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RADIOMETRIC DATING OF SEDIMENT FROM LAKES OHAU AND TEKAPO, NEW ZEALAND

Introduction

GNS Science aims to determine New Zealand's paleoclimatic record using sediment cores from South Island glacial lakes.

Lakes Ohau and Tekapo, located on the eastern side of the Southern Alps, have received sediment from their catchments since forming about 16,000 years ago.

Sediment cores could reveal high-resolution records of paleoclimatic fluctuations provided that fine-scale chronologies can be established.

Dating climate related events in sediment deposited in the past 100 years should facilitate dating similar events in the deeper sediment.

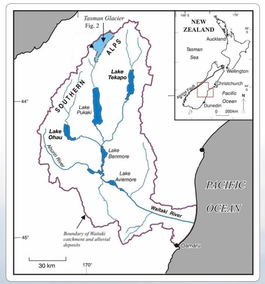
In a pilot experiment, the sedimentation rates were established using radioactive isotopes

- ^{137}Cs (half-life = 30.2 years), from atmospheric nuclear weapons testing
- ^{210}Pb (half-life = 22.3 years), produced by the decay of atmospheric ^{222}Rn gas
- ^{10}Be (half-life = 1.36 My), a cosmogenic isotope produced mainly in the Earth's upper atmosphere

^{10}Be, measured by accelerator mass spectrometry, was employed as an adjunct for the ^{210}Pb method to:

- Correct for sedimentological variation in the unsupported ^{210}Pb used to obtain sediment accumulation rates
- Identify changes in sedimentation rate

Feed to lakes



Tekapo

- Two major glacial run-offs
- Six rivers

Ohau

- One minor glacial run-off
- Two rivers
- Relatively uncomplicated

Sediment dating with ^{210}Pb

Lacustrine sediment contains ^{210}Pb, termed excess or unsupported, that is continuously produced by atmospheric ^{222}Ra gas.

- In a sediment core, excess ^{210}Pb decreases with depth due to radioactive decay.
- The dating method commonly relies on establishing an exponential decay curve for the excess ^{210}Pb but the sedimentation rate must be uniform.
- ^{210}Pb has a half-life of 22.3 years so the technique can only be applied to the past ~100 years.
- ^{210}Pb and ^{137}Cs are frequently analyzed and interpreted together, with ^{137}Cs providing some absolute tie points for the ^{210}Pb profile.

There is a background of ^{210}Pb, supported by ^{226}Ra (via ^{222}Rn) within the sediment, to deduct from the total measured ^{210}Pb.

Ideally, each sediment sample would be completely decomposed and the total ^{210}Pb and ^{226}Ra (background), measured.

- ^{210}Pb activities in New Zealand sediments are low, 5-10% of continental sites
- The difference between excess and supported ^{210}Pb is relatively small, making ^{210}Pb dating difficult.
- Therefore the excess ^{210}Pb is extracted by acid leaching.

Objectives

- Acid leach meteoric ^{10}Be, excess ^{210}Pb and a minimum of supported ^{210}Pb from the sediment
- Leach more strongly to obtain the supported ^{210}Pb profile.
- Assess the sediment solubility. (The supported ^{210}Pb background varies with depth and is partly dependent on the sediment solubility.)
- Introduce the use of ^{10}Be (half-life = 1.36 My) to check if the excess ^{210}Pb content of the freshly depositing sediment has fluctuated, assuming that ^{10}Be and ^{210}Pb are input from the Earth's atmosphere in a reasonably constant ratio

Results from acid leaching experiments where ^{210}Pb is estimated via its grand-daughter ^{210}Po

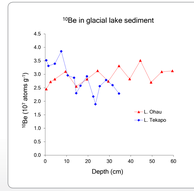
Cold leaching wet or dry sediment with 6M HCl for less than 10 minutes:

- Dissolves minimal sediment
- Recovers all the excess ^{210}Po
- About 50% of the acid extractable supported ^{210}Po
- 90% of the ^{10}Be

Second leach: Hot 6M HCl for 60 minutes

- Dissolves 12–15% of the sediment
- Recovers the remaining ^{10}Be

^{10}Be trends



If the atmospheric ^{10}Be flux is reasonably constant, the overall gradients indicate changes in sedimentation rate

- L. Ohau increased
- L. Tekapo decreased

Short-term ^{10}Be fluctuations

- Occur every ~20 years in the L. Ohau core
- Are not due to solar cycles
- May be climate related

Summary

Dating sediment with ^{210}Pb and ^{10}Be

- Fresh sediment contains ^{210}Pb and ^{10}Be input from the atmosphere
- The flux of atmospheric ^{210}Pb and ^{10}Be is reasonably constant
- In an ideal core, the ^{10}Be activity is virtually constant with depth for the past 100 years of sediment accumulation
- The decrease in ^{210}Pb or ^{210}Pb/^{10}Be with depth, due to radioactive decay, can be used for dating sediment

Lakes Ohau and Tekapo

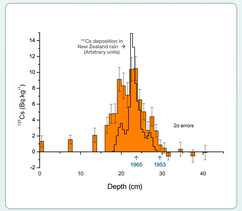
- The ^{210}Pb$_{excess}$/^{10}Be method compensates for changes in initial ^{210}Pb content of the sediment and changes in deposition rate
- Each layer is dated using the decrease in ^{210}Pb$_{excess}$/^{10}Be value with respect to the initial ratio determined from the surface sediment
- The ^{10}Be profiles show fluctuations, which may be climate related, and have overall gradients due to changes in sedimentation rate

Future studies

- "Fill-in" samples to improve the ^{10}Be profile for the Lake Ohau sediment core
- ^{10}Be data from a long core may help establish the South Island climate history
- Possibly use the ^{10}Be inventory for sediment dating

ohau

^{137}Cs distribution in Lake Ohau sediment



^{137}Cs, a fission product from atmospheric nuclear weapons testing, reached a concentration peak c. 1965 prior to international bans on atmospheric testing

^{137}Cs dating relies on establishing the stratigraphic location of the isotope's first appearance in c. 1953 and its concentration peak c. 1965

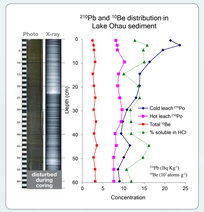
^{137}Cs deposition in New Zealand rain

- Originally expressed in mCi.Km^{-2}
- Decay corrected to a common date

^{137}Cs distribution in Lake Ohau sediment

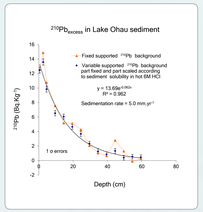
- Similar to deposition from rainfall
- 1965 fallout maximum at 230 mm
- 1953 initial fallout at 295 mm
- Sedimentation rate = 5.1 mm.yr^{-1}

Overview of results



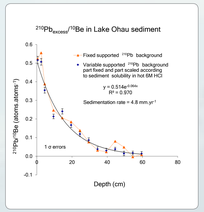
- ^{210}Pb and sediment solubility in 6M HCl are correlated
- Data for the 44.5 cm layer suggests that cold 6M HCl removes most of the ^{210}Pb from surface sites of a sediment component that later fully dissolves in hot 6M HCl
- ^{10}Be decreases towards the surface - Sedimentation rate is increasing

Separating ^{210}Pb$_{excess}$ from total measured ^{210}Pb



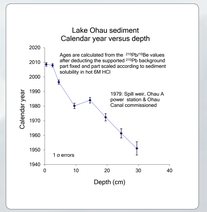
- Deducting a fixed supported ^{210}Pb background is acceptable down to ~30 cm
- Individual backgrounds fully scaling according to the sediment solubility in 6M HCl tend to be "over-corrected"
- Deducting supported ^{210}Pb backgrounds part fixed and part scaled according to the sediment solubility in hot 6M HCl suits all the data
- Sedimentation rates established using ^{137}Cs and ^{210}Pb are in close agreement

Normalizing ^{210}Pb$_{excess}$ to ^{10}Be



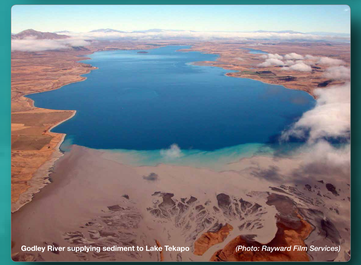
- Generally improves fit of exponential to the data set
- Results in outliers at 9.5 cm and 14.5 cm but dating individual layers provides a likely explanation

Dating individual layers using ^{210}Pb$_{excess}$/^{10}Be

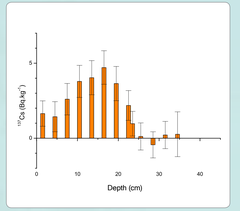


- Initial ^{210}Pb$_{ex}$/^{10}Be is known from surface samples
- Each layer is dated using the decrease in ^{210}Pb$_{ex}$/^{10}Be value due to radioactive decay
- Influxes of older sediment and changes in sedimentation rate can be identified
- The low value at 9.5 cm is probably due to managing the lake for hydroelectric power generation in 1979
- Variations in ^{10}Be production due to 11 year solar cycles do not seriously affect the dating method

tekapo

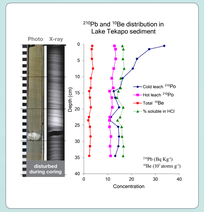


^{137}Cs distribution in Lake Tekapo sediment



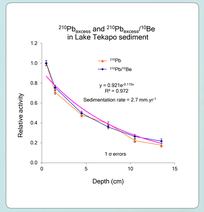
- Spread due to delayed input from catchment
- 1964-5 fallout maximum at ~180 mm Sedimentation rate = ~4.0 mm.yr^{-1}
- 1952-1953 initial fallout at 240 mm Average rate for the 0–240 mm section = 4.2 mm.yr^{-1}

Overview of results



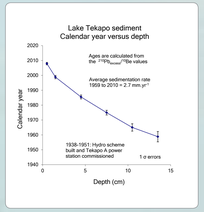
- ^{210}Pb is erratic below 14 cm due to hydro dam construction 1938-1951
- ^{10}Be increases towards the surface - Sedimentation rate is decreasing

^{210}Pb$_{excess}$/^{10}Be profile



- Smooth compared ^{210}Pb$_{excess}$ profile
- Not purely exponential because the sedimentation rate has decreased since the hydro dam was constructed and the water level raised
- Sedimentation rate is low compared with 4.2 mm.yr^{-1} estimated from the first appearance of ^{137}Cs in 1953 when the sedimentation rate was faster

Dating individual layers using ^{210}Pb$_{excess}$/^{10}Be



- Necessary when the sedimentation rate has changed
- Curvature is consistent with a progressive decrease in sedimentation rate