SIGNATURES OF THE RADIOLYTIC SULFUR CYCLE ON EUROPA: A NEW TOOL FOR INTEGRATED COMPOSITIONAL AND STRATIGRAPHIC INVESTIGATIONS. J. H. Shirley1, J. B. Dalton1, L. M. Prockter2, and L. W. Kamp1, 1Jet Propulsion Laboratory, MS 183-601, 4800 Oak Grove Drive, Pasadena, CA 91109 USA, (James.H.Shibley@jpl.nasa.gov), 2Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, USA.

Introduction: The radiolytic sulfur cycle of Carlson et al. [1] produces hydrated sulfuric acid from endogenic sulfates of sodium and magnesium and from exogenic sulfur ions implanted on the surface of Europa. From a geological perspective, the radiolytic processing of surface materials is expected to progress rapidly [2-4], with most materials in the optically sensed layer predicted to experience multiple interactions within intervals of 10-1000 yr. The surface of Europa is accordingly thought to be in a state of chemical equilibrium between radiolytically-driven production and destruction of hydrated species. Because of the asymmetric magnetospheric bombardment of Europa’s surface, among other effects, relatively higher abundances of sulfur-bearing hydrated compounds are detected on the trailing hemisphere. A spatial gradient of hydrated species abundance, with concentrations increasing toward the trailing side apex, was documented in the first Near-Infrared Imaging Spectrometer (NIMS) observation of the Galileo Mission [5].

Recent results: Prior work [6, 7] confirms the existence of a well-defined spatial gradient of sulfuric acid hydrate abundance within one NIMS observation that spans the leading side-trailing side boundary. Near-infrared spectra for more than 50 non-overlapping exposures of Europa’s ridged plains, smooth low albedo plains, and other terrains have been extracted from despiked cubes and analyzed by means of linear mixture modeling [7]. The linear mixture modeling algorithms [8] employ cryogenic (100-120 K) reference spectra of hydrated salts, hydrated sulfuric acid, and water ice of varying grain sizes to obtain best-fit estimates of surface compositions. Figures 1 and 2 illustrate the distinctively different compositions obtained for two geologic terrains on Europa. Fig. 1 gives the derived composition of an exposure of background ridged plains from Europa’s Argadnel Regio. The composition is dominated by water ice (46% abundance), with a substantial abundance of hydrated sulfuric acid (35%) and lesser amounts of hydrated salts. The compositional solution for a nearby exposure of dark, smooth low albedo plains materials (Fig. 2) shows 0% abundance of water ice, a significantly lower abundance of sulfuric acid hydrate (23%), and much greater abundance of hydrated salts.

Figure 1. Linear mixture model fit to a NIMS spectral average (circles) extracted from ridged plains in Argadnel Regio (R2 in Fig. 3). The fitted spectrum (solid line) represents a linear combination of the reference spectra. Layer thickness at each wavelength is proportional to the product of the material’s reflectance with its percent abundance.

Figure 2. Linear mixture model fit to a NIMS spectral average (circles) extracted from low albedo plains (L1D in Fig. 3) in Argadnel Regio. The fitted spectrum (solid line) represents a linear combination of the reference spectra. Note the higher MgSO4 brine but lower H2O and H2SO4 hydrate abundances.

Figure 4 shows the gradient of sulfuric acid hydrate abundance obtained for our study area in Argadnel Regio [6-7]. The abundances for ridged plains, for
chaos, and for low albedo plains units show a reasonably consistent gradient with longitude. Much of the scatter about the best-fit line in Fig. 4 is due to a secondary gradient in latitude, which has not been compensated in this representation, but is consistent with estimates of variations in the radiative flux.

Remarkably, the sulfuric acid hydrate abundance (and its gradient) generally seems to be independent of the composition of the underlying geologic terrain. This strongly suggests “overprinting” of the underlying surface by the sulfuric acid hydrate component, which we attribute to the effects of radiolytic processing linked with magnetospheric bombardment [1].

Exposures with reduced H$_2$SO$_4$ hydrate abundance: A cluster of exposures of low albedo plains materials with significantly lower sulfuric acid hydrate concentrations is seen at the left of Fig. 4. This cluster of exposures includes and is contiguous with area L1d, whose spectrum is presented in Fig. 2. The sulfuric acid hydrate abundance found for area L1d is $\sim$33% lower than would be predicted by the gradient shown in Fig. 4. While analysis is ongoing, we currently interpret the low abundance as an indication that the radiolytic overprinting of the surface composition here has not yet progressed to equilibrium. The L1d exposure may not have been exposed to Europa’s radiation environment for as long as its surroundings. Because radiolytic modification of the surface is expected to occur rapidly on Europa [2-4], this implies that exposure L1d may be significantly younger than nearby exposures such as R2.

Implications: Local variations in Europa’s surface chemistry may identify prime targets for future investigation by spacecraft remote sensing experiments and landed instruments. While there is potential for additional refinement of surface abundance and exposure age estimates, we suggest that the observable consequences of the radiolytic sulfur cycle [1] provide a powerful means of investigating the chemistry and history of Europa’s surface. The method described in [7] represents a significant step forward in the effort to disentangle the exogenic effects from the endogenic compositional components of Europa’s surface. Further investigation of other areas on Europa’s surface where high-resolution imaging and near-infrared spectral data exist are clearly needed.


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