Placers Outline

• Placer Deposit Types
• Environments of Placer Mineral Occurrence
• Exploration Methods in Shallow Waters
• Sand & Gravel, Mineral Aggregates
  – Sources and Uses of Major US Nonmetallic Construction Raw Materials
  – Projected US Sand & Gravel Demand
  – Sources & Fates of Offshore Sand & Gravel Deposits
• Exploitation (Mining) Methods
  – Dislodgement Needs for Mining Marine Minerals
  – Depth of Marine Minerals & Equipment Capability
• Marine Diamond Exploration & Mining Areas of Southern Africa
Target Commodities

Source: IHC Deep Sea Dredging & Mining
Dredging technology has been expanding its horizons since the discovery of the treasures of the deep sea. Deep Sea Dredging or Mining is a greenfield activity since no proven technology is available for deep sea activities. A serious transition is needed in order to develop new excavation techniques and vertical transport systems for deep sea activities. The main challenges are the hyperbaric conditions, the slurry transport, the remote control and maintenance aspects.
Placer Deposit Types


Table 1. Examples of placers, aggregates and other minerals.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Ore mineral</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-metallic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica</td>
<td>quartz sand</td>
<td>2.65</td>
</tr>
<tr>
<td>Lime</td>
<td>shells and shell sands</td>
<td>2.7</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>various</td>
<td>3.0</td>
</tr>
<tr>
<td>Topaz</td>
<td>topaz</td>
<td>3.4–3.6</td>
</tr>
<tr>
<td>Spinel</td>
<td>spinel</td>
<td>3.5–4.0</td>
</tr>
<tr>
<td>Corundum</td>
<td>corundum</td>
<td>3.9–4.1</td>
</tr>
<tr>
<td><strong>Heavy mineral sands</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beryllium</td>
<td>beryl</td>
<td>2.75–2.8</td>
</tr>
<tr>
<td>Titanium</td>
<td>rutile</td>
<td>4.18–4.25</td>
</tr>
<tr>
<td>Titanium</td>
<td>ilmenite</td>
<td>4.7</td>
</tr>
<tr>
<td>Chromium</td>
<td>chromite</td>
<td>4.6</td>
</tr>
<tr>
<td>Zirconium</td>
<td>zircon</td>
<td>4.68</td>
</tr>
<tr>
<td>Manganese</td>
<td>haussmannite</td>
<td>4.72–4.84</td>
</tr>
<tr>
<td>Manganese</td>
<td>braunite</td>
<td>4.72–4.83</td>
</tr>
<tr>
<td>Iron</td>
<td>magnetite</td>
<td>5.18</td>
</tr>
<tr>
<td>Thorium</td>
<td>monazite</td>
<td>5.0–5.3</td>
</tr>
<tr>
<td>Nb, Ta</td>
<td>columbite, tantalite</td>
<td>5.2–7.9</td>
</tr>
<tr>
<td>Rare-Earths</td>
<td>group of 15 REE oxides</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cassiterite</td>
<td>6.8–7.1</td>
</tr>
<tr>
<td></td>
<td>cinnabar</td>
<td>8.10</td>
</tr>
<tr>
<td><strong>Precious and rare</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diamond</td>
<td>diamond</td>
<td>3.5</td>
</tr>
<tr>
<td>Copper</td>
<td>native metal</td>
<td>8.9</td>
</tr>
<tr>
<td>Silver</td>
<td>native metal</td>
<td>10.5</td>
</tr>
<tr>
<td>Gold</td>
<td>native metal</td>
<td>15–19.3</td>
</tr>
<tr>
<td>Platinum</td>
<td>native metal</td>
<td>14–19</td>
</tr>
</tbody>
</table>

Where Specific Gravity = Density relative to H₂O (=1.00) in cgs units of g/cm³
Environments of Possible Placer Mineral Occurrence

Cronan (1980)
Global Distribution of Continental Shelves, with Extent of Knowledge
Continental Shelf and Slope off East Florida: The Blake Plateau
Global Distribution of Placer Deposits circa 1970

M = monazite (yielding U, Th)
D = diamonds
Exploration Methods in Shallow Waters

• SCUBA/NITROX Diving
• Sediment Sampling
• Geophysical Surveys
  ROV, AUV, shipboard

With contacts interpretation

Raw seismic
Example of Geology Leading to Possible Location of Tin (Sn, Cassiterite) Placers in Indochina (SE Asia)

Note location of “tin belts”, or SnO₂-bearing granites (source rocks) on land, and possible seaward extension into Gulf of Thailand
Seaward extension of cassiterite (SnO$_2$) placers formed in streams off Sinkep Island, Indonesia

Can you suggest a simple method of delineating potential areas of offshore placer deposits?
Consumption of mineral aggregates by the US construction industry, for the periods 1959 and 1972 (in millions of tons)

<table>
<thead>
<tr>
<th>Construction use</th>
<th>1959</th>
<th></th>
<th></th>
<th>1972</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Sand</td>
<td>Gravel</td>
<td>Crushed stone</td>
<td>Sand</td>
<td>Gravel</td>
<td>Crushed stone</td>
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<tr>
<td>Building</td>
<td>123</td>
<td>114</td>
<td></td>
<td>188</td>
<td>153</td>
<td></td>
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<tr>
<td>Paving</td>
<td>105</td>
<td>313</td>
<td></td>
<td>131</td>
<td>280</td>
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<tr>
<td>Fill^a</td>
<td>16</td>
<td>17</td>
<td></td>
<td>49</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Railroad ballast</td>
<td>1</td>
<td>5</td>
<td></td>
<td>1</td>
<td>2</td>
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<td>Other</td>
<td>6</td>
<td>7</td>
<td></td>
<td>10</td>
<td>13</td>
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<tr>
<td>Concrete aggregates</td>
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<td>134</td>
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<tr>
<td>Bituminous aggregates</td>
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<td></td>
<td></td>
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<td>83</td>
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<td>Macadam aggregates</td>
<td></td>
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<td>357</td>
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<td></td>
<td>33</td>
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<tr>
<td>Road-base aggregates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>337</td>
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<tr>
<td>Surface treatment</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>52</td>
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<tr>
<td>aggregates</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
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<td></td>
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<td>113</td>
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<tr>
<td>Total construction</td>
<td>250</td>
<td>456</td>
<td>357</td>
<td>378</td>
<td>492</td>
<td>752</td>
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<tr>
<td>Cement manufacture</td>
<td></td>
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<td></td>
<td>91</td>
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<tr>
<td>Percentage of total</td>
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<tr>
<td>production used in</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>construction</td>
<td>92.9</td>
<td>98.9</td>
<td>12.2</td>
<td>92.8</td>
<td>97.3</td>
<td>81.6</td>
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<tr>
<td>Total production</td>
<td>269</td>
<td>461</td>
<td>582</td>
<td>408</td>
<td>506</td>
<td>922</td>
</tr>
</tbody>
</table>

Source: Baram et al. (1978)
US Sources and Uses of Major Nonmetallic Construction Raw Materials

Source: Morgan (1973)
Projected US Sand & Gravel Demand

Source: Cooper (1972)

Which trend was correct?
Sources & Fates of Offshore Sand & Gravel Deposits: West Coast USA
Sources & Fates of Offshore Sand & Gravel Deposits: East Coast USA

Note formation of longshore barrier islands from headland erosion
Placer Exploitation (Mining) Methods

Dredging methods at different water depths

Kent (1980)
Basic Mining Strategies & Techniques
Placer Mining on Land

- Alluvial Diamond Mining, Africa
- Bolivian Tin Mine
- Hydraulic Gold Mining, Alaska
- Open-Pit Iron Ore Mining, Brazil
Placer Mining at Sea

Source: IHC Deep Sea Dredging & Mining
Mining Industry Aspects

Source: IHC Deep Sea Dredging & Mining
Grade-Volume Curve for Surficial Sediments of Nome, Alaska

Marine Placers

High Volume = Low Grade; High Grade = Low Volume!
Progressive Dredging of a Reserve Block off Nome, Alaska
Dislodgement Needs for Mining Marine Minerals
Depth of Marine Minerals & Equipment Capability

- Depth (feet)
  - 0
  - 100
  - 200
  - 300
  - 400
  - 500
  - 600
  - 1000

- Sand and gravel
  - Phosphorite

- Mineral occurrence
  - Diamonds
  - Heavy minerals
  - Cassiterite
  - Barite
  - Shells
  - Gold

- Airlift
- Bottom-mounted dredge pump

- Equipment capability
  - Ladder-mounted pump
  - Suction
  - Dragline
  - Bucket-ladder
  - Grab

- Depth (meters)
  - 50
  - 100
  - 150
  - 200
  - 325
Project Development: From customers expectations to realization.

1. **Initiating phase**
   - **Initial exploration**
   - **Initial requirements**

2. **Analysis phase**
   - **Detailed exploration**
   - **Detailed requirements**

3. **Conceptual design phase**
   - **Excavation process**
   - **Process sequence**
   - **Production**
   - **Mining plan**

4. **Definition phase**
   - **Utilisation**
   - **Availability**

5. **Execution phase**
   - **Design**
   - **Engineering**
   - **Manufacturing**
   - **Testing**

**Scope**
- **Initial exploration**
  - **Scoping**
    - **Initial exploration, benching**
      - deposits (geological aspects)
      - seabed (geotechnical aspects)
      - the environment
    - **Results**
      - Detailed information on the content of deposits
      - Input for the selection of the excavation process
      - Surface transportation system
      - Initial mining installation
  - **Sampling**
    - Evaluate initial results of exploration of deep sea greenfield mine sites
    - Determine the feasibility and profitability of mining these sites
    - Decide to take further steps for detailed analysis

- **Detailed exploration, benching**
  - deposits (geological aspects)
  - seabed (geotechnical aspects)
  - the environment

- **Detailed requirements**
  - List of demands
  - Deposits
  - Seabed
  - Environment
  - Production
  - Costs

- **Excavation process**
  - **Excavation process under hyperbaric conditions**
    - Effect of rock cutting, cutting forces and installed power
    - Double rock plowing versus brittle clipping
  - **Excavation process under hyperbaric conditions**

- **Engineered design**
  - **Engineering procedure**
    - **Engineering**
      - **Installed power**
      - **Installation costs**
    - **Utility**
      - **Production**
      - **Utilization**

- **Time plan**
  - **Conceptual design**
    - **Exploitation calculation**
  - **Conceptual design**
    - **Exploitation calculation**

- **Feasibility**
  - **Feasibility**
    - **Feasibility**
      - **Feasibility**
      - **Feasibility**

**Crucial challenges**
- Adaptable selection of excavation processes in mining and wet mining equipment
- Equipment for a dedicated solution for an end-to-end deep sea mining installation
- Integration process to determine optimal design specifications
- As the integrator, IHC will manage all the interfaces of the mining system to supply a mining system with top performance

**Research and development**
- Long distance vertical transport under harsh deep sea conditions
- Offload
- Deep sea exploration
- Torque variation, subject to pitch point position
- Numerical analysis of cutting forces subjected to penetration levels and hydrostatic pressure
- Cotton soil geometry for deep sea mining applications (turbine, hydrokinetic, transport, process monitoring, ore concentration, etc.)
- Deep sea system
  - Pump shaft-sealing at great depth under high internal pressure
  - Crawler design related to deep sea conditions (submerged pump motor combination, umbilicals, etc.)

Source: IHC Deep Sea Dredging & Mining
Marine Diamond Exploration & Mining Areas of Southern Africa

Historical annual diamond mining from Namibian sources
Diamond-bearing Igneous Pipes

Interpretive section of a pipe in Australia
Inner & Middle Shelves of Nambia & South Africa: Diamond Sizes (Carots)

Along the coastline
Target Paleo-Features

Typical diamond accumulation features on inner shelf.

Progressive sampling of a “diamondiferous” feature.
DeBeers’ High-Tech Seabed Mining Machines Now in Use

FIGURE 5.9 Large drilling systems modified for marine use.
It’s Where You Find It.

Sluice, Alaska

Gold Pan

Oro, Au, Gold