Oxygen Isotopic Composition of Some Right- and Left-Coiled Foraminifera

Abstract. *Right- and left-coiled foraminiferal species were collected from living and fossil faunas from different habitats. A difference in the oxygen isotopic composition of right- and left-coiled specimens was observed. Deposition of calcium carbonate by right- and left-coiled Foraminifera takes place, at least in the species measured, during non-coincident periods of the year.*

Few paleontological works (*1*) have shown that the relative percentage of right- and left-coiled specimens of some Foraminifera has ecologic implications. Among the factors in some way affecting the variability of these percentages, water temperature seems to be important. The percentage of right coiled specimens usually increases with water temperature. It is therefore possible that right- and left-coiled Foraminifera of the same species deposit their calcium carbonate during different periods of the year or, at least, the maximum calcium carbonate deposition occurs at different periods.

Because of the relation between water temperature and oxygen isotopic composition of shells, it is possible to verify the hypothesis by measuring the oxygen isotopic composition of right- and left-coiled Foraminifera of the same species from the same sample. The following living and fossil faunas were collected for this purpose.

1) Samples 1, 2, and 3 were selected from Holocene sediments from the plain of Pisa (43°42′N, 10°24′E; 43°37′N, 10°22′E; 43°37′N, 10°23′E). The percentage of right-coiled specimens of *Rotalia beccarii* L. ranges from 26 to 43 percent. The maximum values are observed in lagoon sediments from very shallow waters where nearly all Foraminifera are *R. beccarii.*

Table 1. Oxygen isotope composition of right- and left-coiled Foraminifera. The results are differences per mil (δ) of the ratio O^{18}/O^{16} between the samples and the PDB-1 Chicago Standard. Numbers in the last column are differences between the results obtained for the right- and the left-coiled specimens of each sample.

No.	Species	δO^{18} Right	δO^{18} Left	Δ $(r-l)$
1	*Rotalia beccarii*	−5.07	−3.80	−1.27
2	*R. beccarii*	−2.46	−2.05	− .41
3	*R. beccarii*	−2.34	−1.86	− .48
4	*R. beccarii*	−1.65	−1.12	− .53
5	*R. beccarii papillosa*	−2.00	−1.54	− .46
6	*Globigerina bulloides*	+0.42	+1.10	− .68
7	*G. inflata*	+0.56	+0.75	− .19
8	*Cibicides lobatulus*	+2.02	+2.11	− .09
9	*Cassidulina crassa*	+3.05	+2.58	+ .47
10	*Discorbis isabelleana*	+2.52	+2.69	− .17

2) Sample 4 was collected by superficial dredging at a depth of 6 meters in the Gulf of La Spezia (44°04′N, 09°56′E). *Rotalia beccarii* was selected from a rich foraminiferal fauna. In this area the relative percentage of right-coiled specimens of *R. beccarii* decreases from 33 percent in very shallow waters to 7 percent at a depth of 146 meters.

3) Sample 5 was collected near Volterra (43°24′N, 10°52′E) from sandy littoral sediments of Upper Pliocene (Astiano) age. *Rotalia papillosa* and *Elphidium crispum* are the only species of this fauna.

4) Samples 6 and 7 were obtained from two different portions of a deep-sea core taken from a depth of 2000 meters off Cartagena (Spain) (37°15′N, 00°55′E). Sediments are of Quaternary age.

5) Samples 8, 9, and 10 are from a bottom sample collected by superficial dredging at 47°34′N, 49°50′W on the Newfoundland Grand Banks. The depth at this location is about 70 meters. The foraminiferal fauna is very rich. The bottom water temperature and oxygen isotopic composition ranges are not well known. However, from the data we have, it is possible to suppose that the bottom temperature interval is probably about 3° to 4°C and that a variation of 1.0 to 1.5 per mil in the oxygen isotopic composition of the water is probably caused by an influx of water from the Labrador current. The temperature effect on the isotopic composition of shells might be completely inverted or masked by the effects of seasonal changes in the isotopic composition of the water.

The classic procedure (*2*) was used for the chemical preparations of the samples but the material was roasted longer in the oven under elium flux because of the high organic content of recent Foraminifera. Samples of about 10 mg were generally used. Each sample was measured by means of an Atlas-Werke M86 mass spectrometer against the working standard (CO_2 from a very pure Carrara white marble) on both sides of the inlet system. Moreover, samples of right- and left-coiled specimens were measured directly one against the other.

The results obtained (Table 1) are expressed in terms of difference per mil (δ) of the ratio O^{18}/O^{16} between the samples and the Chicago (PDB-1) Standard. Numbers are averages of repeated measurements of Foraminifera of the same species, with the same coiling direction and from the same faunas. The Δ $(r-l)$ values in the last column are differences between the results obtained for the right- and left-coiled specimens of each sample. The standard error of the Δ values is not higher than $\pm$ 0.1 δ units.

It is impossible to interpret quantitatively the differences observed for the following reasons. We do not know the seasons during which each species precipitates calcium carbonate. The right- and left-coiled specimens may begin deposition of calcium carbonate at different times but continue it for relatively long overlapping time intervals, thus reducing the relative difference in the oxygen isotopic composition.

The possible variations of the isotopic composition of the water during the year are not known in the case of fossil specimens and sometimes are not known in the case of living specimens (samples 8, 9, and 10). During the summer on the Newfoundland Grand Banks it is possible for the temperature of the bottom water to decrease and for the δ values to decrease at the same time owing to influx of meltwater from northern ice. These isotopic effects may explain the results given by *Cassidulina crassa,* which shows a more positive δ value for the right-coiled specimens than that for the left-coiled ones. In a littoral lagoon, on the other hand, it is possible to have either the same effect or just the opposite one, owing to influx of rain water or to evaporation.

While it may not be possible to interpret the observed differences in terms of temperature, one may conclude that, generally, the deposition of calcium carbonate by right- and left-coiled Foraminifera occurs during different periods of the year or with different velocities during the same period. The Δ $(r-l)$ values are rather small. It is interesting to note that the two highest Δ values were obtained from a lagoon sample (number 1) and a pelagic sample (number 6).

In regard to paleotemperature measurements carried out on mixed right-and left-coiled Foraminifera from open-sea sediments, the differences observed and the relative percentage of right- and left-coiled specimens indicate that the paleoclimatic conclusions should maintain, in a general way, their validity. However, in such a case, there is a factor of uncertainty of the measurements higher than the standard error.

This is due to the possibility that the percentages of right- and left-coiled specimens and the seasonal difference in the deposition of calcium carbonate by each vary in different species of the same fauna.

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Strontium-90 in Plants and Animals of Arctic Alaska, 1959–61

Abstract. *The strontium-90 content of the biota near Cape Thompson, Alaska, was related to environmental factors. In plants, perennials with persistent aerial parts had maximum and similar concentrations of strontium-90. The content of caribou muscle varied seasonally and was highest in winter when lichens were an important caribou food.*

Beginning in 1959, the U.S. Atomic Energy Commission sponsored a bioenvironmental study in the vicinity of Ogotoruk Creek (latitude 68°6′N, longitude 168°46′W) near Cape Thompson in northwestern Alaska. This study was made in conjunction with Project Chariot, a proposed test excavation employing nuclear energy. Project Chariot was part of the AEC's Plowshare Program for the development of peaceful uses of atomic energy (*1*).

The Chariot test site is located in a tundra region where the average annual precipitation is 20 cm. In this area of permafrost the ground is frozen to the surface during much of the year. Winds are strong and persistent, with average velocities of 36 km/hr during the winter and 22 km/hr in the summer (*1*). The vegetation is composed of sedges, mosses, willows, birches, lichens, and low-growing perennial herbaceous forbs. Much of the area is poorly drained and snow accumulates in the depressions during the winter. The exposed ridge tops are swept free of snow in winter by the strong winds.

Radionuclides originating from nuclear weapons testing were measured in the biota from 1959 through 1961 to determine distribution and concentration of radioelements in the environment before the test, and to aid in predicting the fate of radioactive materials which might be released to the environs by the excavation test.

Samples of plants and small animals were collected during the summers of 1959, 1960, and 1961 when no nuclear testing, except for the low-yield French Sahara Desert tests, were conducted. Most samples were collected within 24 km of the Project Chariot site. Caribou, however, were obtained in locations (Fig. 1) 160 km or more from the test site.

Vegetation was collected by clipping the tips of willow branches and the parts above ground of sedges, lupine, and the aquatic emergents *Arctophila* and *Hippurus*. Leaves and stems of heather (*Ledum*), *Dryas*, *Sphagnum* moss, and lichen were picked by hand. Samples were sealed in plastic bags in the field, weighed on the day of collection, transferred to cheesecloth bags, and dried.

Birds and small mammals were trapped or shot and were weighed and frozen on the day of collection. In most cases, wet-weight determinations were made on frozen caribou samples. Caribou muscle was taken from the hind leg and bone samples were obtained from the mid-shaft of the femur.

All Sr^{90} measurements were made at Hanford Laboratories. Before radioassay for Sr^{90}, all samples were ground, thoroughly mixed, and a portion was removed for determination of standard dry and ash weights (*2*). Samples were then dry ashed in a muffle furnace at 525°C for 12 hours or more. Usually the amounts used per sample were as follows: vegetation, 250 to 500 g air dry weight; entire animals, 100 to 500 g wet weight; muscle, 200 to 2000 g wet weight; bone and antler, 7 to 30 g air dry weight; and rumen contents, 500 to 1000 g wet weight. To obtain a countable amount of Sr^{90} in small birds and mammals, the tissues of several individuals were included in a single sample.

Strontium-90 was separated by a modification of the method described by Silker (*3*), and calcium determinations were made by a modification of the method of Yofe and Finkelstein (*4*).

Samples below 20 count/min were counted on low-background beta counters. Count rates twice that of the background and below were rejected. Samples with rates of 20 count/min or more were counted on a beta proportional counter having a counting error of about 2 percent.

There was surprisingly little difference, on a dry weight basis, in the Sr^{90} content (Table 1) of the plants examined with respect to species or time. Possible routes of entry of Sr^{90} in the vegetation are several, including uptake from the soil by way of the plant roots, foliar uptake from the water in which the plants were growing, and direct foliar sorption from the atmosphere. These routes are modified by environmental conditions such as exposure, chemical and physical properties of the substrate, and by variations in growth habits and specific mineral requirements of different plant species.

Foliar sorption is the main route of Sr^{90} uptake in lichens. Maximum concentrations were found in lichens adhering to the rocky substrates of exposed ridges; there were lesser amounts in lichen in areas of winter-snow accumulation. The persistence of lichen aerial parts, their very slow growth rate of 5 mm or less per year (*5*), their long life span of up to 100 years (*6*), and the high ratio of surface area to mass all contribute to their relatively high levels of Sr^{90}. Their capacity to obtain most of their nutriment through absorbed moisture and the hypothesized property of the cell walls of the lichen thalli to behave as hydrophilic gels (*6*) also enchances aerial sorption of fallout Sr^{90}.

The calcium content in lichen samples was quite variable owing to the inclusion of different amounts of mineral material in the form of soil particles. The lichen communities sampled grew on stoney soils, making the possibility of incorporation of inorganic materials greater in these than in other plant samples. As a consequence, the measured ratio of Sr^{90} to calcium in lichen samples is exceedingly questionable.

Relatively high concentrations of Sr^{90} were found in *Dryas octopetala* and heather (*Ledum decumbens*), both of which grow on well drained slopes.