ices, which have been detected spectroscopically on Europa's surface (*Carlson et al.*, 1999). These materials are expected to be well mixed to a depth of 1.3 meters (*Cooper et al.*, 2001). The steady-state biomass that could be sustained by the equilibration of formaldehyde and hydrogen peroxide is estimated to be $\sim 10^{23}$ cells (*Chyba and Phillips*, 2002), or 0.1 to 1 cell cm^{-3}, assuming the top 1.3 meters of ice is transported to the ocean every 10^7 years.

The basic elemental building blocks of life and additional nutrients for life may be delivered to Europa through cometary impacts. Although a large percentage of the ejecta from a large impact exceeds Europa's escape velocity, at least 10^{12} to 10^{13} kg of carbon, and 10^{11} to 10^{12} kg of nitrogen, sulfur, and phosphorous may have been delivered to Europa's surface by giant impacts over the age of the solar system (*Pierazzo and Chyba*, 2002). Endogenic resurfacing events perhaps coupled with downward motion of ice in a convecting ice shell would be required to deliver these materials to Europa's ocean.

Abundant endogenic resurfacing and active tidal dissipation on Europa suggests that among the large icy satellites in our solar system, Europa holds the most potential for finding life or interesting chemistry near its surface. The formation of surface features such as domes (*Pappalardo and Barr*, 2004) and ridges (*Nimmo and Gaidos*, 2002) on Europa may allow small areas of the surface ice to be mixed into the subsurface, but a global mechanism of surface-ocean communication is required to sustain a biosphere.

Unlike an ocean on Europa which may be in direct contact with hydrothermal systems on a rocky sea floor, Ganymede's ocean is sandwiched between an outer layer of ice up to 160 km thick, and a mantle of high density ice polymorphs. Callisto's ocean is sandwiched between an outer layer of ice I up to 180 km thick and its partially differentiated interior. As a result, both oceans are seemingly isolated from the chemical nutrients that might sustain a biosphere.

Callisto and Ganymede experience a less intense radiation environment than Eu-