Late Caradoc and early Ludlow Radiolaria from Baltic erratic boulders

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Glacial erratic boulders of the Ostseekalk type, late Caradoc in age, contain spumellarian radiolarians with their skeleton substituted by iron minerals secondarily oxidized to goethite. Species of both the Inaniguttidae, characterized by the presence of a small spherical central shell, and Entactiniidae, with a transverse central bar, have been identified. A similar radiolarian assemblage, but with original siliceous skeletons preserved, has been identified in a graptolitic limestone boulder, early Ludlow in age.

Key words: Radiolaria, taxonomy, Ordovician, Silurian, Baltic region.

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Introduction

Baltic Ordovician and Silurian radiolarians are still inadequately known. Among the few reports of importance is that by Eisenack (1971) who noted the presence of three indeterminate spumellarian species with pyritized shells within glacial erratic boulders from northern Germany. Rare pyritized or limonitized shells of radiolarians from a small erratic boulder from the Late Ordovician of Estonia were described by Nazarov & Nylvak (1983). Some glacial erratic boulders in northern Poland also contain radiolarians which are associated with conodonts or graptolites in acid-resistant residues. The present paper is based on materials collected by Roman Kozłowski during his studies on the Ordovician and Silurian graptolites and organic microfossils.

Unfortunately, in the studied material the central parts of radiolarian shells are rarely preserved well enough to enable recognition of the way in which spines are attached. Therefore taxonomic identifications have been

based mostly on external similarity of the shells to those of species recognized in better preserved materials from elsewhere.

Classification of early Paleozoic spumellarian radiolarians is mainly based on the way in which the spines merge within the center of the shell. According to Nazarov (1988) the ancestral status is the presence of imperforated internal shell from which usually six spines radiate. This is typical for the inaniguttid radiolarians common in the late Early and Middle Ordovician. Already within this radiolarian group, a median bar may develop together with the internal shell, which branches at both ends into radial spines, usually six in number. This skeletal organization is typical for the entactiniid radiolarians. Several modifications of this spine branching style have been recognized among late Paleozoic spumellarians by Furutani (1990). Already in the Ordovician, the branch of the haplentactiniids developed with spines radiating from one point that is eccentric with respect to the center of spherical shell. Members of all these early groups of Radiolaria are probably present in the studied Baltic material.

Material

The studied radiolarian shells have been extracted by dissolution of their enveloping limestone matrix in hydrochloric acid. The only Ordovician rock type in which they occur commonly is the 'Baltic limestone'; their shells are substituted there with pyrite or goetite. Better preserved radiolarian shells occur in a graptolitic limestone boulder of early Ludlow age where they still have a siliceous composition.

The Ordovician erratic boulders of the so called Ostseekalk (the name introduced by German authors; see Hucke & Voigt 1967) lithic type represent usually a compact, lightly colored limestone, sometimes with red patches and calcitic sparite veins. The graptolite *Orthograptus gracilis* (Roemer) which occurs rarely in this kind of rock constrains its formation to the Late Ordovician (Caradoc-Ashgill).

The microfossil content of this type of limestone has been investigated by numerous authors. Chlorophycean algae *Tasmanites* were described by Eisenack (1958, 1963a) and the present author (Górka 1969), melanosclerites by Eisenack (1965, 1967, 1971) and Górka (1971), Chitinozoa by Kozłowski (1963), Chitinozoa and Acritarcha by Eisenack (1958, 1959, 1963a, b, 1965), Acritarcha by Górka (1969), radiolarians were illustrated by Eisenack (1971), graptolites (Crustoidea) by Kozłowski (1962, 1970a,b), hydroids by Kozłowski (1959), conodonts by Dzik (1976), scolecodonts by Kielan-Jaworowska (1961, 1962, 1966), and bryozoans by Kiepura (1962) and Dzik (1981, 1991). Besides the listed fossils, acid residues of erratic boulders also contain so called 'pseudochitinous linings' of foraminifers (Eisenack 1967, 1971). There are also ostracods and sponge spicules, which are commonly pyritized or limonitized.

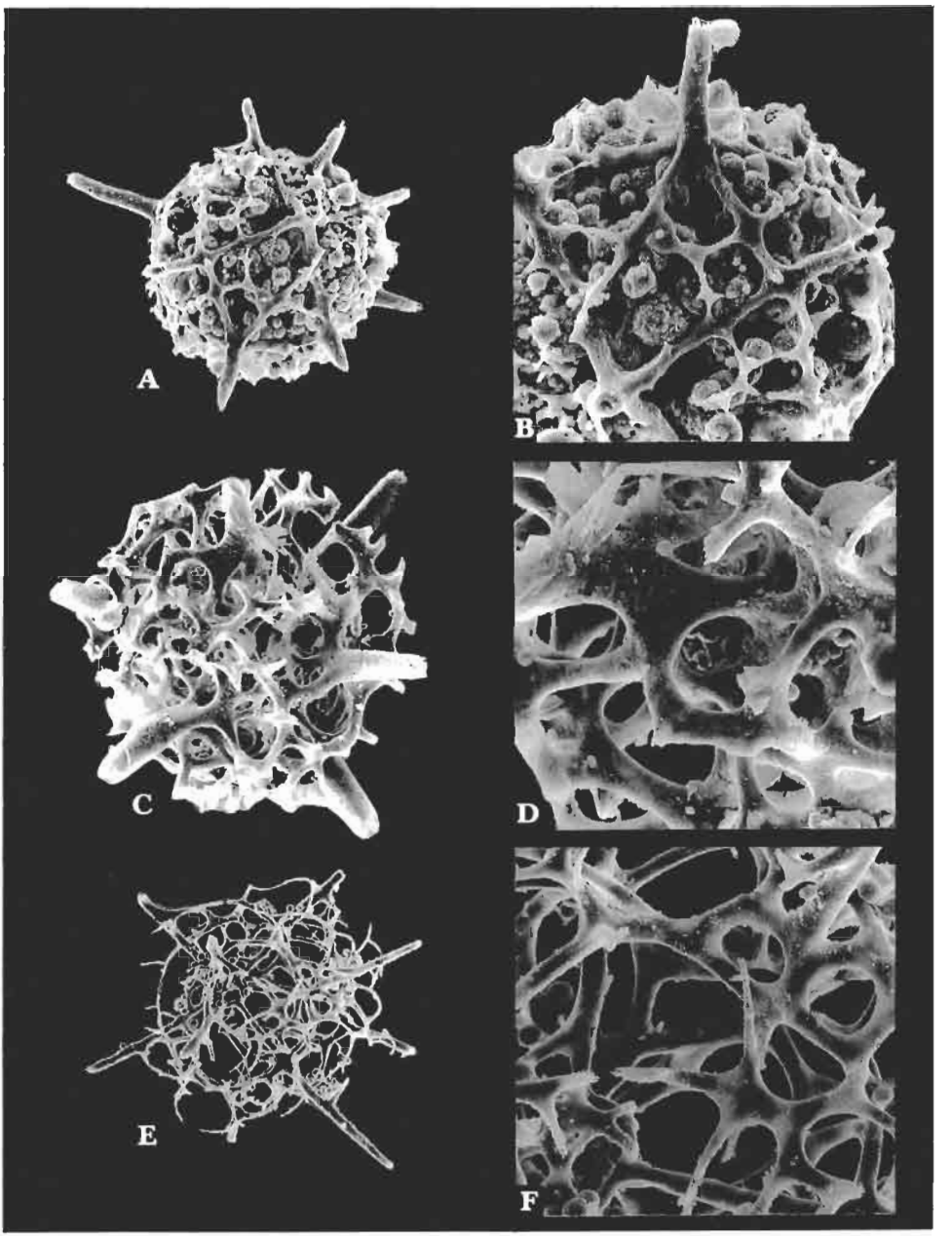

Fig. 1. Radiolarians from the erratic boulder O.101 of Ostseekalk, late Caradoc, Jarosławiec, Pomerania. ❑A–D. *Polyentactinia? estonica* Nazarov 1983. A–B. Specimen IGPUW-IV-8; × 350 and × 600. C–D. Specimen IGPUW-IV-9; × 200 and × 300. ❑E–F. *Haplentactinia?* sp., specimen IGPUW-IV-10; × 200 and × 600.

Although radiolarians occur abundantly in the Ostseekalk facies only two such boulders from the collection of Roman Kozłowski yielded material rich enough to deserve detailed study.

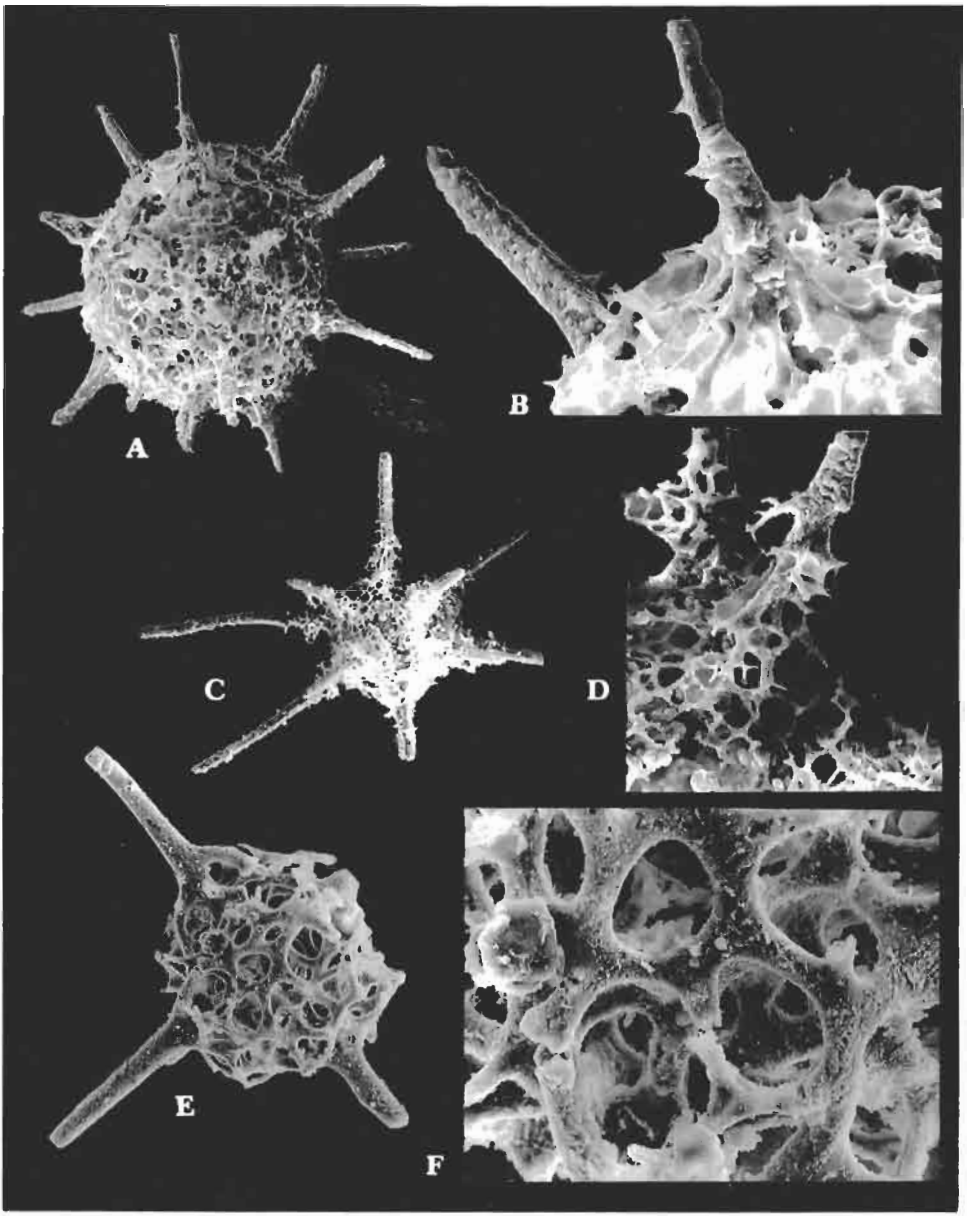

Fig. 2. ❑A–B. *Oriundogutta?* sp. from erratic boulder S.160 of Graptolithengestein, Ludlow, Rewal; holotype IGPUW-IV-15; × 150 and × 500. ❑C–D. *Spongentactinia?* sp. from erratic boulder O.433 of Ostseekalk, Caradoc, Rewal; specimen IGPUW-IV-16; × 90 and × 350. ❑E–F. *Haplentactinia? juncta* Nazarov 1975 from the same boulder; specimen IGPUW-IV-17; × 400 and × 600.

The only Silurian age boulder with well-preserved radiolarians is a common type of the Graptolithengestein, a marly limestone, perhaps a concretion derived from graptolitic shales.

The investigated radiolarian specimens are housed in the Institute of Geology, Warsaw University under the abbreviation IGP-UW-IV. Numbers of Ordovician boulders start with 'O' and Silurian ones with 'S'.

Assemblage from Ordovician boulder O.101

The boulder was collected in Jarosławiec near Słupsk, Pomerania. This is a light coloured micritic Baltic limestone with limonitic radiolarian shells. It also contains the scolecodont *Mochtyella* which is typical of the Ordovician. Among chitinozoans there are: *Conochitina elegans* Eisenack 1931, *Cyatochitina calix* (Eisenack 1931) and *Conochitina micracantha* Eisenack 1931 (typical of the Baltic limestone). Sicules of *Orthograptus gracilis* are also common.

Polyentactinia? estonica Nazarov 1983

Fig. 1A–D.

Remarks. — About 30 well-preserved, limonitized shells in the sample bear 8 spines which are wider at the base. The spine base is connected with bars, bearing secondary finer and pointed spines, in effect, producing a net with irregular meshes. The spines are rounded in cross section. These radiolarians closely resemble specimens of the type population of the species from the Ashgill of Estonia (Nazarov & Nylvak 1983)

Haplentactinia? sp.

Fig. 1E–F.

Remarks. — 15 specimens from the same sample also have 8 spines (4 well-preserved). In this species the spines are in two groups connected by a very small cross-bar. The spines taper slightly distally; along each spine there is one or several spinules, which are also tapering and join each other, forming a net with irregular meshes. Fine spines commonly occur at spinule junctions. Some spinules branch dichotomously. The specimens bear a faint resemblance to the Late Devonian *Haplentactinia arrhina* Foreman 1963 (Foreman 1963) which, however, has only 6 radial spines. The central cross-bar of this species makes generic, and even familial, affiliation problematic. According to Nazarov (1988) the spines in *Haplentactinia* originate at one point, located eccentrically although near the shell center. The Ostseekalk species may thus belong to the Entactiniidae rather than the Haplentactiniidae.

One pyritized specimen in the sample differs from members of the two above species in having a shell which is irregularly spherical, thick, irregularly perforated, and armed with 8 massive solid and long conical spines. The spines have 2–3 apophyses. Numerous other spines are fine, thin and pointed. This specimen may represent *Oriundogutta litterula* Nazarov & Ormiston 1990 from the Late Silurian of southern Urals (Nazarov & Ormiston 1990).

Assemblage from Ordovician boulder O.433

The boulder was collected in Rewal near Kołobrzeg, Pomerania. It is a variety of Baltic limestone containing a lot of sparite. It contains rare radiolarians and sponge spicules. Among other taxa there are chitinozoans *Lagenochitina baltica* Eisenack 1931, melanosclerites, brachiopods, cornulitids, *Climacograptus* sp. and Hydroidea.

Haplentactinia? juncta Nazarov 1975

Fig. 2E–F.

Remarks. — The boulder has yielded 18 pyritized specimens that show shells which are irregularly spherical and have 6–8 massive basally conical spines. The spines are round in cross section, tapering distally. Sometimes they are covered with irregularly distributed apophyses. Meshes of the shell net are relatively large and irregularly oval in outline. The specimens are closely similar to those of *Haplentactinia juncta* Nazarov 1975 from the Llandeilo to Middle Caradoc of central Kazakhstan (Nazarov 1975; Nazarov & Popov 1980).

The spines originate at a small, centrally located bar. As with the similar species from the sample O.101 this makes the generic affiliation somewhat uncertain.

Spongentactinia sp.

Fig. 2C–D.

Remarks. — Three well-preserved specimens from the same sample have a spherical shell with six longer spines of triangular cross section. The spines are wider at the base and may be basally branched and/or anastomozing, thus forming part of the shell surface. They also bear fine, conical, irregularly distributed spinules along their whole length. There are also eight shorter spines which originate at the outer surface of the shell; they are round in cross section and supplied with branching spinules. They may represent a species of *Spongentactinia* but inaniguttid affinities cannot be excluded.

Assemblage from Silurian boulder S.160

The boulder was collected in Rewal near Kołobrzeg. It is finely crystalline, grey graptolitic limestone, composed of fine calcite crystals, with patches of sparite. In thin section quartz silt is also visible. The presence of the graptolite *Pristiograptus dubius* (Suess 1851) indicates early Ludlow (?Gorstian) age. Radiolarian skeletons are siliceous and all approximately the same size.

Along with the radiolarians, there are numerous scolecodonts in the residue: *Paulinites polonensis* Kielan-Jaworowska 1966, *Langeites glaber* Kielan-Jaworowska 1966, *Hindeites gladiatus* (Kielan-Jaworowska 1966)

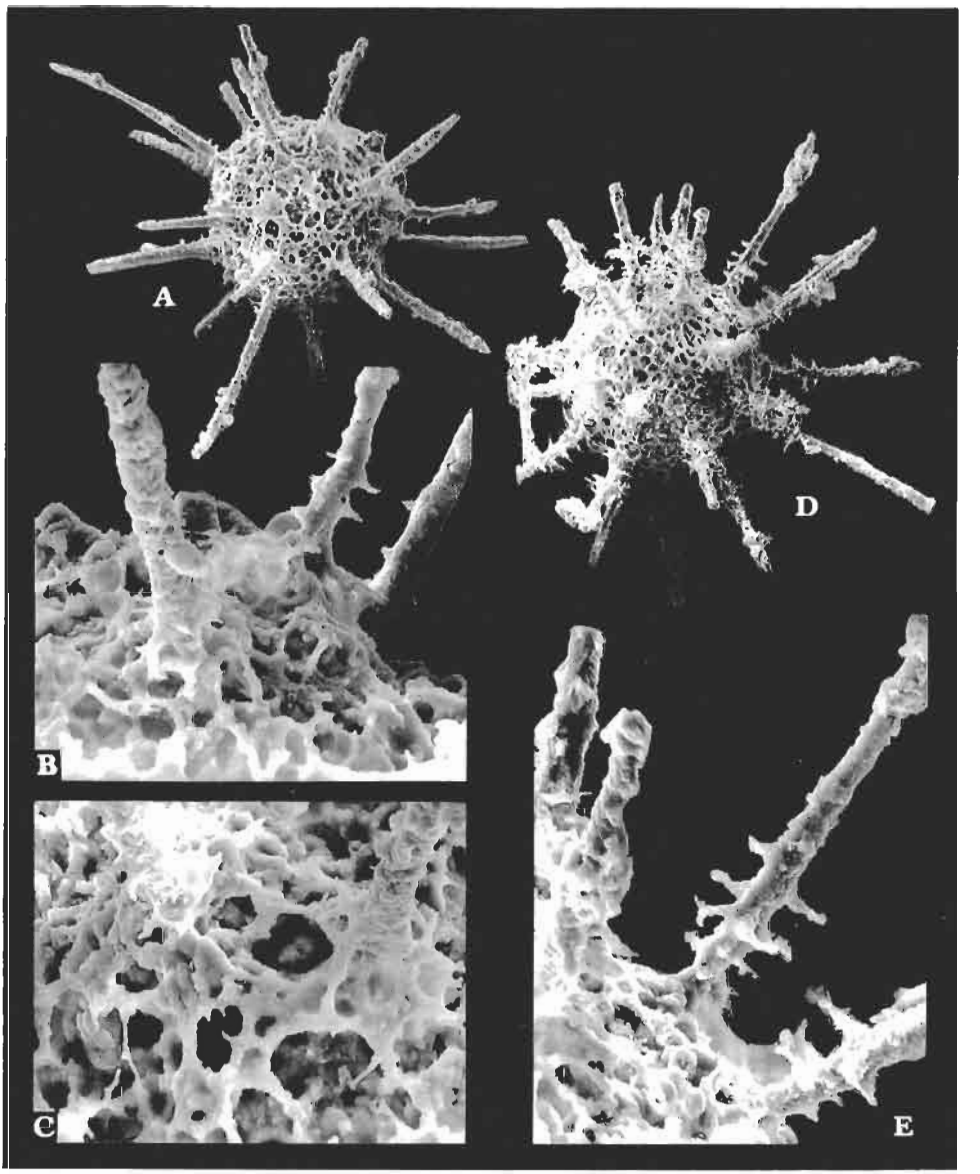

Fig. 3. *Inanihella*? sp. from erratic boulder S. 160 of Graptolithengestein, Ludlow, Rewal. A–C. Holotype IGPUW-IV-18; × 150, × 500, and × 600, respectively. D–E. Specimen IGPUW-IV-19; × 150 and × 300.

and *Lanceolatites gracilis* Bergman 1987. Graptolites from the Silurian erratic boulders in Roman Kozłowski collection were described by Urbanek (1958, 1959).

Spherical radiolarian shells armed with 6 spines, slightly tapering distally, make a significant contribution to the sample (25 specimens). The spines are round in cross-section, and supplied with fine, more or less

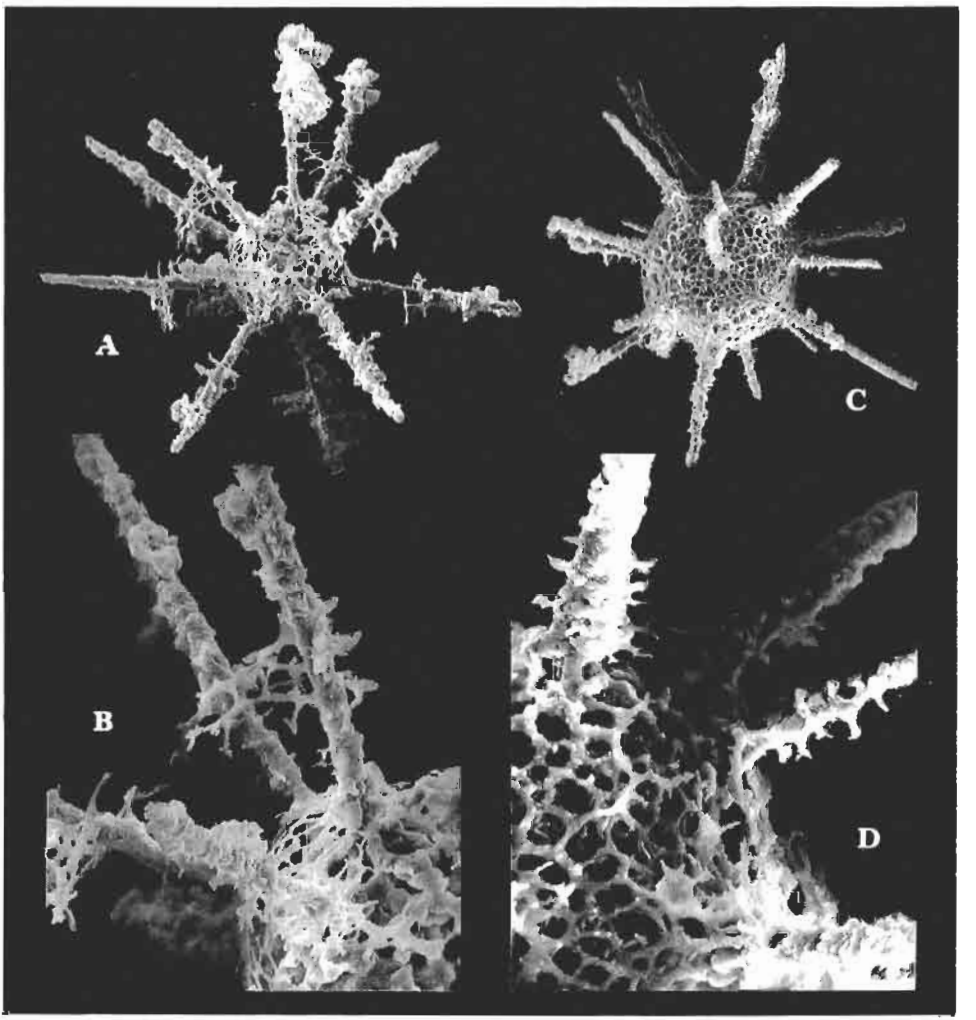

Fig. 4. *Inanihella?* sp. from erratic boulder S.160 of Graptolithengestein, Ludlow, Rewal. A–B. Specimen IGPUW-IV-20; × 200 and × 500. C–D. Specimen IGPUW-IV-21; × 120 and × 300.

numerous 'spinules' oriented perpendicular to the spine axis. However, shells are too poorly preserved to allow generic or even family level identifications.

Oriundogutta? sp.

Fig. 2A–B

Remarks. — Outer shell bears 16–20 conical spines of angular cross-section. The spines are solid, with considerably widened bases, and taper toward bluntly cut tips. They are supplied with fine 'spinules'. The shell surface is spongy with irregular meshes. In some places there are very fine spines originating at the edges of meshes. Inner shell spherical, perfor-

ated, having diameter equal to 1/4 of the diameter of outer spherical shell. 15 well-preserved specimens of this form are present in the sample.

All specimens assigned to this species display a perforated inner shell in transmitted light which indicates that it belongs to the Inaniguttidae Nazarov & Ormiston 1985. The angular cross-section of spines is an advanced character.

Inanihella? sp.

Figs 3A–E, 4A–D.

Remarks. — The outer shell is regularly spherical, supplied with about 20 long and thin, needle-like spines, which are round in cross-section. They have slightly widened bases. Nearly all spines bear fine, conical spinules perpendicular to the main axis of the spine; spinules are better developed in a proximal part. In some specimens spinules can branch dichotomously (Figs 3E, 4D) or several times (Fig. 4B), or they can form a part of outer shell (Fig. 4A–B). The surface of the outer shell, with fine meshes, is irregular, sometimes spongy. In places, at the edges of meshes, fine spines may occur (Figs 3C, 4D). 15 very well-preserved specimens of the species have been extracted.

In the transmitted light, an inner spherical shell is visible which is the base of 6 primary spines. The only character which makes this species different from co-occurring *Oriundogutta?* sp. are longer and more slender spines with only slightly widened bases. There is a high variability in outer shell size, degree of branching of spinules, as well as in the size and shape of perforations, sometimes also in the spongy structure.

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Streszczenie

Opracowano Radiolaria (Polycystina) z ordowickich i sylurskich głazów narzutowych regionu bałtyckiego. Ordowickie głazy narzutowe, to tak zwany „wapień bałtycki", którego wiek określa się na późny karadok. Zawarte w nich szkielety Radiolaria są zlimonityzowane lub spirytyzowane, co jest częstym zjawiskiem w przypadku tej grupy mikroorganizmów kopalnych.

Przedstawiono historię badań nad skamieniałościami zawartymi w wapieniu bałtyckim ze szczególnym uwzględnieniem prac polskich autorów oraz nad Radiolariami z ordowickich i sylurskich osadów.