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ScienceDirect
Russian Geology and Geophysics 57 (2016) 809–821
RUSSIAN GEOLOGY AND GEOPHYSICS
www.elsevier.com/locate/rgg

Distribution of PGE in Permo-Triassic basalts of the Siberian Large Igneous Province

A.E. Izokh [a,b,*], A.Ya. Medvedev [c], G.S. Fedoseev [a,b], G.V. Polyakov [a], I.V. Nikolaeva [a], S.V. Palesskii [a]

[a] *V.S. Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, Novosibirsk, 630090, Russia*
[b] *Novosibirsk State University, ul. Pirogova 2, Novosibirsk, 630090, Russia*
[c] *A.P. Vinogradov Institute of Geochemistry, Siberian Branch of the Russian Academy of Sciences, ul. Favorskogo 1a, Irkutsk, 664033, Russia*

Received 8 May 2015; accepted 24 September 2015

Abstract

We have revealed the spatio-temporal regularities of distribution of platinum group elements (PGE) in basaltoids related to the activity of the Siberian mantle plume. As objects of study, we chose rift and flood basalts from the Norilsk district (sampled from the SD-9 borehole), flood basalts from the central part of the Tunguska syneclise (Lower Tunguska), Kuznetsk Basin traps, and subalkalic basalt from the Semeitau volcanoplutonic structure in eastern Kazakhstan. Based on the PGE patterns of basaltoids related to the activity of the Permo-Triassic Siberian plume, we have shown that the rocks that formed in the central part of the Siberian Large Igneous Province (LIP) at the early rift stage have low contents of PGE, whereas picrites and tholeiitic flood basalts have high contents. The rift (Semeitau structure) and flood (Kuznetsk Basin traps) basalts from the peripheral regions are characterized by extremely low PGE contents. The high PGE contents in magmas of the plume head are responsible for the high productivity of ultramafic–mafic trap magmatism. The elevated K contents in magmas and the high PGE contents in the mantle plume head are probably due to the ascent of deep-seated material from the core–lower-mantle boundary, as follows from the thermochemical model of the Siberian plume.

Keywords: ultramafic–mafic intrusions; PGE; Large Igneous Provinces; geochemistry

Introduction

Most of commercial Cu–Ni–PGE deposits are related to ultramafic–mafic magmatism of Large Igneous Provinces (LIPs) (Abbott and Isley, 2002; Dobretsov et al., 2010; Maier, 2005). Among them are Cu–Ni–PGE deposits of ultramafic–mafic intrusions (Monchegorsk, Fedorova–Pana, Penikat, Koilismaa, Kivakka, and Lukkulaisvaara) of the Kola–Karelian region. These deposits are located in two LIPs: Mistassini and Matachewan (Ernst and Jowitt, 2013). In the south of the Siberian craton, there are widespread Cu–Ni–PGE deposits of different ages associated with ultramafic–mafic magmatism. The Chinei deposit (1880 Ma) is related to the Superior LIP (Canada). The Yoko-Dovyren intrusion and Kingash Cu–Ni–PGE deposit are assigned to the Franklin LIP (Ernst and Jowitt, 2013; Polyakov et al., 2013). The unique Cu–Ni–PGE deposits of the Norilsk district are confined to the highest-temperature trap province of the Siberian craton (250 Ma) (Medvedev, 2004; Sobolev et al., 2009, 2011), considered as the central part of the head of deep-seated mantle plume (Dobretsov et al., 2010). Similar deposits are also located in the central parts of the Emeishan and Tarim plumes (Borisenko et al., 2006; Izokh et al., 2005).

The relationship of Cu–Ni–PGE deposits with ultramafic–mafic trap magmatism is due to the high degrees of melting of the mantle, on the one hand, and to high PGE contents in the parental melt, on the other. The presence of platinoids in ore objects has been well studied (Distler, 1994; Distler et al., 1980; Sarah et al., 2010; Wolfgang and Sarah-Jane, 2003). There are many data on PGE contents in the host rocks of ore-bearing massifs of the Urals platiniferous belt (Volchenko et al., 2007), in ophiolite volcanics (Oshin and Crocket, 1986), and in rocks of different ultramafic–mafic complexes (Izokh et al., 1991; Philipp et al., 2001; Polyakov et al., 2006). In the recent decade, a series of publications concerned with PGE

* Corresponding author.
E-mail address: izokh@igm.nsc.ru (A.E. Izokh)

1068-7971/$ - see front matter © 2016, V.S. Sobolev IGM, Siberian Branch of the RAS. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.rgg.2016.04.005

presence in basaltoids of different geodynamic settings has appeared (Chazey and Neal, 2005; Crocket, 2002; Park et al., 2012; Woodland et al., 2005). Naldrett (1989) reported high PGE contents in traps, which increase with the Mg# value of melts. The goal of this work is to elucidate the spatio-temporal regularities of PGE distribution in basalts related to the activity of the Siberian mantle plume. As objects of study, we chose flood basalts from different formations of the Norilsk district, sampled from the SD-9 borehole (Medvedev, 2004), flood basalts from the central part of the Tunguska syneclise (Al'mukhamedov et al., 2004), Kuznetsk Basin traps (Karakan and Elbak quarries) (Nastavko et al., 2012), and subalkalic basalt from the Semeitau volcanoplutonic structure (Lyons et al., 2002). The SD-9 borehole was chosen as it penetrated the most complete trap section in the Norilsk district. It is here that Lightfoot and Keays (2005) carried out comprehensive studies of PGE distribution, which we compared with out results.

Methods

Analysis of the chemical composition of rocks was carried out by the X-ray fluorescence method at the Institute of Geochemistry, Irkutsk, by the technique borrowed from Afonin et al. (1984). The composition of basaltoids was measured by ICP MS with acid digestion at the Institute of Geology and Mineralogy, Novosibirsk, following the technique from Nikolaeva et al. (2012). The contents of PGE at the clarke level were determined by isotope dilution followed by MS analysis, after their acid (concentrated HCl + HNO_3 (1:3)) digestion in a microwave oven and chromatographic separation from the matrix on an AG50Wx8 cation exchange resin (Palesskii et al., 2009). The contents and isotope ratios of elements were measured on an ELEMENT2 mass spectrometer at the Institute of Geochemistry, Irkutsk. The detection limits were from 0.005 ppb (Ir) to 0.2 ppb (Pd). This technique was tested on the spinel lherzolite GP-13 and serpentinite UB-N standard samples.

Mineralogical and petrographic description of the rocks

The studied volcanics from the Norilsk district (SD-9 borehole) are of different types, from picrite basalts to tholeiitic basalts. Their compositions are listed in Tables 1 and 2. The samples from the Ivakino, Gudchikha, and Nadezh-

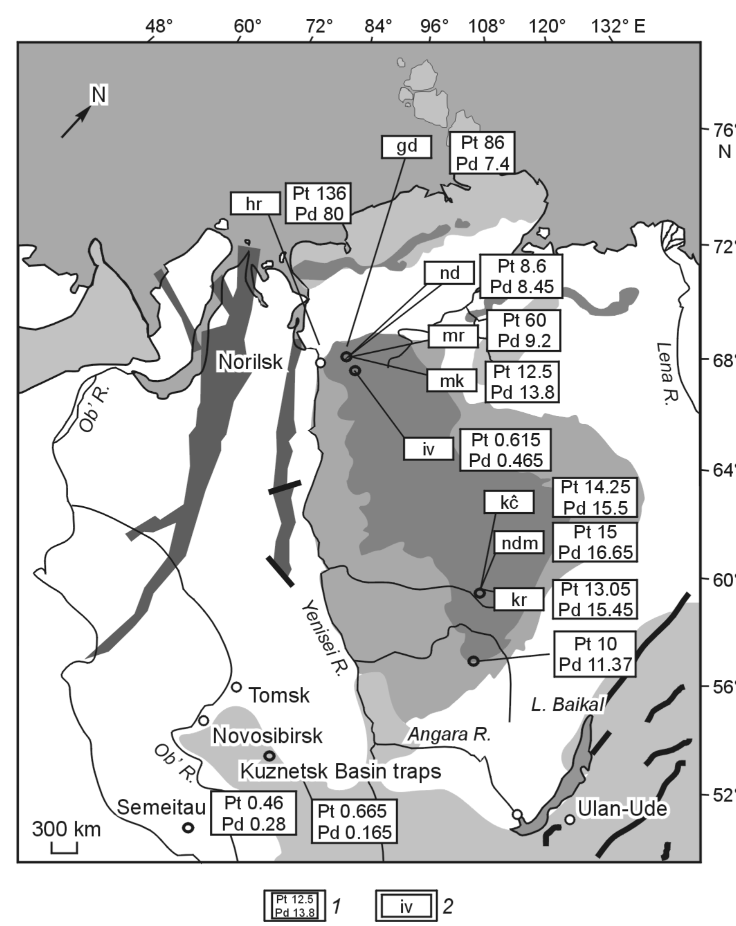

Fig. 1. Scheme of the spread of Permo-Triassic magmatism related to the Siberian LIP (Medvedev, 2004). *1*, sampling localities and contents of Pt and Pd in the samples (ppb); *2*, formations (for designations, see Table 1).