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Polychaete-attributable faecal pellets, *Tibikoia sanctacrucensis* ichnosp.n., from the Korytnica Clays (Middle Miocene; Holy Cross Mountains, Central Poland)

ABSTRACT: The aggregates of faecal pellets that are common components of the topmost part of the Korytnica Clays (Middle Miocene; Holy Cross Mountains, Central Poland) are attributed to polychaetes, presumably related closely to the present-day species *Heteromastus filiformis* (Claparède). As a direct relationship to the latter species has not however been displayed, these faecal pellets are put into ichnological taxonomy and, consequently, a new ichnospecies is established, *Tibikoia sanctacrucensis* ichnosp. n. A comparison of ecological requirements of the faeces-producing polychaete species with its present-day analogues supports and/or modifies some conclusions on the environmental conditions under which the topmost part of the Korytnica Clays was deposited.

INTRODUCTION

In the topmost part of the Korytnica Clays sequence that fills a part of the Middle Miocene (Badenian) marine bay on the southern slopes of the Holy Cross Mountains, Central Poland, there occur aggregates of small pellets which in some places become an important component of the sediment. The aggregates display a patchy distribution throughout a few last layers of the clay sequence (Text-fig. 1). The environmental conditions under which this portion of the sequence has been deposited, are recognized (Bałuk & Radwański 1977, 1979) as extreme shallow marine, with the bottom almost flat, covered by a pattern of dense seagrass vegetation; the sedimentary area has then been some few hundred meters distant to the shoreline, either of small islands or of the mainland, is some spots fringed by a kelp bed (*cf.* Text-fig. 1).

THE INVESTIGATED AGGREGATES OF FAECAL PELLETS

The aggregates are built of pellets of uniform size and shape, the latter having been characterized as ellipsoidal to cylindrical with bluntly rounded ends. These pellets are composed of clay

material, probably bound by organic matter which was responsible for a firm consistency of the pellets and their lithological contrast against the clay background. The pellets should therefore be regarded as being the faeces produced by a sediment feeder which was letting larger amounts of the clay deposit through its intestines.

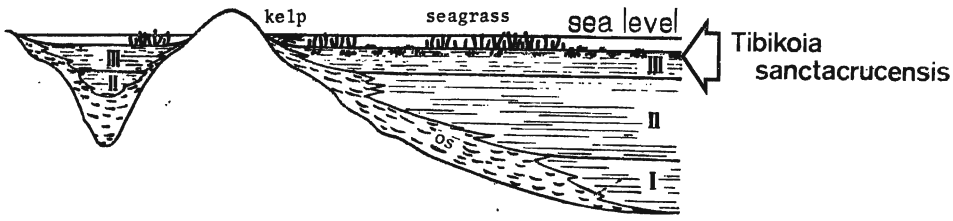


Fig. 1. Position of the layers yielding *Tibikoia sanctacrucensis* ichnosp. n. within the sedimentary sequence of the Korytnica Clays; detailed explanation in the text; adopted *from* Bałuk & Radwański (1977, Text-fig. *6C*)

The whole aggregates, attaining even to about 20 mm in their diameter, are rather brittle, and consequently only their fragmented parts could have been separated from the clay sediment. Some of the aggregates disintegrated into pieces when being washed and cleaned. The best preserved are usually the central parts of the aggregates (*cf.* Fig. 1 and Pl. 1); these might have certainly been firmer soon after their shedding into heaps by the animal.

RECOGNITION OF THE PRODUCER

Very few characteristic features of the investigated faecal pellets make up some difficulties with their biological attribution. The faces of a similar shape have been reported from such diverse animal groups as polychaetes, and gastropods and chitons. The faeces shed by mollusks, either by such gastropods as *Assiminea*, or chitons *Ischnochiton* are usually much more elongated (*see* Schäfer 1962, Text-fig. 246; Bandel 1974, Text-fig. 1; *cf. also* Arakawa 1962, 1963, 1965, 1968, 1972), and they do not aggregate into heaps (*cf. also* Schäfer 1953, Text-fig. 6). Of the comparable faeces produced by the present-day forms, only those being shed by polychaetes are accumulated to heaps.

The greatest resemblance in polychaete pellets is displayed by droppings of *Heteromastus filiformis* (Claparède) which is a bottom dweller burrowing more or less vertically, but with a branching array of the tunnel system at its base; the proximal part of the burrow and its aperture project through a heap of faeces laid down onto the sediment surface (*see* Text-fig. 2, adopted *from* Schäfer 1962, Text-fig. 159; *cf. also* Schäfer 1952, Text-fig. 6; Howard & Dörjes 1972, Text-fig. 8; Reineck & Singh 1975, Text-fig. 236).

As apparent from recent investigations of diverse burrows and their laboratory models, such a construction of the burrow by *Heteromastus filiformis* (Claparède) permits the polychaete to keep the burrow well ventilated (*cf.* Vogel & Bretz 1972, Vogel 1978). A heap of faeces, with the aperture of the vertical burrow at its top induces passive flow of water through the burrow when the current runs over the sediment surface; this is the type of single-apertured burrow demonstrated in terres-

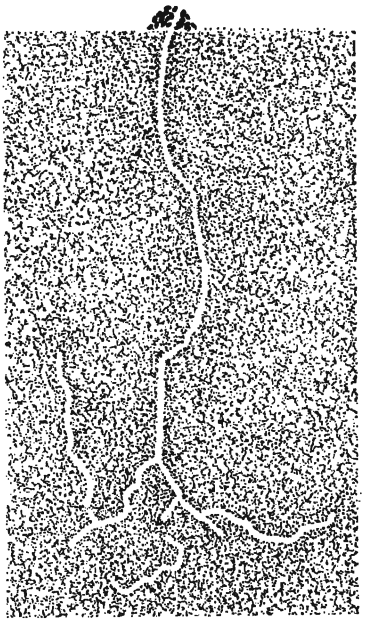


Fig. 2
A burrow and a heap of the faecal pellets produced by the present-day polychaete *Heteromastus filiformis* (Claparède); reduced about twice to actual size; adopted *from* Schäfer (1962, Text-fig. 159)

trial environments by the turret spiders (*see* Vogel 1978, Text-fig. 1*b*). The other polychaetes construct the burrow furnished with two apertures, one of which being situated at the top of a sediment mound; the same type of construction is realized by callianassid shrimps and, in terrestrial environments, by prairie dogs (*cf.* Vogel & Bretz 1972, Vogel & *al.* 1973, Vogel 1978).

The only comparable ancient forms are those occurring in aggregates and coming from the Neogene Kogota Formation of Japan, first reported by Hatai & Kotaka (1968), and subsequently described under the new ichnogeneric and ichnospecific names, *Tibikoia fudoensis*, by Hatai, Kotaka & Noda (1970). The new names introduced by the latter authors have recently been accepted in the *Treatise* by Häntzschel (1975, p. *W*143), the same as the attribution of the faeces themselves to a general group of marine worms.

Consequently, the Korytnica faecal pellets which have been shed in relatively great quantities and arranged into heaps by animals devoid of skeletal parts possible for preservation in the nearby sediment, are to be attributed to the polychaete annelids, presumably related closely to the present-day species *Heteromastus filiformis* (Claparède). As a direct relation to the latter species is not however displayed by them evidently, the investigated faecal pellets are regarded in the limits of an independent category of the trace fossils.

ICHNOLOGICAL TAXONOMY

Although most of the Neogene ichnofossils are highly comparable, or even directly attributable to the present-day ichnia and their well recognized producers (*cf.* Radwański 1977a, b), it is also true that any ichnofossil should be named to survive in the literature (Osgood 1970). In regard to

the investigated Korytnica specimens, keeping in mind their morphological individuality, the present authors decide to introduce a new ichnological name, and this one being of an ichnospecific rank. These specimens are therefore thought to belong to the ichnogenus *Tibikoia* of Hatai, Kotaka & Noda (1970), but represent a separate species, *Tibikoia sanctacrucensis* ichnosp. n. It differs from the type species of the ichnogenus, *T. fudoensis* Hatai, Kotaka & Noda, in its size and slightly in shape, as it is apparent from the following description.

Ichnogenus *TIBIKOIA* Hatai, Kotaka & Noda, 1970
Tibikoia sanctacrucensis ichnosp. n.
(Text-fig. 3 and Pl. 1, Figs 1—8)

Holotype: The aggregate presented in Text-fig. 3 (the best preserved of the collected specimens).
Paratypes: The aggregates presented in Pl. 1, Figs 1—8.
Type locality: Korytnica, 24 km SSW of Kielce, southern slopes of the Holy Cross Mountains, Central Poland.
Type horizon: Middle Miocene (Badenian).
Derivation of the name: Latin *sanctacrucensis*, after the Holy Cross region.
Diagnosis: Small pellets of equal size, ellipsoidal to cylindrical with bluntly rounded ends and smooth surface; composed of clay material; gathered into aggregates of hundreds specimens.
Material: Numerous fragmented aggregates.
Dimensions: The individual pellets range 1.4—1.7 mm in length, and 0.7—0.9 mm in width; the aggregates attain to about 20 mm in diameter.

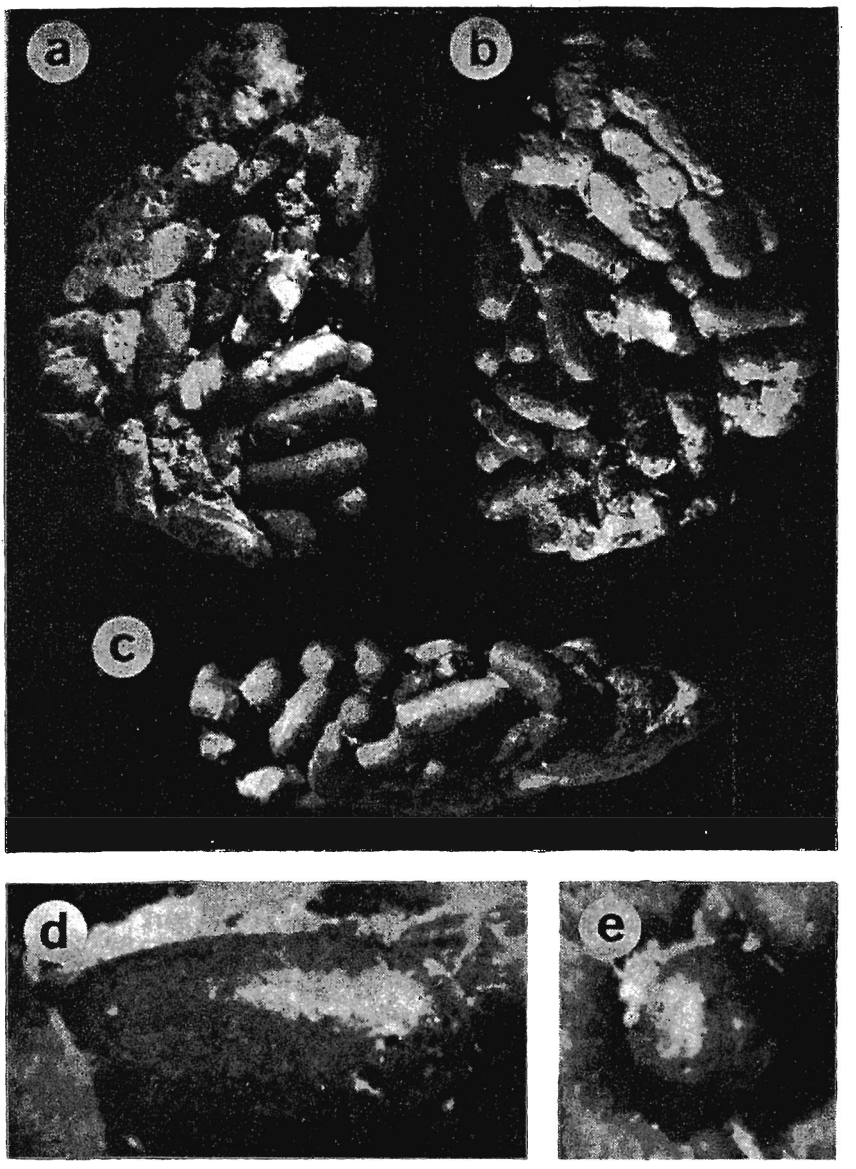
REMARKS: The pellets are generally circular in cross section, some of them being however slightly flattened due to compaction. Within the aggregates, the pellets do not show any orientation with their longer axis. An indistinct, flexible chevron-like pattern is observable locally in some aggregates.

The pellets of type species of the ichnogenus, *Tibikoia fudoensis* Hatai, Kotaka & Noda, 1970, are smaller (average 1 mm in length, and 0.5 mm in diameter) and slightly less slender, although some of them become shorter and thicker; the size of the aggregates is approximately the same as of the Korytnica specimens.

BIOLOGICAL ATTRIBUTION: Polychaetes, presumably related closely to the present-day species *Heteromastus filiformis* (Claparède). The same attribution should also be ascribed to the type species of the ichnogenus (*cf.* Hatai, Kotaka & Noda 1970; Häntzschel 1975, p. *W*143). The faecal pellets shed by *Heteromastus filiformis* (Claparède) are in average slightly longer than the both *Tibikoia* species (*cf.* Schäfer 1962, Text-fig. 246; Reineck & Singh 1975, Text-fig. 236).

ENVIRONMENTAL CONDITIONS

The investigated faecal pellets, *Tibikoia sanctacrucensis* ichnosp. n., are typical only of the topmost part of the Korytnica Clays sequence. As it is apparent from the ecological analysis of diverse organic communities (Bałuk & Radwański 1977, 1979), the Korytnica Clay sequence has been accumulated in a terminal zone of the sea bay which has successively been filled with clay deposits. This resulted in a successive shallowing of the basin, since the moderate depths of about 60—40 m to which the organic Community *I* was confined, through the intermediate depths with the organic Community *II*, up to the shallows of a few meters deep and populated by the organic Community *III*. The corresponding portions of the clay sequence (*I*, *II*, and *III* in Text-fig. 1) were filling the basin to such an extent that during the

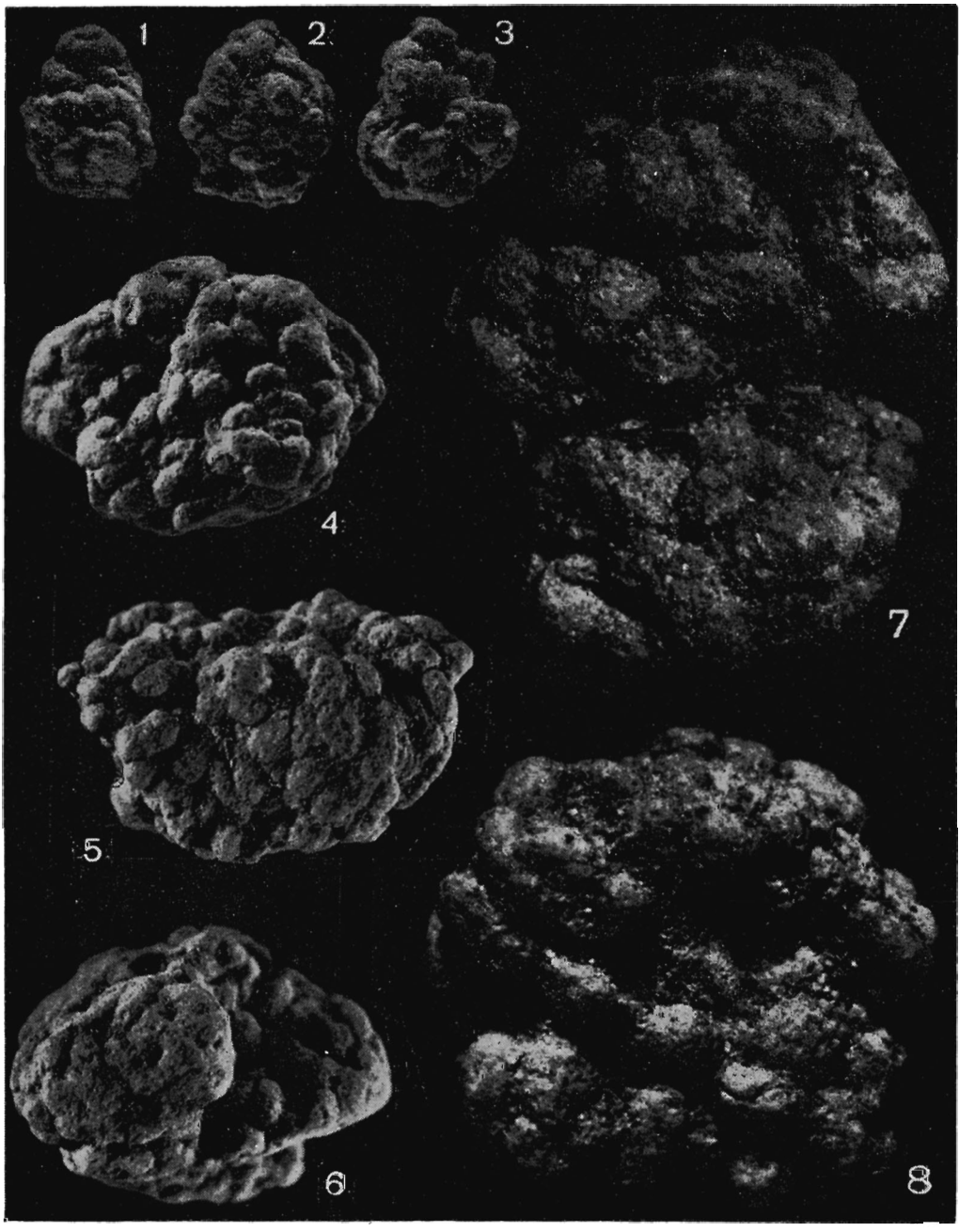


Aggregate (fragment of a heap) of the faecal pellets *Tibikoia sanctacrucensis* ichnosp. n., attributable to polychaetes related to the present-day species *Heteromastus filiformis* (Claparède); uppermost part of the Korytnica Clays, Middle Miocene (Badenian) of the Holy Cross Mountains, Central Poland

a, b, c — Three general views of the aggregate being the holotype of the ichnospecies; magn. × 10

d, e — Close-up views of two individual pellets (*d* side, *e* end view); magn. × 40

All photos taken by L. Łuszczewska, M. Sc.



Aggregates (fragments of heaps) of the faecal pellets *Tibikoia sanctacrucensis* ichnosp. n., attributable to polychaetes related to the present-day species *Heteromastus filiformis* (Claparède); uppermost part of the Korytnica Clays, Middle Miocene (Badenian) of the Holy Cross Mountains, Central Poland

1–6 — General view of the aggregates; magn. ×5, taken by K. Zielińska; **7–8** — close-up view of the aggregates; magn. ×15, taken by L. Łuszczewska, M. Sc.

formation of its topmost parts either the sediments or at least the seagrass cover was reaching almost sea level (*cf.* Text-fig. 1). Under such very conditions of that latter period the polychaetes producing the investigated faecal pellets have prosperously lived.

The discussed environmental conditions of the Korytnica basin are well comparable to those under which the present-day polychaete *Heteromastus filiformis* (Claparède) is known. Along the North Sea coasts this species is primarily reported from the intertidal (*Watt*) zone where it is associated with other polychaetes (Schäfer 1952, 1953, 1962); along the Atlantic coasts of the United States it is characteristic of muddy sands of the tidal flats associated with barrier islands (Howard & Dörjes 1972), as well as of the estuarine mud areas (Howard, Frey & Reineck 1973; Howard & Frey 1975). From both these regions there are no more detailed data available on its spreading into the shallow subtidal zones, although it evidently enters their limits (*see* Dörjes 1972, Plate 2; Howard & Dörjes 1972, Text-fig. 5).

As compared with the present-day tidal flats, the Korytnica environment when the clay sequence was almost at its completion, should therefore be regarded as slightly deeper and rather always submerged. The common occurrence of *Tibikoia sanctacrucensis* ichnosp. n., if its attribution to the polychaetes closely related to *Heteromastus filiformis* (Claparède) is correct, should however focus our attention that the true intertidal conditions, temporary at least, may then be also taken into account. It is noteworthy that such temporary intertidal conditions have previously been recognized (Radwański 1977a) for marly sands yielding large burrows attributable to the present-day ghost crab *Ocypode*, and these sands build up a member that overlies directly the Korytnica Clays. Consequently, it is thought that the appearance of the faecal pellets *Tibikoia sanctacrucensis* ichnosp. n. in the clay sequence of Korytnica indicates the first echoes of approaching and forthcoming the most extreme shallow and/or emersion conditions during the decline of sedimentation in the Korytnica basin.

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