This work was undertaken on the supposition that fine-grained, undisturbed sedimentary rocks which had been laid down in tranquil water millions of years ago might still retain a magnetic polarization acquired as a result of the orientation of magnetic particles in the direction of the earth's field existing at the time of deposition.

Measurements were made at eight sites in Colorado, Utah, Washington, Idaho, Wyoming, and South Dakota. These sites, together with a number of others, were suggested as suitable for the work by members of the United States Geological Survey. The rocks range in age from Jurassic (100 million years) to Miocene (10 million years). Altogether sixteen sites were examined for suitability, the requirements being that the rock have a workable exposure, be fine-grained, be flat-lying, appear undeformed, lack any history of thermal disturbance, have sufficient cohesion to permit preparation of 3 cm cubic samples, and be sufficiently magnetic to be measurable (minimum measurable moment 10^{-7} c.g.s. units per cc).

The expedition had a staff of three, and utilized two six-by-six 2½ ton trucks as mobile equipment. One of these was fitted as living quarters and the other was fully equipped to make complete determinations of magnetic polarization in the field.

At the eight sites a total of 94 samplings was made, the smallest number at a given site being two and the largest twenty-one.

The directions of magnetization for all 94 samples are used in plotting the frequency distribution curves in Fig. 1. At the eight sites the present magnetic declination ranges from 13° to 22° east of geographic north, and the inclination from 66° to 72°. It is seen from Fig. 1 that there is a marked tendency for the horizontal component of rock magnetism to center on geographic north rather than on the present geomagnetic north. This result is to be expected if, through geologic time, magnetic north has oscillated 30 to 40 degrees to either side of a mean which is geographic north, a cyclic pattern found from magnetic measurements made in 1947[1] on 5000 years of glacial clay deposits in New England (15,000 to 20,000 years old[2]) and on ocean bottom samples (1,000,000 years). The magnetic stability of glacial clays has been established by studies of folded strata.

The inclination values in the rocks are seen in Fig. 1 to be slightly less than the present inclination of the earth's field.

All the sites did not give equally concordant results. At Glenns Ferry, Idaho, for example, thirteen samples averaging 2° east of geographic north in declination gave a very small scatter of polarizations, whereas the 21 samples from the Badlands at South Dakota gave a very great scatter. Stream bedding may be one of the factors responsible for the scattered polarizations at the latter site.

At one site, studies of the polarizations of sedimentary pebbles in a conglomerate give evidence that fine-grained, water-deposited material can retain a direction of magnetization for millions of years. Polarizations of the same material in the undisturbed condition at this site are included in the data of Fig. 1.

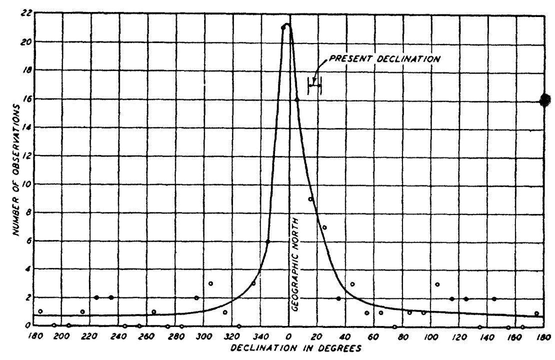

FIG. 1A. Frequency distribution of declination measurements on rock samples.

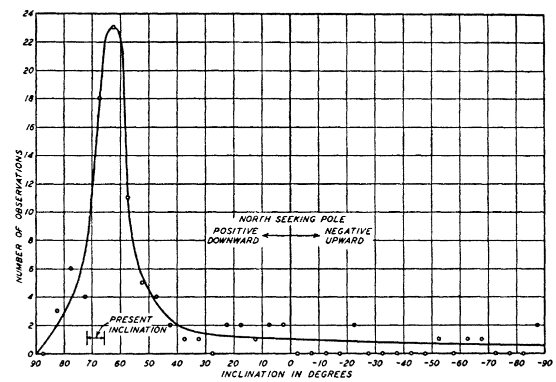

FIG. 1B. Frequency distribution of inclination measurements on rock samples.

These observations, with two-thirds of the declination values in a narrow band centered on geographic north and inclination values differing little from present inclination are consistent with the idea that, for the past 100 million years, the earth's magnetic field has been approximately centered on the earth's geographic axis. They do not support the contention, recently reiterated on the basis of measurements of the polarizations of 50-million year old igneous dikes in England,[3] that the earth's field in the past has had a reverse polarity.

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[1] Terr. Mag. **53**, December, 1948.

[2] Am. J. Sci. **246**, 689–700 (1948).

[3] Nature **161**, 462–464 (1948).

The Formation of U^{232} by Helium Ions on Thorium

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September 27, 1948

GOFMAN and Seaborg first produced the isotope U^{232} by deuteron bombardment of thorium.[1] Studier and Hyde[2] have reported the occurrence of the α, $p3n$ reaction

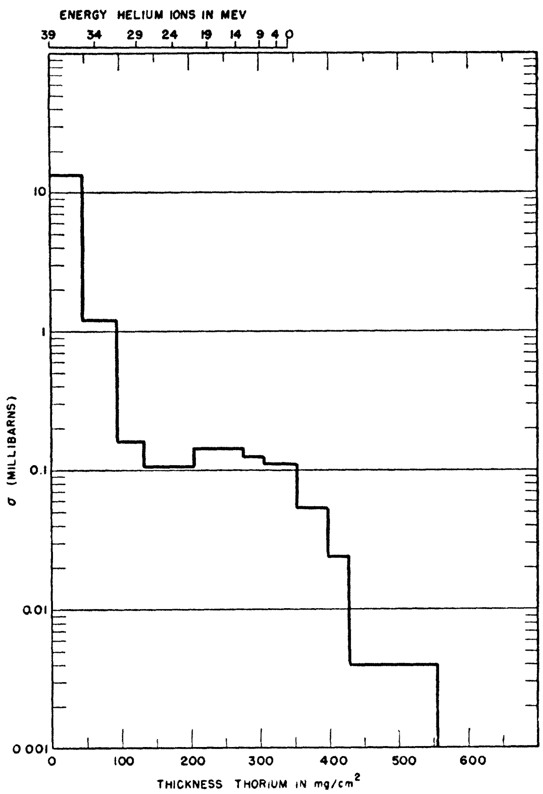

FIG. 1. Cross section for U^{232} production from thorium+helium ions.

on thorium to give Pa^{232} which decays by beta-emission to U^{232}. In neither of the above mentioned experiments was the cross section for formation of U^{232} determined.

In connection with work on the fission of thorium with helium ions,[3] a long bombardment of a thick target was obtained from which it was possible to calculate the cross section and measure roughly the threshold for the formation of U^{232} by helium ion bombardment of thorium. From the active area of this target thin layers were milled, the millings from each respective layer collected quantitatively, weighed, dissolved in hydrochloric acid, and diluted to a known volume. About six months after bombardment, uranium was extracted from aliquots of each of these solutions by ether extraction of uranyl nitrate. The thorium aliquot was added to 1 ml concentrated nitric acid in a 30 ml Kjeldahl flask and boiled until fumes of NOCl were no longer evolved. Then 3 ml of 10*M* ammonium nitrate were added and the solution extracted with 3 ml ether, the water phase being frozen in a dry ice-acetone bath to separate the phases. The ether was washed twice with 4 ml portions of 10*M* ammonium nitrate. Three successive extractions of the original sample were made and the ether extracts combined. To the combined ether extracts a few drops of concentrated nitric acid were added and the solution evaporated to eliminate the ether. The resulting solution was transferred to a platinum plate with a micropipette and the beaker and pipette washed three times with 3-drop portions of nitric acid. The solution on the platinum plate was evaporated under a heat lamp and then flamed to give samples for alpha-counting. This method gave reproducible results and was probably quantitative for the uranium since further extractions of the sample gave no activity.*

Since U^{232} decays by alpha-emission to $RdTh^{228}$ which has a 1.9-year half-life, measurements made soon after separation of the U^{232} are not contaminated with daughter products. To check for possible contamination from other alpha-emitters, samples from the first five layers were pulse analyzed and shown to contain no alphas of range differing from the 3.85-cm range of U^{232},[4] the range being checked against an ionium standard.

Table I contains the data used in calculating the cross sections. In these calculations the half-life of U^{232} was taken as 70 years from the work of James, Florin, Hopkins, and Ghiorso.[4] The initial 39-Mev energy of the alpha-particles is degraded to an average energy of 37.5 Mev in the first layer. At this energy the average cross section for formation of U^{232} is 13.2 millibarns, this figure representing the sum of the cross sections for the $\alpha, 4n$ and $\alpha, p3n$ reactions. No independent yields for these two modes of formation of U^{232} were obtained since the 1.4-day Pa^{232} had completely decayed at the time of the uranium separation.

In Fig. 1, in which the cross section for formation of U^{232} has been plotted against the thickness of thorium, it is seen that there is apparently a deuteron contamination of the helium ion beam causing the production of U^{232} beyond the threshold for the helium ion reaction. The indicated yield is a minimum in the fourth layer indicating that the $d, 2n$ reaction probably has a maximum yield in the fifth layer and some helium ion formation of U^{232} is still occurring in the third layer. This places a maximum value of 31.6 Mev and a minimum of 28 Mev on the threshold for the formation of U^{232} by helium ions, with an average value of 30 Mev. The yield from deuterons is observed to fall off rapidly when the thickness of thorium absorber becomes greater than 430 mg/cm² which corresponds to a reduction in energy of 20 Mev deuterons to about 10 Mev.

TABLE I. The yield of U^{232} from the bombardment of thorium with 39-Mev helium ions.*

Layer	Wt. Th in layer grams	Fraction of layer analyzed	α-Counting rate at 52% geometry c/m	σ (Units 10^{-27} cm²)	Thickness Th layer mg/cm²
1	0.380	.01	4544	13.4	44.2
		.01	4385	12.9	
2	0.408	.025	1336	1.2	47.4
		.025	1340	1.2	
3	0.332	.025	122	0.165	38.6
		.05	230	0.155	
4	0.640	.05	303	0.106	74.4
		.05	300	0.105	
5	0.612	.05	385	0.141	71.3
6	0.250	.05	140	0.125	29.1
7	0.411	0.1	401	0.11	47.8
8	0.396	0.1	187	0.053	46.1
9	0.252	0.1	55	0.024	29.3
10	1.082	0.1	38	0.004	126.0

* Area target = 8.60 cm²; Total bombardment = 3020 μah; $T_{\frac{1}{2}}U^{232}$ = 70 years.

The author wishes to thank Mr. A. Ghiorso for making pulse analyses of the samples and Dr. J. G. Hamilton and the crew of the Crocker Laboratory cyclotron for bombarding the sample.

This work was performed under the auspices of the Atomic Energy Commission and the Radiation Laboratory, University of California, Berkeley, California.

[1] J. W. Gofman and G. T. Seaborg, PPR Vol. 17B, No. 2.4 (to be issued). First reported in Report CN-332, October 20, 1942.
[2] M. Studier and E. Hyde, PPR Vol. 17B, No. 9.2 (to be issued).
[3] A. S. Newton, "The Fission of Thorium by Helium Ions," Phys. Rev. **75**, 17 (1949).
* This chemical method is not original with the author but its development was due to the efforts of many individuals on several branches of the Manhattan Project.
[4] R. A. James, A. E. Florin, H. H. Hopkins, and A. Ghiorso, PPR Vol. 14B, No. 22.8 (to be issued).

The Gamma-Rays of W^{187} in the Low Energy Region*

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November 16, 1948

THE use of a very thin window g-m tube detector in a small 180° spectrometer has made it possible to extend our study of W^{187} to energies of about 3 kev. The beta-ray source consisted of a thin deposit of finely divided WO_3 about one mg/cm² thick backed by a 0.06 mg/cm² Zapon film. The 24-hour W^{187} was obtained from Oak Ridge. Figure 1 shows the electron spectrum in the low energy region. Conversion lines are found at 7, 66, 127, and 136 kev. The first of these appears low in intensity since it is close to the window cut-off and corresponds to a gamma-ray at 0.078 Mev, if it is assumed to be a K-line. The remaining three lines are found to be the K, L, and M components associated with the conversion of a gamma-ray at 0.138 Mev. Using photographic plate detection, Valley[1] has found conversion lines in this region which he attributes to three gamma-rays at 0.086, 0.135, and 0.101 Mev. Our results are in accord with the assignment of two of these, with somewhat different energy values, but the presence of a gamma-ray at 0.101 Mev cannot be inferred from our data.

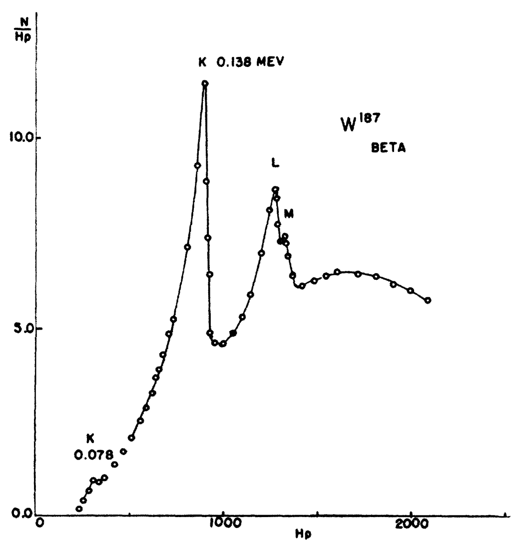

FIG. 1. Low energy electron spectrum of W^{187}.

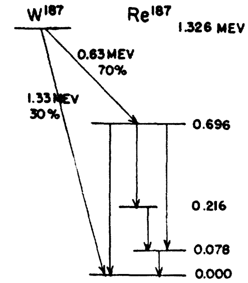

FIG. 2. Decay scheme of W^{187}.

From a study of the photoelectrons ejected from a thin lead radiator, gamma-rays at 0.14 and 0.21 Mev have been previously suggested.[2] The photoelectron line caused by the 0.14-Mev gamma-ray was very close to window cut-off and the energy assignment in doubt. It would now appear that the photoelectron line previously ascribed to a 0.21-Mev gamma-ray is really the L line of the 0.138-Mev gamma-ray. This correction makes the decay scheme previously given more consistent.[2] Figure 2 shows the decay scheme which is consistent with our earlier studies and the present low energy measurements. In addition, coincidence studies and an analysis of the relative intensities support this picture. However, since the decay is complex and cannot be inferred directly from the data, it is perhaps best to regard the scheme as a tentative one. In any case, Fig. 2 may be regarded as a summary of the radiations of W^{187} and their energies which we have obtained.

* Assisted by the joint program of the Office of Naval Research and Atomic Energy Commission.
[1] G. E. Valley, Phys. Rev. **59**, 686 (1941).
[2] C. L. Peacock and R. G. Wilkinson, Phys. Rev. **74**, 601 (1948).

The Possible Magnetic Field of a Rotating Metallic Body Containing a Stress Gradient

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November 12, 1948

IN view of the recent interest in the magnetic fields of the earth, the sun and other astronomical bodies, and in mechanisms for producing magnetic fields by rotation,[1]