Geophysical Research Abstracts
Vol. 14, EGU2012-11943-1, 2012
EGU General Assembly 2012

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[1,2].
Previous studies on foraminiferal photosymbiosis using cultivated specimens have shown that the δ^{13}C value of each foraminiferal chamber increases with the growth of the specimens. This is because symbiotic algae preferentially use ^{12}C for photosynthesis, resulting in the ambient seawater surrounding the foraminifers to be enriched in ^{13}C[3]. This observation implies that the increase in δ^{13}C 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 δ^{13}C within a single individual haven't been practically applied because of analytical limitations.

Here, we analysed the ontogenetic variation in δ^{13}C and δ^{18}O 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 δ^{13}C of the photosymbiotic species, *Gs. conglobatus* and *Gs. sacculifer* show successive increases by 1.2‰ and 2.1‰ , respectively, through their ontogeny, their δ^{18}O remain relatively constant at –0.1 ±0.3‰ and –0.9 ±0.2‰ , respectively. On the other hand, both δ^{13}C and δ^{18}O of the asymbiotic species *Gr. truncatulinoides* increases through ontogeny, showing a significant positive correlation. Additionally, the median δ^{18}O value of +2.5‰ in *Gr. truncatulinoides* is considerably higher than those of *Gs. conglobatus* and *Gs. sacculifer* mentioned above.
The increases observed in δ^{13}C associated with growth in *Gs. conglobatus* and *Gs. sacculifer* indicate that these species have photosymbiotic natures. Furthermore, their δ^{18}O 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 globegerinoids, 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.

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2) Houston and Huber, 1998, Marine Micropaleontology, DOI:10.1016/S0377-8398(99)00007-9.
3) Spero and Lea, 1993, Marine Micropaleontology, DOI:10.1016/0377-8398(93)90045-Y.
4) Ishimura et al., 2004, Rapid Comm. Mass Spectrom., DOI:10.1002/rcm.3571.