SECTION 4 : MARS (2 lectures)

Mars shows a distinct hemispheric asymmetry, having a densely cratered southern hemisphere which is 1-3km above the topographic “sea-level”. The northern hemisphere generally has far fewer craters and lies below this level. It is considered that the heavily cratered terrains are the more ancient material, and that the lower areas are younger, having been modified by lava sheets and sedimentary deposits. The surface of Mars shows evidence for many processes having been active on its surface throughout time. These include wind, water, cratering, volcanism and tectonism, and these will be dealt with in turn.

4.1 Tectonics

Unlike the Earth, Mars is a one-plate planet and therefore has not been as tectonically active. There are areas however, which do show a great deal of evidence for structural deformation. One of the key areas on Mars where tectonic features are found is at the Tharsis bulge. Tharsis is a large high-elevation volcanic area, but it is clear from returned spacecraft data that not all of the uplift is due to volcanics alone, and that a considerable amount of tectonic activity must have occurred in the area before the Tharsis volcanoes formed. The region has extensive swarms of radial graben extending to the south, north, and west of the uplift. Some of these graben may be hundreds of kilometres long and may have resulted from the initial uplifting of the area.

The most spectacular fracture feature on Mars is undoubtedly Valles Marineris, a huge rift valley 4000km long. Structural ridge patterns are also seen on Mars, again in the Tharsis region but concentric to it. Although structural features are seen over most of the planet, the highest concentration is around the Tharsis region.

FIGURE 4.1 (Figure 6.22, Mutch; distribution of tectonics)

4.2 Volcanism

Mars has certainly been volcanically active in its past. It boasts the largest known shield volcano in the solar system, despite being half the size of the Earth. Once again, the Tharsis region is prominent in the volcanic of Mars.

FIGURE 4.2 (schematic of position of Tharsis volcanoes)

Three large volcanoes are aligned along the Tharsis ridge with Olympus Mons located to the north-west. All are shield volcanoes with Olympus Mons probably being the most impressive. They all have calderas at their peak, Olympus and Ascreas showing several successive collapse structures.

Although these are the largest volcanoes, there are several other features that have an unambiguous volcanic origin including the Elysium region. When plotted on a figure of Mars, the location of volcanic features appears to be restricted to areas on or near the smooth plains. Extensive lava flows can be seen in the northern hemisphere and some believe that entire hemisphere is covered with lava’s, but with some flows covered themselves by eolian deposits.

FIGURE 4.3 (Figure 5.46, Mutch; distribution of volcanoes)

The volcanic region of Tharsis is believed to be very young based on crater counts on the flanks of its volcanoes, perhaps on a few hundred million years ago. This is very recent compared to the timescale of the solar system.

4.3 Craters

Impact cratering affects all solid bodies in the solar system and Mars is no exception. Like the Moon, Mars has impact scars of all sizes from large basin sized impacts down to craters of simple form. Craters with complex form are also seen.

FIGURE 4.4 a-c (Ejecta forms)

Mars craters often show unusual ejecta blanket patterns. Lobate ejecta appear as flow-like patterns with round edges to the ejecta, like flower petals. Rampart craters also have a flow like form, but with more evenly spread ejecta. They take their name from the rampart (raised rim) at the edge of the ejecta. We also see stacked flows, where it appears that one or more ejecta blankets have flowed on top of another. All of these forms often show radial striations on their ejecta.

The flow-like ejecta has been interpreted as showing the presence of ground-ice which lowered the strength of the target material. The ejecta may well have been in a mud-like form. Experiment has shown that when ejecta is mud like, the ejection angle from the crater is very steep. As the ejecta falls, the material is unable to support itself against gravity and it flows along the ground. This may well explain the flow-like forms seen on Mars.

FIGURE 4.5 (Collapse of peak to surge of material)

Also seen on Mars are central pits, rather than peaks. These are probably the result of the initial central peak being unstable against gravity and collapsing down, freezing into its "pit" configuration. This phenomenon may also explain the stacked flows. As the peak collapses, it causes a surge of material to be pushed away from it. In some cases, this surge may be strong enough to flow over the crater rim and form another ejecta sheet on top of the original.

The asymmetrical distribution of craters across Mars points to the young age of the northern hemisphere.

FIGURE 4.6 (Figure 4.29, Mutch; distribution of craters)

Remember, on Mars there is a vigorous atmosphere which acts to modify the craters far quicker than on the Moon. It is therefore common to see craters at various stages of degradation.

4.4 Wind

Although the atmosphere of Mars is thin, it is efficient in eroding surface features of Mars. Wind speeds on Mars have been measured to be very high indeed, carrying particles at high velocity with the potential to inflict damage on anything in its path. There are several features that are considered to be evidence of wind erosion on Mars.

Chains of pits known as deflation pits are caused by wind where loose material has been picked up and carried elsewhere. Yardangs are formed by wind acting upon weak material and form grooved or furrowed terrain in the direction of the prevailing wind. There is evidence of wind deposition, such as bright or dark wind streaks. Dune fields are also observed across Mars, especially in the floors of old craters where dark patches of deposits may bee seen. Vast dune fields are also seen around the north polar ice cap too. Wind streaks are particularly prominent around craters.

FIGURE 4.7 (helical patterns around craters)

These forms have also been reproduced in the laboratory, showing that the helical patterns may either erode or deposit material, depending on the conditions. On occasion craters are found that have wind streaks in several different directions, indicating that wind direction is variable in those particular regions.

The material which is picked up and deposited my be made up of material broken up by surface weathering, or there may have been a contribution of fragmented material produced by explosive volcanism. Material of sand-grained size moves by the process of saltation. Grains collide with one another and cause erosion to heights of only a few tens of centimetres. As the sand grains are broken down into smaller sizes, dust -sized particles are produced which are picked up by the winds and are responsible for obscuring large parts of the surface during major dust storms. The largest particles, pebbles and rocks etc., erode by the creep process.

FIGURE 4.8 (Figure 7.1, Mutch)

4.5 Water

The lower temperature and pressure conditions on Mars means that water would not be stable at the surface of the planet today. The conditions on Mars have not always been the same, and there is ample evidence that water once flowed there.

4.5.1 Outflow channels

These are some of the largest fluvial features on Mars, some extending 100's km in length. Most of them occur to the north and east of the Tharsis region. Many emerge from chaotic terrain, large areas of jostled blocks situated 1-2km below the surrounding terrain and have an inward facing cliff - these areas look as though they formed from collapse. They extend for many 100's km until they reach the northern plains. These channels have few, if any, tributaries and tend to be narrow and deep in the cratered highlands, but wide and shallow once they reach northern latitudes. The features associated with outflow channels suggest that they formed as the result of catastrophic outpourings of water. The channelled scablands of eastern Washington are believed to have been caused by a similar release of water. 10 million cubic metres of water per second were released in that event at its peak. The Martian outflows are estimated to have released 10-100 times that rate.

Another possible cause for the release of this water is the sudden eruption of ground water under high pressure from areas of chaotic terrain. Imagine a large collection of water trapped beneath a permafrost layer - pressures could get very high. If the overlying layer became weakened or cracked (i.e. by an impact), the water could be released under high pressure. This would cause very efficient erosion of the terrain - the permafrost layer would collapse, leaving behind the chaotic terrain. From age estimates, these events seem to have occurred throughout early Martian history.

FIGURE 4.9 (schematic of an outflow channel)

4.5.2 Dendritic channels

Dendritic channels are tree like patterns similar to valley systems on Earth. They occur almost everywhere in the cratered highlands, but very few are seen on younger terrain. Therefore whatever caused them happened early on in Mars' history. Like terrestrial river valleys they probably formed by the slow erosion of running water rather than catastrophic floods. This theory requires that Mars was once much warmer than it is now. The features of these systems also imply that the fluvial action was a short-lived phenomenon.

FIGURE 4.10 (schematic of a dendritic channel)

4.5.3 <u>Other evidence</u>

There are many streamlined flows, particularly easy to see in the outflow channels as they move to northern latitudes. These are very similar to Earth-like features, and show the direction of the flow of water quite nicely.

FIGURE 4.11 (schematic of a streamlined island)

Stubby channels. These are smaller and stubbier than the dendritic channels, typically 10km in diameter. They have a box-like profile, caused by sapping. Sapping occurs by the removal of surface material as a slurry (mixture of groundwater and surface material). Some of the water may have been present beneath the surface, again as a layer of permafrost or liquid water below.

FIGURE 4.12 (schematic of a stubby channel)

Evidence for ground ice comes in the form of pingo's, the result of a mass of ice below the surface being buoyant and rising, lifting the top rocks into domes - cracked at the top. The features on Mars are larger on Earth, perhaps because of a thicker layer of frost. These layers may be thick in some places, as evidenced by large polygonal patterns seen in polar regions which are 10's of metres across.

FIGURE 4.13 (schematic of polygonal patterns)

<u>Reference List</u>

Carr M.H., 1996, "Water on Mars", Oxford University Press

Mutch T.A., et al., 1976, "The Geology of Mars", Princeton University Press