

THE PROBLEM OF SCALE IN PLANETARY GEOMORPHOLOGY

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Recent planetary exploration has shown that specific landforms exhibit a significant range in size between planets. Similar features on Earth and Mars offer some of the best examples of this scale difference. The difference in heights of volcanic features between the 2 planets has been cited often; the Martian volcano Olympus Mons stands approximately 26 km high, but Mauna Loa rises only 11 km above the Pacific Ocean floor. Polygonally fractured ground in the northern plains of Mars has diameters up to 20 km across; the largest terrestrial polygons are only 500 m in diameter. Mars also has landslides, aeolian features, and apparent rift valleys larger than any known on Earth.

No single factor can explain the variations in landform size between planets. Controls on variations on Earth, related to climate, lithology, or elevation, have seldom been considered in detail. The size differences between features on Earth and other planets seem to be caused by a complex group of interacting relationships.

The major planetary parameters that may affect landform size include the following:

Gravitational acceleration is a driving force in geomorphic activity, especially in mass movement and fluvial processes.

Radius of the planetary body seems to influence plate tectonics, which causes mountain building, rifting, and volcanism.

Lithospheric thickness affects the isostatic compensation of large-scale features, including the heights to which mountains and volcanoes can grow.

Atmospheric density influences the intensity of degradational processes at a planetary surface, and particularly the effectiveness of wind.

The presence of water contributes to both chemical and physical weathering; in solid and liquid form, it is an effective geomorphic agent.

Ambient temperature range, particularly the frequency

with which the temperature crosses 0°C in the presence of water, influences the effectiveness of numerous processes.

Observing resolution has proven to be a factor in the observed sizes of Martian landforms. High-resolution Viking images collected late in the mission reveal polygonal patterns with diameters similar to those of terrestrial polygons.

The control listed above that is most conducive to experimental testing is gravitational acceleration (g). Remotely sensed data about the surfaces of other planetary bodies offer a passive way of studying the possible effect of variations in g , but the influences of other parameters are impossible to eliminate. The establishment of a permanent space station later in this decade should make it possible to study the role of gravity in geomorphic processes further. The importance of time in most geomorphic processes makes long-term studies on a space station more desirable than short-term experiments in high-altitude aircraft like the KC-135.

Plate tectonics has a major effect on the geomorphology of a planetary body, by recycling crust and producing volcanoes and mountain chains. Mercury and the Moon are probably too small to have plate tectonics; Mars may have had tectonism earlier in its history. Whether Venus has had tectonic activity is unclear. For the inner planets, the energy source for tectonism is primarily radioactive decay.

Several of the Galilean satellites also have a form of tectonism, as with the "sulfur volcanism" on Io and the "ice tectonics" on Ganymede. In both of these cases, the energy seems to come from tidal heating caused by gravitational interaction between the satellite and Jupiter. Both size and composition seem to play a role in tectonics. A minimum size for plate tectonics may be somewhere between the radius of Earth and that of Mars. A logical extension is whether there is an upper limit to the size of a planet that can support plate tectonics.

The atmosphere plays a multiple role in geomorphology, and it might be possible to generalize about the geomorphology of a planet based on its atmospheric density. The absence of an atmosphere seems to result in a surface characterized almost exclusively by impact craters. If an atmosphere exists, its density, the wind speed, and the availability of loose material will control the formation of aeolian landforms.

Freezing and thawing of water is an important mechanism in mechanical weathering; its significance depends on both the availability of water and the temperature range on a planetary surface. Presumably other ices could do the same type of geomorphic work. The length and magnitude of these temperature cycles may also play a role in the size of resulting geomorphic features. This possibility has been

suggested to explain the large size of polygonal-fracture patterns on Mars.

Explaining the relative sizes of landforms is just one problem in planetary geomorphology, and several other aspects of the subject that have received little attention lately may offer valuable insights into global mega-geomorphology. These include (1) physiographic provinces as a large-scale subdivision of the Earth's surface, (2) the use of an index correlating the size of a feature with the planetary radius, and (3) the consideration of relatively rare or poorly understood landforms. Division of the Earth's surface into large-scale sub-units, by physiography or climate, may provide new insights into how to subdivide the surfaces of other planets.

Attempting to understand the size differences in landforms among the terrestrial planets and some satellites of the outer planets prompts a further question: Is there an upper limit to how big a certain geomorphic feature can be? For example, if polygonally patterned ground ranges up to 500 m in diameter on Earth and 20 km across on Mars, could even larger polygons occur elsewhere - and, if so, under what conditions? Investigation of these questions may lead to a broader understanding of the physics underlying geomorphic processes.