Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

BPT011-02 Room: 301B Time: May 24 15:45-16:00

Ecological reconstruction of fossil vertebrates using isotope analyses

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Ecological restorations of fossil vertebrates have often been made on the basis of the morphological characteristics commonly found in the living animals. However, it is difficult to make paleoecological reconstructions for fossil animals that have no comparable morphological features that were found in the living animals and that have become extinct at higher taxonomic levels. Molars in particular have often yielded important information to understand the ecology, especially for mammals. Apatite is the main substance of hard tissues such as bones and teeth that are often well preserved as fossils. In biogenic apatite, carbonate and phosphate ions occur in certain locations in crystals. Carbon and oxygen isotopes of carbonate and phosphate ions can reflect ecological and behavioral processes. Therefore, isotopic records from enamel can help to restore paleoecological information.
Higher plants have the role of primary producer for mammals in terrestrial ecosystems and are divided primarily into two groups, C3 and C4 plants, through their distinct photosynthetic pathways. C3 and C4 plants generally include woody plants and grass plants, respectively, and are distinct in their carbon isotope values. In marine ecosystems, carbon isotope values of primary producers are increased from offshore to nearshore regions due to differences in organic matter productivity. The oxygen isotope value of biogenic apatite depends mostly on the isotopic composition of precipitation and the species ecological characteristics. Differences in the population-level standard deviation of oxygen-isotope values can allow segregation between marine and terrestrial taxa. Terrestrial mammals, for instance, generally have greater physiological and environmental variability than marine mammals, resulting in higher variability in oxygen-isotope values.
Enigmatic beasts, Desmostylusand Paleopardoxiaare members of the Desmostylia within the Tethytheria (Afrotheria, Mammalia) and have been known from the Early to late Middle Miocene (ca. 20-10Ma) in the North Pacific realm. There were no living taxa that have same morphologies as Desmostylusand Paleoparadoxia. The lack of any satisfactory analogy has stimulated a number of controversies on dietary and habitat preferences, and locomotion or postural reconstruction. It is currently unclear which interpretation is correct.
A number of teeth belonging to Desmostylusand Paleoparadoxiahave been excavated from the Tonokita Formation in Hokkaido, Japan. We analyzed the carbon and oxygen isotope compositions from the teeth. Both Desmostylusand Paleoparadoxiayielded high carbon isotope values, revealing that two species probably ingested nutrients from an aquatic ecosystem. However, oxygen isotope of both species showed that of freshwater like terrestrial mammals. The results of our analyses demonstrate that Desmostylusand Paleoparadoxiamay have lived in brackish water and foraged at a place where estuarine and/or freshwater nutrition resources were available. Both Desmostylusand Paleoparadoxiahave been thought to be semiaquatic ungulates to date, having gravipodal legs to walk around coasts based on the morphology of robust limbs. However, the results of isotopic analyses suggest that two species should be reconstructed as marine mammals that were fully adapted to aquatic life in the water. Identification of the nutrient sources during the Early to late Middle Miocene environments in which Desmostylusand Paleoparadoxialived and their ecological segregation should be the focus of future work.

Keywords: carbon isotope, oxygen isotope, Desmostylus, Paleoparadoxia,
paleoecological reconstruction