A simulation of paleo-ocean in the mid-Cretaceous

Kazuhiro Misumi[1]; Yasuhiro Yamanaka[1]

[1] Environ. Earth Sci., Hokkaido Univ

The mid-Cretaceous is a period with warm climate due to high atmospheric CO2 concentration. Thermohaline circulation (THC) and marine biogeochemical cycles in the period are considered to be quite different from those of the present. The idea of formation of warm saline bottom water (WSBW) that is saline bottom water formed in the subtropical Tethys has been believed. The wide spread depositions of the black shale containing rich organic carbon are regarded as the anoxic condition in the deepwater. The depositional events that take place several times in the mid-Cretaceous are called oceanic anoxic events (OAEs). At least two of OAEs are identified as global scale events. The time scales of the events are roughly several hundred thousand years. There are two types of ideas explaining the causes of OAEs: decreased oxygen supply to the deepwater with THC being inactive and increased oxygen consumption in the deepwater with increase in export production.

Previous modeling studies have investigated mechanisms of WSBW formation and causes of OAEs. Results using ocean general circulation model (OGCM) suggested difficulties of WSBW formation. Results using OGCM combined with biogeochemical cycles (BGCM) suggested that inactive state of THC is feasible for anoxic condition in the deepwater. The inactive state, however, is only sustained for several thousand of years, it cannot account for the time scale of OAEs known in geological evidence. In this study, we reexamine mechanisms of WSBW formation and causes of OAEs using BGCM.

Our simulated THC oscillates between active and inactive states (Fig. 1a). Oxygen concentration in the deepwater decreases during the inactive state (Fig. 1b). Since the oxygen concentration in the Tethys is kept higher than that in the Panthalassa, horizontal gradient of oxygen concentration being high in the Tethys and low in the Panthalassa is formed at the end of inactive state. The gradient does not formed by the different ages in their deepwater as the present ocean but rather by the difference between biological productions in their surface water. This horizontal gradient misleads us to the WSBW formation by the present relationship of the Broecker's conveyer belt, where the deepwater flows from a high oxygen concentration area to low. Therefore, when we reconstruct ancient THC from geological evidence recorded under the inactive state, we must be aware of the change in the relationship between THC and biogeochemical cycles.

During the active state, large oxygen supply by active THC increases oxygen concentration in the deep Panthalassa and Tethys (Fig. 1b). Export production during the active state increases to 14 GtC/year due to enhanced supply of phosphate to euphotic layer. It is interesting to note the insensitivity of export production to strength of THC. Export production is only 1.4 times higher than that in the present ocean, though the active THC reaches about 7.5 times higher than that in the present ocean. This insensitivity of export production suggests the difficulty of causing OAEs by increasing export production. On the other hand, since the time scale of inactive state is much shorter than that of OAEs known from geological evidence, it seems difficult to attribute cause of OAEs only to inactive state of THC. Oxygen concentration in the Atlantic is hardly increases despite similarly forming the deepwater during the active state. We investigated the mechanisms keeping low oxygen in the Atlantic. We found the source of deepwater in the Atlantic is not the surface water but the intermediate water. Since the intermediate water contains low oxygen, oxygen concentration in the deep Atlantic is kept low. This is a possible mechanism of OAEs in the Atlantic longer than tens of thousands of years.

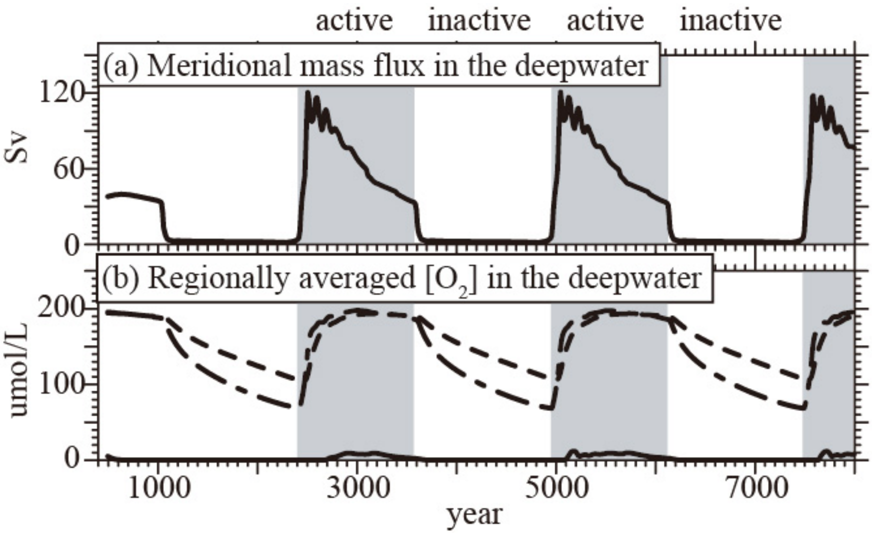

Fig. 1 Time series of (a) meridional mass flux in the deepwater (in Sverdrups≡$10^6 m^3$/sec) and (b) regionally averaged $[O_2]$ in the deepwater (in umol/L). Dark shaded periods indicate active states of thermohaline circulaiton.