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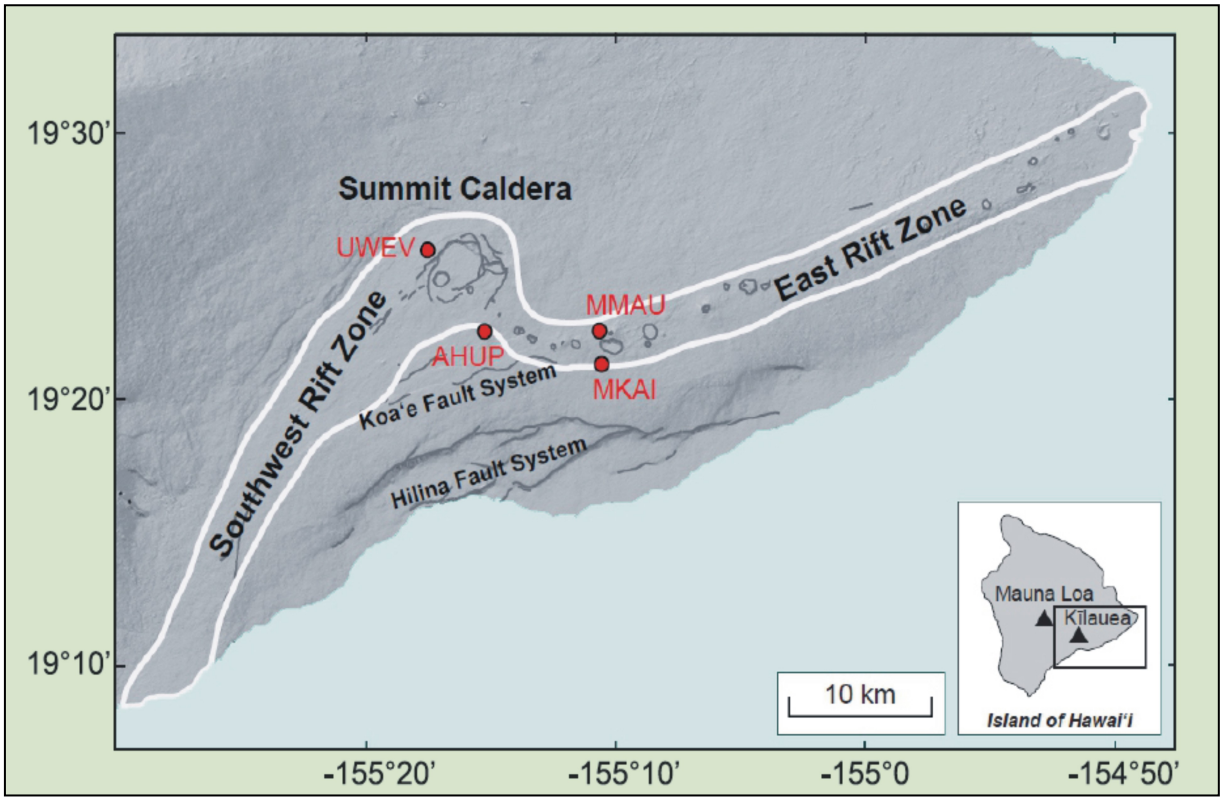
Mechanical interactions between pressure sources and rift zones at Kilauea Volcano, Hawaii

Pulvirenti F.[1*], Aloisi M.[2], Carbone D.[2], Poland M.[3], Vinciguerra S.[4]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA
[2] INGV - Osservatorio Etneo, Catania, Italy
[3] Cascades Volcano Observatory, Vancouver, USA
[4] Department of Earth Science, University of Turin, Italy
* Presenting author

Introduction

Underground pressure sources and rift zones may act jointly during phases of volcanic activity. Degradation of the mechanical properties of the host rock, can enhance tensile stress along zones of weakness, as suggested at different volcanoes, including Mt. Etna, Piton de la Fournaise and Montserrat, from seismic, gravity and ground deformation data (e.g., Carbone et a., Earth-Sci. Rev., 2014).

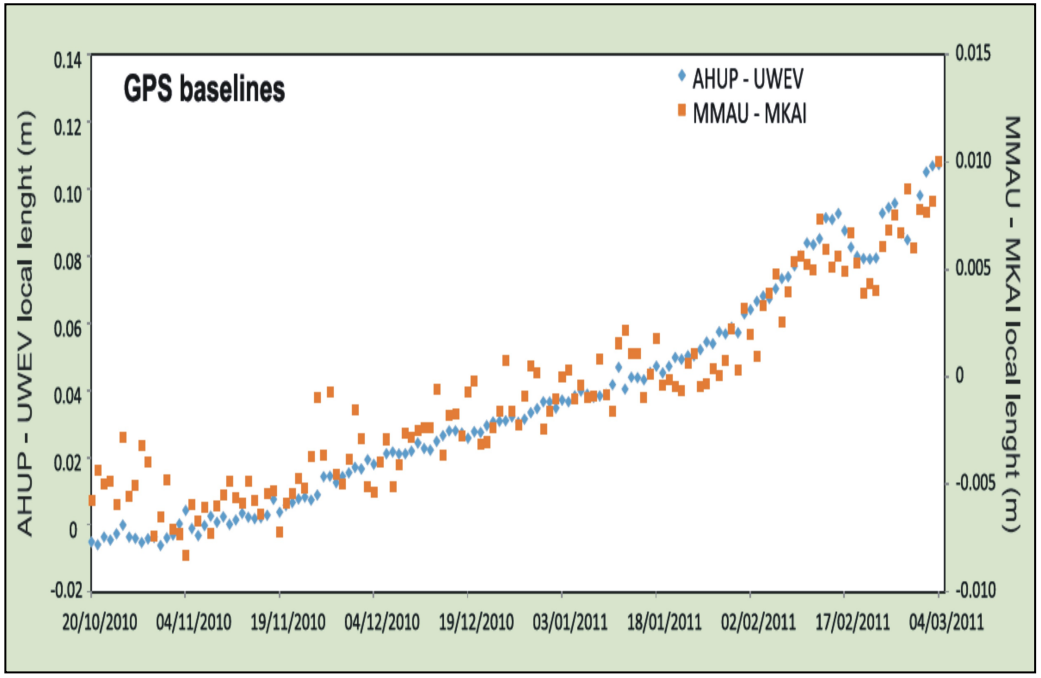


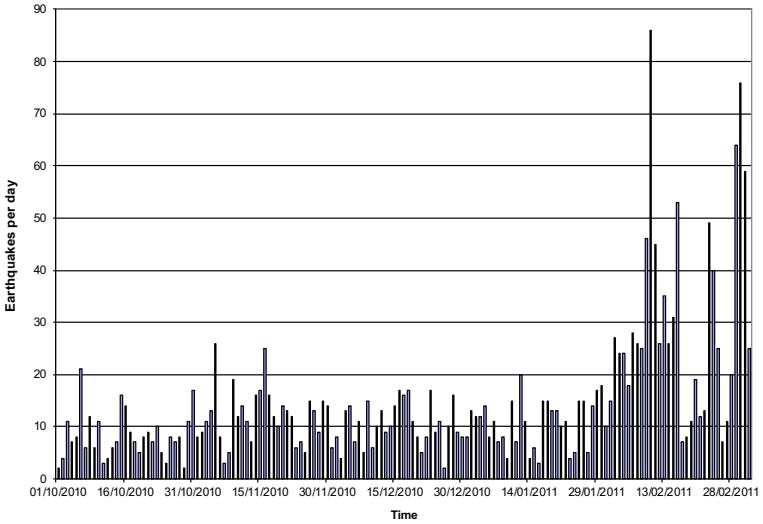
At least two magma storage zones are present beneath the summit of Kilauea:

(i) a smaller reservoir about 1.5 km beneath the central part of the caldera

(ii) (ii) a larger reservoir 3-5 km beneath the southern part of the caldera.

Ground deformation

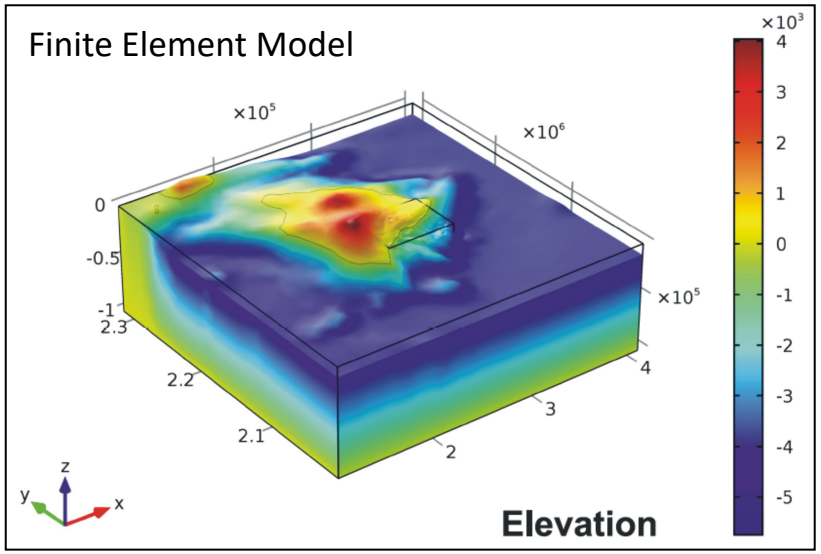


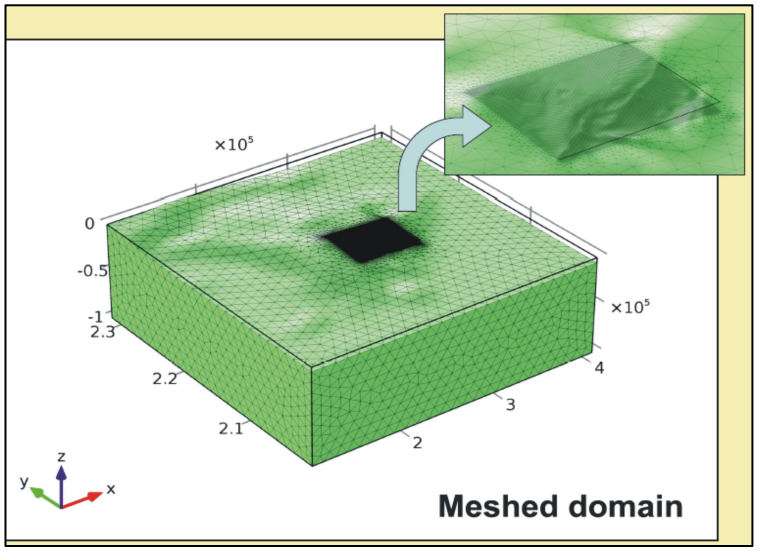


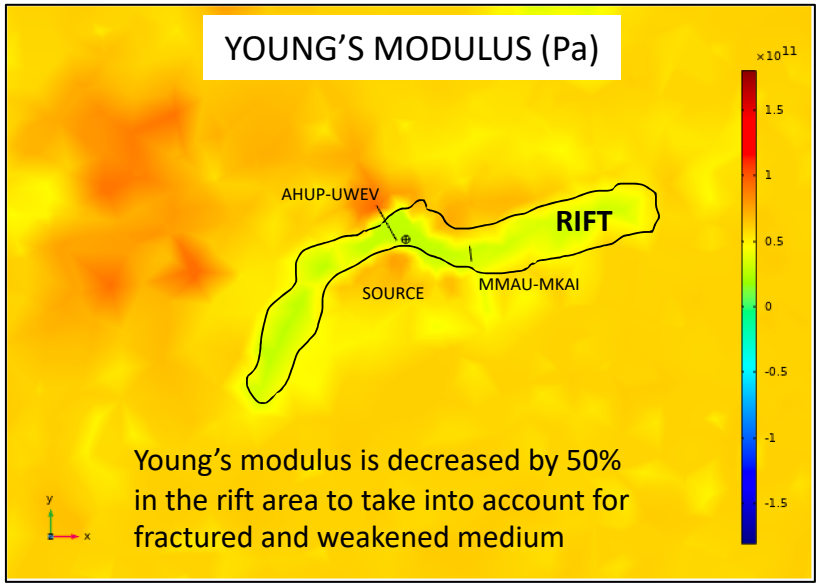
Changes in distance for the baseline across the summit crater (AHUP-UWEV) and the central part of the East Rift zone (MMAU-MKAI). Positive changes indicate extension.

For 4.5 months before the March 5-9, 2011 fissure eruption, the two baselines were affected by coupled extension with an amplitude ratio (summit vs ERZ) on the order of 7. During the same period, a significant increase in seismicity was also observed along the upper ERZ.

Modeling source position and pressure



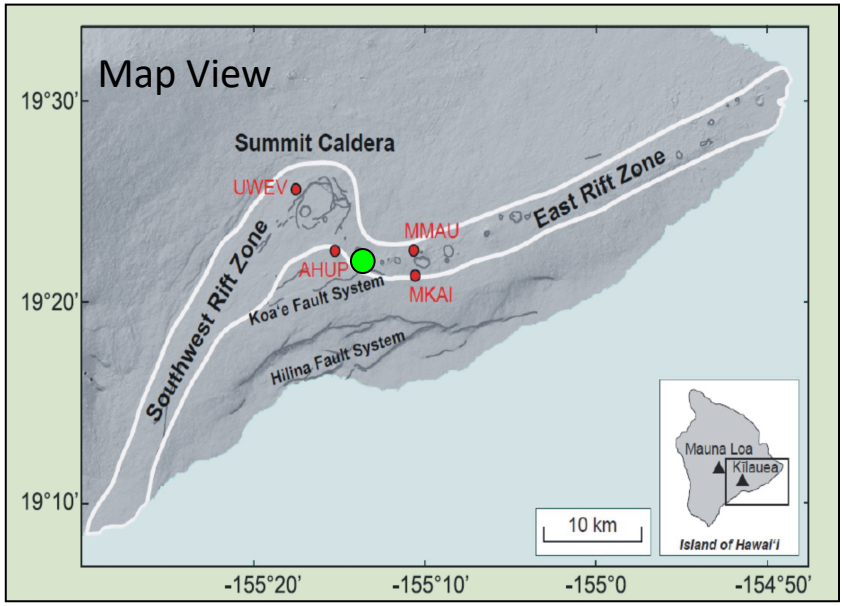


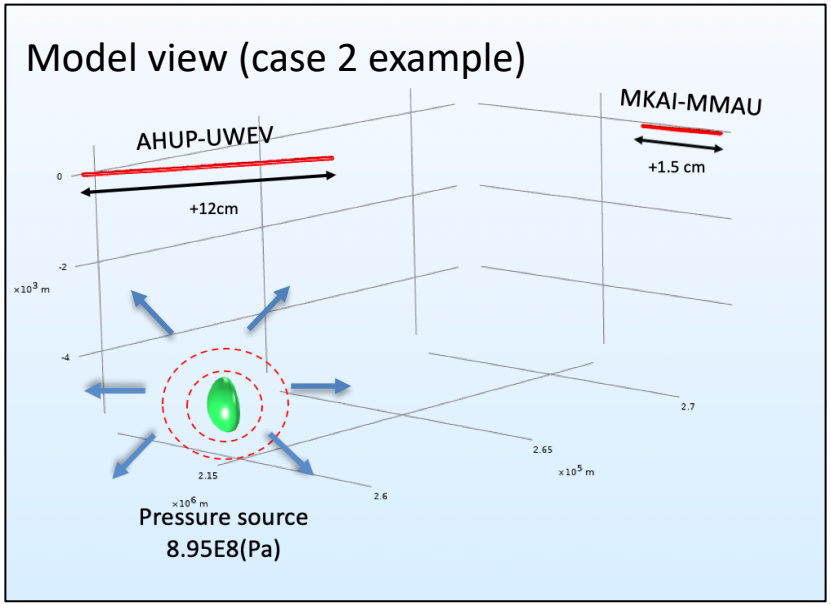


A finite element model is used to find the position and pressure of the large reservoir (SOURCE) in order to fit the recorded cumulative elongation at the baselines AHUP-UWEV (+12cm) and MMAU-MKAI (+1.5cm)
Source starting position (UTM):260761 East, 2146003 North and -3.5km b.s.l.

CASE 1: Tomography from Lin et al., 2014
CASE 2: Same as case 1 but with Young's modulus reduced by 50% in the rift area (Heap et al., 2009)

Preliminary results





Case 1
(Tomography from Lin et al 2014)

Best match with recorded data is obtained for a source shifted 2.4km east, 1.2km south and at 5km b.s.l. with respect to the original position. Required pressure is about 2.2 GPa.

We obtain +12cm at AHUP-UWEV and +1.4 cm at MKAI-MMAU.

Case 2
(50% reduced Young's mod. at the Rift)

Best match with recorded data is obtained for a source shifted 2.4km east, 1.5km south and at 5km b.s.l. with respect to the original position. Required pressure is about 0.9GPa.

We obtain 12cm at AHUP-UWEV and 1.5cm at MKAI-MMAU.

Preliminary Conclusions

Assuming the deformation at the baselines as induced by one pressure source, preliminary results suggest that:

- The source should be located slightly eastward of AHUP station and should be deep (5km b.s.l.).
- The range of pressure is between 0.9-2.2GPa. The lower limit is found considering degradation of mechanical properties in the Rift, as suggested from experimental tests of stress cycles on rock samples.
- Changes of the medium mechanical properties in extensional stress regime can favor magma intrusion along the rift.

Future steps

- Improve the source position and pressure constraint with other geodetic dataset
- Assess the effect of the shallower source (not considered in this study)
- Assess how the coupling between the underground pressure sources and the degradation of the mechanical properties of the rift zone modulates magma accumulation and transport processes.