LINKS BETWEEN VOLCANISM AND TECTONISM ON IO: A COMPARATIVE STUDY OF MONAN PATERA, AMIRANI AND PROMETHEUS.

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Introduction: Past studies have suggested that the differences in mountain formation on Io are caused by the rise of large batches of magma impinging at the base of the lithosphere coupled with the surface recycling movements which create compressive stresses in Io's crust [1, 2, 3]. Stresses are locally relieved along thrust faults [1, 4] which are then exploited by rising magmas in their path towards the surface [1, 3]. Evidence of this process has been observed at Prometheus where lavas erupted from a thrust fault formed some of its western flow fields [5]. Hot spots are required to feed volcanic activity, and compressive stresses play their role, but different geological and physical processes influence the volcanic and tectonic features observed on the surface. Why do the magma bodies causing mountain uplift only rarely erupt within the edifices they build? What are the mechanisms that create paterae associated with the mountains? Why do we observe very long lava flows such as those at Amirani? Density difference between magma and host rock influences magma rise towards the surface and thus the amount of magma available to feed the eruptions. The presence or absence of volatiles in magmas, juvenile and/or entrained, influences magma density. If the density difference with the host rock is too small, magmas tend to stall and cool within the crust. If the density difference is sufficient, magmas can form reservoirs which, given a large enough magma supply, can feed the high eruption rates necessary for the longest lava flows. From the study of the available Galileo imagery we model and constrain the possible geological and physical settings that may have influenced the formation of various volcanic centers such as Monan, Amirani and Prometheus.

Prometheus: Previous estimates of some possible configurations of the Prometheus magma storage region [6] have indicated that reservoirs may exist at depths between 10 and 20 km on Io and be centered at a depth of 16 km (Fig.1). The roofs of shallow reservoirs may reach a depth of ~3 km, allowing some dikes to exploit local tectonic fractures to feed observed eruptions. Thrust faults may be deep enough to cross magma reservoirs and thus offer a direct path to the surface for rising magmas until they are clogged by magma solidification processes. No recent eruptions have been observed from the Prometheus main thrust fault. From the superposition relationships of the western flow fields we see that the lavas erupted from the main thrust fault are older than those erupted from the 1999 vent. Thus is likely that the main thrust fault was clogged after the eruption that has created the flow fields along the Prometheus Patera western boundary.

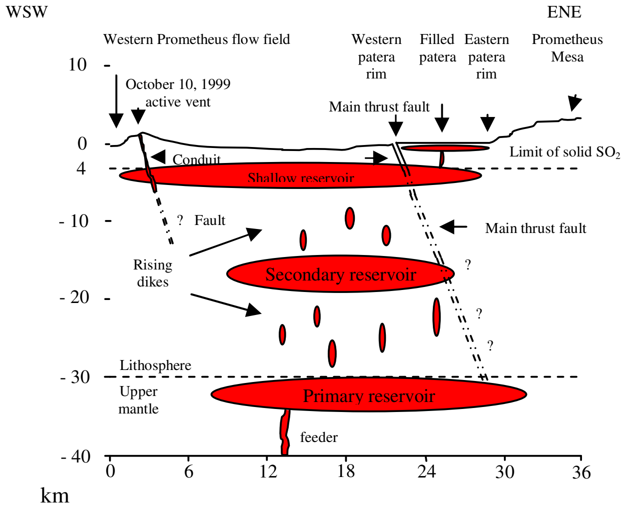

Figure 1: Proposed cross-section of the Prometheus subsurface down to the base of the lithosphere. In red is indicated hot active magma.

Volcanic style is episodic at Prometheus [6] with new eruptions taking place from the same vent after a slowdown or pause in activity.

Amirani: This Prometheus-type volcanic centre, surrounded by the mountains of Monan Patera and Skythia Mons to the east and Euxine Mons to the west, shows long lava flows extending for more than 300 km from south to north. According to available Galileo images (PIA02585), the new lava flows at Amirani covered about 620 km^2 of Io in less than five months. By comparison, Kilauea covered 117 km^2 in the 1983-2004 period while Prometheus covered 6,700 km^2 between 1979 and 1996 [6].

The absence of a volcanic edifice [7] and the presence of long flows may lead to the conclusion that lavas could be low silica content, maybe basalt. Peak temperatures of more than 1000 K were detected during the I27 Galileo flyby [8,9]. The fading thermal output detected during the I31 and the I32 flybys indicated a decrease in the activity [8]. The high eruption rates observed suggest a reservoir large enough to sustain such a magma supply and to allow patera formation processes supporting the interpretation that Maui Patera may be related to the Amirani flow field [3, 8]. Available estimates of depths for shallow reservoirs of basaltic composition range from 4 to 10 km depending on magma volatile content [10], so this could be the depth interval where the Amirani shallow magma reservoir may be located (Fig.2).

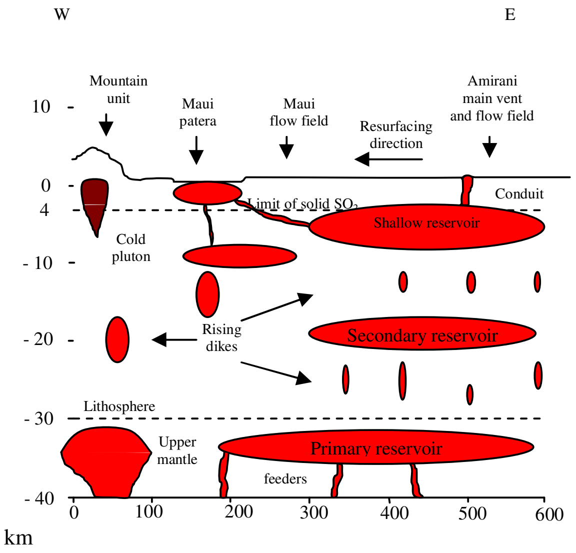

Figure 2: Proposed cross-section of the Maui Patera - Amirani subsurface down to the base of the lithosphere. In dark red are indicated cold plutons which are thought to be at the base of the mountain formation processes [1]. In red is indicated hot active magma.

Asthenospheric diapirs impinging at the base of the lithosphere cause deformation into the crust with subsequent mountain formation process and the resulting stresses, combined with magma rise movements and crust recycling, form faults and cracks which can be exploited by rising magmas to reach the surface [1]. However, no active volcanism is seen to correspond to the main mountain units thus suggesting that diapirs slowly rise until they cool within the crust under the mountains.

Monan Patera: Monan Patera is a nearly 100 km long patera extending in W-E direction and located to the north of Monan Mons. Together with Ah Peku Patera, Monan Patera appears closely associated with Monan Mons but no flow units have been mapped so far around it [7]. However, hot spot activity both at Monan Patera and Ah Peku Patera was detected by the Galileo spacecraft [7]. Both paterae are about the same distance from Amirani as Maui measured from the Amirani southern eruptive vent. Bright flow units have been mapped between Maui and Ah Peku as well as between Amirani and Monan at nearly symmetric distances [7]. The Amirani southern vent is located nearly along the side (connecting Monan and Maui) of a triangle having the three paterae (Maui, Monan and Ah Peku) at its vertexes. The overall extents of the Amirani formation boundaries run parallel to the main directions of the mountains surrounding it. Considering the model of formation proposed [1], it seems that the compressive stress at the base of the "bowstring" faulting system and the crescent shape of Monan Mons might be caused by the high resurfacing rate due to the Amirani activity. It is interesting to note that the symmetric position of Amirani with respect to Maui and Monan paterae (see fig. 2 and 3) and the surrounding mountains suggests how it might be considered a source of magma upwelling like the mid-ocean Atlantic ridge on Earth contributing with compressive stresses towards the mountains.

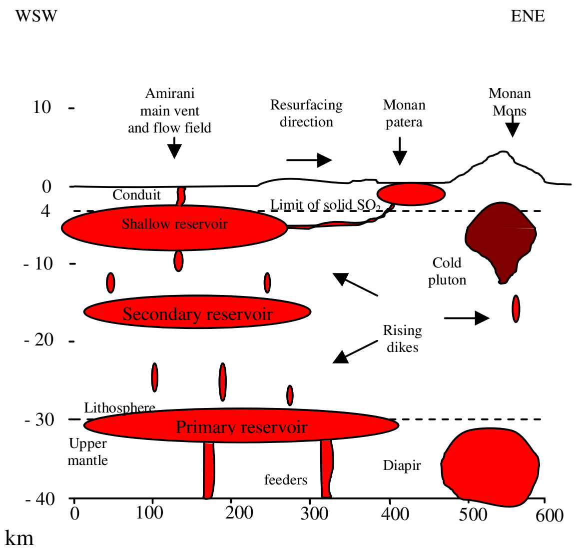

Figure 3: Proposed cross-section of the Monan Patera - Amirani subsurface down to the base of the lithosphere. In dark red are indicated cold plutons which are thought to be at the base of the mountain formation processes [1]. In red is indicated hot active magma.

Conclusion: A key consequence of the volcanism induced compressive stresses is the formation of magma reservoirs into the crust of Io. Melt will accumulate in such reservoirs until it is allowed to escape by changing stress conditions, perhaps induced by magma interaction with liquid or solid SO_2 or S_2 in the crust, or magma crystallization with consequent volume and pressure changes.

References: [1] Jaeger W. L. *et al.* (2003) *JGR 108*, E8, 5093 [2] Schenk P. M. and Bulmer M. H. (1998) *Science 279*, 1514. [3] McEwen A. S. *et al.* (2000) *Science 288*, 1193. [4] Keszthelyi L. et al. (2004) *Icarus 169*, 271. [5] Leone G. *et al.* (2007) *AGU Fall Meeting*. [6] Davies A.G. *et al.* (2006) *Icarus 184*, 460. [7] Williams D. A. *et al.* (2007) *Icarus 186*, 204. [8] Lopes R. M. C. *et al.* (2004) *Icarus 169*, 140. [9] Keszthelyi et al., (2001) JGR 106, 33,025. [10] Leone G. and L. Wilson (2001) *JGR 106*, 32,983.