



RESEARCH ARTICLE

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Key Points:

- InSAR and microseismic study following the 2011 eruption at Nabro, Eritrea.
- InSAR shows subsidence, best modeled by a Mogi source at 6 km depth.
- Seismicity suggests that subsidence is controlled by changes in the magma chamber.

Supporting Information:

- Readme
- Figure S1
- Figure S2

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Seismicity and subsidence following the 2011 Nabro eruption, Eritrea: Insights into the plumbing system of an off-rift volcano

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Abstract Nabro volcano, situated to the east of the Afar Rift Zone, erupted on 12 June 2011. Eruptions at such off-rift volcanoes are infrequent, and consequently, the plumbing systems are poorly understood. We present posteruption Synthetic Aperture Radar (SAR) images from the TerraSAR-X satellite and posteruption continuous seismic activity from a local seismic array. Interferometric analysis of SAR data, reveals a circular, 12 km wide, signal subsiding at ~ 200 mm/yr. We inverted for the best fit Mogi source finding a $4 \pm 1 \times 10^7$ m³/yr volume decrease at 7 ± 1 km depth. Between 31 August and 7 October 2011, we located 658 and relocated 456 earthquakes with local magnitudes between -0.4 and 4.5 . Seismicity beneath the SE edge of Nabro at 11 km depth is likely associated with high strain rates from deep magma flow into the modeled reservoir. This suggests that magma is supplied through a narrow conduit and then stored at ~ 7 km depth. We interpret seismicity at 4–6 km depth as brittle fracturing above the inferred magma reservoir. Focal mechanisms delineate a thrust fault striking NE-SW and dipping 45° to the SE across the caldera floor. We propose that the crustal response is to slip on this fault which crosscuts the caldera rather than to deform on ring faults. The NE-SW fault plane is not associated with measurable surface deformation, indicating that it does not contribute much to the caldera deformation. We show that subsidence of the caldera is controlled by magma chamber processes rather than fault slip.

1. Introduction

During continental rifting the majority of active volcanism typically becomes focused in a central rift axis [Ebinger and Casey, 2001]. In the Afar region of Ethiopia, this is expressed as laterally stepping en echelon volcanic ranges that accommodate most of the extension [Floyd and Ebinger, 1996]. However, volcanic structures are also commonly found off-set from the axis of spreading [Ebinger, 1989; Kiselev, 1987; Abebe et al., 1998; Sturkell et al., 2003; Bosworth et al., 2005]. Termed "off-axis" or "off-rift" volcanoes, their magma supply and their role in accommodating extension remains unclear (e.g., Micallef et al., 2014). Furthermore, eruptions of off-rift volcanoes are infrequent, limiting opportunities to observe them when active. The eruption of Nabro volcano on 12 June 2011 was only the second eruption of an off-rift volcano associated with the Afar Rift Zone (ARZ) in modern times (since Dubbi volcano in 1861 [Wart and Oppenheimer, 2000]). It was also the volcano's first in the historical period [Wart and Oppenheimer, 2005]. Here we analyze posteruption seismicity and Interferometric Synthetic Aperture Radar (InSAR)-derived surface deformation to understand the subsurface magmatic system of this hazardous, off-rift volcano.

Nabro volcano is located on the central part of the Danakil microplate on the southern margin of the Danakil Alps [Berhe, 1990] in NE Afar (Figure 1). It is the largest volcano in the ~ 110 km long Nabro Volcanic Range (NVR), which trends NNE-SSW and extends from Ban' Ale volcano in Ethiopia to the Kod Ali formation in the Red Sea [Wart and Oppenheimer, 2005]. A subsection of the NVR is the Bidu Volcanic Complex (BVC) composed of the Nabro and Mallahle calderas. Nabro comprises a horseshoe-shaped caldera reaching 8 km in diameter, open to the SW and facing the smaller 6 km diameter caldera of Mallahle volcano [Wart and Oppenheimer, 2005]. The summit of Nabro is 2248 m above sea level (asl), making the BVC one of the largest massifs in the Afar region.

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