Mars Geology and Volcanic Activity

Summary
In this writing we are going to explore the geology and volcanic activity on Mars. We will discuss rocks, impact craters, soil, dunes, volcanoes, faults, river deltas, and drainage basin features. In some instances we will consider features on Earth comparing them to Mars by writing a short paragraph distinguishing the characteristics for each set of features. We will also discuss how the geology and volcanic activity on Mars may affect the navigation and locomotion of a robot on Mars.

Comparative geology is one of the most important methods we have for deciphering the geological history of the other terrestrial planets. In this sense, the study of Mars has been exceedingly rewarding since there are a number of analogous features to those seen on Earth. The features examined in this writing are but a few that exist. We are going to compare Mars and Earth trying to decipher the history of geology and volcanic activity on Mars. While we compare we will also familiarize the uninformed people about the topics discussed on Mars.

Introduction
Mars’s geology and volcanic activity is an important topic for our HEDS-UP Program at Penn State University. The geology and volcanic activity of Mars is important due to the fact that the robot while need navigate sufficiently through Mars’s harsh terrain. By researching previously found data, from NASA, we will to be able to forecast a new model for a prototype robot that will navigate and collect geological data in order to make new discoveries.

Rocks
The types of rocks found on Mars and their lithology are still very poorly constrained topics. We have not yet made definite petrologic examinations on the surface of Mars. The only direct samples of the surface of Mars are from the SNC meteorites. Based on orbital images we expect that some types of rocks found on Mars include might include igneous and sedimentary rocks. In other words, these rocks are created from material of the planet's interior. Tharsis and Elysium, which are volcanoes, are covered with volcanic rocks. The morphology of the flows and the volcanoes suggests that they are basaltic or ultramafic in nature.

The northern plains on Mars have sedimentary rocks, both in terms of windblown materials and material deposited by floods. Sedimentary rocks are formed from "sediments", when the igneous or metamorphic rocks have broken down in the weathering process into individual grains. People on the Pathfinder suggested that conglomerates and sandstones occur at the landing site, but this is based on morphology and orbital images.

Overall, igneous rocks-volcanic and plutonic- would be the most voluminous, with sedimentary second. Metamorphic rocks (gneisses, schists, etc.) are not likely to be
found on the surface of Mars, although they may occur under the surface. But probably if found at depth they are results of ejecta from large craters and in some of the faulted rings around large impact basins.

Rocks on Mars are enriched with sulfur and iron. Also the isotopes in Mars rocks distinguish them from rocks coming from other planets. Rocks are rusty red in color due to the iron and sulfur content, which makes them very easy to distinguish between a rock from Earth (grayish in color).

We can prove that a rock or meteorite came from Mars by knowing that a rock is relatively young as in the dozen meteorites found on Earth. This suggests that they are crystallized from melted rock recently (within the last billion years). A planet would need to be big in order to be geologically active this recently to produce a rock. So the only possible planets that are big are: Earth, Venus, and Mars. Also, the content of oxygen contained within the various minerals of rocks, rule out the Earth as a place of origin. The most convincing evidence is that the two of the dozen rocks contain a gas trapped within the rocks, and that gas is identical in composition to Mars’s atmosphere and different from any other known source of gas in the solar system. It is thought that the gas was implanted into the rock by the force of the asteroid impact that also ejected the rock into space. So if the rocks are not from Mars there is no other planet or place in the solar system for them.

The image below is a view to the northeast of the lander and is annotated to show the variety of rocks in this landing site and what they tell us. The red arrows point to rounded boulders and rocks, thought to have been shaped by the forces of water in flood (rough edges knocked off by the tumbling action of the water). The blue arrows indicate rocks with sharp edges and points, most probably ejected from nearby impact craters and/or ancient volcanic activity. The white areas (of which Scooby Doo is one) are believed to be deposits left behind by evaporating water, or aggregates of materials fused together by the action of water.
Soil

The soil from Mars has the following composition
(Expressed as oxides in weight percents):

<table>
<thead>
<tr>
<th>Compound/Element</th>
<th>Weight %</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na2O</td>
<td>2.3</td>
<td>1.3-3.8</td>
</tr>
<tr>
<td>MgO</td>
<td>7.7</td>
<td>7.1-8.3</td>
</tr>
<tr>
<td>Al2O3</td>
<td>8.5</td>
<td>7.4-9.1</td>
</tr>
<tr>
<td>SiO2</td>
<td>49.5</td>
<td>47.9-51.0</td>
</tr>
<tr>
<td>SO3</td>
<td>5.5</td>
<td>4.0-6.5</td>
</tr>
<tr>
<td>Cl</td>
<td>0.6</td>
<td>0.5-0.7</td>
</tr>
<tr>
<td>K2O</td>
<td>0.3</td>
<td>0.2-0.5</td>
</tr>
<tr>
<td>CaO</td>
<td>6.5</td>
<td>5.6-7.3</td>
</tr>
<tr>
<td>TiO2</td>
<td>1.2</td>
<td>0.9-1.4</td>
</tr>
<tr>
<td>FeO</td>
<td>16.0</td>
<td>13.4-17.4</td>
</tr>
</tbody>
</table>

These add up to 98%, not 100%, due to averaging. Also there may have been elements in the soil which were not measured. The size of the particles range from microns (dust) to millimeters to meters. The exact size-frequency distribution has not been measured for the soil particles. The surface around the Viking Lander and the Pathfinder Rover is 16% covered with rocks. Rocks greater than 0.5m cover only 1.5% of the surface of Mars.
Impact Craters

Impact craters are undoubtedly the most common geological features in the solar system. They form by the violent transformation of kinetic energy into thermal energy as the impactor is brought to an abrupt stop at the planet’s surface. The various parts of complex craters are: basin floor, central peak, terraces, rim, ejecta blanket, and secondary craters. Simple craters lack most of these features, being basically a "bowl-like" depression with a rim and overturned strata.

The 3 km diameter crater in the MOC image shown below is three times wider than the famous Meteor Crater in northern Arizona, USA. The high resolution image shows many small windblown drifts or dunes in the low areas both within the crater and outside on the surrounding terrain. Some portions of the crater’s walls exhibit outcrops of bare, layered rock. Large boulders have been dislodged from the walls and have tumbled down the slopes to the crater floor. Many of these boulders are bigger than school buses and automobiles.

Comparing Earth and Mars; Arandas is an example of a Martian crater with "fluidized" ejecta deposits, a distinguishing characteristic of rampart craters. A thick concentric platform, or pedestal deposit, surrounds the rim. The crater is about 13 km in diameter. On Earth, Meteor Crater formed roughly 50,000 years ago when a 30-meter-wide iron-rich meteor weighing 100,000 tons struck the Arizona desert at an estimated 20 kilometers per second. The resulting explosion exceeded the combined force of today’s nuclear arsenals and created a 1.1-kilometer-wide, 200-meter-deep crater.

Dunes

Mars has been known for centuries to experience large dust storms, but it wasn’t until the Mariner 9 mission in 1971-1972 that pictures were returned from the planet that showed sand dunes. Dunes are also good evidence that the Martian atmosphere is presently capable of transporting loose sediment and depositing it elsewhere. Dunes are, in fact, deposits of sand that have accumulated usually over periods measured in
thousands of years. Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) images obtained since September 1997 provide new clues about Martian dune activity. MOC has found that some dunes appear to be moderately active today, but they do not appear to have moved downwind since the Viking missions more than 20 years ago. MOC also finds some sand dune fields that appear to be inactive because the dunes are either covered by dust and landslide debris, or cemented and eroded into ridged and grooved terrain, or because they have many old impact craters on them. The five sets of pictures presented here show the variety of dunes from recently active to solidified and cratered. These pictures were taken at various times throughout the MGS MOC mission.

Types of Dunes:

1. Active slip face
2. Dunes overriding dunes
3. Streaks overriding dunes
4. Cemented grooved
5. Cratered paleodunes
Volcanoes

The largest volcanoes in the solar system can be found on Mars. The volcanoes are of the basaltic shield type, similar to those found in Hawaii. Shield volcanoes erupt low viscosity lava and do not typically produce large blasts. This was determined by studying the volcanic structure. As of today, there has not been any recording of current or lack of future volcanic activity, leaving us to believe that the volcanoes are dormant.

The shield volcanoes on Mars have become much larger than Earth volcanoes because of two important facts, lower gravity and lack of plate tectonics. Since Mars has lower gravity, the volcanoes have less force to keep them low to the ground. Also, unlike Earth, there are no plate tectonics on Mars, so the "hot spot" forming the volcanoes stays under one area.

Olympus Mons is the largest volcano on Mars and in the solar system. The base of this volcano can be compared to the state of Arizona, 550 kilometers (340 miles) in size. The incline for Olympus Mons is about 2 degrees where the volcanoes on Earth can get up to 7 degrees in incline. Olympus Mons is approximately 24 kilometers (15 miles) high, which is approximately two and a half times the height of Mount Everest and three times the flight altitude of commercial planes. In comparison, Mauna Loa, in Hawaii, is only 9 kilometers (6 miles) high and 120 kilometers (75 miles), if measured from the sea floor.

Other volcanic areas include Tharsis Ridge, where many of Mars’s volcanoes are located. Dimensions at the base of this ridge are approximately 4,000 kilometers (2,500 miles) across, twice that of the United States. The domes in the ridge can be approximately 10 kilometers (6.2 miles) in height, still larger than the largest Earth volcano. The below image is that of the Tharsis Ridge.
**Faults**

Faults occur when the movement in a planet’s crust fractures the rock and displace the separated sections. Sometimes faults separate large masses of rock from the surrounding crust and form fault-block mountains. The Sierra Nevada is a westward-tiled fault block. Erosion is gradually modifying the slopes.

The Valles Marineris on Mars is a gigantic split in the crust of the planet, thought to be brought about by the pressure of the build up of the lava on the Tharsis bulge. This canyon is approximately 3,000 kilometers (1,860 miles) long and can be up to 8 kilometers (5 miles) deep. In the picture below, the upper portion is an image of the canyon wall. The lower portion of the image is of the bottom of the canyon.

![Image of the Valles Marineris canyon](image)

**River Deltas**

Deltas are formed as a river flows into a standing body of water. As it enters into the standing body, it carries derbies that gradually build up and form a structure, which resembles the Greek letter Delta, hence, the name. The stream spreads through the delta in a complex of channels called distributaries. By flowing through the delta the power of the river is greatly decreased. Finding this structure can help us understand the history of the presence of water on the planet.
**Drainage Basins**

A drainage basin is the area that supplies streams and their tributaries with water. As a stream flows, it erodes its bed creating a chasm or valley. The drainage basins on Mars are less defined than those on Earth; these valley networks are less developed than typical terrestrial drainage systems. Since Martian drainage basins are lacking small-scale streams feeding into the larger valleys, it is thought that the valleys were carved primarily by ground water flow rather than by runoff of rain. Other thoughts include that rivers of dust may have created these valleys. It is important to study these valleys in order to better understand the evolution of Mars. In the below image, the length of the canyons that could have been created by rivers or streams is shown. It also shows the tributaries that may have feed the streams and rivers.

![Image of Martian drainage basins](image-url)

**Conclusion**

The geological and volcanic features of Mars we presented in this paper will all affect how a robot should be built to navigate on Mars. Perhaps building a robot that has each feature programmed into its memory and when it senses a specific feature it will adapt to the new feature with a different movement. To sufficiently build such a robot to navigate Mars, one must consider all the possible geological features for a robot to encounter. We discussed rocks, impact craters, soil, dunes, volcanoes, faults, river deltas, and drainage basin features on Mars. Overall, we sufficiently covered and discussed the topics giving examples, comparisons, and how features relate to our own planet.
Reference List:
Reference list by: Joseph Yagloski Jr. and Christian L. Feisel
General Task #10: Geology and Volcanic Activity
Literature Survey Assignment
2/3/00

Literature


Web Sites


