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To Media Outlets

Chiba Institute of Technology

Oceanic anoxic event 1a in the Early Cretaceous did not extend into pelagic deep sea

Key Points

- The manganese oxide deposits distributed in the Tokoro Belt, northeastern Hokkaido, were formed by submarine hydrothermal activity on oceanic islands during Oceanic Anoxic Event (OAE) 1a in the Early Cretaceous.
- Since an oxic environment is essential for the formation of manganese oxides, it has been proven that the deep-sea environments in pelagic regions remained oxygen-rich even during OAE 1a.
- This discovery is crucial for evaluating the impact of OAE 1a on ecosystems and oceanic circulation.

Overview

In Earth's history, Oceanic Anoxic Events (OAEs), during which the oceans became oxygen-depleted, have occurred multiple times. Rapid global warming is often associated with the occurrence of OAEs, making it essential in modern times, where global warming is a common issue for humanity, to accurately evaluate the impact of past OAEs on ecosystems and ocean circulation. However, it remains uncertain whether the anoxic conditions of the Early Cretaceous OAE 1a[*1], which lasted 1.116 million years from 119.55 million years ago (Ma), reached the deep-sea environments of pelagic regions.

The Tokoro Belt, distributed in northeastern Hokkaido, consists of sedimentary and igneous rocks formed on the seafloor during the Jurassic and Cretaceous periods (Figure 1). The Nikoro Group within the Tokoro Belt contains iron oxide and manganese oxide deposits, which were previously mined (Figures 2 and 3). This study examined the chemical composition and osmium (Os) isotope ratios[*2] of iron and manganese deposits to clarify their formation processes.

As a result, it was revealed that iron oxide deposits were formed by hydrothermal activity at mid-ocean ridges[*3] during the Callovian stage in the Middle Jurassic (165.3–161.5 Ma), while manganese deposits were formed by hydrothermal activity on oceanic islands[*4] in the Early Cretaceous (approximately 120 Ma) (Figure 4). Additionally, the Os isotope ratios of the iron deposits indicated that volcanic activity at mid-ocean ridges (which releases carbon dioxide) was already active before the onset of global warming that triggered the Late Jurassic OAE[*5].

On the other hand, the Os isotope ratios of the manganese deposits indicated that the manganese oxide deposits in the western Nikoro Group formed just before the onset of OAE 1a (124–119.55 Ma), while those in the southern Nikoro Group formed during OAE 1a (119.5–118.5 Ma). Since manganese oxides require highly oxic environments to precipitate, these findings demonstrate that deep-sea environments in pelagic regions remained oxygen-rich even during OAE 1a.

This research was conducted by a collaborative team from Chiba Institute of Technology, Tohoku University, and the University of Tokyo, and was published in *Ore Geology Reviews* on May 7, 2025.

Detailed Explanation:

Research Background

Multiple OAEs occurred from the Jurassic to the Cretaceous periods, however many aspects of their occurrence processes and impacts on global environment remain unclear. One of the key parameters for understanding past oceanic conditions is the Os isotope ratio recorded in sedimentary rocks. However, the reconstruction of marine Os isotope ratios in the Jurassic and Cretaceous periods has been incomplete. Furthermore, most OAE research has focused on sedimentary rocks formed in relatively nearshore regions due to their ease of sampling and high temporal resolution, leading to a lack of information on deep-sea environments in pelagic regions. Thus, this study focused on the Tokoro Belt, where rocks formed in the deep-sea environments from the Jurassic to the Cretaceous are exposed.

In the eastern section of the Nikoro Group in the Tokoro Belt, iron deposits are distributed, while manganese deposits are found in the western and southern sections. Since both iron and manganese deposits are associated with basalt (volcanic rock), they were initially believed to have formed through submarine hydrothermal activity at mid-ocean ridges. However, recent studies have revealed that the basalts in the eastern Nikoro Group were formed at mid-ocean ridges, while the basalts in the western and southern sections were formed on oceanic islands, necessitating a reassessment of the formation process of iron and manganese deposits. Therefore, we aimed to clarify the formation processes of the iron and manganese deposits in the Nikoro Group in the Tokoro Belt, as well as the marine Os isotope ratios at the time of their formation.

Research Findings

The chemical composition of the iron and manganese deposits showed that they are typical hydrothermal-origin ferromanganese oxides, with little content beyond iron and manganese. Additionally, basalts in the eastern Nikoro Group and in the western and southern sections were classified as mid-ocean ridge basalt and oceanic island basalt, respectively, based on their chemical composition analyzed in this study and previous studies. Combining these results with microfossil-based age constraints from previous studies, it was determined that the iron deposits formed in the Callovian stage or older through hydrothermal activity at mid-ocean ridges, while the manganese deposits formed between approximately 124 Ma and 117 Ma through hydrothermal activity on oceanic islands. Additionally, the averaged total rare-earth element content in the iron deposits was 517 ppm, indicating that they correspond to rare-earth rich mud[*6] of the hydrothermal type.

The low Os isotope ratio of the iron deposits (0.411–0.445) indicates that volcanism at mid-ocean ridges (which releases carbon dioxide) was active in the Callovian. Since this period immediately preceded the rapid warming that led to the Late Jurassic OAE, this finding is crucial for understanding the triggers of that global warming.

On the other hand, the Os isotope ratios of the manganese deposits were approximately 0.6 (0.599–0.615) in the western section and about 0.3 (0.310–0.369) in the southern section. During the period around OAE 1a, when the manganese deposits were formed, marine Os isotope ratios have been well reconstructed. Therefore, we compared the Os isotope ratios of the manganese deposits with those of the ocean to estimate the formation age of the manganese deposits. As a result, the western manganese deposits formed just before OAE 1a (124–119.55 Ma), while the southern manganese deposits formed during OAE 1a (119.5–118.5 Ma). This study is the first to provide direct evidence that deep-sea environments in pelagic regions were oxic enough for manganese oxides to precipitate even during OAE 1a.

Although OAE 1a is considered to have occurred due to the expansion of oxygen minimum zone (OMZ) [*7] caused by increased biological production in the ocean surface due to global warming, this study indicates that the expansion of OMZ did not reach deep-sea environments in pelagic regions. The findings of this study challenge previous estimates of the scale and global impact of OAE 1a and necessitate a reconsideration of its effects on the Earth's system.

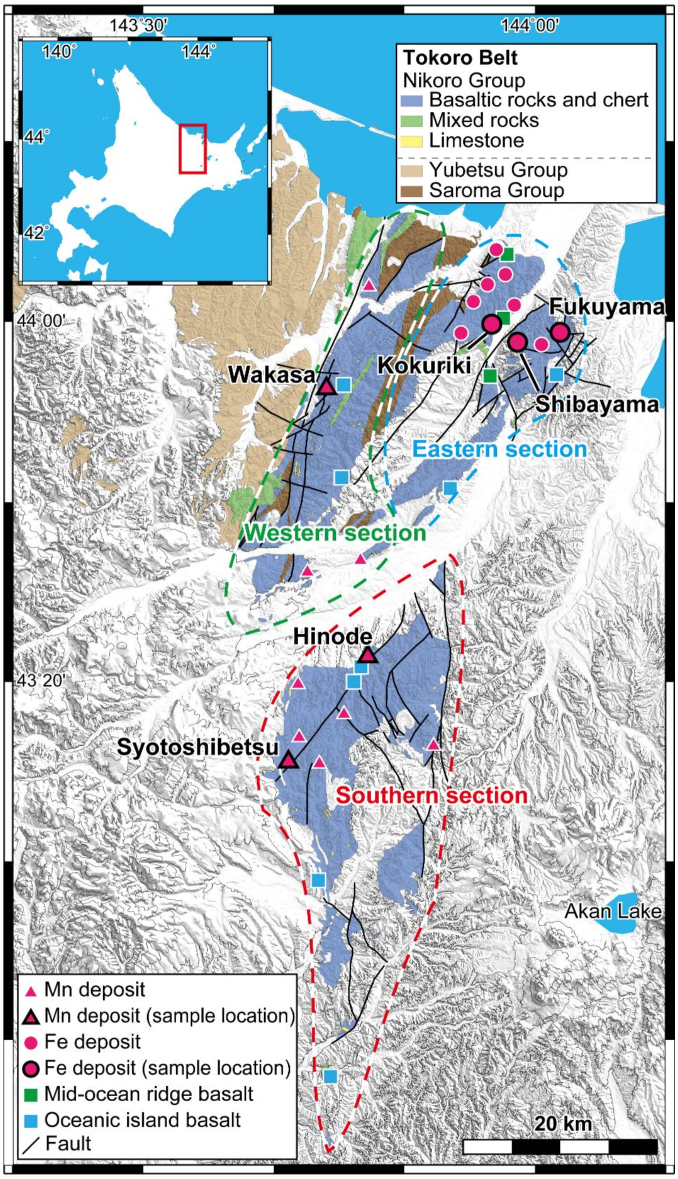

Figure 1. Sample Locations.

Figure 2. Photo of outcrop in Kokuriki.

Figure 3. Fe and Mn deposits analyzed in this study.

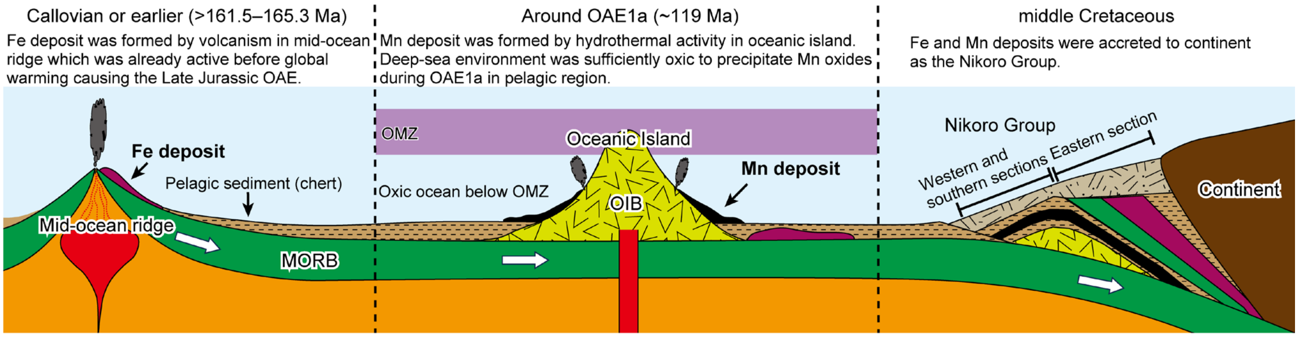

Figure 4. Formation process of iron and manganese deposits in the Tokoro Belt.

Glossary

Note 1: OAE 1a

OAE 1a refers to an Oceanic Anoxic Event (OAE) that lasted for 1.116 million years from 119.55 Ma. OAE 1a is one of the most intense OAEs in the Cretaceous. It is considered that large-scale volcanic activity triggered rapid global warming, leading to increased biological productivity in the ocean surface and subsequent ocean deoxygenation.

Note 2: Osmium (Os) isotope ratio

The marine Os isotope ratio ($^{187}Os/^{188}Os$) decreases during periods of intense volcanic activity and increases during periods of active continental weathering. The Os isotope ratio is uniform throughout the global ocean and is recorded in marine sediments.

Note 3: Mid-ocean ridge

A region where magma rises from the upper mantle and erupts, forming new oceanic plates.

Note 4: Oceanic island

A volcanic island formed by a hotspot. A modern example is the Hawaiian Island.

Note 5: Late Jurassic OAE

An OAE that is considered to have occurred approximately 150 Ma due to global warming. The widespread formation of sulfide deposits (Besshi-type deposits) and petroleum source rocks indicates oceanic anoxia.

Note 6: Rare-earth rich mud

A deep-sea sediment with a total rare-earth element content exceeding 400 ppm. It has been identified in a wide area of the Pacific Ocean, including the exclusive economic zone around Minamitorishima Island, and is considered as a potential deep-sea mineral resource.

Note 7: Oxygen minimum zone (OMZ)

A depth zone where the dissolved oxygen content in seawater becomes extremely low due to the decomposition of organic matter (such as dead marine organisms). In modern oceans, OMZ is typically distributed at depths of about 600–1000 meters.

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