Quantifying Sedimentation and Mixing Processes using Radioisotopes

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Marine or lake sediment cores (Figure 56) contain information needed to improve our understanding of past environmental conditions, such as climate variability. Therefore they serve as valuable archives of climate change. A better knowledge of the triggers, drivers and dynamics of past sedimentation processes, provides us with the necessary evidence that climate models and future climatic projections can be built upon.

An additional condition for the successful interpretation of information contained in sediment archives is reliable chronology - dating of individual sediment layers. For different time scales, different methods are used. These include radioactive nuclides such as radiocarbon (^{14}C dating). Gamma emitting radionuclides play an important role in the chronology of sediments deposited during recent history. This is especially true since the beginning of 20th Century, when our living environment was affected by intensified industrial activities.

Sediment chronology of the last 100-150 years is constructed using the decay of ^{210}Pb, a member of the natural ^{238}U decay chain. This isotope has a suitable half-life of 22.3 years and its origin within the sediment is two-fold: Firstly, radioactive decay from its long-lived parent nuclide ^{226}Ra, being a common trace element in mineral grains in the sediment, is responsible for a part of ^{210}Pb, which is called “supported” ^{210}Pb. The second source is the deposition from the atmosphere, where ^{210}Pb originates from the gaseous intermediate decay chain member ^{222}Rn, which escapes from the soil.

Figure 56: Sediment sampling on board RV Maria S. Merian, Amazon delta. Left: obtaining short sediment cores with a multi-corer. Right: documenting a long sediment core obtained by a gravity corer.

This additional ^{210}Pb contribution is called “excess” ^{210}Pb. With increasing depth (and age) within an undisturbed sediment the “excess” ^{210}Pb decreases with a known rate. This enables us to date the sediment layers and therefore determine an age model for the sediment core.

There are several other radionuclide tracers which can be used to verify the accuracy of the age model: Those of natural origin – ^{228}Ra and ^{228}Th (both members of the ^{232}Th decay chain), ^{234}Th (a ^{238}U decay product) or ^{7}Be (of cosmogenic origin) – help to distinguish sedimentation processes from biological or physical mixing due to their wide range of half-lives. Also, traces of anthropogenic radionuclides that are products of nuclear fission or activation in nuclear reactors or weapons, can be detected in certain sediment horizons as markers of nuclear fallout events. Examples of man-made isotopes with suitable half-lives are ^{137}Cs or ^{241}Am.

All mentioned isotopes can be quantified in individual sediment samples by gamma spectrometry within a single spectrum. The method is non-destructive, and the samples therefore remain preserved for further analyses. Resulting chronologies using ^{210}Pb together with other gamma emitting tracers, provide high temporal resolution and are complementary to radiocarbon based chronologies, which are not suitable for the last century, but in turn, can cover history of several millennia. In our laboratory mathematical efficiency calibration was introduced recently and verified against a more classical experimental method. This approach, which is rather innovative for environmental radioactivity samples, brings more freedom for sample matrix and measurement geometry and in effect, the measurement efficiency can be optimized and lower detection limits achieved. We co-operate with other national or international institutions and provide sediment chronologies within paleoclimate or environmental studies.

Anthropogenic input of particulate Phosphorus in the Gulf of Eilat

(in co-operation with: University of Kiel; Israel Oceanographic and Limnological Research, Haifa, Israel)

In this project we studied a possible connection of eutrophication of the gulf and consequential environmental changes with industrial pollution caused by phosphorus ore mining and processing and transporting of fertilizers. For the first time, sedimentation and mixing rates in this region were quantified.

Australian–Indonesian summer monsoon variability

(in co-operation with: MARUM – Center for Marine Environmental Sciences, University of Bremen)

A deep sea sediment core taken off the Indonesian island of Sumba was studied in order to reconstruct the Australian–Indonesian summer monsoon variability in the last 6000 years (see Figure 57). Assuming that riverine detrital input is linked to the summer monsoon rainfall, we used selected main element ratios as a measure for relative monsoon intensity. Interpretation of the natural and man-made gamma emitters' depth profiles provided a solid base for high resolution chronology of the youngest core section.

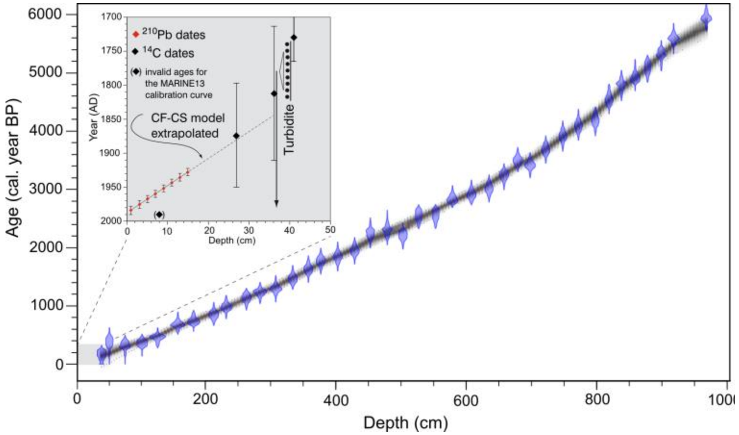

Figure 57: Chronology of a sediment core taken off the Indonesian island of Sumba extending to 6000 years before present. It is based on 39 radiocarbon ages (Steinke et al., 2014). The youngest section of the core covering the latest 160 years, for which the use of ^{14}C method is obviously restricted, was dated using gamma emitting ^{210}Pb and ^{241}Am (see insert), providing a reliable age model.

References

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