Stalled Eruption or Dike Intrusion at Harrat Lunayyir, Saudi Arabia?

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The extensive harrat lava province in Saudi Arabia formed during the past 30 million years in response to Red Sea rifting and mantle upwelling. The area was regarded as seismically quiet, but between April and June 2009 a swarm of more than 30,000 earthquakes struck one of the lava fields, Harrat Lunayyir, in northwest Saudi Arabia. Concerned that larger damaging earthquakes might occur, the Saudi Arabian government evacuated 40,000 people from the region. We combine geologic, geodetic and seismic data to show that the earthquake swarm resulted from a magmatic dike intrusion. We document a surface fault rupture that is 8 km long with 91 cm of offset. InSAR measured surface deformation is best modelled by the shallow intrusion of a north-west trending dike that is about 10 km long. Seismicity associated with the swarm consisted primarily of 'normal' high frequency tectonic earthquakes. However, a percentage of the earthquakes exhibit overlapping very low- and high-frequency components. Based on the temporal occurrence and signal characteristics, we interpret the low frequencies to represent the extensional crustal accommodation of the intruded magma and the high frequencies to represent brittle fracturing of the crystalline basement rocks. Rather than extension being accommodated entirely by the central Red Sea rift axis, we suggest that the broad deformation observed in Harrat Lunayyir indicates that rift margins can remain as active sites of extension throughout rifting. Our analyses allowed us to forecast the likelihood of a future eruption or large earthquake in the region and informed the decisions made by the Saudi Arabian government to return the evacuees.