European Journal of Taxonomy 910: 115–160
https://doi.org/10.5852/ejt.2023.910.2365

ISSN 2118-9773
www.europeanjournaloftaxonomy.eu
2023 · Kiel S. *et al.*

Research article

urn:lsid:zoobank.org:pub:DED6151F-FD3A-488D-9CAF-1B0DAD697BA3

Mollusks (Gastropoda, Bivalvia) from Miocene cold-seep deposits in northern Italy: revisions and additions

Steffen KIEL [1,*], Marco SAMI [2] & Marco TAVIANI [3]

[1] Swedish Museum of Natural History, Department of Palaeobiology, Box 50007, 10405 Stockholm, Sweden.
[2] Museo Civico di Scienze Naturali, 51, Via Medaglie D'Oro 51, 48018 Faenza, Italy.
[3] Institute of Marine Sciences, Italian National Research Council, Via Gobetti 101, 40129 Bologna, Italy; and Stazione Zoologica Anton Dohrn, Villa Comunale, 80121 Napoli, Italy.

[*] Corresponding author: steffen.kiel@nrm.se
[2] Email: marco.sami@cheapnet.it
[3] Email: marco.taviani@bo.ismar.cnr.it

[1] urn:lsid:zoobank.org:author:2BC780D7-8596-4A88-B679-43D4DF7D7E62
[2] urn:lsid:zoobank.org:author:84B3092F-9552-4BA5-9D8A-6B0D4EB9C18F
[3] urn:lsid:zoobank.org:author:693853C3-940F-43BE-AE69-6344CD02A001

Abstract. Here, we report on 33 molluscan species from Miocene 'Calcari a *Lucina*' hydrocarbon-seep deposits in northern Italy. Three new species are described: the chilodontaid gastropod *Putzeysia diversii* sp. nov., the lucinid bivalve *Miltha* (sensu lato) *romaniae* sp. nov., and *Sisonia ultimoi* sp. nov., a heterodont bivalve of uncertain taxonomic affinity. Fourteen species are described in open nomenclature. The common but enigmatic gastropod species *Phasianema taurocrassa* is here suggested to belong to the seguenzioid genus *Cataegis*. Most gastropod species are inhabitants of the deep-sea floor in general, and are not restricted (obligate) to sites of hydrocarbon-seepage. The gastropod *Putzeysia diversii* sp. nov. and the bivalve *Sisonia ultimoi* sp. nov. are the geologically oldest members of their genera known to date. While the genus *Putzeysia* is geographically restricted to the NE Atlantic Ocean and the Mediterranean Sea, *Sisonia ultimoi* sp. nov. represents another link of the Miocene Mediterranean seep fauna to that of the central Indo-West Pacific Ocean.

Keywords. Chemosymbiosis, deep sea, Mediterranean Sea, Neogene, biogeography.

Kiel S., Sami M. & Taviani M. 2023. Mollusks (Gastropoda, Bivalvia) from Miocene cold-seep deposits in northern Italy: revisions and additions. *European Journal of Taxonomy* 910: 115–160. https://doi.org/10.5852/ejt.2023.910.2365

Introduction

The Neogene deep-water deposits of northern Italy host scattered, localized carbonate deposits locally known as 'Calcari a *Lucina*' due to the abundance of lucinid bivalves (Manzoni 1876; Coppi 1877; Scarabelli 1880). These deposits are now recognized as representing ancient hydrocarbon-seep deposits

(Taviani 1994, 1996; Conti & Fontana 1999; Taviani 2001, 2011; Conti *et al.* 2021). Like the fauna living around deep-sea hydrothermal vents, the methane-seep fauna is composed mainly of taxa living in symbiosis with chemotrophic bacteria, from which they derive the majority of their nutrients (Fisher 1995; Nelson & Fisher 1995). This quasi-independence from photosynthetically derived food makes these faunas interesting for evolutionary biology, because they appear to have had a distinct, independent evolutionary history (Tunnicliffe 1991; Campbell & Bottjer 1995; Kiel & Little 2006; Kiel 2015). Because the fossil record provides the only direct evidence for the evolutionary history of these faunas, thorough taxonomic work on the species found in ancient hydrocarbon seep deposits is crucial to understand the ecological and biogeographic history of these ecosystems.

Over the last one-and-a-half decades, we (in different constellations) have published several faunistic and taxonomic updates of the mollusks of the Calcari a *Lucina* deposits. These included most bivalve groups (Taviani *et al.* 2011; Kiel & Taviani 2017, 2018) and various reports on individual new sites or noteworthy taxa (Berti *et al.* 1994; Lucente & Taviani 2005; Sami & Tabanelli 2013; Sami & Taviani 2015; Kiel *et al.* 2018, 2023). The purpose of this study is to revise all species that we have not covered previously (mostly the gastropods), to describe new species, to provide new records of known species from various sites, and to supply new taxonomic data for known species.

Material and methods

Material

The material documented here originates from eleven Miocene localities in the Emilia-Romagna and Toscana regions in northern Italy (Fig. 1). The material from Castel di Casio, Castiglion dei Pepoli, and Guzzano, was collected by a private collector from erratic blocks and outcrops of different (sometimes uncertain) ages, hence the stratigraphic context is difficult to interpret. Some rock units that host these fossil are known to range back into the latest Oligocene (late Chattian) in age. Some geological information on these sites and the associated fossils was reported in the historical literature (Capellini 1881a, 1881b, 1881c), and more recently reconsidered by Vai *et al.* (2023). Rich collections from this area are hosted at the MGGC and the 'Sala della Terra' of the territorial museum Castiglion dei Pepoli (Vai *et al.* 2023).

Castel di Casio

This village is located SSE of Bologna in the Emilia-Romagna region; the late Oligocene (late Chattian) to Aquitanian Macigno Formation outcrops in this area, and the material reported here was collected from float blocks. The specimens are enclosed in a micritic limestone rich in foraminiferans, quartz grains, and patches of silt, includes pelagic gastropods and a few large terebratulids; mollusks shell are recrystallized to sparite.

Guzzano

Guzzano is located SSE of Bologna, between Castel di Casio and Castiglion dei Pepoli, surrounded by outcrops of the "Arenarie di Vallorsara" of the Macigno Formation, which is of Aquitanian age according to Bettelli *et al.* (2002). This geosite provided abundant lucinids and associated fauna, plus many geodes (Vai *et al.* 2023). Overall, the lithology is similar to that of the Castel di Casio and Castiglion dei Pepoli sites; notable is that virtually all lucinids have a hollow interior with large calcite crystals. It also includes small (up to 20 mm length) specimens of the nautiloid *Aturia* Bronn, 1838.

Castiglion dei Pepoli

Located SSE of Bologna and about 8 km east of Castel di Casio, in the Emilia-Romagna region, surrounded by sediments mapped as Cervarola Formation, Aquitanian to Langhian (Vai *et al.* 2023). The lithology is very similar to that of the Castel di Casio site, and the fossil inventory includes a few small specimens of the nautiloid *Aturia*.

Casola

Specimens from this site were found in the MGGC collection. The site is located about 5 km West of Castel di Casio, and the fossils are sourced from the lower Burdigalian 'Stagno Member' of the Cervarola Formation (Vai *et al.* 2023). Specimens are embedded in a micritic limestone with very few other components, but the style of shell preservation is similar to that of the aforementioned three sites. It is one of the historical fossiliferous sites described by Capellini (1881a).

Ca' Cavalmagra

This is a limestone deposit SSE of Palazzuolo (Tuscany, Province of Florence) in the Tuscan Romagna Appenine (approx. 44°05′46″ N, 11°37″ E), Marnoso-arenacea Formation, Middle Miocene (upper

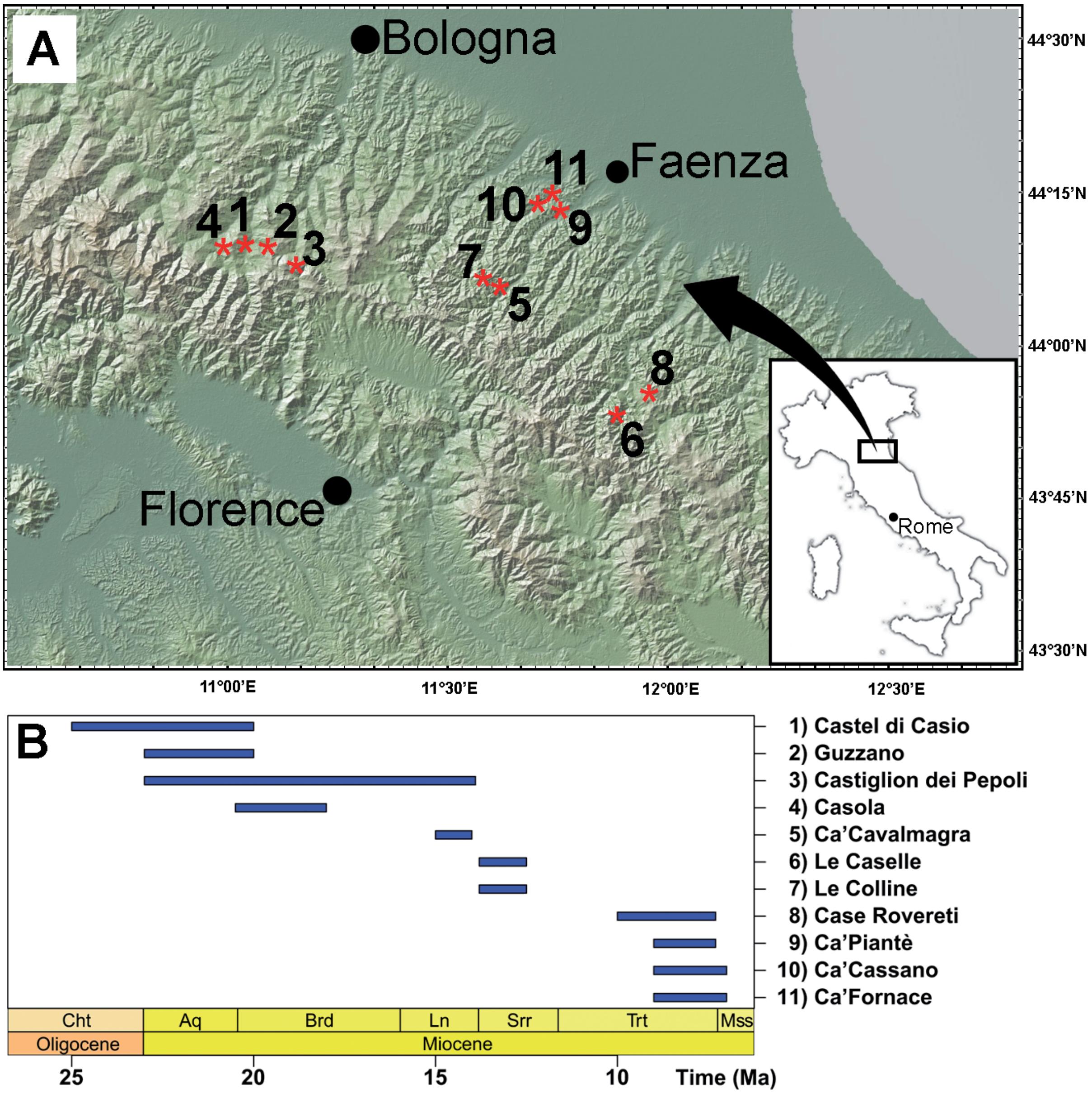

Fig. 1. Sampling sites in northern Italy. **A**. Their locations in northern Italy, numbers correspond to those in panel B. **B**. Stratigraphic ages of the sampling sites. Map produced using the GeoMapApp (https://www.geomapapp.org/, Ryan *et al.* 2009).

Langhian). Bivalves from this locality were described earlier by Kiel & Taviani (2017); the present material is deposited at MSF.

Le Caselle

Marls of the Le Caselle Olistostrome are contained within the early Serravallian section of the Marnoso-arenacea Formation (Berti *et al.* 1994) and crop out near Le Caselle in the Emilia-Romagna province about 4 km NEE of Lago Ridracoli. They contain three clearly distinguishable olistoliths with seep-associated carbonate nodules, numbered A, B, and C (Berti *et al.* 1994). The bivalves reported here are from olistoliths A (at 43°53′05″ N, 11°53′05″ E) and C (at 43°53′19″ N, 11°52′50″ E), and are deposited at NRM.

Le Colline

Scattered marly to micritic limestone blocks outcrop near Le Colline, NE of Salecchio, near Palazzuolo (Tuscany region) in the Tuscan Romagna Appenine (approx. 44°06′42″ N, 11°34′26″ E), Marnoso-arenacea Formation, middle Miocene (early Serravallian); further information on this outcrop is provided by Conti & Fontana (1998), bivalves have been reported by Kiel & Taviani (2017). The present material is deposited at MSF.

Case Rovereti

Large isolated limestone block are found at Case Rovereti, just NW of the small village of Raggio, near Santa Sofia (Forlì province; 43°55′38″ N, 11°6′43″ E); they are located on San Paolo Marls but may not belong to this stratigraphic unit (Late Miocene; middle Tortonian–lower Messinian). This deposit has previously been described in detail (Moroni 1966; Taviani 1994; Terzi *et al.* 1994; Kiel & Taviani 2017). The material reported here is deposited at NRM.

Ca’ Pianté

Scattered marly to micritic limestone blocks occur SW of Ca’ Pianté near Brisighella (Ravenna province, 44°13′45″ N, 11°43′53″ E); fossils from these blocks are Late Miocene (late Tortonian) in age. Additional information can be found in Conti & Fontana (1998), bivalves have been described by Kiel & Taviani (2017). The material reported here is deposited at MSF.

Ca’ Cassano

An in-situ block of carbonate-cemented, detrital siltstone was recently reported from Ca’ Cassano along Via Monte Mauro, at 44°13′59.6″ N, 11°42′21.2″ E, just to the west of Brisighella, in Late Miocene (upper Tortonian–?lower Messinian) pre-evaporitic “Euxinic Shales” (Sami & Taviani 2019; Kiel *et al.* 2023). Here we provide a taxonomic update on a bivalve previously reported as *Myrtea* W. Turton, 1822 or *Miltha* Adams & Adams, 1857; the specimens are deposited at MSF.

Ca’ Fornace

Erratic limestone blocks were collected from the bed of Sintria Creek downstream of the bridge near Ca’ Fornace, near Brisighella (Ravenna province) in the Romagna Apennine (at 44°14′38.9″ N, 11°44′0″ E); Late Miocene (Tortonian/?early Messinian) in age. Seep limestones from this site were first reported by Vai *et al.* (1997) and several mollusks have been described from these blocks (Kiel & Taviani 2017; Kiel *et al.* 2018). The new material reported here is deposited at MSF.

Methods

Macrofossils were coated with ammonium chloride prior to photography to enhance morphological details. Most specimens were photographed using a Nikon D80 digital camera, some were imaged using a Cognisys Stackshot 3X stacking image system and the Zerene Stacker software, combining 15–25 pictures for each composite image. Microfossils were imaged using a scanning electron microscope (LEO 1530 SEM at 3.8 KV; specimens coated with 14 nm of platinum).

Institutional abbreviations

MGGC = Museo Geologico Giovanni Capellini, Bologna, Italy
MSF = Museo Civico di Scienze Naturali, Faenza, Italy
NRM = Swedish Museum of Natural History, Stockholm, Sweden

Results

Systematics

Class Gastropoda Cuvier, 1795
Subclass Vetigastropoda Salvini-Plawen, 1980
Order Seguenziida Haszprunar, 1986
Family Cataegidae McLean & Quinn, 1987

Genus ***Cataegis*** McLean & Quinn, 1987

Type species

Homalopoma finkli Petuch, 1987 (= *Cataegis toreuta* McLean & Quinn, 1987), by original designation.

Cataegis taurocrassa (Sacco, 1895)
Fig. 2A–J

Phasianema costatum (Br.) var. *taurocrassum* Sacco, 1895: 18, pl. 1 fig. 37.

Phasianema (*Phasianema*) *taurocrassum* – Moroni 1966: pl. 4 figs 2–3.

Material examined

ITALY – **Emilia-Romagna** • 2 specs; Ca' Piantè; MSF 2352 (H = 4.8 mm), MSF 2353 (H = 7 mm). – **Tuscany** • 2 specs; Le Colline; MSF 1230 (H = 6.8 mm), MSF 2351 (W = 3.5 mm).

Stratigraphic and geographic range

Middle to Upper Miocene, northern Italy.

Remarks

This species was originally reported from the Calcari a *Lucina* deposits by Moroni (1966) as *Phasianema taurocrassum*, and was subsequently cited as such from other Calcari a *Lucina* sites in the Romagna Apennines (Sami & Taviani 2019; Kiel *et al.* 2023). Sacco (1895) introduced *Phasianema costatum* var. *taurocrassum* for rare specimens from the 'Helvetian' of Cinzano in the Turin hills (coll. Rovasenda). Ferrero Mortara *et al.* (1981) indicated that fossils from Cinzano locality are late Miocene in age. Moroni (1966) wrote that compared to the variants of the Aquitaine and Loire basins, and of the Italian Pliocene, *Phasianema taurocrassum* (elevated to species level by her) differs in size, by having a thicker shell, different proportion between the spiral cords and the interspaces, growth striae on the cords and interspaces, a the clearer umbilicus that is well delimited by the last spiral cord, a columellar callus with a straight margin that is oblique to the axis and parallel to the direction of the umbilical rim, a much narrower subsutural depression due to the twisted coil and therefore a less slender general shape. We follow her interpretation and consider the respective specimens from the Calcari a *Lucina* deposits as conspecific with *Phasianema taurocrassum*.

The genus *Phasianema* Wood, 1842, however, is a pyramidellid (van Aartsen *et al.* 1998), based on the Pliocene fossil *Phasianema sulcata* Wood, 1842, as indicated by van Regteren Altena (1956). We find it questionable that a thick-shelled species like *Phasianema taurocrassum* should belong to the pyramidellids, although its protoconch, which could provide more definitive evidence, remains unknown. The holotype of *Phasianema sulcata* illustrated by Wood (1842: pl. 5 fig. 15) is much higher spired than *P. taurocrassum*, has more numerous spirals with the typical "opisthobranch" pitted grooves, and the outer lip does not show the flaring, reinforced endings of the spiral ribs. Recently, Kaim (2022) re-assigned the Calcari a *Lucina* specimens of *Phasianema taurocrassa* to the late Pliocene pyramidellid *Carinorbis clathrata*. However, that species has high, angular spiral cords crossed by widely spaced axial (oblique) lamellae (see Tabanelli *et al.* 2022: figs 1–2) very unlike beaded spirals and fine, dense oblique striations of the Calcari a *Lucina* specimens.

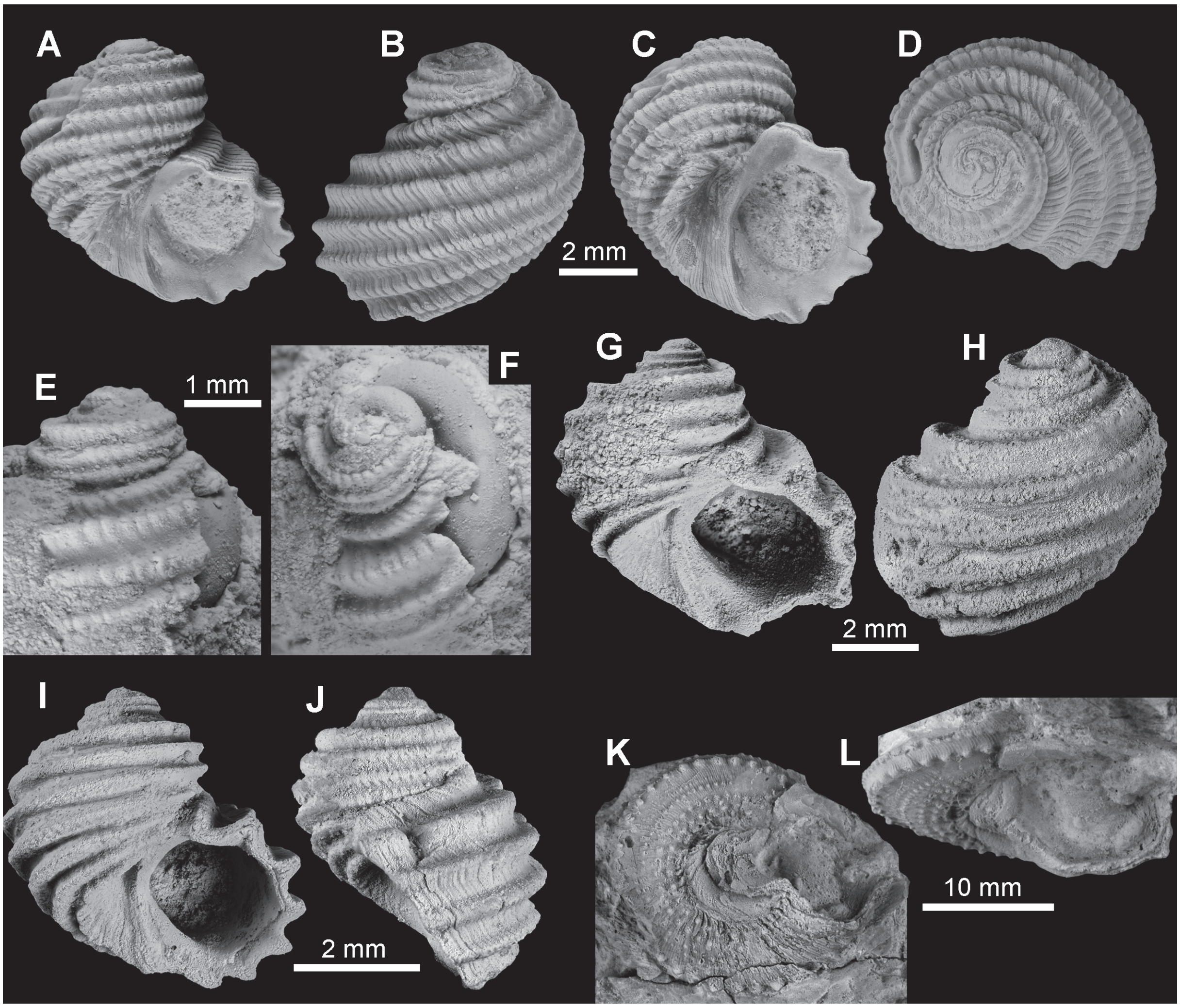

Fig. 2. Seguenzioidea A.E. Verrill, 1884 (Vetigastropoda) from the Calcari a *Lucina* seep deposits in northern Italy. **A–J**. The cataegid *Cataegis taurocrassa* (Sacco, 1895). **A–D**. Complete specimen from Le Colline (MSF 1230). **E–F**. Specimen partly embedded in rock matrix (MSF 2351). **G–H**. Complete specimen from Ca' Piantè (MSF 2352). **I–J**. Complete specimen from Ca' Piantè (MSF 2353). **K–L**. The calliotropid *Calliotropis* sp. from Ca' Piantè (MSF 1076).

We place *Phasianema taurocrassum* in the seguenzoid genus *Cataegis* (as *Cataegis taurocrassa*) based on its overall shell shape; distinctive, nodular spiral ornament; and the oblique, circular aperture with callused inner lip. The genus *Kanoia* Warén & Rouse, 2016 was introduced for *Cataegis*-like species from Caribbean and tropical eastern Pacific deep-water methane-seeps, mainly based on radula characters (Warén & Rouse 2016). As pointed out earlier in the context of a species of *Cataegis* from the Pliocene of the Philippines, *Cataegis* appears to have a higher, more conical spire whereas the spire of *Kanoia* appears somewhat dome-shaped (Kiel *et al.* 2020), unlike *Cataegis taurocrassa*.

The most distinctive features of *C. taurocrassa*, which clearly set it apart from other species of *Cataegis*, include the 'twisted' coiling of the last whorl, the large umbilical slit, and the strongly nodular spiral ornament. Among the extant species, *Cataegis tallorbioides* Vilvens, 2016, from 543–593 m depth around the Solomon Islands (Vilvens 2016), has perhaps the most distinct nodular ornament, though not as nodular as in *C. taurocrassa*. In most other extant species of *Cataegis*, the spiral ornament is granular rather than nodular (McLean & Quinn 1987; Fu & Sun 2006; Vilvens 2016). The Oligocene/Miocene species from the Caribbean region assigned to *Cataegis*, including *Cataegis godineauensis* (Van Winkle, 1919), have rather strong spiral ridges that are only finely crenulated (Gill *et al.* 2005; Kiel & Hansen 2015), in contrast to the strong nodular ornament of *C. taurocrassa*. The Pliocene *Cataegis ramosi* Kiel, Aguilar & Kase, 2020 from Philippines differs by lacking an umbilical slit and having non-tuberculate spiral sculpture (Kiel *et al.* 2020).

Family Calliotropidae Hickman & McLean, 1990

Genus ***Calliotropis*** Seguenza, 1903

Type species

Trochus ottoi Philippi, 1844, by original designation.

Calliotropis sp.
Fig. 2K–L

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Ca' Piantè; MSF 1076 (W = 23.3 mm).

Description

Base about 20 mm in diameter, rather flat, basal margin sharp, marked by beaded spiral cord, umbilicus about ¼ of base diameter, bordered by smooth callus; base sculptured by three beaded spirals, outermost fine with dense nodes, and two equally strong beaded spirals with widely spaced nodes near umbilicus; aperture subcircular, entire.

Remarks

This fragmentary specimen preserving only the base resembles many fossil and recent species of *Calliotropis* (i.e., Jansen 1994; Pérez *et al.* 2022). *Calliotropis* today is essentially a deep-water genus and most Cenozoic fossil records are also from deep-water strata (Dall 1909; Pérez *et al.* 2022).

Stratigraphic and geographic range

Upper Miocene, northern Italy.

Family Chilodontaidae Wenz, 1938

Genus ***Putzeysia*** Sulliotti, 1889

Type species

Trochus clathratus Aradas, 1847, by monotypy. See Reitano *et al.* (2022) for a detailed discussion and re-description of the type material.

Putzeysia diversii sp. nov.
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Fig. 3A–C

Diagnosis

Shell turbiniform made of at least 4 whorls; suture deep; whorls slightly convex, sculpture cancellate, made of 20–24 opisthocyrt axial ribs per whorl, crossed by 4–5 spirals, intersections tuberculate; basal margin rounded-angular, marked by spiral cord; base weakly sculptured, at least two spiral cords near umbilical slit; aperture nearly circular.

Etymology

The new taxon is dedicated to the amateur paleontologist Mauro Diversi (1964–2021) who provided over the years many important samples to the 'Museo Civico di Scienze Naturali' of Faenza, including specimens from the Calcari a *Lucina* deposits discussed in previous papers by the authors.

Material examined

Holotype

ITALY – **Emilia-Romagna** • Ca' Piantè; MSF 1079 (H = 3.3 mm).

Other material

ITALY – **Tuscany** • 3 specs; Ca' Cavalmagra; MSF 1300 (H = 3.2 mm), MSF 1301 [2 specs].

Remarks

Putzeysia diversii sp. nov. differs from the type species *Putzeysia clathrata* by having much less convex whorl flanks, a less incised suture, and more pronounced sculpture on the base (Reitano *et al.* 2022). A specimen from uppermost Miocene (Messinian) deep-water strata in Spain identified as *Putzeysia* cf. *clathrata* (see Barrier *et al.* 1991: fig. 4.2) differs notably from *Putzeysia diversii* by its much stronger ornament, consisting of only two strong spiral cords per whorl and the axial ribs being more oblique; the ornament is also very strong on the base, in contrast to *Putzeysia diversii*.

Putzeysia diversii sp. nov. differs from the extant *Putzeysia rickyi* Reitano & Scuderi, 2021, from Sicily mainly by a slightly lower spire, straighter whorl flanks, and the much weaker ornamentation on the base (Reitano & Scuderi 2021). Even more similar is the Early Pleistocene to Recent *Putzeysia wiseri* (Calcara, 1842), also from the Mediterranean Sea, and fossil in southern Italy, which has a spire of similar height, but the whorls are more convex and it has a sculptured base (Guidastri *et al.* 1984; Reitano & Scuderi 2021). The same applies to two extant species of *Putzeysia* from the Canary Islands (Engl & Rolán 2009). *Putzeysia wiseri* is common at mud volcanoes, and carbonate and coral mounds in the deep Gulf of Cadiz (Génio *et al.* 2013). The Middle Miocene (upper Langhian) *Putzeysia diversii* appears to be the earliest fossil record of the genus, previously known from the Messinian (uppermost Miocene) of Spain (Barrier *et al*. 1991).

Stratigraphic and geographic range

Middle to Upper Miocene (upper Langhian to upper Tortonian), northern Italy.

Chilodontaidae indet.
Fig. 3D–F

Material examined

ITALY – **Tuscany** • 1 spec.; Le Colline; MSF 1209 (H = 7.8 mm).

Description

Tall, turbiniform shell, about 7 mm high, four convex whorls with incised suture, sculptured by six equally spaced, fine spirals cords, crossed by likewise sized and spaced, oblique axial ribs; basal margin sharp, base smooth, slightly convex, narrow umbilical slit; aperture circular, entire.

Remarks

This worn specimen is difficult to place. It shows cancellate sculpture similar to that of *Putzeysia diversii* sp. nov. described above, but all described species of *Putzeysia* are in the size range of 3.5 to 4.5 mm height, were the specimen concerned here is 8 mm high. Furthermore, most species of *Putzeysia* show sculpture on the base, in contrast to the genuinely smooth base of the specimen concerned here. We place

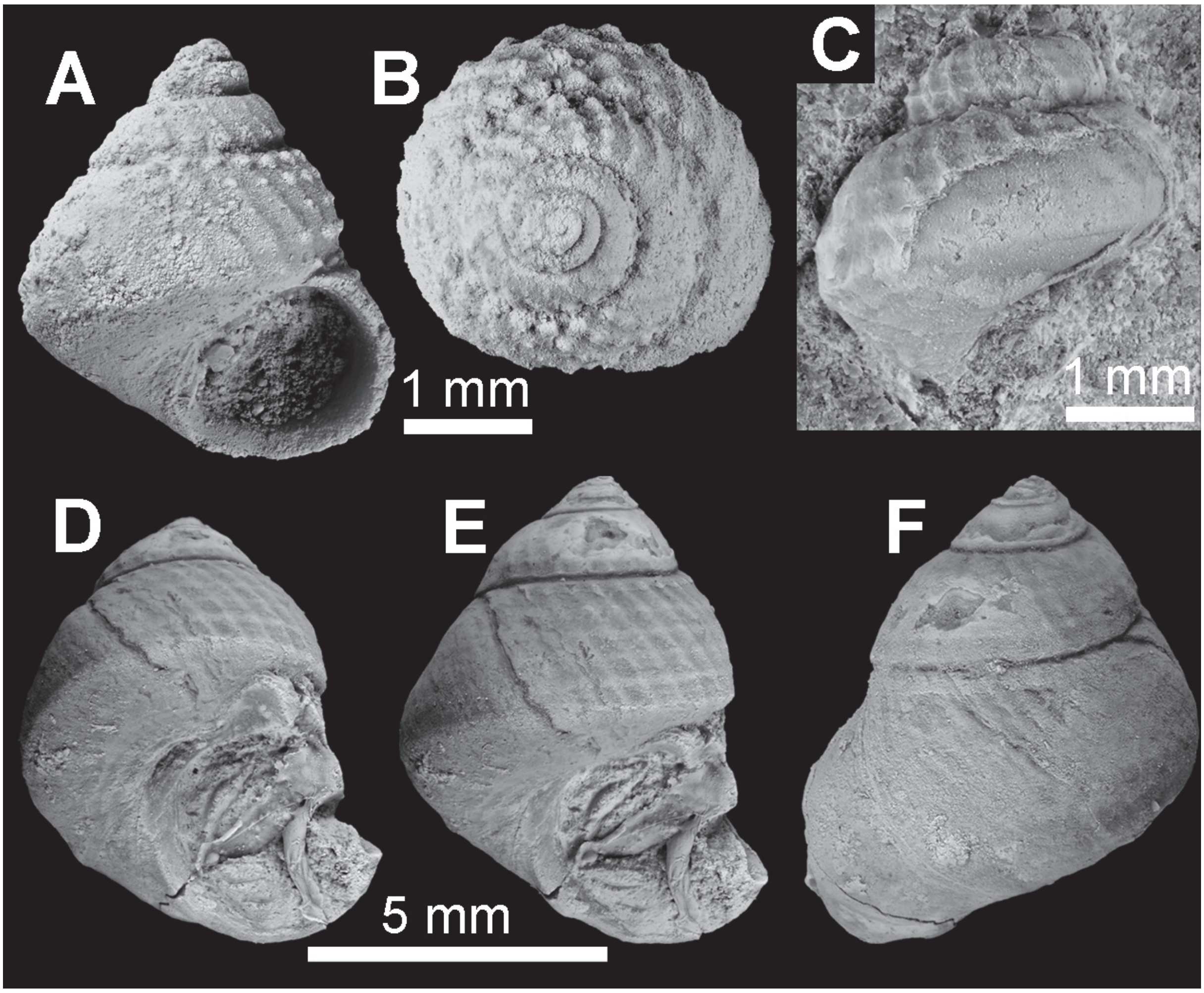

Fig. 3. Chilodontaidae Wenz, 1938 (Vetigastropoda) from the Miocene Calcari a *Lucina* seep deposits in northern Italy. **A–C**. *Putzeysia diversii* sp. nov. **A–B**. Holotype, Ca' Piantè (MSF 1079). **C**. Paratype, Ca' Cavalmagra (MSF 1300). **D–F**. Chilodontaidae indet., Le Colline (MSF 1209).

this specimen in the family Chilodontaidae due to its general resemblance of members of this family, but do not assign it to any genus. A Miocene species with similar shape and sculpture is *Monodontella*? *taurelegans* Sacco, 1896 re-illustrated in Ferrero Mortara *et al.* (1984: pl. 46 fig. 5a–c), but that species has a taller spire than *Putzeysia* sp., and distinct denticles in the aperture. The Early Miocene *Magulus tauracutus* Sacco, 1896 re-illustrated in Ferrero Mortara *et al.* (1984: pl. 47 fig. 6a–b) is considered as belonging to *Gibbula* Risso, 1826 (Harzhauser 2021) and has a more dome-like spire.

Family Calliostomatide Thiele, 1924

Genus ***Calliostoma*** Swainson, 1840

Type species

Trochus conulus Linnaeus, 1758, by subsequent designation.

Calliostoma sp.
Fig. 4A–C

Material examined

ITALY – **Tuscany** • 1 spec.; Le Colline; MSF 1207 (H = 10 mm).

Description

Conical shell, about 10 mm high, at least seven straight-sided whorls beaded spiral cords at upper and lower suture, smooth in between; basal margin sharp, base smooth, almost flat; aperture subcircular, entire.

Remarks

Sacco (1896) illustrated various species of *Calliostoma* (as *Ampullotrochus*) from Miocene and Pliocene strata of northern Italy. Similar regarding the nodular subsutural cords are *Ampullotrochus cinculatus* (Verrill, 1884) (Sacco 1896: 45, pl. 4 fig. 46) and *A. granulatus* Born, 1778 (Sacco 1896: 42–43, pl. 4 figs 34–37). The latter species has, as the name indicates, a more granular sculpture (see Gardella & Tabanelli 2017: figs 3–4). A similar fossil *Calliostoma* with smooth whorl flanks but less distinct subsutural nodular cords is *Calliostoma margarita* Lozano-Francisco & Vera-Peláez, 2002 from the Pliocene of southern Spain and northern Italy (Lozano-Francisco & Vera-Peláez 2002; Gardella & Tabanelli 2017). Similarly high-spired but with more distinct spiral ornament is the Pliocene *Ampullotrochus perstriolatus* Sacco, re-illustrated by Ferrero Mortara *et al.* (1984: pl. 49 fig. 5).

Stratigraphic and geographic range

Middle Miocene (lower Serravallian), northern Italy.

Calliostoma? sp.
Fig. 4D–F

Material examined

ITALY – **Tuscany** • 1 spec.; Le Colline; MSF 1208 (W = 7.3 mm).

Description

Dome-shaped shell, ca 6 mm high, whorls with slightly convex flanks and indistinct suture, sculpture cancellate with 10 spirals on last whorl, crossed by equally sized and spaced, oblique and sinuous axial ribs.

Remarks

The cancellate sculpture and dome-shaped spire of this species are somewhat unusual for *Calliostoma*, but the specimen is within the morphological range of other *Calliostoma* species (Quinn 1992; Dornellas & Simone 2013). Shells with similar sculpture and a general dome-like habitus, though with much broader spire, are built by members of the genus *Ancistrobasis* Dall, 1889 (i.e., Ortega & Gofas 2019; Gofas *et al.* 2021).

The shell resembles certain species of *Jujubinus* Monterosato, 1884, for example *Jujubinus* cf. *proximus* (Millet, 1865) and *Jujubinus sceauxensis* Landau, Van Dingenen & Ceulemans, 2017, from the Loire Basin in northwestern France (Landau *et al.* 2017: pls 23, 25). But *Jujubinus* inhabits intertidal to shallow submarine habitats (Rueda *et al.* 2008; Reich *et al.* 2014) and is unlikely to be found in a deep-marine seep environment. Similar sculpture and shell shapes can also be seen in members of the trochoid genus *Odontotrochus* Fisher, 1879, for example the extant species *Odontotrochus suni* Huang & Fu, 2022 and *O. poppei* (Lan, 1991) from North Australia (Huang & Fu 2022). The Late Miocene *Phorculellus taurangulosus* Sacco, 1896 from the Turin hills (Ferrero Mortara *et al.* 1984: pl. 48 fig. 1) has similar sculpture but less straight-sided whorls than *Calliostoma*? sp.

Stratigraphic and geographic range

Middle Miocene (lower Serravallian), northern Italy.

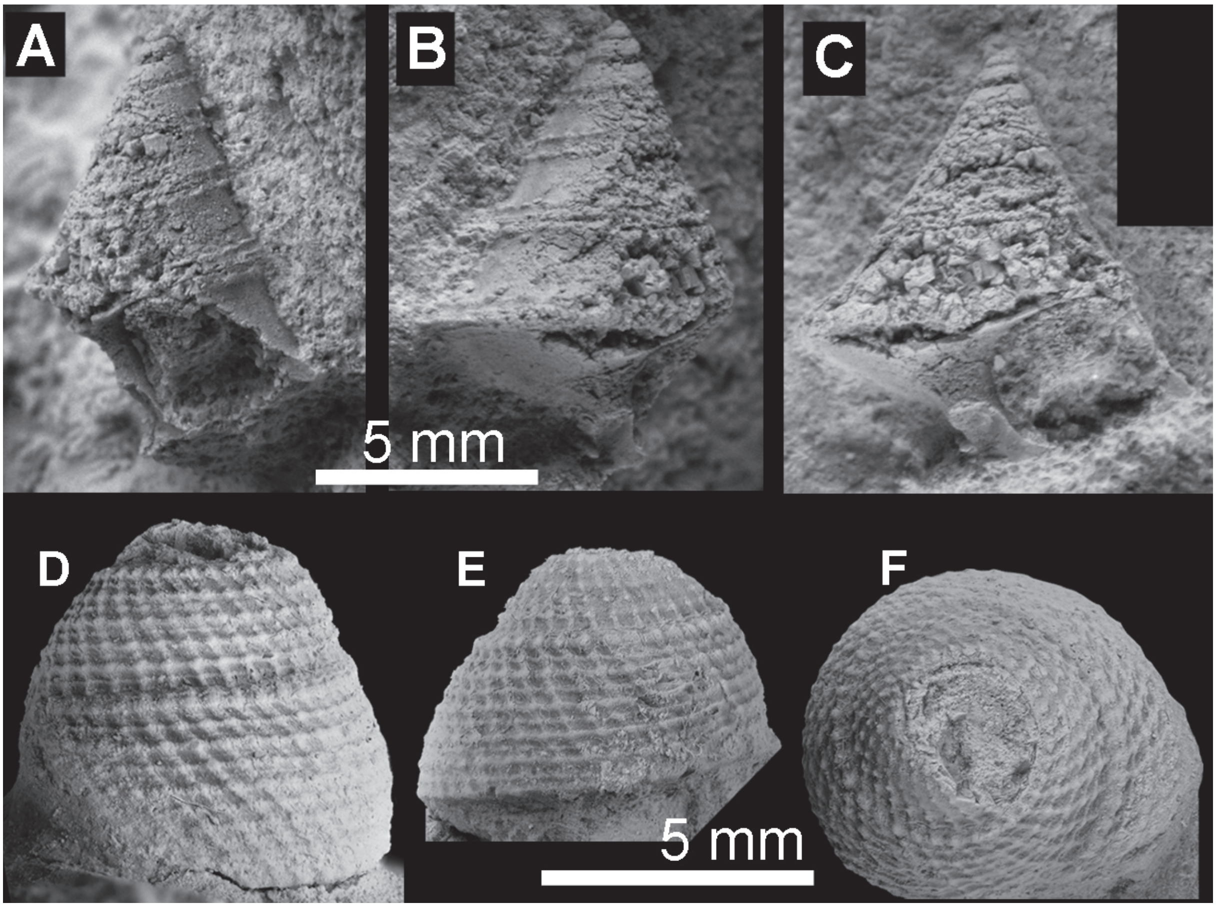

Fig. 4. Calliostomatidae Thiele, 1924 (1847) (Vetigastropoda) from the Calcari a *Lucina* seep deposits in northern Italy. **A–C**. *Calliostoma* sp., Le Colline (MSF 1207). **D–F**. *Calliostoma*? sp., Le Colline (MSF 1208).

Family Colloniidae Cossmann, 1917

Genus ***Homalopoma*** Carpenter, 1864

Type species

Turbo sanguinaeus Linnaeus, 1758, by monotypy.

Homalopoma domeniconii Moroni, 1966
Fig. 5A–G

Homalopoma (*Homalopoma*) *domeniconii* Moroni, 1966: 72, pl. 2 figs 1, 4–6.

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Ca' Cassano; MSF 2356 • 2 specs; Ca' Piantè; MSF 2357 (W = 9.7 mm), MSF 2365 (W = 8.8 mm). – **Tuscany** • 5 specs; Le Colline; MSF 1216 (W = 8 mm), MSF 1217 (W = 9 mm), MSF 2354 (W = 6.3 mm), MSF 2355 [2 specs] • 2 specs; same collection data as for preceding; NRM Mo 204844 (2 specs).

Remarks

We believe Moroni (1966) correctly assigned this species to *Homalopoma*. Initially reported from outcrops at Santa Sofia (Moroni 1966; Taviani 1994, 1996), it has since been reported from other Calcari a *Lucina* sites only rarely (Sami & Taviani 2019; Kiel *et al.* 2023). *Homalopoma* sp. reported by Gill *et al.* (2005) from the Eocene to Miocene seep deposits of Barbados has more numerous spiral cords per whorl than *H. domeniconii*. Several species of *Homalopoma* have been reported from the Eocene Humptulips Formation in western Washington State, USA, associated with methane-seep deposits and wood-falls (Goedert & Squires 1990; Saul *et al.* 1996; Kiel 2008), all of which are much taller than *H. domeniconii*. Species of *Homalopoma* have also been reported from methane-seep deposits of Cretaceous age (Kaim *et al.* 2009, 2013; Kaim 2022), indicating that this genus has a long history of taking advantage of methane-seep areas.

Stratigraphic and geographic range

Middle to Upper Miocene, northern Italy.

Order Lepetellida Moskalev, 1971
Family Fissurellidae Fleming, 1822

Genus ***Fissurella*** Bruguière, 1789

Type species

Patella nimbosa Linnaeus, 1758, by subsequent monotypy.

Fissurella costicillatissima Sacco, 1896
Fig. 5H–L

Fissurella costicillatissima Sacco, 1896: 11, pl. 1 figs 46–47.

Fissurella costicillatissima – Ferrero Mortara *et al.* 1984: 277, pl. 51 fig. 5a–b. — Harzhauser *et al.* 2014: 87, pl. 1 figs 3–4, 5a–b.

? *Fissurella* cf. *costicillatissima* – Cowper Reed 1932: 516.

? *Fissurella costicillatissima* – Konior & Krach 1965: 78, pl. 4 fig. 10.
? *Fissurella* aff. *costicillatissima* – David 1967: 12.

Material examined

ITALY – **Tuscany** • 2 specs; Le Colline; MSF 1213 (L = 15 mm), MSF 1214 (L = 20.5 mm).

Remarks

Fissurella costicillatissima was originally described from the Upper Miocene of the Turin hills (Sacco 1897). It could potentially be widely distributed in the Miocene of the Mediterranean region, with a reliable record from an Early Miocene rocky shore deposit in the North Alpine Foreland Basin (Harzhauser *et al.* 2014), and unconfirmed records from the Upper Miocene of Cyprus (Cowper Reed 1932), Poland (Konior & Krach 1965), and France (David 1967). A specimen illustrated as *Fissurella* cf. *costicillatissima* from the Mio-Pliocene of Lanzarote (Canary Islands) has a much more elongate foramen (Betancort Lozano 2012: 96, pl. 4 fig. 3) and is unlikely to belong to this species. With this potentially wide geographic distribution, *Fissurella costicillatissima* is not unlike the extant fissurellid *Diodora tanneri* Verrill, 1882, which is widespread in the western North Atlantic Ocean (Verrill 1882; Barroso *et al.* 2016; Meyer *et al.* 2017) and has been reported from methane seeps in the Gulf of Mexico (Cordes *et al.* 2010) and the southern Caribbean Sea (Gracia *et al.* 2012).

Stratigraphic and geographic range

Middle to Upper Miocene, northern Mediterranean basin.

Subclass Patellogastropoda Lindberg, 1986
Family Lottiidae Gray, 1840

Genus ***Tectura*** Gray, 1847

Type species

Patella parva da Costa, 1778 (= *Tectura virginea* (O.F. Müller, 1776)), by original designation.

Tectura*? cf. *taurinensis Sacco, 1897
Fig. 5M–N

Tectura taurinensis Sacco, 1897: 20, pl. 2 fig. 53.

Tectura cf. *taurinensis* – Cossmann & Peyrot 1917: 34, pl. 2 figs 47–49.
Tectura taurinensis – Ferrero Mortara *et al.* 1984: 279, pl. 51 fig. 3.

Material examined

ITALY – **Tuscany** • 1 spec.; Ca' Cavalmagra; MSF 1310 (L = 2.4 mm).

Remarks

Sacco (1897) reported this species from the Turin hills and as being 4–6 mm long and up to 1.5 mm high. This matches the size of the specimen from Ca' Cavalmagra. However, as protoconch and shell microstructure of this species remain unknown, its assignment to the patellogastropod *Tectura* remains tentative.

Stratigraphic and geographic range

Middle to Upper Miocene, northern Italy.

Subclass Neomphaliones Bouchet *et al.* 2017
Family Neomphalidae McLean, 1981

Genus ***Retiskenea*** Warén & Bouchet, 2001

Type species

Retiskenea diploura Warén & Bouchet, 2001, by original designation.

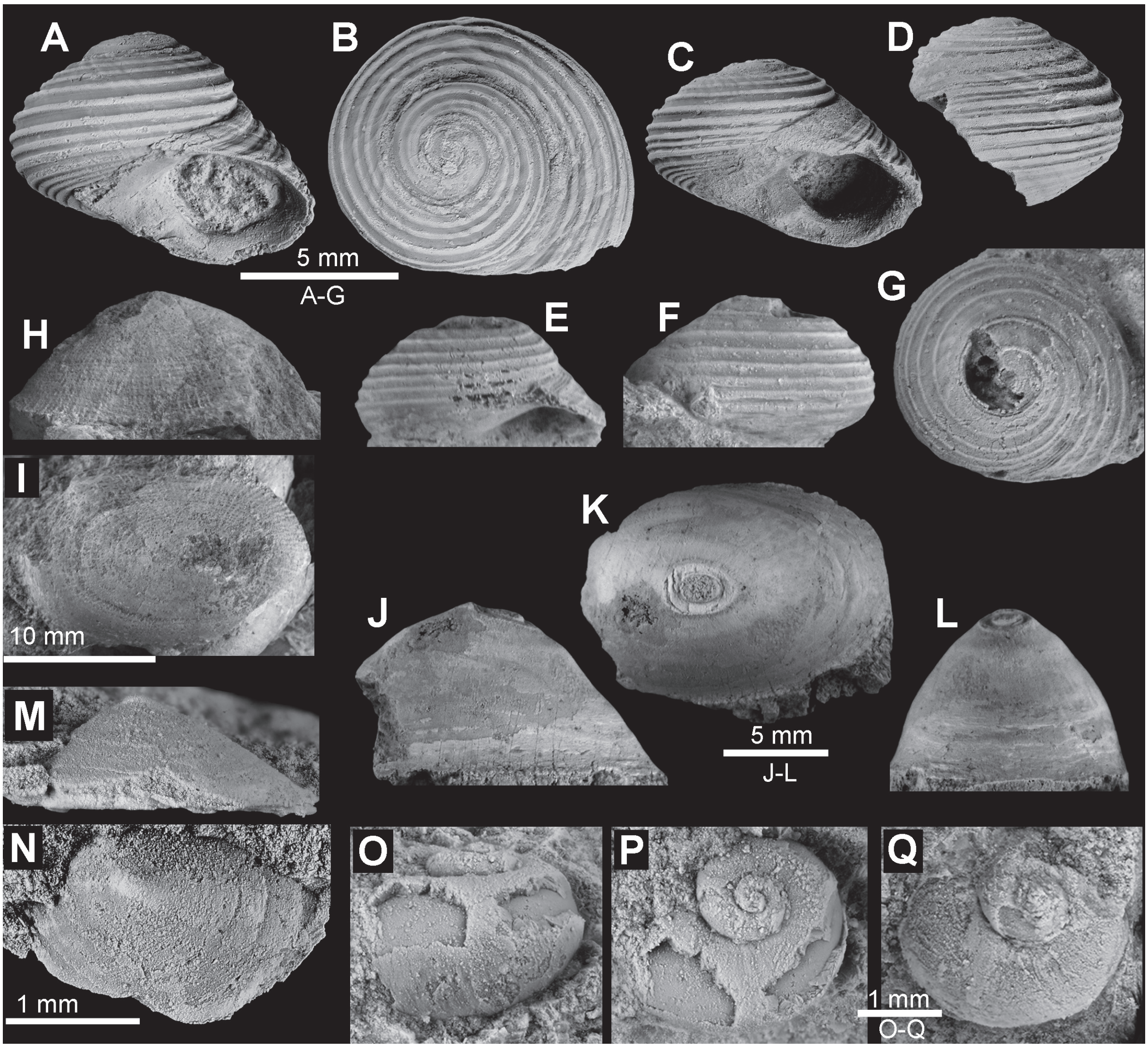

Fig. 5. Vetigastropoda Salvini-Plawen, 1980, Patellogastropoda Lindberg, 1986 and Neomphalina McLean, 1981 from the Calcari a *Lucina* seep deposits in northern Italy. **A–G**. The colloniid (Vetigastropoda) *Homalopoma domeniconii* Moroni, 1966. **A–B**. MSF 2357 from Ca' Piantè. **C–D**. MSF 2365 from Ca' Piantè. **E–G**. MSF 1216 from Le Colline. **H–L**. The fissurellid (Vetigastropoda) *Fissurella costicillatissima* Sacco, 1897, from Le Colline. **H–I**. Specimen with remnants of surface sculpture (MSF 1214). **J–L**. Internal mold showing mantle attachment scars and foramen (MSF 1213). **M–N**. The lottiid (Patellogastropoda) *Tectura*? cf. *taurinensis* Sacco, 1897, from Ca' Cavalmagra (MSF 1310). **O–Q**. The neomphaline *Retiskenea*? sp. from Ca' Cavalmagra. **O–P**. MSF 2364. **Q**. MSF 1312.

***Retiskenea*? sp.**
Fig. 5O–Q

Material examined

ITALY – **Tuscany** • 2 specs; Ca' Cavalmagra; MSF 1312, MSF 2364.

Description

Low, turbiniform, smooth shell with about 2.5 whorls, about 3 mm across; whorls nearly circular in cross section, suture deep, slight bulge near upper suture.

Remarks

The two available specimens are embedded in rock matrix and are rather poorly preserved. They have the size and habitus of specimens belonging to the neomphaline *Retiskenea* (e.g., Warén & Bouchet 2001; Kiel 2006; Campbell *et al.* 2008; Kaim *et al.* 2014; Kaim 2022), but do not preserve details of the protoconch, which would be needed for a reliable assignment to the neomphalids. The specimens are quite similar to a 'skeneimorph gastropod' reported by us from the Late Miocene Ca' Fornace seep deposit (Kiel *et al.* 2018).

Stratigraphic and geographic range

Middle Miocene (upper Langhian), northern Italy.

Subclass Neritimorpha Golikov & Starobogatov, 1975
Family Phenacolepadidae Pilsbry, 1895

Genus ***Thalassonerita*** Moroni, 1966

Type species

Nerita (*Thalassonerita*) *megastoma* Moroni, 1966, by original designation.

Thalassonerita megastoma Moroni, 1966
Fig. 6A–B

Nerita (*Thalassonerita*) *megastoma* Moroni, 1966: 71, pl. 1.

Material examined

ITALY – **Emilia-Romagna** • 5 specs; Caselle C; NRM Mo 204846. – **Tuscany** • 3 specs; Le Colline; MSF 1203 (W = 7 mm), MSF 1220 (H = 7.6 mm), MSF 1223 (W = 15.2 mm) • 6 specs; same collection data as for preceding; NRM Mo 204845.

Remarks

Thalassonerita megastoma has been reported and at times figured from various Calcari a *Lucina* sites of the Romagna Apennines (Moroni 1966; Taviani 1994, 1996, 2001, 2011; Sami & Taviani 2015, 2019; Kiel *et al.* 2023). Specimen MSF 1223 from Le Colline shows scars of the left and right columellar muscles, consistent with the anatomical sketch of the closely related extant species *Thalassonerita naticoides* (Clarke, 1989) provided by Warén & Bouchet (1993: fig. 2). *Thalassonerita naticoides* is a very common species at methane-seeps in the Gulf of Mexico and the Caribbean Sea (Clarke 1989; Warén & Bouchet 1993; Olu *et al.* 1997; Amon *et al.* 2017).

Stratigraphic and geographic range

Middle to Upper Miocene, northern Italy.

Subclass Caenogastropoda Cox, 1960
Order Littorinimorpha Golikov & Starobogatov, 1975
Family Elachisinidae Ponder, 1985

Genus ***Laeviphitus*** van Aartsen, Bogi & Giusti, 1989

Type species

Laeviphitus verduini van Aartsen, Bogi & Giusti, 1989, by original designation.

Laeviphitus sp.
Fig. 6C–E

Laeviphitus sp. Kiel, Sami & Taviani 2018: fig. 6d–e.

Material examined

ITALY – **Emilia-Romagna** • 2 specs; Santa Sofia; Ca' Rovereti; NRM Mo 204837, Mo 204838 • 2 specs; Ca' Fornace; MSF 2139, MSF 2140. – **Tuscany** • 1 spec.; Le Colline; MSF 1204 (H = 8 mm).

Description

Protoconch low-turbiniform, sculpture cancellate with numerous closely-spaced, strong, slightly oblique axial ribs crossed by about 10 finer spiral lines; transition to teleoconch straight and abrupt; teleoconch smooth, initially egg-shaped, later whorls becoming taller.

Remarks

Sacco (1895) described and illustrated numerous smooth rissoiform gastropods from the Neogene of northern Italy. Most similar to *Laeviphitus* sp. is perhaps the rare Miocene *Cingula* (*Setia*?) *taurinomiocenica* Sacco, 1895 (Sacco 1895: 32, pl. 1 fig. 82) (re-illustrated by Ferrero Mortara *et al.* 1984: pl. 40 fig. 3) from the Turin hills. But Sacco described the protoconch as "depressed", which seems an unlikely description for the cancellate, low-turbiniform protoconch of *Laeviphitus* sp. Another similar species is *Putilla* (*Pseudosetia*) *taurominima* (Sacco, 1895), though Bałuk (1975: 65) wrote that "no boundary [is] visible between proto- and teleoconch". Members of *Laeviphitus* have been reported from extant vents and seeps worldwide, and several species are known from the Cenozoic fossil record of Europe, ranging back to the early Paleocene (Sasaki *et al.* 2010; Lauridsen & Schnetler 2014; Kiel *et al.* 2018).

Stratigraphic and geographic range

Middle to Upper Miocene, northern Italy.

Family Naticidae Guilding, 1834

Naticidae indet. 1
Fig. 6F–G

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Castiglion dei Pepoli; MGGC 22304 (H = 18.6, W = 15 mm) • 1 spec.; Caselle C; NRM Mo 204847. – **Tuscany** • 2 specs; Le Colline (operculae); MSF 1218 (H = 8 mm).

Description

Naticiform shell with moderately elevated spire, about four whorls, nearly 20 mm tall, suture deep, growth increments compressed into oblique bulges near upper suture, remaining whorl smooth; operculum half-moon shaped, coiling expands rapidly, nucleus subcentral.

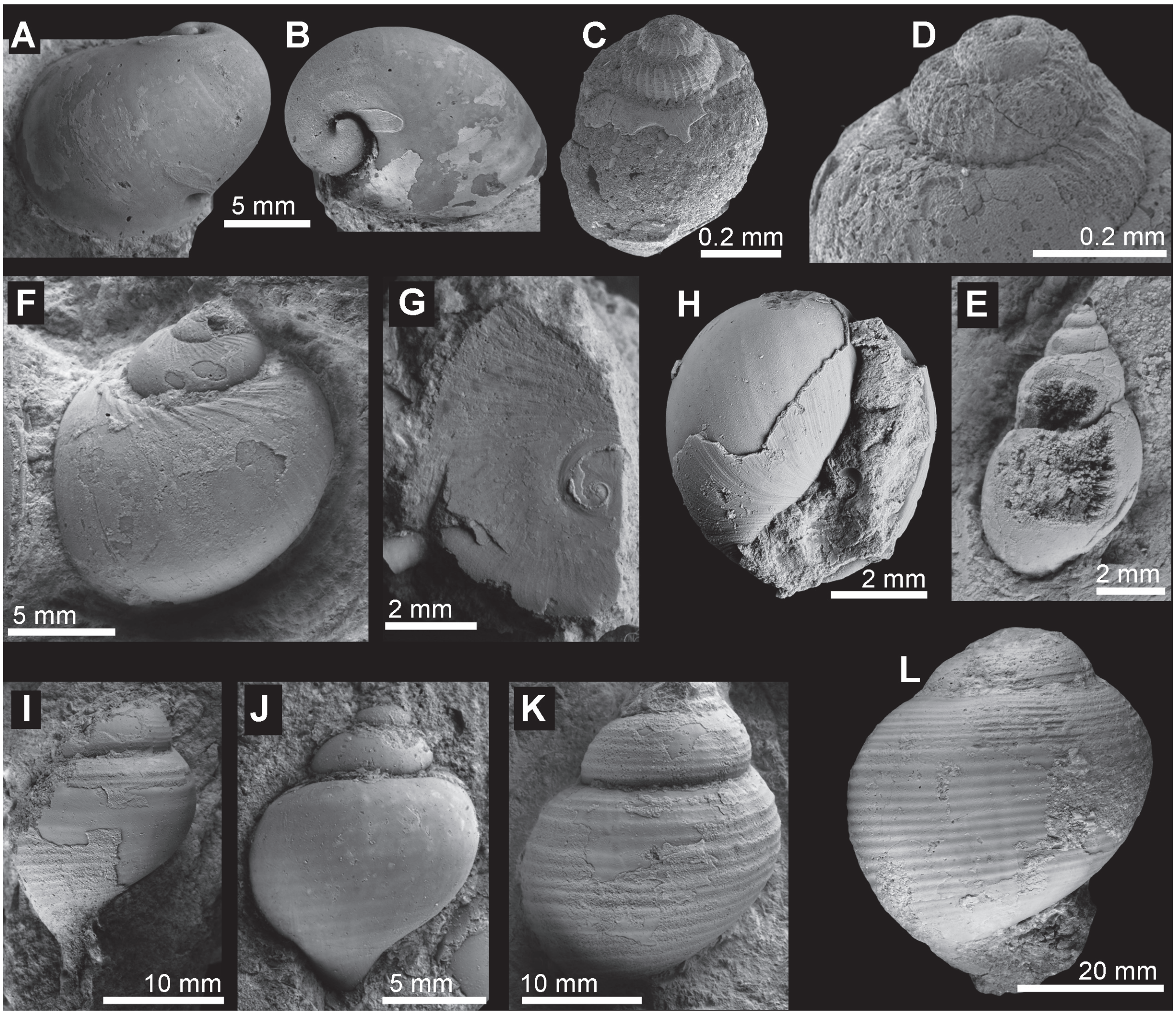

Fig. 6. Neritimorpha Golikov & Starobogatov, 1975 and Caenogastropoda Cox, 1960 from the Calcari a *Lucina* seep deposits in northern Italy. **A–B**. The phenacolepid (Neritimorpha) *Thalassonerita megastoma* Moroni, 1966, Le Colline (MSF 1223), internal mold showing columellar muscle scars. **C–E**. The elachisinid (Caenogastropoda) *Laeviphitus* sp. **C**. Small specimen with preserved protoconch, from Ca' Rovereti (NRM Mo 204837). **D**. Close-up on transition between proto- and teleoconch, from Ca' Rovereti (NRM Mo 204838). **E**. Tall specimen (MSF 1204) from Le Colline. **F–G**. Naticidae indet. sp. 1. **F**. Shell embedded in rock matrix, from Castiglion dei Pepoli (MGGC 22304). **G**. Operculum (MSF 1218). **H**. Naticidae indet. sp. 2 from Guzzano (MGGC 22305). **I–K**. *Pisanianura*? *pusilla* Bellardi 1872, from Castel di Casio. **I**. Specimen with remains of siphonal canal and shell sculpture (MGGC 22306). **J**. Small, internal mold (MGGC 22307). **K**. Large specimen with preserved shell (MGGC 22308). **L**. *Semicassis* aff. *reticulata* (Bellardi & Michelotti, 1840), Castiglion dei Pepoli (MGGC 22310).

Remarks

Generic assignments among Naticidae rely heavily on the morphology of the aperture and the umbilicus, both of which are obscured in the available specimens.

Naticidae indet. 2
Fig. 6H

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Guzzano; MGGC 22305 (H = 6.4, W = 5.7 mm).

Description

Naticiform shell with very low spire, smooth apart from fine growth increments, aperture relatively narrow.

Remarks

This single specimen has a very low spire and is almost involute. With these features it differs markedly from the species mentioned above, as well as from any other fossil naticid reported from Italy (Robba *et al.* 2016).

Superfamily Tonnoidea Suter, 1913
Family Laubierinidae Warén & Bouchet, 1990

Genus ***Pisanianura*** Rovereto, 1899

Type species

Murex inflatus Brocchi, 1814, by subsequent designation.

Pisanianura*? *pusilla Bellardi, 1873
Fig. 6I–K

Anura pusilla Bellardi, 1873: 204, pl. 11 fig. 24.

Material examined

ITALY – **Emilia-Romagna** • 4 specs; Castel di Casio; MGGC 22306 (H = 25.4, W = 15.3 mm), MGGC 22307 (H = 15.8, W = 10.8 mm), MGGC 22308 (H = 27.0, W = 23.4 mm), MGGC 22309 (H = 23.4, W = 17.7 mm).

Remarks

Anura pusilla was originally described by Bellardi (1873) from the Middle Miocene of the Turin hills; it was reported to reach 19 mm in height and as being rare. The specimens of *P.*? *pusilla* from Castel di Casio appear to have fewer and more widely spaced spiral threads than *P. craverii* (Bellardi, 1873) (see illustrations in Bellardi 1873; Ferrero Mortara *et al.* 1981; Landau & Harzhauser 2012). Miocene and Pliocene species of *Anura* Bellardi, 1873 reported by Bellardi (1873) were mentioned by Warén & Bouchet (1990) when discussing *Pisanianura*. They regarded the middle Miocene *A. craverii* as belonging to *Pisanianura*, but considered the position of *A. pusilla* as "more doubtful". This view was adopted by Landau & Harzhauser (2012). Because our specimens neither preserve the protoconch nor allow a clear view on the aperture, we assigned *A. pusilla* only hesitantly to *Pisanianura*.

Stratigraphic and geographic range

Upper Oligocene (upper Chattian) to Upper Miocene, northern Italy.

Family Cassidae Latreille, 1825

Genus ***Semicassis*** Mörch, 1852

Type species

Cassis japonica Reeve, 1848 (= *Cassis bisulcata* Schubert & Wagner, 1829), by subsequent designation.

Semicassis aff. ***reticulata*** (Bellardi & Michelotti, 1840) (Bon.)
Fig. 6L

Cassis reticulata Bon. Bellardi & Michelotti, 1840: 53 (145) [Bon. refers to an unpublished museum catalog].

Semicassis reticulata – Sacco 1904: pl. 20 figs 18–19. — Ferrero Mortara *et al.* 1984: pl. 1 figs 9–10.

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Castiglion dei Pepoli; MGGC 22310 (H = 48.6, W = 42.0 mm).

Remarks

This specimen is here assigned to *Semicassis* based on the similarities with the species outlined below. It should be noted, though, that certain deep-sea buccinids produce very similar globular shells with fine spiral sculpture. Examples include a *Latisipho* sp. that was recently reported from hydrothermal vent in the Bering Sea (Nekhaev *et al.* 2022), and *Buccinum cascadiense* Clarke, 2022, from the Northeast Pacific (Clark 2022).

The Middle Miocene *Semicassis reticulata* (Bellardi & Michelotti, 1840) as illustrated in Sacco (1904: pl. 20 figs 18–19) and Ferrero Mortara *et al.* (1984: pl. 1 figs 9–10) has a less globular last whorl and lacks the distinct shoulder. All species of *Semicassis* from the Miocene of the Paratethys (Landau *et al.* 2009: pl. 4) have a lower spire with less convex whorls than the specimen from Castiglione dei Pepoli. A similar whorl profile as the specimen from Castiglione dei Pepoli has *Semicassis miolaevigata* Sacco, 1890, but that species typically has less distinct spirals on the whorls' flank (Sacco 1904: 97, pl. 20 figs 5–10) and Ferrero Mortara *et al.* (1984: pl. 1 fig. 6). Another species with similar fine spiral sculpture on the entire whorl is the Early Miocene *Sconsia ottnangensis* (Sacco, 1890). However, the specimens illustrated by Landau *et al.* (2009: pl. 5 figs 1–2) are somewhat deformed and the similarity in shell shape to the specimen from Castiglione dei Pepoli may be an artifact. Specimens reported as *Phalium* (*Semicassis*) *bituminatum* (Martin, 1943) from a presumed mud volcano or seep deposit in the Late Miocene of Waisiu, Buton Island, Indonesia (Beets 1942: 277, pl. 28 fig. 58), have much stronger tubercles than the specimen reported here.

A morphologically very similar species was reported by Moroni (1966: 75–76, pl. 3 fig. 2) as *Galeodea delibrata* Moroni, 1966, from the Late Miocene Calcari a *Lucina* deposits in the Santa Sofia area. In addition to being much larger (up to 95 mm high) than *Semicassis* aff. *reticulata* from Castiglion dei Pepoli, it also differs by having a slightly more slender shell. Miocene Mediterranean/Paratethyan species of *Galeodea* Link, 1807 are generally much higher spired than *Galeodea delibrata* (see Landau *et al.* 2009) and due to its overall similarity to *Semicassis* aff. *reticulata*, we provisionally re-assign that species to *Semicassis* (as *Semicassis delibrata* (Moroni, 1966)).

Stratigraphic and geographic range

Miocene, northern Italy.

Order Neogastropoda Wenz, 1938
Family Eosiphonidae Kantor, Fedosov, Kosyan, Puillandre, Sorokin, Kano, Clark & Bouchet, 2021

Genus ***Eosipho*** Thiele, 1929

Type species

Chrysodomus (*Sipho*) *smithi* Schepman, 1911, by original designation.

Eosipho hoernesi (Bellardi, 1873)
Fig. 7A–C

Chrysodomus Hörnesi Bellardi, 1873: 153, pl. 11 figs 14–15.
Neptunea (*Neptunea*) *hoernesi* (Bellardi) *subdilatata* Moroni, 1966: 76, pl. 19 fig. 1.

Eosipho hoernesi – Brunetti & Della Bella 2016: fig. 19f. — Kovács 2021: 72, figs 22–23. — Kaim 2022: 332.

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Ca' Piantè; MSF 1070 (H = 54.7 mm) • 1 spec.; Ca' Rovereti; NRM Mo 204839 (H = 45.8 mm).

Remarks

This species was originally placed in *Neptunea* Röding, 1798 or its synonym *Chrysodomus* Swainson, 1840, but Harzhauser *et al.* (2014) regarded it as not belonging to this genus. Both Brunetti & Della Bella (2016) and Kovács (2021) placed it in *Eosipho*, and this treatment is followed here. Moroni (1966) introduced a new subspecies – *Neptunea hoernesi subdilatata* – for a buccinid from the Calcari a *Lucina* deposits. We find our specimens difficult to distinguish from Bellardi's (1873: pl. 11 fig. 14) original illustration of *Chrysodomus hoernesi*, though his "Varietá A" (Bellardi 1873: pl. 11 fig. 15) does have less convex whorls with a shallower suture. Brunetti & Della Bella (2016: fig. 19f) illustrated a specimen of *Chrysodomus hoernesi* from the Bellardi-Sacco collection, which differs marginally by its slightly broader last whorl from the Calcari a *Lucina* specimens available to us. A specimen identified as *Eosipho hoernesi* from the Middle Miocene of Romania (Kovács 2021: figs 22–23) has a distinctly higher spire and more oblique axial ribs than the Italian specimens assigned to this species. Buccinoid species are known to show variation in shell shape, especially the height of the spire, along depth gradients (Bouchet & Warén 1985; Olabarria & Thurston 2003). Hence, we are not in favor of distinguishing subspecies or variants among *Eosipho hoernesi*.

A similar species is *Siphonalia* (*Pseudoneptunea*) *semisulcata* Martin in Beets (1942: pl. 28 fig. 68) from a presumed, Late Miocene seep deposit in Buton, Indonesia, but its spirals are less distinct on the whorls' flanks but stronger on the base than in *E. hoernesi*. *Neptunea* (*Sipho*?) *altenai* Beets, 1942, from the same locality also has very similar axial and spiral sculpture, but a much short siphonal canal than *E. hoernesi*. The late Eocene to Oligocene *Colus sekiuensis* Kiel & Goedert, 2007, from organic substrates and seep deposits in western Washington State, USA (Kiel & Goedert 2007), has similar though more incised sculpture, is smaller, and its siphonal canal is more strongly twisted than that of *E. hoernesi*.

Stratigraphic and geographic range

Middle to Upper Miocene, northern Italy.

Family Buccinidae Rafinesque, 1815

Genus ***Neptunea*** Röding, 1798

Type species

Murex antiquus Linnaeus, 1758, by subsequent designation.

***Neptunea*?** sp.
Fig. 7D

Material examined

ITALY – **Tuscany** • 1 spec.; Le Colline; MSF 2359 (H = 19.6 mm).

Description

Tall, slender shell, incised suture, at least three whorls, ten or more low, flat-topped spiral cords, earlier whorls with ca 10 broad, blunt axial ribs with wide interspaces.

Remarks

Shows the typical sculpture of *Neptunea*, but also of other buccinids including *Buccinum* or *Beringius* Dall, 1886, or the high-spired species of *Aulacofusus* Dall, 1918 (Kosyan & Kantor 2013). The only available specimen has a much higher spire than *Eosipho hoernesi* reported above.

Stratigraphic and geographic range

Middle Miocene (lower Serravallian), northern Italy.

Family Olividae Latreille, 1825

Genus ***Olivella*** Swainson, 1831

Type species

Voluta dama Wood, 1828 (= *Olivella purpurata* Swainson, 1831), by subsequent designation.

Olivella cf. ***longispira*** Bellardi, 1882
Fig. 7E–F

Olivella longispira Bellardi, 1882: 221, pl. 12 fig. 37.

Olivella longispira – Ferrero Mortara *et al.* 1981: 133, pl. 35 fig. 3a–b.

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Guzzano; MGGC 22311 (H = 11.8 mm). – **Tuscany** • 1 spec.; Le Colline; MSF 1202 (H = 13.4 mm).

Remarks

Although the base of the aperture is not preserved in either of the two available specimens, they are here assigned to *Olivella longispira* due to their slender shells with a tall spire. This species was originally described from the Middle Miocene of the Turin hills, where it reaches 20 mm in height (Bellardi 1882).

Stratigraphic and geographic range

Lower to Middle Miocene, northern Italy.

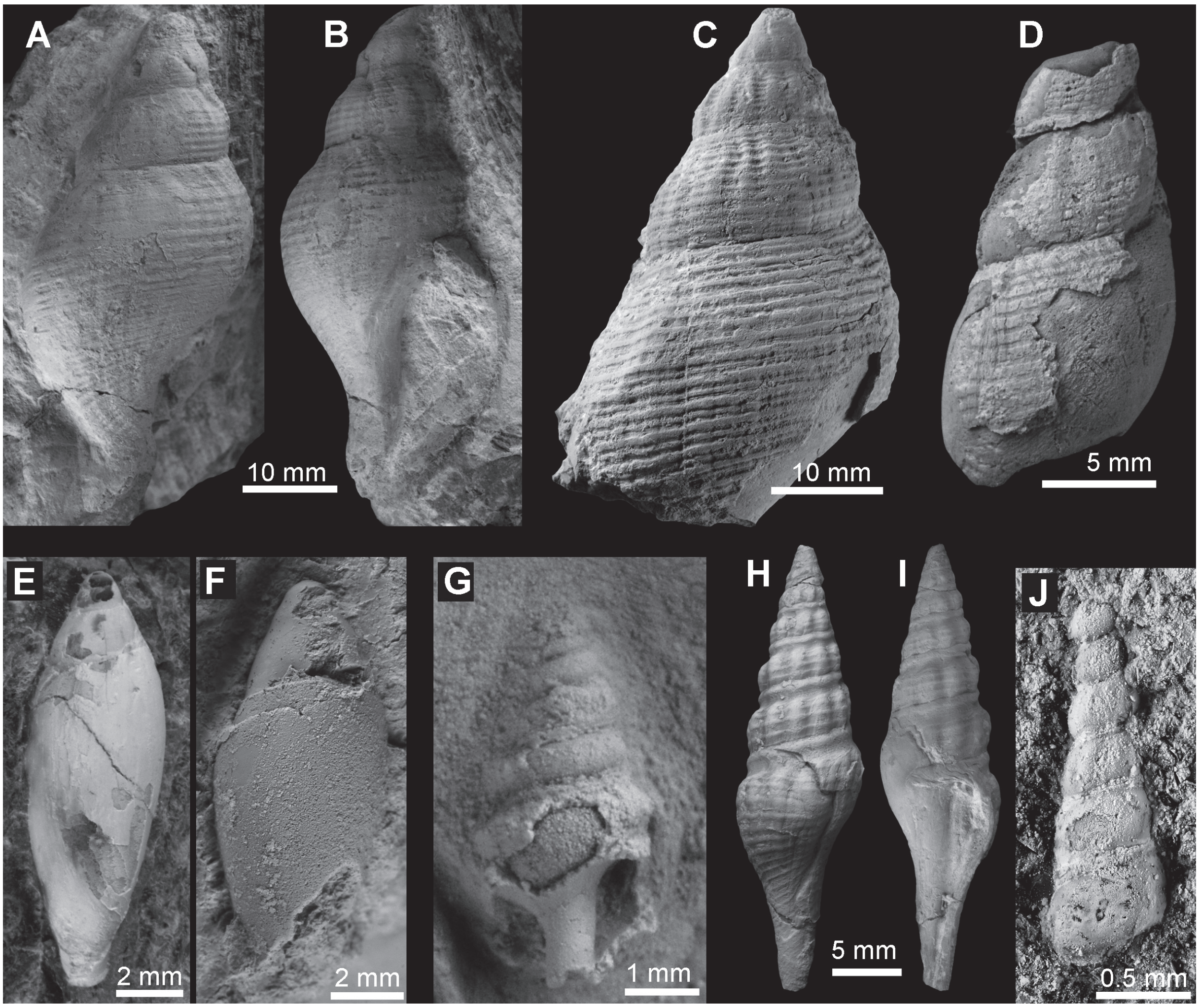

Fig. 7. Neogastropoda Wenz, 1938 and Heterobranchia Burmeister, 1837 from Miocene Calcari a *Lucina* seep deposits in northern Italy. **A–C**. The eosiphonid *Eosipho hoernesi* (Bellardi, 1872). **A–B**. Specimen with well-preserved aperture, from Ca' Piantè (MSF 1070). **C**. Specimen showing details of spiral ornament, from Ca' Rovereti (NRM Mo 204839). **D**. The buccinid *Neptunea*? sp. from Le Colline (MSF 2359). **E–F**. The olivid *Olivella longispira* Bellardi, 1882. **E**. From Le Colline (MSF 1202). **F**. From Guzzano (MGGC 22310). **G**. The turrid *Turris citima* (Bellardi, 1877), from Ca' Cavalmagra (MSF 1307). **H–I**. The turrid *Turricula* sp., from Ca' Piantè (MSF 1081). **J**. The pyramidellid (Heterobranchia) *Turbonilla* sp., from Ca' Cavalmagra (MSF 1305).

Family Turridae Adams & Adams, 1853

Genus ***Turris*** Batsch, 1789

Type species

Murex babylonius Linnaeus, 1758, by subsequent designation.

Turris citima (Bellardi, 1877)
Fig. 7G

Pleurotoma citima Bellardi, 1877: 17, pl. 1 fig. 7.

Pleurotoma citima – Ferrero Mortara *et al.* 1981: pl. 8 fig. 1a–b.

Material examined

ITALY – **Tuscany** • 1 spec.; Ca' Cavalmagra; MSF 1307 (H = 6 mm).

Remarks

Bellardi (1877) reported this species as being infrequent in Middle Miocene strata of the Turin hills.

Stratigraphic and geographic range

Middle Miocene, northern Italy.

Family Clavatulidae Gray 1853

Genus ***Turricula*** Schumacher, 1817

Type species

Murex javanus Linnaeus, 1767 (= *Turricula flammea* Schumacher, 1817), by monotypy.

Turricula sp.
Fig. 7H–I

Turricula sp. – Sami & Tabanelli 2013: 17–18, fig. 1.

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Ca' Piantè; MSF 1081 (H = 32.4 mm).

Description

Tall, slender, fusiform shell, at least seven whorls with strong subsutural collar and incision, sinus in growth lines within this incision; about 8–10 thick axial ribs per whorl, starting below subsutural incision, crossed by four fine, evenly spaced spiral cords; aperture elongate lens-shaped with long, straight siphonal canal, inner lip callus-covered; transition from flank of last whorl to base sinuous and smooth, axial ribs fade on base, spiral sculpture of last whorl continuous onto base.

Remarks

Sami & Tabanelli (2013) noted that this specimen is quite similar to the Miocene *Surcula consobrina* Bellardi, 1877. The syntype of *Surcula consobrina* (Bellardi 1877) illustrated by Ferrero Mortara *et al.* (1981: 65, pl. 10 fig. 2) and specimens identified as *Turricula* (*Surcula*) *consobrina* (Bellardi, 1877) from the Middle Miocene of Poland (Bałuk 2003: pl. 14 fig. 3) have weaker and more numerous spiral cords, and a shorter siphonal canal than the specimen reported here. *Clavatula* (*Surcula*) *consobrina badensis* from the Middle Miocene of Hungary (Csepreghy-Meznerics 1953) has a shorter siphonal canal.

Stratigraphic and geographic range

Upper Miocene, northern Italy.

Subclass Heterobranchia Burmeister, 1837
Family Pyramidellidae Gray, 1840

Genus ***Turbonilla*** Risso, 1826

Type species

Turbo lacteus (Linnaeus, 1758), by subsequent designation.

Turbonilla sp.
Fig. 7J

Material examined

ITALY – **Tuscany** • 1 spec.; Ca' Cavalmagra; MSF 1305 (H = 2.3 mm).

Description

Tall slender shell made of at least six whorls sculptured by indistinct, blunt, slightly oblique axial ribs.

Remarks

This specimen resembles species of *Turbonilla* reported from the Neogene of northern Italy (Sacco 1892). Quite similar is the Late Miocene *Turbonilla costellatoides* var. *dertocolligens* Sacco, 1892, but our specimen is too poorly preserved for a species-level identification.

Class Bivalvia Linnaeus, 1758
Subclass Protobranchia Pelseneer, 1889
Order Nuculida Dall, 1889
Family Nuculidae Gray, 1824

Genus ***Nucula*** Lamarck, 1799

Type species

Arca nucleus Linnaeus, 1758, by monotypy.

Nucula aff. ***sulcata*** Bronn, 1831
Fig. 8A–D

Material examined

ITALY – **Tuscany** • 3 specs; Le Colline; MSF 1210 (L = 6.2 mm), MSF 1212 (H = 7.3 mm), MSF 2366 • 1 spec.; same collection data as for preceding; NRM Mo 205366 • 1 spec.; Ca' Cavalmagra; MSF 1311 (L = 10.7 mm).

Remarks

Nucula sulcata is an extant taxon, common in the European Neogene and Quaternary, its taxonomic history, nomenclature, and distribution was extensively discussed by La Perna (2007). The specimens illustrated here resemble *Nucula sulcata* in general outline, but with the hinge features obscured, our assignment remains tentative. Lucente & Taviani (2005) recorded a *Nucula* sp. of comparable dimensions (only a mold) associated with large vesicomyids from Serravallian-aged hydrocarbon-imprinted sediments in the Romagna Apennines.

Order Solemyida Dall, 1889
Family Solemyidae Gray, 1840

Genus ***Acharax*** Dall, 1908

Type species

Solemya johnsoni Dall, 1891, by original designation.

Acharax doderleini (Mayer, 1861)
Fig. 8E–F

Solenomya doderleini Mayer, 1861: 364–365.

Solenomya doderleini – Sacco 1901: 128, pl. 27 figs 1–4. — Merlino 2007: 188, pl. 17 fig. 5. — Harzhauser *et al.* 2011: 221, fig. 10.1–2. — Mikuž & Gašparič 2016: 156, fig. 10.1–2.
Acharax doderleini – Taviani *et al.* 2011: 1068, figs 4–6.

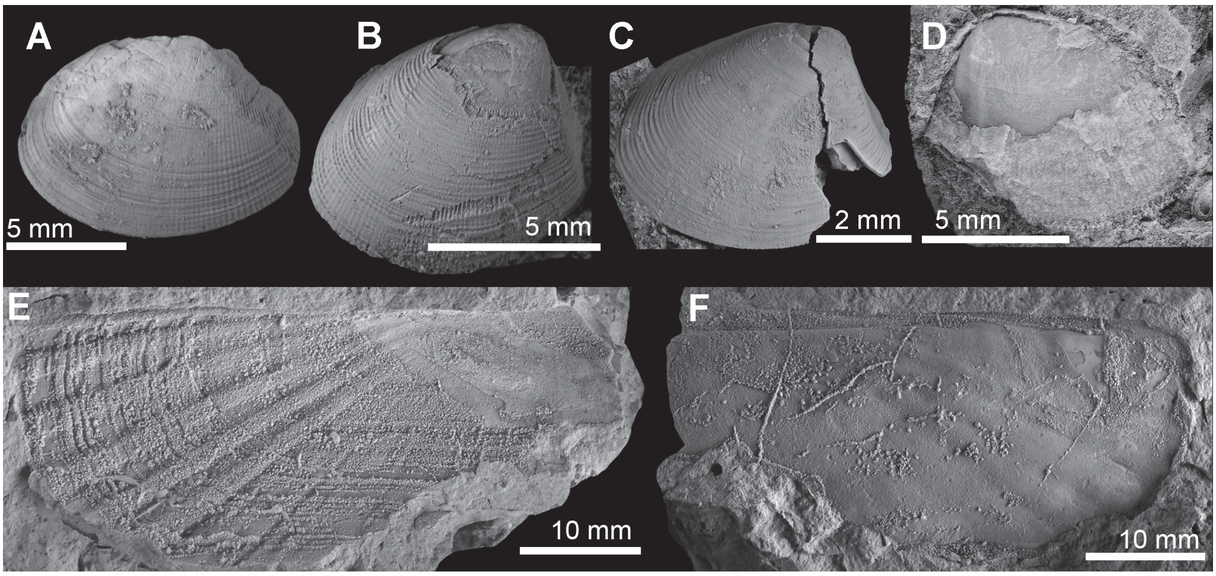

Fig. 8. Protobranch bivalves from Calcari a *Lucina* seep deposits in northern Italy. **A–D**. The nuculid *Nucula* aff. *sulcata* Bronn, 1831. **A**. MSF 2366. **B**. Right valve from Le Colline (MSF 1212). **C**. Right valve from Le Colline (MSF 1210). **D**. Left valve from Ca' Cavalmagra (MSF 1311). **E–F**. The solemyid *Acharax doderleini* (Mayer, 1861) from Ca' Fornace erratics. **E**. External mold of right valve (MSF 2361). **F**. Internal mold of right valve (MSF 2360).

Material examined

ITALY – **Emilia-Romagna** • 3 specs; Ca' Fornace; MSF 2360 (L = 46.4 mm), MSF 2361 (L = 53.0 mm) • 2 specs; Caselle A; NRM Mo 204848.

Remarks

See Mikuž & Gašparič (2014) for a more extensive synonymy. Taviani *et al.* (2011) re-assigned "*Solenomya*" *doderleini* to *Acharax*, which is followed here. They gave its geologic range in northern Italy as Early Miocene (Burdigalian) to Late Pliocene (Piacenzian). The new material documented here falls well within this geologic range. This species occurs mainly in deep-water marls and at methane seep deposits. Already Mayer (1861: 365) wrote "I have found this [species] in the layer with large globular *Lucines*, forming the base of the Tortonian stage, at Pino, near Torino", indicating the association of this species with members of the chemosymbiotic bivalve family Lucinidae, probably *Meganodontia* Bouchet & Cosel, 2004 or *Lucinoma* Dall, 1901, as in many Calcari a *Lucina* seep deposits. Whilst frequently found in Mio-Pliocene deep-sea reducing sediments of the Italian Peninsula, *Acharax* is by contrast rarely found in Calcari a *Lucina* deposits (Taviani *et al.* 2011). In the erratics found near Ca' Fornace, *A. doderleini* is associated with a few specimens of the lucinid *Anodontia mioinflata* Kiel, Sami & Taviani, 2018.

Stratigraphic and geographic range

Neogene, northern Italy.

Family Thyasiridae Dall, 1901

Remarks

Thyasirids are generally small and rare in the Calcari a *Lucina* deposits. The only previous records are three specimens assigned to *Channelaxinus* sp. from the Ca' Cavalmagra site (Kiel & Taviani 2017). This is a remarkable contrast to coeval seep deposits in both the Pacific and the Caribbean regions (Amano *et al.* 2015, 2022; Kiel & Hansen 2015; Hryniewicz 2022; Kiel *et al.* 2022), where large thyasirids typically assigned to *Conchocele* Gabb, 1866 often dominate the assemblages. In the Cenozoic seep deposits of the Mediterranean region, only a few larger thyasirids reaching 30 mm were reported from the Eocene Buje site in Croatia (Natalicchio *et al.* 2015), large thyasirids are absent from the Pliocene Stirone river seep deposit (Kiel & Taviani 2018), and thyasirids tend to be small and uncommon at present-day Mediterranean seeps (Olu *et al.* 2004; Taviani 2014).

Genus ***Thyasira*** Lamarck, 1818

Type species

Tellina flexuosa Montagu, 1803, by monotypy.

Thyasira sp. 1
Fig. 9A–B

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Castiglione dei Pepoli; MGGC 22311 (H = 12 mm).

Description

Small, well-inflated, smooth, rounded-pentagonal shell, about as long as high, umbones elevated, blunt, slightly prosogyrate; posterior sulcus close to posterodorsal margin, deep, bordered distinct, round-topped ridge; submarginal sulcus narrow; anterodorsal margin slightly concave

Remarks

The two species of *Thyasira* reported here are all small, poorly preserved, and represented by a single specimen each, making a robust identification difficult. They are placed in *Thyasira* due to their overall shape and size, and the presence of a shallow posterior sinus. Furthermore, *Thyasira* sp. 1 appears to have a submarginal sulcus. The two specimens differ in inflation and outline: *Thyasira* sp. 1 from Castiglione dei Pepoli is more globular than *Thyasira* sp. 2 from Casola; the latter is taller (it has a longer anterior margin) than *Thyasira* sp. 1.

Stratigraphic and geographic range

Lower to Middle Miocene (Aquitanian to Langhian), northern Italy.

Thyasira **sp. 2**
Fig. 9C

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Casola; MGGC 22312 (L = 7 mm).

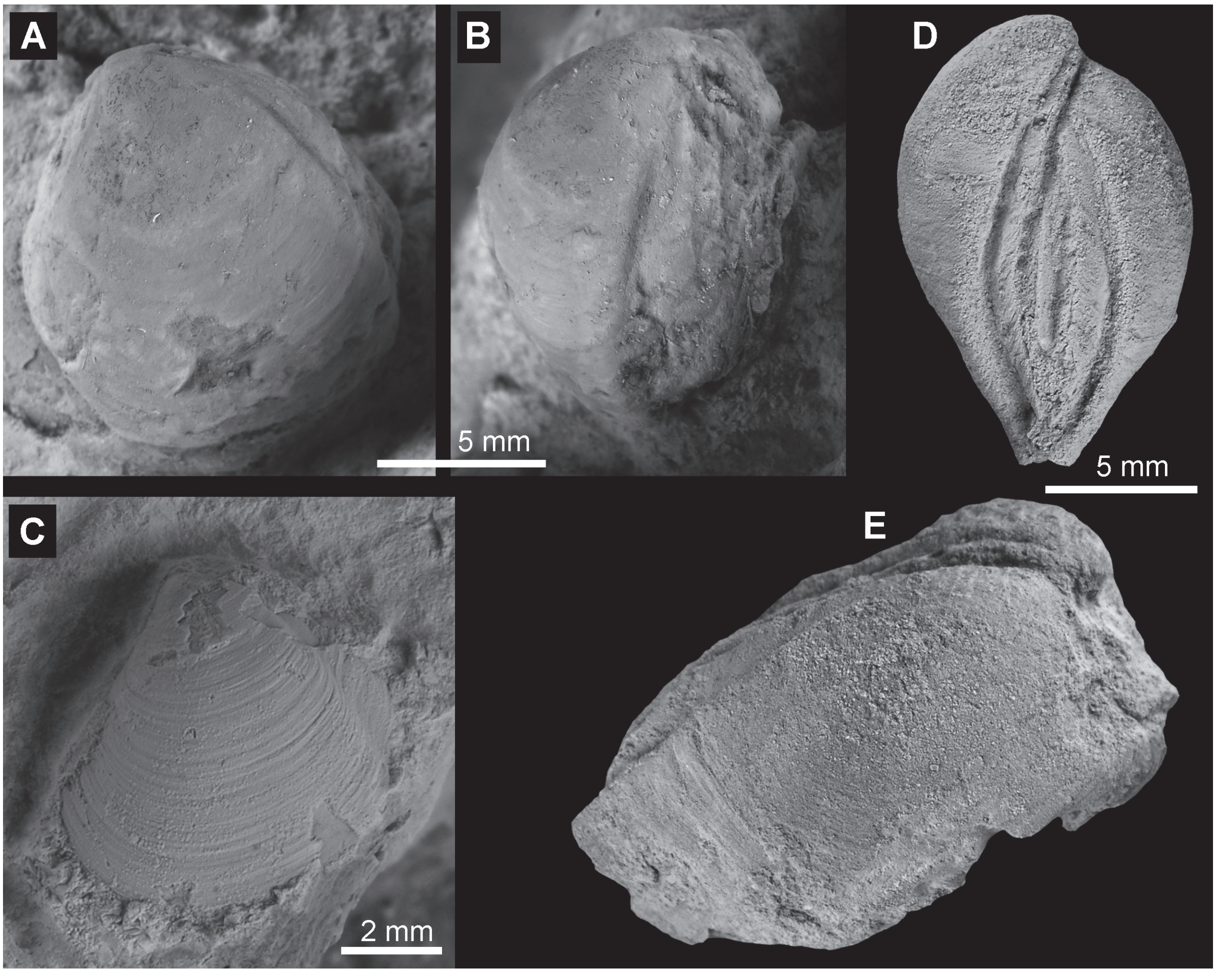

Fig. 9. Thyasirid bivalves from Calcari a *Lucina* seep deposits in northern Italy. **A–B**. *Thyasira* sp. 1, Castiglione dei Pepoli (MGGC 22311). **C**. *Thyasira* sp. 2, Casola (MGGC 22312). **D–E**. *Channelaxinus*? sp., Caselle A (NRM Mo 204840).

Description

Small, little inflated, sub-triangular shell, surface with distinct, irregular growth increments, umbones elevated, pointed, slightly prosogyrate; posterior sulcus present, widening posteriorly, bordered by indistinct ridge; anterodorsal margin very long, slightly concave.

Stratigraphic and geographic range

Lower Miocene (lower Burdigalian), northern Italy.

Genus ***Channelaxinus*** Valentich-Scott & Coan in Coan & Valentich-Scott, 2012

Type species

Channelaxinus oliveri Valentich-Scott & Coan in Coan & Valentich-Scott, 2012, by original designation.

***Channelaxinus*? sp.**
Fig. 9D–E

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Caselle A; NRM Mo 204840 (L = 20 mm).

Description

Moderately inflated shell; umbones elevated, small, pointed, prosogyrate; posterior sulcus very close to posterodorsal margin, deep, bordered by sharp ridge; two faint, posterodorsal ridges.

Remarks

With its sharp posterior ridge and groove, and the faint, radial posterodorsal ridge, this specimen resembles *Channelaxinus* sp. from the Middle Miocene Ca' Cavalmagra seep deposit (Kiel & Taviani 2017: 450, fig. 5), and is hence tentatively place in *Channelaxinus*. With about 20 mm in length *Channelaxinus* sp. is notably larger than *Thyasira* sp. 1 and 2 reported above.

Stratigraphic and geographic range

Middle Miocene, northern Italy.

Family Lucinidae Fleming, 1828

Genus ***Lucinoma*** Dall, 1901

Type species

Lucina filosa Stimpson, 1851, by original designation.

Lucinoma perusina (Sacco, 1901)
Fig. 10A–D

Dentilucina perusina Sacco, 1901: 83, pl. 19 figs 12–14.
Dentilucina perusina var. *pseudorotunda* Sacco, 1901: pl. 21 fig. 15.

Phacoides (*Lucinoma*) *perusinus* – Moroni 1966: 82, pl. 5 figs 1, 3, pl. 6 figs 1–2.
Lucinidae – Taviani 1996: fig. 4b.
Lucinoma perusina – Kiel & Taviani 2017: 453, figs 8–9. — Sami & Taviani 2019: fig. 1b. — Kiel *et al.* 2023: figs 2a, 3c.

Material examined

ITALY – **Emilia-Romagna** • 13 specs; Caselle C; NRM Mo 204849 • 3 specs; Guzzano; MGGC 22314 • 6 specs; Casola; MGGC 22315 • 3 specs; Castel di Casio; MGGC 22316 (L = 37.6, H = 41.5, W = 25.7 mm); MGGC 22318 (L = 41; H = 38, W = 22.8 mm) • 13 specs; Castiglion dei Pepoli; MGGC 22319 (L = 41.8, H = 43.2, W = 29.4). – **Tuscany** • 29 specs; Le Colline; NRM Mo 204850.

Remarks

Lucinoma perusina is widespread in Miocene seep deposits in Italy, emphasized once more by the abundant new material reported here. The label associated with the specimens from Casola read "*Lucina strigosa* Michlt". Chavan (1959) assigned the Miocene *Lucina strigosa* Michelotti, 1861 to *Pseudolucinisca* Chavan, 1959, but Glover & Taylor (2008) questioned this placement, pointing out that *Pseudolucinisca* has a large, strongly asymmetrical lunule. The specimens from Casola are too poorly preserved to show much external sculpture or the lunule. But one specimen shows a long and elongate anterior adductor muscle scar, unlike that of *Pseudolucinisca lacteola* (Tate, 1897) (type species of *Pseudolucinisca*), and instead resembling that of *Lucinoma perusina*.

Stratigraphic and geographic range

Upper Oligocene (upper Chattian) to Upper Miocene, northern Italy.

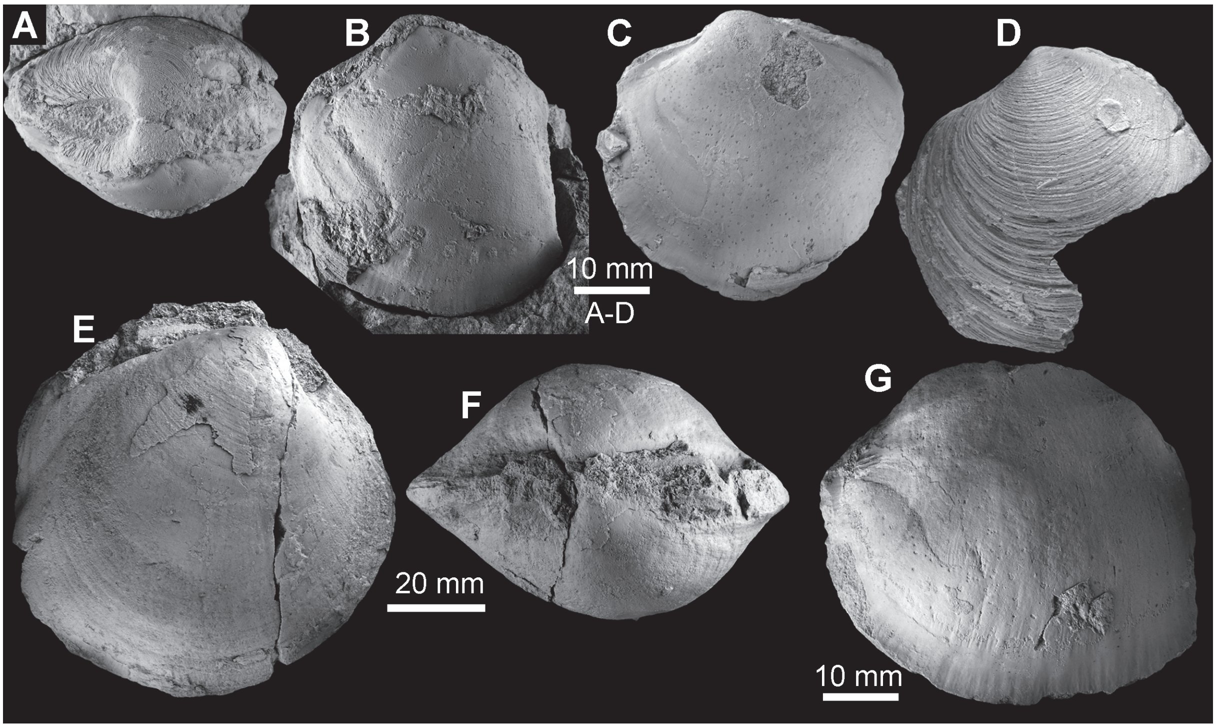

Fig. 10. Lucinid bivalves from Calcari a *Lucina* seep deposits in northern Italy. **A–D**. *Lucinoma perusina* (Sacco, 1901). **A–B**. Articulated specimen showing lunule and anterior adductor muscle scar, from Castel di Casio (MGGC 22316). **C**. Internal mold from Castel di Casio (MGGC 22317). **D**. Specimen with preserved shell sculpture from Castiglion dei Pepoli (MGGC 22319). **E–G**. *Meganodontia hoernea* (Des Moulins, 1868). **E–F**. Complete specimen with some shell remains from Castel di Casio (MGGC 22321). **G**. Incomplete internal mold showing long and curved anterior adductor muscle scar, from Guzzano (MGGC 22320).

Genus ***Meganodontia*** Bouchet & Cosel, 2004

Type species

Meganodontia acetabulum Bouchet & Cosel, 2004, by original designation.

Meganodontia hoernea (Des Moulins, 1868)
Fig. 10E–G

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Guzzano; MGGC 22320 (L = 50+ mm) • 2 specs; Castel di Casio; MGGC 22321 (Fig. 10E: L = 78, H = 79.5, W = 51.5 mm). – **Tuscany** • 2 specs; Le Colline; NRM Mo 205351, Mo 205352.

Remarks

See Kiel & Taviani (2017) for an extensive synonymy of this species. The few available Middle Miocene specimens (from Guzzano and Castel di Casio) are smaller (maximum length 77 mm) than those from the Upper Miocene, but are morphologically well within the range known of the Upper Miocene specimens (Moroni 1966; Kiel & Taviani 2017).

Stratigraphic and geographic range

Upper Oligocene (upper Chattian) to Late Miocene, northern Italy.

Genus ***Miltha*** Adams & Adams, 1857

Type species

Lucina childrenae Gray, 1825, by monotypy.

Miltha (s. lat.) ***romaniae*** sp. nov.
urn:lsid:zoobank.org:act:2B925733-211D-4EBA-9212-DAB02264F43C
Fig. 11

Diagnosis

Shell oval, flat, reaching 30 mm in length, with anterior and posterior groove producing narrow antero- and posterodorsal areas; umbones little elevated, pointed, slightly prosogyrate, displaced anterior at about ⅓ of shell length; anterodorsal margin nearly straight; anterior margin gently rounded, with smooth transition to convex ventral margin; posterodorsal margin almost straight, with angular transition to posterior margin; posterior margin with indent at end of posterior groove; ventral commissure slightly undulating; external surface covered by numerous densely-spaced, fine commarginal ribs that become stronger toward the outer margin; at antero- and posteroventral margin, the ribs their interspaces are often covered by obliquely tangential thread-like ridges; no radial sculpture; aams thin, elongate, reaching just below mid-line of shell, deviating from pallial line at an angle of about 15°; pallial line entire, running close and parallel to ventral margin.

Etymology

Named after ‘Romània’, Latin name for ‘Romagna’ (Emilia-Romagna region) where a number of key Calcari a *Lucina* sites are located.

Material examined

Holotype

ITALY – **Emilia-Romagna** • Ca’ Cassano; MSF 2346, a left valve with preserved shell material.

Paratypes

ITALY – **Emilia-Romagna** • 9 specs; Ca' Cassano; MSF 2345, MSF 2347, MSF 2348, MSF 2362 (L = 30, W = 7.0 mm), MSF 2363 (L = 29.2).

Remarks

Miltha (s. lat.) *romaniae* sp. nov. shows many characteristics of the genus *Miltha*, except that it has a very thin and only moderately long aams, whereas typical species of *Miltha* have a very long and lenticular aams that widens in the center, and reaches almost to the ventral margin (Ludbrook 1969; Vokes 1969). In addition, most species of *Miltha* have a narrower posterodorsal area, and they are significantly larger (70 mm and more) compared to *Miltha* (s. lat.) *romaniae* (40 mm max). *Miltha* (s. lat.) *romaniae* has a slightly undulating ventral margin (Fig. 11F) but seems not to show differences in inflation between left and right valves, as in *Miltha* (Vokes 1969). Also the subgenus *Miltha* (*Matanziella*) Frassinetti, 1978, is larger and has a broader aams than *Miltha* (s. lat.) *romaniae*, and furthermore differs by lacking the distinct grooves separating the antero-and posterodorsal areas (Frassinetti 1978). Species of *Miltha* show differences in inflation between left and right valves. This was not observed in the few available, articulated specimens of *Miltha* (s. lat.) *romaniae*. However, Vokes (1969) noted that this feature appears only later during ontogeny, and is only detectable in specimens larger than about 25 mm length. With the largest available articulated specimen of *Miltha* (s. lat.) *romaniae* being about 32 mm long, the lack

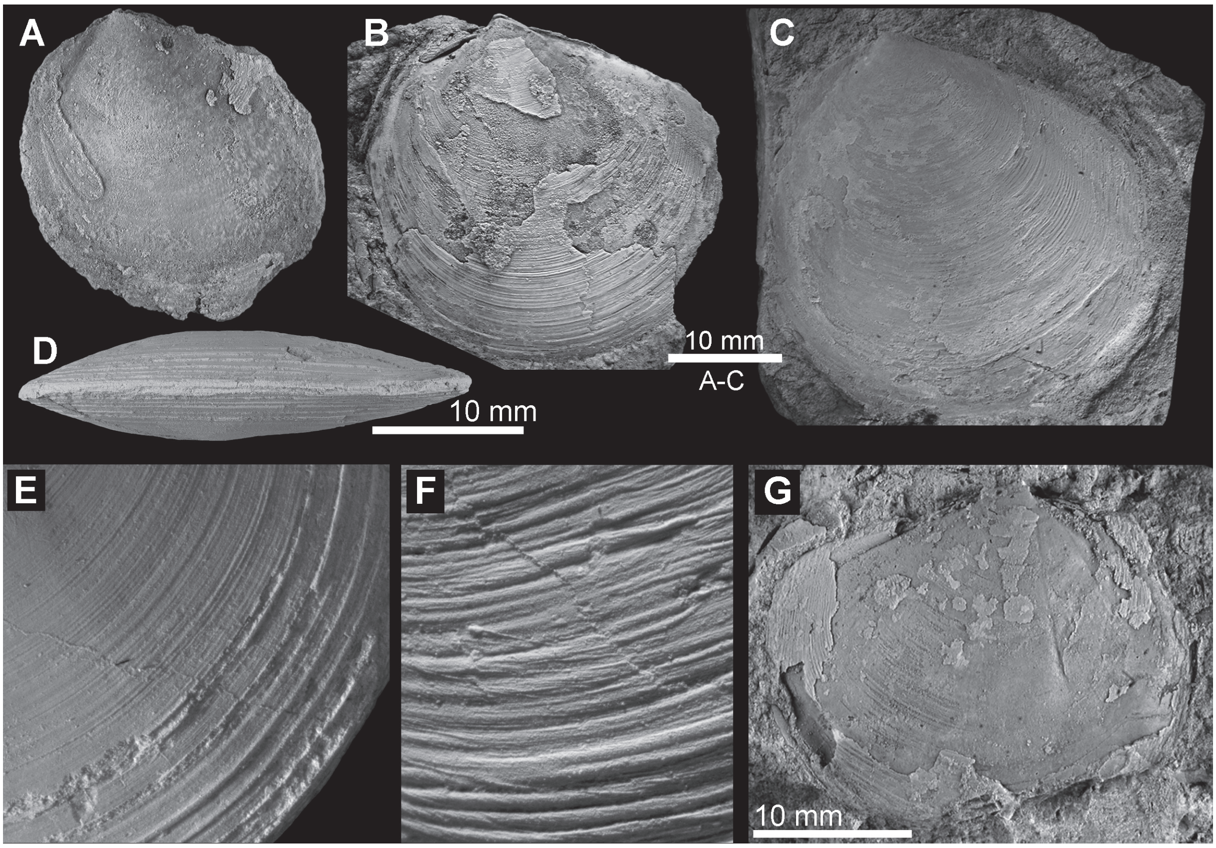

Fig. 11. The lucinid bivalve *Miltha*? *romaniae* sp. nov., from the Ca' Cassano seep deposit in northern Italy. **A**. Paratype (MSF 2345). **B**. Paratype (MSF 2347). **C**. Holotype (MSF 2346). **D–F**. Paratype with well-preserved ventral side (MSF 2362). **D**. Ventral view showing the slight undulation of the ventral margin. **E**. Posteroventral surface showing the increasing strength and spacing of the commarginal ribs. **F**. Close-up on anteroventral surface, showing the fine obliquely tangential thread-like ridges. **G**. Paratype (MSF 2363), right valve embedded in rock matrix, showing the aams.

of this feature might just be a matter of its small size relative to *Miltha*. Due to the differences outlined above, *Miltha* (s. lat.) *romaniae* might represent a new genus or subgenus closely related to *Miltha*, but with its hinge area remaining unknown, we prefer to assign this species to *Miltha* (s. lat.).

Stratigraphic and geographic range

Upper Miocene, northern Italy.

Family Vesicomyidae Dall & Simpson, 1901

Genus ***Archivesica*** Dall, 1908

Type species

Callocardia gigas Dall, 1895, by original designation.

Archivesica strigarum Kiel & Taviani, 2017
Fig. 12A–H

Archivesica strigarum Kiel & Taviani, 2017: 459, fig. 13.

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Castel di Casio; MGGC 22322 • 2 specs; Castillon dei Pepoli; MGGC 22323 (L = 79.8, H = 39.8 mm) • 13 specs; Caselle A; NRM Mo 204841 (L = 73.2, H = 38.8, W = 27.8 mm), NRM Mo 204842, NRM Mo 204843 • 13 specs; Casola; MGGC 22326 (L = 41.5, H = 23.5, W = 13.3), MGGC 22325 (L = 45.0, H = 27.0, W = 16.1), MGGC 22324 (L = 48.6, H = 27.4 mm) • 1 spec.; Guzzano; MGGC 22328.

Remarks

Archivesica strigarum was initially described based on only a few specimens from the Middle Miocene Sasso delle Streghe and Deruta localities (Kiel & Taviani 2017), but our new collections indicate that this species is quite common in the Middle Miocene seep deposits in Italy. The new specimens illustrated here show the previously only poorly known external surface and provide a better view on the hinge.

Stratigraphic and geographic range

Upper Oligocene (upper Chattian) to Middle Miocene, northern Italy.

Genus ***Wareniconcha*** Cosel & Olu, 2009

Type species

Vesicomya guineensis Thiele, 1931, by original designation.

***Wareniconcha*? sp.**
Fig. 12I–J

Material examined

ITALY – **Emilia-Romagna** • 1 spec.; Castel di Casio; MGGC 22329 (L = 31.0, H = 26.8, W = 15.8 mm).

Description

Shell outline roundish-oval, umbo elevated, blunt; anterior margin acutely rounded, ventral margin convex; anterior adductor muscle scar elongate-oval; pallial line crenulate, close and parallel to ventral margin; no pallial sinus, but at its posterior end, the pallial line curves sharply upward and attaches to posterior adductor muscle scar at its anterior side. Shell with fine, radial, internal striations; posterior adductor muscle scar bound anteriorly by weak but distinct posterior ridge.

Remarks

This shell is insufficiently preserved for a confident assignment to *Wareniconcha*: it lacks the external shell and hence the lunule and escutcheon remain unknown; the posterior margin is broken off; and the hinge dentition cannot be examined. However, overall the shell is very similar to the type species *Wareniconcha guineensis* (Thiele, 1931). It certainly is too short and has a too narrow and elongate anterior adductor muscle scar to be an aberrant specimen of *Archivesica aharoni* Kiel & Taviani, 2017, or other Italian Miocene species of *Archivesica*.

Stratigraphic and geographic range

Upper Oligocene (upper Chattian) to Lower Miocene (Aquitanian), northern Italy.

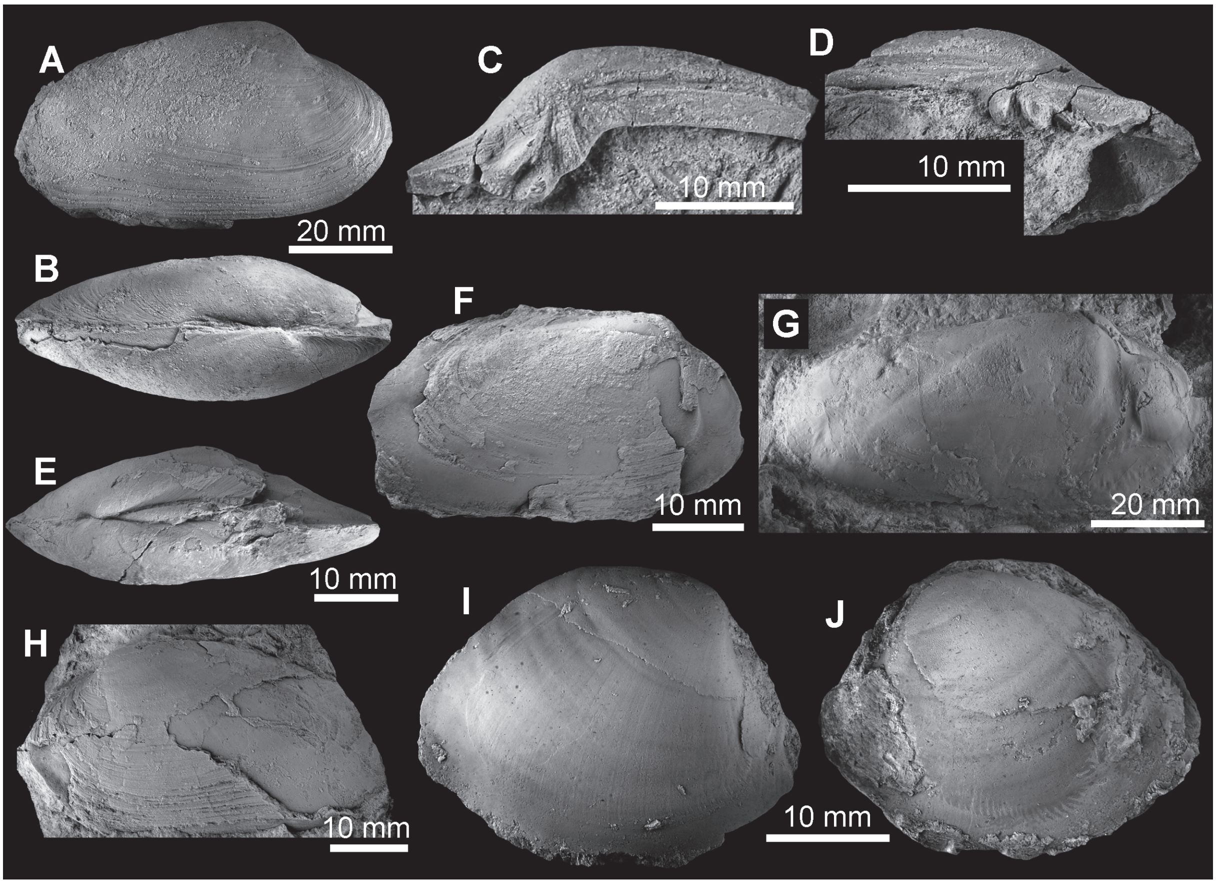

Fig. 12. Vesicomyid bivalves from Miocene Calcari a *Lucina* seep deposits in northern Italy. **A–H**. *Archivesica strigarum* Kiel & Taviani, 2017. **A–B**. Articulated specimen from Caselle A (NRM Mo 204841). **C**. Hinge of RV (Caselle A, NRM Mo 204842). **D**. Hinge of LV (Caselle A, NRM Mo 204843). **E**. Articulated specimen from Casola showing ligament (MGGC 22325). **F**. Articulated specimen from Casola, view on RV showing anterior adductor muscle scar (MGGC 22326). **G**. Internal mold of RV showing muscle scars and pallial line, from Castillon dei Pepoli (MGGC 22323). **H**. Left valve with shell remains, from Casola (MGGC 22324). **I–J**. *Wareniconcha*? sp., external view on articulated specimen from Castel di Casio (MGGC 22329).

Family uncertain

Genus ***Sisonia*** Kiel, Fernando, Magtoto & Kase, 2022

Type species

Sisonia frijellanae Kiel, Fernando, Magtoto & Kase, 2022, by original designation.

Sisonia ultimoi sp. nov.
urn:lsid:zoobank.org:act:C6300134-6227-42D0-94C9-EED1086B8634
Fig. 13

Diagnosis

Shell small for genus; only moderately inflated; posterior ridge present but not very distinct, central-posterior sulcus weakly developed; umbones in anterior third; regular, fine commarginal ribs.

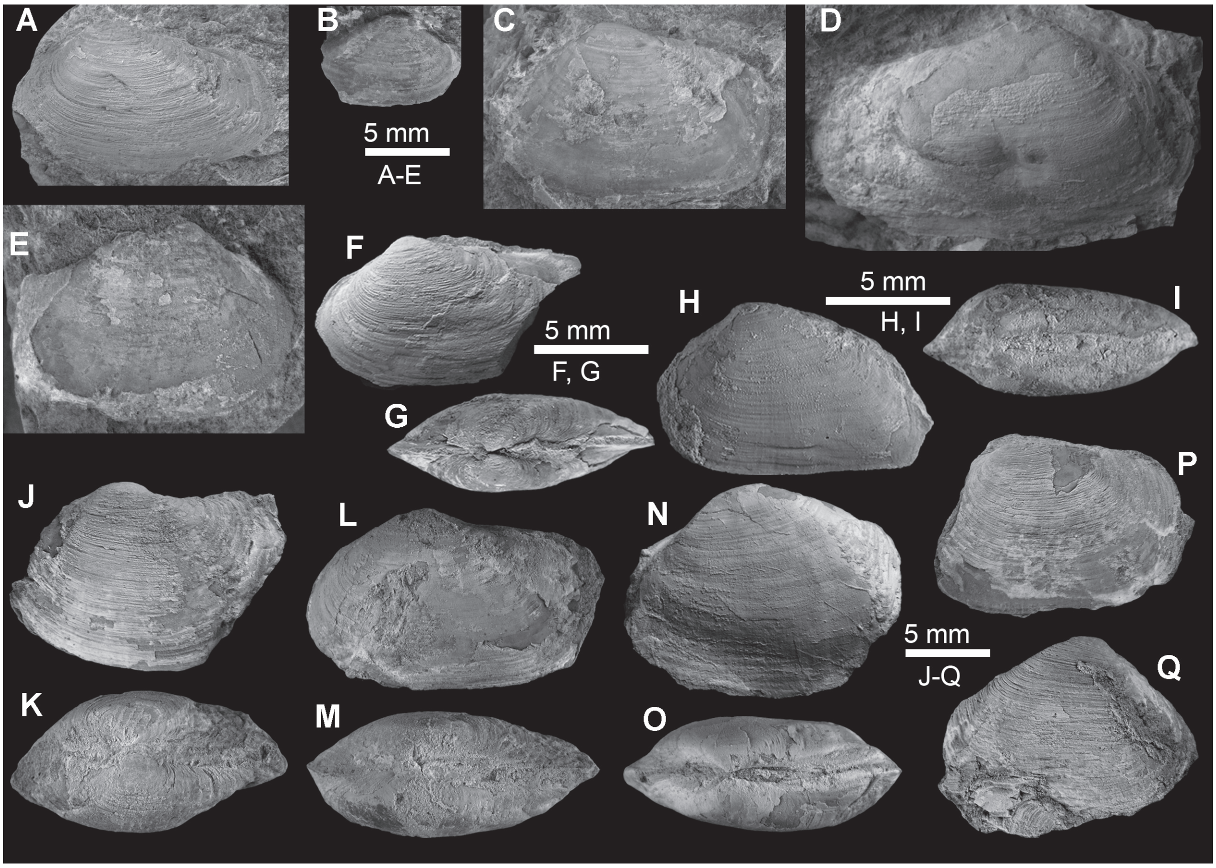

Fig. 13. The bivalve *Sisonia ultimoi* sp. nov. from the Middle Miocene Ca' Cavalmagra seep deposit in northern Italy. **A**. Left valve (MSF 1280). **B**. Small right valve (MSF 1265). **C**. Left valve (MSF 2372). **D**. Large right valve with severe shell injury (MSF 1278). **E**. Right valve (MSF 1281). **F–G**. Articulated specimen with broken posterior end (MSF 2367). **H–I**. Holotype (MGGC 22330), articulated specimen showing outline of shell. **J–K**. Paratype, articulated specimen with deformed posterior side, showing the regular commarginal ornament; this specimen preserves the most realistic inflation of all available specimens (MSF 2368). **L–M**. Articulated specimen (MSF 2369). **N–O**. Articulated specimen showing fine internal striation (MSF 2370). **P–Q**. Deformed specimen showing the regular commarginal ornament (MSF 2371).

Etymology

Named for Ultimo Bazzani (Castiglione dei Pepoli), who collected many of the specimens studied here.

Material examined

Holotype

ITALY – **Tuscany** • Ca' Cavalmagra; MGGC 22330.

Paratypes

ITALY – **Tuscany** • 10 specs; Ca' Cavalmagra; MSF 1265 (2 specs, MSF 1265a, L = 9.3 mm, MSF 1265b, L = 13.8 mm), MSF 1278 (26.3 mm), MSF 1280 (18.3 mm), MSF 1281 (19 mm), MSF 1235 (5 specs).

Description

Shell small for genus, reaching 26.3 mm in length, trapezoid to cunaeiform, moderately inflated with maximum inflation mid-shell at the umbones; umbones in anterior third of shell, moderately elevated, pointed, orthogyrate to very slightly prosogyrate; blunt ridge running from umbo to posteroventral margin, with weak sulcus to its anterior; ventral margin convex to straight; no lunule, escutcheon lanceolate, short; shell surface covered by numerous weak but distinct and regularly spaced commarginal ribs; interior covered by fine, radial striations. The largest articulated specimen, with broken posterior margin, is 16 mm high and 11 mm wide.

Remarks

Compared to the Late Miocene Philippine type species *Sisonia frijellanae* (Kiel *et al.* 2022), *Sisonia ultimoi* sp. nov. is much smaller (max. 20 mm vs 68.7 mm in length), is posteriorly less inflated, and the median sulcus is weakly developed and does not always produce a concavity in the ventral margin.

Stratigraphic and geographic range

Middle Miocene (upper Langhian), northern Italy.

Discussion

The abundance of food coupled with the toxicity of the environment (mainly due to hydrogen sulfide) make hydrocarbon seeps and hydrothermal vents rather extreme environments whose biomass consists mostly of highly specialized, chemosymbiotic or bacteria-grazing taxa (Van Dover 2000; Levin *et al.* 2016). Many of these taxa are found exclusively at vents, seeps, and similar organic- and sulfide-rich habitats, and are called 'endemic' or 'obligate' to these environments. However, there are also taxa that occasionally venture into these habitats due to the abundance of food, and potentially because those taxa have a certain tolerance toward hydrogen sulfide. These taxa are called 'vagrants' or members of the 'background fauna'. In the case of the Miocene Calcari a *Lucina* deposits concerned here, most gastropods should be considered as background fauna. Exceptions are the seguenzoid *Cataegis taurocrassa* and the neritoid *Thalassonerita megastoma*, which appear to occur exclusively at seeps. Bivalves are more commonly endemic at seeps than gastropods, especially taxa with an intimate symbiosis with, and dependence on, chemotrophic bacteria. At the Calcari a *Lucina* deposits, these include the mytilids *Bathymodiolus* Kenk & Wilson, 1985 and *Samiolus* Kiel & Taviani, 2017 (Taviani 1994; Kiel & Taviani 2017; Kiel *et al.* 2023), large vesicomyids belonging to *Archivesica* and *Wareniconcha*, and the enigmatic *Sisonia ultimoi* sp. nov. The lucinids are a diverse family of chemosymbiotic bivalves inhabiting a wide range of environments (Taylor & Glover 2006). Among them, probably only the very large *Meganodontia hoernea* (Des Moulins, 1868) is truly restricted to hydrocarbon seeps, whereas most genera, including *Lucinoma*, *Megaxinus* Brugnone, 1880, and possibly the newly described species *Miltha* (s. lat.) *romaniae* sp. nov., are general inhabitants of organic-rich sediments.

Two species described here are the geologically oldest members of their genera: the gastropod *Putzeysia diversii* sp. nov. and the bivalve *Sisonia ultimoi* sp. nov. Previous fossil occurrences of the former include Pleistocene records of *P. wiseri* (see Reitano & Scuderi 2021) and a Late Miocene record of *P.* cf. *clathrata* (see Barrier *et al.* 1991), thus the Middle to Late Miocene *Putzeysia diversii* is an extension of the geologic history of this genus. *Sisonia* is a genus of uncertain taxonomic affinities, recently described from late Miocene seep deposits in the Philippines (Kiel *et al.* 2022). The middle Miocene *Sisonia ultimoi* thus extends the geologic range, and emphasizes the biogeographic link between the two regions.

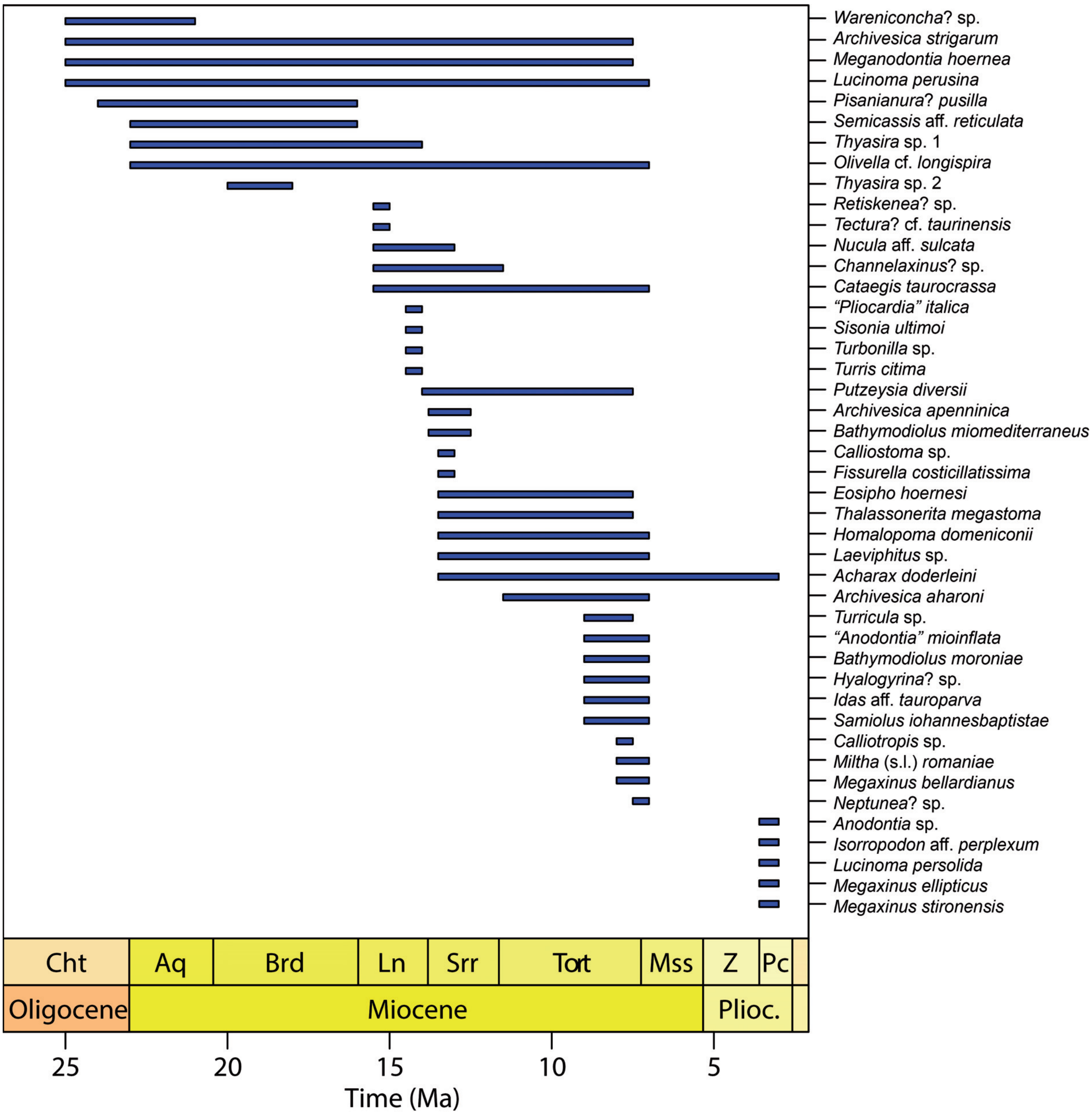

Fig. 14. Range chart of all taxa identified to genus or species level that have been described from Calcari a *Lucina* deposits. Not included are taxa reported by Moroni (1966) that we were not able to revise.

Some species recorded here have rather long geologic ranges, for example *Archivesica strigarum*, *Meganodontia hoernea*, *Lucinoma perusina*, and *Olivella* aff. *reticulata* (Fig. 14). This may partly because the respective specimens belong to cryptic species with so minor morphologic differences that they could not be detected with the insufficient material available. Another reason is the poor stratigraphic resolution of the older sites (Castel di Casio, Castiglion dei Pepoli, Guzzano), where our dating represents the overall age of the known rock formations in the area.

Acknowledgments

We thank Ultimo Bazzani (Castiglione dei Pepoli) for making many specimens from his private collection available for research and donating them to MGGC; Gian Battista Vai (Bologna) for his constant encouragement, enthusiastic cooperation in the field, and advice on stratigraphic issues; Antonio ("Tonino") Benericetti for collecting fossil material from various Calcari a *Lucina* sites; Mathias Harzhauser (Vienna) for advice on Miocene Mediterranean gastropods; Krzysztof Hryniewicz (Warsaw) for discussions on thyasirids. The reviewers Andrzej Kaim and Krzysztof Hryniewicz (both Warsaw) are thanked for their constructive comments on the manuscript. Financial support was provided by the Deutsche Forschungsgemeinschaft through grant Ki802/6–1, the Swedish Research Council (Vetenskapsrådet) through grant 2016–03920, and the Alméns fund of the Kungliga Vetenskaps-Akademien to SK. This is ISMAR-CNR Bologna scientific contribution n. 2074.

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Manuscript received: 27 February 2023
Manuscript accepted: 6 July 2023
Published on: 11 December 2023
Topic editor: Marie-Béatrice Forel
Desk editor: Pepe Fernández