Workshop: Determination of sedimentation rate using radioactice isotope ^{210}Pb

This activity requires the use of special laboratory equipment. To get access to this equipment please contact Per Roos (roos(at)dtu.dk)

Introduction

Sediments are the material in the world oceans and lakes that make up the reservoir of all the material that rains down through the water column until the bottom is reached. These sediment are ultimately made up of material that derives from land (rivers and streams) and the atmosphere (dust and gases that dissolve in water) but which are altered by biological and chemical activity in the water. In the sediments we find the history of what has been going on in the water above, for that reason it is of interest to make age determination of the sediments. To be able to tell the age at a given depth in the sediments or to determine how many centimeters of sediment accumulate every year (cm/y - the sedimentation rate) it is useful to apply radioactive isotopes.

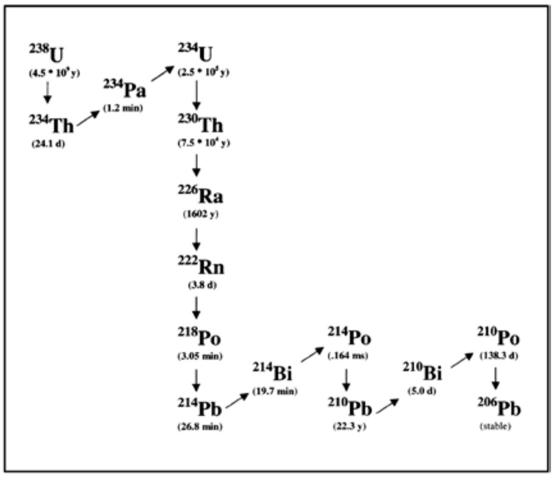


Fig. 1: The 238U decay chain with the 210Pb isotope almost in the end of the chain. Numbers in parenthesis are the half-life of the isotopes.

One method to determine the sedimentation rate is by using the so called ^{210}Pb method. The radioactive lead isotope ^{210}Pb is constantly produced in the atmosphere due to the decay of a radioactive gas, ^{222}Rn, which in turn constantly is 'leaking' from soils and rocks where uranium exist (see figure 1 – the ^{238}U decay chain) In fact uranium is a rather common element, roughly 2-3 milligrams are found in every kilogram of soil so the amount of ^{210}Pb produced in the atmosphere is quite high, good for us since it will be easier to measure.

The ^{210}Pb raining down on the ocean or lake surface quickly ends up on the sediment surface. Since the radioactive half-life of ^{210}Pb is 22 years we can expect that at a sediment depth which corresponds to an age of 22y half of the ^{210}Pb remains. At a 'depth' of 44 years (2 half-lives) 1/4 remains and at a 'depth' of 66y (3 half-lives) only 1/8 remains. The fact that we know exactly how fast ^{210}Pb decays (half in 22y) makes it possible to determine the sedimentation rate. If we for example finds that half of the ^{210}Pb activity relative to the activity at the surface appears 10cm down the sediment the sedimentation rate must be 10cm/22y or approximately 0.45 cm/y.

In the experiment below you will determine the sedimentation rate in a real sediment core extracted from the bottom of the Baltic Sea in the Bornholm basin. To measure the ^{210}Pb you need to use an instrument that measures the gamma radiation that is emitted from the ^{210}Pb. This radiation is emitted at a very exact energy (46 kiloelectron volt, 46 keV) and nearly no other radioactive isotopes emit gamma photons with this energy. So, if we can measure how many gamma photons a sample emits at 46 keV we have a measure of the amount of ^{210}Pb in that specific sample, which is what we need. In our case we have a gamma-detector (figure 2) that has the ability to transfer the energy from the gamma photons that hit the detector in to light, in fact it is a salt crystal like NaCl but where we have changed the Cl-atom into an iodine atom. The higher energy in the gamma-photon the more light is produced. The screen shows a diagram where the gamma photon energy is shown on the x-axis and the amount of gamma-photons of a certain energy are shown on the y-axis. If we have sufficient ^{210}Pb in the sample a peak will be shown at the 46 keV region.

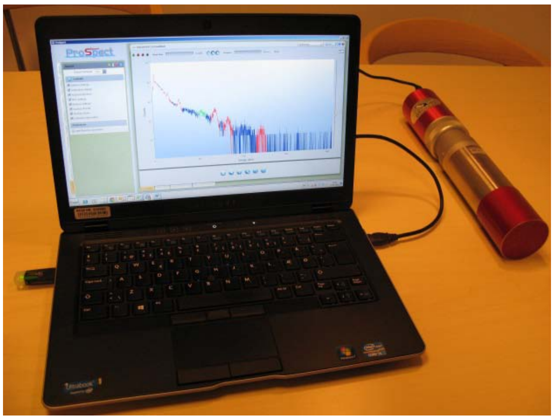
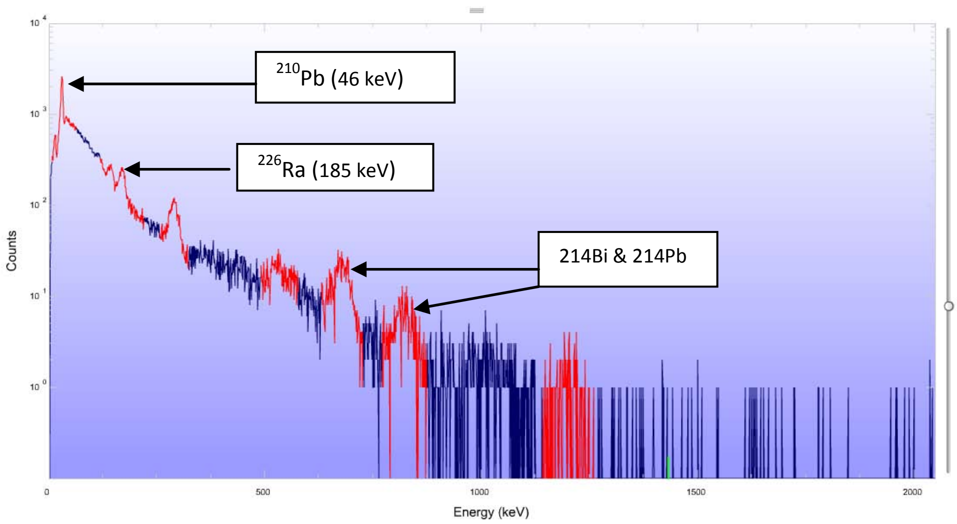


Fig. 2: A NaI-detector (scintillation detector) connected to an ordinary laptop. The detector is capable of measuring gamma photons from 20-2000 keV.

Fig. 3 (below): Gamma energy spectrum of a sediment obtained with a NaI-detector. The spectrum was acquired over a period of several hours and shows peaks from 210Pb and 226Ra, 214Bi and 214Pb which are all naturally occurring in the environment. The area of the 210Pb peak at 46 keV is proportional to the amount of 210Pb in the sample being measured.



Experiment

Since ^{210}Pb is present everywhere (for example in air and in the ground) you need first to obtain a background spectrum. The amount of ^{210}Pb is to be subtracted from the sediment data. The background is also the reason why we have a lead-shield around the detector, it's not for protecting people against radioactivity from the sample!

After the background measurement put the uppermost sediment sample in the detector well and measure for at least 5 minutes. Make note of the amount of pulses in the 46 keV peak and take note of which sample you are measuring. Go on measure the sediment samples at deeper levels and find out at which depth you have approximately half of the activity relative to the uppermost layer.

Plot the activity (counts per 5 minutes) versus sediment depth.

What is the sedimentation rate of this core?

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