Available online at www.sciencedirect.com

ScienceDirect

Russian Geology and Geophysics 57 (2016) 653–671

RUSSIAN GEOLOGY AND GEOPHYSICS

www.elsevier.com/locate/rgg

The 1501 Ma Kuonamka Large Igneous Province of northern Siberia: U–Pb geochronology, geochemistry, and links with coeval magmatism on other crustal blocks

R.E. Ernst [a,b,*], A.V. Okrugin [c], R.V. Veselovskiy [d,e], S.L. Kamo [f], M.A. Hamilton [f], V. Pavlov [d,g], U. Söderlund [h], K.R. Chamberlain [i], C. Rogers [a]

[a] *Department of Earth Sciences, Carleton University, Ottawa, ON, K1S 5B6, Canada*
[b] *Faculty of Geology and Geography, Tomsk State University, pr. Lenina 36, Tomsk, 634050, Russia*
[c] *Diamond & Precious Metal Geology Institute, Russian Academy of Sciences, pr. Lenina 39, Yakutsk, 677000, Russia*
[d] *Institute of Physics of the Earth, Russian Academy of Sciences, ul. Bol'shaya Gruzinskaya 10, build. 1, 123995, Moscow, Russia*
[e] *Geological Department, Lomonosov Moscow State University, ul. Leninskie Gory 1, 119991, Moscow, Russia*
[f] *Jack Satterly Geochronology Laboratory, University of Toronto, Toronto, ON, M5S 3B1, Canada*
[g] *Kazan Federal University, ul. Kremlevskaya 18, Kazan, 420000, Russia*
[h] *Department of Geology, Lund University, Lund, 223 62, Sweden*
[i] *Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming, 82071, USA*

Received 29 December 2015; accepted 29 January 2016

Abstract

A new large igneous province (LIP), the 1501 ± 3 Ma Kuonamka LIP, extends across 700 km of northern Siberia and is linked with coeval dikes and sills in the formerly attached São Francisco craton (SFC)–Congo craton to yield a short-duration event 2000 km across. The age of the Kuonamka LIP can be summarized as 1501 ± 3 Ma (95% confidence), based on 7 U–Pb ID-TIMS ages (6 new herein) from dolerite dikes and sills across the Anabar shield and within western Riphean cover rocks for a distance of 270 km. An additional sill yielded a SIMS (CAMECA) age of 1483 ± 17 Ma and sill in the Olenek uplift several hundred kilometers farther east, a previous SIMS (SHRIMP) age of ca. 1473 Ma was obtained on a sill; both SIMS ages are within the age uncertainty of the ID-TIMS ages. Geochemical data indicate a tholeiitic basalt composition with low MgO (4–7 wt%) within-plate character based on trace element classification diagrams and source between E-MORB and OIB with only minor contamination from crust or metasomatized lithospheric mantle. Two subgroups are distinguished: Group 1 has gently sloping LREE ($(La/Sm)_{PM} = 1.9$) and HREE ($(Gd/Yb)_{PM} = 1.8$) patterns, slightly negative Sr and moderate TiO_2 (2.2 wt%), and Group 2 has steeper LREE ($(La/Sm)_{PM} = 2.3$) and HREE ($(Gd/Yb)_{PM} = 2.3$), strong negative Sr anomaly, is higher in TiO_2 (2.7 wt%), and is transitional from tholeiitic to weakly alkaline in composition. The slight differences in REE slopes are consistent with Group 2 on average melting at deeper levels. Proposed reconstructions of the Kuonamka LIP with 1500 Ma magmatism of the SFC–Congo craton are supported by a geochemical comparison. Specifically, the chemistry of the Chapada Diamantina and Curaça dikes of the SFC can be linked to that of Groups 1 and 2, respectively, of the Kuonamka LIP and are consistent with a common mantle source between EMORB and OIB and subsequent differentiation history. However, the coeval Humpata sills and dikes of the Angola block of the Congo craton represent a different magma batch.

Keywords: magmatism; dikes; sills; igneous province; northern Siberia

Introduction

Large Igneous Provinces (LIPs) represent large volume (>0.1 Mkm^3; frequently above >1 Mkm^3), mainly mafic (ultramafic) magmatic events of intraplate affinity, that occur in both continental and oceanic settings, and are typically of short duration (<5 m.y.) or consist of multiple short pulses over a maximum of a few 10s of m.y. (Ernst, 2014 and references therein). They comprise volcanic packages (flood basalts), and a plumbing system of dikes, sills and layered intrusions, and can be associated with silicic magmatism, carbonatites and kimberlites. LIPs are linked with continental

* Corresponding author.
E-mail address: Richard.Ernst@ErnstGeosciences.com (R.E. Ernst)

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.2016.01.015

breakup, global climate change including extinction events, and ore deposits of a variety of commodity types.

The Siberian craton is best known for the 252 Ma Siberian Trap Large Igneous Province (LIP), which covers several million km^2, was emplaced mostly within a million years and hosts the important Ni-Cu-PGE Noril'sk deposits (e.g., Burgess and Bowring, 2015; Ernst, 2014; Ivanov et al., 2013; Kamo et al., 2003; Naldrett, 2010; Reichow et al., 2009; Ryabov et al., 2014). Recently, Proterozoic LIPs of comparable scale to the Siberian Trap LIP have been discovered in Siberia through a campaign of U–Pb dating of dolerite dikes and sills by the LIPs Industry Consortium Project (www.supercontinent.org; Ernst et al., 2013a). For example a 1750 Ma giant radiating swarm extends over an area of >750,000 km^2 (e.g., Ernst et al., 2008; Gladkochub et al., 2010a,b). Furthermore, this and a number of other important southern Siberia LIPs can be linked with comparable age LIPs in northern Laurentia which indicates they were connected from 1.9–0.7 Ga (Ernst et al., 2015, 2016); thus increasing the size and advancing the importance of each of these LIPs.

Here we profile the 1500 Ma Kuonamka LIP of northern Siberia (Figs. 1 and 2; Ernst et al., 2014), which can also potentially be linked with dikes and sills in the formerly attached São Francisco–Congo craton (Ernst et al., 2013b) to delineate an event some 2000 km across (Fig. 3). We present new U–Pb ages, and geochemistry and consider the implications of a reconstruction with the São Francisco and Congo cratons.

Rock sample descriptions and locations

Sample locations are provided in Fig. 1 and Table 1, and some characteristics of the samples units are also listed in Table 1. Note that samples were provided by various co-authors, sampled at different times; details are provided below.

Dolerite dike samples of the EQ94 series: 01-01 (0.7 m wide), 02-05 (20 m wide), 03-05 (30 m wide), 04-05 (50 m wide), 13-01 (30-40 m wide) and 14-02 (35 m wide) were collected by R. Ernst and A. Okrugin during a 1994 sampling expedition along the Bolyshaya Kuonamka river in northern Siberia. Paleomagnetic results on these sites as well as a U–Pb baddeleyite age of 1503 ± 5 from site EQ94-04-05 were reported in Ernst et al. (2000). Previously reported K-Ar ages for some of these dikes include a date of 1242 ± 20 Ma at site EQ94-02, 1487 ± 10 Ma at site EQ94-03, 1391 ± 42 Ma at site EQ94-04, 1200 ± 8 Ma at site EQ94-13, 1537 ± 34 at site EQ94-14, and ages of 2728–2679 Ma reported by U–Pb ages on xenocrystic zircons at site EQ94-02 (Table 1 in Ernst et al., 2000).

In Ernst et al. (2000; and based on Okrugin et al., 1990) the EQ94 sites 01, 02, 03, 04 and 14 were linked, based on trend, composition, paleomagnetism, petrography and K–Ar ages, into the Kuonamka swarm and site 13 to the Juken swarm.

On the basis of geochemical evidence provided herein, the dolerite dike at site 13 instead appears correlative with the Kuonamka swarm.

Dolerite sill samples cutting Riphean cover rocks to the west of the Anabar shield include #11 (30 m thick), #14 (30 m thick), #24 (300 m thick), #81-108 (30 m thick), #139-153 (30 m thick), #181-200 (30 m thick), #215-225 (30 m thick), and #3 (100 m thick). In contrast, sample #259-273 (30 m thick) was collected from a dike. All samples in this series were collected by R. Veselovskiy.

Sample VP-2008 was collected by V. Pavlov from a dolerite sill (~15 m thick), exposed on the right bank of the Kotuykan River and the host rock is Riphean sandstones.

Sample F1 (Fomich River sill) for this study was collected by R. Veselovskiy and A. Shatsillo along the Fomich River in the Riphean cover of the 'northern slopes' of the Anabar uplift. Sample F1 is from a dolerite sill with a visible thickness of greater than 30 meters exposed on both banks of the Fomich River, about 10 km downstream from the mouth of the Burustakh brook. Four sills from the Fomich River valley studied previously yielded K-Ar ages of 912 Ma (for two sills), 1100 Ma and 1540 Ma (Kuteynikov et al., 1967). A Sm–Nd age of 1513 ± 51 Ma was also reported (Veselovskiy et al., 2006) on the same location as site F-1, dated in this report.

Samples AB81, AB85 and AB87 were collected by A. Okrugin along the Kotuykan River in the Riphean cover west of the Anabar shield. AB-81 and AB-87 are from 30 and 25 m thick dolerite sills, respectively, and AB-85 is from an ESE (110^o)-trending 50 m-wide dolerite dike. Previously reported K–Ar ages determined on these bodies include 1139 ± 31 Ma (AB-81), 1079 ± 45 Ma (AB-85), and 1314 ± 14 Ma (AB-87) (Okrugin et al., 1990).

Sample #22 was collected on the shore of the Kotuy river. The sill is about 300 m thick and was sampled from about 20 m from the margin. The host rocks are dolostones of the Usmastakh Formation (Pr2) or Staraya Rechka Formation (Vendian). This sill was sampled because it yields a very good paleomagnetic record (Veselovskiy and Pavlov, 2009). Previously, these rocks were considered as Vendian (or Permian-Triassic) in age, but paleomagnetic results indicate that they have about the same paleomagnetic direction as the other dolerites of age about 1500 Ma, a prediction that is confirmed by the U–Pb dating herein.

Petrography

All the collected samples have mineralogy of a dolerite with clinopyroxene and plagioclase as the main minerals and with minor Fe-Ti oxides and occasional apatite in a texture ranging from intersertal, to subophitic, to ophitic with increasing grain size. Minor alteration has partially sausseritized the plagioclase and uralitized the pyroxene. The two geochemical groups distinguished below on the base of trace element chemistry have the same mineralogy.