Geophysical Research Abstracts
Vol. 14, EGU2012-8709-3, 2012
EGU General Assembly 2012

Zircon and baddeleyite from the economic ultramafic-mafic Noril'sk-1 intrusion (Russia): Hf-isotope constraints on source composition

K.N. Malitch (1,2), E.A. Belousova (2), I.Yu. Badanina (1), and W.L. Griffin (2)

(1) Institute of Geology and Geochemistry, the Uralian Branch of Russian Academy of Sciences, Ekaterinburg, Russian Federation (knm_2004a@yahoo.com), (2) The ARC National Key Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC), Macquarie University, Sydney, Australia

The ultramafic-mafic Noril'sk-1 intrusion in the northwestern part of the Siberian Craton (Russia) represents one of three known Noril'sk-type, ore-bearing intrusions, which host one of the world's major economic sulphide platinum-group-element (PGE)-Cu-Ni deposits. Zircon and baddeleyite dated previously both by SHRIMP (i.e. 248.0 ± 3.7 Ma, *Campbell* et al. 1992) and ID-TIMS (251.1 ± 3.6 Ma, *Kamo* et al. 1996) have been restricted to one lithology (e.g. leucogabbro) of the Noril'sk-1 intrusion.

To better constrain the age of igneous event and sources involved in its generation our multi-technique study utilized ten rock samples characteristic of unmineralized and mineralized lithologies. The rocks investigated comprise (from top to bottom) gabbro-diorite (sample N1-1), leucogabbro (N1-3), olivine-free gabbro (N1-2 and N1-4), olivine-bearing gabbro (N1-5), olivine gabbro (N1-6), plagiowehrlite and plagiodunite (N1-7), taxitic-textured rocks comprising melanotroctolite, olivine gabbro with relics of ultramafic rocks (N1-8, N1-9) and contact fine-grained gabbro (N1-10). Sulphide PGE-Cu-Ni ores occur in ultramafic (N1-7) and taxitic-textured rocks (N1-8 and N1-9), which have thickness of about 17 m, whereas the low-sulphide horizon of about 1 m thick occurs in the upper part of intrusion (N1-3).

In situ U-Pb analyses of zircon from these rocks, combined with detailed study of crystal morphology and internal structure, identify four zircon populations (*Malitch et al*. 2012). The U-Pb ages of baddeleyite and the defined zircon populations cover a significant time span, from Late Paleozoic to Early Mesozoic (e.g., 290 ± 2.8; 261.3 ± 1.6; 245.7 ± 1.1; 236.5 ± 1.8 and 226.7 ± 0.9 Ma). The established distribution of U-Pb ages implies that crystallization of baddeleyite and zircon corresponds to several stages of protracted evolution of ultramafic-mafic magmas at deep-seated staging chambers and/or probably characterizes interaction of distinct magmas during formation of the Noril'sk-1 intrusion, which served as the favorable factor for accumulation of ores of unique scales and concentrations,

To test this hypothesis, *in situ* Hf-isotope data were collected on the dated spots within single zircon grains. The analysis used a New Wave LUV213 laser-ablation microprobe attached to a Nu plasma MC-ICP-MS at GEMOC (*Griffin et al*. 2002). Hf-isotope results grouped on the basis of lithology show notable differences. Zircons from the unmineralized 'layered rock sequence' (e.g., olivine-free gabbro, olivine-bearing gabbro and olivine gabbro) are characterized by the most 'radiogenic' initial $^{176}Hf/^{177}Hf$ and some of ε_{Hf} values close to those of the Depleted Mantle. Irrespective of zircon population most radiogenic Hf-isotope compositions are typical for olivine-free gabbro (mean ε_{Hf} 7.3 ± 1.1 for sample N1-4), olivine-bearing gabbro (9.2 ± 3.8, sample N1-5) and olivine gabbro (8.3 ± 2.0, sample N1-6). In contrast, zircons from the leucogabbro that encloses the low-sulphide horizon (N1-3), and plagiowehrlite (N1-7) and taxitic-textured rocks (N1-8 and N1-9) with disseminated sulphide ores have less radiogenic Hf-isotope values (e.g., mean ε_{Hf}6.2 ± 1.4, 5.9 ± 2.3, 6.4 ± 1.2 and 4.9±1.4, respectively). The least radiogenic values ($\varepsilon_{Hf}$from -2.9 to +2.3, mean ε_{Hf} = 0.1 ± 1.9) are recorded in gabbro-diorite from the upper part of intrusion. The baddeleyite from olivine-free gabbro has the narrowest range of ε_{Hf} values (e.g. 6.8-8.4), with a mean of $\varepsilon_{Hf}$of 7.6 ± 0.8, closely matching that of zircon (mean ε_{Hf}= 7.3 ± 1.1).

Zircons from the leucogabbro that hosts the low-sulphide horizon (N1-3), and ultramafic and taxitic-textured lithologies with disseminated sulphide ores (N1-7, N1-8 and N1-9) have less radiogenic ε_{Hf} values than those in barren lithologies. The Hf-isotope data for zircons from ore-bearing rocks thus suggest that the Noril'sk magmas represent mixing between a juvenile source equivalent to the Depleted Mantle and a subcontinental lithospheric source probably at least Neoproterozoic in age. We propose that the SCLM component is especially prominent in the mineralized portions of the intrusion. This is consistent with the suggestion of *Zhang* et al (2008) that ancient cratonic lithospheric mantle may have contributed significantly to the PGE and Ni budget of the "fertile" Siberian Large Igneous Province. Small population of zircons from the gabbro-diorite show the least 'radiogenic' Hf-isotope

values, indicating the input of a distinctly older lithospheric, possibly crustal, component, being consistent with a hybrid nature of this lithology.

Our approach for deciphering the origin of zircon and baddeleyite from mafic and ultramafic rocks provides a unique set of U-Pb and Hf-isotope constraints on temporal evolution and petrologic history of the Noril'sk-1 intrusion. The study was supported by Uralian Branch of Russian Academy of Sciences (12-U-5-1038).

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