LECTURE-7

Radio-isotopes Dating of Lakes Sediments

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INTRODUCTION

Systematic Studies of sedimentation rate variations are essential for interpretation of a variety of lake sediment interaction processes and also important in the study of the kinetics of transfer between the lake sediment reservoirs. Mass accumulation rates of minerals, but also organic debris, nutrient elements, and trace metals in sediments and their temporal variations require accurate sedimentation rate measurements. Studies of temporal variations in lacustrine sedimentation and the relation of such variations to climatic and/or anthropogenically induced changes in lakes, require knowledge of sedimentation rates and their temporal variations over time scale generally ranging from a few years to tens of thousands of years.

Various methods have been adopted for estimation of rate of sedimentation. In the latter part of the last century, the common technique used, in estimation of sedimentation rate is based on the study of rapid rise of ragweed pollen (Ambrosia) due to extensive forest cutting and soil cultivation by many (Bortleson and Lee, 1972; Craig, 1972; Kemp et al., 1974; and Maher, 1977). However, the recent dating techniques involve natural radio-isotope lead-210 estimation (Krishnaswami et al., 1971; Koide et al., 1973) and the bomb fallout nuclide Cesium-137 (Pennington et al., 1973). The relatively short lived isotopes (22.3 years for Pb^{210} and 30 years for CS^{137} are ideally suited for lake sediments whose rates of sedimentation are on the order of a few millimeters per year (for details see Krishnaswami and Lal, 1978).

Pb^{210} DATING METHOD

The Pb^{210} dating technique is one of the most commonly used dating techniques of recent lacustrine sedimentary deposits. Many human impact and pollution studies rely on it to calculate recent increases of anthropogenic fluxes. The common assumptions of the Pb^{210} technique are: (i) Steady-state conditions exist in the sedimentary deposit with respect to the Pb^{210} flux and radioactive decay (half-life of 22.3 yrs); (ii) sediments can be considered as a closed system with respect to the sediment and Pb^{210} fluxes; (iii) the Pb^{210} has a short removal residence time in comparison with the residence time of the lake water, which means, that most of the Pb^{210} reaching the lake will be transferred efficiently to the sediments; (iv) no post depositional mobility of Pb^{210} occurs in the sediments; and (v) the excess Pb^{210} can be calculated from the total Pb^{210} and the Ra^{226} activity in the sediments, i.e. as the difference between the activities of the two nuclids, often it is assumed that the Ra^{226} activity is constant throughout the core, and therefore, that its activity can be determined from the constant Pb^{210} activity at depth, where Pb^{210} and Ra^{226} can be assumed to be in radioactive equilibrium. Pb^{210} enters a lake

or reservoir either directly or through rain or indirectly in run-off from the catchment. A secondary source of Pb^{210} in the water column is from the decay of Rn^{222} in solution, which may or may not be maintain by Ra^{226}. Pb^{210} is deposited at the mud/water interface by sedimentation and the exchange processes, and becomes incorporated into the sediments column. Ra^{226} is also present in the sediment as part of the erosive input of particulate material from the catchment. Pb^{210} formed within the sediment by decay of Ra^{226} is referred to as Supported Pb_{supp}^{210}, which is normally assumed to be in equilibrium with the Ra^{226}. Pb^{210} in excess of the supported activity is termed the Unsupported Pb_{exe}^{210} and is considered to be derived predominantly from atmospheric input. This is measured as:

$$Pb_{exc}^{210} = Pb_{total}^{210} - Pb_{supp}^{210}$$

Pb_{supp}^{210} is determined from Ra^{226}, which is in secular equilibrium with Pb^{210} (Krishnaswami and Lal, 1978). Since Ra^{226} is fairly constant throughout the length of the core, the activity of supported Pb^{210} is also assumed to be constant. The exponential decay of the atmospherically derived Pb_{exc}^{210} can be used to estimate the age of a sediment layer as long as it is significantly higher in activity than the Pb^{210} already present in the soil Pb_{supp}^{210}.

The vertical distribution of Pb_{exc}^{210} is studied from the equation

$$A_x = A_0 e^{-\lambda t} \qquad (1)$$

where A_x is excess Pb^{210} activity per unit weight of sample at depth x (cm) beneath the water-sediment interface, t is age corresponding to depth 'X' and A_o is activity of excess Pb^{210} at sediment-water interface.

λ = decay constant (0.0311 yr-l), therefore it can be shown as:

$$t = 1/\lambda \ln (A_o/A_x)$$

Since annual rate of accumulation is constant such as b= x/t, where b is the annual rate of accumulation then:

$$\ln A_x = \ln A_o (\lambda - x/b)$$

A plot of ln A as a function of depth (x) gives a curve, the slope of which is proportional to the sedimentation rate, i.e.

$$S = -\lambda/b$$

where, S = rate of sedimentation
and b=slope of the curve

CS^{137} DATING METHOD

The use of radionuclids with relatively short half-life, such as Pb^{210} and CS^{137}, to date recent sediment is well established (Krishnaswami and Lal, 1978). Cesium-137 is an artificial radioisotope formed by nuclear fission and has a half-life of about 30 yrs (Lederer and others, 1967). This isotope has been introduced into the atmosphere in irregularly varying amounts since nuclear testing above ground began in 1945 (Durham and Joshi, 1980). Dating methods based on Cs-137 depends on the imprint of an irregular influx of wet and dry atmospheric deposition in sediment layers or its absence before 1945 (Krishnaswami and Lal, 1978). Cs-137 like Pb-210 is strongly bound by sediments and tends to remain trapped in a sediment layer, which is subsequently buried. Koide et al., (1973) have speculated that in normal coring devices, there is a possibility of losing the top portions of the deposit and have therefore suggested, that this loss may be checked by the presence of Cs-137.

The Cs-137 activity is determined by gamma counting 20g of the over-dried samples for up to 800 min. using a 4inX4in Nal detector-multichannel analyzer system. A Cs-137 standard, having essentially the same geometry and density is used. The limit of detection for Cs-137 by this method is 0.1 pci/g and the counting error is $<\pm 10$ percent in the upper layers of the core. Measurement is also made for this nuclide using a 30 ml lithium-drifted germanium detector coupled to a 4096 channel multi-channel analyzer. This method permits a clear separation of the 661 Kev Cs-137 gamma rays from possible contributions from 208 T1 (583 Kev) and 214 Bi (609 Kev). The samples are counted for at least 24 hr to obtain good statistical accuracy.

REFERENCES

Bortleson, G. C. and Lee, G. F. (1972), Recent sedimentary history oflake Mendota, Wis. Environ. Sci. Tech., 9,799-808.

Craig, R. J. (1972), Pollen influx to laminated sediments: a pollen diagram from North-Easter Minnesota, Ecologyy, 53, 46-57.

Durham, R. W. and Joshi, S. R. (1980), The Pb^{210} and Cs^{137} profiles in sediment cores from Lakes Maatagami and Quevillon, North-West Quebec, Canada: Canadian Jour. Earth Scie, 147, 1746-1750.

Kemp, A. L. W., Anderson, T. W., Thomas, R. L. and Modrochova, A. (1974), Sedimentation rates and recent sediment history of Lakes Ontario, Erie and Huron, J. Sed. Petrol., 44, 207-218.

Koide, M. Bruland, K. W. and Goldberg, E. D. (1973), Th-228/Th-232 and Pb210 geochronologies in marine and lake sediments, Geochim. et Cosmochim, Acta. 37,1171-1187.

Krishnaswami, S., Lal, D., Martin, J. M. and Meybeck, M. (1971), Geochronology of lake sediments, Earth Planet. Sci.Lett.11, 407-414.

Krishnaswami, S. and Lal, D. (1978), Radionuclides limnochronology, In : A Lerman

(Ed.), Lakes Chemistry, Geology and Physics, Springer, New York, Ny, 153-177.

Lederer, C. M., Hollander, J. M., and Perlman, I. (1967), Table of isotopes, 6th. Ed., John Wiley and Sons, New York.

Maher, L. J., Jr. (1977), Palynological studies in the western-arm of lake Superior, Quat. Res., 7, 14-44.

Pennington, W., Cambray, R. S. and Fisher, E. M. (1973), Observation on lake sediments using fallout 137 Cs as a trace,. Nature, 242, 324-326.