Dome Craters on Ganymede

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Voyager observations reveal impact craters on Ganymede that are characterized by the presence of broad, high albedo, topographic domes situated within a central pit (Fig. 1). Although elsewhere termed Type II penepalimpsests[1], they are referred to here by the descriptive term "dome craters." Fifty-seven craters with central domes have been identified in images covering ~50% of the surface of Ganymede at resolutions between 0.5 to 3.0 km per picture element. Owing to limitations in resolution, and viewing and illumination angles, the features identified in this study are most likely a subset of dome craters on Ganymede. The sample appears to be sufficiently large to infer statistically meaningful trends.

Dome craters appear to fall into two distinct populations on plots of the ratio of dome diameter to crater rim diameter (Fig. 2). Large-dome craters have dome to crater diameter ratios of 0.25 to 0.56 (mean 0.33) while small-dome craters have dome to crater diameter ratios of 0.05 to 0.19 (mean 0.10). Large-dome crater rim diameters range from 30 km to 185 km (mean 96 km), while small-dome craters diameters begin at 52 km and increase to 108 km (mean 81 km). Large domes have diameters from 10 km to 50 km (mean 31 km) while small-dome diameters range from 3 km to 20 km (mean 9 km).

Large-dome craters preferentially occur on dark terrain. Of the twenty samples in this class, fifteen (75%) are on dark terrain, three (15%) occur on light terrain, and two (10%) occur on the border between the two terrains. Small-dome craters tend to occur on light terrain. Of a sample of thirty-four, twenty-two (65%) occur on light terrain, four (12%) on dark terrain, and eight (23%) on the border. No latitudinal or longitudinal trend in dome crater distribution could be identified.

The two "classes" of dome craters are morphologically distinct from one another. In general, large-dome craters (Fig. 1a) show little relief and their constituent landforms appear subdued with respect to fresh craters. They display the generic morphology widely described as "viscously relaxed"[1,2,3,4], or hypothesized to have formed as a consequence of the presence of sub-surface liquid(s) at the time of impact[5,6]. The physical attributes of small-dome craters (Fig. 1b) are more sharply defined, a characteristic they share with young impact craters of comparable size observed elsewhere in the solar system. Although their morphology may generally resemble fresh craters of similar size on the terrestrial planets, it should be noted that the small-dome craters display less relief[1,2,3].

Both types of dome craters exhibit central pits in which the dome is located. This is not surprising as virtually all craters on Ganymede > 20 km in diameter have a central pit[1], and the smallest crater with a dome has a rim diameter of 30 km.

As it is difficult to produce domes by impact and/or erosional processes[7,8], an endogenic origin for the domes is reasonably inferred. Several hypotheses for their origin have been proposed. Squyres[9] has suggested that two large domes situated in the center of impact features > 100 km in diameter were formed either by

H_2O liquid volcanism and/or isostatic upwarping of a thinned ice crust. Croft[6,10] suggested that icy target material, uplifted within a complex crater during formation will melt if the bolide velocity is sufficiently high. In this scenario, newly formed complex craters will have a "melt lake" within a central pit rather than a central peak, and the dome is formed by the subsequent freezing and expansion of this lake. Malin[7,11] proposed that the domes may be the tips of diapirs.

The diapir hypothesis, while as speculative as the other hypothesis, appears most consistent with contemporary models of Ganymedian internal and thermal evolution. Kirk and Stevenson[12] have investigated the potential for diapirism in the lithosphere of Ganymede and have found that the likelihood of its occurrence is great over a wide range of values for lithospheric physical properties. If the domes are the tips of diapirs, it would explain the relief and the albedo displayed by these features. A diapir, once exposed to the surface, would cool and become more viscous. The ice in the dome would be able to maintain relief comparable to that of the crater in which it formed.

It is hypothesized that perturbation of a low density layer underlying a "viscously relaxing" impact crater initiated diapir formation. The diapir rose to penetrate the surface at the center of the crater, forming a dome. Provided that the high albedo material covering approximately half of Ganymede is the same material that forms the domes, two alternative hypotheses may be posed to explain the partition of dome sizes between dome craters on light and dark terrain. Both hypotheses assume that the reduction in size reflects a reduction in supply: small domes may have formed after the emplacement of light terrain had depleted the available source material, or they may have formed after cooling had reduced the thickness (and volume) of the source region. In both scenarios, large-dome craters formed at a time when the light material source region was voluminous and relatively untapped. A global disturbance of the source then resulted in creation of light terrain, presumably by effusion. Subsequent, local disturbances of the reduced amount of light material remaining at depth produced smaller domes. The present observations cannot distinguish between depletion of the source zone by effusion and "depletion" by thinning as a consequence of other factors, such as increased strength of its outer portions owing to cooling following light terrain formation.

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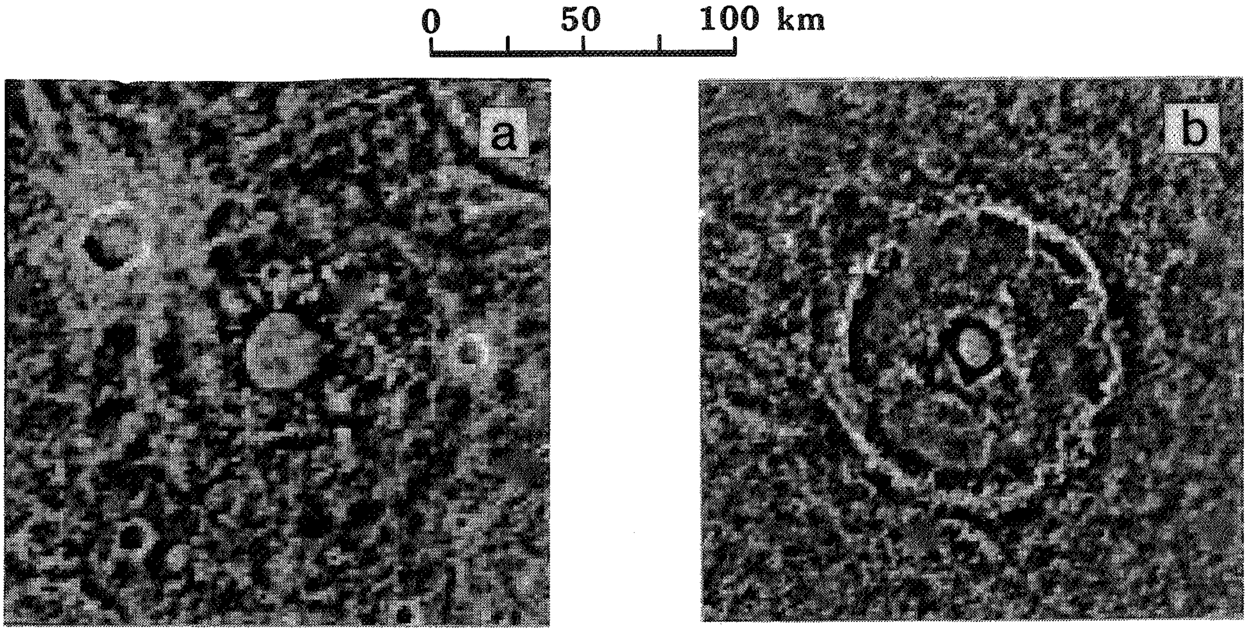

Figure 1. Dome craters on Ganymede: a. Large-dome crater with subdued rim and pit wall (5° N, 175° W, image FDS 20635.49). b. Small-dome crater. Note morphological freshness and surrounding field of secondary craters (13° S, 140° W, image FDS 20637.23).

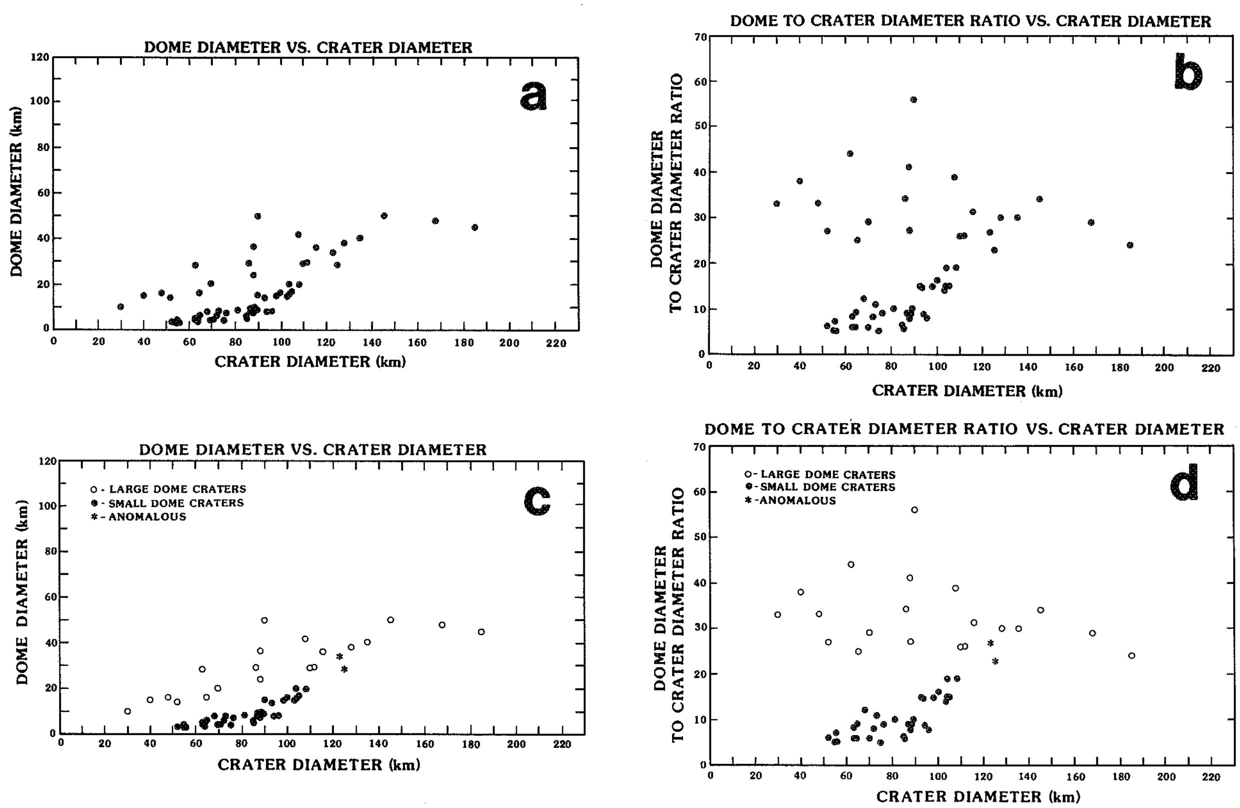

Figure 2. a. A plot of dome diamter versus crater rim diameter of all 57 recognized dome craters. b. A plot of the ratio of dome diameter to crater rim diameter versus crater rim diameter. c. Same as plot (a) with different dome crater types marked. d. Same as plot (b) with different types marked.