Revealing Europa’s Ocean

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Pioneer 10 Views Europa (1973)

- Scan by imaging photopolarimeter
- Dec. 3, 1973, ~200 km/pixel

Voyagers View Europa (1979)

- Few large impact craters
  - young surface or “relaxation”?  
- Mottled terrain
  - internal activity or only impacts?  
- Bright, lineated plains
  - crustal mobility
  [Schenk & Kuyper, 1980; Schenk & McKinnon, 1989]

The Galilean Satellites: January 1610

Galileo’s sketches
JPL Solar System Simulator

Oceans Come and Go, and Return Again

- 1971–1977: Early satellite oceans proposed from thermal-compositional models [Lewis, Consolmagno, Fanale]
- Late 1979–1983: Tidal heating might maintain oceans, but convection of overlying ice might freeze oceans [Cassen, Peale, Reynolds, Squyres]
- 1989: Tidal heating of Europa’s ice could be sufficient to maintain a conductive ice shell above a global ocean [Ojakangas & Stevenson]

Voyagers View Europa (1979)

- Voyager 1 (20 km/pixel)
- Voyager 2 (2 km/pixel)

Galileo Orbital Tour (1996-1999)

- 22 Europa Encounters
- 9 “Non-Targetted” Encounters
- “Global Exploration Mission (GEM)” Campaign
- 10x Earth-Moon Dist.
Galileo Imaging Team (1996)

Galileo’s First Views of Europa (1996)
- Pits (endogenic?)
- Spots (volcanic?)
- Age brightening
- Nonsynchronous rotation
- Crustal mobility

Europa’s Surface
- Ridges
- Mosaic by Ryan Sicilia

Europa’s Interior

Europa’s Magnetic Interactions
Art by Michael Carroll

Ridges
Made by Brian Marks
Ridge Formation Models

Bands

Impacts

Surface Composition

Non-ice candidates:
- Sulfate salts (MgSO₄ • nH₂O)
- Sulfuric acid (H₂SO₄ • nH₂O)

Lenticulae (Freckles)

Icy Lava Lamp?

cold, stiff ice

warm, flowing ice

T = 100 K

T = 260 K

Mosaic by Ryan Sicilia
Chaos

Icebergs?

Europa: Ingredients for Life?
- **Water**: More than 2x all of Earth’s oceans
- **Essential elements**: From formation and impacts
- **Chemical energy**: Potentially from above and below
- **Stability**: Variable, but "simmering" for 4 billion years

"Black smoker" on Earth’s ocean floor

Woods Hole Oceanographic Institution

Understanding Europa’s Habitability: Key Issues
- **Ocean**: Existence, extent, and salinity
- **Ice Shell**: Existence and nature of water within or beneath, and nature of surface-ice-ocean exchange
- **Composition**: Distribution and chemistry of key compounds and the links to ocean composition
- **Geology**: Characteristics and formation of surface features, including sites of recent or current activity

Looking Forward: Europa Clipper

Operations Concept:
- 32 low altitude flybys of Europa from Jupiter orbit over 2.3 years
- Detailed investigation of globally distributed regions of Europa
- Simple repetitive science operations
- Landing site recon siteamce capability

Payload:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Clipper</th>
<th>Enhanced or Recon</th>
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<tbody>
<tr>
<td>Ocean</td>
<td>yes</td>
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<tr>
<td>Ice Shell</td>
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<tr>
<td>Composition</td>
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<tr>
<td>Geology</td>
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Technical Margins
- **Mass**: 39% 40% 75%
- **Power**: 60% 60% 75%
- **Data**: 39% 40% 75%

Cost: $2.0B

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Pre-Decisional — For Planning and Discussion Purposes Only