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How Strombolian is a "Strombolian" scoria cone? Some irregularities in scoria cone architecture from the Transmexican Volcanic Belt, near Volcán Ceboruco, (Mexico) and Al Haruj (Libya)

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Abstract

Scoria cone modelling focuses on ballistic (no-drag) ejection that are termed Strombolian as a result of weak-intensity, strongly intermittent activity associated with bursting of gas bubbles resulting ballistic emplacement of clasts 10+ cm. Particles with a size <10 cm are normally unable to follow ballistic trajectories instead depositing from sub-Plinian eruption clouds. The Neogene volcanic field near Volcán Ceboruco in the San Pedro–Ceboruco graben, Mexico includes fissure fed flows, domes, and monogenetic scoria cones. The scoria cones near Ceboruco consist of normal (proximal) to inverse (distal) graded welded and/or non-welded scoria lapilli and coarse ash. The grain size pattern observed from scoria cones at Ceboruco is not consistent with the classic ballistic model of cone growth. Instead it is more consistent with recently proposed model where cones grow by accumulation of clasts falling from a sustained eruption column. Al Haruj a Miocene to Holocene intracontinental basaltic volcanic field in Libya preserves pyroclastic rocks indicating hot emplacement from eruptions of scoria cones and lava fountains. However, craters are commonly wide and surrounded by rims of strongly welded tephra, they closely resemble maar-structures. It is inferred that magmatic fragmentation of the uprising melt often has changed to phreatomagmatic interaction leading to enigmatic explosive events that have removed the top of the volcanic cones and produced maar-like depressions. In the two fields at least four different types of scoria cones have been distinguished that indicates a far greater diversity in eruptive mechanisms of scoria cones than those proposed by earlier researchers.

Keywords: Strombolian; Hawaiian; pit crater; maar; phreatomagmatic; tuff ring; erosion; scoria; spatter

1. Introduction

Scoria cones are the most common subaerial volcanic landforms on Earth and are generally considered to be a result of mild explosive eruption of mafic magmas in a short period of time (days, weeks) (Vespermann and Schmincke, 2000), however long-lived scoria cone eruption such as Paricutin in Mexico was active for 9 years (Luhr and Simkin,

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1993). In spite of the numerous scoria cones associated with volcanic fields and central volcanoes (e.g. along rift zones) there are only a few detailed studies that have been carried out on their architecture (McGetchin et al., 1972; Chouet et al., 1974; McGetchin et al., 1974; Head and Wilson, 1989; Riedel et al., 2003). Most studies are focused on clustering the scoria cones and their relationship to lithospheric structures (Connor, 1990; Condit and Connor, 1996; Conway et al., 1997), cinder cone degradation (Wood, 1980; Hooper and Sheridan, 1998; Inbar and Risso, 2001), and the geochemistry of the commonly present mantle nodules in the scoriaceous pyroclastic deposits of scoria cones (Pier et al., 1992; D'Orazio et al., 2000). Textural analysis of the eruptive products that are associated with intermittent magma/water interaction demonstrate the potential role of phreatomagmatism in the formation of the ejecta construct of the scoria cones (Houghton and Hackett, 1984; Houghton and Schmincke, 1986, 1989). Detailed analyses of deposits preserved on scoria cones lead to the clarification of the role of the shallow seated magmatic system in the control of the explosive eruptions of such volcanoes (Houghton et al., 1999). Among the identified parameters the variations in degassing patterns, magma ascent rates and degrees of interaction with external water are thought to be responsible for sudden changes in the eruption sequence from deposits representative for "wet" and "dry" eruption conditions (Houghton et al., 1999). Very recently particular attention has been payed toward the unusual explosiveness of some mafic volcanoes. This interest is driven by the potential volcanic hazards that such eruptions may pose to the environment and human society on active volcanoes. In general scoria cone-forming eruptions are linked to Strombolian-type activity driven by magmatic fragmentation occurring in the near surface region of the open volcanic conduit (Blackburn and Sparks, 1976; Houghton et al., 1999; Vespermann and Schmincke, 2000). Among scoria cones a great variety has been observed and described, which show gradual transitions between Hawaiian lava fountaining to moderate Strombolian-type eruptions. It has been suggested that magma ascent speed is the most important factor causing such transitions, with gas content and viscosity also influencing the ascent speed at which the transition occurs (Parfitt and Wilson, 1995). A decrease in gas content does not cause a transition from Hawaiian to Strombolian activity, but instead causes a transition to passive effusion of vesicular lava (Parfitt and Wilson, 1995). Some authors suggest that a change from Hawaiian to Strombolian style requires a significant reduction in magma ascent speed (Parfitt and Wilson, 1995). Strombolian eruptions are also common in eruptive periods of major composite volcanoes such as Etna, Italy (Harris and Neri, 2002) or Villarica, Chile (Lara, 2004). Such eruptions are often violent and produce large volume of ash distributed over large areas, such as the Vesuvius (Arrighi et al., 2001). However, some moderate to large explosive eruptions at several basaltic volcanoes were extremely violent in character, including large phreatomagmatic, sub-Plinian and Plinian types at Massaya, Nicaragua (Williams, 1983) or 1790 AD Keanakakoi eruption of Kilauea (Hawaii) (McPhie et al., 1990). Among many of the recently identified deposits related to basaltic explosive volcanism Tarawera 1886 eruption is a classical example of this type of eruptions, which was characterised by mafic (sub)-Plinian style (Houghton et al., 2004a). Such violent Strombolian eruption perhaps are known from Etna as well (Houghton et al., 2004a). "Violent Strombolian" eruptions are explosive eruptions of mafic magma characterised by eruption column heights <10 km, voluminous ash production, and simultaneous lava effusion (Cashman et al., 2004). The mechanism of generation, fragmentation, transportation and deposition of ash in these eruptions is poorly understood, however such eruption was just recently identified to have occurred not only during eruption of composite volcanoes but also in single scoria cones. The best example for such eruptions is Volcán Parícutin, Mexico (1943–1953). Eruptive products of Parícutin eruption include thick tephra deposits of alternating ash and lapilli beds few kilometres from the cone building pyroclastic units. Comparative studies indicated that other young monogenetic cones in the Michoacán, Mexico region may have erupted in a similar style as Parícutin. Here we give further field evidences that mafic violent Strombolian style eruptions among scoria cones may be more common than expected. A characterisation of scoriaceous ash and lapilli beds associated with scoria cones of the western Transmexican Volcanic Belt, near Volcán Ceboruco and Al Haruj, Libya is given here. The observations of these two volcanic fields allowed us to distinguish at least four different types of small-volume mafic explosive volcanoes on the basis of their pyroclastic succession preserved in the cone building units stratigraphic successions, on the areas surrounding the cones, the cone morphology and its relationship with the type of the preserved pyroclastic units (Table 1). The identified four types of cones however rather end-members. The transition between different types of cones is seemingly continuous. The formation and the