Geochemical characterization of deep-sea sediments in the western North Pacific Ocean by an integrated multivariate statistical technique

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Recently, deep-sea sediments highly enriched in rare-earth elements and yttrium (REY) were discovered within the Japanese exclusive economic zone (EEZ) surrounding Minamitorishima Island [1]. To clarify the distribution of the “extremely REY-rich mud”, eight research cruises (KR13-02, MR13-E02, KR14-02, MR14-E02, MR15-E01 Leg2, MR15-02, MR16-07, and KM17-14C) have collected 71 sediment core samples in total from 2013 to 2018. Now we have constructed a comprehensive dataset of major- and trace-element contents of 1,646 samples by X-ray fluorescence and inductively coupled plasma mass spectrometry analyses [1-8].

Here, in order to depict geochemical features of the deep-sea sediments including the extremely REY-rich mud, we applied an integrated method of k-means cluster analysis (KCA) and independent component analysis (ICA) [9] to the huge (1,646 samples x 41 elements) dataset of the deep-sea sediments in and out of the Minamitorishima EEZ. We demonstrate that the data clusters are distributed not randomly but systematically in the real space; the clusters are vertically aligned from the seafloor to depth in a specific order and thus constitute stratigraphic units defined by geochemical features. In addition, the downhole variation of an extracted independent component (IC) shows a stepwise transition across the extremely REY-enriched layer. This transition is ubiquitous in the studied area of several-hundred-kilometer wide. The geochemical clusters just below the IC transition are variable among the cores, which implies that the IC transition corresponds to an unconformity in the sediment column probably due to erosion [5, 6]. These characteristics of the spatial distributions of the geochemical clusters and ICs support a hypothesis previously proposed by Ohta et al. [10]: an enhanced bottom current caused a physical separation of sedimentary particles, or a winnowing effect, and contributed to form the extremely REY-enriched layer by a selective deposition of relatively coarse and dense grains of biogenic Ca-phosphate that significantly accumulate REY from ambient seawater.

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