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The ca. 1380 Ma Mashak igneous event of the Southern Urals

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A B S T R A C T

A review of the geochronology, geochemistry and distribution of the 1380 Ma Mashak Large Igneous Province (LIP) of the eastern margin of the East European craton indicates a potential link to a major breakup stage of the Mesoproterozoic supercontinent Columbia (Nuna), link to a major stratigraphic boundary (Lower–Middle Riphean), and economic significance for hydrocarbons and metallogeny. Specifically, the Mashak event likely has much greater extent than previously realized. Two U–Pb baddeleyite (ID TIMS) age determinations on dolerite sills obtained from borehole (Menzelinsk–Aktanysh-183) confirm the western extent of the Mashak event into the crystalline basement of the East European Craton (1382 ± 2 Ma) and into the overlying Lower Riphean sediments (1391 ± 2 Ma), and the imprecise ages reported elsewhere indicate the possible extension into the Timan region, with an overall areal extent of more than 500,000 km^2 (LIP scale). It has tholeiitic compositions and is associated with breakup on the eastern margin of the craton – in addition, precise SHRIMP zircon ages of 1386 ± 5 Ma and 1386 ± 6 Ma (this paper) provide confirmation of previous approximate 1380–1383 Ma zircon age determination of the same formation, and suggest an age of ca. 1.4 Ga for the Lower/Middle Riphean boundary which was formerly considered to be 1350 ± 10 Ma. Contemporaneous magmatic rocks in the north-eastern Greenland part of Laurentia (Zig-Zag Dal and Midsommerso formations) and Siberia (Chieress dykes and other dolerites) together with the Mashak event are suggested to be fragments of a single huge LIP and to correspond to breakup stage of the Columbia (Nuna) supercontinent. The Mashak LIP also has some significance, at least in Volgo-Uralia, for hydrocarbons and metallogeny.

1. Introduction

1.1. Objectives and geological background

The East European craton is an important “puzzle piece” in the efforts to reconstruct the proposed ca. 1.7–1.4 Ga Columbia (Nuna) and ca. 1.0–0.7 Ga Rodinia supercontinents (e.g., Li et al., 2008; Meert, 2012 and references therein). The craton consists of three crustal blocks that came together in the Paleoproterozoic: Fennoscandia (including the Karelian craton), Sarmatia, and Volgo-Uralia (Fig. 1) (e.g. Bogdanova et al., 2008).

Of great importance in the history of Volgo-Uralia and the closely connected western part of the Southern Urals, is the ca. 1380 Ma Mashak magmatic event. This event is represented by a NNE-trending belt of volcanic rocks in the Southern Urals, interpreted as a rift complex (e.g., Ernst et al., 2006; Parnachev, 1981; Puchkov, 2000). It is associated with the Kama Belsk aulacogen (rift), and also includes a NW-trending dyke swarm (Fig. 1) potentially related to this event on the basis of K–Ar ages (Postnikov, 1976). Another, smaller aulacogen – Sernovodsk–Abdulino – originated in Mashak time and branches from the Kama–Belsk aulacogen in a sublatitudinal (E-W) direction. The Mashak event has been best characterized in the Bashkirian anticlinorium of the Southern Urals, wherein basement rocks are exposed (Fig. 2). The event divides the Riphean succession into two major sequences separated by a significant regression and break in platformal sedimentation

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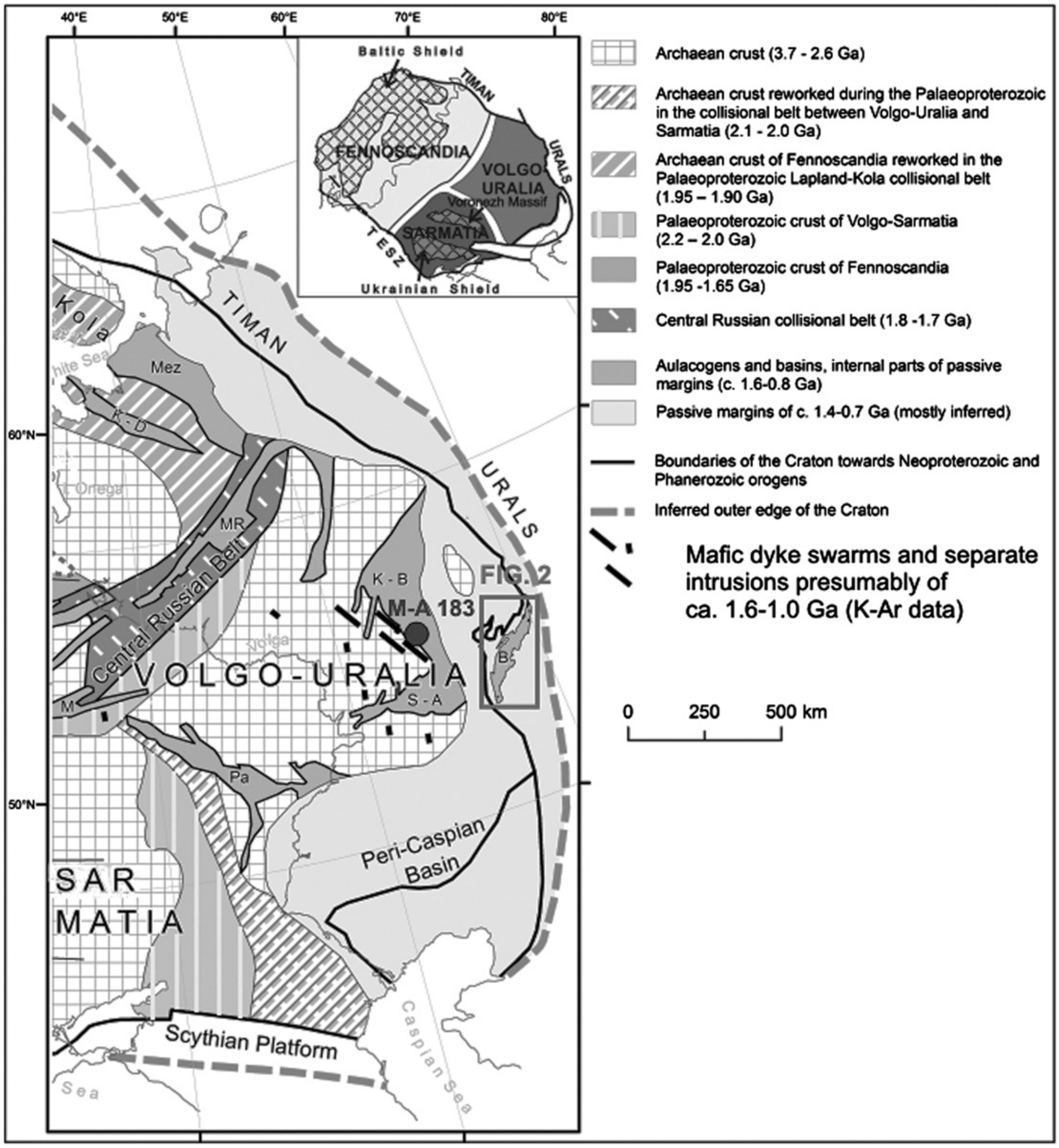

Fig. 1. Regional geology of the eastern part of the East European craton (Baltica) showing its three components: Fennoscandia, Volga-Uralia, and Sarmatia (insert). The basemap is after Bogdanova et al. (2008), to which has been added the location of the drill hole (marked by the blue circle and labeled M-A-183) and dykes of NW trend with possible ages between 1600 and 1000 Ma (Postnikov, 1976). Rifts, aulacogens, basins, and internal parts of passive margins are labeled as follows: K–B = Kama–Belsk aulacogen, B = Bashkirian anticlinorium (S. Urals), S–A = Sernovodsk–Abdulino aulacogen, Pa = Pachelma aulacogen, MR = Mid-Russian aulacogen, K–D = Kandalaksha–Dvina graben, Mez = Mezen rifts.

(Puchkov, 2010; Fig. 3). The subdivisions Lower, Middle and Upper Riphean correspond broadly to the use of Stenian (1000–1200 Ma), Ectasian (1200–1400 Ma, and Calymmian (1400–1600 Ma) in Gradstein et al. (2004) and Ogg et al. (2008). A detailed comparison of the Riphean classifications with this alternative classification is provided in Puchkov (2010).

Here we wish to review the characteristics of this Mashak magmatic event and associated rifting, metallogeny, and potential links with coeval magmatism on other blocks.

2. Mashak event

2.1. General stratigraphy

The NNE-trending belt of Middle Riphean volcanic and volcano-sedimentary rocks of the Mashak Formation is parallel to the typical Uralian strike (20–30 degrees NE), and is more than 270 km long and 1–12 km wide (points 1–3, 6–8 and 12 in the Fig. 2). The Mashak Formation, up to 3000 m thick, thins out and completely disappears at a distance of 10–20 km to the west, suggesting a buried shoulder of a deep NNE-trending graben; the coarse grain size of many sedimentary rocks and geochemistry of the volcanics support this suggestion. The Formation in its stratotype (Mashak Range) and hypostratotype (Bolshoi Shatak Range) is represented by basalts, rhyodacites, rhyolites, rhyolite and basalt tuffs, tuff breccias and terrigenous rocks: conglomerates with quartzitic pebbles and boulders, quartzites, siltstones and black shales; volcanic rocks predominate in the lower part but are also present in the middle parts of the section. Rhyolites occur 400–600 m above the base of the section (Fig. 4). A more detailed description of the type section follows below. In the northern part of the Bashkirian anticlinorium (Fig. 2, points 8 and 12) analogs of the Mashak Formation are metamorphosed to greenschist and amphibolite facies and are known as the Kuvash Formation. The most comprehensive section of the Mashak Formation is found in the No. 3 Karagas borehole (Fig. 2, point 3). The borehole penetrates basic metavolcanic rocks of extrusive and volcanoclastic facies.