Composition and Habitability of Europa's Ocean Through Time

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Europa is proposed to host a global liquid water ocean in contact with a silicate mantle. Understanding the composition of the ocean and the underlying mantle is crucial for evaluating the habitability of Europa. However, the presence of an ice shell impedes direct observation or analysis of the ocean and rock – leaving their compositions largely unknown.

It has been shown that if Europa accreted entirely from CI or CM chondrites, enough volatiles could be released during prograde metamorphism to account for the current size of the water/ ice layer. However, thermal models predict that temperatures in Europa's interior would gradually increase over billions of years. This could result in a changing ocean composition over time due to the progressive release of volatiles.

In this study, possible ocean compositions were explored using computer modelling to simulate the thermal evolution of Europa's interior over its ~4.5 Gyr lifetime and assess the volatiles released from the starting material as it is heated. The composition of Murchison (a CM chondrite) was chosen to represent the silicate material that accreted to form Europa because the CMs formed close to early Jupiter (unlike the CIs) and contain sufficient water, largely held within hydrated silicates.

A 1-dimensional thermal evolution code was used to model the temperatures achieved within Europa's interior [*1*]. Temperature-depth profiles were then extracted at two points in time to reflect the formation of the proto-ocean (*i.e.* when the thermal evolution code predicts that the ocean stops growing in size) and the current-day ocean. Rcrust [*2*] and Perple_X [*3*] were used to predict the electrolytic fluid speciation from the starting material when heated to the temperatures predicted by the first temperature-depth profile and then the second. The released volatiles were then equilibrated using SOLVEQ-XPT [*4*], where supersaturated gases were exsolved and minerals precipitated, allowing comparison between the residual liquid ocean components of the proto-ocean and current-day scenarios.

We will present the results of the thermal and geochemical models, including the mass and composition of exsolved gases, precipitated minerals, and the residual liquid for the proto-ocean. The composition of the mantle and volatiles released between proto-ocean formation and the current day will also be presented.

Exploring how the ocean composition may have changed over time is important for evaluating Europa's continuous habitability.

References: [1] Trinh *et al.*, *Sci. Adv.* **9**, eadf3955 (2023). [2] Mayne *et al.*, *J. Metamorph. Geol.* **34**, 663–682 (2016). [3] Connolly, *Earth Planet. Sci. Lett*. **236**, 524–541 (2005). [4] Reed *et al.*, *University of Oregon, Department of Geological Sciences, Eugene*. **43** (2010).