PART 2

ORE-FORMING PROCESSES IN DYNAMIC MAGMATIC SYSTEMS

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Ore-Forming Processes in Dynamic Magmatic Systems — IUGS UNESCO IGCP 427 — Minéralisations dans les systèmes dynamiques magmatiques

PREFACE

This part of the thematic issue focusses largely on a selection of the papers presented at a field conference of International Geological Correlation Program 427, which was held in Rouyn–Noranda in July 1999. The abstracts for the meeting are available at http://dsaing.uqac.uquebec.ca/~sjbarnes/rouyn-99. The theme of IGCP 427 is "Ore-Forming Processes in Dynamic Magmatic Systems". Although there is a vast literature on the general geology and composition of magmatic ore deposits, relatively little has been published on the mechanics of how the deposits form. Project 427 is designed to fill this gap.

Sulfides rich in Ni, Cu and the platinum-group elements (PGE) are found at the base of komatiitic and picritic flows from around the world. These sulfides formed in one of the most dynamic settings of all magmatic ore deposits. Rouyn–Noranda is surrounded by outcrops of classic komatiite flows, and these have direct relevance to the Ni-sulfide deposits associated with basaltic komatiites in the Raglan camp of northern Quebec. This association made it a natural venue for the field conference, with field trips to both the Abitibi and the Raglan camp (Davis 2000, Lesher 2000).

A classic problem in forming a Ni–Cu–PGE deposit bears on the mechanism of sulfide saturation in a silicate magma and of formation of an immiscible sulfide liquid that concentrates the metals. It is frequently suggested that the S is introduced into the magma from sedimentary units of the underlying country rock. The papers by Lesher & Burnham, Barnes *et al.* and Lahaye *et al.* all present geochemical evidence that sulfide-bearing komatiites were contaminated by sedimentary material, but the mechanism of how the sedimentary S is absorbed is not clearly understood. The papers by Rice & Moore, Cas & Beresford and Beresford & Cas all suggest that thermal erosion of the sediments by the lavas is unlikely to occur. These authors suggest that the sedimentary component could be introduced by physical erosion. In contrast, Baker *et al.* and Barnes *et al.* investigate an alternative model for introducing S into the magma, and possibly other volatile elements as well: pyrite in the sediments is converted to pyrrhotite, and S is released as a volatile phase from the sediments into the overlying magma.

Regardless of how the S is introduced into the magma, published equations for modeling the geochemistry of the process are inadequate because they only consider two-component systems; a sulfide liquid and silicate magma. Lesher & Burnham present new equations, which deal with more complex scenarios.

In order for the sulfide liquid be rich in metals, it must interact with a large of volume of silicate magma. This may be achieved in dynamic environments, where the sulfides are transported. Rice & Moore point out that eddies that form on the upstream side of hollows in flow floors are ideal sites for the sulfide droplets to remain suspended in the flowing silicate magma and thus interact with a large volume of silicate magma. Maier *et al.* point out that sulfides that segregate in the conduits of intrusive complexes may have the chance to interact with large volumes of magma, as the same conduit maybe used for each fresh input of magma.

In order for an ore deposit to form, the Ni–PGE-bearing sulfides droplets must eventual collect in sufficient quantity for the whole rock to contain at least 1% Ni or 2 ppm Pt plus Pd. Rice & Moore point out that as the flow wanes, the suspended droplets of sulfide in the eddies that form on the upstream side of the irregularities in the floor could be expected to settle out, and to form massive and matrix sulfides. Maier *et al.* make a similar point in the case of intrusions, namely that massive Ni–Cu sulfides are not found at the margins of intrusions, but rather in the feeders to the intrusions, particularly in places where the flow of magma slowed and the magma was no longer capable of transporting the sulfide droplets. A particular example of this is provided by the Uitkomst Complex, discussed by de Waal *et al.*

After the sulfide droplets collect, they may undergo fractional crystallization to produce a cumulate consisting of monosulfide solid-solution (*mss*) enriched in Os, Ir, Ru, and Rh, and a sulfide liquid enriched in Cu, Pt, Pd and Au. Examples of this are given in Glotov *et al.* and Barnes *et al.*, with the former authors focussing on the Permo-Triassic komatiite–basalt magmatism of the Ban Phuc deposit of northwestern Vietnam. Gornostayev *et al.* present details of the magmatic crystallization of anduoite, ruthenium arsenide, associated with chromitite horizons.

During cooling of the intrusions, deuteric fluids may circulate. It is frequently argued that these fluids are rich in Cl and capable of transporting PGE. An example of this type mineralization from the Lukkulaisvaara intrusion is discussed in two papers by Glebovitsky *et al.* and Barkov *et al.* Glebovitsky *et al.* consider the PGE-rich sulfide mineralization as of metasomatic origin, but derived from magmatic sulfide. They also note an association of the metasomatic sulfides with pothole structures. As an added complication, it is possible that there is some movement of the metals as a result of metamorphism. Heath *et al.* argue that the source of the Ni variations in the Edwards Lode at Kambalda is due to Ni mobility during metamorphic recrystallization.

A summary paper by Lesher *et al.* addresses the distinctions in trace-element geochemistry and petrogenesis between barren and ore-associated komatiites. Their findings are based on studies of four well-known examples: Kambalda and Perseverance in Western Australia, Raglan, in northern Quebec, and the Thompson Nickel Belt, in Manitoba. The emphasis is on the use of geochemical and isotopic indicators of the main processes, both magmatic and post-magmatic.

This volume would not have been possible without the hard work of a number of people. We naturally thank the authors for their contributions. The reviewers are acknowledged for their efforts in ensuring quality control. We thank Robert F. Martin for all his careful and thoughtful editing. We would thank the sponsors of the conference and field trips: IGCP, Géologie Québec, Society of Economic Geologists, the City of Rouyn–Noranda, and Falconbridge Limited.

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