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GANYMEDE AND CALLISTO: BEAUTY IS ONLY SKIN DEEP. Steven K. Croft. Dept. of Planetary Science. University of Arizona. Tucson. AZ 85721

Ganymede and Callisto, the two giant icy satellites of Jupiter, have very nearly the same size, composition, and location in the solar system, yet their surfaces are profoundly different. A new scenario of their geologic histories indicates that the differences may be only skin deep.

The disparate appearances of Ganymede and Callisto constitute a major puzzle to our understanding of planets. Ganymede's surface consists of roughly equal portions of light and moderately dark terrain. The dark terrain is moderately cratered and marked by frequent curved furrows and seams. The light terrain is only thinly cratered, but almost completely covered by closely spaced grooves in patterns reminiscent of contour-plowed fields or broom-sweep patterns in loose sand. The light terrain is evidence of extensive flooding due to internal melting, while the furrows and grooves are the result of internal stresses and strains. In contrast, Callisto's surface is very dark and heavily cratered, with no evidence of the flooding and cracking so common on Ganymede. Current theories of the formation of planets and the shaping of their surfaces indicate that two planets of similar size and composition, like Ganymede and Callisto, should be subject to the same geologic processes both inside and out, and should have similar surface features. Thus, since Ganymede underwent extensive flooding and fracturing, Callisto should have also. Explaining how Callisto came to have none of the features (except craters) so common on Ganymede is comparable to explaining how one tract house had no water inside during a major flood while the neighboring house was filled to a depth of, say, 8 feet.

Previous geologic models proposed for Ganymede have suggested that its interior was largely or completely melted, allowing the rocky material inside to sink to the center and leaving behind a thick rind of pure ice on the outside. Such models have difficulty explaining either how Callisto underwent similar extensive melting without ending up with Ganymede-like surface features or what subtle factor allowed Ganymede to melt completely while Callisto remained solid. An additional problem for a largely melted Ganymede concerns the nature of the material forming the light terrain. The light terrain, with its sharp, linear edges and depressed topography, is suggestive of flooding of valleys by liquid water. But water being more dense than ice, could not reach the surface of a pure ice layer. Blobs of warm ice could rise to the top of a cold icy layer and flow outward across the surface like glaciers to form the bright material. But such deposits would be rounded and stand above the surrounding terrain, an appearance very different from that actually observed for the bright terrain.

The new geologic model resulted from further analysis of Ganymede's surface features. The dark terrain has a lower crater density than Callisto implying that it, like the light terrain, is a flooded surface. Recent work on the distribution of craters with dark ejecta and on patterns of different shades within the dark terrain show that the dark terrain is complexely layered, both vertically and horizontally, again indicative of surface flooding. Similarly, the light terrain has been shown to be at most a few kilometers thick and considerably thinner in many places. The complexity and appearance of the light and dark terrains virtually require flooding by liquid water. The presence of liquid water on the surface of Ganymede requires that the outermost layer had to retain enough rocky material to keep subsurface pressures high enough to force the water out. Thus, the outermost layer never completely melted. The lack of extensive disruption of Ganymede's surface after the formation of the bright terrain which would have been produced had melting continued at depth implies that the interior of Ganymede did not melt either. Thus, the new geologic model suggests that, at most, only part of the outermost layer of Ganymede underwent melting. Compared to the rest of the planet, the melting of only the outer 100 kilometers or so of Ganymede represents only a few percent of the planet's volume, and thus is merely a "skin effect." The reason this skin effect produces such a dramatic change in the visual appearance of Ganymede is because it is precisely the altered surface that we see. We do not directly see the virtually unchanged bulk of Ganymede's interior.

This model for marginal melting provides a natural explanation for the difference between Ganymede and Callisto: The heat required to melt the outermost layer of Ganymede is only a few percent (or less) of the total radioactive heat output during the estimated billion years or so over which the light and dark terrains formed. Thus the temperature at depth only just barely reached the melting point of ice under pressure (had the temperature ever substantially exceeded the melting point. Ganymede would have melted completely). Thus if the interior heat production were slightly less (figuratively, if the interior "thermostat" were lowered slightly), melting would not have occurred at all. Callisto is somewhat smaller than Ganymede and has slightly less rocky material (which contains the radioactive elements), thus its "thermostat" is approximately 20% lower than Ganymede's and thus melting never occurred. In the analogy of the flooded houses above, the flood was only a small one and the flooded house had only a few inches of water in it. The floor of the neighboring house was a foot or so higher and thus remained dry.

In addition, the new "marginal melting" scenario for Ganymede will allow us to better understand the heat transport properties of ice-rock mixtures found in icy satellites, and thus improve our understanding of the geologic histories of the other icy satellites. It also provides a new framework for attempting to understand the unique, even bizarre, appearance of the grooved terrain on Ganymede, which as yet have no satisfactory explanation. This new framework is rich enough in possibilities to be able to account for the observed complexity of features on Ganymede's surface. Some promising preliminary steps in the detailed study of the origin of many of Ganymede's unusual features have already been taken.