

NEW DATA ON THE LATE MIOCENE BRACHIOPOD FAUNA OF TETTI BORELLI (PIEDMONT, N ITALY)

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Abstract. After a small brachiopod fauna was published in 2010 from the Tortonian Sant'Agata Fossili Formation of Tetti Borelli (N Italy), two new and more numerous brachiopod collections turned up from this locality. The Roest Collection in the Naturalis Biodiversity Center (Leiden, the Netherlands), and the Pavia-Giuntelli Collection in the Department of Earth Sciences of Torino University (Torino, Italy) contain 199 and 131 specimens, respectively. Based on the study of these collections, the Tetti Borelli brachiopod fauna is now much better known and more diverse. Additionally to the previously described six species (*Cryptopora lovisati*, *Eucalathis* aff. *tauriniensis*, *Megathiris detruncata*, *Joania* aff. *falunica*, *Megerlia truncata*, *Lacazella mediterranea*), another four taxa have been found (*Lingula* sp., *Terebratulina retusa*, *Joania cordata*, *Argyrotheca* sp.), and a new Megathyrididae genus and species (*Borellithyris gaetanii* n. gen. n. sp.) has been discovered. Another new species (*Eucalathis giulioi* n. sp.) is introduced on the basis of a dorsal valve of the Roest Collection and a previously illustrated ventral valve from the Janssen Collection. This is the sixth known fossil *Eucalathis* species, most of which are described on the basis of a few specimens. The Tetti Borelli brachiopods are mostly resedimented with different degree of transport, but the minute rhynchonellide *Cryptopora* seems to be more or less autochthonous.

INTRODUCTION

Tetti Borelli is a well-known Late Miocene locality at the northern part of the Piedmont Basin, near to Moncucco Torinese (North Italy) (Fig. 1). Its diverse and well-preserved fauna was published in several papers; however, brachiopods were rather neglected for a long time. Both Pavia & Robba (1979) and Girone et al. (2010) listed the different fossil groups represented in Tetti Borelli layers, but brachiopods were not identified. Dell'Angelo et al. (1999) mentioned that investigation of some fossil groups from Tetti Borelli was also in progress, including brachiopods by Benigni. However, this fauna was never published, and moreover, this brachiopod collection most probably was lost (pers. comm. G. Pavia, 2018).

A Synthesys visit was performed by the author in the Naturalis Biodiversity Center (Leiden, the Netherlands) in 2008 (NL-TAF-3270), when several unpublished brachiopods were found in the collection, among them those from Tetti Borelli collected by Arie W. Janssen. The small fauna with six species was described by Dulai (2010): *Cryptopora lovisati* (Dreger, 1911), *Eucalathis* aff. *tauriniensis* (Seguenza, 1866), *Megathiris detruncata* (Gmelin, 1791), *Joania* aff. *falunica* (de Morgan, 1915), *Megerlia truncata* (Linnaeus, 1767), *Lacazella mediterranea* (Risso, 1826). On the basis of NBC collection labels, Dulai (2010) erroneously indicated Tetti Borelli fauna as Messinian in age. However, according to the pteropods of the same locality (actually from the same samples as the brachiopods), the age is Tortonian (see details in Janssen 2012). As the published brachiopod material was not so numerous (39 specimens) and contained some rare forms in very limited number (e.g., *Eucalathis* aff. *tauriniensis*: 1 ventral valve; *Joania* aff.

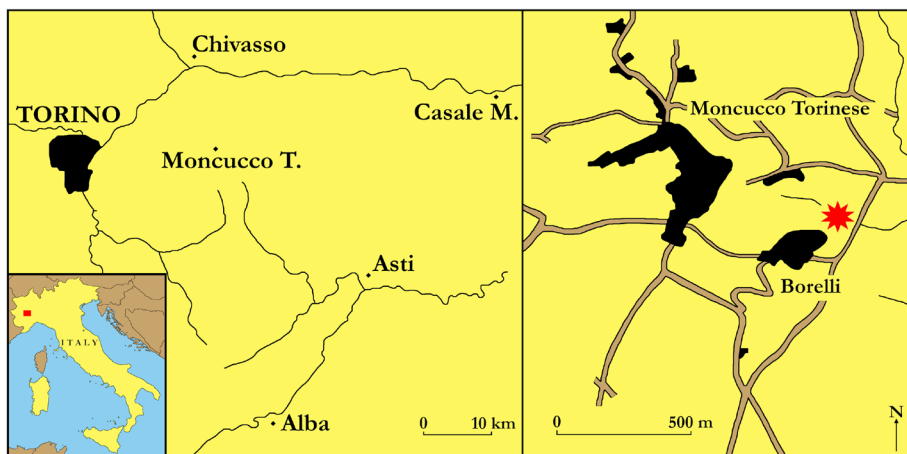


Fig. 1 - Sketch map of the location of the studied locality (modified after Pavia & Robba 1979).

falunica: 1 dorsal valve), Dulai (2010) concluded, that the study of more abundant brachiopod fauna from Tetti Borelli would be desirable.

Recently, the Naturalis Biodiversity Center has received a new fossil collection from Ben G. Roest (Silvolde, the Netherlands), who has a very extensive collection from Tetti Borelli, too. The Roest Collection includes also some brachiopods from this locality (199 specimens). Further brachiopod material from Tetti Borelli locality was looked for and Professor Giulio Pavia (Torino, Italy) provided 131 additional specimens, which had been collected by him and Piero Giuntelli. By the investigation of these collections, the Tetti Borelli brachiopod fauna became much better known and more diverse. The new materials yielded some new taxa, which are significant contributions to the European Neogene brachiopod fauna.

GEOLOGICAL SETTING

The pre-evaporitic deep-water sediments of Tetti Borelli consist of turbidites and therefore most of their fossils are allochthonous (Pavia & Robba 1979). The molluscan assemblage indicates deposition at bathyal depths (200-500 m) (Sturani 1978), and the rich otolith material with abundant pelagic components and absence of benthic and benthopelagic-neritic elements also reflects deeper depositional environment (Girone et al. 2010). The geological age of this section was debated for a long time as Tortonian or Messinian. Sacco (1890-1904) described several Tortonian molluscs from this locality, but later based on the abundant and well-preserved foraminifers (d'Onofrio et al. 1975), and on the basis of pteropods (Pavia & Robba 1979) the age of the

sediments was referred as Early Messinian. However, a more recent revision of the pteropod fauna of Tetti Borelli indicates again a Tortonian age (Janssen 2012). In his monograph, Janssen (2012) also refers to renewed foraminifera analysis which confirms the Tortonian age. The serpentinite sands (Montaldo Member of Sant'Agata Fossili Formation) contain a rich fauna, which was published in several papers. The different groups of molluscs were most intensely investigated. Sacco (1890-1904) published several gastropods, while Pavia & Robba (1979) described 47 bivalve, 7 scaphopod and 79 gastropod species from the locality. Later some groups were studied in more detail: e.g., scaphopods (Pavia 1991), Cancellariidae gastropods (Davoli 1995), polyplacophorans (Dell'Angelo et al. 1999), Conidae and Terebridae gastropods (Davoli 2003).

MATERIAL AND METHODS

This paper is based on two different collections from Tetti Borelli: the Roest Collection (Naturalis Biodiversity Center, Leiden, the Netherlands: RGM.1351053-1351096) and the Pavia-Giuntelli Collection (University of Torino, Italy: MGPU-PU 111342-111360). One paratype of *Borellithyris gaetanii* n. gen. n. sp. from the Pavia-Giuntelli Collection is deposited in the Hungarian Natural History Museum, Budapest (HNHM, PAL 2018.22.1).

Ben Roest has collected fossils several times at an outcrop just outside of the classic Tetti Borelli locality, which was totally overgrown. In this 'new' outcrop the layers were sloping from down-left to up-right. There was a distinctive thin clay layer with hardly any fossils in it. This clay layer has served as reference for the samples taken (pers. comm. B. Roest, 2018). The Pavia-Giuntelli material was not collected bed-by-bed, but Professor Pavia confirmed, that their specimens derived more or less from the same layers, as the Roest's brachiopods (pers. comm. G. Pavia, 2018).

Both collections are listed below with respective inventory numbers (Tab. 1a, b). Abbreviations used in Tab. 1a, b, and later in the text: A = articulated specimens; V = ventral valves; D = dorsal valves; fr = fragments; RGM = Rijksmuseum van Geologie en Mineralogie;

MGPU-T-PU = Museo di Geologia e Paleontologia dell'Università di Torino - Paleontologia Università; HNHM PAL = Hungarian Natural History Museum, Budapest, Paleontological Collection.

SYSTEMATIC PALAEOLOGY

Phylum **BRACHIOPODA** Duméril, 1805
 Subphylum LINGULIFORMEA Williams,
 Carlson, Brunton, Holmer & Popov, 1996
 Class **LINGULATA** Gorjansky & Popov, 1985
 Order **Lingulida** Waagen, 1885
 Superfamily Linguloidea Menke, 1828
 Family Lingulidae Menke, 1828
 Genus *Lingula* Bruguière, 1791

Type species - *Lingula anatina* Lamarck, 1801, subsequent designation by Rowell (1964).

Lingula? sp.

Pl. 1, figs. 1-2

Material: Roest Collection (11 fr) (Tab. 1a).

Remarks. Recent lingulides show a worldwide distribution (Emig 1997b) and the Family Lingulidae has a very long fossil record from the Carboniferous (Curry & Brunton 2007: 2974). However, lingulides are unknown in the present-day Mediterranean (Logan 1979; Logan et al. 2004), and they had also very limited representation in the Neogene. *Lingula* cf. *dregeri* Andreae, 1893 was described from the Miocene of Sardinia by Dreger (1911) and this is the only Neogene lingulide of the Mediterranean identified at specific level. Recently Bertolaso et al. (2009) mentioned some *Lingula?* sp. from the Upper Miocene of Emilia without any illustrations. They refer also to Miculan's (1992) ostracod paper, in which lingulides were mentioned from the Messinian of Vigoleno (Piacenza).

The very limited lingulide material of Tetti Borelli locality contains only some small fragments. They can be identified as Lingulidae specimens; however, the very small size of the fragments hinders not only the specific, but also the definite generic identification. Until now, two Lingulidae genera were recognized in the European Neogene. *Lingula* was recorded in the Mediterranean (Dreger 1911), in the Atlantic Ocean (Emig et al. 2007) and in the Central Paratethys (Emig & Bitner 2005; Bitner & Schneider 2009; Bitner et al. 2012; Mikuž et al. 2012), while *Glottidia* Dall, 1870 was common constituent of brachiopod assemblages in the North Sea

Basin (Chuang 1964; Dulai 2013, 2016). As all of the previously published Mediterranean – Central Paratethyan lingulide records belong to *Lingula*, and the confirmed occurrence of *Glottidia* is confined to the North Sea Basin, the Tetti Borelli fragments were tentatively identified as *Lingula?* sp.

Subphylum RHYNCHONELLIFORMEA
 Williams, Carlson, Brunton, Holmer & Popov, 1996
 Class **RHYNCHONELLATA** Williams, Carlson,
 Brunton, Holmer & Popov, 1996
 Order **Rhynchonellida** Kuhn, 1949
 Superfamily Dimerelloidea Buckman, 1918
 Family Cryptoporidae Muir-Wood, 1955
 Genus *Cryptopora* Jeffreys, 1869

Type species - *Atretia gnomon* Jeffreys, 1869, by monotypy of Jeffreys (1869: 136).

Cryptopora lovisati (Dreger, 1911)

Pl. 1, figs. 3-9

- 1911 *Rhynchonella Lovisati* n. sp. - Dreger, p. 136, figs. 3-6.
 2010 *Cryptopora lovisati* (Dreger, 1911) - Dulai, p. 24, pl. 1, figs. 1a-b, 2, 3a-b, 4a-b, 5a-c. (cum syn.)
 2013 *Cryptopora lovisati* (Dreger, 1911) - Dulai, pp. 34-37, figs. 41-44, 45-58.
 2013b *Cryptopora lovisati* (Dreger, 1911) - Bitner et al., p. 83, fig. 2B-K.

Material: Roest Collection (63 A, 38 V, 25 D), Pavia-Giuntelli Collection (1 A, 1 V, 1 D) (Tab. 1a, b).

Remarks. The only rhynchonellide of the studied fauna is *C. lovisati*. During the last decades several papers confirmed that genus *Cryptopora* was a common member of European Neogene brachiopod assemblages (Popiel-Barczyk 1980; Bitner 1990; Bitner & Cahuzac 2004; Dulai 2010, 2013, 2015; Bitner et al. 2013b; Bitner & Motchurova-Dekova 2016). In the earlier brachiopod literature they were rarely mentioned, but most probably only overlooked because of their small size and very thin shells. Cryptoporides can be observed mostly in washed residues, but washing process commonly and easily breaks or even destroys the very fragile shells.

In the Mediterranean, *C. lovisati* was described from the Middle Miocene of Sardinia by Dreger (1911), but after that several decades passed away without newer records. Recently the same species was recognized from the Tortonian of Tetti Borelli (Dulai 2010: 5 A, 11 V, 10 D) and from the Langhian-Serravallian of Melpignano (Dulai 2013: 1 A).

Roest Collection (NBC, Leiden, the Netherlands)			
Species	Material	Inventory number	Illustration
Tetti Borelli, 2.75-3.50 m below clay layer (20.06.1996)			
<i>Cryptopora lovisati</i>	1 V	RGM.1351053	Pl. 1, fig. 5.
<i>Cryptopora lovisati</i>	1 A, 9 V, 2 D	RGM.1351054	-
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 A	RGM.1351055	-
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 V, paratype	RGM.1351056	Pl. 2, figs. 26-27.
<i>Joania cordata</i>	1 A	RGM.1351057	-
<i>Joania cordata</i>	1 V	RGM.1351058	-
<i>Megerlia truncata</i>	1 D	RGM.1351059	Pl. 3, figs. 15-16.
Tetti Borelli, just under the clay layer (1995)			
<i>Cryptopora lovisati</i>	1 A	RGM.1351060	Pl. 1, fig. 3.
<i>Cryptopora lovisati</i>	1 V	RGM.1351061	Pl. 1, fig. 9.
<i>Cryptopora lovisati</i>	5 A, 2 V	RGM.1351062	-
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 D	RGM.1351063	-
<i>Joania</i> aff. <i>falunica</i>	1 D	RGM.1351064	-
<i>Megerlia truncata</i>	1 D	RGM.1351065	Pl. 3, fig. 13.
<i>Megerlia truncata</i>	1 V, 3 D	RGM.1351066	-
<i>Lacazella mediterranea</i>	1 D	RGM.1351067	Pl. 3, figs. 23-24.
<i>Lacazella mediterranea</i>	1 V, internal mould	RGM.1351068	-
Tetti Borelli, no stratigraphic sampling (09.06.1994)			
<i>Lingula?</i> sp.	2 fr	RGM.1351069	-
<i>Cryptopora lovisati</i>	21 A, 8 V, 1 D	RGM.1351070	-
<i>Joania</i> aff. <i>falunica</i>	1 D	RGM.1351071	Pl. 3, figs. 11-12.
<i>Joania cordata</i>	1 V	RGM.1351072	-
<i>Megerlia truncata</i>	1 V, 1 D	RGM.1351073	-
Brachiopoda indet. sp.	1 A	RGM.1351074	-
Tetti Borelli, just above clay layer			
<i>Cryptopora lovisati</i>	14 A, 5 V, 6 D	RGM.1351075	-
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 V, paratype	RGM.1351076	Pl. 2, figs. 24-25.
<i>Megerlia truncata</i>	1 V	RGM.1351077	Pl. 3, fig. 14.
<i>Megerlia truncata</i>	1 V, 1 D	RGM.1351078	-
<i>Lacazella mediterranea</i>	1 D	RGM.1351079	Pl. 3, fig. 22.
Tetti Borelli, 0.75-1.20 m above clay layer (1995)			
<i>Lingula?</i> sp.	1 fr	RGM.1351080	Pl. 1, fig. 1.
<i>Lingula?</i> sp.	1 fr	RGM.1351081	Pl. 1, fig. 2.
<i>Lingula?</i> sp.	9 fr	RGM.1351082	-
<i>Cryptopora lovisati</i>	1 D	RGM.1351083	Pl. 1, figs. 6-7.
<i>Cryptopora lovisati</i>	1 V	RGM.1351084	Pl. 1, fig. 8.
<i>Cryptopora lovisati</i>	20 A, 12 V, 15 D	RGM.1351085	-
<i>Terebratulina retusa</i>	1 V, 2 D	RGM.1351086	-
<i>Eucalathis giulioi</i> n. sp.	1 D, holotype	RGM.1351087	Pl. 1, figs. 16-21.
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 V	RGM.1351088	-
<i>Argyrotheca</i> sp.	1 D	RGM.1351089	Pl. 3, figs. 1-2.
<i>Joania cordata</i>	1 A	RGM.1351090	Pl. 3, fig. 3.
<i>Joania cordata</i>	1 V	RGM.1351091	Pl. 3, fig. 4.
<i>Joania cordata</i>	2 V	RGM.1351092	-
<i>Joania</i> aff. <i>falunica</i>	1 D	RGM.1351093	-
<i>Megerlia truncata</i>	5 V, 9 D	RGM.1351094	-
<i>Lacazella mediterranea</i>	1 A	RGM.1351095	Pl. 3, fig. 21.
<i>Lacazella mediterranea</i>	2 A, 1 V, 10 D	RGM.1351096	-

Tab. 1a - The studied brachiopod fauna in the Roest Collection (Leiden), with detailed inventory data.

It was also discovered in Malta, partly as internal moulds from the Globigerina Limestone (Dulai et al. in prep.: 90 specimens from 21 localities of the Lower, Middle and Upper Globigerina Limestone, the Blue Clay Formation and base of the Upper Coralline Limestone).

In the studied material this species is rather limited in the Pavia-Giuntelli Collection, but very well-represented in the Roest Collection (see possible reasons of these differences in Discussion). In washed samples it is the absolute dominant species

of Tetti Borelli brachiopod assemblage. *C. lovisati* was discussed in detail by several recently published papers (e.g., Bitner & Cahuzac 2004; Dulai 2010, 2013; Bitner et al. 2013b) and the Tetti Borelli specimens were also illustrated in more detail by Dulai (2010: pl. 1, Figs. 1-5).

Order **Terebratulida** Waagen, 1883

Suborder **Terebratulidina** Waagen, 1883

Superfamily Cancellothyridoidea Thomson, 1926

Family Cancellothyrididae Thomson, 1926

Tab. 1b - The studied brachiopod fauna in the Pavia-Giuntelli Collection (Torino), with detailed inventory data.

Pavia-Giuntelli Collection (Torino, Italy)			
<i>Cryptopora lovisati</i>	1 A, 1 V, 1 D	MGPUP-PU 111342	-
<i>Terebratulina retusa</i>	1 V	MGPUP-PU 111343	Pl. 1, figs. 10-11.
<i>Terebratulina retusa</i>	1 D	MGPUP-PU 111344	Pl. 1, figs. 12-13.
<i>Terebratulina retusa</i>	1 V	MGPUP-PU 111345	Pl. 1, fig. 14.
<i>Terebratulina retusa</i>	1 D	MGPUP-PU 111346	Pl. 1, fig. 15.
<i>Terebratulina retusa</i>	8 V, 5 D	MGPUP-PU 111347	-
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 A (1D, 1V), holotype	MGPUP-PU 111348	Pl. 2, figs. 1-8.
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 A (1D, 1V), paratype	MGPUP-PU 111349	Pl. 2, figs. 9-12.
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 A (1D, 1V), paratype	HNHM, PAL 2018.22.1.	Pl. 2, figs. 13-17.
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 A (1D, 1V), paratype	MGPUP-PU 111350	Pl. 2, figs. 18-21.
<i>Borellithyris gaetanii</i> n. gen. n. sp.	1 D, paratype	MGPUP-PU 111351	Pl. 2, figs. 22-23.
<i>Borellithyris gaetanii</i> n. gen. n. sp.	13 V, 5 D	MGPUP-PU 111352	-
<i>Joania cordata</i>	1 D	MGPUP-PU 111353	Pl. 3, figs. 5-8.
<i>Joania cordata</i>	1 D	MGPUP-PU 111354	Pl. 3, figs. 9-10.
<i>Joania cordata</i>	4 D	MGPUP-PU 111355	-
<i>Megerlia truncata</i>	1 V	MGPUP-PU 111356	Pl. 3, figs. 17-18.
<i>Megerlia truncata</i>	1 D	MGPUP-PU 111357	Pl. 3, figs. 19-20.
<i>Megerlia truncata</i>	34 D, 13 V	MGPUP-PU 111358	-
<i>Megerlia truncata</i>	5 V, 6 D	MGPUP-PU 111359	-
<i>Lacazella mediterranea</i>	3 A, 8 V, 16 D	MGPUP-PU 111360	-

Subfamily Cancellothyridinae Thomson, 1926

Genus *Terebratulina* d'Orbigny, 1847

Type species - *Anomia retusa* Linnaeus, 1758, by subsequent designation of Brunton et al. (1967: 176).

Terebratulina retusa (Linnaeus, 1758)

Pl. 1, figs. 10-15

- 1758 *Anomia retusa* Linnaeus, p. 701.
 1797 *Terebratulina retusa* (Linnaeus, 1758) - Logan, pp. 37-40, pl. 3, figs. 1-18. (cum syn.)
 2005 *Terebratulina retusa* (Linnaeus, 1758) - Álvarez & Emig, pp. 139-140, figs. 14, 16, 24D-F, 27D, 27F, 28, 53B, 54E, 54F, 61.
 2005a *Terebratulina retusa* (Linnaeus, 1758) - Álvarez et al., p. 220. (cum syn.)
 2013a *Terebratulina retusa* (Linnaeus, 1758) - Bitner et al., pp. 584-586, fig. 2E-H.
 2016a *Terebratulina retusa* (Linnaeus, 1758) - Álvarez, pp. 47-50, pl. 12E-DD, 13A-II, 14A-II, 15A-C (cum syn.)
 2016b *Terebratulina retusa* (Linnaeus, 1758) - Álvarez, pp. 113-114, pl. 80V-EE, 81A-LL.
 2016 *Terebratulina retusa* (Linnaeus, 1758) - Treguier & Álvarez, p. 126, pl. 89A-B.

Material: Roest Collection (1 V, 2 D), Pavia-Giuntelli Collection (10 V, 7 D) (Tab. 1a, b).

Remarks. *Terebratulina retusa* is a common and well-known member of Neogene and Recent brachiopod assemblages in the Mediterranean – Central Paratethyan and North Atlantic – North Sea provinces (e.g., Brunton & Curry 1979; Logan 1979; Gaetani & Saccà 1985a; Bitner & Dulai 2004). In the present-day Mediterranean it is common in the western part, but very limited in the eastern territory (Logan 1979: 39). It had similar distributional

pattern in the Neogene with several records in the Western Mediterranean (e.g., see the long synonymy list in Gaetani & Saccà 1985a), but some *T. retusa* were also found in the Pliocene of the Eastern Mediterranean (Koskeridou 2007). *T. retusa* is also known from the Pliocene of northern Algeria (Bitner & Moissette 2003). The complex nomenclatural problems of *Terebratulina retusa* – *T. caputserpentis* (Linnaeus, 1767) species group were discussed in detail by Emig et al. (2015).

It is the first record of this species from Tetti Borelli locality. Not so common in the Roest Collection, but numerous separate dorsal and ventral valves are present in the Pavia-Giuntelli Collection. These are the largest known brachiopods of Tetti Borelli. The shell outline is rather variable as usual, from elongated oval (Pl. 1, figs. 10-11) to subtriangular (Pl. 1, fig. 14). The shell surface is covered with numerous fine ribs, which are typically bifurcated or intercalated (Pl. 1, figs. 11, 13-14).

Family Chlidonophoridae Muir-Wood, 1959

Subfamily Eucalathinae Muir-Wood, 1965

Genus *Eucalathis* Fischer & Ehlert, 1890

Type species - *Terebratulina murrayi* Davidson, 1878, by original designation of Fischer & Ehlert (1890: 72)

Eucalathis giulioi n. sp.

Pl. 1, figs. 16-21

- 2010 *Eucalathis* aff. *tauriniensis* (Seguenza, 1866) - Dulai, pp. 24-26, pl. 2, figs. 1-7.

Derivation of name: In honour to Professor Giulio Pavia (University of Torino), who collected some of the studied brachiopods, and published several papers on the fossil fauna of Tetti Borelli.

Holotype: RGM.1351087 (Roest Collection, NBC, Leiden), dorsal valve (Pl. 1, figs. 16-21).

Paratype: RGM.1351178 (Janssen Collection, NBC, Leiden), ventral valve (published by Dulai 2010, pp. 24-26, pl. 2, figs. 1-7; under the name *Eucalathis* aff. *tauriniensis*).

Type locality: Tetti Borelli, Piedmont Basin, North Italy.

Type horizon: Montaldo Member of Sant'Agata Fossili Formation, Late Miocene, Tortonian (Janssen 2012).

Diagnosis: *Eucalathis* with 16 strong, wide, single and rounded ribs, without bifurcation or intercalation. Narrow intercostal spaces. Short and wide umbo with well-developed pedicle collar. Long, incurved, but not united crural processes. Short and thick loop, with complete and anteriorly slightly wavy transverse band.

Description

Dorsal valve: broadly triangular outline, slightly longer than wide (L: 4.5 mm; W: 4.05 mm). Greatest width at the mid-length. Straight lateral commissures, rectimarginate anterior commissure. Outer surface ornamented by strong, single, and rounded coarse ribs (16). Costae not beaded, and crossed by some weak growth lines. Ribs significantly wider, than intercostal spaces. Ribs run through from beak to anterior margin. Slightly curved hinge margin, less than half of the width. Inner sockets deep, with massive inner socket ridges extending beyond the margin. Cardinal process not prominent. Crura short and stout. Crural processes long, incurved, but not united. Short thick loop, with complete transverse band, not angular but slightly wavy at the anterior. Inner margin broadly crenulated.

Ventral valve (see Dulai 2010, pp. 24-26, pl. 2, figs. 1-7): broadly subtriangular (L: 3.0 mm, W: 2.8 mm), greatest width at the anterior third. Straight lateral commissures, rectimarginate anterior commissure. Outer surface ornamented by 15 strong, rounded ribs, run from the beak to the anterior margin without any bifurcations or intercalations. Ribs twice wider than intercostal spaces. Ribs are without any beads or crenulations, growth lines rare and weak. Short umbo obliquely truncated, with well-developed wide pedicle collar. Short and wide teeth. Anterior part of inner margin broadly crenulated.

Remarks. *Eucalathis* is a widely distributed cosmopolitan genus in the present-day oceans with 16 different species (Logan 2007; Bitner & Logan 2016), but its fossil record is very poorly known and its fossil occurrence is limited. *Eucalathis* was indicated from the Paleogene (Eocene) in the revised Treatise (Lee et al. 2006a) referring to Cooper

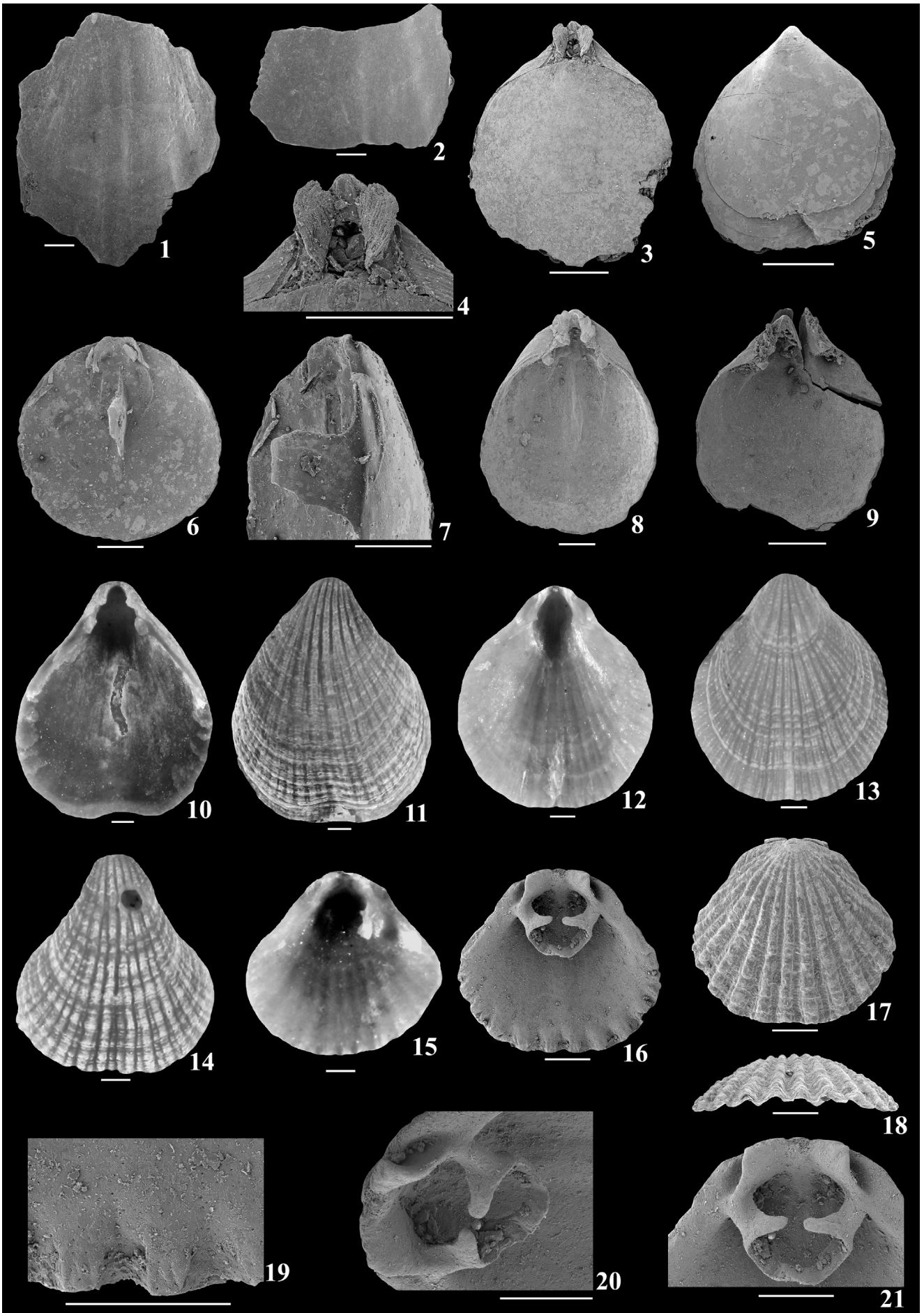
(1988) who published two uncertain *Eucalathis* species from North and South Carolina in the USA. Soon after the Treatise, two older representatives of the genus were published. Kaim et al. (2010) described a monospecific assemblage of *E. methanophila* Bitner, 2010 from the Upper Cretaceous seep deposits of Japan, while Pacaud (2015) introduced *E. paleocaenica* Pacaud, 2015 from the Thanetian (Late Paleocene) of France. *E. tauriniensis* was recorded from the Miocene of Italy (Seguenza 1866; Davidson 1870) and was accepted also by the revised Treatise (Lee et al. 2006a).

Eucalathis giulioi n. sp. is significantly different from all known fossil *Eucalathis* species (Tab. 2); therefore, the description of a new species is justified, even if the available material is rather limited. Kaim et al (2010) mentioned 21 studied specimens, but all the other fossil *Eucalathis* species based on very scarce materials, too: *E. paleocaenica*: 2 dorsal valves (Pacaud 2015); *Eucalathis?* sp. 1: 1 specimen, *Eucalathis?* sp. 2: 3 specimens (Cooper 1988); *E. tauriniensis*: 1 dorsal valve (Seguenza 1866) and an articulated specimen (Davidson 1870).

E. methanophila shows similar size and outline, but it has more numerous (20-30) and beaded tu-

PLATE 1

- 1-2 - *Lingula?* sp. 1 - Roest Collection (RGM.1351080); 2 - Roest Collection (RGM.1351081);
 3-9 - *Cryptopora lovisati* (Dreger, 1911). 3-4 Articulated specimen, Roest Collection (RGM.1351060), 3 - Dorsal view, 4 - Detail of beak region; 5 - Articulated specimen, Roest Collection (RGM.1351053), ventral view; 6-7 - Dorsal valve, Roest Collection (RGM.1351083), 6 - Internal view, 7 - Oblique lateral view to show the median septum; 8 - Ventral valve, Roest Collection (RGM.1351084), internal view; 9 - Broken ventral valve, Roest Collection (RGM.1351061), internal view;
 10-15 - *Terebratulina retusa* (Linnaeus, 1758). 10-11 - Ventral valve, Pavia-Giuntelli Collection (MGPUT-PU 111343), 10 - Internal view, 11 - External view; 12-13 - Dorsal valve, Pavia-Giuntelli Collection (MGPUT-PU 111344), 12 - Internal view, 13 - External view; 14 - Ventral valve, Pavia-Giuntelli Collection (MGPUT-PU 111345), external view; 15 - Dorsal valve, Pavia-Giuntelli Collection (MGPUT-PU 111346), internal view;
 16-21 - *Eucalathis giulioi* n. sp., holotype, dorsal valve, Roest Collection (RGM.1351087), 16 - Internal view, 17 - External view, 18 - Anterior view, 19 - Detail of broadly crenulated internal rim of dorsal valve, 20 - Oblique lateral view of deep inner sockets and long crural processes, 21 - Internal detail of massive inner socket ridges and the short and thick loop.
 Scale bars correspond to 1 mm.



Species	Material	Age	Distribution	L (mm)	Ribs	Beaded	R v. IC	Intercalation	Angle
<i>E. methanophila</i>	21 A	Cretaceous	Japan	5.7	20-30	yes	R<IC	yes	85-95°
<i>E. paleocaenica</i>	2 D	Paleocene	France	2.9 (D)	10	yes	R<<IC	no	-
<i>Eucalathis?</i> sp. 1	1 A	Eocene	S Carolina	2.5	16	slightly	R~IC	yes	100°
<i>Eucalathis?</i> sp. 2	3 A	Eocene	N Carolina	2.5	11	yes	R>IC	no	100°
<i>E. tauriniensis</i>	1 D, 1 A	Miocene	Italy	~3	16	yes	R~IC	no	90°
<i>E. giulioi</i> n. sp.	1 D, 1 V	Miocene	Italy	4.5 (D)	15-16	no	R>>IC	no	65°

Tab. 2 - Comparison of some significant characteristics of known fossil species of *Eucalathis*. R v. IC = comparison of width of ribs and intercostal spaces; Intercalation = intercalated and/or bifurcated ribs; Angle = Apical angle of ventral valve (data from Davidson 1870; Cooper 1988; Kaim et al. 2010; Pacaud 2015).

berculate ribs, which are not so strong and wide, and their number increase by both intercalations and bifurcations. Its reconstructed loop is without transverse band (Kaim et al. 2010: fig. 4), and the crural processes are very short compared with those at the Tetti Borelli dorsal valve. The dorsal valve of *E. paleocaenica* is unknown, but its ventral valve is more auriculate and has very different ribbing pattern: there are less (10) and clearly beaded tuberculate ribs, the intercostal spaces are much wider than ribs, and the ribs do not appear at the beak, the posterior third of the shell is smooth (Pacaud 2015). Cooper's (1988) *Eucalathis?* sp. 1 is more auriculate and its outline is rather subpentagonal than subtrigonal. It has similar number (16) of major costae as *E. giulioi* n. sp., but several small secondary costae intercalated at the anterior margin which is unknown at the Italian species. Its ribs are not so wide, and sometimes slightly beaded. *Eucalathis?* sp. 2 has rounded outline and ornamented by much less ribs (11); the ribs are beaded at the posterior two-thirds of the ventral valve. The generic attributions of both *Eucalathis?* species of Cooper (1988) are uncertain because the internal morphological characters are inadequately known. Although *E. tauriniensis* is also described from the Italian Miocene, it is clearly different from the Tetti Borelli material. It has not a subtrigonal, but a subcircular outline, and its beak is very acute, while *E. giulioi* n. sp. has much wider and more rounded beak. The number of ribs is very similar; however, Seguenza's species has strongly beaded ribs, and its ribs only slightly wider than the intercostal spaces (Seguenza 1866; Davidson 1870). Apical angle of ventral valve of *E. giulioi* n. sp. is significantly smaller (65°), than that of any other known fossil *Eucalathis* species (85-100°). The new species is larger than most

of the fossil forms, the only comparable-sized is *E. methanophila* (Tab. 2).

Range. *Eucalathis giulioi* n. sp. is known from the Late Miocene of Italy (Dulai 2010, and this paper).

Superfamily Megathyridoidea Dall, 1870

Family Megathyrididae Dall, 1870

Genus *Borellithyris* n. gen.

Type and only species: *Borellithyris gaetanii* n. gen. n. sp.

Derivation of name: After the type locality Tetti Borelli, plus thyris (opening).

Diagnosis: Semi-circular Megathyrididae with 10-12 weak, low and rounded ribs. Straight hinge line, equal to the maximum width. Long, but low ventral median septum. Two or three strong, straight or slightly wavy lateral septa on both sides of ventral median septum. Small, wide and short teeth parallel to the hinge line. Long, high, triangular dorsal median septum. Partly preserved loop, anteriorly attached to the median septum, descending branches united with valve floor.

Comparisons with related genera. Although the Family Megathyrididae belongs to the most common brachiopods in Cenozoic and Recent shallow-water environments, it contains relatively few genera which are rather unevenly distributed in brachiopod assemblages. *Phragmothyris* Cooper, 1955 is limited to the Paleogene of Cuba (Cooper 1955). *Bronnothyris* Popiel-Barczyk & Smirnova, 1978 was mentioned from the Late Cretaceous and Early Danian of Western Europe by Treatise (Lee et al. 2006b), but later it was also recorded in the Oligocene of Germany by Bitner & Kroh (2011) and in the Eocene of Ukraine by Bitner & Müller (2017). The other three genera (*Megathiris* d'Orbigny, 1847; *Argyrotheca* Dall, 1900; *Joania* Álvarez, Brunton & Long, 2008) are much more common

and widely distributed (Lee et al. 2006b; Logan 2007; Álvarez et al. 2008). *Argyrotheca* is especially rich in species and known from all recent oceans (Logan 2007).

Borellithyris n. gen. is externally similar to *Megathyris*; however, they are different in internal morphological characters. In the ventral valve, *Megathyris* has only the median septum, without the several (generally 4-6) strong lateral septa. Some descriptions, e.g., Lee et al. (2006b) in the revised Treatise mentioned 2 subdued lateral septa; however, they are always very weak or nearly insensible. In the dorsal valve, the two lateral septa characteristic for *Megathyris* are missing in *Borellithyris* n. gen. The beak in *Megathyris* is usually sharper, and dorsal median septum of *Megathyris* has less and not so evenly strong serrations, than *Borellithyris* n. gen. (compare Pl. 3, Fig. 8. with Álvarez et al. 2008: Fig. 10). The ventral valve of *Argyrotheca* has shorter median septum, and it is also lacks the several lateral septa (see e.g., Lee et al. 2006b: fig. 1473, 2e). In the dorsal valve the median septum may be similar, but it is less serrated in several species of *Argyrotheca* (see e.g., Álvarez et al. 2008: figs. 1B, 6B, and 6E). In *Argyrotheca* the loop is long, formed of two slender, arcuate descending branches, attached to base of crura, valve floor and anterior end of median septum (Lee et al. 2006b: fig. 1473, 2d; Álvarez et al. 2008: fig. 6), while the loop of *Borellithyris* n. gen. is very poorly visible in all available specimens. *Joania* is clearly distinguishable from *Borellithyris* n. gen. on the basis of the absence of ventral lateral septa, and the marginal row of tubercles along the interior margin of both valves (Álvarez et al. 2008: figs. 5, 13). *Bronnothyris* is characterized by short septal flanges extending ventrally from dorsal septum (Lee et al. 2006b), which are missing in species of *Borellithyris* n. gen.; loop is similarly poorly developed at both genera. The ventral valve has very short median septum, without any lateral septa (see e.g., Bitner & Kroh 2011: fig. 2C). *Phragmothyris* is externally multicostellate with several fine, wavy and bifurcating ribs. Its dorsal valve has elevated socket ridges; the adductor scars are on elevated platform; the ventral valve is without lateral septa (Cooper 1955; Lee et al. 2006b).

Range. *Borellithyris* n. gen. is known from the Late Miocene of Italy (this paper). An uncertain record is also reported from the Eocene of Ukraine (Zelinskaya 1962; see below).

Borellithyris gaetanii n. gen. n. sp.

Pl. 2, figs. 1-27

Derivation of name: In honour to late Professor Maurizio Gaetani, who studied intensively the Italian Neogene brachiopod faunas in the 1980's.

Holotype: MGPU-PU 111348 (Pl. 2, figs. 1-8).

Paratypes: MGPU-PU 111349 (Pl. 2, figs. 9-12), PAL 2018.22.1. (Pl. 2, figs. 13-17), MGPU-PU 111350 (Pl. 2, figs. 18-21), MGPU-PU 111351 (Pl. 2, figs. 22-23), RGM.1351076 (Pl. 2, figs. 24-25), RGM.1351056 (Pl. 2, figs. 26-27).

Additional materials: Roest Collection (1 A, 2 D, 1 V), Pavia-Giuntelli Collection (13 V, 5 D) (Tab. 1a, b).

Type locality: Tetti Borelli, Piedmont Basin, North Italy.

Type horizon: Montaldo Member of Sant'Agata Fossili Formation, Late Miocene, Tortonian (Janssen 2012).

Diagnosis: As for the genus.

Size (Tab. 3):

	Inventory number	Length (mm)	Width (mm)
Holotype	MGPU-PU 111348	4.8	5.7
Paratype 1	MGPU-PU 111349	4.3	5.3
Paratype 2	HNHM PAL 2018.22.1.	6.6	8.4
Paratype 3	MGPU-PU 111350	5.1	6.0
Paratype 4	MGPU-PU 111351	4.4	5.8
Paratype 5	RGM.1351076	3.7	3.5
Paratype 6	RGM.1351056	5.5	5.8

Tab. 3 - Dimensions of the holotype and paratypes of *Borellithyris gaetanii* n. gen. n. sp. (paratype 4: dorsal valve only, paratypes 5-6: ventral valves only).

Description

External characters: small-sized shell (maximum observed length is 6.6 mm), always wider than long (Tab. 3). Both valves coarsely endopunctate (Pl. 2, figs. 6, 17). Outline rounded, maximum width at the posterior third. Hinge line straight and long, equal to the maximum width. Ventral valve semi-circular (Pl. 2, fig. 1) to wide rounded subrectangular (Pl. 2, fig. 13) with low (Pl. 2, fig. 13) to moderately high (Pl. 2, fig. 9) umbo and erect beak. Sharp beak ridges subtending an angle of about 110-135° at umbo. Wide interarea (Pl. 2, figs. 2, 5, 10, and 14) sometimes transversely striated (Pl. 2, figs. 5, 14, and 26). Large, subtriangular, hypothryid foramen, restricted by two narrow, disjunct deltidial plates. Dorsal valve wide semi-circular, the posterior margin straight (Pl. 2, figs. 3, 11) or with very slightly emergent umbo (Pl. 2, fig. 15). Ventral umbo sometimes asymmetrical: one side slightly convex, other side slightly concave (Pl. 2, figs. 1-2, 9-10). Ventri-biconvex shell, with dorsal valve nearly flat. Straight lateral commissures, rectimarginate anterior commissure. Shell surface ornamented by 10-12 wide, low and rounded ribs (Pl. 2, figs. 1, 9, 13, and 18). Space between ribs narrower than ribs. In most cases ribs

run through from umbo to anterior margin (Pl. 2, figs. 1, 9, 15, 20, and 22); however, they become less distinct at the anterior margin of the largest shells (Pl. 2, figs. 13, 18). No bifurcation. Intercalated ribs frequently appear at the mid-line of the shell (Pl. 2, figs. 1, 11, 15, and 22). Growth lines may be indistinct (Pl. 2, figs. 9, 11, 13, and 15), or distinct (Pl. 2, figs. 1, 18, and 20), sometimes denser near to the anterior margin (Pl. 2, figs. 3, 20, and 22).

Internal characters: ventral valve interior with large, wide, triangular pedicle collar (Pl. 2, fig. 5), supported by long but low median septum extending near to the anterior margin (Pl. 2, figs. 2, 10, 14, 19, 25, and 26). At the anterior part of ventral median septum some shallow ovoid depressions appear for serrations of dorsal septum (Pl. 2, figs. 14, 26). Two or three strong, long, straight or slightly wavy lateral septa on both sides of the ventral median septum. Lateral septa appear near to the end of pedicle collar (Pl. 2, fig. 5) and nearly as long as the median septum (Pl. 2, figs. 14, 26) or slightly shorter (Pl. 2, figs. 2, 10, and 19). The number of lateral septa changes between 2 and 4, occasionally shorter additional septa may appear between primary lateral septa (Pl. 2, figs. 14, 17) or near to the anterior end of median septum (Pl. 2, figs. 14, 26). Lateral septa low, with more or less straight upper margin (Pl. 2, fig. 6), or slightly wavy (Pl. 2, fig. 17), or even strongly wavy (Pl. 2, fig. 26). Small-sized, wide and short teeth lying parallel to hinge line (Pl. 2, figs. 2, 5, 10, 14, 19, 25, and 26). Dorsal valve interior with high and narrow, triangular cardinal process (Pl. 2, fig. 7), and relatively narrow divergent inner socket ridges (Pl. 2, figs. 4, 12, 16, 21, and 23). Dorsal median septum long, high and triangular in profile (Pl. 2, figs. 4, 8, 12, 16, 21, and 23). Posteriorly starting with a short low part, and then abruptly emerged to very high with smooth and evenly arched posterior edge (Pl. 2, fig. 8). Anterior flank of median septum also steeply descends with serrated edge in lateral view (5 wide and low, rounded serrations; Pl. 2, fig. 8). Loop only partly preserved, anteriorly attached to median septum (Pl. 2, figs. 4, 8, 12, 16, 21, and 23), descending branches united with valve floor (Pl. 2, figs. 4, 8, 12, and 16), other parts of loop only occasionally preserved (Pl. 2, fig. 23).

Remarks. Representatives of Family Megathyrididae are the commonest members of Neogene shallow-water brachiopod assemblages. *Megathyris* and *Argyrotheca* have a long research history,

while *Joania* was separated recently from *Argyrotheca* by Álvarez et al. (2008).

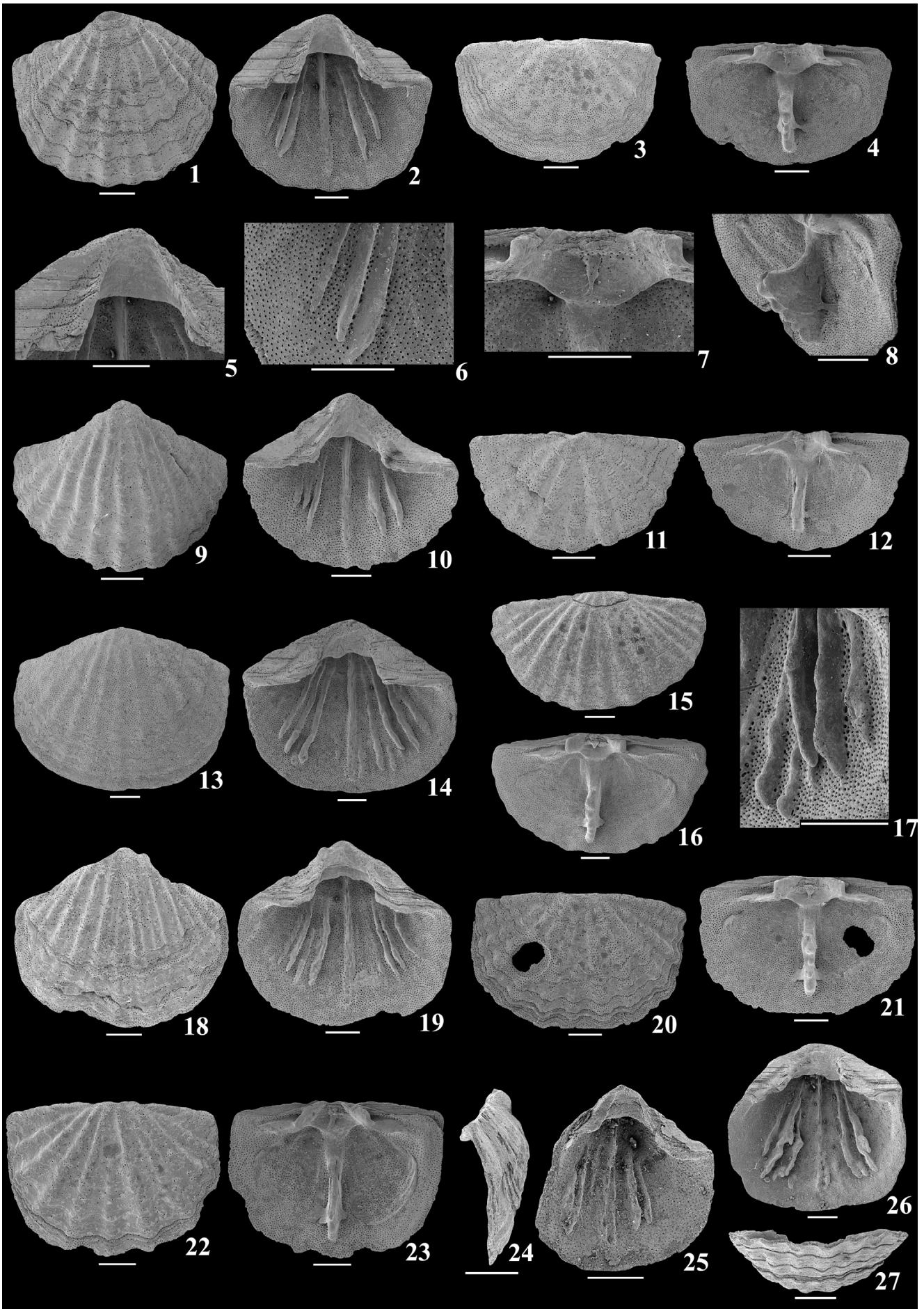
Borellithyris gaetanii n. gen. n. sp. is significantly different from all known megathyridids, as it was discussed in the description of the genus. In some cases, ventral valves of *Megathyris detruncata* can also show some very weak lateral septa (e.g., Álvarez 2016a: pl. 31, figs. I, J), but only some nearly indiscernible septa appear, and the brachial valve clearly indicate their attribution to *Megathyris*.

Zelinskaya (1962: text-fig. 2) illustrated a very similar form from the Eocene of Ukraine under the name *Megathyris lunula percostata* (von Koenen, 1894). The outline, the pedicle collar, the triangular hypothyrid foramen, the wide interarea and the three ventral lateral septa are similar to the Tetti Borelli specimens; however, the median septum is higher and shorter. In case of the dorsal valve, Zelinskaya's specimen is higher and not so wide, the median septum not so high and emerged very gently, and according to her drawing its anterior end is not serrated. Although photos are not available in her pa-

PLATE 2

1-27 - *Borellithyris gaetanii* n. gen. n. sp. 1-8 - Separate valves of the same specimen, holotype, Pavia-Giuntelli Collection (MGPUT-PU 111348), 1-2 - Ventral valve, 1 - External view, 2 - Internal view, 3-4 - Dorsal valve, 3 - External view, 4 - Internal view, 5 - Detail of beak region of ventral valve to show the pedicle collar, 6 - Detail of lateral septa of ventral valve, 7 - Detail of beak region of dorsal valve to show the triangular cardinal process, 8 - Oblique lateral view of dorsal valve to show the median septum; 9-12 - Separate valves of the same specimen, paratype, Pavia-Giuntelli Collection (MGPUT-PU 111349), 9-10 - Ventral valve, 9 - External view, 10 - Internal view, 11-12 - Dorsal valve, 11 - External view, 12 - Internal view; 13-17 - Separate valves of the same specimen, paratype, (HNHM PAL 2018.22.1), 13-14 - Ventral valve, 13 - External view, 14 - Internal view, 15-16 - Dorsal valve, 15 - External view, 16 - Internal view, 17 - Oblique lateral view of lateral septa of ventral valve; 18-21 - Separate valves of the same specimen, paratype, Pavia-Giuntelli Collection (MGPUT-PU 111350), 18-19 - Ventral valve, 18 - External view, 19 - Internal view, 20-21 - Drilled dorsal valve, 20 - External view, 21 - Internal view; 22-23 - Dorsal valve, paratype, Pavia-Giuntelli Collection (MGPUT-PU 111351), 22 - External view, 23 - Internal view; 24-25 - Ventral valve, paratype, Roest Collection (RGM.1351076), 24 - lateral view, 25 - internal view; 26-27 - Ventral valve, paratype, Roest Collection (RGM.1351056), 26 - internal view, 27 - anterior view.

Scale bars correspond to 1 mm.



per, and the original specimens were not revised, Zelinskaya's (1962) very characteristic drawing may refer to an Eocene record of *Borellithyris* n. gen.

As all megathyridids, *Borellithyris gaetanii* n. gen. n. sp. most probably also lived in relatively shallow, cryptic environments of sub-boulders, and submarine caves, but it is remarkably more numerous, than any other megathyridid species of the Tetti Borelli assemblage. Possibly it attached strongly to hard substrates by short and strong pedicle. The ventral beak is generally more or less intact and not eroded, suggesting not very short pedicle, and not too close attachment to the substrate. The wide and short teeth, lying parallel to the hinge line suggest that their gapes were wider than usual and their lophophores were fully accessible to seawater, as it was suggested for other megathyridids by Álvarez et al. (2008). This allows them easier access to the food and oxygen without long and complex lophophore. This assumption is in accordance with the very limited remnants of the partly preserved loop, attached directly to the valve floor.

Range. *Borellithyris gaetanii* n. gen. n. sp. is known from the Late Miocene of Italy (this paper).

Genus *Argyrotheca* Dall, 1900

Type species - *Terebratulina cuneata* Risso, 1826, by original designation of Dall (1900: 44).

Argyrotheca sp.

Pl. 3, figs. 1-2

Material: Roest Collection (1 D) (Tab. 1a).

Remarks. *Argyrotheca* is a common member of shallow-water Neogene and Recent brachiopod assemblages. However, it is very limited in the Tetti Borelli material, represented by a single dorsal valve. It can be separated from all other megathyridid dorsal valves of this locality. Both species of *Joania* are clearly different because of the row of tubercles at the internal rim of the valve (compare Pl. 3, Fig. 1. with Fig. 6. and Fig. 12). *Borellithyris* n. gen. is also easily confinable by the wide semi-circular outline of its dorsal valve (Pl. 2, Figs. 4, 12, 16, 21, and 23). The single available *Argyrotheca* dorsal valve is not very well-preserved and slightly eroded. The median septum seems to be low, but it is also strongly eroded. The outline is well-visibly rounded; therefore, unambiguously different from the wider and lower *A. cuneata* (Risso, 1826), which is the commonest

Argyrotheca species in Neogene and Recent Mediterranean – Paratethyan – Atlantic brachiopod assemblages (e.g., Logan 1979; Bitner 1990). It is more similar to *A. bitnerae* Dulai, 2011 described by Dulai & Stachacz (2011) from the Middle Miocene of the Central Paratethys, which has subpentagonal dorsal valve. However, they are different as the maximum width of *A. bitnerae* is at anterior third, while it is at the hinge line in the Italian specimen. The specimen is left in open nomenclature due to the paucity of available material.

Genus *Joania* Álvarez, Brunton & Long, 2008

Type species - *Terebratulina cordata* Risso, 1826, by original designation of Álvarez et al. (2008: 400).

Joania cordata (Risso, 1826)

Pl. 3, figs. 3-10

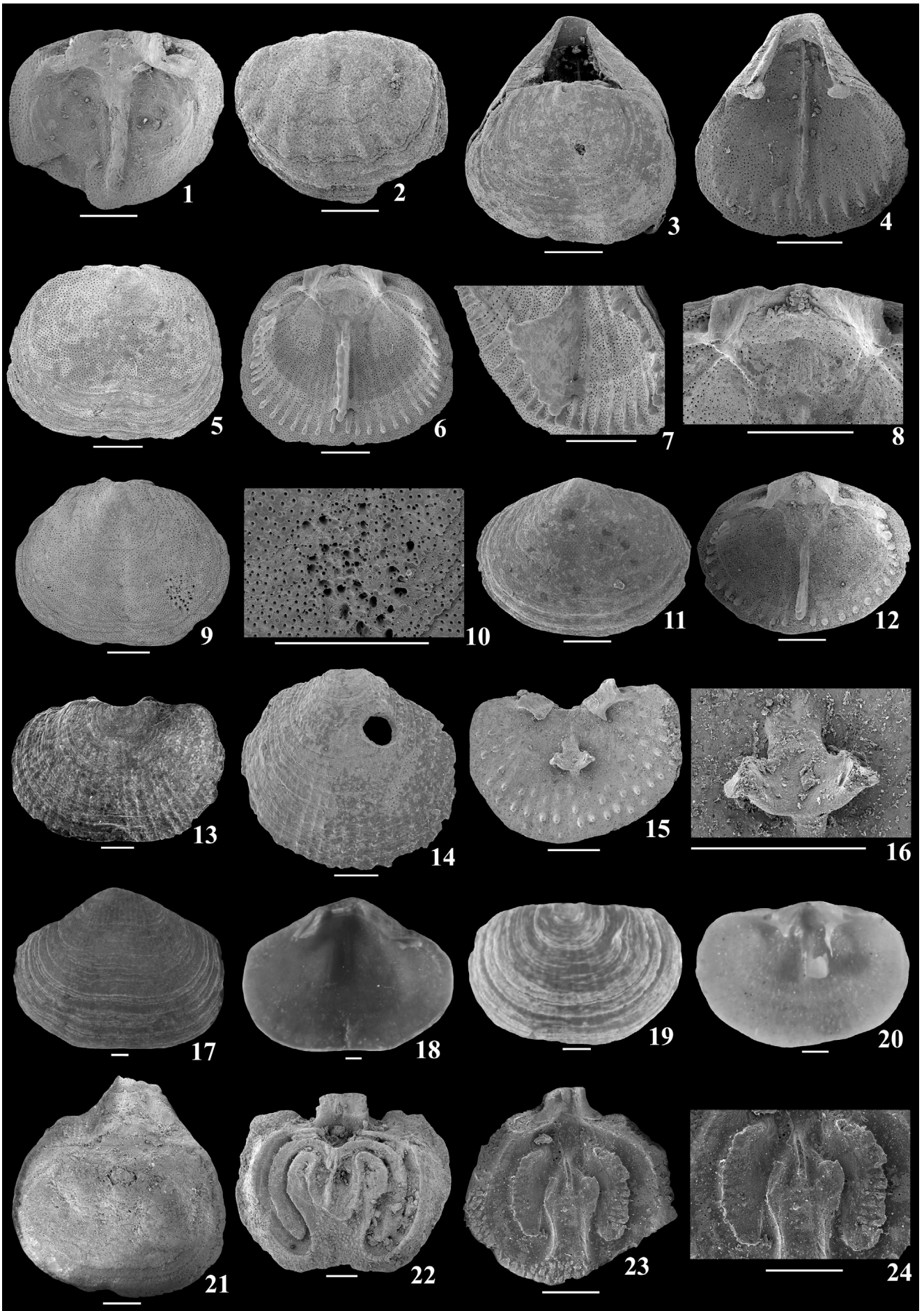
1826 *Terebratulina cordata* Risso, p. 389.

1990 *Argyrotheca cordata* (Risso, 1826) - Bitner, pp. 141-143, text-figs 7-8, pl. 5, figs. 1-14, pl. 7, fig. 1. (cum syn.)

PLATE 3

- 1-2 - *Argyrotheca* sp., dorsal valve, Roest Collection, (RGM.1351089), 1 - internal view, 2 - external view;
- 3-10 - *Joania cordata* (Risso, 1826). 3 - Articulated specimen, Roest Collection (RGM.1351090), dorsal view, 4 - Ventral valve, Roest Collection (RGM.1351091), internal view, 5-8 - Dorsal valve, Pavia-Giuntelli Collection (MGPUT-PU 111353), 5 - External view, 6 - Internal view, 7 - Oblique lateral view to show the median septum, 8 - Detail of the beak region, 9-10 - Dorsal valve, Pavia-Giuntelli Collection (MGPUT-PU 111354), 9 - External view, 10 - *Podichnus centrifugalis* Bromley & Surlyk, 1973 trace fossil on the anterior part of the valve;
- 11-12 - *Joania* aff. *jalunica* (de Morgan, 1915), dorsal valve, Roest Collection (RGM.1351071), 11 - External view, 12 - Internal view;
- 13-20 - *Megerlia truncata* (Linnaeus, 1767). 13 - Dorsal valve, Roest Collection (RGM.1351065), external view, 14 - Drilled ventral valve, Roest Collection (RGM.1351077), external view; 15-16 - Dorsal valve, Roest Collection (RGM.1351059), 15 - Internal view, 16 - Detail of median septum and fragment of brachidium, 17-18 - Ventral valve, Pavia-Giuntelli Collection (MGPUT-PU 111356), 17 - External view, 18 - Internal view; 19-20 - Dorsal valve, Pavia-Giuntelli Collection (MGPUT-PU 111357), 19 - External view, 20 - Internal view;
- 21-24 - *Lacazella mediterranea* (Risso, 1826). 21 - Articulated specimen, Roest Collection (RGM.1351095), dorsal view; 22 - Dorsal valve, Roest Collection (RGM.1351079), internal view; 23-24 - Dorsal valve, Roest Collection (RGM.1351067), 23 - Internal view, 24 - Detail of median septum and major interbrachial lobes.

Scale bars correspond to 1 mm.



- 2005 *Argyrotheca cordata* (Risso, 1826) - Álvarez & Emig, pp. 155-158, 222, figs. 14, 25F-G, 47, 48.
- 2005a *Argyrotheca cordata* (Risso, 1826) - Álvarez et al., p. 222. (cum syn.)
- 2005b *Argyrotheca cordata* (Risso, 1826) - Álvarez et al., p. 267. (cum syn.)
- 2007 *Argyrotheca cordata* (Risso, 1826) - Dulai, pp. 4-5, fig. 4: 1-9.
- 2008 *Joania cordata* (Risso, 1826) - Álvarez et al., pp. 400-402, figs. 11-13.
- 2015 *Joania cordata* (Risso, 1826) - Dulai, p. 197, pl. 4, figs. 1-5.
- 2016a *Joania cordata* (Risso, 1826) - Álvarez, pp. 74-76, pl. 35H-FF, 36A-Z. (cum syn.)
- 2016b *Joania cordata* (Risso, 1826) - Álvarez, pp. 115-116, pl. 82SS-MMM, 83A-P.

Material: Roest Collection (2 A, 5 V), Pavia-Giuntelli Collection (6 D) (Tab. 1a, b).

Remarks. *Joania cordata* is a typical member of the Neogene and Recent shallow-water brachiopod faunas. This species was not present in the Janssen Collection from Tetti Borelli (Dulai 2010); however, it is relatively common in both the Roest and the Pavia-Giuntelli Collections. Although it is not very frequent, *J. cordata* is the second commonest megathyridid species in Tetti Borelli assemblage. As most of the specimens are separated ventral or dorsal valves, they may be resedimented. Detailed description and discussion of the species was given in several papers (e.g., Logan 1979; Bitner 1990; Dulai 2007; Álvarez et al., 2008; Álvarez 2016a). One of the dorsal valves shows characteristic etching trace fossil created by the pedicle of a brachiopod (*Podichnus centrifugalus* Bromley & Surlyk, 1973; Pl. 3, figs. 9-10). The trace fossils left by the rootlets or papillae of brachiopod pedicles and the ichnogenus *Podichnus* were discussed in detail by Bromley & Surlyk (1973) and recently by Robinson & Lee (2008).

Joania aff. *falunica* (de Morgan, 1915)

Pl. 3, figs. 11-12

- 2010 *Joania* aff. *falunica* (de Morgan, 1915) - Dulai, p. 26, pl. 3, figs. 2a-c.

Material: Roest Collection (3 D) (Tab. 1a).

Remarks. One dorsal valve of this rare taxon was published from Tetti Borelli by Dulai (2010) on the basis of the Janssen Collection. The Roest Collection contains three additional separated valves, but unfortunately, all of them are also dorsal ones. Its densely punctated shells can be easily distinguished from *Joania cordata*, the other *Joania* species of this assemblage. Its valves are transversely elon-

gated and oval in outline (Pl. 3, figs. 11-12; and Dulai 2010: Pl. 3, figs. 2a-c), while *J. cordata* has not so wide dorsal valve, with subpentagonal outline (Pl. 3, figs. 5-6). *J. cordata* shows a characteristic shallow median sulcus (Pl. 3, figs. 3, 5, and 9), which is missing in all available valves of *J. aff. falunica* (Pl. 3, fig. 11; Dulai 2010: Pl. 3, fig. 2a). Tuberculate radial ridges are missing in *J. aff. falunica* (Pl. 3, fig. 12; Dulai 2010: Pl. 3, figs. 2b-c), while long ridges are present in *J. cordata* (Pl. 3, figs. 6-7). The anterior tubercles at the internal rim seem to be stronger and less numerous in *J. aff. falunica* (compare Pl. 3, figs. 6 and 12). The dorsal median septum of *J. cordata* is higher, the posterior side is steeper, and it has more serrations on the anterior side; 7 and 4, respectively (compare Pl. 3, fig. 7, and Dulai 2010: Pl. 3, fig. 2c).

The slightly similar *Cistella dertomutinensis* Sacco, 1902 was described by Sacco (1902) and later recorded by Friedberg (1921) and Moreschi (1930). Bitner (1990) synonymized the Ukrainian specimens of Friedberg (1921) with *J. cordata*, and she also mentioned the close similarity of Sacco's (1902) two species (*C. dertotaurinensis* Sacco, 1902 and *C. dertomutinensis*) to *J. cordata*. Recently, Bertolaso et al. (2009) regarded *J. dertomutinensis* again as a separate species. It has strongly elongated dorsal valve (Bertolaso et al. 2009: Pl. 5, figs. 2a-b, 3a-b, 5a-b, 6a-b), which can be separated from *cordata* and are more similar to the discussed *J. aff. falunica*. However, it is also different from *J. aff. falunica* with the posteriorly more angular outline, the small median sulcus, the tuberculate radial ridges, and the smaller tubercles at the interior rim.

The most similar form to the Tetti Borelli valves is *Cistella falunica* introduced by de Morgan (1915) from the Langhian of Pontleroy (France). Its dorsal valve is transversely elongated in outline, and its surface is covered by strong growth lines (lamellae). However, the Italian dorsal valves have a more elongated outline with much narrower lateral parts, and the growth lines are much less developed on the outer surface. The new specimens from the Roest Collection confirm the existence of this form, which can be separated from the other *Joania* species, but in absence of the ventral valve, a formal description of a new species is still not possible.

Superfamily Kraussinoidea Dall, 1870
Family Kraussinidae Dall, 1870

Genus *Megerlia* King, 1850

Type species - *Anomia truncata* Linnaeus, 1767, by the original designation of King (1850: 145).

***Megerlia truncata* (Linnaeus, 1767)**

Pl. 3, figs. 13-20

- 1767 *Anomia truncata* Linnaeus, p. 1152.
 1990 *Megerlia truncata* (Linnaeus, 1767) - Bitner, pp. 145-147, pl. 2, figs. 6-9, pl. 7, figs. 3-6, pl. 8, figs. 1-7. (cum syn.)
 2005 *Megerlia truncata* (Linnaeus, 1758) - Álvarez & Emig, pp. 167-168, 223, figs. 14, 25J-M, 53F, 71.
 2005a *Megerlia truncata* (Linnaeus, 1767) - Álvarez et al., p. 223. (cum syn.)
 2010 *Megerlia truncata* (Linnaeus, 1767) - Dulai, p. 28, pl. 3, figs. 4-5.
 2016a *Megerlia truncata* (Linnaeus, 1767) - Álvarez, pp. 99-106, pl. 59A-Z, 60A-AA, 61A-DD, 62A-AA, 63A-KK, 64A-V, 65A-Q, 66A-EE, 67A-BB, 68A-AA. (cum syn.)
 2016b *Megerlia truncata* (Linnaeus, 1767) - Álvarez, pp. 116-118, pl. 83Q-SS, 84A-I.
 2016 *Megerlia truncata* (Linnaeus, 1767) - Treguier & Álvarez, p. 127, pl. 89T.

Material: Roest Collection (9 V, 16 D), Pavia-Giuntelli Collection (18 V, 42 D) (Tab. 1a, b).

Remarks. *Megerlia* is the second commonest brachiopod in the Tetti Borelli assemblage after *Cryptopora*, and it was discussed earlier from this locality by Dulai (2010). It is a typical member of deeper-water recent brachiopod assemblages (Logan 1979). The species and its high variability is discussed in detail by Bitner (1990; Miocene of the Roztocze Hills, Poland) and Logan (1979; Recent fauna of the Mediterranean). The extreme variability in outline, convexity and ornamentation, as well as the common asymmetrical shape is confirmed also by the studied material. Both Logan (1979) and Bitner (1990) gave detailed synonymy lists. Some of the specimens are rather large-sized, compared with other species of this assemblage.

M. truncata is frequently cited from the Neogene Mediterranean localities: from Miocene of Italy (e.g., Costa 1851-52; Seguenza 1865, 1866, 1870; Davidson 1870; Sacco 1902), from the Pliocene of Italy (e.g., Foresti 1893; Gaetani & Saccà 1985a, b; Gaetani 1986; Borghi 2001; Bertaloso et al. 2009), from the Pliocene of Spain (e.g., Pajaud 1977; Encinas & Martinell 1992; García Ramos 2004; Toscano-Grande et al. 2010), from the Pliocene of Greece (Koskeridou 2007).

Order **Thecideida** Elliott, 1958

Superfamily Thecideoidea Gray, 1840

Family Thecideidae Gray, 1840

Subfamily Lacazellinae Backhaus, 1959

Genus *Lacazella* Munier-Chalmas, 1880

Type species - *Thecidea mediterranea* Risso, 1826, by original designation of Munier-Chalmas (1880: 279).

***Lacazella mediterranea* (Risso, 1826)**

Pl. 3, figs. 21-24

- 1826 *Thecidea mediterranea* Risso, p. 394.
 1970 *Lacazella mediterranea* (Risso, 1826) - Pajaud, pp. 128-138, pl. 1, fig. 4, pl. 5, fig. 4, pl. 7, fig. 3, pl. 10, figs. 1-6, pl. 11, fig. 3, pl. 12, fig. 2, pl. 16. (cum syn.)
 2001 *Lacazella mediterranea* (Risso, 1826) - Borghi, p. 57, pl. 7, figs. 1-4.
 2005 *Lacazella mediterranea* (Risso, 1826) - Álvarez & Emig, pp. 117-119, 218, figs. 14, 34A-C.
 2005a *Lacazella mediterranea* (Risso, 1826) - Álvarez et al., p. 218. (cum syn.)
 2008 *Lacazella mediterranea* (Risso, 1826) - Bitner & Dulai, p. 40, fig. 5.7-8.
 2010 *Lacazella mediterranea* (Risso, 1826) - Dulai, p. 28, pl. 3, figs. 3a-b.
 2016a *Lacazella mediterranea* (Risso, 1826) - Álvarez, pp. 37-39, pl. 4F-BB, 5A-CC, 6A-DD, 7A-JJ. (cum syn.)
 2016b *Lacazella mediterranea* (Risso, 1826) - Álvarez, pp. 111-112, pl. 80A-F.
 2017 *Lacazella mediterranea* (Risso, 1826) - Bitner & Müller, pp. 223-224, fig. 10. (cum syn.)

Material: Roest Collection (3 A, 2 V, 12 D), Pavia-Giuntelli Collection (3 A, 8 V, 16 D) (Tab. 1a, b).

Remarks. This species was already mentioned from the Tortonian of Tetti Borelli by Sacco (1902), as *L. mediterranea* var. *testudinaria* (Michelotti, 1839) and a single dorsal valve was also recognized by Dulai (2010). However, in the new material, both the Roest and the Pavia-Giuntelli Collections yielded several specimens, and this is the third commonest species in this assemblage. *L. mediterranea* has long stratigraphic range from the Late Paleocene (Pajaud & Plaziat 1972) to the recent Mediterranean environments (Logan 1979). Nowadays the species is known from the western part of the Mediterranean (Álvarez & Emig 2005; Logan 2007; Álvarez 2016a, b; Emig 2016) and it is considered as a neoendemic species (Logan et al. 2004). This species was mentioned from the Middle Miocene of the Turin Hill (Davidson 1870), and from the Late Miocene (Tortonian) of Montegibbio (Moreschi 1930; Borghi 2001). It was also reported from the Pliocene of Spain (e.g. Pajaud 1977; Garcia Ramos 2004).

MacDonald (1863) described a *Lacazella* species from Malta under the name *Thecidium Adamsi* MacDonald, 1863. Soon after Davidson (1864a, b) followed MacDonald's attribution; however, both authors mentioned the very close similarity with *Th. mediterranea*; according to Davidson it may be only

a variety of the latter species. More recently Gatt (2006) also mentioned *Tb. adamsi* from Malta. Until now, nobody has attempted a revision of *Lacazella adamsi*; a description of an extensive Oligocene-Miocene brachiopod material from Malta is in progress (Dulai et al. in prep.).

DISCUSSION

After the investigation of the nearly 200 specimens of the Roest Collection, some new even if not fully satisfying information were obtained on the two rare and questionable species of this locality. The association contains three additional specimens of *Joania* aff. *falunica*; however, all of these are dorsal valves, just like the previous one in the Janssen Collection (Dulai 2010). In the case of *Eucalathis* aff. *tauriniensis*, the situation is more fortunate, because a dorsal valve was found; so, at the moment one ventral and one dorsal valves are available from two different collections, which make possible to describe a new *Eucalathis* species (*E. giulioi* n. sp.). Additionally to these species, the Roest Collection yielded five further brachiopod taxa, which were not represented earlier in the Janssen Collection. The occurrence of *Lingula?* sp., *Terebratulina retusa*, *Joania cordata*, and *Argyrotheca* sp. is an important contribution to the Tetti Borelli brachiopod assemblage; however, the most interesting component of this material is an until now unknown Megathyrididae species. Three such ventral valves were recognised in the Roest Collection, but the dorsal valve remained unknown. Fortunately, the Pavia-Giuntelli Collection contains several specimens of this new megathyridid form and the two new collections from Tetti Borelli allow describing a new Megathyrididae genus and species, *Borellithyris gaetanii* n. gen. n. sp.

Taxonomic composition. The taxonomic composition of Tetti Borelli brachiopod fauna (including this paper, as well as the previously published small Janssen Collection in Dulai 2010) is provided in Tab. 4. In every species the minimal number of individuals (MNI) was calculated ($A + V$ or D , depending on the higher value), with the exception of *Lingula?* sp. In case of *Lingula?* sp., the fragments were so small, that separation of dorsal and ventral valves was not possible, and therefore number of fragments was taken into consideration resulting in a probable over-representation of this taxon.

The most common brachiopods of Tetti Borelli assemblage are *C. lovisati* (42.2%), *M. truncata* (22.7%), and *L. mediterranea* (12.42%). *Borellithyris gaetanii* n. gen. n. sp. is relatively numerous (7.45%), but all the other species are below 5%. The taxonomic composition of various collections is significantly different, most probably because of the different collecting methods. The Janssen and the Roest Collections are based on washed samples and therefore contain lots of small specimens, contrary to the large-size dominated Pavia-Giuntelli Collection. Studying together the different collections yielded a more representative fauna for Tetti Borelli locality. At the same time study of different collections from the same locality shows the unambiguous significance of washed samples. While *C. lovisati* is nearly missing from the conventionally collected Pavia-Giuntelli Collection (2%), this species is the dominant brachiopod of both washed collections (61% and 62%, respectively). It also significantly influences the diversity of the samples: the Roest Collection is the most diverse (10 species/161 MNI), while the Janssen Collection with very small sample size (6 species/26 MNI) is nearly as diverse as the much more numerous Pavia-Giuntelli Collection (7 species/99 MNI).

Paleoecology. The Tetti Borelli brachiopod fauna contains both shallow water and deeper water taxa. The known bathymetric distribution of recent lingulides is 0-477 m, but most of them occur between 0 and 60 m depth (Emig 1997a). *Cryptopora* has a single shallow-water species (*C. curiosa*), but all the other species are neritic and upper bathyal zone dwellers, or even ranging down into the abyssal zone (Logan 2007). In the Middle Miocene of France and Moravia *C. lovisati* also was a member of a deeper water brachiopod assemblage (Bitner & Cahuzac 2004; Bitner et al. 2013b). Most species of *Terebratulina* are neritic and upper bathyal zone dwellers (Logan 2007). *T. retusa* is an eurybathic species, usually in association with *Gryphus vitreus* and commonly found on the gravel and shell substrates of the bathyal zone (Logan 1979). *Eucalathis* species show a significant depth range, some of them were recorded from 2-3000 m depth (Logan 2007). Representatives of recent megathyridids (*Megathiris*, *Argyrotheca*, *Joania*) occur in neritic to upper bathyal zones, but they are most common in cryptic shallow water habitats (Logan 2007). Most of them attach to the undersides of coral colonies (Logan 1975, 1977; Álvarez et al.

Species	Dulai 2010 (MNI)	Roest Coll. (MNI)	Pavia-Giuntelli Coll. (MNI)	Altogether MNI	Percentage of MNI (%)	Separated valves (%)
<i>Lingula?</i> sp.	-	11 fr (11)	-	11	3.9	100
<i>C. lovisati</i>	5 A, 11 V, 10 D (16)	63 A, 38 V, 25 D (101)	1 A, 1 V, 1 D (2)	119	42.20	55.5
<i>T. retusa</i>	-	1 V, 2 D (2)	10 V, 7 D (10)	12	4.25	100
<i>E. giulioi</i> n. sp.	1 V (1)	1 D (1)	-	2	0.70	100
<i>M. detruncata</i>	1 V (1)	-	-	1	0.35	100
<i>B. gaetanii</i> n. gen. n. sp.	-	1 A, 3 V, 1 D (4)	4 A, 13 V, 2 D (17)	21	7.45	79.1
<i>Argyrotheca</i> sp.	-	1 D (1)	-	1	0.35	100
<i>J. cordata</i>	-	2 A, 5 V (7)	5 D (5)	12	4.25	83.3
<i>J. aff. falunica</i>	1 D (1)	3 D (3)	-	4	1.43	100
<i>M. truncata</i>	6 V, 3 D (6)	9 V, 16 D (16)	18 V, 42 D (42)	64	22.70	100
<i>L. mediterranea</i>	1 D (1)	3 A, 2 V, 12 D (15)	3 A, 8 V, 16 D (19)	35	12.42	86.6
Altogether	39 (26)	199 (161)	131 (95)	282	100.00	91.3

Tab 4. - Taxonomic composition of Tetti Borelli brachiopod fauna, with data of minimal number of specimens (MNI) and percentage of separate valves.

2005b). The extinct *Borellithyris* n. gen., as member of Megathyrididae, can be considered probably as a shallow-water taxon. However, the Pavia-Giuntelli Collection contains several articulated specimens and the percentage of its disarticulated valves is less than 80%. This suggests short transport, and it may imply the possibility that *Borellithyris* n. gen. was a deeper water representative of the family. *Megerlia truncata* is common in the neritic and upper bathyal zones of the Mediterranean and the eastern North Atlantic (Logan 2007). *Lacazella* species are small cementing forms typically occur in shallow but poorly accessible cryptic habitats at depths between 1-110 m (Álvarez & Emig 2000, 2005; Logan 2007; Emig 2016).

The taxonomic composition of the brachiopod fauna (with a dominance of *Cryptopora* and *Megerlia*) suggest deeper water settings around 300-400 m depth (Dulai 2010). This estimate is in agreement with the results of other studies on different fossil groups (e.g., Sturani 1978; Girone et al. 2010). However, the sporadic occurrence of rarer shallow-water brachiopods (*Lacazella*, *Joania*, *Argyrotheca*, *Megathiris*) indicate the presence of resedimented material, which corresponds to Pavia & Robba's (1979) theory on the turbiditic origin of these sediments. The very high percentage of disarticulated brachiopod valves (see last column of Tab. 4) also indicates strong resedimentation. Most of the brachiopod species (7 of 11 taxa) have only disarticulated valves. Some specimens of *Lacazella* (3) and *Joania* (2) may remain articulated because of their small size and rounded-globular appearance or because of cementing habit of *Lacazella*.

In case of *Borellithyris* n. gen., we may suppose short distance transportation and a possible deeper water habitat. However, the most remarkable in this aspect is the minute rhynchonellide *Cryptopora*, which is not only the dominant species of the assemblage, but nearly half of the specimens are articulated (69 articulated specimens). As *Cryptopora* has extremely thin and fragile shell, this species must be more or less autochthonous, without having been transported.

CONCLUSIONS

The Tortonian brachiopod fauna of the Tetti Borelli locality contains 11 taxa, including a new species of *Eucalathis* (*E. giulioi* n. sp.) and a new megathyridid genus and species (*Borellithyris gaetanii* n. gen. n. sp.). Dominant species of the assemblage are the deeper water *Cryptopora lovisati* and *Megerlia truncata*. The taxonomic composition of the fauna, the sporadic presence of shallow water brachiopods, and the very high percentage of disarticulated brachiopod valves confirm the previous suggestion of a deep settings (300-400 m) characterized by turbiditic flows. In case of *Borellithyris* n. gen., the relatively high number of articulated specimens may indicate shorter transport and a relatively deeper habitat for this species with respect to the generally shallow water taxa of the family. *Cryptopora lovisati* (with extremely fragile shells, and with surprisingly numerous articulated specimens) can be considered as a more or less autochthonous element of the prevalingly allochthonous fauna.

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