

GEOLOGY

Vendian Suprasubduction Volcanism in the Uraltau Tectonic Zone (South Urals)

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The Uraltau tectonic zone is located between paleocontinental and paleoceanic segments of the South Urals and is characterized by a complex structure. It is composed of variably metamorphosed and repeatedly deformed rock complexes with unknown primary ages. Their geodynamic formation settings are also debatable [1, 2]. The Maksyuta eclogite–glaucophane schist complex, which occupies the eastern part of the Uraltau zone, is of key importance for understanding its tectonic history. This complex is divided into two main rock associations: the “subcontinental” metaterigenous association with metaryhyolites and the “suboceanic” metaophiolitic association. Less common are metavolcanics of the island-arc type, which have never been purposefully studied partly due to their strong metamorphism. All Maksyuta sequences with compositionally different protoliths are represented by isolated fragments tectonically displaced in different combinations. The southern ending of the Uraltau zone, known as the Ebeta antiform [3], is substantially simpler (Fig. 1). This region hosts reliably dated pre-Ordovician rocks (pre-Uralides), which are similar to the Maksyuta complex (although less metamorphosed) in terms of their formation setting [2]. Among them, a significant role belongs to volcanoplutonic rocks that occupy a distinct structural position. The Vendian age and geodynamic setting of these rocks, which are characteristic of convergent margins, were established by our recent studies. Therefore, we can correlate tectonomagmatic events recorded in the pre-Uralides of different areas in the western continental margin of the Urals.

In the northern part of the Ebeta antiform, the core is composed of the Lushnikovka volcanosedimentary complex overlain by Tremadocian strata with organic remains (Fig. 2). The complex is dominated by volcanic sandstones, siltstones, and inequigranular tephroids with a subordinate share of lithic and crystalloclastic tuffs, tuff breccia, and lavas. Approximately one-third of the section is represented by volcanic and subvolcanic rocks. The geochemical properties of Lushnikovka volcanics were studied in two areas: along the left bank of the Ebeta River upstream from the eponymous village and on the left side of its middle reaches (Fig. 2). In total, 35 samples were taken. In terms of composi-

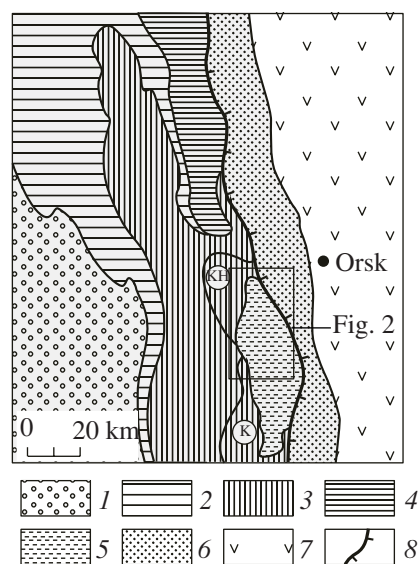


Fig. 1. Position of the Ebeta antiform among tectonic structures in the southwestern part of the South Urals. (1–3) Paleocontinental segment: (2) Uralian Foredeep, (2) Zilair synform (synclinorium), (3) Sakmara zone (allochthon) with the Khabarninsk (KH) and Kempirsai (K) mafic–ultramafic massifs; (4) Uraltau zone; (5) Ebeta antiform; (6, 7) paleoceanic segment: (6) Voznesensk–Sakmara suture; (7) Magnitogorsk zone; (8) Main Uralian Fault.

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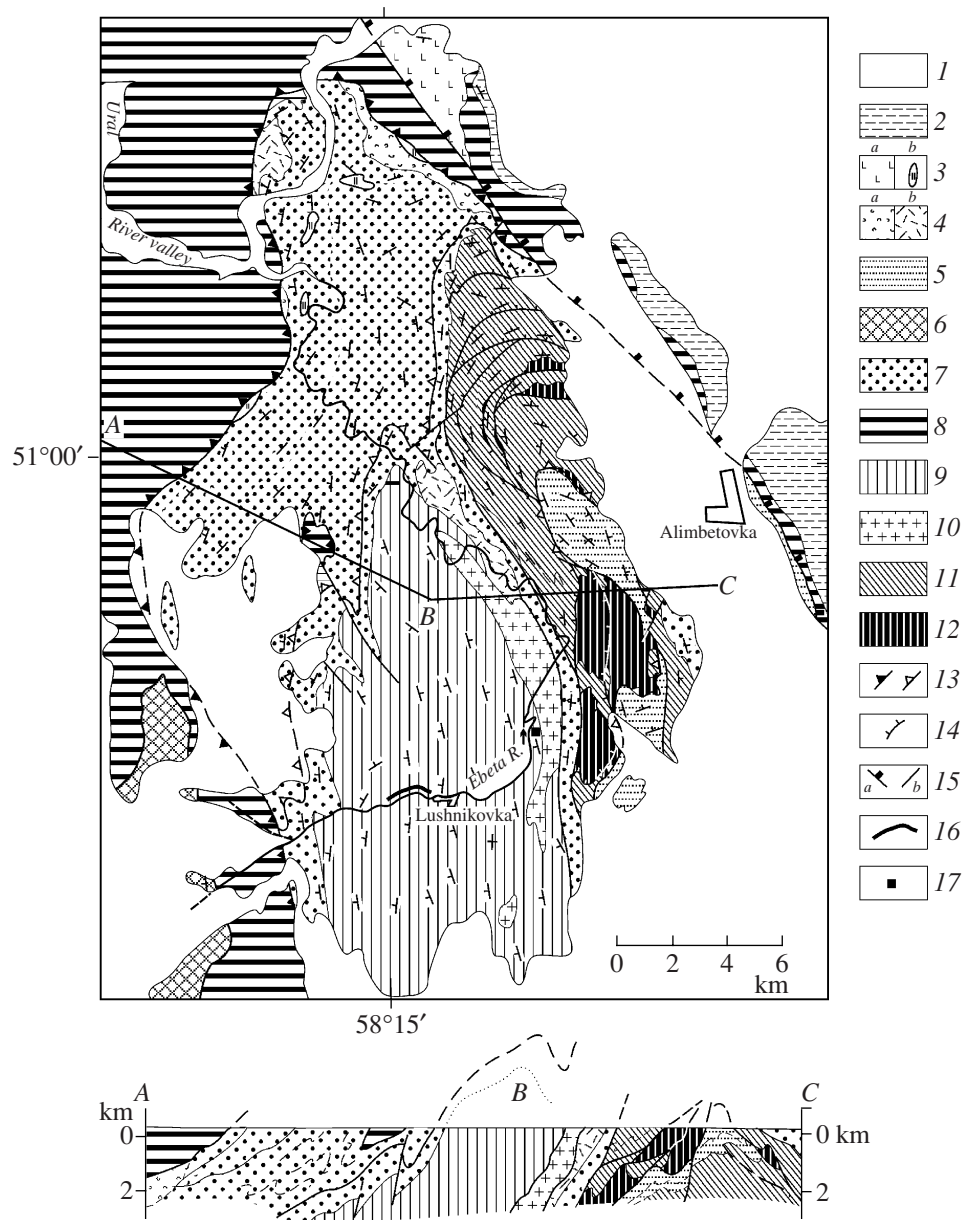


Fig. 2. Schematic geological structure of the northern Ebet antiform (after [2]).

(1) Incoherent sediments (MZ–KZ); (2) siliceous and clayey shales, graywackes (D_3); (3) (a) basic volcanics and carbonaceous-siliceous shales (S_1), (b) chert klippen (S_{1-2}); (4) (a) tuffs and tuffaceous siliciliths, (b) acid subvolcanic bodies ($O_2^2-O_3$); (5) metamorphosed siliceous–terrigenous sediments (O_{1t} , D_{2ef}); (6) metamorphosed rocks of unclear age ($PZ_{1-2}?$); (7) various Lower Ordovician sediments; (8) mafic–ultramafic complex of the Khabarninsk Massif; (9–12) pre-Uralides: (9) Lushnikovka volcanosedimentary complex, (10) granitoids, (11) East Ebete accretionary complex, (12) ultramafics and small gabbroid blocks; (13) boundaries of large tectonic sheets; (14) thrusts in the East Ebete complex; (15) (a) Main Uralian Fault, (b) other fractures; (16) areas of geochemical sampling of volcanics from the Lushnikovka Complex; (17) site of Sample 2420.

tion, the volcanics can be divided into two groups. The first (older) group includes the differentiated basalt–andesite–dacite–rhyolite volcanics with distinct prevalence of moderately acid varieties. The basalts are characterized by high concentrations of Al_2O_3 (16.07–17.99%) and low concentrations of TiO_2 (0.82–1.32%) and P_2O_5 (0.09–0.21%). The contents of rare elements

are as follows (ppm): Sr 120–170, Y 14–20, Zr 43–330, and V 120–220 ppm. The second (younger) group, which includes dikes intruding the rocks of the first group, is represented exclusively by alkaline basalts with low contents of Al_2O_3 (14.06–15.43%) and high contents of TiO_2 (1.81–3.65%) and P_2O_5 (0.25–0.71%). Relative to rocks of the first group, basalts of this group

differ also in concentrations of rare elements (ppm): Sr 160–440, Y 31–40, Zr 83–240, and V 220–400. The P_2O_5/TiO_2 – P_2O_5 diagram clearly demonstrates the difference between rocks from these two groups (Fig. 3). At the same time, all basalts of the Lushnikovka Complex occupy the field of island-arc volcanics in the Zr/4–2Nb–Y diagram.

Based on the structural position, the petrogeochemical characteristics of volcanics, and the structure of the section, the Lushnikovka volcanosedimentary complex is considered a fragment of the pre-Ordovician volcanic belt developed at the margin of the East European paleocontinent or near-continental ensialic arc [2, 4]. In the east, the complex is intruded by a linear stratiform granitoid massif, which provided pebbles for Tremadocian conglomerates. In this area, the Lushnikovka Complex is subjected to intense foliation and adjoined with the antiformal packet of sheets and slices of the East Ebeta greenschist complex with local manifestation of high-pressure blueschist metamorphism (Fig. 2). The East Ebeta Complex is interpreted as an accretionary prism in front of the marginal volcanic belt or as a forearc prism. [2, 4].

To determine the U–Pb isotopic age of volcanics from the older part of the Lushnikovka Complex, we sampled the 300-m-wide outcrop of subvolcanic diorites and quartz diorites on the right bank of the Ebeta River 650 m east of the channel mark 308.8 located 4 km downstream of the settlement of Lushnikovka (Fig. 2). In the west, these rocks adjoin foliated tuffaceous siliciliths that are replaced by medium- to coarse-detrital dacite tephroids. In the east, they adjoin medium-grained gneissic plagiogranites. Thin plagiogranite veins crosscut the subvolcanic body, which, in turn, is intruded by a thin dike of fine-grained diabbases of the late series of alkaline basalts.

The subvolcanic rocks are irregularly replaced by minerals of the metamorphic greenschist facies. The rocks are subjected to sericitization, chloritization, and epidotization with the development of alkaline amphibole in some places. In line with the standard procedure, accessory zircons were extracted from sample 2420 taken from the least altered variety of quartz diorites.

Zircon in the quartz diorite sample is represented by transparent prismatic and elongate-prismatic light yellow crystals. The morphological features of grains indicate their magmatic origin. Only transparent well-developed crystals were selected from four size fractions (table).

The U–Pb study of zircons was carried out by Krogh's method [5]. The procedure blank was 0.2 ng for Pb and 0.05 ng for U. The mixed $^{235}U + ^{208}Pb$ tracer was used for determining the U and Pb concentrations. The isotopic composition was measured with a Triton solid-phase mass spectrometer (GEOkhi RAN). The age correction for the admixture of common lead was

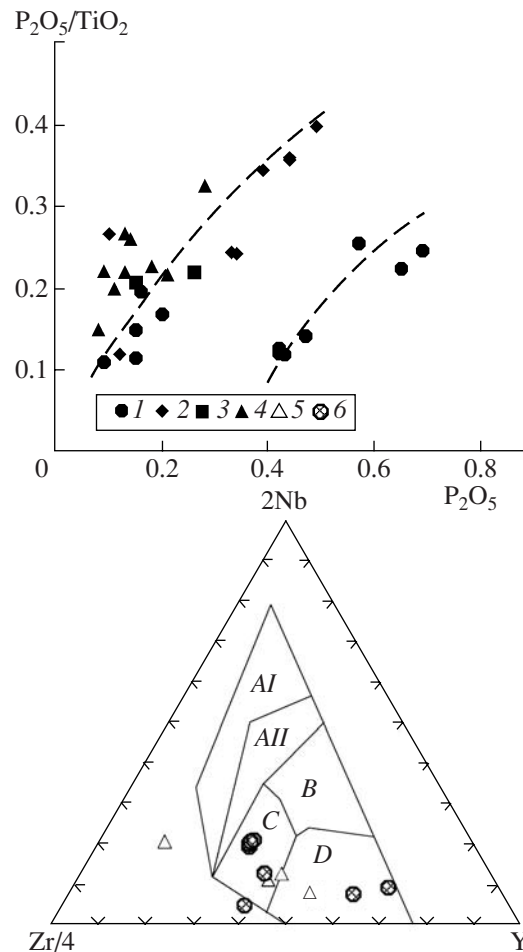


Fig. 3. Geochemical diagrams for volcanics of the Lushnikovka Complex. (1) Basalts; (2) basaltic andesites; (3) andesites; (4) dacites and rhyolites; (5) basalts of the older group; (6) basalts of the younger group.

Dashed lines indicate trends of volcanic series; (AI + AII) field of intraplate alkaline basalts; (AII + C) field of intraplate tholeiites; (B) field of E-MORB basalts; (D) field of N-MORB basalts; (C + D) field of island-arc basalts.

introduced according to the model [6]. Ages were calculated using the PbDAT program [7] and accepted values of U decay constants [8]. The table presents the obtained results.

In the concordia diagram, the data points obtained for zircons of four size fractions determine discordia (MSWD = 0.26), the upper intercept of which with concordia yields an age of 590 ± 4 Ma (Fig. 4). The lower intercept located close to zero indicates the lack of any metamorphic impact that would result in the loss of radiogenic lead by zircons. Taking into consideration morphological properties of zircons typical of their magmatic origin, the obtained age estimate of 590 ± 4 Ma may be attributed to the crystallization period of quartz diorites.

These data indicate the convergent pattern of the South Uralian margin of the East European paleoconti-

U–Pb isotopic data on zircons from quartz diorites of the Lushnikovka Complex

Fraction, mg	Weight, mg	Content, ppm		Isotopic ratio					Age, Ma	<i>Rho</i>
		U	Pb	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{206}\text{Pb}/^{208}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$		
>125	0.14	388.8	147.5	5238	2.996	0.0595	0.7458 ± 15	0.0909 ± 2	585.9 ± 1.6	0.92
<125	0.17	353.9	134.8	6480	3.073	0.0595	0.7497 ± 15	0.0913 ± 2	587.0 ± 1.2	0.96
<100	0.22	173.0	62.0	3340	3.373	0.0594	0.7027 ± 14	0.0858 ± 2	582.1 ± 2.3	0.87
<75	0.28	118.2	43.6	3720	3.162	0.0595	0.7247 ± 15	0.0884 ± 2	583.6 ± 1.5	0.95

Note: Isotopic $^{206}\text{Pb}/^{208}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$, $^{207}\text{Pb}/^{235}\text{U}$ and $^{206}\text{Pb}/^{238}\text{U}$ values are corrected for procedure blank and common lead; (*Rho*) correlation coefficient of errors for $^{207}\text{Pb}/^{235}\text{U}$ – $^{206}\text{Pb}/^{238}\text{U}$ values.

ment and the Middle Vendian age of suprasubduction volcanism. A similar situation is observed in the Subpolar Urals, where the western slope (paleocontinental segment) is characterized by wider distribution of rocks typical of Andean-type active margins: basalts, andesites, rhyolites (Sablegorsk and Man'ino formations), associated granitoids, and basic intrusions [9]. The formation of the suprasubduction volcanoplutonic association in the last region commenced, however, substantially earlier in the terminal Late Riphean (695 ± 19 – 632 ± 7 Ma ago) and probably lasted until the mid-Cambrian (518 – 515 Ma ago) [10]. The pre-Ordovician granite–plagiogranite massif, which intrudes the Lushnikovka volcanosedimentary complex, was also emplaced in the South Urals in the first half of the Cambrian or slightly earlier.

In both regions, the subduction zone dipped westward (in present-day coordinates) [2, 9]. In the polar

segment, it was initiated earlier and probably characterized by a lower dip angle. The subduction produced magmatic rocks in a wide zone along the margin of the East European paleocontinent. In the South Urals, pre-Ordovician suprasubduction rocks formed most likely within a relatively small island arc that was developed above the deep subduction zone and separated from the East European paleocontinent by the back-arc basin locally underlain by the oceanic crust. This basin was closed due to accretion in the terminal Cadomian epoch of tectogenesis. It is conceivable that its sedimentary sequence of the greenschist facies represents an element of the Suvanyak terrigenous complex in the western Uraltau zone. Small but more intensely metamorphosed fragments are also present in the Sakmara allochthon (Fig. 1) among the serpentinite melange and Late Devonian olistostrome. They are composed of metaarkoses and graywackes, clay–siderite rocks, and metaevaporites [11]. The melanocratic composition of the basement of the pre-Ordovician back-arc basin is indicated by the presence of abundant chrome spinel grains (up to 10% of the heavy fraction) in Tremadocian sandstones in the Sakmara zone [12].

Thus, the Cadomian convergent geodynamic setting in the pre-Uralides of the western Urals was characterized by different lithotectonic forms along the strike: the active continental margin in its polar segment and the island-arc system in the southern one. The tectonic scenario described above was generally similar to the present-day situation in the Kuril–Kamchatka region.

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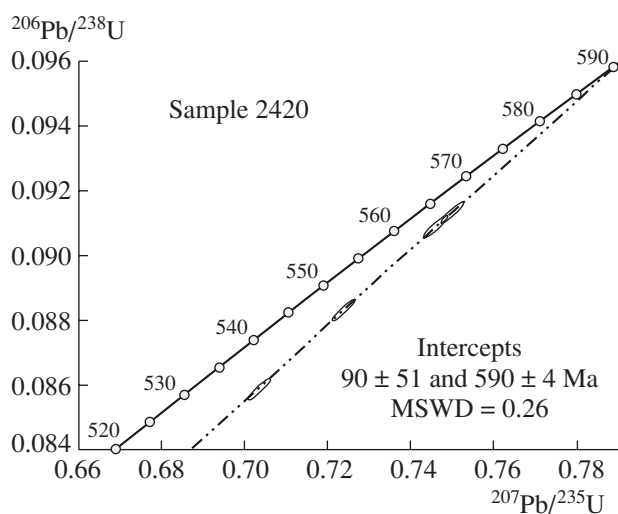


Fig. 4. Diagram with concordia for four size fractions of zircon from quartz diorites of the Lushnikovka Complex.

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