EPSC Abstracts
Vol. 6, EPSC-DPS2011-554, 2011
EPSC-DPS Joint Meeting 2011

FEM modelling of concentric and radial structures on Ascraeus Mons

R.Pozzobon (1), A. Bistacchi (2), M. Massironi (3), G. Cremonese (1)

(1) INAF – Istituto Nazionale di Astrofisica, Padova, Italy, (2) Department of Geoscience and Geotechnologies, Milano-Bicocca University, Italy, (3) Department of Geoscience, University of Padova, Italy

Abstract

Ascraeus Mons is the northernmost of the three large shield volcanoes on the Tharsis Rise on Mars. In this work we test the hypothesis that the latest volcano-tectonic evolution of the Ascraeus Mons could have been driven by an oblate magma chamber inducing injection of sheeted and radial dikes with distribution that recall the ones of the Cuillins cone sheet complex on the isle of Skye (Scotland). Indeed in this latter case Finite Element Modelling (FEM) has demonstrated that the distribution of dykes predict an oblate shallow magma chamber. On the basis of an accurate mapping of the Ascraeus Mons structures on high resolution stereo camera (HRSC) image mosaic, we were able to recognize concentric and radial structures, and to assess their interactions and attitudes. These remote sensing observations, combined with other physical parameters such as crustal thickness, critical distance of transition between concentric and radial fracture systems, gravitational load of the volcanic body, allow to infer, trough a FEM analysis, the possible presence of an oblate magma chamber at the time of the youngest volcano-tectonic event, its dimensions, depth and the tensional state of the system within particular overpressure/inflation conditions within the magma chamber itself. In addition the age of the deformational event that formed the fracture patterns was calculated through crater counting.

1. Introduction

The spatial distribution and orientation of dykes propagating from a shallow magma chamber is a key element in understanding the stress field and internal growth of volcanoes on terrestrial planets. The observed structures on Ascraeus flanks show strong analogies with concentric dykes (cone sheets) and fractures on many terrestrial volcanoes such as Isla Fernandina (Galapagos), Tejeda Complex (Canary Islands) and Cuillins Complex (Isle of Skye, Scotland).

In this last case inward dipping cone-sheets, developed under magma inflation conditions, displaying either pure dilatational or hybrid shear kinematics. Cone sheets disappear beyond a critical distance and are substituted by a set of parallel subvertical dykes perpendicular to the regional least compressive stress axis.

To explain this structural setting Bistacchi et al. (2010) [1] developed a finite element model analysis, which for the first time include an elasto-plastic rheology and consider the total stress field deriving from gravity, tectonics and magma chamber overpressure. Their numerical modeling shows that only in the case of a shallow oblate magma chamber cone sheets may be predicted for realistic magma overpressure values.

The typical dyke geometries required by an inflating oblate magma-chamber in the transition zone between radial and concentric dykes include: intersection or substitution of coeval inward-dipping cone sheets and vertical radial dykes, hybrid structures showing both a radial and concentric behavior.

2. Structural Interpretation

The cartography of the main structures on the Ascraeus Mons was performed on a HRSC nadir level 3 images mosaic with 12 m/pixel of spatial resolution. Concentric pit chains and grabens, dominate the volcano-tectonic structures, particularly near the foot of the summit shield and increase their concentration towards the two NE-SW big aprons, especially the northern one. Pit craters are organized into single elongated collapse pits or long chains (up to 70 km of length) formed by small incipient pits, in some cases linked by normal faults. Grabens are usually longer than pit chains, and may present collapse pits in their inner part.

Radial structures are almost the same features of the concentric ones including grabens and pit chains, but they are in general less common than the concentric and are generally restricted to the NNE and SSW quadrants on the two big aprons. In between a transition zone show interactions geometries between radial and concentric structures suggesting their coeval activity and a frequent permutation between $\sigma 2$ and $\sigma 3$.

Concentric and radial structures were dated by crater counts on coeval lava flows using a mosaic obtained by Context Camera images (CTX, Mars Reconnaissance Orbiter mission) with a spatial resolution of 6 m/pixel. The resulting ages range from 60 to 100 Ma.

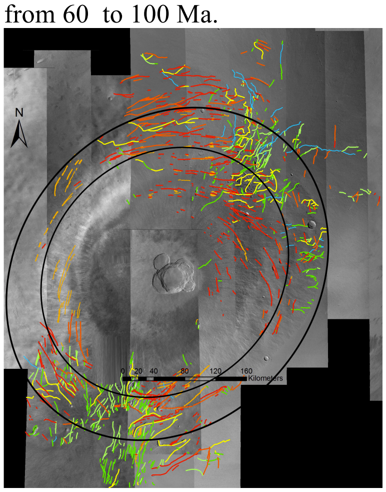

Figure 2: interpretation of Ascraeus structures (red: concentric, green: radial, yellow: transitional). The transitional zone is highlighted

3. FEM modelling

According to Bistacchi et al. (2010) [1] cone sheets appear to be confined within a distance from the central axis of about 1-1.2 diameters of the magma chamber, whilst radial dikes dominate beyond this critical limit. From our measurements the transition zone on Ascraeus occurs at 180-200 km (fig.2) we estimated a magma chamber radius of ~150 km. The model geometry was built using MOLA (Mars Orbiter Laser Altimeter) topographic data and a cylindrical axial symmetry. Several magma chamber depths were tested going form a state of deflation to a maximum overpressure of 40 MPa with steps of 5 MPa. The most likely depths in agreement with the observed structures on the volcano flanks range from 70 to 90 Km.

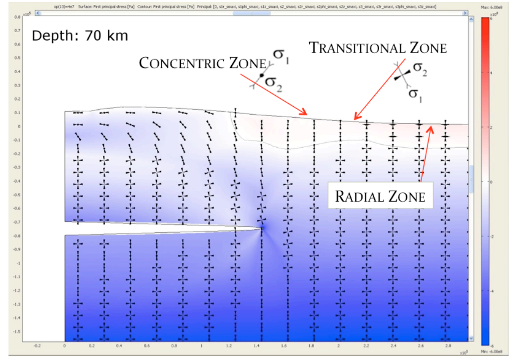

Figure 3: resulting stress field in the FEM model with an oblate magma chamber at 70 km of depth

4. Summary and Conclusions

The distribution, interaction and orientation of the youngest concentric and radial structures of the Ascraeus Mons are comparable with the conesheet and radial dikes of the Cuillins Complex. This seems to support a renewed inflation of the Ascraeus volcanic edifice due to an oblate magma chamber which led to the formation of and dilatant and extensional structures possibly postdating the compressional flank terraces (Byrne et al., 2009) [2]. The most compatible stress field originating the structures mapped on the HRSC images, was obtained from the FEM modeling which consider an oblate magma chamber at a depth of ~70-90 km and with a radius of ~150 km. One remarkable aspect that come from the modeling is that the stress field which creates the tensional zone depends only on the depth of the magma chamber, its diameter and its oblate shape. The thickness and the curvature at the tip of the chamber do not affect sensibly the resulting stress field. This suggest that the position of the upper part of the magma chamber is crucial, whereas it is almost impossible to confirm a presence of a plume through the applied FEM modeling.

References

[1] Bistacchi A, Tibaldi A., Pasquarè F.A., Rust D., 2010, Magma migration below volcanoes: the Isle of Skye, Scotland, the intrusive system revisited, In Press

[2] Byrne P. K., Van Wyck de Vries B., Murray J. B., Troll V., 2009, The geometry of volcano flank terraces on Mars: Earth and Planetary Science Letters 281, 1–13