EPSC Abstracts
Vol. 6, EPSC-DPS2011-1601, 2011
EPSC-DPS Joint Meeting 2011

Lunar Impact Craters: The Cratering Process

J. B. Plescia (1) and M. S. Robinson (2)
(1) The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD, USA (2) Arizona State University, School of Earth and Space Exploration, Tempe, AZ, USA. (jeffrey.plescia@jhuapl.edu / Fax: +001 2402281468)

Abstract

The high resolution images and topography from LRO LROC images provide an important data set to study impact cratering on the Moon at an unprecedented resolution. Those images can be used to refine the morphologic characteristics of impact craters to provide constraints on the cratering process. Two types of craters are of interest here: impacts of spacecraft and simple highlands craters containing melt. Craters formed by spacecraft impacts are important calibrations as the energy and properties of the impactor are known. Simple craters in the lunar highlands that contain melt have been identified with diameters as small as 200 m. These craters, which are rare, are interpreted to be formed by vertical, rather than the more common oblique impacts.

1. Introduction

Impact cratering is an important geologic process on all planetary bodies. Much of the understanding of the geology of craters is derived from studies of terrestrial impact and explosion craters. However, there are few impact craters on the Earth and most are buried or eroded making study difficult or impossible. Thus, planetary surfaces provide an important source of information about the cratering processes, albeit from a surface perspective only.

2. Spacecraft Impact Craters

All spacecraft orbiting the Moon eventually impact its surface once their attitude control propellant is exhausted. Over the years tens of spacecraft have produced impact craters which can be resolved from LROC images. A subset of those are of particular importance because of their velocity and impact angle - Ranger and Apollo SIVB craters (Figure 1). These spacecraft impacted the surface with a known mass, velocity and geometry, thus they serve as calibration points for the cratering process. Four (4) Range spacecraft having masses of ~370 kg impacted the surface at velocities of about 2.7 km s^{-1} resulting in events with a kinetic energy of 1 x 10^9 J. The Apollo SIVB was the upper stage of the Saturn V stack sent on a trajectory to impact the Moon. These five (5) impacts had an objective of providing an energy source for the seismic experiment. The SIVB impact had considerably more energy than the Ranger, about 4.5 X 10^{10} J. Impact velocities were a little lower, ~2.5 km s^{-1}, but the masses were much greater, ~14K kg. The Lunar Module ascent stage was also used as a source, but these impacts occurred at very low angle 4° and at a lower speed, 1.4 km s^{-1}.

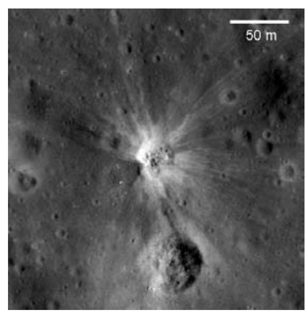

Figure 1. Apollo 17 SIVB impact crater. Note the asymmetric ejecta pattern due to the impact orientation. The impact crater is ~30 x 25 m.

Figure 1 illustrates an SIVB impact crater about 30 m in diameter. A characteristic of all spacecraft impact is an extensive ray system extends several km from the impact. The SIVB craters are non-circular and exhibit a unique inner morphology. These craters have elongate mounds with the crater interior. This may be due to the low density of the projectile.

3. Highland Melt Craters

Melt deposits on the floors of impact craters are common features of large (tens of km and larger) complex impact craters (e.g., Copernicus) on the Moon and other silicate bodies. A key question has been the smallest diameter crater in which a melt deposit occurred as this provides constraints on the amount of energy that goes into melt production and the how material is ejected from the crater.

Early studies [1-4] indicated that melt on the floor and rim of impact craters was common on craters a few km or larger in diameter. The smallest crater observed that had melt was about 750 m [3]. Using LROC images we have identified craters as small as about 200 m that well defined impact melt deposits on the their floor. Figure 2 illustrates an example.

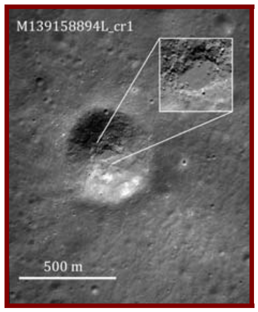

Figure 2. Simple impact crater with a diameter of ~470 m with a melt pool. The pool is 40 x 72 m and the melt material embays boulders on the crater floor.

Such craters have been observed across the highlands. Modeling studies [6-9] suggest that the amount of melt that should be produced by such impacts is small and that most should be ejected from the crater. Yet sufficient amounts of melt are produced and collected on the floor to form a well-defined pond. Modeling indicates that variations in the properties of the projectile are not sufficient to account for these craters. Target properties are important to the amount of melt produced, but the megaregolith is more or less uniform within the highlands to the extent that it cannot account for these craters. Vertical impacts, however, can explain small diameter craters with melt [98-9]. Such impacts produce higher stresses on the crater floor with respect to oblique impacts. Because the momentum direction is largely vertical with little or no horizontal component, more the melt is retained within the crater cavity such that it can collect on the floor.

4. Summary and Conclusions

Impact cratering is an important geologic process on the terrestrial planets and icy satellites. LROC observations of impact craters provide important data on the impact process. Craters formed by spacecraft impact and small diameter simple craters in the lunar highlands having well defined melt on their floor have been identified. Impacts from Ranger the Apollo SIVB have extensive ray systems and a unique interior morphology. Simple craters in the lunar highlands that have melt have been identified in craters as small as ~200 m. They are rare, are observed only in the freshest craters, and are interpreted to be the result of vertical impacts.

References

[1] Hawke, B. R., and Head, J. W.: Impact melt in lunar crater interiors. Lunar Planet. Sci. Conf. 8th, pp. 415-417, 1977a.

[2] Hawke, B. R., and Head, J. W.: Impact melt on lunar crater rims, in Roddy, D., J., Pepin, R. O., and Merrill, R. B., eds, Impact and Explosion Cratering, Pergamon Press, NY, pp. 815-841, 1977b.

[3] Hawke, B. R., and Head, J. W.: Impact melt volumes associated with lunar craters. Lunar Planet. Science Conf. 10th, pp. 510-512, 1979.

[4] Howard, K A., and Wilshire, H. G.: Flows of impact melt at lunar craters, J. Res. U. S. Geol. Sur., Vol. 3, pp. 237-251, 1975.

[5] Moore, H. J.: Ranger and other impact craters photographed by Apollo 16. in Apollo 16 Preliminary Science Report, NASA SP-315, pp. 29-25 to 29-51, 1972.

[6] Cintala, M. J., and Grieve, R. A. F.: The effects of differential scaling of impact melt and crater dimensions on lunar and terrestrial craters: Some brief examples. In Large Meteorite Impacts and Planetary Evolution, pp. 51-59, GSA Spec. Paper 293, Geological Society of America, Boulder, Colorado, USA, 1974.

[7] Cintala, M. J., Wood, C. A. and Head, J. W.: The effects of target characteristics on fresh crater morphology on the Moon and Mercury, Proc. Lunar Sci. Conf. 8th, pp. 3409-3425, 1977.

[8] Pierazzo, E., and Melosh, H. J.: Melt production in oblique impacts, Icarus, Vol. 145, pp. 252-261, 2000.

[9] Pierazzo, E., Vickery, A, M., and Melosh, H. J.: A reevaluation of impact melt production, Icarus, Vol. 172, pp. 408-423, 1997.