# Analysis of lava flow features on Venus for radar sounder simulations

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## Introduction

Venus, with a surface temperature around 475°C and a surface pressure of 93 bar, may have been in origin very similar to Earth. Understanding why it developed such hellish environment can have important implications on the evolution of the Earth. Previous missions imaged the surface and provided compositional informations. However, these data are imprecise, with low resolution and uncertain geologic correlation. To improve our knowledge, new missions towards Venus are planned for the future: NASA's DaVinci+ and Veritas, and ESA's EnVision.

EnVision main objective is to study the surface and subsurface of Venus and its relationship with the atmosphere, and it is going to achieve this thanks to various instruments, among which a subsurface radar sounder (SRS). SRS is going to operate at a central frequency of 9 MHz with a bandwidth of 5 MHz, allowing a penetration of few hundred meters through the subsurface, with a vertical resolution of about 20 m [1].

One of SRS targets are lava flow features, fundamental in understanding the eruptive processes that shaped and are probably still shaping the surface of Venus. This work is focused on the analysis of existing literature related to lava flow features on Venus, in order to extract morphometric and compositional information to improve the SRS performance prediction through simulations based on geological analogues. This approach has already been tested for the analysis of lava flows on Mars, and it exploits existing radargrams in geologically analogous terrains to produce realistic simulations of the investigated target, using parameters related to the composition and morphometry of the target [2].

## Lava flow morphology and morphometry

Lava flow features on Venus have been classified based on morphology and synthetic aperture radar backscatter measured in S band. The classes (Figure 1,2) reflect different emplacement styles, source characteristics, influence of the topography and local emplacement processes. These morphologies are then compared to terrestrial common effusive features: pahoehoe, a'a, and blocky.

Main characteristics:

- Magellan radar backscatter, comparison with terrestrial lava flows, and values of rms slopes at Magellan SAR resolution of 75 m ranging from 2.5° to 8° are consistent with pahoehoe morphology.
- Panoramas of the Venera landing sites reveal decimetric layering similar to sheet pahoehoe.
- Estimates of flow thicknesses from Magellan altimetric data and stratigraphic relationships yielded a lower limit of 10-30 m for individual lobes, while a maximum thickness estimate is of the order of 400 m.
- The extension of flows ranges from tens up to thousands kilometres.

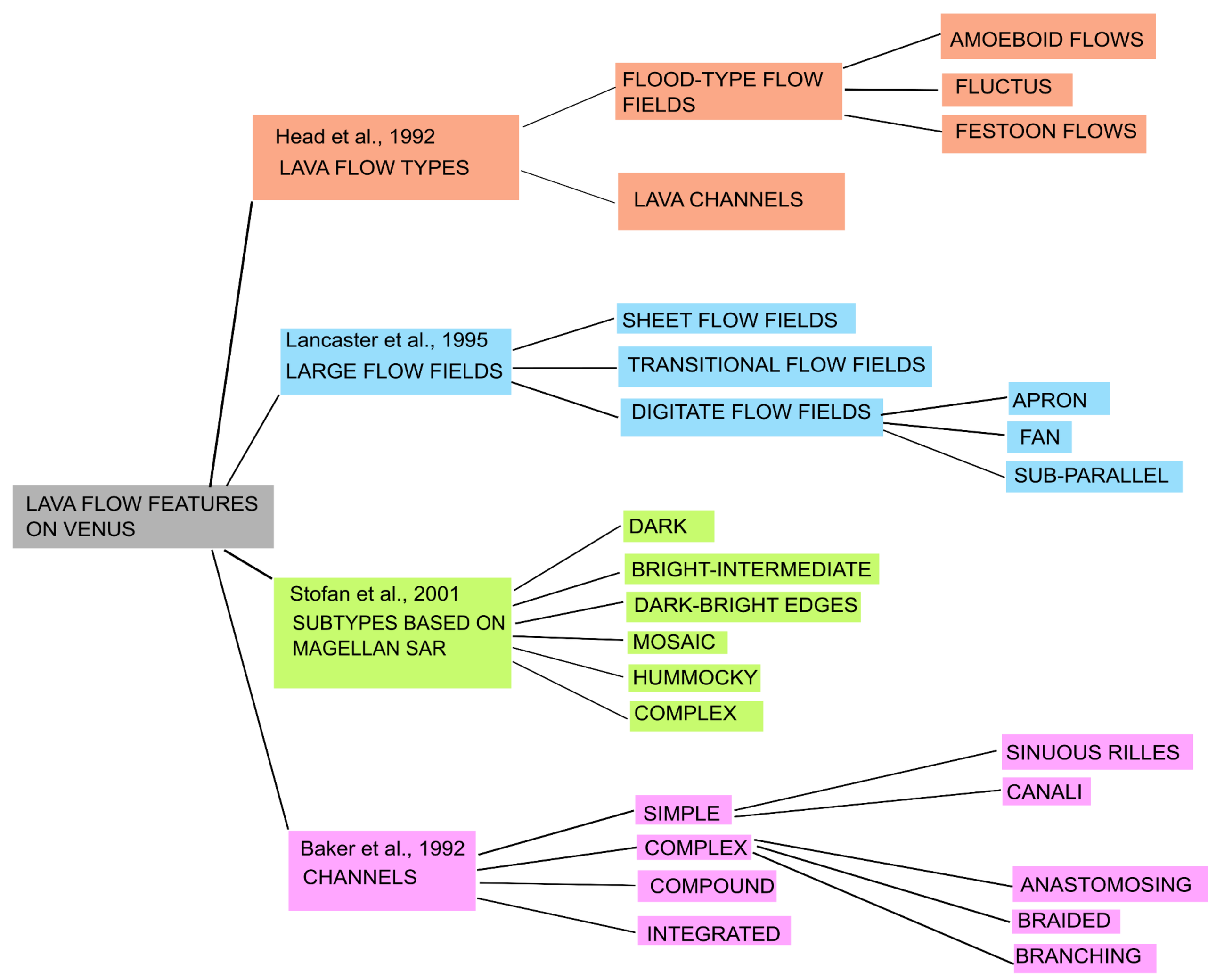

Figure 1: Classifications of lava flow features (elaboration from [3], [4], [5], [6]).

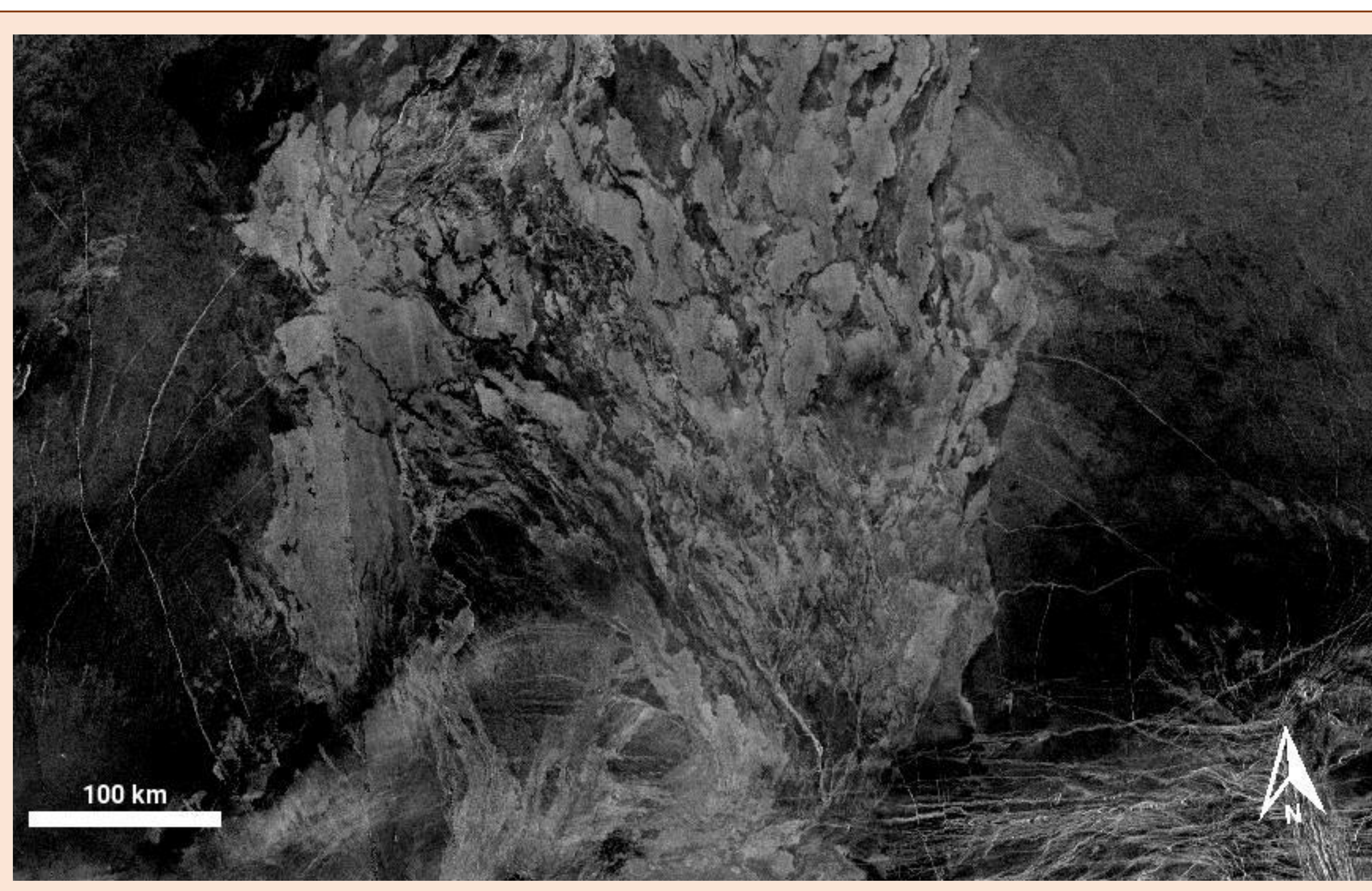

Figure 2: Example of digitate subparallel flow field, Mylitta Fluctus, from JMARS [11].

## Lava flow composition and trends of physical and dielectric properties

Previous missions and morphological observations suggest a predominantly mafic composition, mostly tholeiitic and alkali basalts (Table 1)[7]. The pahoehoe-like behaviour supports a basaltic composition as on Earth, but unlike terrestrial basalts the high pressure on Venus' surface probably prevents high porosity. Predicted values of porosity for Venusian basaltic magmas vary from 0.05 to 0.75 (bubble volume fraction), considering different concentrations of $CO_2$ and $H_2O$, while on Earth they may reach 0.9. More exotic compositions for the longest flows are considered, such as carbonatite or sulphur and more evolved compositions are possible. Emissivity measurements of Venus flows range from 0.7 to 0.9, with corresponding dielectric constants ranging from 3.5 to 7, consistent with basaltic samples. High emissivity may also be indicative of fresh or currently active lava flows.

| Landing site (Lat°, Long°) | Geochemistry | Inferred porosity |
|---|---|---|
| Venera 8 (-10.70, 335.24) | Very high K, Th, U | - |
| Venera 9 (31.01, 291.64) | Low K, U; high Th | - |
| Venera 10 (15.42, 291.51) | Low K, U, Th | 1–7% |
| Venera 13 (-7.55, 303.69) | High K basalt | 50–53 % |
| Venera 14 (13.05, 310.19) | Tholeiitic basalt | 60–62 % (top layer)/ 50–53 % (below) |
| VEGA 1 (8.10, 175.85) | Low K, U, Th | - |
| VEGA 2 (-7.14, 177.67) | Tholeiitic basalt; low K, U, Th | 13% |

Table 1: Characteristics of Venera and VEGA missions landing sites from [7].

In general, it can be observed that the dielectric constant:

- Increases from felsic to mafic compositions.
- Increases for higher density, lower porosity.

The loss tangent, and thus the attenuation:

- Increases from felsic to mafic content and with increasing metallic content.
- Increases with higher density, lower porosity.

Clutter increases for rougher surfaces.

## Lava flow distribution and geodynamic context

Lava flows have been observed in association with:

- Volcanic edifices.
- Rift zones.
- Coronae.

There is a distinctive concentration in the eastern Lavinia Planitia-Alpha Regio area, within Aphrodite Terra and Atla Regio, in Beta-Phoebe regiones, and in Sedna Planitia (Figure 3) [4].

The geodynamic context can be inferred by comparison with terrestrial analogues:

- Tholeiitic basalts → melting of peridotite in the shallow mantle, NMORB, islands arcs and hot spots.
- Alkaline basalts → melting at greater depth [8].
- Flows emanating from coronae → mantle upwelling and hot spots [10] .
- Carbonatite volcanism → intraplate regions, on hotspots, near plate margins associated with orogenic activity or plate separation, mantle-derived [6].

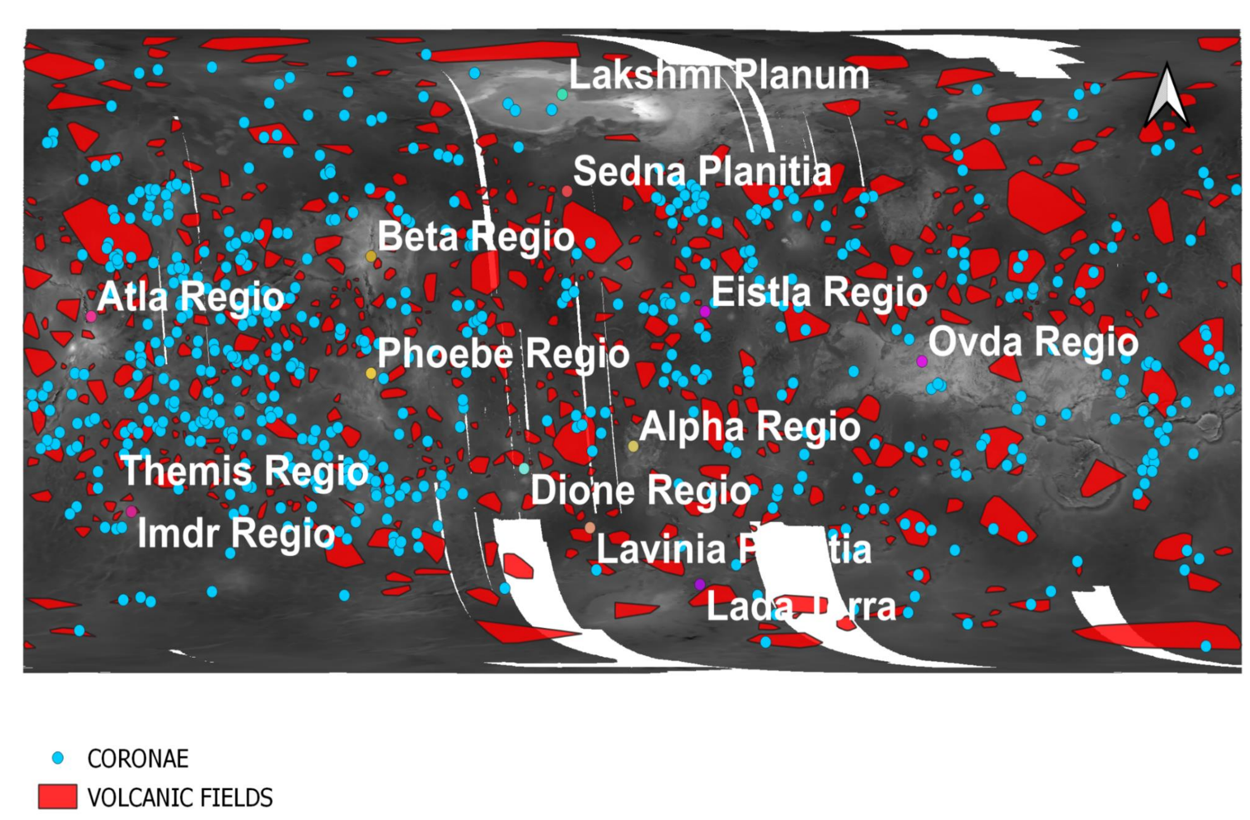

Figure 3: Map of Venus with major volcanic environments (elaboration from [9], [10]).

## CONCLUSIONS

The analysis and elaboration of the existing literature on lava flows on Venus is useful for both fine tuning the expected performance of SRS on this kind of features and defining detailed scenarios to be accurately simulated and studied. Considering the morphological parameters, SRS is expected be able to detect changes between individual lobes or sequences of flows to a depth of several hundred meters. The discrimination between individual lobes or sequences of lava flows may be possible considering interfaces related to differences in composition, porosity and surface roughness. Investigation of the lava flow features with SRS, in combination with the other instruments on board of EnVision, could provide a new stratigraphic perspective of Venus history.

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PhD SST
Space Science and Technology

Finanziato dall'Unione europea
NextGenerationEU

## ACKNOWLEDGEMENT

This publication was produced while attending the PhD program in in Space Science and Technology at the University of Trento, Cycle XXXVIII, with the support of a scholarship co-financed by the Ministerial Decree no. 351 of 9th April 2022, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 2 "From Research to Business", Investment 3.3.

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