Conodonts in the Silurian of Severnaya Zemlya and Sedov archipelagos (Russia), with special reference to the genus *Ozarkodina* Branson & Mehl, 1933

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ABSTRACT
The studied conodont faunas indicate that the main part of the Silurian sequence on Severnaya Zemlya and Sedov archipelagos (Vodopad, Golomyannyj, Srednij formations and the lower part of the Samojlovich Formation) is of Llandovery age. Llandovery ozarkodinids are dominated by *Ozarkodina waugoolaensis* Bischoff, 1986; *Oz. aldridgei* Uyeno & Barnes, 1983 occurs at some levels; *Oz. guiyangensis* Zhou, Zhai & Xian, 1981 and *Ozarkodina* sp. E characterize the Golomyannyj Formation. From the Wenlock strata only *Oz. confluens bucerus* (Viira, 1983) has been found. *Oz. polinclinata* Nicoll & Rexroad, 1968 is very rare, and *Oz. excavata* (Branson & Mehl, 1933) is evidently missing in this region. Several poorly represented new species of *Ozarkodina* Branson & Mehl, 1933 are kept in open nomenclature.

KEY WORDS
Conodonts,
Ozarkodina,
Silurian,
Severnaya Zemlya,
Sedov Archipelago,
Russia,
stratigraphy.

RÉSUMÉ
Étude des conodontes des niveaux stratigraphiques siluriens des archipels de Severnaya Zemlya et de Sedov (Russie), et en particulier du genre Ozarkodina *Branson & Mehl, 1933.*
Dans les niveaux siluriens des archipels de Severnaya Zemlya et de Sedov (formations de Vodopad, de Golomyannyj, de Srednij et la partie inférieure de la Formation Samojlovich), les faunes de conodontes indiquent que la majeure partie de ces niveaux sont d'âge Llandovery. Les ozarkodinides de cet âge sont représentés majoritairement par *Ozarkodina waugoolaensis* Bischoff, 1986. Dans certains niveaux, on trouve *Oz. aldridgei* Uyeno & Barnes, 1983 ; alors que la Formation Golomyannyj est caractérisée par la présence de *Oz. guiyangensis* Zhou, Zhai & Xian, 1981 et *Ozarkodina* sp. E. C'est dans les niveaux du Wenlock que domine *Oz. confluens bucerus* (Viira, 1983). D'autres taxons sont rares, c'est le cas de *Oz. polinclinata* Nicoll & Rexroad, 1968, d'autres sont absents du niveau silurien de ces archipels, c'est le cas de *Oz. excavata* (Branson & Mehl, 1933). Une nomenclature ouverte a été appliquée à quelques espèces mal représentées du genre *Ozarkodina* Branson & Mehl, 1933.

MOTS CLÉS
Conodontes,
Ozarkodina,
Silurien,
Severnaya Zemlya,
archipel de Sedov,
Russie,
stratigraphie.

INTRODUCTION

The Silurian sequence on Severnaya Zemlya and Sedov archipelagos is represented by fossiliferous carbonates of shallow-water origin, with thin interbeds of sandstone at some levels (Markovskij & Smirnova 1982; Kurik *et al.* 1982). Silurian marine carbonates are underlain by variegated, mainly terrigenous rocks (sandstones and marlstones) of Ordovician age (Markovskij & Makar'ev 1982). The system boundary is taken at the top of the uppermost sandstone layer, which is overlain by limestone. The upper part of the Silurian was eroded before Devonian sedimentation started in the central and western areas, but in the east it is mostly preserved (Markovskij & Smirnova 1982; Matukhin *et al.* 1982; Kurik *et al.* 1982). The sequences available for study are exposed in the river valleys perpendicular to the outcrop belts on October Revolution Island (sections on the Strojnaya, Ushakov, Matusevich, Spokojnaya and Obryvistaya rivers; sampled by V. Karatajūtē-Talimaa in 1978, and by P. Männik and E. Mark-Kurik in 1979), and in the cliffs along the southern coast of Srednij Island (collections of E. Mark-Kurik from 1974, and P. Männik and E. Mark-Kurik from 1979; Männik *et al.* 2002: figs 1, 2, 6, 9). Silurian strata are exposed also in the south-western part of Komsomolets Island and in several regions on Pioneer Island (Männik *et al.* 2002: fig. 1). Several samples were studied from the Silurian sections located in the northern and north-western parts of Pioneer Island (collections of E. I. Kachanov from 1976, passed me by V. Karatajūtē-Talimaa). In total, 328 samples (= about 400 kg of rock) were studied. The collection of conodonts contains more than 12 000 identifiable specimens.

The conodont elements from Srednij and Pioneer islands are generally amber in colour, although some variation occur. On October Revolution Island the colour of conodonts is more variable – from dark brown in the base to light amber in the top of the Silurian sections. With reference to the conodont colour alteration index (CAI), the conodonts from Srednij and Pioneer islands have a CAI of about 1-1.5 and those from October Revolution Island 1-3, reflecting diagenetic temperatures of less than 90 °C and up to 200 °C, respectively (Epstein *et al.* 1977). All illustrated specimens are housed in the Institute of Geology, Tallinn Technical University.

CONODONT FAUNAS AND BIOSTRATIGRAPHY

In general, the Silurian conodont fauna from Severnaya Zemlya is quite specific including rare taxa also known from Europe and North America. It is closest to that from the Timan-northern Ural region, Russia (pers. obs.). Several common taxa can be found in the collections described from South China (Zhou *et al.* 1981; Wang Cheng-Yuan & Aldridge 1996) and from New South Wales in Australia (Bischoff 1986), but also from the Gaspé Peninsula in Canada (Nowlan 1981, 1983).

Study of conodonts shows that the main part of the Silurian sequence on Severnaya Zemlya, i.e. up to the middle of the Samojlovich Formation, corresponds to the Llandovery (Männik 1997, 1999) (Figs 1-6).

Rare conodont specimens (mostly fragments), found in the carbonate interbeds from the upper part of the Ordovician sequence (Ozernaya and Strojnaya formations – Markovskij & Makar'ev 1982), represent the faunas of the North American Midcontinent Province (Männik 1999). *Aphelognathus* is the most characteristic taxon in this interval.

The appearance of *Panderodus unicostatus* (Branson & Mehl, 1933) and *Panderodus greenlandensis* Armstrong, 1990 together with gen. et sp. indet. 1 *sensu* Männik 1994 in the lowermost Vodopad Formation indicates a late Rhuddanian age for this interval (Fig. 2). Based on these data, it seems that the lowermost Silurian (i.e. the main part of the Rhuddanian) corresponds to a gap on Severnaya Zemlya (Männik 1999) (Fig. 6).

Ozarkodina waugoolaensis Bischoff, 1986, *Ozarkodina* sp. D, *Oulodus*? *panuarensis*

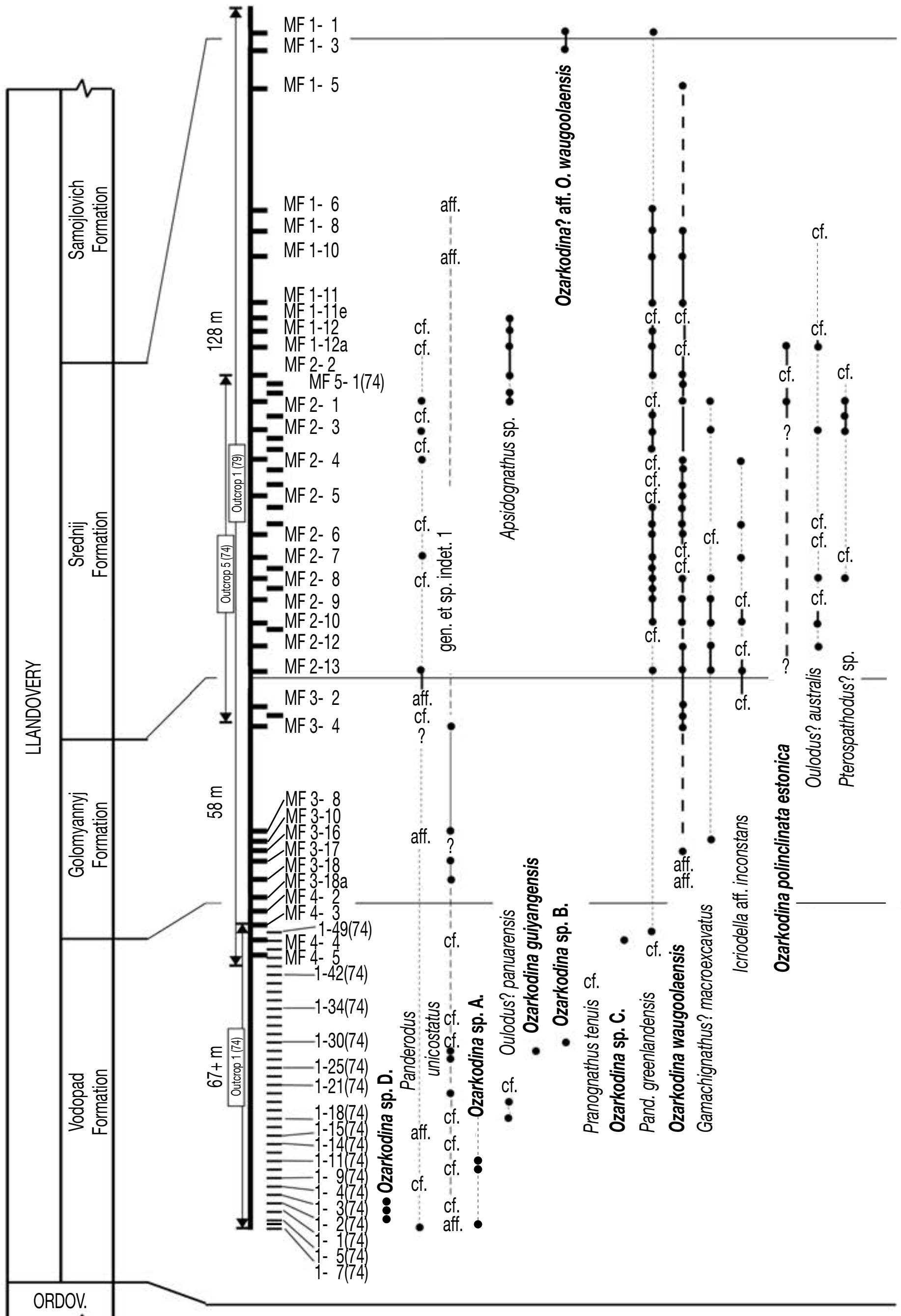

FIG. 1. — Distribution of selected conodont taxa. Outcrops on Srednij Island, Sedov Archipelago. To the left of the thick vertical line are shown the thicknesses of formations, and the ranges and numbers of separate outcrops studied; to the right of it: location and numbers of samples. The names of the *Ozarkodina* species are given in bold. For location of outcrops refer to Männik *et al.* 2002: fig. 1.

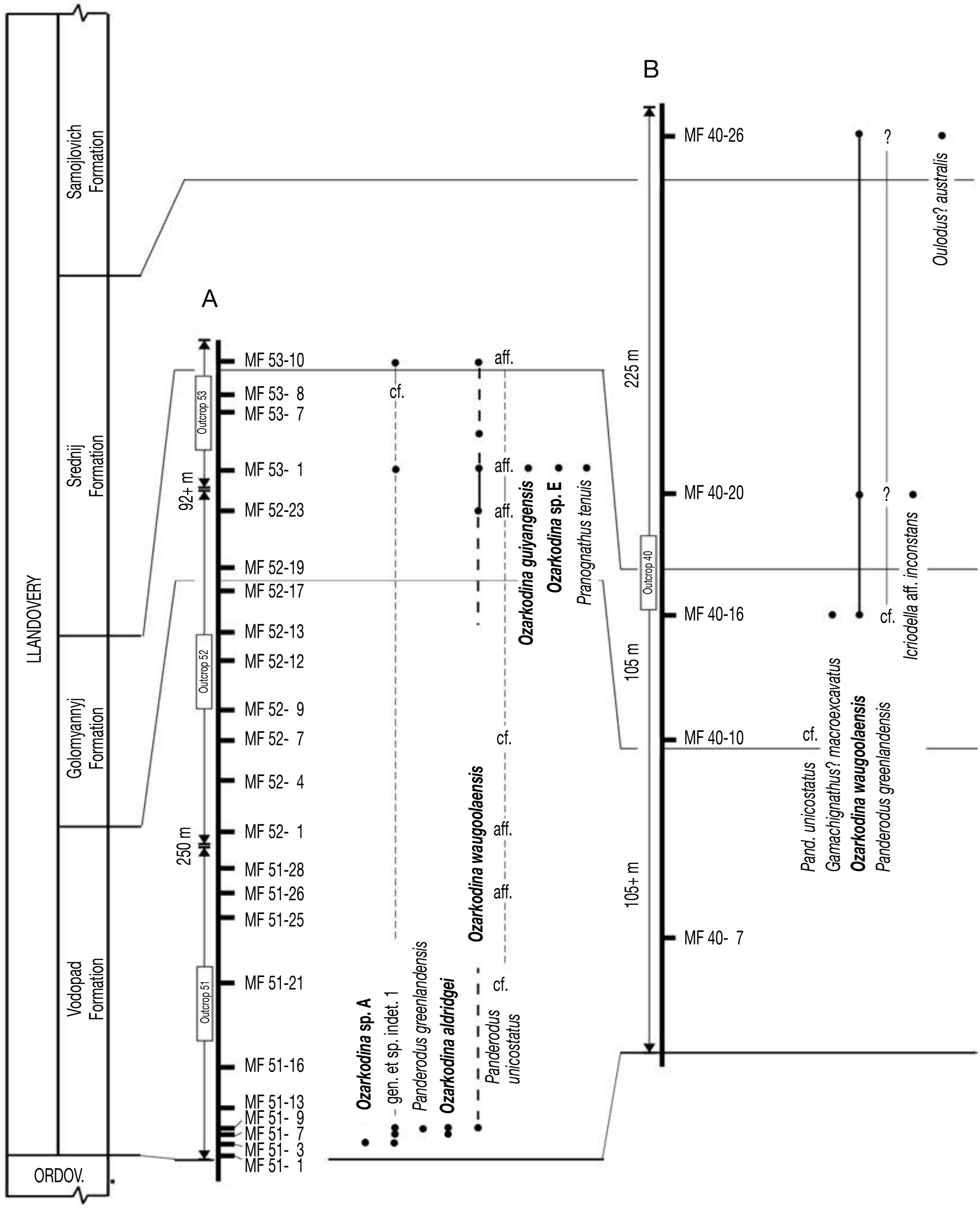

FIG. 2. — Distribution of selected conodont taxa; **A**, outcrops on the Strojnaya River, October Revolution Island; **B**, sections in the Obryvistaya River region, October Revolution Island. For location of outcrops refer to Männik *et al.* 2002: figs 1, 6. See also explanations to Fig. 1.

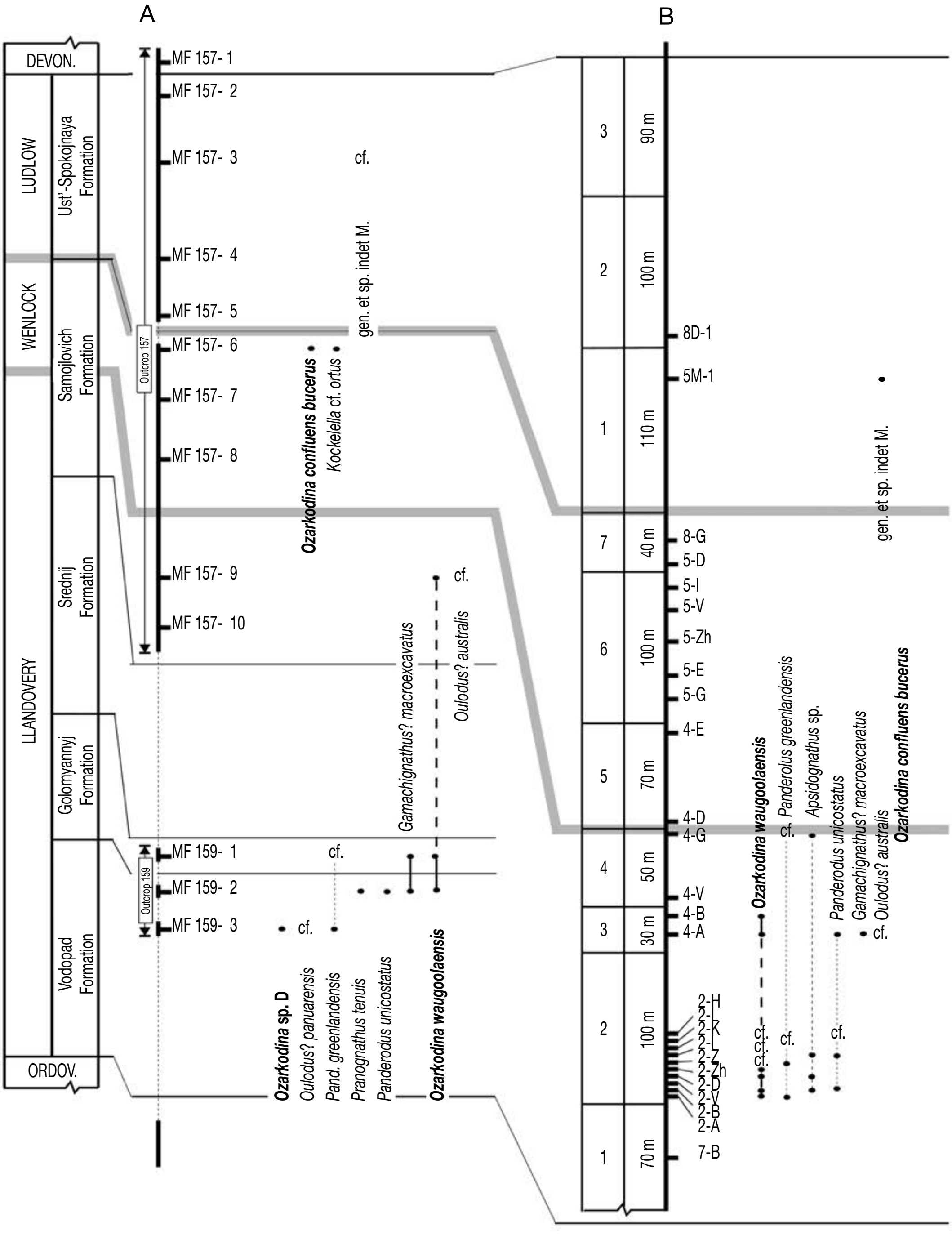

FIG. 3. — Distribution of selected conodont taxa; **A**, outcrops in the Spokojnaya River region, October Revolution Island; **B**, composite sequence from the northern part of Pioneer Island: numbers in the left column indicate to the beds and in the right to the thicknesses of these beds according to Klubov *et al*. 1980. For location of outcrops refer to Männik *et al.* 2002: figs 1, 9. See also explanations to Fig. 1.

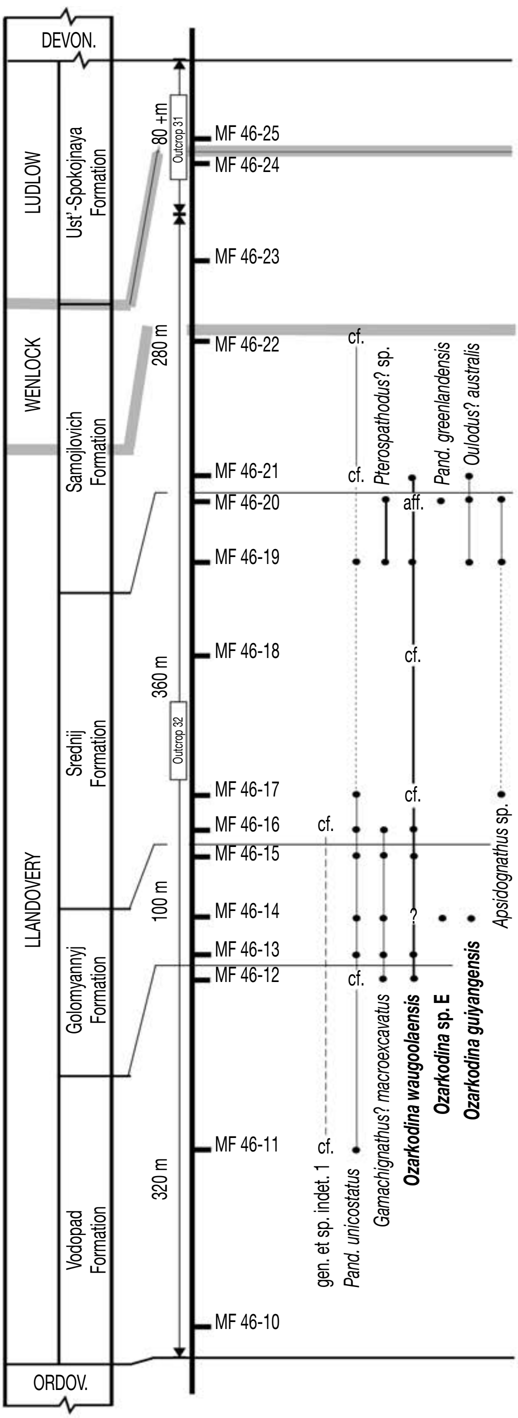

FIG. 4. — Distribution of selected conodont taxa. Outcrops on the Ushakov River, October Revolution Island. For location of outcrops refer to Männik *et al.* 2002: figs 1, 6. See also explanations to Fig. 1.

Bischoff, 1986 and *Pranognathus tenuis* (Aldridge, 1972), appearing in the upper beds of the Vodopad Formation (Figs 1; 3; 4), are known from strata of Aeronian age in Estonia (upper part of the Raikküla Stage), Australia, Great Britain, etc. It means that the upper part of the Vodopad Formation, but also the overlying Golomyannyj Formation, correlate with the Aeronian Stage (Fig. 6). Most probably, on Severnaya Zemlya the Aeronian-Telychian boundary lies very close to the boundary between the Golomyannyj and Srednij formations, and is indicated by the appearance of *Oz. polinclinata* (Nicoll & Rexroad, 1968), *Oul.*? *australis* Bischoff, 1986, *Icriodella* aff. *inconstans* and *Apsidognathus* sp. (Figs 1; 2B; 4).

The occurrence of *Apsidognathus* sp., *Oz. polinclinata* and *Oz. waugoolaensis*, and two probable representatives of *Pterospathodus* Walliser, 1964, known also from the sections on the Gaspé Peninsula in East Canada – *Pterospathodus*? sp. (identified by Nowlan as *Pt. pennatus* [Walliser, 1964] [Nowlan 1981: pl. 7, figs 1, 4]) and *Pterospathodus*? sp. A (Nowlan 1983: fig. 4W, Z) – allows us to correlate the Srednij Formation and the lower half of the Samojlovich Formation with the interval from the *Pt. eopennatus* Superzone below up to the *Pt. amorphognathoides* Zonal Group above (= Velise Formation in Estonia; zonation according to Jeppsson 1997 and Männik 1998).

The Llandovery-Wenlock boundary (corresponding to the second Datum of the Ireviken Event; Jeppson & Männik 1993) lies in the middle part of the Samojlovich Formation. On Severnaya Zemlya, at this level, *Apsidognathus* sp., *Oz. waugoolaensis*, *Oul.*? *australis*, *Panderodus unicostatus* and *Panderodus greenlandensis* disappear (Figs 5; 6). However, as the Telychian conodont fauna is overlain by the middle Wenlock conodont complex (see below), it is quite probable that the uppermost Llandovery and the lowermost Wenlock (including the Ireviken Event) correspond to a gap on Severnaya Zemlya (Fig. 6).

In the northern area of Pioneer Island (Männik *et al.* 2002: fig. 1) the last specimen of

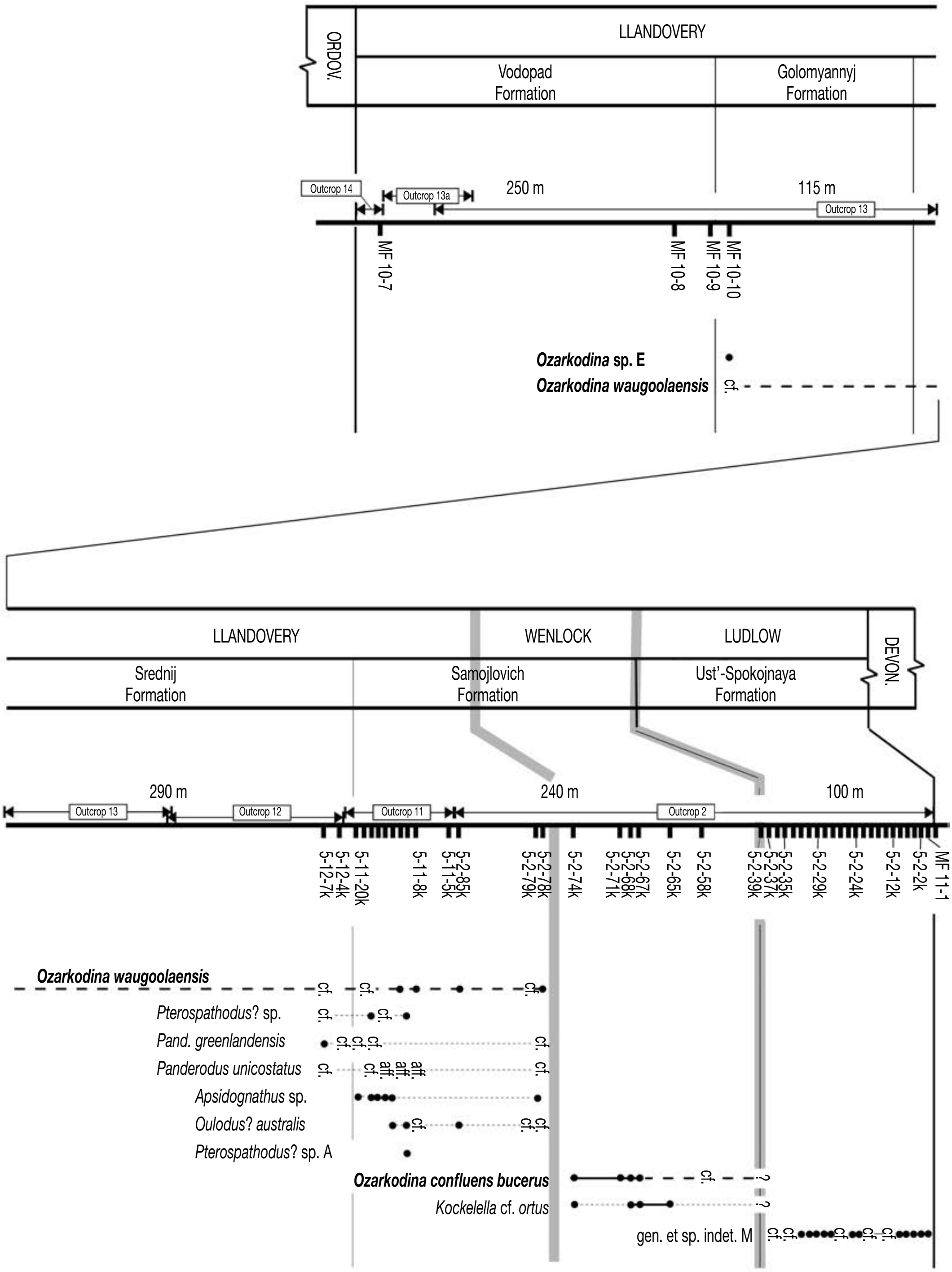

Fig. 5. — Distribution of selected conodont taxa. Outcrops on the Matusevich River, October Revolution Island. For location of outcrops refer to Männik *et al.* 2002: figs 1, 2, 4. See also explanations to Fig. 1.

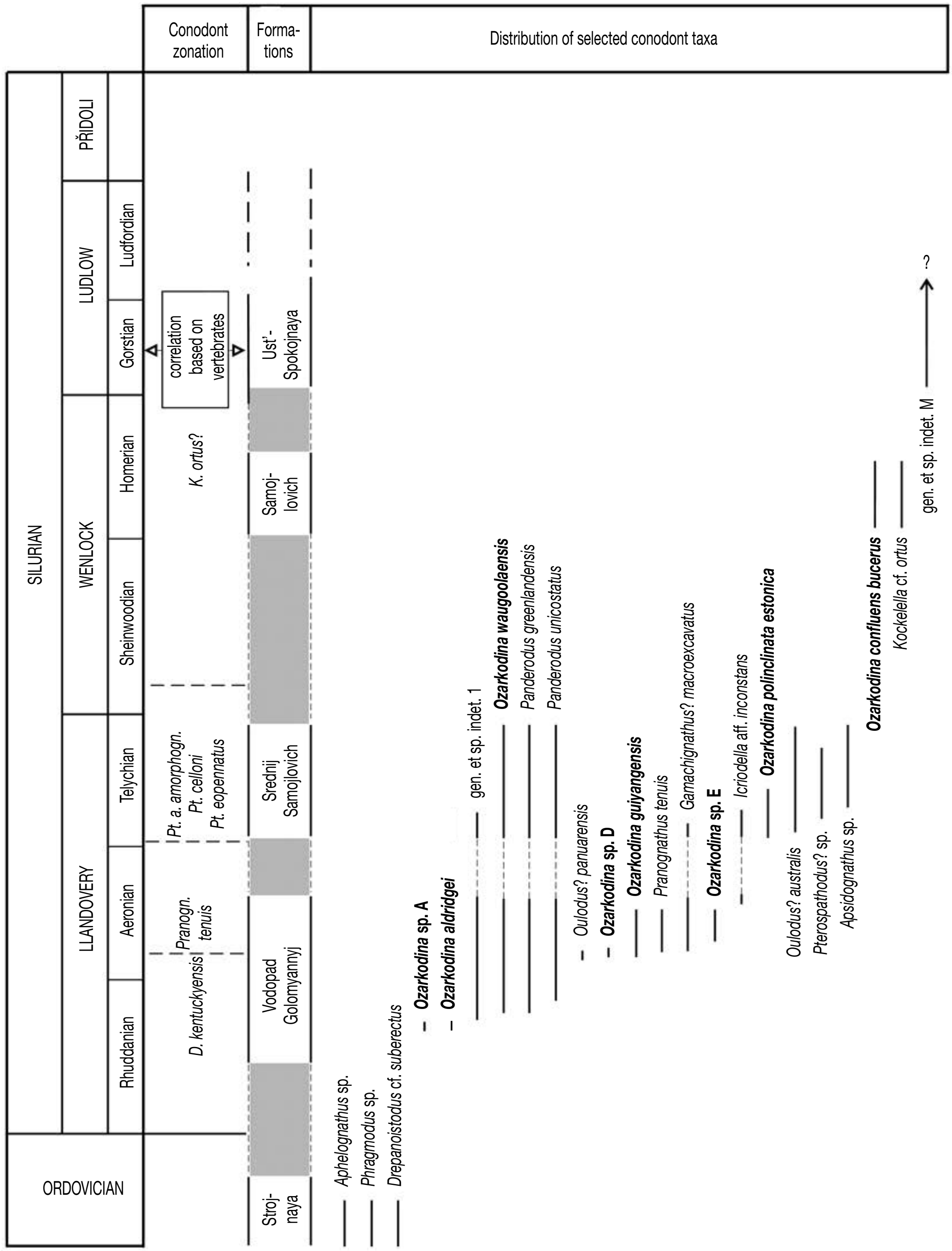

FIG. 6. — Conodont-based correlation of the Silurian sequence on Severnaya Zemlya with the international Silurian standard epochs and stages.

Apsidognathus sp. comes from sample 4G, from the uppermost strata of bed 4 (Fig. 3B) (Klubov *et al.* 1980). As *Apsidognathus* sp. disappears at the second Datum of the Ireviken Event (Jeppsson & Männik 1993), it is evident that the Llandovery-Wenlock boundary in this region lies at or above sample 4G.

The upper strata in the Samojlovich Formation and the lower Ust'-Spokojnaya Formation are characterized by *Oz. confluens bucerus* (Viira, 1983) and *Kockelella* cf. *ortus* (Walliser, 1964) only (Figs 3; 5). Both taxa are typical of the Wenlock strata in Baltoscandia (*Oz. confluens bucerus* has been described from the Jaagarahu Formation in Estonia [Viira 1983], and *K. ortus* occurs in the Slite Beds on Gotland [Jeppsson 1998]). The Wenlock age of this interval is also indicated by *Loganellia grossi* Fredholm, 1990 found in the upper part of the Samojlovich Formation (Märss & Karatajūtē-Talimaa in press).

Oz. confluens bucerus and *K.* cf. *ortus* disappear in the uppermost Samojlovich Formation (Figs 3; 5). The overlying Ust'-Spokojnaya Formation is characterized only by one undescribed conodont apparatus – gen. et sp. indet. M – elements of which have been illustrated in Männik (1983) as belonging to two different taxa: *Oulodus*? sp. C (Männik 1983: fig. 5G, H, L, M, U) and *Ozarkodina*? sp. B (Männik 1983: fig. 5O, V). The vertebrates (*Phlebolepis elegans* Pander, 1956) from the Ust'-Spokojnaya Formation indicate a Ludlow age for these strata (Karatajūtē-Talimaa & Märss in press) (Fig. 6).

So far, conodonts have not been found in the uppermost, Krasnaya Bukhta Formation of the Silurian sequence in Severnaya Zemlya.

SYSTEMATICS

Family Spathognathodontidae Hass, 1959

Genus *Ozarkodina* Branson & Mehl, 1933

Type species. — *Ozarkodina typica* Branson & Mehl, 1933 (= junior synonym of *Ozarkodina confluens* [Branson & Mehl, 1933)].

Remarks

The genus *Ozarkodina* is well represented in the studied sections. However, *Ozarkodina polinclinata*, one among the most characteristic Telychian conodont species in several regions of Europe and North America (Männik 1992), is extremely rare, and *Oz. excavata excavata*, known all over the world from the strata of Wenlock age and younger, has not been found on Severnaya Zemlya. In the studied region, *Oz. waugoolaensis* is the most common among the Llandovery ozarkodinids. Very often it is the dominant taxon. Also *Oz. confluens*, usually very frequent in the strata younger than Llandovery all over the world, is quite rare on Severnaya Zemlya, being represented only by one subspecies: *Oz. confluens bucerus*. In the interval of its occurrence *Oz. confluens bucerus* is the most abundant, or the only, taxon in the samples.

Several undescribed ozarkodinids as well were found in the collections from Severnaya Zemlya. However, as most of them are represented by few specimens only, and as the study is still in progress (additional samples were processed and conodonts wait to be picked out), the probable new taxa will only be briefly described below, and kept in open nomenclature.

Ozarkodina aldridgei Uyeno & Barnes, 1983 (Figs 7G, J; 8E, F)

Ozarkodina aldridgei Uyeno & Barnes, 1983: pl. 3, figs 16-19, 23?

Spathognathodus sp. B — Aldridge 1972: 216, pl. 4, fig. 5.

Ozarkodina sp. B — Aldridge 1972. — Uyeno & Barnes 1981: pl. 1, fig. 4.

Ozarkodina oldhamensis (Rexroad, 1967) – Nowlan 1981: pl. 4, figs 16, 18, 20; 1983: fig. 3C, G, K.

Material examined. — 9 Pa, 15 Pb, 2 M, 4 Sc, and 3 Sb elements.

Occurrence. — The lowermost part of the Vodopad Formation in the Strojnaya River section (Männik *et al.* 2002: fig. 6) (Fig. 2A).

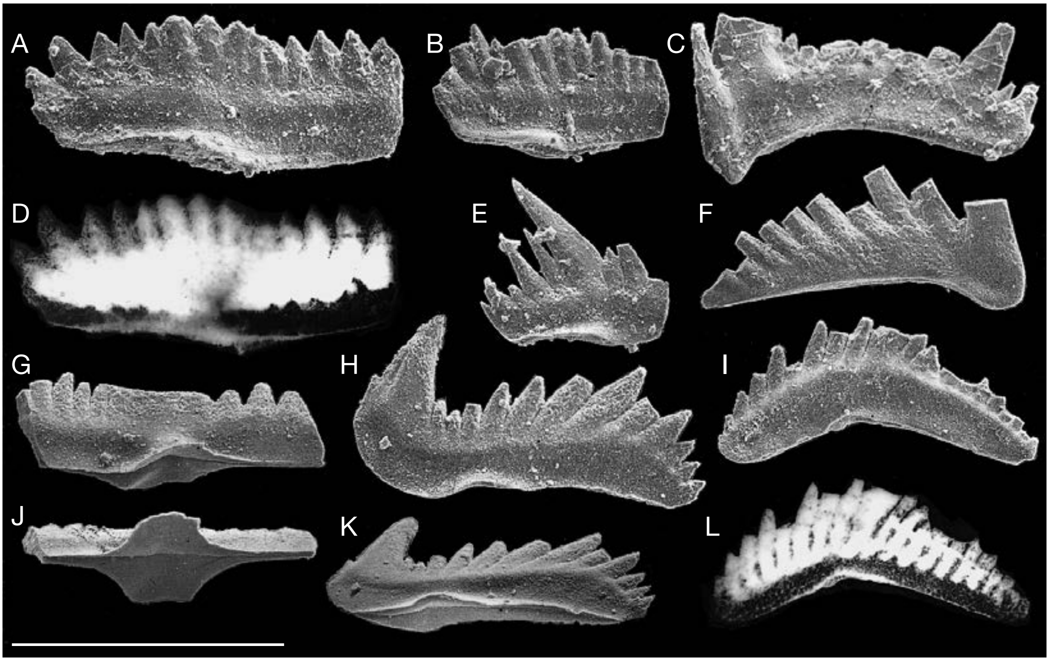

FIG. 7. — **A**-**F**, *Ozarkodina polinclinata estonica* Männik, 1992; **A**, **D**, Cn 5992; lateral view of Pa element (D in translucent light); **B**, Cn 5988, lateral view of Pa element; **C**, Cn 5995, lateral view of Sc element; **E**, Cn 5993, lateral view of Pb element; **F**, Cn 5998, lateral view of M element; all specimens from the middle part of the Srednij Formation, Srednij Island: **A**, **C**-**E**, from section 1(79), sample MF 1-12a; **B**, from section 1(79), sample MF 2-1; **F**, from section 5(74), sample 5-3 (74); **G**, **J**, *Ozarkodina aldridgei* Uyeno & Barnes, 1983, specimen Cn 5957, lateral and lower views of Pa element, from the lower part of the Vodopad Formation, October Revolution Island, Strojnaya River, section 51, sample MF 51-9; **H**, **I**, **K**, **L**, *Ozarkodina guiyangensis* Zhou, Zhai & Xian, 1981; **H**, **K**, Cn 5980; lateral and lower views of Pa element; **I**, **L**, Cn 5985, lateral views of Pb element (L in translucent light); all specimens from the lower part of the Golomyannyj Formation, October Revolution Island; **H**, **K**, from Strojnaya River, section 52, sample MF 52-23; **I**, **L**, from Ushakov River, section 32, sample MF 46-14. Scale bar: 0.5 mm

REMARKS

The denticulation pattern and the general shape of the basal cavity of the Pa element of *Oz. aldridgei* is similar to those of *Oz. oldhamensis* (Rexroad 1967: pl. 3, figs 1, 2; Pollock *et al.* 1970: pl. 111, figs 13-16). The main distinctive criterion between these two species appears to be the size of the almost rounded basal cavity flare of the Pa element. In *Oz. oldhamensis* the flare is relatively small in comparison with that of *Oz. aldridgei*. In both species the denticulation of the Pa element is highly variable. The principal common characteristic is the fusion of some denticles immediately above and/or adjacent to the flaring of the basal cavity. However, in both taxa Pa elements without fused denticles can be found. Also, in both taxa the cusp of the Pa element is poorly developed and, as a rule, cannot be distinguished by size.

The other elements of *Oz. aldridgei* seem to be morphologically inseparable from those of *Oz. oldhamensis*. The elements, which Uyeno & Barnes in their original description of *Oz. aldridgei* referred to as its Pb, M and Sc elements (Uyeno & Barnes 1983: pl. 3, figs 20-22, 24; pl. 8, fig. 20), evidently do not belong to this species but to an early representative of the *Oz. excavata* lineage (it possesses some similarities to *Oz. excavata puskuensis* of Männik 1994).

Ozarkodina confluens (Branson & Mehl, 1933)

REMARKS

This species is known to be represented by a morphologically highly variable Pa element (Walliser 1964; Klapper & Murphy 1974; Viira

1983). Viira (1983) recognized several chronological subspecies including also *Oz. confluens bucerus* in the *Oz. confluens* lineage.

Ozarkodina confluens bucerus (Viira, 1983) (Fig. 8L, Q)

Spathognathodus primus bucerus Viira, 1983: 51-53, pl. 1, figs 3-6, 8-10, text-fig. 5.

MATERIAL EXAMINED. — About 200 Pa, 19 Pb, 6 Sc, 1 Sb and 3 Sa elements.

OCCURRENCE. — Upper part of the Samojlovich Formation: in outcrop 2 on the Matusevich River (Männik *et al.* 2002: figs 2, 5) (Fig. 5) and in outcrop 157 in the Spokojnaya River region (Männik *et al.* 2002: fig. 9) (Fig. 3A).

REMARKS

In the Silurian of Severnaya Zemlya only one type of *Oz. confluens* – morphologically closest to *Oz. confluens bucerus* – has been found. In the samples with *Oz. confluens bucerus* this subspecies is dominating. Other taxa are mainly represented by *Kockelella* cf. *ortus*. As a rule, only the Pa element of *Oz. confluens bucerus* occurs in most of my samples. Other elements of this apparatus are very rare and poorly preserved.

Ozarkodina guiyangensis Zhou, Zhai & Xian, 1981 (Figs 7H, I, K, L; 8A-D, G, J)

Ozarkodina guiyangensis Zhou, Zhai & Xian, 1981: 11, 12, pl. 2, figs 5, 6.

MATERIAL EXAMINED. — 35 Pa and 2 Pb elements.

OCURRENCE. — Upper part of the Vodopad Formation in outcrop 1(74) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1); Golomyannyj Formation in outcrop 52 on the Strojnaya River (Männik *et al.* 2002: fig. 6) (Fig. 2A) and in outcrop 32 on the Ushakov River (Männik *et al.* 2002: fig. 6) (Fig. 4).

REMARKS

Pa elements in my collection are longer (possess 10 to 12 denticles) than those described in Zhou *et al.* (1981). Other elements of this apparatus are poorly represented in the collection from Severnaya Zemlya. Only probable Pb elements can be identified (Fig. 7I, L). Their processes are relatively long, almost equal in size and form an arc in lateral view. A distinct cusp is located in the middle of the element. The cusp and denticles are inclined posteriorly. The shallow basal cavity is widest below the cusp and continues as a narrow groove below the processes.

In general morphology the Pa element of *Oz. guiyangensis* is very similar to that of *Oz. broenlundi* (Aldridge 1979: 16, 17, pl. 1, figs 18, 19). The main difference lies in the denticulation of the anterior part of the blade: instead of having one large denticle as does *Oz. guiyangensis*, *Oz. broenlundi* possesses up to three denticles in this part of the element. Also, in *Oz. broenlundi* the anterior and posterior processes are either almost equal in length or the anterior one is somewhat longer. As a rule, on the Pa element of *Oz. guiyangensis* the posterior process is about twice as long as the anterior one.

Ozarkodina polinclinata estonica Männik, 1992 (Fig. 7A-F)

Ozarkodina polinclinata estonica Männik, 1992: 60, 61, pl. , figs 1-7, 9, fig. 3: 1-30, fig. 5: 8-29.

Spathognathodus polinclinatus Nicoll & Rexroad, 1968 – Aldridge 1972: 214, 215, pl. 4, fig. 13. — Liebe & Rexroad 1977: pl. 1, fig. 27.

Ozarkodina polinclinata (Nicoll & Rexroad, 1968) – Cooper 1977: 1058-1062, pl. 1, fig. 17. — Uyeno & Barnes 1981: pl. 1, fig. 7; 1983: 22, pl. 5, figs 11, 12.

Ozarkodina polinclinata subsp. nov. Aldridge, 1985: 82, pl. 3.2, fig. 5.

MATERIAL EXAMINED. — 9 Pa, 4 Pb, 4 M, 6 Sc and 3 Sb elements.

OCCURRENCE. — Middle part of the Srednij Formation in outcrop 1(79) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1).

REMARKS

Nicoll & Rexroad (1968) noted a great morphological variation in *Spathognathodus polinclinatus* s.f. which was later recognized as the Pa element of *Oz. polinclinata* (Cooper 1977; etc.). The study of rich and well-preserved collections

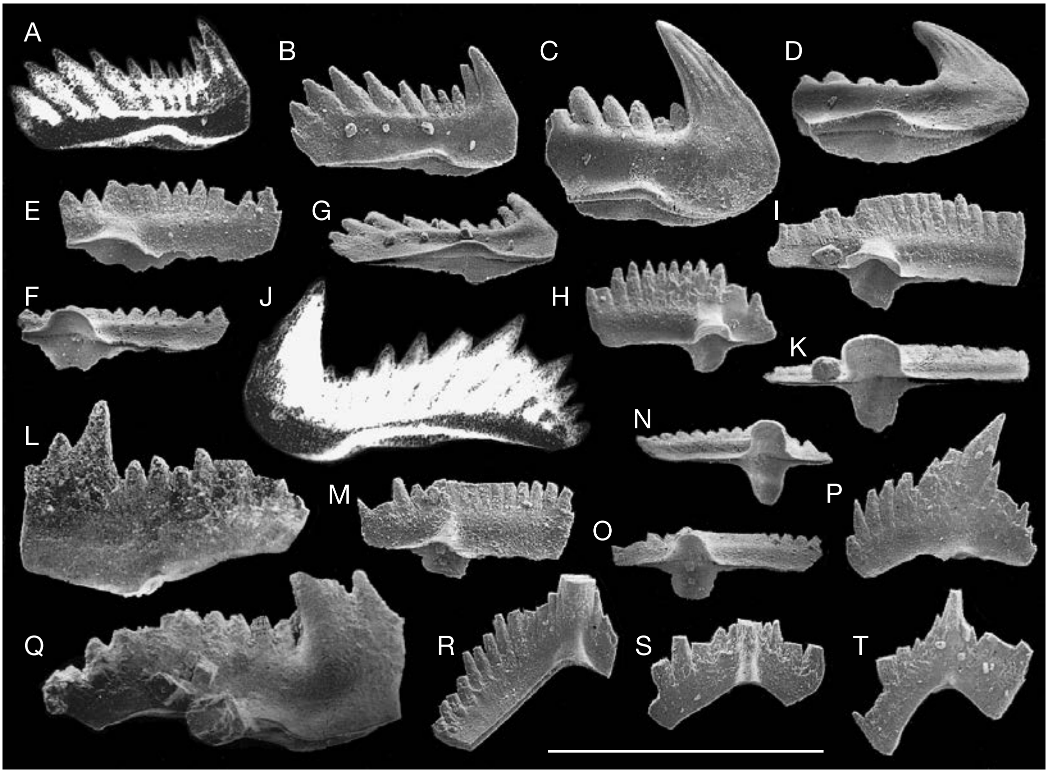

FIG. 8. — **A-D**, **G**, **J**, *Ozarkodina guiyangensis* Zhou, Zhai & Xian, 1981; **A**, **B**, **G**, Cn 5981, lateral and lower views of Pa element (A in translucent light); **C**, **D**, Cn 5983, lateral and lower views of Pa element; **J**, Cn 5980, lateral view of Pa element in translucent light; all elements from the lower part of the Golomyannyj Formation, October Revolution Island: **A**, **B**, **G**, **J**, from Strojnaya River, section 52, sample MF 52-23; **C**, **D** from Ushakov River, section 32, sample MF 46-14; **E**, **F**, *Ozarkodina aldridgei* Uyeno & Barnes, 1983, specimen Cn 5960, lateral and lower views of Pa element; from the lower part of the Vodopad Formation, October Revolution Island, Strojnaya River, section 51, sample MF 51-9; **H**, **I**, **K**, **M**-**P**, **R**-**T**, *Ozarkodina* sp. A.; **H**, **N**, Cn 5971, lateral and lower views of Pa element; **I**, **K**, Cn 5973, lateral and lower views of Pa element; **M**, **O**, Cn 5972, lateral and lower views of Pa element; **P**, Cn 5974, lateral view of Pb element; **R**, Cn 5975, lateral view of M element; **S**, Cn 5977, posterior view of Sa element, **T**, Cn 5976, posterior view of Sb element; all specimens from the lowermost part of the Vodopad Formation, October revolution Island, Strojnaya River, section 51, sample MF 51-3; **L**, **Q** *Ozarkodina confluens bucerus* (Viira, 1983); **L**, Cn 6091, lateral view of Pa element; **Q**, Cn 6089, lateral view of Pa element; both specimens from the upper part of the Samojlovich Formation, October Revolution Island: **L**, from Matusevich River, section 2, sample 5-2-68k; **Q**, from the Spokojnaya River region, section 157, sample MF 157-6. Scale bar: 0.5 mm.

from Estonia (Männik 1992) revealed two main types of Pa elements in *Oz. polinclinata.* These elements differ in the number and pattern of denticles, and have been described as the Pa elements of two different chronological subspecies named accordingly as *Oz. polinclinata estonica* Männik, 1992 and *Oz. p. polinclinata*. The former occurs in the *Pterospathodus eopennatus* Superzone, and in the *Pt. amorphognathoides angulatus* and *Pt. a. lennarti* zones of the *Pt. celloni* Superzone. *Oz. p. polinclinata* is characteristic to the *Pt. a. amorphognathoides* and Lower *Pseudooneotodus bicornis* zones (zonation according to Jeppsson 1997 and Männik 1998). The ranges of *Oz. p. estonica* and *Oz. p. polinclinata* are separated by an interregnum corresponding to the *Pt. a. lithuanicus* Zone (upper part of the *Pt. celloni* Superzone; Männik 1998). The other elements in these two subspecies of *Oz. polinclinata* are almost identical and difficult to separate at our present stage of knowledge.

Armstrong (1990: 95) noted a great similarity of the M elements of *Oz. polinclinata*, *Oz. pirata* Uyeno & Barnes, 1983 and *Aspelundia fluegeli* (Walliser, 1964). However, the reconstruction of the apparatus of *Oz. pirata* is very problematic. Based on the illustrations in Uyeno & Barnes (1983: pl. 2, figs 12, 13, 19-28) it seems that, most probably, elements of two different apparatuses have been described as belonging to *Oz. pirata*: those in figs 22, 23, and probably also in fig. 21, belong to *Aspelundia*, and most of the other illustrated elements (i.e. Uyeno & Barnes 1983: pl. 2, figs 12, 13, 19, 20, 24, 25, 27, 28) evidently represent the *Oz. excavata* lineage.

The main differences allowing us to separate the M element of *Oz. polinclinata* from that of *Aspelundia* are: 1) the rounded shape of the anterior basal corner of its cusp in *Oz. polinclinata,* whereas the M element of *Aspelundia* possesses a sharp basal corner; 2) more erect and completely fused denticles on the posterior process of the M element of *Oz. polinclinata* compared to *Aspelundia*.

Oz. polinclinata is extremely rare in Severnaya Zemlya and is represented only by its older subspecies, i.e. *Oz. p. estonica*.

Ozarkodina waugoolaensis Bischoff, 1986 (Figs 9D-M; 10; 11R, S, V)

Ozarkodina waugoolaensis Bischoff, 1986: 145-147, pl. 23, figs 22-45, pl. 24, figs 1-10.

MATERIAL EXAMINED. — About 900 Pa, 325 Pb, 47 M, 121 Sc, 100 Sb and 23 Sa elements.

OCCURRENCE. — From the Vodopad Formation to the Srednij Formation on the Strojnaya River (outcrops 51, 52, 53; Männik *et al.* 2002: fig. 6) (Fig. 2A); from the Vodopad Formation to the lower part of the Samojlovich Formation in outcrop 32 on the Ushakov River (Männik *et al.* 2002: fig. 6) (Fig. 4), and in the Spokojnaya River region (outcrops 157 and 159; Männik *et al.* 2002: fig. 9) (Fig. 3A); from the Golomyannyj Formation to the upper part of the Srednij Formation in outcrop 1(79) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1); from the Golomyannyj Formation to the lower part of the Samojlovich Formation in the Obryvistaya River region (outcrop 40; Männik *et al.* 2002: fig. 1) (Fig. 2B), and on the Matusevich River (Männik *et al.* 2002: figs 2, 4) (Fig. 5).

REMARKS

Diagnostic for this species is the Pa element most characteristic to which are a well-developed cusp and a denticle of almost the same size as the cusp just anterior to it. This denticle and the cusp display a different degree of posterior inclination and are separated by a V-shaped gap. The relatively narrow basal cavity of the Pa element has a lanceolate configuration basal cavity. However, the Pa element of *Oz. waugoolaensis* is morphologically highly variable (Figs 9D-I, L, M; 10A-C, E, I, K, L; 11R, S, V; Bischoff 1986: pl. 23, figs 23, 28-40). In the collections from Severnaya Zemlya, the elements assignable to *Oz. waugoolaensis* are dominating among the representatives of the genus *Ozarkodina*. *Oz. waugoolaensis* is also frequent in the Kozhym River region, Subpolar Urals (Melnikov pers. comm.).

In New South Wales, Australia, *Oz. waugoolaensis* is known from strata correlated with the *turriculatus* and *crispus*, but probably also with the uppermost *sedgwieckii* and *erenulata* graptolite zones (Bischoff 1986). In Estonia, a few specimens of *Oz.* cf. *waugoolaensis* are found in the lowermost part of the Velise Formation of the Adavere Stage (Männik unpubl. data), corresponding to the *Pterospathodus eopennatus* ssp. 1 Zone of the *Pt. eopennatus* Superzone (Männik 1998). Recently, based on the co-occurrences of conodonts and graptolites, this interval was correlated with the upper part of the *turriculatus* graptolite zone (Loydell *et al.* 1998).

On Severnaya Zemlya the interval of occurrence of *Oz. waugoolaensis* seems to be considerably longer – probably from late Rhuddanian up to the late Telychian (Figs 1-6).

Ozarkodina*? aff. *waugoolaensis Bischoff, 1986 (Fig. 11A-Q, T, U, W)

MATERIAL EXAMINED. — 292 Pa, 127 Pb, 61 M, 168 Sc, 94 Sb, 36 Sa elements without a posterior process and 20 Sa elements with a denticulated posterior process.

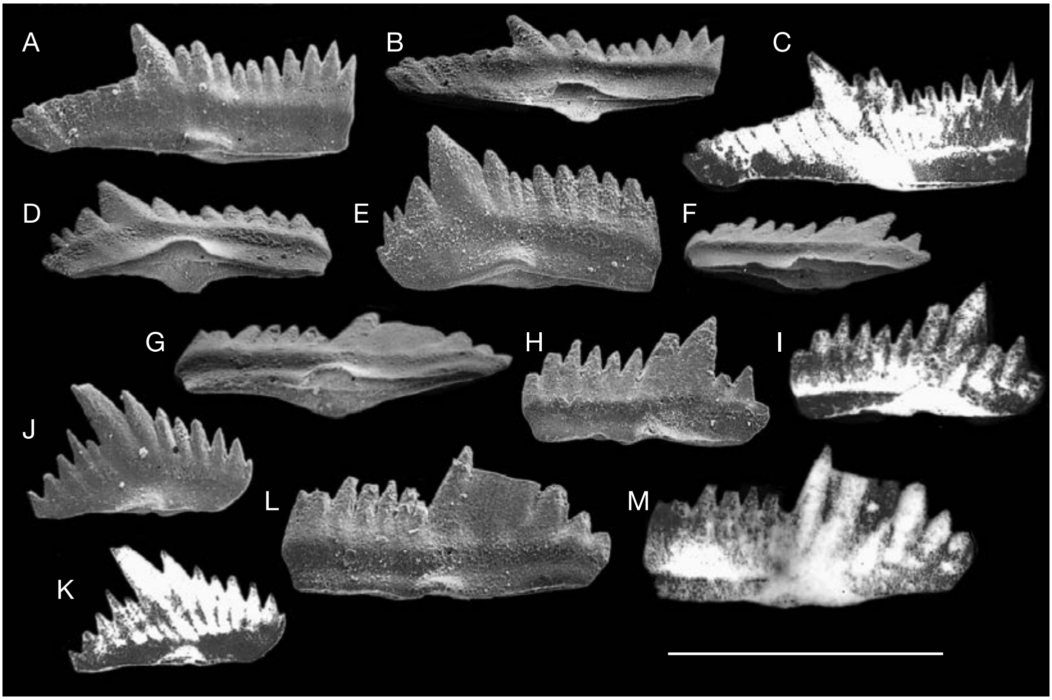

FIG. 9. — **A**-**C**, *Ozarkodina* aff. *waugoolaensis* Bischoff, 1986, Cn 6075, lateral and lower views of Pa element (C in translucent light), upper part of the Srednij Formation, October Revolution Island, Ushakov River, section 32, sample MF 46-19; **D**-**M**, *Ozarkodina waugoolaensis* Bischoff, 1986; **D**, **E**, Cn 6059, lower and lateral views of Pa element; **F**, **H**, **I**, Cn 6058, lower and lateral views of Pa element (I in translucent light); **G**, **L**, **M**, Cn 6072, lower and lateral views of Pa element (M in translucent light); **J**, **K**, Cn 6040, lateral views of Pb element (K in translucent light); **D**-**F**, **H**, **I**, from the lowermost part of the Srednij Formation, October Revolution Island, Strojnaya River, section 53, sample MF 53-10; **G**, (**L**-**M**), from the middle part of the Golomyannyj Formation, October Revolution Island, Ushakov River, section 32, sample MF 46-14; **J**, **K**, from the lowermost part of the Srednij Formation, Srednij Island, section 1(79), sample MF 2-10. Scale bar: 0.5 mm.

OCURRENCE. — The uppermost part of the Srednij Formation and the lowermost part of the Samojlovich Formation in outcrop 1(79) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1).

REMARKS

The uppermost part of outcrop 1(79) studied on Srednij Island (Sedov Archipelago; Männik *et al.* 2002: fig. 1) (Fig. 1) contains a number of elements of an apparatus, elements of which are morphologically very similar to those of *Oz. waugoolaensis*. The main difference of this apparatus, if compared with *Oz. waugoolaensis*, is that it contains two types of symmetrical, Sa elements – one of them is a typical trichonodelliform, without a posterior process (Fig. 11U), and the other one possesses a short denticulated posterior process (Fig. 11N). Also, the basal cavity on the elements of *Oz.*? aff. *waugoolaensis* seems to be smaller, the denticles narrower and taller and more needle-like than those of *Oz. waugoolaensis*.

The position of this apparatus in the taxonomy of conodonts has not been surely established. Although morphologically its elements seem to be closest to *Ozarkodina*, the occurrence of two types of Sa elements causes problems and may be indicative of another type of apparatus (another genus). The apparatus of ozarkodinid conodonts is known to possess only one Sa element (Purnell & Donoghue 1997). At the moment, it is difficult to judge if the apparatus of *Oz.*? aff. *waugoolaensis* really contains seven elements (i.e. each individual had two Sa ele-

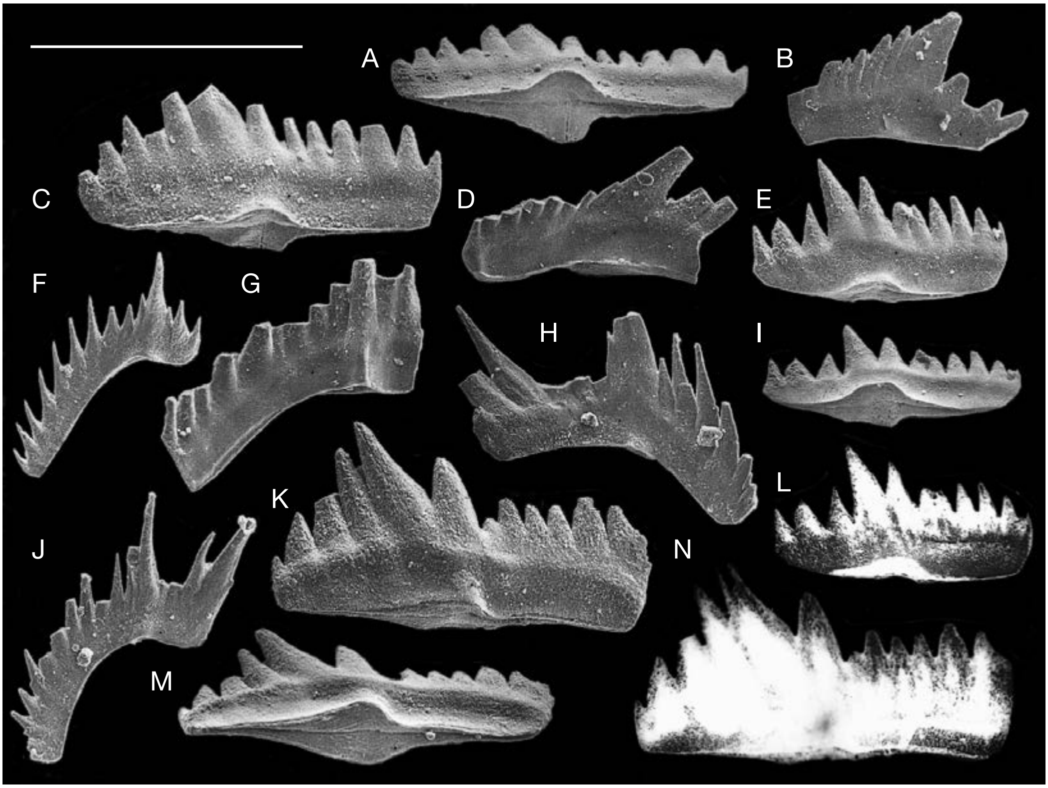

FIG. 10. — *Ozarkodina waugoolaensis* Bischoff, 1986; **A**, **C**, Cn 6064, lower and lateral views of Pa element; **B**, Cn 6035, lateral view of Pb element; **D**, Cn 6079, lateral view of Sc element; **E**, **I**, **L**, Cn 6067, lateral and lower views of Pa element (L in translucent light); **F**, Cn 6041, lateral view of M element; **G**, Cn 6078, lateral view of M element; **H**, Cn 6042, lateral view of Sc element; **J**, Cn 6043, posterior view of Sb element; **K**, **M**, **N**, Cn 6066, lateral and lower views of Pa element (N in translucent light); **A**, (**C**), from the lower part of the Golomyannyj Formation, October Revolution Island, Strojnaya River, section 52, sample MF 52-23; **B**, from the lowermost part of the Srednij Formation, Srednij Island, section 1(79), sample MF 2-13; **D**, **G**, from the upper part of the Srednij Formation, October Revolution Island, Ushakov River, section 32, sample MF 46-19; **F**, **H**, **J**, from the lowermost part of the Srednij Formation, Srednij Island, section 1(79), sample MF 2-10; **K**, (**M**, **N**); **E**, (**I**-**L**), from the upper part of the Vodopad Formation, October Revolution Island, Ushakov River, section 32, sample MF 46-14. Scale bar: 0.5 mm.

ments), or if these are only two different morphotypes (that is, some individuals had Sa element with a short posterior process whereas other ones survived equally well without one).

Ozarkodina sp. A
(Fig. 8H, I, K, M-P, R-T)

MATERIAL EXAMINED. — 66 Pa, 12 Pb, 8 M, 3 Sc, 3 Sb and 8 Sa elements.

OCCURRENCE. — The lowermost part of the Vodopad Formation in outcrop 51 on the Strojnaya River (Männik *et al.* 2002: fig. 6) (Fig. 2A); and the lower part of the Vodopad Formation in outcrop 1(74) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1).

DESCRIPTION

The Pa element is diagnostic for *Ozarkodina* sp. A and is described below. Pa element in upper view with a straight blade. The anterior process is up to twice as long as the posterior one. In juvenile specimens (Fig. 8H) denticles tend to be higher and wider on the anterior part of the blade and above the basal cavity. In mature specimens the cusp and the denticles just anterior of it are fused almost up to their tips (Fig. 8K, M). The asymmetrical basal cavity is about 2-3 times as wide as long, with the flare on the outer side bigger in size. The cavity continues as a narrow groove to the ends of the blade.

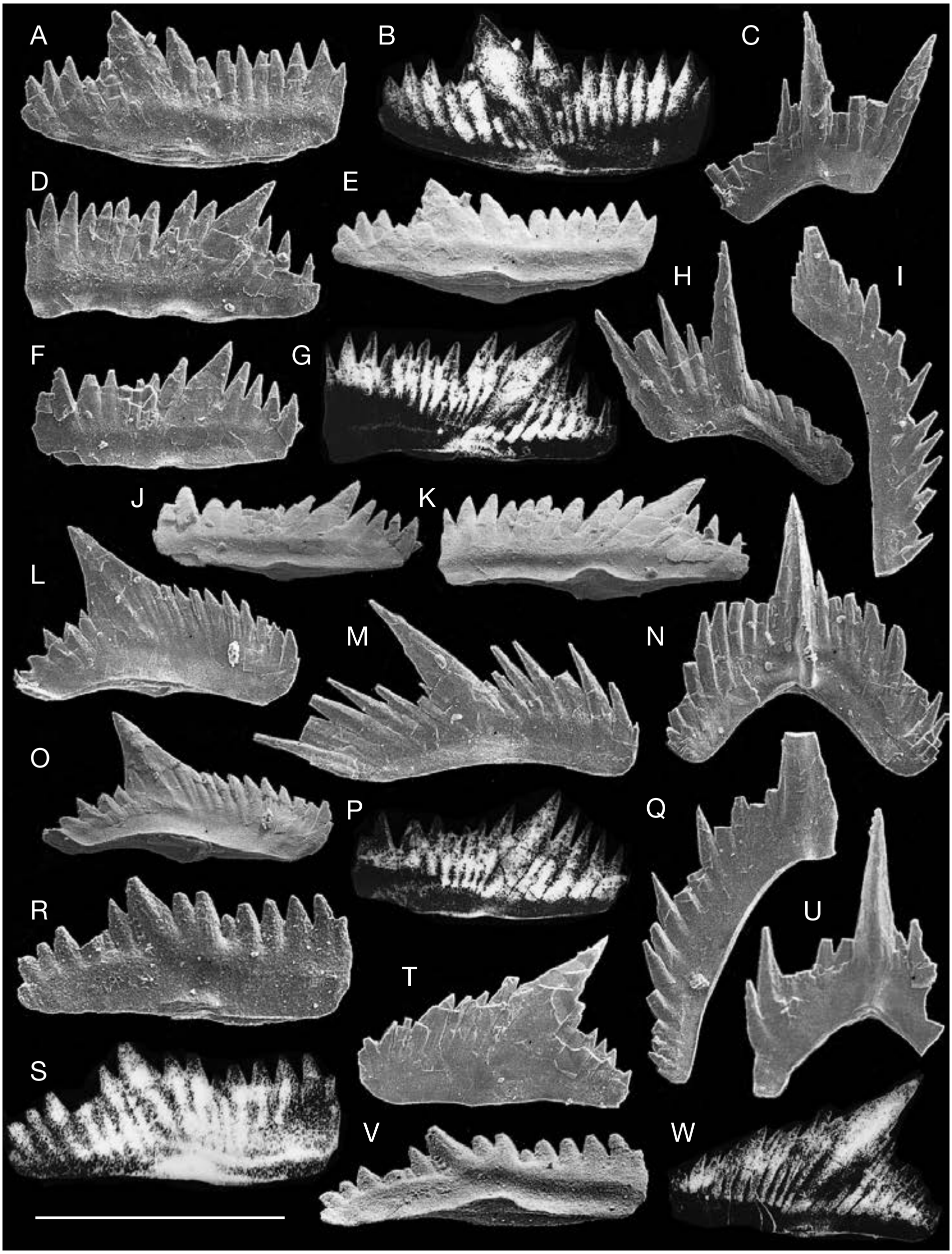

FIG. 11. — **A**-**Q**, **T**, **U**, **W**, *Ozarkodina*? aff. *waugoolaensis* Bischoff, 1986; **A**, **B**, **E**, Cn 6045, lateral and lower views of Pa element (B in translucent light); **C**, Cn 6057, posterior view of Sb element; **D**, **G**, **K**, Cn 6044, lateral and lower views of Pa element (G in translucent light); **F**, **J**, **P**, Cn 6046, lateral and lower views of Pa element (P in translucent light); **H**, Cn 6053, posterior view of Sb element; **I**, Cn 6050, lateral view of M element; **L**, **O**, Cn 6047, lateral and lower views of Pb element; **M**, Cn 6051, lateral view of Sc element; **N**, Cn 6055, posterior view of Sa element with denticulated posterior process; **Q**, Cn 6049, lateral view of M element; **T**, **W**, Cn 6047, lateral views of Pb element (W in translucent light); **U**, Cn 6057, posterior view of Sa element without posterior process; all specimens from the lowermost part of the Samojlovich Formation, Srednij Island, section 1(79), sample MF 1-1; **R**, **S**, **V**, *Ozarkodina waugoolaensis* Bischoff, 1986, Cn 6082, lateral and lower views of Pa element (S in translucent light); uppermost part of the Srednij Formation, October Revolution Island, Ushakov River, section 32, sample MF 46-20. Scale bar: 0.5 mm.

The lower margin of the blade is almost straight or slightly concave.

Remarks

The widely opened basal cavity, the almost completely fused denticles above it and the poorly developed cusp evidently indicate close relations between *Ozarkodina* sp. A and *Oz. oldhamensis*, but also *Oz. aldridgei*. Also, probable Pb, M, Sb and Sa elements of *Ozarkodina* sp. A, occurring in the studied collection (Fig. 8P, R-T) are morphologically almost identical to those described as belonging to the *Oz. oldhamensis* apparatus (e.g., McCracken & Barnes 1981: pl. 7, figs 3, 5, 14-18). The most characteristic feature separating the Pa elements of *Ozarkodin*a sp. A from those of the taxa listed above is connected with the configuration of the basal cavity. The Pa elements of *Ozarkodina* sp. A possess a cavity which is at least twice as wide as it is long whereas the Pa elements of *Oz. oldhamensis* and *Oz. aldridgei* have almost round cavities.

Ozarkodina sp. B
(Fig. 12K, O, P)

Material examined. — 1 Pa element.

Occurrence. — Upper part of the Vodopad Formation in outcrop 1(74) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1).

Description

Pa element with a shorter anterior and longer posterior process. The anterior process is almost straight, the posterior one is curved downwards and also slightly to one side. The base of the element is relatively high and laterally slightly thickened just below denticles. The denticles are fused almost up to their tips and highly variable in size but, in general, relatively tall. Most characteristic of the denticulation of the Pa element of *Ozarkodina* sp. B are two regions with higher (larger) denticles. One is located in the anterior end of the blade and the other one around the cusp. The cusp is inclined posteriorly. Denticles in the anterior part of the element are almost erect but become slanted posteriorly towards the posterior part. Shallow antero-posteriorly elongated basal cavity is widest just below the cusp. Here the cavity possesses a heart-shape flaring.

Ozarkodina sp. C
(Fig. 12A, C, D)

Material examined. — 1 Pa element.

Occurrence. — Upper part of the Vodopad Formation in outcrop 1(74) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig. 1).

Remarks

This taxon is represented by a single specimen of the Pa element. In general morphology it is quite similar to that of *Ozarkodina* sp. B (Fig. 12K, O, P). The main differences can be noticed in the denticulation, and in the size and shape of the basal cavity. The denticulation of the Pa element of *Ozarkodina* sp. C is more regular, and its basal cavity has well-developed laterally elongated lips below the cusp and continues as a narrow groove below the processes.

Ozarkodina sp. D
(Fig. 12B, E, G, I)

Material examined. — 6 Pa elements.

Occurrence. — Vodopad Formation in outcrop 1(74) on Srednij Island (Männik *et al.* 2002: fig. 1) (Fig.1) and in outcrop 159 in the Spokojnaya River region (Männik *et al.* 2002: fig. 9) (Fig. 3A).

Description

Pa element with long low blade. Anterior process almost straight. Posterior process laterally bowed and aborally arched. Relatively low base of the element bears well-developed lateral thickening/narrow platform ledges just below the denticles. Denticles are short, relatively wide, laterally compressed, with sharp edges. They are fused almost up to their rounded tips. The size of denticles tends to be irregular on the

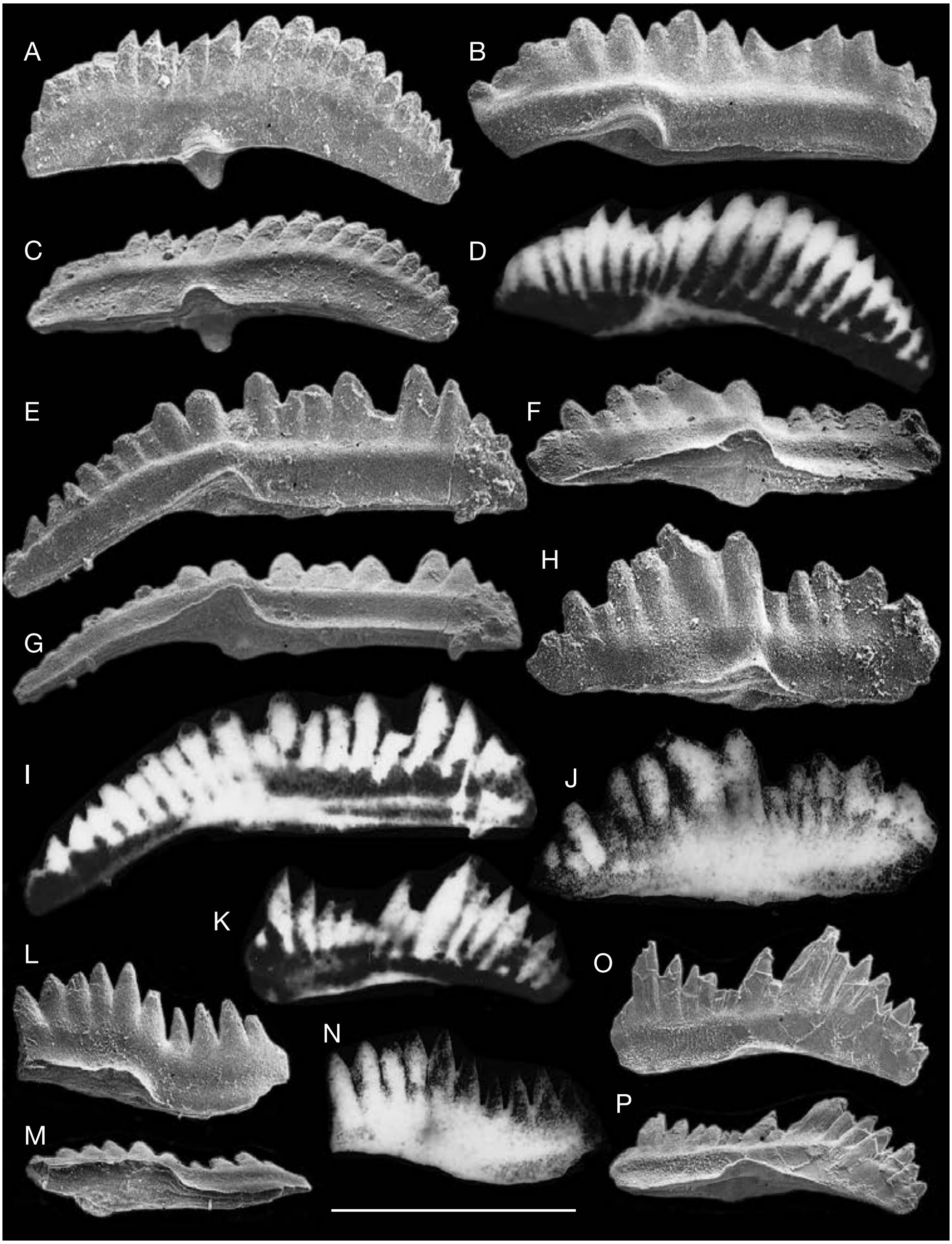

Fig. 12. — **A**, **C**, **D**, *Ozarkodina* sp. C, Cn 6245, lateral and lower views of Pa element (D in translucent light), upper part of the Vodopad Formation, Srednij Island, section 1(74), sample 1-48 (74); **B**, **E**, **G**, **I**, *Ozarkodina* sp. D; **B**, Cn 5956, lateral view of Pa element; **E**, **G**, **I**, Cn 5955, lateral and lower views of Pa element (I in translucent light); both specimens from the Vodopad Formation, Srednij Island, section 1(74): **B**, from sample 1-1 (74); **E**, (**G**-**I**), from sample 1-5 (74); **F**, **H**, **J**, **L**-**N**, *Ozarkodina* sp. E; **F**, **H**, **J**, Cn 6068, lateral and lower views of Pa element (J in translucent light); **L**-**N**, Cn 6069, lateral and lower views of Pa element (N in translucent light); both specimens from Golomyannyj Formation, October Revolution Island, Ushakov River, section 32, sample MF 46-14; **K**, **O**, **P**, *Ozarkodina* sp. B, Cn 5953, lateral and lower views of Pa element (K in translucent light); upper part of the Vodopad Formation, Srednij Island, section 1(74), sample 1-30 (74). Scale bar: 0.5 mm.

anterior process but more regular on the posterior one. In general, the denticles are bigger on the anterior process. Denticles on the anterior process are almost erected, those on the posterior process are inclined posteriorly. The posteriorly inclined cusp is poorly developed. Basal cavity is widest below the cusp, where it possesses strongly asymmetrical flares. Basal flare is larger, broader on the side to which the posterior process is bowed.

REMARKS

Conodonts, almost identical to *Ozarkodina* sp. D, have been found from the upper part of the Raikküla Stage in central Estonia (Männik unpubl. data). In Estonia, these conodonts come from the strata containing elements of *Pranognathus tenuis*, correlating them with the middle Aeronian *Pr. tenuis* Zone.

Ozarkodina sp. E
(Fig. 12F, H, J, L-N)

MATERIAL EXAMINED. — 57 Pa elements.

OCCURRENCE. — Golomyannyj Formation in outcrop 53 on the Strojnaya River (Männik *et al.* 2002: fig. 6) (Fig. 2A), in outcrop 32 on the Ushakov River (Männik *et al.* 2002: fig. 6) (Fig. 4) and in outcrop 13 on the Matusevich River (Männik *et al.* 2002: figs 2, 5) (Fig. 5).

DESCRIPTION

Pa element with, in lower view, slightly curved or sigmoidal blade. The basal outline in lateral view is highly variable – almost straight to sigmoidal (with convexity below the anterior and concavity below the posterior process). Denticles are large, laterally compressed, with sharp edges and slightly rounded tips. They are considerably bigger and higher and more completely fused in the posterior process than in the anterior one. The size of denticles in the anterior process increases slightly towards the distal part of it. Cusp is inseparable in size from the adjacent denticles on the posterior process. Here, the denticles decrease in size from the cusp towards the distal part of the process. The shallow basal cavity is widest below the cusp, where it has narrow asymmetrical lips. The cavity tapers gradually towards the posterior and rapidly towards the anterior end of the element. In many specimens the cavity becomes inverted below the posterior process.

REMARKS

Pa elements considered to belong to this species show a great morphological variation. The denticulation, basal outline, size and configuration of the basal cavity might differ in great deal. However, the general shape of the element, i.e. lower denticles on the anterior and higher denticles on the posterior process, does not change. No other elements than Pa have been identified so far.

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