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Magma accumulation and segregation during regional-scale folding: The Holland's dome granite injection complex, Damara belt, Namibia

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ABSTRACT

The regional-scale, upright fold of the Holland's dome in the Damara belt of central Namibia contains a kilometre-scale network of intrusive, highly fractionated uraniferous leucogranites. Three broadly orthogonal and intersecting sets of leucogranite sheets that intruded parallel and at right angles to the axial plane of the first-order fold can be distinguished. The granites are internally sheeted and illustrate the growth of the injection complex through the successive addition of thousands of smaller magma batches. Spatial and timing relationships point to a stepwise evolution of the injection complex. Early dilatancy-driven segregation and accumulation of granitic magmas in the core of the fold, above a basal detachment, was followed by compaction-driven segregation of a melt phase during fold tightening. The intersecting leucogranite sets provide a suitably organized permeability structure for melt segregation, while the successive injection of magma batches ensures compatibility between regional strain rates during folding and the rates of magma segregation. The three-dimensional network of melt-bearing structures further assisted regional shortening past the lock-up of the fold. The Holland's dome injection complex illustrates the geometric complexity of magma transfer pathways and the significance of regional-scale folding for the accumulation, segregation and fractionation of granitic magmas in suprasolidus crust.

1. Introduction

Our understanding of the ascent of felsic magmas through the crust largely relies on observations and interpretations of granitic dyke networks from mid-crustal anatectic terrains (e.g. Wickham, 1987; Brown, 1994, 2007, 2010; Sawyer, 1994; Collins and Sawyer, 1996; Weinberg, 1996; Bons and van Milligen, 2001; Bons et al., 2004, 2010; Brown et al., 2011). These networks are interpreted to represent the vestiges of original melt migration pathways recording the initial segregation of melts from their partially molten protoliths into veins and stringers to the transfer and accumulation of magmas to form larger sheets or interconnected vein complexes (Jurewicz and Watson, 1984; Vigneresse, 1995; Weinberg, 1999; Weinberg and Searle, 1998; Brown, 2007; Sawyer, 2008, 2014; Hall and Kisters, 2012; Diener et al., 2014; Soesoo and Bons, 2014). Deformation plays an integral role in the mobilization of melts and magmas which, in turn, leads to strain localization and the partitioning of deformation (van der Molen and Paterson, 1979; Hollister and Crawford, 1986; Rushmer, 1995; Brown and Solar, 1998; Rosenberg and Handy, 2001, 2005). It is therefore not surprising that many studies describe processes of magma migration from crustal-scale transcurrent or transpressive shear zones. In shear zones, shear zone foliations, but also shear zone kinematics provide subvertical permeability pathways that facilitate the vertical and mainly buoyancy-driven ascent of the granitic magmas (e.g., Brown and Solar, 1998). However, the high finite strains invariably associated with shear zones also tend to overprint and transpose initial sheet geometries so that the original permeability networks may not be preserved (Weinberg et al., 2009; Reichardt and Weinberg, 2012; Morfin et al., 2013).

Folds are ubiquitous features of any anatectic terrain and numerous studies have documented a close spatial and temporal relationship between folds and granitic magmas or plutons (e.g., Allibone and Norris, 1992; Hand and Dirks, 1992; Vanderhaeghe, 1999; Barraud et al., 2001, 2004; Vernon and Paterson, 2001; Weinberg et al., 2015). Granite networks in folds may not have contributed to a crustal-scale transfer of melts, given their

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