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Preface

Preface to the special issue of Lithos on isotopes in igneous petrogenesis

The genesis of igneous rocks is part of the dynamic processes involving mantle, crust and interactions between them. Over the last 50 years, gradual changes in the foci of igneous petrology have occurred as technological innovations permitted ever-increasing sophistication, accuracy and precision of analytical measurements. From the petrographic microscope to punctual isotope analysis by SHRIMP, from low-precision analyses of the Rb–Sr system to application of the Re–Os system, isotope geology has become an integral and indispensable tool in igneous petrogenesis.

Some of the important steps in the process were De Paolo's development of Sm–Nd systematics in the 1970s. Applications of model T_{DM} ages of granites became an important tool in regional studies of underlying source rocks. Equally important was Tilton's and Krogh's work (with their principal collaborators) on the U–Th–Pb systems which resulted in high precision isotope dilution results, adding Pb isotope data to the growing number of tools for the study of the origin of igneous rocks. Over four decades, Tatsumoto contributed to the knowledge of the U–Th–Pb, Sm–Nd and Lu–Hf systems, especially to volcanic rocks and meteorites. The recent addition of the Re–Os system, with its very particular behavior during mantle differentiation, has broadened even more the number of tools available.

Stable isotopes have been equally important in the study of igneous petrogenesis, and also of hydrothermal systems. Here, H.P. Taylor's early studies of granitoids deserve mention, as does Valley's more recent contribution "zircons are forever", preserving original magmatic O-isotope compositions throughout subsequent rock modifications, and therefore adding another tool for igneous petrogenesis and regional tectonic evolution.

Many other research workers have, of course, contributed to the present state of the art—too many to mention in this preface. The papers that comprise this special issue range from applications of a few of the long-established isotope systems to many different petrogenetic problems, to the use of Pt–Re–Os systematics and SHRIMP U–Pb point measurements in zircon grains.

R. Carlson uses the Pt–Os and Re–Os isotopic systems to provide a new view into the geochemical evolution of the solid Earth that is complementary to that obtained through the study of traditional radiometric systems since, unlike other systems, Re and Os are preferentially but differently retained in the mantle during partial melting and therefore can provide chronology of mantle differentiation.

Low- and high-Ti tholeiitic magmatism related to the initial fragmentation of the Pangaea supercontinent is discussed by Deckart and co-authors, who concluded on the basis of whole rock major and minor element chemistry and Sr, Nd and Pb isotopic compositions that the first magma type is derived from enriched lithospheric mantle, while for the second, a large contribution from a depleted asthenospheric source is required.

Mantle xenoliths are the subject of four petrogenetic studies in this volume. Schilling and co-authors discuss the interaction between mantle xenoliths and

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their host basalts, showing that some of them have suffered selective isotopic and trace element modifications, as well as decoupling of the Sr–Nd system where Sr ratios increase at constant Nd ratios, possibly caused by chromatographic process. This process is one of the hypotheses invoked by Conceição and co-authors to explain enrichment in radiogenic Sr without dramatic changes of the Nd isotopic composition, as observed in several Andean subduction-related mantle xenoliths. Mixture of a depleted mantle with an enriched source (enriched mantle II—EMII), or a mixture of a depleted mantle with a mixture of mantle-derived and slab-derived melts, are the other hypotheses discussed by these authors.

Garnet-free and garnet-bearing peridotites as well as spinel peridotites from the Colombian Andes present very distinct OIB and MORB isotopic signatures and equilibrated in their source mantle region in quite distinct P–T conditions as discussed by Rodriguez-Vargas and co-authors.

Lucassen and co-authors discussed P (below garnet-in) and T (>1000 °C) conditions of equilibrium of spinel lherzolite xenoliths from Argentinean Central Andes that together with major and trace element whole-rock chemistry, and Nd and Pb isotopic data indicate a dominant depleted mantle source, although a late Mesozoic metasomatism provoked changes in the original radiogenic isotope compositions giving rise to samples that display depleted and enriched isotopic compositions. Pb isotopic ratios of many xenoliths indicate at least two Pb sources that are characterized by similar U/Pb but different Th/Pb ratios.

Tertiary, relatively primitive alkaline basalts from southern Chilean Patagonia constitute probes to explore the nature of the asthenosphere beneath the region, and the way it interacts with the lithospheric mantle and continental crust. Espinoza and co-authors show that the basalts of that region have OIB-like isotopic and elemental signatures and that Neogene lavas can be divided into two groups, of which one of them has imprints of contamination by slab-derived or/or crustal components, leading the authors to the conclusion that magma sources were related to the opening of two slab windows during Eocene and Mio-Pliocene beneath Patagonia.

Modelling of subduction components in the genesis of basalts and gabbros from the South Shetland arc, Antarctica, by Machado and co-authors using Sr, Nd and Pb isotopic data suggests that the rocks were derived from a dominant depleted MORB source modified by mixture of two enriched slab-derived melts and/or fluids, and small fractions of oceanic sediment.

Lustrino and co-authors using Sr and Nd isotopic data of Early Cretaceous felsic volcanic and plutonic rocks from SE Uruguay suggested that they require involvement of lower crustal material of EMI composition in their genesis, either as contaminant or as protolith. Partial melting may has been triggered either by decompression melting related to Gondwana continental rifting before the opening of the South Atlantic Ocean or thermal anomaly related to the Tristan plume. Contamination of upper mantle by lower crust/uppermost mafic/ultramafic keel is also a hypothesis compatible with the presented isotopic data.

Nd-isotopic compositions of Neoproterozoic and Cretaceous igneous rocks from southern Brazil are discussed by Gastal et al. who found complex, time dependent and regionally different mantle/crust interactions between mantle and lower crust material. At the end of the collisional period, abundant production of granitic melts is attributed to lithospheric delamination. Mesozoic volcanic rocks register the presence of two enriched-mantle components with different origins.

Pleistocene andesites to rhyolites from the Aclatan volcanic field in central Mexico studied by Maldonado and Schaaf show depletion in HFS elements and enrichment in LILE and LREE, typical for subduction-related magmas. Sr, Nd and Pb isotope data suggest that the different magmas series derived from distinct parental magmas, which were generated by partial melting of a heterogeneous mantle source.

SHRIMP U–Pb data associated with SEM backscattered and cathodoluminescence imagery of zircons allowed da Silva and McNaughton to recognize and date magmatic-textured cores sharply bounded by melt-precipitated overgrowths, as well as homogenous new grains which define the Neoproterozoic ages of crystallization of post-collisional granitic plutons from southern Brazil, and of the inherited cores. Reassessment of previous SHRIMP data of two other granitoids of the region reveals similar textural patterns, but a Paleoproterozoic age for the magmatic-textured inherited cores vs. a Neoproterozoic age for the rims. This interpretation contradicts previous ones.

The motivation for this special volume came from the IV South American Symposium on Isotope Geology (IV SSAGI) that was held in Salvador, Brazil, in August 2003 (Sial et al., 2004, Episodes vol. 27, no. 2, pp. 132–133). Since the first meeting of this series, which was held in 1997 in Campos do Jordão, Brazil, an increasing number of contributions attests to the growing South American interest in the application of isotopes in all fields of geology. The recent establishment of both stable and radiogenic isotope laboratories in Brazil and other South American countries has maintained interest in classical geology, igneous petrology and the role of igneous rocks in deciphering mantle processes and crustal growth, and has guaranteed continuing support for research in these areas.

Since this volume is dedicated to presentations to the IV SSAGI, most papers deal with South American igneous systems, but as year after year the symposium has been attracting contributions from other continents, this volume also includes papers on Mexico and Antarctica. Many groups of authors and the reviewers of some papers also, are not native English speakers. The invited editors have therefore made minor changes where necessary, though phrases which are perfectly intelligible but not as compact as they could be, have been left as they are.

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