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# Fractal Analysis of *In Situ* Host Rock Nepheline Syenite Xenoliths in a Micro-Shonkinite Dyke (The Elchuru Alkaline Complex, SE India)

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## ABSTRACT

**Formation of the fragments of the wall-rock during dyking is one of the important manifestations of instantaneous magmatic events. This process is well documented at shallower depths of Earth's crust but not at deeper levels. In this paper the *in situ* xenoliths of host rock nepheline syenite within a micro-shonkinite dyke emplaced at mid-crustal depths is described and the fractal theory applied to evaluate origin of the xenoliths. The nepheline syenite xenoliths are angular to oval shaped and sub-millimetre to ~50 cm long. The xenoliths are matrix supported with clasts and matrix being in equal proportions. Partly detached wall-rock fragments indicate incipient xenolith formation, which suggested that the model fragmentation processes is solely due to dyke emplacement. Fractal analytical techniques including clast size distribution, boundary roughness fractal dimension and clast circularity was carried out. The fractal data suggests that hydraulic (tensile) fracturing is the main process of host rock brecciation. However, the clast size and shape are further affected by post-fragmentation processes including shear and thermal fracturing, and chemical erosion. The study demonstrates that dyking in an isotropic medium produces fractal size distributions of host rock xenoliths; however, post-fragmentation processes modify original fractal size distributions.**

## INTRODUCTION

Fractal distribution of fragments i.e. scale-invariant size distribution was recorded in many physical processes including breaking of sea ice (Rothrock and Thorndike, 1984), rock fragmentation in nuclear explosions (Schoutens, 1979), projectiles (Lange et al., 1984), and asteroids (Donnison and Sugden, 1984). Most of the geological processes are also self-similar in nature i.e. follow fractal distribution. Statistically, power-law distribution of objects signifies fractal geometry. Ever since Mandelbrot (1967 and 1983) has applied this statistical distribution tool to analyze the coastlines of Briton, fractal analysis of the geologic features became a powerful means to test the scale-independent nature of geological processes (Matsushita, 1985; Turcotte, 1986; Sammis et al., 1986; Storti et al., 2003; Gonnermann and Manga, 2005; Perugini et al., 2007; Perugini et al., 2011). Many workers have demonstrated power-law variation of geological attributes from continental scale (mega faults) to micro-scale (micro-cracks) including river order (Korvin, 1992), fracture and fault dimensions (Marrett and Allemendinger 1991; Cowie and Scholz, 1992; Walsh and Watterson 1992; Pickering et al., 1995; Clark and Cox, 1996; Knott et al., 1996; Schlische et al., 1996; Gross et al., 1997; Poulimenos, 2000; Van Dijk et al., 2000; Volland and Kruhl, 2004), magmatic enclaves (Perugini and Poli, 2000; Holtz et al., 2004; Ventura et al., 2006; Ferreira et al., 2015), fragment boundaries (Jebrak, 1997; Bérubé and Jebrak, 1999; Bonnet et al., 2001; Dellino and Liotino, 2002; Lorilleux et al., 2002) and hydraulic conductivity in porous rocks (Korvin, 1992) validating their fractal behaviour. However, non-fractal behaviour of the fault and fracture growth (Cladouhos and Marrett, 1996; Nicol et al., 1996; Cello, 1997; Gudmundsson, 2004; Klausen, 2004; Mandal et al., 2006) and xenolith formation (Wolak et al., 2005; Marko et al., 2005; Hodge and Jellinek, 2012) have also been extensively documented. It is generally assumed that fractal size distribution results from stoping whereas non-fractal distribution of xenoliths sizes results from dyking (Glazner and Bartley, 2006).

Fragments associated with magma result from intrusion along pre-existing discontinuities (Platten, 1982; Delaney et al., 1986; Parkar et al., 1990) or dyke propagation and emplacement in an elastic medium (Johnson and Pollard, 1973; Delaney and Pollard, 1981; Pollard, 1987; Rubin, 1993). Fragmentation of the wall-rock during emplacement of dykes at shallower depths is well recorded and the processes of fragmentation are well constrained (see Jebrak, 1997). However, studies on fragmentation mechanisms at deep crustal levels are few (Morin and Corriveau, 1996) and at these depths the associated processes of thermal fracturing and chemical erosion modify fragments' original size and shape. It is widely shown that brittle materials fracture in a fractal pattern i.e., shows a linear relationship on a log-log plot between cumulative fragment frequency and fragment size. Fundamental fractal dimension (D) governs the scale-invariant growth of fractures during fragmentation, therefore, it is suggestive of the fragmentation process (Perfect, 1997). Xenoliths (fragments) are quantitatively classified (Jebrak, 1997) based on size distribution fractal dimension ($D_s$), the shape fractal dimension ($D_r$) and circularity (C).

In the present study possible mechanisms of fragmentation of the host rock nepheline syenite are evaluated by applying fractal analytical methods including clast size distribution, boundary roughness fractal dimension, and clast circularity analysis. The *in situ* nepheline syenite xenoliths occur within a micro-shonkinite dyke. The incipient nature of the xenoliths allows us to decipher the cause of fragment size reduction and change in shape due to magmatic processes but not due to attritional/tectonic comminution (see Platten, 1982; Mitchell, 1986; Jebrak, 1997). The main objective of the present study is two-fold: to evaluate (1) whether the fragmentation of the host nepheline syenite is fractal or non-fractal and (2) if fractal, how originally fractal distribution clast sizes and shapes may be affected by the post-fragmentation equilibration processes. In the paper alternatively xenolith/fragment/clast, which essentially define brecciated host rock is used.

## GEOLOGICAL SETTING

In the Prakasam Alkaline Province (PAP), Eastern Ghats Belt

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