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# THE HALOBIIDS FROM THE NORIAN GSSP CANDIDATE SECTION OF PIZZO MONDELLO (WESTERN SICILY, ITALY): SYSTEMATICS AND CORRELATIONS

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*Key words*: *Halobia*, Triassic, Carnian/Norian boundary, GSSP, taxonomy, correlations, Tethys, North America.

*Abstract*. A review of the *Halobia* faunas and biostratigraphy of the uppermost Carnian – lowermost Norian of western Sicily is provided, through the study 166 fossiliferous beds of the 143 metres thick Pizzo Mondello Scillato Formation succession. The major role of the halobiids as biostratigraphic markers and tools for global correlations at the Carnian/Norian boundary is described. New morphometrical data on the ten species (*Halobia carnica*, *H. lenticularis*, *H.* cf. *rugosa*, *H. radiata*, *H. simplex*, *H. superba*, *H. austriaca*, *H. styriaca*, *H. beyrichi*, and *H. mediterranea*) occurring in this time interval are provided, as well as a revision of the correlations between western Sicily, the rest of the Tethys and North America. The *Halobia lenticularis* zone corresponds to the *Anatropites spinosus* ammonoid zone, the *Halobia radiata* zone spans the Carnian/Norian boundary interval, and the *Halobia austriaca*, *Halobia styriaca* and *Halobia beyrichi* zones correspond to the *Guembelites jandianus* ammonoid zone. The correlation of the distributions of these ten forms with those from other sections in both Tethys and North America allows to recognise the key role of *Halobia austriaca* as best halobiid marker for the definition of the base of the Norian GSSP.

*Riassunto*. Viene fornita una revisione delle faune a *Halobia* e della biostratigrafia del Carnico sommitale -Norico basale della Sicilia occidentale, attraverso lo studio di 166 livelli fossiliferi dei 143 metri della successione della Formazione Scillato di Pizzo Mondello. Viene descritto il ruolo principale degli halobiidi quali indicatori biostratigrafici e strumenti di correlazione a scale globale al limite Carnico/Norico. Vengono forniti nuovi dati morfometrici sulle dieci specie (*Halobia carnica*, *H. lenticularis*, *H.* cf. *rugosa*, *H. radiata*, *H. simplex*, *H. superba*, *H. austriaca*, *H. styriaca*, *H. beyrichi* e *H. mediterranea*) presenti in questo intervallo di tempo, così come una revisione delle correlazioni tra Sicilia occidentale, resto della Tetide e Nord America. La zona a *Halobia lenticularis* corrisponde alla zona ad ammonoidi a *Anatropites spinosus*, la zona a *Halobia radiata* è a cavallo dell'intervallo del limite Carnico/Norico, e le zone a *Halobia austiaca*, *Halobia styriaca* e *Halobia beyrichi* corrispondono alla zona ad ammonoidi a *Guembelites jandianus*. La correlazione delle distribuzioni di queste dieci forme con quelle di altre sezioni sia nella Tetide sia in Nord America permette di riconoscere il ruolo chiave di *Halobia austriaca* quale miglior indice a halobiidi per la definizione del GSSP della base del Norico.

## Introduction

*Halobia* is an extinct genus of thin-shelled bivalves which proliferated globally during the last part of the Triassic period (Carnian-Norian). It is classified in the family Halobiidae, along with the closely related genera *Daonella*, *Aparimella* and *Enteropleura*. From a phylogentic point of view, *Halobia* probably evolved from *Daonella* and, from a stratigraphic point of view, 'replaced' it. The importance of *Halobia* in biostratigraphy is due to the fact that the species of this genus exhibit high rates of origination and extinction, at times equalling or even exceeding the resolution of ammonoids (McRoberts 1997, 2010, 2011). This factor, along with their wide distribution through the Mesozoic seas, makes them notable biostratigraphic indexes.

The Upper Triassic *Halobia* faunas of Sicily, along with the ammonoid ones, where first studied by Gemmellaro (1882 and 1904 respectively) from various localities of the western part of the island, mainly from the Sicanian and Imerese Basins. Unfortunately, his material was not collected with a strict stratigraphic control, and the specimens were grouped in morphological faunal associations rather than in stratigraphically significant ones. This material is stored at the Museo Geologico G.G. Gemmellaro in Palermo, and it consists of about one hundred specimens belonging to 11 species: *Halobia mojsisovicsi* Gemmellaro, *H. curionii* Gemmellaro, *H. beneckei* Gemmellaro, *H. mediterranea* Gemmellaro, *H. sicula* Gemmellaro, *H. subreticulata* Gem-

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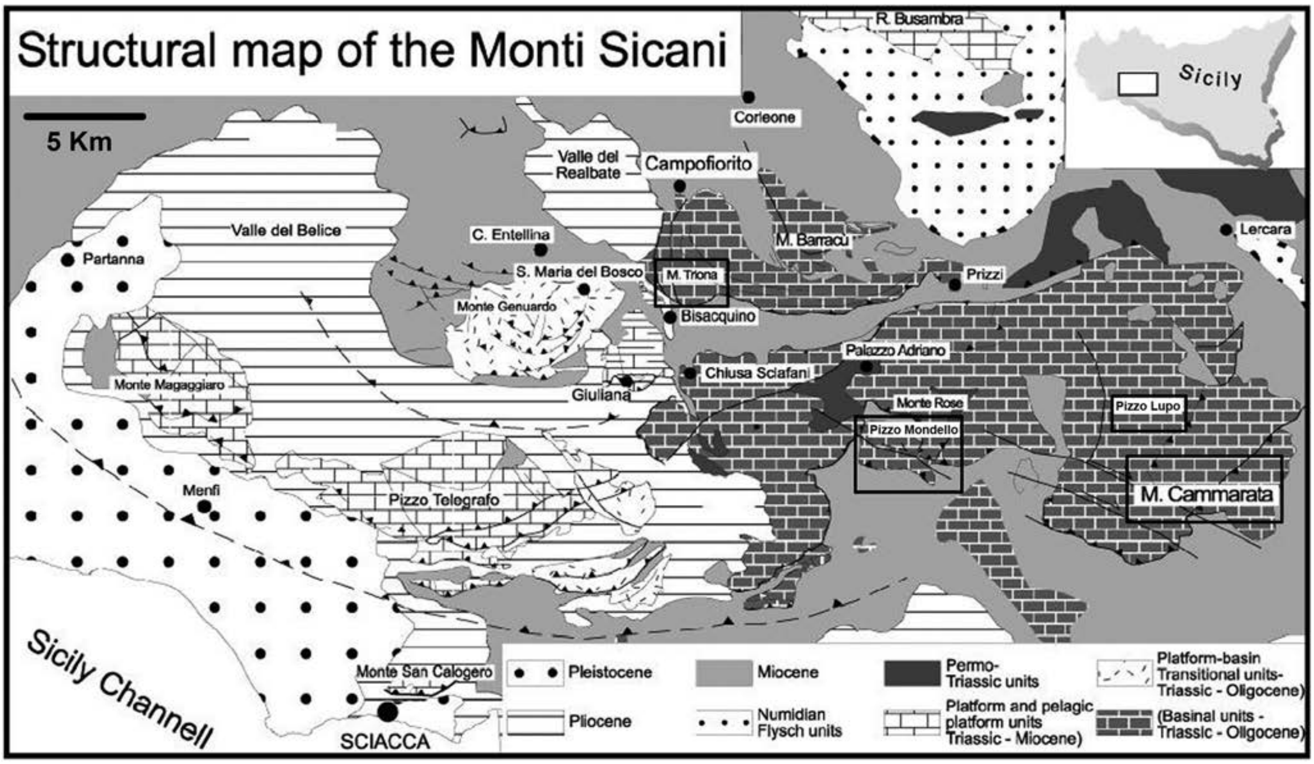


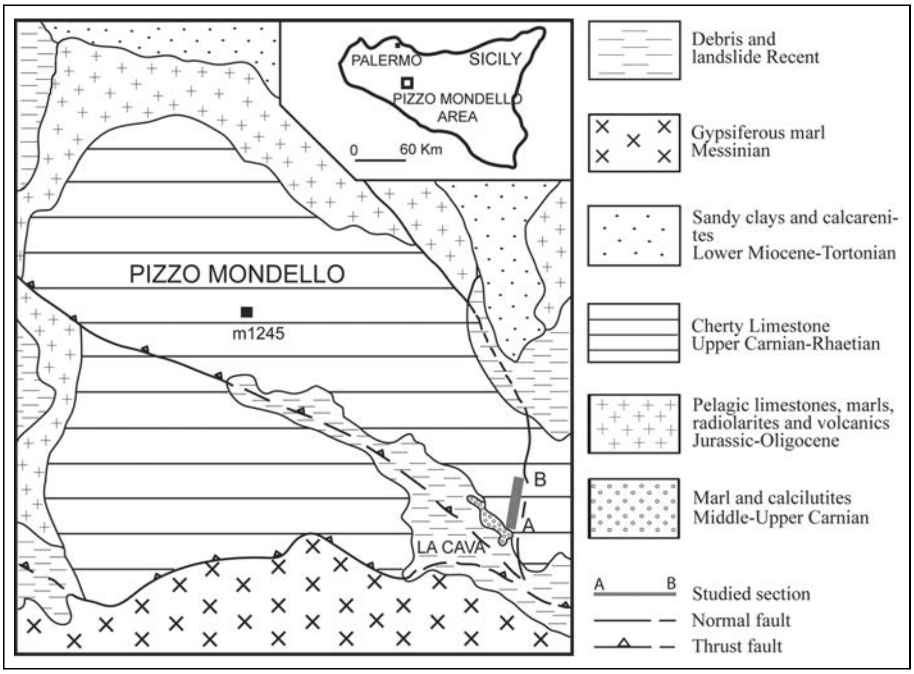

Fig. 1 - Structural map of the Sicanian Mountains. The rectangles indicate the position of Pizzo Mondello and the localities of Monte Cammarata and Monte Triona studied by Gemmellaro (1882) and by De Capoa Bonardi (1982, 1984), and Pizzo Lupo studied by Gruber (1975). Modified after Guaiumi et al. 2007.

mellaro, *H. inisgnis* Gemmellaro, *H. radiata* Gemmellaro, *H. simplex* Gemmellaro, *H.* (*Daonella*) *styriaca* Mojsisovics and *H.* (*D.*) *lenticularis* Gemmellaro (Gemmellaro 1882: 8). Most of the species were erected by Gemmellaro based on his Sicilian collection; as a matter of fact, some of them are known from Sicily only (*Halobia sicula* and *H. mojsisovicsi*). Comparing the original material with these illustrations provided in Gemmellaro's monograph (Gemmellaro 1882), it can be noticed that some details are exagerated at times (for example, the auricle of some specimens is noticeably higher in the illustrations than in the fossil samples). This will be treated in more detail within the Discussion on Synonymy paragraph for the single species.

More recent studies (Montanari & Renda 1976; Cafiero & De Capoa Bonardi 1982; De Capoa Bonardi 1984) integrated and updated Gemmellaro's information, providing a better stratigraphic control. Most of these studies were centred on two of the classical successions by Gemmellaro, one located at Monte Cammarata and one located at Monte Triona (Monte Irona of Gemmellaro 1882 and 1904). A crucial contribution to the understanding of the Sicilian *Halobia*-bearing successions came from the papers of De Capoa Bonardi, who, working together with Cafiero, published a 'contribution to the knowledge on the biostratigraphy of the Mediterranean pelagic Triassic' (Cafiero & De Capoa Bonardi 1982: 37). She provided new descriptions and bed-by-bed sampling for bivalves from the Capo Grosso section located in the Imerese Basin, the Monte Triona and Monte Cammarata sections, together with the Prizzi area, located in the Sicanian Basin, and the Monte Judica and Monte Scalpello sections located in the eastern termination of the Imerese and Sicanian basins.

Compared to these classic localities, the Pizzo Modello succession represents a relatively new outcrop of Upper Triassic *Halobia*-bearing limestones, first described by Bellanca et al. (1995) and Gullo (1996). The section is impressive for the combination of great thickness, almost uniform facies, good exposure and easy accessibility, and it is located in an area that is very important for the paleontology for the Permian and the Upper Triassic pelagic facies. For instance, Pizzo Mondello is located in the Sicani Mountains about 4 km SE of the worldwide known Permian megablocks of the Sosio Valley (Fig. 1). In the second half of the 1990s, integrated paleomagnetic, isotopic and conodont stratigraphic investigations were carried out at Pizzo Mondello. This locality soon became one of the world references for the unusual combination of upper Carnian-lower Norian magnetostratigraphic, stable isotope and conodont records, to the point that Muttoni et al. (2001) proposed the section as candidate for the base of the Norian GSSP. However, these investigations were not detailed enough from the macropaleontological point of view to support the presentation of a GSSP proposal, as pointed out by Krystyn & Gallet (2002).

Fig. 2 - Detailed structural map of the Pizzo Mondello area. The thick line indicates the position of the studied section, on the southern slope of the Pizzo Mondello mountain. Modified after Guaiumi et al. 2007.




Thus a new cycle of samplings was started in 2007 for macrofossils.

In this study the new data on halobiids collected from the Pizzo Mondello section are presented. A revision of the systematic of these forms and their biochronostratigraphy, together with a summary of their world-wide correlations, is also provided. As a matter of fact, as ammonoids are not very frequent in many Upper Triassic successions, other macrofossils, and in particular bivalves, are often regarded as key tools for world-wide correlation. Biostratigraphic schemes based on *Halobia* species have been established in many regions and in general are correlated with the so-called 'world standard' for Triassic time (see Krystyn & Gallet 2002; Krystyn et al. 2002).

## Geological setting

The Pizzo Mondello section, part of the Pizzo Mondello tectonic unit, preserves a 450 m thick, almost continuous succession of pelagic to hemipelagic carbonates, radiolarites, and marls ranging from late Carnian to Rhaetian in age (Preto et al. 2012). The entire succession is overthrust onto a thick allochthonous complex of Neogene mudstones and evaporites attributed to the Gela Nappe (Bellanca et al. 1993, 1995; Guaiumi et al. 2007; Mazza et al. 2010; Balini et al. 2010; Fig. 2). The Carnian to Rhaetian succession has been subdivided into three lithostratigraphic units (Di Stefano 1990; Gullo 1996; Di Stefano & Gullo 1997). The lowermost unit (Fig. 3) consists of a few meters of upper Carnian dark grey marls alternating to marly limestones. These beds are assigned to the Mufara Formation (Schmidt di Friedberg 1962). At Pizzo Mondello this formation lies tectonically on Tortonian-Messinian clays. A change from marls-calcilutite alternations to monotonous calcilutite beds marks the transition from the Mufara Formation to the next thick unit, informally known as Scillato Formation (Schmidt di Friedberg et al. 1960) (or "Cherty limestone", "Cherty limestones" or *Halobia* limestones). At Pizzo Mondello (Figs. 2 and 4) the lower part of this unit is very well exposed in an old quarry (known as 'La Cava') active until 30 years ago, which is the site studied and described in this paper. The intermediate and upper parts outcrop extensively along a small creek bounding the eastern slope of Pizzo Mondello: the Acque Bianche creek. The unit consists of about 430 m of evenly-bedded to nodular *Halobia*-bearing cherty calcilutites. White marly calcilutites, reaching a thickness of about 20 m, follow by a sharp conformable contact. These beds were described by Gullo (1996) as Portella Gebbia Limestone.

Lithofacies and sedimentology

Muttoni et al. (2001, 2004) divided the cherty limestone succession of Pizzo Mondello into four parts or lithozones, bottom to top (Fig. 5):

I. The basal 3 m, above the Mufara Formation, is characterized by calcilutites with rare cherty nodules;

II. 143.5 m of dm-thick, well-bedded white-yellow calcilutites with black chert nodules, intercalated with cm-thick marly levels, follow. In the calcilutites of this lithozone, thin-shelled bivalves (halobiids), foraminifers, radiolarians, sponge spicules, sparse ammonoids and ostracods (Gullo 1996), as well as calcispheres and calcareous nannofossils (Bellanca et al. 1993, 1995) are present;

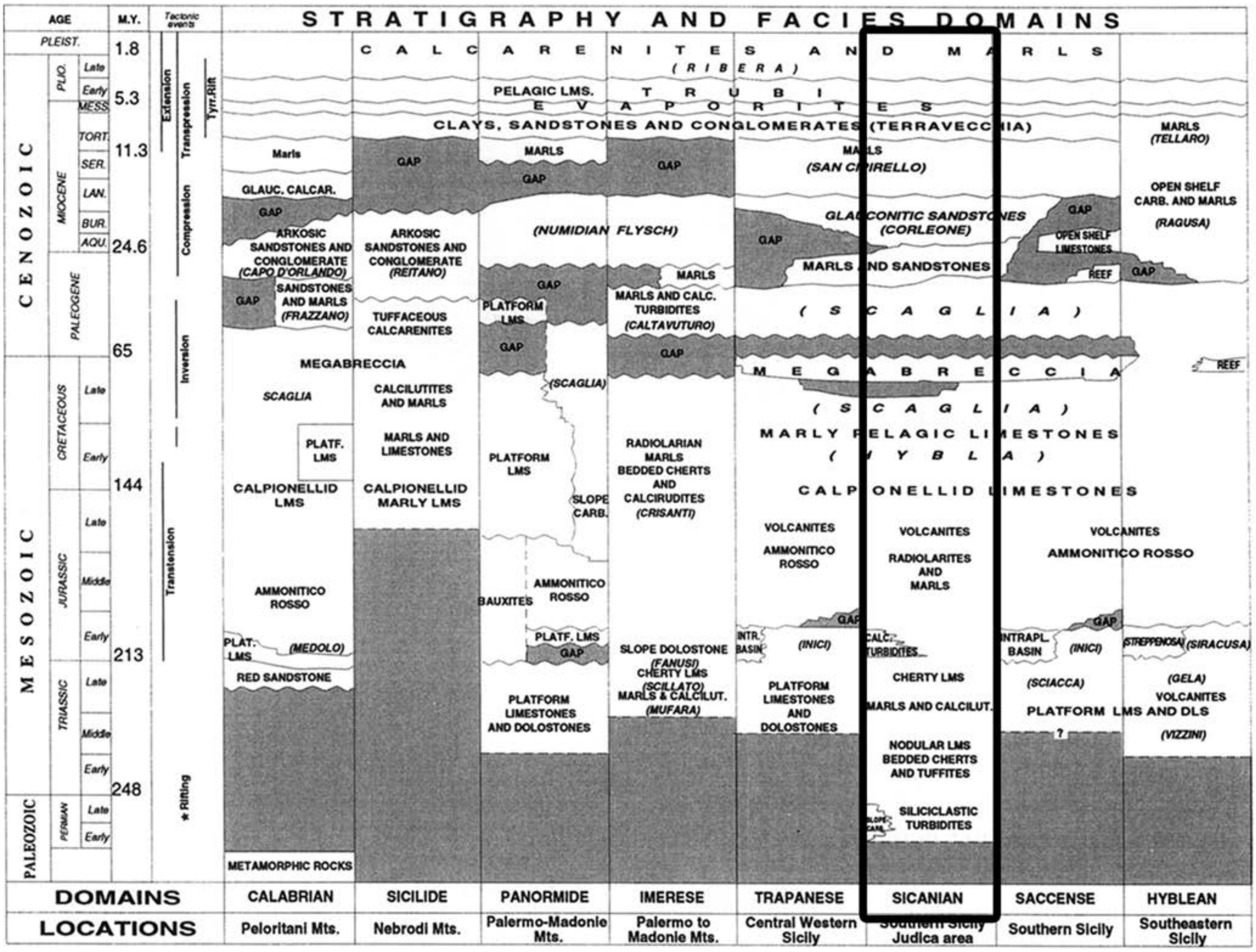



Fig. 3 - Stratigraphy and facies domains of mainland of Sicily. The rectangle marks the succession of the Sicanian Basin. From Catalano et al. 1996.

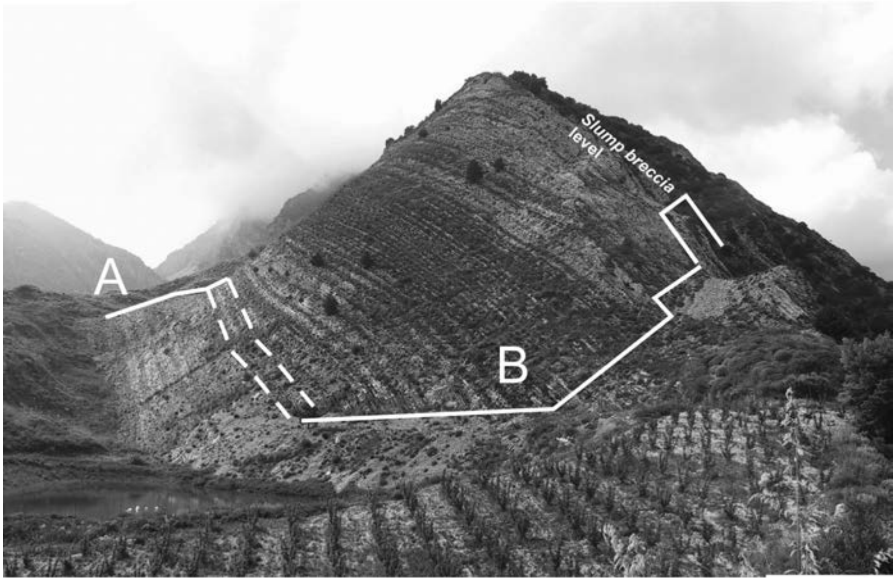



Fig. 4 - The Pizzo Mondello section with the trace of the stratigraphic section. The dotted lines show the correlation and sovrapposition between segments A and B.

III. 11.5 m of brecciated limestones, hereafter referred to as the *Slump breccia* level;

IV. 267.5 m of dm- to cm-thick, well-bedded to nodular whitish calcilutites with cherty nodules are found above the *Slump breccia* level. Chert disappears at meter 290 ca from the base of the section.

The interval II of Muttoni et al. (2004), after a high-resolution sedimentological study (see Guaiumi et al. 2007; Nicora et al. 2007; Balini et al. 2010), has been subdivided into three facies: A, B and C. These facies are very

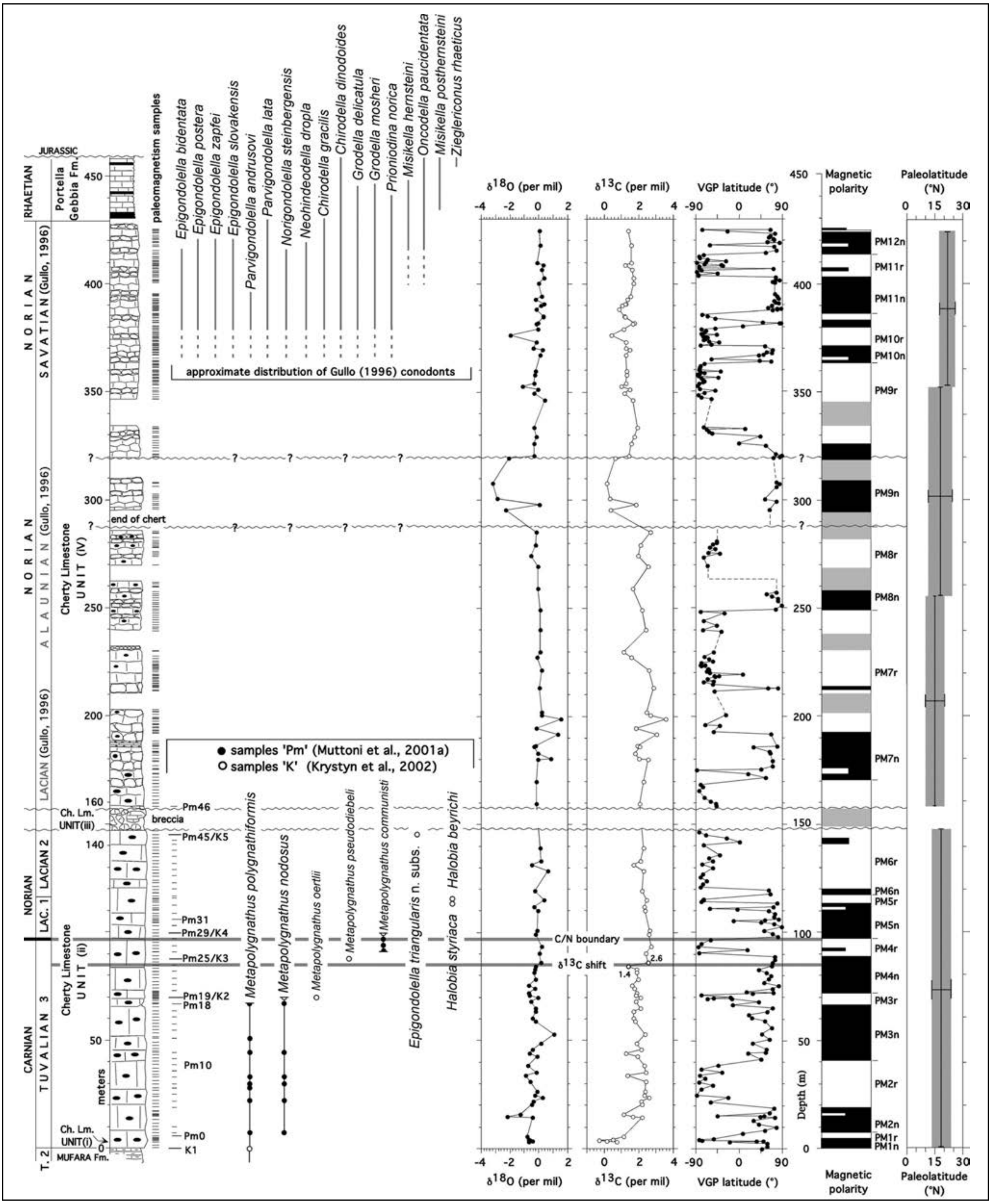



Fig. 5 - The Pizzo Mondello section, with the position of the four lithostratigraphic intervals described by Muttoni et al. 2004. From Muttoni et al. 2004.

similar between one another, but they can be discriminated due to an increasing (from facies A to C) abundance of cherty nodules, bioturbation, lamination, and fossil content (thin-shelled bivalves, calcispheres, coquinas, and conodonts). In the logged section (Fig. 6), these three facies alternate following the scheme A-B-C-B-A with interval C centered at m 73 ca. of the section (Guaiumi et al. 2007; Nicora et al. 2007; Balini et al. 2010).

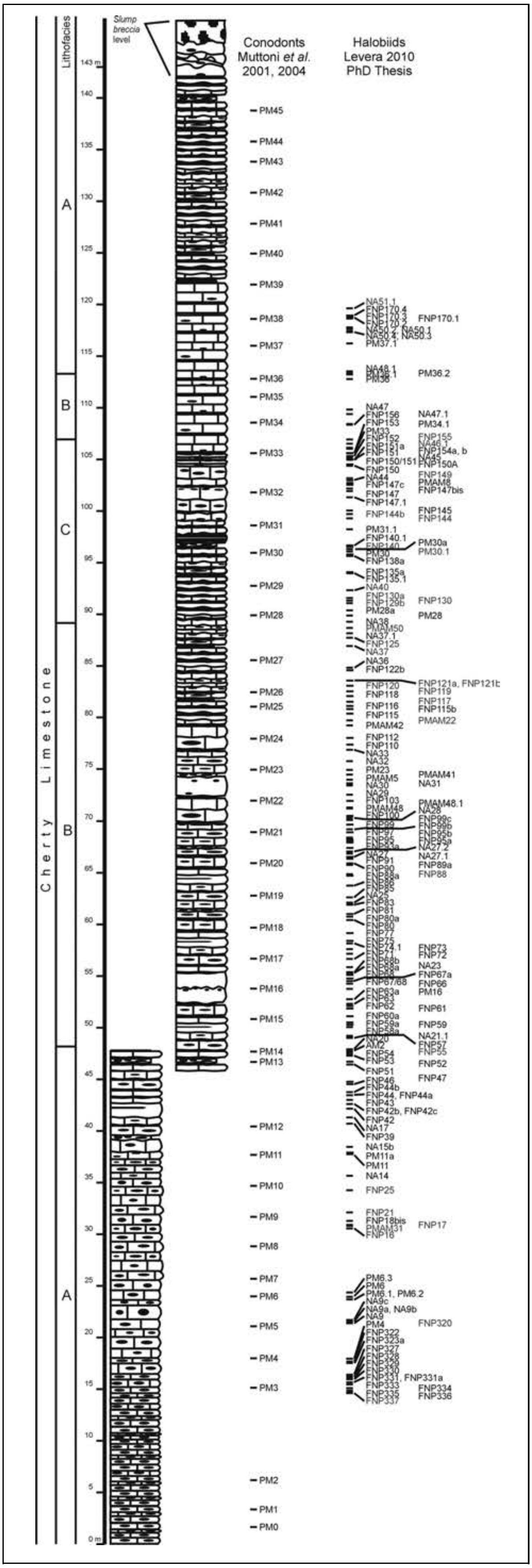



Fig. 6 - Stratigraphic log of the Pizzo Mondello section with the position of the levels sampled for halobiids. On the left, the position of the A, B and C facies is indicated. The lower portion refers to segment A and the upper portion to segment B of the section. The conodont samples PM are from Muttoni et al. 2001 and 2004; they have been plotted on this log to allow direct comparison with the stratigraphic logs in Muttoni et al. (2001, 2004) and the one reported in Figure 5 of this paper.

**The Pizzo Modello collection**

The material described in this paper was collected during 6 seasons of bed-by-bed samplings (from spring 2007 to autumn 2010). The fossiliferous rock samples including *Halobia* specimens, from 166 levels (Fig. 6), were trimmed using various tools including hammers and cold chisels, and they were refined with a pneumatic scribe using a binocular microscope. The studied halobiid collection includes 1120 specimens. Of these, 580 were classified at species level and the best preserved individuals were further studied for biometric analysis. These specimens are housed at the Museo di Paleontologia dell'Università degli Studi di Milano. The collection and the study of the macrofossils from the new locality of Pizzo Mondello are particularly important. In fact, since ammonoids are not very frequent in many successions of this age, the bivalves play a key role as world-wide correlation tools. *Halobia* species, in particular, have always been considered as useful biostratigraphic markers, and their ranges are well calibrated with those of the ammonoids both in the Tethys and in North America (see Krystyn et al. 2002; McRoberts 2011). From the systematic study, a total of ten *Halobia* species have been recognised in the Pizzo Mondello record. They are (in stratigraphic succession): *Halobia carnica*, *H. lenticularis*, *H.* cf. *rugosa*, *H. radiata*, *H. simplex*, *H. superba*, *H. austriaca*, *H. styriaca*, *H. beyrichi* and *H. mediterranea*.

**Taphonomy**

The specimens form Pizzo Mondello are preserved as simple internal and external molds, as wholly or partially re-crystallised shells or as thin films of silicified skeletal material. This last case is typical of the *Halobia styriaca* specimens, which, due to their thin shells and to postdepositional compaction, frequently show also superimposed sculptural features (mainly ribbing) from vertically adjacent specimens. Halobiids have a wide distribution within the succession, ranging from almost the base (level FNP 337 in Fig. 6), to the top of the studied interval (level NA 51.1 in Fig. 6), about 23 meters below the slump breccia. A total number of 1120 specimens, coming from 157 levels, were studied. Within this range, their preservation is not homogenous:

• The most common kind preservation is as three-dimentional moulds and casts of single valves, without evidence of crushing by compaction, normally dispersed within the matrix, either at the base or top of the levels, generally with no particular dominance of convex- or concave-up orientation. Some samples (e.g. levels FNP 67/68, FNP 68 and FNP 88a) show a different pattern, with the shells accumulated in layers at the top of the beds, with the majority of the valves in convex-up orientation (60 to 80 % of the valves). The size of the specimens varies between 1 and 1.5 cm in diameter for the lenticular forms and 1.5-2 cm for the elongated forms. Exceptionally large specimens (up to 3.5-4 cm in length) can be found in the levels PM 23, PMAM 42 and PM 31.1, where they are associated with smaller specimens of the same species, indicating a bimodal distribution of their sizes without occurrence of specimens with a length comprised between 1.5 and 2.5 cm. The reason of this *hiatus* may be connected to a selection of the valves or to a difference in the life habits of the organisms in different life stages.

• Bigger (length between 2.5 and 3.5 cm) specimens, recorded as moulds and casts of single valves, normally with convex-up orientation (70-80% of the valves), are common in the middle part of the section (from level FNP 144 to level FNP 149 in Fig. 6). The valves are dispersed in the matrix, mainly at the base or the top of the beds.

• Finally, in a short interval ranging between levels FNP 150 and FNP 156 (Fig. 6), the fossiliferous beds are represented by pseudo-nodular limestones with thick chert lenses frequently forming the middle of the levels. The halobiids from these beds are the largest found in the whole succession (between 3.5 and 5 cm in diameter). They are heavily compressed and reduced to thin films or laminas. No imbrication could be recognised, while even 65% up to 90% of the valves are oriented convex-up. They occur both as isolated specimens (single valves) and, predominantly, as coquina-like accumulations, mostly at the base or at the top of beds. In fact, in some cases (eg. FNP 150, FNP 151 and FNP 153; Fig. 6) more than 70% of the levels are made of halobiids' remains.

## Systematic paleontology

The genus *Halobia* was erected by Bronn in 1830, together with *Monotis*, based on specimens of thin-shelled, gregarious fossil bivalves coming from grey-whitish dolomitic limestones from the Ausse-Hallstätt area of the Salzkammergut, Austria. In order to establish higher taxonomic affinities (such as family and superfamily designation), some major morphological criteria should be considered. This characters include: shell composition, structure of the hinge and ligament area and arrangement of the muscle scars. Several attempts have been made to subdivide the genus *Halobia* into subgenera (Yin & Hsu 1938; Cox & Newell 1969; Farsan 1972; Gruber 1976; Polubotko 1984, 1988), however, there is no clear consensus on which are the subgeneric criteria as opposed to a generic criteria or even a specific criteria (McRoberts 1993, 2011). For instance, characters like the number of ribs and their pattern, which vary considerably between specimens of the same species, cannot be considered as reliable indicators for species determination.

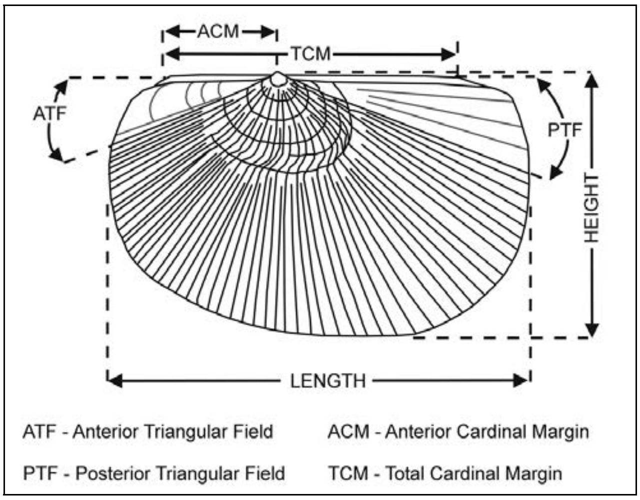



Fig. 7 - Shell morphology and dimensional terminology considered in this paper. Modified after McRoberts 2000.

Because of differences in usage among halobiid workers, shell morphology and dimensional terminology used in this paper are summarised in Fig. 7. Description and measurement of morphological characters in the Halobiidae are relatively easy because of their flattened, equivalve condition. The shell sculpture is best described with the combined use of both text and photographs. Accordingly, species descriptions presented herein include a diagnosis and, whenever possible, commarginal plots and photographs. One of the most important characters in *Halobia* is the position of the beak (Fig. 7), which largely determines the shell shape and the size of the anterior auricle (angular value; a). The interdependence of these characters makes it easy to determine the values of pre-umbonal length, post-umbonal length, hinge length and angle subtended by the auricle directly from the commarginal plots. Total hinge length is often difficult to measure because of incomplete or poor preservation.

**Terminology and abbreviations for measurements used in this paper:**

**L**= Maximum length (of complete/unbroken shells)

**$L_{mis}$** = Measurable length (maximum measurable length on broken shell)

**H**= Maximum height

**$H_{mis}$**= Measurable height

**ACM**= Anterior cardinal margin length

**PCM**= Posterior cardinal margin length

**TCM**= Total cardinal margin length

**BP**= Ratio of anterior cardinal margin length to cardinal margin total length (position of the beak)

**ATF**= Anterior triangular field (equal to the auricle or 'byssal tube')

**PTF**= Posterior triangular field (or area)

**$L_{or}$**= Auricle length

**$H_{or}$**= Auricle height

**α**= Angular breadth of the anterior triangular field (in °)

**β**= Angular breadth of the posterior triangular field (in °)

**R**= Number of ribs measured across a 45° arc at the height of 1 centimetre from the beak

**GS**= Position of the growth stop

All linear measurements' values are expressed in centimetres, unless stated otherwise.

**Codes for the repositories of the reference material studied**:

**MPUM**= Museo di Paleontologia dell'Università degli Studi di Milano

**GBA**= Geologishes Bundsanstalt, Vienna

**NHMW**= Naturhistorisches Museum, Vienna

**MGUP**= Museo Geologico G.G.Gemmellaro, Palermo

All figured specimens from Pizzo Mondello are housed in the Museo di Paleontologia of the Dipartimento di Scienze della Terra 'A. Desio', Milan. All the specimens for all species are listed in stratigraphic order. In the text, the material is listed with the number of catalogue, then the field number between brackets (e.g., MPUM 10690 (FNP 336-1) is the 10690th specimen in the Museo di Paleontologia's catalogue and the 1st specimen from level FNP 336).

## Family, genus and species systematic

Class **Bivalvia** Linnaeus, 1758

Subclass **Pteriomorphia** Beurlen, 1944 [emend. Waller, 1978]

Order **Pterioida** Newell, 1965 [emend. Waller, 1978]

Suborder **Pteriina** Newell, 1965 [emend. Waller, 1978]

Superfamily Posidonioidea Frech, 1909 [emended Waller, *in* Waller and Stanley, 2005]

**Discussion.** Waller (*in* Waller & Stanley 2005) emended this superfamily as comprising the two families: Posidonidae (genera *Posidonia* Bronn, 1828, *Bositra* De Gregorio, 1886 (= *Peribositra* Kurushin & Trushchelev, 1989 according to Waller, *in* Waller and Stanley 2005), and *Lentilla* Conti and Monari, 1992), and Halobiidae (including the genera *Enteropleura* Kittl, 1912, *Daonella* Mojsisovics, 1874, *Aparimella* Campbell, 1994 and *Halobia* Bronn, 1830). Because of the new use the Posidonioidea as containing only two families, Waller (*in* Waller & Stanley 2005) considered the superfamily Halobioidea Campbell, 1994 to be unwarranted. On the contrary, Waterhouse (2008) used Halobioidea as a superfamily uniting the Halobidae Kittl, 1912 and the Claraiidae Gavrilova, 1996 (elevated to family rank). As suggested by McRoberts (2011), this union by Waterhouse is not substantiated as Halobiidae possesses a horizontally striated ligament system (e.g., Waller, *in* Waller and Stanley 2005), whereas the ligament in claraiids was clearly duplivincular (see Zhang 1980; Newell & Boyd 1995; Gavrilova 1996).

Family Halobiidae Kittl, 1912 [emended Waller, 2005]

**Discussion.** Waller (*in* Waller and Stanley 2005) recently emended the family, considering the fact that halobiids are monomyrian and possess a canalivincular (horizontally striated) ligament (*sensu* Waterhouse 2008) as in *Daonella* Mojsisovics and *Halobia* Bronn, and perhaps an alivincular ligament in *Enteropleura* Kittl. As Waller (*in* Waller and Stanley 2005) points out, an alivincular ligament for *Enteropleura* has not been confirmed beyond the single sketch by Arthaber (1896, fig. 12). Though Waller's emended diagnosis described the radial ornament to as costellate rather than plicate, the radial ornament of *Enteropleura* and to a greater extent *Daonella*, *Apiramella* Campbell, and *Halobia* is truly plicate. It is formed by folding on the shell margin. As suggested by McRoberts (2011), this group is considered here as composed of thin-shelled pteriaceans with low valve convexity, primitive radial plications, and commarginal rugae retained from a posidoniid ancestor. Within the family Halobiidae, based on characteristics of the hinge region and byssal system, three genera are recognized: *Daonella* (devoid of anterior auricle), *Aparimella* (with upper anterior auricle), and *Halobia* (with two-fold anterior auricle). A fourth genus, *Enteropleura*, is based on the occurrence of an internal ridge which distinguishes it from *Daonella* (Chen & Stiller 2007).

Genus *Halobia* Bronn, 1830 [emended McRoberts 2011]

Type species: *Halobia salinarum* Bronn, 1830, by subsequent designation (Mojsisovics, 1874).

**Discussion.** Since the late 18$^{th}$ century, *Halobia* has been separated from *Daonella* Mojsisovics based on the presence of the anterior auricle (also called 'byssal tube' by Campbell 1994). McRoberts (2000) interpreted *Halobia* Bronn as different from *Aparimella* Campbell in its development of the lower division of the anterior auricle. Moreover, McRoberts (2011: 623) stated that 'it is the opinion of this author that most of these genus-rank groupings (e.g., *Perihalobia* Gruber, *Zittelihalobia* Gruber, *Obruchevihalobia* Polubotko, *Indigirohalobia* Polubotko, and others) are not of generic, but of subgeneric or specific, significance. Although it is desirable to subdivide such a speciose group, it should be done on phylogenetic grounds. For example, if it can be shown that the anterior tube (and associated anterodorsal flange) of *Halobia* is twice derived by homoplasy (e.g., once from *Aparimella* and once from *Daonella*) then erection of a new genus and a revision of *Halobia* and its membership will be required to accommodate the separate lineages for which generic names may already exist.'. As suggested by Campbell (1994) and McRoberts (2011), species of *Halobia* are distinguished on characters of the shell design: outline shape of the commarginals, position of the beak relative to shell length, length to height ratio, prominence of the byssal tube of the anterior auricle, and nature of shell sculpture including presence or absence of growth stops.

### **Halobia carnica** Gruber, 1976

Pl. 1, figs 1-11, 16-17

1976 *Halobia carnica* Gruber, p. 96, pl. 17, figs. 1-3

**Types:** Holotype: Gruber (1976), pl. 17, fig. 1a, b: Wi II 1992/3787.

**Type locality:** Raschberg-Karlgraben/Bad Goisern, Austria.

**Stratum typicum**: Hallstätt Limestone (upper Carnian *sensu* Gruber 1977).

**Material:** 62 specimens: MPUM 10690 (FNP 336-1), MPUM 10691 (FNP 331-4), MPUM 10692 (FNP 330-3), MPUM 10693 (FNP 330-4), MPUM 10694 (FNP 328a-4, FNP 328a-5), MPUM 10695 (FNP 327-3), MPUM 10696 (FNP 327-5, FNP 327-9), MPUM 10697 (PM 6.2-4), MPUM 10698 (CAM 1-2), MPUM 10699 (FNP 336-2, FNP 336-4, FNP 335-1, PM 3-1, PM 3-2, PM 3-3, PM 3-4, FNP 331-1, FNP 331-3, FNP 331a-6, FNP 331a-7, FNP 331a-8, FNP 330-1, FNP 330-2, FNP 330-5, FNP 330-6, FNP 330-7, FNP 330-8, FNP 330-9, FNP 330-10, FNP 330-11, FNP 330-15, FNP 329-2, FNP 329-3, FNP 328a-1, FNP 328a-6, FNP 328a-7, FNP 328a-8, FNP 328a-9, FNP 328a-11, FNP 328a-12, FNP 327-6, FNP 327-7, FNP 327-8, FNP 327-9, FNP 323-5, FNP 323-9, FNP 323-10, FNP 323a-5, FNP 323a-7, FNP 323a-27, FNP 323a-28, FNP 323a-34, NA 9-1, NA 9-2, PM 6.1-1, PM 6.1-2, PM 6.1-3, PM 6.1-4, PM 6.2-2, PM 6.2-3, PM 6-1, PM 6.3-7, PM 6.3-8, CAM 1-1, CAM 1-3).

**Description**. Shells of small to medium size, slightly longer than high (H/L ratio ratio ranges between 0.60 and 0.86; mean = 0.75; Tab. 1), with not much inflated, not much protruding beak, located at about one third anterior of the cardinal margin (BP ranges between 0.43 and 0.47; mean = 0.45).

The outline of the shell is oblique-elongated, with a rounded anterior margin which passes, through the ventral margin, to a strongly oblique posterior margin (Fig. 8). The maximum H is located at about 1 mm behind the beak in the juvenile stages (H less than 0.5 cm) and shifts further towards the posterior in the adults (about 2 mm behind the beak at 1 centimetre of H; Fig. 9).

The anterior auricle is narrow to moderately broad ($\alpha$ ranges between 20° and 30.5°; mean 26°; Tab. 1), inflated ("byssal tube"), with a more or less deep groove at its base; an upper flat or sloping towards the cardinal margin portion is sometimes visible.

Radial ribs are strong, slightly bent towards the anterior margin, and are separated by narrow and deep furrows; the ribs are split into two or three secondary ribs by the intercalation of secondary furrows that are shallower than the primaries (R ranges between 15 and 27; mean = 18; Tab. 1). Commarginal ornamentation consists of by growth stirae and large, more or less strong ridges.

The posterior triangular field is broad ($\beta$ ranges between 28° and 42.4°; mean = 37°; Tab. 1), and the ribs fade and disappear at about 0.4-0.6 cm from the cardinal margin.

**Discussion**. At Pizzo Mondello, *Halobia carnica* Gruber can be considered as a very distinctive species for the combination of its shape, size and costation pattern. The only somewhat similar species that can be found in the same section is *H. mediterranea*. However, their relative stratigraphic position prevents possible confusion.

Before this study *Halobia carnica* had been reported only from Raschberg-Karlgraben (Bad Goisern), Feuerkogel (Bad Aussee) and S. Stefano (Sicily, Italy) (Gruber 1976). The occurrence of this species in both Pizzo Mondello and Monte Cammarata (sample CAM 1) sections suggests that it is probably present in all the Sicilian Upper Carnian Scillato Formation successions. This new datum provides a more complete figure of the biostratigraphy of *Halobia* in Sicily.

**Occurrence**. At Pizzo Mondello, this species has been found only in the lowermost part of the section, from 17 levels (FNP 336, FNP 335, PM 3, FNP 331, FNP 331a, FNP 330, FNP 329, FNP 328a, FNP 327, FNP 323, FNP 323a, NA 9, PM 6.1, PM 6.2, PM 6 and PM 6.3), were it can be found in monospecific accumulations or, more rarely, in association with *Halobia mediterranea*.

**Age**. *Halobia carnica*, the lower species in the Pizzo Mondello fossil record, is considered here as belonging to the middle upper Carnian (middle Tuvalian 2).

### **Halobia lenticularis** Gemmellaro, 1882

Pl. 1, figs 12-20

v 1882 *Daonella lenticularis* Gemmellaro, p. 466, pl. 1, figs. 3-5

v 1912 *Halobia disperseinsecta* Kittl, p. 88, pl. 1, figs. 24-29

v 1969 *Daonella (Daonella)* cf. *lenticularis* - De Capoa Bonardi, p. 60, pl. 8, figs. 1-5

1977 *Perihalobia lenticularis* - Gruber, p. 23, pl. 1, figs. 1-4

v 1980 *Halobia lenticularis* - Cafiero & De Capoa Bonardi, p. 192, pl. 3, figs. 7-8

v 1982 *Halobia lenticularis* - Cafiero & De Capoa Bonardi, p. 56, pl. 2, figs. 1-10, textfig. 6

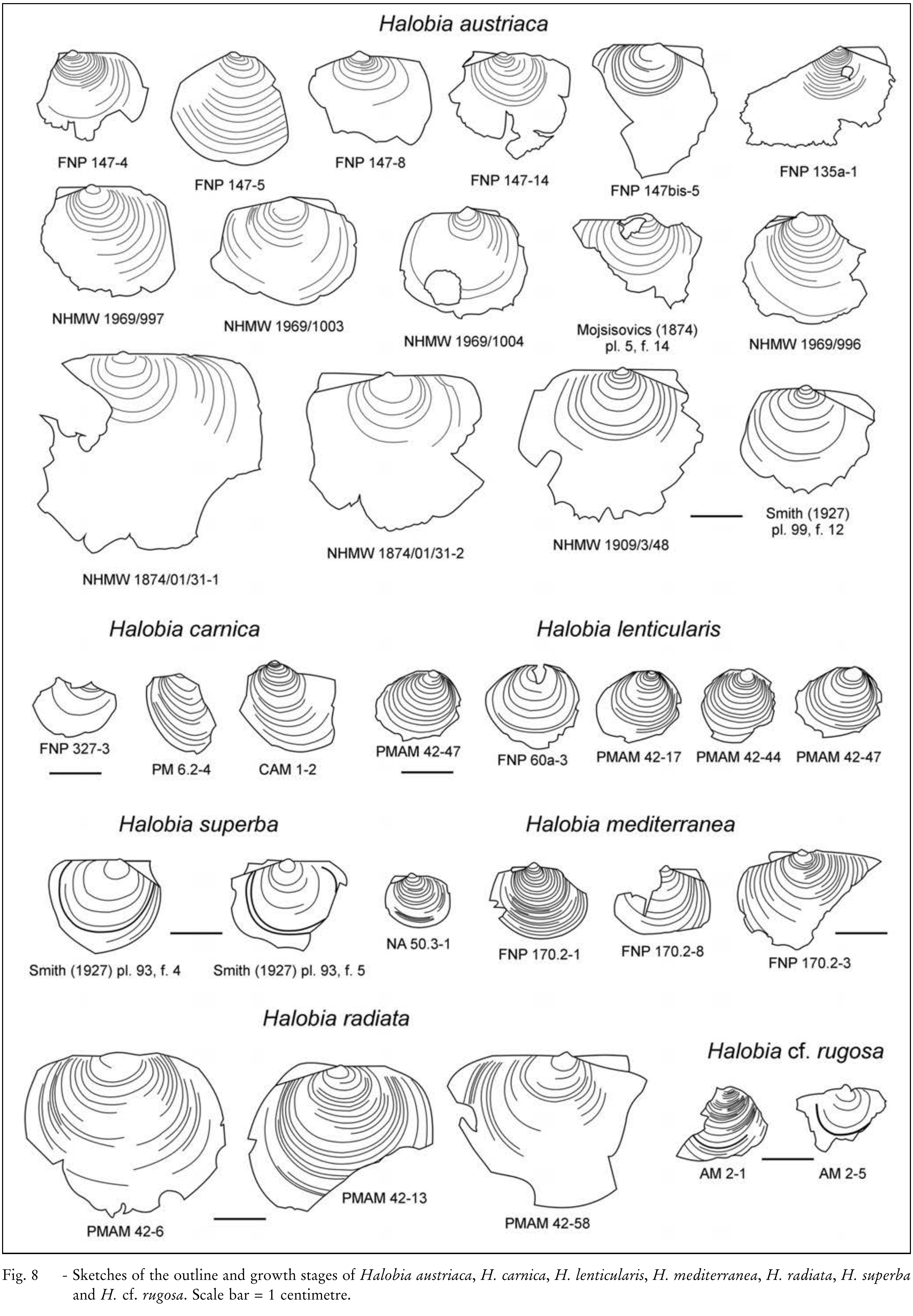



Fig. 8 - Sketches of the outline and growth stages of *Halobia austriaca*, *H. carnica*, *H. lenticularis*, *H. mediterranea*, *H. radiata*, *H. superba* and *H.* cf. *rugosa*. Scale bar = 1 centimetre.

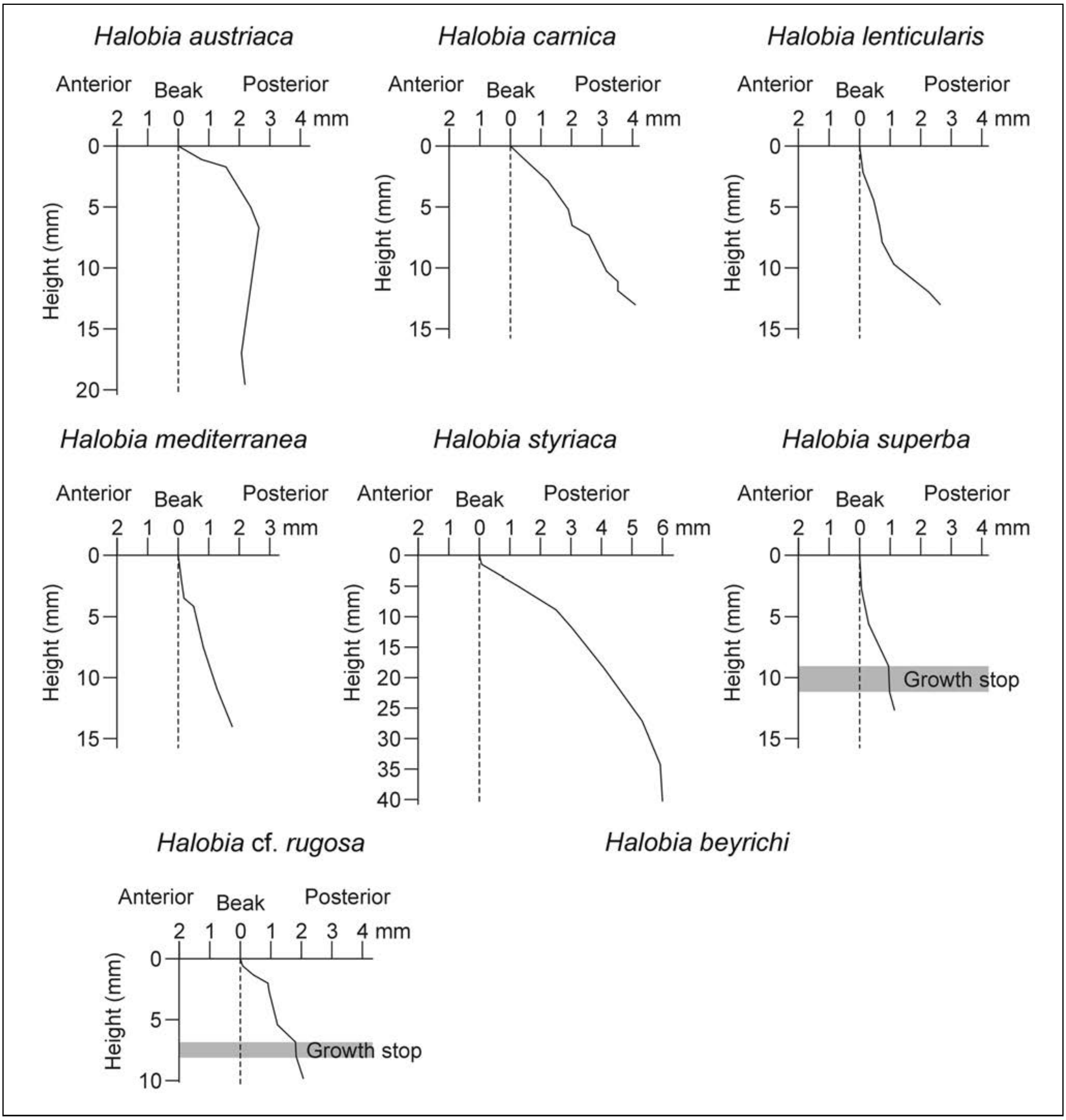



Fig. 9 - Graphic showing the shift in the position of the maximum height (H) with ontogeny with respect to the position of the beak, in *Halobia austriaca*, *H. beyrichi*, *H. carnica*, *H. lenticularis*, *H. mediterranea*, *H. styriaca*, *H. superba* and *H.* cf. *rugosa*.

1984 *Halobia lenticularis* - De Capoa Bonardi, p. 94 and references therein

2002 *Halobia lenticularis* - Krystyn & Gallet, p. 15

**Types:** Lectotype: original by Gemmellaro, 1882, pl. 1, fig. 4, selected by Gruber (1976: 23): MGUP 002.305/3.

**Type locality:** Contrada Scaletta (Cassaro di Castronuovo), Sicilia, Italy.

**Stratum typicum**: Cherty Limestones, Grenzbereiches (Carnian-Norian *sensu* Gruber 1977).

**Material**: 164 specimens: MPUM 10700 (FNP 60a-3), MPUM 10701 (PMAM 42-17), MPUM 10702 (PMAM 42-44), MPUM 10703 (PMAM 42-47), MPUM 10704 (FNP 67/68-8), MPUM 10705 (FNP 67/68-1), MPUM 10706 (FNP 336-3, FNP 331a-1, FNP 331a-2, FNP 331a-3, FNP 331a-5, FNP 330-12, FNP 330-13, FNP 330-14, FNP 329-1, FNP 328a-2, FNP 328a-3, FNP 328a-10, FNP 323-1, FNP 323-2, FNP 323-3, FNP 323-4, FNP 323-6, FNP 323-7, FNP 323-8, FNP 323-11, FNP 323a-2, FNP 323a-6, FNP 323a-9, FNP 323a-10, FNP 323a-11, FNP 323a-12, FNP 323a-16, FNP 323a-17, FNP 323a-18, FNP 323a-19, FNP 323a-20, FNP 323a-25, FNP 323a-26, FNP 323a-29, FNP 323a-30, NA 9a-1, NA 9a-2, NA 9b-1, NA 9b-2, NA 9b-3, NA 9b-4, NA 9b-5, NA 9b-6, NA 9b-7, NA 9b-10, NA 9b-11, NA 9b-12, NA 9b-13, NA 9c-2, PM 6.2-5, PM 6.3-1, PM 6.3-4, PM 6.3-5, PM 6.3-6, PM 6.3-7, FNP 18bis-1, PM 11-1, PM 11-2, PM 11-6,

FNP 39-1, FNP 39-2, FNP 39-3, FNP 39-4, FNP 39-5, FNP 39-6, FNP 39-7, FNP 39-8, FNP 39-9, FNP 42c-1, FNP 42c-2, FNP 42c-4, FNP 42c-5, FNP 42c-7, FNP 42c-8, FNP 44-6, FNP 44-8, FNP 44-9, FNP 44-10, FNP 44b-1, FNP 44b-2, FNP 44b-3, FNP 47-1, FNP 52-1, FNP 52-7, FNP 54-5, FNP 54-6, FNP 54-7, NA 20-15, FNP 59-1, FNP 59-2, FNP 59-4, FNP 59-5, FNP 59-6, FNP 59-7, FNP 59-8, FNP 59a-2, FNP 59a-4, FNP 59a-5, FNP 59a-6, FNP 60a-1, FNP 60a-4, FNP 66-1, FNP 67a-1, FNP 67a-2, FNP 67a-3, FNP 67a-4, FNP 67a-5, FNP 67/68-14, FNP 67/68-17, FNP 67/68-19, FNP 67/68-21, FNP 68-1, FNP 68-3, FNP 68-4, FNP 68-5, FNP 74.1-2, FNP 74.1-3, FNP 74.1-7, FNP 75-10, FNP 75-11, FNP 75-13, FNP 75-14, FNP 103-2, FNP 103-3, FNP 103-6, FNP 103-12, FNP 103-13, NA 29-3, NA 29-12, NA 30-6, NA 30-9, PMAM 5-2, PMAM 5-5, PMAM 5-6, PMAM 5-7, PMAM 41-4, PMAM 41-5, PMAM 41-7, PMAM 41-8, PMAM 41-10, PMAM 41-14, PMAM 41-16, PMAM 41-17, PM 23-6, PMAM 24c-3, NA 33-3, PMAM 42-9, PMAM 42-12, PMAM 42-30, PMAM 42-32, PMAM 42-45, PMAM 42-51, PMAM 42-53, PMAM 42-70, PMAM 42-73, PMAM 42-88, PMAM 42-94, FNP 118-8).

**Description**. Shells of small to medium size (usually up to 1 centimetre in H and 1.2 centimetres in length; rarely up to 2 cm in L), lenticular shape (H/L ratio ranges between 0.69 and 1.01; mean = 0.86; Tab. 1), not much inflated, with rounded, very little prominent, moderately inflated umbo, located slightly anterior to the half of the cardinal margin (BP is about 0.35; Tab. 1).

The outline of the shell is lenticular (Fig. 8). The maximum H is located at about 0.3 mm behind the beak in the juvenile forms (H about 3 mm) and constantly shifts towards the posterior, reaching a distance of about 2.5 mm behind the beak in adult forms with a H of about 1.2 cm (Fig. 9).

Anterior auricle is narrow (α ranges between 11.7° and 19.6°; mean = 15°; Tab. 1), generally not much inflated, apparently un-divided. It seems to be only a moderately high 'marginal list'. It can show a more or less deep groove at its base.

Radial sculpture consists of extremely large ribs, flat and separated by very superficial and weak furrows. The ridges are easily visible, especially near the beak and on the posterior portion of the shell. Since the ribs are very broad, it is difficult to determine where the costation ends and where the posterior triangular field and anterior ribs-free area start. The primary ribs are sometimes split into two secondary ribs in the last portion of the shell towards the ventral margin (this is visible only in specimens with H more than 2 cm).

The posterior triangular field is not always clearly recognizable, due to the fact that the furrows are very shallow and often not well preserved. In many specimens, the lack of ribs on a large part of the shell seems to be an artefact of preservation. When measurable, it is quite broad (β ranges between 39° and 32°; mean = 30.5°; Tab. 1).

**Discussion**. *Halobia lenticularis* (Gemmellaro) can be easily recognized because of the generally small size (in the Pizzo Mondello material only few specimens have a L of more than 2 cm), the lenticular shape, and sculpture. The extremely broad and weak ribs, separated by very shallow and narrow to moderately broad furrows, at times simulating of a smooth shell, lacking of any radial sculpture.

At Pizzo Mondello, the occurrence of *Halobia lenticularis* is also very distinctive because it is comprised in an interval delimited by two species (*H. carnica* Gruber and *H. radiata* Gemmellaro) which are characterized by a very dense and strong radial sculpture.

Like most of the species collected from Pizzo Mondello, *Halobia lenticularis* is normally found in monotypic assemblages, except for the lowermost and topmost portions of its range, where it can be found in association with *H. carnica* and *H. radiata* respectively. In this intervals, *H. lenticularis* is always, with respect to the number of specimens per sample, the less abundant species. Other exceptions are represented by the levels FNP 60a and FNP 67/68, where *H. lenticularis* can be found in association with few specimens of *H. simplex* Gemmellaro and *H. superba* Mojsisovics respectively.

This stratigraphic distribution, along with its peculiar morphological features, make *Halobia lenticularis* a very good marker for the lower part of the Pizzo Mondello succession.

**Occurrence**. The specimens collected at Pizzo Mondello come from the lower to middle part of the section, from 40 levels: FNP 336, FNP 331a, FNP 330, FNP 329, FNP 328a, FNP 323, FNP 323a, NA 9a, NA 9b, NA 9c, PM 6.2, PM 6.3, FNP 18bis, PM 11, FNP 39, FNP 42c, FNP 44, FNP 44b, FNP 47, FNP 52, FNP 54, NA 20, FNP 59, FNP 59a, FNP 60a, FNP 67a, FNP 67/68, FNP 68, FNP74.1, FNP 75, FNP 103, NA 29, NA 30, PMAM 5, PMAM 41, PM 23, PMAM 24c, NA 33, PMAM 42 and FNP 118.

**Age**. *Halobia lenticularis* is here considered as a good datum for the uppermost Carnian (Tuvalian 3 *sensu* Krystyn & Gallet 2002; Krystyn et al. 2002).

### **Halobia** cf. **rugosa**

Pl. 5, figs 10-18

**Material:** 10 specimens: MPUM 10707 (FNP 323a-23), MPUM 10708 (AM 2-1), MPUM 10709 (AM 2-5), MPUM 10710 (FNP 42b-1), MPUM 10711 (FNP 80a-26), MPUM 10712 (FNP 99-1), MPUM 10713 (FNP 99-2), MPUM 10714 (FNP 75-3, FNP 75-7, FNP 80a-42).

**Description.** The shape of *Halobia* cf. *rugosa* is sub-lenticular in the first growth stages, then it becomes longer than high (H/L ranges between 0.67 and 0.83; mean = 0.77; Tab. 1). The beak is slightly inflated and does not protrude much beyond the cardinal margin. It is located slightly before the half of the cardinal margin (BP ranges between 0.31 and 0.41; mean = 0.37; Tab. 1). The maximum H is located at about 1 mm behind the beak in the juveniles (H less than 2 mm), and shifts to about 2 mm behind the beak at the growth stop (H about 8 mm), then its shifts toward the posterior margin is less marked (Fig. 9).

The auricle is quite narrow (α ranges between 19.4° and 26°; mean = 23°; Tab. 1) and slightly inflated; it is delimited by a deep furrow at its base. The radial sculpture consists of numerous fine and thick ribs (R ranges between 22 and 25; mean = 24; Tab. 1), which start at about 1-2 millimetres from the beak. The commarginal sculpture consists of very fine and thick growth striae, not visible at the growth stop. The growth stop is located at about 0.7-0.8 cm (GS ranges between 0.62 and 1.04 cm; mean = 0.86 cm; Fig. 8).

The posterior triangular field is moderately broad (β ranges between 27.2° and 27.7°; mean = 27.5°; Tab. 1).

**Discussion**. This form is very similar to *Halobia rugosa* Mojsisovics (Pl. 5, Figs. 12-14), but somewhat differs from it in the costation pattern, the position of the growth stop, and in the more elongated outline. Given the very limited number of specimen, the relatively poor preservation and the stratigraphic position, it has been preferred to keep it separate *H. rugosa*.

**Occurrence**. At Pizzo Mondello, *Halobia* cf. *rugosa* is rare and occurs only in 5 levels: FNP 42b, AM 2, FNP 75, FNP 80a and FNP 99.

**Age**. Considering its stratigraphic position in relation to the other species, *Halobia* cf. *rugosa* is here attributed to the Tuvalian 3 (upper Carnian).

### **Halobia radiata** Gemmellaro, 1882

Pl. 2, figs 1-16

v 1882 *Halobia radiata* Gemmellato, p. 465, pl. 1, figs. 9-12
v 1912 *Halobia hyatti* Kittl, p. 141, pl. 9, fig. 32
v 1912 *Halobia verbeeki* - Kittl, p. 142
v 1912 *Halobia daltoni* Kittl, p. 143, pl. 9, figs. 33-34
1976 *Halobia radiata radiata* - Gruber, p. 61, pl. 9, figs. 1-4
1976 *Halobia radiata hyatti* - Gruber, p. 63, pl. 9, figs. 5-7
1980 *Halobia radiata radiata* - Cafiero & De Capoa Bonari, p. 196, pl. 3, figs. 1-2
v 1982 *Halobia radiata radiata* - Cafiero & De Capoa Bonardi, p. 64, pl. 3, figs. 1-10, text fig. 10
v 1982 *Halobia radiata hyatti* - Cafiero & De Capoa Bonardi, p. 66, pl. 3, figs. 11-12, text fig. 11
1983 *Halobia radiata radiata* - Gruber, p. 244, pl. 17, fig. 3
1984 *Halobia radiata radiata* - De Capoa Bonardi, p. 94, pl. 1, figs. 2-4 and references therein
1984 *Halobia radiata hyatti* - De Capoa Bonardi, p. 94
v 1993 *Halobia radiata radiata* - McRoberts, p. 204, figs. 7.1-7.3
2011 *Halobia radiata* - McRoberts, p. 627, figs 15.1-15.3, 16

**Types:** Lectotype: original by Gemmellaro (1882, pl. 1, fig. 9), selected by Gruber (1976: 61): MGUP 002.300/1. Paralectotypes: originals by Gemmellaro (1882, pl. 1, fig. 10-11 and non figured [see Cafiero and De Capoa Bonardi 1982, pl. 3, figs. 2-10]): MGUP 002.302/1, MGUP 002.302/2.

**Type locality:** Contrada Scaletta, Mt. Cassaro di Castronuovo, Sicily.

**Stratum typicum:** "Cherty limestone" *sensu* Gemmellaro 1882 (Carnian-Norian).

**Material**: 217 specimens: MPUM 10715 (FNP 67/68-6), MPUM 10716 (FNP 68a-9), MPUM 10717 (FNP 95a-5), MPUM 10718 (FNP 112-14), MPUM 10719 (PMAM 42-6), MPUM 10720 (PMAM 42-11), MPUM 10721 (PMAM 42-13), MPUM 10722 (PMAM 42-20), MPUM 10723 (PMAM 42-29), MPUM 10724 (PMAM 42-58), MPUM 10725 (PMAM 42-61), MPUM 10726 (PMAM 42-62), MPUM 10727 (FNP 52-6, FNP 59a-7, FNP 59a-8, FNP 59a-9, FNP 59a-10, FNP 67/68-3, FNP 67/68-4, FNP 67/68-7, FNP 67/68-9, FNP 67/68-10, FNP 67/68-15, FNP 68a-1, FNP 68a-3, FNP 68a-4, FNP 68a-6, FNP 68a-7, FNP 68a-8, FNP 68a-10, FNP 68a-11, FNP 75-1, FNP 75-2, FNP 75-5, FNP 75-6, FNP 75-8, FNP 75-9, FNP 80-1, FNP 80a-2, FNP 80a-3, FNP 80a-4, FNP 80a-6, FNP 80a-10, FNP 80a-18, FNP 80a-21, FNP 80a-24, FNP 80a-25, FNP 80a-31, FNP 80a-33, FNP 80a-34, FNP 80a-44, FNP 80a-45, FNP 90-3, FNP 90-4, FNP 90-12, FNP 90-13, FNP 90-15, FNP 90-16, FNP 91-4, NA 27-1, NA 27-2, NA 27-4, NA 27.1-1, NA 27.2-3, FNP 93-2, FNP 93-3, FNP 93-4, FNP 95-1, FNP 95-2, FNP 95-6, FNP 95-8, FNP 95-9, FNP 95-10, FNP 95-11, FNP 95-14, FNP 95-15, FNP 95-16, FNP 95-18, FNP 95-20, FNP 95-21, FNP 95-22, FNP 95-23, FNP 95-25, FNP 95a-1, FNP 95a-2, FNP 95a-3, FNP 95b-1, FNP 97-2, FNP 99b-2, FNP 99b-10, FNP 99a-1, FNP 99a-3, FNP 99a-4, FNP 99a-5, FNP 99c-1, FNP 99c-4, FNP 99c-14, FNP 99c-15, FNP 99c-16, NA 28-1, NA 28-2, NA 28-4, NA 28-6, NA 28-8, NA 28-11, NA 28-14, FNP 100-1, FNP 100-2, FNP 100-3, FNP 103-7, FNP 103-10, FNP 103-15, NA 29-4, NA 29-5, NA 29-8, NA 29-9, NA 29-10, NA 29-11, NA 29-18, NA 29-19, NA 29-21, NA 30-3, NA 30-4, NA 30-8, NA 31-2, PMAM 41-6, PMAM 41-9, PMAM 41-13, PMAM 41-15, PM 23-1, PM 23-2, PM 23-3, PM 23-11, PM 23-12, PM 23-13, PM 23-14, PM 23-15, PM 23-16, PMAM 24c-4, PMAM 24c-9, FNP 110-1, FNP 110-2, FNP 112-1, FNP 112-2, FNP 112-3, FNP 112-5, FNP 112-7, FNP 112-8, FNP 112-9, FNP 112-10, FNP 112-11, FNP 112-13, FNP 112-15, FNP 112-16, FNP 112-17, PMAM 42-1, PMAM 42-2, PMAM 42-3, PMAM 42-4, PMAM 42-5, PMAM 42-7, PMAM 42-10, PMAM 42-15, PMAM 42-17, PMAM 42-18, PMAM 42-19, PMAM 42-34, PMAM 42-41, PMAM 42-42, PMAM 42-48, PMAM 42-49, PMAM 42-52, PMAM 42-55, PMAM 42-56, PMAM 42-57, PMAM 42-60, PMAM 42-63, PMAM 42-64, PMAM 42-66, PMAM 42-68, PMAM 42-69, PMAM 42-74, PMAM 42-75, PMAM 42-76, PMAM 42-77, PMAM 42-81, PMAM 42-82, PMAM 42-83, PMAM 42-84, PMAM 42-85, PMAM 42-86, PMAM 42-87, PMAM 42-90, PMAM 42-91, PMAM 42-92, PMAM 42-93, FNP 115b-2, FNP 115b-3, FNP 115b-5, FNP 115b-6, FNP 116-1, FNP 116-2, FNP 116-3, FNP 118-1, FNP 118-2, FNP 118-4, FNP 118-5, FNP 118-6, FNP 122b-1, FNP 122b-2, FNP 138a-1, FNP 138a-3, PM 30-2, FNP 140.1-1, PM 31.1-1, PM 31.1-5).

**Description**. Forms slightly longer than high (H/L ratio ranges between 0.47 and 1.03; mean = 0.80; Tab. 1), with moderately inflated, slightly protruding beak positioned slightly in front of the middle of the cardinal margin (BP ranges between 0.35 and 0.48; mean = 0.43; Tab. 1).

The outline of the shell is ovate-oblique in the first growth stages and tends to become more lenticular during the ontogenesis (Fig. 8). The maximum H is located behind the beak at about 0.5 millimetres in the juveniles (H about 2.5 mm), shifts further towards the posterior in later growth stages (about 2 mm behind the beak at a H of 0.5-1 cm), and then shifts again towards the anterior in the adults, reaching a distance of 1-2 mm behind the beak in the adult stages (H about 2-2.5 mm and greater).

The anterior auricle is generally quite small (α ranges between 7° and 36.4°; mean = 17°; but some in specimens a reaches a value of about 30°; Tab. 1) and inflated; it can be clearly delimited by a deep groove at its base or not.

The radial sculpture consists of dense ribs; the primary ribs are moderately large and separated by quite wide and shallow furrows; they are split into 2 or 3 secondary ribs by secondary furrows, which are finer and shallower than the primary (R ranges between 17 and 28; mean = 24; Tab. 1). The commarginal sculpture is represented by growth striae and ridges. The ridges become more spaced and less strong with the growth.

The ribs stop at a variable, normally small distance from the anterior margin and at a greater distance (normally between 3 and 5 mm) from the posterior margin, leaving a broad posterior triangular field (β ranges between 32° and 53.6°; mean = 41.5°; Tab. 1) devoid of radial sculpture.

**Discussion on morphology**. *Halobia radiata* Gemmellaro is a very distinctive species amongst those present at Pizzo Mondello. The shell outline, the peculiar radial ornamentation and the lack of growth stop make it stand out when compared with the other species from the same interval (*Halobia lenticularis* (Gemmellaro), with broader ribs and *H. superba* Mojsisovics and *H*. cf. *rugosa*, with a growth stop).

**Discussion on synonymy**. As already observed by De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982), *H. radiata* Gemmellaro comprises *H. radiata radiata* Gemmellaro and *H. radiata hyatti* (Kittl) as its extreme forms. *Halobia radiata radiata* specimens generally show a smaller size, a more symmetrical outline and a beak in a more median position. *Halobia radiata hyatti*, on the other hand, is slightly more elongated, with a beak more shifted towards the anterior and a larger size. In fact, these two forms occur in the same sample (e.g., PM 23, PMAM 42 and PM 31.1). The smaller and larger specimens are here considered as different growth stages of *Halobia radiata*, having the same number of ribs (R), the same size of the auricle (α) and posterior triangular field (β) and having a constant H/L ratio (see Fig. 10). De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982), like other authors (e.g., Gruber 1976; McRoberts 1993), preferred to consider them as separate sub-species, even if recognising the fact that the two forms represented the morphological extremes of the same species.

*Halobia radiata* closely resembles *H. beyrichi* (Mojsisovics), but it can be distinguished by its smaller size, the lack of ribbing in the early ontogenetic stage and the extremely fine ribbing characteristic of later stages.

**Occurrence**. At Pizzo Mondello it can be found in association with *Halobia lenticularis*, *H. simpex, H. superba* and *H.* cf. *rugosa* in the middle part of the succession, from 39 levels: FNP 52, FNP 59a, FNP 67/68, FNP 68a, FNP 75, FNP 80, FNP 80a, FNP 90, FNP 91, NA 27, NA 27.1, NA 27.2, FNP 93, FNP 95, FNP 95a, FNP 95b, FNP 97, FNP 99b, FNP 99a, FNP 99c, NA 28, FNP 100, FNP 103, NA 29, NA 30, PMAM 41, PM 23, PMAM 24c, FNP 110, FNP 112, PMAM 42, FNP 115b, FNP 116, FNP 118, FNP 122b, FNP 138a, PM 30, FNP 140.1 and PM 31.1.

**Age**. *Halobia radiata* has a relatively short range spanning from the upper Carnian (Tuvalian 2-3) to the

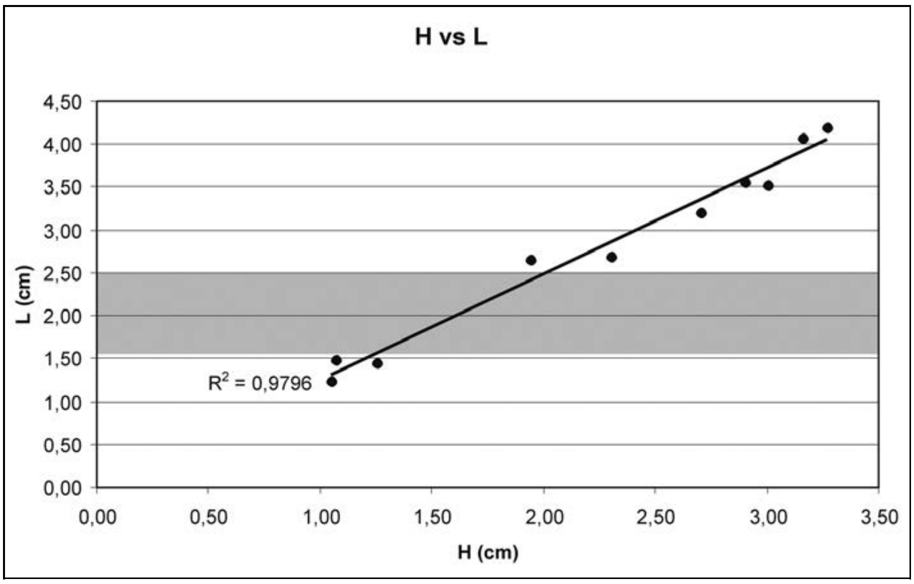



Fig. 10 - Scatter plot of H *vs* L data from *Halobia radiata* specimens from the samples PM 23, PMAM 42 and PM 31.1. Note the gap between the lengths of 1.5 and 2.5 cm.

lower Norian (Lacian 1) (Gruber 1977; Cafiero & De Capoa Bonardi 1982; Krystyn & Gallet 2002; Krystyn et al. 2002; McRoberts 1993, 2011).

### **Halobia simplex** Gemmellaro, 1882

Pl. 5, fig. 19

v 1882 *Halobia simplex* Gemmellaro, p. 466, pl. 1, figs. 7, 8.
1977 *Halobia simplex* - Gruber, p. 145.

**Types**: Lectotype: Original by Gemmellaro (1882, pl. 1, fig. 7), selected by Gruber (1976: 145): MGUP 002.304/1.

**Type locality**: Madonna del Balzo, Sicily.

**Stratum typicum:** "Cherty limestone" *sensu* Gemmellaro 1882 (lower Norian).

**Material**: 5 specimens: MPUM 10728 (FNP 62-1), MPUM 10729 (FNP 60a-3, FNP 60a-6, FNP 72-7, FNP 80a-35).

**Description**. Very thin shells, slightly longer than high (H/L ratio is about 0.85; Tab. 1), with not much inflated or protruding umbo located at about one third anterior of the cardinal margin (ACM:PCM ratio equal to 1:2).

The outline of the shell is sub-lenticular in the juvenile stages and tends to become slightly more elongated. The margins are rounded: the anterior and posterior are in continuity with the ventral margin, with no evident interruptions in the flexure.

Anterior auricle is quite narrow, not much inflated ("byssal tube"), apparently without the 'marginal list'. It is delimited at its base by a very shallow groove.

Radial sculpture consists of very thin, not easily visible ribs. Commarginal sculpture composed of growth striae and very light ridges.

The posterior triangular field is broad.

**Discussion**. *Halobia simplex* Gemmellaro is distinctive for its very thin ribs, that may not be visible without the magnifying glass or the microscope. It is similar to the juvenile stages of *Halobia radiata* Gemmellaro, but the latter can be distinguished on the basis of the more ovate outline and the larger ribs.

Since its original description by Gemmellaro (1882) the species has not been reported from Sicily by other authors, with the exception of Gruber (1976). It is considered an uncommon form.

**Occurrence**. This rare species is present in the middle part of the Pizzo Mondello succession, from 4 levels: FNP 60a, FNP 62, FNP 72 and FNP 80a.

**Age**. *Halobia simplex* is here attributed to the lower Norian (Lacian 1 *sensu* Gruber 1977).

### **Halobia superba** Mojsisovics, 1874

Pl. 1, figs 21-22

v 1874 *Halobia superba* Mojsisovics, p. 30, pl. 4, figs. 9, 10
1904 *Halobia superba* - Smith, p. 403, pl. 48, figs. 1, 2
1906 *Halobia superba* - Renz, p. 35, pl. 3, fig. 5
1908 *Halobia* aff. *superba* - Diener, p. 94, pl. 16, fig. 7
v 1912 *Halobia superba* - Kittl, p. 151, pl. 7, figs. 17, 18
1924 *Halobia superba* var. *timorensis* Krumbeck, p. 171, pl. 12, figs. 14-17
v 1927 *Halobia gigantea* Smith, p. 116, pl. 93, figs. 6, 7, pl. 94, figs. 1-3
v 1927 *Halobia oregonensis* Smith, p. 117, pl. 95, figs. 1, 2
v 1927 *Halobia superba* - Smith, p. 118, pl. 93, figs. 1-5, pl. 94, fig. 7, pl. 97, fig. 13
non 1959 *Monotis (Halobia) superba* Aubouin, pl. 4, fig. 2
v 1966 *Halobia superba* - Scandone & De Capoa Bonardi, pl. 6, fig. 1
1967 *Halobia superba* - Scandone, pl. 5, figs. 1, 2, pl. 7, figs. 1, 2
v 1969 *Halobia superba* - De Capoa Bonardi, p. 104, pl. 14, figs. 1-12, pl. 15, figs. 1-20
1977 *Halobia superba* - Gruber, p. 80, pl. 13, figs. 1-3
1986 *Halobia superba* - Chen & Ba, pl. 3, figs. 4, 7, 13
1991 *Zittelihalobia superba* - Vu Khuc, p. 62, pl. 12, figs. 13-16
1993 *Halobia superba superba* - McRoberts, p. 206, figs. 6.8-6.11
1994 *Halobia (Zittelihalobia) superba* - Campbell, p. 87, pl. 11, figs. 9, 11, 12, 13, 14, 15, frontispiece fig. 7

**Types:** Lectotype: Original specimen of Mojsisovics (1874, pl. 4, fig. 10) selected by Campbell (1994: 87): GBA 1874/001/0040.

**Type locality:** Vorderer Sandling, Alt Aussee, Austria.

**Stratum typicum:** Hallstätt Limestone *sensu* Gruber 1977.

**Material:** 6 specimens: MPUM 10730 (NA 23-5), MPUM 10731 (FNP 67/68-23, FNP 80a-17, FNP 80a-30, FNP 85-2, PMAM 48-1).

**Description**. Medium sized form, with sub-lenticular outline (H/L ratio ranges between 0.74 and 0.83; mean = 0.78; Tab. 1) in the early growth stage, becoming longer than high in the adult stages (H/L ratio ranges between 0.64 and 0.67; mean = 0.72; Tab. 1). Umbo is not much inflated, not much protruding, located at about one third of the cardinal margin towards the anterior (ACM:PCM ratio is 1:2).

Maximum height is located at about 0.3 mm behind the beak in the juvenile stages with H less than 0.6 cm, then it shifts at about 1 mm behind the beak before the growth stop (H of about 0.8-1.1 cm), remains in that position for about 2-3 mm of height across the growth stop, and then moves further towards the posterior (about 1.5 mm behind the beak at a H of 1.3 cm; Fig. 9).

Anterior auricle is moderately broad ($\alpha$ ranges between 19.7° and 26°; mean = 23°; Tab. 1), inferiorly convex ("byssal tube") and superiorly narrow and flat ('marginal list'). It is delimited at its base by a broad and shallow groove.

Radial sculpture consists of very thin and dense ribs, rounded on top, divided by furrows of approximately the same width and strength. The ribs are almost straight dorsal to the growth stop, and present a sharp forward shift after the growth stop, from which they start to become slightly divaricated (R ranges between 18 and 20; mean = 19; Tab. 1). Growth striae are very fine and dense; they seem to disappear at the growth-stop (GS ranges between 0.80 and 1.20 centimetres; mean = 1.00 cm; Figs. 8 and 9), then they become visible again. Growth stop at about 1.3-1.5 cm of height from the beak (Fig. 8). The growth stop represents an easily visible bulge on the shell.

The posterior triangular field is moderately large and free of ribs.

**Discussion on morphology**. Due to its peculiar pattern of radial ornamentation and to its distinctive shape of the shell, *Halobia superba* Mojsisovics can be easily distinguished from other *Halobia* forms, with the exception of *H.* cf. *rugosa*. In fact, the latter taxon shows a great similarity with *H. superba* in terms of ribs' broadness and shell outline. *Halobia superba* and *H.* cf. *rugosa* can be distinguished on the bases of the distance from the beak at which the ribs arise: in the first form the ribs arise at about 1-3 mm from the beak, while in the latter they arise at about 7-8 mm from the beak. The ease in its recognition, in association with the widespread distribution of this form in both Tethyan and North American, as well as Boreal (Campbell 1994), realms, makes *Halobia superba* a very useful tool for biostratigraphic correlations.

**Discussion on synonymy**. Gruber (1983) considered *H. oregonensis* Smith, *H. gigantea* Smith and *H. ornatissima* Smith to be conspecific with *H. superba*. After the study of the plastotypes of the original specimens by Smith (1927) stored at SUNY, Cortland and at the Dipartimento di Scienze della Terra, Milan, the writer came to the same conclusions as the previous authors in considering *H. oregonensis* and *H. gigantea* to be probably conspecific with *H. superba*, or at least part of a common lineage (refer to Mull et al. 1982 for the stratigraphic information). As stated by McRoberts (2011), *H. ornatissima* represents a different taxon. A form described by Krumbeck (1924) from Timor as *Halobia superba* var. *timorensis* is also considered by Campbell (1994) probably conspecific. The specimens from Sicily are always smaller than those of the classic collections from North America. This difference in size is certainly due to taphonomy: in the material from Pizzo Mondello most of the specimens are clearly fractured and incomplete, so what remains is only a small portion of the younger growth stages. Comparing our specimens with North American material of comparable size, they result to belong to the same species. In fact, they show the same outline, ribbing pattern and position of the growth stop.

**Occurrence**. The specimens of this rare form come from the middle part of the Pizzo Mondello succession, from 5 levels: FNP 67/68, NA 23, FNP 80a, FNP85 and PMAM 48.

**Age**. Given its stratigraphic position at Pizzo Mondello, *Halobia superba* is here considered as belonging to the upper Cranian (Tuvalian 3).

### **Halobia austriaca** Mojsisovics, 1874

Pl. 3, figs 1-19; Pl. 5, figs 20-21

v 1874 *Halobia austriaca* Mojsisovics, p. 26, pl. 4, figs. 1-3, pl. 5, fig. 4
v 1912 *Halobia austriaca* - Kittl, p. 101, pl. 6, figs. 11, 14
v 1912 *Halobia* cf. *austriaca* Kittl, p. 101, pl. 6, figs. 12, 13
v 1912 *Halobia subaustriaca* Kittl, p. 101, pl. 6, figs. 15-16
v 1912 *Halobia bukovinensis* Kittl, p. 103, textfigs. 20-22
v 1912 *Halobia siciliana* Kittl, p. 104, pl. 8, figs. 1, 2
v 1912 *Halobia ocevjana* Kittl, p. 158, pl. 7, f. 22, textfig. 36
v 1927 *Halobia austriaca* - Smith, p. 113, pl. 99, figs. 10-13
v 1927 *Halobia brooksi* Smith, p. 114, pl. 99, figs. 7-9
v 1966 *Halobia austriaca* - Scandone & De Capoa Bonardi, pl. 7, f. 2
v 1966 *Halobia* cf. *fascigera* Scandone & De Capoa Bonardi, pl. 6, fig. 2
v 1969 *Halobia austriaca* – De Capoa Bonardi, p. 64, pl. 12, figs. 1-12, pl. 13, figs. 1-13
1975 *Halobia austriaca* - Gruber, p. 128, pl. 3, figs. 1-4
1977 *Halobia austriaca* - Gruber, p. 48, pl. 6, figs. 1-4
1982 *Halobia lilliei* Marwick; Campbell, p. 490, fig. 3
v 1984 *Halobia austriaca* - De Capoa Bonardi, p. 94, pl. 2, figs. 1-8 and references therein
1986 *Halobia asutriaca* - Chen & Ba, pl. 1, figs. 1, 2, 6
1991 *Halobia austriaca* - Vu Khuc, p. 64, pl. 13, figs. 15-19
1994 *Halobia (Halobia) austriaca* - Campbell, p. 99, pl. 10, figs. 1, 3-11, frontispiece figs. 13, 14, 15
2002 *Halobia austriaca* - Krystyn & Gallet, p. 15
2011 *Halobia radiata* - McRoberts, p. 627, figs 18.1-18.6, 20

**Types:** Lectotype: Original specimen of Mojsisovics (1874, pl. 4, fig. 3) selected by Campbell (1994: 99): GBA 1874/001/0031

**Type locality:** Raschberg, Bad Goisern, Austria.

**Stratum typicum:** Hallstätt Limestone (lower Norian *sensu* Gruber 1977).

**Material:** 20 specimens: MPUM 10732 (FNP 147bis-5), MPUM 10733 (FNP 147-14), MPUM 10734 (FNP 147-8), MPUM 10735 (FNP 147-4), MPUM 10736 (FNP 135a-1), MPUM 10737 (PM 30a-4, FNP 145-1, FNP 147-1, FNP 147-2, FNP 147-3, FNP 147-6, FNP 147-11, FNP 147-12, FNP 147-13, FNP 147-15, FNP 147bis-1, FNP 147bis-2, FNP 147bis-3, FNP 147bis-4), MPUM 10752 (FNP 147-5).

**Description**. Shells of medium to large size (up to 4 centimetres in length), longer than high (H/L ratio ranges between 0.57 and 0.89; mean = 0.75; Tab. 1), of low inflation, with sharp beak located at little less than one third anterior of the cardinal margin (BP ranges between 0.29 and 0.46; mean = 0.40; Tab. 1).

The outline of the shell is slightly elongated to elongated in the juvenile stages and tends to become lenticular or sub-lenticular during the ontogenesis (Fig. 8). The maximum H is located at about 0.5 mm behind the beak in the juvenile forms (H about 3 mm) and it shifts to about 2.5-3 mm behind the beak in the adult forms, since it seems to be stable in that position for H of more than about 1 centimetre. Sometimes the position of the maximum H shifts slightly forward at H of about 2 cm or more (Fig. 9).

Anterior auricle is quite broad (α ranges between 14° and 31°; mean = 22°; Tab. 1), often divided into a lower inflated portion ("byssal tube"), at times bipartite by a weak furrow, and an upper narrow and flat to slightly convex portion ('marginal list'). It is separated from the rest of the shell by a deep groove.

Radial sculpture consists of quite broad, top rounded primary ribs, slightly bent forward (at least on the anterior portion of the shell), separated by deep furrows. The ribs are split into two or three secondary ribs by the introduction of narrower and shallower furrows at variable distance from the beak (generally between 0.6 and 1.1 centimetres; R ranges between 6 and 11; mean = 9; Tab. 1). Commarginal sculpture of growth striae and weak ridges limited to the first few millimetres from the beak.

Posterior triangular field broad (β ranges between 28° and 34°; mean = 30.5°; Tab. 1), with the ribs that fade and stop at considerable distance from the cardinal margin.

**Discussion on morphology**. *Halobia austriaca* Mojsisovics is a distinctive form because of its outline, and pattern of ribbing. These characters, together with the medium to large size, make this species clearly recognisable when compared to *H. radiata* Gemmellaro. The difference between this species and *H. styriaca* (Mojsisovics) can be less evident. Nonetheless, the more inflated, and slightly broader, auricle and the greater inflation of the shell can be used as distinctive characters for the identification of *H. austriaca*.

**Discussion on synonymy**. De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982) observed that the species *Halobia siciliana* Kittl, *H. bukowinensis* Kittl and *H. subaustriaca* Kittl, originally described by Kittl in 1912, bear a great resemblance with *H. austriaca*, to the point that she proposed to consider them as synonyms. Through the careful study and comparison of the new specimens with the specimens collected by Mojsisovics (1874), Kittl (1912), Smith (1927), De Capoa Bonardi (1984) and Krystyn (various years) it is possible to confirm the synonymy of these species. Moreover, as suggested by Gruber (1976), *H. ocevjana* Kittl, 1912 resulted to be another synonym of *H. austriaca*.

*Halobia austriaca* is one of the species of *Halobia* with the widest geographic distribution. It was reported from the upper Carnian (Tuvalian) of the Alps by Mojsisovics (1874), Schlosser (1898), Arthaber (in Frech, *Lethaea Mesozoica*) and Kittl (1912). Arthaber also refers its occurrence in the *Trachyceras aonoides* zone of the Hallstatt Limestones. Later workers, like De Capoa Bonardi (1966) and Scandone (1967) found *H. austriaca* in Lucania (Italy), and dated this occurrence as Carnian, while Butrico (1930) reported this species from Sicily (contrada Modanesi).

In Grece, *H. austriaca* was identified for the first time by Renz (1906) then it was reported by Renz (1916), Frech & Renz (1916) and Renz & Frech (in Frech 1095) and De Capoa Bonardi (1984). However, Renz himself later (1955) corrected and simplified his previous attributions, while Arthaber (in Frech, *Lethaea Mesozoica*) reported this species from the Carnian of the Eastern Carpathians.

In Hungary *Halobia austriaca* was found by Kutassy (1928) in Carnian rocks. This species was identified by Krumbeck (1924) from Timor. Rothpletz (1892) attributed a specimen (Rothplez 1892, pl. 14, fig. 6) from Timor to *Daonella lommeli* (Wissmann), howerver Kittl (1912) identified the same specimen as *Halobia nadamalensis* Kittl. According to Krumbeck, the sample belongs to *H.* cf. *austriaca*. Also Wanner (1956) reported finding *H. austriaca* from the upper Carnian (*Tropites subbullatus* zone, Tuvalian) of Timor, while Saurin (1956) found it in the upper Carnian of the Indochina. The species seems to be present also in the Upper Triassic of Himalaya: Krumbeck (1924) identified as *H. austriaca* the material previously attributed to *Halobia* sp. by Bittner (1899).

In Japan, Ichikawa (1954) found *Halobia* cf. *austriaca*, attributed by De Capoa Bonardi (1969) to *H. austriaca*, in the Sakawano, corresponding to about the middle of the Carnian. In North America, *H. austriaca* is present in California and Alaska in the *Tropites subbullatus* zone (Smith 1927). Moreover, according to De Capoa Bonardi (1969), forms which can be referred to *H. austriaca* were found, but not described, by Bittner (1902) in the Triassic of Bosnia, and by Nakazawa (1955) in the Upper Triassic of Japan.

**Occurrence**. *Halobia austriaca* occurs at Pizzo Mondello in the upper part of the succession, right below the *H. styriaca* (Mojsisovics) interval, in 5 levels: FNP 135a, PM 30a, FNP 145, FNP 147 and FNP 147bis.

**Age**. *Halobia austriaca* is considered as the best datum for the lower part of the Lacian 1 (corresponding to the lower Kerri Zone in North America *sensu* McRoberts 1993, and to the lower Jandianus Zone in the Tethyan realm *sensu* Krystyn & Gallet 2002; Krystyn et al. 2002) at Pizzo Mondello.

### **Halobia styriaca** (Mojsisovics, 1874)

Pl. 4, figs 1-12

v 1874 *Daonella styriaca* Mojsisovics, p. 10, pl. 1, figs. 4, 5
v 1874 *Daonella cassiana* Mojsisovics, p. 10, pl. 1, figs. 4-5
v 1874 *Daonella solitaria* Mojsisovics, p. 11, pl. 1, fig. 6
v 1874 *Halobia rarestricta* Mojsisovics, p. 24, pl. 5, figs. 10, 11

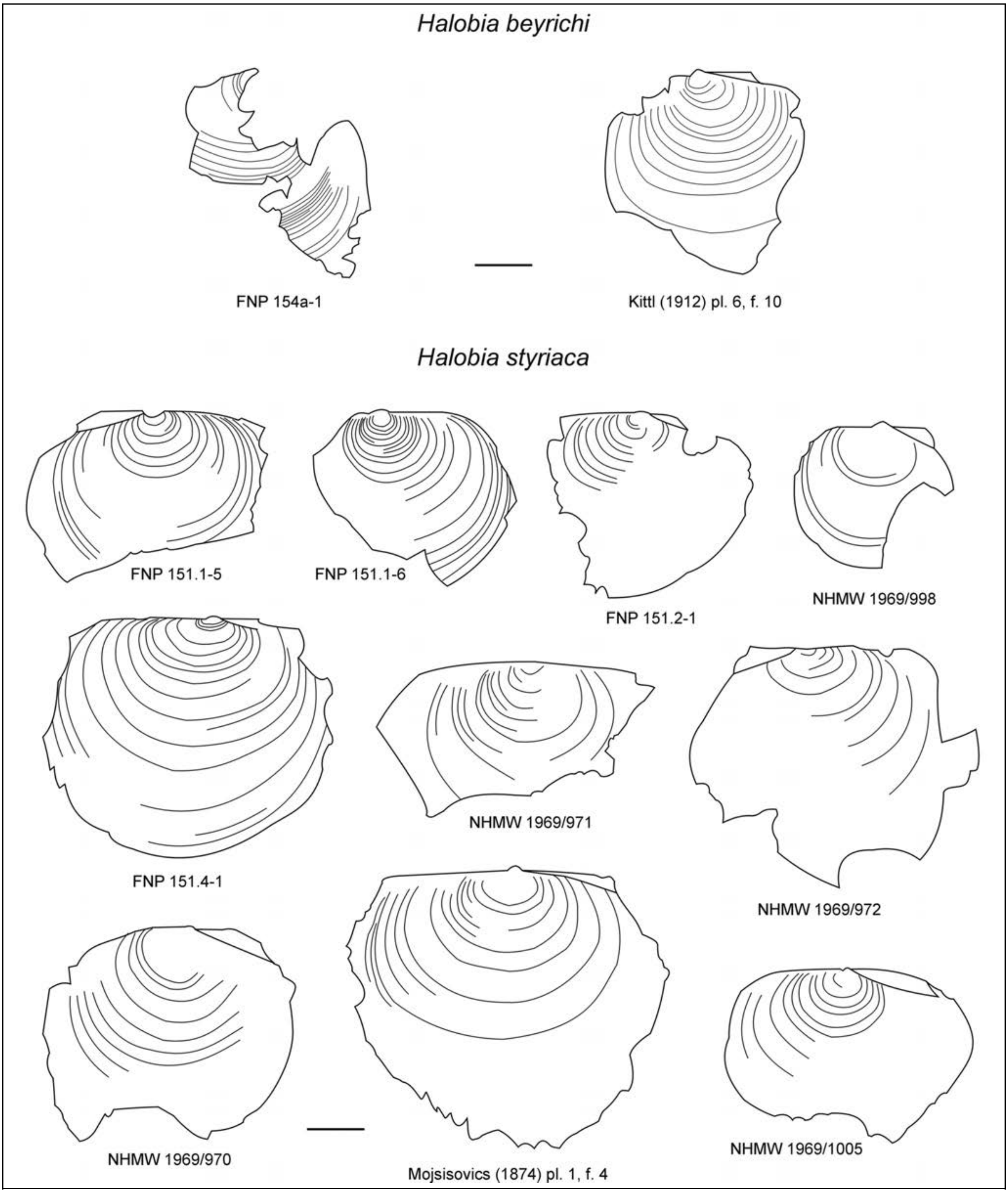



Fig. 11 - Sketches of the outline and growth stages of *Halobia beyrichi* and *H. styriaca*. Scale bar = 1 centimetre.

v 1882 *Daonella styriaca* - Gemmellaro, p. 467, pl. 1, figs. 1, 2

v 1912 *Halobia styriaca* - Kittl, p. 91, pl. 6, figs. 4.5 partim

v 1966 *Halobia styriaca* - Scandone & De Capoa Bonardi, pl. 3, fig. 2

1967 *Halobia styriaca* - De Capoa Bonardi, in Scandone, pl. 4, fig. 3, pl. 8, fig. 3

non 1967 *Halobia* cf. *cassiana* (emend. Krumbeck) De Capoa Bonardi, in Scandone, pl. 4, fig. 1-2, pl. 8, fig. 4

v 1969 *Halobia styriaca* - De Capoa Bonardi, p. 95, pl. 9, figs. 1-10, pl. 10, figs. 1-8

non 1969 *Halobia* cf. *cassiana* (emend. Krumbeck) - De Capoa Bonardi, p. 111, pl. 11, figs. 2, 6

1976 *Perihalobia styriaca* - Gruber, p. 192

1977 *Perihalobia styriaca* - Gruber, p. 28, pl. 1, fig. 5, pl. 2, figs. 1-2

v 1980 *Halobia styriaca* - Cafiero & De Capoa Bonardi, p. 197, pl. 3, figs. 9-10, pl. 4, figs. 1-3

v 1984 *Halobia styriaca* - De Capoa Bonardi, p. 94, pl. 1, fig. 7 and references therein
1986 *Halobia styriaca* - Chen & Ba, pl. 1, figs. 5, 8, 9, 12, 16, 17
1991 *Halobia styriaca* – Vu Khuc, p. 66, pl. 13, figs. 22-23
1991 *Halobia substyriaca* - Vu Khuc, p. 66, pl. 13, figs. 20-21
1994 *Halobia (Halobia) styriaca* - Campbell, p. 97, pl. 10, fig. 2
2002 *Halobia styriaca* - Krystyn & Gallet., textfig. 5

**Types:** Lectotype: Original specimen of Mojsisovics (1874, pl. 1, fig. 4) selected by Gruber (1976: 192): GBA 1874/001/0007.

**Type Locality:** Feuerkogel, Bad Aussee, Austria.

**Stratum typicum:** Hallstätt Limestone; Kerri Zone *sensu* Gruber (1977) of the Roter-Bank Limestone (corresponding to the Jandianus Zone in the Tethys).

**Material:** 70 specimens: MPUM 10738 (NA 45-1), MPUM 10739 (FNP 151.1-5), MPUM 10740 (FNP 151.1-6), MPUM 10741 (FNP 151.2-1), MPUM 10742 (FNP 151.4-1), MPUM 10743 (NA 44-1, FNP 150a-1, FNP 150a-2, FNP 150a-3, FNP 150a-4, FNP 150/151-1, FNP 150/151-2, FNP 151det-1, FNP 151det-2, FNP 151det1-1, FNP 151det1-2, FNP 151det1-3, FNP 151det1-4, FNP 151det1-5, FNP 151.1-1, FNP 151.1-2, FNP 1511.-3, FNP 151.1-4, FNP 151.1-7, FNP 151.1-8, FNP 151.1-9, FNP 151.1-10, FNP 151.1-11, FNP 151.1-12, FNP 151a-1, FNP 151a-2, FNP 151.4-2, FNP 151.4-3, FNP 151.4-4, FNP 151.4-5, FNP 151.4-6, FNP 151.4-7, FNP 151.4-8, FNP 151.4-9, FNP 151.4-10, FNP 151.4-11, FNP 151.4-12, FNP 151.4-13, FNP 151.4-14, FNP 151.4-15, FNP 151.4-16, NA 45-2, NA 45-3, NA 45-4, NA 45-5, NA 45-6, NA 45-7, NA 45-8, FNP 152-1, FNP 152-2, FNP 152-3, FNP 152-4, FNP 152-5, PM 33-1, PM 33-2, PM 33-3, PM 33-4, PM 33-5, PM 33-6, PM 33-7, PM 33-8, PM 33-9, PM 33-10, PM 33-11, FNP 153det-1, FNP 153det-2).

**Description**. The specimens of this species are larger than those of the other species form Pizzo Mondello, easily reaching a diameter of 3 to 5 cm.

The shell is very flat, slightly elongated in the juvenile stages, then lenticular to sub-lenticular in the adults (H/L ratio ranges between 0.70 and 0.90; mean = 0.76; Tab. 1; Fig. 11), with a not much inflated or protruding umbo, in a sub-central position (BP ranges between 0.37 and 0.52; mean = 0.44; Tab. 1), stable through the ontogenesis. The maximum H is located at about 0.5-1 mm behind the beak in the first growth stage (H less than 1 centimetre), then shifts constantly to the posterior reaching a distance of 2.5-3 mm from the beak in the adults (H between 2.4 and 3.4 cm; Fig. 9).

The anterior auricle is large ($\alpha$ ranges between 17° and 26.4°; mean = 21°; Tab. 1), with a lower, moderately inflated portion ("byssal tube") and an upper, almost as large, flat portion 'marginal list'); it is delimited by a more or less deep groove at its base.

The radial sculpture consists of broad, with round to flat tops primary ribs separated by narrow furrows (R ranges between 9 and 12; mean = 10; Tab. 1). Secondary ribs develop at about one third to half of the shell height and are delimited by narrower and shallower secondary furrows. The commarginal sculpture presents dense growth striae and rare, low ridges.

The posterior triangular field is moderately broad ($\beta$ ranges between 16° and 33°; mean = 22°; Tab. 1) and only sculptured by the thin growth striae.

**Discussion**. *Halobia styriaca* (Mojsisovics) is easily recognizable for its large size, generally circular shape and broad radial sculpture. *Halobia austriaca* Mojsisovics is the species most similar to *H. styriaca*, but the first is distinguishable from the latter because of the higher inflation and the slightly broader auricle.

**Occurrence**. At Pizzo Mondello, the *Halobia styriaca* specimens come from a well defined and easily recognisable stratigraphic interval of about 4 metres, including 12 levels NA 44, FNP 150a, FNP 150/151, FNP 151det, FNP 151.1, FNP 151a, FNP 151.2, FNP 151.4, NA 45, FNP 152, PM 33, FNP 153det.

**Age**. *Halobia styriaca* is another good marker for the lower Norian (*sensu* Krystyn & Gallet 2002; Krystyn et al. 2002).

### **Halobia beyrichi** (Mojsisovics, 1874)

Pl. 1, figs 23-24

v 1874 *Daonella beyrichi* Mojsisovics, p. 11, pl. 1, fig. 7
v 1912 *Halobia beyrichi* - Kittl, p. 96, pl. 1, figs. 30-31; pl. 6, fig. 10
v 1912 *Halobia arthaberi* Kittl, p. 97, pl. 5, fig. 11, textfig. 19
non1927 *Halobia alaskana* Smith, p. 113, pl. 100, figs. 5-7
1927 *Halobia dilatata* - Smith, p. 115, pl. 100, figs. 1-4
1959 *Monotis (Halobia) superba* - Aubouin, pl. 4, fig. 2
1963 *Halobia cassiana* - Stefanov, p. 94, pl. 4, figs. 1, 2, 6
1964 *Halobia cassiana* - Aubouin, pl. 36, fig. 1
1975 *Halobia beyrichi* - Gruber, pl. 3, fig. 5
1976 *Halobia* cf. *suessi* - Patrulius et al., pl. 2, figs. 2-3
1976 *Perihalobia beyrichi beyrichi* - Gruber, p. 32, pl. 3, figs. 1-3
non 1976 *Perihalobia beyrichi alaskana* - Gruber, p. 35, pl. 4, figs. 1-2
2002 *Halobia beyrichi* - Krystyn & Gallet, p. 17, textfig. 5
non 2008 *Halobia* cf. *beyrichi* - Levera & McRoberts, p. 20

**Types**: Original specimen of Mojsisovics (1874, pl. 1, fig. 7), selected by Gruber (1976: 32): GBA 1874/001/0008.

**Type locality**: Feuerkogel / Bad Aussee, Stmk.

**Stratum typicum:** Hallstätt Limestone (lower Norian, Lacian 1 *sensu* Gruber 1977).

**Material:** 7 specimens: MPUM 10744 (FNP 154a-1), MPUM 10745 (FNP 154a-2), MPUM 10746 (FNP 154a-3, FNP 154b-1, FNP 154b-2, FNP 154b-3, FNP 154b 4).

**Description.** The shape of *Halobia beyrichi* is sub-lenticular to lenticular in all growth stages (H/L ranges between 0.55 and 0.77; mean = 0.70; Tab. 1, Fig. 11). The beak is slightly inflated and does not protrude much beyond the cardinal margin; it is located slightly before the half of the cardinal margin.

The auricle is quite narrow (only one auricle is preserved enoguh to be measured and shows a value of $\alpha$ = 17°; Tab. 1) and slightly inflated; sometimes it is delimited by a furrow at its base.

The radial sculpture consists of a quite high number of ribs (R ranges between 18 and 20 mean = 19; Tab. 1), which start at about 7-8 mm from the beak. They subdivide into 2-3 fine secondary ribs, separated by finer and shallower furrows, at about 1 cm from the beak. The secondary ribs may be in bundles. The ribs stop at a great distance from both the anterior and posterior cardinal margins. The commarginal sculpture consists of very fine growth striae and weak ridges which become more wide and spaced towards the ventral margin.

The posterior triangular field is quite broad (mean β = 50°; Tab. 1).

**Discussion on morphology.** In *Halobia beyrichi* (Mojsisovics), the beak can be either weak and rounded or sharp and protruding. This is due to the preservation: it is weak and rounded in the internal moulds and sharp and protruding in specimens with the test (Gruber 1976).

**Discussion on synonymy.** Smith (1927: 115) classified as *Halobia dilatata* Kittl (a junior synonym of *Halobia halorica* Mojsisovics) some specimens clearly belonging to *Halobia beyrichi*. The first species is distinguished by a strongly elongated outline in the posterior portion of the shell, and ribs which are fasciculate up to the posterior margin of the shell. Since Kittl (1912), *Halobia beyrichi* has always been confronted with *Halobia styriaca* (Mojsisovics), but it has a greater number of ribs, as well as a smaller auricle, delimited at the base by a furrow.

**Occurrence.** *Halobia beyrichi* occurs at Pizzo Mondello in the upper part of the succession, the interval between the *H. styriaca* and *H. mediterranea* Gemmellaro, in 4 levels: PM 33, FNP 154a, FNP 154b and FNP 154.

**Age.** *Halobia beyrichi* is regarded here as a good datum for the upper part of the Lacian 1 (lower Norian).

### **Halobia mediterranea** Gemmellaro, 1882

Pl. 5, figs 1-9

v 1882 *Halobia mediterranea* Gemmellaro, p. 462, pl. 3, figs. 7-9

v 1882 *Halobia beneckei* Gemmellaro, p. 460, pl. 3, figs. 3, 4, pl. 4, figs. 4, 5

v 1882 *Halobia curionii* Gemmellaro, p. 461, pl. 3, figs. 5, 6

? 1899 *Halobia kwaluana* var. *multistriata* Volz, p. 34, pl. 1, fig. 11

? 1910 *Halobia mediterranea* - Scalia, p. 46, pl. 3, fig. 43

1912 *Halobia beneckei* - Kittl, p. 127

1969 *Halobia charlyana* - De Capoa Bonardi, (*partim*), pl. 16, figs. 13-14, 18-21

1977 *Halobia beneckei* - Gruber, p. 113, pl. 20, figs. 1-5

1980 *Halobia beneckei* - Cafiero & De Capoa Bonardi, p. 189, pl. 5, figs. 2-3

v 1982 *Halobia beneckei* - Cafiero & De Capoa Bonardi, p. 46, pl. 4, figs. 1-9, textfig. 4

v 1982 *Halobia mediterranea* - Cafiero & De Capoa Bonardi, p. 58, pl.7, figs. 1-10, textfig. 7

1984 *Halobia mediterranea* - De Capoa Bonardi, p. 96 and references therein

**Types:** Lectotype: Original by Gemmellaro (1882, pl. 3, fig. 7), selected by De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982: 58): MGUP 002.293/1. Paralectotypes: Originals by Gemmellaro (1882, pl. 3, figs. 5, 6, 8 and 9): MGUP 002.292/1, MGUP 002.292/2, MGUP 002.293/2, MGUP 002.293/3.

**Type locality:** Madonna del Balzo (Bisacquino), Sicily, Italy.

**Stratum typicum:** "Cherty limestone" *sensu* Gemmellaro 1882 (lower Norian).

**Material:** 23 specimens: MPUM 10747 (FNP 170.2-1), MPUM 10748 (FNP 170.2-3), MPUM 10749 (FNP 170.2-8), MPUM 10750 (NA 50.3-1), MPUM 10751 (PM 36.1-1, PM 36.1-2, PM 36.2-1, NA 48.1-1, NA 48.1-2, NA 48.1-4, NA 48.1-5, NA 50.3-2, NA 50.3-3, NA 50.2-2, NA 50.1-1, PM 37.1-1, PM 37.1-2, FNP 170.2-2, FNP 170.3-2, FNP 170.3-3, FNP 170.3-4, FNP 170.3-5, FNP 170.4-1).

**Description**. Ovate-oblique forms, with rounded anterior margin which passes, in continuity with the ventral margin, to the oblique posterior (at times slightly receding at the connection with the cardinal margin, with 'hook' shape; Fig. 8). Umbo is quite inflated, being one of the most inflated observed in this genus, pointed, moderately protruding, located at one third (juveniles) to one fourth (adults) anterior of the cardinal margin (ratio ACM:PCM equal to 1:2 and 1:3 respectively; BP ranges between 0.37 and 0.43; mean = 0.40; Tab. 1).

L greater than H (H/L ratio ranges between 0.65 and 0.80; mean = 0.75; Tab. 1). The maximum H is located slightly in front of the beak (about 0.4 mm for H less than 2 mm) in the first juvenile stages and rapidly shifts to about 0.5 mm behind the beak (H about 3 mm), to reach a stable position at about 2.5-3 mm behind the beak in the adult stages (H about 1.5 cm; Fig. 9).

Anterior auricle is moderately broad (α ranges between 14° and 21.5°; mean = 17°; Tab. 1), often clearly divided into a lower inflated, at times strongly inflated, portion ("byssal tube") and an upper flat or slightly sloping towards the cardinal margin portion ('marginal list'), which is not always present or is very narrow. The auricle is delimited by a deep groove at its base and may show a light furrow between its upper and lower parts.

The radial sculpture consists of broad, flat or slightly top rounded primary ribs, slightly bent forward at least on the anterior portion of the shell, which are separated by narrow and light furrows slightly broader on the anterior portion of the shell. The ribs appear at 3-5 mm from the beak and, at about 0.7-1 cm from the beak, they are often split into two or rarely three secondary ribs by the introduction of secondary furrows, narrower and lighter than the primary (R ranges between 17 and 19; mean = 18; Tab. 1). The costation pattern fades and stops at 2-3 mm from the base of the anterior auricle and at a variable distance of about 0.5-1 cm from the posterior cardinal margin. The commarginal sculpture consists of growth striae and ridges, thick and strong near the beak, more easily visible in the area not yet covered by the ribs. The ridges, often stronger on the middle portion of the shell, are more spaced and less strong towards the ventral margin. In the juvenile specimens, the ridges are always more visible.

The posterior triangular field is broad (β ranges between 40.5° and 48°; mean = 45°; Tab. 1). It can show a narrow "list" towards the cardinal margin, apparently separated by a light furrow and slightly inflated.

During the ontogeny, the position of the beak frequently 'shifts' towards the anterior margin. As a consequence, the proportion between the ACM and the PCM changes from 1:2 to 1:3 or 1:4 from the juveniles to the adults, implying a greater development in the posterior part of the shell with respect to the anterior.

**Discussion on morphology**. The distinctive pattern of ornamentation, together with the shell shape and size, allows the easy recognition of *Halobia mediterranea* Gemmellaro.

**Discussion on synonymy**. In literature there are different opinions on the morphology of *Halobia mediterranea* and its synonymies with the other two species of the same group erected by Gemmellaro (1882): *Halobia beneckei* Gemmellaro, *H. curionii* Gemmellaro and *H. mediterranea*.

Gruber (1977), in his upublished PhD thesis, considered *Halobia beneckei* as valid species, including *H. curionii* and *H. mediterranea* as synonyms, probably because of priority of pages. This kind of consideration is not valid for establishing the priority of synonymies based on the rules of the International Code of Zoological Nomenclature (1999, Chapter 12, Article 52), which suggests to select the best species with the best description of the characters of the form, and secondarily the most used in literature.

Montanari & Renda (1977) reported *Halobia beneckei* from M. Triona (without figuring it), and they considered it to be in synonymy with *H. mediterranea* and *H. mojsisovicsi* Gemmellaro.

De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982), while revising the original material by Gemmellaro (1882), proposed the synonymy between *Halobia mediterranea* and *H. curionii*, both by Gemmellaro (1882), where the last would represent a juvenile/subadult form of the first, having the same characters, but smaller size. At the same time, De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982: 48) argued that: "riteniamo inoltre che *H. beneckei* si distingua facilmente da *H. mediterranea* per l'assenza della vasta area posteriore priva di coste, per le coste radiali più incise, più sottili e meno suddivise e per l'orecchietta, indivisa, più stretta e più alta."

A translation reads as follows: 'we moreover believe that *Halobia beneckei* can be easily distinguished from *H. mediterranea* for the absence of the broad posterior triangular field free of ribs, for the more incised, thinner and less split radial ribs and for the un-divided, narrower and more inflated anterior auricle.'

In order to contribute to the solution of the problem of the relationships between *Halobia beneckei*, *H. curionii* and *H. mediterranea*, the type material housed at the Museo Paleontologico G. G. Gemmellaro in Palermo has been studied.

*Halobia curionii* is represented by 4 specimens, all of which smaller than 2 cm in length. The general outline is consistent with that of the younger stages of both *H. mediterranea* and *H. beneckei*. The position of the beak is also typical of the younger stages of both those species, being the ACM:PCM ratio about 1:2 to 1:2.5. Finally, the radial and commarginal sculptures show the pattern of the inner stages of *H. mediterranea*. Thus, *H. curionii* is confirmed as synonym of *H. mediterranea*, of which represents a juvenile/sub-adult form, as suggested by De Capoa Bonardi (in Cafiero & De Capoa Bonardi 1982).

*Halobia mediterranea* is represented by 6 specimens, with length up to 4 cm, while *H. beneckei* is represented by 4 specimens, with length up to 3 cm. The specimens of both species show consistent inflation and height/length ratio, as well as ACM/PCM ratio. The radial sculpture is very similar, as well as the outline and the broadness of both the auricle and the posterior triangular field. Moreover, comparing the original descriptions of *H. mediterranea* and *H. beneckei*, it is clear that the first is more complete, including details about size, general outline, subdivisions of the cardinal margin and position of the beak, shape and size of the anterior auricle, pattern of radial and commarginal sculptures, shape and size of the posterior triangular field and characters of the juvenile stages. On the other hand, the description of *H. beneckei* is less complete with respect to the size, the pattern of costation and the characters of the juveniles.

Therefore, the name of *Halobia mediterranea* is used in this paper for this species because it has the best original description by Gemmellaro (1882: 462) and because it is the one which best corresponds to that description, as required by the International Code of Zoological Nomenclature (1999, Chapter 6, Article 24).

**Discussion on the original illustrations.** As a general note, the furrows are always more evident in the illustrations in Gemmellaro's monograph (1882) than they are in the actual specimens. This may give a wrong impression on the sculpture pattern, and even hide some important features. For example, in the specimen of *Halobia curionii* from fig. 5 of pl. 3 of Gemmellaro (1882), the very shallow and incomplete furrows on the posterior side are drawn so that the ribs seem to continue with the same strength almost until the cardinal margin, delimiting a smaller posterior triangular field. On the same specimen, there is also a small area devoid of ribs just below the anterior auricle, but in the illustration it is shown again as covered by the ribs.

Moreover, in the description of *Halobia curionii*, Gemmellaro stated that the furrows in his specimens were always as broad as the ribs, and he considered this to be a distinctive character between this form and *H. mediterranea*. Looking at the original material, it can be noted that only one of the figured specimens (Gemmellaro 1882: pl. 3, fig. 6) shows furrows as broad as the ribs, while in all the others (even the ones not illustrated by Gemmellaro), the furrows are thinner than the ribs. This is here considered to be an individual variation, rather than a distinctive character of a new species.

**Occurrence**. The material from Pizzo Mondello comes from the uppermost part of the succession, below the *slump breccia* unit, from 10 levels: PM 36.1, PM 36.2, NA 48.1, NA 50.3, NA 50.2, NA 50.1, PM 37.1, FNP 170.2, FNP 170.3 and FNP 170.4 (Figure 5.1). The species is reported by Gruber (1977) from Italy and Nordsumatra (Gruber 1977; De Capoa Bonardi 1984).

**Age**. At Pizzo Mondello, the levels bearing *Halobia mediterranea* overlie those with *H. styriaca* (Mojsisovics) and represent the beginning of the Lacian 2 (lower Norian). It is not known how further the range of this species extends in the section, due to the lack of halobiid fossils in the topmost levels between sample FNP 170.4 and the *slump breccia* level.

The data in Tab. 1 summarise the measurement of the distinctive characters for the *Halobia* species occurring at Pizzo Mondello. It can be observed as the most distinctive features which allow the recognition of the different *Halobia* forms are the H/L ratio, the angular breadth of the anterior triangular field ($\alpha$), the angular breadth of the posterior triangular field ($\beta$) and the number of ribs measured across a 45° arc at the height of 1 cm from the beak (R). Moreover, it is very important to consider a combination of these values, since the single character may not show a significant variation between two or more species (e.g., the values of the H/L ratio and a of *Halobia superba* Mojsisovics and *H*. cf. *rugosa*).

#### Carnian/Norian halobiids from Sicily and the revised biostratigraphy

Many authors in the past used *Halobia* zonations. Most notably De Capoa Bonardi (1984) proposed a detailed scheme for the Central Mediterranean area, later expanded and updated by Krystyn (for example in Krystyn & Gallet 2002; Krystyn et al. 2002) for the Tethys. The zonation proposed in this paper is largely based on the latest version of the scheme by Krystyn (in Krystyn et al. 2002), and it is meant as a further update of that provided by De Capoa Bonardi in 1984.

*Halobia* zonation of the Pizzo Mondello succession

From the analysis of the distributions of the 10 *Halobia* species from Pizzo Mondello, 7 zones have been recognised (for discussion see the next chapter; Fig. 12):

- the *Halobia carnica* zone. The lower limit is represented by the FO of the species and the upper boundary by its LO. In this zone, two species occur: *H. carnica* Gruber and *H. lenticularis* (Gemmellaro) (Fig. 12);
- the *Halobia carnica - Halobia lenticularis* interval zone. The lower boundary is represented by the LO

| **Species** | **H** | **L** | **H/L** | **BP** | **α** | **β** | **R** |
|---|---|---|---|---|---|---|---|
| *H. austriaca* | 0.57<<2.70 | 1.00<<3.43 | 0.57<<0.89 | 0.29<<0.46 | 14°<<31° | 28°<<34° | 6<<11 |
| *H. beyrichi* | 1.12<<4.10 | 2.02<<5.30 | 0.55<<0.77 | | 17° | 56.7° | 19 |
| *H. carnica* | 0.50<<1.40 | 0.70<<2.10 | 0.60<<0.85 | 0.43<<0.47 | 20°<<30° | 28°<<42° | 15<<27 |
| *H. lenticularis* | 0.57<<1.89 | 0.60<<2.16 | 0.69<<1.01 | 0.34<<0.36 | 12°<<20° | 29°<<32° | 6<<8 |
| *H. mediterranea* | 0.74<<1.40 | 1.05<<2.40 | 0.65<<0.79 | 0.37<<0.43 | 14°<<22° | 40°<<48° | 17<<19 |
| *H. radiata* | 0.52<<3.50 | 0.54<<4.07 | 0.47<<1.03 | 0.35<<0.48 | 11°<<36° | 32°<<54° | 17<<28 |
| *H. simplex* | 0.98 | 1.15 | 0.85 | | | | |
| *H. styriaca* | 1.57<<4.10 | 2.20<<4.60 | 0.70<<0.90 | 0.37<<0.52 | 17°<<26° | 16°<<33° | 9<<12 |
| *H. superba* | 0.49<<1.97 | 0.50<<2.02 | 0.74<<0.83 | | 19°<<22° | | 18<<20 |
| *H. cf. rugosa* | 0.62<<1.50 | 0.76<<1.29 | 0.67<<0.83 | 0.31<<0.41 | 19°<<26° | 27°<<28° | 23<<24 |

Tab. 1 - Summary of the measurements of distinctive characters for the *Halobia* species occurring at Pizzo Mondello. Measurements of linear features are expressed in centimentres, angular values expressed are in degrees.

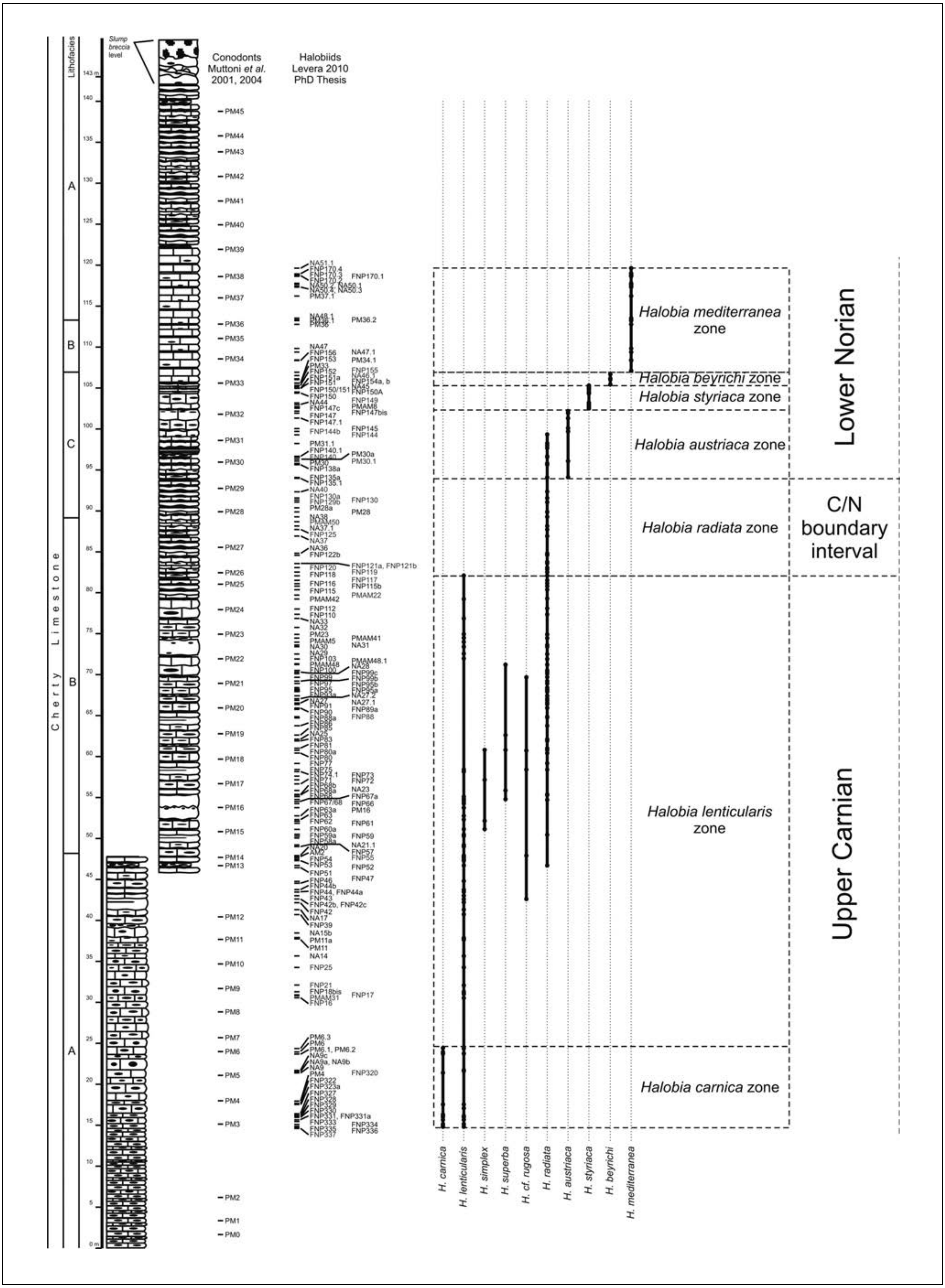



Fig. 12 - Stratigraphic log of the Pizzo Mondello section showing the seven zones based on the *Halobia* species and their bio-chronostratigraphic significance.

of *Halobia carnica* and the upper limit by the LO of *H. superba*. In this zone, 5 species are present: *H. lenticularis*, *H. simplex* Gemmellaro, *H. superba* Mojsisovics, *H.* cf. *rugosa* and *H. radiata* Gemmellaro (Fig. 12);

- the *Halobia lenticularis* - *Halobia austriaca* interval zone; the lower limit is represented by the LO of *Halobia superba* and the upper boundary by the FO of *H. austriaca* Mojsisovics. In this zone, 2 species occur: *H. lenticularis* (lower part of the zone only) and *H. radiata* (Fig. 12);
- the *Halobia austriaca* zone; the lower boundary is represented by the FO of *H. austriaca* and the upper by its LO. In this zone, 2 species occur: *H. radiata* (lower half of the zone only) and *H. austriaca* (Fig. 12);
- the *Halobia styriaca* zone; the lower boundary is represented by the FO of *H. styriaca* (Mojsisovics) and the upper by its LO. In this zone, only the marker species *H. styriaca* occurs (Fig. 12);
- the *Halobia beyrichi* zone; the lower limit is represented by the FO of *H. beyrichi* (Mojsisovics) and the upper by its LO. In this zone, only the marker species *H. beyrichi* occurs (Fig. 12);
- the *Halobia mediterranea* zone; the lower boundary is represented by the FO of *H. mediterranea* Gemmellaro and the upper by its LO. In this zone, only the marker species *H. mediterranea* occurs (Fig. 12).

## Bio-chronostratigraphy

Whereas biozones are the basic units of biostratigraphy, they are often somewhat limited in use, for example when dealing with discontinuous fossil records. Therefore, it is a common practice to select the best bioevents to use as markers in bio-chronostratigraphic studies. For instance, this is the standard practice with conodonts. The bioevents are then correlated to standard bio-chronostratigraphic scales, mainly based on ammonoids for the Triassic.

Upper Carnian (Tuvalian)

From level FNP 337 (Fig. 12), about 15 metres from the base of the section, to level FNP 118, at about 83 metres, the succession is dominated by a typical Tuvalian (late Carnian) fauna, mainly characterized by the dominance of *Halobia carnica* Gruber and *H. lenticularis* (Gemmellaro), with a minor occurrence of *H. superba* Mojsisovics, *H.* cf. *rugosa* and *H. simplex* Gemmellaro. This corresponds to the above mentioned *Halobia carnica* and *Halobia carnica – Halobia lenticularis* zones.

The first species occurring at the bottom of the section is *Halobia carnica* (from level FNP 337 to level PM 6.3), with associated rare specimens of *H. lenticularis*. The first species, reported here for the first time from Sicily, is typical of the Tuvalian 2 (Gruber 1977). This is consistent with the range of *Halobia carnica* in the Pizzo Mondello section, where it disappears right below the level PMAM 17 containing *Discotropites plinii* (Mojsisovics, 1893) (Balini et al. 2012), marker of the first ammonoid zone of the late Tuvalian 3.

The overlaying *Halobia carnica – Halobia lenticularis* interval zone (from level FNP 16 to level PMAM 48) is instead typically Tuvalian 3, being composed by *H. lenticularis*, *H. superba*, *H.* cf. *rugosa*, rare *H. simplex* specimens, and *H. radiata* Gemmellaro (Krystyn et al. 2002; Nicora et al. 2007; Levera & McRoberts 2008). *Halobia lenticularis* was firstly known only from Sicily (Gemmellaro 1882; Scalia 1910; Butrico 1930) and Lucania (De Lorenzo 1892, 1894, 1896; De Capoa Bonardi 1969). In Sicily, the portion of Scillato Formation with *H. lenticularis* has been considered not older than Carnian by all the authors (Gemmellaro 1882, 1904; Scalia 1910; Butrico 1930). De Capoa Bonardi (1969) considered the *H. lenticularis* from Lucania to be Ladinian in age. Afterwards, De Capoa Bonardi (1984) re-considered that datum and recognized that *H. lenticularis* ranged from probably the upper part of the Tuvalian 2 to the uppermost Carnian, but did not pass the Carnian/Norian boundary. Gruber (1977) found this species from Italy (Sicily and Lagonegro) and Austria (Miesenbach, Bad Ischl, and Landl) and attributed it from the Tuvalian 2 to the lower part of the *Stikinoceras kerri* zone (lowermost Norian in the ammonoid bio-chronostratigraphic scale). Based on its stratigraphic position between *Halobia carnica* and *H. radiata*, the *H. lenticularis* from Pizzo Mondello is here considered as ranging from the upper part of the Tuvalian 2 to the Carnian/Norian boundary (top Tuvalian 3).

Concerning the other forms co-occurring within the *Halobia carnica – Halobia lenticularis* interval zone, Gruber (1977) indicates for *H. simplex* an early Norian (Lacian 1) age. At Pizzo Mondello, the occurrence of *H. simplex* in association to *H. lenticularis* and *H. radiata*, about 38 meters below the FO of *H. austriaca* Mojsisovics, indicates a latest Carnian (Tuvalian 3) age. This datum adds a piece to the understanding of *H. simplex* and allows to extend its range from Tuvalian 3 to Lacian 1, crossing the Carnian/Norian boundary.

*Halobia superba*, according to Gruber (1977: 191) and McRoberts (2007, 2011), ranges through at least three zones of the upper Carnian (Tuvalian), and into the lowermost Norian. The forms described by Campbell (1994) from New Zealand, co-occurring with probable *H. austriaca*, are considered as corresponding to the Tethyan material of the earliest Norian *Stikinoceras kerri* zone. Campbell did not regard at *H. superba* as especially age-diagnostic. On the contrary, Krystyn (in

Krystyn et al. 2002), while proposing a revision of the integrated upper Carnian to lower Norian biochronology, considered *Halobia superba* as marker for the upper Carnian (Tuvalian), but not passing the Carnian/Norian boundary. Given its stratigraphic position in the middle part of the *Halobia lenticularis* range and in the lowermost part of the *H. radiata* range, *H. superba* from Pizzo Modello is here considered to be Tuvalian 3 (latest Carnian) in age. Lastly, considering its stratigraphic position in relation to the other species, *Halobia* cf. *rugosa* is here attributed to the Tuvalian 3 (uppermost Carnian).

The FO of *Halobia radiata*, marker species for the upper Tuvalian (Tuvalian 3 *sensu* Krystyn et al. 2002) throughout the Tethys, is recorded in level FNP 52. This species is frequently found with *H. superba* and below *H. styriaca* (Mojsisovics) and *H. beyrichi* (Mojsisovics) in North America (McRoberts 1993, 2007, 2011), in the Northern Calcareous Alps (Gruber 1977), in the Mediterranean (Cafiero & De Capoa Bonardi 1980, 1982) and possibly in the upper Carnian strata of northeast Russia (Polubotko 1984). At Pizzo Mondello, frequent *H. lenticularis*, *H. superba* and more rare *H.* cf. *rugosa* and *H. simplex* are found in association with this species in the lower part of its range, while *H. austriaca* co-occurs in the upper part. Its LO is about 3 metres below the FO of *H. styriaca*. Given its stratigraphic position in the Pizzo Mondello section and the relations with the other species recorded in the succession, *Halobia radiata* is here considered as spanning the Carnian/Norian boundary (Tuvalian 3 to lower Lacian 1), at least in the upper part of its range. The occurrence of this species would thus indicate that the upper half of the *H. lenticularis* assemblage is entirely upper Tuvalian 3, while the lower part is still lower Tuvalian 3. This fact would also confirm that the *H. carnica* assemblage is limited to the Tuvalian 2 only.

The specimens of *Halobia radiata* occurring in this lower portion of the species' range are mostly small forms, probably representing juveniles to sub-adults stages. It is worth noting that the original material from Gemmellaro (1882), later selected as lectotype and paralectotypes by Gruber (1977) and De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982) respectively, is totally composed of these smaller forms, called by the authors *H. radiata radiata* Gemmellaro. Adult specimens of *Halobia radiata*, equal to the *Halobia radiata hyatti* (Kittl) sub-species, occur at Pizzo Mondello in levels FNP 103, PMAM 42 (between metres 73 and 79 from the base of the section) and PM 31.1 (at about 98 m from the base of the section). The sporadic occurrence of these adult forms seems to be related to preservation issues rather than to an effective difference in the life habits of the two sub-species *H. radiata radiata* and *H. radiata hyatti*.

Carnian/Norian boundary interval

From level FNP 118 to level FNP 135a (about 94 meters from the base of the section; *Halobia lenticularis* – *Halobia austriaca* interval zone) the succession is dominated by *Halobia radiata* Gemmellaro. In facts, *Halobia lenticularis* (Gemmellaro) disappears at level FNP 118, marking the lower limit of the Carnian/Norian boundary interval, as identified on the basis of bivalves.

Lower Norian (Lacian)

Since the base of the Norian Stage has yet to be defined, and a bioevent marking this boundary is still being debated, the FO of *Halobia austriaca* Mojsisovics (at level FNP 135a; Fig. 12) is here considered as a datum for the upper limit of the Carnian/Norian boundary interval based on halobiids. In Tethyan sections, *Halobia austriaca* usually occurs in shell beds and is generally considered to be restricted to a narrow stratigraphic range below *H. styriaca* (Mojsisovics) shell beds (Gruber 1977; De Capoa Bonardi 1984). Gruber (1977) regarded *H. austriaca* as ranging in age from late Carnian to early Norian. Campbell (1994) considered the *H. austriaca* occurrence in New Zealand to be a good correlation level that along with *H. styriaca* indicates 'firm location presence of the Carnian/Norian boundary within the Murihiku succession' (Campbell 1994: 100). The occurrence of *Halobia austriaca* both in the Tethyan and the Boreal provinces and the fact that its FAD is globally recognizable, as suggested by Krystyn et al. (2002), McRoberts (pers. comm.), Levera & McRoberts (2010) and McRoberts (2011), make this species a good correlation tool. In fact, *H. austriaca* is now regarded as marker for the lower part of the Lacian 1 (lower *Stikinoceras kerri* zone in North America; McRoberts 2011; lower *Guembelites jandianus* zone in the Tethyan realm; Krystyn & Gallet 2002).

At Pizzo Mondello, *Halobia austriaca* belongs to the early Norian Jandianus Zone (Lacian 1). This datum is based on the ammonoid calibration based on the occurrence, within the *Halobia austriaca* zone (in the levels FNP 145 and FNP 147; Fig. 12), of two species of *Dimorphites* (for further discussion see Balini et al. 2010; Balini et al. 2011), which are the markers for the two ammonoid subzones of the *Guembelites jandianus* zone according to Krystyn & Gallet (2002).

From level FNP 147c to level PM 33 (between metres 102.5 and 105.6 from the base of the section), the succession is characterized by the mass occurrence of specimens belonging to the species *Halobia styriaca*, restricted in stratigraphic range between the intervals of *H. austriaca* and *H. beyrichi* (Mojsisovics). The FO of *Halobia styriaca* is another important biomarker for the lower Norian (as proposed by Krystyn et al. 2002): *H. styriaca* is generally regarded as marker for the lower

Norian in the Tethys (see Krystyn & Gallet 2002; Krystyn et al. 2002), and in particular it is attributed to the upper part of the *Guembelites jandianus* zone (Lacian 1, lower Norian).

Between levels PM 33 and FNP 154 (from 105.6 to 106.3 meters from the base of the section), only *Halobia beyrichi* occurs. Together with *H. styriaca*, this species is generally regarded as marker for the lower Norian in the Tethys (Krystyn & Gallet 2002; Krystyn et al. 2002).

From level PM 34.1 to level NA 51.1 (from 108 to 120.2 metres from the base of the section), the section is characterized by the occurrence of *Halobia mediterranea* Gemmellaro, a species never found in North America. This species was reported from the Lacian 1 to the Alaunian 1 (lower to lower middle Norian) by De Capoa Bonardi (Cafiero & De Capoa Bonardi 1982), based on its stratigraphic position in relation to other *Halobia* species. Later works by De Capoa Bonardi (1984) and by Krystyn (in Krystyn et al. 2002) emphasised this species as the halobiid marker for the Lacian 2, in particular corresponding to the *Malayites paulkei* zone (Krystyn et al. 2002). At Pizzo Mondello, the FO of *H. mediterranea*, less than 0.5 metres above the LAD of *H. beyrichi*, marks the base of the Lacian 2 in the Tethyan realm (Krystyn et al. 2002).

**World-wide correlations of Pizzo Mondello**

Tethys

*Halobia* faunas were studied from Tethyan section in Austrian Alps (e.g., Mojsisovics 1874; Kittl 1912; Gruber 1976; Krystyn & Gallet 2002), Slovakia, Turkey (Gallet et al. 2000; Krystyn & Gallet 2002), Northern Italy (Dolomites), Southern Italy (Sicily and Lucania), Greece and Yugoslavia (e.g., De Capoa Bonardi 1984).

In the Austrian Alps, detailed information on halobiids' faunal succession is restricted to the Feuerkogel area and thus this locality is the only one which provides direct intercalibration between ammonoid, halobiid and conodont zonal schemes (Krystyn & Gallet 2002). Moreover, given the historical relevance of the locality in the study of pelagic megafossils such as *Halobia*, this place is of great importance for the understanding of the stratigraphic subdivision of the Carnian/Norian boundary interval. Rich ammonoid faunas were found in a number of small quarries, and provide a constrain for the *Halobia* biostratigraphy from the same area. The FO of *Halobia austriaca* Mojsisovics, replacing *H. lenticularis* (Gemmellaro), occurs in a lithologically peculiar interval. This interval is characterised by two distinctive lithostratigraphic marker horizons which can be followed laterally over relatively large distances. The first level (level A in fig. 2, Krystyn & Gallet 2002) allows the exact recognition of the Carnian/Norian boundary in other sites of the Feuerkogel (Krystyn & Gallet 2002). The level B shows the same characteristics of the *Halobia styriaca*-bearing beds from Pizzo Mondello. De Capoa Bonardi recognised this interval all over the Mediterranean (Sicily, Lucania, Greece and Montenegro). The occurrence of a lithologically similar interval, with the same fauna and in the same stratigraphic position in Austria, provides another confirmation on the relevance of these event at least in the Tethyan realm.

Furthermore, a similar biostratigraphy based on *Halobia* has been proposed for Slovakia and Turkey, supported by the ammonoid collections from the same localities (for more detailed discussion, see Gallet et al. 2000; Krystyn & Gallet 2002).

In summary, the data from the Tethyan sections indicate that:

- the FO of *Halobia austriaca* is the *Halobia* event closest to the base of the Norian;
- the range of *Halobia styriaca* (Mojsisovics) is directly above the one of *H. austriaca*, and it occurs in a distinctive lithological interval that can be traced throughout most of the Western Tethys;
- each species is restricted to just one ammonite sub-zone, representing a valuable bio-chronological tool in the lack of other macrofossils.

North America

The Carnian through middle Norian of North America can be subdivided into several zones based on *Halobia* species (McRoberts 2010: fig. 6), as shown in Fig. 13. In western North America, *Halobia zitteli* Lindstöm, a form typical of the lower Carnian, is poorly represented, and is replaced by *H. rugosa* Mojsisovics, which may extend into the upper Carnian, into the *Klamathites macrolobatus* zone or even *Stikinoceras kerri* zone, where it co-occurs with *H. ornatissima* Smith, *H. septentrionalis* Smith and *H. radiata* Gemmellaro (McRoberts 1997, 2007, 2010, 2011). A short zone spanning the Carnian/Norian boundary is based on *H. radiata* that is well represented across the Tethys, Boreal, and low to mid latitude strata in western North America (De Capoa Bonardi 1984; Nicora et al. 2007; McRoberts 2007, 2010, 2011). The base of the Norian stage closely corresponds to the first occurrence of *Halobia austriaca* Mojsisovics, *H. styriaca* (Mojsisovics), *H. beyrichi* (Mojsisovics) and *H. selwini* McRoberts (a form closely related to *H. beyrichi*; McRoberts 2011) and similar species best represented in low palaeolatitudes with notable occurrences in the Tethys and Eastern Panthalassa (Gruber 1976; De Capoa Bonardi 1984; McRoberts 1997, 2010, 2011). While *H. styriaca* is common in these regions, it has not yet been reported in

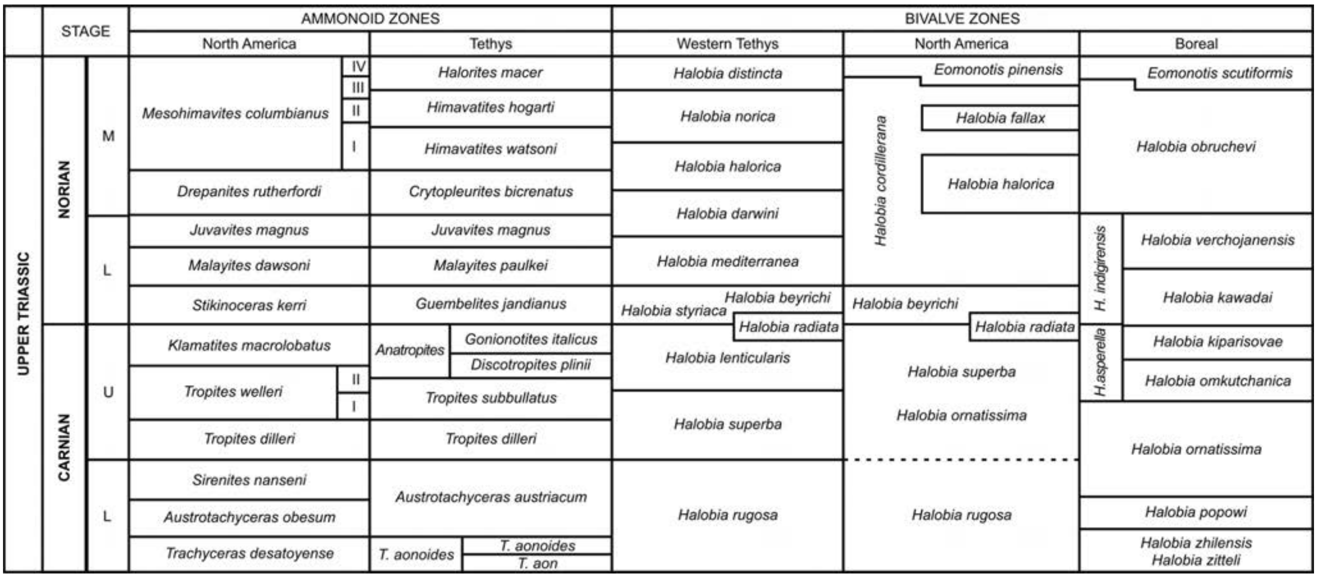



Fig. 13 - Stratigraphical ranges of Late Triassic *Halobia* for western Tethys, North America and Boreal realms. Ammonoid Zones modified from Orchard & Tozer (1997) Zakharov et al. (1997), Kozur (2003) and Gallet et al. (2007). Modified after McRoberts (2010).

western North America (McRoberts 2010, 2011). Similarly, *Halobia beyrichi*, which is only known from a few occurrences in the terranes of British Columbia, is not known to occur in craton-bound strata such as at Black Bear Ridge (the North America candidate section for the Norian GSSP). *Halobia austrica*, on the other hand, is a taxon that is most wide-spread, occurring in the tropical western and eastern Tethys, throughout Indonesia and the Western Panthalassa, the Boreal of northeastern Russia and throughout the North American Cordillera (Levera & McRoberts 2010).

Boreal regions

The halobiid correlations of the Boreal regions, including northeastern Siberia (Kiparisova et al. 1966; Polubotko 1980, 1984, 1986), Arctic Alaska (Blome et al. 1988; Dutro & Silberling 1988), Arctic Canada (Tozer 1961, 1967), and Svalbard (Campbell 1994), were described in detail by McRoberts (2010; Fig. 13). A summary of the data is proposed here.

*Halobia zitteli* Lindstöm is the best taxon representing the lower Carnian *Trachyceras desatoyense* through *Sirenites nanseni* ammonoid zones and equivalents in the Boreal regions of Russia, Canada, and Svalbard (e.g. Tozer 1961; Polubotko 1980; Campbell 1994; McRoberts 2010). In NE Siberia, *H. zitteli* seems to be restricted to the lowermost Carnian (*Trachyceras desatoyense* Zone) and is subsequently overlain by four halobiid zones including *H. zhilnensis* Polubotko, *H. popowi* Polubotko, *H. ornatissima* Smith and *H. asperella* Polubotko (Polubotko 1980, 1986; Zakharov et al. 1997; McRoberts 2010; Fig. 13). As well as in the Tethys, the temporally-limited zone spanning the Carnian/Norian boundary based on *H. radiata* Gemmellaro is well represented in the Boreal regions (McRoberts 2010). In the Lower Norian, above the zone of *H. beyrichi* (Mojsisovics) and *H. styriaca* (Mojsisovics) are a suite of similar forms referable to *H. obruchevi* Kiparisova in NE Russia (e.g. Kiparisova et al. 1966; Polubotko 1984) and *H. hochstetteri* Mojsisovics in New Zealand (Campbell 1994)(Fig. 13).

China

General discussions on the distributions of Chinese *Halobia* have been published by Reed (1927), Chen (1976), Chen & Ba (1986) and McRoberts (1997). In general, similarities to the halobiid faunas of the eastern and central Tethyan regions are to be expected, because of geographic proximity, and significant co-occurrences of several species have provided limited correlations to North American strata (McRoberts 1997).

The uppermost Carnian, characterised by *Halobia superba* and *H. pluriradiata* Reed (which occurs throughout southern China), as well as *H. radiata* Gemmellaro (listed as *H. septentrionalis* Smith by Chen & Ba, 1986), can be directly correlated to the Tethyan and North American successions. As for the Lower Norian, although *H. styriaca* (Mojsisovics) occurs in Tibet and other areas, providing a good marker for correlation with the Tethyan realm, the most abundant taxa are *H. superbescens* Kittl and *H. subrugosa* Chen (less common in the Tethys).

## Conclusions

The taxonomic study of the Pizzo Mondello halobiids, collected in a bed-by-bed sampling, has led to the classification of ten *Halobia* forms (in stratigraphic succession): *Halobia carnica* Gruber, *H. lenticularis* (Gemmellaro), *H.* cf. *rugosa*, *H. radiata* Gemmellaro, *H. simplex* Gemmellaro, *H. superba* Mojsisovics, *H. austriaca* Mojsisovics, *H. styriaca* (Mojsisovics), *H. beyrichi* (Mojsisovics) and *H. mediterranea* Gemmellaro. In all the cases where it has been possible, a new set of morphometric parameters has been provided together with the representations of the outlines and maximum height position for different stages of growth. A high resolution biostratigraphy based on the pelagic bivalve *Halobia* from the Pizzo Mondello section has been obtained, together with a revised biostratigraphy for *Halobia* from Sicily.

The most important features of the biostratigraphic scheme based on *Halobia* are summarised in the following list:

- The *Halobia carnica* zone, with the species *H. carnica* and subordinate *H. lenticularis* Gemmellaro is the oldest fauna of the succession and dates to the Tuvalian 2;
- the *Halobia lenticularis – Halobia austriaca* interval zone, with the only species *H. radiata* Gemmellaro, occurring between the LO of *H. lenticularis* and the FO of *H. austriaca* Mojsisovics, represents a transition fauna between Carnian and Norian groups, Tuvalian 3 – Lacian 1 in age;
- the *Halobia austriaca* zone, with the species *H. austriaca* and, only in the lower half, *H. radiata* is the first surely Norian assemblage, dating to the lower part of the Lacian 1;
- the *Halobia styriaca* and the *H. beyrichi* zones, with only *H. styriaca* and *H. beyrichi* specimens respectively, mark the upper part of the first zone of the Lacian 1 (upper *Stikinocras kerri* zone in North America; upper *Guembelites jandianus* zone in the Tethyan realm *sensu* Krystyn & Gallet 2002).

A revision of the world-wide correlations based on *Halobia* species has been proposed. This objective has been achieved through the comparison of the faunas from Pizzo Mondello and those from Austria, Lucania (Southern Italy), Greece, Montenegro, and North America. The species *Halobia austriaca* is the best marker for correlations in both the Tethyan and North American realms, and it can be used to mark the Carnian/Norian boundary. Thus, first appearance datum of *Halobia austriaca* can be recognised as the best proxy of the base of the Norian stage in world-wide correlations, strengthening the role of the Pizzo Mondello section as a candidate for the Norian GSSP.

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PLATE 1

1) *Halobia carnica* - MPUM 10690 (FNP 336-1); right valve exterior.
2) *Halobia carnica* - MPUM 10691 (FNP 331-4); right valve exterior.
3) *Halobia carnica* - MPUM 10692 (FNP 330-3); left valve exterior.
4) *Halobia carnica* - MPUM 10693 (FNP 330-4); right valve exterior.
5) *Halobia carnica* - MPUM 10694 (FNP 328a-4 and FNP 328a-5); A - FNP 328a-4: left valve exterior; B - FNP 328a-5; right valve exterior.
6) *Halobia carnica* - MPUM 10695 (FNP 327-3); right valve exterior.
7) *Halobia carnica* - MPUM 10696 (FNP 327-5); 1.5 x; left valve exterior.
8) *Halobia carnica* - MPUM 10696 (FNP 327-9); 1.5 x; left valve exterior.
9) *Halobia carnica* - MPUM 10699 (FNP 327).
10) *Halobia carnica* - MPUM 10697 (PM 6.2-4); left valve exterior exterior.
11) *Halobia carnica* - MPUM 10698 (CAM 1-2); left valve exterior.
12) *Halobia lenticularis* - MGUP 305, Gemmellaro (1882, pl. 1, f. 3); left valve exterior.
13) *Halobia lenticularis* - MPUM 10700 (FNP 60a-3); right valve exterior.
14) *Halobia lenticularis* - MPUM 10701 (PMAM 42-17); right valve exterior.
15) *Halobia lenticularis* - MPUM 10702 (PMAM 42-44); right valve exterior
16) *Halobia lenticularis* - MPUM 10703 (PMAM 42-47); right valve exterior
17) *Halobia carnica* and *H. lenticularis* - MPUM 10706 (FNP 327)
18) *Halobia carnica* and *H. lenticularis* - MPUM 10706 (FNP 328a)
19) *Halobia lenticularis* - MPUM 10704 (FNP 67/68-8); right valve exterior
20) *Halobia lenticularis* - MPUM 10705 (FNP 67/68-1); left valve exterior
21) *Halobia superba* - MPUM 10730 (NA 23-5); left valve exterior
22) *Halobia superba* - NHMW 1900/5/13, Kittl (1912, pl. 7, f. 17); left valve exterior
23) *Halobia beyrichi* - MPUM 10744 (FNP 154a-1); left valve exterior
24) *Halobia beyrichi* - MPUM 10745 (FNP 154a-2); right valve exterior
Scale bar: 1 cm.

PLATE 2

1) *Halobia radiata* - MPUM 10715 (FNP 67/68-6); left valve exterior.
2) *Halobia radiata* - MPUM 10716 (FNP 68a-9); left valve exterior.
3) *Halobia radiata* - MPUM 10717 (FNP 95a-5); left valve exterior.
4) *Halobia radiata* - MPUM 10718 (FNP 112-14); left valve exterior.
5) *Halobia radiata* - MPUM 10719 (PMAM 42-6); left valve exterior.
6) *Halobia radiata* - MPUM 10720 (PMAM 42-11); right valve exterior.

7) *Halobia radiata* - MPUM 10721 (PMAM 42-13); left valve exterior.
8) *Halobia radiata* - MPUM 10722 (PMAM 42-20); right valve exterior.
9) *Halobia radiata* - MPUM 10723 (PMAM 42-29); right valve exterior.
10) *Halobia radiata* - MPUM 10724 (PMAM 42-58); right valve exterior.
11) *Halobia radiata* - MPUM 10725 (PMAM 42-61); left valve exterior.
12) *Halobia radiata* - MPUM 10726 (PMAM 42-62); right valve exterior.
13) *Halobia radiata* - MGUP 300, Gemmellaro (1882), 1.5x; left valve exterior.
14) *Halobia radiata radiata* - SC 034-1, Cafiero & De Capoa Bonardi (1982); synonym to *H. radiata*; right valve exterior.
15) *Halobia radiata radiata* - SC 034-2, Cafiero & De Capoa Bonardi (1982); synonym to *H. radiata*; right valve exterior.
16) *Halobia hyatti* - Kittl (1912), pl. 9, f. 32; synonym to *H. radiata*; right valve exterior.
Scale bar: 1 cm.

PLATE 3

1) *Halobia austriaca* - MPUM 10732 (FNP 147bis-5); right valve exterior.
2) *Halobia austriaca* - MPUM 10733 (FNP 147-14); left valve exterior.
3) *Halobia austriaca* - MPUM 10734 (FNP 147-8); left valve exterior exterior.
4) *Halobia austriaca* - MPUM 10752 (FNP 147-5); left valve exterior.
5) *Halobia austriaca* - MPUM 10735 (FNP 147-4); left valve exterior.
6) *Halobia austriaca* - NHMW 1969/996, Kittl (1912, pl. 6, f. 14); left valve exterior.
7) *Halobia austriaca* - NHMW 1969/997, Kittl (1912, pl. 6, f. 12); left valve exterior.
8) *Halobia austriaca* - NHMW 1969/1003, Kittl (1912, pl. 6, f. 13); right valve exterior.
9) *Halobia austriaca* - NHMW 1969/1004, Kittl (1912, pl. 6, f. 11); right valve exterior.
10) *Halobia austriaca* - GBA 1874/001/0031-1, Mojsisovics (1874, pl. 4, f. 1); left valve exterior.
11) *Halobia austriaca* - GBA 1874/001/0031-2, Mojsisovics (1874, pl. 4, f. 2); left valve exterior.
12) *Halobia austriaca* - GBA 1874/001/0031-3, Mojsisovics (1874, pl. 5, f. 14); right valve exterior.
13) *Halobia austriaca* - B1-1; left valve exterior.
14) *Halobia austriaca* - B1-2; right valve exterior.
15) *Halobia austriaca* - B1-3; left valve exterior.
16) *Halobia austriaca* - B1-4; left valve exterior.
17) *Halobia austriaca* - B1-5; right valve exterior.
18) *Halobia austriaca* - B1-6; right valve exterior.
19) *Halobia austriaca* - MPUM 10736 (FNP 135a-1); right valve exterior.
Scale bar: 1 cm.

PLATE 4

1) *Halobia styriaca* - MPUM 10738 (NA 45-1); left valve exterior
2) *Halobia styriaca* - MPUM 10739 (FNP 151.1-5); left valve exterior
3) *Halobia styriaca* - MPUM 10740 (FNP 151.1-6); left valve exterior
4) *Halobia styriaca* - MPUM 10741 (FNP 151.2-1); right valve exterior
5) *Halobia styriaca* - MPUM 10742 (FNP 151.4-1); right valve exterior
6) *Halobia styriaca* - NHMW 1969/970, Kittl (1912, pl. 6, f. 3); right valve exterior
7) *Halobia styriaca* - NHMW 1969/971, Kittl (1912, pl. 6, f. 4); left valve exterior
8) *Halobia styriaca* - NHMW 1969/972, Kittl (1912, pl. 6, f. 6); left valve exterior
9) *Halobia styriaca* - NHMW 1969/998, Kittl (1912, pl. 6, f. 7); right valve exterior
10) *Halobia styriaca* - NHMW 1969/1005, Kittl (1912, pl. 6, f. 5); right valve exterior
11) *Halobia styriaca* - Mojsisovics (1874), pl. 1, f. 4; right valve exterior
12) *Halobia styriaca* - Mojsisovics (1874), pl. 1, f. 5; right valve exterior
Scale bar: 1 cm.

PLATE 5

1) *Halobia mediterranea* - MPUM 10747 (FNP 170.2-1), 1.5x; left valve exterior.
2) *Halobia mediterranea* - MPUM 10748 (FNP 170.2-3), 1.5x; left valve exterior.
3) *Halobia mediterranea* - MPUM 10749 (FNP 170.2-8), 1.5x; right valve exterior.
4) *Halobia mediterranea* - MPUM 10750 (NA 50.3-1), 2x; left valve exterior.
5) *Halobia mediterranea* - MGUP 293, Gemmellaro (1882, pl. 2, f. 7), 1.5x; left valve exterior.
6) *Halobia mediterranea* - MGUP 293, Gemmellaro (1882, pl. 3, f. 8), 1.5x; right valve exterior.
7) *Halobia mediterranea* - MGUP 293, Gemmellaro (1882, pl. 3, f. 9); left valve exterior.
8) *Halobia curionii*- MGUP 290, Gemmellaro (1882, pl. 3, f. 5), 1.5x; right valve exterior.
9) *Halobia curionii* - MGUP 290, Gemmellaro (1882, pl. 3, f. 6), 1.5x; left valve exterior.
10) *Halobia* cf. *rugosa* - MPUM 10710 (FNP 42b-1), 2x; left valve exterior.
11) *Halobia* cf. *rugosa* - MPUM 10707 (FNP 323a-23), 1.5x; left valve exterior.
12) *Halobia* cf. *rugosa* - MPUM 10709 (AM 2-5), 1.5x; left valve exterior.
13) *Halobia* cf. *rugosa* - MPUM 10711 (FNP 80a-26), 1.5x; right valve exterior.
14) *Halobia* cf. *rugosa* - MPUM 10712 (FNP 99-1), 2x; right valve exterior.
15) *Halobia* cf. *rugosa* - MPUM 10713 (FNP 99-2), 2x; left valve exterior.
16) *Halobia rugosa* - T 54-1, Cafiero & De Capoa Bonardi (1982); left valve exterior.
17) *Halobia rugosa* - T 54-2, Cafiero & De Capoa Bonardi (1982); left valve exterior.
18) *Halobia rugosa* - T 66-1, Cafiero & De Capoa Bonardi (1982); right valve exterior.
19) *Halobia simplex* - MPUM 10728 (FNP 62-1), 2x; right valve exterior.
20) *Halobia siciliana* - NHMW 1909/3/48, Kittl (1912), pl. 8, f. 1; synonym to *H. austriaca*; right valve exterior.
21) *Halobia siciliana* - NHMW 1909/3/49, Kittl (1912), pl. 8, f. 2; synonym to *H. austriaca*; right valve exterior.
Scale bar: 1 cm.

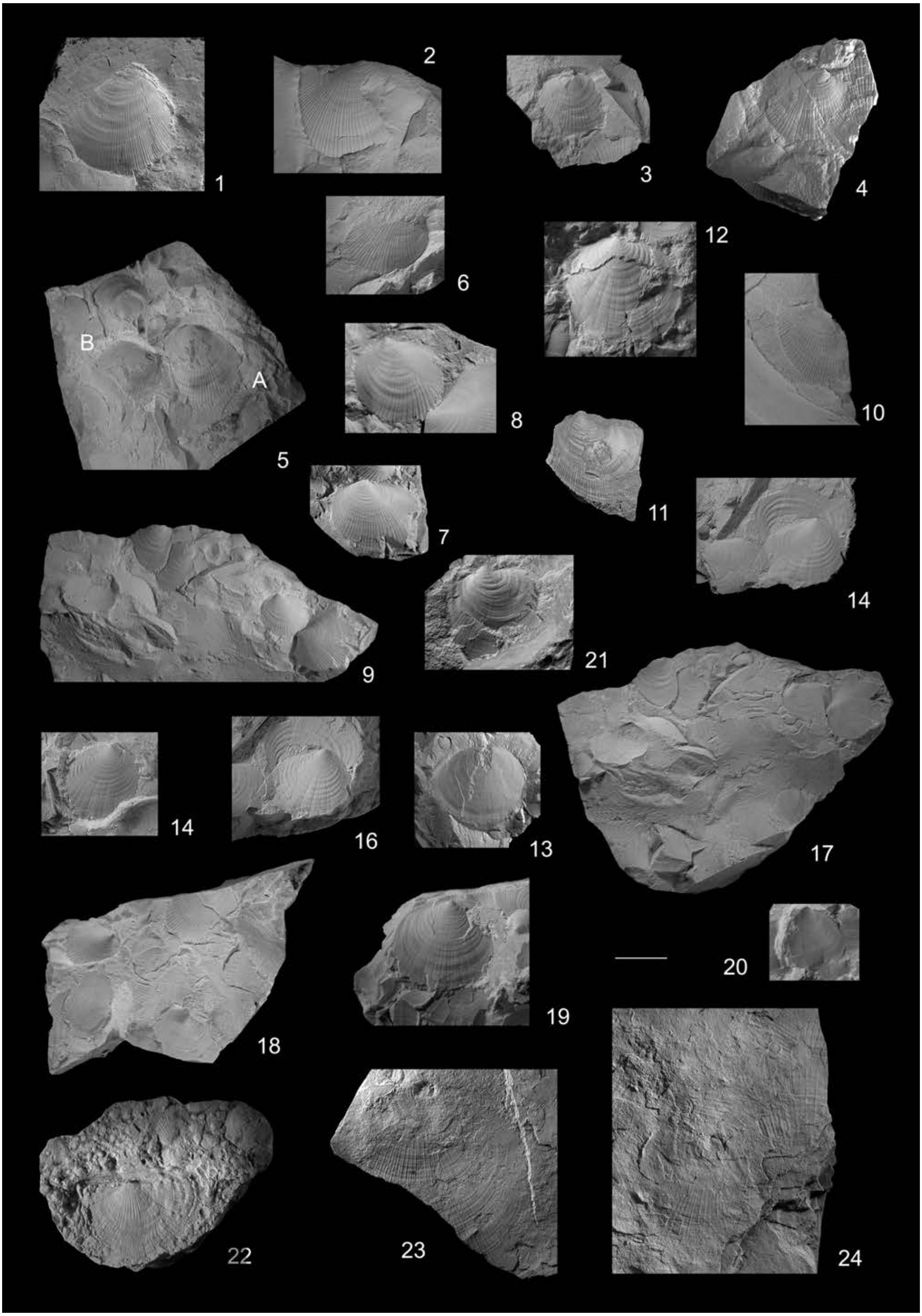
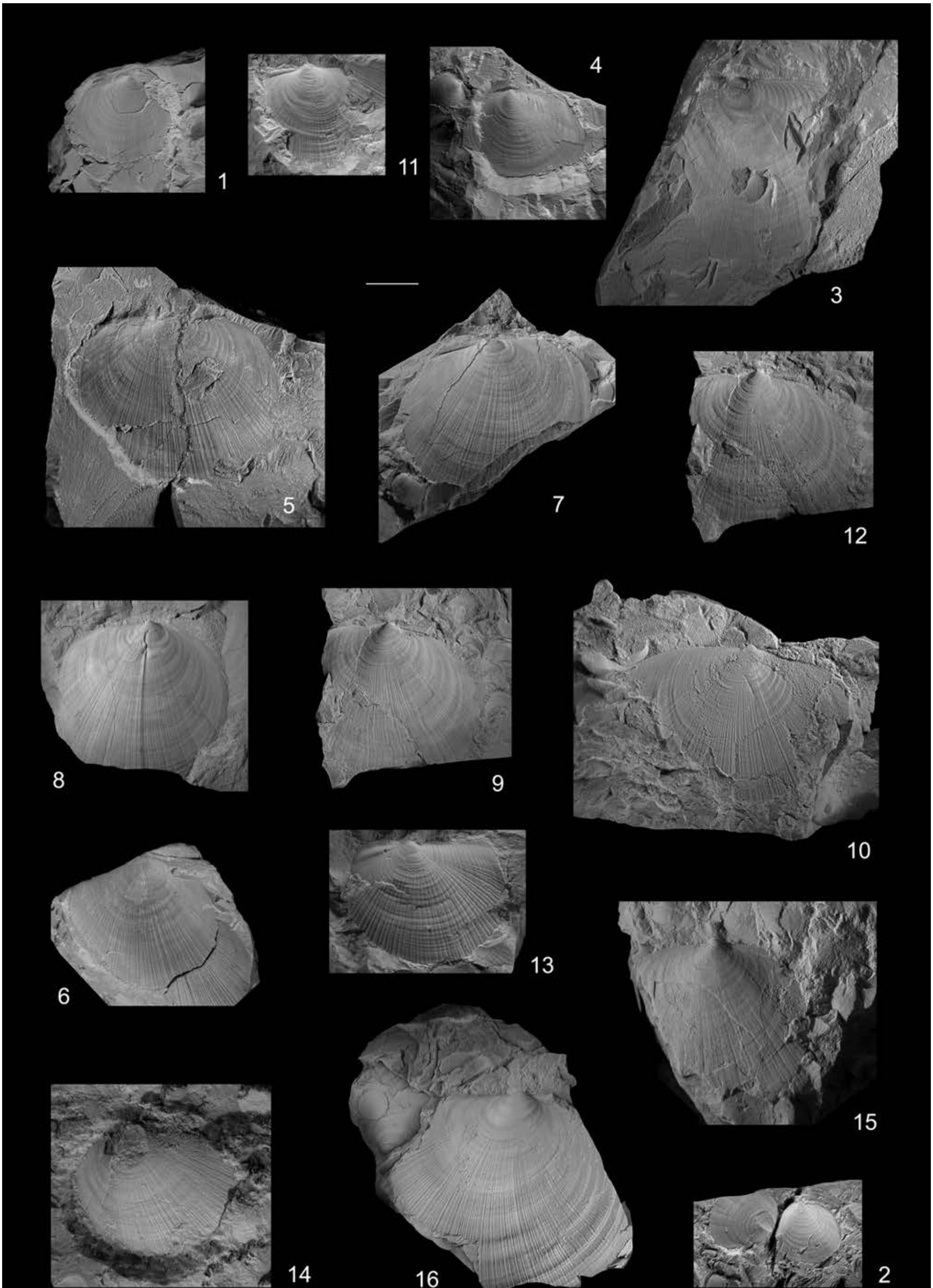



PLATE 1

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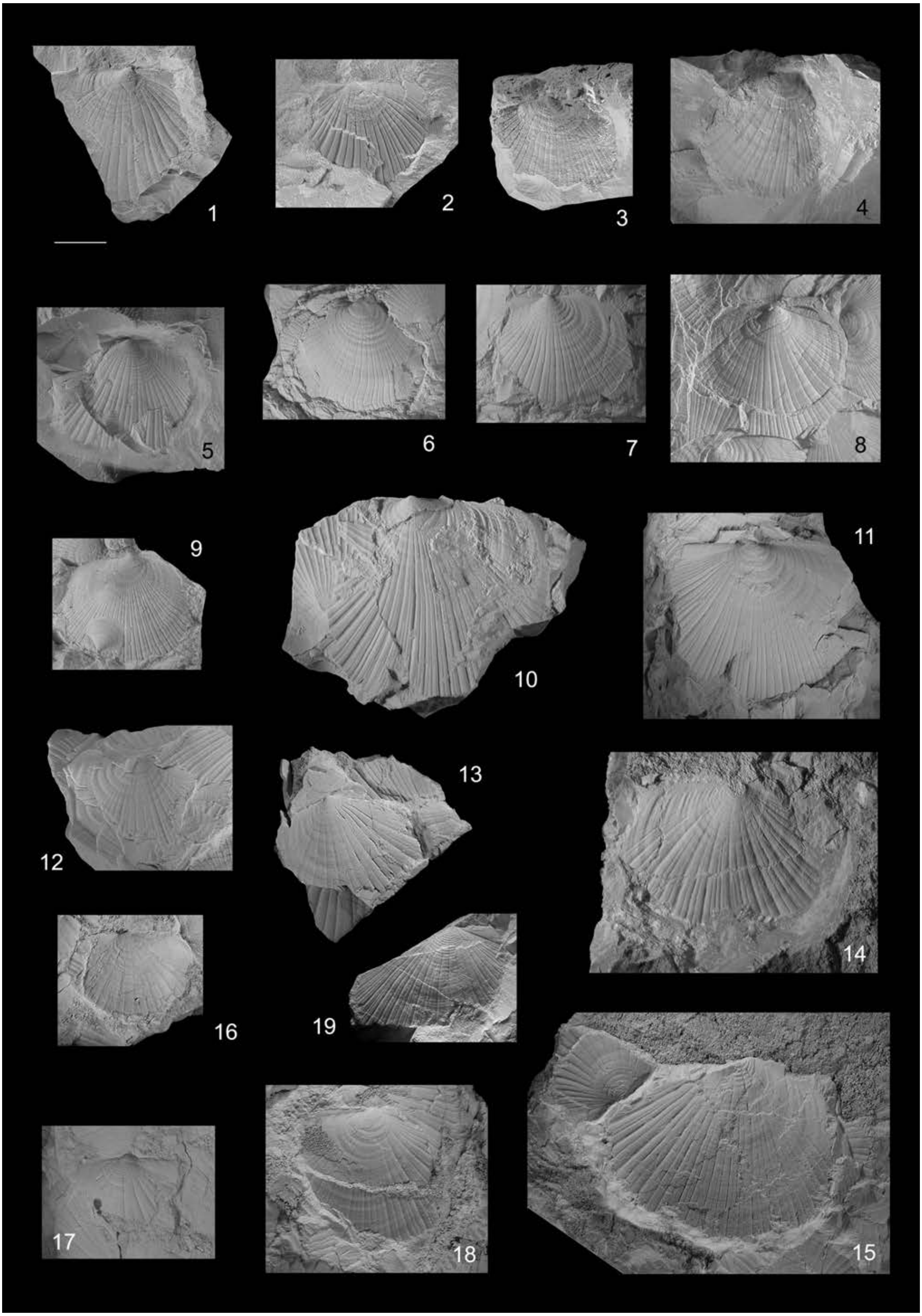


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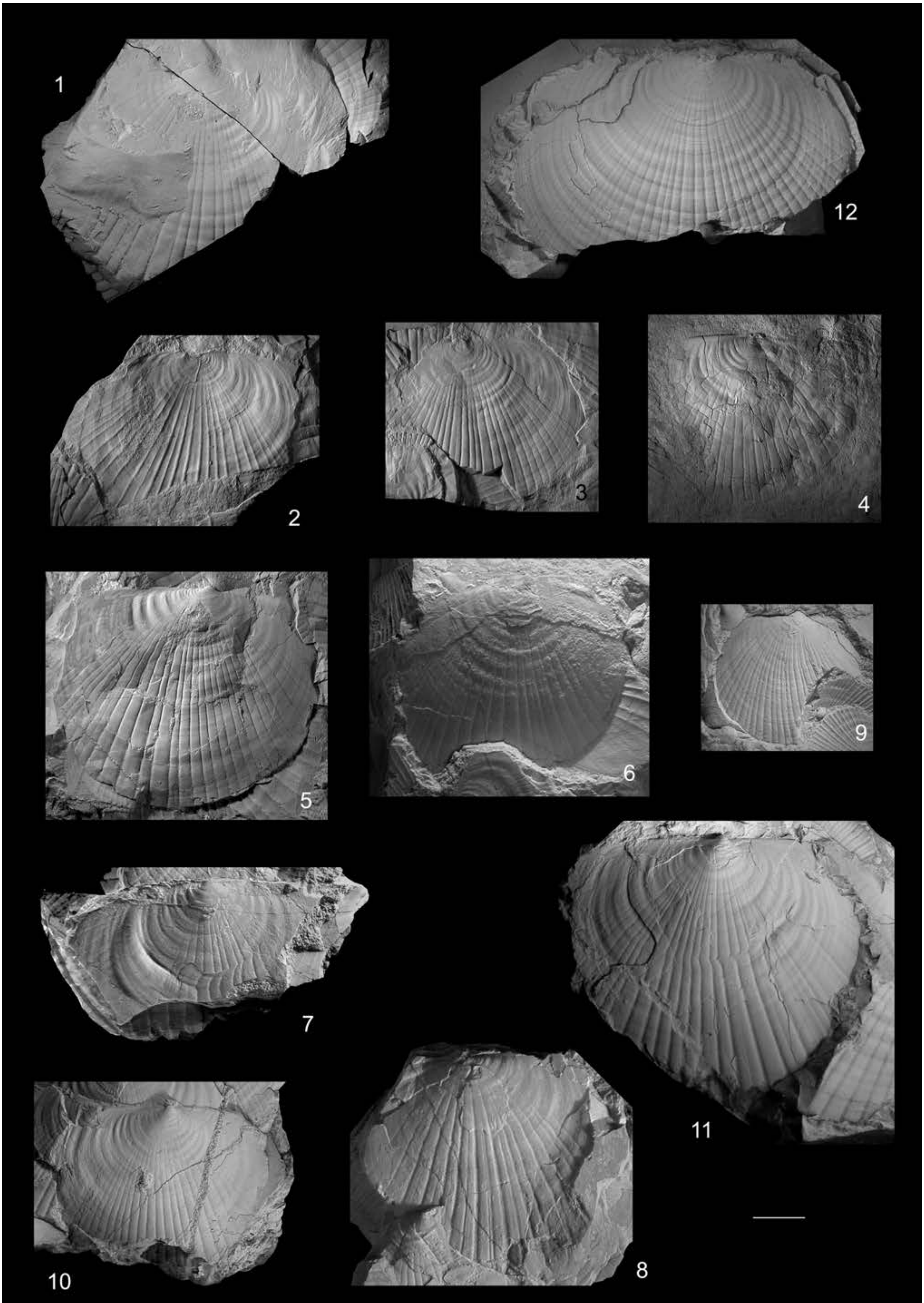


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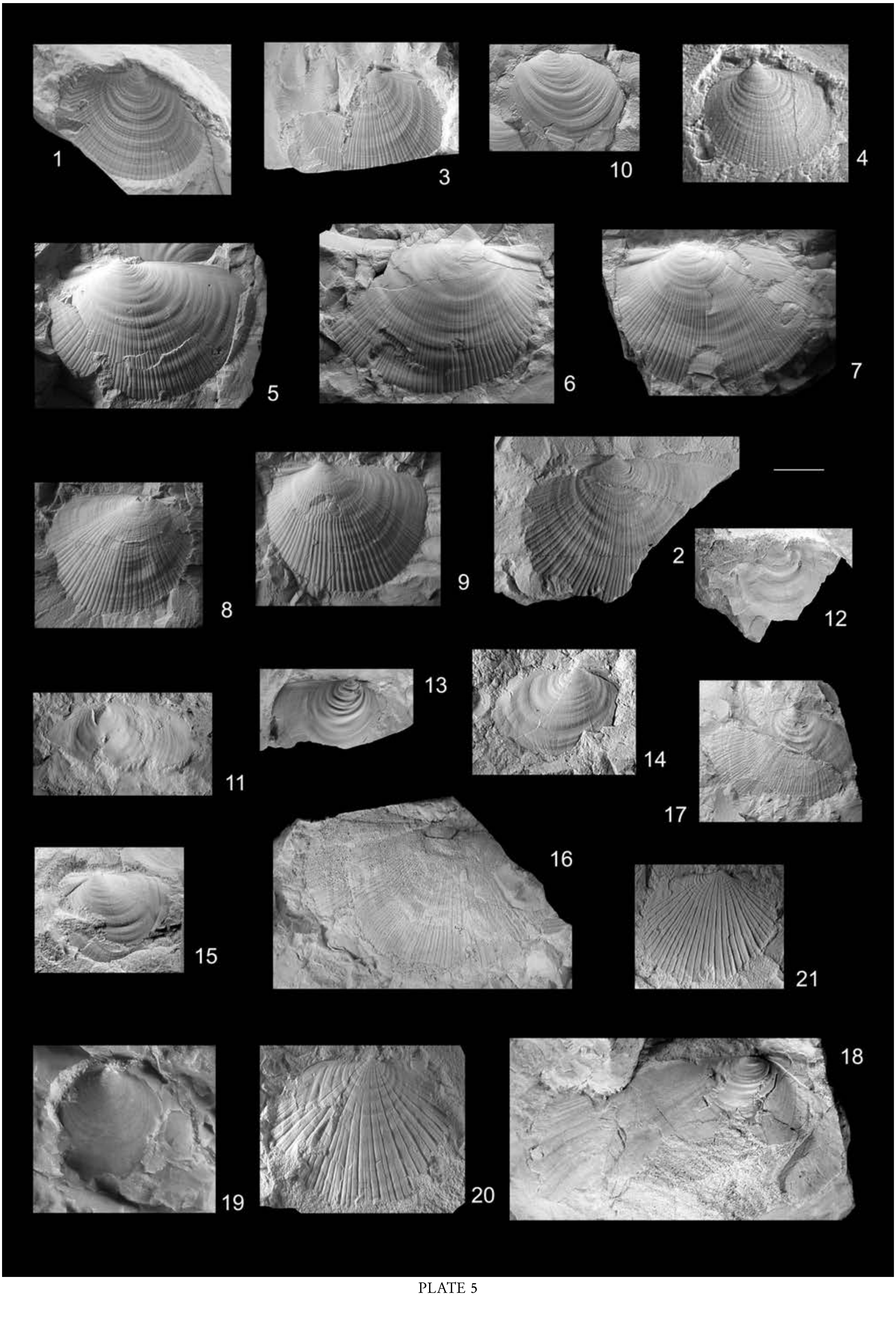


PLATE 5

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**Appendix**

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 331-4 (MPUM 10691)** | | 2.06 | 1.15 | 1.53 | 0.47 | 0.75 | | |
| **FNP 330-1 (MPUM 10699)** | 1.13 | | 0.73 | 0.94 | | | 27 | 42.4 |
| **FNP 330-3 (MPUM 10692)** | | | 0.66 | 0.93 | 0.43 | 0.78 | | |
| **FNP 328a-1 (MPUM 10699)** | | | 0.75 | 0.90 | | 0.83 | | |
| **FNP 328a-4 (MPUM 10694)** | | | 0.60 | 0.70 | | 0.86 | | |
| **FNP 328a-5 (MPUM 10694)** | | | 0.80 | 1.08 | | 0.74 | | |
| **FNP 328a-7 (MPUM 10699)** | | | 0.64 | 0.94 | | 0.68 | | |
| **FNP 327-5 (MPUM 10696)** | 1.03 | | 0.74 | 0.95 | 0.46 | 0.78 | 30.5 | 28 |
| **PM 6.1-2 (MPUM 10699)** | 0.64 | 0.88 | 0.64 | 0.88 | | 0.73 | | |
| **PM 6.2-4 (MPUM 10697)** | 1.35 | 1.87 | 0.50 | 0.83 | 0.44 | 0.72 | 20 | 39 |

Tab. 1 - Summary of the measurements on the *Halobia carnica* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 328a-10 (MPUM 10706)** | | | 0.72 | 1.04 | | 0.69 | 19 | 32 |
| **FNP 323a-23 (MPUM 10706)** | | | | | | | 14 | |
| **NA 9b-5 (MPUM 10706)** | 1.14 | 1.34 | 1.14 | 1.34 | | 0.85 | 19.6 | |
| **NA 9b-6 (MPUM 10706)** | 0.92 | 1.05 | 0.92 | 1.05 | | 0.87 | | |
| **NA 9b-7 (MPUM 10706)** | 0.87 | 1.00 | 0.87 | 1.00 | | 0.87 | | |
| **NA 9b-10 (MPUM 10706)** | 1.89 | 2.16 | 1.89 | 2.16 | | 0.88 | | |
| **NA 9b-12 (MPUM 10706)** | 1.43 | | 1.04 | 1.39 | | 0.75 | | |
| **PM 11-1 (MPUM 10706)** | | | 1.17 | 1.30 | | 0.90 | | |
| **PM 11-6 (MPUM 10706)** | 0.98 | 1.18 | 0.98 | 1.18 | | 0.83 | 17.1 | |

Tab. 2 - Summary of the measurements on the *Halobia lenticularis* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 47-1 (MPUM 10706)** | | | 1.14 | 1.30 | | 0.88 | | |
| **NA 20-15 (MPUM 10706)** | | | 0.75 | 0.80 | | 0.94 | | |
| **FNP 67a-1 (MPUM 10706)** | 1.50 | 1.58 | 1.50 | 1.58 | | 0.95 | | |
| **FNP 67a-2 (MPUM 10706)** | | | 0.80 | 0.86 | | 0.93 | | |
| **FNP 67a-4 (MPUM 10706)** | | 1.60 | | | | | | |
| **FNP 67a-5 (MPUM 10706)** | 1.33 | 1.46 | 1.33 | 1.46 | | 0.91 | 11.7 | |
| **FNP 67/68-1 (MPUM 10705)** | | | 1.36 | 1.50 | | 0.91 | | |
| **FNP 67/68-8 (MPUM 10704)** | 0.96 | 1.17 | 0.96 | 1.17 | | 0.82 | | |
| **FNP 74.1-1 (MPUM 10706)** | 0.76 | 0.77 | 0.76 | 0.77 | | 0.99 | | |
| **FNP 74.1-2 (MPUM 10706)** | 0.58 | 0.60 | 0.58 | 0.60 | | 0.97 | | |
| **FNP 74.1-3 (MPUM 10706)** | 0.96 | 1.06 | 0.96 | 1.06 | | 0.90 | | |
| **FNP 74.1-7 (MPUM 10706)** | 0.66 | 0.65 | 0.66 | 0.65 | | 1.01 | | |
| **FNP 75-10 (MPUM 10706)** | 0.97 | 1.03 | 0.97 | 1.03 | | 0.94 | | |
| **FNP 75-11 (MPUM 10706)** | 1.00 | 0.05 | 1.00 | 1.06 | | 0.94 | | |
| **FNP 75-13 (MPUM 10706)** | | | 0.93 | 1.05 | | 0.88 | | |
| **FNP 103-6 (MPUM 10706)** | 1.21 | 1.57 | 1.21 | 1.57 | | 0.77 | 15 | |
| **NA 29-3 (MPUM 10706)** | | | 1.36 | 1.52 | | 0.89 | 12.8 | |
| **NA 30-6 (MPUM 10706)** | 1.03 | 1.26 | 1.03 | 1.26 | | 0.82 | | |
| **NA 30-9 (MPUM 10706)** | | | 0.74 | 0.97 | | 0.76 | | |
| **PMAM 5-2 (MPUM 10706)** | | | 1.84 | 2.00 | | 0.92 | | |
| **PMAM 41-7 (MPUM 10706)** | | | 0.57 | 0.72 | | 0.79 | | |
| **PMAM 41-8 (MPUM 10706)** | 0.72 | 0.91 | 0.72 | 0.91 | | 0.79 | 16 | |
| **PMAM 41-16 (MPUM 10706)** | 0.80 | 1.00 | 0.80 | 1.00 | | 0.80 | | |
| **PMAM 41-17 (MPUM 10706)** | 1.10 | 1.25 | 1.10 | 1.25 | | 0.88 | | |
| **PM 23-6 (MPUM 10706)** | | | 0.82 | 0.94 | | 0.87 | 13.5 | |
| **PMAM 24c-3 (MPUM 10706)** | | | 1.00 | 1.10 | | 0.90 | | |
| **PMAM 42-12 (MPUM 10706)** | | | 0.75 | 1.00 | | 0.75 | | |
| **PMAM 42-45 (MPUM 10706)** | 0.81 | 0.92 | 0.81 | 0.92 | | 0.88 | | |
| **PMAM 42-47 (MPUM 10703)** | 1.26 | 1.46 | 1.26 | 1.46 | 0.35 | 0.86 | 15 | 29 |
| **PMAM 42-51 (MPUM 10706)** | 1.40 | | 1.05 | 1.25 | | 0.84 | | |
| **PMAM 42-53 (MPUM 10706)** | | 1.23 | 0.90 | 1.10 | | 0.82 | | |
| **PMAM 42-70 (MPUM 10706)** | | | 1.32 | 1.44 | | 0.92 | | |
| **FNP 118-3 (MPUM 10706)** | 1.10 | 1.60 | 1.10 | 1.60 | | 0.69 | | |

Tab. 3 - Summary of the measurements on the *Halobia* cf. *rugosa* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 42b-1 (MPUM 10710)** | 0.90 | | 0.76 | 1.02 | 0.31 | 0.74 | | |
| **FNP 75-3 (MPUM 10714)** | 1.50 | | 0.93 | 1.15 | | 0.81 | | |
| **FNP 80a-26 (MPUM 10711)** | | | 0.75 | 0.90 | 0.37 | 0.83 | 19.4 | |
| **FNP 80a-42 (MPUM 10714)** | | | 0.62 | 0.76 | | 0.82 | | |
| **FNP 99-1 (MPUM 10712)** | 0.86 | 1.29 | 0.86 | 1.29 | 0.37 | 0.67 | 23 | 27.2 |
| **FNP 99-2 (MPUM 10713)** | 0.87 | 1.14 | 0.87 | 1.14 | 0.41 | 0.76 | 25.9 | 27.7 |

Tab. 4 - Summary of the measurements on the *Halobia radiata* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 67/68-6 (MPUM 10715)** | 1.53 | 2.00 | 1.20 | 1.42 | | 0.85 | | |
| **FNP 67/68-7 (MPUM 10727)** | 1.13 | | 0.40 | 0.55 | | 0.73 | | |
| **FNP 67/68-9 (MPUM 10727)** | 0.94 | 1.00 | 0.94 | 1.00 | | 0.94 | | |
| **FNP 68a-1 (MPUM 10727)** | 1.15 | 1.36 | 1.15 | 1.36 | | 0.85 | | |
| **FNP 80-1 (MPUM 10727)** | 1.23 | 1.42 | 1.23 | 1.42 | | 0.87 | | |
| **FNP 80a-10 (MPUM 10727)** | | | 0.86 | 1.27 | | 0.68 | 24.3 | |
| **FNP 80a-18 (MPUM 10727)** | 0.70 | 1.04 | 0.52 | 0.67 | | 0.78 | | |
| **NA 27.1-1 (MPUM 10727)** | | | 1.08 | 1.26 | | 0.86 | 18 | |
| **FNP 95a-1 (MPUM 10727)** | | 3.00 | 1.20 | 1.60 | | 0.75 | 36.4 | |
| **FNP 95a-3 (MPUM 10727)** | 3.50 | | 1.06 | 1.52 | | 0.70 | | |
| **FNP 95b-1 (MPUM 10727)** | 0.77 | 0.80 | 0.77 | 0.80 | | 0.96 | | |
| **FNP 99b-1 (MPUM 10727)** | 1.00 | 1.20 | 1.00 | 1.20 | | | | |
| **FNP 99b-10 (MPUM 10727)** | | | 0.40 | 0.45 | | 0.89 | | |
| **FNP 99a-1 (MPUM 10727)** | | | 0.90 | 1.00 | | 0.90 | 9.5 | |
| **FNP 99a-4 (MPUM 10727)** | | | 0.80 | 0.94 | | 0.85 | | |
| **FNP 99a-5 (MPUM 10727)** | | | | 2.15 | | | | |
| **FNP 99c-1 (MPUM 10727)** | 1.02 | | 0.50 | 0.76 | | 0.66 | 7 | |
| **FNP 99c-4 (MPUM 10727)** | 1.77 | 2.00 | 1.77 | 2.00 | | 0.89 | 13.6 | |
| **FNP 99c-14 (MPUM 10727)** | 1.28 | 1.56 | 1.28 | 1.56 | | 0.82 | | |
| **FNP 99c-15 (MPUM 10727)** | 1.13 | 1.41 | 1.13 | 1.41 | | 0.80 | 12.8 | |
| **NA 28-1 (MPUM 10727)** | 1.10 | 1.20 | 0.63 | 0.81 | | 0.78 | | |
| **NA 28-2 (MPUM 10727)** | 1.00 | 1.29 | 0.67 | 0.78 | | 0.86 | | |
| **NA 28-4 (MPUM 10727)** | 1.14 | 1.23 | 0.24 | 0.35 | | 0.69 | | |
| **NA 28-6 (MPUM 10727)** | 0.90 | 1.00 | 0.66 | 0.76 | | 0.87 | | |
| **NA 28-8 (MPUM 10727)** | 0.52 | 0.54 | 0.52 | 0.54 | | 0.96 | | |
| **NA 28-11 (MPUM 10727)** | 0.80 | | 0.14 | 0.30 | | 0.47 | | |
| **NA 28-14 (MPUM 10727)** | 1.31 | 1.27 | 1.31 | 1.27 | | 1.03 | | |
| **FNP 103-7 (MPUM 10727)** | | | 1.09 | 1.23 | | 0.89 | 22.3 | |
| **FNP 103-10 (MPUM 10727)** | 1.37 | | 0.87 | 1.03 | | 0.84 | 20.8 | |
| **NA 29-4 (MPUM 10727)** | 1.76 | 2.05 | 1.76 | 2.05 | | 0.86 | 16.4 | |
| **NA 29-5 (MPUM 10727)** | | | 0.87 | 1.06 | | 0.82 | | |
| **NA 29-8 (MPUM 10727)** | | | 0.96 | 1.16 | | 0.83 | 24.3 | |
| **NA 29-9 (MPUM 10727)** | | | 0.70 | 0.97 | | 0.72 | 16.2 | |
| **NA 29-10 (MPUM 10727)** | | | 0.58 | 0.74 | | 0.78 | 16.5 | |
| **NA 29-11 (MPUM 10727)** | | | 1.07 | 1.52 | | 0.70 | | |
| **NA 29-21 (MPUM 10727)** | 1.76 | 2.16 | 1.76 | 2.16 | | 0.81 | | |
| **NA 30-3 (MPUM 10727)** | | | 0.40 | 0.47 | | 0.85 | | |
| **NA 30-4 (MPUM 10727)** | | | 0.60 | 1.00 | | 0.60 | | |
| **NA 30-8 (MPUM 10727)** | | | 0.54 | 0.75 | | 0.72 | 14.8 | |
| **NA 31-2 (MPUM 10727)** | 1.20 | 1.32 | 0.46 | 0.54 | | 0.85 | | |
| **PMAM 41-9 (MPUM 10727)** | 0.57 | 0.70 | 0.57 | 0.70 | | 0.81 | | |
| **PMAM 41-13 (MPUM 10727)** | | | 0.97 | 1.05 | | 0.92 | 18.4 | |
| **PM 23-1 (MPUM 10727)** | 1.07 | 1.48 | 1.07 | 1.48 | | 0.72 | 13.1 | |
| **PM 23-12 (MPUM 10727)** | 1.25 | 1.46 | 1.25 | 1.46 | | 0.86 | | |

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **PM 23-13 (MPUM 10727)** | | | 0.63 | 0.92 | | 0.68 | 19 | |
| **PM 23-14 (MPUM 10727)** | | | 0.53 | 0.67 | | 0.79 | 11.3 | |
| **PM 23-15 (MPUM 10727)** | | | 0.58 | 0.70 | | 0.83 | 14 | |
| **PM 23-16 (MPUM 10727)** | 1.05 | 1.24 | 1.05 | 1.24 | | 0.85 | 14 | |
| **PMAM 24c-4 (MPUM 10727)** | | | 1.03 | 1.22 | | 0.84 | | |
| **PMAM 24c-9 (MPUM 10727)** | 1.50 | | 0.80 | 0.96 | | 0.83 | 18.4 | |
| **FNP 112-1 (MPUM 10727)** | 1.47 | 1.66 | 1.47 | 1.66 | | 0.89 | | |
| **FNP 112-10 (MPUM 10727)** | 1.20 | 1.73 | 1.20 | 1.73 | | 0.69 | | |
| **FNP 112-14 (MPUM 10718)** | 0.67 | 0.70 | 0.67 | 0.70 | | 0.96 | | |
| **FNP 112-15 (MPUM 10727)** | 1.70 | | 0.82 | 1.26 | | 0.65 | | |
| **PMAM 42-1 (MPUM 10727)** | | 3.33 | 2.25 | 2.73 | | 0.82 | 18 | |
| **PMAM 42-3 (MPUM 10727)** | 3.16 | 4.07 | 3.16 | 4.07 | | 0.78 | | |
| **PMAM 42-4 (MPUM 10727)** | | | 0.90 | 1.50 | | 0.60 | | |
| **PMAM 42-5 (MPUM 10727)** | | 2.10 | 1.22 | 1.52 | | 0.80 | 13.5 | |
| **PMAM 42-6 (MPUM 10719)** | 3.13 | | 2.80 | 3.54 | 0.48 | 0.82 | 10.5 | 43.5 |
| **PMAM 42-7 (MPUM 10727)** | | | 1.53 | 2.05 | | 0.75 | 15.8 | |
| **PMAM 42-10 (MPUM 10727)** | 2.54 | | 1.56 | 2.33 | | 0.67 | 21.8 | |
| **PMAM 42-11 (MPUM 10720)** | 3.00 | 3.53 | 2.04 | 2.52 | | 0.81 | | |
| **PMAM 42-13 (MPUM 10721)** | 2.90 | 3.56 | 2.90 | 3.56 | 0.48 | 0.81 | 17.8 | 53.6 |
| **PMAM 42-20 (MPUM 10722)** | 2.76 | 3.02 | 2.80 | 3.24 | 0.35 | 0.86 | 19 | 39 |
| **PMAM 42-41 (MPUM 10727)** | 2.30 | 2.70 | 2.30 | 2.70 | | 0.85 | 21.8 | |
| **PMAM 42-48 (MPUM 10727)** | | | 1.00 | 1.25 | | 0.80 | | |
| **PMAM 42-49 (MPUM 10727)** | | | 1.70 | 2.25 | | 0.76 | | |
| **PMAM 42-52 (MPUM 10727)** | 1.65 | | 0.74 | 0.97 | | 0.76 | | |
| **PMAM 42-58 (MPUM 10724)** | | | 2.46 | 2.78 | 0.40 | 0.88 | 16.7 | 42 |
| **PMAM 42-61 (MPUM 10725)** | 1.94 | 2.65 | 1.32 | 1.84 | 0.44 | 0.72 | 15.7 | 32 |
| **PMAM 42-62 (MPUM 10726)** | 2.70 | 3.20 | 1.13 | 1.80 | 0.43 | 0.63 | 15.6 | 38.7 |
| **PMAM 42-63 (MPUM 10727)** | | 2.70 | 1.05 | 1.33 | | 0.79 | 12.7 | |
| **PMAM 42-91 (MPUM 10727)** | | | 1.27 | 1.75 | | 0.73 | | |
| **PMAM 42-92 (MPUM 10727)** | 2.03 | | 0.90 | 1.22 | | 0.74 | | |
| **FNP 115b-2 (MPUM 10727)** | | | 0.96 | 1.15 | | 0.83 | | |
| **FNP 115b-3 (MPUM 10727)** | | | 1.26 | 1.42 | | 0.89 | | |
| **FNP 118-4 (MPUM 10727)** | 2.00 | | 1.20 | 1.34 | | 0.90 | 16.7 | |
| **FNP 118-5 (MPUM 10727)** | | | 0.60 | 0.62 | | 0.97 | 18 | |
| **PM 30-2 (MPUM 10727)** | 0.89 | 1.00 | 0.89 | 1.00 | | 0.89 | 14.6 | |
| **PM 31.1-5 (MPUM 10727)** | | | 0.66 | 0.88 | | 0.75 | | |

Tab. 5 - Summary of the measurements on the *Halobia simplex* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 62-1 (MPUM 10728)** | 0.98 | 1.15 | 0.52 | 0.57 | | 0.85 | | |

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **NA 23-5 (MPUM 10730)** | 1.54 | 2.02 | 1.54 | 2.02 | | 0.76 | 19.7 | |
| **FNP 80a-17 (MPUM 10731)** | 1.16 | 1.80 | 0.49 | 0.50 | | 0.64 | | |
| **FNP 80a-30 (MPUM 10731)** | 1.97 | | | | | | | |
| **FNP 85-2 (MPUM 10731)** | | | 1.15 | 1.38 | | 0.83 | | |
| **PMAM 48-1 (MPUM 10731)** | 0.67 | 0.90 | 0.67 | 0.90 | | 0.74 | | |
| **Smith (1927), pl. 93, f. 3** | 4.70 | 5.10 | 4.70 | 5.10 | | 0.78 | 26.3 | |
| **Smith (1927), pl. 93, f. 4** | 1.69 | 2.33 | 1.69 | 2.33 | | 0.76 | 17.5 | |
| **Smith (1927), pl. 93, f. 5** | 1.69 | 1.92 | 1.69 | 1.92 | | 0.85 | 26.3 | |

Tab. 6 - Summary of the measurements on the *Halobia superba* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 135a-1 (MPUM 10736)** | 1.92 | | 1.62 | 2.19 | | 0.74 | 21.4 | |
| **FNP 147-1 (MPUM 10737)** | 2.70 | 3.43 | 2.70 | 3.43 | | 0.79 | 24.8 | |
| **FNP 147-2 (MPUM 10737)** | 2.43 | 3.27 | 2.04 | 2.30 | | 0.74 | 18 | |
| **FNP 147-4 (MPUM 10735)** | | | 0.57 | 1.00 | 0.46 | 0.57 | | 28 |
| **FNP 147-6 (MPUM 10737)** | 2.10 | 2.70 | 2.10 | 2.70 | | 0.78 | 25.8 | |
| **FNP 147-8 (MPUM 10734)** | | | 0.74 | 1.03 | 0.46 | 0.72 | 24.5 | 28 |
| **FNP 147-11 (MPUM 10737)** | | | 1.25 | 1.58 | | 0.79 | 18 | |
| **FNP 147-14 (MPUM 10733)** | | | 1.15 | 1.79 | 0.40 | 0.64 | 21 | 32 |
| **FNP 147-15 (MPUM 10737)** | | | 2.25 | 2.70 | | 0.83 | | |
| **FNP 147bis-5 (MPUM 10732)** | 2.00 | | 1.14 | 1.50 | 0,29 | 0.76 | 22 | 34 |
| **Smith (1927), pl. 99, f. 10** | 2.32 | 2.98 | 2.32 | 2.98 | | | | |
| **Smith (1927), pl. 99, f. 11** | 2.15 | 2.81 | 2.15 | 2.81 | | | 21.4 | |
| **Smith (1927), pl. 99, f. 12** | 1.98 | 2.49 | 1.98 | 2.49 | 0.50 | 0.76 | 20 | 27 |
| **Smith (1927), pl. 99, f. 13** | 1.32 | 1.83 | 1.32 | 1.83 | | | 20 | 29 |
| **Mojsisovics (1874) GBA 1874/01/31-1** | 3.83 | | 0.88 | 1.32 | | 0.67 | | 33 |
| **Mojsisovics (1874) GBA 1874/01/31-2** | 3.03 | | 1.82 | 2.56 | 0.43 | 0.71 | 16.8 | 26 |
| **Kittl (1912) NHMW 1969/996** | 2.09 | | 0.59 | 0.85 | 0.40 | 0.69 | 24 | |
| **Kittl (1912) NHMW 1969/1003** | | | 1.75 | 2.31 | 0.42 | 0.76 | 15.2 | 28 |
| **Kittl (1912) NHMW 1969/997** | 2.12 | | 1.31 | 1.79 | 0.43 | 0.73 | 24.4 | 27.5 |
| **Kittl (1912) NHMW 1969/1004** | 2.12 | | 1.74 | 2.09 | 0.48 | 0.83 | 15.4 | 33 |

Tab. 7 - Summary of the measurements on the *Halobia austriaca* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | H mis | L mis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 151det-1 (MPUM 10743)** | 3.70 | 4.60 | 3.70 | 4.60 | | 0.80 | | |
| **FNP 151.1-1 (MPUM 10743)** | 3.13 | | 2.25 | 2.50 | | 0.90 | | |
| **FNP 151.1-2 (MPUM 10743)** | 2.60 | 3.58 | 2.60 | 3.58 | | 0.73 | | |
| **FNP 151.1-5 (MPUM 10739)** | 3.02 | | 2.47 | 3.50 | 0.52 | 0.70 | 17 | 20 |
| **FNP 151.1-6 (MPUM 10740)** | 3.16 | | 2.50 | 3.20 | 0.46 | 0.78 | | 18.7 |
| **FNP 151.2-1 (MPUM 10741)** | | 2.86 | 1.57 | 2.20 | 0.40 | 0.71 | 23 | 32.8 |
| **FNP 151.4-1 (MPUM 10742)** | 4.18 | | 3.38 | 4.48 | 0.37 | 0.75 | 26.4 | 16.2 |
| **NA 45-1 (MPUM 10738)** | | 3.50 | 2.00 | 2.70 | | 0.74 | | |
| **NA 45-4 (MPUM 10743)** | 3.80 | 4.45 | 3.80 | 4.45 | | 0.85 | | |
| **NA 45-6 (MPUM 10743)** | 3.60 | | 2.05 | 2.90 | | 0.71 | | |
| **NA 45-7 (MPUM 10743)** | 3.50 | | 2.13 | 2.77 | | 0.77 | | |
| **Kittl, 1912 NHMW 1969/970** | 3.90 | 4.45 | 2.45 | 3.15 | | 0.78 | 23 | |

Tab. 8 - Summary of the measurements on the *Halobia styriaca* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | H mis | L mis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **Kittl, 1912 NHMW 1969/971** | | 3.66 | 2.07 | 2.84 | | 0.73 | | |
| **Kittl, 1912 NHMW 1969/972** | 3.97 | | 2.21 | 3.25 | | 0.68 | 26 | |
| **Kittl, 1912 NHMW 1969/998** | 2.46 | 2.82 | 1.04 | 1.47 | | 0.87 | 26.5 | |
| **Kittl, 1912 NHMW 1969/1005** | 2.64 | 3.75 | 2.01 | 2.92 | | 0.69 | 17.2 | |
| **Mojsisovics 1874, pl. 1, f. 4** | 4.89 | | 3.43 | 4.49 | | 0.76 | 12.4 | |

Tab. 9 - Summary of the measurements on the *Halobia beyrichi* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **FNP 154a-1 (MPUM 10744)** | 4.10 | 5.30 | 1.81 | 3.12 | | 0.77 | | 56.7 |
| **FNP 154a-3 (MPUM 10746)** | 3.84 | 5.00 | 2.68 | 3.30 | | 0.77 | 17 | |
| **FNP 154b-1 (MPUM 10746)** | 1.12 | 2.02 | 1.12 | 2.02 | | 0.55 | | |

Tab. 10 - Summary of the measurements on the *Halobia mediterranea* specimens. All linear values are in centimetres, angular values in degrees.

| | H | L | Hmis | Lmis | BP | H/L | α | β |
|---|---|---|---|---|---|---|---|---|
| **PM 36.1-1 (MPUM 10751)** | | | 0.84 | 1.05 | | 0.80 | | |
| **NA 48.1-4 (MPUM 10751)** | 0.86 | 1.14 | 0.86 | 1.14 | | 0.75 | | |
| **NA 50.3-1 (MPUM 10750)** | 1.00 | 1.27 | 1.00 | 1.27 | | 0.79 | 25 | 40.5 |
| **NA 50.1-1 (MPUM 10751)** | 1.07 | | 0.80 | 1.14 | | 0.70 | | |
| **PM 37.1-1 (MPUM 10751)** | 0.85 | 1.10 | | | | 0.77 | | |
| **FNP 170.2-1 (MPUM 10747)** | | | | | 0.43 | | 20 | 47.8 |
| **FNP 170.2-2 (MPUM 10751)** | 1.02 | 1.30 | 1.02 | 1.30 | | 0.78 | 19 | |
| **FNP 170.2-3 (MPUM 10748)** | | 2.37 | 1.26 | 1.72 | 0.39 | 0.73 | 21.5 | 48 |
| **FNP 170.2-8 (MPUM 10749)** | | | | | | | 18.7 | |
| **FNP 170.3-2 (MPUM 10751)** | 1.35 | | 0.74 | 1.14 | | 0.65 | 14 | |