CONODONTS FROM THE EARLY ORDOVICIAN (MID-ARENIG) DEEP WATER DEPOSITS OF CENTRAL ASIAN PALEOBASINS

SVETLANA V. DUBININA

Dubinina, S.V. 1998. Conodonts from the Early Ordovician (mid-Arenig) deep water deposits of Central Asian paleobasins. *In:* H. Szaniawski (ed.), Proceedings of the Sixth European Conodont Symposium (ECOS VI). — *Palaeontologica Polonica* **58**, 79–86.

Conodont associations from deep water mid-Arenig deposits (*Prioniodus elegans–Oepikodus evae* zones) of Central Asian paleobasins are summarized. Deep water conodont communities living apparently below the permanent thermocline had the same composition in similar deep water paleoenvironments in different types of basins in Central Asia. They are similar to the Acado-Baltic communities, but differ from the latter by lower taxonomic diversity and, very often, by numerical domination of some species. *Juanognathus*, typical of the transitional faunal realm, as well as warm-water Midcontinent faunal components, are absent from all Central Asian deep water communities, which are composed exclusively of Acado-Baltic cold-water fauna and thus are related to the cold-water realm.

Key words: Conodonta, paleobasins, Early Ordovician, mid-Arenig, Central Asia.

Svetlana V. Dubinina [dubinina@ginran.msk.su], Geological Institute, Russian Academy of Sciences, Pyzhevsky per.,7, 109017 Moscow, Russia.

Received 21 January 1997, accepted 15 December 1997

INTRODUCTION

The mid-Arenig time-interval is the chronological equivalent of the *Prioniodus elegans* and *Oepikodus evae* conodont zones. The relative displacement of the continental masses such as Baltic- and Gondwana-lands occurred in the *Prioniodus elegans* time interval (SCOTESE and MCKERROW 1991). The continuous, gradual change from terrigenous to carbonate sedimentation in the shallow-water Baltic paleobasin, that started in the *Oepikodus evae* time interval is considered as evidence for the movement of Baltica from the relatively high to middle paleolatidudes (POPOV and KOREN 1996).

The paleogeographic distribution of the *Prioniodus elegans–Oepikodus evae* conodont fauna was generally similar to that of the earlier, Late Cambrian–Tremadoc fauna (DUBININA 1991). This is despite the evidence for decrease in latitudinal climatic gradient in early Ordovician time.

Taking into account the influence of the permanent thermocline upon the distribution of trilobite (COOK and TAYLOR 1975; TAYLOR 1977) and conodont communities (as proposed by DUBININA [1991: fig. 6; 1994: figs 1, 2] for the Iapetus and Proto-Pacific Oceans), a similar paleoenvironmental model is proposed here to explain conodont distribution in the paleobasins of Central Asia.

The Paleo-Asian Ocean was represented by several separate paleobasins of different types (YAKUBCHUK 1990; NIKITIN *et al.* 1991; DEGTYAREV 1993). The main purpose of this paper is to recognize the characteristics of the *Prioniodus (P.) elegans–Oepikodus evae* deep-water conodont communities in all basin types of this paleo-ocean system.

Conodont collections from the sections of the Baikonur Synclinorium, the Sarykum Section of the Aktau-Mointy Anticlinorium, the Blue Ridge Section of southwestern Betpak-Dala, and the sections of the Chingiz Anticlinorium are reposited in the Geological Institute, Russian Academy of Sciences, Moscow. The conodont collections from the sections of northern Betpak-Dala (Buruntau Anticlinorium) and the sections of southwestern Prechingiz region are reposited in the Institute of Geological Sciences, Academy of Sciences of Kazakhstan, Alma-Ata and in All-Russian Geological Research Institute (VSEGEI), St. Petersburg.

Acknowledgements. — I am thankful to Dr. John E. REPETSKI (U.S. Geological Survey, Virginia) for his valuable advice and critical comments.

TYPES OF EARLY PALEOZOIC BASINS OF CENTRAL ASIA

Based on the structural and lithologic characteristics of Lower Paleozoic complexes, four types of basins have been recognized in the Central Asian region (YAKUBCHUK 1990; NIKITIN *et al.* 1991; DEGTYAREV 1993). These have been interpreted as back-arc basins, island arc belts, epicontinental basins, and passive marginal basins (Fig. 1).

The back-arc paleobasins developed on oceanic crust. The back-arc complexes start with siliceous-basalt and siliceous sequences that record spreading phase of the basin, and are overlain by siliceous-terrigenous and olistostrome sequences that record the closed basin stage. This type of basin is represented by (1) the complexes of Ishkeolmess, Erementau-Niyaz, Atasu, Buruntau, and Maikain-Kyzyltass anticlinoria; (2) the complexes of southwestern and northeastern Prechingis regions and northern Betpak-Dala of Central Kazakhstan; and (3) the Middle Ordovician complexes of Tekturmass and North-Balkhash anticlinoria.

The island-arc belt basins formed both on oceanic and continental crust. Their sequences are represented by alternation of calc–alkaline extrusive, siliceous-tuffaceous, flysch and reef carbonate deposits. Complexes of the Chingiz and Boschekul anticlinoria, the Kendyktin and Stepnyak synclinoria, and, apparently, the complexes of southwestern Betpak-Dala, represent this type of paleobasin.

The epicontinental basins developed on continental crust. They typically include siliciclastic-carbonate and siliceous facies in the Lower Ordovician, and terrigenous-carbonate rocks in the Middle Ordovician. The complexes of the Aktau-Mointy and Tekeli anticlinoria represent this type of paleobasin.

Finally, the passive, marginal Ishim-Karatau-Naryn paleobasin also formed on continental crust. Siliceous-terrigenous and terrigenous facies predominate, whereas carbonate facies are less common. The complexes of the Baikonur synclinorium, Bolshoy Karatau, and Dzhebagly Mountains, as well as the complexes of the Middle Tien-Shan (Sandalash, Dzhetymtau, Sarydzhaz Ridges) in Kyrgyzstan, have been used for the reconstruction of this narrow but elongated basin.

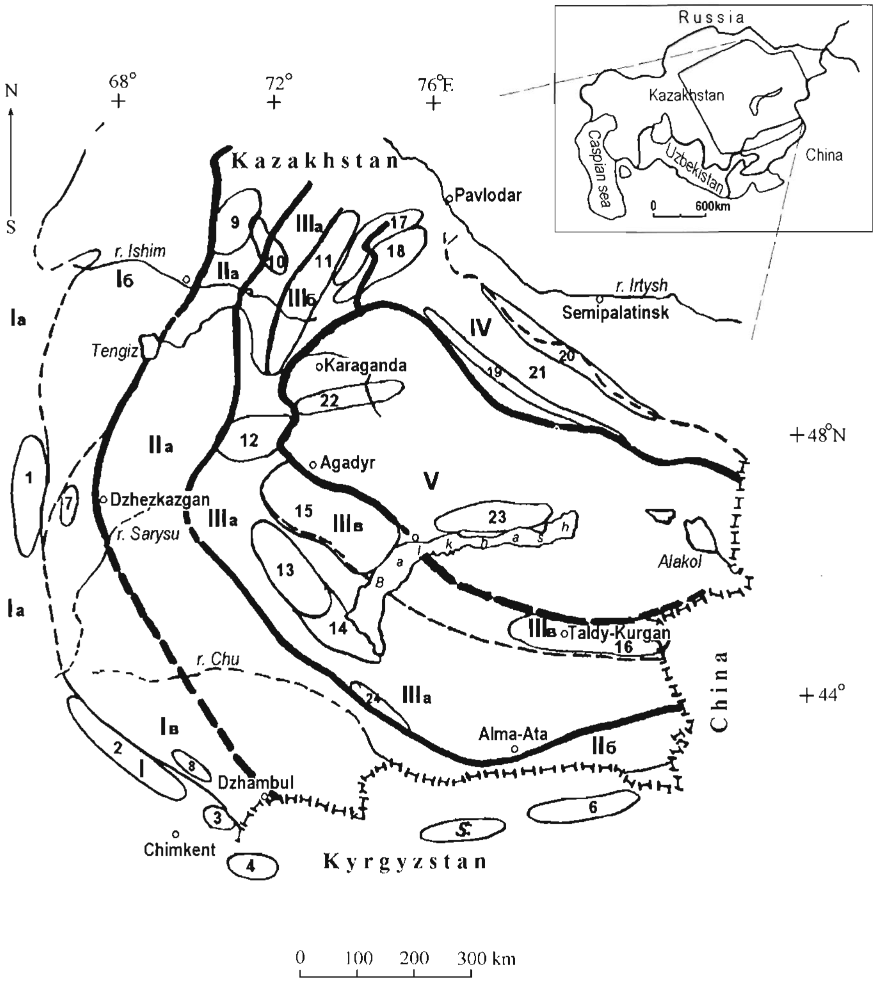

Fig. 1

Map showing Ordovician tectono-facies zonation in Kazakhstan and Tien-Shan (modified from NIKITIN (1972) and NIKITIN and others (1991)). I–V – tectono-facies zones: I – Ishim-Karatau-Naryn; II – Stepnyak-Betpak-Dala-North Tien-Shan; III – Erementau-Chu-Ili; IV – Chingiz-Tarbagatay; V – Dzhungariya-Balkhash. Main tecnonic structures, containing Ordovician formations with conodont faunas: 1 – Baikonur Synclinorium; 2 – Bolshoy Karatau; 3 – Dzebagly Mountains; 4 – Sandalash Ridge; 5 – Dzhetymtau Ridge; 6 – Sarydzhaz Ridge; 7 – Ulutau Anticlinorium; 8 – Maly Karatau; 9 – Stepnyak Synclinorium; 10 – Ishkeolmess Anticlinorium; 11 – Erementau-Niyaz Anticlinorium; 12 – Atasu Anticlinorium; 13 – N. Betpak-Dala; 14 – Buruntau Anticlinorium; 15 – Aktau-Mointy Anticlinorium; 16 – Tekeli Anticlinorium; 17 – Boschekul Anticlinorium and Kendyktin Synclinorium; 18 – Maikain-Kyzyltass Anticlinorium; 19 – SW Prechingiz; 20 – NE Prechingiz; 21 – Chingiz Anticlinorium; 22 – Tekturmass Anticlinorium; 23 – N. Balkhash; 24 – SW Betpak-Dala. Tectonic structures related to the following types of Central Asian paleobasins: 10–14, 18–20, 22, 23 – back-arc; 9, 17, 21, 24 – island arc belts; 15, 16 – epicontinental; 1–6 – passive marginal.

THE MID-ARENIG CONODONT ASSOCIATIONS OF CENTRAL ASIA

The deep-water deposits included in this study are: (1) pelagic abyssal siliceous sequences preserved in ophiolite complexes; (2) siliceous-terrigenous and siliceous-volcanogenic deposits of island arc slopes; and (3) thin bedded mudstones and siliceous mudstones, deposited in hemipelagic environment near or at the base of a continental slope.

Conodonts from siliceous facies of Central Kazakhstan were first reported from the Karatass Formation of the Atasu Anticlinorium (GRIDINA and MASHKOVA 1977). GERASIMOVA *et al.* (1977) investigated conodonts in siliceous-terrigenous facies of the Monadyr and Karatass formations of the Atasu Anticlino-

Table 1
Conodont associations of *Prioniodus elegans–Oepikodus evae* Zone time from deep water deposits of the Central Asian (Kazakhstan, Kyrgystan) paleobasins.

Species	Types of paleobasins																		
	Back-arc									Island arc					Epicontinental		Passive marginal		
	Atasu Anticlinorium	Eremantau-Niyaz Anticlinorium	Ishkeolmess Anticlinorium	Buruntau Anticlinorium	N. Betpak-Dala	Maikain-Kyzyltass Anticlinorium	SW Prechingiz	NE Prechingiz	Stepnyak Anticlinorium	Boschekul Synclinorium	Kendyktin Synclinorium	Cingiz Anticlinorium	SW Betpak-Dala	Aktau-Mointy Anticlinorium	Tekeli Anticlinorium	Baikonur Synclinorium	Sandalash Ridge	Dzhetymtau Ridge	Sarydzhaz Ridge
Prioniodus elegans					•		•									•			
Oepikodus evae	•	•	•	•	•	•	•				•	•	•	•		•		•	•
Prioniodus delatus longibasis																•			
Paroistodus parallelus	•	•		•	•			•				•	•	•	•	•			•
Paroistodus proteus					•		•							•		•		•	•
Drepanoistodus forceps					•					•	•	•	•	•		•		•	•
Drepanoistodus arcuatus			•		•	•	•	•					•	•		•		•	•
Periodon flabellum	•	•		•	•		•		•	•		•	•	•		•			•
Periodon primus																•			
Protopanderodus rectus					•						•		•			•			
Paracordylodus gracilis	•	•	•	•	•		•	•		•		•	•	•		•	•	•	•
Oistodus lanceolatus	•	•	•					•		•						•			•
Oistodus tablepointensis																•			
Oistodus elongatus								•								•			
Stolodus stola	•																		
Microzarkodina flabellum	•							•											
Oistodus emanuelensis		•																	
Drepanoistodus suberectus					•														
Periodon sp.						•		•											

rium (for taxonomic composition of all conodont associations mentioned here see Table 1). NOVIKOVA *et al.* (1978, 1980) investigated conodonts from siliceous beds of the Mynshokur Formation of the Eremen-tau-Niyaz Anticlinorium and from analogous facies of the Ishkeolmess Anticlinorium; NIKITIN *et al.* (1980) from the Burubaital Formation of the Buruntau Anticlinorium; and APOLLONOV *et al.* (1990) and DUBININA (1990, 1991) from siliceous deposits of the Chazhagay Formation (Sarykum Subzone) of the Aktau-Mointy Anticlinorium. Additional information about conodonts from the Chazhagay Formation (Chazhagay Subzone) of the Aktau-Mointy Anticlinorium was published by BESSTRASHNOV *et al.* (1989).

Conodonts from the Ushkyzyl Formation of southwestern Prechingiz region were investigated by ZHILKAIDAROV (1991), NIKITIN *et al.* (1992), KOREN *et al.* (1993), and TOLMACHEVA (1996). The mid-Arenig conodonts were determined from siliceous beds of the ophiolite complex of northeastern Prechingiz region (DVOICHENKO and ABAIMOVA 1987; ZVONTSOV and FRID 1991). A conodont fauna that included *Oepikodus evae* was found in siliceous-tuffaceous beds of the Maikain-Kyzyltass ophiolite belt (NOVIKOVA *et al.* 1993).

The siliceous-terrigenous member of the Burubaital Formation of northern Betpak-Dala is very rich in conodonts (GERASIMOVA *et al.* 1984; KURKOVSKAYA 1985; KOREN *et al.* 1993; TOLMACHEVA 1996). In the western part of the Stepnyak Synclinorium only *Periodon flabellum* was reported (KURKOVSKAYA 1985).

The siliceous facies of the island arc complexes of the Kendyktin Synclinorium (TENYAKOVA and KALININ 1980) and Boschekul Anticlinorium (KHROMYKH 1986) are represented by moderate numbers of conodonts. Recently, I have found a very similar conodont association in siliceous-tuffaceous beds of the Chingiz Anticlinorium (DEGTYAREV *et al.* in press).

Additional information is needed about the mid-Arenig conodonts from mudstones of the Kerimbek Formation of the Tekely Anticlinorium, from which only rare conodont and graptolite occurrences have been reported so far (NIKITIN *et al.* 1993). That would be very interesting, because the representative associations that contain both conodonts and graptolites have been documented so far only from two Central Asian formations: the siliceous-terrigenous Kushekin Formation in the Blue Ridge Section of southwestern Betpak-Dala (DUBININA *et al.* 1996b) and the terrigenous Karasuir Formation of the Baikonur Synclinorium (DUBININA *et al.* 1996a). My conodont collection of Baikonur Section comprises 45,000 conodont elements, well- preserved on surfaces of the shale bedding planes. Preliminary data on conodonts from the sections of the Baikonur Synclinorium were published by PUCHKOV (1986) and GERASIMOVA and KURKOVSKAYA (1993).

Also, it is desirable to get additional conodont data from the graptolite cherts of the Sandalash Formation in the Middle Tien-Shan, where only *Paracordylodus gracilis* has been reported so far (MAMBETOV 1993). Mid-Arenig conodonts from the siliceous Oldzhobay Formation in Dzhetymtau and Sarydzhaz Ridges of the Middle Tien-Shan have been reported by CHERNYSHUK (1993) and PUCHKOV *et al.* (1986), respectively (Table 1).

In summary, the Ishim-Karatau-Naryn tectono-facies zone, corresponding to the Ishim-Karatau-Naryn passive marginal paleobasin, is characterized by mid-Arenig conodonts that occur over a large area from the Baykonur Synclinorium in the west to the Sarydzhaz Ridge in the east (Fig. 1). Data on conodonts from the Kurugtag Ridge in northwestern China, that is, from the eastern end of this extensive zone, have not been reported so far.

Among all of the above listed occurrences of mid-Arenig conodonts (Table 1), those from continuous Lower-Middle Ordovician sections have the most value for paleobiogeographic analysis. They include: (1) the sections of the Baikonur Synclinorium (passive marginal basin); (2) the Sarykum Section of the Aktau-Mointy Anticlinorium (epicontinental type of paleobasins); (3) the sections of northern Betpak-Dala, southwestern Prechingiz region and the Maikain-Kyzyltass Anticlinorium (back-arc paleobasins); and (4) the sections of the Chingiz Anticlinorium (island arc belts).

COMPARISON OF MID-ARENIG DEEP WATER CONODONT COMMUNITIES FROM CENTRAL ASIA AND OTHER REGIONS OF THE WORLD

It is known that Arenig conodont faunas, when compared with their predecessors, are more differentiated and more dependent on specific environments. The overal conodont diversity in mid-Arenig times can be estimated by taking into account three faunal units (DUBININA 1991, 1994): Acado-Baltic, Midcontinent, and *Juanognathus* faunas. The first and second faunas characterize both the early- and mid-Arenig times, whereas the third fauna appears since *P. elegans* time.

The *Juanognathus* fauna (LINDSTRÖM 1976) comprises the following species: *Juanognathus variabilis* SERPAGLI, *Reutterodus andinus* SERPAGLI, *Protopanderodus gradatus* SERPAGLI, *Bergstroemognathus extensus* (GRAVES *et* ELLISON), *Tropodus australis* (SERPAGLI), *"Acodus" sweeti* (SERPAGLI), and *"Oistodus" americanus* (SERPAGLI). It is worth mentioning that the *Juanognathus* fauna is typical only for the transitional faunal realm where it is considered to be relatively cold-water component (DUBININA 1994). Apparently, the species of the *Juanognathus* fauna did not cross below the level of the permanent thermocline. Only the Acado-Baltic species were able to inhabit the deeper water layers, below the thermoclines level. Therefore, they were related to the cold-water component of the transitional realm. In the environment of this realm, the warm-water Midcontinent faunal component was extremely rare.

The communities of the transitional realm show continuous transition from the open shelf to the hemipelagic environment. This transition is reflected by a gradual replacement of the rare Midcontinent warm-water and typical transitional relatively cold-water species by the cold-water species. The communities of the transitional realm are replaced by those of the cold-water realm possibly reflecting the fact that sufficient basinal depth was reached for the development of the cold-water zone below the thermocline.

The representatives of the Acado-Baltic fauna in the deep-water communities of the cold-water realm could possibly overcome the thermocline boundary. In the Central Asian basins, the pelagic abyssal siliceous deposits preserved in the ophiolite complexes, siliceous-terrigenous and siliceous-volcanogenic deposits of the island arc slopes, and the thin bedded mudstones and siliceous mudstones of continental slope' base, all correspond to the conditions optimal for the Acado-Baltic species habitats. The representatives of the *Juanognathus* and Midcontinent faunas are absent in those deposits, except for rare, redeposited *Juanognathus* and Midcontinent species (for example, in the sections of the Baikonur Synclinorium; DUBININA *et al.* 1996a), which are not taken into account when the deep-water communities are reconstructed.

The fauna of southeastern China and Malyi Karatau was related to the transitional faunal realm (DUBININA 1991). The communities from deep water environments of the basins of Central Asia were related to the cold-water realm (this paper). They can serve for comparison of the communities of the transitional and cold water realms in Central and South-Eastern Asia. In the transitional realm the communities included three faunal components (dominant *Juanognathus*, Acado-Baltic, and minor Midcontinent component), whereas in the cold water realm, the communities were represented only by the Acado-Baltic fauna. The latter included the following species: *Prioniodus elegans* (PANDER), *P. deltatus longibasis* (MCTAVISH), *Paroistodus parallelus* (PANDER), *P. proteus* (LINDSTRÖM), *Drepanoistodus forceps* (LINDSTRÖM), *Drepanodus arcuatus* PANDER, *Periodon flabellum* (LINDSTRÖM), *P. primus* STOUGE *et* BAGNOLI, *Protopanderodus rectus* (LINDSTRÖM), *Paracordylodus gracilis* LINDSTRÖM, *Oistodus lanceolatus* PANDER, *O. tablepointensis* STOUGE, *Oelandodus elongatus* (LINDSTRÖM), and *Oepikodus evae* (LINDSTRÖM).

In North America, similar conodont communities, but with a small number of the Midcontinent and *Juanognathus* fauna species, are known from: (1) lower-slope deposits of the western margin of the Iapetus Ocean in western Newfoundland (Cow Head Group) (JOHNSTON 1987; STOUGE and BAGNOLI 1988); and (2) continental slope successions formed at the margin of the Proto-Pacific Ocean in central Nevada (ETHINGTON and REPETSKI 1984). Similar conodont communities are known from the Ouachita Mountains slope facies (ETHINGTON and REPETSKI 1984; ETHINGTON *et al.* 1989); the Black Warrior basin, Mississippi (ALBERSTADT and REPETSKI 1989); and slope deposits of the Hamburg klippe, eastern Pennsylvania (REPETSKI 1984). They are mentioned here to demonstrate the presence of the transitional realm communities near the predicted boundary with the cold-water realm.

Sections in Kurugtag Ridge, northwestern China, might serve as good candidates for future investigations of the cold-water realm fauna in siliceous depositional environments of the passive marginal basin of Central Asia.

It is clear that species that could cross the thermocline boundary in the transitional realm could also inhabit both deep- and shallow-water environments of the cold-water realm.Thanks to this fact, it is possible to define more exactly the range of the cold-water realm (DUBININA 1991) and to compare the deep-water communities living below the level of the thermocline in the Central Asian basins with the Acado-Baltic communities.

The *P. elegans–O. evae* communities of Sweden (see BERGSTRÖM 1988; LÖFGREN 1993a, b), Estonia (VIIRA 1974), Latvia (DUBININA 1983), and the Leningrad region (SERGEEVA 1963) are taxonomically diverse. The deep water communities of the Central Asian basins appear less taxonomically diverse (Table 1), but there are no major differences in their composition. However, the conodont associations from Kazakhstan and Kyrgyzstan, unlike those of Europe, are very often characterized by numerical domination of elements of one or two species, *Paracordylodus gracilis* and *Periodon flabellum*, in particular (DUBININA *et al.* 1996a). The alternation of mono- and polyspecific associations in siliceous and terrigenous sections of Kazakhstan is a typical phenomenon. Frequent appearances of monospecific communities in deep water environments of any Central Asian basin are, most likely, due to other reasons (for example, eustatic events or/and oceanic bottom currents).

In conclusion, it should be emphasized that the mid-Arenig deep water conodont communities appear to have been similar when compared throughout deep water environments of Central Asian basins of different types. These similarities may be due to the relative stability of oceanic water masses below the thermocline. The data on conodont communities from different paleoenvironments and habitats, when coupled with related sedimentological data that have been obtained during the recent years from various types of early Palaeozoic basins of Central Asia, will be useful when applied to basinal analysis of the Central Asian region and also to paleobiogeographic reconstructions of this and other areas.

REFERENCES

ALBERSTADT, L. and REPETSKI, J.E. 1989. A Lower Ordovician Sponge/Algal Facies in the Southern United States and its Counterparts Elsewhere in North America. — *Palaios* **4**, 225–242.

APOLLONOV, M.K., ZHEMCHUZHNIKOV, V.G. (Žemčužnikov, V.G.), and DUBININA, S.V. 1990. The Ordovician of northwestern Balkhash region [in Russian]. — *Izvestiâ* AN *Kazahskoj SSR. Seriâ geologičeskaâ* **4**, 3–16.

BERGSTRÖM, S.M. 1988. On Pander's Ordovician conodonts: distribution and significance of the *Prioniodus elegans* fauna in Baltoscandia. — *Senckenbergiana Lethaea* **69**, 217–251.

BESSTRASHNOV, V.M. (Besstrašnov, V.M.), GERASIMOVA, N.A., and KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.). 1989. The Ordovician stratigraphy of Aktau-Mointy Rising. *In:* E.P. Pushko and V.Ya. Koshkin (eds), *Palaeozoic stratigraphy of Kazakhstan* [in Russian]. Alma-Ata, 68–77.

CHERNYSHUK, V.P. (Černyšuk, V.P.) 1993. Conodont biostratigraphy of the Middle Tien-Shan Lower Palaeozoic. *In:* A.M. Mambetov (ed.), *New data on the Precambrian and Palaeozoic biostratigraphy of Kyrgyzstan* [in Russian], 70–80. Ilim, Biškek.

COOK, H.E. and TAYLOR, M.E. 1975. Early Paleozoic continental margin sedimentation, trilobite biofacies, and the thermocline, western United States. — *Geology* **3**, 559–562.

DEGTYAREV, K.E. (Degtârev, K.E.) 1993. Two types of the Early Palaeozoic island-arc systems in Central Kazakhstan [in Russian]. — *Doklady RAN. Seriâ geologičeskaâ* **331**, 74–77.

DEGTYAREV, K.E. (Degtârëv, K.E.), DUBININA, S.V., and ORLOVA, A.R. (in press). Stratigraphy and peculiarities of sections structure of the Lower Palaeozoic carbonate-siliceous-tuffaceous complex in Chingiz Ridge (Eastern Kazakhstan). *Stratigraphy and Geological Correlation* [in Russian]. MAIK Nauka, Interperiodica Publishing (Russia), Moskva.

DUBININA, S.V. 1983. On the Lower and lower Middle Ordovician conodont stratigraphy of north-western Latvia [in Russian]. — *Izvestiâ AN Éstonskoj SSR* **32**, 45–52.

DUBININA, S.V. 1990. Conodont zonal stratigraphy of the Cambrian–Ordovician boundary deposits of Kazakhstan. Ph. D. thesis [in Russian]. 539 pp. Geological Institute AN SSSR, Moskva.

DUBININA, S.V. 1991. Upper Cambrian and Lower Ordovician conodont associations from open ocean paleoenvironments, illustrated by Batyrbay and Sarykum sections in Kazakhstan. *In:* C.R. Barnes and S.H. Williams (eds), Advances in Ordovician Geology. — *Geological Survey of Canada, Paper* **90–9**, 107–124.

DUBININA, S.V. 1994. Reconstruction of the Late Cambrian and Early Ordovician conodont communities in different paleoenvironments. *In:* A.Yu. Rozanov and M.A. Semikhatov (eds), *Ecosystem restructurions and the evolution of the biosphere. Issue 1* [in Russian], 71–79. Nedra, Moskva.

DUBININA, S.V., ORLOVA, A.R., and KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.) 1996a. Sequence of conodont and graptolite assemblages in terrigenous Lower-Middle Ordovician of Ishim-Karatau structural-facial Zone in Kazakhstan (Baikonur and Sarysay sections) [in Russian]. — *Bûlleten' MOIP. Seriâ geologičeskaâ* **71**, 2, 64–75.

DUBININA, S.V., ORLOVA, A.R., and KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.) 1996b. Joint conodont and graptolite occurences in chert-terrigenous Lower Ordovician of southwestern Betpak-Dala (Kazakhstan) [in Russian]. — *Bûlleten' MOIP. Seriâ geologičeskaâ* **71**, 5, 44–50.

DVOICHENKO, N.K. (Dvojčenko, N.K.) and ABAIMOVA, G.P. 1987. Conodonts and biostratigraphy of the Lower Palaeozoic volcanogenic-siliceous formations in Central Kazakhstan. *In:* A.V. Kanygin (ed.), *Microfauna and Phanerozoic biostratigraphy of Siberia and adjacent regions* [in Russian], 160–178. Nauka, Novosibirsk.

ETHINGTON, R.E. and REPETSKI, J.E. 1984. Paleobiogeographic distribution of Early Ordovician conodonts in central and western United States. — *Geological Society of America, Special Paper* **196**, 89–101.

ETHINGTON, R.E., FINNEY S.C., and REPETSKI, J.E. 1989. Biostratigraphy of the Paleozoic rocks of the Ouachita Orogen, Arkansas, Oklahoma, west Texas. *In:* R.D. Hatcher, W.A. Thomas, and G.W. Viele (eds), The Geology of North America. The Appalachian-Ouachita Orogan in the United States. — *Geological Society of America* **F-2**, 563–574.

GERASIMOVA, N.A., DUBININA, S.V., and ZARDIASHVILI, N.I. (Zardiašvili, N.I.) 1977. On the age of siliceous-terrigenous complex of Atasu Anticlinorium (Central Kazakhstan) [in Russian]. — *Doklady AN SSSR. Seriâ geologičeskaâ* **235**, 1, 151–154.

GERASIMOVA, N.A., BESSTRASHNOV, V.M. (Besstrašnov, V.M.), NOVIKOVA, M.Z., and KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.). 1984. The Lower Palaeozoic stratigraphy and conodont complexes of northern Betpak-Dala (Central Kazakhstan) [in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **5**, 12–18.

GERASIMOVA, N.A. and KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.). 1993. Problems of the Lower Palaeozoic stratigraphy in Central Kazakhstan. *In:* E.E. Milanovsky (ed.), *Problems of Geology and Metallogeny in Central Kazakhstan* [in Russian]. MGU, MOIP, Nauka, Moskva, 24–32.

GRIDINA, N.M. and MASHKOVA, T.V. (Maškova, T.V.) 1977. Conodonts in siliceous-terrigenous formations of Atasu Anticlinorium[in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **6**, 47–48.

JOHNSTON, D.I. 1987. Early Ordovician (Arenig) conodonts from St. Pauls Inlet and Martin Point, Cow Head Group, western Newfoundland. *M.Sc. thesis*. 226 pp. Memorial University of Newfoundland, St. Johns, Newfoundland.

KHROMYKH, B.F. (Hromyh, B.F.) 1986. New data on the Vendian-Early Palaeozoic Development and Metallogeny of Boschekul ore region [in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **6**, 20–34.

KOREN, T.N. (Koren', T.N.), LYTOCHKIN, V.N. (Lytočkin, V.N.), POPOV, L.E., and TOLMACHEVA, T.Yu. (Tolmačëva, T.Û.) 1993. *Biostratigraphical Analysis of the Palaeozoic Pelagic Structural-Material Complexes for GS-50 and-200. Methodical Recommendation* [in Russian], 1–78. Roskomnedra. VSEGEI, Sankt-Peterburg.

KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.) 1985. Conodont complexes from the Ordovician siliceous- and volcanogenic-siliceous formations of Central Kazakhstan. *In:* Yu.A. Zaitsev (ed.), *Geology of the early-geosyncline complexes in Central Kazakhstan* [in Russian], 164–177. MGU, Moskva.

LINDSTRÖM, M. 1976. Conodont palaeogeography of the Ordovician. *In:* M.G. Bassett (ed.), The Ordovician System: proceedings of a Palaeontological Association symposium, Birmingham. — *University of Wales Press and National Museum of Wales, Cardiff*, 501–522.

LÖFGREN, A. 1993a. Conodonts from the lower Ordovician at Hunneberg, south-central Sweden. — *Geological Magazine* **130**, 215–232.

LÖFGREN, A. 1993b. Arenig conodont successions from central Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **115**, 193–207.

MAMBETOV, A.M. 1993. On the stratigraphy of Sandalash Formation in the Middle Tien-Shan. *In:* A.M. Mambetov (ed.), *New data on the Precambrian and Palaeozoic biostratigraphy of Kyrgyzstan* [in Russian], 41–55. Ilim, Biškek.

NIKITIN, I.F. 1972. *The Ordovician System in Kazakhstan. Part I –Stratigraphy* [in Russian]. 242 pp. Nauka, Alma-Ata.

NIKITIN, I.F., APOLLONOV, M.K., TSAJ, D.T. (Caj, D.T.), BURENIN, V.M., DUBININA, S.V., and KUZNECHEVSKY, A.G. (Kuznečevskij, A.G.) 1980. On the age of the Lower Palaeozoic formations of south-western Balkhash region [in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **3**, 42–50.

NIKITIN, I.F., FRID, N.M., and ZVONTSOV, V.S. (Zvoncov, V.S.) 1991. Paleogeography and main features of volcanicity in the Ordovician of Kazakhstan and North Tien Shan. *In:* C.R. Barnes and S.H. Williams (eds), Advances in Ordovician Geology. — *Geological Survey of Canada, Paper* **90–9**, 259–270.

NIKITIN, I.F., ZHILKAIDAROV, A.M. (Žilkajdarov, A.M.), and FRID, N.M. 1992. The Ordovician siliceous-basalt complex of south-western Prechingiz region [in Russian]. — *Izvestiâ AN Kazahstana. Seriâ geologičeskaâ* **4**, 57–70.

NIKITIN, I.F., TSAJ, D.T. (Caj, D.T.), SHLYGIN, A.E.(Šlygin, A.E.), and NIKITINA, O.I. 1993. Ore-bearing formations of Koksu-Tekeli ore region [in Russian]. — *Otečestvenna geologiâ, Moskva* **10**, 33–41.

NOVIKOVA, M.Z., RYAZANTSEV, A.V. (Râzancev, A.V.), and DUBININA, S.V. 1978. On the age of the Akdym Series in Erementau-Niyaz Anticlinorium [in Russian]. — *Doklady AN SSSR. Seriâ geologičeskaâ* **241**, 2, 453–455.

NOVIKOVA, M.Z., BORISENOK, V.I. (Borisënok, V.I.), BUYAKOVSKA, K. (Buâkovska, K.), DUBININA, S.V., GERASIMOVA, N.A., and MINERVIN, O.V. 1980. New data on the Lower Palaeozoic stratigraphy of early-geosyncline volcanogenic-siliceous formations in Ishkeolmess and Erementau-Niyaz anticlinoriums. *In:* Yu. A. Zaitsev (ed.), *Problems of Geology in Central Kazakhstan* [in Russian], 85–102. MGU, Moskva.

NOVIKOVA, M.Z., GERASIMOVA, N.A., KURKOVSKAYA, L.A. (Kurkovskaâ, L.A.), STEPANETS, V.G. (Stepanec, V.G.), and YAKUBCHUK, A.S. (Âkubčuk, A.S.) 1993. Stratigraphy of the Lower Palaeozoic volcanogenic-siliceous formations of Maikain-Kyzyltass ophiolite belt (Central Kazakhstan) [in Russian]. — *Bûlleten' MOIP. Seriâ geologičeskaâ* **68**, 6, 47–63.

POPOV, L.E. and KOREN, T.N. 1996. Eustatic Events and Black Shale Sedimentation at the Cambrian-Ordovician Boundary. — *Stratigraphy and Geological Correlation* **4**, 5, 419–427.

PUCHKOV, V.N. (Pučkov, V.N.) 1986. Conodont findings in the Lower Palaeozoic siliceous formations of Baikonur Synclinorium and their stratiraphical significance [in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **1**, 53–57.

PUCHKOV, V.N. (Pučkov, V.N.), KHRISTOV, E.V. (Hristov, E.V.), IVANOV, K.S., and NASEDKINA, V.A. 1986. On the age of siliceous formations in the Sarydzhaz river basin (Middle Tien-Shan) [in Russian]. — *Doklady AN SSSR. Seriâ geologičeskaâ* **290**, 5, 1190–1194.

REPETSKI, J.E. 1984. Conodonts from Spitzenberg. *Guidebook for the 49th Annual Field Conference of Pennsylvania Geologists. Geology of an accreted terrane: the eastern Hamburg klippe and surrounding rocks, eastern Pennsylvania, Harrisburg*, 94–103.

SCOTESE, C.R. and MCKERROW, W.S. 1991. Ordovician plate tectonic reconstructions. *In:* C.R. Barnes and S.H. Williams (eds), Advances in Ordovician Geology. — *Geological Survey of Canada, Paper* **90–9**, 271–282.

SERGEEVA, S.P. 1963. Early Ordovician conodonts of Leningrad region and their stratigraphical significance. *Synopsis of Ph. D. thesis* [in Russian]. 25 pp. LGU, Leningrad.

STOUGE, S. and BAGNOLI, G. 1988. Early Ordovician Conodonts from Cow Head Peninsula, Western Newfoundland. — *Palaeontolographia Italica* **75**, 89–179.

TAYLOR, M.E. 1977. Late Cambrian of western North America: Trilobite biofacies, environmental significance, and biostratigraphic implications. *In:* E.G. Kauffman and J.E. Hazel (eds), *Concepts and Methods of Biostratigraphy*, 397–425. Stroudsburg, Pennsylvania.

TENYAKOVA, R.G. (Tenâkova, R.G.) and KALININ, I.F. 1980. On the Lower Ordovician stratigraphy of Kendyktin Synclinorium (northeastern part of Central Kazakhstan) [in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **6**, 20–24.

TOLMACHEVA, T.Yu. (Tolmačëva, T.Û.) 1996. Late Cambrian and Early Ordovician pelagic conodonts of Central Kazakhstan. *Abstract of the Ph.D. thesis* [in Russian]. 23 pp. All-Russian Geological Research Institute (VSEGEI), St. Petersburg.

VIIRA, V. (Vijra, V.) 1974. *Conodonts from the Ordovician of the East Baltic* [in Russian]. 142 pp. Valgus, Tallin.

YAKUBCHUK, A.S. (Âkubčuk, A.S.) 1990. Tectonic position of the ophiolite zones in the Palaeozoic structures of Central Kazakhstan [in Russian]. — *Geotektonika* **5**, 55–68.

ZHILKAIDAROV, A.M. (Žilkajdarov, A.M.) 1991. Conodonts and Stratigraphy of the Ordovician volcanogenic-siliceous deposits of southwestern Prechingiz region. *Abstract of the Ph. D. thesis* [in Russian]. 19 pp. Institute of Geology and Geophysics, Siberia Branch of the AN SSSR, Novosibirsk.

ZVONTSOV, V.S.(Zvoncov, V.S.) and FRID, N.M. 1991. The Early Palaeozoic of north-eastern Prechingiz and western Tarbagatay [in Russian]. — *Izvestiâ AN Kazahskoj SSR. Seriâ geologičeskaâ* **1**, 23–42.