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Turbidity Currents and Displaced Fresh-Water Diatoms

Kolbe (*1, 2*) called attention to an abundance of displaced fresh-water diatoms in deep-sea cores of the eastern Atlantic Ocean. He considered three possible theories to explain this distribution of such out-of-place floras. The theories considered are: potamic or ocean-current theory, aeolian theory, and Atlantis theory (modified from Malaise, *3*). The first two are tenable, and we feel that an additional possible method of distribution of the forms should also have been considered, that of distribution by turbidity currents.

Evidence of oceanic turbidity currents has been presented by Heezen and Ewing (*4*), Erickson, Ewing, and Heezen (*5*), Kuenen (*6*), and many others. Perhaps among the better documented ones is the movement associated with the Grand Banks earthquake, described by Heezen and Ewing (*4*). Other evidence has been pointed out by Andrée (*7*), who noted that Atlantic submarine cables are most frequently broken during the rainy seasons along the African and South American coasts. This would support the inference that sediments move along the ocean bottom in turbidity-current or slump fashion.

Several examples of displaced foraminiferal faunas appear in geologic literature. Phleger (*8*) described a displaced fauna from a deep-sea core consisting of shallow-water foraminifera and, lower in the core, sand containing twigs, nuts, and bark fragments of dicotyledonous bushes and trees. Phleger (*9*) concluded that "Deep-sea sands, having only shallow-water species, are believed to have moved down as a unit without contaminating other sediments," thus inferring movement by turbidity currents. Natland (*10*) concluded that turbidity currents are of considerable importance in distribution of microfossils.

Turbidity currents are considered to be common features of the continental slopes and of all other major submarine slopes. Evidence of them in the area described by Kolbe (*1, 2*) can be found in deep-sea cores. An interesting deep core taken from the Romanche Deep shows interbedded sand of angular fragments of mafic rocks, clay, and silt, with occasional streaks rich in organic remains (Pettersson, *11*). The lower part of the core consists of calcareous ooze. Recently published photographs (*12*) of the floor of the Romanche Deep show the coarse texture of particles at the surface. Pettersson (*11*) concludes that the general area is tectonically active, supplying brecciated rock fragments to slumps which moved down the steep slope into the Romanche Deep. Core No. 238, mentioned by Kolbe (*1, 2*), occurs in the deep and contains an abundance of displaced diatoms.

Diatomaceous cores studied by Kolbe (*1, 2*) fall into two categories or areas—those east of the Mid-Atlantic Ridge, in which diatoms were common in many horizons, and those west of the ridge, in which diatoms occur only at individual horizons and even there are relatively uncommon. Core No. 246 is practically at the crest of the ridge and contains *Melosira granulata* at a single horizon. Although this form is by far the most abundant one in cores east of the ridge, it does not occur west of the ridge, as reported in Kolbe's tabulation (*2*). Fresh-water species do occur in cores on the ridge and in cores No. 255 and 267 west of the ridge. Floras of the last two localities have nothing in common with those east of the ridge, according to Kolbe's tabulation (*2*), and certainly seem to have been derived from a different source. Generalizations that suggest a single source and homogeneity of the flora seem unwarranted.

A distribution other than by oceanic currents is suggested for these fresh-water forms in view of the above distribution. Lohman (*13*) concluded that the settling time of diatoms through three miles of sea water must be measured in hundreds of years. It would thus seem improbable that a current of moderate velocity, such as the equatorial Atlantic currents, could selectively distribute the fresh-water diatoms in the pattern documented by Kolbe (*2*). A more localized phenomenon is suggested, one in which the diatoms were probably part of the flocculent of fine sediments which forms at the mouths of most major streams as they enter the sea, a flocculent which then moved downslope with the entrapped diatom flora without contamination by contemporary marine forms and without contamination of the normal oceanic currents.

If the displaced diatoms were brought into the area of the Cape Verde basin either by wind of the Harmattan haze or by oceanic currents, distribution of diatoms through thick sequences of sediments would be expected to be more constant than Kolbe infers. The relatively slow rate of sedimentation and the near constancy of wind and oceanic currents over hundreds of years would tend to produce a constant or nearly constant supply of organic material through time. On the other hand, turbidity currents can disrupt the average rate of sedimentation and can deposit relatively thick layers of near-shore material into the deeps at irregular intervals. It would thus be possible to deposit nearly pure, near-shore displaced faunal and floral elements in thick layers in deep water in a very short time. Because of this marked variation in assumed depositional rate, it seems unlikely that rate of sedimentation is a reliable means of telling geologic ages, even back to the Tertiary.

Turbidity currents might explain the concentrated occurrence of diatoms in the cores mentioned by Kolbe (*1*) (Nos. 229, 230, 234, 235, and 238), for all these cores occur in deeps east of the Mid-Atlantic Ridge or on the continental slope west of Africa.

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Rigby and Burckle do not believe in my suggestion No. 3 (*1*) based on Malaise's theory (fresh-water diatoms found in deep-sea sediments of the Atlantic but originating in a fresh-water biotype, which subsequently became submerged) and ascribe the layers of these diatoms, as in core No. 234, to the action of turbidity currents.

Rigby and Burckle suggest that fresh-water diatoms from the mouth of African streams were entrapped in fine sediments, "a flocculent which then moved downslope. . . ." Is it possible that this flocculent mass could travel with a turbidity current and be deposited at a distance of more than 900 km from the African coast? This seems highly improbable, and, to my knowledge, there are no records to support this hypothesis. Regarding the breaks of submarine cables off the Great Banks in 1929, which Rigby and Burckle mention, the Swedish oceanographer B. Kullenberg (*2*) has pointed out that the breaks could not have been caused by turbidity currents but must have been caused by the earthquake itself because, among other evidences, one cable broke simultaneously in two different places.

Even if we should accept the faint possibility of a turbidity current flowing from the African coast and dumping its load of fresh-water diatoms at a distance of 930 km from this coast, it remains to be explained how it was possible for this current not only to carry its load such a distance but, at the same time, to climb uphill more than 1000 m before dumping the load on top of a submarine hill. Core No. 234, with its fresh-water diatom maximum, was taken at a depth of 3577 m, and depths between the coring point and the African coast were measured to 4586 and 4967 m.

I think that Malaise's theory (*1*) explains the phenomenon in a far more plausible way than the hypothesis of Rigby and Burckle.

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Effect of Calcium on Deposition of Strontium-90 and Calcium-45 in Rats

As the principal hazardous constituent of the radioactive fallout from atomic bomb tests, strontium-90 has been the object of much recent study with respect to its progression along the food chain from soil to plant to animal, and eventually to man. In nearly all of these studies, attention has been directed to the comparative behavior of strontium and calcium, the rationale being that strontium and calcium, because of their close chemical similarity, will behave similarly in biological processes. If one can determine the extent to which strontium and calcium differ in their behavior at each step in the food chain, the Sr^{90}/Ca ratio of the material at the end of the chain can be readily deduced from the Sr^{90}/Ca ratio at the beginning of the chain. Since the calcium concentration in human bone is physiologically controlled within rather narrow limits, the Sr^{90}/Ca ratio will be a measure of the actual Sr^{90} concentration, and thus a measure of the potential hazard.

Table 1. Effect of dietary calcium level on Sr^{90} and Ca^{45} concentrations in bone.

Ca content of diet (%)	Time on labeled diet (day)	Percentage daily intake per gram bone ash*			Milligrams of dietary calcium deposited and retained per gram of bone ash*
		Sr^{90}	Ca^{45}	Sr^{90}/Ca^{45}	
0.1	3	2.6 ± 0.6	13 ± 2	0.20 ± 0.02	1.2 ± 0.2
0.1	6	5.8 ± 0.9	30 ± 6	0.19 ± 0.02	2.3 ± 0.5
0.1	13	9.4 ± 1.6	64 ± 9	0.15 ± 0.02	5.8 ± 0.8
0.1	24	10.9 ± 2.3	88 ± 15	0.12 ± 0.01	9.3 ± 1.6
0.5	3	1.3 ± 0.3	4.1 ± 0.9	0.32 ± 0.10	1.9 ± 0.4
0.5	6	1.9 ± 0.3	7.3 ± 0.8	0.26 ± 0.02	3.1 ± 0.4
0.5	13	3.3 ± 0.9	14.3 ± 3.5	0.23 ± 0.01	6.3 ± 1.6
0.5	24	5.0 ± 0.6	21.8 ± 3.3	0.23 ± 0.02	10.3 ± 1.5
2.0	3	1.3 ± 0.5	2.4 ± 0.8	0.55 ± 0.09	4.4 ± 1.5
2.0	6	2.1 ± 0.2	4.7 ± 0.5	0.45 ± 0.03	7.5 ± 0.7
2.0	13	2.8 ± 0.3	6.3 ± 0.8	0.44 ± 0.01	11.8 ± 1.5
2.0	24	4.6 ± 1.8	11.4 ± 4.2	0.41 ± 0.02	23.2 ± 8.5

* All values: average of four animals ± one standard deviation.

This approach to the problem is exemplified by the work of Comar and associates, who have studied the comparative behavior of calcium and strontium in rats, cattle, and man, for all of the steps in the progression of these elements from plant material to human bone (*1*). By applying such data to the over-all Sr^{90} hazard problem, it has been estimated that the Sr^{90}/Ca ratio will be reduced from 6- to 12-fold in the passage from contaminated vegetation to human bone (*2*).

In applying this procedure to the evaluation of the Sr^{90} hazard, the question arises whether the discrimination between strontium and calcium at any step in the food chain may be properly considered as a constant, or whether this discrimination may actually vary considerably, depending upon environmental and physiological factors. The experiment described in this report was designed to study the effects of dietary calcium level and the duration of the feeding period on the ratio of Sr^{90}/Ca^{45} deposited in the bone of rats.

Three groups of 16 mature female rats were maintained for 30 days on diets containing 0.5 percent phosphorus, and 0.1, 0.5, or 2.0 percent calcium (*3*). After this 30-day conditioning period, Sr^{90}, Ca^{45}, and insoluble Cr_2O_3 labeled with Cr^{51} were added to the diets. Four animals from each group were sacrificed after 3, 6, 13, or 24 days on the labeled diet. One femur and a blood sample were assayed for Ca^{45} and Sr^{90}. Total calcium and phosphorus were determined in the second femur. Food consumption (Sr^{90} and Ca^{45} intake) was estimated from measurements of Cr^{51} in the total feces and contents of the gastrointestinal tract from the animals in each experimental group.

Food consumption was essentially the same on all three diets, and weight changes during the course of the experiment were negligible. Results of total calcium and phosphorus analyses indicated no significant effects of the dietary regimens on gross bone composition.

The Sr^{90} and Ca^{45} concentrations in the femur, expressed as percentages of daily intake per gram of bone ash, and the ratios of these percentage concentrations, are shown in Table 1. Within each dietary group there was an evident trend toward lower values for the Sr^{90}/Ca^{45} ratio as time on the labeled diet increased. In view of the small number of animals involved, the significance of this trend may be questioned, particularly in the higher calcium level groups. There can be no question, however, that the Sr^{90}/Ca^{45} ratios are a function of the dietary calcium level. While the content of both Sr^{90} and Ca^{45} in bone varies inversely with dietary calcium level, the effect is quantitatively different for the two isotopes and is not simply proportional in either case. Reducing calcium five fold, from 0.5 to 0.1 percent of the diet, increased the percentage retention of Ca^{45} by a factor of approximately four, at all time periods, but increased Sr^{90} retention by a factor of only two to three. Increasing calcium four fold from 0.5 to 2.0 percent of the diet decreased