Geophysical Research Abstracts
Vol. 17, EGU2015-4802-1, 2015
EGU General Assembly 2015

Dynamics of Santorini volcano (Greece) during the 2011-2012 unrest

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At Santorini (Thera) caldera, all known significant volcanic activity following the Minoan eruption about 3,500 years ago, have been confined to the nearly-linear tectono-volcanic zone of Kameni Line (KL). Although there has been geodetic evidence for small-scale inflation of the northern part of the caldera in the 1990's, probably associated with intrusions along another major tectono-volcanic zone (Columbo Line, CL), KL has remained seismically quiescent for decades. Hence, swarms of microseismicity that occurred along KL in 2011 and 2012 were regarded as evidence of a possible reactivation of the volcano. Because of extensive hydrothermal venting in the areas, hydrothermal activity was considered as a possible cause of at least a part of the observed deformation, but no strong evidence to support this possibility was found. Analytic modeling of available GPS and InSAR geodetic data permitted the identification of a single inflationary source within the north rim of the caldera, several kilometers north of the seismicity along the KL. While this source explains most deformation data, it underestimated the magnitude of inflation along southern sites. Likewise, Coulomb failure modeling of stresses associated with the northern inflationary source precludes the possibility of the pressure source directly caused microseismicity along the KL, contrary to the expectation of most researchers studying the activity.
For these reasons we explored new analytic models that allow for multiple distinct spherical inflationary sources to describe the geodetic observations between 2011 and 2012. The new models evaluated deformation across four distinct intervals, each several months long and corresponding to different levels of seismicity and magnitudes of deformation, using the internally developed TOPological INVersion method. This analysis showed that ground deformation reflects the possible interplay of two different magma sources. The first source is located similarly to what has been previously observed in the northern portion of the caldera at about 4 km depth, however the second source is about 8 km depth and below most of the microseismicity along the KL. The deeper sources appear short-lived, probably reflecting rapid pulses of magma injections from depth. Because of their location, they increase the Coulomb failure stresses along the KL, but are insufficiently long to generate easily discernable geodetic signals from intermittent observational methods including InSAR and campaign GPS.