Structure and Emplacement of High-level Magmatic Systems

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Sills, dykes and related laccoliths are the physical record of the transfer of magma through the upper crust. Those who study such rocks meet every four years and this book is the outcome of LASI II, the second conference on Laccoliths, Sills and Dykes. Results from the first such conference were published in 2004 in the same series. This book is a collection of thirteen rather diverse papers on various aspects of the emplacement of laccoliths, sills and dykes. The topic is of broad interest, having implications for volcanology, igneous petrology, magma dynamics, and tectonics. This broad scope is covered by the range of papers in the volume.

An introductory paper by Ablay et al. proposes a new mechanical description that attempts to relate intrusion along fractures to magma generation and buoyancy, hydraulic overpressure, and regional tectonic stresses. The authors argue that neither analogue nor numerical modelling has been particularly successful in resolving questions related to high-level magma emplacement. Their mechanical description accounts for much of the observed spatial and temporal variability in high-level magmatic systems. As this book is a collection of stand-alone papers, the applicability of the Ablay et al. mechanical model is not evaluated in other papers in this volume. The Ablay et al. paper does provide a brief introduction to the key uncertainties in the understanding of high-level magmatic systems, but the average reader will find that a good knowledge of the relevant literature is needed to appreciate the scope of the issues.

The majority of the papers, 10 out of 13, are essentially case studies based on field data of sill and dyke emplacement. Thomson and Schofield report on the relationship between sills, dykes, laccoliths and pre-existing basin structure in the NW European Atlantic Margin through the use of high-resolution 3-D seismic images. They conclude that sills are predominantly concave-upwards with a flat inner sheet connected to a flat outer rim by a steeply inclined sheet (dyke) that may also rise to feed a higher sill. Overall, sills propagate upwards and outwards away from a magma feeder. Ductile horizons such as overpressured shales may allow sills to form below the level of magma buoyancy. Bermúdez and Delpino provide evidence for the economic importance of high-level intrusion in petroleum basins. Leat uses field observations and geochemical relationships to study the Farrar large igneous province basalts of Antarctica, which include voluminous sills and dykes. Geochemical data is used to argue for lateral transport of magma over thousands of kilometres, principally in sills, during continental breakup.

Mazzarini and Musumeci use field data from the sheet-like intrusions emplaced close to the surface on Elba island, Italy, and demonstrate the significant role that fractures and overpressure play in the emplacement of sills and dykes. Such studies are important in giving clues on fluid pressure conditions and the stress state at the time of magma emplacement. Dini et al., also on Elba, focused their work on a late Miocene complex of nested Christmas-tree laccoliths, plutons and dykes. They attempt to correlate the distribution of magmatic centres to regional tectonics. Magmatism was focused by a transfer zone developed during back-arc extension, with the reactivaion of former faults. The paper by Morris et al. is also focused on the relationship between magmatism and regional tectonics, in this case a Caledonian dyke swarm that resulted from passive upwelling of magmas into fractures created by regional tectonic stresses. Magmatic flow directions were interpreted from magnetic data. Stevenson et al. also use magnetic and petrofabric analysis and field structural measurements to reassess the emplacement of ring dykes in Slieve Gullion Igneous Centre, Northern Ireland, and suggest that the complex was emplaced as a series of subhorizontal sheets. Winter et al. report on the textural and petrographic analysis of late Paleozoic pyroclastic rhyolitic dykes from Saxony, Germany. These rhyolites represent welded fall-back tuffs formed in vents positioned above an active magmatic dyke system.

Nemeth et al. studied the interaction between magma and sea water in the Miocene rhyolitic shallow intrusions, cryptodomes, and endogenous lava domes emplaced into and onto soft, wet pelitic sediments in a shallow submarine environment in NE Hungary. Nemeth and Cronin report on pit craters and high-level magma-feeding systems of a mafic island-arc volcano in the South Pacific. The present crater exposes portions of solidified lava lakes and magma pods that fed spatter cones, small shallow-level intrusions and larger sills that connect through a complex network of dykes to the surface. These features can be used to elegantly explain growth of scoria and spatter cones and how magma finally escapes laterally to form lava flows.

Two papers use experimental data to better understand the emplacement of dykes and sills. Vinciguerra et al. use melt concentration and strain distributions around basalt dykes to show that melt migration is enhanced by porosity of the microstructure and loading conditions. Bunger et al. present analogue experiments and quantitative analysis designed to gain better insight into the mechanics of formation of saucer-shaped sills.

This is a very useful collection of papers for specialists in high-level intrusions and volcanic complexes. More general readers will have to dig quite hard.