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First Record of *Crassostrea cyathula* (Lamarck 1806) from 'the Rupelian–Lower Chattian of Sarıbuğday-Kovancılar (NE Palu), Eastern Taurides, E Turkey

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Abstract: *Crassostrea cyathula* (Lamarck 1806), a valuable biostratigraphic marker, was found for the first time in eastern Turkey (Eastern Mediterranean), in the Rupelian–Lower Chattian sedimentary sequences of northeastern Palu, Elazığ region, and its palaeoecological characters, palaeobiogeographic and stratigraphic distribution are discussed. These oyster specimens are also the first abundant macrofossils from the Oligocene sediments of the Sarıbuğday-Kovancılar section, which were formerly only recorded by micropalaeontological data.

Key Words: Bivalvia, *Crassostrea*, Rupelian–Lower Chattian, systematics, Elazığ, Turkey

'Sarıbuğday-Kovancılar (KD Palu) Rüpeliyen–Erken Şattiyen'inden' *Crassostrea cyathula* (Lamarck 1806)'ın İlk Kaydı, Doğu Toroslar, D Türkiye

Özet: Elazığ bölgesinde Palu'nun kuzeydoğusunda (D Türkiye, D Akdeniz), Rüpeliyen–Erken Şattiyen sedimenter istiflerinde ilk defa tanımlanan *Crassostrea cyathula* (Lamarck 1806)'ın paleoekolojik özellikleri, paleobiyocoğrafik ve stratigrafik dağılımı tartışılmıştır. Mikropaleontolojik veriler ile de desteklenen bu bulgu, Sarıbuğday-Kovancılar kesitinde Oligosen çökelleri içindeki ilk ostrealı makrofosillerdir.

Anahtar Sözcükler: Bivalvia, *Crassostrea*, Rüpeliyen–Erken Şattiyen, sistematik, Elazığ, Türkiye

Introduction

The oyster *Crassostrea cyathula* (Lamarck 1806) is widely recognised as an important stratigraphic marker for the Oligocene. The aim of this paper is to document *Crassostrea cyathula* for the first time from Rupelian to Lower Chattian sequences in eastern Turkey. Tertiary deposits ranging from Palaeocene to Miocene in age crop out in the Elazığ region. The Oligocene rocks exposed in northern Palu in eastern Elazığ (Figure 1a) contain a rich benthic foraminiferal fauna dominated by nummulites (Sirel 2003). Rich fossiliferous strata of Late Eocene–Oligocene age are thick and widespread in eastern Anatolia. Nummulitidae, Lepidocyclinadae, Alveolinidae, Miogypsinidae and other larger benthic foraminiferal taxa of these strata have been studied in detail (Sirel & Gündüz 1981; Sirel 1998, 2003). No previous work has been carried out on the mollusca of this time interval.

The dating of Palaeocene–Oligocene sequences in central and eastern Turkey is commonly done using foraminifera. The larger benthic foraminiferal taxa in the shelf sediments, especially shallow water limestones of Palaeocene–Eocene age, have been previously reported from the various localities of eastern Turkey by the following authors for the

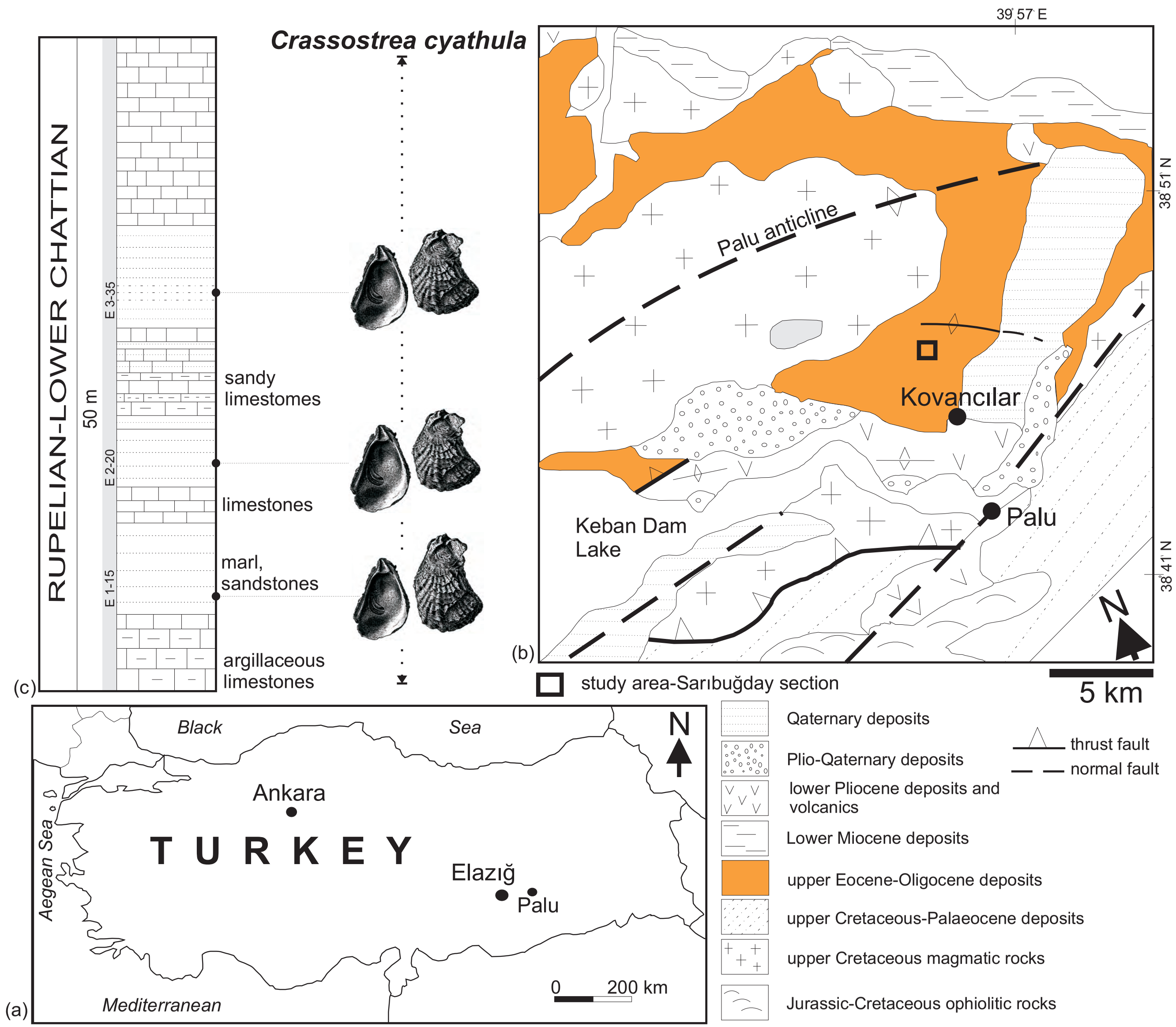

Figure 1. **(a)** Location and **(b)** geological map of the study area Palu (Turan 1993). **(c)** Measured section of the Sarıbuğday section and occurrence of *Crassostrea cyathula*.

purpose of describing new foraminiferal taxa or giving a foraminiferal inventory for the lithostratigraphic units: Sirel *et al.* (1975), Sirel & Gündüz (1981, 1985), Avşar (1991, 1996), Özgen *et al.* (1993), Sirel & Acar (1993), Sirel (1976, 1986, 1997, 1998, 1999, 2003). In Turkey, Oligocene rocks are widely distributed, covering approximately 1/9 of the area of exposed sedimentary rocks. They are mainly exposed in shallow water deposits occurring in Thrace (Lebküchner 1974; Sirel & Gündüz 1976; İslamoğlu *et al.* 2006), in the Denizli region (Gedik 2008; İslamoğlu 2008), in the Burdur area (Saraycık formation) (Gedik & Karadenizli 2007), in the Sivas Basin (Poisson *et al.* 1997), in Muş (Özcan & Sakınç 2007), in the Adana-Karsantı Formation (Şafak & Ünlügenç 1992), and in the Gaziantep (Stchepinsky 1943), Malatya (Ayyıldız & Önal 2005), Elazığ (Sirel *et al.* 1975; Sirel 2003; this study), and Diyarbakır (Sirel 1996) regions. However, in some cases molluscs are used for dating Tertiary shallow marine sequences. Only nine species, placed in one genera, of Early–Middle Miocene ostreid bivalves, had been described from the Sivas Basin, the Mut Basin, and the Kahramanmaraş Basin (Stchepinsky 1939; Erünal-Erentöz 1958; Hoşgör 2008).

The stratigraphic, sedimentological and tectonic characteristics of the Elazığ area have been studied by several researchers (Bingöl 1984; Aksoy 1993; Turan 1993; Aksoy & Çelik 1995; Özkul & Kerey 1996; Turan & Türkmen 1996; Türkmen *et al.* 2001; Aksoy *et al.* 2005). However, only a few monographs have been devoted to the Palaeogene benthic foraminifera of this area, such as the works of Sirel & Gündüz (1981), Avşar (1991, 1996) and Sirel (2003). *Crassostrea cyathula* is described for the first time near Kovancılar (Sarıbuğday village-section) and establishes its age and palaeobiogeographic affinities.

Stratigraphy of the Sarıbuğday Section

Rock units of Late Eocene–Oligocene age crop out in the studied area (Figure 1b). In Sarıbuğday village, northern Palu town, eastern Elazığ, there are good exposures of the Oligocene sequence with abundant foraminifera (Sirel 2003). The section known as the Sarıbuğday section starts from 1.5–2 km east of Sarıbuğday village. The lithologic units recognized are, from bottom to top: argillaceous limestones, marl, sandstones, sandy limestones and limestones. One profile, measured from Sarıbuğday village, demonstrates the general stratigraphy of the investigated area and the stratigraphic position of the marl and sandstones containing *Crassostrea cyathula*. The type profile is about 50 metres thick, measured from the small outcrop in the Sarıbuğday section (Figure 1c). The age of this part of the succession has previously been elusive due to a lack of index fossils. Herein, we assign these sediments to a Rupelian–Late Chattian age, based on foraminifera (Sirel 2003).

The macrofossils are represented mainly by gastropods and bivalves, among which oysters are the most abundant group, and also the most abundant fossils at many levels. In addition to the species of *Crassostrea cyathula*, the following mollusc taxa are also recognized: *Tellina (Laciolina) sacyi*, *Panopea angusta, Globularia grossa* and *Ampullinopsis crassatina.*

Systematic Palaeontology

Oysters are classified mainly on the basis of their internal and external shell characters and, in some cases, shell microstructure. Important internal characters are the shape of the ligament area, the umbonal cavity, the outline and location of the posterior adductor muscle scar, and the type and presence of chomata. External characters include size, the general outline of the shell, the tendency and type of coiling of the umbo, the shape and development of the attachment area (Figure 2), and shell ornamentation such as concentric growth lines, radial ribs, folds, nodes and spines (Stenzel 1971; Aqrabawi 1993; Checa & Jiménez-Jiménez 2003). Generally, these morphological characters are described and discussed in detail by Stenzel (1971), Malchus (1990) and Aqrabawi (1993). The classification of these species in this study follows that of Bieler & Mikkelsen (2006).

Terminology and Abbreviations

The descriptive terminology for the external and internal characters of the oyster shell follows that of

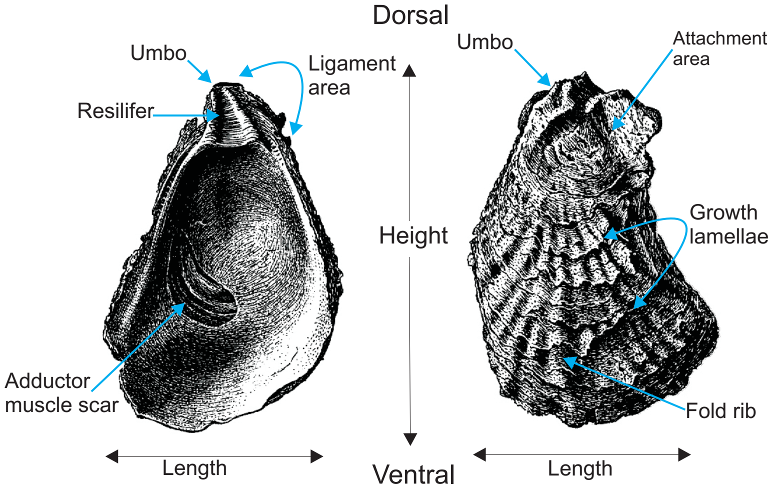

Figure 2. Internal and external morphological features of *Crassostrea cyathula* (modified after Aqrabawi 1993).

Stenzel (1971) and Aqrabawi (1993). The terminology for size is based on the height of the left valve. Linear measurements are in milimetres. The following measurements are used in *Crassostrea cyathula*: H= height; L= length; H/L= height to length to ratio (Figure 3).

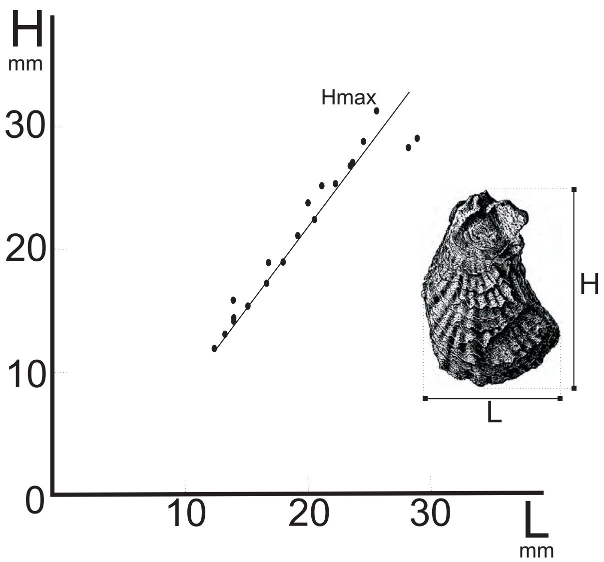

Figure 3. Scatter diagram with regression line showing the length (L) to height (H) ratio of *Crassostrea cyathula*.

Class Bivalvia Linne, 1758

Subclass Pteriomorphia Beurlen, 1944

Order Pterioida Newell, 1965

Suborder Ostreina Ferussac, 1822

Superfamily Ostreoidea Rafinesque, 1815

Family Crassostreidae Scarlato & Starobogatov, 1979

Genus *Crassostrea* Sacco, 1897

Type Species

Ostrea (C.) virginica (Gmelin 1791).

***Crassostrea cyathula* (Lamarck 1806)**

Plate 1, Figure 1–5; Plate 2, Figure 1–7

1824 *Ostrea cyathula* Lamarck, Deshayes, p. 369–370, pl. 54, figs. 1–2; pl. 61, figs. 1–3.

1861 *Ostrea cyathula* Lamarck, Wood, p. 19, pl. 7, fig. 7; pl. 8, fig. 3.

1863 *Ostrea cyathula* Lamarck, Sandberger, p. 379, pl. 34, fig. 1; pl. 35, fig. 2.

1896 *Ostrea cyathula* Lamarck, Bontscheff, p. 376.

1896 *Ostrea cyathula* Lamarck, Kissling, p. 69, pl. 9, fig. 10–11.

1897 *Ostrea cyathula* Lamarck, Wolff, p. 231, pl. 20, figs. 5–8.

1904 *Ostrea cyathula* Lamarck, Sacco, p. 135, pl. 27, fig. 1.

1911 *Ostrea cyathula* Lamarck, Boussac, p. 177–179, pl. 8, fig. 8.

1922 *Ostrea cyathula* Lamarck, Cossmann, p. 200–201, pl. 11, figs. 40–45; pl. 12, figs. 5–6.

1933 *Ostrea cyathula* Lamarck, Gocev, p. 190.

1936 *Ostrea cyathula* Lamarck, Alimen, p. 282, pl. 7, figs. 6–8.

1954 *Ostrea cyathula* Lamarck, Glibert & Heinzelin, p. 325, pl. 1, fig. 19.

1955 *Ostrea cyathula* Lamarck, Tzankov & Belmustakov, p. 164, pl. 2, figs. 1–2.

1956 *Ostrea cyathula* Lamarck, Ilieva-Vergilova, p. 82.

1962 *Ostrea cyathula* Lamarck, Hölzl, p. 60, Pl. 2, Fig. 5.

1964 *Ostrea (Ostrea) cyathula* Lamarck, Karagıuleva, p. 57–58, pl. 14, figs. 1–3, 5; pl. 15, figs. 1–2.

1972 *Crassostrea (Crassostrea) cyathula* (Lamarck), Moisescu, p. 20–21, pl. 9, figs. 1–3.

1984 *Ostrea cyathula* Lamarck, Janssen, p. 115.

1986 *Ostrea cyathula* Lamarck, Gitton *et al*. pl. 1, figs. 1, 3, 5–9.

1987 *Crassostrea cyathula* (Lamarck), Rusu *et al*. pl. 13, figs. 1–5.

Material

This study is based on 20 specimens collected from a single locality in Sarıbuğday village, to the east of the Elazığ area. More complete geographic and stratigraphic details of the listed localities can be found in Sirel & Gündüz (1981) and Sirel (2003). Specimens are housed in the collections of the Palaeontology Laboratory of the University of Ankara, Turkey.

Figured Specimens

AUGE 07.01; AUGE 07.02; AUGE 07.03; AUGE 07.04; AUGE 07.05;

AUGE 07.06; AUGE 07.07; AUGE 07.08; AUGE 07.09; AUGE 07.10; AUGE 07.11; AUGE 07.12.

Horizons and Localities

Sarıbuğday village, east of the Elazığ area, Sarıbuğday section, Bed 15, level 1; Bed 20, level 2; Bed 35, level 3.

Dimensions

(Measurements in mm.)

Specimen	**Height**	**Length**
AUGE 07.01 Left valve	28	29
AUGE 07.02 Left valve	28	27
AUGE 07.03 Left valve	32	26
AUGE 07.04 Left valve	21	19
AUGE 07.05 Left valve	24	20
AUGE 07.06 Left valve	25	21
AUGE 07.07 Left valve	25	22
AUGE 07.08 Left valve	15	16
AUGE 07.09 Left valve	19	17
AUGE 07.10 Left valve	14	13
AUGE 07.11 Left valve	17	14
AUGE 07.12 Right valve	14	13
AUGE 07.13 Left valve	26	24
AUGE 07.14 Left valve	16	14
AUGE 07.15 Left valve	22	21
AUGE 07.16 Left valve	27	25
AUGE 07.17 Left valve	19	16
AUGE 07.18 Left valve	26	24
AUGE 07.19 Left valve	14	12
AUGE 07.20 Left valve	12	11

Description

Relatively small for the species, its maximum height is 32 mm (AUGE 07.03) (Figure 3). The shell is relatively thick, inequivalved and of variable shape (rounded trigonal, vertical to oblique oval, spoon-like, oblique rhombic or suborbicular). The ligamental area is narrow; the right valve moderately thick and slightly convex. The left valve is strongly convex, with a rounded keel near the anterior margin, very irregular some specimens, with a large attachment area which in some specimens is almost as large as the interior of the valve, although it is usually smaller. The umbo is more or less curved in a posterior direction, and ornamented with weak radial riblets. In *Crassostrea cyathula*, the radial ribs are straight or weakly undulating in their crest direction, continuous from near the umbo to the commissure as a general trend. Aqrabawi (1993) suggested that the variation in shell thickness and ornament is possibly related to water energy, so strong ribs with tubercles and spines may indicate strong water currents. The commissure is plicate, interlocking at the valve margin. Plication is only impressed on the internal valve surface in thin-shelled valves.

Remarks

Most of the European Oligocene oysters have been assigned to *Ostrea cyathula* Lamarck, 1806 (=*Crassostrea cyathula* (Lamarck 1806)). *Ostrea (Cubitostrea) flabellula*, from the Late Eocene of Bulgaria (Karagiuleva 1964: 60, pl. 9, figs. 1–3; pl. 12, fig. 2; pl. 14, fig. 2) or *Crassostrea (Cubitostrea) flabellula*, from the Early Oligocene of the Cluj Basin (Romania) (Moisescu 1972: 21–22, pl. 10, fig. 2), seem to resemble the species. They are differentiated from *Crassostrea cyathula* by strongly convex left valves, umbo and ligament area. *Cubitostrea* (Sacco 1897) is the sister taxon of the Ostreinae, or it may contain its stem species (Malchus 1995). It differs from *Crassostrea* only in its generally strong chomata (Malchus 1990). This character is completely reduced in *Crassostrea* (Malchus 1995).

Ostrea linguatula (Goldfuss 1834–1840: 26, pl. 82, fig. 7) is a very similiar species, described from the Late Eocene to Late Oligocene of the Mediterranean province (Piccoli & Mocellin 1962). The main distinction between these species is the large attachment area of *Crassostrea cyathula* and its strongly convex left valve. There is some similarity with *Ostrea syrtica*, but the latter species has larger, well-developed chomata, which cover the whole interior of the shell (Cox 1962; 1–2, pl. 1, figs. 1–3; pl. 2, figs. 1–3).

Ostrea cyathula is synonymous with *Crassostrea (Crassostrea) cyathula* and these synonyms have been used, in lieu of *Ostrea cyathula*, by Moisescu (1972).

The specimens of *Crassostrea cyathula* from the Sarıbuğday section are relatively small compared with material from other areas. For instance, Karagiuleva (1964) recorded 66 mm as the maximum height of specimens. The determination of different species in the Sarıbuğday section is based on H/L ratio and individual shapes for species of crassostrea cyathula.

Palaeoecologic Characters, Palaeobiogeographic and Stratigraphic Distribution Discussed

Palaeoecologically, like their modern representatives, Tertiary oysters lived near the shore in shallow, low-energy marine environments. Oysters cement themselves to the substrate by their left valves. Most cementing bivalves are found in shallow marine conditions in warm temperate to tropical waters (Stenzel 1971; Hoşgör 2008). In the Sarıbuğday material, right and left valves are rarely found together, and are strongly inequivalve. The lower, left valve is heavy, cup-shaped and more durable than the upper, right valve, which is thinner, lighter and more fragile.

The bivalves of the superfamily Ostreoidae Rafinesque originated during the Late Triassic and reached maximum taxonomic diversity and geographic distribution in the Tertiary (Hoşgör 2008). The biostratigraphic importance of this family of ostrerid bivalves is due to the species *Crassostrea cyathula*, which is known to have occurred from the Late Eocene to Late Oligocene. From the Oligocene, the only important abundant species *Crassostrea cyathula,* are restricted to the western Tethys, the NE Atlantic, the Paratethys and the North Sea Basin (Figure 4) (Rögl 1998, 1999). In Turkey it occurs in the Rupelian–Lower Chattian of the Elazığ Tertiary

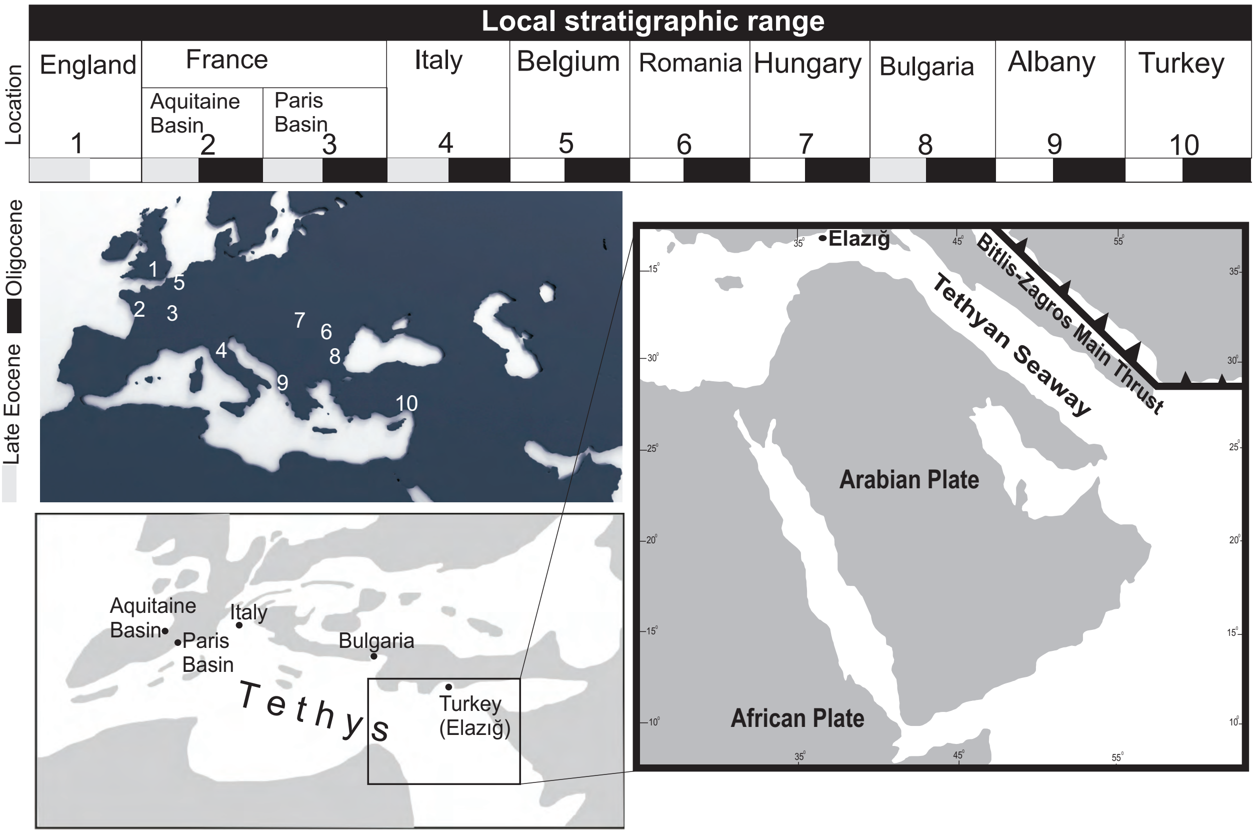

Figure 4. Paleogeographic and stratigraphic distribution of the *Crassostrea cyathula* during the Rupelian-Early Chattian (modified after Harzhauser 2004). Palaeogeographic map of the Oligocene in the eastern Mediterranean (modified after Boukhary *et al.* 2008).

beds (Figure 4) (Sarıbuğday section). It is also described from the Late Eocene to Late Oligocene of Europe, for example England, France (Aquitaine and Paris basins), Italy, Belgium, Bulgaria, Hungary, Romania, and Albany (Deshayes 1824; Wood 1861; Bontscheff 1896; Wolf 1897; Sacco 1904; Boussac 1911; Cossmann 1922; Gocev 1933; Alimen 1936; Glibert & de Heinzelin 1954; Tzankov & Belmustakov 1955; Ilıeva-Vergilova 1956; Karagiuleva 1964; Moisescu 1972; Janssen 1984; Gitton *et al*. 1986; Rusu *et al*. 1987; Bäldi *et al*. 1999).

In particular, the class Bivalvia, with a long larval life of planktotrophic type, represents one of the best ways for reconstruction of the migration pathways along marine currents through geologic time. The approximately 30 species of the Ostreidae, which make up the bulk of living oysters, are many recent oysterids that possess teleplanic (long distance) larvae, capable of being transported over long distances (Foighil & Taylor 2000; Hoşgör 2008). Such larvae might have also been present in *Crassostrea cyathula* and, along with external factors such as climatic and palaeoceanographic conditions, controlled its wide distribution. Palaeoceanographic changes, such as the opening and closing of seaways between oceans, caused the development of palaeogeographic differences in three different regions within the Alpine-Caucasus orogenic belt. These regions are named as: Tethys in the south, Central Paratethys for central Europe and Eastern Paratethys between eastern Europe, and Caucasia (Rögl 1998, 1999). As a consequence of Alpine orogenesis in the Late Palaeogene and in the Neogene, a series of tectonic molasse basins were formed along the northern foreland of the uplifting mountain chains in central and southeastern Europe. Rupelian–Early Chattian times were characterized by marine sedimentation, as in the whole Paratethys

(Voronina & Popov 1985). Generally, the investigation of the Paratethys faunas suggests an open connection with the Atlantic ocean. According to Staesche (1972) a continuous shallow water succession from the Oligocene extended from southeastern Anatolia to similar Mediterranean provinces. Also, at this time the eastern Mediterranean (Figure 4) and the Indian Ocean were connected across the northern part of the Arabian Peninsula, southeastern Anatolia and western Iran (Meulenkamp & Sissingh 2003; Boukhary *et al*. 2008).

Conclusion

As a result of the present studies, representatives of the family Crassostreidae, belonging to the species *Crassostrea cyathula,* are reported for the first time from Turkey. The studied section was part of the Late Palaeogene eastern Mediterranean province during a time of rich species diversity of foraminifera fauna. In fact their discovery points to a more easterly point of origin for the species than was previously known, a position which is supported by the foraminiferal assemblages in these localities.

The present paper records *Crassostrea cyathula* from the Elazığ region, eastern Turkey. The species was previously known from various regions of Europe, but not from the eastern Mediterranean Oligocene. Thus, the Kovancılar record markedly extends the geographical range of this stratigraphically important species.

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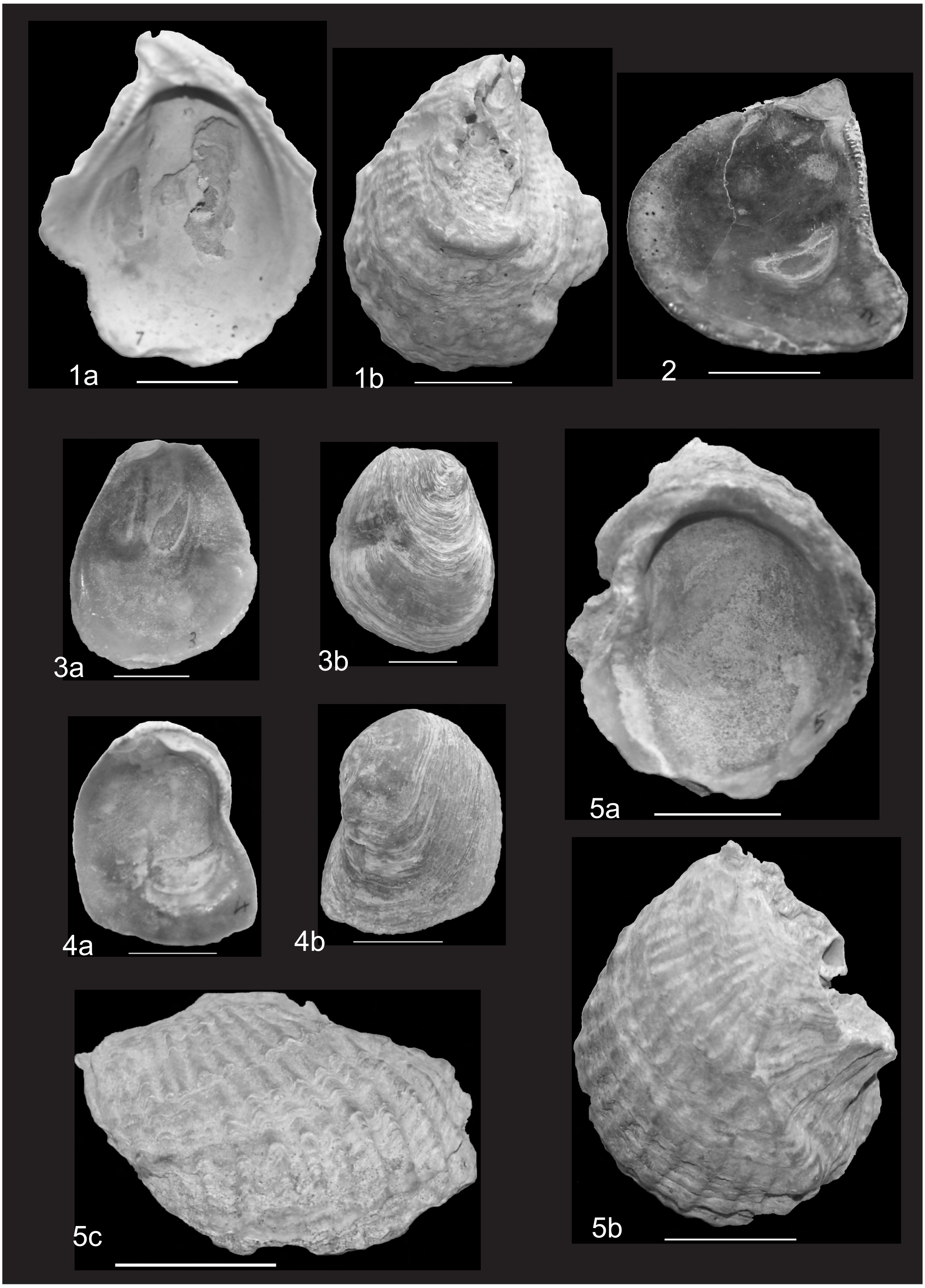
PLATE 1

All specimens are from the marl, sandstones and sandy limestones member in the Elazığ area (Sarıbuğday section). **(1–5)** *Crassostrea cyathula*, **(1a)** left valve, internal view, Locality E 1-15 AUGE 07.01; **(1b)** left valve, external view, Locality E 1-15 AUGE 07.01; **(2)** left valve, internal view, Locality E 1-15 AUGE 07.02; **(3a)** left valve, internal view, Locality E 1-15 AUGE 07.03; **(3b)** left valve, external view, Locality E 1-15 AUGE 07.03; **(4a)** left valve, internal view, Locality E 1-15 AUGE 07.04; **(4b)** left valve, external view, Locality E 1-15 AUGE 07.04; **(5a)** left valve, internal view, Locality E 2-20 AUGE 07.05; **(5b)** left valve, external view, Locality E 2-20 AUGE 07.05; **(5c)** external views of left valve with ribs, Locality E 2-20 AUGE 07.05. (Scale bars 10 mm).


1a
1b
2
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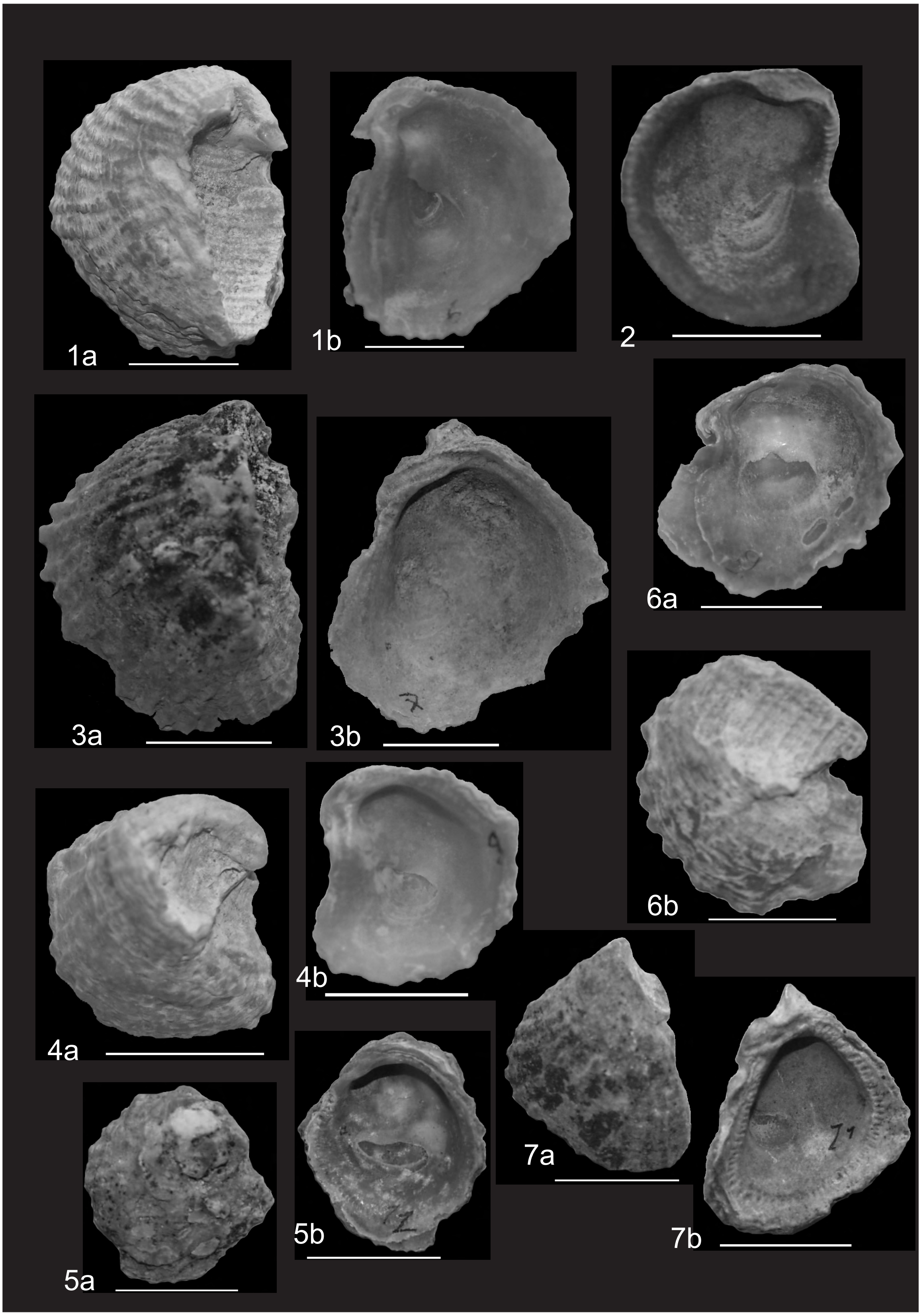
4a
4b
5b
5c

PLATE 2

All specimens are from the marl, sandstones and sandy limestones member in the Elazığ area (Sarıbuğday section). **(1–7)** *Crassostrea cyathula*, **(1a)** left valve, external view, Locality E 2-20 AUGE 07.06; **(1b)** left valve, internal view, Locality E 2-20 AUGE 07.06; **(2)** left valve, internal view, Locality E3-35 AUGE 07.10; **(3a)** left valve, external view, Locality E 2-20 AUGE 07.07; **(3b)** left valve, internal view, Locality E 2-20 AUGE 07.07; **(4a)** left valve, external view, Locality E 2-20 AUGE 07.08; **(4b)** left valve, internal view, Locality E 2-20 AUGE 07.08; **(5a)** right valve, external view, Locality E 2-20 AUGE 07.12; **(5b)** right valve, internal view, Locality E 2-20 AUGE 07.12; **(6a)** left valve, internal view, Locality E 2-20 AUGE 07.09; **(6b)** left valve, external view, Locality E 2-20 AUGE 07.09; **(7a)** left valve, external view, Locality E 3-35 AUGE 07.11; **(7b)** left valve, internal view, Locality E 3-35 AUGE 07.11 (Scale bars 10 mm).


1a
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