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GEOLOGY

Relationships of Late Paleozoic Volcanic Rift Belts and Granitic Batholiths on the Eastern Slope of the Urals to Plume Tectonics

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In an increasing number of recent publications, one can find the statement that it is impossible to explain the formation of foldbelts, especially at late stages of their evolution, in terms of plate tectonics [1 among others]. The Ural Foldbelt is not an exception in this respect.

The suggested suprasubduction development of the Late Paleozoic Magnitogorsk, Irgiz, and Valer'yanovka volcanic belts on the eastern slope of the Urals and their analogy with active island arcs [2] comes into conflict with the succession of their evolution and composition of rocks (table). As is known, the evolution of suprasubduction island-arc volcanic belts is characterized by progressive increase in their alkalinity (potassium content) from the ocean toward the continent, i.e., from forearc to backarc zones. Such zoning is not revealed in the Late Paleozoic rift-related volcanic belts of the eastern slope of the Urals either from west to east (from the Magnitogorsk belt to the Irgiz belt and farther to the Valer'yanovka belt) or in the opposite direction (Fig. 1).

The Late Paleozoic rift-related magmatism on the eastern slope of the Urals developed at the postsubduction stage of the evolution of the active margin of the Siberian paleocontinent [3]. The Devonian subduction zone along the western margin of the Siberian paleocontinent [4] was blocked at the end of the Frasnian Age by an ascending mantle plume that affected the entire eastern Urals, Transural region, and a considerable segment of the West Siberian Plate. This is supported by waning of the Middle Devonian–early Frasnian volcanism on the eastern slope of the Urals and the Transural region in the Famennian Age and its replacement by subsidence of the Famennian–early Tournaisian Zilair, Irgiz, and other compensated troughs filled with graywackes. It cannot be ruled out that this mantle diapir was a part of the Eurasian superplume [5]. This is indirectly confirmed by the compositional and chronological similarity of tholeiitic basalts on the eastern

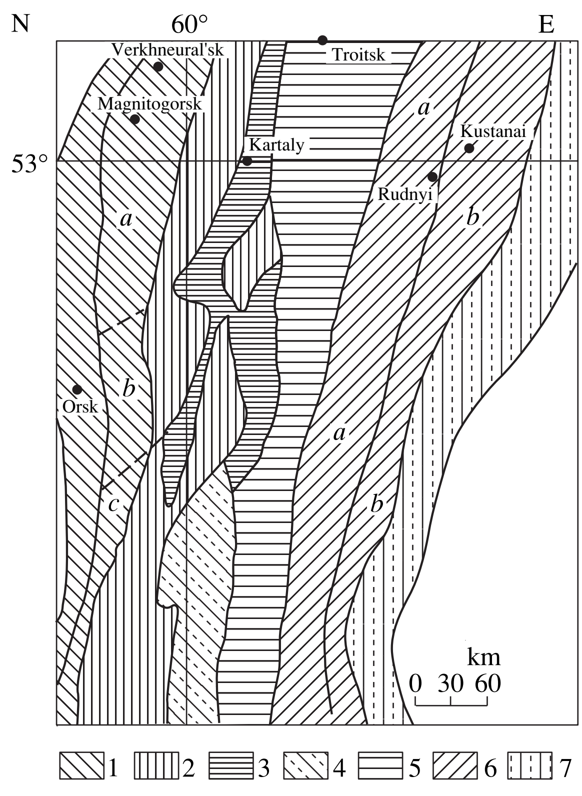

Fig. 1. Tectonic sketch map of the eastern slope of the southern Urals, based on the Geological Map of the Urals (scale 1 : 1 000 000) edited by I.D. Sobolev. (*1*) Magnitogorsk Trough; volcanic zones of the Magnitogorsk–Mugodzhary island arc: (*a*) Magnitogorsk, (*b*) Aschebutak, (*c*) West Mugodzhary; (*2*) East Ural Rise; (*3*) marginal volcanic belt; (*4*) Irgiz Trough; (*5*) Transural Rise; (*6*) Tyumen–Kustanai Trough: (*a*) Valer'yanovka volcanic zone, (*b*) Borovsky zone; (*7*) Tobol–Ubagan Rise.

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Average chemical compositions of Fe-rich basalts from the Late Paleozoic rift-related volcanic belts on the eastern slope of the Urals

Component	1 (14)	2 (137)	3 (12)	4 (23)	5 (5)	6 (22)	7 (7)	8 (3)
SiO_2	50.26	48.98	49.26	49.14	49.39	48.35	46.72	49.95
TiO_2	1.26	1.79	1.6	1.41	1.24	1.99	1.74	1.7
Al_2O_3	16.45	17.20	17.47	17.20	17.44	15.16	15.03	14.62
Fe_2O_3	5.24	4.54	3.91	4.37	3.70	5.18	4.13	5.76
FeO	4.98	5.52	5.56	5.21	5.13	5.70	5.63	4.17
MnO	0.19	0.19	0.19	0.18	0.24	0.18	0.17	0.15
MgO	5.37	5.54	5.01	5.37	5.75	5.42	5.93	4.28
CaO	10.81	7.99	7.74	7.68	7.74	8.91	11.51	8.86
Na_2O	2.93	4.07	5.48	3.60	2.88	3.88	3.52	5.09
K_2O	0.25	0.86	0.17	1.94	3.00	0.59	0.55	0.23
P_2O_5	0.17			0.25				
L.O.I.	2.46	2.59	3.30	3.07	3.60	3.51	4.01	4.38
Total	100.37	99.27	99.69	99.42	100.11	98.87	98.94	99.19

Component	9 (16)	10 (9)	11 (4)	12 (232)	13 (16)	14 (51)	15 (15)
SiO_2	50.64	50.25	51.52	50.20	49.94	49.56	49.86
TiO_2	0.86	0.80	0.96	1.06	1.11	1.01	0.95
Al_2O_3	17.32	18.88	18.10	17.36	17.72	18.24	18.22
Fe_2O_3	3.14	6.63	3.95	5.20	5.83	5.12	5.05
FeO	4.92	2.26	6.2	4.91	4.01	5.10	5.64
MnO	0.15	0.17	0.14	0.16	0.10	0.16	0.16
MgO	5.10	4.75	4.91	5.03	4.74	4.71	4.55
CaO	8.00	6.49	7.58	7.17	7.93	5.86	4.88
Na_2O	4.25	4.34	2.29	4.22	4.93	4.21	3.83
K_2O	0.48	1.29	0.46	1.04	0.23	1.97	2.85
P_2O_5		0.21	0.21	0.24	0.27	0.23	0.24
L.O.I.	3.55	2.43	3.59	2.86	3.34	3.41	3.29
Total	98.41	98.29	99.91	99.45	100.15	99.58	99.52

Note: (1–5) Late Tournaisian–Visean volcanic series of the Magnitogorsk Belt: (1) basalt–andesite–dacite (tholeiitic), (2) basalt–andesite–rhyolite, (3) basalt–andesite–dacite (sodic), (4) trachybasalt–trachyandesite–trachyrhyolite, (5) absarokite–shoshonite–latite–trachyte; (6–10) Late Visean–Bashkirian volcanic series of the Irgiz Belt: (6, 7) basalt–andesite–rhyolite, (8) basalt–rhyolite (sodic), (9) basalt–basaltic andesite, (10) basalt–rhyolite (potassic–sodic); (11–15) Middle Visean–Bashkirian volcanic series of the Valer'yanovka Belt: (11) basalt–andesite–dacite (tholeiitic), (12) basalt–andesite, (13) basalt–andesite–dacite (sodic), (14) trachybasalt–trachyandesite, (15) absarokite–shoshonite–latite–trachyte. The average chemical compositions of basalts in the Magnitogorsk Belt were calculated from the data of I.A. Smirnova and [7]; in the Irgiz Belt, from [8]; and in the Valer'yanovka Belt, from the data of A.M. Pumpyansky. Numerals in parentheses are numbers of analyses.

slope of the Urals, Transural region, and the West Siberian Plate [6–8].

The development of the mantle plume along the eastern slope of the Urals is supported by the URSEIS'95 seismic profile [9, 10]. The uplifted base of the lithospheric mantle is clearly seen in the eastern segment of this profile to the east of the Magnitogorsk volcanic zone (Fig. 2). Judging from geological interpretation of the URSEIS'95 seismic profile, the base of the lithospheric mantle beneath the eastern Urals and Transural region is uplifted by more than 50 km in comparison with the Ural Foredeep, Bashkir Anticlinorium, and Central Ural Rise in the west [10].

The rise of the lithospheric and asthenospheric mantle layers on the eastern slope of the Urals and a low-angle (15°–40°) westward tilt of reflectors at the eastern end of the seismic profile toward the Magnitogorsk volcanic zone clearly expressed in the URSEIS'95 seismic profile [9] along with enormous eruption of tholeiitic basaltic magma of elevated alkalinity in the Early Carboniferous are in line with the suggested formation of a mantle diapir along the eastern slope. The seismic pro-

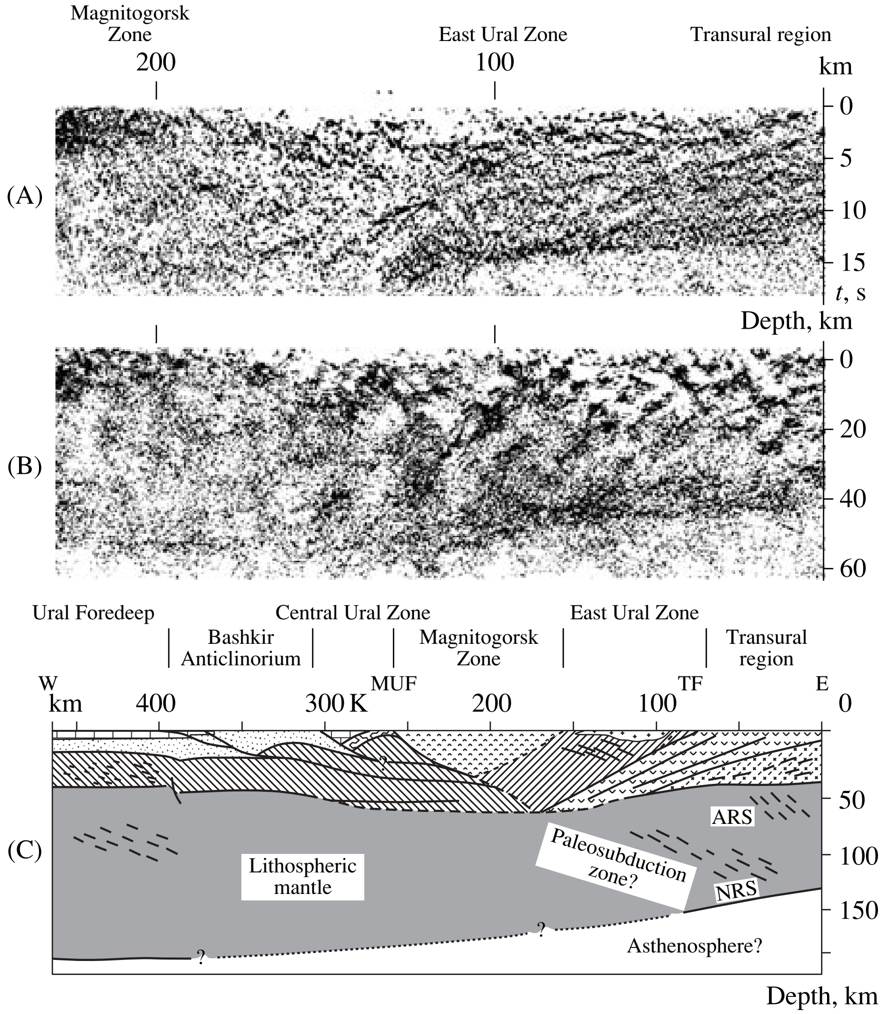

Fig. 2. (A, B) Eastern segment of the URSEIS'95 seismic profile [9]; (C) geological interpretation of the URSEIS'95 seismic profile [10].

file crossed only the western segment of the mantle plume. This is evident from the nearly horizontal roof of the lithospheric mantle at the eastern end of the profile [9, 10]. The ascent of the mantle plume along the eastern slope of the Urals began in the Late Devonian (late Frasnian–early Famennian) and continued until the early Visean, when this process fostered the development of land, shallow-water epicontinental seas, and basaltic eruptions [3, 11, 12].

The ascent of the mantle diapir resulted in rifting and the eastward migration of the Late Paleozoic rifts on the eastern slope of the Urals and compositional similarity of basaltoid series therein. In the Magnitogorsk volcanic zone, the related tectonic reactivation in the Famennian and early Tournaisian was accompanied by progressive eruptions of basaltic magma of the calc-alkaline, subalkaline, and shosonitic series above the western deeper segment of the mantle plume. To the east, the tholeiitic and calc-alkaline series were developing above the shallower Irgiz segment of the plume.

On the eastern slope of the Urals and in the Transural region, the most intense volcanic eruptions related to the mantle diapir ascent took place in the late Tournaisian–early Visean (Magnitogorsk Zone), the middle Visean–Serpukhovian (Valer'yanovka Zone), and the late Visean–Serpukhovian (Irgiz Zone). Thus, the volcanic activity migrated from eastward from the Magnitogorsk Zone to the Irgiz Zone and farther to the Tyumen–Kustanai Trough.

The ascent of the mantle diapir ceased in the middle Visean, and the Great Visean transgression spread over the Urals [11]. However, extension of the Early Carboniferous rifts on the eastern slope of the Urals and in the Transural region went on. Intense volcanic eruptions occurred in the Magnitogorsk, Irgiz, and Valer'yanovka rifts until the Bashkirian Age in the Irgiz and Valer'yanovka volcanic belts. Despite a certain shift in time, basaltic magmatism in these rifts evolved according to the same scenario from low- to high-K series. The medium-K series are predominant in all rifts. The Fe-rich basalts of the medium-K and Na series belong to the hawaiite–mugearite group of igneous rocks (table).

The onset of collision in the Middle Carboniferous is marked by the emergence of insular land as indicated by deposition of red beds documented in many localities on the eastern slope of the Urals and in the Transural region. Collision blocked the basaltic volcanic eruptions on the eastern slope of the Urals. However, in the Transural region, the effect of the plume was felt still in the Middle–Late Carboniferous and the Permian, as follows from the K–Ar ages of silicic igneous rocks: rhyolite and granite porphyry of the Khutora massif (263, 259, 253, 253 Ma) and leucogranites of the Lobanovo (334, 293, 289 Ma), Koklanovo (328, 293, 289, 252, 226 Ma), and Kurgan (301, 270 Ma) plutons [14]. The relationships of granitic rocks with mantle plumes were also established elsewhere [5, 15]. Numerous K–Ar datings of rhyolites from the central Transural region also fall within the range from the Middle Carboniferous to the Late Triassic [14]. The documented crosscutting of rhyolites by dolerite dikes corroborates the effect of basaltic magma on the formation of volcanoplutonic associations in the Transural region. The recently determined age of zircon from basalt and gabbro in the West Siberian Plate previously regarded as Triassic turns out to be 346 and 342 Ma [6]. This fact confirms the long-term influence of the mantle diapir on the tectonic evolution of the eastern slope of the Urals, Transural region, and West Siberian Plate.

Thus, the influence of the mantle plume on the tectonic evolution and magmatism of the eastern slope of the Urals and Transural region did not cease in the Late Carboniferous and Permian, i.e., during the period of emplacement of granitic batholiths on the eastern slope of the Urals. The batholiths of the Main Granitic Belt of the Urals were formed in the Late Carboniferous–Early Permian simultaneously with hypabyssal leucogranitic and rhyolitic plutons in the Transural region under thermal impact of the mantle diapir in the course of collision. This model eliminates the problem of the source of heat needed for the generation of enormous bodies of granitic magma in the course of the formation of the Ural Foldbelt. A similar interpretation of granitic batholiths was applied to the Central Asian Foldbelt [15]. The evolution of the Ural mantle plume completed in the Triassic with formation of the basalts of the Tura Formation that are widespread in the Transural region and West Siberia. The compositional similarity of the Transural traps and basalts of the Tura Formation with tholeiitic basalts in the Early Carboniferous rifts on the eastern slope of the Urals indicates that they were derived from a common magma source. As follows from the aforesaid, the influence of the mantle plume on the geodynamics and magmatism on the eastern slope of the Urals, Transural region, and a part of the West Siberian Plate continued from the Famennian Age to the Triassic, i.e., for ~150 Ma.

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