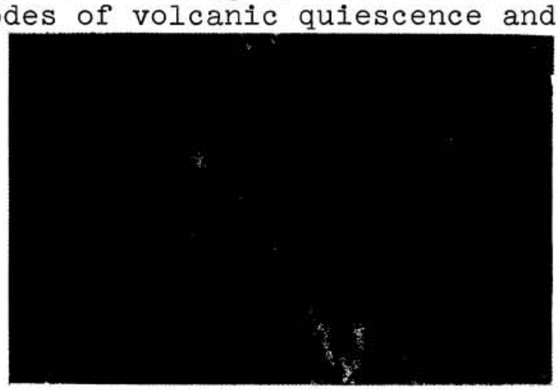
LUNAR KIPUKAS AS EVIDENCE FOR AN EXTENDED TECTONIC AND VOLCANIC HISTORY OF THE MARIA. D.J. Nichols, R.A. Young, and W.J. Brennan, SUNY, Geneseo, New York, 14454

Local areas within the lunar maria exhibit features that distinguish them from adjacent "typical" mare surfaces, and may provide evidence of their origin, and of the origin and history of the maria in general. Such areas are widespread but not randomly distributed; good examples are covered by Apollo 16 metric and panoramic photography of the region west of Mare Cognitum. Here as elsewhere patches of topographically higher mare(?) surfaces exhibit crater densities indicative of ages greater than that of the surrounding mare. These areas are further characterized by higher albedo, and by embayed margins especially notable where rilles in the surface end abruptly at the margin. Most have been interpreted and mapped as plains materials of Imbrian age (1). An example is the feature designated Darney Chi (Fig. 1A) in western Mare Cognitum. Features bearing resemblance and presumably of similar origin include the Aristarchus Plateau in Oceanus Procellarum and the unnamed "patch" transected by the Opelt rilles, southeast of Mare Cognitum. In all of these examples the terrain is more densely cratered than the adjacent mare surface and has a somewhat higher albedo, but more closely resembles mare materials than highlands in having low relief and prominent rilles. These areas appear to be analogous to terrestrial steptoes or kipukas--the "islands" of older surface surrounded by younger flows in volcanic fields. Areas within Mare Orientale (Fig. 2) suggest the way in which irregular volcanic topography could be submerged by subsequent flows leaving higher-standing patches as kipukas. Interpretation of these distinctive local areas as lunar kipukas supports the growing body of evidence for the complex volcanic history of the maria, especially the concept of filling by successive flooding events separated by episodes of volcanic quiescence and structural deformation.



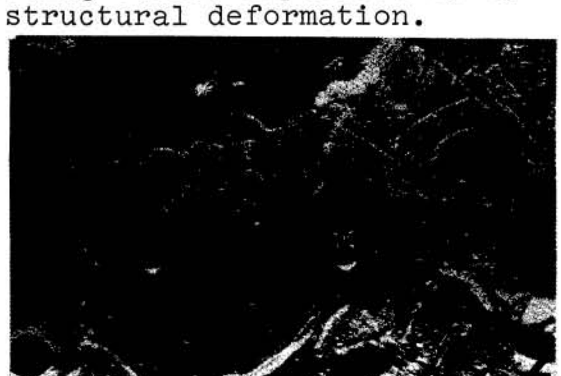


Figure 1: (A) Lunar kipuka Darney Chi in Mare Cognitum; (B) Dome-like features (also kipukas?) (Apollo metric frame 16-2213).
Figure 2: Irregular mare surface in southwestern Mare Orientale; north to left, framelet width 11 km (LOIV-195H).

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West of the highland remnants near Darney Chi are two small (ca. 6 km) dome-like features that also may be kipukas (Fig. 1B). Other similar features occur farther west toward the crater Letronne in this region and elsewhere, including Mare Imbrium, near the crater Brayley (2), western Mare Crisium and western Mare Serenitatis. Although crater density on the surface of such features does not always clearly reveal significant age differences from surrounding mare materials, the kipuka-like nature of some of them is indicated by distinctness of margins and termination of cross-cutting fractures exactly at margins, apparently as result of submergence by later volcanic flows. The dome-like features are characterized by circular to oval outlines and by one or more cross-cutting fractures expressed as normal faults and/or short, straight or arcuate rilles. In most cases one or more small terra remnants are exposed within the perimeter, in many cases adjacent to the point of greatest elevation of the feature. The small features (Fig. 1B) differ from the Darney Chi kipuka in having albedos and crater densities much like those of the adjacent mare surface. These kipuka-like domes differ also from previously described mare domes of presumed extrusive origin (1) in that they show no obvious volcanic vents, and in the presence of the characteristic fractures. They appear to have originated by flexuring and tensional fracturing of the mare surface. Features of this kind could have been produced by local isostatic adjustment of the pre-mare surface or by regional differential settling of mare materials, or alternatively by volcanic subsidence or intrusion. Terra remnants associated with these features may represent exposed portions of buried topography around which foundering mare surface materials settled, causing flexing and fracturing. It is probably quite significant that these features occur either toward the edges of mare basins or in mare regions lacking well developed basin structure, such as Mare Cognitum; these are regions where mare materials are most likely to be relatively thin deposits on buried terrain.

Kipuka-like domes in Fig. 1 are typical of most but not all of these features in characteristics and relations with surrounding mare materials. In contrast, one feature located north of the ring structure near the Herigonius rilles is more clearly submerged terrain of possible volcanic origin and thus is more comparable with Darney Chi. It has sinuous rille segments and a possible endogenic crater at its crest. This feature has been mapped as dome material of Eratosthenian age (1), but crater density relations in the area do not provide convincing evidence for this feature being younger than the mare surface. In apparent age, in topographic relations, and in albedo it compares with the dome-like features with fractured crests (Fig. 1B). The submergence of its flanks indicates that it pre-dates latest mare flooding. A dome-like feature in western Mare Serenitatis

(Apollo 15 70mm frame 91-12373) differs in that its surface fractures extend into the surrounding mare; they were not submerged by subsequent lava flows. Generalizations about the nature and origin of these features may tend to obscure the possibility that features of similar appearance might be different in origin, but one aspect common to all possible modes of origin is the implication of an extended sequence of events leading to development of the present mare topography.

The mode of origin of kipuka-like features in the maria may have some bearing on the origin of the problematic "high water marks" (3) that ring some highland masses within some mare regions. The evidence for a complex history of mare filling suggested by kipukas such as Darney Chi that predate present mare surfaces indicates that these "high water marks" are unlikely to have developed simply as a result of changing mare surface levels, like some sort of shoreline features of a single, deep lava lake. Further, evidence that the maria were filled progressively with numerous relatively thin flows alternating with horizons of ejecta and regolith (4,5,6) argues against the accumulation of very deep fluid lava late in mare evolution. The small kipuka-like domes with fractured crests suggest that widespread subsidence has affected some regions of the maria, perhaps induced by tectonism, volcanism, isostatic adjustment, or differential compaction of subsurface regolith horizons.

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