Fish debris and rare-earth deposition caused by topographically induced upwelling in the latest Eocene

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Microscopic fish skeletal debris (fish teeth, denticles, and bones) are the only fossil remains well preserved in pelagic brown clay in which calcareous and siliceous nannofossils are hardly preserved. Since pelagic brown clay deposited in world wide areas of open ocean, fish debris can be a biological proxy in these areas. In addition, fish debris highly concentrates rare earth element after deposition. Thus, fish debris-rich deep-sea sediment is now recognized as a new deep-sea resource for rare earth elements [1].

In 2013, a deep-sea sediment extremely enriched in fish skeletal debris and rare earth elements was found in western North Pacific [2,3]. The maximum contents of fish debris and rare earth elements were reported to be ~30% and ~7000 ppm, respectively [2,3]. To unravel the causes of the anomalous accumulation of fish debris and rare earth elements, we determined the depositional age of this fish debris-rich sediment based on osmium isotope stratigraphy. Depositional ages of sediment samples can be obtained by comparing the measured osmium isotope ratios ($^{187}Os/^{188}Os$) in the samples with the reconstructed seawater $^{187}Os/^{188}Os$ curve [4].

Our osmium isotope measurement and age assignment revealed that the deposition of the fish debris-rich sediment was contemporaneous with the first appearance of the Antarctic ice-sheet in the latest Eocene. At this time, the ice-sheet cooled high southern latitude and could have invigorated Antarctic bottom water formation [5]. The enhanced northward flow of bottom water would have stirred nutrient-rich deep ocean and led to nutrient upwelling on topographic barriers such as seamounts [6], which resulted in flourishment of pelagic organisms
including fish. Consequently, an anomalous amount of fish debris has deposited and now constitutes a huge storehouse for rare-earth elements.

[1] Takaya et al. (2018) *Sci. Rep.* **8**, 5763. [2] Iijima et al. (2016) *Geochem. J.* **50**, 557-573. [3] Ohta et al. (2016) *Geochem. J.* **50**, 591-603. [4] Peucker-Ehrenbrink & Ravizza (2012) In *Geologic Time Scale 2012*, 145-166. [5] Goldner et al. (2014) *Nature* **511**, 574-577. [6] Hein et al. (1993) *Paleoceanography* **8**, 293-311.

Keywords: Fish skeletal debris, Rare-earth elements, Osmium isotope

