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The continued 2008-2010 subsidence of Dallol on the spreading Erta Ale ridge: InSAR observations and source models

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Volcanoes commonly subside during eruptions as magma flows out of a chamber, but continued subsidence during non-eruptive episodes is not easy to explain. In this work, we use InSAR and source modelling to understand the causes of the continued subsidence of Dallol, a nascent volcano along the spreading Erta Ale ridge of Afar (Ethiopia). The Dallol volcano never erupted and no volcanic deposits originating from the volcano exists at the surface. Recent seismicity, diking and continuous deformation of a crustal magma chamber indicate the Dallol is a nascent central volcano with its own rift segment. An active magma plumbing exists and the injection of a dike beneath the volcano was imaged in 2004 from InSAR data. This unrest episode was followed by complete quiescence until subsidence started in 2008. We analysed InSAR data from 2004-2010 to create time-series of line-of-sight (LOS) surface deformation. Average velocity maps show that subsidence centred at Dallol initiated in October 2008 and continued as far as February 2010 at an approximately regular rate of up to 10 cm/yr. The inversion of InSAR average velocities found that a sill-like source, located a depth between 1.2 and 1.5 km under Dallol with a mean volume change of -0.62 to -0.53 10^6 km^3/yr and a radius of approximately 1.6 km, best fits the InSAR observations. The observed volume change could be explained by changes in pore fluid pressure in a confined hydrothermal aquifer or by thermoelastic deformation caused by changes in temperature in a volume of rock. Simple models of poro-elastic and thermo-elastic contraction indicates that the observed deformation would require either a decrease in pore fluid pressure of the order of 10^{-2}G, where G is the rock shear modulus, or a decrease in temperature between 60 °C and 80 °C.