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Linking gravity and seismic data encompassing the 2001 eruption at Mt Etna volcano (Italy): the analogy with rock deformation laboratory experiments

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We investigate the relationship between changes of the gravity field and the release of the seismic energy at Mt. Etna during a 12-year period encompassing the 2001 eruption. Through the joint analysis of the seismic and gravity data new inferences can be drawn about the dynamics of the upper southeastern flank of the volcano.

Even though independent evidences indicate that, during the 1994-2001 period, this sector was external to the magma ascent path from the deep seated source to the summit craters, using gravity data we show that it was the focus of long-term mass decreases occurring at a depth between 2 and 4 km b.s.l. and during the two sub-periods of higher strain release rate. Furthermore, almost half of the 2-4 km deep earthquakes, observed during each sub-period, had hypocenters that clustered within the volume inferred to contain the gravity source. We propose that the joint occurrence of mass decrease and increase in the strain release rate images phases of higher tensional stress in the upper southeastern flank, inducing rarefaction of the weak crust along the NNW-SSE structural alignment (thus a local mass decrease) and higher then usual release of seismic energy.

This behavior mirrors the mechanical response, coupled with the monitoring of microseismicity, of a rock volume during a triaxial rock deformation experiment. Constant strain rate deformation experiments carried out on Etna basalt revealed that, after the early stages of loading when the sample is affected by significant volume decrease (compaction), accompanied by low seismic output randomly distributed, cracks start to interact and the volume of the sample increases (dilatancy), as well as the rate of the seismic energy released. A slowly expanding nucleation volume is observed and clusters of seismic events localize within it, till the macrofracture propagates dynamically. The experimental observation is consistent with the patterns observed at Etna during the periods when gravity decreases (indicating fracturing/rarefaction of the medium), due to density decrease in the volume releasing most of the seismic energy.

The second period of gravity decrease/strain release increase culminated in the breakout of the 2001 flank eruption, as a pressurized deeper magma accumulation used the inferred zone of increasing microfracturing as a path to the surface. This eruption marked an important modification in the structure of Etna's plumbing system, as also testified by the absence of long-term gravity changes and accelerations in the strain release curve for five years after its breakout and by the post-2001 neat modification of the seismicity and ground deformation patterns.

Besides shedding new light on the dynamics of the upper southeastern flank of Etna, we discover non-clichéd possibilities of microgravity studies at active volcanoes: if utilized in particular geodynamic contexts, such as Etna's, and in conjunction with the information derived from seismic studies, they can allow to discover the ongoing formation of zones of rarefacting medium, and thus of "paths" able to convey the ascent of magma, months to years before the occurrence of a lateral intrusion.