公益財団法人日本国際問題研究所
The Japan Institute of International Affairs

POLICY BRIEF

June 29, 2020

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Mining and R&D of Rare Earth Elements: Prospects, Challenges, and Avenues for Indo-Japan Partnership

Dr. Monika Chansoria

The prospects for exploring seabed minerals, specifically rare earth elements (REEs) have risen courtesy technological innovations in the field of deep-sea exploration. REEs are identified as a group of 17 chemical elements in the periodic table, found relatively in abundance in the Earth's crust.[1] They share similar chemical and physical properties and are of vital use in a variety of sectors, including by military manufacturers and technology firms. The largest subgroup within the REEs are the 15 lanthanides. The two other elements being scandium and yttrium. Based on quantity, the lanthanides, cerium, lanthanum, and neodymium are the most produced rare earths elements.[2] These elements earn the distinction of being 'rare' for their availability in quantities which are significant enough to support viable economic mineral development of the deposits. However, from a cost-effective point of view, they are not consumable. It is not economically viable to extract these elements for consumption purposes since they are not concentrated enough and remain thinly dispersed as deep as 6.4 kilometers underwater.[3]

According to the January 2018 US Geological Survey report, the worldwide reserves of rare earths are approximately 120 million metric tons, of which, China alone has 37 percent or 44 million metric tons (Mt) of reserve. Brazil and Vietnam jointly occupy the second position with 22 million Mt of reserve each, followed by Russia in the third place with 18 million Mt. India, Australia and United States come next with 6.9 million Mt, 3.4 million Mt and 1.4 million Mt

1 For further details see, Monika Chansoria, "Indo-Japanese Strategic Partnership: Scope and Future Avenues," *Note de la FRS*, no. 17, Fondation pour la Recherche Stratégique, Paris, September 19, 2017.

2 "Rare earth reserves worldwide as of 2019," cited at https://www.statista.com/statistics/277268/rare-earth-reserves-by-country/

3 Monika Chansoria, "India, Japan alliance must for rare earth search," *The Sunday Guardian*, October 17, 2015.

respectively.[4] Raw rare earth discoveries in Canada, Burundi and Tanzania are expected to reduce China's stronghold on REEs supply, given that Beijing remains the major power in the REEs industry, accounting for more than 80 percent of supply, and over 66 percent of global demand, as per 2017 figures.

The prospects for exploring seabed minerals has attracted the attention of marine scientists and technology experts globally. This quest received a momentous fillip for Japan when a team of Japanese researchers—led by Yutaro Takaya of Waseda University, along with the University of Tokyo, and the Japan Agency for Marine-Earth Science and Technology or JAMSTEC—published a significant study in *Scientific Reports* on April 10, 2018.[5] The study revealed that an estimated 16 million Mt of REEs—enough to fulfill global demands potentially for hundreds of years on a semi-infinite basis have been discovered in Japanese waters near Minami-Torishima, an island in the Ogasawara Island group located about 1,800 kilometers southeast of Tokyo. The study declared that the deposits are spread across a 2,500-square-kilometer area within Japan's exclusive economic zone.[6] This rare earth resource discovery has pushed Japan among the top countries having such a colossal volume at its disposal. However, the resources are located deep inside the seabed, thereby posing a challenge to devise a commercially viable technique to extract the deposits. Presently there is no profitable way of extracting rare earths from that depth. According to experts, it takes almost a decade or more to advance a rare-earth project from discovery to full-scale commercial mining.

Rare Earth Import Dependencies on China

By means of mining almost 89 percent of the world's rare earth elements output until 2011, China restricted the exports of these elements by employing quotas and export tariffs. The policy was seemingly aimed at maintaining lower prices for Chinese firms, through which Beijing managed to obtain a one-sided competitive advantage in the international marketplace. While Chinese-owned companies were allocated 74 percent of the rare-earth products export quota, joint ventures with foreign partners stood at 26 percent.[7] China's rare earth export policies induced foreign rare earth users to move their operations into China, and subsequently, to transfer technology to Chinese firms.[8]

In reference to this, the World Trade Organization panel took note of China's rare earth export restrictions, and following detailed examination concluded that the export duties on rare earths, tungsten, and molybdenum were inconsistent with China's obligations under WTO Accession Protocols.[9] The panel

4 For related readings see, Marc Humphries, "Rare Earth Elements: The Global Supply Chain," *Congressional Research Service Report for the Congress*, December 16, 2013.

5 For details see, "Semi-Infinite supply of rare-earth elements found in Japan," *Waseda University News*, Tokyo, April 13, 2018; also see, Monika Chansoria, "Newly-Discovered 16 Million MTs of Rare Earth Minerals Can Make Japan Independent of China," *Japan Forward*, June 1, 2018, available at https://japan-forward.com/newly-discovered-16-million-mts-of-rare-earth-minerals-can-make-japan-independent-of-china/

6 Ibid.

7 Chansoria, *Note de la FRS*, n. 1.

8 For details see, Wayne M. Morrison and Rachel Tang, "China's Rare Earth Industry and Export Regime: Economic and Trade Implications for the United States," *Congressional Research Service Report for the Congress*, April 30, 2012.

9 For more details see, *China—Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum*, Dispute Settlement DS431, World Trade Organization, March 13, 2012, available at https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm; and see, Morrison, et al., n. 8.

established that China's export quotas on rare earths, tungsten, and molybdenum were inconsistent with the General Agreement on Tariffs and Trade (GATT) Article XI, and that export quotas were not justified under the exception in GATT Art. XX (g) "relating to the conservation of exhaustible natural resources."[10] The panel further found that none of China's arguments constituted cogent reasons for departing from the WTO appellate body's finding. More significantly, the WTO panel noted that the restrictions China had imposed on the trading rights of enterprises exporting rare earths and molybdenum—such as minimum registered capital, prior export experience and export performance—are contrary to paragraphs 83 and 84 of China's Working Party Report on the issue.

China is the world's biggest rare-earth consumer and has not displayed focus on exporting rare earth elements for profit. Instead, it accumulated the same to feed the needs of its domestic high-tech industries and also encourage foreign corporations to manufacture inside China.[11] The phenomenon of imposing a "rare earth metals embargo" was interpreted as a potent tool that China's policymakers sought to intertwine with the larger objective of securing other geopolitical objectives.[12]

The leading export markets for China's REEs are Japan, the United States, and France. Two REEs, namely yttrium and scandium have been subjected to 10 percent levies as part of the $200 billion worth of Chinese products facing tariffs by the Trump administration.[13] China's rare earth policies are part of a complex web of its industrial policies that seek to promote the development of domestic industries deemed essential for economic modernization.[14] The US was the world's leader in production of rare earth metals until the 1980s, post which, China overtook this lead completely.

As per data by the US International Trade Commission, Beijing is the largest exporter of REEs to the United States that have been targeted by tariffs. The figure accounts for nearly 60 percent of the $234.4 million imported to America.[15] China's influence extends well beyond raw materials from refining to making components that use rare earth materials. Dudley Kingsnorth, Executive Director of the Industrial Minerals Company of Australia, notes that China's road ahead is evidently clear with its "Made in China 2025" strategy to modernize the country and encourage development of technology domestically, instead of relying on foreign companies.[16] "The US imposing a 10 percent tariff on rare earths will assist China to become dominant … manufacturers in the US will find it difficult to purchase rare earths and incorporate them in equipment and be competitive with China," Kingsnorth summarized.[17]

In the above context, the 16 million Mt rare earth deposits discovery by Japan can theoretically free Tokyo from overt dependence

10 Ibid.
11 Lee Simmons, "Rare Earth Market," *Foreign Policy*, July 12, 2016.
12 Monika Chansoria, "China monopolizes rare earth trade," *The Sunday Guardian*, September 12, 2015.
13 "Is the US shooting itself in the foot with tariffs on Chinese rare earth elements?" *South China Morning Post*, July 13, 2018, available at https://www.scmp.com/business/commodities/article/2155101/us-shooting-itself-foot-tariffs-chinese-rare-earth-elements
14 Morrison, et al., n. 8.
15 For related information see, "U.S. dependence on China's rare earth: Trade war vulnerability," *Reuters Business News*, June 28, 2019.
16 For detailed and related reading see, *Commodities at a Glance: Special Issue on Rare Earths*, no. 5, United Nations Conference on Trade & Development (UNCTAD), Geneva, 2014.
17 Ibid.

on Chinese supply. The heavy dependency on rare earth imports from China can be gauged from the fact that Japan receives 82 percent of its rare earth elements from China. On the contrary, for Beijing, rare earth elements exported to Japan stand at just 40 percent. In March 2012, the Obama administration had announced its decision of jointly filing a case along with Japan and the European Union (EU) against China at the World Trade Organization, citing unfair trade practices in rare earths and limiting rare earth exports.[18] In what proved to be a major setback for Beijing, the WTO found China in clear violation of global trade rules.[19] Subsequently, Beijing lost the August 2014 appeal, with the Appellate Body ruling, "China has not demonstrated that the export quotas that China applies to various forms of rare earths ... by virtue of the series of measures at issue are justified." The WTO further stated that China's export duties on rare-earth metals are inconsistent with its obligations.[20] Subsequently, all export quotas for rare earths were abolished.

Given the scope of dependencies elaborated above, nations have observably been increasingly reliant on importing rare earth elements from China, primarily owing to two reasons: 1) almost 75 percent of the permanent Nd-Fe-B magnet production is concentrated in China; and 2) the cost of operations is comparatively lower. It would not be an exaggeration to point out that there is nearly one-sided Chinese dominance in global rare earth production.[21] This consequently has driven Beijing to employ restrictive export policies over these elements. Besides, China holds 37 percent of the world's natural rare earth reserves and a reserve base of 89 million metric tons. The Industrial Minerals Company of Australia (IMCOA) has estimated China's REEs output at around 130,000 tons per year in 2016 (up from 105,000 tons in 2011).[22]

Very recently, China has published a second batch of products to be exempt from US trade war tariffs, effective from May 2020 until one year. China's Ministry of Finance issued a list of 79 items, including rare earth mineral ores, among others. Importers in China are required to apply to the General Administration of Customs within six months of the announcement to be considered for waivers. The first batch of exclusions were announced in September 2019. China's imports of US goods fell by a colossal 85.5 percent in March 2020, and by 11.1 percent in April 2020, as per data released by Chinese customs.[23]

According to an April 2020 report, a remote Mountain Pass mine in the US' California desert is poised to get a boost from the Pentagon. The mine is America's only domestic source for rare-earth minerals—critical for applications used in weapons systems for national defense.[24] The minerals require special processing after extraction, which is carried out in China since the US does not possess any facilities to do so. To eliminate the dependence of processing these minerals following their extraction, the

18 WTO, DS431, n. 9.

19 Chansoria, *Note de la FRS*, n. 1.

20 Ibid.

21 Ibid.

22 Ibid.

23 "China announces new raft of US imports eligible for trade war tariff waivers amid rising superpower tensions," *South China Morning Post*, May 12, 2020, available at https://www.scmp.com/economy/china-economy/article/3083973/china-announces-new-raft-us-imports-eligible-trade-war-tariff

24 As cited in, Timothy Puko, "Pentagon Invests in Strategic Metals Mine, Seeking to Blunt Chinese Dominance," *The Wall Street Journal*, April 26, 2020, available at https://www.wsj.com/articles/pentagon-invests-in-strategic-metals-mine-seeking-to-blunt-chinese-dominance-11587924001?mod=searchresults&page=1&pos=1

Department of Defense is assisting to fund developing a processing facility at the Mountain Pass mine, controlled by the Chicago hedge fund JHL Capital Group.[25]

The ongoing global pandemic caused by the Coronavirus, which originated from Wuhan in China, has impacted upon supply-chain issues because of which the industrial policy is in the midst of a long-term crisis. The eventual possibility of nations ramping up rare earth production/seeking alternative sources of rare earth materials, will not take away the reality that a major part of the processing, alloying, and metal fabrication would still apparently take place in China. This would be concentrated largely in the Chinese provinces, namely, Jiangxi, Guangdong, Hunan, Shandong, Fujian, Yunnan, and Sichuan, and in the Autonomous Regions of Guangxi and Inner Mongolia. The supply of REEs to consumers outside of China is determined not by mine capacity but by production and export quotas set by China's Ministry of Commerce (MOFCOM) and the Ministry of Industry and Information Technology. With as many as six large state-owned Chinese companies in the fray, it will be a challenge for other countries to profitably match the production level or integration of China's rare earth operations.

The availability of rare earths is in transition from a temporary decline mainly due to quotas being imposed by China on exports. This reduction in availability coupled with increasing demand, led to an increase in prices of rare earths in 2012 and 2013.[26] The increasing demand for rare earths in a range of applications meant that the rare earth market will likely remain demand-driven in times to come. This particularly shall be the case for rare earths used in high field strength magnets.[27] Notwithstanding the ruling of the WTO, China continued expansion of seabed mineral explorations in southwest of the Indian Ocean Region—facilitated as the follow-up of an approval of China's bid by the International Seabed Authority to mine for polymetallic sulphide ore. China's Ocean Mineral Resources R&D Association signed a 15-year exploration contract with the International Seabed Authority that shall grant pre-emptive rights for it to develop ore deposits in the future.

Beijing released a significant guideline pertaining oceanic science and technology development from 2011-2015—a key pronouncement of which was promoting investments to boost China's maritime economy. The guideline prepared jointly by China's State Oceanic Administration, the Ministry of Science and Technology and the Ministry of Education and the National Natural Science Foundation, underscored the growing emphasis on innovation for breakthroughs in key technologies that would stimulate development of emerging oceanic industries.[28] In January 2015, Beijing's manned deep-sea submersible vessel, Jiaolong carried out its first dive mission to research polymetallic sulphides, hydrothermal microbes, and genetic resources during a four-month long expedition.

By means of securing the approval for seabed exploration, Beijing acquired access to explore a 10,000 sq km seabed area in southwest Indian Ocean—making a case for harboring strategic-security concerns for regional players including India and Japan.[29] Following a total of 13 dives, Jiaolong successfully discovered

25 Ibid.

26 For details see, N. Haque, A. Hughes, S. Lim, and C. Vernon, "Rare Earth Elements: Overview of Mining, Mineralogy, Uses, Sustainability and Environmental Impact," *Resources*, no. 3, 2014, p. 630.

27 Ibid.

28 Chansoria, *Note de la FRS*, n. 1.

29 Ibid.

active hydrothermal “chimney vents” in the southwestern Indian Ocean in March 2015. Apparently, China had ‘offered’ India to participate in joint seabed mining in the Indian Ocean, given that both are contractors with the International Seabed Authority. Chen Lianzeng of China’s State Oceanic Administration made the offer for joint seabed exploration in May 2015. India’s Directorate of Naval Intelligence reportedly expressed concerns regarding Chinese operations of its warships in the Indian Ocean Region. While the manifest objective of China’s operations in the IOR was ‘compiling data on vast mineral resources,’ ‘area familiarization purposes’ too were simultaneously getting served for the Chinese military.

Global Defense Equipment Industry: Significance of Rare Earth Elements

The most significant end-use of rare earth elements is found in defense-related applications such as jet fighter engines, precision-guided missile systems, anti-missile defense, satellite and communication systems, lasers, radars, solar night vision systems and the alloys on armored vehicles.[30] REEs are found in two types of commercially available, permanent magnet materials, i.e. samarium cobalt (SmCo), and neodymium iron boron (Nd-Fe-B), both considered the world’s strongest permanent magnets which remain indispensable for many military weapons systems.[31] While the SmCo retains its magnetic strength at elevated temperatures, rendering it ideal for military technologies such as precision-guided missiles, smart bombs, and aircraft, it is the superior strength of Nd-Fe-B magnets containing a small amount of added dysprosium that allows for the use of smaller and lighter magnets in defense weapon systems.[32]

More specifically, rare earth metals in defense-related applications remain essentially vital for:

1) Fin actuators in missile guidance and control systems, controlling the direction of the missile
2) Disk drive motors installed in aircraft, tanks, missile systems, and command and control centers
3) Lasers for enemy mine detection, interrogators, underwater mines, and countermeasures; and
4) Components for satellite communications, radar, and sonar on submarines and surface ships, and optical equipment and speakers.[33]

In defense equipment terminology, being strategic primarily is what serves as a critical component in weapon platforms such as aircraft, ships, armored vehicles, in addition to sensors, radars, optronics systems, and command, control, communications, intelligence, surveillance and reconnaissance systems. In economic terms, being strategic denotes facilitating the supply of power to the economy, delivering mass consumer product industries, serving as key feedstock for high technology in the civilian industries.[34] The US’ Strategic and Critical Minerals 2013 Report, the British House of Commons Science and Technology Committee’s list, and France’s Committee

30 Ibid.

31 For more details see, Reed M Izatt, “Military Success, Rare Metals and the Periodic Table,” *Investor Intel Corp.*, January 28, 2016.

32 Ibid.

33 For a detailed debate on the subject see, Reed M Izatt, et al., “Challenges to Achievement of Metal Sustainability in Our High-Tech Society,” *Chemical Society Reviews*, vol. 43, 2014, pp. 2451-2475.

34 For more details see, Keith Campbell, “Strategic minerals and the aerospace and defense industries: Vulnerability and Criticality,” *Creamer Media Mining Weekly*, April 30, 2015.

for Strategic Metals set up by the Ministry of Industry, much alike, do not distinguish those metals that are strategic, specifically in defense, or economic terms.

Role in Clean Energies and Associated Technologies

REEs have an instrumental role in increasing the production of clean energies and associated technologies. They increase performance in electric power steering motors, wind and hydropower turbines, high-performance batteries, energy-efficient appliance motors, magnetic refrigeration, and fuel cells that contribute to reducing greenhouse gas emissions and mankind's dependence on fossil fuel. In particular, neodymium and praseodymium (Nd-Pr) are most common in the manufacture of permanent magnet alloys. The use of permanent magnets in electric motors for hybrid and electric vehicles is forecast to create a sustained demand growth for these materials. The ore grade and recovery of particular REEs is a primary factor in deciding upon related environmental footprints. For instance, Lanthanum and Cerium is generally available in higher amounts in ore and concentrate and thus can be recovered more readily compared to other REEs.[35] Since the energy footprint of REE oxides is similar to that of other metals, the footprints of REE metals would be significantly higher (with further processing stages). Most REEs are expectedly used in energy reduction, energy efficiency and renewable energy technologies.[36] To reduce greenhouse gas impact of REEs processing, the focus needs to be on how to reduce the acid and energy consumption during the processing stage.[37]

A number of key technologies such as medical R&D, and energy technology use rare earth elements. They are vital also for hi-tech lasers, battery electrodes, magnets, MRI contrast agents, catalysts, alloys, etc. Consumer electronics too require REEs for cell phones, laptops, and green energy technologies. It is expected that in the near future, most of the rare earth metals will be needed for magnets and metal alloys. Alloys created with scandium and aluminum are used for fighter jets and lightweight frames for mountain bikes, while yttrium is used in the manufacture of lasers and LED lights. Cerium is often found in cigarette lighters and flat-screen televisions. Another rare earth metal, neodymium, is used in magnets critical to the guidance systems of smart bombs used by the US military and among the audio components of Apple Inc.'s iPhones.

At greatest risk are those rare earths that have high volume, low reserves, and significant dispersion. Essentially, REEs are concentrated from very low grade in the ground and then dispersed into various equipment in small quantities. Thus, unless recovered, there is a greater chance of these materials being lost with the disposal of the equipment. Recycling and recovery of rare earth poses numerous challenges in terms of use of energy to collection, reprocessing, and reproducing products at specification that can replace primary metals.[38] This notwithstanding, in its environmental sustainability report, Apple Inc. stated that it has been recycling rare earth materials from older iPhones to reduce the impact of mining for new sources of the metals–acknowledging that 11 kilograms of rare earth elements are recovered from every 100,000 recycled iPhones.

35 Haque, et al., n. 26.
36 Ibid.
37 Ibid.
38 Ibid.

Enhancing Sustainable Marine Resource Governance in the Indian Ocean Region: Deep-Sea Exploration of Rare Earths

Japan is known to invest heavily in deep-sea exploration activities. The areas identified for deep-sea mining in Japan are hydro-thermal deposits in the Okinawa trough northwest of Okinawa Islands, and the Bayonnaise submarine caldera—believed to contain among the world's richest seabed deposits of gold, silver and rare earth elements. A Japanese consortium, led by Mitsubishi Heavy Industries Ltd. and Nippon Steel & Sumitomo Metal Corp.'s engineering unit, has been conducting a pilot mining and lifting of ore at the Izena sea hole in the area off the southern island of Okinawa, commencing April 1, 2017. The consortium had confirmed deposits of 7.4 million tons of ore approximately. In this reference, Japanese policy has moved towards sourcing more than 60 percent of its rare earths' requirements from outside of China by 2018, with major Japanese corporations developing mining projects in cooperation with local entities in Australia, India, and Kazakhstan. By means of earmarking a $1.5-billion corpus for developing alternative sources of rare earths, there is an effort to notch up joint venture partnerships to secure supplies of rare earth elements, with Japanese firms receiving governmental back-up to enter into international partnerships.[39] These include the Sumitomo Corp and the Kazakhstan National Mining Co.—Kazatomprom; Toyota Tsusho and Sojitz partnering with Vietnam's Dong Pao project; and state-run Japan Oil, Gas and Metals National Corporation (JOGMEC) partnering with India to explore for REEs and establishing a processing facility. Additionally, JOGMEC sought investments in Australia's Lynas Corporation. Japan has also been the pivot in building capacities including opening a Rare Earth Research and Technology Transfer Centre in Hanoi, Vietnam.

Advances in high-end technologies, depleted easy-to-reach minerals onshore have boosted the idea for offshore mining, mainly because, metals can be 15 times the quality of land deposits using these methodologies. JOGMEC, which has been instrumental in securing energy and mineral supplies, and providing support for seabed ventures, has identified an area off Okinawa that demonstrates great potential.[40] Moreover, Japan's Natural Resources and Energy Agency has commissioned Japan Oil, Gas, Metals National Corporation to develop robotic deep-sea mining technology to evacuate minerals. The primary aim being stabilizing the supply of rare metals used for high-tech equipment. Tokyo-based Waseda University's official news release confirmed that its researchers have succeeded in establishing a mineral processing procedure that selectively recovers host minerals of rare earth elements from deep-sea mud.[41] According to Yutaro Takaya, "Rare-earth elements and yttrium (REY) are critical in renewable energy technologies and electronics, for example, hybrid vehicles, rechargeable batteries, wind turbines, and light-emitting diodes, as well as medical technologies."[42] Takaya's team remains hopeful that their findings could alter Japan's policy and strategy on natural resource management.

While Japan is working towards element extraction methodologies within the next five years that would contribute to Japan's resource security, obstacles do remain. The primary of them being economic viability and sustainability. Extraction of these minerals is highly costly and complex. Ongoing R&D in Japan is reportedly

39 Chansoria, *Note de la FRS*, n. 1.

40 As cited in Masumi Suga and Ichiro Suzuki, "Japan plans to search for, mine metals deep beneath the ocean," *Bloomberg News*, August 9, 2016.

41 *Waseda University News*, n. 5.

42 Ibid.

considering recycling products containing rare earths to re-use the elements, as well as undertaking research for technologies that do not require the use of rare earths at all.

Indo-Japanese Collaboration in the Indian Ocean Region: Rare Earths' Exploration and Processing

Currently, Japan is the second-largest consumer of rare earths globally after China. A key component of Tokyo's policy of regional integration is its "rare earths diplomacy initiative." In this backdrop, Indo-Japanese collaboration in the Indian Ocean Region in the field of rare earths exploration and processing holds immense potential. This is significant in reference to the recommendations of a Steering Committee constituted by India's Ministry of Mines.[43] The committee was assigned the task to prepare a strategy paper prescribing short, medium, and long-term policy options, along with proposals for specific policy and legislative interventions, for exploration, extraction and recycling for ensuring an uninterrupted supply chain for REEs and Energy Critical Elements (ECEs). This, ostensibly, would aid in meeting the requirements of clean energy and strategic sectors.[44]

With respect to exploration, the 2012 Committee recommended a need to pursue exploration efforts with modern concepts and tools including remote sensing and computerization capabilities to produce detailed and accurate data and information of unexplored areas, both by Geological Survey of India and Atomic Minerals Division during the XII Five Year Plan for locating suitable target areas for further search of economically exploitable deposits of REEs.[45] Additionally, a proposed policy initiative emphasized on cooperative research in geological modeling of the mineral deposits, ore forming systems, basic geochemistry and development of indigenous extraction and processing technologies of these elements. Further, the options of collaborating with foreign laboratories were proposed to be kept open.[46]

Deep-sea mining has officially been recognized as a future frontier of scientific research in India as remains evident from the acquisition of deep-sea exploration ship *Samudra Ratnakar*, which is equipped with sophisticated deep-sea survey instruments. The vessel provides India with a qualitative edge over other survey ships when it comes to oceanographic research, and enables it for accurately surveying the seabed, and analyzing excavated material. According to an estimate, the total mass of nodules in the area allocated to India in the Indian Ocean Region is 380 million metric tons. However, *Samudra Ratnakar* alone will not be sufficient to find and extract materials. Based on this consideration, India should contemplate a proposal for deep-sea mining and production technology from Tokyo under the strategic dialogue framework as well as acquisition of deep-sea exploration vessels.

Furthermore in terms of collaborating with Japan, the Industrial Development Corporation of Odisha Limited (IDCOL) and Indian Rare Earth Limited (IREL) that operate under the Department of Atomic Energy have signed an MoU to set up a mineral separation plant in the Ganjam district of Orissa (an eastern Indian state situated on the Bay of Bengal).[47] This MoU seeks to undertake beach sand mining

43 Chansoria, *Note de la FRS*, n. 1.

44 Ibid.

45 Report by the Indian Ministry of Mines, "Rare Earths and Energy Critical Elements: A Roadmap and Strategy for India," Government of India, New Delhi, July 2012.

46 Ibid.

47 Chansoria, *Note de la FRS*, n. 1.

and mineral processing to produce limonite, garnet, sillimanite, rutile, zircon and monazite. A subsidiary of Japan's Toyota Tsusho Corporation is based at Vishakhapatnam–a port city and industrial center in India's south-eastern coastal state, Andhra Pradesh.[48] The Tsusho Corp. is involved in the production of REEs while also operating a monazite sand rare earth production base. Of late, Indian Rare Earths Ltd. sought clearance for rare earths mining from sand in the coastal stretch of around 2,500 hectares at Bramhagiri (in the Puri district of Orissa). With these mechanisms in place, expanding the scope and avenues of Indo-Japanese collaboration in these spheres could prove mutually beneficial.

Amid the larger framework of the Indo-Japanese strategic collaboration, Tokyo and New Delhi agreed for a commercial contract in September 2014 between Indian Rare Earths Limited (IREL) and Toyota Tsusho Corporation for the exploration, production of rare earths, and commencement of commercial production. The Ministry of Earth Sciences of India and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) agreed to innovatively cooperate in the field of ocean and earth science and technology, which includes ocean observation, climate variability, and geophysical studies in the Indian Ocean Region and deep-sea technologies.

In a June 2016 cabinet meeting chaired by Prime Minister Narendra Modi, New Delhi approved signing of a 15-year exclusive rights contract between the Ministry of Earth Sciences and the International Seabed Authority for undertaking exploration and other developmental activities related to polymetallic sulphides in the Indian Ocean in an allotted area of 10,000 sq km in parts of Central, and South-West Indian Ridges. This was a follow up of the decision of the International Seabed Authority, under UNCLOS, that approved an application submitted by India requesting for the allocation.[49] Notably, the International Seabed Authority governs non-living resources of the seabed lying in international waters. According to an official statement issued subsequently, "… [It] will enhance India's presence in the Indian Ocean where other players like China, Korea and Germany are active."[50]

Deep-sea Mining: Challenges and Prospects

Given that rare earth minerals are buried nearly 6,000 meters deep in the ocean, the challenges for related technologies remain galore ranging from limitations of the existing methods of production, to the prolonged timeline of bringing rare earth projects to fruition. The challenges surrounding REEs also include those related to economics such as demand, supply, price stability, technology, and scientific research entailed. Related questions include those of ready availability and affordability of processed REE compounds for technology applications. At present, there are no economically sustainable methods of producing existing and newly discovered rare earth minerals embedded more than 5-6 kilometers below the deep seabed.

Unproven methods of profitable extraction of such minerals will take a prolonged period of time to come to fruition. The cost for a single mining site could be anywhere over $1.6 billion. It is one thing to be in possession of an unrivalled deposit of unmined ore, and quite another to create a profitable chain of production that would allow for its measureless potential to be unlocked. Amid this, the claim made by Japanese researchers of having developed an

48 Ibid.

49 Ibid.

50 Press Information Bureau, Government of India, Cabinet release, "Cabinet approves contract for exploring metals in Indian Ocean," June 15, 2016.

efficient method to extract these minerals, offers an optimum ray of hope. Questions remain over the timeline that would allow Japan to wean itself off its dependence on Chinese rare earth materials. Japan's commitments to increased R&D investments into material use efficiencies can be united ingeniously with India's desire to being at the forefront of sustainable marine resource governance. With the above narrative as a backdrop framework, it would only be prudent to argue that augmented joint collaboration between India and Japan in the Indian Ocean Region to explore and produce rare earth elements remains the way to go forward. More so, it provides definitive direction and enhanced scope for Tokyo and New Delhi's joint Indo-Pacific vision and collaborative strategy.