

学 位 論 文 題 名

Last glacial-Holocene paleoenvironmental changes of the Okinawa Trough
in the East China Sea and the Ryukyu Fore Arc region in the northwest Pacific

(東シナ海の沖縄トラフ及び北西太平洋の琉球前弧海域における最終氷期から後氷期にかけての環境変動)

学位論文内容の要旨

This thesis presents the results of a study of the down-core changes in carbonate, organic carbon and nitrogen concentrations, atomic C/N ratio, stable oxygen and carbon isotopic composition in planktonic and benthic foraminifera and sedimentary carbonate, stable carbon and nitrogen isotopic composition of organic matter, and abundance of two benthic foraminifera *C. wuellerstorfi* and *U. peregrina* from two marine sediment cores taken from Okinawa Trough and Ryukyu Fore Arc region. The objective of the study was to investigate the factors that control the changes of concentration and accumulation rate of carbonate and organic carbon and to determine the factors that influence the changes in stable isotopic composition in order to reconstruct paleoceanography in the Okinawa Trough and the Ryukyu Fore Arc region. Cores PN-3 and SST-4 were chosen for this study. PN-3 in Okinawa Trough is just below the Kuroshio current which characterized by warm, very low nutrient and high salinity, but PN-3 also close to the high productivity area of the East China Sea continental shelf, and became closer during lowering sea level in the last glacial time. SST-4 in Ryukyu Fore Arc region located at the open ocean side which low nutrient and low productivity. Core PN-3 and SST-4 were expected to record past environmental changes that could have provided a new paleoceanographic evidence from the East China Sea.

Based on the $\delta^{18}\text{O}$ Stages 1/2 and 2/3 boundaries and AMS ^{14}C ages, the bottom of cores PN-3 and SST-4 were estimated to be as old as 42 kyr and 30 kyr, respectively. The $\delta^{18}\text{O}$ records of *Globigerinoides sacculifer* for cores PN-3 and SST-4 are quite similar with the standard $\delta^{18}\text{O}$ curve of Martinson et al. (1987), reflected continuous deposition for the last 42 kyr in the Okinawa Trough and 30 kyr in the Ryukyu Fore Arc region. Surface water temperature during LGM inferred from the *G. sacculifer* $\delta^{18}\text{O}$ suggests that in the Okinawa Trough sea surface water temperature was as much as 2.0°C cooler than the present and in the Ryukyu Fore Arc region 1.5°C cooler than the present. The *G. sacculifer* $\delta^{13}\text{C}$ record for cores PN-3 and SST-4 reflected both the local and global signals.

Carbonate contents in PN-3 and SST-4 were lower during glacial than Holocene, implying increased dilution by non carbonate materials during glacial low stands of sea level. Carbonate accumulation in PN-3 is interpreted as transported from the ECS continental shelf water to the Okinawa Trough and carbonate production in this area, and that in SST-4 is primarily controlled by carbonate production in the Ryukyu Fore Arc region. Organic carbon accumulation rate in the Okinawa Trough was approximately 3 times higher during LGM than Holocene, and more than 5 times higher at LGM than Holocene in the Ryukyu Fore Arc region. The C/N ratios and Organic $\delta^{13}\text{C}$ values of these cores indicate that the most organic carbon is marine origin. The higher glacial organic carbon accumulation rates both in PN-3 and SST-4 suggest higher surface water productivity during the last glacial age. However, the most organic matter accumulated in PN-3 is interpreted as originally transported from high production of surface water in ECS continental shelf. Accumulation rates of organic carbon and carbonate show a good correlation in both cores PN-3 and SST-4, suggesting there is causal link between production of organic matter and carbonate in the euphotic zone. The glacial-interglacial $\delta^{15}\text{N}$ records for cores PN-3 and SST-4 show the constant values, implying the efficiency of nitrate utilization in surface water was almost constant throughout the last 40 kyr. There was no drastic change of the contribution of the Kuroshio Current to the paleoenvironmental changes in the Okinawa Trough since the last glacial. It was suggested that the Kuroshio Current has been flowing for the last 40 kyr in this area.

High accumulation rate of organic carbon in Okinawa Trough and Ryukyu Fore Arc region during the last glacial period coincide with increasing individual numbers of two benthic foraminifera, *Uvigerina peregrina* and *Cibicidoides wuellerstorfi*, and great $\delta^{13}\text{C}$ difference between both species. Increased abundance of *U. peregrina* and *C. wuellerstorfi* during the last glacial episode are interpreted as a result of higher flux of organic matter (food) reached the sediment surface as a consequent of increased surface water productivity. A good correlation between difference $\delta^{13}\text{C}$ values of *U. peregrina* and *C. wuellerstorfi* and organic carbon accumulation rates suggests that more flux of organic matter reached the sediment, more release of ^{13}C depleted CO_2 by organic matter decomposition within the sediment. I suggest that the $\delta^{13}\text{C}$ differences between benthic epifauna *C. wuellerstorfi* and infauna *U. peregrina* can be utilized as an indicator of surface water productivity changes.

学位論文審査の要旨

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現在の東シナ海は、大陸棚の表層水における生物生産が高いが、沖縄トラフは黒潮が流れているため生物生産が低く、外洋の琉球前弧も生物生産が低い。一方、最終氷期に東シナ海は大陸棚域が広がっており、揚子江や黄河などの河口が現在の大陸棚付近に位置していたと思われる。本研究は、最終氷期以降の東シナ海の古海洋環境が、その後どのように変化したかを調べることを目的とした。沖縄トラフと琉球前弧から採取した2本の海底コアについて、浮遊性・底生有孔虫殻の酸素・炭素同位体比、 CaCO_3 濃度、有機態炭素窒素濃度及び安定同位体比、C/N比を測定した。その結果、次のようなことを明らかにすることができた。

1. PN3 及び SST4 コアの浮遊性有孔虫の $\delta^{18}\text{O}$ カーブは、外洋の標準的な $\delta^{18}\text{O}$ カーブと酷似しており、その対比及び AMS ^{14}C 年代から PN3 コアの最下部は約 4 万年、SST4 コアの最下部は約 3 万年まで達していると判断される。浮遊性有孔虫の $\delta^{13}\text{C}$ カーブは、これまでに報告された多くの深海コアのものと類似しており、氷期-間氷期の海水の $\delta^{13}\text{C}$ 変化を反映している。
2. PN3 及び SST4 コアの有機物は、 $\delta^{13}\text{C}_{\text{org}}$ 、 $\delta^{15}\text{N}$ 及び C/N 比の分析結果によって、ほとんど海起源のものと考察される。
3. CaCO_3 及び TOC の MAR は、いずれのコアでも最終氷期の方が後氷期より高い。その結果、沖縄トラフ及び琉球前弧海域の生物生産は最終氷期の方が後氷期より高かったと考えられる。
4. 海底表層に生息している底生有孔虫の *Cibicidoides wuellerstorfi* と表層堆積物中に生息している *Uvigerina peregrina* の産出量及び両者の $\delta^{13}\text{C}$ 値の差は TOC の MAR と比例しており、海洋表層の生物生産量に影響されていることが判明した。
5. CaCO_3 及び TOC の MAR は、良い相関を示し、表層における有機物生産と CaCO_3

生産は密接に関係していたと考えられる。

以上の結果から、沖縄トラフには過去 4 万年間黒潮が流入しており、最終氷期の最寒期に海洋表層の生物生産量が相対的に多くなったと結論される。そして、最終氷期に大気 CO₂ 濃度が薄かった原因の一つとして、海洋表層の生物生産が増加したことが考えられる。

申請者の本論文をまとめるにあたっての精力的な海洋調査および膨大なデータの詳細な分析、そして古海洋学の幅広い範囲での研究努力は高く評価できる。大学院では、原著投稿論文を速やかに取りまとめていく実力も培ってきた。一方で申請者は後進大学院生への助言・指導にも熱心であり、さらに国内外の共同研究にも加わって活動しており、今後、独立した研究者として高い能力を発揮していくことが期待できる。以上から、審査員一同は申請者が博士（地球環境科学）の学位に相当する、十分な資格を有するもの判定した。