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LATE PRECAMBRIAN MAFIC DYKE SWARMS OF THE ALDAN SHIELD AND THEIR IMPORTANCE IN ORE-MAGMATIC PROCESSES

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Introduction

Integrated petrological-geochemical, geochronological, and ore-mineralogical studies of mafic magmatism are of prime importance in reconstructing the formation history and metallogeny of ancient platforms (Gladkochub et al., 2012; Guryanov et al., 2013; Okrugin et al., 2018; Ernst et al., 2016). This paper presents geochemical and age data for the swarms of Late Precambrian unmetamorphosed mafic dykes of the Aldan shield, which formed in course of a long evolution of the Siberian platform following consolidation of the ancient basement of the Siberian (North Asian) craton, but are overlain by the Phanerozoic sedimentary cover.

Results

Mafic dykes are widespread within the Aldan shield that represents the northern Chara-Aldan domain of the Aldan-Stanovoy superterrane including the West Aldan, Nimnyr, Sutam, Uchur, and Batomga terranes separated by tectonic mélange zones (Fig.1). The dykes dip steeply (70-90°) showing clear intrusive contacts with the enclosing rocks. Their traceable length varies from a few to 15 km and the thickness – from several to 200-300 m. The dykes form 200-500 km long and 20-60 km wide swarms crosscutting different terranes. The ENE dyke swarms occur mainly in the western part of the Aldan shield where the Nirekta (NR), Olondo (OL), Udokan-Tommot (UT), and Kalar-Nimnyr (KN) swarms are identified (Mironyuk et al., 1971). In the middle part of the Aldan shield, apart from the Timpton-Gynym (TG) swarm there are recognized the Timpton-Algama (TA) and the El'kon-Gonam (EG) belts of NW strike (Okrugin et al., 2000). In the east of the shield, the dykes of the Maimakan Complex are grouped into the Uchur-Uyan (UU), South-Uchur (SU), and Ukikan (UK) fields of dyke swarms (Guryanov et al., 2013).

The Precambrian age of the dykes was earlier supported by K-Ar dating (1050-1650 Ma) of the rocks (Okrugin et al., 2000). More well-constrained ages were obtained recently from U-Pb dating of zircon and baddeleyite (Ernst et al., 2016), which are shown in Fig.1 with a star (*).

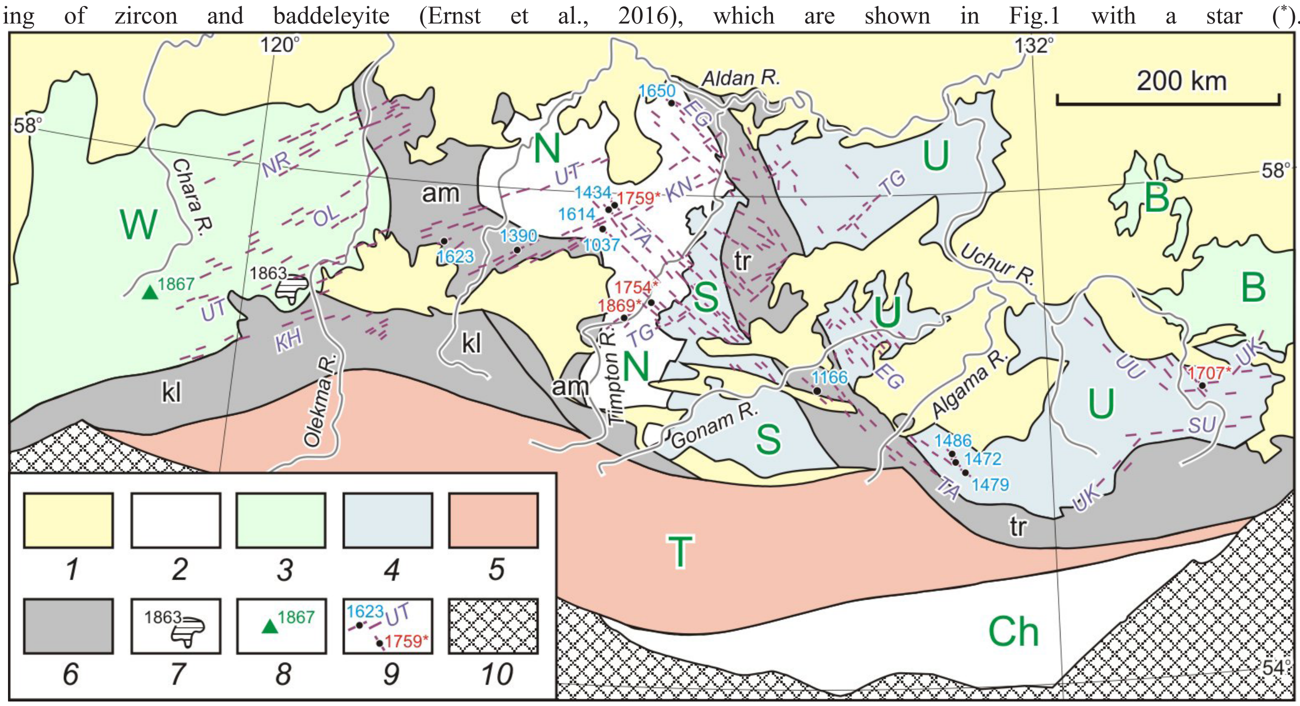

Figure 1. Sketch map of Late Precambrian dyke swarms in the Aldan shield

1 – Siberian platform cover; 2-5 – terranes of the Aldan-Stanovoy shield (after Smelov et al., 2009): 2 – Nimnyr (N) and Chogar (Ch) granite-orthogneiss; 3 – West Aldan (W) and Batomga (B) granite-greenstone; 4 – Sutam (S) and Uchur (U) granite-paragneiss; 5 – Tynda (T) tonalite-trondhjemite-gneiss; 6 – tectonic mélange zones (am - Amga, kl - Kalar, tr - Tyrkanda; 7 – Lower Khani graben-syncline with metagabbro-diabase dykes and sills (Popov et al, 2012); 8 – Chiney layered gabbroic massif; 9 – dyke swarms; 10 – folded complexes of South Siberia.

The age of the NE Kalar-Nimnyr belt (1869 Ma) obtained from dating of a dyke of the TG swarm is close to that (1844 Ma) of the NE dyke swarm in northern Cisbaikalia, which suggests they had a similar origin (Gladkochub et al., 2012). The dates (1754-1759 Ma) of the NW dykes from the TA belt coincide with the ages of the SE dyke swarms in the Anabar uplift and the NE Chay swarm in the Baikal uplift. The swarms are proposed to intersect in the lower Vilyui river area where the center of the Timpton plume aged at 1758-1752 Ma was located (Gladkochub et al. 2012; Ernst et al., 2016).

The dykes under consideration were not subjected to metamorphism. According to the Russian Petrographic Code (2008) they belong to basalts (B) and andesite basalts (BA), more rarely to trachybasalts (TB) and andesites (A) (Fig.2).

In terms of mineral and chemical compositions, the dyke rocks are divided into two groups. The first group consists of the rocks of the differentiated dolerite-diorite series, and the second one includes dolerites with transition to trachydolerites. The dolerite-diorite rocks are characterized by a high SiO_2 content (49-59%), the presence of interstitial quartz-feldspar micropegmatite (up to 10%), and by the appearance of hypersthene. This series exhibits significant variation (0.52-0.86) in the fractionation ratio $F = FeO_{tot}/(FeO_{tot}+MgO)$. SiO_2, K_2O, Na_2O, P_2O_5, and TiO_2 increase and CaO decreases with the growing fractionation ratio. That behavior of petrogenic elements suggests the formation of homogeneous dykes in course of multiple injections of tholeiite-basalt melts and their differentiates from deep-seated intermediate magma chambers. The rocks of the second group are marked by a lower SiO_2 content and by higher values of TiO_2 (1.5-3.1%), P_2O_5 (0.2-0.7%), and alkalis, mainly K_2O, thus corresponding to dolerites and subalkaline dolerites. Unlike the rocks of the first group, the subalkaline dolerites exhibit no clear relationship between the distribution of petrogenic elements and the fractionation ratio.

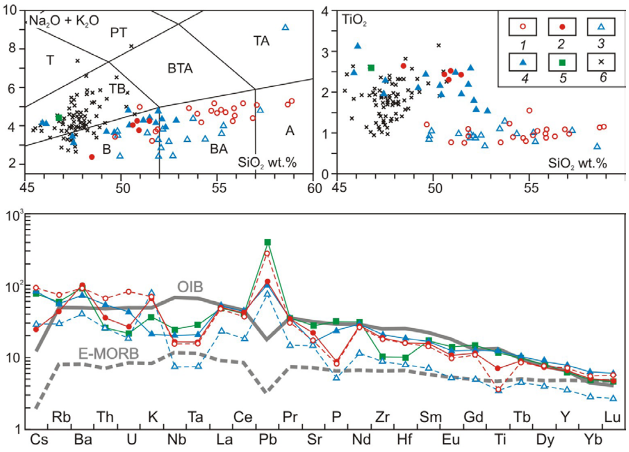

Figure 2. Compositions of Late Precambrian dykes in the Aldan shield

1 – NE dykes, low-Ti; 2 – same, high-Ti; 3 – NW dykes, low-Ti; 4 – same, high-Ti; 5 – dykes of the Uchur-Uyan swarm, high-Ti (Guryanov et al., 2013); 6 – metagabbro- diabases of the Kuranakh Complex (Smelov et al., 2009); spidergram, normalized by primitive mantle (Sun, McDonough, 1989).

In the distribution of elements on a spidergram, the high-Ti mafic dykes are very close to intraplate basalts of oceanic islands, but differ from them by the presence of well-defined negative Th-U and Nb-Ta anomalies and a positive Pb peak. The low-Ti rocks of the differentiated dolerite-diorite series (open symbols connected by dotted lines) are characterized by a lower P_2O_5 content and a deeper Nb-Ta minimum.

The age of metagabbro-diabase dykes and sills of the Kuranakh Complex (1863±9 Ma) in the Lower Khani graben-syncline is identical to that of basic rocks (1867±3 Ma) in the Chiney layered massif (Popov et al, 2012).

Conclusions

The source of magma for the Late Precambrian dyke swarms in the Siberian (North Asian) craton were undepleted intraplate plume-type mafic melts. Magma retardation in deep chambers could have resulted in contamination of the melts by crustal material, and could also be responsible for a dual behavior of Ti during fractionation of various Ti-bearing minerals.

Intrusion of significant volumes of mafic material in the form of plumes leads to the formation of large igneous provinces with mafic-ultramafic complexes that can host high-grade deposits of platinum-group metals (PGM), Ni, Cu, Cr, rare elements, etc. Within the limits of the Aldan-Stanovoy shield there are present numerous Au-Pt placers with various PGM associations for which the bedrock sources are as yet unknown.

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