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Transport of Organics through the Europa Icesheet

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Abstract

We consider the large scale transport of material through the bulk ice sheet on Europa. This occurs on terrestrial Antarctic ice sheets, with material removed by wind ablation on the surface constantly being replaced by water frozen on to the underside of the sheet. This leads to transport of material, including the corpses of fish, through the icesheet, and its deposition on the surface. We propose that a similar mechanism might occur at Europa, with the high radiation levels causing sputtering over the Solar System age which could have the same effect as wind in Antarctica .

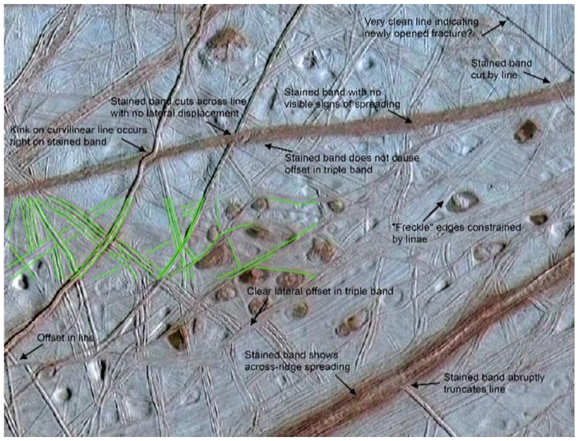
1. Introduction

The surfaces of icy moons, in a high radiation environment, undergo significant modification and erosion (eg Paranicas et al, 2007). We are recalculating the observed heavy ion fluxes (Lee-Payne et al this meeting) and this may have a significant effect on the calculated erosion rates of icy moon surfaces in a high radiation environment, since these heavy ions are the main agents for the sputtering of the surface. We will further extend our GEANT based model to consider ice sputtering and erosion by the radiation environment, thus obtaining a more sophisticated analysis of the erosion of the dirty ice of Europa. Into this we will feed our revised heavy ion flux measurements. The end result should be a revised, and more robust, estimate for the timescales for ice erosion and turnover. A key further question we can model is the survival of recognisable life signatures in the harsh radiation environment at the surface.

We will compare these sputtering losses, with the losses and gains due to other processes such as impacts, condensation of ejecta, plumes, dew formation and upflow through fissures, derived from observations in the current literature, and applied to Europa and other icy moons. They will be augmented by modelling, and by comparison with temporal imagery of icy moon processes. Surface frosts have been recorded at high latitudes craters on sun shaded slopes on Callisto and other icy moons (Khurana *et al.*, 2007), and plume activity from Saturn's icy moon Enceladus has been observed off the planetary limb, against the night sky. Similar frosts are observed in Antarctica. Icy moon surface temporal differences can be found using correlation quality, a by-product of automated patch-based stereo matching software (Cook and Robinson, 2000), when applied to temporal image pairs. We can then investigate whether these changes support current models of charged particle bombardment, sputter redistribution, radiation damage, or thermal sublimation and freezing (Khurana *et al.*, 2007), and modify our own model accordingly.

We are to investigating the morphology of the surface ice sheets of Europa. It is attractive to draw comparisons, as illustrated by the images below. We will study: impact morphologies, lenticulae, cryovolcanic features, pull-apart bands, chaos terrain, ridges, surface frosts, topography, and global tectonic structures, all of which can be used to provide evidence of an extant subsurface ocean. These structures bear many similarities to terrestrial, floating Antarctic ice shelves which contain similar rifts, fractures, pull-apart structures, calved blocks and debris-rich folds and fractures (see image below for our analysis). We propose to use Earth's Antarctic ice shelves to provide structural insights into the features on Europa, to understand better their origin and significance.

A significant factor on Earth is the erosion of the ice surface by surface melt and wind, which transports organic and other material to the surface (Glasser *et al* 2006). It may be that erosion in the severe radiation environment at Europa plays a similar role. However, the accurate knowledge of heavy ion populations (sulphur and oxygen) which are the main species producing sputter erosion of ice (Johnson, 1999) is based on Gallileo measurements which were compromised by radiation damage. The results of our reanalysis will also be extended to Ganymede and Calisto, in preparation for JUICE arrival.



Comparison of Europa and terrestrial ice sheets.
Left: *Interpretation of part of the surface of Europa showing key geological features including lines and the prominent stained bands that indicate spreading of rifts and healing from within. "Freckles" are also visible. Note that different generations of features can be inferred from the relative movement implied by the different cross-cutting relationships. Image credit: NASA/JPL/University of Arizona/University of Colorado.*

Right*: Rifts on McMurdo Ice Shelf. The rifts clearly show along-rift spreading with the addition of new material in the rift as it spreads. This partly explains how water (and life) from underneath gets to the surface. This Earth example shows the types of structures that form on a thin floating Antarctic ice shelf and demonstrates how geological principles on Earth can be applied to Europa. Could a similar process operate on Europa?*

Conclusion

Connecting ice sheet morphology with radiation environment and survivability of biosignatures is new. It is clear that ablation by hard radiation will take place. Sputtering is momentum dependent, efficiency peaking at velocities where the ion stops in the surface monolayers - the material that escapes. This efficiency peak corresponds to Europa orbital velocity; the most efficient sputtering is by heavy particles, and sulphur fluxes are the most seriously underestimated due to the EPD radiation damage. Sputtering yield in dirty ice requires careful modelling, which the JUICE radiation modelling equips us for, and are far higher than for simple solids. The nature of "dark material" on Europa is a matter of extreme current controversy (eg radiation modified sea-salt *Hand and Carlson, GRL 15 May 2015*). Relating bulk transport to upflow through cracks and differential erosion/modification of material is key. In the Antarctic ablation leads to the appearance on the surface of organics (fish corpses) which have been transported through the bulk ice *Swithinbank et al Science 1961*. Our code can model contrast changes and survival of such material.

References

1. *Cook, A.C. and Robinson, M.S., 2000, Mariner 10 stereo image coverage of Mercury, Journal of Geophysical Research, 105(E4) p9429-9443*
2. *Glasser, N.F., Goodsell, B., Copland, L. and Lawson, W. (2006). Debris characteristics and ice-shelf dynamics in the ablation region of the McMurdo Ice Shelf, Antarctica. Journal of Glaciology, 52(177), 223.*
3. *Johnson, R.E., 1999, Energetic Ion Sputtering of Europa's surface: Loss of Na, American Astronomical Society, DPS meeting 31, 62.03*
4. *Khurana, K.K., Pappalarado, R.T., Murphy, N., and Denk, T., 2007, The Origin of Ganymede's Polar Caps, Icarus, 91, 193-202*
5. *Krupp et al., Global Flow patterns in the Jovian magnetosphere: Galileo/EPD and Galileo/PLS measurements; 2014, EPSC 2014-236.*
6. *Paranicas, C.; Mauk, B. H.; Khurana, K.; Jun, I.; Garrett, H.; Krupp, N.; Roussos, E., 2007, Europa's near-surface radiation environment, Geophysical Research Letters, 34, 15, L15103*
7. *Radioti, A.; Krupp, N.; Woch, J.; Lagg, A.; Glassmeier, K.-H.; Waldrop, L. S., 2005, Ion abundance ratios in the Jovian magnetosphere, Journal of Geophysical Research: Space Physics, 110, A7, A07225*
8. *K.P. Hand and R.W. Carlson, GRL 15 May 2015, DOI:10.1002/2015GL063559.*
9. *C.W.M. Swithinbank et al. Science 1961. Vol 133 no 3455 pp. 764-766* .