EPSC Abstracts
Vol. 5, EPSC2010-743, 2010
European Planetary Science Congress 2010

Association of late cone sheets and radial dykes on Ascraeus Mons

R.Pozzobon (1), A. Bistacchi (2) and E. Simioni (3) M. Massironi (1) G. Cremonese (4)

(1) Department of Geoscience, University of Padua, Italy, (2) Department of Geoscience and Geotechnologies, Milano-Bicocca University, Italy, (3) Department of Information Engineering, University of Padua, Italy, (4) Department of Astronomy, University of Padua, Italy

Abstract

Ascraeus Mons is the northern of the three large shield volcanoes on the Tharsis Rise on Mars. In this paper 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 image (HiRiSE, HRSC) and DTMs, we were able to recognize concentric and, radial structures, and to assess their interactions and attitudes. These observations, combined with other physical parameters such as crustal thickness, critical distance of transition from local to regional stress field, 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 and the tensional state of the system within particular overpressure/inflation conditions within the magma chamber itself.

1. Cuillins cone sheet complex and the related oblate magma chamber

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 classical Cuillins cone-sheet complex on the Isle of Skye, where the roots of a Tertiary basaltic volcano are exposed (Anderson,1936), shows inward dipping cone-sheets, developed under magma inflation conditions, displaying either pure dilational 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) 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 (ca. 15-30 MPa, figure 1).

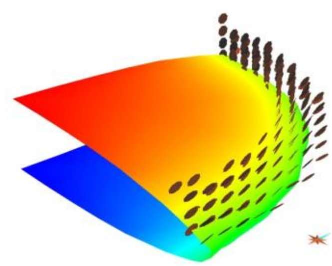

Figure 1: 3D oblate magma chamber; cone-sheets annular region is visualized with planes normal to σ_3 axes (gOcad).

In contrast, they should not develop with sub-spherical or prolate magma chambers. In any case, cone sheets appear to be confined within a distance from the central axis of about 1-1.2 diameters of the magma chamber and in the volume immediately above it, whilst radial dikes dominate beyond the 1-1.2 diameter limit. When a realistic regional stress field is considered, the radial dikes progressively merge into a regional swarm of parallel dikes, oriented perpendicular to the least compressive stress axis.

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, conjugate sets of fractures of low and high-angle cone sheets, high-angle cone-sheets with hybrid reverse-opening kinematics. These geometries has been documented in the Cuillins cone-sheet complex and at the Galapagos, in the Isla Fernandina volcanic complex.

2. The Ascraeus Mons youngest structures

In this work we have interpreted broad MOLA DTMS as well as HRSC images and high resolution stereo-3D reconstructions to verify if a Cuillins-like model could be potentially applied also to the Ascreus Mons.

In particular, we have recognized that the youngest structures cutting the volcanic edifices like pit-chains, aprons, straight and sharp rills, intersection between radial and concentric structures show geometries recalling the Cuillins complex ones (fig 2a,b).

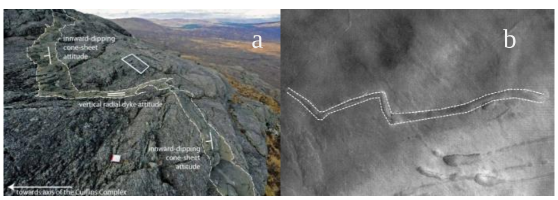

Figure 2: interaction and substitution between radial and concentric dykes in the a) Cuillins complex and b) Ascraeus Mons

More in detail, we have distinguished an internal region characterized by concentric grabens, normal faults, pit-chains interpreted as cone sheets, and an external one with radial structures as pit-chains, grabens and sharp rilles controlled by the structural framework. In between a transition zone show interactions geometries between radial and concentric structures suggesting their coeval activity and a frequent permutation between σ2 and σ3. Far from the transition zone, the radial structures tend to assume a NE-SW trend according to the major regional stress field.

Measurements of the graben flanks attitudes and dips has been carried out on high resolution DTMs obtained from HRSC stereo-pairs using a new algorithm based on *snakes* (UWE software by Simioni et al., 2010).

These measures combined with physical parameters (crustal thickness and density, position of local/regional stress field transition) allowed the FEM mechanical models to investigate the relations between sheet/dyke swarm geometris and the possible presence of an oblate magma chamber.

3. Summary and Conclusions

The distribution, interaction and orientation of the youngest concentric and radial structures of the Ascraeus Mons are comparable with the cone-sheet 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 extensional and dilational structures clearly post-dating the compressional ones (flank terraces of Byrne et al., 2009).

Measurements obtained from UWE-generated DTMs of the most significant structures, and the application of the Finite Element modeling, enabled us to verify the consistency of a possible shallow oblate magma chamber below the Ascraeus Mons and thus reach a better understanding of its volcano-tectonic evolution.

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

[3] Murray J. B., van Wyk de Vries B., Marquez A., Williams D. A., Byrne P., Muller J., Kim J., 2009, Late stage water eruptions from Ascraeus Mons volcano, Mars: Implications for its structure and history: Earth and Planetary Science Letters, In Press

[4] Simioni E. et al., 2010, A new stereo algorithm based on snakes, Photogrammetric Engineering and Remote Sensing (PE&RS), In Press