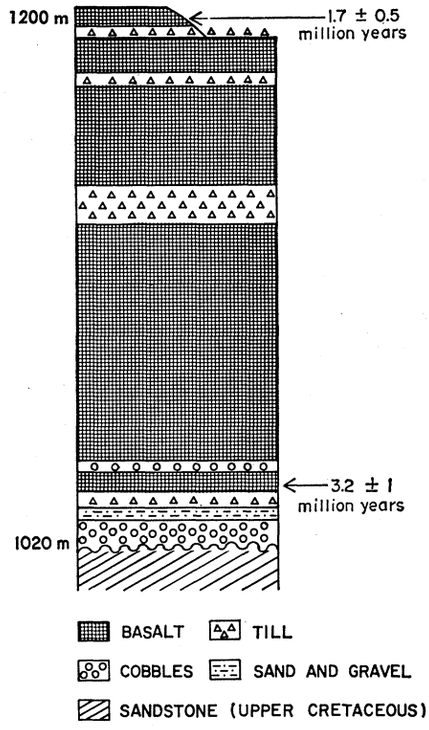

Fig. 3. Stratigraphic section of interbedded till, alluvium, and lava flows at Cerro del Fraile. Ages determined at positions indicated.

lying lava and suggests a former soil (Fig. 2B). No erratics lie on the surface of the uppermost lava flow which covers only part of the summit platform. The till unit below this flow continues over the rest of the summit platform as a lag concentrate of pebbles and boulders, the matrix having been removed by erosion (Fig. 3). Apparently the uppermost till unit was deposited by the last glacier that covered the hill, and the youngest lava flow has probably never been covered by ice. Perhaps by the time of the deposition of the uppermost till unit the excavation of the present Lago Argentino depression had proceeded far enough to channel much of the ice flowing east from the mountains, leaving the bordering plateau remnants ice-free.

The ages of the oldest and youngest lava flows—3.2 ± 1 and 1.7 ± 0.5 million years—indicate that glaciation in southern Argentina began before 2 million years ago. Glaciation 2 to 3 million years ago has been reported from other temperate parts of the world; in Iceland a till bed is inferred from studies of rock magnetism to be either about 1.9 million or 2.4 to 3 million years old, but other till beds are probably older (*2*); a till bed in the Sierra Nevada, California is about 3 million years old (*3*); and in New Zealand, where apparently ancient tills are known but have not been dated, the earliest major climatic cooling, as shown by the pollen sequence, is thought to have been about 2.5 million years ago (*4*). In Antarctica, glaciers reached the coast more than 2.7 million years ago (*5*) and probably at least 5 million years ago (*6*). A prerequisite for extensive glaciation in southernmost South America would have been the northward surface spread of Antarctic water. Goodell and his co-workers (*6*) believe that cold conditions, during which the 0°C surface-water isotherm was more than 5° of latitude north of its present position, prevailed during the Gauss paleomagnetic epoch (3.35 to 2.35 million years ago) and that the Matuyama epoch was warmer. According to Hays and Opdyke (*7*), however, temperatures fell about 2.5 million years ago, at about the Gauss-Matuyama transition. Ericson and Wollin (*8*) believe that the change to a colder world-wide climate began before 2 million years ago, but that extensive glaciation in temperate latitudes did not start until the Nebraskan glaciation 2 million years ago at the Pliocene-Pleistocene boundary.

Extensive glaciers existed in southernmost South America before 2 million years ago. Because of the imprecision of the dates obtained by whole-rock K/Ar analyses, particularly of the older sample, the age difference between the oldest and youngest till beds is uncertain; thus, it is not known whether one or more glaciations are represented. Furthermore, because the till beds owe their preservation to the covering lava flows, the oldest surviving till bed may not represent the first occasion that the site was ice-covered. The concentration of the fluvial beds near the base of the section perhaps indicates that a glacial climate was less well established when the first flow was erupted than later, but it may merely reflect changes in local topography. More precise dating of these till beds should be possible when studies of the magnetic polarity of the lava flows have been made.

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Strontium-90: Concentrations in Surface Waters of the Atlantic Ocean

Abstract. *From the large body of analyses of strontium-90 in surface waters of the Atlantic Ocean, annual average concentrations (from 10°N to 70°N) have been compared to those predicted. The data indicate higher fallout over ocean than over land and confirm the rapid rates of down-mixing shown by most studies of subsurface strontium-90.*

With the resumption of atmospheric nuclear testing in 1961, there began several new programs of systematic analysis of strontium-90 or cesium-137 in surface waters of the Atlantic Ocean and its adjacent seas and such programs already operating were expanded. In view of the large body of data, we have collected and collated all the available analyses since 1954, some unpublished and many published only in relatively inaccessible periodicals or reports. These data proved remarkably concordant; this is especially important because of the considerable difficulties involved in the analysis of fallout radionuclides, even in surface seawater. Over 750 analyses from the open-ocean Atlantic were compiled from British, Danish, German, Polish, Russian, South African, and United States sources; after using reasonable criteria of internal consistency and cross-comparability, we have not felt justified in summarily dismissing any data points.

We summarize here the bearing of this body of data on two major problems: (i) the question of the delivery of excess fallout over the ocean, compared to that over land (*1–6*); and (ii) the question of the extent to which fallout Sr^{90} has penetrated to the "deep Atlantic," that is, below the main thermocline (*3, 4, 7*). Previous discussions of both these points have rested almost exclusively on relatively

small numbers of analyses of Sr^{90} or Cs^{137} in actual deepwater samples and have been seriously beclouded by the real difficulty of obtaining unequivocally acceptable analytical results at the very low concentration ranges to which importance must be given. As Broecker (*4*) implied, however, any model of ocean circulation necessarily predicts both the shape of the curve of surface-water Sr^{90} plotted against time and the actual mean surface-water concentrations, making only the assumptions that data from a large enough area of ocean have been averaged to eliminate or minimize the effects of horizontal advection and that the annual increment of Sr^{90} to the ocean can be predicted from measurements made over the land surface. The North Atlantic is a good ocean for such analysis, since it experiences very little loss of water by surface currents moving out of it, the net gain in water from northward movement in the South Equatorial Current being balanced by southward return flows at depth. The surface circulation through the Barents Sea and into the Arctic Ocean produces only a small perturbation.

Figure 1 presents annual average surface-water Sr^{90} concentrations in the Atlantic Ocean from 10°N to 70°N for the years 1959 through the first half of 1967; this boundary of southern latitude was set to include that part of the ocean which lies always within conditions of "northern hemisphere" deposition as predicted by Volchok's (*8*) data on land surface when averaged over belts of latitude 10° wide. Against these observed values, obtained by averaging all available data, are shown the curves predicted by Broecker's model (*4*) at two different values for "mixing rate": the upper curve uses 30 m/year, his best estimate for the Caribbean Sea up to 1961, and the lower curve uses 300 m/year (to compare with his "best estimate" of 90 m/year for the North Atlantic up to 1963). The shapes of the curves are independent of the actual amount of fallout delivery; the concentrations predicted by Broecker are based on the assumption that the sea surface receives 1.5 times as much fallout per unit surface as land does in the same band of latitude.

For comparison, we have indicated across the top of the figure the average annual increment of fallout over land [from Volchok (*8*)] expressed as a percentage of the sum delivered to

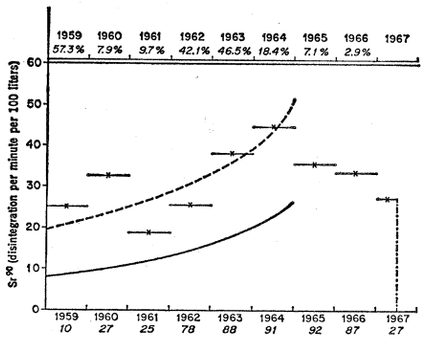

Fig. 1. Annual mean concentration of strontium-90 in surface-water samples of the Atlantic Ocean from 10°N to 70°N, compared to curves predicted from Broecker's (*4*) model for rates of mixing of 30 m/year (---) or of 300 m/year (——). Values across the bottom of the figure indicate number of analyses per year; across the top of the figure are shown the annual mean deliveries [from Volchok (*8*)] measured over land at corresponding latitudes, calculated as the percentage increment over the total accumulated at the end of the previous year.

the end of the previous year, also calculated as the average for latitudes between 10°N and 70°N. No matter what model for ocean circulation is used, the surface concentrations of Sr^{90} must be the resultant of two competing rates; that of its addition to the surface and its removal to deeper water. It seems reasonable to assume that the annual percentage increment of fallout to the ocean surface did not differ greatly from that observed over land and that major annual differences in rates of removal may be neglected; the sensitivity shown (Fig. 1) by the average surface Sr^{90} concentration to changes in the annual increment of fallout provides an important clue to the magnitude of the removal rate of Sr^{90}.

Neither curve from Broecker's model predicts the reduction in surface-water concentration actually observed from 1960 to 1961 and from 1964 to 1967. The shape of the observed curve of surface-water Sr^{90} plotted against time requires a mixing rate much larger even than the 300 m/year shown, so that, at rates of delivery representing annual increments below 15 percent or so, negative slopes will be predicted.

In addition to the implications of the shape of the curve of surface-water Sr^{90} concentration plotted against time, the actual values of concentrations observed are significant. At high mixing rates, Broecker's model, like any other, predicts surface concentrations much lower than those actually observed. The mean surface concentrations in the interval from 1961 to 1964 were several times those that could be predicted for rates of down-mixing large enough to explain the negative slopes observed in 1964 to 1965 and 1966 to 1967. We believe that these high surface concentrations are consistent only with deliveries of fallout over the ocean closer to three to four times those observed over land, as measured by Chesselet *et al.* (*6*).

No mechanism has yet been suggested that accounts for this; it seems clear from inspection of the ocean delivery patterns and of aerosol radioactivity over the ocean (*9*) that the discrepancy cannot be attributed simply to faster tropospheric purging over the ocean, but that an actual difference exists in the rate of transfer of stratospheric debris to the lower troposphere.

These analyses of surface-water Sr^{90} concentrations thus confirm the conclusions reached from analyses of deepwater samples (*1–3, 5, 7*), namely, that fallout radionuclides thought to move only as solutes have penetrated to depth much faster than would have been predicted, and that rates of delivery of fallout over the ocean have substantially exceeded those measured over land. This confirmation is especially gratifying because the analyses used and the concentration changes observed are not subject to the sort of criticism, derived from questions of blank measurement or of sample contamination or provenance, that has been directed at the subsurface sample data.

We are well aware that the best available estimates of the Sr^{90} inventory (*10*) do not allow sufficient fallout to extend a differential delivery of this magnitude over the whole world ocean. We must emphasize that the data used here apply only to the North Atlantic Ocean, and that some of their details to show evidence of special events that would not justify their extrapolation either to other years or to other oceans. However, tritium analyses by Bainbridge (*11*) in the Pacific showed a similar curve of concentration plotted against time in 1960 to 1961, but with even greater negative slope.

These data have been presented elsewhere (*12*), along with a discussion of some aspects of the horizontal variations in Sr^{90} concentration with time. Another discussion presents data for

both surface and subsurface Sr^{90} in the Atlantic contrasted with data from other oceans (*13*).

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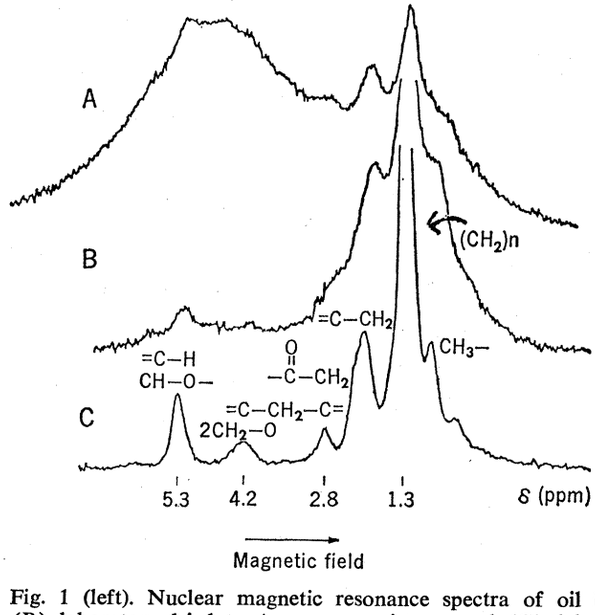
Nuclear Magnetic Resonance Measurement of Oil "Unsaturation" in Single Viable Corn Kernels

Abstract. *High-resolution nuclear magnetic resonance spectroscopy has been used to demonstrate the feasibility of determining iodine value and average molecular weight of oil in individual corn kernels. The procedure is rapid and nondestructive. Depending on heritability of individual fatty acids, this technique may greatly increase selection efficiency in breeding programs to alter the fatty acid composition of corn oil.*

Traditionally, selection for chemical composition of plants has been accomplished by methods that destroy the sample. Consequently, in plant breeding programs, selections normally are made on the basis of population averages. Nondestructive methods to identify variant individuals permit specific choices in breeding for a desired trait. One such method is wide-line nuclear magnetic resonance (NMR) spectroscopy adapted to the analysis of single seeds for total oil content (*1*, *2*). This technique has been applied advantageously in selecting for higher oil content in corn. Bauman *et al.* (*3*) and Dumanović and Trifunović (*4*) showed that differences in oil content of kernels from the same ear were heritable. Silvela (*5*), using NMR selection techniques, was able to increase the average oil content of corn 2.25 times faster than was possible with traditional selection methods. Of practical importance, the number of plants grown each year was reduced significantly while a germ plasm base at least five times greater than that retained by the classical selection method was maintained. Applying somewhat similar NMR techniques at higher selection pressures and using conventional methodology Zupančič *et al.* (*2*) increased the oil content of corn in four to five generations by an amount that normally would have been obtained only in 20 to 30 generations.

A negative correlation between the total amount of oil in corn and the iodine value of oil exists (*6*). However, since the correlation is not so high as to preclude the development of high-oil lines with oil of medium or high iodine values, there is a need for a rapid, nondestructive method to measure the iodine value of oil *in situ* in single corn kernels. In a study of a set of diallel crosses of nine inbred lines of corn, Poneleit (*7*) found additive gene action to predominate in control of total oil and fatty acid composition. Therefore,



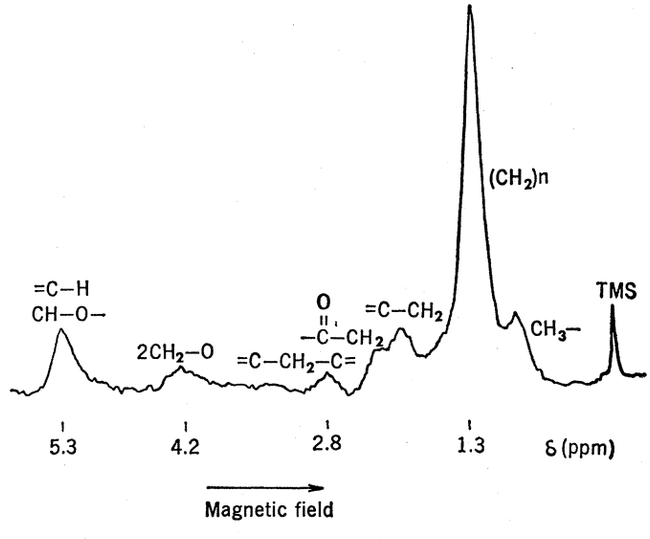


Fig. 1 (left). Nuclear magnetic resonance spectra of oil in single corn kernels. (A) Commercial-dried to 15 percent moisture; (B) laboratory-dried to 4 percent moisture; and (C) laboratory-dried to 4 percent moisture and soaked in Freon-113 for 6 days; (100 Mhz). Fig. 2 (right). Fourier transform spectrum of oil in single intact corn germ soaked in Freon-113; (100 Mhz).