CALLISTO: JUPITER'S IAPETUS? J. F. Bell, Planetary Geosciences Div., Hawaii Inst. of Geophysics, Univ. of Hawaii, Honolulu HI 96822

Both the Voyager images of Iapetus and reflectance spectroscopy from terrestrial telescopes have recently provided a wealth of new information on the origin of the extreme difference in composition between the leading and trailing hemispheres of this unusual satellite. While the trailing hemisphere appears to be a normal icy satellite surface, the leading side is covered with a dark material which appears to be a mixture of hydrated silicates and organic compounds similar to those in the most primitive meteorites, and possibly the D-type asteroids (1,2). It is now generally agreed that this pronounced asymmetry in surface properties is probably due to Iapetus' unusual orbital position (next inward prograde satellite from Saturn's only retrograde satellite, Phoebe). Dust ejected from Phoebe will spiral toward Saturn due to light-pressure effects (3) and collide head-on with Iapetus at high velocity. The bombardment environment on the leading hemisphere will therefore be dominated by projectiles in a very narrow range of sizes and velocities, which may produce a thin, intensely gardened regolith enriched in non-ice components due to the preferential volatilization of ice. A question which naturally arises is whether or not any other objects in the solar system are subjected to such an unusual bombardment.

Two large satellites have Iapetus-like relationships to small outer satellites: Neptune's Triton and Jupiter's Callisto. Triton is in a retrograde circular orbit, while Neptune's only other known satellite (Nereid) is in a distant irregular prograde orbit. Dust in the critical size range ejected from Nereid will spiral inward on prograde orbits and be swept up by the leading side of Triton. However Triton has a considerable methane atmosphere, and possibly even a liquid nitrogen ocean (4). Although the atmosphere has a low surface pressure (0.1-0.3 atm) the scale height is large (about 20 km) due to Triton's low gravity. Micron-sized particles entering such an extended atmosphere at high velocity will be completely destroyed long before they reach the surface, as are similar particles in the thin upper reaches of the Earth's atmosphere. At best a rain of "Brownlee particles" from Nereid may fall onto Triton's surface. Evolution of the surface of Triton is probably dominated either by large heliocentric projectiles capable of penetrating the atmosphere, or by meteorology.

The situation in the Jupiter system is more complex. There are four known retrograde satellites all at about 320 Jupiter radii from the planet, and four known prograde satellites orbiting at about half that distances. Solar perturbations on the orbits of the outer group are strong and they precess rapidly (Fig. 2 of ref. 5). Material ejected from these objects would travel on similar chaotic orbits. Collisions would seem to provide an ample supply of fine dust susceptible to light-pressure effects. However, some unknown fraction of this dust will be swept up by the prograde minor satellites before reaching Callisto, possibly reducing the magnitude of the effect on regolith evolution.

Does any evidence exist of a hemispheric asymmetry on Callisto caused by a retrograde dust bombardment? The Voyager images show a monotonous cratered surface with little apparent difference between leading and trailing hemispheres. This is, however, deceptive since the expected effect occurs on a scale of microns rather than kilometers. Hemispheric differences in surface microstructure were detected as early as 1926 (6,7) when the solar phase function of Callisto was found to differ with longitude (in the sense that the leading hemisphere brightens more as the phase angle approaches zero). Polarization measurements (8) demonstrate that the leading hemisphere has a deeper negative branch in its polarization/phase curve than the trailing hemisphere, and that the variation is roughly sinusoidal, consistent with an Iapetus-like distribution of high-polarization regolith. Both solar phase function and polarization are largely controlled by particle size and porosity in the uppermost regolith. These two properties are both more Ganymede-like on the trailing side than on the leading, suggesting that it is the leading side which is anomalous. The retrograde dust bombardment postulated above could produce just such an effect by biasing the flux of regolith-gardening projectiles toward small particles. The absence of a gross compositional difference as on Iapetus may be due either to the sweeping effect of the prograde minor satellites, or to the lesser abundance of ice in Callisto's original surface (9). This effect may also be at least partly responsible for the difference in depth and shape of ice absorption bands observed (9). (Many other sources for global surface asymmetries on the Galilean satellites have been proposed, but they generally predict decreasing effects with increasing distance from Jupiter.) A recent search for hemispheric color or albedo differences in the Voyager global mosaics of Callisto (10) provided no definitive results due to registration and calibration problems, possibly due to the phase function variations mentioned. A phase function analysis with high spatial resolution performed according to the method recently developed at USGS-Flagstaff (11) would clarify this problem.

In the case of Callisto it is necessary to consider also the possible effect of dust spiraling in from the inner group of small satellites on prograde orbits. This material would tend to strike Callisto at lower velocities and in a more isotropic manner. These characteristics would tend to make any effects indistinguishable from those of the usual bombardment by heliocentric particles. However, both of these special bombardment sources should be considered by those attempting comprehensive models of the projectile flux near Jupiter (12).

The evidence from Callisto thus strongly supports the retrograde dust bombardment hypothesis for the origin of the surface pattern on Iapetus and suggests that mutual transference of ejecta between satellites may be an important process in other satellite systems. The Galileo mission may provide important further insights into this issue.

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