Geology of the moon

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The moon is a little more accessible than other bodies in the solar system and this talk aimed to explain what moon rock reveals about the geology of the moon, which is an igneous cumulate complex. After some facts about the moon it looked at early ideas of the nature and origin of the moon, observations from earth, a look at both sides of the moon, major surface types – maria, highlands – craters and fieldwork near and on the moon. It finished with modern ideas on how the moon formed and some thoughts on impacting asteroids and volcanic eruptions.

Facts

The moon's mass is 7.35×10^{22}kg, 1.25% that of the earth. Its radius is 1,737km, 27.25% of the earth's and its surface area 3.79×10^{7}km^2, 7% of the earth's. Its density is 60% of earth's at 3.3g/cm^3 and its gravity is 16.5% of earth's at 1.62m/sec^2. Its day is 27.322 earth days and temperatures range from +130^{o}C to -130^{o}C. As the only long-term natural companion of earth, the moon is a fairly large planetary body in its own right and has a complex geological history. 1t is 384,400km distant from earth, the equivalent of 60 earth radii.

Early ideas

Galileo Galilei was one of the first to make observations of the moon using a 20X telescope and published drawings of it in his *Sidereii nunclus* (1610). Thomas Harriot used a 6X telescope and produced the first drawings of the moon in 1609, before Galileo, and produced a map of the moon. Patrick Moore produced his map of the moon in 1969. All you can do from the earth is to map the moon. Richard Procter (1872) in hi *The moon – her motions, aspect, scenery and physical condition* drew lunar landscapes.

The moon's craters (a term coined by Galileo) were considered to be possibly volcanic or due to meteorite impact. Almost all those we now know are impact craters. There are many more craters on the moon than on earth, where only about 150 have been recorded because they weather away easily.

There were 3 ideas of the moon's origin. George Darwin suggested rotational fission, wherby the earth was spinning rapidly and threw off a large chunk of mass which became the moon, leaving the Pacific in the hole left behind. Others were binary accretion and gravitational capture.

Observations from earth

Colour enhancing of telescope imagery allows interpretation of mineralogy and shows the moon to be a small but geologically diverse world. The main features are:

- The highlands, bright areas of ancient terrain which are very heavily cratered with rugged contours;
- The maria (seas), darker younger areaswhich are sparsely cratered low-lying flat plains of basalt lavas;
- Large impact basins, which are very ancient, the youngest being 3.8 billion years old, and many are filled with dark maria;
- Craters of all sizes: and
- Regolith, along with old volcanics, cooled lava rivers and tubes, caves, low ridges, lava mountains, fissures, landslides andmysterious markings.

The moon is not very active geologically.

The first images of the dark side f the moon were obtained from Luna 3 in 1959 with the first pictures of the eastern farside of the moon by Zond 3 in 1965. Lunar orbiting missions used 5 craft

to photograph the entire lunar surface, in preparation for selection of a landing site. These showed that 30% of the nearside of the moon were maria but only 1% for the farside, as shown in the *National Geographic* map in 1976.

The highlands, at 4.2-4.5 billion years, are heavily cratered. The maria are younger, at 3.1-3.9 billion years and comprise up to 2km thick lava laying directly on the mantle. Impact craters are widespread and some very large, such as Copernicus (93km across and Tycho, 89km across. These have a central peak surrounded by a flat plain and a crater rim with landslides and impact melt. Small, single-slump craters are <10-15 and 15-30km across with slopes of 1 in 5 to 1 in 6, while large complex craters range from 30-300km across. Protobasins 140-175km across with slopes of 1 in 30 to 1 in 50 are very rare. They have a central peak and a ring of mountains. Small ringed basins with no central peak but just a ring of mountains are 300-900km across with slopes of 1 in 50 to 1 in 100. Large multi-ringed basins 900-2,600km across have slopes of 1 in 100 to 1 in 200. There are lava tubes and channels, such as the Hadley Rille visited by Apollo 15 and pits and caves.

Basic geological thoughts

Like the earth, the moon had extensive volcanism with flood basalt eruption and was subject to both intensive and non-intensive bombardment by asrteroids and comets. It lacks an atmosphere and the surface is directly exposed to the space environment and continual micrometeoroid impacts lead to surface erosion. It is smaller than the earth so it lost its heat quickly and has produced no major volcanic activity for the last billion years. Since it has no plate tectonics, the moon has largely a complete rock record of early volcanicity and bombardment processes preserved.

Geological mapping

The first geological map of part of the moon was produced by Shoemaker and Hickman (1986) with a map of the farside with the stratigraph6 based on craters by Wilhelms (1987) of the USGS. There have been unmanned landings by 8 Russian Luna craft, 6 US Surveyors as well as the 6 Apollo manned landings. The US has also had 5 lunar orbiters, 3 of which had hard landings.

In Apollo 17, Harrison Schmidt, as the first professional geologist on the moon, landed on the edge of the Sea of Serenity in a valley 30km wide with landslides which contained boulders from the lower crust. The seismometer network installed by Apollo 11 failed but 5 reflectors were installed, which show that the moon is moving away from earth. 381kg of samples were brought back by the Apollo missions as well as 0.326kg of Luna amples. The moon is now thought to have a solid inner core, a fluid outer core with partial melting, a large mantle and a thin crust. Rocks include basalt, breccia, anorthosite, a norite boulder from the lower crust with orthopyroxene and a troctolite with olivine instead of pyroxene and lots of soil, including the orange soil consisting of volcanic glass beads. 95% of the highlands is anorthosite. In addition to samples brought back by 20th century missions, lunar meteorites are found on earth, 240 of them to date totalling 137kg. The only landing in the 21st century was by the Chinese.

Origin of the moon

The modern theory for the origin of the moon is “The big whack”, in which the early earth was impacted by a Mars-sized plaet and the debris fromed the moon. The moon is quite low in ironand the debris was from mantle material rather tha from iron cores . Early development of a magma ocean allowed mafic minerals to sink and leave the plagioclase highlands. This explains the low iron, absence of water and volatiles and the anorthositic highlands but it does not explain the fact that the moon and earth have identical isotopic cpompositions.

Recent changes to the theory suggests that it was possibly two half-earth bodies that collided with the impactor having the ame composition as the earth, unlike M<ars or the asteroids.. Tiny amounts of water have been found in the regolith probably due to hydrogen from the sun reacting with oxygen ion moon rocks.