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Contact metamorphism, partial melting and fluid flow in the granitic footwall of the South Kawishiwi Intrusion, Duluth Complex, USA

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The footwall of the South Kawishiwi Intrusion (SKI) a part of the Mesoproterozoic (1.1 Ga) Duluth Complex consists of Archean granite-gneiss, diorite, granodiorite (Giant Range Batholith), thin condensed sequences of Paleoproterozoic shale (Virginia Fm.), as well as banded iron formation (Biwabik Iron Fm).
Detailed (re)logging and petrographic analysis of granitic footwall rocks in the NM-57 drillhole from the Dunka Pit area has been performed to understand metamorphic processes, partial melting, deformation and geochemical characteristics of de-volatilization or influx of fluids.
In the studied drillhole the footwall consists of foliated metagranite that is intersected by mafic (dioritic) dykes of older age than the SKI. In the proximal contact zones, in the mafic dykes, the orthopyroxene+clinopyroxene+plagioclase+quartz+Fe-Ti-oxide+hornblende±biotite porphyroblasts embedded in a plagioclase+K-feldspar+orthopyroxene+apatite matrix indicate pyroxene-hornfels facies conditions. Migmatitization is revealed by the euhedral crystal faces of plagioclase and pyroxene against anhedral quartz crystals in the in-situ leucosome and by the presence of abundant in-source plagioclase±biotite leucosome veinlets.
Amphibole in the melanosome of mafic dykes was formed with breakdown of biotite and implies addition of H_2O to the system during partial melting. Towards the deeper zones, the partially melted metatexite-granite can be characterized by K-feldspar+plagioclase+quartz+ortho/clinopyroxene+biotite+Fe-Ti-oxide+apatite mineral assemblage.
The felsic veins with either pegmatitic or aplititic textures display sharp contact both to the granite and the mafic veins. They are characterized by K-feldspar+quartz±plagioclase±muscovite mineral assemblage. Sporadic occurrence of muscovite suggest local fluid saturated conditions.
Emplacement of gabbroic rocks of the SKI generated intense shear in some zones of the granitic footwall resulting in formation of biotite-rich mylonites with lepidoblastic texture. High modal content of syn-tectonic biotite in these shear zones indicate involvement of large amount of fluids during deformation.
Apatite is an omnipresent accessory mineral in all rock types, with up to 1-3% modal proportion. Crystal habit is columnar or rarely needle-like. XCl/XF and XOH/XF ratios of apatite were compared with depth in the drillhole and in relation to the host rock type. Apatite in the metagranite and in the mafic dyke is fluorine-rich (XFgranite≈1,27-1,63; XFmafic dyke≈1,51-1,83) and their XCl/XFgranite≈0,083 to 0,051 and XCl/XFmafic dyke≈0,051 to 0,044 ratios decrease towards the distal parts of the contact. Apatite in biotite-rich mylonite, as well as in the porphyroblasts of mafic dykes, is extremely depleted in chlorine- and hydroxyl-anions (XCl/XFmylonite≈0,02 and XOH/XFmylonite≈0,14), whereas apatite in felsic dykes and in the in-source leucosome are enriched in hydroxyl and chlorine relative to fluorine (XCl/XFfelsic vein≈0,21 and XOH/XFfelsic vein≈0,37). These variations suggest release of chlorine enriched fluids from the partially melted contact zones and movement and enrichments of these fluids in migration channels of partial melts.
It has been for a long time accepted that fluids emerging from the metamorphosed Virginia Formation played an essential role in the formation of the Cu-Ni sulphide and PGE mineralization at the bottom of the gabbroic intrusions in the northwestern marginal zones of the Duluth Complex. Our study proves that the granitic footwall was also an important source of fluids and melts.

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