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The Cosmic-Ray Intensity at High Elevations in Northern Latitudes

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Balloon flights with vertical coincidence counters for cosmic-ray measurements have been made at geomagnetic latitudes 56°N and 69°N. Within the accuracy of the measurements there is no further increase of intensity above 56°N at atmospheric depths greater than 2 meters of water.

THE airplane flights with an unshielded electroscope made by Bowen, Millikan and Neher[1] up to an elevation corresponding to an atmospheric depth of 4.5 meters of water showed about a twenty percent increase in cosmic-ray intensity between the magnetic latitudes 41°N and 54°N but from there on up to 63°N there was no further increase. Their failure to find a dependence upon latitude at these highest latitudes could have been interpreted either as an inability of rays of energy less than the 2.2 billion volt limit corresponding to 54° latitude to penetrate to the depth of 4.5 meters, or as an absence of such low energy rays in the primary cosmic-ray spectrum. If the knee at 40°N in the curve representing intensity at sea level *vs.* latitude were due to the stopping of the corresponding 6-billion volt rays in ten meters, and if range were proportional to energy, one would have expected the stopping power of the atmosphere at 4.5 meters depth to produce a knee at 50°N, and therefore no variation of intensity above 54°N could have been expected on either hypothesis. The same conclusion is reached by considering the effect of the soft component at this depth in the theory of Bhabha and Heitler.[2]

In view of the interesting suggestion of Vallarta[3] and Janossy[4] that the magnetic field of the sun might be sufficient to exclude these low energy radiations from the region within the earth's orbit, with the consequence that the cosmic-ray spectrum would possess a low energy limit other than that imposed by the earth's magnetic field, a series of balloon flights were planned and carried out in August and September 1937 in central Minnesota, 56°N, and in Churchill, Manitoba, 69°N. Vertical coincidence counters were used for the cosmic-ray measurements in order to realize shorter path lengths through the atmosphere, and the ultra-high frequency radio technique was employed for transmission of the data.[5] Each coincidence was transmitted as a dot and at regular intervals a series of dashes counted off the number of immersed taps on a mercurial barometer so that the exact times when the balloon passed through definite pressure intervals were recorded. The counters were 6 cm long by 1.2 cm in diameter and were placed horizontally

[1] I. S. Bowen, R. A. Millikan and H. V. Neher, Phys. Rev. **46**, 641 (1934).
[2] H. J. Bhabha and W. Heitler, Proc. Roy. Soc. **A159**, 432 (1937). A convenient table for calculation is given by L. W. Nordheim Phys. Rev. **53**, 694 (1938). The probability of a ray of energy greater than 10^8 ev appearing at a depth of 4.5 meters when one ray of 2.2×10^9 ev enters the atmosphere is about 0.05.
[3] M. S. Vallarta, Nature **139**, 839 (1937).
[4] L. Janossy, Zeits. f. Physik **104**, 430 (1937).
[5] For a fuller description of the experimental technique see T. H. Johnson, J. Frank. Inst. **223**, 218 (1937).

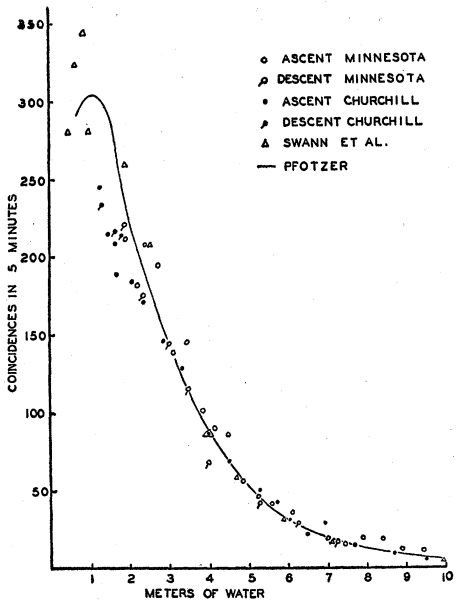

FIG. 1. Cosmic-ray intensities measured with vertical coincidence counters. Results in Churchill mag. lat. 69°N are compared with similar data at lower latitudes.

one above the other with a 2.5 cm separation between axes. In this configuration the coincidence rate at sea level was about 2 per minute. The counters were filled with 25 cm of a one to one mixture of neon and hydrogen and operated at about 1100 volts. The discharges were quenched with 300 megohm resistors and the plateau of uniform counting rate extended over such a wide range of overvoltage that it was possible to use a capacity multiplication of the B voltage for the operation of the counters without trouble from counter voltage variations. A multivibrator type of feedback circuit[6] was used for prolongation of the pulses from the coincidence selecting stage and this could be tripped off with such a small input of power that exceedingly short resolving times were realized; with the radiation intensity equal to that encountered in the stratosphere there was no appreciable alteration of the coincidence rate either from accidentals or from the inefficiency resulting from the high counting rate.

The shaded points in Fig. 1 indicate the numbers of coincidences recorded in five minute intervals on a flight made in Churchill, plotted against the mean pressure during the interval. The open points are the corresponding data for a flight in Minnesota with exactly similar apparatus. The curve represents the corrected data of G. Pfotzer[7] obtained at the latitude 52°N and the triangles represent the data of Swann, Locher and Danforth.[8] Both these and Pfotzer's data were obtained with triple coincidence counters in the vertical direction. They have been adjusted by suitable factors to bring about agreement in the central part of the curve.

The results indicate no increase of intensity with latitude north of Minnesota (56°N) up to an atmospheric depth of two meters of water. If the sea-level knee were attributable to absorption of rays of energy less than 6 billion volts then with proportionality between range and energy a knee at two meters depth could be expected at 60°N where, according to Lemaitre and Vallarta, 1.2-billion volt rays are excluded by the earth's field. Thus it would have been reasonable to expect an increase of intensity at Churchill over that found at Minnesota equal to the contribution of rays in the energy range between 1.2 and 1.5 billion volts. The fact that no such increase was found favors the interpretation that there is very little intensity in the primary spectrum within this range of energies,[9] but in view of the experimental inaccuracies which may be judged by the dispersion of the points about a smooth curve and especially of the uncertainties in present knowledge of the stopping power of air for these low energy rays, it is impossible to insist too strongly upon this interpretation. It is possible that coincidence counter flights to still higher elevations would be able to give a more conclusive answer to this question.

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[6] T. H. Johnson, Rev. Sci. Inst. **9**, 218 (1938).

[7] G. Pfotzer, Zeits. f. Physik **102**, 23 (1936).

[8] W. F. G. Swann, J. Frank. Inst. **224**, 415 (1937).

[9] This conclusion is in agreement with the results presented at the Washington Meeting of the American Physical Society by Bowen, Millikan and Neher.