Geophysical Research Abstracts
Vol. 15, EGU2013-13777, 2013
EGU General Assembly 2013

Coronae as a result of giant magma intrusions in the lithosphere of Venus: insights from laboratory experiments

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Coronae on the surface of Venus are unique volcano-tectonic structures in the solar systems. Their circular morphology is associated with various topographic signatures, from bell-shape domes, flat-topped plateaus, to uplifted rings surrounding a subsided centre similar to caldera. Their extensive size and associated lava flows erupting from their periphery, indicate that they result from deep processes in the Venus mantle. Understanding their origin is thus essential for unraveling the dynamics of Venus through time. There are several scenarios explaining the formation of coronae, the most popular being the interaction between an upwelling mantle plume and the lithosphere, creating dynamic topography. In this contribution, we propose that coronae can result from the emplacement of giant magma intrusions below the Venus' lithosphere, on the basis of laboratory experiments.

The experimental apparatus consists of a square box filled with compacted fine-grained silica flour (model crust), in which a low viscosity vegetable oil (model magma) is injected at constant flow rate. The initial conditions are such that magma initially flows horizontally, forming a sill-like body, to simulate magmatic underplating. During the experiments, oil injection triggers deformation of the model surface, which is monitored periodically using a moiré projection device, producing time series topographic maps of the model surface. Our results show that the surface evolution of the models follows three stages: (1) initial bell-shaped doming occurs above the injection inlet, producing radial open fractures at the model surfaces; (2) the bell-shape dome evolves to a flat-topped plateau, at the rim of which the oil erupts; (3) after the injection stops, the centre of the plateau subsides, and a positive topographic ring surrounding a depression, like a caldera, remains. The collapse of the plateau also generates concentric extensional fractures at the rims of the caldera. After the dynamic experiment, the oil solidifies and we extracted the intrusion, which exhibits a sill-shape, feeding outward circular inclined sheets at its external edges (i.e. a saucer-shaped sill). From a series of experiments in which the depth of injection h was varied, we show that the diameter of the intrusion and its associated topographic structure correlates linearly with h.

The three evolutionary stages simulated in the experiments reproduce remarkably well (1) the three main corona morphologies observed on Venus, and (2) their established succession through time. In addition, the relationships between the structures and the oil flow in our experiments are also similar to those observed on Venus. Therefore, our experimental results suggest that corona structures are the result of giant magma intrusions in the lithosphere of Venus. In addition, our experiments suggest that the diameters of coronae are related to the depth of emplacement of the underlying intrusions, which might be controlled by the rheological architecture of the Venus' lithosphere. Therefore, the analysis of the dimensions and morphologies of coronae are likely to provide crucial information of the structure of the lithosphere of Venus.