# The roles of fluid in the genesis and modification of reef-type PGE deposits in large layered intrusions

CHUSI LI AND EDWARD M. RIPLEY

Department of Geological Sciences, Indiana University, Bloomington, IN 47405 (cli@indiana.edu, ripley@indiana.edu)

Several hypotheses have been proposed for the origin of reef-type PGE deposits in large layered intrusions. These include: (1) alloy or immiscible sulfide liquid segregation from magma and (2) concentration by magmatic fluid. Our results of textural, mineralogic and isotopic studies indicate that fluids played important roles in the genesis and modification of the reef-type PGE deposits.

The Merensky Reef of the Bushveld Complex is a good example where magmatic fluid played a major role in the development of the reef. Abundant composite mineral inclusions are found in many chromite crystals in the basal chromite seam of the reef. Phlogopite and orthopyroxene are most abundant in the inclusions. The average compositions of the inclusions are characterized by higher MgO, $Na_2O$ and $H_2O$, and lower CaO and FeO than the parental magma of the Merensky Reef. The chemical compositions of the inclusions are consistent with melts formed by hydration melting of orthopyroxene cumulate on the floor of the chamber in response to addition of fluid. Sulfide saturation in the Merensky Reef may have been induced by addition of S from the fluid.

In the J-M reef of the Stillwater Complex, replacement of braggite by the mixture of Pt alloy and base metal sulfides is found in unaltered ore samples from the Stillwater Mine. This is direct evidence for desulfurization of Pt-Pd sulfides by S-undersaturated magmatic fluid.

In the PGE-rich Main Sulfide Zone of the Great Dyke the base metal sulfides are variably replaced by actinolite, epidote and carbonates. PGM mostly occur within base metal sulfides, and to a much less extent in their replacement aureoles.

Our observations suggest that primary concentration of PGE in the reefs resulted from fluid-induced sulfide saturation and segregation whereas decoupling of PGE at sample scale was due to subsequent hydrothermal modification.

# Re/Os isotopic and fluid inclusion studies of fluid-rock interaction in the contact aureole of the Duluth Complex, Minnesota

EDWARD M. RIPLEY

Department of Geological Sciences, Indiana University, Bloomington IN 47405, USA (ripley@indiana.edu)

Re/Os isotopic data from igneous rocks and massive sulfides from the Duluth Complex of Minnesota, along with sulfide-bearing Proterozoic (~1.85 Ga) country rocks of the Virginia Formation, indicate a complex history of assimilation and fluid-rock interaction. Sulfide-free troctolites plot along a chondritic 1.1 Ga reference isochron, and show little or no geochemical evidence for contamination by country rocks. Troctolites with disseminated sulfides and massive sulfides are variably anomalous with $\gamma_{Os}$ (1.1 Ga) values from 3 to 1200.

Sulfide separates from metasedimentary country rocks located outside of the contact aureole have Os isotopic values that are distinct from whole rock and kerogen values. The shale/siltstone is only slightly recrystallized, yet Re/Os isotopic values of sedimentary sulfide minerals indicate mixing at the time of emplacement of the Duluth Complex, and plot along a 1.1 Ga chondritic reference isochron. Quartz veins and stringers occur along pyrite beds in the sedimentary country rocks, and contain up to 15% of pyrrhotite, and lesser amounts of chalcopyrite, cubanite, bornite, pentlandite, and sphalerite. This assemblage is very similar to that found in the magmatic sulfide mineralization of the Duluth Complex. Fluid inclusions found in the quartz veins homogenize at ~300° to 380°C, and with a minimum P correction suggest that a fluid of ~500°C reached the outer margins of the contact aureole along microfractures. Although the initial water content of the Duluth Complex magma is not considered to have been anomalous, water saturation would have been achieved in the melt interstial to primocrystic olivine and plagioclase. The Re/Os isotopic characteristics of sedimentary sulfides in the country rocks are consistent with exchange and mixing between minerals and a Re-rich magmatic fluid characterized by a chondritic $^{187}Os/^{188}Os$ ratio. This fluid appears to have been derived from uncontaminated mafic magma, rather than the contaminated magma that produced sulfide-bearing troctolites.