maltose, etc.) to foods which are to be heat processed. Likewise, one may question the advisability of adding glyceraldehyde to ordinary sugar for the purpose of preventing dental caries, as has been proposed (*9*).

References

1. HILL, E. G., and PATTON, A. R. *Science*, 1947, **105**, 481.
2. LANKFORD, C. E. Private communication.
3. PATTON, A. R., and HILL, E. G. *Science*, 1948, **107**, 68.
4. RIESEN, W. H., CLANDININ, D. R., ELVEHJEM, C. A., and CRAVENS, W. W. *J. biol. Chem.*, 1947, **167**, 143.
5. RIMINGTON, C. *Annu. Rev. Biochem.*, 1936, **5**, 138.
6. STEVENS, J. M., and MCGINNIS, J. *J. biol. Chem.*, 1947, **171**, 431.
7. STOKES, J. L., GUNNESS, M., DWYER, I. M., and CASWELL, M. C. *J. biol. Chem.*, 1945, **160**, 35.
8. ————. *Nutrition Rev.*, 1947, **5**, 83.
9. ————. *Food Field Rep.*, 1948, **16**, 61.

Newly Discovered Outcrops of the Cannonball Formation in North Dakota[1]

ROLAND W. BROWN and RICHARD W. LEMKE

U. S. Geological Survey, Washington, D. C.

About 60,000,000 years ago, near the beginning of the Tertiary period, western North Dakota was inundated by the readvance of a sea or an arm of the sea that had been in existence in the same general region and to the eastward since late Cretaceous time. The 300′ of brown, sandy, fossiliferous sediments that were deposited in this sea in the vicinity of Bismarck and southwestward were first recognized as a marine unit by E. Russell Lloyd in 1912 and named the Cannonball marine member of the Lance formation in 1914 from typical exposures along the Cannonball River, southwest of Mandan. However, the discovery in 1907 by A. G. Leonard, former state geologist of North Dakota, of an oyster bed, interbedded with the lignitic strata of the Fort Union formation exposed in the bluffs of the Little Missouri River just south of Yule, North Dakota, had indicated the existence of an early Tertiary sea toward the east. This oyster bed is now regarded as evidence of a brackish-water estuary leading into the Cannonball sea.

A map showing the distribution of the Cannonball deposits and a description of the fauna contained therein were published in 1921 by T. W. Stanton (*2*), who, although recognizing a few species with Tertiary aspect, assigned the fauna to the late Cretaceous because of the large percentage of forms theretofore identified as Cretaceous. This age assignment served to continue the already warm debate concerning the Cretaceous-Tertiary boundary in the Rocky Mountains and Plains region. In 1940, S. K. Fox, Jr., and R. J. Ross, Jr. (*1*), reported that an analysis of 64 species of foraminifers from the Cannonball showed clear relationships to those of the Midway strata of the Gulf Coast and indicated Paleocene age. On this evidence the U. S. Geological Survey in 1944 formally adopted the name Cannonball formation, with assignment to the Paleocene series.

Interest in the Cannonball formation continues because its outcrops provide readily identifiable stratigraphic markers and because clues are sought to determine whether the Cannonball sea had Arctic or Gulf of Mexico connections. As no marine fauna of Cannonball time has ever been found in the Canadian region toward the Arctic Ocean, the Midway aspect of the Cannonball fauna, for lack of competitive comparison, must be regarded as one-sided evidence that the connections of the Cannonball sea were with the Gulf of Mexico.

Eastward and northeastward from the Missouri River at Bismarck the bedrock strata of the Plains are for the most part concealed beneath a mantle of glacial drift, so that only in few places can satisfactory outcrops be seen, but not many miles east of Bismarck late Cretaceous strata appear at the surface, showing that the Cannonball deposits, if they were ever present there, were eroded before Wisconsin glaciation. The probability, however, that some of the Cannonball deposits are preserved beneath the glacial cover is confirmed by the fact that in July 1947 the writers came upon such outcrops on the south side of the Souris River, in road cuts on U. S. Highway 52 about 1½ miles east of Sawyer (SW¼ sec. 12, T. 153 N., R. 81 W.) and about 2½ miles east of Velva (SW¼ sec. 18, T. 153 N., R. 79 W.), North Dakota, respectively. These localities are approximately 55 miles north of the nearest hitherto reported outcrops of the Cannonball on the Missouri River, near Washburn. The exposures, at altitudes of 1,540′ and 1,520′, respectively, may be near the top of the Cannonball, because they are overlaid to the northwest at a slightly higher level by lignitic strata whose stratigraphic position and fossil content suggest equivalence to the Tongue River member of the Fort Union formation of regions to the westward.

The thinly bedded brown sands and sandy shales of the outcrops yielded the foraminifers (identified by J. A. Cushman) *Dentalina gardnerae* (Plummer), *Nodosaria affinis* (Reuss), *Robulus wilcoxensis* Cushman and Ponton var. *dissentia* Cushman and Todd, *Robulus* cf. *inornatus* (D'Orbigny); the mollusks (identified by J. B. Reeside, Jr.) *Drepanochilus americanus* (Evans and Shumard) var. *pusillus* Stanton, *Polynices* sp., *Dentalium* sp., *Nucula* sp., *Nuculana* sp., *Trigonarca*? sp., *"Corbula" mactriformis* Meek and Hayden, *Neptunella gracilis* (Stanton), *Neptunella newberryi* (Meek and Hayden), *Fasciolaria (Mesorhytis) dakotensis* Stanton; the worm *Serpula* sp.; the ostracodes (identified by F. M. Swain) *Cytheridea* cf. *fornicata* Alexander, *C.* cf. *ruginosa* Alexander, *C.* cf. *multipunctata* Alexander, *Cythereis* cf. *prestwichiana* Jones, *Brachythere* cf. *interrasilis* Alexander; and shark teeth (identified by D. H. Dunkle) *Odontaspis* sp.

From these outposts of the Cannonball formation one may perhaps look hopefully toward the glaciated country north and northeastward with the expectation that still other outcrops or subsurface evidence may be found that will provide further information about Cannonball paleogeography and the line of retreat of the Cannonball sea in the latter half of the Paleocene. Since that date

[1] Published by permission of the Director, U. S. Geological Survey, Washington, D. C.

the interior of North America has not been invaded by marine waters.

References

1. Fox, S. K., Jr., and Ross, R. J., Jr. *Geol. Soc. Amer. Bull.*, 1940, 51, No. 12, Pt. 2, 1970; *J. Paleontology*, 1942, 16, 660–673.
2. Stanton, T. W. The fauna of the Cannonball marine member of the Lance formation. *U. S. Geological Survey Prof. Paper 128*, 1921.

The Effects of X-Rays on the Mitotic Activity of Mouse Epidermis

Norman P. Knowlton, Jr., Louis H. Hempelmann, and Joseph G. Hoffman[1]

Radiobiology Section of the University of California, Los Alamos Scientific Laboratory,[2] Los Alamos, New Mexico

With the increased interest in various types of ionizing radiation as a result of the Atomic Energy Program, there is a great need for a practical method for the quantitative evaluation of the effects of sublethal doses of such radiation. Many investigators have shown that small doses of radiation result in a temporary but marked depression of the mitotic activity of lower animal, plant, embryonal, and tumor cells. This suggests that similar studies of mitosis in mammalian tissues might lead to a relatively simple and reasonably specific method of expressing radiation damage. The usual technique of determining the mitotic index of a tissue involves the actual counting of many thousands of individual cells. Since this is extremely laborious, considerable effort has been devoted to developing simpler, more expeditious methods. This preliminary report describes a simplified technique of obtaining the mitotic index of mouse skin and indicates the surprising sensitivity of the mitotic activity of mouse epithelium to the effects of X-rays.

Groups of animals (CF_1 strain white mice, 6–8 weeks of age) were exposed to specific doses of 250-KV peak voltage X-rays at the rate of 50 r/min and then autopsied at definite time intervals after exposure. Immediately after the animal had been killed by crushing the cervical spine, the ears were removed and placed in 1% acetic acid. After 16 hrs at 5° C, a homogeneous layer of epidermis two cells thick was separated from the dermis according to the technique mentioned by Hoepke (*3*) and described in detail by Cowdry (*2*). The section of epidermis was then stained with Mayer's hematoxylin and mounted on slides for study. The cells in mitosis (arbitrarily defined as the period between the breakdown of the nuclear membrane in prophase and the complete separation of the cytoplasm in telophase) in a given number of microscopic fields outlined by a Whipple disc were then counted. The number of epidermal cells in the field delimited by each Whipple disc was carefully determined for animals of the strain and age used in this study so that the final value of the mitotic index can be expressed in terms of mitoses/100,000 cells. Variation in cell numbers from field to field is statistical in nature and introduces an error of 1–2% not encountered when individual cells are counted. The much larger number of cells which can be examined practically by the field method compensates for this error by reducing the over-all statistical error. It has been shown that X-ray dosage up to 325 r does not significantly alter the number of cells per field, so this method is valid for mouse skin after radiation exposure.

The change in mitotic index of mouse epithelium produced over a range of sublethal doses of X-rays from 5 to 325 r has been studied. The graphic response of the mitotic index in animals receiving 35 and 325 r is shown in Fig. 1. Each point on the experimental curve represents the average mitotic index obtained by examining a total of approximately 200,000 epithelial cells in 4–5 experimental animals. The diurnal variation in mitotic activity has been taken into account in the exposure groups, since there is twice as much mitotic activity during the morning as there is in the evening. This has been previously reported (*1*) and confirmed in our laboratory by means of the control animals for the above experiments.

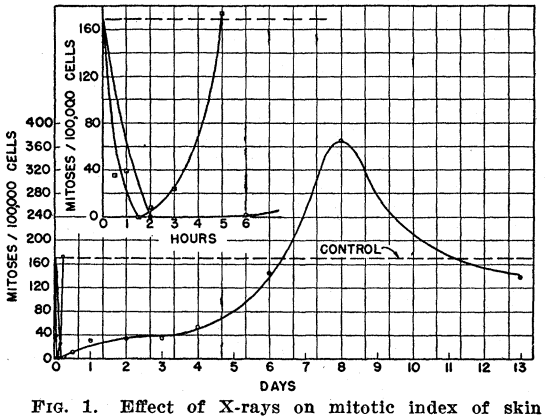

Fig. 1. Effect of X-rays on mitotic index of skin of the mouse: Broken line—Average control counts (average of 44 mice, 169/100,000 cells); Squares—35-r X-ray (5 mice/point); Circles—325-r X-ray (4 mice/point).

In both of the experimental groups the minimum point of mitotic activity is less than 1 mitosis/100,000 cells. This minimum was reached in less than 2 hrs after exposure. On the other hand, the time required for the mitotic index to return to normal varies from 5 hrs at 35 r to 6 days at 325 r. An "overcompensation" phenomenon is quite evident at the 325-r dosage level, with the mitotic activity more than double that of normal on the 8th day

[1] With the technical assistance of Norma Lanter, Clare Morrison, Joan Thrap, and Julie Wellnitz. The writers gratefully acknowledge the personal help given them by Dean Robert A. Moore, Washington University, St. Louis, and Zola K. Cooper, University of Oklahoma School of Medicine, in organizing this experimental program.

[2] This document is based on work performed at Los Alamos Scientific Laboratory of the University of California under Government Contract W-7405-eng-36, and the information contained therein will appear in Division V of the National Nuclear Energy Series (Manhattan Project Technical Section) as part of the contribution of the Los Alamos Laboratory.