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TIMING OF COLLISION OF THE KOKCHETAV MASSIF WITH THE STEPNYAK ISLAND ARC ON THE BASIS OF CONODONTS AND RADIOLARIANS FROM SILICEOUS ROCKS OF JUXTAPOSED TERRANES OF DIFFERENT GEODYNAMIC SETTINGS

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The siliceous rocks from structures of the junction zone of the Kokchetav massif and Stepnyak trough that occur in turbidites of the accretionary wedge, silica-volcanogenic sequence of the Stepnyak trough and syntectonic olistostrome were dated on the basis of findings of conodonts and radiolarians within the Middle-Upper Arenigian (conodont zones O. evae, B. navis—lower Par. originalis). This range of time is marked by a powerful tectonic rearrangement, involved with the rearrangement of the accretionary wedge and overriding of the Kokchetav massif upon the Stepnyak fore-arc trough.
Collision, olistostrome, thrust, conodonts, Kokchetav massif

INTRODUCTION

In northern Kazakhstan, siliceous rocks are widespread, often associated with volcanics, which are traditionally referred to as the Nikolskoe-Burluk Group recognized by Shlygin [1]. Structurally, this group belongs to the framing of the Kokchetav massif, in particular, to the zone of junction with the Stepnyak trough [2, 3]. The lower part of the group includes metamorphosed diabases, basalts, andesite-basalts, spilites, liparites and their tuffs, and siliceous siltstones. The upper part is made up of jaspers, jasper-quartzites, sandstones, conglomerates, siliceous mudstones. The group is exposed best of all near the town of Kokchetav and at the Chaglinka River. In the late 1980s, Ivanov [2] was first to find conodonts at the Chaglinka River. In the early 1990s, large-scale surveys were carried out with the purpose to date the siliceous and volcanogenic-siliceous formations of the Kokchetav massif, to outline their distribution in area, to locate them stratigraphically, and to correlate them with the regional stratigraphic scale of Kazakhstan. In 1990–92, the studies were carried out by a working group headed by Tsay [3]. They found about 50 new occurrences of the Ordovician conodonts in the Nikolskoe-Burluk Group of the northern Kokchetav massif and in the Zhanasui Formation of the southern Shat massif. These findings corroborated the Early Ordovician (Arenigian) age of the Nikolskoe-Burluk Group and its analogs rather than their Precambrian or Cambrian age as was supposed earlier.

This paper reports new data on findings of conodonts in the siliceous-volcanogenic formations of the zone of junction of the Kokchetav massif and Stepnyak trough. Siliceous rocks were sampled in the process of detailed geological mapping, which permitted them to be referred to different structures: turbidite olistostrome-bearing sections of accretionary wedge, syntectonic olistostrome, and association of basalts of the Stepnyak fore-arc trough (Fig. 1). More than 40 samples of siliceous rocks were collected, and some of them contain radiolarians and conodonts of different degrees of preservation. In general, the radiolarians are poorly preserved, and only sample

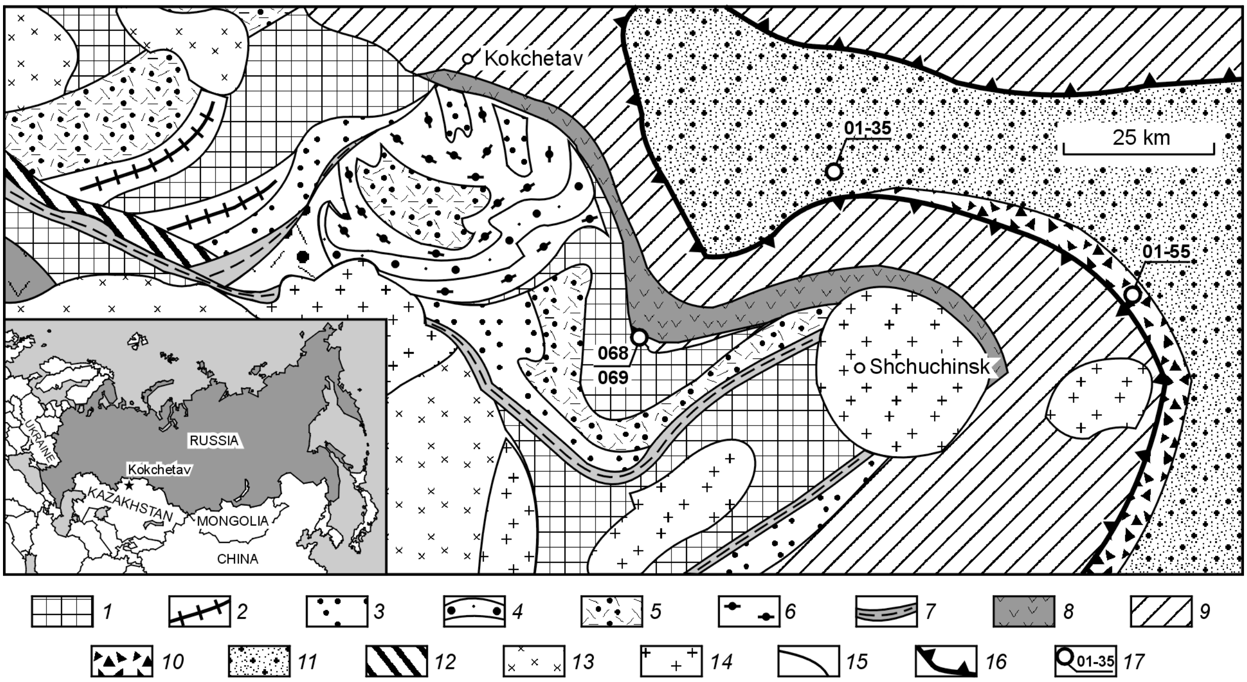

Fig. 1. Tectonic scheme of northern Kazakhstan and location of samples with conodonts and radiolarians. ***1*** **— fragments of the sedimentary cover of the Kokchetav microcontinent,** ***2–6*** **— megamelange belt (terranes of paleosubduction zone):** ***2*** **— diamondiferous gneisses and coesite eclogites,** ***3*** **— coesite eclogites, eclogites and garnet amphibolites in mica schists,** ***4*** **— garnet peridotites, eclogites, amphibolites,** ***5*** **— eclogites and garnet amphibolites in granite gneisses,** ***6*** **— garnet-sillimanite-cordierite schists (mylonites and blastomylonites) with boudins of eclogites and garnet amphibolites;** ***7*** **— garnet-cordierite-biotite schists and gneisses (Daulet Formation);** ***8*** **— Vendian(?) volcanosedimentary rocks;** ***9*** **— Early Ordovician accretionary prism;** ***10*** **— Late Arenigian-Early Caradocian syntectonic olistostrome;** ***11*** **— Ordovician volcanosedimentary rocks of the Stepnyak trough;** ***12*** **— Cambrian Krasnomaisky alkaline-ultrabasic complex;** ***13*** **— Ordovician granites;** ***14*** **— Devonian granites;** ***15*** **— deformed Late Cambrian-Early Ordovician faults;** ***16*** **— Late Arenigian-Early Caradocian forethrust of the Kokchetav massif;** ***17*** **— sampling localities and number of specimen. The study area is starred in the inset.**

068 (Plate 1) contains sufficiently good forms. The recognized complexes of conodonts are preserved better (Plate 2). They are taken from turbidite olistostrome-bearing sections of accretionary wedge (sp. 068 and sp. 069), which are analogs of the Chaglinka sections, as well as from the matrix of the syntectonic olistostrome (sp. 01-55) and from the association with the basalts of the Stepnyak fore-arc trough (sp. 01-35). The faunal findings permitted dating the host deposits found in different geodynamic settings and timing the collision of the Kokchetav microcontinent with the Stepnyak island arc.

STRUCTURE OF ZONE OF JUNCTION OF THE KOKCHETAV MASSIF AND THE STEPNYAK TROUGH

The Kokchetav massif as part of the geological complexes of northern Kazakhstan is a tectonic collage of repeatedly deformed fragments of the Precambrian Kokchetav microcontinent, Vendian-Cambrian megamelange belt (terranes of paleosubduction zone), and Early Ordovician accretionary wedge [4–7]. The junction zone of the Kokchetav massif hosts a complex nappe-imbricated structure, in which siliceous rocks are recognized in the accretionary wedge, in the siliceous-volcanogenic sequence of the Stepnyak trough, and in the syntectonic olistostrome (see Fig. 1).

The accretionary wedge is represented by folded tectonic sheets and slices made up of Late Vendian-Early Cambrian(?) volcanosedimentary rocks of island-arc composition, Ordovician turbidites containing lenses and interbeds of olistostromes, amphibolized gabbros and gneisses, quartz-muscovite-microcline gneisses (with bodies of garnet amphibolites and eclogites), micaceous quartzites, ophiolite gabbros, and basalts. The sheets and slices

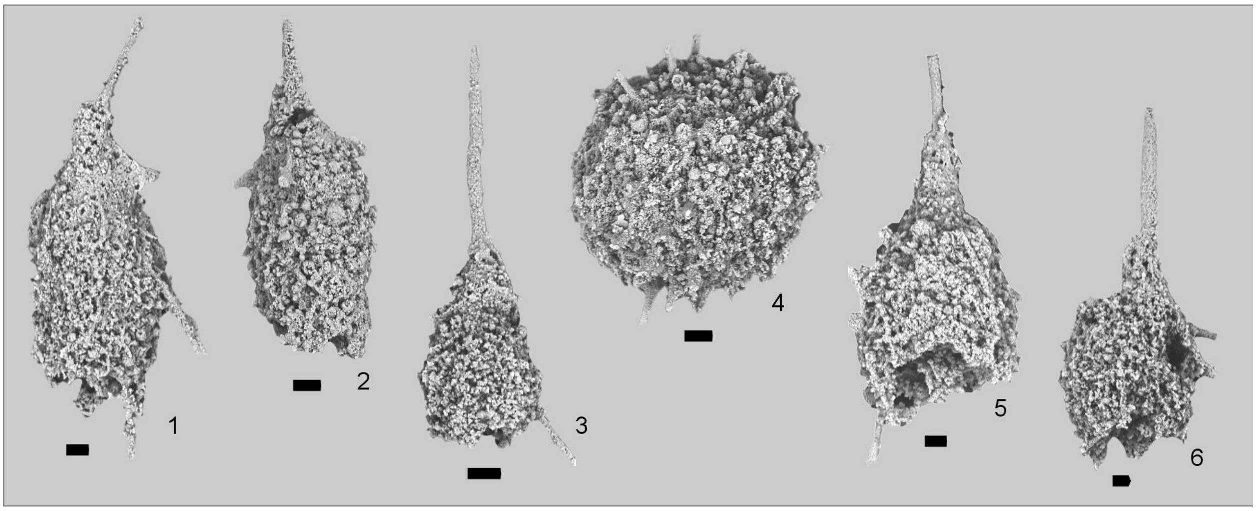

Plate 1. Radiolarians from the turbidite section near Igelyk Village (sp. 068), accretionary wedge. Figs. 1–3, 5, 6 — *Proventocitum procerulum* (Nazarov); fig. 4 — *Inanigutta* sp. cf *unica* (Nazarov). Scale rule 20 μm.

are outlined by zones of blastomylonites and mylonites of Early Ordovician age (490–478 Ma, $^{40}Ar/^{39}Ar$ dating) [5–7].

Turbidites form sheets of variable thickness in the accretionary wedge and are traced from the coastal outcrops of the Chaglinka River to the region of Lakes Bol'shoe Chebach'ye and Maloe Chebach'ye. They consist of rhythmically alternating sandstones, siliceous mudstones, and siltstones. The upper parts of the rhythms whose thickness reaches few tens of centimeters, are often made up of siliceous rocks. The olistostromes form lenses and interbeds up to few tens of meters thick within a terrigene section.

At the right bank of the Chaglinka River 2 km west of Kokchetav, Tsay and colleagues [3] found Arenigian conodonts *Paracordylodus gracilis* Lindström and *Distacodus* cf. *expansus* (Graves et Ellison) among yellow cherts [3]. Arenigian conodonts were also found in a quarry west of the Chaglinka water reservoir near a road. In the eastern part of the quarry, among lilac and red cherts occur interbeds of yellow cherts with *Protopanderodus rectus* (Londström), *Baltoniodus* cf. *navis* (Lindström), and *Microzarcodina* cf. *flabellum* (Lindström). In the strike, 600 m southeast of the quarry, *Periodon flabellum* (Lindström) and *Paroistodus parallelus* (Pander) were found also in yellow cherts. At the southern outskirts of Kokchetav, southeast of a hospital, the lilac cherty siltstones host remains of *Oepikodus evae* (Lindström) [3].

Earlier we also sampled siliceous rocks in the Chaglinka basin (Table 1). All of them contain conodonts and radiolarians but are poorly preserved and cannot be dated precisely. The best-preserved microfaunal remains were found in siliceous rocks (sp. 068 and sp. 069, see Fig. 1) from the turbidite section near Igelyk Village. The rocks are represented by dark-red siliceous mudstones and jasperoids. The fossils sampled from the first location (sp. 068) are conodonts *Periodon flabellum* (Lindström), *Paroistodus originalis* (Sergeeva), and *Protopanderodus rectus* (Lindström), *Microzarkodina* cf. *flabellum* (Lindström), and radiolarians *Proventocitum procerulum* (Nazarov) and *Inanigutta* sp. cf. *I. unica* (Nazarov) (see Plate 1). The obtained association of conodonts is typical of the intervals of conodont zones B. navis—lower Par. originalis of the Middle-Upper Arenigian [8, 9]. The radiolarians are similar to those found in the Kyzylzhar Formation of the Lower-Middle Ordovician of Kazakhstan [10]. At the second locality (sp. 069) numerous radiolarians *Inanigutta* sp. were found.

The syntectonic olistostrome was produced by the destruction of the nappes of the Kokchetav microcontinent and accretionary prism while they were thrusting upon the Stepnyak trough [4–7]. The time of formation of the olistostrome unit resulting from the breakup of the Kokchetav massif records the time of collision of the microcontinent with the Stepnyak island arc. The olistostrome makes up the top of the section of the Stepnyak trough and overlaps, in places tectonically, the horizon of conglobreccias, which lies upon the siliceous-terrigene rocks of the Stepnyak trough. The conglobreccias are few tens of meters thick. The olistostrome clastics is chiefly composed of granite gneisses, quartzites, and quartz sandstones typical of the Precambrian Kokchetav massif. The fragments are flat, several tens of meters long. Smaller fragments are usually angular. At the bottom of the olistostrome occur lenses and interbeds of variegated siliceous-clayey rocks similar to the rocks widespread in the

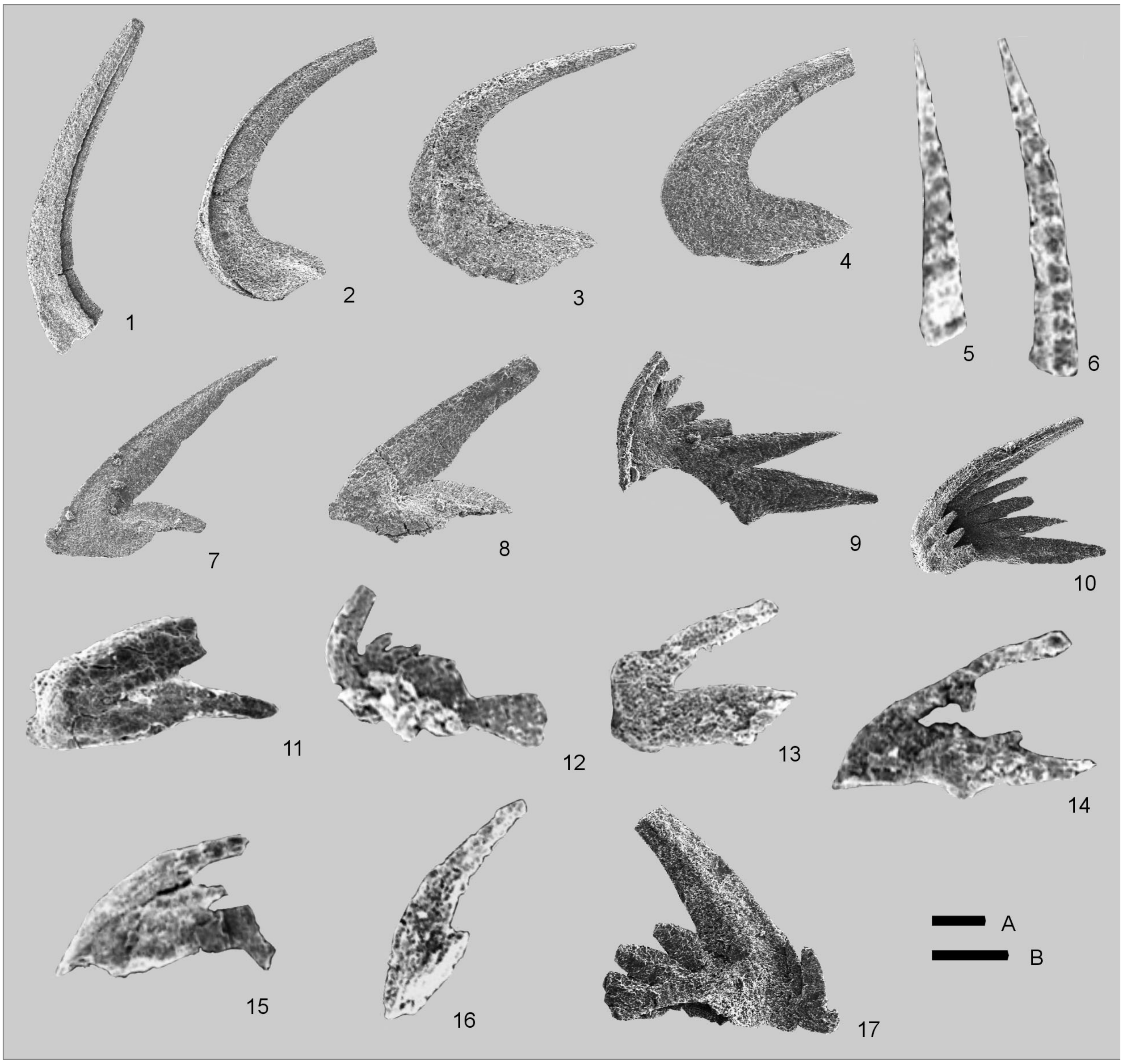

Plate 2. Association of conodonts from turbidite section of accretionary wedge (sp. 068, figs. 1–4, 7–10, 17), from rocks of groundmass of syntectonic olistostrome (sp. 01-55, figs. 11, 12, 14, 15), and basalt-siliceous unit (sp. 01-35, figs. 5, 6, 13, 16) of the Stepnyak trough. Fig. 1 — *Protopanderodus rectus* (Lindström), side view; figs. 2–4 — *Paroistodus originalis* (Sergeeva): 2, 3 — *S*-element, side view; 4 — *P*-element, side view; 5, 6 — *Panderodus* sp., side view; figs. 7–12 — *Periodon flabellum* (Lindström): 7, 8, 11 — *M*-element, side view; 9, 10, 12 — *S*-element, side view; figs. 13, 16 — *Drepanoistodus* sp., side view; figs. 14, 15 — *Paracordylodus gracilis* Lindström, *P*-element, side view; fig. 17 — *Microzarkodina* cf. *flabellum* (Lindström), *P*-element, side view. Scale rule 100 μm: A — 1–3, 5–7; B — 4, 8–17.

underlying sheet of conglobreccia composition. The olistostrome heavily varies in thickness, composition, and habit, with considerable changes in the strike. Its thickness reaches 300 m. The olistostrome matrix is represented by siliceous-clayey rocks, which preserved traces of deformation of plastic layers of the nonlithified sediment indicating that mud flows were brought to the sedimentation basin. The presence of siliceous interbeds and, often, of siliceous cement suggest that the sedimentation occurred under the conditions of hemipelagic sedimentation, under relatively deep-water conditions, possibly, of paleosubduction trench. Synsedimentary structures and textures of sliding also testify to a great role of slope processes in the formation of the sequence habit.

Table 1

List of Specimens of Siliceous Rocks Tested for Microfauna

No.	Specimen	Latitude	Longitude	Location	Color
			Accretionary wedge		
1	30-1	N°5317′60″	E069°15′15″	Lower reaches of Chaglinka, 2 km west of Kokchetav	Red
2	30-2	N53°17′62″	E069°15′16″	The same	Gray
3	03-55	N53°17′60″	E069°15′15″	»	Red
4	03-55-1	N53°17′61″	E069°15′17″	»	»
5	03-155-2	N53°17′63″	E069°15′16″	Near Voronovka Village, 60 km east of Kokchetav	Gray
6	03-155-3	»	»	The same	»
7	03-155-4	»	»	»	Brown
8	25	N53°17′66″	E069°14′62″	Lower reaches of Chaglinka, 2 km west of Kokchetav	Red
9	03-134-1	N53°17′60″	E069°15′15″	The same	Gray
10	03-134-2	»	»	»	»
11	03-134-3	»	»	»	»
12	03-134-4	N53°17′50″	E069°15′05″	»	Red
13	03-59-3	N53°17′60″	E069°15′15″	»	Lilac
14	03-59-3-1	N53°17′65″	E069°15′55″	»	Green
15	03-59-3-2	N53°17′65″	»	»	Gray
16	03-59-3-3	»	»	»	Light-gray
17	03-59-3-4	»	E069°15′59″	»	Light-green
18	03-58-1	N53°17′60″	E069°15′15″	»	Brown
19	03-58-2	»	E069°15′18″	»	Gray
20	03-61	»	E069°15′75″	»	»
21	068	N52°59′53″	E069°48′89″	Quarry 700 m south of Igylyk Village	Red, with visible radiolarians
22	068-1	»	»	The same	The same
23	068-2	»	»	»	»
24	068-3	»	E069°48′88″	»	»
25	069	N52°59′04″	E069°48′87″	Top of Orazymbet hill, 500 m southeast of Igylyk Village	»
26	069-1	»	»	The same	»
27	069-2	»	»	»	»
28	069-3	»	»	»	»
29	059	N53°06′67″	»	2 km north of Aleksandrinka Village, quarry in northern piedmont at point 388.2 m	Red
30	059-1	»	»	The same	»
31	059-2	»	»	»	»
32	059-3	»	»	»	»
33	058	N53°06′75″	E069°52′17″	2 km north of Aleksandrovka Village, quarry in NW piedmont at point 388.2 m	Yellow

Table 1 **(continued)**

No.	Specimen	Latitude	Longitude	Location	Color
			Syntectonic olistostrome		
34	II-1	N53°12′35″	E070°36′01″	2 km east of Zhanatalap Village, 100 km southeast of Kokchetav	Gray
35	II-1-1	N53°12′45″	E070°36′41″	The same	Red
36	II-6	N53°12′35″	E070°36′01″	»	Gray
37	II-6-1	N53°12′25″	E070°36′43″	»	»
38	3-146-3	N53°12′35″	E070°36′01″	»	Dark-green
39	O1-55	N53°07′52″	E070°37′14″	»	Red
			Stepnyak trough		
40	01-1	N53°13′11″	E070°09′29″	3 km NE of Frunze Village (Kyzylagash)	Gray
41	01-1	»	E070°09′30″	The same	»
42	01-35	»	»	»	Red

The overthrust zone is underlain by conglobreccia-siliceous unit, whose siliceous matrix contains remains of conodonts. The cement is porous, of graywacke. There is no sizing of fragments. The thickness of conglobreccia reaches few tens of meters. Siliceous rocks retained traces of deformation of plastic beds of nonlithified sediment, which were left, most likely, by turbidite flows coming to the sedimentation basin. The red siliceous rocks contain (see Fig. 1, sp. 01-55) the conodonts *Paracordylodus gracilis* Lindström and *Periodon flabellum* (Lindström) (see Plate 2). The recognized association is known from the interval of the conodont *O. evae* Zone of the Middle Arenigian [9–11].

The Stepnyak trough in the zone of junction with the Kokchetav massif is represented by alternating members of volcanogenic-siliceous, siliceous-silty, and conglomerate-sand-tuffaceous rocks, whose age was determined generally for the trough within Llanvirnian–Early Caradocian [12]. Detailed geologic mapping revealed tectonic contacts between them, while the drastic variability of rock composition along the section and the structural relationships permit the zone of junction of the trough with the Kokchetav massif to be considered a package of tectonic sheets (see Fig. 1). The section is considerably variable in the strike: Most members significantly change in thickness, wedge out to naught, or change in appearance at relatively short distances (few hundreds of meters). The presence of siliceous interbeds suggests that the sedimentation occurred under the conditions of hemipelagic sedimentation, in relatively deep-water conditions. The presence of synsedimentary structures and textures of landsliding can be due to the effect of turbidity flows on the trough sediments.

The volcanogenic-siliceous sequence (Zhanasui Group) is made up of lavas and tuffs of basalt and andesite compositions as well as jasperoids and tuffaceous sandstones at the bottom, and of layered red and green siliceous and silica-clayey rocks, at the top. The age of the Group, inferred from its structural location at the bottom of the section of the Stepnyak synclinorium, was interpreted as the Upper Cambrian-Tremadocian, though findings of graptolites and conodonts in other parts of the Stepnyak structure indicate the Tremadocian age of the host deposits [12].

In the volcanogenic-siliceous sequence, we explored layered red siliceous mudstones and jasperoids from the volcanogenic-siliceous sequence (see Fig. 1, sp. 01-35). The distinguished association of conodonts includes *Periodon flabellum* (Lindström), *Drepanoistodus* sp., and *Panderodus* sp. typical of the Middle Arenigian.

CONCLUSIONS

Our results on the structural position and age of siliceous rocks lying in different geodynamic settings of the zone of junction of the Kokchetav massif and Stepnyak fore-arc trough reliably date their collision and formation of nappe-imbricated structure. On the basis of conodonts, the siliceous rocks from the matrix of the olistostrome of accretionary wedge and syntectonic olistostrome and the rocks associated with island-arc volcanics are dated by the Middle–Late Arenigian (conodont *O. evae* and *B. navis—lower Par. originalis* Zones). This age interval is characterized by a powerful tectonic rearrangement linked with the reorganization of the accretionary wedge and overthrust of the Kokchetav massif upon the Stepnyak fore-arc trough [4–7].

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