Modelling surface processes on Venus: in support of the EnVision mission

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Summary

High surface temperatures, combined with the dense and acidic atmosphere, should mean very active weathering and erosion cycles on Venus. There are also relatively few craters on the surface of Venus, which combined with their apparently random distribution, is taken as evidence that the surface is uniformly young. However, the surface also shows many signs of crustal complexity and deformation and there is much debate about the mechanisms which may drive tectonics on Venus. There are volcanoes which we now know are active and extensive rift valleys, both of which point to the active renewal of its surface. Venus's thick atmosphere prevents small meteors impacting the surface and is likely to contribute to erosional processes which modify the larger craters.

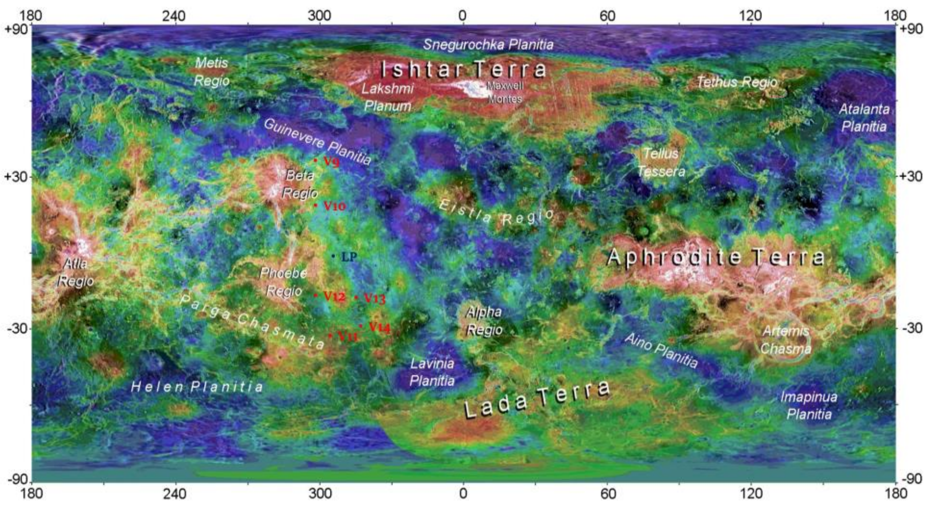
This project will involve the modelling of potential surface processes on Venus, i.e. erosion, deposition and weathering which act to degrade Venus's topography, drawing on existing geophysical, topographic and geological data. The research will attempt to predict likely rates, styles and distribution of degradation at varying scales and settings across the planet's surface.

Project

Surprisingly little is known about our nearest planetary neighbour, not even the basic sequence and timing of events that formed its dominant surface features. NASA's 1989-1994 Magellan mission provided a global image of the surface at 100 – 200 m resolution, comparable in coverage and resolution to that of Mars after the Viking missions in the 1970s. Magellan revealed an enigma: a relatively young surface, rich in apparent geological activity, but with a crater distribution which appeared random. The initial conclusion was that a global catastrophe half a billion years ago had resurfaced the planet: suggesting that Venus was solved! Yet ESA's 2006-2014 *Venus Express*, the most successful mission to Venus in the last two decades, revealed a far more dynamic and active planet than was expected, uncovering tantalising evidence for present day volcanic activity that demands further investigation (Svedhem et al. 2007).

The outstanding science questions for Venus are many and varied: to determine the level and nature of current surface and sub-surface geological activity and the sequence of geological events that have generated its range of surface features; to assess whether Venus once had oceans or was hospitable for life; and to understand the organising geodynamic framework that controls the release of internal heat over the history of the planet.

Sedimentary features are rarely observed in Magellan data and so assumed to be unimportant, with research focussing instead on volcanic processes as agents of surface change on Venus. However, the four Venera landers that recorded surface panoramas reveal landscapes dominated by clastic rocks and mobile sediment (Venera 13 even recorded sediment being removed from the lander over a 40-minute period). Rapid lithification can reconcile these contrasting observations. Using reprocessed Magellan data, sedimentary rocks are estimated to cover almost half the Venus surface, primarily in the plains. Venera elemental abundance data indicate that calcium and alkali sulphates are the most likely cementing agents, in agreement with experimental data, and that in the dry hornfels facies of the Venus surface, carbon may occur within the rock matrix primarily as scapolite and only secondarily as a magnesium carbonate cement. The main sediment sources appear to be upland erosion and the mass wasting of steep slopes, from which sand-sized granular material is transported globally to be deposited across the plains and lithified as thinly layered clastic rocks. Sedimentation rates are likely low and probably similar to marine environments on Earth; it may therefore be more helpful to consider the supercritical fluid-like Venus



lower atmosphere as an oceanic system. Nonetheless, erosion has likely significantly affected upland terrains, particularly tesserae, and sedimentation may bury crater ejecta and floors, such that we may have underestimated rates of surface change on Venus. Quantifying these processes and their importance in geochemical cycles, particularly as a sink for sulphur dioxide, is crucial to understanding Venus evolved so differently to Earth.

The research will help to define areas of likely erosion and deposition on Venus using 75 m/pixel Magellan imagery, supported by radiometry (which can be used to indicate surface densities) and Doppler Centroid data, (which can indicate wind directions and velocities and thus cause surface sediment ripples). The areas will be used to infer near-surface circulation, informing global climate models that currently lack this vital input; to estimate rates of surface change based on crater modification; and to understand the relative importance of impact ejecta, mass wasting, and aeolian erosion as sediment sources. The research will inform, and benefit from, collaborative research with the Glenn Venus Environmental Chamber facility, which is currently conducting a range of experiments on the weathering of materials, and the lithification of grains, under Venus environmental conditions.

The results of this PhD research will contribute to a growing body of work on Venusian science. The PhD candidate will support the work of and join an international collaborative research group involved in a new ESA funded mission to Venus, called *EnVision (www.envisionvenus.net),* which will be launched in 2032. *EnVision*'s science goals are broad and include gaining a better understanding of the current rate of geodynamic and geological activity on Venus, providing hints at is internal structure, determining its geological history, as well as providing insights into the origin and maintenance of its hostile atmosphere; thus to understand how Venus and Earth could have evolved so differently. These analyses will directly inform the determination of key targets for imaging during *EnVision*'s operational life.

Candidates for this PhD should have geophysics, physics or computing background, with strong coding skills and an interest in planetary geoscience.

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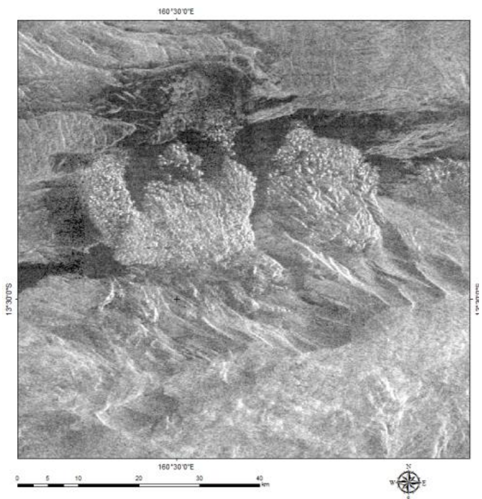
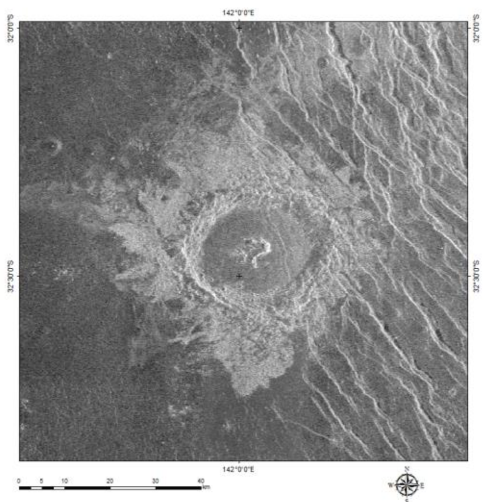


Left-looking SAR images from Magellan, aquired around 1990.
Left: landslides north of Thetis Regio
Right: undeformed impact crater at the boundary between vast flat, smooth plains and faulted and deformed terain



Optical image from Venera 13, Soviet probe which landed in March 1982, showing slabs and flat-lying sedimentary rocks containing ripple-like features, and loose clastic debris being swept across the surface.

Ghail, R. C., Hall, D., Mason, P. J., Herrick, R. R., Carter, L. & Williams, E. 2017. VenSAR on EnVision: taking Earth Observation radar to Venus. *International Journal of Applied Earth Observation and Geoinformation*, 64, 365-376 dx.doi.org/10.1016/j.jag.2017.02.008.

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