# THE EVOLUTION OF VOLCANISM IN SYRTIS MAJOR PLANUM

P. Fawdon (peter.fawdon@open.ac.uk) Abstract No.: 2232

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## 1. Syrtis major Planum

### Introduction:

We investigate the volcanic evolution of Syrtis Major Planum using the 3D visualisation software Geovisionary™ and aim to build an architectural model of the evolution of the Syrtis Major volcanic complex.

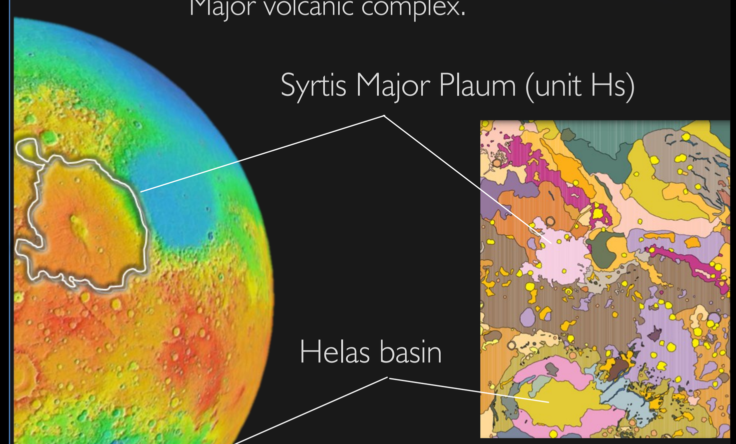



*Figure1: The location of Syrtis Major Planum; a) colourised, hillshaded MOLA topography b) Unit Hs, shown in Geological map of Greeley and Guest 1987 [1]*

### Presented are:

- The mapping of volcanic sub-units within the unit Hs [1] Syrtis Major. (Fig 1)
- Eruption rate, flow viscosity and yield strength data for a subset of the observed flows calculated from a simple cooling model.

The Syrtis Major Planum, originally mapped as unit Hs in the Greeley and Guest (1987) map [1], is a Hesperian age (3.7 – 3.0 Ga), low-angle, basaltic plains volcano on Mars which covers 3.6 % of the martian surface. The edifice is composed of 1500 km by 1100 km of basaltic lava plains with a total thickness of ~500 m [2]. There are two distinct central calderas, believed to contain evolved volcanic products, within a central caldera depression [3]. Extensional and compressional fault systems orientated concentrically and radially from the central caldera complex dissect the flanks.

### Data and approach:

We have used NASA and ESA datasets, and have compared Syrtis Major to terrestrial volcanic analogue sites. For Mars we have used THEMIS Mosaic (100 m/pix), HRSC (12.5 m/pix) and MOLA elevation. For terrestrial sites we have utilized LiDAR data at 1 m/pix with accompanying aerial photographs for 1) Krafla, Iceland, and 2) The Manda-hararo rift segment, Afar, Ethiopia. These data were provided by ARSF (Airborn Research and Survey Facility) and the British Geological Survey, and were obtained in 2009.

Acknowledgments

We would like to thank; The British geological survey for LiDAR and image from Afar and proving the Geovisionary™ software, Susan Conway for compiling the Krafla LiDAR DEM and for field assistance in Iceland and John Murray for insight into lava flows on Mt Etna.

## 2. Stratigraphy

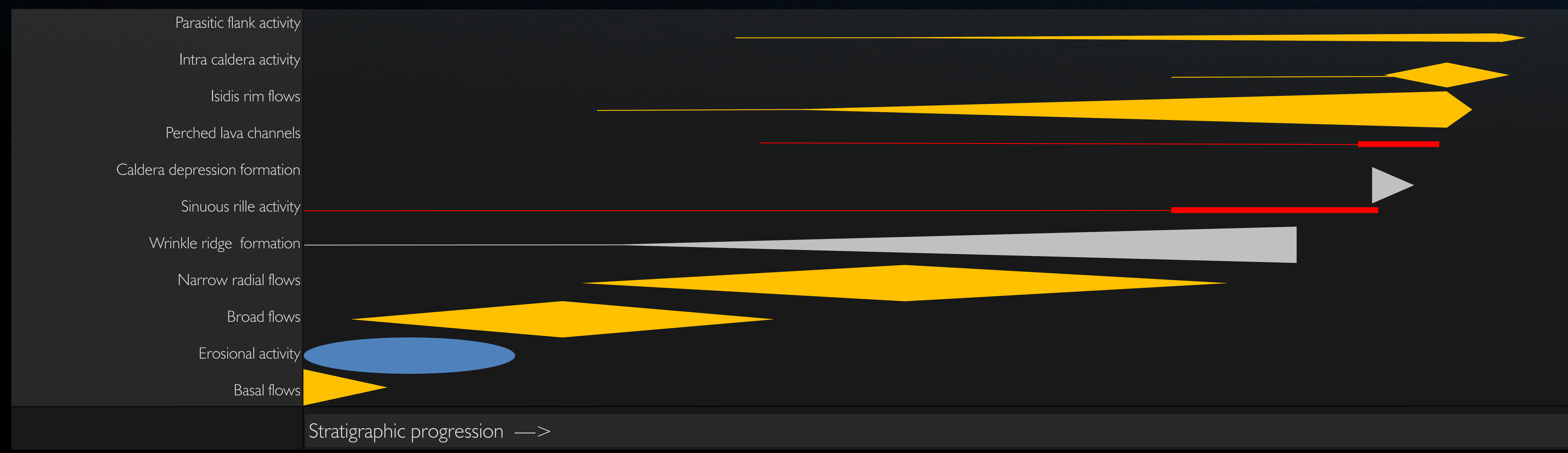



*Figure 2: Cartoon illustrating the stratigraphic relationships between major geological surfaces observed on Syrtis Major Planum. Orange = lava units, red = lava transport activity, grey = tectonic activity and blue = erosional activity. The sizes of the shapes are an initial estimate of the relative longevity and intensity of events on Syrtis Major Planum.*

## 3. Plains lava flows

### Volcanic Flank stratigraphy

The region covering Unit Hs [1] has been surveyed using the latest data, and volcanic surfaces and their relative stratigraphy have been assessed.

We observe six major groups of volcanic terrain:

1. **Basal flow unit.** Exposed at the perimeter of Syrtis Major. This unit onlaps the surrounding Noachian highlands. To the north east it has been eroded, exposing underlying highland terrain, but its relationship to units in the Isidis basin is unclear.
2. **Broad flows.** Emplaced radially from the central caldera depression with a stepped-edge morphology (likely erosional). Flows follow topography, curving away from the highlands near the Planum boundary. Sinuous rilles are found within this unit
3. **Narrow flows.** Emplaced radially from the central caldera depression traceable to the caldera rims. Commonly host large lava channels.
4. **Flows emplaced from lava transport structures.** Morphologically similar to narrow flows but originate from sinuous rills or perched channel structures impinging into the Isidis basin.
5. **Intra caldera activity.** Late stage rifting, caldera floor dome formation and cones of evolved compositions within the Nili Patera [3]
6. **Parasitic flank activity.** Small cones and flows across the flanks can be identified by their distinctive Themis night-time IR signature.

Described in more detail are units 2,3 and 4 which cover the majority of the area of Cyrtis Major Planum.

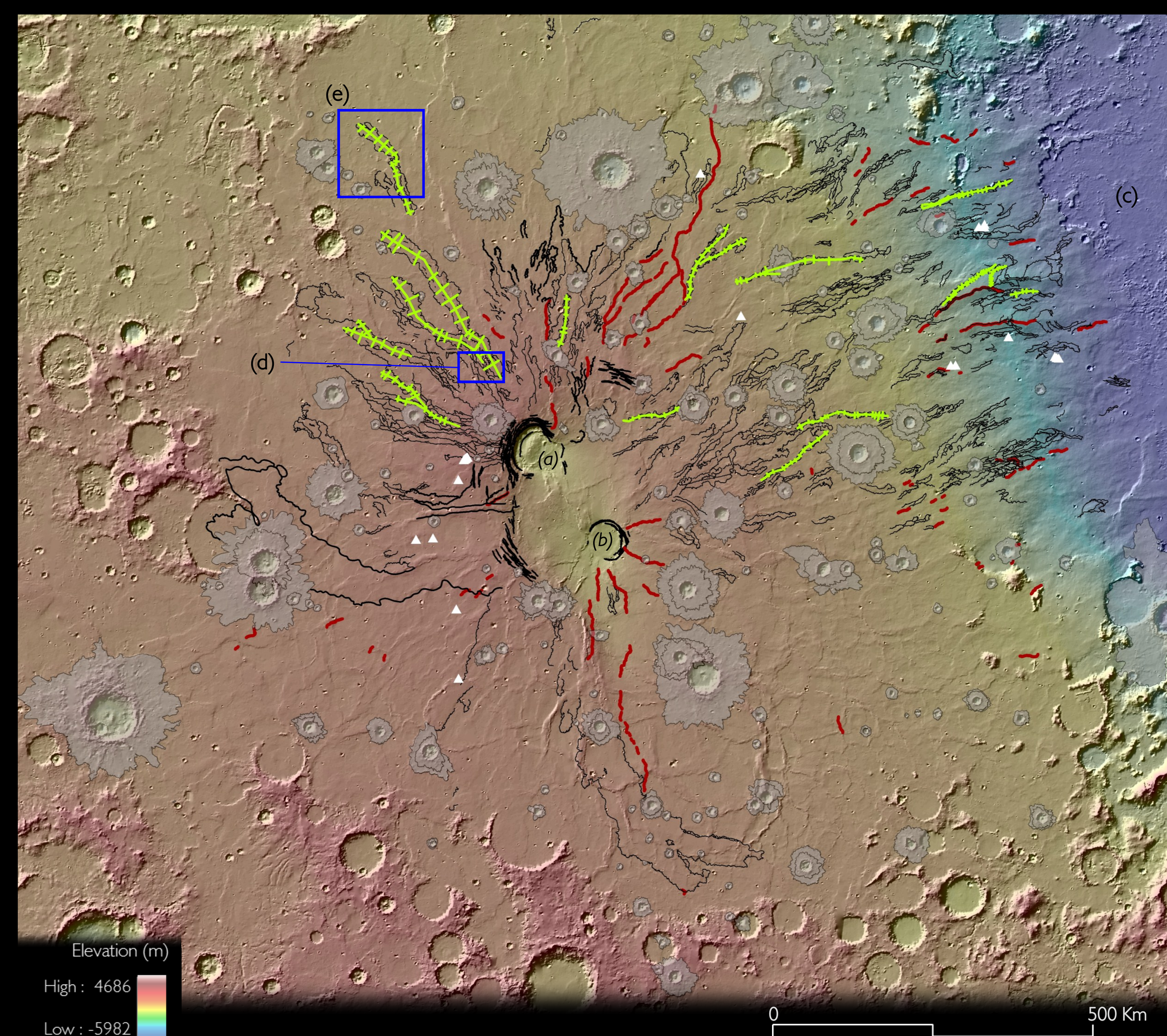



*Figure 3: Showing Syrtis Major Planum MOLA hillshade with overlain MOLA topography. Black outlines show work in progress lava flow boundaries. Green lines highlight lava flows used for rheology calculations. Grey areas show continuous ejecta. White cones show parasitic cones. Red lines are sinuous rilles and rille-like channels, black lines show normal faults around the central calderas. (a) Nili Patera (b) Mereo Patera, (c) Isidis basin, (d) figure 5, (6) figure 6.*

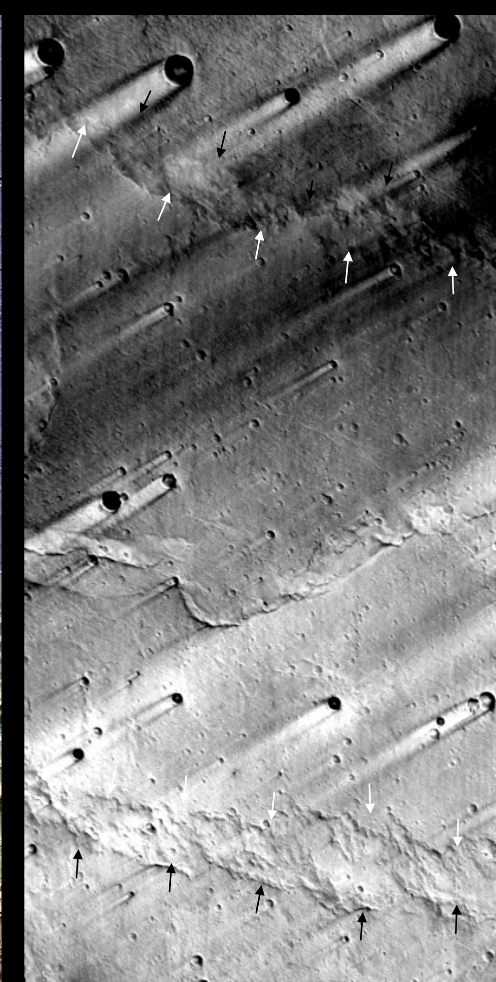
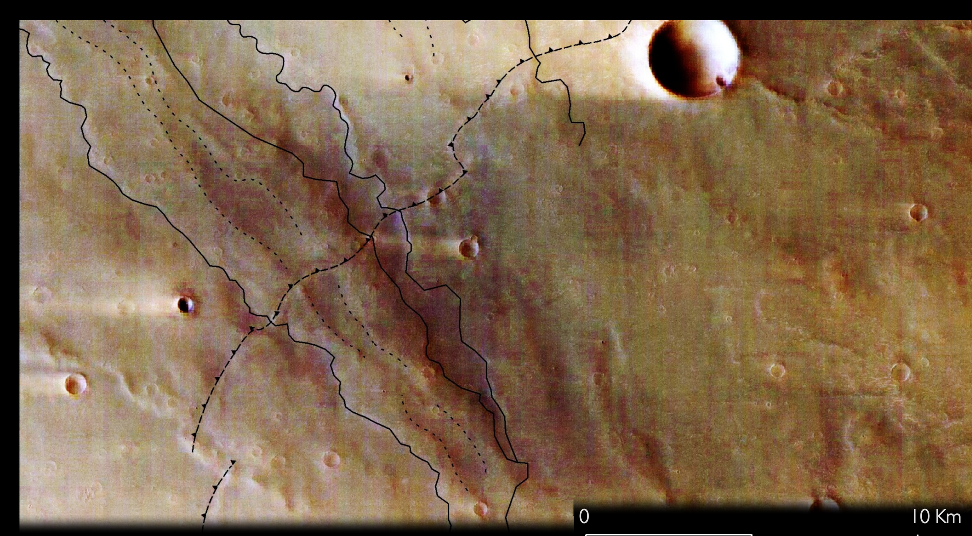


*Figure 4: Showing the 38 Km width of a broad flow in the south of Syrtis Major. Black arrows point to the bottom of the stepped edges of the flow white arrow point to the top of the upper scarps (CTX image P12005763_1818_XN_10N294W)*



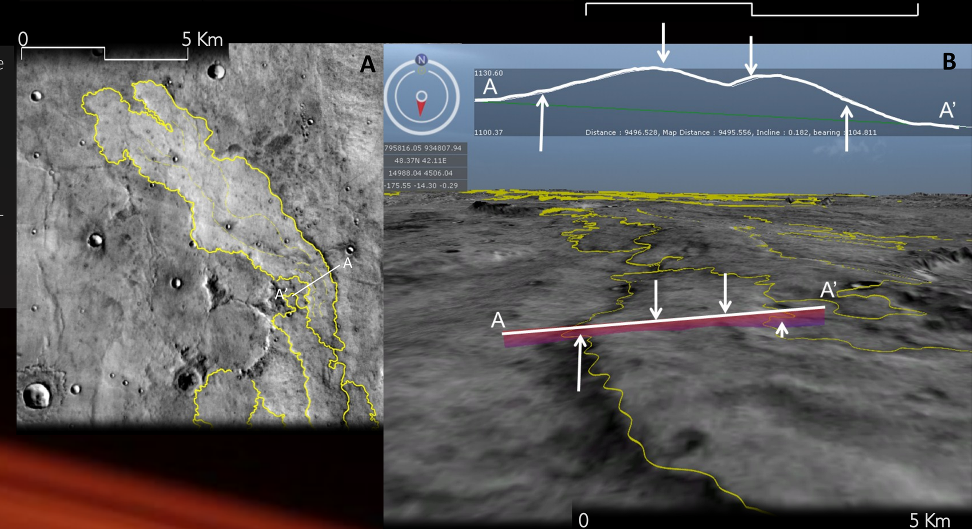




*Figure 5: (above right) shows a narrow flow with a medial channel close to the Nilli Patera. The flow is cross-cut by a wrinkle ridge. Black lines outline the lava flow. Channel demarked by dashed line. (HRSC H2001_0000 pan-sharpened false colour composite.)*

*Figure 6: (right) (a) termination of a narrow flow in Themis daytime. Channel cross-section A-A' (b) Low angle perspective view from the north of the channel cross-section form (a), showing the MOLA profile highlighting the medial channel form.*

### Broad lava flow units (Fig 4, above)

| | |
|---|---|
| Observed and Inferred flow lengths: | ~350 – 500 Km |
| Flow widths: | 35 - 90 Km |
| Flow Heights: | 35 - 90 m |
| slope: | 0.1 - 0.3° |

### Narrow lava flows (Fig 5, 6)

| | |
|---|---|
| Observed flow length: | ~ 40 -100 Km |
| Additional distance to vents: | ~ 80 Km |
| Widths on observed length: | 6 -10 Km |
| Height along the observed length: | 20 - 40 m |
| Radial flow slope: | ~ 0.3° |
| Flow slope on the Isidis rim: | ~ 0.95° |

### Channel observations.

Many of the narrow flows have a topographic depression running along the flow axis throughout the majority of the observed length. This depression is hard to distinguish in the relatively poor imagery but is clear in MOLA PEDR data (fig 5,6).

Channels form between 25 - 50% of the flow width. And channel surfaces where not evacuated at 10-20% lower than maximum levee relief.

## 4. Rheology modelling

### Rheology Modelling.

For the narrow channel flow unit observed on Syrtis Major we have calculated model eruption and rheological parameters.

Models developed in [4, 5] and presented in [6] describe a cooling-limited relationship connecting effusion rate to final flow dimensions (total length (x), width (w), flow thickness (h)) (eq 1.). The time taken for a flow to stop moving, while it's temperature-dependant viscosity increases with cooling, is described by the empirically defined Gratz number (Gz) and assumed thermal conductivity (κ).

Eq.1: $Q = Gz\,\kappa\,x\,w / h$

### Model rheological parameters.

Rheological parameters of yield strength (τ) and viscosity (μ) are calculated using models from [5, 6]. We model the lava emplacement both as a lamina Newtonian flow [7] and in accordance with the observed levee structure a Bingham model [4].

Such model would not be valid for flows which have undergone significant lava tube transport or inflation emplacement. Therefore we have excluded flows without consistent observations of medial channels from our dataset.

### Results: interpretation and comparison.

The data set comprises 14 well-constrained flows, ten emplaced from the central caldera complex and four from the transport network on the slopes bordering the Isidis basin.

### Effusion rates (Q)

- Model effusion rates are higher for flows from the caldera complex than flows impinging into the Isidis basin. (Fig 7a)

### Yield strength (τ)

Calculated Bingham yield strength using models sensitive and insensitive to slope (Fig 7b).

- Flows radial to the caldera complex have lower yield strengths
- Transported flows on the Isidis rim have higher yield strengths.

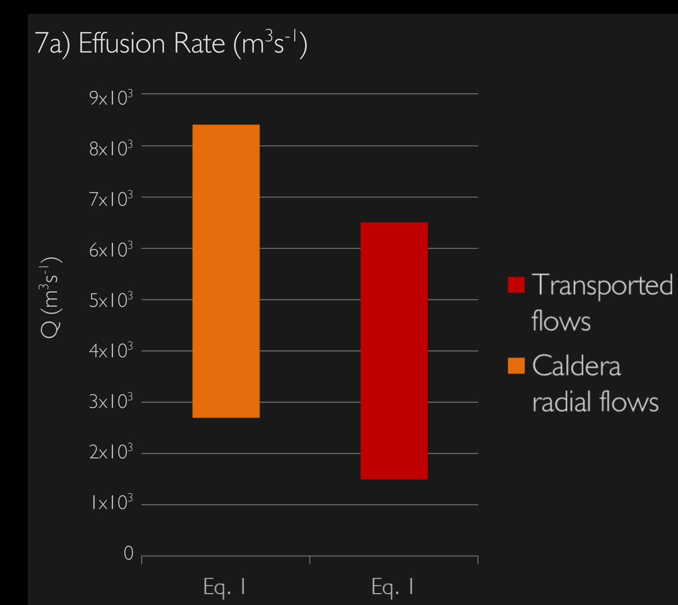
This difference, seen with and without sensitivity to slope, suggest that the flows impinging on the Isidi basin are of a more evolved composition.

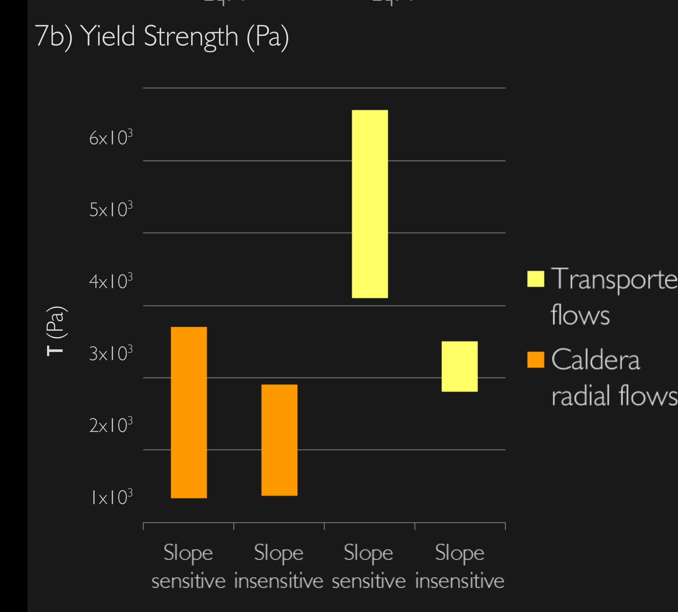
### Viscosity (μ)

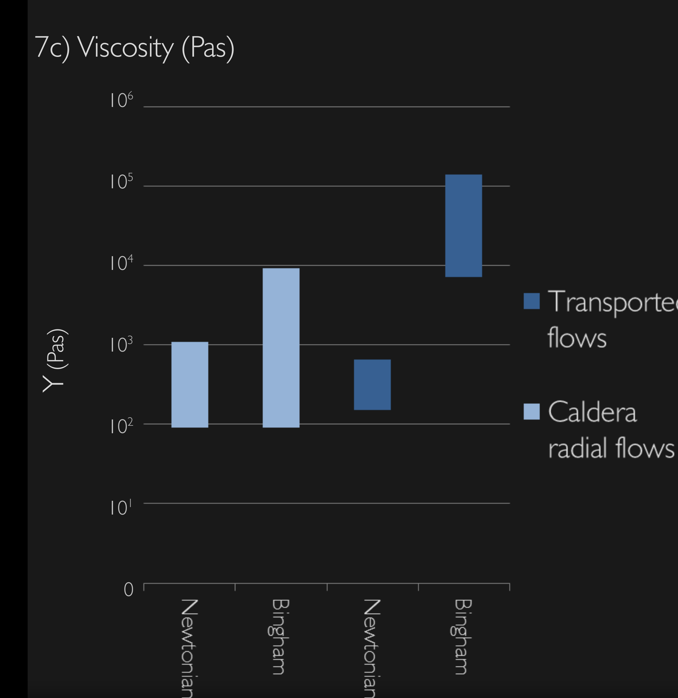
Viscosities are calculated for both a lamina Newtonian fluid and a Bingham fluid using the mean shear strengths calculated as above (Fig 7c).

- Flows radial to the caldera complex have a consistently lower viscosity than flows from the rim of Isidis basin.
- This is true for both models, although is more pronounced in the Bingham model.

This also demonstrates a difference in properties from the two sets of flows suggesting either compositional evolution




## Conclusion

- Lava emplacement has evolved from massive (probably) inflated layered flows, through caldera-centric channel flows to increasingly sector localised activity of an evolving composition.
- Tectonically Syrtis Major has undergone a net deflation and sector localised compression expressed in the wrinkle ridge patterns. Subsequently, there has been massive collapse and subsidence, forming the central caldera depression coeval with a changing lava emplacement regime and compositional evolution.
- Calculated model rheologies are comparable to both terrestrial and martian results calculated in the same way. Thus indicating these lavas to have been basaltic to basaltic andesite.

## Further work

- The next step is to use impact crater size frequency statistics to assess the relative timing of the mapped surfaces, and to look for changes in eruptive parameters over time.
- We may expand the data set of narrow flows as part of the mapping process and continue with parallel terrestrial studies.
- We are also working on a quantitative estimate of subsidence of the central caldera depression, based upon extracting the gross post-eruption tectonic displacements by measuring the number and orientation of wrinkle ridges on the flanks of Syrtis Major .

References:

[1] Greeley, R. Guest, J. E. : *Geologic Map of the Eastern Equatorial Region of Mars, Map I-1802-B, U.S. Geol. Surv., 1987* [2] Hiesinger, H., and Head III, J. W. (2004) *J. Geophys. Res., 109* [3] Skok, J., R., et, al., (2010) *Nature Geoscience Vol. 3 383*[4] Moore, H. J., et, al., (1987) *Proc. 9th Lunar planet, Sci. Conf. 3351-3378* [5] Wilson, L. and Head III, J. W. (1983) *Nature Vol. 302 21* [6] Hiesinger, H., Head III, J. W. and Neukum, G. (2007) *J. Geophys. Res., 112* [7] Sakimoto S. E. H. and Gregg T. K. P. (2001) *J. Geophys. Res., 106.*

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