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THE GENERA *GLYCYMERIS, AEQUIPECTEN* AND *ARCTICA*, AND ASSOCIATED MOLLUSK FAUNA OF THE LOWER PLEISTOCENE ARDA RIVER SECTION (NORTHERN ITALY)

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Abstract. The Lower Pleistocene marine succession of the Arda River, cropping out at Castell'Arquato (Northern Italy), is well exposed, continue and richly fossiliferous. It consists of sandstones, siltstones and claystones and it is topped by continental conglomerates which indicate a major sea level drop. In the present paper *Glycymeris glycymeris, Glycymeris inflata, Glycymeris insubrica, Aequipecten scabrella, Aequipecten opercularis* and *Arctica islandica* are described and revised. In addition, the associated fauna is illustrated, and its biostratigraphic and palaeoclimatic significance is analyzed. This study points out that: 1) the fauna has a high biodiversity, comprising 159 taxa; bivalves are dominant, followed by gastropods, corals, serpulids, brachiopods, echinoids, arthropods (e.g. barnacles), bryozoans and scaphopods; 2) the last occurrences of the bivalves *Aequipecten scabrella*, *Glycymeris inflata* and *Chama placentina*, the first occurrence of *Arctica islandica* and the last occurrences of the gastropods *Turritella tricarinata pliorecens* and *Nassarius prysmaticus* suggest a late Gelasian-Calabrian age (Early Pleistocene) for the investigated marine succession; 3) the occurrence of boreal guests, such as *Arctica islandica, Pseudamussium peslutrae* and possibly *Mytilus edulis,* testify to a climatic change with a shift from warm to cold seawater temperatures.

Introduction

The Arda River marine succession, cropping out in Northern Italy, is well exposed, continue and very rich in fossil invertebrates.

The stratigraphically lower part of the succession (Zanclean-Piacenzian in age) cropping out between the town of Lugagnano Val d'Arda and Castell'Arquato (Northern Italy) was the subject of several researches; in fact its fossiliferous sediments were soon adopted as the boundary stratotype for the Piacenzian Stage (e.g. Pareto 1865; Barbieri 1967). Subsequently, integrated calcareous plankton biostratigraphic studies by Rio et al. (1988) and by Raffi et al. (1989) demonstrated that a hiatus was present right at the base of the stratotype, making thus this area unsuitable to define a stratotype. Although numerous studies have been performed on this part of the Arda River section, less has been done on the upper part of the succession, which extends downstream the bridge located at the entrance of the town of Castell'Arquato (Dominici 2001, 2004; Monegatti et al. 2001). This part of the succession is very rich in macrofossils and it covers without significant gaps the Early Pleistocene, a key-time interval to understand the climate change leading to the Middle Pleistocene continental glaciation. The Early Pleistocene was characterized by several climatic oscillations linked to glacial/interglacial cycles, which affected also the Mediterranean area and culminated at the end of the Early Pleistocene with the onset of the northern hemisphere continental glaciations (e.g. Bertini 2001; Clark et al. 2006).

This work represents the first of a series of papers, which will be aimed to describe and revise the most controversial and questionable Pliocene-Pleistocene mollusk species found along the Arda section. Here, we focus on the descriptions and revisions of six species belonging to the genera *Glycymeris, Aequipecten* and *Arctica*. The associated mollusk fauna is also illustrated

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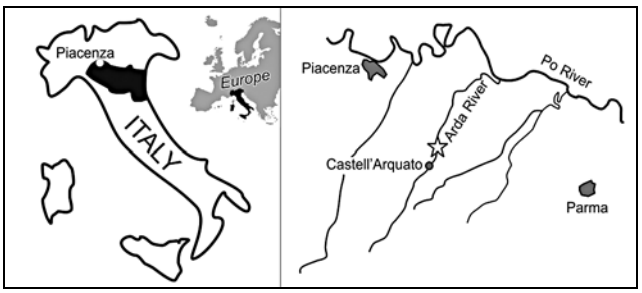

Fig. 1 - Sketch map with the position of the Lower Pleistocene Castell'Arquato Formation cropping out along the Arda River, Western Emilia, Italy (modified after Pervesler et al. 2011 and Crippa 2013). Base of the section at 44°51'12.5"N; 9°52'22.4"E.

and the biostratigraphic and palaeoclimatic significance of some of its taxa is analyzed with the aim of understanding how the Arda biota responded to the climatic changes of the Early Pleistocene.

Geological setting

The studied marine succession belongs to the upper part of the Castell'Arquato Formation, belonging to the 'Quaternario Marino Supersynthem' (Gelasian-Calabrian; Calabrese & Di Dio 2009), which crops out in Northern Italy along the Arda River at Castell'Arquato (Western Emilia, Northern Italy) (Fig. 1); it extends downstream the bridge present at the entrance of the town toward N-NE for nearly 2 km (base at 44°51'12.5"N; 9°52'22.4"E).

The section belongs to the Castell'Arquato piggyback basin (Roveri & Taviani 2003), which developed after the fragmentation of the Po Plain foredeep in the late Messinian (Calabrese & Di Dio 2009). The basin is filled by a sedimentary succession of late Messinian to Holocene age, organized in a large scale transgressive-regressive cycle controlled by tectonics (Monegatti et al. 2001). Beds form a regular monocline dipping towards the N-NE and no major faults occur in this area (Monegatti et al. 2001). The marine layers at the base of the Castell'Arquato basin consist in deep sea sediments deposited after the end of the Messinian salinity crisis (Calabrese & Di Dio 2009), when marine conditions were restored in the Mediterranean sea; upward they pass to slope and shelf facies and then through a regressive trend to the Middle Pleistocene alluvial continental deposits, which represent the final retreat of the sea in this area and the establishment of a continental environment with vertebrate faunas and fresh water mollusks (Cigala Fulgosi 1976; Pelosio & Raffi 1977; Cianghe-rotti et al. 1997).

The studied section is 240 m-thick and consists of sandstones, siltstones and claystones bounded at the top by continental conglomerates indicating a major sea level drop (Fig. 2).

The alternations of thick silty-muddy intervals (hemipelagic suspension settling) and sandstones (Fig. 2) which characterize the overall marine succession can be interpreted as flood-generated delta-front lobes recording the final sandy deposition of high-density flows triggered by river floods (Dominici 2001; Crippa et al. in progress). This suggests that it was deposited in a tectonically active setting during phases of advance of fan deltas (Dominici 2001; Felletti, pers. comm.).

Material and methods

Fossil specimens were collected using a bed by bed approach from 200 fossiliferous beds (one sample for each bed), positioned on the Arda River log meter by meter (Fig. 2; Appendix). A bulk sample of at least 0.5 liters was sampled; sampling was then continued until new species were found. The collected specimens were then prepared, washed and cleaned from the sediment using an air drill, in case of hard sediment, or a scalpel, in case of soft sediment. The length and the width of fossil specimens were measured using a caliper (to the nearest 0.1 mm) and at each of them has been assigned a unique ID to identify it (ID used: ACG; progressive numbers from the base to the top of the section, see Appendix). Every fossil specimen was identified at generic and specific level using the common techniques of identification and classification, in order to obtain a consistent taxonomy (see next paragraph). A complete list of the species found in each stratigraphic bed is reported in the Appendix.

The fossil preservation is generally good; articulated bivalve specimens in life position are present (autochthonous assemblages), but usually the assemblages are dominated by disarticulated valves. Notwithstanding disarticulation, the shells are fresh and preserve the fragile spiny ornamentation and in some cases the color pattern, indicating in situ disarticulation (by bioturbation) or short-distance transport (see Fig. 2 for the position of the transported beds). Shells are usually white, rarely black or grey, showing little abrasion (see table 2, p. 342 in Dominici 2001 for taphonomic signatures and interpretations). The taphonomic signatures and the biofabric thus suggest the presence in some beds of transport or winnowing, but not over distance (mostly parautochthonous assemblages). Furthermore, in the majority of cases, shells do not show the presence of microboring, which, in shallow water, usually indicates a prolonged exposure to biological or physical factors after death. This lack of microboring thus suggests a quick burial and short residence time on the sea floor that have preserved the shells fresh and their ornamentation intact (Parsons-Hubbard et al. 2014).

Fossil assemblages

The fauna is characterized by a high biodiversity, including both infaunal and epifaunal species, of shallow and deep infralittoral and circalittoral environments; a detailed palaeoecological analysis of the Arda biota is in progress and will be the subject of a separate paper.

The fauna, here examined, is composed by 159 taxa (Tab. 1; Pls 1-15) coming from 200 shell beds, of which bivalves are dominant with 105 taxa, followed by

gastropods (44 taxa) and a few corals (3 taxa) and serpulids (2 taxa); brachiopods, echinoids, arthropods (e.g. barnacles), bryozoans and scaphopods do also occur in the fauna, testifying that it is characterized by a high biodiversity.

As said above, bivalves represent the dominant taxon in the Arda fauna; in particular, here we focus on the description and revision of three bivalve genera (*Glycymeris, Aequipecten* and *Arctica*). For these reasons, we mainly deal with the problematics that characterize bivalve systematics. The classification of most specimens was made difficult by the fact that bivalve taxonomy is a complicated topic in constant evolution; in fact, as Bieler & Mikkelsen (2006, p. 224) observed "much of the taxonomic instability in bivalve research is not a result of conflicting hypotheses of relationships, but one of an overabundance of available names" and this is the main problem we dealt with the bivalve classification of the Arda assemblages. According to Jimenez et al. (2009) the status of many genera is still uncertain and species are assigned to different genera depending on the authors; nonetheless, there is a certain stability in the species concept that allows adequate identification at the species levels. The Treatise on Invertebrate Paleontology - Mollusca, part N (Cox et al. 1969, 1971) has always been used as a starting point for bivalve systematics, but it is now outdated and hence do not include recent findings.

In the last few years, bivalve workers have been increasingly involved in larger-scale phylogenetic analyses, using a combination of morphological, palaeontological and molecular data sources to investigate evolutionary patterns and refine systematics for various parts of the bivalve tree. In the meantime, a revised volume of Treatise on Invertebrate Paleontology – Mollusca, part N is in preparation (Lawrence, University of Kansas, Paleontological institute).

The World Register of Marine Species (WoRMS) has been consulted for resolving critical issues of nomenclature (valid name and so on). In some cases, however, we preferred to maintain the specific name used for fossil specimens instead of the one used for extant species as the link with modern species has not always been verified and the latter may differ a lot from the corresponding fossil ones [*Tellina corbis* (fossil) rather than *Tellina carnicolor* (recent); *Acteon semistriatus* (fossil) instead of *Acteon tornatilis* (recent)].

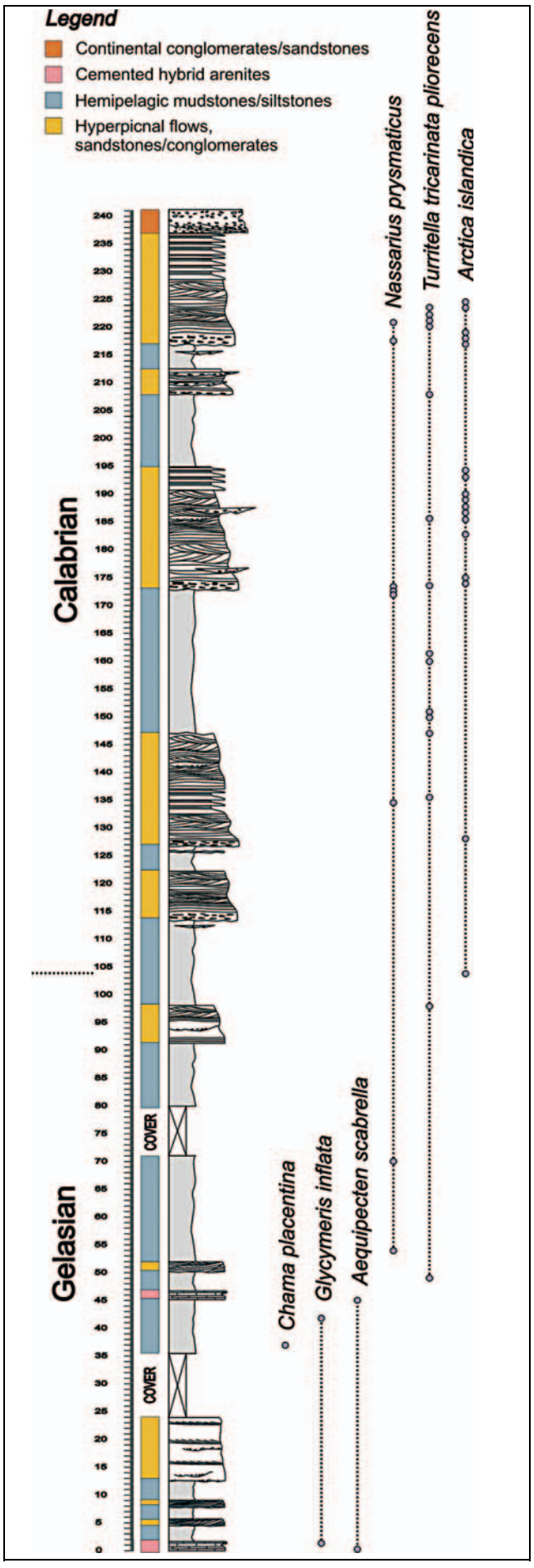

Fig. 2 - Stratigraphic log of the Arda section in which are located the most significant first and last occurrences; a simplified sedimentological description is also shown (Courtesy of Dr. F. Felletti).

List of taxa occurring in the Arda marine section

Bivalves

Nucula placentina (Lamarck, 1819)
Nucula sulcata Bronn, 1831
Nucula sp.
Nuculana pella (Linnaeus, 1758)
Saccella commutata (Philippi, 1844)
Arcoidea indet.
Arca noae Linnaeus, 1758
Arca tetragona Poli, 1795
Arca sp.
Barbatia mytiloides (Brocchi, 1814)
Anadara cf. *A.diluvii* (Lamarck, 1805)
Striarca lactea (Linnaeus, 1758)
Bathyarca sp.
Glycymeris glycymeris (Linnaeus, 1758)
Glycymeris inflata (Brocchi, 1814)
Glycymeris insubrica (Brocchi, 1814)[1]
Glycymeris sp.
Mytilus edulis Linnaeus, 1758
Mytilus galloprovincialis Lamarck, 1819
Mytilus sp.
Pinna sp.
Amusium cristatum (Bronn, 1827)
Pseudamussium peslutrae (Linnaeus, 1771)[2]
Aequipecten opercularis (Linnaeus, 1758)
Aequipecten scabrella (Lamarck, 1819)
Mimachlamys varia (Linnaeus, 1758)
Talochlamys cf. *T.multistriata* (Poli, 1795)
Flexopecten flexuosus (Poli, 1795)
Flexopecten glaber (Linnaeus, 1758)
Pecten flabelliformis (Brocchi, 1814)
Pecten jacobaeus (Linnaeus, 1758)
Anomia ephippium Linnaeus, 1758
Anomia sp.
Monia patelliformis (Linnaeus, 1761)
Loripes lacteus (Linnaeus, 1758)
Lucinoma borealis (Linnaeus, 1767)
Loripinus fragilis (Philippi, 1836)
Lucinella divaricata (Linnaeus, 1758)
Chama gryphoides Linnaeus, 1758
Chama placentina (Defrance, 1817)
Carditidae indet.
Venericardia sp.
Cardites antiquatus (Linnaeus, 1758)
Astarte fusca (Poli, 1791)
Astarte sp.
Cardium indicum Lamarck, 1819
Acanthocardia aculeata (Linnaeus, 1758)
Acanthocardia echinata (Linnaeus, 1758)
Acanthocardia paucicostata (G. B. Sowerby II, 1834)
Acanthocardia tubercolata (Linnaeus, 1758)
Acanthocardia sp.
Papillicardium papillosum (Poli, 1791)
Papillicardium sp.
Parvicardium exiguum (Gmelin, 1791)
Laevicardium crassum (Gmelin, 1791)
Laevicardium oblongum (Gmelin, 1791)
Laevicardium sp.
Mactra stultorum (Linnaeus, 1758)
Spisula subtruncata (da Costa, 1778)
Lutraria angustior Philippi, 1844
Lutraria oblonga (Gmelin, 1791)
Lutraria sp.
Ensis ensis (Linnaeus, 1758)
Tellina albicans Gmelin, 1791[3]
Tellina corbis Sowerby, 1867
Tellina incarnata Linnaeus, 1758
Tellina pulchella Lamarck, 1818
Tellina serrata Brocchi, 1814
Tellina tenuis da Costa, 1778
Tellina sp.
Moerella distorta (Poli, 1791)[4]
Donax cf. *D.trunculus* Linnaeus, 1758
Donax cf. *D.venustus* Poli, 1795
Donax sp.
Solecurtidae indet.
Solecurtus scopula (Turton, 1822)
Azorinus chamasolen (da Costa, 1778)
Arctica islandica (Linnaeus, 1767)
Glossus humanus (Linnaeus, 1758)
Venus nux Gmelin, 1791[5]
Venus sp.
Pitar rudis (Poli, 1795)
Callista chione (Linnaeus, 1758)
Pelecyora brocchi (Deshayes, 1836)
Chamelea gallina (Linnaeus, 1758)
Clausinella fasciata (da Costa, 1778)
Clausinella sp.
Dosinia lupinus (Linnaeus, 1758)
Dosinia sp.
Polititapes cf. *P.rhomboides* (Pennant, 1777)
Polititapes rhomboides (Pennant, 1777)
Polititapes senescens (Cocconi, 1873)
Polititapes sp.
Timoclea ovata (Pennant, 1777)
Corbula gibba (Olivi, 1792)
Hiatella rugosa (Linnaeus, 1767)
Panopea glycymeris (Born, 1778)
Panopea sp.
Pholas dactylus Linnaeus, 1758
Teredo sp.
Pandora inaequivalvis (Linnaeus, 1758)
Thracia pubescens (Pulteney, 1799)
Thracia sp.
Clavagella sp.
Ostrea edulis Linnaeus, 1758
Ostrea sp.
Saccostrea cf. *S.cucullata* (Born, 1778)

Gastropods	
Diodora graeca (Linnaeus, 1758)	*Nassarius musivus* (Brocchi, 1814)
Trochidae indet.	*Nassarius mutabilis* (Linnaeus, 1758)
Calliostoma cf. *C.conulus* (Linnaeus, 1758)	*Nassarius obliquatus* (Brocchi, 1814)
Jujubinus striatus (Linnaeus, 1758)	*Nassarius prysmaticus* (Brocchi, 1814)
Jujubinus sp.	*Nassarius semistriatus* (Brocchi, 1814)
Diloma patulum (Brocchi, 1814)	*Nassarius* sp.
Turritella tricarinata (Brocchi, 1814)	*Mitra* sp.
Turritella sp.	*Acteon semistriatus* Glibert, 1952
Turridae indet.	*Acteon* sp.
Aporrhais uttingeriana (Risso, 1826)	*Ringicula auriculata* (Ménard de la Groye, 1811)
Aporrhais pespelecani (Linnaeus, 1758)	*Ringicula* sp.
Aporrhais sp.	*Cylichna cylindracea* (Pennant, 1777)
Calyptraea chinensis (Linnaeus, 1758)	*Conus ventricosus* Gmelin, 1791
Calyptraea sp.	*Conus* sp.
Capulus ungaricus (Linnaeus, 1758)	*Pyramidella* sp.
Xenophora crispa (König, 1825)	
Naticarius stercusmuscarum (Gmelin, 1791)	**Other macroinvertebrates**
Naticarius sp.	*Cladocora* sp.
Euspira sp.	*Flabellum* sp.
Neverita josephinia Risso, 1826	Corals indet.
Neverita sp.	*Terebratula* sp.
Galeodea echinophora (Linnaeus, 1758)	Echinoids indet.
Epitonium tiberii (de Boury, 1890)	*Dentalium* sp.
Epitonium turtonis (Turton, 1819)	*Serpulorbis* sp.
Bolinus sp.	*Ditrupa* sp.
Murex sp.	Barnacle indet.
Nassarius cf. *N.gibbosulus* (Linnaeus, 1758)	Bryozoa indet.
Nassarius cf. *N.clathratus* (Born, 1778)	

Tab. 1 - List of taxa occurring in the Arda marine section. [1]Also known as *Glycymeris nummaria* (Linnaeus, 1758) or *Glycymeris violacescens* (Lamarck, 1819); [2]Also known as *Pseudamussium septemradiatum* (Müller, 1776); [3]Also known as *Tellina nitida* (Poli, 1791); [4]Also known as *Tellina distorta* (Poli, 1791); [5]Also known as *Venus multilamella* (Lamarck, 1818).

Biostratigraphic implications

The Arda fauna is mainly composed of species that made their first appearance in the Miocene (Tortonian) or in the Early Pliocene (Raffi et al. 1985); this fauna established in the Mediterranean Sea after the Messinian salinity crisis, when normal marine waters invaded the basin from the Atlantic (Raffi et al. 1985). The majority of the species found in the Arda River succession belongs to the modern mollusk fauna currently thriving in our seas; thus, they do not provide biostratigraphic informations.

Among the Arda biota, there are however species that made their first appearance or become extinct during the time of deposition of the section, thus representing a useful tool to assess the age of the marine succession, taking into account the problems described below. Previous works (e.g. Dominici 2001; Monegatti et al. 2001) inferred an Early Pleistocene age for the fauna under exam, mostly based on the comparison with the better known Stirone River section (Dominici 2001; Gunderson et al. 2012), cropping out 10 km SE from the Arda River Section, which has very similar biota.

The analysis of the biostratigraphic significance of the range of the species of the Arda fauna is made difficult by two main problems: 1) Available literature: data on ranges of extinct species are very fragmentary and confusing as often several authors give a different time of disappearance for the same species (often referring to local disappearance); see for example the case of the bivalves *Chama placentina* and *Glycymeris inflata* described below. 2) Sampling bias: macrofossils are discontinuously occurring along the section; when rare they may have not been found during sample collection (Signor-Lipps effect) (Signor & Lipps 1982). In addition, the last occurrences of some species may be the result of a change in the palaeoecological conditions, thus representing a local extinction. Considering these problems and using a cautious approach, it has been possible to identify fifteen species of bivalves and gastropods firstly or lastly occurring along the section. The most significant of these first and last occurrences are here described (Fig. 2).

Aequipecten scabrella lastly occurs in the succession at 45.65 m; according to Monegatti & Raffi (2001) it became extinct at 2.1 Ma.

Chama placentina and *Glycymeris inflata* show their last occurrence in the section well before the FO of *A. islandica* (respectively at 37.05 m and 42 m). This is in agreement with the findings of Raffi (1986) and Monegatti & Raffi (2001) who suggested that these species got extinct in the Mediterranean Sea at 1.8 Ma; however, some authors observed that they survived also after this time interval and they probably died out at the end of the Early Pleistocene (Greco 1970; Caprotti 1972).

Nassarius prysmaticus lastly occurs at 221.40 m in the section. According to several authors (Società Italiana di Malacologia, corresponding web page), this taxon got extinct at the end of the Early Pleistocene and this seems to be in agreement with our findings.

Turritella tricarinata has is last occurrence at 224.20 m in the section. This species has three sub-species: *T. tricarinata tricarinata, T. tricarinata pliorecens* and *T. tricarinata communis*, which differ by few characters in the ornamentation and by the outline of the aperture (see Borghi & Vecchi 2005). The Arda specimens are mostly similar to *T. tricarinata tricarinata* and *T. tricarinata pliorecens* rather than to *T. tricarinata communis*; although it is difficult to discern between the former two species, the majority of the Arda specimens belonging to *Turritella* seem to be more similar to *T. tricarinata pliorecens.* In particular, *T. tricarinata communis* is considered a Recent subspecies, whereas *T. tricarinata tricarinata* and *T. tricarinata pliorecens* are respectively Miocene-Pliocene and Lower Pleistocene subspecies. The Arda specimens thus belong to *T. tricarinata pliorecens*, the species that got extinct at the end of the Early Pleistocene.

Althoug the last occurrences of *N. prysmaticus* and *T. tricarinata pliorecens* in the section may be due to a palaeoecological control (Fig. 2), preliminary data based on nannofossil seem to be in agreement with the age given by these two taxa (Bottini & Raffi, pers. comm.).

A very important biotic event in the Arda succession is represented by the first occurrence of the bivalve *Arctica islandica* at 103.70 m from the base of the section, which until 2010 has been used to mark the Pliocene-Pleistocene boundary (Pelosio & Raffi 1974; Raffi 1986); nowadays it marks the Gelasian-Calabrian boundary. Raffi (1986) dated the first appearance of *Arctica islandica* into the Mediterranean Sea at the top of the Olduvai magnetic subchron at 1.67 Ma; however, this age has to be corrected as, after 1995, a new astronomically tuned time scale began to be used to define the magnetostratigraphic boundaries (Van Couvering 1997). The new age for the top of the Olduvai subchron and the corresponding first appearance datum for *A. islandica* in the Mediterranean Sea is thus 1.77 Ma. According to Kukla et al. (1979) *A. islandica* first appears about 2.00 Ma ago in the Santerno Valley (Northern Italy), based on magnetostratographic evidence and radiometric age obtained by corals.

According to Rio et al. in Van Couvering (1997), the stratigraphically lowest level where *A. islandica* occurs seems to be right in the Arda and the Stirone sections; the first appearance of *A. islandica* in the Arda section should thus be bracketed between 1.77-2.00 Ma depending on the different interpretation discussed above.

This species became extinct in the Mediterranean Sea around 9.8 ka, but it is still living nowadays in the Atlantic Ocean along the American coast and in Europe along the coasts of Iceland, Great Britain, Scandinavian peninsula, Denmark, Netherlands, Belgium up to the northern coast of France (Brittany and Normandy) (Dahlgren et al. 2000).

The presence of mollusk species that are known to disappear at the end of the Early Pleistocene in the upper part of the section (taking into account the problematics explained above) and the lack of taxa of strictly Middle Pleistocene age, allow excluding a younger age for the Arda section cropping out downstream the bridge of Castell'Arquato. The stratigraphic ranges of the bivalves and gastropods suggest an Early Pleistocene age, more exactly late Gelasian-Calabrian, and this is supported by preliminary data on nannofossils. Further analyses are now in progress based on foraminifers and magnetostratigraphy to better constrain the age of the section.

Palaeoclimatic implications

The evolution of the biota of the Mediterranean basin has been strongly affected by Pliocene-Pleistocene climatic changes (Raffi et al. 1985). In the Arda section the most important biotic event from a palaeoclimatic perspective is the appearance of the "Boreal (or Northern) Guests" (BG). These species, mainly mollusks, ostracods and foraminifers, migrated into the Mediterranean Sea through the Strait of Gibraltar from higher northern latitudes, in consequence of the climatic cooling beginning in the Calabrian (Garilli 2011). Malatesta & Zarlenga (1986) and Raffi (1986) developed an exhaustive discussion on boreal guests, their arrival and their distribution in the Mediterranean fossil communities and in the present seas.

Arctica islandica is the most famous BG, but other interesting climatic indicators have been found in the section: *Mytilus edulis* and *Pseudamussium peslutrae* both appearing stratigraphically above the *A. islandica* first occurrence. *A. islandica* is found nowadays at high latitudes in the Atlantic Ocean along the American coast and in Europe along the coasts of Iceland, Great

Britain and the Scandinavian peninsula (Dahlgren et al. 2000); according to Malatesta & Zarlenga (1986) *Mytilus edulis* has a similar geographic distribution, whereas *Pseudamussium peslutrae* is now widespread in the eastern part of the Atlantic ocean from Iceland to Morocco coasts. However, their interpretation as boreal guests is not always straightforward and in fact, only the bivalves *Arctica islandica* and *Pseudamussium peslutrae* can be considered good markers in this regard.

According to Malatesta & Zarlenga (1986), *Mytilus edulis* appears in the Mediterranean Sea in the Calabrian. However, it is often difficult to distinguish it from *Mytilus galloprovincialis,* which is a typical Mediterranean form and thus not a boreal guest, as they both show great variation in shell shape due to environmental conditions (Seed 1992); they can also be hybridized (Skibinski et al. 1978). Gosling (1992) and Seed (1992, 1995) observed that not a single morphological characteristic can be used to distinguish these *Mytilus* species. For these reasons it has been very difficult, if not impossible, to distinguish the two species in the Arda section and it is thus problematic to consider the occurrence of this taxon as a boreal guest.

Acanthocardia echinata does also occur in the fauna; it was considered by several authors a BG (e.g. Malatesta & Zarlenga 1986; Raffi 1986), appearing in the Calabrian in the Mediterranean Sea. However, some authors (e.g. Monegatti & Raffi 2001) reported that it was present in the Mediterranean Sea already since the Pliocene. It is not clear though if the authors here refer to *A. echinata echinata* or to *A. echinata mucronata*; in fact the first subspecies is an Atlantic restricted taxon (the boreal guest of Malatesta & Zarlenga 1986 and Raffi 1986), whereas the latter is the typical Mediterranean subspecies. Nowadays they are considered synonyms and this may add problems to the interpretation. La Perna & D'Abramo (2009) gave a clarifying discussion on this topic observing that also *Acanthocardia echinata echinata* was already present in the Pliocene as shown in several records (Palla 1966; Cavallo & Repetto 1992). Thus, according to La Perna & D'Abramo (2009) *Acanthocardia echinata* should not be considered as a boreal guest; here we follow this interpretation.

Aside from the occurrence of boreal guests, the analysis of the composition of the fauna does not allow having more precise palaeoclimatic information; in fact, it is mainly dominated by eurythermal species having a cosmopolitan distribution, including boreal to warm temperate water species; the strictly arctic or tropical taxa are instead absent from the associations.

In the Mediterranean basins, other bioevents in addition to the appearance of boreal guests testify to a shift towards cold climate conditions, as for instance a significant change in the pollen flora (Lona & Bertoldi 1972). Also, in concomitance with the appearance of the boreal guests, there is a gradual decrease of warm-temperate faunas, from the Upper Pliocene to the Middle Pleistocene, which has been considered a consequence of an increase in seasonality and a decrease in precipitation and in temperature (Pelosio & Raffi 1977; Raffi 1986; Dominici 2001).

The arrival of boreal guests, the change in the flora and the disappearance of warm-temperate taxa thus indicate a progressive climate deterioration during the Early Pleistocene, which was probably caused by a complex interplay of factors such as colder seawater temperatures, increase in seasonality and aridity. However, the importance and timing of each of these environmental variables in driving the observed changes remains unsolved.

Conclusions

The Lower Pleistocene part of the Arda River succession has proved to be an interesting section for its continuity and its well preserved and very rich fossil specimens which allow to constrain its age and infer its palaeoclimatic evolution.

The systematic study of the Arda fauna led to conclude that:

1. It is characterized by a high biodiversity with 159 taxa; bivalves are the dominant taxon, followed by gastropods, corals, serpulids, brachiopods, echinoids, arthropods (e.g. barnacles), bryozoans and scaphopods.

2. The last occurrences of the bivalves *Aequipecten scabrella*, *Glycymeris inflata* and *Chama placentina*, the first occurrence of *Arctica islandica* and the last occurrences of the gastropods *Turritella tricarinata pliorecens* and *Nassarius prysmaticus* suggest a late Gelasian-Calabrian age (Early Pleistocene) for the succession.

3. The occurrence of boreal guests along the section, such as *Arctica islandica, Pseudamussium peslutrae* and possibly *Mytilus edulis,* suggests that a climatic change occurred in the section with a shift to colder seawater temperatures. The evolution of this climatic deterioration is complex, but it prepares the ground for the onset of the continental glaciation of the Middle and Late Pleistocene.

Systematics and descriptions

The description of the species belonging to the genus *Glycymeris* Da Costa, 1778, *Aequipecten* Fischer, 1886 and *Arctica* Schumacher, 1817 are here presented. These species are very abundant and regularly present along all the Arda River marine succession, for these reasons they are here described. Waiting for the publication of the revised volume of the "Treatise on Invertebrate Paleontology" the descriptions below follow the

classification of Cox et al. (1969) and Oliver & Holmes in Bieler & Mikkelsen (2006) for the Arcoidea, of Waller et al. in Bieler & Mikkelsen (2006) for the Pectinoidea and of Cox et al. (1969) and Bieler & Mikkelsen (2006) for the Arcticoidea.

Class **Bivalvia** Linnaeus, 1758 (Buonanni, 1681)
Subclass **Pteriomorphia** Beurlen, 1944
Order **Arcoida** Stoliczka, 1871
Superfamily Arcoidea Lamarck, 1809
Family Glycymerididae Dall, 1908

Genus *Glycymeris* Da Costa, 1778
Type-species: *Glycymeris glycymeris* (Linnaeus, 1758) from the Recent of the Mediterranean Sea.

Remarks. Cox et al. (1969) identified two subgenera for *Glycymeris* Da Costa, 1778: *Glycymeris* s.s. and *Glycymerita*. Here, we follow Squires (2010) in abandoning subgenera definition for *Glycymeris* and in considering *Glycymerita* as a distinct genus (Squires 2010), as its shell surface has many prominently raised radial ribs with well defined narrow interspaces in contrast to the mainly smooth surface of *Glycymeris*.

Glycymeris, as other Glycymerididae, has a deceptive valve orientation, which do not follow the classical rules: the larger adductor scar is the anterior one and not the posterior as usually happens in other bivalve groups (see Nicol & Jones 1984).

Glycymeris glycymeris (Linnaeus, 1758)

Pl. 1, figs 1, 2; Pl. 2, figs 1, 3

1758 *Arca glycymeris* Linnaeus, p. 695
1966 *Glycymeris glycymeris* (Linnaeus) – Tebble, p. 33, pl. 2, figs. a-c
1970 *Glycymeris glycymeris* (Linnaeus) – Buccheri, p. 256
1974 *Glycymeris glycymeris* (Linnaeus) – Parenzan, p. 47, pl. 5, fig. 40
1980 *Glycymeris (Glycymeris) glycymeris* (Linnaeus) – Anfossi & Brambilla, p. 58, pl. 5 (1), figs. 7a-c
1986 *Glycymeris (Glycymeris)* aff. *G. (G.) glycymeris* (Linnaeus) – Domènech, p. 135, figs. 4I-J (cum syn.)
1986 *Glycymeris glycymeris* (Linnaeus) – Riedl, p. 359, pl. 122
1988 *Glycymeris glycymeris* (Linnaeus) – Gomez-Alba, p. 168, pl. 83, fig. 11
1993 *Glycymeris (Glycymeris) glycymeris* (Linnaeus) – Lozano Francisco et al., p. 172, pl. 5, figs. 1,2.

Material: Six right valve: ACG14-12-22-24, ACG27bis-7, ACG243-1-2; twelve left valves: ACG14-1-2-3-4-5-11-13-23, ACG26-4, ACG27bis-8, ACG35-1, ACG241-1; one undetermined valve: ACG28-1.

Occurrence: AGC14, ACG26, ACG27bis, ACG28, ACG35, ACG241, ACG243, Arda River section, Castell'Arquato, Italy

Description. Large to medium sized biconvex shell, equivalve, slightly inequilateral with circular outline; shell substance thick; valves slightly inflated with low and not very prominent orthogyrate to slightly opisthogyrate umbo; dorso-ventral diameter nearly equal to antero-posterior one.

Ornamentation of both valves consisting of thin radial costellae, and irregular concentric growth lines; the latter pass to coarse growth lamellae in the postero-ventral part of the valve; ventral internal margin regularly fluted.

Interior of both valves with prionodont dentition with teeth relatively short, laterally V shaped, obsolescent in the central part and more evident laterally, determining a division in two part of the dentition; ligament area high, narrow, triangular and flat or slightly concave; external ligament amphidetic duplivincular well preserved.

Dimyarian anisomyarian and integripalliate shell; circular pallial line; anterior adductor muscle scar with triangular shape and larger than the posterior subcircular and suboval muscle scar; both adductor muscle scars are well impressed on a low myophoric platform; scars of radially directed fibers of muscle mantle along the pallial line.

Dimensions. See Figs 3 and 4.

Discussion. *Glycymeris glycymeris* has a circular outline and poorly inflated valves; for these characters it differs from *Glycymeris bimaculata* (Poli, 1795), *Glycymeris inflata* (Brocchi, 1814) and *Glycymeris insubrica* (Brocchi, 1814). Furthermore, the ligament area is slightly different from the other species of *Glycymeris*, because it is high but not laterally expanded.

Glycymeris glycymeris together with *Glycymeris inflata,* represents the larger species (Fig. 3) with a H/L ratio nearly equal 1 (Fig. 4), which allow to distinguish it from the other *Glycymeris* species.

Stratigraphic and geographic occurrence. *Glycymeris glycymeris* is known from the Miocene to the Recent from the Western Atlantic coast to the Mediterranean Sea (Marasti & Raffi 1980).

Glycymeris inflata (Brocchi, 1814)

Pl. 1, fig. 3; Pl. 2, figs 4, 5; Pl. 3, fig. 1

1814 *Arca inflata* Brocchi, p. 494, pl. 11, fig. 7
1877 *Pectunculus inflatus* (Brocchi) – Seguenza, p. 282-283
1879-1882 *Pectunculus insubricus* var. (Brocchi) – Fontannes, p. 175, pl. 11, fig. 3
1898 *Pectunculus inflatus* (Brocchi) – Almera & Bofill, p. 126
1898 *Axinea inflata* (Brocchi) – Sacco in Bellardi & Sacco, p. 32, pl. VIII, figs. 1-10 (cum syn.)
1907 *Pectunculus inflatus* (Brocchi) – Cerulli Irelli, p. 119, pl. 9, fig. 7; pl. 10, figs. 1, 9
1914? *Pectunculus (Axinaea) insubricus* (Brocchi) – Bongo, p. 475
1933 *Pectunculus (Axinea) inflatus* (Brocchi) – Boni, p. 146

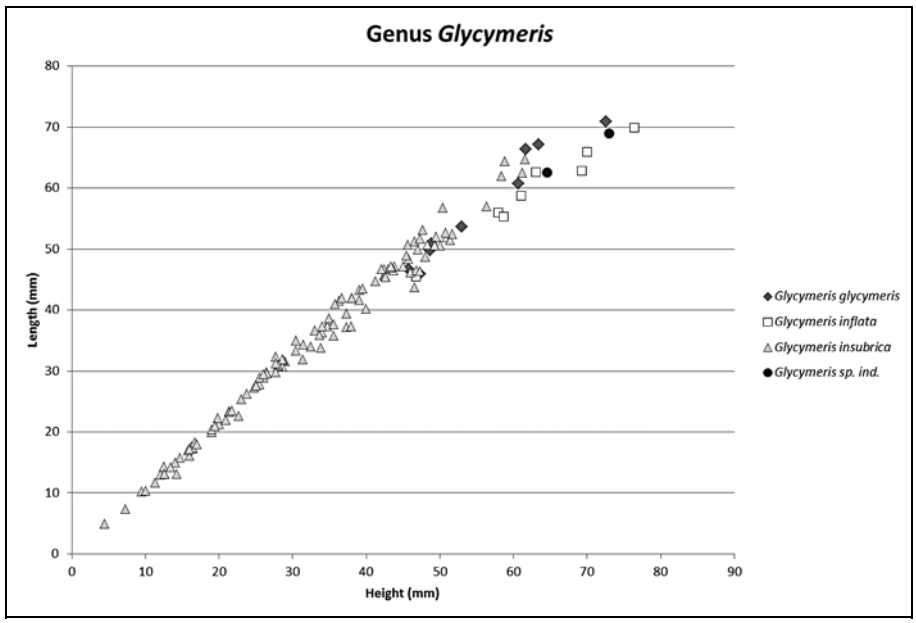

Fig. 3 - Height and length values of species of *Glycymeris*.

1935 *Pectunculus (Axinea) inflatus* (Brocchi) – Cowper Reed, p. 510

1937 *Pectunculus inflatus* (Brocchi) – Dubertret et al., p. 100

1938 *Pectunculus (Axinea) inflatus* (Brocchi) – Tavani, p. 147, pl. 5, fig. 2

1950 *Pectunculus (Axinea) inflatus* (Brocchi) – Festa, p. 96

1951 *Glycymeris inflata* (Brocchi) – Imbesi, p. 11

1951 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Rossi Ronchetti, p. 20, figs. 5a-f

1952 *Pectunculus inflatus* (Brocchi) – Lecointre, p. 61

1955 *Pectunculus (Axinea) inflatus* (Brocchi) – Malatesta & Nicosia, p. 176

1957 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Nicosia, p. 176

1957 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Malatesta, p. 22

1958 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Erunal Erentoz, p. 144, pl. 22, figs. 19,20

1962 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Papani & Pelosio, pp. 306, 316, pl. 2, fig. 12

1963 *Glycymeris (Glycymeris) inflata* (Brocchi) – Malatesta, p. 233, pl. XIII, fig. 3

1968 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Bonadonna, p. 286

1971 *Glycymeris (Glycymeris) inflata* (Brocchi) – Pesce & Rapetti, p. 124, pl. 1, fig. 3

1972 *Glycymeris (Glycymeris) inflata* (Brocchi) – Caprotti, p. 56, pl. 3, fig. 19

1973 *Glycymeris (Glycymeris) inflatus* (Brocchi) – Marasti, p. 100

1974 *Glycymeris (Glycymeris) inflata* (Brocchi) – Malatesta, p. 30, pl. 2, figs. 2a,b

1976 *Glycymeris inflata* (Brocchi) – Caprotti, p. 4, pl. 6, fig. 19

1980 *Glycymeris (Glycymeris) inflata* (Brocchi) – Anfossi & Brambilla, p. 58, pl. V(I), figs. 8a,b

1993 *Glycymeris (Glycymeris) inflata* (Brocchi) – Lozano Francisco et al., p. 174, pl. 5, figs. 5,6

Material: Three articulated specimens: ACG10-4, ACG14-25, ACG24-33; twelve right valves: ACG9-3, ACG14-14, ACG29bis-1-5-7-9-28-29-30-33-34-36; nine left valves: ACG9-4, ACG14-6, ACG29-bis-2-3-6-31-32-35-37.

Occurrence: ACG9, ACG10, ACG14, ACG24, ACG29bis, Arda river section, Castell'Arquato, Italy.

Description. Large sized, biconvex shell slightly inequivalve and inequilateral with subcircular, slightly elongated outline; shell substance thick; valves strongly inflated with prominent orthogyrate to slightly opisthogyrate umbo; dorso-ventral diameter larger than antero-posterior one. Both valves show a ridge in their posterior part, extending from the umbo to the ventral margin and forming an obtuse angle in the shell outline.

Ornamentation of both valves consisting of very fine, regular and dense radial costellae and in numerous concentric growth lines; the latter become growth lamellae irregularly spaced in the postero-ventral part of the valve; ventral interior margin regularly fluted.

Interior of both valves with prionodont dentition with teeth relatively short, laterally V shaped, becoming obsolescent or vertically directed in the middle part; ligament area high, laterally expanded, triangular and flat or slightly concave; external ligament amphidetic duplivincular well preserved.

Dimyarian anisomyarian and integripalliate shell; circular pallial line; anterior adductor muscle scar with triangular shape and slightly larger than the posterior subcircular to suboval muscle scar; both adductor muscle scars are well impressed on a myophoric platform (the posterior one is more elevated); scars of radially directed fibers of muscle mantle along the pallial line. Posterior pedal retractor scar with a small calcified platform.

Dimensions. See Figs 3 and 4.

Discussion. *Glycymeris inflata* mainly differs from *Glycymeris bimaculata* (Poli, 1795), *Glycymeris glycymeris* (Linnaeus, 1758) and *Glycymeris insubrica*

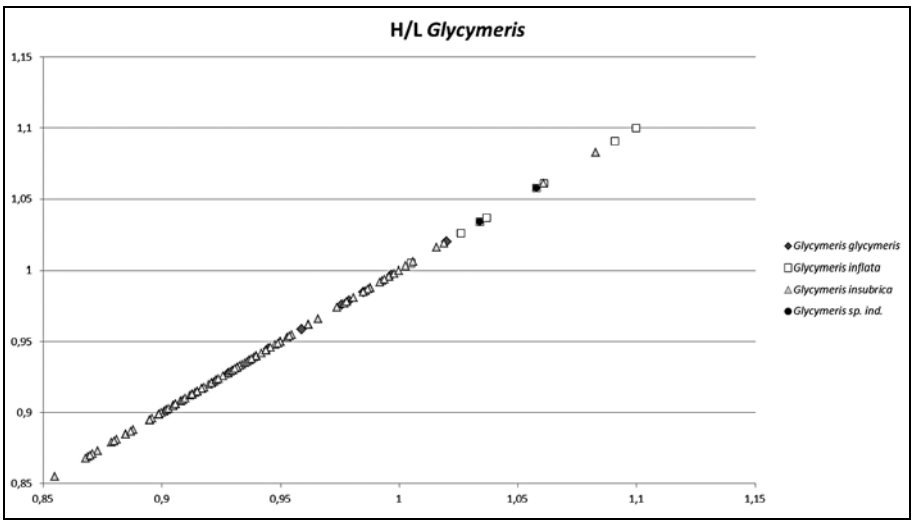

Fig. 4 - Height/length ratio of species of *Glycymeris.*

(Brocchi, 1814) for its more elongated outline and for its peculiar ridge in the posterior part of the valve, which defines an obtuse angle in the shell outline. The height/length ratio is always higher than 1. Furthermore it differs from *Glycymeris glycymeris* (Linnaeus, 1758) because it is strongly inflated and from *Glycymeris insubrica* (Brocchi, 1814) because it is larger and it has a weaker radial ornamentation.

Glycymeris inflata together with *Glycymeris glycymeris*, represents the larger species (Fig. 3) with a H/L ratio higher than 1 (Fig. 4), which allow to distinguish it from the other *Glycymeris* species.

Stratigraphic and geographic occurrence. *Glycymeris inflata* is a species known from the Miocene to the Pleistocene (Marasti & Raffi 1980) of the Mediterranean Sea. Its recent occurrence (Altaba et al. 2006) is still debated.

Glycymeris insubrica (Brocchi, 1814)

Pl. 1, fig. 4; Pl. 2, fig. 2; Pl. 3, figs 2-7

1758 *Arca nummaria* Linnaeus, p. 695
1805 *Pectunculus cor* Lamarck, p. 217
1814 *Arca insubrica* Brocchi, p. 492, pl. XI, figs. 10a, b
1819 *Pectunculus violacescens* Lamarck, p. 52
1825 *Pectunculus insubricus* (Brocchi) – Borson, p. 124
1826 *Pectunculus insubricus* (Brocchi) – Risso, p. 318
1831 *Pectunculus insubricus* (Risso) – Bronn, p. 108
1837 *Pectunculus insubricus* (Brocchi) – Goldfuss, p. 161
1868 *Pectunculus insubricus* (Brocchi) – Mayer, p. 44-46
1873 *Pectunculus violacescens* (Lamarck) – Cocconi, p. 126
1878 *Pectunculus insubricus* (Brocchi) – Parona, p. 91
1879 *Pectunculus nummarius* (Linnaeus) – Jeffreys, p. 32
1886 *Pectunculus insubricus* (Brocchi) – Verri, p. 442
1895 *Pectunculus violacescens* (Lamarck) – Arduini, p. 50
1898 *Pectunculus insubricus* (Brocchi) – Almera & Bofill, p. 126
1898 *Axinea insubrica* and var. (Brocchi) – Sacco in Bellardi & Sacco, p. 33, pl. 8, figs. 11-21
1907 *Pectunculus (Axinea) insubricus* (Brocchi) – Cerulli Irelli, p. 121, pl. XI, fig. lb, 2.
1915 *Pectunculus insubricus* (Brocchi) – Dalloni, p. 453

PLATE 1

All specimens are x1; a) external view, b) internal view, except when indicated.
1a-b - *Glycymeris glycymeris*, left valve (ACG14-3); 2a-b - *Glycymeris glycymeris*, right valve (ACG14-22); 3a-b- *Glycymeris inflata*, right a) and left b) valves of an articulated specimen (ACG24-33); 4a-b- *Glycymeris insubrica*, right valve (ACG97-10).

PLATE 2

All specimens are x1; a) external view, b) internal view.
1a-b- *Glycymeris glycymeris*, right valve (ACG27bis-7); 2a-b- *Glycymeris insubrica*, left valve. Note the well preserved color pattern (ACG197-5); 3a-b- *Glycymeris glycymeris,* right valve (ACG243-1); 4a-b- *Glycymeris inflata*, right valve (ACG29bis-7); 5a-b- *Glycymeris inflata*, right valve (ACG29bis-28).

PLATE 3

All specimens are x1; a) external view, b) internal view.
1a-b- *Glycymeris inflata*, left valve (ACG29bis-32); 2a-b- *Glycymeris insubrica*, left valve (ACG204-3); 3a-b- *Glycymeris insubrica*, right valve (ACG264-4); 4a-b- *Glycymeris insubrica*, left valve. Note the well preserved external ligament (ACG259-1); 5a-b- *Glycymeris insubrica*, left valve (ACG94-6); 6a-b- *Glycymeris insubrica*, left valve (ACG204-4); 7a-b- *Glycymeris insubrica*, right valve (ACG197-4).

PLATE 4

All specimens are x1; a) external view, b) internal view.
1a-b - *Aequipecten opercularis,* right valve (ACG197-6); 2a-b - *Aequipecten opercularis*, right valve (ACG222-1); 3a-b - *Aequipecten opercularis*, right valve (ACG97-8); 4a-b - *Arctica islandica*, right valve (ACG215-8); 5a-b - *Aequipecten opercularis*, right valve (ACG198-2); 6a-b - *Aequipecten opercularis*, left valve (ACG239-2); 7a-b - *Aequipecten opercularis*, right valve (ACG104-2).

PLATE 5

All specimens are x1; a) external view, b) internal view.
1a-b - *Aequipecten opercularis*, left valve (ACG194-5); 2a-b - *Aequipecten scabrella*, left valve (ACG4-2); 3a-b - *Aequipecten scabrella*, right valve (ACG4-9); 4a-b - *Aequipecten scabrella*, right valve (ACG4-5); 5a-b - *Arctica islandica*, left valve (ACG254-6); 6a-b - *Arctica islandica*, left valve (ACG253-2).

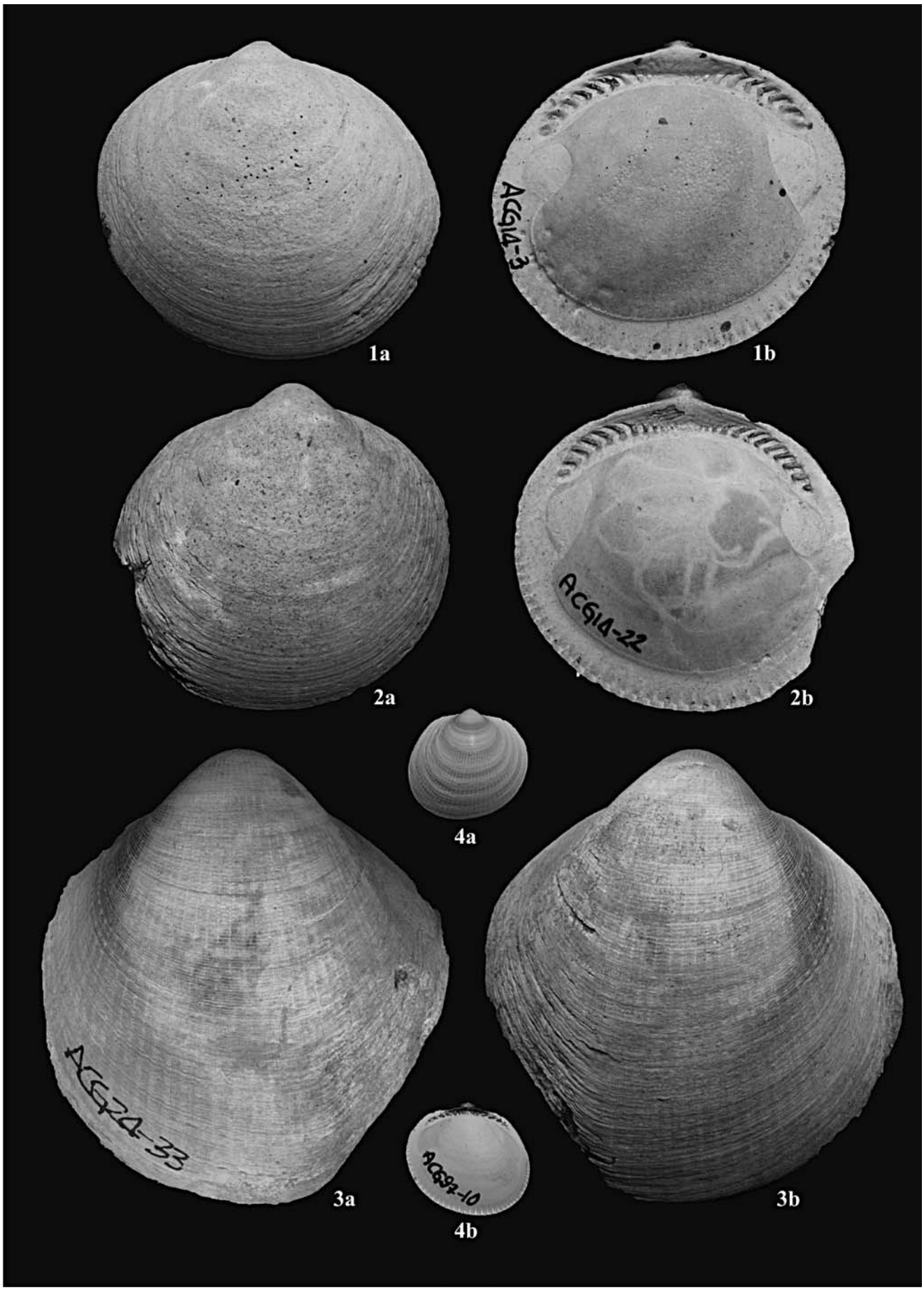

PLATE 1

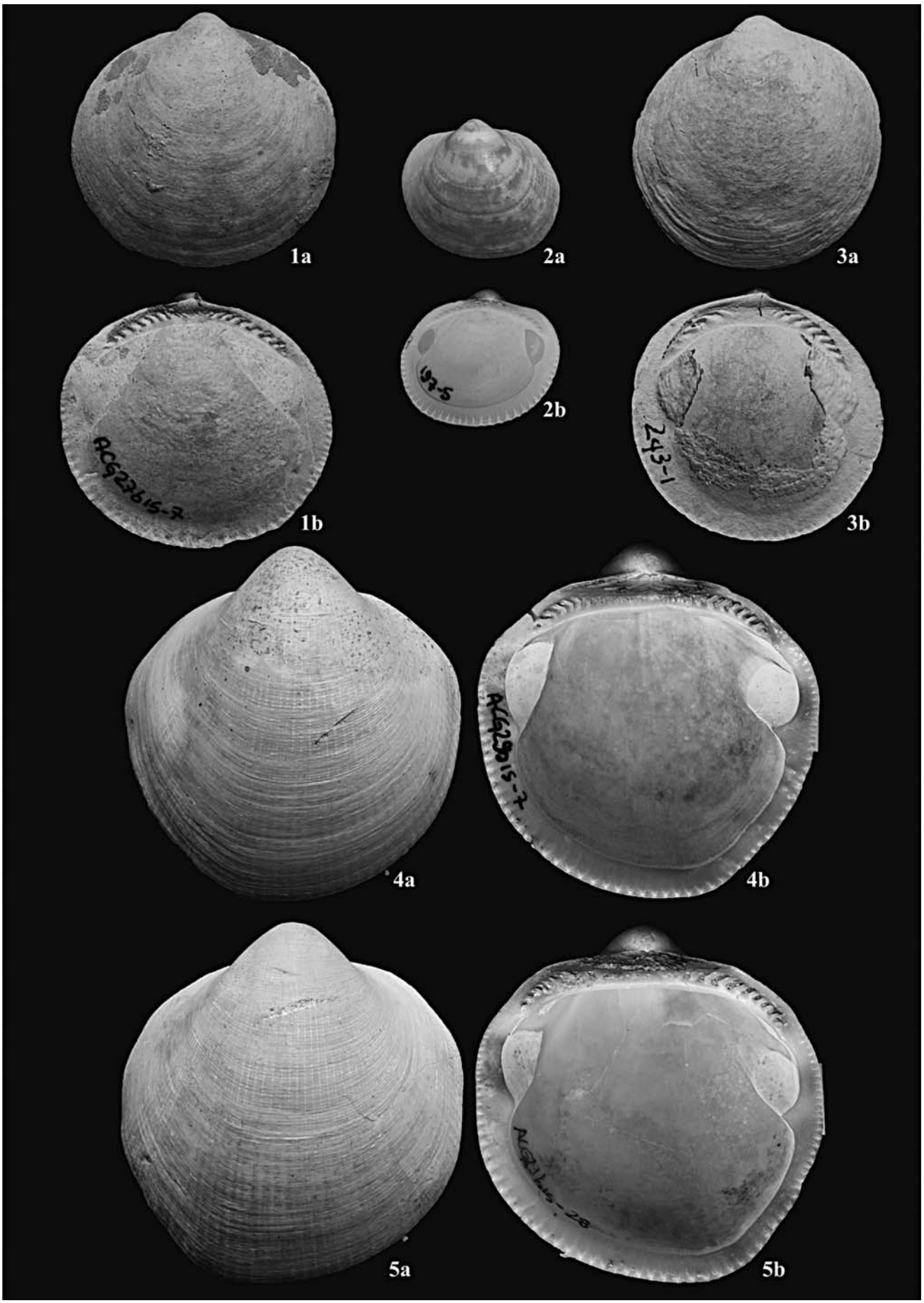

PLATE 2

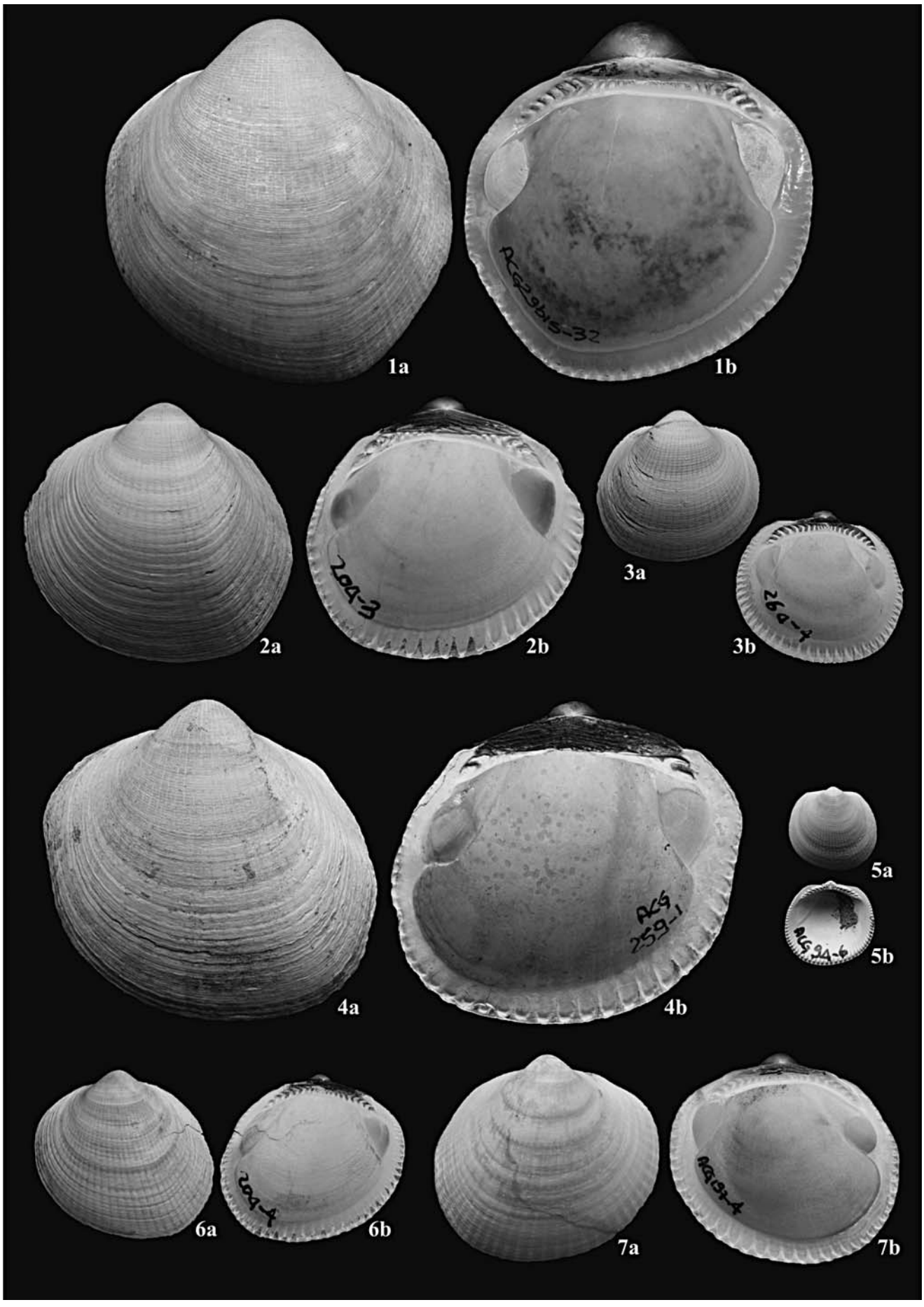

PLATE 3

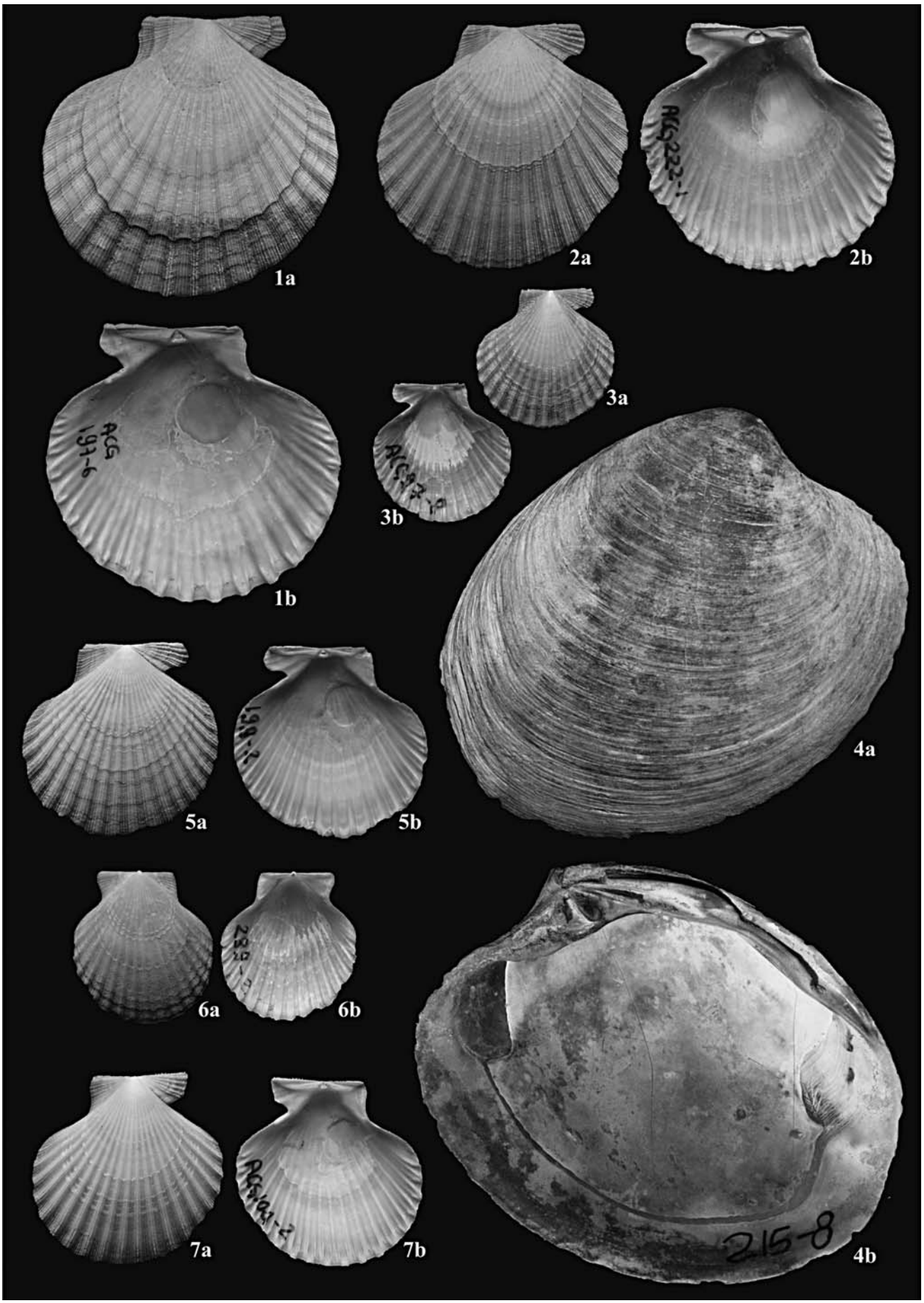

PLATE 4

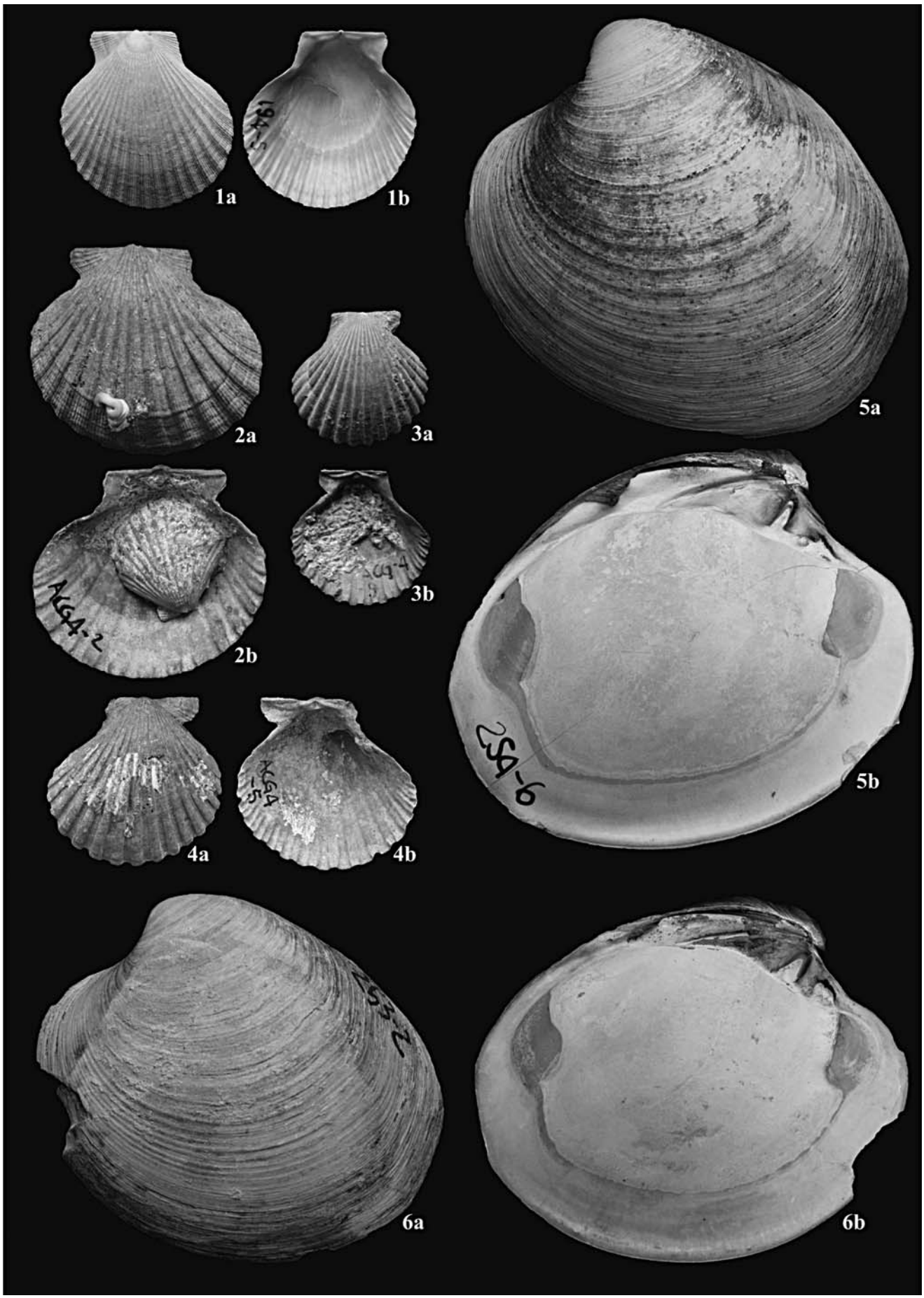

PLATE 5

1949a *Glycymeris insubricus* (Brocchi) – Ruggieri, p. 27
1949b *Glycymeris insubricus* (Brocchi) – Ruggieri, p. 69
1950 *Pectunculus (Axinea) insubricus* (Brocchi) – Festa, p. 96
1951 *Glycymeris (Glycymeris) insubricus* (Brocchi) – Rossi Ronchetti, p. 22, figs. 6a-f
1951 *Glycymeris violacescens* (Lamarck) – Imbesi, p. 129
1952 *Pectunculus violacescens* (Lamarck) – Lecointre, p. 62
1957a *Glycymeris insubricus* (Brocchi) – Ruggieri, p. 31
1957b *Pectunculus insubricus* (Brocchi) – Ruggieri, p. 6
1962 *Glycymeris insubricus* (Brocchi) – Papani & Pelosio, p. 16
1964 *Glycymeris (Glycymeris) cor* (Lamarck) – Erunal Erentoz & Oztemur, p. 262
1967 *Glycymeris (Glycymeris) cor* (Lamarck) – Conato et al., p. 261
1971 *Glycymeris (Glycymeris) cor* (Lamarck) – Pesce & Rapetti, p. 122, pl. 1, fig. 2
1974 *Glycymeris (Glycymeris) violacescens* (Lamarck) – Malatesta, p. 31, pl. 2, figs. 1a-c
1974 *Glycymeris violacescens* (Lamarck) – Parenzan, p. 50, pl. 6, fig. 43
1980 *Glycymeris (Glycymeris) insubrica* (Brocchi) – Marasti & Raffi, p. 8
1982 *Glycymeris (Glycymeris) insubrica* (Brocchi) – Benigni & Corselli, p. 675
1982 *Glycymeris (Glycymeris) insubricus* (Brocchi) – Andrés, p. 118, pl. 2, figs. 1-4
1982 *Glycymeris (s.s.)* aff. *violacescens* (Lamarck) – Martinell & Domènech, p. 382
1983 *Glycymeris (Glycymeris)* aff. *insubrica* (Brocchi) – Domènech, p. 93, pl. 3, figs. 1-3, 7, 8
1986 *Glycymeris (Glycymeris)* aff. *G. (G.) insubrica* (Brocchi) – Domènech, p. 137, figs. 4K-L
1988 *Glycymeris insubrica* (Brocchi) – Gomez-Alba, p. 170, pl. 84, fig. 4
1989 *Glycymeris (Glycymeris) insubrica* (Brocchi) – Andrés, p. 336, pl. 2, figs. 1-4 (cum syn.)
1992 *Glycymeris insubrica* (Brocchi) – Cossignani et al., p. 31, fig. 268
1993 *Glycymeris (Glycymeris) insubrica* (Brocchi) – Lozano Francisco et al., pl. 1, figs. 9-10

Material: Forty articulated specimen: ACG29-2, ACG46-1-2-3, ACG49-2-3, ACG91-3-10, ACG94-13; ACG97bis-1, ACG197-1-2, ACG198-5-6, ACG200-6-7, ACG202-1, ACG204-1-2, ACG210-1, ACG252-2, ACG256-1-2-3-4, ACG256bis-1-2, ACG258-1-2, ACG259-4, ACG261-1-2, ACG261bis-1-2-3, ACG262-1-2-3, ACG263-1-4; sixty-three right valves: ACG29bis-4-8-10-13, ACG30-5, ACG31-1, ACG42-2, ACG42bis-2, ACG43-1, ACG45-2, ACG60-1, ACG66-1-2-5, ACG89-1-2-3, ACG90-3, ACG91-2-5, ACG92-1-2, ACG93-3-4-5-6-7, ACG94-1-4, ACG95-1-2, ACG96-3-4, ACG97-2-3-5-10, ACG98-1-2, ACG99-1, ACG197-4, ACG198-3, ACG200-15; ACG201-4, ACG204-7; ACG215-4, ACG252-1-6, ACG255-1, ACG257-1, ACG258-3-4, ACG259-2, ACG260-2, ACG262-4-5, ACG263-2, ACG264-1-2-4-5, ACG267-1-2; sixty-four left valves: ACG9-2, ACG13-2, ACG29bis-12-14-17-19, ACG45-1, ACG49-1, ACG53-16, ACG59-1, ACG66-3-4-6, ACG68-1, ACG83-1, ACG90-1-2-4-12, ACG91-1-4, ACG92-3, ACG93-1-2-13, ACG94-2-3-5-6, ACG96-1-2, ACG97-1-4-9-11-12, ACG98-3, ACG197-5-11, ACG199-1-2, ACG203-1-2-3, ACG204-3-4-5-6, ACG205-1-2-3, ACG206-1, ACG211-1, ACG252-3-4, ACG257-2, ACG259-1-3-5, ACG260-1, ACG263-5, ACG264-3, ACG266-1, ACG267-3.

Occurrence: ACG9, ACG13, ACG29, ACG29bis, ACG30, ACG31, ACG42, ACG42bis, ACG43, ACG45, ACG46, ACG49, ACG53, ACG59, ACG60, ACG66, ACG68, ACG83, ACG89, ACG90, ACG91, ACG92, ACG93, ACG94, ACG95, ACG96, ACG97, ACG97bis, ACG98, ACG99, ACG197, ACG198, ACG199, ACG200, ACG201, ACG202, ACG203, ACG204, ACG205, ACG206, ACG210, ACG211, ACG215, ACG252, ACG255, ACG256, ACG256bis, ACG257, ACG258, ACG259, ACG260, ACG261, ACG261bis, ACG262, ACG263, ACG264, ACG266, ACG267, Arda river section, Castell'Arquato, Italy.

Description. Medium sized, biconvex shell, nearly equivalve, slightly inequilateral with transverse, subquadrate to subrectangular outline; shell substance not so thick; some specimens have a rounded anterior margin and a straight posterior one; valves inflated with orthogyrate to slightly opisthogyrate umbo.

Ornamentation of both valves consisting of fine, regular and dense radial costellae, numbering 1-3 in 5 mm at the ventral margin in adult specimens; radial ornamentation more marked than concentric one; concentric and very thin growth lines, which in some specimens become more pronounced in the ventral part where they form coarse lamellae; ventral interior margin regularly fluted. In some juvenile specimens and in the juvenile region of the adult specimens the violet color ornamentation is preserved with concentric variations of tone and reddish mottles.

Interior of both valves with prionodont dentition with teeth relatively short, laterally V shaped, becoming obsolescent or vertically directed medially; ligament area laterally expanded but low, triangular, flat or slightly concave; external ligament amphidetic duplivincular.

Dimyarian anisomyarian and integripalliate shell; circular pallial line; anterior adductor muscle scar with triangular shape, slightly larger than the posterior subcircular to suboval muscle scar; both adductor muscle scars are well impressed on a myophoric platform; scars of radially directed fibers of muscle mantle along the pallial line. Subrhomboidal posterior pedal retractor scar.

Dimensions. See Figs 3 and 4.

Discussion. *Glycymeris insubrica* has a great intraspecific variability; according to Andrés (1989) two forms can be distinguish: the first, called "*insubrica*", corresponds to that described by Brocchi (1814), whereas the second, called "*violacescens*", corresponds to that described by Lamarck (1819); these two forms differs mainly for the outline, more quadrangular, regular and equilateral in the "*violacescens*" form. *Glycymeris violacescens* and *Glycymeris insubrica* are now considered synonym; *G. violacescens* is usually used to identify the Recent specimens, whereas *G. insubrica* is for fossil ones.

According to several authors (from Sacco in Bellardi & Sacco 1898 to Sirna 1978), in addition to *Glycymeris violacescens* (Lamarck, 1819), other synonyms of *G. insubrica* are *Glycymeris cor* (Lamarck, 1805) and *Glycymeris nummaria* (Linnaeus, 1758). *Glycymeris nummaria* is considered a *nomen oblitum* by Sirna

(1978), although WoRMS considers this specific name as the valid one. *Glycymeris cor* has been invalidated because of the inadequate description given for it by Lamarck (1805). For these reasons, we have determined the specimens under exam as *Glycymeris insubrica* (Brocchi, 1814).

In general, *Glycymeris insubrica* has a medium sized shell, a subquadrate to subrectangular outline, a pronounced radial ornamentation and a low ligament area; for these characters it differs from *Glycymeris inflata* (Brocchi, 1814), from *Glycymeris bimaculata* (Poli, 1795) and from *Glycymeris glycymeris* (Linnaeus, 1758).

Looking at the graph in fig. 3 *Glycymeris insubrica* is the species with the smallest size but it also represents the species with the higher number of specimens; among these specimens juvenile forms may occur, which thus lower the measurements; despite that, the majority of the specimens remains of smaller size than other *Glycymeris* species. *G. insubrica* has a H/L ratio smaller than 1, which allow to distinguish it from other *Glycymeris* species (Fig. 4).

Stratigraphic and geographic occurrence. *Glycymeris insubrica* is known from the Early Miocene to the Recent from the Atlantic Ocean to the Mediterranean Sea (Marasti & Raffi 1980).

Glycymeris sp. ind.

Material: Two right valves: ACG14-7, ACG24-4; one left valve: ACG76-25.

Occurrence: ACG14, ACG24, ACG76, Arda river section, Castell'Arquato, Italy

Description. Large sized, biconvex shell, equivalve, equilateral with subcircular to subquadrate outline; shell substance very thick; valves inflated with orthogyrate to slightly opisthogyrate umbo.

Ornamentation consisting of very fine and regularly arranged radial costellae and concentric growth lines; the latter in the ventral part of the valve become dense and coarse growth lamellae; this produces a clear division of the valve in two parts: 1) the juvenile-adult dorso-median part characterized by thin growth lines and 2) the oldest ventral part with coarse growth lamellae; ventral interior margin regularly fluted.

Interior of valve with prionodont dentition with coarse teeth, curved, lacking medially; ligament area high, laterally expanded, triangular and flat; external ligament amphidetic duplivincular.

Dimyarian anisomyarian and integripalliate shell; circular pallial line; anterior adductor muscle scar with triangular shape and larger than the posterior subcircular one; both adductor muscle scars are well impressed on a myophoric platform; scars of radially directed fibers of muscle mantle along the pallial line.

Dimensions. See Figs 3 and 4.

Discussion. These specimens have intermediate characters among the above described species: they have a H/L ratio higher than 1 as *Glycymeris inflata* (Fig. 4), a subcircular outline as *Glycymeris glycymeris* and a thick shell with strong teeth as *Glycymeris bimaculata* (Poli, 1795). At the same time they differ from specimens of *Glycymeris inflata* because they lack the characteristic angle in the anterior valve outline and from *Glycymeris glycymeris* because they are more inflated and have a more prominent umbo. *Glycymeris bimaculata* is the most similar species even if the Arda specimens do not attain the large size typical of the representatives of this species; furthermore, they are not well preserved so a specific assignment is difficult.

Glycymeris sp. ind. is similar in size to *G. inflata* and *G. glycymeris* (see Fig. 3), presuming the affinity with one of these two species; however, as observed in the systematic description, the external and internal characters of *Glycymeris* sp. ind. are different from *G. inflata* and *G. glycymeris*, promoting the fact that it is a distinct species, although the preservation conditions do not allow a more accurate assignment.

Order **Pectinoida** Adams & Adams, 1857
Superfamily Pectinoidea Rafinesque, 1815
Family Pectinidae Rafinesque, 1815
Subfamily Aequipectininae Nordsieck, 1969

Genus *Aequipecten* Fischer, 1886

Type-species: *Ostrea opercularis* Linnaeus, 1758 from the Recent of France.

Remarks. Similar to *Chlamys* Roding, 1798, but it differs by its more rounded outline, nearly equal auricles, shallower byssal notch, and fewer, usually not bifurcating radial ribs.

Aequipecten opercularis (Linnaeus, 1758)

Pl. 4, figs 1-3, 5-7; Pl. 5, fig. 1

1758 *Ostrea opercularis* Linnaeus, p. 698
1873 *Pecten opercularis* (Linnaeus) – Cocconi, p. 385
1884 *Pecten opercularis* (Linnaeus) – Meli, p.12
1898 *Pecten opercularis* (Linnaeus) – Almera & Bofill, p. 112
1902 *Pecten opercularis* (Linnaeus) – De Stefani, p. 5
1906 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Ugolini, p. 163
1907 *Chlamys (Aequipecten) scabrella* (Lamarck) – Cerulli Irelli, p. 92, pl. 5, figs. 17, 18
1910 *Aequipecten opercularis* (Linnaeus) – Schaffer, p. 36, pl. 16, figs. 11-15
1962 *Chlamys opercularis* (Linnaeus) – Boni & Sacchi Vialli, p. 109, pl. 12, figs. 4, 6; pl. 13, fig. 17; pl. 14, fig. 10
1962 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Papani & Pelosio, p. 15

1965 *Lyropecten (Aequipecten) opercularis* (Linnaeus) – Glibert & Van de Poel, p. 26

1966 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Tebble, p. 60, pl. 5, fig. b,d

1968 *Aequipecten (Aequipecten) opercularis* (Linnaeus) – Bonadonna, p. 282

1969 *Aequipecten opercularis* (Linnaeus) – Waller, pl. 1, figs. 5, 7-10

1969 *Aequipecten opercularis* (Linnaeus) – Nordsieck, p. 49, pl. VII, fig. 32.00

1970 *Lyropecten (Aequipecten) opercularis* (Linnaeus) – Buccheri, p. 256

1970 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Raffi, p. 110

1971 *Aequipecten (Aequipecten) opercularis* (Linnaeus) – Pesce & Rapetti, p. 126, pl. 2, fig. 2 (cum syn.)

1972 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Caprotti, p. 58, pl. 1, fig. 5

1974 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Malatesta, p. 45, pl. 3, figs. 3a,b

1976 *Chlamys opercularis* (Linnaeus) – Caprotti, pl. 4, fig. 5

1986 *Chlamys (Aequipecten) opercularis* (Linnaeus) – Faraone, p. 42, figs. 7-14

2009 *Aequipecten opercularis* (Linnaeus) – Jimenez et al., p. 7, figs. 3c-e

Material: Two articulated specimens: ACG132-4, ACG133-1; 261 right valves: ACG2-2-3-4, ACG4-10-13, ACG6-5, ACG9-6, ACG11-1, ACG12-5, ACG13-3-8, ACG14-15, ACG24-7-14, ACG25-2-3-7-8-14-18, ACG26-1-2-3-6-8, ACG27-6, ACG27bis-3-5-6, ACG30-1-7-8, ACG32-1-2, ACG34-3, ACG37-8, ACG41-1-3-4-5-6-7-9-10-12-13-15-16-24-25-26-27-29, ACG41bis-2-3-4-5-6, ACG42-1-3-4-5-6-7-8-9-10-13-14-18-19-20-21-22-23, ACG42bis-1-5-6-7-8-10-11-14-16-17-20-23, ACG43-3, ACG44-1-2, ACG51bis-1-2-3-4-6-7-8-10, ACG52-1B, ACG53-1-3-6-7-8-9-10-11-12-14, ACG54-1-4-5, ACG55-1, ACG56-5, ACG57-2-3-4, ACG59-2-3-5-6-8, ACG60-2-3-5, ACG66-12-13, ACG68-2, ACG70-1-3, ACG76-4-5-6-7-8-9-10-11-12-13-18-20-21, ACG77-1, ACG80-1-2-3, ACG81-1-2-3, ACG82-2, ACG83-2-3, ACG84-1-2-3-4-5-6-7, ACG85-1, ACG89-6-8, ACG90-6-10, ACG91-1-2-3-8,, ACG92-4-8, ACG93-8-10-11, ACG94-10, ACG97-7-8; ACG100-1-2-4, ACG101-1-2, ACG102-3, ACG103-1-2-3, ACG104-1-2-3, ACG105-1, ACG116-1, ACG132-1-3, ACG194-2-4-6-7, ACG195-1-3-5-7, ACG197-6-7-9-10, ACG198-2-3-4, ACG199-3, ACG200-1-3-4-5, ACG200bis-1-2, ACG201-1-2-3, ACG207-1-3-4, ACG208-2-3-4, ACG215-1-2-3, ACG217-1-2-6, ACG220-4-5, ACG222-1-2-3-6, ACG223-2-3-4-5, ACG235-2-3-5, ACG236-1-3-4-6, ACG237-1-4, ACG238-1-2, ACG239-1-3-4, ACG240-1-2-3, ACG243-4, ACG252-5, ACG253-1, ACG255-2; 150 left valves: ACG6-6, ACG12-1, ACG13-4-10, ACG25-4-5-6-13-20, ACG26-5-7, ACG27-7, ACG27bis-1-2-4, ACG29bis-16-18, ACG30-2, ACG31-2, ACG33-1-2, ACG34-1-2, ACG37-8, ACG41-2-8-11-14-22-23-31, ACG41bis-1, ACG42-11-15-16-17, ACG42bis-3-4-9-12-13-15, ACG44-3, ACG50-1, ACG51-1-2-3-4, ACG51bis-5-9-11-12, ACG52-1A, ACG53-5-13-15, ACG55-2-3, ACG56-1-2-4-10, ACG57-1, ACG59-4-7, ACG60-4-6, ACG61-1, ACG66-7-8-9-10, ACG70-2, ACG76-14-15-16-17-18, ACG82-1-5, ACG89-4-5-7-9-10, ACG90-7-8-11-14-20, ACG91-6-7-9, ACG92-5-6-7, ACG93-9, ACG94-7-8-9, ACG97-6, ACG101-3-4, ACG102-1-2, ACG103-4-5-6, ACG104-4-5, ACG132-2, ACG133-2-3-4, ACG194-1-3-5, ACG195-2-4-6, ACG196-1, ACG197-8-11, ACG198-1-7, ACG199-4-5, ACG200-2, ACG202-2, ACG207-2, ACG208-1, ACG209-1-2, ACG212-1, ACG213-1, ACG213bis-1, ACG217-3, ACG222-4, ACG223-1, ACG235-1-4, ACG236-2-5-6, ACG237-2-3, ACG238-3-4-5, ACG239-2, ACG243-3; One undetermined valve: ACG196-2.

Occurrence: ACG2, ACG4, ACG6, ACG9, ACG11, ACG12, ACG13, ACG14, ACG24, ACG25, ACG26, ACG27, ACG27bis, ACG29bis, ACG30, ACG31, ACG32, ACG33, ACG34, ACG37, ACG41, ACG41bis, ACG42, ACG42bis, ACG43, ACG44, ACG50, ACG51, ACG51bis, ACG52, ACG53, ACG54, ACG55, ACG56, ACG57, ACG59, ACG60, ACG61, ACG66, ACG68, ACG70, ACG76, ACG77, ACG80, ACG81, ACG82, ACG83, ACG84, ACG85, ACG89, ACG90, ACG91, ACG92, ACG93, ACG94, ACG97; ACG100, ACG101, ACG102, ACG103, ACG104, ACG105, ACG116, ACG132, ACG133, ACG194, ACG195, ACG196, ACG197, ACG198, ACG199, ACG200, ACG200bis, ACG201, ACG202, ACG207, ACG208, ACG209, ACG212, ACG213, ACG213bis, ACG215, ACG217, ACG220, ACG222, ACG223, ACG235, ACG236, ACG237, ACG238, ACG239, ACG240, ACG243, ACG252, ACG253, ACG255, Arda river section, Castell'Arquato, Italy

Description. Medium sized biconvex shell, inequivalve with orthogyrate, convex umbo; circular outline with height/length ratio nearly equal to 1. Right valve equilateral with slightly curved cardinal margin; anterior and posterior auricles very different in size and shape: the anterior one is large, subrectangular with a deep byssal notch; the posterior one is smaller and with a triangular outline. Left valve slightly inequilateral, more convex than the right valve, with the dorsal region representing the great convexity; posterior part more developed than the anterior one; cardinal margin straight; anterior and posterior auricles nearly similar in size, the anterior is slightly larger than the posterior one and has a shallow byssal notch.

Ornamentation of both valves consisting of 16-21 radial costae, coarser in some specimens, flatter in others; costae subquadrangular to subrounded in section, nearly of the same width of the interspaces; some specimens show a secondary ornamentation on the costae, consisting in 1-2 thinner costae; growth lines thin and dense, more evident in the costal interspaces; in some specimens growth lines are coarser and impart a lamellose pattern. Auricles ornamented by thin costae and growth lines; anterior auricle of the right valve ornamented by coarser costae and by very dense growth lines in a triangular zone in correspondence of the byssal notch; ctenolium present. Valve interior reflects the external ornamentation.

Interior of both valves with a triangular resilium pit. Monomyarian shell, well marked muscle scar; the rounded and larger muscle scar represents the attachment of the striated muscle, and the beanlike muscle scar represents the attachment of the smooth muscle.

Dimensions. See Fig. 5.

Discussion. *Aequipecten opercularis* is a very common species in the Arda River succession. According to Jimenez et al. (2009) this species is similar to *A. scabrella* (Lamarck, 1819); they differ as *A. opercularis* has a less curved umbo and a circular and more regular outline than *A. scabrella*, which is very asymmetric (the antero-posterior diameter is larger than the dorso-ven-

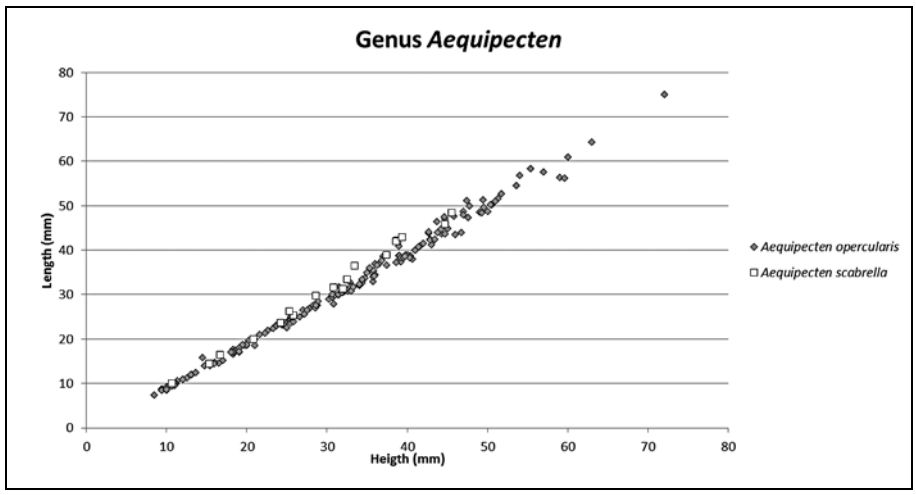

Fig. 5 - Height and length values of species of *Aequipecten.*

tral one); furthermore *A. scabrella* has coarser and fewer costae and more convex valves. Probably these two species had a common origin in the Miocene as in this time interval they are difficult to distinguish one from the other (Malatesta, 1974).

Aequipecten angelonii (De Stefani & Pantanelli, 1878) is also similar to *A. opercularis*, mainly in the juvenile stages. In adulthood, representatives of the two species differ since the shell of *A. angelonii* is thicker, the auricles are less developed, the radial ribs have a very characteristic triangular section, and it has spines.

Between the two species of *Aequipecten* (Fig. 5) we do not observe particular trend as in *Glycymeris* (Fig. 3). In fact *A. scabrella* and *A. opercularis* show similar size and in both cases height and length are nearly equal (H/L ratio equal 1) indicating a subcircular outline.

Stratigraphic and geographic occurrence. *Aequipecten opercularis* is known from the Miocene to the Recent of the Atlantic Ocean and the Mediterranean Sea (Marasti & Raffi 1980).

Aequipecten scabrella (Lamarck, 1819)

Pl. 5 figs 2-4

1819 *Pecten seniensis* Lamarck, p.182
1819 *Pecten scabrellus* Lamarck, p. 183
1879 *Pecten scabrellus* (Lamarck) – Meli, p. 5, 6
1879-1882 *Pecten scabrellus* (Lamarck) – Fontannes, p. 187, pl. 12, figs. 2, 3
1898 *Pecten scabrellus* (Lamarck) – Almera & Bofill, p. 111
1902 *Pecten scabrellus* (Lamarck) – De Stefani, p. 5
1906 *Aequipecten scabrellus* (Lamarck) – Ugolini, p. 167
1913 *Chlamys scabrellus* (Lamarck) – Gignoux, p. 369
1914 *Chlamys (Aequipecten) scabrellus* (Lamarck) – Bongo, p. 472
1933 *Chlamys (Aequipecten) seniensis* (Lamarck) – Venzo, p. 81, pl. 7, figs. 18, 21; p. 82
1936 *Pecten (Aequipecten) seniensis* (Lamarck) – Friedberg, pl. II, figs. 37-3
1940 *Chlamys scabrella* (Lamarck) – Roger, p. 332, 342
1950 *Chlamys (Aequipecten) scabrella* (Lamarck) – Festa, p. 94
1952 *Chlamys scabrella* (Lamarck) – Lecointre, p. 55
1955 *Chlamys (Aequipecten) scabrella* (Lamarck) – Moroni, p. 130
1958 *Chlamys scabrella* (Lamarck) – Erunal Erentoz, p. 149, pl. 24, figs. 3, 4
1959 *Chlamys (Aequipecten) seniensis* (Lamarck) – Anderson, p. 98, pl. XIV, figs. 8a, b
1963 *Chlamys scabrella* (Lamarck) – Venzo & Pelosio, p. 148, pl. 47, fig. 2
1966 *Aequipecten (Aequipecten) seniensis* (Lamarck) – Compagnoni, p. 168, pl. 1, figs. 2a,b
1970 *Chlamys (Aequipecten) scabrella* (Lamarck) – Raffi, p. 114, pl. 27, figs. 1,2; pl. 29, figs. 2a,b (cum syn.)
1972 *Chlamys (Argopecten) seniensis* (Lamarck) – Caprotti, p. 59, pl. 1, fig. 3
1974 *Chlamys (Aequipecten) seniensis* (Lamarck) – Malatesta, p. 47, pl. 3, figs. 6a,b
1976 *Chlamys (Aequipecten) seniensis* (Lamarck) – Caprotti, pl. 4, fig. 3
1986 *Chlamys (Aequipecten) scabrella* (Lamarck) – Faraone, p. 14, fig. 15
2009 *Aequipecten scabrella* (Lamarck) – Jimenez et al., p. 7, figs. 3f-i, 4a,b

Material: Twenty-two right valves: ACG1-1, ACG2-5, ACG3-4-5-6-7, ACG4-3-5-6-7-8-9-11-15, ACG5-3-4, ACG6-2, ACG8-2, ACG12-4, ACG13-11, ACG33-4,? ACG66-11; thirteen left valves: ACG1-2, ACG2-6, ACG3-3, ACG4-2-4-12, ACG5-2, ACG6-4-8, ACG12-2-3-6, ACG13-5.

Occurrence: ACG1, ACG2, ACG3, ACG4, ACG5, ACG6, ACG8, ACG12, ACG13, ACG33,? ACG66, Arda River section, Castell'Arquato, Italy.

Description. Medium sized biconvex shell, inequivalve and inequilateral; slightly transverse suboval outline and orthogyrate, convex umbo; cardinal margin straight; dorso-ventral diameter smaller than antero-posterior one; posterior region more developed than the anterior one. Right and left valves auricles similar in shape (triangular) and size, with the anterior one larger than the posterior one; the anterior auricle has a small byssal notch in both valves.

Ornamentation of both valves consisting of 13-17 coarse radial costae, thinner than the costal interspaces, and of thin and dense concentric growth lines; costae are quadrangular in section near the umbo, becoming rounded in the ventral region; the change in the outline of the section usually occurs in correspondence of a growth halt where the shell forms a sharp step; after this transition radial costae and interspaces near the ventral margin become ornamented by thinner ribs: 3-6 on the costae, 2-3 in the costal interspaces; in some specimens, mainly adult ones, there are 1-3 growth halts forming 1-3 sharp steps, but only in correspondence of the first halt the change in section and in ornamentation of the costae takes place. Auricles ornamented by thin costae, more numerous in the posterior one. Valve interior reflects the external ornamentation.

Interior of both valves with a triangular resilium pit. Monomyarian shell with not well impressed, rounded muscle scar.

Dimensions. See Fig. 5.

Discussion. According to several authors (e.g. Raffi 1970; Faraone 1986; Jimenez et al. 2009) *Aequipecten scabrella* shows a wide morphological intraspecific variability and, therefore, some species should be considered synonyms. In particular, based on comparison and revision of the available literature (e.g. Raffi 1970, Malatesta 1974), *Aequipecten radians* (Nyst & Westendrop, 1839), *Aequipecten seniensis* (Lamarck, 1819) and *Aequipecten bollenensis* (Mayer, 1876), here considered junior synonyms of *Aequipecten scabrella*.

Aequipecten opercularis (Linnaeus, 1758) differs from *A. scabrella* by its more symmetrical valves, its more regular outline, its lower convexity and by its thinner and more numerous costae.

As observed in the *A. opercularis* discussion, *A. scabrella* and *A. opercularis,* show similar size (Fig. 5) and in both cases height and length are nearly equal (H/L ratio equal 1) indicating a subcircular outline.

Stratigraphic and geographic occurrence. *Aequipecten scabrella* is known from the Miocene to the Gelasian of the Mediterranean Sea (Lower Pleistocene) (Marasti & Raffi 1980).

Subclass **Heterodonta** Neumayr, 1884

Order **Veneroida** Adams & Adams, 1856

Superfamily Arcticoidea Newton, 1891

Family Arcticidae Newton, 1891

Genus *Arctica* Schumacher, 1817

Type-species: *Arctica vulgaris* (Linnaeus, 1767) from the Pliocene of England.

Remarks. *Arctica* differs from *Pelecyora* Dall, 1902, because the former has a thicker shell and lacks the pallial sinus; it differs from *Callista* Poli, 1791 as the latter is glossy, usually without sculpture and with the pallial sinus.

Arctica islandica (Linnaeus, 1767)

Pl. 4 fig. 4; Pl. 5, figs 5-6

1767 *Venus islandica* Linnaeus, p. 1131
1778 *Venus buccardium* Born, p. 63, pl. 4, fig. 11
1778 *Pectunculus crassus* Da Costa, p. 183, pl. 14, fig. 5
1817 *Arctica vulgaris* Schumacher, p. 145, pl. 13, fig. 3
1864 *Cyprina islandica* var. *crassior* Jeffreys, p. 305
1898 *Cyprina islandica* - Sacco in Bellardi & Sacco, V. 28, p. 10, pl. II, figs. 1-2 (cum syn.)
2001 *Arctica islandica* Gofas et al. in Costello et al., p. 2010

Material: Four articulated specimens: ACG253-2, ACG254-1-4-6; thirty-one ventral valves: ACG77-1, ACG86-4-5, ACG200-9-10-12-13, ACG202-3, ACG213bis-3, ACG214-1-2, ACG215-5-6-8-10, ACG216-1-2-3, ACG217-5-6, ACG220-1-2-3, ACG224-1, ACG226-3, ACG228-1-2, ACG242-1-2, ACG243-5, ACG253-3-4, ACG254-3; sixteen dorsal valves: ACG78-1-2-6, ACG200-11-14, ACG213bis-2, ACG215-7-9, ACG216-4, ACG217-4, ACG222-5, ACG225-1, ACG226-1-2, ACG229-1, ACG254-2; fragments: ACG78-3, ACG241-4.

Occurrence: ACG77, ACG78, ACG86, ACG200, ACG202, ACG213bis, ACG214, ACG215, ACG216, ACG217, ACG220, ACG222, ACG224, ACG225, ACG226, ACG228, ACG229, ACG241, ACG242, ACG243, ACG253, ACG254, Arda River section, Castell'Arquato, Italy.

Description. Large sized, biconvex and strong shell, equivalve and inequilateral; height ranging between 41 and 90 mm, lenght ranging between 44 and 92.4 mm; suboval outline with rounded anterior margin and straight posterior one; shell substance very thick; both valves show a low ridge in the posterior part, extending from the umbo to the ventral margin; umbo convex, prosogyrate and prominent; cardinal margin strongly curved; narrow nymphs occupied by thick, arched and black external ligament; dorso-ventral diameter is nearly equal to antero-posterior one.

Ornamentation of both valves consisting of: 1) irregular and numerous concentric growth lines in the anterior and middle part of the valve and 2) growth lamellae in the posterior part; these two different ornamentation pattern are bounded by a low ridge.

Interior of both valves with heterodont dentition; right valve with three prominent cardinal teeth and a single posterior lateral tooth; left valve with three cardinals teeth and one posterior lateral tooth, with the anterior cardinal continuous with a series of small ridges and denticulations.

Dimyarian anisomyarian, integripalliate shell with suboval muscle scar and circular pallial line; anterior adductor muscle scar slightly larger than the posterior one; scars of radially directed fibers of muscle mantle along the pallial line.

Discussion. *Arctica islandica* is the only living species of its family. The taxonomy and nomenclature is well defined although the old name *Cyprina islandica* is sometimes still used in recent literature. This species probably represents the most popular boreal guest, which migrates into the Mediterranean Sea during the climatic deterioration of the Early Pleistocene. The Mediterranean populations became extinct about 9.8 ka ago as a consequence of the climate shift to warm water conditions (Dahlgren et al. 2000).

Arctica islandica is the species with the widest size range (min. 41 mm, max 92,4 mm) and usually have a H/L minor than 1, pointing out a slightly transverse outline.

Stratigraphic and geographic occurrence. *A. islandica* is known from 1.77-2.00 Ma to 9.8 ka (Calabrian-Late Pleistocene) of the Mediterranean Sea (Dahlgren et al. 2000). Nowadays is found at high latitudes in the Western Atlantic Ocean along the American coast and in Europe along the coasts of Iceland, Great Britain and the Scandinavian Peninsula (Dahlgren et al. 2000).

Note of the authors. While the paper was in press, a fragment of the dorsal area of *A. islandica* was recovered from a bed at about 5 metres from the base of the section of Fig. 2. This suggests a first arrival of the species in the basin possibly in the late Gelasian. However, so early it was not able to recruit successfully and establish large populations as it did stratigraphically above from 103 m onward.

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PLATE 6

All specimens are x1, except when indicated; a) external view, b) internal view, except when indicated.
1a-b - *Nucula placentina*, right valve (ACG10-2); 2a-b - *Nucula sulcata*, left valve (ACG90-13); 3a-b - *Nuculana pella*, right valve, x2 (ACG197-13); 4a-b - *Saccella commutata*, left valve, x2 (ACG104-6); 5a-b -? *Barbatia mytiloides*, rigth valve of a juvenile specimen, x3 (ACG23-1); 6a-b - *Striarca lactea*, right valve, x2 (ACG197-14); 7a-b - *Arca noae*, left valve (ACG235-7); 8a-b - *Arca* sp., left valve, x2 (ACG252-7); 9a-b - *Anadara* cf. *A.diluvii*, left valve (ACG12-7); 10a-b - Articulated specimen of *Barbatia mytiloides*, right a) and left b) valves (ACG62-1); 11a-b - *Bathyarca* sp., left valve, x2 (ACG13-12); 12a-b - *Amusium cristatum*, left valve (ACG6-1); 13 - Fragment of *Pinna* sp. (ACG200-16); 14 - Fragment of *Mytilus edulis* (ACG117-1); 15a-b - *Mimachlamys varia*, right valve (ACG119-1); 16a-b - *Talochlamys* cf. *T. multistriata*, left valve, x2 (ACG14-18); 17a-b - *Pseudamussium peslutrae*, left valve (ACG219-1); 18 - Unidentified valve of *Amusium cristatum* (ACG2-1).

PLATE 7

All specimens are x1; a) external view, b) internal view.
1a-b - *Pecten flabelliformis*, left valve (ACG4-1); 2a-b - *Flexopecten glaber*, right valve (ACG227-1); 3a-b - *Pecten jacobaeus*, left valve (ACG41-28); 4a-b - *Flexopecten flexuosus*, left valve (ACG80-5).

PLATE 8

All specimens are x1, except when indicated; (a) external view, (b) internal view, except when indicated.
1a-b - *Anomia* sp., left valve (ACG197-15); 2a-b - *Pecten jacobaeus*, left valve (ACG29bis-38); 3a-b - *Anomia ephippium*, left valve (ACG42-26); 4a-b - *Anomia ephippium*, left valve (ACG41-30); 5a-b - *Monia patelliformis*, left valve (ACG118-1); 6a-b - *Loripes lacteus*, left valve (ACG259-6); 7a-b - Articulated specimen of *Loripinus fragilis*, right a) and left b) valve (ACG28-3); 8a-b - *Lucinoma borealis*, left valve, x2 (ACG41-32); 9a-b - *Lucinella divaricata*, left valve, x5 (ACG259-7); 10a-b - *Chama gryphoides*, left valve (ACG37-7); 11a-b - *Flexopecten glaber*, left valve (ACG80-4); 12a-b - *Chama placentina*, right valve (ACG24-12).

PLATE 9

All specimens are x1, except when indicated; a) external view, b) internal view.
1 - *Pecten jacobaeus*, right valve (ACG24-1); 2a-b - *Venericardia* sp., left valve (ACG14-8); 3a-b - *Cardites antiquatus*, right valve (ACG29-1); 4a-b - *Astarte fusca*, right valve (ACG29-6); 5a-b - *Astarte fusca*, left valve (ACG25-12); 6a-b - *Astarte* sp., left valve, x2 (ACG13-9); 7a-b - *Acanthocardia aculeata*, left valve (ACG217-7); 8a-b - *Acanthocardia paucicostata*, right valve (ACG223-6); 9a-b - *Acanthocardia echinata*, right valve (ACG232-1); 10a-b - *Acanthocardia aculeata*, right valve (ACG207-5).

PLATE 10

All specimens are x1, except when indicated; a) external view, b) internal view, except when indicated.
1a-b - *Acanthocardia tubercolata*, left valve (ACG253-5); 2a-b - Articulated specimen of *Acanthocardia tubercolata*, left a) valve and anterior view b) (ACG251-1); 3a-b - *Laevicardium crassum*, left valve (ACG197-16); 4a-b - *Laevicardium oblongum*, right valve (ACG197-17); 5a-b - *Papillicardium papillosum*, right valve, x2 (ACG197-18); 6a-b - *Papillicardium papillosum*, left valve, x2 (ACG198-8); 7a-b - *Mactra stultorum*, left valve (ACG205-4); 8a-b - *Parvicardium exiguum*, right valve, x2 (ACG256bis-3); 9a-b - *Laevicardium* sp., left valve (ACG198-9); 10a-b - *Spisula subtruncata*, right valve (ACG236-7); 11a-b - *Spisula subtruncata*, left valve (ACG236-8); 12a-b - *Tellina albicans*, right valve (ACG53-4); 13a-b - *Tellina incarnata*, right valve (ACG223-7); 14a-b - *Tellina incarnata*, right valve (ACG259-8); 15a-b - *Lutraria angustior*, right valve (ACG237-5).

PLATE 11

All specimens are x1, except when indicated; a) external view, b) internal view, except when indicated.

1a-b - *Lutraria oblonga*, left valve (ACG12-1); 2a-b - *Moerella distorta*, right valve, x2 (ACG259-9); 3a-b - *Tellina pulchella*, left valve (ACG207-5); 4a-b - *Tellina pulchella*, right valve (ACG265-5); 5a-b - *Tellina serrata*, right valve (ACG41bis-7); 6a-b - *Donax* cf. *D. trunculus,* left valve (ACG219-2); 7a-b - *Donax* cf. *D. venustus*, left valve (ACG213bis-4); 8a-b - Articulated specimen of *Solecurtus scopula*, right a) and left b) valves (ACG131-1); 9a-b - *Azorinus chamasolen*, right valve (ACG10-1); 10a-b - *Tellina tenuis*, right a) and left b) valve, x2 (respectively ACG17-6 and ACG17-7); 11 - *Glossus humanus*, right valve (ACG200-15); 12 - *Venus nux,*dorsal view (ACG130-1); 13a-b - *Venus nux*, left valve (ACG130-2); 14a-b - *Pitar rudis*, left valve (ACG82-8); 15a-b - *Pitar rudis*, right valve (ACG80-7); 16a-b - *Callista chione,* right valve (ACG197-19).

PLATE 12

All specimens are x1, except when indicated; a) external view, b) internal view.
1 - *Pelecyora brocchi*, left valve (ACG37-4); 2a-b - *Chamelea gallina*, left valve (ACG207-6); 3a-b - *Dosinia lupinus*, left valve (ACG248-1); 4a-b - *Chamelea gallina*, left valve (ACG90-15); 5a-b - *Clausinella fasciata*, right valve, x2 (ACG25-10); 6a-b - *Clausinella* sp., right valve, x2 (ACG23-8); 7a-b - *Dosinia lupinus*, right valve (ACG235-8); 8a-b - *Polititapes senescens*, left valve (ACG242bis-1); 9a-b - *Polititapes rhomboides*, left valve (ACG200-16); 10a-b - *Polititapes* cf. *P. rhomboides*, left valve (ACG237-6); 11a-b - *Timoclea ovata*, right valve (ACG200-17); 12a-b - *Corbula gibba*, right valve, x3 (ACG194-8); 13a-b - *Corbula gibba*, right valve, x2 (ACG253-6); 14 - Articulated specimen of *Corbula gibba*, left valve view, x3 (ACG14-20); 15a-b - *Hiatella rugosa*, left valve (ACG200-18).

PLATE 13

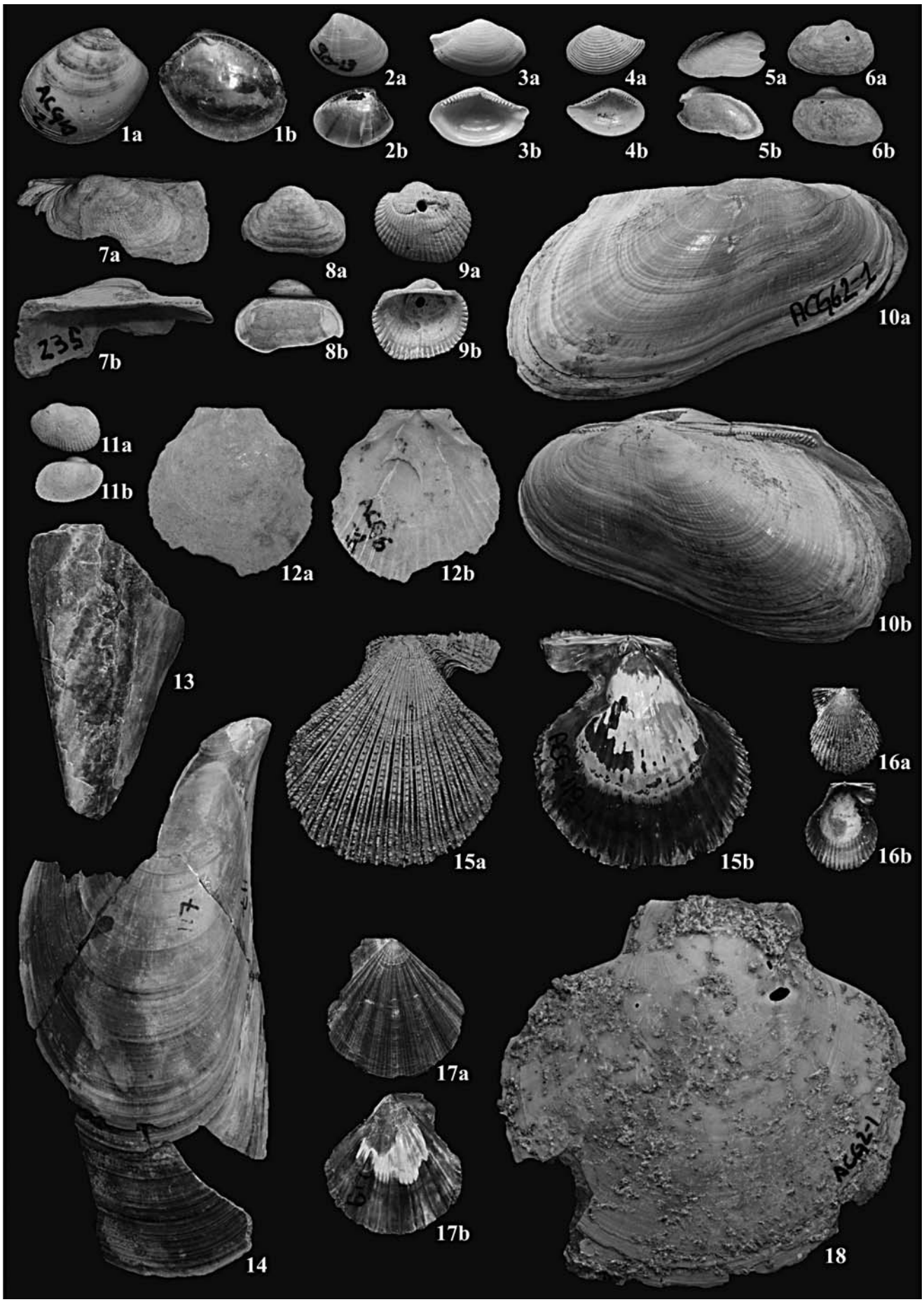
All specimens are x1, except when indicated.
1 - *Panopea glycymeris*, right valve (ACG111-1); 2a-b - *Pholas dactylus*, right valve, external view a), internal view b), x2 (ACG259-10); 3 - Fragment of *Pandora inaequivalvis* (ACG236-9); 4 - *Thracia* sp., right valve (ACG12-11); 5a-b - *Thracia pubescens*, right valve, external view a), internal view b), x2, (ACG259-11); 6 - Tubular structure of *Clavagella* sp. (ACG195-8); 7a-b - *Ostrea edulis*, right valve, external view a), internal view b) (ACG235-9); 8a-b - *Ostrea* sp., right valve, external view a), internal view b) (ACG80-9); 9a-b - *Diodora graeca*, apical a) and lateral b) views, x2 (ACG32-3); 10a-b - *Calliostoma* cf. *C. conulus*, abapertural a) and apertural b) views, x2 (ACG56-13a); 11a-b - *Jujubinus striatus*, abapertural a) and apertural b) views, x2 (ACG194-9); 12a-b - *Jujubinus* sp., abapertural a) and apertural b) views, x2 (ACG194-10); 13a-b - *Turritella tricarinata pliorecens*, abapertural a) and apertural b) views (109-1); 14a-c - *Diloma patulum*, apical a), umbilical b) and apertural c) views (ACG53-23).

PLATE 14

All specimens are x1, except when indicated; a) abapertural, b) apertural view, except when indicated.
1 - *Ostrea edulis*, articulated specimen (ACG133-5); 2 - *Capulus ungaricus*, lateral view, x3 (ACG194-11); 3a-b - *Aporrhais pespelecani* (ACG236-10); 4a-b - *Calyptraea chinensis*, apical (a) and lateral views (b) (ACG41bis-10); 5a-b - *Aporrhais uttingeriana* (ACG197-20); 6a-c - *Calyptraea chinensis*, apical a), umbilical b) and lateral c) views, x2 (ACG253-7); 7a-c - *Calyptraea* sp., apical a), umbilical b) and lateral c) views (ACG59-9); 8a-c - *Xenophora crispa*, apical a), umbilical b) and lateral c) views (ACG199-6); 9a-c - *Xenophora crispa*, apical a), umbilical b) and lateral c) views (ACG11-5); 10a-b - *Naticarius stercusmuscarum* (ACG29bis-20); 11a-b - *Euspira* sp., x2 (ACG261-3); 12a-c - *Neverita josephinia*, umbilical view c) (ACG235-10); 13a-c - *Naticarius* sp., umbilical view c) (ACG256bis-4).

PLATE 15

All specimens are x1, except when indicated; a) abapertural, b) apertural view, except when indicated.
1a-b - *Galeodea echinophora* (ACG200-19); 2a-b - *Epitonium tiberii* (ACG220-1); 3a-b - *Epitonium turtonis* (ACG198-10); 4a-b - *Nassarius* cf. *N. gibbosulus* (ACG258-1); 5 - *Bolinus* sp. (ACG133-6); 6a-c - *Neverita josephinia*, umbilical view c), x2 (ACG251-2); 7a-b - *Nassarius musivus* (ACG258-2); 8a-b; 9a-b - *Nassarius mutabilis* (235-11; 235-12); 10a-b - *Nassarius obliquatus* (ACG53-21); 11a-b - *Nassarius prysmaticus*, x2 (ACG56-13b); 12a-b - *Nassarius* cf. *N. clathratus* (ACG12-3); 13a-b; 14a-b - *Nassarius semistriatus*, x 2 (ACG41bis-8a, ACG41bis-8b); 15a-b - *Nassarius* sp. (ACG43-6); 16a-b - *Mitra* sp., x2 (ACG207-7); 17a-b - *Acteon semistriatus* (ACG235-13); 18a-b - *Ringicula auriculata*, x3 (ACG198-11); 19a-b - *Cylichna cylindracea*, x3 (ACG263-6); 20a-b - *Conus ventricosus* (ACG28-5); 21a-b - *Conus* sp., x2 (ACG29bis-43); 22 - *Pyramidella* sp. (ACG102-4); 23a-b - Echinoids indet., apical a) and oral b) views, x3 (ACG26-10); 24 - *Cladocora* sp. (ACG200-20); 25 - *Dentalium* sp. (ACG29-4); 26 - *Serpulorbis* sp. (ACG29bis-41); 27 - *Ditrupa* sp. (ACG95-4); 28 - Barnacle indet., top a) and lateral b) views (ACG25-17); 29 - Bryozoa indet. (ACG199-7).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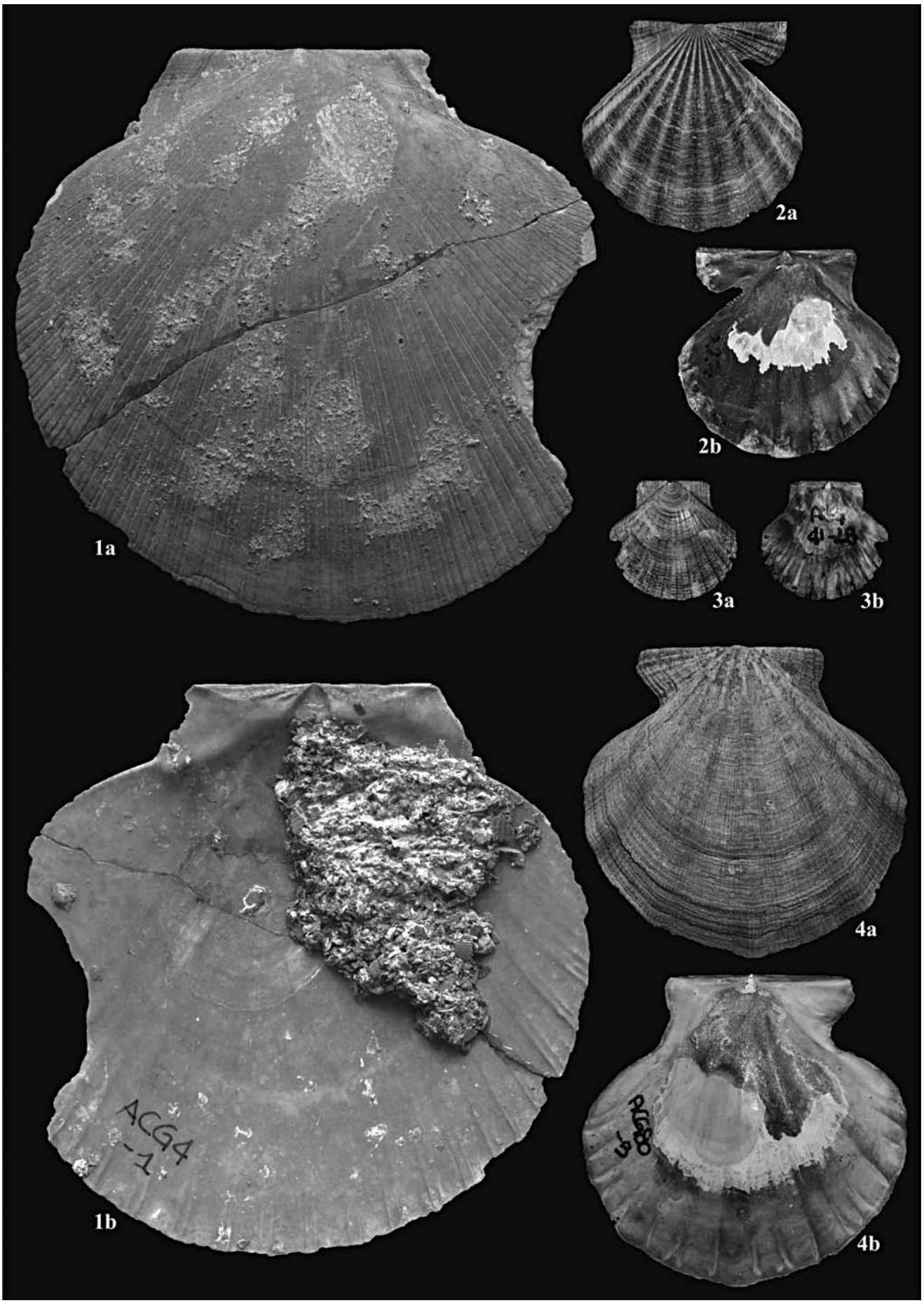

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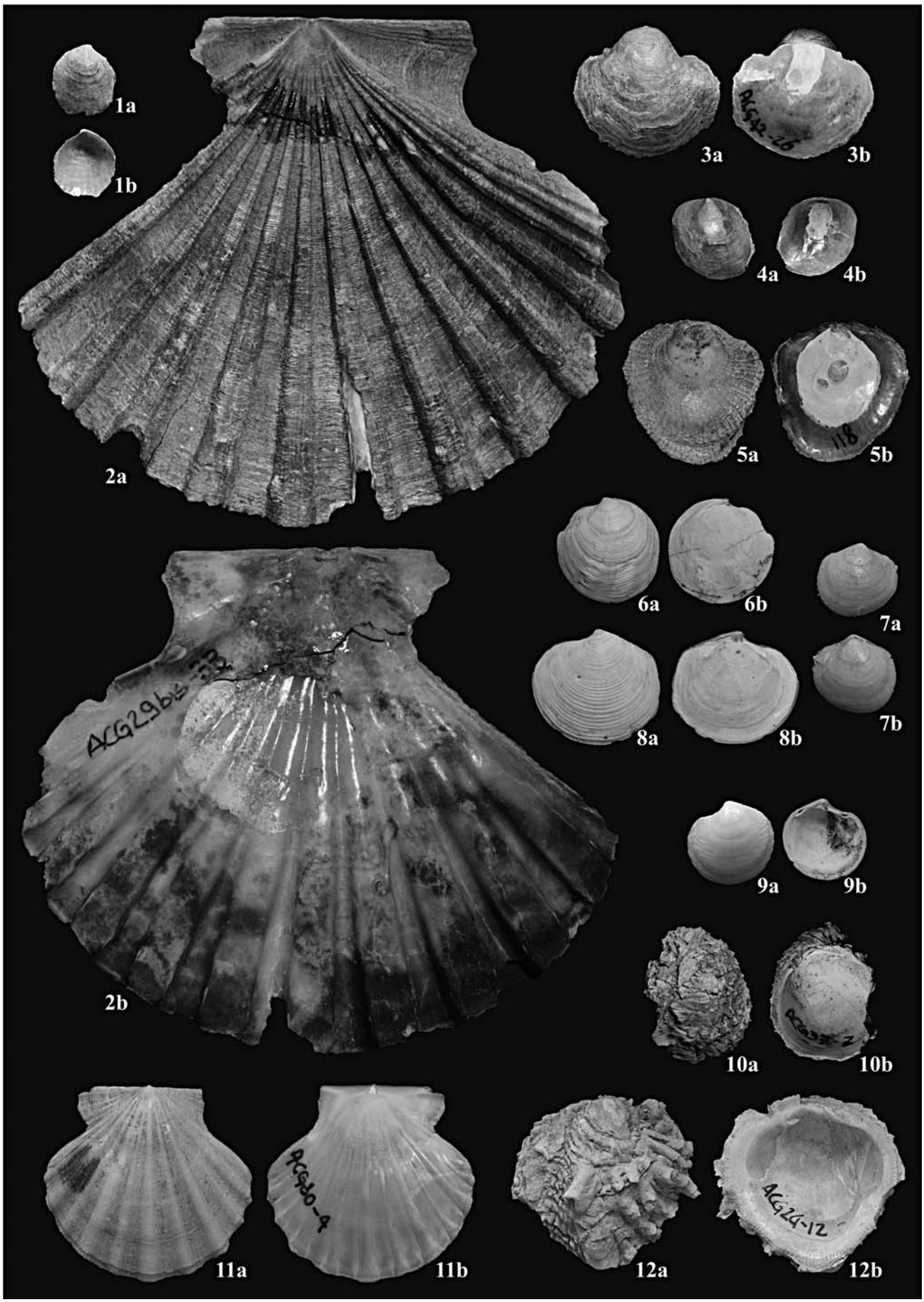
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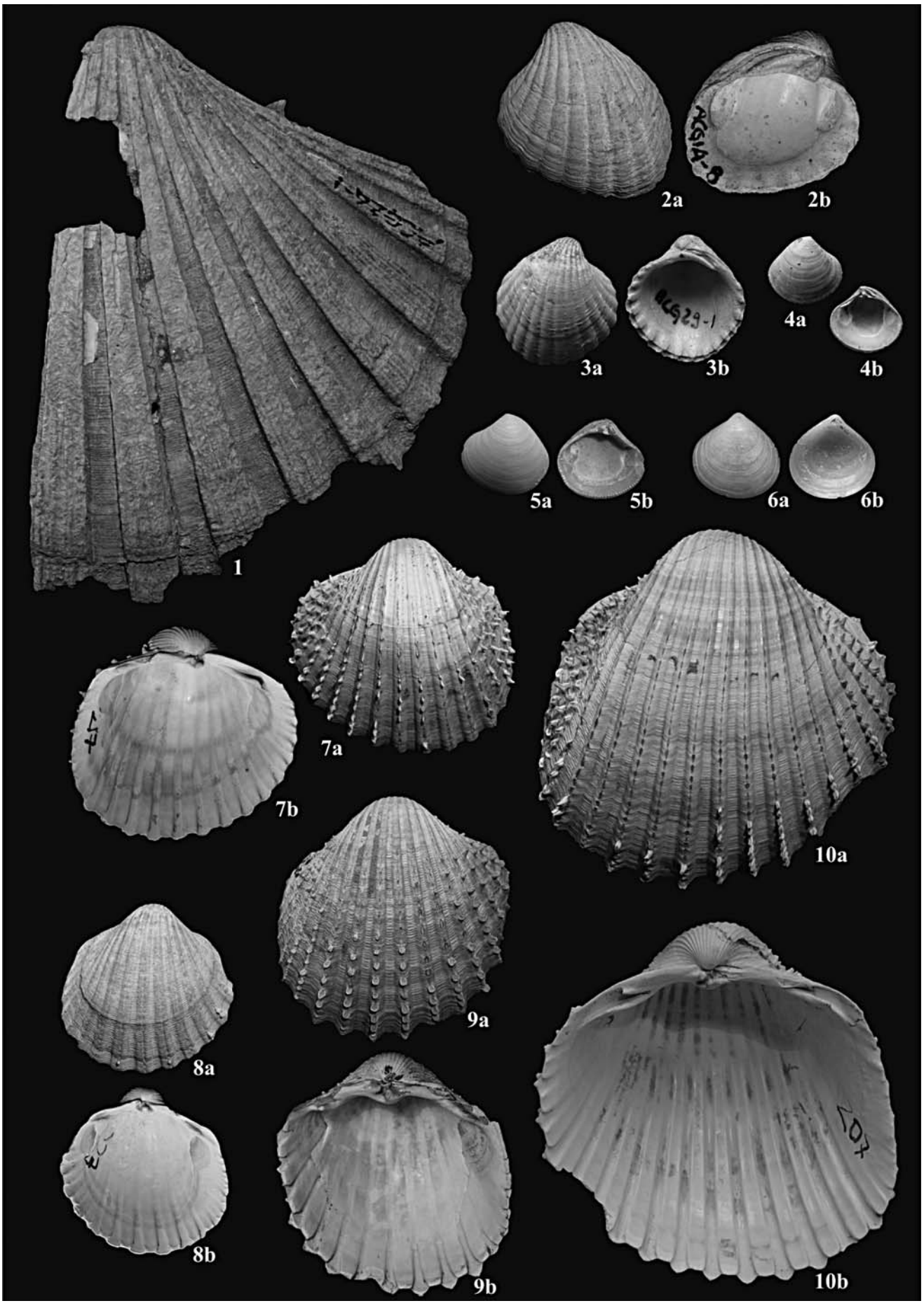

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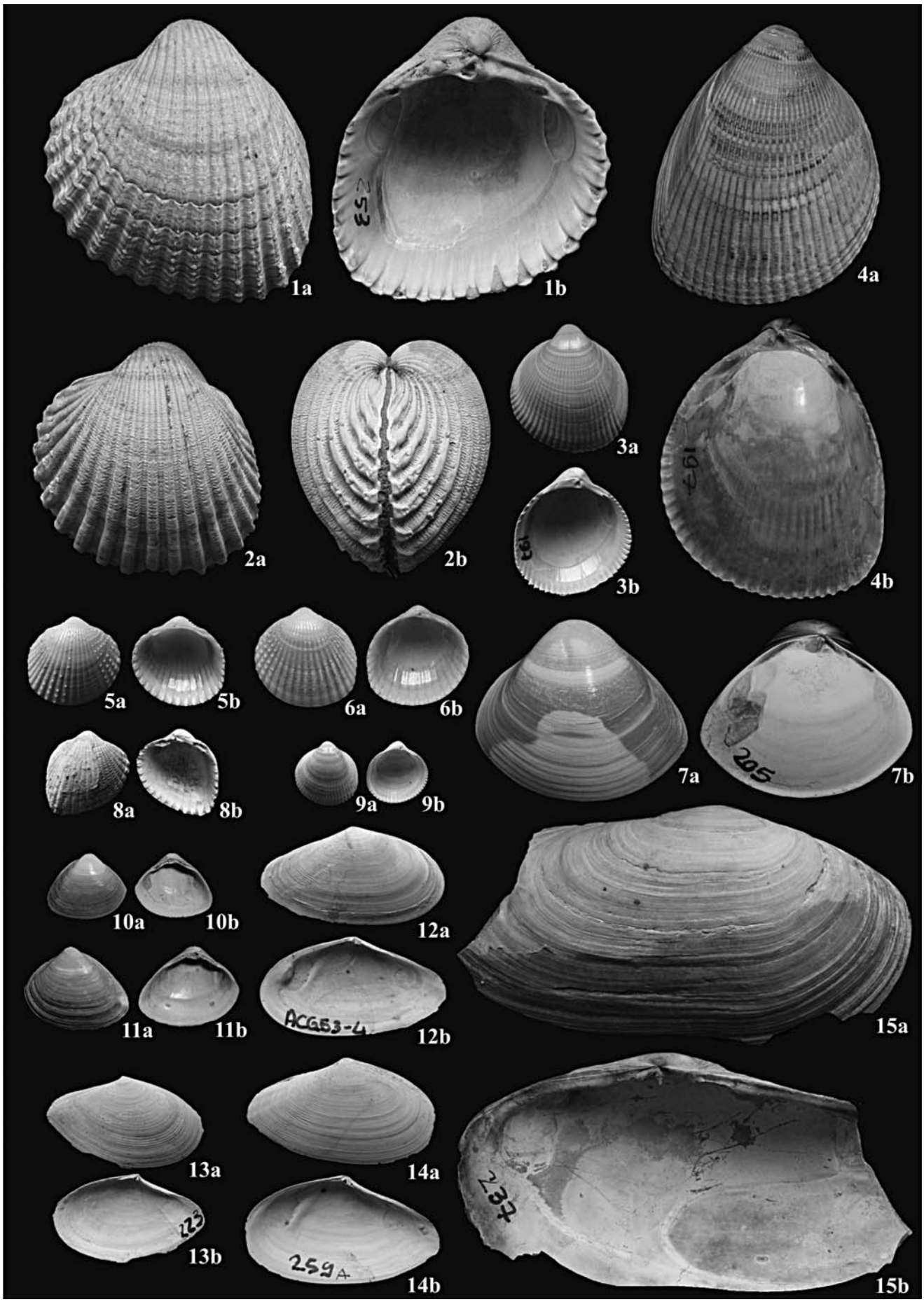
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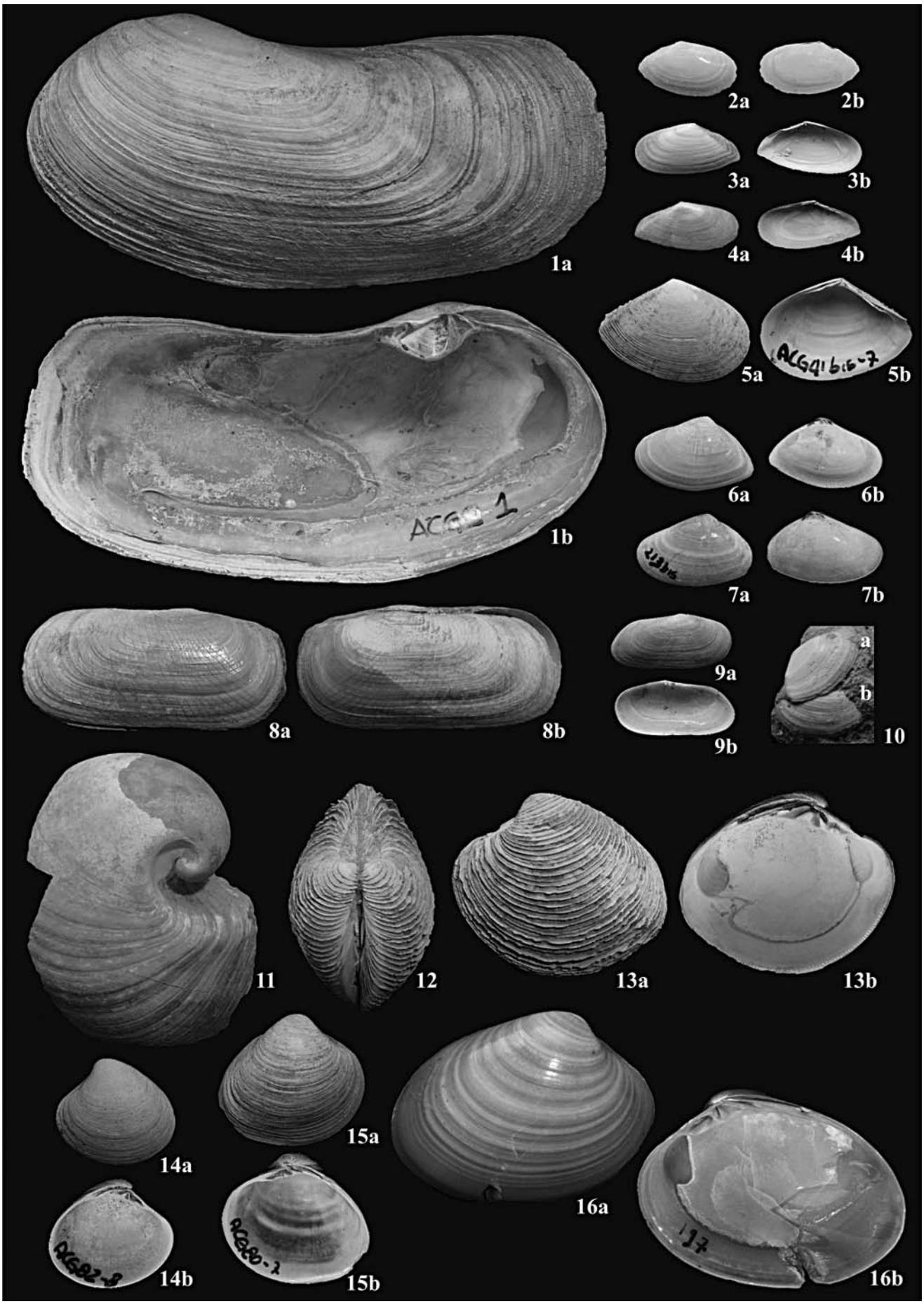
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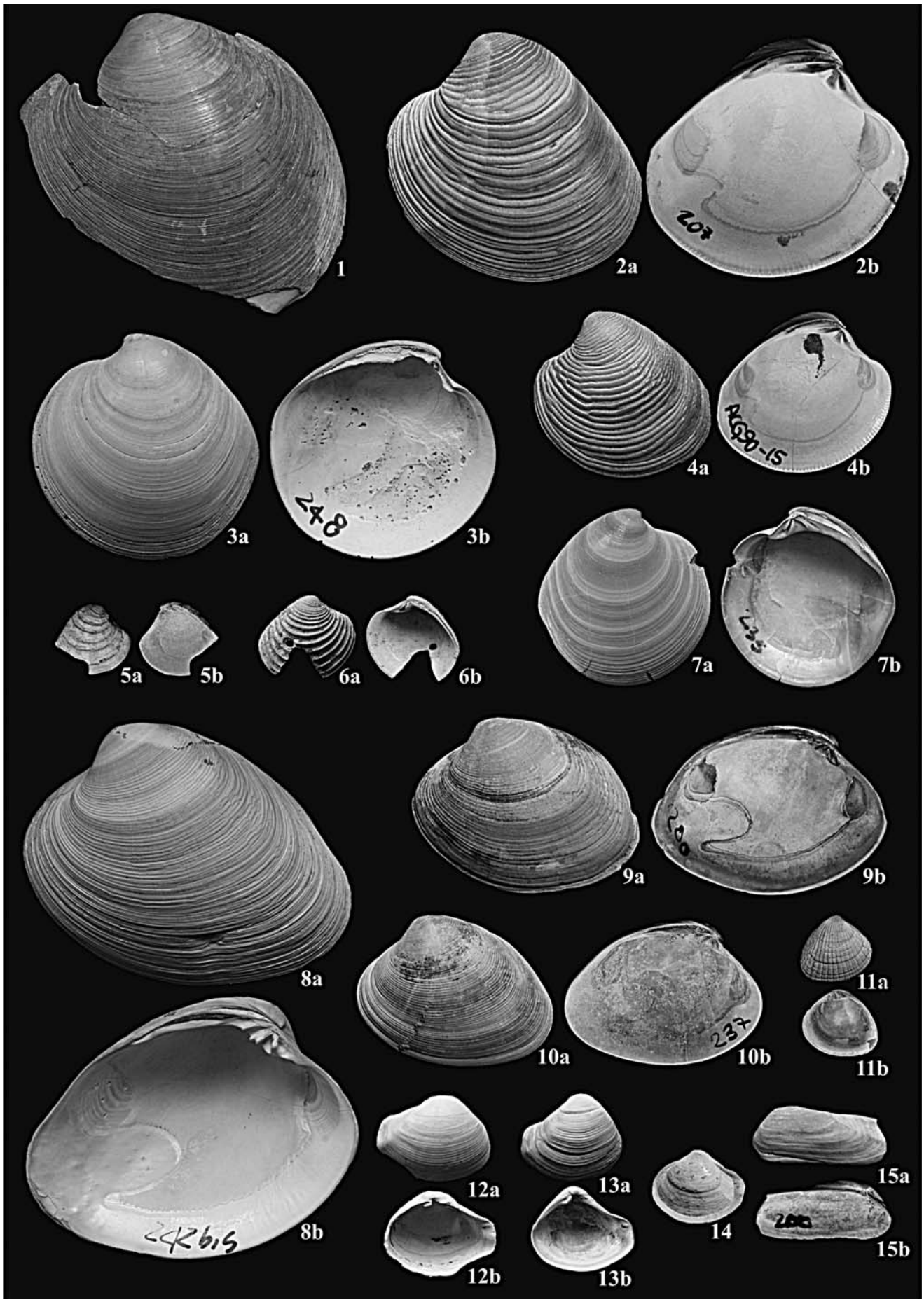
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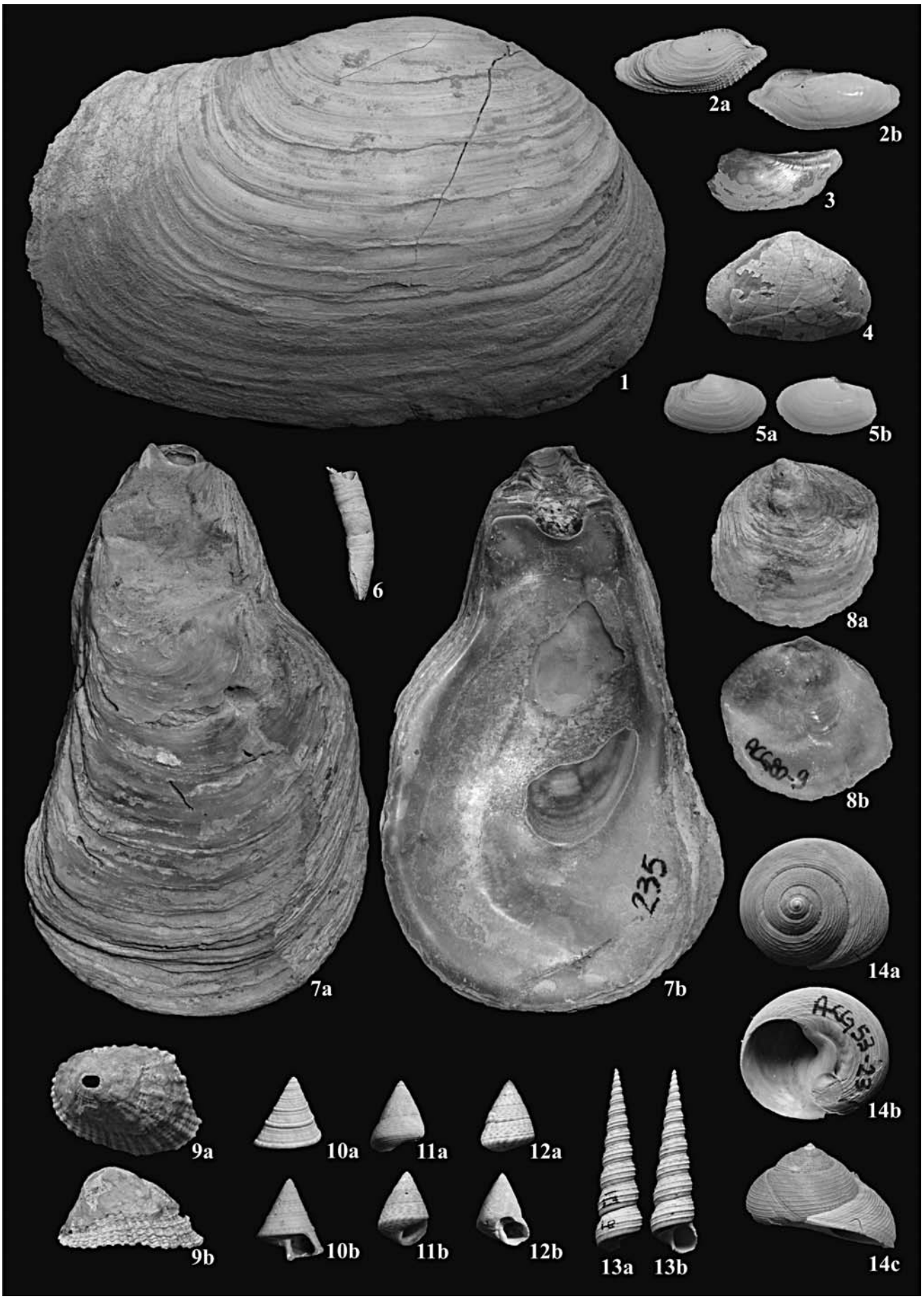
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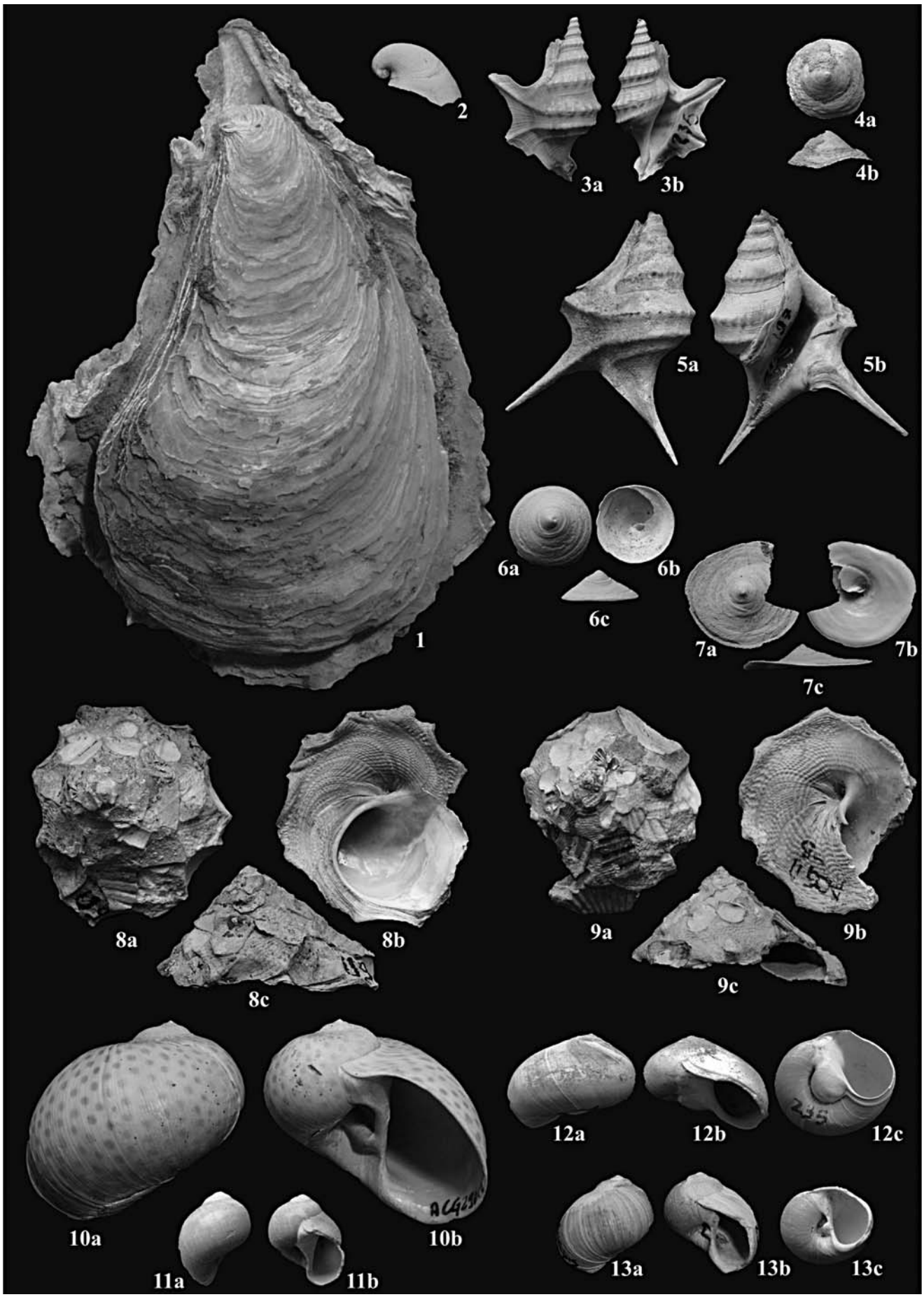
PLATE 13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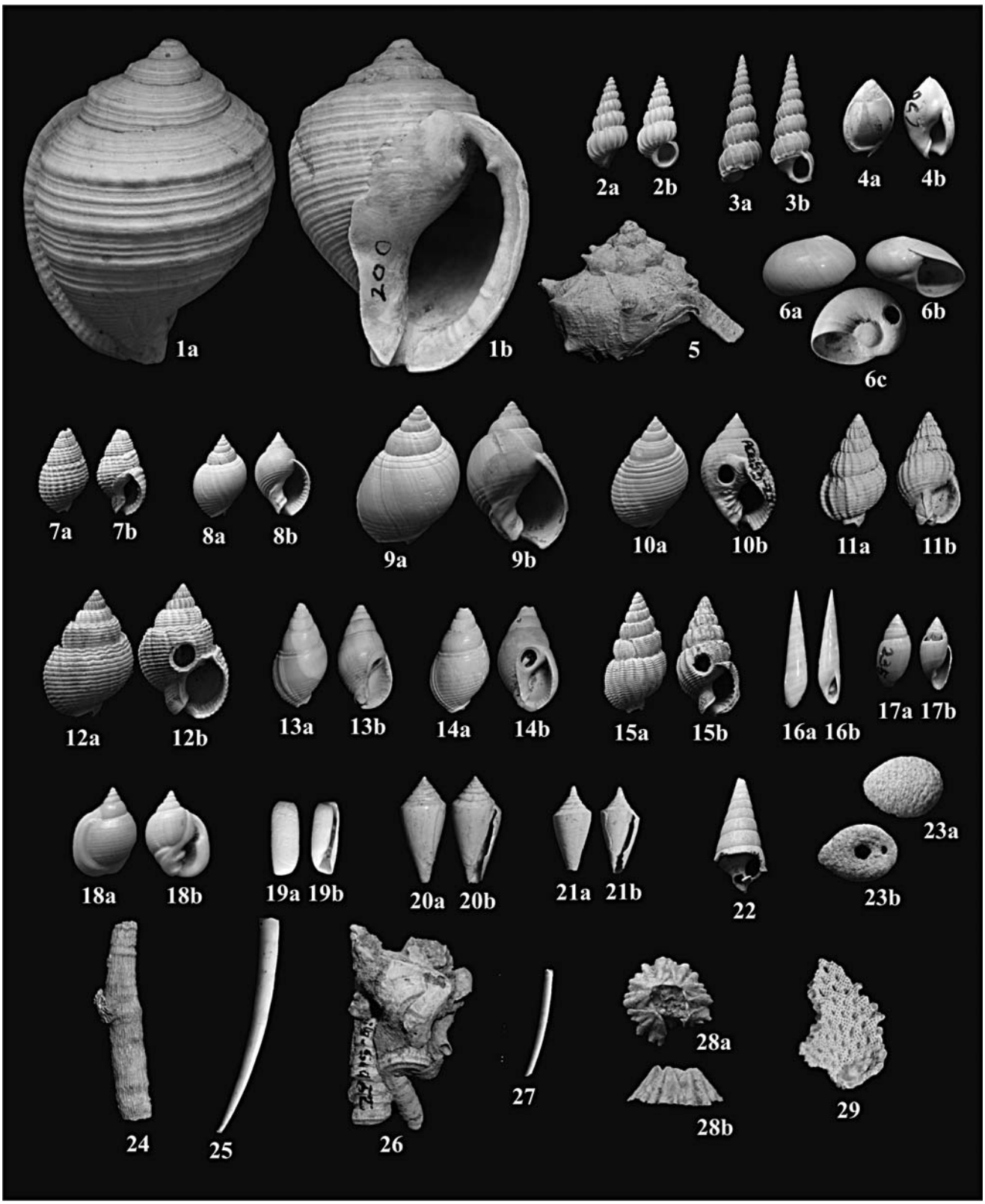
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PLATE 15

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Appendix

Meters	ID Number	Biota
0 m	ACG12	*Aequipecten opercularis, Anadara* cf. *A.diluvii, Astarte fusca, Corbula gibba, Dosinia* sp., *Flabellum bertii, Glycymeris inflata, Glycymeris insubrica, Glossus humanus, Lutraria oblonga, Nassarius* cf. *N. clathtratus, Terebratula* sp., *Thracia* sp., *Turritella* sp.
0.15 m	ACG13	*Acanthocardia* sp., *Aequipecten opercularis, Aequipecten scabrella, Amusium cristatum, Astarte* sp., *Bathyarca* sp., *Glycymeris insubrica, Pecten flabelliformis*
1.20 m	ACG14	*Aequipecten opercularis, Astarte fusca, Cardites antiquatus, Corbula gibba, Glycymeris glycymeris, Glycymeris inflata, Glycymeris* sp., *Talochlamys* cf. *T. multistriata, Venericardia* sp., *Venus nux*
2.90 m	ACG15	*Corbula gibba*
3.50 m	ACG16	*Dosinia* sp., *Tellina* sp., Echinoids indet.
4.50 m	ACG17	?*Acteon* sp., *Anomia* sp., Carditidae indet., *Nucula placentina, Tellina tenuis*
7.90 m	ACG18	*Ostrea edulis*
8.70 m	ACG19	*Acanthocardia* sp., *Anomia* sp., Echinoids indet., *Nassarius semistriatus, Pinna* sp., *Saccella commutata, Tellina pulchella, Tellina* sp.
12.92 m	ACG20	fragments
15.60 m	ACG21	*Acanthocardia paucicostata,* ?*Corbula gibba,* Echinoids indet.
16.50 m	ACG22	fragments
18.70 m	ACG23	*Aequipecten opercularis, Arca tetragona,* ?*Barbatia mytiloides, Clausinella* sp., *Corbula gibba, Dosinia* sp., Gastropods indet., *Glycymeris* sp., *Spisula subtruncata, Tellina pulchella*
37.05 m	ACG24	*Aequipecten opercularis, Anomia* sp., *Calyptraea chinensis,* Carditidae indet., *Chama gryphoides, Chama placentina, Chamelea gallina,* Corals indet., *Dentalium* sp., *Dosinia lupinus, Glycymeris* sp., *Laevicardium oblongum, Naticarius* sp., *Nassarius* sp., *Ostrea edulis, Pecten jacobaeus, Ringicula auricolata, Spisula subtruncata, Tellina sp., Timoclea ovata, Xenophora crispa*
37.50 m	ACG25	*Aequipecten opercularis, Astarte fusca, Anomia ephippium, Anomia* sp., Barnacles indet., *Cardium indicum, Clausinella fasciata, Pecten jacobaeus, Spisula subtruncata*
37.90 m	ACG26	*Aequipecten opercularis, Astarte fusca,* Echinoids indet., *Glycymeris glycymeris*
39.88 m	ACG27	*Aequipecten opercularis, Dosinia lupinus, Ostrea edulis, Venericardia* sp.
40.60 m	ACG27bis	*Aequipecten opercularis, Glycymeris glycymeris*
41.35 m	ACG28	*Capulus ungaricus, Conus ventricosus, Glycymeris glycymeris, Loripinus fragilis, Ostrea edulis*
42 m	ACG29bis	*Aequipecten opercularis,* Bryozoa indet., *Callista chione, Calyptraea chinensis, Conus* sp., *Corbula gibba, Dentalium* sp., Echinoids indet., *Glycymeris inflata, Glycymeris insubrica, Loripinus fragilis, Nassarius* sp., *Naticarius stercusmuscarum, Ostrea edulis, Pecten jacobaeus, Ringicula auricolata, Serpulorbis* sp., Trochidae indet., *Turritella* sp.
42.25 m	ACG29	*Cardites antiquatus, Dentalium* sp., *Glycymeris insubrica, Ostrea edulis*
43.25 m	ACG30	*Aequipecten opercularis, Arca noae, Dosinia lupinus, Glycymeris insubrica, Timoclea ovata*
43.60 m	ACG31	*Aequipecten opercularis, Calyptraea chinensis, Glycymeris insubrica*
44.90 m	ACG32	*Aequipecten opercularis,* Bryozoa indet., *Capulus ungaricus, Clavagella* sp., Corals indet., *Diodora graeca,* Echinoids indet., *Terebratula* sp.
45.65 m	ACG33	*Aequipecten opercularis, Aequipecten scabrella, Ostrea edulis*
46.05 m	ACG34	*Aequipecten opercularis*
47.35 m	ACG35	*Glycymeris glycymeris*
47.50 m	ACG36	*Aporrhais pespelecani,* Corals indet.
49 m	ACG37	*Aequipecten opercularis, Chama gryphoides, Naticarius stercusmuscarum, Ostrea edulis, Pelecyora brocchi, Turritella tricarinata pliorecens, Venus nux*
51 m	ACG38	*Mimachlamys varia, Ostrea edulis*
52.50 m	ACG39	*Dosinia lupinus*
53.95 m	ACG40	Bivalves indet., *Murex* sp.
54 m	ACG41-42	*Acanthocardia paucicostata, Aequipecten opercularis, Anomia ephippium, Aporrhais sp., Dentalium sp., Ditrupa* sp., *Dosinia lupinus, Glycymeris insubrica, Lucinoma borealis, Nassarius prysmaticus, Nassarius semistriatus, Papillicardium papillosum, Pecten jacobaeus,* ?*Pitar rudis, Pitar rudis, Tellina pulchella, Timoclea ovata*
54.10 m	ACG41bis-42bis	*Aequipecten opercularis, Aporrhais* sp., *Callista chione, Calyptraea chinensis, Dentalium* sp., Echinoids indet., *Glycymeris insubrica, Nassarius semistriatus, Ostrea edulis, Papillicardium papillosum, Tellina serrata*
54.20 m	ACG43	*Acanthocardia aculeata, Aequipecten opercularis, Callista chione, Clavagella* sp., *Glycymeris insubrica, Nassarius* sp., *Ostrea edulis, Pinna* sp., *Saccostrea* cf. *S. forskaeli*
55 m	ACG44	*Aequipecten opercularis*
55.40 m	ACG45	*Glycymeris insubrica*
56.35 m	ACG46	*Dentalium* sp., *Glycymeris insubrica, Pelecyora brocchi*
57.35 m	ACG47	*Lutraria* sp., *Pelecyora brocchi*
58.35 m	ACG48	Echinoids indet., *Pelecyora brocchi, Pinna* sp.
59 m	ACG49	*Glycymeris insubrica*
64.20 m	ACG50	*Acanthocardia tubercolata, Aequipecten opercularis*
65.80 m	ACG51	*Aequipecten opercularis*
66.50 m	ACG51bis	*Aequipecten opercularis*

67.70 m	ACG52	*Aequipecten opercularis, Chamelea gallina, Diloma patulum, Ostrea* sp.
68.40 m	ACG53	*Acanthocardia tubercolata, Aequipecten opercularis, Diloma patulum, Glycymeris insubrica, Nassarius obliquatus, Naticarius stercusmuscarum, Neverita josephinia, Ostrea edulis, Tellina albicans, Tellina corbis*
68.53 m	ACG54	*Aequipecten opercularis, Chamelea gallina, Ostrea edulis, Spisula subtruncata*
69.85 m	ACG55	*Acanthocardia tubercolata, Aequipecten opercularis, Chamelea gallina, Diloma patulum, Nassarius obliquatus, Naticarius stercusmuscarium, Ostrea* sp., *Spisula subtruncata*
70.02 m	ACG56	*Acanthocardia tubercolata, Aequipecten opercularis, Calliostoma* cf. *C. conulus, Chamelea gallina, Diloma patulum, Flexopecten glaber, Jujubinus striatus, Naticarius stercusmuscarum, Nassarius prysmaticus, Neverita josephinia, Spisula subtruncata*
80.30 m	ACG56bis	*Pinna* sp.
81 m	ACG56bis2	*Pinna* sp.
81.60 m	ACG57	*Aequipecten opercularis*
84.30 m	ACG58	*Dosinia lupinus*
85.35 m	ACG59	*Aequipecten opercularis,* ?*Calyptraea* sp., *Glycymeris insubrica*
86 m	ACG60	*Aequipecten opercularis, Flexopecten flexuosus, Glycymeris insubrica, Laevicardium oblongum, Pitar rudis*
86.90 m	ACG61	*Aequipecten opercularis*
89 m	ACG62	*Barbatia mytiloides*
89.60 m	ACG63	*Venus nux*
91 m	ACG64	? *Dosinia* sp.
91.40 m	ACG65	*Venus nux*
92.50 m	ACG66	*Acanthocardia tubercolata, Aequipecten opercularis,* ?*Aequipecten scabrella, Callista chione, Glycymeris insubrica, Naticarius stercusmuscarum*
94.20 m	ACG67	Echinoids indet., *Pecten jacobaeus, Turritella* sp., *Venus nux*
94.60 m	ACG68	*Aequipecten opercularis, Glycymeris insubrica*
96.20 m	ACG69	*Pitar rudis*
98.30 m	ACG70	*Aequipecten opercularis, Spisula subtruncata, Turritella tricarinata pliorecens, Venus nux*
101 m	ACG75	*Acanthocardia aculeata, Venus nux*
102.20 m	ACG76	*Aequipecten opercularis, Glycymeris* sp., *Naticarius* sp., ?*Ostrea* sp., *Panopea glycymeris, Venus nux*
103.70 m	ACG77	*Acanthocardia tubercolata, Aequipecten opercularis, Arctica islandica, Ostrea* sp.
104.10 m	ACG78	*Arctica islandica, Turritella tricarinata pliorecens*
104.80 m	ACG79	*Ostrea edulis*
106.50 m	ACG80	*Aequipecten opercularis, Flexopecten flexuosus, Flexopecten glaber, Ostrea edulis, Ostrea* sp., *Pitar rudis, Polititapes senescens*
108 m	ACG81	*Aequipecten opercularis, Pinna* sp.
111.60 m	ACG82	*Aequipecten opercularis,* Bryozoa indet., *Barbatia mytiloides, Calyptraea chinensis, Capulus ungaricus, Chamelea gallina, Ostrea edulis, Papillicardium papillosum, Pitar rudis, Spisula subtruncata*
114.30 m	ACG83	*Aequipecten opercularis, Glycymeris insubrica*
122.90 m	ACG84	*Aequipecten opercularis, Flexopecten flexuosus, Ostrea edulis, Talochlamys* cf. *T. multistriata, Venus nux*
125.50 m	ACG85	*Acanthocardia echinata, Aequipecten opercularis, Venus nux*
127.95 m	ACG86	*Arctica islandica, Chamelea gallina*
130 m	ACG88	*Chamelea gallina*
132.25 m	ACG89	*Aequipecten opercularis, Barbatia mytiloides, Glycymeris insubrica, Ostrea edulis, Turritella* sp.
133.25 m	ACG90	*Aequipecten opercularis, Chamelea gallina, Glycymeris insubrica, Laevicardium oblongum, Nassarius obliquatus, Nucula sulcata, Pinna* sp., *Venus nux*
133.90 m	ACG91	*Aequipecten opercularis, Chamelea gallina, Capulus ungaricus, Glycymeris insubrica, Pinna* sp.
134.35 m	ACG92	*Acanthocardia tubercolata, Aequipecten opercularis, Chamelea gallina, Dentalium* sp., *Ditrupa* sp., *Ensis ensis, Glycymeris insubrica, Laevicardium* sp., *Tellina incarnata*
134.70 m	ACG93	*Aequipecten opercularis, Chamelea gallina, Glycymeris insubrica, Laevicardium* sp., *Nassarius prysmaticus, Papillicardium papillosum*
135.70 m	ACG94	*Acanthocardia aculeata, Acanthocardia tubercolata, Aequipecten opercularis, Glycymeris insubrica, Mactra stultorum, Nassarius mutabilis, Ostrea edulis, Turritella tricarinata pliorecens*
140 m	ACG95	*Ditrupa* sp., *Glycymeris insubrica*
142.50 m	ACG96	*Glycymeris insubrica*
142.95 m	ACG97bis	*Glycymeris insubrica*
143.40 m	ACG97	*Aequipecten opercularis, Ensis ensis, Glycymeris insubrica*
143.60 m	ACG98	*Glycymeris insubrica*
144 m	ACG99	*Glycymeris insubrica*
145.35 m	ACG100	*Aequipecten opercularis, Pitar rudis*

145.70 m	ACG101	*Aequipecten opercularis*
146.20 m	ACG102	*Aequipecten opercularis*, ?*Aporrhais* sp., *Ditrupa* sp., *Pyramidella* sp.
146.45 m	ACG103	*Acanthocardia tubercolata*, *Aequipecten opercularis*, *Aporrhais pespelecani*
146.55 m	ACG104	*Aequipecten opercularis*, *Naticarius* sp., *Ostrea edulis*, *Saccella commutata*
146.80 m	ACG105	*Aequipecten opercularis*
147.10 m	ACG106	*Pitar rudis*, *Spisula subtruncata*, *Turritella tricarinata pliorecens*, *Venus nux*
150 m	ACG107	*Anomia sp.*, *Turritella tricarinata pliorecens*, *Venus nux*
150.50 m	ACG108	*Dosinia lupinus*, *Pinna* sp., *Venus nux*
151 m	ACG109	*Acanthocardia paucicostata*, *Pinna sp.*, *Turritella tricarinata pliorecens*, *Venus nux*
151.10 m	ACG111	*Panopea glycymeris*
152.40 m	ACG110	*Dosinia lupinus*, *Mytilus edulis*, *Pinna* sp., *Venus nux*
152.80 m	ACG112	*Acanthocardia* sp., *Panopea* sp., *Venus nux*
154 m	ACG113	*Venus nux*
154.50 m	ACG114	*Acanthocardia* sp., *Venus nux*
155.80 m	ACG115	*Venus nux*
156 m	ACG116	*Aequipecten opercularis*, *Ostrea edulis*, *Venus nux*
156.10 m	ACG117	*Acanthocardia echinata*, *Mytilus edulis*, *Venus nux*
157.90 m	ACG118	*Mimachlamys varia*, *Monia patelliformis*, *Ostrea edulis*
158.10 m	ACG119	*Glossus humanus*, *Mimachlamys varia*, *Mytilus edulis*, *Ostrea edulis*, ?*Terebratula* sp., *Venus nux*
158.70 m	ACG120	*Acanthocardia* cf. *A. paucicostata*, *Ostrea edulis*, *Serpulorbis* sp., *Venus nux*
159.10 m	ACG121	*Acanthocardia echinata*, *Teredo* sp., *Venus nux*
160 m	ACG122	*Ostrea edulis*, *Turritella tricarinata pliorecens*, *Venus nux*
160.15 m	ACG123	*Venus nux*
161 m	ACG124	*Ostrea edulis*, *Venus nux*
161.40 m	ACG125	*Ostrea edulis*, *Turritella tricarinata pliorecens*, *Venus nux*
164 m	ACG126	*Venus nux*
164.80 m	ACG127	*Azorinus chamasolen*, *Venus nux*
166.10 m	ACG128	*Venus nux*
166.70 m	ACG129	*Venus nux*
167.90 m	ACG130	*Venus nux*
170 m	ACG131	*Solecurtus scopula*
171 m	ACG132	*Aequipecten opercularis*
171.50 m	ACG133	*Acanthocardia paucicostata*, *Aequipecten opercularis*, *Bolinus* sp., *Capulus ungaricus*, *Flexopecten flexuosus*, *Ostrea edulis*, *Pinna* sp., *Xenophora crispa*
172 m	ACG194	*Aequipecten opercularis*, ?*Anomia* sp., *Capulus ungaricus*, *Corbula gibba*, *Dentalium* sp., *Jujubinus striatus*, *Jujubinus* sp., *Laevicardium* sp., *Lucinoma borealis*, *Nassarius prysmaticus*, *Ringicula auricolata*, *Spisula* sp., *Tellina pulchella*, *Venus nux*
172.20 m	ACG195	*Aequipecten opercularis*, *Clavagella* sp., *Dentalium* sp., *Ditrupa* sp., *Jujubinus striatus*, *Nassarius prysmaticus*, *Ringicula* sp., *Spisula subtruncata*, *Tellina* sp.
172.30 m	ACG196	*Aequipecten opercularis*
172.70 m	ACG197	*Acanthocardia echinata*, *Acanthocardia tubercolata*, *Aequipecten opercularis*, *Anomia* sp., *Aporrhais uttingeriana*, *Callista chione*, *Chamelea gallina*, *Corbula gibba*, *Dentalium* sp., *Glycymeris insubrica*, *Jujubinus striatus*, *Laevicardium crassum*, *Laevicardium oblongum*, *Nassarius mutabilis*, *Nassarius prysmaticus*, *Naticarius* sp., *Nuculana pella*, *Papillicardium papillosum*, *Pitar rudis*, *Striarca lactea*, *Timoclea ovata*, *Venus nux*, *Venus* sp.
173.30 m	ACG198	*Acanthocardia tubercolata*, *Aequipecten opercularis*, *Calyptraea chinensis*, *Ditrupa* sp., *Epitonium turtonis*, *Glycymeris insubrica*, *Laevicardium oblongum*, *Laevicardium* sp., *Nassarius prysmaticus*, *Nuculana pella*, *Papillicardium papillosum*, *Ringicula auricolata*, *Spisula subtruncata*, *Tellina pulchella*
173.60 m	ACG199	*Acanthocardia tubercolata*, *Aequipecten opercularis*, Bryozoa indet., *Glycymeris insubrica*, *Laevicardium* sp., *Nucula placentina*, *Xenophora crispa*
174 m	ACG200	*Acanthocardia echinata*, *Acanthocardia paucicostata*, *Acanthocardia tubercolata*, *Aequipecten opercularis*, *Aporrhais pespelecani*, *Arctica islandica*, *Calyptraea chinensis*, *Cladocora* sp., *Ditrupa* sp., *Galeodea echinophora*, *Glycymeris insubrica*, *Glossus humanus*, *Hiatella rugosa*, *Laevicardium oblongum*, *Mytilus galloprovincialis*, *Nassarius* sp., *Nucula sulcata*, *Ostrea edulis*, *Papillicardium papillosum*, *Pinna* sp., *Pitar rudis*, *Polititapes rhomboides*, *Polititapes senescens*, *Pseudamussium peslutrae*, *Spisula subtruncata*, *Timoclea ovata*, *Turritella tricarinata pliorecens*, *Venus nux*
174.30 m	ACG200bis	*Aequipecten opercularis*
174.70 m	ACG201	*Aequipecten opercularis*, *Dosinia lupinus*, *Glycymeris insubrica*, *Laevicardium* sp., ?*Pitar rudis*, *Polititapes* sp., *Spisula subtruncata*
175 m	ACG202	*Aequipecten opercularis*, *Arctica islandica*, *Glycymeris insubrica*

175.70 m	ACG203	*Acanthocardia tubercolata, Chamelea gallina, Glycymeris insubrica, Naticarius* sp.
176 m	ACG204	*Acanthocardia paucicostata, Acanthocardia tubercolata, Acanthocardia* sp., *Chamelea gallina, Corbula gibba, Ditrupa* sp., *Donax* sp., *Glycymeris insubrica, Laevicardium oblongum, Ostrea edulis, ?Panopea* sp., *Spisula subtruncata, Tellina pulchella*
176.10 m	ACG205	*Chamelea gallina, Glycymeris insubrica, Mactra stultorum, Spisula subtruncata*
176.60 m	ACG206	*Glycymeris insubrica*
177.40 m	ACG207	*Acanthocardia aculeata, Aequipecten opercularis, ?Anomia* sp., *Azorinus chamasolen, Chamelea gallina, Ditrupa* sp., *Mitra* sp., *Naticarius* sp., *Nucula* sp., *Pinna* sp., *Tellina pulchella, Tellina* sp.
177.60 m	ACG208	*Aequipecten opercularis, Dosinia lupinus*
177.80 m	ACG209	*Aequipecten opercularis, Dosinia lupinus, Nassarius mutabilis, Spisula subtruncata*
180.40 m	ACG211	*Glycymeris insubrica*
181.20 m	ACG210	*Glycymeris insubrica, Naticarius stercusmuscarium, Ostrea edulis*
181.80 m	ACG212	*Aequipecten opercularis, Venus nux*
182.10 m	ACG213	*Aequipecten opercularis*
182.80 m	ACG213bis	*Aequipecten opercularis, Arctica islandica, Donax* sp. *D. venustus, Naticarius stercusmuscarum, Spisula subtruncata*
185.60 m	ACG214	*Arctica islandica*
185.70 m	ACG215-216	*Aequipecten opercularis, Arctica islandica, Calyptraea chinensis, Chamelea gallina, Glycymeris insubrica, Laevicardium* sp., *Nassarius* sp., *Nucula placentina, Nucula sulcata, Papillicardium papillosum, Pitar rudis, Polititapes rhomboides, Polititapes senescens, Spisula subtruncata, Turritella tricarinata pliorecens, Venus nux*
186.40 m	ACG217	*Acanthocardia aculeata, Acanthocardia echinata, Acanthocardia paucicostata, Aequipecten opercularis, Anomia* sp., *Arctica islandica, Ditrupa* sp., *Ensis ensis, Laevicardium oblongum, Spisula subtruncata, Tellina* sp.
186.50 m	ACG218	*Acanthocardia aculeata, Spisula subtruncata*
187 m	ACG219	*Arctica islandica, Chamelea gallina, Cladocora* sp., *Donax* cf. *D. trunculus, Dosinia lupinus, Flexopecten glaber, Naticarius* sp., *Papillicardium papillosum, Pitar rudis, Pseudamussium peslutrae, Spisula subtruncata,* Turridae indet.
188.80 m	ACG220	*Aequipecten opercularis, Arctica islandica, Calyptraea chinensis, Chamelea gallina, Epitonium tiberii, Spisula subtruncata*
189.30 m	ACG221	*Acanthocardia paucicostata, Pitar rudis*
189.70 m	ACG222	*Acanthocardia echinata, Aequipecten opercularis, Aporrhais pespelecani, Arctica islandica, Chamelea gallina, Pitar rudis, Spisula subtruncata, Turritella* sp.
189.90 m	ACG223	*Acanthocardia aculeata, Acanthocardia paucicostata, Aequipecten opercularis, Chamelea gallina, Laevicardium oblongum, Tellina incarnata*
193.20 m	ACG224	*Arctica islandica*
193.40 m	ACG225	*Aporrhais* sp., *Arctica islandica, Pitar rudis, Polititapes rhomboides, Polititapes senescens, Spisula subtruncata, Venus nux*
193.60 m	ACG226	*Arctica islandica, Calyptraea chinensis, Pitar rudis, Polititapes senescens, Spisula subtruncata, Venus nux, Venus* sp.
193.90 m	ACG227	*Calyptraea chinensis, Flexopecten glaber*
194 m	ACG228	*Arctica islandica, Mytilus* cf. *M. galloprovincialis, Neverita* sp., *Spisula subtruncata*
194.10 m	ACG229	*Acanthocardia paucicostata, ?Anomia* sp., *Calyptraea chinensis, Corbula gibba, Flexopecten glaber*
196 m	ACG230	*Acanthocardia echinata, Acanthocardia paucicostata*
197.80 m	ACG231	*Lutraria* sp.
202.40 m	ACG232	*Acanthocardia echinata, Venus nux*
205.40 m	ACG233	*Ostrea* sp., *Venus nux*
207 m	ACG234	*Venus nux*
208.40 m	ACG235	*Acanthocardia echinata, Acanthocardia paucicostata, Acteon semistriatus, Aequipecten opercularis, Anomia ephippium, Aporrhais sp., Arca noae, Dentalium* sp., *Ditrupa* sp., *Donax* sp., *Dosinia lupinus, Ensis ensis, Flexopecten glaber, Laevicardium oblongum, Monia patelliformis, Nassarius mutabilis, Neverita josephinia, Ostrea edulis, Pitar rudis, Polititapes rhomboides, Spisula subtruncata, Tellina pulchella, Turritella tricarinata pliorecens*
208.60 m	ACG236	*Aequipecten opercularis, Anomia ephippium, Aporrhais pespelecani, Calyptraea chinensis, Dentalium* sp., *Laevicardium oblongum, Ostrea edulis, Ostrea* sp., *Pandora inaequivalvis, ?Pitar* sp., *Polititapes senescens, Spisula subtruncata, Tellina pulchella, Turritella* sp., *Venus* sp., *Xenophora crispa*
209 m	ACG237	*Aequipecten opercularis, Calyptraea chinensis, Lutraria angustior, Mytilus* sp., *Ostrea edulis, Pitar rudis, Polititapes* cf. *P. rhomboides, Spisula subtruncata, Tellina pulchella*
209.80 m	ACG238	*Aequipecten opercularis,* Bryozoa indet., *Spisula subtruncata*
210.40 m	ACG239	*Acanthocardia tubercolata, Aequipecten opercularis,* Bryozoa indet., *Calyptraea chinensis, Dentalium* sp., *Ditrupa* sp., *Ensis ensis, Neverita josephinia, Pitar rudis, Spisula subtruncata*
210.60 m	ACG240	*Aequipecten opercularis, Ditrupa* sp.
217.20 m	ACG241	*Arctica islandica, Anomia* sp., *?Carditidae* indet., *Glycymeris glycymeris, Naticarius* sp., *Polititapes senescens*
217.90 m	ACG242	*Arctica islandica,* Solecurtidae sp.
218 m	ACG242bis	*Dosinia lupinus, Mytilus* sp., *Polititapes senescens*

218.60 m	ACG243	*Aequipecten opercularis, Aporrhais* sp., *Arctica islandica, Chamelea gallina, Dosinia lupinus, Glycymeris glycymeris, Mactra stultorum, Nassarius prysmaticus, Papillicardium papillosum, Pitar rudis, Spisula subtruncata, Tellina pulchella, Venus* sp.
218.80 m	ACG244	*Chamelea gallina*
220.40 m	ACG245	*Acanthocardia tubercolata, Chamelea gallina, Corbula gibba, Dentalium sp., Dosinia lupinus, Flexopecten glaber, Neverita josephinia, Ostrea edulis, Spisula subtruncata, Tellina pulchella, Turritella tricarinata pliorecens*
220.50 m	ACG246	*Acanthocardia tubercolata, Dosinia lupinus, Flexopecten glaber*
221.20 m	ACG247	*Acanthocardia tubercolata, Acanthocardia* sp., *Dentalium* sp., *Dosinia lupinus, Nassarius* sp., *Nucula* sp., *Tellina pulchella*
221.40 m	ACG248	*Acanthocardia paucicostata, Acanthocardia tubercolata, Chamelea gallina, Corbula gibba, Dosinia lupinus, Flexopecten glaber, Nassarius prysmaticus, Tellina pulchella*
221.90 m	ACG249	*Acanthocardia tubercolata, Chamelea gallina, Dosinia lupinus, Flexopecten glaber, Neverita josephinia, Tellina pulchella*
223 m	ACG250	*Acanthocardia tubercolata, Chamelea gallina, Dosinia lupinus, Flexopecten glaber*
223.20 m	ACG251	*Acanthocardia tubercolata, Chamelea gallina, Corbula gibba, Dentalium* sp., *Donax* sp., *Dosinia lupinus, Flexopecten glaber, Nassarius* cf. *N. gibbosulus, Neverita josephinia, Spisula subtruncata, Tellina pulchella, Turritella tricarinata pliorecens, Turritella* sp.
223.80 m	ACG252	*Acanthocardia tubercolata, Aequipecten opercularis, Arca* sp., *Arctica islandica, Azorinus chamasolen, Chamelea gallina, Corbula gibba, Dentalium* sp., *Glycymeris insubrica, Spisula subtruncata, Turritella tricarinata pliorecens, Venus nux*
224.20 m	ACG253	*Acanthocardia tubercolata, Aequipecten opercularis, Anomia* sp., *Arctica islandica, Calyptraea chinensis, Chamelea gallina, Corbula gibba, Dentalium* sp., *Ditrupa* sp., *Mytilus* sp., *Nassarius* sp., *Turritella tricarinata pliorecens, Venus nux*
224.30 m	ACG254	*Arctica islandica, Calyptraea chinensis, Nassarius* cf. *N. prysmaticus, Spisula subtruncata, Tellina* sp.
224.50 m	ACG255	*Aequipecten opercularis, Glycymeris insubrica, Venus nux*
230.80 m	ACG256	*Dosinia lupinus, Flexopecten glaber, Glycymeris insubrica*
231.10 m	ACG256bis	*Glycymeris insubrica, Naticarius* sp., *Parvicardium exiguum*
231.80 m	ACG257	*Acanthocardia aculeata, Acanthocardia tubercolata, Chamelea gallina, Dosinia lupinus, Glycymeris insubrica, Mactra stultorum*
231.90 m	ACG258	*Chamelea gallina, Dosinia lupinus, Glycymeris insubrica, Nassarius* cf. *N. gibbosulus, Nassarius musivus*
234 m	ACG258bis	*Chamelea gallina*
234.40 m	ACG259	*Acanthocardia tubercolata, Chamelea gallina, Donax* cf. *D. trunculus, Donax* cf. *D. venustus, Dosinia lupinus, Ensis ensis, Glycymeris insubrica,* Helicidae indet, *Loripes lacteus, Lucinella divaricata, Moerella distorta, Nassarius mutabilis, Nassarius* sp., *Neverita josephinia, Pholas dactylus, Spisula subtruncata, Tellina albicans, Tellina incarnata, Tellina pulchella, Thracia pubescens*
234.80 m	ACG260	*Acanthocardia* sp., *Chamelea gallina, Glycymeris insubrica*
235.70 m	ACG261-261bis	*Acanthocardia tubercolata, Acanthocardia* sp., *Chamelea gallina, Euspira* sp., *Glycymeris insubrica, Ostrea edulis*
236 m	ACG262	*Chamelea gallina, Cylichna cylindracea, Glycymeris insubrica, Lucinella divaricata, Moerella distorta, Pholas dactylus, Spisula subtruncata, Tellina albicans, Tellina pulchella*
236.40 m	ACG263	*Acanthocardia* sp., *Chamelea gallina, Cylichna cylindracea, Donax* sp., *Glycimeris insubrica, Lucinella divaricata, Moerella distorta, Nassarius mutabilis, Nassarius* sp., *Spisula subtruncata, Tellina* sp.
237 m	ACG264	*Acanthocardia tubercolata, Calyptraea chinensis, Chamelea gallina, Glycymeris insubrica, Nassarius* sp., *Tellina incarnata*
239.20 m	ACG266	*Acanthocardia tubercolata, Glycymeris insubrica*
241 m	ACG267	*Glycymeris insubrica, Spisula subtruncata*