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From steep feeders to tabular plutons – Emplacement controls of syntectonic granitoid plutons in the Damara Belt, Namibia

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ABSTRACT

Granitoid plutons in the deeply eroded south Central Zone of the Damara Belt in Namibia commonly show tabular geometries and pronounced stratigraphic controls on their emplacement. Subhorizontal, sheet-like pluton geometries record emplacement during regional subhorizontal shortening, but the intrusion of spatially and temporally closely-related granitoid plutons at different structural levels and in distinct structural settings suggests independent controls on their levels of emplacement. We describe and evaluate the controls on the loci of the dyke-to-sill transition that initiated the emplacement of three syntectonic (560–530 Ma) plutons in the basement-cover stratigraphy of the Erongo region. Intrusive relationships highlight the significance of (1) rigidity anisotropies associated with competent sedimentary packages or pre-existing subhorizontal granite sheets and (2) rheological anisotropies associated with the presence of thick ductile marble horizons. These mechanical anisotropies may lead to the initial deflection of steep feeder conduits as well as subsequent pluton assembly by the repeated underaccretion of later magma batches. The upward displacement of regional isotherms due to the heat advection associated with granite emplacement is likely to have a profound effect on the mechanical stratification of the upper crust and, consequently, on the level at which granitoid pluton emplacement is initiated. In this way, pluton emplacement at progressively shallower crustal depths may have resulted in the unusually high apparent geothermal gradients recorded in the upper crustal levels of the Damara Belt during its later evolution.

1. Introduction

Granitoid plutons (granites sensu lato) are increasingly being recognized as subhorizontal, tabular bodies with high length: thickness ratios (e.g. Benn et al., 1999; Vigneresse et al., 1999; Westraat et al., 2005; Burchardt et al., 2010) formed through the under- or overaccretion of multiple intrusive sheets (e.g. Blenkinsop and Treloar, 2001; Coleman et al., 2004; Westraat et al., 2005; de Saint-Blanquat et al., 2006; Morgan et al., 2008; Farina et al., 2010; Miller et al., 2011; Leuthold et al., 2012; Saumur and Cruden, 2015). In contrast, the ascent of magma from lower-crustal sources to mid-to upper-crustal sinks must take place along conduits steep enough to allow buoyancy-driven magma ascent to occur sufficiently rapidly to prevent the freezing of magma within the subsolidus sections of crust along the ascent path (Clemens and Mawer, 1992; Hutton, 1992; Brown, 1994; Vigneresse and Clemens, 2000; Kisters et al., 2009; Diener et al., 2014; Menand et al., 2015). Conduits suitable for successful far-field ascent are now widely believed to be fracture-controlled and probably take the form of rooted dykes/dyke networks or self-driven magma-filled (hydro) fractures that have separated from the zones of partial melting (Lister and Kerr, 1991; Hutton, 1992; Petford et al., 1993; Rubin, 1995; Bons et al., 2001, 2009). Both dykes and hydrofractures are commonly extension fractures that open against the least compressive stress (σ_3 with $\sigma_1 \geq \sigma_2 \geq \sigma_3$; Anderson, 1951). Deviations from this general rule allow fracture-controlled magma ascent to take place at high angles to σ_1 in the mid-crust of convergent orogens where the temperature-dependent plasticity of most rock-forming minerals means that differential stresses are low ($\sigma_1 - \sigma_3 \leq 20$ MPa; Davidson et al., 1994; Behr and Platt, 2011). In such cases, anisotropies such as bedding or foliation planes can promote fracture propagation at high angles to the commonly subhorizontal tectonic compression (e.g. Lucas and St-Onge, 1995; Brown and Solar, 1998; Kisters et al., 2009).

Pluton emplacement is initiated with the deflection from steep

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