SECTION 5: Venus

Venus holds much interest for planetary scientists because of its similarity to the Earth in terms of size and density. It's thick atmosphere however has prevented ground- and space-based imaging cameras from revealing the geology of its surface. To discover more about the surface of Venus, it's atmosphere has to be penetrated by radar wavelengths. The most comprehensive mission to study Venus was the Magellan mission, launched in 1989, mapping 98% of the planet at an average resolution of 250m. Most of our current understanding of Venus comes from the results of this mission.

5.1 Tectonism

Venus does not possess a global-scale system of linear features such as we see on Earth (i.e. ocean spreading centres). It does however, show extensive evidence for localised tectonism occurring on large and small scales.

5.1.1 Tesserae

The most complicated of the tectonic features are the "complex ridged terrain" or "tesserae". These are deformed surface layers, characterised by at least two sets of intersecting structural elements. They usually occur in highland areas and show a high surface roughness (indicated by a bright radar return). Each linear feature in the tessarae are usually 10-20km apart, and cover approximately 8-10% of the Venusian surface. There are several types of form of tessarae including fold fabrics and extensional and compressional features. Not all of these necessarily have to form by the same process. It's important to study the different forms as the style of feature is related to the rheology and may therefore provide clues regarding the crustal rheology at the time of formation. One problem here though is that we really don't know for sure when these features formed.

5.1.2 Lowland plains

The lowland plains of Venus account for 80% of the surface, and therefore the tectonic styles apparent on the plains will characterise the planet itself.

As the name suggests, the plains lie below the mean planetary radius (MPR), and generally have faults and fractures present everywhere. As with the tesserae, the lowland plains show evidence for both compressional and extensional tectonic activity. Wrinkle ridges are an abundant feature and occur in roughly evenly spaced parallel ridges. They are believed to be younger than the plains themselves and are generally up to 300-400km long and 1km wide. An interesting observation is that more wrinkle ridges occur on the older plains material than the younger .

Extensional features manifest themselves in the form of narrow graben usually less than 2km wide, but several thousand km long. Most graben are associated with volcanic constructs. Some form intense belts of deformation of varying dimensions with overall widths of up to 300km and lengths between 100 and 2000km. Ridge belts are also found but are generally raised by up to 1km above the surrounding plains units. These too can be quite large areas, up to 200km wide and 1000km long.

5.1.3 Coronae and Crustal Plateau's

Although coronae themselves are volcanic in nature, tectonic features are always present in their vicinity, and obviously related to them. Coronae are quasi circular features that display radial fractures both inside and outside the rim, and /or concentric fractures outside the rim. In some cases, lava appears to have escaped through the fractures which may or may not be related to the fact that coronae are formed by volcanic activity which causes the surface to fracture.

Crustal Plateau's: These forms range in size from about 3000×2000km down to 1700×1000km and are generally elevated by about 1-4km above the surrounding terrain. They exhibit complex deformation patterns and extensional features are common in plateau tesserae. By looking at the number of craters it appears that the majority of plateau tectonism occurred before the mean surface age of the plateaus themselves.

5.2 Impact Cratering

Venus has a well documented catalogue of impact craters thanks to the Magellan mission. With just over 900 craters distributed randomly across the whole surface, we can deduce that the surface of Venus is relatively young and also uniform in age. We see many differences between Venusian and lunar craters, primarily because of the presence of a dense atmosphere and much higher gravity.

5.2.1 Craters

There is a dearth of craters below 2km in diameter, and this is probably due to the atmosphere breaking up anything smaller. The smallest craters are clearly non-circular, and only a handful have the simple form usually applicable to small diameter craters. Greater than 12km in diameter, the crater form becomes circular and then as the diameter increases, changes in the morphology of the craters occur along similar line for those of the Moon, i.e. as the diameter increase we see peaks, rings, terraces etc, but the changes occur for smaller diameters than on the Moon (due to the increased gravity). Most of the craters show little degradation compared with the craters on the Moon or Mars. Only 38% of craters appear to have been modified by tectonism or volcanic flooding.

The dense atmosphere on Venus makes it more likely that a meteorite will break up or explode before reaching the surface. The explosion of a meteorite, if sufficiently close to the ground, would cause a shock wave to hit the surface, creating "splotches" in the radar return. Around 400 of these features have been seen, with diameters of a few kilometres in general. If the projectile does not explode, but instead breaks up, multiple crater fields may be formed. Just under a hundred multiple impacts have been identified, ranging from those which overlap, making a "multiple-floored" crater, to those which are completely separate, but clustered in the same locality. There are some unusual occurrences where craters are too close to be unrelated, but are also too large to have been formed from the break up of a single incoming meteoroid.

5.2.2 Ejecta

Venusian craters have distinct ejecta patterns, the nature of which changes with increasing diameter of primary crater. Rather than the ejecta being emplaced ballistically, as on the Moon, on Venus, it appears to have been emplaced in a cloud. Despite this, secondary craters do exist, and for craters with diameters greater than 100km, SIC's are found deposited in all directions from the crater and are found beyond the continuous ejecta sheet. For craters in the range of 50-100km diameters, SIC's appear inside the continuous eject as well as outside. Only a few rays of SIC's are found around craters with smaller diameters than this. Approximately one third of the ejecta blankets are seen to be surrounded by radar-dark zones, either as a diffuse boundary or with a sharp margin. These may have been formed by the incoming shock wave or by the deposition of fine-grained ejecta.

A feature unique to Venusian impact craters are ejecta outflows, which are believed to be fluid flows of impact melt. They have rough margins, and it seems that the more oblique the impact, the more voluminous were the ejecta outflows. Outflows appear preferentially downrange and the higher temperature on Venus has the effect of making surface melting more easy and allows the melted ejecta to remain molten for longer. There are currently two main theories for their formation; hot clouds of turbulent impact melt & vapour and impact melt. There are a great diversity of forms of ejecta outflow which suggests that there is more than one creation mechanism at work.

5.3 Eolian Processes

Since the atmosphere of Venus is so dense, wind velocities are not as high as on Mars, and have less destructive power. The surface does, however, show ample evidence for wind erosion having occurred. By looking at the eolian features we get an insight into the atmosphere and also provides information on the nature of the surface.

5.3.1 Dune fields

Dune fields are just one of the eolian features we see on Venus. The Aglaonice dune field has hundreds of dunes around 200m and larger. The entire field covers and area of approximately 1300km^2. As well as the large scale dunes, features called microdunes are also found. The presence of these has been inferred from variations in radar brightness on different mapping cycles.

5.3.2 Yardangs

One example of yardangs are believed to south-west of the largest known crater on Venus. However, it is still unsure as to whether they are yardangs or just wind streaks due to the resolution of the Magellan images. This particular yardang field a vast area of 40000km^2, with individual yardangs reaching approximately 25km in length and half a kilometre in width, spaced 0.5 to 2km apart.

5.3.3 Wind Streaks

Thousands of wind streaks have been found on Venus of varying kinds. Most linear streaks are also the longest, measuring up to 700km in length. Some though are as short as 1km long, although shorter ones probably do exist. The distribution of the wind streaks is not uniform, with most occurring on the plains, but this may be a selection effect, in that streaks on smooth plains are easier to identify than on heavily deformed highland areas.

5.4 Volcanism

5.4.1 Large Volcanoes

Volcanoes are classed as large if their diameter is greater than 100km. They are identified by lava flows centred on a region of positive topography, tend to be relatively high and appear to overlie regional plains. Thus far over 160 have been identified. Only a few have a diameter larger than 700km, and their slopes are rarely greater than a few degrees, far lower than Martian shields. Often a variation in the slope occurs near the summit. Three different profiles of large volcano are found: 1) straight-sloped shield; 2) straight-sloped shield with a) truncated or b) shallow upper flank slope or c) depressed summit area; 3) irregular, asymmetric or domical in form. It is uncertain as to whether these differences are evolutionary or not.

Large volcanoes are classified into 9 classes:

I. Simple. Symmetrical outline with radial flows.
II. Caldera. Same as I) but with a caldera.
III. Flanking Rift Zone. One or more rift zones on the flank, positioned radial to the edifice.
IV. Elongated Summit. The summit of the volcano is elongated rather than circular.
V. Multiple and Steep Summits. A volcano with more than one summit.
VI. Radially Fractured Exterior. Radial fractures appear outside the flanks of the volcano. Commonly predate flow units.
VII. Rift-related. Found on the axis of a ridge.
VIII. Radially Fractured Interior. Fractures occur in the centre or top of the volcanoes, often with high density.
IX. Corona-like Interior. If the corona-like structure comprises 50% or more of the volcano diameter, but which does not obscure distinctive radial flow like features.

FIGURE 5.1 (The different classes of large volcano)

5.4.2 Intermediate Volcanoes

These are volcanoes with diameters less than 100km. They exhibit a range of morphologies similar to those seen in large volcanoes, but in addition have a variety of steep sided and modified morphologies. Almost 300 have been identified to date, with 4 basic morphologies.

I. Simplest. These are circular with no radial flows. They have a radar bright/dark dichotomy which implies shallow slopes. Often have a small caldera, volcanic crater or pit. In some cases, part of the circularity may be the result of flooding by the plains material and therefore may actually be large volcanoes which have been partially buried.
II. Radially Patterned Flows. Informally called “anemone-type”, these are similar to the class I large volcano. The shields appear to have been constructed from an accumulation of multiple lava flows of more or less uniform length and width erupted from a central vent.
III. Pancake Domes/Steep Sided Domes. These have relatively steep sides, are circular with relatively flat or upwardly convex profiles and variable fractures and pits. Have volumes of ~100km^3 compared to ~1km^3 on Earth.
IV. Steep Sided, Irregular Shapes. Often referred to as “ticks”, “scalloped-margin”, “fluted” or “modified” domes. They are probably formed due to the collapse of the margins of the class III intermediate volcanoes.

The steep sided domes could have formed in this way due to either the chemistry, temperature or volatile content of the magma. Many of the modified domes appear near the summit of large volcanoes. This implies that there has been an evolved geochemistry in the region or gas-rich late stage eruptions. Steep sided domes are frequently found with coronae, which again implies a long term evolution of the magma reservoir or chamber.

5.4.3 Small Volcanoes

These are less than 20km in diameter, and although often called domes or cones, they are most often small shield volcanoes. The basal diameter of these shields have been measured down to as small as 1km, but whether this is a real cut-off point, or a limit of detection is not clear. Summit pits do occur, but not on all small volcanoes observed. When they are present, they are usually between 0.5-1.8km. Where the pits are large relative to the base, they appear as cone shaped edifices. Two classification schemes exist for small volcanoes, one which is based on the assumption that the variety of forms represent different compositions, and one that represents the opinion that they are all basaltic eruptions with different eruption parameters. The number of small volcanoes can be used to understand global rates of resurfacing and magma production. It is estimated that there are up to a million small volcanoes distributed over the planet.

The most common form is observed to be a shield-like, single summit pit. Some appear to be flat-topped, similar to the steep sided domes of intermediate size. Edifice margins appear scarp like, sometimes with radially striated aprons. Some with very shallow slopes are seen as radial lava flows, and they are frequently aligned along local structural trends.

Fields of small volcanoes are termed as “dome fields” or “shield fields” and may contain tens or hundreds with a density of 4 to 10 per 10^3 km^2 in an area >10^4 km^2. The fields can have diameters from 50 to 350km and can be broken down into 4 basic classes:

I. Simple field. Randomly scattered on the plains unit with no apparent association between the plains and edifices.
II. Apron shield fields. Clusters of volcanoes spatially associated with bright or dark volcanic flows.

III. Companion shield fields. Spatially associated with another type of volcanic centre. This class includes close to intermediate volcanoes or one or more coronae.
IV. Plains units with abundant small shield that have consistent stratigraphic relations with other mappable units.

5.4.4 Volcanic rises

Volcanic rises form a major part of the highlands in the equatorial region. They are often associated with broad tectonic junctions and so demonstrate well the interaction between volcanism and tectonism at large scales. Often the distinction between the volcanic and tectonic relief is uncertain, but they do contain obvious centres of volcanism. They are up to 1000km to 3000km across and have large gravitational anomalies which perhaps are due to dynamic mantle phenomena.

5.4.5 Large Flow Fields

Centres of large flow field eruptions can be placed into three forms:

I. Dark streaked flows.
II. Fluctus. Large flow fields often flowing in one direction from a source.
III. Festoon. Radar bright flows with organised patterns of internal ridges and flow bands.

These flows are of a similar scale to terrestrial flood basalts, and over 200 have been located which are larger than 50,000km^2. No correlation between flow morphology and the total area has been found.

5.4.6 Coronae

Coronae are roughly circular features a few hundred km in diameter. They can come in a variety of forms, but in general have raised rims above the surrounding terrain with a pattern of fracturing and ridges associated with it. They are interpreted as surface expressions of thermal plumes rising from the mantle to the near surface, probably causing a doming of the surface. Once convection had switched off, there was a collapse over the top of the plume causing a sagging of the domed structure, and resulting is the corona-like form we observe. Coronae are often associated with large flood lavas and other features.

FIGURE 5.2 (Morphology of a corona)

5.4.7 Sinuous Rilles and Canali

Sinuous rilles are a feature commonly found on the Moon, but they are also found on Venus too. Another form of channel found on Venus are called canali. They often start in an irregular depression and travel in a sinuous way. Their widths (~3km) remain constant for large portions of its length and can be as long as 1600km, which is the largest found on Venus. Where the canali are well developed, they may bifurcate, sometimes rejoining, sometimes staying separate. In the most fresh, they may give rise to a large spread similar to the appearance of a flow of lava, the diameters of which can be 100’s of km. In profile, close to the vent, they seem to have a box-shaped profile with no raised rim. Further away from the vent, they develop a raised rim relative to the surface. This difference in profile has lead to many queries as to how the canali formed, i.e. erosional or constructional. Their origin is still debated.

FIGURE 5.3 (Morphology of canali)

Reference List

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