Magmatic Ni-Cu-PGE sulphides in the Labrador Trough, Canada

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Overview

My PhD project aimed to better constrain the formation of magmatic Cu-Ni-(PGE) and PGE-Cu sulphide deposits in the Labrador Trough, northeast Canada. I am applying a holistic and multi-scale approach to identify the processes that are favourable and detrimental to ore-forming processes in the region. This project is in collaboration with Northern Shield Resources.

The Labrador Trough in northern Quebec, Canada, is a site of ongoing exploration for magmatic sulphide deposits. The region is considered prospective for magmatic sulphide ores, since it is host to voluminous mafic-ultramafic rocks that occur in proximity to trans-crustal faults and sulphidic supracrustal rocks. The location, tectonic structure, and major mineral occurrences of the Labrador Trough are shown in Figure 1.

Fig. 1. The Labrador Trough

The Idefix PGE-Cu prospect

The Idefix PGE-Cu prospect (Figure 2) represents a ca. 400-m-thick stack of aphyric mesogabbroic sills that host stratiform disseminated sulphides (0.2 to 0.4 g/t Pt+Pd+Au) over a thickness of ca. 20 m, for up to km. In addition, globular sulphides occur at the base of the sill, adjacent to metasedimentary floor rocks. Whole-rock lithophile and chalcophile element geochemistry indicates that the sills share a common source and that the magma(s) underwent significant fractionation before emplacement in the upper crust. To develop PGE-enriched sulphides, sulphide melt saturation was attained before the final emplacement of the host magma, peaking at R factors at or greater than 10,000. The globular sulphides were entrained along the base of the sill, where they ingested crustally-derived arsenic and sulphur.

Fig. 2. The Idefix prospect

This occurrence highlights the challenges explorationists face in determining way-up of aphyric mesogabbro sills. Where whole-rock and mineral geochemistry prove ineffective (since mafic-ultramafic sills have the tendency to display what is known as geochemical reversals), geologists must search for way-up structures, perhaps located in the supracrustal country rock. In a 2020 publication, we propose several scenarios (Figure 3) for the formation of the Idefix PGE-Cu prospect and outline the implications this has for regional prospectivity.

Fig. 3. Petrogenetic models for the Idefix sill stack and its sulphides

The Huckleberry Cu-Ni-PGE prospect

The Huckleberry PGE-Cu prospect (Figure 4) represents a 200-m-thick stack of glomeroporphyritic gabbro sills intruded in their centre by a 200-m-thick gabbro-peridotite sill. In addition, several 30-m-thick olivine cumulate protrusions occur in the glomeroporphyritic gabbro footwall to the gabbro-peridotite sill. Globular sulphides occur at the base of the sill complex, and return peak grades of 0.36% Cu, 0.1% Ni, and 0.06 g/t Pt+Pd+Au over around 4 m. Net-textured sulphides occur in the peritotitic base of the gabbro-peridotite sill, within the glomeroporphyritic gabbro footwall, and within footwall olivine cumulate sills in the footwall. Grades between the three disseminated to net-textured occurrences vary only slightly, returning 0.12-0.36% Cu, 0.09-0.2% Ni, and 0.14-0.41 g/t Pd+Pd+Au.

Fig. 4. The Huckleberry Cu-Ni-(PGE) prospect

It is proposed that the glomerocrysts represent remobilised mush dislodged from a flotation cumulate in a staging chamber during episodic expulsion of magma. Whole-rock geochemistry and mineral compositions of the gabbro-peridotite and footwall olivine cumulate sills suggest that they share a common source and that they underwent minor degrees of pre-emplacement fractionation. Chalcophile element geochemistry suggests that the parent magma attained sulphide saturation prior to its final emplacement at relatively low R factors (1,000-5,000). It is proposed that fractionated sulphide melt was entrained during emplacement of the gabbro-peridotite sill, which split the antecedent glomeroporphyritic gabbro sill into two. Sulphide melt percolated downward through the peridotitic cumulate pile and extended downward into the glomeroporphyritic gabbro footwall. The footwall olivine cumulate sills may represent downward injections of olivine and sulphide melt from the overlying gabbro-peridotite sill along contacts between individual glomeroporphyritic gabbro sills intersected by erosional troughs formed during the emplacement of the gabbro-peridotite sill (Figure 5). Further detail on the Huckleberry prospect can be found in a 2021 publication.

Fig. 5. Petrogenetic model for the Huckleberry sill stack and its sulphides

Distribution of noble metals in the Montagnais Sill Complex

The distribution of noble metals in six magmatic sulphide environments of the Labrador Trough in northern Quebec have been characterised using optical and electron microscopy combined with LA-ICP-MS trace element analysis of sulphides (Figure 6). The principle sulphides include pyrrhotite, chalcopyrite, and pentlandite with accessory sphalerite and sulpharsenides. In addition, cubanite, troilite, and mackinawite are present in ultramafic-hosted assemblages. The precious metal mineral assemblages are dominated by tellurides, electrum, and sperrylite which generally occur at sulphide margins. Few IPGE- and Rh-bearing grains were identified and mass balance calculations show that most of these elements are hosted in pyrrhotite and pentlandite. Virtually all Pt and Au are hosted in precious metal grains, whereas Pd is distributed between precious metal grains and pentlandite. Where present, sulpharsenides are a key host of IPGE, Rh, Pd, Te, and Au. The presence of troilite, cubanite, and mackinawite and the absence of pentlandite exsolution lamellae in the ultramafic-hosted sulfides indicates an initial sulphide melt with a high metal/S ratio. Sulpharsenides present among globular sulphide assemblages derive from an immiscible As-rich melt that exsolved from the sulphide melt in response to the assimilation of the As-bearing floor-rocks. In this study, the composition of sulphides is consistent with those derived from Ni-Cu-dominated deposits and not PGE-dominated deposits. Further detail on this subject can be found in a forthcoming publication.

Fig. 6. Evolution of sulphide melt in magmatic sulphide occurrences of the Montagnais Sill Complex

The S/Se and S isotope composition of sulphide occurrences in the Labrador Trough

The interaction between mafic-ultramafic magma and crustal sulphide is considered a key process in the formation of magmatic Ni-Cu-platinum group element sulphide deposits. Integrated S/Se and multiple sulphur isotope studies are the most robust in constraining the role of crustal sulphur during ore genesis. In the present study, we report the first integrated S/Se and multiple sulphur isotope study of magmatic sulphide occurrences in the Labrador Trough, namely on the recently discovered Idefix PGE-Cu and Huckleberry Cu-Ni-(PGE) prospects.

Whole-rock and in situ S/Se values (ca. 810-3115) of magmatic sulphides and their host rocks are consistent with S loss during post-magmatic hydrothermal alteration, negating their use in interpreting the origin of S. Values of 33S 0 indicate no record of the assimilation of Archaean sulphur. Disseminated (-0.5 to 2.5???) and globular (3.0-4.5???) sulphides at Idefix as well as globular sulphides (2.1-9.6???) at Huckleberry have 34S values greater than the accepted mantle range, suggesting that crustal S has played a role in the formation of these sulphides. In contrast, disseminated and net-textured sulphides at Huckleberry have variable 34S values (-4.6 to 3.2???) that are mostly within the accepted mantle range, excluding one anomalous sample that records relatively higher 34S values (11.9-15.0???). It is proposed that sulphide melt segregated in response to the addition of small proportions of crustal S prior to the final emplacement of the host intrusions, i.e., in a feeder conduit or staging chamber. Isotopic exchange between the sulphide melt and silicate magma has diluted and in places eradicated a crustal 34S signature.

Fig. 7. Multiple sulphur isotope compositions of magmatic sulphides in the Montagnais Sill Complex

Accessory phase perspectives on ore-forming processes in the Labrador Trough

Coming soon

Fig. 8. The composition of apatite and Fe-Ti oxides in magmatic sulphide occurrences of the Montagnais Sill Complex