

Late Jurassic–Early Cretaceous Sandstones of the Algan Formation: Composition, Origin, and Provenance Areas (Northwest of the Koryak Highland)

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Abstract—This article presents the results of the petrographic and mineralogical study of the sandstones of the Algan Formation. Sandstones are represented by ultrafine-, fine-, and medium-grained quartz–feldspar greywackes according to the classification of (Shutov et al., 1972). Two tectonically juxtaposed sandstone lithotypes were distinguished. These lithotypes were deposited in two basins of different ages from high- and medium-velocity turbidity currents off the coast in moderately deep marine environments. Sedimentation conditions are typical of areas near river deltas and prodeltas. The provenance areas of these basins were different, being associated with volcanic areas of different-ages in the north of the studied region.

Keywords: Koryak Highland, Algan Formation, sandstones, genetic diagrams, mineralogical analysis, granulometric analysis

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INTRODUCTION

The studied area located in the northwestern part of the Koryak Highland (Fig. 1) is a part of the Anadyr–Koryak fold system (Fig. 2B), representing the accretion-type continental margin, which formed due to the amalgamation of different terrains to the continent (Sokolov, 2010). Among these terranes is the Algan terrane, which is located in the interfluvium between the Anadyr, Main, and Velikaya rivers (Fig. 1).

The volcanogenic–siliceous–terrigenous deposits of the Algan Formation (Pekulnevem Formation in earlier works (Kaigorodtsev, 1964)) are widespread within the Algan terrane. The total thickness of the Algan Formation is estimated at 1500 m (Gulpa, 2014). The age of the formation is estimated as Tithonian–Valanginian based on single finds of buchians (Zakharov, 1974). The thematic studies (Moiseev, 2015; Palechek et al., 2016) of siliceous rocks included in the composition of the formation made it possible to substantiate their Bajocian–Hauterivian age. As well, another origin of siliceous rocks enclosed as tectonic sheets and olistoliths in terrigenous rocks was substantiated. This formation in the modern geological maps is characterized by a wide age range, from Bajocian to Hauterivian (Gulpa, 2014; *Legenda...*, 1999). The rocks of the formation were formed under

coastal sea conditions to the southeast from the Late Jurassic–Early Cretaceous Uda–Murgal island arc (Sokolov and Byalobzheskii, 1996). Terrigenous rocks of the Late Albian–Turonian Perekatnaya Formation lie unconformably higher in the section (Gulpa, 2014; Zakharov, 1974). They are considered as shallow-water deposits that formed in the frontal part of the Okhotsk–Chukotka volcano–plutonic belt (Sokolov and Byalobzheskii, 1996). Rocks of both formations are difficult to recognize in the field.

The study area is remote and difficult to access. Despite the fact that terrigenous deposits occupy most of the Algan Formation, only igneous and siliceous rocks of the studied region were previously studied (Ledneva, 2012; Moiseev et al., 2014; Palechek et al., 2016; Tikhomirov, 2010; Vishnevskaya, 1996). Since terrigenous rocks are poorly studied here, our aim is one of the first attempts to apply the lithological methods to the identification of the mineral composition and sedimentation conditions of the Algan Formation deposits.

This article aims to determine the mineral and granulometric composition of sandstones of the Algan Formation, the parameters of provenance areas, sedimentation conditions, and the facies setting.

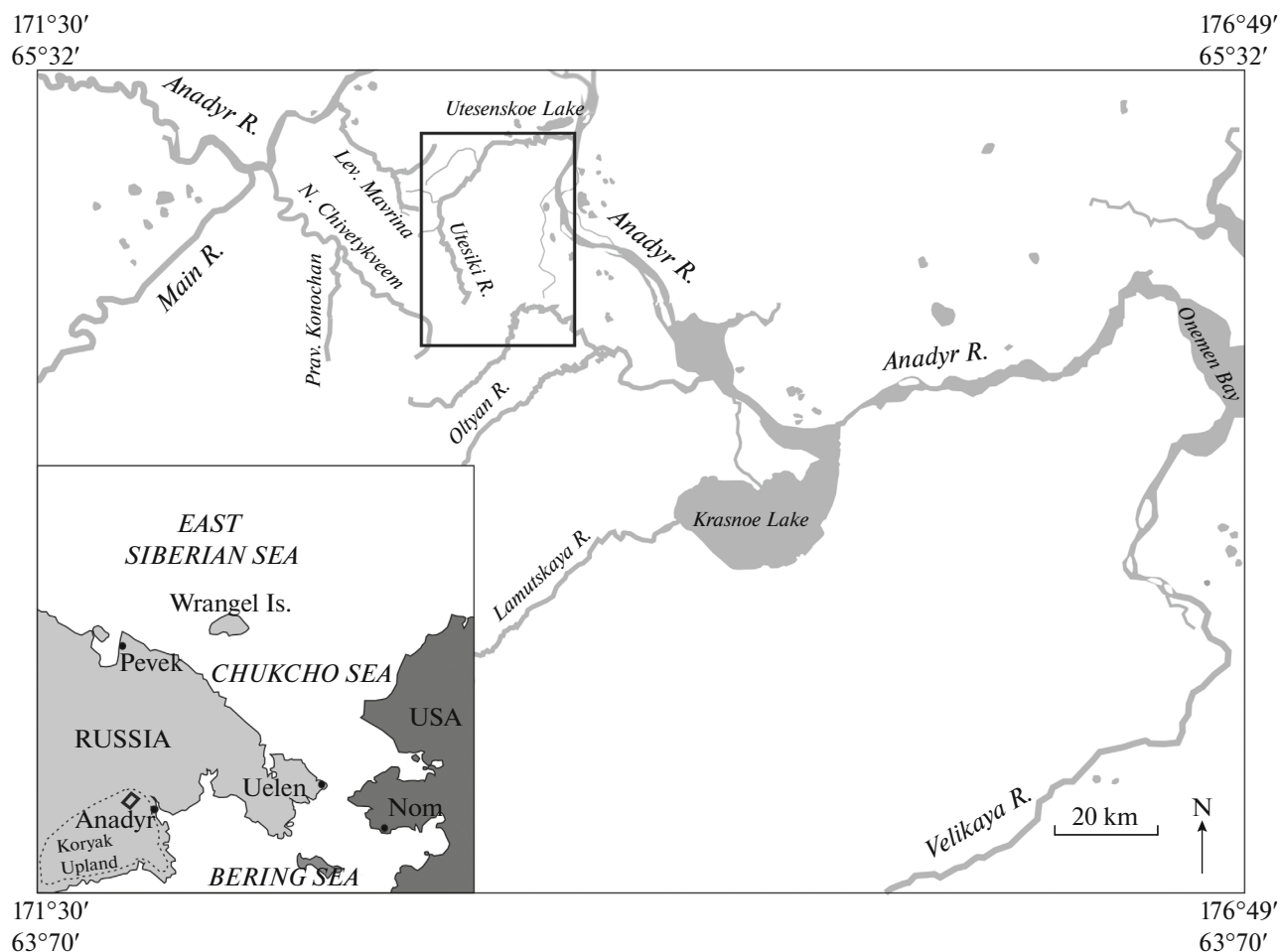


Fig. 1. The location scheme of the study area, marked by a black square.

MATERIALS AND METHODS

The materials discussed below were collected during the field works in the areas of Nizhny Chivetykveem, Perevalnaya, Anadyr (the Utesiki River mouth area), and Borozda rivers and the Pakhuchii stream (Figs. 2a, 3), performed in 2007, 2011, 2012, and 2016 by a team of the Geological Institute of the Russian Academy of Sciences. The deposits of the Algan Formation are mostly represented by irregular alternation of sandstones, siltstones, and mudstones; the units vary in thickness from 25 to 400 m. Sandstones are gray–green, gray, massive, compact, ultrafine-, fine- and medium-grained, poorly rounded and poorly sorted. Gravelstones and conglomerates occur rarely; the units vary in thickness from 5 to 25 m. Within the field of sedimentary rocks are horizons with olistoliths of deep red cherts and single outcrops and small debris of basalts, andesites and deep red, black, and green cherts. Volcanics form independent horizons with a thickness not exceeding 100 m. Andesites have a massive structure. Basalts are most often characterized by a pillow structure. Cherts occur as

boudins in basalts of the siliceous–basalt association. Siliceous deposits, which form independent horizons, are dated to the Kimmeridgian–Tithonian and Tithonian–Berriasian. Olistoliths of siliceous rocks are confined to the Aalenian–Kimmeridgian interval (Moiseev, 2015; Palechek et al., 2016; Vishnevskaya, 1996). The relationships between the siliceous–basalt and terrigenous associations are not defined. All rock varieties are characterized by a higher degree of fracturing and deformation; they are folded into NE-striking folds.

The mineral composition and granulometric parameters of sandstones were studied by counting grains in thin sections. When studying the mineral composition, grains were calculated following the Frolov's method (1993). The calculation results are plotted on triangle diagrams: Q–F–R (quartz–feldspar–lithoclasts) (Shutov et al., 1972), Lm–Ls–Lv (lithoclasts of metamorphic, sedimentary, and volcanic rocks, respectively) and Qm–F–Lt (Qm, quartz monocrystalline; F, feldspar, Lt, all lithoclasts, including polycrystalline quartz Qp) (Dickinson and

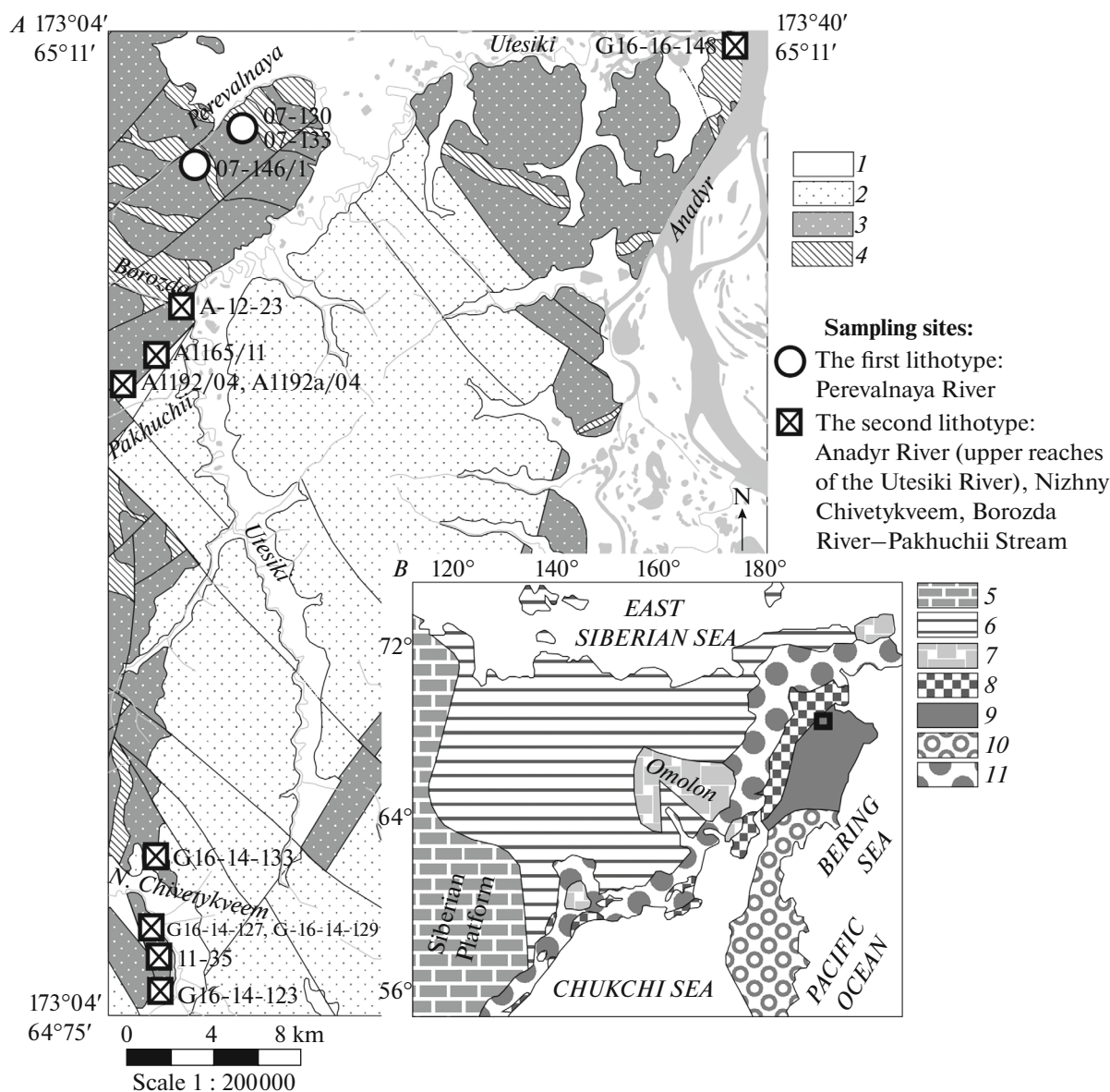


Fig. 2. A geological map of the study area (Gulpa, 2014) (A) and the tectonic scheme of the northeastern Asia (B), modified after (Sokolov, 2010). The study area is marked by a black square. (1) Quaternary deposits; (2) Perekatnaya Formation (K_{1al}–K_{2t}); (3) Algan Formation (J_{2b}–K_{1g}); (4) polymictic serpentinite mélange; (5) Siberian Platform; (6–7) Verkhoyansk–Chukotka fold belt; (8) Paleozoic–Mesozoic deposits, (9) terranes with the continental crust; (10) Koryak–Kamchatka fold region (10) West Koryak fold system, (11) Anadyr–Koryak fold system, (12) Olyutor–Kamchatka fold system; (13) Okhotsk–Chukotka volcanogenic belt.

Suczek, 1979). The diagrams were constructed using TriDraw software.

When studying the granulometric composition, grains were calculated following Logvinenko's method (1986). The results were plotted on cumulative curves of the 25, 50, 75% quartiles; the 10 and 90% percentiles and 1% quartile, which characterizes the maximum lifting stream capacity, were obtained. Based on the quartiles, the granulometric coefficients of sorting and asymmetry were calculated (Logvinenko, 1986):

$$S = \sqrt{\frac{Q_3}{Q_1}},$$

where S is the coefficient of sorting; Q_3 is the 75% quartile, mm; and Q_1 is the 25% quartile, mm;

$$A = \frac{Q_1 Q_3}{Q_2^2},$$

where A is the Trask asymmetry coefficient (Trask, 1932); Q_3 is the 75% quartile, mm; Q_2 is the 50% quartile, mm or median; and Q_1 is the 25% quartile, mm.

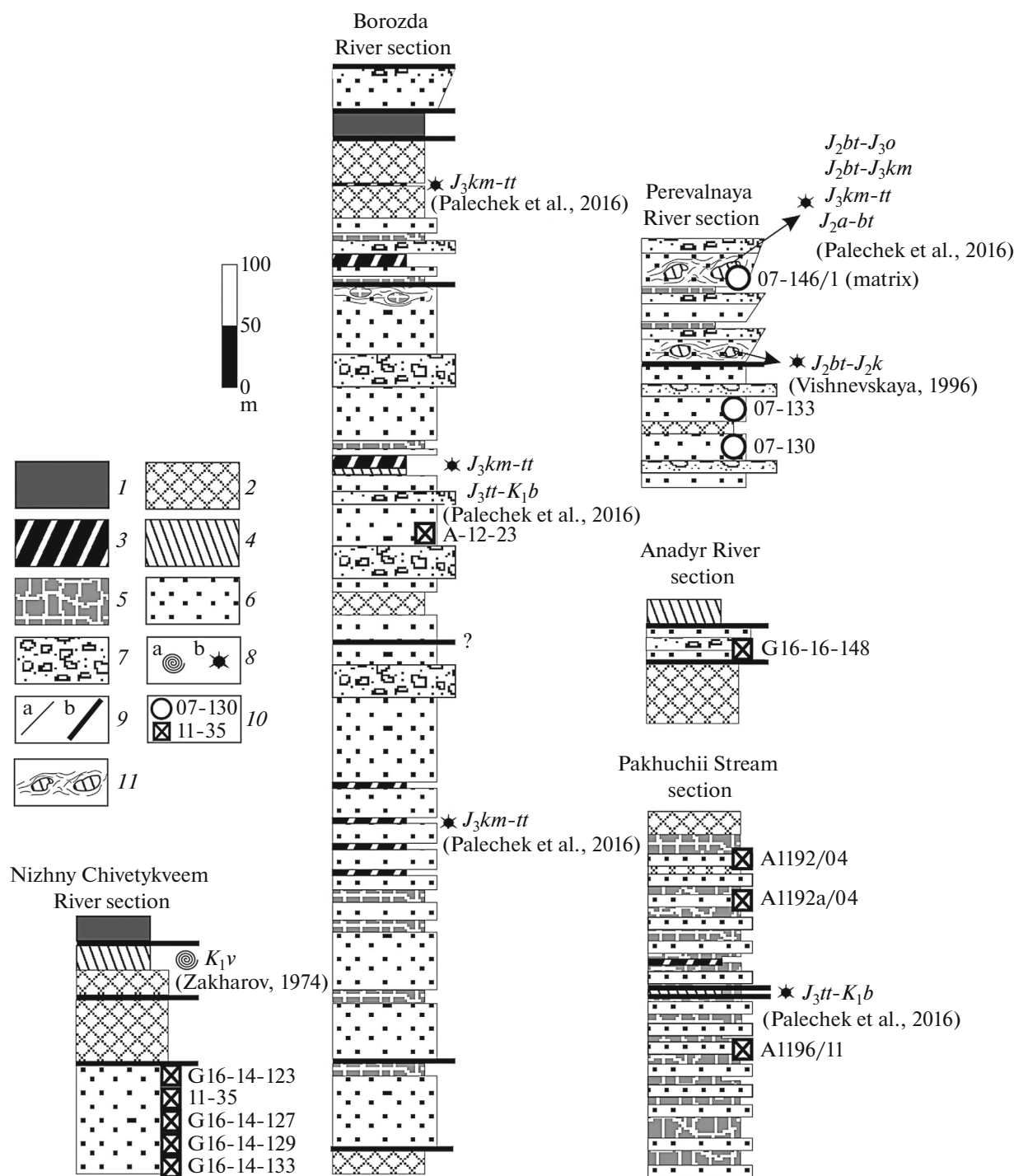


Fig. 3. The tectono-stratigraphic columns of the Algan Formation, modified after (Moiseev, 2015; Palechek et al., 2016): (1) mélange; (2) basalt and andesite horizons; (3) brown, gray, and green siliceous rocks; (4) deep red jasper; (5) siltstones; (6) sandstones; (7) conglomerates; (8) fauna ((a) buchians, (b) radiolarians); (9) contacts ((a) stratigraphic, (b) proposed tectonic (thrust faults)); (10) sampling sites; (11) olistoliths.

Based on the 10% and 90% percentiles, the excess was calculated using the following formula (Krashennikov, 1988):

$$Ex = \frac{Q_3 - Q_1}{2(P_{90} - P_{10})},$$

where *Ex* is the excess; Q_3 and Q_1 are the 75% and 25% quartiles; respectively, P_{90} is the 90% percentile; P_{10} is the 10% percentile.

Based on the obtained coefficient, Rozhkov, Passegi, and Bjorlykke diagrams were constructed using Excel

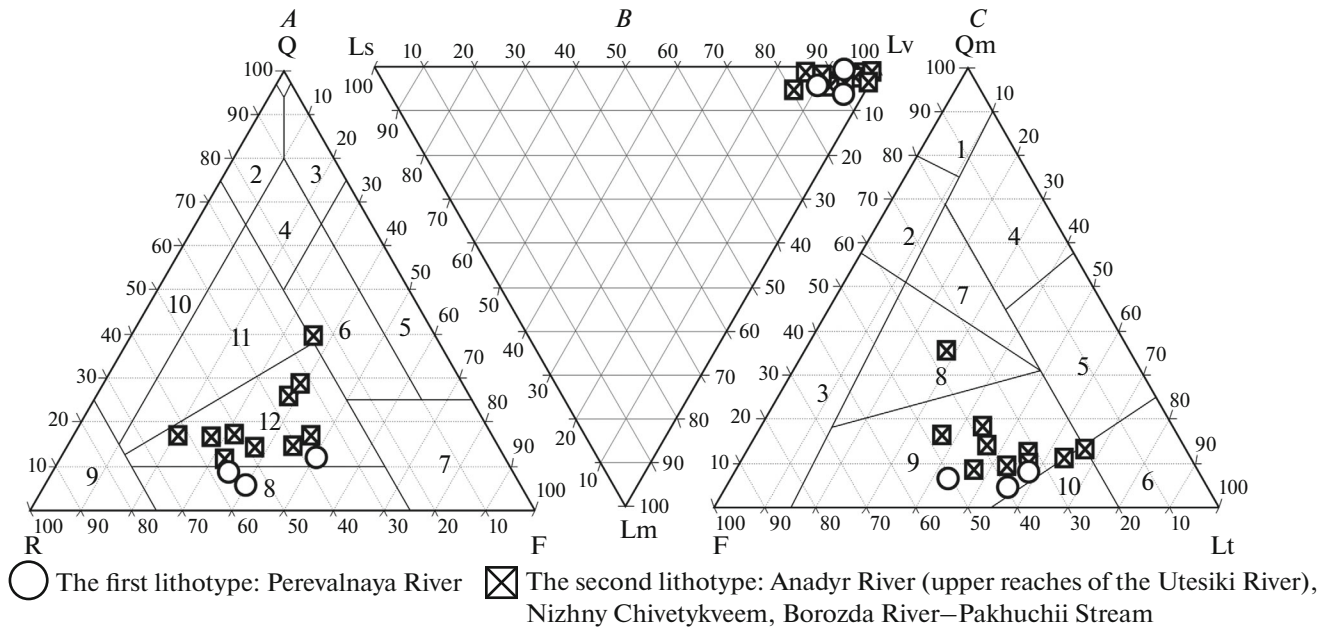


Fig. 4. The Shutov diagram of the mineral composition of sandstones (Shutov, 1972) (A): Q, quartz, F, feldspars, R, lithoclasts: (1) monomineral quartz, (2) siliciclastic-quartz, (3) feldspar-quartz, (4) mesomictic quartz, (5) properly arkoses, (6) greywacke arkoses, (7) field of non-terrigenous rocks, (8) feldspar greywackes, (9) properly greywackes, (10) quartz greywackes, (11) feldspar-quartz greywackes, (12) quartz-feldspar greywacke. The evolutionary diagram of the composition of rock lithoclasts (B): Lm, metamorphic rocks (quartzites), Ls, sedimentary rocks, Lv, volcanic rocks. Triangular diagram (C) Qm–F–Lt (Qm, monocrystalline quartz, F, feldspar, Lt, all lithoclasts, including polycrystalline quartz Qp), after (Dickinson and Suczek, 1979): (1–10) rocks of: (1) ancient platforms (predominantly quartz rocks); (2) marginal seas (feldspar-quartz); (3) highs of the crystalline basement (feldspar rocks); (4) reworked quartz, lithic quartz; (5) transitive reworked (lithic quartz); (6) reworked (lithic rocks); (7) mixed rocks; (8) divided island arcs (lithic feldspar rocks); (9) transition island arcs (lithic feldspar rocks); (10) undivided (active) island arcs (lithic rocks).

software (Bjorlykke, 1989; Reinek and Singh, 1981; Rozhkov, 1974).

RESULTS AND DISCUSSION

The quantitative petrographic analysis has shown that sandstones of the Algan Formation are represented by poorly sorted quartz–feldspar greywackes with poorly rounded components. The composition points of single samples lie in the field of feldspar greywackes and greywacke arkoses (Fig. 4).

There are lithoclasts of medium and good roundness. Quartz is represented by mono- and polycrystalline varieties, the most frequently irregularly shaped ones have ragged–undulating edges, sometimes angular and rounded. Feldspar grains are fractured, irregular angular, and euhedral tabular with polysynthetic twins. Most plagioclase grains are albitized; some grains are represented by andesine, sometimes with a characteristic zoning. There are labradorite grains. Feldspars and lithoclasts of volcanic rocks are altered by secondary micaceous minerals up to the formation of complete pseudomorphs.

Based on the petrographic composition, two lithotypes of sandstones were distinguished:

(1) Sandstones from the Perevalnaya River area are composed of quartz (5–11%), feldspar, including

polycrystalline plagioclase and potassium feldspar (34–51%), and lithoclasts (38–56%). Quartz grains are sometimes represented by varieties of volcanic origin with resorbed edges. Andesine grains often have a zonal structure (Fig. 5a). Lithoclasts are dominated by mafic and intermediate volcanic rocks (86–93%) and volcanic glass. The mafic rock fragments are often represented by spilite lithoclasts, unrounded (Fig. 5b) and rounded (Fig. 5c). Metamorphic rocks (0–6%) are represented by quartzites, metasedimentary and metavolcanic formations. Lithoclasts of sedimentary rocks (1–7%) are represented by siltstones, mudstones, carbonates, and cherts. There are single shell fragments of bivalve mollusks and foraminifers (Fig. 5d). The cement amounts to 5–10%. The primary cement is volcanogenic–clayey, closed interstitial, the most frequently massive; there are no signs of interaction with the matter of detrital grains. Some samples are characterized by the secondary carbonate, developed after the cement (up to 7%) and feldspar grains.

(2) Sandstones from the areas of the Nizhny Chivetykveem, Anadyr, and Borozda rivers and Pakhuchii stream are composed of quartz (11–39%) and feldspar (20–45%) grains, as well as lithoclasts (24–63%). There is volcanic quartz with resorbed edges (Fig. 5e). Lithoclasts are dominated by intermediate and felsic volcanic rocks (81–98%) and volcanic glass. Granit-

oid lithoclasts occur in the form of quartz–feldspar intergrowths (Fig. 5). Among metamorphic rocks' lithoclasts (1–5%) are quartzites, metasedimentary, and metavolcanic formations. The sedimentary rocks (0–14%) are represented by lithoclasts of siltstones, mudstones, carbonates, and cherts. Large fragments of intraclasts of siltstones and mudstones occur in the form of weakly lithified rolls, sometimes fractured and elongated in one direction (Fig. 5g). The presence of biotite (Figs. 5e, 5h) and partially chloritized mica with blue interference color (up to 2%) is typical. Mica grains are fractured, often altered by chlorite. The volume of the cement is 7–12%. The cement is sericite or clayey, contoured, massive, sometimes irregular, and of the filmy type.

The granulometric analysis has shown that the Algan Formation sandstones are mostly fine- to medium-grained, ultrafine- to fine-grained, and poorly sorted. Sandstone grains in the Perevalnaya River area are larger than in deposits of other regions. Sandstone grains from the Borozda River and Pakhuchii stream are smaller than those from the Perevalnaya River area but are larger than grains from the Nizhny Chivetykveem River area. The median grain size in sandstones from the Perevalnaya River area is 0.17–0.25 mm, in Borozda River and Pakhuchii stream it is 0.14–0.20 mm, Nizhny Chivetykveem River it is 0.08–0.16 mm (Fig. 6). Deposits of the Algan formation in the Anadyr River area are represented by gravelstones. This rules out the ability to reliably estimate the grain size in thin sections. Due to this, their granulometric parameters are plotted on granulometric diagrams and are not compared with other samples.

The composition points of samples in the Rozhkov dynamic genetic diagram (Rozhkov, 1974; Fig. 7) lie in field III, which is evidence of the influence of strong river or alongshore currents and their belonging to the river and coastal-marine facies.

The deposits of the Algan Formation form several groups in the Passegi genetic diagram (Reinek and Singh, 1981) (Fig. 8) in accordance with the distinguished lithotypes. The composition points of the first-lithotype deposits lie in the field of turbidite sediments with a small amount of rolling sediments (deposits of high-velocity currents). The second-lithotype deposits were deposited from medium-velocity currents; sample A1192a/04 lies in the field of turbidite sediments with a small amount of rolling sediments (deposits of high-velocity currents); sample 11–35 is in the field of homogenous turbidite sediments (deposits of low-velocity currents).

Based on the sorting–asymmetry ratio, sandstones belong to turbidite varieties (Fig. 9). The deposits in the Perevalnaya River area are better studied than deposits in the areas of Nizhny Chivetykveem and Borozda River, and Pakhuchii stream.

Thus, the first-lithotype deposits are characterized by the maximum grain sizes and good sorting and were deposited from high-velocity flows. The second-lithotype deposits are different in the minimum dimensions of grains and low sorting and were deposited from a medium-velocity current.

The mineral and granulometric compositions of sandstones of the Algan Formation were studied. They are mostly represented by quartz–feldspar greywackes. Based on the results of the analysis of the rocks with an abundant admixture of the volcanic material, one can suggest that they were accumulated simultaneously with volcanic rocks. The pyroclastic origin of these sandstones is evidenced by the presence of basic and intermediate plagioclases (andesine and labradorite), characterized by the minimum chemical stability (Wang and Kazanskii, 1985). The origin of these plagioclases is an indicator of one-cycle formation (Shutov et al., 1972; Wang and Kazanskii, 1985). Based on the ratio of quartz, feldspars, and lithoclasts, one can suppose that the volcanism was associated with the development of a volcanic arc (Fig. 5c).

Based on the sorting–asymmetry ratio, all sandstones are referred to as turbidites (Fig. 9); based on the asymmetry coefficient–excess coefficient ratio are deposits of the heavy river or alongshore currents, that is, continental river and coastal-marine facies (Fig. 8). The marine fauna in deposits is evidence that these rocks were not formed under the continental conditions. Moreover, the well-sorted material was accumulated under the conditions of longshore currents in coastal-marine settings. Due to this, all studied sandstones are poorly sorted. Therefore, the sedimentation was probably associated with detrital cones of submarine deltas. These sedimentation settings correlate the activity of both river and coastal-marine processes. The low sorting and a degree of roundness of rocks and unstable components in the composition of sandstones (feldspar grains, fractured mudstone fragments, and spilites) indicate the proximity of a provenance area. Thus, sediments were deposited from turbidite currents in a moderately marine environment not far away from river deltas, supplying the detrital material for subsequent transfer.

We have distinguished two lithotypes in the composition of the Algan Formation. Based on the material composition, the first lithotype distinguished in the northern part of the area is characterized by a low quartz content and a large number of lithoclasts of mafic and intermediate volcanics. The second lithotype, which is confined to the southern part, is characterized by a high quartz content and a large amount of felsic and medium volcanics, lithoclasts of granitoids, large intraclasts of terrigenous rocks, and biotite grains.

Thus, every lithotype is characterized by its provenance area. The intermediate and basic volcanics were the source for the first lithotype. The second lithotype is characterized by several provenance areas: granit-

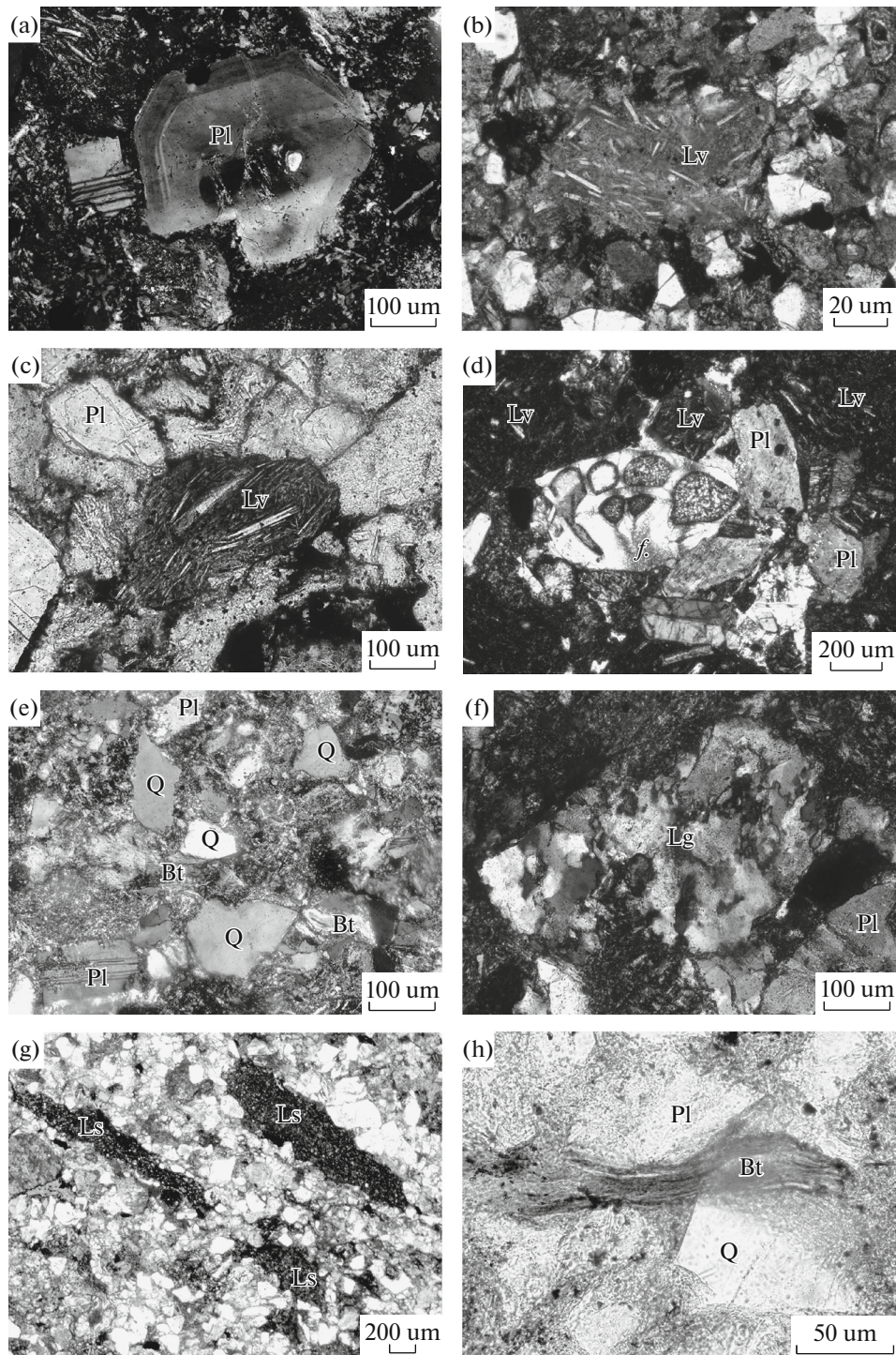


Fig. 5. Images of thin sections of sandstones of the Algan Formation. Scale bar in the right bottom angle: (a) andesine with the zonal structure (Pl), thin section no. 07-130, crossed nicols; (b) a fragment of poorly rounded spilite (Lv), thin section no. 07-146/1, parallel nicols; (c) a rounded spilite fragment (Lv), thin section no. 07-130, parallel nicols; (d) a fragment of foraminifer shell (*f*), thin-section no. 07-130, crossed nicols; (e) quartz grains with resorbed edges (Q), thin-section no. 11-35, crossed nicols; (f) a granitoid fragment (Lg), thin section no. A1192a/04, crossed nicols; (g) siltstone intraclasts (Ls), thin section no. G16-16-148, parallel nicols; (h) fractured biotite (Bt), thin section no. G16-14-129, parallel nicols.

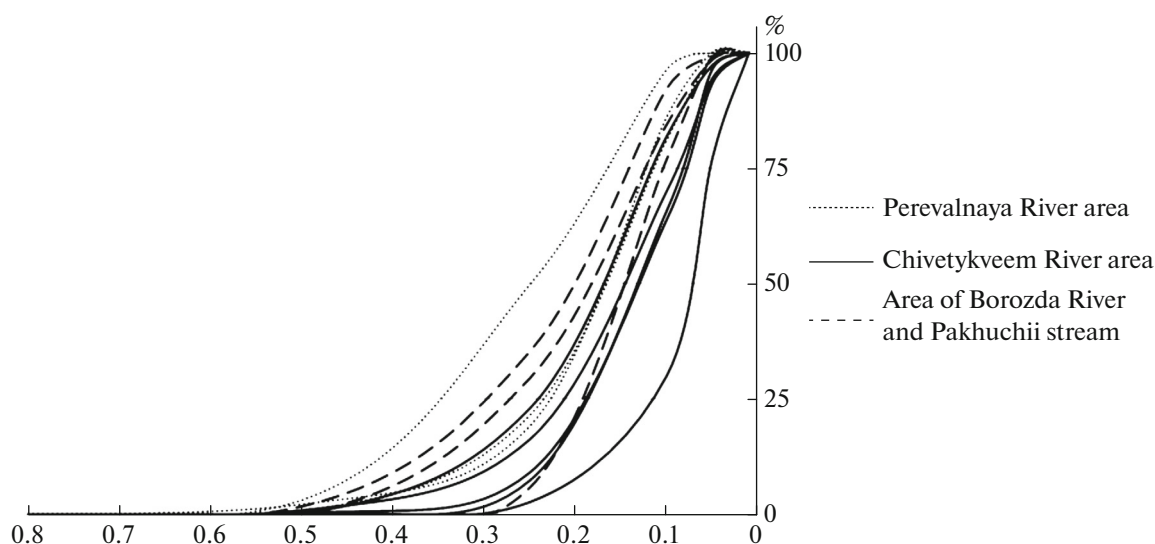


Fig. 6. The cumulative curve for the deposits of the Algan Formation, on the x-axis, the average grain size, mm; on the y-axis, the proportion of every fraction (%).

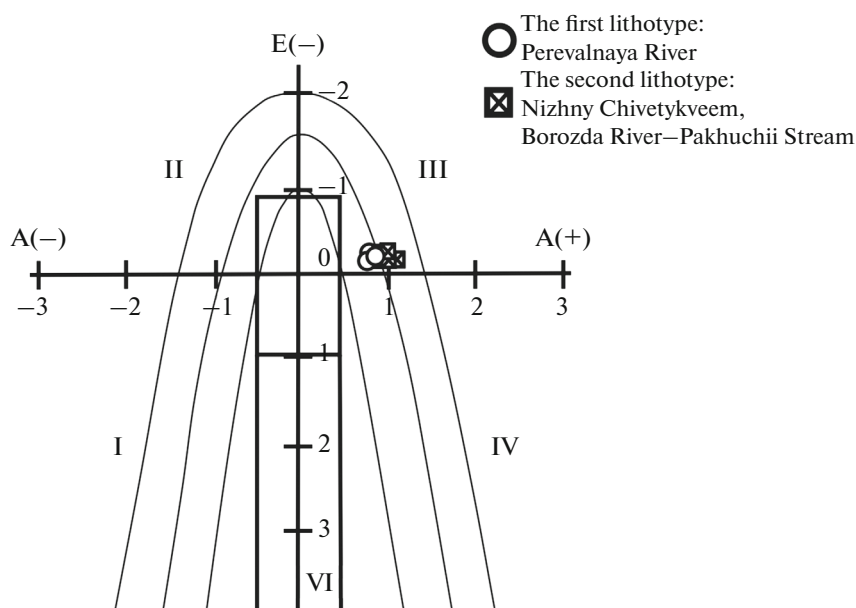


Fig. 7. The dynamic genetic diagram (Rozhkov, 1974) for rocks of the Algan Formation. Fields: I, bottom or turbidite currents—marine facies; hydromechanical or physical destruction of igneous rocks, the rock erosion of the marine origin—continental facies of provenance areas, weathering crusts; II, weak, mainly river currents—continental river facies; III, strong river or alongshore currents—continental river or coastal marine facies; IV, shallow-water waves, strong alongshore currents, surge—coastal marine facies, continental offshore microfacies of large plain rivers; V, eolian reworking of alluvial sediments—the top half of a rectangle—continental facies of deserts (continental dunes); the bottom right quarter of a rectangle—wave processes in the shallow-water zone, neutral coastal zone—coastal marine facies; VI, shallow-water waves, heavy surge—surf, the rate of dynamic resorting exceeds the velocity of supplying detrital material—coastal facies of vast open water areas.

oids, terrigenous rocks, as well as felsic and intermediate volcanics.

The differences in the compositions of the provenance areas can be associated with those in eroded complexes of the volcanic arc along the strike. Thus,

the different complexes of the Uda–Murgal island arc that existed at that time could supply the volcanic lithoclastics. However, this arc is not characterized by a large volume of felsic volcanoclastics (*Teoreticheskie...*, 1999). The basement of the Uda–Murgal arc could be a source of granitoids. The underlying coeval,

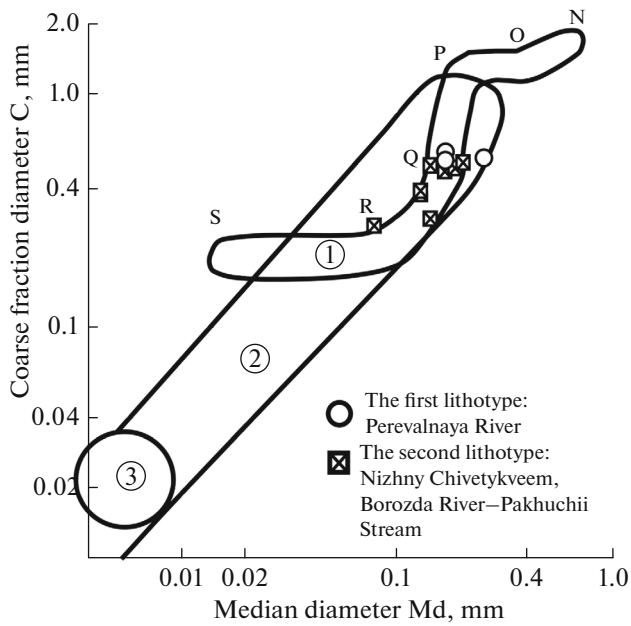


Fig. 8. The CM diagram, allowing to determine the transfer patterns of sediments after (Reineck and Singh, 1981), where C, 1% quartile; M, 50% quartile or a median size. N–O, rolling sediments; O–P, rolling sediments with a small amount of turbidite sediments; P–Q, turbidite sediments with a small amount of rolling sediments (deposition from high-velocity currents); Q–R, sediments deposited from medium-velocity currents; R–S, homogenous turbidite sediments (deposition from low-velocity currents); (1) flow sediments; (2) turbidite sediments; (3) turbidite sediments deposited in calm-water environment.

partly lithified sediments would probably be a source of terrigenous rocks.

Based on the granulometric composition, the first lithotype rocks are characterized by a larger average grain size than the second-type lithotype and they were deposited from higher-velocity currents (Fig. 8). The change in the current velocity at the deposition of

different lithotypes may be due to the formation of a fan-shaped detrital cone, where, by Bernoulli's law, the flow velocity decreases at an increase in the cross-section or damping of the flow force. Therefore, compared to the first-lithotype rocks, the second-lithotype rocks accumulated far from a provenance area. However, the first-lithotype rocks are better sorted than the second-lithotype ones. This contradicts the direction of migration of the material from the first lithotype to the second one, as the sorting becomes better during the migration of the material. Due to this, one can consider that the sedimentation of every lithotype occurred separately by turbidity currents of different systems. The spatial changes in the average grain size and the sorting in the second lithotype were established. One can observe a decrease in the average grain and the improvement in the roundness of the sedimentary material from the varieties of the second (northern) lithotype (Anadyr River) to those of the first (southern) one (Nizhny Chivetykveem River). Thus, the granulometric analysis results indicate the southern location of the sedimentation areas of the second lithotype relative to the provenance areas. However, the first lithotype is located in the north of the region, whereas the second one is in the south. The first-lithotype deposits contain no lithoclasts of felsic volcanics and terrigenous rock, which occur in the second lithotype. Simultaneously, the migration direction of the material indicates the transportation of the detrital material from the north, that is, from the sedimentation area of the first-lithotype deposits. Thus, the granulometric analysis indicates the change of lithotypes across the strike of a volcanic structure. The similar location, differences of provenance areas, and paths of migration of both lithotype materials were likely determined by their formation in different periods due to the erosion of volcanic structures of different ages.

The Algan Formation is overlain by Albian–Turonian terrigenous deposits of the Perekatnaya Forma-

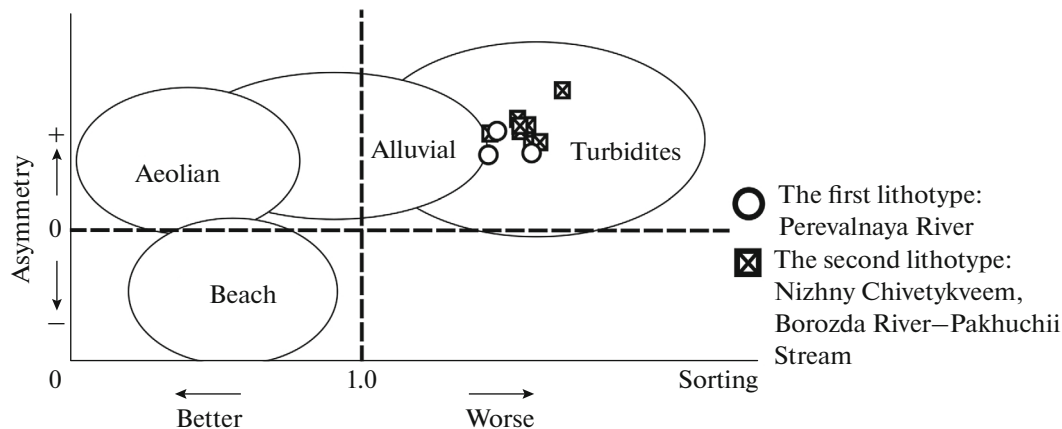


Fig. 9. The sorting–asymmetry ratio in sandstones of the Algan Formation, after (Bjorlykke, 1989).

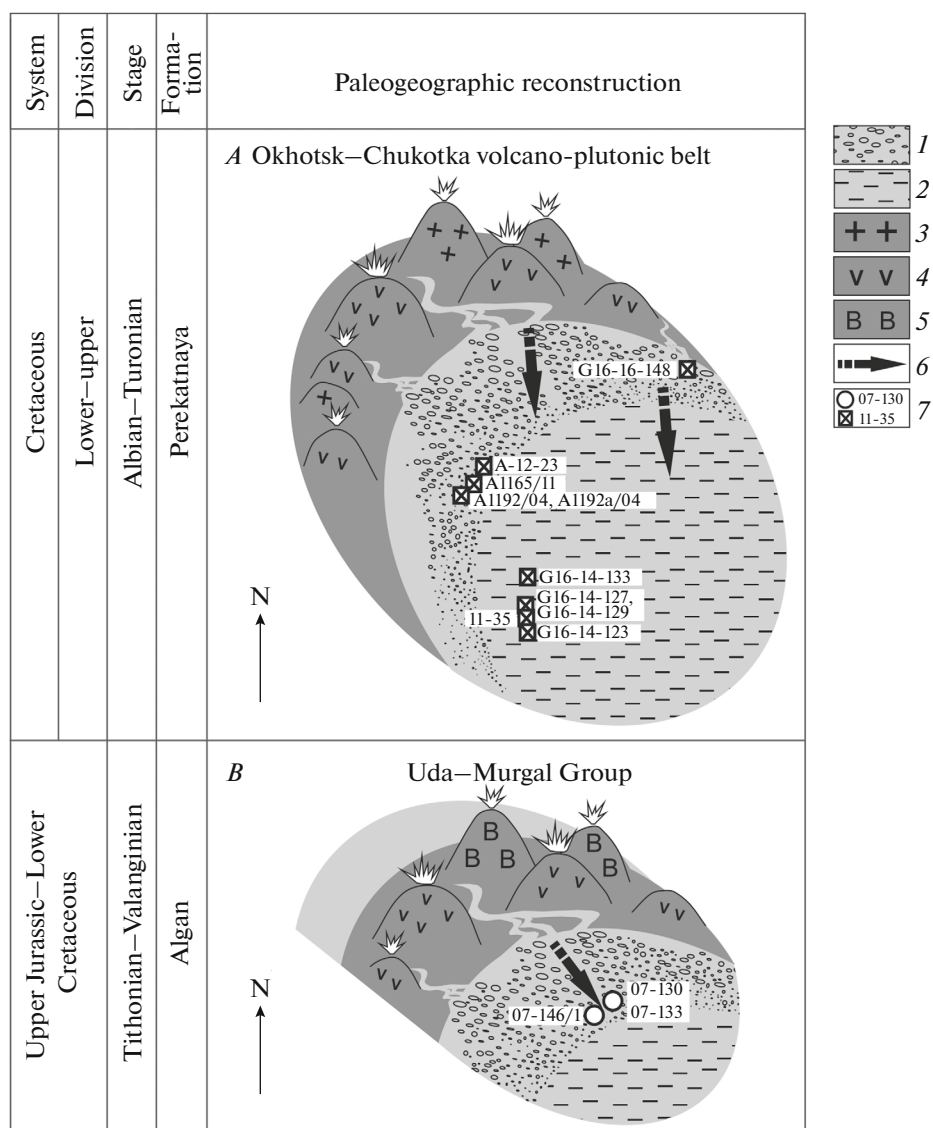


Fig. 10. The paleogeographic reconstruction of sedimentation conditions: (A) the second (southern) lithotype, modified after (Gushchina et al., 2019); (B) the first (northern) lithotype: (1) a part of the basin, where the coarser-grained sediments were accumulated; (2) the part of the basin where the smaller-grained sediments were accumulated; (3) felsic volcanics; (4) intermediate volcanics; (5) mafic volcanics; (6) the main migration directions of detrital material from a provenance area; (7) sampling sites.

tion (Fig. 4) (Gulpa, 2014; Zakharov, 1974), which are considered as shallow-water deposits accumulated in the frontal part of the Okhotsk–Chukotka volcano-plutonic belt (Sokolov and Byalobzheshkii, 1996). The deposits of the Perekatnaya Formation are as follows: quartz (7–28%), feldspar (20–41%), and lithoclasts (40–71%), dominated by felsic and intermediate volcanics, as well as rounded siltstone lithoclasts, which are sometimes elongating unidirectional (Gushchina et al., 2019).

The Okhotsk–Chukotka volcano-plutonic belt was a provenance area of a large amount of felsic volcanoclastics from the Perekatnaya Formation. This formation and the southern lithotype in the Algan Forma-

tion composition are similar in the mineral composition. It cannot be ruled out that the distinguished second lithotype is represented by younger rocks than previously suggested, and it should be attributed to the Perekatnaya Formation. These statements require confirmation by geochronological data, which are absent at present.

Based on the obtained data, we developed the paleogeographic map of the formation of the studied rocks (Fig. 10). As seen in this model, the migration of the first-lithotype material (northern) occurred from northwest to southeast (in the present-day coordinates). The material was supplied due to the erosion of the active Uda–Murgal volcanic arc that existed

during the Late Jurassic–Early Cretaceous in the northwest of the region. The material of the second (southern) lithotype was transferred from north to south (in the present-day coordinates). It is most likely that it was a part of the Okhotsk–Chukotka volcano-plutonic belt, which already existed in the Albian–Turonian and which supplied a large volume of the felsic material. The sedimentation occurred under the marine conditions off the coast and was connected with detrital cones of submarine deltas.

CONCLUSIONS

Two lithotypes were distinguished among the sandstones of the Algan Formation. The accumulation of deposits of the northern lithotype occurred synchronously with the manifestation of volcanism, supplying a large amount of the volcanic material of mafic and intermediate compositions. A segment of the Uda–Murgal arc, which developed in the Late Jurassic–Early Cretaceous, was probably a provenance area. Deposits were accumulated from high-velocity turbidite currents in the moderately deep environment relatively not far away from the coast. The rivers (their deltas) supply the detrital material.

The accumulation of the southern lithotype occurred synchronously with the manifestation of volcanism, which supplied a large amount of the felsic and intermediate volcanic material. Along with volcanics, the volcanic structure basement fragments, as represented by granitoids, and the erosion products of terrigenous complexes were supplied. The provenance area was located in the north of the region and it most likely was the volcanic system of the Okhotsk–Chukotka volcano-plutonic belt. Sediments were deposited from medium-velocity turbidite currents under the marine conditions near river deltas off the coast. The sedimentation conditions can be correlated with the settings typical of detrital cones of submarine deltas.

Deposits of the basins were accumulated in different periods during the activity of different volcanic structures.

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