論文の内容の要旨

論文題目　Phanerozoic Megatrends in Marine Benthic Ecosystems: Ichnologic Evidence
（顕生代における海洋底生生態系の大規模変遷：生痕化石からの証拠）

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Organic matter produced by phytoplankton is a key agent to connect benthos to marine surficial zone. In particular, marine benthic animals (especially abyssal benthos) rely heavily on phytodetritus for their growth and reproduction. Because phytoplankton have been diversified through geologic time, especially since the Mesozoic, body-fossil evidence suggests that marine benthos have also changed their diversity, habitat and ecology in response to the Mesozoic phytoplankton diversification. However, existing data (i.e., body-fossil evidence) are mainly concentrated on benthos with skeleton, and much fewer researches have been focused on soft-bodied benthos (i.e., benthos without skeleton). Considering that the most marine benthos are soft-bodied, it is essential to enhance ichnologic studies in order to uncover the full scope of the benthic response to the Mesozoic phytoplankton diversification. For this purpose, the present study focused on the specific ichnogenus, and investigated its changes through geologic time.

The present study systematically described the specimens of the ichnogenus *Phymatoderma*, which is composed of fecal pellets excreted by a deposit feeder, from eleven localities (e.g., Permian–Quaternary), and morphometric, geochemical, and microscopic analyses of these specimens, in order to clarify the trends and patterns in response of soft-bodied benthos to the phytoplankton evolution/diversification during the Mesozoic and subsequent sea-floor eutrophication.

First, to make the obtained data and interpretations more reliable as possible, the present study revealed, for the first time, that *Phymatoderma* was a fecal trace produced by the echiuran worm as a result of the sediment ingestion at the seafloor, based on carbon-isotope analysis and the discovery of the fossil counterpart of a modern star-shaped feeding trace produced by an echiuran worm.

The obtained data from morphometric, geochemical, and microscopic analysis were then considered chronologically, along with the existing data on marine-plankton diversity. As a result, several megatrends in *Phymatoderma* were recognized; namely, 1)

deep-seaward migration during the mid-Mesozoic, 2) diversification of ingested diets, 3) increased efficiency in deposit-feeding strategy since the Cretaceous, 4) size increase since the Late Cretaceous, 5) increased frequency in reburrowed *Phymatoderma* specimens (i.e., evidence of coprophagy by small benthos) during the Cenozoic. Previous studies have already demonstrated the similar pattern to the first megatrend (i.e., deep-seaward migration) using both body- and trace-fossil evidence, which was further confirmed by the present study. Other megatrends were revealed for the first time, which have been also supported by the systematic compilation of the published data on the other deposit-feeding ichnogenera. All the recognized megatrends in marine soft-bodied benthos appear to have been synchronized with the Mesozoic phytoplankton diversification and subsequent sea-floor eutrophication, and with the associated increase in benthic-food competition; therefore, the five megatrends, which generally occurred since the mid-Mesozoic, might represent the benthic response to the coeval phytoplankton diversification and its associated biological/environmental changes.

The present study could provide the comprehensive and reliable trace-fossil evidence of the benthic response to the Mesozoic phytoplankton diversification and associated environmental changes.