ington. I have observed moraines of three different ages at Carbon Glacier, Mount Rainier, and moraines of two separate periods of comparable intensity at the Nisqually Glacier.

The tentative interpretation of this evidence suggests that at least two periods of glaciation occurred in this country before the most recent advance and that the age of these glaciations is more than 500 years and probably no older than the Cochrane advance in Canada.

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References and Notes

1. T. N. V. Karlstrom, *Bull. Geol. Soc. Amer.* 66, 1581 (1955).
2. J. T. Hack, *Am. Antiquity* 8, 235 (1943); J. H. Moss, *Am. J. Sci.* 249, 864 (1951); G. M. Richmond, *Science* 119, 614 (1954).
3. A. E. Harrison, *Sierra Club Bull.* 35, 113 (1950).
4. F. E. Matthes, *ibid.* 33, 87 (1948).
5. The aerial photographs were taken for the U.S. Geological Survey in 1947, 1948, and 1951. They were made available by a grant-in-aid of research by Sigma Xi, and the assistance of this grant is gratefully acknowledged.
6. D. R. Crandell and H. H. Waldron, *Am. J. Sci.*, in press.

4 June 1956

Penetration of Slow Electrons through Spore Walls of Bacillus megaterium

Electrons in the energy range of from a few hundred to a few thousand electron volts serve as a probe for studying surface features of biological organisms (*1*). The work described in this report was undertaken to study the coats of spores of *Bacillus megaterium* by slow-electron bombardment (*2*). The apparatus used was that described by Davis (*3*), who studied spores of *Bacillus subtilis.*

Electrons from a hot tungsten filament, which are accelerated by voltage from a variable power supply, strike the dry spores on a stainless-steel disk in an evacuated bombardment chamber. Subsequently, the disk with 12 bombarded samples and four controls is layered with nutrient agar and incubated for 6 hours or more. Colonies formed by the surviving spores are counted under a low-power microscope, and the number of colonies in a bombarded sample compared with the number of those in controls on the same disk is taken as the survival ratio. The rate of electron flow from disk to ground, which is indicated by a galvanometer, is held constant, so that the dose, in electrons per unit area, can be calculated from the time of exposure and the area bombarded.

Table 1. Dose in electrons per square micron for 37-percent survival of *B. megaterium* spores as a function of voltage.

Volts	Dose (10^3 electrons)
800	270,000
1000	30,000
1200	8,000
1400	1,600
1600	800
1800	500
2000	300
2200	150
2600	30
2800	30
3000	14
3200	8
3400	7

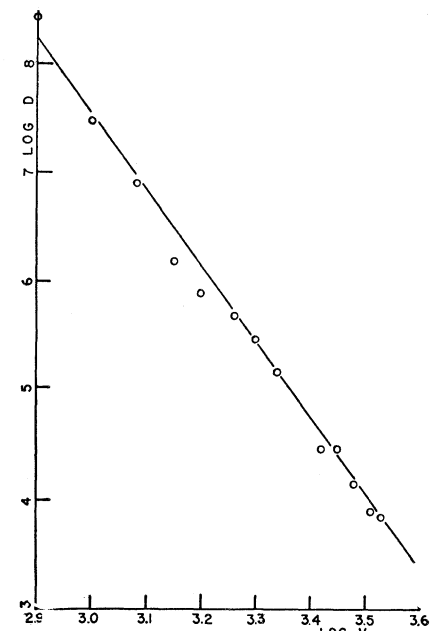

Fig. 1. Log dose in electrons per square micron for 37-percent survival versus log voltage. The line is represented by the equation $DV^{7.26} = 10^{29.38}$.

The percentage of survival was plotted on a logarithmic scale as a function of dose, with voltage as a parameter. The points generally lay on straight lines typical of single-hit killing except that, at the lower voltages and below about 10-percent survival, points were obtained on a second straight line with a smaller slope than the first. The presence of bacterial debris on a small fraction of the spores might be inferred from their survival in spite of a large dose.

Bombardments were made at 200-v intervals from 400 to 3400 v. From the plotted survival curves, the 37-percent survival dose D, in electrons per square micron, was found for each voltage V. Typical data are presented in Table 1.

Inspection shows that, on a plot of log D versus log V (Fig. 1), the experimental points lie rather close to a straight line represented by the equation, $DV^{7.26} = 10^{29.38}$. The interpretation offered is that this function represents the probability of electron penetration through the spore wall with enough residual energy to produce a fatal ionization. At the highest voltage used, about 7000 electrons strike a square micron, which is the order of magnitude of a cross-sectional area of a spore. The portions of the spore that are sensitive to killing by ionization, assumed to be distributed at random inside the spore wall, appear to occupy an area of about 1.4×10^{-4} μ^2 each.

The absorption of 600- to 2000-v electrons has been studied by Davis (*4*) in invertase for comparison with theoretical values for tissue which were calculated by Lea (*5*). In neither case was the probability of penetration expressed as a function of electron energy, but their results indicate that the spore wall in the experiments reported here probably has a thickness of about 0.15 to 0.2 μ. The lower value is in better agreement with electron-microscope pictures of spore sections obtained by Robinow (*6*), which themselves must be interpreted in the light of possible dimensional distortion by the treatment required to prepare the specimens for the electron microscope.

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References and Notes

1. See discussion by F. Hutchinson, *Ann. N.Y. Acad. Sci.* 59, 494 (1955).
2. This work was done at Yale University while I was on sabbatical leave from the University of Connecticut, Storrs. I wish to express thanks for the many courtesies extended.
3. M. Davis, *Arch. Biochem. and Biophys.* 48, 469 (1954).
4. ———, *Phys. Rev.* 94, 243 (1954).
5. D. E. Lea, *Actions of Radiations on Living Cells* (Cambridge Univ. Press, Cambridge, England, 1947), p. 23.
6. C. F. Robinow, *J. Bacteriol.* 66, 300 (1953).

15 May 1956

There was nothing wrong with the old inference that if I know all about the present I can forecast the future exactly; the trouble was the impossibility of knowing the present. Once this is seen, the whole argument becomes obvious, but nobody saw it until Heisenberg.—C. G. Darwin (*1938*).