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Future Deep Ocean Resources and the Technologies for Commercial Development

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Abstract. During the 11 year period of 1995-2005, there was about a 40% increase in the world copper demand mainly because of the Asian economic growth. In the increase, about a half was consumed by China. Most of the China's copper demand increase has been taken place over the final 5-6 years of that period. The growth is expected to continue for several years, and in 10 years or sooner the same situation is expected for India. Copper is the third metal in global demand, but its little abundance in the Earth's crust is not well recognized. From the production rate and the abundance, a copper shortage, or crisis, has a high probability than the other metals. Deep ocean mineral resources such as manganese nodules in the Clarion-Clipperton Fracture Zones, Kuroko-type massive seafloor sulfides (SMS), and cobalt-rich manganese crusts in the EEZ and the high sea areas have big potentials for the future sources. We need to re-evaluate their potentials as copper resources and other metals to realize their developments. The same situation is under progress in the hydro-carbon markets. Methane hydrates that are classified into non-conventional hydro-carbon resources have an important role as the future sources, too.

Introduction

Manganese nodules, seafloor massive sulfides, and cobalt-rich manganese crusts in deep ocean have been considered as future metal sources [1, 2, 3]. Manganese nodules were the first recognized deep ocean mineral resource and many efforts concentrated on the R&D of mining systems [4, 5, 6] and assessment of environmental impacts [7, 8, 9]. No mining venture, however, has been active for this potential resource. The reason is that the rate of world economic growth in these 3 decades has been slower than anticipated in 1960s.
The potential of natural methane hydrates for an energy resource has been highlighted and a national R&D project to fined out the deposits and to develop the exploitation technologies has been conducted in Japan since 2000 [10]. There is less domestic oil and natural gas resources in Japan, but many potential deposition areas for methane hydrate in ocean around Japan are the alternative reasons. However, because methane hydrates distribute in shallower sediment layer in ocean floor and the accumulation may not be sufficient as a bulk energy resource, technical and economical difficulties have been expected for the development.
Because of the recent market trends, however, both the deep ocean minerals and methane hydrates may be commercially developed in 10 to 20 years or earlier. The market situations are introduced and the technical and commercial realities are discussed in the paper.

Deep Ocean Minerals

Recent Metal Market Trends. Copper is one of popular metals in the human history and the daily life. The amount of production is the third largest in metals [11] as shown in Table 1. It is about a half of aluminum one. The abundance, however, is three orders less than aluminum [12]. The unbalance between the production and the abundance is the most significant in metals. Because of this higher consumption compared with the abundance, copper is fundamentally the most dangerous in the shortage. On the other hand, as shown in Fig. 1, the demand in China has been quickly increased [13]. The growth is expected to continue for several years, and in 10 years or sooner the same situation is expected for India. The recent trend of copper price shown in Fig. 2 [14] is affected with these circumstances. The same trends have been remarkable in the metal markets as shown in Fig. 3 [14].

Table 1 Metal production and abundance

Metal or product	World production in 2004 [metric ton] [11]	Abundance in earth's crust [ppm in weight] [12]
Platinum	467	0.01
Mercury	1260	0.08
Gold	2430	0.004
Silver	19700	0.07
Cobalt	52400	25
Molybdenum	141000	1.5
Tin	262000	2
Magnesium	584000	23300
Nickel	1390000	75
Lead	3110000	12.5
Zinc	9600000	70
Copper	14600000	55
Manganese ore	26300000	950
Alminium	29800000	82300
Steel	105000000	56300

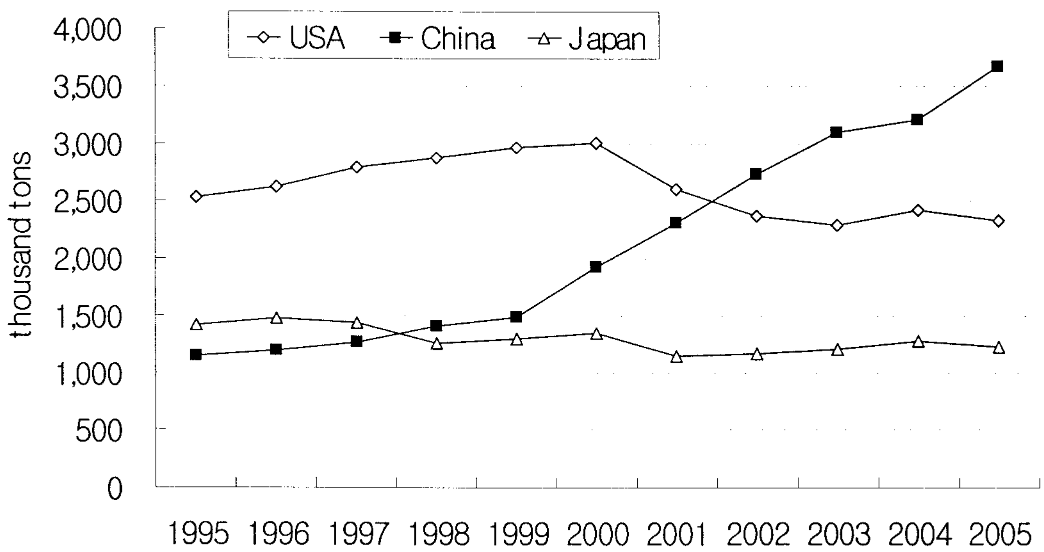

Fig. 1 Trend of copper demands in the world top three countries [13]

Potential of Deep Ocean Minerals. Japan has a mining clam for manganese nodules in the Clarion-Clipperton Fracture Zones [15] and found some attractive Kuroko-type SMS in the EEZ [16, 17]. The two contain considerable percentage copper for the resources. Therefore, it is necessary to concentrate our efforts in developing these resources. Because Japan has no domestic on-land copper resource, the roles of these resources are much significant than the other countries. The preliminary economic validity analyses have been already introduced [18, 19, 20].

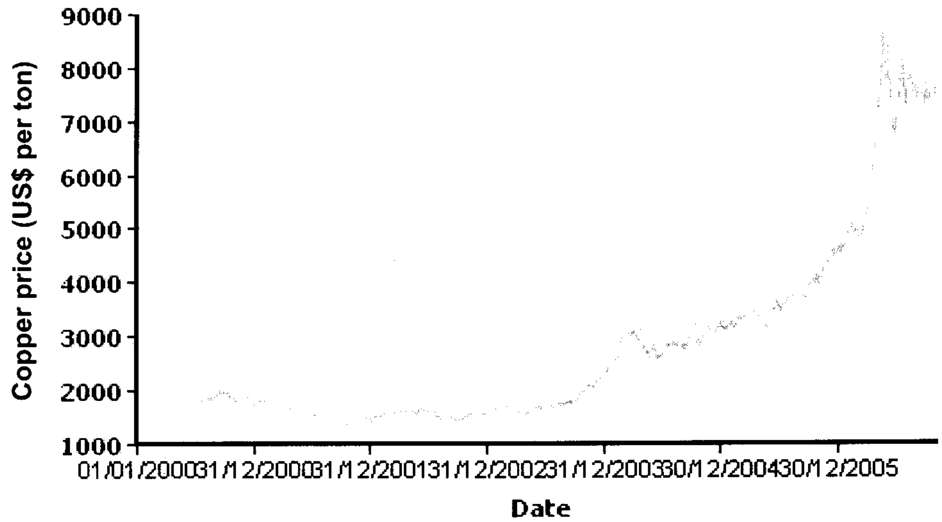

Fig. 2 Recent trend of copper price [14]

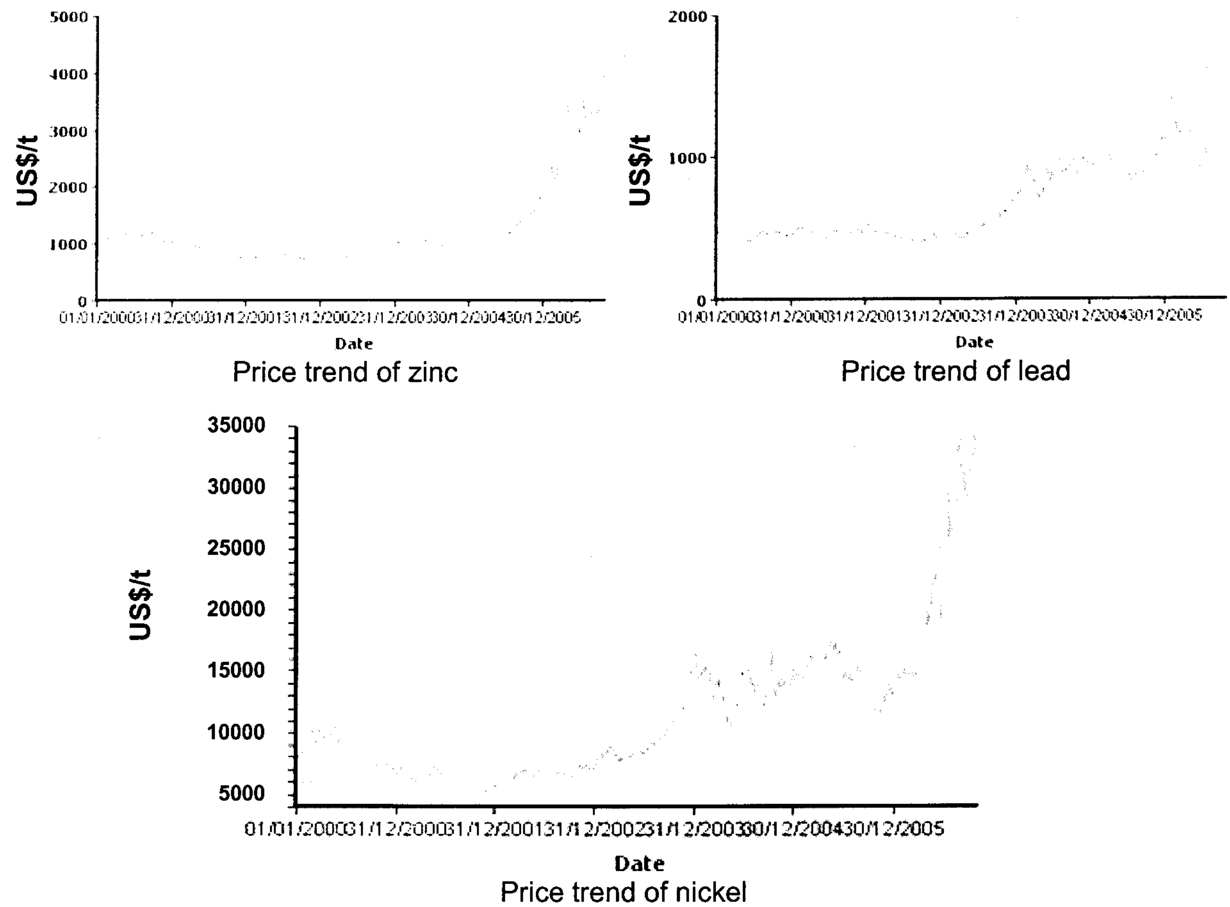

Fig. 3 Recent trends of zinc, lead, and nickel prices [14]

Methane Hydrates

Recent Oil Market Trends. Because of China's economic growth and the increasing energy demand, oil market price gradually increased from 2002. The recent oil crisis-like quick increase was triggered in September 2005 by the Hurricane Katrina as shown in Fig. 4 [21]. Though the current status is relatively gentle and cheaper, however, the tight supply situation has not yet be solved. The long term price trend is expected to increase gradually. Therefore, it is necessary to look for a chance of methane hydrate development for Japan.

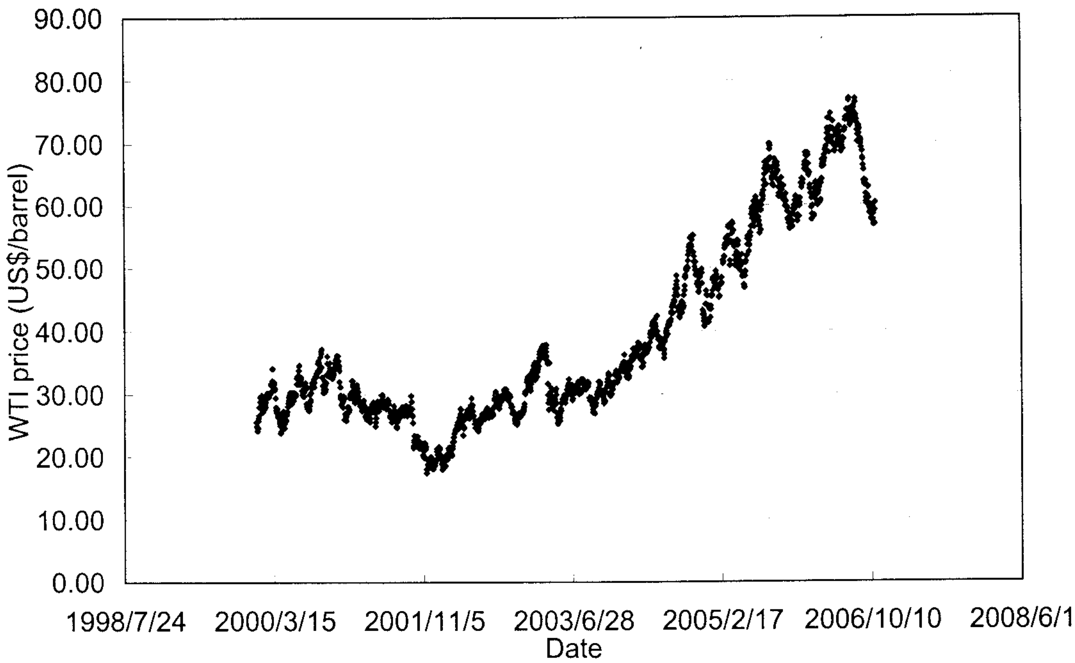

Fig. 4 Recent trend of oil price [21]

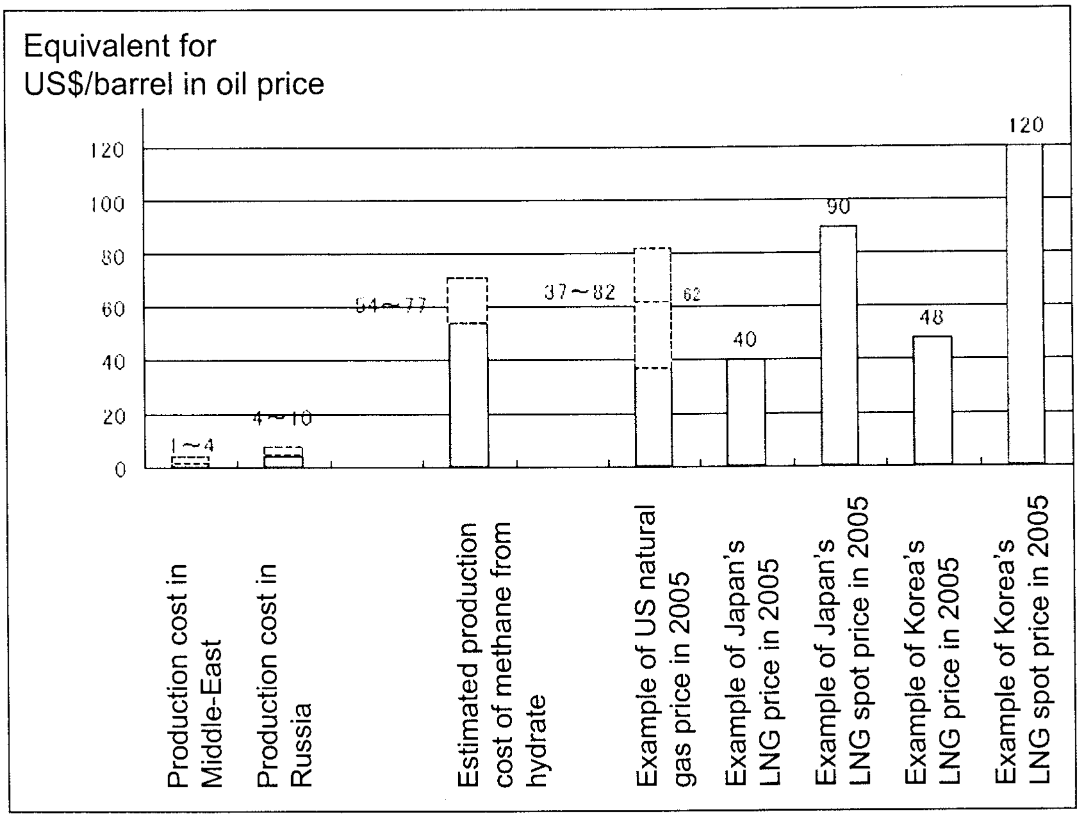

Fig. 5 Preliminary cost estimation of methane production from hydrates [22]

Preliminary Cost Estimation of Methane Production from Hydrate. Results of survey test drilling in Nankai Trough Area in 2004 showed less accumulation of methane hydrates in sediment layer than the one expected. The hydrate bearing strata are composed of silt-sand sediments and less permeable than the ones expected. Both the characteristics were considered to be negative for methane production from the hydrates. The quick increase of oil price after the Hurricane Katrina, however, again re-spotlighted the possibility in commercial development. The Ministry of Economy, Trade and Industry has estimated the methane production cost from hydrates in Nankai Trough Area in 2006. It is equivalent for US$54-77 per barrel in oil price [22]. The comparisons among other hydro-carbon prices in 2005 are summarized in Fig. 5.

Technical and Commercial Realities of Deep Ocean Mining

Heavy Duty ROVs. Some heavy duty ROVs are under actual operations in ocean. The marine diamond miner in Namibia and seafloor cable trencher shown in Fig. 6 [23] are the examples. These ROVs realize seafloor miner for deep ocean minerals. The ROVs are also popularly used in marine oil industries both in survey and production phases.

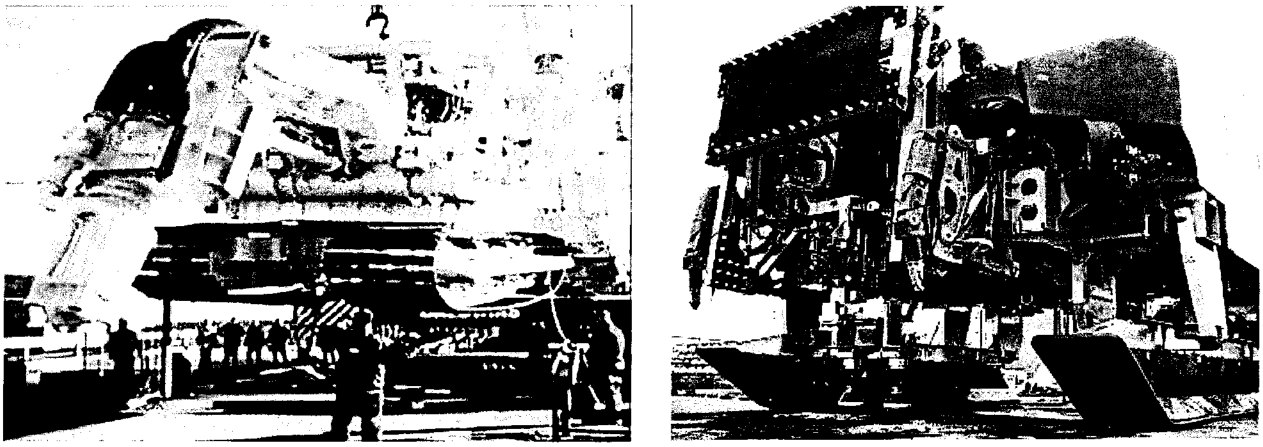

Fig. 6 Heavy duty ROVs (left: marine diamond miner, right: 1,000HP cable trencher) [23]

Deep Sea Drilling Vessel (D/V) *CHIKYU*. D/V *CHIKYU* shown in Fig. 7 is the first riser equipped scientific drilling vessel built for earth sciences. It is capable of drilling up to 7,000m deep in seafloor at maximum water depth in 2,500m. The vessel length is 210m, breadth 38.0m, height 130m (from ship bottom to top of drill rig), depth 16.2m, draft 9.2m, and gross tonnage 57,087 tons, respectively [24]. The maximum length of drill string is 10,000m and 13-14cm in diameter, maximum length of riser pipe 2,500m and 50cm in diameter. The derrick hanging capacity is 1,250 tons. D/V *CHIKYU* has finished the first riser drilling test offshore Shimokita peninsula, Japan.

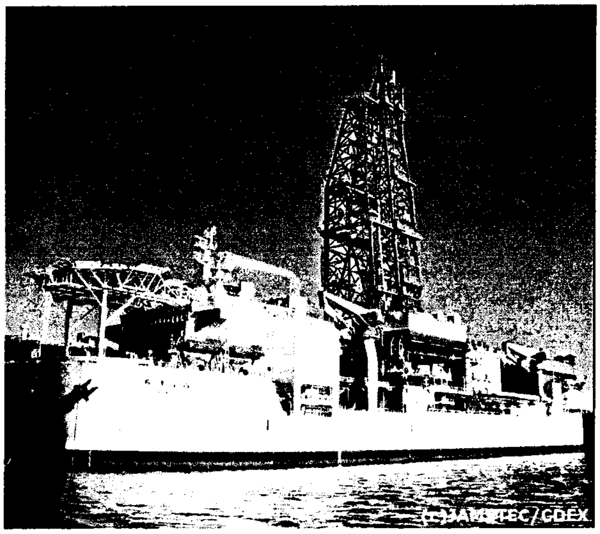

Fig. 7 Photo of D/V CHIKYU [24]

From November 2006 through August 2007, D/V *CHIKYU* goes to offshore Kenya and Australia for 2,500-4,400m deeper drilling experiences at water depths 1,000-2,200m. These cruises are planned to build up knowledge of drilling techniques in a variety of geological conditions. The operations planned for these cruises will keep D/V *CHIKYU* on track to complete its deep-sea scientific drilling mission; these ongoing sea trials will permit D/V *CHIKYU* to implement riser drilling in international operations smoothly. The experience gained through work at these sites will build the mastery of drilling techniques necessary to carry out D/V *CHIKYU*'s future mission.

Comparisons between D/V *CHIKYU* and Deep-Ocean Mining System. The mining system assumed in the preliminary economic analyses [18, 20] for manganese nodules are almost the same as D/V *CHIKYU*. The vessel length is 235m, beam 43m, hull depth 16.5m, draft 12.5m, and loaded displacement 100,000 tons, respectively. The total weight of pipe and flexible hose hanged by the derrick is about 1,000 tons. The nodule distribution water depth is 4,000-6,000m. The construction cost of nodule mining system is estimated about US$203 millions and operating cost about US$56 millions per year in 2004 economic factors, respectively. The construction cost of D/V *CHIKYU* is about US$540 millions and operating cost is estimated about US$85 millions per year, respectively. If we consider the differences between industrial and scientific conditions, the sizes and costs show good agreements. The construction and operation experiences are important for the mining system of course.

Concluding Remarks

The economic circumstances for deep ocean resources have been drastically improved these several years. It is necessary to cover our future demands in energy and metals with the development of deep ocean resources. Actual experiences in deep ocean in ROV and scientific drilling are helpful for realizing the development of deep ocean resources.

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