ropa; therefore, fewer oxidants are available by particle and radiation bombardment. However, abundant dust on the surfaces of Callisto and Ganymede generated by asteroidal and cometary impacts may provide nutrients for life within their sub-surface oceans. As in Europa, decay of ^{40}K may generate oxidants within the icy layers and ocean.

Ganymede's ocean may receive additional nutrients from the top of its rocky core. Silicate eruptions at the core/ice boundary can generate nutrient-rich pockets of melt water, which are buoyant relative to the surrounding high-pressure, high-density ice polymorphs. Provided these pockets of melt are large enough, they might reach the ocean on geologically a short time scale of $\sim 10^6$ years (*Barr et al.*, 2001).

Despite these potential nutrient sources, the oceans in Callisto and Ganymede are likely less hospitable to life than Europa's ocean. If biological activity existed within Ganymede's ocean, it would be more difficult to detect than life on Europa due to its older surface and limited period of endogenic resurfacing. Callisto appears to have experienced essentially no endogenic resurfacing in the recent geologic past, indicating that detection of a biosphere within Callisto would require sampling beneath the rigid surface ice with a sophisticated landed spacecraft, or searching within a large impact crater.

1.4 Rheology of Ice I

A large volume of experimental data and observations exist regarding the rheology of ice I in terrestrial and planetary contexts (*Durham and Stern*, 2001, and references therein). Recent laboratory experiments seeking to clarify the deformation mechanisms responsible for flow in terrestrial ice sheets suggest that a composite flow law which includes terms due to diffusional flow, grain boundary sliding, basal slip, and dislocation creep (*Goldsby and Kohlstedt*, 2001) can match both viscosity measurements from terrestrial ice sheets (*Peltier et al.*, 2000) and previous laboratory experiments. Conceptual