acta geologica polonica

Vol. 27, No. 2 Warszawa 1977

ANDRZEJ RADWAŃSKI

Burrows attributable to the ghost crab *Ocypode* from the Korytnica basin (Middle Miocene; Holy Cross Mountains, Poland)

ABSTRACT: Large burrows that occur in marly sands of the upper part of the Middle Miocene (Badenian) sedimentary sequence of the Korytnica basin (Holy Cross Mountains, Central Poland) are ascribed to the ghost crab *Ocypode*. The burrows, well comparable to those produced by the present-day ghost crabs, especially those from the Georgia coast, are indicative of extreme shallow marine or supratidal conditions. The sedimentary processes that prevailed under such conditions in the Korytnica basin are discussed, and their bearing upon paleogeographical interpretation of the deposits containing the *Ocypode* burrows, and of the whole Korytnica sequence is presented.

INTRODUCTION

Within the Middle Miocene (Badenian) sedimentary sequence of the Korytnica basin that developed on the southern slopes of the Holy Cross Mountains, Central Poland, the occurrence of any burrows is confined to the marly sands that overlie the Korytnica Clays. These sands have been preserved mostly in the northern part of the basin, and now are best exposed in the sand-pit at Chomentów (*cf.* Text-fig. 1, Pl. 1, Figs 1—2; and Bałuk & Radwański 1977, Text-figs 1—2 and 4).

The burrows are pronouncedly featuring the upper part of the sands (Unit *2* in Text-fig. 1) in which they are distributed sparsely, and never in groups. Their considerable size (diameter), although they are usually preserved in fragments (*cf.* Pls 2—3), make them the easily distinguishable fossils in the exposure.

The discussed burrows have previously been ascribed by the author (Radwański 1969, 1970) to large callianassids, as at that time only these shrimps were commonly known to produce more or less comparable burrows. Subsequent reports on the activity of littoral crabs from Recent environments (Farrow 1971, Frey & Mayou 1971, Braithwaite & Talbot 1972, Hill & Hunter 1973, Allen & Curran 1974) however allow now to present another attribution of these burrows. Such a new attribution is based primarily on the comparisons with data from Recent shores, as the hitherto known reports of similar biogenic structures from ancient environments are very inadequate or questionable (*cf.* Hayasaka 1935, Robertson 1965, Frey & Mayou 1971). Since the comparable Recent burrows have not been named ichnologically, those from the Miocene time are also left unnamed, and they are considered as the ancient counterparts of the present-day traces. In this respect, the here presented forms from the Korytnica basin have recently been also included into a general review of present-day types of traces from the Neogene sequence (Radwański 1977). The aim of this contribution is therefore to discuss primarily the environmental consequences of the suggested attribution upon the sedimentary conditions prevailing within the Korytnica basin by the decline of its development.

THE ICHNOTOPE

The fine-grained marly sands at Chomentow that yield the burrows may be subdivided into two parts (Units *1* and *2* in Text-fig. 1). The lower part displays larger calcitic cementations, over 1 m in diameter, and featured with smooth or knobby surface. The fossils are badly preserved, and these comprise mostly microfauna, some echinoids (*Schizaster*), and rather small-sized pelecypods (*Meretrix*). In the upper part of the sands, the cementations become less distinct and smaller, more knobby, and they gradually vanish in the sequence (*cf.* Text-fig. 1). The burrows, which are confined to that interval, are associated with some echinoids (*Echinocyamus*), and various pelecypods, both small (*Meretrix,* some *Cardium*) and such larger ones as *Panope menardi rudolphii* Eichwald, *Cardium hians danubianum* Mayer, and finally with large individuals (20—30 cm in length) of the oyster *Crassostrea gryphoides* (Schlotheim) and the pinnid *Atrina radwanskii* Jakubowski. Of the latter forms, *Crassostrea gryphoides* occurs as isolated valves, or parts of larger clusters, usually abraded, and densely bored by various rock-borers and/or encrusted by epizoans, mostly acorn barnacles (*cf.* Radwański 1969, 1970). This is a situation opposed to that of *Atrina radwanskii* whose shells are usually undamaged, preserved in life position, and only locally encrusted by barnacles (*cf.* Radwański 1969, 1970; Jakubowski 1977); their mode of life is recently suggested (Jakubowski 1977) as endobenthic.

The bedding within the marly sands is very indistinct, mostly evidenced by streaks of shell detritus. The so-pronounced bedding is of the planar type, and no cross stratifications are visible. In many places, the sands look as if being almost homogenous. Up in the sequence, the marly content increases, and the sands gradually pass into marly limestones composed mostly of nodular colonies of the red alga *Lithothamnium,* or their detritus (Unit *3* in Text-fig. 1). Overlying are similar limestones composed of larger lithothamnian colonies, and containing pebbles, cobbles, and boulders (up to 1.1 m in diameter) derived from the shore (Jurassic limestones) and densely bored by various rock-borers (Unit *4* in Text-fig. 1; *cf.* Radwański 1969, 1970).

THE BURROWS

The investigated burrows (Pls 2—3) are preserved as the casts completely filled with the sediment identical with that in which they occur. From the latter they differ by stronger lithification and, when cleaned, by their surface sometimes marked either by cracks resulting presumably from synaeresis (*cf.* Pl. 2, Fig. 1), or by a grooved pattern of uncertain origin (*cf.* Pl. 2, Fig. 2a). This pattern, characterized locally by a radial array of superficial cracks, is supposedly also due to synaeresis which partly at least could have propagated along the specific, primary structure of the burrow wall.

The casts are preserved in fragments which certainly correspond to more lithified parts of the burrows. The more lithified fragments may result from such diverse causes as: (*1*) partial filling of locally dammed burrows; (*2*) irregular cementation by the animal; (*3*) irregular lithification, limited i.a. by primary cementation, or by propagation of the synaeretic cracks. In any case however, all the fragments are preserved *in situ,* as indicated by the bedding occasionally impressed on the burrow wall, and identical with that of the adjacent sand to which it continues (*cf.* Pl. 3, Fig. 1). All these fragments of various shapes and usually oblique to the sediment surface, are found in the exposure in such position (*cf.* Text-fig. 1 and Pl. 3) as requested by the Recent biogenic structures to which they are compared (see below). None of the fragments are therefore reworked from fully developed burrows, and redeposited by hydrodynamic agents.

The longest fragment attains 75 cm in its length. The most common fragments are usually much smaller, only about 10 to 20 cm long. All are cylindrical in section (about 4—6 cm wide), and the central canal (1.5 to 2.5 cm in diameter) ranges from almost circular to slightly oval (*cf.* Pl. 2, Fig. 2b). The canal is usually completely filled with the sediment, and weakly contrasted against the burrow wall.

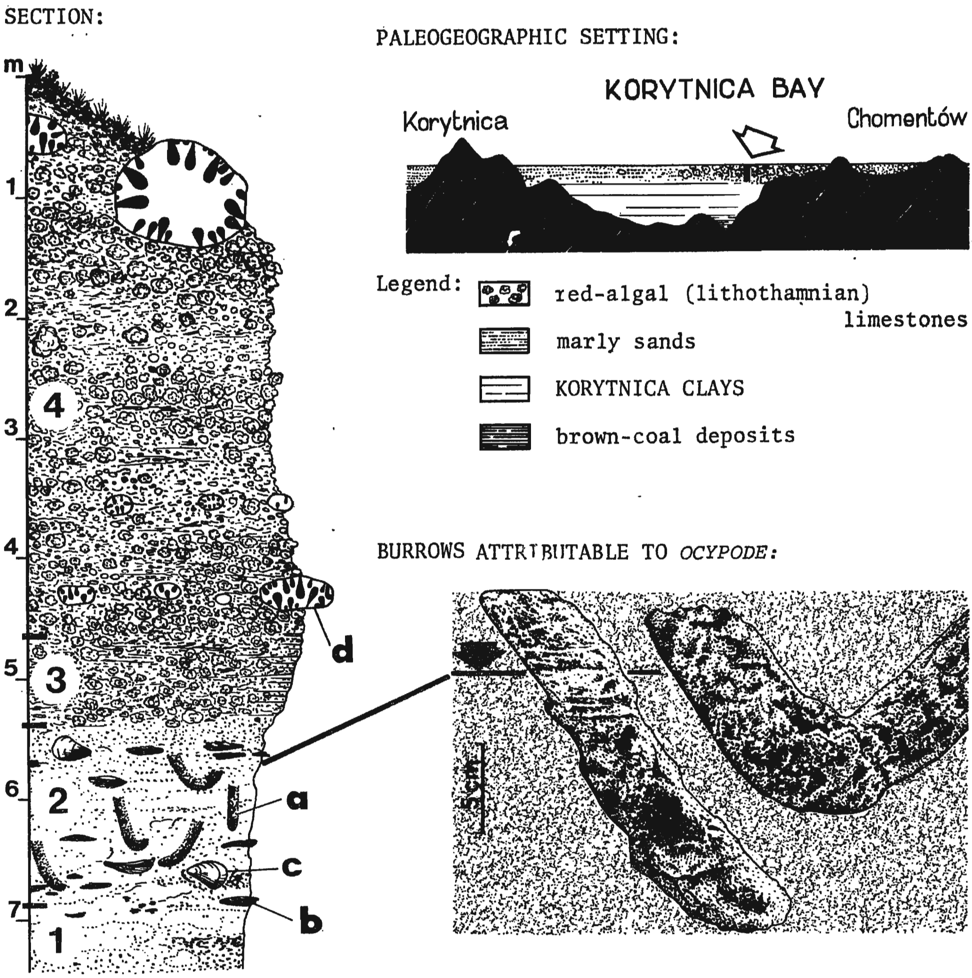


Fig. 1. General situation of the deposits yielding burrows attributable to the ghost crab *Ocypode*, and exposed in the sand-pit at Chomentów (*cf.* Pl. 1, Figs 1—2) in the Korytnica basin (this is locality *4 in*: Bałuk & Radwański 1977, Text-fig. 2)

SECTION: The numbers denote the units (*1*—*4*) discussed in the text:

1 marly sands with scarce fossils, mostly microfauna; *2* marly sands yielding large fossils:

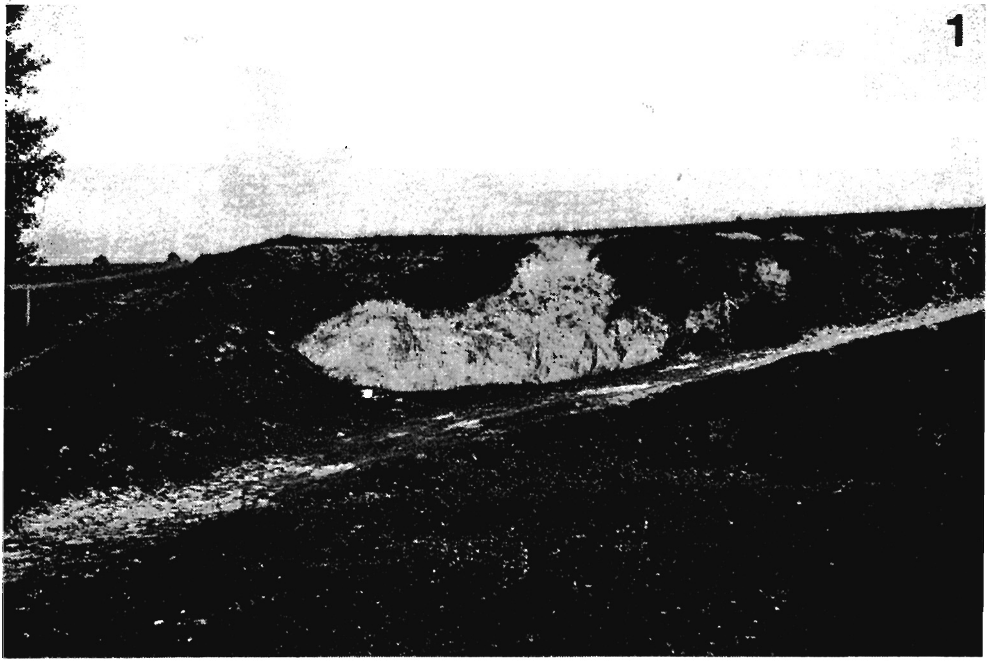
a — burrows attributable to the ghost crab *Ocypode*; their position in the sediment and relation to the bedding plane (marked with a black bar, and arrowed) is also shown in the enlarged fragment (*cf.* Pl. 3);

b — segregated valves of the oyster, *Crassostrea gryphoides* (Schlotheim), commonly bored by various rock-borers, and encrusted by acorn barnacles (*cf.* Radwański 1969, Pl. 41, Figs 1—2);

c — complete shells of the pinnid, *Atrina radwanskii* Jakubowski, preserved in their life position (*cf.* Radwański 1969, Pl. 42; Jakubowski 1977, Pls 1—4);

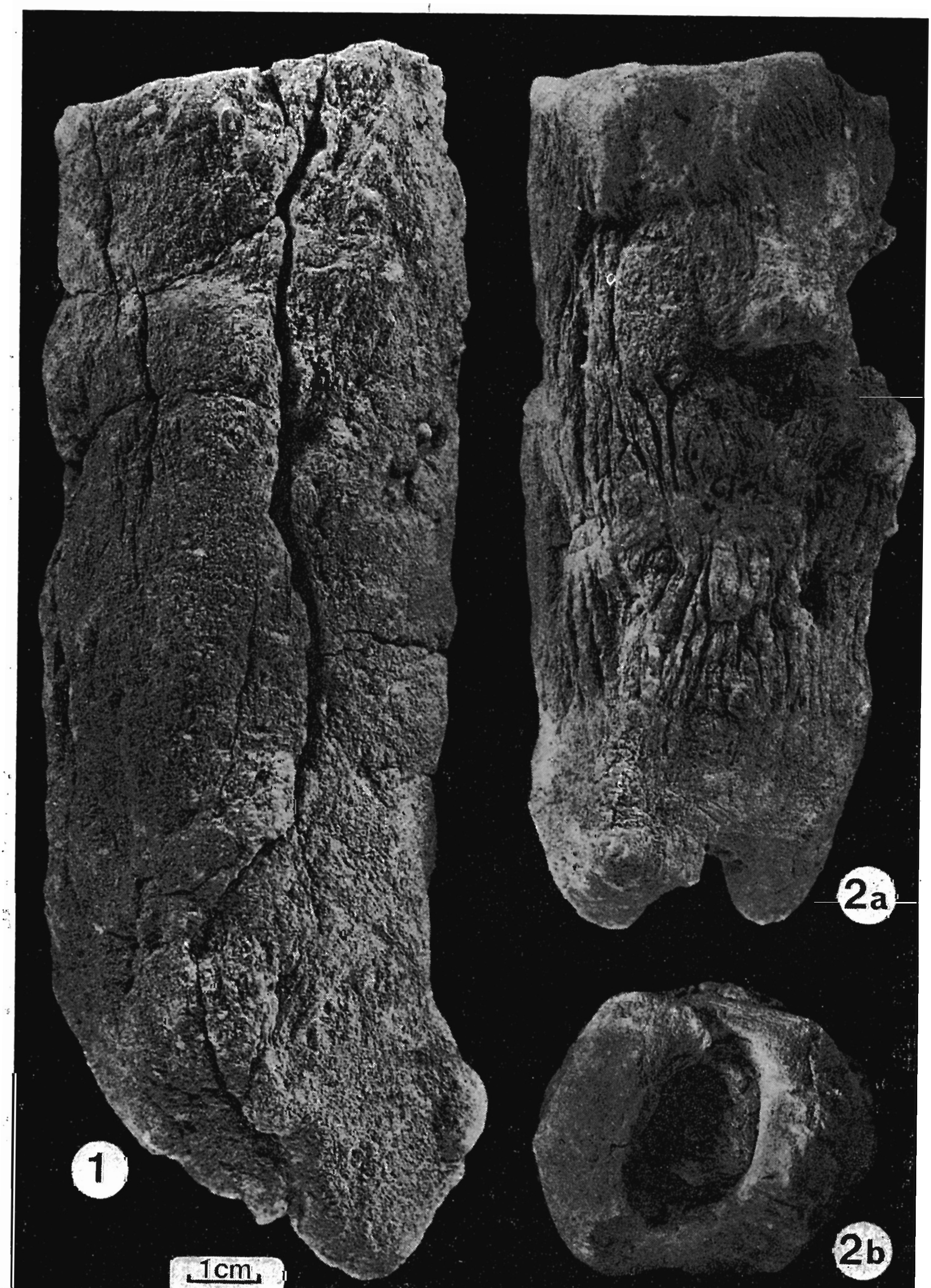
3 marly, red-algal (lithothamnian) limestones; *4* red-algal (lithothamnian) limestones containing large pebbles and boulders (marked d) derived from the shore, and densely bored by various rock-borers, mostly pelecypods (*cf.* Radwański 1969, Pls 39—40)

PALEOGEOGRAPHIC SETTING: Idealized section through the Korytnica basin (*cf.* Bałuk & Radwański 1977, Text-fig. 4), being a part of the Korytnica Bay (*cf.* Bałuk & Radwański 1977, Text-figs 1—2), to show the position of the investigated section (marked by a vertical bar, and arrowed) in the sedimentary sequence of the basin



1 — General view of the sand-pit at Chomentow in the Korytnica basin (*cf.* section in Text-fig. 1).

2 — Close-up view of the section, to show the marly sands yielding burrows attributable to the ghost crab *Ocypode*; the layer containing the most numerous burrows is arrowed (*cf.* interval between 6.0 and 6.5 m in the section, Text-fig. 1).



Burrows attributable to the ghost crab *Ocypode*, from the Middle Miocene (Badenian) marly sands at Chomentow in the Korytnica basin (*cf.* Radwański 1970, Pl. 6)

1 — Slightly arching part of the burrow, close to its lower termination; cracks are supposedly due to synaeresis

2 — Fragment of another burrow, to show its grooved pattern on the surface (*2a*), and the central canal (*2b*)

When longer fragments are found in the exposure, it is evident that in their upper parts they are sharply terminated by a flat cutting which should be ascribed to the synsedimentary truncation by hydrodynamical agents (*cf*. section in Text-fig. 1).

ATTRIBUTION OF THE BURROWS TO *OCYPODE*

The collected burrows display a variety of shapes which range from almost straight, although occurring obliquely to the bedding (Pl. 3, Fig. 1), to slightly arching, especially in their lower part to aquire a *J*-shaped form (Pl. 2, Fig. 1; Pl. 3, Figs 3—4), and finally to broad *U*-shaped forms (Pl. 3, Fig. 2). The intermediate forms are not very common, the same as those with additional arms of which only their basal parts remain preserved. In some burrows, an indistinct, gently swollen knob is recognizable which makes such a basal part of the additional arm.

The above presented size, structure and morphological features of the burrows are identical with those of the present-day ghost crab *Ocypode*, the burrows of which vary in shape dependant on littoral subenvironments [1] ranging from foreshore-backshore transitional zone through beach dunes (*cf*. Hayasaka 1935, Frey 1970, Frey & Mayou 1971, Farrow 1971, Braithwaite & Talbot 1972, Hill & Hunter 1973, Allen & Curran 1974). The best comparable burrows of the ghost crab *Ocypode quadrata* (Fabricius) from the Georgia coast are those occurring within the upper backshore and dune zones (*cf*. Frey & Mayou 1971, Text-fig. 3 and Pls 2—3).

In the investigated section there are however no depositional structures typical of the last-named zones [2]. The sedimentary area should therefore be regarded as presumably submerged, and comprising the life habitats of the ghost crabs slightly different from their present--day environments (see discussion below).

ANCIENT ANALOGS

The heretofore reports on ancient burrows attributable to the ghost crab *Ocypode* are very scant. All of them are very inadequately illustrated, and they cannot be used for any detailed comparison with the specimens found at Chomentow.

[1] Another variation is also caused by sexual dimorphism: females produce "normal" burrows, whereas males can produce spiral forms (Farrow 1971, p. 465; *cf*. also Stephenson 1965, Braithwaite & Talbot 1972). If this is a common rule (*cf*. objections by Braithwaite & Talbot 1972), the investigated burrows from Chomentow should be ascribed to the activity of females.

[2] Missing are also any other decapod burrows so typical for the Recent littoral (supratidal including) environments (*cf*. Hayasaka 1935, Shinn 1968, Farrow 1971, Frey & Mayou 1971, Braithwaite & Talbot 1972, Allen & Curran 1974).

Frey & Mayou (1971, Pl. 4, Fig. 3) presented a burrow, visible in a section of deposits, from the Pleistocene Pamlico Formation of Florida. In the Pleistocene deposits, similar burrows are also known from the coast of Kenya (Stephenson 1965). An older report by Hayasaka (1935, Pl. 2, Fig. 2) concerns the burrows from the Tertiary (?Miocene) of Taiwan. If this latter attribution is correct, it evidences a world-wide distribution of the *Ocypode* burrows along the warm-water seashores already at the Miocene time.

Until more examples are delivered, the investigated burrows cannot be thoroughly considered within the ichnologic category of the trace fossils, and they are therefore regarded only as ancient counterparts of the present-day forms (*cf.* Radwański 1977).

CLIMATIC REQUIREMENTS

The genus *Ocypode* Weber, 1795, to which the investigated burrows are ascribed, is mostly confined to tropical and/or subtropical climatic zones.

The heretofore recognized burrowing activity of this genus has been reported from Taiwan and southern Japan (*cf.* Hayasaka 1935, Takahasi 1935), Aldabra Atoll (Farrow 1971), Seychelles (Braithwaite & Talbot 1972), Kenya and Mozambique (*cf.* Stephenson 1965), as well as from the Atlantic (Gulf of Mexico including) coast of the southern United States (*cf.* Frey 1970, Frey & Mayou 1971, Hill & Hunter 1973, Allen & Curran 1974). In the latter region, the geographic extent of the genus, due to the Gulf Stream, is wider, and it runs to the north as far as North Carolina (*cf.* Frey 1970, Allen & Curran 1974). To the south this extent reaches Brasil (*cf.* Frey & Mayou 1971).

The conjectured occurrence of the genus *Ocypode* in the Korytnica basin, if the presented attribution of the investigated burrows is acceptable, may therefore be regarded as an additional indicator of tropical and/or subtropical climatic conditions within that basin at the Miocene time (for further data see Bałuk & Radwański 1977).

ENVIRONMENTAL CONDITIONS

The marly sands that contain the discussed burrows attributable to *Ocypode* appeared, during the sedimentary history of the Korytnica basin, just after deposition of the Korytnica Clays. The uppermost part of these clays yields a rich community of diverse fossils, some of which are extreme shallow marine, and indicative of the depth of a few meters (*cf.* Radwański 1969, Bałuk & Radwański 1977). Overlying the marly sands are red-algal (lithothamnian) limestones with large boulders derived from the littoral zone, and which are interpreted as deposited at the depth decreasing to almost zero when the lithothamnian meadows carpeted the shallowing basin up to sea level (*cf.* Radwański 1969, 1970; Bałuk & Radwański 1977).

Consequently, the marly sands interval of the Korytnica sedimentary sequence represents an extreme shallow marine environment. As indicated by the truncation of *Ocypode* burrows, and by segregation and abrasion of large oysters or their clusters, this was a high-energy environment, presumably strongly influenced by stormy and/or tidal agitation. This agitation was responsible for a partial erosion of the *Ocypode* burrows, whose topmost parts might had been less consolidated, to such an extent as it occurs in the Recent callianassid burrows (*cf.* Weimer & Hoyt 1964). A partial scouring of the bottom material is also evident from the mode of preservation of the large, endobenthic pinnid pelecypod, *Atrina radwanskii* Jakubowski, whose shells were temporarily exposed to the epibionthic activity (*cf.* Jakubowski 1977). The bottom was then, partly at least, stabilized by seagrasses in patchy spots [3] in which small echinoids (*Echinocyamus*) and associated small-sized fauna lived (*cf.* Bałuk & Radwański 1977). This may explain why the burrows were partly eroded, but never dug out of the bottom and reworked.

A very indistinct bedding of the marly sands, and their almost homogeneity may also be ascribed to such conditions under which either the agitation, or bioturbation both by vagile endobenthic animals and by roots of seagrasses, were responsible for blurring any primary physical structures of the deposits.

The depth of the basin at that time, as it appears from the above presented shapes of the *Ocypode* burrows, should be estimated as extreme low, ranging just below, or even being within the intertidal zone.

INTERPRETATION OF THE SEDIMENTARY SEQUENCE

The structure of the marly sands that yield the *Ocypode* burrows (*cf.* Text-fig. 1) shows that these sands cannot be ascribed to sedimentation in any backshore or dune zone. As therefore suggested before, the life habitat of the ghost crab *Ocypode* had to be then confined to a shallow submerged environment. There is also possible another interpretation, namely that the sands preserved in the section represent only the lowest part of the sandy deposits, the upper parts of which, featured in the backshore zone, have been completely swept away. In such a case, this explains the truncation of the burrows, and

[3] The subaqueous scenery being then comparable to that presented by Shinn (1968, Text-fig. 6*A*) from the Florida and Bahama offshores.

preservation only of their parts constructed beneath the scouring surface. Finally, it is also possible that at the discussed time the sediment surface in the Korytnica basin, being a protected part of the Korytnica Bay (*cf.* Bałuk & Radwański 1977, Text-figs 1—2), was exposed over sea level as a wide tidalflat, but the eolian processes could not develop and feature the shore with structures typical of Recent upper backshore and dune zones.

In any case, the discussed interval of the sedimentary sequence evidences an extreme shallow, or temporarily emerged episode in the history of the Korytnica basin. It is noteworthy that the foraminifer assemblage, and the structure of the tests of some particular foraminifer species from that interval, show an environment highly influenced by fresh-water supplies (Walkiewicz 1975). If so, it really might have been then a temporary halt in the normal marine development of the sequence.

The red-algal (lithothamnian) limetones that overlie the marly sands (Units *3—4* in Text-fig. 1) evidence a return of marine sedimentation. This was connected with a rise of the sea level at least to about 5—6 meters, as such is the thickness of the lithothamnian limestones preserved in the section. Large pebbles and cobbles, densely bored by various rock-borers, were then temporarily supplied from the seashore (distant *c* 200—300 m). The largest boulders, attaining over 1 m in their diameter, and embedded in the topmost part of the preserved sequence (*cf.* Text-fig. 1) were certainly hurled over the lithothamnian meadows when they carpeted the basin almost up to sea level, and it happened in the same way as such boulders and huge blocks are sledded by hurricanes over a slippery surface of the Recent coral reefs (*cf.* Newell 1955; Radwański 1969, 1970). If so, the depth of the Korytnica basin is to be said as decreasing again to zero. The boulder-bearing horizon is now the highest in the preserved sedimentary sequence of both the investigated section, and of the whole Korytnica basin (*cf.* Bałuk & Radwański 1977). As the section is bounded by the erosional surface (*cf.* Text-fig. 1), it is however difficult to recognize if this was the last ever-existing episode that completed the marine sedimentation in the Miocene Korytnica Bay.

Institute of Geology
of the Warsaw University,
Al. Żwirki i Wigury 93,
02-089 Warszawa, Poland

REFERENCES

ALLEN, E. A. & CURRAN, H. A. 1974. Biogenic sedimentary structures produced by crabs in lagoon margin and salt marsh environments near Beaufort, North Carolina. *J. Sedim. Petrol.*, **44** (2), 538—548. Menasha.

BAŁUK, W. & RADWAŃSKI, A. 1977. Organic communities and facies development of the Korytnica basin (Middle Miocene; Holy Cross Mountains, Central Poland). *Acta Geol. Polon.*, **27** (2) *[this issue]*. Warszawa.

BRAITHWAITE, C. J. R. & TALBOT, M. R. 1972. Crustacean burrows in the Seychelles, Indian Ocean. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **11** (4), 265—285. Amsterdam.

FARROW, G. E. 1971. Back-reef and lagoonal environments of Aldabra Atoll distinguished by their crustacean burrows. *Symp. Zool. Soc. London,* **28**, 455—500. London.

FREY, R. W. 1970. Environmental significance of Recent marine lebensspuren near Beaufort, North Carolina. *J. Paleontol.*, **44** (3), 507—519. Menasha.

— & MAYOU, T. V. 1971. Decapod burrows in Holocene barrier island beaches and washover fans, Georgia. *Senckenberg. Maritima,* **3**, 53—77, Frankfurt a.M.

HAYASAKA, I. 1935. The burrowing activities of certain crabs and their geologic significance. *Amer. Midl. Nat.*, **16** (1), 99—103. Notre Dame, Indiana.

HILL, G. W. & HUNTER, R. E. 1973. Burrows of the ghost crab *Ocypode quadrata* (Fabricius) on the barrier islands, south-central Texas coast. *J. Sedim. Petrol.*, **43** (1), 24—30. Menasha.

JAKUBOWSKI, G. 1977. A new species of large pinnid pelecypods from the Korytnica basin (Middle Miocene; Holy Cross Mountains, Poland). *Acta Geol. Polon.*, **27** (2) [*this issue*]. Warszawa.

NEWELL, N. D. 1955. Depositional fabric in Permian reef limestones. *J. Geol.*, **63** (4), 301—309. Chicago.

RADWAŃSKI, A. 1969. Lower Tortonian transgression onto the southern slopes of the Holy Cross Mountains. *Acta Geol. Polon.*, **19** (1), 1—164. Warszawa.

— 1970. Dependence of rock-borers and burrowers on the environmental conditions within the Tortonian littoral zone of Southern Poland. *In*: T. P. CRIMES & J. C. HARPER (*Eds*), Trace Fossils (*Geol. J. Spec. Issues,* **3**), 371—390. Liverpool.

— 1977. Present-day types of traces in the Neogene sequence; their problems of nomenclature and preservation. *In*: T. P. CRIMES & J. C. HARPER (*Eds*), Trace Fossils **2** (*Geol. J. Spec. Issues,* **9**). Liverpool.

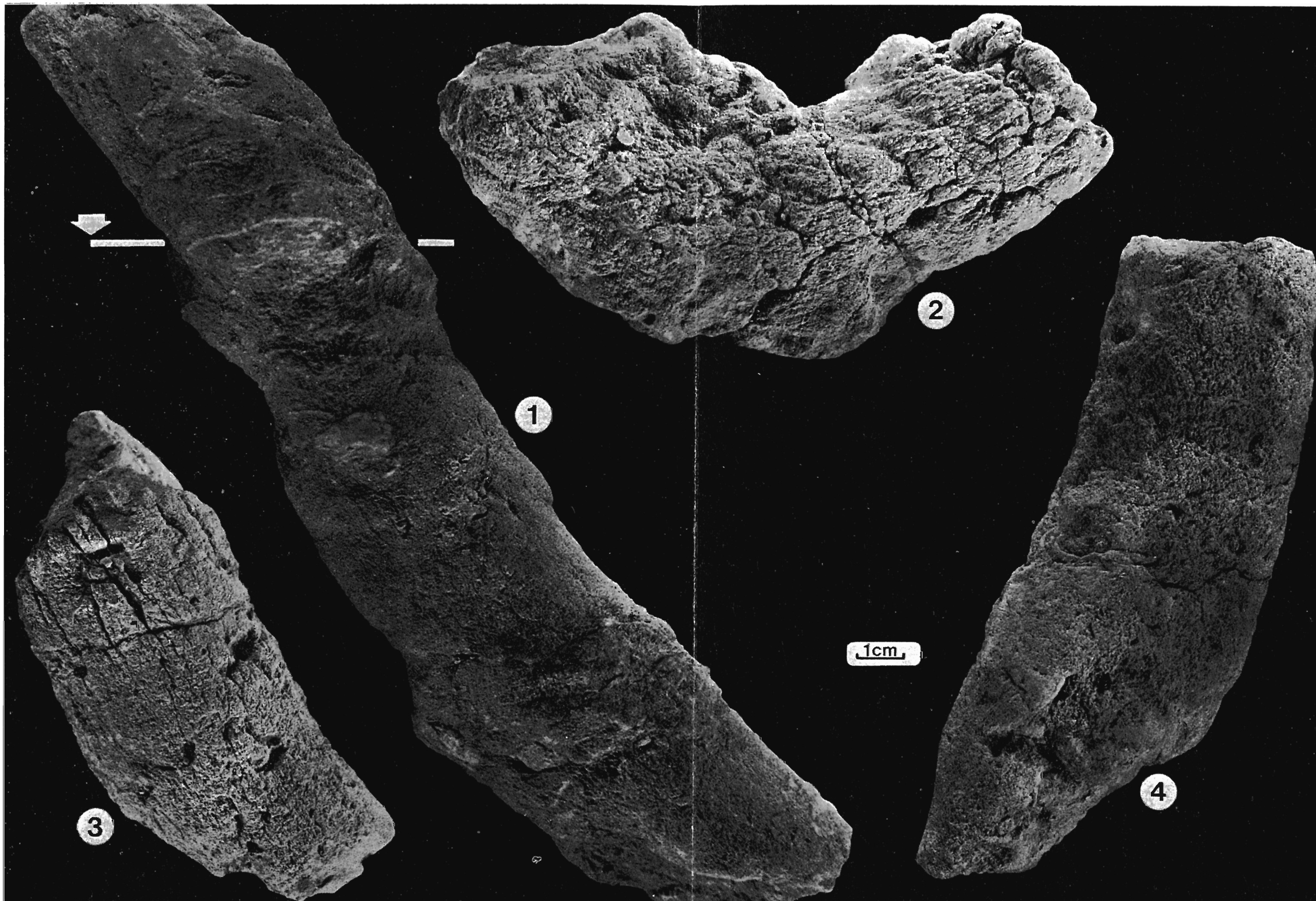
SHINN, E. A. 1968. Burrowing in Recent lime sediments of Florida and the Bahamas. *J. Paleontol.*, **42** (4), 879—894. Menasha.

STEPHENSON, D. G. 1965. Fossil burrows on the coast of Kenya. *Nature,* **207** (4999), 850—852. London.

TAKAHASI, S. 1935. Ecological notes on the ocypodian crabs (Ocypodidae) in Formosa. *Annotat. Zool. Japan.*, **15** (1), 78—87. Tokyo.

WALKIEWICZ, A. 1975. Some examples of ecological interpretation based on foraminifers from the Tortonian of Korytnica. *Przegl. Geol.*, No. **11** (271), 525—529. Warszawa.

WEIMER, R. J. & HOYT, J. H. 1964. Burrows of *Callianassa major* Say, geologic indicators of littoral and shallow neritic environments. *J. Paleontol.*, **38** (4), 761—767. Menasha.



Burrows attributable to the ghost crab *Ocypode*, from the Middle Miocene (Badenian) marly sands at Chomentow in the Korytnica basin (*cf.* Radwański 1977, Pl. 3*b*); the burrows are photographed in such position as they occurred in the section (*cf.* Text-fig. 1)

1 — Longer fragment, displaying indistinct horizontal bedding of the adjacent sands (the level is marked with a white bar, and arrowed) 2 — *U*-shaped, lower part (the "knee") of the burrow; 3—4 — Parts of the burrows, close to their *J*-shaped arching; further explanations in the text