Environments of planet formation and effects on differentiation.

G. JEFFREY TAYLOR

Hawaii Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, Univ. of Hawaii, Honolulu, HI 96822; gjtaylor@higp.hawaii.edu

Global data for the Moon and Mars

We have samples and global remote sensing data for the Moon and Mars. These form a solid basis for comparison to each other and to Earth of bulk compositions, compositions of primary crusts, nature of earliest differentiation, extent and character of secondary differentiation, and the abundance of tertiary crust. There are significant differences among these bodies, a few highlighted here. (1) They vary in K/Th (and any other ratio of a moderately volatile to a refractory element). Moon: 360; Earth: 2900; Mars: 5300. (2) The Moon has a clear-cut primary crust in the form of the anorthostic highlands. This is a cumulate from a magma ocean. Recent work on lunar meteorites and remote sensing data indicate that the anorthosites are more compositionally diverse than thought previously, implying that crystallization of the magma ocean was complex. The primary crust on Mars appears to be basaltic. There is no evidence for a component highly enriched in incompatible elements (analogous to lunar KREEP) residing close enough to the surface to have been excavated by the many basins on Mars. (3) All bodies differentiated very early, within a few tens of million years of CAI formation. (4) Mars and the Moon are both enriched in FeO compared to Earth (13 wt% in both Moon and Mars versus 8 wt% in Earth). (5) The Moon appears to be enriched in refractory elements by about 50%, though more data are needed to verify this. (6) Earth is the only one of the three that contains a substantial amount of tertiary crust.

Environments of planet formation

These distinctive characteristics of the Moon, Mars, and Earth suggest different processes operating as nebular dust was transformed to planets. The Moon had a particularly hot origin involving the impact of a large planetary embryo with the Earth. This may have caused loss of volatiles, but it is possible that the impactor was depleted in volatiles. The event may have led to equilibration of oxygen and chromium isotopes in Earth and Moon, and the preferential accretion of refractory elements into the Moon. The event was so energetic that the Moon was molten when it formed, creating the magma ocean and its primary anorthositic crust. The lunar FeO content was inherited from the impactor. Mars may itself be a planetary embryo. Its high FeO might have been caused by accretion of planetesimals rich in water and other volatiles (accounting for its high K/Th). Mars probably had a magma ocean, but the presence of water and the larger size of Mars compared to the Moon led to a different style of differentiation and a basaltic primary crust.