Syndepositional formation of calcareous nodules on muddy sea floor: elucidating depositional history by C, O, S isotope characterization

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*長谷川 卓[1]、媚山 陽介[2]
*Takashi Hasegawa[1], Yosuke Kobiyama[2]

1.金沢大学自然システム学系、2.金沢大学理工研究域自然システム学専攻
1.Department of Earth Sciences, Kanazawa University, 2.Devision of Natural System, Graduate School of Natural Science and Technology, Kanazawa University

Calcareous nodules are commonly observed in mudstone sequences, however, paleodepositional condition including paleothermometry have never been discussed based on its chemistry without exceptional case such as methane seepage. It partly owes to their complicated deposional history. We characterized dark grey muddy carbonate nodules collected from Cretaceous strata in Hokkaido, Japan with carbon, oxygen, sulfide sulfur and sulfate sulfur isotopes, and demonstrated the syndepositional formation of some nodules. It is notable that initial formation of carbonate “precursor” for all muddy nodules studied here were syndepositional near oxic/anoxic boundary at shallower depth of muddy sea floor.

Some outcrop observations demonstrate calcareous nodules can be formed just below the sea bottom (JBSB). Structure suggesting consolidation JBSB includes burrows that eject calcareous precursor material from nodule. JBSB origin of the nodules consolidated associated with anaerobic oxidation of methane (identified by carbon isotope ($d^{13}C$) values) with sulfate reduction are also demonstrated with oxygen isotope ($d^{18}O$) and sulfur isotope ($d^{34}S$) values. Such nodules show the exactly same $d^{18}O$ values with that of benthic foraminifers. A bivalve fossil found on one of the methane seep nodules preserved aragonite of the shell and yielded close $d^{18}O$ paleotemperature with that of host nodule.

The cross-plot of the $d^{13}C$ and $d^{18}O$ data can emerge “upper limit line” of $d^{18}O$ values showing syndepositional formation. On the other hand, nodules from the Oyubari area characterized with $d^{34}S$(sulfate) lower than -18 permil indicating JBSB formation had conflicting $d^{18}O$ values. It can be ascribed to the difference of burial depth between sediments of the Haboro and Oyubari areas. Even if precursor of the nodules initially crystalized JBSB, strong compaction during burial would have caused permeation of pore water into the incomplete nodules. Carbon dioxide or bicarbonate ions derived from decomposed organic matter would have caused recrystallization of calcite with $d^{18}O$ as low as -10 permil in the nodule.

キーワード：石灰質ノジュール、酸素同位体比、硫黄同位体比、炭素同位体比
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