Age determination of pelagic clay using Monte Carlo simulation constrained by ichthyolith biostratigraphy and bulk cobalt concentrations

*Kazuhide Mimura[1], Kentaro Nakamura[1], Kazutaka Yasukawa[1,2], Junichiro Ohta[1,2], Koichiro Fujinaga[2,1], Yoichi Usui[3], Yasuhiro Kato[1,2]

1. Department of Systems Innovation, School of Engineering, the University of Tokyo, 2. Ocean Resources Research Center for Next Generation, Chiba Institute of Technology, 3. Japan Agency for Marine-Earth Science and Technology

Pelagic clay is one of the most widely-distributed types of seafloor sediment in the global ocean [1]. It has been, therefore, regarded as an important medium recording global and long-term environmental changes in Earth’ s history, such as changes in atmospheric/oceanic circulations and surface ocean productivity [2]. Recent studies show that bulk chemical compositions of pelagic clay are highly variable, reflecting changes in depositional position and environment [3, 4]. However, paleoenvironmental reconstructions from pelagic clay are still challenging due to difficulties in determination of depositional ages resulting from scarcity in age-diagnostic calcareous/siliceous microfossils and an ambiguity in paleomagnetic reversals.

Some previous studies constrained depositional ages of pelagic clay using biostratigraphy of fish teeth and denticles, called ichthyoliths, which are only the microfossils that commonly occur in pelagic clay of deep-sea basins [5]. However, in contrast to the well-developed biostratigraphy of siliceous/calcareous microfossils, depositional ages constrained by ichthyoliths still have large uncertainties. In addition to the ichthyolith biostratigraphy, some previous studies estimated the depositional ages of pelagic clay by assuming that cobalt precipitates to seafloor at a constant flux [2, 6], whereas the assumption that the cobalt precipitates at a constant rate throughout the geologic time is questioned [6].

Here, we develop a new practical method to constrain depositional ages of pelagic clay by combining ichthyolith biostratigraphy and a cobalt-based age model. We first assume that a depositional flux of cobalt from seawater to seafloor can vary in accordance with a probability distribution. Then, a Monte Carlo simulation is performed to calculate a reasonable range of sedimentation rates under constraints of depositional ages inferred from the ichthyolith biostratigraphy. We have applied this method to pelagic clay cores recovered from the Pacific Ocean, and obtained the reasonable depositional ages with uncertainties significantly smaller than that constrained only by ichthyolith biostratigraphy. This new method is applicable to a variety of sediments having some constraints in depositional ages and sedimentation rates.

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