Dating sediment profiles using radionuclides: the need for corroborating evidence

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Radionuclides provide important, and often unique ways of dating of soil and sediment profiles. However, changes in the rate and mechanism of delivery of radionuclides to sediments, and biogeochemical processes operating in the sediment profile invalidate many of the assumptions required for age determination. In these cases direct application of radionuclide dating models can yield spurious ages, and interpretation without corroborating evidence is risky. This presentation will explore the effects of some of these confounding processes by discussing a series of case studies. Lake Barrine, a tropical crater lake in Northern Australia exhibits many characteristics suitable for successful application of radionuclide dating techniques; ie. a small catchment relatively undisturbed by European settlement. Distinct laminations in the deposited sediment indicate little or no post-depositional mixing. Sediment core and frozen slabs samples covering a period of up to 5000 y^{r} BP have been collected and dated using ^{14}C, excess ^{210}Pb and ^{226}Ra, together with proxy age indications from charcoal, exotic pollen and meteorological data. These laminations are probably due to thermally induced water column overturn events, allowing the formation of excess ^{226}Ra in bottom sediment by co-precipitation of dissolved ^{226}Ra delivered from the catchment with Fe accumulated in anoxic bottom waters. In the period 1000-4000 yr BP ^{14}C and excess ^{226}Ra ages agree well. However in younger sediment the spread of ^{14}C ages increases to the point where many of the ^{14}C ages are clearly much too old. The spread is probably due to the delay in transport of organic material from the shallows to deeper water. Taking the youngest ^{14}C ages, and extrapolating the excess ^{226}Ra depth vs age

curve gives acceptable ages up to 1000 y^r BP. Sections of the ^{210}Pb profile closely approximate the exponential decline expected in a system where recent sedimentation rates have been approximately constant. However the profile is separated by a thick amorphous layer, below which the sediment ages estimated by the two commonly used dating models (the CRS and CIC models) differ. Exotic pollen and charcoal data support CRS ages for sediment below the amorphous band. The ^{210}Pb ages provide evidence for the ^{14}C 'contamination' of young sediment by organic material with an older ^{14}C signature. In many Australian lakes sediment profiles show ^{210}Pb profiles characteristic of highly variable sediment influx. Non-monotonic decreases in ^{210}Pb activity are common, and can be related to catchment disturbance associated with European settlement. In these sediments, the CRS model is usually the most appropriate, but ages should checked by independent means. Examples will be presented which show how dilution of ^{210}Pb activity by large sediment influxes could lead to the erroneously old ages. Mixing of the upper layers of sediments is common in near-shore marine sediment, and if not recognised can lead to the determination of spuriously young ages in the mixed zone. Mixing depths can vary greatly, as can the mixing process. Examples of simple 2-layer mixing models will be presented, where the sedimentation accumulation rate is determined from the ^{210}Pb below the mixing zone. Knowledge of the mixing time constant can help constrain the accumulation rate within the mixed layer, and the presence of second tracer with a half-life different to ^{210}Pb can allow the estimation of both mixing and accumulation rates. This approach has been applied in Port Philip Bay, using the decay profiles of excess ^{210}Pb and ^{228}Th.