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Kiss of death of a hunting fish: trace fossil *Osculichnus labialis* igen. et isp. nov. from late Eocene – early Oligocene prodelta sediments of the Mezardere Formation, Thrace Basin, NW Turkey

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ABSTRACT:

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The trace fossil *Osculichnus labialis* igen. et isp. nov. occurs as hypichnial pairs of uneven bilobate mounds in early Oligocene prodelta sediments of the Thrace Basin. *Osculichnus* is generally elliptical or crescentic in outline and has two lip-like lobes: a smaller and a larger one, which are separated by an undulate furrow. Herein, it is interpreted as a hunting trace (praedichnion) of a fish penetrating a surficial sand layer and into an underlying mud horizon. The fish hunted for small endobenthic bivalves and perhaps other invertebrates such as polychaetes. Penetration into surficial mud rather than sand resulted in poorly preserved variants of this trace fossil, whose median furrow is commonly not visible. The probability of fish trace makers is supported by experiments.

Key words: *Osculichnus labialis*; Ichnology; Ichnotaxonomy; New taxa; Praedichnia; Predation; Eocene; Oligocene; Thrace Basin; Turkey.

INTRODUCTION

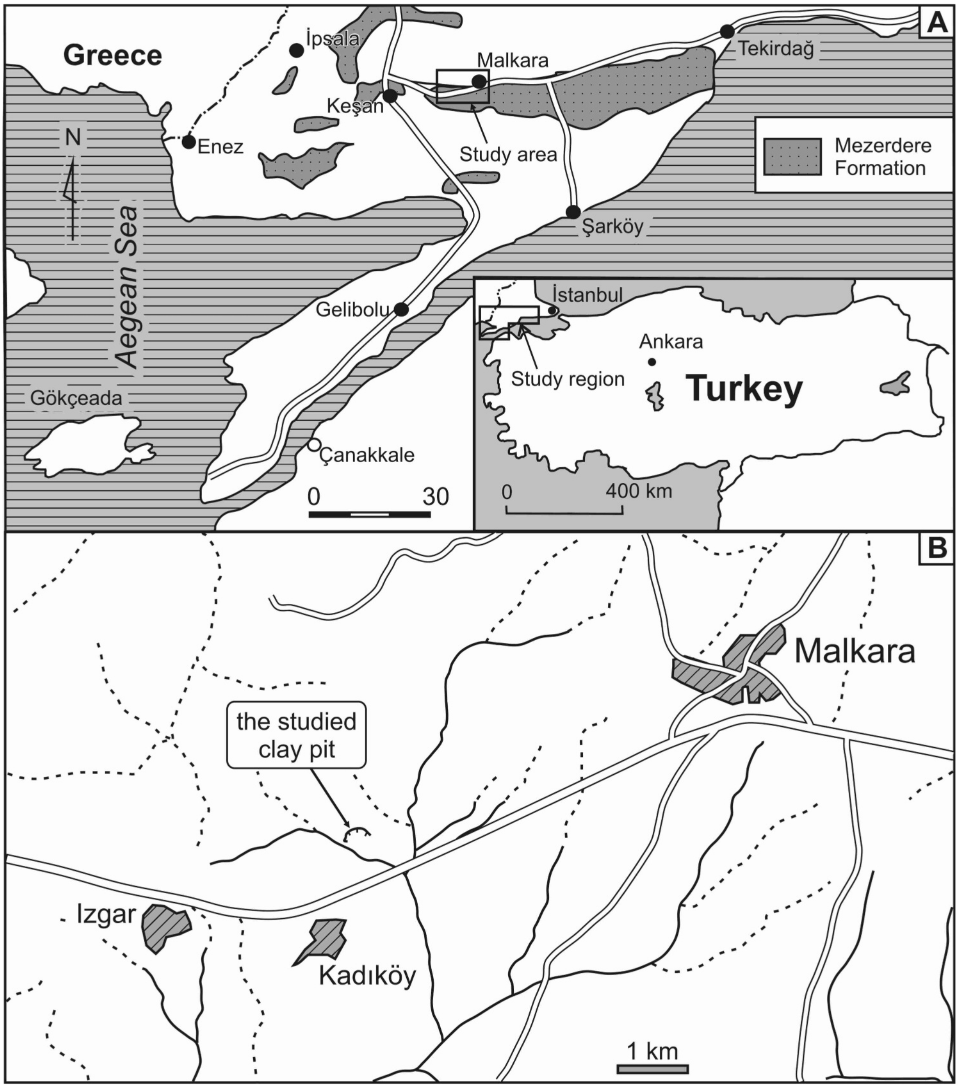
Benthic fishes are known for their diverse trace-making activity. Examples including resting traces (Seilacher 1953), large predation depressions (Gregory *et al.* 1979), deep, domichnial burrows (e.g., Stanley 1971; Able *et al.* 1987; Boyer *et al.* 1989; Atkinson and Taylor 1991) and shallow feeding depressions (Pearson *et al*. 2007) have been described from recent environments. Swimming trails *Undichna* Anderson, 1976 have been common since the Devonian (e.g., Trewin 2000; Gibert 2001; Soler-Gijón and Moratalla 2001). Another swimming trail, *Parundichna* Simon *et al.*, 2003, occurs rarely in the Triassic, and *Broomichnium* Benner *et al.*, 2008 occurs in the Pleistocene and probably in the Permian. Less common are pot-like feeding burrows *Piscichnus* Feibel, 1987 attributed to rays (Gregory 1991), which are known since the Late Cretaceous (Martinell *et al.* 2001 and references therein).

Deltaic sediments of the Mezardere Formation in the Thrace Basin near Malkara, NW Turkey (Text-fig. 1), contain bilobate trace fossils that can be attributed to hunting fishes. Their description and interpretation are the main objectives of this paper.

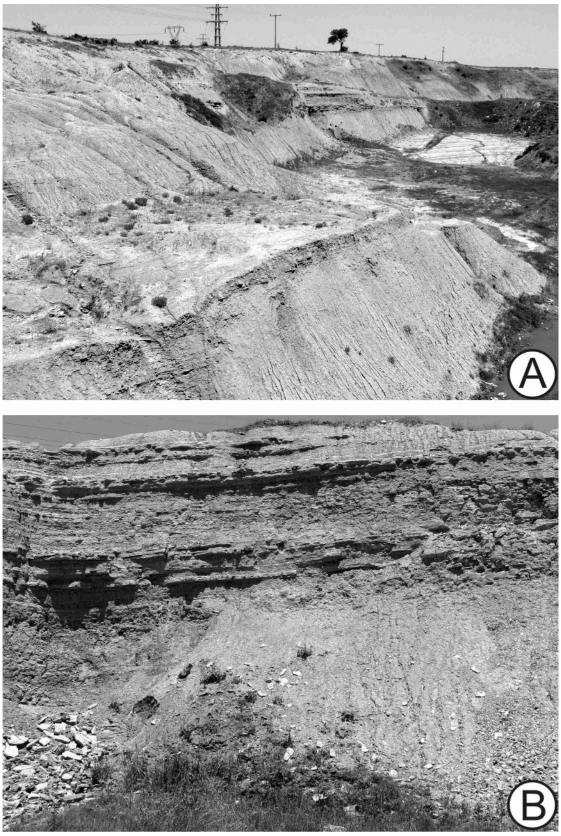
Geological setting

The Thrace Basin, located in the European part of Turkey, is filled with 9000 m of thick Eocene-Miocene deep-sea to shallow- and non-marine, mostly clastic sediments (e.g., Turgut *et al.* 1983; Turgut and Eseller 2000). The Yenimuhacir Group (upper Eocene to Oligocene), composed mostly of deltaic sediments, is part of the basin fill. It is subdivided into the Mezardere, Osmancık, and Danişment formations (Siyako 2006; Siyako and Huvaz 2007). The Mezardere Formation, named by Ünal (1967), is the lowest unit of the group and is dated to the late Eocene – early Oligocene on the basis of nannoplankton and palynomorphs. The unit is a 500–2500 m thick sequence composed mostly of mudstone shales, siltstones and rare sandstones. The Mezardere Formation is overlain by sandy flysch of the Keşan Formation (middle to upper Eocene) and shale to sandy flysch with tuffites of the Ceylan Formation (upper Eocene). The Ceylan Formation is overlain by delta front sediments with coal, limestones and volcanics of the Osmancık Formation (Siyako 2006).

The studied section occurs in a clay pit west of Malkara (GPS co-ordinates: N50°52′14.9″, E026°50′21.2″; ±5 m) north of the main road from Istanbul to Thessaloniki (Text-figs 1, 2A). The upper 20 m of the Mezardere Formation is exposed here. The section is composed mostly of light grey calcareous mudstones and siltstones. In the middle of the section two packages of coarsening and thickening upwards sandstones are interbedded with siltstones and mudstones,



Text-fig. 1. Location maps. **A** – The study region and its location in Turkey. Distribution of the Mezardere Formation adopted from Siyako (2006). **B** – Detailed map with location of the outcrop



Text-fig. 2. The main outcrop of the Mezardere Formation west of Malkara. **A** – general view. **B** – Highwall about 5 m tall. The beds at the top contain *Osculichnus*

which have been interpreted as distal mouth bars. Locally, packages of lenticular beds indicate filling of small channels. The overall sedimentary character and previous interpretations suggest a prodelta environment.

The trace fossils occur at the top of the outcrop in parallel- and cross-laminated fine-grained 2.5–5 cm thick, tabular sandstone beds (Text-fig. 2B). Sandstone beds from the lower and middle part of the outcrop are barren of trace fossils and display flat bases.

Additionally, a few specimens of the described trace fossil have been found to the west of the main outcrop, in a road cut section on the main Istanbul – Thessaloniki road, close to Yenimuhacir village (GPS coordinates: N40°51′49.2″, E026°45′16.0″; ±5 m).

DESCRIPTION OF THE TRACE FOSSIL

Osculichnus igen. nov.

TYPE AND ONLY ICHNOSPECIES: *Osculichnus labialis* isp. nov.

DERIVATION OF NAME: Latin *osculare* – to kiss; *ichnos* – latinised Greek *ikhnos* – trace.

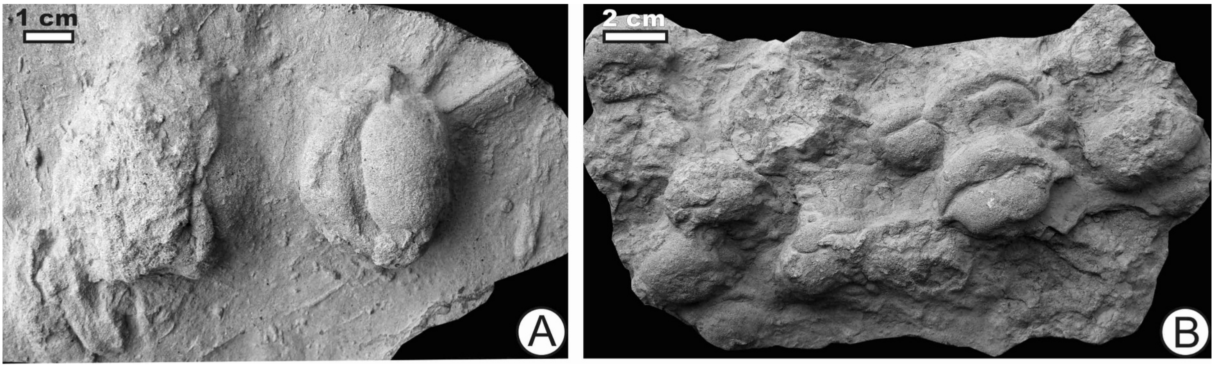
DIAGNOSIS: Hypichnial, bilobate mounds, generally elliptical or crescentic in outline, having a smaller and a larger, lip-like lobe separated by undulate furrow. Deviations from this morphology are common.

DISCUSSION: The diagnosis concerns well preserved specimens. In poorly preserved specimens, the median furrow is not visible, and such specimens cannot be related to *Osculichnus* when they occur alone without connection to well preserved specimens.

Osculichnus labialis isp. nov.
(Text-figs 3–6)

DERIVATION OF NAME: Latin *labialis* – labial, pertaining to the lips.

MATERIAL: 56 specimens on 49 slabs housed in the Museum of Natural History of the General Directorate



Text-fig. 3. Types of *Osculichnus labialis* igen. et isp. nov.; hypichnial in fine-grained sandstone. A – holotype in the right side; the larger lobe is probably slightly displaced, Tr19. B – a slab with several specimens of different preservation, with the paratype in the middle right side (lips-like specimen), Tr22

Specimen	Maximum width of the narrower lobe	Maximum width of the wider lobe	Length
Tr12a	11	14	44
Tr12b	13	17	46
Tr12c	11	14	48
Tr12d	9	12	41
Tr16	10	18	33
Tr18a	9	14	29
Tr19, holotype	12	14	44
Tr21a	17	28	38
Tr21b	19	29	35
Tr22, paratype	13	28	44
Tr24	10	14	34
Tr25	6	17	40
Tr27	15	19	41
Tr28	11	17	43
Tr29	10	13	22
Tr32	8	10	35
Tr33	5	20	32
Tr93	11	14	44
Tr95	5	20	34
Tr97	10	17	41
Tr98	11	24	39
Tr99	9	20	30
Tr101	8	17	41
Tr102	7	13	29
Tr103	9	19	39
Tr105	6	19	41
Tr107	5	16	29
Tr108	8	16	37
Tr110	8	19	32
Tr111	4	17	34
Specimens without the lobe divide			
Specimen	Total width		Length
Tr8a	25		31
Tr8b	15		26
Tr9	44		48
Tr11	23		34
Tr15	25		35
Tr18b	24		34
Tr26a	22		40
Tr26b	20		41
Tr30	25		31
Tr94	19		35
Tr96	30		43
Tr100	18		36
Tr104	20		31
Tr106	25		41
Tr109	26		40
Tr112	25		35

Table 1. Morphometric parameters of *Osculichnus labialis*. All values in millimetres

of Mineral Research and Exploration in Ankara (institutional abbreviation Tr, specimens Tr1-Tr32; Tr93-112).

TYPES: Holotype – Tr19 (Text-fig. 3A); paratype Tr22 (Text-fig. 3B).

DIAGNOSIS: As for the ichnogenus.

DESCRIPTION: Well preserved specimens including the types are hypichnial, bilobate mounds, generally elliptical or crescentic in outline, having a smaller and a larger, lip-like lobe. The lobes are separated by a narrow, undulate, fissure-like furrow. This trace fossil has been found in fine-grained, slightly muscovitic sandstone beds that are 20–35 mm thick. They are massive, parallel-laminated or poorly cross-laminated. On upper surfaces of some sandstone beds, oval, shallow depressions can be seen. These are epichnial expressions of the trace fossil.

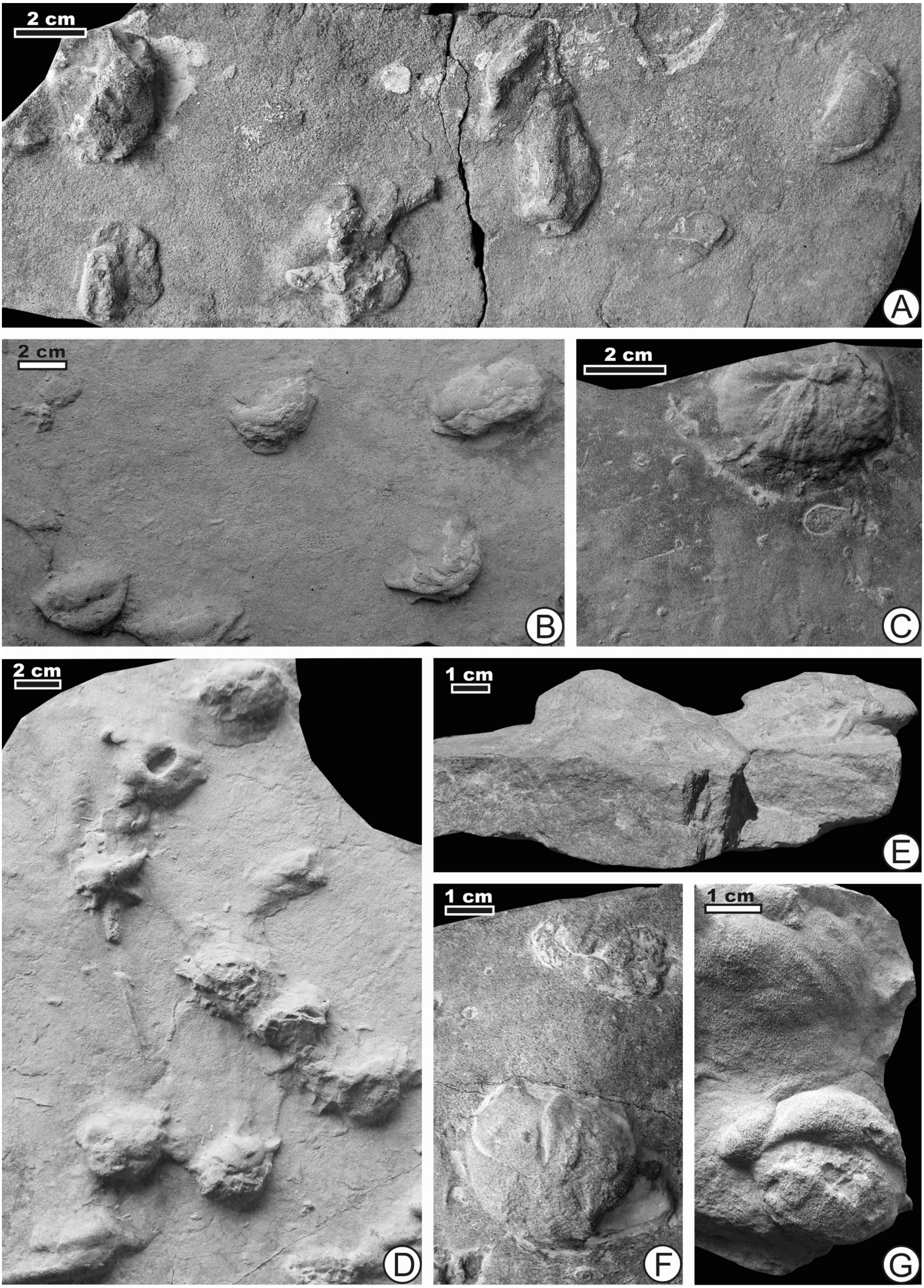
The maximum width of the narrower lobe ranges from 5 to 19 mm, mostly from 9 to 13 mm (mean = 11 mm; n = 17). The maximum width of wider lobes ranges from 10 to 29 mm, mostly from 14 to 20 mm (mean = 17.5 mm; n = 17). Total length of mounds range from 22 to 48 mm, and mostly between 21 to 44 mm (mean = 37 mm; n = 26). The mounds are up to 20 mm high. For morphometric parameters see Table 1.

Sides of the lobes are generally smooth; however, wider lobes of some specimens may display up to at least 8 semicircular ribs running down the side (Text-fig. 4C). Therefore margins of the lobes are sinuous. The ribs are 2–3 mm wide. In other specimens 3–6 protrusions of the lobe can be seen from one side (Text-figs 6A, B). They are up to 6 mm wide, become narrower distally and plunge into the bed. Some sides display larger, irregular protrusions (Text-fig. 4A). The sides are gentle to steep; some are overhanging (Text-fig. 4E).

The central part of some mounds displays a small elliptical lobe (knob) that interrupts the median furrow (Text-fig. 4C). The lobe is elongated along the run of the furrow. Tips of the lobes in the prolongation of the middle furrow are slightly protrusive. Some of them display semicircular, straight or curved ribs that are about 1.5 mm wide.

Many specimens are less irregular, in that the median furrow cannot be recognized (Text-figs 3B, 4A).

Text-fig. 4. Morphological variability of *Osculichnus labialis* igen. et isp. nov.; hypichnial in fine-grained sandstone. **A, B** – poorly preserved specimens; note their concordant orientation; Tr33 and Tr12, respectively. **C** – a specimen with an apical knob and side ridges, Tr33. **D** – specimens arranged in a row; Tr14. **E** – lateral view of two specimens (up-side down); the right one shows overhang margin; Tr16. **F** – a specimen with radial lobes, which are probably slightly displaced due to rotation movement of the tracemaker; at the top a fragmentary preserved specimen Tr30. **G** – a specimen with a widely separated lobes in the lower part and much poorly preserved specimen in the upper part, Tr103


2 cm
A
2 cm
B
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C
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1 cm
E
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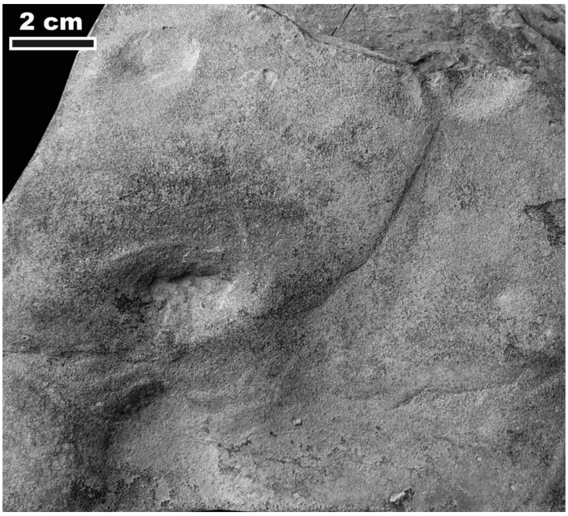


Text-fig. 5. Probable *Osculichnus labialis* igen. et isp. nov. at the top sandstones seen as depressions, Tr17

In some, an apical, elongate depression can be seen (Text-fig. 4D). In other, more rounded specimens, three or more partly overlapping and twisted lobes occur (Text-fig. 4F). At the foot of some mounds, a gently sloping fringe can be seen (Text-figs 4A, C). The overall shape of these specimens and their close association with well preserved specimens points to their having a common origin.

In some specimens, a discontinuity can be seen between the lobes (mostly one lobe) and of the hosting bed surface, between the lobes and the median furrow, or between the fringe and the bedding surface (Text-fig. 3A). The discontinuity suggests a small displacement of these elements related to overthrusting by pushing during tracemaker action.

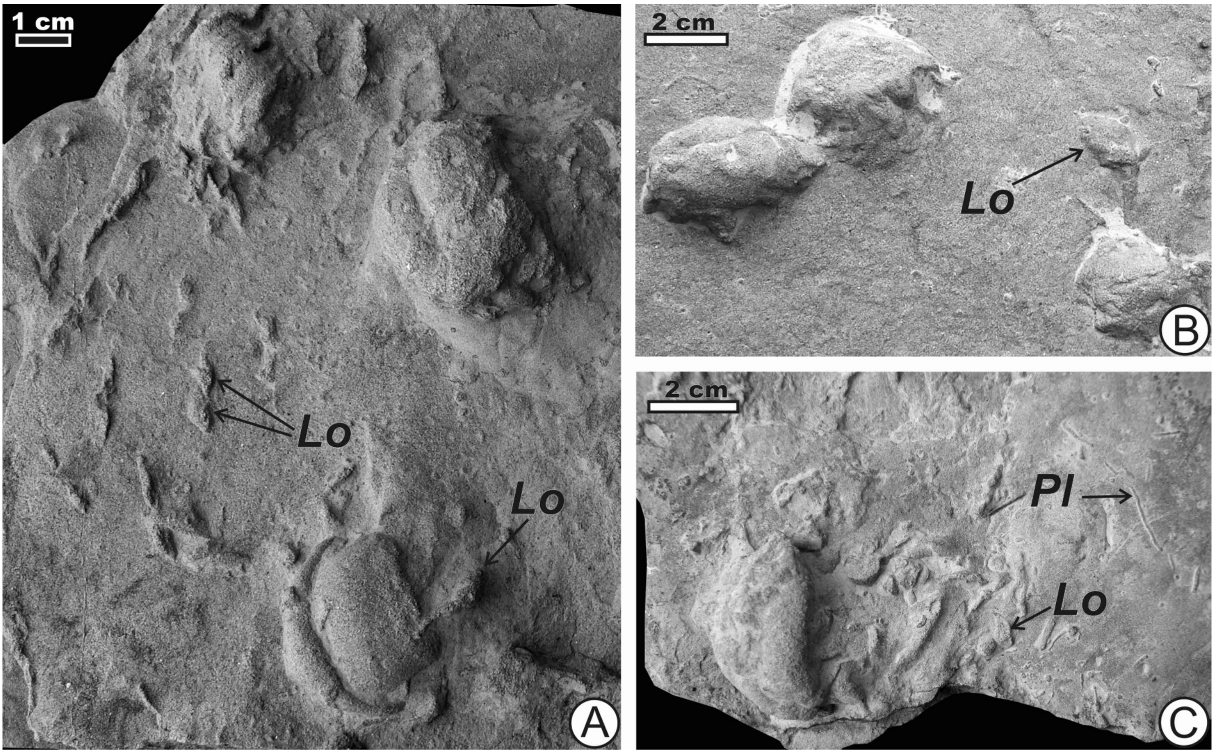
In one slab a few *Osculichnus* are arranged in curved rows, in which centres of the trace fossils are 30–40 mm apart (Text-fig. 4D). Longer axes of specimens in larger slabs are oriented in the same direction (Text-figs 3B, 4A, B, 6A).

Shallow, epichnial depressions are present in one slab (Text-fig. 5). Their size, and to a lesser extent their shape, correspond to *Osculichnus labialis* isp. nov. These depressions are probably epichnial variants of this trace fossil.

DISCUSSION

Comparison with other trace fossils

Bergaueria elliptica Orłowski and Żylińska, 1996 known from the shallow-marine Upper Cambrian sandstones of central Poland displays similar overall shapes, and the lobes are more or less of the same



Text-fig. 6. *Osculichnus labialis* igen. et isp. nov. and associated trace fossils; hypichnial in fine-grained sandstone. **A** – several specimens of *Lockeia* isp. (*Lo*), Tr21. **B** – a larger specimen of *Lockeia* isp. (*Lo*). **C** – *Planolites* isp. (*Pl*) and *Lockeia* isp. (*Lo*), Tr32 width and minor morphological features (ribs, protrusions) are not present. This is an atypical *Bergaueria* because of its longitudinal median furrow. Some specimens of *Bergaueria prantli* Książkiewicz, 1977 also display an apical furrow, but the division into two lobes as in *Osculichnus* is not evident. Ascription of this ichnospecies to *Bergaueria* has been questioned (Uchman 1998). *Bergaueria* Prantl, 1945, typified by *B. perata* Prantl, 1945, displays an apical depression; it is ascribed to actinian anemones (Pemberton *et al.* 1988).

Cardioichnus Smith and Crimes, 1983, typified by *C. planus* Smith and Crimes, 1983 and produced by irregular echinoids, displays symmetrical lobes separated by a wide furrow. This is also so for *C. reniformis* Mayoral and Muñiz, 2001.

In addition, *Rusophycus* Hall, 1852, typified by *R. biloba* (Vanuxem, 1842) and produced by trilobites, displays symmetrical, cleft lobes that are covered by oblique scratch casts. The same is true of other ichnospecies of *Rusophycus*.

We are not aware of any ichnotaxa that are more similar to *Osculichnus* than the discussed trace fossils, and hence a new ichnogenus and ichnospecies is erected.

Associated trace fossils

The only two trace fossils typically associated with *Osculichnus labialis* are *Lockeia* and *Planolites*. *Lockeia siliquaria* James, 1879 occurs as small, hypichnial amygdaloidal mounds, pointed at both ends, with one side more acute and the other side more obtuse (Text-fig. 6A–C). Most are 5–6 mm long and 3–4 mm wide; larger specimens may be up to 11 mm long and 7 mm wide. Some of the smaller specimens are arranged in series. The best-preserved specimens derive from a road-cut on the main road between Istanbul and Thessaloniki, a few kilometres east of the main outcrop with *Osculichnus*. *Lockeia* is produced by bivalves (Seilacher and Seilacher 1994).

The other trace fossil is *Planolites* isp. (Text-fig. 6C), which is seen as hypichnial, straight to slightly winding, semi-circular, smooth ridges that are 1–2 mm wide. In some cases the ridge terminates at the margin of an *Osculichnus* lobe. *Planolites* is an actively filled burrow (pascichnion) that occurs in many environments and is probably produced by a number of different organisms (Pemberton and Frey 1982; Keighley and Pickerill 1995).

The trace fossil assemblages are of very low diversity but this is a common characteristic of deltaic environments (e.g., Gingras *et al.* 1998). The high sedimentation rate and input of fresh, commonly turbid waters are the main stress factors. In such conditions, many tracemakers, especially stenohaline and filter-feeding organisms, are excluded.

The puzzle of the tracemaker

Because of consistently uneven size of the lobes, neither actinians producing *Bergaueria* nor irregular echinoids producing *Cardioichnus* can be considered tracemakers of *Osculichnus labialis*. Some crustaceans penetrating obliquely in the sediment can be considered, but traces reflecting digging action of their legs should be registered in the sediment, considering the preservation of other trace fossils, and this signature is not present. It is inferred that *Osculichnus labialis* has been produced by the mouths of fish hunting small prey in the sediment. The uneven size of the lobes and the crescentic shape could result from the jaws' shape and oblique penetration of the sediment. The narrower lobe can be related to the upper jaw and the wider lobe to the lower jaw. The "rib and appendage" sculpture of *Osculichnus* could be incomplete imprints of barbels, which are common sensor organs in many fish species. The most distinct traces were evidently produced when the fish's mouth penetrated through the sand layer and entered the underlying mud. The sand then could infill the resulting depression immediately after action and conserve its shape. The sediment was compressed by penetration and minor displacements of the casting sand is possible. The more rounded specimens with numerous, overlapping and twisted lobes can be attributed to rotational movement of the foraging fish. Badly preserved specimens were evidently produced in mud before deposition of sand layer. Near-surface muds were softer and the resulting depression was deformed and partly smoothed. Further obliteration of its original shape was probably accomplished by bottom currents, including those bringing the sand.

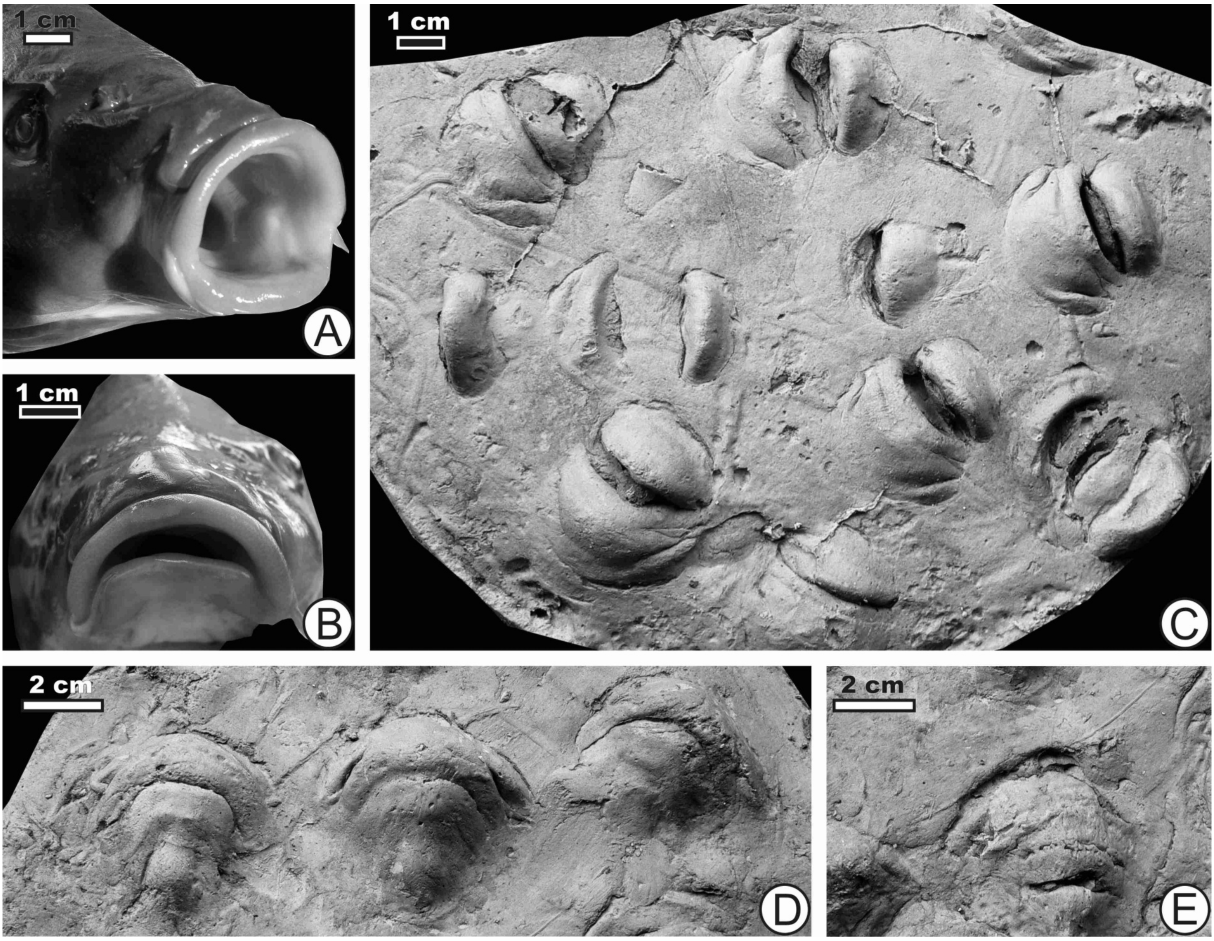
The fish probably hunted for *Lockeia*-making bivalves and maybe for polychaetes, which could be responsible for *Planolites*. The small lobes in the centre of some *Osculichnus* could be bivalve traces. This type of hunting is similar to that of bottlenose dolphins when burrowing for fish (e.g., Rossbach and Herzing 1997) documented in some films and images. Dolphins penetrate the sediment and rotational movement is commonly part of their action. Thus, *Osculichnus labialis* can be ascribed to the category praedichnia (predation traces). Well preserved *Osculichnus* is similar to the kissing mouth but this was a mortal kiss.

The preferred orientation of the long axes of *Osculichnus* suggests that the tracemaking fishes fed in some relations to bottom currents (?up-current). Such an adjustment can help to stabilize the body position and perhaps locate prey by chemical or other signals. Orientation of fish traces on tidal flats has been noted also by Pearson *et al.* (2007).

Modern analogues are few but show strong similarities with the Turkish material. Stanley (1971) illustrated clusters of elongate depressions ("snout-markings") from Wilmington Submarine Canyon off the eastern USA, which were produced by fishes of families Moridae (at water depth 1316 m) and Halosauridae (at 1828 m). In halosaurids the lower jaw is shorter than the upper jaw and potentially could produce traces having uneven lobes. Occasionally, shell debris has been seen near the depressions and can be attributed to burrowing bivalves. For instance, Jones *et al.* (1992) mentioned numerous depressions produced by fish, e.g. *Lethrinus nebulosus* (Forsskål), *Diagramma pictum* (Thunberg) and *Pseudocarnax dentex* (Bloch and Schneider) feeding on molluscs in a coral reef lagoon of the Great Barrier Reef. The shape of the depressions deteriorated with time. Also, the Australian *Upeneichthys lineatus* (Bloch and Schneider) feeds on infaunal bivalves (Platell *et al.* 1998).

Neoichnologic experiment

In order to test the producer affinity, an experiment was made with the use of the head of carp *Cyprinus carpio* Linné, which is a common fresh-water fish eaten on Christmas Eve in Poland. The shape of the mouth is very labile (Text-fig. 7A, B). The head was intruded at different angles and with different degrees of opening of the mouth in a plastic mud layer in a container. The resulting depressions were cast with plaster of Paris and observed as convex negatives of the depressions. About twenty different casts were obtained (Text-fig. 7C–E).



Text-fig. 7. Experiments with fish head pushed into mud. **A, B** – carp head with open and nearly closed mouth**. C, D, E** – plaster of Paris casts of depressions produced by carp head pushed into a mud layer, along with some surface invertebrate trails; opening of the mouth, angle and depth of penetration were varied in the experiments

Most of the casts display a bilobate shape with uneven, crescentic lobes separated by a narrower or wider fissure, or a wider area. The uneven size of lobes is maintained even if the head is intruded vertically. The distance between the lobes is wider when the mouth is opened broadly. Similar results were obtained with the head of trout (*Salmo* sp.).

The tracemaker certainly belongs to a different, marine fish taxon than the experimental carp, and the experiments are made in artificial conditions with dead specimens, and under a protocol that does not exactly match the interpreted taphonomic conditions. Therefore, the morphological details of the experimental casts and *Osculichnus labialis* are different. However, the casts and the trace fossil display the same major features. Foremost, the overall shape is similar; the lobes are of uneven size and crescentic. Thus, the experiment confirms that the tracemaker of *Osculichnus labialis* belongs to fish that intruded their head into sediment, vertically or obliquely, with a nearly closed mouth.

CONCLUSIONS

A new trace fossil preserved as bilobate, generally elliptical, hypichnial mounds has been found in early Oligocene prodelta sediments of the Thrace Basin of NW Turkey. Its two lobes, a smaller and a larger one, are lip-like, crescentic in outline, and separated by an undulate furrow.

The trace fossil is named *Osculichnus labialis* igen. et isp. nov.

It is interpreted as a hunting trace (praedichnion) of a fish penetrating in the seafloor through a sand layer into underlying mud (as in the best preserved specimens) or directly in surficial mud (poorly preserved specimens). The idea of a fish trace-maker is supported by neoichnologic experiments using heads of fish (carp) pushed into mud and cast with plaster of Paris.

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