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Top down formation of the Sonju Lake intrusion (Duluth Complex USA) with implications for formation of PGE reef deposits

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Platinum Group Element (PGE) "reefs," found within layered mafic intrusions (LMIs), provide the most important source of Pt worldwide. Layered mafic intrusions provide the textbook example of magma differentiation. The current paradigms of formation of both assume that differentiation occurs by gravitational crystal settling. While there is little doubt both follow predictions of mineral-melt equilibrium, calling upon mechanical separation process remains an interpretation.

We will present a variety of works concerning the Sonju Lake Intrusion (SLI), a 1200 m thick layered mafic intrusion, within the Duluth Complex. The SLI has the Finland Granophyre (FG), an equal volume silicic intrusion of identical age that directly overlies it, providing a puzzle to standard models of igneous differentiation. Mineral modes, compositions and even incompatible trace element ratios show smooth gradation between the two bodies as if the two intrusions were genetically related. Yet, differences in Sr and Pb isotope ratios and simple volume relationships argue against any fractional crystallization-like process linking the intrusions. Lundstrom et al. [1] provided an alternative model showing that SLI modes and compositional trends could be reproduced by a top down sill emplacement process involving injection of uniform composition basalt where differentiation occurs by temperature gradient based diffusion-reaction process above each emplaced sill. Lundstrom and Gajos [2] present experiments showing that sulphides are mobile and form at a discrete isotherms in thermal gradient experiments; they then provide a model showing that the observed PGE-rich horizon in the SLI can form by the same top down sill emplacement process. Testable predictions to the top down hypothesis include non-traditional stable isotope ratios and geochronology.

New non-traditional isotope ratio data (δ^{56}Fe, δ^{26}Mg, δ^{30}Si) for 40+ samples from the SLI and FG show systematic variations. Heavier δ^{56}Fe occurs as the top of the SLI is approached and light δ^{56}Fe occurs at the bottom contact of the SLI—both observations are consistent with the prediction of the thermal gradients occurring during the top down sill emplacement process. Little variation in δ^{26}Mg and δ^{30}Si are observed in the SLI, consistent with lack of SiO_2 enrichment. Notably, two diorite-to-leucogranite differentiation sequences occur in sills forming the FG and these show spectacular positive covariations of δ^{30}Si and δ^{56}Fe, consistent with thermal gradient effects [3]. In terms of geochronology, we dated 3 rocks by mineral isochron analysis using both Lu-Hf and Rb-Sr methods. Not surprisingly major minerals (PL, CPX) produced scatter isochrons for both systems. However, the apatite gabbro in the upper SLI produces an excellent 2 apatite – WR isochron with low MSWD of age =1088 +/- 1 Myrs. This is 8 Myrs younger than the same rock previously dated at 1096 Ga ([4] by badelyite U-Pb). The age discrepancy is unlikely to reflect issues with either analysis. Instead, we interpret the younger apatite age to reflect the slow top down formation of the SLI with the 1088 age representing the shutting off of ascending reactive fluids which reset apatite ages.

References:

[1] Lundstrom CC et al. (2011) Intl Geol Rev 53: 377-405
[2] Lundstrom CC and Gajos N (2014) Econ Geol 109: 1257-1269
[3] Zambardi T et al. (2014) Earth Planet. Sci Lett. 405, 169-179
[4] Paces J and Miller J (1993) J. Geophys Res. 98, 13997-14013