



PROCESSING AND ECONOMIC EVALUATION OF POLYMETALLIC NODULE BY DORD

Tadayuki Ishiyama

DEEP OCEAN RESOURCES DEVELOPMENT CO., LTD

contents

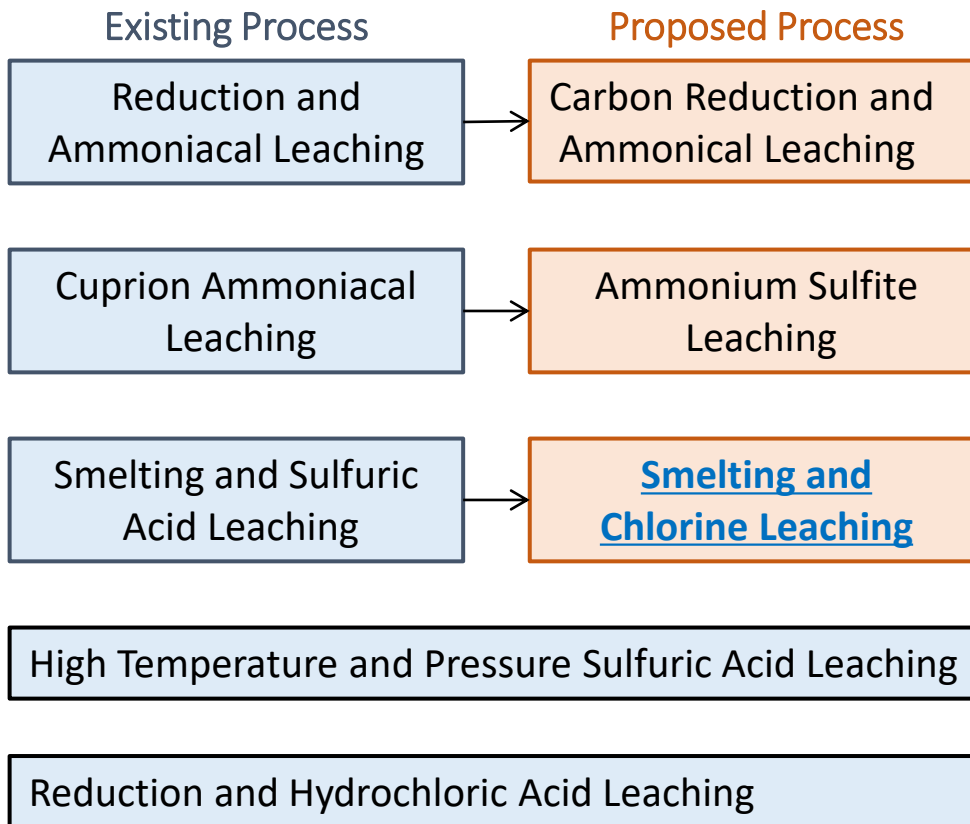


Background

1. Economic Evaluation of Polymetallic Nodules Development
2. Economic Assessment of Processing
3. Process Simplification - Consideration of option –
4. Future Tasks

Background

Development of a smelting and chlorine leaching process in 1997 by comparing existing and proposed processes:



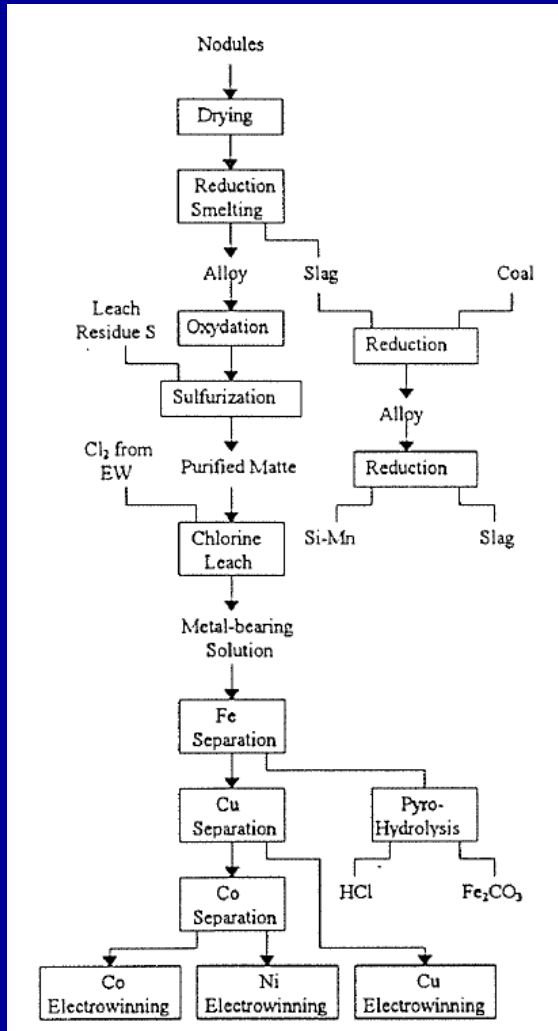
Criteria

- a) ambient operating pressure
- b) maximum reduction of nodule matrix
- c) use of inexpensive reagent
- d) minimal energy demand
- e) high recovery of metals
- f) non-corrosive materials for tanks, pipes, etc.
- g) acceptable environmental impact

(Kojima 1997 Review of studies on Manganese Nodules Processing)

Background

Smelting and chlorine leaching process:



- A process improved from the smelting and sulfuric acid leaching process by Sridhar et al., 1976

- Combination of dry and wet processes

- Characteristics

Advantages:

- High recovery rate of metals
- Easier to separate metals from metal-bearing solution
- Repeatable use of sulfur

Disadvantages:

- Necessity of using corrosion-resistant materials against chlorine gas
- Possibility of negative effect caused by chlorine ion on copper recovery through the electrowinning process
- High CAPEX

- No pilot plant test done so far

(Kojima 1997 Review of studies on Manganese Nodules Processing)

1. Economic Evaluation of Polymetallic Nodules Development



- Conducted by DORD in 2015
- Estimates IRR (Internal Rate of Return) by DCF (Discount Cash Flow) Method
- At scoping study stage (Lower than Pre-feasibility study)

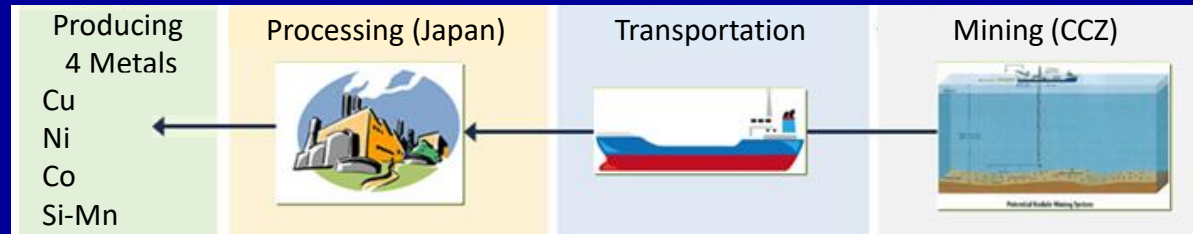
Settings:

- Construction period : 4 years
- Operation period : 20 years
- Metal Prices : based on a long-term prediction of the balance of international supply and demand
Cu (6,500) 、 Ni (18,000) 、 Co (35,000) 、 Si-Mn (1,400) USD/t
- Exchange rate : 120 JPY / USD
- Royalty : Not Considered

1. Economic Evaluation of Polymetallic Nodules Development

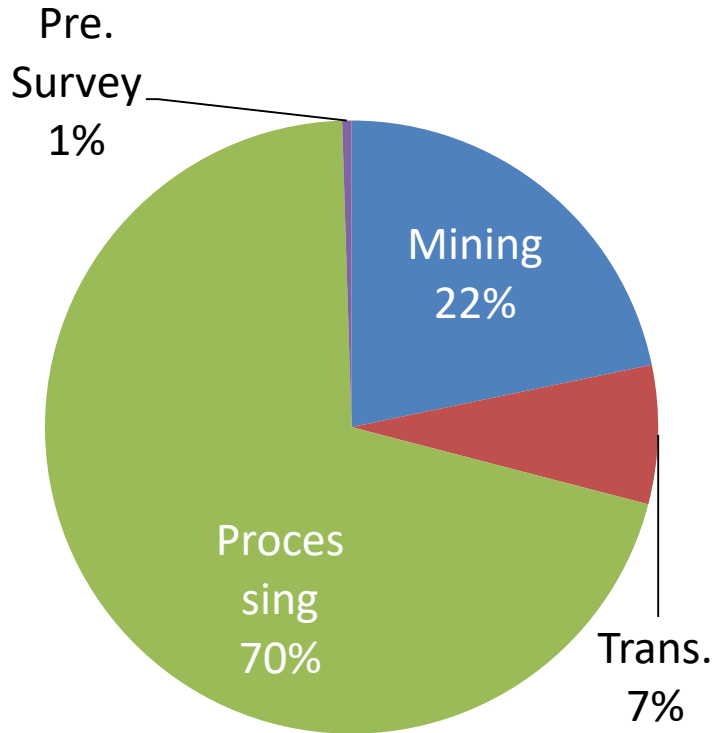


Settings

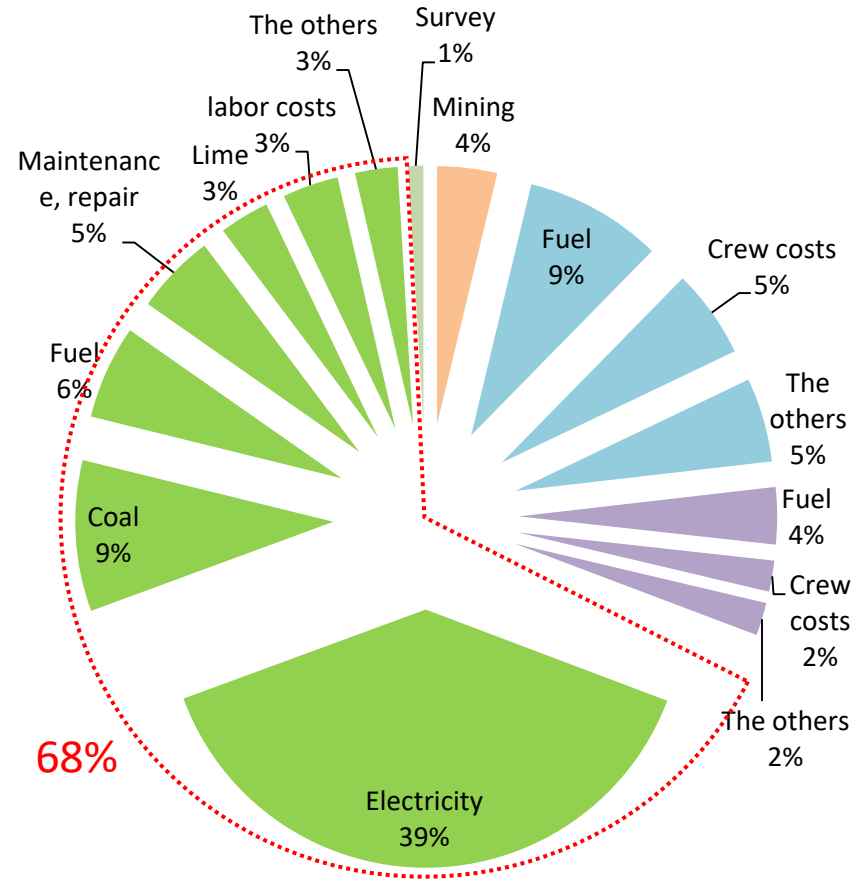


- Annual production : 2,000,000 t (dry)
- Smelting and chlorine leaching method
- Yield four metals (Cu, Ni, Co, Si-Mn)
- Construction of a processing plant in Japan
- Capital ratio 100%, Tax not included
- Results
 - IRR : 6.9% Cash flow : \$3,840,000,000
 - CAPEX : \$3,568,000,000 OPEX : \$927,000,000
 - Payback period : 14.5 years

1. Economic Evaluation of Polymetallic Nodules Development



CAPEX 3,568M US\$



OPEX 927M US\$



1. Economic Evaluation of Polymetallic Nodules Development



- Results of the evaluation:
 - IRR of 6.9% is not considered as “particularly high”
 - Economic efficiency may be achieved if cost reduction is made on:
 - Processing cost (accounts for 70% of the overall CAPEX and OPEX)
 - Electricity tariff or fuel cost (accounts for 40% of the overall OPEX)
- For processing cost reduction:
 - Simplifying the process flow (production of concentrate)
 - Utilizing existing technologies and facilities
 - Evaluation on applicability of “Aqueous Reduction in Sulphuric Acid” process as a low-cost process
- For electricity tariff reduction
 - Assessment on potential overseas sites for construction of processing plants

2. Economic Assessment of Processing

- Necessity of cost reduction

Precondition used for DORD's previous evaluation in 2015:

Mining (in the CCZ) → Smelting (In Japan)

Current flow under consideration:

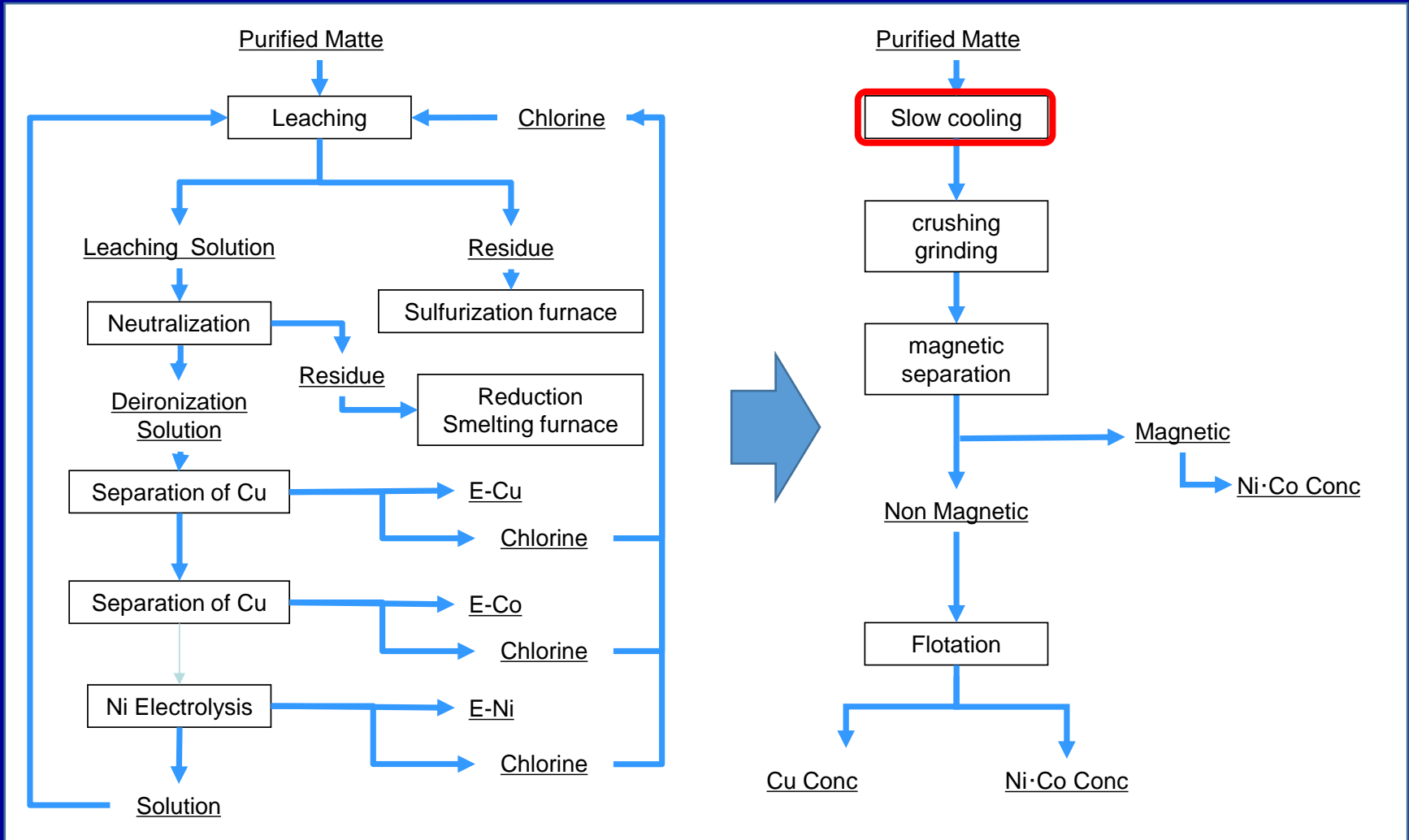
Mining (in the CCZ) → Smelting (Concentration produced outside of Japan) → Refining (In Japan)

- Proposed flow may:
 - Reduce OPEX (electricity tariff) by smelting overseas
 - Reduce CAPEX by utilizing existing facilities in Japan
- However, it may require additional costs for:
 - Transit cost, TC / RC, and etc.

3. Process Simplification - Consideration of option -



Proposed flow for producing Cu, Ni/Co concentrate as a final product



3. Process Simplification - Consideration of option -



Producing concentrates by slow cooling of purified matte

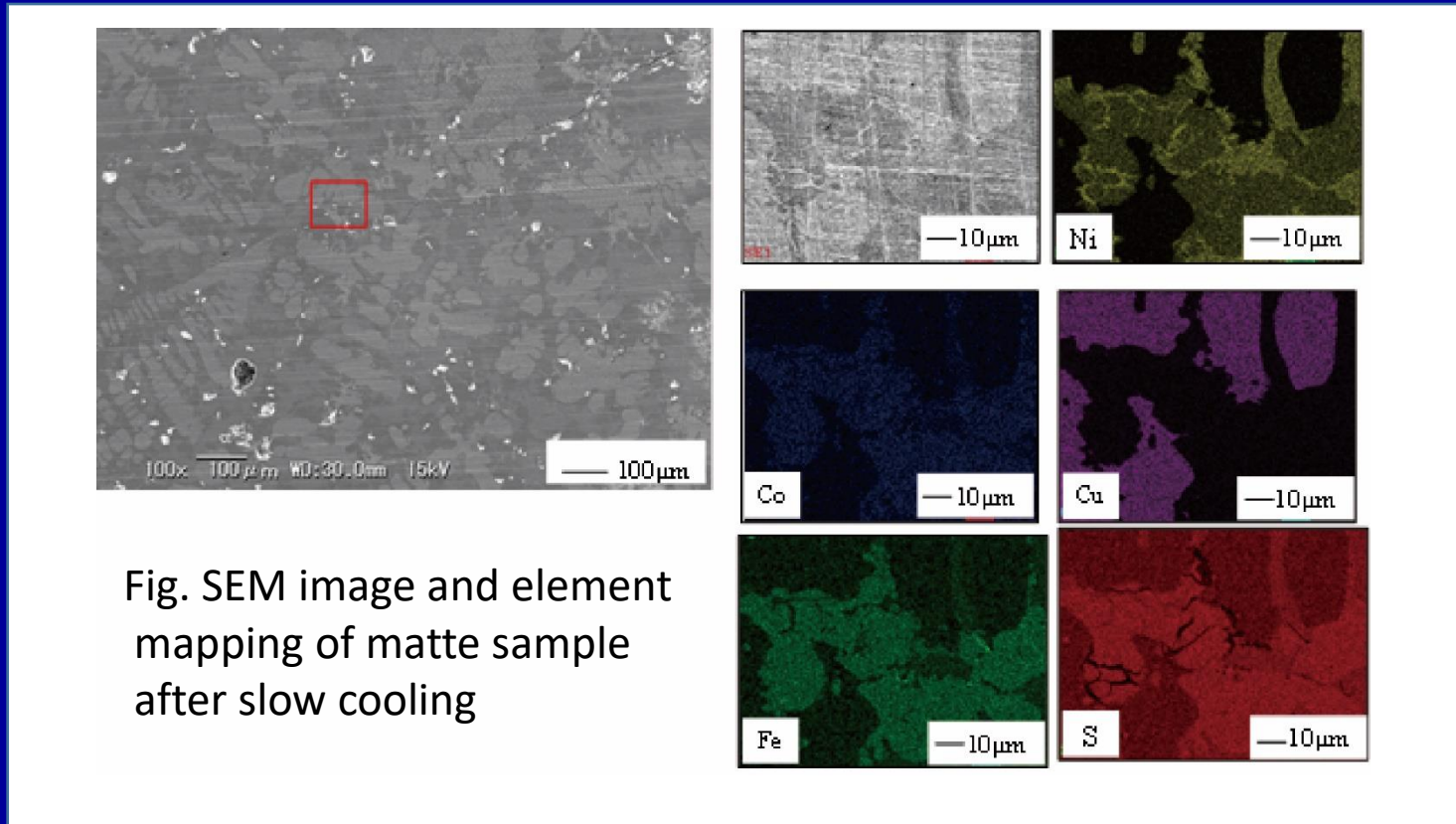


Fig. SEM image and element mapping of matte sample after slow cooling

Maximization of recovery is the crucial key to assess economic feasibility

- High technical feasibility (Lawson 2012, Sproule 1960)

4. Future Tasks

- Minimizing uncertainty
 - Technology
 - ✓ To establish/improve mining technology
 - ✓ To establish/improve processing technology
 - ✓ To increase geological confidence (into “indicated resources”)
 - Environment
 - ✓ To understand possible impacts on environment
 - Metal Markets
 - ✓ To identify serious risk factor of price fluctuations after commencement of operation
 - ✓ To examine possible impacts on the market by supplying deep seabed mineral resources, especially cobalt
 - Marketing
 - ✓ To investigate potential market for products, especially silicon-manganese



Thank you for your kind attention