Conodonts from Ordovician ophiolites of central Kazakhstan

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Central Kazakhstan is frequently referred to as a hypothetical Paleozoic continent Kazakhstania, although its geological structure suggests that in the early Paleozoic it was either a series of island arcs or microcontinents separated by small oceanic basins, each having its own history of development. The cherty and volcanogenic-cherty deposits of the south-western Predchingiz Region and the North Balkhash Region in central Kazakhstan represent an ophiolite rock association with pelagic sediments. The Early–Middle Ordovician conodonts found in the cherty rocks are the only fossils useful for precise dating of the strata and for interpretation of the palaeobiogeographic relations. A low taxonomic diversity is typical of conodonts from these pelagic sediments. Most of them are of the Baltic type, and only some, like *Paroistodus horridus* and *Histiodella tableheadensis*, represent other, apparently more warm-water faunal elements. Deep-water conodont faunas from central Kazakhstan are coeval with the Early–Middle Ordovician conodonts from the shelf deposits of southern Kazakhstan, but the latter are taxonomically more diverse and contain warm-water forms (e.g., *Juanognathus variabilis*, *Reutterodus andinus*, *Serratognathus bilobatus*, and *Bergstroemognathus extensus*). This corroborates the idea that Kazkhstania was closer to the equator, than to the Baltic region in the Ordovician.

Key words: conodonts, Ordovician, Kazakhstania, biostratigraphy, palaeogeography, ophiolites.

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Introduction

In the Early and Middle Ordovician, several basins separated by land massifs occupied the present area of Kazakhstan, especially its central and eastern part. There is a variety of views concerning the tectonics and palaeogeography of this region. The area, frequently referred to as Kazakhstania, is interpreted as a series of island arcs and basins (Nikitin *et al.* 1991; Peive 1980), or to have been composed of a few microcontinents separated

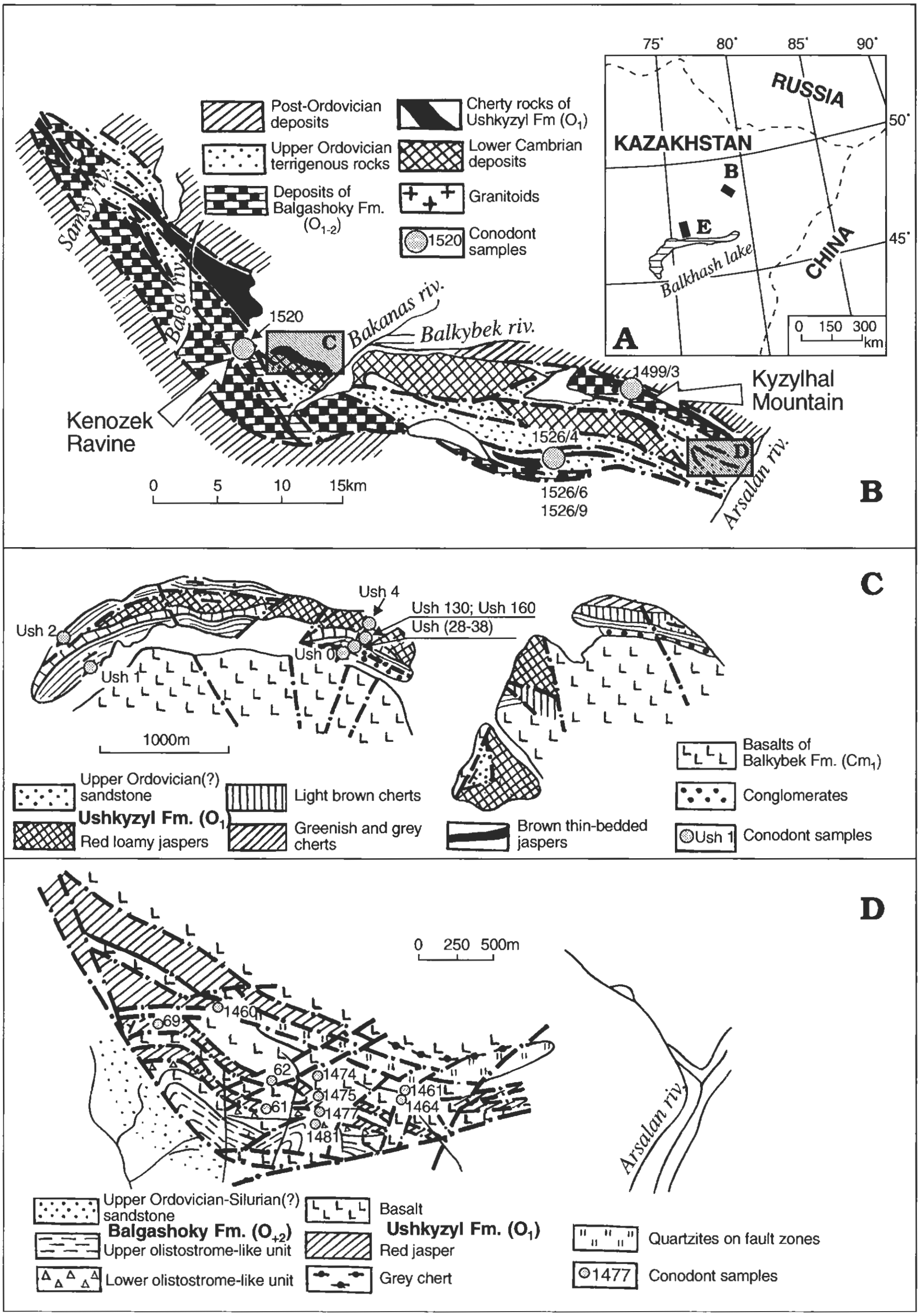


Fig. 1. **A**. General location of the studied areas on the territory of Kazakhstan. **B**. Distribution of the Ushkyzyl and Balgashoky Formations in South Predchingiz Region (after Nikitin *et al.* 1992, modified). **C**. Ushkyzyl Mountains (after Nikitin *et al.* 1992, modified). **D**. Arsalan locality (after Nikitin *et al.* 1992). **E**. Distribution of ophiolites in North Balkhash Region (after Koshkin *et al.* 1987, modified).

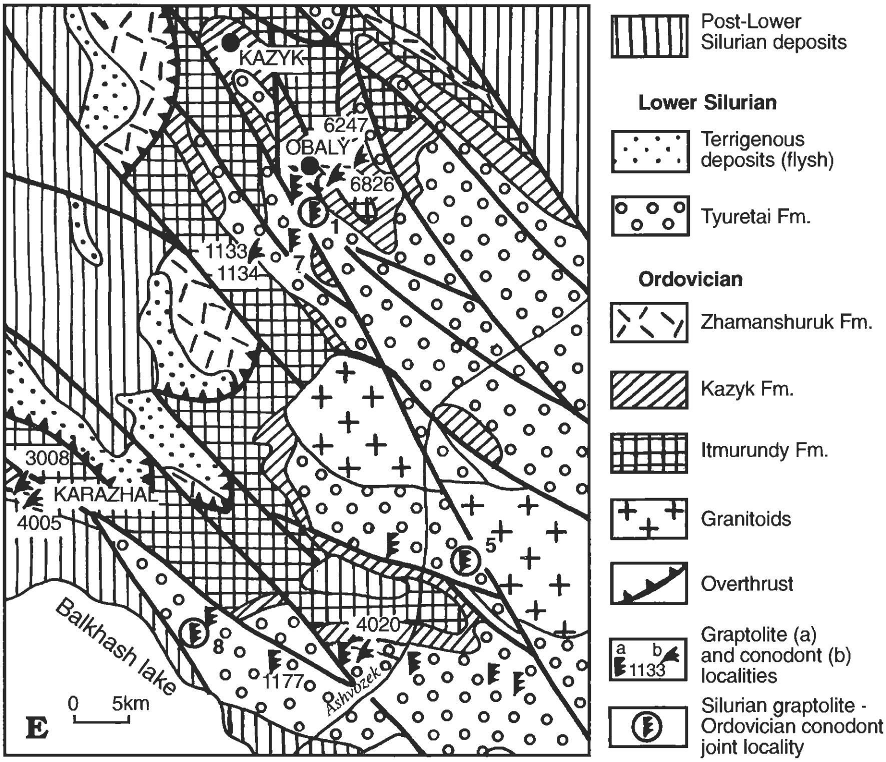


Fig. 1. (continued).

by small oceanic basins, each having its own history of development (Avdeev 1984; Seitov 1992). Deep-water, mainly cherty, deposits of Ordovician age are widely exposed in Kazakhstan. Their age was generally considered to be Precambrian or Cambrian until the first finds of Ordovician conodonts in cherts in the Atasu anticlinorium by Gridina & Mashkova (1977). Subsequent conodont studies clarified the stratigraphic position of the numerous cherty and ophiolitic formations. However, most published papers lack any palaeontological documentation, which is a notable shortcoming. The only short description of fossils with drawings and photographs of conodonts preserved in transparent cherts was given by Dvoichenko & Abaimova (1987).

Conodonts are the only stratigraphic tool which may help in understanding the geological composition of the ophiolitic units. In the present paper, new evidence on the conodonts of central Kazakhstan (Fig. 1) will be presented and their stratigraphic significance discussed.

Stratigraphy of the Ordovician ophiolitic rocks of south-western Predchingiz and North Balkhash Regions has been studied for several years by a team of the Institute of Geological Sciences, the Academy of Sciences of the Republic of Kazakhstan led by I.F. Nikitin. The description presented below is based on their research, as well as on contributions from M.K. Apollonov and D.T. Tsai.

The collection of the conodonts described in this paper is housed at the Institute of Geological Sciences at Almaty (abbreviated as IGSA).

Biostratigraphy of the south-western Predchingiz Region

The cherty deposits in this region have been recognized as the Ushkyzyl Formation by Zhautikov & Ivshin (1971). Zvontsov & Frid (1982) defined the Balgashoky Formation, which comprises volcanogenic-cherty deposits of ophiolitic nature. The first finds of Ordovician conodonts in the Ushkyzyl cherts by D.T. Tsai in 1981 stimulated stratigraphic research in the region. Subsequently, the succession of cherts in the Ushkyzyl and Akirek Mountains (Ushkyzyl Formation) and in volcanogenic-cherty sections on the right bank of the Arsalan river, Kyzylzhal Mountain and Kenozek Ravine (Balgashoky Formation) have been sampled. These Ordovician cherty and volcanogenic-cherty strata are exposed in the Balkybek anticlinorium. The Lower to Middle Ordovician Ushkyzyl and Balgashoky Formations and the Upper Ordovician terrigenous sediments crop out in slopes of the anticlinorium (Fig. 1B). In the center of the anticlinorium there occur volcanogenic-sedimentary deposits of Early Cambrian age (Balkybek Formation). A detailed description of the local stratigraphy was given by Nikitin *et al.* (1992).

The Lower Ordovician Ushkyzyl Formation. — The formation is represented by variegated cherts and red loamy jaspers. It unconformably overlies the volcanogenic-sedimentary Balkybek Formation of Early Cambrian age. The type section of the formation in the central part of the Ushkyzyl Mountains is composed of three units of varied and conformably bedded chert rocks with a total thickness of about 180 m (Fig. 1C).

The jasper-like brown thin-bedded siliceous rock in the basal part of the succession occurs here and there along the base of the mountains. The rock may be defined as a siliceous fine grained sandstone, being composed of various small clasts within a siliceous matrix. Some microclasts resemble radiolarian remains. This unit is about 15 m thick and contains rare conodonts of early Arenig age, including *Prioniodus elegans* Pander, 1856, *Prioniodus* cf. *deltatus* (Lindström, 1955), *Paroistodus proteus* (Lindström, 1955), *Paracordylodus gracilis* Lindström, 1955, and *'Oistodus' papiliosus* van Wamel, 1974 (sample Ush-0).

This unit is overlain by a series of thick variegated cherts. Numerous Arenig conodont species appear at successive levels, among them *Paracordylodus gracilis* Lindström, 1955, *Oepikodus evae* (Lindström, 1955), *Prioniodus* cf. *deltatus*, *Periodon flabellum* (Lindström, 1955), and *Paroistodus originalis* (Sergeeva, 1963) (samples Ush-1, Ush-2, Ush-28–38, Ush-130, and Ush-160). The chert unit is about 120 m thick and comprises the *Oepikodus evae* to *Paroistodus originalis* conodont zones. The rocks generally dip at a high angle to the north. The top of the succession consists of red loamy jaspers of 40–50 m thickness. There occur *Periodon flabellum* (Lindström, 1955), *P. aculeatus* Hadding, 1913, *Ansella jemtlandica* (Löfgren, 1978), and other species. This conodont assemblage can be correlated with the *Lenodus variabilis* Zone of the latest Arenig. The jaspers, especially the red loamy ones, here and at other places, are thin to thick bedded and intensely folded. The surfaces of the jasper beds often bear nodules. These nodules probably developed as a result of the tendency of the siliceous gel to form spheroids during diagenesis.

The type section is the only complete section of the Ushkyzyl Formation. In other places, the formation occurs as tectonic blocks.

The Lower to Middle Ordovician Balgashoky Formation. — The volcanogenic-cherty Balgashoky Formation, together with the Ushkyzyl Formation, is represented at the Arsalan River, where both formations crop out at one wing of an overturned fold. At this locality the early Arenig conodonts *Prioniodus elegans*, *P.* cf. *deltatus*, *Oepikodus evae*, and *Drepanoistodus forceps* (samples 1460, 1461) (Fig. 1D) were recovered from the jaspers of the Ushkyzyl Formation. The Balgashoky Formation conformably overlies the Ushkyzyl Formation and is represented by tholeiitic basalts interbedded with a red jasper and siliceous tuffite. Because its conodont assemblage contains *Baltoniodus navis* (Lindström, 1955) and *Paroistodus originalis* (samples 1464, 1474), these strata are referable to the nominal conodont zones of these species.

Higher in the section, basalts disappear and two olistostrome-like units follow. They are composed of a brecciated matrix and red jasper olistoliths. The matrix apparently represents reworked cherts and volcanics of the Balgashoky Formation. In the lower olistostrome-like unit the blocks and intercalations of red jaspers are relatively numerous and reach up to a few meters in diameter. The upper unit differs from the lower one by a marked decrease in the number of olistoliths, which often appear as rare and brecciated blocks of red jaspers with a maximum diameter of 15 meters. The olistoliths of the lower olistostrome-like unit contain the geologically youngest conodonts of the Balgashoky Formation. The early Llanvirn conodonts *Paroistodus horridus*, *Histiodella tableheadensis*, and *Ansella jemtlandica* were found in the jasper blocks of the lower part of the 'olistostrome' (sample 1477, Fig. 1D). *Periodon aculeatus* appears slightly higher (sample 1478, 1480). *Periodon aculeatus* and *Pygodus anitae* Bergström, 1983 were recovered from the jasper, taken from the top of the lower olistostrome-like unit (sample 1481). In the upper olistostrome-like unit, only some indeterminable conodont fragments have been found.

The total thickness of the Balgashoky Formation at the Arsalan River is estimated to be about 250 m. The conodont finds enable a tectonic interpretation of the Arsalan area structure. The rocks are strongly dislocated and the whole structure is apparently thrusted over younger terrigenous deposits. Some parts of the succession are repeated as tectonic nappes (sample 61, 62, 69, 1475 with early Arenig conodonts). The presence of the youngest conodonts of the Balgashoky Formation in the olistostrome-like deposits indicates that their source deposits represented the topmost strata of the formation. Apparently, the tectonically lifted ophiolitic deposits slumped down the slope a short distance with subsequent reworking of the material. A similar gravel-size of the matrix and partly rounded form of the blocks in the upper olistostrome-like unit confirm this. Other exposures of the Balgashoky Formation with conodonts are in the Kyzylzhal Mountain and Kenozek Ravine (Fig. 1B). Jasper intercalations within basalts at the Kyzylzhal Mountain contain *Paroistodus horridus*, *Microzarkodina flabellum*, *Periodon* sp., and other species (sample 1499/3). The youngest conodonts of the formation, *Pygodus anitae* and *Periodon aculeatus*, have been identified in the Kenozek Ravine (sample 1520).

Biostratigraphy of the north Balkhash Region

The stratigraphy of the volcanogenic-cherty formations of the south-western Predchingiz Region is generally not controversial, but analogous strata of the North Balkhash Region are still the subject of significant differences in opinion, both regarding their age and geological situation. The formations discussed here were defined by Koshkin (1971). His Itmurundy Formation in the lowermost part of the succession is represented mainly by lavas of tholeiitic basalts with cherty strata. The overlying Kazyk Formation is mainly composed of jaspers, and is conformably overlain by the Tyuretai Formation which comprises basalts, jaspers, and different clastic rocks. Because of the lack of fossils and intense folding, these formations were previously arbitrarily attributed to the Precambrian and Cambrian.

Ordovician conodonts were found by Novikova *et al.* (1983) in the jaspers of the Itmurundy, Kazyk, and Tyuretai Formations. *Pygodus serra* (Hadding, 1913) and *P.* cf. *anserinus* Lamont & Lindström, 1957 are among the conodonts collected by these authors from the Kazyk and Tyuretai Formations. Kurkovskaya (1985) and Zhylkaidarov (1988) identified conodonts in all three formations, including the stratigraphically important species *Pygodus serra* and *P. anserinus*, diagnostic of their own zones of the late Llanvirn (including the Llandeilo). Graptolites occur in thin terrigenous rocks of the Tyuretai Formation in several areas of the North Balkhash Region. *Demirastrites triangulatus*, *Glyptograptus tamariscus vasians*, *G. nicolaevi*, and other species typical of the Llandovery have been identified (samples 5, 27, and 1577, Fig. 1E). This is in clear conflict with the Middle Ordovician age of the conodonts (Koshkin *et al.* 1987). The Silurian graptolites and the Ordovician conodonts were found in layers of siltstones and jaspers that do not show visible signs of tectonic disturbance at some localities.

Based on the graptolites, Koshkin *et al.* (1987) dated the Tyuretai Formation as being of Llandovery age. At the same time he established a new Ashyozek Formation, characterized by the dominance of terrigenous rocks and the presence of scarce basalt and jasper interlayers. Both these formations were correlated with the Llandeilo Stage, i.e. the conodont *Pygodus anserinus* Zone, in tables published after the Third Kazakhstan Stratigraphic Meeting in 1986 (Anonymous 1991). Herein, the term Tyuretai Formation is used as previously understood, that is, without separating a part of it as the Ashyozek Formation.

The area where the rocks of the ophiolite complex crop out, has a very complex geological structure. The available data on conodonts and graptolites suggest that the Itmurundy and Kazyk Formations are of the same age, corresponding roughly to the Llandeilian *Pygodus anserinus* Zone. The terrigenous rocks containing the middle and late Llandovery graptolites probably represent the matrix that encloses basalt, tuff and jasper bodies in the overlying Tyuretai Formation. The jaspers of that formation contain conodonts of the *Pygodus anserinus* Zone. This means that the jaspers in the Tyuretai Formation are alien bodies in the Silurian terrigenous succession.

The formation of cherty strata and the thick flows of tholeiitic basalts took place in the Middle Ordovician, mostly within the *Pygodus anserinus* Zone. Probably, the Late Ordovician was a time of obduction-subduction processes and an accretionary prism formation which led to an intensive tectonization of the cherty-basalt complex. The

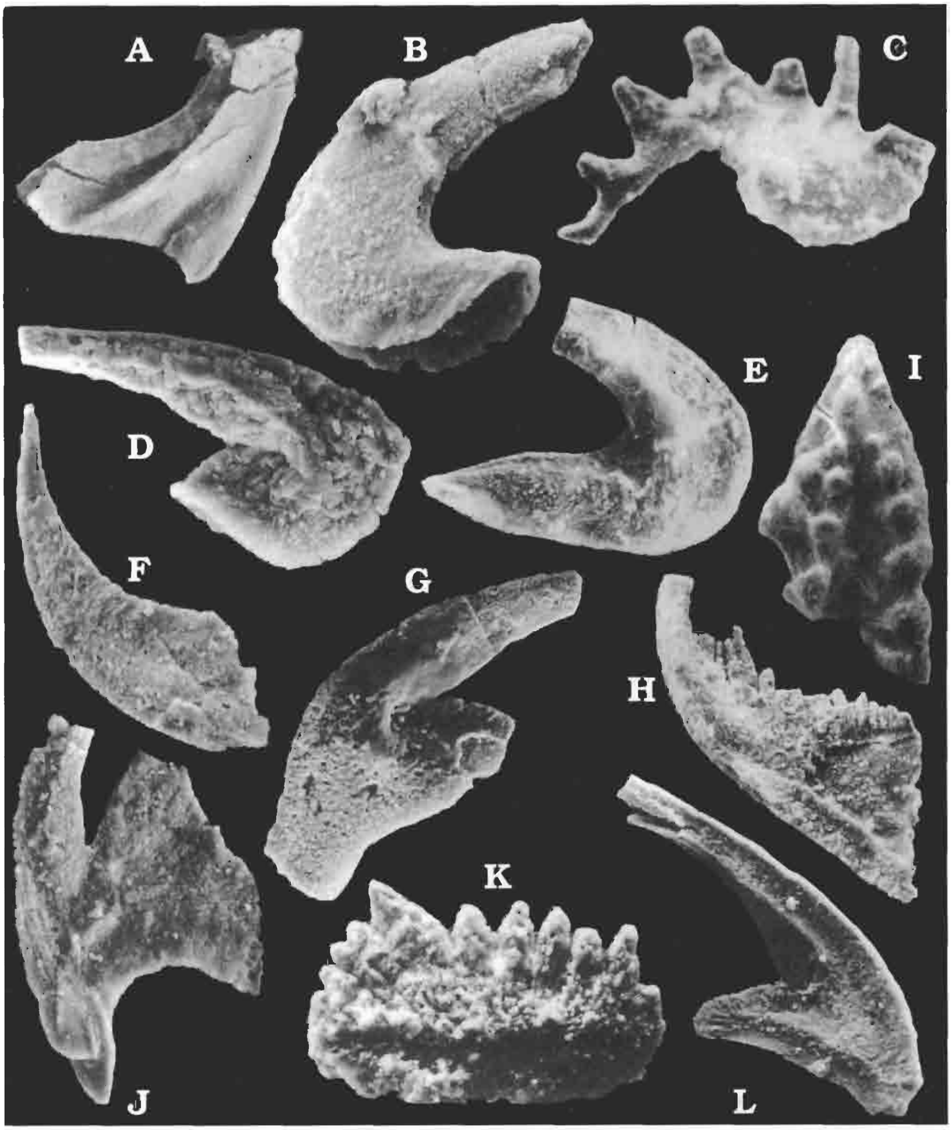


Fig. 2. Conodonts from Middle Ordovician ophiolites of central Kazakhstan. **A**. *Protopanderodus rectus* (Lindström, 1955), element **hi** IGSA C/1, sample 1480, × 80. **B**. *Paroistodus parallelus* (Pander, 1856), element **hi** IGSA C/2, sample 1461, × 110. **C**. *Paroistodus horridus* (Barnes & Poplawski, 1973), element **hi** IGSA C/3, sample 1477 of the Balgashoky section, × 115. **D**. *Paroistodus proteus* (Lindström, 1955) element **hi** IGSA C/4 from the Ushkyzyl section, sample Ush-0, × 137. **E**. *Paroistodus originalis* (Sergeeva, 1963), element **hi** IGSA C/5, sample 1474, × 125. **F–H**. *Ansella jemtlandica* (Löfgren, 1978); elements **hi** IGSA C/6 (F, × 86), sample Ush-4, **ne** IGSA C/7 (G, × 55), sample Ush-4, **tr-hi** IGSA C/8 (H, × 60), sample 1474. **I**. *Pygodus* cf. *anitae* Bergström, 1983; element **sp** IGSA C/9, sample 1520 (× 180). **J, L**. *'Oistodus' papiliosus* van Wamel, 1974; elements **tr-hi** IGSA C/10 (J, × 112), sample 1461 of the Balgashoky section and **ne** IGSA C/11 (L, × 83) sample Ush-0 of the Ushkyzyl section. **K**. *Histiodella tableheadensis* Stouge, 1984, element **oz** IGSA C/12, sample 1477, × 240.

Zhamanshuruk Formation, represented by acidic lavas, tuffs and units of sandstones, tuff-sandstones, siltstones, jaspers and lenses of reef limestones with the Late Ordovician trilobite and brachiopod assemblages, was distributed along the north-western border of the ophiolite deposition area in the region (Fig. 1E).

Sandstones and siltstones of the Tyuretai Formation, containing Early Silurian graptolites, correspond to the initial stage of the slumping processes which promoted the development of the tectono-gravitational deposits. The fragmented and more extensive strata of the transported Ordovician jaspers might have been pseudoconformably buried together within the Silurian fine clastic sediments which resulted in their seemingly conformable interbedding. The upper half of the Tyuretai Formation, including rare jasper pieces, was deposited when the slumping process was near completion.

Review of conodonts

The conodonts have been extracted from cherty rocks using hydrofluoric acid (Zhylkaidarov 1990). In general, the conodont species are represented in the studied samples by relatively small numbers of specimens ranging from a few specimens as *Pygodus* cf. *anitae* to several dozens in the case of *Pygodus serra* and *Periodon aculeatus*. This may result from both collecting and taphonomical bias. The preservation of the fauna is generally satisfactory. The conodonts represent well known taxa and do not require any formal description. The species discussed below are arranged in alphabetic order.

Ansella jemtlandica **(Löfgren, 1978)**. — Two serrate **tr-hi** elements, a single analogous non-serrate element, two serrate **hi**, a single non-serrate **hi** and two **ne** elements (Fig. 2F, G) have been found. They were recovered from samples Ush-4 (Ushkyzyl section) and 1477 (Arsalan section).

Baltoniodus navis **(Lindström, 1971)**. — Two **sp-oz**, three **pl-lo**, two **tr**, two **ke**, two **hi**, and two **ne** elements (Fig. 3I–K) were found in the samples 1464 and 1474 (Arsalan section).

Eoplacognathus **sp.** — One fragmentary **sp** element (Fig. 3H) recovered from sample 1474 (Arsalan section). It resembles the right **sp** element of *Lenodus variabilis* (Sergeeva, 1963).

Histiodella tableheadensis **Stouge, 1984**. — Fifteen **oz** elements (Fig. 2K) were found in samples 1477 (Arsalan section) and Ush-4 (Ushkyzyl section). The shape of the blade shows some variability.

Oepikodus evae **(Lindström, 1955)**. — Eleven **sp-oz**, 28 **tr-hi**, 20 **ne** elements (Fig. 4C–H) were recovered from cherts of the samples Ush-2, Ush-3, Ush-28–38 (Ushkyzyl section), 61, 62, 69, 1460, and 1461 (Arsalan section). In the collection **sp-oz** elements show some morphological variability. The antero-lateral denticulate processes of some of them are directed downward and more anteriorly (Fig. 4C) while the processes of others are directed downwards and perpendicular to the posterior process (Fig. 4D).

'Oistodus' papiliosus **van Wamel, 1974**. — Three **ne**, two **tr-hi** and two **tr** elements (Fig. 2J, L) were recovered from samples Ush-0, Ush-28–38, Ush-1, Ush-130 (Ushkyzyl section) and 1461 (Arsalan section). Van Wamel (1974) included this

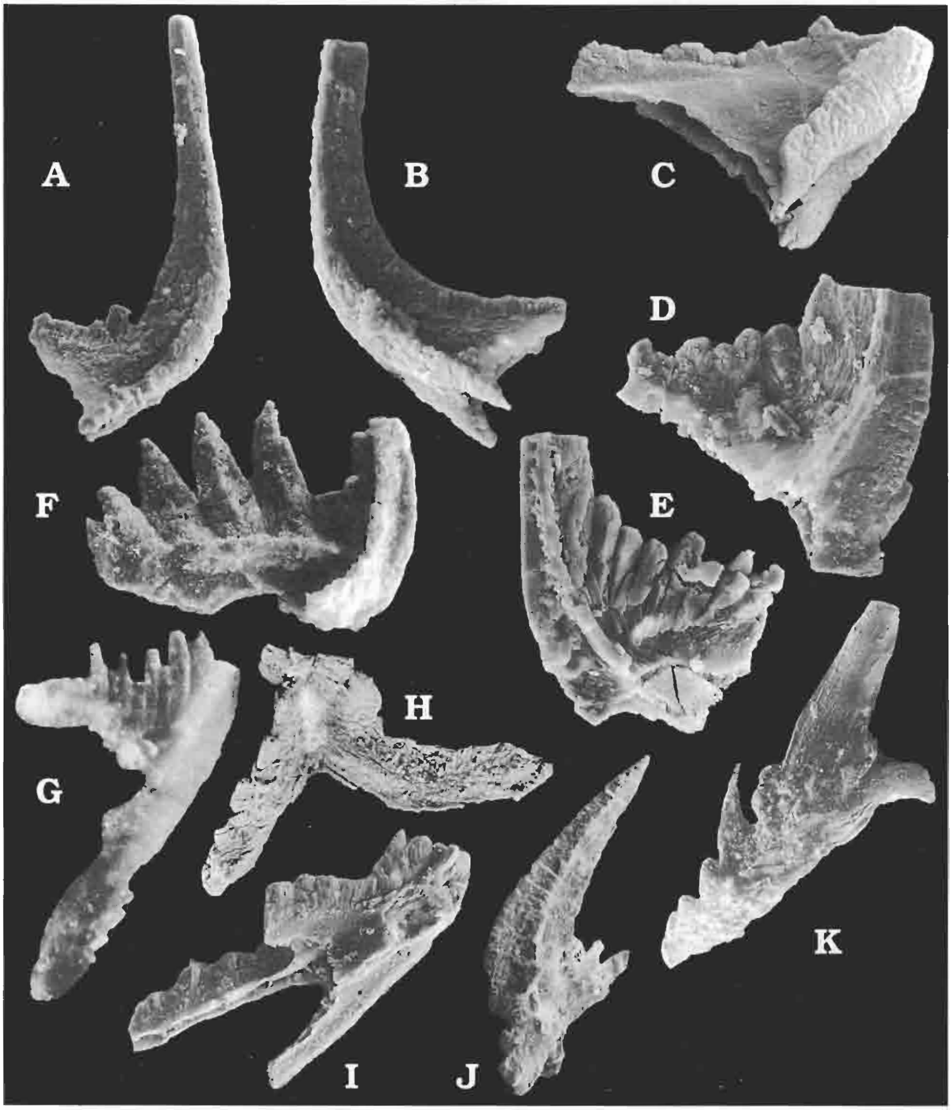


Fig. 3. Prioniodontid conodonts from Middle Ordovician ophiolites of central Kazakhstan. **A–B.** *Prioniodus* cf. *deltatus* (Lindström, 1955); elements **tr**, sample Ush-2 (**A** IGSA C/13, × 62) and Ush-0 (**B** IGSA C/14, × 78). **C–E.** *Prioniodus* sp.; elements **tr**, sample 1464 of the Balgashoky section (**C** IGSA C/15, × 80), **sp**, same sample (**D** IGSA C/16, × 77), and **pl**, sample Ush-1 of the Ushkyzyl section (**E** IGSA C/17, × 143). **F–G.** *Prioniodus elegans* (Pander, 1856); element **sp** from the Arsalan section, sample 1461 (**F** IGSA C/18, × 220) and **hi** from the Ushkyzyl section, sample Ush-0 (**G** IGSA C/19, × 47). **H.** *Eoplacognathus* sp., element **sp** IGSA C/20, sample 1474, × 100. **I–K.** *Baltoniodus navis* (Lindström, 1955) from the Arsalan section, element **pl-lo** IGSA C/21, sample 1464 (**I**, × 83), elements **sp-oz**, sample 1474 (**J** IGSA C/22, × 35, **K** IGSA C/23, × 63).

species in *Oistodus*. The apparatus composition is rather complex and resembles in some respects that of *Prioniodus*.

***Paracordylodus gracilis* Lindström, 1955.** — Thirty **tr-ke**, twelve **hi**, and ten **ne** elements (Fig. 4A, B) were found in samples Ush-0, Ush-1,Ush-2, Ush-3, Ush 130 (Ushkyzyl section), 1526/6 (Akirek Mt.) and 1461 (Arsalan section). A significant variability is exhibited by non-**ne** elements, in the curvature of the posterior process and in the length and the outline of the anticusp of the ribbed elements.

***Paroistodus horridus* (Barnes et Poplawski, 1973).** — Ten **hi** elements (Fig. 2C) were found in samples 1526/4 (Akirek Mt.), 1499/3 (Kyzylzhal Mt.), and 1477 (Balgashoky section). Some morphologic variability has been noticed, which is displayed in the curvature of the processes.

***Paroistodus originalis* (Sergeeva, 1963).** — There are eight **hi** and two **ne** elements (Fig. 2E) in samples Ush-160 (Ushkyzyl section), 1526/9, 1526/4 (Akirek Mt.), 1464, 1474, and 1477 (Arsalan section).

***Paroistodus parallelus* (Pander, 1856).** — The material at hand consists of four **hi** and few **ne** elements (Fig. 2B) which were recovered in samples Ush-1 and Ush-2 (Ushkyzyl section).

***Paroistodus proteus* (Lindström, 1955).** — Five **hi** and two **ne** elements (Fig. 2D) were found in samples Ush-0, Ush-1, and Ush-2 (Ushkyzyl section).

***Periodon aculeatus* Hadding, 1913.** — There are 35 **ne**, 30 **hi**, 25 **tr**, and about 23 three **pl** elements (Figs 4J–O, 5A, B). They were recovered from samples Ush-4 (Ushkyzyl section), 1477, 1478, 1480, 1481 (Arsalan section), 1520 (Kenozek Ravine), and 1526/4 (Akirek section) and from samples 6247, 4020, 4005, 3008, 1133, 1134, and 6828 (North Balkhash Region).

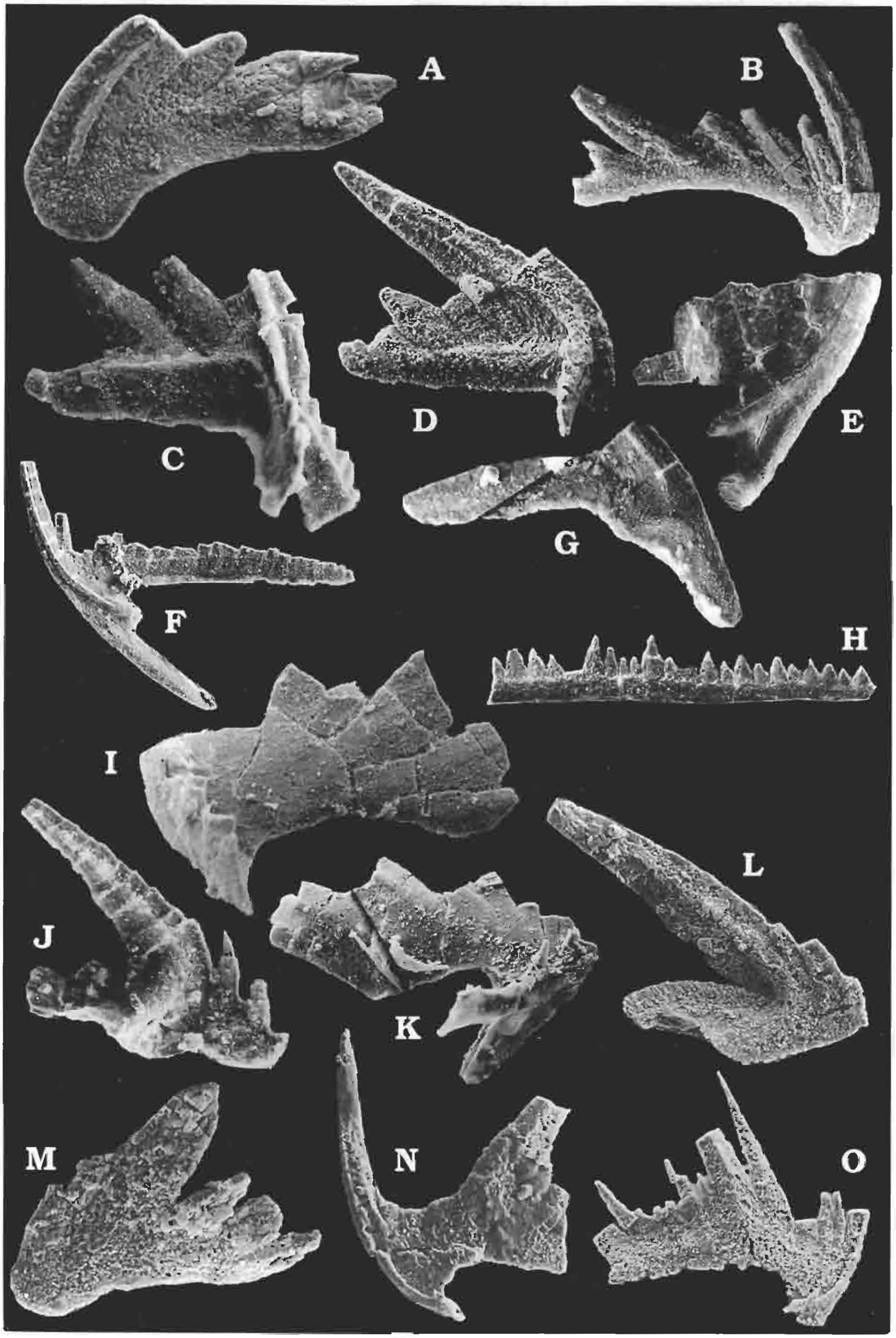
***Periodon flabellum* (Lindström, 1955).** — Ten **hi**, four **pl**, **oz**, and **tr** elements (Fig. 4I) were found in samples Ush-2, Ush-130, Ush-160, Ush-4 (Ushkyzyl section), 1526/9 (Akirek Mt.), and 1461 (Arsalan section).

***Periodon* cf. *grandis* (Ethington, 1959).** — Four or five **ne** elements (Fig. 5C) were found in sample 3008 (Norh Balkhash Region). According to Bergström & Sweet (1966) a subtriangular shape of the base is diagnostic for the species.

***Prioniodus elegans* Pander, 1856.** — In the collection there are present two **sp**, three **pl**, two **tr**, and two **ke-hi** elements (Fig. 3F, G). The samples with the elements are Ush-0 (Ushkyzyl section) and 1461 (Arsalan section.).

***Prioniodus* cf. *deltatus* (Lindström, 1955).** — There are five **tr** and four **pl** elements (Fig. 3A, B) which resemble those from the apparatus of *P. deltatus* as described by Van Wamel (1974). They were found in samples Ush-0 (Ushkyzyl section) and 1461 (Arsalan section).

Fig. 4. Pelagic conodonts from Middle Ordovician ophiolites of central Kazakhstan. **A–B.** *Paracordylodus gracilis* Lindström, 1955 from the Ushkyzyl section; element **sp** (**A** IGSA C/24, × 78) from sample Ush-0 and **hi** (**B** IGSA C/25, × 64), sample Ush-130 of the Arsalan section. **C–H.** *Oepikodus evae* (Lindström, 1955); elements **sp-oz** from Arsalan section, sample 1461 (**C** IGSA C/26, × 100)) and from Ushkyzyl section, sample Ush-2 (**D** IGSA C/27, × 115), elements **tr-hi** from sample Ush-2, (**E** IGSA C/28, × 68), Ushkyzyl section, sample 1461 (**F** IGSA C/29, × 33), and sample 1474 (**H** IGSA C/30, × 45), both from the Arsalan section), element **ne** from sample 1461 of the same section (**G** IGSA C/31, × 50). **I.** *Periodon flabellum* (Lindström, 1955); element **hi** IGSA C/32 from sample 1461 of the Arsalan section, × 75. **J–O.** *Periodon aculeatus* Hadding, 1913; elements **oz**, sample 1477 (**J** IGSA C/33, × 60), **tr**, sample 1478 (**K** IGSA C/34, × 48) of the



Balgashoky section and elements **ne** (**L** IGSA C/35, × 110), **oz**, (**M** IGSA C/36, × 90), **tr** (**N** IGSA C/37, × 58), and **pl** (**O** IGSA C/38, × 100) from sample Ush-4 from the Ushkyzyl section.

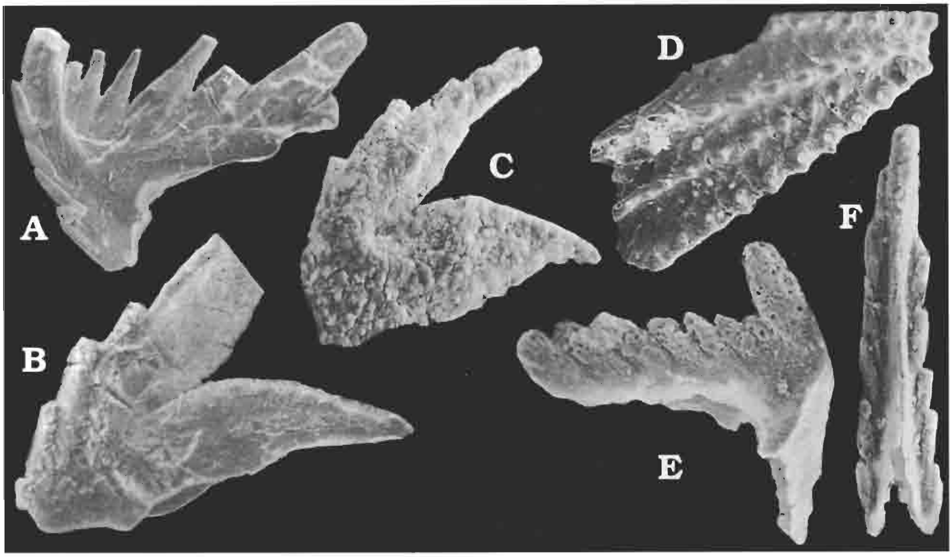


Fig. 5. Conodonts of the North Balkhash Region. **A–B**. *Periodon aculeatus* Hadding, 1913; elements **pl**, sample 1134 (**A** IGSA C/39, × 88) and **ne**, sample 1133 (**B** IGSA C/40, × 100). **C**. *Periodon* cf. *grandis* (Ethington, 1959); element **ne** IGSA C/41, sample 3008, × 140. **D–E**. *Pygodus anserinus* Lamont & Lindström, 1957 from sample 3008; elements **sp**, (D IGSA C/42, × 35), **oz** (**H** IGSA C/43, × 132), and **tr** (**F** IGSA C/44, × 140).

***Prioniodus* sp.** — Eight **sp**, four **pl**, and four **pl** elements (Fig. 3C–E) are included here on the basis of their morphologic similarity. They may belong to different species, however. These elements were met in samples Ush-1, Ush-4 (Ushkyzyl section), 1464, and (probably) 1977 (Arsalan section).

***Protopanderodus rectus* (Lindström, 1955)**. — One **ne** and five **hi** elements (Fig. 2A) are present in samples 1509 and 1525 (Kenozek Ravine).

***Pygodus* cf. *anitae* Bergström, 1983**. — There are only two **sp** elements (Fig. 2I) with three rows of denticles and the middle row somewhat closer to one of the others. Such forms were originally described by Löfgren (1978) as *Pygodus* sp. C. The elements were found in samples 1481 (Arsalan section) and 1520 (Kenozek Ravine).

***Pygodus anserinus* Lamont & Lindström, 1957**. — Eight **sp** and eight **oz** elements (Fig. 5D–F) were recovered from samples 4005, 3008, and 6828 (North Balkhash Region). Other elements are indistinguishable from those of *P. serra*.

***Pygodus serra* (Hadding, 1913)**. — About 42 **sp**, 46 **oz**, nine **pl** and ten **tr** elements were found in samples 6828, 6247, 3008, 4020, 1133, and 1134 (North Balkhash Region). Some **pl** and **tr** elements may belong to its successor – *P. anserinus*.

Other fossils. — Sponge spicules and radiolarians are the only fossils accompanying the conodonts in many samples. Spicules are stratigraphically useless. Radiolarians are not preserved well enough to permit identification.

Comparison with coeval shallow-water conodonts of Kazakhstan

Ordovician conodont assemblages are known in Kazakhstan not only from ophiolitic deposits, but also from rocks of shallow-water origin (Fig. 6). They occur in the Arenig part of the calcareous Shabakty Formation in the Malyi Karatau Region and in the Uzunbulak Formation of the Llanvirn age in the Chu-Ili Mountains. Both localities are in southern Kazakhstan. The Shabakty limestone represents an inner shelf environment (Apollonov & Zhemchuzhnikov 1988). The Uzunbulak Formation, composed of terrigenous rocks with limestone interbeds, is evidently of shelf origin.

The Arenig conodonts from the Shabakty Formation were sampled along the Wostochnyi Ravine in Malyi Karatau. Along with typically Baltic or cosmopolitan species, the assemblage contains forms of Argentine (Serpagli 1974) and Newfoundland (Stouge & Bagnoli 1988) type. These are *Paroistodus numarcuatus*, *P. parallelus*, *P. proteus*, *P. originalis, Paracordylodus gracilis*, *Oepikodus evae*, *O.* cf. *intermedius*, *Juanognathus variabilis*, *Reutterodus andinus*, *Serratognathus bilobatus*, *Bergstroemognathus extensus*, *Protopanderodus* sp., *Scolopodus rex*, and *Periodon flabellum.* In some samples *Oepikodus evae* and *Bergstroemognathus extensus* elements reach 60 per cent of the total number of specimens.

The Llanvirn Uzunbulak Formation assemblage is also of mixed affinities and resembles faunas occurring along the south-east and east margin of North America (see Barnes & Poplawski 1973; Stouge 1984). The following species are represented in the Uzunbulak Formation: *Paroistodus horridus*, *Juanognathus* sp., *Semiacontiodus* cf. *asymmetricus*, *Protopanderodus* cf. *robustus*, ?*Erraticodon balticus*, *Periodon aculeatus*, *Polonodus* sp., *Parapaltodus simplicissimus*, *Ansella jemtlandica*, *Cornuodus longibasis*, *Protopanderodus varicostatus*, *Panderodus gracilis*, and *Walliserodus* sp.

Some of the conodonts which are not typical for the Baltic realm, for instance *Paroistodus horridus* (known from Sweden only, see Löfgren 1995), were also recovered from the ophiolite deposits described above. But non-Baltic species are rare in deep-water assemblages which are generally of low taxonomic diversity. In contrast, the shallow-water conodonts from Kazakhstan are rich in species and comprise a lot of relatively warm-water forms. The material from Kazakhstan does not include such stratigraphically important Baltic taxa as *Eoplacognathus* or *Lenodus*, except for fragmentary specimens of questionable affinities. Perhaps, these platform conodonts of the Baltic realm preferred cold and shallow-water environments, or perhaps their distribution was controlled by some local factors. All this confirms an Ordovician palaeogeographic position of Kazakhstania not far from the equator and much closer to it than to Baltica (Scotese & McKerrow 1991).

Conclusions

The cherty Ushkyzyl Formation in the South–Western Predchingiz Region is dated by means of conodonts as ranging from the *Oepikodus evae* (perhaps *Prioniodus elegans*, sample Ush-0) to the *Lenodus variabilis* Zone. The Balgashoky cherty-basaltic formation, which conformably overlies the Ushkyzyl Formation, is dated as representing *Baltoniodus navis* and *Eoplacognathus suecicus* conodont zones. This means that the

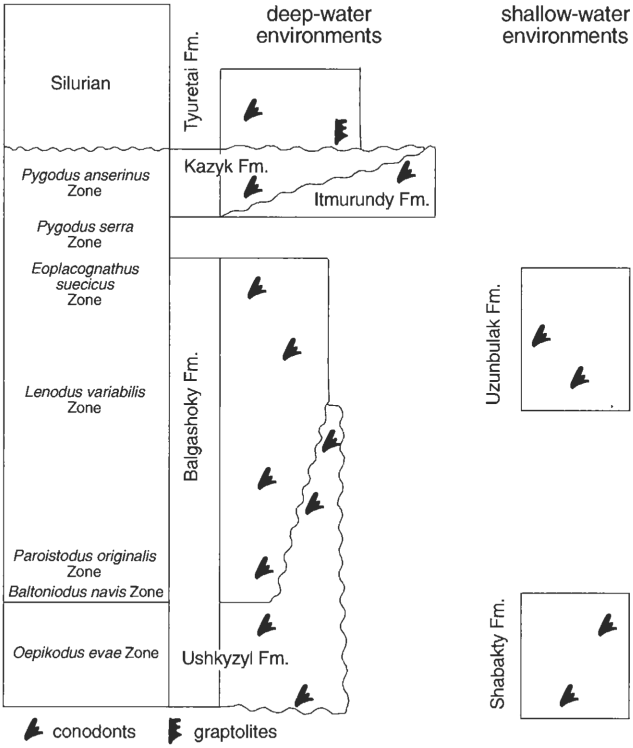


Fig. 6. Correlation of ophiolitic deposits of central Kazakhstan with shallow-water formations of southern Kazakhstan.

boundary between the Ushkyzyl and Balgashoky Formations is diachronous. The presence of exotic tectonic units and signs of extensive slumping in the upper part of the Balgashoky Formation is documented by finds of stratigraphically diagnostic fossils at the Arsalan locality.

The jasper-basaltic strata are assigned to the Itmurundy Formation, the cherty rocks are referred to the Kazyk Formation, and the volcanite-jasper interbeds with terrigenous rocks are separated as the Tyuretai Formation in the North Balkhash Region. Numerous conodont finds from the jaspers of all three formations show that they belong to the same Llandeilian *Pygodus anserinus* Zone. The Early Silurian graptolites in the Tyuretai Formation siltstones show that there are slumped bodies of the Ordovician jaspers in the Silurian terrigenous matrix.

Low taxonomic diversity is typical of conodonts from the studied pelagic sediments. Most of them are of the Baltic type, and only some, like *Paroistodus horridus* and *Histiodella tableheadensis*, represent other, apparently more warm-water faunal elements.

The deep-water faunas studied here are coeval with the Early–Middle Ordovician conodonts from the shelf deposits of southern Kazakhstan, but the shallow-water assemblages are taxonomically more diverse and warm-water forms contribute approximately half of the specimen number. This corroborates the proposed idea that Kazakhstania was closer to the equator than to the Baltic region in the Ordovician.

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Konodonty z ordowickich ofiolitów środkowego Kazachstanu

AIDAR ZHYLKAIDAROV

Streszczenie

Środkowy Kazachstan często bywa określany jako hipotetyczny paleozoiczny kontynent Kazachstania, chociaż budowa geologiczna wskazuje, że obszar ten we wczesnym paleozoiku był szeregiem łuków wysp lub mikrokontynentów, przedzielonych niewiekimi basenami oceanicznymi i mających własną historię geologiczną. Czerty i osady pochodzenia wulkaniczno-czertowego w pd.-zach. Regionie Przedczyngiskim i w Regionie Północnego Bałchaszu reprezentują zespół skał ofiolitowych z osadami pelagicznymi. Znajdowane w czertach konodonty są jedynymi skamieniałościami nadającymi się do dokładnego datowania tych utworów i ich interpretacji paleobiogeograficznej.

Małe zróżnicowanie taksonomiczne jest typowe dla konodontów z osadów pelagicznych. Większość należy do typu bałtyckiego, a tylko nieliczne np. *Paroistodus horridus* i *Histiodella tableheadensis* reprezentują inne, bardziej ciepłowodne elementy faunistyczne. Te głębokomorskie fauny odpowiadają wczesno- i środkowoordowickim zespołom konodontowym z osadów szelfowych południowego Kazachstanu, ale zespoły płytkowodne są bardziej zróżnicowane taksonomicznie i zawierają gatunki ciepłolubne (np. *Juanognathus variabilis*, *Reutterodus andinus*, *Serratognathus bilobatus* i *Bergstroemognathus extensus*). Potwierdza to pogląd, że Kazachstania w ordowiku leżała bliżej równika niż obszaru bałtyckiego.

Zhamanshuruk Formation, represented by acidic lavas, tuffs and units of sandstones, tuff-sandstones, siltstones, jaspers and lenses of reef limestones with the Late Ordovician trilobite and brachiopod assemblages, was distributed along the north-western border of the ophiolite deposition area in the region (Fig. 1E).

Sandstones and siltstones of the Tyuretai Formation, containing Early Silurian graptolites, correspond to the initial stage of the slumping processes which promoted the development of the tectono-gravitational deposits. The fragmented and more extensive strata of the transported Ordovician jaspers might have been pseudoconformably buried together within the Silurian fine clastic sediments which resulted in their seemingly conformable interbedding. The upper half of the Tyuretai Formation, including rare jasper pieces, was deposited when the slumping process was near completion.

Review of conodonts

The conodonts have been extracted from cherty rocks using hydrofluoric acid (Zhylkaidarov 1990). In general, the conodont species are represented in the studied samples by relatively small numbers of specimens ranging from a few specimens as *Pygodus* cf. *anitae* to several dozens in the case of *Pygodus serra* and *Periodon aculeatus*. This may result from both collecting and taphonomical bias. The preservation of the fauna is generally satisfactory. The conodonts represent well known taxa and do not require any formal description. The species discussed below are arranged in alphabetic order.

***Ansella jemtlandica* (Löfgren, 1978)**. — Two serrate **tr-hi** elements, a single analogous non-serrate element, two serrate **hi**, a single non-serrate **hi** and two **ne** elements (Fig. 2F, G) have been found. They were recovered from samples Ush-4 (Ushkyzyl section) and 1477 (Arsalan section).

***Baltoniodus navis* (Lindström, 1971)**. — Two **sp-oz**, three **pl-lo**, two **tr**, two **ke**, two **hi**, and two **ne** elements (Fig. 3I–K) were found in the samples 1464 and 1474 (Arsalan section).

***Eoplacognathus* sp.** — One fragmentary **sp** element (Fig. 3H) recovered from sample 1474 (Arsalan section). It resembles the right **sp** element of *Lenodus variabilis* (Sergeeva, 1963).

***Histiodella tableheadensis* Stouge, 1984.** — Fifteen **oz** elements (Fig. 2K) were found in samples 1477 (Arsalan section) and Ush-4 (Ushkyzyl section). The shape of the blade shows some variability.

***Oepikodus evae* (Lindström, 1955)**. — Eleven **sp-oz**, 28 **tr-hi**, 20 **ne** elements (Fig. 4C–H) were recovered from cherts of the samples Ush-2, Ush-3, Ush-28–38 (Ushkyzyl section), 61, 62, 69, 1460, and 1461 (Arsalan section). In the collection **sp-oz** elements show some morphological variability. The antero-lateral denticulate processes of some of them are directed downward and more anteriorly (Fig. 4C) while the processes of others are directed downwards and perpendicular to the posterior process (Fig. 4D).

***'Oistodus' papiliosus* van Wamel, 1974.** — Three **ne**, two **tr-hi** and two **tr** elements (Fig. 2J, L) were recovered from samples Ush-0, Ush-28–38, Ush-1, Ush-130 (Ushkyzyl section) and 1461 (Arsalan section). Van Wamel (1974) included this