Thermal-Compositional Evolution of Europa’s Interior and Ocean Since Accretion

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Europa’s compositional evolution is not well constrained. Observations only provide approximations of the current interior structure of Europa. However, dynamic models [Hussmann & Spohn 2004] resolve the magnitude of interior heating produced by tidal interaction over time. We couple the heat production to thermodynamic and chemical equilibrium models *Perple_X* [Connolly 2005], *Rcrust* [Mayne+ 2016] and *CHIM-XPT* [Reed 1998] to compute compositional changes of the interior and ocean.

Assuming that Europa's interior is not molten now, a Fe core could have accommodated up to 24 wt % S during accretion, assuming chondritic accretion material. However, a metal-silicate segregated magma ocean was needed to allow such high S content in the core. More likely, accretion proceeded with low impact rates that allowed heat dissipation. Based on this and experimental metal-silicate partition behavior, Europa’s core contains ~1 wt % S.

Two mantle melting events were calculated corresponding to putative events in Europa’s thermal-orbital evolution: a first event that melted up to 30 vol % of the volatile-rich silicate shell, at pressures of 2.5 – 1.2 GPa ≥4 Ga ago, and a possible melting event ~1.3 Ga ago resulting from increased dissipation as the mantle’s rigidity increased [Hussmann & Spohn 2004]. Melt intrusive to extrusive ratios (I/E) for Europa are unknown, but eruption to the ocean-rock interface would have been hindered by high stress needed to cause fracture propagation and melt migration at depth [Byrne+ 2018]. Assuming I/E = 10, < 7 wt % melt would have erupted (Fig 1). Even if lava erupted during the first event, limited heat transfer from, and dehydration of, the mantle may not have prevented the second event from occurring.

Considering Europa’s volcanism enables us to predict the minerals likely to have influenced the ocean’s composition and the mineralogy of concurrent water-rock activity. Erupted lava reacting with the ocean results in water-to-rock ratio dependent proportions of sulfides, saponite, chlorite and carbonates. We will describe implications for the ocean's composition and habitability.

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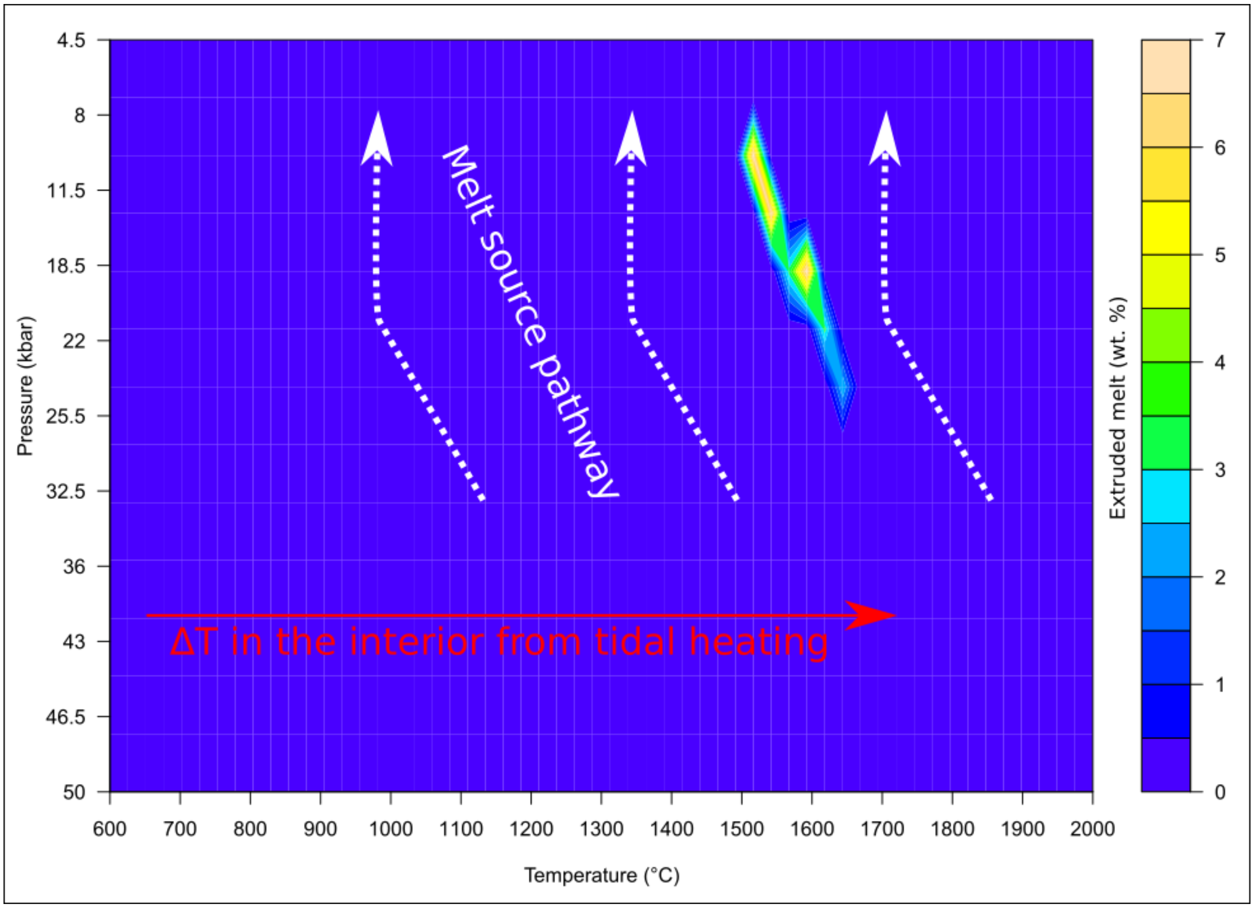

Pressure (kbar)
4.5
8
11.5
18.5
22
25.5
32.5
36
43
46.5
50
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Temperature (°C)
Melt source pathway
ΔT in the interior from tidal heating
Extruded melt (wt. %)
0
1
2
3
4
5
6
7