FLOOR-FRACTURED LUNAR CRATERS. P. H. Schultz, NRC Fellow,NASA-Ames Research Center, Moffett Field CA 94035.

The floors of 192 lunar craters exhibit large-scale fracturing arranged in annular, polygonal, and radial patterns. Such craters have been described and interpreted as isostatically adjusted impact craters (1), as possible resurgent cauldrons (2), and as volcanically modified impact craters (3,4). Annular fracture patterns comprise 56% of the total number of patterns; polygonal, 33%; and radial, 11%. Histograms of crater sizes in 10 km intervals reveal that the most common diameter of floor-fractured craters is approximately 20 km with the mean being 42 km. Craters having concentric patterns tend to be larger (mode 35 km) with less skewness in the size distribution (mean 44 km) than craters having polygonal (mode, 15 km; mean, 42 km) or radial (mode, 15 km; mean, 52 km).

Approximately 11% of the floor-fractured craters exhibit preserved ejecta blankets, some of which resemble the ejecta facies surrounding Copernicus, and the ejecta blanket from the floor-fractured crater Taruntius overlaps portions of Mare Fecunditatis. Although floor-fractured craters commonly postdate the formation of the major impact basins but predate the emplacement of the last mare units, those craters that can be compared stratigraphically to such basins indicate that many were formed prior to the basin-forming event and that their floors were fractured during a later and separate stage.

The spatial distribution of floor-fractured craters shows pronounced concentrations in the highlands along the margins of the maria. Notable clustering occurs along western Oceanus Procellarum, Mare Nectaris, Mare Smythii, and the Apollo-Ingenii complex on the lunar farside. Such a close spatial association suggests a genetic association with the magma responsible for the maria. However, approximately 12% of those craters recognized occur deep in the lunar highlands and are not spatially associated with mare-filled regions. In addition, Mare Australe shows a marked absence of craters with fracturing, although this particular mare is characterized by mare-filled craters.

Floor units exhibiting fracture patterns include relatively high-albedo units with complex small-scale hummocky topography, Cayley-like plains, and marelike units. The complex hummocky units exhibit wide variations in preserved crater populations and an assortment of small-scale structural and volcanic surface features (3). This and the Cayley-like floor units commonly are mantled locally by low-albedo material derived from vents along the fracture system. In addition, several floor-fractured craters contain relatively smooth plains-forming units surrounding the central peak complex and adjacent to the wall.

Approximately 14% of those craters with floor fractures also exhibit an annular depression, or "moat," adjacent to the crater wall. Such moats range in width from a narrow crevice to a wide depression and commonly exhibit a discontinuous ridge on the adjacent floor edge. The most common crater diameter is approximately 35 km with a mean diameter of 29 km. Ratios of the moat area to the total crater area were compared with the ratios of the wall area to the total crater area of "normal" (Copernicus-like) craters. The

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wall-area ratios plotted against the crater diameter describe a straight line decreasing with crater size. The moat-area ratio shows a similar relation but consistently has a lower value than the wall-area ratio. It is thought that these lower values reflect a structural separation of a floor plate, the border of which extends beneath the old wall slumps. The moatlike depression commonly is partly filled with either a high-albedo plains unit or mare units which bury remnants of the old wall slumps.

Comparison between the heights of central peaks that are found within floor-fractured craters and Copernicus-like craters reveals that the central peaks within craters having floor fractures tend to be slightly smaller than those within Copernicus-like craters. However, the peak-to-rim distance within floor-fractured craters are typically smaller than this distance within Copernicus-like craters, and in at least two floor-fractured craters the peak extends above the surrounding rim. This comparison is interpreted as evidence for en bloc uplift of a floor that originally resembled the floor of an impact crater. Approximately half of those floor-fractured craters with available Earth-based topographic data exhibit a floor level comparable to or greater than the elevation of the adjacent maria.

In half of those floor-fractured craters with central peaks, the peak complex can be described as a small annulus, an acentral arc, or a peak with a central pit. Such morphologies can be explained if the central portion of the peak complex collapsed during floor uplift. The central peak complex in the Sudbury structure on Earth has been suggested (5) to have undergone possibly analogous collapse. In craters with concentric floor fractures, the central peak complex commonly is separated intact from the surrounding floor and may remain as an insular peak or platform after inundation of the floor by mare units. In contrast, a few floor-fractured craters show evidence for collapse of the entire central peak complex with subsequent pooling of mare units in its place.

The rim appearance of floor-fractured craters shows considerable variety which generally reflects the stage of crater modification prior to floor fracturing. Several craters adjacent to the maria (for example Gassendi and Doppelmayer), however, exhibit a transition from a normal outward-dipping rim region to a symmetric ridge or platform profile. An exterior annular depression can be identified adjacent to the ridgelike segment of the rim. This profile is thought to be related to the modification of the crater indicated by floor fracturing.

These observations and interpretations can be fitted into an idealized sequence of events. An impact crater generates fractures into the lunar crust and during the epochs of mare emplacement, these fractures act as escape routes for the mare-producing magma. The magma is trapped as a sill beneath the crater floor, and as this magma reservoir enlarges, the floor plate rises. Wall slumping is triggered, and as the floor plate rises, a moat develops with a discontinuous ridge on the old floor corresponding to the remnants of the old wall slumps. Mare units typically are emplaced in the moat on the side of the crater closest to a mare plains region, and the moat commonly is widest and best-developed in this direction. This asymmetry is thought to reflect, in part, an acentral concentration of trapped

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magma where the remnant weaknesses beneath the old impact crater first intersect fractures extending from the mare-producing magma chamber beneath the maria. Pyroclastic eruptions may occur and blanket portions of the floor with low-albedo deposits. In some craters, the entire central peak complex may collapse out of site. If a large magma reservoir develops and if enough surficial extrusions occur, the floor may founder, resulting in a mare-filled crater without evidence for a central peak. During the later stages, the magma finds a path to the rim region through old slump faults, and parasitic eruptions may break out on the rim (several mare-filled craters have the head craters of sinuous rilles on their rims). Structural modifications of the rim region produce segments that have a ridge profile. Extensive modification results in a multirimmed plan or a platformlike profile. The Flamsteed Ring and the ghost ring Lamont are thought to represent partly and completely mare-inundated craters, respectively, that have undergone such final stages of floor and rim modification. If the magma reservoir becomes large enough, a positive gravity anomaly may result, as in the craters Grimaldi and Crüger. More typically, floor-fractured craters and partly mare-inundated craters remain as negative gravity anomalies.

The above sequence is not the complete description for there are several ways, for example, to produce concentric fracturing, and radial patterns are believed to reflect less planar sub-floor intrusions. In addition, not all craters evolve to the mare-filling stage. There is also morphologic evidence that numerous floor-fractured craters have had an entirely new floor emplaced prior to the last stage of structural modification.

In terms of lunar history, floor-fractured craters are visible indicators of the internal thermal history and become precursors to regional inundation by mare units. Furthermore, they take an active role in the inundation of the irregular maria. Those floor-fractured craters occurring deep in the highlands indicate a preserved form of isolated highland volcanism. If a similar period of crater modification occurred prior to the formation of the last major impact basin, then a mechanism is available that can remove the central peak complex and reduce the depth of some ancient highland impact craters without extensive fill deposits.

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