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BOOK REVIEW

C. Breitkreuz and N. Petford (eds): Physical geology of high-level magmatic systems *and* K. Thomson and N. Petford (eds): Structure and emplacement of high-level magmatic systems

Geological Society, London 2004, Special Publications 234, Hardcover, 262 pages, ISBN 978-1-86239-169-7 £90.00 *and* Geological Society, London 2008, Special Publications 302, Hardcover, 240 pages, ISBN 978-1-86239-256-4 £85.00

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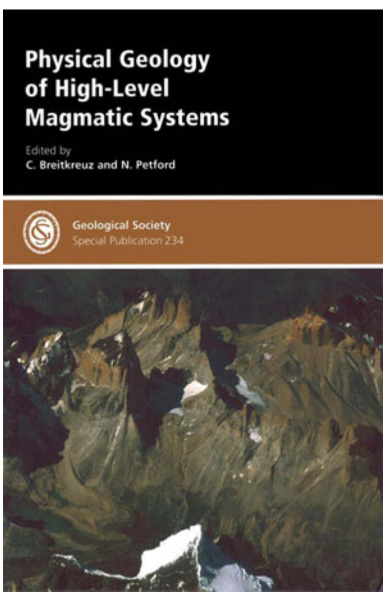

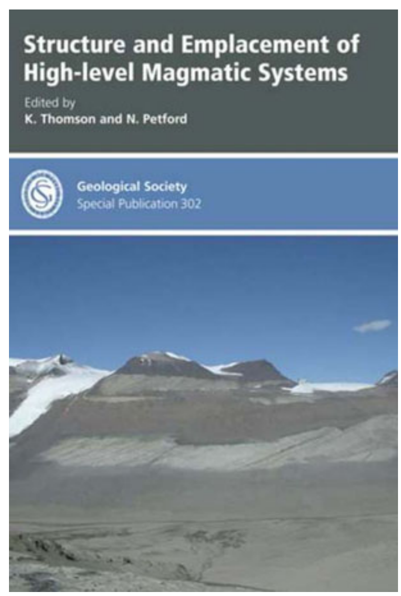

These two books, hereafter referred to as LASI 1 and LASI 2, are collections of articles published as an outcome of the 1st and 2nd LASI (LAccoliths and SIlls) International Workshops held in Freiberg, Germany (October 12–14, 2002) and the Isle of Skye, Scotland (April 1–3, 2006), respectively. As the editors state in the preface to the LASI1 volume, there had been no similar publication recorded since "Mechanism of igneous intrusion" (Geological Journal Special Issue 2, 1970, edited by G. Newall and N. Rast). It is extremely fortunate that the attention of igneous petrologists, structural geologists, and volcanologists was again focused on the shallow intrusive environment of magma emplacement after so long a gap. Judging from the content of the two books published over only a 4-year interval, following the two LASI workshops, it seems that there is now substantial interest in this research topic. That is not

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only because a wealth of new observational and analytical data accumulated meanwhile and improved and new analytical techniques and research tools became available for the study of magmatic systems but also because the new and deep insight gained in this domain is highly relevant to other Earth science disciplines as well such as volcanology.

The 28 contributions in the two volumes (15 and 13, respectively) display a state-of-the-art “cross section” of knowledge in the domain of shallow intrusive systems at the turn of the millennium. The papers range from short presentations of experimental results (e.g., Vinciguerra in LASI 1 and LASI 2 volumes, 6 and 7 pages, respectively) and a 3D seismic study of “sill complex geometry and internal architecture” (Thomson, 4 pages in LASI 1) to large, detailed case studies such as that of Lorenz and Haneke (LASI 1 volume, 50 pages).

The geographic coverage of the subjects addressed is large enough that the scope of the workshops and their printed outcome can be considered global. These volumes are, however, a bit “Euro-centric” since 16 of the 23 geographically localizable study areas are located in Europe, mostly including classical localities in Britain and Central Europe. Somehow surprisingly, only one US case study is present, while three are located in Africa/Gondwana, one in the South Pacific (Vanuatu), one in the Indian Ocean (Kerguelen Islands), and one in South America (Argentina).

The age range covered is truly representative for the whole Phanerozoic: Caledonian, Variscan, and Alpine intrusive and volcanic rocks are all represented, with ages from Lower Palozoic (411–415 Ma, Morris et al., LASI 2 volume, and 315–316 Ma, Machowiak et al., LASI 1 volume), through Upper Paleozoic (four papers), Mesozoic (Triassic and Jurassic, one and two papers, respectively), Paleogene (two papers), and Neogene (seven papers) up to recent manifestations and active volcanism (Bonin et al., LASI 1, Németh and Cronin, LASI 2).

The chemical types of magmas involved in the generation of the intrusions studied range from rhyolitic to basaltic, from oceanic to continental affinities, with magmas originated from mantle and crustal sites. Intrusion types range from common dykes, sills, and laccoliths to rarer types such as phacoliths (in the Intra-Sudetic Basin, Poland, Awdankiewicz, LASI 1) and bysmaliths (in the Henry Mts., Utah, USA, Habert and de Saint-Blanquat, LASI 1).

The LASI 1 volume is better organized with contributions involving modeling and experimental approaches grouped at the end of the volume following a larger number of papers mainly based on detailed field studies and observational data. It starts with a short introduction by the Editors focused on the typology of sill–laccolith–pluton intrusions pictured as an S curve in the now classical McCaffrey and Petford (1997) T vs. L plot relating intrusion thickness to intrusion diameter.

The LASI 2 volume starts with an obituary of Ken Thomson who passed away in 2007 during the inter-LASI 1–2 period. The contributions to the volumes can be grouped in three classes, according to the authors' approaches: case studies (based on observational/analytical data, structural analysis or combinations of those), modeling (numerical, e.g., Habert and de Saint-Blanquat, Malthe-Sørenssen et al., LASI 1, Ablay et al., LASI 2, and analogue, e.g., Bunger et al., LASI 2), and experimental (e.g., Vinciguerra et al. in both LASI 1 an LASI 2).

Some readers might be interested in following the progress achieved in knowledge during the inter-LASI 1–2 period, looking for recurrent authors and subjects in the two volumes as a testimony of long-lasting programmatic research conduits and efforts. Németh (1+2 contributions), Mazzarini et al. (1+1), Thomson (1+1), Westerman et al. (1+1), and Vinciguerra et al. (1+1) are the authors/coauthors present in both volumes. Thomson (3D seismic imaging and interpretation of saucer-shaped sill complexes), Németh (the shallowest intrusive level and interaction of intruded magma with near-surface volcanic features and rocks/sediments), and Vinciguerra et al. (dyke emplacement experiments with partially molten olivines) appear as conducting and accounting for programmatic research strategies, at least judging from the reviewed volumes.

Recurring subjects, addressed by different authors, are also not missing from the two volumes, suggesting that the attention of researchers has been focused on a number of topics of particular interest. Saucer-shaped sills, their morphology, and emplacement mechanisms are the central subject of four papers (Malthe-Sørenssen et al., Thomson in LASI 1, Thomson and Schofield, Bunger et al. in LASI 2). Ring–dyke complexes attracted the attention of authors in two papers (Bonin e al., LASI 1, Stevenson et al., LASI 2). Intrusive complexes known from the classical geological literature have been revisited and reinterpreted (e.g., in Britain) on the basis of new observations and investigative techniques (Morris et al., Stevenson et al, both in LASI 2). The role of pre- and syn-emplacement regional and local tectonics and stress fields in shallow dyke–sill–laccolith emplacement is addressed in a number of papers (Awdankiewicz, Breitkreuz and Mock, Mazzarini et al., LASI 1, Thomson and Schofield, Mazzarini and Musumeci, Dini et al., Morris et al. in LASI 2).

Basin studies benefit highly from insights arising from the shallow igneous perspective in these volumes. Sedimentation, volcanism and subvolcanic intrusions are interrelated in the basins, as investigated and reported in a number of papers (Awdankiewicz, Breitkreuz and Mock, Lorenz and Haneke, Jamtveit et al. in LASI 1, and Thomson and Schofield, Bermudez and Delpino in LASI 2). The Saar-Nahe Basin (Germany) is the common study area of two papers (Breikreuz and Mock, Lorenz and Haneke, both in LASI 1).

Basically, all processes and conditions related to high-level magmatic systems are subjected to research scrutiny, as the contribution of Ablay et al. paradigmatically illustrates, clearly stating that the scope of this paper is: “a coherent mechanical account from source to post-emplacement” (LASI 2 volume, p.4), a welcome state-of-the-art synthesis-like approach. This contributes to a high-level “added value” to the volumes, which complement each other well. For that reason, I strongly recommend that the interested geologist obtain both volumes (and, perhaps, any follow-up volumes that appear). It seems that some areas, either classical such as Elba Island, Italy (Westerman et al., LASI 1, Mazzarini and Musumeci and Dini et al., LASI 2), Northern Britain (Morris et al., Stevenson et al., both in LASI 2), Central Europe (Germany and Poland) (Awdankiewicz, Awdankiewicz et al., Breitkreuz and Mock, Machowiak et al., Lorenz and Haneke in LASI 1, Winter et al. In LASI 2), Karoo, South Africa (Thomson, Jamtveit et al., both in LASI 1), or newly investigated locations such as Eastern Europe (Hungary) (Martin and Németh, LASI 1, Németh et al., LASI 2) have helped of late to focus research interests.

Some “exotic” results, such as hydrothermal vent complexes arising from sill intrusions (Jamtveit et al, LASI 1), and long distance (>4,100 km!) transport of Ferrar magmas in dykes (“the longest magma flow known on Earth”, Leat, LASI 2) complete the colorful and exciting picture of the shallow-level intrusive environment.

Volcanological connections are commonly made and important. In particular, there are articles highly relevant to the volcanology community that address issues related to the shallowest intrusions at extinct and active volcanoes. Volcanologists would find a great deal of useful information in these books as well as new insights and fruitful ideas to follow up and develop through their own research. No doubt, volcanology teachers and students will also strongly benefit from reading them.

It seems that Németh, with his coworkers, championed investigation of the shallowest intrusive environments, located in volcanic vent/crater areas where volcanic and intrusive features may intermix in surprising forms. The 1 m (!) intrusion depth, hypothetized at Ambrym volcano, Vanuatu, SW Pacific, is probably the world record-holder in this respect. Shallow intrusion into consolidated or unconsolidated water-saturated sediments results in a rich spectrum of interaction phenomena and features (hyaloclastites, peperites, soft-sediment deformation, and brecciation), thoroughly explored and reported in a couple of papers of high volcanological interest (Martin and Németh, Lorenz and Haneke, Corazzato and Groppelli, Jamtveit et al. in LASI 1, Németh et al. in LASI 2).

The discussions and interpretations of sills, laccoliths, intrusive and extrusive domes, and surface volcanic features (including lava flows and block-and-ash-flow deposits) in eroded igneous assemblages are of particular interest for the volcanologist because they relate exposed subsurface features to partially preserved or inferred surface volcanic features. This is a perspective “from below,” in contrast with the “from above” perspective offered from recent/active volcanic areas where the surface features are readily accessible to observation, while the subsurface features are much less exposed (e.g., the contributions of Németh in both LASI volumes). These two perspectives apparently come in conflict with each other, as the “from below” perspective seem to ignore (at least partially) the surface features such as volcanic constructs/edifices. The feeling of an innocent reader after digesting, for instance, the paper of Lorentz and Haneke (LASI 1 volume) is that the major intrusive systems may have some minor manifestations at the surface, according to the observed intrusive/volcanic volume ratios found in the deeply eroded areas (e.g., Fig. 13, p. 97) but that no large-scale volcanic edifices (such as composite volcanoes) fed by the well-exposed subsurface magmatic system, existed at the surface. In contrast, recent/active volcano-based studies might suggest to the same naive reader that volcanic systems are underlain by minor intrusive features at the shallow crustal level, with any large scale intrusions hidden far beneath. In fact, one may conclude from these two LASI volumes that further investigation is needed, dedicated to, and focused on the shallowest level magmatic domains where surface and subsurface processes interact in complex ways. The domain is far from fully explored or understood. The complexity and dynamics of these interacting magmatic subsystems (surface and shallow subsurface) arises not only from the governance of surface volcanism by the subsurface plumbing system but also from the feedback mechanisms of the major volcanic events occurring at the surface (such as edifice instability-related processes) on the subsurface intrusive system as suggested recently (e.g., Szakács and Canon-Tapia 2010).

Unfortunately, the two LASI volumes are plagued by a number of flaws. In at least one case, even the authors' approach to their study subject is questionable. In the contribution of Jamtveit et al. (LASI 2) hydrothermal vent complexes inferred from seismic profiles from the Northeast Atlantic margin serve as a prototype for the interpretation of geometrically similar complexes found in Karoo Basin, South Africa, inferred to emanate from the tips of putative sills, but no positive evidence is mentioned (other than the “farfield” analogy) in favor of the existence of such sills in the Karoo; this is really a quite questionable approach.

Terminological accuracy is certainly not a strength of the LASI volumes. Although experienced geologists are not impeded in comprehending the texts, students might be easily confused when reading formulations such as “the intrusive origin of this lava” (p. 42, Fig. 8 caption in Martin and Németh, LASI 1), “volcanic–granodioritic intrusions” in a title (p. 67) and “volcano-granitic rocks” (p.69) (both in Machowiak et al. LASI 1), “evidence for the above volcanic bodies being sills” and “sediments both below and above *the* *volcanic rock* became contact-metamorphosed from 10 cm to about 1–2 m, depending on the thickness *of the same sill*" (both on p. 89 in Lorenz and Haneke, LASI 1), and "breccias composed of volcanic bombs" (p. 131, Bonin et al., LASI 1); use of these terms is at odds with what students are taught at their physical geology or volcanology courses.

Sill terminology appears somehow abusive in places in Thomson and Schofield (LASI 2), when describing "transgressive sheets," i.e., unconformable portions of the intrusion which may prevail over its conformable portions (such as in the case of "sill B" in Fig. 6a, page 37), which actually could be "dykes" according to classical terminology in which the term "sill" is reserved merely for dominantly conformable features.

The usage of the term "cupola" in the contribution of Lorenz and Haneke (LASI 1) as a particular intrusion type is questionable, since they actually refer to structural updoming structures affecting the roof sediments, with some minor intrusions (sills or dykes) in their cores, and mostly hypothetical laccoliths beneath them at depth; this is not consistent with their conjectural definition given ("in the Saar-Nahe Basin the concealed and some exposed laccoliths have been called cupolas"), according to which the cupolas are one particular type of laccoliths (p. 92). Later on, however, it is stated that "the overlying sediments clearly form a cupola structure" (p. 108). So, the "cupolas" are both updomed "structures" and a particular type of "laccoliths", according to the authors. ["cupola: A small, dome-shaped, satellite intrusion projecting upwards from the main body of a larger intrusion or batholith", Oxford Dictionary of Earth Sciences, 3rd edition, 2008]. Then, the term "dome" is also used with various meanings by the same authors. First, as a tectonic structure resulting from roof-updoming of sediments, so that it can also be termed a cupola when some intrusions are found or inferred within or beneath it, and second, as a type of igneous rock body of intrusive, extrusive, or mixed origin (intrusive–extrusive dome). The terminological confusion is well illustrated by the authors themselves when describing domes (e.g., Wilzenberg dome and Himmelberg Dome, p. 95) under the heading of "Laccoliths and cupolas" (p. 92) and not under the heading "Intrusive–extrusive domes" (p. 96), as the reviewer would expect after reading the introduction to the section (p. 92).

Under the heading "Plutonic ring *dykes*," Bonin et al. (LASI 1) discuss aspects related to their *roof, floor and thickness* which "could exceed the 500 m [!] observed on the cliffs" (p. 132). After reading that, a person—a student, in particular—may honestly question whether the rock bodies presented are actually dykes.

Terminological inconsistency is also present within some articles. For instance, different terms are used in text and figure labelings in Németh and Cronin (LASI 2): "scoriaceous agglomerate" on Fig. 6, p. 95, while "lapilli and bomb breccias" in the text and "lava pond" label on Fig. 9, p. 97, but "lava pod" and "magma pods" in text, p. 96, and both "lava pond" and "lava pod" in the figure caption.

Some logical flaws can be found in the volumes: "In contrast, several 100 to several 1000 m below the basin floor, all these magmas were intruded within the sediments of the basin fill"! (p. 108 in Lorenz and Haneke, LASI 1). One may understand, and wonder, from this sentence that the basin fill is found below the basin floor!

Formal flaws abound too in the two volumes, in particular in LASI 1, such as text redundancy (e.g., in Martin and Németh, LASI 1, where the same sentence is repeated in different parts of the same section, on p. 40 and p. 41), inconsistency between section titles and content (e.g. "Peperitic contact zones of dykes, sills, cryptodomes and lava domes" is a section title, p. 75, in Németh et al., LASI 2, but no dyke—apart from sedimentary dykes—or sill is even mentioned by the authors in their study area), improper or pleonastic formulations such as "in the exposure levels of the exposure" (p. 41, in Martin and Németh, LASI 1, "Pyroclastic and lava flows filled up *caldera craters*", p. 138, and "intrusive plutons", p. 126, both Bonin et al., LASI 1, "the size and geometry of this event", Malthe-Sørenssen et al., p. 222, LASI 1), reference-related flaws (Martin and Németh, 2002 cited in text, p. 59, but missing from the Reference list in Awdankiewicz et al., LASI 1), figure-related flaws (labeling or pattern not explained, incomplete legend, misreferencing of figures, mismatch of figure labeling and figure caption), formula-related flaws, and typos. The Volume Editors should have taken more care with these formal aspects.

All in all, these two LASI volumes represent one major step forward in understanding morphological, structural, and genetic complexity in the shallow intrusive environment. Active research is going on. Two more workshops have been held: LASI 3 in Elba Island, Italy in 2008, and LASI 4 at Moab, Utah, USA in 2010.

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