TWO CLASSES OF IMPACT BASINS ON THE MOON; Alfred S. McEwen and Eugene M. Shoemaker, U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001.

Overview

The diameter/depth ratios of impact basins on the Moon group into two classes. Most basins have diameter/depth ratios of less than 300 (class 1), whereas some have diameter/depth ratios greater than 400 (class 2). All impact basins that are mostly or entirely within the Procellarum basin fall into class 2; all impact basins outside of Procellarum are class 1, except for Mare Australe. Class 2 basins appear to be significantly shallower than class 1 basins primarily due to much thicker fill by mare lavas. Many class 1 basins occur just outside of the circular Procellarum margin, including Humboltianum, Crisium, Nectaris, Schiller-Zucchius, Orientale, Grimaldi, Lorentz, Coulomb-Sarton, and Birkhoff. The mare fill within the Procellarum basin is all within 1 km of the same absolute elevation. The idea that mare basalts have flooded to a hydrostatic level is clearly incorrect for the Moon as a whole, but the absolute mare elevations seem to confirm the hydrostatic model for the Procellarum basin, the South-Pole/Aitken basin, and perhaps other basins. Mare Australe may bear similarities to the Procellarum basin in terms of age and thermal history.

Introduction

Many lunar controversies from the early 1960's have been settled to the satisfaction of most planetary scientists. However, one issue that continues to elicit lively debate among lunar scientists is whether or not there is unequivocal evidence for the hypothesized Procellarum basin [1-2]. Progress on resolving this controversy has suffered from a paucity of new data in recent decades, but has been sustained by new theoretical evidence for the occurrence of giant impacts during the growth of the terrestrial planets [3]. The Clementine mission has added two major global datasets which bear on this issue: near-global altimetry and global multispectral mapping. The multispectral data will require a few years for processing and analysis before it can be best applied to global issues [but see ref. 4]. The Clementine altimetry [5, 6] however, is a readily available dataset of great importance to this question.

Topographic Analysis

A near-global altimetry map of the Moon with 1-degree binning has been prepared by NASA/Goddard [7], from which we have produced a series of color-coded altimetry images with 200-m contour lines or merged with the USGS airbrush map of the Moon, in a variety of geometric projections. We extracted depth measurements for all lunar impact basins that are well resolved by the altimetry (i.e., all basins except those above $\pm 75°$ latitude or those with a complex structure due to overlapping basins). Basin diameters are from Wilhelms [2], except as refined by Spudis et al. [6], and except for the NW Procellarum basin [8] for which we estimated a diameter of 850 km from the altimetry. Measuring the depths of each basin is complicated because of the rugged topography of the rings. We attempted to measure the "characteristic" height of the outermost rings--the highest sections of continuous rings as seen in the altimetry--but avoided isolated high massifs. The floor elevation is less equivocal, and we measured the lowest elevation in the dataset except where a large superposed crater exists. These numbers should be refined in the future with more quantitative metrics, but we are confident in the basic identification of two classes of impact basin.

Discussion and Interpretations

The diameter/depth ratios fall into two groups: those less than 300 (class 1) and those greater than 400 (class 2; see Figure 1). The two classes are further distinguished by a trend of increasing diameter/depth ratio with increasing basin depth in class 1, whereas there is no such trend in class 2. All impact basins that are mostly or entirely within the Procellarum basin fall into class 2; all impacts outside of Procellarum are class 1, except for the Australe basin. Class 2 basins appear to be

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significantly shallower than class 1 basins primarily due to much thicker mare fill. Many class 1 basins occur just outside of the roughly circular Procellarum margin, including Humboltianum, Crisium, Nectaris, Schiller-Zucchius, Orientale, Grimaldi, Lorentz, Coulomb-Sarton, and Birkhoff. The class 2 basins near but outside of the Procellarum margin can also be distinguished from class 1 basins by the absolute elevations of their floors, which are mostly at least a kilometer deeper than the class 1 basin floors. These topographic relationships are striking on a stereographic projection centered on the Procellarum basin (latitude 26°N, longitude 15° W).

The mare fill within the Procellarum and South-Pole/Aitken basins are all within 1 km of the same absolute elevation. We interpret these observations as evidence that the concept of mare flooding to a hydrostatic level [9] may be applicable within large impact basins.

The Clementine altimetry data shows that the Procellarum basin exists: it is a circular region of thick and apparently hydrostatic mare fill. This evidence does not prove an impact origin for the Procellarum basin, but an impact origin must be considered a reasonable hypothesis given the clear importance of impacts on the lunar topography and the high probability of giant impacts late in the accretion process [3].

Mare Australe is unusual as it is the only class 2 basin on the Moon that resides outside of the Procellarum basin. Wilhelms et al. [10] consider Australe to possibly overlie and postdate the South-Pole/Aitken basin, but the relations are unclear from pre-Clementine datasets. Perhaps Australe is older than South-Pole/Aitken and is a contemporary of the Procellarum basin, and both formed in a significantly warmer and ductile lunar crust. The topographic relief of the Procellarum basin is only a few km or less [5], so perhaps the more fundamental distinction between impact basins is (1) ancient basins that formed in a relatively warm, ductile crust, of which Procellarum and Australe are the only recognizable remnants; and (2) all subsequent basins.

The evidence in favor of the Procellarum impact hypothesis bolsters the companion hypothesis for Mars' global dichotomy via the Borealis impact [11]. Perhaps the case could be made for two classes of basins on Mars as well. The largest basins on Mars are significantly deeper in the southern hemisphere (Hellas and Argyre) than those in the northern plains (Isidis, Chryse, Elysium, Utopia). However, Mars has experienced a complex geologic history since heavy bombardment; the Moon remains the body of choice for study of the earliest crustal evolution of a terrestrial planet.

References: [1] Whittaker, E.A., 1981, LPSCP 12, 105. [2] Wilhelms, D.E., 1987, U.S. Geological Survey Prof. Paper 1348, 302 pp. [3] Wetherill, G.W., 1985, Science 228, 877. [4] Lucey, P.G., et al., 1994, Science 266, 1855. [5] Zuber, M.T., et al., 1994, Science 266, 1839. [6] Spudis, P.D. et al., 1994, Science 266, 1848. [7] Zuber, M.T., et al., 1995, this volume. [8] McEwen, A.S., et al., LPSC 25th, 869. [9] Solomon, S.C., 1979, PLPSC 6th, 1021. [10] Wilhelms, D.E., et al., 1979, USGS Map I-1162. [11] Wilhelms, D.E. and Squyres, S.W., 1984, Nature 309,

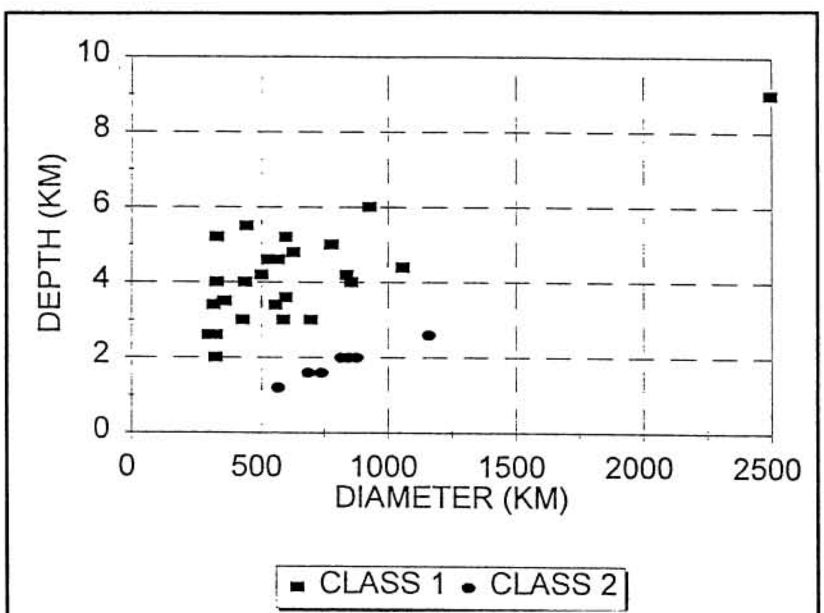

Figure 1. Plot of depth vs. diameter of lunar impact basins.