Technological and economical challenges of manganese nodule mining in the Clarion-Clipperton-Zone

Future Ocean – Seafloor Mineral Resources
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Technology & Innovation | Aker Wirth GmbH, Erkelenz

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Open pit mines are facing challenges in the near future

- Discoveries of higher grade deposits are becoming less frequent (declining average grades)
- Depth of open pit mines at their limits
- More underground mines are producing copper at a smaller output capacity
- Infrastructure challenges (remote locations)
- Aker Wirth offers unique cutting technologies and machines for infrastructure tunnels in hard rock deposits
Global distribution of known marine mineral resources

Marine mineral resources as a source for metallic raw materials with high ratios of important metals

© ISA
## Manifold types of marine mineral resources

<table>
<thead>
<tr>
<th>Seafloor Massive Sulphides</th>
<th>Cobalt-rich Manganese Crusts</th>
<th>Manganese Nodules</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Seafloor Massive Sulphides" /></td>
<td><img src="image2.jpg" alt="Cobalt-rich Manganese Crusts" /></td>
<td><img src="image3.jpg" alt="Manganese Nodules" /></td>
</tr>
<tr>
<td>© Nautilus Minerals</td>
<td>© ISA</td>
<td>© BGR</td>
</tr>
</tbody>
</table>

- **Seafloor Massive Sulphides**:
  - Metals: Cu, Zn, Pb, Au
  - Water depth: 1,000 – 3,000 m

- **Cobalt-rich Manganese Crusts**:
  - Metals: Co, Ni
  - Water depth: 1,000 – 2,500 m

- **Manganese Nodules**:
  - Metals: Ni, Cu, Co, Mn
  - Water depth: 4,000 – 6,000 m
Benefits of seafloor minerals compared to onshore mines

- **Infrastructure expense**
  no site-specific infrastructure, moveable mining systems

- **Flexibility**
  mining ships can move to different types of deposits / minerals to suit market conditions

- **Overburden**
  no overburden to be removed and lower waste to ore ratio

- **Environmental concerns**
  minimal carbon footprint and small environmental impact
Basic conditions for sustainable manganese nodule mining

Sustainable, ecological choice of mining areas:
- occupancy rate > 10 kg / m²
- gradient < 3°
→ 18 % of the eastern German license territory: 10,500 km²
→ compliance of guidelines for protection of environment

Conveying 2.2 Mio. t manganese nodules per year allows mining for approx. 42 years

93 Mio. t of manganese nodules → value of metals > 71 Mia. €
## Technical challenges of the deep sea – Strategies & Solutions

<table>
<thead>
<tr>
<th>Water depth &amp; distance to shore</th>
<th>Restrictions in communication &amp; visibility</th>
<th>Effectivity of operation &amp; production</th>
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<tr>
<td>▪ pressure compensation</td>
<td>▪ using intelligent acoustic systems for</td>
<td>▪ exploration systems for mission</td>
</tr>
<tr>
<td>▪ remote operating or autonomous systems</td>
<td>positioning, monitoring, communication</td>
<td>planning</td>
</tr>
<tr>
<td>▪ maintenance free durable systems</td>
<td>▪ specially adapted visualisation software</td>
<td>▪ standardized control &amp; automation</td>
</tr>
<tr>
<td></td>
<td>▪ safety &amp; emergency zones with stepwise</td>
<td>system</td>
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<tr>
<td></td>
<td>autonomous emergency shut down</td>
<td>▪ flexible orientation &amp; module-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>exchange</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ monitoring &amp; metering</td>
</tr>
</tbody>
</table>

-restrictions in communication & visibility

- water depth & distance to shore

-effectivity of operation & production

-exploration systems for mission planning

-standardized control & automation system

-flexible orientation & module-exchange

-monitoring & metering
Strong progress of offshore-technologies since the 70s

technologies of the 70s

© Historic Naval Ships Association

© Lockheed Martin

today 40 years later

© Vantage Drilling

© CTC

Techn. & economical challenges of manganese nodule mining
Performed studies manganese nodule deep sea mining

- Demonstrator Subsea Intervention Tool ISUP – 2009
- Technical concept study for the Federal Institute for Geosciences and Natural Resources (BGR) (administrator of the German licence territory) - 2010
- Profitability analysis - 2012
- Expansion of the system boundaries for offshore technologies from 3,000 m up to 4,500 m water depth
Manifold offshore-technologies are necessary for deep sea mining
Minimized environmental impact:
- crawler chassis → minimal impact on the seafloor
- hauling drums → no plowing of the seafloor
- nodule cleaning at the collector → minimal turbidity
- totally shielded → minimal turbidity
- air-lift technology → no oil-leakage

Collector dimensions:
- width → 17 m
- weight → 250 t (100 t under water)
Functionality of the air-lift system

- air compressor mounted on topside
- compressed air is transported from a separate vertical pipe
- injecting compressed air horizontally into the riser pipe
- reduced phase density, the air-water mixture above injection level will adept a flow upwards
- due to the continuous injection of compressed air also a flow in the riser below injection level adapt
- upward flow of solids, if the fluid speed in the riser under injection level is higher as the ‘solid sink velocity’
Airlift system for ultra deep water subsea mining

Main advantages of the airlift system

- wide range of particle size inside the riser string (theoretically close to inner passage Ø)
- steady flow conditions in riser string pipe without any valves, pistons etc.
- reducing mechanical systems subsea
  → all maintenance demanding systems staying on the vessel
  → no wear or blockage in pump system
- highest availability under rough conditions up to 98%

Mining Ship

Multiple air injection nozzles

Riser string system stepwise increased diameter

Connectivity point to any equipment

Buffer & rotary gate valve

Collectors

Armored hoses

Mining Ship
Challenges of the metallurgical process for manganese nodules

- manganese nodules with high ratios of important metals (Cu, Ni, Co) developed → recovery 89% - 95%
- price development and recovery uncertain for Mn → no consideration
- processing for strategic metals (micronutrients) in development → recovery uncertain → no consideration

Profitability analysis bases exclusively on familiar processing
Conservative analysis of all factors in the complete system

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<tr>
<th>Capital / Operational Expenditures</th>
<th>Profitability analysis</th>
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<tr>
<td>Collector system</td>
<td>Capital &amp; Operational Expenditures</td>
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<tr>
<td>Riser string</td>
<td>Price estimations for raw materials</td>
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<tr>
<td>Mining ship</td>
<td>Recovery after processing</td>
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<tr>
<td>Transport ship (bulker)</td>
<td>Chronological development of revenues</td>
</tr>
<tr>
<td>Harbor facility / onshore logistic</td>
<td>- actual market situation</td>
</tr>
<tr>
<td>Processing</td>
<td>- scenario analysis 2020-2032 (nominal, worst-case, best-case)</td>
</tr>
</tbody>
</table>

- based on the Aker Wirth study from 2010
- detailing / actualizing in 2012

conservative evaluations
- high expenditures
- low revenues
Technologies are available, but a system integrator is missing

### Technological & economic challenges

- Expansion of the system boundaries for offshore technologies from 3,000 m up to 4,500 m water depth
- Industrial testing of the mining and conveying system
- Proofing environmental safety and sustainability
- Developing the processing for strategic metals

### Industrial-politic challenges

- Absence of a German, globally operating raw materials conglomerate
- To date there is worldwide no MMR system integrator in place
- Configuring an international political framework
- Creating investment plans for an industrial consortium
Next steps… Deep sea pilot mining test

Test objectives
- Recover a defined quantity of manganese nodules from the seabed
- Test of relevant technical components of the deep sea mining system
- Assessment of environmental impacts

Test scenario
- Deployment of crawler and buffer on the sea bed with an appropriate flexible interface

Target Generation & Access | Reconnaissance | Deposit Assessment | Resource Definition | Resource Definition | Ore Reserve
---|---|---|---|---|---
Exploration Phase

Project Phase
- Desktop
- Conceptual
- Pre-Feasibility
- Feasibility
- Implementation
- Commissioning
- Operation
- Closure

2-4 years | 2-3 years | 2,5-4 years | 2,5-3 years

9 – 14 years until start of operations

Source: based on Aurumar website

Source: based on Aurumar website
Opportunities for a German marine mineral resources industry

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