Bivalves and other macrobenthic fauna from the Ladinian "Muschelkalk" of Punta del Lavatoio (Alghero, SW Sardinia)

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Abstract

Bivalves from the Muschelkalk of Punta del Lavatoio (NW Sardinia) are described and illustrated here for the first time. Two species determined here (*Septifer* ? *eduliformis* and *Costigervillia substriata*) have never been quoted from this outcrop before, while the remaining ones have been listed by past authors, even if in some cases a different specific determination is proposed (e.g. *Placunopsis plana* and *Curionia gastrochaena*). The macrobenthic assemblage also yields rare brachiopods (*Coenothyris vulgaris*) and gastropods (? *Loxonema*); scaphopods are frequent and represented by *Laevidentalium laeve*.

The Muschelkalk succession of Punta del Lavatoio, ? latest Fassanian-Early Longobardian in age, has been overturned, so that the biostratigraphic distribution of the taxa determined here is presented in the right position. Bivalve palaeoecolgy and palaeoenvironmental evolution of the succession are also discussed.

Introduction

The Punta del Lavatoio is a famous and historical outcrop of the Muschelkalk of Sardinia, already recorded and described at the end of the 19th century and beginning of the 20th century (De Stefani, 1891; Tornquist, 1904; Deninger, 1907; Oosterbaan, 1936). The outcrop is located along the cliff and seaside, immediately south of Alghero town (Fig. 1). The succession yields some rich fossiliferous horizons in which Germanic species, mostly represented by bivalves, are associated with Alpine species cited in the past literature (e.g. *Protrachyceras longobardicum* (Mojsisovics), Tornquist, 1904). For this reason, the outcrop has been used for correlations between the Middle Triassic of the Germanic basin and Alpine province (e.g Kozur, 1974; 1999). Recent research has concerned lithostratigraphy and sedimentology (Gandin, 1978), and microfossils. Pittau Demelia & Flaviani (1983) have worked on palynomorphs, while algae, foraminifers and conodonts have been studied by Bagnoli *et al.* (1985a, b).

As concerns macrofossils, despite the rich fossiliferous content, only fossil lists (e.g. Tornquist, 1904; Posenato, 1995; Màrquez- Aliaga *et al.*, 2000) or very short descriptions of some of them (Oosterbaan, 1936) have till now been available in the literature. The aim of this work is to describe and illustrate the bivalves and other benthic macrofauna collected by the author during some field excursions and to recognize their original stratigraphical distribution: in fact field research has made it possible to establish that the Muschelkalk succession of Punta del Lavatoio is overturned, a position never recognized before. The overturning of the sequence is mainly supported by geopetal and sedimentological structures, geometry of shell accumulations and bivalves in life position.

The fossiliferous layers are mainly represented by storm accumulations. Those occurring in the lower clayey horizon (top in the field), corresponding with the "*obere Nodosen-Horizont*" of Tornquist (1904), reveal the highest taxonomical diversity and contain almost all the species described here. The diversity of the fossil assemblage decreases upward. At the top of the sequence only sparse valves of Costatoriids occur (Fig. 1). For the stratigraphical and sedimentological aspects of the section see Posenato *et al*. (this volume).

Age

The chronological position of the Punta del Lavatoio succession is mostly based on conodonts. Bagnoli *et al*. (1985a) quoted the occurrence of "*Epigondolella*" (now *Budurovignathus*) *truempyi* (Hirsch), both from the lower fossiliferous horizon F0 (= *oberer Nodosus Horizont* of Tornquist, 1904) and above the dasycladacean banks (Fig. 1). On the basis of this conodont species a Late Fassanian age (upper *Curionii* Zone) was proposed (Bagnoli *et al*., 1985a).

However, a preliminary conodont revision (1), new data on the stratigraphical range of *B. truempyi* (2), and the detection of the overturning of the succession (3) may suggest a slightly younger age, probably corresponding to the earliest Longobardian.

1) The specimens of *B. truempyi* from Punta del Lavatoio, illustrated by Bagnoli *et al*. (1985a), have been considered by Kozur *et al*. (1994) as a new, younger subspecies of *B. truempyi*, transitional to *B. hungaricus*. The latter species is Early Longobardian in age.
2) The *B. truempyi* Zone has recently been correlated by Kozur (1999) to the Recubariense Subzone, uppermost Fassanian in age. However, a younger upper limit for this conodont zone is suggested by the discovery in the Bagolino area (Southern Alps) of *B. truempyi* from a bed located above *Eoprotrachyceras margaritosum* and included in the Gredleri Zone, lowermost Longobardian in age (Nicora & Brack, 1995).
3) Tornquist (1904) quoted the occurrence of *Protrachyceras longobardicum* (Mojsisovics) in the *oberer Nodosus Horizont* (horizon F0, Fig. 1) which, if the sequence is "overturned" to its original position, falls at its base. If Tornquist's determination of this ammonoid is correct, then the clayey and limestone segment of Punta del Lavatoio is entirely Longobardian in age.

SYSTEMATIC PALAEONTOLOGY*

*Supra-generical classification of the subclasses Pteriomorphia and Isofilibranchia according to Carter (1990).

Subcl. Pteriomorphia Beurlen, 1944
Ord. Pterioida Newell, 1965
Subord. Pteriina Newell, 1965
Superfam. Pterioidea Gray, 1847
Fam. Bakevelliidae King, 1850

Gen. *Bakevellia* King, 1848
Bakevellia subcostata (Goldfuss, 1838)
(Pl. 1; Fig. 11)

B. subcostata is represented by an almost complete right valve (L = >16.5 mm; H = 16mm), whose surface is covered only by growth lines. The valve is strongly inflated but this character may has been accentuated by deformation, as suggested by irregular breakages occurring in the middle and anterior valve regions. The angle of maximum obliquity (*sensu* Allasinaz, 1964) is about 40°.

The valve is yielded in a small slab (D) collected from fossiliferous horizon F0.

Gen. *Costigervillia* Cox & Arkell, 1948
Costigervillia substriata (Credner, 1851)
(Pl. 1; Fig. 2)

Two valves are available, one left (L = 19.4 mm; H = 7.3 mm) and a one right (L = 22.5 mm; H = 9.9 mm). The left valve is strongly elongated and has a very sharp posterior keel. Its surface is covered by fine radial riblets, which are about 20 in the middle region; a relatively deep radial groove, clearly separating the anterior region from the middle one, gives rise to a shallow byssal notch along the anterior – ventral margin. The right valve is smooth, feebly convex, and has a rounded radial posterior ridge. The angle of maximum obliquity is about 25°.

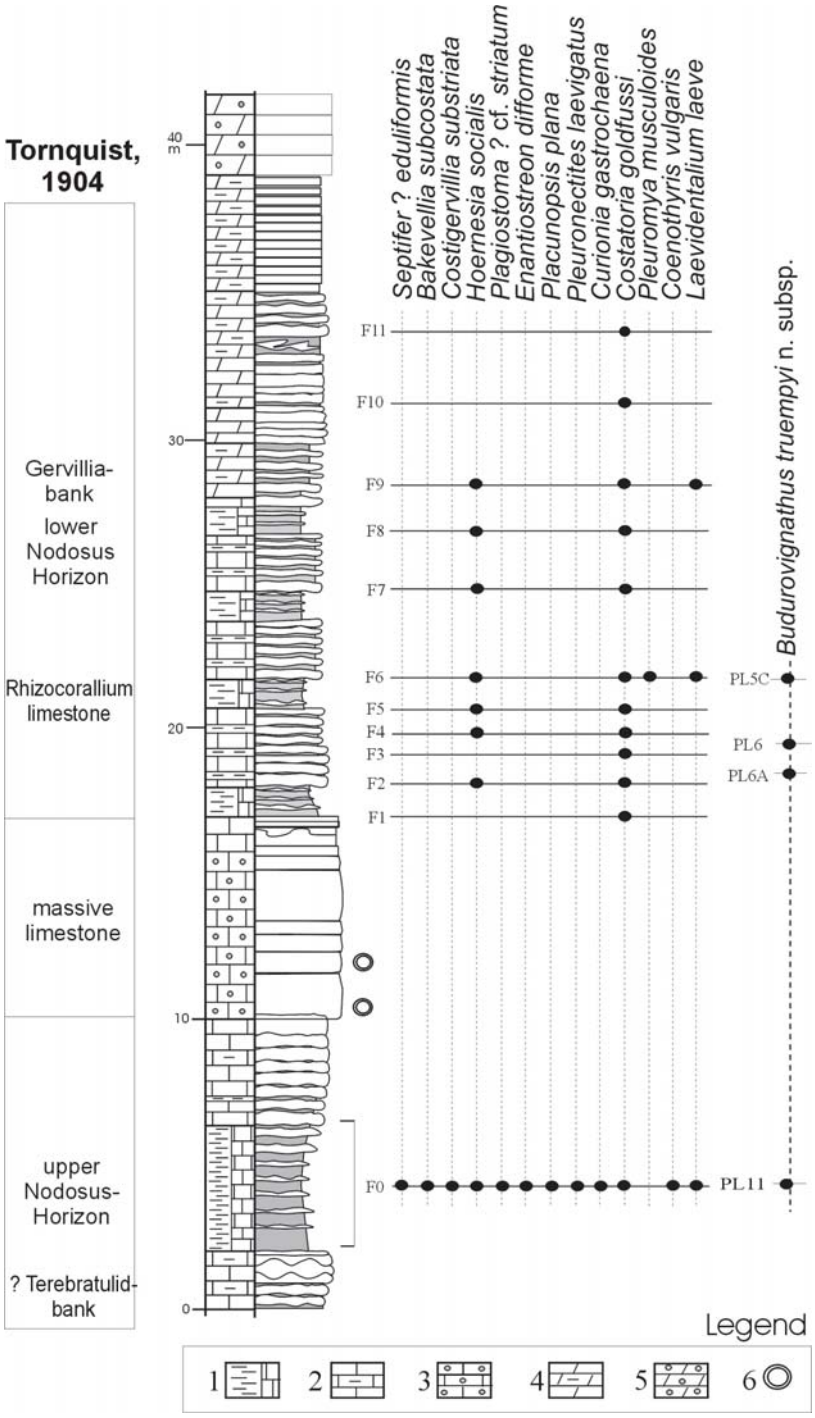


Fig. 1 – Stratigraphic column of the Punta del Lavatoio section and vertical distribution of the here described benthic taxa. Conodont data from Bagnoli *et al*. (1985a). Legend: 1) claystone with mudstone/wackestone lenses; 2) mudstone/wackestone with thin claystone intercalations; 3) grainstone/packstone; 4) dolostone and dolomitized claystone; 5) dolostone with re-crystallized clasts; 6) dasycladacean algae. The section is overturned. In opposite to this interpretation, Tornquist (1904) assumed a normal succession; therefore, his stratigraphical scheme is inverse.

The left valve is preserved in slab A, while the right valve is in sample D, both collected from the debris of fossiliferous horizon F0.

Gen. *Hoernesia* Laube, 1866
Hoernesia socialis (Schlotheim, 1820)
(Pl. 1; Figs. 9a, b)

Individuals of this easily detectable Bakevelliid species, characterized by a twisted commissural plane, are common in the Punta del Lavatoio section. In particular, they occur in the marly horizon (F0) both in the shell pavements of thin limestone layers and in the marl intercalations, where still articulated valves suggest an autochthonous position. The largest shells (about 60 mm long and 35 mm high) are present in the middle part (bed F7) of the section. Other occurrences are located in fossiliferous beds F2, F4, F5, F6, F8 and F9.

Ord. Limoida Rafinesque, 1815
Superfam. Limoidea Rafinesque, 1815
Fam. Limidae Rafinesque, 1815

Gen. ? *Plagiostoma* J. Sowerby, 1814
Plagiostoma ? cf. *striatum* (Schlotheim, 1820)
(Pl. 1, Figs. 2, 3, 10)

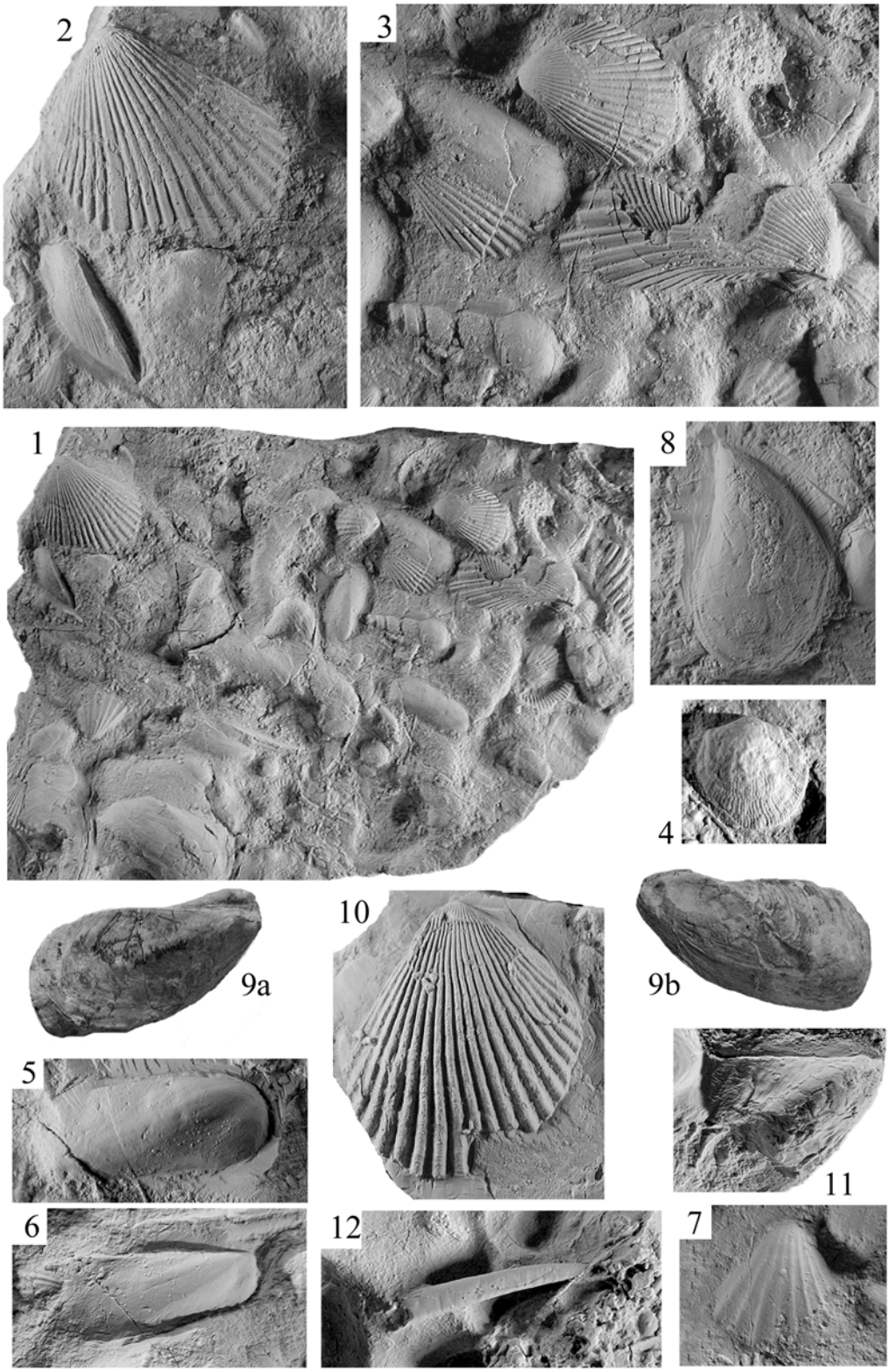
The valves are of medium size (H = 40 mm; L = 35 mm of the largest valve), higher than they are long, with about 28 radial ribs. The anterior ridge ranges from rounded to almost acute. The middle and posterior valve surface is covered by rounded, strong ribs which are separated by grooved interspaces, almost as wide as the ribs toward the ventral and posterior margins in large specimens. The ribs occurring near the anterior ridge and on the lunula are sharp and separated by interspaces which become wider and wider towards the anterior margin. The anterior auricle is small, gradually connected to the anterior margin, and clearly separated from the valve body. The posterior auricle is short and with radial riblets, as in the anterior one.

Limids are exclusive to the lower part (upper in the field) of the section, where they are recorded by frequent disarticulated valves (8 are here available) and fragments. They generally occur on the shell pavements, and are interpreted as storm accumulations, which constitute thin limestone intercalations or lenses within the prevailing clay of the fossiliferous horizon F0.

The Limids from Punta del Lavatoio, though never described and illustrated, have been determined in literature as follows: Tornquist (1904) cited *Lima striata*; Oosterbaan (1936) recorded both *Lima striata* and *Lima striata* var. *lineata* (Schlotheim); while *Limea costata* (Goldfuss) is cited by Márquez-Aliaga *et al*. (2000).

Plate 1

Fig. 1 - Slab A from horizon F0 (1, x 0.5); Figs. 2-7 show details of some specimens of the shelly pavement of slab A.
Fig. 2 - *Plagiostoma* ? cf. *striatum* (Schlotheim), right valve and, on the left corner, *Costigervillia substriata* (Credner), left valve, x 1.2.
Fig. 3 - *Plagiostoma* ? cf. *striatum* (Schlotheim), anterior and posterior auricles are detectable in the specimen (a right valve) located below; an internal mould of ? *Loxonema* sp. is present on the left corner, x 1.2.
Fig. 4 - *Placunopsis plana* (Giebel), upper valve, x 2.
Figs. 5, 6 - *Curionia gastrochaena* (Dunker), internal moulds of right valves with rounded (5) or sharp (6) posterior radial ridge;
Fig. 7 - *Costatoria goldfussi* (Alberti), internal mould of a right valve;
Fig. 8 - *Septifer* ? *eduliformis* (Schlotheim), left valve, slab C from horizon F0, x 1.5;
Fig. 9a, b - *Hoernesia socialis* (Schlotheim), right (a) and left views, horizon F0, x 1;
Fig. 10 - *Plagiostoma* ? cf. *striatum* (Schlotheim), left valve, horizon F0, x 1.
Fig. 11 - *Bakevellia subcostata* (Goldfuss), right valve, horizon F0, x 1.5.
Fig. 12 - *Laevidentalium laeve* (Schlotheim), bed F6, x 1,5.


2
3
1
8
4
9a
10
9b
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11
6
12
7

These specimens have a number of ribs intermediate between *Lima costata* (Goldfuss) and *L. striata*. *L. costata* is characterized by a low number of sharp ribs (10-20) separated by large, flat interspaces, twice as wide as the ribs, and furrowed by small secondary ribs; it has relatively small sizes, reaching at most 28 mm in height (Schmidt, 1928; Assmann, 1937). *L. striata* has large shells (up to 60 mm) with a rather variable number of ribs, ranging from 30 to 50 (Schmidt, 1928), which are rounded and separated by concave grooves, equal in width. These Sardinian specimens therefore have a sculpture pattern similar to that of *L. striata*, but their lower number of ribs suggests, at present, a determination in open nomenclature.

This species is frequently attributed in literature to the genus or subgenus (e.g. Diener, 1923) *Plagiostoma*, which is characterized by smooth shells or with weak radial ribs (Newell, 1969). Because in the examined material ornamentation is strong, this generic position is not at all convincing. However, the attribution to the genera *Lima* or *Limea* does not seem to be correct either, because *Lima* has scaly radial ribs, while *Limea* has short denticles on each side of the hinge, not detectable in these specimens.

Ord. Ostreoida Férussac, 1822
Superfam. ? Plicatuloidea Watson, 1930
Fam. ? Plicatulidae Watson, 1930

Gen. *Enantiostreon* Bittner, 1901
Enantiostreon difforme (Schlotheim, 1820)
(Pl. 2; Fig. 3)

This cemented, oyster-like bivalve has an irregular subovate outline and strongly costate ornaments. In the Punta del Lavatoio, *E. difforme* is only represented by disarticulated valves, frequently broken in small pieces. The largest specimen, represented by a complete and strongly convex right (attached) valve, is 13 mm long and 19 mm high. *E. difforme* is common in the shell pavements of fossiliferous horizon F0. Small monospecific clusters can be detected; otherwise the valves are always detached and separated from the host substrate.

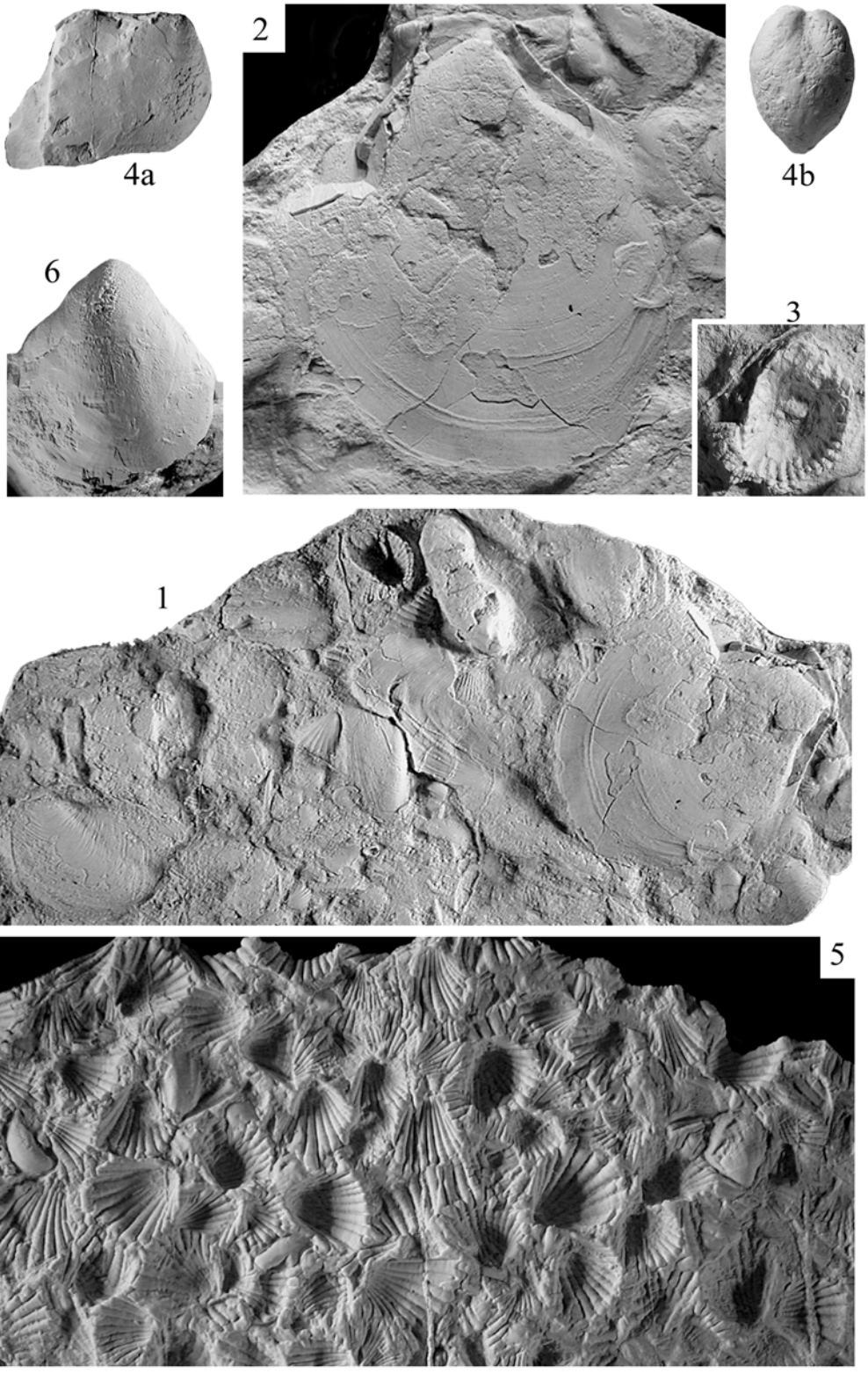
Ord. Pectinoida Rafinesque, 1815
Superfam. Aviculopectinoidea Meek & Hayden, 1864
Fam. ? Terquemiidae Cox, 1964

Gen. *Placunopsis* Morris & Lycett, 1853
Placunopsis plana (Giebel, 1856)
(Pl. 1; Fig. 4)

Flattened (lower) valves, cemented on other mollusc shells (e.g. ? *Plagiostoma*, *Pleuronectites*, ammonoids), are relatively common (max length =12 mm) in the lower part of the section. However, the specific determination is based on a single upper valve (free, ? left valve). It is small (8 mm long), suborbicular and moderately inflated, with an external ornamentation consisting of radial, slightly undulated threads; besides, near the margins, concentric foliaceous and slightly spiny lamellae are detectable. *P. plana* has been found only in horizon F0, from which Oosterbann (1936) cited the occurrence of *P. ostracina* Schlotheim, a species without radial ornaments (Schmidt, 1928). Some authors considered *P. plana* as synonym of *P. ostracina* (e.g. Linstow, 1904 *fide* Schmidt, 1928), but following Assmann (1937) the two species are here maintained separate.

Plate 2

Fig. 1 - Slab B from horizon F0, x 0.6; Figs. 2, 3 show details of some specimens.
Fig. 2 - *Pleuronectites laevigatus* Schlotheim, right valve with some *Placunopsis* valves cemented on the shell surface, x 1.
Fig. 3 - *Enantiostreon difforme* (Schlotheim), right (attached) valve, x 1,2.
Fig. 4a, b - *Pleuromya musculoides* (Schlotheim), right and anterior views, x 1.5.
Fig. 5 - *Costatoria goldfussi* (Alberti), lower surface (top in the field) of storm accumulation, x 1.5.
Fig. 6 - *Coenothyris vulgaris* (Schlotheim), ventral valve, horizon F0, x 1.


4a
2
4b
6
3
1
5

Superfam. Pectinoidea Rafinesque, 1815
Fam. Pectinidae Rafinesque, 1815

Gen. *Pleuronectites* Schlotheim, 1820
Pleuronectites laevigatus Schlotheim, 1820
(Pl. 2; Fig. 2)

This beautiful large sized bivalve, typical of Germanic-type fauna, is represented by two valves, both collected from the debris at horizon F0. The best preserved individual is a right valve, feebly convex and a little deformed (L = 62.6 mm; H = 68.8 mm); its external surface bears some cemented lower valves of *Placunopsis*. The other specimen, with badly preserved umbonal region, is more inflated and thus probably represents a left valve. It is also encrusted by *Placunopsis* and small *Spirorbis* individuals.

Subcl. Isofilibranchia Iredale, 1939
Ord. Modiomorphoida Newell, 1969
Superfam. Kalenteroidea Marwick, 1953
Fam. Permophoridae van de Poel, 1959
Subfam. Permophorinae van de Poel, 1959

Gen. *Curionia* Rossi Ronchetti 1965
Curionia gastrochaena (Dunker, 1851)
(Pl. 1; Figs. 5, 6)

Three internal moulds of right valves are preserved on the shelly pavement of slab A (horizon F0). The valves are of medium size (the largest is 24 mm long and 10 mm high) and elongated, with the umbo placed near the anterior end. The surface is smooth and can be divided into three parts. The anterior is placed between the anterior muscle scar and a shallow radial groove, particularly detectable toward the umbo, which forms a small broad concavity on the ventral margin. The second is posteriorly delimited by a radial ridge, ranging from sharp to rounded. The third is placed between the ridge and dorsal margin, near which an elongated groove (cast of the lateral teeth) is easily detectable.

This species, with a wide stratigraphic range in the Germanic Trias, is very similar to *C. woehrmanni* (Waagen), a Longobardian species more recently described from the *Pachycardientuffen* of Seiser Alm/Alpe di Siusi (Dolomites), which may thus be considered a juvenile synonym of *C. gastrochaena*. Tornquist (1904) quoted the occurrence from this Sardinian locality of *Myoconcha* (= *Curionia*) *laevis* Philippi. However, the latter species is characterized by the absence of a mid umbonal radial groove, a character easily detectable in these specimens.

Order Mytiloida Férussac, 1822
Superfam. Mytiloidea Rafinesque, 1815
Fam. septiferidae Scarlato & Starabogatov, 1979

Gen. ? *Septifer* Recluz, 1848
Septifer ? *eduliformis* (Schlotheim, 1820)
(Pl. 1; Fig. 8)

Only a single, left valve is available (L = 14.2 mm; H = 23 mm). It has a mytiliform shape with pointed terminal beaks. The anterior margin is broadly concave and the surface has only growth lines towards the margins. The generic position of this species, generally cited in the past literature as "*Mytilus*", is a matter of discussion because this genus is considered to appear in the Upper Jurassic (Soot-Ryen, 1969). Diener (1923) attributed some Triassic mytiloid species to *Septifer*, a genus characterized by shells with a septum in the beak and radial sculpture. This generic attribution is supported by the occurrence of the septum in *Mytilus eduliformis preacursor* Frech (M. Urlichs, pers. com.), but with some doubt because the shell is smooth.

This specimen occurs in a bivalve coquina (slab C), which has been collected from the debris of fossiliferous horizon F0.

Subcl. Palaeoheterodonta Newell, 1965
Ord. Trigonioida Dall, 1889
Superfam. Trigoniacea Lamarck, 1819
Fam. Costatoriidae Newell & Boyd, 1975

Gen. *Costatoria* Waagen, 1906
Costatoria goldfussi (Alberti, 1830)
(Pl. 1; Fig. 7; Pl. 2, Fig. 5)

The shell is subtriangular and subequidimensional (or slightly longer than it is high); it has generally small sizes (about 7-8 mm long), particularly in individuals from the middle part of the section. The maximum sizes (14.3 mm long and 14 mm high) are generally reached by the older specimens coming from horizon F0. The flank is covered by 8-10 rather regularly spaced ribs; secondary intercalated ribs are occasionally detectable in some individuals. The marginal carina has an acute tip and the first groove, anterior to it , is slightly wider than the following ones. The area bears from 2 to 4 ribs.

Costatoriids are very frequent throughout the section. In the lower part (horizon F0) scattered individuals are present within the highly diversified fossil assemblages of the shell pavements, while they become very common in the middle, where they form monospecific accumulations (tempestites), with some still articulated shells. In the upper, dolomitic part of the section, the benthonic macrofauna is only represented by sparse valves of this pelecypod.

Because Costatoriids are very common in the Punta del Lavatoio outcrop, it is impossible that Tornquist (1904) did not find them, thus they probably correspond to *Myophoria* sp., cited in Tornquist's fossil list. Oosterbaan (1936, p. 100), on the basis of the occurrence of ribs on the area, determined them as *Myophoria* (now *Costatoria*) *goldfussi*, and all authors subsequently working in this outcrop have attributed them to the same species (e.g. Gandin, 1978; Posenato, 1995; Márquez-Aliaga *et al*., 2000).

Subcl. Anomalodesmata Dall, 1889
Ord. Pholadomyoida Newell, 1965
Superfam. Pholadomyacea Gray, 1847
Fam. Pleuromyidae Dall, 1900

Gen. *Pleuromya* Agassiz, 1842
Pleuromya musculoides (Schlotheim, 1820)
(Pl. 2; Fig. 4a, b)

Only one incomplete internal mould of an articulated shell is available. It was discovered in life position (with the anterior part upward in the field !) in bed 6. It is about 15 mm high, but the lack of posterior part impedes measurement of its length. The umbones are located near the anterior end of the shell. A radial shallow groove runs from the umbo to the ventral margin, where a feeble recess is detectable on the outline. This species had already been cited by Oosterbann (1936) from the fossiliferous marl horizon F0.

Rare infaunal bivalves are also present in the shell pavement of the horizon 0, but incompleteness and/or bad conditions of preservation impede their determination.

Other Macrobenthic Groups

Brachiopoda are very scarce in the collected material. They are represented only by a ventral valve (L = 24.6 mm, W = 24.6 mm), which is slightly asymmetrical due to growth damage and diagenetic deformation (Pl. 2, Fig. 6), and by an umbonal fragment of a dorsal valve. Both the specimens have been collected from the debris of horizon 0. They are attributed to *Coenothyris vulgaris* (Schlotheim) (Pl. 2, Fig. 6), a species already cited from this outcrop (e.g. Tornquist, 1904; Oosterbaan, 1936, etc).

Gastropoda are represented by rare individuals generally of very small size. Only one relatively large internal mould (23 mm high) has been found. It occurs on the slab A (Pl. 1, Fig. 3) and is partially covered by sediment, thus a precise determination is impossible

(? *Loxonema* sp.). It has similarities with *Loxonema schlotheimi* (Quenstedt) (= *L. obsoletum* Ziethen according to Schmidt, 1928), a species already cited by Tornquist (1904) from the "untere Nodosen-Horizont".

Scaphopoda shells are very common, both from the horizon F0 and from the limestone marl intercalations of the middle part of the section (e.g. bed F6; Pl. 1, Fig. 12). The shell is smooth and is maximum 20 mm high. The shell's original composition was probably calcitic, because the aragonitic shells of cephalopods and bivalves are preserved in the same beds as only internal moulds. These Scaphopoda belong to *Laevidentalium laeve* (Schlotheim) (Pl. 1, Fig. 12), a species already quoted by past authors (e.g. Tornquist, 1904) from this outcrop.

Palaeoecology

The highly diversified fossil assemblage from horizon F0 comprises both nektonic and benthonic species. On the surface of some storm accumulated shelly pavements, 87 specimens of benthic (95%) and nektonic taxa (ammonoids, 5%) have been detected. *Hoernesia socialis* is the most abundant species (22%), followed by *Plagiostoma* ? cf. *striatum* (16%), *Enantiostreon difforme* (14%), *Curionia gastrochaena* (10%), *Placunopsis plana* (9%), *Costatoria goldfussi* (9%) and *Laevidentalium laeve* (6%). *H. socialis* is surely autochthonous, because still articulated individuals occur also in the claystone. This bivalve is considered a semi-infaunal byssate recliner belonging to a soft bottom deep ramp assemblage, which also comprehends *Laevidentalium* and *Pleuromya* (Hagdorn, 1982; 1991). The absence of the latter genus in these tempestites probably depends on its mode of life (deep burrowing), which prevented its reworking (Aigner, 1982).

In the Germanic Upper Muschelkalk, the epi-byssate (e.g. *Plagiostoma* and *Pleuronectites*, here represented by 1%) and encrusting (*Placunopsis*) bivalves, crinoids and brachiopods (*Coenothyris vulgaris*) are characteristic of the middle ramp environment in which shell-, firm-bottom conditions were originated by storm waves (tempestitic condensed facies of Hagdorn & Mundlos, 1982). Storms swept the mud from the shelly tempestites or eroded the bottom, determining the exposure of firm- hard-substrates (Hagdorn & Mundlos, 1982). Therefore, the above quoted taxa can be considered as allochthonous elements which were settled in the mid ramp, located slightly above, and transported into a deeper environment. The low abundance of brachiopods (1%) and crinoids (few ossicles detected in thin section) inside the F0 assemblage could indicate slightly hyperhaline conditions (ammonoids are mostly represented by internal mould fragments, thus they were probably affected by lateral displacement), even if unsuitable substrate conditions cannot be completely excluded.

The bivalves, represented by a very few individuals such as the byssate *Costigervillia substriata* (2%), *Bakevellia subcostata* (1%), *Septifer* ? *eduliformis* (1%) and by the rapidly burrowing *C. goldfussi*, are characteristic of mobile substrate of shallow marine environment (Aigner, 1985). Thus, they can be affected by a longer transport than that of the mid ramp assemblage. The relatively high frequency of *C. goldfussi* suggests the existence of hyperhaline conditions around the basin. The occurrence of relatively thin distal tempestites within a dominant clay-/marlstone horizon allow us to refer the clayey segment to a deep ramp sedimentary environment (*sensu* Aigner, 1985); this segment records the deepest marine conditions of the whole sequence.

After a phase of shallowing, represented by the massive dasycladacean grainstones which suggest a shore face environment, a new deepening is recorded by the grey-blackish nodular limestone and yellowish dolomitic marl alternations (= *Rhizokorallienkalke* and

oberer Nodosen-Horizont of Tornquist, 1904). However, the taxonomical diversity of the benthic mollusc assemblages is here decidedly lower than that of horizon F0.

In some layers (e.g. F6, F9), the benthic macrofauna is characterized by the occurrence of elements of soft bottom assemblage, such as *Hoernesia socialis*, *Pleuromya musculoides* and *Laevidentalium laeve*, which probably were settled within the marly and clayey alternations. However, this unit is characterized by a high abundance of *C. goldfussi*, which sometimes form monospecific shelly pavements (tempestites). The decrease of taxonomical diversity and the mass occurrence of small sized shells of *Costatoria*, a eurytopic genus typical of Triassic hyperhaline and shallow environments, suggest a shallower and/or more restricted and hyperhaline environment than that of horizon F0. As formerly suggested by Gandin (1978), a scarce bottom oxygenation could also have occurred, caused probably by a strong input of organic matter. The occurrence of some ammonoid bearing layers (F6 and F8) indicates phases in which connections with a fully marine environment may have existed. Because *Costatoria* is considered a shallow and rapidly burrowing bivalve (Hagdorn, 1991), a higher sedimentation rate with respect to horizon F0 seems to have occurred. If this hypothesis is correct, then the absence of shell-firm-bottom dwellers in this unit was caused by prevailing mobile and soft substrates which prevented their settlement.

At the top of the fossiliferous succession, made up of prevailing dolomites, the fossil assemblage contains only sparse valves of *C. goldfussi*. These lithological and palaeontological characteristics suggest a new phase of shallowing and higher values of water salinity.

Acknowledgements

I am grateful to Hans Hagdorn and Max Urlichs for their comments and suggestions on the manuscript. Thanks to Antonietta Cherchi and Rolf Schroeder, who proposed me this work and for their bibliography support.

Financial support was provided by grants from MURST (Cofin and ex 60%).

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