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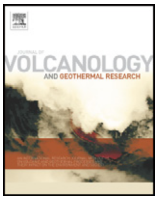

Shallow plumbing and eruptive processes of a scoria cone built on steep terrain

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ABSTRACT

Dark Peak (Lunar Crater Volcanic Field, central Nevada, USA) is an eroded Pliocene, monogenetic basaltic volcano that exposes intrusions while preserving some pyroclastic deposits and lavas, allowing reconstruction of the shallow magma feeding system and its relation to eruptive processes. Variably welded agglomerates record Strombolian and Hawaiian fountaining. Dikes fed degassed magma to a bocca on the lower cone slopes and fed a small lava field. The cone was built on the side of a steep ridge with small side drainages, had a maximum diameter of about 1 km, and was ~125 m high above the highest point on the paleotopography. The eruption was fed by an ~1 km long, narrow (1–3 m) feeder dike that locally flared in the upper tens of meters to form an ~30 m wide conduit around which the cone was built. The conduit shape and the transition depth from feeder dike to conduit are consistent with data from other exposed plumbing systems of small volume basaltic volcanoes that were dominated by magmatic volatile-driven eruption styles, supporting inferences that their conduits are relatively shallow features (upper ~150 m).

1. Introduction

Monogenetic volcanic eruptions driven by magmatic volatiles typically result in scoria cones often, with related tephra deposits, and lava fields. The eruptions can have durations of days to years with varying eruption styles that produce complex deposits (e.g. Parícutin, Mexico; Luhr and Simkin, 1993). Previous workers have related variable eruption styles to the geometry of shallow magma feeding systems (plumbing). For example, Pioli et al. (2008) discussed the role of lateral diversion of melt to feed lavas, while gas-rich magma feeds explosive eruptions from a cone summit. Genareau et al. (2010) suggested that the focusing of magma flow from an initial dike geometry to that of a central conduit can cause an eruption to shift in style. Models of the shallow plumbing typically assume simple shapes, such as a flared or straight-sided cylinder (Delaney and Pollard, 1981; Wilson and Head, 1981; Papale et al., 1998; Mastin and Ghiorso, 2000; Mitchell, 2005). Limited field measurements of subsurface plumbing of scoria cones exist (Keating et al., 2008; Geshi et al., 2010; Hintz and Valentine, 2012), but are needed to better constrain eruption models.

One way to gather data on shallow plumbing is to study volcanoes that have been deeply eroded. Dark Peak, a scoria cone remnant in the southern Lunar Crater Volcanic Field, has sufficient erosion (~100 m) to expose its feeder intrusions while preserving proximal pyroclastic deposits that give information on eruptive processes. Here we provide detailed descriptions and reconstruction of the eruptive sequence and its plumbing, and compare this information with existing published data.

2. Geological setting

The Lunar Crater Volcanic Field (LCVF) is located in central Nevada, USA, within the central Basin and Range Province. It forms a linear, north-northeast trending belt of mafic volcanoes that were preceded by Oligocene–Lower Miocene caldera-forming volcanism (Hintz and Valentine, 2012). Basaltic activity began ~6 Ma (Yogodzinski et al., 1996) and continued until ~38 ka (Shepard et al., 1995). The >100 volcanic centers are preserved in the Reveille Range in the south and the Pancake Range to the north (Fig. 1). The volcanoes occur in clusters, linear chains of vents, and as isolated vents (Hintz and Valentine, 2012; Tadini et al., 2014). They preserve evidence of a range of volatile-driven eruption styles including Hawaiian, Strombolian, and violent Strombolian (Hintz and Valentine, 2012; Valentine and Cortés, 2013; Johnson et al., 2014). The most abundant eruptive landforms are scoria cones with associated lava flow fields. At least three maars and tuff rings also exist in the Pancake Range, suggesting phreatomagmatic activity (Scott and Trask, 1971; Dickson, 1997; Valentine et al., 2011; Valentine and Cortés, 2013). While at any given time volcanic activity was occurring throughout a large part of the field, there was a general migration of volcanism from south to north (Naumann et al., 1991; Foland and Bergman, 1992; Yogodzinski et al., 1996). The result is variably eroded volcanic vents in the southern part of the field and pristine vents with little erosion in the north.

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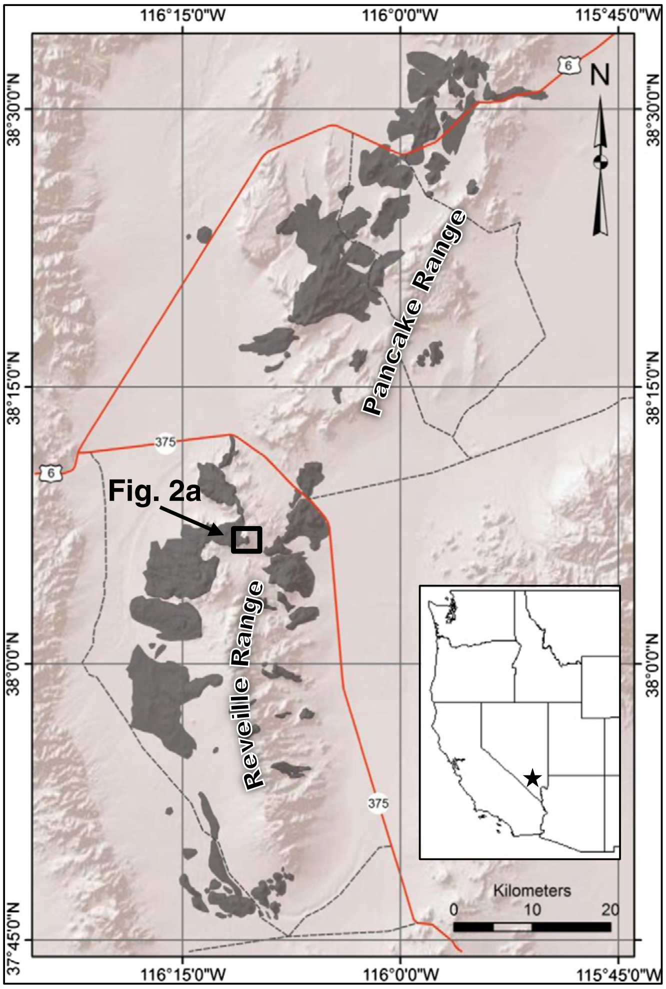

Fig. 1. Map of the Lunar Crater Volcanic Field indicating the locations of basaltic volcanism (in black). Based on previous maps Scott and Trask (1971), Ekren et al. (1973), Martin and Naumann (1995), and Dickson (1997).

Dark Peak (Fig. 2) belongs to the Pliocene age group of eroded volcanoes in the Reveille Range. The host rock through which Dark Peak magma erupted is a silicic ignimbrite related to the Oligocene Caldera of the Northern Reveille Range. Erosion incised deep east–west trending drainages into the ignimbrites providing topographic lows that were filled by later basalts. Dark Peak and its associated deposits are located along the eastern rim of the Caldera of the Northern Reveille Range, which was characterized at the time of eruption by a series of steep knobs and drainages. Dark Peak is rugged black peak that erupted along a topographic ridge in the center of the Reveille Range. The peak and its immediate surroundings preserve remnants of a scoria cone, with a range of pyroclastic deposits and lavas, and a group of intrusions that formed within tens of meters of the surface and within the cone. A large lava field that was partly fed by Dark Peak eruptions extends to the west of the peak. We first describe Dark Peak's intrusions, followed by eruptive products.

3. Shallow intrusions

Five intrusions were observed on the flanks of Dark Peak, two within the Tuff of the Northern Reveille Range (the feeder dike and conduit), and three emplaced in the pyroclastic material (AgN) of the scoria cone (the radial dike, bocca, and south dike; Table 1).

3.1. The feeder dike

The feeder dike is a subvertical tabular body ~908 m long and 1–3 m wide, with the exception of two local sill-like features that widen the intrusion up to 15 m, each along about 20 m of dike's length (Table 1). The sills are located ~550 m and ~900 m north of Dark Peak. The dike is three distinct groups of en echelon segments <50 m long located northeast of Dark Peak (Fig. 3). It is composed of coherent basalt (DB; note we use the term coherent basalt for intrusive basaltic rocks or clastogenic lavas with few to no highly deformed relic clasts, while the term dense refers to low vesicle contents) which is dense, poorly vesicular, and rich in plagioclase phenocrysts. The petrography of samples collected from each segment reveals the presence of plagioclase and altered olivine phenocrysts within a microcrystalline matrix (Table 2).

Plagioclase phenocrysts are preferentially oriented to form a fabric within the dike that can be measured in the field and in thin sections from oriented samples. Fabrics along dike margins are strongly influenced by simple shear forces acting on any high-aspect-ratio crystals (Geoffroy et al., 2002), and those crystals would tend to align their long axes at low angles to the magma flow direction (Ildefonse et al., 1992; Arbaret et al., 1996). Rose diagrams (Fig. 4A) of crystal orientations in the thin sections coupled with outcrop observations and oriented vesicles (Fig. 4B, C) reveal both horizontal and vertical flows.

3.2. The conduit

The conduit is exposed on the northeast side of Dark Peak, ~25 m below the summit (Fig. 3), and is characterized by an upward widening of the feeder dike (Table 1). It is exposed along a steep (~40°) northeast-facing hillside that provides a three-dimensional exposure: 50 vertical meters, 50 m north–south (horizontal), and 60 m east–west (horizontal). The conduit and feeder dike are composed of coherent basalt with minor proportions of welded and nonwelded agglomerates (Fig. 5), which cut through, and merge with, eruptive deposits lying on the Tuff of the Northern Reveille Range. At the lowermost exposure of the outcrop, 23 m below the paleosurface (pre-eruptive surface), the feeder dike strikes 040° and dips 60° to the southeast, consistent with jointing in the host rock. There, the dike is 1.2 m wide, massive with blocky joints, and poorly vesicular (<3%). Its contacts are parallel and smooth without breccia zones, splays, or included wall rock. Approximately 21 m below paleosurface the dike is 1.4 m wide. At the same depth, intrusive splays of basalt ~10–15 cm wide and 1–2 m long extend from the feeder dike along the western margin whereas the eastern margin is relatively sharp and planar (Fig. 6A). Along the dike's margin is an ~25 cm wide zone of flattened vesicles which are <6 cm long and containing fragments of host rock 1–6 cm in size. A dike sample collected ~20 m below the paleosurface was thin sectioned and the orientations of plagioclase crystals were determined, showing a sub-vertical fabric consistent with vertical magma flow (Fig. 6B). Orientations of stretched tuff fragments indicate flow directions similar to those shown by plagioclase fabric. Fifteen meters below the paleosurface, the feeder dike transitions to the conduit as the boundaries with the host rock flare outward at ~60° (Fig. 7). Slicken lines within the basalt along the southern margin indicate that sub-vertical emplacement, and along the northern margin a vertical domain of basalt-dominated breccia with angular, 15–25-cm-long clasts of host tuff, defines the contact with the Tuff of the Northern Reveille Range.

The upper parts of the conduit, which transition from subvertical to subhorizontal contact orientations, allow partial reconstruction of the paleotopography (pre-existing topography). The southeast part consists of coherent basalt that contains host rock fragments. Angular blocks of weathered tuff, 5–200 cm in size, formed the paleosurface on which this basalt was initially emplaced. The paleotopography sloped to the south with a topographic high immediately north of the vent. As a result, lava flow emplacement was southward (and possibly westward). Flows range from 2 to 5 m in thickness, and relic clasts of host rock