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Preface – Special Issue: New frontiers in research on NiS–PGE mineralization: introduction and overview

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Introduction

Despite highly distinctive physical and chemical characteristics, world-class NiS–PGE deposits remain very difficult to find. The paucity of recent major discoveries means that the conventional models for magmatic ore genesis have come under scrutiny. Arguably, research in the previous 20 years has been too focused in scale and limited in approach. Ore deposit-scale research is of value in mine and district-scale exploration, but its relevance to terrane-scale area selection for mineral exploration remains tenuous. Although the understanding of global geodynamics, tectonics, deformation mechanisms and relationship of structural controls to magma flow and magmatic mineralization continues to progress, effective application of these advances in mineral exploration lags behind igneous petrology. Selecting the area of the next world-class discovery requires knowledge of how NiS–PGE ore deposits fit into a terrane-scale or even a crustal-scale context.

In an effort to present and discuss new ideas on the genesis of magmatic NiS–PGE deposits, a workshop entitled "*New Frontiers in Research on Magmatic NiS–PGE Mineralization*", was convened at the University of Western Australia, in Perth. Sponsors of the workshop were the Minerals Council of Australia and the Centre for Global Metallogeny and it was run as part of the National MSc-by-Coursework Program. The industry setting of Perth was an ideal locale to attract participants, attendees and students from industry, university and government organizations of Western Australia, Australia and overseas. Thirty-nine oral presentations and four poster presentations were made, many by world experts, over five days in February 2003. Archean and post-Archean NiS deposits and PGE deposits in Australia, North America, Asia and Africa were covered.

Some participants kindly agreed to contribute the papers that constitute this Special Issue and others generously acted as Journal reviewers. The papers are arranged in order of scale, from mantle plumes and magmatic ore deposits through

the world-class NiS districts at Sudbury and in Western Australia to the role of chromite crystallization in PGE distribution. In the first paper, *Pirajno* considers the role of mantle plumes in the genesis of magmatic ore deposits. The author examines relationships between the tectonic and magmatic manifestations of mantle plume activity and NiS–PGE ore genesis. The ascent of mantle plumes produces crustal uplift, rifting, subsidence and voluminous high-MgO magmatism. The magmas ascend along rift structures, intrude and assimilate country rocks, and form ore deposits via magmatic segregation processes. A result is large igneous provinces (LIPs) that host NiS–PGE ore deposits formed in magma conduits. The magmatic deposits are Ni–Cu (PGE) in flood basalt provinces (Noril'sk), Cu–Ni–Co deposits in troctolite-anorthosites (Voisey's Bay), Cr–PGE–V–Ti–Ni–Cu ores in layered basic-ultrabasic intrusions (Bushveld), and other examples. Interestingly, the Sudbury Igneous Complex is considered to be a product of mantle plume activity induced by meteoric impact.

Moving to the district scale, *Keays* and *Lightfoot* offer important new constraints on the relationship of Cu–Ni–PGE–S metals and the various magma reservoirs of the Sudbury Igneous Complex (SIC). They employ PGE data to address the outstanding mass balance problem of metals in the sulfide ores of the SIC and conclude that the melt sheet of crustal rocks could have provided all the metals for the sulphide ores. The authors employ theoretical analysis and numerical modeling to demonstrate that a single sulphide saturation event explains the Ni and Cu variations in the SIC, but not the PGE variations. Their model invokes multi-stage sulphide saturation and ''insufficient'' separation of immiscible sulphide liquids from magma during the evolution of the impact melt sheet. Accordingly, the ($>$100 km in diameter and $<$5 km thick) melt sheet failed to convectively homogenize laterally, such that heterogeneity in magmatic sulphide distribution was retained on cooling.

Barnes et al. address the interesting problem of the significance of rock alteration in lithogeochemical exploration for NiS deposits in Archean terranes, based on a review of $>$5000 published whole-rock analyses of komatiites. One of the challenges in NiS research is to extract value from lithogeochemical data for Archean komatiites. The most serious problem is identifying primary igneous controls in komatiites overprinted by alteration mineral assemblages and weathering products. The process of serpentinisation through talc-carbonate alteration can influence the contents of the compatible elements Ni, Co, Mg, Fe, Cr, Cu and Zn and the incompatible REE, LILE and HFSE. This is an important problem, because the channel facies of komatiite flows control sulphide deposition and localize structural modification and talc-carbonate alteration. The authors make a comprehensive effort to identify primary geochemical variations linked to sulphide saturation history and NiS–PGE mineralization.

Stone et al. investigate the role of secondary overprint processes on Ni tenor (content of Ni in 100 wt% sulphide) variation in the Kambalda ore field, Western Australia. Conventional ore genesis models appeal to primary magmatic processes. The deposits such as those at Kambalda have, however, important features in discord with this model. Observations on a wide range of scales are synthesized into a final model. The authors emphasize the role of metamorphic modification and its relation to the release of oxidizing fluids and talc-carbonate alteration, and

considers implications for exploration in tectono-metamorphic terrains. The authors also postulate that the NiS deposits could represent metal reservoirs for gold hydrothermal systems, which bears on strategies for gold exploration in Archean terrains.

Moving to the deposit scale, *Seat* et al. provide new information on the Ni tenor variation in the komatiite-associated NiS deposit at Wannaway Mine, Widgiemooltha Dome, WA. The authors extend the knowledge of the nature and origin of this variation to a higher strain and higher metamorphic-grade setting than previously documented for Kambalda. Several possible models are examined to explain the two-fold variation in Ni-tenor, which is reflected in the relative abundance of pentlandite and pyrrhotite. Their model invokes subsolidus deformation-related, differential remobilization of the sulphides. In other words, pentlandite appears to be less mobile than pyrrhotite when deformed. This finding has important implications for NiS exploration and mining in tectono-metamorphic terranes.

In the final paper, *Fiorentini* et al. investigate the role of primary magmatic phases in the fractionation and concentration of PGE in Archean magmas. The authors address the long-standing problem of the stability of PGE-bearing alloys in Archean komatiitic, tholeiitic and ferropicritic magmas through in-situ measurement of PGE contents by laser ablation ICP-MS of chromites from NiS mineralized and unmineralized Archean units in Western Australia and Ontario. The results constrain the relative roles of sulphur supersaturation and melt oxidation state on PGE distribution.

Collectively, these papers confirm that integration of all available datasets is required to advance the understanding of the controls on the localization of NiS–PGE mineralization. Igneous petrology will remain a leading area of the research. Indeed, conventional models of magma chambers as bodies of near-liquidus material are being superceded by more recent ones in which the chamber consists mainly of crystal-liquid mush subject to mobilization and re-intrusion. Melt percolative flow and sub-liquidus reaction in this mush and fluid-rock reaction in the subsolidus may compliment liquidus and crustal contamination processes in driving NiS–PGE mineralization. Continued petrological advances need to be integrated with research in global geodynamics and high-MgO magmatism, magma dynamics, magmatic volatiles, and tectono-metamorphic overprints, including deformation mechanisms. For more effective mineral exploration, the results of such integrated multi-disciplinary research need to fit into a strategy of utilizing the mineral systems approach across a range of scales relevant to different exploration priorities, from terrane-scale area selection through district-scale prospectivity to deposit-scale studies.

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