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Ontogenetic stable isotope records for disclosing evolutional 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 foraminfers, 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 ontogeny[1)]. Those experimental results indicate that d^{13}C value becomes ^{13}C-enriched chamber-by-camber with growth, because the number of symbiotic algae, preferentially using ^{12}C for photosynthesis, increases in association with growth of the host foraminifers. This observation indicates that the successive increase of each chamber's d^{13}C 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 analyses[2, 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-scalpels.

Two symbiotic species, *Gs. conglobatus* and *Gs. sacculifer*, exhibit successive increase of d^{13}C with growth by 1.2 permil and 2.1 permil, respectively, in contrast to relatively stable d^{18}O; -0.1 (+/-)0.3 permil and -0.9 (+/-)0.2 permil, respectively. On the other hand, d^{13}C and d^{18}O of asymbiotic species of *Gr. truncatulinoides* displays significant positive correlation. In addition, d^{18}O of *Gr. truncatulinoides* is considerably higher than those of the other two symbiotic species.

In *Gs. conglobatus* and *Gs. sacculifer*, successive increases in d^{13}C associated with ^{18}O-depleted and stable d^{18}O represent the symbiotic nature of these species within a shallow euphotic zone. On the other hand, d^{18}O 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 d^{13}C in fossil planktonic foraminifers can be utilized as a proxy of algal photosymbiosis.

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2) Houston and Huber, 1998, Marine Micropaleontology, DOI:10.1016/S0377-8398(99)00007-9.
3) Bornemann and Norris, 2007, Marine Micropaleontology, DOI:10.1016/j.marmicro.2007.05.005.
4) Ishimura et al., 2004, Rapid Comm. Mass Spectrom., DOI:10.1002/rcm.3571.

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