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Size-distribution of scoria cones within the Eğrikuyu Monogenetic Field (Central Anatolia, Turkey)

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ABSTRACT

Eğrikuyu Monogenetic Field (EMF) is one of the five clusters of monogenetic volcanoes in Quaternary Central Anatolian Volcanic Province (CAVP). EMF consists mainly of scoria cones and a few maars (e.g. Kutören, Obruk). Previous studies on monogenetic volcanoes of CAVP mainly focused on petrologic evolution of scoria cones rather than the statistical analyses of their morphological parameters.

Using the database compiled by Arcasoy (2001) for the morphometric parameters of the scoria cones in the EMF, we present the power-law behavior of their size distribution with respect to basal diameters (Wco) of 77-scoria cones from the whole database. Both empirical (maximum likelihood estimation, MLE) and graphical (log–log plot) methods are used for the estimation of scaling parameter "*b-value*" of power-law for the scoria cones which have basal diameter greater than or equal to 0.36 km. However, graphical method gives the precise result with the *b-value* of 2.78 ± 0.08 for 77-scoria cones over the width range 0.1–1.23 km. Herein, *b-value* indicates the relative number of the small scoria cones with respect to large ones for a given area.

The power-law behavior of the size distribution of scoria cones in the EMF suggests that their occurrence is self-organized critical phenomena similar to earthquakes. Since the size-distribution of scoria cones provides information about their eruptive magnitude and occurrence mechanism, our results can be directly applied to future risk assessment of the CAVP.

1. Introduction

Monogenetic volcanic fields, as the name implies, consist of accumulation of numerous monogenetic volcanoes produced by a single episode of volcanic activity, lasting from few days to a few decades (Walker, 1993). The morphology and formation mechanisms of these volcanoes can be variable depending on magma compositions, volatile contents, and the effect of external water. When the monogenetic volcanoes form entirely under dry conditions, the main edifices are scoria (or cinder) cones, lava shields, and lava flows (Valentine and Gregg, 2008; Németh, 2010). However, if the magma encounters any sort of external water, the final edifices are different from those formed under dry conditions, including tuff rings, tuff cones, and maars (Lorenz, 1986). Such volcanoes have typically small eruptive volume individually. However, the eruptive volume of a monogenetic volcanic field might be as much as composite volcanoes (Németh, 2010).

Monogenetic volcanoes not only occur in relatively flat volcanic fields (e.g. Michoacán-Guanajuato Volcanic Field-MGVF), but also upon the flanks of polygenetic volcanoes as in the case of Erciyes Volcanic Complex (Turkey), Mauna Kea (Hawaii), Kilimanjaro (Tanzania) (Settle, 1979). Monogenetic volcanism is generally associated with the extensional tectonic regime (e.g., Springerville Monogenetic Field, USA). However, petrologic studies (Hasenaka and Carmicheal, 1987; Ercan et al., 1992; Luhr et al., 1995; Notsu et al., 1995; Alıcı-Şen et al., 2004) reveal that it can also occur in convergent (e.g., Abu Monogenetic Field, Japan), and transitional tectonic regimes (e.g. Pinacate Monogenetic Field, Mexico).

Scoria cones are the most common type of monogenetic volcanoes on Earth (Wood, 1980a, 1980b). The scoria cone forming eruptions controlled by magma flux, volatile content, viscosity, and vent setting are commonly called as "dry" processes such as Hawaiian or Strombolian-type eruptions (Cashman et al., 1999; Valentine and Gregg, 2008; Németh et al., 2011). Therefore, the scoria-rich pyroclastic deposits and related lava flows as resultant products of such eruptions are mostly basaltic in composition (Riedel et al., 2003; Martin and Németh, 2006; Valentine and Gregg, 2008).

Scoria cone can be defined as a simple truncated cone with a bowl-shaped crater at or near their summits (MacDonald, 1972). However, its resultant morphology can be elongated when the feeder dykes occur along a fissure (Valentine and Gregg, 2008). Eruptive processes (e.g. multiple feeder dykes, eruptive fissure and flank instability) and environmental effects (e.g. inclined pre-eruptive surface, wind) can all contribute to morphology of the final volcanic edifice (Martin and

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Németh, 2006). For instance, breached-type scoria cones owe their morphology to lava flow emittance, flank collapse and basal inclination (Németh et al., 2011).

The height (Hco), basal diameter (Wco) and crater diameter (Wcr) (if exists) with the repose angle close to 30° are typical geometrical parameters of the scoria cones (Porter, 1972; Wood, 1980a). Their basal diameters generally range from 250 m to 3000 m (Wood, 1980a). In addition, different geometrical parameters are correlated mathematically: Wcr/Wco = 0.4, Hco/Wco = 0.18 (Wood, 1980a). However, Favalli et al. (2009) questioned the validity of the latter ratio for the flank cones on large central volcanoes.

The morphometric parameters and spatial distributions of scoria cones have been commonly used as a proxy for, (1) the estimation of crustal thickness (Mazzarini, 2007; Mazzarini et al., 2010; Di Traglia et al., 2014), (2) their relative ages (Wood, 1980b; Dohrenwend et al., 1986; Hooper and Sheridan, 1998; Inbar et al., 2011), (3) clustering and alignment analyses (Connor, 1990; Connor and Hill, 1995; Lutz and Gutmann, 1995; Conway et al., 1998; Arcasoy et al., 2004; Bleacher et al., 2009; Richardson et al., 2013), and (4) understanding of their occurrence mechanisms (McGetchin et al., 1974; Head and Wilson, 1989; Riedel et al., 2003; Valentine et al., 2005; Martin and Németh, 2006; Rapprich et al., 2007; Kereszturi et al., 2010; Kereszturi and Németh, 2012a, 2012b; Kereszturi et al., 2012). Various statistical methods (e.g. Poisson nearest neighbor analysis, power-law, Kernel density method, two-point azimuth method, Hough transform method) have been applied to the analysis of spatial distribution of scoria cones in relation to their geological environments (Connor, 1990; Hooper and Sheridan, 1998; Thouret, 1999; Pyle, 2000; Mazzarini and Armienti, 2001; Riedel et al., 2003; Arcasoy et al., 2004; Pérez-López et al., 2011; Le Corvec et al., 2013).

The relationship between fracture systems and spatial distribution of scoria conesis explained by power-law, similar to many processes in nature (e.g., earthquakes, volcanic eruptions, landslides, floods) (Malamud and Turcotte, 1999; Pyle, 2000; Mazzarini and Armienti, 2001; Malamud, 2004; Malamud and Turcotte, 2006; Mazzarini et al., 2010). It might be used as a proxy for determining the feeder dykes as well (Takada, 1994; Mazzarini and Armienti, 2001). Pérez-López et al. (2011) suggested similar power-law relation between the relative numbers of small-sized scoria cones with respect to larger ones. In addition, the morphometric parameters of monogenetic volcanoes provide information about their eruption magnitudes (Pyle, 2000), and their classification (Dóniz-Páez et al., 2012).

In spite of increasing number of studies related to morphology of monogenetic volcanoes all over the world, there are few studies about the morphological characteristics of Quaternary scoria cones within the Central Anatolian Volcanic Province (CAVP) (Toprak, 1998; Arcasoy, 2001; Arcasoy et al., 2004) (Fig. 1). Most studies in the region focused on the petrologic evolution of the monogenetic volcanoes in CAVP (Keller, 1974; Batum, 1978; Ercan et al., 1992; Aydar et al., 1995; Notsu et al., 1995; Dhont et al., 1998; Alıcı-Şen et al., 2004; Gençalioğlu-Kuşcu et al., 2007; Gençalioğlu-Kuşcu, 2011). Eğrikuyu Monogenetic Field (EMF) is one the five clusters of monogenetic volcanoes in CAVP (Figs. 2 and 3) (Ercan et al., 1992; Notsu et al., 1995; Toprak, 1998), and includes mainly scoria cones and a few maars (i.e. Kutören, Obruk) (Toprak, 1998).

In this study, we aim to present the morphometric parameters of 77-scoria cones within the EMF and the power-law behavior of their size-distributions similar to Gutenberg-Richter (GR) law for the earthquakes. In order to estimate the scaling parameter *b*, both empirical and graphical methods are used. The indication for self-similarity of the size-

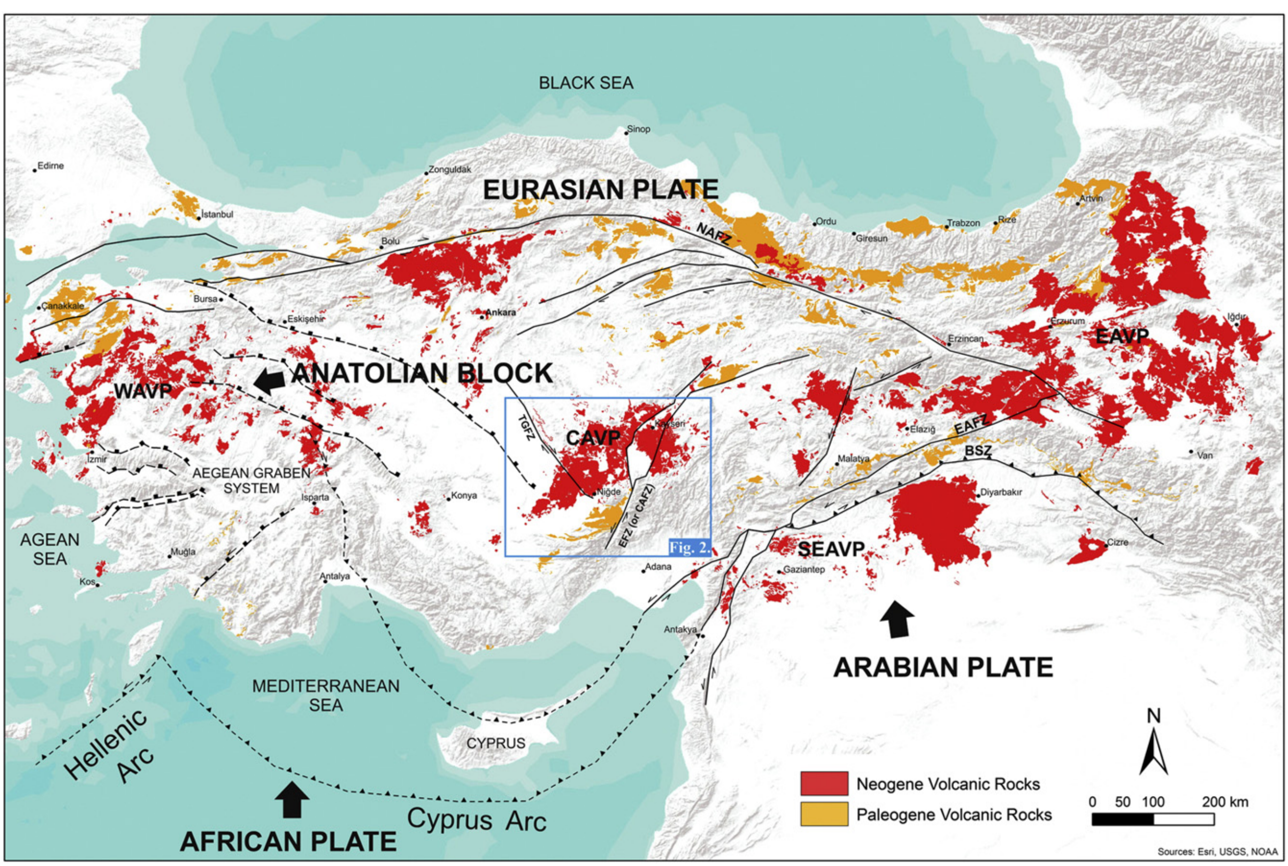

Fig. 1. Tectonic framework and Cenozoic volcanics of Turkey (compiled from Şengör and Yılmaz, 1981; MTA, 2002). Tectonic lineaments are North Anatolian Fault Zone (NAFZ); Tuz Gölü Fault Zone (TGFZ); Ecemiş Fault Zone (EFZ) (or Central Anatolian Fault Zone (CAFZ)); and Eastern Anatolian Fault Zone (EAFZ). Rectangle represents the CAVP.