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CAMBRIAN LINGULID AND ACROTRETID BRACHIOPODS FROM THE IGLESIENTE AREA (CAMPO PISANO FORMATION, SOUTHWESTERN SARDINIA)

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Abstract. Cambrian brachiopods from Sardinia are investigated for the first time in this paper. The specimens come from nodular limestones of the late Early to Middle Cambrian Campo Pisano Formation of Gutturu Pala (southwestern Sardinia). The brachiopod fauna consists of lingulids and acrotretids and yields two new acrotretid species, described here as *Opisthotreta sardica* n. sp. and *Vandalotreta proclinis* n. sp. Material attributed to the genus *Schmidtites* is reported here for the first time from both the Middle Cambrian and western Gondwana. The genus *Linnarssonella* is reported for the first time from the Middle Cambrian and from outside North America. Whereas most brachiopods from Gutturu Pala biostratigraphically indicate a rather undifferenciated Middle Cambrian age, the last mentioned genus points to a late Middle Cambrian age for the uppermost part of the Campo Pisano Formation.

Riassunto. Brachiopodi cambriani della Sardegna sono qui descritti per la prima volta. Gli esemplari silicizzati provengono dai calcari nodulari della Formazione di Campo Pisano (tardo Cambriano Inferiore-Cambriano Medio) di Gutturu Pala (Sardegna sudoccidentale). La fauna a Brachiopodi consiste di lingulidi e acrotretidi e contiene anche due nuove specie di acrotretidi, *Opisthotreta sardica* n. sp. and *Vandalotreta proclinis* n. sp. Esemplari attribuiti al genere *Schmidtites* sono qui citati per la prima volta sia per quanto concerne il Cambriano Medio sia per il Gondwana occidentale. Il genere *Linnarssonella* è riportato per la prima volta nel Cambriano Medio ed all'infuori del Nord-America. Anche se molti brachiopodi di Gutturu Pala indicano un generico Cambriano Medio, il genere *Linnarssonella* suggerisce un'età tardo Cambriano Medio per la parte sommitale della Formazione di Campo Pisano.

Introduction

In southwestern Sardinia autochthonous Cambro-Ordovician sediments outcrop in the Iglesiente and Sulcis area (Fig. 1).

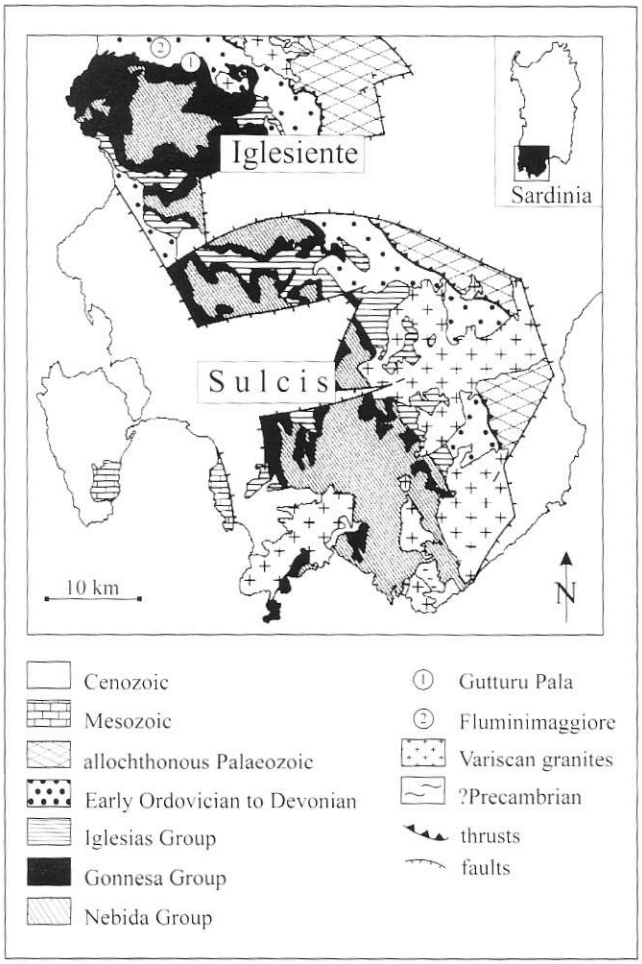

Fig. 1 - Geological map of southwestern Sardinia (modified after Bechstädt et al. 1988) indicating the working section at Gutturu Pala locality.

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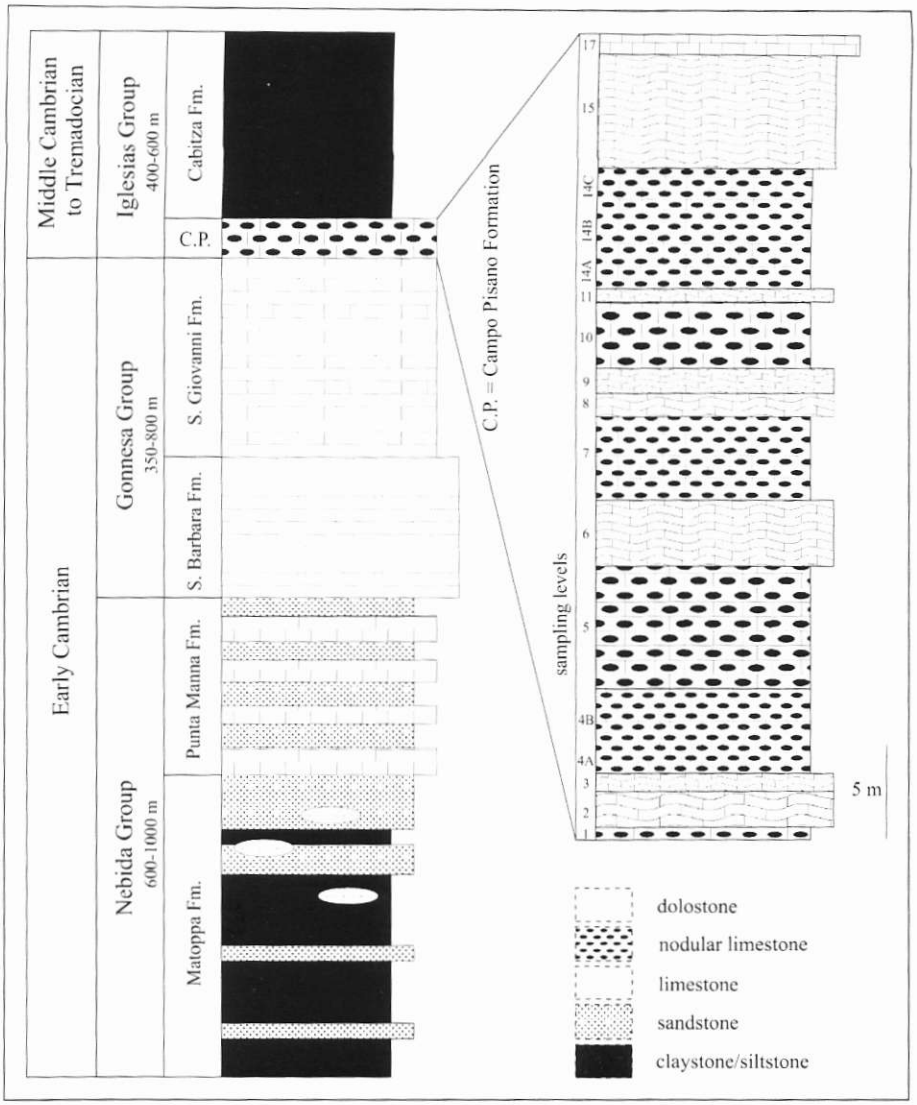


Fig. 2 - Geological column of the Cambrian succession of southwestern Sardinia and of the Campo Pisano Formation at Gutturu Pala (sampling horizons are indicated).

The Cambrian succession of Iglesiente is about 2000 m thick and represents the development of a carbonate platform starting with an initial phase (siliciclastics and carbonates: Nebida Group), followed by the carbonate maximum stage (dolostones and limestones: Gonnesa Group). The final stage of this development indicates drowning of the platform, represented by the nodular Campo Pisano Formation, followed by a phase of siliciclastic deposition (Cabitza Formation of the Iglesias Group; Fig. 2). For a detailed description of the sedimentary record and evolution of the SW-Sardinian carbonate platform, see Bechstädt & Boni (1994) and references therein.

The focus of this paper is the Campo Pisano Formation part of the Iglesias Group, which represents the drowning of the platform. This subsidence stage has been the subject of intensive investigation during recent years by the Freiberg research group and this has led to a lot of new data regarding microfacies, micropalaeontology, and on the process of platform destruction (Elicki 2001, 2002; Elicki & Wotte 2003; Elicki et al. 2003; Elicki & Pillola in press; Hamann in press).

This paper is the first systematic report of the Sardinian Cambrian brachiopod fauna. The material comes from Gutturu Pala which is an abandoned sulphide ore mine situated in the northern Iglesiente area about 4 km southeast of Fluminimaggiore (Fig. 1). All specimens were extracted from the limestone-samples by chemical preparation using formic acid. The illustrated specimens are housed at Geological Institute of the Freiberg University (archive number: FG 533).

Geological framework

The Campo Pisano Formation overlies subtidal to intertidal limestones of an isolated carbonate platform (San Giovanni Formation, Gonnesa Group), which developed during the higher Early Cambrian (Bechstädt & Boni 1994). At Gutturu Pala locality the Campo Pisano Formation is about 46 metres thick and passes continuously into the overlying siliciclastics of the Cabitza Formation. The whole sedimentary succession is tectonically disturbed, so that now the bedding is oriented vertically.

The Campo Pisano Formation consists of limestones which are generally rich in mud and mostly represented by wackestones. Mudstones and floatstones occur occasionally. Large parts of the limestone succession show a diagenetic nodular texture. Primary sedimentary features are not clearly observed. The transition from the underlying limestones of the San Giovanni Formation (Gonnesa Group) is very distinct, whereas the upper transition into the overlying Cabitza Formation (Iglesias Group) is gradual over a few decimetres. A more detailed description of the sedimentary succession, and the origin of the texture as well as discussions on the origin of the Campo Pisano Formation were published

by Schledding (1985), Bechstädt et al. (1988), Cocozza & Gandin (1990) and Elicki (2001). Deposition is interpreted as having taken place in a non-pelagic, morphological weakly differentiated, subtidal shelf environment (Elicki 2001). In contrast, the depositional environment of the overlaying Cabitza Formation (Iglesias Group) is interpreted as deeper basinal, based on sedimentological and taphonomic features (Gandin et al. 1987; Cocozza & Gandin 1990; Loi et al. 1995). The higher parts of the Cabitza Formation show distinct characteristics of a shallowing of the depositional environment (Loi et al. 1995).

Loi et al. (1995) summarised the biostratigraphical data for the Iglesias Group. They introduced a subdivision based on trilobites and graptolites from the latest Early Cambrian up to the Early Ordovician. Following this subdivision, the Campo Pisano Formation spans a biostratigraphic interval from the uppermost Early Cambrian until lower part of Middle Cambrian.

Remarks on taphonomy and biofacies

Many specimens from the Gutturu Pala microfauna are preserved as silicified pseudomorphs. Trilobites and brachiopods were particularly affected in this way during diagenesis. Original preservation can be assumed for phosphatic taxa, such as hyolithelminthids, bradoriids, and some brachiopods. Multisclerite specimens are generally disarticulated, but not affected by intensive transport processes. No pieces show distinct signs of physical abrasion, chemical dissolution or biological destruction.

The most common skeletal elements found in the Campo Pisano Formation are from trilobites, echinoderms, brachiopods, and poriferids. Additionally, chancelloriids and hyolithids occur in some layers. In contrast, hyolithelminthids, bradoriids and pelagiellids are rather rare. The vertical distribution of this faunal content is different through the succession. At the base of the Campo Pisano Formation sponges predominate the fauna (level GP 1). These are occasionally accompanied by some isolated echinoderm plates, by infrequent trilobite remains or small brachiopods and extremely rarely by bradoriids and hyolithelminthids.

Above this basal fauna the following biofacies is characterized by a distinct increase in echinoderm and trilobite remains (level GP2-GP9), flanked by brachiopods, chancelloriids and hyolithids. Above these, a fauna clearly dominated by sponges occurs (level GP10-GP14A). The following portion of the Campo Pisano Formation at Gutturu Pala shows a decrease in poriferids and an increase in trilobites (level GP14B). Near the base of the overlaying Cabitza Formation (level GP14C-GP17) all faunal elements decrease significantly.

Systematic palaeontology

Order **Lingulida** Waagen, 1885

Superfamily Linguloidea Menke, 1828

Family Obolidae King, 1846

Subfamily Obolinae King, 1846

Genus *Lingulella* Salter, 1866

Type species: *Lingula davisii* M'Coy, 1851, p. 405-406; by subsequent designation, Dall 1870, p. 159; Upper Cambrian, Wales.

Lingulella (?) sp.

Pl. 1, figs 9-10

Material. Two complete shells, six ventral and four dorsal valves, several fragments.

Description. Valves small, equally biconvex, 4 mm long in the largest entire valve (some 120-140 % as long as wide), thin-walled.

The dorsal valve is moderate convex, widest slightly anterior to midlength, with rounded posterior margin. The dorsal pseudointerarea is apsacline, short, deeply concave and anteriorly excavated. The median groove is broadly triangular and bordered by minute propareas with distinct flexure lines.

The ventral valve differs from the dorsal valve by a slightly acuminate posterior margin; an apical angle is 80-90°. The maximum width lies approximately at the midlength. The valve is moderately convex and deepest at the midlength. The ventral pseudointerarea is short and narrow (some 40-50 % of the valve width). Pedicle groove is deep and short, widening anteriorly, with the bottom at

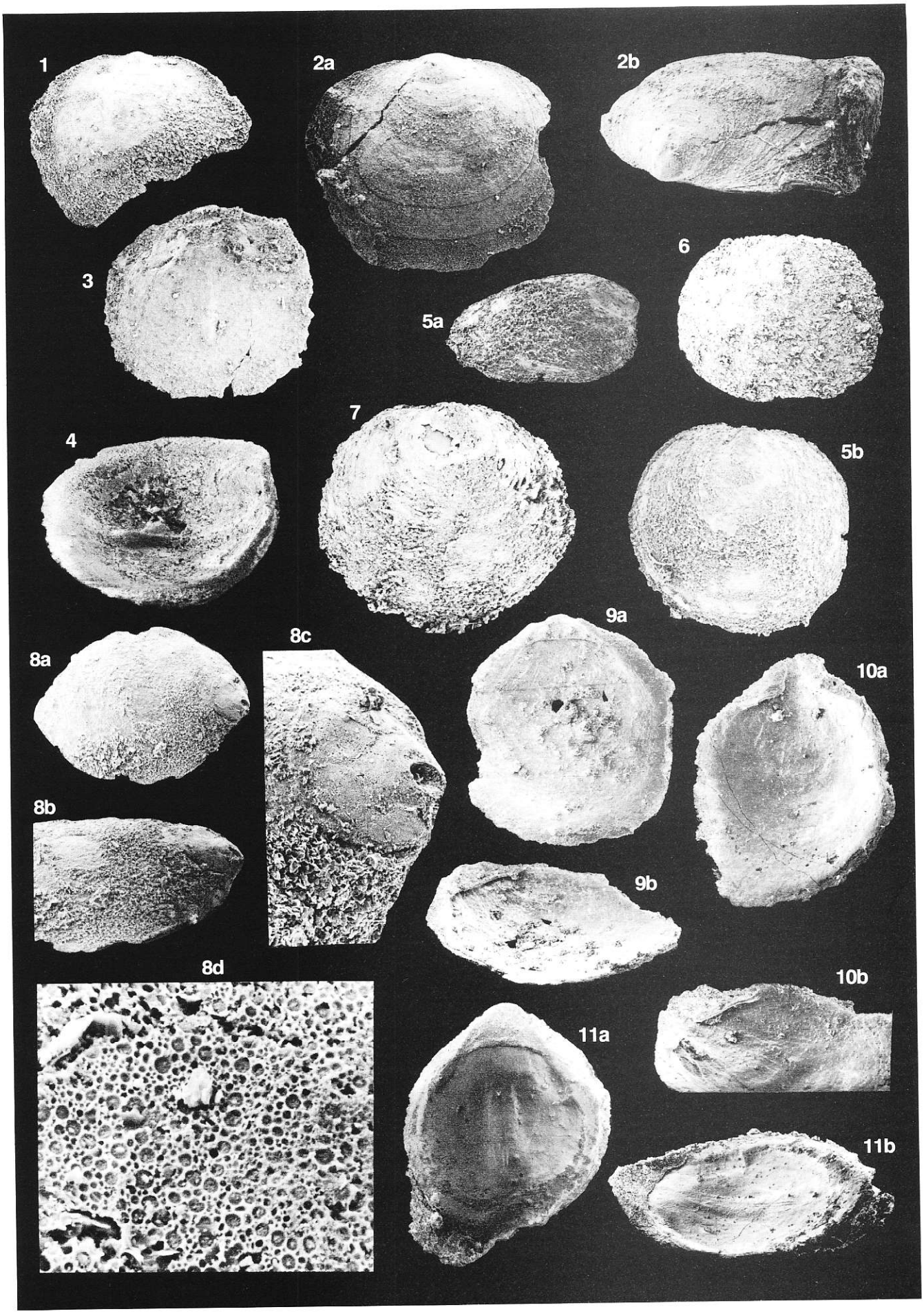
PLATE 1

Opisthotreta sardica n. sp. - Fig. 1 – Dorsal valve, exterior, FG 533/27, x 40. Fig. 2 – Dorsal valve, exterior (a) and posterolateral view (b), FG 533/26, x 50, x 57. Fig. 3 – Dorsal valve, interior, FG 533/20, x 40. Fig. 4 – Dorsal valve, interior, FG 533/20, x 40. Fig. 5 – Dorsal valve interior, exterior in lateral (a) and ventral (b) views, FG 533/21, x 57, x 57. Fig. 6 – Ventral valve, exterior, FG 533/31, x 38. Fig. 7 – Ventral valve, exterior, FG 533/30, x 55.

Linnassonella sp. – Fig. 8 – Ventral valve, exterior in oblique view (a), lateral view (b), detail of larval shell (c), pitting of the larval shell (d), FG 533/10, x 37, x 62, x 150, x 1500.

Lingulella (?) sp. Fig. 9 – Dorsal valve, interior (a) and oblique view (b), FG 533/19, x 24, x 24. Fig. 10 – Ventral valve, interior (a) and oblique view (b), FG 533/17, x 24, x 24.

Schmidtites sp. Fig. 11 – Dorsal valve, interior (a) and oblique view (b), FG 533/9, x 18, x 20.


1
2a
2b
3
6
5a
7
4
5b
9a
8a
8c
10a
8b
9b
8d
10b
11a
11b

the valve floor. Propareas are defined by distinct flexure lines. The inner proparea is steeply sloping toward the pedicle groove - its anterior edge is raised above the visceral area. The outer proparea is narrower, orthocline and resting directly at the valve wall. Visceral area is poorly defined, some 40 % as long as the valve and has a slightly elevated anteromedian border. Central muscle scars are small, oblique and anteromedianly located.

The exterior of the shell is covered by fine growth lines, which are interrupted by a few low lamellae.

Discussion. Small elongate obolids of Cambrian age are poorly known and they are traditionally referred to genus *Lingulella* Salter. However, recent revision of the type species *Lingulella davisii* M'Coy by Sutton et al. (2000) indicates that these small obolides have almost nothing in common with the type species except for their general morphology. The customary practice to use the generic name *Lingulella* for these small species is confusing and as such this identification must be considered provisional until more material is available.

A few species similar to the Sardinian specimens are known from several European sites. Mergl & Šlehoferová (1991) described *Lingulella sufi* from the lower part of the Jince Formation (early Middle Cambrian) of Central Bohemia. Both valves of *Lingulella sufi* are similarly shaped, but this species has a more acuminate ventral valve and a larger dorsal pseudointerarea with a longer median groove. Small obolids are also poorly known from the Middle Cambrian of Spain (Liñan & Mergl 2001). Similar small obolids have been found in the early Middle Cambrian of Morocco (Mergl 1988: pl. 2, figs 6-8), but these differ in their triangular outline and more acuminate ventral valve. The small Sardinian obolids are smooth while the otherwise similar eoobolids are characterized by their finely pustulose postlarval shell.

Occurrence. Samples GP1, GP9, GP14B, GP15.

Genus *Schmidtites* Schuchert & LeVene, 1929

Type species: *Schmidtia celata* von Volborth, 1869, p. 209, pl. 17, figs 1-6; Upper Cambrian; Estonia.

Schmidtites (?) sp.

Pl. 1, fig. 11

Material. Two dorsal valves.

Description. Dorsal valve thick, subcircular, 110 % as long as wide and with evenly curved margins; the posterior margin is broadly rounded. Valve convexity is low, with depressed anteromedian part of the valve. Dorsal pseudointerarea is apsacline, with large and poorly concave and broad median groove and a straight anterior margin. Propareas are not divided by flexure lines. Anterior edge of the pseudointerarea is undercut. The surface of the pseudointerarea is covered by distinct growth lines. Posterolateral margins are thickened, forming a broad brim that gradually disappears anteriorly. The visceral area is well defined and shows a weak median ridge. A pair of large muscle fields (transmedian, outside and middle lateral muscles) are situated posterolaterally. The central muscle scar is shallow and near the centre of the valve. The anterior projection is short, with a small pair of anterior lateral muscle scars anterior to the midlength of the valve.

The shell exterior is covered by fine concentric fila of uniform size, which are regularly arranged (0.03-0.04 mm apart).

Discussion. This obolid has a remarkably thick shell indicating that both valves belong to mature specimens. Their generic affinity remains difficult to evaluate because of the absence of information about the ventral valve. Large dorsal pseudointerarea, undivided propareas, and deeply impressed visceral area indicate an affinity to the genera *Schmidtites* Schuchert & LeVene and *Ungula* Pander. In their distribution, these genera are restricted to the Upper Cambrian of the Baltic area (Estonia, Lithuania, Russia). The presence of these small obolids in Sardinia, although poorly understood, is the first report of thick-walled obolids in both the early Middle Cambrian and western Gondwana.

Occurrence. Sample GP11.

Order **Acrotretida** Kuhn, 1949

Superfamily Acrotretoidea Schuchert, 1893

Family Acrotretidae Schuchert, 1893

Genus *Linnarssonella* Walcott, 1902

Type species: *Linnarssonella girtyi* Walcott, 1902, p. 602. Upper Cambrian, USA.

Linnarssonella sp.

Pl. 1, fig. 8.

Material. One ventral valve.

Description. The only available ventral valve is 1.2 mm long and 1.2 mm wide, with subcircular outline. The valve is strongly convex in transverse profile, depressed posteriorly and strongly vaulted in the anterior half. Ventral pseudointerarea is apsacline, low and covered by coarse transverse growth lines. The larval shell is subcircular, shows a raised periphery and a large pedicle foramen open posteroventrally. The foramen is enclosed within the larval shell. Shell exterior ornamented by weak growth lines. The micro-ornamentation of the larval shell consists of shallow circular pits of various sizes (Pl. 1, fig. 8d).

Discussion. Only one ventral valve can be referred to the genus *Linnarssonella* Walcott, so it cannot be confidently compared with other species of the genus how-

ever, some broad comparisons can be drawn. Detailed description and comment regarding the genus, has been presented by Robson et al. (2003). The type species *Linnarssonella girtyi* Walcott, 1902 differs from this specimen in having a larger and posteriorly directed foramen. The other species described by Robson et al. (2003) also differ from the Gutturu Pala valve. *Linnarssonella elongata* Bell, 1941 differs by having a triangular outline and more depressed ventral valve, and *Linnarssonella tubicula* Robson, Nowlan and Pratt, 2003 by its prominent ridge on the larval shell.

This genus is known from the Upper Cambrian, with all known occurrences restricted to USA and Canada. Its occurrence in Sardinia is the first report in Europe and indicates a late Middle or early Upper Cambrian age of the upper part of the Campo Pisano Formation.

Occurrence. GP15.

Genus *Opisthotreta* Palmer, 1954

Type species: *Opisthotreta depressa* Palmer, 1954, p. 771-772, pl. 90, fig. 19; Upper Cambrian, USA.

Opisthotreta sardica n. sp.

Pl. 1, figs 1-7

Origin of the name. Sardus (Latin), referring to the Sardinia Island.

Holotype. Ventral valve figured on Pl. 1, fig. 5a, 5b (FG 533/21).

Paratypes. Ventral valve figured on Pl. 1, fig. 6 (FG 533/31), ventral valve figured on Pl. 1, fig. 7 (FG 533/30), dorsal valve figured on Pl. 1, fig. 1 (FG 533/27), dorsal valve figured on Pl. 1, fig. 2 (FG 533/26), dorsal valve figured on Pl. 1, fig. 3 (FG 533/20), and dorsal valve figured on Pl. 1, fig. 4 (FG 533/25).

Type horizon. Campo Pisano Formation.

Type locality. SW Sardinia, Gutturu Pala mine.

Repository. Freiberg University, Geological Institute, Freiberg, Germany.

Diagnosis. Species of the genus *Opisthotreta* which is characterized by highly convex ventral valve with low, catacline ventral pseudointerarea and deep intertrough; dorsal valve with low median ridge, ornamentation of fine, low, concentric fila.

Description. Valves thin, ventri-biconvex, with rectimarginate commissure. The maximum width is 1.6 mm. The dorsal valve is subcircular, 85 % as long as wide, with the maximum width and depth at the midlength. The valve is strongly convex (transversally and longitudinally) with depressed posterolateral corners and weakly flattened anteromedian sector. The lateral margins are evenly rounded. The anterior margin is slightly straighter; the posterior margin is straight, with prominent larval shell extending over the posterior margin. Dorsal pseudointerarea is orthocline, 40 % as wide as the valve. Median groove is broadly triangular, very shallow and with rounded apex. The surface of the groove is covered by transverse growth lines. Propareas are small and short, anterolaterally they pass into a wide brim, which disappears at about the midlength. A low but massive median ridge extends from the median buttress for over two-thirds of the valve length, the highest point is at its anterior edge. The cardinal scars are large, oblique, elevated and located at posterolateral slopes. Weak anterocentral muscle scars adjoin to median ridge near the centre of the valve. Vascula lateralia are shallow, with broadly diverging proximal parts. The ventral valve is highly convex, deepest between the apex and the posterior third, with catacline, low and broadly triangular pseudointerarea. Anterior and lateral slopes are moderately convex. The apex is indistinct, with posteriorly directed pedicle foramen enclosed within the larval shell. Borders of the larval shell are poorly defined and very fine pits cover its surface. The surface of pseudointerarea is covered by weak growth lines crossed by a narrow, deep intertrough. The ventral interior shows prominent, highly elevated boss-like apical process, bordered by deep vascula lateralia, diverging at about 60°. Internally the pedicle foramen is situated posteriorly to the apical process and it is encircled by an incipient collar. The posterolaterally located cardinal muscle scars are prominent, large and raised slightly above the valve floor. Small apical pits (= scars of umbonal muscles) lay anterolaterally to the foramen.

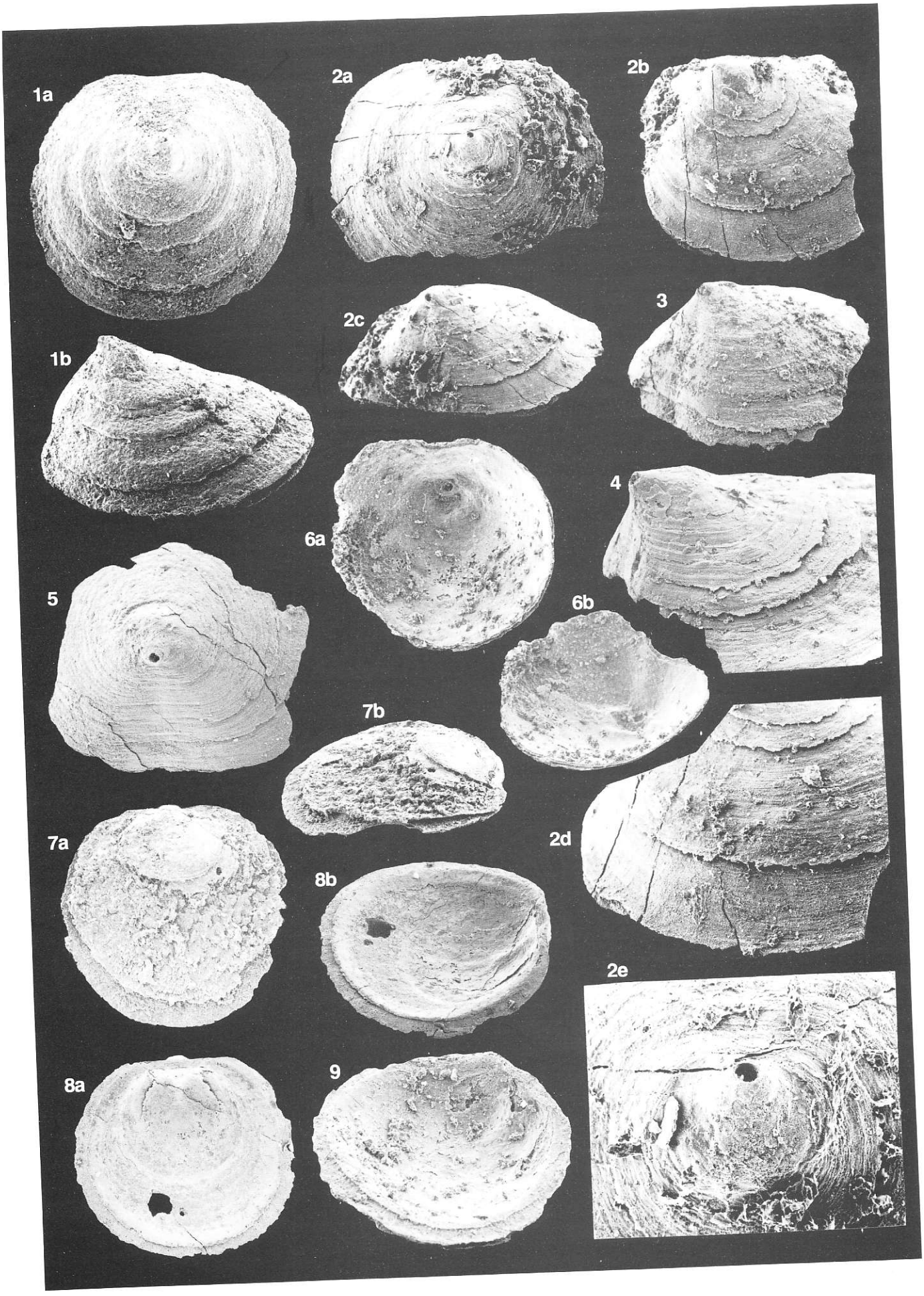
Shell exterior is covered by low concentric fila of uniform size. Growth lamellae are weak, unevenly sized, and restricted to later growth stages, two in number in available shells.

Discussion. The species is referred to the genus *Opisthotreta* as it has a ventral valve with a low pseudointerarea and rounded posterior margin. Unlike the other species referred to this genus (Palmer 1954; Holmer et al. 1999; Robson et al. 2003), *O. sardica* has a catacline ventral pseudointerarea and a distinct dorsal median septum.

Occurrence. GP1, GP2, GP4, GP9, GP14, GP14a.

PLATE 2

Vandalotreta proclinis n. sp. Fig. 1 – Ventral valve, holotype, ventral valve exterior in apical (a) and lateral (b) views, FG 533/5, x 37, x 40. Fig. 2 – Ventral valve, exterior in apical (a), oblique (b), posterolateral (c) views, detail of ornament (d), and detail of larval shell (e), FG 533/6, x 37, x 40, x 37, x 70, x 125. Fig. 3 - Ventral valve, exterior in oblique view, FG 533/7, x 50. Fig. 4 – Ventral valve, detail showing larval shell, FG 533/8, x 60. Fig. 5 – Ventral valve, posteroventral view showing pseudointerarea, FG 533/15, x 55. Fig. 6 – Ventral valve, interior (a) and oblique (b) view, FG 533/1, x 40, x 45. Fig. 7 – Dorsal valve, exterior (a) and lateral view (b), FG 533/12, x 45, x 45. Fig. 8 – Dorsal valve, interior (a) and oblique view (b), FG 533/3, x 33, x 37. Fig. 9 – Dorsal valve, interior in oblique view, FG 533/2, x 60.


1a
2a
2b
2c
3
1b
6a
4
5
6b
7b
2d
7a
8b
2e
8a
9

Genus *Vandalotreta* Mergl, 1988

Type species: *Vandalotreta vafra* Mergl, 1988, p. 293, pl. 1, figs 1-5; Middle Cambrian, Morocco.

Vandalotreta proclinis n. sp.

Pl. 2, figs 1-9

Origin of the name: Proclinis (Latin), referring a form of the ventral pseudointerarea.

Holotype. Ventral valve figured on Pl. 2, fig. 1 (FG 533/5)

Paratypes. Ventral valve figured on Pl. 2, fig. 2a-e (FG 533/6), ventral valve figured on Pl. 2, fig. 3 (FG 533/7), ventral valve figured on Pl. 2, fig. 4 (FG 533/8), ventral valve figured on Pl. 2, fig. 5 (FG 533/15), ventral valve figured on Pl. 2, fig. 6a,b (FG 533/1), dorsal valve figured on Pl. 2, fig. 7a,b (FG 533/12), dorsal valve figured on Pl. 2, fig. 8a,b (FG 533/3), dorsal valve figured on Pl. 2, fig. 9 (FG 533/2).

Type horizon. Campo Pisano Formation.

Type locality. SW Sardinia, Gutturu Pala mine.

Repository. Freiberg University, Geological Institute, Freiberg, Germany.

Diagnosis. Species of the genus *Vandalotreta* that is characterized by procline ventral pseudointerarea, vestigial dorsal median groove and by coarsely lamellose shell ornamentation.

Description. Valves thin, maximum width is 1.5 mm. Ventral valve asymmetrical, conical, dorsal valve moderately convex. The commissure is weakly unisulcate.

The dorsal valve is subcircular, 85% as long as wide, with the maximum width at the midlength. Maximum depth is at posterior third, and it equals to less than 20 % of the width. Lateral and anterior margins are evenly rounded; the posterior margin is weakly concave. The dorsal pseudointerarea is short, almost orthocline, and 40 % as wide as the valve. The median groove is broadly triangular, shallow, concave and weakly but distinctly extended posteriorly over the margin. The surface of the groove is covered by fine anteriorly convex growth lines. Propareas are obscure and pass anterolaterally into a broad brim, which is less distinct from about the midlength. The median buttress is distinct and supported by a vestigial, low and short median ridge. Cardinal scars are large and located at posterolateral slopes. Anterocentral muscle scars are weakly impressed near the centre of the valve. Epithelian cell moulds cover the posterior slope close to the median ridge. Vascula lateralia are not impressed.

The ventral valve is asymmetric, conical, with the apex at posterior one-four to one-fifth of the valve. Anterior and lateral slopes are straight to weakly concave. The ventral pseudointerarea is procline, well defined, with flat surface and with a shallow intertrough axially. The pseudointerarea is ornamented by fine, distinct growth lines. The apex is formed by a 350-400 μm wide cap of larval shell, with a posteroventrally directed conical node pierced by a circular pedicle foramen. Foramen is wholly confined to the larval shell. Ventral interior shows low apical process, which fills the apical chamber. The internal pedicle foramen lies at the bottom of the posterior slope. Cardinal scars are large and located posterolaterally outside inner surface of the pseudointerarea. Vascula lateralia are distinct only proximally as broadly diverging canals.

Shell ornamentation consists of low, wavy growth lines interrupted by few much stronger, low and long growth lamellae of uneven size. The lamellae are almost regularly spaced (three to five coarse to very coarse lamellae on the surface of adult shells). Micro-ornamentation of the larval shell is formed by very fine, small and deep pits.

Discussion. The new species differs from the type species *Vandalotreta vafra* Mergl (early Middle Cambrian, Morocco) in its procline ventral pseudointerarea and by lamellose ornamentation on both valves. Although the species *Vandalotreta pompeckji* (Mergl & Šlehoferová) (Middle Cambrian, Bohemia) shares procline ventral pseudointerarea and lamellose ornament, it differs by the more posterior ventral apex, by the deeply concave ventral pseudointerarea and by the deep intertrough.

The morphology of the new species is remarkably similar to the genus *Anabolotreta* Rowell & Henderson, 1978, especially the procline ventral pseudointerarea and distinctive growth lamellae. However, in our species the pedicle foramen is enclosed within the larval shell and there is a weak dorsal median ridge.

Occurrence. Samples GP9, GP15.

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