



Fig. 1. Observed concentrations, expressed as percentage of D<sub>2</sub>O in water, plotted against the theoretic values. The error ( $\pm 0.014$ ) is expressed as deviation from the theoretic straight line shown.

Table 1. Evaluation of accuracy of the method.

No. of determinations	Standard error (%) D <sub>2</sub> O	D <sub>2</sub> O concn. range (%)	Type of measurement
14	$\pm 0.014$	0-2	Blind
210	$\pm 0.019$	0-5	Repetitive

is 3.802°C. Hence, a method for measuring freezing points to a thousandth of a degree should permit differentiation of at least 0.01 percent deuterium oxide in water. Such a method is now available in the form of the Fiske osmometer (1). The operation of this instrument is based on the principle that slightly supercooled solutions can be rapidly frozen by agitation and that the temperature of the ice crystals can be measured during the several seconds it remains constant. This temperature is considered to be the freezing point. The apparatus is designed to operate at temperatures below zero, but proper adjustments of the calibration will allow measurements a degree or so above zero. The temperature is measured by means of a thermistor in a bridge circuit. If measurements are confined to a narrow temperature range (a degree or so), potentiometer readings are essentially linear.

When the instrument is used as an osmometer, the thermistor is calibrated by determining the potentiometer readings at which 100 and 500 milliosmolar solutions of sodium chloride freeze. When these are adjusted to provide dial readings of 100 and 500 on the potentiometer, the osmolarity can be read directly.

Since the freezing point of 100 milliosmols of sodium chloride in distilled water is  $-0.1858^{\circ}\text{C}$  and that of distilled

water is  $0^{\circ}\text{C}$ , these liquids were used for the purpose of calibrating the osmometer. One hundred scalar divisions extended over a temperature range of  $0^{\circ}$  to  $0.2044^{\circ}\text{C}$  for 0 to 5 percent solutions of D<sub>2</sub>O in distilled water. For assessment of linearity, 0.5, 1, 2, 3, 4, 10, 15, 20, and 25 percent solutions of D<sub>2</sub>O in distilled water were studied. Calibration was checked by determining concurrently the 100 milliosmolar solution of sodium chloride and the water with each series of measurements of the freezing points. Thirty separate determinations were made of each dilution.

It was apparent that the precision of the method was limited by the sensitivity of the osmometer, which, incidentally, can be increased. Repeated determinations were reproducible to 0.2 scalar division of the potentiometer. Linearity within the range of 0 to 5 percent D<sub>2</sub>O was also within less than 0.2 scalar division. Figure 1 and Table 1 show the sensitivity and accuracy of the method. For a concentration range of 0 to 2 percent D<sub>2</sub>O in water, the D<sub>2</sub>O was determined to a concentration of 0.05 percent.

The simplicity and reliability of this method ensure its usefulness in the study of many problems involving D<sub>2</sub>O in the medical, biologic, physical, and chemical fields, provided that levels of concentration of D<sub>2</sub>O are such as to fall within the range of the osmometer. The sensitivity of the method can be increased by more precise determinations of the freezing points (2).

PAUL B. REASER  
GEORGE E. BURCH

*Department of Medicine, School of Medicine, Tulane University, and Charity Hospital of Louisiana, New Orleans*

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### Accumulator Plants and Rock Weathering

Accumulator plants may be defined as those that take up certain specific elements to a much greater degree than most plants. Accumulators that selectively take up elements harmful to agriculture—such as selenium and molybdenum—have been extensively studied, but little has been written about the problems posed by plant accumulators of major constituents of the earth's crust such as silica, aluminum, and iron. Although it is generally recognized that

biochemical factors are important agents in surficial processes, the possibility that accumulator plants may withdraw from the earth geologically significant amounts of various elements has not previously been pointed out so far as I am aware. The amount of silica taken out of the ground by certain plants is sufficiently large to warrant consideration of this process as an important factor in the development of silica-deficient soils such as the laterites. Horsetail or "scouring-rush," some dicotyledons, and many of the monocotyledons such as corn, palm trees, bamboo, reeds, and other grasses take up large amounts of silica (see Table 1).

According to Amos and Dadswell (1), more than 375 species of tropical timber trees must be classed as silicic—that is, they contain more than 0.05 percent SiO<sub>2</sub> (dry weight). Many species of the tropical hardwoods studied by Amos and Dadswell range between 2 and 3 percent SiO<sub>2</sub> (dry weight); some species of bamboo and rush contain 3 times this amount. One order of trees common in Brazil, the Chrysobalanaceae, especially the genus *Moquilea*, is unusually rich in silica, and the heavy bark of trees of this genus contains slightly more than 50 percent SiO<sub>2</sub> (dry weight) (2).

According to Bear (3), tropical forests produce from 10 to 20 tons dry weight of new growth per acre above ground each year. If we assume that a forest in the tropics containing good silica accumulators averages 3 percent dry weight of silica and produces approximately 13 tons dry weight of new growth per acre per annum, it is readily calculated that such a forest would abstract from the soil about 0.4 ton of silica per acre per year. This is equivalent to 1 ton of silica per acre each 2½ years.

A basaltic lava having a density of about 3 and containing 49 percent SiO<sub>2</sub> would have about 2000 tons of silica per acre foot. It is apparent, then, that a tropical jungle of silica-accumulator vegetation could in 5000 years easily remove silica equivalent to that in 1 acre foot of basalt. The bulk density of the lateritic soils commonly ranges from 30 to 40 percent of the bulk density of the parent basalt. If we assume that 3 to 1 is a fair approximation of the ratio of parent rock to residual lateritic soil, volume for volume the laterite and parent basalt would be nearly equivalent, but the lateritic soil would represent only about one-third the weight of the fresh parent rock. If this lateritic soil contained about 35 weight percent SiO<sub>2</sub> (see Hough and Byers, 4) there would be approximately 475 tons of silica per acre foot residual from the 2000 tons of silica in 1 acre foot of fresh basalt. The hypothetical tropical jungle of silica-ac-

Table 1. Analyses of some silica- and iron-accumulator plants (arranged in order of decreasing silica content, dry weight).

SiO <sub>2</sub> (% dry wt.)	Ash (% of dry wt.)	Weight percent in ash*									
		SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	SO <sub>3</sub>	Cl
9.5	12.5	76.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
			Giant reed, <i>Arundo donax</i> (leaves) †								
8.11	29.30	27.68	n.d.	0.28	3.15	59.01	0.77	6.17	2.17	0.77	n.d.
			Common gromwell, <i>Lithospermum officinale</i> ‡								
5.53	19.62	28.00	n.d.	26.51	6.36	16.28	2.06	6.47	n.d.	2.63	0.55
			Water chestnut, <i>Trapa natans</i> §								
5.40	17.39	31.08	n.d.	0.96	23.39	2.20	13.50	1.41	9.26	1.26	8.95
			Giant horsetail, <i>Equisetum telmateja</i> (Ehrh)								
3.9	5.5	70.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
			Giant reed, <i>Arundo donax</i> (stems) †								
3.46	12.12	28.51	n.d.	1.04	2.34	10.15	1.26	37.80	9.64	5.78	5.57
			English rye grass, <i>Lolium perenne</i> L. #								
3.23	6.81	47.48	n.d.	4.58	2.99	4.28	10.05	11.37	4.42	1.75	11.09
			Bluegrass, <i>Poa maritima</i> ‡								
2.97	4.26	69.72	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
			China laurel, <i>Antidesma pulvinatum</i> (Hil.) **								
2.15	3.16	67.96	n.d.	0.33	11.81	16.97	0.56	0.65	0.29	0.76	n.d.
			Palm, <i>Calamus rotang</i> ‡								
0.37	6.05	6.19	n.d.	37.35	6.90	19.80	7.72	4.26	2.87	6.78	5.49
			Field horsetail, <i>Equisetum arvense</i> (L.)								

\* n.d., not determined. † Collector and analyst, C. G. Engel, U.S. Geological Survey, Pasadena, Calif., Feb. 1958. ‡ E. T. von Wolff, single analysis (7, pp. 110, 111, 121). § E. T. von Wolff, av. of two analyses (7, p. 133). || G. Mariani, individual analysis (8). # E. T. von Wolff, av. of 11 analyses (7, p. 121). \*\* L. E. Wise, wood samples from Hawaii (9).

accumulator vegetation would require 2.5 × (2000–475) years or about 3800 years to convert 1 acre foot of fresh basalt to 1 acre foot of this lateritic soil if silica were removed solely through the agency of these plant accumulators.

Not all the silica moving into plant accumulators would be lost. Nevertheless, whether the silica is present in the plant as opal, as fine-grained quartz, as inorganic compounds, or as organic compounds, it would be highly vulnerable to chemical and physical erosion while the plant matter was decomposing. In areas of high rainfall where a tropical downpour equivalent to several inches of precipitation may take place in a few hours, much of the organic debris could be washed into the nearest drainage channel. The reality of such a process is evident in the high organic content of the brown and black waters so common in the tropics.

Some of the silica—and other elements—in forest litter is recycled, and some of it is dissolved and enters groundwater circulation; under favorable conditions, however, substantial quantities of silica must be pumped out of the ground at depth, spread over the surface in organic debris, and then swept off by erosive agents.

Although I have taken silica as an example, it is, of course, evident that the accumulator plants that select aluminum in preference to silica would tend to deplete the soil of this element and leave the ground enriched in silica. Hutchinson (5) has described many aluminum-accumulator plants, several of which would apparently be competent to

change materially the ratio of alumina to silica in the soil if the plant community contained a preponderance of them and a dearth of silica accumulators. The quantitative aspects of the process suggested above must remain speculative until field studies are made in suitable areas, but the entire geobiochemical history of silica—and of other elements taken up by accumulator plants—is one of great interest and seems worthy of further investigation (6).

T. S. LOVERING

U.S. Geological Survey,  
Denver, Colorado

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## Long-Lived Cobalt Isotopes Observed in Fallout

It has generally been assumed that the long-term radiological hazards due to fallout from a nuclear detonation depend primarily upon the long-lived fission products. However, other radioactive products which are not derived from fission reactions may be present in fallout and may contribute to the hazard. These latter products would be created by neutron activation of elements in the immediate vicinity of the detonation. The presence of one such product, Co<sup>60</sup>, has been indicated by analyses of fallout material (1) and of biological specimens recovered from fallout areas (2).

The investigation discussed in this report, which was carried out to determine the amounts of Co<sup>60</sup> in fallout samples from the 1956 test series, revealed the existence of two additional cobalt nuclides, Co<sup>57</sup> and Co<sup>58</sup>. The amounts of these nuclides were determined. To permit assessment of the relative internal hazards from the cobalt isotopes, determinations of Sr<sup>90</sup> were made on the same samples. From these data the Co<sup>60</sup>/Sr<sup>90</sup>, Co<sup>58</sup>/Sr<sup>90</sup>, and Co<sup>57</sup>/Sr<sup>90</sup> ratios were derived. Since all three cobalt isotopes emit gamma radiation, they would also contribute to an external hazard. The amount of this hazard was estimated by summing the photon energy release per unit time from the observed amounts of radiocobalt and comparing this value with similar values calculated for the associated fission products.

Radiochemical analyses were carried out on three samples of fallout obtained after one detonation of the 1956 nuclear weapon test series in the Marshall Islands. The samples consisted of large trays which had been exposed at various locations within the fallout pattern. After removal of the radioactive material and solution by acid treatment, aliquots were taken for strontium and cobalt analyses.

After the addition of strontium carrier and Sr<sup>85</sup> (used as a tracer for chemical yield determinations), the strontium was separated by precipitation with fuming nitric acid and determined finally as the oxalate (3). The oxalates were dried and mounted for beta counting. The Sr<sup>90</sup> was determined by measurement of the growth of the daughter, Y<sup>90</sup>. The samples were quantitatively redissolved, and the chemical yield was determined through a gamma-ray spectrometer measurement of the remaining Sr<sup>85</sup> tracer. After application of the usual corrections, the number of Sr<sup>90</sup> atoms present at zero time was determined; a half-life value of 27.7 ± 0.4 years was used (4).

Cobalt was separated by adaptation of existing procedures (3). Since Mn<sup>54</sup> was known to be present, manganese carrier