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Research paper

Carboniferous-Permian long-term sea-level change inferred from Panthalassan oceanic atoll stratigraphy

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Abstract

This paper traces late Palaeozoic second-order sea-level change based on the stratigraphy of the Akiyoshi Limestone, an accreted Carboniferous-Permian Panthalassan atoll carbonate succession in SW Japan. The estimated subsidence of a volcanic edifice and the variable rate of carbonate accumulation reveal the long-term sea-level history of the late Palaeozoic. During Bashkirian time, just after the lowstand stage at the mid-Carboniferous boundary, a slow progressive long-term sea-level rise began. This sea-level rise then increased greatly during Moscovian time. The following Kasimovian to Asselian interval represents a stable highstand stage. Beginning in the Sakmarian, sea level fell slowly and became stable in the Yakhtashian (= Artinskian). This stable sea level was maintained into the Midian (= Capitanian), although a small-scale sea-level rise of approximately 55–70 m is recognized in the Murgabian (= Wordian). The most noteworthy aspect of this change of sea level is the rapid sea-level rise during the Moscovian that created a very large accommodation space and resulted in accumulation of a thick carbonate succession. The eustatic rise from the earliest Bashkirian lowstand to the latest Moscovian highstand had an amplitude of approximately 230–240 m. Such a large-scale eustatic rise in the long-term sea-level change would most likely be caused by greater uplift of the ocean floor along the mid-oceanic ridges, as a result of an increase in the production of oceanic crust during that time.
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Keywords: Long-term sea-level change; Carboniferous-Permian; Panthalassa; Atoll stratigraphy; Akiyoshi Limestone

1. Introduction

Sea-level change in geologic time has been commonly inferred from reviews of onlap/offlap curves interpreted from sequence stratigraphic analyses of sedimentary successions on continental shelves (Haq et al., 1987, 1988; Ross and Ross, 1987, 1988; Izart et al., 2003; Haq and Schutter, 2008). This method is useful for recognizing high-frequency cyclostratigraphic units. However, the pattern of the sea-level change and its amplitude, particularly of long-term sea-level change, remains controversial, because changes in the basin morphology on continental shelves, induced by complicated local tectonic settings, would make it difficult to understand eustatic sea-level history. Therefore, we need to evaluate and test previous interpretations of sea-level change using another method.

Atoll carbonates are formed upon mid-oceanic volcanic edifices on an ocean floor with a very simple subsidence history over a long period of time. Mid-oceanic atoll carbonates, therefore, are a sensitive "recorder" of sea-level change over geologic time (Wheeler and Aharon, 1991). Carbonate sedimentation keeps up with sea-level rises of long-term sea-level change, and is eroded during lowstand stages. Accordingly, the subtraction of subsidence from aggradation during each stage simply represents ancient long-term sea-level change. By using this method, changes in sea-level records since Cretaceous time were obtained from atolls and guyots in the modern Pacific (Major and Matthews, 1983; Wardlaw and Quinn, 1991; Lincoln and Schlanger, 1991; Röhl and Ogg, 1998). Unfortunately, pre-Cretaceous seamounts have already been accreted in subduction zones along margins of the ocean. Atoll carbonates in an ancient accretionary complex of an arc-trench system setting such as the Japanese Islands, therefore, are very important for the reconstruction of pre-Cretaceous sea-level changes (Nakazawa and Ueno, 2004).

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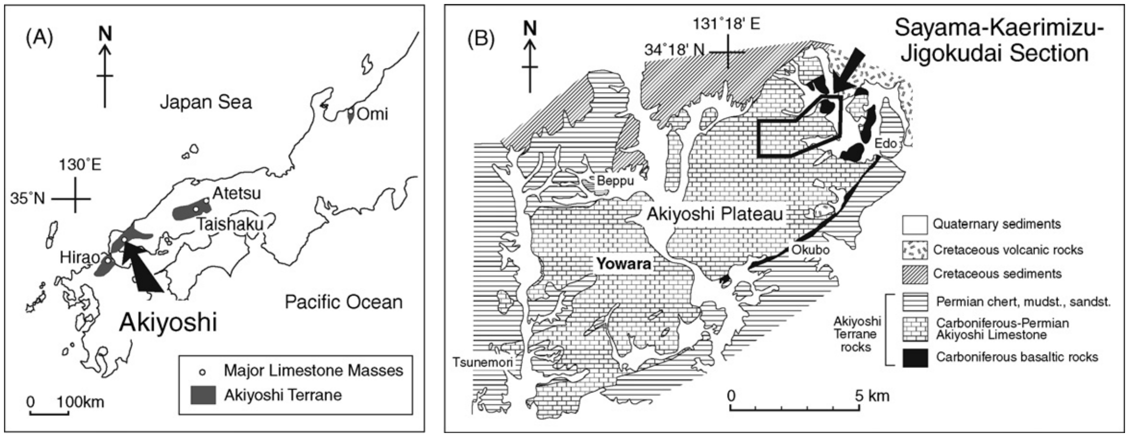

Fig. 1. (A) Distribution of Akiyoshi Terrane in SW Japan and location of Akiyoshi Limestone. (B) Index map of Sayama-Kaerimizu-Jigokudai section. Geologic map simplified from Ota (1968) and Kanmera and Nishi (1983).

This paper discusses late Palaeozoic second-order sea-level change based on the stratigraphy of accreted Carboniferous-Permian mid-oceanic atoll carbonates in SW Japan, the Akiyoshi Limestone.

2. Geologic setting

The Japanese Islands are underlain by subduction-related accretionary complexes formed since the Late Palaeozoic (Ichikawa, 1990; Isozaki et al., 1990). They are composed mainly of a mixture of oceanic rocks such as basalt, carbonates, and chert, and trench fills such as sandstone and mudstone. The carbonate rocks in this mixture are mostly of mid-oceanic atoll origin, and overlie oceanic-island basalt and related volcaniclastic sediments. The examined Akiyoshi Limestone is one of the most typical representative carbonate bodies in the Akiyoshi Terrane, a Permian accretionary complex in SW Japan (Fig. 1A). The limestone is approximately 1000 m thick without terrigenous siliciclastic intercalations (Sano and Kanmera, 1988) and accumulated on the alkali basalt of an oceanic island produced by the activity of a large-scale thermal plume (Tatsumi et al., 2000; Sano et al., 2000). The limestone was formed in the Panthalassa Ocean (Ozawa, 1987) during Viséan (Middle Mississippian/Early Carboniferous) to Midian (Guadalupian/Middle Permian) time, and was accreted to the eastern margin of Asia in latest Middle to Late Permian time (Kanmera et al., 1990).

The Akiyoshi Limestone comprises mostly shallow-water carbonates, limestone, and small amounts of dolostone. Ota (1968) described five atoll facies and their distributions in the Akiyoshi Limestone: talus, true reef, beach sand, marginal lagoon, and central lagoon facies.

3. Biostratigraphy and estimation of stratal thickness

As has been argued by Sano and Kanmera (1991), the Akiyoshi Limestone in most places suffered structural disturbance in various degrees due to the collapse of the seamount and the succeeding structural deformation during accretion. This is particularly true in the western part of the Akiyoshi Plateau, a karst plateau composed of the Akiyoshi Limestone. In this area, the geology is much more complicated and chaotic (Sano and Kanmera, 1991). However, the eastern part of the Akiyoshi Plateau is less deformed, and its stratigraphic record remains relatively complete.

Our study is primarily focused on the Sayama-Kaerimizu-Jigokudai area (Fig. 1B) in the northeastern part of the Akiyoshi Plateau. Tectonic disturbance of the Akiyoshi Limestone in this area is minimal (Ota et al., 1973; Ueno, 1989, 1991, 1992), and almost complete stratigraphic and biostratigraphic information is available. Three sections, Sayama, Jigokudai, and Kaerimizu, provide a composite section ranging from the Viséan (Middle Mississippian/Early Carboniferous) up to the lower part of the Midian (Late Guadalupian/Middle Permian). The limestone of these sections is composed of marginal and central lagoonal facies represented by grainstone and packstone (Ota, 1968).

The base of the Sayama section (Ueno, 1989) is about 230 m of basalt and basaltic volcaniclastics. This volcanic sequence is overlain by 625 m of massive and pure limestones, in which 12 consecutive foraminiferal (mostly fusulinoidean) biozones from the *Endothyra* Zone (middle Viséan) to the *Quasifusulinoides toriyamai* Zone (middle Kasimovian) have been recognized (Fig. 2).

The Jigokudai section (Igawa, 2003), about 115 m thick, is composed of strata ranging from the upper Kasimovian to the Sakmarian. In this section, seven fusulinoidean biozones from the *Carbonoschwagerina satoi* (late Kasimovian) to the *Schwagerina krotowi* Zone (Sakmarian) are identified (Fig. 2).

The Kaerimizu section (Ueno, 1991, 1992, 1995) covers strata from the Artinskian to the early Midian. A very detailed biostratigraphic framework was obtained using the abundant fusulinoideans in this section that could be compared directly with the standard Tethyan scale (cf. Leven, 1976, 1980). A total of 13 fusulinoidean biozones from the Artinskian/Yakhtashian *Chalaroschwagerina inflata*-*Chalaroschwagerina exilis* Zone to the early Capitanian/Midian *Colania douvillei* Zone have been recognized in the structurally undisturbed limestone succession (Fig. 2).

The uppermost fusulinoidean biozone in the Akiyoshi Limestone is the *Lepidolina multiseptata* Zone (Ota, 1977; Ueno,

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