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研究課題名（和文）Sustainability and stakeholder engagement for remote deep ocean resources of critical minerals

研究課題名（英文）Sustainability and stakeholder engagement for remote deep ocean resources of critical minerals

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研究成果の概要（和文）：本研究の課題は海底熱水鉱床の環境・社会への影響を評価することでした。海底熱水鉱床の開発をするときには、必要な情報だと考えます。研究の結果として、鉱山の（原鉱の1トン当たり）深海金属資源開発の環境影響・エネルギー・CO2排出量は大きいですが、深海金属資源開発による金属生産（金属の1トン当たり）は、陸上鉱山開発による金属生産に比べ、環境への影響が小さいときもあると考えます。だいろいろな影響評価ができていないのでもっと研究が必要です。

研究成果の概要（英文）：This research project aimed to assess the environmental and social aspects of mining deep ocean metal ores. The project found that when we extract ore from the bottom of ocean it is generally more energy and emissions intensive than from on land. However, when we consider the production of metal from this ore (which has a higher concentration of metal than deposits on land) it is likely to be better (less impact). There is still more research needed to confirm this.
A survey of Japanese stakeholders was also undertaken, and the results are being analysed to understand whether local or other stakeholders understand and support deep ocean mining. Other options, such as recycling and importing metals were also discussed.

研究分野：Chemical Engineering

キーワード：Deep ocean resources　minerals　sustainability　stakeholder　LCA　energy　mineral-energy nexus　metal

１．研究開始当初の背景

Deep ocean resources of minerals are interesting due to their high ore grades (concentration of useful minerals), and in particular for resource-poor countries like Japan, because they offer potential resources that are unavailable or becoming scarce on-land. The Japanese government has invested in exploration and research, aiming to try to exploit Japan`s domestic deep ocean resources (see Figure 1), as well as the resources in the international exploration zone. No deep ocean mining is currently operational, and there is significant research interest in the local environmental impacts of this mining.

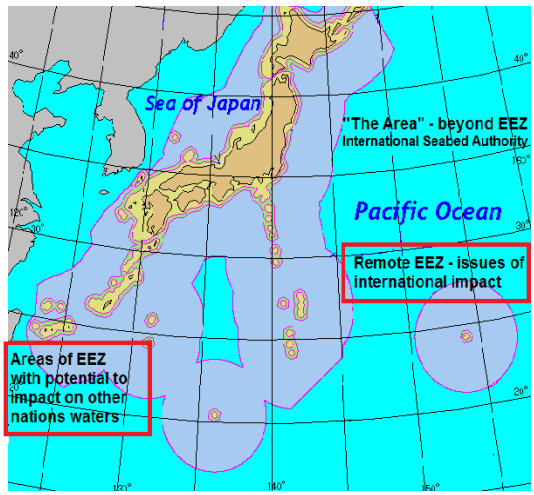

Figure 1: Deep ocean resource potential in Japan

However, there has been insufficient investigation of the supply-chain impacts of utilizing these resources. This project set out to try to quantify the environmental impacts and compare the mining and processing of deep ocean mineral deposits with on-land equivalents. In order to do this, lifecycle assessment was used as a key tool, examining (at first) the energy and emissions along the supply chain (see Figure 2).

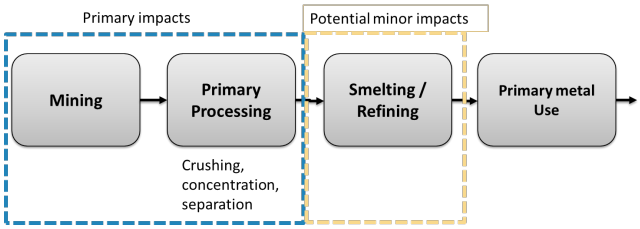

Figure 2: General life cycle of mineral products

２．研究の目的

This project was seeking to examine the environmental and social impacts and the mechanisms and preferences of stakeholders for the extraction of critical minerals from deep ocean deposits. The project examined not only the supply chain of minerals from deep ocean mines but also the utilisation of critical minerals in key energy technologies as the final component of the life cycle analysis. The project was largely able to fulfil its aims, although more work can be undertaken in this important field, particularly with regards to assessing environmental impacts beyond energy and greenhouse emissions, and in widening the technologies and level of detail of the data utilised.

３．研究の方法

The major methods utilised in the research were lifecycle assessment (LCA) and a stakeholder survey. Collaboration and hearings with researchers from across various regions – predominately Australia, Europe, Japan and elsewhere in Asia – was undertaken to obtain data and better insights into the technical, environmental, economic and social aspects of deep ocean resources extraction. Two major collaborations were developed – with Macquarie University and the University of Queensland in Australia. One month was spent in Australia, part-funded by the

University of Queensland, in which time a large number of hearings were conducted – with companies (Nautilus Minerals, Neptune Minerals), institutional stakeholders (Minerals Council of Australia), and with relevant researchers. In Japan, linkages have been made with JOGMEC and DORD, and with other researchers involved largely in the development of technologies. The mid-term findings of the LCA study have been published, and the stakeholder engagement component is in the process of final analysis and write-up.

In the course of the research, LCA was conducted for three alternative extraction methods from three major ore types – seafloor massive sulphides (SMS), deep sea muds with rare earth content and manganese nodules. The major LCA impact categories examined were the embodied energy and embodied emissions from the supply chain of metals from deep ocean ores, but some consideration to toxic waste streams was also undertaken. As there is no currently operating deep sea mining operation (the Nautilus Minerals Solwara I operation in Papua New Guinea (PNG) is anticipated to start in 2018), the data on operational parameters and units was obtained from an extensive review of literature, and through consultation with experts (including from Nautilus Minerals). The production of a number of important metals – gold, silver, copper, zinc, lead, nickel and cobalt – were examined.

Regarding the stakeholder engagement component, a number of aspects were investigated. Firstly, a review indicated that stakeholder engagement had not been effectively undertaken for the most remote deposits, and that the countries with relatively near-shore deposits had in general had minimal engagement. Experts in Australia at the CSIRO were interviewed about an existing study that had been undertaken there, while reports from studies in the South Pacific were also reviewed. A collaboration with Macquarie University in Sydney, Australia, was utilised to develop the first component of a survey to undertake with stakeholders. Two social science intern students were engaged to develop the survey, which was later edited, adapted and translated into Japanese. The survey was formally undertaken via an internet survey company in March, 2016. The results of the survey are currently being analysed and written-up for publication.

４．研究成果

With regards to research outcomes, the project has provided perhaps the first ever life cycle supply-chain environmental assessment of the production of metal from deep ocean resources, applying LCA to the task. The results have indicated that the benefits of high ore grade associated with deep ocean deposits may be beneficial overall in the life cycle of metals supply. However, when considered on its own, the extraction of ore is likely to be higher impact than existing mines, due to the deeper depths of deep sea deposits (700 – 6000m) and the distance offshore. Additionally, emissions are likely to be higher, due to the requirement of using electricity generated on-board the ship from heavy fuel oil or diesel. (see Figure 3 and Figure 4) The impacts of land usage,

the need for waste storage of toxic tailings, and some economic considerations have been examined.

The materials intensity and resource availability of critical metals was also examined in the project, and has provided data for published scenarios on renewable energy mineral requirement. Additionally, these become the demand requirement for examining LCA impacts of deep ocean resources in products, and for comparison with recycling urban ores.

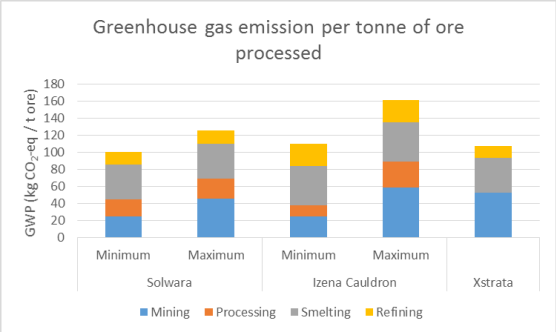

Figure 3: Lifecycle global warming potential for processing each tonne of ore through to refined metal product (see ISOPE paper)

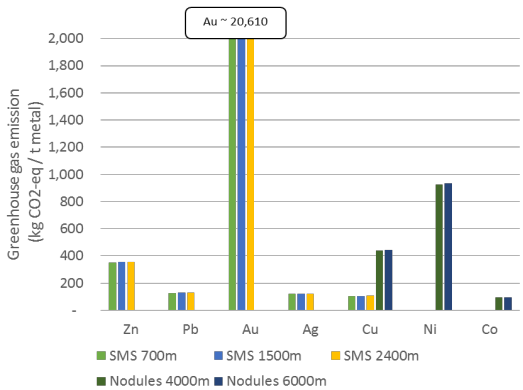

Figure 4: Lifecycle GHG emissions for each tonne of produced metal (see Future Mining paper)

The stakeholder survey, undertaken in Japan, is currently being further analysed, and is expected to be published in the near future. Again, it is believed that this is the first survey of its kind in the Japanese context – despite the government`s investment in research and exploration for deep ocean minerals.

The research is expected to be expanded in future, in both the context of the LCA and the stakeholder engagement. It is apparent that there is more need for a serious discussion in society about where and how resources are sourced, and this requires more data and more investment (for example in multimedia resources to explain deep ocean mining). Ongoing efforts are attempting to source funding for undertaking a joint study on the community and environmental impacts of the Solwara I project in PNG, as well as seeking further collaboration on the downstream usage of critical deep ocean minerals.

5．主な発表論文等

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６．研究組織

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