The formation mechanism of numerous giant carbonate concretions found in Oga peninsula, Japan

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Carbonate concretions occur in sedimentary rocks of widely varying geological ages throughout the world. Previous studies focused on concretions have suggested that carbonate concretions are formed mainly by the rapid reaction of carbon associated with the decay of organic matter with calcium in seawater. However, it is still unclear how concretions are actually formed in marine sediments. In this study, we focused on the giant concretions of 1-9 m in diameter distributed in the Unosaki coast of Oga Peninsula, Akita Prefecture, Japan. We investigated the formation mechanism and depositional environment of these giant carbonate concretions, some of which contain whalebone in the center of concretion.

In this study, microscopic observations and elemental mapping using X-rays were carried out on carbonate concretions. Stable carbon and oxygen isotope ratios, elemental and mineral compositions analysis were also conducted for the fossil body, concretion and matrix, respectively. Based on the field observation, the giant carbonate concretions are found in the uppermost part of the Nishikurosawa Formation and the Onnagawa Formation. Especially, Lenticular, spindle-shaped, and spherical carbonate concretions were found in the carbonaceous sandstone beds. The carbonaceous sandstone and siltstone showed graded structures and parallel lamination, and some of them showed cross stratification indicating unidirectional flow. In the carbonaceous sandstone beds, various trace fossils were found, and the internal structures were disturbed. The sedimentary structure in the carbonate concretions is unclear, but small trace fossils of millimeters in scale were found by fluorescence microscopic observation. The mineral composition analysis revealed that the major mineral of the concretion was dolomite. Considering the location of dolomite precipitation, it suggests that the concretions were formed in a reducing environment where sulfate ions were removed. The results of stable carbon and oxygen isotope analysis showed an inverse correlation between $\delta^{13}C$ and $\delta^{18}O$ in the fossil body, concretion, and matrix. Low $\delta^{13}C$ & high $\delta^{18}O$ are possibly carbonates formed by the reaction of whale organic matter as carbon source with seawater, while high $\delta^{13}C$ & low $\delta^{18}O$ are considered to be carbonates formed by benthic organisms and microorganisms repeatedly taking up low $\delta^{13}C$, and the remaining relatively high $\delta^{13}C$ reacting with seawater. These results suggest that the giant carbonate concretions were formed by the formation of whalebone communities, followed by the burial of whale with high sedimentation rates, and the reaction of carbon decomposed by benthic and microbial activities with seawater.

Keywords: Concretion, Marine Sediment, Onnagawa Formation, Whale Bone, Dolomite

