Deep Sea Mineral Resources Project

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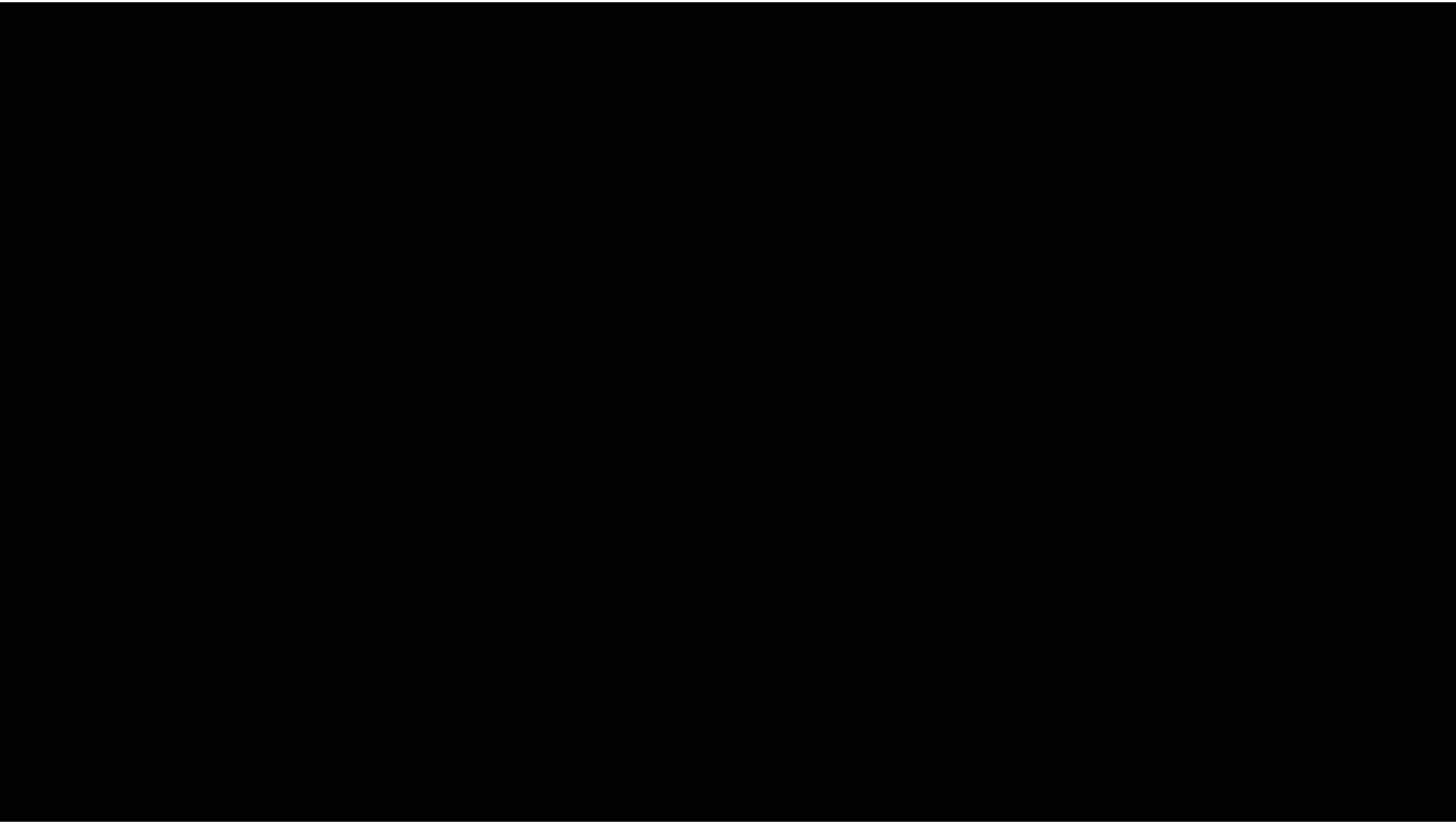
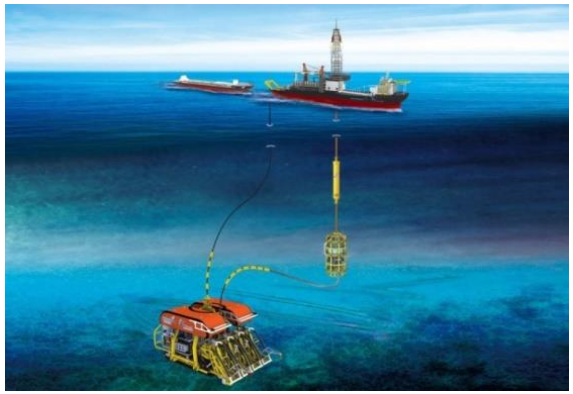
Importance of development of deep-sea mineral resources



Aims of SMR Project in Korea

Aims

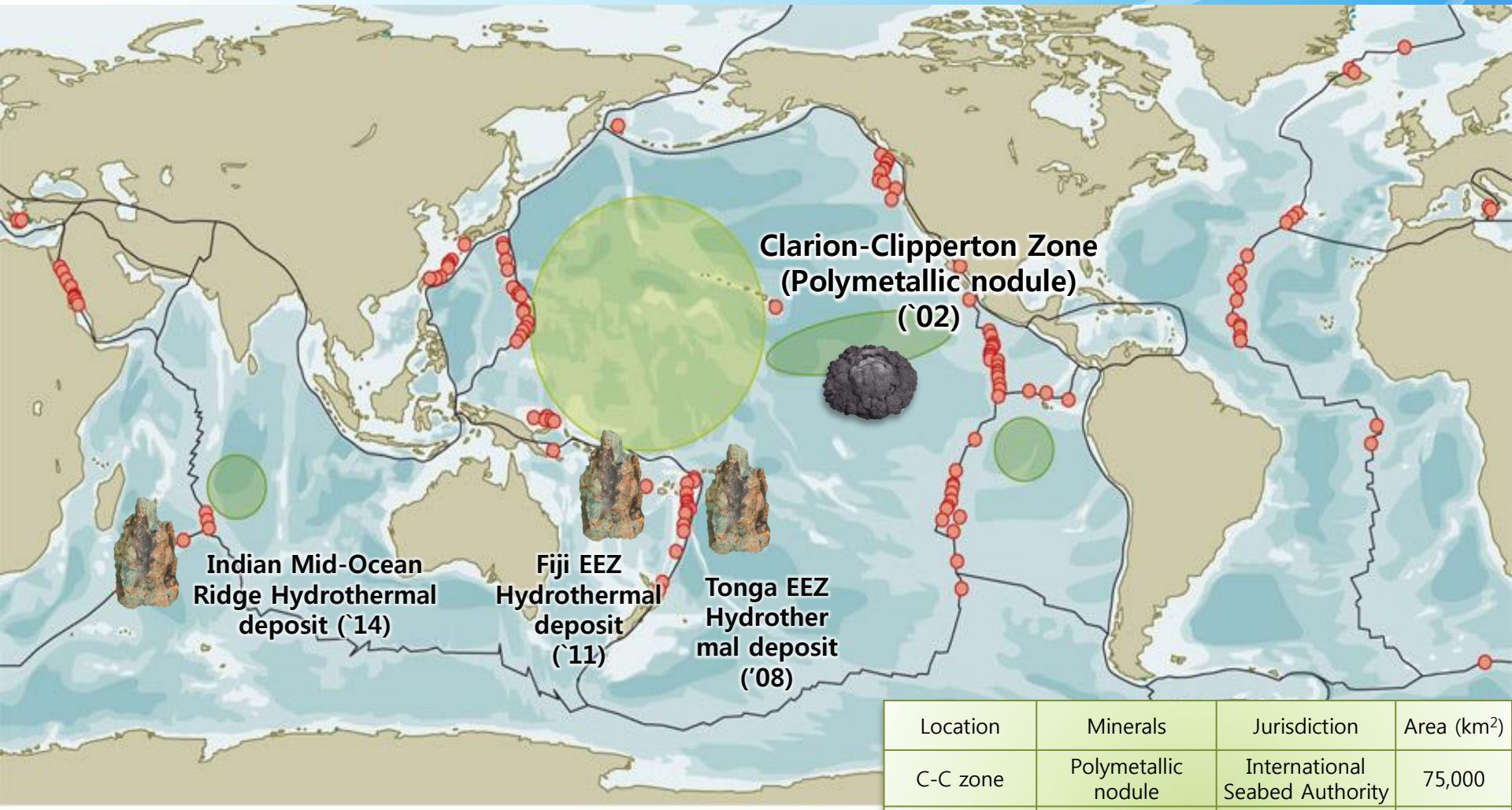
- To secure long-term supply source of metallic resources
- To create new marine industries



Research Subject

- Selection of prospective mining sites for SMR (Nodules, SMS deposit) and development mining/processing technologies
  - Mining route mapping and environmental impact assessment
  - Development of integrated mining system and performance test
  - Establishment of integrated processing system & basic design for commercial processing plant

Distribution of SMR & Area licensed to Korea



Location	Minerals	Jurisdiction	Area (km^2)
C-C zone	Polymetallic nodule	International Seabed Authority	75,000
Tonga EEZ	Hydrothermal deposit	Tonga Ministry of Lands, Survey & Nat. Resources	24,000
Fiji EEZ	Hydrothermal deposit	Fiji Ministry of Lands & Mineral Resources	3,000
Indian Mid-Ocean Ridge	Hydrothermal deposit	International Seabed Authority	10,000

Brief history

- **1994:** Registration of polymetallic nodule exploration area (150,000 km^2) in the Northeast Pacific (7th pioneer investor)
- **2002:** Exclusive exploration right for 75,000 km^2 of polymetallic nodule area
- **2008:** Acquisition of exclusive exploration license for Seafloor Massive Sulphide (SMS) deposit in Tonga EEZ
- **2009:** At-sea test of pre-pilot scale (1/20) mining robot at 100 m water depth
- **2009:** Group B Council member of International Seabed Authority (ISA)
- **2011:** Acquisition of exclusive exploration license for SMS deposit in Fiji EEZ
- **2013:** At-sea performance test of pilot scale (1/5 scale; 1,000 t/day) mining robot at 1,370 m water depth & large-scale performance test of processing system (2 t/day)
- **2014:** Contract with ISA for exploration of allocated SMS deposit in Indian Ocean for 15 years (`14~`29)
- **2015:** Performance test of lifting system (buffer, pump, riser) with operating capacity of 2,500 m

Seabed Mineral Resources deposits

Polymetallic Nodule

Characteristics	Polymetallic oxy-hydroxides formed by precipitation of dissolved metals (e.g., iron and manganese) in seawater Potato-shaped metal balls carpeting deep-sea basins (1–15 cm in diameter)
Occurrence	Deep-sea basin (4,500–5,000 m depth), most common occurrence in Clarion-Clipperton Zone (C-C zone) in Northeast Pacific
Metal components	Mn (27%), Fe (8%), Ni (1.4%), Cu (1.3%), Co (0.2%), Mo (0.04%), REE (0.12%), etc.
Value	Economic value: 828 US$/ton (from metal prices in 2007–2011) (If REE-extraction gets more efficient, 1.944 US$/ton)

Seafloor Massive Sulphide (SMS)

Characteristics	Metal sulphides precipitated around the hydrothermal vent and nearby seabed Formed when heated hydrothermal fluids discharge and mix with cold surrounding seawater, Possessing unique chemosynthetic ecosystem without solar energy – catching scientific attention as a possible origin of life and a source of unique materials
Occurrence	Mid-Ocean Ridges and volcanic arc (300 ~ 3,700 m depth)
Metal components	Cu (1~15%), Au (5~30g/ton), Ag (200~1,900g/ton), Zn (4~36%), Pb
Value	Economic value: 489-1360 US$/ton

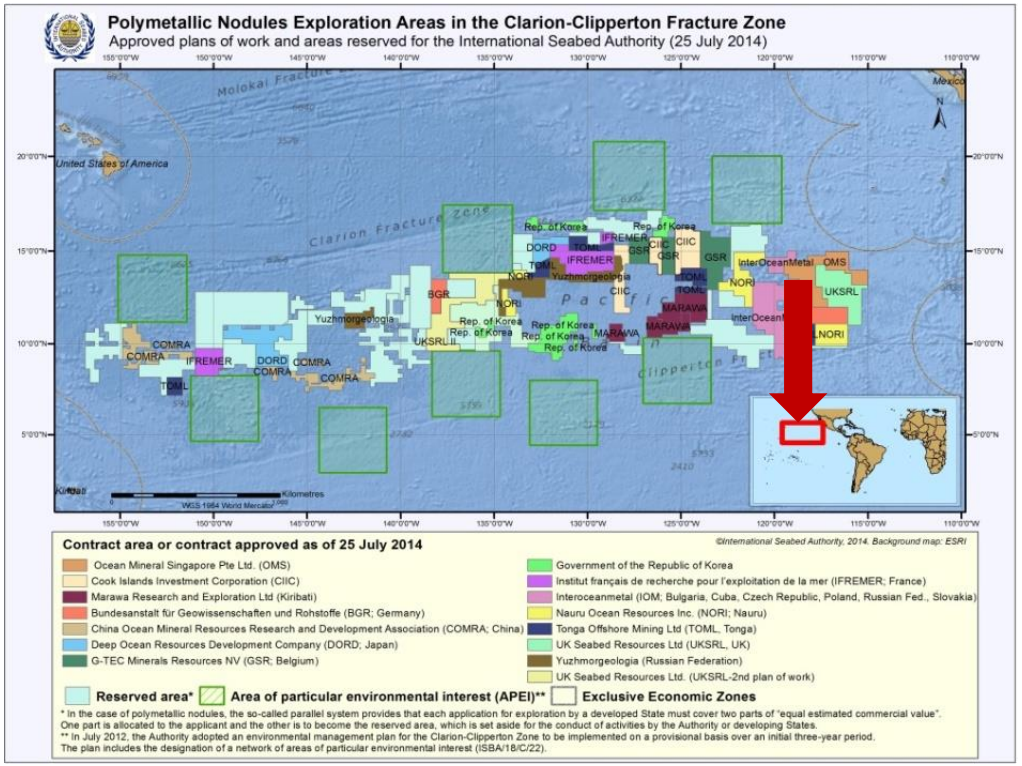
Cobalt-rich Ferromanganese Crusts

Characteristics	Seabed mineral deposit created when metal ions in the water react with oxygen to form oxides Deposited on the rock surface at seamounts
Occurrence	Flanks and summits of seamounts (800 ~ 2,500 m depth)
Metal components	Co (0.5~1.2%), Ni (0.2~0.9%), Cu (0.1~0.44%), Mn (17~27%), Pt (0~40 ppm), REEs
Value	Cobalt-rich & highest REE content (0.14~0.20%) among the seabed mineral deposit Economic value: 337-1,051 US$/ton

Licensed Area for Nodule

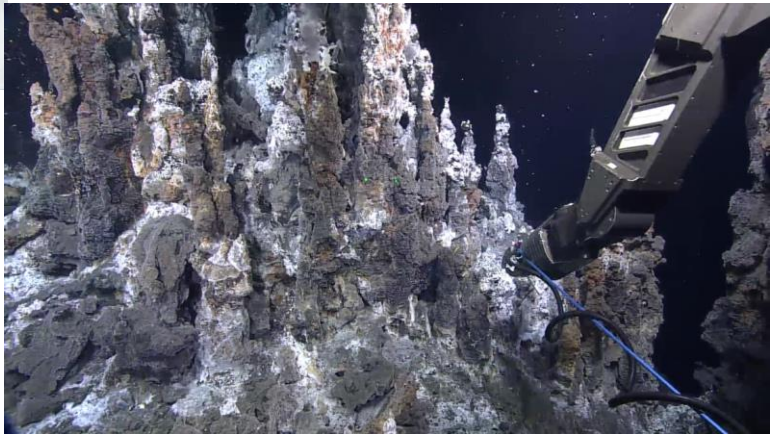
- Area: 75,000 km^2 (3/4 of South Korea)
- Total estimated resources : 560 million tons
- Mn: 119 million ton, Cu: 5 million ton, Ni: 6 million ton, Co: 1 million ton

3 million tons annually for 30 years

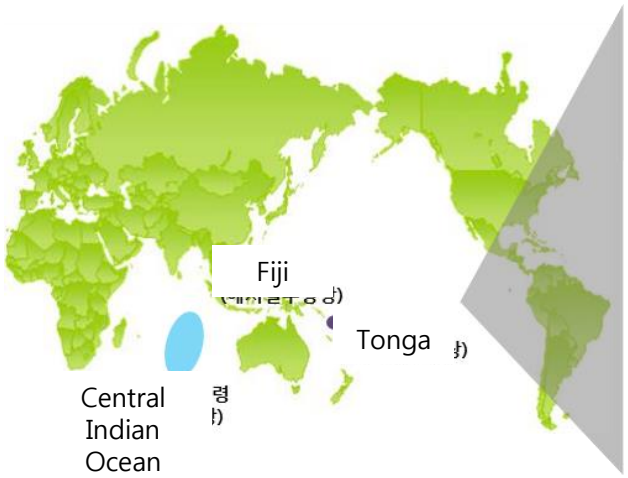


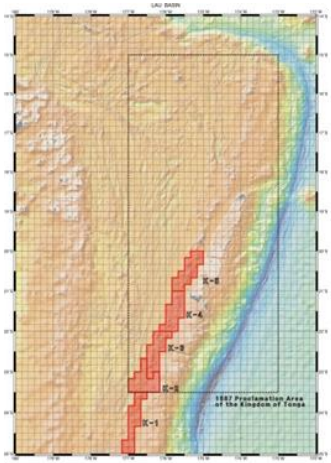
※ http://www.mining.com/scientists-find-way-to-extract-vast-amounts-of-rare-earths-from-seafloor-73254/
http://www.ubergizmo.com/2014/04/rare-earth-metals-extraction-gets-more-efficient/

Licensed Area for SMS

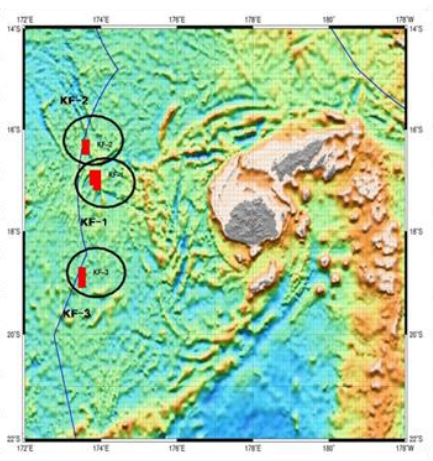


- Tonga EEZ (23,700 km^2)
- Fiji EEZ (3,000 km^2)
- Central Indian Ocean in the Area (10,000 km^2)
- Expected resource amount: 6 Mt in each area (Tonga, Fiji & Indian Ocean)
- Provision of strategic metals (e.g., copper, zinc, gold, silver, …)

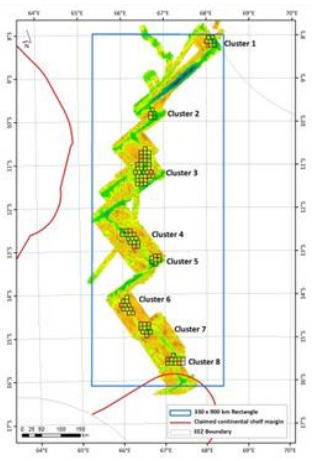




Tonga SMS deposit



Fiji SMS deposit



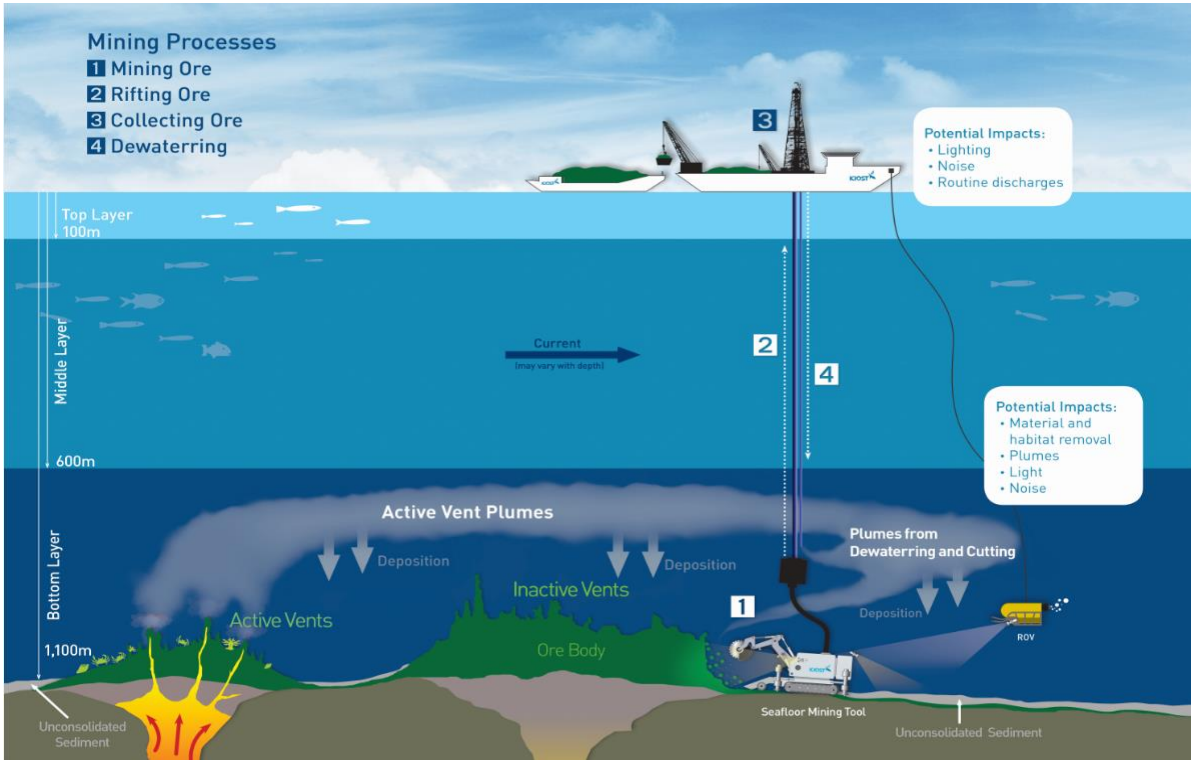
Central Indian Ocean SMS deposit

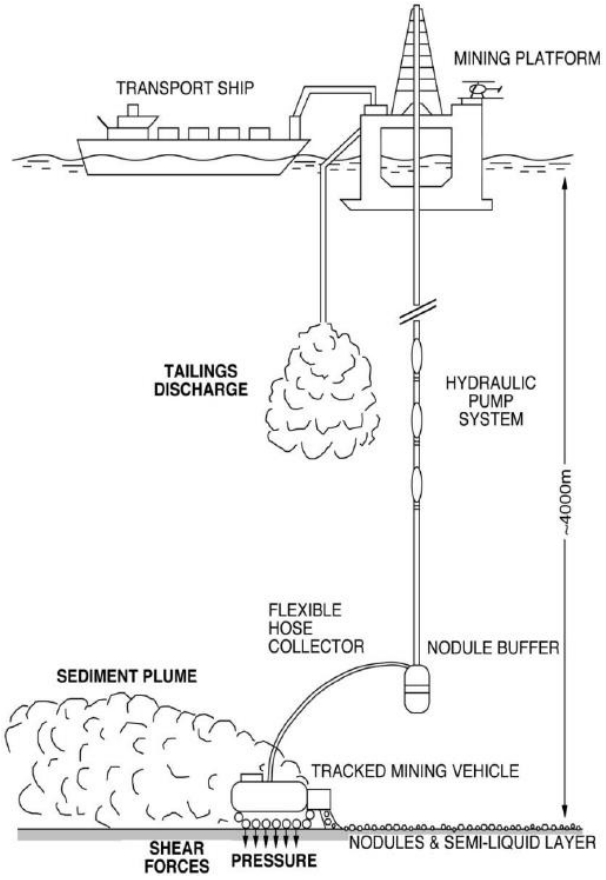
※ **Economic value of SMS deposits vary with their metal contents**

Deep Sea Environmental Study

Potential environmental impacts by mining

- Sediment plumes in water column and near bottom
- Noise & light
- Habitat removal





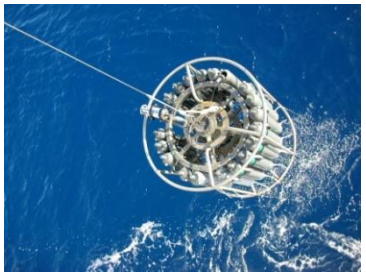
Oebius et al., 2001

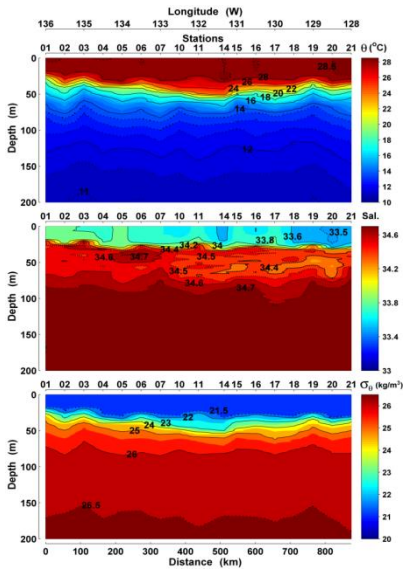
Deep Sea Environmental Study

Understanding natural variability

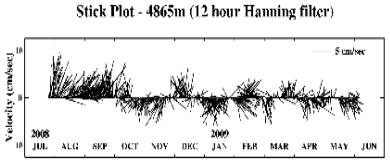
- To assess potential impact of mining activities on marine environment
- Protection of marine environment from mining activities

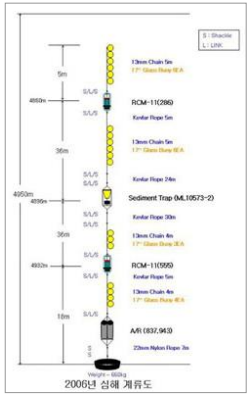
Physical properties



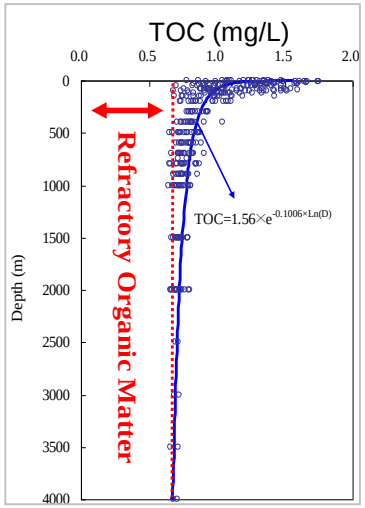


Deep sea current

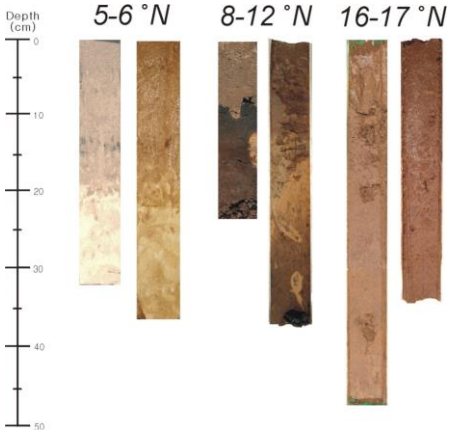


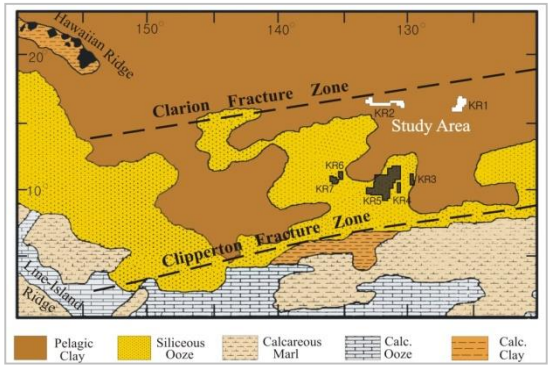


Chemistry



Geology

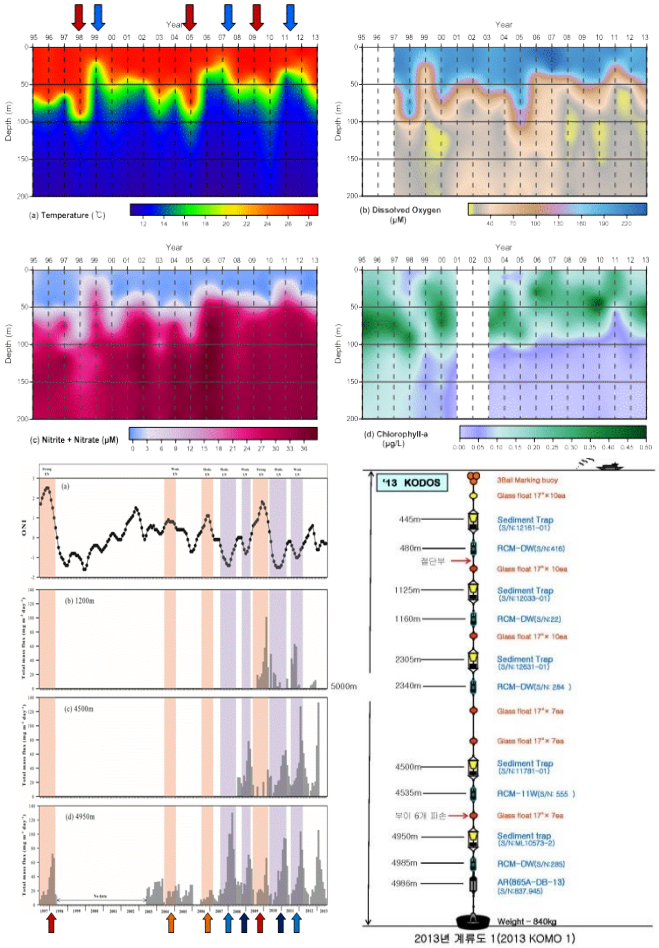




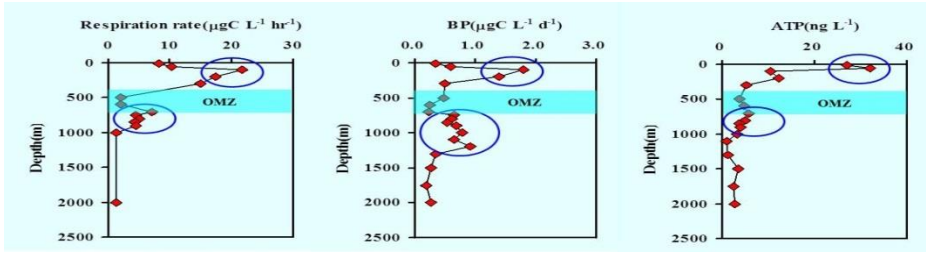
Deep Sea Environmental Study

Understanding natural variability-Nodule field (C-C zone)

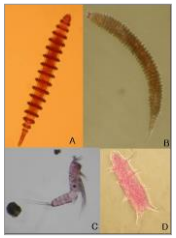
- Environmental monitoring of water column and seabed

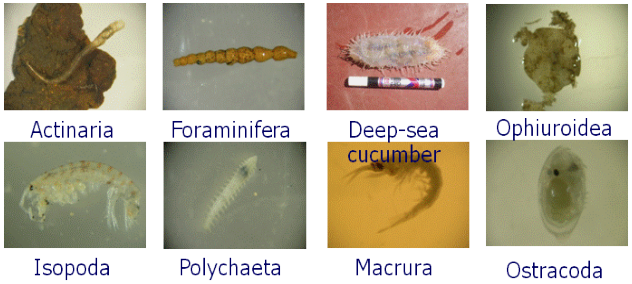


Biomass and production rate of water column microbes

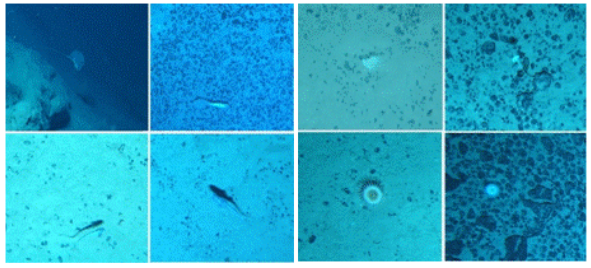


Micro-meiobenthos





Macrobenthos



Predator

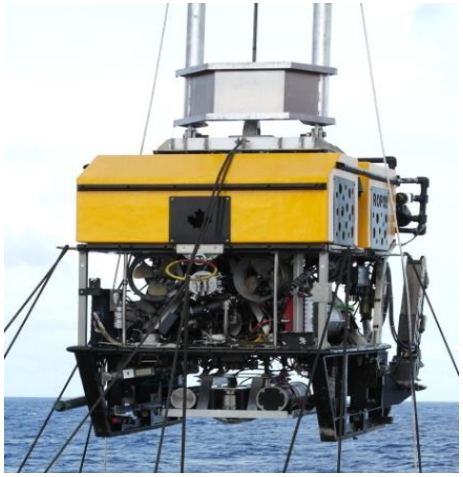
Deep Sea Environmental Study

Understanding natural variability-SMS deposit

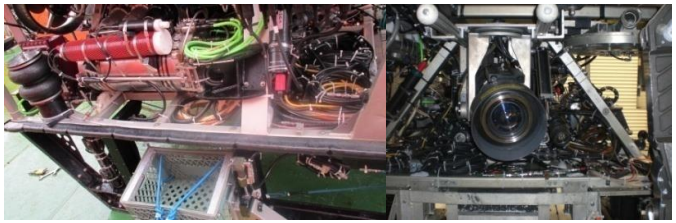
- Remotely Operated underwater Vehicle (ROV)
  - Spatial distribution of vent
  - Benthic fauna with environmental parameters

ROV survey (Video)

ROPOS (ROV)



Sensors mounted on ROV

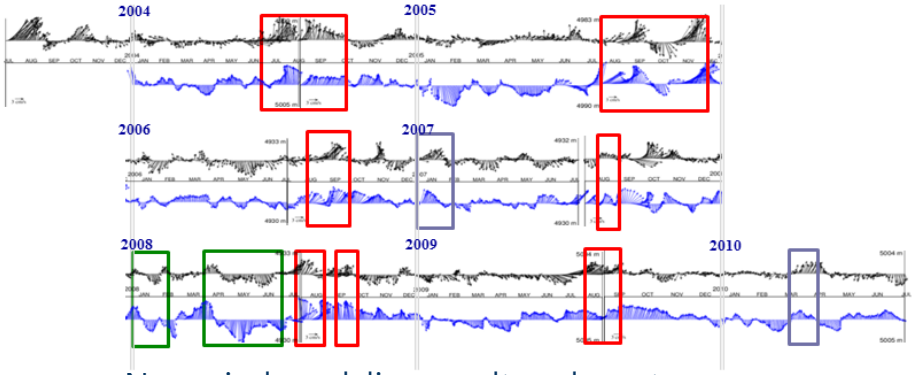


Sampling gears & tools

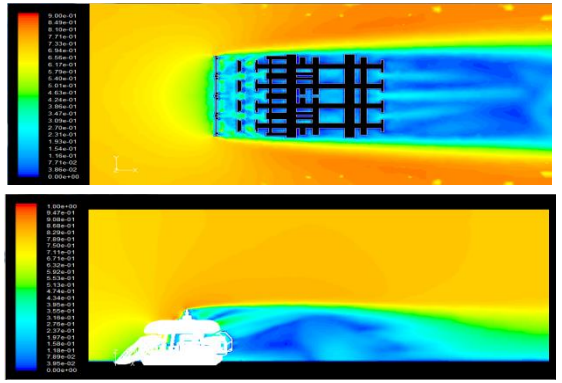
Vent fauna

Deep Sea Environmental Study

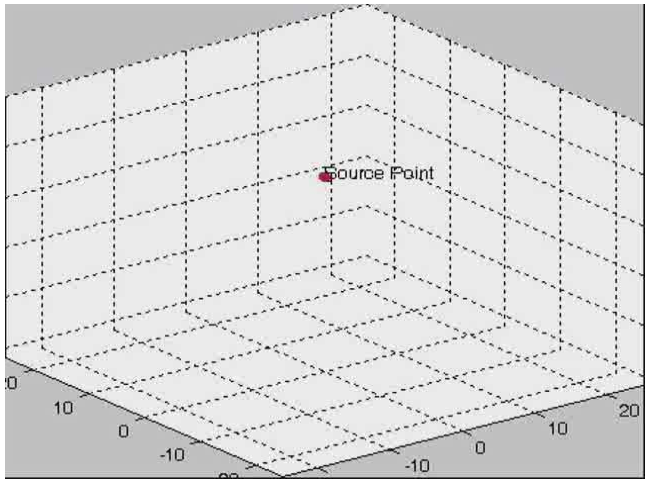
Modeling of sediment diffusion during nodule mining procedure



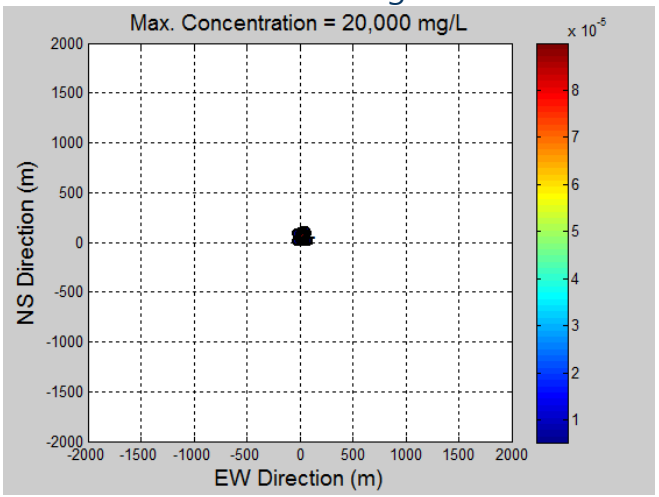
Numerical modeling result vs. long-term monitoring data of ocean current



Flow field characteristics with outflow discharge from mining device



Particle diffusion in the water column by deep-sea tailing (modelling)

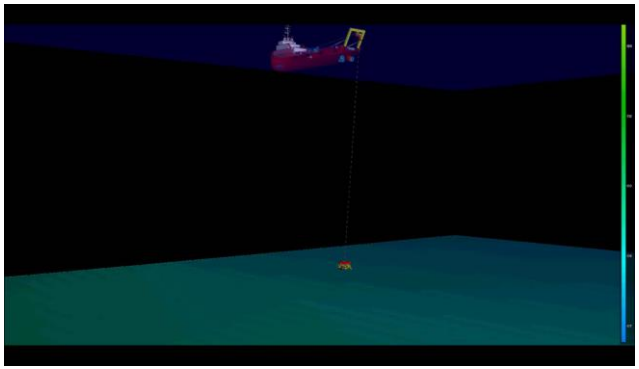


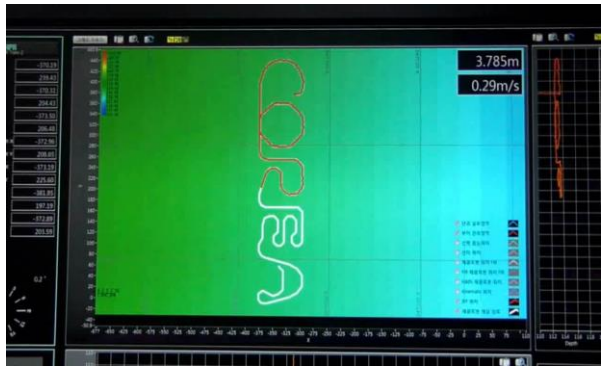
Diffusion of suspended particles from bottom sediment (modelling)

Technologic Development

Mining system for nodule

- Development of pilot-scale (1/5 of commercial production) automatic path tracking mining robot, "MineRo", with operating capacity of 6,000 m depth (2012)
  - 28ton in air, 6.5m(L) x 4.7m(W) x 3.6m(H), 530kW
- Performance test completed at 1,370 m depth (2013)
- Outcomes:
  - Underwater collecting and crushing of nodules
  - Deep sea localization & Driving Control
  - Automatic path tracking on the soft sediment

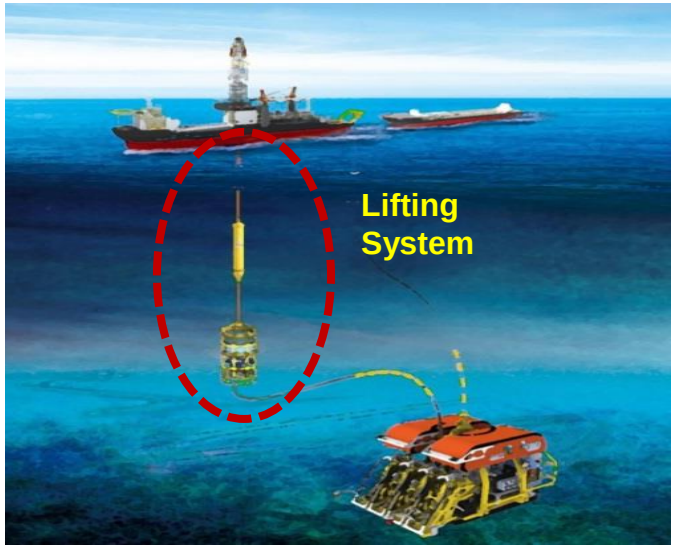


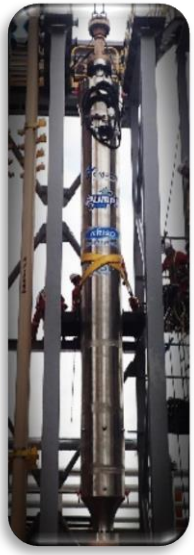


Technologic Development

Lifting system for nodules (performance test completed in 2015)

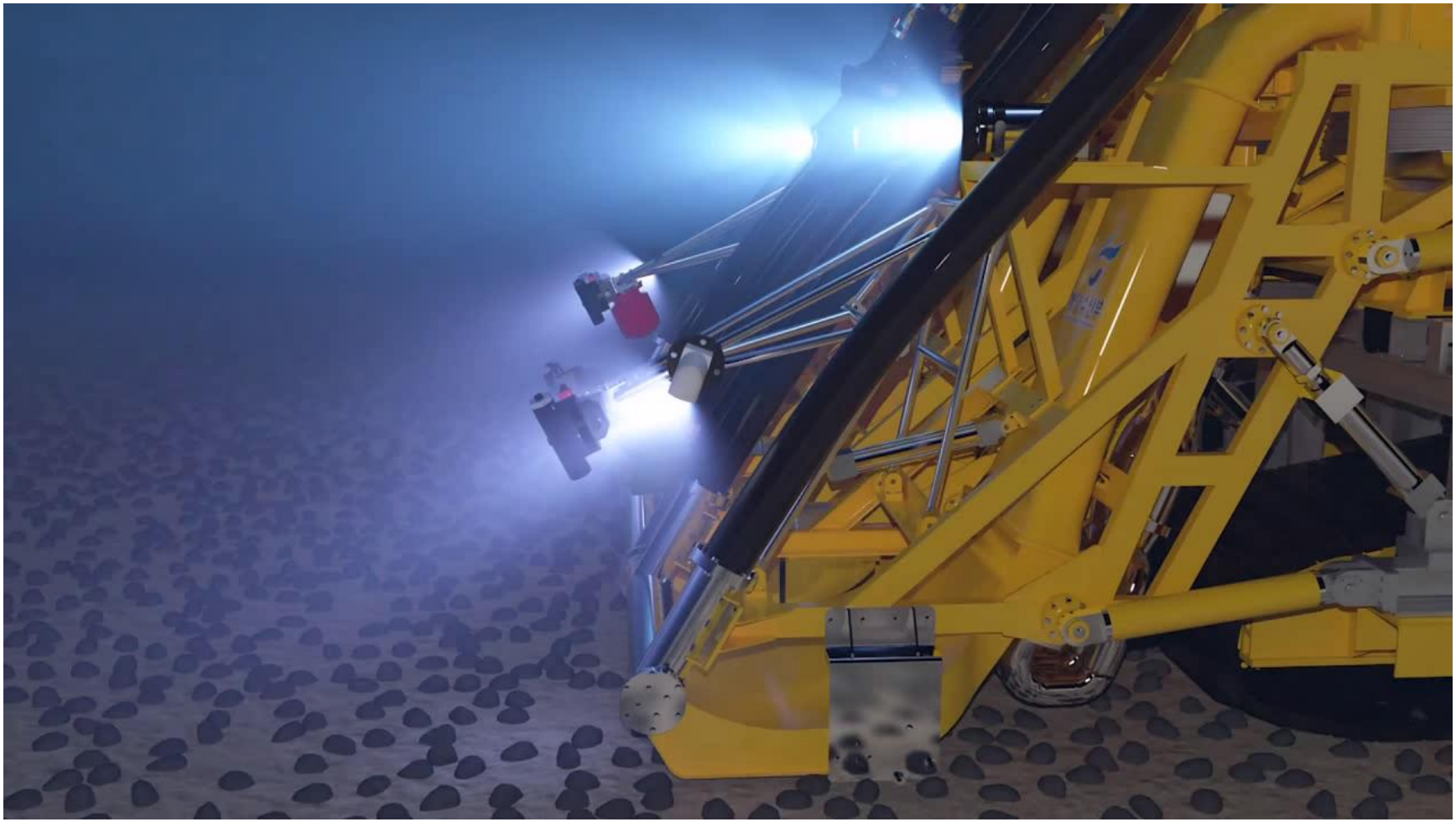
- **Lifting pump**: 1,000 t/day (1/5 of commercial production) for nodules
  - Capacity: 500 m^3/h, 6-stage Centrifugal Slurry Pump, 800kW, size: H 10m, D 900mm, W 8tons
  - Installed at 500 m depth; lifting from 5,000 m depth if additional pumps are installed
- **Buffer system**: providing maximum mobility by **temporary storage and stable supply of nodules (assuring slurry flow)**
  - Underwater hydraulic: 150kW, size: H 7.2m, D 3.0mm, W 8tons
- **Lifting riser**: 12 m-length each, 202.7 mm in inner diameter, 8.2 mm thickness





Technologic Development

Deep sea mining system for nodule



Future Plan

Exploration and Environment Research

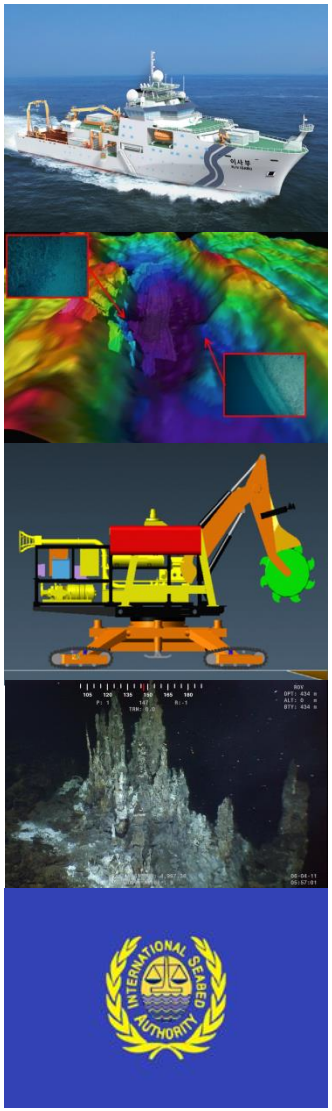
- **Polymetallic nodule**
  - Assessment of resources potential and environmental impact to comply with newly established regulations and recommendations in 2016 (using RV ISABU, a newly-built research vessel)
- **Seafloor Massive Sulphide**
  - A drilling campaign for assessment of 3-D distribution of deposit in Tonga EEZ

Mining and Processing (nodule)

- Analysis of performance test result for mining/processing technology
- Promoting technological advancement of ocean engineering for deep-sea mining
- Application of mining/processing technologies for nodules to the other DSM deposits and other fields of ocean engineering industries

Legal and Economic works

- Active participation in development of the exploitation code
- Establishment of domestic legislation and policy for deep seabed mining
- Economic feasibility study reflecting technological advances and metal prices




UMC 2016, Songdo, Incheon
2016, October 9 - 13
Resource and Environmental Assessment
for Deep Seabed Mining
http://www.underwatermining.org

Thank you

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