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COLLISIONAL AND DYNAMICAL HISTORY OF GASPRA

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Interpretation of the impact record on Gaspra requires understanding of the effects of collisions on a target body of Gaspra's size and shape, recognition of impact features that may have different morphologies from craters on larger planets, and models of the geological processes that erase and modify impact features.

Crater counts on the 140 km^2 of Gaspra imaged at highest resolution by the Galileo spacecraft show a steep size-frequency distribution (cumulative power-law index near -3.5) from the smallest resolvable size (150m diameter) up through the largest feature (1.5km diameter crater) of familiar crater-like morphology [1].

In addition, there appear to be as many as eight roughly circular concavities with diameters >3km visible on the asteroid. If we restrict our crater counts to features with traditionally recognized crater morphologies, these concavities would not be included. However, if we define craters to include any concave structures that may represent local or regional damage at an impact site, then the larger features on Gaspra are candidates for consideration.

Acceptance of the multi-km features as craters has been cautious for several reasons. First, scaling laws (the physically plausible algorithms for extrapolating from experimental data) indicate that Gaspra could not have sustained such large-crater-forming impacts without being disrupted; second, aside from concavity, the larger structures have no other features (e.g. rims) that can be identified with known impact craters; and, third, extrapolation of the power-law size distribution for smaller craters predicts no craters larger than 3 km over the entire surface.

On the other hand, recent hydrocode modeling of impacts [2] shows that for a given impact (albeit into a sphere), the crater size is much larger than given by scaling laws. Gaspra-size bodies can sustain formation of up to 8-km craters without disruption. Besides allowing larger impact craters, this result doubles (relative to estimates in [1]) the lifetime since the last catastrophic fragmentation event up to one billion years.

Events that create multi-km craters also globally damage the material structure, such that regolith is produced, whether or not Gaspra "initially" had a regolith, contrary to other models in which initial regolith is required in order to allow current regolith. Because the globally destructive shock wave precedes basin formation, crater size is closer to the large size extrapolated from gravity-scaling rather than the strength-scaling that had earlier been assumed for such small bodies (e.g. [1]). This mechanism may also help explain the existence of Stickney on Phobos [3].

Moreover, rejection of the large concavities as craters based on unfamiliar morphology would be premature, because (aside from Stickney) we have no other data on such large impact structures on such a small, irregular body. The eight candidate concavities cover an area greater than that counted for smaller craters, because they are most apparent where small craters cannot be seen: on low resolution images and at the limb on high resolution images. We estimate that there are at least two with diameter >4 km per 140 km^2, which would have to be accounted for in any model that claims these are impact craters.

While the existence of a few multi-km craters would imply a sharp bend in the size-distribution, which is implausible in the impacting population, such a distribution might result from geological processes that modify the surface.

One important geological process is the global jolting of surface material by large impacts, discovered by the hydrocode models [2]. When a crater of diameter 5 km is formed, for example, regolith over the entire surface jumps about 30 m, which erases topography on that scale and thus erases craters up to 150 m, while preserving compositional inhomogeneities. The large impact events are analogous to erosional and tectonic processes on terrestrial planets in terms of their ability to modify crater size distributions. The sub-km craters now counted on Gaspra may have accumulated only since the last multi-km crater was formed (a time much shorter than the asteroid's age), consistent with their relative depletion with respect to the big ones. The size distribution has been also modified by local erasure (cookie-cutting) at the site of large craters and just around them.

Such geological processes may have modified the production size-distribution of craters considerably, allowing a non-power law shape. However, the generally steep slope for sub-km craters still would require a steep asteroid size distribution, similar to that assumed in [1].

An implication of the hydrocode results is that Gaspra must be a rubble pile due to the global shock of large impacts. The elongated figure (with a somewhat pinched waist confirmed by the recently received low resolution images) probably requires the support of two or more internal solid blocks, overlain by a substantial regolith. Other observational evidence for this physical model are the surface grooves, which may be related to sinkage of regolith into the interstices between blocks after the formation event or as a result of impact jolting. Whether the required internal blocks could survive the repeated impact shock is problematical; hydrocode studies of non-spherical targets will be needed.

References:

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