Enhanced dinoflagellate productivity by ocean stratification and eutrophication in the Anthropocene, Miocene, and Cretaceous

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Dinoflagellate is one of the main marine organisms causing red-tide near coastal region. Red-tide, especially harmful algal bloom (HAB), impact on not only fishery but also human health, and therefore, the prediction of red-tide/HAB are important for understanding variability in marine ecosystem in the future. Red-tide events are also related to the expansion of nutrient-rich water. For example, dinoflagellate bloom caused by eutrophication near the coastal area of Japan during high economic growth period (~Anthropocene). Summer stratification is the other factor to enhance occurrence of red-tide. A large number of marine organisms near the coast of Florida are actually killed by the blooming of toxic dinoflagellate (*Karenia brevis*) owing to oceanic stratification during summer in 2018 (Weisberg et al., 2019, *JGR Oceans*). These obvious changes in marine ecosystem in the present gain on importance to reveal relationship between dinoflagellate bloom and climate change. Dinosterol is biosynthesized by dinoflagellate and used as dinoflagellate biomarker in the sediments/sedimentary rocks. Triaromatic dinosteroid is applicable dinoflagellate biomarker for mature sedimentary rocks. In this presentation, we focus on the Anthropocene, late Miocene and mid-Cretaceous OAEs, and compare the variation in dinosteroid percentage with the paleoclimatological /paleoceanological proxies.
We collected the sediment/sedimentary rock samples from Seto Inland Sea (Japan, Anthropocene), Andaman Sea (IODP Exp.353, site U1447, late Miocene), Hokkaido (Yezo Group, Japan, the mid-Cretaceous OAE2) and Vocontian Basin (south eastern France, the mid-Cretaceous OAEs).
Dinosterol are main dinosteroid among the samples collected from Seto Inland Sea and Andaman Sea. We defined DSIP (Dinosteroid index for polar fraction; %) as the percentage of dinosterol/dinostanol among the sterols without C_{29} sterols mostly originated from terrestrial plants. The values of DSIP are higher in the surface sediments deposited near the coast in Seto Inland Sea compared with the samples collected from Pacific Ocean and Yodo River flowing into Osaka Bay. Especially, DSIP is the highest value in the Sea of Harima which is characterized by stratified and eutrophic water in summer season. On the other hand, DSIP values increased from ~7 Ma in the sediment core samples collected from Andaman Sea. Holbourn et al (2018, *Nature Commun.*) suggested that the cooling event in Andaman Sea after 7 Ma was related to strengthening of the dry and cold East Asian winter monsoon. Winter monsoon enhance the North Equatorial Current and the East Indian Current which transport nutrient-rich water from the Strait of Malacca into the Andaman Sea (Brewer et al., 2015, *CSIRO Oceans and Atmosphere*). It is likely that dinoflagellate productivity is also higher under eutrophic condition during the late Miocene.
Triaromatic dinosteroids are main identifiable dinosteroids in the Cretaceous sedimentary rocks collected from Hokkaido and SE France. TADS (Triaromatic dinosteroid index %; Ando et al., 2017a, *Org. Geochem.*), which indicates the productivity of dinoflagellate, were higher in the samples from the mid-Cretaceous OAE1b and 2 levels in Vocontian Basin, SE France. The marine environment in Vocontian Basin during OAE1b and 2 were characterized by eutrophic and stratified condition due to wet and warm climate (Herrle 2003, *Mar. Micropaleontol.*; van Helmond et al., 2014, *Geology*). However, there is no obvious change in TADS values in the samples of OAE2 level collected from the Yezo Group, Hokkaido. The biomarker-based redox indicated the timing of oceanic anoxia in Hokkaido are different from OAE2 in the Tethys and Atlantic regions (Ando et al., 2017b, *Island Arc*). These results imply that dinoflagellate bloom was mainly related to ocean stratification and eutrophication during the Anthropocene, Miocene, and Cretaceous.

Keywords: dinoflagellate, ocean stratification, eutrophication, red-tide

