Anatomy of the Holocene raised coral reef at Kikai Island,central Ryukyus

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学 位 論 文 要 旨
ABSTRACT

Coral reefs have been characterized by in-situ growth of hermatypic corals. In contrast, recent studies on Grand Cayman have pointed out an importance of storm processes, that is rather destructive on reef development (Blanchon and Jones, 1997; Blanchon *et al.*, 1997). Thus, not only "growth (biological)" but also "depositional (physical)" processes and mechanisms should play an important roll in reef history.

A comprehensive study of the Holocene raised coral reef at the Shidooke area, northeastern coast of Kikai has been conducted by detailed chronological (α-spectrometric $^{230}Th/^{234}U$ method), biological and sedimentological investigations for the purpose of understanding of growth processes and mechanisms of Holocene reef sequence in distinct scales of time and extend.

In the large scale, contributions of antecedent topography and postglacial sea level rise to Holocene reef growth have been assessed. Relative sea level change during the OIS 3 unique to Kikai might has formed basal topography, where Holocene sequence began to deposit. During the Holocene transgression, turbid water condition has derived from coastal erosion have constructed large sedimentary bank as TST. After the maximum transgression, the thin Holocene reef at Shidooke has begun to construct abruptly on sediment platform by regression-induced increase of carbonate production.

Within a frame of large scale reef growth, two detailed processes and mechanisms of formation and erosion of the reef frame have been appeared. A scrutiny of the reef frame with attentions to textures of coral limestone brings new insight into formation processes of reef

crests. Rapid accumuration of larger corals and bioclastics is dominant in the crest formation stage suffering destruction by storms. Then completion of a storm-proof barrier, a reef crest would produce steady wave currents and facilitate slower but rigid formations of spurs by abundance of relatively small coral colonies and algal crusts in the post-crest formation stage.

A formation model of terraces controlled by newly proposed tear-off erosion is put forward. A primary cause of this erosion is a generation of horizontal cracks just above mean high-tide by a differential thermal expansion between wet and dry parts of Holocene coral limestone. This erosion can restrict not only paleo-sea level estimations but also recognition of depositional surfaces to provide ages indicating clear relations to paleo-shorelines.

A comprehensive study of the Holocene raised coral reef at Shidooke, northeastern coast of Kikai has been conducted for the purpose of understanding of formation processes and mechanisms of the Holocene reef sequence.

The Shidooke reef represents topographic and biologic zonation consistent with typical modern reefs. Five boring cores drilled along the transect perpendicular to the coastline have revealed that the Holocene sequence, which has the maximum thickness of 25 m beneath the crest, overlies unconformably basal siltstone (the Shimajiri Group) and is composed of the lower siliceous detrital limestone and the upper limestone units. Three kinds of grains, reworked silisiclastic silt from the Shimajiri Group, sand-sized lithoclasts of the Pleistocene Riukiu limestone and Holocene bioclastics constitute the lower loose sediment unit. The upper limestone represents lateral zonation corresponding to a typical reef topography, beach sediments, poorly sorted moat facies and coral limestone constructing the reef frame. The oldest age derived beneath the crest is 9.87 ± 0.16 ka, and the youngest is 5.32 ± 0.11 ka on the crest.

To achieve the purpose, external factors controlling reef growth have also been examined independently: age determination by α-spectrometric $^{230}Th/^{234}$ method, relative sea level change during the OIS 3 and Holocene relative sea levels, have been studied before reconstructing a reef history.

α-spectrometric $^{230}Th/^{234}U$ dating, which attained age error to be less than 5 % in 2σ has been used in this study as a sidereal time scale. Duplicate analyses of the same coral proved

the repeatability of isotopic analyses within 2σ age errors, and comparisons with cal. ^{14}C ages using same samples confirmed the reliability of α-spectrometric $^{230}Th/^{234}U$ ages of Holocene corals.

Relative sea level changes during late Pleistocene should modify topography, which would become pre-Holocene substrate. Pleistocene coral limestone showing shallowing and deepening upward sequences in facies and coral assemblages have been dated by the α-spectrometric $^{230}Th/^{234}U$ method, and represented that two coral reef terraces have been formed during two highstand at 61 and 52 ka. On the basis of altitudes of these paleo shorelines, mean uplift rates during the past 61 and 52 ka are estimated to be 1.5 m/kyr agreeing with each other. It is expected that a buried terrace would occur in a depth of ca. 20 m, by expanding a eustatic curve during the OIS 3 (Sasaki, 1995MS) according to an assumed constant uplift rate as a unique one in Kikai.

Relative Holocene sea level change at Kikai Island is reconstructed. For pre-7.5 ka, which is correspond to transgressive phase, the relative curve revealed from the 51-m core drilled on a Holocene raised reef at Huon Peninsula (Chappell and Polach, 1991). Concordant rates of uplift permit to adapt the curve to Kikai Island.

For post-7.5 ka, Holocene marine terraces at the northern Shidooke area have been surveyed. Through this investigation, a terrace formation model is proposed based mainly on the newly discovered and described erosion process, tear-off erosion. This erosion style is a kind of thermal erosion. A primary mechanism of a generation of horizontal cracks is deduced to be the differential thermal expansion between wet and dry parts of Holocene coral limestone. Coral limestone blocks are torn-off from horizontal cracks flawed just above mean high-tide level by wave action. This tear-off erosion has left smooth and flat surfaces on the inner part of coral reef terraces, the flat sub-zones. This erosion model can restrict not only paleo-sea level estimations but also recognition of depositional surfaces to obtain ages representing clear relationships with inferred paleo-shorelines.

Consequent estimations of relative sea level change from altitudes of abrasion

surfaces cutting Pleistocene limestone, torn-off surfaces carving Holocene coral limestone and depositional surfaces of coral limestone are summarized as follows. The maximum transgression reached an altitude of 9 m at 7.5 ka. Three stillstands at 4.8, 3.4 and 2.0 m in the mean sea level have been interrupted by two uplift events, of which ages are 4.0 - 5.1 and 2.6 - 2.9 ka. According to a mean recurrent interval (ca. 1.5 kyr) of uplift events, such an uplift might have happened at 6 - 7 ka.

Total of thirty-one $^{230}Th/^{234}U$ ages derived from the Holocene raised coral reef at Shidooke coast have lead the following history of a development of Holocene sequence.

An initial growth has occurred on an expected 20-m surface at ca. 10 ka by a thin coral limestone. During the transgression, reworked terrigenous sediments have constructed a non-reefal sediment platform as transgressive systems tract by sea level induced two processes of catastrophic and steady terrigenous influx. Former has caused rapid sedimentaion of poorly sorted detrital sediments during stillstands at the time of the maximum transgression. In contrast, the later has progressed bypassing of fine to deposit well-sorted type during rises of the sea. Thin veneer of Holocene reef has abruptly begun to grow stimulated by low turbidity, which has been caused by a termination of coastal erosion after a rapid fall of the relative sea, in a shallow and wide accommodation produced by TST.

A scrutiny of the reef frame with attentions to textures of coral limestone brings new insight into formation processes and rolls of reef crests. Fast growth and pile of large colonies of hermatypic corals and abundant biogenic fragments have constructed the most part of the crest suffering destruction by stomy typhoons (crest formation stage). Completion of a crest formation as a storm-proof barrier would produce steady wave currents and facilitate slower but rigid formations of spurs by abundance of relatively small corals and algal crusts (post-crest formation stage).

学位論文審査結果の要旨

本論文は，南西諸島喜界島の周囲に発達する完新世サンゴ礁段丘の多面的な調査・研究結果から，その形成過程を導いたものである。この種の研究には，特に高い精度の年代測定が不可欠であるが，本研究では，先ず，(1) αスペクトル$^{230}Th/^{234}U$法の適用範囲を１万年より新しい年代域にまで広げ，高精度の年代値を得ることに成功した。その上で，島の北東部志戸桶海岸を研究対象地と定め，地表踏査と試掘調査による完新世サンゴ礁の三次元解析を実施して，その形成過程を以下のように明らかにした。すなわち，(2) 30～40kaの海面変化によって形成された砕屑性堆積物から成る浅瀬が，完新世サンゴ礁の基盤として誕生し，その後，(3)約10kaから，生物源炭酸塩堆積物が堆積を開始した。(4)海面高度が最高位に達した約7.5ka，海岸域の波食によって陸源物が供給され，生物源炭酸塩粒子と珪質砕屑物が混ざり合う特徴的な海進期堆積体を形成した。そして，(5) 6.6ka以降の海面低下とともに，陸源堆積物の供給が絶たれ，浅海域にサンゴ礁が形成された。その後は，(6)少なくとも4.0－5.1kaと2.6－2.9kaの２回にわたる間欠的な相対的海面低下が起こり，サンゴ礁は離水し，浸食されて現在に至ったが，その過程を“剥離浸食作用”を提唱して論じた。

このように本論文は，最近１万年間に形成されたサンゴ礁およびその構成物から，氷河性海面変動などの海洋環境変遷史を独創的に論じたものであり，審査委員会は，２回の審査委員会における協議の結果として，博士(理学)の学位に値するものと認定した。