Individual ontogenetic stable isotope records of Recent planktonic foraminifers: Testing for algal photosymbiosis

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Photosymbiotic ecology is widely distributed in modern surface-dwelling planktonic foraminifers. Since the symbiotic relationship is assumed to offer a great advantage in inhabiting the oligotrophic oceans, the evolution of the photosymbiotic ecology would provide a new habitat for planktonic foraminifers, which would accelerate speciation and diversification in a newly explored niche. Therefore, identifying the timing and pace of evolution of algal photosymbiosis is very important for understanding the dynamics of paleobiodiversity in planktonic foraminifers. Photosymbiosis in fossil species, however, has mainly been estimated on the basis of their morphological similarities to modern species. Therefore, objective supporting evidence such as geochemical proxy records, must be required for precise discussion

Previous studies on foraminiferal photosymbiosis using cultivated specimens have shown that the δ13C value of each foraminiferal chamber increases with the growth of the specimens. This is because symbiotic algae preferentially use 12C for photosynthesis, resulting in the ambient seawater surrounding the foraminifers to be enriched in 13C. This observation implies that the increase in δ13C through individual ontogeny can be attributable to the characteristic signal of algal photosymbiosis. Although several studies have been conducted on both modern and fossil specimens (1,2), the analyses of ontogenetic δ13C within a single individual haven’t been practically applied because of analytical limitations.

Here, we analysed the ontogenetic variation in δ13C and δ18O in a single foraminiferal test to identify the photosymbiotic signals. Three Recent species recovered from IODP Exp. 330 were used for stable isotopic analyses: Globigerinoides conglobatus (symbiotic), Globigerinoides sacculifer (symbiotic), and Globorotalia truncatulinoides (asymbiotic). To identify the ontogenetic isotopic variation, foraminiferal tests were successively dissected chamber-by-chamber, with micro-scalpels under a binocular microscope. For each chamber, isotopic measurements were performed using the customized continuous-flow IRMS (IsoPrime) at Geological Survey of Japan (AIST), which enables measurements of microvolume carbonate samples as small as a single chamber of a foraminiferal individual (4).

While δ13C of the photosymbiotic species, Gs. conglobatus and Gs. sacculifer show successive increases by 1.2‰ and 2.1‰, respectively, through their ontogeny, their δ18O remain relatively constant at –0.1 ±0.3‰ and –0.9 ±0.2‰, respectively. On the other hand, both δ13C and δ18O of the asymbiotic species Gr. truncatulinoides increases through ontogeny, showing a significant positive correlation. Additionally, the median δ18O value of +2.5‰ in Gr. truncatulinoides is considerably higher than those of Gs. conglobatus and Gs. sacculifer mentioned above.

The increases observed in δ13C associated with growth in Gs. conglobatus and Gs. sacculifer indicate that these species have photosymbiotic natures. Furthermore, their δ18O values suggest that the calcification temperature of Gs. conglobatus and Gs. sacculifer are higher than that of Gr. truncatulinoides, consistent with shallower euphotic habitats for symbiotic globigerinoids, and deeper colder habitats for asymbiotic globorotalids. These results represent ecological differences, and suggest that our isotopic analyses have revealed photosymbiotic signals recorded in the fossil foraminiferal tests.

1) Bornemann and Norris, 2007, Marine Micropaleontology, DOI:10.1016/j.marmicro.2007.05.005.
3) Spero and Lea, 1993, Marine Micropaleontology, DOI:10.1016/0377-8398(93)90045-Y.