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Structure, Composition, and Depositional Settings of the Lower Cretaceous Rocks of the Zhuravlevka Terrane, Central Sikhote Alin

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Abstract—The structure, mineralogical-petrographic composition, and formation settings of the Berriasian–Albian terrigenous rocks of the Zhuravlevka terrane (Central Sikhote Alin) are considered. The rocks
6 are interpreted as sediments accumulated in a virtually nonvolcanic basin along the transform plate boundary. Judging from the composition of terrigenous rocks, the main sources of clastic material were represented by the eroded granitic-metamorphic rocks of a mature continental crust, and, possibly, granitoid intrusions of ancient arc roots. Genetic features of the sediments suggest their accumulation on the shelf, underwater slope, foothill, and the adjacent basin plains of an oceanward-open marginal sea.

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INTRODUCTION

The Early Cretaceous was marked by several events that formed the present-day pattern of structures in the northwestern Pacific. Traces of these events are
1 2 recorded in the terranes of ancient orogenic belts
3 accreted to Eurasia. One of the most important fundamental problems of modern geology is related to deci-
4 5 phering of the paleogeographic and paleogeodynamic settings of the formation and evolution of sedimentary basins, the fragments of which are identified in these
1 terranes. Solution of this problem is required for the correct interpretation of geological processes in the ancient and modern sedimentation basins in the Pacific–Eurasia transition zones. Of special significance in this respect are basins spatially and genetically related to transform plate movements. Understanding of pull-apart basins related to transform (strike-slip) plate boundaries, as well as their typification, origin, evolution, and identification in ancient structures, represent the spectrum of new and very urgent questions widely discussed recently (Golozubov and Khanchuk, 1995; Golozubov, 2006; Golozubov et al., 2006; Khanchuk and Ivanov, 1999; Khanchuk, 2001).

The basin of this type can be exemplified by the Early Cretaceous Zhuravlevka terrane (Central Sikhote Alin), which is composed of thick and strongly deformed terrigenous sequences usually accumulated
6 in a virtually nonvolcanic setting.

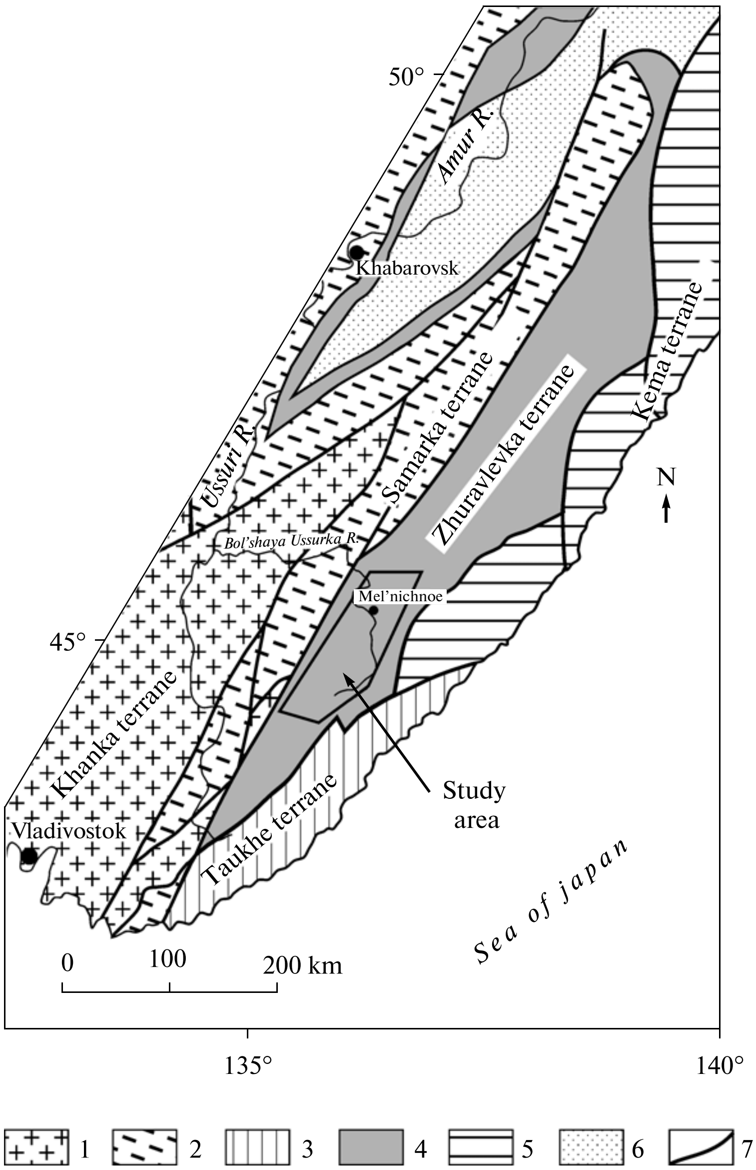
7 This work presents the results of detailed lithological studies of the Lower Cretaceous rocks of the terrane, in particular, their structure, petrographic and chemical compositions, relationships of rock-forming components, and detrital heavy minerals. This information made it possible to determine the composition of provenances of the sedimentation basins and to unravel the paleogeographic and paleotectonic set- 4
tings of their formation.

GEOLOGICAL SETTING

The modern tectonic structure of Sikhote Alin represents a combination of diverse terranes that were 1
accreted to the eastern Asian margin in the Paleozoic 3
and Mesozoic (Golozubov, 2006; Natal'in, 1991; Parfenov, 1984; Khanchuk et al., 1995; Nokleberg et al., 2000). Most part of the Sikhote Alin territory is occupied by Jurassic and Early Cretaceous terranes of 1
different geodynamic patterns (Fig. 1).

The Zhuravlevka terrane, which occupies the most part of Sikhote Alin, extends as a NW-trending band 800 km long and up to 80 km wide. It is separated from the northwestern Samarka terrane (a fragment of the Jurassic accretionary wedge) by the Central Sikhote Alin Fault system. The Zhuravlevka terrane is bordered by the Taukhe terrane (a fragment of the Early Cretaceous accretionary prism) in the south and by the Early Cretaceous Kema island-arc terrane in the east. In the Gur River basin (northern Sikhote Alin), the Zhuravlevka terrane pinches out, but its continuations likely extend from the estuary of the Ussuri River to the northeast along the right and left banks of the Amur River (Fig. 1).

The Berriasian–Albian complexes of the terrane (approximately 11 000 m thick) are mostly composed of thick terrigenous sequences of sandstones, siltstones, and mudstones with numerous units of turbidites, conglomerates, gravelstones, mixtites, and sili-



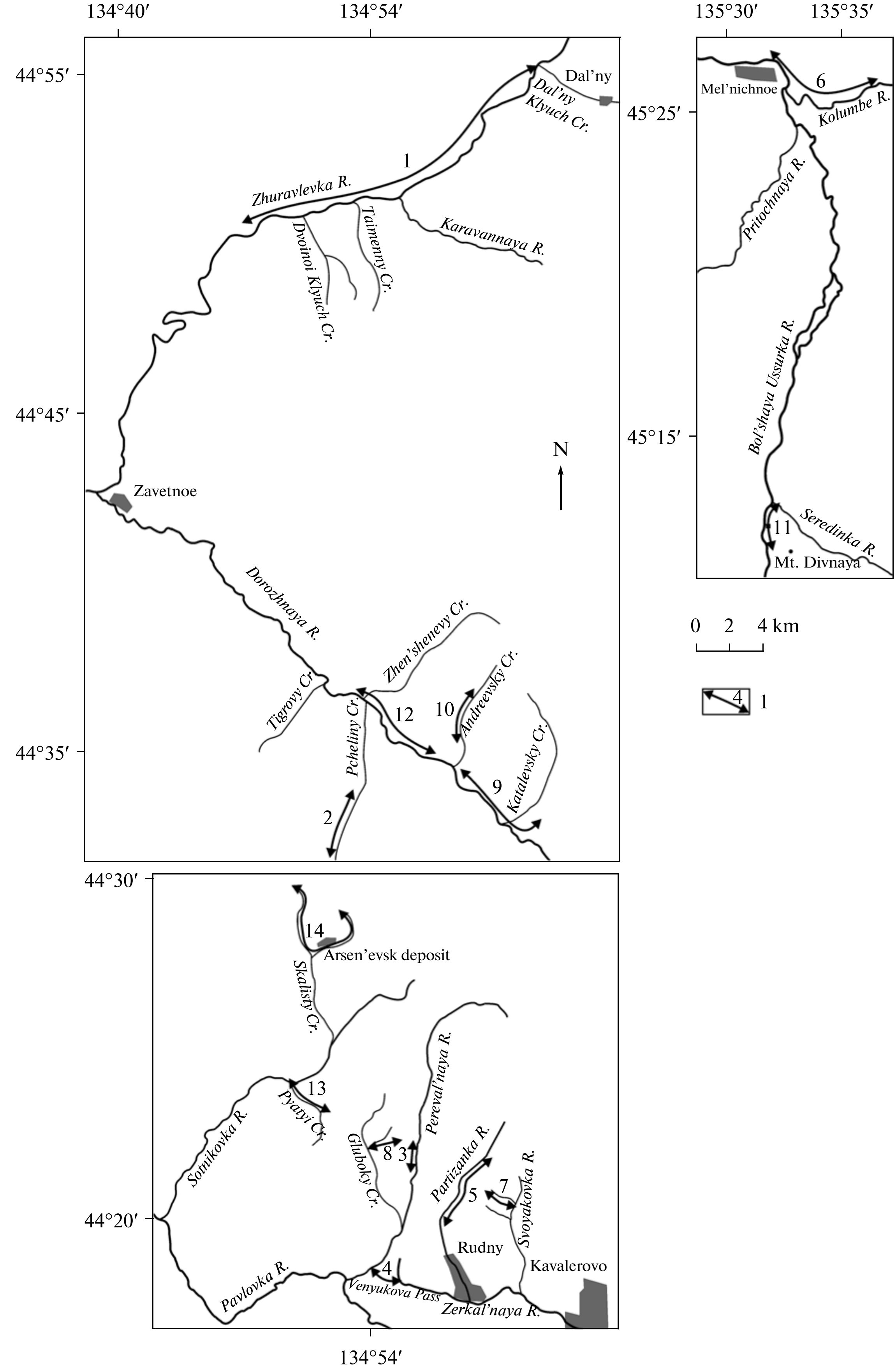
1 **Fig. 1.** Terrane scheme in the southern Russian Far East (Khanchuk et al., 1995; Malinovsky et al., 2002). (1–6) Terranes: (1) Pre-Mesozoic, (2) Jurassic accretionary wedge, (3) Early Cretaceous accretionary wedge, (4) Early Cretaceous transform margins, (5) Early Cretaceous island-arc, (6) Early–Late Cretaceous and Cenozoic; (7) faults.

ceous–clayey rocks. The rocks are intensely dislocated and deformed into a system of tightly compressed NE-striking folds, which are crosscut by numerous (mainly NE- and NS-striking) left-lateral faults.

OBJECTS AND METHODS

The Lower Cretaceous sandy and clayey–silty rocks from the southern Zhuravlevka terrane were examined. We studied 14 most representative sections (more than 75 km in total). along mining profiles or natural exposures of the Bol'shaya Ussurka, Zhuravlevka, Kolumbe, Dorozhnaya, Sotnikovka, Partizanka, Pereval'naya, and Zerkal'naya rivers and their tributaries (Fig. 2). The attitude and structure of rocks were studied in exposures and oriented polished samples. The least altered samples of terrigenous rocks were taken for analytical studies (the degree of secondary alterations was controlled by petrographic observations).

Fig. 2. Schematic location of the studied sections in the Zhuravlevka terrane. (1) Studied sections and their numbers (see columns in Fig. 3).


134°40′
134°54′
44°55′
44°45′
44°35′
Dal'ny
Dal'ny Klyuch Cr.
1
Zhuravlevka R.
Dvoinoi Klyuch Cr.
Taimenny Cr.
Karavannaya R.
N
Zavetnoe
Dorozhnaya R.
Zhen'shenevy Cr.
Andreevsky Cr.
Tigrovy Cr.
Peheliny Cr.
12
10
9
Katalevsky Cr.
2
135°30′
135°35′
45°25′
45°15′
Mel'nichnoe
6
Kolumbe R.
Pritochnaya R.
Bol'shaya Ussurka R.
Seredinka R.
11
Mt. Divnaya
0 2 4 km
4
1
44°30′
44°20′
14
Arsen'evsk deposit
Skalisty Cr.
Pereval'naya R.
13
Pyatyi Cr.
Sotnikovka R.
Glubokу Cr.
8
3
Partizanka R.
Svyakovka R.
7
5
Rudny
Kavalerovo
4
Pavlovka R.
Venyukova Pass
Zerkal'naya R.
134°54′

The petrographic composition of rocks was studied with polarization microscope. Contents of the major rock-forming components were determined by the point method using an integration table. No less than 200 grains were calculated in each thin section. Heavy minerals were extracted from sandstones with heavy liquid after crushing samples to 0.25 mm and their washing in the distilled water in order to remove fractions less than 0.01 mm. The mineral composition of heavy fraction was determined in the transmitted and polarization light under a microscope using immersion liquids. When calculating the content of minerals, only the detrital portion was taken into consideration and the authigenic portion was omitted to guarantee the highest reliability in determination of the composition and relative role of provenances. The chemical composition of heavy minerals was determined on a JXA-8100 microprobe. The proportions and chemical compositions of heavy minerals were interpreted using an original technique developed in the Laboratory of Sedimentary Geology (Far East Geological Institute, Far East Branch, Russian Academy of Sciences). This method allows the identification of analogues of modern geodynamic settings in the geological past (Markevich et al., 1997; Nechaev et al., 1996). Contents of the major elements in rocks were determined by the traditional weight chemical method. All analyses were performed at the Institute of Far East Geological Institute, Far East Branch, Russian Academy of Sciences (Vladivostok).

STRUCTURE AND COMPOSITION OF SECTIONS

The Zhuravlevka terrane is characterized by poor exposure, significant overlapping of rocks by the Late Cretaceous volcanics, and complex tectonic setting. Therefore, its stratigraphic section was compiled from numerous fragments, which characterize the structure of different tectonic blocks (Figs. 2, 3). The section is divided into eight formations, which conformably overlie each other and vary in age from the Berriasian to Late Albian. The stratigraphic sequence and composition of the rocks are as follows.

The base of the visible section is made up of the Upper Berriasian–Lower Valanginian *Zhuravlevskaya Formation* (up to 1800 m thick). It is composed of siltstones and mudstones often intercalated with sandstones and inequigranular sandstones; rhythmic alternation of sandstones, siltstones, and mudstones with elementary rhythm (cyclite) varying from 3–5 to 20–30 cm thick; and rare mixtite units. On the left bank of the Bikin River, the Zhuravlevskaya sequence contains single basalt flows with within-plate geochemical signatures (Levashov et al., 1989).

In terms of lithology, the overlying Valanginian *Klyuchevskaya Formation* is subdivided into five units. Unit I includes inequigranular sandstones (with plant detritus) and layers of sandy siltstones, gravelstones, and conglomerates (thickness 700 m). Unit II is mainly composed of siltstones with rare intercalations of fine-grained sandstones and beds of rhythmically alternating sandstones and siltstones (600 m). Unit III is subdivided into two parts. The lower part represented by fine-grained sandstones; the upper part, by rhythmic alternation of sandstones and siltstones with individual gravelstone and conglomerate beds (total thickness 570 m). Unit IV includes alternating inequigranular sandstones and siltstones, individual beds of rhythmic alternation of sandstones and siltstones, and horizons of mixtites (850 m). Unit V consists of siltstones and mudstones (sometimes siliceous) with rare intercalations of sandstones (530 m). Total thickness of the formation is up to 3250 m.

Age of the Zhuravlevskaya and Klyuchevskaya formations was constrained on the basis of faunal finds—mainly *Buchia* and less common ammonites (Golozubov, 2006; Markov et al., 2000).

The Hauterivian *Ust-Kolumbinskaya Formation* (up to 2160 m thick) is mainly composed of the fine- to medium-grained sandstones with thin siltstone intercalations and rhythmic alternation of sandstones and siltstones.

The Late Hauterivian–Barremian *Primankinskaya Formation* (up to 700 m thick) consists of thin rhythmic alternation of the fine-grained sandstones and siltstones (with cyclites 3–10 cm thick), which are separated by rare intercalations of the medium- to coarse-grained sandstones with abundant plant detritus. The upper part is dominated by siltstones (often sandy) with rare intercalations of the fine-grained sandstone.

The Hauterivian–Barremian age of the Ust-Kolumbinskaya and Primankinskaya formations is based only on rare finds of prismatic layers with single inoceram shells (Golozubov, 2006; Markevich et al., 2000).

The Aptian *Katalevskaya Formation* comprises thick beds of inequigranular sandstones often containing dispersed coalified plant detritus and angular siltstone fragments. The beds are separated by coarse-rhythmic intercalations of sandstones and subordinate siltstones, as well as alternations of siltstones, gravelstones, and conglomerates. Thickness of the formation is up to 1560 m.

The Early Albian *Divninskaya Formation* (no more than 950 m thick) is composed of siltstones and mudstones with scarce thin (up to 30 cm) intercalations of the fine-grained sandstones. Siltstones in the upper part of the sequence often contain coalified plant detritus. The sequence also includes scarce rhythmic intercalation of sandstones and siltstones (predominant component), beds of the fine- to medium-grained sandstones and mixtites, and lenses of gravelstones and conglomerates.

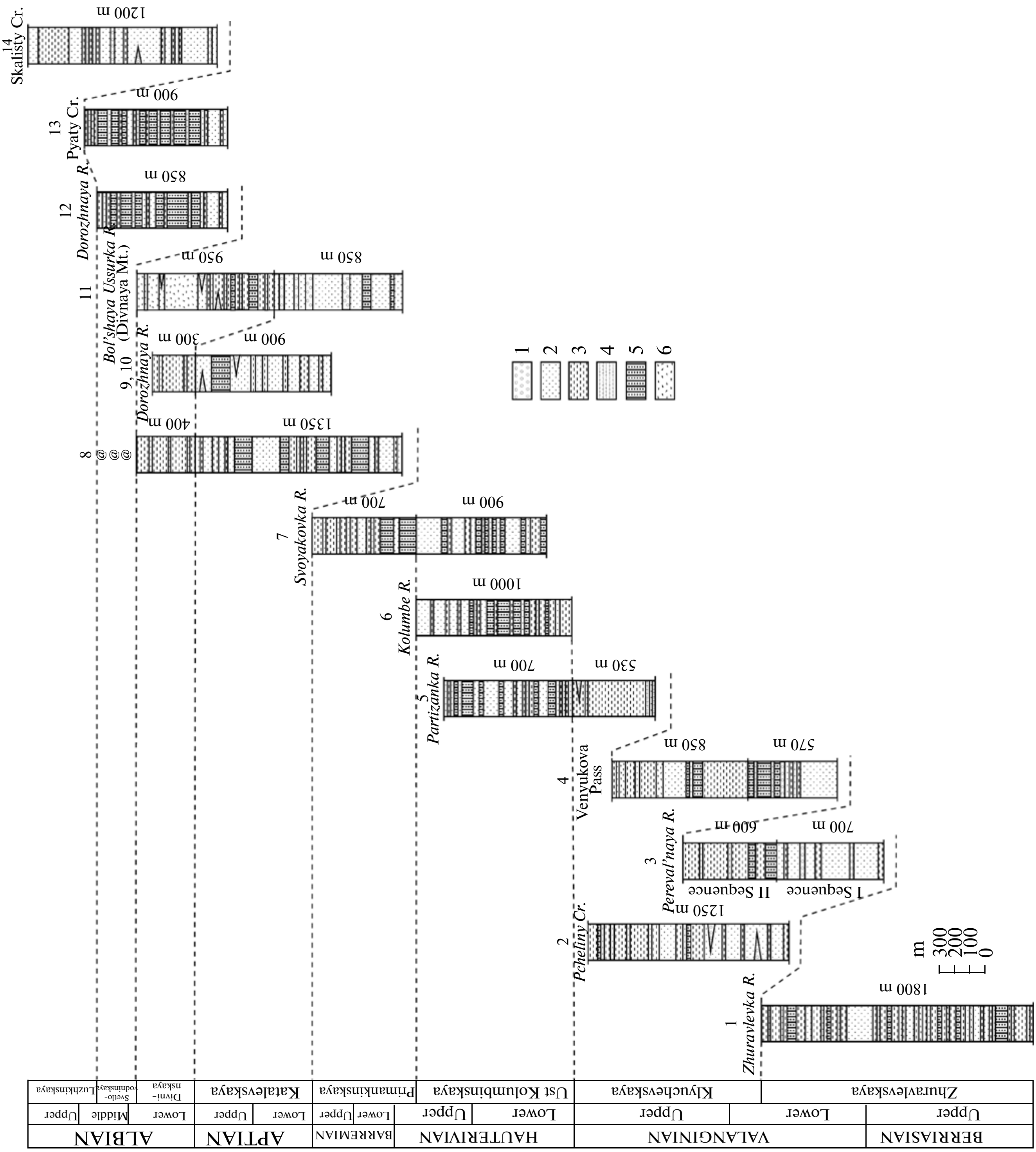


Fig. 3. Correlation scheme of the studied Lower Cretaceous sections in the Zhuravlv terrane. (1) Conglomerates and gravelstones; (2) sandstones; (3) siltstones and mudstones; (4) siliceous–clayey rocks; (5) rhythmic intercalation of sandstones and siltstones; (6) mixtites. Column numbers correspond to the section numbers in Fig. 2.

The appearance of the Early and Middle Albian *Svetlovodninskaya Formation* is determined by the rhythmic intercalations (150–300 m) of sandstones and siltstones. Thickness of the rhythm in them varies from 5–10 to 50–100 cm. The sandstone/siltstone ratio in the rhythms is commonly equal, and domination of one component is rare). The monotonous alternation is sometimes disturbed by individual beds of siltstones, mixtites, and sandstones, which predominate in the lower part of the formation. Thickness of the formation is up to 2000 m.

The Aptian–early Albian age of the Katalevskaya, Divninskaya, and Svetlovodninskaya formations is based on numerous finds of Aucellina and ammonites (Golozubov, 2006; Markevich et al., 2000).

The lower Cretaceous sequence of the terrane is completed by the Middle–late Albian *Luzhkinskaya Formation* up to 1200 m thick. It consists of the medium- to fine-grained sandstones and sandy siltstones (often with coalified plant detritus) with scarce horizons and lenses of conglomerates, gravelstones, and siltstones. Age of the formation was determined on the basis of numerous finds of the characteristic Trigonia–Aktaeoneolla faunal assemblage (Golozubov, 2006, Markevich et al., 2000).

COMPOSITION OF TERRIGENOUS ROCKS AND SETTINGS OF THEIR FORMATION

We studied the composition of terrigenous rocks to determine the type and composition of provenances and to reveal the paleogeodynamic sedimentation settings in the Zhuravlevka basin. Sandstones were the most informative rocks in this respect. Data on the clayey–silty and coarse-clastic rocks were used as additional material.

Petrographic Composition and Rock-Forming Components of Sandstones

Sandy rocks of all formations are usually represented by the fine- and medium-grained varieties. The coarse-grained and gravel-size varieties are rare. The rocks are usually marked by good sorting, but it becomes worse with increase in grain size. They occasionally contain small (up to 2 cm) angular sandstone and siltstone fragments that are scattered over the entire volume. Sandy grains are typically subangular and subrounded. Angular and rounded grains are subordinate. Grains of igneous, siliceous, and sedimentary rocks are best rounded, whereas grains of volcanic and metamorphic rocks are least rounded.

In terms of the major components, all sandstones are similar and, in general, ascribed to polymictic rocks. Clasts (70–90 vol %) consist of quartz, feldspars, and biotite along with fragments of terrigenous, siliceous, carbonate, intrusive, volcanic, metamorphic rocks, and ore minerals. The coarse-grained rocks are characterized by higher contents of fragments of sedimentary rocks (siltstones, cherts, and rare limestones), as well as igneous and metamorphic rocks (granites, rhyolites, and less common basalts, micaceous schists, and quartzites).

In the classification diagram proposed by Shutov (1967) (Fig. 4a), sandstones define a single field ascribed mainly to the feldspathic arkoses and to a lesser extent to the quartz–feldspar and feldspar–quartz graywackes.

Quartz, the most abundant component of sandstones, ranges from 21 to 42% (Table 1). The highest (34–42%) and lowest (24–35%) contents were found in the Primankinskaya and Zhuravlevskaya formations, respectively. The mineral is mainly represented by the monocrystalline intrusive variety (usually equant grains with abundant tiny fluid inclusions) and acicular rutile. Pure volcanic quartz (often with wavy extinction, irregular, elongated, and angular or subrounded) grains and metamorphic quartz (elongated, usually polycrystalline, and irregularly shaped) grains are less common.

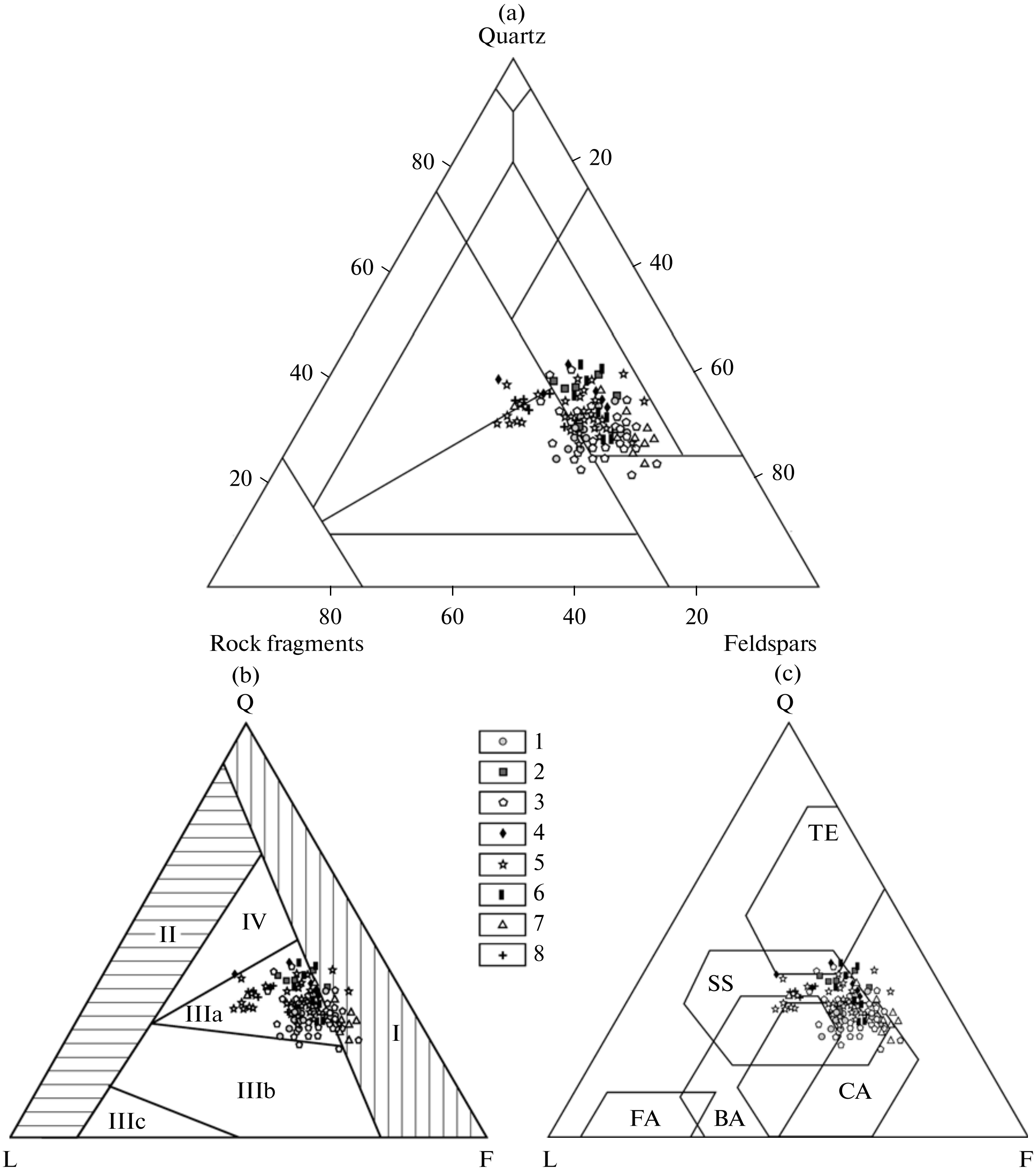
Feldspars account for 23–62% of sandstones. The content varies from 37–62% in the Ust-Kolumbinskaya Formation to 23–56% in the Katalevskaya Formation. The mineral is observed as elongated, tabular, and less common equant grains of acid plagioclases (up to 90% of all feldspars), which are dominated by albite and oligoclase. The content of potassium feldspars usually ranges within 5–15% and reaches 20–23% in the Svetlovodninskaya Formation. They are observed as equant pelitized grains of orthoclase. The cross-hatched microcline is less common. Basic and intermediate plagioclases account for no more than 5%.

Lithic fragments (15–45%) are dominated by siliceous (up to 60 of all fragments) and terrigenous (up to 55%) rocks. The contents of metamorphic and felsic igneous rocks widely vary and rarely reaches 50%. Fragments of volcanic and carbonate rocks are rare.

The clay component of sandy rocks in all formations is sufficiently uniform—hydromica (up to 90%), with minor smectite and chlorite.

Thus, the major component composition of sandstones makes it possible to suggest that sediments of the Zhuravlevka terrane were delivered from diverse sedimentary, felsic intrusive, and metamorphic rocks. The essentially arkosic composition of sandstones points to the erosion of granitic-metamorphic crust. We can also suggest that siliceous and terrigenous rocks, which occupy a significant part of sandstone clasts, are related to the erosion of fragments of the Jurassic accretionary wedge (Samarka terrane). In the modern structure, the wedge borders the Zhuravlevka terrane in the west-northwest.

The paleogeological interpretation of composition of the major components of sandstones was based on the well-known techniques of W. Dickinson, C. Suczek, J. Maynard, and others. In the diagram of Dickinson and Suczek (1979) showing the tectonic settings of provenances (Fig. 4b), the Zhuravlevka sandstones fall in two fields: field of crystalline basement blocks (I) located along rift belts or transform faults; field of the rugged and deeply eroded magmatic arcs (IIIa),



5 **Fig. 4.** Rock-forming components of sandstones in the Lower Cretaceous rocks of the Zhuravlevka terrane and their paleogeodynamic interpretation. (a) Classification diagram of rock types (Shutov, 1967); (b) types of provenances (Dickinson and Suczek, 1979): (I) stable cratons and uplifted basement blocks, (II) remobilized orogens, (III) magmatic arcs: (IIIa) rugged and deeply eroded, (IIIb) transitional; (IIIc) undivided and weakly eroded, (IV) mixed provenances; (c) types of basin settings (Maynard et al., 1982): passive settings (trailing edge (TE) including intercontinental rifts and aulacogens; basins of active continental margins conjugated with strike-slip dislocations along transform zones (SS), continental margin arc (CA), and oceanic volcanic arc. Basins: (FA) fore-arc, (BA) back-arc). (1–8) Formations: (1) Zhuravlevskaya, (2) Klyuchevskaya, (3) Ust-Kolumbinskaya, (4) Primankinskaya, (5) Katalevskaya, (6) Divninskaya, (7) Svetlovodninskaya, (8) Luzhkinskaya.

where erosion reached batholiths of holocrystalline rocks beneath the volcanic pile.

Geotectonic settings of sedimentation basins were reconstructed using the diagram of Maynard et al. (1982) (Fig. 4c). Here, data points of the sandstones are grouped into the fields of basins associated with virtually nonvolcanic Californian-type continental 6
margins complicated by the strike-slip transform faulting (SS), and partially, into the fields of basins with the continental-margin magmatic arcs (CA).

Thus, sedimentation settings reconstructed from the rock-forming components can be ascribed to the

Table 1. Contents of the rock-forming components (%) in sandstones of the Zhuravlevka terrane

Component	Zhuravlevskaya Formation (13)	Klyuchevskaya Formation (6)	Ust-Kolumbinskaya Formation (28)	Primankinskaya Formation (6)	Katalevskaya Formation (31)	Divninskaya Formation (8)	Svetlovodninskaya Formation (21)	Luzhkinskaya Formation (7)
Quartz	24–35 / 29 ± 3.1	30–40 / 36 ± 4.5	21–41 / 29 ± 5.2	34–42 / 37 ± 2.9	26–40 / 33 ± 1.2	28–42 / 35 ± 5.5	23–37 / 30 ± 4.1	29–36 / 33 ± 2.8
Potassium feldspars	8–15 / 10 ± 2.4	5–6 / 5 ± 0.6	2–19 / 10 ± 5.7	2–7 / 4 ± 1.7	2–16 / 8 ± 1.2	2–11 / 5 ± 3.0	5–23 / 13 ± 6.3	1–6 / 4 ± 1.6
Basic and intermediate plagioclases	0–2 / 1 ± 0.8	2–4 / 3 ± 1.0	0–5 / 2 ± 1.3	1–4 / 2 ± 1.7	0–4 / 2 ± 1.2	0–2 / 1 ± 0.9	0–4 / 1 ± 1.3	0–2 / 1 ± 0.6
Acid plagioclases	32–42 / 37 ± 3.6	30–41 / 36 ± 4.6	28–49 / 39 ± 6.3	21–40 / 34 ± 7.4	21–46 / 35 ± 7.4	31–46 / 40 ± 4.9	26–51 / 38 ± 7.7	30–45 / 36 ± 6.4
Mafic and intermediate volcanics	0–3 / 2 ± 0.9	1–2 / 2 ± 0.6	1–4 / 2±1.1	0–2 / 1±0.8	0–2 / 1±0.8	0–2 / 1±1.1	0–3 / 1±1.2	1–3 / 1±0.9
Felsic volcanics	1–4 / 2±1.1	1–4 / 3±1.3	1–7 / 3±1.9	1–4 / 2±1.2	0–4 / 1±1.2	0–3 / 1±1.1	1–4 / 1±1.2	1–4 / 3±1.0
Felsic intrusive rocks	2–7 / 4±1.7	2–5 / 4±1.4	2–10 / 4±2.1	2–8 / 4±2.3	2–9 / 4±1.2	1–4 / 2±1.2	1–7 / 3±1.6	1–2 / 1±0.5
Metamorphic rocks	1–6 / 3±1.6	1–4 / 2±1.5	2–11 / 4±2.4	1–4 / 2±1.0	2–12 / 5±1.2	2–4 / 3±0.7	1–9 / 4±2.0	1–8 / 4±2.7
Cherts	5–15 / 10±3.6	5–9 / 7±1.8	2–14 / 7±2.9	5–10 / 8±2.0	3–24 / 9±1.2	2–10 / 6±2.5	1–7 / 4±1.2	5–16 / 13±3.9
Terrigenous rocks	1–8 / 4±2.0	2–7 / 4±2.4	2–11 / 4±2.2	3–15 / 7±5.6	2–13 / 5±1.2	4–13 / 7±2.8	2–10 / 4±1.7	3–7 / 5±1.5
Carbonate rocks	0–2 / 1±0.5	0–2 / 1±0.8	0–1 / 1±0.2	0–2 / 1±0.8	0–3 / 2±0.9	0–1 / 1±0.2	0–4 / 1±1.2	0–1 / 1±0.2

Note: No less than 200 grains were calculated in each sample. The numerator shows the range of values; the denominator, average contents with the standard deviation. The number of measurements is shown in parentheses.

Table 2. Average mineral composition (%) of the heavy fraction in sandstones of the Zhuravlevka terrane

Heavy minerals	Zhurav-levskaya Formation (12)	Klyuchev-skaya Formation (6)	Ust-Kolumbin-skaya Formation (22)	Primankin-skaya Formation (6)	Kata-levskaya Formation (19)	Divninskaya Formation (15)	Svetlovodn-inskaya Formation (13)	Luzhkin-skaya Formation (5)
Chromite	1.1	0.7	2.4	0.1	0.9	0.6	0.7	0.3
Magnetite	0.5	2.2	0.5	3.5	0.3	4.1	0.9	6.4
Ilmenite	0.1	0.4	0.2	0.2	0.2	tr.	tr.	–
Leucoxene	2.2	8.6	4.5	7.5	11.0	6.2	7.3	8.7
Orthopyroxene	–	–	tr..	0.3	–	–	tr.	0.5
Clinopyroxene	0.3	5.1	0.8	1.1	0.4	1.0	0.2	1.1
Hornblende	0.4	0.3	0.9	5.9	2.3	1.4	3.0	0.6
Epidote	0.3	12.4	0.1	tr.	0.9	1.5	0.2	2.5
Zircon	44.2	61.9	62.6	74.4	56.4	66.5	59.2	66.5
Garnet	11.9	0.1	9.9	1.2	2.0	3.5	4.6	2.8
Titanite	0.5	–	–	–	0.1	tr.	0.2	–
Tourmaline	26.5	4.0	6.6	3.0	19.2	11.6	13.4	0.6
Apatite	11.8	1.4	8.1	0.1	5.6	2.4	6.6	5.9
Rutile	0.1	2.9	3.3	2.8	0.8	1.1	3.5	3.8
Anatase	–	0.1	0.1	tr.	0.1	0.1	0.2	0.6
Brookite	–	–	0.1	–	tr.	–	–	–

Note: Number of samples used in calculations is shown in parentheses; (tr.) trace amounts; (–) not found.

settings of basins related to the continental margins complicated by large strike-slips, i.e., settings of transform continental margins (Golozubov, 2006; Kenneth, 1987; Khanchuk, 2001).

Heavy Detrital Minerals of Sandstones

Heavy detrital minerals in sandstones of all studied formations of the Zhuravlevka terrane account for 0.01–0.8 vol % (occasionally, up to 2%). It should be noted that the heavy fraction has a sufficiently steady mineral composition throughout the section (Table 2). Figure 5 demonstrates proportions between the average contents of individual minerals. All heavy minerals can be arbitrarily divided into two mineral assemblages. The first, mainly sialic assemblage (often, up to 100% of all heavy minerals) includes minerals related to the disintegration of igneous and metamorphic felsic rocks: zircon, tourmaline, epidote, titanite, rutile, apatite, anatase, and brookite. The main mineral of the assemblage is zircon (average 60%, up to 90% in some places). It is mainly represented by the colorless or slightly colored prismatic crystals with small fluid inclusions. This is the typomorphic feature of granite zircons (Lyakhovich, 1979). Minor minerals are represented by tourmaline (average 22.7%, up to 44% in some samples), garnet (5.5 and 57%, respectively), apatite (6.0 and 23%), rutile (2 and 22%), and epidote (1.2 and 21%). The total content of other minerals is *n*%. The second, femic assemblage is subordinate (average up to 5%, up to 20% in some places). It consists of the typical volcaniclastic minerals: ortho- and clinopyroxenes, hornblende, chromite, and magnetite. Their contents are low: magnetite (average 1.6%, 20% in one sample; chromite 1.1 and 14%, respectively; clinopyroxene 0.9 and 16.7%, and hornblendes 1.7 and 15%. Other minerals are subordinate or rare.

It is known that tectonic settings of sedimentation are characterized by typomorphic heavy mineral assemblages (Malinovsky and Markevich, 2007; Nechaev and Isphording, 1993; Nechaev et al., 1996; Markevich et al., 2007). Examination of the heavy mineral assemblages of sandstones from the Zhuravlevka terrane in the MF–MT–GM diagram (Nechaev et al., 1996) (Fig. 6) shows that sedimentation was mainly controlled by the erosion of mature continental (passive or transform) margins mainly composed of the felsic igneous and metamorphic rocks. The influence of volcanic source was negligible.

In order to obtain additional information on the character of sources of heavy detrital minerals, we studied the chemical compositions of detrital garnets and chromites (Table 3).

Detrital garnets are mainly ascribed to almandine (Al_2O_3 20.25–23.84%; FeO + Fe_2O_3 22.20–36.83%). They contain the grossular or spessartine component in rare cases. Judging from the distribution of data points in the Mg–Mn–Ca diagram (Teraoka, 2003), their sources were presumably represented by the eroded granulite- and amphibolites-facies metamor-

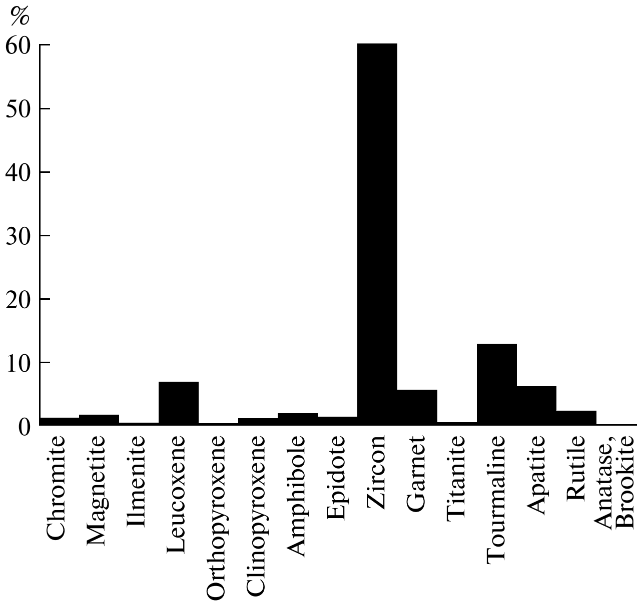


Fig. 5. Distribution of heavy detrital minerals in sandy rocks of the Zhuravlevka terrane (average contents).

phic rocks, as well as felsic intrusive rocks (Fig. 7.). The provenance was likely represented by a mature continental crust with intensely metamorphosed rocks and granitoids.

Detrital chromites are chemically homogeneous. They are distinguished by the absence or extremely low contents of Ti (no more than 0.64%, up to 2.05% in two samples). In the Al_2O_3–Cr_2O_3–$10TiO_2$ diagram (Shcheka and Vrzhosek, 1983) (Fig. 8), they correspond to the alpine-type dunite–harzburgite assemblage. Chromites could be derived from the ophiolitic ultramafic rocks in the Jurassic accretionary wedge of the Samarka terrane located west-northwest of the Zhuravlevka sedimentation basin.

Thus, judging from the heavy mineral composition of sandstones, the main sources of clastic material were represented by the felsic igneous and metamorphic rocks of a mature continental margin. Ophiolite complexes, which presumably represented fragments of the pre-Cretaceous active margins, were less eroded.

Chemical Composition of Sandstones

In terms of chemical composition (Table 4), sandstones from the Zhuravlevka terrane have a homogenous composition, with only insignificant variations of the following components in individual samples (%): SiO_2 65.55–85.90, TiO_2 0.08–0.53, Al_2O_3 6.55–15.27, FeO + Fe_2O_3 0.84–5.97, MgO 0.21–1.93, CaO 0.02–5.58, Na_2O 0.04–5.64, and K_2O 0.75–3.56. In terms of these geochemical features, they resemble the felsic igneous rocks and occupy an intermediate position between arkoses and graywackes (Pettijohn et al., 1972). As compared to the average composition of arkoses, the Zhuravlevka sandstones are marked by a lower content of SiO_2, elevated contents of Al_2O_3 and TiO_2, as well as the predominance of Na_2O over K_2O. This pattern is typical of graywackes, except for rocks of the Katalevskaya and Luzhkinskaya formations.

In the Si–Al–Fe diagram based on (Moor and Dennen, 1970) (Fig. 9), data points of the Zhuravlevka sandstones are aligned to the granite–basalt curve. They approach the granite composition and fall in the fields of arkoses and subgraywackes.

Since absolute contents of the major oxides reflect the composition of both the clastic component and matrix of terrigenous rocks, their geochemical features can be more reliably estimated by consideration of the most informative ratios of oxides and their sums, i.e., petrochemical moduli (Table 3), as well as module diagrams proposed by Yudovich and Ketris (Yudovich, 1981; Yudovich and Ketris, 2000) (Fig. 10). In terms of these characteristics, the sandstones are similar and characterized by the following features: (1) relatively low maturity (hydrolyzate module, HM varies from 0.10 to 0.29), indicating their formation by the mechanical disintegration of parental rocks and a subordinate role of chemical weathering; (2) low femic module (FM from 0.02 to 0.09), which is consistent with the low contents of fragments of mafic volcanics and the high contents of quartz, siliceous rocks, and granitoids (based on this index, they occupy an intermediate position between graywackes and arkoses); (3) low titanium module (TM varies from 0.009 to 0.042) due to the admixture of felsic rock fragments with low TM and virtually complete absence of mafic volcaniclastics; and (4) relatively high (typical of arkoses) values of the normalized alkalinity module (NAM varies from 0.30 to 0.69) that reflect a sufficiently high content of mica and feldspars, including K-feldspars.

Genetic interpretation of the chemical composition (Fig. 11) was based on the same principles as for the rock-forming components and was conducted using the technique of M. Bhatia and J. Maynard. In the diagrams of Bhatia (1983) (Fig. 11a) used for the discrimination of sandstones accumulated in basins of different tectonic settings, most data points of the Zhuravlevka sandstones correspond to or approximate those of sandstones in active continental margins, which include sedimentary basins of both the Andean-type continental margins and their counterparts complicated by the transform strike-slip faults. Some points are shifted to the fields of passive margins due to the concentration of quartz and siliceous rock fragments in sandstones of individual beds.

Geotectonic settings of the sedimentation basins were reconstructed based on the diagram proposed in (Maynard et al., 1982). A significant scatter of data points of the Zhuravlevka sandstones (Fig. 11b) prevents their unambiguous interpretation. In general, sandstones occupy an intermediate position between

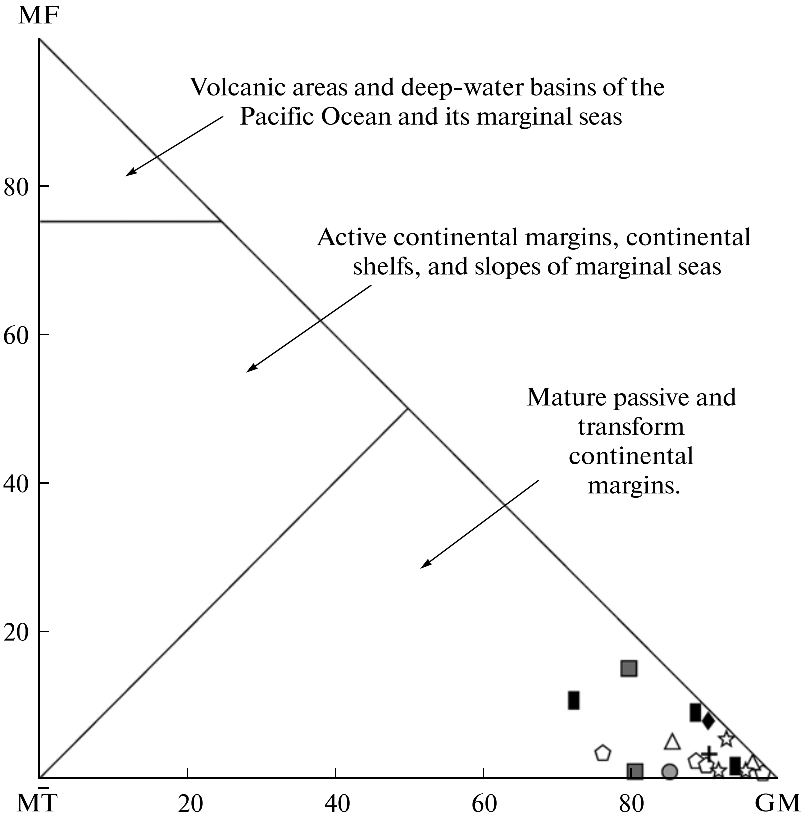


Fig. 6. Comparison of the composition of heavy fraction of sandstones from the Lower Cretaceous rocks in the Zhuravlevka terrane and from modern sediments in different geodynamic settings (Nechaev et al., 1996). Total contents: (MF) olivine, pyroxenes, green hornblende; (MT) epidote, garnet, blue-green amphiboles; (GM) zircon, tourmaline, staurolite, disthene, sillimanite, and andalusite. Symbols are shown in Fig. 4 (hereinafter, average values for individual sections of rock formations are given).

the sands from basins associated with passive and active continental margins.

Clayey–Silty Rocks

7 Depending on the lithological composition of clayey–silty rocks (siltstones, mudstones, and silty mudstones), the content of silt-size clastic material varies from 3 to 60–80 vol %. Rocks are typically well sorted, although some varieties are less sorted because of uneven distribution of the silty material that makes up microaccumulations. The rocks are characterized by horizontal or gentle wavy microbedding due to oriented arrangement of clay minerals and micas or enrichment in carbonaceous microbeds. In terms of composition, the clastic component matches sandstones, although they are depleted in lilthic fragments but enriched in feldspars and quartz. Rounded and subrounded silty grains are typically represented by quartz, feldspars, and less common cherts, fine-clastic rocks, felsic volcanics, biotite, and ore minerals. The rocks are often enriched in fine plant dispersion. The clay component of rocks is mainly represented by hydromica and, to a lesser extent, smectite and chlorite. The hydromica-rich composition of clay minerals testifies to the sialic composition of source rocks.

The chemical composition of clayey–silty rocks is close to that of sandstones (Tables 4). Since the clayey–silty rocks are enriched in clay minerals and depleted in clastic components as compared to sandstones, they are marked by lower contents of SiO_2 (58.90–73.51%) and Na_2O (0.39–3.59%), but elevated contents of Al_2O_3 (11.38–20.79%), TiO_2 (0.18–0.90%), FeO + Fe_2O_3 (1.69–7.14%), CaO (0.08–6.04%), MgO (0.15–2.81%), and K_2O (1.37–5.16%). In addition, the clayey–silty rocks show high values of hydrolyzate (0.21–0.45), femic (0.04–0.17), and titanium (0.022–0.054) moduli, but lower value of the normalized alkalinity module (0.28–0.45). This is obviously related to the following facts: contents of quartz and feldspars in the rocks are lower, whereas contents of clayey matter are higher; the formation of terrigenous rocks was not accompanied by a significant mechanical differentiation of the pelitic and psammitic fractions (Yudovich and Ketris, 2000). In the module diagrams (Fig. 10), the clayey–silty rocks are distinctly separated from the field of sandstones. At the same time, both rocks demonstrate positive FM–

Table 3. Chemical composition (wt %) of garnets and chromites in sandstones of the Zhuravlevka terrane

Sample no.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO*	MnO	MgO	CaO	Total
Garnets									
Zh-21/1	36.92	–	21.33	–	35.52	0.57	4.36	0.79	99.49
Zh-21/2	36.91	–	20.85	–	36.09	0.61	4.58	0.74	99.78
Zh-21/3	36.48	–	20.81	–	34.94	2.98	2.64	1.73	99.58
Zh-21/4	36.74	–	21.00	–	35.49	2.60	2.80	1.97	100.60
Zh-21/5	38.95	–	22.38	–	31.46	0.50	4.85	0.83	98.97
Zh-21/6	37.77	–	21.33	–	34.18	2.45	2.77	1.64	100.14
Zh-31/1	43.14	–	40.66	–	10.22	2.16	3.59	–	99.77
Zh-31/2	43.18	0.99	36.62	–	10.56	2.91	5.21	0.33	99.80
Zh-31/3	43.34	0.73	36.99	–	10.20	2.95	5.56	0.27	100.04
Zh-31/4	43.34	0.37	36.64	–	10.13	3.26	5.91	0.34	99.99
Zh-33/1	36.79	–	20.70	–	36.74	1.19	2.77	1.97	100.16
Zh-33/2	37.29	–	20.49	–	35.25	0.89	4.61	1.16	99.69
Zh-33/3	36.93	–	20.85	–	35.28	0.66	4.68	1.04	99.44
Zh-33/4	36.47	–	20.27	–	36.83	1.19	2.70	1.97	99.43
Zh-33/5	41.87	–	23.84	–	26.66	0.63	5.16	1.17	99.33
Zh-33/6	38.31	–	21.13	–	34.39	1.29	2.89	1.96	99.97
Zh-33/7	41.83	–	22.41	–	28.12	0.73	5.58	1.34	100.01
Zh-45	37.04	0.05	20.25	0.07	34.98	1.51	4.08	1.21	99.19
Zh-56/1	37.08	0.07	20.43	0.04	29.63	9.35	2.03	0.60	99.22
Zh-56/2	38.35	0.02	20.81	0.11	29.86	0.56	8.04	1.06	98.82
Zh-56/3	38.00	–	21.25	0.06	30.34	0.53	8.39	1.12	99.69
Zh-56/4	39.43	0.11	21.93	0.14	31.90	0.76	6.98	1.03	102.27
Zh-56/5	38.02	0.01	20.30	0.04	34.75	2.13	4.44	1.04	100.72
Zh-56/6	37.55	0.18	20.71	0.01	33.83	2.21	4.46	0.68	99.63
Zh-57/1	37.19	0.01	20.25	–	34.61	1.59	3.48	2.24	99.38
Zh-57/2	37.11	0.09	20.68	0.14	34.64	1.40	3.58	2.45	100.08
Zh-57/3	36.66	0.09	20.47	0.09	36.85	0.98	1.41	2.87	99.41
Zh-84	37.13	–	20.70	0.06	35.14	0.80	4.09	1.31	99.23
Zh-85	37.92	0.04	21.25	–	30.27	3.70	5.74	1.39	100.32
Zhr-15/1	37.56	–	21.51	–	22.20	10.00	6.81	1.19	99.27
Zhr-15/2	36.34	–	21.28	–	34.76	1.33	4.54	0.78	99.03
Zhr-24/1	37.22	–	21.17	–	31.35	0.90	7.38	1.27	99.29
Zhr-24/2	37.75	–	21.77	–	30.10	0.59	8.36	1.05	99.64
Zhr-63/1	36.35	–	20.92	–	24.74	9.26	2.41	6.55	100.24
Zhr-63/2	37.13	–	21.36	–	31.84	0.71	6.88	1.41	99.33
Zhr-63/3	34.56	0.48	19.08	–	14.48	27.78	0.78	0.83	97.98
Zhr-63/4	34.88	0.45	19.58	–	14.06	28.02	1.10	0.86	98.95
Zhr-88/1	37.94	–	22.16	–	33.23	0.56	6.57	1.14	101.59
Zhr-88/2	37.50	–	21.93	–	33.40	0.53	6.63	1.10	101.08
Chromites									
Zh-1/1	–	–	6.17	64.77	18.66	–	9.41	–	99.01
Zh-1/2	–	–	2.76	68.62	19.58	0.30	8.63	–	99.89
Zh-1/3	–	–	9.48	56.49	25.39	0.82	7.41	–	99.59
Zh-1/4	–	–	3.31	68.43	19.28	0.75	8.33	–	100.10
Zh-1/5	–	–	9.52	59.25	22.70	–	8.40	-	99.87
Zh-1/6	–	–	9.52	57.14	24.52	0.80	8.34	–	100.32
Zh-2/1	–	–	11.67	60.31	15.32	0.41	11.31	–	99.02
Zh-2/2	–	–	10.76	55.66	25.69	–	6.32	–	98.43
Zh-2/3	–	–	10.38	62.07	16.08	0.46	11.04	–	100.03
Zh-2/4	–	–	10.27	61.90	16.46	0.46	11.08	–	100.17
Zh-2/5	–	–	10.79	56.69	25.12	0.26	7.57	–	100.43

Table 3. (Contd.)

Sample no.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO*	MnO	MgO	CaO	Total
Zh-2/6	–	–	10.49	56.55	25.82	0.32	6.58	–	99.76
Zh-2/7	–	–	11.55	60.37	15.52	0.29	11.67	–	99.40
Zh-2/8	–	–	11.85	58.69	16.88	0.77	10.72	–	98.91
Zh-2/9	–	–	11.57	62.68	13.60	–	11.77	–	99.62
Zh-23/1	–	–	7.35	63.19	19.84	0.53	9.54	–	100.45
Zh-23/2	–	–	6.71	63.16	20.11	0.31	8.36	–	98.64
Zh-23/3	–	–	7.00	64.77	17.90	0.53	10.95	–	101.15
Zh-23/4	–	–	6.52	65.66	18.43	0.38	9.70	–	100.69
Zh-23/5	–	–	6.85	64.61	17.64	0.59	9.54	–	99.23
Zh-23/6	–	–	6.99	65.38	18.43	–	9.01	–	99.81
Zh-30/1	–	–	5.24	64.64	20.54	0.37	8.41	–	99.20
Zh-30/2	–	–	12.93	58.34	17.18	0.25	10.51	–	99.21
Zh-30/3	–	–	5.20	65.29	20.34	0.15	7.71	–	98.68
Zh-30/4	–	–	12.99	57.82	17.58	0.50	10.69	–	99.58
Zh-30/5	–	–	5.20	65.81	19.04	–	8.32	–	98.37
Zh-30/6	–	–	13.47	57.34	18.77	–	10.20	–	99.78
Zh-31/1	–	–	10.88	57.92	21.53	–	7.88	–	98.98
Zh-31/2	–	–	11.24	59.37	20.42	–	7.45	–	98.48
Zh-33/1	–	–	13.69	58.07	14.47	–	12.31	–	98.54
Zh-33/2	–	–	22.50	49.39	13.39	0.23	14.44	–	99.96
Zh-33/3	–	–	14.14	58.16	14.01	0.34	12.67	–	99.32
Zh-33/4	0.18	0.18	6.97	63.96	17.64	–	10.96	–	99.89
Zh-33/5	0.05	0.01	18.35	52.61	17.31	–	11.29	–	99.62
Zh-45/1	0.04	0.44	23.37	43.34	19.97	–	11.50	–	98.65
Zh-45/2	0.05	0.11	17.75	48.04	23.63	–	9.76	–	99.34
Zh-56	0.18	0.48	11.99	52.90	22.52	–	10.50	–	98.56
Zh-64/1	–	0.04	15.23	55.97	14.39	–	12.75	–	98.39
Zh-64/2	0.11	–	15.90	53.63	16.25	–	11.76	–	97.64
Zh-64/3	0.19	0.03	16.09	54.14	15.88	–	11.73	–	98.07
Zh-64/4	0.22	–	13.51	59.23	14.41	–	12.60	–	99.97
Zh-74	0.10	0.20	21.28	43.17	22.68	–	10.55	–	97.99
Zh-76/1	0.33	2.05	10.95	48.32	23.26	–	13.00	–	97.91
Zh-76/2	0.08	0.64	10.66	51.58	26.47	-	9.42	–	98.84
Zh-85	0.10	0.27	14.86	51.04	18.87	–	12.76	–	97.89
Zhr-15	–	0.64	9.94	48.67	31.92	0.64	7.42	–	99.23
Zhr-22	–	2.04	13.00	45.05	27.37	0.78	11.24	–	99.48
Zhr-63	–	–	8.27	64.08	18.03	0.70	9.69	–	100.77

Note: (FeO*) total iron; (-) not found. Analyses were carried out on a JXA-8100 microprobe at the Far East Geological Institute, Far East Branch, Russian Academy of Sciences (N.I. Ekimova and G.B. Molchanova, analysts).

TM and HM–TM correlations and negative HM–NAM, FM–NAM, TM–NAM, and FM–SiO_2 correlations, indicating that the studied rocks have mainly petrogenic nature (disintegration of felsic intrusions).

Paleotectonic interpretation of the chemical composition of the clayey–silty rocks in the diagram (Maynard et al., 1982) is also ambiguous but consistent with the interpretation based on the composition of sandstones (Fig. 11c): the clayey–silty rocks occupy an intermediate position between sediments typical of the basins of passive and active continental margins. More clear interpretation of compositions of the sandy and clayey–silty rocks can be obtained from the K_2O/Na_2O–SiO_2 diagram proposed in (Roser and Korsch, 1986) (Fig. 12). In this diagram, all studied rocks are plotted mainly in the field of basins associated with active continental margins. Only sometimes, they approximate the compositions of sediments deposited in the basins of passive tectonic settings.

Coarse-Clastic Rocks

Coarse-clastic rocks (conglomerates and gravelstones) occur at different levels of the studied section,

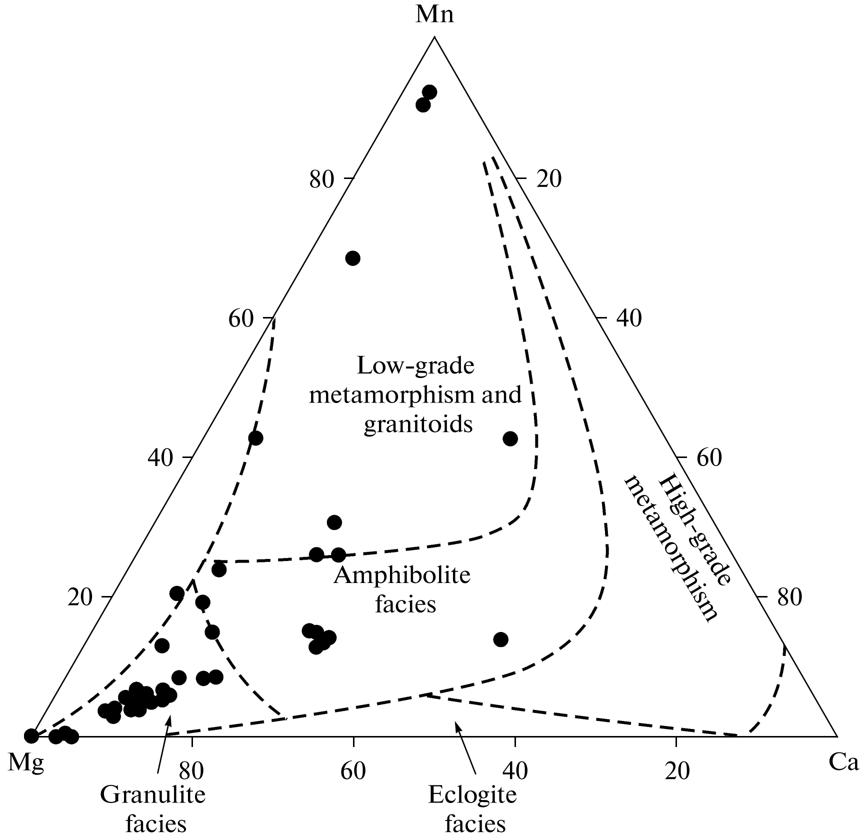


Fig. 7. Compositional diagram for detrital garnets from different metamorphic rocks and granitoids (Teraoka, 2003).

but their highest content (up to 20 vol %) is observed in the Katalevskaya Formation.

The conglomerates are fine- to medium-pebble (1–5 cm), rarely coarse-pebble (up to 10–15 cm) rocks. The clastic material (70–85 vol %) is usually equant or elongated. Pebbles are well- to medium-sorted and rounded. Gravelstones are mainly represented by the medium- to coarse-gravel varieties (grain size 3–10 mm). The fine-gravel (up to 3 mm) variety is less common. The clastic component occupies 50–80 vol %. Gravelstones are usually medium- to well-sorted rocks with rounded and subrounded particles. Fragments of conglomerates and gravelstones are represented by siliceous and siliceous–clayey rocks (up to 80%), with a lesser amount of sedimentary (up to 30%), metamorphic, and felsic rocks (up to 20%). The sandy–silty matrix is significantly less sorted and rounded. It is mainly composed of quartz, feldspar, and chert fragments. Psephitic fragments are mainly represented by siliceous rocks, presumably, due to their significantly higher resistance to weathering as compared to granitoids, which are easily disintegrated and concentrated as quartz and feldspar grains in the matrix.

Thus, the composition of terrigenous rocks of the terrane indicates that the provenances were mainly composed of felsic igneous and metamorphic rocks. In addition, they could contain ophiolitic assemblages of the Jurassic accretionary wedge. Sedimentation settings reconstructed from the lithological composition 7
correspond to the active continental margins (most probably, basins complicated by strike-slip deformations along transform faults). In some diagrams, the studied rocks are formally close to those from basins formed at passive continental margins. This is likely related to the existence of different sources of clastic material rather than a common geotectonic setting.

SETTINGS AND CONDITIONS OF THE TERRIGENOUS ROCK ACCUMULATION

Rocks of the Zhuravlevka terrane are marked by a wide distribution of beds with the rhythmic intercalations of sandstones and siltstones. Rhythms in these beds are characterized by the graded sorting of material, sharp boundaries at the base with erosion traces as hieroglyphs in the underlying rock, its disintegration products, and set of sedimentary structures with Bouma successions: abcde, abde, ade, bde, bcde, and cde. All these features are typical of turbidites (Walker, 1978). The turbidites are usually associated with mixtites, sandstones, gravelstones, and fine-gravel conglomerates commonly linked by gradual transitions.

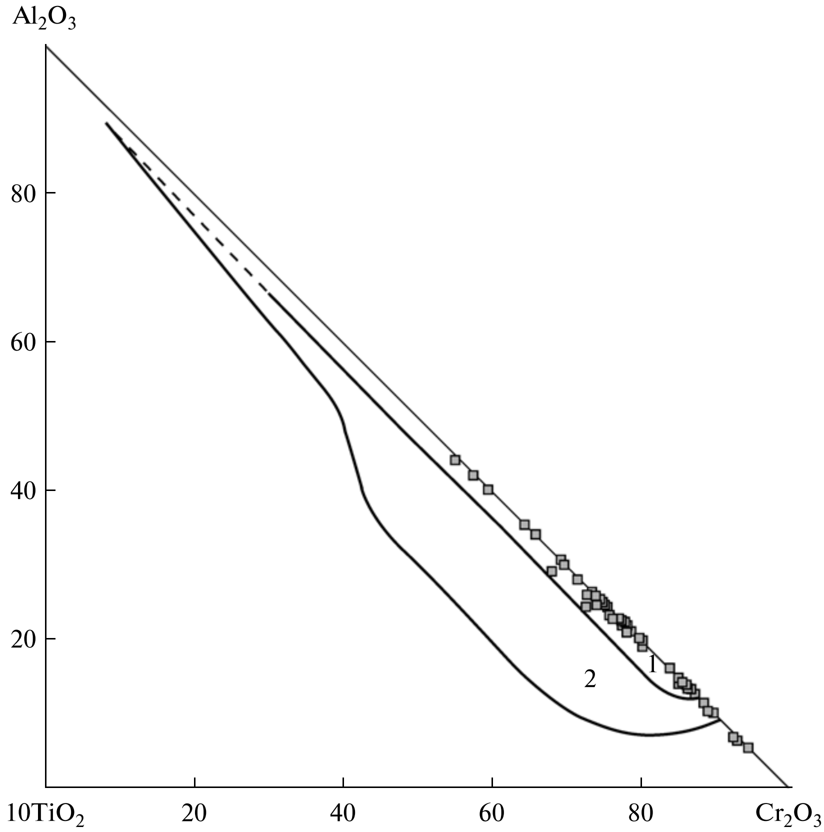


Fig. 8. Compositional diagram for detrital chromites from different magmatic rocks (Shcheka and Vrzhosek, 1983). Fields of chromites from (1) dunite–harzburgite (alpine-type) and (2) basaltoid ultramafic formations.

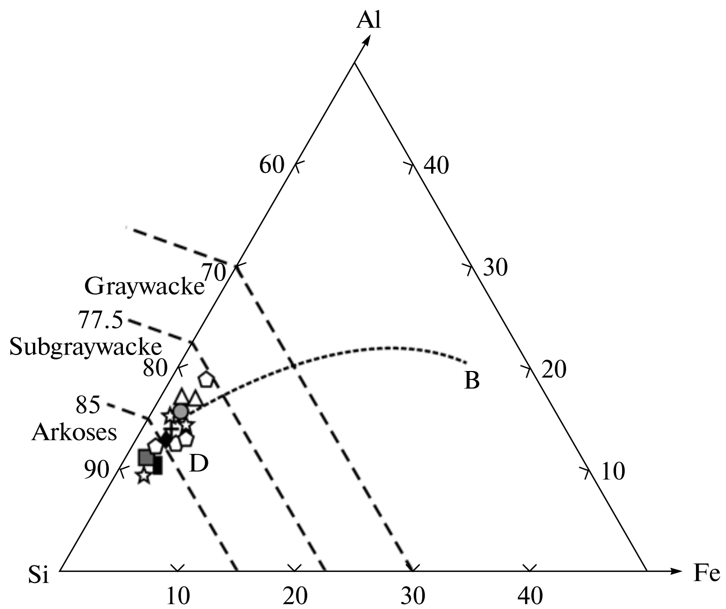


Fig. 9. Si–Al–Fe diagram for sandy rocks of the Zhuravlevka terrane (Moor and Dennen, 1970) (at wt). Line D–C denotes the granite–basalt trend. Symbols are shown in Fig. 4.

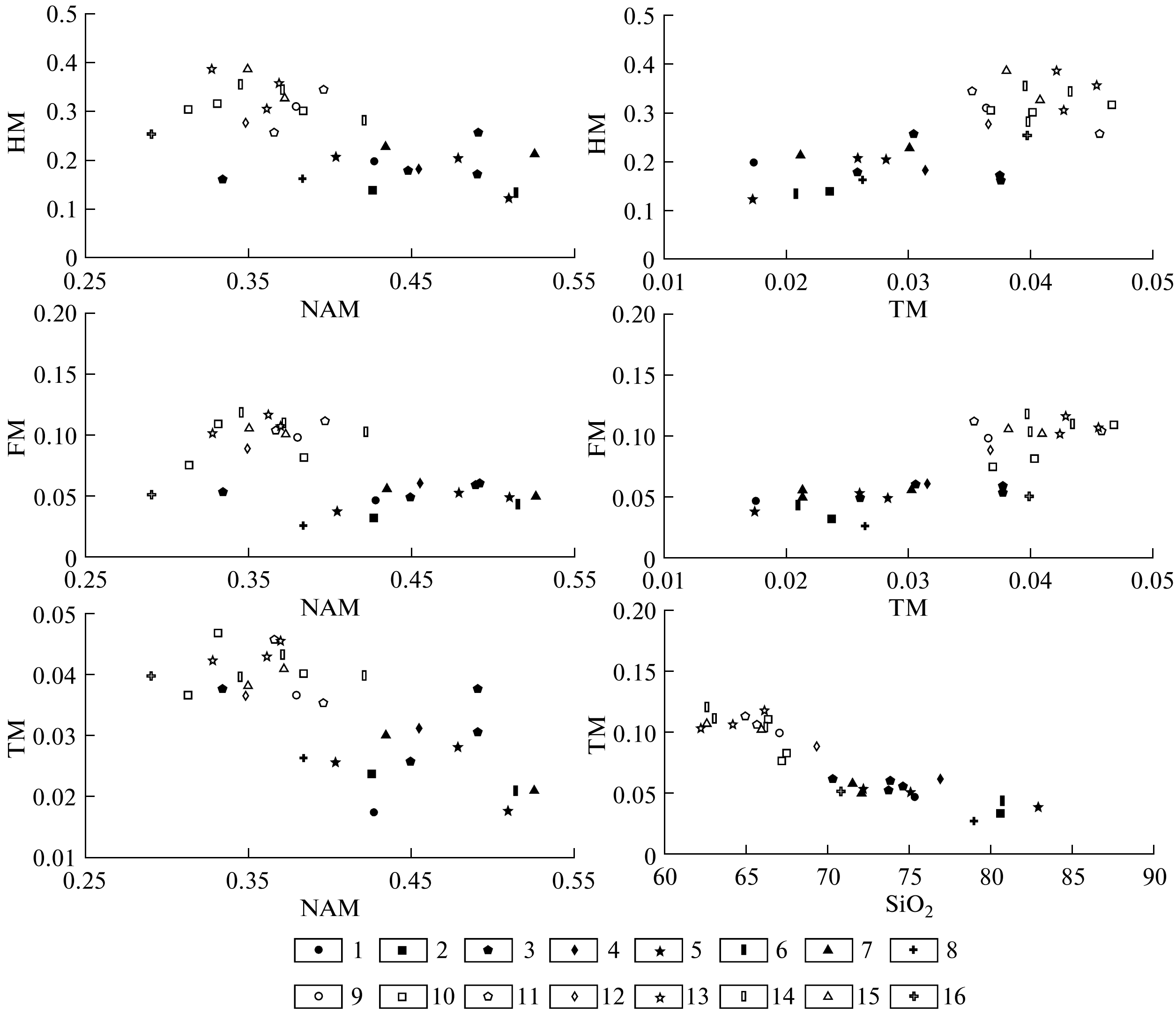
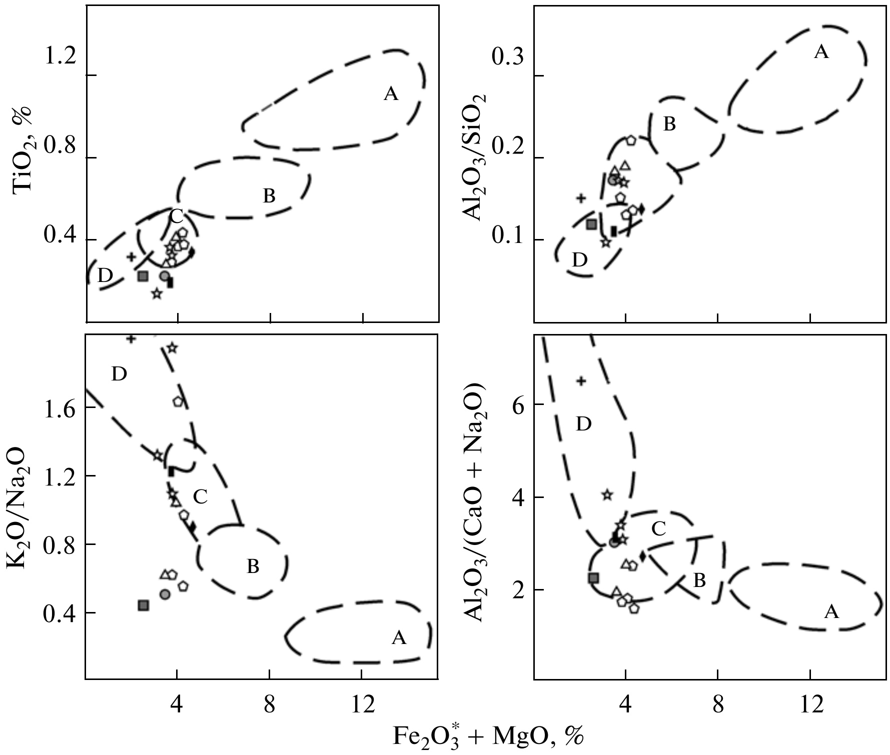


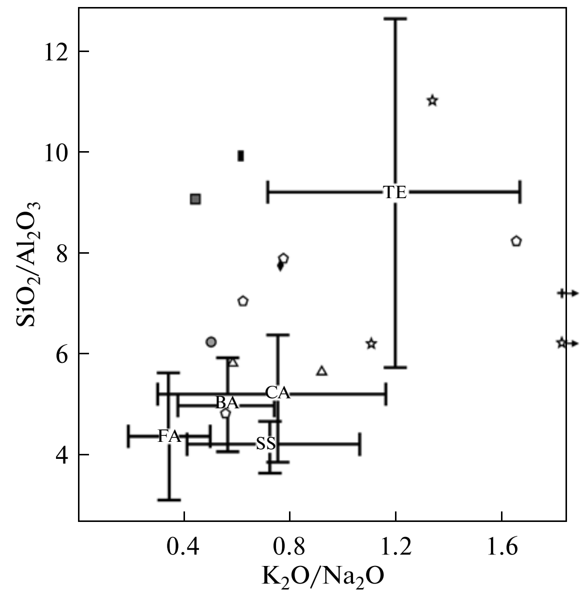
Fig. 10. Module diagrams for sandy and clayey–silty rocks of the Zhuravlevka terrane (Yudovich and Ketris, 2000). (1–8) Sandy rocks; (9–16) clayey–silty rocks. Formations: (1, 9) Zhuravlevskaya, (2, 10) Klyuchevskaya, (3, 11) Ust-Kolumbinskaya, (4, 12) Primankinskaya, (5, 13) Katalevskaya, (6, 14) Divninskaya, (7, 15) Svetlovodninskaya, (8, 16) Luzhkinskaya.

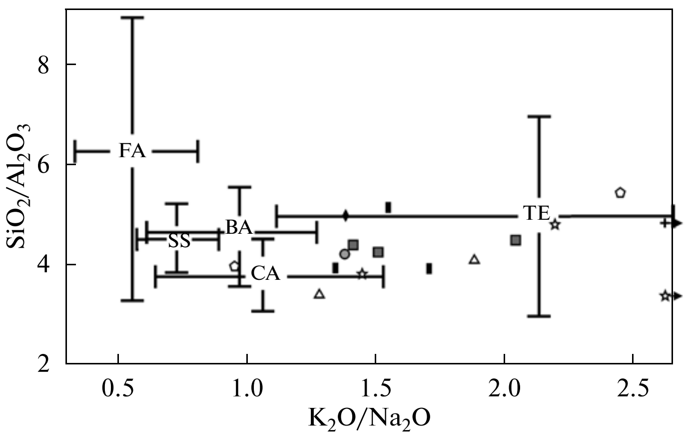
The chaotic structure, high matrix content, and absence of sorting and bedding typical of the coarse-clastic rocks indicate that the turbidites were deposited by high-density (granular) and debris flows. In addition, they are often associated with thin beds of fine (from 3–5 mm to a few centimeters) alternation of siltstones and sandstones formed by bottom (contour) currents. Such a genetic set of sediments suggests their accumulation in the lower part and near the foot of underwater slope and in the adjacent areas of seafloor plains. The clastic material was mainly transported and deposited by gravitational flows varying in density, composition, and origin. It could also be deposited by bottom currents that intensely reworked the sedimentary material supplied into sedimentation areas by turbidite flows.

The gravitational and contour sediments usually produce thick sequences of massive silty mudstones, which can be considered as hemipelagic sediments

Fig. 11. Diagrams of the chemical composition of sandy and clayey–silty rocks from different geodynamic settings. (a) Basin types (Bhatia, 1983): dashed lines denote fields corresponding to geochemical parameters of ancient sandstones from basins conjugated with (A) oceanic and (B) continental island-arcs, (C) active and (D) passive continental margins. (Fe_2O_3) Total iron. (b, c) Basin settings: (b) for sandy rocks, (c) for clayey–silty rocks (Maynard et al., 1982). Intersecting lines denote standard deviations from the average compositions of modern abyssal sands and clays in different geodynamic settings. Symbols and abbreviations are shown in Fig. 4.


TiO2, %
Al2O3/SiO2
K2O/Na2O
Al2O3/(CaO + Na2O)
Fe2O3* + MgO, %
A
B
C
D


SiO2/Al2O3
K2O/Na2O
TE
CA
BA
FA
SS


SiO2/Al2O3
K2O/Na2O
FA
SS
BA
CA
TE

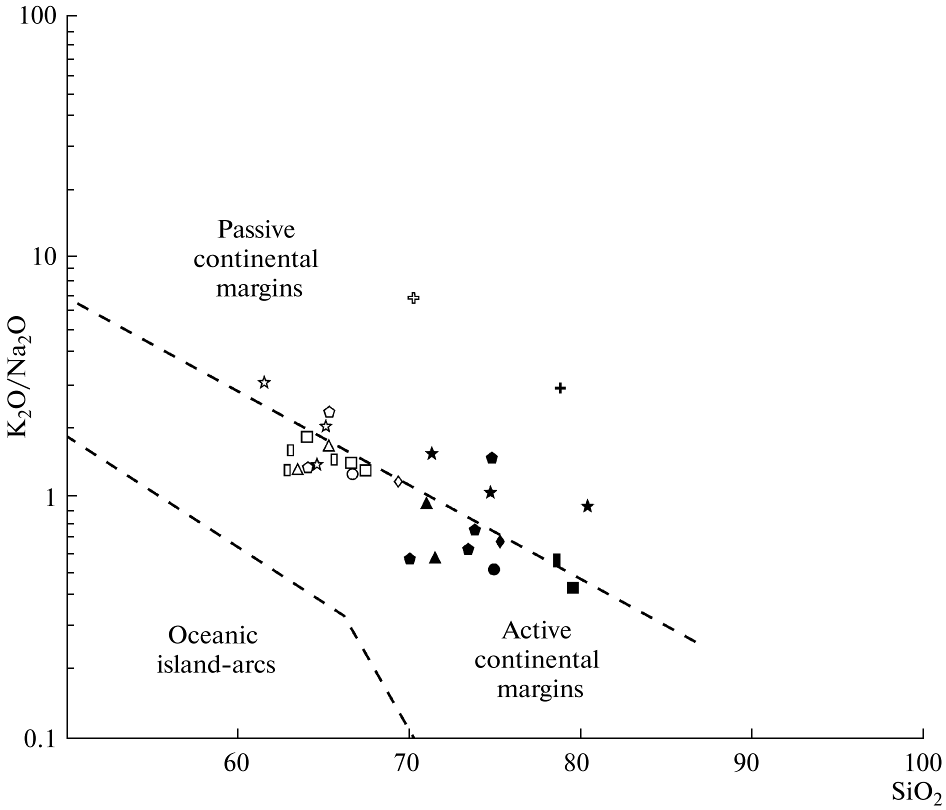


Fig. 12 K_2O/Na_2O–SiO_2 diagram for sandy and clayey–silty rocks from different basin settings (Roser and Korsch, 1986). Basins of tectonic settings: (PM) passive continental margins, (ACM) active continental margins, (ARC) oceanic island-arcs. For symbols, see Fig. 10.

deposited in relatively calm hydrodynamic conditions. Thin horizontal or gentle wavy bedding in rocks can suggest an insignificant reworking of the matter by waves and currents.

One more type of sediments widespread in the Zhuravlevka terrane is represented by thick sequences of inequigranular sandstones that contain interbeds and lenses of conglomerates and gravelstones, as well as abundant plant remains and shallow-water fauna. Sediments were presumably accumulated in the relatively shallow-water conditions typical of the littoral and open-sea sublittoral settings.

DISCUSSION

The data presented above unambiguously indicate that the clastic material for terrigenous rocks of the Zhuravlevka terrane was derived mainly from a sialic (continental) source. This follows, in particular, from the predominance of quartz and acid plagioclase in the detrital component of sandstones, as well as from the sharp predominance of the typical sialic assemblage among the heavy detrital minerals. The hydromica-rich composition of clay minerals both in the sandstone matrix and in the clayey-silty rocks can serve as additional argument in support of this point of view. This conclusion is consistent with the chemical composition of detrital garnets typical of intensely metamorphosed rocks and granitoids.

At the same time, the provenances presumably contained abundant fragments of pre-Cretaceous active margins, primarily, accretionary wedges with chert and ophiolite slices at some structural levels, for example, the Samarka-type Jurassic–Early Cretaceous accretionary wedges, which are traced as a virtually uninterrupted band along the eastern margin of Asia to the Sea of Okhotsk coast in the north and to Kalimantan Island in the south (Mitzutani et al., 1990). This assumption is supported by high contents of cherts in the clastic component of sandstones and their absolute predominance among the gravelstone and conglomerate fragments. This fact is also suggested by the compositional features of detrital chromites, in particular, their low Ti index typical of ultramafic rocks from ophiolitic belts and active margins.

Mixing of these two sharply different sources is also demonstrated by the diagrams that interpret not only compositions of the rock-forming components and detrital heavy minerals, but also the chemical features of terrigenous rocks in the Zhuravlevka terrane (Figs. 4, 9, 11, 12). Presumably, such mixing is the major charac-

Table 4. Chemical composition (wt %) of terrigenous rocks of the Zhuravlevka terrane

Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	H_2O^-	Total	HM	TM	FM	NAM
Sandy rocks																		
Zhuravlevskaya Formation																		
Zhr-4	76.42	0.16	11.81	1.49	0.96	0.03	0.73	0.27	3.50	2.74	0.12	1.06	0.22	99.51	0.19	0.014	0.04	0.53
Zhr-7	68.85	0.29	14.66	2.13	2.32	0.05	1.62	0.46	3.93	2.79	0.14	1.98	0.28	99.50	0.28	0.020	0.09	0.45
Zhr-10	73.34	0.20	12.60	1.46	1.13	0.03	0.97	1.10	3.57	3.04	0.09	2.00	0.15	99.68	0.21	0.016	0.05	0.52
Zhr-11	74.24	0.37	12.22	1.95	1.01	0.07	0.92	0.72	3.55	2.45	0.11	1.71	0.18	99.50	0.21	0.030	0.05	0.49
Zhr-15	77.31	0.10	10.76	0.80	1.13	0.07	0.57	1.21	3.14	2.66	0.09	1.56	0.11	99.51	0.17	0.009	0.03	0.54
Zhr-21	75.87	0.26	12.56	0.82	1.29	0.03	0.70	0.21	3.55	2.90	0.07	1.21	0.16	99.63	0.20	0.021	0.04	0.51
Zhr-24	74.34	0.23	12.68	1.42	1.15	0.02	0.88	0.43	3.26	3.41	0.08	1.42	0.18	99.50	0.21	0.018	0.05	0.53
Zhr-29	82.03	0.10	9.14	1.13	0.58	0.03	0.21	0.24	2.93	1.76	0.08	1.12	0.18	99.53	0.13	0.011	0.02	0.51
Klyuchevskaya Formation																		
Zh-43	85.66	0.21	7.48	1.98	0.18	0.09	0.29	0.81	1.85	0.75	0.01	0.68	0.00	99.98	0.12	0.028	0.03	0.35
Zh-45	74.32	0.26	9.58	1.77	0.58	0.16	0.87	2.98	2.99	1.19	0.14	4.79	0.00	99.63	0.17	0.027	0.05	0.44
Zh-47	81.70	0.10	9.60	1.12	0.68	0.02	0.14	0.35	3.04	1.54	0.14	1.26	0.22	99.91	0.14	0.010	0.02	0.48
Ust-Kolumbinskaya Formation																		
Zh-1	71.10	0.38	9.08	2.26	1.01	0.06	1.51	5.08	1.75	1.51	0.28	5.55	0.27	99.84	0.18	0.042	0.07	0.36
Zh-2	78.10	0.29	9.00	1.20	0.85	0.08	1.21	2.78	0.53	2.25	0.08	3.35	0.27	99.99	0.15	0.032	0.04	0.31
Zh-21	75.60	0.34	11.60	1.48	1.01	0.05	0.89	1.40	3.19	1.88	0.11	1.89	0.19	99.63	0.19	0.029	0.05	0.44
Zh-23	71.90	0.19	9.28	1.48	1.01	0.06	1.64	5.08	2.58	1.71	0.26	4.49	0.23	99.91	0.17	0.020	0.06	0.46
Zh-29	72.70	0.27	10.30	1.36	1.35	0.05	1.58	3.50	2.62	1.79	0.17	4.04	0.25	99.98	0.18	0.026	0.06	0.43
Zh-30	76.00	0.15	7.95	0.88	0.85	0.05	1.50	3.47	2.89	1.62	0.12	4.32	0.26	100.06	0.13	0.019	0.04	0.57
Zh-31	77.70	0.23	9.18	1.59	0.68	0.09	0.26	2.80	2.81	2.56	0.14	1.62	0.30	99.96	0.15	0.025	0.03	0.58
Zh-33	71.80	0.29	9.60	3.02	1.18	0.06	1.50	3.47	2.47	2.05	0.17	4.10	0.21	99.92	0.20	0.030	0.08	0.47
Zh-37	71.00	0.29	9.60	3.12	1.18	0.06	1.50	3.83	2.09	1.99	0.24	4.71	0.29	99.90	0.20	0.030	0.08	0.43
Zhr-97	69.92	0.30	13.47	1.90	0.94	0.14	0.88	2.82	3.71	2.70	0.13	2.79	0.10	99.80	0.24	0.022	0.06	0.48
Zhr-100	70.52	0.44	15.17	2.03	1.12	0.03	1.16	0.27	4.48	2.98	0.14	1.53	0.12	99.99	0.27	0.029	0.06	0.49
Zhr-107	69.29	0.52	15.27	1.94	2.00	0.02	1.55	0.54	3.92	2.40	0.16	2.06	0.17	99.84	0.29	0.034	0.08	0.41
Zhr-109	68.07	0.51	14.78	1.73	1.84	0.05	1.44	1.63	4.43	2.89	0.16	2.32	0.07	99.92	0.28	0.035	0.07	0.50
Zhr-112	72.96	0.42	13.40	0.81	1.61	0.02	0.77	1.08	5.23	2.18	0.13	1.20	0.07	99.88	0.22	0.031	0.04	0.55
Zhr-116	70.99	0.46	14.46	0.97	1.87	0.03	0.88	0.95	5.64	1.98	0.14	1.34	0.05	99.76	0.25	0.032	0.05	0.53
Primankinskaya Formation																		
Zh-12/1	80.90	0.19	7.75	2.68	1.01	0.06	0.40	1.40	2.66	1.31	0.09	1.27	0.27	99.99	0.14	0.025	0.05	0.51
Zh-14	77.90	0.27	8.98	2.89	0.68	0.02	0.50	1.58	2.74	1.88	0.22	2.17	0.22	100.05	0.16	0.030	0.05	0.51
Zh-15	76.90	0.29	9.70	3.25	1.01	0.04	0.69	0.88	2.61	1.88	0.19	2.29	0.22	99.95	0.19	0.030	0.07	0.46
Zh-16	71.85	0.47	13.06	4.10	0.19	0.15	1.30	0.41	2.17	2.67	0.16	2.90	0.00	99.43	0.25	0.036	0.08	0.37

Table 4. (Contd.)

Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	H_2O^-	Total	HM	TM	FM	NAM
Katalevskaya Formation																		
Zh-56	71.20	0.53	12.50	3.38	2.20	0.08	1.07	0.55	2.96	3.04	0.14	2.11	0.21	99.97	0.26	0.042	0.09	0.48
Zh-59	75.30	0.19	11.93	1.81	1.18	0.04	0.65	0.50	2.58	3.46	0.14	1.51	0.32	99.61	0.20	0.016	0.05	0.51
Zh-62	75.70	0.19	11.93	1.26	1.35	0.04	0.58	0.60	2.74	3.27	0.28	1.59	0.22	99.75	0.20	0.016	0.04	0.50
Zh-63	78.90	0.27	11.00	0.56	1.35	0.04	0.51	0.35	2.51	2.84	0.09	1.20	0.34	99.96	0.17	0.025	0.03	0.49
Zh-64	74.40	0.52	12.93	1.23	0.72	0.02	0.60	1.50	2.89	2.55	0.15	2.22	0.13	99.86	0.21	0.040	0.03	0.42
Zhr-33	73.53	0.28	11.05	1.88	0.39	0.03	0.37	2.70	2.02	3.43	0.07	3.55	0.24	99.54	0.19	0.025	0.04	0.49
Zhr-34	71.38	0.30	12.17	2.22	0.54	0.04	0.45	2.73	2.03	3.39	0.09	4.13	0.25	99.72	0.21	0.025	0.05	0.45
Zhr-38	74.40	0.18	10.88	0.70	1.48	0.03	1.00	1.65	1.91	3.26	0.07	3.79	0.19	99.54	0.18	0.017	0.04	0.48
Zhr-41	70.98	0.40	11.77	4.36	0.72	0.07	0.74	1.89	0.06	3.30	0.15	4.70	0.38	99.52	0.24	0.034	0.08	0.29
Zhr-43	76.87	0.25	11.54	1.47	0.51	0.03	0.41	1.03	0.97	3.46	0.07	2.65	0.24	99.50	0.18	0.022	0.03	0.38
Zhr-47	65.55	0.38	12.11	2.04	1.47	0.07	1.93	4.10	1.40	2.83	0.11	7.56	0.29	99.84	0.25	0.031	0.08	0.35
Zhr-71	80.30	0.16	7.30	0.76	3.16	0.10	0.94	0.52	2.57	1.20	0.25	2.40	0.14	99.80	0.15	0.022	0.06	0.52
Zhr-76	85.20	0.12	7.32	0.01	0.96	0.01	0.43	0.02	0.53	2.86	0.09	2.13	0.22	99.90	0.10	0.016	0.02	0.46
Zhr-84	85.90	0.08	6.55	0.93	0.76	0.02	0.21	0.22	2.53	1.85	0.13	0.62	0.06	99.86	0.10	0.012	0.02	0.67
Zhr-86	83.40	0.11	7.19	1.39	0.59	0.01	0.22	0.18	2.45	2.52	0.09	1.61	0.14	99.90	0.11	0.015	0.03	0.69
Zhr-88	78.40	0.15	8.04	4.43	1.54	0.02	0.63	0.28	1.74	2.83	0.37	1.44	0.22	100.09	0.18	0.019	0.08	0.57
Zhr-93	84.31	0.18	8.64	1.51	0.01	0.01	0.39	0.01	0.04	1.90	0.10	2.34	0.37	99.79	0.12	0.021	0.02	0.22
Divninskaya Formation																		
Zhr-82	80.70	0.17	8.15	1.50	1.29	0.01	0.67	0.07	2.59	1.60	1.05	2.17	0.20	100.17	0.14	0.021	0.04	0.51
Zhr-79	80.61	0.16	7.98	0.82	2.17	0.08	0.84	0.66	2.63	1.33	0.98	2.22	0.24	100.72	0.14	0.020	0.05	0.50
Svetlovodninskaya Formation																		
Zh-67	76.00	0.38	12.43	1.20	1.01	0.02	0.26	0.55	2.51	2.84	0.22	1.88	0.37	99.67	0.20	0.031	0.03	0.43
Zh-70	69.80	0.48	12.23	3.03	1.52	0.19	0.79	2.50	2.81	2.61	0.10	3.48	0.21	99.75	0.25	0.039	0.08	0.44
Zh-72	68.80	0.32	11.93	1.72	1.35	0.23	1.01	4.55	3.19	1.99	0.14	4.61	0.14	99.98	0.23	0.027	0.06	0.43
Zh-74	76.20	0.29	13.12	1.04	0.85	0.04	0.36	0.35	2.89	2.84	0.13	1.60	0.27	99.98	0.20	0.022	0.03	0.44
Zh-76	66.80	0.44	13.36	2.88	1.86	0.18	0.90	2.70	2.89	2.84	0.11	4.79	0.22	99.97	0.28	0.033	0.09	0.43
Zhr-54/1	71.45	0.44	12.40	0.95	2.56	0.08	1.14	1.91	3.30	2.49	0.19	2.61	0.10	99.62	0.23	0.035	0.07	0.47
Zhr-56/1	72.50	0.21	12.22	1.38	0.95	0.09	0.53	2.42	4.28	1.93	0.10	3.27	0.09	99.97	0.20	0.017	0.04	0.51
Zhr-58	68.96	0.24	10.84	1.37	0.75	0.34	0.38	5.58	5.01	0.98	0.10	5.41	0.09	100.05	0.20	0.022	0.04	0.55
Zhr-63	73.57	0.26	12.85	0.67	2.12	0.04	1.36	0.81	3.62	2.79	0.11	1.68	0.04	99.92	0.22	0.020	0.06	0.50
Zhr-65	72.16	0.23	12.68	0.88	1.73	0.06	1.00	1.86	4.15	3.36	0.09	2.22	0.09	99.51	0.22	0.018	0.05	0.59
Zhr-68	73.81	0.17	12.66	0.93	1.56	0.05	0.95	1.14	4.21	2.61	0.08	1.48	0.02	99.67	0.21	0.013	0.05	0.54
Luzhkinskaya Formation																		
Zh-79/1	78.40	0.28	12.08	0.53	0.42	0.02	0.55	0.30	1.26	3.16	0.14	2.69	0.00	99.83	0.17	0.023	0.02	0.37
Zh-80	79.90	0.29	9.28	1.48	1.01	0.04	0.40	0.70	1.14	2.75	0.06	2.45	0.18	99.68	0.15	0.031	0.04	0.42
Zh-82	77.60	0.34	11.53	1.57	0.68	0.03	0.43	0.55	0.66	3.56	0.10	2.85	0.28	100.18	0.18	0.029	0.03	0.37

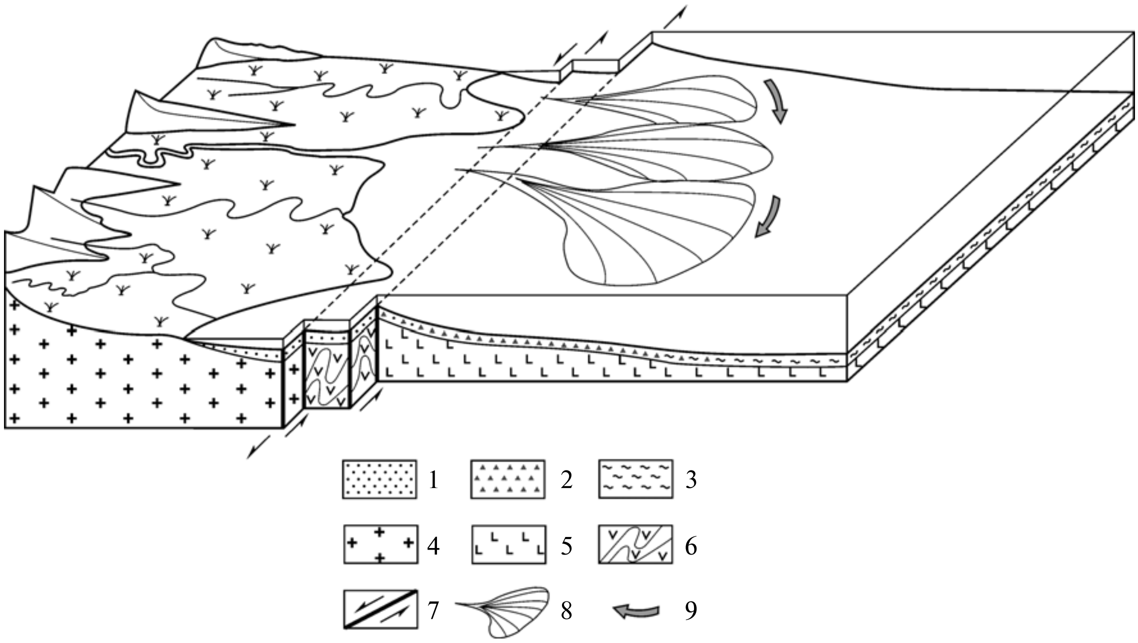
Table 4. (Contd.)

Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	H_2O^-	Total	HM	TM	FM	NAM
Zh-84	80.70	0.30	10.41	0.42	0.42	0.01	0.50	1.20	0.29	3.32	0.16	2.07	0.07	99.87	0.14	0.029	0.02	0.35
Zh-85	78.30	0.24	11.80	0.73	0.54	0.03	0.55	0.35	2.00	3.00	0.13	1.78	0.09	99.54	0.17	0.020	0.02	0.42
Clayey–silty rocks																		
Zhuravlevskaya Formation																		
Zhr-1	64.75	0.64	15.80	3.34	2.48	0.06	2.02	0.54	2.52	3.12	0.16	3.58	0.58	99.59	0.34	0.041	0.12	0.36
Zhr-8	61.59	0.75	17.42	3.18	2.40	0.02	2.12	0.51	2.26	3.88	0.20	4.36	0.90	99.59	0.39	0.043	0.13	0.35
Zhr-17	66.26	0.55	15.53	3.32	1.75	0.05	1.77	0.41	2.47	3.45	0.16	3.31	0.51	99.54	0.32	0.035	0.10	0.38
Zhr-25	66.39	0.71	16.42	2.77	1.93	0.08	1.55	0.39	2.30	3.90	0.17	2.65	0.25	99.51	0.33	0.043	0.10	0.38
Zhr-30	73.51	0.18	15.23	1.79	0.98	0.04	0.90	0.46	2.97	2.10	0.11	1.31	0.08	99.66	0.25	0.022	0.05	0.33
Zhr-32	64.68	0.51	16.71	3.62	1.63	0.03	1.86	0.32	2.18	3.81	0.15	3.70	0.32	99.52	0.35	0.031	0.11	0.36
Klyuchevskaya Formation																		
Zh-18	68.18	0.57	14.43	4.55	0.18	0.22	1.71	0.91	1.28	3.31	0.28	4.12	0.00	99.74	0.29	0.040	0.10	0.32
Zh-28	64.52	0.61	15.11	5.72	0.35	0.15	1.69	2.19	1.94	3.24	0.28	3.78	0.00	99.58	0.34	0.040	0.12	0.34
Zh-42	71.90	0.19	13.94	1.66	0.85	0.02	0.14	5.07	2.51	1.37	0.08	1.81	0.25	99.79	0.23	0.014	0.04	0.28
Zh-44	65.34	0.89	17.05	3.60	0.20	0.09	0.96	1.06	1.90	3.93	0.30	4.33	0.00	99.65	0.33	0.052	0.07	0.34
Zh-48	64.21	0.65	16.49	5.65	0.22	0.24	1.61	0.59	1.53	3.64	0.27	4.54	0.00	99.64	0.36	0.039	0.12	0.31
Zh-93	65.40	0.72	16.78	2.40	1.80	0.05	1.17	2.07	2.50	3.64	0.22	3.01	0.03	99.79	0.33	0.043	0.08	0.37
Zh-95	69.00	0.58	12.89	3.20	1.10	0.04	1.24	3.30	2.50	3.18	0.22	2.54	0.00	99.79	0.26	0.045	0.08	0.44
Zh-99	70.60	0.61	13.76	2.31	2.37	0.04	0.68	0.75	2.45	3.00	0.19	2.89	0.33	99.98	0.27	0.044	0.08	0.40
Zh-100	64.80	0.58	18.20	3.37	1.08	0.02	1.09	0.35	2.40	3.96	0.30	3.50	0.00	99.65	0.36	0.032	0.09	0.35
Ust-Kolumbinskaya Formation																		
Zh-39	65.65	0.55	12.04	4.04	0.22	0.15	2.48	4.51	0.28	3.13	0.35	6.55	0.30	100.25	0.26	0.046	0.10	0.28
Zhr-103	68.50	0.51	14.86	2.74	1.68	0.04	1.64	0.88	3.59	2.37	0.17	2.39	0.19	99.56	0.29	0.034	0.09	0.40
Zhr-105	65.99	0.54	16.28	1.72	3.49	0.03	1.67	0.54	3.35	3.11	0.19	2.66	0.22	99.79	0.33	0.033	0.10	0.40
Zhr-110	58.90	0.62	18.58	4.39	2.75	0.07	2.62	0.50	3.47	3.79	0.20	3.33	0.36	99.58	0.45	0.033	0.17	0.39
Zhr-115	66.37	0.66	16.08	3.65	1.11	0.04	1.39	0.41	2.96	3.46	0.20	3.13	0.45	99.91	0.32	0.041	0.09	0.40
Primankinskaya Formation																		
Zh-5	61.38	0.63	17.04	5.98	0.52	0.10	2.58	0.92	1.32	3.40	0.28	5.49	0.00	99.64	0.40	0.037	0.15	0.28
Zh-7	73.07	0.47	12.51	3.65	0.52	0.08	0.90	0.78	2.06	2.48	0.18	3.10	0.00	99.80	0.24	0.038	0.07	0.36
Zh-8	67.55	0.56	15.23	4.85	0.25	0.10	1.21	0.35	2.13	2.99	0.35	4.11	0.00	99.68	0.31	0.037	0.09	0.34
Zh-9	71.22	0.51	13.21	3.70	0.20	0.10	1.29	0.82	2.09	2.57	0.16	3.48	0.00	99.35	0.25	0.039	0.07	0.35
Zh-12	73.30	0.38	11.73	2.78	1.01	0.03	0.64	1.75	2.61	2.65	0.08	2.76	0.22	99.94	0.22	0.032	0.06	0.45
Katalevskaya Formation																		
Zh-57	68.40	0.54	16.60	1.58	1.60	0.04	1.32	0.35	3.11	3.73	0.22	2.38	0.17	100.04	0.30	0.033	0.07	0.41
Zh-60	61.10	0.90	16.67	3.75	2.63	0.05	1.91	2.03	2.15	3.82	0.41	4.15	0.19	99.76	0.39	0.054	0.14	0.36
Zh-61	63.00	0.87	17.56	3.04	3.01	0.06	1.38	1.05	2.43	3.56	0.09	3.55	0.27	99.87	0.39	0.050	0.12	0.34

Table 4. (Contd.)

Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	H_2O^-	Total	HM	TM	FM	NAM
Zhr-36	65.24	0.63	15.65	4.83	0.89	0.04	1.08	0.38	1.28	4.34	0.13	4.55	0.67	99.71	0.34	0.040	0.10	0.36
Zhr-46	59.10	0.90	20.79	3.34	1.05	0.02	1.45	0.34	1.16	5.16	0.13	5.45	0.74	99.63	0.44	0.043	0.10	0.30
Zhr-70	66.32	0.60	13.92	3.74	2.14	0.10	1.90	1.19	1.73	3.05	0.18	4.74	0.23	99.84	0.31	0.043	0.12	0.34
Zhr-73	65.90	0.58	13.68	2.75	2.92	0.07	1.75	0.19	1.39	3.80	1.51	4.48	0.92	99.94	0.30	0.042	0.11	0.38
Divninskaya Formation																		
Zh-49	60.86	0.70	17.34	5.52	0.22	0.10	2.81	1.73	2.05	3.31	0.33	4.75	0.00	99.72	0.39	0.040	0.14	0.31
Zh-51	64.02	0.72	15.77	5.56	0.45	0.09	2.47	1.50	1.78	2.79	0.35	4.15	0.00	99.65	0.35	0.046	0.13	0.29
Zh-53	63.60	0.66	15.50	3.51	1.80	0.05	1.54	3.00	2.80	3.32	0.39	3.27	0.08	99.52	0.34	0.043	0.11	0.39
Zh-54	63.80	0.66	15.80	4.02	0.72	0.04	1.31	2.50	3.44	3.55	0.33	3.52	0.14	99.83	0.33	0.042	0.10	0.44
Zh-55	62.60	0.72	15.45	2.52	0.72	0.03	1.27	6.04	2.60	4.00	0.30	3.57	0.14	99.96	0.31	0.047	0.07	0.43
Zhr-48	59.89	0.64	16.01	4.53	1.49	0.03	1.92	2.60	1.63	3.74	0.18	6.54	0.60	99.80	0.38	0.040	0.13	0.34
Zhr-51	61.59	0.67	16.68	4.11	1.49	0.03	1.78	1.32	2.21	3.47	0.16	5.31	0.75	99.57	0.37	0.040	0.12	0.34
Zhr-53	59.40	0.74	17.55	4.51	1.43	0.04	2.05	1.23	1.65	4.06	0.19	6.50	0.57	99.92	0.41	0.042	0.14	0.33
Zhr-54	69.28	0.48	13.51	3.59	1.63	0.04	1.30	0.81	2.64	2.56	0.15	3.30	0.25	99.54	0.28	0.036	0.09	0.38
Zhr-78	61.60	0.64	14.80	2.10	4.35	0.03	1.88	0.11	1.97	3.93	1.66	6.03	1.06	100.16	0.36	0.043	0.14	0.40
Zhr-79	62.90	0.51	12.96	1.72	3.35	0.05	1.86	2.26	2.61	3.16	1.58	6.22	0.68	99.86	0.30	0.039	0.11	0.45
Zhr-80	67.30	0.50	12.08	2.14	3.14	0.04	1.75	0.94	2.23	2.85	1.68	4.99	0.58	100.22	0.27	0.041	0.11	0.42
Zhr-81	66.20	0.55	12.95	2.59	2.84	0.03	1.78	0.34	1.96	3.51	1.50	4.88	1.02	100.15	0.29	0.042	0.11	0.42
Zhr-83	72.50	0.35	11.38	1.93	1.84	0.01	0.87	0.08	1.82	2.94	1.74	3.75	0.78	99.99	0.21	0.031	0.06	0.42
Svetlovodninskaya Formation																		
Zh-65	62.30	0.72	19.13	3.51	1.04	0.05	1.14	0.35	2.79	3.86	0.36	4.31	0.08	99.64	0.39	0.038	0.09	0.35
Zh-71	62.80	0.68	17.63	3.03	2.63	0.09	1.76	0.35	2.85	3.36	0.37	4.16	0.11	99.82	0.38	0.039	0.12	0.35
Zhr-57	64.49	0.68	16.55	2.24	2.91	0.03	1.91	0.39	2.10	4.43	0.18	3.64	0.27	99.82	0.35	0.041	0.11	0.39
Zhr-64	69.05	0.60	14.76	2.80	1.79	0.04	1.82	0.45	1.54	3.40	0.19	3.34	0.21	99.99	0.29	0.041	0.09	0.33
Zhr-69	64.75	0.71	17.20	2.00	2.67	0.03	1.99	1.26	2.63	3.96	0.18	2.50	0.13	100.01	0.35	0.041	0.10	0.38
Luzhkinskaya Formation																		
Zh-87	71.60	0.57	14.01	2.44	1.69	0.03	0.73	0.75	0.40	3.48	0.22	3.88	0.29	100.09	0.26	0.041	0.07	0.28
Zh-88	68.50	0.64	15.50	1.05	1.44	0.02	0.80	3.50	0.69	3.96	0.27	3.86	0.00	100.23	0.27	0.041	0.05	0.30
Zh-89	72.30	0.54	14.25	0.97	0.72	0.03	0.90	2.50	0.39	3.82	0.24	3.38	0.18	100.22	0.23	0.038	0.04	0.30

Note: Analyses were performed at the Far East Geological Institute, Far East Branch, Russian Academy of Sciences (V.N. Kaminskaya, V.N. Zalevskaya, and V.U. Kramarenko, analysts).



4 **Fig. 13.** Schematic paleogeographic and geodynamic settings of the accumulation of Early Cretaceous rocks in the Zhuravlevka terrane.(1–3) Sediment types: (1) shelf (littoral and sublittoral), (2) underwater slope, foothill, and adjacent basin plain, (3) hemipelagic; (4, 5) types of the Earth's crust: (4) continental, (5) oceanic; (6) fragments of active continental margins; (7) left-lateral strike-slips; (8) underwater fans; (9) contour currents.

teristic feature of sedimentation at the Californian-type transform margin, where the erosion area spanned both continental margins and previously
3 accreted fragments of active margins.

CONCLUSIONS

The setting, composition, and structural features of terrigenous sediments in the Zhuravlevka terrane indicate that its Early Cretaceous sedimentation basins were mainly fed by clastic material from the eroded granitic-metamorphic rocks of a mature continental crust. At the same time, a significant part of the provenance was occupied by fragments of the pre-Cretaceous active margin, which contained chert and ophiolite slices. Presumably, such a mixed composition of clastics is the major and typomorphic feature of sedimentation in a transform plate margin setting.

Mainly sialic composition of clastic material suggests that the paleobasin under consideration initially adjoined the Eurasian margin, rather than, for example, a volcanic island-arc. Thick terrigenous sediments of the terrane with a significant amount of gravitational sediments were accumulated on the shelf, underwater slope, foothill, and adjacent plains of an oceanward-open marginal sea (Fig. 13). Sediments were deposited in the course of large-scale displacements along the left-lateral Tan-Lu strike-slip system that separated the continental and oceanic plates. Sedimentation was not accompanied by volcanic processes (Golozubov and Khanchuk, 1995).

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SPELL: 1. terranes, 2. orogenic, 3. accreted, 4. paleogeographic, 5. paleogeodynamic, 6. nonvolcanic, 7. lithological