Journal of Volcanology and Geothermal Research 318 (2016) 1–18

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Reconstructing the evolution of an eroded Miocene caldera volcano (Yamanlar volcano, İzmir, Turkey)

Özgür Karaoğlu [a,b,*], Richard J. Brown [c]

[a] Eskisehir Osmangazi University, Department of Geological Engineering, 26040 Eskisehir, Turkey
[b] Department of Earth Sciences, Royal Holloway University of London, Egham TW20 0EX, UK
[c] Department of Earth Sciences, Durham University, Durham DH1 3LE, UK

ARTICLE INFO

Article history:
Received 5 November 2015
Received in revised form 8 March 2016
Accepted 8 March 2016
Available online 9 March 2016

Keywords:
Caldera
Explosive volcanism
Pyroclastic density current
Ignimbrite
Yamanlar
Turkey

ABSTRACT

The Miocene Yamanlar composite volcano is located in the central part of a shear zone in western Turkey. The volcano's deeply-eroded interior provides excellent three-dimensional exposure of a faulted caldera-floor and caldera-fill rocks as well as surrounding extracaldera ignimbrites. We present a much-revised stratigraphy and geological map of Yamanlar in order to quantify the evolutionary stages of the volcano. The Yamanlar volcanic cone was composed of >800 m of basaltic-andesite to andesite lavas and lava domes. The volcano underwent at least one phase of caldera formation associated with an explosive eruption that deposited an ignimbrite sheet within and outside the caldera. Lithofacies architecture analysis is applied to the proximal and medial exposures of the Early-Middle Yamanlar Formation, which occurs outside of the caldera. Field evidence of the succession indicates a caldera-forming eruption. Our results indicate that the formation of the Yamanlar caldera resulted from one major catastrophic eruption that generated several sustained pyroclastic density currents (PDCs) subdivided by fall deposits with sharp contacts. The ignimbrite sheet is composed of four flow units. The presence of numerous coarse-grained lithic-rich horizons within the ignimbrite sheet is consistent with caldera subsidence. Post-caldera volcanism is indicated by intrusions and lava domes erupted along the inferred caldera-bounding faults, some of which record ~90 m of displacement. Widespread, coarse-grained breccias that overlie the ignimbrite sheet are interpreted as debris avalanche deposits resulting from gravitational failure of the flanks of the volcano or the caldera wall during or after caldera subsidence.

1. Introduction

Large polygenetic composite volcanoes can have lifetimes that can exceed 1 My (Elmadağ volcano in western Turkey, 16.28–17.29 Ma; Karaoğlu et al., 2010) and have complex histories involving effusive and explosive eruptions, large-scale failure, and caldera formation. Their evolutionary pathways are controlled by the regional stress regime and by the flux and chemical evolution of magma in the crust. Composite volcanoes can consist of a single volcanic edifice, or nested and/or overlapping edifices such as stratovolcanoes (e.g. Wood, 1978; Davidson and de Silva, 2000; Kereszturi et al., 2010). Large composite volcanoes are constructed by hundreds to thousands of eruptions (0.52–0.01 Ma, 200 km^3 in volume for Mount Adams, Davidson and de Silva, 2000; from 0.53 Ma to recent, 64 km^3 in volume for Nemrut Caldera, Karaoğlu et al., 2005; Sumita and Schmincke, 2013). They undergo both constructive and destructive phases throughout their lifetime. Early phases involve initiation of a centralised vent feeder system. In volcanic fields, early shields can develop to such composite systems as is the case in many large and complex composite volcanoes such as Chichinautzin field in Toluca, Guilbaud et al. (2015); Tongariro — New Zealand, Scott and Potter (2014); China — North Korea, Utkin (2014). A large part of their lifecycle is dominated by effusion of lava and the construction of a volcanic cone (e.g. Taranaki volcano — New Zealand, Procter et al., 2009; Zernack et al., 2011). Large cones are prone to periodic collapse and debris avalanche formation. Generation of sufficiently debris avalanche deposits can occur during the latter stages of cone growth. Extinct composite volcanoes undergo substantial erosion (e.g. Wood, 1978; Hackett and Houghton, 1989; Thouret, 1999; Davidson and de Silva, 2000; Bishop, 2009). Sedimentary responses to volcanic eruptions depend on a complex interplay between the volume, nature and distribution of the pyroclastic material (dispersal, vesiculation, fragmentation, welding etc.), the physiography and hydrology of the affected environment, its energetic conditions, the availability of accommodation space, and temporal effects such as the repose interval between the additions of new material (Manville et al., 2009; e.g. Taraniki — New Zealand; Procter et al., 2009; Zernack et al., 2009).

* Corresponding author at: Eskisehir Osmangazi University, Department of Geological Engineering, 26040 Eskisehir, Turkey.
E-mail address: ozgur.karaoglu@deu.edu.tr (Ö. Karaoğlu).

http://dx.doi.org/10.1016/j.jvolgeores.2016.03.007
0377-0273/

Yamanlar volcano, in the Yuntdağı volcanic region, western part of the Menderes Massif, Turkey, is an eroded Miocene caldera volcano that provides an opportunity to study processes related to composite volcano growth, caldera-forming eruptions and degradation in a region of strong tectonic deformation (Figs. 1 and 2). With the exception of a few volcano-stratigraphic studies (e.g. Karacık and Yılmaz, 1998; Karaoğlu, 2014; Seghedi et al., 2015), previous work on the western part of the Menderes Massif (Fig. 1b) was mainly focussed on geochemistry and petrology, or on post-collision related volcanism at a regional scale. In many cases, the physical volcanology and volcanic history of the volcanoes remains poorly constrained.

Yamanlar volcano has a 5.5 × 8.5 km Cenozoic caldera that exhibits evidence for chaotic, highly fragmented piecemeal collapse. An ignimbrite forming explosive eruption devastated an area of at least 100 km^2. A large volume for the ignimbrite has been inferred based on the inundation area and thickness of pyroclastic deposits in the İzmir Gulf (Fig. 1a). Tectonically and erosionally dissected topography provides three-dimensional exposures through the caldera and its related rocks.

In this paper we document the volcanic rocks and eruptive history of the Yamanlar volcano in the Yuntdağı volcanic region (Fig. 2). We present a detailed lithostratigraphy through previously undescribed lavas, and pyroclastic and volcaniclastic deposits, which we use to reconstruct the growth history of the volcano, and provide insights into the formation of the caldera. We document the first evidence for tectonic faulting at Yamanlar immediately before and during caldera development.

1.1. Terminology and methodology

The deposits of Yamanlar volcano have been mapped over 250 km^2 at a scale of 1:25,000 (Fig. 2). Lithofacies descriptions for the pyroclastic rocks (Table 1) are based upon sedimentary structure, grain size, sorting, and follow the terminology of Branney and Kokelaar (2002). Grain-size nomenclature follows that developed by Cas and Wright (1987) for volcanic deposits. The pyroclastic rocks are indurated and grain-size and clast abundance data have been visually estimated using estimation charts in the field. Lateral lithofacies associations were identified by tracing marker horizons such as fine-grained tuff layers across the region. We use primary volcaniclastic terminology (e.g. breccia, tuff, lapilli-tuff, ignimbrite, or tuff) since they show features common of deposits of pyroclastic density currents (cf. White and Houghton, 2006). The term pyroclastic density current (PDC) is used for any type of gaseous current carrying pyroclastic material, and ignimbrite for the pumiceous deposit of a PDC. We use flow unit to define an ignimbrite (e.g. ign-1) bounded by horizons (such as fall deposits) that indicate pauses in activity.

2. Geological setting

The Yamanlar and Yuntdağı volcanic region forms part of an extensive province of Miocene monogenetic and polygenetic volcanoes that extends from Balıkesir to Karaburun (Fig. 1) on a shear zone that reactivated across faults. Miocene volcanism in western Anatolia was mainly controlled by: (1) exhumation processes of the northern part of the Menderes Massif core complex (MMCC) resulted in the NE–SW-trending extensional basins (Ersoy et al., 2010; Karaoğlu et al., 2010; Karaoğlu and Helvacı, 2012a, 2012b); (2) the western part of the MMCC which is directly controlled by a shear zone (Kaya, 1981; Ring et al., 1999) and (3) the eastern side of the MMCC which is bounded by a sustained driven Uşak Muğla Transfer Zone (UMTZ) (Karaoğlu and Helvacı, 2012a, 2012b, 2014) (Fig. 1).

The geology of the western part of the Menderes Massif core complex is dominated by high-K, calc-alkaline to potassic and ultrapotassic volcanic rocks (e.g. Ersoy et al., 2010; Karaoğlu, 2014). Although intermediate composition volcanism was active between 23 and 7 Ma, most of the explosive volcanic eruptions from composite volcanoes that produced voluminous deposits (e.g. ignimbrites) and most monogenetic volcanoes erupted between 23 and 16 Ma ago (Borsi et al., 1972; Savaşçın, 1978; Ercan et al., 1996; Seghedi et al., 2015). The products of explosive volcanism in the region include widespread intensely welded ignimbrites and lithic breccias. The welded ignimbrites include two that are rheomorphic and are concentrated around the Bigadiç-Koza area, in the northern part of the Yuntdağı volcanic region (Fig. 1). Extensive non-welded ignimbrites outcrop in the southern part of this region (in the Yuntdağı and Karaburun volcanic regions, Fig. 1).

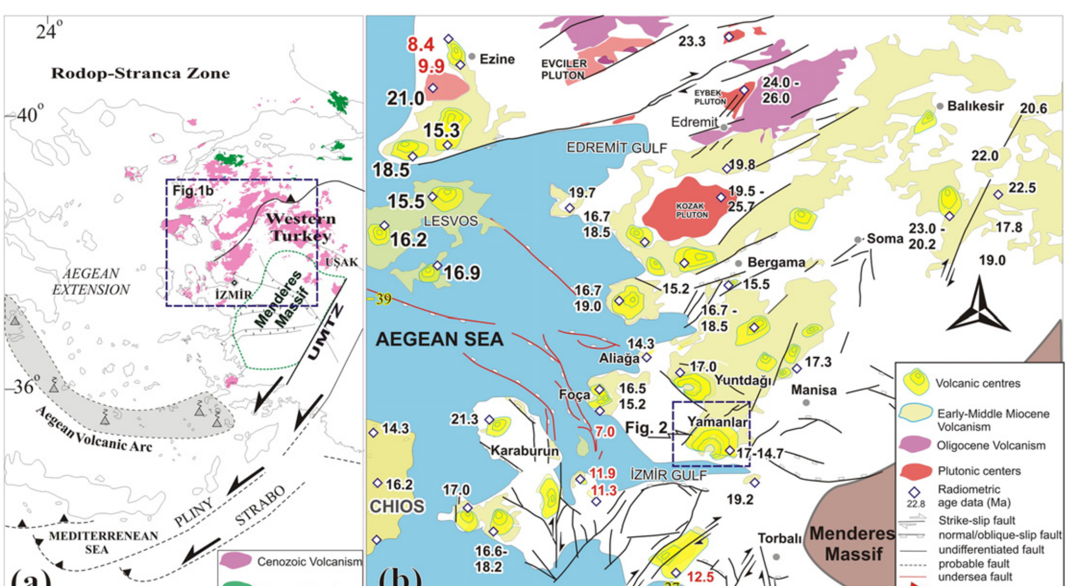

Fig. 1. (a) Tectonic map of western Turkey and distribution of the Cenozoic magmatic rocks in the region (modified from Ersoy et al., 2014; Karaoğlu, 2014, references therein). Green area showing pre-Cenozoic and pink area showing Cenozoic magmatic rocks; (b) simplified geologic map showing main faults/fault zones and Neogene magmatic units. The numbers next to diamonds indicate the ages of the volcanic units in millions of years. See Karaoğlu (2014) for references about the age and fault data. UMTZ: Uşak-Muğla transfer zone. For colour images the reader is referred to the online version of the paper.