Chapter 10 Mars

Orbital Properties

Mars is the 4th planet from the Sun and the last of the terrestrial planets. Since Mars is beyond the Earth, we see both oppositions and conjunctions. From our view Mars crosses all the way across the sky. Mars has an eccentricity of .093, which means that at perihelion it is 1.38 A.U. as compared to the aphelion distance of 1.67 A.U. This means that at perihelion Mars receives a substantial increase in sunlight. When the Earth is between Mars and the Sun, the distance from the Earth to Mars is .37 A.U. Even though Mars is close, it is considerably dimmer than Venus. This is due to 3 factors: 1) It is 2x farther from the Sun than Venus. 2) The surface area of Mars is 30% of Venus so it reflects less light. 3) Mars is much less reflective than Venus since Venus has all those clouds.

Physical Properties

We can determine the radius of Mars by simple geometry and what we find is that it is about 3400 km. More accurate measurements give us 3394 km or .53 Earth radius. Mars has 2 small moons named Phobos and Deimos. They are thought to be captured asteroids since they are so small and odd shaped. Phobos is 9378 km from the center of Mars and it goes around once every 459 minutes. From Kepler's third law we can determine that the mass of Mars is about .11 of the Earth. From its mass and radius we calculate a density of 3900 kg/m^3. This is a little more than the Moon's density. If the rocks here are similar to those of the other bodies, this would mean the existence of higher density material in the core. It is thought that it is made up of iron sulfide and has a radius of about 2500 km.

Surface features are easy to see since Mars rotates once every 24.6 hours. It tilts on its axis at 24°. Just like on Earth, we find daily and seasonal changes on Mars. The seasons are a little complicated by the eccentric orbit. This means that it is significantly hotter in the north than in the south.

Long Distance Observations of Mars

When Mars is at opposition, it is closest to us and the easiest to see. We can see some light and dark areas and the polar ice caps are prominent. When seen from the Earth, the polar ice caps are the most easily seen features since they stand out against the darker planet. If you watch them over the course of a year, you can see them grow and shrink as the seasons change. The changing polar caps are frozen carbon dioxide (dry ice). The polar caps do contain water, but it never gets warm enough to melt, so the water is permanently frozen. The dark areas that were once thought to be canals are actually cratered areas where the dust blows around and gives the impression of surface variability.

This dust is blown around by hurricane force winds. When Mariner 9 went into orbit around Mars in 1971 there was a planet wide dust storm going on.

The Surface of Mars

The surface of Mars shows a wide variety of features as seen by our orbiting spacecraft. It has volcanoes, canyons, craters, and dune fields.

Large-Scale Topography

Our orbiters have mapped Mars' surface to an accuracy of a few meters. This was done by using a laser altimeter. A big difference was between the northern and southern hemispheres. The northern hemisphere is mainly volcanic plains just like the maria on the Moon. These were formed by large eruptions of material. The southern hemisphere contains heavily cratered highlands. Most of the dark areas seen from Earth are the mountainous regions in the south.

The northern hemisphere is much less cratered which implies that it is younger than the south. Maybe the north is 3 billion years old and the south is 4 billion years old. The boundary between the north and the south is quite sharp. The elevation can drop as much as 4 km over a distance of less than 100 km. It is thought that the south is the original crust. How the north dropped is a mystery to scientists.

The main feature on the surface is Tharsis Bulge. It is about the size of North America and is 10 km high. To the east lies Chryse Planitia (plains of Gold) and to the west is the Isidis Planitia (plains of Isidis). These are huge depressions which are hundreds of kilometers across and as much as 3 km deep. If we want to consider that Mars has continents, then Tharsis is the only one. Just like on Venus, there doesn't appear to be any plate tectonics. Tharsis appears to be much younger than the rest of the northern hemisphere. It is only about 2 – 3 billion years old. Almost diametrically opposite from the Tharsis Bulge is the Hellas Basin. This is an area which is 3000 km across and nearly 9 km below the crater's rim, making it the lowest point on Mars. The shape and structure of Hellas Basin make it an impact crater. Due to the high cratering, it must have occurred about 4 billion years ago.

Volcanism

Mars contains some of the largest volcanoes in the solar system. Three of these are found on the Tharsis Bulge. The largest is Olympus Mons which is the largest mountain in the solar system. Its base is 700 km across which would cover up Arizona and it is about 25 km high. The caldera at the top of the volcano is 80 km across. The other 3 volcanoes are a mere 18 km high. These are shield volcanoes sitting on top of hot spots, not due to plate tectonics. They show lava channels and other flow features. Viking and Global Surveyor showed that there are hundreds of volcanoes on Mars. Most are associated with the Tharsis Bulge.

The main reason that these volcanoes are so tall is due to the low gravity on Mars. Are they still active? We don't know, but they appear to have been active as recently as 100 million years ago as determined by crater counts.

Impact Cratering

Spacecraft have shown us that Mars and its 2 moon are pitted with craters. Many of the smaller craters seem to be filled in with material which helps confirm that Mars is a dry world. There are few craters less than 5 km in size. The thin atmosphere carries dust very effectively and fills in the small craters. This helps determine the age of Mars' surface. The southern hemisphere is about 4 billion years old and the northern hemisphere is a few hundred million years old. The ejecta blankets on Mars are different from those on the Moon. On Mars it looks like water has splashed out of the crater. This is called a *fluidized ejecta*. This indicates that there might be *permafrost* just below the

surface. It was thought that all of the water on Mars is frozen, but now we are seeing gullies from the recent past. These gullies resemble flash flood channels carved out on Earth. They might be as old as a million years, but some may still be active.

The Martian "Grand Canyon"

Another feature associated with the Tharsis Bulge is a canyon called Valles Marineris. Unlike the Grand Canyon, it was not formed by running water. This is a crack in the surface, which is called a tectonic fracture. It was formed by the same forces that formed the Tharsis Bulge. These cracks have been dated to about 2 billion years ago. It runs for 4000 km or $1/5^{th}$ of the planets circumference. It is as wide as 120 km wide and 7 km deep. There are side canyons of Valles Marineris that are larger than the Grand Canyon. It is so large that it can be seen from the Earth.

Evidence for Running Water

We have photographic evidence that water has run on the surface of Mars. It comes in 2 forms: 1) runoff channels and 2) outflow channels. Runoff channels are found in the southern highlands. Some are hundreds of kilometers in length. They are twisting interconnecting channels. They bear a strong resemblance to rivers on the Earth. They are probably about 4 billion years old.

The outflow channels are the remnants of *catastrophic flooding*. They are found in the equatorial region and are not interconnecting. They are due to huge amounts of water draining off. The runoff was enormous, as much as hundreds of times more water than the 100,000 tons per second carried by the Amazon River. These were formed about 3 billion years ago. These ideas are still controversial. In 2003 data was released that pointed out that there was less carbonate material present than there should have been if there had been ancient oceans. Bottom line is that there is no evidence for liquid water of any kind and the amount of water vapor on Mars is tiny. Many think that the water is locked up as the permafrost under the surface of Mars. It s thought that 4 billion years ago the climate changed and the water started freezing out. Much later as volcanic activity warmed the ground the ice was melted quickly and you had an enormous runoff causing the outflow channels.

Polar Caps

The polar caps on Mars are made up of 2 parts: 1) the *seasonal cap* and 2) the *residual cap*. The seasonal cap is made up of frozen carbon dioxide or dry ice. It grows and shrinks each year due to the temperature change. At its maximum the southern cap is 4000 km across and the northern cap is 3000 km at its maximum. The sizes are different due to the eccentricity of Mars' orbit.

The residual caps are permanent. The southern cap is about 350 km across and it is probably made up of CO_2 as well as some water ice while the northern cap is about 1000 km across and it is made up of mainly water ice. This is because the northern cap warms up to about 200 K which is too warm for the dry ice (150K). The differences in the caps seem to be related to the giant dust storms that occur on Mars.

The View from the Martian Landers

When Viking 1 landed it showed a desolate plain covered by rocks of all sizes. Viking 2 landed farther north and the plain looked pretty featureless. One of the main things that they found out was that the soil was high in iron content. This is why Mars appears red, it's rusting. Pathfinder and Sojourner found the same types of soil that the Vikings did, but found that the rocks were of a different composition. Spirit and Opportunity have been searching for evidence of water on Mars. Spirit showed the same types of geology as before, but Opportunity hit the jackpot buy showing that the rocks here show evidence of having been wet at one time. This is the best evidence yet for standing water.

The Martian Atmosphere

The pressure of the Martian atmosphere is only $1/150^{th}$ of the Earths atmosphere. Like Venus, it is made up of about 95% CO_2. It contains a troposphere which varies from place to place and season to season. At noon in the summer the temperatures can reach 300 K and you have strong convection currents while at night the temperatures can drop to 100 K. On the average the temperature on Mars is about 50 K cooler than the Earth. These cooler temperatures can cause early morning fog on Mars. For the most part there are little day to day variations. In the southern summer you can have the huge dust storms that can last for months and cover the planet.

Evolution

Around 4 billion years ago the atmosphere was thick and there was liquid water on Mars. The sky may have been blue and rain could have fallen. The greenhouse effect would have kept it fairly warm. Somehow the atmosphere was lost over a few billion years, possibly due to large impacts. As this happened a runaway refrigerator effect occurred. With the water present, the CO_2 would have been absorbed and the greenhouse effect would have gotten less. Water vapor would have frozen out lessening the greenhouse effect even more. The temperature on Mars would have dropped even more until we have the Mars of today. There are those that think that if all of the water that is in the permafrost would melt that it would cover Mars to a depth of several meters.

Martian Internal Structure

Seismographs on the Viking landers didn't work so we have no information on movement in the crust. By looking at the stresses that uplifted the Tharsis Bulge and others, it is thought that the crust is 100 km thick. In 1965 Mariner 4 detected no magnetic field. In 1997 Mars Global Surveyor detected a magnetic field about $1/800^{th}$ of the Earths. They think that it is a local anomaly or just localized to that area. Since Mars rotates rapidly, this means that there is no metallic core or that it has solidified. Due to the volcanoes this shows that at least some parts of the interior were molten but due to the small size most of the heat is gone. The relatively low density, 3900 kg/m^3, and no significant magnetic field and a high concentration of iron on the surface says that Mars may not have been molten through and completely differentiated.

The Moons of Mars

The 2 moons of Mars are Phobos and Deimos. They are thought to be captured asteroids due to their shape and size. They are heavily cratered and irregular in shape. Phobos is

20 x 28 km in size and has a crater that is 10 km in size and Deimos is 10 x 16 km in size and has a crater that is 2.3 km wide. They rotate synchronously (keeping the same side to Mars). Phobos lies 9378 km from Mars and orbits Mars every 7 hours and 39 minutes. Deimos lies 23,459 km away and orbits in about 30 hours. The density of these moons is about 2000 kg/m^3. They contain from the very beginning of the solar system so we study them not to gain insight to Mars, but rather to see what the early solar system was like.