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Late Permian–Early Triassic traps of the Kuznetsk Basin, Russia: Geochemistry and petrogenesis in respect to an extension of the Siberian Large Igneous Province

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ABSTRACT

The Late Permian–Early Triassic (~252 Ma) volcanic rocks in the central part of the Kuznetsk Basin (the Altay–Sayan Folded Area) are a good example of intraplate magmatism in a plume-influenced environment within the platform framework. The Kuznetsk lavas are dominantly basaltic andesites, contain 5.3–3.4 wt.% MgO and 1.4–1.9 wt.% TiO_2, and are enriched in LILE and LREE and depleted in Nb and Ta ($(La/Yb)_{CN} = 5.2–7.7$); $Nb/La = 0.3–0.4$). The major and trace element data suggest that all lava units of the Kuznetsk Basin are moderately evolved (Mg# = 34.6–46.6) through fractional crystallization and linked by a common deep-seated magma chamber. They are predominantly derived from non-contaminated magmas that have experienced potential early-stage sulfide segregation and Cr-spinel crystallization prior to fractionation. The Kuznetsk lavas originated from low degrees of partial melting of amphibole- and Fe–Ti oxide-bearing spinel lherzolite, with the involvement of pyroxenite component. Lavas are characterized by both OIB-like and subduction-like signatures and originated by melting of a subduction-modified lithospheric mantle by OIB-like asthenospheric fluid/melt additions. The Kuznetsk lavas are compared in petrology and geochemistry with the Siberian Traps basalts, especially the Nadezhdinsky suite from the Noril'sk region, and the West Siberian Basin basalts, and, in general, may be considered as more evolved varieties of the Nadezhdinsky basalts. Thus, the Kuznetsk volcanic rocks are genetically related to the Siberian LIP and the Kuznetsk Basin may be considered as a part of the Siberian Large Igneous Province.

1. Introduction

Large-scale eruptions of continental flood basalts (traps) are the most striking manifestations of intraplate magmatism, and large igneous provinces (LIPs) are variously attributed to mantle plumes. At the same time, the fingerprints of mantle plumes within the folded framing of the platforms are more difficult to recognize due to a complex tectonic history of such regions. The world's largest LIP comprises the traps of the Siberian Platform also including the basalts of the West Siberian Basin and the Taimyr and is perhaps one of the best and well-known examples of intraplate magmatism. Different non-plume models have been proposed to explain the origin of the Siberian traps (Ivanov, 2007), including mantle diapirs from the mantle transition zone (Yasuda et al., 1997; Ivanov and Litasov, 2014), upper mantle heat redistribution melting (King and Anderson, 1998; Coltice et al., 2007), perispheric and/or lithospheric melting (Zorin and Vladimirov, 1989; Anderson, 1995; Puffer, 2001), and bolide impact (Jones et al., 2002). Although, the plume model is considered the conventional one (e.g., Campbell et al., 1992; Lightfoot et al., 1993; Wooden et al., 1993; Nikishin et al., 2002; Reichow et al., 2005; Saunders et al., 2005; Dobretsov et al., 2010; Sobolev et al., 2011; Ernst, 2014). However, with respect to the folded surroundings, there is no consensus among researchers about where the boundary of Siberian Traps Province should lie, whether or not including the Altay–Sayan Folded Area (in particular, the Kuznetsk Basin). It is because to date there is no reliable evidence that the Permian–Triassic basic magmatism in this region is plume-generated (Kruk et al., 1999; Buslov et al., 2010), although igneous rocks of the Kuznets Basin are traditionally present in most geological maps as part of the 252 Ma Siberian LIP (Reichow et al., 2009; Dobretsov et al., 2010).

The Kuznetsk Basin (often abbreviated as Kuzbass or Kuzbas) is located ~300 km to the south of the West Siberian Plain, in the northwestern part of the Altay–Sayan Folded Area (Fig. 1a). It lies in the Kuznetsk Depression and has an area of 70,000 km^2. The Kuznetsk Basin is bordered on all four margins by fold and thrust belts and shear zones, namely: the Tom'–Kolyvan in the north, the Kuznetsk Alatau in the north to the east, the Gornaya Shoria in the south, and the Salair Range in the west (Fig. 1b). Mafic lavas, sills, and dykes of the Kuznetsk Basin are comparable in age with the Siberian traps (~252 Ma) (Reichow et al., 2009). Despite a long history of study of magmatism in the Kuznetsk Basin (Usov, 1937; Nastavko, 2013), up to

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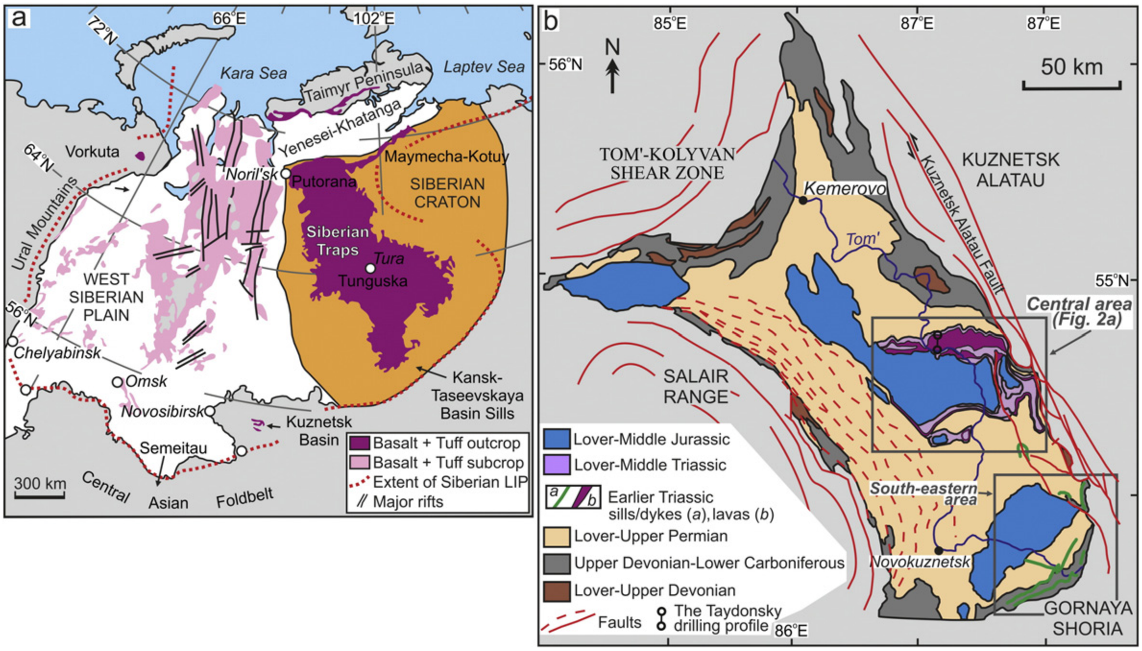

Fig. 1. (a) Location map of the Kuznetsk Basin with respect to the Siberian Traps Large Igneous Province, showing the position of the basin south of the main West Siberian Basin (after Reichow et al., 2009). (b) Simplified geological map of the Kuznetsk Basin (from Buslov et al., 2010). The structural framework of the basin and its location in proximity to marginal fold and thrust belts as well as the priority development areas of the Permian–Triassic lavas (the central area) and sills/dykes (the south-eastern area) are shown. The location of the Taydonsky drilling profile (after Lavrenov et al., 2001) is also shown.

date a number of issues, such as the degrees of partial melting and fractionation of primary magmas, the potential crustal contamination, mineralogy of the mantle source, correlation with the individual regions of the Siberian LIP remain unclear, in particular because of the insufficient geochemical knowledge of the rocks. This paper presents the first systematic study of major and trace element abundances in lava units from six different outcrops of the central area of the Kuznetsk Basin. These new data are used for tracing the geochemical evolution of the Permian–Triassic magmatism in the region and in deciphering whether or not the Kuznetsk volcanic rocks are genetically related to the Siberian LIP.

2. Geological background

2.1. Regional geological framework with respect to the geodynamic context

The Kuznetsk Basin is a Late Paleozoic (Late Carboniferous–Permian) depression superimposed on accretionary complexes of pre-Devonian age (e.g., Lavrenov et al., 2001, 2003; Buslov et al., 2010). The unexposed and undrilled pre-Devonian basement of the Kuznetsk Basin that is common in the Kuznetsk Alatau and probably (based on geophysical data) in the Kuznetsk Basin combines several subduction-related complexes, which were formed in island arc/back-arc environments by the mantle plume(s) (Lavrenov et al., 2001, 2003; Kuzmin et al., 2010 and references therein), and are separated by periods of hiatus, deformations and erosion. A great stratigraphic hiatus, accompanied by regional deformations and a significant surface denudation, marks large-scale accretion–collision events (collision of the Altay–Sayan terrane(s) with the Siberian platform) in the Kuznetsk Alatau during Middle Ordovician–Devonian time.

Supracrustal complexes of the Kuznetsk Basin range in age from Devonian to Jurassic and involve the Devonian–Triassic and the Jurassic structural levels (Fig. 1b). The Devonian–Triassic structural level consists of the following complexes (after Lavrenov et al., 2001, 2003): (1) A Lower–Middle Devonian complex: alluvial to marginal marine terrigenous rocks and trachybasalt to trachydacite sequences that are considered to be formed in an Andean-type active continental margin setting. A stratigraphic hiatus and the formation of weathering crusts mark the presumptive conversion of the Andean-type margin to an Atlantic-type passive continental margin resulting from the final amalgamation of the Altay–Sayan composite terrane and Siberian continent (Kuzmin et al., 2010 and references therein); (2) An Upper Devonian–Early Carboniferous complex: terrigenous successions and carbonate-dominated sequences which are interpreted as formed in epeiric sea environments (Davies et al., 2010); (3) An Upper Carboniferous–Permian complex: paralic non-marine coal-bearing successions deposited in fluvial environments (Davies et al., 2010). From the Late Carboniferous onwards, the Kuznetsk Basin begins to exist as an individual structure, a depression superimposed on the pre-Devonian complexes. (4) A Permian–Triassic complex: volcanic-sedimentary sequences, which will be discussed below in detail. The strata were deposited in a variety of fluvial settings (Reichow et al., 2009; Davies et al., 2010), and volcanism is believed to have occurred in an intracontinental rift environment.

In summary, during Early–Middle Devonian, the present eastern part of the Kuznetsk Basin was part of an Andean-type continental volcanic arc system. The Late Paleozoic period was marked by a major tectonic restructuring, which is likely triggered by intraplate stretching and thinning of the continental crust (Lavrenov et al., 2001, 2003; Stanevich et al., 2010). It is possible to reconstruct the pattern of significant crustal downwarping throughout the whole territory at the very end of the Middle Devonian. At the Permian–Triassic boundary, the studied region had experienced short-lived magmatic activity, which resulted in the emplacement of the lava flow sequence and the dyke-sill complex in dominant continental depositional environments.

2.2. Permian–Triassic volcanic stratigraphy of the Kuznetsk Basin

The Permian–Triassic magmatic rocks within the Kuznetsk Basin belong to the Abinsky Complex, and are localized in two areas, in the south-eastern and in the central parts of the depression (Fig. 1b). In the south-eastern area, the Abinsky Complex is represented only by sills and dykes; no extrusive rocks are observed in this part. Sills and dykes are mostly well differentiated from quenched dolerites to