

## JpGU-EGU 国際セッションの意義と狙い JpGU-EGU Biogeosciences Joint Session: aims and challenge

北里 洋<sup>1\*</sup>  
KITAZATO, Hiroshi<sup>1\*</sup>

<sup>1</sup> 独立行政法人海洋研究開発機構  
<sup>1</sup> Japan Agency for Marine-Earth Science and Technology

JpGUに地球生命科学セクションが創立されて以来、EGUとの国際セッションを行なっている。本セッションは、石灰化する生物をプロキシ生物として、殻に記録された地球化学情報からその生態および海洋環境を読み取ることを目指している。そのために、殻を作る生物の生態や生理、そして地球化学的な特徴を検討するような、地球科学と生物学をまたぐ研究を奨励している。本講演では、プロキシ生物として重要な分類群である有孔虫の多様性とそのプロキシへの有用性を論ずる。

キーワード: 地球生命科学, 有孔虫, プロキシ, 自然史, 基礎研究  
Keywords: Biogeosciences, foraminifera, proxy, natural history, basic

## 浮遊性有孔虫・遺伝子型の季節変動 Seasonal variation in genetic types of a planktonic foraminifer

氏家 由利香<sup>1\*</sup>; 上田 拓史<sup>2</sup>  
UJIE, Yurika<sup>1\*</sup>; UEDA, Hiroshi<sup>2</sup>

<sup>1</sup> 信州大学・理学部生物科学科, <sup>2</sup> 高知大学・総合研究センター海洋生物研究教育施設  
<sup>1</sup>Department of Biology, Shinshu University, <sup>2</sup>Utsunomiya Marine Biological Institute, Kochi University

Planktonic foraminifers have been employed in paleoceanographic studies due to two major characters: wide geographic distributions of species and chemical composition of their calcareous shells, which reflect temperature and chemistry of ambient seawater. Accumulating phylogeographic knowledge, high genetic diversity of planktonic foraminifers has been known today and these genetically isolated species are distributed in narrower geographic area than we expected. The previous studies re-established temperature dependences of genetic types according to the pattern of their geographic distributions in many area. Moreover, genetic differentiation among geographically distant populations examined the role of ocean currents in dispersal of planktonic foraminifers. In order to improve the use of planktonic foraminifers as ocean environmental indicators, understanding ecological characters of genetic types is a crucial issue. In the previous studies for molecular phylogenetic analyses, living specimens of planktonic foraminifers were collected at each site as occasion arises. The present study therefore collected samples every month for 1 and half years at same location, the Tosa Bay, where the branch of the Kuroshio Current reaches. We focused on *Globigerinoides ruber*, the most commonly used species for paleoceanography, and found this morphospecies during the whole years in the study area. Four genetic types are detected throughout our survey, though the frequency of each type varied at each sampling time. We demonstrate the effect of external environment to productivity of planktonic foraminifers by analyzing the relationship among water-temperature, chlorophyll concentration, and frequency of genetic types. We furthermore test whether the distance from the main path of the Kuroshio Current is efficiently caused to transport a population of specific genetic type. These examinations provide us the exact information to address seasonal variation of planktonic foraminifers at genetic-type level.

キーワード: 時系列試料, 浮遊性有孔虫, 遺伝子型, 生態的特徴

Keywords: time-series collection, planktonic foraminifer, genetic type, ecological feature

**Cryptic diversity in planktonic foraminifera and the relationship between molecular and morphological classification**  
**Cryptic diversity in planktonic foraminifera and the relationship between molecular and morphological classification**

WEINER, Agnes<sup>1\*</sup> ; KITAZATO, Hiroshi<sup>2</sup> ; KUCERA, Michal<sup>1</sup>  
WEINER, Agnes<sup>1\*</sup> ; KITAZATO, Hiroshi<sup>2</sup> ; KUCERA, Michal<sup>1</sup>

<sup>1</sup>MARUM, University of Bremen, <sup>2</sup>JAMSTEC

<sup>1</sup>MARUM, University of Bremen, <sup>2</sup>JAMSTEC

Planktonic foraminifera are marine single celled eukaryotes that are found globally in the ocean. They construct calcite shells that accumulate in the sediment and are used for micropaleontological studies to reconstruct past climate conditions. Modern planktonic foraminifera have been classified into about 40 species on the basis of morphological characteristics of their calcite shell. Molecular investigations however uncovered an unexpectedly high cryptic genetic diversity within these morphospecies, implying that their biodiversity has been largely underestimated. These cryptic species show distinct biogeographic distribution patterns and ecological adaptations. Therefore, understanding the extent of genetic diversity within a morphospecies as well as the ecological adaptations of its cryptic species is highly important in order to enhance the applicability of foraminifera as proxies in micropaleontological studies. We are applying a single cell approach to survey the extent of cryptic diversity within the SSU rDNA of individual morphospecies and to examine the biogeography, habitats and ecological adaptations of cryptic species. In addition, we are trying to establish a connection between genetic diversity and morphological variability of the calcite shells by morphometric analysis in order to taxonomically revise the morphospecies and to create a connection between living specimens and the fossil record.

## 採光の機能を持った大型底生有孔虫の棘状突起 A fundamental function of calcareous spine of large benthic foraminifers for lighting inside

石谷 佳之<sup>1\*</sup>; Cusack Maggie<sup>1</sup>  
ISHITANI, Yoshiyuki<sup>1\*</sup>; CUSACK, Maggie<sup>1</sup>

<sup>1</sup> グラスゴー大学地球科学科

<sup>1</sup>School of Geophysical and Earth Science, Glasgow University

Major groups of foraminifers precipitate calcium carbonate and form calcareous shells with unique and complicate structure. One characteristic structure is a spine, covering the exterior surface of the shells. These shells and spines are though to have a function for the protection of the cell from predators or for the prop to extend the pseudopodia. However, in other organisms (e.g., land plants), calcareous crystals play a role for increasing light intensity into the photosynthetic tissue more efficiency by scattering light. Our question is what are ecological functions of the shell and spines of calcareous crystals in foraminifers.

Large benthic foraminifers (e.g., *Calcarina*) are the dominant species in the tropical reef waters, where is under exposure of strong light with nutrient depletion. They harbor a vast amount of photosynthetic symbionts inside the cell and utilize these symbionts for uptake recycle-nutrients to survive in the oligotrophic waters. Morphologically, *Calcarina* have blunt spines, which help to spread the pseudopodia, extended in a single circle round a central axis. Their pseudopodia attach to the basement, and avoid to be flowed over by tidal wave. However, our knowledge to ecological function of calcareous spines of *Calcarina* is still limited. We investigated the crystal orientation of calcareous spines of *Calcarina gaudichaudii* by using Electron Back Scatter Diffraction (EBSD) analysis. Calcareous crystals are arranged horizontally to the axis of the spine in the center and gradually vent to the edge. This orientation of calcareous crystals makes a pathway of light through spines to the interior of the shell. Our finding suggests that calcareous spines of *C. gaudichaudii* have ecological function to focus light into the cell and promote photosynthesis of their harboring symbionts.

キーワード: カルカリナ属, 炭酸塩鉱物, 電子線後方散乱回折法

Keywords: Calcarina, calcareous, Electron Back Scatter Diffraction analysis

## トランスジェニックアコヤガイを用いた貝殻タンパク質の機能解析 Functional analysis of shell proteins using transgenic pearl oysters

趙然<sup>1\*</sup>; 遠藤一佳<sup>1</sup>  
ZHAO, Ran<sup>1\*</sup>; ENDO, Kazuyoshi<sup>1</sup>

<sup>1</sup> 東京大学 地球惑星科学専攻

<sup>1</sup>Dept of Earth and Planetary Sciences, University of Tokyo

For the study of biomineralization, the mollusc *Pinctada fucata* is arguably an attractive genetic model system, with its draft genome sequence having been deciphered recently. It produces two crystallographically different shell layers, including the industrially important nacreous layer. We are interested in developing knock-out pearl oysters to analyze the functions of shell matrix proteins, the key players in biomineralization processes, including the unusually acidic protein Aspein. In this study, the widely used Minos transposon system is applied to generate insertional mutagenesis. The first step in developing transposons as tools for mutagenesis is to demonstrate their mobile elements function efficiently and stably in the target organism. Therefore, green fluorescent protein (GFP) is integrated into the transposon to reflect its efficiency.

## 共焦点顕微鏡による大型有孔虫の細胞質形態と小胞内 pH の可視化 Morphological observation of cytoplasm with acidic and alkaline vesicles in large foraminifera cell by confocal imaging

大野 良和<sup>1\*</sup>; 藤田 和彦<sup>2</sup>; 豊福 高志<sup>3</sup>; 中村 崇<sup>1</sup>

OHNO, Yoshikazu<sup>1\*</sup>; FUJITA, Kazuhiko<sup>2</sup>; TOYOFUKU, Takashi<sup>3</sup>; NAKAMURA, Takashi<sup>1</sup>

<sup>1</sup> 琉球大学理工学研究科, <sup>2</sup> 琉球大学理学部物質地球科学科, <sup>3</sup> 独立行政法人海洋研究開発機構

<sup>1</sup>Graduate school of Engineering and science, University of Ryukyus, <sup>2</sup>Department of Physics and Earth Sciences, University of Ryukyus, <sup>3</sup>Institute of Biogeosciences (BioGeos), Japan Agency for Marine-Earth Science and Technology

Algal symbiont-bearing large benthic foraminifers are primary and carbonate producers as well as paleoenvironmental indicators in tropical and subtropical reef environments. Despite their importance, their cellular physiology is not well known. In the present study, we have developed methods to observe in vivo images of a living symbiotic porcelaneous large foraminifer, *Amphisorus kudakajimensis*. The Nikon A1 confocal laser scanning microscope with Calcein-AM was used as a fluorescent indicator for visualizing the morphology and streaming of cytoplasm in living *A. kudakajimensis*. The observations indicated that the cytoplasmic density decreased and reticulopodia were formed at the aperture in the marginal part of intrashell cytoplasm. We also observed vesicles with elevated pH (pH 9.0) and lowered pH (pH 6.0) in reticulopodia-like cytoplasm using a pH-sensitive probe molecule, 8-hydroxypyrene-1,3,6-trisulfonic acid (HPTS). The present study demonstrates the use of confocal microscopy in studying cytoplasmic dynamics and the initial calcification processes such as seawater endocytosis and alkalization of seawater vacuoles.

キーワード: 大型有孔虫, 共焦点顕微鏡, 生体観察, pH, 石灰化

Keywords: Large foraminifera, Confocal imaging, Live imaging, pH, Calcification

## Calcification mechanisms in foraminifera and proxy incorporation Calcification mechanisms in foraminifera and proxy incorporation

Bijma Jelle<sup>1\*</sup>; Nehrke Gernot<sup>1</sup>; Raitsch Markus<sup>1</sup>; de Nooijer Lennart<sup>2</sup>; Funcke Antje<sup>1</sup>; Keul Nina<sup>3</sup>  
BIJMA, Jelle<sup>1\*</sup>; NEHRKE, Gernot<sup>1</sup>; RAITSCH, Markus<sup>1</sup>; DE NOOIJER, Lennart<sup>2</sup>; FUNCKE, Antje<sup>1</sup>;  
KEUL, Nina<sup>3</sup>

<sup>1</sup>Marine Biogeosciences, Alfred Wegener Institute, <sup>2</sup>Marine Geology, Royal NIOZ, <sup>3</sup>Biology and Paleo Environment, Lamont-Doherty Earth Observatory

<sup>1</sup>Marine Biogeosciences, Alfred Wegener Institute, <sup>2</sup>Marine Geology, Royal NIOZ, <sup>3</sup>Biology and Paleo Environment, Lamont-Doherty Earth Observatory

Calcifying organisms, such as pteropods, bivalves, corals and foraminifera provide a rich resource for pale-oceanographers and climatologists because their geochemical make-up (proxies) can be used to reconstruct past ocean history and evolution during and after natural carbon perturbations. However, it has been shown for all geochemical proxies that the main assumption of only one environmental variable controlling a target proxy is too simple. Empirical calibrations introduce a lot of uncertainty because the mechanisms of proxy incorporation are not well understood. The major problem is that the calcification mechanisms are still a black box. In this presentation I will review our current understanding of calcification and proxy incorporation in foraminifera, specifically with respect to the impact of carbonate chemistry and the new opportunities arising from this.

キーワード: 石灰化, 有孔虫, 古環境指標  
Keywords: Calcification, proxy

## Minor element partitioning and mineralogy in limpets from a CO<sub>2</sub> vent site Minor element partitioning and mineralogy in limpets from a CO<sub>2</sub> vent site

Nehrke Gernot<sup>1\*</sup>; LANGER Gerald<sup>2</sup>; SADEKOV Aleksey<sup>2</sup>; BAGGINI Cecilia<sup>3</sup>; RODOLFO-METALPA Riccardo<sup>4</sup>; HALL-SPENCER Jason<sup>3</sup>; Bijma Jelle<sup>1</sup>; ELDERFIELD Henry<sup>2</sup>  
NEHRKE, Gernot<sup>1\*</sup>; LANGER, Gerald<sup>2</sup>; SADEKOV, Aleksey<sup>2</sup>; BAGGINI, Cecilia<sup>3</sup>; RODOLFO-METALPA, Riccardo<sup>4</sup>; HALL-SPENCER, Jason<sup>3</sup>; BIJMA, Jelle<sup>1</sup>; ELDERFIELD, Henry<sup>2</sup>

<sup>1</sup>Biogeosciences, Alfred-Wegener-Institut, <sup>2</sup>University of Cambridge, <sup>3</sup>School of Marine Science and Engineering, University of Plymouth, <sup>4</sup>CoReUs, IRD, Centre IRD de Noumea

<sup>1</sup>Biogeosciences, Alfred-Wegener-Institut, <sup>2</sup>University of Cambridge, <sup>3</sup>School of Marine Science and Engineering, University of Plymouth, <sup>4</sup>CoReUs, IRD, Centre IRD de Noumea

Specimens of the patellogastropod limpet *Patella caerulea* were collected within and outside a CO<sub>2</sub> vent site at Ischia, Italy. The shells were sectioned transversally and scanned for polymorph distribution by means of confocal Raman microscopy. Minor element to calcium ratios were measured using laser-ablation-inductively-coupled-plasma-mass-spectroscopy (LA-ICPMS). Mg/Ca, Sr/Ca, and Li/Ca ratios were determined in calcitic as well as aragonitic parts of the shells. This approach allows for investigating the effects of the polymorph and the seawater carbonate chemistry on minor element partitioning separately.

キーワード: calcification, proxy, CO<sub>2</sub>, mineralogy, patellogastropod limpet  
Keywords: calcification, proxy, CO<sub>2</sub>, mineralogy, patellogastropod limpet



## 底生有孔虫の石灰化過程におけるプロトン、炭素、カルシウム輸送の数理分析 Mathematical analysis of proton, carbon, and calcium transport during calcification process of benthic foraminifera

山本 美希<sup>1\*</sup>; 豊福 高志<sup>1</sup>; 阪口 秀<sup>1</sup>; デ ヌーエヘル レナート<sup>2</sup>  
MATSUO, Miki Y.<sup>1\*</sup>; TOYOFUKU, Takashi<sup>1</sup>; SAKAGUCHI, Hide<sup>1</sup>; DE NOOIJER, Lennart J.<sup>2</sup>

<sup>1</sup> 海洋研究開発機構, <sup>2</sup> ユトレヒト大学

<sup>1</sup> Japan Agency for Marine-Earth Science and Technology, <sup>2</sup> Utrecht University

海洋性単細胞生物である有孔虫は、今日の海洋の炭酸カルシウムのおよそ 50%を生成しており、海洋における炭素サイクルの重要な部分を担っている。しかしながらその石灰化過程がどのようなメカニズムで進行し、どのように環境を変えているのかは未だ理解されていない。

今回我々は、有孔虫の石灰化過程を理解するために行った pH 分析の結果を報告する。まず pH を可視化することにより、石灰化過程にともなって有孔虫のまわりの pH が急速に低下することが確かめられた。これは有孔虫が石灰化時にプロトンを能動的に外界に輸送していることを意味している。次に可視化した pH 分布からプロトンの流束を見積もり、その流束と釣り合うような内部へのカルシウム輸送を仮定して、そのカルシウムの流入総量と新しいチャンバーを作るために必要な炭酸カルシウム量と比較した。これら結果を用いて、プロトンとカルシウムとの交換が石灰化過程に重要な役割を果たしていることを提唱する。

キーワード: 底生有孔虫, 石灰化, プロトン輸送, 数理分析

Keywords: benthic foraminifera, calcification, proton transport, mathematical analysis

## 浮遊性有孔虫光共生系の栄養機構の理解にむけた飼育実験からのアプローチ An experimental approach to understand trophic interaction of photosymbiosis in planktic foraminifers

高木 悠花<sup>1\*</sup>; 木元 克典<sup>2</sup>; 藤木 徹一<sup>2</sup>; 平野 弘道<sup>3</sup>

TAKAGI, Haruka<sup>1\*</sup>; KIMOTO, Katsunori<sup>2</sup>; FUJIKI, Tetsuichi<sup>2</sup>; HIRANO, Hiromichi<sup>3</sup>

<sup>1</sup> 早稲田大学・院・創造理工, <sup>2</sup> 海洋研究開発機構, <sup>3</sup> 早稲田大学・教育・地球科学

<sup>1</sup>CSE Grad. School, Waseda University, <sup>2</sup>Japan Agency for Marine-Earth Science and Technology, <sup>3</sup>Dep. Earth Sciences, Sch. Education, Waseda University

Planktic foraminifers are marine heterotrophic protists. Of about 50 species of modern planktic foraminifers, about 10 species that especially dominate in warm and low-nutrient surface water harbor autotrophic algae as endosymbionts (photosymbiosis). It is generally considered that foraminifers benefit from photosynthates of symbionts, and in return, they provide nutritious environment for symbionts to live. At the same time, however, the host's degree of dependence on symbionts is still enigmatic. This is because growth of the host primarily depends on food (prey) availability. In this context, a common assumption that photosymbiosis is an advantageous ecology for host foraminifers to live in oligotrophic oceans still has room to discuss. To understand trophic interaction between host and symbionts, we conducted culture experiments and analyzed vitality of host-symbiont consortia under controlled nutrient conditions.

We cultured dinoflagellate-bearing species *Globigerinoides sacculifer* for two weeks. Assuming the two sources of nutrients for symbionts, i.e., from the host's metabolites and from the ambient seawater, we controlled feeding regime (fed *Artemia* every other day or unfed) and nutrient concentration of culture media (0.22- $\mu\text{m}$  filtered seawater [SW] or nutrients-added filtered seawater [NSW]). Four experimental groups are set; (a) fed and SW, (b) unfed and SW, (c) fed and NSW, and (d) unfed and NSW. Nutrient concentrations of SW and NSW were respectively 0.2 and 16  $\mu\text{mol L}^{-1}$  of  $\text{NO}_3+\text{NO}_2$ , and 0.07 and 1.0  $\mu\text{mol L}^{-1}$  of  $\text{PO}_4$ . Temperature was set to 26.5-27.5 °C. Photosynthetic active radiation was set to 170-220  $\mu\text{mol quanta m}^{-2} \text{s}^{-1}$ , and its light/dark cycle was 14/10 hours. Test growth of the host, chlorophyll content, and photo-physiology of the symbionts were used as criteria of their vitality. We measured maximum test length of host foraminifers and chlorophyll fluorescence of individual host-symbiont consortium during the culture period almost every day. For fluorometric analysis, we used fast repetition rate (FRR) fluorometry. From FRR measurement,  $F_m$  (an index of chlorophyll content), and  $F_v/F_m$  (an index of potential photosynthetic activity) were obtained and analyzed for each individual consortium.

During the culture period, foraminifers grew and formed new chambers in the fed groups (a, c). On the contrary, specimens in the unfed groups (b, d) gradually decreased their cytoplasm volume, and in accordance with the decrease they often shed chambers one by one. The chlorophyll content, thus the biomass of symbionts per foraminifer, tended to increase in the fed groups (a, c), whereas it decreased or kept nearly constant in the unfed groups (b, d). Despite the apparent diminishment of the unfed groups,  $F_v/F_m$  was significantly higher in the unfed groups (b, d) than that in the fed groups (a, c). It indicates that symbionts in starved foraminifers photosynthesized more actively. Nutrient concentration in the culture media (SW or NSW) did not necessarily affect on  $F_v/F_m$ .

Considering the fact that foraminifers maintained their life and symbionts were capable of photosynthesis in starved condition, it can be said that foraminifers have survived only by photosynthates derived from the symbionts or digesting the symbionts themselves for about two weeks of the culture period. If this relationship is true in natural environment, photosymbiotic interaction should help foraminifers to survive for certain duration even if they cannot capture any prey. This should be an advantage for them to live in low-nutrient and well-lit environment.

キーワード: 浮遊性有孔虫, 光共生, 栄養塩, FRRF, 飼育

Keywords: planktic foraminifers, photosymbiosis, nutrients, FRRF, culture

## 沖ノ鳥島シラナミガイ殻に記録された2005年巨大台風の痕跡 Strong typhoon in 2005 recorded in the shell growth lines and geochemical signals of *T. maxima* from Okinotori Island

駒越 太郎<sup>1\*</sup>; 渡邊 剛<sup>1</sup>; 宮地 鼓<sup>2</sup>; 白井 厚太郎<sup>3</sup>; 山崎 敦子<sup>3</sup>

KOMAGOE, Taro<sup>1\*</sup>; WATANABE, Tsuyoshi<sup>1</sup>; MIYAJI, Tsuzumi<sup>2</sup>; SHIRAI, Kotaro<sup>3</sup>; YAMAZAKI, Atsuko<sup>3</sup>

<sup>1</sup> 北海道大学理学院自然史科学専攻, <sup>2</sup> 苫小牧市美術博物館, <sup>3</sup> 東京大学大気海洋研究所

<sup>1</sup>Department of Natural History, Graduate School of Science, Hokkaido Univ., Sapporo, Japan, <sup>2</sup>Tomakomai City Museum, Tomakomai, Japan, <sup>3</sup>Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan

The giant clam (*Tridacnidae*) widely distributes over the coral reefs in Indo-Pacific oceans and forms the largest shells in bivalves. The giant clam has symbiotic algae, facilitating fast growth rate and forming daily shell growth patterns. By measuring and counting the daily growth lines, we can know exactly when the daily growth lines were deposited. This growth pattern analysis is useful for reconstruction of the past environments at daily resolution. The aim of this study was to validate whether the shell of the giant clam (*Tridacna maxima*) in Okinotori Island, the southern edge island in Japan, could record daily environmental events such as typhoons.

The shell samples were collected alive in Okinotori Island on 5th Jun 2006. The shells were cut into two slices along the maximum growth axis. The number and interval width of microgrowth lines were measured under a digital microscope (KYENCE VHX-2000). Sub-sampling for oxygen stable isotope measurements were performed along the growth direction on another slice of the shell by using dental drill. The powder samples were introduced to carbonate preparation device (Kiel Device IV), and the produced CO<sub>2</sub> was analyzed by a stable isotope ratio mass spectrometer (Thermo Scientific MAT253). Stable oxygen isotope ratios ( $\delta^{18}\text{O}$ ) were compared with sea surface temperature (SST) and maxima values were assigned the lowest SST in February. The correspondence between reconstructed SST and daily observed SST indicated that the microgrowth lines were formed daily basis. Growth disturbances were observed as v-shaped breaks in the shell outer layers. The high  $\delta^{18}\text{O}$  peaks corresponded with these growth disturbances suggested that this specimen recorded the strong typhoon in Okinotori Island on 3th September 2005. Trace element analysis using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) (Agilent 7700) with 100 $\mu\text{m}$  and 30 $\mu\text{m}$  spots (Mg, Ca, Mn, Sr, Ba) revealed that the specimen has Ba/Ca positive peaks as an after-signature of strong typhoons. Moreover, the significant positive peaks observed in Ba/Ca profile suggested the upwelling events due to typhoons in Okinotori Island.

These results indicated that sclerochronological and geochemical record in giant clam shells could be useful for reconstruction of past typhoon events.

キーワード: シャコガイ, 酸素同位体, 炭素同位体, 微量元素, 成長縞

Keywords: Giant clam, Oxygen isotope, Carbon isotope, Trace elements, Growth line

## 近年の北西太平洋の海洋酸性化がハマサンゴの石灰化に与える影響 Effects of recent ocean acidification in the western North Pacific on Porites coral calcification

窪田 薫<sup>1\*</sup>; 横山 祐典<sup>1</sup>; 石川 剛志<sup>2</sup>; 鈴木 淳<sup>3</sup>; 石井 雅男<sup>4</sup>

KUBOTA, Kaoru<sup>1\*</sup>; YOKOYAMA, Yusuke<sup>1</sup>; ISHIKAWA, Tsuyoshi<sup>2</sup>; SUZUKI, Atsushi<sup>3</sup>; ISHII, Masao<sup>4</sup>

<sup>1</sup> 東京大学 大気海洋研究所, <sup>2</sup> 海洋研究開発機構, <sup>3</sup> 産業技術総合研究所, <sup>4</sup> 気象庁 気象研究所

<sup>1</sup> Atmosphere and Ocean Research Institute, The University of Tokyo, <sup>2</sup> Japan Agency for Marine-Earth Science and Technology,

<sup>3</sup> National Institute of Advanced Industrial Science and Technology, <sup>4</sup> Meteorological Research Institute, Japan Meteorological Agency

人間活動の結果大気へと放出された二酸化炭素の約3分の1は海洋表層水によって吸収されたと考えられている。その結果、海水 pH は例にない速さで低下しており（海洋酸性化）、産業革命以降、すでに 0.1 低下したと考えられている。海水 pH の低下は炭酸塩飽和度を低下させるため、造礁サンゴに対して重大な影響をもたらすと考えられている。これまで、海洋酸性化が造礁サンゴに与える影響の評価は一般に飼育実験を通じて行われてきており、野外において影響を評価した研究はほとんどない。環境変化に対してサンゴそしてサンゴ礁生態系がどのように適応するか、或いは影響を被るかをより良く理解するためにも野外観測は必要不可欠である。そこで本研究では、北西太平洋・小笠原諸島父島で得られた塊状ハマサンゴに対して、表面電離型質量分析器を用いて過去 100 年間のホウ素同位体比 ( $\delta^{11}\text{B}$ ) の分析を行った。測定結果は、1960 年以降のホウ素同位体比が顕著に低下していること ( $-0.17 \pm 0.07 \text{‰/decade}$ )、すなわち石灰化流体の pH が低下していることを示唆している。さらに、ハマサンゴの飼育実験の予想よりも早く石灰化流体の pH が低下していること（感度が高い）も分かった。このことは、石灰化流体の pH の上方調整機構にもかかわらず、アラゴナイト飽和度が予想よりも早く低下する可能性を示唆するものである（2050 年頃に海水の pH が 8.0 程度になった時には石灰化流体の pH は 8.3 程度）。従って、海洋酸性化は、温暖化に代表される種々の環境ストレスに既に晒されている造礁サンゴに対してさらなる悪影響を既にもたらしている可能性が高いと考えられる。

キーワード: ホウ素, サンゴ, ハマサンゴ, 海洋酸性化, 石灰化

Keywords: boron, coral, Porites, ocean acidification, calcification

## Proton Management of Foraminiferal Calcification Proton Management of Foraminiferal Calcification

TOYOFUKU, Takashi<sup>1\*</sup> ; DE NOOIJER, Lennart jan<sup>2</sup> ; FUJITA, Kazuhiko<sup>4</sup> ; SHIRAISHI, Fumito<sup>3</sup> ;  
REICHART, Gert-jan<sup>2</sup> ; KITAZATO, Hiroshi<sup>1</sup>  
TOYOFUKU, Takashi<sup>1\*</sup> ; DE NOOIJER, Lennart jan<sup>2</sup> ; FUJITA, Kazuhiko<sup>4</sup> ; SHIRAISHI, Fumito<sup>3</sup> ;  
REICHART, Gert-jan<sup>2</sup> ; KITAZATO, Hiroshi<sup>1</sup>

<sup>1</sup>JAMSTEC, <sup>2</sup>NIOZ, <sup>3</sup>Hiroshima University, <sup>4</sup>Universoty of Ryukyus, <sup>5</sup>Utrecht University

<sup>1</sup>JAMSTEC, <sup>2</sup>NIOZ, <sup>3</sup>Hiroshima University, <sup>4</sup>Universoty of Ryukyus, <sup>5</sup>Utrecht University

Marine calcification plays an important role in the global carbon cycle. Currently, approximately half of all carbon buried in the seafloor is the result of biogenic calcium carbonate production. Perforate foraminifera are a prime example of marine carbonate producers and responsible for a large portion of today's production. The physiological processes involved in calcification, however, are still unclear. Here we present some results on the intra- and extracellular pH changes in benthic perforate foraminifera during calcification. These observations allow for calculating the budgets of ion fluxes that are taken up and removed from the calcification space, which are placed in the context of previously obtained results and published calcification models to construct a unifying model for perforate foraminiferal calcification. This model also accounts for general patterns in observed fractionation factors of various elements.

キーワード: foraminifera

Keywords: foraminifera

## 無機的環境下における炭酸カルシウム多形の形成過程とその前駆物質 Inorganic precipitation mechanism of calcium carbonate polymorphs and their precursors

川野 潤<sup>1\*</sup>  
KAWANO, Jun<sup>1\*</sup>

<sup>1</sup> 北海道大学 創成研究機構

<sup>1</sup> Creative Research Institution, Hokkaido University

Calcium carbonate,  $\text{CaCO}_3$ , occurs in six different forms: three crystalline polymorphs (calcite, aragonite, and vaterite), two hydrate phases, and amorphous calcium carbonate (ACC). These polymorphs are important both in life and material sciences, especially the occurrence of  $\text{CaCO}_3$  in living organisms has received considerable attention. As a basis for understanding biomineralization, inorganic precipitation mechanism of these polymorphs has been extensively investigated for over a hundred years. Recently, crystallization pathway through non-classical mechanism such as stable prenucleation cluster aggregation has been proposed, which give a new picture of the early stages of calcium carbonate growth. However our knowledge of formation process of  $\text{CaCO}_3$ , especially that of the mechanism of polymorph selection, is far from complete.

We have investigated experimentally and theoretically the metastable formation of  $\text{CaCO}_3$  polymorphs and their precursors. In particular, the effect of  $\text{Mg}^{2+}$  on the nucleation and growth of  $\text{CaCO}_3$  polymorphs has been focused and the quantum chemical calculations of Mg-containing  $\text{CaCO}_3$  surfaces and clusters appearing in the early stages of  $\text{CaCO}_3$  formation have been performed. As a result,  $\text{Mg}^{2+}$  substituted for  $\text{Ca}^{2+}$  affects the structure of surfaces and clusters, and may have significant effect on the polymorph selection of  $\text{CaCO}_3$ . In this presentation, we will report our results in detail based on the recent progress in this field.

Keywords: calcium carbonate, metastable phase, precursor

## 生体由来および生体模倣カルサイト結晶におけるメソテクスチャー構造 Mesoscopic textures of biogenic and biomimetic calcite crystals

今井 宏明<sup>1\*</sup>; 宮島 諒一<sup>1</sup>; 緒明 佑哉<sup>1</sup>; 小暮 敏博<sup>2</sup>

IMAI, Hiroaki<sup>1\*</sup>; MIYAJIMA, Ryoichi<sup>1</sup>; OAKI, Yuya<sup>1</sup>; KOGURE, Toshihiro<sup>2</sup>

<sup>1</sup> 慶應義塾大学理工学部, <sup>2</sup> 東京大学大学院理学系研究科

<sup>1</sup>Faculty of Science and Technology, Keio University, <sup>2</sup>Graduate School of Science, The university of Tokyo

The mesoscale granular textures having a single crystalline feature are generally observed on the continuous body of various biogenic and biomimetic calcite crystals. The distribution of the organic phase and lattice strain in the textured crystals vary with organism species or the growth conditions. The prismatic layer of a fan mussel, *A. pectinata*, exhibits a relatively homogeneous, low-strain texture consisting of the nanoscale grains with discrete organic inclusions; the prism structure of a pearl oyster, *P. fucata*, and an avian eggshell have a high-strain granular texture with localized organic phases. A variety of the mesoscopic textures similar to the biogenic calcite crystals are artificially produced in a supersaturated solution containing specific organic molecules. The high-strain textures were produced through mesoscopic dendritic growth of calcite by physical impedance of a rigid gel matrix and subsequent thickening of the branches. Continuous growth of the crystal involving nanoscale segregation of soluble polymers would result in the formation of the low-strain body having mesoscopic textures. The chemical durability of the low-strain biogenic and biomimetic textured calcites are enhanced by the combination of the inorganic crystal and the organic molecules.

Keywords: Biomineral, Calcium carbonate, Mesocrystal

喜界島の上部更新統より産する *Kikaithyris hanzawai* の炭素・酸素同位体組成および  
微量元素濃度の個体差  
Intraspecific variation in isotopic composition and trace element concentrations of Pleis-  
tocene brachiopods

滝澤 護<sup>1\*</sup>; 高柳 栄子<sup>1</sup>; 山本 鋼志<sup>2</sup>; 佐々木 圭一<sup>3</sup>; 井龍 康文<sup>1</sup>  
TAKIZAWA, Mamoru<sup>1\*</sup>; TAKAYANAGI, Hideko<sup>1</sup>; YAMAMOTO, Koshi<sup>2</sup>; SASAKI, Keiichi<sup>3</sup>; IRYU, Yasufumi<sup>1</sup>

<sup>1</sup> 東北大学大学院理学研究科, <sup>2</sup> 名古屋大学大学院環境学研究科, <sup>3</sup> 金沢学院大学美術文化学部

<sup>1</sup>Graduate School of Science Tohoku University, <sup>2</sup>Graduate School of Environmental Studies Nagoya University, <sup>3</sup>The Faculty of Fine Arts and Informatics Kanazawa Gakuin University

Carbon and oxygen isotope composition ( $\delta^{13}C_{VPDB}$  and  $\delta^{18}O_{VPDB}$ ) in fossil rhynchonelliform brachiopod shells has been used as a powerful tool to reconstruct paleoenvironmental conditions. Several petrographic and chemical techniques, such as transmitted light microscopy, cathodoluminescence, scanning electron microscope (SEM), and trace element analysis were applied in those studies to select brachiopod shells that have not been diagenetically altered and retain their original isotopic and chemical composition. However, there are few references that showed how the isotopic and chemical composition is modified by several processes operating during meteoric diagenesis. Therefore, we conducted a comparative study of isotopic composition and trace element (Na, Mg, Sr, Mn and Fe) concentrations in modern and fossil brachiopod (*Kikaithyris hanzawai*) shells. The modern and fossil specimens were collected off Amami-o-shima and the Upper Pleistocene Wan Formation in Kikai-jima, respectively. The isotopic profiles of inner shell surface along the maximum growth axis can be divided into three stages that were likely to be related to changes in life mode and shell morphology of this species. The trace element concentrations are irregularly varied on the sampling transects. There are some spots on the sampling transects, where Mn and Fe concentrations are anomalously high. These spots are likely generated by metabolic factor(s) because they are not associated with decreases in  $\delta^{13}C_{VPDB}$  and  $\delta^{18}O_{VPDB}$  values which are indicative of meteoric diagenesis. Our results suggest that brachiopods with complicated shell morphology which may be related to the change in life mode during the growth are not suitable for paleoenvironmental reconstructions based on their isotopic composition. It is also suggested anomalously high Mn and Fe concentrations cannot be used to identify diagenetically altered portions within brachiopod shells.

キーワード: 炭素同位体, 酸素同位体, 微量元素濃度, 腕足動物, 代替指標, 更新世

Keywords: carbon isotope, oxygen isotope, trace element concentration, brachiopoda, proxy, Pleistocene



## ココビミドリイシ (*Acropora digitifera*) 骨格中化学成分の温度指標としての評価 Assessment of skeletal compositions in *A. digitifera* coral as temperature proxies

阪田 祥子<sup>1\*</sup>; 井上 麻夕里<sup>1</sup>; 田中 泰章<sup>2</sup>; 中村 崇<sup>3</sup>; 酒井 一彦<sup>2</sup>; 池原 実<sup>4</sup>; 鈴木 淳<sup>5</sup>  
SAKATA, Shoko<sup>1\*</sup>; INOUE, Mayuri<sup>1</sup>; TANAKA, Yasuaki<sup>2</sup>; NAKAMURA, Takashi<sup>3</sup>; SAKAI, Kazuhiko<sup>2</sup>;  
IKEHARA, Minoru<sup>4</sup>; SUZUKI, Atsushi<sup>5</sup>

<sup>1</sup> 岡山大学大学院自然科学研究科, <sup>2</sup> 琉球大学熱帯生物圏研究センター瀬底研究施設, <sup>3</sup> 琉球大学理学部, <sup>4</sup> 高知大学海洋コア総合研究センター, <sup>5</sup> 産業技術総合研究所 地質情報研究部門

<sup>1</sup>Graduate School of Natural Science and Technology, Okayama University, <sup>2</sup>Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, <sup>3</sup>Faculty of Science, University of the Ryukyus, <sup>4</sup>Center for Advanced Marine Core Research, Kochi University, <sup>5</sup>Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST)

### はじめに

炭酸塩生物殻による古環境復元は、古気候・古海洋学の分野で威力を発揮しており、造礁サンゴも、有孔虫や円石藻など同様に広く用いられており、熱帯から亜熱帯の海洋環境を月単位の高時間分解能で復元できるという特徴を持っている。実際に骨格中の酸素同位体比 ( $\delta^{18}\text{O}$ ) やストロンチウム・カルシウム比 (Sr/Ca 比) などを用いて、海水温や塩分などの海洋環境変動に関する数多くの研究成果がこれまでに報告されている。現状の古気候・古環境学分野では、骨格に明瞭な年輪が刻まれる塊状のハマサンゴ属 (*Porites* spp.) が古くから用いられているが、本研究ではココビミドリイシ (*A. digitifera*) を研究対象とし、その環境指標、特に温度指標としての有用性を評価することを目的とした。

### 試料と方法

試料となる *A. digitifera* の 3 群体は琉球大学熱帯生物圏研究センター瀬底研究施設前のサンゴ礁にて採取した。飼育水槽の水温は、18、21、24、27、30 °C に設定し、各温度区に水槽を 2 セット設置した (1 つの水槽に 3 片 × 3 群体)。骨格成長率は 2 週間に一度、水中重量測定を行うことで算出した。骨格中の酸素・炭素同位体比 ( $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ ) と各元素比 (Sr/Ca, Mg/Ca, U/Ca, Ba/Ca) はそれぞれ、安定同位体比質量分析計と誘導結合プラズマ質量分析計によって測定を行った。

### 結果と考察

温度指標としてよく用いられている  $\delta^{18}\text{O}$  に関しては、3 群体とも温度と明瞭な逆相関関係が見られ、温度依存性もハマサンゴと整合的であった。よってミドリイシの  $\delta^{18}\text{O}$  は精度の高い海水温指標として有用であることが示唆される。Sr/Ca 比についてもハマサンゴと整合的な温度との逆相関関係が見られたが、相関は  $\delta^{18}\text{O}$  ほど強くはなかった。しかし、Sr/Ca 比は骨格成長率への依存性は無く、Sr/Ca 比は温度のみに影響されることへの信頼性は高まったと言える。以上より、ミドリイシ属の中でも少なくとも *A. digitifera* の  $\delta^{18}\text{O}$  はハマサンゴと同様に温度指標として有用であることが示された。Sr/Ca 比については今後もさらに調査が必要である。

Keywords: coral skeleton, temperature, proxy

底生有孔虫 *Uvigerina* 属の炭素酸素安定同位体組成とその均質性：海洋環境指標としての信頼性評価  
Reliable stable isotopic compositions of individual *Uvigerina* spp. as sea environmental proxy

田中 崇史<sup>1</sup>; 石村 豊穂<sup>1\*</sup>; 原田 尚美<sup>2</sup>; 木元 克典<sup>2</sup>  
TANAKA, Takashi<sup>1</sup>; ISHIMURA, Toyoho<sup>1\*</sup>; HARADA, Naomi<sup>2</sup>; KIMOTO, Katsunori<sup>2</sup>

<sup>1</sup>茨城工業高等専門学校, <sup>2</sup>海洋研究開発機構  
<sup>1</sup>National Institute of Technology, Ibaraki College, <sup>2</sup>JAMSTEC

底生有孔虫の炭素・酸素安定同位体比 ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ ) は海洋底層環境の環境変動を記録することから、古環境解析に広く用いられてきた。特に *Uvigerina* 属は、汎世界的に産出し、殻が厚く堆積物中に保存されやすいという特性から、古環境解析に広く用いられる種である。先行研究では *Uvigerina* 属の複数種を一括して同位体比分析をおこない環境の「相対変動」解析に用いられることもあったが、同じ *Uvigerina* 属でも種によって一様に環境指標としての信頼性があるかどうかは明らかにされていない部分が多い。より信頼性の高い環境解析をおこなうためには種毎の環境指標としての信頼性についても検証する必要がある。そこで本研究ではオホーツク海の4地点で得られた海洋表層試料を用い、微量炭酸塩安定同位体比分析法を用いて各地点の個別分析から①種毎の安定同位体比の均質性を評価して環境指標としての汎用性を明らかにすること、また②種間での安定同位体比に違いが無いのかどうかを明らかにすることを目的に、*Uvigerina* 属の環境指標としての有用性を再検討した。

分析の結果、*Uvigerina* 属の  $\delta^{13}\text{C}$  と  $\delta^{18}\text{O}$  は収集地点・堆積深度によらず均質性は高い ( $<\pm 0.2\%$ ) ことがわかった。これは国際標準物質 NBS-19 の均質性とほぼ一致し、*Uvigerina* 属の安定同位体組成の高い均質性を裏付けるものであり、*Uvigerina* 属は高精度な古環境解析に適した有孔虫属であることが明らかとなった。さらに  $\delta^{18}\text{O}$  は海水の同位体値・水温から換算される同位体平衡値とほぼ一致することから、殻形成当時の水温を直接復元する「絶対変動解析」への利用が可能である。一方で、全ての地点で  $\delta^{18}\text{O}$  値は一定値を示すのに対し、 $\delta^{13}\text{C}$  値は *U. akitaensis*, *U. ochotica* の2種間で、いずれの地点でも約 0.7% の有意な差を示すことが明らかとなった。検討の結果、この有意な差は装飾・体形・殻の汚れ・体長の違いに依存するものではないため、両種の生態や石灰化メカニズムの違いに起因すると考えられる。

本研究の結果より、*Uvigerina* 属の  $\delta^{18}\text{O}$  は生物的・地理的要因に影響を受けない、均質な安定同位体組成を持ち、水温を直接反映するため、古環境指標としての高い信頼性が保証された。

キーワード: 安定同位体, 微量分析, 底生有孔虫, 環境指標

Keywords: stable isotope, benthic foraminifera, microscale analysis, *Uvigerina*