# ORE 330
# Mineral and Energy Resources of the Sea

Mining Technology

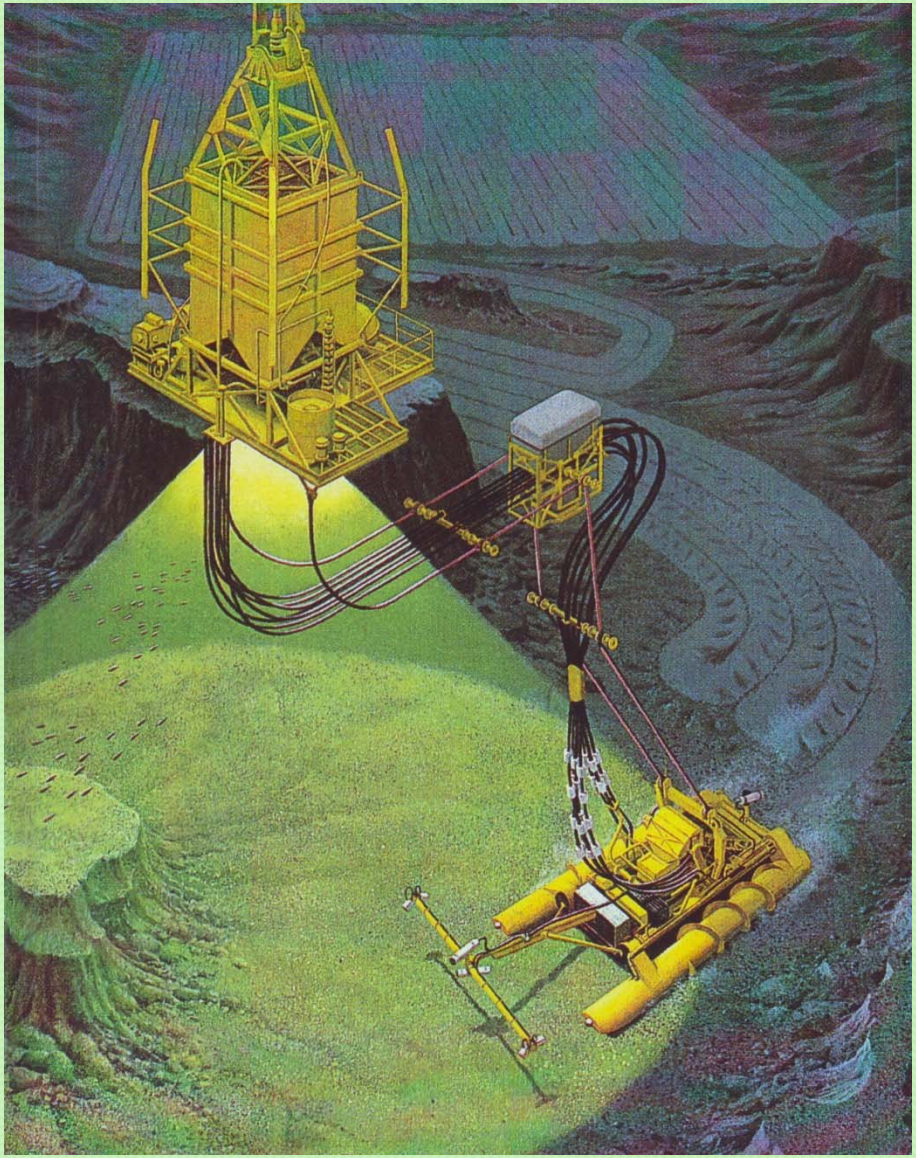
# Deep-Sea Mining Systems

A. Manganese Nodule Systems
   1. Tested systems
      a) Robotic Miners
         - Design parameters
         - Pick-up systems
         - Airlift systems
      b) Continuous Line Bucket
   2. Untested systems
      a) Submersible Shuttle System

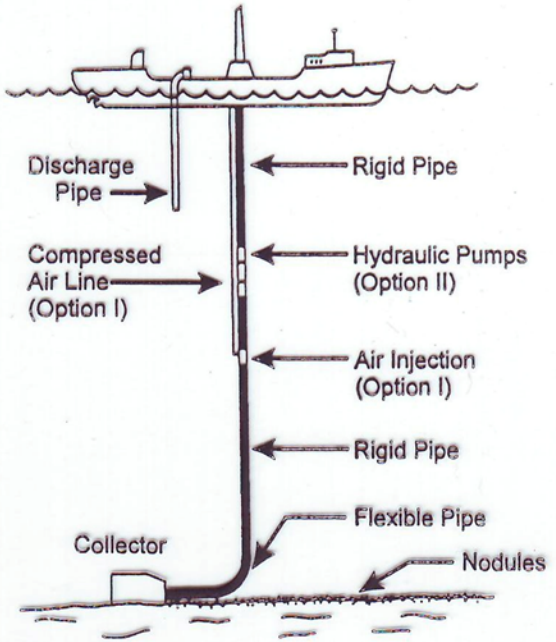
B. Manganese Crust Mining System
   - Design Parameters
   - Crust thickness problem
   - Cutter depth optimization
   - Ripper design – fragmentation criteria
   - Air lift design

C. In-Situ Leach Mining Systems
   - Operations for manganese crust and harbor sediment cleanup
   - Single point mooring systems for leach mining
   - Adaptation for biomining

D. Polymetallic Sulfide Mining Systems Concepts



## Mining System in General




| Collector Vehicle Types : | | |
|---|---|---|
| Self - propelled | | Towed |
| | | |
| Tracked | Archimedes Screw | Sled |

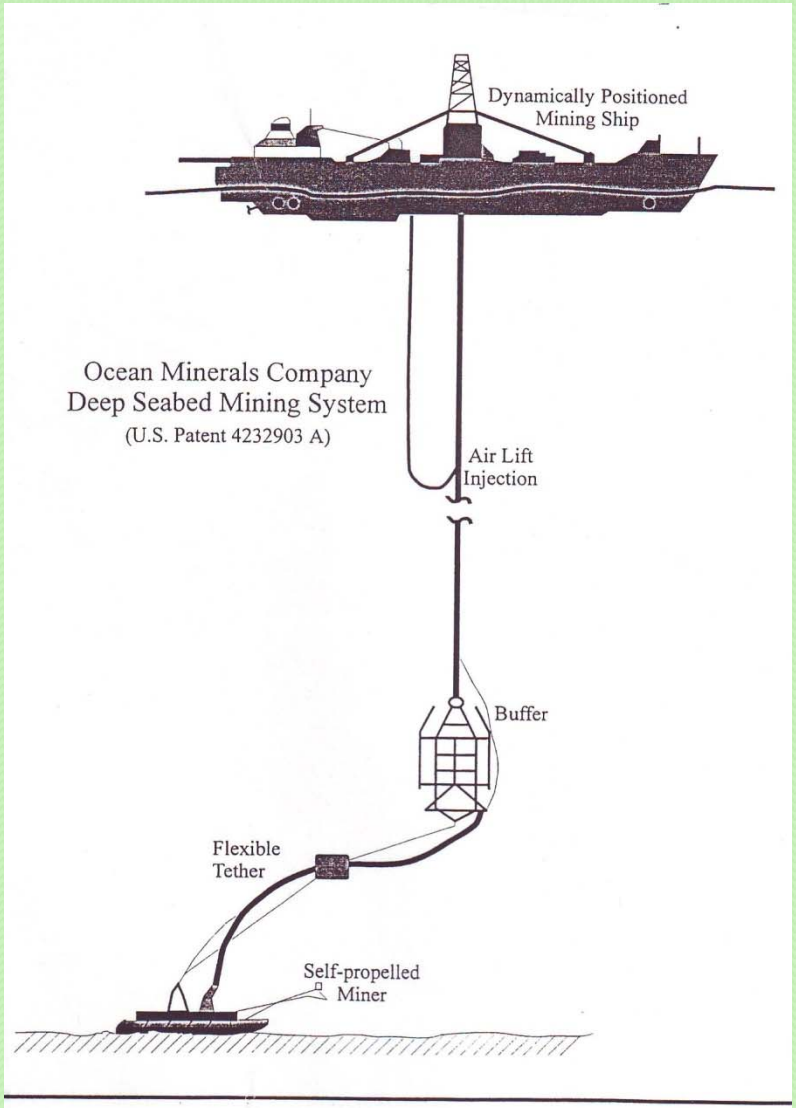



**Figure 2.** Complexity of design of hydraulic system.

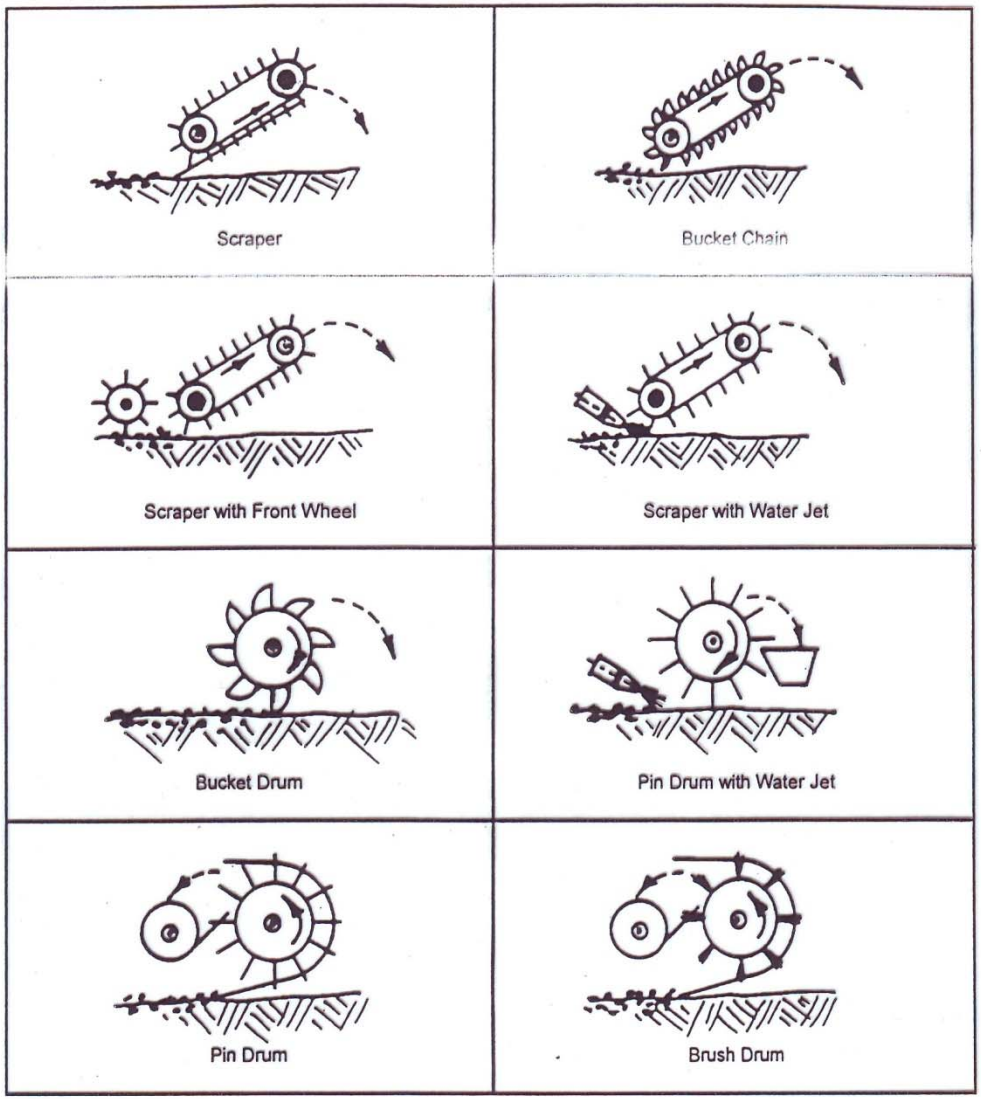
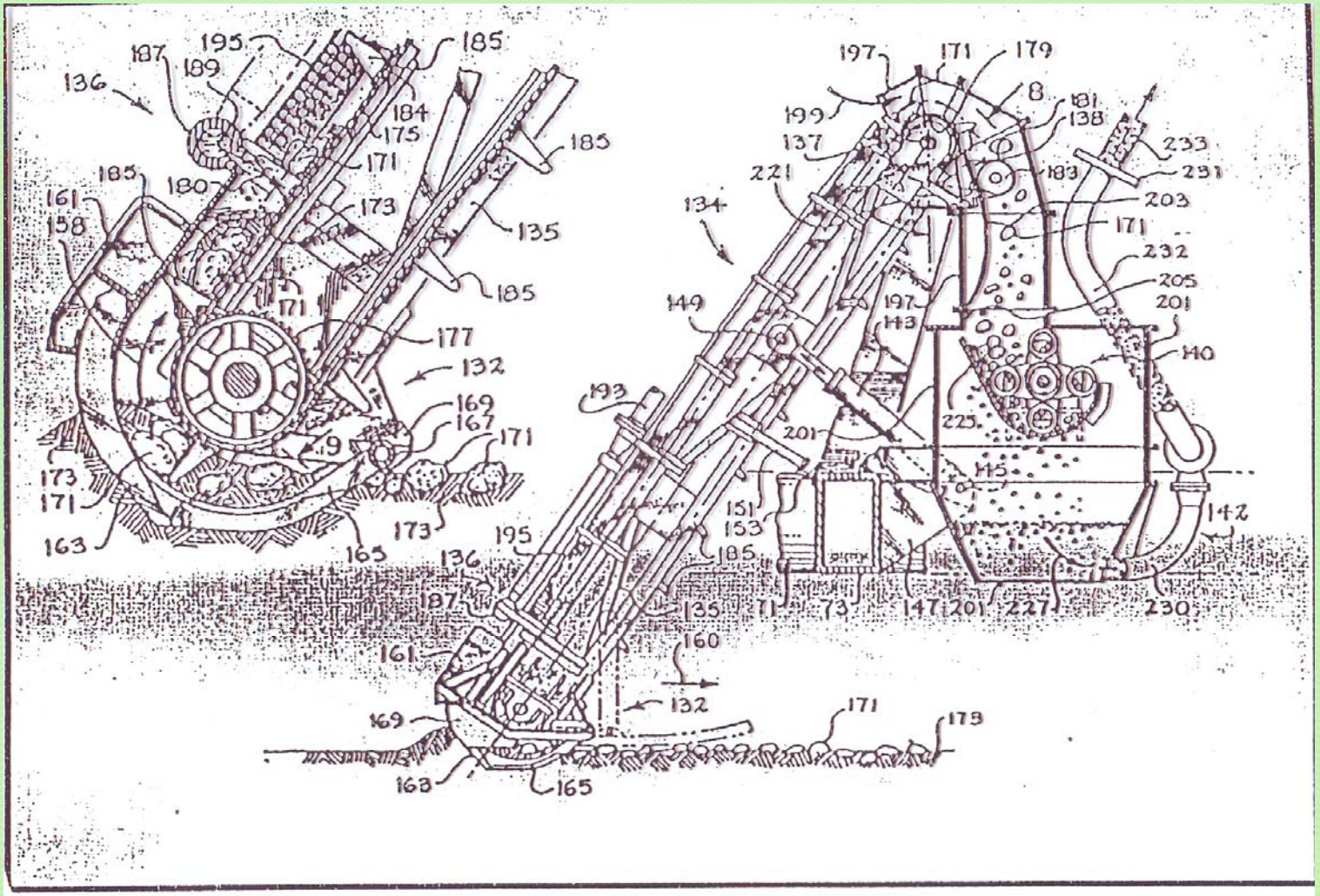
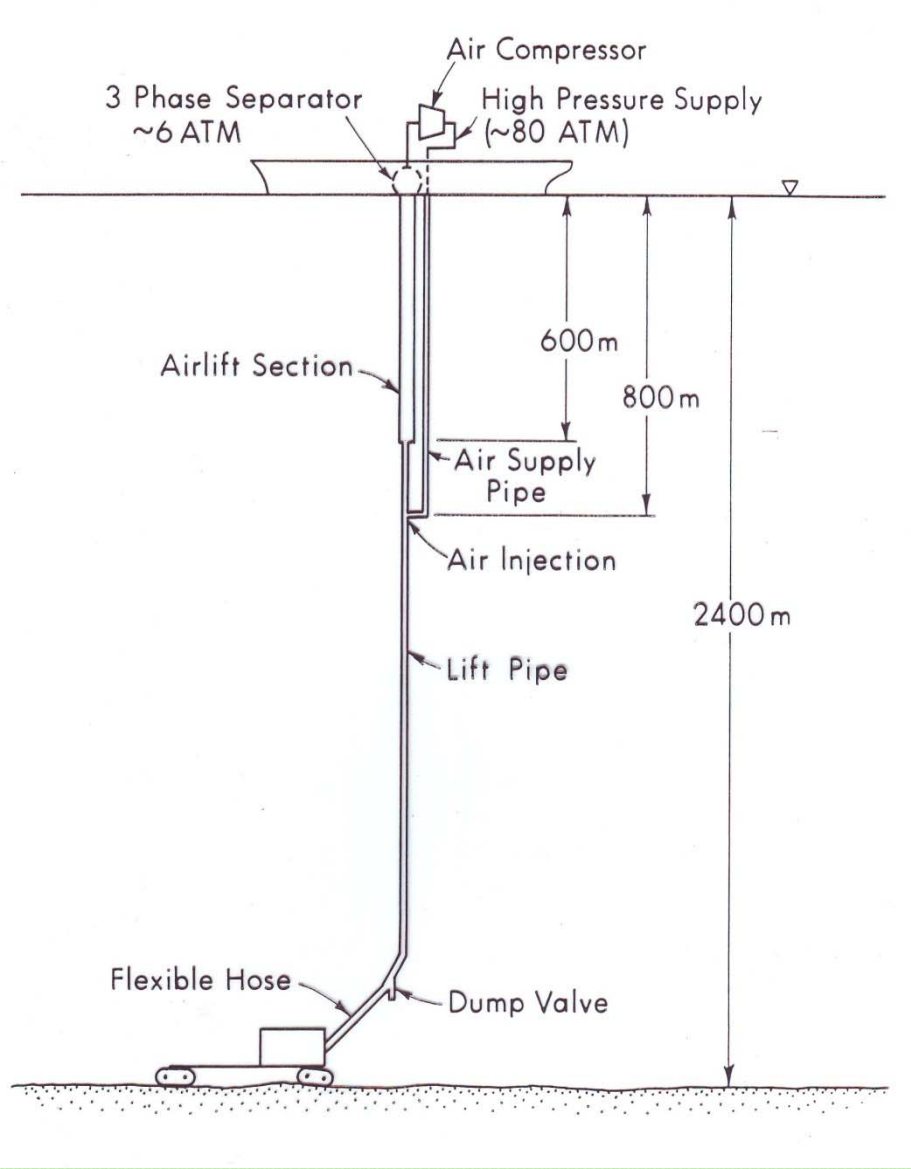



**Figure 2.1.4** Various nodule pick-up principles. (from Thiel *et al.* 1991 redrawn from Bath 1989)




Ocean Minerals Company Nodule Pick-up System (from U.S. Patent 4232903 A)


Air Compressor
3 Phase Separator
~6 ATM
High Pressure Supply
(~80 ATM)
600m
800m
Airlift Section
Air Supply
Pipe
Air Injection
2400m
Lift Pipe
Flexible Hose
Dump Valve

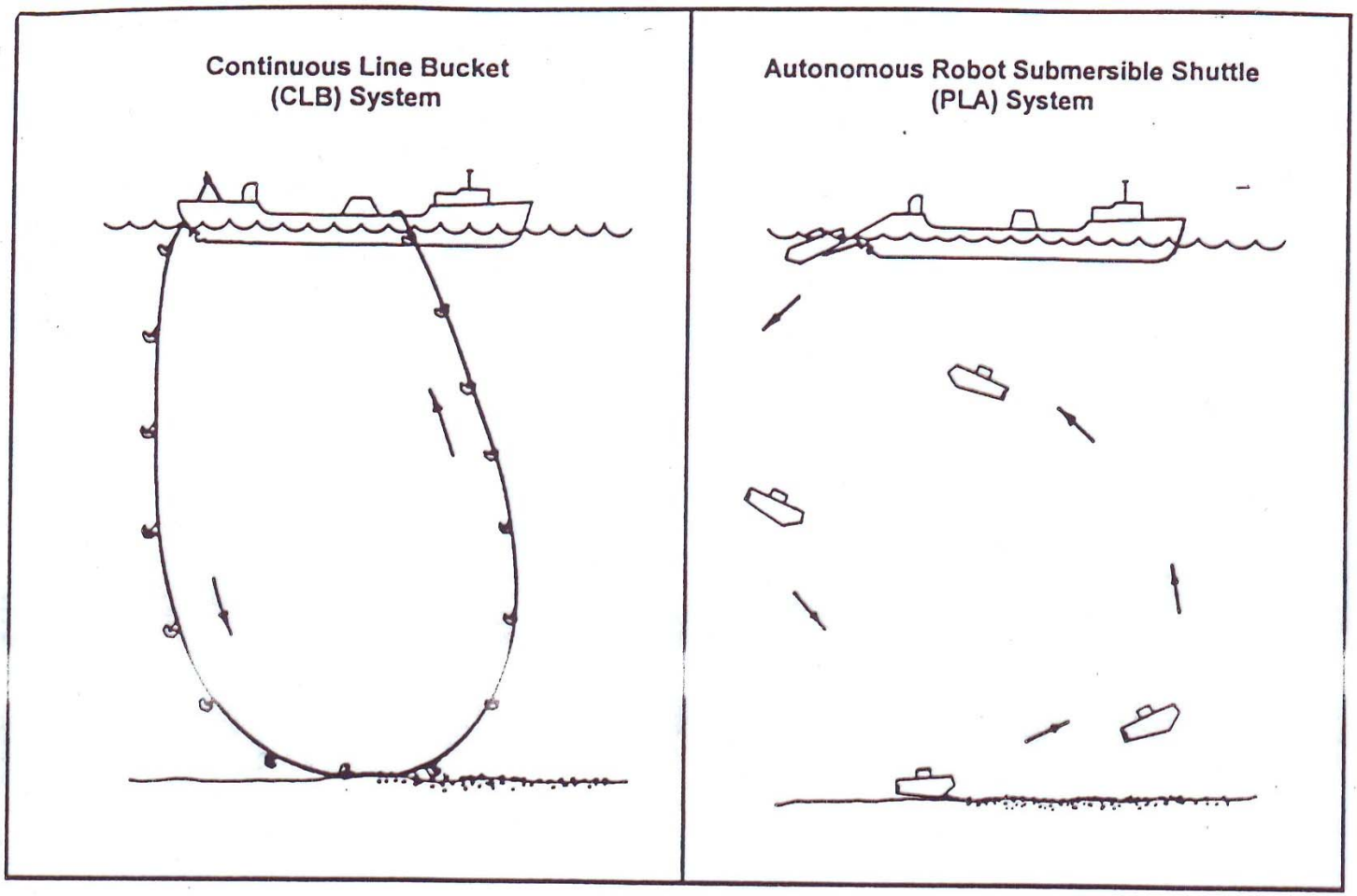



**Figure 2.1.2** Continuous Line Bucket (CLB) mining system and the Preleveur Libre Autonome (PLA) or autonomous robot submersible shuttle system. (not to scale) (from Thiel *et al.* 1991)

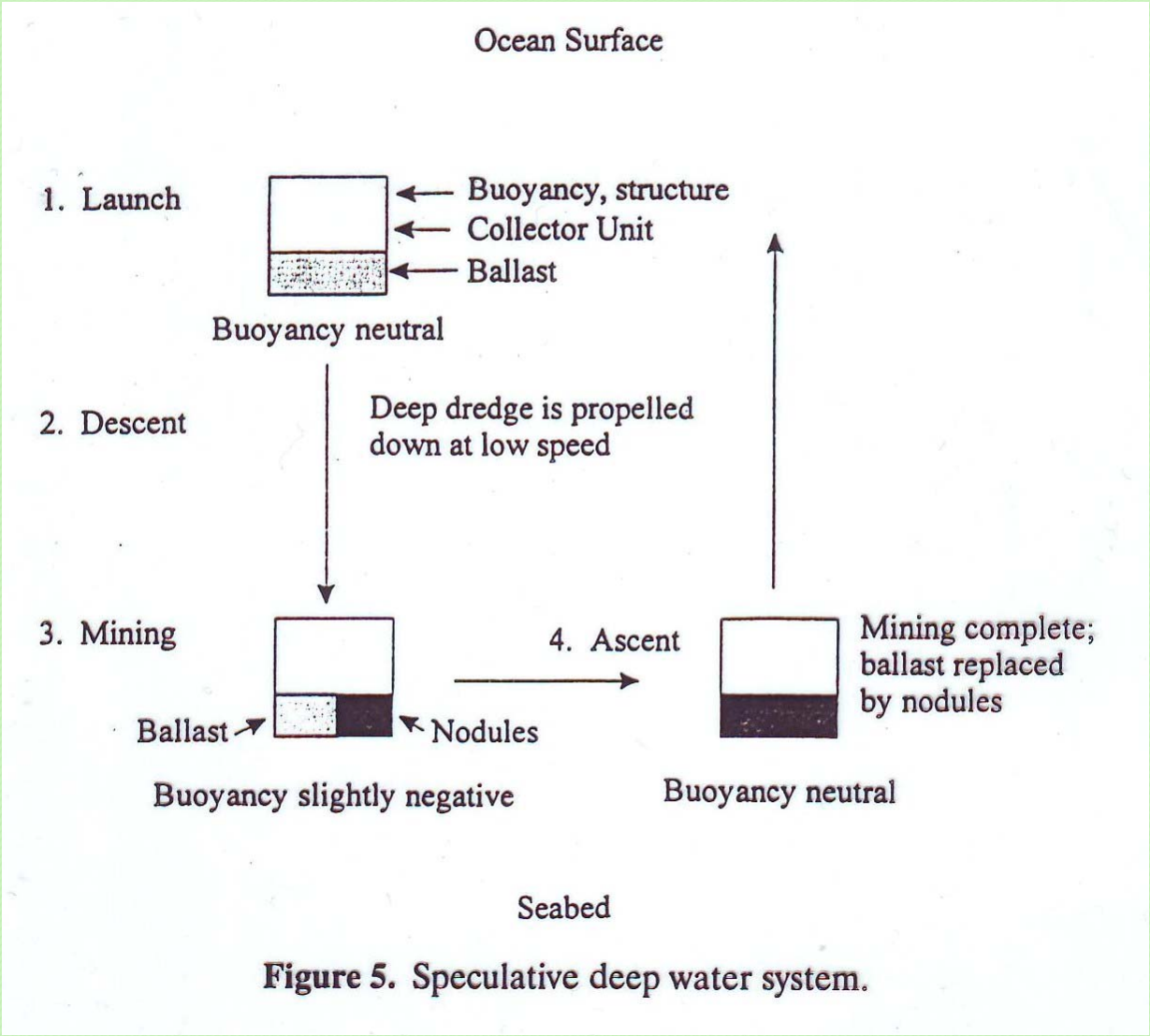
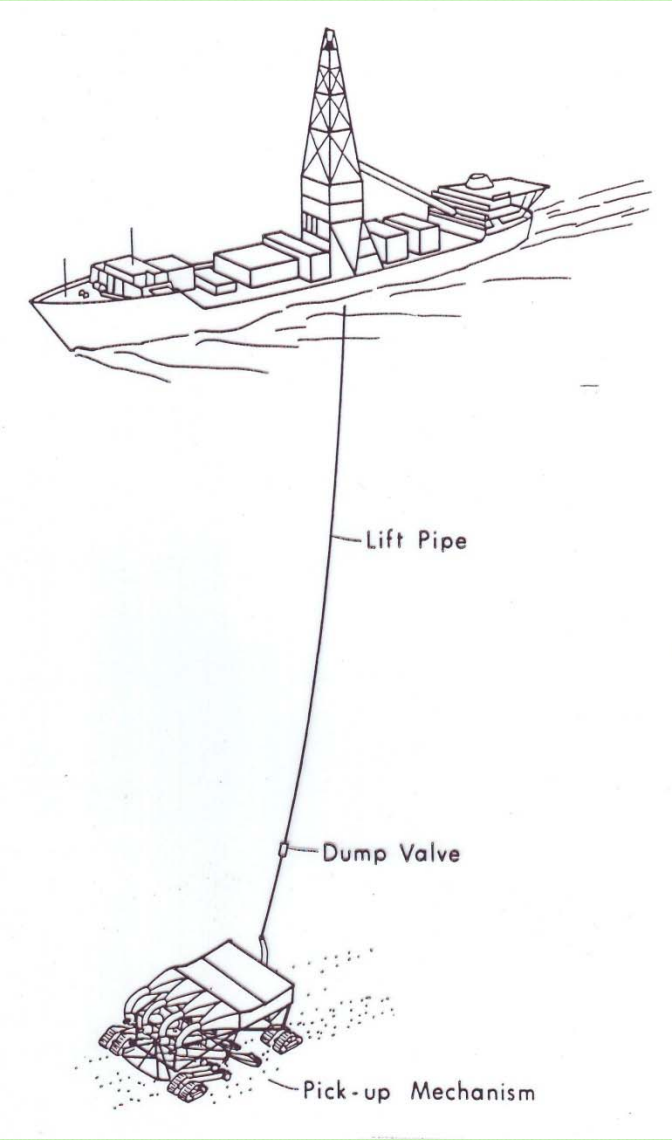
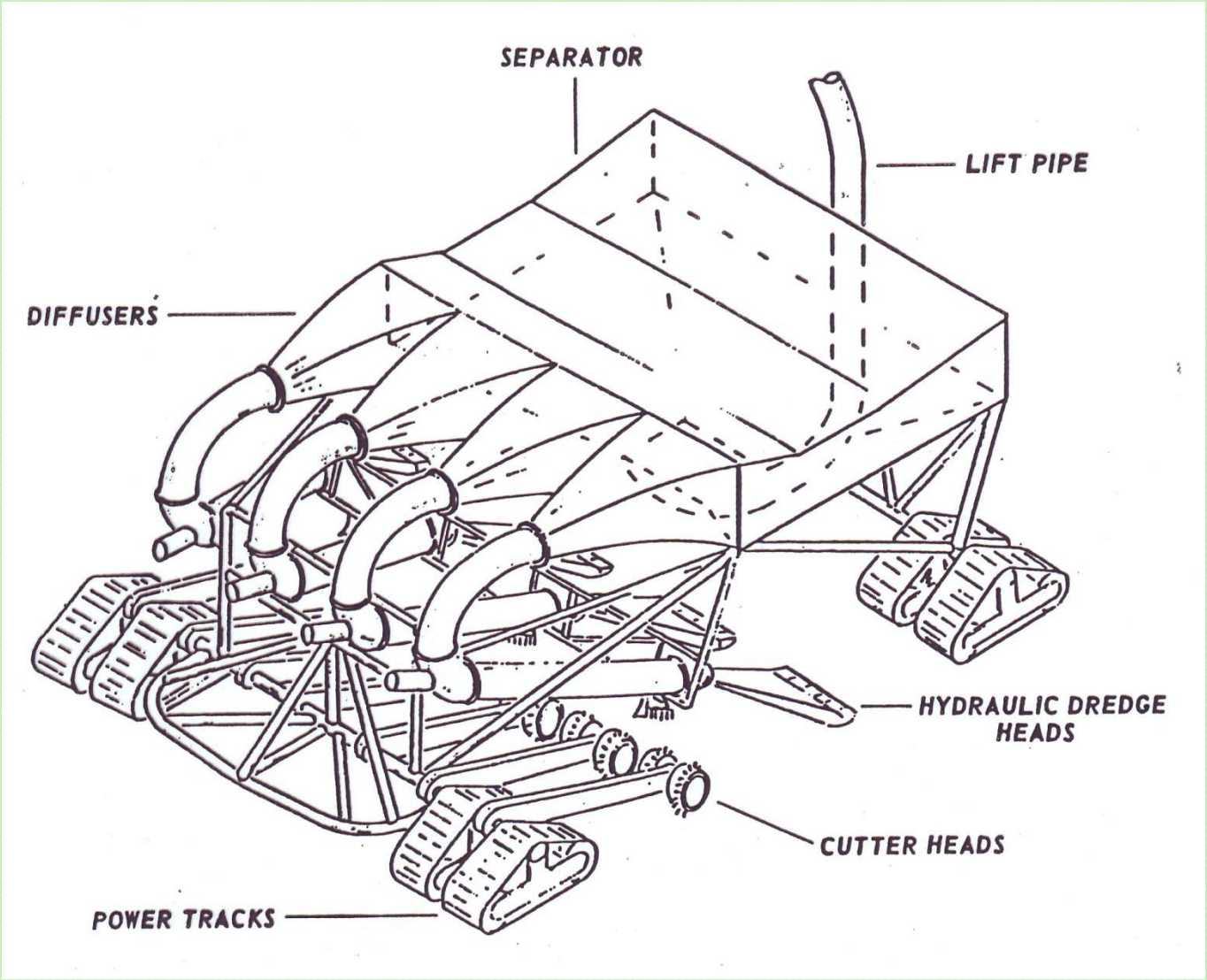



**Figure 5.** Speculative deep water system.


Lift Pipe
Dump Valve
Pick-up Mechanism


SEPARATOR
LIFT PIPE
DIFFUSERS
HYDRAULIC DREDGE HEADS
CUTTER HEADS
POWER TRACKS

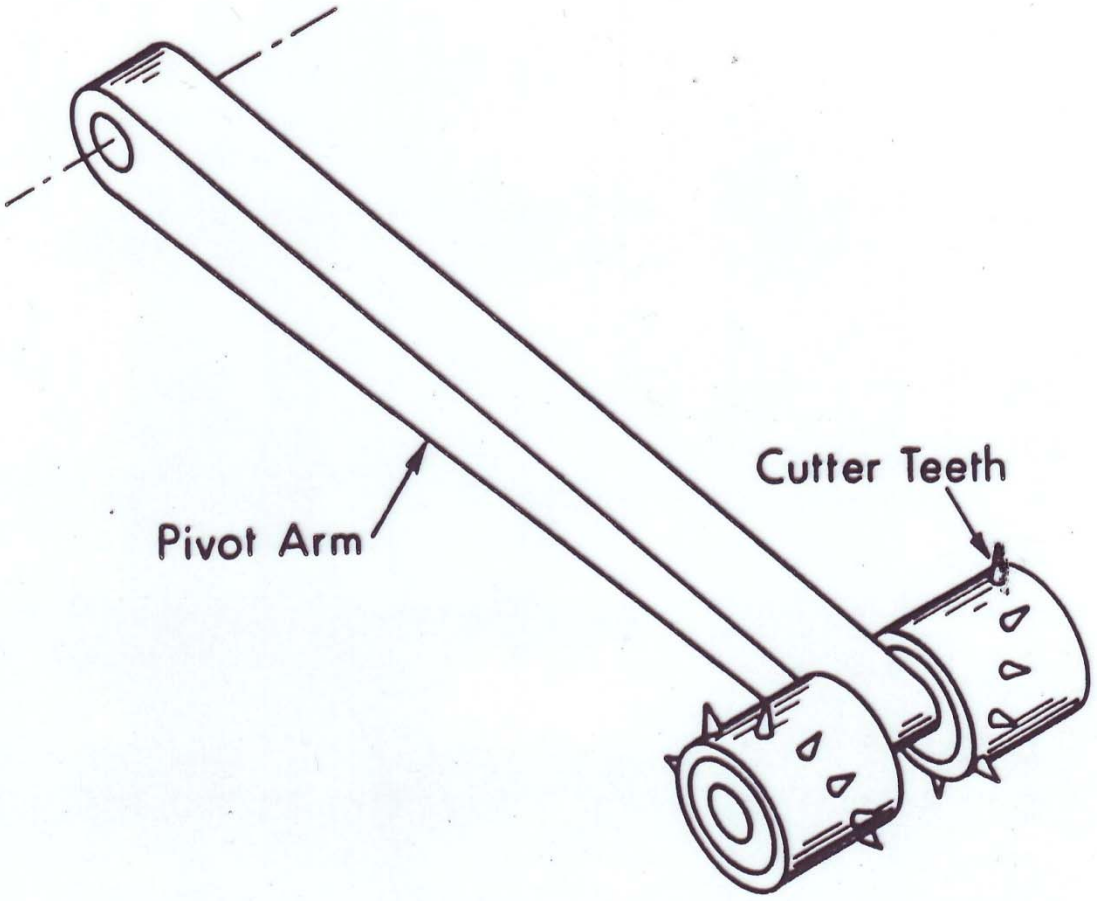



Figure 3. Cutter head design for manganese crust miner (after Halkyard 1985).

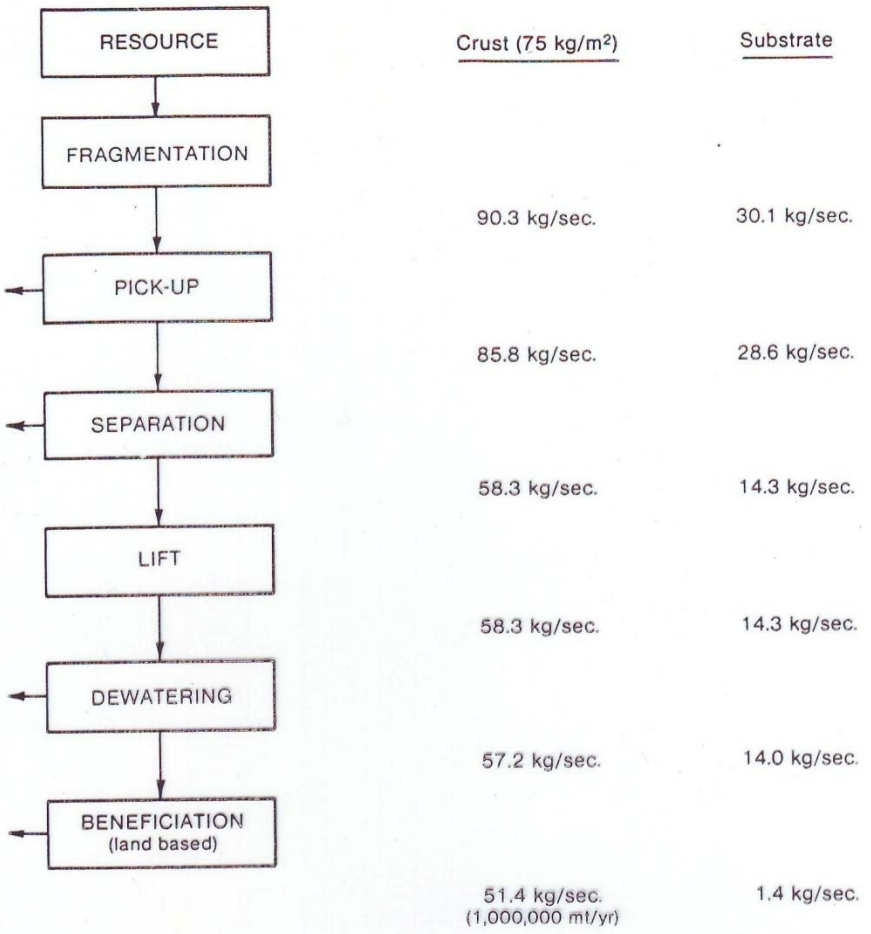
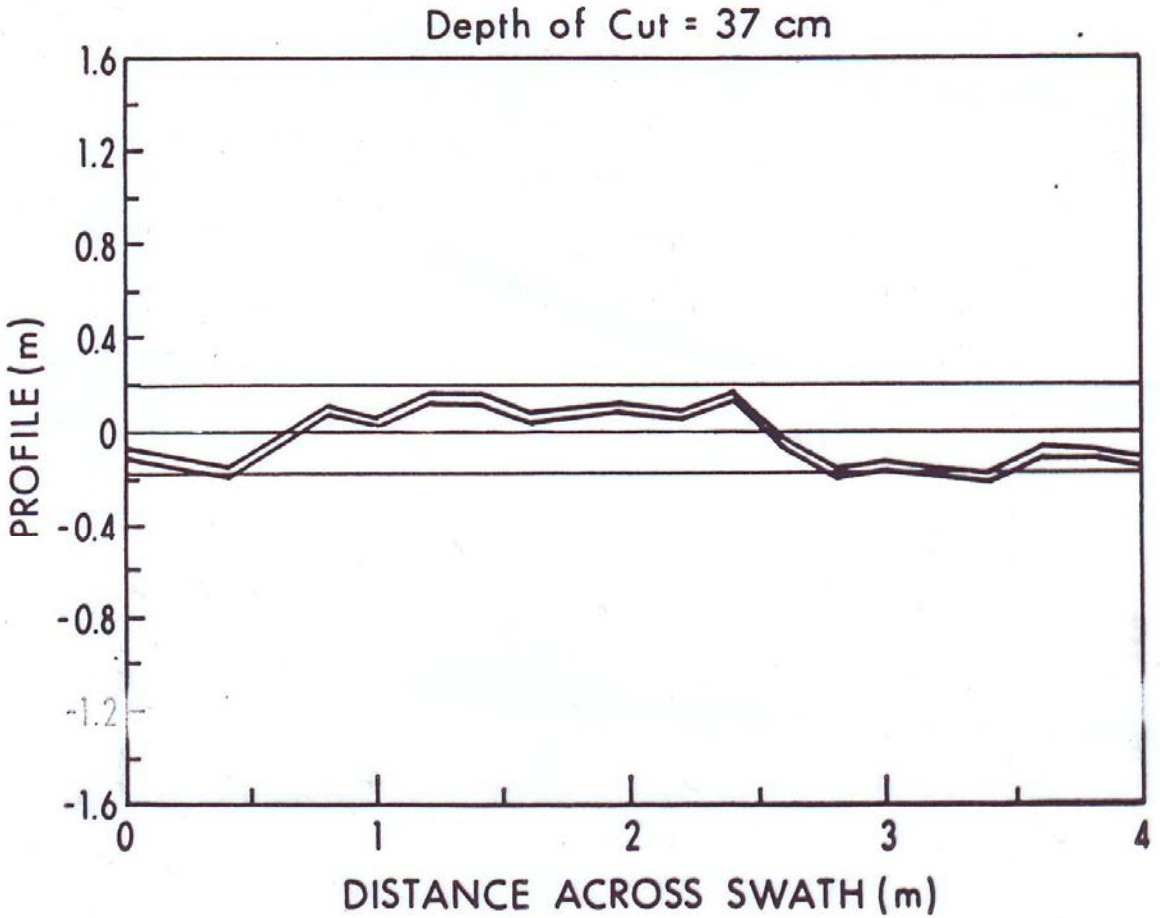


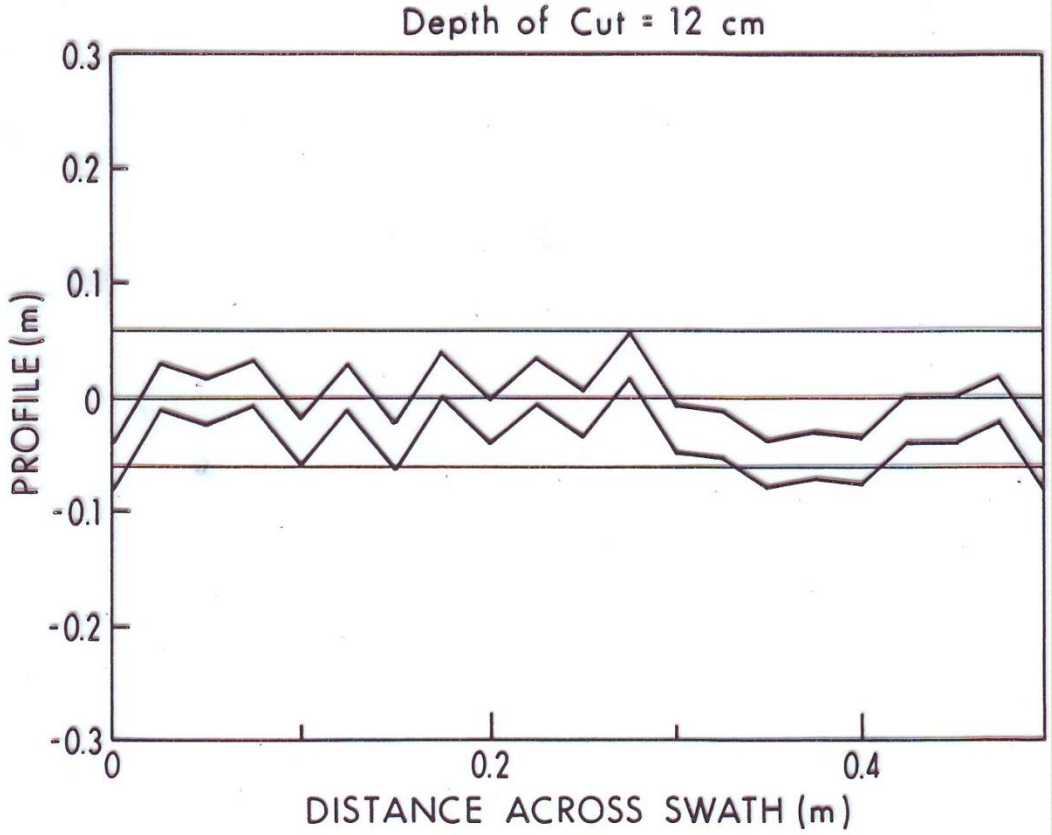

Figure 4-4. Base-case material flows (wet weight)

BASE-CASE MINING PARAMETERS
(25% Substrate in Recovered Ore)

| Operation | Recovery Efficiency (%) |
|---|---|
| Crust Fragmentation | 80 |
| Pickup Crusts | 95 |
| Pickup Substrate | 95 |
| Separation @ 0.25 m/s | |
| Crust Recovery | 68 |
| Substrate | 52 |
| Shipboard Dewatering | |
| Crust | 98 |
| Substrate | 98 |
| Beneficiation | |
| Crust | 90 |
| Substrate | 10 |

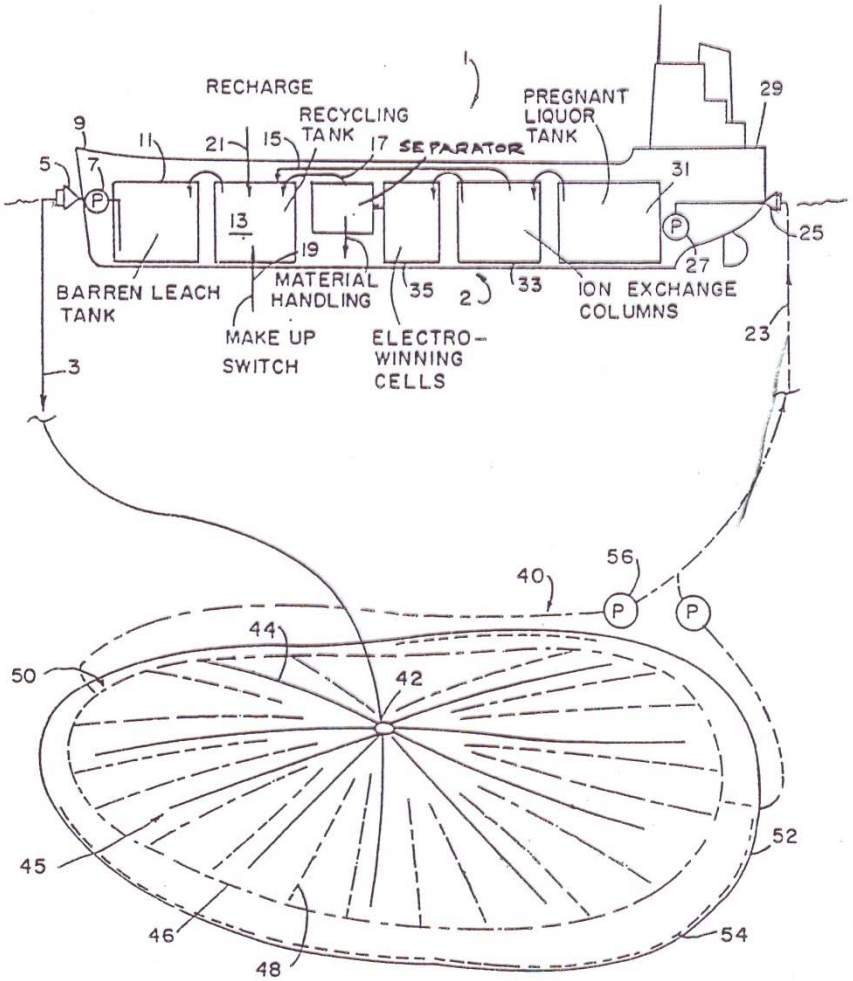



Example of "Level" Cutting Line (Example Profile Across 4.0-meter Swath).




Example of "Level" Cutting Line (Example Profile across 0.5-meter Swath).

FIG. 1


RECHARGE
RECYCLING TANK
SEPARATOR
PREGNANT LIQUOR TANK
BARREN LEACH TANK
MATERIAL HANDLING
MAKE UP SWITCH
ELECTRO-WINNING CELLS
ION EXCHANGE COLUMNS
1
2
3
5
7
9
11
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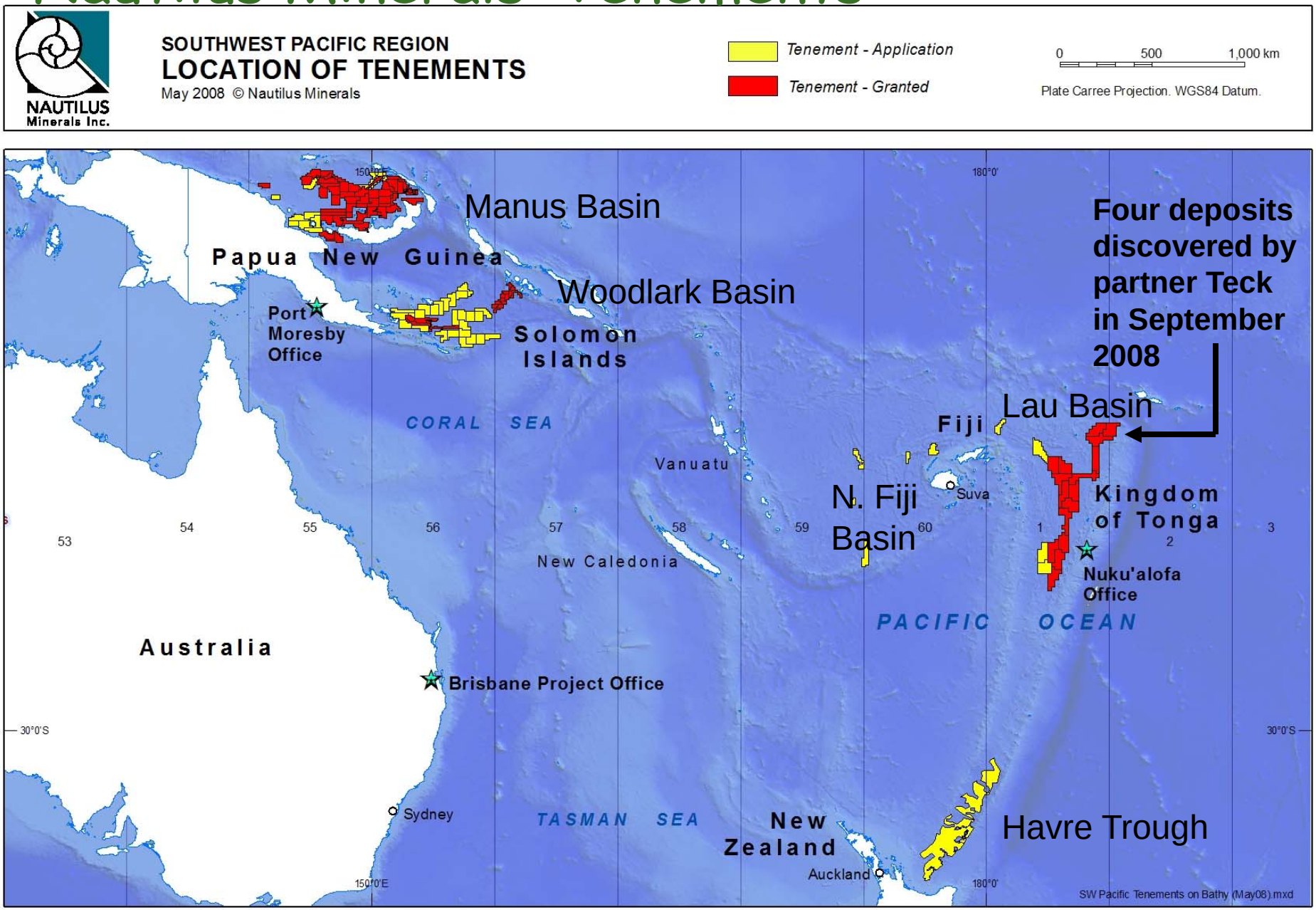
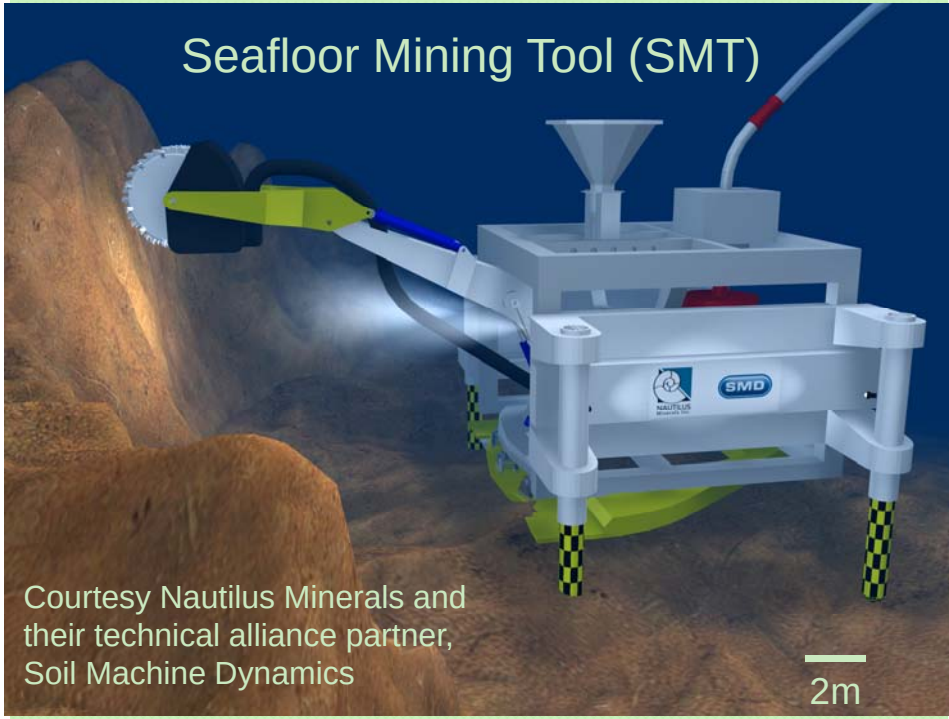
# Nautilus Minerals' Tenements



# Mining system to be deployed by Nautilus Minerals

North Sea Shipping (Bergen, Norway) to provide a new 160m dynamic positioning Mining Support Vessel (MSV) on 5 year lease with an option for 5 more years




Technip (Houston) to build RALS using offshore oil technology and Soil Machine Dynamics (UK) to build two 6000 peak tpd SMTs

**Mining to start in 2013 subject to timely permitting by PNG**

# Extracting Value - Seafloor Mining Tools (SMTs)

- Soil Machine Dynamics (UK) contract to design and build
  - Experts in deep sea ROV and trenching machine design
  - US$84 million contract for three specialized mining machines
  - Includes control systems and associated umbilicals, handling, and deck equipment
- Engineering has been underway for over two years
- Contract suspension released in March 2009

**Auxiliary Miner**– cuts ore on uneven surfaces; benching the site

**Bulk Miner**– cuts ore at high rates on areas benched by Auxiliary Miner

**Gathering Machine** – slurries cut ore with seawater and transfers to RALS

# Existing Seafloor Trenching and Mining Equipment

RT-1 from SMT facility (contractor for Solwara 1 equipment)

Second generation 200 ton offshore diamond mining machine, DeBeers, Namibia
Courtesy Marine Minerals Pty

- 30+ years seafloor trenching for pipelines and communications
- De Beers 20+ years seafloor crawlers for diamond mining
- Utilizing cutting expertize from

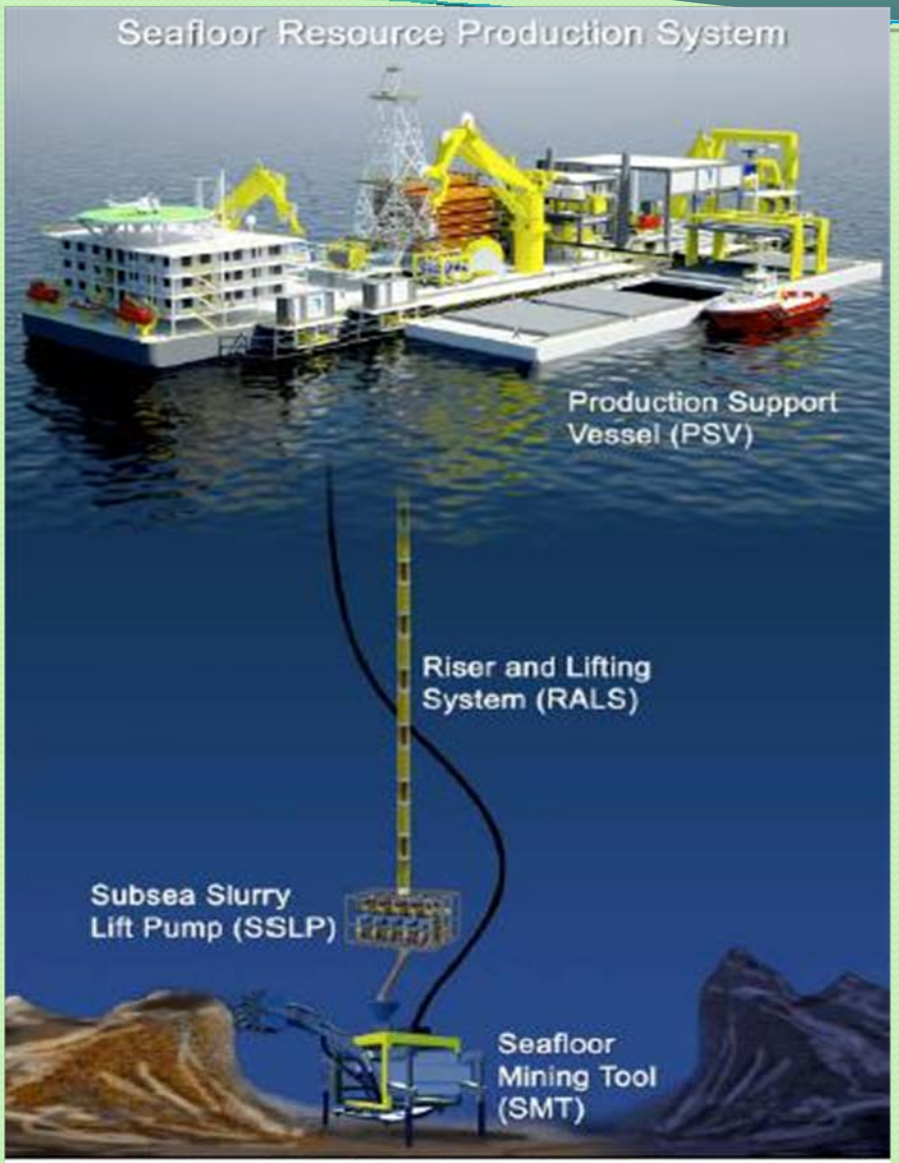
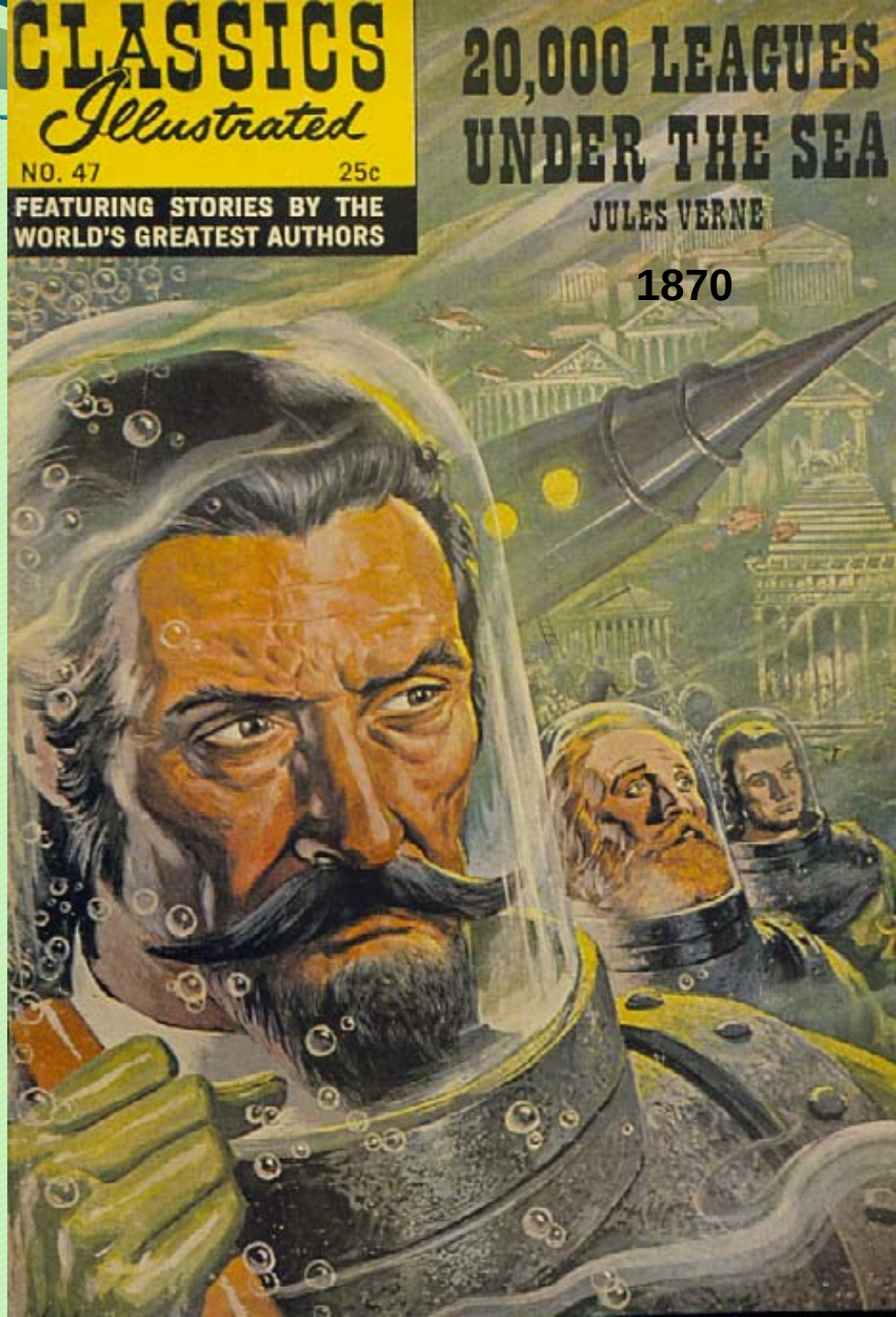



**Figure 19-5: Seafloor Resource Production System**

"... in the ocean depths, there are mines of zinc, iron, silver and gold that would be quite easy to exploit"