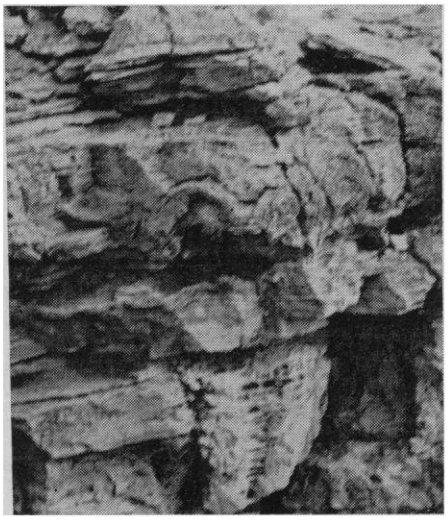

Fig. 2. Layered limestone transected by fossil gas channels. See vertical channel near the center of the photograph.

by x-ray diffraction and proved to be mostly quartz and goethite; x-ray fluorescence revealed chiefly Ca, Fe, and Mn, and traces of Sr and K. The iron occurs as oxide giving the tan color to the limestone. The manganese occurs as secondary pyrolusite dendrites.

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Note

1. We thank Professor Ralph W. G. Wyckoff, Physics Department, University of Arizona, for the use of laboratory facilities.

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Strontium Fixation by Lime Contained in Soils

Abstract. *The suitability of soils for the disposal of radioactive strontium waste products is determined in part by the amount and properties of calcium carbonate in the soil. Analyses of the strontium ion concentrations in the effluent solution of soil columns and x-ray diffraction patterns suggest that a fraction of the strontium ions is precipitated as strontium carbonate.*

The incorporation of radioactive waste products from nuclear plants into the soil is one of the proposed solutions for the disposal of these wastes. The suitability of soils for retaining radioactive waste containing strontium-90 is determined both by the composition and concentration of the waste and by soil properties such as cation exchange capacity and *p*H.

Many soils in arid and semiarid regions contain high concentrations of calcium carbonate which might increase the capacity of the soil for retaining strontium ions. We are now reporting on the adsorption process of strontium ions.

Two soils were used. The clay content of soil No. 1 was 1.5 percent and that of soil No. 2 was 47.0 percent, both determined by the Sudan method (*2*). The cation exchange capacities, measured in soil columns with a solution of CsCl containing Cs^{137}, were 1.00 and 13.7 meq per 100 g for soil Nos. 1 and 2, respectively. Soil No. 1 contained 26 percent carbonates and 0.9 percent "active" lime. The carbonates percentage of soil No. 2 was 24.2 and the active lime content in it was 13.8 pecent. The carbonates were determined gasometrically (*3*) and the active lime by Drouineau's method (*4*). The *p*H of a water-saturated soil paste (*5*) of soil No. 1 was 8.9 and that of soil No. 2 was 8.2. The gypsum content (*5*) was 0.025 and 0.030 percent in soil Nos. 1 and 2, respectively.

Soil columns were prepared by packing the soil samples in glass cylinders (10 cm by 2.5 cm in diameter) closed at the bottom by a plastic sponge. A solution of $0.01N$ $SrCl_2$ containing 10^{-2} μc per ml of Sr^{85} was supplied to the surface from a Mariotte bottle which maintained a constant head. Constant-volume fractions of the effluent were collected by means of a syphon and transferred to plastic containers for counting. The radioactivity was measured with a sodium iodide scintillation counter. Two flow rates of the solution through the soil columns were used for each soil, 2 to 4 cm per hour and 20 cm per hour. With soil No. 2, these high flow rates were achieved by mixing the soil with pure quartz sand. Each experiment was carried out in triplicate at a constant temperature of 22° ± 0.1°C.

Figure 1 shows the curves relating the strontium concentration in the effluent to the volume, for the two soils.

Both curves approach values of c/c_0 (concentration of effluent to that of influent at a given volume) less than unity, the values being 0.78 and 0.69 for soils Nos. 1 and 2, respectively. These values were independent of the flow rates. The concentrations (c/c_0) of the effluent could not be raised even by the passage of two to three times the volume required to attain the asymptotic value. The constant effluent value of less than unity was presumably caused by precipitation of the strontium ion.

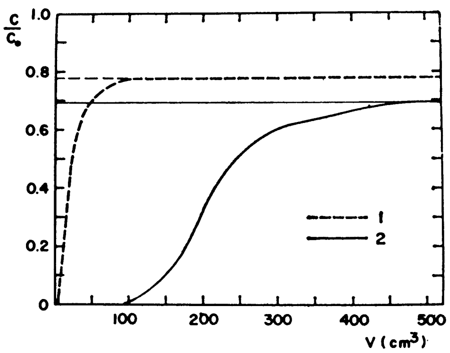

Fig. 1. The relation of the effluent concentration to the volume. (The quantity c/c_0 is the ratio of the concentration of the effluent at a given volume to that of the influent.)

Strontium may be precipitated in the soil as its sulfate, phosphate, or carbonate salt. In the soils investigated, the low concentration of soluble sulfates and of phosphates soluble in dilute acid, $0.01N$ HCl (a few parts per million), could not account for the relatively large amounts of strontium inactivated.

Thus, by elimination, it appeared that the reaction:

$$Sr^{++} + CaCO_3 \rightleftarrows SrCO_3 + Ca^{++}$$

took place in the fixation and resulted in final values of c/c_0 smaller than unity.

To check the foregoing assumption that strontium is precipitated as carbonate, portions of each of the two soil samples were washed with either NaCl or $SrCl_2$, and the x-ray diffraction pattern of their clay fraction was determined. Sodium carbonate was used as the dispersing agent. The surplus electrolyte was removed, and the water in the clay suspension was replaced by a solution of one part glycerol and two parts ethanol (*6*). A Philips x-ray diffractometer model PW 30 with a copper tube was used for the analysis.

The data showed a remarkable diminishing intensity of the $CaCO_3$ line and appearance of $SrCO_3$. It seems that the appearance of $SrCO_3$ was caused both by the aforementioned reaction and by the precipitation of exchangeable Sr with the carbonate associated with the dispersing agent. That the suggested reaction is taking place is shown by the disappearance of $CaCO_3$. Thus, part of the strontium is being fixed, in these soils, by reaction with $CaCO_3$. The differences between the curves for the two soils (Fig. 1) would suggest that fixation process depends on the properties of the individual soil—probably the quality of the calcium carbonate and its particle size.

The high concentration of calcium carbonate in soils of arid and semiarid regions could in some instances enlarge considerably the capacity of these soils for the strontium ion. The quantity of lime in these soils exceeds by far the amount of exchangeable ions in the double layer, and its importance in the fixation of strontium may be considerable.

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16 April 1964

Oysters: Composition of the Larval Shell

Abstract. *The shell of the free-swimming veliger larval stage of the common North American oyster* Crassostrea virginica (*Gmelin, 1791*) *is composed of aragonite. This composition contrasts with that of the adult shell, which is composed mainly of calcite, the rhombohedral allomorph of calcium carbonate, and minor amounts of aragonite.*

In view of the largely calcitic composition of the adult oyster shell, it is surprising to find that the prodissoconch, the shell of the free-swimming veliger larval stage, is composed of aragonite—for both the prodissoconch and the postlarval shell are secreted by the epithelium of the mantle of the same oyster, although not at the same time.

Adult oyster shells consist mainly of calcite, the rhombohedral allomorph of calcium carbonate, and minor amounts of aragonite, the orthorhombic allomorph of the same substance. Aragonite is restricted in the adult shell to five small, distinct areas: the resilium (*1*), which is the midportion of the ligament between the valves, the pads at which the ends of the large posterior adductor muscle are inserted, and the pads, one on each valve, at which Quenstedt's muscles are inserted (*2*).

Larvae of the common North American oyster *Crassostrea virginica* (Gmelin, 1791) were reared in breeding tanks at the Biological Laboratory of the U.S. Bureau of Commercial Fisheries, Milford, Connecticut. When any of them died, they were collected, washed with distilled water and dried at 35°C; no preservatives were used (*3*).

The dried larvae were picked carefully under a binocular microscope to avoid the inclusion in the sample of any accidental impurities or any larvae in the process of metamorphosis. Larvae in metamorphosis can be recognized by a narrow rim of white opaque postlarval shell encircling the hyaline prodissoconch. The sample thus selected included various larval stages, from the straight-hinge veliger larva with its shell, the protostracum, to the very latest stage of the umbo larva with its shell, the prodissoconch.

The shell of either larval stage is very thin, hyaline, and translucent. On the shell of a full-grown veliger larva, ready to settle on a substratum, the boundaries between the various stages are not sharply defined (Fig. 1); one has grown imperceptibly into the other, and there is no reason to suspect any differences in composition between them. The x-ray diffraction pattern (Fig. 2) shows that the sample is composed of aragonite; no calcite is indicated. The pattern proves that aragonite continues to be deposited through both stages.

In view of the largely calcitic composition of the adult shell, the question arises as to why the larval shell of the oyster is composed of aragonite. The specific gravity of aragonite is 2.95, and that of calcite is 2.72. As far as weight is concerned, no advantage would be gained by the planktonic or free-swimming animal if it built its shell of aragonite rather than calcite. The answer to the question is not to be found in a comparison with the adult oyster, but in a comparison with the larval shells of other Bivalvia. Although I have tested only larval shells of *Mercenaria mercenaria* (Linné, 1758) (Fig. 2), it is most likely that all, or nearly all, Bivalvia have aragonitic larval shells because the great majority of them have aragonitic adult shells (*5*). It may be assumed, therefore, that the larvae of the oysters merely conform to the general pattern in the Bivalvia. The larval oyster shells have aragonitic shells because their ancestors did, and there was and is no adaptive need for the free-swimming larvae to have shells of a composition other than aragonite.

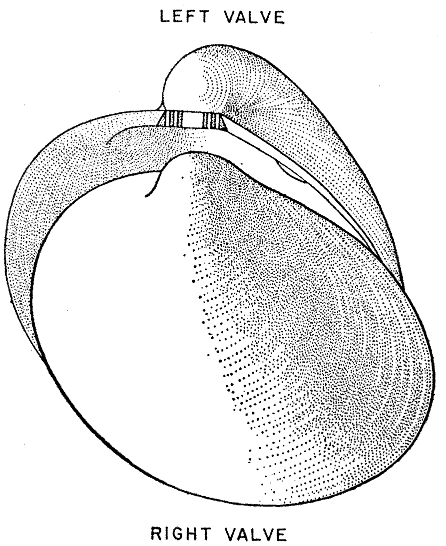

Fig. 1. Prodissoconch of veliger larva of *Crassostrea virginica*, modified from Ranson (*4*) (× 165).

The question should be put the other way around. Why do larval oysters suddenly begin depositing calcite after they have attached themselves to a substratum and begun metamorphosis? Adult oysters are permanently immobilized and live in an environment different from that of the larvae which requires different adaptations. Arago-

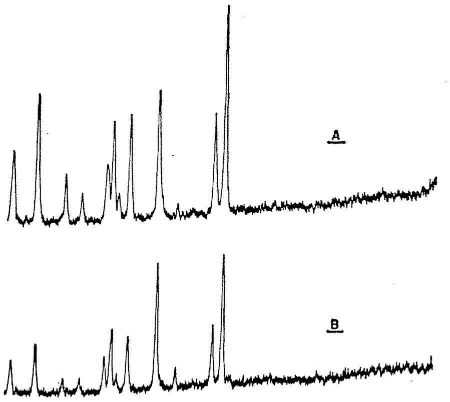

Fig. 2. X-ray diffraction pattern of veliger larvae of *Crassostrea virginica* (Gmelin, 1791) (*A*) and *Mercenaria mercenaria* (Linné, 1758) (*B*).