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# Growth of an emergent tuff cone: Fragmentation and depositional processes recorded in the Capelas tuff cone, São Miguel, Azores

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**Abstract**

The Capelas tuff cone is an emergent Surtseyan-type tuff cone that erupted in shallow seawater off the coast of São Miguel, Azores. In this paper, we present a detailed stratigraphic study which is used to infer depositional processes and modes of fragmentation for the Capelas tuff cone deposits. The growth of the tuff cone can be divided into three stages based on variations in depositional processes that are probably related to differences in water/magma (W/M) ratios. The first stage corresponds well to wet Surtseyan-type activity where wet fallout is the dominant depositional process, with only minor representation of pyroclastic surge deposits. The second stage of the eruption is suggested to be the result of alternating wet and slightly drier periods of Surtseyan activity, with an overall lower W/M-ratio compared to the first stage. The drier Surtseyan periods are characterized by the presence of minor grain-flow deposits and undulating pyroclastic surge deposits that occasionally display relatively dry structures such as strongly grain-segregated layers and brittle behavior when impacted by ballistic ejecta. The first deposits of the second stage show an intense activity of pyroclastic surges but fallout, commonly modified by surges, is still the dominant depositional process during the second stage. The third stage represents a final effusive period, with the build-up of a scoria cone and ponded lava flows inside the tuff cone crater.

Phreatomagmatic fragmentation, as seen by studies of the fine ash fraction (<64 μm), is dominant in the Capelas tuff cone. However, particles with shapes and vesicularities characteristic of magmatic fragmentation are abundant in proximal deposits and present in all investigated beds (in various amounts). Emergent Surtseyan-type tuff cones are characterized by a domination of fallout deposits, both wet and dry, where dry periods are characterized by the deposition of relatively dry falling tephra transforming into grain-flow deposits. However, this study of the Capelas tuff cone shows that drier Surtseyan periods may also be represented by an increased amount of thin surge deposits that occasionally display dry features.


*Keywords:* Azores; tuff cone; phreatomagmatic; Surtseyan; depositional processes; facies; Scanning Electron Microscopy

## 1. Introduction

Monogenetic volcano fields occur in a variety of geological settings (Walker, 2000; Németh et al., 2003) and consist of volcanic landforms and products produced during single eruptions over a relative short time span. Products of such fields include scoria cones, small lava flows, tuff rings, tuff cones and maars (White, 1991; Walker, 2000; Connor and Conway, 2000). One of the main factors controlling the morphology of the resultant landform is the amount of external water present at the time of eruption (Sheridan and Wohletz, 1983; Wohletz

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and Sheridan, 1983; Wohletz and McQueen, 1984; Lorenz, 1986; Sohn, 1996; Vespermann and Schmincke, 2000). Eruptions occurring in well-drained areas generally produce scoria cones, whereas maars and tuff rings/cones are produced by explosive phreatomagmatic eruptions as the result from magma interaction with ground- and/or surface-water (Wood, 1980; Wohletz and Sheridan, 1983; White, 1991). Eruptions that emerge through standing water generally produces tuff cones and are commonly termed Surtseyan eruptions, after the eruption of Surtsey 1963–1967 (Thorarinsson et al., 1964; Kokelaar, 1983; Moore, 1985; Sohn and Chough, 1992, 1993; Cole et al., 2001). Tuff cone-forming eruptions are characterized by a domination of fallout deposits, resulting in steep cone morphology and a high aspect ratio (i.e. height/crater diameter; Wohletz and Sheridan, 1983) (Thorarinsson et al., 1964; Sohn and Chough, 1992, 1993; Sohn, 1996; Vespermann and Schmincke, 2000). Tuff rings are suggested to consist mainly of base-surge deposits resulting in low angle ring morphology and a low aspect ratio (Wohletz and Sheridan, 1983; Sohn, 1996; Vespermann and Schmincke, 2000). The resultant morphology of the pyroclastic construct is directly controlled by depositional processes (Sohn, 1996), which are in turn controlled by a number of combined factors such as the properties, behavior, premixing, and mass-ratios of water and magma, vent geometry and physical properties of the surrounding bedrock (Kokelaar, 1986; Sohn, 1996; Vespermann and Schmincke, 2000; White and Houghton, 2000). Several studies have shown that a phreatomagmatic landform may consist of both tuff ring and tuff cone deposits due to changes in eruption style and depositional processes (Aranda-Gómez and Luhr, 1996; Sohn and Park, 2005). Thus, several factors need to be considered when classifying a phreatomagmatic landform. It is therefore essential to make more detailed stratigraphic studies of tuff cones/rings in order to consider what causes the observed variation in the deposits during growth, and finally to achieve a common classification scheme for phreatomagmatic landforms.

This study aims to identify various characteristic sedimentary deposits occurring in a well-exposed and nearly complete diagonal sequence of the Capelas tuff cone in order to deduce the processes responsible for the growth of the tuff cone. The tuff cone does not have any other rings/cones or maar-structures in the immediate vicinity and we thus infer a single vent to be responsible for the investigated deposit. We use morphology and textures of ash-particles, determined using images

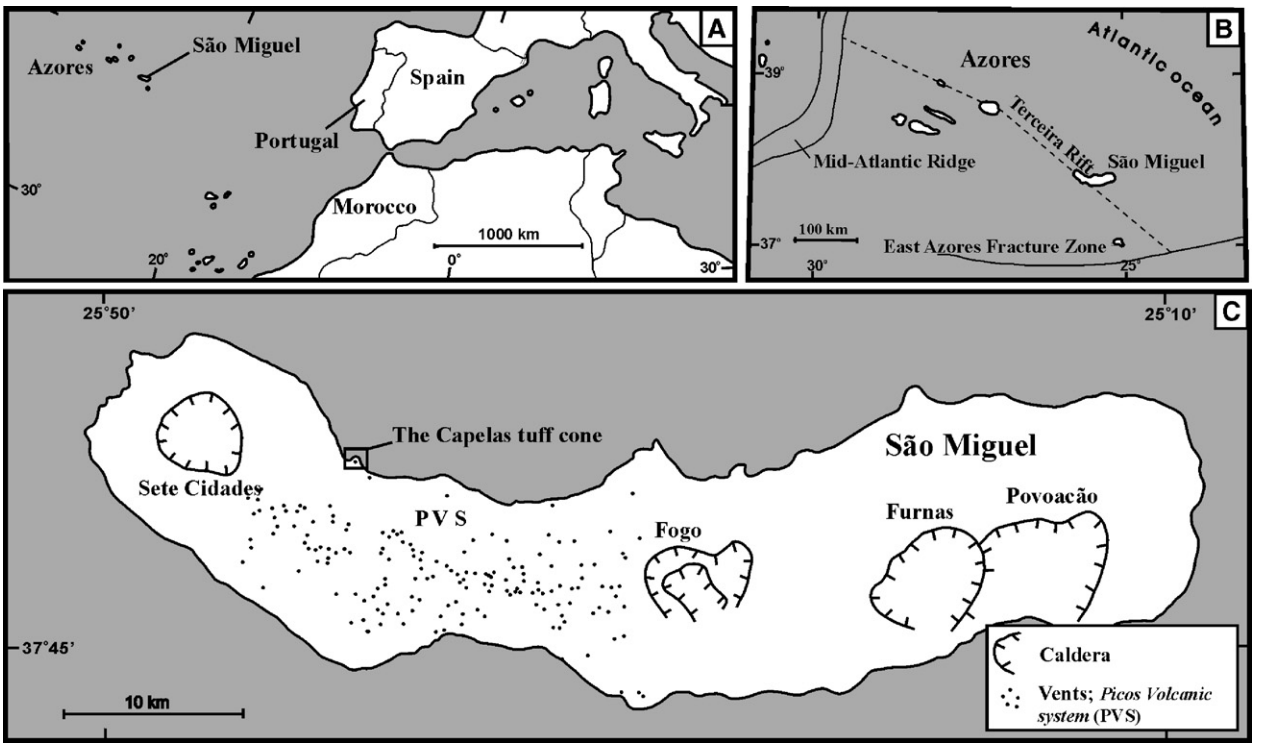


Fig. 1. Map showing (A) the location of the Azores (B) the Azores archipelago in relations to the Mid-Atlantic Ridge (MAR) and the Terceira Rift (C) the island of Sao Miguel with position of the Capelas tuff cone and Picos Volcanic System (PVS) (maps modified after Moore, 1990).