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Upper Ordovician Olistostromes of the Agyrek and Kosgombai Mountains: Problems of Correlation between Lower Paleozoic Sedimentary and Sedimentary–Volcanogenic Complexes in Central Kazakhstan

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In memory of Igor Fedorovich Nikitin

Abstract—The analysis of data on the stratigraphy of Lower Paleozoic sedimentary and sedimentary–volcanogenic sequences in central Kazakhstan made it possible to specify their ages, structural relationships, and correlation with coeval sections of neighboring areas. It is shown that olistostromes widespread in the Agyrek–Arsalan accretionary wedge of the central Kazakhstan Paleozoides are of Katian age. Three stratigraphic units are defined in continuous siliceous sections: *Paracordylodus gracilis* Beds, *Periodon flabellum* Beds, and *Paroistodus horridus* Beds. It is established that Lower Cambrian carbonate–basaltic, Middle–Upper Cambrian carbonate, Upper Cambrian–Lower Ordovician carbonate–terrigenous, and Lower–Middle Ordovician volcanogenic, tuffaceous–siliceous, and siliceous sequences associated with serpentinite melange belong to different lithotectonic zones of Early Paleozoic basins.

Keywords: Cambrian, Ordovician, olistostromes, allochthons, Kazakhstan.
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INTRODUCTION

Problems related to stratigraphic ranges, relationships and tectonic positions of sedimentary and sedimentary–volcanogenic units, as well as the age of olistostromes developed in the Agyrek and Kosgombai mountains, have been debated for a long time (Koneva, 1979; Bespalov, 1980; Dvoichenko and Abaimova, 1986; Stepanets, 1988, 1992; Novikova et al., 1993; Stepanets et al., 1998; Nikitin, 2002; Ryazantsev, 2005). These structures represent one of the best-known and best-exposed geological objects, where the doctrine of fixism in the geology of Kazakhstan was first subverted (Bespalov, 1980).

N.K. Ivshin (Ivshin, 1978) was the first to discuss the development of olistostrome facies along the western slopes of the Agyrek Mountains. Slightly later, when describing terrigenous–siliceous sequences of the Agyrek Mountains, S.P. Koneva (Koneva, 1979) noted a limestone terrane with different-age Cambrian fossils in Member E. Subsequently, R.M. Antonyuk in (*Ob"yasnitel'naya*..., 1981) emphasized that this member with limestone blocks inside the undivided Cambrian sequence "resembles olistostrome" correlated by N.K. Dvoichenko (Dvoichenko and Abaimova, 1986) with the middle of the Late Ordovician.

By that time, the cement of the Agyrek olistostrome was still undated by paleontological remains, and its formation time was estimated from its structural position and correlation of terrigenous rocks with their formation analogs from neighboring areas. Novikova (in Novikova et al., 1993) dated the Agyrek olistostrome as O_{3sa}(?) and O_{3ka} correlating it with sections of the Olenty-Shiderta area (Ryazantsev and Rumyantseva, 1987).

R.M. Antonyuk (Antonyuk, 1971; *Ob"yasnitel'naya*... 1981) united tectonic slices of volcanogenic rocks into the Vendian–Lower Cambrian Maikain Formation, while siliciliths and associated terrigenous rocks were defined by this researcher as Lower–Upper Cambrian Kosgombai Formation. These two formations are considered as corresponding to the second and third oceanic layers, respectively.

Conodont finds in Kosgombai siliciliths provided grounds for attributing them to the Lower Ordovician (Koneva, 1979; Dvoichenko and Abaimova, 1986). Slightly later, siliciliths yielded conodonts characteristic of the Dapingian Stage and the lower part of the

Darriwilian Stage, while tuffite layers among pillow basalts were found to contain conodonts of the Floian Stage (Novikova et al., 1993), allowing these researchers to define two sequences: basaltic (lower) and siliceous (upper).

Conflicting views on the age and succession of siliceous and siliceous–volcanogenic sequences were primarily determined by the lack of bed-by-bed conodont sampling in any of the blocks, where only single finds of organic remains were registered.

N.M. Gridina, V.E. Konik, and V.G. Stepanets were the first to accomplish bed-by-bed sampling of conodonts in siliceous and siliceous–volcanogenic sequences and corals from the cement of the Agyrek olistostrome during detailed stratigraphic–tectonic investigations in 1988–1991 (Stepanets et al., 1998). Until now, a significant proportion of this material remains unpublished and olistostrome, siliceous, and siliceous–volcanogenic sequences remained uncorrelated with coeval deposits of neighboring areas (Fig. 1). At present, no such investigations are conducted in this area of central Kazakhstan, which shows the necessity to revise these materials and correlate them with the modern International Stratigraphic Scale of the Ordovician System (Bergström et al., 2008).

GEOLOGICAL STRUCTURE AND TECTONIC POSITION

Based on published data (Koneva, 1979; Avdeev, 1986; Novikova et al., 1993) and original observations, deposits of the Agyrek Mountains and Mount Kosgombai areas are subdivided into three lithotectonic first-order units (Fig. 2).

Paraautochthonous and neoautochthonous complexes. The paraautochthon includes the Katian carbonate–terrigenous sequence (Middle Cambrian greywacke sequence, after Bespalov, 1980; Middle–Upper Ordovician terrigenous sequence, after R.M. Antonyuk in *Ob''ysnitel,'naya...*, 1981; Erkebidaik flyschoid sequence of the Sanbyan Stage, after Novikova et al., 1993) and overlying frontal olistostrome (Stepanets et al., 1998).

The carbonate–terrigenous sequence is exposed only along the western slope of the Agyrek Mountains (Fig. 2), where it is represented by rhythmically alternating siliceous siltstones, siltstones, silty sandstones, and greywackes with subordinate small (2 × 15 m) lenses and thin (5 m) beds of brecciated limestones with corals of the Katian Stage: *Nyctopora* sp., *Lichenaria* sp., *Tetradium* sp., *Rhabdotetradium* sp. (Outcrop 4589), *Reuschia* cf. *sokolovi* Dziubo, *Plasmoporella* sp. (Outcrop 3289); hereinafter, V.E. Konik identified corals from his own collection). Higher in the section, sandstones are replaced by calcareous sandstones and organogenic-detrital limestones (Fig. 2, Outcrop 2789). In the last outcrop, from where A.G. Pospelov identified terminal Late Cambrian–Ordovician microphytolites (Koneva, 1979), V.E. Konik found corals most likely from the *Holorynchus giganteus* Beds of the Katian Stage: *Agetolites* cf. *minor* Lin, *Agetolitella prima* Kim, *Hemiagetolites* cf. *columellus* Koval, *Palaeofavosites?* sp., *Catenipora* sp., *Rhabdotetradium* sp., *Heliolites?* sp., *Propora* sp., *Plasmoporella* cf. *grata* Poltavzeva.

Structurally higher, these rocks are overlain by the Agyrek olistostrome. The latter is subdivided into the frontal and back parts. The frontal olistostrome is most completely exposed along the southwestern slope of the Agyrek Mountains, where it conformably overlies, as a pinching out sequence up to 100 m thick, the carbonate–terrigenous sequence of the Katian Stage, or replaces laterally its upper layers (Fig. 3).

The olistostrome is composed of structureless carbonate–clayey and silty–sandy frequently intensely foliated groundmass with fragments and blocks of jaspers, aphyric basalts, limestones, which yield organic remains from all the Cambrian series (Ivshin, 1978; Koneva, 1979), and rare blocks of amygdaloid basalts with lenses of re-worked limestones of the Botomian Stage (Ivshin, 1978), which have never been found in authochthonous sequences of the Paleozoides in northeastern central Kazakhstan (Bespalov, 1980). One of the blocks of siltstones and calcareous sandstones yielded Upper Cambrian–Tremadocian conodonts (Dvoichenko and Abaimova, 1986). N.M. Gridina found in the same block (Fig. 2, Outcrop 341a) conodonts *Gapparodus bokononi* (Landing), *Phakelodus tenuis* (Müller), *Mamillodus* sp., and *Proacontiodus* sp. The olistostrome encloses also fragments of conglomerate, gravelstone, and sandstone beds saturated with ophiolitic clastic material and jaspers, as well as blocks of limestones and limy breccia–conglomerate with Upper Ordovician corals most likely from the upper half of the Katian Stage such as *Agetolites* sp., *Fletcheriella* sp., *Nyctopora* sp., *Reuschia* sp., *Propora tumulosa* Hill, *Heliolites* cf. *ramosus* Kovalevskii, *Vermiporella* sp. (Fig. 2, Outcrop 2989) and its *Holorynchus giganteus* Beds (Outcrop 4389).

In the Mount Kosgombai area (Fig. 2), the Agyrek frontal olistostrome is fragmentarily exposed in form of small erosional windows among oligomictic serpentinite melange. As in the Agyrbek Mountains, the olistostrome from this locality contains limestone blocks with Katian corals most likely correlating them with the *Holorynchus giganteus* Beds (Outcrop 4489).

Structurally higher, there are tectonic slices of reduced sections composed of different-age sedimentary, volcanogenic–sedimentary, and serpentinite melange sequences overlain by neoautochthonous carbonate–terrigenous members of the Chokpar Horizon (Katian Stage), the basal layers of which are replaced both upward the section and laterally by the back olistostrome. The latter is most widespread north of Mount Kosgombai (Fig. 2).

Dissimilar to the frontal olistostrome, the back one is free of Cambrian limestone blocks and less tecton-

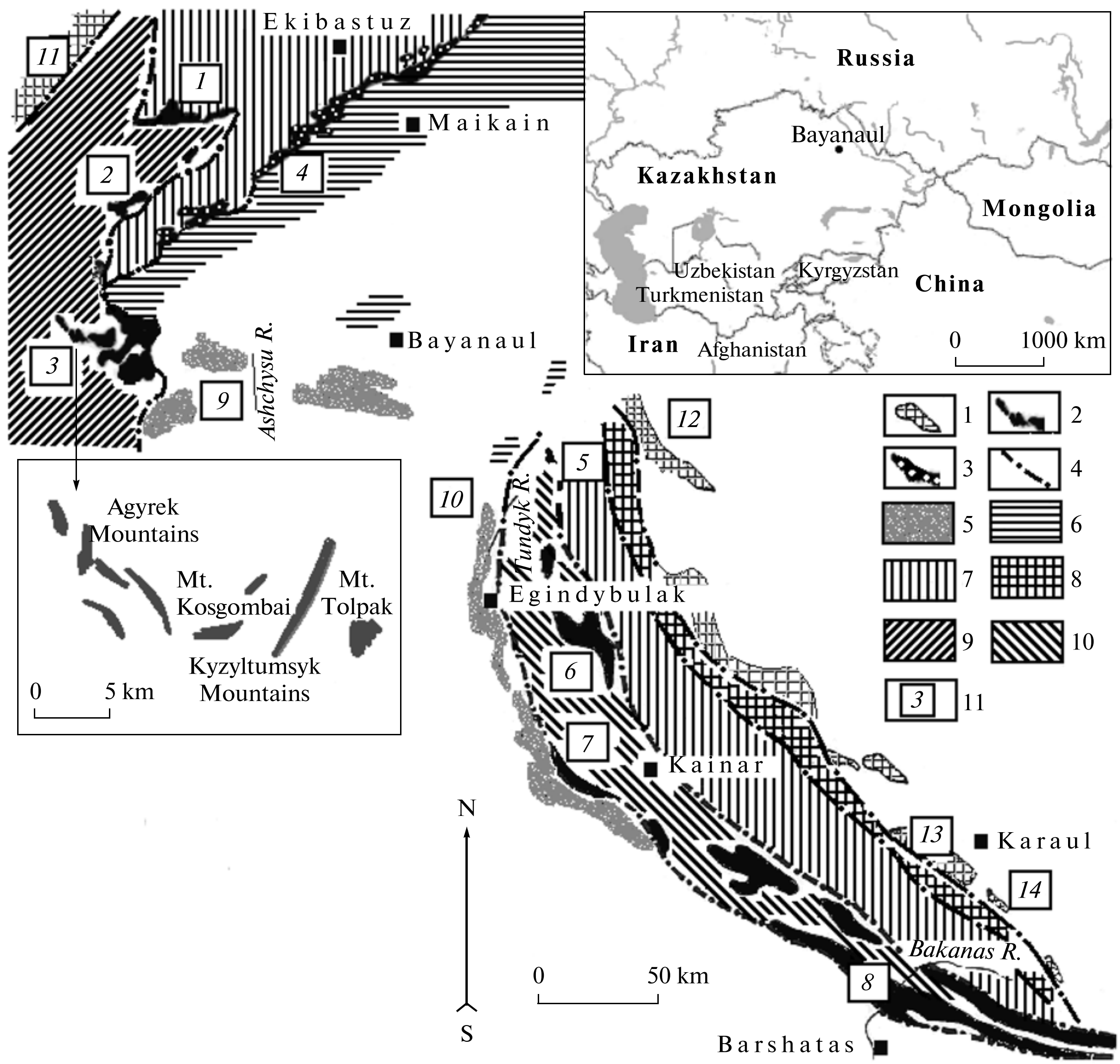

Fig. 1. Schematic map of lithotectonic zones in northeastern central Kazakhstan, southwestern Cisshyngyz and adjacent regions, compiled using the data from (Nikitin et al., 1995; Antonyuk and Vasyukov, 2003; Degtyrev and Ryzantsev, 2007; Stepanets, 2008b).

(1, 2) accretionary wedges: (1) Ermentau–Naimanzhal, (2) Agyrek–Arsalan; (3) Bogembai–Angrensor suture of fore-arc ophiolites; (4) boundaries of lithotectonic zones; (5–10) lithotectonic zones: (5) Bayanaul–Akshatau, (6) Angrensor–Mainkain, (7) Kendakty–Shyngyz, (8) Arkalyk, (9) Shakshan, (10) Otyzbes–Arsalan; (11) localities: (*1*) Lake Maisor, Sergili Ravine and Mount Baiakhmet, (*2*) Odak Ravine, (*3*) Agyrek and Kosgombai Mountains, (*4*) mounts Adil'bek and Balaarkalyk, (*5*) Mount Mayalzhen, (*6*) Mount Tokai, (*7*) Mount Otyzbes, (*8*) Mount Ushkyzyl, Arsalan River, (*9*) Karaulcheky Ravine, (*10*) left side of the Balatundyk River, (*11*) Mount Ermentau, (*12*) Mount Toksambai, (*13*) Mount Saryshoky, Naiman Ravine, (*14*) Kyzyltas.

ized. It contains blocks of serpentinites, gabbroids, pyroxenites, dolerites, basalts, and siliciliths. The groundmass surrounding different size olistholiths is usually represented by destruction products of tectonic slices: acute-angled block breccias and conglomerates cemented by finer material of similar composition. Away from slices, the last rocks are gradually replaced by poorly sorted conglomerates, gravelstones, and sandstones with obscure gradation bedding. The sandstones contain admixture of carbonate material and rare limestone lenses with corals (Outcrop 4189) *Reuschia* sp., *Propora* sp., and *Plasmoporella* sp. 1 and 2 indicating evidently their late Katian age (Chokpar Horizon of Kazakhstan).

Westward, the olistostromes pinch out to be replaced near the eastern slope of the Agyrek Mountains by upper Katian biohermal limestones, which overlie the serpentinite melange. The central part of the biohermal massif yielded corals of the *Holorynchus giganteus* Beds (Chokpar Horizon, Fig. 2,

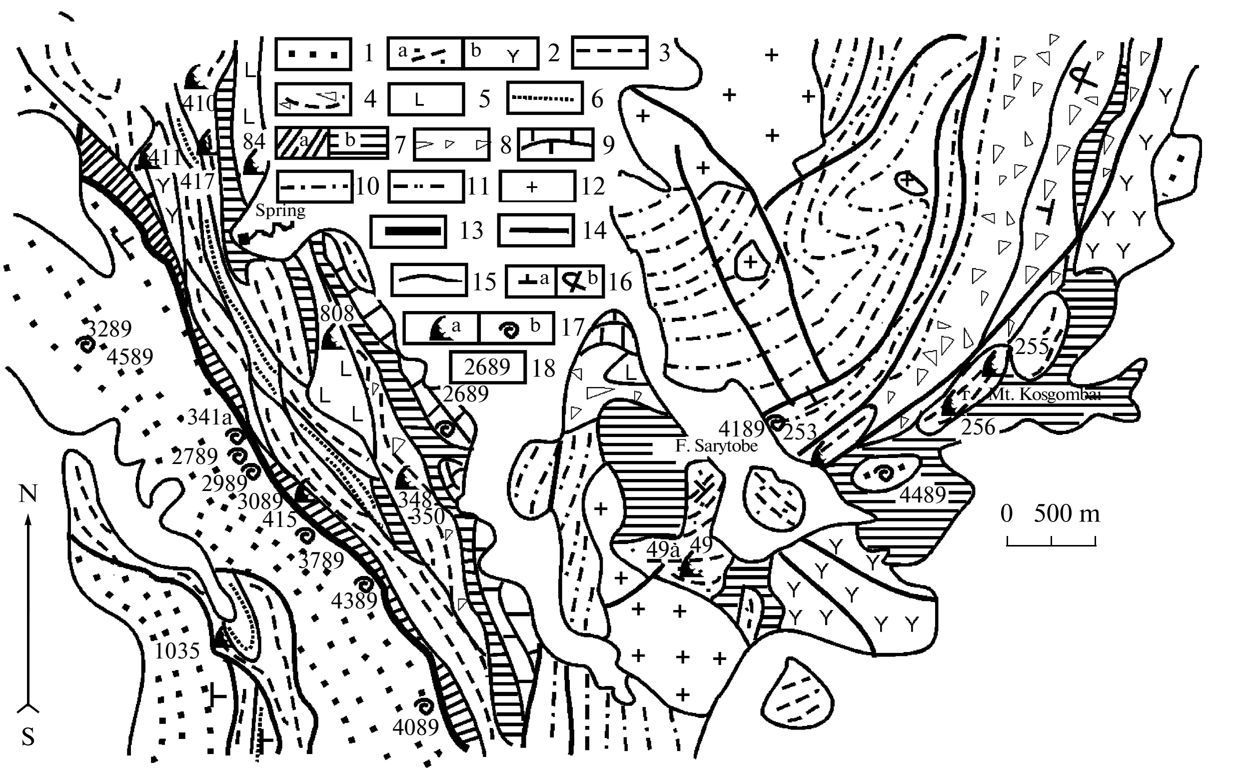

Fig. 2. Schematic geological map of the Mount Kosgombai and Agyrek Mountains (50.8°N, 74.2°E), after V.G. Stepanets, N.M. Gridina, and V.E. Konik, compiled using materials from Novikova et al. (1993).

(1) paraautochthon, carbonate–terrigenous sequence (O_3); (2–7) allochthons: (2) alkali basalt—uffaceous–siliceous: (a) tuffaceous–siliceous rocks, (b) alkali basaltoids, (3) Kosgombai siliciliths;, (4) siliceous–detrital rocks, (5) tholeiitic basalts, (6) greywacke sandstones of the Erkebidaik affinity, (7) melanges: (a) polymictic, (b) oligomictic; (8–11) neoautochthon: (8) back olistostrome, (9) limestones, (10) alternating calcareous sandstones, silty sandstones, and siltstones (O_3), (11) Karaaigyr Formation (S_1); (12) Middle Devonian granite–porphyries and felsites; (13) basement of the pre-folding slice; (14) tectonic faults; (15) boundaries of geological bodies; (16) attitude elements: (a) normal, (b) overturned; (17) finds of conodonts (a) and corals (b); (18) sample numbers.

Outcrop 2689). Higher in the section, the Agyrek back olistostrome is overlain by a carbonate–terrigenous sequence with brachiopods (Nikitin, 1972) and graptolites (*Ob''yasnitel'naya...*, 1981) of the Abak and Chokpar horizons of the Katian Stage. In the northern part of the Shakshan zone, it corresponds to the uppermost Tynkuduk Group the Late Ordovician in age (Ryzantsev and Rumyantseva, 1987). The carbonate–terrigenous sequence is gradually replaced by green-colored Lower Silurian siltstones of the Karaaigyr Formation (*Ob''yasnitel'naya...*, 1981).

Allochthonous complexes of the Agyrek–Kosgombai area are subdivided into several sequences distinctly differing in lithology, although close to each other in age: Kosgombai siliciliths ($?O_1fl_1–O_2da$), greywacke (O_3?), alkali basalt–tuffaceous–siliceous ($O_1tr?–O_2da$), tholeitic basalts (O_1fl), terrigenous–siliceous (O_1fl), and serpentinite melange units.

Figures 2 and 3 illustrate the distribution of these allochthonous complexes and their position in the section, respectively. It is clearly seen that they occupy certain positions in the section of the Agyrek olistostrome.

The lower packet of slices is composed of polymictic serpentinite melange and fragments of the alkali basalt–tuffaceous–siliceous sequence. The polymictic serpentinite melange outcrops along the southwestern slope of the Agyrek Mountains as a narrow discontinuous band up to 150 m wide and extending for >8.5 km. The intensely deformed harzburgite chrysotile–lysardite serpentinites, milonites, and listvenites envelope blocks of tectonized Lower Cambrian amygdaloid olivine basalts and dolerites petrogeochemically resembling intraplate low-Ti (TiO_2 = 1.90 wt. %; Al_2O_3 = 13.20 wt. %; Sr = 260 ppm; Rb = 24 ppm; Nb = 18 ppm; Y = 22 ppm; Cr = 240 ppm; Ni = 120 ppm) and high-Ti (TiO_2 = 2.50 wt. %; Al_2O_3 = 13.20 wt %; Sr = 98 ppm; Rb = 11 ppm; Nb = 11 ppm; Y = 28 ppm; Cr = 35 ppm; Ni = 34 ppm) basalt varieties. There are also bluish gray to gray schists and small rare blocks of brecciated glaucophane schists (*Ob''yasnitel'naya...*, 1981; Avdeev, 1986). The most common components in the

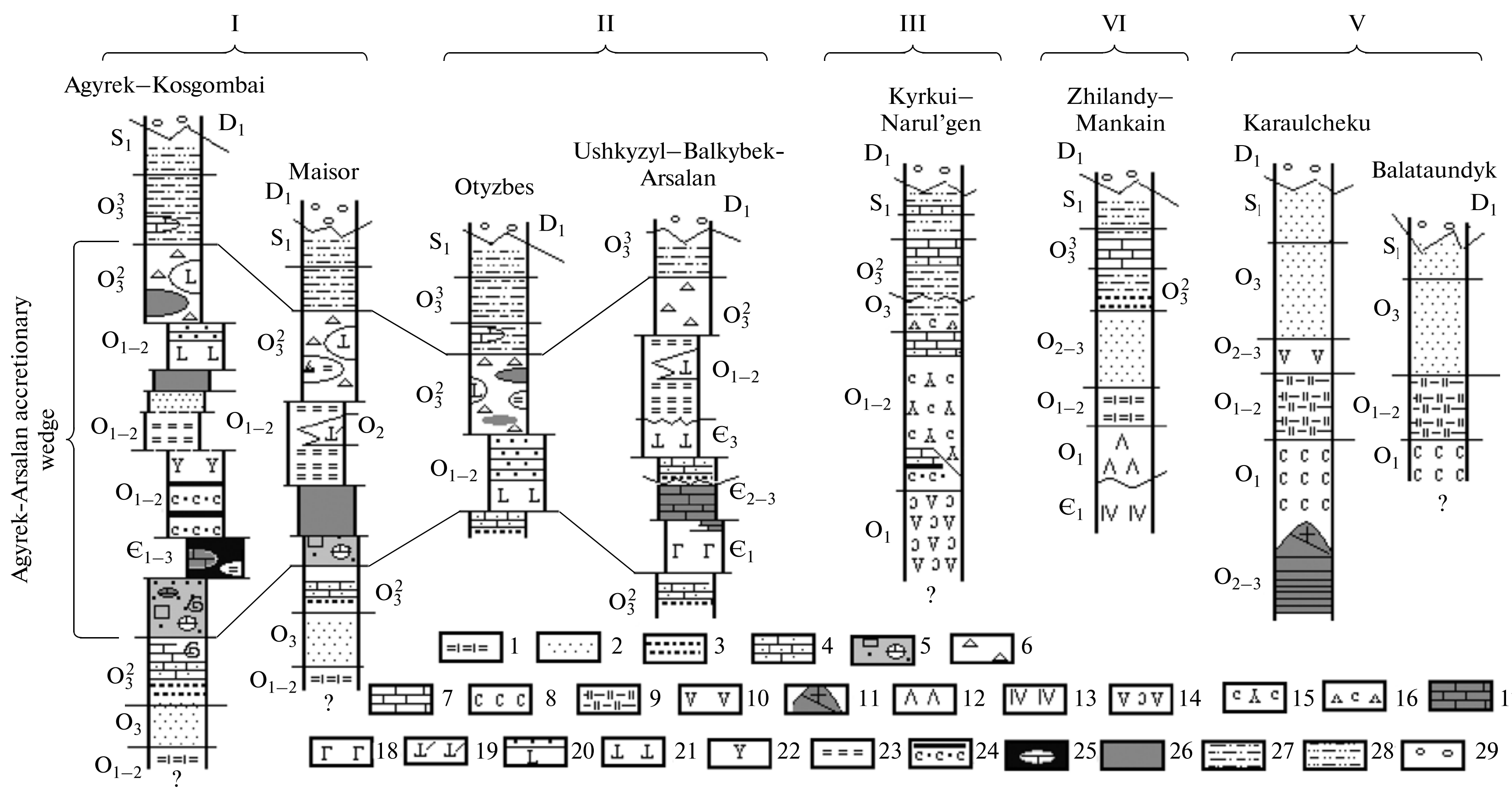

Fig. 3. Schematic sections of Lower Paleozoic complexes in the northeastern central Kazakhstan and southwestern Cisshyngyz area.

(I–V) lithotectonic zones: (I) Shakshan, (II) Otyzbes–Arsalan, (III) Kendykty–Shyngyz, (IV) Angrensor–Miakain, (V) Bayanaul–Akshatau.

(1–16) paraautochthonous complexes: (1) terrigenous–siliceous, (2) terrigenous green-colored flysch, (3) siltstones, sandstones, (4) calcareous sandstones, (5) frontal olistostrome, (6) back olistostrome, (7) limestones, (8) spilite–dolerites, (9) tuffaceous–siliceous–terrigenous, (10) calc–alkaline low-silica volcanics, (11) supra-subduction plutonic ophiolites, (12) alkali rhyolites and basalts, (13) green tuffs, (14) low-Ti high-silica porphyric andesites and basaltic andesites and their agglomerate tuffs, (15) low-Ti moderately silica basalts, basaltic andesites, andesites, dacitic andesites, and their tuffs, and rare boninites alternating with sandstones, siliceous siltstones, and jaspers, (16) high-silica andesites and their tuffs; (17–26) allochthonous complexes: (17) Cambrian limestones, (18) alkali olivine basalts, (19) differentiated volcanics, (20) tholeiitic basalts and tuffaceous–siliceous rocks, (21) primitive basalts, (22) alkali basalts, (23) siliciliths, (24) tuffaceous–siliceous rocks; (25, 26) serpentinite melanges: (25) polymictic, (26) oligomictic; (27–29) neoautochthonous complexes: (27) terrigenous and terrigenous–carbonate, (28) variegated siltstones and sandstones, (29) terrestrial conglomerates.

polymictic melange are blocks of jaspilites, variegated siliciliths, and detrital siliceous rocks with conodonts *Paracordilodus gracilis* Lindström (Fig. 2, Outcrop 415) of the Floian Stage (hereinafter, conodont identifications by N.M. Gridina).

In addition to blocks of rocks belonging to the ophiolitic triad, the polymictic melange encloses single blocks of marbled limestones with archaeocyathids (Fig. 2, Outcrop 3089) such as *Vologdinocyathus borovikovi* (Konjuschkov) and *Korovinella vistulata* (Konjuschkov), which are characteristic, according to A.Yu. Zhuravlev, of the Lower Cambrian and blocks of recrystallized limestones (Fig. 2, Outcrop 3789) with corals typical of the *Holorynchus giganteus* Beds. I.E. Kuznetsov described in (Novikova et al., 1993) peculiar ophiolitic clastites consisting of fragments of serpentine, biotite, chlorite, chrome spinel, and amphibole cemented by chlorite–serpentine material.

Thin slices of the alkali basalt–tuffaceous–siliceous sequence outcrop along the western slope of the Agyrek Mountains. Thick slices of alkali basaltoids are widespread near the Sarytobe farm (Fig. 2). They spatially associate with tectonic slices of the tuffaceous–siliceous sequence. L.A. Kurkovskaya found in siliciliths of the last sequence (Outcrop 49a) a fragment of the platfrom conodont of the Middle Ordovician affinity and *Protopanderodus* cf. *rectus* (Lind.), in addition to conodonts of the Floian Stage (Outcrop 49): *Paracordylodus gracilis* Lindström*, Oepikodus communis* (Ethington et Clark), *Baltoniodus* sp., ?*Acodus deltatus* McTavish.

The paleontologically best characterized section of the alkali basalt–tuffaceous–siliceous sequence outcrops at the northwestern piedmont of the Agyrek Mountains (Fig. 2). In this area, the listvenite zone up to 8 m thick is overlain by a variegated sequence (up to 72 m thick) of light gray and dark green cherts, siltstones, silty tuffites, and rare sandstones with intercalations of red clayey jaspers, cherry-colored argillites and tuffites. This sequence overlies terrigenous–carbonate rocks of the paraautochthon. The massive dark green cherts contain conodonts conditionally attributed to *P. elegans* and *O. evae* zones of the Floian Stage: *Paracordylodus gracilis* Lindström, M element of *Tropodus sweeti* (Sepragli), and *Prioniodus* sp. Higher in the section, banded light gray and dark green siliciliths with Middle Ordovician conodont *Periodon* sp. are overlain by cherts with conodonts *Periodon aculeatus* Hadding, probably, of Darrivilan age. Red massive thick-bedded clayey jaspers from the uppermost part of the section yielded Darriwilian conodonts *Periodon aculeatus* Hadding, *Periodon flabellum* (Lindström), *Histiodella* cf. *holodenata* (Ethington et Clark), *Paroistodus* sp. These rocks are overlain by a sequence (up to 72 m thick) of lilac–gray and dark gray amygdaloid phonotephrites, tephrites, and trachybasalts with beds of red massive jaspers. The basaltoids are highly enriched with large-ion lithophile (Nb < 65 ppm, Zr < 760 ppm, Rb < 75 ppm, Y < 40 ppm, TiO_2 < 3.70 wt %, P_2O_5 < 1.12 wt. %) and depleted in coherent (Cr > 10 ppm, Ni > 25 ppm) elements (Stepanets, 2008a), which makes them close to similar rocks from Sakhalin superplumes (Tatsumi et al., 1998).

Structurally higher, these rocks are overlain by tectonic slices of deformed Kosgombai siliciliths and greywacke rocks. In the northern part of the western slope of the Agyrek Mountains (Fig. 2), N.M. Gridina described in one of the fragments of distorted homocline (azimuth of the strike 80° and dip angle 60°) a slightly reduced section of Kosgombai siliciths 18.7 m thick (Stepanets et al., 1998). Four stratigraphic levels of this section yielded different-age conodonts (Outcrop 417): (1) *Prioniodus elegans* Pander, *Paracordylodus gracilis* Lindström, M element of *Tropodus sweeti* (Serpalgi), *Ansella?* sp., *Paraistodus proteus* of the Floian Stage (Lower Ordovician); (2) *Baltoniodus* cf. *navis* Lindström, *Oepikodus intermedius* (Serpagli), *Periodon flabellum* (Lindström), *Paroistodus* sp., from the basal part of the Dapingian Stage of the Middle Ordovician (probably, the *B. navis* Zone); (3), rare *Periodon flabellum* (Lindström) from the unnamed zone of the uppermost Dapingian Stage; (4) *Paroistodus horridus* (Barnes et Poplawski) and *Periodon flabellum* (Lindström) from the basal part of the Darriwilian Stage.

The central part of intermontane depressions of the Agyrek Mountains hosts a sequence of graywackes barren of fossils. The sequence is composed of green shelly highly magnetic greywackes, gravelstones, and subordinate conglomerates up to 300 m thick. By their lithology and textural–structural properties, the graywackes are conditionally correlated with the stratotype section of the Erkebidaik Formation (Nikitin, 1972).

The greywacke sequence is thrust by a slice of intensely deformed siliciliths >300 m thick with conodonts of the Dapingian Stage (Outcrop 410): *Paracordylodus gracilis* Lindström, *Periodon* sp., and *Tropodus sweeti* (Sepragli).

This slice is, in turn, overlain by the upper packet of slices, where oligomictic serpentinite melange alternates with allochthonous sequences of tholeiitic basalts and fragments of sequences composed of siliceous detrital rocks, siliceous siltstones, and siliciliths. The oligomictic serpentinite melange (Fig. 2) forms tectonic lenses and wedges 1 to 7 km long and up to 1000 m wide in the Mount Kosgombai and Sarytobe farm area. The melange groundmass is composed of tectonized (up to schists) lizardite, chrysotile, and chrysotile–asbest harzburgite serpentinites with boudins of dunites, chromites, garnet-bearing serpentinized ultramafics, gabbroids, gabbro–amphibolites, amphibolites, dolerites, boninites, rare diorites, quartz diorites, and plagiogranites, blocks of basalts similar to tholeiitic basalts from the Floian Stage, and siliciliths.

A large slice of green to greenish gray basalts of the Floian Stage up to 120 m thick outcrops along the eastern slope of the Agyrek Mountains (Fig. 2) and small blocks of similar basalts are observable within the serpentinite melange and back olistostrome. Massive lavas alternate with tuffstones and siliceous silty tuffites, amygdaloid basalts contain limestone lenses, and pillow basalts enclose rare boudins of brown–red jaspers with the conodonts *Oepikodus evae* Lindström, *Drepanodus arcuatus* Pander, *?Peiodon* sp. (Fig. 2, Outcrop 84; Novikova et al., 1993) and *Paracordylodus gracilis* Lindström, *Oepikodus communis* (Ethington et Clark), *Acodus (?) longibasis* (McTavish) (Fig. 2, Outcrop 808; Stepanets, 1992; Stepanets et al., 1998), which are characteristic of the lower and middle parts of the Dapingian Stage (according to L.A. Kurkovskaya). The tholeiitic basalts (Al_2O_3 < 17.0 wt %), depleted in K_2O (0.10–0.42 wt %) and enriched with N_2O (<5.54 wt. %), TiO_2 (1.11–1.55 wt. %), FeO_{tot} (<11.91 wt %), Nb (5.0–6.6 ppm), Y (<37 ppm), and characterized by wide variations in concentrations of coherent elements ((Cr = 32–170 ppm, Ni = 2–54 ppm), which is typical of basalts from back-arc spreading basins (*Geologiya*..., 1987). Petrogeochemically similar pillow basalts outcrop also in intensely deformed slices near northern spurs of Mount Tolpak (Fig. 1, *3*). In this area, they were first included into the Vendian Tolpak Formation (Antonyuk, 1971) and later were attributed to the Lower–Middle Ordovician basaltic–tuffaceous–siliceous sequence (Stepanets, 1990).

Near the eastern slope of the Agyrek Mountains, the sequence of tholeiitic basalts are overlain by a thick slice of detrital siliceous rocks, siliciliths, and subordinate siliceous siltstones. Samples taken from three outcrops of these rocks (348–350) yielded only conodonts of the Floian Stage (Lower Ordovician): *Paracordylodus gracilis* Lindström, *Tropodus sweeti* (Serpalgi), *Periodon* sp.

CORRELATION OF ALLOCHTHONS AND OLISTOSTROMES

In the classical model of the upper part of the ophiolitic association corresponding to sections of oceanic basins, basalts are located stratigraphically below siliceous and carbonate–siliceous facies or alternate with them in the upper part of the section (Peive, 1969). Our predecessors followed this classical model (Antonyuk, 1971; Dvoichenko and Abaimova, 1986; Novikova et al., 1993) considering it valid for the entire development area in central Kazakhstan and a priori considering all the basalts as being oceanic (Antonyuk, 1971). The last author described a succession composed of basalts of the Maikain Formation in the lower part and siliciliths of the Kosgombai Formation in the upper one, and other researchers (Novikova et al., 1993) united them into the Kosgombai Group.

As is evident from the lithological and paleontological analysis of siliceous and siliceous–volcanogenic sequences of the area under consideration (Stepanets et al., 1998), this succession is distorted in allochthons of the Agyrek Mountains. This is best exemplified by the alkali basalt–tuffaceous–siliceous sequence outcropping in the Agyrek Mountains. In this area, jaspers of the tuffaceous–siliceous member occurring structurally below alkali basaltoids contain Early Ordovician (Floian Stage) conodonts of the *P. elegans–O. evae* zones and Middle Ordovician (lower Darriwilian Stage) conodonts of the *M. ozarkodella* Zone. The occurrence of conodonts *Paracordylodus gracilis* Lindström characteristic of the uppermost Tremadocian and basal Floian stages in similar rocks of the Sarytobe farm area (Fig. 2) indicates that the lower boundary of the alkali basalt–tuffaceous–siliceous sequence may be as old as the Tremadocian (Fig. 4).

The classical basalt–silicilith succession finds no confirmation in correlation models of Kosgombai siliciliths and tholeiitic basalts through the eastern slope of the Agyrek Mountains. The occurrence of conodonts characteristic of the *P. elegans–M. ozarkodella* zones in the Kosgombai “sterile” siliciliths indicates that tholeiitic basalts enclosing siliceous–tuffaceous members with conodonts the *O. evae* Zone and older (Stepanets et al., 1998) are coeval with the basal part of the Kosgombai siliciliths, not underlie them (Fig. 4).

It is conceivable that the model, where basalts are overlain by siliceous–tuffaceous rocks, is likely suitable for sections of northern spurs of Mount Tolpak. In this area, tholeiitic basalts compositionally corresponding to volcanics of back-arc spreading basins (Stepanets, 1992) and tholeiitic basalts from the eastern slope of the Agyrek Mountains are overlain by siliceous–terrigenous rocks of the Darriwilian Stage (Middle Ordovician) with members of intraformation breccia–conglomerates (Stepanets, 1990).

Despite many finds of conodonts in the Kosgombai siliciliths, their age remains debatable. In the continuous succession, these rocks are marked by four faunal levels: from the uppermost Lower Ordivician *P. elegans* Zone of the Floian Stage to the Middle Ordovician *M. ozarkodella* Zone of the Darriwilian Stage (Fig. 4). The block of cherts in the Odak Ravine (Fig. 1, *2*) yielded Late Cambrian conodonts *Phakelodus tenuis* (Müller), *Prooneotodus gallantini* (Müller), *P. rotundatus* (Druce et Jonas), and *Eoconodontus* (*E.*) *notchpeakensis* (Müller) (unpublished data by L.A. Kurkovskaya) and variegated siliciliths in the Sergili Ravine area(Fig. 1, *1*) contain late Darriwilian conodonts from the *P. serra* Zone (Stepanets, 2008b). M.Z. Novikova assumes in (Novikova et al., 1993) the unconformable occurrence of sandstones of the Erkebidaik affinity with conglomerates at the base above the siliciliths with conodonts of the middle and late Dapingian in the southwestern spur of the Agyrek Mountains (Fig. 2, Outcrop 1035), although this

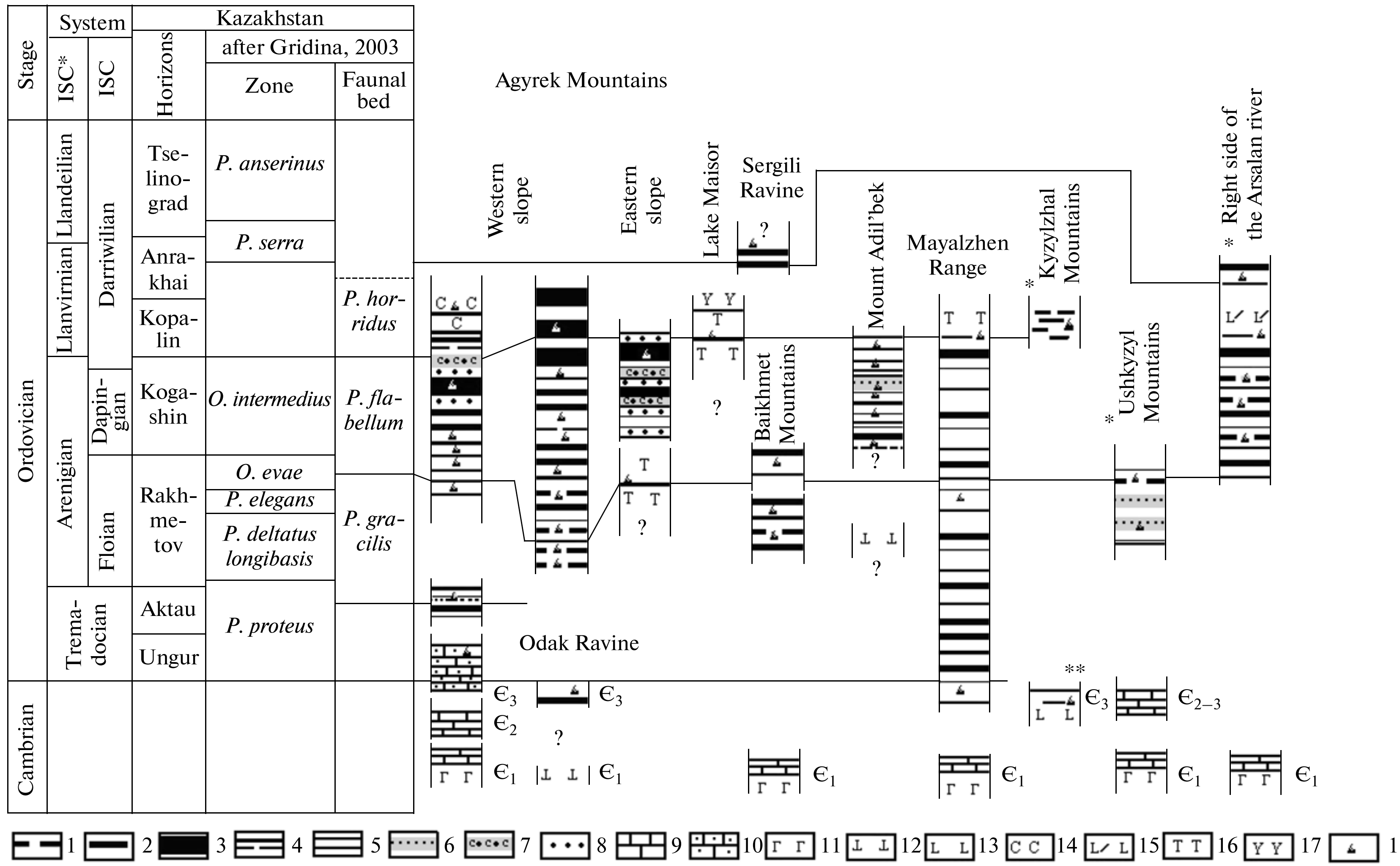

Fig. 4. Schematic correlation between allochthonous complexes of the Agyrek–Arsalan accretionary wedge.

(1–6) lithological characteristic of siliciths: (1) porcelain cherts, (2) mostly red cherts, (3) massive red-colored radiolarites, (4) alternating green and red radiolarites, (5) green cherts, (6) light gray banded detrital jaspers; (7) tuffstones and tuffaceous siltstones; (8) alternating sandstones and siltstones with silicilith intercalations; (9) limestones; (10) calcareous sandstones and siltstones; (11–17) volcanics: (11) Balkybek OIB, (12) Balaarkalyk N-MORB, (13) Kyzylzhal volcanics, (14) Agyrek alkali basaltoids, (15) Balgashok primitive basalts, (16) tholeiitic basalts, (17) calc-alkaline volcanic; (18) conodonts. (ISC) International Stratigraphic Scale, 2008; (ISC*) after (Harland et al., 1985); (*) sections compiled after data by (Nikitin et al., 1992); (**) sections compiled after data by (Degtyarev, 1999). Black lines designate boundaries of faunal beds.

boundary remained, in fact, unstudied. The lower boundary of the Erkebidaik Formation in the Shakshan zone (Fig. 1) is placed at the base of the Katian Stage (Tolmacheva et al., 2009) and there are insufficient grounds to correlate the upper boundary of the Kosgombai siliciliths in this region with the Sandbian Stage, as it was proposed by Yakubchuk et al.(1989). In addition, it is conceivable that terrigenous–siliceous strata outcropping in the southwestern part of the Agyrek Mountains (Fig. 2) may represent a fragment of the Erzhan Formation widespread near Lake Sasyksor east of Ermentau (*Ob"yasnitel'naya*..., 1981). This assumption needs, however, to be tested by additional mapping and bed-by-bed sampling of conodonts in siliceous rocks outcropping in southwestern spurs of the Agyrek Mountains.

It is impossible to determine the complete stratigraphic range of the Kosgombai siliciliths primarily because of unknown stratigraphic relationships at their upper and lower boundaries. Taking the paleontological data into consideration, the Kosgombai siliciliths forming tectonic slices mainly on the eastern slope of the Shakshan zone may be accepted, with certain conditionality, as the Late Cambrian–Middle Ordovician in age, i.e., attributed to the Darriwilian Stage. Since no Tremadocian conodonts have so far been found in the Kosgombai siliciliths, the Late Cambrian age of their basal layers remains doubtful. Corresponding conodont assemblages are identified in the continuous silicilith section of the Burubaital Formation in the western Balkhash region (Popov and Tolmacheva, 1995) and in siliciliths of the Naimanzhal Formation (Ergaliev et al., 1998) of the Ermentau–Naimanzhal accretionary wedge in central Kazakhstan (Fig. 1).

The thickness of the Kosgombai siliciliths is considerably lower than it is believed (*Ob"yasnitel'naya*..., 1981; Novikova et al., 1993) likely reaching 20 m, not more, in the interval from the base of the *Paracordylodus gracilis* Beds to the top of the *Periodon flabellum* Beds. Comparable thicknesses of silicilith sections are also known for the Naimanzhal Formation in the Mount Toksambai area (Fig. 1, *12*) of the Ermentau–Naimanzhal accretionary wedge (Gridina, 2003), Burubaital Formation of the western Balkhash region (Popov and Tolmacheva, 1995), and siliciliths in the Mount Adil'bek area (Fig. 1, *4*) of the Bogembai–Angrensor ophiolitic suture (Stepanets, 1992).

Despite the distinct structural relationships between allochthonous complexes of the Agyrek olistostrome (Fig. 3), it remains unclear, which types of basalts and sedimentary rocks occurring in serpentinite melanges formed primarily single ophiolitic associations. The fundamental questions concerning the stratigraphy of upper members of ophiolitic associations in the northeastern part of central Kazakhstan, as to which volcanics were overlain by the Kosgombai siliciliths and whether or not they were of oceanic origin, remain unanswered as well. The basal part of the silicilith sequence is universally detached; therefore, their underlying rocks are unknown.

Thus, it is of interest that the base of the allochthonous Kosgombai siliciliths, which are observed in accretionary wedges of the eastern flank of the Shakshan zone and correlated with facies of the back-arc basin (Stepanets, 1992), is usually represented by blocks of Lower Cambrian basalts belonging to the Balkybek Formation (Fig. 4), for example, on the western slope of the Agyrek Mountains (Fig. 1, *3*; Fig. 4) and northern slope of the Baiakhmet Mountains (Fig. 1, *1*; Fig. 4). A similar position is also occupied by blocks of Lower Cambrian basalts in the Mayalzhen (Fig. 1, *5*; Fig. 4) and Ushkyzyl (Fig. 1, *8*; Fig. 4) mountains of the southwestern Cisshyngyz region. Consequently, we observe a complete similarity between sections of Lower Cambrian carbonate–basaltic allochthons of the Balkybek Formation within the Agyrek–Arsalan accretionary wedge, although the age of allochthonous Ordovician island-arc complexes is changeable (Fig. 4).

If it is accepted that abyssal basalts of the Agyrek–Arsalan accretionary wedge reflect the composition of the Vendian–Early Cambrian oceanic crust, one may assume with some caution that they could serve as the basement for the Kosgombai siliciliths, while in the Middle and Late Cambrian, summits of uplifted islands were occupied by algal and algal–archaeocyathid bioherm biuldups. The Middle Cambrian–Middle Ordovician period was marked by accumulation of sedimentary–volcanogenic complexes of the Shakshan and Otyzbes–Arsalan back-arc spreading basins on the Vendian–Early Cambrian oceanic and, probably, fragmentarily on the continental crust. Fragments of sections of the fore-arc basin (Azerbaev, 2009) are preserved in the Arkalyk zone and, in the form of a narrow band along the southeastern branch of the Kendykty–Shyngyz zone (Fig. 1).

The formation analogs of fragmentary tectonic slices of the Agyrek olistostrome are represented by allochthonous Lower–Middle Ordovician volcanogenic and siliceous–tuffaceous–terrigenous deposits in the Otyzbes Mountains (Fig. 1, *7*; Fig. 3). In this area, tectonic slices are overlain, similar to the Agyrek Mountains, by the upper KatianKatian (Otyzbes) olistostrome, which are reliably attributed based on brachiopod assemblages to the Chokpar Horizon of the upper Katian Stage (Nikitin et al., 1995). The olistostromes of the Otyzbes Mountains are gradually replaced higher in the section by the sedimentary sequence with early Llandovery graptolites (Bandaletov, 1969).

Previously, these deposits were correlated with sections of the Kuv Formation (Nikitin et al., 1995) in the left side of the Balatundyk River (Fig. 1, *10*). These sections are constituents of the Bayanaul–Akshatau zone (Antonyuk et al., 1995), where flyschoid sediments accumulated during the Late Ordovician and Early Silurian. Taking into consideration the

KatianKatian age of the olistostrome in the Otyzbes Mountains, it is reasonable to attribute tectonic slices of Lower–Middle Ordovician volcanogenic and siliceous–tuffaceous–terrigenous sequences to structures of the Agyrek–Arsalan accretionary wedge (Fig. 1, *7*). This conclusion is consistent with the occurrence of blocks composed of Upper Cambrian–Lower Ordovician siltstones and sandstones in the Otyzbes Mountains (Nikitin et al., 1995). Similar rocks occur also in the Agyrek Mountains (Fig. 4). The Bayanaul–Akshatau zone hosts the Karaulcheku dolerite–spilite complex that occurs at the base of the Lower–Upper Ordovician volcanogenic–tuffaceous–siliceous Akozek Formation that represents an age and formation analog of the Kuv Formation in the left side of the Balatundyk River (Fig. 3). These deposits are correlated with facies of the fore-arc basins (Stepanets, 1992). This is consistent with the occurrence of layered mafics–ultramafics in the basement of the paraautochthon in the Karaulcheky with wehrlites and lherzolites containing high-Ti and high-Fe chrome spinelids (Stepanets, 2007) characteristic of peridotites from fore-arc basins (Azer and Stern, 2007).

Tectonic slices outcropping in the interfluve of the Samsy–Bakanas–Arsalan rivers (Fig. 1, *8*) in the southwestern Cisshyngyz area (Nikitin et al., 1992; Nikitin, 2002) are also analogs of the Agyrek olistostrome. According to many studies (Zhautikov, 1976; Kherskova, 1986; Stetsyura, 2006), blocks of Middle and Upper Cambrian limestones and slices of Lower Cambrian Balkybek basalts, fragments of which are known among polymictic melange and Agytrek frontal olistostrome, are widespread in this area. Numerous blocks of variegated Ushkyzyl siliciliths and high-Fe Balgashok basalts the Early and Middle Ordovician in age are found in the Samsy–Bakanas–Arsalan river interfluve (Nikitin et al., 1992).

While correlation between Early Cambrian basalts of the carbonate–basaltic Balykbek association in these areas is undoubted, analogs of the Balgashok basalts in the eastern flank of the Shakshan zone are unknown. The defined petrogeochemical properties of Balykbek volcanics that were formed on the Balykbek guyot (or seamount) (Azerbaev, 2009) provide grounds for their correlation with island plume basalts of the underwater Kinan Ridge in the Philippine Sea (Sato et al., 2002).

Based on the analysis of conodonts in continuous Lower and Middle Ordovician (Floian–Darriwilian Darriwilian stages) siliceous sections, Gridina (Stepanets et al., 1998) defined three their successive complexes (faunal beds). They correspond to acme zones, i.e., layers that reflect the bloom or maximal development of some taxon, not its complete stratigraphic range. The maximal development means highest abundance of some species or highest number of species in a genus (*Mezhdunarodnyi*..., 1978). The characteristic of defined faunal beds and their correlation with the conodont zonation for the Baltoscandia region (Löfgren, 1977; Dubinina, 1990) and International Stratigraphic Scale of the Ordovician System (Begström et al., 2008) are given below.

(1) *Paracordylodus gracilis* Beds: (a) *Prionodus elegans* Zone: *Paracordylodus gracilis, Prionodus elegans, Acodus deltatus longibasis, Paroistodus proteus, Protopanderodus robustus, Tropodus sweeti, Drepanodus arcuatus, Protoprionodus* sp., *Bergstroemognathus* sp., *Drepanodus* sp.; (b) *Oepikodus evae* Zone: *Paracordylodus gracilis, Oepikodus evae, Prioniodus elegans, Periodon flabellum, Drepanodus arcuatus, Tropodus sweeti, Acodus* aff. *emanuelensis, Acodus* aff. *deltatus, Paroistodus* sp., *Protoprionodus* sp., *Drepanodus* sp., *Oistodus* sp.; The *Paracordylodus gracilis* Beds consisting of the successive *Prioniodus elegans* and *Oepikodus evae* zones are correlative with the uppermost part of the Latorp Horizon of Baltoscandia and correspond to the uppermost Rakhmetov Horizon of Kazakhstan and uppermost Floian Stage of the Lower Ordovician Series in the International Stratigraphic Scale (ISC, Fig. 4).

(2) *Periodon flabellum* Beds: *Periodon flabellum, Oepikodus intermedius, Baltoniodus navis, Prioniodus* aff. *oepkii, Oepikodus* aff. *communis, Paroistodus* sp., *Paroistodus originalis, Drepanodus arcuatus, Protoprioniodus* sp., *Paracordylodus* sp., *Drepanodus* sp., *Oistodus* sp. The *Periodon flabellum* Beds are correlated with the Volkhov Horizon and basal part of the Kundak Horizon in the Baltoscandia region and the Kogashik Horizon of Kazakhstan corresponding to the Dapingian Stage of the Middle Ordovician (ISC, Fig. 4). It should be emphasized that basal layers of the *Periodon flabellum* Beds contain abundant specimens of *Oepikodus intermedius*, which is atypical for Baltoscandia and is described from the San Juan Formation of Argentina (Serpagli, 1974) in the middle and upper parts of the Zone P. correlated with the *B. triangularis–navis* Zone. There are observations that *O. intermedius* is widespread in central Kazakhstan, where it characterizes the synonymous zone corresponding to the *B. triangularis–navis* Zone. The conodont assemblage from the upper part of the *Periodon flabellum* Beds is impoverished consisting only of the index species accompanied by rare representatives of other taxa.

(3) *Paroistodus horridus* Beds: *Paroistodus horridus, Periodon flabellum*, and appearing slightly higher, *Periodon aculeatus, Histiodella* cf. *holodentata*, and *Paroistodus* sp. The *Paroistodus horridus* Beds are correlative with the uppermost Kundas Horizon and Azeris Horizon of Baltoscandia (*Microzarkodina ozarkodella* and *Eoplacognathus suecicus* zones (subzones), respectively), Kopalin Horizon and basal Anrakhai Horizon (or basal Darriwilian Stage of the Middle Ordovician) of Kazakhstan (ISC, Fig. 4). *Paroistodus horridus* is widespread in siliceous sequences of Central Kazakhstan; in addition, it is described from limestones of the Uzunbulak Formation (Zhilkaidarov, 1991), basal layers of which form a stratotype of the Kopalin Horizon.

CONCLUSIONS

The occurrence of corals from the *H. giganteus* Beds in rocks underlying and overlying tectonic slices as well as in olistostrome facies and serpentinite melanges indicates short duration of thrusting periods and burial of tectonic imbricate sections within the Agyrek–Arsalan accretionary wedge. The lithology of tectonic slices reflects the composition of different lithotectonic zones in Early Paleozoic basins of central Kazakhstan.

The peridotite melange and tectonically juxtaposed Early Cambrian basalts, Lower–Middle Ordovician alkali basalt–tuffaceous–siliceous and siliceous sequences overlain by the Katian olistostrome belonged to different Early Paleozoic associations.

The Lower Cambrian and Ordovician volcanics are not geochemical analogs of MORB facies; considerable variations in concentrations of coherent elements and Mg make them close to volcanics of back-arc spreading basins.

The occurrence of chromite, gabbroid, amphibolites, dolerite, boninite, basalt, rare diorite, quartz diorite, and plagiogranite boudins within the serpentinite melange implies that these rocks originate from a destroyed ensimatic island arc.

The data presented just outlined the main problems and defined objects, which may help, in case of their further investigation, to understand the geodynamic history of the central Kazakhstan Paleozoides.

Further studies should be aimed at the search for tectonically slightly disturbed blocks of siliceous rocks, which should be subjected to bed-by-bed sampling for conodonts in order to reveal their Cambrian and Tremadocian levels within both the Kosgombai siliciliths and siliceous–terrigenous sequences of the Agyrek Mountains. Taking into consideration high Zr concentrations in alkali basaltoids of the Agyrek Mountains, they should be sampled for discovery of potential zircon deposits as well; jaspers intercalating these volcanics should be sampled for conodonts.

Thorough geochemical studies of Early Cambrian basalts in the Agyrek –Arsalan accretionary wedge are important for determining whether they are products of the enriched (U+Th/Pb) mantle or whether they correspond compositionally to EMI or EMII facies. The answer to this question solve the long standing problem of the origin of the central Kazakhstan structures, whether they were constituents of the Paleoasian ocean in the Early Cambrian (Antonyuk, 1971) or formed in small oceanic basins (Seitov, 1988) that resulted from rifting of the continental crust.

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