.

The relationship with *D. ebneri* Mojsisovics, 1896 is more confused because Mojsisovics did not clearly described the features of this species and subsequent attributions to this taxon in the literature are not fully consistent with Mojsisovics' type specimens. A revision of this species is necessary, but here we emphasize only a few aspects. According to Mojsisovics, *D. ebneri* (type locality Lauka, central Himalaya) is characterized by a low rate of coiling (H~U) and a slightly subtriangular whorl section at a diameter of 70-75 mm (specimen's venter is severely damaged). At a comparable size the whorl section of *D. insignis* is clearly subtriangular. The suture line is not well preserved on the venter. Diener (1906) redescribed the species, but did so on the basis of new specimens from Lilinthi and Kalapani (Byans). His figured specimen most likely is not conspecific with the type specimen of *D. ebneri*, since it is characterized by involute coiling (H>U), an elliptical whorl section and a suture line with triphyllic symmetrical saddles clearly different with respect to the asymmetrical *D. patens*-like saddles figured by Mojsisovics (1896: pl. 19, fig. 6). An additional difference in the suture line of Diener's specimen is its very deep external lobe, which differs notably from the external lobe of *D. patens* and *D. insignis*. However, this particular portion of the suture line is not preserved on the type specimen figured by Mojsisovics (1896); hence a comparison is impossible.

We cannot exclude that it may be possibile to synonymize *D. insignis* Gemmellaro, 1904 with *D. ebneri* Mojsisovics, 1896 but, pending a revision of the latter, we prefer to keep *D. insignis* Gemmellaro, 1904 separated.

Occurrence. The species occurs in Sicily (Gemmellaro 1904), but it has also been collected from the Tuvalian 3 at Feuerkogel in the Northern Alps (Krystyn 1973: 120; Fig. 10), in the Spinosus Zone. Both new specimens from Pizzo Mondello were collected from levels PMAM52 and FNP166. Level PMAM52 most likely belongs to the *Gonionotites italicus* subzone, Spinosus Zone, Tuvalian 3 Upper Carnian because of the occurrence of *Microtropites* in the immediately overlying level, while FNP166 is located within the range of *Halobia mediterranea*, a species usually referred to the Paulckei Zone (Lacian 2) (see Ammonoid bio-chronostratigraphy and Levera 2012).

Ammonoid chronostratigraphy

Bio-chronostratigraphic subdivision of the Pizzo Mondello section

Ammonoids collected from the Pizzo Mondello section include short ranging age-diagnostic forms as well as long ranging taxa. Among the first group the most interesting taxa, in stratigraphical order, are *Discotropites plinii*; *Anatropites*, *Microtropites*, *Dimorphites noricus* n. sp. and *Dimorphites selectus*. *Gonionotites* would also be of some interest, but only on the species level. This genus is reported in the literature from the last zone of the Carnian to the first zone of the Norian (Krystyn 1982; Tozer 1994); this long range is in part confirmed by the distribution at Pizzo Mondello, where it has been identified in levels FNP80A, PMAM36, PMAM54, PMAM7, PMAM42, PMAM43, PMAM35, PM28a and PM 28d (Fig. 6).

These short-ranging taxa document all four subzones of the uppermost Carnian and lowermost Norian and firmly tie the Carnian/Norian boundary succession under study to the Tethyan chronostratigraphic scale. Ammonoid rarity does not allow for continuous zonation of the section, but the discrete intervals with ammonoid-controlled chronostratigraphic standardization are presented below (from bottom to top; Fig. 6), together with pertinent comments on the intermediate intervals without age diagnostic ammonoids.

– The lower 25 m of the section has thus far yielded only very small ammonoids, including one Sandlingitidae, one Arcestidae and *Hyattites* cf. *praefloridus*. The stratigraphic significance of *Hyattites* has not yet been defined as the genus is rare and the literature quite inconclusive (see Systematic paleontology). Those levels yielding Sandlingitidae and *H.* cf. *praefloridus* are referred to the Upper Carnian, and the single level with *Hyattites* may well represent Tuvalian 3 due to its close relationship with *Gonionotites*.

Discotropites plinii subzone, Spinosus Zone (Tuvalian 3, I)

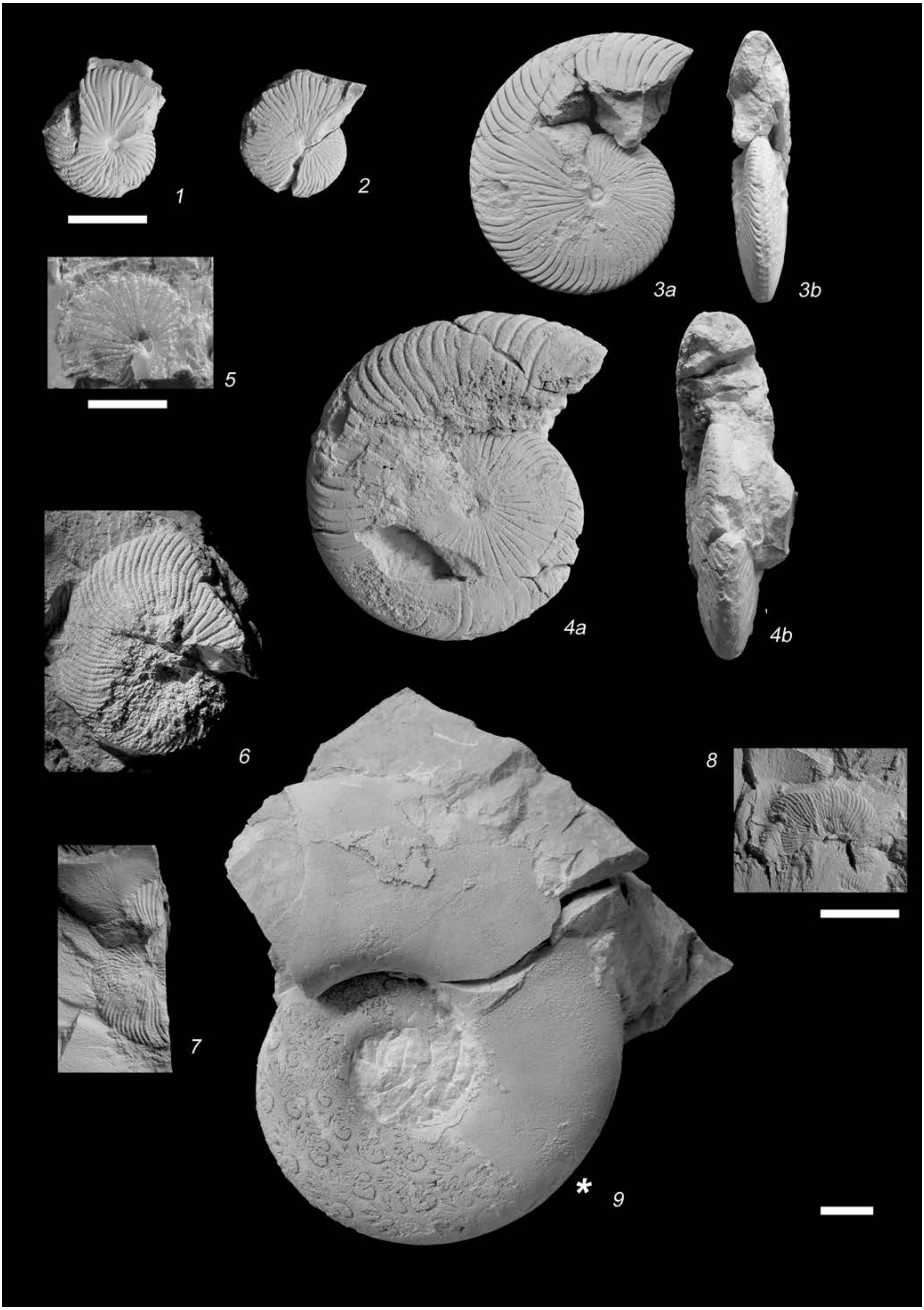
The index ammonoid *D. plinii* was identified in level PMAM17 about 25 m above the base of the section. *Projuvavites boehmi* was collected from level PMAM27, just slightly above the level with *D. plinii*. However, the stratigrahic position of *P. boehmi* is not defined with respect to a particular bio-chronostratigraphic scale, so only level PMAM17 is definitely referred to the *Discotropites plinii* subzone.

Gonionotites italicus subzone, Spinosus Zone (Tuvalian 3, II)

This subzone is characterized by *Microtropites* and *Anatropites*. *Microtropites* occurs only in the *G. italicus* subzone (Krystyn 1982) while *Anatropites* first occurs in the underlying *Discotropites spinosus* subzone (Krystyn 1982). The *Anatropites* specimens from Pizzo Mondello were found in beds overlying level PMAM52A, which yields *Microtropites* aff. *paronai*; hence, these levels are useful for tracing the upper boundary of the *G. italicus* subzone. Based on our available collection, the boundaries of the Spinosus Zone are drawn at

PLATE 3

Upper Carnian and Lower Norian ammonoids from Pizzo Mondello and Feuerkogel (Northern Alps, Austria). 1) *Dimorphites noricus* n. sp., paratype GBA 2011/055/0002, lateral view. 2) *Dimorphites noricus* n. sp., paratype GBA 2011/055/0003, lateral view. 3) *Dimorphites noricus* n. sp., holotype GBA 2011/055/0001, a, lateral view; b, apertural view. 4) *Dimorphites noricus* n. sp., paratype GBA 2011/055/0004, a, lateral view; b, apertural view. 5) *Dimorphites noricus* n. sp., specimen MPUM 10978 (NA42.1), lateral view. 6) *Dimorphites selectus* Mojsisovics, specimen MPUM 10981 (det-1), lateral view. 7) *Dimorphites selectus* Mojsisovics, specimen MPUM 10979 (FNP145-19), lateral view. 8) *Dimorphites* sp., specimen MPUM 10985 (PM36.1), lateral view. 9) *Discophyllites insignis* Gemmellaro, specimen MPUM 10987 (PMAM52-1), lateral view.
All specimens whitened with ammonium chloride except Fig. 5. Bar scale is always 1 cm, that in the lower right corner is for all the figures except for 1, 5 and 8. Asterisk marks the last septum.


1
2
3a
3b
5
4a
4b
6
8
7
* 9

the base of level PMAM52A and at the top of level PMAM22bis.

The fauna includes frequent *Gonionotites* sp., as well as *Gonionotites* cf. *italicus*, *Discophyllites insignis* (Gemmellaro), *Projuvavites inflatus* (Gemmellaro), *Pinacoceras* sp. and *Pregriesbachites* n. gen. *bukowskii* (Gemmellaro).

– The interval between level PMAM22bis and NA42.1 yielded very few ammonoids, especially from the lower and very uppermost parts. *Gonionotites* cf. *recuperoi* was collected less than 1 m above the last occurrence of *Anatropites* and a small *Tropiceltites* specimen was collected one-half meter below the level yielding *Dimorphites noricus* n. sp. No stratigraphic information is available for *G. recuperoi* Gemmellaro and the bio-chronostratigraphic significance of *Tropiceltites* is not fully clear. In North America Tozer (1994) reported the genus from the Macrolobatus to Kerri Zones (Upper Carnian-Lower Norian). Very little information is available from the Tethyan successions apart from the report by Krystyn (1973) concerning the Lacian 1 Jandianus Zone at Feuerkogel and a new identification from the top of Spinosus Zone at F4 (Fig. 10). Because of the lack of reports in the literature, we do not consider *Tropiceltites* to be a marker genus.

Dimorphites noricus n. sp. subzone, Jandianus Zone (Lacian 1 I)

The index species occurs only in level NA42, at about 99.5 m above the base of the section.

Dimorphites selectus subzone, Jandianus Zone (Lacian 1 II)

Dimorphites selectus, index species of the subzone, was recorded from levels FNP144, FNP144b and FNP145, which range from about 99.5 to about 102 m above the base of the section, in direct stratigraphic succession with respect to the *Dimorphites noricus* n. sp. subzone. This subzone also includes *Metathisbites* cf. *affinis* Gemmellaro.

– Level NA43, located about 2 m above the last occurrence of *Dimorphites selectus* yielded one cross section that could possibly be referred to *Tropiceltites*. This occurrence may indicate a Lacian age since the genus has not been recorded from younger beds.

Paulckei Zone (Lacian 2)

Dimorphites sp. ind., *Discophyllites insignis* (Gemmellaro) and *Placites* sp. ind. occur in levels FNP166 and NA49.1. These taxa are not bio-chronostratigraphically significant, but they occurr with *Halobia mediterranea* (see Levera 2012), which is considered as a good marker for the Paulckei Zone (Krystyn 1980; Krystyn et al. 2002).

Chronostratigraphic correlations of the Pizzo Mondello section based on ammonoids

Ammonoid-bearing successions documenting the latest Carnian through the earliest Norian are very rare in the world and only a few have been studied utilizing the bed-by-bed sampling method. In the Tethys realm, Pizzo Mondello can be compared and correlated with a small number of localities in the Salzkammergut area, above all with Feuerkogel, and with Jomsom in the Tethys Himalaya. In North America the most important localities are West Union Canyon (Shoshone Range, Central Nevada) and Black Bear Ridge on Williston Lake (British Columbia, Canada). There are a few localities in northeastern Russia that are of interest for comparison with the Boreal realm, especially in the Yana Okhotskaya River basin. With respect to such a global approach to correlation, it is obvious that the faunal composition of the different sites will be strongly influenced by provincialism (see Tozer 1981b, 1994; Dagys 1988; Zakharov 1997; Konstantinov 2008), but minor changes are also the result of paleoecologic control.

Tethys realm

Tethyan successions have provided huge collections of Upper Carnian to Lower Norian ammonoids, especially from the Hallstatt red limestone facies of the Northern Alps and Timor, which were first documented in the literature in the mid 19th century. Upper Triassic successions from the Himalayas have also contributed significantly to advance the knowledge of ammonoid taxonomy, notwithstanding the fact that very few sites have been subjected to the bed-by-bed sampling approach. The best site in the Northern Alps is Feuerkogel, in the Salzkammergut area (Krystyn 1973 and 1980; Fig. 10), and in the Himalayas it is Jomsom in the Kali Gandaki (Nepal; Krystyn 1982). A limited quantity of ammonoid data are available from sections encompassing the Carnian/Norian boundary in Antalya, Turkey (Kavaalani: Gallet et al. 2000; Erenkolu Mezarlik 2: Krystyn & Gallet 2002). Other localities have recently provided stratigraphically controlled collections, but these are only Upper Carnian (eastern Southern Alps: De Zanche et al. 2000; Gianolla et al. 2003) or Lower Norian (Alborz, Iran: Seyed-Emami et al. 2009). Interesting Upper Carnian faunas have also been described in the 1970s from Okinawa, Japan (Ishibashi 1970, 1973 and 1975).

Correlation of the Pizzo Mondello ammonoid record with the record documented at Feuerkogel F5 and Jomsom is illustrated in Fig. 12. At both Pizzo Mondello and Jomsom, the successions are expanded, whereas at Feuerkogel the Hallstatt Limestone is condensed. This notwithstanding, the *Discotropites plinii*, *Gonionotites italicus*, *Dimorphites noricus* n. sp. and *Dimorphites selectus* subzones are easily correlated by the

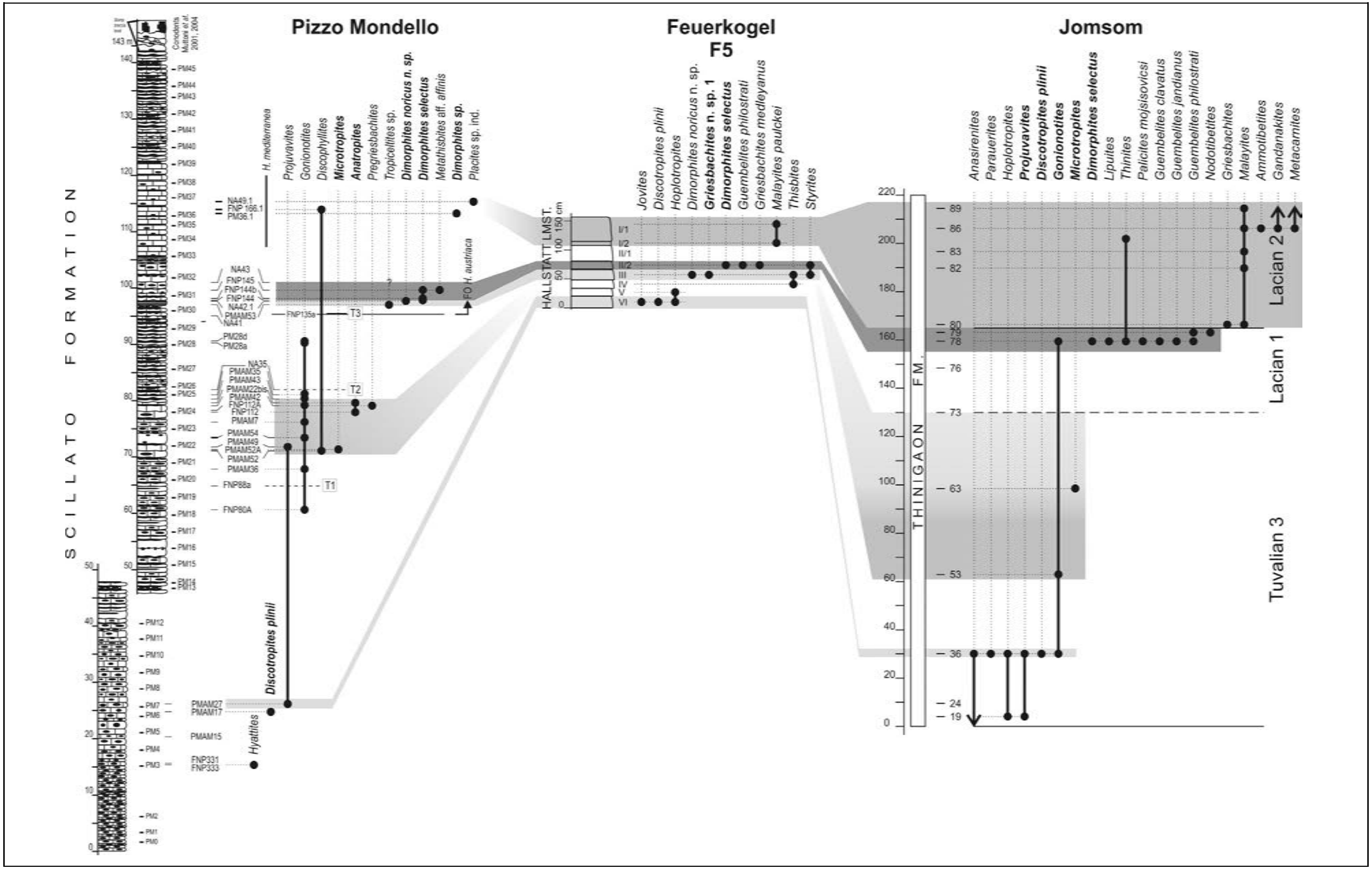


Fig. 12 - Ammonoid record of Pizzo Mondello section compared to the record of Feuerkogel F5 section (Hallstatt Limestone, Northern Alps, Austria; Krystyn 1980) and Jomsom (Thinigaon Formation, Nepal; Krystyn 1982). Jomsom log is based on the range chart of Krystyn's fig. 4, but the scale is added here. Feuerkogel F5 section is described in Krystyn (1980) and it has been included in this correlations chart because it is the type locality of *Dimorphites noricus* n. sp. Feuerkogel F4 record is more complete and shown in Fig. 10. The most significant age-diagnostic taxa are emphasized in bold. See text for discussion. Labels T1, T2 and T3 refer to conodont faunal turnovers described by Mazza et al. (2010).

occurrence of nominal species, or by the occurrence of genera (e.g., *Microtropites*), whose range is limited to a single subzone. When documenting the wide paleogeographic distribution and correlation of certain ammonoid groups such as *Discotropites*, *Anatropites*, *Microtropites* and *Dimorphites* over large distances, it is not surprising that some other groups show some differences. The Pizzo Mondello fauna lacks certain genera, such as *Griesbachites* and *Guembelites*, that are well documented not only at Feuerkogel and Jomsom, but also in other Tethyan successions of the Himalayas (Bordet et al. 1971), Tibet (Wang & He 1976), Timor (Welter 1914) and Alborz (Seyed-Emami et al. 2009). Even though faunal distribution is quite wide from a paleogeographic point of view, the frequency of biostratigraphically complete successions is rather low. Not even one of the three sections illustrated in Fig. 12 includes a direct superposition of lowermost Norian ammonoids on uppermost Carnian faunas. At Pizzo Mondello, the uppermost Carnian *G. italicus* and the lowermost Norian *D. noricus* n. sp. subzones are documented, but the actual Carnian/Norian boundary falls within an interval of about 18 meters without age diagnostic ammonoids. At Feuerkogel F5, level III is the *stratum typicum* of *Dimorphites noricus* n. sp., but *G. italicus* occurs only in the underlying level IV(Fig. 10 and 12), thereby demonstrating the high rate of sedimentary condensation. At Jomsom the unfossiliferous interval between the latest Carnian level 63 (*G. italicus* subzone) and earliest Norian level 78 (Jandianus Zone, *Dimorphites selectus* subzone) is more than 55 m thick and unfortunately lacks documentation of the *D. noricus* n. sp. subzone.

West Union Canyon (central Nevada, U.S.A.)

The most important ammonoid locality in North America for the Carnian/Norian boundary is West Union Canyon in the Shoshone Range (central Nevada). This is the type locality of both the Schucherti and Macrolobatus Zones, the two latest Carnian ammonoid zones of the North American Triassic standard scale (Silberling 1959; Silberling & Tozer 1968). At this locality there is also a good record of the earliest Norian Kerri Zone, which was actually defined at Brown Hill (Peace River Valley, British Columbia; Tozer 1965, 1967).

Ammonoid faunas from West Union Canyon were described by Silberling (1959), who also provided a good description of the sedimentary succession (Luning Formation). Silberling collected ammonoids and carefully documented the faunal changes from bed to bed (at least for the Macrolobatus Zone), but unfortunately he did not include in his paper the log with the bed-by-bed distribution of the faunas. This log provided the basis for a preliminary sampling of the site carried out in 2010 (Balini et al. 2011), which resulted in the collection of the same faunas reported by Silberling in 1959.

The ammonoid record of the Luning Formation is not continuous and fossil rich intervals are separated by shaly intervals without macrofossils, at least on the basis of surface sampling. Ammonoid faunas of the Schucherti and Macrolobatus Zones are dominated by Tropitidae (*Tropites* and *Anatropites*), but they lack Juvavitinae. At Pizzo Mondello section, the faunal composition of this particular part of the Carnian is reversed, with Juvavitinae (*Projuvavites*, *Gonionotites*, *Pregriesbachites*) dominant over Tropitidae (*Hoplotropites* [from literature], *Discotropites*, *Anatropites*, *Microtropites*). Ammonoids of the Kerri Zone include of *Guembelites* and *Stikinoceras*, but *Dimorphites* apparently is not present. As previously emphasized in the discussion regarding correlation with Tethyan localities, *Guembelites* has not been reported from the Scillato Formation, and *Gonionotites* has not been found at West Union Canyon, neither by Silberling (1959) nor by Balini et al. (2011). Thus, direct correlation between West Union Canyon and Pizzo Mondello is possible for the Upper Carnian, but not for the Lower Norian, at least on the basis of the available ammonoid data.

Black Bear Ridge (British Columbia, Canada)

The Peace River Valley (British Columbia, Canada) is an important area for Middle to Upper Triassic ammonoids. Several localities were found and first described by McLearn from the 1940s through the early 1960s, and then Tozer spent the next 40 years or so expanding the ammonoid collections, improving their taxonomy and revising the biostratigraphy of the area. Although construction of the WAC Bennet dam (1968) and the subsequent flooding of the valley (1970s) destroyed several of McLearn and Tozer's paleontologic sites, the new shorelines of this vast lake have provided the opportunity to collect from new and perfectly washed Triassic exposures, often of tens of kilometers in lenght. Black Bear Ridge, on the northern shore of the Lake, is the best locality for study of the Carnian/Norian boundary because it is the only site in the Williston Lake area, where the succession encompassing the boundary is not affected by a lithologic change (Zonneveld et al. 2010; cf. McRoberts 2011: fig. 3). At the well-known Pardonet Hill site on the southern lake shore, just in front of Black Bear Ridge, the Carnian-Norian boundary nearly coincides with the lithologic boundary between the Baldonel Formation and the Pardonet Formation (Zonneveld & Orchard 2002). A similar setting is documented at Brown Hill, on the northern shore of the lake, East of Black Bear Ridge (Zonneveld & Orchard 2002).

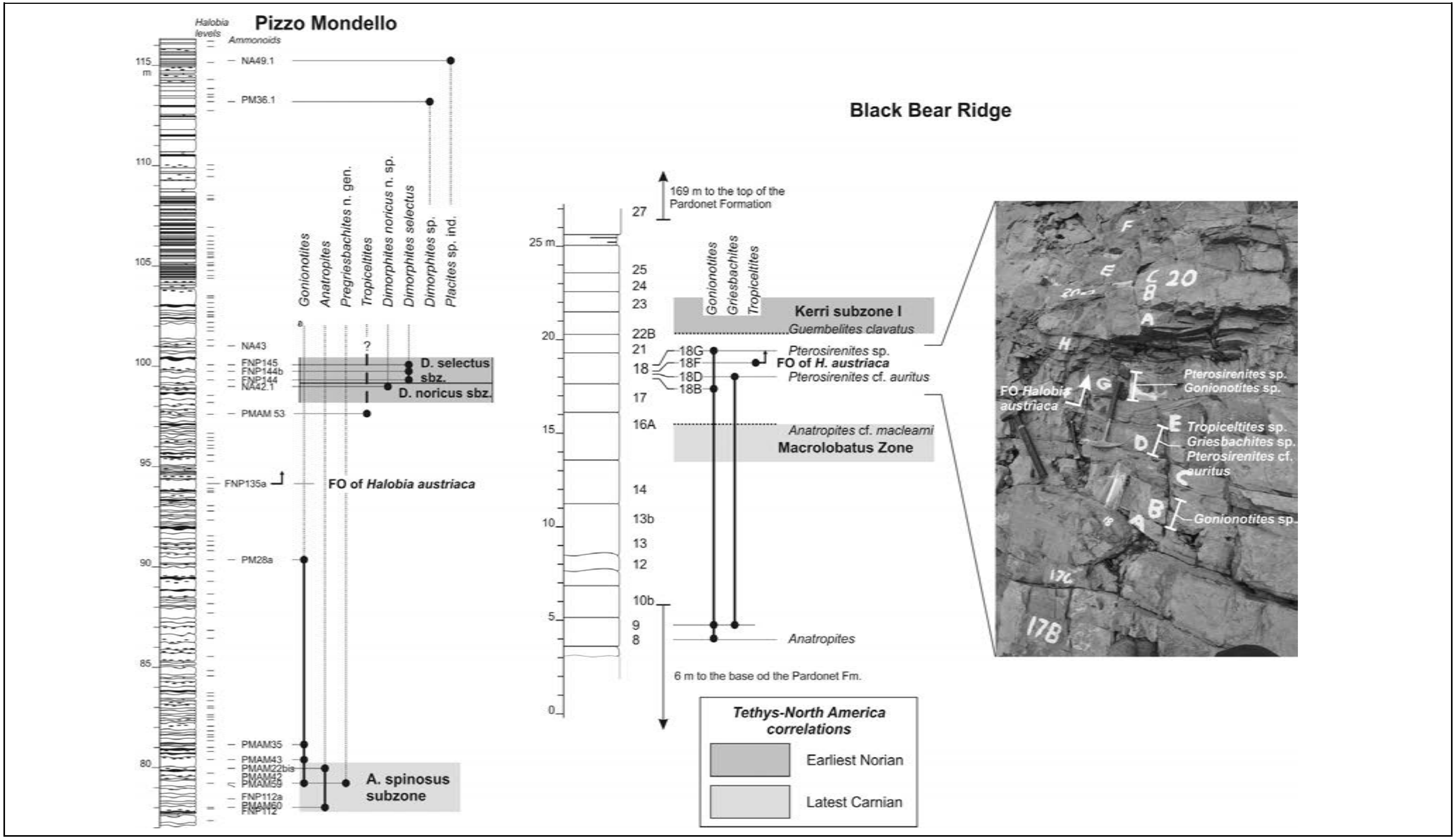


Fig. 13 - Ammonoid record of the Carnian/Norian boundary interval at Pizzo Mondello compared to the record at Black Bear Ridge (Williston Lake, British Columbia, Canada). Bedding of the two sections is to scale. Black Bear Ridge section is from McRoberts (2011: fig. 9). The BBR level numbers refer to intervals of beds. Every interval is further subdivided into beds, each of which is identified by a letter. The field picture (right) shows the beds of the Carnian/Norian boundary interval. McRoberts & Krystyn (2011) proposed to define the base of the Norian at the base of level 18F, where the FO of the suggested primary marker *Halobia austriaca* is recorded. Ammonoid determinations from BBR section by LK.

In both sections, ammonoids occur in discrete levels. At Pizzo Mondello, an interval of about 18 meters without age-diagnostic ammonoids exists between the last occurrence of late Carnian *Anatropites* and the first occurrence of Norian *Dimorphites noricus* n. sp. At Black Bear Ridge an interval of about 4.5 meters exists between the level yielding definite late Carnian *Anatropites* cf. *maclearni* and the level providing definite early Norian *Guembelites clavatus*. No good age-diagnostic taxa are documented within this interval; see text for discussion of the significance of *Pterosirenites*.

Ammonoids from Black Bear Ridge (GSC collection, Vancouver and a new, small collection 2010, herein classified by LK) are rather meager, documented by only few specimens. However, their stratigraphic position permits an accurate correlation (Fig. 13). Two ammonoids from levels 16A and 22B tie the succession to the North American chronostratigraphic scale and at the same time, allow for correlation with the Tethyan scale. From the lower level (16A) a single specimen of *Anatropites* cf. *maclearni* documents the uppermost Carnian Macrolobatus Zone. Level 22B is referred to the *Discostyrites ireneanus* subzone, Kerri Zone (correlative with the lower Jandianus Zone of the Tethys) based on the occurrence of *Guembelites clavatus*, a species which, according to Tozer, is restricted to this subzone. The interval between these two levels is not barren of ammonoids, but thus far, it has only yielded *Gonionotites* and *Tropiceltites*, both of which range through the Carnian/Norian boundary and *Pterosirenites*, the only Boreal element in the Black Bear Ridge ammonoid fauna (Fig. 13). This genus, introduced by Tozer in 1980 from the Kerri Zone of northeastern British Columbia, has been recognized since 1981 as a typical component of the Norian Boreal assemblage (Tozer 1981b; Dagys 1988; see below).

At Black Bear ridge *Pterosirenites* has been identified both below and above (18D and 18G) the FO of *H. austriaca* (McRoberts 2011; McRoberts & Krystyn 2011; level 18F: Fig. 13). However, the chronostratigraphic position of *Pterosirenites* is not yet fully defined. In the Boreal realm (see below) ammonoid faunal composition is very different with respect to that of British Columbia, and the C/N boundary is based on an ammonoid faunal change that is different with respect to the faunal changes recorded in North America and the Tethys realm. If the problem is approached from the opposite side of the Panthalassa Ocean, *Pterosirenites* occurs in four localities in northeastern British Columbia, including the Williston Lake shorelines (eastern British Columbia) and Mount McLearn (Toad River area, northern British Columbia), but even here its range is not well defined. According to its documented record, *Pterosirenites* is not abundant and at the few Lower Norian sites (e.g. Brown Hill, type locality of the Kerri Zone) from which it has been reported. These occurrences are somewhat scattered (Fig. 14), but more importantly, there is no record of uppermost Carnian ammonoids underlying *Pterosirenites* at these four localities. Apparently the ammonoid record at these four sites has been influenced by the facies change that occurred at the boundary of the Baldonel-Pardonet formations.

Boreal realm

Ammonoid correlation of the Tethyan successions with those of the Boreal realm are very difficult because of their significantly different faunal composition, but it is possible to directly link the Boreal successions to northeastern British Columbia by the common occurrence of *Pterosirenites*.

The Carnian/Norian successions of northeastern Russia are dominated by Sirenitinae, with the minor contribution of a few additional genera from different families (Dagys 1988; Bychkov 1995; Zakharov 1997; Konstantinov 2008). Carnian faunas are composed of *Yakutosirenites*, *Neosirenites*, "*Striatosirenites*", *Sirenites*, *Proarcestes*, *Arctophyllites*, *Arctoarpadites* and *Obruchevites*, while Norian ammonoids include "*Striatosirenites*", *Pterosirenites*, *Norosirenites*, *Wangoceras*, *Yanotrachyceras*, *Arctophyllites*, *Arcestes* and *Pinacoceras*. Based on this very general summary, the Carnian/Norian boundary is marked (Konstantinov 2008) by the disappearance of *Sirenites*, *Neosirenites*, *Yakutosirenites* and *Proarcestes*, and by the first occurrence of *Pterosirenites*, *Arcestes* and *Pinacoceras*.

The best successions are located in the Primorye region (summary in Zakharov 1997) and the Yana Okhotskaya River area (Bychkov 1995). While the former is characterized by a few Tethyan elements (Zakharov et al. 1996; Zakharov 1997), Boreal faunas are best developed in the latter, which also has the highest sedimentation rate.

The uppermost Carnian of the Yana Okhotskaya River, well described by Bychkov (1995), is represented by the 290 m thick Yakutensis Zone (index ammonoid *Sirenites yakutensis* Kiparisova) and the lowermost Norian is documented by the 300 m thick Verchojanicum Zone. *Pinacoceras verchojanicum* Archipov is the index taxon of the Verchojanicum Zone, but the most common taxa of this zone are *Pterosirenites* and *Norosirenites*. *Pterosirenites*, which predates the FO of *Norosirenites*, in particular is documented in the Trans-Baikal, Amur, Khabarovsk areas (see Zakharov 1997) as well as in Yana Okhotskaya River basin (Bychkov 1995), and is therefore of great potential as guide fossil for the base of the Norian in the Boreal realm. However, the FO of its range, at least on the basis of ammonoids, has not yet been calibrated. *Pterosirenites* is part of the evolutionary lineage within the subfamily Sirenitinae, but a stratigraphic interval with no ammonoid record exists (e.g., Bychkov 1995) between the last occurrence of Carnian Sirenitinae and the FO of *Pterosirenites*. In addition to the FO of *Pterosirenites*, Konstantinov (2008) emphasized that the base of the Norian in the Boreal realm is also characterized by the FO of *Arcestes* and of *Pinacoceras*. These two genera are common in the Tethys realm and they also occur in North America, but they are long ranging and their FO in the Boreal realm is clearly younger than in the Tethys and North America.

Data herein summarized suggest the need for an intergrated approach to the correlation of the various localities of the Boreal realm because ammonoids alone will not facilitate a final solution. Conodont, halobiid and integrated ammonoid data may provide this solution, and the key area is probably southern Primorye, where the ammonoid record shows a Tethyan influence, according to literature (Zakharov et al. 1996; Zakharov 1997). Unfortunately, the occurrence of *Pterosirenites* in the southern Primorye successions, first mentioned by Zakharov (1997), has been refuted by Markevitch & Zakharov (2008). They have modified the generic attribution of the two species previously recognized in the area, *Pterosirenites kiparisovae* (Zharnikova) and *P. evolutus* Zakharov & Zharnikova, to the genus *Norosirenites* Tozer.

Conclusions: towards the definition of a world standard

Even now, one centrury after Gemmellaro's monograph on Upper Triassic ammonoids from western Sicily, the "cherty limestone" (Scillato Formation) still provides a huge amount of paleontologic information, including not only ammonoids and halobiids first discovered by Gemmellaro, but also conodonts, radiolarians and nannofossils. The results of the extensive investigations conducted during the last four years (Preto et al. 2012; Levera 2012; Mazza et al. 2012) demonstrate the significance of the pelagic successions of western Sicily as a world reference for the understanding of the Late Carnian to Norian transition, in terms of both time and changes in marine biofacies.

New ammonoid data improve the understanding of the faunal changes across the Carnian/Norian boundary, and are significant in perspective for the definition of the GSSP of the base of the Norian stage. Recognition of the *Discotropites plinii*, *Gonionotites italicus*, *Dimorphites noricus* n. sp. and *Dimorphites selectus* subzones links without question certain parts of the Pizzo Mondello section to the Upper Carnian-Lower Norian standard scale and facilitates the chronostratigraphic calibration of conodont and *Halobia* bioevents.

Conodont bioevents

Several conodont bioevents have been identified at Pizzo Mondello during the last few years (Mazza et al. 2010; Mazza et al. 2011; Mazza et al. 2012). Mazza et al. (2010) identified three main faunal turnovers (Fig. 12) and selected two possible conodont biovents for the definition of the GSSP of the Norian stage as follows: Turnover 1, at level FNP 88A (64.76 m above the base), where *Epigondolella* replaces *Carniepigondolella*; Turnover 2, between AM23 and NA35 (80 m above the base), with a decreasing of *Epigondolella* and increasing of *Metapolygnathus*; and Turnover 3, between samples NA41 and PM30A, characterized by the disappearance of *Metapolygnathus* and replacement with advanced specimens of *Epigondolella*. Mazza et al. (2010: 123) identified the FAD of *Epigondolella quadrata* at level FNP88A as the most suitable bioevent for the definition of the GSSP of the Norian stage, while the FAD of *Metapolygnathus communisti* at level NA35 was considered an alternative solution.

Taxonomic studies of the conodont populations has lead Mazza et al. 2012 to reconsider the position and significance of the most significant bioevents. The revision of *E. quadrata* and the separation of the primitive specimens of this group into the new species *E. miettoi* has resulted in the placement of the FAD of *E. quadrata* from FNP88A up to FNP112. Furthermore, the study of conodont populations around the FO of the bivalve *Halobia austriaca*, recently proposed as marker event for the GSSP (McRoberts & Krystyn 2011), has lead Mazza et al. to identify three new possible conodont bioevents as follows: the FO of *Metapolygnathus parvus* at sample AM24; the FO of *Metapolygnathus echinatus* at sample NA36; and the FAD of *Carnepigondolella gulloae* at sample FNP134.

New ammonoid data presented in this paper allow the dating of these bioevents. The FAD of *E. quadrata*, in both of its possible locations, and the conodont turnover T1 definitely occur together with Carnian ammonoids of the Spinosus Zone, *Gonionotites italicus* subzone. The FADs of *M. communisti*, *M. parvus* and *M. echinatus*, as well as the conodont turnover T2 are located within the interval between the last record of the Spinosus Zone and the first record of the *Dimorphites noricus* n. sp. subzone of the Jandianus Zone, but they are very close to the uppermost levels yielding ammonoids of the Spinosus Zone; hence, they are probably latest Carnian in age, as also suggested by halobiids (see Levera 2012). The FAD of *C. gulloae* and conodont turnover T3 occur very close to the FO of *Halobia austriaca* in level FNP135A, and are likely earliest Norian in age.

Halobia bioevents

At the present stage of the discussion within the Carnian/Norian boundary Task Group of the Subcommission on Triassic Stratigraphy, the most interesting bioevent for the definition of the base of the Norian stage appears to be the First Occurrence of the bivalve *Halobia austriaca*, as discussed during the Palermo Workshop (September 2010) and proposed by McRoberts & Krystyn (2011). At Pizzo Mondello this bioevent is located within the 18 m thick interval with a very poor ammonoid record between the Spinosus and the Jandianus zones (Fig. 12). More precisely the FO of

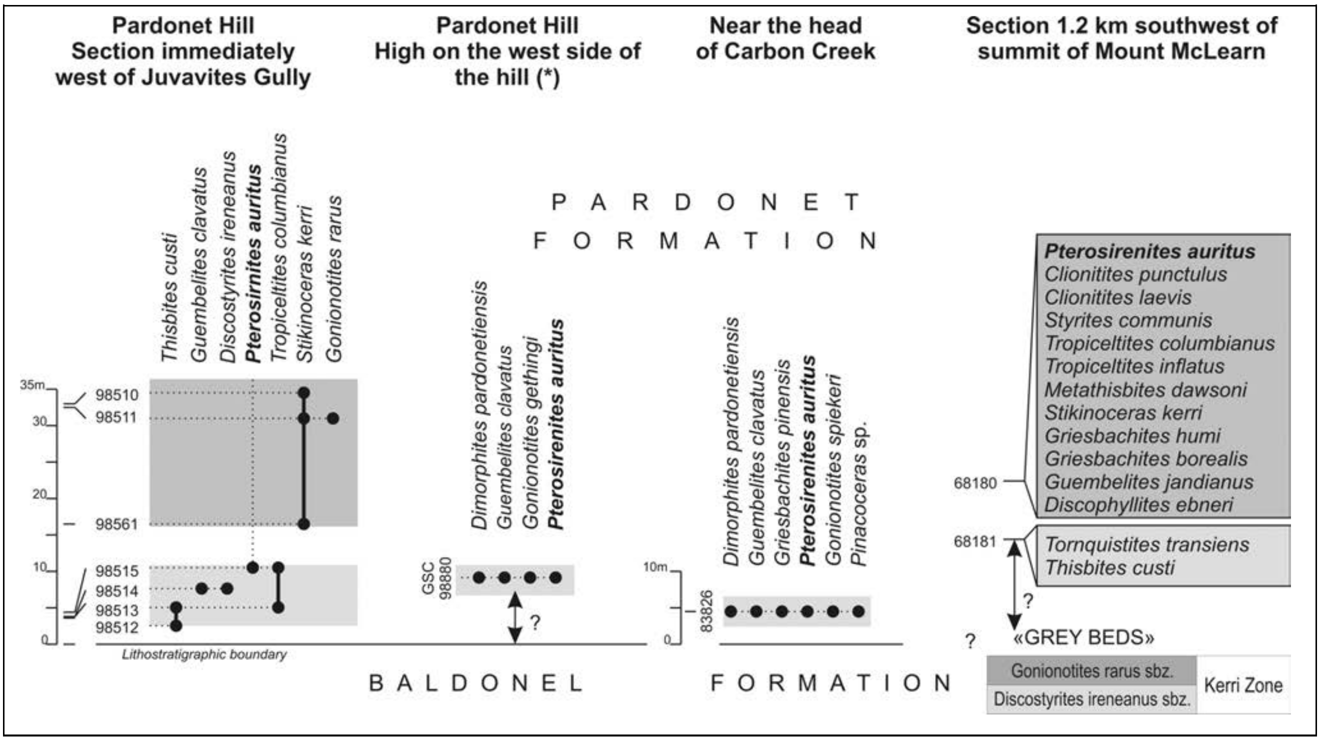


Fig. 14 - Stratigraphic distribution of *Pterosirenites* Tozer, 1980 from eastern and northern British Columbia, based upon data from Tozer (1994). All sites yielding *Pterosirenites* are included, but the genus has not been found in a few other Lower Norian sites (e.g., Brown Hill, type locality of the Kerri Zone). Note (*): Position of GSC locality 98880 was described by Tozer (1994:347) as "probably stratigraphically between GSC loc. 64628 (Macrolobatus Zone) and GSC loc. 64607 (Kerri subzone II)". Only site GSC 98880 was used for this figure because the exact position of the three sites was not fully clear to Tozer, who sampled GSC 64628 and GSC 64607 in 1964 (Tozer 1967, 1994), and GSC 98880 in 1982. *Pterosirenites* was not found in the samples taken in 1964.

H. austriaca is located 4 m below the level NA42, that marks the top of the *Dimorphites noricus* n. sp. subzone, the 1st subzone of the Norian stage. For the purpose of a pure speculation, we assume that level FNP135A can not be far from the Carnian/Norian ammonoid boundary. The (weak) elements in support of this speculation are derived from the comparison of the range of certain species that suggests a reduction of the sedimentation rate from the Tuvalian 3 to the Lacian 1. The Spinosus Zone (Tuvalian 3) is at least 55 m thick (Fig. 6), whereas the interval between the FO of *Dimorphites selectus* and the FO of *Halobia mediterranea*, which is equivalent to the *D. selectus* subzone (Lacian 1 II, sensu Krystyn et al. 2002), is only 6-7 m thick. In this respect, the position of FNP135A at four meters below the boundary between the *D. noricus* n. sp. and *D. selectus* subzones most likely corresponds to an earliest Norian age.

Future steps

At this point in time, comparison of the Pizzo Mondello ammonoid record to that from Black Bear Ridge does not solve the problem of the definition of the Carnian/Norian boundary. Both sections are relatively expanded and ammonoids are rather scarce; thus, it seems clear that the GSSP of the Norian stage cannot be defined on an ammonoid bioevent alone. However, due to their very high power of resolution, ammonoids are the unrivaled tool for calibration of bioevents of fossil groups with a lower power of resolution, such as conodonts and in part halobiids.

The two GSSP candidate sections can be accurately correlated with ammonoids (Fig. 13), but not the interval around the FO of *Halobia austriaca*. At Pizzo Mondello, ammonoids have not been collected from level FNP135A, which records the FO of *Halobia austriaca*. Thus, it is necessary to conduct a new ammonoid sampling program for the interval NA41-NA42 (i.e., from the FAD of *Carniepigondolella gulloae* to the FO of *Dimorphites noricus* n. sp.). With regard to ammonoid data at Black Bear Ridge, the FO of *H. austriaca* at level 18F, as suggested by McRoberts & Krystyn (2011), falls within the range of the *Pterosirenites* Norian element according to Tozer (1994), whose FO is recorded in bed 18B, slightly below 18F (Fig. 13). However, it is conceptually wrong to use data from scattered localities, such as isolated outcrops sampled by McLearn and Tozer in northern and eastern British Columbia (Fig. 14), to calibrate the cm-by-cm sampled section Black Bear Ridge. The correct approach is to resample the relevant portion of the Black Bear Ridge section such that the first occurrence of *H. austriaca* can be better constrained.

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