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Emplacement and growth of alkaline dikes: Insights from the shonkinite dikes (Elchuru alkaline complex, SE India)

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ABSTRACT

The Mesoproterozoic Elchuru alkaline complex in the Prakasam Alkaline Province (PAP), Eastern Ghats Belt, SE India is intruded by coeval shonkinite dikes. Magmas parental to both the host nepheline syenite and shonkinite dikes formed during ca. 1350 Ma continental-rift related magmatism. The shonkinite dikes show fine-to medium-grained equigranular to foliated textures with clinopyroxene, biotite, amphibole, K-feldspar perthite and nepheline as major mineral phases. The dikes grew by inflation and coalescence of dike segments along intrusive steps, anastomosis and subsequent coalescence, and thermal/mechanical erosion of the host rocks. A few dikes resulted by filling the fractures created by shearing. Inflation of intrusive steps between magma segments by Mode I opening is the major mechanism of shonkinite dike emplacement and growth. However, the shonkinite dikes also demonstrate the application of remote shear stress on the dike walls resulting in anastomosis, entrapment and segmentation of tabular host rock xenoliths, and in extreme cases brecciation of the host rocks under volatile-rich and low-viscous melt conditions. Fractal analysis of xenolith-bearing dike further illustrates that thermal erosion was facilitated and accentuated by mechanical breakdown of host rock xenoliths due to interactions of tensile and shear forces. Cross-cutting relationships between the shonkinite dikes suggest local deviation in the least compressive stress direction during dike emplacement. The shonkinite dikes of Elchuru demonstrate that spatially- and temporally-restricted high-volatile low-viscous alkaline magmas may have distinctly different styles of emplacement, as controlled by interaction of near field (magmatic) tensile stress and far field (tectonic) shear stress, in an evolving continental-rift setting.

1. Introduction

Dikes offer physical evidence to understand the mechanisms of magma transportation in the Earth's crust. Emplacement and growth of dikes also provide clues to crustal evolution at scales ranging from that of a fracture to fragmentation of supercontinents. Dikes inject either through pre-existing fractures or create their own pathways by hydraulic magmatic fracturing involving the dilation of country rocks (Walker et al., 2017). Additionally, viscous indentation and fluidization of the host rock can also facilitate dike emplacement (Schofield et al., 2012a,b; Spacapan et al., 2016a). Dike emplacement occurs by hydraulic magmatic fracturing when magma pressure exceeds the lithostatic pressure. It is generally assumed that the dikes emplace perpendicular to least compressive stress σ_3 (Anderson, 1951; Gudmundsson, 1990) provided the magma propagates in self-generated hydraulic fissure. In the hydraulic magmatic fracturing model dike tips tend to be irregular to sub-rounded whereas in pre-existing fracture-fill model the dike tips would be straight and wedge-shaped (Motoki and Sichel, 2008). Examples of dikes emplacing in both self-generated (Anderson, 1938; Delaney et al., 1986) or in pre-existing (Currie and Ferguson, 1970; Baer et al., 1994; Jolly and Sanderson, 1995) fissures both exist. However, dike emplacement is not restricted to mode I (tensile) fractures alone. If the differential stress at the site of dike injection, due to addition of tectonic stress to the magma pressure, is greater than ~4T (where T is the tensile strength of the rock) then the rock will fail by shear stress and the dike will be injected into the shear fractures at oblique angles to the principal stresses (Escher et al., 1976; Delaney et al., 1986; Correa-Gomes et al., 2001; Khodayar and Einarsson, 2002; Paquet et al., 2007; Skarmeta, 2011; Gerbault, 2012; Spacapan et al., 2016b; Morozov et al., 2017). Dikes may also propagate and grow through thermal erosion of the country rocks in a non-dilation environment (Fialko and Rubin, 1999).

Magma pressure and the regional stress field in addition to the host rock characteristics are the dominant factors that control the length/

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