Scavenging of ^{230}Th and ^{231}Pa in the western North Pacific: Implications for the ^{231}Pa/^{230}Th ratio as a palaeoproductivity proxy

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Particle reactive elements introduced into the ocean in dissolves form are generally removed by scavenging onto settling particle. While the composition of settling particles mainly influence the partitioning of reactive chemical substances between particulate phase and dissolved form, the intensity of scavenging controlled by the flux of particulate matter through the water column. Fluxes and concentration of reactive chemical elements on particulate matter trend to be much greater in the ocean-margin and high latitude than those in the open ocean and oligotrophic regions, because of relatively high levels of primary productivity supported by land discharge and upwelling. This processes is generally realized as boundary scavenging. Science the first study of boundary scavenging focused on ^{226}Ra-^{210}Pb disequilibrium in sea water, naturally occurring radionuclides are often used to study this process. All above, ^{230}Th and ^{231}Pa are very good tracer to study those process (e.g. Anderson *et al.*, 1994).

Recently the ^{231}Pa /^{230}Th ratio has been used as a palaeoproductivity proxy, because ^{231}Pa is more enriched in biogenic particles (Kumar *et al.*, 1993). Furthermore, the ratio is not a reliable indicator for the mass flux of particulate in regions, where the settling flux is dominated by biogenic opal, such as the Southern Ocean (Walter *et al.*, 1997). In response to the questions: 'How much ^{231}Pa is scavenged in the western North Pacific?', 'Which factor is controlled the scavenging of ^{231}Pa or the ^{231}Pa /^{230}Th ratio?' and 'Can we use the ^{231}Pa/^{230}Th ratio as a palaeoproductivity proxy in the western North Pacific?', we examined seasonal and regional change in the scavenging of ^{231}Pa and the ^{231}Pa/^{230}Th ratio caused by primary productivity determining ^{230}Th and ^{231}Pa in the settling particles, collected with time-series sediment traps at five stations in the western North Pacific. In this paper, we discuss lateral transport of fine-grained aluminum-rich particles in the western North Pacific influencing on the fluxes of ^{231}Pa and ^{230}Th and their ratio.

Results and discussion

The results showed the enhanced scavenging of ^{231}Pa by biogenic opal in the western North Pacific, giving the activity ratios are larger than their production ratio of 0.093. Particularly, the fluxes of ^{231}Pa$_{ex}$ and ^{230}Th$_{ex}$ near the Japan Islands (Sta. HT, EM and WP) were 3 to 8 times and 2 to 4 times larger than their production rate in the overlying the water column. Those fluxes are extremely larger than previous studies in western North Pacific (Taguchi *et al.*, 1989) and the low latitudes of the Pacific and Atlantic Oceans. Although the results in the Middle Atlantic Bight only showed enhanced scavenging of their two nuclides, the activity ratio of ^{231}Pa$_{ex}$/^{230}Th$_{ex}$ were consistently less than their production ratio of 0.093 (Anderson *et al.*, 1994). Our results suggests that ^{231}Pa and ^{230}Th transported from oligotrophic regions is being actively removed near the Japan Islands. On the other hand, both fluxes were quickly decreasing with distance from Japan Islands. The fluxes of ^{230}Th$_{ex}$ in open basin (Sta. KNOT and NP) were almost same as its production rate, although the fluxes of ^{231}Pa$_{ex}$ were still larger than its rate of production in the water column. This means that the

content of biogenic opal of the settling particles in Sta. KNOT and NP is higher than those in the low latitudes of the Pacific Ocean, although the total mass fluxes in this area are smaller than those near the Japan Islands.

The activity ratio of $^{231}Pa_{ex}/^{230}Th_{ex}$ near Japan Islands (Sta. HT and WP) were much larger than those in the basin sites (Sta. KNOT and NP), except Sta. EM located in the continental slope toward Japan Trench. In Sta. EM, the activity ratio of $^{231}Pa_{ex}/^{230}Th_{ex}$ (ab. 0.14) were the smallest at every stations, while both fluxes (F/P for ^{230}Th = 3.8, F/P for ^{231}Pa = 5.6) were much larger than its rate of production in the water column. On the other hand, the vertical particulate fluxes of both nuclides in Sta. NP were significantly increased as well as ^{232}Th and Al fluxes and the $^{231}Pa_{ex}/^{230}Th_{ex}$ ratios were decreased with depth. This means laterally transport of fine-grained aluminum-rich particles containing more ^{230}Th are added to the particles sinking through the abyssal water.

Another evidence of existing those particles is that the $^{231}Pa_{ex}/^{230}Th_{ex}$ ratios in the settling particles collected with narrower sediment traps (cylindrical type), which deployed at same depth and same time, were smaller than those collected with cone type sediment traps. Pervious works showed that the narrower sediment traps more effectively collected fine particles similar to suspended particles (Noriki and Tsunogai, 1986) and the $^{231}Pa_{ex}/^{230}Th_{ex}$ ratios in the suspended particles collected using in situ pumping in the western North Pacific were much smaller than those of settling particles and sea waters (Nozaki, 1986). The $^{231}Pa_{ex}/^{230}Th_{ex}$ ratios in the bottom sediments, therefore, does not reflect that of particles produced in the surface water by biological activity and we must be careful for the use of $^{231}Pa_{ex}/^{230}Th_{ex}$ ratio as a palaeoproductivity proxy especially for the pelagic sediments.

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