Reports

Ratio of Thorium-230 to Thorium-232 in Deep-Sea Sediments

Abstract. The ionium-thorium method for age determination in deep-sea sediments is critically reviewed, and its shortcomings are discussed. A method that allows an estimate of the rate of sedimentation in the superficial layer of the sediment is presented. A formula for calculating the error in age determination by the method is given for the case when the rate of sedimentation is changing and, with it, the rate of thorium-232 sedimentation.

The increasing use of the thorium-230/thorium-232 ratio for dating deep-sea sediments (*1–4*) requires a critical review of the validity of the basic assumptions involved. As pointed out by Goldberg and Koide (*2*), these assumptions are: (i) The Th^{230}/Th^{232} ratio has remained constant in the waters adjacent to the sediments during the time interval involved. (ii) The chemical species of Th^{230} and Th^{232} in seawater are the same, and these isotopes have identical distributions. (iii) The analyzed materials do not contain detrital materials of continental or volcanic origin with significant contributions of Th^{230} or Th^{232}, or both.

The last assumption is not valid in nature because it would imply that deep-sea sediments are entirely authigenic. That this cannot be true is demonstrated by several factors, such as the rather high potassium-argon ages obtained by P. M. Hurley *et al.* (*5*), indicating that the bulk of the sediment is of terrigenous origin. This difficulty was realized by Goldberg and Koide, and a preferential dissolution of the sediment was attempted in order to obtain only the Th^{232} precipitated from seawater. The use of hot concentrated hydrochloric acid may achieve a preferential solution of thorium, but it has not been proved that only the Th^{232} that was originally precipitated together with Th^{230} is dissolved by this procedure. On the other hand, a procedure involving the total dissolution of the sediment in order to obtain the Th^{232} implies the assumption that all Th^{232} in the sediment originated from seawater. This assumption will certainly give generally inaccurate results.

A comprehensive check of the validity of the method in determining geochemical concentration is made difficult, since most investigators measure only the ratios and do not determine the actual concentration of the two thorium isotopes because of the difficulties involved in determining the chemical yield. It may be possible, however, to use the available data to demonstrate that the method must be improved considerably and handled very carefully before it can yield valuable dating results.

Picciotto and Wilgain (*1*) found 3 to 11 × 10^{-6} g of Th^{232} per gram of sediment in superficial layers of sediment from the central Pacific Ocean. Miyake and Sugimura (*4*) found values of 10 to 30 × 10^{-6} g of Th^{232} per gram of sediment for samples from the western Pacific. Goldberg and Koide do not give absolute concentrations. The Th^{230} concentrations given by Picciotto (*6*) range from 2 to 60 × 10^{-12} c/g of sediment, corresponding to 1 to 30 × 10^{-10} g of Th^{230} per gram, with values ranging from 10 to 30 in the superficial layer. Miyake and Sugimura do not give values for their samples, but maximum values can be calculated from the ratios of the thorium isotopes and the concentration of Th^{232}. Thus, a maximum value of 8 × 10^{-10} g of Th^{230} per gram of sediment is obtained. It has been shown conclusively (*6, 7*) that the Th^{230} contained in the sediment is derived mainly from the uranium dissolved in seawater and that, on the average, about 1.7 × 10^{-9} g of Th^{230} is precipitated per square meter of ocean floor per year, corresponding to the total production of Th^{230} from uranium contained in seawater (3 × 10^{-6} g of uranium per liter). This value allows the rate of sedimentation of the superficial sediment layer to be estimated in grams per square meter and year. The rate is given by the following formula:

$$\text{Rate of sedimentation} = \frac{1.7 \times 10^{-9}}{\text{Th}^{230}\ \text{concentration}}$$

The smallest possible rate for the western Pacific sediment investigated by Miyake and Sugimura is 2.5 g/m² per year, corresponding to about 4 mm of sediment per 1000 years if a water content of 50 percent is assumed. Higher water content would give higher rates. This result is higher by a factor of 10 than the rate given by Miyake and Sugimura. If the values of Picciotto and Wilgain are used, the rate of sedimentation in the central Pacific would range from 0.5 to 1.7 g/m² per year, corresponding to 0.8 to 3 mm per 1000 years (assuming a water content of 50 percent).

The amount of Th^{232} that must be precipitated per year in order to give the ratios of the two thorium isotopes found in the sediment can easily be calculated from the ratio of the isotopes in the superficial layers and the amount of Th^{230} precipitated per year. The ratio of activities obtained by Miyake and Sugimura is about 4, corresponding to a Th^{230}/Th^{232} ratio (in grams) of 23 × 10^{-6}. Consequently, 7.3 × 10^{-5} g of thorium must be precipitated per square meter and year, and the same amount must be added to the ocean water in order to keep the thorium concentration constant (a general geochemical assumption). A consequence of this calculation is that river water should show the same concentration of thorium as uranium, and that this thorium should reach and be mixed into the main part of the ocean water. This is not the case for uranium, which is trapped by reducing environments in basins bordering the oceans (*7*). It seems unlikely, therefore, that only a small portion, if any, of the thorium found in deep-sea sediments is derived from thorium dissolved in ocean water. The bulk of Th^{232} used for obtaining the ratio of Th^{230} to Th^{232} must be derived from minerals of terrigenous or volcanic origin. Consequently, the third assumption listed above is not valid.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to contributors" [*Science* **125**, 16 (1957)].

If we now assume that Th^{232} in deep-sea sediments is a constituent of the nonauthigenic minerals, the dates obtained by the use of the ratio are subjected to rather large errors, since the rate of sedimentation may change with time as Broecker, Turekian, and Heezen (*8*) have shown. The postglacial rate of noncarbonate sedimentation in the equatorial Atlantic is only one-third or less of that during the last glacial age. A smaller change can be expected in the Pacific. This change would alter the Th^{230}/Th^{232} ratio by the same factor when the rate of Th^{230} precipitation from seawater is assumed to have remained constant. It can easily be shown that the error in the age determination becomes

$$t_1 - t = \frac{1}{\lambda_{io} - \lambda_{th}} \ln p = 1.1 \times 10^5 \ln p \text{ years}$$

where t_1 is the age obtained under the assumption that the rate of sedimentation has not changed, t is the real age, and p is the ratio of the rates of sedimentation at the deeper level to the recent rate of sedimentation. If the rate has changed by a factor e, the error becomes as large as 110,000 years. Already a change of 38 percent causes an error of 52,000 years. This would explain the low rates of sedimentation obtained by Miyake and Sugimura.

In general, it can be concluded that the Th^{230}/Th^{232} methods will not give correct ages or rates of sedimentation unless the basic assumptions are carefully controlled and investigated. In fact, in the Caribbean cores dated by the ratio of Pa^{231} to Th^{230} (*9*), the ratio of Th^{230} to Th^{232} was shown to give conspicuously discrepant ages (*10*).

F. F. KOCZY

Marine Laboratory,
University of Miami, Miami, Florida

References and Notes

→ E. Picciotto and S. Wilgain, *Nature* **173**, 632 (1954).
2. E. D. Goldberg and M. Koide, *Science* **128**, 1003 (1958).
3. V. I. Baranov and L. A. Kuzmina, *Geochemistry* **2**, 131 (1958); I. Almodovar, thesis, Carnegie Institute of Technology, Pittsburgh, Pa. (1960).
4. Y. Miyake and Y. Sugimura, *Science* **133**, 1823 (1961).
5. P. M. Hurley *et al., U.S. Atomic Energy Comm. Rept. NYO-3939* (1958), p. 114; P. M. Hurley *et al., U.S. Atomic Energy Comm. Rept. NYO-3941* (1960), p. 267.
6. E. Picciotto, *Ciel et terre* **3–4**, Mar.–Apr. (1960).

→ F. F. Koczy, *Deep-Sea Research* **3**, 93 (1956); –→–, E. Picciotto, G. Poulaert, S. Wilgain, *Geochim. et Cosmochim. Acta* **11**, 103 (1957).

8. W. S. Broecker, K. K. Turekian, B. C. Heezen, *Am. J. Sci.* **256**, 503 (1958).
9. J. N. Rosholt *et al., J. Geol.* **69**, 262 (1961).
10. This report is contribution No. 340 from the Marine Laboratory, University of Miami.

18 July 1961

Sex as Regulator of Triglyceride Metabolism in the Mosquito

Abstract. The female mosquito, in contrast to the male mosquito or the male and female house fly, synthesizes triglycerides when maintained on glucose; after 7 days, the amount of triglycerides in the female may be 50 times that in the male. Polyunsaturated fatty acids are absent from the newly synthesized triglycerides.

Labeled precursors of metabolic products facilitate the study of biosynthesis, since newly formed products can be differentiated from products already present. In living animals, however, quantitative estimation of synthesis from labeled precursors requires a steady state, detailed knowledge of specific activity-time relationships between precursors and product, or knowledge of the distribution of the product over many metabolic pools. It is therefore customary to carry out studies of biosynthesis in vitro, where the specific activity of the environment can be kept constant, but where the physiological control mechanisms of the intact animal are no longer functional. To study synthesis of triglycerides in vivo, we have used the adult female mosquito because it can be starved until virtually no triglycerides remain. Therefore, the triglycerides that appear after subsequent feeding on a lipid-free diet are due entirely to new synthesis.

Adult mosquitoes [*Aedes sollicitans* (Walker) and *A. taeniorhynchus* (Wied.)] were obtained from larvae reared at 25°C on rabbit pellets and yeast. House flies (*Musca domestica* L., susceptible strain) were obtained as pupae from the U.S. Department of Agriculture, Orlando, Florida. Within 2 hours after emergence, males and females were selected and kept at 25°C in glass jars provided with a moist cheesecloth pad and a feeding vial containing a cheesecloth wick soaked in 10-percent glucose solution. The glass jars and the feeding solution were changed daily. Duplicate samples of ten mosquitoes or three flies each were killed at various intervals by brief exposure to chloroform vapor. This pooling of samples reduced biological variation between duplicates to 10 percent or less. The insects were homogenized, and the homogenate was extracted twice with 1 ml of methanol and chloroform (1 : 1), with centrifugation after each extraction. Chloroform (2 ml) was added, methanol and water-soluble impurities were removed by washing twice with ½ ml of water, phospholipids were absorbed by shaking the chloroform eluate with 100 mg of silicic acid, and triglycerides were determined from the glycerol moiety (*1*). Phospholipids were determined (*2*) after elution from the silicic acid with 2 ml of methanol.

On emergence, triglyceride levels of males and females were quite similar. Subsequently, triglycerides of the male and female house flies and of the male mosquito diminished gradually. By contrast, the female mosquito (both *Aedes sollicitans* and *A. taeniorhynchus*) showed a constant net synthesis of triglycerides from the first until the sixth or seventh day after emergence (Fig. 1), ranging from 70 to 115 μg/day in different experiments. At the maximum, the amount of triglycerides may exceed the lipid-free dry weight. In the same interval, the triglycerides in the male dropped to 10 to 20 μg (Fig. 1*A*). The observed differences were not due to

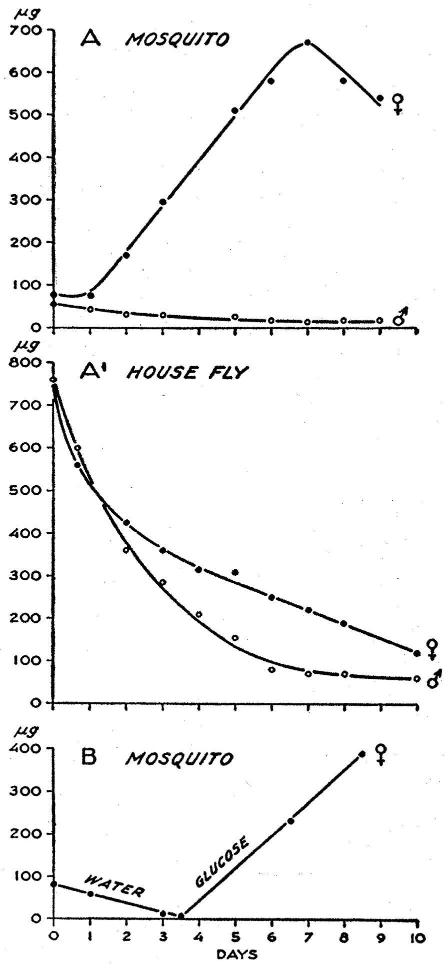

Fig. 1. Triglyceride levels of *Aedes sollicitans* (*A*) and *Musca domestica* (*A'*) maintained on glucose after emergence. (*B*) Triglyceride levels of *Aedes sollicitans* that were maintained on water and then fed glucose.