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The genus *Palmula* and some other rare Nodosariidae (Foraminiferida) from the Korytnica Clays (Middle Miocene; Holy Cross Mountains, Poland)

ABSTRACT: The Korytnica Clays yield well preserved and exceptionally rich assemblage of foraminifers of the family Nodosariidae Ehrenberg. The paper presents descriptions of the foraminifer species rare in the Miocene of Poland: two species of the genus *Palmula* Lea (including a new one, *Palmula inornata* sp. n.), three of the genus *Frondicularia* Defrance, and single species of the genera *Plectofrondicularia* Liebus and *Amphimorphina* Neugeboren.

INTRODUCTION

The foraminifer microfauna of the Korytnica Clays is still poorly known, and only tentatively recognized (*cf.* Alexandrowicz 1959, 1965; Janiszewska-Pactwa 1960; Walkiewicz 1972, 1975; Łuczkowska 1974). In the middle of the road from Korytnica to Karsy (*cf.* Text-fig. 1), a new locality of plastic clays was recently found (*cf.* Bałuk 1975). Samples taken at this locality were washed for foraminifers by Docent W. Bałuk and the author; about 1 ton of clays was treated to collect the foraminifers of the genus *Palmula* Lea, and about 3 kg sample for those of other genera.

The species of the family Nodosariidae Ehrenberg, described here, are relatively rare in the Miocene of Poland (*cf.* Bieda 1936; Łuczkowska 1957, 1964; Alexandrowicz 1963). This is especially the case of the genus *Palmula*, a single species of which, *Palmula jonesi* (Karrer), was the only one hitherto recorded by Alexandrowicz (1963) from the Upper Silesia region.

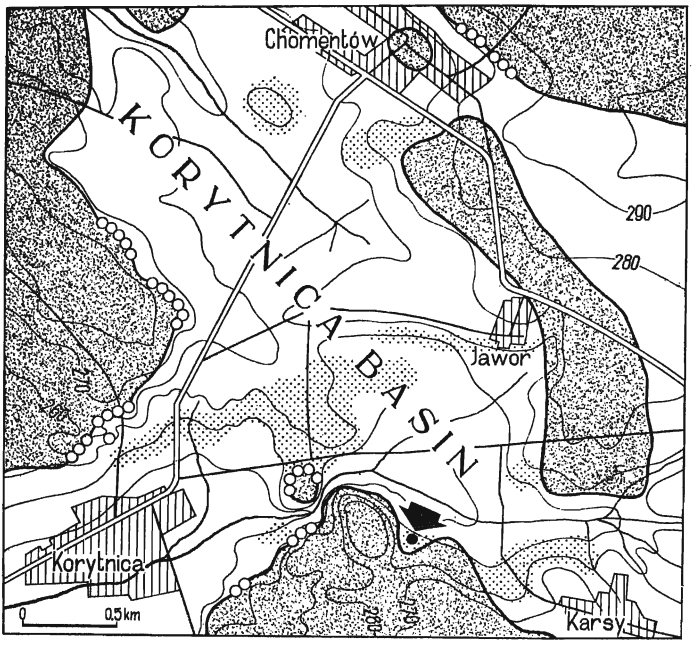

Fig. 1. Paleonvironmental sketch of the Korytnica basin (*from:* Bałuk & Radwański 1977, Text-fig. 2)
Indicated are: marine area of the Korytnica basin during the Middle Miocene (Badenian) transgression *(blank)* and present-day outcrops of the Korytnica Clays *(stippled)*; preserved fragments of littoral structures *(circled)*; land or island areas along the seashore *(hachured)* Arrowed is the sampling place for the investigated assemblage of foraminifers; these are the plastic clays, deposited just at the shoreline of the Korytnica basin

The newly discovered locality of plastic clays is characterized by the occurrence of an assemblage of the species belonging to the family Nodosariidae; it is rich both in species and individuals. The species of the genera *Palmula* Lea, *Frondicularia* Defrance, *Plectofrondicularia* Liebus and *Amphiomorphina* Neugeboren are accompanied by numerous species of *Astacolus* de Montfort, *Dentalina* Risso, *Dimorphina* d'Orbigny, *Lagena* Walker & Jacob, *Lenticulina* Lamarck, *Lingulina* d'Orbigny, *Marginulina* d'Orbigny, *Nodosaria* Lamarck, *Planularia* Defrance, *Saracenaria* Defrance and *Vaginulina* d'Orbigny. The deposits yielding them are developed in similar facies as the Miocene clays at Baden in the Vienna Basin, Austria (*cf.* Karrer 1862, 1865, 1877), Szokolya in the Börzsöny Mts, Hungary (*cf.* Nyirö 1958), Lapugy and Kostej in the Transylvanian Basin, Rumania (*cf.* Karrer 1868), all of them containing the nodosariid assemblage close to that from Korytnica and primarily characterized by the presence of the genera *Palmula* and *Frondicularia*.

In the Korytnica basin, the genera *Palmula* and *Frondicularia* are limited to the investigated facies of plastic clays, and they have not hitherto been found in the facies of typical Korytnica Clays. These

foraminifers seem to be really confined to very fine-grained bottom material, as the same relation was also noticed by Pożaryska (1957) for their Upper Cretaceous representatives.

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SYSTEMATIC DESCRIPTION

Family **Nodosariidae** Ehrenberg, 1838
Subfamily **Nodosariinae** Ehrenberg, 1838
Genus *PALMULA* Lea, 1833
Palmula jonesi (Karrer, 1877)
(Pl. 1, Fig. 8)

1877. *Flabellina jonesi* Karrer; F. Karrer, p. 362, Pl. 16b, Fig. 32.
Material: Three, well preserved specimens (Coll. No. *F—1*).
Dimensions: Length 4.15—4.92 mm; width 2.85—3.10 mm.

Remarks. — The investigated specimens do not differ from that described from the clays *(Tegel)* of Baden by Karrer (1877). The species previously mentioned from Poland by Alexandrowicz (1963).

Palmula inornata sp. n.
(Pl. 1, Figs 1—7 and Pl. 2, Figs 8—9)

Holotype: The specimen (macrospheric form) presented in Pl. 1, Fig. 6; housed in the author's collection.
Paratypes: Specimens presented in Pl. 1, Figs 1—5, 7 and Pl. 2, Figs 8—9.
Type locality: Korytnica, 24 km SSW of Kielce, southern slopes of the Holy Cross Mts.
Type horizon: Middle Miocene (Badenian).
Derivation of the name: Latin *inornata* — after smooth test surface.

Diagnosis: Test almost rhomboidal in outline, smooth, with strongly incised peripheral outline; proloculum convex, large.

Material: Forty six, well preserved specimens (Coll. No. *F—2*).
Dimensions of the holotype (macrospheric form): 6.05 mm long, 5.62 mm wide, 0.25 mm thick, maximum diameter of proloculus — 0.65 mm. *Paratypes* (macrospheric form): 4.64—8.30 mm long, 3.32—5.82 mm wide, 0.24—0.63 mm thick, maximum diameter of proloculus — 0.49—0.68 mm.

Description. — Test large, massive, subrhomboidal in outline, thickest in the middle of its length. Proloculus smooth. Two types of chambers may be distinguished: 2—3 arched chambers rising over the proloculus and numerous equitard chambers, the first of which completely overlaps both proloculus and the arched chambers. Equitard chambers markedly narrowing towards test margin; suture between chambers wide, markedly convex. Marginal parts are developed in the form of strongly incised, uneven ledge, except for the margin of the last chamber. Apertures of proloculus and a few first chambers are situated at medial axis of test; otherwise terminal, radial, somewhat elevated.

Variability. — Test outline variable, from ovate to rhomboidal. Some forms (8 specimens) display apertures of proloculus and a few first chambers shifted eccentrically in relation to medial axis of test. The degree of incision of the marginal ledge is also variable.

Dimorphism and ontogeny. — The material studied comprises a small number of microspheric forms (4 specimens) characterized by spiral arrangement of first chambers (*cf.* Pl. 1, Fig. 5 and Pl. 2, Fig. 9). The microspheric forms are markedly more slender than the macrospheric; they are more numerous (42 specimens) and characterized by proloculus partly overlapped by 2—3 first chambers (*cf.* Pl. 1, Fig. 7 and Pl. 2, Fig. 8). The juvenile stage of macrospheric form is characterized by the development of two arched chambers and first equitard chamber (Pl. 1, Figs 1—3).

Remarks. — The new species is similar to *Palmula jonesi* (Karrer) from the Tegel of Baden (*cf.* Ellis & Messina 1940), differing in larger and more massive test, wider inter-chamber suture and the spiral part not differentiated from the rest of test. It differs from *Palmula appendicifera* Nyirö from the Szokolya Clays (*cf.* Nyirö 1958, p. 243, Pl. 24, Fig. 1) in larger and more convex proloculus and in arrangement of chambers in older part of the test.

Genus *FRONDICULARIA* Defrance, 1826

Frondicularia monacantha Reuss, 1850
(Pl. 2, Figs 5—7)

1850. *Frondicularia monacantha* Reuss; A. Reuss, p. 368, Pl. 46, Fig. 14.

Material: Twenty four, well preserved specimens (Coll. No. *F*—3).
Dimensions: Length 1.25—1.75 mm, width 0.80—0.95 mm, diameter of proloculus 0.40 mm.

Variability. — The variability concerns the shape of older part of the test changing from triangular to ovate.

Remarks. — The investigated specimens differ from that described by Reuss (1850) from the Tegel of Baden in somewhat larger test and more elongated spine from proloculus. They are somewhat similar to *F. rovasendae* Dervieux from the Miocene of Italy, and *F. tenuissima* Hantken from the Oligocene of Hungary (*cf.* Ellis & Messina 1940), but they differ in a marked proloculus with spine and less elongated shape of the test.

Frondicularia raricosta Karrer, 1877
(Pl. 1, Fig. 11)

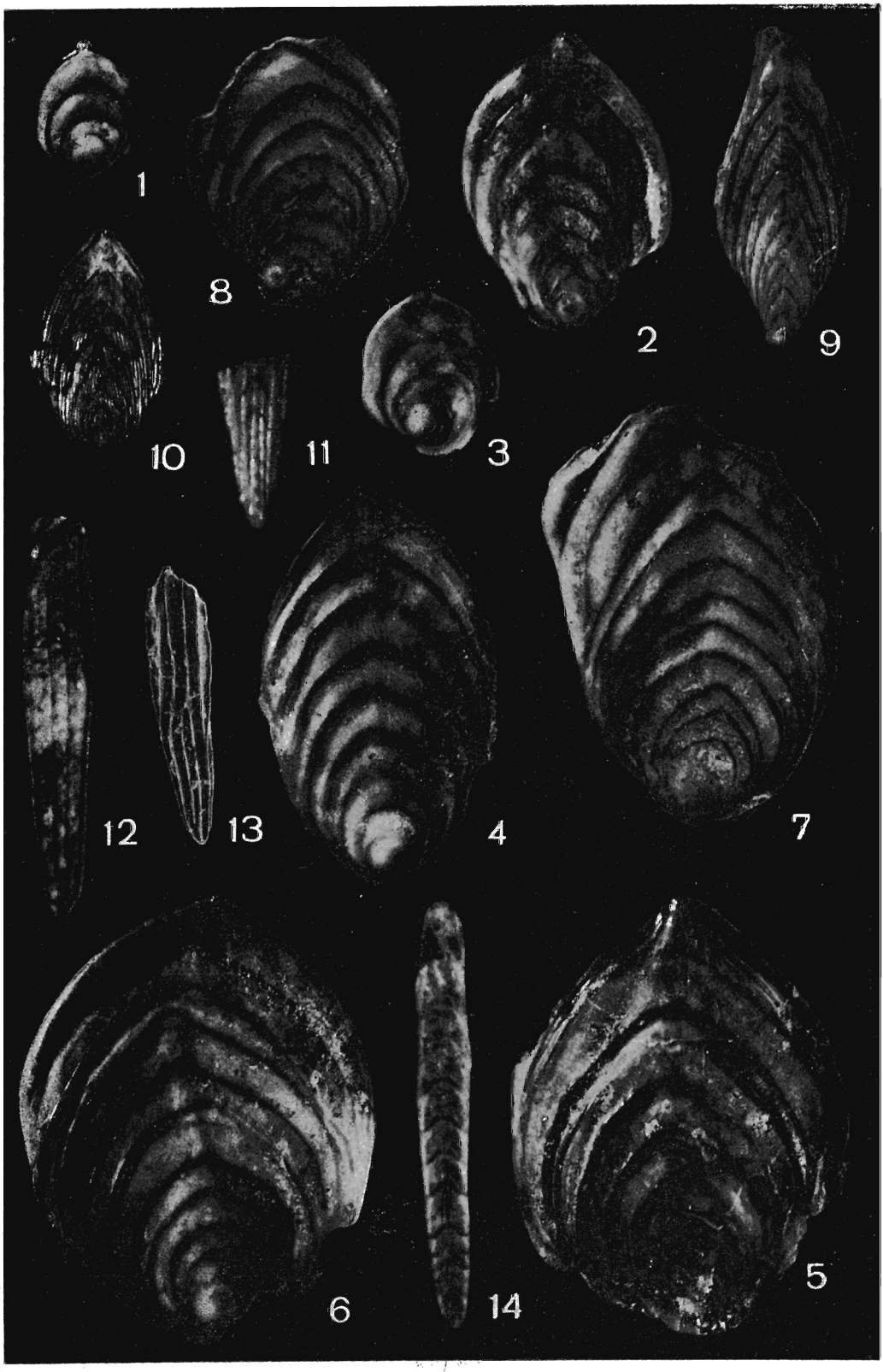
1877. *Frondicularia raricosta* Karrer; F. Karrer, p. 381, Pl. 16b, Fig. 28.
1968. *Frondicularia raricosta* Karrer; I. Korecz-Laky, p. 82, Pl. 9, Fig. 3.

Material: Five specimens with apertural part broken off (Coll. No. *F*—4).
Dimensions: Length unknown, width 0.30—0.50 mm.

Remarks. — The investigated specimens differ from that from the Tegel of Baden described by Karrer (1877) in markedly longer striae. The discussed species differs from *Frondicularia semicosta* Karrer, also from the Tegel of Baden (*cf.* Karrer 1877, p. 380, Pl. 16b, Fig. 26) in less numerous striae and gentler curvature of inter-chamber suture.

PLATE 1

1—7 *Palmula inornata* sp. n.: *1—3* juveniles of macrospheric forms, *4—6* macrospheric forms (6 presents the holotype), 7 microspheric form; × 12
8 *Palmula jonesi* (Karrer); × 12
9—10 *Frondicularia sculpta* Karrer; × 12
11 *Frondicularia raricosta* Karrer; × 50
12—13 *Plectofrondicularia diversicostata* (Neugeboren); × 50 (*13* is SEM photo)
14 *Amphimorphina haueriana* Neugeboren; microspheric form, × 50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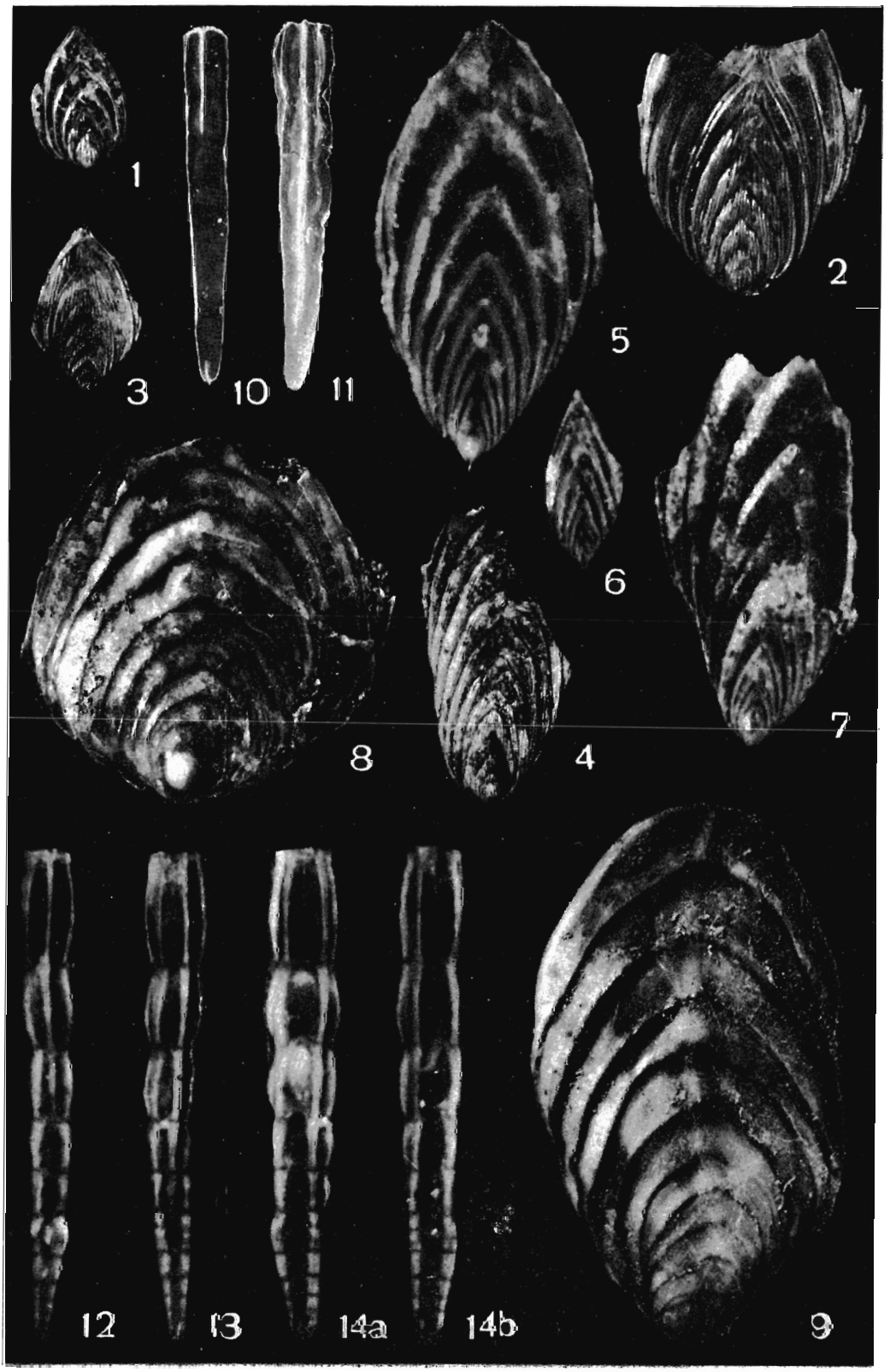
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Frondicularia sculpta Karrer, 1862
(Pl. 1, Figs 9—10 and Pl. 2, Figs 1—4)

1862. *Frondicularia sculpta* Karrer; F. Karrer, p. 442, Pl. 1, Fig. 2.
1877. *Frondicularia sculpta* Karrer var. *seminuda* Karrer; F. Karrer, p. 381, Pl. 16b, Fig. 30a.
1877. *Frondicularia sculpta* Karrer var. *parvinuclea* Karrer; F. Karrer, p. 381, Pl. 16b, Fig. 30b.
1958. *Frondicularia sculpta* Karrer; R. Nyriö, p. 243, Pl. 24, Fig. 2a—b.
Material: Fourteen specimens usually with aperture broken off (Coll. No. *F*—5).
Dimensions: Length 3.52—4.39 mm, width 2.52—2.94 mm.

Variability. — Fairly high variability, concerning the shape of the initial part of the test which changes from sharply triangular (Pl. 1, Fig. 9) to gently ovate (Pl. 2, Fig. 2), as well as ornamentation consisting of fine striae or thick costae. The shape of proloculus changes from spherical to slightly elongated in direction of longer axis of the test.

Remarks. — The investigated specimens do not differ from that described from the Tegel of Baden by Karrer (1862). The discussed species differs from *Frondicularia reussi* Karrer from the Tegel (*cf.* Karrer 1862, p. 441, Pl. 1, Fig. 1a—b) in lanceolate test outline and arrangement of chambers following the proloculus.

Subfamily **Plectofrondicularriinae** Cushman, 1927
Genus *PLECTOFRONDICULARIA* Liebus, 1902
Plectofrondicularia diversicostata (Neugeboren, 1850)
(Pl. 1, Figs 12—13)

1850. *Frondicularia diversicostata* Neugeboren; J. Neugeboren, p. 122, Pl. 3, Figs 7—8 (*fide* Ellis & Messina, 1940).
1914. *Plectofrondicularia diversicostata* (Neugeboren); R. Jaeger, p. 130.
1968. *Plectofrondicularia diversicostata* (Neugeboren); I. Korecz-Laky, p. 97, Pl. 9, Fig. 2.
Material: Seven, well preserved specimens (Coll. No. *F*—6).
Dimensions: Length 0.89—0.99 mm, width 0.19—0.26 mm.

Variability. — Variability concerning the degree of compression of the test, distance between frontal ribs and thickness of lateral rib; both ends of the test are more or less elongated in outline.

Remarks. — The investigated specimens do not differ from that described by Neugeboren (*fide* Ellis & Messina, 1940) from Lapugy in Transylvania. The discussed species is similar to *Frondicularia semicostata* Neugeboren (*fide* Ellis & Messina, 1940), differing in more elongated test outline and fully developed frontal ribs.

Genus *AMPHIMORPHINA* Neugeboren, 1850
Amphimorphina haueriana Neugeboren, 1850
(Pl. 1, Fig. 14 and Pl. 2, Figs 10—14)

1865. *Amphimorphina Hauerana* Neugeboren; F. Karrer, pp. 705—706, Pl. 1, Fig. 6.
1963. *Amphimorphina haueriana* Neugeboren; V. Pokorny, p. 328, Text-fig. 327.
1968. *Amphimorphina haueriana* Neugeboren; I. Korecz-Laky, p. 97, Pl. 8, Fig. 10.

PLATE 2

1—4 *Frondicularia sculpta* Karrer; × 12
5—7 *Frondicularia monacantha* Reuss; × 50
8—9 *Palmula inornata* sp. n.: *8* macrospheric form, *9* microspheric form; × 12
10—14 *Amphimorphina haueriana* Neugeboren: *10* microspheric form, *11—14* macrospheric forms (in *14* — *a* front view, *b* rear view; *10* and *11* are *SEM* photos); × 50

Material: Fourteen, well preserved specimens (Coll. No. F—7).
Dimensions: Length 1.20—2.05 mm, width 0.24—0.30 mm.

Variability. — Variability relatively low, usually concerning the length and thickness of ribs.

Dimorphism. — Microspheric forms (9 specimens) are characterized by a very small proloculus and biserial arrangement of chambers of initial test part (Pl. 1, Fig. 14; Pl. 2, Fig. 10), whilst macrospheric forms (14 specimens) are featured by larger proloculus and uniserial arrangement of chambers through the development of the test (Pl. 2, Figs 11—14).

Remarks. — The investigated specimens do not differ from that described by Neugeboren (*cf.* Karrer 1865) from Lapugy. The described species is similar to *Amphimorphina miocenica* Cushman (*cf.* Ellis & Messina 1940) from the Miocene of Florida, differing in more elongated test outline and poorer ornamentation.

Occurrence. — The species was also recorded from the Miocene of other parts of the Holy Cross Mts (Łuczkowska 1964), and from Upper Silesia (Alexandrowicz 1963).

REMARKS ON ECOLOGY

Foraminifers of the genera *Palmula* Lea and *Frondicularia* Defrance reached their peak development in the Late Cretaceous and since that time they have been loosing importance and do not have any greater significance now (Pożaryska 1957). Some present-day species of the latter genus have been reported at 9—12 m depth in warm waters off the California coast (Cushman & McCulloch 1950) and at 80 m depth off the New Zealand coasts (Eade 1967). In the material studied, these genera are represented by single specimens and cannot be considered as reliable ecological indices. The ecological reconstruction should be based on the analysis of the whole foraminifer assemblage of the Korytnica Clays (*cf.* Walkiewicz 1972, 1975).

The common occurrence of benthic foraminifers of the genera *Amphistegina* d'Orbigny, *Heterostegina* d'Orbigny, *Gypsina* Parker & Jones, *Discorbis* Lamarck, *Asterigerina* d'Orbigny, and of such species as *Eponides repandus* (Fichtel & Moll), *Elphidium crispum* (Linnaeus) and *Ammonia beccarii* (Linnaeus), and of the whole family Miliolidae Ehrenberg is typical of shallow and warm marine basins. The planktic, philothermic species *Candorbulina universa* Jedlitschka and *Globigerinoides triloba* (Reuss) are good indices of the temperature of the waters (*cf.* Phleger 1960, Łuczkowska 1967). In estimating depth of the basin attention was paid to both typical shallow-water foraminifers and the benthic/planktic foraminifers ratio. The contribution of benthic foraminifers equals 89.4% of the whole foraminifer assemblage (Walkiewicz 1975) which is typical of shallow basins (*cf.* similar conclusions on the depth of the basin by Radwański 1969, Bałuk 1975, Bałuk & Radwański 1977). A large number of individuals and species and their

features such as normal dimensions, i.e. the lack of giant, dwarf, or asymmetric forms evidence normal salinity typical of open marine zones during sedimentation of the Korytnica Clays.

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