**EVIDENCE FOR VARIABLE THICKNESS IN EUROPA'S ICY SHELL: IMPLICATIONS FOR ASTROBIOLOGY MISSION DESIGN.** A. G. Fairén[1], R. Amils[1,2]. [1]Centro de Biología Molecular, CSIC-Universidad Autónoma de Madrid, Spain. (agfairen@cbm.uam.es). [2]Centro de Astrobiología, CSIC-INTA, Madrid, Spain.

**Introduction.**

The exploration of Europa's subsurface ocean is hardly constrained by the presence of an outer ice shell of unknown thickness: a somewhat thin crust would allow easier access to the ocean below. Current estimates for the thickness of Europa's icy surface range from a few km [1] to a few tens of km [2], the shell overlying a liquid water ocean up to 150 km thick [3-5]. The surface is believed to be young (mean age of 30-80 Myr [6]) and geologically active [7-9], as it is sparsely cratered. Here we report geological evidence indicating that the thickness of Europa's ice crust is actually a complex combination of thicker and thinner areas, highlighting the implications of such structure in the future exploration of the inner ocean.

**Geological assessment.**

Detailed geologic mapping of impact craters, palimpsests and chaotic terrains distribution on Europa's surface, offers an initial approach to a comprehensive description of the thickness variation in the ice shell. Our analysis is based in:

(1) Crater distribution, morphology, diameter and depth. Seminal work by Schenk [2] of transitions in crater shape/diameter suggested enhanced structural collapse of craters with diameter >27-33 km, that will consequently form multiring basins, due to weaker ice or a global ocean at depths >19-25 km. This being true, strictly can only be interpreted regionally: multiring basins indicate regions where the ice shell is thick; in those regions where the icy surface is thin, a bolide impact will breach the ice and leave neither crater nor multiring basin behind, but probably Ganymede's type palimpsests.

(2) Palimpsest-type features distribution, indicating regions where the ice shell is too thin to support crater formation after big bolide impacts. In Ganymede, palimpsests are circular, low albedo and relief features formerly formed by impacts [10,11].

(3) Chaotic terrain distribution, considering features tens to hundreds of km across, that may be the evidence for very thin ice areas (from ~2 km to zero shell thickness [12]) with liquid water at shallow depths [5], allowing for bolide penetration, diapirism and the extrusion of water to the surface.

The heterogeneity in shell's thickness may be originated in spatial variations in tidal heating [13] and/or warm water upwellings from the silicate interior capable of melt-through the ice from below [12,14]. This thickness heterogeneity can be embedded in a general equatorward thickening trending, due to tidal dissipation and surface temperature variations [15].

**Long-term ice shell behaviour:**

The dynamism of ductile ice near the base of the shell may drive to decay in lateral thickness contrasts. But this effect has been examined both assuming ice as a Newtonian [16-18] and a non-Newtonian material [19], broadly reaching to similar conclusions: global shell thickness variations may survive for up to 100 Myr. In addition, lateral pressure gradients may not decay if they comprise only shallow depths [19]. Therefore, our results point to a dynamic non-uniform Europa's icy shell, displaying some regional and temporal heterogeneity in thickness. As thin/thick ice distribution is as time dependent as the surface ice features are (both are reshaped in periods ~100 Myr), the analysis performed here offers an estimation of the current thickness distribution in the ice shell, estimation that cannot be extrapolated to ancient (e.g., >100 Myr) times.

**Implications for life.**

A somewhere thin outer crust allows the possibility for some exogenous materials delivered by asteroids and comets to reach the inner liquid water ocean by breaching the brittle lithosphere [20], and so join to those generated in the interior of Europa via volcanic and hydrothermal activity [21]. In addition, pressure gradients driving the ductile ice at the base of the shell to flow laterally may help to redistribute such materials among the inner ice shell and/or ocean through time.

Our results have a direct deal with the investigation of Europa's interior. Mission design will need to incorporate a drill system routine well suited to penetrate the ice shell tens of meters in the thinner areas, allowing to deep subsurface access and sampling. Landing and drilling targets should be selected among the zones where mapping indicates the presence of a thinner ice shell, as it may potentially suggest the existence of nutrient-rich hydrothermal plumes rising from the rocky interior and melting the ice from below, probably creating chaotic terrains [14]. Little-cratered, thin-crust areas would consequently be interpreted as key pacemakers to detect both the ice/ocean interface and the most complex environments under the ice shell. Additionally, drilling processes will be clearly easier in such zones.

**References:**

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