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THE OSTRACOD GENUS *NIPPONOCYTHERE* ISHIZAKI, 1971 FROM THE MIDDLE MIOCENE OF THE FORE-CARPATHIAN DEPRESSION, CENTRAL PARATETHYS; ITS ORIGIN AND PALEOENVIRONMENT

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Abstract: Two new ostracod species, belonging to the loxoconchid genus *Nipponocythere* Ishizaki, 1971, i.e. *N. karsyensis* sp. nov. and *N. silesiensis* sp. nov., are described from the Middle Miocene (Badenian) of the Fore-Carpathian Depression, Central Paratethys. We consider them "exotic" forms, that is rare and previously unknown from the Badenian of the Paratethys. Their occurrence in the Middle Miocene of the Polish part of the Central Paratethys is thought to prove oceanic water influence into the northernmost parts of the Fore-Carpathian Depression (basins). The unusual morphometric features of these *Nipponocythere* species and of their associated "exotic" ostracods, in the Upper Badenian of the Upper Silesia, is presumed to be due to a paleoenvironment rich in food and undersaturated in $CaCO_3$ and/or O_2.

Key words: Middle Miocene, Fore-Carpathian Depression, paleoecology, paleogeography, Ostracoda.

Introduction

Among the Middle Miocene (Badenian) ostracods of the Polish part of the Fore-Carpathian Depression (Central Paratethys), are two species of *Nipponocythere* Ishizaki, 1971, which was unknown previously from Europe (except for the Basque Basin, i.e. its Atlantic border), including the whole Mediterranean, prior to the Upper Miocene. These species are herein described as *Nipponocythere karsyensis* sp. nov., from the Lower Badenian, and *Nipponocythere silesiensis* sp. nov. from the Upper Badenian of the studied area.

Among the Middle Miocene ostracods of the Central Paratethys, *Nipponocythere* are "exotic" forms, that is rare and so far unknown from the Badenian of Paratethys, although occasionally encountered in past and Recent oceans. Other exotics, such as *Cluthia*, *Xylocythere*, *Nunana* and *Elofsonia* were described earlier (Szczechura 1986, 1995; Aiello & Szczechura 2001a, 2002), while the discovery of others will be published soon. The presence of *Nipponocythere* in the Middle Miocene (Lower and Upper Badenian) of the northern part of the Central Paratethys provides additional data for the reconstruction of the Neogene (Middle Miocene) paleogeography and paleoecology of this area.

The material described here is housed at the Institute of Paleobiology of the Polish Academy of Sciences in Warszawa (abbreviated ZPAL).

Material (General setting)

In the Fore-Carpathian Depression of southern Poland, which represents the northern margin of the Central Paratethys, ostracods belonging to *Nipponocythere* Ishizaki, 1971, occur throughout the entire Middle Miocene (Badenian). The representatives of this genus were found in the Badenian sediments of the Działoszyce Trough (Posądza 10-S borehole) as well as in the Korytnica Basin (Karsy outcrop), on the southern slopes of the Holy Cross Mts, and in the Upper Silesia (Gliwice G-19 and Gliwice G-21 boreholes) (Fig. 1).

Posądza 10-S borehole (Działoszyce Trough)

A species of *Nipponocythere* was found in the Lower Badenian (corresponding to the Langhian stage) marly sediments in the borehole Posądza 10-S (depth 101.8–100.2 m), in the Działoszyce Trough (Osmólski 1972; Szczechura 2000). The entire section, representing Badenian and Sarmatian evaporite-bearing deposits, is about 90 m thick. It overlies Upper Cretaceous carbonates and consists of marls and marly clays passing upwards into clays. Ostracods are associated with rich foraminiferal assemblages (both planktonic and benthic) indicating a bathyal and rather oligotrophic environment with warm surface waters (Szczechura 2000). The chronology was based on planktonic foraminifers (mostly *Praeorbulina* and *Orbulina*). Bolboforms (calcareous phytoplankton) and radiolarians are very rare. Ostracods (mentioned in Szczechura 2000) are also scarce and mostly poorly preserved; they include species of *Argilloecia*, *Buntonia*, *Bythocypris*, *Cnestocythere*, *Costa*, *Cytherella*, *Cytheropteron*, *Eucythere*, ?*Eucytherura*, *Henryhowella*, *Krithe*, *Paijenborchella*, *Parakrithe*, *Pterygocythereis*, *Saida* and *Xestoleberis.* These genera are mostly typical of the deeper waters and rather ubiquitous in their geographical (and paleogeographical) distribution. Both the taxonomic composition of the ostracod assemblage and their rarity confirm the bathymetrical (and perhaps trophic) conditions suggested by the foraminifers.

Karsy outcrop (Korytnica Basin)

Nipponocythere was also found in the Lower Badenian silty sediments, in the so called Korytnica Clays, cropping out in Karsy near Korytnica (Bałuk & Radwański 1977). The Korytnica Clays are represented by 40–60 m of undisturbed and highly fossiliferous marly silts and clays, overlain by marly sands and red-algal (lithothamnian) limestones. *Nipponocythere* is associated with an unusually abundant, diverse and very well preserved microfauna consisting mostly of benthic and planktonic foraminifers and ostracods, although, rare radiolarians and bolboforms are also present. Calcareous benthic foraminifers are dominated by forms typical of shallow (shelf) waters. The presence of large foraminifers (*Borelis*, *Amphistegina*) and some characteristic planktonic foraminifers (e.g. *Globigerinoides*, *Globoquadrina, Orbulina*) suggests a warm-water environment (cf. Rögl & Brandstötter 1993; the present authors' observations). The planktonic as well as larger foraminifers were used as biostratigraphical indices.

The ostracod assemblage consists of abundant, well preserved, adult and juveniles; mostly the ubiquitous taxa *Acanthocythereis*, *Aurila*, *Bosquetina*, *Buntonia (B. subulata subulata)*, *Callistocythere*, *Costa*, *Cytherella*, *Cytheridea*, *Cytheropteron*, *Hemicytherura*, *Incongruellina*, *Loxoconcha*, *Pterygocythereis*, *Semicytherura* and *Xestoleberis.* These taxa indicate a low-energy near-shore (?infralittoral) environment, most probably with plants. Rare specimens belonging to the genera *Henryhowella*, *Krithe*, *Paijenborchella* and *Parakrithe* and species known to prefer deeper-water conditions such as *Buntonia dertonensis,* may suggest influence of the deeper waters, possibly by means of bottom currents.

It should be noted, however, that the Korytnica Clays faunas are strongly variable, both laterally and vertically, so the studied samples may actually represent mixtures of ostracods of somewhat different origin. According to Radwańska (1992), working on the fish otoliths from the Korytnica Clays, there are mixed assemblages, containing both shallow and deeper-waters taxa, which could be the result of storm activity. Radwańska (*op. cit.*) proposed that the depth of deposition of the Korytnica Clays corresponded to the littoral zone. Kowalewski & Miśniakiewicz (1993), working on the shell material from the Korytnica Clays, considered it a storm deposit.

Gliwice G-19 and G-21 boreholes (Działoszyce Trough)

Nipponocythere was also recorded from Upper Badenian (corresponding to the Serravallian stage of the Mediterranean region) argillaceous sediments, with limestones and tuff intercalations, about 70 m thick, overlying evaporites, in the Gliwice G-19 (depth 51.0–90.0 m) and G-21 (depth 19.2–51.0 m) boreholes (Gonera 1997; Alexandrowicz 1997; Szczechura 1997). The entire section consists of nearly 290 m thick Badenian sediments, overlying Carboniferous strata and covered by Quaternary deposits. The associated microfossils include very diverse, abundant, and well preserved foraminifers (Alexandrowicz 1963, 1997; Gonera 1997), radiolarians (Barwicz-Piskorz 1997), bolboforms (Szczechura 1997), dinoflagellates (Gedl 1997), holothurian sclerites (Górka 1997), pteropods (Janssen & Zorn 1993) and diatoms (Witkowski & Gonera 1997). Interestingly, some microfossils are dark and/or infilled with pyrite. Mainly microfossils were used for the biostratigraphical subdivision of the studied section, which has been attributed by Peryt (1997) to the calcareous nannoplankton zone NN6. The foraminifers belong to a so-called "IIIB assemblage" (Gonera 1997), distinguished by Alexandrowicz (1963) and recognized by him from numerous Upper Badenian sections of the Fore-Carpathian Depression, although exhibiting much variation both geographically and stratigraphically. The abundant benthic (mostly calcareous) foraminifers include epifaunal (including epiphytics) as well as infaunal elements. Planktonic forms are less diversified and less abundant.

Witkowski & Gonera (1997) state that the diatoms, consisting mostly of benthic (epiphytic and sediment dwelling) forms, indicate deposition within the photic zone, in a relatively shallow, quiet-water environment. It seems important, that *Thalassionema nitzschioides* (although rare) occurs among the diatom flora recognized by Witkowski & Gonera (1997). This species was regarded as an upwelling indicator in the Miocene of the eastern equatorial Pacific (Funnell et al. 1996). On the other hand, Barwicz-Piskorz (1997) considered the radiolarian bloom in the studied part of the section from Gliwice as an effect of volcanic activity, which enriched seawater in silica. At the same time Barwicz-Piskorz (1997) also pointed out that the occurrence of *Nasselaria* is characteristic of upwelling areas. Moreover, dinoflagellates (as other phytoplankton) also seem to prefer zones of upwelling (Brasier 1995; Hutchings et al. 1995; Summerhayes et al. 1995). The microfossils therefore suggest an especially attractive, mostly eutrophic, open marine (oceanic origin), but not very deep (?circalitoral) environment, most probably influenced by upwellings.

It should be added that some authors (e.g. Łuczkowska 1974; Szczechura 1982, 2000; Durakiewicz et al. 1997; Gonera 1997) suggested that during the late Badenian the climate in the Fore-Carpathian Depression area was cooler than that during the early Badenian, that is there was drop in temperature before the deposition of evaporites.

The ostracods are represented by numerous adults and juveniles (mostly disarticulated valves), and despite being small-sized and thin-shelled they are, in general, well preserved suggesting quiet-water sedimentation. The species richness (more than one hundred species) as well as the abundance of ostracods seems to suggest particularly favourable environmental conditions. The occurrence of phytal, shallow-water forms appears to demonstrate shallow, photic zone depths. The ostracod assemblage contains quite common representatives of *Argilloecia*, *Callistocythere*, *Cytherois*, *Cytheropteron*, *Hemicytherura*, *Loxoconcha*, *Microcytherura*, *Paracytherois*, *Pseudocytherura*, *Sagmatocythere*, *Semicytherura*, *Xestoleberis*, while species belonging to the genera *Henryhowella*, *Krithe, Parakrithe* and *Pseudocythere* are less common. Particularly significant, however, is the cooccurrence of ostracods (besides *Nipponocythere* and those earlier mentioned *Cluthia*, *Xylocythere*, *Elofsonia* and *Nunana*) previously unknown in the Middle Miocene of the Central Paratethys. They

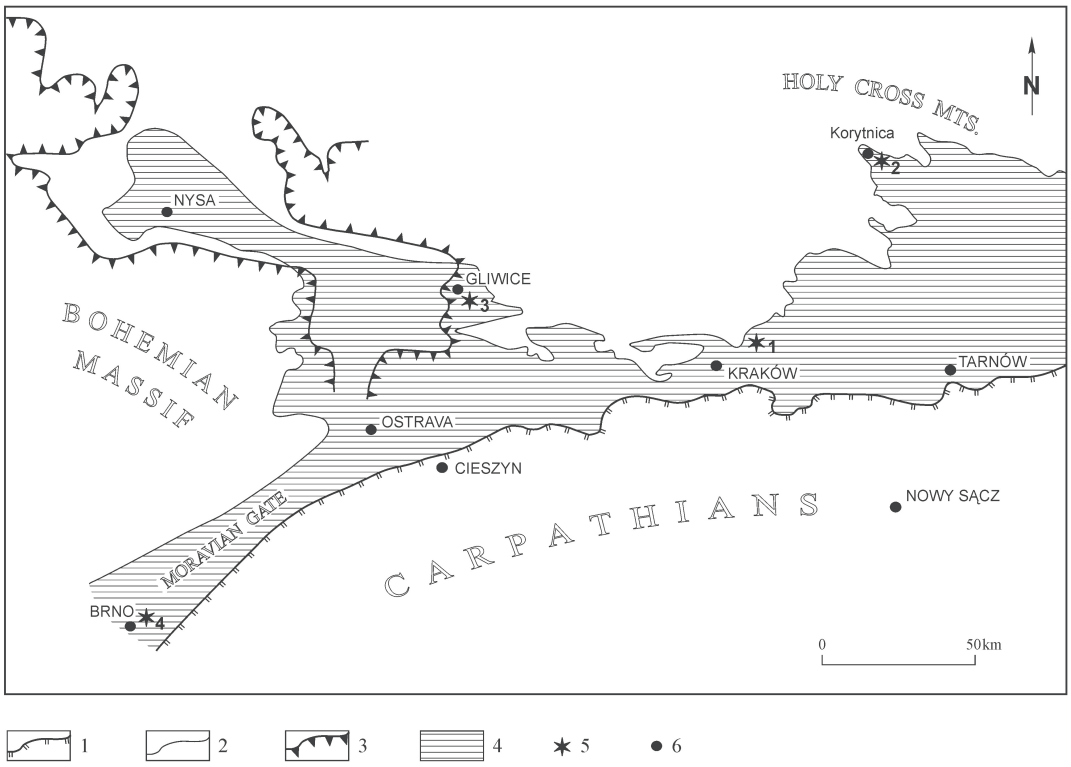

Fig. 1. Extent of the Middle Miocene sea in the Fore-Carpathian Depression and the location of sampled sections. **1** — edge line of the Carpathian nappes. **2** — northern edge of the Miocene Basin. **3** — extent of the continuous cover of the terrestrial "Poznań series". **4** — Miocene deposits from the Fore-Carpathian Depression in Poland. **5** — locality (1 — Posądza, 2 — Karsy, 3 — Gliwice, 4 — Brno). **6** — cities. (Modified after Łuczkowska 1998.)

include species of *Rimacytheropteron*, *Swainocythere*, *Kunihirella*, *Loxoconchidea*, *Polycope*, *Saida*, *Hemiparacytheridea* and *Ruggieriella*. All these forms are mentioned, among ostracods of different age (mostly Cainozoic) and different areas (including Recent oceans), as typical of deeper waters (Whatley & Ayress 1988; Coles et al. 1990; Van Harten 1990; Rodriguez-Lazaro & Garcia-Zarraga 1996). In the Mediterranean basins, the above mentioned genera first appeared (as is so far known) in the Upper Miocene. From our prior knowledge of the ostracod assemblages of the Middle Miocene of the Fore-Carpathian Depression, the present occurrence of these "exotic" taxa is unique.

It is worth mentioning, that in the supra-evaporitic sediments in the Gliwice sections, the diversity of ostracods gradually increases (suggesting gradual appearance of new species by migration) and reaches a maximum at the height of the late Badenian transgression in the studied area.

Discussion and conclusions

Paleozoogeography

According to a review by Barra (1995) the genus *Nipponocythere* is represented by more than 20 species and first appeared in Costa Rica, where it spans the Lower and basal Middle Miocene. During the Middle Miocene it entered the Western Atlantic including central Haiti, Trinidad and Venezuela. *Nipponocythere* persisted in the Caribbean area until the Recent, but during the Pliocene it invaded the southwestern Pacific and South China Sea, while during the Pleistocene it appeared in southwestern Taiwan and central Japan. In the Recent it also colonized the northwestern Pacific, including Japan and the East China Sea, and the Gulf of Panama.

If (as is suggested here) *Nipponocythere* is congeneric with *Bidgeecythere* McKenzie, Reyment et Reyment, 1993, its first appearance could in fact have been in southwestern Australia (Victoria), where *Bidgeecythere* ranges from Eocene to Middle Miocene (McKenzie 1974; McKenzie et al. 1993). It subsequently spread to the Caribbean region; however, the representatives of *Heinia* (another junior synonym of *Nipponocythere*) are also recorded from the Lower Eocene of the Atlantic border of the Basque Basin (Biscay Synclinorium) (Rodriguez-Lazaro & Garcia Zarraga 1996). It is worth mentioning that other ostracods associated with *Nipponocythere* in the Middle Miocene of the Central Paratethys, for example *Cluthia* (Szczechura 1986; Ayress & Drapala 1996) and *Nunana* (Aiello & Szczechura 2001a) appeared earlier (in the Eocene) in the Southern Hemisphere than in the Northern Hemisphere.

The existence of *Nipponocythere* in both hemispheres during the Eocene provides new evidence of the possibilities of exchange of this microfaunal group (ostracods) between these areas, perhaps along the already existing latitudinal routes of migration (Benson 1990; Coles et al. 1990).

The presence of *Nipponocythere* in the Atlantic (and the Central Paratethys) during the Middle Miocene suggests that it arrived in the Fore-Carpathian Depression at the same time.

It is not impossible, however, that *Nipponocythere* (like other ostracods known from the Middle Miocene of the northern part of the Central Paratethys) could already have invaded the more southern part of the Central Paratethys, at least during the Early Miocene. The presence of *Nipponocythere* in the Lower Badenian of Moravia (Fig. 1) suggests its northward migration from southern to central Europe, possibly through the Moravian Gate. The existence of an early Middle Miocene connection between the Atlantic Ocean and the Mediterranean basins, *via* the Iberian Portal, was suggested (using ostracod distributions) by Benson (1976) as well as by Nascimento & Říha (1996). These latter authors found more than thirty ostracod species common to the Middle Miocene of Portugal and the Central Paratethys as well as the Mediterranean Basin. Szczechura (1994, 1997, 2000) documented the existence of the early Middle Miocene extension of the Atlantic influence into the Central Paratethys, using ostracods as well as bolboforms and foraminifers. This early Middle Miocene connection between Atlantic and the Central Paratethys basins, *via* the Mediterranean, has also been confirmed and/or suggested by other fossil groups, such as the pteropods (Janssen & Zorn 1993), bivalves (Studencka et al. 1998) and fish otoliths (Radwańska 1992). However, according to Radwańska (1992), Rögl (1998) and others there was an Indo-Pacific influence during the Badenian (mostly the Early Badenian), in the Central Paratethys.

The occurrence of *Nipponocythere* (although belonging to different species) in the Lower as well as in the Upper Badenian of the Fore-Carpathian Depression indicates that this genus could have persisted there through the Middle Badenian salinity crisis, like numerous other associated ostracod genera and species. Refugia must have existed somewhere, or *Nipponocythere silesiensis* reappeared in the Upper Badenian of the Upper Silesia as a result of a new (or only enlarged) Atlantic oceanic influence in the Central Paratethys. This latter supposition may be confirmed by the invasion, during the Late Badenian in the Polish part of the Fore-Carpathian Depression, of a new ostracod fauna, which has not hitherto been recorded in the sub-evaporitic sediments (Szczechura 1995, 1996, 1998; Aiello & Szczechura 2001a, 2002). The late Middle Miocene distribution of *Carinocythereis* in Europe (Szczechura 1998; Aiello & Szczechura 2001b) indicates beyond doubt that, at that time, a connection existed between the northern part of the Central Paratethys and the Mediterranean basins, possibly *via* the southeastern areas of Europe. At the same time, other common groups of microfossils appeared including bolboforms (Szczechura 1997), radiolarians (Barwicz-Piskorz 1997) and pteropods (Janssen & Zorn 1993). Interestingly, some of them are also known from the northern Atlantic.

Paleoecology

The literature (e.g. Ishizaki 1981; van den Bold 1985; Whatley & Ayress 1988; Coles et al. 1990; Van Harten 1990; McKenzie et al. 1993; Bonaduce et al. 1994; Barra 1995) indicates, that *Nipponocythere* is a marine genus with no particular environmental preferences in respect of temperature and depth. Its Recent and fossil representatives are recorded from shallow (though generally not very shallow) as well as deep waters in various areas of both hemispheres, independently of climate.

The distribution of *Nipponocythere* in the Middle Miocene of the Fore-Carpathian Depression seems to provide, however, some new indications on its environmental preferences.

In the Middle Miocene of the Fore-Carpathian Depression *Nipponocythere* occurs, most probably in situ, in the lower Middle Miocene sediments from the Działoszyce Trough in Posądza (Szczechura 2000), where it is very rare and is associated with taxa typical of the normal marine, bathyal environments, characterized by cold and rather oligothrophic bottom waters, as in the Lower Badenian of the Czech Republic (Říha 1989). In the approximately coeval but shallow-water sediments of the Korytnica Basin (Karsy), *Nipponocythere* could be derived (by storm activity), as are some other coexisting ostracod species and this, therefore, may be not have been its typical habitat.

In the Upper Badenian of Upper Silesia (Gliwice area) *Nipponocythere* is more common than in the Korytnica Basin and it certainly proliferated there. However, the environment seems to have been shallow marine, probably nearshore and, as is suggested by the associated microfauna, rich in food supply. Even more surprising is that *Nipponocythere* is accompanied by deeper-water ostracods and the newly described, "exotic" species. It also seems significant that all of them are generally small and thin-shelled, and sometimes dark in colour. Large and thick-shelled forms are lacking. Moreover, this ostracod assemblage seems to be unique when compared to others known from the Middle Miocene deposits of the Fore-Carpathian Depression.

According to Szczechura (1986), the first appearance in the Upper Badenian of the Central Paratethys of *Cluthia miocenica* (one of the "exotic" forms from Gliwice), was the result of the cooling; *Cluthia* is known as a northern "guest", that is a cold-water ostracod form (cf. e.g. Carbonnel & Ballesio 1982). Also Brouwers et al. (2000), reviewing the spatiotemporal distribution of *Cluthia,* have concluded that this genus followed its preferred lower temperature range, invading shallow but cold waters. A similar relationship, that is the migration of Recent deep-water ostracods onto the shelf (at shallow depths), in the southeastern Pacific, as the result of cold temperature and low salinity, was suggested by Whatley et al. (1997); these authors, however, highlighted the importance of upwelling for ostracod distribution in such circumstances as the southern end of the Magellan Strait.

These conclusions seem to be supported by the case from Gliwice, where ostracods thrived in rather shallow (relatively shallow) but cool waters influenced by upwelling. Such upwelling may explain the high diversity and abundance of ostracods; but it does not explain the distinctive taxonomic structure or the peculiar morphometry of the "exotic" as well as the associated ostracods. It is broadly known (e.g. Murray 1991, 1995; Brasier 1995; Dingle 1995), that the high productivity of the surface waters may have an impact on bottom-water chemistry and, in consequence, the distribution as well as the character of the fauna (including ostracods).

In this respect it seems significant that the ostracod assemblage that is most taxonomically similar to that from Gliwice

(containing numerous common genera and some conspecific and/or very close species), is described from the Upper Miocene of Italy (Piedmont, Sicily, Calabria) (Ciampo 1986) and from the Pleistocene of Calabria (Colalongo & Pasini 1980). In the Pleistocene of Calabria (*op. cit.*) ostracods occur in sediments, which according to the cited authors were deposited under poorly aerated, bathyal conditions. Elements of the Gliwice fauna discussed here also occur in the Azores at the Mid-Atlantic Ridge (Van Harten 1990), as well as in the Scoresby Sund Fiord of East Greenland (Whatley et al. 1996). This latter site represents a fairly deep-water basin, silled in its front and interpreted as a stagnating basin rich in organic carbon and at least seasonally impoverished in oxygen in its bottom waters. The ostracods (somewhat) similar to those from Gliwice are also described by Coles et al. (1996) from the Quaternary carbonate mounds, associated with gas seepages, from the Porcupine Basin (offshore western Ireland). This rather deep-water ostracod association (mostly paradoxostomatids) contains xylophile (although without *Xylocythere*) forms and is thought to be an indirect result of nutrient increase. The large diversity and abundance of ostracods is correlated here with wide niche variety. Interestingly, one of the "exotic" forms from Gliwice, the genus *Xylocythere,* is known as the typical xylophile (wood-loving) and at the same time deep-water form (Maddocks & Steineck 1987; Steineck et al. 1990). Van Harten (1992) found it in deep-water sediments, in the Pacific, coexisting with ostracods characteristic for shallow waters, associated with hydrothermal vents. He considered that it proliferated in the highly eutrophic (and specifically, rich in chemical energy) environment, impoverished in oxygen (Van Harten 1992, 1993). According to Van Harten (*op. cit.*), this latter factor may have caused the poor biocalcification of the ostracod carapaces, expressed in their thin shells.

In almost all the cases reviewed above, the ostracods discussed are correlated with an environment rich in food and poorly oxygenated. Therefore, both these environmental factors could apply to the Upper Badenian bottom waters in Upper Silesia. This suggestion may be additionally supported by the occurrence of pyrite as well as the dark colour of the microfossils (including ostracods) (cf. Neale 1971; Oertli 1971). According to Oertli (1971), the small size and pyritization of ostracod shells, is a consequence of reducing environments rich in organic carbon. Neale (1971), working on the Lower Cretaceous microfauna (foraminifers and ostracods) of the Speeton Clay, England, suggested that pH, food supply and rate of sedimentation are the most important factors influencing the abundance and composition of faunas. Moreover, Neale (*op. cit.*) stated that at least partial de-oxygenation of the bottom waters was tolerated only by the specialized fauna, represented by small forms, as opposed to the large and varied forms occurring in horizons abundant in food and $CaCO_3$.

A close relationship between the availability of food and the chemistry (mostly pH and CO_2 content) of the bottom waters, as influencing biocalcification in ostracods, have also been considered by Peypouquet (1977), Carbonel & Hoibian (1988), Peypouquet et al. (1988), Babinot et al. (1991) and Braccini & Peypouquet (1996). Moreover, as is shown e.g. by Curry (1999), Mezquita et al. (1999) and Cronin et al. (1999), various (different) ostracods species and/or groups have their particular ecological requiements, including physical and chemical parameters.

It is worth mentioning, that a much more severe (mostly in terms of the lowered oxygen content) environment was recognized in the more central part of the Fore-Carpathian Depression, in the Jamnica borehole, near Tarnobrzeg (Szczechura 1995). In this section a few specimens of *Xylocythere* (*X. carpathica)* were found in association with a low diversity microfauna (foraminifers and ostracods) and they were thought to occur there in a stressed (low-oxygen) but at the same time rather shallow-water environment. More recently, *Xylocythere carpathica* was also recorded from the approximately coeval sediments of the Działoszyce Trough (the Posądza 10-S borehole) (Szczechura 2000). In the Posądza section, just above the evaporites, benthic microfauna is absent, although radiolarians are abundant and seem to mark a distinct biosiliceous event. Somewhat above, in the overlying sediments rather rare and weakly diversified benthic and planktonic foraminifers appear, indicating a stressed bottom water environment. They are associated with a bispecific ostracod assemblage, consisting of numerous (considering the small size of sample), unusually delicate and small-sized, adult and juvenile representatives of *Xylocythere* (*X. carpathica)* and ?*Microxestoleberis* sp.

These findings (from Gliwice, Jamnica and Posądza) prove that during the Later Badenian of the Fore-Carpathian Depression, the environment was more or less depleted in oxygen and highly euthrophic, which favoured the development of distinctive ostracod populations. In all these cases, abundance of nutrients, dysaerobic bottom microhabitats (i.e. lowered pH of the bottom waters), resulting in their undersaturation in $CaCO_3$ and causing poor biocalcification, allowed only small, thin-shelled ostracods to proliferate.

Interestingly, small and thin-walled tests of calcareous benthic foraminifers (mostly particular morphogroups) are known from low-oxygen bottom water environments (Sen Gupta & Machain-Castillo 1993; Gooday 1994; Kaiho 1994, 1999) resulting from high primary productivity of the surface waters, and the consequent flux of organic matter to the sediment. These authors argued that biomineralization was more difficult in the suboxic environment.

It must be added that the Upper Badenian marine environment of the Fore-Carpathian Depression was particularly susceptible to eutrophication. It could have been caused, except for the (local) pericoastal upwelling, by contemporary volcanic activity enhancing primary productivity. In Upper Silesia (Gliwice area), eutrophication could have been additionally strengthened by its paleogeographical situation, that is its marginal location within the Fore-Carpathian Depression enhancing support of the continentally derived organic matter, sea level rise, as well as the existence of the so called Cracow Ridge (Ney et al. 1974), a submarine barrier preventing exchange of waters between the Upper Silesia area and the rest of the Fore-Carpathian Depression (an "inflow" circulation model); the presence of some common species, in the western as well as in the eastern part of the Polish part of the Fore-Carpathian Depression, indicates that there was water mass exchange (at least to some extent) between these areas. Another factor favouring euthrophic conditions, resulting in the dys-

Fig. 2.

aerobic bottom environment, was probably slow sedimentation (quiet environment, weak circulation), suggested by the thin-shelled but well preserved ostracod remnants, only as valves, and the vegetation (sea grasses) covering the seafloor. At the same time the activity of vents and/or seeps in the Fore-Carpathian Depression is not excluded.

According to Garlicki & Szybist (2001), working on the organic matter content in the Middle Miocene sediments from the southern areas of the Polish part of the Fore-Carpathian Depression south-west of Tarnów (Fig. 1), organic matter occurs throughout the entire evaporites-bearing sections. In the sediments overlying the evaporites it attains up to 9.3 % of weight. Garlicki & Szybist (2001) considered these results mostly the effect of high phytoplankton productivity. They also found a close relationship between the supply of the organic matter and the bottom water conditions.

Systematic descriptions

The following abbreviations are used: a — adult, C — carapace, RV — right valve, LV — left valve.

Suborder **Podocopina** Sars, 1866
Superfamily **Cytheracea** Baird, 1850
Family **Loxoconchidae** Sars, 1925

The family assignment of the examined genus is far from equivocal. *Heinia* was referred by its author (van den Bold 1985) to Cytheridae Baird, 1850; *Bidgeecythere* was considered by McKenzie et al. (1993) as belonging to Pectocytheridae Hanai, 1957, while *Nipponocythere* was included by Ishizaki (1971) as well as by Malz (1981) and Barra (1995) in the Loxoconchidae Sars, 1925.

Genus *Nipponocythere* Ishizaki, 1971

We agree with Drapala & Ayress (1993), Bonaduce et al. (1994) and Barra (1995) that *Nipponocythere* Ishizaki, 1971 is congeneric with *Heinia* van den Bold, 1985. The genus *Bidgeecythere,* described by McKenzie, Reyment et Reyment (1993) from the Eocene of Australia, is considered here as a junior synonym of *Nipponocythere* because it possesses all the external and internal diagnostic features typical of the above mentioned genus.

Nipponocythere silesiensis sp. nov.
(Fig. 2.6; Fig. 3.1–8)

Holotype: RV ZPAL O.48/60 illustrated in Fig. 3.4.

Paratypes: The specimens ZPAL O.48/62,61, illustrated in Fig. 3.3,7.

Type horizon: Upper Badenian (upper part of the Middle Miocene).

Type locality: Gliwice (Upper Silesia).

Derivation of the name: *silesiensis*, occurring in Silesia.

Diagnosis: A *Nipponocythere* species rather weakly and mostly centrally punctate, indistinctly (finely) ribbed anteroventrally, weakly reticulate postero-laterally, bearing a short ear-shaped rib along the posterior part of the dorsal margin.

Material: 15 adult valves and one adult carapace, well preserved.

Description: Carapace small, subovate to subtriangular in lateral view, weakly and almost evenly inflated laterally, elongated and pointed posteriorly especially in the posteroventral part of RV. It is somewhat truncated in LV, being moderately rounded anteriorly, straight dorsally, weakly incised ventrally. The valve surface rather densely punctate, mostly centrally; if well preserved provided with the indistinct net work-like reticulation at the posterior end. A few weak, subparallel ribs extend over the ventro-lateral surface. The anterior margin is bordered by a more or less distinct but rarely preserved, delicate frill-like flange. A short ear-shaped rib occurs along and near the posterior part of the dorsal margin.

Inner lamella moderately wide anteriorly and posteriorly. It is subparallel to the valve margins. Vestibulum small, below mid-height, in the anterior part, less distinct posteriorly. Muscle scars (Fig. 3.8b) consist of four oval scars of the main group and a thickly arcuate concave forward antennal scar. Hinge (Fig. 2.6b–c; Fig. 3.8a) modified gongylodont. In the RV the anterior terminal element is a locule which surrounds the antero-median element; the median element is a long, smooth groove with an antero-median boss-like tooth. The postero-terminal element is a boss-like tooth. Complementary elements occur in the LV hinge. Marginal pore canals simple, rather rare; 7–9 in frontal part, while 6–7 in distal part.

Variability: It is expressed in size, and degree and extent of ornamentation.

Dimensions of adults (in mm):

ZPAL O.48/60	ZPAL O.48/62	ZPAL O.48/61
holotype	paratype	paratype
RV	LV	LV
Length 0.44	Length 0.39	Length 0.39
Height 0.23	Height 0.23	Height 0.20

Remarks: This species is similar to that described by Drapala & Ayress (1993), from the Late Quaternary of Aus-

Fig. 2. **1** — *Nipponocythere karsyensis* sp. nov., aLV, holotype; **a** — lateral view, **b** — oblique ventral view, **c** — dorsal view; ZPAL O.48/319. **2** — *Nipponocythere karsyensis* sp. nov., aRV; **a** — lateral view, **b** — ventral view; ZPAL O.48/304. **3** — *Nipponocythere karsyensis* sp. nov., aLV, paratype, ZPAL O.48/318. **4** — *Nipponocythere karsyensis* sp. nov., aRV, paratype; **a** — lateral view, **b** — ventral view; ZPAL O.48/305. **5** — *Nipponocythere karsyensis* sp. nov., aC, right side, ZPAL V.27/731. **6** — *Nipponocythere silesiensis* sp. nov., aRV; **a** — general internal view, **b** — enlarged proximal part of the hinge margin, **c** — enlarged distal part of the hinge margin; ZPAL O.48/20. 1–4 — Lower Badenian, Karsy outcrop; 5 — Lower Badenian, Posądza 10-S borehole, depth 100.2 m; 6 — Upper Badenian, Gliwice G-19 borehole, depth 51.0 m. Scale bars = 1 mm.

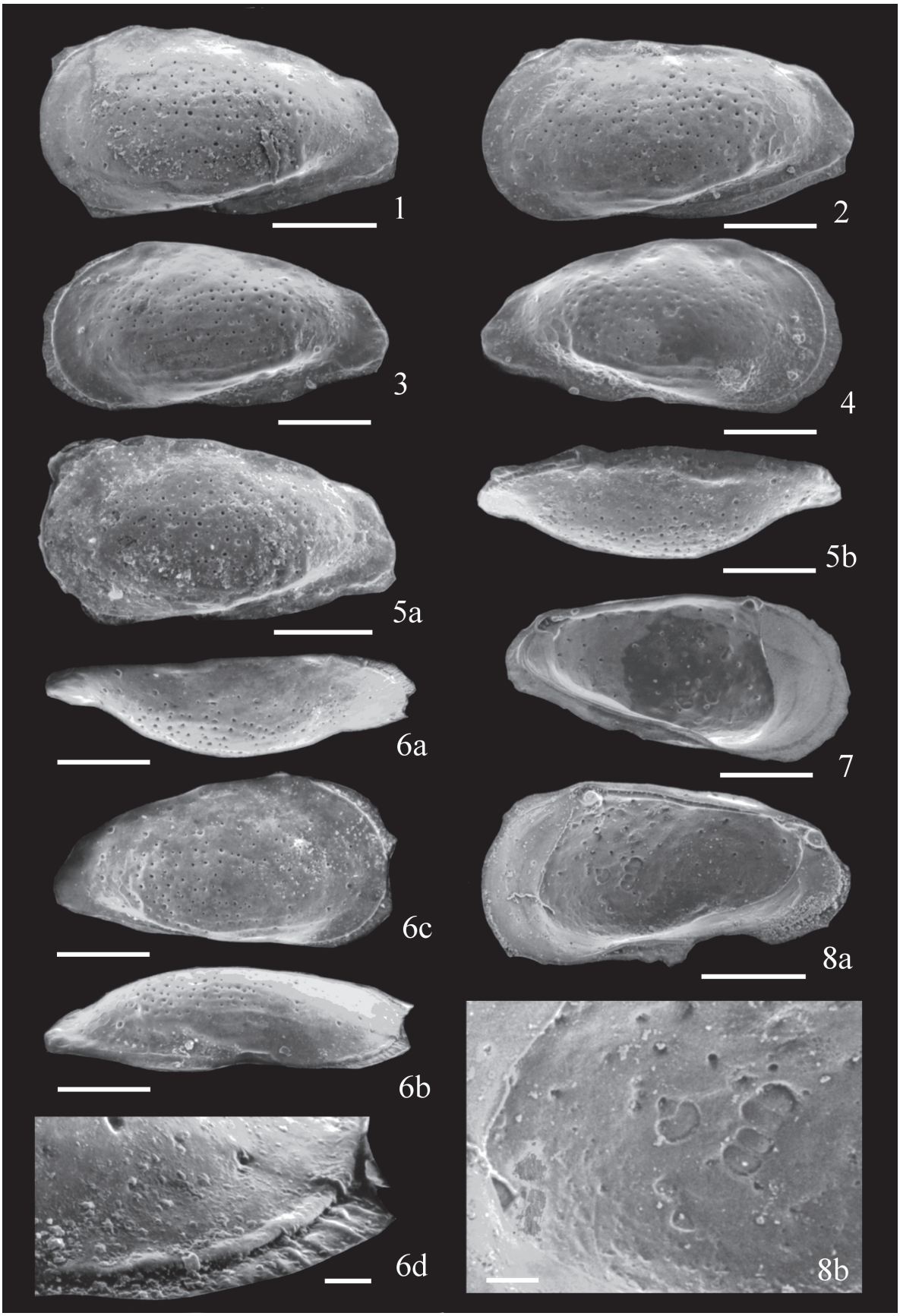

Fig. 3.

tralia, as *Nipponocythere colalongoae* (Ciampo, 1985), proposed by Bonaduce et al. (1994) as *Nipponocythere drapalaensis* sp. nov. *Nipponocythere silesiensis* is more elongate, more pointed posteriorly, more densely foveolate, and bears a shorter, less pronounced ear-shaped rib along the posterior part of the dorsal margin. In comparison with *Nipponocythere karsyensis* sp. nov. from the Lower Badenian of the Carpathian Foredeep, this species is more posteriorly elongated, more laterally inflated, less densely and mostly centrally punctate, and only weakly reticulated at the posterior margin. Its posterodorsal rib is short, ear-shaped, and does not branch anteriorly.

Distribution: Upper Badenian of Upper Silesia, Gliwice (Central Paratethys).

Nipponocythere karsyensis sp. nov.
(Fig. 2.1–5)

1983 *Bosquetina carinella* (Reuss, 1850); Říha, fig. 5, pl. 1, fig. 5.

Holotype: RV ZPAL O.48/319, illustrated in Fig. 2.1.

Paratypes: The specimens ZPAL O.48/318, 305, illustrated in Fig. 2.3,4, respectively.

Type horizon: Lower Badenian (lower part of the Middle Miocene).

Type locality: Karsy (Korytnica Bay).

Derivation of the name: *karsyensis,* occurring in Karsy.

Diagnosis: A *Nipponocythere* species being densely and rather evenly punctate, mostly centrally (except the anterior and posterior ends), and somewhat reticulate posteriorly. Along the posterior part of the dorsal margin there is a short, anteriorly branching rib.

Material: Seven adult valves and two carapaces, well preserved.

Description: Small, subcuneate in lateral outline, weakly and almost evenly inflated laterally, broadly rounded anteriorly, distinctly elongated and weakly truncated posteriorly, nearly straight dorsally, indistinctly incised ventrally. The valve surface somewhat rough, densely and rather regularly punctate, mostly centrally, with a weak reticulation in the posterior part. Indistinct subparallel ribs cover ventro-lateral surface, while a short but pronounced rib, branching frontally, occurs along the posterior part of the dorsal margin. Anterior margin bordered by a delicate frill-like flange.

Inner lamella moderately wide, with small anterior vestibulum. Muscle scars consist of four semicircular adductors arranged in a vertical row, and one, somewhat heart-shaped frontal scar. Hinge gongylodont, in the right valve consisting of the anterior tooth, bounded by a narrow furrow, which passes into the median groove, and posteriorly into a steep dentate bar passing into terminal knob-like tooth. Marginal pore canals not visible.

Variability: This involves shape, especially lateral outline, and posterodorsal inflation, probably resulting from sexual dimorphism. Supposed males seem to be more triangular in lateral outline, higher anteriorly and less posterodorsally inflated than supposed females. However the sexual dimorphism found in *Nipponocythere drapalaensis pithekoussaii* (Barra, 1995), from the Late Quaternary of the Mediterranean Basin (Isle of Ischia) is restricted mostly to a different lenght to height ratio of males and females. The type of punctation of specimens referred to *N. silesiensis* is somewhat variable and may be a consequence of different states of preservation.

Dimensions of adults (in mm):

ZPAL O.48/319, holotype	ZPAL O.48/305, paratype	ZPAL O.48/318, paratype
LV	LV	RV
Length 0.38	Length 0.36	Length 0.40
Height 0.23	Height 0.25	Height 0.23

Remarks: In comparison with *Nipponocythere parva* (Colalongo et Pasini, 1980) from the Plio-Pleistocene of Italy (Calabria), the present species is more triangular in side view, higher frontally, not truncated posteriorly, and punctate rather than reticulated laterally. In contrast to *Nipponocythere colalongoae* (Ciampo, 1986), from the Upper Miocene of Italy (Piedmont), this species is less elongated, not truncated posteriorly and less distinctly rimmed and rather smooth along the anterior margin. Our specimens also seem to be very close to those referred to *Cytheromorpha bimarginata* Brestenská, 1975, described from the Lower Miocene (Egerian) of Slovakia and Hungary. The Middle Miocene material, however, is more coarsely and more regularly punctate. It lacks a posterior rib, bordering posteriorly lateral inflation, distally bounded by less distinct parallel ribs, more pronounced in the LV. Moreover, our specimens have a much less pronounced posterodorsal rib, extending along the dorsal margin. Internal features, including the hinge margin of *Cytheromorpha bimarginata,* appear typical for *Nipponocythere.*

The material described by Říha (1983) from the Lower Badenian of the Czech Republic, referred to *Bosquetina carinella* (Reuss, 1850), seems markedly different from those representing *B. carinella* and falls within the variability of *Nipponocythere karsyensis* sp. nov.

Distribution (Occurrence): Lower Badenian of the Działoszyce Trough (Posądza) and the Korytnica Bay. Outside Poland — Lower Badenian of the Czech Republic (near Brno) (Central Paratethys).

Fig. 3. **1** — *Nipponocythere silesiensis* sp. nov., aLV, lateral view, ZPAL O.48/555. **2** — *Nipponocythere silesiensis* sp. nov., aLV, lateral view, ZPAL O.48/556. **3** — *Nipponocythere silesiensis* sp. nov., aLV, paratype, lateral view, ZPAL O.48/62. **4** — *Nipponocythere silesiensis* sp. nov., aRV, holotype, lateral view, ZPAL O.48/60. **5** — *Nipponocythere silesiensis* sp. nov., aLV; **a** — lateral view, **b** — dorsal view; ZPAL O.48/294. **6** — *Nipponocythere silesiensis* sp. nov., aRV; **a** — dorsal view, **b** — ventral view, **c** — lateral view, **d** — enlarged details of the anterior margin; ZPAL O.48/23. **7** — *Nipponocythere silesiensis* sp. nov., aLV, paratype, internal view, ZPAL O.48/61. **8** — *Nipponocythere silesiensis* sp. nov., aRV; **a** — general internal view, **b** — enlarged muscle scars field; ZPAL O.48/554. 1, 3–5, 7, 8 — Upper Badenian, Gliwice G-21 borehole, depth 40.10 m; 2 — Upper Badenian, Gliwice G-21 borehole, depth 51.0 m; 6 — Upper Badenian, Gliwice G-19 borehole, depth 51.0 m. Scale bars = 0.1 mm.

Conclusions

Two ostracod species belonging to the genus *Nipponocythere* Ishizaki, 1971, have been found in the Middle Miocene (Badenian) deposits of the Polish part of the Fore-Carpathian Depression. *Nipponocythere karsyensis* sp. nov. occurs in the Lower Badenian, while *Nipponocythere silesiensis* sp. nov. is characteristic of the Upper Badenian. In the studied area, that is the northern part of the Central Paratethys, *Nipponocythere* could have invaded in the early Middle Miocene (Lower Badenian) from the more southern parts of Europe, where they could be a remnant fauna of the former Tethys, or they could have arrived, in the early Middle Miocene, from the Atlantic Ocean *via* a southern European route.

The Upper Badenian *Nipponocythere silesiensis* sp. nov. is described from Upper Silesia, where it is associated with an exceptionally abundant and diversified microfauna (various groups, including ostracods). Apart from the ostracods, typical of the neritic and phytal (?) environment, there are numerous "exotic" forms, which are extremely rare or (mostly) unknown from the Middle Miocene outside the studied sections. They are characterized by their small-size and thin-walled shells. These specific features of this group of ostracods are considered to be related to environmental conditions. The environment is considered to have been exceptionally favourable for ostracods, that is highly eutrophic, mostly with high primary productivity of the surface waters. Such environmental conditions could have led to undersaturation in O_2 and/or $CaCO_3$ of the bottom waters, resulting in poor biocalcification of ostracods.

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