Ontogenetic stable isotope records for disclosing evolutionary history of algal symbiosis in planktonic foraminifers

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In modern planktonic foraminifers, symbiont-bearing species have successfully adapted to oligotrophic environment, because of nutritional advantage from photosynthesis of symbiotic algae. Through the evolutional history of planktonic foraminifers, the establishment of photosymbiotic system allowed them to radiate into a new ecological niche in oligotrophic open ocean. Therefore, disclosing the evolutional history of algal photosymbiosis is crucial for understanding the dynamics of paleobiodiversity in planktonic foraminifers.

In several studies on extinct species of planktonic foraminifers, putative photosymbiotic ecology was estimated from specific morphology commonly observed in modern symbiotic taxa. However, since morphological diversity in planktonic foraminifers would be inconsistent with their general ecological variety reasoned by analogy, independent and objective analyses are required. From this point of view, previous studies using cultured specimens proposed a possible geochemical signature of photosymbiotic ecology, i.e., stable isotopic compositions through ontogeny1). Those experimental results indicate that d13C value becomes 13C-enriched chamber-by-chamber with growth, because the number of symbiotic algae, preferentially using 12C for photosynthesis, increases in association with growth of the host foraminifers. This observation indicates that the successive increase of each chamber’s d13C through individual ontogeny represents the characteristic signal of photosymbiosis. However, this technique has rarely been practically applied to analyses of fossil foraminifers, because the amount of carbonate of each fossil foraminiferal chamber is too small for conventional isotope analyses2, 3).

Here, we present ontogenetic stable isotopic records in a single foraminiferal test, obtained from newly developed stable isotope measurement for micro-volume carbonate samples; customized continuous-flow analytical system attached to IRMS (IsoPrime) at Geological Survey of Japan (AIST)4). This device allows us to analyze a single foraminiferal chamber as small as 1.5 micro grams of carbonate. In this study, three species of Recent planktonic foraminifers recovered from IODP Exp. 330 were used for the isotopic analyses; Globigerinoides conglobatus (symbiotic), Globigerinoides sacculifer (symbiotic), and Globorotalia truncatulinoides (asymbiotic). Tests of each specimen were dissected into 5-7 pieces of chamber(s) with micro-scalkels.

Two symbiotic species, Gs. conglobatus and Gs. sacculifer, exhibit successive increase of d13C with growth by 1.2 permil and 2.1 permil, respectively, in contrast to relatively stable d18O: -0.1 (+/-)0.3 permil and -0.9 (+/-)0.2 permil, respectively. On the other hand, d13C and d18O of asymbiotic species of Gr. truncatulinoides displays significant positive correlation. In addition, d18O of Gr. truncatulinoides is considerably higher than those of the other two symbiotic species.

In Gs. conglobatus and Gs. sacculifer, successive increases in d13C associated with 18O-depleted and stable d18O represent the symbiotic nature of these species within a shallow euphotic zone. On the other hand, d18O of Gr. truncatulinoides indicates the deeper habitat, which is consistent with the modern plankton tow observations. These results suggest that the photosymbiotic signal has been successfully detected in this study. We then confirmed that the chamber-by-chamber increase of d13C in fossil planktonic foraminifers can be utilized as a proxy of algal photosymbiosis.

Keywords: planktonic foraminifers, photosymbiosis, stable isotopes, ontogeny

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