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ON THE VALIDITY OF *TEREBRATULA SINUOSA* (BROCCHI)

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*Abstract***.** Here we aim to fix some nomenclatural problems relating to the definition of *Terebratula sinuosa*. In 1616 Fabio Colonna first described two different brachiopod specimens from Italy which were later attributed to the genus *Terebratula*. In 1758 Linnaeus erected *Anomia terebratula* in reference to the drawings of Colonna. He described the heavily sulciplicate specimen figured on the upper left (specimen number 4) but addressed the specimen as if it was the number 1 in the figure (upper right). Several authors later inadvertently followed the error of Linnaeus. The neotype for *T. terebratula*, indicated in 1998 by Lee & Brunton, refers to the specimen number 1 in Colonna's figure (the one to the upper right). The two specimens in Colonna were originally considered synonyms. However, the sulciplicate specimen number 4, originally figured by Colonna, refers to a distinctive Miocene *Terebratula* species, which has been often referred to as *Terebratula sinuosa*. We review evidence in favour of such a designation and provide stratigraphic and morphological evidence that *T. sinuosa* deserves the full rank of species. The name *T. sinuosa* should be maintained given the long tradition of the name in the literature, and the definition of *T. terebratula* should therefore be amended.

Introduction

In 1616 Fabio Colonna first described two brachiopod specimens (Fig. 1) as "*concha anomia vertice rostrato*". On page 22 of his book he figured the specimens and referred to the individual on the upper right as n. 1. This specimen comes from the "Calcareniti di Gravina" Formation (near Andria, Apulia, Southern Italy) and is Pliocene-Pleistocene in age. The individual on the upper left, indicated as n. 4, refers to a specimen with sulciplicate commissure coming from the private collection of Ferrante Imperato, a famous XVIth century Neapolitan natural scientist. The provenance of this particular individual is uncertain, although it was possibly found in Miocene outcrops of Apulia (Southern Italy). Unfortunately, both specimens were lost.

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Linnaeus (1758) applied his formal nomenclature scheme to the drawings of Colonna erecting the species *Anomia terebratula*. Unfortunately, he misinterpreted the captions of the original illustration. While the description of Linnaeus clearly refers to Colonna's specimen n. 4, he reported it as if it was the specimen originally labelled as n.1. Consequently, the reference of Linnaeus to the formal name *Anomia terebratula* did not match the original numbering scheme.

In 1814, Brocchi erected the species *Anomia sinuosa* and *Anomia ampulla*. He referred to the former describing a brachiopod possessing *"testa oblonga, valva superiore uniplicata, altera biplicata, margine infero sinuoso, apice perforato. Column., De purp., pag. 22, fig.*1 (fossilis)" addressing the same figure as Linnaeus' *A. terebratula* (which is indeed specimen number 4 in Colonna). Then, he described and figured *A. ampulla* as having *"testa inflata, valva inferiore basim versus obscure biplicata, altera rotundata, laevi, apice prominente*

pertuso" referring to a specimen figured in Agostino Scilla's *Vana speculazione* (1670, tab. 14, figs. 1, 2). From this moment onward, most authors have followed Linnaeus's wrong reference to Colonna's illustration, or used Brocchi's *A. sinuosa* in reference to a heavily sulciplicate, late Neogene *Terebratula* from the Mediterranean area.

This enduring attitude is obviously wrong because the definition of either *Terebratula terebratula* or *Terebratula sinuosa* was clearly incomplete. To fix this problem, in 1998 Lee & Brunton designated the specimen BM(NH) BG152 from the Pliocene of Andria (Southern Italy) as the neotype of *T. terebratula*. Lee et al. (2001) later revised the species *T. terebratula*. They grouped under *T. terebratula* exclusively sulciplicate Miocene specimens and uniplicate to sulciplicate Pliocene forms, thus considering the two individuals of Colonna as conspecifics. Here, we aim to fix the nomenclatural problems regarding the genus *Terebratula*. In particular, we find it timely to propose an amendment of the current definition of *T. terebratula* recognizing *T. sinuosa* as a separate valid species. Several studies have highlighted the profound morphological distance between typical *T. terebratula* and specimens usually referred to as *T. sinuosa*. We revise these studies and the stratigraphic distribution of the two species.

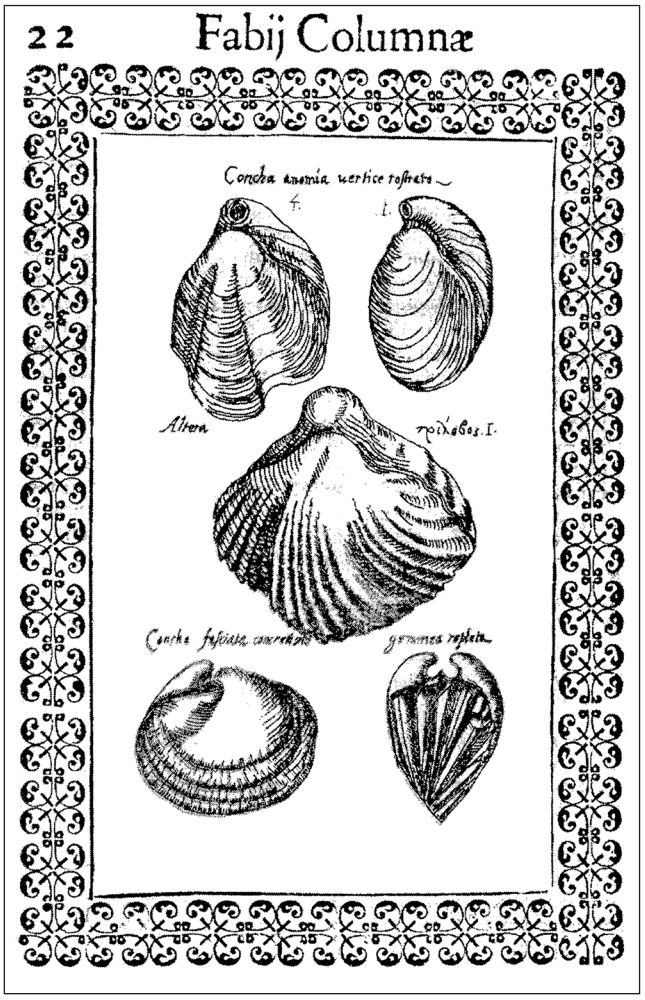

Fig. 1 - Page 22 of *Purpura* (Colonna 1616). The small numbers close to the specimens in the upper part of the figure are respectively number 4 and 1, from the left to the right. The specimen on the upper left (number 4) probably came from the Miocene of the Pietra Leccese Formation (Apulia, Southern Italy). The specimen on the upper right came from the Pliocene calcarenites of Andria (Southern Italy). It represents a topotype of *Terebratula terebratula*.

Previous reference to *Terebratula sinuosa* in the scientific literature

After Brocchi (1814), the name *T. sinuosa* was used by Davidson (1864) to indicate fossil specimens from Malta. Davidson himself later (1870) described several Tertiary brachiopods from Italy including *Terebratula bisinuata*, *T. sinuosa*, *Terebratula rovasendiana*, *Terebratula grandis*, *Terebratula pedemontana*, *Terebratula ampulla* and *Terebratula regnolii*.

The name *T. sinuosa* was used by Seguenza (1865) in reference to specimens found near Messina, and later re-used by the same author in reviewing the collection of Costa (Seguenza 1870). Subsequently, Seguenza (1871) reviewed Tertiary brachiopods from Southern Italy. In his focus on *Terebratula,* Seguenza described *T. sinuosa, T. ampulla, T. pedemontana, T. philippi, T. regnolii, T. romboidea,* and *T. siracusana*. In the same paper he erected the species *Terebratula calabra, Terebratula costae,* and *Terebratula scillae*. It is worth noticing that Seguenza erected *T. costae* from the Miocene of Monteleone (now Vibo Valentia, Calabria) and Malta, including the taxon *T. biplicata* previously recognized by Costa within the list of synonyms.

Further reference to *T. sinuosa* was made by Bertrand & Kilian (1889) for Spanish individuals coming from near Granada.

Sacco (1902) cited *T. sinuosa* in a study on Tertiary brachiopods from Piedmont and Liguria (Northern Italy).

In 1933 Boni proposed the name *Terebratula maugerii* for a Miocene specimen of Monte Vallassa. Studying a large number of well-preserved specimens from the same locality, Boni (1934) recognized the similarities between *T. maugerii* and *T.*

sinuosa, but, despite this, he divided the latter into a number of subspecies and 'varieties'.

In 1966 Sirna reviewed the stratigraphic distribution and systematics of *T. sinuosa*. He further collected this species in Serravallian (Miocene) deposits from Scanno and Monte Maiella (Abruzzo, Central Italy). These levels could be dated up to the Messinian according to Cornacchia et al. (2017). Sirna considered *T. sinuosa pedemontana,* Boni's (1934) subspecies, and *T. costae,* described by Nelli (1910) in reference to specimens found close to L'Aquila (Central Italy), as synonyms of *T. sinuosa*.

Marasti (1973) described a number of beautifully preserved specimens from the Miocene deposits of the Stirone River (Emilia, Northern Italy) as *T. sinuosa*.

Cooper (1983) described *T. ampulla* from Pliocene sediments at Monte Mario (Roma, Central Italy), illustrating individuals morphologically similar to *T. terebratula*, and *T. sinuosa* from Malta. In the same paper he established the new genus *Maltaia* which externally resembles *Terebratula* but yields a different brachidium. Cooper further erected the new species *Maltaia maltensis*. He pointed out that *"The loop of* Maltaia *is similar to that of* Terebratula *in its great width, lack of inner hinge plates, and well-defined terminal points. The loop of* Terebratula*, however, has the transverse band flattened medianly and not extended ventrally to form a protuberant tongue"* (Cooper 1983, p. 232).

Gaetani & Saccà (1983), studying Tertiary deposits from Calabria and Sicily (Southern Italy), described *T. sinuosa* from Cessaniti (Calabria) and considered *T. pedemontana, T. costae, M. maltensis* and all of Boni's (1934) *T. sinuosa* subspecies to be synonyms. They further accepted as valid *T. calabra* (Seguenza, 1871), for a number of specimens described from the Upper Pliocene of Santa Tecla (Sicily) and Terreti-Monte Gonì (Calabria). They considered *T. biplicata* described by Costa (1851), *T. sinuosa* by Seguenza (1865, 1870, 1871) and Taddei-Ruggiero (1983), and *T. terebratula* by Pajaud (1976) as synonyms of *T. calabra*.

Taddei Ruggiero (1994) identified *T. sinuosa*, *T. calabra, T. siracusana* and *T. scillae* in Neogene sediments of Salento (Apulia, Southern Italy).

Lee & Brunton (1998) selected a neotype for *Terebratula terebratula* from the "Calcareniti di Gravina" Formation near Andria (Apulia), since the specimen originally figured by Colonna (1616) was lost. Lee et al. (2001) discussed the considerable taxonomic confusion surrounding the taxon *T. terebratula*. They considered *T. sinuosa* as a synonym of *T. terebratula*. They further put *T. calabra* and *T. costae* into the synonymy of *T. terebratula*, and therefore accepted that the latter species extends back to the Miocene.

Borghi (2001) described Neogene brachiopods from Emilia (Northern Italy), reporting that both *T. sinuosa* and *T. ampulla* were present.

In 2006, García-Ramos provided an extensive revision of European Tertiary brachiopods. He recognized *T. sinuosa* and *T. maugerii* as conspecifics and took the latter specific name as valid. He further acknowledged the validity of *T. calabra* and of the genus *Maltaia*, including the species *M. maltensis*, *M. costae* and the new species *M. pajaudi*. García-Ramos considered the specimens referred to as *T. sinuosa* by Sirna (1966) as *Maltaia costae*. He further listed a number of Iberian fossil sites where *T. sinuosa* is actually present. According to García-Ramos (2006) further possible conspecific (or at least closely related) forms are *Terebratula carryensis* from the Lower Miocene of France and *Terebratula hoernesi* found in the Miocene of Hungary.

Bertolaso et al. (2009) figured a specimen of *T. ampulla* from the Pliocene of Castell'Arquato (Piacenza, Emilia) and two Tortonian specimens of *T. maugerii,* which are remarkably similar to each other in spite of their different origins. One of the specimens of *T. maugerii* comes from Scipione Ponte (Parma, Emilia, Northern Italy) and the other from Los Brianes, Corvera (Murcia, Spain).

The validity of *Terebratula sinuosa*

Keys to determining whether *T. sinuosa* deserves the status of a full species include the stratigraphic distribution and the peculiar morphology. Typical *T. sinuosa* shells are not just sulciplicate. The most distinctive external character is a long, massive and well-defined fold running longitudinally along the ventral valve from the umbonal zone (Fig. 2). Specimens with these characters are known in, at least, Miocene deposits of Italy, Spain, and possibly Malta (see García-Ramos 2006 for an extensive review).

Many researchers have used the specific name *Terebratula sinuosa* in reference to such heavily sulciplicate *Terebratula* brachiopods. We have

Fig. 2 - *Terebratula sinuosa*. Row a) juvenile specimen from Cessaniti (Calabria, Southern Italy). Rows b-c-d) specimens coming from the Stirone River section (b juvenile; c-d adults, specimen d is housed in the collections of the Castell'Arquato Geological Museum). From the left: dorsal view (first column), ventral view (second column); side view (third column), frontal view (fourth column).

statistically tested the morphological uniqueness of *T. sinuosa* in reference to other species belonging to this genus. We performed a three-dimensional geometric morphometric analysis of 142 undeformed brachiopod specimens belonging to four nominal species (*T. ampulla, T. sinuosa, T. terebratula,* and *T. scillae*; Taddei Ruggiero et al. 2008a). The individuals tentatively referred to *T. ampulla* in Taddei Ruggiero et al. (2008a) come from Valle Botto (Asti, Northern Italy), but they could actually belong to a different species. Nevertheless, we found that, from a morphological point of view, *T. sinuosa* is the most derivate *Terebratula* species (see fig. 5 in Taddei Ruggiero et al. 2008a). All the specimens analysed by Taddei Ruggiero et al. (2008a) were adult, meaning that the morphological distance between *T. sinuosa* and other *Terebratula* species could depend on a late ontogenetic variation within an otherwise highly variable *Terebratula* lineage. To deal with this issue, we studied the developmental basis (ontogeny and ontogenetic allometry) of the same four species, still using three-dimensional geometric morphometrics. We demonstrated that the typical, heavily sulciplicate anterior commissure in *T. sinuosa* is already present at juvenile stages and did not depend on size differences between the morphotypes (Taddei Ruggiero et al. 2008b, Fig. 2). This indicates that the difference between *T. sinuosa* and other *Terebratula* is profound, justifying its recognition as a distinct species.

In addition, *T. sinuosa* specimens are Miocene in age, whereas larger *Terebratula*, and most importantly its presumed synonym *T. terebratula,* are Pliocene to Pleistocene in age. Hence, the ontogeny, morphology and stratigraphy all point to the same evidence, that is *T. sinuosa* is a different species, which deserves its own taxonomic species status. Other authors have advanced similar evidence in support of our conclusions, among the others Gaetani & Saccà (1983), Garcìa-Ramos (2006) and Bertolaso et al. (2009).

It should be noted that sulciplicate specimens, not as strongly folded as *T. sinuosa,* are known in the Miocene and in the Pliocene as well.

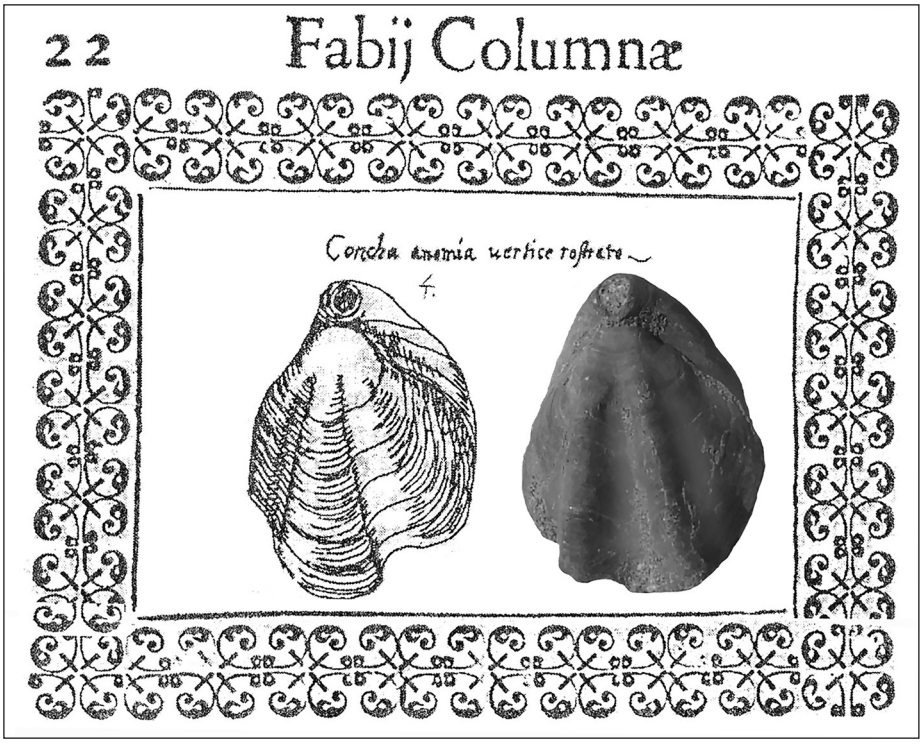

Fig. 3 - The specimen illustrated in figure n.4 by Colonna (1616) together with a typical Miocene *T. sinuosa* specimen coming from the Stirone River section.

Such individuals were recognized as *T. sinuosa* in Seguenza (1865, 1870, 1871) and Taddei Ruggiero (1983), and as *T. calabra* in Gaetani & Saccà (1983) and García-Ramos (2006). The presence of such a sulciplicate anterior commissure was considered part of the morphological variability of *T. terebratula* by Lee et al. (2001). However, it is important to consider that these forms lack the long and prominent fold on the ventral valve which is present in *T. sinuosa*. We deem it is probably incorrect to keep considering these specimens as synonyms of *T. terebratula,* yet they clearly do not belong to *T. sinuosa* and therefore deserve further study. The same holds true for *Terebratula costae*. The extensive collections for these forms including the specimens studied by Costa (held at the Museum of Paleontology in Naples), the collection of Seguenza (held at the "Gemmellaro" Museum in Palermo), and the possibly conspecific sample from Águilas (Murcia, Spain, García-Ramos 2006) deserve further analysis.

Several authors have used the taxonomic name *T. maugerii* as a junior but valid synonym of *T. sinuosa*. However, the species epithet *maugerii* was erected on a single deformed specimen by Boni (1933) and is only valid under the hypothesis that *T. sinuosa* is a synonym of *T. terebratula* (Garcìa-Ramos 2006), which we proved to be incorrect. In addition, given the obvious reference of the '*sinuosa*' morphotypes to the heavily sulciplicate specimen of Colonna (e.g. Sacco 1902; Marasti 1973; Gaetani & Saccà 1983), we propose to protect the taxon *T. sinuosa* as a 'conserved name', in keeping with the rules of the International Code of Zoological Nomenclature (ICZN, Art. 23). Therefore, *T. maugerii* falls within the valid name *T. sinuosa*.

The provenance of the specimen n. 4 figured by Colonna (1616) is unknown, although in his description Colonna refers to it as *"replete erat concretione candida terrea"* (filled with pale sediment, most probably a calcarenite) which is consistent with the Pietra Leccese Formation. We found *T. sinuosa* specimens from silts of Stirone River (Emilia, Northern Italy, Fig. 3), from sandstone of Cessaniti (Calabria, Southern Italy), and from calcarenites within the Pietra Leccese Formation (Salento, Apulia, Southern Italy). In erecting *Anomia sinuosa* Brocchi explicitly referred to Colonna's sulciplicate specimen and further indicated that fossil deposits near Piacenza (Emilia, Northern Italy) yield the species. It is thus plausible that Colonna's specimen belongs to the Pietra Leccese calcarenites. Hence, we deem that the neotype and type locality for *T. sinuosa* must be found and eventually defined (ICNZ, Art. 76.3). The Miocene outcrops in Emilia indicated by Brocchi could be used for a suitable neotype investigated for the same aim (ICNZ, Art. 76.2).

Conclusions

We remark that Miocene, sulciplicate *Terebratula* having a massive, well-defined and distinctive fold running longitudinally along the ventral valve from the umbonal zone should be attributed to *Terebratula sinuosa* which we therefore consider a valid taxon of full species rank. This species occurs in Miocene deposits of Italy, Spain, and possibly Malta. A neotype and the relative type locality should be selected for the taxon *Terebratula sinuosa*. *Terebratula maugerii* should be considered a junior synonym of *T. sinuosa*. The definition of *T. sinuosa* as a valid species requires the amendment of the stratigraphic distribution of *T. terebratula*, which is consequently limited to Pliocene-Pleistocene deposits.

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