LARGE METEOR AND COMET IMPACTS AND ORIGIN OF LIFE. Harrison H. Schmitt, Department of Engineering, University of Wisconsin-Madison. P.O. Box 90730, Albuquerque, NM, (hhschmitt@earthlink.net).

Introduction: Sample, photo-geological, and mineralogical analyses related to the Moon and Mars provide the foundation for understanding the environment in which early life evolved in our Solar System. Data and conclusions from these analyses show that thermal and mechanical energy produced by a large size and frequency spectrum of meteor and cometary impacts dominated the pre-biotic surfaces of the Earth and Mars. This constituted a major potential factor in the environment in which the molecular precursors to life evolved here and probably on other terrestrial planets in other solar systems.

Early Earth Environment: Many types and compositional varieties of phyllosilicate minerals likely dominated the early Earth's surface environment. The remote identification of extensive phyllosilicate deposits in ancient Martian terrain supports this conclusion. Phyllosilicates would have been produced by rapid weathering of impact generated glass and rock and mineral debris in wet, salty, chemically complex, reducing (oxygen-poor) oceanic and early continental chemical niches. Phyllosilicate-rich locales would have been highly varied in their temperature and pressure regimes, favoring rapid evolution of different compositions and structures.

The Moon and, in a currently supportive role, Mars provide a record of the impact history of the inner solar system and therefore that of the Earth.[1] The Moon probably began its existence about 4.57 billion years ago [2] as a small planet of chondritic composition orbiting the Sun near or around the Earth that was subsequently captured intact by the Earth.[3] An alternative of lunar origin by giant impact assisted capture remains a favorite of computer modelers.[4] Whatever its origin as a satellite of Earth, at least the outer 500km of the Moon initially consisted of an impact-generated, volatile poor magma ocean[5] overlying a volatile-rich chondritic proto-core.[6] The sequential crystallization of silicate minerals from that magma produced a 34-43km thick crust[7] dominated by the calcium-aluminum silicate plagioclase including some iron-rich accessory minerals. As this crust became coherent enough to record continuing impacts, impact craters about 60km in diameter gradually saturated its surface.[8] In this same period of saturation-cratering, very large impacts occurred, forming basins of continental scale from about 1000 to 3200km in diameter, with the largest hypothesized as being the ~4.3? Gyr old Procellarum Basin followed by the ~4.2? Gyr old South Pole-Aitken at 2500km.[9]

After saturation cratering subsided, another period of large (300-1000km diameter) impact basin formation began, producing at least 45 such basins.[10] Apollo samples directly date two of the youngest of these large basins, Serenitatis and Imbrium, as having formed in that sequence 3.8-3.9 billion years ago.[11] The creation of the youngest large basin, Orientale, has not been dated directly; however, photo-geological analysis indicates that it formed about 3.8 billion years ago.[12]

From about 4.4 to 3.8 billion years ago, therefore, the upper ~35km of the Moon's crust consisted of a continuously re-formed calcium-aluminum silicate debris layer comprised of rock fragments within a matrix of much smaller mineral and glassy particles. Exposed to the same inner Solar System environment as the Moon, but with the addition of significant indigenous water in its crust and at its surface, the geological consequences of this violent impact history on Earth would be profound in terms of hydrous alteration of primary minerals. The same also can be said of early Mars.

Rock Alteration to Clays: On Earth and Mars, the fine crustal impact debris would alter rapidly to hydroxyl-rich phyllosilicates as that debris formed. Alteration of silicate minerals to phyllosilicates is a well-documented geological phenomenon at the Earth's surface and in its subsurface as well as in hot water (hydrothermal) environments near and beneath volcanic eruptions.[13] Silicates like feldspars that are rich in alkali elements and olivines that are rich in magnesium are particularly susceptible to such alteration. Of particular interest in this regard are minerals of the smectite group and, to a lesser extent, serpentine. Smectites[14] are composed of continuous two-dimensional sheets of SiO_4 tetrahedrons, with the composition Si_2O_5. Each tetrahedron shares three corners with other tetrahedra, resulting in an overall hexagonal mesh. Aluminum and ferric iron can substitute for silicon at the center of each tetrahedron with the ensuing charge imbalance satisfied by various cations placed between sheets. The resulting complex surface structures and geochemistry[15] of these minerals may offer significant potential for pre-biotic selective organization of organic molecules.

The remote identification of various phyllosilicates in the oldest surface regions on Mars provides strong clues as to those that may have been present at the surface of the early Earth. To date, most Martian phyllosilicates[16] are associated with the oldest visible terrains. They appear to be Fe/Mg- and Al-rich, specifically including members of the smectite group (saponite, nontronite vermiculite, and montmorillonite) as the most common. Spectral signatures of illite (or muscovite) and chlorite (or clinochlore) also have been detected. Varieties of the serpentines could explain some other, more local signatures. Hydrated silica and sorosilicate pumpellyites, with a broad range of compositions, also have been identified. At one specific location, an iron-magnesium smectite appears to be dominant and is overlain by hydrated silica, montmorillonite, and kaolinite.[17] Mars Exploration Rovers also discovered opaline silica at Gusev Crater and possibly at Meridiani Planum[18].

Clay's Potential Role in Origin of Life: The availability of a broad spectrum of phyllosilicate catalysts and structural templates for the organization of pre-biotic molecules, and their potential for enhancing the stability of their hosts in various pre-biotic environments, may have provided critical steps along the path to self-replicating macromolecules.[19] Phyllosilicate mineral surfaces also may have been the initial structural frameworks that organized amino acid formation as well as providing fixed availability of necessary inorganic components, such as phosphate-oxygen groups. Further, some surface structures may have constituted the scaffolding for the first cells, later to be replaced by more evolutionarily advantageous organic systems.[20] For example, phyllosilicate scaffolds may have anticipated a RNA function in providing spatial organization for cellular metabolism, specifically offering protein attachment sites for hydrogen production.[21] Further, crystallographic mobility of sodium ions in phyllosilicates similarly may have anticipated the sodium channels in cell membranes that trigger bioelectrical events within cells.

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