Long periodicity (3.5 m.y.) Milankovitch cycles and its potential impacts on the Earth system dynamics

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Abstract

Sedimentary rhythms provide useful information to explore dynamics of the Earth system. However, its application to deep sea sediments has been limited. Our recent study on middle Triassic bedded chert demonstrated its Milankovitch cycle origin with series of periodicities including ca. 3.5 m.y. cycle. Our preliminary study also suggests that ca. 3.5 m.y. cycle may correspond to the variation in diversity of radiolarian fossils and the third order sea level changes. The cause of the cyclicities of bedded chert is also an interesting problem to solve. We hypothesize that the sedimentary rhythm of bedded chert was resulted from dry-wet cycles of continental climate controlled by Megamonsoon activity in Pangea (We call a "Megamonsoon hypothesis"). Namely, chert beds were deposited during stronger summer monsoon periods as a result of increased biogenic Si due to enhanced runoff, whereas shale beds were deposited during weaker summer monsoon periods due to increased dust flux caused by expansion of deserts. If our Megamonsoon hypothesis is correct, understanding of the Earth system response to 3.5 m.y. cycle and the nature of internal feedbacks functioning in this time scale will provide critical knowledge on the Earth system dynamics. Here, we propose to retrieve continuous high-resolution pelagic biosiliceous sedimentary records to examine the amplitudes and phase relationships between variations in sea level change, summer monsoon intensity, biodiversity, and insolation. It is essential to examine the variations in terrestrial monsoon intensity, pelagic productivity, and biodiversity with high-resolution, and IODP in conjunction with ICDP will provide us the best opportunity.

Research Focus:

Milankovitch forcing is regarded as one of the main drivers of climate changes in 10^4 to 10^5 year scale, and Milankovitch cycles preserved in sedimentary records provide us excellent high-resolution time controls to calculate rates and magnitudes of wide range of processes related to the Earth system dynamics. However, its application to deep sea sediments of older ages (before Late Cretaceous) and especially to non-calcareous sediments (below CCD) has been limited. Also, exploration for the evidence of the Earth system response to longer-periodicity Milankovitch cycle, such as 3.5 m.y. eccentricity cycle, is limited because high quality and high-resolution proxy record of over 10 M.y.-long is rarely obtainable.

Our recent research of middle Triassic bedded chert (see out poster) demonstrated its Milankovitch cycle origin with series of periodicities including ca. 20, 40, 100, 400, and 3500 k.y. Especially notable is a consistent presence of 3500 k.y. (=3.5 m.y.) -cycle with a relatively large amplitude (Figure 1). The 3.5 m.y. cycle was also reported from Triassic Newalk Basin in North America (Olsen & Kent, 1999). Our preliminary study also suggests that the variation in diversity of radiolarian fossils was associated with 3.5 M.y.-cycle, suggesting the possibility that extinction/diversity is controlled by long-periodicity Milankovitch cycle (Figure 1). It is also possible that ca. 3.5 m.y. cycle may correspond to the third order sea level changes.

Megamonsoon Hypothesis:

We consider that these sedimentary rhythms of bedded chert were resulted from dry-wet cycles of continental climate in Pangea (Olsen, 1986) that is controlled by variations in the Megamonsoon activity (Kutzbach & Gallimore, 1989) paced by Milankovitch cycle (we call a "Megamonsoon hypothesis"). Namely, chert beds were deposited during the stronger summer Megamonsoon periods due to the increased biogenic Si flux caused by stronger chemical weathering and consequent increase in nutrients supply to the ocean, whereas shale beds were deposited during weaker summer Megamonsoon periods due to expansion of dry areas in Pangea and consequent increase in dust flux. To test this hypothesis and explore the behind mechanism is the objective of this proposal.

Expected outcome:

If our Megamonsoon hypothesis is correct, sedimentary rhythms paced by Milankovitch cycle should be common features for pelagic sediments, especially bio-siliceous sediments accumulated below CCD, which could have formed as a result of dynamic response of global climate and geochemical cycles to Milankovitch cycle through Megamonsoon. Forcings and internal feedbacks that control million year scale changes in global climate are poorly understood. In this respect, 3.5 m.y. cycle could be important, still largely overlooked component of external forcing that strongly control m.y.-scale behaviors of the Earth system. So, understanding of the Earth system response to 3.5 m.y. cycle and the nature of internal feedbacks functioning in this time scale will provide critical knowledge on the structure of the Earth system.

Proposal:

We propose to retrieve long, continuous high-resolution pelagic biosiliceous sedimentary records of Jurassic to Cretaceous age to examine the amplitudes and phase relationships between variations in sea level change, summer monsoon intensity, biodiversity, and insolation, and investigate the response of the Earth system to the long periodicity Milankovitch forcing and the nature of internal feedback mechanisms. It is essential to examine the variations in eolian flux, grain-size, mineral composition, chemical composition (e.g. Si/Al, and CIA), and diversity of microfossils with high-resolution. A systematic and coordinated approach to conduct a detailed reconstruction of the variations in terrestrial monsoon intensity, pelagic productivity, and biodiversity is desirable, and integration of terrestrial (such as ICDP) and marine (such as IODP) drilling will provide us the best opportunity in this respect.

Reference:

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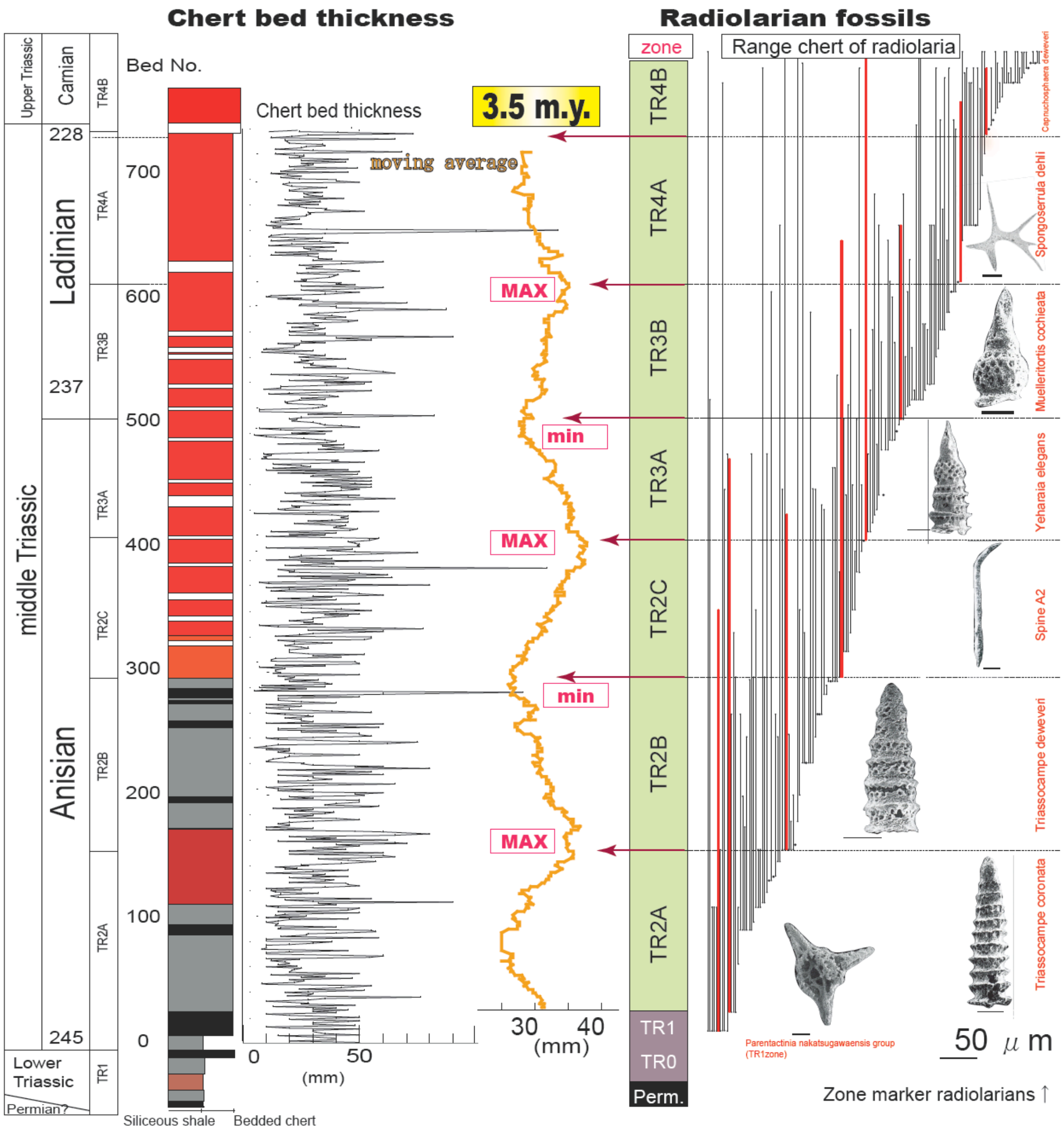

Fig.1. The possible linkage between ca. 3.5 m.y. (200 chert bed thickness) cycle and the diversity dynamics of the radiolarian fossils (Sugiayam, 1997) of the middle Triassic bedded chert sequence.

Figure 1. Possible linkage between ca. 3.5 m.y. cycle detected from the variations in the chert bed thickness and the diversity dynamics of radiolarian fossils (Sugiyama, 1997) in the middle Triassic bedded chert sequence.