COMPARISON OF POROSITY AND RADAR MODELS FOR EUROPA'S NEAR SURFACE.

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Introduction: Our intent is to compare models of Europa's near-surface porosity developement with models that explain Europa's radar anomalies to determine the most probable structure of Europa's shallow subsurface. Some of the radar models suggest that the near surface may have properties that would produce the observed echoes.

Radar Properties: At radar wavelengths Europa is very unusual. The icy Galilean moons were illuminated at 3.5 cm, 13 cm, and 70 cm wavelengths from Arecibo [1]. They showed to varying degrees three unexpected anomalies. First, the albedo was greater than one, corresponding to a smooth perfectly conducting sphere. Second, the linear and circular polarization ratios were very high. Any known single reflection event reverses the polarization of incident electromagnetic waves. Therefore, the anomalous echoes were not reflected in a single event because the ratio of same sense to opposite sense is greater than one. Third, there is no quasi-specular reflection. The sub-radar point should show as a bright spot because the surface normals are directed back toward the source. The lack of a bright spot indicates that surface reflection is not noticeable in the observed returns from the icy Galilean moons. Together, these three problems have challenged the planetary science community and have led to many theories and models to explain them.

Porosity models working from either first principles or visible and (IR) imagery have only begun to address the problem of void or porosity formation and distribution, and they have not yet related the distribution of structures capable of backscattering with the observed radar echoes. Herein, I compare the assumptions of porosity models with the physical parameters of radar models to map connections between these two ways of determining Europa's real physical properties. Any correlations between the models will strongly support the involved models and invalidate the others.

Porosity Model: Gardening and sputtering are the two post-accretion porosity forming surface processes that appear to have the most influence on the porosity of the near surface. [2] Propose a gardening rate of 1 m per ~10^7 years. [3] Estimate a new gardening rate for Europa of 67 cm per 10 Myr. A problem with this new gardening rate is it implies the surface is saturated with 2.7 m diameter craters, but there are few craters visible in the Galileo images of Europa. The authors suggest that there is a steep power law curve to the impactor population that would permit the existence of many craters smaller than the limit of resolution of current images. Secondary craters from large impacts may be an additional source of small craters that is apparently not included in current calculations of cratering rates. [4] Suggest that impact erosion and regolith formation are minimal, but [5] suggests that up to 45% of small (< 2 km) craters are secondary. [6] Note that secondary impact craters range from ~1 km in diameter to the limit of resolution (~10 m), and that secondary icy ejecta fragments are generally smaller than ejecta fragments from a silicate body. In addition, every high resolution sequence examined contains a few crater clusters which indicate that primary craters can "efficiently launch and disperse ejecta around Europa" [5].

Results: [7] Suggests some characteristics of the scattering layer. The scatterers follow a fairly steep power-law curve with the size distribution weighted toward the smaller scatterers. Although silicate scatterers are geologically plausible, their modeled scattering signature does not fit the anomalies. The anomalies are best explained by ice or void space scatterers. Their Coherent Backscatter Effect model only defines the density of the scatterers and the approximate depth of the layer. The scattering layer on Europa is optically thick because the majority of the incident radar waves are scattered at 3.5 cm and 13 cm however this scattering can be achieved by a layer that is meters thick. The best fit models of Europa's surface imply that scatterers occupy 80% of the volume of the scattering layer. The decrease in radar scattering on Europa between 13 cm and 70 cm may be due to a layer that is too shallow to permit multiple scattering and the relative scarcity of larger scatterers. [1] States that measurements at 3.5 cm and 13 cm wavelengths show similar anomalous properties for all Galilean satellites, but at 70 cm the backscatter is much less for Callisto and Ganymede and is undetectable for Europa. At 70 cm the polarization ratios remain high and there is no quasi-specular reflection for Callisto and Ganymede [1]. Therefore, the same processes are probably functioning on Callisto and Ganymede at 70 cm as are functioning at 3.5 cm and 13 cm. This may indicate they have older and deeper gardening layers. Europa's younger surface may lack a radar echo at 70 cm if the gardening layer is shallower or if it has fewer large scatterers.

Conclusion: This review of the assumptions and parameters of these porosity and radar models indicates that these two types of models rarely if ever take into account the constraints each type of model places on the physical and electromagnetic properties of Europa's surface. Gardening of the surface by small (often secondary) impactors appears to assist in creating a porous medium in which multiple scattering at radar wavelengths can occur. The older surfaces and presumably deeper gardening layers on Callisto and Ganymede may allow these moons to anomalously scatter at 3.5 cm, 13 cm, and at 70 cm. Europa may lack a radar echo at 70 cm due to its younger surface and consequently shallower gardening layer that may allow the longer wavelengths to penetrate until absorbed. Bistatic radar observation of Europa from some non-zero phase angle would test for the presence of the opposition backscatter peak that is an integral part of the CBE model. In addition, better detection of Europa at longer radar wavelengths by either a ground based radar or by an orbiting spacecraft would significantly improve models of Europa's surface. In brief, the high albedo, linear and circular polarizations ratios, and the lack of quasi-specular reflection at all radar wavelengths are best explained by the Coherent Backscatter Effect operating in a porous surface layer.

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