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Lagoonal to normal marine Late Silurian – Early Devonian ostracode assemblages of the Eurasian Arctic

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ABSTRACT:

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In the Eurasian Arctic the ostracode faunas indicate mostly normal marine environments during the Late Silurian. The Lower Devonian deposits are characterized by ostracode assemblages, which indicate the presence of marine outer shelf to lagoonal environments during the Early Devonian. The dynamics of their taxonomic diversity and some examples of the marine and lagoonal assemblages are shown. Correlation of facially mono- and heterogenous deposits is based on ostracode data.

Key words: Late Silurian, Early Devonian, Ostracodes.

INTRODUCTION

The Upper Silurian of almost the entire Eurasian Arctic is represented by various, usually fossiliferous, limestones. These limestones yield abundant ostracode faunas, reported for the first time by the first geological expeditions to Novaya Zemlya, Vaigach and the Timan-Urals in the thirties, headed by I.F. PUSTOVALOV, N.A. KULIK and others. The Upper Silurian successions in this area are represented mainly by monotonous facies, correlated by means of ostracode associations. The palaeontological description of this fauna began with the publication of GLEBOVSKAYA (1936) and is continued by one of us (ABUSHIK 1962, 1970, 1980, 1997).

By contrast, the Lower Devonian successions of the region are represented by facially heterogeneous strata, with very complicated inter-relationships.

The ostracodes, found in most of the facies represented in the Eurasian Arctic, appeared to be

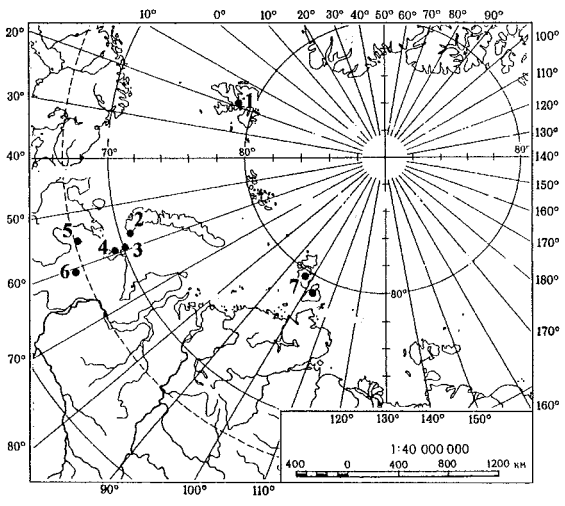

Fig. 1. Geographical sketch-map of the Eurasian Arctic to show the location of studied areas
1 – Spitsbergen; 2 – Novaya Zemlya; 3 – Vaigach Island; 4 – Dolgii Island; 5 – Timan-Pechora region; 6 – Polar and North Urals (Kozhim and Shchugor rivers); 7 – Severnaya Zemlya

very useful both for stratigraphical purposes and for environmental analysis. Unfortunately, Early Devonian ostracodes are still inadequately known, in spite of a number of papers devoted to them from different parts of the Eurasian Arctic: SOLLE's (1935) study on leperdicopes from Spitsbergen; REIN (1936) and ABUSHIK (1961) worked on the same group from Novaya Zemlya and the Polar Urals respectively; studies of ostracode assemblages of Novaya Zemlya, Taimyr and Sette-Daban by POLENOVA (1974), and from Timan-Pechora and the Polar Urals by ABUSHIK (1980, 1982). Early Devonian non-leperditicopes of Eurasian Russia are currently being studied by L.L. SCHAMSUTDINOVA and I.O. EVDOKIMOVA.

Both Late Silurian and Early Devonian ostracodes were taxonomically diverse and constituted an ecologically variable group. Some of them, e.g. leperditicopids, were euryfacial, being represented in a wide spectrum of environments ranging from lagoonal to normal marine. In lagoons they were usually the dominant faunal element, forming local monospecific populations. Although less abundant, they were taxonomically more diverse in marine shelf environments, where they were characterized by a more uniform distribution. Shallow-water shelf successions contain practically every ostracode group, with leperditicopids, primitiopsicopins, beyrichiocopids and kloedenellocopids being especially numerous. The podocopids were less common and, in contrast, dominated the outer shelf (deeper) settings, where they were associated with myodocopids. Leperditicopids contributed to this fauna only in very limited numbers.

This paper is based on a study of collections from Spitsbergen, Novaya Zemlya, Dolgii and Vaigach islands, the Timan-Pechora region, the western slope of the Urals and Severnaya Zemlya (Text-fig. 1). Data from other regions of Eurasia are also included. The taxonomic concepts adopted

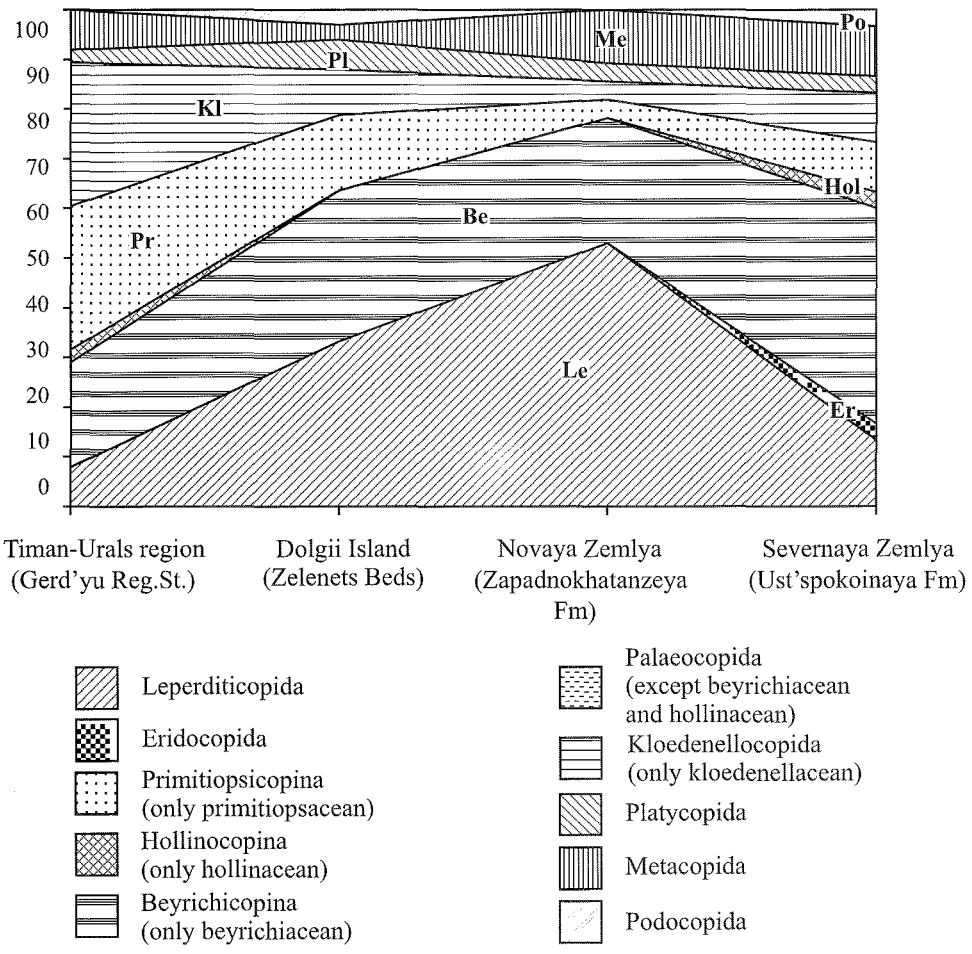

Fig. 2. Relative abundance of the Ludlow ostracode assemblages at order or suborder level

here follow the Treatise (1961), with the recent emendations of ABUSHIK (1990).

LATE SILURIAN

Except for those of Spitsbergen, the Late Silurian deposits of the Eurasian Arctic are represented by marine successions.

Ludlow

The ostracodes from the Ludlow strata of the Timan-Urals region, Dolgii Island, Vaigach Island and Novaya Zemlya are invariably represented by normal marine assemblages (Text-fig. 9).

In the type section of the Gerd'yu Stage [Regional Stage in the Timan-Ural region; equivalent to the Ludlow Stage elsewhere] the ostracode assemblage consists of *Tollitina minuta*, *Herrmannina hebes*, *Kiaeria crassa*, *Signetopsis bicardinata*, *S. eobicardinata*, *Leiocyamus paulus*, *L. variabilis*, *L. enucleatus*, *L. clausus*, *Sulcyamus parvisulcatus*, *S. grandisulcatus*, *Scipionis ordinarius*, *S.? praecox*, *S.? dorsocostatus*, *Beyrichia posterior*, *Simplicibeyrichia parva*, *S.* aff. *globifera*, *Asperibeyrichia simplex*, *Calcaribeyrichia confluens*, *Bingeria punctulata*, *B. indistincta*, *B.* aff. *infrequens*, *Eokloedenia subbacata*, *Eukloedenella grandifabae*, *E. kureikiensis*, *E. altifabae*, *E. posterioalta*, *E. iniqua*, *Kloedenella mucronata*, *K. calva*, *K. posterioalveolata*, *Eoevlanella dizygopleuroides*, *E. costata*, *Cavellina dubia*, *Cytherellina* aff. *inornata*, *Silenis modestus* and *S.? acutus* (see ABUSHIK 1997).

A similar assemblage was reported from the Gerd'yu (Ludlow) of the Polar Urals (Kozhim river section) by TSYGANKO & CHERMNYKH 1983), as well as from the equivalent strata of Dolgii Island (ABUSHIK 1980).

In Novaya Zemlya (*see* Pl. 1) and Vaigach Island, the assemblages of the Khatanzeya Formation are characterized by more diverse leperditicopids: *Leperditia quinqueangulata*, *L.* aff. *lumea*, *Herrmannina hebes*, *H.* aff. *hebes*, *H.* aff. *nana*, *Schrenckia grandis*, *Sch. nordenskjoeldi*, *Bispinitia pigmea*, *Kiaeria crassa*, *K. kiaeri*, *K. elegans* etc. (ABUSHIK 1970, NEKHOROSHEVA 1981).

In Severnaya Zemlya, the assemblage of the Ust'-Spokoinaya Formation consists of *Herrmannina nana*, *H.* aff. *nana*, *Tollitina minuta*, *Bispinitia* aff. *pigmaea*, *Cryptophyllus* sp., *Leiocyamus* aff. *paulus*, *Signetopsis* aff. *michailensis*, *S.* sp., *Platybolbina angustimarginata*, *Mesomphalus* ? sp., *Beyrichia* aff. *kureikiana*, *Simplicibeyrichia* aff. *globifera*, *S.* aff. *impersonalis*, *Calcaribeyrichia* sp., *Gannibeyrichia*? sp., *Bingeria* aff. *indistincta*, *B.* aff. *infrequens*, *B. fluida*, *B. microrete*, *Saccarchites tumefactus*, *Eukloedenella kureikiensis*, *E. clivula*, *E. posterioalta*, *Invisibila* sp., *Cytherellina inornata*, *C. emaciata*, *Kuresaaria* ? sp. and *Pseudorayella ellipsoidea*, as well as some new forms (see ABUSHIK, *in press*).

The Ludlow ostracode assemblages are represented by endemic and provincial species of the widespread genera of leperditicopids (*Leperditia*, *Schrenckia*, *Kiaeria*), primitiopsicopins (*Leiocyamus*, *Signetopsis*, *Scipionis*) and beyrichiocopids (*Asperibeyrichia*, *Beyrichia*, *Bingeria*), as well as some cosmopolitan species. However, following the Late Ludlow regression, which is well recorded in the Eurasian Arctic basins (Upper Gerd'yu, Zelenets, Zapadnokhatanzeya formations; Severnaya Zemlya – Ust-Spokoinaya Formation), ostracode faunal endemism increased. The endemic leperditicopids (*Tollitina*, *Bispinitia*), primitiopsicopins (*Sylciamus*) and beyrichiocopids (*Dolgitia*, *Eokloedenia*, and a new genus of the Hexophthalmoididae, which remains to be described) characterize this part of the succession.

In general, Ludlow successions are characterized by wide distribution of shallow water shelf assemblages. They are characterized by great taxonomic variability (Text-fig. 2) with leperditicopids, beyrichiocopids, primitiopsicopins, kloedenellocopids, platycopids, metacopids and podocopids represented in almost equal amounts. In places, monotaxonic assemblages consisting either of leperditicopids (*Herrmannina*, *Leperditia*) or beyrichiocopids (*Hexophthalmoididae*) or primitiopsicopins (*Leiocyamus*) prevailed. Such assemblages reflect the specific character of short-term shallowing, isolation and change of salinity. The monotaxonic association of *Herrmannian* aff. *nana* from the Upper Klenov Formation of Novaya Zemlya is an example of such an impoverished Ludlow assemblage (Pl. 3, Fig. 1).

Pridoli

In the Greben', the Regional Stage of the Eurasian Arctic that corresponds to the Pridoli, the

ostracode fauna is still abundant. This fauna, in the type section of the Greben' Stage on Vaigach Island, includes: *Schrenckia grandis*, *Sch. nordenskjoeldi*, *Sch. waigatschensis*, *Kiaeria lindstroemi*, *K. kuliki*, *K. alata*, *K. katerinae*, *Tollitina nota*, *Hogmochilina subformosa*, *Calcaribeyrichia grebeni*, *C. angusta*, *Bingeria bella*, *Eokloedenia bacata*, *Microcheilinella lacrima* and *Kuresaaria circulata* (ABUSHIK 1970).

Very similar assemblages are known from the Pridoli of the Polar Urals and Novaya Zemlya (Pl. 2) (*see also* ABUSHIK & MODZELEVSKAYA 1973, NEKHOROSHEVA 1981).

In Dolgii Island ostracodes were found only in the lower part of the Greben'. The assemblage is not complete here but it contains some typical species of the Greben' Stage, including: *Schrenckia waigatschensis*, *Sch. tuberculata*, *Calcaribeyrichia*

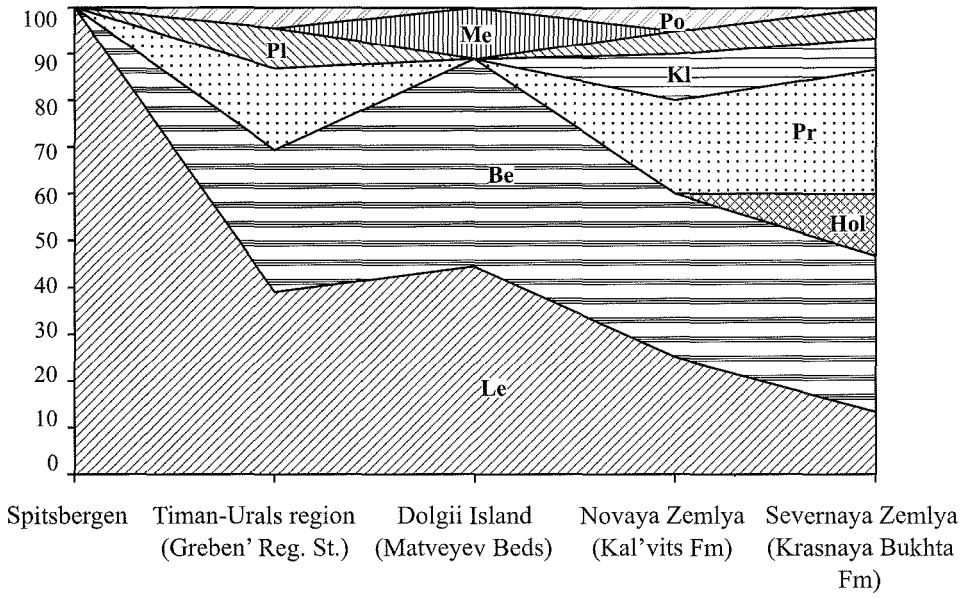

Fig. 3. Relative abundance of the Pridoli ostracode assemblages at order or suborder level

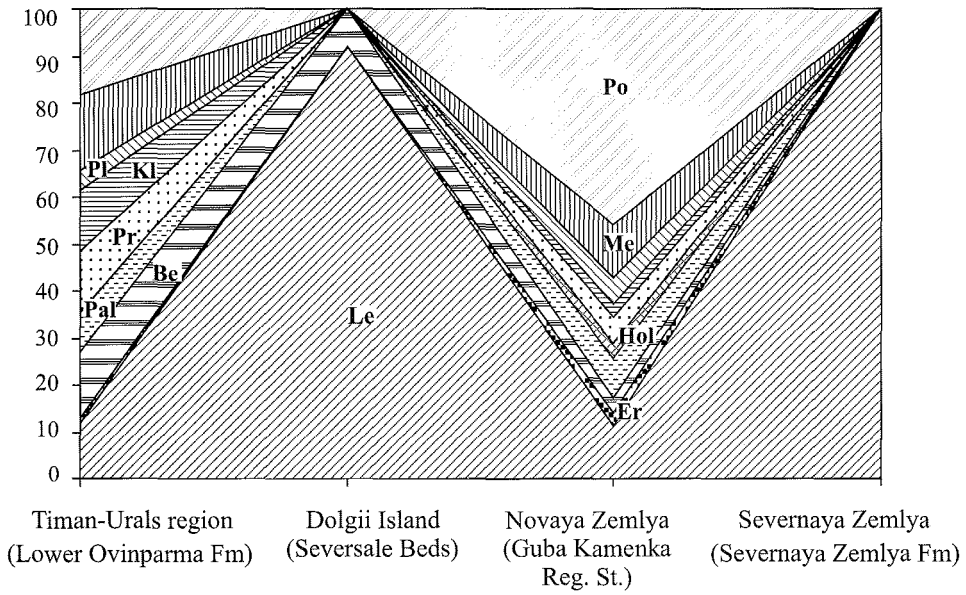

Fig. 4. Relative abundance of the Early Lochkovian ostracode assemblages at order or suborder level

aff. *grebeni*, *C. angusta*, *Bingeria foveolata* and *Kuresaaria circulata*.

In Severnaya Zemlya, the Pridoli (Krasnaya Bukhta Formation) is characterized by *Herrmannina* aff. *nana*, *Platybolbina angustimarginata*, *P.* sp., *Signetopsis quadrilobata*, *S. michailensis*, *Sulcyamus* sp., *Bingeria microrete*, *Eokloedenia bacatiformis*, *Scaldianella* aff. *novozemelica*, and *Invisibila* sp. In this region many Greben' species that occur commonly in the Urals and Novaya Zemlya are absent. Some beyrichiocope genera typical of the province (*Bingeria*, *Eokloedenia*) are represented by endemic species.

Summarizing, the Pridoli assemblages, as in the case of the Ludlow ones, were taxonomically diverse (Text-fig. 3). During marine intervals, many of these forms (particularly representatives of the beyrichiocopids and leperditicopids) spread throughout the European Arctic (Timan-Pechora region, the Polar Urals, Vaigach, Novaya Zemlya). Marine conditions persisted longest in the the Polar Urals and Novaya Zemlya. However, in the latter area, the Silurian/Devonian boundary is marked by an hiatus. With the end of the Silurian, extremely shallow-water conditions occurred in the western part of the area (Spitsbergen – Upper Raudfjord Formation). The ostracode fauna found here is represented by a single leperditicopid, *Herrmannina* sp. (SOLLE 1935). The end-Pridoli regression (and shallowing) is likewise documented in the eastern part of the Eurasian Arctic, in Severnaya Zemlya (uppermost Krasnaya Bukhta Formation). The depauperate ostracode assemblage found here consists of representatives of *Herrmannina*, *Signetopsis*, *Eukloedenella*?, *Nyhamnella*?, and *Invisibila*.

EARLY DEVONIAN

In the Early Devonian (Lochkovian and Pragian), a marked palaeogeographical re-arrangement of the Eurasian Arctic took place. Novaya Zemlya was the only region with shallow marine conditions and carbonate sedimentation throughout the Early Devonian. Other parts of the Eurasian Arctic were temporarily emergent, especially in the Pragian. The return of stable marine conditions in the area began with the Emsian transgression.

Early Lochkovian

In the Early Lochkovian (Text-fig. 4), the marine environments persisted in the Timan-Urals region and Novaya Zemlya (Ovinparma and Guba Kamenka Regional stages respectively). Marine conditions, albeit extremely shallow, occurred in Spitsbergen (Red Bay Formation) and lagoonal environments probably existed in Severnaya Zemlya (Severnaya Zemlya Formation) and Dolgii Island (Seversale Formation).

In the Polar Urals, the Early Lochkovian (=Ovinparma Stage) assemblage contains ostracodes belonging to various groups: leperditicopids (*Leperditia marinae*, *L. dorsocornuta*, *L. extrema*, *Herrmannina immensa*, *H. elongata*, *Tollitina simplex*, *T. acuta*, *T. minima*, *Hogmochilina subformosa*), eridocopids (*Cryptophyllus* sp.), beyrichiocopids (*Kozlowskiella* sp., *Eokloedenia kozhimica*, *Cornikloedenina binata*, *C. triangularis*, *C.* aff. *binata*), platycopids (*Invisibila porrecta*), metacopids (*Cytherellina clara*), and podocopids (*Praepilatina* aff. *praepilata*, *Acanthoscapha* aff. *bohemica*). The Early Ovinparma assemblage from the Timan-Pechora Province is somewhat more diverse. In addition to the species recognized in the Polar Urals, it was characterized by *Bispinitia cymbiforme* (leperditicopids) and diverse non-leperditicopids: *Kielciella sulcata*, *Chlybovella dorsicostata*, *Parapribylites punctatus*, *P.* aff. *lochkovianus*, *Rozhdestvenskajites messleriformis*, *R. koneprusiensis*, *Coeloenellina asymmetrica asymmetrica*, *Pseudozygobolbina* aff. *splendida*, *Eoevlanella salebrosa*, *Kloedenellitina uralica*, *Invisibila orbicularis*, *Microcheilinella regularis*, *M.* aff. *ventrosa*, *Bairdia* sp., *Baschkirina tuberculata*, *B. arta*, *Bairdiocypris krekovskiensis sachaniensis*, *B.* aff. *prominens*, *Bairdiohealdites* aff. *karcevae* etc. (ABUSHIK & SHAMSUTDINOVA, *in press*).

The taxonomic composition of the Early Lochkovian assemblage from Novaya Zemlya is similar to those from the Polar Urals and Timan-Pechora region, although dominated by leperditicopids and podocopids. In Novaya Zemlya, however, the fauna seems to be much more abundant and some of leperditicopids (*Leperditia marinae*, *Hogmochilina subformosa*) and beyrichiocopids (*Cornikloedenina althi*) are characterized by gigantism. This association consists of *Leperditia marinae*, *Herrmannina* aff. *orbiculata*, *H. convexa*, *H. immensa*, *Tollitina* cf. *simplex*, *T.* cf. *acuta*, *Hogmochilina subformosa*, *Cryptophyllus* sp., *Clavofabellina abunda miscella*, *Parapribylites* sp., *Parabolbina* sp., *Eokloedenia kozhimica*, *Nezamyslia* aff. *magnifica*, *Rozhdestvenskajites messleriformis instabilis*, *Uchtovia usensis usensis*, *Eoevlanella* sp., *Invisibila porrecta*,

Orthocypris tschumyshensis, *Microcheilinella regularis*, *Newsomites* sp., *Cytherellina* cf. *vicina*, *Bairdia salairica*, *Baschkirina* cf. *elongata*, *B.* cf. *retusa*, *B. novozemelica novozemelica*, *Bairdiohealdites karcevae*, *Praepilatina praepilata sibirica* and *Acanthoscapha* sp. (Pl. 4).

In Spitsbergen ostracode assemblages of this age are not known, probably due to extremely shallow-water conditions (Red Bay Formation). The Early Lochkovian assemblage from Severnaya Zemlya (Severnaya Zemlya Formation) exhibits a very low generic and specific diversity (Pl. 3, Figs

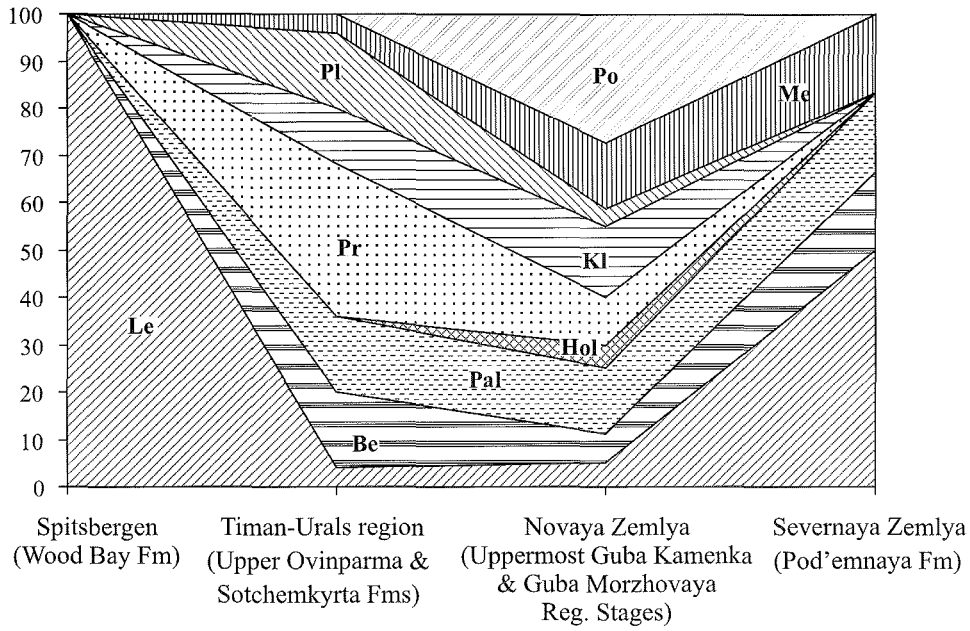

Fig. 5. Relative abundance of the Late Lochkovian ostracode assemblages at order or suborder level

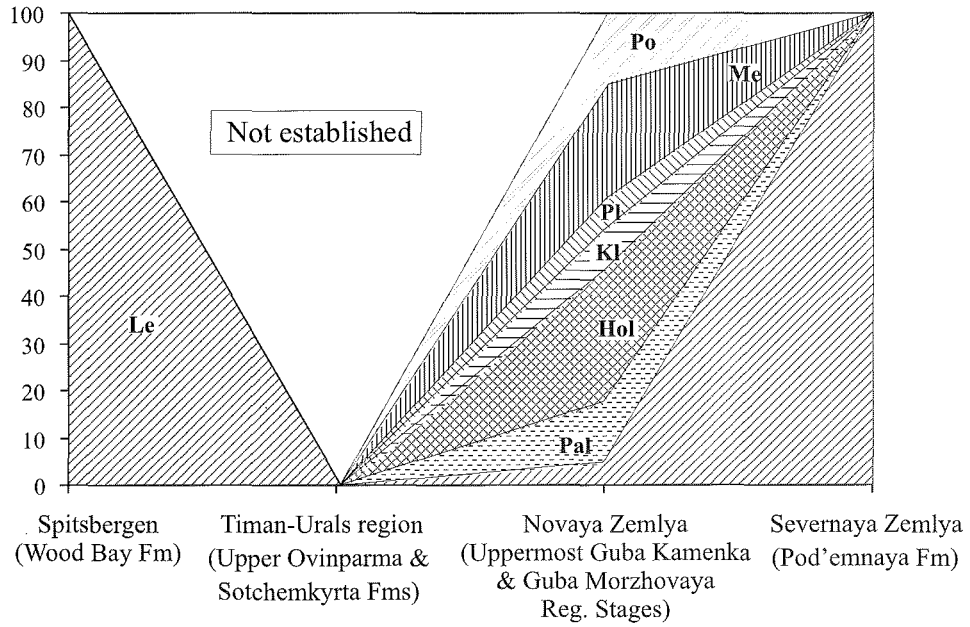

Fig. 6. Relative abundance of the Pragian ostracode assemblages at order or suborder level

2-3), consisting only of *Herrmannina convexa* and *H.* aff. *orbiculata*. In Dolgii Island (Seversale Beds) the assemblage is more diverse, but it is also dominated by leperditicopids (*Leperditia marinae*, *L. dorsocornuta*, *L. extrema*, *L. elongata*, *L. salairica*, *Herrmannina convexa*, *H. immensa*, *Tollitina simplex*, *T. acuta*, *T. minima*, *Bispinitia cymbiforme* and *Hogmochilina subformosa*). Non-leperditicopids are represented by a single species, *Eokloedenia kozhimica* (see ABUSHIK 1980).

Late Lochkovian

In the Late Lochkovian a slight deepening of the Arctic basins took place, normal salinity was restored and a diverse marine fauna spread over large areas (Text-fig. 5).

In Novaya Zemlya (Uppermost Guba Kamenka and Guba Morzhovaya Regional stages), the ostracode assemblage was still diverse, but leperditicopids and podocopids decreased in abundance (POLENOVA 1974).

In the Timan-Pechora Province the Late Lochkovian assemblage consists of *Herrmannina immensa*, *Primitiopsella multifoveata*, *Clavofabellina abunda minor*, *C. costata*, *C. attenuata*, *Kielciella* sp., *Costokloedenia bicostata*, *Welleriella ventriumbonata*, *Mesomphalus* aff. *longicornis*, *Paraschmidtella plana*, *Nezamyslia* sp., *Uchtovia fabacea*, *Eoevlanella* aff. *marginata*, *Invisibila* sp. and *Cytherellina vicina* (ABUSHIK & SHAMSTDINOVA, *in press*). As in the case of Novaya Zemlya, the leperditicopids and podocopids exhibit a marked decrease in diversity.

In Spitsbergen, the Late Lochkovian assemblage (Lower? Wood Bay Formation) consists entirely of representatives of the genus *Hogmochilina*, and includes *H. teres*, *H. isochilinoides* and *H.* aff. *isochilinoides* (SOLLE 1935, FRIEND & MOODY-STUART 1972). In Severnaya Zemlya, the assemblage is characterized by leperditicopids (*Leperditia* cf. *marinae*, *Herrmannina* aff. *orbiculata*, *Hogmochilina isochilinoides* and *H. teres*; Pl. 3, Figs 4-7) along with non-leperditicopids (*Welleriella ventriumbonata*, *Paraschmidtella plana* and *Samarella* cf. *vetusta*) that are common in the Timan-Urals region (Pod'yemnaya Formation).

Pragian

In the Pragian (Text-fig. 6), marine environments with diverse ostracode assemblages persisted only in Novaya Zemlya (Val'nev Regional Stage; POLENOVA 1974). In Severnaya Zemlya, only *Eomoelleritia kondiaini* was found (Lower Russanov Formation; Pl. 3, Figs 9-10). Ostracodes are completely absent from all the other regions, indicating extremely unfavourable environments (emersion?).

Emsian

At the beginning of the Emsian marine conditions existed only in Novaya Zemlya, but the sea very quickly encroached into all the adjacent areas.

In the Early Emsian (Text-fig. 7) marine and lagoonal – marine ostracode assemblages were found in the Timan-Pechora Province and in Severnaya Zemlya (Late? Russanov Formation). The assemblage from the Timan-Pechora area includes diverse non-leperditicopids and is dominated by metacopids and podocopids (*Cryptophyllus ivanicus*, *Hollina arctica*, *Clavofabellina borealis*, *C. straba*, *Sulcatiella* sp., *Aparchitellina* cf. *irgizlensis*, *A.* sp., *Coeloenellina* sp., *Libumella* aff. *inaudata*, *Nezamyslia magnifica*, *Fellerites* sp., *Eukloedenella* cf. *striatella*, *Knoxiella cristata*, *Evlanella intertexta*, *E. bella*, *Barychilina gibbera*, *Timanella* sp., *Invisibila* aff. *symmetrica*, *Birdsalella arctica*, *Cytherellina clara*, *C. vicina*, *Carbonita longa*, *Rishona auriculifera*, *Longiscula* sp., *Rectella nana*, *Microcheilinella* sp., *Newsomites* sp., *Bairdia salairica*, *B. costata*, *B.* aff. *navicula*, *B.* sp., *Parabairdiacypris subsymmetricus*, *P. postacutus*, *Bairdiocypris subprofluens*, *Baschkirina densa*, *B. novozemelica capitata*, *B. hexagonalis*, *B.* sp., *Praepilatina angulata*, *Bivlada tsygankovi*, and *B. chlybovi*). The Late? Russanov assemblage of Severnaya Zemlya is characterized by leperditicopids (*Moelleritia obliqua*) along with diverse non-leperditicopids. In general, the Severnaya Zemlya assemblage resembles the above-mentioned one, but is dominated by beyrichiocopids and kloedenellocopids.

In the Late Emsian (Text-fig. 8; Pl. 5) full marine conditions, with very rich and diverse ostracode assemblages (*Moelleritia egorovi*, *Aparchitellina domratchevi*, *A. glabra*, *A. decorata*, *Evlanella amabilis*, etc.), were established almost throughout the Eurasian Arctic (Urals, Timan-Pechora region, Novaya Zemlya and Severnaya Zemlya). The appearance of some marine forms (*Paenaequina*, "*Evlanovia*") was also noted in the Grey Hoek assemblage of

Spitsbergen (OERVIG 1969). In Severnaya Zemlya the assemblage consisted exclusively of non-leperditicopids and is composed mainly of representatives of genera: *Aparchitellina*, *Mosolovina*, *Kloedenellitina*, *Evlanella*, and *Timanella*.

As in the case of the Silurian, the Emsian (especially Late Emsian) assemblages were characterized by a high taxonomic diversity and included leperditicopids (*Moelleritia*, *Paenaequina*), beyrichiocopids (*Kozlowskiella*, *Aparchitellina*, *Mosolovina*), abundant primitiopsicopins (*Clavofabellina*) and various kloedenellocopids and podocopids (*Eoevlanella*, *Evlanella*, *Marginia*, *Barychilina*, *Kloedenellitina*, *Timanella*, *Cytherellina*, *Rectella*, and *Bairdia*).

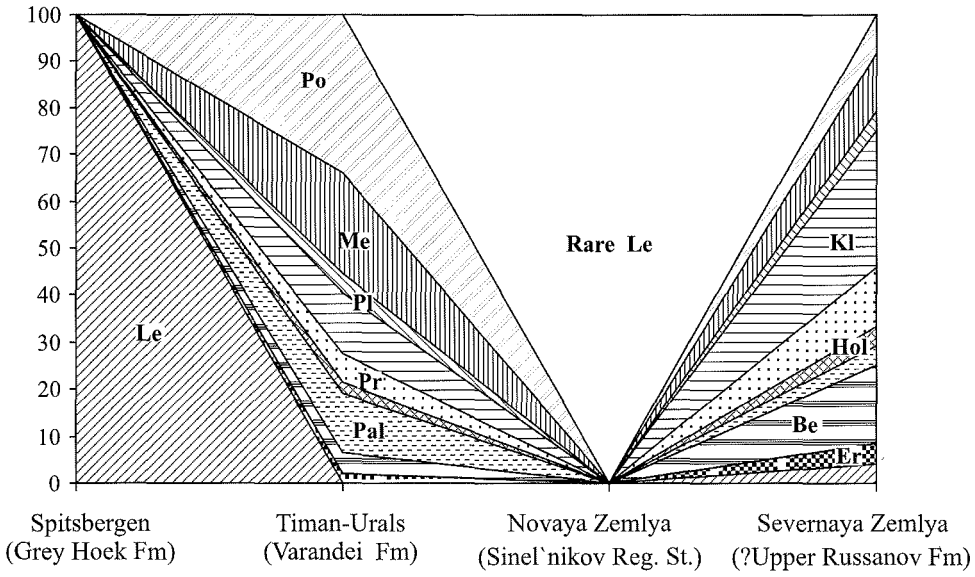

Fig. 7. Relative abundance of the Early Emsian ostracode assemblages at order or suborder level

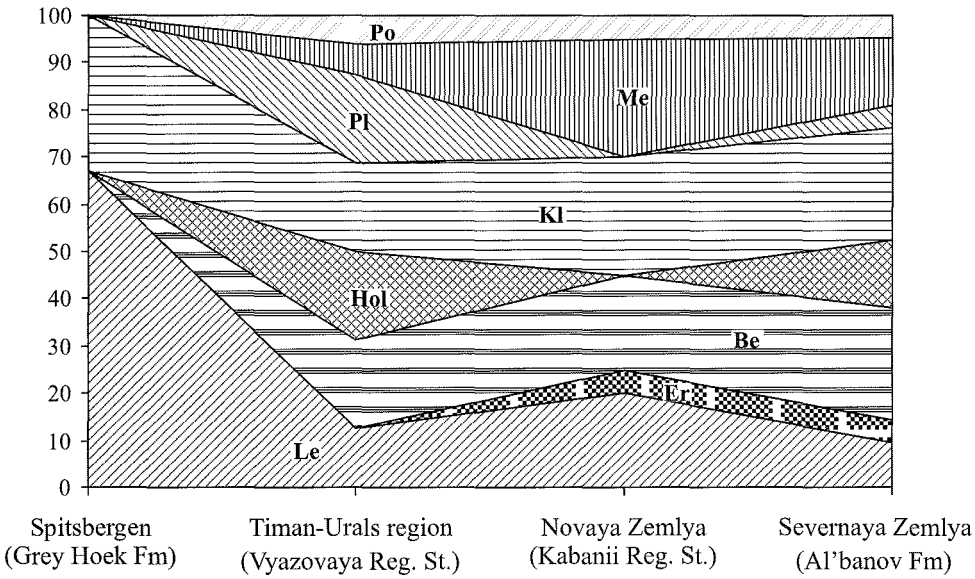

Fig. 8. Relative abundance of the Late Emsian ostracode assemblages at order or suborder level

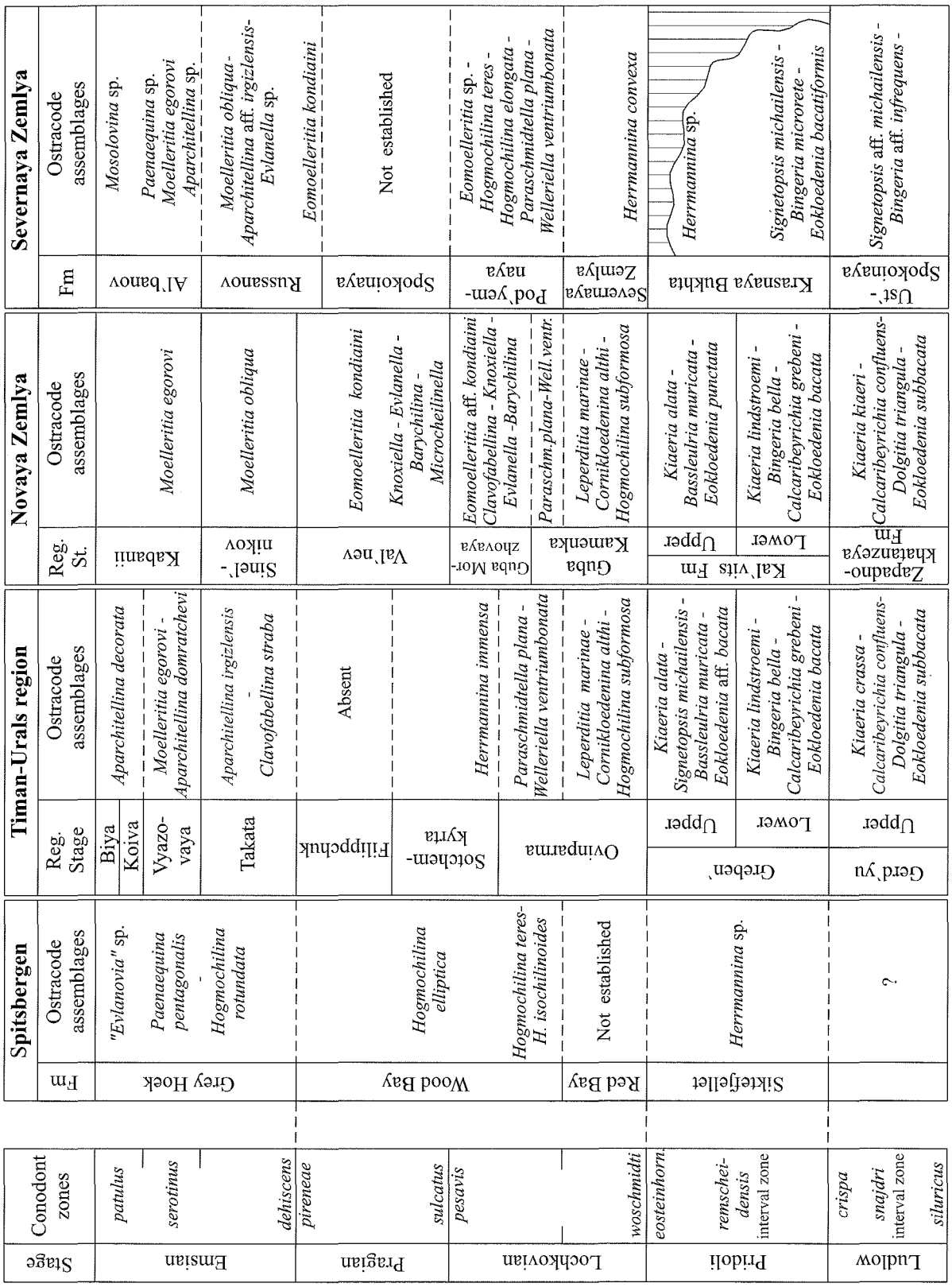

Fig. 9. Correlation of the Upper Silurian – Lower Devonian successions within the Eurasian Arctic by means of ostracode assemblages

CONCLUSIONS

In the Late Silurian – Early Devonian of the Eurasian Arctic the following types of ostracode assemblages may be distinguished:

1. Open, rather deep-water shelf assemblages.

Conditions: Normal salinity, decreased illumination and warming of the bottom.
Lithofacies: Nodular limestone.
Population characteristic: Small separated populations. Moderate taxonomic diversity. Most common podocopids, rare leperditicopids.
Associated fauna: Corals, brachiopods (can be rock-forming), bryozoans, crinoids, trilobites.
Examples: The Lower Greben' assemblages from the Polar Urals, Timan-Urals region and Vaigach Island.

2. Open, shallow-water shelf assemblages.

Conditions: Normal salinity, rather high hydrodynamics, good aeration, illumination and warming of the bottom,
Lithofacies: Diverse organic and organodetrital limestones.
Population characteristic: Uniformly distributed populations of moderate numbers of specimens. Maximum taxonomic diversity, especially among leperditicopids, beyrichiocopids and primitiopsicopins. Podocopids are less diverse.
Associated fauna: Diverse benthic fauna.
Examples: The Ludlow ostracode assemblages from the Gerd'yu Regional Stage of the Polar Urals and Timan-Pechora region, Khatanzea Regional Stage of Vaigach Island and Novaya Zemlya. The Pridoli assemblage from the Ust'-Syv'yu Formation of the Polar Urals, the Kal'vits Formation of Novaya Zemlya and the Lower Krasnaya Bukhta Formation of Severnaya Zemlya.

The Devonian ostracode assemblages from some levels of the Lower Ovinparma Formation of the Polar Urals and Timan-Pechora region (Early Lochkovian), the Guba Morzhovaya and Valnev formations of Novaya Zemlya (Late Lochkovian – Pragian) and the Al'banov Formation of Severnaya Zemlya (Late Emsian).

3. Restricted shallow-water shelf and marine lagoon assemblages.

Conditions: Unstable salinity, moderate to low hydrodynamics, commonly stagnant water.
Lithofacies: Grey chemogenic limestones and dolomites, organic and bioclastic limestones.
Population characteristic: Ostracodes are either rare or rock forming. Populations large, but of low diversity (leperditicopids, or primitiopsicopins, or beyrichiocopids, or others only). High ostracode population densities (sometimes rock forming) are common.
Associated fauna: rare bivalves and gastropods.
Examples: Some Late Ludlow assemblages: limestone with *Leiocyamus* from the Sizim Subformation of the Polar Urals and also limestone with *Herrmannina* aff. *nana* from the Upper Klenov Formation of Novaya Zemlya.

The Lochkovian leperditicopid assemblages from the Polar Urals and Novaya Zemlya (Ovinparma, Guba Kamenka, Guba Morzhovaya Regional stages) and also *Cytherellina* and *Invisibila* assemblages from the Lochkovian of the Timan-Pechora region.

4. Near-shore extremely shallow-water shelf (peritidal carbonate platform and estuarine) assemblages.

Conditions: Abnormal salinity, often very low. High hydrodynamics or stagnation. Intensive supply of clastic sediments. Predominance of deformed or incomplete carapaces and fragments.
Population characteristic: Rare and local monotaxonic leperditicopid assemblages.
Associated fauna: Fishes and charophytes.
Examples: Lochkovian assemblages from the Wood Bay Formation (Spitsbergen) and the Severnaya Zemlya and Pod'yemnaya Formations (Severnaya Zemlya).

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REFERENCES

ABUSHIK, A.F. 1961. Middle Devonian leperditicopes from the Urals, Novaya Zemlya and the Middle Asia. *Trudy VSEGEI, Novaya Serya*, **67**, 133-152. Leningrad. [*In Russian*].

— 1962. New genus of Ludlowian ostracodes from the Polar Urals. *Trudy VSEGEI, Novaya Serya*, **86**, 83-85. Leningrad. [*In Russian*].

— 1970. The Late Silurian ostracodes of the Vaigach Island. *In*: S.V. CHERKESOVA (*Ed.*), *Stratigraphy and fauna of the Silurian deposits of the Vaigach Island*, pp. 165-194. Leningrad. [*In Russian*].

— 1980. The Silurian and Early Devonian ostracodes. *In*: V.P. SAPEL'NIKOV (*Ed.*), *Silurian and Devonian deposits of the Dolgii Island*, pp.107-140. Sverdlovsk. [*In Russian*].

— 1997. Ostracodes from the stratotype of the Gerd'yu Regional Stage (Silurian, Ludlow) from the north of the Urals. *In*: G.A. STUKALINA (*Ed.*), Atlas of the standard complexes of the Palaeozoic benthic fauna from the Northeast of European Russia. St. Petersburg, pp. 5-34. [*In Russian*].

— (*in press*). The Silurian ostracodes from Severnaya Zemlya. *Geodiversitas*.

ABUSHIK, A.F. & MODZELEVSKAYA, T.L. 1973. About the Silurian-Devonian boundary in the western slope of the Polar Urals. *Doklady Akademii Nauk SSSR*, **209** (3), 1171-1173. Moscow. [*In Russian*].

ABUSHIK, A.F. & SHAMSUTDINOVA, L.L. (*in press*). Early Devonian ostracodes of the Timan-Pechora province. [*In Russian*].

CHEKHOVICH, P.A. 1994. The Late Caledonian unconformity in the Sredniy Ural: diagnostic on isotopic-carbonic evidence. *Doklady Akademii Nauk*, **336** (4), 515-517. Moscow. [*In Russian*].

FRIEND, P. & MOODY-STUART, M. 1972. Sedimentation of the Wood-Bay Formation (Devonian) of Spitsbergen. Regional analysis of a late orogenic basin. *Norsk Polarinstitutt Skrifter*, **157**, 9-74. Oslo.

GLEBOVSKAYA, E.M. 1936. Silurian ostracodes from the north-western shores of Novaya Zemlya. *Trudy Arkticheskogo Instituta*, **58**, 33-43. Leningrad. [*In Russian*].

NEKHOROSHEVA, L.V. (*Ed.*). 1981. The explanatory note to stratigraphic scheme of the Late Silurian deposits of the Vaigach-Southern Novaya Zemlya region, pp. 1-205. *Izdatelstvo VNII Okeangeologiya*; Leningrad. [*In Russian*].

OERVIG, T. 1969. Thelodont scales from the Grey Hoek formation of Andree Land, Spitsbergen. *Norsk Geologisk Tidsskrift*, **49**, 387-401. Oslo.

POLEVNOVA, E.N. 1974. Early Devonian ostracodes of the Arctic regions of the USSR, pp. 1-155. *Nauka*; Moscow. [*In Russian*].

REIN, E.F. 1936. Palaeozoic ostracodes from the north-eastern shores of Novaya Zemlya. *Trudy Arkticheskogo Instituta*, **58**, 45-90. Leningrad. [*In Russian*].

SOLLE, G. 1935. Devonischen Ostracoden Spitzbergens. 1. Leperditiidae. *Skrifter om Svalbard og Ishavet*, **64**, 1-61. Oslo.

TSYGANKO, V.S. & CHERMNYKH, V.A. (*Eds*). 1983. Key sections of the Silurian-Devonian boundary deposits of the Polar Urals, pp. 3-104. Syktyvkar. [*In Russian*].

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PLATE 1

Open shallow-water shelf assemblage; Upper Klenov and Zapadnokhatanzeya formations (Ludlow, Novaya Zemlya)

1 – *Leperditia quinqueangulata* ABUSHIK; right valve, × 1.5; Khatanzeya Peninsula (7706-17d); Upper Klenov Formation

2 – *Herrmannina hebes* ABUSHIK; right valve, × 1.5; Khatanzeya Peninsula (7708-3); Zapadnokhatanzeya Formation

3 – *Bispinitia pigmaea* ABUSHIK; right valve, × 1.5; Khatanzeya Peninsula (7706-21a); Upper Klenov Formation

4 – *Schrenckia grandis* (SCHMIDT); left valve, × 1.5; Khatanzeya Peninsula (7706-17d); Upper Klenov Formation

5 – *Schrenckia nordenskjoeldi* (SCHMIDT); left valve, × 1.5; Khatanzeya Peninsula (7706-17b); Upper Klenov Formation

6 – *Schrenckia tumefacta* ABUSHIK; right valve, × 1.5; Fedotov Cape (7813-8/1); uppermost Zapadnokhatananzeya Formation

7-8 – *Kiaeria kiaeri* GLEBOVSKAYA; right (7) and left (8) valves, × 1.5; Fedotov Cape (7813-3/2, 7813-6/3); uppermost Zapadnokhatananzeya Formation

9 – *Kiaeria crassa* ABUSHIK; left valve, × 1.5; Khatananzeya Peninsula (7808-5a); Zapadnokhatanzeya Formation

10 – *Kiaeria elegans* ABUSHIK; left valve, × 1.5; Khatanzeya Peninsula (7804-4); Zapadnokhatanzeya Formation

11 – *Zenkopsis* sp.; female left valve, × 35; Fedotov Cape (7813-8/1); uppermost Zapadnokhatanzeya Formation

12 – *Signetopsis*? sp.; male right valve, × 35; Fedotov Cape (7813-5/1); Zapadnokhatanzeya Formation

13 – *Simplicibeyrichia parva* ABUSHIK; right valve, × 35; Khatanzeya Peninsula (7706-17d); Zapadnokhatanzeya Formation

14 – *Simplicibeyrichia bispina* ABUSHIK; male right valve, × 35; Fedotov Cape (7813-5/2); Zapadnokhatanzeya Formation

15 – *Beyrichia posterior* ABUSHIK; male left valve, × 35; Fedotov Cape (7813-4/1); Zapadnokhatanzeya Formation

16-17 – *Altibeyrichia* sp.; female right (16) and male left (17) valves, × 35; Fedotov Cape (7813-4/1); Zapadnokhatanzeya Formation

18 – *Bingeria arctica* ABUSHIK; male right valve, × 35; Fedotov Cape (7813-8/1); uppermost Zapadnokhatanzeya Formation

19-20 – *Calcaribeyrichia confluens* ABUSHIK; male right (19) and female left (20) valves, × 35; Fedotov Cape (7813-5/2); Zapadnokhatanzeya Formation

21 – *Eokloedenia subbacata* ABUSHIK; male right valve, × 35; Fedotov Cape (7813-5/2); Zapadnokhatanzeya Formation

22 – *Cavellina concinna* NECKAJA; carapace, left lateral view, × 35; Fedotov Cape (7813-8/1); uppermost Zapadnokhatanzeya Formation

23 – *Cavellina kubensis* ZENKOVA; carapace, left lateral view, × 35; Fedotov Cape (7813-8/1); uppermost Zapadnokhatanzeya Formation

24 – *Cytherellina* aff. *siliqua* JONES; carapace, right lateral view, × 35; Khatanzeya Peninsula (7706-17d); Upper Klenov Formation

25 – *Cytherellina* cf. *inornata* ABUSHIK; inner cast of left valve, × 35; Khatanzeya Peninsula (7706-17d); Upper Klenov Formation

26 – *Silenis*? aff. *modestus* ABUSHIK: carapace, right lateral view, × 35; Fedotov Cape (7813-8/1); uppermost Zapadnokhatanzeya Formation

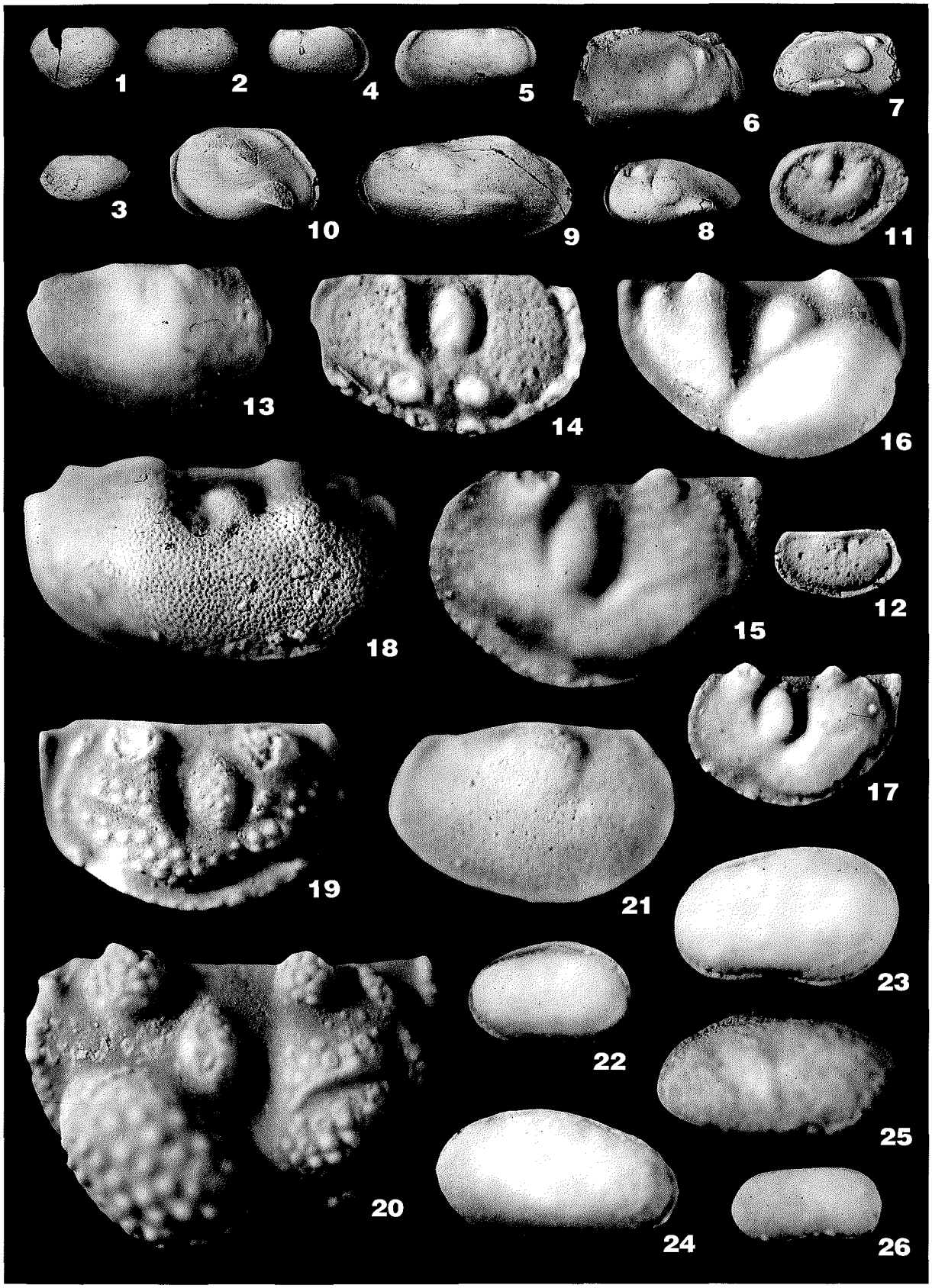
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PLATE 2

Open shallow-water shelf assemblages (Kal'vits Formation, Novaya Zemlya)

1-2 – *Leperditia submarinae* ABUSHIK; right and left valves, × 1.5; Fedotov Cape (7819-12/6)
3 – *Herrmannina orbiculata* ABUSHIK; left valve, × 1.5; Kuznetsov River (7950-3/4)
4 – *Schrenckia nordenskjoeldi* (SCHMIDT); left valve, × 1.5; Khatanzeya Peninsula (7708-15a)
5 – *Schrenckia tuberculata* ABUSHIK; left valve, × 1.5; Khatanzeya Peninsula (7708-15a)
6 – *Kiaeria lindstroemi* (SCHMIDT); right valve, × 1.5; Khatanzeya Peninsula (7708-15a)
7 – *Kiaeria kuliki* GLEBOVSKAYA; right valve, × 1.5; (7819-15)
8 – *Primitiopsis* sp.; right valve, x 35; Khatanzeya Peninsula (7708-14)
9 – *Leiocyamus limpidus* GAILITE; right valve, × 35; Fedotov Cape (7819-12/2)
10 – *Signetopsis michailensis* ZENKOVA; right valve, × 35; Khatanzeya Peninsula (7708-14)
11 – *Clavofabellina uralica* ZENKOVA; left valve, × 35; Khatanzeya Peninsula (7708-14)
12 – *Bassleulria muricata* (ULRICH & BASSLER); right valve, × 35; Kuznetsov River (7950-19/1)
13 – *Bassleulria* aff. *muricata* (ULRICH & BASSLER); left valve, × 35. Kuznetsov River (7950-19/4)
14 – *Calcaribeyrichia angusta* ABUSHIK; male left valve, × 35; Kuznetsov River (7950-7/7)
15 – *Navibeyrichia*? sp.; female right valve, × 35; Khatanzeya Peninsula (7708-14)
16 – *Bingeria foveolata* ZENKOVA; female left valve, × 35; Kuznetsov River (7950-3/4)
17 – *Bingeria* aff. *foveolata* ZENKOVA; male left valve, × 35; Kuznetsov River (7950-19/1)
18 – *Bingeria* aff. *bella* ABUSHIK; male left valve, × 25; Fedotov Cape (7819-12/2)
19 – *Bingeria* aff. *microrete* ABUSHIK; male right valve, × 35; Kuznetsov River (7950-9/2)
20 – *Noviterria mira* (ABUSHIK); male right valve, × 35; Khatanzeya Peninsula (7708-14)
21 – *Eokloedenia bacata* (ABUSHIK); male left valve, × 35; Kuznetsov River (7950-19/2)
22 – *Eokloedenia punctata* ABUSHIK; male left valve, × 35; Kal'vits Bay (7812-16)
23 – *Scaldianella novozemelica* ABUSHIK; male left valve, × 35; Fedotov Cape (7819-12/4)
24 – *Cavellina michailensis* ZENKOVA; male carapace, left lateral view, × 35; Kuznetsov River (7950-9/2)
25-26 – *Dizygopleura*? *terra* ABUSHIK; 25 – male carapace, right lateral view, 26 – female carapace; left lateral view, × 35; Kuznetsov River (7950-7/7)
27 – *Pseudorayella scala* NECKAJA; carapace, right lateral view, × 35; Khatanzeya Peninsula (7708-14)

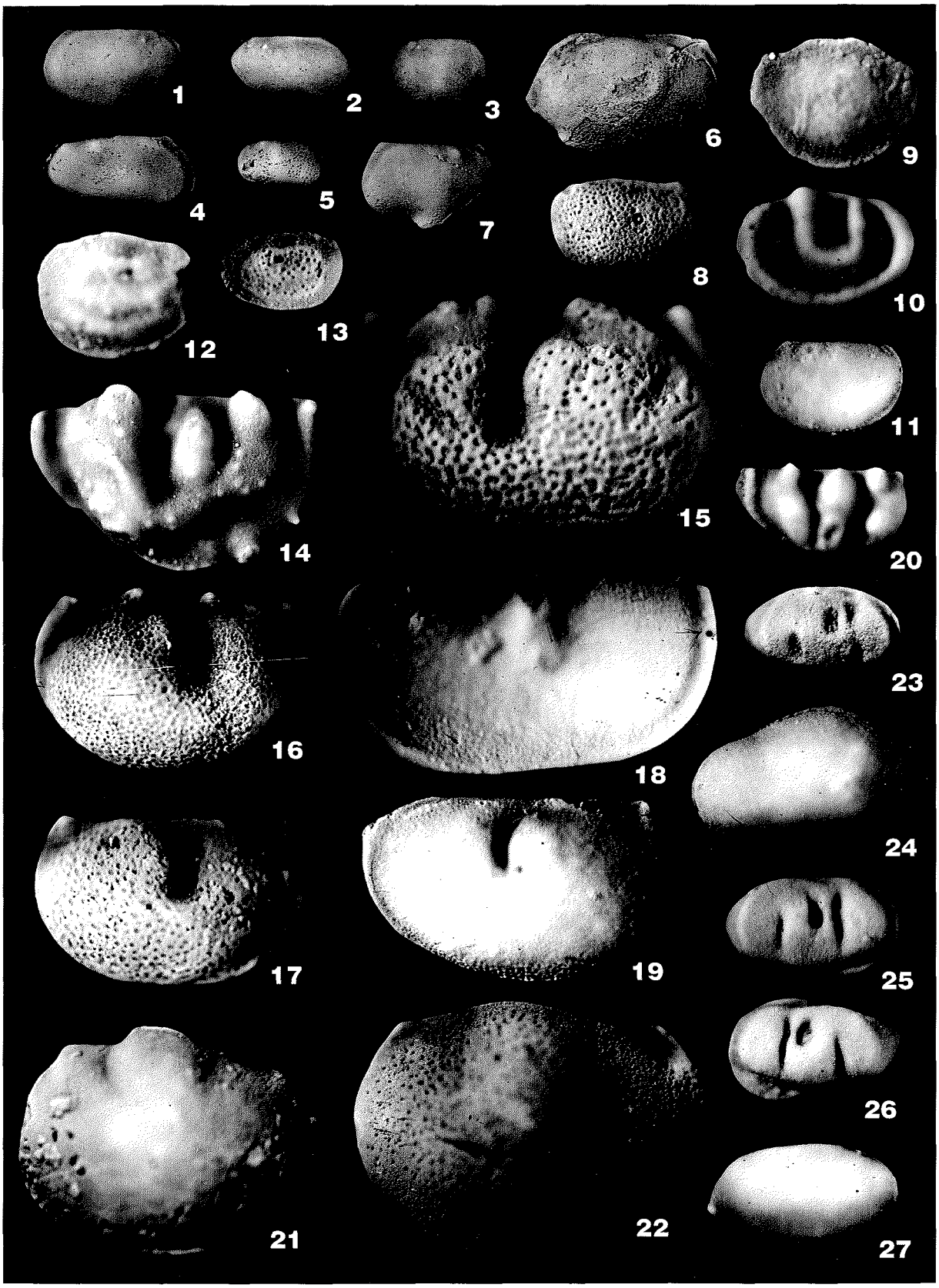
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PLATE 3

Lagoonal leperditicope assemblages

1 – Concentration of *Herrmannina* aff. *nana* ABUSHIK (monospecific assemblage), × 2; Novaya Zemlya, Khatanzeya Peninsula; Ludlow, Upper Klenov Formation

2-3 – Carapaces of *Herrmannina convexa* ABUSHIK, × 5; 2 – valves with conserved ligament hinge, 3 – crushed left valve; Severnaya Zemlya, October Revolution Island; Lochkovian, Severnaya Zemlya Formation

4-7 – Monogeneric assemblage from the Pod'emnaya Formation (Severnaya Zemlya): 4 – *Hogmochilina teres* SOLLE, right valves, × 3, 5 – *H.* aff. *subformosa* ABUSHIK, left valves, × 3, 6 – *H. isochilinoides* (JONES), right valves, × 1, 7 – *H. isochilinoides* (JONES), left valves, × 3,

8 – *Hogmochilina teres* SOLLE; right valve, × 3; Spitsbergen, Wood Bay Formation

9-10 – *Eomoelleritia kondiaini* ABUSHIK (monospecific assemblage); right (9) and left (10) valves, × 3; Severnaya Zemlya, October Revolution Island; Pragian, ?Lower Russanov Formation

11 – Concentration of *Moelleritia* sp. (with rare *Eoevlanella* aff. *fregis* POLENOVA and *Cytherellina* sp.), × 1; Severnaya Zemlya, Figurnyi Island; ?Early Emsian, ?Upper Russanov Formation

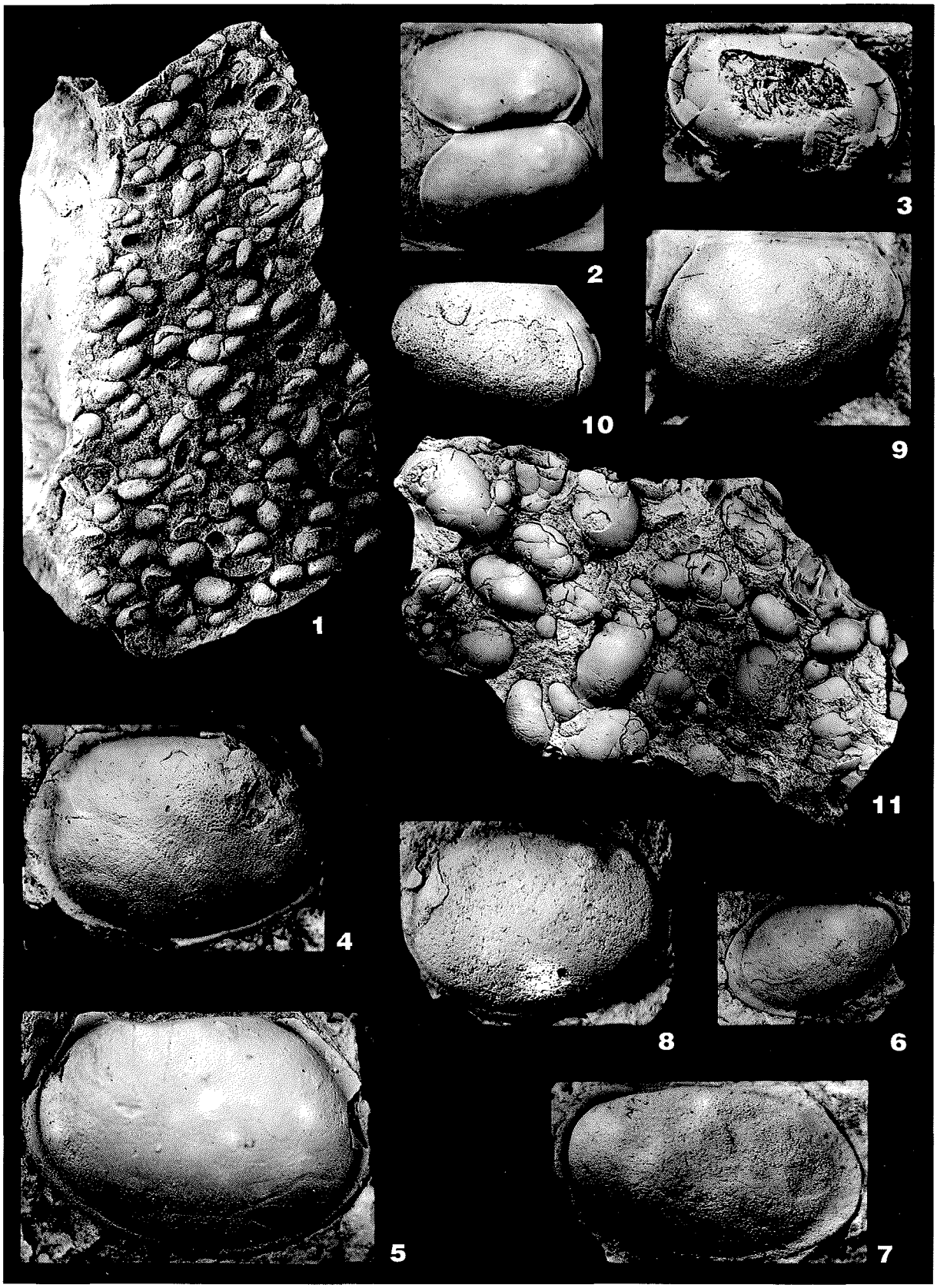
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PLATE 4

Early Lochkovian restricted shelf assemblage (Novaya Zemlya, Guba Kamenka Reg.St.)

1 – *Leperditia marinae* ABUSHIK; right valve, lateral view (7837-2), × 1
2 – *Hogmochilina subformosa* ABUSHIK; left valve, lateral view (7837-2), × 1
3 – *Cryptophyllus* sp.; carapace (7838-3/1), × 110
4 – *Clavofabellina abunda* (POLENOVA); male carapace, left lateral view (7838-3/3), × 78
5 – *Chlybovella* sp.; female left valve, lateral view (7838-2/2), × 57
6-7 – *Kielciella*? sp.; female right valve, 6 – lateral view, 7 – ventral view (7838-3/3), × 50
8 – *Eokloedenia kozhimica* ABUSHIK; male right valve, lateral view, × 35; Polar Urals, Kozhim River, Lower Ovinparma Formation
9 – *Welleriella abushikae* ZENKOVA; female left valve, lateral view (7838-2/2), × 40
10 – *Cornikloedenina althi* ABUSHIK; female right valve, ventral view (7838-3/1), × 35
11 – *Nezamyslia* aff. *magnifica* POLENOVA; male left valve, lateral view (7838-3/2), × 50
12 – *Uchtovia usensis usensis* ZENKOVA; female carapace, left lateral view (7838-3/2), × 57
13 – *Uchtovia* aff. *usensis* ZENKOVA; male carapace, left lateral view (7838-3/1), × 78
14 – *Uchtovia fabacea* ABUSHIK; female carapace, right lateral view (7838-3/1), × 68
15 – *Timanella* sp.; male carapace, left lateral view (7838-3/2), × 78
16 – *Baschkirina* sp.; carapace, right lateral view (7838-3/3), × 68

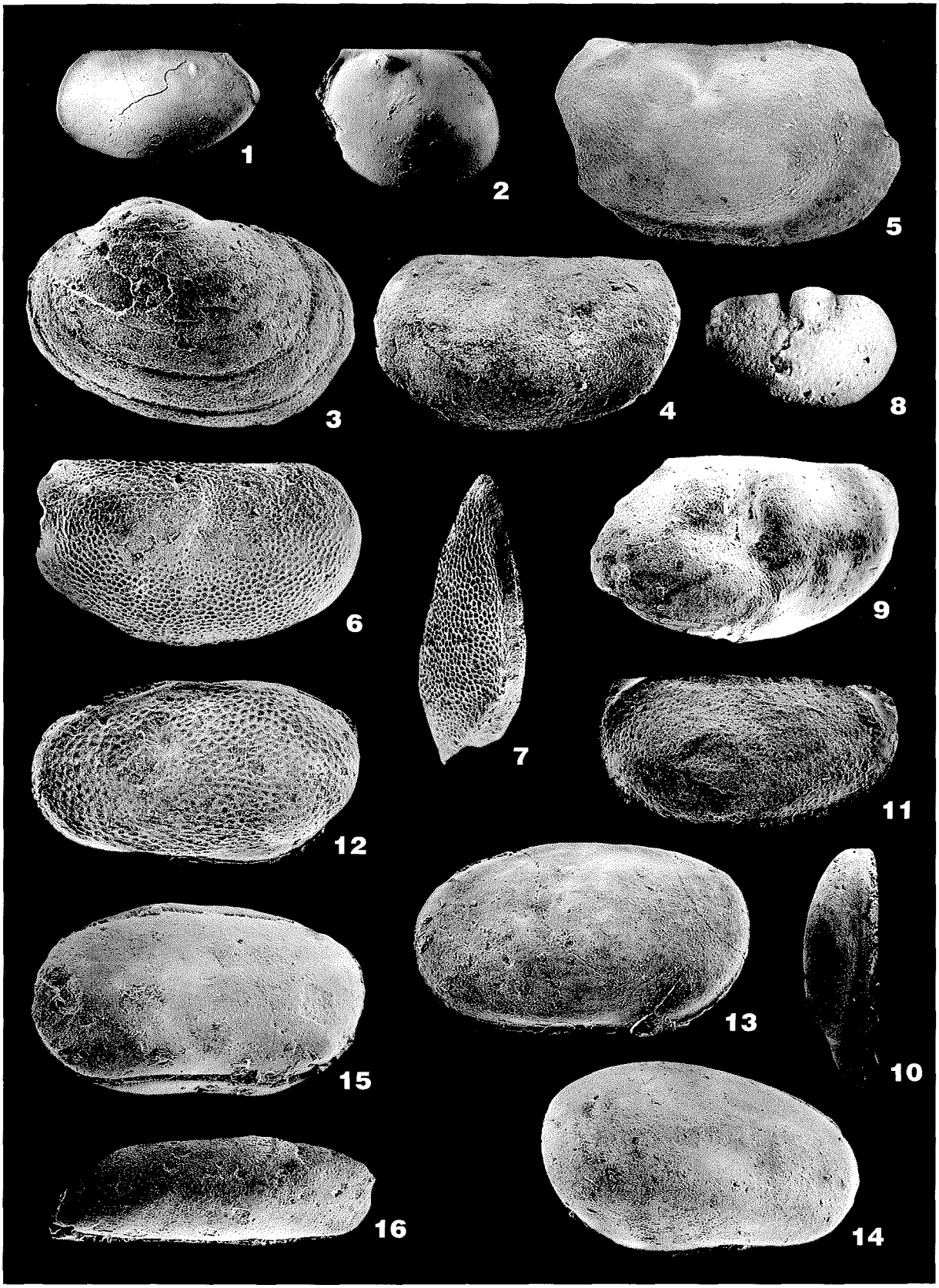
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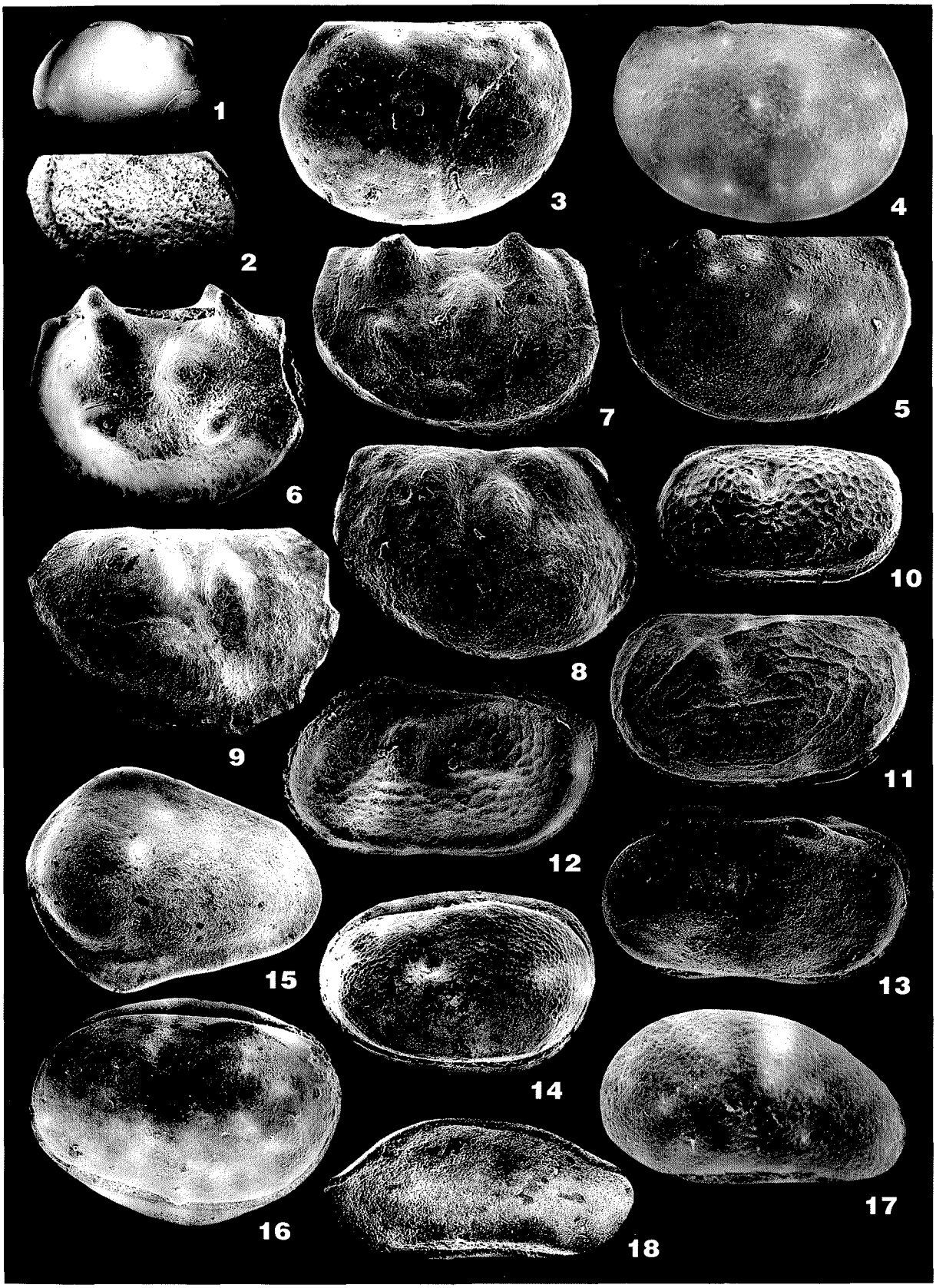
PLATE 5

Emsian open shallow-water shelf assemblage (Severnaya Zemlya, Al'banov Formation)

1 – *Moelleritia* aff. *quadrigibbera* ABUSHIK; right valve, lateral view, × 1; Komsomolets Island, loc.18091
2 – *Paenaequina* sp.; right valve, lateral view, × 1; October Revolution Island, loc.144
3 – *Aparchitellina* aff. *glabra* ROZHDESTVENSKAYA; tecnomorphic carapace, left lateral view, × 70; Pioneer Island, loc.2669
4 – *Aparchitellina irgizlensis* ROZHDESTVENSKAYA; tecnomorphic carapace, right lateral view, × 62; Figurnyi Island, loc.7411-B1; Russanov Formation
5 – *Aparchitellina* sp.; male carapace, right lateral view, × 85; Komsomolets Island, loc.18102-7
6 – *Mosolovina* sp.; male carapace, right lateral view, × 57; Komsomolets Island, loc.18102-7
7 – *Mosolovina* sp.; male carapace, right lateral view, × 70; Pioneer Island, loc.2669-6
8 – *"Kozlowskiella"* sp.; female right valve, lateral view, × 57; Komsomolets Island, loc.18102-10
9 – *Hollinella* sp.1; female right valve, lateral view, × 57; October Revolution Island, loc.627-1
10 – *Eoevlanella* aff. *fregis* (POLENOVA); tecnomorphic carapace, left lateral view, × 78; Pioneer Island, loc.2362-10; Russanov Formation
11 – *Evlanella* aff. *bella* POLENOVA; male left valve, lateral view, × 57; Pioneer Island, loc.2479
12 – *Evlanella* sp.; tecnomorphic carapace, left lateral view, × 92; Komsomolets Island, loc.18102-7
13 – *Kloedenellitina* sp.; tecnomorphic carapace, left lateral view, × 90; Komsomolets Island, loc.18102-7
14 – *Barychilina* aff. *gibbera* POLENOVA; female carapace, left lateral view, × 57; Pioneer Island, loc.2803; Russanov Formation
15 – *Timanella* sp.; female carapace, right lateral view, × 42; Komsomolets Island, loc.18102-7
16 – *Timanella* sp.; male carapace, left lateral view, × 70; October Revolution Island, loc.627-1
17 – *Cytherellina clara* (POLENOVA); carapace, right lateral view, × 39; October Revolution Island, loc.136; Russanov Formation
18 – *Bairdia* aff. *carinata* POLENOVA; carapace, right lateral view, × 51; Pioneer Island, loc.2803; Russanov Formation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