SALTS ON EUROPA’S SURFACE FROM THE GALILEO NIMS INVESTIGATION


We present observational evidence for hydrated salt minerals in the surface material of the icy Galilean Satellite Europa [1,2,3] using the Galileo NIMS reflectance spectra. Hydrated minerals have been suggested by many authors for some time as existing on the surfaces of the Galilean satellites [e.g., 4,5]. Extensive areas on Europa show distinct water-related absorptions in their spectrum in the 1-2.5 µm region from NIMS and telescopic data. We show that these must be due to high concentrations of hydrated materials. Further, the H$_2$O molecule (not just OH) has to be present and it has to be strongly active spectrally, indicating heavy hydration. The H$_2$O must be relatively closely bound to the host molecule and in numerous slightly different bonding configurations, because of the evident strong and multiple distorting effects the host electric potential has on the H$_2$O energy levels exhibited in the spectra [6].

A search of spectral libraries (e.g., from U.S.G. S.) and some new laboratory measurements indicate that only a few heavily hydrated minerals have spectra resembling that of Europa’s (Fig.1). Clay minerals have been suggested as the Europa non-ice constituent [e.g., 4,5] but hydrated clays contain absorptions, due to metal-OH vibrations, in the 2.2-2.4 µm region which are not seen in the Europa spectra even though the SNR is sufficient. Further, hydrated clays do not exhibit the degree of water-band distortions required. However, a few heavily hydrated salts such as magnesium- and sodium-magnesium sulfates [NaMgSO$_4$ • 6H$_2$O] and one sodium-carbonate, natron [Na$_2$CO$_3$ • 10H$_2$O], are good candidates. From physical chemistry arguments, including solubilities, sodium-magnesium sulfates are preferred for Europa’s ocean [7,8].

We have mapped the salts concentrations for each of the NIMS Europa data sets by developing a function giving reflectance versus salt concentration for each spectral channel and searching the spectrum for each pixel to determine the best spectral match. The results show [1,3] that the salts seem to have about the same composition everywhere studied, are concentrated in areas with lower visual/very-near-infrared albedo, including a large area centered near but not on the trailing side and in the lineaments (Fig. 2) [1,3,9]. Some areas have almost 100% salts and little water ice.

These salt minerals are typical of evaporite deposits on Earth [6] and they are found in some water-altered meteorites. The possible presence of hydrated salts on the surface lends support to the concept of resurfacing by liquid water from an ocean under a frozen ice crust. The ocean water appears to be rich in dissolved salts which, when extruded onto the surface, is lost, leaving evaporite deposits. The ocean must be extensive and well-mixed to produce similar evaporate compositions everywhere over a hemispherical scale.

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Figure 1. Reflectance spectra from the Galileo NIMS instrument are shown for Europa non-icy (1) and icy (2) areas. Spectrum (3) is for the salt mineral Hexahydrite \( \text{MgSO}_4 \cdot 6\text{H}_2\text{O} \) and shows very similar features; this is the prime candidate for the material composing much of the non-ice portion of the surface. Spectra (4) and (5) are for hydrated clay minerals Sepiolite \( \text{Mg}_2\text{Si}_6\text{O}_{18}\text{(OH)}_2 \cdot \text{H}_2\text{O} \) and Montmorillonite \( [(\text{Na},\text{Ca})_{0.33}(\text{Al},\text{Mg})_2\text{Si}_4\text{O}_{10}(\text{OH})_2] \cdot n\text{H}_2\text{O} \), respectively. Clay minerals have been suggested as the non-ice constituent of Europa’s surface, but clays do not have the broadened water features found for Europa. Further, clays have metal-OH absorptions in the 2.2 to 2.4-µm region which do not occur for Europa. The non-Europa spectra are offset by +0.35.

Figure 2. The upper left image shows a near-global region of Europa at 77 km/pixel in the 0.7 µm passband for the NIMS instrument. The gray-scale bar indicates the reflectance for each pixel. The upper-right image shows the relative concentrations of the non-ice to ice components of the surface, with dark corresponding to the highest non-ice concentration. The gray-scale bar indicates the relative amount of non-ice component, where 1 = 100 % non-ice material. Note that the non-ice material is associated with the dark regions. The bottom-left image shows at high-resolution (~4 km/pixel) a small region of Europa in the 0.7 µm passband for the NIMS instrument. Note that the non-ice material is associated with the dark regions including the linea.