CONSTRAINTS ON THE IMPACT-ON-MARS ORIGIN OF SNC METEORITES, by John D. O'Keefe and Thomas J. Ahrens, Seismological Laboratory, 252-21, California Institute of Technology, Pasadena, CA 91125.

Petrologic modeling of the shergottite (S), nakhlites (N) and chassignite (C), (SNC), meteorites suggest that these anomalously young (1.3-1.6 Gy old) objects may have resulted from impact ejection from the surface of an object in which igneous processes took place under pressures of tens of kilobars and caused rare earth element fractionation to occur in the presence of garnet (within the planetary interior) rather than resulting from impact ejecta sampling from an igneous event on a smaller asteroid (1, 2, 3). Recent analyses of the composition of gas inclusions in the SNC meteorites indicate that the gases are consistent with the present atmosphere of Mars, as observed by Viking. This gas may have been trapped as a result of a shock event on Mars (4). In contrast, Singer and Melosh (5) point out the difficulty of accelerating by impact these, in some cases, only slightly metamorphosed meteorites to speeds so as to escape Mars (5.04 km/s) without causing more extensive shock effects. Moreover, if SNC meteorites represent samples of the Martian surface it is difficult to understand the lack of a significant number of meteorite samples which are from the moon. With the possible exception of one recently discovered object (from the Antarctic) (6) which appears to be similar to a lunar highland breccia, the lack, and perhaps, now varity of finding samples from the moon, which has a lower escape velocity of 2.37 km/s, in the terrestrial meteorite collections needs to be explained if the Martian origin of SNC meteorites is plausible.

In the present study we examine the effect of porosity on acceleration of impact ejecta to escape velocities as this is pertinent to the Martian and lunar surface regolith. Separately we examine effect of volatiles on acceleration to escape velocity. Because the Martian surface contains perhaps copious quantities of volatiles (H_2O and CO_2) whether the process of impact vaporization of volatiles assists surface materials in achieving greater than escape velocity (without extreme exposure to high shock pressures) has long been suggested by Stolper et al. (3), Nyquist (7), and others.

Previous numerical calculations of meteorite impact onto a refractory gabbroic anorthosite planetary surface (8, 9) suggests that impact induced acceleration of silicate ejecta to speeds of greater than 5 km/s induces 2×10^{10} erg/g internal energy densities. This energy density will give rise to melting. We have now investigated the effect of impact onto ice and 30% porous, silicate materials. We employ a finite-difference Eulerian mesh numerical technique (10) to calculate the impact induced flow using previously described equations of state of silicate and ice (11) for the interaction of kilometer-sized silicate objects with half-spaces of ice and porous silicates at 15 and 5 km/s, respectively. These impact flows have been used in turn to calculate the amount of ejecta leaving a planetary surface as a function of planetary escape velocity (Fig. 1, 2). We have discovered (Fig. 1) that upon impact onto a dry, porous silicate planet such as the moon, a factor of at least 10 less ejecta is produced which has a velocity such that it can escape the moon or Mars (2.37 to 5.04 km/s) than if the impact were to occur on a nonporous silicate surface. From Fig. 1 it follows that a solid silicate planet will lose from ~0.1 to 3 times the mass of the impactor for an impact at 5 km/s depending on whether the impact occurs on Mars or the moon. The mass (and energy) loss at other speeds for solid planets has been reported previously (11). For an impact onto a porous (30% porosity) refractory surface at 5 km/s the mass of material ejected and lost from the planet is ~0.003 to ~0.3 times the impactor mass for Mars and the moon, respectively. Fig. 2 demonstrates that in spite of the poorer impedance match for the impact of a silicate impactor onto ice (versus impact onto silicate) the amount of ejecta produced is within a factor of 1.5 to 1.7 of the mass ejecta (accelerated to Martian escape velocity) for a silicate-silicate impact. The above calculations demonstrate that optimum impact ejection of planetary materials to exceed Martian escape velocities requires both a high-impedance target and high volatile content. The latter has the effect of reducing the degree of shock metamorphism required to accelerate materials to the appropriate planetary escape velocity. We conclude that it is possible, even within the framework of continuum cratering models to eject substantial, and possibly more materials, from a wet and dense Martian surface than from the low gravity, but refractory, and, possibly, more porous surface of the moon. Further calculations which combine high volatile content and high density, and taking into account the slightly higher rotation rate of Mars, as well as, the drastically different geometries of earth capture of ejecta from the moon and Mars needs to be carried out. The inefficiency of ejection via cratering of a refractory and porous surface (the moon) versus, impact upon a denser and more volatile-rich surface (Mars) favors the Martian origin of SNC meteorites.

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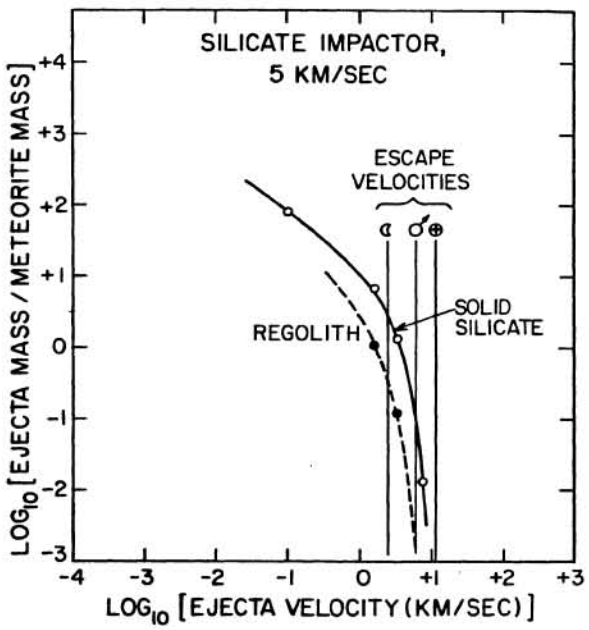

Fig. 1 Normalized ejecta mass escaping from a planet, versus, planetary escape velocity for impact at 5 km/s of a silicate object. Escape velocities for the moon, Mars, and Earth are indicated. Regolith means gabbroic anorthosite with initial porosity of 30%.

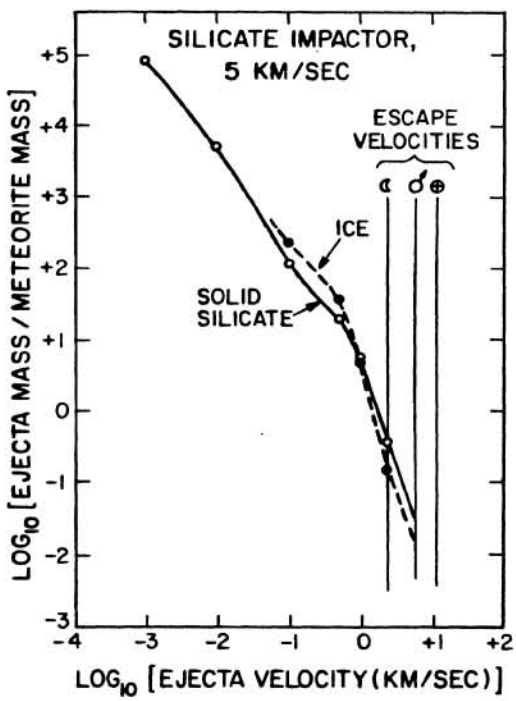

Fig. 2 Relative ejecta mass, versus, planetary escape velocity for a silicate object impacting a solid silicate surface and ice at 15 km/s.