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Recent Advances in Research on Terrestrial and Marine Sequences from the mid-Cretaceous Oceanic Anoxic Events (OAEs)

By Reishi Takashima, Pitambar Gautam, Hiroshi Nishi

The Cretaceous was a time of greenhouse climates characterized by at least 15 ˚C warmer sea surface temperatures than the present one. During the climax of Cretaceous warming, anoxic condition in the oceans globally expanded, resulted in accumulations of organic rich sediments (so-called black shales). These events are called Oceanic Anoxic Events (OAEs), and occurred at least 8 times during the Cretaceous period (Figure 1). The study of OAEs is important from three different perspectives: (i) the OAEs acted as the thermostat during the greenhouse climate because they eliminated carbon from atmosphere (CO_2) to sediments (black shales); (ii) the expansions of anoxic condition in the oceans caused mass extinctions of marine biota; (iii) most of source rocks were formed during Cretaceous time under anoxic oceanic environments.

Discovery of the Cretaceous OAEs (Schlanger and Jenkyns 1976) was one of the most important achievements of the Deep Sea Drilling Project, and understanding Cretaceous OAEs is regarded as major scientific objective of "the Extreme Climate" research program outlined in the Integrated Ocean Drilling Program (IODP). To review the recent advances and gain new insights on the study of OAEs, a symposium entitled "Recent Advances in Research on Terrestrial and Marine Sequences from the mid-Cretaceous Oceanic Anoxic Events (OAEs)" was held at Hokkaido University, Sapporo during 21-23 September, 2005. The symposium was hosted by the 21st Century Center of Excellence (COE) Program for the Neo-Science of Natural History, and was organized by Hisatake Okada (COE program leader) and Hiroshi Nishi. There were 13 talks (eight of which were given by invited scientists from abroad) and 8 posters dealt with land and marine OAE sections shown in Figure 2. Discussion on land sections concentrated on: (i) Umbria-Marche Basin, Western Interior, NW German Basin and Vocontian Basin, all of which have OAEs accompanied by black shales; and (ii) Anglo-Paris Basin, Yezo Basin and Great Valley Basin, in which the OAEs are devoid of black shales. As regards type (i), results of high-resolution (at a scale of cm~mm order) studies on microfossils and geochemical analyses (both organic and inorganic) of the black shales related to OAEs were discussed. It was demonstrated that the black shales in the continental interior and continental margins were deposited during marine transgressions, each individual lamina corresponding to the increased runoff from the land areas. For type (ii) sections, attention was paid to the integrated analysis of macro and microfossil and carbon isotope stratigraphies for identification of the precise horizons of OAE levels. Although development of conspicuous anoxic environment didn't occur in these sections, clear evidences of remarkable faunal turnover, involving various taxa, were shown at the OAE levels. Studies on the marine sections dealt with core-based data mainly from the Blake Nose situated off Florida, and Demerara Rise off Brazil. Both sections have yielded extremely well preserved calcareous fossils being suitable for isotope geochemical analysis. Oxygen and carbon isotope data on planktic and benthic foraminifers reveal the development of two types

of water-column structure during OAEs. The first type, represented by collapse of the vertical structure of the water column caused by abrupt deep water warming, is recognized in OAE2 and OAE1d. Such OAEs are characterized by the increased primary production, drawing of carbonate platform and world-wide deposition of black shales. The second type corresponds to intensified vertical water column stratification triggered by an increase in the surface water temperature or a decrease in salinity (e.g. Pacquier level of OAE1b).

A question related to OAEs is the identification of factors that are responsible for the increased runoff observed in the land sections and the warming of the surface as well as deep water observed in marine sections. The emplacements of the large igneous provinces (LIPs) are thought to be most plausible trigger because each OAE occurred contemporarily with them. However, the emplacement positions of LIPS, their depths of eruption, the amount of magma production and the composition of the magma were highly variable and we still lack in adequate data which could allow us to deduce the relationship between the formation of the LIPs and the development of the anoxic water-column in the oceans.

The concluding session of the symposium was devoted to introduction of the activities of IODP and Japan Drilling Earth Science Consortium and discussion on the Cretaceous IODP drilling site for OAE research. Understanding how the OAEs occurred requires knowledge on the thermal structure of the ocean during those greenhouse periods. As reliable data for water temperature for pre-Aptian as well as for the high latitude regions are still inadequate, these aspects need due consideration in future. The Falkland Plateau (Argentina) was chosen as the most appropriate target for the next drilling.

At the end of the symposium, a day-long field excursion to observe the OAE 2 section in Hokkaido was organized. It was explained that there are evidences of prominent positive excursion of $\delta^{13}C_{organic}$, weaken bioturbation and occurrence of abundant pyrite, although deposition of typical black shales didn't occur in this section.

Symposium Program and Abstracts can be downloaded from:
http://nature.sci.hokudai.ac.jp/symposium/050921/OAE-Sapporo-abstracts.pdf

Figure Captions

Figure 1: OAE horizons, sea level changes and production rate of the oceanic crust.

Figure 2: Study areas (presenters) considered during the OAE Sapporo Symposium.
1. Anglo-Paris Basin (A.S. Gale), 2. NW-German Basin (J. Mutterlose), 3. Vocontian Basin (R. Takashima, K. Nagai et al., K. Okano et al.), 4. Italy (J. Kuroda et al.), 5. Western Interior (M. Leckie et al., B. Sageman et al.), 6. Great Valley (A. Fernando et al., T. Tomosugi et al.), 7. Yezo Basin (H. Ando, K. Kurihara & F. Kawabe), 8. Blake Nose (B. Huber et al., J. Erbacher et al.), and, 9. Demerara Rise (J.

Erbacher et al., A. Bornemann & R. D. Norris, P.A. Meyers & J. –G. Yum, A. Forster et al.)

Figure 3: Outcrop of the OAE2 horizon in the Yezo Group, Hokkaido.

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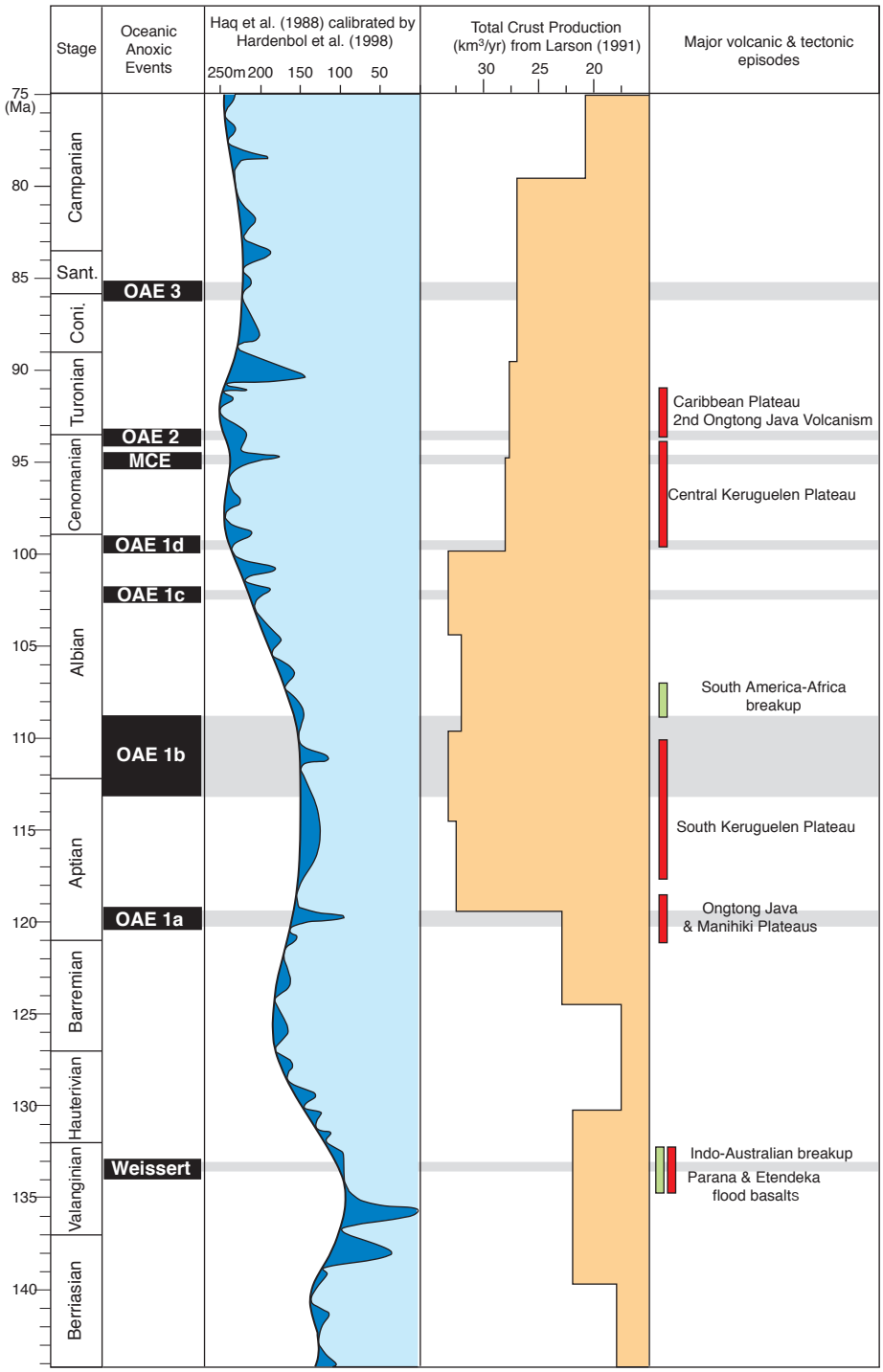
Stage
Oceanic Anoxic Events
Haq et al. (1988) calibrated by Hardenbol et al. (1998)
250m 200 150 100 50
Total Crust Production (km³/yr) from Larson (1991)
30 25 20
Major volcanic & tectonic episodes
75 (Ma)
80
85
90
95
100
105
110
115
120
125
130
135
140
Campanian
Sant.
Coni.
Turonian
Cenomanian
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian
OAE 3
OAE 2
MCE
OAE 1d
OAE 1c
OAE 1b
OAE 1a
Weissert
Caribbean Plateau
2nd Ongtong Java Volcanism
Central Keruguelen Plateau
South America-Africa breakup
South Keruguelen Plateau
Ongtong Java & Manihiki Plateaus
Indo-Australian breakup
Parana & Etendeka flood basalts

N. America
Asia
1
2
3
4
5
6
7
8
9
Pacific Ocean
Tethys Sea
Atlantic Ocean
Africa
Pacific Ocean
S. America
India
Ontong Java
Plateau
Panana
Keruguelen
Plateau