Sediment reworking rates and long-term sedimentation: a multi-tracer approach

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Sampling

We took part in the *PE121*, *M43/2* and *PE138* cruises for sampling sediment cores at the seawater-sediment interface.

Laboratories

Sediment cores were sliced at 0.5 and 1-cm intervals, dried at 60° and conditioned in sealed tubes ready for direct gamma counting in high efficiency well-type Ge detectors.

Very short half-lived nuclides determination: $^{234}Th_{xs}$ ($T_{1/2}$=24 d) and $^{228}Th_{xs}$ ($T_{1/2}$=1.91 y) are only present in freshly deposited sediment. They will be used for three purposes: - to check for a good recovery of the uppermost sediment layer, - to study mixing rates and - to link sediment trap material data to those of deposited sediments. 31 top surface sediment activities were measured and the mapping of $^{234}Th_{xs}$, $^{228}Th_{xs}$ and $^{210}Pb_{xs}$ in the OMEX area will be achieved.

Short half-lived nuclides determination: $^{226/228}Ra$, $^{210}Pb_{xs}$, ^{137}Cs are used in order to establish short-term mass accumulation and mixing rates in surface sediments. Measurements are conducted in the underground laboratory of Modane by non-destructive gamma spectrometry using two high efficiency well type germanium detectors. 4 to 10 grams of dry sediment are measured during 2 days and their activities compared with a standard. At different depths across the Iberian margin, density and mineralogical composition of the sediment are highly variable, therefore variations in the self absorption process for low energy gamma emitters like ^{210}Pb (46 keV) become important and must be controlled in order to be able to give precise data. We selected 8 samples in cores with variable composition and measured ^{210}Po by radiochemical method followed by alpha spectrometry. By comparing alpha and gamma spectrometry results on $^{210}Po/^{210}Pb$, we are now able to correct the efficiency of our gamma detectors for low energy gamma rays in various samples. For the other radionuclides, with gamma rays of high energy, the sample composition does not affect the counting efficiency.

Results.

Very short half-lived nuclides: $^{234}Th_{xs}$ and $^{228}Th_{xs}$ activities at the top (0.1 or 0.5 cm) of 31 cores sampled during the recent OMEX cruises (*PE121*, *M43/2* and *PE138*) were determined. Most cores contain ^{234}Th and ^{228}Th in excess, which proves a good recovery of the seawater sediment interface layer sampled with multi-corers as well as with box corers. ^{234}Th excesses measured at the top of *PE131* cores, in summer 1998, vary from negligible values up to 250 Bq kg^{-1}. This range is similar to data observed in summer 1997 (*PE109*). On the other hand, in winter 1999 (*M43/2*), $^{234}Th_{xs}$ reach highest levels (up to 500 Bq kg^{-1}) along the margin. The treatment of data (inventories, mapping) would allow to conclude if such variations are due to differences in sites or reflect a real seasonal trend.

Anyway, the most surprising feature is radionuclide profiles in the Nazaré canyon (Figure 1). Indeed, in addition to very high activities, $^{234}Th_{xs}$ presents a deep penetration in sediment. Usually, due to its short period (24 days), and despite bioturbation effect, ^{234}Th is observed only in the top 2 cm of sediment (Legeleux *et al.*, 1994). This result seems to indicate strong sediment mixing and/or more probably huge deposit events.

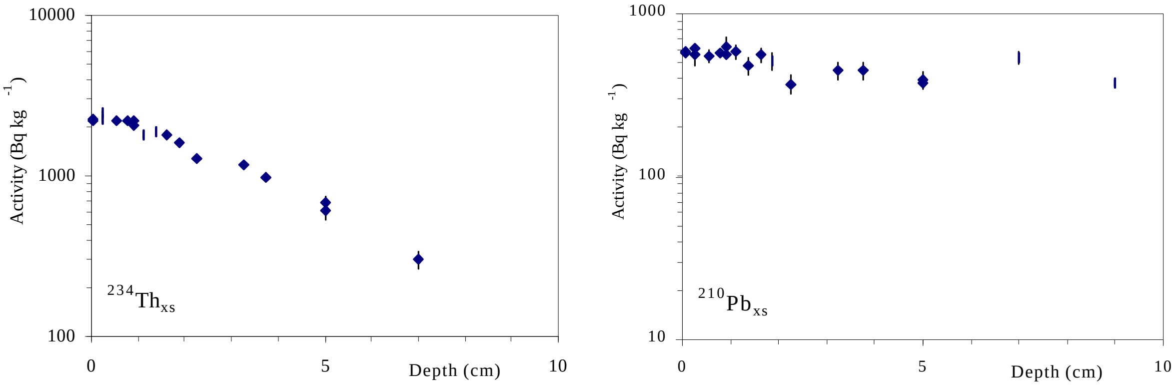

Figure 1: Profiles of $^{234}Th_{xs}$ and $^{210}Pb_{xs}$ with depth in the Nazaré Canyon (*MC26-4*, *M43/2* cruise)

Short half-lived nuclides: we measured detailed ^{210}Pb, $^{226-228}Ra$, ^{137}Cs, ^{228}Th and ^{40}K profiles with depth in 15 sediment cores of *PE109* and *CD105* cruises.

- Potassium content is mainly governed by the mineralogical composition of the sediment. In all studied cores, K content is constant with depth, which means a quite homogeneous composition of the sediment in the cores. Potassium content varies from 0.4% for deep cores to 3.1% for shelf cores.
- Radium isotope activities increase from the surface to 15 cm depth in most cores of about 30% as a result of their diffusive behaviour from the sediment to the bottom sea water.
- $^{210}Pb_{xs}$ and ^{137}Cs profiles display two different behaviours:

(1) for shallow cores (Fig. 2) a mixed layer of about 11 cm overlaying an exponential decay which is interpreted in term of ageing of the sediment.

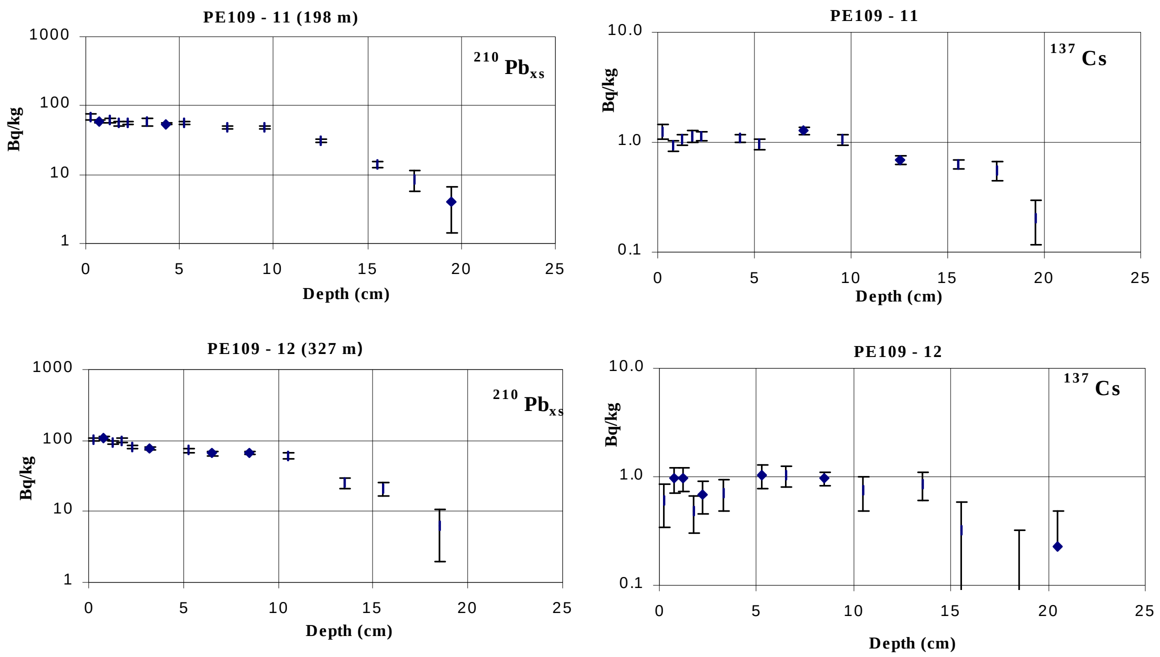

Figure 2 - $^{210}Pb_{xs}$ and ^{137}Cs profiles with depth for shelf cores

(2) for deep water cores (Fig. 3), profiles suggest a mixing process with three different regimes, with subsurface sediment been mixed more rapidly than those at the surface as often quoted elsewhere (Legeleux *et al.*, 1994). Subsurface maximum attributed to non-local mixing process as reported in Soetaert *et al.* (1997) are not observed but the occurrence of $^{210}Pb_{xs}$ as well as weak ^{137}C deep under the mixed layer, between 10 and 20-cm depth, suggests an additional mixing process.

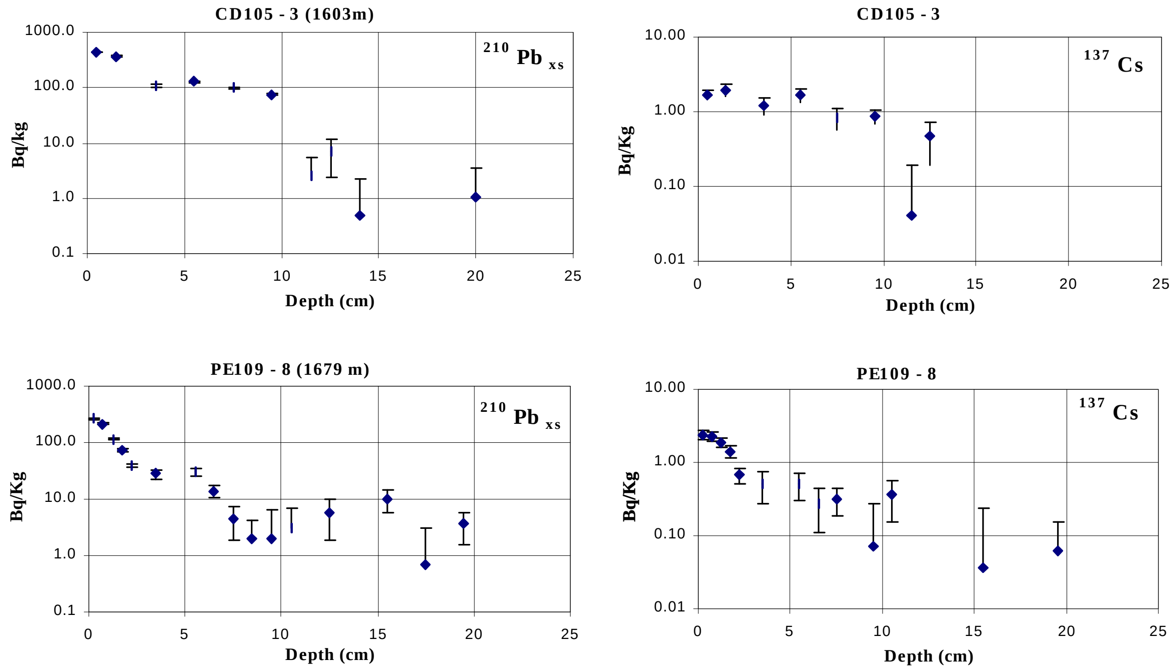

Figure 3 - $^{210}Pb_{xs}$ and ^{137}Cs profiles with depth for deep sediment cores

Long-term accumulation rates.

Core *PE109-5* was investigated in details for oxygen isotopic composition and U/Th inventories.

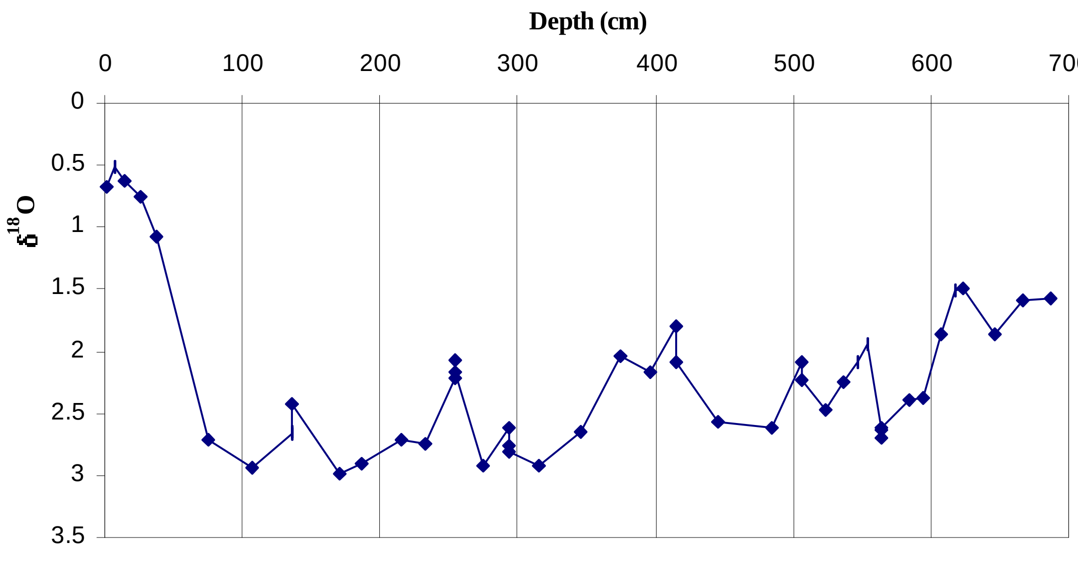

Figure 4 - Oxygen isotopic composition ($\delta^{18}O$ in ‰) from planktonic foraminifera *G. bulloides* as a function of depth in core *PE109-5*

The stratigraphy was established from the oxygen isotopic composition ($\delta\,^{18}O$) of the planktonic *foraminifera G. bulloides*. This first estimation will be completed by the analyses of the *Cibicides wuellerstorfi* benthic species. Core *PE109-5* covers from roughly 90 ky to the Modern Period (Fig. 4).

The sedimentation rate varies from 5 cm ky^{-1} during the last deglaciation to 10 cm ky^{-1} during stage 3. The glacial interglacial amplitude is of 2.4 per mil, corresponding to the melting of the big ice caps of northern latitudes as well as the warming of surface waters at the latitude of the core during the transition to the interglacial period.

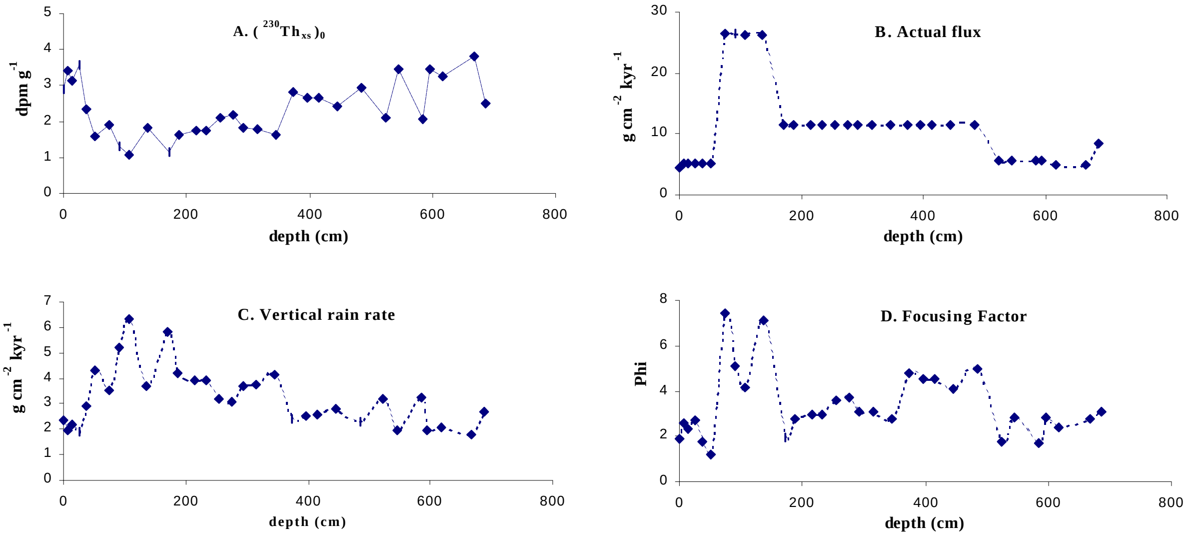

Figure 5: Depth profiles in core *PE109-5* of: A. specific activity of $(^{230}Th_{xs})_0$, B. actual accumulation, C. rain rate and D. focusing factor (see definition in text).

Vertical sedimentary flux is estimated by comparing $^{230}Th_{xs}$ flux recovered in the core to its production rate in the overlaying water column (Suman and Bacon, 1989; Thomson *et al.* 1999). We present in Figure 5A $^{230}Th_{xs}$ supposed to originate from seawater, versus depth in the core. As a general feature, this curve parallels to the $\delta^{18}O$ curve with low specific activities associated with glacial stages. Actual accumulation flux (Fig. 5B) is deduced from the dry weigh of sediment accumulated during the time duration of each isotopic stage. The sediment rain rate (vertical flux) calculated from the "constant $^{230}Th_{ex}$ method" is plotted versus depth in the core (Fig. 5C). As in Thomson *et al.* (1999), the actual flux is higher than this vertical flux. The deduced focusing factor (Phi) plotted in Figure 5D averages a factor of 3 and reaches a very high, up to 7, factor during the last glacial maximum (stage 2). By a similar isotopic study of selected long cores sampled during the different OMEX cruises, we will compare this focusing factor in the other areas and try to decipher the origin of the high sedimentary flux and its links with climatic change. The glacial/interglacial transition will be precise with ^{14}C datation.

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