EUROPAN MACULA: POSSIBLE ORIGINS. J.M. Moore[1], K.C. Bender[2], R.J. Sullivan[2], R. Greeley[2], A.S. McEwen[3], B.R. Tufts[3], J.W. Head III[4], R.T. Pappalardo[4], M.J.S. Belton[5], and the Galileo SSI Team ([1]NASA Ames, MS 245-3, Moffett Field, CA 94035; [2]Geology Dept., Arizona State University, Tempe, AZ 85287; [3]LPL, University of Arizona, Tucson, AZ 85721; [4]Geological Sciences Dept, Brown University, Providence, RI 02912; [5]NOAO, Box 26732, Tucson, AZ 85717)

Voyager images of the surface of Europa revealed many diverse features, including bright and dark linea, triple bands, gray bands, ridges, pits, and dark spots termed maculae (Smith et al., 1979; Lucchitta and Soderblom, 1982). Seen at *Voyager* resolution, maculae are circular to irregularly shaped low albedo patches with little additional morphologic character. Maculae occur in both bright and mottled terrains, commonly in association with dark linea. These intriguing dark patches are high priority for the *Galileo* Solid State Imaging (SSI) experiment.

On Dec. 19, 1996 the *Galileo* spacecraft made its first close encounter with Europa. During this encounter three images were taken of a macula located at 334°W, 16°S. This feature was identified as an interesting target on low resolution (6.9 km/pixel) images taken earlier in the mission as a 100 km diameter low albedo spot . The low altitude of the December encounter permitted high resolution (120 m/pixel) imaging of much of the feature. Morphologically, the macula can be divided into three zones. The inner zone is approximately 50 km in diameter and is characterized by a rugged surface. The middle zone encircles the central rough zone and is characterized by ridges, smooth areas, and several small depressions. The outer zone is dominated by two large, concentric, continuous graben, additional smaller graben, numerous fractures, and a generally smooth surface. Graben widths (~800 m) were used to estimate the depth of the mechanical discontinuity at ~500 m, and indicate a fractured uppermost surface layer in contrast to previous assumptions (Golombek and Banert, 1990). Just outside the macula, to the southwest, are two large depressions (each ~10 km across). Two prominent ridges intersect the macula, one from the WNW, the other from the ESE. Both ridges are modified in the portions that cross the different zones of the macula, indicating they either predate the formation of the macula or that their own formation was affected by the presence of the macula. Additionally, there are numerous small depressions, often with raised rims, found in the area surrounding the macula, some of which form pit chains oriented radially to the macula center.

These images provide the first look at the detailed morphology of a specific macula, enabling interpretations of this feature's mode of formation. For example, the radial pit chains could represent secondary craters, suggesting an impact (exogenic) origin. On the other hand, the pit chains could be collapse pits, and a thermal or tectonic (endogenic) origin might be more likely. Detailed examination of macula morphology and relations to the surrounding terrain, and comparison to similar features seen elsewhere in the solar system enables testing of possible modes of formation for this type of feature on Europa. Preliminary comparisons can be made with palimpsests on Ganymede (exogenic) and small coronae on Venus (endogenic).

Exogenic Hypothesis: The Palimpsest Analog

Palimpsests were identified on Ganymede and Callisto (e.g., Passey and Shoemaker, 1982), and possibly Europa (Lucchitta and Soderblom, 1982). Initial Voyager-based work characterized these features on Ganymede and Callisto as roughly circular, high albedo patches or spots with little or no relief. Their centers are usually smooth but may become texturally rough around the peripheries. Palimpsests are generally thought to represent impact "scars" whose morphology either: a) developed by viscous relaxation of the original impact crater with initially "classic" morphology (e.g., Passey and Shoemaker, 1982); or b) promptly formed as its presently appears due to unusual (non-brittle) target properties with little change since the impact event (e.g., Greeley et al., 1982). Alternatively, they could be of endogenic origin (e.g., Squyres, 1980), but the predominant interpretation of these features remains exogenic.

Work using *Voyager* images of Ganymede Greeley et al. (1982) and Schenk (1996) favor the present appearence of palimpsests as representing the original morphology; in which a liquid slurry, or slurry with solid chunks, was ejected at the time of impact, forming a smooth marginal plateau unit and inner fill while producing either no or else a highly modified and subtle crater rim. Detailed mapping by Schenk (1996) on Ganymede of a number of complex and pedestal craters as well as the penepalimpsest (a palimpsest formed in a slightly more brittle target) Nidaba (centered at 19°N, 124°W) that exhibits secondary craters, a marginal smooth facies, and an identifiable rim was used to scale the crater rim diameters of other palimpsests based on the diameter of the feature as a whole.

If the edge of the 50 km diameter inner rugged zone of the macula on Europa corresponds to a crater rim, then the scaling model of Schenk (1996) would predict the marginal smooth unit to extend outward some 25 to 30 km. The zone of the macula in which patches of smooth terrain occur is coincident with this marginal unit. Strings of pits radial to the macula that could be secondaries are seen beyond the zone containing smooth terrain, just where Schenk's scaling relationship would predict secondaries to be found. The concentric graben preseumably formed subsequent to the imediate effects of the putative impact as they cut the smooth terrain. The graben may have formed by the slow inward flow of warm ice at depth as an initial central mass deficit was filled (see McKinnon and Melosh, 1980). The morphology and distribution of facies composing the macula appear consistent with a palimpsest-style impact origin. If so, this macula and ganymedan palimpsests may represent interpretable and scalable examples of primary landform suites formed by impact into liquid slurry-rich targets on airless icy satellites.

EUROPAN MACULA: POSSIBLE ORIGINS J.M. Moore and the Galileo SSI Team

Endogenic Hypothesis: The Venus Corona Analog

Coronae are a class of features on Venus typified by a concentric annulus of tectonic features (Pronin and Stofan). Generally circular in planform, coronae on Venus range in size from 60 to 2600 km diameter. The tectonic annulus may be comprised of extensional features, compressional features or a mix of the two. The annulus width varies greatly, but generally widens with increased overall corona size. The interiors of most coronae on Venus are typically smooth plains (volcanic deposits); which represent either the pre-existing surface or new flows associated with corona formation. Volcanic flows originating at corona tectonic features, such as annular fractures, are associated with many corona. The topographic expression of coronae ranges from domes to plateaus to plateaus with interior lows to rimmed depressions. Most workers agree that coronae on Venus are the surface manifestations of mantle plumes/diapirs (Stofan et al, 1992; Squyres et al, 1992; Janes et al., 1992).

Broadly similar in size and tectonic structure to small venusian coronae, the macula on Europa differs mainly in the rugged relief of its interior. If we hypothesize that the feature represents the surface expression of diapiric activity (similar to Venus), then the nature of the material (ice) and its behavior under various thermal conditions controls the resultant interior morphology. In this scenario a plume of ductile ice rises toward the surface, perhaps originating over a silicate hot spot. This mechanically lifts the surface and thermally alters the surface ice grain size. Grain size variations can account for up to a 15% albedo variation (Dozier, 1989). Heating would be greatest above the plume, which may explain why this feature is dark. In this model, the annulus of graben was produced by hoop tension forces exerted about the periphery during the initial phase of doming. The material forming the smooth patches may have erupted at this time along the border of the inner zone and flooded low spots along the flanks of the dome. The rugged nature of the center may result from compression as heat is withdrawn and the dome subsides. Pre-existing structures in the area are likely removed or subdued by thermal and mechanical effects of the diapiric activity. However, major features, such as ridges, could be more "resistant" or able to withstand the thermal and mechanical effects to some degree. The numerous depressions found around the macula may be collapse structures related to thermo-karst or areas where material has been sublimated.

Conclusions

Even with the new high resolution images, both exogenic and endogenic hypotheses of origin for this macula remain viable. The morphology of the macula itself, and its relation to the surrounding terrain can be explained by either impact or diapiric activity. Multi-spectral data (from NIMS and later SSI imaging) may provide information that could better delineate one or the other hypothesis, if the composition can be positively identified as deriving from either subsurface materials or cometary/asteroidal material. Comparison with other maculae on Europa at a variety of resolutions may show a range of morphologies of this type of feature and possibly indicate that maculae are formed by different modes (i.e. are not a single class of feature).

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