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Systematic study of three brachiopod orders Dictyonellida, Productida, Orthotetida from the Permian Sosio Limestone, Palazzo Adriano, Sicily

Mattia Lombardi*, Marco Viaretti, Agatino Reitano, Charles M. Henderson, Carolina D'Arpa, Gianni Insacco & Lucia Angiolini

M. Lombardi, Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, via Mangiagalli 34, I-20133 Milano, Italy; mattia.lombardi@unimi.it *corresponding author

M. Viaretti, Centre for Excellence in Evolution of Life, Basin Studies and Applied Palaeontology, Palaeontological Research and Education Centre, Mahasarakham University, 44150 Maha Sarakham, Thailand; Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, via Mangiagalli 34, I-20133 Milano, Italy; marco.v@msu.ac.th

A. Reitano, Museo Civico di Storia Naturale, via degli Studi 9, I-97013 Comiso, Italy; agatinoreitano@gmail.com

C.M. Henderson, Department of Earth, Energy, and Environment, University of Calgary, 2500 University Drive NW, Calgary, Canada; cmhender@ucalgary.ca

C. D'Arpa, Museo Geologico G.G. Gemmellaro, SiMuA, Università degli Studi di Palermo, Corso Tukory 131, I-90134 Palermo, Italy; carolina.darpa@unipa.it

G. Insacco, Museo Civico di Storia Naturale, via degli Studi 9, I-97013 Comiso, Italy; g.insacco@comune.comiso.rg.it

L. Angiolini, Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, via Mangiagalli 34, I-20133 Milano, Italy; lucia.angiolini@unimi.it

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ABSTRACT - The Sosio Limestone is renowned worldwide as one of the most important units for the study of Permian fossil invertebrates of a fore-reef or upper slope environment. This study focuses on 223 brachiopod specimens selected from the much larger collection housed at Museo Civico di Storia Naturale of Comiso (Ragusa, Sicily) and collected from three of the five megablocks of the Sosio Limestone in the Sosio Valley. The systematic description and classification of the specimens led to the identification of 36 taxa belonging to the orders Dictyonellida, Productida and Orthotetida, highlighting a much higher biodiversity within these groups than previously reported in the literature. The identified brachiopods have rather long stratigraphic ranges; however, the occurrence of Costachonetina *sp. and* Comuquia modesta *Grant, 1976 may constrain the age of the Sosio Limestone to the Roadian-Wordian (Guadalupian), as also supported by the recovered conodont fauna. Functional morphological analysis of three identified morphogroups provided insights into the likely modes of life of the studied brachiopods. Both the concavo-convex/plano-convex morphogroup and the conical non-coralliform/subconical/elongated morphogroup are interpreted as having had a semi-infaunal lifestyle. However, their different morphology enabled the latter morphogroup to attain a slightly higher position above the water-sediment interface, allowing more efficient suspension feeding and a larger, even if variable, size. The conical coralliform morphogroup is interpreted as having had an epifaunal lifestyle, attached to hard substrates through cementation by means of a cicatrix of attachment and the spines. This allowed a more efficient suspension feeding, and the attainment of a generally larger size. The occurrence of brachiopods with different lifestyles indicates that a wide variety of substrates was present in the fore-reef or upper slope environment recorded by the Sosio Limestone. The large occurrence of conical coralliform brachiopods, attached to the substrate, suggests the presence of hard substrates. Instead, semi-infaunal brachiopods indicate the occurrence of areas of deposition of fine sediments and muddy bottoms. Such areas could have been variably extended or, if localized, extremely frequent, supporting the high number of semi-infaunal brachiopods.*

INTRODUCTION

The fossil assemblages of the Sosio Limestone near Palazzo Adriano (Sicily) represent one of the most significant paleontological records in Europe for Permian research (Fig. 1c). They capture a highly diverse and complex marine ecosystem and exhibit striking biogeographic affinities with contemporaneous faunas from distant regions, extending to East Asia and Timor (e.g., Muir-Wood & Cooper, 1960; Cooper & Grant, 1974; Grant, 1976; Verna et al., 2010). Consequently, these assemblages have attracted sustained international scientific attention since the pioneering investigations of Gaetano Giorgio Gemmellaro (e.g., Gemmellaro, 1887, 1888, 1889, 1890, 1891, 1893, 1894, 1896, 1898, 1899a, b, c). Diverse and well-preserved Permian fossils were described from the Sosio Limestone, amounting to almost 520 species described, including molluscs, crustaceans, brachiopods, echinoderms, sponges, corals, trilobites, annelids, and bryozoans (Reitano, 2015).

Aware of the exceptional scientific importance of the Sosio Limestone, Gemmellaro sought to protect the Permian limestone exposures from fossil collectors by entrusting their surveillance to respected local inhabitants. This protection remained effective until the death of his son Mariano Gemmellaro in 1921, after which systematic looting of the fossiliferous outcrops began (Ruggieri, 1987). During the first half of the twentieth century, fossil collecting was frequently conducted through what Fabiani & Ruiz (1933) termed as a "vandalistic modus operandi": specimens were acquired from private collections or through amateur collectors hired to recover fossils, and explosives were sometimes employed during the extraction (Reitano, 2015). As a consequence of these destructive collecting practices, the Rupe di San Calogero, the richest of the fossiliferous blocks, was almost completely dismantled, and its fossil fauna dispersed across museums and collections worldwide (Ruggieri, 1987). After the mid-1900s, the application of protective laws for paleontological heritage helped to safeguard

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the Sosio megablocks from indiscriminate collections (Reitano, 2015). More recently, fieldwork and collection undertaken by Agatino Reitano and the staff of the Museo Civico di Storia Naturale of Comiso have revitalized research interest in the Sosio Limestone (Jones et al., 2015; Sanfilippo et al., 2015, 2017, 2018).

The aim of this work is to provide a systematic revision of the brachiopods from the Sosio Limestone of the newly collected material housed in the Museo Civico di Storia Naturale of Comiso. However, given the exceptional richness of the collection both in terms of taxonomic diversity and number of specimens (1152 brachiopod specimens), only three brachiopod orders are here presented: Dictyonellida, Productida, and Orthotetida. These groups include taxa characterized by atypical shell shapes (among which a coralliform shape) that depart from the usual biconvex morphology typical of most brachiopods, and they were the main focus of the earliest studies on the Sosio fossil fauna (e.g., Gemmellaro, 1889, 1896, 1899; de Gregorio, 1930; Parona, 1933a; Greco, 1938, 1947). Given their atypical morphologies, this work not only revises their systematic classification, but also conducts a functional morphological analysis and suggests an interpretation of their mode of life. The study of the brachiopod fauna and associated conodonts also provides further constraints on the age and paleoenvironment of the Sosio Limestone, long debated in the literature (e.g., Rudwick & Cowen, 1967; Flügel et al., 1991; Catalano et al., 1992; Di Stefano & Gullo, 1997a, b; Sanfilippo et al., 2015).

GEOLOGICAL SETTING

The Sosio Limestone crops out in five megablocks (Fig. 1a, b) near Torrente San Calogero, in the Sosio Valley, south of Palazzo Adriano (Palermo) in the Sicani Mountains, western Sicily. These megablocks are named: Pietra di Salomone, which is the largest and most fossiliferous, Pietra dei Saraceni, Rupe di San Benedetto (to be noted that some authors previously treated Pietra dei Saraceni and Rupe di San Benedetto as a singular outcrop; e.g., Catalano et al., 1991; Di Stefano & Gullo, 1997a, b), Rupe di San Calogero, and Rupe del Passo di Burgio (Catalano et al., 1991). Four of them, Pietra di Salomone, Pietra dei Saraceni, Rupe di San Benedetto and Rupe del Passo di Burgio, were first discovered and investigated by Gemmellaro (e.g., Gemmellaro, 1887, 1888, 1889, 1890, 1891, 1893, 1894, 1896, 1898, 1899a, b, c) whereas the fifth, Rupe di San Calogero megablock, was later discovered (Fabiani, 1926, 1953).

According to Catalano et al. (1991), Flügel et al. (1991), and Di Stefano & Gullo (1997a), the megablocks are in tectonic contact with the Permian units of the Lercara Complex. The Lercara complex has been dated to the Late Permian-Middle Triassic (Flügel et al., 1991; Di Stefano & Gullo, 1997a, b; Basilone, 2012) and forms the basal part of the sedimentary succession deposited in the Sicanian basin. Such basin represents a southern Tethyan domain originally located along the African margin and subsequently incorporated into the Sicilian orogenic belt as part of the Sicanian Thrust System. The Permian units of the Lercara Complex comprise deep-water siliciclastic and clastic-carbonate deposits, generally interpreted as base of slope deposits, mainly consisting of turbidites and debris flows deposits (Di Stefano & Gullo, 1997a). These Permian units are overlain by two Lower Triassic units consisting of mainly deep-water marls and limestones (Catalano et al., 1991; Di Stefano & Gullo, 1997a). The association of siliciclastic and carbonatic turbidites supports the existence of a mixed terrigenous/carbonate shelf area at the margins of the Sicanian Basin (Di Stefano & Gullo, 1997a).

The Sosio Limestone forming the megablocks consists of light-coloured limestone, composed of thick, generally poorly defined, and locally graded beds of coarse calcareous breccia alternating with subordinate fine-grained bioclastic packstone and grainstone (Di Stefano, 1990; Flügel et al., 1991; Di Stefano & Gullo, 1997a, b). The breccia clasts derive from platform-slope carbonates, mainly reef-derived boundstone/rudstone with subordinate floatstone and grainstone, yielding a wide variety of fossils, such as sponges, *Tubiphytes* Maslov, 1956, *Archaeolithoporella* Endo, 1959, phylloid algae, richthofenioid brachiopods, together with highly diverse assemblages comprising fusulinids (Di Stefano & Gullo, 1997a).

Flügel et al. (1991) proposed that sea-level fluctuations during the Wordian, including intervals of relative sea-level lowering and subaerial exposure, promoted fracturing of cemented reef margins. The resulting material was transported downslope and deposited on the fore-reef slope, forming a periplatform talus. Subsequent sea-level rise facilitated redeposition of this talus by debris flows at the base of the slope (Flügel et al., 1991).

The age of the Sosio Limestone is still debated. Flügel et al. (1991) proposed an Artinskian-Wuchiapingian (Early to Late Permian) age for the breccia elements, based on fusulinids and conodonts (Skinner & Wilde, 1966; Flügel et al., 1991; Catalano et al., 1992; Di Stefano & Gullo, 1997a, b), with some blocks also yielding Changhsingian age (Flügel et al., 1991). The blocks represent the type locality for the conodont species *Mesogondolella siciliensis* (Kozur, 1975) and were considered Roadian-Wordian in age, but the age has been contested for many years which is in part related to the complex tectonic relationships, provincialism, and lack of good stratigraphic sections. Henderson & Mei (2003) considered several alternative ages based on fusulinids and *M. siciliensis* from several locations. In Oman some rare specimens within a *M. siciliensis* population exhibit subtle serration and an asymmetric pointed posterior margin. Catalano et al. (1991) referred a comparable specimen as *Mesogondolella slovenica* (Ramovs, 1982) from the Sosio Limestone blocks, but this specimen differs from the holotype. Henderson & Mei (2003) referred to such specimens as the species *Mesogondolella rustaqensis* Mei & Henderson, 2002 and suggested that a late Kungurian age was preferred, but discussed the possibility of a Roadian age. Kozur & Wardlaw (2010) synonymized *M. rustaqensis* with *Jinogondolella aserrata* (Clark & Behnken, 1979) a species that is diagnostic of a Wordian age. The most common fusulinid associated with these conodonts is *Neoschwagerina sosioensis* (Skinner & Wilde, 1966) which is compared with *Neoschwagerina craticulifera* (Schwager, 1883) and correlated with a subzone in the

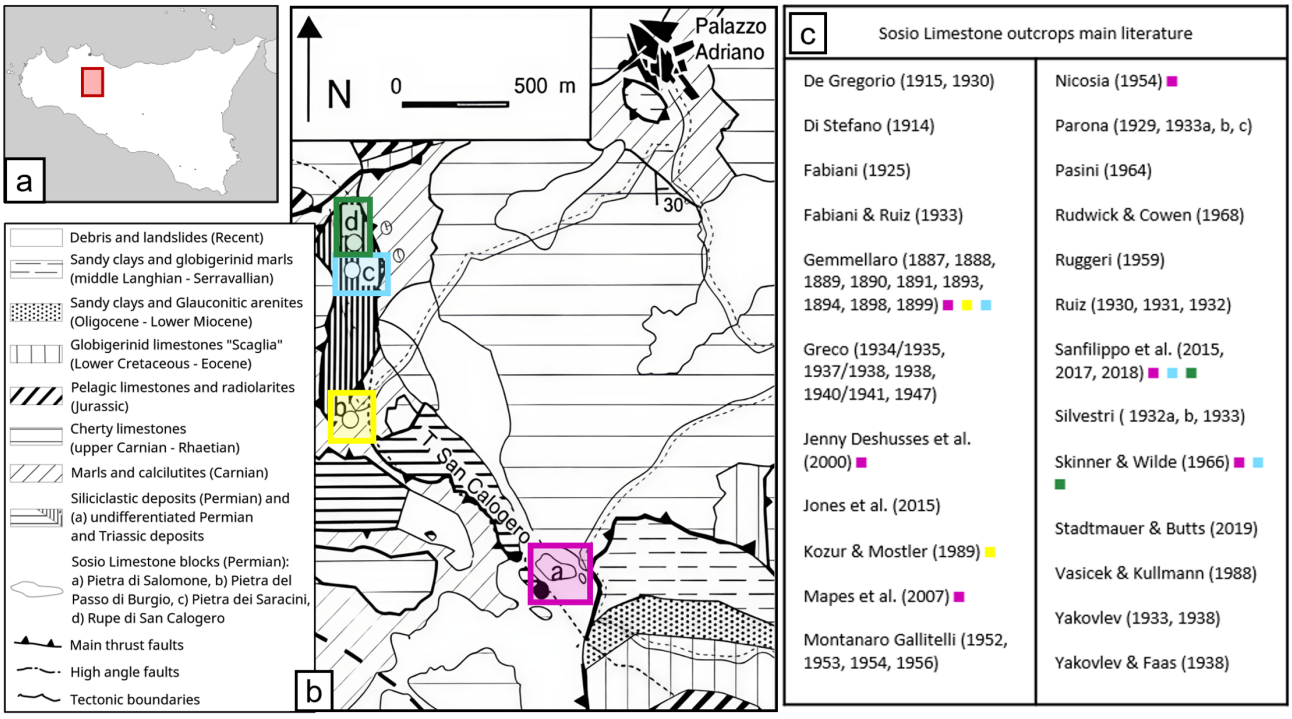


Fig. 1 - (color online) Geographical and geological setting of the Sosio Valley. a) Schematic map of Sicily, red square locates the study area. b) Geological map of the Sosio Valley, focusing on the area of Palazzo Adriano and Torrente San Calogero. The four main Sosio Limestone megablocks are highlighted in different colours (modified from Di Stefano & Gullo, 1997a). For each of these, in c), a synthetic list of previous works is reported: pink squares indicate works focusing on the fauna from the Pietra di Salomone megablock; light blue squares indicate works focusing on the fauna from the Pietra dei Saraceni and the Rupe di San Benedetto megablocks; green squares indicate works focusing on the fauna from the Rupe di San Calogero; yellow squares indicate works focusing on the fauna from the Rupe del Passo di Burgio megablock.

Murgabian Tethyan stage which is roughly Wordian in age (Flügel et al., 1991). Miller (1933) indicated that the Sosio ammonoids are "strikingly similar" with those of the Word Formation in west Texas; this formation is now regarded as spanning the Roadian to Wordian. A Guadalupian to Lopingian (Middle to Late Permian) age has also been proposed for the matrix based on fusulinids and conodonts (Flügel et al., 1991).

MATERIAL

The brachiopod specimens studied in the present work are part of the material discovered and collected during research conducted in October 2014 by the Museo Civico di Storia Naturale of Comiso and authorized by the Department of State Forestry of Sicily, in the Monti di Palazzo Adriano and Valle del Sosio Oriented Nature Reserve (Palazzo Adriano, Palermo).

The fossil brachiopods were prepared by one of the authors (Agatino Reitano) and housed at Museo Civico di Storia Naturale, Comiso. The material was collected from three of the five Sosio Limestone megablocks: Pietra di Salomone, Rupe di San Benedetto, and Rupe di San Calogero megablock (Fig. 2). The collection comprises five sub-collections identified with an alphanumerical coding, referring to the megablock from which the material was collected: PA = Palazzo Adriano, PDS = Pietra di Salomone, PSB = Pietra di San Benedetto (= Pietra dei Saraceni/Rupe di San Benedetto), PSC = Pietra di San Calogero (= Rupe di San Calogero). Sub-collections 4549-PA-PDS, 4550-PA-PDS, 4551-PA-PDS (for simplicity referred to as sub-collections A, B and C in this work) include most of the material, collected from a collapsed portion on the southern cliff of the Pietra di Salomone megablock and the upper part of the same megablock. Sub-collection 4551-PA-PSB (referred to as sub-collection D) includes specimens collected from the Rupe di San Benedetto megablock. Sub-collection 4551-PA-PSC (referred to as sub-collection E) includes specimens collected from the Rupe di San Calogero megablock.

THE BRACHIOPOD FAUNA

Among a total of 1152 brachiopod specimens collected in 2014, this study describes 223 specimens belonging to 36 taxa (Tab. 1), some of which have never been reported before from the Sosio Limestone. The most abundant and diverse order is Productida, represented by 152 specimens assigned to 28 taxa, followed by Orthotetida with 67 specimens belonging to seven taxa, and Dictyonellida with four specimens belonging to a single species. Of the material examined, 200 specimens were collected from the Pietra di Salomone megablock (Tab. 1). The Rupe di San Benedetto megablock yielded 18 specimens, with taxa comparable to those from the Pietra di Salomone megablock, except for *Neochonetes* (*Nongtaia*) sp. and ?*Juresania* sp., which occur exclusively in this megablock. The Rupe di San Calogero megablock yielded only five specimens (Tab. 1), including three species in common

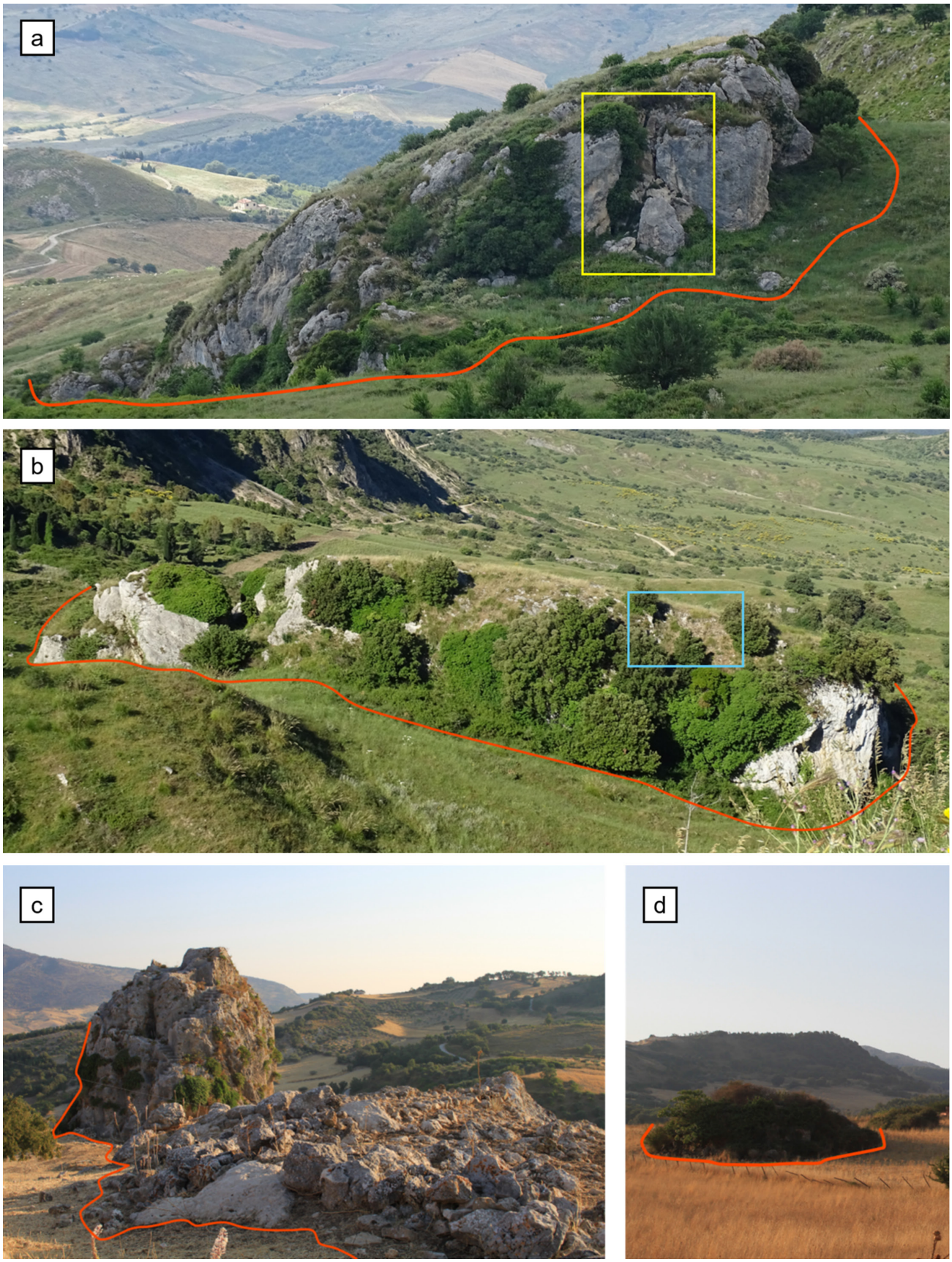


Fig. 2 - (color online) The three megablocks outcrops. a) Southern view of the Pietra di Salomone megablock in 2025, yellow square highlights a collapsed portion where part of the material was collected by the Museo Civico di Storia Naturale of Comiso. b) South-eastern view of the Pietra di Salomone megablock in 2025, the light blue square indicates the area where the sample for the conodont study was collected in 2025. c) Rupe di San Benedetto megablock in the foreground, and Pietra dei Saraceni in the background. d) Rupe di San Calogero megablock. Both c) and d) show the megablocks as they appeared in 2014 when the brachiopod material here studied was collected.

	Pietra di Salomone	Rupe di San Benedetto	Rupe di San Calogero	All outcrops
Megapleuronia grecoi	4			4
Costachonetina sp.	2			2
Neochonetes (*Nongtaia*) sp.		2		2
Haydenella sp.	2	4		6
Comuquia modesta	12	1	1	14
Dyschrestia sp.	2			2
Spinomarginifera cf. *S. spinosocostata*			1	1
Incisius sp.	2			2
Caricula cf. *C. salebrosa*	11		2	13
Transennatia sp.	1			1
Chaoina reticulata	9	1		10
Stereochia sp.	2			2
Calliprotonia sp.	1			1
Juresania sp.	4			4
?*Juresania* sp.		1		1
Anidanthus sp.	7	1		8
Compressoproductus compressus	5			5
Heteralosia sp.	2			2
Chonostegoides sp.	1	1		2
Urushtenia cf. *U. murina*	6			6
Edriosteges sp.	2			2
Girlasia superelegans	5			5
Strophalosiina sp.	3	1		4
Scacchinella variabilis	15			15
Coscinarina communis	19	4		23
Sicularia sicula	10			10
Gemmellaroia marii	7			7
Leptodus sp.	1			1
Pirgulia conica	1			1
Geyerella gemmellaroi	8			8
Geyerella rex	20	1		21
Geyerella cf. *G. distorta*	4			4
Perigeyerella cf. *P. tricosa*	5			5
Sicelia merlai	9	1		10
Streptorhynchus sinuatus	17		1	18
Streptorhynchus sp.	1			1
Total	**200**	**18**	**5**	**223**

Tab. 1 - Distribution of brachiopod taxa with number of specimens in the three Sosio Limestone megablocks. Taxa never reported before from the Sosio Limestone are highlighted in grey. For specimen counts, each articulated specimen was counted as one individual. To this number, the number of disarticulated valves of the most abundant valve type (either dorsal or ventral) was added. When only disarticulated valves were recovered, each valve of the most abundant valve type was counted as one specimen. Casts were counted only when the corresponding valve was absent; when the valve was preserved, the cast was excluded from the count.

with the other megablocks and the exclusive occurrence of *Spinomarginifera* cf. *S. spinosocostata* (Abich, 1878).

Interestingly, the fauna investigated in this study is characterized by a high number of taxa represented by relatively few specimens, usually less than ten specimens per species across all three megablocks. Only a small number of taxa reach about 20 specimens, such as *Coscinarina communis* (Gemmellaro, 1894), *Geyerella rex* (de Gregorio, 1930), and *Streptorhynchus sinuatus* (Merla, 1928). Moreover, most identified taxa are small in shell size (i.e., narrower than 20 mm, according to the size terms used by Brunton et al., 2000), with some being exceptionally small, including *Costachonetina* sp., *Comuquia modesta* Grant, 1976, *Incisius* sp., and *Perigeyerella* cf. *P. tricosa* Grant, 1976.

AGE OF THE BRACHIOPOD FAUNA

According to the stratigraphic ranges reported in the revised treatise of brachiopods (Brunton et al., 2000; Holmer, 2000; Williams et al., 2000) and in

online databases, such as The Paleobiology Database (Paleobiology Database, 2026) and Mindat (Mindat, 2026), most taxa identified in the Pietra di Salomone megablock exhibit distributions ranging the entire Permian (Fig. 3). Only few taxa show more restricted stratigraphic ranges: *Costachonetina* sp. and *Comuquia modesta* occur from the Roadian to the Wordian (Guadalupian), whereas *Chaoina reticulata* Jin in Jin et al., 1974 ranges from the Kungurian (Cisuralian) to the Capitanian (Guadalupian). Furthermore, *Compressoproductus compressus* (Waagen, 1884) is not known prior to the Roadian.

The stratigraphic distribution of the fauna from Rupe di San Benedetto megablock is overall comparable. This outcrop also holds specimens of *Comuquia modesta* and *Chaoina reticulata*, representing the taxa with the most restricted stratigraphic ranges. *Neochonetes* (*Nongtaia*) sp. and ?*Juresania* sp., which occur only in this megablock, range respectively from the Roadian (Guadalupian) to the Changhsingian (Lopingian) and throughout the entire Permian. The fauna from the Rupe di San Calogero megablock also shows a comparable distribution, with *Comuquia modesta* again representing the taxon with the most restricted stratigraphic range (Roadian-Wordian).

The coexistence of *Costachonetina* sp. and *Comuquia modesta* across the studied outcrops constrains the age of the assemblages to the Roadian-Wordian interval,

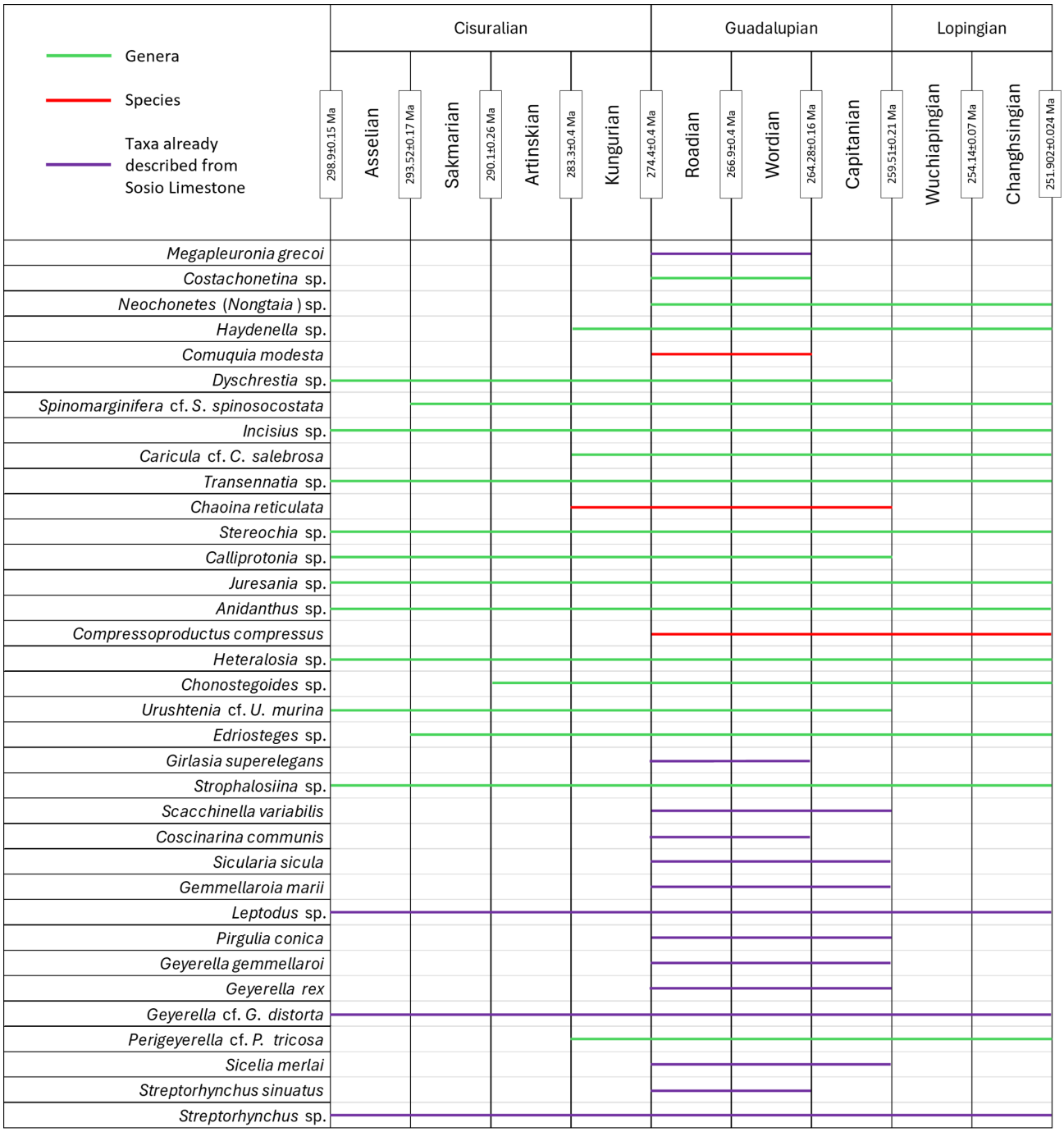


Fig. 3 - (color online) Stratigraphic distribution of the brachiopod taxa of the three Sosio Limestone megablocks.

which also overlaps with the stratigraphic ranges of the remaining taxa (Fig. 3).

A small rock sample (2 kg) was collected from the upper portion of the Pietra di Salomone megablock (Fig. 2b) in June 2025, in order to investigate the conodont fauna and gain additional age constraints. The recovered conodont fauna (Fig. 4) is relatively poor and includes *Mesogondolella* cf. *M. rustaqensis* (Mei & Henderson, 2002) (two fragments, 400 μm long), *Mesogondolella* sp. (a single indeterminate juvenile), *Sweetognathus* sp. (one very small fragment), and two ramiform elements. *Mesogondolella* cf. *M. rustaqensis* (Fig. 4a, b) exhibits transitional characters with *Jinogondolella aserrata* and is therefore slightly older (later Roadian?). These conodonts indicate a late Roadian/Wordian age, in agreement with the overlap of the brachiopod stratigraphic ranges.

In conclusion, the age of the brachiopod fauna described here is most probably Guadalupian, specifically within the Roadian-Wordian interval.

BRACHIOPOD FUNCTIONAL MORPHOLOGY

The identified taxa exhibit a range of morphologies and can be grouped into three distinct morphogroups (Fig. 5). A large number of specimens belong to the concavo-convex/plano-convex morphogroup (Fig. 6a). This is followed by specimens belonging to the conical non-coralliform, subconical, and elongated morphogroup, whereas brachiopods assigned to the conical coralliform morphogroup are the least abundant. A similar pattern emerges when the number of taxa is considered instead of the number of specimens (Fig. 6b). However, in this case, taxa belonging to the concavo-convex/plano-convex morphogroup are markedly more numerous, whereas the conical coralliform morphologies are comparatively rare. The general pattern is dominated by the larger sub-collection of brachiopods from the Pietra di Salomone megablock (Fig. 6c). The Rupe di San Benedetto megablock has a larger percentage of concavo-convex/plano-convex morphologies (Fig. 6d), whereas this percentage is even higher in the Rupe di San Calogero megablock, where conical coralliform brachiopods are absent (Fig. 6e). The different morphologies identified in this work may reflect different lifestyles, particularly in terms of substrate interaction, modes of support and feeding adaptations (Rudwick, 1970, 2018; Alexander, 2001).

Concavo-convex/plano-convex morphogroup

Brachiopods included in the concavo-convex/plano-convex morphogroup are characterized by a variably convex ventral valve and a concave to almost flat dorsal valve (Fig. 5a); they are mainly ornamented by a variable number of spines, with the exception for *Megapleuronia grecoi* Cooper, 1952. The concavo-convex/plano-convex taxa belong to the orders Dictyonellida and Productida. This group includes specimens that are variable in size, both in length and width. Most of the specimens, approximately 68%, range from 7 mm to 15 mm both in length and width. The smallest ones (approximately 22% and less than 7 mm both in length and width), are represented by specimens of *Comuquia modesta* and *Costachonetina* sp. The largest specimens, approximately

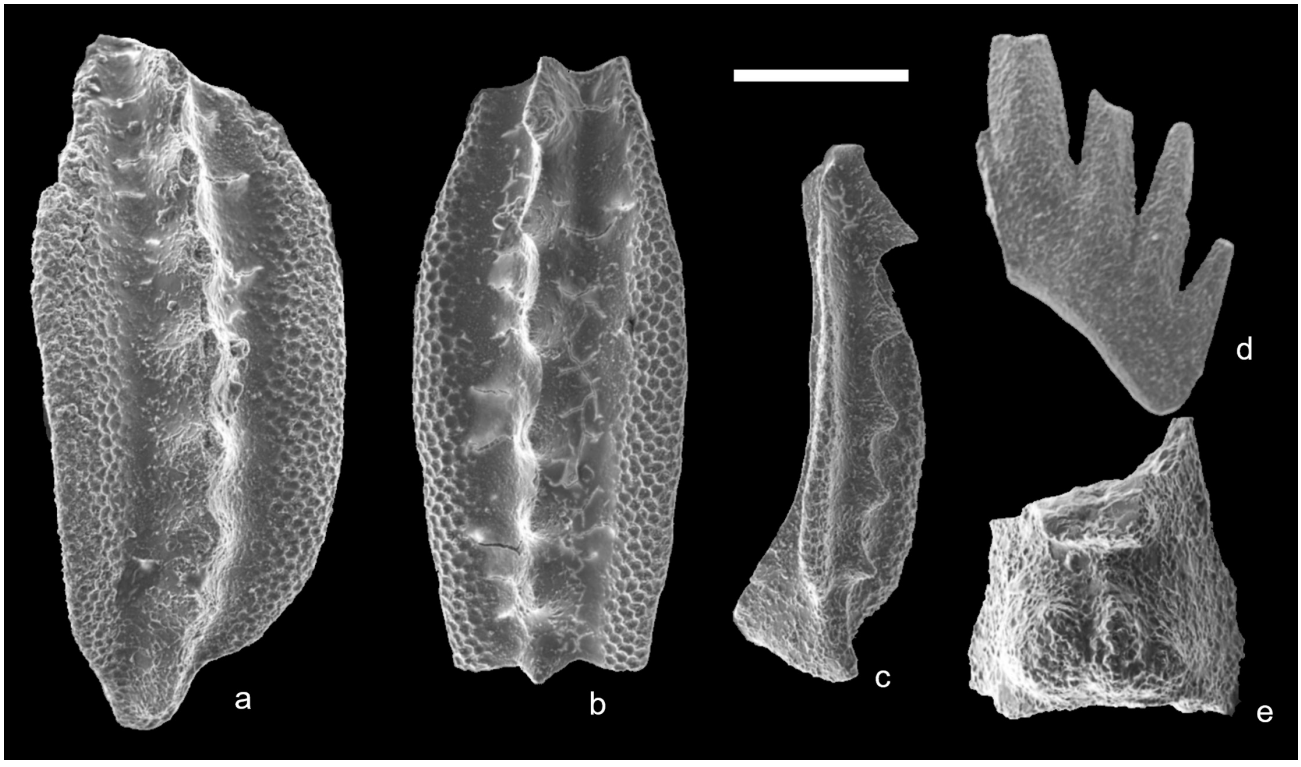


Fig. 4 - Conodont fauna from the Pietra di Salomone megablock collected in June 2025. Scale bar is 100 μm. a) *Mesogondolella* cf. *M. rustaqensis*, upper view. b) *Mesogondolella* cf. *M. rustaqensis*, upper view. c) *Mesogondolella* sp., juvenile, oblique lateral view. d) *Mesogondolella* sp., ramiform fragment. e) *Sweetognathus* sp., upper view of fragment, given age it may be *Sweetognathus subsymmetricus*.

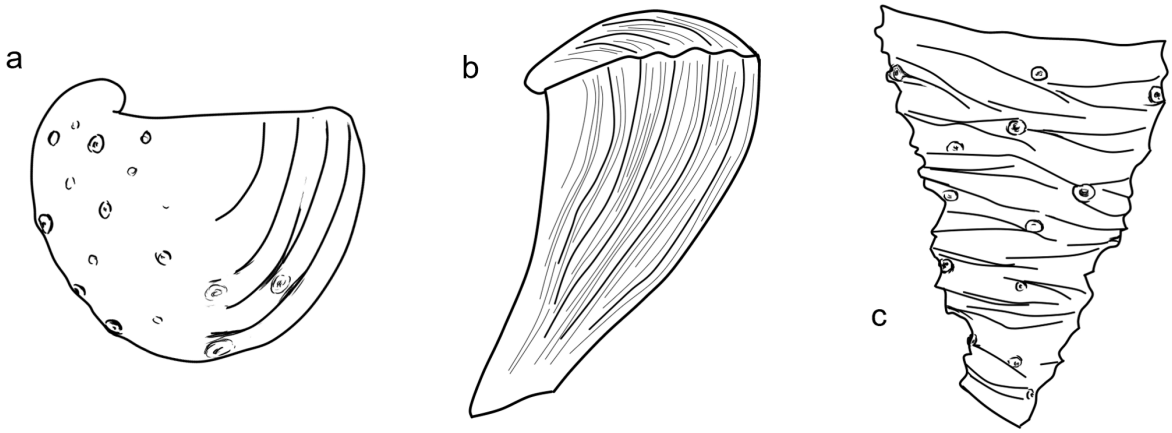


Fig. 5 - Schematic drawings of the three identified morphological groups, based on the most typical example for each morphology. a) Concavo-convex/plano-convex morphological group, the ornamentation can vary, but spines are almost always present (drawing based on specimen E13-2 assigned to *Spinomarginifera* cf. *S. spinosocostata*). b) Conical non-coralliform/subconical/elongated morphological group, generally lacking spinose ornamentation (drawing based on specimen A109-3 assigned to *Geyerella rex*). c) Conical coralliform morphological group, characterized by having an ornamentation of spines (drawing based on specimen A40-10 assigned to *Sicularia sicula*).

15 mm to 25 mm in length corresponding to 30-35 mm in width (thus medium-sized brachiopods according to the size terms used by Brunton et al., 2000), are the fewest, around 10% (see Appendix 2 for detailed measurements).

Based on their morphology, these specimens are interpreted as having had a semi-infaunal lifestyle, with much of the ventral valve buried in a soft substrate following an "iceberg" strategy in which only a limited portion of the shell projected above the water-sediment interface (Fig. 7a), as proposed by Grant (1968) for species of *Marginifera* Waagen, 1884. Ventral spines may have increased the surface area of the shell, contributing to the iceberg strategy and preventing sinking in soft, muddy substrates. Spines on the dorsal valve, when present, may deter predators.

Among the studied taxa, only *Chaoina reticulata* shows a distinct cicatrix of attachment. This may suggest a juvenile stage attached to objects rising from the sea floor, for instance crinoid stems or sponges, followed by a free semi-infaunal lifestyle, as suggested by Grant (1966) for species of *Waagenoconcha* Chao, 1927a.

The Family Isogrammidae, to which the concavo-convex/plano-convex *Megapleuronia grecoi* belongs, is described as holding an open, triangular delthyrium by Holmer (2000). However, Cooper (1952) did not describe such feature when establishing the species, and in the available specimens of *M. grecoi* the delthyrium is not visible. The same specimens show the characteristic elongated decorticated area on the ventral umbo which, according to Cooper (1952), represents the attachment site of the pedicle. The pedicle anchors the animal to hard substrates, but it is also efficient in conferring stabilization in soft substrates, so that pedicle attached brachiopods are considered ubiquitous (Grant, 1971). The pedicle elevates the body slightly into the water column, improving feeding efficiency.

According to Muir-Wood & Cooper (1960), the concavo-convex/plano-convex Strophalosiidae and Aulostegidae lived attached to the substrate with a cicatrix on the ventral umbo, supported by spines near the attachment scars and even a number of additional spines. However, a cicatrix of attachment was not observed in the studied specimens, even if this lack could be related to poor preservation. Lacking clear evidence of a cicatrix, Strophalosiidae and Aulostegidae of the Sosio Limestone are here interpreted as having had a semi-infaunal lifestyle, or possibly having had a juvenile attached stage followed by a free semi-infaunal lifestyle, similar to other concavo-convex/plano-convex brachiopods previously described (e.g., Grant, 1966, 1968).

Concavo-convex/plano-convex brachiopods represent a primary-tier life habit, with the commissure positioned at or slightly above the water-sediment interface (Fig. 7a; Bottjer & Ausich, 1986). This low feeding position may help explain their generally small size, as access to suspended food resources would have been limited both in quantity and quality.

Conical non-coralliform/subconical/elongated morphogroup

The conical non-coralliform brachiopods (with a conical ventral valve, but no spines) are included in the same group along with the brachiopods with subconical ventral valve and elongated ventral umbo morphology (Fig. 5b). Specimens of this group belong to species of the orders Productida and Orthotetida. These specimens are highly variable in sizes, ranging from approximately 5 mm to 40 mm in both length and width; most of the specimens (approximately 61%) range from 9 mm to 25 mm in both length and width. The smallest specimens (approximately 21% and less than 9 mm in both length and width) are considered juvenile specimens (mostly belonging to *Sicelia* Gortani & Merla, 1934 and *Perigeyerella* Wang, 1955) or are partly broken specimens. The largest (approximately 18% and over 25 mm in length) mostly belong to species of *Geyerella* Schellwien, 1900, with few specimens belonging to species of *Sicelia* and *Streptorhynchus* King, 1850 (see Appendix 2 for detailed measurements).

The conical non-coralliform morphology is mainly recorded by *Geyerella* and *Streptorhynchus*, which usually have a strongly conical ventral valve, but always lack spines. According to Rudwick & Cowen (1967), *Geyerella* is interpreted as epifaunal, free-lying on its posterior

side. The occurrence of a small cicatrix of attachment led the authors to suggest a juvenile stage attached to the substrate. An epifaunal lifestyle appears unlikely, owing to the narrow interarea relative to the overall width of the specimens and the variably twisted umbo. Accordingly, specimens of species of *Geyerella* in this study are interpreted as having had a semi-infaunal lifestyle (Fig. 7b). However, because most specimens described herein do not preserve a complete ventral umbo, no cicatrix could be observed. Consequently, the possibility of a juvenile attached stage cannot be ruled out.

Streptorhynchus was initially considered to have had a lifestyle similar to that inferred for *Geyerella* (Rudwick & Cowen, 1967) but was later interpreted as semi-infaunal (Verna et al., 2010). A similar interpretation has been proposed for *Sicelia*, which has a generally elongated ventral valve (Verna et al., 2010). The present study follows this interpretation and considers these taxa to have adopted a semi-infaunal lifestyle.

Also, here we report the occurrence of a species of *Perigeyerella*, a genus never described before from the Sosio Limestone. The species of this genus are described in literature as having a biconvex shape, with a variably elongated ventral umbo (Cooper & Grant, 1974), to a conical shape (Grant, 1976). The specimens of the species of *Perigeyerella* from the Sosio Limestone have a subconical to elongated morphology and are interpreted as semi-infaunal. A semi-infaunal lifestyle for several taxa of Orthotetida has been proposed by Grant (1976, 1980), based on the occurrence of koskinoid holes in

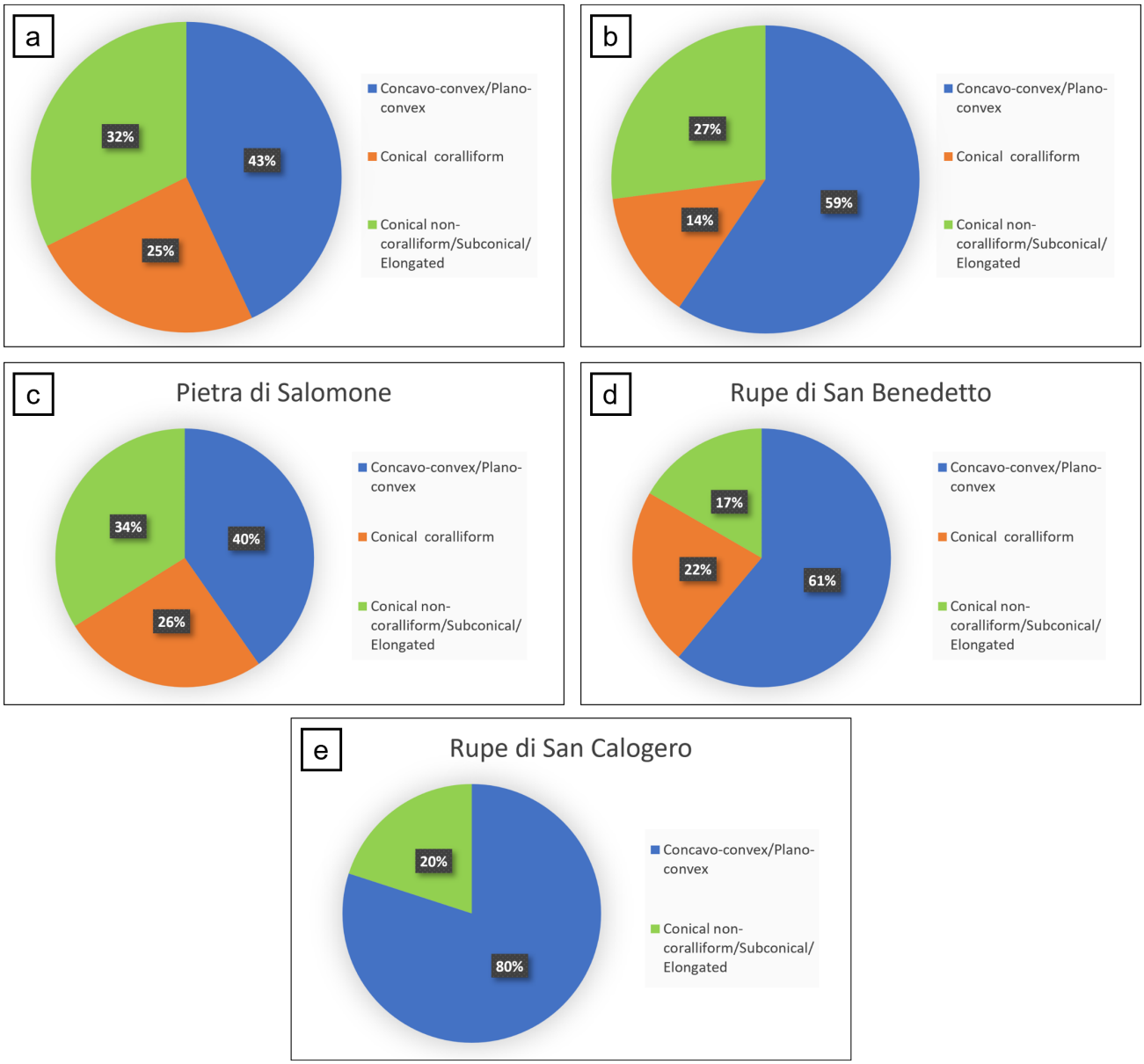


Fig. 6 - (color online) Pie charts showing the abundances of the three morphological groups observed in the Sosio Limestone. a-b) Pie charts showing the abundances of the three morphological groups observed in the three Sosio Limestone megablocks: a) based on the number of specimens; b) based on the number of taxa. c-e) Pie charts showing the abundances of the different brachiopod morphologies observed in each of the Sosio Limestone megablocks, based on the number of specimens: c) Pietra di Salomone megablock; d) Rupe di San Benedetto megablock; e) Rupe di San Calogero megablock.

species of *Geyerella*, *Sicelia*, *Streptorhynchus*, and also in *Perigeyerella tricosa* Grant, 1976 from Thailand, a species comparable to the specimens described herein. Koskinoid holes are small perforations, typically located near the ventral umbo, through which pedicular fibres emanate to anchor the brachiopods to the substrate (e.g., Cooper, 1973; Grant, 1976, 1980; Richardson 1979).

Pirgulia Cooper & Muir-Wood, 1951 was initially interpreted as epifaunal by Rudwick & Cowen (1967), suggesting a free-lying lifestyle on its ventral valve with only juvenile forms cemented to the substrate, as other lyttonid brachiopods described by the authors. However, *Pirgulia* is reported lacking an attachment cicatrix, which led Stadtmauer & Butts (2019) to later reinterpret the lifestyle of this taxon. The strong conical morphology, without particular thickening of the shell, together with the lack of attachment structures (cicatrix of attachment, apical spines) suggest a semi-infaunal lifestyle for *Pirgulia* (Stadtmauer & Butts, 2019). The specimens may have lived partially buried within the sediment, where shell rugosity could have promoted sediment accumulation around the shell, thereby enhancing stabilization (Stadtmauer & Butts, 2019).

An interesting case is the presence of *Strophalosiina* sp., which represents another taxon never reported before from the Sosio Limestone. It has a peculiar morphology, characterized by a strongly elongated ventral umbo that differentiates the specimens identified in this study from those of other species of the genus described in literature. Species of *Strophalosiina* Licharew, 1935 are interpreted to have had an attached lifestyle, supported by the spines (Muir-Wood & Cooper, 1960). However, the elongated umbo of the specimens described herein is consistent with a semi-infaunal lifestyle, as that of the other taxa included in this morphogroup. The available specimens of *Strophalosiina* could represent a case of convergent evolution with the development of an elongated umbo, slightly twisted and adapted to live partially buried in the sediment, with the spines promoting stabilization.

Taxa with conical non-coralliform/subconical/elongated morphologies may have occupied an intermediate-tier life-habit, allowing them to attain a slightly higher position above the substrate than concavo-convex/plano-convex brachiopods (Fig. 7b), thereby facilitating more efficient suspension feeding. This interpretation is consistent with the size of these taxa, which ranges from 5 mm to 40 mm in both length and width. Although specimens of species of *Streptorhynchus* and *Sicelia* are the most variable in size in this morphogroup, they generally remain comparable to the largest concavo-convex/plano-convex brachiopods. *Geyerella*, on the other hand, can occasionally attain sizes comparable, or even larger, than most conical coralliform taxa.

Conical coralliform morphogroup

The specimens included in the conical coralliform morphogroup have a slightly to strongly conical ventral valve associated with a distinct ornamentation of spines and/or the presence of cicatrix of attachment, even if not always clearly preserved (Fig. 5c). They belong to the order Productida. These specimens have a generally larger size when compared with the other morphogroups. The majority of these specimens (around 56%) approximately range from 10 mm to 20 mm in length and from less than 10 mm to 39 mm in width, and so are small to medium-sized according to the size terms used by Brunton et al. (2000). Some specimens (approximately 27%) are quite small, approximately less than 10 mm both in length and width, and possibly represent juvenile or partly broken specimens, mostly belonging to *Scacchinella* Gemmellaro, 1891 and *Coscinarina* Muir-Wood & Cooper, 1960. The largest specimens (approximately 15% and over 20 mm in width) belong to *Sicularia* Grant, 1993, with only two specimens reaching also 35 mm and 39 mm in width (see Appendix 2 for detailed measurements).

According to Rudwick & Cowen (1967), *Coscinarina* and *Sicularia* are usually strongly coralliform and have a variable number of spines. This is consistent with the features observed in the specimens described herein. *Scacchinella* and *Gemmellaroia* Cossmann, 1898 have a variably conical ventral valve (Rudwick & Cowen, 1967).

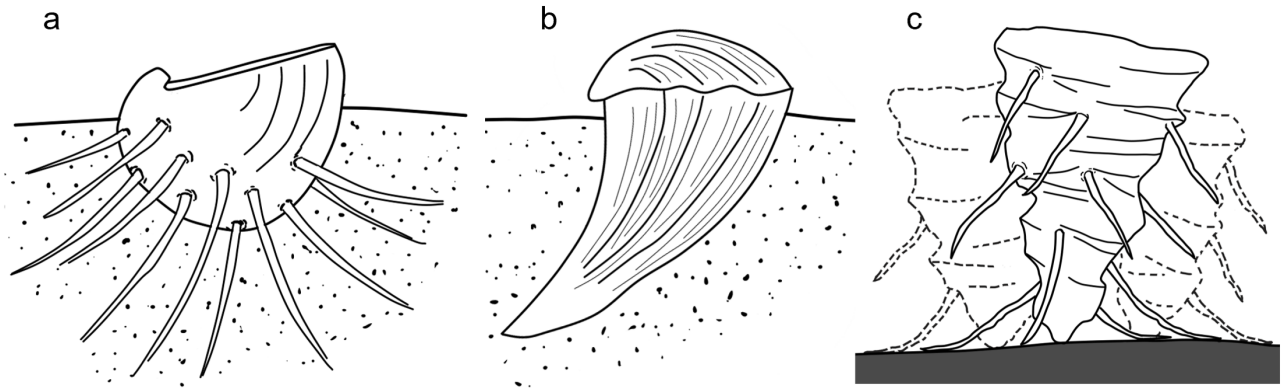


Fig. 7 - Schematic drawings of the interpreted lifestyle for the three morphological groups, based on the lifestyle proposed by Ager (1967), modified using the morphology of taxa identified in this work. a) Semi-infaunal lifestyle (based on specimen E13-2 assigned to *Spinomarginifera* cf. *S. spinosocostata*). b) Semi-infaunal lifestyle (based on specimen A109-3 assigned to *Geyerella rex*). c) Epifaunal cemented lifestyle (based on specimen A40-10 assigned to *Sicularia sicula*).

Moreover, *Scacchinella* has by far more numerous spines than *Gemmellaroia*. According to Rudwick & Cowen (1967), these taxa would have adopted an erect epifaunal lifestyle, being attached with a cicatrix located in the umbonal area and further stabilized by rhizoid spines (Fig. 7c; Rudwick & Cowen, 1967; Verna et al., 2010), an interpretation which is followed herein. Muir-Wood & Cooper (1960) interpreted species of *Scacchinella* as frequently forming clusters, as observed in the Permian assemblages of the Glass Mountain of Texas. However, the specimens studied here do not show any evidence of forming clusters, suggesting a solitary lifestyle.

Leptodus Kayser, 1883 is described as having a cup-like morphology and an attachment cicatrix in the apical portion, hence it is included in this morphogroup. Rudwick & Cowen (1967) originally described species of *Leptodus* as having an attached lifestyle in the juvenile stage followed by a free lying epifaunal lifestyle. However, more recent interpretations suggest that *Leptodus*, like most lyttoniids, was attached to hard substrates (hardgrounds or neighbouring individuals), and grew more or less vertically from the substrate (Seilacher, 2013). Attachment to the substrate would have been established through root lamellae of the ventral valve and cementation at hinge (Stadtmauer & Butts, 2019) forming subparallel arrays of individuals that stick out of the hard substrate (Seilacher, 2013).

Erect coralliform forms would have attained a higher position above the water-sediment interface (Fig. 7c) characteristic of a secondary-tier life habit (Bottjer & Ausich, 1986). This may have enabled more efficient suspension feeding, and, consequently, the development of larger shells.

Paleoenvironmental interpretation

The functional morphology analysis of the brachiopods studied here suggests the occurrence of different types of substrate in the reef recorded by the Sosio Limestone. The presence of a high number of coralliform specimens suggests the occurrence of widely distributed hard substrates, whereas the abundance of semi-infaunal brachiopods indicates the existence of widespread low-energy areas characterized by the deposition of mud on the reef or slope. The occurrence of *Pirgulia* supports a low energy environment, with deposition of fine sediments, as proposed by Stadtmauer & Butts (2019). Co-occurring crinoids, bryozoans and sponges may have favoured the trapping of calcareous mud and the formation of soft substrates. If not widespread, the muddy bottoms could have been localized, but extremely frequent, allowing colonization by a large number of semi-infaunal brachiopods. This preliminary interpretation requires further testing on the additional brachiopod taxa of the collection of the Museo Civico di Storia Naturale of Comiso. However, it is in agreement with the paleoenvironmental interpretation already proposed by Rudwick & Cowen (1967) and Sanfilippo et al. (2018). The latter authors studied the serpulid fauna of the Sosio Limestone and identified well calcified and stout serpulids, adapted to an exposed shallow-water shelf environment, along with smaller and brittle species, suggesting a reef characterized by sheltered micro-environments (Sanfilippo et al., 2018).

CONCLUSIONS

1. The systematic study of 223 brachiopod specimens resulted in the identification of 36 taxa belonging to the orders Dictyonellida, Productida, and Orthotetida, several of which are reported from the Sosio Limestone for the first time. Being the largest and better preserved of the megablocks, the Pietra di Salomone megablock yields the most diversified fauna.

2. The occurrence of *Costachonetina* sp. and *Comuquia modesta* suggests a Roadian-Wordian age (Guadalupian) for the Sosio Limestone. This is supported by the conodont findings.

3. The functional morphological analysis of the three identified morphogroups allowed the reconstruction of the likely modes of life of the studied brachiopods. The concavo-convex/plano-convex morphogroup is the most abundant both in terms of taxa and specimens and is interpreted as having had a semi-infaunal lifestyle. The conical non-coralliform/subconical/elongated morphogroup represents the second most abundant group, also interpreted as having had a semi-infaunal lifestyle. The conical coralliform morphogroup is the least represented, and taxa belonging to this morphogroup are interpreted as epifaunal, erect and attached to hard substrates with a cicatrix and spines.

4. The size differences observed among the studied brachiopods are consistent with vertical tiering within the paleocommunity. Concavo-convex/plano-convex semi-infaunal taxa represent a primary-tier life habit, living near the water-sediment interface, and attaining smaller sizes. The variable sizes of the conical non-coralliform/subconical/elongated morphogroup could reflect an intermediate-tier, attaining a slightly higher position above the water-sediment interface than concavo-convex/plano-convex taxa. The coralliform erect epifaunal brachiopods represent a higher secondary-tier life habit, allowing more efficient suspension feeding and the attainment of a larger size, but still in medium-size range for brachiopods.

5. The fossil association of the Sosio Limestone is in agreement with previous interpretations of the Sosio Limestone recording a fore-reef or upper slope environment (Flügel et al., 1991; Di Stefano & Gullo, 1997a, b). The occurrence of epifaunal brachiopods suggests the existence of hard substrates where they could attach and develop. The semi-infaunal brachiopods were instead adapted to live in soft substrates, colonizing low energy muddy substrates. Their abundance suggests the occurrence of widespread muddy bottoms. Alternatively, if the muddy substrate was restricted to more confined areas, such areas could have been numerous. This interpretation should be regarded as preliminary and will be further tested and refined through the study of additional brachiopod taxa housed in the collections of the Museo Civico di Storia Naturale of Comiso.

SYSTEMATIC PALEONTOLOGY

The classification follows: Holmer (2000) for the order Dictyonellida; Brunton et al. (2000) for the order Productida; Williams et al. (2000) for the order Orthotetida. Dimensions of each specimen examined are included in Appendix 2.

Subphylum Rhynchonelliformea Williams, Carlson, Brunton, Holmer & Popov, 1996
Class Chileata Williams, Carlson, Brunton, Holmer & Popov, 1996
Order Dictyonellida Cooper, 1956
Superfamily Eichwaldioidea Schuchert, 1893
Family Isogrammidae Schuchert, 1929

Genus *Megapleuronia* Cooper, 1952
Type species *Productus fabianii*, Greco 1947

Remarks - The genus *Megapleuronia* Cooper, 1952 is similar to *Isogramma* Meek & Worthen, 1870 in its concentric ornamentation, but the latter has more flattened valves and a larger interarea and generally lacks a strong radial ornamentation. *Schizopleuronia* Liao, 1983 is another comparable genus, distinguished by its larger shell and more transverse outline, together with weaker or less distinct costae; internally, it also differs in lacking a muscle platform in the dorsal valve.

Megapleuronia grecoi Cooper, 1952
(Pl. 1, figs 1-2)

1952 *Megapleuronia grecoi* Cooper, p. 119, Pl. 22, figs 5-7; Pl. 23, figs 2-7.

Material - Two articulated specimens: A41-2, C59-1; two ventral valves: A41-1, B08-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Medium sized (> 13-> 33 mm wide, > 10.9-> 22 mm long, 4.5-8 mm thick), plano-convex to concavo-convex shell, with transverse outline; maximum width at hinge; posterior margin straight, with ears not clearly separated from flanks. Ventral valve slightly convex; visceral disk more convex than anterior part; umbo small, recurved, slightly extended beyond the posterior margin, with triangular decorticated area. Dorsal valve flat to slightly concave. Shell ornamentation of costae and concentric fila; costae thick, simple, rounded, totally numbering ten to 12 on each valve; median ventral costa wider than others; concentric fila dense and pervasive.

Remarks - The ornamentation of the rounded costae and fila, together with the transverse outline, supports assignment of these specimens to *Megapleuronia grecoi*, previously known from the Sosio Limestone (Cooper, 1952). *Megapleuronia grecoi* differs from *Megapleuronia fabianii* (Greco, 1947) described by Greco (1947) from the Sosio Limestone (Roadian-Wordian) in possessing a slightly more transverse outline and lower but more widely spaced, anteriorly widening costae. In contrast, *M. fabianii* exhibits narrower, higher costae that remain uniform along the valve length. Additionally, our specimens also display fewer costae (ten to 12) than *M. fabianii* (12 to 14). Cooper (1952) further distinguished the two species by the shape of the dorsal valve: concave consistently throughout growth stages in *M. grecoi*, but more convex, especially in later growth stages in *M. fabianii*. However, Greco (1947) described the dorsal valve of *M. fabianii* as mostly flattened, with a variably developed sulcus corresponding to the central costa of the ventral valve. The dorsal valve in the studied specimens appears flattened or uniformly slightly concave, lacking any sulcus, therefore confirming their identification as *M. grecoi*.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Cooper, 1952).

Class Strophomenata Williams, Carlson, Brunton, Holmer & Popov, 1996
Order Productida Sarytcheva & Sokolskaya, 1959
Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetoidea Bronn, 1862
Family Anopliidae Muir-Wood, 1962
Subfamily Caenanopliinae Archbold, 1980

Genus *Costachonetina* Waterhouse, 1981
Type species *Costachonetina krotowi* Waterhouse, 1981

Remarks - The genus *Costachonetina* Waterhouse, 1981 was originally regarded as *Chonetina* Krotow, 1885 by Grant (1976). Grant noted that the description of *Chonetina* as "smooth apart from growth lamellae" by both Krotow (1885) and Muir-Wood & Cooper (1960) was inaccurate, thus proposing that *Chonetina* possessed costellate ornamentation to accommodate the radial ornamentation present in his specimens. Waterhouse (1981) subsequently introduced the genus *Costachonetina* to differentiate the costellate specimens described by Grant (1976) from true *Chonetina*.

Distribution - Roadian-Wordian of Thailand (Grant, 1976; Waterhouse, 1981).

Costachonetina sp.
(Pl. 1, fig. 3)

Material - Two ventral valves: C131-1, C131-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Ventral valve small sized (2.9-4 mm wide, 2-3.8 mm long), strongly convex, with transverse outline; posterior margin straight, almost as wide as maximum shell width; ears clearly differentiated from flanks, nearly flat; median sulcus narrow and deep. Costellae numerous, fully ornamenting venter and ears.

Remarks - These specimens are poorly preserved but are assignable to *Costachonetina* on the basis of their dimensions, the pervasive costellae, and the presence of a deep ventral sulcus. The specimens resemble "*Chonetina* species undetermined" from the Roadian-Wordian of Thailand figured by Grant (1976, p. 62, pl. 12), later

renamed *Costachonetina krotowi* Waterhouse, 1981, mainly for their small size together with the narrow and deep sulcus and the numerous costellae. The nomenclature is left open here due to the limited preservation of the specimens.

Family Rugosochonetidae Muir-Wood, 1962
Subfamily Rugosochonetinae Muir-Wood, 1962

Genus *Neochonetes* Muir-Wood, 1962
Subgenus *Neochonetes* (*Nongtaia*) Archbold, 1999
Type species *Neochonetes* (*Nongtaia*) *taoni* Archbold, 1999

Remarks - The subgenus *Neochonetes* (*Nongtaia*) Archbold, 1999 is similar to other subgenera of *Neochonetes*, yet remains distinguishable on several morphological grounds. *Neochonetes* (*Huangichonetes*) Shen & Archbold, 2002 differs in having more numerous costellae along the anterior margin and in possessing more prominent ears. *Neochonetes* (*Nongtaia*) is distinguished from *Neochonetes* (*Zechiella*) Archbold, 1999 and *Neochonetes* (*Zhongyingia*) Shen & Archbold, 2002 by its deeper sulcus and somewhat coarser ornamentation. *Neochonetes* (*Sommeriella*) differs in having a weaker sulcus and finer costellae.

Distribution - Guadalupian of Peninsular Malaysia (Sone et al., 2003); Roadian-Wordian of Thailand (Archbold, 1999); Wordian of Oman (e.g., Angiolini & Bucher, 1999; Angiolini et al., 2003); Wordian-Capitanian of North Iran (e.g., Crippa & Angiolini, 2012); Capitanian of Turkey (Verna et al., 2011); Wuchiapingian of Australia (e.g., Webster & Jell, 1992; Archbold, 1993); Changhsingian of China (Xu et al., 2019).

Neochonetes (*Nongtaia*) sp.
(Pl. 1, fig. 4)

Material - Two ventral valves: D84-1, D84-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Description - Ventral valve small sized (> 10.5-12 mm wide, > 5.5-8.5 mm long), convex with transverse to semicircular outline; posterior margin straight, corresponding to maximum shell width. Umbo small, slightly recurved, slightly extended beyond the posterior margin; ventral median sulcus narrow, shallow, faintly developed. Capillae fine, numerous, occasionally bifurcating, numbering eight to ten in 1 mm width near anterior commissure.

Remarks - The studied specimens are comparable to *Neochonetes* (*Nongtaia*) *asseretoi* (Fantini Sestini, 1964) from the Wordian-Capitanian of North Iran figured by Crippa & Angiolini (2012; fig. 11 a, b), particularly in their small shell size and fine radial ornamentation. However, the Sosio specimens show a much weaker median sulcus. This reduced ventral sulcus makes them superficially similar to *Neochonetes* (*Huangichonetes*), although the latter differs in its more trapezoidal outline and more prominent ears.

Suborder Productina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productellidae Schuchert, 1929
Subfamily Productininae Muir-Wood & Cooper, 1960
Tribe Chonetellini Licharew, 1960

Genus *Haydenella* Reed, 1944
Type species *Productus kiangsiensis* Kayser, 1883

Remarks - The genus *Haydenella* Reed, 1944 differs from *Chonetinella* Waagen, 1884 in having a less strongly nasute outline, radial ornamentation and spines, and weaker internal lateral ridges. *Ogbinia* Sarytcheva in Sarytcheva & Sokolskaya, 1965 is another similar genus, differing in having a more elongate outline, lacking rugae and having spines only in rows near the hinge.

Distribution - Kungurian-Changhsingian of China (e.g., Chang, 1987; Zeng et al., 1995; Shen et al., 2017); Guadalupian-Lopingian of Transcaucasia (e.g., Ruzhentsev & Sarytcheva, 1965; Kotlyar et al., 1983); Roadian-Wordian of Thailand (e.g., Grant, 1976; Sone et al., 2009); Wordian of Oman (e.g., Angiolini & Bucher, 1999; Angiolini et al., 2003); Wordian-Wuchiapingian of Iran (e.g., Angiolini & Carabelli, 2010; Crippa & Angiolini, 2012; Ghaderi et al., 2014); Capitanian of Cambodia (Delpey, 1941); Capitanian-Wuchiapingian of Malaysia (e.g., Leman, 1994); Lopingian of Pakistan (e.g., Reed, 1944); Lopingian of Svalbard Island (e.g., Nakamura et al., 1987); Wuchiapingian-Changhsingian of Greece (e.g., Nakazawa et al., 1975; Clapham & Bottjer, 2007); Wuchiapingian-Changhsingian of Japan (e.g., Shimizu, 1961).

Haydenella sp.
(Pl. 1, figs 5-6)

Material - Six ventral valves: C130-8, C132-1, D86-1, D86-2, D86-3, D86-4.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Description - Small sized valve (7.5-> 13 mm wide, 7-> 10 mm long), strongly convex, roughly subcircular to slightly transverse in outline. Maximum width anterior to hinge. Ventral valve convex; umbo small, recurved and only slightly extended beyond posterior margin. Ears flat, partly preserved only in specimen C132-1. Costellae numerous on venter and ears, numbering ten to 12 in 1 mm on the venter at almost 5 mm from the umbo; in the umbonal region, costellae rounded and extremely weak. Low rugae on the ears. Up to four spine bases in rows in the umbonal region, between the venter and ears. Other spine bases, few, scattered through the valve.

Remarks - The extremely weak costellae exhibited in the specimens stand as the main difference from the type species *Haydenella kiangsiensis* Kayser, 1883 from the Lopingian of South China which typically shows well-defined and stronger costellae. *Planihaydenella* Chang, 1987, as reported by Shen et al. (2017), is characterized by low, rounded costellae, with narrow interspaces. This description matches well with the morphology of the Sosio specimens. However, Shen et al. (2017) regarded the ornamentation of *Planihaydenella* as representing intraspecific variation within *Haydenella*, synonymizing the two genera. Here we follow the interpretation proposed by Shen et al. (2017).

Subfamily Overtoniinae Muir-Wood & Cooper, 1960
Tribe Costispiniferini Muir-Wood & Cooper, 1960

Genus *Comuquia* Grant, 1976
Type species *Comuquia modesta* Grant, 1976

Remarks - The shape and the ornamentation of *Comuquia* Grant, 1976, particularly the arrangement of ventral spines, are generally similar to those of *Overtonia* Thomas, 1914 and *Fimbrinia* Cooper, 1972. However, both genera differ from *Comuquia* in possessing strong concentric laminae with spines arranged in rows, as opposed to the generally weaker lamellae and more scattered spine distribution characteristic of *Comuquia* (Grant, 1976). *Avonia* Thomas, 1914 is also comparable in the ovate outline and weak lamellae but differs in the presence of costae, which are absent in *Comuquia*.

Comuquia modesta Grant, 1976
(Pl. 1, fig. 7)

1976 *Comuquia modesta* Grant, p. 99, Pl. 21, figs 1-29.
2002 *Comuquia modesta* Grant - Grunt & Novikova, p. 33, Pl. 1, fig. 7a-c.

Material - Fourteen ventral valves: A68-3, C130-2, C130-3, C130-4, C130-5, C130-6, C130-9, C130-10, C130-11, C130-12, C130-13, C130-14, D83-2, E13-3; one external cast of a dorsal valve: A68-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Pietra dei Saraceni (Rupe di San Benedetto) megablock, Rupe di San Calogero megablock; Roadian-Wordian.

Description - Shell small sized (2-6 mm wide, 3-6 mm long), slightly ovate in outline, concavo-convex in profile; posterior margin straight; ears small. Ventral valve convex; umbo small, recurved, slightly extended beyond the posterior margin. Spine bases small, rounded, scattered on ventral valve; concentric growth lines weakly developed, mostly visible on umbo, not extending to ears.

Remarks - These specimens are closely similar to *Comuquia modesta* from the Roadian-Wordian of Thailand (Grant, 1976, pl. 21), particularly in the slightly ovate outline and small size. *Comuquia himalayaensis* Jin & Sun, 1981 from the Guadalupian of Tibet differs in having less developed ventral spines (Xu et al., 2021). These specimens are more likely to resemble *C. modesta* in their stouter spine bases. Some of the Sosio Limestone specimens have fewer spines than typical material of *C. modesta*; however, this reduction is likely attributable to preservation.

Distribution - Rat Buri Limestone, Roadian-Wordian, Thailand (Grant, 1976); Kichkhi-Burnu Block, Permian, Ukraine (Grunt & Novikova, 2002).

Genus *Dyschrestia* Grant, 1976
Type species *Dyschrestia spodia* Grant, 1976

Remarks - According to Grant (1976), *Dyschrestia* Grant, 1976 differs from *Comuquia* in its larger shell and denser spines. *Echinauris* Muir-Wood & Cooper, 1960 differs by having numerous, closely spaced spines on the ears and flanks. *Kemeria* Verna & Angiolini in Verna et al., 2011 is also comparable to *Dyschrestia*, although the latter differs in having a smaller shell size and in lacking rugae on the visceral disk of both valves.

Distribution - Cisuralian-Guadalupian of Australia (e.g., Archbold, 1984); Kungurian of China (Chen & Shi, 2006); Roadian-Wordian of Thailand (Grant, 1976; Waterhouse, 1981).

Dyschrestia sp.
(Pl. 1, fig. 8)

Material - Two ventral valves: A68-1, C130-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Shell small sized (> 10-11 mm wide, > 11-12 mm long); outline subrectangular, slightly elongated longitudinally; maximum width anterior to hinge. Ventral valve strongly convex, with narrow spiral lateral profile; umbo small, recurved; visceral disk swollen; flanks steep. Ornamentation of spine bases, small but rarely distinct, slightly elongated, densely spaced on visceral disk with apparent quincunx arrangement, roughly arranged along concentric rows on trail; growth lines pervasive, sometimes developed as lamellae; spine ridges relatively wide, originating at approximately two-thirds of valve length, widening and becoming higher anteriorly.

Remarks - The ornamentation of the studied specimens is similar to that of *Dyschrestia*, but differs in having strong spine ridges in the anterior portion of the ventral valve. The ornamentation of the specimens is close to that of *Kemeria* mainly for the numerous spines on the visceral disk and the strong spine ridges (as in specimen C130-1); however, the lack of distinct rugae on the visceral disk confirms their position within the genus *Dyschrestia*. Due to the poor preservation, the nomenclature is left open.

Subfamily Marginiferinae Stehli, 1954
Tribe Marginiferini Stehli, 1954

Genus *Spinomarginifera* Huang, 1932
Type species *Spinomarginifera kueichowensis* Huang, 1932

Remarks - The genus *Spinomarginifera* Huang, 1932 differs from *Marginifera* in having finer radial ribs and less localized spines that are not arranged in rows on the flanks. *Entacanthadus* Grant, 1993 is also comparable, but it differs in possessing more rounded spine bases, as opposed to those slightly elongated in *Spinomarginifera*.

Distribution - Sakmarian-Changhsingian of Russia (Licharew & Kotlyar, 1978; Kotlyar et al., 1989); Kungurian-Roadian of Oman (Viaretti et al., 2022); Roadian of Afghanistan (Termier et al., 1974); Roadian-Changhsingian of Iran (e.g., Angiolini & Carabelli, 2010; Crippa & Angiolini, 2012; Ghaderi et al., 2014; Viaretti et al., 2021); Roadian-Changhsingian of Japan (e.g., Tazawa, 2012, 2016, 2017); Wordian-Changhsingian of Transcaucasia (e.g., Ruzhentsev & Sarytcheva, 1965; Kotlyar et al., 1983, 1989); Wordian-Changhsingian of Pakistan (Reed, 1944; Grant, 1970; Angiolini, 1995, 2001); Wordian-Changhsingian of Turkey (Angiolini et al., 2007; Verna et al., 2011); Capitanian of Hong Kong (Liao et al., 1997); Capitanian-Wuchiapingian of Malaysia (Yanagida & Aw, 1979; Sone et al., 2001); Lopingian of China (e.g., Shen et al., 1992, 2019; Chen et al., 2005; Zeng et al., 2007; Zhang et al., 2013; Wu et al., 2022); Lopingian of Hungary (e.g., Posenato et al., 2005); Lopingian of India (Diener, 1903); Lopingian of Serbia (Albrecht, 1924); Wuchiapingian of Greece (Clapham & Bottjer, 2007); Changhsingian of Italy (Farabegoli et al., 2007); Changhsingian of Thailand (Waterhouse, 1983; Shi et al., 1996); Changhsingian of Texas, USA (Walter, 1953); Changhsingian of Vietnam (Shi & Shen, 1998).

Spinomarginifera cf. *Spinomarginifera spinosocostata* (Abich, 1878)
(Pl. 1, fig. 9)

Material - One ventral valve: E13-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Rupe di San Calogero megablock; Roadian-Wordian.

Description - Small sized valve (about 15 mm wide and long), with a subrectangular, longitudinally elongated outline; maximum width at the hinge. Ventral valve strongly convex, geniculated, trail long; umbo small, quite swollen. Ears small, mostly flattened. Spine bases scattered on visceral disk and arranged in quincunx, rounded in the most posterior portion of the visceral disk and umbonal area, becoming slightly elongated towards the trail. At least three spine bases arranged in row occur between the venter and the ears. Ribs on the trail, low and wide, some bifurcating anteriorly; growth lines are pervasive on the valve, mostly visible in the umbonal area.

Remarks - The studied specimen is assigned to *Spinomarginifera* because of the elongated, subrectangular outline and strongly convex ventral valve, with a long trail, together with the ornamentation made of densely spaced spine bases on the visceral disk, not in rows. The ornamentation of quincunx arranged spine bases on the visceral disk and ribs on the trail are diagnostic features of *Spinomarginifera spinosocostata* (Abich, 1878) from the Lopingian of Armenia and comparable with the description of *S. spinosocostata* from the Wuchiapingian of Iran (Viaretti et al., 2021).

Tribe Incisiini Grant, 1976

Genus *Incisius* Grant, 1976
Type species *Incisius concisus* (Grant, 1976)

Remarks - Grant (1976) considers *Cyrtalosia* Termier & Termier, 1970 the most similar genus to *Incisius*, but the former differs in lacking spines on the ventral valve.

Distribution - Cisuralian-Changhsingian of China (e.g., Li et al., 1986; Liao & Meng, 1986; Shen et al., 2003); Asselian of Slovenia (Schellwein, 1900); Sakmarian of Japan (Tazawa et al., 2022); Roadian-Wordian of Thailand (Grant, 1976); Roadian of Ukraine (Boiko et al., 1991); Changhsingian of Transcaucasia (Licharew, 1937).

Incisius sp.
(Pl. 1, fig. 10)

Material - Two ventral valves: C110-1, C110-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized valve (6 mm wide, 7-7.5 mm long), elongated in outline, with a strongly convex ventral profile; umbo small, recurved; posterior margin with small ears partly preserved. Ventral valve convex, slightly geniculated, with a wide and deep median sulcus originating at umbo. Spine bases arranged in rows on flanks of the valve and on the venter near the sulcus. The sulcus has low rugae/lamellae.

Remarks - The specimens are assigned to the genus *Incisius* for the elongated outline of the valves, the deep median sulcus and ornamentation. The specimens from this collection are similar to *Incisius incisus* Schellwein, 1900 as described by Grant (1976) from the Roadian-Wordian of Thailand, but differ in having a slightly wider sulcus with somehow steeper flanks. Due to the poor preservation, the nomenclature is left open.

Tribe Paucispiniferini Muir-Wood & Cooper, 1960

Genus *Caricula* Grant, 1976
Type species *Caricula salebrosa* Grant, 1976

Remarks - The genus *Caricula* Grant, 1976 differs from *Retimarginifera* Waterhouse, 1970 (Tab. 2) in having a smaller size and weaker costae. The sulcus of *Caricula* lacks costae and internally *Caricula* has a slenderer cardinal process than *Retimarginifera*. *Caricula* also resembles *Transennatia* Waterhouse, 1975, however the latter is generally larger, more uniformly convex and less sharply geniculated than *Caricula* (Tab. 2). Moreover, *Caricula* has a deeper median sulcus, fewer spines and costae, and more extended and somehow smoother ears than *Transennatia*.

Distribution - Kungurian of Oman (Viaretti et al., 2022); Roadian-Wordian of Thailand (Grant, 1976; Waterhouse, 1981); Changhsingian of China (He et al., 2009); Changhsingian of Malaysia (Sone et al., 2003).

Caricula cf. *Caricula salebrosa* Grant, 1976
(Pl. 1, figs 11-13)

Material - One ventral valve: E12-1; twelve external casts of dorsal valves: A70-1, C96-1, C96-2, C96-3, C96-4, C96-5, C124a-1, C124a-2, C124a-3, C124a-4, C124a-5, E13-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Rupe di San Calogero megablock; Roadian-Wordian.

Description - Shell small sized (7.5-16 mm wide, > 9-> 10.5 mm long), subrectangular to transverse in outline; maximum width at the hinge; ears extended, smooth, bending following geniculation. Ventral valve convex, geniculated, with slightly convex to flat visceral disk; umbo small, only slightly extended beyond the posterior margin; trail partly visible, almost twice as long as visceral disk; median sulcus generally deep and narrow, originating from umbo, variable in width but generally reaching its maximum width at geniculation and trail, forming bilobate shape. Dorsal valve concave, strongly geniculated; median fold narrow, quite high, corresponding to the ventral median sulcus. Ornamentation of the ventral valve reticulated on visceral disk made by strong rugae and low but distinct costae; costae stronger anteriorly on visceral disk and at the start of the trail, numbering one to two in 1 mm at almost 2 mm from the start of the trail; some costae bifurcate at the sides of the sulcus, which internally lacks ornamentation. Costae disappear at almost 5 mm from the start of the trail, leaving the distal portion of the shell smooth. Row of five/six spine bases on the shell flanks; other spine bases more scattered on the venter of the ventral valve. Ornamentation of dorsal valve reticulated on visceral disk, with costae disappearing on the distal portion of the trail; spines absent.

Remarks - Most of the studied specimens are external casts of dorsal valves belonging to a species of the genus *Caricula*. The specimens are similar to *Caricula salebrosa* Grant, 1976 from the Roadian-Wordian of Thailand, but the ears are partly incomplete in almost every specimen and only rarely are comparable in size. Specimen E12-1, which is considered the only preserved ventral valve, seems to have slightly more extended ears than those of *C. salebrosa* figured by Grant (1976; pl. 31, figs 1-30).

EXPLANATION OF PLATE 1

(color online) Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm. Yellow arrows highlight characteristic features (e.g., decorticated areas, spine bases).

Figs 1-2 - *Megapleuronia grecoi.*
1 - B08-1, (a) detail of the decorticated area on the ventral umbo.
2 - A41-2, (a) ventral view; (b) dorsal view; (c) enlargement of ventral view; (d) enlargement of dorsal view.

Fig. 3 - *Costachonetina* sp. C131-1, (a) ventral view; (b) enlargement of ventral view.

Fig. 4 - *Neochonetes* (*Nongtaia*) sp. D84-2, (a) dorsal view; (b) ventral view; (c) enlargement of ventral view; (d) enlargement of dorsal view.

Figs 5-6 - *Haydenella* sp.
5 - C132-1, (a) postero-ventral view; (b) enlargement of postero-ventral view.
6 - D86-4, (a) lateral view; (b) ventral view; (c) enlargement of lateral view; (d) enlargement of ventral view.

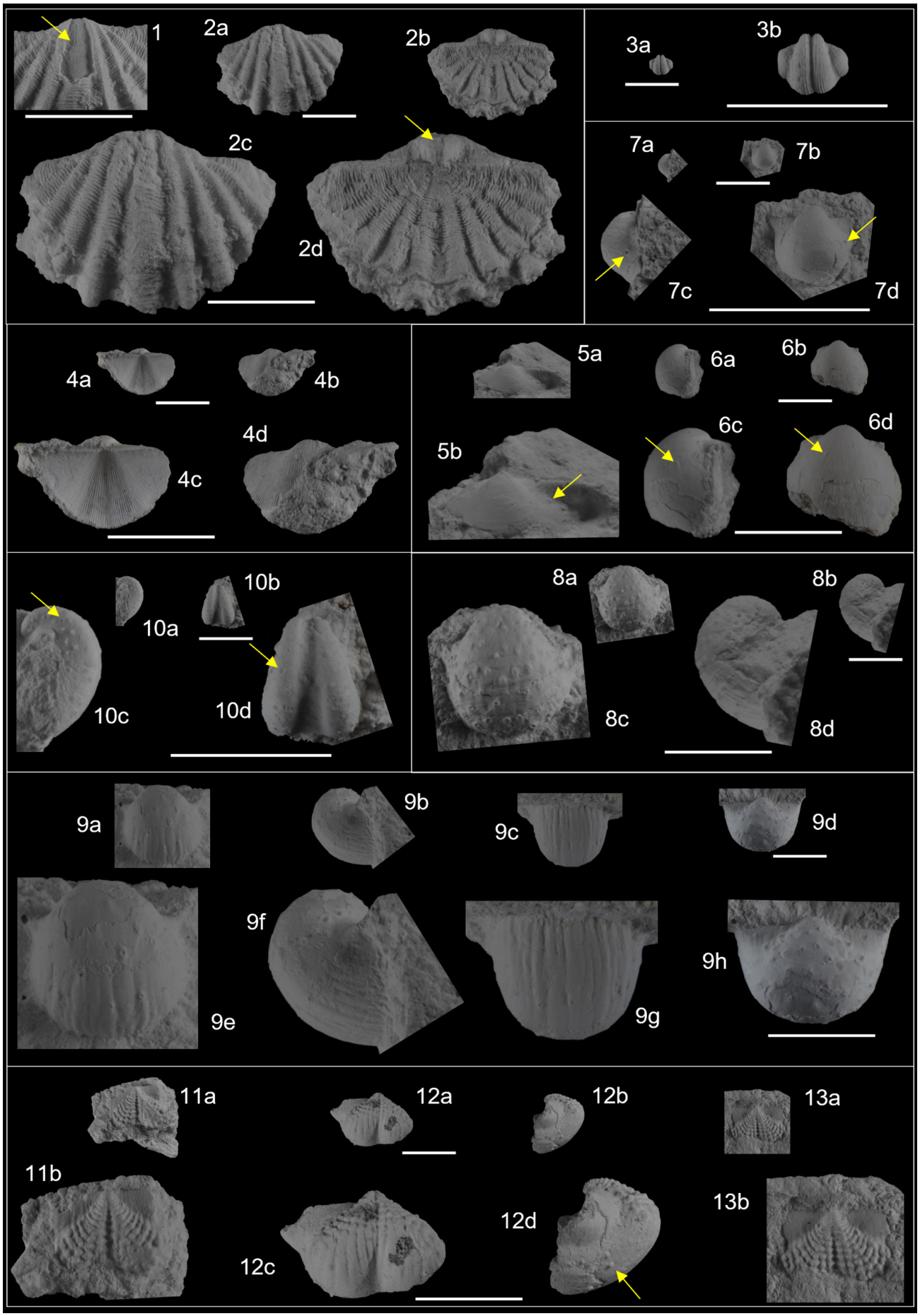
Fig. 7 - *Comuquia modesta.* C130-5, (a) lateral view; (b) ventral view; (c) enlargement of lateral view; (d) enlargement of ventral view.

Fig. 8 - *Dyschrestia* sp. C130-1, (a) ventral view; (b) lateral view; (c) enlargement of ventral view; (d) enlargement of lateral view.

Fig. 9 - *Spinomarginifera* cf. *Spinomarginifera spinosocostata.* E13-2, (a) ventral view; (b) lateral view; (c) anterior view; (d) posterior view; (e) enlargement of ventral view; (f) enlargement of lateral view; (g) enlargement of anterior view; (h) enlargement of posterior view.

Fig. 10 - *Incisius* sp. C110-2, (a) lateral view; (b) ventral view; (c) enlargement of lateral view; (d) enlargement of ventral view.

Figs 11-13 - *Caricula* cf. *Caricula salebrosa.*
11 - C96-5, (a) ventral view; (b) enlargement of ventral view.
12 - E12-1, (a) ventral view; (b) lateral view; (c) enlargement of ventral view; (d) enlargement of lateral view.
13 - C96-1, (a) ventral view; (b) enlargement of ventral view.


1
2a
2b
2c
2d
3a
3b
7a
7b
7c
7d
4a
4b
4c
4d
5a
6a
6b
5b
6c
6d
10a
10b
10c
10d
8a
8b
8c
8d
9a
9b
9c
9d
9e
9f
9g
9h
11a
11b
12a
12b
12c
12d
13a
13b

Genus *Transennatia* Waterhouse, 1975
Type species *Productus gratiosus* Waagen, 1884

Remarks - The genus *Transennatia* is similar to *Retimarginifera* but, according to Grant (1976), *Retimarginifera* differs in having a less sharp ornamentation, more transverse outline, more extended ears; spines in *Transennatia* are more numerous and more evenly distributed on the ventral valve and flanks (Tab. 2). Internally, *Retimarginifera* has a defined marginal ridge, longer median septum and in the ventral valve an adductor platform which is not raised.

Distribution - Asselian-Capitanian of Laos (Mansuy, 1913); Sakmarian-Wuchiapingian of Malaysia (Leman, 1994; Sone et al., 2003); Artinskian-Wuchiapingian of China (e.g., Campi & Shi, 2007; Shen & Shi, 2008; Chen et al., 2009; Shen et al., 2010; Wu et al., 2022); Kungurian-Roadian of Oman (Viaretti et al., 2022); Kungurian-Capitanian of Japan (e.g., Tazawa, 2001, 2008; Tazawa & Araki, 2017); Kungurian-Wuchiapingian of Pakistan (e.g., Reed, 1944; Angiolini, 1995); Guadalupian of Russia (e.g., Licharew & Kotlyar, 1978; Shi et al., 2022); Roadian of Ukraine (Boiko et al., 1991; Kotlyar et al., 1999); Roadian of Myanmar (Diener, 1911); Roadian of Vietnam (Mansuy, 1908); Roadian-Changhsingian of Thailand (Grant, 1976; Waterhouse, 1983; Shi et al., 1996); Wordian-Capitanian of Cambodia (Mansuy, 1913; Delpey, 1941); Lopingian of India (Diener, 1915); Wuchiapingian of Armenia (Kotlyar et al., 1983); Wuchiapingian of Azerbaijan (Kotlyar et al., 1983); Wuchiapingian of Greece (Clapham & Bottjer, 2007); Wuchiapingian of Indonesia (e.g., Archbold & Bird, 1989).

Transennatia sp.
(Pl. 2, fig. 1)

Material - One ventral valve: C95-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized valve (15 mm wide, 13 mm long), with subrectangular outline; maximum width at the hinge. Umbo partially preserved, recurved, slightly extended beyond the posterior margin. Ears partially preserved, poorly ornamented with rugae. Ventral valve strongly convex, geniculated; median sulcus wide and deep, originating near the umbo. Ornamentation reticulated on the visceral disk with costae and rugae. Costae sharp and irregular, numerous on the entire valve, numbering two to three in 1 mm in the distal part of the trail; some costae bifurcating on the flanks and trail, anteriorly converging in the sulcus. Rugae posteriorly high and sharp, particularly evident in the central trough of the sulcus in the visceral disk where they cross two distinct costae.

Remarks - The studied specimen shows the characteristic reticulated ornamentation of *Transennatia* on the visceral disk and strong costae on the trail. *Transennatia insculpta* Grant, 1976 from the Roadian-Wordian of Thailand differs in having a less inflated ventral valve. *Transennatia gratiosa* (Waagen, 1884) from the Roadian-Wordian of Thailand figured by Grant (1976; pl. 33, figs 19-26) has a similar ornamentation but differs in having a shallower median sulcus. Due to the poor preservation, the nomenclature is left open.

Family Productidae Gray, 1840
Subfamily Productinae Gray, 1840

Genus *Chaoina* Jin in Jin et al., 1974
Type species *Chaoina reticulata* Jin in Jin et al., 1974

Remarks - The genus *Chaoina* Jin in Jin et al., 1974 was first assigned to Monticuliferidae by Hu (1983) and later left uncertain by Brunton et al. (2000). More recently, Shen et al. (2017) assigned *Chaoina* to Productinae, based on the developed reticulation on the ventral valve. *Chaoina* differs from *Transennatia* by having simple costae with few bifurcations, an umbonal cicatrix of attachment, and a smooth adductor platform and a breviseptum in the dorsal valve interior (Shen et al., 2017).

Main features	*Caricula*	*Retimarginifera*	*Transennatia*
Size	Small	Small	Small to medium
Outline	Transverse	Transverse	Subquadrate
Ears	Extended	Extended	Small
Visceral disk	Strongly rugose, slightly reticulated	Reticulated	Strongly reticulated
Geniculation	Strong	Strong	Weak
Costae	Stronger on visceral disk, low on trail, absent in its anteriormost portion	Generally low on the entire valve, converging into the sulcus	Strong, converging into the sulcus
Rugae	Strong on visceral disk, low on ears	Low on visceral disk and ears	Strong on visceral disk and ears
Spines	Few on ears and venter	Few on ears and venter	More numerous and scattered
Sulcus	Narrow, deeper, starting near the umbo	Deep, starting at 10 mm from the umbo	Wide, shallower
Internal features	Cardinal process V-shaped. Median septum raised anteriorly. Lateral and marginal ridges extended around corpus, brachial ridges prominent	Cardinal process sessile, trifid. Lateral and marginal ridges extended, lost anteriorly	Cardinal process sessile, quadrifid. Marginal ridge only along ridge and across ears

Tab. 2 - Comparison of the main features of *Caricula*, *Retimarginifera* and *Transennatia*. Data used for the comparison are based on descriptions by Grant (1976) and Brunton et al. (2000).

Chaoina reticulata Jin in Jin et al., 1974
(Pl. 2, fig. 2)

1974 *Chaoina reticulata* Jin in Jin et al., p. 308, Pl. 162, figs 8-9.
1978 *Chaoina reticulata* Jin in Jin et al. - Tong, p. 230, Pl. 81, fig. 5.
1982 *Chaoina reticulata* Jin in Jin et al. - Wang et al., p. 214, Pl. 83, fig. 4.
1995 *Chaoina reticulata* Jin in Jin et al. - Zeng et al., Pl. 5, fig. 9.
2017 *Chaoina reticulata* Jin in Jin et al. - Shen et al., p. 709, Pl. P7, figs 21-22.

Material - Four articulated shells: A53-1, A57-4, A57-5, C96-7; three ventral valves: A53-2, C96-6, C128-1; one dorsal valve: A57-1; five external casts of dorsal valves: A53-3, A57-2, A57-3, A57-6, D82-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Description - Shell small sized (> 7-16 mm wide, > 7.5-> 12.5 mm long, 3.3-8 mm thick), transverse in outline, plano-convex in lateral profile, with slightly uniplicate anterior commissure. Umbo small, pointed, not recurved, with small cicatrix of attachment. Ears generally small and flat, mostly smooth. Ventral valve geniculate, with a flat visceral disc; shallow median sulcus originates from mid length of visceral disc. Dorsal valve with a low median fold starting approximately at mid-length of the valve. Ornamentation of visceral disc reticulated by rugae and costae. Coarse, rounded costae, on the trail, slightly converging in the sulcus, numbering one to two in 1 mm measured on the start of the trail. Some costae bifurcate at the sides of the sulcus.

Remarks - The studied specimens are assigned to *Chaoina* because of the general outline and shape of the shells, the reticulated ornamentation and the presence of a cicatrix of attachment on the umbo. The studied specimens have a strong distinct reticulation on visceral disks as *Chaoina reticulata* from the Kungurian of China, as figured in Shen et al. (2017; pl. P7, figs 21-22).

Distribution - Qixia Fm., Kungurian, China (Jin et al., 1974; Zeng et al., 1995); Maokou Fm., Wordian-Capitanian, China (Tong, 1978; Wang et al., 1982).

Subfamily Dictyoclostinae Stehli, 1954

Genus *Stereochia* Grant, 1976
Type species *Stereochia litostyla* Grant, 1976

Remarks - The genus *Stereochia* Grant, 1976 is similar to *Costiferina* Muir-Wood & Cooper, 1960, but ultimately differs in its overall smaller size, more reticulated dorsal disc and lower costae on the ventral valve. Moreover, *Stereochia* lacks a distinct marginal ridge in the dorsal valve, which is more prominent in *Costiferina*.

Distribution - Artinskian-Wuchiapingian of China (e.g., Sun, 1991; Chen et al., 2003; Shen et al., 2003); Guadalupian of Indonesia (e.g., Archbold, 1981); Roadian-Wordian of Thailand (Grant, 1976; Waterhouse, 1981; Shi et al., 2001); Wordian of Cambodia (Mansuy, 1913); Lopingian of India (Diener, 1903).

Stereochia sp.
(Pl. 2, fig. 3)

Material - One external cast of a dorsal valve: A48-1; one fragment of a ventral valve: A48-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Medium sized valve (> 11.5-> 37.5 mm wide, > 12-> 22 mm long), rectangular in outline; maximum width at the hinge. Ears extended, triangular, weakly ornamented with rugae. Dorsal valve strongly geniculated with a narrow angle between the visceral disk and the trail; visceral disk concave; dorsal fold originating from mid visceral disk. Ornamentation of visceral disk reticulated by costae and rugae, the latter finer. Costae low and quite fine on the trail, numbering four-five in 5 mm at the start of the trail.

Remarks - The studied specimens are assigned to *Stereochia* for the general shape and ornamentation of reticulated visceral disk and costae on the trail. Due to the poor preservation, the available specimens are left in open nomenclature.

Superfamily Echinoconchoidea Stehli, 1954
Family Echinoconchidae Stehli, 1954
Subfamily Juresaniinae Muir-Wood & Cooper, 1960
Tribe Calliprotoniini Lazarev, 1985

Genus *Calliprotonia* Muir-Wood & Cooper, 1960
Type species *Calliprotonia renfrarum* Muir-Wood & Cooper, 1960

Remarks - The genus *Calliprotonia* Muir-Wood & Cooper, 1960 closely resembles *Vediproductus* Sarytcheva in Sarytcheva & Sokolskaya, 1965, differing because of its less prominent and more lamellose bands. Spine bases in *Vediproductus* are generally coarser and elongated posteriorly and smaller and more rounded anteriorly on each band, differing from the ones in *Calliprotonia* which are usually more numerous and appear more uniformly rounded; also in *Calliprotonia* the posterior part of each band is devoid of spines. Moreover, the outline in *Vediproductus* is subtriangular while that of *Calliprotonia* is sub-ovate or sub-quadrate.

Distribution - Pennsylvanian of USA (e.g., Langenheim et al., 1985; Kues, 2009); Moscovian of South Korea (Lee et al., 2010); Gzhelian of Russia (Lazarev, 1985); Cisuralian of Canada (e.g., Yole, 1963; Logan & McGugan, 1968; Nassichuk & Spinosa, 1972; Shi & Waterhouse, 1996); Cisuralian of Russia (Kalashnikov,

1993); Cisuralian-Roadian of USA (e.g., Cooper, 1957; Cooper & Grant, 1972; Mills & Langenheim, 1987); Asselian of Iran (Angiolini & Stephenson, 2008); Kungurian- Wordian of Oman (Angiolini & Bucher, 1999; Viaretti et al., 2022); Guadalupian of Japan (Tazawa & Shen, 1997).

Calliprotonia sp.
(Pl. 2, fig. 4)

Material - One articulated specimen: C94a-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Medium sized shell (> 17 mm wide, > 26 mm long), plano-convex, with an incomplete, longitudinally elongated subrectangular outline. Maximum width anterior to the hinge. Ventral valve strongly convex, with a swollen recurved umbo. Trail recurved, with a shallow median sulcus, but poorly preserved. Dorsal valve flat. Ornamentation of ventral valve of strong asymmetrical concentric bands, with rows of mostly rounded spine bases of two sizes, with larger ones in the central portion of the band; the posterior part of each band bears dense growth lines and usually no spines. Dorsal valve shows a similar ornamentation with more densely arranged and lamellose concentric bands.

Remarks - The specimen shows all external diagnostic features of typical *Calliprotonia*. The studied specimen is mostly similar to *Calliprotonia* sp. from the Guadalupian of Southeastern Oman (Angiolini & Bucher, 1999) mainly for the subrectangular outline and the ornamentation of concentric bands bearing spines bases, but a specific identification is difficult due to its preservation. The specimen differs from *Calliprotonia renfrarum* Muir-Wood & Cooper, 1960 and *Calliprotonia* sp. from the Permian of Texas (Muir-Wood & Cooper, 1960; Cooper & Grant, 1975) mainly for its less transverse outline. Due to the poor preservation, the nomenclature is left open.

Tribe Juresaniini Muir-Wood & Cooper, 1960

Genus *Juresania* Fredericks, 1928
Type species *Productus juresanensis* Tschernyschew, 1902

Remarks - The genus *Juresania* Fredericks, 1928 is closely similar to the genera *Vediproductus* and *Calliprotonia*, but differs in having quincunx arranged spines, whereas the latter genera have spines on concentric bands on both valves (Viaretti et al., 2022).

Distribution - Carboniferous of USA (e.g., Pérez-Huerta, 2007; Suess et al., 2009); Pennsylvanian of Belize (Dixon, 1956); Kasimovian-Gzhelian of China (Chen, 2004); Moscovian of Spain (Amerom et al., 1970); Permian of USA (e.g., Yochelson & Van Sickle, 1968; Cooper & Grant, 1972); Artinskian-Changhsingian of China (e.g., Sun, 1983; Li et al., 1986; Yang et al., 1987; Chen et al., 2003; Chen & Shi, 2006); Asselian of Iran (Angiolini & Stephenson, 2008); Asselian of Laos (Mansuy, 1913); Asselian-Sakmarian of Peru (Newell et al., 1953); Asselian-Sakmarian of Russia (Lazarev, 1982; Kalashnikov, 1993); Asselian-Kungurian of Thailand (Waterhouse, 1981); Sakmarian-Roadian of Japan (e.g., Tazawa & Shintani, 2010; Tazawa et al., 2016); Capitanian of Malaysia (Campi et al., 2000); Kungurian-Wordian of Oman (Angiolini & Bucher, 1999; Angiolini et al., 2003; Viaretti et al., 2022); Wordian of Turkey (Verna et al., 2011); Lopingian of Tibet (Yang et al., 1990); Wuchiapingian of Pakistan (Reed, 1944).

Juresania sp.
(Pl. 2, fig. 5)

Material - One articulated specimen: A50-2; three ventral valves: A50-1, A50-3, A50-4.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small to medium sized shell (11-20 mm wide, 9-> 19 mm long, 9.5 mm thick), subquadrate in

EXPLANATION OF PLATE 2

Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm.

Fig. 1 - *Transennatia* sp. C95-1, (a) ventral view; (b) posterior view; (c) lateral view; (d) enlargement of ventral view; (e) enlargement of posterior view; (f) enlargement of lateral view.

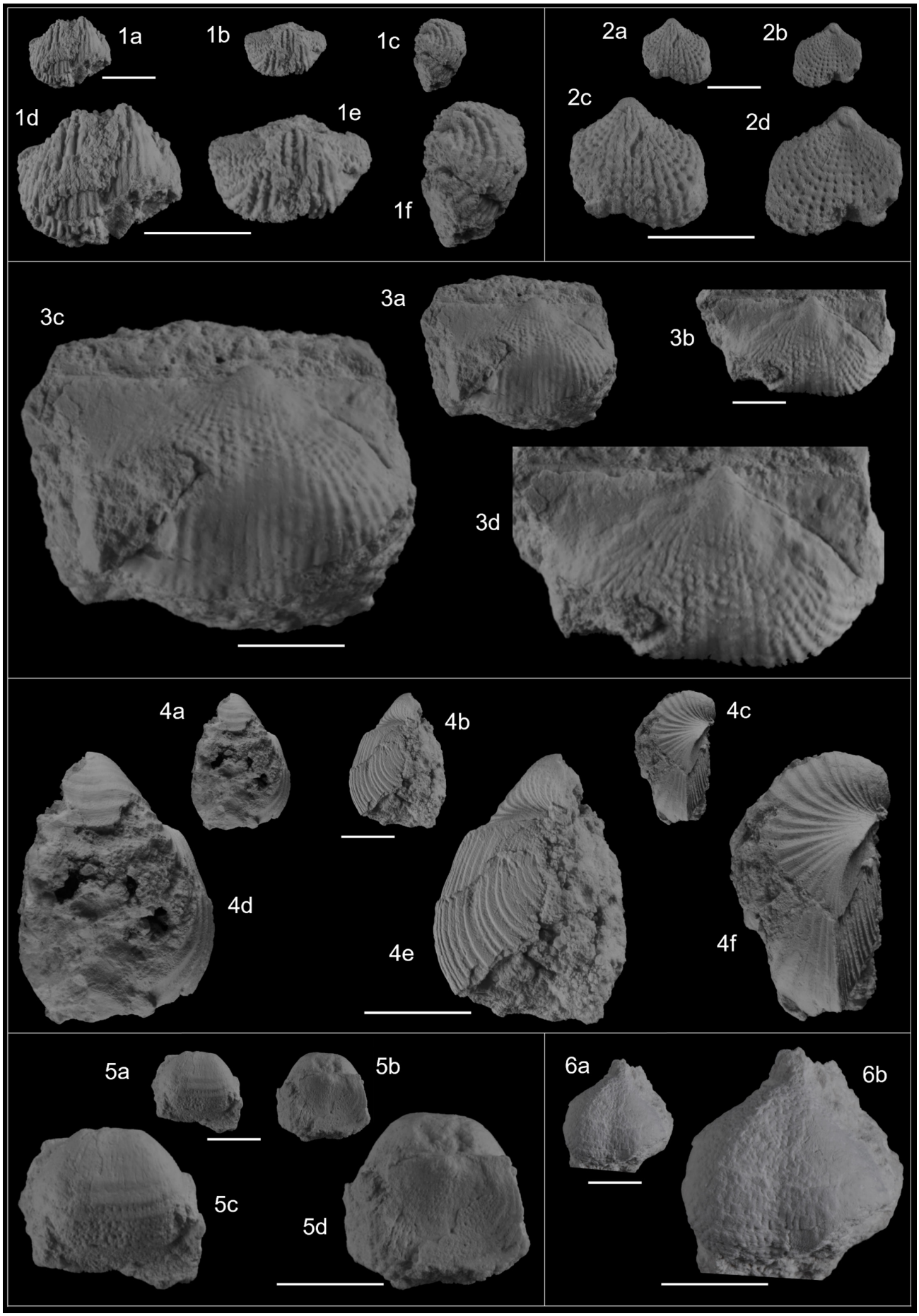
Fig. 2 - *Chaoina reticulata.* A57-4, (a) ventral view; (b) dorsal view; (c) enlargement of ventral view; (d) enlargement of dorsal view.

Fig. 3 - *Stereochia* sp. A48-1, (a) ventral view; (b) view of ventral visceral disk; (c) enlargement of ventral view; (d) enlarged view of ventral visceral disk.

Fig. 4 - *Calliprotonia* sp. C94a-1, (a) ventral view; (b) dorsal view; (c) lateral view; (d) enlargement of ventral view; (e) enlargement of dorsal view; (f) enlargement of lateral view.

Fig. 5 - *Juresania* sp. A50-1, (a) ventral view; (b) dorsal view; (c) enlargement of ventral view; (d) enlargement of dorsal view.

Fig. 6 - ?*Juresania* sp. D85-1, (a) ventral view; (b) enlargement of ventral view.


1a
1b
1c
1d
1e
1f
2a
2b
2c
2d
3c
3a
3b
3d
4a
4b
4c
4d
4e
4f
5a
5b
5c
5d
6a
6b

outline, concavo-convex; maximum width at the hinge. Ventral valve strongly geniculated with convex visceral disk and narrow and recurved umbo; trail almost twice the length of the disk. Dorsal valve concave, slightly geniculated. Ornamentation of small spines, some slightly elongated; on ventral valve arranged in quincunx posteriorly, in concentric lamellae anteriorly. On dorsal valve spines generally smaller, arranged in sort of bands, mostly visible in the anteriormost portion, roughly in two sizes.

Remarks - The quincunx arranged spine bases posteriorly and in bands anteriorly, together with the subquadrate outline, strongly convex and geniculated ventral valve correspond to the diagnostic characters of typical *Juresania*. However, due to the poor preservation, the nomenclature is left open.

?*Juresania* sp.
(Pl. 2, fig. 6)

Material - One ventral valve: D85-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Remarks - This single ventral valve is comparable to *Juresania* in the ornamentation of quincunx arranged spine bases and the valve outline. It differs from *Juresania* sp. from Pietra di Salomone megablock mainly in having a wide and low median sulcus on the ventral valve originating at the mid visceral disk. A reliable and definitive identification is hampered by the extremely poor preservation of the specimen.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Anidanthinae Waterhouse, 1968

Genus *Anidanthus* Hill, 1950
Type species *Linoproductus springsurensis* Booker, 1932

Remarks - The genus *Anidanthus* Hill, 1950 closely resembles *Megousia* Muir-Wood & Cooper, 1960 in size and ornamentation but the latter genus differs in having its alate ears, ornamented with radial costellae. *Protoanidanthus* Waterhouse & Briggs, 1986 is similar in its strongly convex and geniculated ventral valve, together with its ornamentation of numerous costellae. The main difference is represented by the smaller shell size and smaller ears of *Protoanidanthus*. Briggs (1998) considered *Protoanidanthus* as a synonym of *Anidanthus*, however differences between the two genera are yet to be fully clarified (Briggs, 1998; Williams et al., 2006), hence in this work the two genera are still kept separate following Crippa et al. (2014).

Distribution - Carboniferous of Alaska (Hahn et al., 1985); Cisuralian-Roadian of Australia (e.g., Waterhouse & Briggs, 1986; Briggs, 1998); Cisuralian-Changhsingian of Russia (Sarytcheva, 1977; Kotlyar et al., 1989); Asselian-Roadian of Canada (Waterhouse & Waddington, 1982; Shi & Waterhouse, 1996); Asselian-Changhsingian of China (e.g., Yang et al., 1990; Shen & He, 1994; Shen et al., 2003, 2016; Chen & Shi, 2006; Chen et al., 2009; He et al., 2014); Artinskian-Wordian of Mongolia (Afanasjeva, 2004; Manankov, 2004); Kungurian-Wuchiapingian of USA (Cooper, 1957; Yochelson & Van Sickle, 1968); Guadalupian-Changhsingian of Japan (e.g., Nakamura, 1972; Tazawa, 2008); Wordian of Mexico (Cooper et al., 1953); Wordian-Changhsingian of Iran (Stepanov et al., 1969; Angiolini & Carabelli, 2010); Capitanian of Cambodia (Nakamura, 1972); Capitanian-Wuchiapingian of Malaysia (Yanagida & Aw, 1979; Campi et al., 2000, 2005); Changhsingian of Nepal (Waterhouse, 1975, 1978); Changhsingian of Tajikistan (Grunt & Dimitriev, 1973).

Anidanthus sp.
(Pl. 3, figs 1-2)

Material - Six ventral valves: A47-1, A47-2, C101-1, C101-2, C125-1, D80-1; two moulds of dorsal valves: C100-1, C100-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Description - Medium sized shell (> 10-> 30 mm wide, > 6-> 16 mm long), subrectangular in outline, maximum width at the hinge; umbo recurved extending beyond the posterior margin; ears extended, costellate. Ventral valve strongly convex, geniculated, with a swollen visceral disk and a more flattened trail, only partly preserved; median sulcus wide and shallow, almost absent, originating near the end of the visceral disk. Dorsal valve geniculated with flat visceral disc. Ornamentation of ventral valve of fine and low costellae, variably spaced and rarely bifurcating anteriorly, numbering ten to 12 in 5 mm near mid-valve on the venter; rugae low, generally stronger on flanks and ears while disappearing on the corpus of the valve; spine bases few, scattered on the surface of the corpus. Ornamentation of dorsal valve of strong concentric rugae and very fine costellae interrupted by the rugae.

Remarks - The studied specimens share similarities both with *Anidanthus* and *Protoanidanthus*. The ornamentation of mainly costellae on the ventral valve and costellae paired with strong rugae interrupting the ribs on the dorsal valve represents a common feature of both genera. However, the studied specimens are assigned to *Anidanthus* because of their medium size, slightly larger than that of the species of *Protoanidanthus*. The studied specimens are similar to *Anidanthus ussuricus* Fredericks, 1924 from the Guadalupian of Japan (Nakamura, 1972) but differ because the latter has fewer costellae and no visible sulcus. *Anidanthus minor* Cooper, 1957 from the Kungurian of Oregon (Cooper, 1957) differs in its smaller dimensions. Due to the poor of preservation, the nomenclature is left open.

Family Monticuliferidae Muir-Wood & Cooper, 1960
Subfamily Compressoproductinae Jing & Hu, 1978

Genus *Compressoproductus* Sarytcheva, 1960
Type species *Productus compressus* Waagen, 1884

Remarks - The genus *Compressoproductus* Sarytcheva, 1960 is similar to *Striatifera* Chao, 1927a, but, according to Cooper & Grant (1975), it differs in its smaller size and the more distinct rugose ornamentation. Moreover, spines in *Compressoproductus* are generally coarser than in *Striatifera*.

Compressoproductus compressus (Waagen, 1884)
(Pl. 3, fig. 3)

1884 *Productus compressus* Waagen, p. 710, Pl. 81, figs 1-2.
1925 *Productus compressus* Waagen - Reed, p. 25, Pl. 5, fig. 3, 3a.
1927a *Striatifera compressa* (Waagen) - Chao, p. 99, Pl. 11, fig. 4a, b.
1961 *Compressoproductus compressa* (Waagen) - Zhang & Jin, p. 409, Pl. 3, figs 15-17.
1964 *Compressoproductus compressus* (Waagen) - Wang Y. et al., p. 334, Pl. 53, fig. 11.
1975 *Compressoproductus compressus* (Waagen) - Cooper & Grant, p. 1205, Pl. 457, figs 9-17.
1978 *Compressoproductus compressus* (Waagen) - Jin & Hu, p. 115, Pl. 2, figs 30-31.
1979 *Compressoproductus compressus* (Waagen) - Jin et al., p. 94, Pl. 27, fig. 17.
1982 *Compressoproductus compressus* (Waagen) - Liu et al., p. 188, Pl. 136, fig. 10.
1982 *Compressoproductus compressa* (Waagen) - Wang G. et al., p. 225, Pl. 86, fig. 17; Pl. 93, figs 15-16.
1984 *Compressoproductus compressus* (Waagen) - Wang S., p. 196, Pl. 81, figs 5-6.
1990 *Compressoproductus compressus* (Waagen) - Liang, p. 209, Pl. 34, fig. 4.
1995 *Compressoproductus compressus* (Waagen) - Zeng et al., Pl. 7, fig. 5.
2000 *Compressoproductus compressus* (Waagen) - Tazawa et al., Pl. 1, fig. 2a, 2b.

Material - five ventral valves: B21-1, C115-1, C115-2, C133-1, C134-1; internal cast of a ventral valve: B21-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small to medium sized shell (> 5-19 mm wide, > 7-22 mm long), subtriangular to elongated in outline, maximum width in the anterior part; posterior margin narrow; umbo small, recurved. Ventral valve convex with steep flanks, only slightly convex in the posterior region, flattening anteriorly. Ornamentation of irregular rugae; costellae numerous, irregular, some bifurcating anteriorly, numbering eight to ten at approximately 5 mm from the umbo.

Remarks - The specimens are assigned to *Compressoproductus compressus* from the Wordian-Changhsingian of Pakistan mainly because of their ornamentation and shape. *Compressoproductus mongolicus* (Diener, 1897) from the Wuchiapingian of Chitichun (Tibet) is very similar to the studied specimens, but differs in having coarser radial ornamentation (Tazawa et al., 2000).

Distribution - Oyakejima Fm., Guadalupian, Japan (Tazawa et al., 2000); Kufeng Fm., Maokou Fm., Wordian, China (Jin & Hu, 1978; Jin et al., 1979; Zhao & Tan, 1984); Amb and Chhidru Fms, Wordian-Changhsingian, Pakistan (e.g., Waagen, 1884; Reed, 1944); Lengwu Fm., Capitanian, China (Liang, 1990); Chandalaz Fm., Capitanian, Russia (Licharew, 1937; Licharew & Kotlyar, 1978); Dalong Fm., Loping Fm., Shuizhutang Fm., Wuchiapingian, China (Zhang & Jin, 1961; Zhao et al., 1978; Yang et al., 1987); Changhsing Fm., Changhsingian, China (Li et al., 1989; Shen & He, 1991; Zeng et al., 1995); Nikitina Balka, Changhsingian, Transcaucasia (Licharew, 1937).

Suborder Strophalosiidina Waterhouse, 1975
Superfamily Strophalosioidea Schuchert, 1913
Family Strophalosiidae Schuchert, 1913
Subfamily Strophalosiinae Schuchert, 1913

Genus *Heteralosia* King, 1938
Type species *Heteralosia slocomi* King, 1938

Remarks - The genus *Heteralosia* King, 1938 closely resembles *Strophalosia* King, 1844 for the outline and ornamentation, but according to Lee et al. (2023) it differs because of its smaller size and the occurrence of dimples on dorsal valve.

Distribution - Middle Devonian-Permian of USA (e.g., Rodriguez & Gutschick, 1967; Cooper & Grant, 1972; Wardlaw, 1977, Ausich et al., 1979; Langenheim et al., 1985); Famennian of China (Chen, 2010); Sakmarian-Kungurian of Australia (e.g., Waterhouse, 1970; Archbold & Thomas, 1985; Archbold, 1986; Dixon & Haig, 2004); Artinskian of Indonesia (Archbold, 1991); Cisuralian of Mongolia (Pavlova et al., 1991); Roadian-Wordian of Thailand (Grant, 1976); Wordian of Mexico (Cooper et al., 1953); Wordian-Wuchiapingian of Pakistan (e.g., Reed, 1944; Grant, 1966); Changhsingian of Transcaucasia (Licharew, 1937).

Heteralosia sp.
(Pl. 3, fig. 4)

Material - Two articulated specimens: A64-1, A64-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (10-11.5 mm wide, > 6.5-9 mm long, 4 mm thick), roughly subrectangular in outline, plano-convex; posterior margin straight, wide; umbo slightly recurved extending beyond the posterior margin. Ventral valve convex with a wide but low triangular interarea. Dorsal valve slightly concave.

Ornamentation of ventral valve of numerous spines, swollen, scattered on the valve roughly in quincunx; very low rugae are visible near the umbo. Ornamentation of dorsal valve with low concentric lamellae and dimples.

Remarks - The shell outline, spine bases scattered over the ventral valve, and dorsal dimples indicate that these specimens are assignable to *Heteralosia*. Due to the poor preservation, the nomenclature is left open.

Superfamily Aulostegoidea Muir-Wood & Cooper, 1960
Family Aulostegidae Muir-Wood & Cooper, 1960
Subfamily Chonosteginae Muir-Wood & Cooper, 1960

Genus *Chonostegoides* Sarytcheva in Sarytcheva & Sokolskaya, 1965
Type species *Chonostegoides ogbinensis* Sarytcheva in Sarytcheva & Sokolskaya, 1965

Remarks - The genus *Chonostegoides* Sarytcheva in Sarytcheva & Sokolskaya, 1965 differs from *Chonosteges* Muir-Wood & Cooper, 1960 and *Urushtenia* Licharew, 1935 in lacking any kind of concentric ornamentation and in having ribs limited to the anteriormost part of the trail.

Distribution - Artinskian-Changhsingian of China (Feng & Jiang, 1978); Wordian of Turkey (Sakagami, 1976); Wordian-Capitanian of Transcaucasia (e.g., Sarytcheva & Sokolskaya, 1965; Kotlyar, 1989); Wordian-Capitanian of Iran (e.g., Nakamura & Golshani, 1981; Taraz et al., 1981; Crippa & Angiolini, 2012).

Chonostegoides sp.
(Pl. 3, fig. 5)

Material - One articulated specimen: C102-1; one ventral valve: D88-1; one external cast of a dorsal valve: C102-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Description - Small to medium sized shell (> 9-14 mm wide, 10.5-13 mm long, 5.5-6.5 mm thick), with a subquadrate, slightly transverse outline, concavo-convex; posterior margin narrow; umbo small and slightly recurved. Ventral valve convex; visceral disk slightly convex to flattened; median sulcus variably developed. Dorsal valve concave, geniculated. Ornamentation of low and rounded spine bases, more numerous on visceral disk, and small, rounded costae on the trail.

Remarks - The studied specimens are assigned to the genus *Chonostegoides* due to their ornamentation. They are similar to *Chonostegoides ogbinensis* Sarytcheva in Sarytcheva & Sokolskaya, 1965 from the Wordian-Capitanian of Transcaucasia in having numerous spine bases on the visceral disk. However, *C. ogbinensis* differs in having ribs only developed on the dorsal valve.

Genus *Urushtenia* Licharew, 1935
Type species *Productus pseudomedusa* Tschernyschew, 1902

Remarks - The genus *Urushtenia* differs from *Chonosteges* in its stronger geniculation, fewer spines on the ventral visceral disk and in a much shallower ventral median sulcus. Costellae in *Chonosteges* are described as originating anteriorly on the trail, while in *Urushtenia* they originate in the anterior part of the visceral disk. *Strophalosiina* is another similar genus, but ultimately differs in having a higher and larger interarea and a more strongly geniculated ventral valve.

Distribution - Asselian of Laos (Mansuy, 1913); Asselian of Slovenia (Schellwein, 1900); Sakmarian-Changhsingian of Russia (Licharew, 1937; Sarytcheva & Grunt, 1969); Kungurian-Guadalupian of China (e.g., Jin

EXPLANATION OF PLATE 3

Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm.

Figs 1-2 - *Anidanthus* sp.
1 - D80-1, (a) ventral view; (b) enlargement of ventral view.
2 - A47-1 (a) posterior view; (b) ventral view.

Fig. 3 - *Compressoproductus compressus.* C115-2, (a) ventral view; (b) enlargement of ventral view.

Fig. 4 - *Heteralosia* sp. A64-1, (a) dorsal view; (b) ventral view; (c) enlargement of dorsal view; (d) enlargement of ventral view.

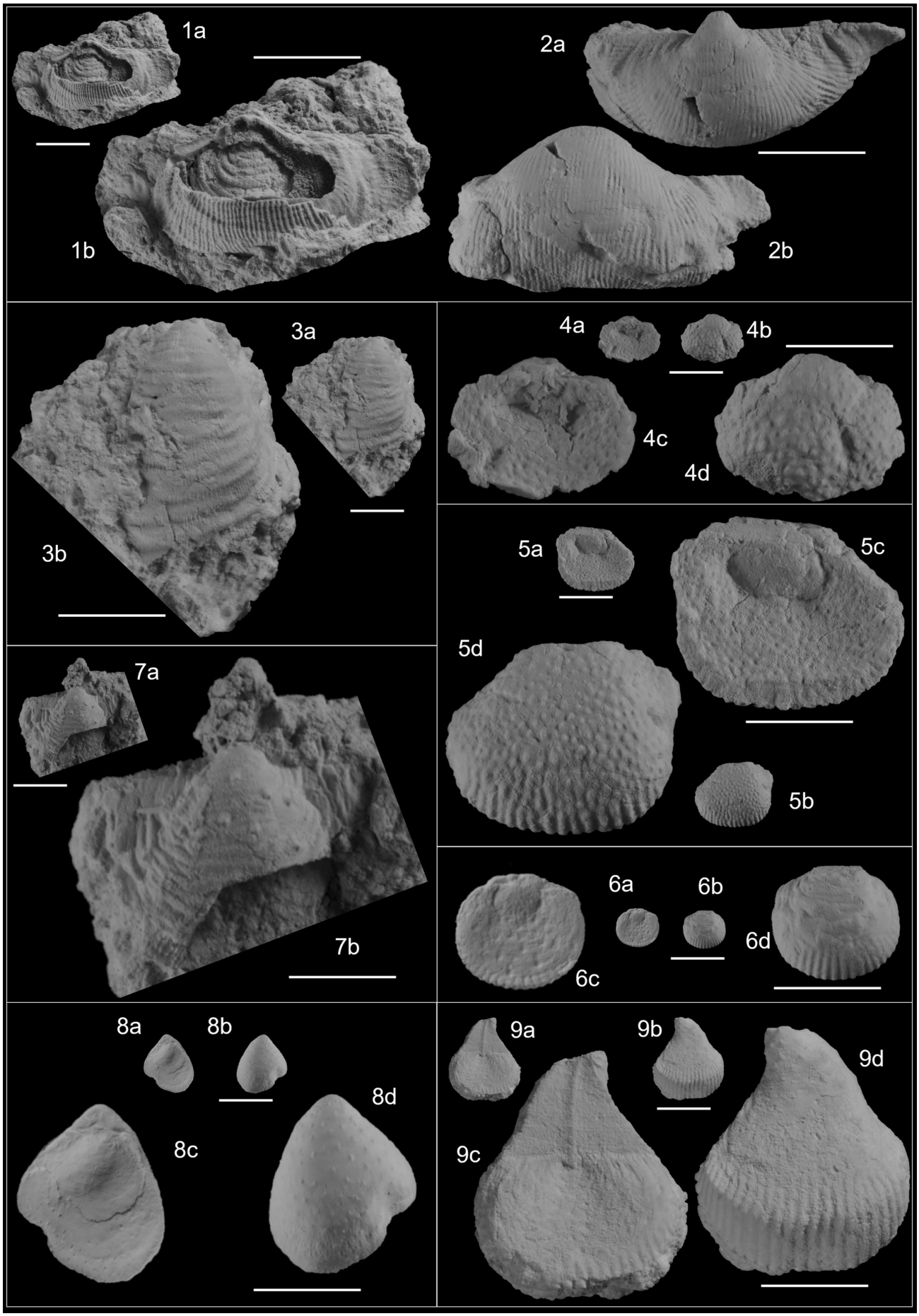
Fig. 5 - *Chonostegoides* sp. C102-1, (a) dorsal view; (b) ventral view; (c) enlargement of dorsal view; (d) enlargement of ventral view.

Fig. 6 - *Urushtenia* cf. *Urushtenia murina.* A63-1, (a) dorsal view; (b) ventral view; (c) enlargement of dorsal view; (d) enlargement of ventral view.

Fig. 7 - *Edriosteges* sp. C104-1, (a) ventral view; (b) enlargement of ventral view.

Fig. 8 - *Girlasia superelegans.* B22-1, (a) dorsal view; (b) ventral view; (c) enlargement of dorsal view; (d) enlargement of ventral view.

Fig. 9 - *Strophalosiina* sp. C136-1, (a) ventral view; (b) dorsal view; (c) enlargement of ventral view; (d) enlargement of dorsal view.


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

et al., 1974; Yang et al., 1977; Zhao & Zeng, 1977; Tong, 1978; Lee & Gu, 1980; Jin & Sun, 1981); Kungurian of Myanmar (Xu et al., 2021); Roadian-Wordian of Thailand (e.g., Grant, 1976; Waterhouse, 1981); Asselian-Roadian of Ukraine (Glushenko, 1975; Kotlyar et al., 1999); Capitanian of Cambodia (Delpey, 1941).

Urushtenia cf. *Urushtenia murina* Grant, 1976
(Pl. 3, fig. 6)

Material - One articulated specimen: A63-1; five ventral valves: A50-5, A63-2, C103-1, C103-2, C103-3.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (> 5-8.5 mm wide, > 5.2-8 mm long, 2.4-3 mm thick), with a transverse outline, plano-convex; maximum width near mid-valve. Ventral valve convex, variably geniculated, with a small, slightly recurved umbo and convex visceral disk. Dorsal valve flattened, only slightly concave near the umbo. Ornamentation of ventral valve of low, irregular rugae and rounded to slightly elongated spine bases scattered on the visceral disk; costellae originating at the anterior end of the disk and pervasive on the trail, numbering seven-eight in 5 mm at approximately mid-length of the trail. Ornamentation of dorsal valve of irregular rugae; fine costellae only near the anterior margin.

Remarks - The studied specimens are assigned to a species of the genus *Urushtenia* because of their ornamentation combining low but well differentiated rugae and spine bases on the visceral disk and distinct costellae on the trail. The outline and the ornamentation are similar to those of *Urushtenia murina* Grant, 1976 from the Roadian-Wordian of Thailand as figured in Grant (1976; pl. 20, figs 1-22), but the latter has costellae originating at mid-length of the visceral disk. *Urushtenia arguta* Grant, 1976 from the Roadian-Wordian of Thailand differs in having more pervasive costellae on the ventral visceral disk (Grant, 1976; pl. 20, figs 22-40).

Subfamily Echinosteginae Muir-Wood & Cooper, 1960

Genus *Edriosteges* Muir-Wood & Cooper, 1960
Type species *Edriosteges multispinosus* Muir-Wood & Cooper, 1960

Remarks - The genus *Edriosteges* Muir-Wood & Cooper, 1960 is similar to *Echinosteges* Muir-Wood & Cooper, 1960, differing in the concentric arrangement of the ventral spines. Moreover, *Echinosteges* has spines on the dorsal valve, absent in *Edriosteges*. *Limbella* Stehli, 1954 differs by having a more transverse outline with a wider posterior margin, and more pervasive capillae on the visceral disk.

Distribution - Permian of USA (Cooper & Grant, 1972); Sakmarian-Changhsingian of Japan (Yanagida, 1973; Tazawa, 1975; Shintani, 2011; Tazawa & Araki, 2014); Artinskian-Changhsingian of China (e.g., Yao et al., 1980; Liang, 1990; Shen & He, 1991; Sun, 1991; Chen et al., 2005; Li & Shen, 2008; Chen & Liao, 2009; Wang et al., 2011); Kungurian of Guatemala (Stehli & Grant, 1970); Kungurian-Wordian of Oman (Angiolini et al., 2003; Viaretti et al., 2022); Wordian-Wuchiapingian of Transcaucasia (Ruzhentsev & Sarytcheva, 1965; Kotlyar et al., 1989); Wordian of Pakistan (e.g., Reed, 1944); Wordian-Capitanian of Iran (Stepanov et al., 1969; Taraz et al., 1981); Capitanian of Malaysia (Campi et al., 2000); Capitanian of Mexico (Torres-Matinez et al., 2019); Capitanian-Wuchiapingian of Russia (Licharew & Kotlyar, 1978; Belyaeva et al., 1997).

Edriosteges sp.
(Pl. 3, fig. 7)

Material - One ventral valve: C104-1; one external cast of a dorsal valve: C129-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Medium sized shell (> 17-> 29.5 mm wide, > 11.5-> 22 mm long), slightly transverse to subquadrate in outline; maximum width at the hinge. Ventral valve convex with swollen, slightly recurved umbo. Dorsal valve with flat visceral disk, strongly geniculated but trail poorly preserved. Both valves ornamented with strong irregular rugae, both on the corpus and ears; short and stout spines and spine bases scattered on the ventral valve with capillae. Dorsal valve with small dimples.

Remarks - The specimens are comparable to *Edriosteges*, mainly in their subquadrate outline and numerous stout spines in the ventral valve only, but they also resemble *Limbella* by having a fine capillation on the ventral valve, although poorly visible on the visceral disk. However, the subquadrate outline of the specimens is atypical for *Limbella*, and the umbonal region of the ventral valve resembles that of specimens of *Edriosteges multispinosus* Muir-Wood & Cooper, 1960 from West Texas figured in Cooper & Grant (1975; pl. 219, figs 5-15). Due to the poor preservation, the nomenclature is left open.

Genus *Girlasia* de Gregorio, 1930
Type species *Strophalosia (Girlasia) superelegans* (de Gregorio, 1930)

Remarks - The genus *Girlasia* de Gregorio, 1930 has been documented only from the Sosio Limestone by de Gregorio (1930) and Muir-Wood & Cooper (1960) and from the Capitanian of Russia by Licharew & Kotlyar (1978). It is similar to *Entacanthadus* belonging to the Productoidea, but the latter is more transverse or rounded in outline and usually has a stronger concentric ornamentation.

Girlasia superelegans de Gregorio, 1930
(Pl. 3, fig. 8)

1930 *Strophalosia* (*Girlasia*) *superelegans* de Gregorio, p. 21, Pl. 4, figs 26-42.
1960 *Girlasia superelegans* de Gregorio - Muir-Wood & Cooper, p. 106, Pl. 19, figs 14-19.

Material - Two articulated specimens: B22-1, C109-1; three ventral valves: B22-2, B22-3, C130-7.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (5-9.5 mm wide, > 5.5-12 mm long, 3.5-5.8 mm thick), with a subtriangular outline. Maximum width at approximately mid-valve. Posterior margin narrow, curved. Ventral valve convex, uniformly recurved; umbo small, slightly recurved and extended beyond the posterior margin. Dorsal valve concave. Ornamentation of scattered, mostly rounded, spine bases, very weak rugae generally visible in the umbonal area of both valves.

Remarks - Due to their subtriangular outline and the characteristic ornamentation of scattered spines the specimens are assigned to *Girlasia superelegans* de Gregorio, 1930.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (De Gregorio, 1930; Muir-Wood & Cooper, 1960).

Genus *Strophalosiina* Licharew, 1935
Type species *Aulosteges tibeticus* (Diener, 1897)

Remarks - The genus *Strophalosiina* resembles the Chonosteginae *Urushtenia* and *Urushtenoidea* Jin & Hu, 1978 mainly because of concentric rugae and spines on the visceral disk and costae on the trail. However, both genera differ from *Strophalosiina* in having a less sharp geniculation and reduced interarea, with an almost absent elytridium (He et al., 2009).

Distribution - Cisuralian-Lopingian of China (e.g., Diener, 1897, 1903; Lee & Gu, 1980; Liao & Meng, 1986; Zhan, 1989; Liang, 1990; He et al., 2009; Shen et al., 2017); Capitanian of Cambodia (Delpey, 1941); Capitanian of Malaysia (Sone et al., 2001; Campi et al., 2005); Capitanian-Changhsingian of Transcaucasia (e.g., Licharew, 1937; Licharew & Kotlyar, 1978; Belyaeva et al., 1997); Wuchiapingian of Japan (Shimizu, 1961); Changhsingian of Tajikistan (Grunt & Dimitriev, 1973).

Strophalosiina sp.
(Pl. 3, fig. 9; Pl. 4, fig. 1)

Material - Two articulated specimens: C119-1, C136-1; one partially preserved ventral valve: C116-1; one dorsal valve: D87-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Pietra dei Saraceni (Rupe di San Benedetto) megablock; Roadian-Wordian.

Description - Small sized shell (> 6-13.5 mm wide, 10.5-18.5 mm long, 5.5-8.1 mm thick), with a transverse outline; posterior margin straight; umbo, extended beyond the posterior margin, and twisted laterally, anterior commissure faintly uniplicate. Ventral valve convex, geniculated; visceral disk longer than the trail; interarea triangular and high for genus; elytridium narrow, almost linear; a shallow median sulcus originates at the anteriormost part of the visceral disk and continues on the trail. Dorsal valve flat to gently concave. Ornamentation of ventral visceral disk of low rugae and spines scattered on the disk; trail with fine costae, numbering seven to eight in 5 mm, measured in the central part of the trail, at approximately 2 mm from the geniculation. Ornamentation of dorsal valve of rugae posteriorly, and low costae originating in the anteriormost part of the valve, near the commissure.

Remarks - The general shell outline and the ornamentation of the studied specimens are comparable to *Strophalosiina*, even if their very high interarea is not typical for the genus. *Strophalosiina chenxianensis* (Liao & Meng, 1986) from the Changhsingian of Hunan (China) is the most similar species, because of the flat ventral visceral disk, ornamented with concentric rugae and spine bases, and the regular fine costae anteriorly, but it differs by lacking the very high interarea typical of the Sosio specimens. These also differ from *Strophalosiina elegans* Lee & Gu, 1980 from the Cisuralian of northeast China as the latter usually has a more roundly triangular outline, lacks a median sulcus, and generally shows large spinose nodules on the visceral disk. The attribution of *S. elegans* to the genus *Strophalosiina* is however putative (Shen et al., 2017), further limiting the comparison with the studied material. *Strophalosiina tibetica* (Diener, 1897) from the Lopingian of China is another similar species, differing by having a less transverse outline and less numerous costae on the trail (Liao & Meng, 1986). *Strophalosiina multicostata* Licharew, 1937 from the Changhsingian of Transcaucasia (Russia) is smaller in size, with a less convex umbo and less geniculated shell (Liao & Meng, 1986). Based on their high interarea, the studied specimens may represent a new species of *Strophalosiina*, but the paucity of the available material prevents the erection of a new taxon.

Family Scacchinellidae Licharew, 1928
Subfamily Scacchinellinae Licharew, 1928

Genus *Scacchinella* Gemmellaro, 1891
Type species *Scacchinella variabilis* Gemmellaro, 1891

Remarks - According to Cooper & Grant (1975), *Scacchinella* has a peculiar shape and internal features which make it almost unique among other brachiopod genera. The overall shape is similar to the richthofeniids, mainly to some forms of *Gemmellaroia*. However, the

latter differs in its distinctive interarea, narrower and variably recurved, a more protruding pseudodeltidium and in a larger cardinal process, bladelike in shape. The external ornamentation of *Gemmellaroia* has fewer spines, or completely lacks them (Grant, 1993). *Derbyella* Grabau, 1931 is considered similar to *Scacchinella* by Cooper & Grant (1975) in the shape and ornamentation, but it has a more defined, convex pseudodeltidium.

Scacchinella variabilis Gemmellaro, 1891
(Pl. 4, figs 2-3)

1891 *Scacchinella variabilis* Gemmellaro, p. 22
1892 *Scacchinella variabilis* Gemmellaro - Gemmellaro, p. 26.
1896 *Scacchinella variabilis* Gemmellaro - Gemmellaro, p. 6, Pl. A, figs 1-13.
1930 *Scacchinella variabilis* Gemmellaro - de Gregorio, p. 20.
1930 *Scacchinella variabilis* var. *erecta* Gemmellaro - de Gregorio, p. 24, Pl. 5, figs 1-2, 13-15.
1947 *Scacchinella variabilis* Gemmellaro - Greco, p. 13, Pl. 2, figs 12-15; Pl. 3, figs 1-12.
1967 *Scacchinella variabilis* Gemmellaro - Rudwick & Cowen, p. 126, Pl. 34, figs 1-12.
2010 *Scacchinella variabilis* Gemmellaro - Verna et al., p. 317, Pl. 1, figs 5-7.

Material - Eleven articulated specimens: A114-1, A114-2, A114-3, A114-4, A114-5, B20-1, B23-1, C117-1, C126-3, C126-4, C126-5; three ventral valves: A113-1, C117-2, C126-1; one dorsal valve: C126-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small to medium sized (8-26.2 mm wide, 5.5-22 mm long, 7-21 mm thick), outline transversally elliptical to subcircular; posterior margin straight, narrower than the maximum width of the shells; anterior commissure rectimarginate. Ventral valve conical, interarea high, triangular and flattened, with longitudinal striae, crossed by transverse lines; pseudodeltidium indistinct or very low. Dorsal valve slightly convex to flat. Ornamentation of numerous spine bases scattered on the valves, smaller on the dorsal valve; concentric fila, generally more pronounced on the ventral valve; rare, low rugae are also present on the ventral valve.

Remarks - The morphology and ornamentation of the specimens, together with the wide and high interarea without a defined pseudodeltidium are distinctive features of the genus *Scacchinella*. *Scacchinella variabilis* Gemmellaro, 1891 from the Sosio Limestone (Roadian-Wordian) is the closest species in the outline, ornamentation and dimensions. *Scacchinella depressa* Gemmellaro, 1896, another species described by Gemmellaro (1896) from the Sosio Limestone (Roadian-Wordian), has a much lower interarea and a ventral valve more recurved posteriorly. The species from West Texas (*Scacchinella americana* Stehli, 1954; *Scacchinella exasperata* Cooper & Grant, 1975; *Scacchinella primitiva* Cooper & Grant, 1975; *Scacchinella titan* Cooper & Grant, 1975; *Scacchinella triangulata* Cooper & Grant, 1975 and *Scacchinella* species undetermined) described by Cooper & Grant (1975) are similar to the specimens under study, but they are larger in size.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Gemmellaro, 1896; de Gregorio, 1930; Greco, 1947); Djebel Tebaga, Wordian-Capitanian, Tunisia (Verna et al., 2010).

Superfamily Richthofenioidea Waagen, 1885
Family Richthofeniidae Waagen, 1885

Genus *Coscinarina* Muir-Wood & Cooper, 1960
Type species *Richthofenia communis* Gemmellaro, 1894

Remarks - The genus *Coscinarina* is similar to *Sicularia*, in its ornamentation of variably strong lamellae and variably numerous spines, but *Sicularia* is larger in size, with a larger diameter and has growth lamellae that appear slightly rugose. *Sicularia* also has larger interarea and pseudodeltidium, while the myocoelidium is present only in juvenile specimens, modified developing a long but low median septum in adult specimens (Grant, 1993).

EXPLANATION OF PLATE 4

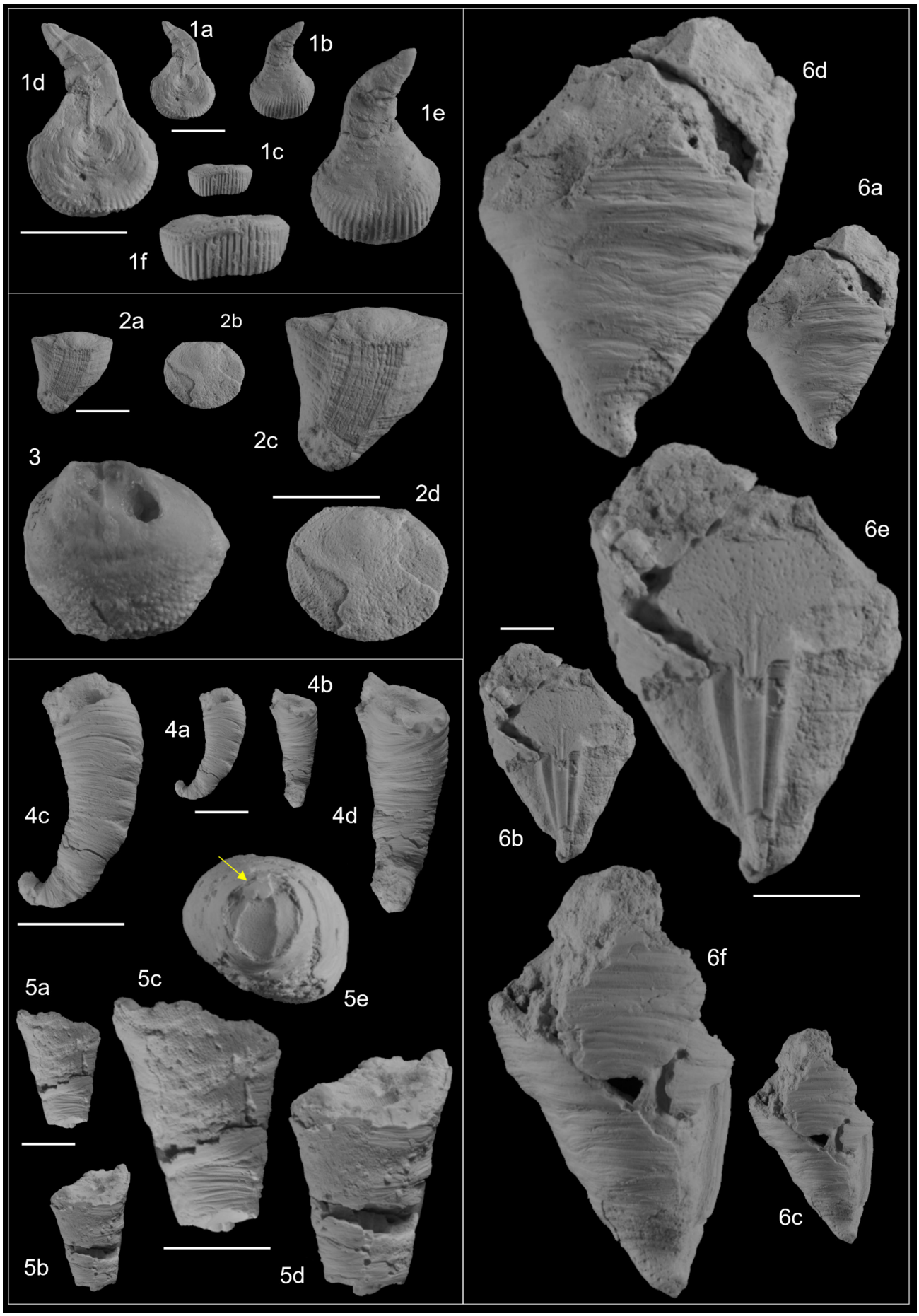
(color online) Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm. Yellow arrows highlight characteristic features (e.g., myocoelidium).

Fig. 1 - *Strophalosiina* sp. C119-1, (a) dorsal view; (b) ventral view; (c) anterior view; (d) enlargement of dorsal view; (e) enlargement of ventral view; (f) enlargement of anterior view.

Figs 2-3 - *Scacchinella variabilis.*
2 - B23-1, (a) posterior view; (b) dorsal view; (c) enlargement of posterior view; (d) enlargement of dorsal view.
3 - C126-3, (a) ventral view, detail of median septum.

Figs 4-5 - *Coscinarina communis.*
4 - A40-3, (a) lateral view; (b) posterior view; (c) enlargement of lateral view; (d) enlargement of posterior view.
5 - B17-9, (a) anterior view; (b) posterior view; (c) enlargement of anterior view; (d) enlargement of posterior view; (e) ventral view, detail of myocoelidium.

Fig. 6 - *Sicularia sicula.* A116-1, (a) anterior view; (b) posterior view; (c) lateral view; (d) enlargement of anterior view; (e) enlargement of posterior view; (f) enlargement of lateral view.


1a
1b
1d
1e
1c
1f
2a
2b
2c
3
2d
4b
4a
4c
4d
5a
5c
5e
5b
5d
6d
6a
6e
6b
6f
6c

Coscinarina differs from *Richthofenia* Kayser, 1881 by its longer and narrower ventral valve, while internally *Richthofenia* lacks a myocoelidium, having instead three septa, diagnostic for the genus (Muir-Wood & Cooper, 1960).

Coscinarina communis (Gemmellaro, 1894)
(Pl 4, figs 4-5)

1894 *Richthofenia communis* Gemmellaro, p. 7.
1930 *Richthofenia communis* Gemmellaro - de Gregorio, p. 28, Pl. 8, figs 1-6.
1947 *Richthofenia communis* Gemmellaro - Greco, p. 17, Pl. 3, figs 14-20.
1967 *Richthofenia communis* Gemmellaro - Rudwick & Cowen, p. 139, Pl. 38, figs 1-13; Pl. 39, figs 1-10; Pl. 40, figs 1-3.

Material - Nineteen ventral valves: A40-1, A40-2, A40-3, A40-4, A40-5, A40-6, A40-8, B17- 3, B17-4, B17-5, B17-6, B17-7, B17-9, C118-6, C127-1, D89-1, D89-2, D89-3, D89-4; four fragments of ventral valve: A40-7, B17-1, B17-2, B17-8.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Rupe di San Benedetto megablock; Roadian-Wordian.

Description - Small to medium sized shell (4.5-28 mm wide, 3.5-19.2 mm long); ventral valve conical, elongated, with subcircular to transversally elliptical outline. Ventral umbo extended, with a wide and flat interarea, triangular and elongated, with a wide, convex pseudodeltidium. Ornamentation of irregular growth lamellae, some stronger than others, slightly converging near the spine bases, which are coarse and scattered on the shell. Decorticated shell reveals the presence of numerous small endospines. Coscinidium rarely observed (specimen D89-1); myocoelidium occurring in specimens B17-4, B17-7, B17-9.

Remarks - The studied specimens are similar to *Coscinarina communis* from the Sosio Limestone (Roadian-Wordian) in the overall shape and size, and in the occurrence of a myocoelidium (Muir-Wood & Cooper, 1960). *Sicularia sicula* (Gemmellaro, 1894) is a very similar species, described from the Sosio Limestone (Roadian-Wordian), but ultimately differs by having a myocoelidium developed only in juvenile stages, a larger interarea and pseudodeltidium and a larger shell size.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Di Stefano, 1914; de Gregorio, 1930; Muir-Wood & Cooper, 1960).

Family Hercosiidae Cooper & Grant, 1975

Genus *Sicularia* Grant, 1993
Type species *Richthofenia sicula* Gemmellaro, 1894

Remarks - The genus *Sicularia* is similar to the genus *Coscinarina*, from which it differs by having a larger diameter of the ventral valve and sometimes more rugose lamellae. Interarea and pseudodeltidium are larger in *Sicularia*, and the pseudodeltidium is more convex. Moreover, the myocoelidium is always present in *Coscinarina*, while in *Sicularia* it can be absent in adults and modified with the development of a long median septum. *Richthofenia* differs from *Sicularia* mainly in lacking a myocoelidium, having three septa instead.

Sicularia sicula (Gemmellaro, 1894)
(Pl. 4, fig. 6; Pl. 5, fig. 1)

1894 *Richthofenia sicula* Gemmellaro, p. 7.
1896 *Richthofenia sicula* Gemmellaro - Gemmellaro, p. 114.
1900 *Richthofenia* sp. Schellwien, p. 28, fig. 1 a, b.
1914 *Richthofenia sicula* Gemmellaro - Di Stefano, p. 22, Pl. 2, figs 6, 17-19, 22, 24-29; Pl. 3, figs 1-4, 6-12, 14-17, 19-20.
1926 *Richthofenia sicula* Gemmellaro - Fabiani, p. 614.
1930 *Richthofenia sicula* Gemmellaro - de Gregorio, p. 29, Pl. 8, figs 7-10.
1947 *Richthofenia sicula* Gemmellaro - Greco, p. 18, Pl. 3, figs 21-25.
1957 *Richthofenia sicula* Gemmellaro - Termier & Termier, p. 204, Pl. 3, figs i-l; Pl. 4, figs a-d.
1967 *Richthofenia sicula* Gemmellaro - Rudwick & Cowen, p. 139, Pl. 36, figs 1-2, 4-12; Pl. 37, figs 2-9; Pl. 40, fig. 4.
1977 *Coscinarina communis* (Gemmellaro) - Termier et al., p. 55.
1993 *Sicularia sicula* (Gemmellaro) - Grant, p. 11.
2010 *Sicularia sicula* (Gemmellaro) - Verna et al., p. 320, Pl. 1, figs 8-13.
2022 *Sicularia sicula* (Gemmellaro) - Galeana-Moran et al., p. 4, Pl. 2, figs 3-4.

Material - Ten ventral valves: A39-1, A40-9, A40-10, A116-1, B17-10, C122-1, C122-2, C122-3, C122-4, C122-5.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Medium sized shells (9-39.7 mm wide, 7.5-33 mm long), outline transversally elliptical. Ventral valve conical, interarea wide, flattened and triangular with wide, protruding convex pseudodeltidium. Ornamentation of strong lamellae, irregular and sometimes rugose; spine bases scattered, sometimes arranged in rows more or less parallel to the commissure. Decorticated shell reveals the presence of numerous small endospines.

Remarks - The studied specimens are similar to those previously described as *Coscinarina communis*. The distinction between the two species was based on the overall larger size of *Sicularia sicula* and the presence in some specimens of a wider interarea and pseudodeltidium, which differs from the narrower one of *C. communis*. Also, the absence of myocoelidium allows assignment to *Sicularia sicula*.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Di Stefano, 1914; de Gregorio, 1930); Djebel Tebaga, Wordian-Capitanian, Tunisia (Termier et al., 1977; Verna et al., 2010); Las Delicias Formation, Wordian, Mexico (Galeana-Moran et al., 2022).

Family Gemmellaroiidae Williams, 1953

Genus *Gemmellaroia* Cossmann, 1898
Type species *Megarhynchus marii* Gemmellaro, 1894

Remarks - The conical shape of the ventral valve and the development of the myocoelidium resemble those of *Richthofenia*, but the latter differs in having a pseudodeltidium enclosed in the outer shell layers, a dorsal valve not forming a clear operculum over the ventral valve and a cystose internal shell layer. The costellate internal surface of *Gemmellaroia* can be related to the denticulate margin of the valves (Muir-Wood & Cooper, 1960).

Gemmellaroia marii (Gemmellaro, 1894)
(Pl. 5, figs 2-3)

1894 *Megarhynchus marii* Gemmellaro, p. 7.
1896 *Megarhynchus marii* Gemmellaro - Gemmellaro, p. 118, Pl. A, figs 18-29.
1926 *Megarhynchus marii* Gemmellaro - Fabiani, p. 14.
1933 *Megarhynchus marii* Gemmellaro - Douvillé et al., p. 22.
1934 *Megarhynchus marii* Gemmellaro - Solignac & Berkaloff, p. 10, 21.
1947 *Gemmellaroia marii* (Gemmellaro) - Greco, p. 21, Pl. 3, figs 26-32.
1957 *Gemmellaroia marii* (Gemmellaro) - Termier & Termier, p. 202, Pl. 3, figs c-h.
1967 *Gemmellaroia mariae* (Gemmellaro) - Rudwick & Cowen, p. 132, Pl. 35, figs 1-14.
1977 *Gemmellaroia marii* (Gemmellaro) - Termier et al., p. 54, Pl. 14, figs 1-2.
2010 *Gemmellaroia marii* (Gemmellaro) - Verna et al., p. 322, Pl. 1, figs 25-27.

Material - Five articulated specimens: A69-1, A105-1, C120-1, C120-2, C120-3; two ventral valves: A105-2, A105-3.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small to medium sized shell (9.5-19.5 mm wide, 8.5-17 mm long, 12-21 mm thick), subcircular in outline; posterior margin only slightly curved; anterior commissure rectimarginate. Ventral valve conical, variably elongated; interarea indistinct, with prominent pseudodeltidium, squared in section. Dorsal valve slightly convex, almost flat. Ornamentation of low lamellae; spine bases extremely rare, scattered on the shell. When decorticated, numerous striae are visible on the entire internal surface of the ventral valve and anteriorly on the dorsal valve. Ventral interior with a partly preserved myocoelidium.

Remarks - The outline of the specimens and the well-developed pseudodeltidium are typical features of species of *Gemmellaroia*. The specimens are assigned to *Gemmellaroia marii* (Gemmellaro, 1894) as described by Gemmellaro (1896) from the Sosio Limestone (Roadian-Wordian) because of their shape and size. Most of the specimens are decorticated, with the external ornamentation partly preserved only in one specimen, matching the ornamentation described for the species. Specimen A105-3 has a smaller size, closer to *Gemmellaroia ornatum* (Gemmellaro, 1896) described from the Sosio Limestone (Roadian-Wordian), but, in absence of other diagnostic features, it is here considered a juvenile of *G. marii*.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Gemmellaro, 1894, 1896; de Gregorio, 1930; Muir-Wood & Cooper, 1960); Djebel Tebaga, Wordian-Capitanian, Tunisia (Termier et al., 1977; Verna et al., 2010).

Suborder Lyttoniidina Williams, Harper & Grant, 2000
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Subfamily Lyttoniinae Waagen, 1883

Genus *Leptodus* Kayser, 1883
Type species *Leptodus richthofeni* Kayser, 1883

Remarks - The identification of *Leptodus* is hampered by the poor preservation of the original material of the type species *Leptodus richthofeni* Kayser, 1883 from the Lopingian of China, and by the occurrence of several synonyms as *Lyttonia* Waagen, 1883, *Spinolyttonia* Sarytcheva, 1964, *Juxholdamina* Liang, 1990, and *Semigluberina* Liang, 1990. *Leptodus* can be distinguished from *Eolyttonia* Frederiks, 1924 because of the more solidoseptate, not crenelated lateral septa; from *Collemataria* Cooper & Grant, 1974 since the latter lacks clear muscle scars in the ventral valve, and has a narrower, slightly more elongate outline (Cooper & Grant, 1974; Wu et al., 2018).

Distribution - Artinskian-Roadian of Afghanistan (Termier et al., 1974); Kungurian-Changhsingian of China (e.g., Yang et al., 1987; Shen & He, 1991, 1994; Shen et al., 1995, 2002, 2010, 2019; Zeng et al., 1995, 2007; Tazawa & Chen, 2006; He et al., 2012; Wu et al., 2018, 2022); Kungurian-Changhsingian of USA (King, 1931; Stehli, 1954; Dutro & Yochelson, 1961; Yochelson & Van Sickle, 1968); Roadian of Croatia (Sremac, 1986); Roadian of Ukraine (Boiko et al., 1991); Roadian-Wordian of Italy (Gemmellaro, 1891; de Gregorio, 1930; Parona, 1933a); Roadian-Wordian of Slovenia (Flügel et al., 1984; Ramovs, 1986); Roadian-Wordian of Thailand (e.g., Grant, 1976); Roadian-Wuchiapingian of Japan (e.g., Tazawa et al., 1998; Tazawa, 2001, 2008, 2016); Wordian of Cambodia (Mansuy, 1913); Wordian-Capitanian of Tunisia (Termier et al., 1977; Verna et al., 2010); Wordian-Wuchiapingian of Transcaucasia (e.g., Ruzhentsev & Sarytcheva, 1965; Kotlyar et al., 1983, 1989); Wordian-Changhsingian of Iran (e.g., Nakamura & Golshani, 1981; Taraz et al., 1981; Angiolini & Carabelli, 2010; Viaretti et al., 2021); Wordian-Wuchiapingian of Pakistan (e.g., Reed, 1944; Grant, 1970; Angiolini, 1995, 2001); Capitanian of Malaysia (Leman, 1994; Campi et al., 2000, 2005); Capitanian of Russia (e.g., Licharew & Kotlyar, 1978; Belyaeva et al., 1997); Lopingian of Serbia (Albrecht, 1924); Wuchiapingian of Australia

(e.g., Thomas, 1957; Archbold, 1988); Wuchiapingian of Greece (Clapham & Bottjer, 2007); Wuchiapingian of Hungary (Schréter, 1963); Wuchiapingian of India (Diener, 1903); Wuchiapingian of Indonesia (Rothpletz, 1892); Changhsingian of Tajikistan (Grunt & Dimitriev, 1973).

Leptodus sp.
(Pl. 5, fig. 4)

Material - One dorsal valve: C97-1; internal cast of a ventral valve: C97-2.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Partly preserved, medium sized shell (> 26 mm wide, 17 mm long), with a slightly ovate outline. The internal surface of ventral valve is partly visible, mostly in the anterior portion, showing a pseudopunctate surface. Lateral septa on the ventral valve are slightly visible, seemingly solidiseptate, intersecting at roughly 90° to the slightly visible median septum. Putative muscle scars are slightly visible near the umbonal area, seemingly elliptical. Dorsal valve with well visible lobes, recurved towards the apex, mostly symmetrical.

Remarks - The studied specimen is assigned to *Leptodus* due to its arched, solidiseptate lateral septa, visible on the ventral valve, and the overall outline of the shell. The studied specimen is similar to specimens of *Lyttonia latiseptata* Gemmellaro, 1891 as described and figured by Gemmellaro (1891) and Parona (1933a; figs 19-23) from the Sosio Limestone. Rudwick & Cowen (1967) distinguished two groups of lyttonids from the Sosio Limestone: *Lyttonia* "Form A", which included *Lyttonia nobilis*, *Lyttonia latiseptata*, *Lyttonia richthofeni*, *Lyttonia waageni* Gemmellaro, 1891 described from the Sosio Limestone (Roadian-Wordian), and *Lyttonia* "Form B" which the authors ascribed to *Pirgulia*. Later, Verna et al. (2010) confirmed that species of *Lyttonia* "Form A" were to be considered as species of *Leptodus*. However, *L. latiseptata* still lacks a proper description, hampering a conclusive identification of the studied specimen. Due to the poor of preservation, the nomenclature is left open.

Genus *Pirgulia* Cooper & Muir-Wood, 1951
Type species *Lyttonia conica* Gemmellaro, 1891

Remarks - The genus *Pirgulia* closely resembles *Leptodus* but differs in having a more conical ventral valve with blunter, closely spaced lateral septa (Stadtmauer & Butts, 2019). *Eolyttonia* is similarly conical but differs because the cone produced by the valve is less tapering, with a broadly rounded base (Verna et al., 2010) and the lateral septa are more recurved posteriorly. *Collemataria* is also similarly conical, but it has less numerous and larger lateral septa than *Pirgulia* (Verna et al., 2010).

Pirgulia conica (Gemmellaro, 1891)
(Pl. 5, fig. 5)

1891 *Lyttonia conica* Gemmellaro, p.1.
1930 *Lyttonia* (*Pirgula*) *pediculata* (Gemmellaro) - de Gregorio, p. 30, Pl. 9, figs 8-10.
1933a *Lyttonia conica* Gemmellaro - Parona, p. 8, figs 1-9.
1967 *Lyttonia* "Form B" Rudwick & Cowen, p. 153, Pl. 43, figs 1-11.
2010 *Pirgulia conica* (Gemmellaro) - Verna et al., p. 324, Pl. 1, figs 32-35.

Material - One articulated specimen: A104-1.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (10.5 mm wide, >20.5 mm long), with conical ventral valve, longitudinally elongated, triangular in outline. Dorsal valve with numerous small lobes, almost symmetrical and slightly arcuate towards the apex of the valve, mainly visible anteriorly. Median lobe well defined, forming a series of small openings anteriorly. Ornamentation of ventral valve poorly preserved, with weak growth lines or lamellae.

Remarks - The conical morphology of the ventral valve and the numerous lateral lobes on the dorsal valve of the studied specimen are comparable to those of *Pirgulia conica* Gemmellaro, 1891 as described and figured by Parona (1933a; p. 8, figs 1-9) from the Sosio Limestone (Roadian-Wordian). The small openings occurring in the anterior portion of the median lobe represent the only difference with *P. conica*. However, the material figured

EXPLANATION OF PLATE 5

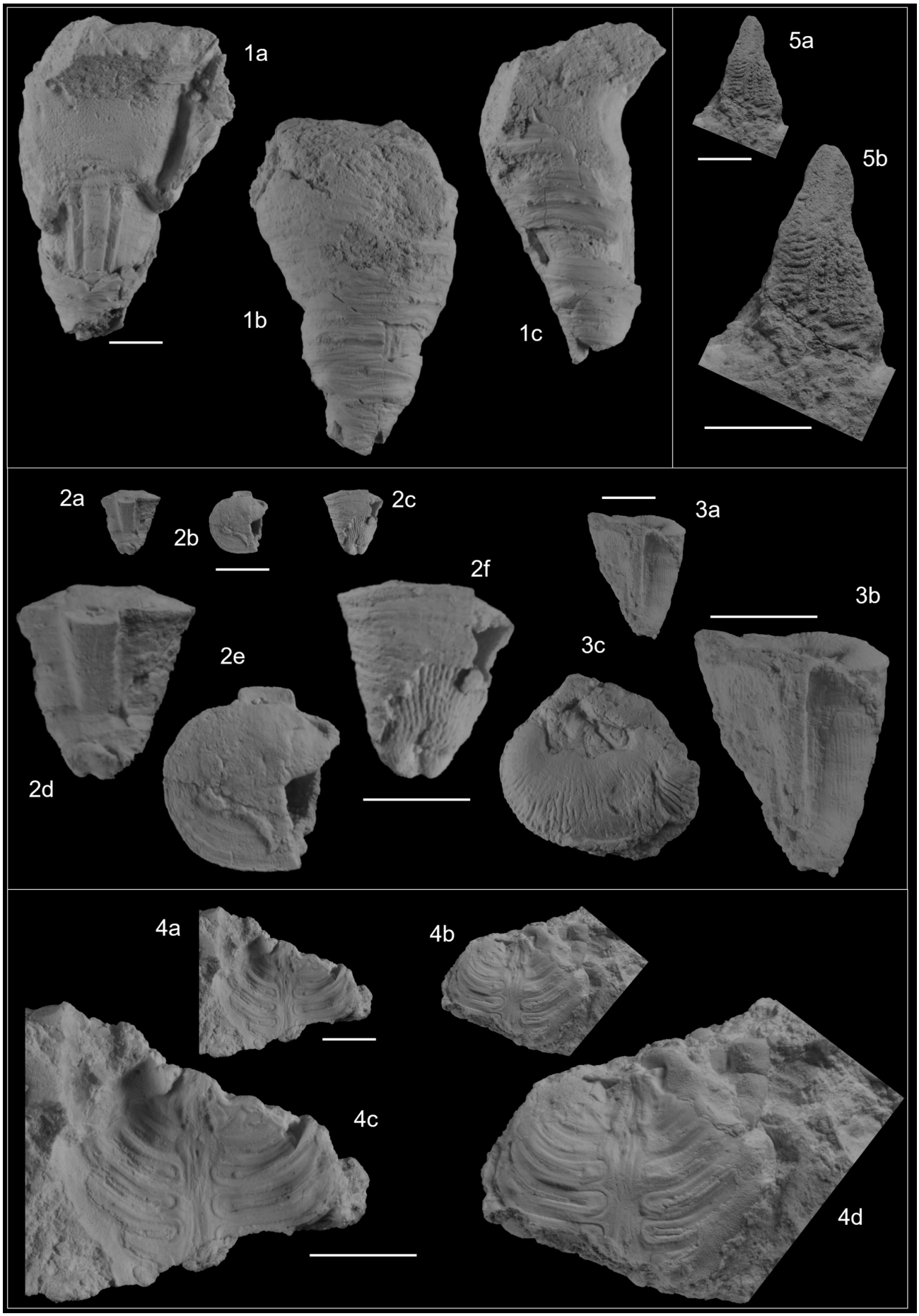
Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm.

Fig. 1 - *Sicularia sicula.* A40-10, (a) posterior view; (b) anterior view; (c) lateral view.

Figs 2-3 - *Gemmellaroia marii.*
2 - A69-1, (a) posterior view; (b) dorsal view; (c) anterior view; (d) enlargement of posterior view; (e) enlargement of dorsal view; (f) enlargement of anterior view.
3 - C120-3, (a) posterior view; (b) enlargement of posterior view; (c) dorsal view.

Fig. 4 - *Leptodus* sp. C97-1 + C97-2, (a) internal view of dorsal valve; (b) internal view of ventral valve; (c) enlargement of internal view of dorsal valve; (d) enlargement of internal view of ventral valve.

Fig. 5 - *Pirgulia conica.* A104-1, (a) dorsal view; (b) enlargement of dorsal view.


1a
1b
1c
5a
5b
2a
2b
2c
2d
2e
2f
3a
3b
3c
4a
4b
4c
4d

in the literature is often poorly preserved, hampering a clear recognition of such features.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Gemmellaro, 1891; de Gregorio, 1930; Parona, 1933a; Rudwick & Cowen, 1967); Djebel Tebaga, Wordian-Capitanian, Tunisia (Verna et al., 2010).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Meekellidae Stehli, 1954
Subfamily Meekellinae Stehli, 1954

Genus *Geyerella* Schellwien, 1900
Type species *Geyerella gemmellaroi* Schellwien, 1900

Remarks - The genus *Geyerella* is similar to *Meekella* White & St. John, 1867, but differs in having an elevated spondylium, while in *Meekella* dental plates converge onto the ventral valve floor. *Perigeyerella* differs in lacking plicae on the surface. Moreover, *Perigeyerella* differs in having an elevated spondylium in the early stages, transitioning to a sessile spondylium, and then, in later stages, to two mostly parallel, separated, dental plates.

Distribution - Gzhelian of USA (Cooper & Grant, 1972); Asselian-Roadian of Slovenia (Schellwien, 1900; Flügel et al., 1984; Ramovs, 1986); Asselian-Capitanian of USA (Cooper & Grant, 1972); Sakmarian of Austria (Schellwien, 1900); Roadian of Ukraine (Boiko et al., 1991); Roadian-Wordian of Italy (de Gregorio, 1930; Greco, 1938); Wordian of Armenia (Ruzhentsev & Sarytcheva, 1965); Wordian-Capitanian of Tunisia (Termier et al., 1977); Wordian-Changhsingian of China (Jin et al., 1979; Niu et al., 2003; Shen & Shi, 2007; He et al., 2009); Wordian-Changhsingian of Japan (Hayasaka, 1963; Ehiro, 1996); Changhsingian of Tajikistan (Grunt & Dimitriev, 1973).

Geyerella gemmellaroi Schellwien, 1900
(Pl. 6, fig. 1)

1899 *Derbyia* sp. Semper, p. 245, Pl. 16, fig. 9a-9b.
1900 *Geyerella gemmellaroi* Schellwien, p. 12, 13, Pl. 1, fig. 7a-7b.
1901 *Geyerella gemmellaroi* Schellwien - Frech, p. 506, 507.
1930 *Turriculum imperans* de Gregorio, p. 26, 27.
1930 *Turriculum imperans* var. *nimbosum* de Gregorio - de Gregorio, p. 26, 27, Pl. 7, figs 3-5.
1930 *Turriculum imperans* var. *abruptum* de Gregorio - de Gregorio, p. 26, 27, Pl. 7, figs 6-7.
1930 *Turriculum imperans* var. *magnum* de Gregorio - de Gregorio, p. 26, 27, Pl. 6, figs 3-9.
1930 *Turriculum imperans* var. *permagnum* de Gregorio - de Gregorio, p. 26, 27, Pl. 6, figs 1-2.
1932 *Geyerella gemmellaroi* Schellwien - Ruiz, p. 18, Pl. 2, figs 2, 4-6.
1933 *Geyerella gemmellaroi* Schellwien - Douvillé et al., p. 22.
1934 *Geyerella gemmellaroi* Schellwien - Solignac & Berkaloff, p. 10, 21.
1938 *Geyerella gemmellaroi* Schellwien - Greco, p. 30-33, Pl. 2, fig. 8a-8b.

Material - One articulated specimen: A109-4; six ventral valves: A108-1, A108-3, A108-6, A110-4, A110-6, C124b-4; two dorsal valves: A109-5, C124b-3.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small to medium sized shell (> 10-> 41 mm wide, > 12-> 35 mm long, 25 mm thick), transversally elliptical to roughly subcircular in outline, widest at approximately mid-valve. Ventral valve conical, umbo quite narrow and twisted; interarea high, triangular, with longitudinal striae crossed by weak transverse lines; pseudodeltidium weakly convex to almost flat, usually with a sharp monticulus, both with transverse lines. Dorsal valve variably convex; umbo weakly swollen, slightly extended beyond posterior margin. Ornamentation of numerous costellae, increasing by intercalation, numbering five-six in 1 mm near the ventral anterior commissure; irregular, coarse and widely spaced plicae numbering two to four in 5 mm at 1 cm from the ventral umbo; weak growth lines cross the radial ornamentation. Ventral interior with dental plates converging on a median septum, producing an elevated spondylium (Fig. 8a).

Remarks - The studied specimens are assigned to *Geyerella* because of the elevated spondylium in the ventral valve, and the overall morphology and ornamentation of the shells. The identification of *Geyerella gemmellaroi* Schellwien, 1900 as described by de Gregorio (1930) from the Sosio Limestone (Roadian-Wordian) is based on the conical ventral valve, wider than longer in cross-

EXPLANATION OF PLATE 6

(color online) Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm. Yellow arrows highlight characteristic features (e.g., spondylium).

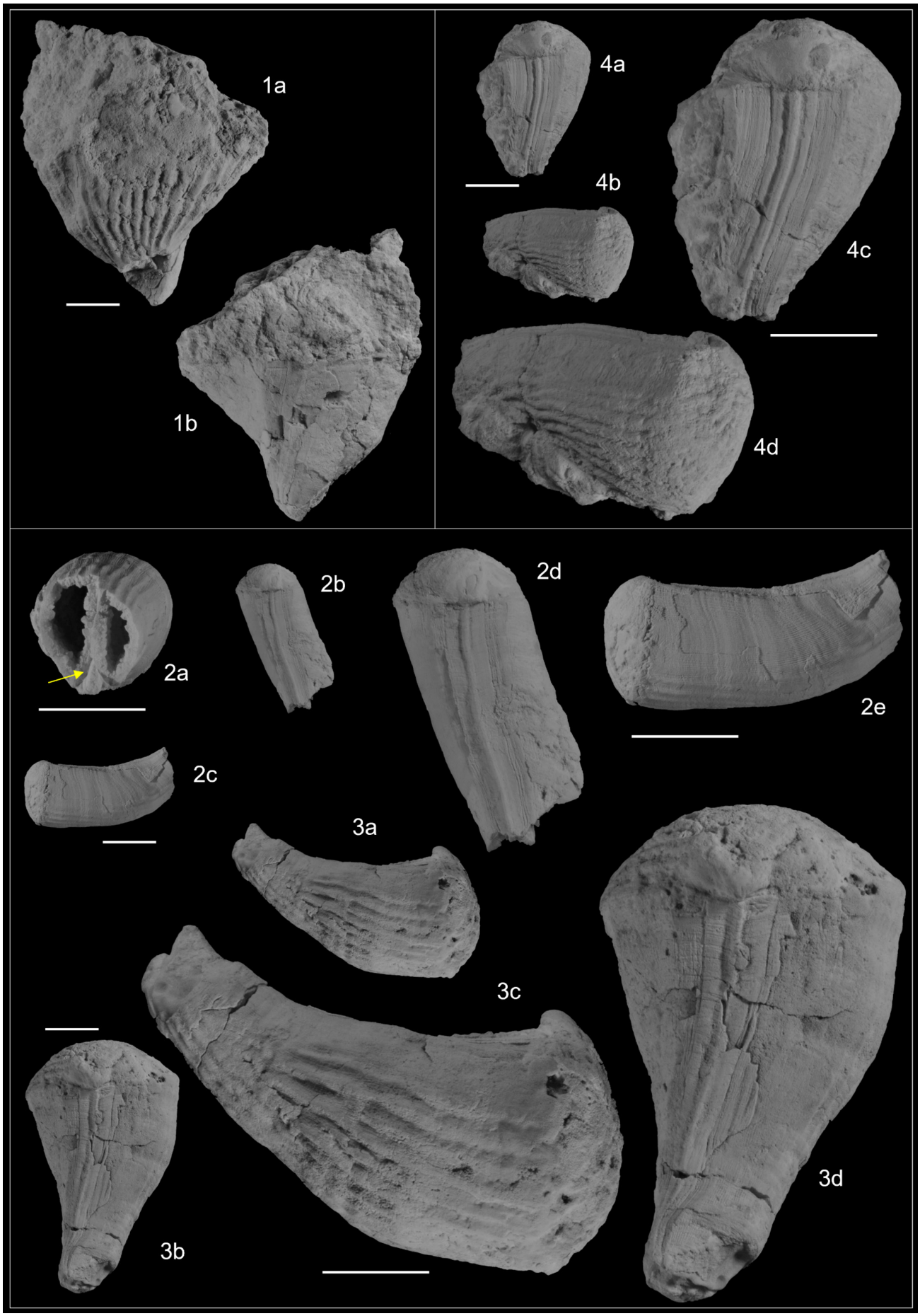
Fig. 1 - *Geyerella gemmellaroi.* A110-6, (a) anterior view; (b) posterior view.

Figs 2-3 - *Geyerella rex.*

2 - juvenile specimen A106-5, (a) ventral view, detail of elevated spondylium; (b) posterior view; (c) lateral view; (d) enlargement of posterior view; (e) enlargement of lateral view.

3 - A109-3, (a) lateral view; (b) posterior view; (c) enlargement of lateral view; (d) enlargement of posterior view.

Fig. 4 - *Geyerella* cf. *Geyerella distorta.* A109-1, (a) posterior view; (b) lateral view; (c) enlargement of posterior view; (d) enlargement of lateral view.


1a
1b
4a
4b
4c
4d
2a
2b
2d
2e
2c
3a
3c
3d
3b

section. *Geyerella rex* from the Sosio Limestone (Roadian-Wordian) is similar, but differs in having a less elliptical outline, especially in the early stages of growth, and the dorsal valve is usually less convex. *Geyerella gemmellaroi* is also smaller than *G. rex*.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (de Gregorio, 1930; Greco, 1938); Djebel Tebaga, Wordian-Capitanian, Tunisia (Termier et al., 1977).

Geyerella rex (de Gregorio, 1930)
(Pl. 6, figs 2-3)

1930 *Turriculum imperans* var. *rex* de Gregorio, p. 27, Pl. 7, figs 1-2.
1932 *Meekella irregularis* Schellwien - Ruiz, p. 17.
1932 *Geyerella gemmellaroi* (Schellwien) - Ruiz, p. 18, Pl. 1, fig. 11; Pl. 2, fig. 3.
1938 *Geyerella rex* (de Gregorio) - Greco, p. 36-40, Pl. 2, figs 12-15.

Material - Seven articulated specimens: A106-4, A106-5, A107-1, A107-2, A107-4, A109-3, C124b-5; nine ventral valves: A106-1, A106-2, A106-3, A107-3, A108-7, A110-5, A110-7, C135-1, D101-1; three dorsal valves: C124b-1, C124b-2, C124b-6; three fragments of ventral valves: A110-1, A110-2, A110-3.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Rupe di San Benedetto megablock; Roadian-Wordian.

Description - Small to medium, at times large sized shell (7-> 42 mm wide, 6-> 40 mm long, > 9-44.5 mm thick), subcircular to transversally ovate in outline, widest near mid-valve. Ventral valve conical; umbo quite narrow, frequently twisted; interarea high, triangular, with longitudinal striae crossed by transverse lines; pseudodeltidium variably wide, mostly flat or very weakly convex, with a weakly sharp monticulus, both with weak transverse lines. Dorsal valve convex with a small, swollen umbo, slightly extended beyond the posterior margin. Ornamentation of numerous costellae, increasing by intercalation, numbering five-six in 1 mm at about 1 cm from the ventral umbo and near the anterior commissure of juvenile specimens; irregular, coarse plicae, numbering one-three in 5 mm at 1 cm from the ventral umbo; weak growth lines cross the radial ornamentation. Internally, ventral valve with dental plates converging on a median septum, forming a rather small, elevated spondylium (Fig. 8a).

Remarks - The studied specimens are assigned to *Geyerella* because of the elevated spondylium in the ventral valve, and the overall morphology and ornamentation of the shells. The morphology of the ventral valve and the medium to large size of the specimens allow their identification as *G. rex*. These specimens differ from *G. gemmellaroi* in having a more subcircular outline, a higher ventral valve and less convex dorsal valve, together with a larger size. The specimens A106-1, A106-2, A106-3, A106-4, A106-5, A107-1, A107-2, A107-3, A107-4, and C135-1 are small for the species and characterized by weaker or at times absent plicae. According to Schellwien (1900) juveniles of *Geyerella*, *G. rex* included, can either present weaker plicae or completely lack this feature. With this premise, the smallest specimens were considered as juvenile specimens of *G. rex*.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (de Gregorio, 1930; Greco, 1938); Djebel Tebaga, Wordian-Capitanian, Tunisia (Termier et al., 1977).

Geyerella cf. *Geyerella distorta* Schellwien, 1900
(Pl. 6, fig. 4)

Material - Two articulated specimens: A109-1, A109-2; two ventral valves: A108-2, A108-4.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (> 13-> 24 mm wide, > 9.5-> 22.5 mm long, > 21-> 29 mm thick) subcircular to elliptical in outline, widest near mid-valve. Ventral valve conical, umbo narrow; interarea high, triangular with striae crossed by weak transverse lines; pseudodeltidium mostly flattened, with a sharply convex monticulus, with transverse lines. Dorsal valve convex, with a quite swollen umbo, slightly extended beyond the posterior margin. Ornamentation of numerous costellae, increasing in number by intercalation, numbering five-seven in 1 mm at 5 mm from the ventral umbo; fine and roughly sharp plicae, weakly irregular, numbering four-five in 5 mm at 1 cm from the ventral umbo; weak growth lines and lamellae cross the radial ornamentation. Ventral interior with dental plates converging on a median septum, producing a small elevated spondylium (Fig. 8a).

Remarks - The specimens here described are similar to *Geyerella distorta* Schellwien, 1900 as described and figured by Greco (1938; pl. 2, fig. 11) from the Sosio Limestone (Roadian-Wordian) and by Shen & Shi (2007; pl. 10, figs 14-24) from the Changhsingian of China in having a high conical shape of the ventral valve, rather fine plicae and small size. However, some specimens of *G. distorta* figured by Greco (1938; pl. 2, figs 9-10) have a more subcircular outline. The studied specimens resemble small specimens of *G. rex* but differ in having more numerous and much narrower, somewhat sharper, plicae. The identification is uncertain as the few available specimens are only partly preserved.

Distribution - Dolzanova Soteska Fm., Asselian, Slovenia (Schellwien, 1900); Zweikofel Fm., Sakmarian, Austria (Schellwien, 1900); Sosio Limestone, Roadian-Wordian, Italy (de Gregorio, 1930; Greco, 1938); Kaixinling Fm., Changhsing Fm., Lopingian, China (Jin et al., 1979; Shen & Shi, 2007).

Genus *Perigeyerella* Wang, 1955
Type species *Perigeyerella costellata* Wang, 1955

Remarks - The genus *Perigeyerella* is characterized by the evolution of the dental plates, having an elevated spondylium in the early stages, transitioning to a sessile spondylium, and then in later stages, evolving into two separated, mostly parallel dental plates. *Perigeyerella* is similar both to *Sicelia* and *Ombonia* Caneva, 1906 in the external ornamentation. However, *Sicelia* has a sessile spondylium throughout all the stages, while *Ombonia* is characterized by an elevated spondylium, hence making the evolution of the plates in *Perigeyerella* a diagnostic character. *Perigeyerella* differs from *Geyerella* because the latter has a small elevated spondylium and plicae on the shell surface.

Distribution - Kungurian-Wordian of Oman (Angiolini & Bucher, 1999; Angiolini et al., 2003; Viaretti et al., 2022); Guadalupian of Turkey (e.g., Verna et al., 2011); Roadian-Wordian of Thailand (Grant, 1976); Wordian-Wuchiapingian of Iran (e.g., Angiolini & Carabelli, 2010; Crippa & Angiolini, 2012; Ghaderi et al., 2014; Viaretti et al., 2021); Lopingian of China (e.g., Zhang & Jin, 1961; Yang et al., 1977, 1987; Feng & Liang, 1978; Zhao et al., 1978; Yao et al., 1980; Liao, 1987; Shen & He, 1994; Xu & Grant, 1994; Zeng et al., 1995; Chen et al., 2005, 2009; Chen & Liao, 2007; Shen & Shi, 2007; He et al., 2008; Wu et al., 2022).

Perigeyerella cf. *Perigeyerella tricosa* Grant, 1976
(Pl. 7, fig. 1)

Material - One articulated specimen B18-10; four ventral valves: B18-1, B18-8, C118-2, C118-5.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (> 4-15 mm wide, > 5-11 mm long, > 3 mm thick), slightly transverse to roughly subtriangular in outline, maximum width near mid-valve. Ventral valve convex, conical, umbo narrow, weakly twisted; ventral interarea high, roughly apsacline, triangular in shape, with a convex, narrow pseudodeltidium showing a poorly preserved monticulus. Dorsal valve weakly convex, almost flat. Ornamentation of costellae, increasing in number by intercalation, numbering six-seven in 1 mm at about 5 mm from the ventral umbo. Ventral interior with dental plates merging on a median septum to form an elevated spondylium in the umbonal area (Fig. 8b).

Remarks - The studied specimens are assigned to *Perigeyerella* because of the elevated spondylium in the umbonal area of the ventral valve. The specimens are characterized by a small size, quite unusual for species of the genus, hence interpreted as juvenile specimens. The studied specimens have an interarea and pseudodeltidium similar to some juvenile specimens of *Perigeyerella tricosa* as figured by Grant (1976; pl. 11, figs 1-13) from the Roadian-Wordian of Thailand, differing in having a somewhat finer ornamentation. A conclusive specific identification is hampered by the poor preservation of the specimens.

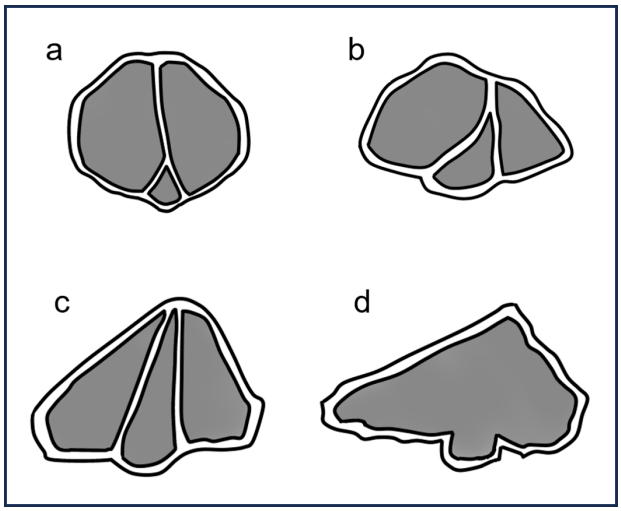


Fig. 8 - Schematic representation of the internal plates of the identified genera of Orthotetida (drawings not in scale). The drawings are based on specimens of a) *Geyerella rex* (de Gregorio, 1930), specimen A106-4; b) *Perigeyerella* cf. *Perigeyerella tricosa* Grant, 1976, specimen B18-8; c) *Sicelia merlai* Greco, 1938, specimen B18-11; d) *Streptorhynchus sinuatus* (Merla, 1928), specimen B19-2.

Genus *Sicelia* Gortani & Merla, 1934
Type species *Canavaria acropedion* Merla, 1928

Remarks - The genus *Sicelia* is characterized by a sessile spondylium, which distinguishes it from externally similar genera such as *Ombonia* and *Perigeyerella*. In *Ombonia*, the spondylium remains elevated with dental plates converging on a septum throughout the entire growth of the shell. *Perigeyerella* has dental plates that initially form an elevated spondylium, transitioning to a sessile spondylium and then to separate, parallel dental plates.

Sicelia merlai Greco, 1938
(Pl. 7, figs 2-3)

1932 *Streptorhynchus pelargonatus* (Von Schlotheim) - Ruiz, p. 12, Pl. 1, figs 4a-4c, 5.
1932 *Meekella evanescens* Schellwien - Ruiz, p. 15, Pl. 1, fig. 9a-9b.
1932 *Meekella uncitoides* Tschernyschew - Ruiz, p. 16, Pl. 1, fig. 10a-10b.
1938 *Sicelia merlai* Greco, p. 23, Pl. 1, figs 15-17.
1942 *Sicelia merlai* Greco - Greco, p. 144, Pl. 19, figs 6-11.
2010 *Sicelia merlai* Greco - Verna et al., p. 326, Pl. 1, fig. 37.

Material - Seven articulated specimens: A111-4, A111-8, A112-1, A115-1, B18-2, B18-9, D81-1; three ventral valves: B18-5, B18-6, B18-11.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Rupe di San Benedetto megablock; Roadian-Wordian.

Description - Small to medium sized shell (4.5-34.5 mm wide, > 5.5-38 mm long, 4-24 mm thick), transversally ovate in outline, widest near mid-valve.

Ventral valve convex, with a long, narrow umbo, variably twisted; interarea high, apsacline, triangular in shape, with longitudinal striae crossed by transverse lines; wide, flat to weakly convex pseudodeltidium showing a sharp monticulus, with transverse lines. Dorsal valve weakly flattened to convex, umbo small, swollen and slightly extended beyond the posterior margin. Ornamentation of fine costellae, increasing by intercalation, numbering four-six in 1 mm at 5 mm from the ventral umbo; growth lamellae rare or poorly preserved, mostly visible on ventral valve of specimen A112-1. Internally, ventral valve with dental plates converging at the floor of the valve forming a sessile spondylium (Fig. 8c).

Remarks - The studied specimens were assigned to a species of *Sicelia* because of the occurrence of a sessile spondylium. The assignment to *Sicelia merlai* Greco, 1938 from the Sosio Limestone (Roadian-Wordian) is supported by the external ornamentation and the wide pseudodeltidium with a sharp monticulus, as described by Verna et al. (2010). *Sicelia explicata* Grant, 1995 from the Lopingian of Hydra Island (Greece) is similar to the studied specimens, but differs in having a narrower pseudodeltidium and coarser ornamentation, especially on the dorsal valve. Moreover, according to Grant (1995) some specimens of *S. explicata* are weakly plicated, while plicae in *S. merlai* are absent. Specimen A115-1 is characterized by a flatter dorsal valve and an ornamentation of somewhat coarser costellae, more widely spaced, numbering three-four in 1 mm near the anterior commissure. It is considered as a juvenile specimen of *S. merlai*, since internally it shows the same diagnostic sessile spondylium.

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Merla, 1928; de Gregorio, 1930; Greco, 1938); Djebel Tebaga, Wordian-Capitanian, Tunisia (Termier et al., 1977; Verna et al., 2010).

Family Schuchertellidae Williams, 1953
Subfamily Streptorhynchinae Williams, 1953

Genus *Streptorhynchus* King, 1850
Type species *Terebratulites pelargonatus* Von Schlotheim, 1816

Remarks - The genus *Streptorhynchus* is easily distinguished from the similar genera *Sicelia* and *Perigeyerella* because it lacks internal plates. Moreover, it differs from *Sicelia* because of a higher dorsal interarea, with a better defined chilidium. *Kiangsiella* Grabau in Chao, 1927b also lacks internal plates, but *Streptorhynchus* differs because of the lack of plicae (Cooper & Grant, 1974).

Distribution - *Streptorhynchus* is a cosmopolitan genus, ranging through the Carboniferous-Permian according to Williams et al. (2000).

Streptorhynchus sinuatus (Merla, 1928)
(Pl. 7, fig. 4)

1928 *Canavaria sinuata* Merla, p. 76, Pl. 1, figs 5-7.
1932 *Streptorhynchus crenistria* (Phillips) - Ruiz, p. 9, Pl. 1, figs 1-2.
1932 *Streptorhynchus crenistria* var. *senilis* (Phillips) - Ruiz, p. 11, Pl. 1, fig. 3; Pl. 2, fig. 1a-1b.
1932 *Streptorhynchus pelargonatus* (Von Schlotheim) - Ruiz, p. 12, Pl. 1, fig. 5.
1932 *Derbyia buchi* (d'Orbigny) - Ruiz, p. 14.
1938 *Streptorhynchus sinuatus* (Merla) - Greco, p. 14-20, Pl. 1, figs 1-8.

Material - Fifteen articulated specimens: A111-1, A111-3, A111-5, A111-6, A111-7, A111-9, B18-3, B18-4, B18-7, B19-1, B19-2, C118-1, C118-4, C118-9, E14-1; two ventral valves: A111-2, C118-3; one dorsal valve: C118-10.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock, Rupe di San Calogero megablock; Roadian-Wordian.

Description - Small to medium sized shell (5.9-35 mm wide, 5-27.5 mm long, 3-25 mm thick), transverse in outline, widest near mid-valve; anterior commissure faintly unisulcate. Ventral valve roughly conical, with a wide and low fold; interarea high, roughly apsacline, widely triangular, with striae crossed by transverse lines; pseudodeltidium narrow, convex, with a monticulus sometimes sharp, with transverse lines. Dorsal valve generally convex, with a variably swollen umbo; dorsal interarea triangular and high; chilidium generally well defined, convex, with a poorly visible monticulus; wide

EXPLANATION OF PLATE 7

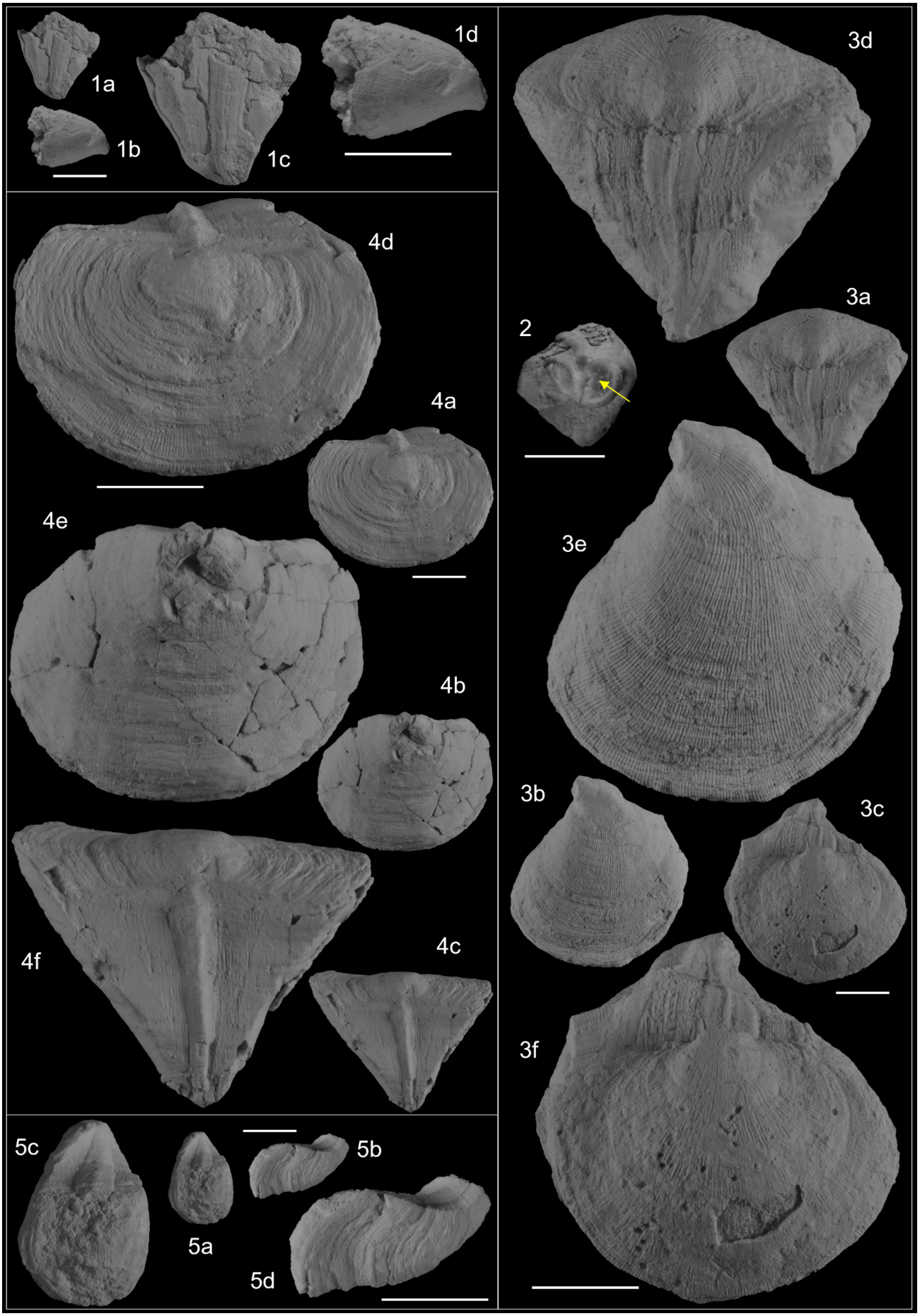
(color online) Permian brachiopods from the Sosio Limestone. All specimens are coated with ammonium chloride. Scale bars are 10 mm; scale bar for Fig. 2 is 5 mm. Yellow arrows highlight characteristic features (e.g., spondylium).

Fig. 1 - *Perigeyerella* cf. *Perigeyerella tricosa.* C118-5, (a) posterior view; (b) lateral view; (c) enlargement of posterior view; (d) enlargement of lateral view.

Figs 2-3 - *Sicelia merlai.*
2 - B18-11, (a) ventral view, detail of sessile spondylium, 3x.
3 - A112-1, (a) posterior view; (b) ventral view; (c) dorsal view; (d) enlargement of posterior view; (e) enlargement of ventral view; (f) enlargement of dorsal view.

Fig. 4 - *Streptorhynchus sinuatus.* A111-9, (a) dorsal view; (b) ventral view; (c) posterior view; (d) enlargement of dorsal view; (e) enlargement of ventral view; (f) enlargement of posterior view.

Fig. 5 - *Streptorhynchus* sp. C118-7, (a) dorsal view; (b) lateral view; (c) enlargement of dorsal view; (d) enlargement of lateral view.


1a
1b
1c
1d
4d
4a
4e
4b
4f
4c
5c
5a
5b
5d
3d
2
3a
3e
3b
3c
3f

and low median sulcus. Ornamentation of numerous costellae increasing in number by intercalation, numbering four-five in 1 mm near the anterior commissure; growth lines and lamellae mainly visible on the dorsal valve. Interior of ventral valve lacking plates (Fig. 8d).

Remarks - The studied specimens were assigned to *Streptorhynchus sinuatus* from the Sosio Limestone (Roadian-Wordian) because of their transverse outline, ornamentation, and the absence of dental plates and septum. The specimens differ from *Streptorhynchus kawanese* Grant, 1976 and *Streptorhynchus sulcatum* Grant, 1976 from the Roadian-Wordian of Thailand in having a more transverse outline and a finer ornamentation. To be noted that the specimens A111-7, A111-9 show a somewhat wider ventral interarea when compared with the specimens of *S. sinuatus* described and figured by both Merla (1928; pl. 1, figs 5-7) and Greco (1938; pl. 1, figs 1-8).

Distribution - Sosio Limestone, Roadian-Wordian, Italy (Merla, 1928; de Gregorio, 1930; Greco, 1938).

Streptorhynchus sp.
(Pl. 7, fig. 5)

Material - One articulated specimen: C118-7.

Occurrence - Sicily, loc. Palazzo Adriano, Sosio Limestone, Pietra di Salomone megablock; Roadian-Wordian.

Description - Small sized shell (12 mm wide, 13 mm long, 15 mm thick), subquadrate in outline, widest near mid-valve; anterior commissure faintly unisulcate. Ventral valve conical, umbo slightly twisted, low, with a wide and low fold; interarea higher than wider, apsacline, with striae crossed by transverse lines; pseudodeltidium wide, weakly convex, with a low monticulus, with transverse lines. Dorsal valve weakly convex. Ornamentation of sharp costellae, numbering five-six in 1 mm at 5 mm from the ventral umbo and increasing in number by intercalation; growth lamellae mostly visible on the ventral valve. Interior of ventral valve lacking plates.

Remarks - The specimen was assigned to *Streptorhynchus* because of the absence of dental plates and septum, and the costellate ornamentation. However, the specimen differs from those identified as *S. sinuatus* in having a higher but narrower interarea, resulting in a more isosceles-like triangular shape. Moreover, costellae in this specimen are somehow sharper than in *S. sinuatus*. Due to the paucity of the material, the nomenclature is left open.

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APPENDIX 1

Additional specimens of taxa of the orders Productida and Orthotetida from the collection of Museo Civico di Storia Naturale of Comiso whose poor preservation prevented a conclusive identification.

Indeterminate taxa	
Taxa	Material
Margniferinae gen. et sp. indet.	Two ventral valves: C99-1; C106-1 One external cast of dorsal valve: C99-2
Linoproductinae gen. et sp. indet.	Three ventral valves: C103-4; C108-1; D83-1
Strophalosiinae gen. et sp. indet.	One external cast of dorsal valve: C107-1
Chonosteginae gen. et sp. indet.	One articulated specimen: C98-1 One ventral valve: C98-2
Meekellidae gen. et sp. indet.	One ventral valve: D81-2
Undetermined brachiopod	One ventral valve: C105-1

APPENDIX 2

Dimensions of the studied specimens (in mm). Legend: symbol ">" indicates measurements taken from broken or matrix-covered specimens; symbol "\" indicates impossibility to obtain the measurement of the specimen due to its poor preservation.

Table 1 - *Megapleuronia grecoi*

Specimen	Length	Width	Thickness
A41-1	> 22	> 33	\
A41-2	> 17	> 24	8
B8-1	> 17.5	> 25	\
C59-1	> 10.9	> 13	4.5

Table 2 - *Costachonetina* sp.

Specimen	Length	Width	Thickness
C131-1	3.8	4	\
C131-2	2	2.9	\

Table 3 - *Neochonetes* (*Nongtaia*) sp.

Specimen	Length	Width	Thickness
D84-1	> 5.5	> 10.5	\
D84-2	8.5	12	\

Table 4 - *Haydenella* sp.

Specimen	Length	Width	Thickness
C130-8	7	7.5	\
C132-1	\	> 13	\
D86-1	8	9	\
D86-2	> 10	> 11	\
D86-3	9.5	> 10	\
D86-4	> 10	11	\

Table 5 - *Comuquia modesta*

Specimen	Length	Width	Thickness
A68-2	4	4.5	\
A68-3	4	4.5	\
C130-2	4	5	\
C130-3	5	> 3	\
C130-4	4	4.5	\
C130-5	4	5	\
C130-6	4.5	4.5	\
C130-9	5.5	6	\
C130-10	6	6	\
C130-11	6	5.5	\
C130-12	5	5	\
C130-13	5	4	\
C130-14	4	3.5	\
D83-2	3	2	\
E13-3	5.5	5	\

Table 6 - *Dyschrestia* sp.

Specimen	Length	Width	Thickness
A68-1	> 11	> 10	\
C130-1	12	11	\

Table 7 - *Spinomarginifera* cf. *S. spinosocostata*

Specimen	Length	Width	Thickness
E13-2	15	14.5	\

Table 8 - *Incisius* sp.			
Specimen	Length	Width	Thickness
C110-1	7	6	\
C110-2	7.5	6	\

Table 9 - *Caricula* cf. *C. salebrosa*			
Specimen	Length	Width	Thickness
A70-1	10	16	\
C96-1	\	9.6	\
C96-2	> 9	13.5	\
C96-3	\	12	\
C96-4	\	10	\
C96-5	\	9.5	\
C124a-1	\	10	\
C124a-2	\	8	\
C124a-3	> 10.5	15	\
C124a-4	\	10	\
C124a-5	\	11	\
E12-1	11	15.1	\
E13-1	\	7.5	\

Table 10 - *Transennatia* sp.			
Specimen	Length	Width	Thickness
C95-1	13	15	\

Table 11 - *Chaoina reticulata*			
Specimen	Length	Width	Thickness
A53-1	12.5	14.5	8
A53-2	> 7.5	> 7	\
A53-3	\	13	\
A57-1	\	15	\
A57-2	\	15	\
A57-3	> 11	16	\
A57-4	> 12.3	13	4.5
A57-5	> 11	12	3.3
A57-6	> 7.5	12	\
C96-6	> 10	> 9.5	\
C96-7	10.5	12	6.5
C128-1	> 8	> 8.5	\
D82-1	\	10	\

Table 12 - *Stereochia* sp.			
Specimen	Length	Width	Thickness
A48-1	> 22	> 37.5	\
A48-2	> 12	> 11.5	\

Table 13 - *Calliprotonia* sp.			
Specimen	Length	Width	Thickness
C94a-1	> 26	> 17	> 15

Table 14 - *Juresania* sp.			
Specimen	Length	Width	Thickness
A50-1	> 19	20	\
A50-2	> 15	> 15.5	9.5
A50-3	9.5	15	\
A50-4	9	11	\

Table 15 - ?*Juresania* sp.			
Specimen	Length	Width	Thickness
D85-1	> 17	18	\

Table 16 - *Anidanthus* sp.			
Specimen	Length	Width	Thickness
A47-1	> 15	> 30	\
A47-2	> 8	> 12.5	\
C100-1	9	> 10	\
C100-2	> 6	> 11	\
C101-1	> 7	> 10	\
C101-2	11	> 14	\
C125-1	> 16	> 30	\
D80-1	> 14	> 30	\

Table 17 - *Compressoproductus compressus*			
Specimen	Length	Width	Thickness
B21-1	13	8.5	\
B21-2	> 9.5	> 6	\
C115-1	> 7	> 5	\
C115-2	> 22	> 19	\
C133-1	> 14	> 18	\
C134-1	> 9	> 7.5	\

Table 18 - *Heteralosia* sp.			
Specimen	Length	Width	Thickness
A64-1	9	11.5	4
A64-2	> 6.5	10	4

Table 19 - *Chonostegoides* sp.			
Specimen	Length	Width	Thickness
C102-1	12	14	6.5
C102-2	10.5	14	\
D88-1	13	> 9	5.5

Table 20 - *Urushtenia* cf. *U. murina*			
Specimen	Length	Width	Thickness
A50-5	> 5.2	7	2.4
A63-1	> 7	7.5	3
A63-2	7	7.5	\
C103-1	8	8	\
C103-2	> 6.5	8.5	\
C103-3	5.5	> 5	\

Table 21 - *Edriosteges* sp.			
Specimen	Length	Width	Thickness
C104-1	> 11.5	> 17	\
C129-1	> 22	> 29.5	\

Table 22 - *Girlasia superelegans*			
Specimen	Length	Width	Thickness
B22-1	11	9	3.5
B22-2	> 7.5	> 7.5	\
B22-3	> 5.5	5	\
C109-1	12	> 9	5.8
C130-7	10	9.5	\

Table 23 - *Strophalosiina* sp.			
Specimen	Length	Width	Thickness
C116-1	> 6	> 6	\
C119-1	18.5	12	5.5
C136-1	15.5	13.5	8.1
D87-1	10.5	12	\

Table 24 - *Scacchinella variabilis*			
Specimen	Length	Width	Thickness
A113-1	8.5	15.5	19
A114-1	15	18	14
A114-2	7.5	8	8
A114-3	5.5	8	7.8
A114-4	9.5	14	15
A114-5	17	21.5	17.5
B20-1	15	> 19	15.5
B23-1	8.5	10.3	7
C117-1	12.2	15	\
C117-2	12	13.5	\
C126-1	18.5	17.5	21
C126-2	13	19	\
C126-3	15.5	19	13.5
C126-4	16.5	20.5	18
C126-5	22	26.2	21

Table 25 - *Coscinarina communis*			
Specimen	Length	Width	Thickness
A40-1	9.5	10.5	\
A40-2	7.5	8	\
A40-3	8.5	7.9	\
A40-4	19	19.1	\
A40-5	17	16	\
A40-6	19.2	28	\
A40-7	\	\	\
A40-8	19	19.5	\
B17-1	\	\	\
B17-2	\	\	\
B17-3	7.5	8.2	\
B17-4	5	7	\
B17-5	6	6	\
B17-6	3.5	4.5	\
B17-7	9	10.5	\
B17-8	\	\	\
B17-9	18	15.1	\
C118-6	9.5	10.2	\
C127-1	\	\	\
D89-1	> 15	> 16	\
D89-2	6	5	\
D89-3	11.5	14.5	\
D89-4	16.5	22	\

Table 26 - *Sicularia sicula*			
Specimen	Length	Width	Thickness
A39-1	26	32	\
A40-9	20.3	25.5	\
A40-10	33	39.7	\
A116-1	22	29.2	\
B17-10	22	35.5	\
C122-1	22.5	22	\
C122-2	7.5	9	\
C122-3	12.2	15.5	\
C122-4	23	21	\
C122-5	20	22	\

Table 27 - *Gemmellaroia marii*			
Specimen	Length	Width	Thickness
A69-1	12	11	12
A105-1	11	12	16.5
A105-2	10	12	\
A105-3	8.5	9.5	\
C120-1	14	13.5	14.5
C120-2	12	19.5	18
C120-3	17	18	21

Table 28 - *Leptodus* sp.			
Specimen	Length	Width	Thickness
C97-1	17	> 26	\
C97-2	17	> 26	\

Table 29 - *Pirgulia conica*			
Specimen	Length	Width	Thickness
A104-1	> 20.5	10.5	\

Table 30 - *Geyerella gemmellaroi*			
Specimen	Length	Width	Thickness
A108-1	> 12	> 10	\
A108-3	> 14.5	> 17	\
A108-6	24	29	\
A109-4	> 22	24	25
A109-5	24	32	\
A110-4	> 29	> 35	\
A110-6	> 35	> 41	\
C124b-3	> 26	> 34	\
C124b-4	> 16	> 21	\

Table 31 - *Geyerella rex*			
Specimen	Length	Width	Thickness
A106-1	10	13.5	\
A106-2	10	11	\
A106-3	10	11	\
A106-4	10	11	> 13
A106-5	12	13	> 28
A107-1	7	8.5	> 9
A107-2	6	7	> 11
A107-3	6.5	7.5	\
A107-4	8.5	9.5	> 15
A108-7	> 17	25.5	\
A109-3	25	29	44.5
A110-1	\	\	\
A110-2	\	\	\
A110-3	\	\	\
A110-5	> 40	> 39	\
A110-7	32	37	\
C124b-1	20	> 16.5	\
C124b-2	16.5	20	\
C124b-5	> 15	20	> 19
C124b-6	19	22	\
C135-1	> 9	> 9	\
D101-1	40	> 42	\

Table 32 - *Geyerella* cf. *G. distorta*			
Specimen	Length	Width	Thickness
A108-2	> 9.5	> 13	\
A108-4	> 22.5	> 24	\
A109-1	> 10.5	15.5	> 21
A109-2	17	> 17.5	> 29

Table 33 - *Perigeyerella* cf. *P. tricosa*			
Specimen	Length	Width	Thickness
B18-1	\	> 4	\
B18-8	> 5	> 6	\
B18-10	> 5	> 5	> 3
C118-2	> 11	> 12	\
C118-5	> 10	> 15	\

Table 34 - *Sicelia merlai*			
Specimen	Length	Width	Thickness
A111-4	10	13	9.5
A111-8	29	27	18
A112-1	38	34.5	24
A115-1	8.5	7.2	7
B18-2	5.5	6	4
B18-5	6	5.5	\
B18-6	7.5	5.5	5
B18-9	> 5.5	5	4
B18-11	7.5	8	\
D81-1	7	4.5	5

Table 35 - *Streptorhynchus sinuatus*			
Specimen	Length	Width	Thickness
A111-1	12	12.5	6.8
A111-2	19	18	\
A111-3	11.8	11	6.5
A111-5	11.8	12	7.5
A111-6	8.5	9	> 8
A111-7	21.2	> 21.5	15
A111-9	27.5	35	25
B18-3	> 7	> 7.5	> 4
B18-4	> 6	7	3
B18-7	5	5.9	> 3
B19-1	14	> 15	10.5
B19-2	14	17	> 12
C118-1	18	> 19	18
C118-3	> 9	12	\
C118-4	9	10	\
C118-9	14	13	11.5
C118-10	10	15	\
E14-1	> 21	> 22	> 15

Table 36 - *Streptorhynchus* sp.			
Specimen	Length	Width	Thickness
C118-7	13	12	15