THE O-H STRETCH TRANSITION INFERRED FROM THE OBSERVATION OF THE 3.15 µm BAND IN THE INFRARED SPECTRA OF IO: TWO POSSIBLE INTERPRETATIONS.

V. Cataldo. Environmental Science Dept., Institute of Environmental and Natural Sciences, Lancaster University, Lancaster LA1 4YQ, U.K. (v.cataldo@lancaster.ac.uk)

Among all absorption features evident in Ionian infrared spectra, the most debatable is perhaps that associated with the likely existence of hydrated minerals, hydroxides, or even water. These infrared bands occur at positions ranging between 3.12 µm (Salama et al., 1990) and 3.16 µm (Sanford et al., 1994). The Galileo spacecraft has recently reported a weak but persistent absorption feature at 3.15 µm, which is probably the same as those previously mentioned (Carlson et al., 1997). In support of this, laboratory experiments have showed that H_2O impurities in SO_2 frosts are responsible for an absorption band centered at approximately 3.1 µm (Nash and Betts, 1995). Although the concentration of the hydrated material at 3.15 µm has not been calculated yet, values ranging from a minimum of 4 ppm (Carlson et al., 1997) up to a maximum of 1000 ppm (Salama et al., 1990) has been estimated. In particular, the Salama et al. (1990) estimations refer to H_2O abundances: according to the same authors, the infrared bands would result from clusters of H_2O in sulfur dioxide ice. All these results, although debatable, lead to a common conclusion: the OH molecule is very likely to exist on Io.

We think that the likely existence of the OH molecule on the Ionian surface can be explained either by H_2O being contained within erupting magmas or released on the satellite through dramatic events like cometary impacts. Most Ionian volcanic centers appear homogeneously distributed over the surface; due to this fact, the H_2O erupted along with other gases into the Ionian environment would be uniformly distributed around most volcanic centers, at a distance at which condensation on the surface was allowed. With respect to other gas species, like SO_2, H_2O would condense earlier. In this case, the clusters of H_2O in sulfur dioxide ice proposed by Salama et al. (1990) could develop. Within erupting plumes, most flakes resulting from gas condensation would consist of H_2O frost coated by outer layers of condensed SO_2. In some cases, tiny volcanic particles within the plume itself could also be coated by both frost species. In such a way, the spontaneous breakage of the O-H stretch in the Ionian environment could be prevented or, at least, reduced in time.

The O-H molecule could also be transported onto Io by comets: this is not such a rare event in the Solar System. On the Moon, Lunar prospector instruments have apparently detected concentrations of H_2O ice mixed with regolith at the bottom of some craters located near the polar regions of the satellite (Wilson, 1998). On Io the total absence of impact craters does not imply that impact events are not likely to occur. Within the Jovian system, the dominant classes of impactors are short-period Jupiter-family comets and asteroids (McKinnon and Schenk, 1995). Thirteen crater chains, probably shaped by cometary impacts, have been observed on Callisto; three have also been identified on Ganymede (Melosh and Schenk, 1993). Such linear strings of ricochet fragments could be produced by impactors striking a given satellite at a very low angle (< 15°) (Halfen et al., 1990). They could also result from impacts of tidally disrupted comets within the Jovian system, similarly to the observed Shoemaker-Levy 9 event on Jupiter (Schenk et al., 1996). This last possibility also appears more likely to occur (McKinnon and Schenk, 1995). Tidally disruptive events are likely to occur within the Jupiter system roughly once every 200 to 400 years (Schenk et al., 1996). Because of the Jovian gravitational focusing effects, Io is expected to suffer more impacts than all other Galilean satellites (Nakamura and Yoshikawa, 1995). The trajectories must pass close to Jupiter, this fact also constraining the impact geometry (velocity and impact angle) of the individual fragments (McKinnon and Schenk, 1995). The impact speed of these cometary bodies with the Ionian surface is very high, ranging from a minimum value of 20 km/s up to a maximum of 42 km/s (Nakamura and Yoshikawa, 1995). According to Melosh and Vickery (1989), this range of velocities would cause all vaporized materials generated through the impact to escape outwards, into space. Such a conclusion is achieved by simply assuming that the impact generation of vapour reflects just the role of waste heat from peak shock pressures controlled by the vertical component of velocity. By laboratory experiments, Schultz (1996) has recently showed that oblique impacts (15° - 30° from horizontal) generate vapor with relatively low internal energy (i.e. low expansion velocities) that does not increase with impact velocity. The maximum velocity obtained in the experiments was 7 km/s. Only for high impact angles (nearly vertical) would the maximum expansion velocity of the vapor cloud be much larger due to the internal energy being increased because of the greater peak pressures. These new results appear to be the consequence of the increasing role of friction from high shear stresses created during oblique impacts and of downrange hypervelocity impacts by the disrupted impactor, following first contact with the surface. Furthermore, both increasing shear stresses and downrange hypervelocity impacts involved in low-angle (15° - 30° from horizontal) impacts would enhance significantly the vaporization process. With regard to the target, only crustal materials at a shallow depth, at the upper surface, would be vaporized (Schultz, 1996). Due to these new experimental results, we can argue that even though very high-velocity impacts are likely to occur on Io's surface, the fractions (albeit small) of them that are oblique would generate high vapor amounts, expanding at relatively low velocity, resulting from the vaporization of both impactor fragments and target surface rocks, rich in volatile deposits.

REFERENCES: Carlson et al. (1997) Geophys.Res.Lett., 24, 20, 2479-2482; Halfen et al. (1990) Lunar Planet. Sci. XXI, 447-448; McKinnon and Schenk (1995) Geophys.Res.Lett., 22, 13, 1829-1832; Melosh and Schenk (1993) Nature, 365, 731-733; Melosh and Vickery (1989) Nature, 338, 227-236; Nakamura and Yoshikawa (1995) Icarus, 116, 113-130; Nash and Betts (1995) Icarus, 117, 402-419; Salama et al. (1990) Icarus, 83, 66-82; Sanford et al. (1994) Icarus, 110, 292-302; Schenk et al. (1996) Icarus, 121, 249-274; Schultz (1996) J.Geophys.Res., 101, E9, 21,117-21,136; Wilson (1998) Chemical & Engineering news, 76, 10, 7.