Magmatic-hydrothermal fractionation of Fe-Ni-Cu-PGE mineralization in the Sudbury Igneous Complex

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The ores in the Sudbury Igneous Complex occur at or near the basal contact (contact ores), within nearby footwall rocks (FW ores), and within quartz diorite dikes (offset ores). All are fractionated to some degree and provide important empirical constraints on metal partitioning in magmatic and magmatic-hydrothermal Ni-Cu-PGE systems. Footwall ores are strongly fractionated relative to massive-disseminated contact ores, grading with increasing distance and decreasing S content from Type 1 sharp-walled magmatic chalcopyrite-pentlandite-pyrrhotite veins through Type 2 magmatic-hydrothermal bornite-millerite-chalcopyrite-pentlandite stockworks to Type 3 magmatic-hydrothermal PPGE-rich disseminations, although progressive thermomechanical erosion of the footwall has resulted in some overprinting of these zones. The large masses and high Cu contents of Type 1 veins preclude an origin by equilibrium or fractional crystallization of MSS in contact ores, but are consistent with a zone-refining process involving remelting of fractionated sulfides during progressive thermomechanical erosion of the footwall rocks and previously-emplaced contact and footwall ores. Systematic depletions in Rh and Ir suggest that Type 2 stockworks formed via a magmatic-hydrothermal process. Type 3 disseminations are enriched in Pd-Pt+/-Au relative to Cu, suggesting deposition from a lower-T magmatic-hydrothermal fluid. The preferential association of footwall ores with pseudotachylite breccias within several hundred metres of the SIC footwall contact suggests that they were more susceptible to fracturing and infiltration of sulfide melts and magmatic-hydrothermal fluids. Disseminated and semi-massive ores in quartz diorite "offset" dikes are less fractionationated, grading outward from internal Ag-Pb-Au-Cu-poor mineralization to peripheral Ag-Pb-Au-Cu-Pt-Pd-rich mineralization. The concentric zonation suggests that evolved sulfide melts invaded partially-crystallized quartz diorite via a capillary infiltration mechanism. Unlike most other deposits of this type, the magmatic sulfide melts at Sudbury crystallized over the same temperature interval as the quartz diotitic silicate magma, facilitating segregation of fractionated sulfide melt from MSS.

X-ray microtomography under extreme conditions

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It is now possible to perform X-ray microtomography at high pressure and temperature on mm^3 samples with a spatial resolution of a few microns. The rotating anvil apparatus (RRA) on the 13-BM-D beamline at the Advanced Photon Source (Argonne National Lab) is compressed by a 250-ton hydraulic press between concentric thrust bearings. Both toroidal and truncated cylindrical (Drickamer) anvils have been tested and perform well up to 11 GPa and 1873K using boron epoxy for the gasket medium, and X-ray transparent aluminum or polytherimide plastic as the containment ring for the Drickamer anvils. The RRA permits coupled rotation of anvils for acquisition of tomographic data, while differential rotation allows for controlled sample deformation. Several types of investigations are possible with the RRA related to minerals, glasses and melts. The volumetric properties of silicate glasses and supercooled liquids can be characterized by measuring volume changes directly as a function of T and P, and a new high temperature cell is being tested for molten sample contained within a diamond capsule. Since the tomographic reconstruction is fundamentally a 3-D map of the linear attenuation coefficient, i.e. the product of the sample's density and mass absorption coefficient, sample density can be readily recovered under experimental conditions. The utility of the latter approach is demonstrated by *in situ* calibration of the linear attenuation coefficients for crystalline materials (BN, qtz, halite, wo, rutile, pyrite, NiS, and Fe metal) and its accuracy shown by the recovery of density of basaltic glass (USGS std BCR-2) to better than 1%. The utility of the RRA to characterize microstructural evolution is illustrated by experiments in which FeS(melt)-impregnated-dunite is deformed in the ductile regime at 6 GPa and 700K.