

TRACE FOSSILS FROM THE MIOCENE TRANSGRESSIVE SILICICLASTICS  
NEAR DYNÓW, SE POLANDJACEK RAJCHEL<sup>1</sup> & ALFRED UCHMAN<sup>2</sup>

**Abstract.** Transgressive Miocene (Badenian) deposits in the San Valley rest unconformably on flysch deposits. Clasts from their basal conglomerate, dominated by flysch sandstones, contain abundant borings, which include *Entobia* isp., *Gastrochaenolites lapidicus*, *G. dijugus*, *G. ampullatus*, *G. torpedo*, and *Trypanites* isp. They belong to the *Entobia* ichnofacies, which indicates long exposition for bioerosion in high energy foreshore environment. The overlying sands and sandstones are almost totally bioturbated. Trace fossils include *Ophiomorpha* isp., *Planolites* isp., *Scolicia* isp., and *Thalassinoides* isp. They belong to the *Cruziana* ichnofacies, which indicates moderate to low energy, middle shoreface environment with soft substrate. Moreover, the sandy deposits contain wood boring *Teredolites longissimus*.

**Keywords:** trace fossils, borings, burrows, siliciclastics, transgression, Miocene, Poland.

## INTRODUCTION

The Middle Miocene (Badenian) transgressive siliciclastics occur in several areas on the nappes of the Polish Flysch Carpathians. Commonly, they are heavily bioturbated and contain different trace fossils (borings and burrows), which document several palaeo-environmental parameters. Description of the trace fossils from the Miocene deposits in the San Valley near Dynów (Fig. 1) and their interpretation is the main aim of this paper. Borings from the basal part of these deposits were reported by Rajchel (1976, 1977) and burrows from sands and sandstones were described by Rajchel & Uchman (1998). The illustrated specimens are housed in Institute of Geological Sciences, Jagiellonian University, Kraków, Poland (acronym 157P).

## GEOLOGICAL SETTING

The Miocene (Badenian) transgressive siliciclastic deposits rest unconformably on the flysch deposits (Upper Cretaceous-Oligocene) of the Skole Unit in the Polish Outer Flysch Carpathians (Rajchel, 1976). Except of some areas adjacent to the thrust front, they form several small isolated patches, which are located up to 16 km from the recent Carpathian margin. The patches are remnants of a large Miocene cover laying unconformably on the flysch deposits.

In the San Valley east of Dynów, the Miocene deposits occur in four sites, i.e. at Dubiecko (0,015 km<sup>2</sup>) (Rajchel, 1976), Przedmieście Dubieckie (0,5 km<sup>2</sup>) (Cieszkowski et al., 1977), Kosztowa (0,15 km<sup>2</sup>), and Laskówka (0,15 km<sup>2</sup>) (Rajchel, 1988, 1989). Their thickness attains about 20 meters (Fig. 2), and their age was determinate on the base of foraminifers as Badenian (Rajchel, 1976) and as Moravian - Lower Wielician (Urbanik, 1977; Gonera, 1994). Similar Badenian deposits are known from the marginal zone of the Skole Nappe from the surrounding of the so-called Rzeszów Bay (Golonka, 1981) and from Olszany east from Dynów (Alexandrowicz & Ney, 1966). The Miocene deposits have been folded during Styrian phase (Kotlarczyk, 1988) and tectonically relocated to the north together with the flysch basement.

These Badenian deposits are composed of a basal

conglomerate (transgressive lag) and overlying sands and sandstones (Fig. 2). Locally, they contain lenses or thin layers of rhodolites. The basal conglomerate contains weathered and poorly abraded blocks, boulders, and pebbles of calcareous sandstones, which derive from the flysch basement, mainly from the Upper Cretaceous-Palaeocene Ropianka Formation (Inoceramian Beds) and the Oligocene-Miocene Krosno Beds. The conglomerate contains also pieces of black shales from the Menilitic Formation (Oligocene), blocks of ferruginous dolomites, quartz pebbles, and locally rhodolites and oyster shells.

## TRACE FOSSILS

Boulders and blocks of calcareous sandstone in the transgressive lag contain abundant borings in the lithic substrate. Small borings were found also in oyster shells in the lower part of the Miocene deposits. The remaining part of the deposits contains different burrows, with exception of wood borings of terenid bivalves. Borings in Miocene basal conglomerates from similar geological situation were described from Niechobrz in the surrounding of the Miocene Rzeszów Bay (Gołąb, 1932), but without their identification.

## Borings

*Entobia* isp. (Pl. I/A) is observed as clusters of irregular, small (maximum 7 mm across) elongated cavities on surface of some oyster shells or chamber inside the shells. The cavities or chambers are connected by narrow passages. *Entobia* is produced in carbonate substrates by boring sponges (e.g., Bromley & D'Alessandro, 1984).

*Gastrochaenolithes lapidicus* Kelly & Bromley 1984 (Pl. I/ B-E) is a smooth ovate chamber with an apertural neck. It is circular in cross-section throughout. The neck is also circular in cross-section or elliptical. The widest diameter is located slightly below the center of the chamber. The boring is 35-50 mm long and maximum 21 mm wide. Borings of this ichnogenus are produced recently by some bivalves of the genus *Lithophaga* and *Hiatella* (Kelly & Bromley, 1984). Rajchel (1977) ascribed borings of this type to the bivalve *Aspidopholas*. At Dubiecko, he determined a shell of the

<sup>1</sup> Department of General and Mathematical Geology, Faculty of Geology, Geophysics and Environmental Protection, University of Mining and Metallurgy, Mickiewicza 30; 30-059 Kraków; Poland; e-mail: jrajchel@geolog.geol.agh.edu.pl

<sup>2</sup> Institute of Geological Sciences, Jagiellonian University, Oleandry 2a; 30-063 Kraków; Poland; e-mail: fred@ing.uj.edu.pl

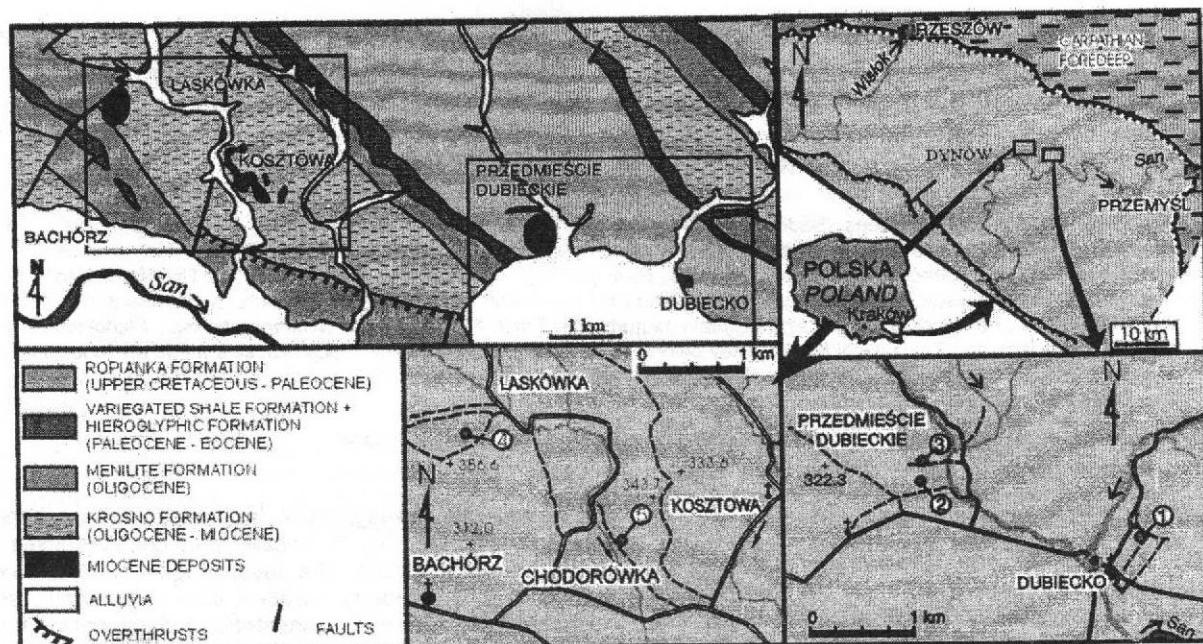


Figure 1 - Map of occurrence of the Miocene deposits in the Dynów region, and locations of the investigated section. The geological map based on Wdowiarsz (1948), Rajchel (1989), and Rajchel & Uchman (1998), changed and simplified.

bivalve *Pholas dactylus* Linneus var. *mucronata* da Costa inside a boring (Pl. I/J). Similar borings have been described earlier from the carbonate substrate of the northern and western part of Polish sector of the Paratethys as „borings of *Gastrochaena*” by Radwański (1965, 1969) or „borings of *Aspidopholas rugosa* (Brocchi) (Radwański, 1969, 1977), which, however, display a figure of eight in cross-section in the upper part of the well preserved necks. This feature is typical of *Gastrochaenolites dijugus* Kelly & Bromley 1984. It was not observed in our material, and therefore we determined the studied borings as *G. lapidicus*. It is not excluded, however, that the upper part of neck in borings from our material is erosionally truncated.

*Gastrochaenolites dijugus* Kelly & Bromley 1984 (Pl. I/F) is a smooth ovate chamber in which neck region form a figure of eight in cross-section. The chamber is up to 21 mm in maximum diameter and the borings is at least 46 mm deep. In the neck part it displays a thick calcite syphon lining. It is very probable that some borings ascribed in this paper to *Gastrochaenolites lapidicus* are truncated *G. dijugus* (see discussion for *G. lapidicus*). The bivalves of the genus *Gastrochaena* are the commonest producers of *G. dijugus* (Kelly & Bromley 1984).

*Gastrochaenolites ampullatus* Kelly & Bromley 1984 (Pl. I/G) is a smooth ovate chamber with fan-shaped, flared neck. The maximum diameter (22 mm) is located at the center of the chamber. The chamber is 39 mm long. Borings of this type are produced by the bivalve *Spengleria rostrata* (Kelly & Bromley, 1984).

*Gastrochaenolites torpedo* Kelly & Bromley 1984 (Pl. I/H-M) is a smooth, strongly elongate chamber, which the upper (neck) part displays ellipsoidal cross-section. The chamber is commonly at least 50-60 mm long. The maximum diameter (18-29 mm) is located at the center of the chamber. Commonly, the neck is not preserved because truncation by erosion. There are also small specimens of this boring, which are commonly no more than 20 mm long and 9 mm wide (Pl. I/ K-M). One specimen of this type contains a shell

of *Lithophaga lithophaga* (Linneus) reported by (Rajchel, 1977). *G. torpedo* commonly displays a calcite lining (e.g. Jones & Pemberton, 1988), which, however, have not been observed in the investigated material. Today, borings of this type are produced by some species of the bivalve *Gastrochaena* and *Lithophaga* (Kelly & Bromley, 1984). This form was reported earlier from the study area as the „*Lithophaga* borings” (Rajchel, 1977). Radwański (1969, 1977) described the same form from the southern slopes of the Holy Cross Mountains and from Zwierzyniec in Kraków in Poland. He noted large size differences in borings of this type. The differences can be related to different ontogenetic stages of the tracemaker or to differences in ecological conditions.

*Trypanites* isp. (Pl. II/A) is a tubular simple, straight boring, 2 mm in diameter and at least 10 mm long. Straight borings of this type are produced by sipunculoids, phoronids or annelids (Bromley, 1967). Radwański (1964, 1969) regarded that borings of this type have been produced by the polychaete *Potamilla reniformis* (Müller), which occurs abundantly on the recent Atlantic coasts of Europe and more rarely in the Adriatic Sea.

*Teredolites longissimus* Kelly & Bromley (1984) (Pl. II/C, D) is preserved as numerous long, simple, winding, slightly tapering, commonly twisted clubs. The clubs are smooth or covered with imprints of wood structure. Some of them are covered with calcite lining. Their diameter ranges from 3 to 20 mm. Termination of the clubs is hemispherical. The clubs are casts of borings of the bivalve *Teredo* in wood. Savrda & Smith (1996) found branched borings of *T. longissimus*, but forms of this type have not been found in the investigated material.

Elongate borings (Pl. II/B) are shallow elongate cavities visible on surface of sandstone pebbles. They are 10-12 mm long, about 1.5 mm wide, and at least 3 mm deep. They are slightly arcuate in horizontal section, with sharp terminations. Borings of this type are very rare. They resemble the borings of the cirriped *Zapfella pattei* Saint-Seine, but this form is more regular and it

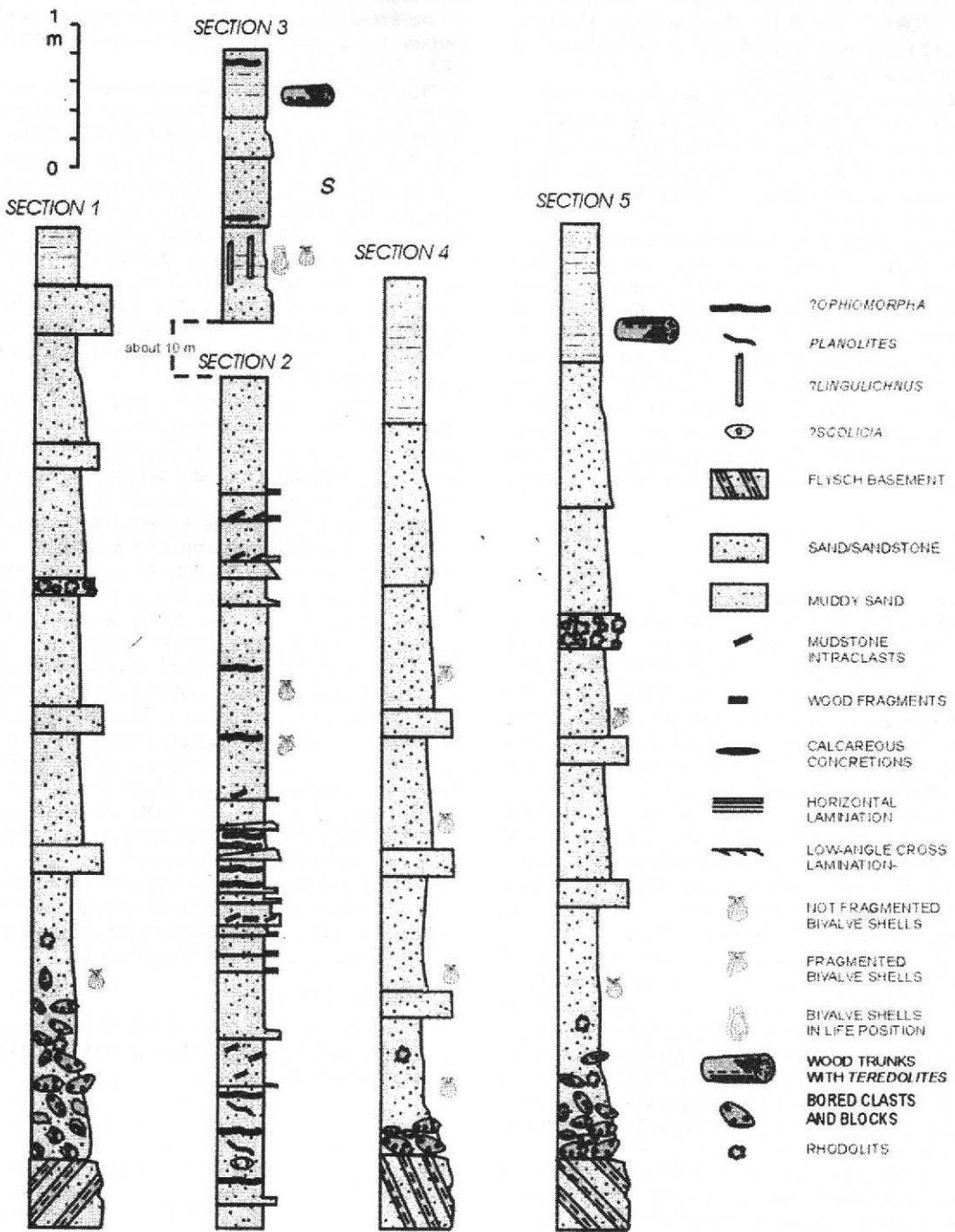


Figure 2 - Lithological columns of the investigated sections based on Rajchel (1988) (for sections 1, 4, 5) and Rajchel & Uchman (1998) (for sections 2, 3), changed and simplified.

displays only one sharp termination in horizontal section (Radwański, 1969).

#### Burrows

*Ophiomorpha* isp. (Pl. II/E) is preserved as horizontal, oblique to vertical slightly winding tubular, simple burrows, 10-25 mm in diameter, filled with sandstone similar to the host rock. The burrows are circular or elliptical in cross-section. They display a distinct sandy wall enriched in clay minerals. The characteristic knobby structure of wall, which is typical of

*Ophiomorpha nodosa* Lundgren (Frey et al., 1978), have not been found.

*Planolites* isp. is represented by poorly preserved fillings of horizontal or oblique, slightly winding tunnels, which are 2-4 mm in diameter. Lithology of the fillings is slightly different than the host rock. This is one of the diagnostic features of *Planolites* (Pemberton & Frey, 1982).

?*Scolicia* isp. is a rare horizontal burrow observed only in cross-section at Dubiecko. It appears as an ellipse with a flattened base. This is a typical cross-

section of *Scolicia*, which occurs abundantly in the Miocene deposits of Lower Austria (Uchman & Krenmayr, 1995) or the Podolia in Ukraine. Unfortunately, there was not possibility to observe the burrow in the longitudinal section.

*Thalassinoides* isp. (Pl. II/F-I) is represented by horizontal or slightly inclined, filled, rarely branched, unwalled tunnels, which display sharp contours and are elliptical in cross-section. They are 15-30 mm wide. *Thalassinoides* is produced by crustaceans, mainly crabs (Frey et al., 1984).

Unidentified ?bivalve burrows are vertical or oblique, straight or slightly curved, unwalled tunnels, which display elliptical cross-sections and sharp contours. They are filled with sandstone similar to the host rock. The tunnels are maximum 10-23 mm wide. The elliptical cross-section, untypical of vertical burrows, suggests that the tracemaker was a flattened organism penetrating in a stable position (? a bivalve). *Lingulichnus* Over (1988), produced by brachiopods *Lingula*, is much shorter and changes his cross-section from elliptical in the upper part to circular in the lower part.

## DISCUSSION

In the transgressive lag, bivalve borings *Gastrochaenolithes lapidicus*, *G. ampullatus*, and *G. torpedo* dominate. In some pebbles, the boring *Trypanites* isp. is present. Some oyster shells contain the clionid sponge borings *Entobia* isp. The ichnoassemblage of borings is typical of the *Entobia* ichnofacies *sensu* Bromley & Asgaard (1993), which normally occurs above the normal wave base and indicate deep, long (several years) bioerosion. *Gastrochaenolithes torpedo* is restricted to shallow, euphotic zone. This one produced by *Lithophaga lithophaga* in the Neogene of Mediterranean is restricted 1-2 m depth (Kleeman, 1974 *vide* Bromley, 1992). Some of the bored shells or small clasts are subsequently incrustated by coralline algae and form rhodolites (Pl. I/A). Most bivalve borings are truncated by erosion (Pl. I/I, N) or by other borings (Pl. I/O). Only some borings contain poorly preserved shells of their tracemakers. Most borings are filled with the Miocene sandstone, some are empty, and others are filled at least partially with radial or blocky calcite cements (Pl. I/G, H). All these features indicate long exposition of the transgressive lag in very shallow water (foreshore), not interrupted by deposition for at least several years.

Most of borings in lithic substrate occur in carbonates, and much less commonly in calcareous sandstone. Probably, several ichnotaxa, which occur in carbonates are not present in sandstones. This certainly concerns *Entobia*, which is restricted to pure carbonate substrates (Bromley & D'Alessandro, 1984) and other

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small borings. The small borings (*Caulostrepsis*, *Meandropolydora*) are common in carbonate substrates of the Parathetys in Poland, especially on the southern slopes of the Holly Cross Mountains (Radwański, 1965, 1967, 1969, 1970).

The overlying transgressive sandstones are arranged in poorly developed parasequences, which are a few metres thick. They are almost totally bioturbated, however only the deepest burrows are preserved. *Ophiomorpha* isp. (crustacean burrow), ?*Thalassinoides* isp. (crustacean burrow), *Planolites* isp. (?polychaete burrow), ?*Scolicia* isp. (irregular echinoid burrow), and vertical burrows of ?bivalves are present locally, but not abundant. The first two forms are commonest. The other forms are rare. Moreover, terenid wood boring *Teredolites longissimus* Kelly & Bromley occurs abundantly in large wood logs, which were found in one horizon at Przedmieście Dubieckie and Kosztowa.

The described trace fossils from the sandy deposits display similarities to the *Cruziana* ichnofacies, which is typical of the zone between the normal and the storm wave base. *Ophiomorpha* with dominant horizontal tunnels and *Thalassinoides*, which predominate in the investigated deposits, are typical of this ichnofacies (Frey & Seilacher, 1980). Also *Scolicia* is typical of the *Cruziana* ichnofacies (Ekdale et al., 1984). Totally bioturbated sands of the Decton Sand (Eocene) in Great Britain, which contain *Ophiomorpha* dominated by horizontal tunnels and *Planolites*, are interpreted by Pollard et al. (1993) as deposits of middle and lower shoreface. Probably, the discussed deposits were accumulated in similar zone in well oxygenated environment. The above cited authors indicated that totally bioturbated sandy deposit can occur already at 10 m depth. *Scolicia* indicates normal salinity, because irregular echinoids which are producers of this forms (Smith & Crimes, 1983) are stenohaline organisms (Smith, 1984). However, rare occurrence of this form can be connected with salinity changes.

The investigated trace fossils well indicate changes of substrate from rocky ground to soft ground, increase of palaeodepth from foreshore to middle shoreface, and help to determine palaeoecological conditions.

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## PLATES

## Plate I

Borings from the transgressive lag.

- A** - *Entobia* isp. (arrows) in an oyster shell coated by rhodolites. Polished and oiled surface. Kosztowa, 157P1.  
**B** - internal mold of *Gastrochaenolites lapidicus* from a flysch sandstone pebble. Laskówka, 157P2.  
**C-E** - *Gastrochaenolites lapidicus*, empty chambers in flysch sandstone pebbles. Polished and oiled surfaces. C - Laskówka, 157P3, D - Dubiecko, 157P4, E - Dubiecko, 157P5.  
**F** - *Gastrochaenolites dijugus*, a chamber in a flysch sandstone pebble, filled partially with Miocene sandstone and calcite cement. Thick calcite syphonal lining in the neck part (arrow). Polished and oiled surface. Kosztowa, 157P6.  
**G** - *Gastrochaenolites ampullatus* in a flysch sandstone pebble, filled partially with Miocene sandstone. Polished and oiled surface. Laskówka, 157P7.  
**H** - *Gastrochaenolites torpedo* in a flysch sandstone pebble, filled with Miocene sandstone in the lower part and with radial calcite cement in the upper part. Polished and oiled surface. Laskówka, 157P8.  
**I** - *G. torpedo* in a flysch sandstone boulder, filled with the Miocene sandstone. Truncated basal part of a boring in the upper left corner. Polished and oiled surface. Laskówka, 157P9.  
**J** - *Pholas dactylus* var. *mucronata* in a flysch sandstone pebble. Parting surface. Laskówka, 157P12.  
**K, L** - very small, empty *G. torpedo* in flysch sandstone pebbles. Polished surfaces. J - Kosztowa, 157P10, K - Laskówka, 157P11.  
**M** - very small, empty *G. torpedo* partially filled with the Miocene sandstone. Surface of a flysch sandstone pebble. Kosztowa, 157P13.  
**N** - fragment of surface of a flysch sandstone boulder intensively bored by *Gastrochaenolites*. Laskówka, 157P14.  
**O** - Large *G. torpedo* cross cuts smaller one (arrow). A flysch sandstone boulder. Polished and oiled surface. Laskówka, 157P15. Scale bar = 1 cm for all figures.

## Plate II

- A-D**: Borings from the Miocene deposits; **E-I**: Burrows from the Miocene deposits.  
**A** - *Trypanites* isp. Surface of a flysch sandstone pebble. Dubiecko, 157P5.  
**B** - elongate borings on surface of a flysch sandstone pebble. Dubiecko, 157P16.  
**C, D**. *Teredolites longissimus*. Upper part of the section at Przedmieście Dubieckie, C - 157P17, D - 157P18.  
**E** - *Ophiomorpha* isp. (arrows). Sandstones at Dubiecko. Field photograph.  
**F, G** - fragments of *Thalassinoides* fillings. Przedmieście Dubieckie, B - 157P20, C - 157P21.  
**H** - large *Thalassinoides* enlarged at the branching point, extracted from sandstones at Przedmieście Dubieckie. 157P22.  
**I** - *Thalassinoides* in cross section, Kosztowa, 157P23. Scale bar = 1 cm for A-D, F-I ; scale in cm and mm for E.

