Blatchford Lake intrusive suite, new geochronology and barometric estimates: implications for mineralization

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Introduction

The Paleoproterozoic Blatchford Lake intrusive suite, can be subdivided into two cogenetic separate lobes: a metaluminous western lobe and a peralkaline eastern lobe which is host to the world class Nechalacho rare metal deposit. The western lobe consists of a multi-phase layered gabbroic sequence, cross-cut by a series of sills varying from syenite to granite. The eastern lobe comprises a large sub-circular granite that grades to a syenite core. Underlying the syenite core is a layered suite of silica-undersaturated rocks collectively known as the Nechalacho layered syenite series (NLSS). Rare metal mineralization occurs in the upper units of the NLSS, which have been overprinted by intense hydrothermal alteration. Approximately two kilometers east of the Nechalacho mineralized zone, two small plutonic stocks, believed to be related to the regional Compton Intrusive suite [2], cross-cut the peralkaline granite.

In situ U-Pb zircon laser ablation ion-coupled plasma mass spectrometry (LA-ICP-MS) was used to date the Compton Intrusives stocks (1895±5 Ma) and to provide the first reliable age estimate for the NLSS (2187±8 Ma). These new dates help define relationships between phases in the eastern lobe, and resolve discrepencies in the chronology of the Blatchford Lake intrusive suite.

Using the Al-in-hornblende barometer [1], pressure estimates were made on hornblende and edenite crystals from granitic and syenitic phases of the western lobe. These result indicate a mid-crustal emplacement (~3.5 kbar) for the late cross-cutting granite and syenite sills. Given that the ages between the eastern and western lobes are within analytical error, these pressure estimates can be used to infer the pressure conditions during crystallization of phases within the eastern lobe.

This new geohronological and barometric information helps to constrain the overall evolution of the Blatchford Lake intrusive suite, and therby aids in developing models to explain the exceptional enrichment in rare-metals in select phases.

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PGE systematics of refractory mantle: role of Pt alloy

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Pt/Pd variability in the mantle and picrites

The primitive mantle has slightly sub-chondritic Pt/Pd values close to 1.1 [1]. Extreme degrees of melt depletion, as recorded by decreases in CaO, Al_2O_3, and increases in Mg/(Mg + Fe) in whole rock or olivine, confer a distinctively high Pt/Pd ratio to the mantle restite, ranging from 5 to 10 in some massif peridotites to as high as > 100 in ultradepleted mantle xenoliths from the Kaapvaal craton [2,3]. A complementary reduction in Pt/Pd to values similar to unity is observed in a global compilation of data for picrites, which evolve to still lower Pt/Pd approaching 0.1 by fractional crystallization in the absence of sulfides [4]. We present data for primitive boninites from Chichi Jima and the northern Tonga arc, which equilibrated with $Fo_{>90}$ olivine and show extremely low Pt/Pd with values ranging from 0.1 to 0.5, while also showing strong depletions in Ir and Ru compared to Rh that we have previously attributed to the existence of Ir-Ru alloy or laurite in the restite [5].

Partition coefficients and models

Bulk partition coefficients D^*_{Pt} and D^*_{Pd} estimated from studies of fractionated lava lakes are approximately 0.2 - 0.6 and 0.1 - 0.2 [6]. Experimental determinations of D_{Pt} and D_{Pd} for olivine are < 0.01 and 0.006 at the FMQ oxygen buffer [7]; values for pyroxenes are similar and, even in chromite they are <0.03 [8].

The existence of Pt/Pd fractionations spanning two to three orders of magnitude between parental picritic magmas and their mantle residues positively requires the existence of a restite phase with dramatically higher D_{Pt} than D_{Pd}. Alloys of Os-Ru-Pt have been observed in mantle peridotite [9,10], and consideration of Os solubility in sulfide liquid and bulk Os concentration in the mantle requires the existence of Os alloy even in the presence of sulfide melt in the mantle [11]. Our models show that the range of Pt/Pd observed in peridotite massifs, mantle xenoliths, boninites, and tholeiitic picrites is consistent with the ubiquitous occurrence of alloy-hosted Pt in amounts ranging from 2 to 7 ppb, whereas Pd appears to be hosted only by sulfide phases, becoming extremely incompatible once sulfide has been consumed during partial melting.

The Bushveld complex of SA, with Pt/Pd between 1.5 and 5, is a unique exception [12]. An unusual process may have destabilized Pt alloy in the highly refractory SCLM of the Kaapvaal craton during emplacement of the Bushveld.

References

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