Alien oceans as a new frontier for geochemistry

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Over the past twenty years, Jupiter's moon Europa, and Saturn's moons Titan and Enceladus have emerged as three of the most compelling astrobiological destinations in the solar system. In this talk, I will present our current understanding of their geochemistry, discuss key questions that are raised, and outline next steps in their exploration.

The discovery of current geological activity at Enceladus must rank as one of the most spectacular discoveries of the Cassini-Huygens mission. There is a plume at the south pole that is releasing materials from a subsurface global ocean into space. These materials include inorganic gases, salts, and complex organic matter. The available data suggest that some of these materials are derived from hydrothermal activity in the rocky core of Enceladus. We are left with many questions to ponder. What is the detailed composition of the ocean, and what geochemical processes control it? How is hydrothermal activity sustained? How long has the ocean existed? How evolved is Enceladus geochemically compared with aqueously altered carbonaceous chondrites? How might we search for evidence of possible life in the ocean?

Cassini-Huygens also taught us a great deal about Titan, which has a unusually thick N_2-CH_4 atmosphere. Geophysical data suggest that Titan has a dense ocean below its icy crust. The ocean is presumed to be salt-rich. Below the ocean is a layer of high-pressure ice, and below that is a rocky core. These findings invite many questions. Which salts are in the ocean, and how did they get there? How long has the ocean been underlain by high-pressure ice? Are there sources of energy that could support life in a "sandwiched" ocean? What can the atmospheric composition tell us about the interior?

Europa is mostly a rocky world. However, it does have a salty ocean that is covered by an ice shell. The nature and extent of chemical communication between the ocean and the surface is a major unknown. Recently, there has been excitement about plumes on Europa. If plumes are present, then they would allow us to sample the subsurface. The Europa Clipper mission has a mass spectrometer, called MASPEX, that can analyze plume gases and diffuse emissions. Important questions will be answered in the next decade, which may include: Do plumes emanate from the ocean? What are the reductant and oxidant budgets in the ocean? Can these budgets support life? Are organic compounds present, and if so, where do they come from?