Distribution of $^{230}Th_{xs}$ and $^{231}Pa_{xs}$ in sediment particle classes of opal-rich and carbonate-rich sediments

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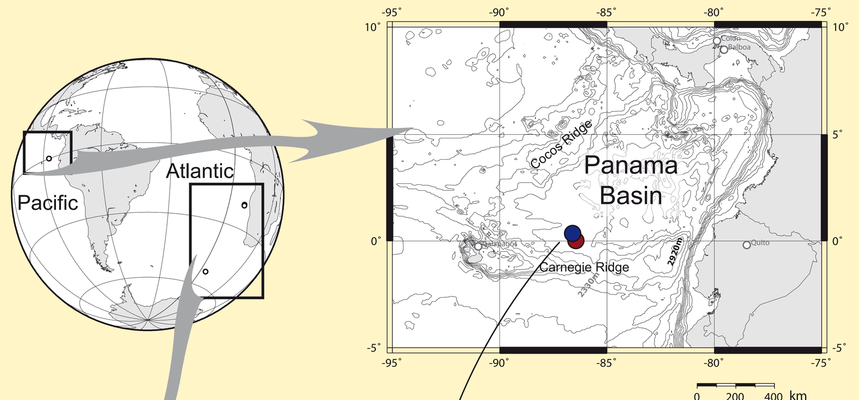
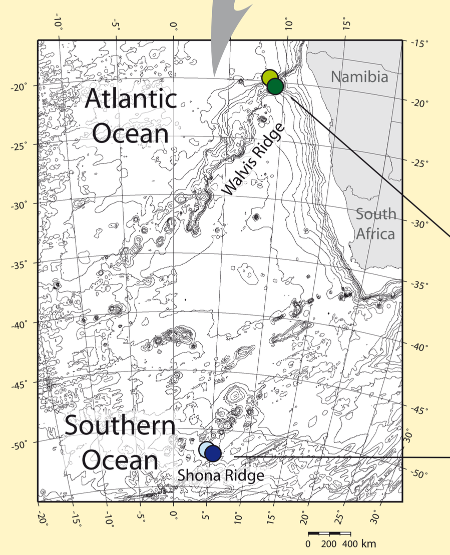
Introduction

In many paleoceanographic studies $^{230}Th_{excess}$-normalization and the $^{231}Pa_{excess}/^{230}Th_{excess}$-ratio are used as tools for the reconstruction of particle fluxes and ocean circulation. $^{230}Th_{xs}$ and $^{231}Pa_{xs}$ analyses are commonly performed on bulk sediment samples. However, it is conceivable that these two particle-reactive radioisotopes are not equally distributed between the different sedimentary components, because Th and Pa show preferential adsorption to specific particle types (Geibert and Usbeck, 2004). Therefore we performed particle size specific analyses of $^{230}Th_{xs}$ and $^{231}Pa_{xs}$ on deep sea sediment samples from three locations with contrasting sediment characteristics.

Location

The deep sea sediment samples were retrieved from the subtropical Atlantic and the tropical Pacific (both carbonate-rich sediments) and from the Southern Ocean (opal-rich sediments). At each location two sediment cores differing in their focusing factors were sampled (see maps).





sediment core	water depth	focusing factor
Y69-71P	2740 m	3-6
ME0005-24JC	2941 m	4-10
GeoB1027-2	2668 m	2.2
GeoB1028-4	2215 m	1.7
PS1768-8	3299 m	2.2
PS1769-1	3269 m	1.0

Method

Bulk sediments were fractionated into distinct particle size classes by sieving and settling. The size classes of the opal-rich Southern Ocean sediments was further split into density classes by settling (slowly and fast sinking particles).

Reference

Geibert and Usbeck (2004): Adsorption of thorium and protactinium onto different particle types: Experimental findings. Geochimica et Cosmochimica Acta, 68(7): 1489-1501

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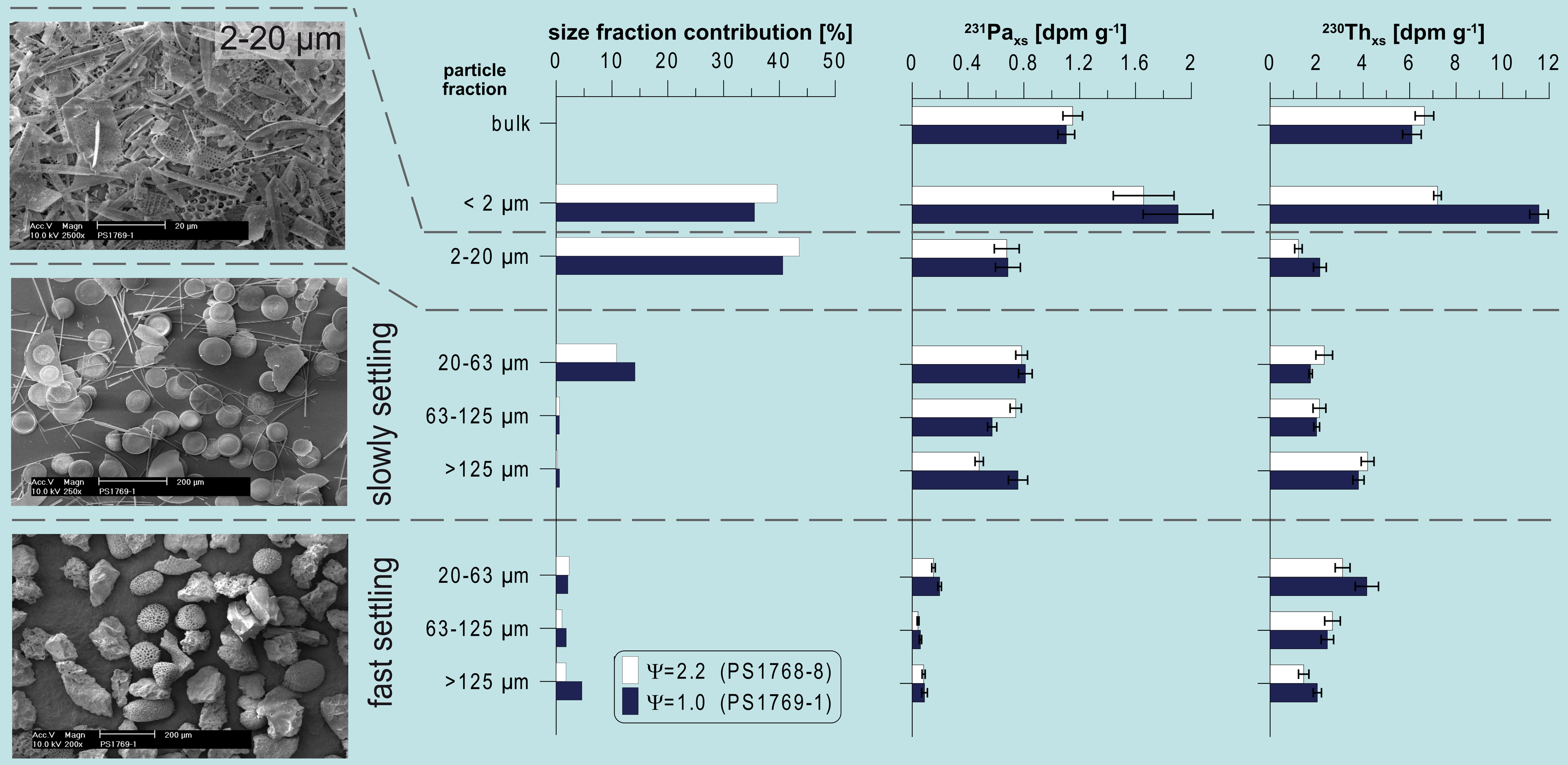
Southern Ocean Opal-Rich Sediment

The grain size distribution in opal-rich sediments shows that clay (<2µm) and fine silt (2-20µm) form the two major fractions (each class ~40%). Sediment at the „focusing location" (PS1768-8, light blue bars) contains slightly more fine material and less coarse particles than at the „non-focusing location" (PS1769-1, dark blue bars).

In particle fractions larger than 2µm $^{231}Pa_{xs}$ is adsorbed preferentially to fine silt and slowly settling diatoms and less strongly to fast sinking particles, while $^{230}Th_{xs}$ does not show any significant preference.

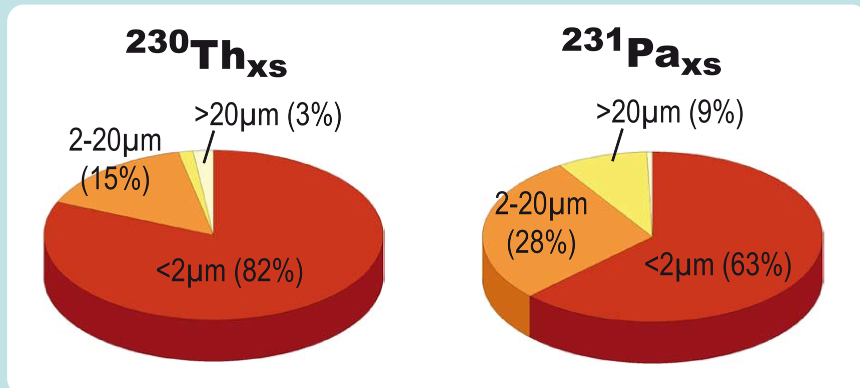
The clay fractions hold the highest specific activities of $^{230}Th_{xs}$ and $^{231}Pa_{xs}$. The focusing location receives more clay with lower $^{230}Th_{xs}$ activity than the non-focusing location, where clay contains higher specific $^{230}Th_{xs}$ activity. However, both cores hold nearly the same amount of $^{230}Th_{xs}$ in the clay fraction (82% and 79%, respectively).

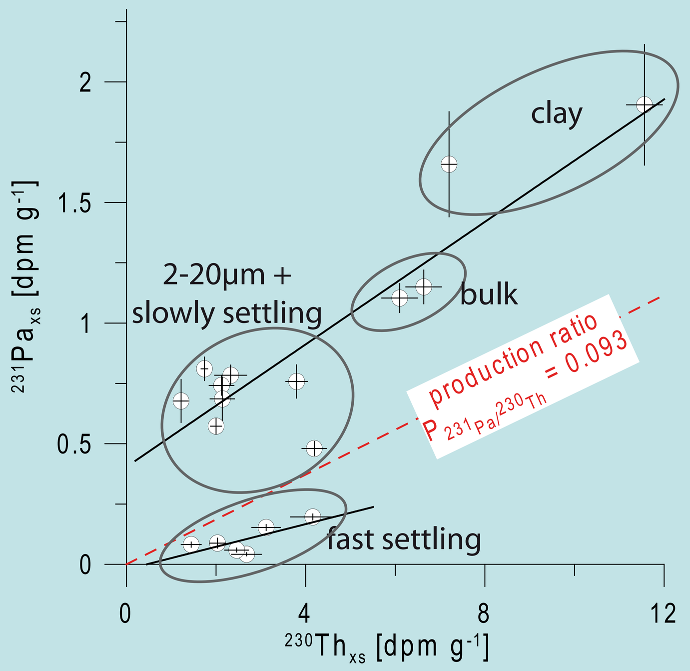


The contribution of $^{230}Th_{xs}$ and $^{231}Pa_{xs}$ in percentage delivered by each size fraction is calculated by multiplication of the specific activity with the size fraction contribution.

Clay contributes 82 % to the total $^{230}Th_{xs}$. In contrast only 63 % of $^{231}Pa_{xs}$ is contained in the clay fraction. Substantial contribution to $^{231}Pa_{xs}$ inventories is made by fine silt and slowly sinking particles (diatom shells).

Contribution by each size fraction in PS1768-8





$^{231}Pa_{xs}/^{230}Th_{xs}$-activity ratio

The ^{235}U- and ^{238}U-decay-series in seawater produce a $^{231}Pa_{xs}/^{230}Th_{xs}$-activity ratio of 0.093 (red dashed line in diagram). The diagram shows that bulk sediments and particle classes do not reflect this ratio. Bulk sediments, clay fractions and slowly settling fractions exceed this ratio by a factor of up to four, whereas the fast sinking particles carry an isotope ratio much lower than the production ratio.

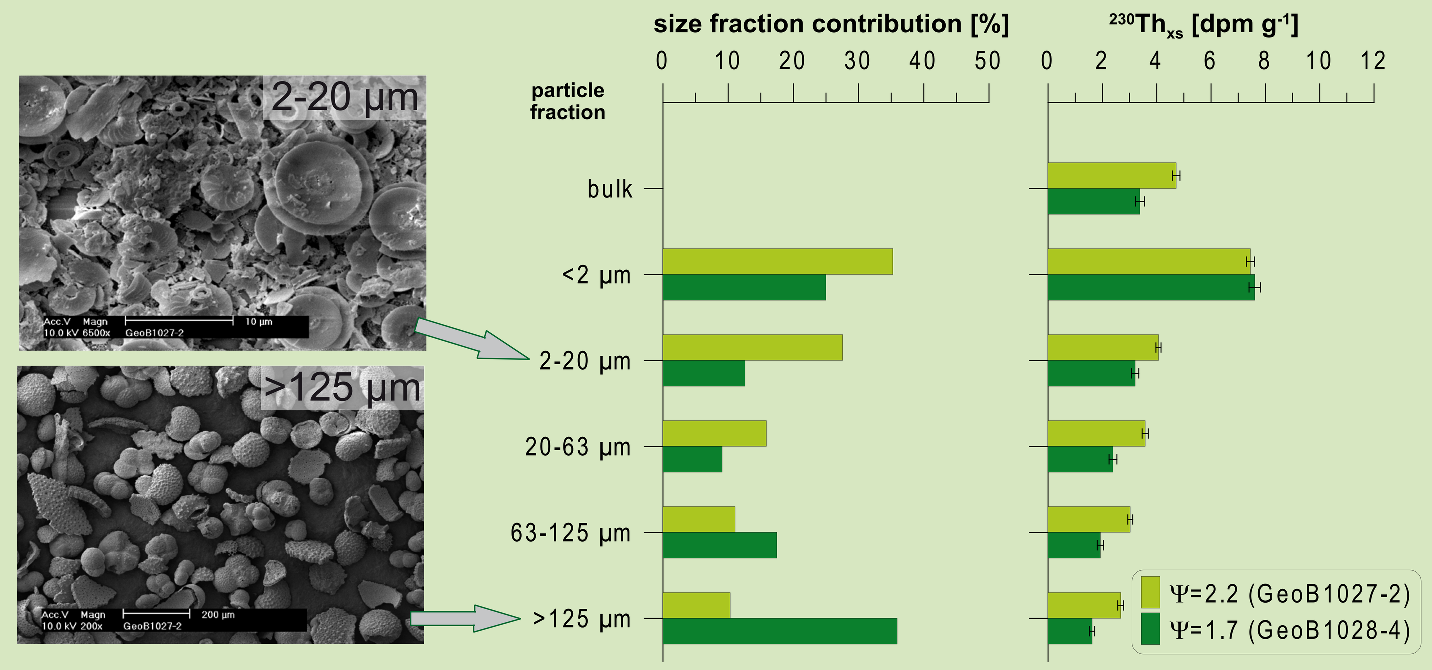
Conclusions

Lateral sediment transport can have a sorting effect on particles. More fine material is accumulated at locations of higher focusing factors.

Generally, $^{230}Th_{xs}$ is adsorbed mostly onto clay and fine silt. However, we find different distribution patterns in opal sediments and carbonate sediments.

Different particle size classes contribute different amounts of $^{230}Th_{xs}$ and $^{231}Pa_{xs}$ to the total inventory. This needs to be considered when using the sedimentary $^{231}Pa_{xs}/^{230}Th_{xs}$-ratio from sites that are strongly affected by sediment redistribution.

Atlantic Carbonate-Rich Sediment



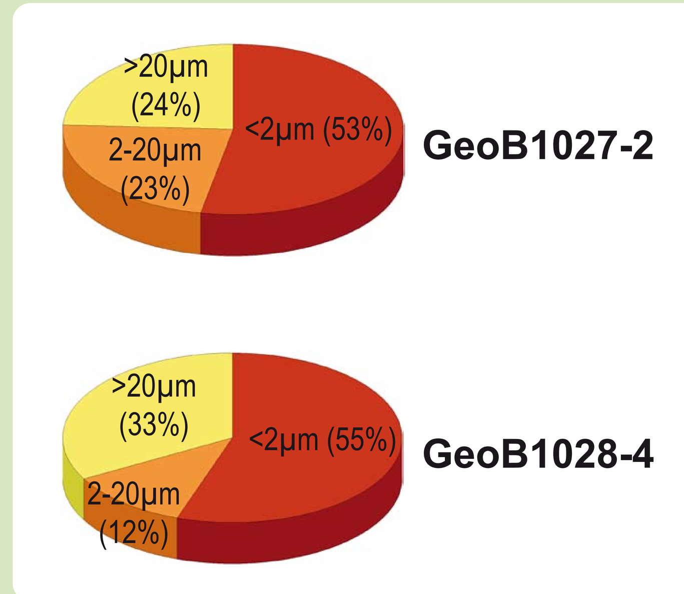
The sediment at the higher focusing location (GeoB1027-2, light green bars) contains more fine material (clay and fine silt) than at the lower focusing location (GeoB1028-4, dark green bars).

The higher focusing location contains more $^{230}Th_{xs}$ in the bulk sediment and in all particles >2µm than the lower focusing location.

Possible explanation: The higher focusing location is 450 m deeper than the other core location, so that it receives 20 % more $^{230}Th_{xs}$ by the particles that sink vertically through the water column.

$^{230}Th_{xs}$ contribution by each size fraction

In Carbonate-rich sediments not only clay but also silt-sized and sand-sized particles (forams and coccoliths) are relevant for $^{230}Th_{xs}$-inventory, because they account for almost half of the total inventory. The $^{230}Th_{xs}$-inventory of the lower focusing site is more strongly supported by the larger (>20µm) particles (33%) than the higher focusing site (24%).



Pacific Carbonate-Rich Sediment

Grain size specific focusing factors

Sediment from the Panama Basin exhibits a similar grain size dependent $^{230}Th_{xs}$ distribution as the Atlantic carbonate-rich sediment. The diagramm shows the contributions of grain size classes to total $^{230}Th_{xs}$ inventories expressed as focusing factors Ψ calculated for the intervals core-top to 9.5 kyr, 9.5 to 13.4 kyr, and 13.4 to 21 kyr. Calculations are based on bulk densities multiplied by relative mass contributions (in %) of individual size classes. In both cores 80 % of the sediment focusing can be attributed to the smallest (<20µm) grain size fraction.