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RECORD OF A RUDIST FROM PELAGIC BASINAL LIMESTONES (UPPER CRETACEOUS, LESSINI MOUNTAINS, NORTHERN ITALY)

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Abstract. The mid-Cretaceous succession of the central Southern Alps (Trento and Verona) is mainly represented by basinal deposits of the Scaglia Variegata.

In this paper, the presence of a radiolitid in the Scaglia Variegata of the Lessini Mountains is reported. It is the first finding of a well preserved rudist, which belongs to the Radiolitidae (*Sauvagesia* aff. *sharpei*) family. The specimen was found in Cenomanian basinal biomicrites.

Riassunto. La successione medio-cretacica del Sudalpino centrale (area trentina e veronese) è rappresentata prevalentemente dai depositi bacinali della Scaglia Variegata.

Viene segnalata la presenza di un radiolitide all'interno della Scaglia Variegata dei Monti Lessini. Si tratta della prima segnalazione di un esemplare di rudista (*Sauvagesia* aff. *sharpei*) all'interno di biomicriti bacinali del Cenomaniano.

Introduction

The Cretaceous of the Southern Alps in the Trentino and Venetian area is represented by basinal marly biomicrites. From the bottom to the top, the sequence can generally be subdivided into: Maiolica (up to lower Aptian), Scaglia Variegata (lower Aptian-lower Turonian) and Scaglia Rossa (lower Turonian to Eocene p.p.). Unlike the corresponding terms in the Appenines, these lithostratigraphic units have not yet been reviewed and approved by the Italian Geological Society Commission of Stratigraphy (Cita et al. 2005). The "Scaglia Variegata" term, in fact, is also used to indicate Late Paleocene and Eocene basinal deposits of the Venetian Prealps, Appennines and Sicily. In this paper, the "Scaglia Variegata" term is used to indicate marly-calcareous successions which are rich in organic matter and succeed to the micritic succession of Maiolica ("Biancone") in the lower Aptian.

The term "Scaglia Variegata Alpina" has been recently introduced by Barbieri & Grandesso (2007) and Avanzini et al. (2010) for those outcrops included in the 1:50.000 scale "Asiago" and "Trento" sheets of the Geological Map of Italy.

Scaglia Variegata formation

In the Central Southern Alps, clay input caused a transition from the micrites of the Maiolica ("Biancone") towards the marly-calcareous levels of the Scaglia Variegata. The latter are characterised by the alternation, on a decimetric scale, of radiolaria and foraminifera-bearing grey-whitish marly limestones with marls and grey-blackish clay marls, occasionally laminated (Bosellini et al. 1978; Bellanca et al. 1996; Lozar & Grosso 1997). Sometimes the marly-calcareous alternations are partially reworked by bioturbation (*Zoophycos*, *Chondrites* and *Planolites*); this process is particularly evident in the calcareous levels, where dark patches occur in the light-coloured micrites. The calcareous cycles often appear in metric bundles delimited by darker and thicker marly levels. Chert lenses or nodules are occasionally present in the calcareous levels.

The Scaglia Variegata age is mainly related to the lower Aptian – lower Turonian interval, even though in

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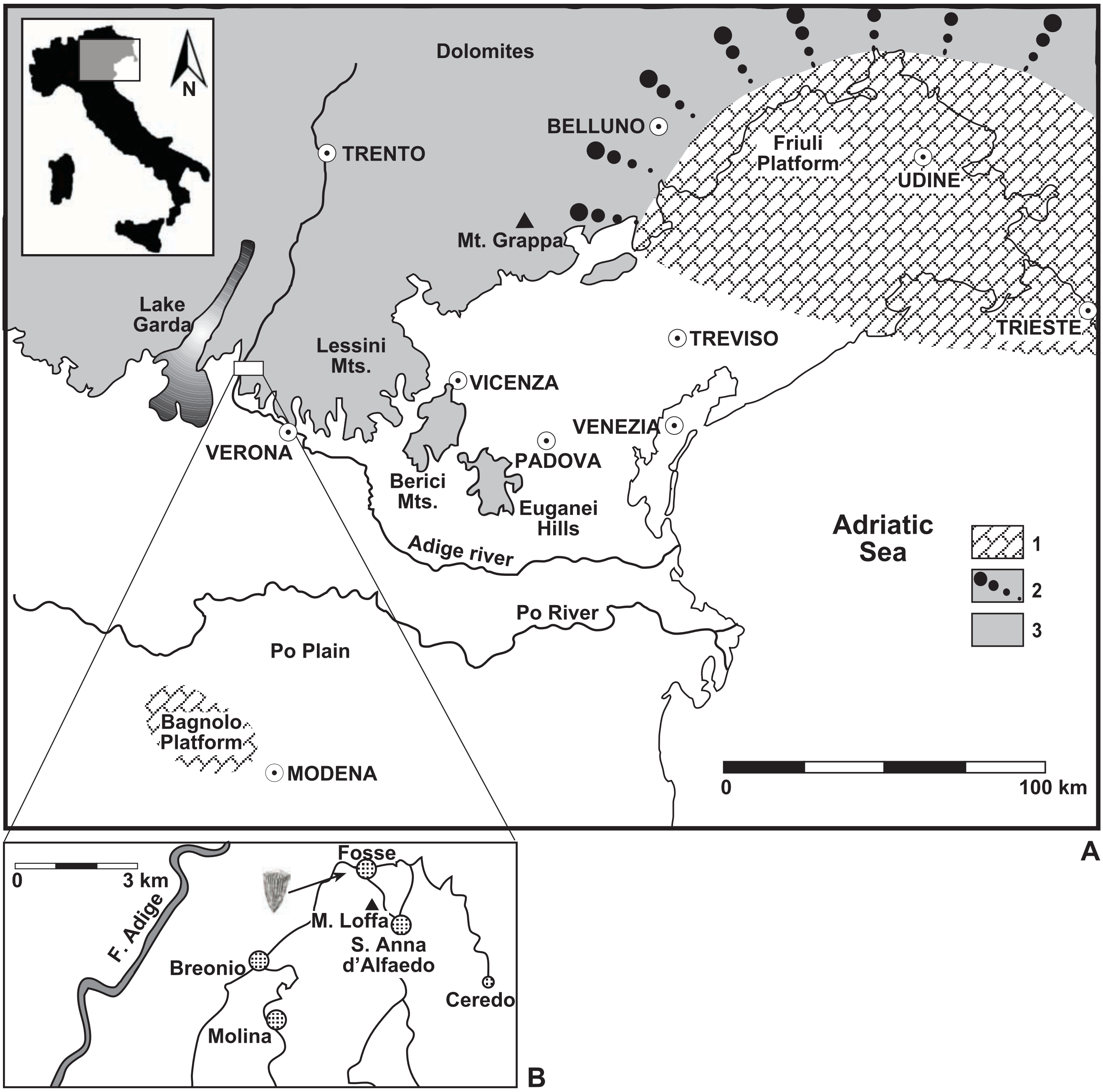


Fig. 1 - A) Schematic paleogeographic map of the central-eastern portion of the Southern Alps during the Late Cretaceous. 1 - Shallow water carbonate platforms (Friuli Platform and buried Bagnolo Platform). 2 - Slope-resedimentation deposits of the Friuli Platform. 3 - Basinal limestones. B) Map of the rudist collection.

some localities it can reach the Santonian (Bosellini et al. 1978). The depositional setting probably corresponds to a middle-low bathyal environment (Luciani & Cobianchi 1999).

The terrigenous input of the lower Aptian is known worldwide and it has been attributed to global climate changes (Castellarin 1972, 1977; Trümpy 1975). Moreover, the terrigenous input due to the mid-Cretaceous tectonic inversion (Weissert 1990), could have played an important role on a regional scale.

As in the analogous pelagic basinal formations of Umbria and Lombardy, black shale horizons are present in the Scaglia Variegata. They represent the local record of oceanic anoxic events (OAEs), which occurred in the mid-Cretaceous (Bosellini et al. 1978; Weissert et al. 1985; Bellanca et al. 1996; Luciani & Cobianchi 1999).

However, the diversified paleobathymetry of the Scaglia Variegata basin is the consequence of the Eo-alpine (Late Cretaceous-Paleogene p.p.) deformation (Doglioni & Bosellini 1987) that affected the western and central sectors of the Southern Alps. This event produced sinistral transpression movements in the central part, where narrow and elongated flower structures occurred in the Late Cretaceous (Bosellini et al. 1978; Doglioni & Bosellini 1987).

During the stratigraphic review of the Cretaceous basinal succession in the Giudicariense area, Poletti et al. (2000) divided the Scaglia Variegata into two members: the Spiazzi member and the Vervò member. This subdivision was based on the different calcium carbonate and organic carbon contents: the Spiazzi member (Aptian p.p.) is represented by whitish marly micrites and clay marls, characterised by low organic carbon content, while the Vervò member (Aptian p.p. -lower Turonian) consists of rhythmite with lower clay and higher organic carbon contents. The Vervò member includes all the black shales of the Giudicariense area.

The rudist-bearing sample was found in debris, at the foot of a Scaglia Variegata outcrop, a few hundred metres west of the village of Fosse (2.5 km north-west of S. Anna d'Alfaedo, Verona Province; Fig. 1).

The outcrop is located at an altitude of 965 m; it represents the top part of the Scaglia Variegata (Vervò member) and lies close to the top boundary with the Scaglia Rossa. The sub-horizontal layers consist of an alternation of decimetric levels of light-coloured micritic limestone with black bioturbation (*Zoophycos*) and dark interlayers of marls, rich in organic matter.

Systematic palaeontology

Rudist bivalves have been reported in carbonates cropping out in the Southern Alps (Northern Italy) as early as the eighteenth century. A revision of the Turonian-Coniacian rudists found in the Scaglia muddy deposits of the area, has recently been carried out by Trevisani & Cestari (2007), but no taxon has yet been found in the Cenomanian carbonates. The study of this specimen embedded in the Scaglia provides new information on these poorly known rudists, pre-dating their first occurrence in pelagic settings of the area.

The identification of this specimen's general features follows the criteria given in Dechaseaux et al. (1969) and the shell structure's description reported in Masse & Philip (1972) and in Pons & Vicens (2008).

Class **Bivalvia** Linné, 1758

Subclass **Heterodonta** Neumayr, 1884

Order **Hippuritoida** Newell, 1965

Family Radiolitidae Gray, 1848

Genus *Sauvagesia* Choffat, 1886

Sauvagesia aff. **sharpei** Bayle, 1857

Material: Two fragments belonging to a single specimen have been examined in this study. A fracture between the anterodorsal side (fragment A in Fig. 2) and the posterodorsal one (fragment B in Fig. 2) separates the two fragments. They are embedded in a calcareous-marly mudstone and show the external side of the shell and part of the commissural area, while the general cavity and the ventral side are hidden in the sediment matrix, making a definite systematic attribution to a particular species impossible. The fragments show features typical of a bivalve taxon belonging to Radiolitidae (Hippuritoida); they are well preserved and in good condition but with most of the shell's external part nearly completely eroded. The specimen is housed at the Natural History Museum of Ferrara (Italy), labelled n° R15.

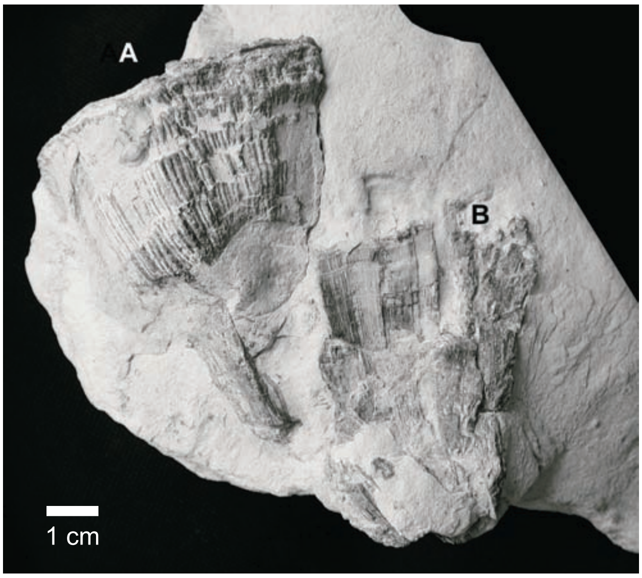


Fig. 2 - Single specimen broken into two fragments: the anterodorsal fragment A and the posterodorsal fragment B are embedded in a calcareous-marly matrix.

Description. The genus *Sauvagesia* differs from other radiolitid taxa in the presence of a well developed ligament ridge on the dorsal side and, on the ventral side, of wide radial bands bearing delicate costellae, which are separated by a narrow interband of costae. Fragment A (FA) is 6.4 cm wide and 8 cm high, with a maximum shell thickness in the commissural area of 1.7 cm. A reconstruction shows that the specimen should have had a conical shape and a width of at least 7 cm in the commissural area, with a height of 10 cm. On the dorsal side the ornamentation is formed by small *costae* 1.5 mm apart (Fig. 3A). Seen from above, the ligament ridge is well developed and formed by a strong folding of the inner shell margin, which projects 3 mm towards the general cavity (Fig. 3C). The upper (left) valve is missing, radial bands are not visible because hidden in the sediment. The shell structure is composed of well bedded laminae, which create walls and form a normal cellular structure (*sensu* Pons & Vicens 2008). The maximum thickness measured on the dorsal side is 18 mm. Prisms have a polygonal shape with dimensions ranging from 0.5 to 1 mm.

In FB the radial natural section (Fig. 3F) shows a discontinuous growth of lamellae (or laminae) sets, with

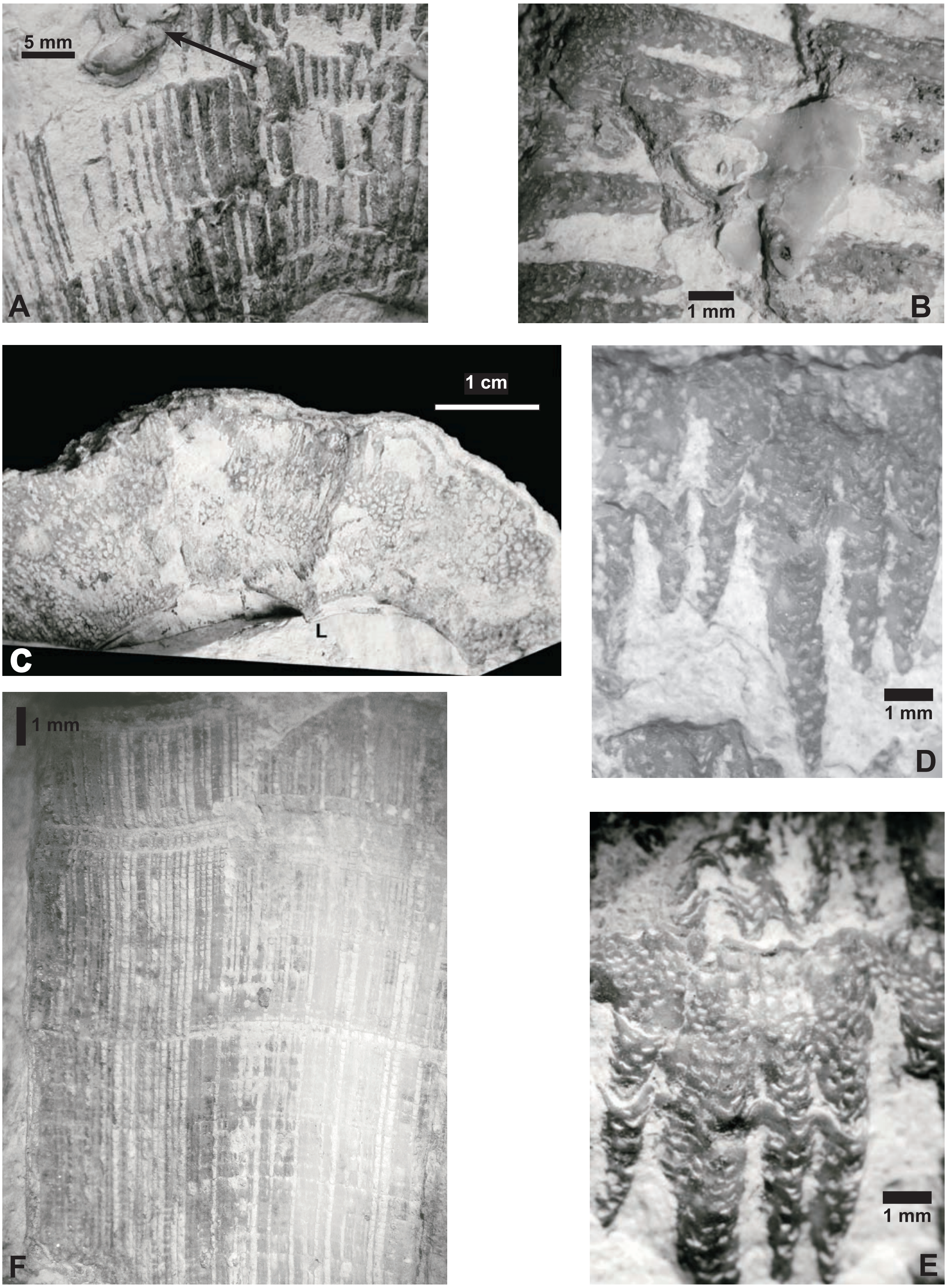


Fig. 3 - A) In the dorsal side of fragment A the ornamentation is formed by small *costae* spaced 1.5 mm. Encrusting small bivalves (*Amphidonte* ostreid) can be seen above (arrow). B) Small shell of *Amphidonte* encrusting directly on the emerging prisms from the external side of the shell. Top is on the left. C) Dorsal side seen from above showing a well developed ligament ridge (L) and normal cellular shell structure; the radial bands are embedded in the sediment. D and E) Side view showing the presence of a compact structure only at the base of the costae; the prisms of the cellular network are directly in contact with the sediment. F) Radial natural section showing a discontinuous growth of lamellae sets with normal cellular microstructure and little folded lamellae with a medium inclination of a few degrees with respect to the growth axis. Shell fragment B.

the normal cellular microstructure being formed by gently folded lamellae generally inclined by a few degrees with respect to the growth axis. The outer shell margin is made of an extremely thin compact structure, which is preserved only in some parts along the costae. The depth to which the lamellae are impressed corresponds to the major growth cycles and can be observed along the shell, marked by their rhythmic superimposition. The frequency is regular, which reflects the regular growth of the specimen, until their distance drastically diminishes. This feature could be indicative of the transition from an adult to senescent ontogenetic stage, rather than to palaeoenvironmental causes.

The morphostructural features of this broken specimen, such as ligament ridge, normal cellular structure, gently folded and well bedded lamellae and shell thickness, are typical of a taxon belonging to the genus *Sauvagesia*. Although the ventral side is hidden in the sediment, together with the radial structures and the interband, the only species showing similar features is *Sauvagesia sharpei*, a taxon typically found in Cenomanian shallow water sediments of shelf settings. It has to be pointed out that almost all of the very thin compact structure is missing so that the prisms of the cellular network are directly in contact with the sediment (Fig. 3D and E). With regards to taphonomic considerations, it has to be noted that small bivalve fragments encrust the external side of the *Sauvagesia* shell (Fig. 3B). They have a fibrous calcite structure and resemble the two left valves plus a right valve of a small ostreid taxon (height nearly 6 mm), possibly the genus *Amphidonte*.

Distribution. This widespread genus is found in the Late Cretaceous (Albian-Maastrichtrian) of European, north African and central and northern America areas (Dechaseaux et al. 1969). In the Mediterranean Tethys it is present in different Cenomanian palaeogeographic settings (Polsak et al. 1982; Pons & Sirna 1992). It is found in shelf margin deposits in association with other rudists such as caprinids and radiolitids of the late Cenomanian and with radiolitids of the Campanian (Central Italy; Stössel 1999). In inner platform deposits *Sauvagesia* is found in slender radiolitid assemblages of the late Coniacian-Santonian (Central Italy, Cestari & Pons 2007; Cestari 2009). In northern Italy scattered specimens are found in upper Turonian-Coniacian pelagic sea mount settings (Trevisani & Cestari 2007).

At least two small ostreid events are recorded in the middle-late Cenomanian (*Pycnodonte* event and *Amphidonte* event; Owen 1996; Wilmsen & Voigt 2006; Jarvis et al. 2006), as monospecific concentrations, which represent valid stratigraphic markers on a regional scale (Northern Germany, England, Northern France).

Microfacies. The microfacies is composed of bioturbated marly limestone with a *mudstone* texture and bears a rich assemblage marked by planktonic organisms such as *Thalmanninella* (formerly *Rotalipora*) *appenninica*, *Rotalipora* cf. *gandolfii* (Fig. 4A-C), Heterohelicidae, *Globigerinelloides* sp., Pithonelloideae, and Calcisphaerulidae, together with echinoderm fragments. The assemblage is referred to the early-middle Cenomanian. The calcisphaerulid-rich facies is linked to marine paleo-productivity influenced by a high nutrient input that facilitated the diffusion of these organisms in eutrophic conditions (Wendler et al. 2002). Nannoplankton analysis revealed a nearly barren sample, apart from a few long ranging forms.

Discussion

The presence of rudists in basinal deposits is often explained by carbonate platform resedimentation processes; instead, the reasons for their occurrence can be numerous.

In this study, some features of the radiolitid and of the including matrix led to the exclusion of such resedimentation processes generally inferred for other types of rudists in a basinal matrix.

- Carbonate platform resedimentation is excluded because of the distance (several tens of km; Fig. 1) from active platforms during the Cretaceous (Friuli Platform and, subordinate, Bagnolo Platform; Bosellini et al. 1981; Nardon et al. 1991) and because of the absence of evidence in support of resedimentation processes.
- Any adaptation to oligophotic/aphotic conditions typical of the Scaglia Variegata depositional environment is also excluded, because the basin was one of the deepest in the Southern Alps during the Cretaceous. Adaptation to oligophotic conditions has been proposed by Trevisani & Cestari (2007) for the majority of rudists included in the nearby Scaglia Rossa, which crops out in the nodular ("lastame") facies of late Turonian-early Coniacian age in the Lessini Mountains. Vera & Molina (1999) reached the same conclusion to justify the presence of radiolitids in the Capas Rojas Formation (Late Cretaceous-Eocene) of the Betic Cordillera, which is the equivalent of the Scaglia Rossa of the Alps and Appenines. In the lower Maastrichtian Cardenas Formation exposed at La Luz (State of San Luis Potosí, east-central Mexico) is pointed out a shallowing-upwards mixed-clastic-carbonate sequence bearing the hippuritid rudist *Laluzia armini* gen. et sp. nov., thought to be adapted in deeper settings (Götz & Mitchell 2009). Instead, this taxon should be considered a morphotype of *Gloria* Grubic, 2004 transported in deeper environments (J.M. Pons pers. comm.).

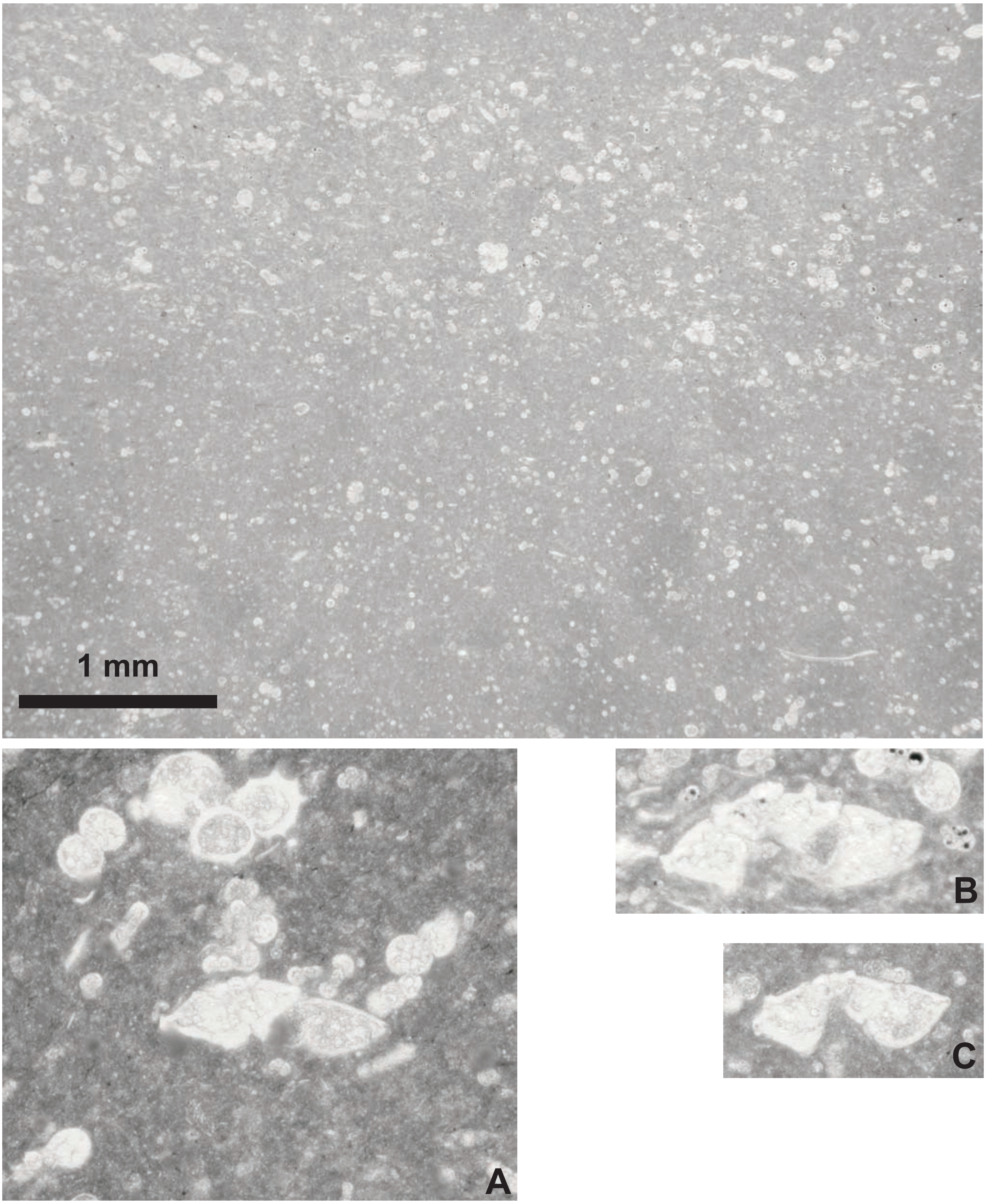
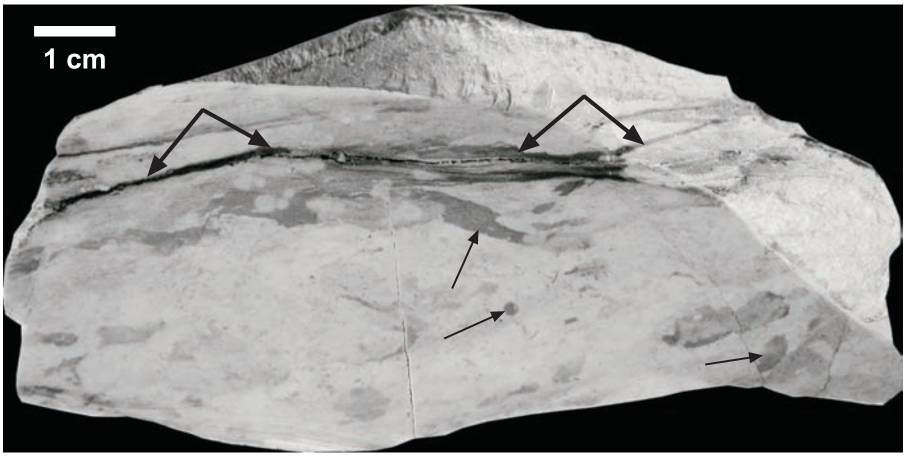


Fig. 4 - Scaglia Variegata microbiofacies marked by mudstone with planktonic foraminifera. A: *Thalmanninella* (formerly *Rotalipora*) *appenninica* (X 40); B and C: *Rotalipora* cf. *gandolfii* (X 50).

• The Late Cretaceous paleobathymetry of the Giudicariense area was certainly not monotonous, yet gravitational transport mechanism in intrabasinal highs – similar to the one proposed for rudists of the Turonian-Coniacian Scaglia Rossa of Lessini Mountains (Trevisani & Cestari 2007) – can be excluded. This is because resedimentation evidence (microturbidites with planktonic foraminifera, lithoclasts etc.) indicate a provenance from deep intrabasinal areas, without indication any of neritic resedimentation.

Fig. 5 - Matrix polished section with evidence of dark bioturbation (thin arrows) and plant remains (thick arrows).



Conclusion

Taking into account the nature of the studied specimen (Scaglia Variegata sample found in debris), the authors concluded that the most likely sedimentation process must have been post-mortem floating followed by sinking to the sediment surface. This caused the bending of the depositional surface, which is represented by unconsolidated carbonate mud.

Plausible process-dynamics are:

• unassisted floating; this kind of transport has also been suggested for other finds (Van Veer 1969; Hattin 1986; Cobban et al. 1991; Lewy 1995);

• floating via a raft (rafting).

The latter, which occurs with the use of driftwood, is the most likely process, based on the presence of iron hydroxide deposits (possibly of plant origin) on the rudist (Fig. 2) and within the matrix (Fig. 5). The mechanism of transport is believed to have been biological rafting (Bennett et al. 1996).

The studied rudist represents a “biological dropstone”, namely an exotic or extrabasinal element of organic origin and not a rock fragment, as in the formal definition “dropstone”. Typical dropstones are instead pebbles and boulders (transported by biological rafting) described by Massari & Savazzi (1981) in Turonian-Coniacian Scaglia Rossa and located approximately 1 km south-east (Mt. Loffa) of where the rudist was found (near Fosse). The raft could have been a plant similar to those found in the clay of the Bonarelli Level, at the Cenomanian-Turonian boundary, in the provinces of Belluno (Gomez et al. 2002) and Treviso (Pigozzo 2002). They mainly consist of conifers.

Other types of rafting are either excluded or considered very unlikely. Ice rafting was not possible due to the low paleo-latitude of the Scaglia Variegata basin during Late Cretaceous. Moreover, the studied rudist represents the only dropstone example in the whole Scaglia Variegata. Kelp rafting can only occur along coastlines and the specimen lacks any trace of algae or other organisms which normally were carried by algae rafts. Finally, transport as gastrolite by large marine vertebrate is also excluded, as no evidence of such process has ever been reported in the whole Scaglia Variegata and it is the least documented rafting method.

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