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Editorial

Preface to the Lithos Special Issue on Granites and Associated Mineralisation

W.E. Stephens [a], A.N. Sial [b], V.P. Ferreira [b]

[a] *Department of Geology, St. Andrews University, St. Andrews, KY16 9ST, Fife, Scotland, UK*
[b] *NEG-LABISE, Department of Geology, Federal University of Pernambuco, Recife, C.P. 7852, Recife, Brazil, 50732-970*

Through granite (*s.l.*) magmatism the earth's continental crust is recycled and differentiated. Granites are typically generated during periods of heat and/or mass transfer from the mantle to the crust, and are thus linked to major tectonic events. Under appropriate circumstances fractional crystallisation of granitoid magmas can lead to economic enrichment of a wide range of metals and rare elements. Thus granite plays a major role in the evolution of the upper crust and in the beneficial concentration of economic quantities of important materials. Given such scientific and economic importance it may appear surprising that so many problems concerning the genesis of granites and related mineral deposits remain unresolved. When the granite corpse has been dead for millions of years it is very difficult to reconstruct its full life history, even with the post-mortem assistance of sophisticated geochemical and structural tools. Yet it is important that we do so, as it is crucial to our understanding of the crust on which we live and the uneven distribution of resources. Our geological, chemical and physical models are necessarily simplistic when the enormous complexities of even a single pluton are considered. Nevertheless steady progress has been made in understanding the processes involved, at least at the first order, such success often building on interdisciplinary approaches.

Many of the problems of granite genesis and related ore deposition, from the Archaean onwards and from crystals to batholiths, were addressed at the Second International Symposium on Granites and Associated Mineralisation (ISGAM), held in Salvador, Bahia, Brazil during August 1997. ISGAM convenes every 4 years and is distinct from other regular meetings on granites in taking a particular interest in the associated mineralisation. Brazil was a particularly appropriate venue given the present extent of mineral exploration associated with granites and felsic volcanics in South America. This Special Issue is one of the outcomes of that symposium (which has also generated three other published volumes), being a selection of the major oral presentations by guest and keynote speakers. The symposium attracted over 150 scientists from about 20 countries to Salvador, former capital of Brazil, many of whom participated in field excursions (of which there were five to various parts of northern, northeastern and eastern Brazil) designed to stimulate discussion of granite-related issues prior to the symposium. One day of the symposium was devoted to IGCP project 371 (COPENA) which is concerned with, among other things, the role of granites in geologic correlation between Proto-South America and Laurentia as well as the other cratons in the Atlantic region.

This Special Issue reflects most of the areas where research into granites and mineralisation is particularly active at present, including melt segregation and ascent mechanisms, petrogenesis from protolith characterisation to higher level processes including magma mixing and fractional crystallisation, the use of granites to constrain tectonomagmatic conditions,

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and modelling of mineralisation processes. The local South American dimension is also well represented in this issue with studies of granites in Archaean, Proterozoic, Palaeozoic and Mesozoic settings, complemented by studies on other continents including the rapakivi granites of Greenland and the Miocene granites of Japan.

One of liveliest areas of granite research at present is the problem of how granitic magmas are extract from the melt zone, collected and transferred to a higher level to form plutons. Rachel Pressley and Michael Brown have used a range of geochemical parameters to characterise individual batches of melt which were used to construct the Phillips pluton (ME, USA). As the integrity of these signatures is retained through dynamic processes of pluton construction they become useful in testing models of emplacement, and these authors show that the Phillips pluton is best modelled as a feeder to a larger pluton. Alcides Sial et al. make use of recent experiments on magmatic stability and dissolution kinetics, along with other mineralogical and magnetic parameters, to estimate the conditions under which magmatic epidote survives to emplacement. These data can, under appropriate circumstances, be used to provide useful estimates of magma transport rates during ascent. Roberto Weinberg uses a physical modelling approach to examine critically the currently-popular model of dykes as the principal route for felsic magma migration from source to shallow crustal levels. He proposes some alternative mechanisms, which are more pervasive in character, and discusses how these various mechanisms might be recognised in practice.

The existence and significance of any distinctive temporal features in granites from the Archaean through Proterozoic to Palaeozoic and Mesozoic granitoid magmatism was a recurring theme of this symposium.

Archaean granitoids belong principally to the TTG suite (tonalite, trondhjemite, and granodiorite). For example, Hervé Martin presents convincing geochemical evidence of similarity between these Archaean TTGs and modern adakite magmas. This correlation has major implications for the geodynamic context of granite magmatism in the Archaean, favouring the melting of a hot subducted slab rather than a hot spot setting.

Proterozoic granites are also distinctive in some respects. Many have the characteristics of A-type granites and a texturally-distinctive subset of these is the well-known rapakivi type. Roberto Dall'Agnol et al. demonstrate that a suite of Palaeoproterozoic granites in the Amazonian craton are anorogenic in setting and bear many similarities to A-type Proterozoic granites in the SW United States they differ significantly from the classic rapakivi granites of the Fennoscandian Shield in being more oxidised (above the NNO buffer). Máricio Pimentel et al. review granite magmatism in the Proterozoic Brasilia Belt in central Brazil and recognise about 1 Ga of tectono-magmatic evolution beginning with extension-related A-type (and tin-bearing) granites, passing into a subduction-dominated magmatic regime, followed by magmatism associated with oceanic closure, culminating in a post orogenic phase of magmatism. Brown et al. describe a most unusual characteristic of the Proterozoic South Greenland (Ketilidian) rapakivi granites, namely the homogeneity of whole rock oxygen isotopes on a regional scale which they show is consistent with a model of a well mixed two-component protolith. Hydrogen isotopes, which are heterogeneous on a scale larger than hand specimen do not match this homogeneity, although when their heterogeneity was introduced is not known.

Younger granites of Palaeozoic and Mesozoic are represented in the Coastal Batholith of central Chile, which was constructed over about 200 Ma. Miguel Parada et al. use radiogenic isotopes to demonstrate that over this period the principal sources of mafic magmas changed from lithosphere-dominated in the Carboniferous to asthenosphere-dominated by the Jurassic, to evidence for a slab component by the Cretaceous. More felsic crustal magmas are only generated until the Middle Jurassic, and these authors argue that the removal of old lithospheric mantle by delamination during the Mesozoic best explains these features. Shunso Ishihara and Yukihiro Matsuhisa have constrained the nature of protoliths in Miocene age granites of southwest Japan using oxygen isotopes. They model the protoliths as mixtures of basaltic magmas and accretionary complex sedimentary rocks, and find the sedimentary contribution to S-type granites to be 45–64% whereas I-type granites have 30–43%.

Although fractional crystallisation has long been accepted as a major process in generating highly evolved granite compositions and related ore deposits, it is often assumed that variable starting compositions converge towards the felsic end of the range. Bruce Chappell rather elegantly demonstrates the reverse. Using an extensive geochemical database of the Lachlan fold belt granites (southeastern Australia) he shows that rather small differences in certain I-type and S-type characteristics, inherited from the source, become exaggerated with strong fractional crystallisation. This is particularly the case for the aluminium saturation index (ASI), phosphorus, and trace elements like Y, Th and the REE which are associated with phosphate accessory minerals. Mixing on the other hand is bound to lead to convergence in composition. Giampiero Poli and Simone Tommasini use geochemical modelling to test field evidence for magma mingling and mixing between granites and coeval gabbros and basic septa in the Sarrabus pluton in Sardinia, Italy. They demonstrate that simple blending is unable to account for the range of compositions found in enclaves in the granite and it is necessary to devise more complex models involving fractional crystallisation and contamination with simultaneous filter pressing.

Accuracy in predicting the occurrence of economic quantities of metals in granites is steadily improving, particularly aided by better understanding of the behaviour of metals in magmas and magmatic–hydrothermal systems gained from experimental and thermodynamic investigations. Pedro Jugo et al. have examined how gold and copper partition between pyrrhotite, intermediate solid solution and haplogranitic melt under various magmatic conditions. Their results are very important to the problem of prediction as they demonstrate that the interplay of these iron sulphide phases and magnetite with felsic melt and sulphur and oxygen fugacities has a marked bearing on the partitioning of these metals and thus their concentrations and metal–metal ratios in the melt. Phil Piccoli et al. have examined aspects of halogen behaviour in the magmatic volatile phase of granites, chlorine in particular being important in ore transportation. They present two methods for estimating the HCl and Cl content of the magmatic volatile phase using, respectively, the bulk composition of aplite (or equivalent vapour-saturated near-minimum melts) for HCl and Cl, and the composition of apatite as a function of temperature to estimate HCl.

The problem of how best to classify granites has long exercised granite *aficionados*, not always productively. Since the seminal work of the Australians Bruce Chappell and Allan White who demonstrated that there was useful information about granite protoliths available in geochemical and mineralogical parameters, numerous classifications with different objectives and critical parameters have been spawned. Bernard Barbarin has reviewed many of the more recent classifications and has rationalised them into a new classification using criteria that may be easily applied to constrain geodymanic environment, even at the scale of the field observation.

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