Drilling Cretaceous chert/shale sequence from deep Pacific basin: paleoceanographic implications and technical problems

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Abstract

Mid-Cretaceous is characterized by repeated depositional periods of organic-rich marine sediments (i.e. black shales) in various oceanic settings, which are referred to as Oceanic Anoxic Events (OAEs). It has been proposed that some OAEs are triggered by massive volcanism associated with formation of large igneous provinces (LIPs), because some OAEs occur almost simultaneously with the formation of LIPs. For example, the timings of early Aptian OAE-1a and end-Cenomanian OAE-2 are almost coincident with those of Onton Java and Caribbean Plateaus, respectively. However, the causal mechanism(s) for OAEs has still been controversial. To address this scientific issue, it is essential to investigate high-resolution geological and geochemical records of deep-sea sediments that covered about half of the Earth's surface.

Spatiotemporal distribution of Cretaceous black shales would also provide us cue to understand its causal processes. Although previous DSDP/ODP expeditions have largely improved our knowledge of the spatiotemporal distribution of Cretaceous black shales, the distribution of Cretaceous black shales in the deep Pacific basins has been poorly reconstructed because of poor core recovery and difficulty in age determination for carbonate-free chert/shale successions.

Here we propose key scientific objectives; 1) to know the distribution of black shale in the deep Pacific basins, and 2) to understand causal mechanism(s) of OAEs, particularly causal linkage with LIP eruptive episodes. A potential area suitable to address these objectives would be the deep basin of northwest Pacific. Development of both drilling technologies to improve core recovery, and laboratory analytical techniques to establish isotopic chemostratigraphy is required to obtain a full sequence of Mesozoic sediment from deep Pacific basin to understand the Mesozoic ocean environments.

1. Research Focus

Mid-Cretaceous is characterized by repeated depositional periods of organic-rich marine sediments (i.e. black shales) in various oceanic settings, referred to as Oceanic Anoxic Events (OAEs). It has been proposed that eruptive events associated with the formation of large igneous provinces (LIPs) such as Ontong Java, Manihiki, Kerguelen and Caribbean Plateaus were an ultimate trigger for OAEs (e.g., Coffin and Eldholm, 1994; Sinton and Duncan, 1997; Larson and Erba, 1999; Snow et al., 2005). Recent geochemical studies have indicated that sediments deposited at the early Aptian (OAE-1a, c.a. 120 Ma) and the Cenomanian/Turonian boundary (OAE-2, c.a. 94 Ma) show high contribution of elements such as osmium and lead from the mantle, which would have been released by LIP eruptive events of Ontong Java and Caribbean Plateaus, respectively (Snow et al., 2005; Kuroda et al., 2007; Tugeon and Creaser, 2008; Tejada et al., 2009). Although we understand that some LIP eruptive episodes are simultaneous with these OAEs, their causal linkage(s) is still controversial (Fig. 2). To understand the real linkage between these marked events, we should address some key scientific questions; how LIP eruptive events affected global environments that resulted in OAEs, what element and molecular were the key to the critical environmental change, and how the depositional environments of organic-rich black shales prevailed over global oceans after the eruption events etc. Most of the geological and geochemical data have been obtained from Atlantic and western Tethys, while the paleoceanographic condition in the deep Pacific basin that covered about half of Earth's surface is poorly understood. We think that it is essential to investigate geological and geochemical records for pelagic sediments deposited on deep Pacific basins. In addition, the distribution of organic-rich sediment in the Pacific Ocean is critical for understanding the nature and causal mechanism(s) of OAEs. It was originally postulated that mid-Cretaceous black shales in the Pacific were deposited only at mid-water depths where the seafloor was directly overlain by a water mass depleted in dissolved oxygen. However, this notion is based on sparse and fragmentary evidence obtained mainly from the flanks of bathymetric highs (e.g., Shatsky Rise and Mid Pacific Mountains); hence, the distribution of black shale in the Pacific Ocean remains to be critically evaluated. Since accumulation rates of deep Pacific sediment are expected to be very low (<10 m/myr), ultra-high-resolution studies of sediment intervals across these OAEs are required for understanding temporal relationships between OAE formation and potential causal events.

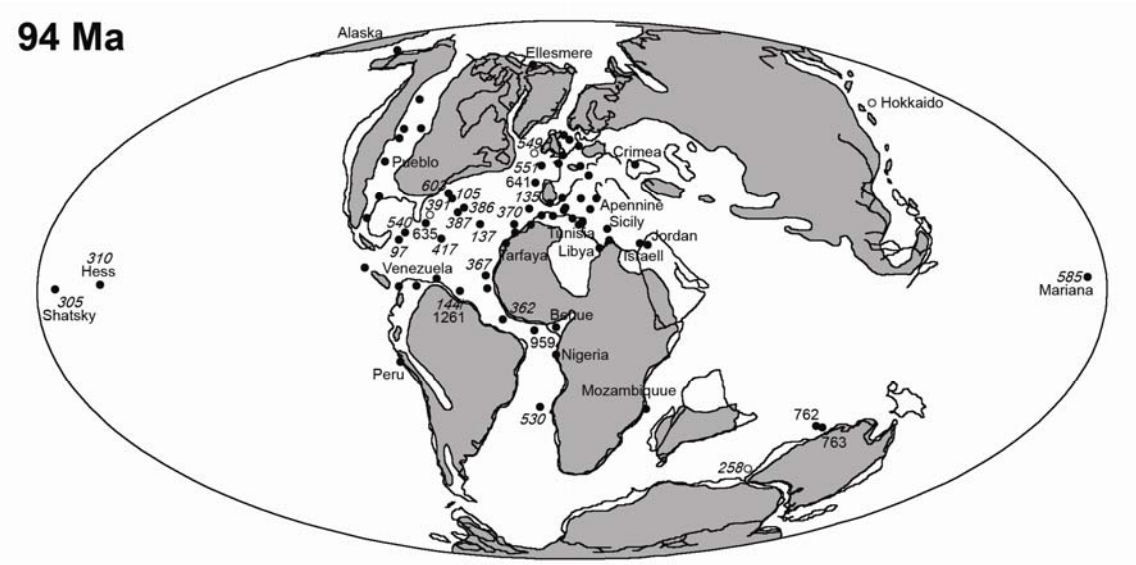

Fig. 1. Distribution of organic-rich black shales (filled circles) deposited around the Cenomanian/Turonian boundary (OAE-2). Modified after Kuroda and Ohkouchi (2006).

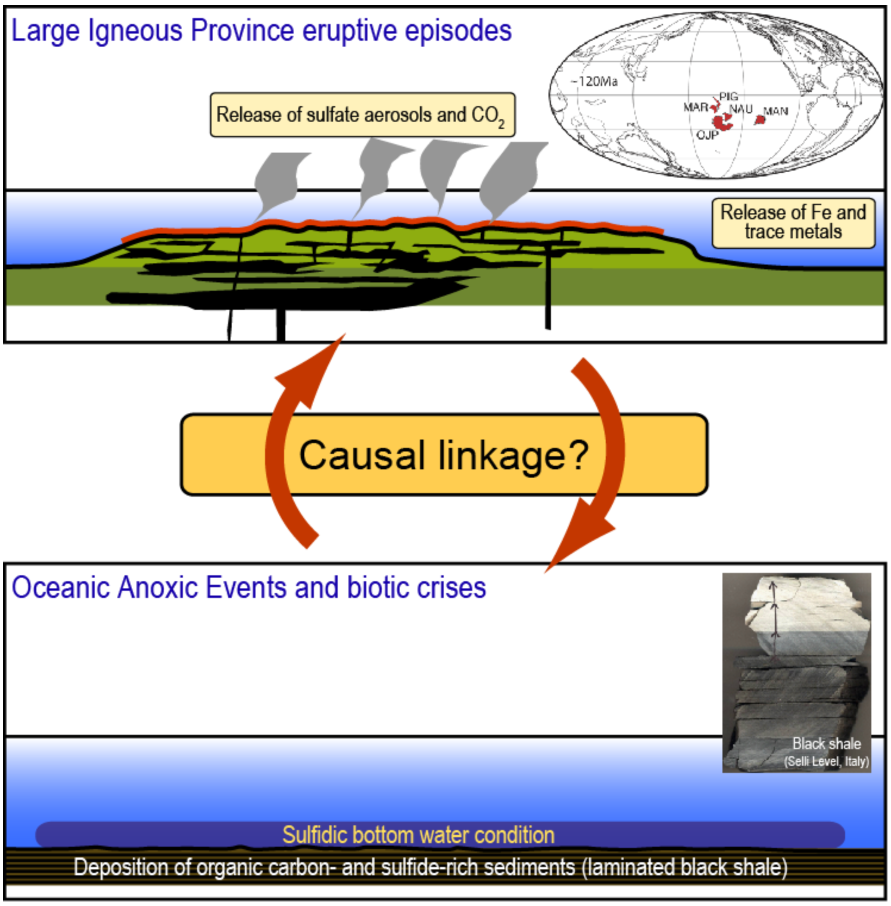

Fig. 2. Schematic images of the potential causal linkage between Large Igneous Province (LIP) eruptive episodes (top) and Oceanic Anoxic Events (bottom) during the middle of Cretaceous time. Paleogeographic reconstruction for for Ontong Java Plateau (OJP), Nauru (NAU), East Mariana (MAR), Pigafetta (PIG) basin flood basalts and Manihiki Plateau (MAN) formed during Aptian is after Eldholm and Coffin (2000).

2. Technical issues to be solved: recovery and age determination

Despite of numerous efforts of DSDP/ODP, core recovery of mid-Cretaceous pelagic sediment from deep basin in the west Pacific has been very low (generally <10%), which contrasts strongly with those from the Atlantic Ocean. Such low core-recovery is attributable mainly to the fact that the sediments deposited beneath carbonate compensation depth (paleodepth >4 km) were composed of chert/shale facies, namely hard/soft sequences that have proven difficult to recover with previous and present drilling technologies (Fig. 3). Under these circumstances, we have a strong desire that new coring technologies such as motor driven core barrel (MDCB) and the 'gel method', will be applied to recover a full sequence of mid-Cretaceous sediment recording continuous paleoceanographic information from the deep basins of the western Pacific.

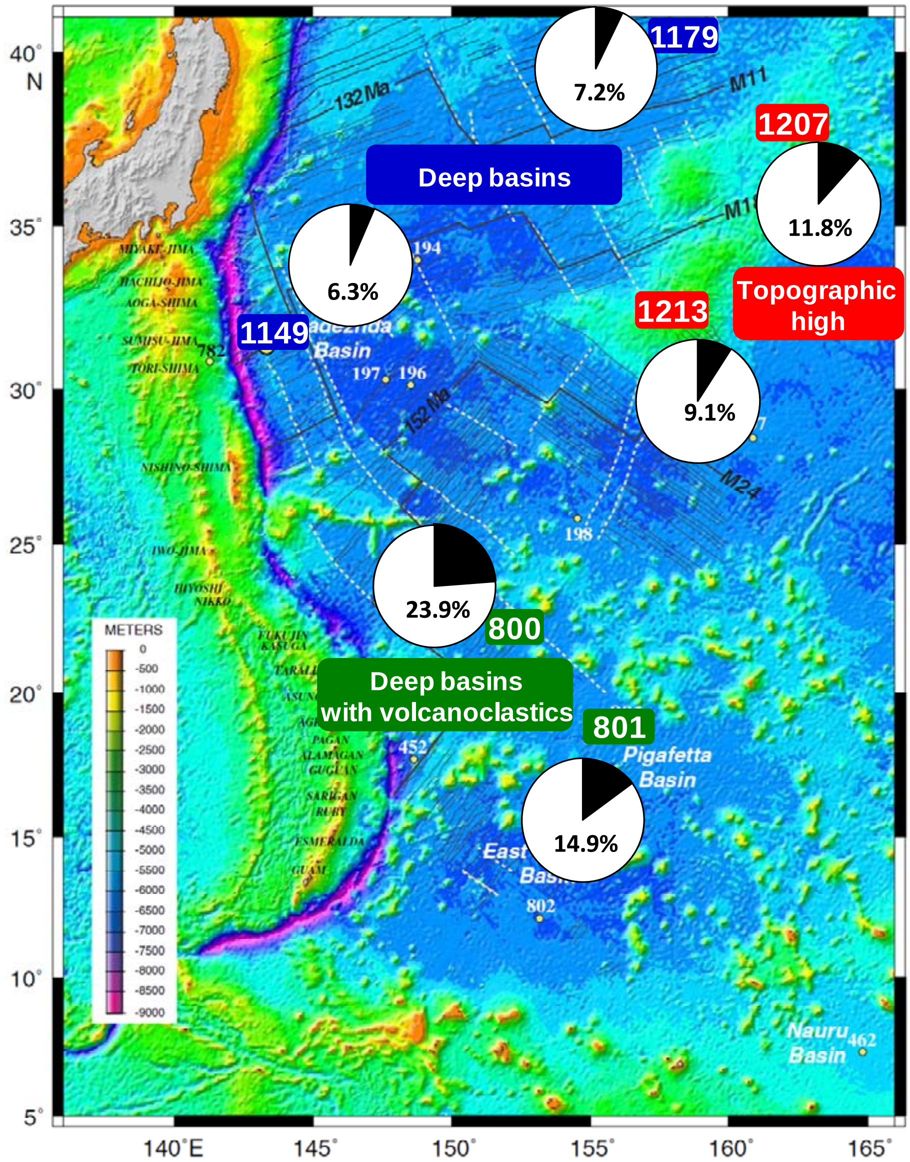

Fig. 3. Average recoveries for the Cretaceous stratigraphic intervals in the western Pacific ODP sites. Note that sediments intercalated with chert and porcellanite (ODP Sites 1149, 1179, 1207 and 1213) show very low recovery down to ~6%.

Age control for carbonate free sediments is another key issue to be solved. It has been considered to be difficult to determine ages of sediments which do not contain foraminifers and nannofossils. There are only few approaches for carbonate-free sediments such as radiolarian biostratigraphy, isotopic chemostratigraphy of sedimentary organic carbon and/or osmium in hydrogenous fraction. In particular, osmium isotopic record has come to be accepted as a new tool for stratigraphic correlation, because 1) in many cases, osmium is well homogenized in the ocean thus its isotopic composition is uniform globally, 2) residence time of osmium in the ocean is on the order of 10,000 years, which is much shorter than strontium and thus has a potential to trace short-time events, and 3) hydrogenous osmium is contained not only in carbonate minerals, but also in organic matter, Fe oxides and sulfides, therefore is used for stratigraphic correlation of shale and chert. Recently many laboratories have developed simple methods to analyze osmium isotopic ratios of sediments using MC-ICPMS.

We believe that recent developments of both drilling technologies and laboratory analytical techniques will enable us to obtain a full sequence of mid-Cretaceous sediment from deep Pacific basins to understand the detailed changes in ocean environments and temporal relationships between OAEs and potential causal events such as LIP formation.

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