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THE LARGE IGNEOUS PROVINCE (LIP) RECORD OF RUSSIA THROUGH TIME: PRELIMINARY SUMMARY

ВРЕМЕННЫЕ РУБЕЖИ КРУПНЫХ ИЗВЕРЖЕННЫХ ПРОВИНЦИЙ РОССИИ: ПРЕДВАРИТЕЛЬНЫЙ ОБЗОР

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This is an initial step toward a full-scale review paper and map of Large Igneous Provinces (LIPs) for Russia.
Данная работа представляет собой первый шаг в написании обширной обзорной статьи и создании карты крупных изверженных провинций России.

Introduction to Large Igneous Provinces (LIPs)

The precise definition of a LIP has varied with time, but generally emphasizes a huge volume of intraplate mafic magma emplaced in a short period (e.g. review in Ernst 2014). The following version is modified after Ernst (2014) and Ernst and Youbi (2017). LIPs represent large volume (>0.1 Mkm^3; frequently above 1 Mkm^3), mainly mafic (-ultramafic) magmatic events of intraplate affinity (based on tectonic setting and/or geochemistry) that occur in both continental and oceanic settings, and are typically either of short duration (<5 Ma) or consist of multiple short pulses over a maximum of a few 10s of Ma. LIPs consist of volcanic packages (flood basalts) and a plumbing system of regional dyke swarms (linear, radiating and a newly identified circumferential type), sill complexes, layered mafic-ultramafic (M-UM) intrusions, and crustal magmatic underplates. Continental LIPs can also be associated with major silicic magmatic events termed Silicic LIPs (SLIPs), as well as carbonatites and kimberlites. LIP events occur at variable rates through time. Since 2500 Ma, there has been an average of one LIP event every 20–30 Ma. The rate of LIP occurrences in the Archean, however, is less certain due to poorer preservation.

LIPs have been the focus of a significant amount of recent research, given their growing importance in constraining paleocontinental reconstructions (Ernst et al. 2013), as a tool in exploration targeting (e.g. Ernst and Jowitt 2013), as analogues for voluminous planetary intraplate magmatism (e.g. Head and Coffin 1997; Ernst 2014), and for their causal role in dramatic climate change throughout Earth history (Ernst and Youbi 2017; Bond and Grasby 2017).

Here we provide a brief summary of LIP events (and possible LIP events) of Russia. A number of more speculative LIP events have not been included. Note that in this compilation we only consider events that are dominantly mafic (cf. definition of LIPs above) and do not discuss the related Silicic LIP (SLIP) events that are also important in Russia (e.g. Kravhinsky 2012; Yarmolyuk et al. 2014). Pre-Mesozoic oceanic plateaus are likely present as fragments in orogenic belts (e.g. in central Asia, Safonova 2009), but have not been listed below. "Dykes" and "sills" mentioned below are mafic and "layered intrusions" are mafic-ultramafic unless otherwise noted.

Preliminary Survey of the Russian LIP Record

Cretaceous LIP [NE Russia]: >700 km long NW-trending Cretaceous dyke swarm (extracted from 1:1 million scale maps; Ernst et al. 2016c).

Jurassic LIP [NE Russia]: Possible >500 km long NW trending Jurassic dyke swarm (extracted from 1: 1 million scale maps; Ernst et al. 2016c).

120 Ma "Hawaii" LIP [NE Russia]: Tectonically fragmented magmatic event that is speculated to be associated with the start of the Hawaiian hot spot track (Portnyagin et al. 2008; Batanova et al. 2014).

125-90 Ma High Arctic LIP (HALIP) [northern Russia]: Part of a widespread LIP in the northern Arctic (Buchan and Ernst 2018a, Oakey and Saltus 2016; Petrov et al. 2016).

150 Ma Okhotsk oceanic plateau [far eastern Russia]: Underlies the Okhotsk sea (Bogdanov and Dobretsov 2002). Similar in age to the Shatsky oceanic plateau in the northern Pacific Ocean.

250 Ma Siberian Traps LIP [Siberian craton and West Siberia basin]: Covering more than 4 Mkm^2, and consists of extensive flood basalts, pyroclastic volcanism, sill complexes, giant radiating and circumferential dyke swarms, and magmatism associated with rifting in the west Siberian basin. Precise U-Pb dating suggests emplacement in less than 1 Ma (Burgess and Bowring 2015). There are also associated Ni-Cu-PGE ore deposits and associated hydrothermal ores (Ryabov et al. 2013; Pirajno et al. 2009), associated kimberlites (ca. 245-220 Ma (Sun et al. 2014) and carbonatites (e.g. Kiselev et al. 2012). Recognized as the cause of the end-Permian global mass extinction (Burgess and Bowring 2015).

370 Ma Yakutsk-Vilvui LIP [eastern Siberian craton]: Giant radiating swarm and rift system (Kiselev et al. 2012). U-Pb geochronology indicates emplacement in two pulses, at ca. 374 Ma, and ca. 363.4 Ma, that have been linked with mass extinctions. (Ricci et al. 2013; Polyansky et al. 2017, 2018). Associated with carbonatites and the diamondiferous kimberlites. Plume centre on the eastern margin of the craton defined by the radiating rift and dyke swarm systems (Kiselev et al. 2012).

370 Ma Kola-Dnieper LIP [Baltic/East European craton]: Includes coeval mafic magmatism of the Dnieper-Donets rift, a dyke swarm extending for 2000 km along the Urals, and magmatism in the Kola Peninsula and elsewhere in the Baltic craton

(Nikishin et al. 1996; Kravchinsky 2012; Puchkov et al. 2016). Two plume centres are recognized (Puckhov et al. 2016). Kimberlites (Archangelsk) and carbonatites (Kola Alkaline province) are also associated with this event. Correlated with the Yakutsk–Vilui event. Potential cause of a global mass extinction event.

440 Ma Suordakh LIP [Verkhovansk belt in eastern Siberia]: Sills and volcanics approximately dated as ca. 440 Ma (Khudoley et al. 2013). More precise dating will test whether it is the cause of the end-Ordovician mass extinction (Chamberlain et al. 2018 [this volume]).

440–450 Ushat complex [Urals]. Subalkaline volcanics within the older Igonino, Mashak and Aiskii volcanics of the western zones of the Urals The early stages of development of the Vishnevogorsk/Ilmeny carbonatite complex (Puchkov,2018 a,b). May be correlated with the Suordakh complex.

475–460 Ma Kidryasovo complex [Urals]. Graben facies of the nascent passive continental margin of volcanic type along the whole Urals (coarse siliciclastic sediments and subalkaline volcanics (Puchkov 2018 a,b).

530-510 Ma Kharaulakh event [NE Siberian craton]: Widespread sills at the mouth of the Lena river and associated volcanics in the Kharaulakh mountains (Khudoley et al. 2013).

564–485 Ma Mankhambo event [Urals] Mankhambo A–granites, gabbro and contrast basalt–rhyolite volcanics in the western zones of the Urals (Puchkov, 2018b).

720 Ma Irkutsk LIP [southern Siberian craton]: Dykes, layered intrusions, and sills (Polyakov et al. 2013; Ernst et al. 2016a; Ariskin et al. 2018). Proposed to be the continuation of the Franklin LIP in a reconstruction of southern Siberia adjacent to northern Laurentia (Ernst et al. 2016a). May be correlated with the Igonino complex of the Urals (Puchkov 2018a).

706 and 735 Ma (two pulses) Igonino complex (Arshinskii - Barangulov- Serebrynaka event) [Urals]: (Krasnobaev et al. 2007, 2012; Puchkov 2012, 2018b; Maslov et al.,2018).). Uncertain size and setting.

1005 Ma Sette-Daban [Verkhovansk belt in eastern Siberia]: Sill province (Rainbird et al. 1998; Khudoley et al. 2007; Gladkochub et al. 2010). Possibly linked with a carbonatite complex of similar age (Savelyeva et al. 2016) in Baikal region.

1260 Ma Srednecheremshanskii event [southern Siberia]: Wide dyke dated at 1260 Ma (U-Pb) and linked to the huge 1270 Ma Mackenzie LIP of northern Laurentia based on a continental reconstruction (Ernst et al. 2016a).

1350-1340 Ma event [southern Siberian craton]: A new event identified by U-Pb dating that may be linked to coeval magmatism in the formerly connected northern Laurentia (Ernst et al. 2016a; Gladkochub et al. 2018b).

1380 Ma Mashak LIP [eastern Baltica]: Widespread LIP recognized in the Ural mountains and in the subsurface further west (Ernst et al. 2008; Puchkov et al. 2013; Puchkov 2018a,b).

1380 Ma Chieress LIP [northern Siberia]: Dyke swarm in eastern Anabar shield (Ernst et al. 2000; Ernst et al. 2008). Likely present as sill in Taimyr (Priyatknia et al. 2017).

1470 (-1500 Ma) Tuna-Trond Gota - Ladoga event [northern Baltica]: Dykes and sills (Ernst et al. 2008; Lubnina et al. 2010).

1501 Ma Kuonamka LIP [northern Siberia]: Dykes and sills extending for 700 km across northern Siberia (Wingate et al. 2009; Ernst et al. 2000, 2016b) and proposed to have been reconstructed adjacent to the Sao Francisco-Congo craton (Ernst et al. 2016b).

1710-1730 Ma Bilyakchan-Ulkan event [SE Siberian craton]: Sills, dykes, rift systems, and associated layered intrusions (e.g., Kun Manye mineralized intrusion) (Larin 2014; Didenko et al. 2015; Guryanov and Peshkov 2017). Also associated with Ulkan–Dzhugdzhur ore-bearing AMCG (Larin 2014). Potential link with Pelly Bay magmatic event in northern Laurentia (Ernst et al. 2016a).

1750 Ma Timpton LIP [Siberian craton]: Dykes and sills in the Aldan shield, Baikal region and Anabar shield, forming an overall radiating pattern marking a plume centre in eastern Siberia and likely later reused by the Vilyui rift arm of the 370 Ma Yakusk-Vilyui LIP (Gladkochub et al. 2010a,b). Linked with the Kivalliq Igneous Event of Northern Laurentia in the reconstruction of Ernst et al. (2016a).

1750 Ma Aiskii event [Urals, part of eastern margin of Baltica]: Aiskii volcanic suite dated by U-Pb (Krasnobaev et al. 2013). Of unknown scale and setting.

1800-1750 Ma Prutivka-Novogol event [Voronezh region, SW Russia]: AMCG (anorthosite-mangerite-charnockite-granite) magmatism, and mafic-ultramafic intrusions including dykes. Extends into the Ukranian shield (Bodganova et al. 2013; Shumlyanskyy et al. 2016).

1870-1860 Ma Kalaro-Nimnyrsky- Malozadoisky LIP [southern Siberian craton]: Dykes in the Aldan shield and in the Irkutsk promontory defining a swarm of potential 1500 km length (Ernst et al. 2016a). Can be linked with the coeval mineralized Ti-V Chiney gabbro (Gladkochub et al. 2018a). A reconstruction link is proposed with a coeval LIP of the Slave craton of northern Laurentia (Ernst et al. 2016a).

.1900 Ma Angaul dyke [Irkutsk promontory, southern Siberia]: Dyke swarm dated at ca. 1920 Ma (Gladkochub et al. 2010a) A link is suggested with magmatism in northern Laurentia in the reconstruction of Ernst et al. (2016a).

1970 Ma Pechenga-Onega LIP [northern Karelia]: Sills in the Pechenga area (associated with Cu-Ni-PGE mineralization), dyke swarms and associated Onega sill province. (Ernst and Buchan 2001; Lubnina et al. 2016, 2017; Glushanin et al. 2011).

2115-2140 Ma events [Karelian craton]: Dyke swarms (Vuollo and Huhma 2005; Stepanova et al. 2014). Linked with coeval LIP events in Superior, Hearne and Wyoming cratons (Ernst and Bleeker 2010; Davey et al. 2016).

2330 Ma Taivalkoski-Kuito LIP [Karelian craton]: Regional dyke swarm (Salminen et al. 2014; Stepanova et al. 2015).

2210 Ma Koli (Karialitic) event [Karelian craton]: Widespread sills (Vuollo and Huhma 2005, Ernst 2014). Linked with the coeval Ungava-Nipissing LIP of Superior craton (Ernst and Bleeker 2010; Davey et al. 2018).

2400 Ma event [northern Karelia]: Dykes (Stepanova et al. 2017).

2500-2450 Ma Baltic (BLIP) [Karelia craton]: Layered intrusions (some mineralized), dyke swarms, and rifting (Smolkin 1996; Ernst and Buchan 2001; Lauri et al. 2012; Kulikov et al. 2010). In the formerly adjacent Superior craton there are distinct 2510 Ma Mistassini and 2480-2450 Ma Matachewan LIPs. On the basis of a reconstruction with Karelia the 2500-2450 Ma of Baltica should be parsed into two events (ca. 2510 and 2480-2450 Ma) (Kulikov et al. 2010).

Archean LIPs

The Russian LIP record continues into the Archean (e.g. Ernst and Buchan 2001), but is not well constrained and is not included in this overview.

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