References and Notes

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2. This work was supported by the National Science Foundation, the National Institutes of Health, U.S. Public Health Service, and the Schweppe Foundation.
3. G. Nishida and R. F. Labbe, *Biochim. et Biophys. Acta* 31, 519 (1959); R. F. Labbe, *ibid.* 31, 589 (1959).
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2 February 1959

Stratospheric Fallout of Strontium-89 and Barium-140

Abstract. A series of nuclear test explosions which occurred in the fall of 1958 caused a very large increase of Sr^{89} and Ba^{140} in the stratosphere. The Ba^{140}/Sr^{89} ratio in the stratosphere, and hence in the troposphere, has decreased steadily since then with a half-life of approximately 17 days.

The last nuclear test explosion seems to have occurred sometime in early November 1958, and it appears as if there will be no more test explosions, at least for the time being. Since the fission products remain in the troposphere for only a month or two, the fallout since December or January must have originated almost exclusively from the stratosphere. In other words, we are now dealing with a "pure" stratospheric fallout, and the period of suspension of nuclear tests provides an excellent opportunity to study the mechanism of the stratospheric fallout.

Samples of rain and snow were collected on the roof of the chemistry building of the University of Arkansas, and the Sr^{89} and Ba^{140} contents were determined radiochemically by a method described earlier (*1*).

Three pancake-type counters (Anton 1007TA) surrounded by cosmic ray counters, and placed within an iron shield, were used for the radioactivity measurements. The backgrounds of the counters were 1.7, 2.0, and 1.8 count/min, respectively, in anticoincidence with the surrounding cosmic ray counters. The experimental results obtained are shown in Table 1 and Fig. 1.

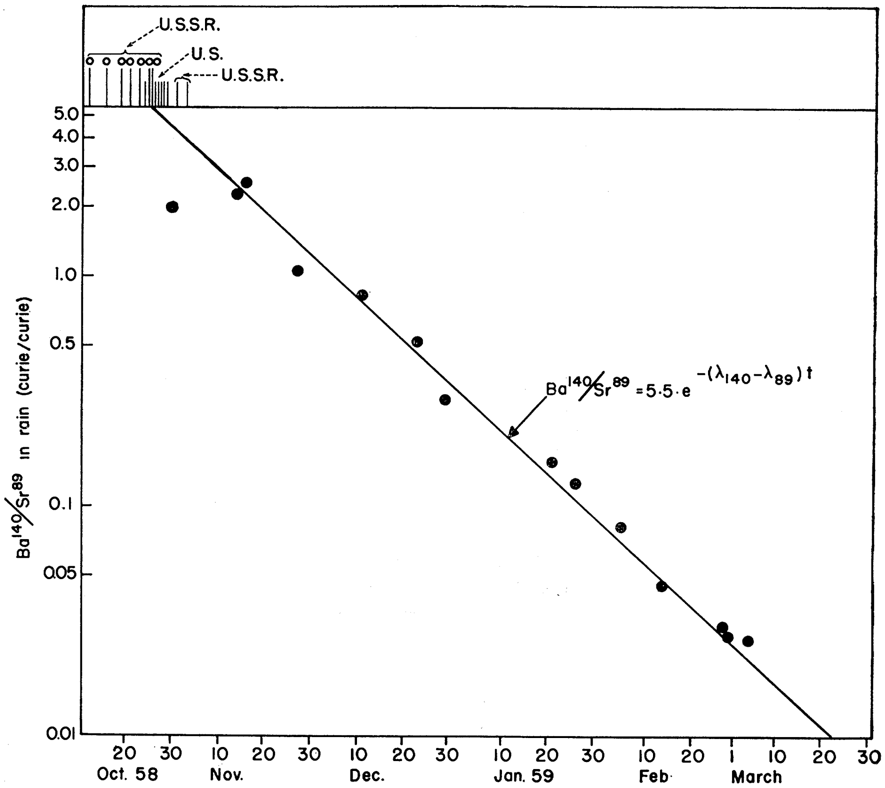


Fig. 1. Variation of the Ba^{140}/Sr^{89} ratio in rain and snow.

The Ba^{140}/Sr^{89} ratios in rain or snow can be expressed by the following empirical equation:

$$[Ba^{140}/Sr^{89}]_R = ke^{-(\lambda_{140}-\lambda_{89})t} \qquad (1)$$

where $[Ba^{140}/Sr^{89}]_R$ is the Ba^{140}/Sr^{89} ratio in rain or snow at the time t of the rainfall, λ_{140} and λ_{89} are the decay constants of Ba^{140} and Sr^{89}, respectively, and k is a constant.

It is interesting to note that the backward extrapolation of the straight line in Fig. 1 to 25 October 1958 gives a value for k of 5.5, which is essentially the same as the Ba^{140}/Sr^{89} ratio in a freshly produced fission product mixture from U^{235} fission. It is known that a series of hydrogen bomb explosions occurred in the arctic during the period between 12 and 25 October 1958.

Equation 1 is a special case of the following general equation which has recently been derived by Kuroda (*2*):

$$\left(\frac{B}{A}\right)_{T,t} = \frac{\frac{k_T-k_S}{k_S}\cdot\frac{A_{T,0}}{A_{S,0}}}{[e^{(k_T-k_S)t}-1]+\frac{k_T-k_S}{k_S}\cdot\frac{A_{T,0}}{A_{S,0}}} \times \left[\left(\frac{B}{A}\right)_{T,0}-\left(\frac{B}{A}\right)_{S,0}\right]\times e^{-(\lambda_B-\lambda_A)t} + \left(\frac{B}{A}\right)_{S,0}\times e^{-(\lambda_B-\lambda_A)t} \qquad (2)$$

where $(B/A)_{T,t}$ is the ratio of nuclides A and B in the troposphere at time t, $A_{T,0}$ and $A_{S,0}$ are the amounts of A in the troposphere and in the stratosphere at $t=0$, k_T and k_S are the reciprocals of the mean storage time of the fission products in the troposphere and in the stratosphere, respectively, $(B/A)_{T,0}$ is the B/A ratio in the troposphere at $t=0$, and $(B/A)_{S,0}$ is the B/A ratio in the stratosphere at $t=0$.

Suppose that $A_{T,0}$- and $A_{S,0}$- of the nuclide A were present in the tropo-

Table 1. Barium-140 and strontium-89 in rain and snow at Fayetteville, Ark.

Date	Rainfall (in.)	Ba^{140} (μμc/lit.)	Sr^{89} (μμc/lit.)	Ba^{140}/Sr^{89}
31 Oct. 1958	0.17	2710	1355	2.00
14 Nov. 1958	2.00	569	246	2.24
16 Nov. 1958	1.53	172	67.9	2.54
27 Nov. 1958	0.54 (snow)	325	312	1.04
11 Dec. 1958	0.10 (snow)	114	138	0.83
23 Dec. 1958	very slight	203	392	0.52
30 Dec. 1958	0.50	98.2	352	0.29
21 Jan. 1959	0.50 (snow)	50.3	320	0.157
26 Jan. 1959	0.15	161	1270	0.127
5 Feb. 1959	0.30 (snow)	26.7	325	0.082
14 Feb. 1959	0.65	12.5	277	0.045
27 Feb. 1959	0.50	20.7	691	0.030
28 Feb. 1959	0.30	7.6	284	0.027
4 Mar. 1959	2.00	6.4	250	0.026

sphere and in the stratosphere, respectively, prior to a nuclear explosion ($t=0$-), and $A^*_{T,0}$ and $A^*_{S,0}$ were added to the troposphere and to the stratosphere, respectively, by a nuclear explosion which took place at $t=0$, and that the total quantities of A in the troposphere and in the stratosphere have increased from $A_{T,0-}$ to $A_{T,0}$ and from $A_{S,0-}$ to $A_{S,0}$. Then we have the following relationships:

$$A_{T,0-} + A^*_{T,0} = A_{T,0} \qquad (3)$$

$$A_{S,0-} + A^*_{S,0} = A_{S,0} \qquad (4)$$

$$\left(\frac{B}{A}\right)_{T,0} = \frac{A_{T,0-} \times (B/A)_{T,0-} + A^*_{T,0} \times (y_B/y_A)}{A_{T,0-} + A^*_{T,0}} \qquad (5)$$

and

$$\left(\frac{B}{A}\right)_{S,0} = \frac{A_{S,0-} \times (B/A)_{S,0-} + A^*_{S,0} \times (y_B/y_A)}{A_{S,0-} + A^*_{S,0}} \qquad (6)$$

where y_B/y_A is the ratio of the fission products B and A freshly produced by the nuclear explosion. If $A^*_{T,0} \gg A_{T,0-}$ and $A^*_{S,0} \gg A_{S,0-}$, Eqs. 5 and 6 give $(B/A)_{T,0} \cong y_B/y_A$ and $(B/A)_{S,0} \cong y_B/y_A$. By introducing these values into Eq. 2, one obtains

$$(B/A)_{T,t} = (y_B/y_A) \times e^{-(\lambda_B - \lambda_A)t} \qquad (7)$$

which corresponds to the empirical relationship shown in Eq. 1.

This indicates that a very large increase of Sr^{89} (and hence Ba^{140}) in the stratosphere must have resulted from the October 1958 hydrogen-bomb test series.

It is worthy of note that the Sr^{89} concentrations in rain and snow have remained fairly constant during the past few months, despite the fact that this nuclide decays with a half-life of 54 days. A marked increase in the rate of transfer of the fission products from the stratosphere to the troposphere in early spring months, which has recently been observed by Stewart *et al.* (*3*) and also by Kuroda (*2*), seems to compensate for the expected activity decrease due to Sr^{89} decay (*4, 5*).

Lois Fry
P. K. Kuroda
Department of Chemistry, University of Arkansas, Fayetteville

References and Notes

1. P. K. Kuroda, *ANL-5829* (Feb. 1957), p. 167.
2. P. K. Kuroda, *ANL-5920* (Oct 1958), pp. 1–40.
3. N. G. Stewart, R. G. D. Osmond, R. N. Crooks, E. M. Fisher, *AERE HP/R 2354* (Atomic Energy Research Establishment, Harwell, Berkshire, 1957).
4. More detailed accounts of this work are in preparation.
5. This investigation was made possible by support from the U.S. Atomic Energy Commission. We are grateful to J. M. Bailey for collecting the rain samples.

6 April 1959

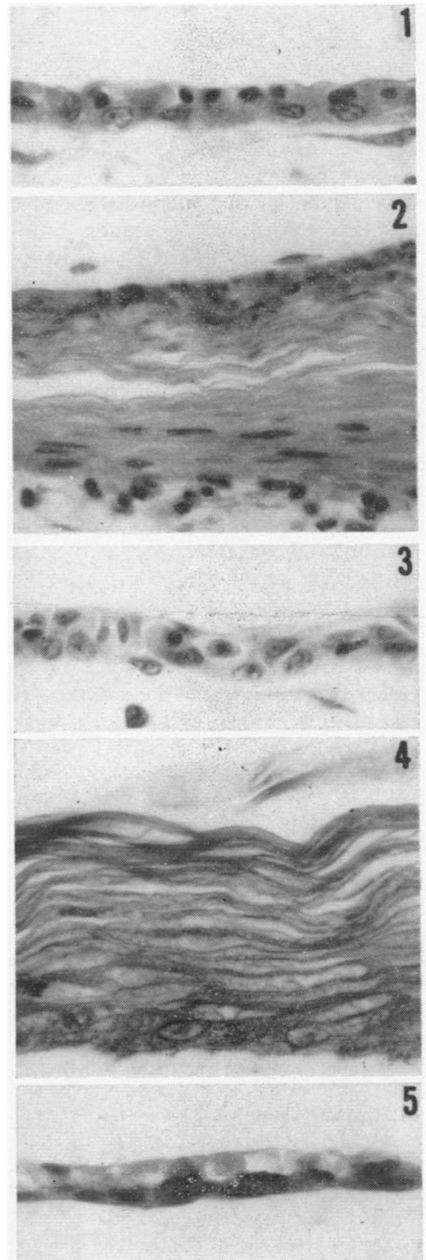
Etiology of Keratogenic Metaplasia in the Chorioallantoic Membrane

Abstract. The effects of elevated O_2 and CO_2 concentrations on the occurrence of experimental keratogenic metaplasia in the chorion of the chick embryo were examined. Exposure to oxygen resulted in advanced keratinization of the chorion; carbon dioxide at elevated concentrations, in mixtures with air or oxygen, repressed the appearance of metaplastic changes, and the chorion retained its respiratory characteristics. The evidence reported here suggests that reduction of the CO_2 content in the gaseous environment of the chorion is causally contributory to the onset of the metaplastic events.

As reported previously (*1*), explants of the chorioallantoic membrane from 8-day chick embryos grown for 8 to 10 days in vitro as organ cultures underwent striking metaplastic changes resulting in transformation of the one-cell-thick chorion into a stratified and keratinized epithelium. It was recently found (*2*) that a similar metaplasia could be consistently produced also *in ovo* by fenestrating embryonated eggs on the 8th day of development and incubating them with the shell-window open. In such eggs there was rapid vertical proliferation of chorionic cells in the exposed area and an alteration in their protein-synthesizing activities resulting in the transformation of the attenuated chorion into a multilayered, highly cornified structure (Figs. 1, 2). The onset of metaplastic changes depended, thus, on the following major conditions: (i) detachment of the chorion from the shell membrane; (ii) exposure of the detached chorion to atmospheric air—that is, to lower carbon dioxide and higher oxygen concentrations than those in the normal environment of this respiratory epithelium. The second of these conditions is discussed in this report.

To account for the effect of exposure to outside air two possibilities were considered: (i) release from inhibition by CO_2, due to a decrease in its relative concentration in the chorionic environment (in this case, similarly fenestrated eggs, when exposed to elevated levels of CO_2, should not show metaplastic changes); (ii) activation by O_2 at the relatively elevated level at which it occurs in outside air (if this is the cause, exposure of chorion to pure O_2 should result in metaplasia, and the advent of metaplasia should not be repressible by admixture of CO_2).

The possibility that CO_2 has an inhibitory effect was tested by incubating eggs, fenestrated on the 8th day of development (a ½-square-inch window was left open), for 10 days in saturation-humidity chambers constantly gassed with a mixture of air and 5- or 8-percent CO_2 (*3*). Similarly prepared eggs, gassed with air, served as controls. Neither the general development nor the viability of the embryos was noticeably affected. Histological examination of the chorionic epithelium failed to reveal metaplastic changes in any of the 28 eggs



Figs. 1–5. Sections through the chorion of the chorioallantoic membrane of 18-day chick embryos fenestrated on the 8th day of development and incubated in saturation-humidity chambers. In Fig. 1 the shell-window was sealed immediately following fenestration and the embryo was incubated in air. In the other figures the shell-window was left open and the egg was incubated (Fig. 2) in air; (Fig. 3) in air plus 8-percent CO_2; (Fig. 4) in O_2; (Fig. 5) in O_2 plus 8-percent CO_2. The sections were stained with hematoxylin and Biebrich scarlet (× 700).