Mining on Seamounts

• Resource Distribution,
• Likely Technologies, and
• Likely Space and Time Scales of Mining Effort
Primary Sources

• Resource Distribution & Scales:
  “Seamounts and Cobalt-rich Ferromanganese Crusts”
  James R. Hein, U.S. Geological Survey
  (unpublished - NOT FOR DISTRIBUTION)

• Likely Technologies:
  “Proposed Marine Mineral Lease Sale: Exclusive Economic Zone Adjacent To Hawai`i and Johnston Island-Final EIS”
  U.S. Dept. of Interior, 1990
Resource Distribution

- Regional Distribution
- Key Properties of Crusts
- Deposit Settings & Areas
- Possible First Generation Sites
Worldwide Occurrence
Important Properties of Co-rich Crusts

- Very high porosity (60%)
- Extremely high surface area (300 m²/g)
- Extremely slow rates of growth (1-6 mm/Ma)

* The above properties are instrumental in allowing for surface adsorption of large quantities of metals from seawater
Trace Metal Maxima

Pew Workshop
Design of Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas
23-26 October, 2007, University of Hawai‘i
Primary Occurrence: O$_2$ Minimum Zone
56 kilometers long
Terraces: smooth and rough
Large area above 2500 m
Debris apron

Typical Guyot
Typical Conical Seamount
Probable First Generation Exploration Region in Area
Total Surface Area of 19 Guyots above 2500 m water depth

- 77 km²/yr mining area
- 1,540 km²/20 yrs mining site
- 7,500 km² for exploration for mine sites

Total surface area of 34 seamounts above 2500 m: 17,470 km²

Total Surface Area of 15 Conical Seamounts above 2500 m water depth
Likely Technologies

• Mining Scenario Constraints
• Pickup System & Other Systems
• Mining Efficiency & Substrate Dilution
PRIMARY DISCUSSION ITEMS

• PURPOSES OF THE SCENARIO

• LIMITATIONS

• CHARACTERIZATION OF DEPOSITS

• SEAFLOOR MINING SYSTEM & SUBSTRATE COLLECTION
PURPOSES OF SCENARIO

• IDENTIFY KEY DEVELOPMENT ISSUES

• PROVIDE BASELINE FOR IMPACT ANALYSIS & POLICY DEVELOPMENT
SCENARIO PRIMARY LIMITATIONS

• PUBLISHED IN 1990

• PRODUCED TO COMPLY WITH U.S.
  LAW AND OCS REGULATIONS

• SITE SPECIFIC TO HI & JOHNSTON
  IS EEZ

Pew Workshop
Design of Marine Protected Areas for Seamounts and the
Abyssal Nodule Province in Pacific High Seas
23-26 October, 2007, University of Hawai`i
## DEPOSIT CHARACTERIZATION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Expected Range</th>
<th>Scenario Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Crust Thickness</td>
<td>&lt; 1 – 15 cm</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>Crust Specific Gravity</td>
<td>1.95 (wet)</td>
<td>1.95 (wet)</td>
</tr>
<tr>
<td>Co</td>
<td>0.8 – 1.1%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Ni</td>
<td>0.4 – 0.6%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Mn</td>
<td>20 – 25%</td>
<td>22%</td>
</tr>
<tr>
<td>Pt</td>
<td>0.4 grams/ton</td>
<td>0.4 grams/ton</td>
</tr>
<tr>
<td>Seamount Slope</td>
<td>5 - 20°</td>
<td>10°</td>
</tr>
<tr>
<td>Crust Coverage</td>
<td>60 – 90%</td>
<td>75%</td>
</tr>
<tr>
<td>Water Depth</td>
<td>800 – 2,400 m</td>
<td>800 – 2,400 m</td>
</tr>
<tr>
<td>Recovery Percentage</td>
<td>50 – 70%</td>
<td>70%</td>
</tr>
<tr>
<td>Production (dry t/yr)</td>
<td>550,000 – 1,000,000</td>
<td>700,000</td>
</tr>
</tbody>
</table>

Pew Workshop
Design of Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas
23-26 October, 2007, University of Hawai`i
MINING SYSTEM COMPONENTS

SUPPORT VESSEL

LIFT PIPE

DUMP VALVE/BUFFER

PICK-UP MECHANISM

Pew Workshop
Design of Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas
23-26 October, 2007, University of Hawai`i
MANGANESE CRUST MINER (HALKYARD 1987)

**MAJOR SPECIFICATIONS**

- Length: 13 m
- Width: 8 m
- Height: 6 m
- Weight: 100 t
- Installed Power: 900 KW

**PICK-UP SYSTEM**

- Power Tracks
- Diffusers
- Separator
- Lift Pipe
- Hydraulic Dredge Heads
- Cutter Heads

Pew Workshop
Design of Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas
23-26 October, 2007, University of Hawai`i
SYSTEM DOWN TIME

• CUTTER-HEAD REPLACEMENT
• OTHER MECHANICAL FIXES
• 10% WEATHER
• 10% DRY DOCK, ETC.

→ MAX. WORKING DAYS: 245
→ 206 DAYS ASSUMED FOR SCENARIO
MATERIAL FLOWS

MILLION METRIC TONS PER YEAR (206 DAYS)

Crust 1.62 1.53 1.04 1.04 1.02 0.91
Substrate 0.54 0.51 0.25 0.25 0.25 0.02

DEPOSITS -> FRAGMENTATION -> PICK-UP -> SEPARATION -> LIFT -> DEWATERING -> BENEFICATION

Pew Workshop
Design of Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas
23-26 October, 2007, University of Hawai‘i
ALSO IN SCENARIO

• LIFT & BUFFER SYSTEMS
• AT-SEA BENEFICIATION
• TRANSPORTATION
• METALLURGICAL PROCESSING
• HAZARDOUS MATERIALS
SUBSTRATE ENTRAINMENT

Cutting Surface (m - t)

m = mean seafloor elevation

h = seafloor elevation

t = mean crust thickness

Recovery Efficiency: E

E = 0
E = \frac{h-(m-t)}{t}
E = 1

Purity: P

P = \text{undefined}
P = 1
P = \frac{t}{h-(m-t)}
## MINING SIMULATION

<table>
<thead>
<tr>
<th>RMS Roughness (cm)</th>
<th>Recovery Efficiency (%)</th>
<th>Crust Purity (% crust)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 cm</td>
<td>50 cm</td>
</tr>
<tr>
<td>8</td>
<td>76</td>
<td>63</td>
</tr>
<tr>
<td>9</td>
<td>80</td>
<td>68</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>66</td>
</tr>
<tr>
<td>12</td>
<td>85</td>
<td>71</td>
</tr>
<tr>
<td>14</td>
<td>82</td>
<td>71</td>
</tr>
<tr>
<td>16</td>
<td>72</td>
<td>63</td>
</tr>
<tr>
<td>38</td>
<td>66</td>
<td>57</td>
</tr>
<tr>
<td>43</td>
<td>65</td>
<td>56</td>
</tr>
</tbody>
</table>

Crust Thickness: 4 cm
Recovery Efficiency vs. Roughness
Normally Distributed Topography

Recovery Efficiency (E)

RMS Roughness (cm)
(crust thickness: 2-10 cm)
MINING ON SEAMOUNTS
KEY CONCLUSIONS

• ONE OPERATION WOULD DIRECTLY IMPACT ~1,500/E KM² IN 20 YR. OF NW PACIFIC GUYOTS (E = MINING EFFICIENCY)

• PRODUCTION SIGNIFICANT % OF WORLD PRODUCTION (1–3 OPS MAX)

• INCORPORATION OF SUBSTRATE KEY ISSUE FOR OVERALL FEASIBILITY