Lucinoma kazani n. sp. (Mollusca: Bivalvia): evidence of a living benthic community associated with a cold seep in the Eastern Mediterranean Sea

C. Salas\textsuperscript{a,\,*}, J. Woodside\textsuperscript{b}

\textsuperscript{a}Department of Biología Animal, Facultad de Ciencias, Universidad de Málaga, 29071- Málaga Spain
\textsuperscript{b}Centre for Marine Earth Sciences, Free University, De Boelelaan, 1085, 1081 HV Amsterdam, Netherlands

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Abstract

Lucinoma kazani, a new deep-water species of Lucinidae from the Eastern Mediterranean Basin, is described and illustrated. The material was collected in the Anaximander Mountains, between Rhodes and Cyprus, Eastern Mediterranean. The first living specimens were collected during the Dutch ANAXIPROBE project in the Kazan volcano, at a depth of 1709 m. Later, during the MEDINAUT programme, both living specimens and shells were collected from several mud volcanoes at different depths in the Anaximander Mountains.

This bivalve holds symbionts in the ctenidia, as do all previously studied Lucinidae. The type of habitat of this new species is gas-saturated mud, with high levels of methane, which diffuses upwards into a low-oxygen deep-water. Therefore, we consider this as evidence of a living cold seep community in the Eastern Mediterranean Sea. © 2002 Published by Elsevier Science Ltd.

Keywords: Bivalve; Lucinoma; Cold seep; Anaximander mountain; Eastern Mediterranean Sea

1. Introduction

Mud volcanoes in the Mediterranean Sea appear to have originated by tectonic compression resulting in the extrusion of methane-rich sediments (mud breccias) (Cita et al., 1996; Limonov et al., 1996; Woodside and Volgin, 1996; Woodside et al., 1998). This mud volcanism is of particular interest, because it is known that methane, stored as gas hydrates in subsurface sediments here (Woodside et al., 1998), could be released by warming of Mediterranean bottom-waters (Pancost et al., 2000). Moreover, massive eruptions at mud volcanoes could also suddenly release large quantities of methane, a potent greenhouse gas.

Trenches and accretionary prisms delimit the subduction zones, which define the edge of the African plate today. The roughly 1500 km long Mediterranean Ridge is an accretionary prism of marine sediments extending from western Greece to southern Turkey and delimited to the south by a thrust front at the southern edge of the subduction zone and to the north by the Hellenic Trench. It formed as a result of compressional forces...
generated by the subduction of the African plate beneath the Aegean plate (McKenzie, 1972; McClusky et al., 2000; Cita and Camerlenghi, 1992; MEDINAUT/MEDINETH Shipboard Scientific Parties, 2000). The collision of the African and European plates, with the subduction of the oceanic part of the African plate below Europe causes hydrothermal vents in the Aegean Sea (Dando et al., 1999) and cold seeps and mud volcanoes on the crest of the Mediterranean Ridge (Cita et al., 1996).

The limestone blocks and lenses collectively grouped under the informal name of “Calcarea Lucina” (usually abbreviated CAL in the paleontological literature) have been recently re-interpreted as constructions linked to chemosynthetic processes involving CH₄ and H₂S venting/seepage (Terzi, 1993; Terzi et al., 1994; Taviani, 1997). These megafaunal communities are dominated by bivalves, such as large lucinids together with mytilids and vesicomyids, which occur within the Miocene in the Apennine chain (Taviani, 1994, 1996; Amadesi et al., 1997; Conti and Fontana, 1997). Conti and Fontana (1998) also studied the different settings of Lucina limestones to distinguish, on the basis of the new field and compositional data, between autochthonous (primary) and allochthonous (secondary) lucinid bearing deposits. Recently such a chemosynthetic environment has been discovered in the Pliocene of the Stirone River, N. Italy (Taviani et al., 1997) and the Quaternary of the Eastern Mediterranean “Napoli Dome” (Corselli and Basso, 1996). Both of them are considered deep-water cold seep communities.

The purpose of this paper is to describe a living bivalve of the family Lucinidae collected from deep mud volcanoes in the Anaximander Mountains (Eastern Mediterranean Ridge) (Fig. 1), which holds bacteriocytes with symbiotic bacteria in the gills. This confirms the presence of a living benthic community associated with a cold seep in the Eastern Mediterranean Sea.

2. Material and methods

The first samples with living material were collected in 1996 during a combined expedition of the Dutch ANAXIPROBE project and the international Training Through Research programme aboard the Russian research vessel R/V Gelendzhik (Woodside et al., 1997). The principal objective of ANAXIPROBE was to determine the origin and subsequent development of the Anaximander Mountains by mapping and sampling them. These seamounts (Fig. 1) lie just south of southwestern Turkey between Rhodes and Cyprus, and are thought to be the southward rifted geological extension of Turkey. The sampling strategy included the coring and dredging of ejecta from a number of mud volcanoes that were discovered in 1995, as an unexpected result of a programme of detailed multibeam bathymetry (Simrad EM-12D from the French research vessel L’Atalante), which was also a part of the ANAXIPROBE project.

Two expeditions to the Eastern Mediterranean Sea to study the mud volcanism were carried out within the MEDINAUT programme in the Anaximander Mountains, following ANAXIPROBE. The first one, on the French research ship Nadir, in November and December of 1998, used the submersible Nautile to examine and take site-specific samples, confirming the association of faults, mud volcanoes, and methane release. During this cruise additional shells and valves of the new species of Lucinoma were also collected in the Anaximander Mountains. The second cruise took place in August 1999 aboard the Russian R/V Professor Logachev with the objective to take cores to greater depths than those collected by the Nautile, together with measurement of methane in the water above the mud volcanoes (MEDINAUT/MEDINETH Shipboard Scientific Parties, 2000).

2.1. Geological setting

Mud volcanoes in the Anaximander Mountains (Fig. 1) erupt a matrix-supported breccia, containing rock clasts plucked from formations lying well beneath the seafloor, and are thus a simple way of obtaining samples from the rocks forming the seamounts. The mud volcanoes are driven by gas and overpressured liquids, but it was still a surprise to discover active gas vents (and
clathrates) there, with their characteristic benthic communities (Woodside et al., 1997, 1998). Kazan mud volcano is the site where most of the material of Lucinoma sp. was collected and the only site at which living material has been found. Measured concentrations of methane in the water column just above Kazan mud volcano range from 0.1 to 0.9 μl/l (J.L. Charlou, pers. comm., 1999). According to Pancost et al. (2000), indirect evidence for methane oxidation derives from the widespread occurrence of authigenic carbonate in mud breccia samples and abundant 13C-depleted carbonate crusts at the sediment–water interface (δ13C values are as low as −95‰). In addition, multiple cores collected during the Medineth cruise, in the Eastern Mediterranean Ridge, including the Kazan mud volcano (Pancost et al., 2000), indicate that methane concentration increases with depth by as much as four orders of magnitude in the upper 1 m of the mud breccias.

Among the various sampling locations were the following four of relevance to this paper:

(1) **Kazan Mud Volcano**: Kazan mud volcano lies on the edge of a plateau in an area of rough bottom topography in the Eastern Anaximander Mountains. It has a diameter of over 2 km and a height of 40–50 m. The sample Anaxiprobe 234G was obtained from a gravity core taken on Kazan and containing about 120 cm of relatively recent mud breccia (i.e. there was no oxidized mud breccia near the surface and only a few centimetres of overlying pelagic sediments). The mud breccia was highly saturated in gas (probably methane; studies of the gas are in progress) and contained many fragments of soft sediments and hard rocks up to 7 cm in size.

(2) **Faulted Ridge**: Faulted Ridge was originally assumed to be a fault escarpment with debris flows near the base and gas seeps and mud volcanic eruptions (‘fissure’ eruption) near the top. Observations from Nautilus during the 1998 MEDINAUT expedition confirmed the presence of a fault escarpment with about 500 m of vertical rock outcrop (out of a total height of over 1000 m), a slope below the steepest upper part, and ubiquitous gas seeps on the cliff face and above. The sample Anaxiprobe 209D was taken in a dredge haul...
from the southern slope of the ridge. Although the dredge started at the bottom of the ridge in 1854 m of water and proceeded up slope to a depth of 1165 m, it is likely that the benthic community sampled was nearer the top than the bottom (i.e. closer to 1200 m in depth than to 1800 m) because (a) it was not buried deeply in the dredged mud, (b) debris flows down slope would make it difficult for benthic animals to survive lower on the slope, and (c) most of the gas seeps and the shells are on upper steps in the topography according to observations from Nautil during the subsequent MEDINAUT expedition. Moreover, along the summit of the ridge, several pockmarks and acoustic wipe-outs suggest that gas is escaping there. The ridge itself is interpreted to be fault-controlled, with gas seeps taking place along the fault at fractures in the outcrop or at bedding plains of the sedimentary rocks. Tube worms also found in dredge 209D were identified as vestimentiferans of the genus Lamellibrachia (E. Southward, pers. comm., 1996). They were attached to a large piece of rock with irregular holes running through it, which were inferred to be gas escape structures. The rock, which incorporated fragments of mollusc shells, was shown to be a methane-derived carbonate crust at the location of active gas venting. The worms were attached at one end to the walls of the holes, and the other end projected about 20 cm beyond the holes. Diagenetic pyrite was present in siltstone clasts from dredge 209D, and there was also a smell of hydrogen sulphide gas from the mud and clasts.

(3) Kula Mud Volcano: Several small mud volcanoes lie on a triangular plateau of limited extension at the northern corner of the eastern Anaximander Mountains. Kula is the largest, measuring about 1600 m across and about 100 m high. It is remarkably circular and dome shaped rather than conical. Observations from Nautil indicate that it has resumed activity in the recent geological past after a long period of dormancy. Recent mud flows are observed only over a small area about 200–300 m across at the summit. Gas hydrates were sampled from Kula mud volcano during the 1996 ANAXIPROBE expedition of R/V Gelendzhik (Woodside et al., 1997) and the 1999 MEDINAUT sampling expedition of R/V Professor Logachev, and so were shells and tube worms.

(4) Amsterdam Mud Volcano: Amsterdam is the largest mud volcano studied. It is about 3 km in diameter and rather flat, with a relief of about 20 m, except for a small actively venting parasitic cone on the western side, which has a diameter of about 350 m and a height of about 90 m. Large volumes of erupted material have flowed downhill to the south from Amsterdam to fill a small basin with over 12 km³ of mud breccia. Concentrations of methane in the water column above Amsterdam are as high as 13.5 μl/l and, gas hydrates were sampled from the central area of the mud volcano during the 1999 MEDINAUT expedition of R/V Professor Logachev.

The lucinid material was collected by different bottom sampling techniques at different locations in the Anaximander Mountains during the ANAXIPROBE Programme expedition on R/V Gelendzhik (Woodside et al., 1997). The main sampling device was a large diameter (14 cm internal diameter) gravity corer with a length of 6.6 m and a weight of about 1500 kg. The secondary sampling device was a pipe dredge with a diameter of 75 cm and a length of 1 m.

2.2. Material examined of Lucinoma kazani n. sp.

ANAXIPROBE Programme

St. 209D (35°25.90’N–30°24.55’E to 35°27.10’N–30°24.61’E; 1854–1165 m deep; Faulted Ridge): One complete shell (38.4 mm length × 35.0 mm height), selected as holotype, in MNHN, Paris.

St. 234G (35°25.73’N–30°33.64’E; 1709 m deep; Kazan Mud Volcano): One live collected specimen (37 mm length × 33.4 mm height), selected as paratype, in MNHN, Paris. Two shells (24.2 mm length × 23.7 mm; 33.7 mm length × 29.1 mm height), both selected as paratypes, in NMNH, Leiden.
MEDINAUT Programme

St. MN10 (33°43.5’N–24°41’E; 1700 m deep; Kazan mud volcano): 5 living juveniles and 90 valves.

St. MN12 (33°43.5’N–24°41’E; 1700 m deep; Kazan mud volcano): 4 juvenile shells and 33 valves.

St. MN9 (35°27.1’N–30°24.4’E; 1300 m deep; Faulted Ridge): 1 shell and 6 valves.

St. MN11 (35°26’N–30°27.5’E; 1630 m deep; Kula mud volcano): 1 valve.

St. MN13 (35°20’N–30°16.5’E; 2030 m deep; Amsterdam mud volcano): 5 valves.

Comparative material examined (all from MNHN, Paris, except where otherwise stated):

Lucinoma borealis: Palermo (Italy), coll. Lamy: 1 shell; Messina (Italy), coll. Lamy: 2 shells; Ajaccio (Corsica), coll. Jousseaume: 3 shells; Portugal, Algarve, Sagres (37°00.7’N, 08°55.0’W, 12–17 m): several juvenile specimens; Brittany, Finistère, Pointe Noire: 1 shell, leg. Gofas; Roscoff: 1 shell, leg. Gofas; Western Norway, Storres oilfield, 25–34 m: 11 specimens, leg. AKVAPLAN-NIVA Programme (Swedish Museum of Natural History, Stockholm); Azores, “Biacores” expedition st. 81 (39°00.5’N, 28°04.5’W, 142 m): 1 juvenile specimen and 1 valve.

Lucinoma ignota Locard (= L. borealis): Gulf of Cadiz (Southern Spain): 1 valve, syntype from “Talisman” 1883 sta. 2 (36°53’N, 08°32’W, 99 m).

Lucinoma filosa (Stimpson, 1851): Philadelphia: 1 shell, leg. Cope; South of Newfoundland, 323–322 m: 7 shells, leg. von Cosel.

2.3. Preparation for SEM observation

To observe the location of the bacteriocytes in the ctenidia and the bacterial morphology by scanning electron microscopy (SEM), small pieces of gills of L. kazani and of L. borealis were taken. The gill tissues were washed in distilled water and dehydrated through a graded ethanol series; the samples were then critical-point dried. After this, the pieces of gills were mounted on stubs, coated by argon sputtered gold-palladium, to be viewed in the SEM and photographed.

The qualitative and quantitative compositional analysis were carried out in a JEOL JSM-6400 scanning electron microscope, with LINK ANALITICAL 6508 electronic microsonde and with LINK ANALITICAL EXL for the detection of light elements and microanalysis. For the elemental analysis, the pieces of gills were coated by argon sputtered silver instead of gold, because the peak generated by gold would mask the sulphur peak in the spectrum.

3. Systematics

3.1. Family Lucinidae

Genus Lucinoma Dall, 1901

Type species: Lucina filosa Stimpson, 1851, by original designation.

The species collected in the Anaximander Mountains is referred to the genus Lucinoma, a taxon originally introduced as subgenus of Phacooides Blainville 1825. Shells are usually large, lenticiform, concentrically lamellose or striated and with periostracum. The cardinal teeth are well developed, with 2a (LV) and 3b (RV) bifid; the lateral teeth are obsolete or absent. The inner margin is entire, and there is no pallial sinus.

In European waters, the genus Lucinoma is represented by only one species L. borealis (Linné, 1767), which ranges from the north of Norway (Høisaeter, 1986) to Morocco (Pasteur-Humbert, 1962) and Mauritania (Cosel, pers. comm.), and into the Western Mediterranean, where it is rare (Lamy, 1920, p. 198). There are no records from the Eastern Mediterranean even in the better surveyed areas such as the Levantine coast (Barash and Danin, 1992), Greece (Zenetos, 1996), or Malta (Cachia et al., 1993).

3.2. Lucinoma kazani new species (Figs. 2 and 3, 6–8, 12–14 and 17)

Type material: Holotype: One shell (38.4 mm length × 35.0 mm height), from ANAXIPROBE 96, St. 209D, deposited in Muséum National d’Histoire Naturelle, Paris, (MNHN). Paratypes: a live collected specimen (37 mm length × 33.4 mm height) from ANAXIPROBE 96, St. 234G, deposited in MNHN; two shells (24.2 mm length × 23.7 mm height; 33.7 mm length × 29.1 mm height)
from ANAXIPROBE 96, St. 234G, deposited in National Museum of Natural History, Leiden.

**Type locality**: Anaximander Mountains, south of southwestern Turkey, Eastern Mediterranean Sea (35°25.90'N–30°24.55'E to 35°27.10'N–30°24.61'E; 1854–1165 m deep).

**Description**: Shell medium-size, convex, thick and solid, equi-valve. Outline subcircular, slightly longer than high; inequilateral. Posterior margin curved, antero-dorsal margin forming an obtuse angle, ventral margin gently curved. Umbos somewhat prominent directed inwards and proso-gyrous, just in front of the vertical midline. A
Slight and ill-defined radial depression from the beginning of ligament to the postero-ventral corner and another one less defined, almost parallel to the anterior dorsal margin.

Sculpture of fine and irregularly spaced concentric lamellae, more prominent near the ventral margin. Outer surface of shell white. Periostracum thin, cream on the umbos, brownish-beige from
the middle part of the valve to the margins. Ligament external, long and sunken, reaching almost to the posterior margin. Escutcheon not visible. Lunule well delimited, lanceolate, \( \approx 2/3 \) the length of the anterior dorsal margin and brownish in colour.

Prodissococonch semicircular, relatively large (240 \( \mu \)m in diameter) without particular sculpture and very eroded by the reduced environment (Fig. 8).

Hinge plate relatively narrow, slightly curved. Right valve with two cardinals, the anterior (3a) simple and the posterior (3b) bifid; one small knob-like anterior lateral (Ia); posterior lateral obsolete. Left valve with two cardinals, the anterior one (2a) bifid and the posterior one (4b) simple; a knob-like anterior lateral (IIa), rather prominent; posterior lateral obsolete.

Well delimited adductor muscle scars; the anterior one longer than the posterior one and relatively large, with the proximal part sunken in the hinge plate, under the anterior lateral; and with a rather long ventral extension, slightly diverging from the pallial line. Posterior adductor scar subelliptical in outline. Small and elliptical anterior pedal muscle scar, close to the anterior front of the anterior adductor muscle scar. Pallial line
well defined and beginning near the anterior border of the anterior adductor scar. Inside of the shell white, with oblique scars about the middle of the valves, and with slight ridges reflecting the exterior depressions of the shell.

Inner margin of the valves smooth. Long and fine pallial blood vessel impressions, crossing obliquely the valves from the postero-dorsal to the antero-ventral side.

**Anatomy:** An elongated cylindrical foot, with a small posterior heel, is present.

Ctenidia large and thickened, composed only of the inner demibranchs. Labial palps minute. Fig. 12 (SEM level) shows a transversal section in part of the large demibranch of *L. kazani* with the bacteriocytes, which contain the intracellular symbionts. These can be observed in Fig. 13 as bulges set very close each other. Fig. 14 shows one open bacteriocyte, in which the intracellular symbionts (bacteria) can be observed. The size of the observed bacteria ranges between ca. 1 and 3 µm, showing different shapes, from round to elliptical forms. The qualitative and quantitative compositional analysis of some of these symbionts from different bacteriocytes (Table 1) shows a percentage of organic carbon higher than 90% and a percentage of sulphur lower than 1%, thus indicating that they are living organisms and not sulphur deposits. The symbionts are smaller than the cystine-rich granules (up to 6.5 µm) described in *Codakia orbicularis* by Frenkiel and Mouëza (1995).

No mantle gills, either near the anterior adductor or near a mantle septum, have been observed. Mantle edge smooth along most of its extension, fused only a short distance anterior to the inhalant aperture. The mantle folds are blunt and bear a single row of minute papillae on each side of the inhalant aperture; there are no papillae around the exhalant aperture (Fig. 17). The “exhalant siphon” (according to the terminology of

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Allen, 1958) is retracted, giving the appearance of a funnel turned inwards on the preserved specimen.

Distribution: The species is known only from the Anaximander Mountains, Eastern Mediterranean Basin.

Habitat: The live specimens were taken on the Kazan mud volcano at a depth of 1700–1709 m, in a mud breccia deposit that was highly saturated in gas and contained many fragments of soft sediments and hard rocks up to 7 cm in size. Other shells and valves were dredged from the southern slope of Faulted Ridge, a fault escarpment exposing several hundreds of metres of vertical rock outcrop with gas seeps evident at bedding planes and fractures. They were found, in the upper part of a dredge haul which started at a depth of 1854 m and finished at 1165 m, in rocks with irregular holes running through them, which were inferred to be authigenic carbonates with gas escape structures.

Etymology: The name refers to the Kazan mud volcano in the Anaximander Mountains, the mud volcano at which living specimens were found (Figs. 2 and 3, 6–8, 12–14 and 17).

4. Discussion

4.1. Taxonomic comparison

The shell of *L. kazani* resembles that of *L. borealis* (Figs. 4–5, 9–11), but the umbos are more prominent and directed more inwards and forwards; the lunule is distinctly broader and better delimited; the hinge plate is slightly larger and less curved than in *L. borealis*. The hinge is also different, *L. kazani* having a rather prominent, knob-like anterior lateral in each valve, whereas these are obsolete in *L. borealis*. Another important difference is the anterior adductor scar, which is broader in *L. kazani*, with the proximal part nearly twice the size of a *L. borealis* of comparable size. Moreover, the angle between the ventral extension of the anterior adductor and the pallial line is greater (ca. 25°) than in *L. borealis* (ca. 15°). We have examined the figured syntype of *Lucina ignota* Locard, 1898, described from the Gulf of Cadiz (Southern Spain) and agree with Lamy (1920) that it is *L. borealis*.

The gills of the two species seem to be different, *L. kazani* having shorter and larger ctenidia than *L. borealis* (Fig. 15). However, according to Hentschel et al. (2000), the phenotype of the gills of the *Lucinoma aequizonata* changes, in colour and size, in relation to their ability to dispose of sulphur from the environment. So, it could be that the phenotypic differences of the gills between *L. kazani* and *L. borealis* were related to their nutritional condition. Both species hold symbionts in bacteriocytes, inside the ctenidial cells, but the bacteriocytes are set very close together in *L. kazani* (Fig. 13), whereas in *L. borealis* they are more separated by intercalary cells (Fig. 16).

The labial palps of *L. kazani* are smaller than those of *L. borealis*, but the feet in the two species are rather similar, with a moderately pronounced heel.

The posterior apertures, derived from the fusion of the inner folds of the mantle, are different. The inhalant aperture in *L. kazani* shows extremely small papillae in both sides of the middle fold (Fig. 17), but in *L. borealis* there are large papillae, as illustrated by Allen (1958, p. 434) and confirmed on our specimens from Norway. Moreover, the mantle folds in *L. borealis* are large and appressed to each other, whereas in our specimen of *L. kazani* these are blunt and remain apart on either side of the aperture. The exhalant apertures are more similar in the two species; they have no papillae and appear as a funnel with a rounded aperture, directed inwards on the fixed specimens but capable of being stretched out a long distance in living specimens (Allen, 1958, p. 438). However, the extension of the exhalant aperture along the margin is greater in *L. borealis*.

The habitats of the two species are also quite different. According to Jeffreys (1863), *Lucinoma borealis* in the British Isles lives in muddy gravel and sand, from spring tide low-water mark to 82 fathoms (ca. 150 m), and in one locality off the Mull of Galloway in 110–145 fathoms (ca. 200–265 m). Allen (1958) reports this species from *Zostera* beds at low-water mark in the Roscoff area, France, and in the sublittoral zone (Plymouth Sound, Firth of Clyde, and Bay of
Mentone, British Isles). Dando et al. (1986) found *L. borealis* in *Zostera* beds at shallow depth, in medium sand sediment (Salcombe estuary, south coast of Devon), in fine sand (Yealm estuary), and in muddy sediments and black mud (Plymouth Sound). The species is very abundant in fjords (Tunberg, 1984), in coarse shell sand and in silty fine sand at shallow depth. Along the West coast of Brittany (France), *L. borealis* may reach densities of 1500 specimens per m² in some seagrass beds (Monnat, 1970, cited in Le Pennec et al. 1988). There are records from deep water (Dautzenberg and Fischer, 1906: 1530 m) from the Azores; however, these are based on valves collected around volcanic islands with very steep slopes, and specimens have been carried downslope. Conversely, *L. kazani* is a genuine deep-water species, with living specimens collected in bathyal depths.

Among the species of lucinids indicated from the different Italian "Calcari a Lucina" deposits (Conti, 1997), *Dentilucina persolida* Sacco, 1901, from the flysch deposits of Outer Marnoso-Arenacea (proximal facies), Parma Foothills, resembles *Lucinoma kazani* in outline and sculpture, but the anterior adductor muscle scar of *D. persolida* shows greater similarity to that of *Lucinoma borealis*, being longer, narrower and more parallel to the pallial line than the anterior adductor muscle scar of *L. kazani*.

Corselli and Basso (1996) found a Quaternary cold seep Molluscan thanatocoenosis on the top of the Napoli Dome, a mud volcano located on the Eastern Mediterranean Ridge, at about 1950 m depth. The valves collected have been identified by the authors as *Myrtea* sp. (Lucinidae), *Vesicomya* sp. 1 and *Vesicomya* sp. 2 (Vesicomyidae), belonging to two families typical of cold seep communities. However, they mention that though living specimens might be present, they were not actually found on the Napoli Dome.

4.2. *Symbiosis in Lucinidae*

The presence of symbiotic sulphide-oxidizing bacteria in all the species of Lucinidae that have been investigated (Felbeck et al., 1981; Cavanaugh, 1983; Berg and Alatolo, 1984; Fisher and Hand, 1984; Schweimanns and Felbeck, 1985; Dando et al., 1985, 1986; Reid and Brand, 1986; Distel and Felbeck, 1987; Cary et al., 1989; Hickman, 1994) has stimulated interest in the basic biology of living lucinids and in their phylogeny. According to Taylor and Glover (2000) bacteria have been reported from at least 30 species of Lucinidae, representing 18 different genera from several clades.

Dando et al. (1985) have found that *Lucinoma borealis*, *Myrtea spinifera* (Montagu, 1803) and *Thyasira flexuosa* (Montagu, 1803), living in a community with the pogonophoran *Siboglinum fiordicum* Webb, had enzymes characteristic of the symbiosis in their ctenidia. Subsequently, Dando et al. (1986) studied the gills of *L. borealis* and observed the presence of numerous prokaryotes in specialized cells in the subfilamental region of the gills, together with high concentrations of elemental sulphur and of a c-type cytochrome. Recently, Gros et al. (2000) have described sulphur-oxidizing endosymbiosis in the lucinid *Divaricella quadrisculeata* (d’Orbigny, 1842), from Guadeloupe Island.

Bacteria from the ctenidia of *Lucinoma borealis*, *Myrtea spinifera*, *Thyasira flexuosa* and *T. sarsi* (Philippi, 1845) were isolated and cultured by Wood and Kelly (1989). The bacteria were either autotrophs, obtaining energy from oxidation of inorganic sulphur compounds or methylotrophs, using methanol or methylamine as the source of carbon and energy. Wood and Kelly proposed that these bacteria are symbiotic with the animals, but Hickman (1994) pointed out that the authors were unable to demonstrate that the bacteria were housed within the ctenidia. On the other hand, Cary et al. (1989) indicated that cultivations in vitro of the symbionts were not successful, and symbiont-free hosts were not yet available.

This metabolic pathway and the methane-trophic nature of the symbionts have been demonstrated only for a seep-mussel from the Louisiana slope (Fisher et al., 1987). These authors tested a variety of animals from the same area, which harbour chemosynthetic bacteria (the seep-mussel, 2 vestimentiferans, 1 pogonophoran, 2 vesicomyids and 1 lucinid), for the presence of methanol dehydrogenase activity, and only the gill
tissue from the mytilid contained detectable levels of this enzyme; therefore, only the mytilid symbionts are capable of methylotrophy.

The presence of symbionts in the ctenidia of the new species (Figs. 12–14) is consistent with: (1) all the studied Lucinidae, which are symbiotic with sulphur-oxidizing bacteria (Reid and Brand, 1986; Hickman, 1994); in particular _L. borealis_ (Dando et al., 1985, 1986; Wood and Kelly, 1989); (2) the habitat of this new species, gas-saturated mud with inferred or observed high levels of sulphide and low-oxygen deep-water, is usually occupied by symbiotic organisms, including the lucinids. In this case the gas released upwards in the Kazan mud volcano is methane (J. L. Charlou, 1999, pers. comm.), but in most cases the methane appears to be associated with the zone of sulphate reduction, resulting in the generation of inorganic carbon and hydrogen sulphide. Such geochemical profiles are expected if methane is oxidized by a consortium of methanogens and sulphate-reducing bacteria (Pancost et al., 2000). Moreover, the cores obtained during the 1999 Medineth cruise on the Eastern Mediterranean Ridge indicate that sulphate reducers are abundant and active in the sediments from mud volcanoes (Pancost et al., 2000); and (3) the presence in the community of vestimentiferans, which are obligate symbiotic metazoans (Childress et al. 1984; Fisher and Childress, 1984; Jones, 1985), typical of cold seep and vent communities.

Therefore, the occurrence of living endosymbiont-bearing organisms, such as _Lucinoma kazani_ described here and Vestimentiferans (studies in progress by E. Southwards, pers. comm.) in the Anaximander Mountains is evidence of a living cold seep community in the Eastern Mediterranean basin.

Extant faunal assemblages that are specific of hydrothermal vents have not been found to date in the Mediterranean, although fossil hydrothermal vent fauna are reported in ancient massive sulphide deposits on Cyprus (Dando et al., 1999). Recent hydrothermal sites in the Mediterranean are scattered and situated in shallow water (<200 m). It is likely that the animals which normally inhabit the nearshore reducing sediments are unable to tolerate the prevailing high temperatures, salinities, and sulphide and metal concentrations around the vents (Dando et al., 1995; Thiermann et al., 1997). Therefore, living chemosymbiotic communities in the Mediterranean seem to be restricted to cold seep environments (such as found in the Anaximander Mountains, present paper) or shallower reducing sediments (such as the substrate of marine sea grasses).

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