# REMANENT MAGNETIZATION OF EASTERN UNITED STATES TRIASSIC ROCKS

by

David Edwin Bowker

B. S. Antioch College
(1953)

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1960

Signature of Author. . . . . . . . . . . . . . . . . . . . . . . .
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Thesis Advisor

Accepted by. . . . . . . . . . . . . . . . . . . . . . . . . . .
Chairman, Departmental Committee on Graduate Studies

Massachusetts Institute of Technology
Cambridge 39, Massachusetts
May 14, 1960

Professor Philip Franklin
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Sir:

In accordance with the regulations of the faculty, I hereby submit a thesis entitled, "Remanent Magnetization of Eastern United States Triassic Rocks," in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Geology and Geophysics.

Respectfully submitted,

David E. Bowker

# ACKNOWLEDGMENTS

The author wishes to express his appreciation and thanks

To Professor R. R. Doell for his help and encouragement in the planning, experimenting, and writing of this thesis.

To D. Greenewalt for his assistance on the field trips and laboratory work connected with this thesis.

To the members of the Department of Geology and Geophysics for their advice, especially to Professors E. Mencher and H. Hughes.

To the members of the Geology Department Machine Shop for their time and many constructive suggestions.

To his wife for her part in the manuscript preparation.

To Alice Seelinger for the many hours she has spent typing and preparing this thesis.

To the National Science Foundation for making this work possible.

# REMANENT MAGNETIZATION OF EASTERN UNITED STATES TRIASSIC ROCKS

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David Edwin Bowker

Submitted to the Department of Geology and Geophysics on
May 14, 1960, in partial fulfillment of the requirements for the
degree of Doctor of Philosophy

## ABSTRACT

Remanent magnetization measurements were made on samples collected from many of the Triassic formations of the Eastern United States. The Nova Scotia igneous rocks were also included. All of the igneous rocks and some of the sedimentary rocks were given an a.c. demagnetization treatment. The results of the igneous rocks are divided according to the three main areas from which the samples were collected: the Nova Scotia, Connecticut Valley, and Pennsylvania-Virginia areas. Except for the Northern Massachusetts sediments, which appear to have been magnetized after deformation, the results of the sedimentary rocks are in reasonably good agreement. The axis of a geocentric dipole field that would account for the remanent magnetization in the sediments is placed within 5 degrees of longitude 105 1/2 E and latitude 65 1/2 N, for a 95% probability.

Thesis Advisor: Richard R. Doell

Title: Assistant Professor of Geology and Geophysics

# BIOGRAPHY

The author, David Edwin Bowker, was born in Richmond, Virginia, on April 19, 1928. After graduating in 1945 from Highland Springs High School, in Highland Springs, Virginia, he attended the Bliss Electrical School in Washington, D. C., and graduated from there in 1946.

After two years in the U.S. Navy as a student and instructor in the Radar School, he entered Antioch College in Yellow Springs, Ohio, in 1948. In June, 1953 he received his Bachelor of Science Degree in Physics.

While at Antioch the author held coop jobs with the Airborne Instruments Laboratory, Mineola, New York; the Kettering Photosynthesis Laboratory, Yellow Springs, Ohio; the U.S. Geological Survey, Washington, D. C.; and the Jarrell-Ash Co., Newtonville, Massachusetts.

The author entered M.I.T. in 1953 and has held assistantships with the G.A.G. and the Rock Magnetics Research Project.

During the summer of 1956, he worked with the California Research Corporation in La Habra, California.

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# INTRODUCTION

The continental deposits of Triassic age in Eastern North America are found from South Carolina to Nova Scotia, and occur in several discontinuous basins (see Fig. I-1). The basins are generally elongated northward and in many areas are bordered by faults. The bedding planes in the deposits generally dip toward the dominant fault, such as the eastern fault along the Connecticut Valley basin and the northern fault along the New York-Virginia basin.

The basins are quite similar in respect to lithology and structure. The sedimentary rocks found in the Triassic basins include arkoses, conglomerates, sandstones, and shales, and several of the southern basins also contain coal seams. Extensive basalt flows are interbedded with the Triassic sediments in Nova Scotia, the Connecticut Valley, New York, and New Jersey, and all the larger basins have been intruded by basic igneous rocks (mainly diabase).

Fig. I-2 is a section of a report by John B. Reeside, et al (1957), correlating the Triassic formations from North Carolina through Massachusetts. A correlation of the Nove Scotia formations is given by McLearn (1953). Since the Triassic sediments are of continental origin, stratigraphic correlation is somewhat difficult. Even within a single basin the results are often subject to doubt.

Results of remanent magnetization studies on most of these Triassic formations are given in this report. Several areas of interest, however, have not been sampled, mainly the Richmond basin

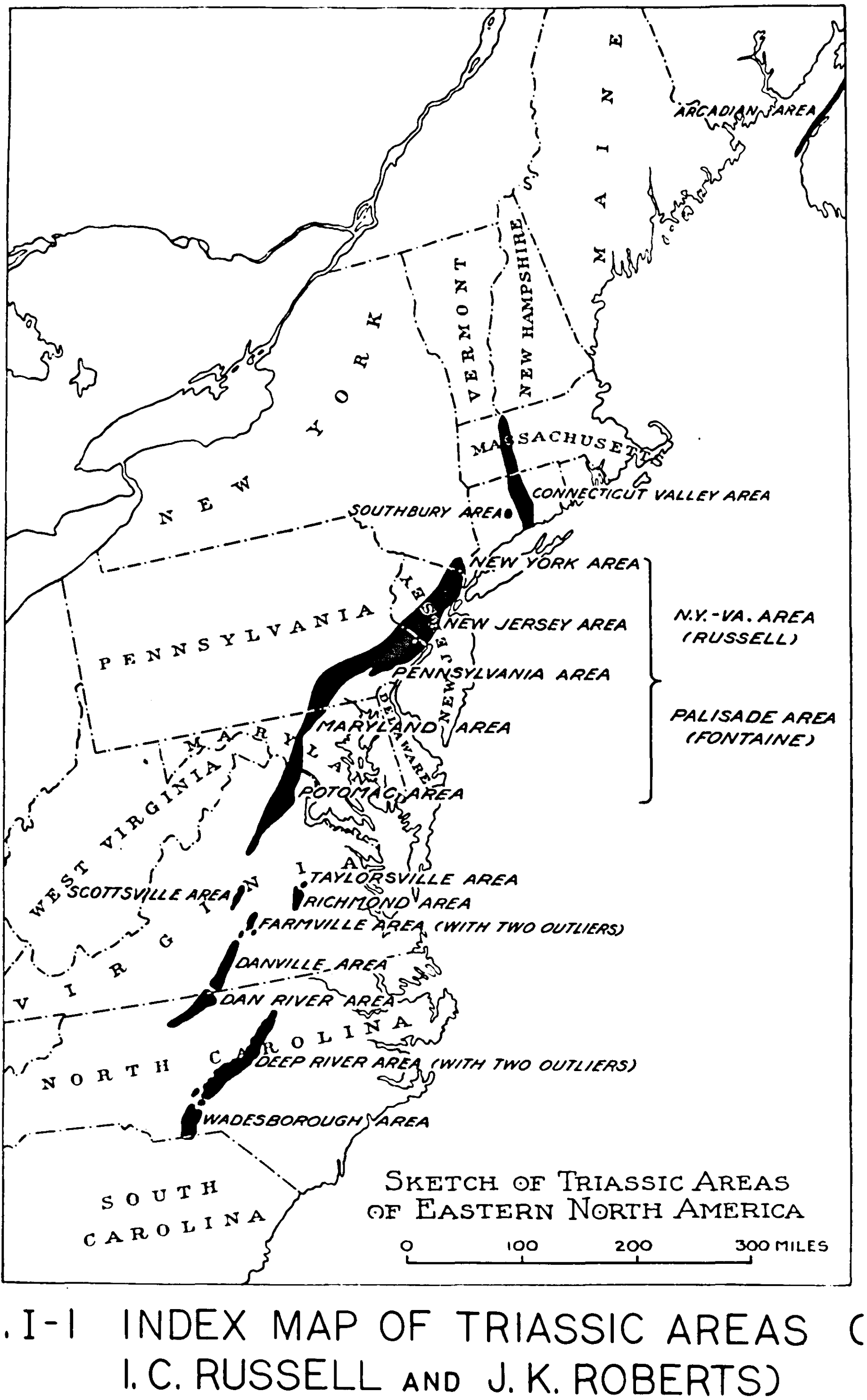
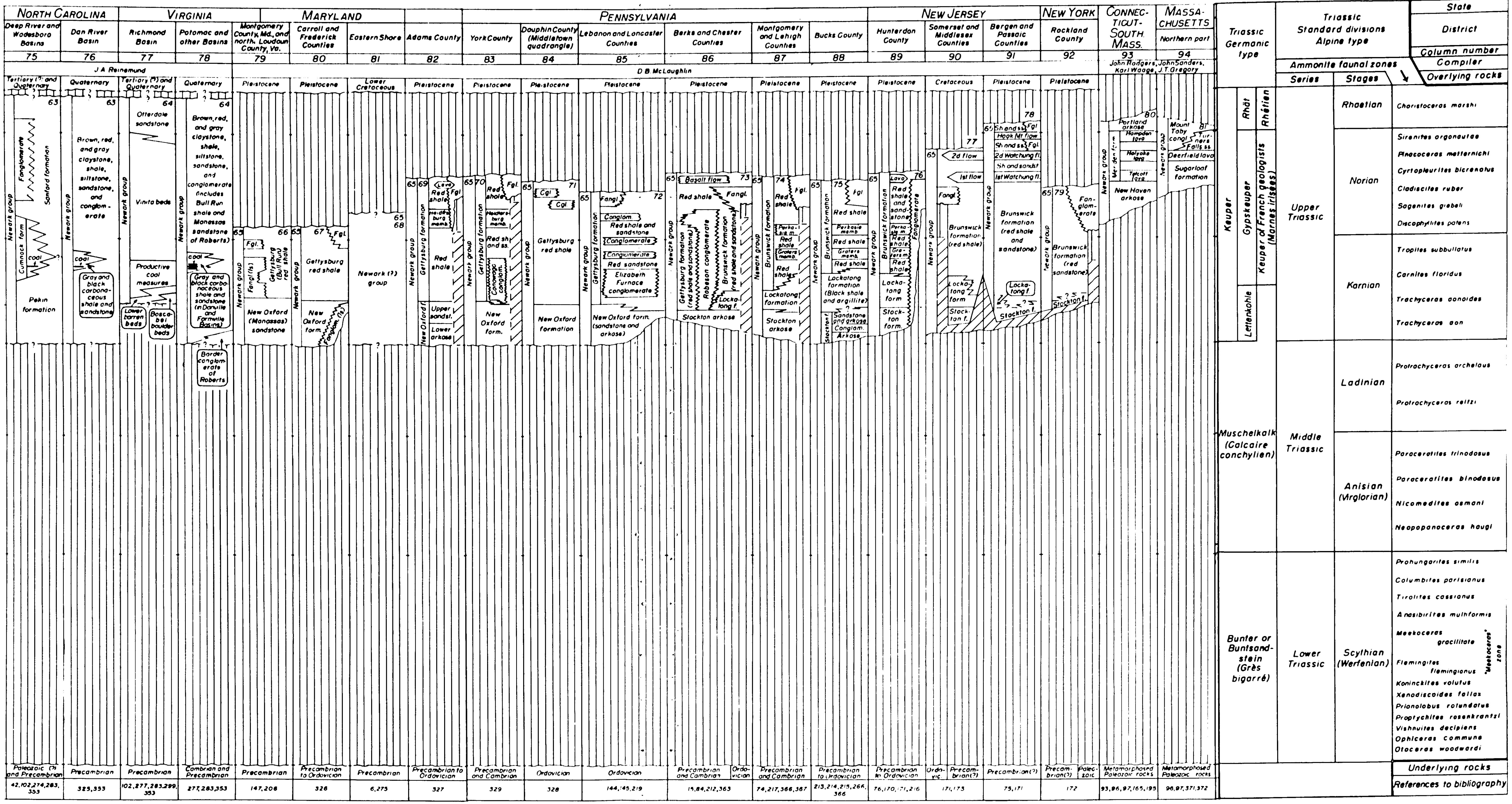


FIG. I-1 INDEX MAP OF TRIASSIC AREAS (after I. C. RUSSELL AND J. K. ROBERTS)

FIG. I-2 CORRELATION OF TRIASSIC FORMATIONS OF NORTH AMERICA EXCLUSIVE OF CANADA

By the Triassic Subcommittee, John B. Reeside, Jr. (Chairman), P. L. Applin, E. H. Colbert, J. T. Gregory, H. D. Hadley, Bernhard Kummel, P. J. Lewis,
J. D. Love, Manuel Maldonado-Koerdell, E. D. McKee, D. B. McLaughlin, S. W. Muller, J. A. Reinemund, John Rodgers, N. J. Silberling and Karl Waage



and Northern New Jersey. Although results from the Nova Scotia basalts are included, sediments from this area have not been collected.

The purpose of this survey is manifold. 1) Primarily, the results should give a more accurate picture of the earth's magnetic field in the eastern United States during Triassic time. It is expected that factors which may introduce errors into remanent magnetic studies, i.e., lightning strikes, corrections for geology, etc., will mostly be averaged out by an extensive survey. 2) Since the formations are located in several isolated basins, any systematic influence of the environment on the remanent magnetism should become apparent. 3) All of the areas sampled contained both igneous and sedimentary Triassic rocks. A comparison of the results from these two kinds of rocks will be important, particularly regarding their respective values in paleomagnetism. 4) Also, the survey may offer a test for non-dipolar latitude variations.

## Collection

The samples were collected in the form of one-inch diameter cores. The coring drill was powered by a small gasoline engine and cooled with water which was supplied by a small pressurized tank (this system has since been described by Graham and Hales, 1957.) The probably error in orientation of the cores was less than one or two degrees.

Approximately eight cores were taken from each site (mostly road cuts) with little consideration of the number of igneous flows. The samples were spaced so as to be representative of the entire outcrop. An attempt was made to select outcrops from widely different locales in order to prevent oversampling any one formation or region. More than 580 cores were taken from 77 outcrops during the survey.

## Measurement

Each core was cut into one or more one-inch long samples. The magnetic moment of each sample was measured with a "rock generator" type magnetometer (employing an air-driven spinner) which rotated at approximately 282 revolutions per second. The basic sensitivity of the instrument was better than $1 \times 10^{-7}$ cgsu/cc, and directions of magnetization could be determined within a few degrees for samples having intensities of magnetization greater than $2.5 \times 10^{-6}$ cgsu/cc.

All of the igneous samples and some of the sedimentary samples were given an a.c. demagnetization treatment to remove part or all of the unstable components of the remanent magnetization. This was accomplished by rotating the sample inside a small pair of Helmholtz coils (supplied by 60 c.p.s. line voltage). The current in the coils was increased to a given value and then slowly reduced to zero. The maximum field attainable was 550 Oersteds, which was usually not sufficient to complete the demagnetization procedure on the sedimentary samples.

# PART I

# PART I: REMANENT MAGNETIZATION

## A. Igneous Rocks

According to the results of the remanent magnetization studies, the igneous rocks can be separated into three main groups. These correspond to the three principal areas from which the samples were collected, the Nova Scotia, Connecticut Valley, and Pennsylvania-Virginia areas. The three groups are characterized primarily by their average direction of remanent magnetization. When subjected to an a.c. field, however, the magnetic behavior of the samples is quite different. The data on the igneous rocks is given in Table I-1.

### 1. Nova Scotia

The Triassic basin of Nova Scotia is a long, narrow belt which borders on the Bay of Fundy. The beds dip gently toward the bay at angles up to 15 degrees. Eleven sites were sampled in this area, ranging from Cape Blomidon in the north to slightly south of Digby. The collection sites were spread in an east-west direction so that they would include a large number of flows.

The results of the measurements on samples from a given core have been averaged to yield only one direction of magnetization for each core. Fig. I-3 shows the direction of the remanent magnetization, after a.c. demagnetization, for the 75 cores. The nomenclature used is the same for all plots. Fig. I-4 is the same plot after correction for the dip of the beds.

The most interesting feature of the Nova Scotia samples was their behavior during the a.c. demagnetization test. It is assumed

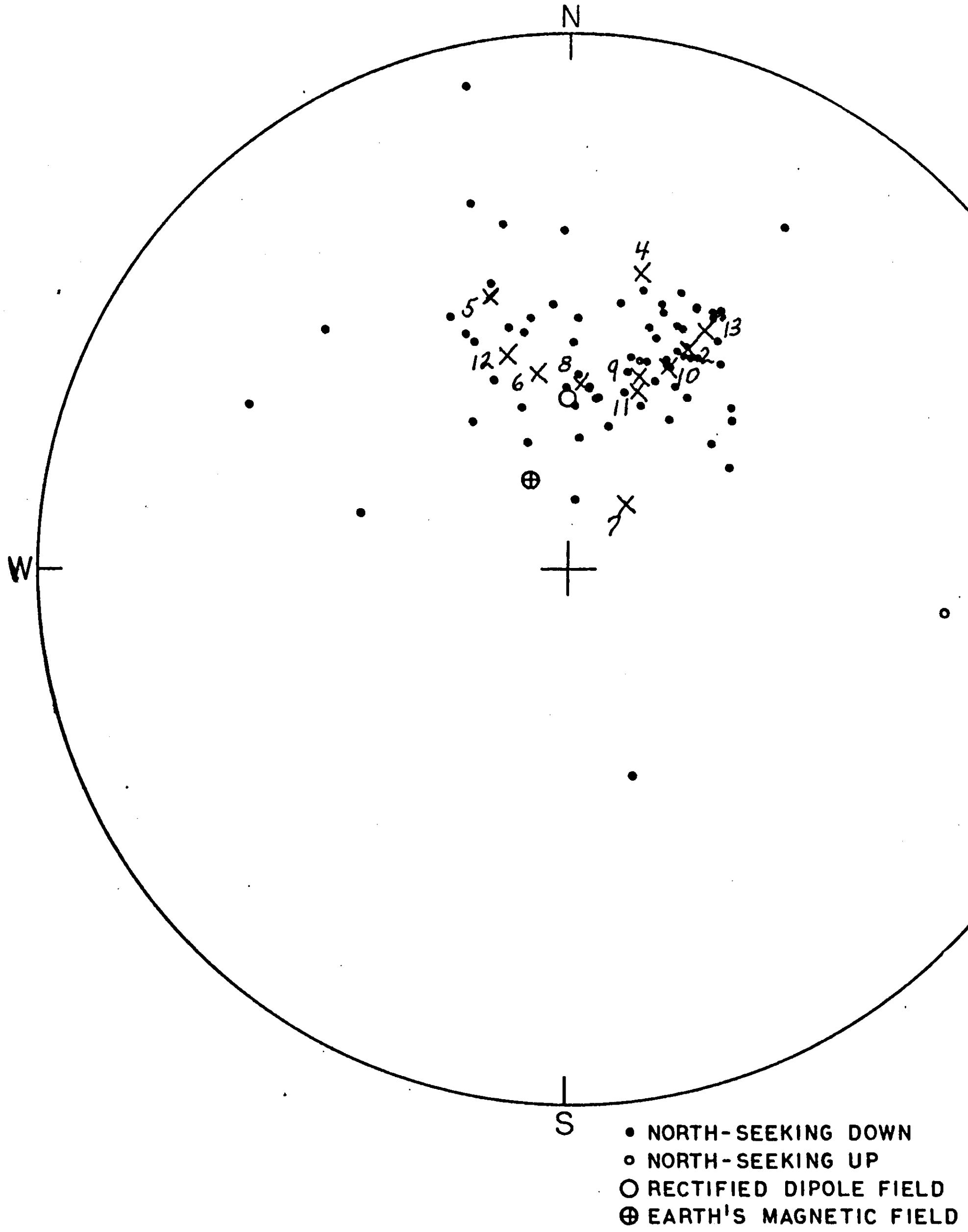


FIG. I-3 NOVA SCOTIA-IGNEOUS

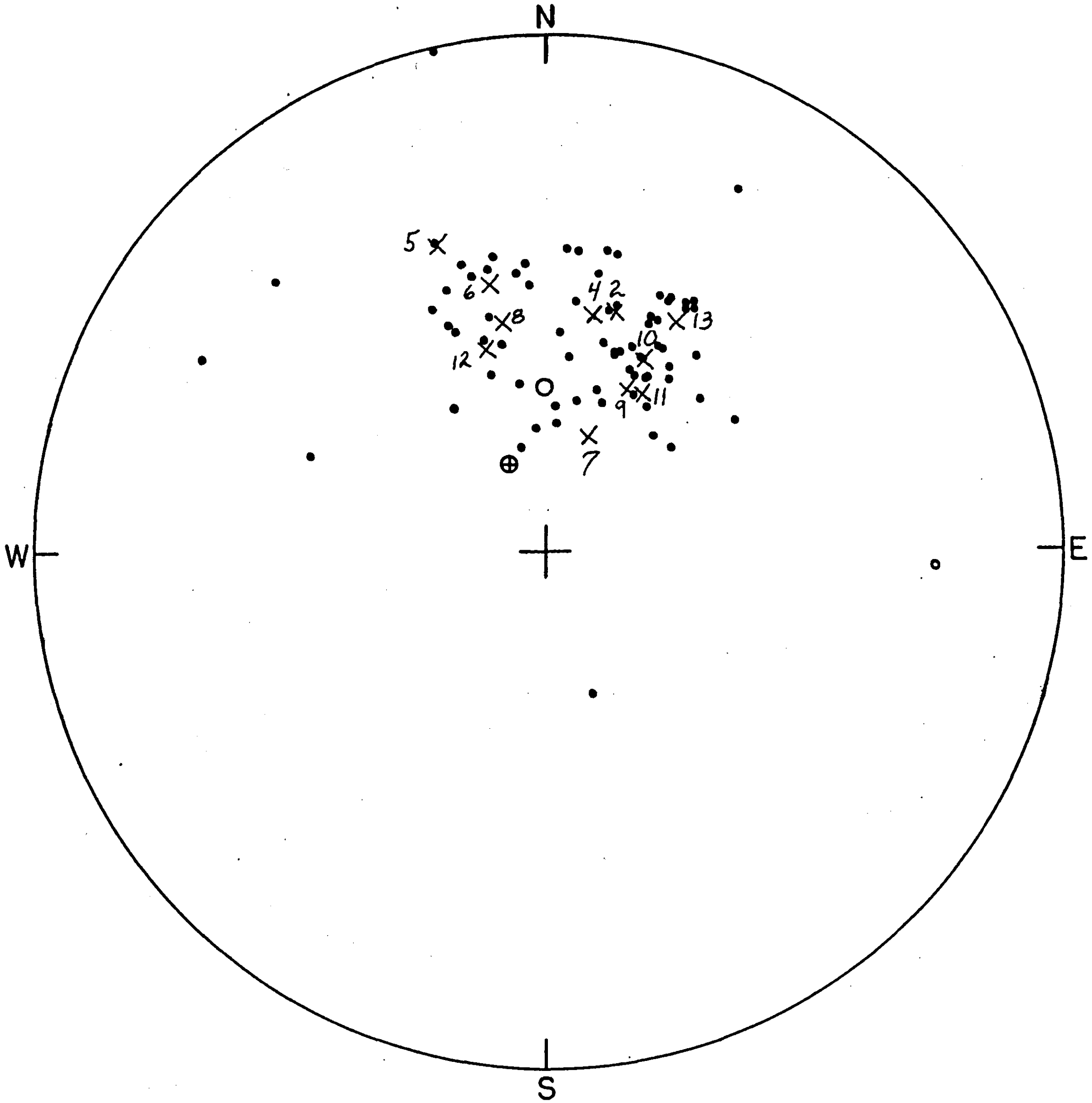


FIG. I-4 NOVA SCOTIA - IGNEOUS (CORR. for GEOL.)

that the remanent magnetization is composed of a "soft" component, which can be removed by placing the sample in an a.c. field and then slowly reducing the intensity of the field to zero, and a "hard" component, which will not be erased during the removal of the "soft" component. The results of As and Zijderveld (1958) and Creer (1958) indicate that unstable components can be removed by partial a.c. demagnetization. Fig. I-19 is a plot of the relative intensity of the remanent magnetization during the demagnetization of several samples. The corresponding paths of the directions of the remanent magnetization is shown in Fig. I-20, (for the sake of simplicity the points have been connected by straight lines). Considering NS35-1, it is noticed that the magnetic vector tends to vary about an average direction for a.c. field intensities greater than 100 Oersteds. The variations, however, are relatively large. NS65-2 shows a similar tendency to vary, at first to a lesser degree. Above 100 Oersteds the variations become much greater. At somewhat lower a.c. field values NS64-1 begins to vary in the same plane as NS65-2.

Many of the samples did not exhibit any obvious patterns of behavior even though their magnetization could be easily changed. Samples from outcrops having very little scatter in their remanent magnetization directions, such as No. 13, were relatively unaffected by the a.c. fields. A comparison of heat treatment (for the removal of "soft" components) and a.c. field treatment on some of the samples from outcrop No. 5 gave similar results.

### 2. Connecticut Valley

Eight of the outcrops sampled in the Connecticut Valley represent the four principal igneous flows: the Deerfield lava of Northern Massachusetts (4), the Talcott lava (2), the Holyoke lava (1), and the Hampden lava (1). A plot of the remanent magnetization direction is shown in Fig. I-5 and Fig. I-6 (after correction for dip of beds).

Because the direction of the earth's magnetic field is dependent upon the location of the site, the influence of the bedding correction is shown with respect to the pole positions in Fig. II-4. A discussion of its significance is given in Part II.

For the most part, the demagnetization of the Connecticut Valley lavas was similar to those of Nova Scotia. The results were still far from ideal, in that the direction of magnetization seldom stayed within a few degrees of an average value during the demagnetization procedure.

As a result of the demagnetization tests, the average direction of magnetization for each outcrop treated was moved a few degrees in a northerly direction. The reduction in scatter of the remanent magnetization was the most significant.

### 3. Pennsylvania - Virginia

Unlike the Nova Scotia and Connecticut Valley areas, the igneous rocks of the Pennsylvania - Virginia area are mostly intrusives. Five of the outcrops sampled are in the eastern part of Pennsylvania, and two are in the western part. The three Virginia outcrops are located in the Potomac area.

The remanent magnetization directions are shown in Fig. I-7 and

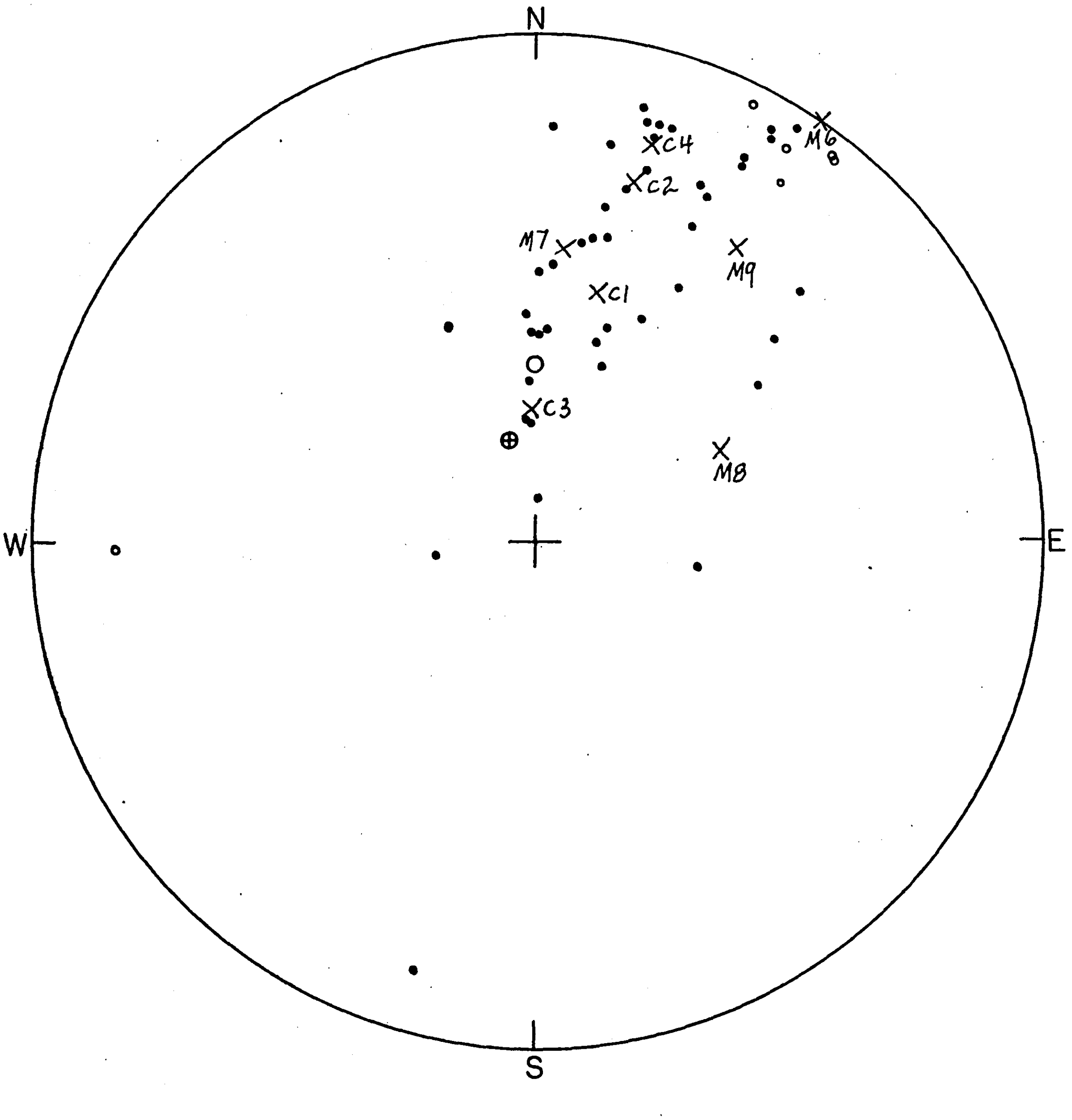


FIG. I-5 MASS. AND CONN.-IGNEOUS

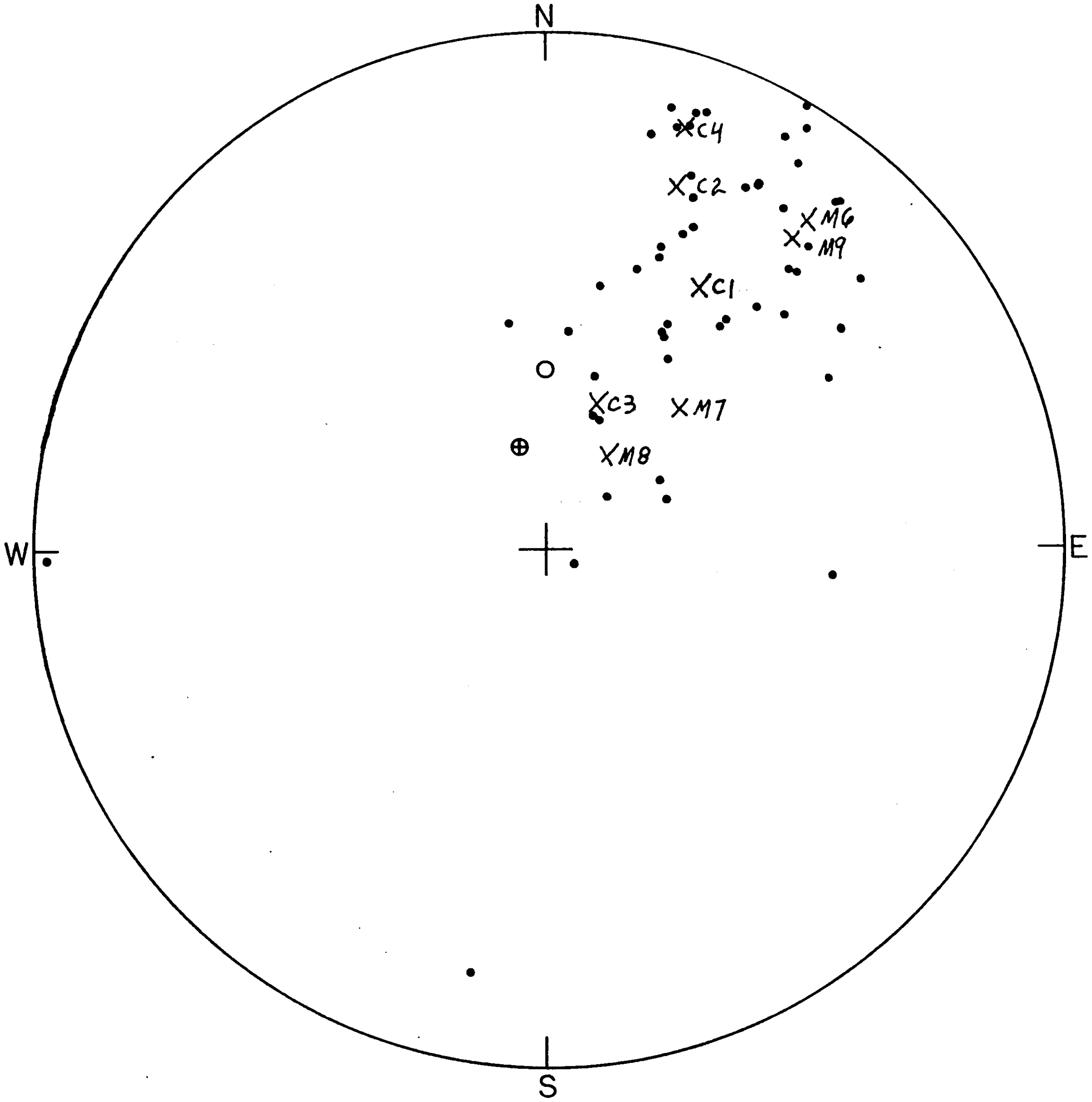


FIG. I-6 MASS. AND CONN.- IGNEOUS (CORR. for GEOL.)

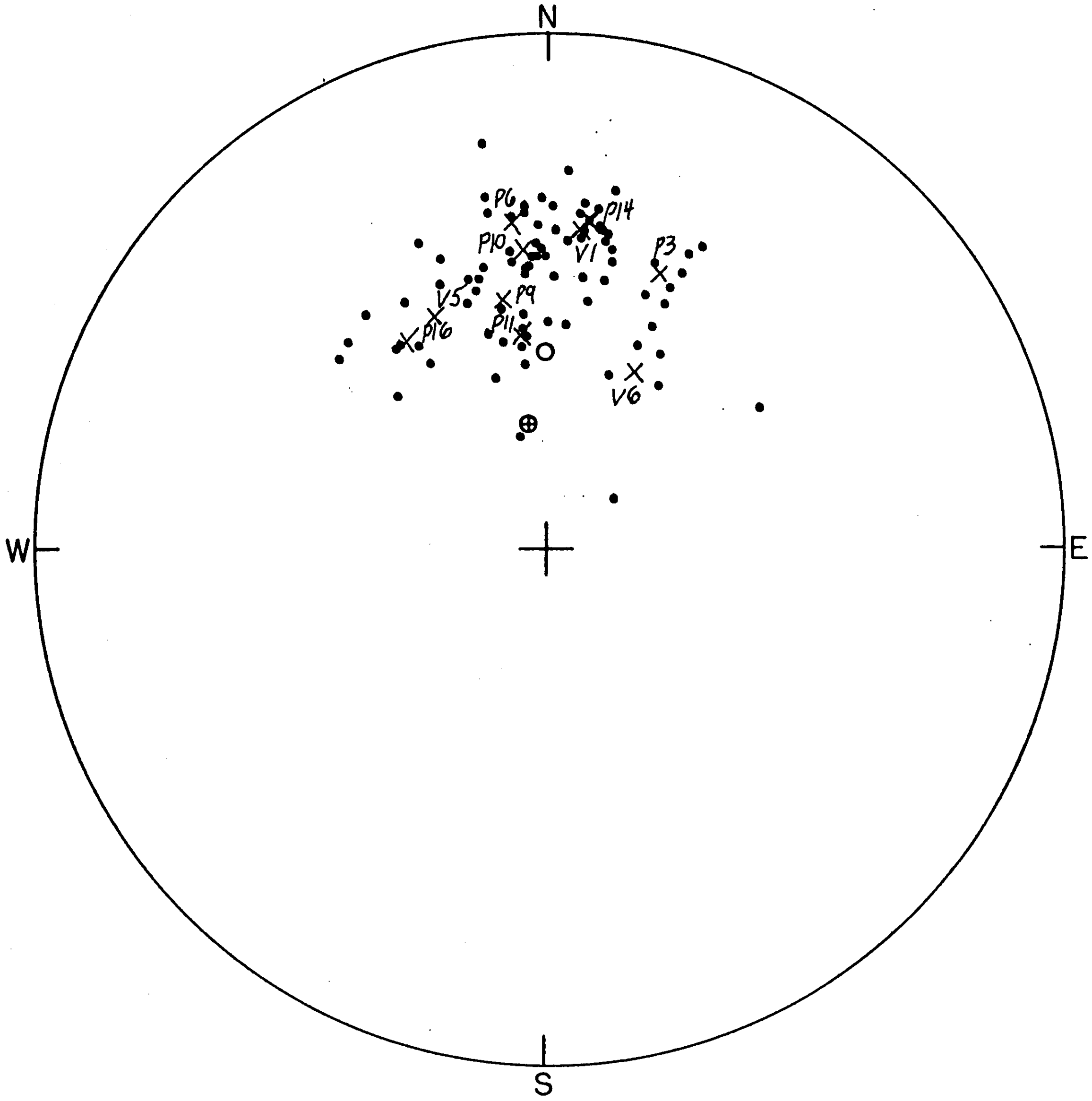


FIG. I-7 PA. AND VA. - IGNEOUS

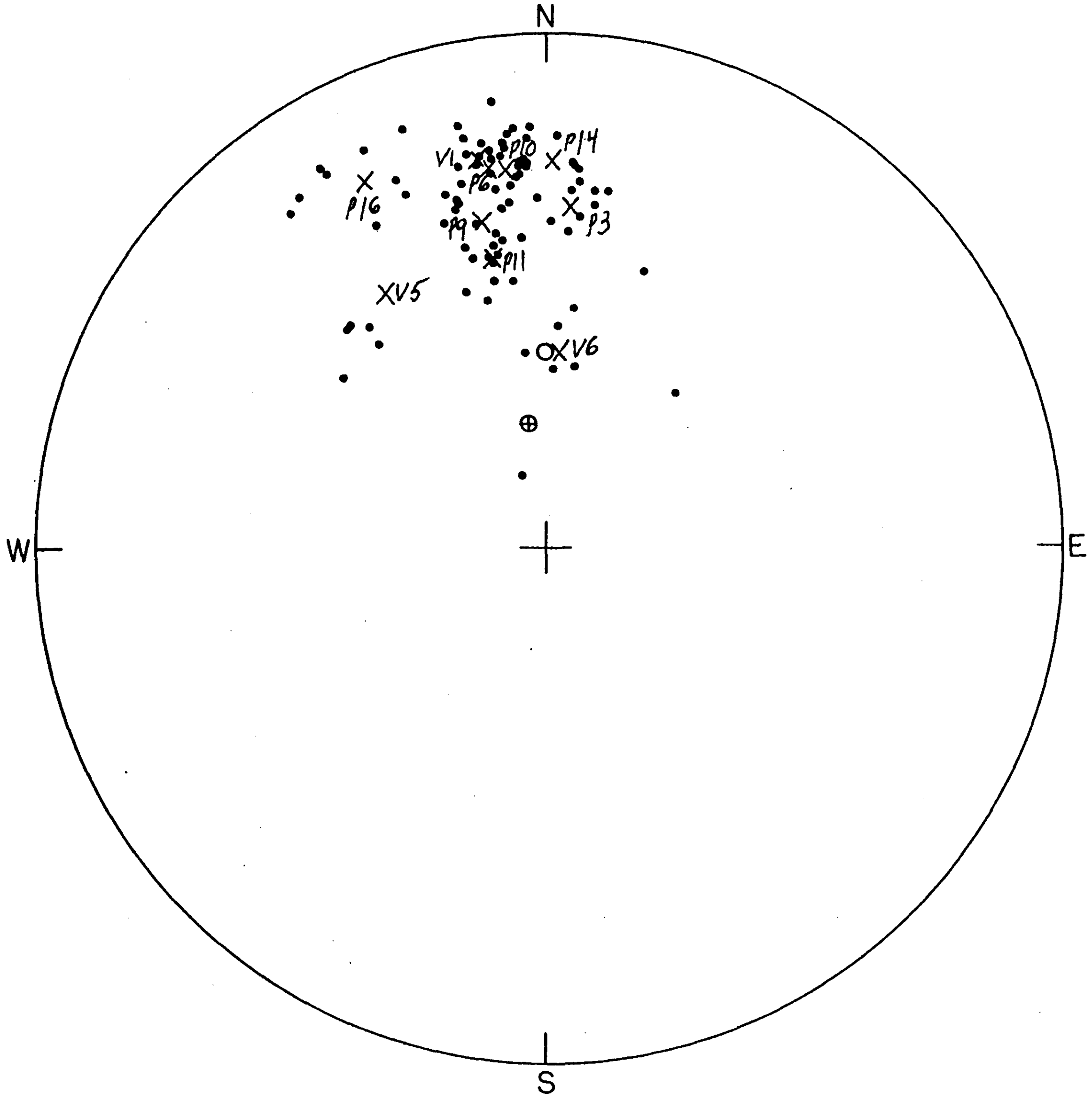


FIG. I-8 PA. AND VA. - IGNEOUS (CORR. for GEOL.)

Fig. I-8. The bedding correction, which restores the beds to a horizontal position, has reduced the dip of the remanent magnetization and has also reduced the scatter. Although the demagnetization tests reduced the scatter within several outcrops, they hardly affected their average direction of magnetization.

The demagnetization of these samples agrees very well with the assumption that the total remanent magnetization is composed of a "hard" and a "soft" component. Fig. I-21 shows the demagnetization paths of three samples. When the peak value of the a.c. field was increased by small increments most of the relative intensity curves exhibited the curious hump that appears just after the magnetic vector has reached a stable direction (see Fig. I-19). This feature is also evident in the Nova Scotia and Connecticut Valley intensity plots, although in some cases it is not as clearly developed.

The accepted value of demagnetization, shown by an open circle on the intensity curves, usually occurs at the bottom of the first trough. Hence, the elimination of the "soft" component can often be predicted from the intensity curves as well as from the direction of magnetization plots.

The average intensities of magnetization for the igneous rocks in the Nova Scotia, Connecticut Valley, and Pennsylvania - Virginia areas are 9.8, 10.0, and 9.7 (x $10^{-4}$ cgsu/cc) respectively. These average values seem remarkably constant since the intensity variations among the samples from a given area were greater than 100x.

The difference in the direction of remanent magnetization for these three areas is certainly significant. One possible explanation is that when the rocks were formed, they failed to acquire a remanent magnetization in the direction of the applied field. To test this hypothesis, six randomly oriented samples were heated to about 650 °C and allowed to cool in the earth's magnetic field. The samples were from the following outcrops: NS13(2), M6(1), M9(1), P14(1), V1(1). Except for a difference of 2 to 3 degrees, accounted for by the error in orientation, the samples acquired the same direction of magnetization. Although the test was not conclusive, it seems to eliminate this possibility.

## B. Sedimentary Rocks

The data on the sedimentary rocks is given in Table I-2. Most of the formations in the New Jersey - Virginia area and in the Deep River area of North Carolina have been sampled. In the Connecticut Valley only the Northern Massachusetts sediments were sampled.

### 1. Connecticut Valley

Five outcrops of Turners Falls sandstone and one outcrop of Longmeadow sandstone were sampled in the Massachusetts area. The results are given in Fig. I-9 and Fig. I-10.

The scatter of outcrop No. 5 was reduced slightly by partial demagnetization in a 20 Oersted field. With a 50 Oersted field the scatter of the Longmeadow sandstone was not only reduced, but the average direction of magnetization was also changed about 10 degrees due west, bringing the results into better agreement with the Turners Falls sandstone.

Because the attitudes of these beds do not differ greatly, the correction for dip does not constitute a good test for stability.

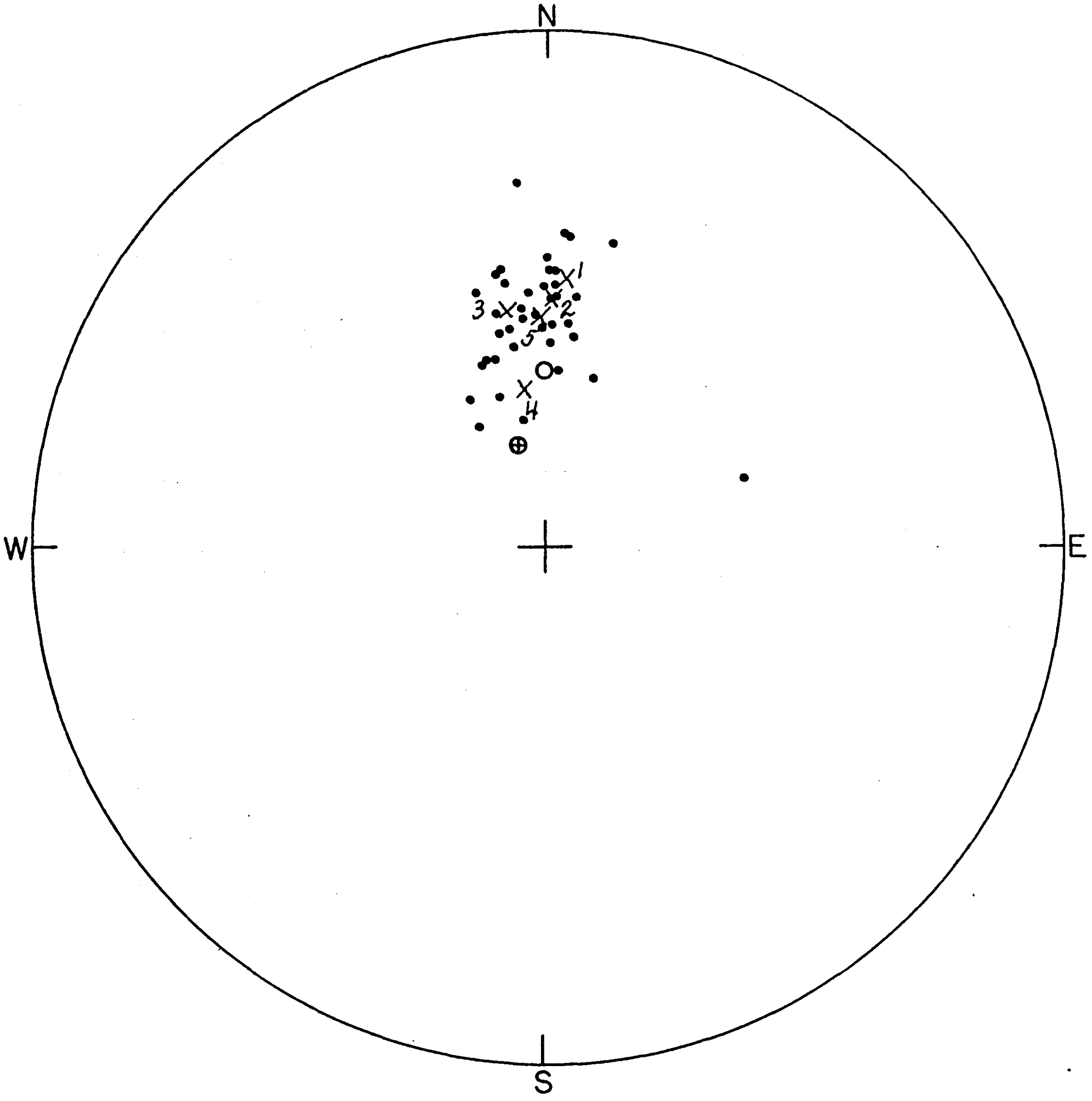


FIG. I-9 MASS.-SEDIMENTARY

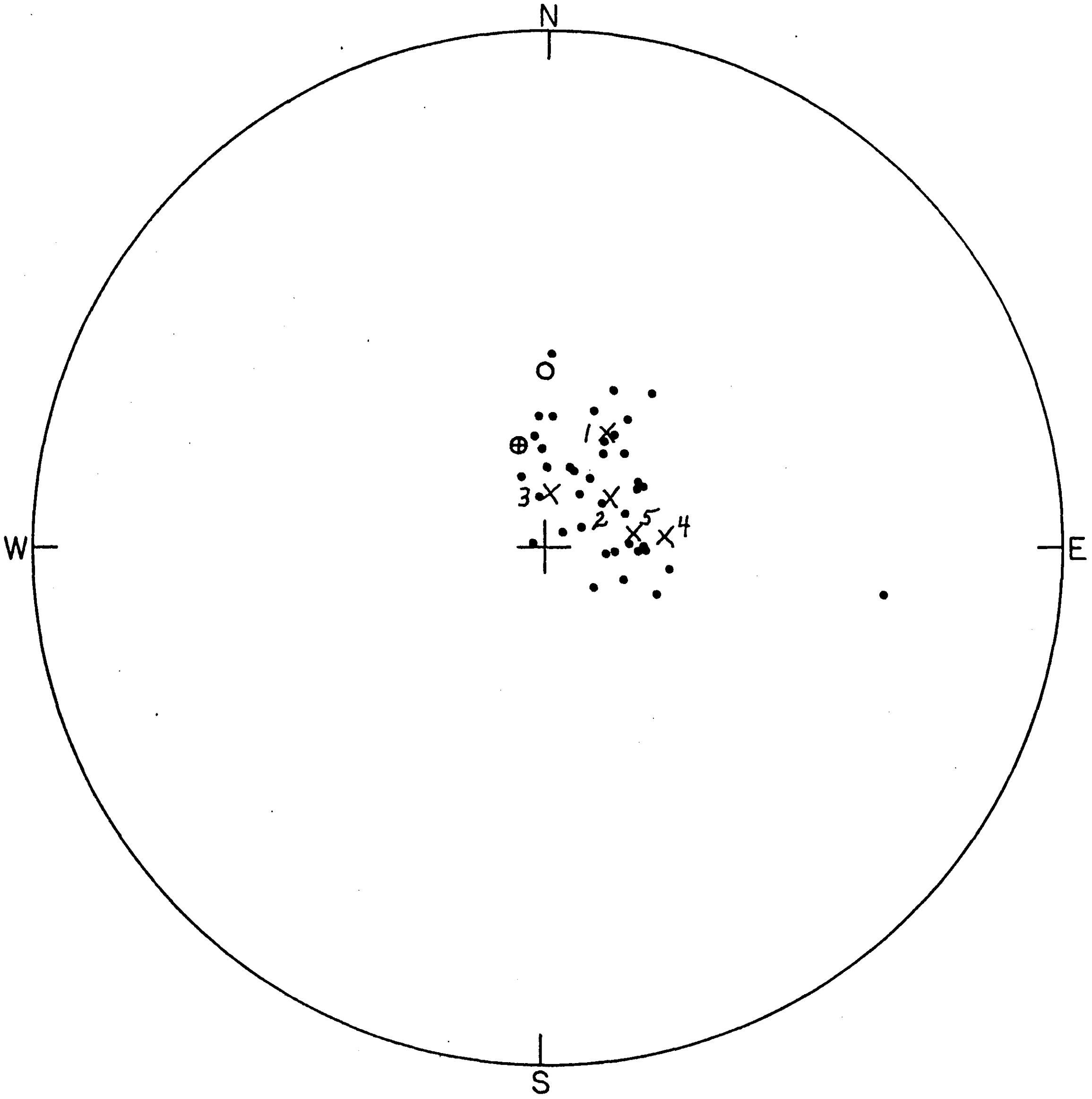


FIG. I-10 MASS.- SEDIMENTARY (CORR. for GEOL.)

However, the influence of the axial dipole field seems to be more evident here than with any of the other sedimentary formations.

The Connecticut Valley beds are resting on the Deerfield diabase and, according to Willard (1952), they are much redder near the contact, probably because of the addition of iron from the lava. It is probable then that the magnetization of the sediments represents a chemical process which reflects the influence of post-Triassic magnetic fields. Thus, pole positions for these sediments have not been plotted in Part II. The average pole position would lie about 20 degrees northeast of Massachusetts.

## 2. New Jersey - Virginia Area

The results from the New Jersey - Virginia area have been divided into three groups. Fig. I-11 and Fig. I-12 show the remanent magnetization directions for the Lockatong and Brunswick formations of eastern Pennsylvania and New Jersey. Fig. I-13 and Fig. I-14 show the directions for the Gettysburg and New Oxford formations of western Pennsylvania and Maryland. The direction of magnetization plots for Virginia, which contain the results from outcrops located in the Potomac, Scottsville and Danville areas, are shown in Fig. I-15 and Fig. I-16. No distinction has been made between the sandstone and shales in this area (nor in the other areas); Roberts (1928) did make such a distinction, however.

Several of the outcrops responded to a.c. demagnetization treatment with field intensities of 20 - 50 Oe. The scatter was reduced slightly, but the average direction of magnetization was relatively unaffected. Most of the outcrops would have required field

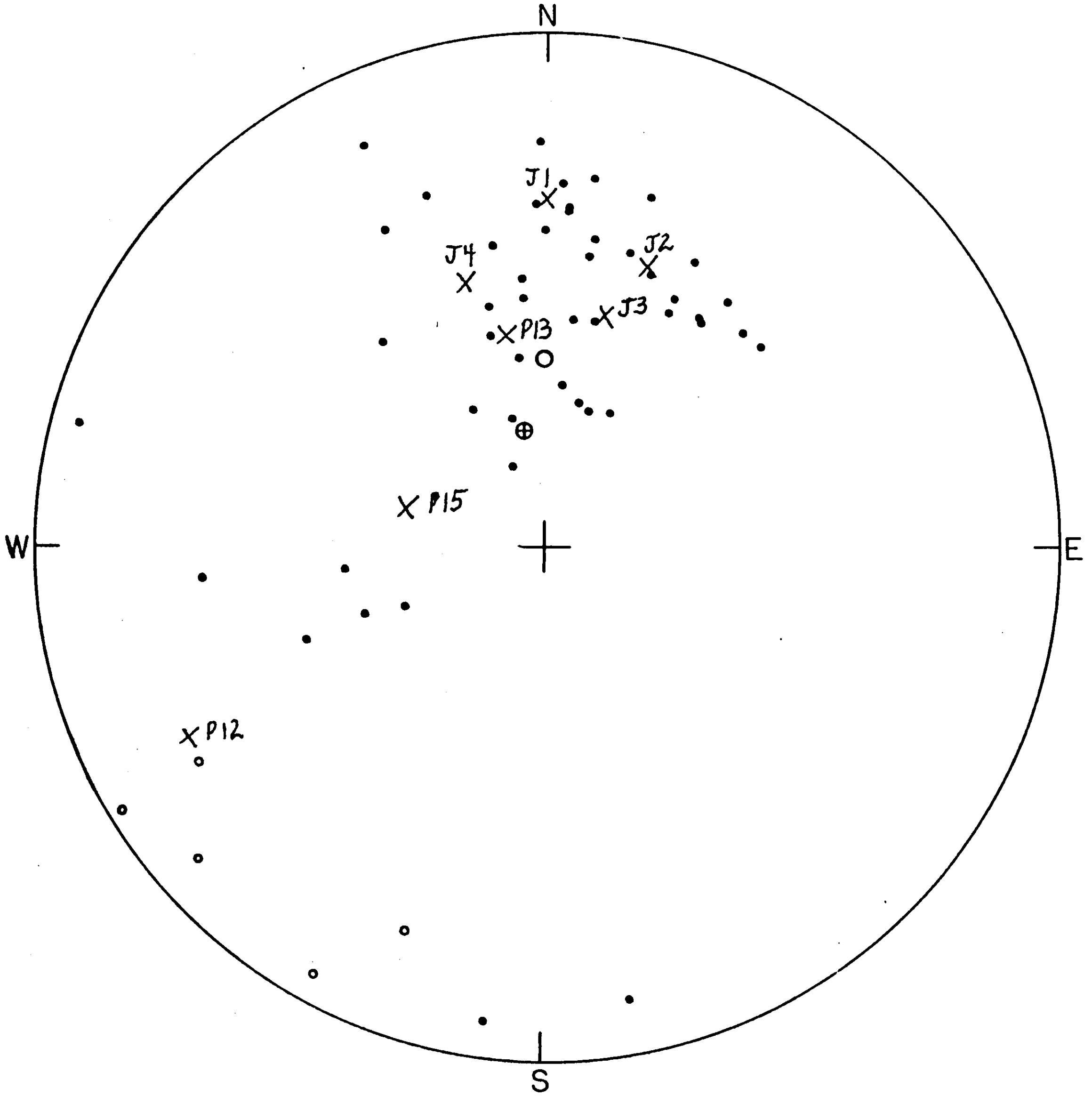


FIG. I-11 N. J. AND EAST PA. - SEDIMENTARY

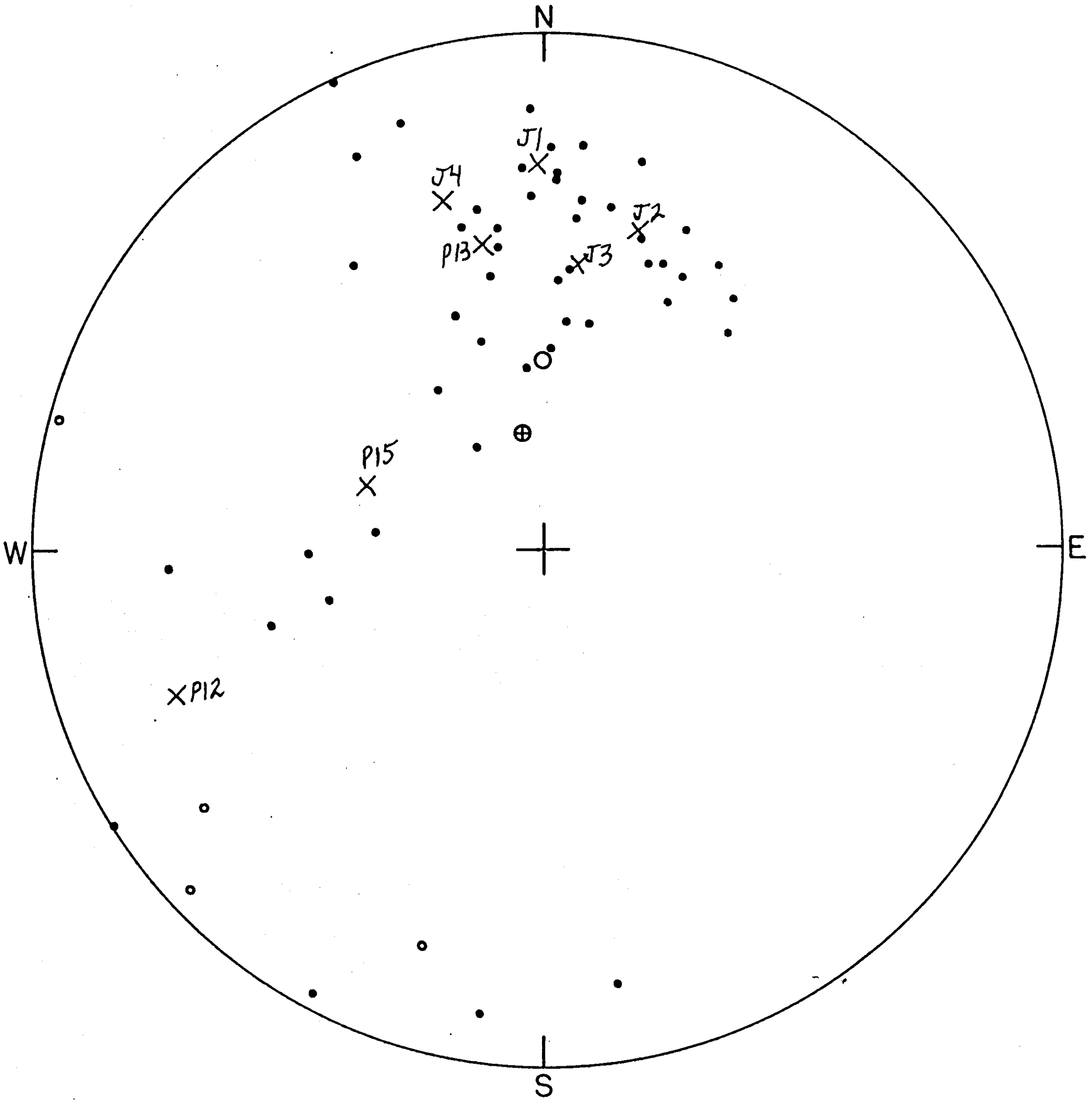


FIG. I-12 N.J. AND EAST PA.-SEDIMENTARY (CORR. for GEOL.)

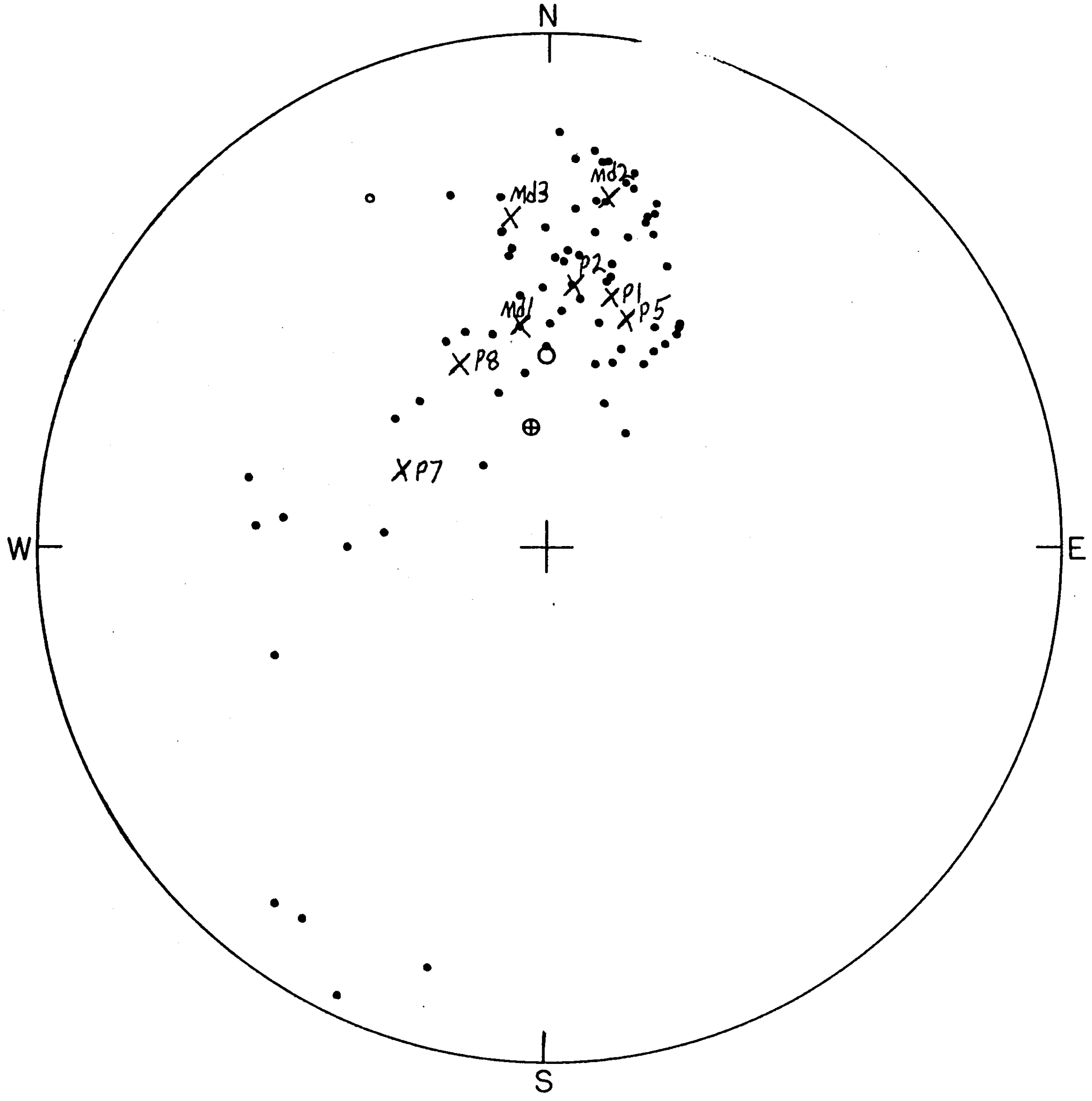


FIG. I-13 MD. AND WEST PA.- SEDIMENTARY

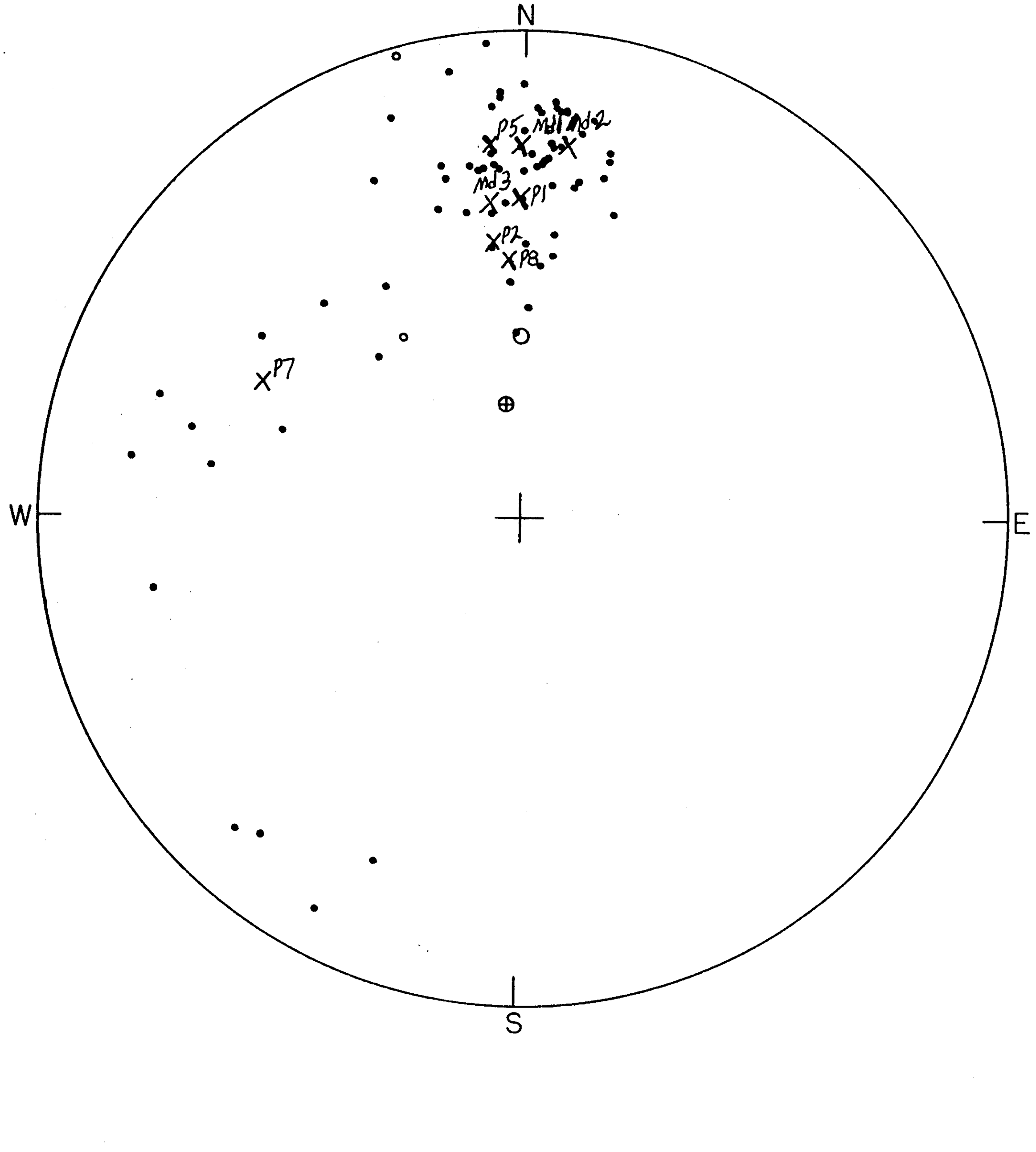


FIG. I-14 MD. AND WEST PA.-SEDIMENTARY (CORR. for GEOL.)

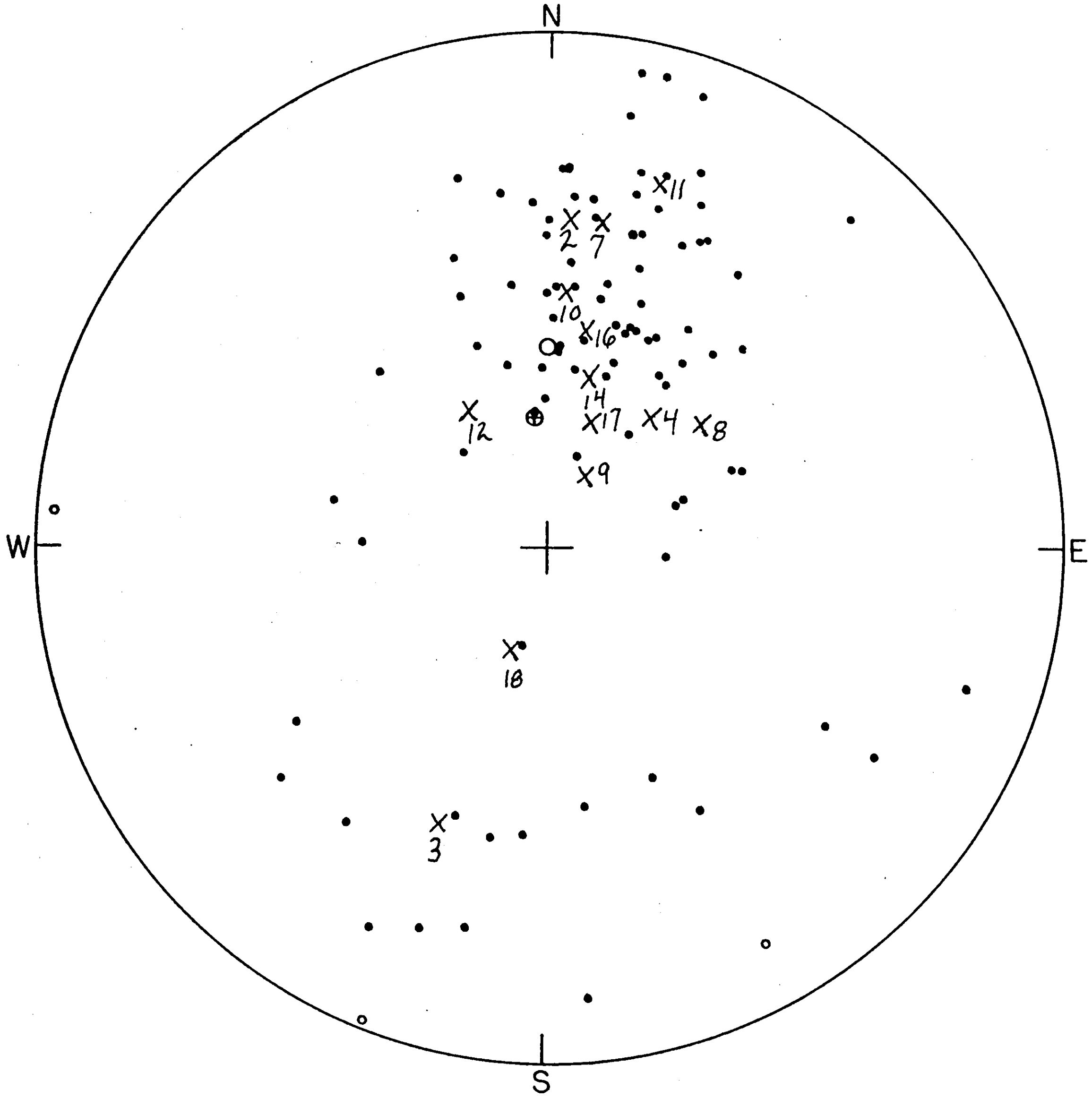


FIG. I-15 VA.-SEDIMENTARY

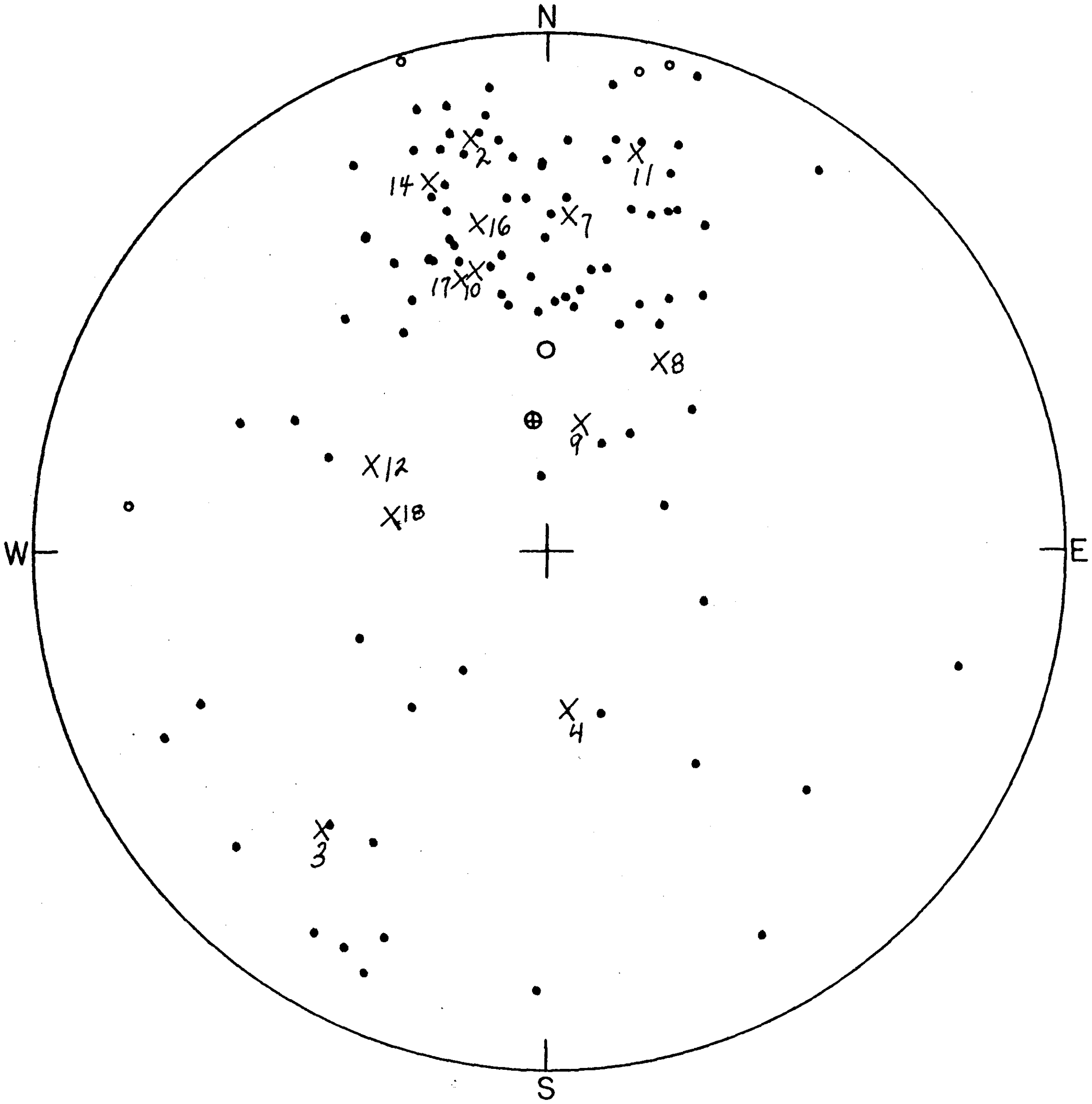


FIG. I-16 VA.-SEDIMENTARY (CORR. for GEOL.)

intensities in excess of 550 Oe. to complete the demagnetization test. It seemed, however, that the a.c. treatment would have brought the average direction of magnetization of the outcrops into much better agreement, and also reduced the scatter within each outcrop.

It may be noticed in the magnetization plots that some of the cores show a tendency toward reversed magnetization. To determine whether the magnetization was reversed or normal, several samples from each outcrop were demagnetized in fields up to 550 Oe. If their directions of magnetization moved toward the reversed direction, the outcrop was labeled reversed (noted by R under remarks in Table I-2). If the movement was in the normal direction, or noncommittal, the outcrop was labeled normal. It is possible, of course, that some of the outcrops contained both normally and reversely magnetized sediments, since only a few samples were tested in most cases.

The bedding corrections suggest that the remanent magnetization of most of the outcrops has been stable since deformation because the scatter among the outcrops was reduced.

### 3. North Carolina

In the Deep River Basin of North Carolina, nine outcrops were sampled to represent the three sedimentary formations. The remanent magnetization plots are shown in Fig. I-17 and in Fig. I-18. The reversal pattern is more clearly developed here than in the sedimentary formations of the New Jersey - Virginia areas. Reversals occur in both the Pekin and Sanford formations.

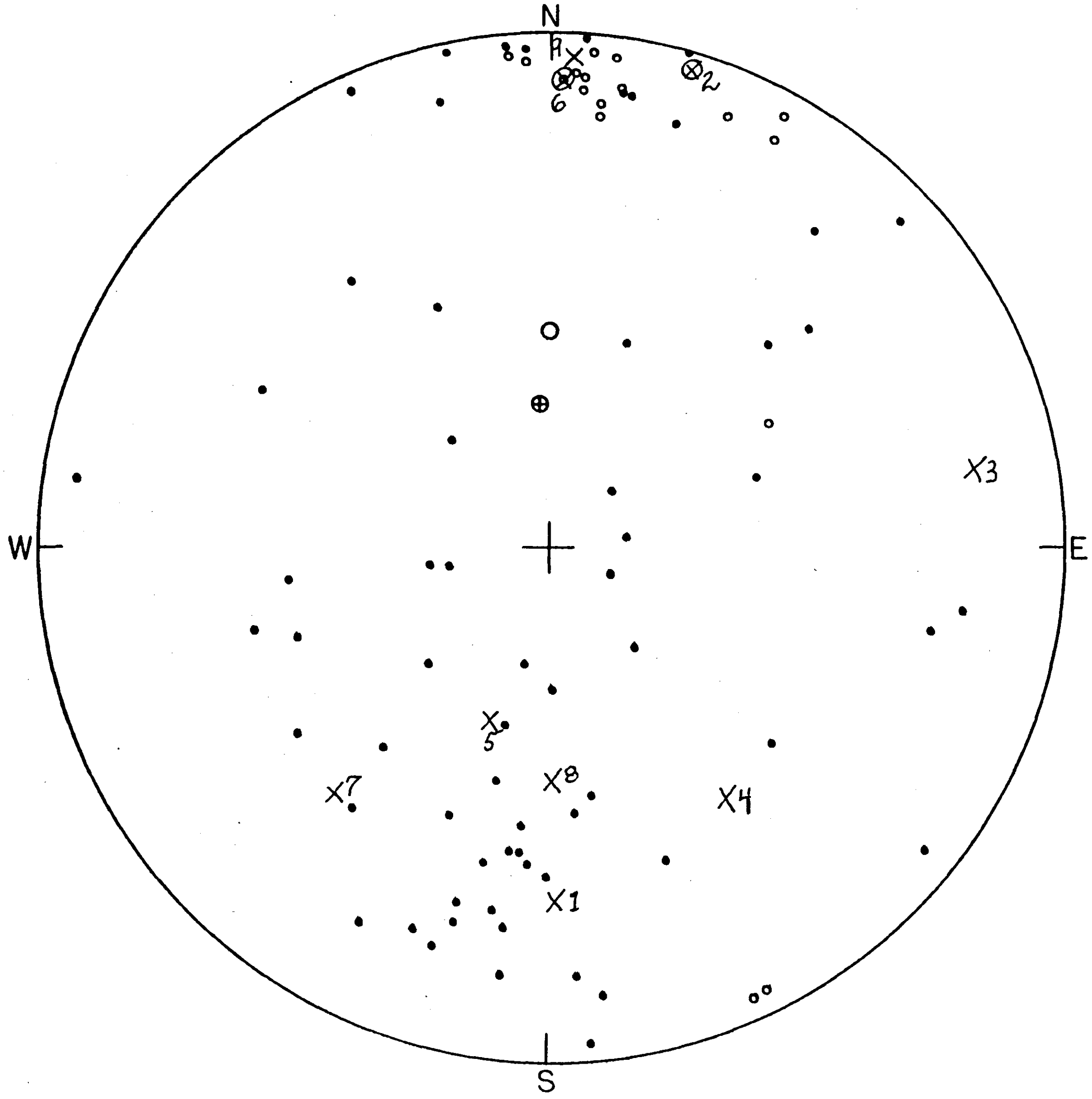


FIG. I-17 N. C. - SEDIMENTARY

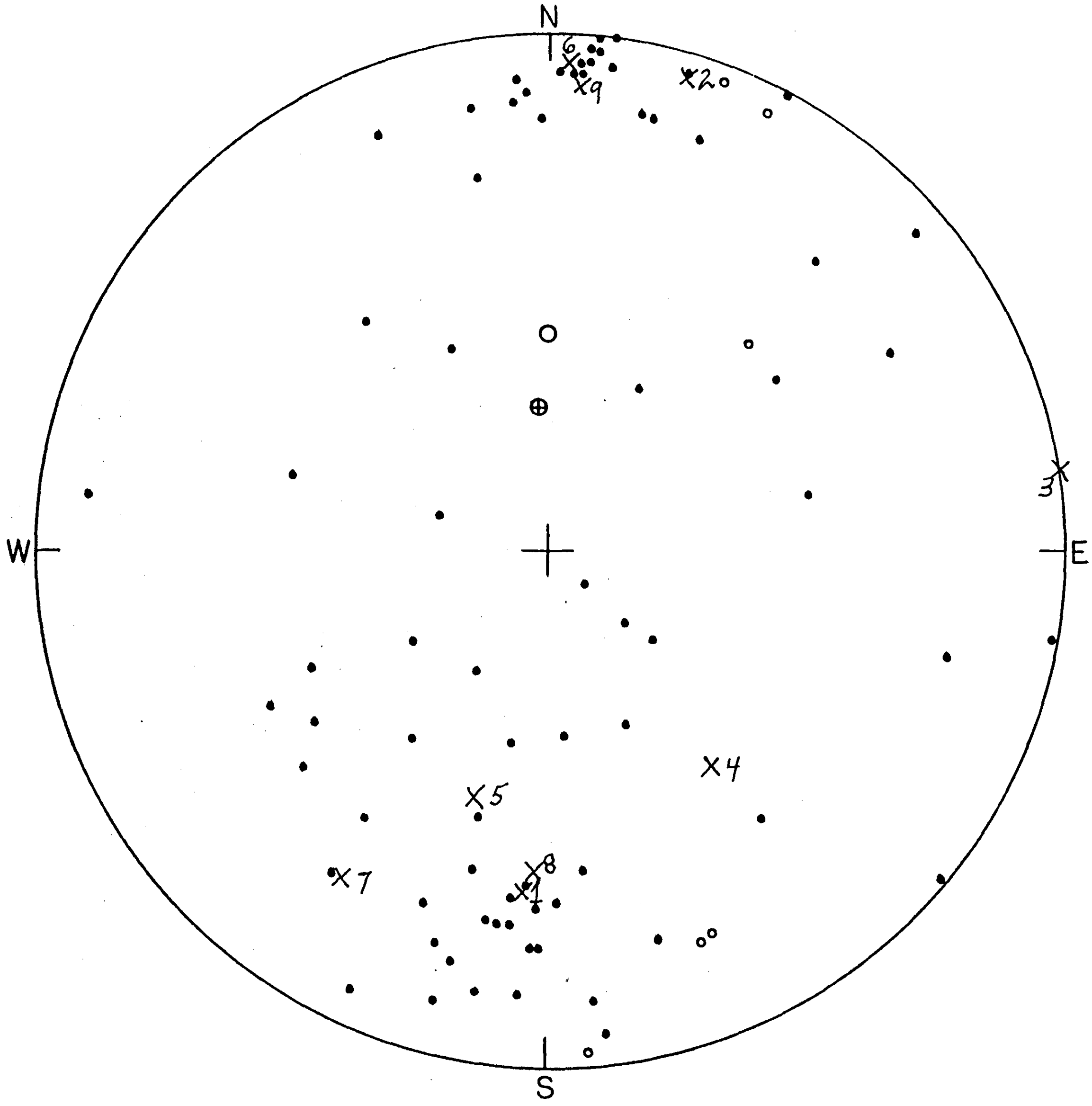


FIG. I-18 N. C.-SEDIMENTARY (CORR. for GEOL.)

The remanent magnetization of outcrop No. 8 was originally scattered between the normal and reversed directions (in the lower hemisphere of the plot). After demagnetization treatment in a 550 Oe. field the magnetization was more clearly reversed. Although the evidence was not conclusive, there was an indication that the reversal was not a complete 180 degrees from the normal direction. The demagnetization treatment was not sufficient to indicate when the "soft" components had been completely removed.

Since the bedding corrections do not reduce the scatter of the remanent magnetization in this area, they cannot be used as a test for stability. When an overall comparison is made, however, between the several basins, the bedding corrections offer much more conclusive evidence of stability (see Part II).

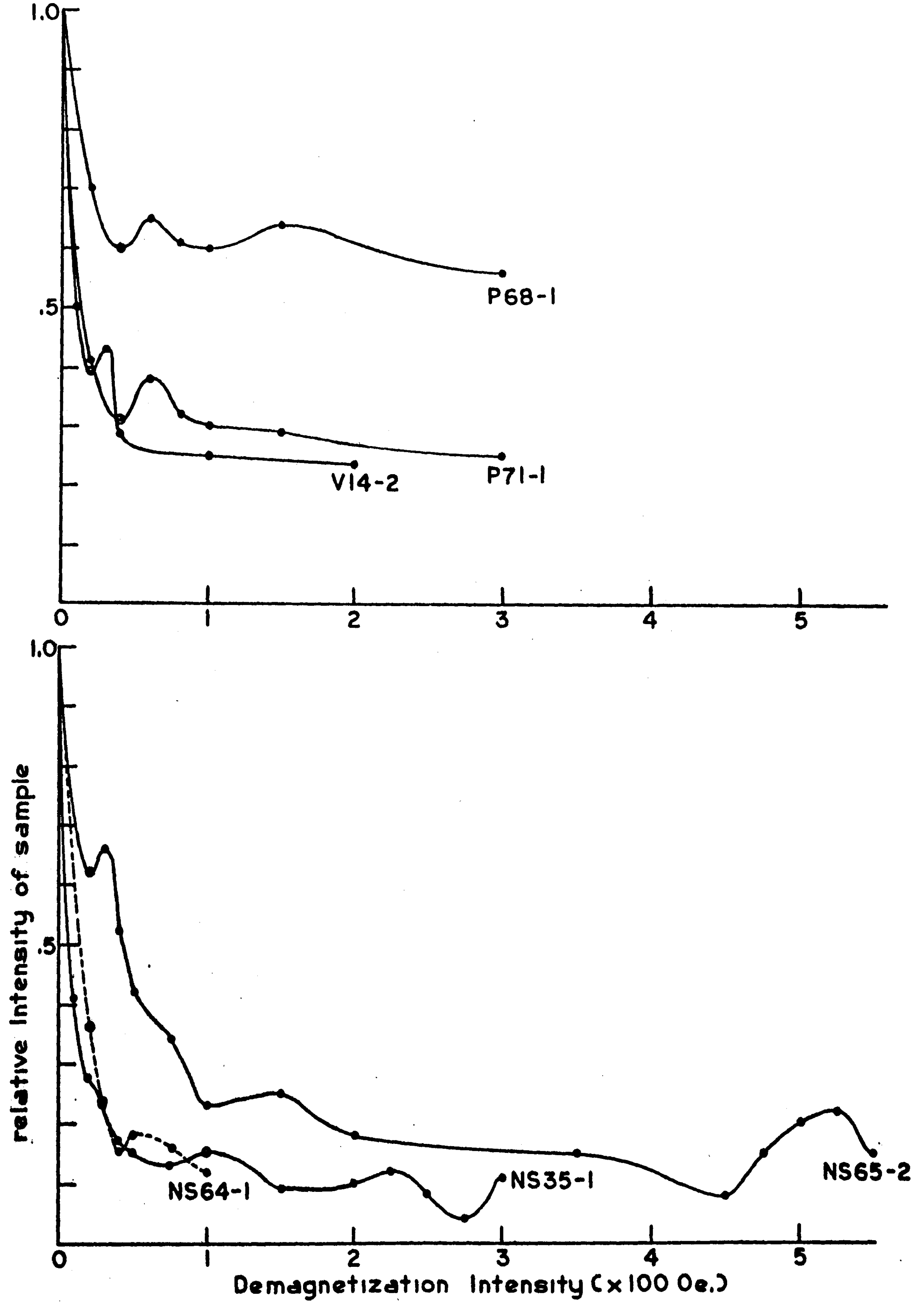


FIG. I-19 INTENSITY DEMAGNETIZATION CURVES

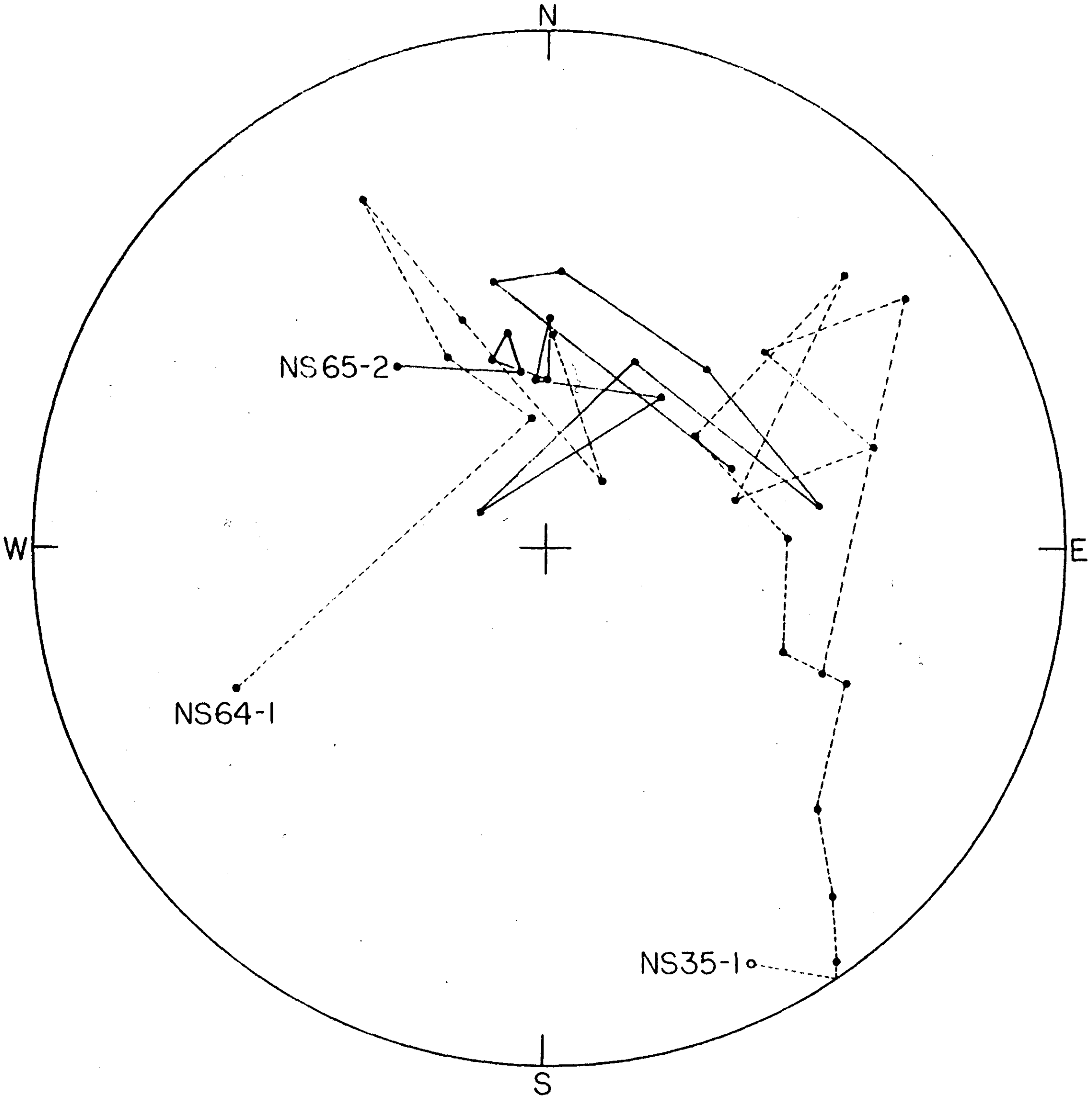


FIG. I -20 MAGNETIC VECTOR DEMAGNETIZATION PATHS

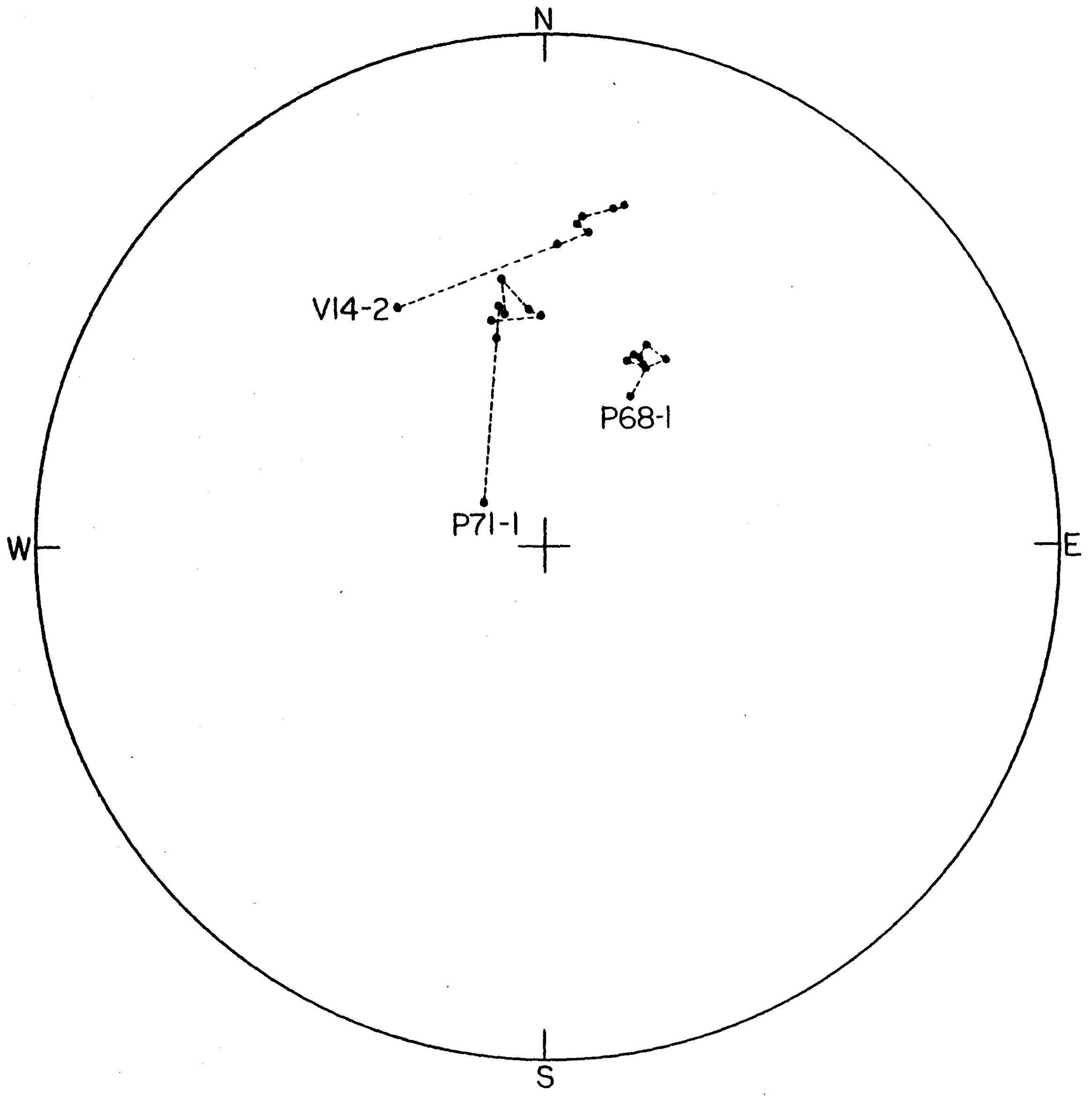


FIG. I-21 MAGNETIC VECTOR DEMAGNETIZATION PATHS

# TABLE I-1

## IGNEOUS ROCK DATA

| No. | C/S | Formation | Geologic Attitude<br>Stk. E | Dip | Location<br>Long. W<br>° ' " | Lat. N<br>° ' " | $I \times 10^4$<br>cgsu/cc | $\theta_{95}$ | k | Pole Position<br>Long. E | Lat. N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NS2 | 4/11 | North Mountain | 35 | 10 W | 64-23-40 | 45-13-40 | 8.9 | 4½ | 137 | 71½ | 70½ |
| NS3 | 4/10 | " " | 35 | 10 W | 64-23-31 | 45-13-45 | | | | | |
| NS4* | 8/24 | " " | 121 | 10 S | 64-25-55 | 45-18-49 | 5.7 | 28½ | 4.7 | 98½ | 74 |
| NS5* | 9/32 | " " | 51 | 10 N | 64-31-34 | 45-13-23 | 21 | 20½ | 7.1 | 153½ | 59½ |
| NS6 | 2/12 | " " | 70 | 14 N | 64-30-57 | 45-13-51 | 8.7 | 35 | 54 | 148 | 70 |
| NS7* | 6/38 | " " | 74 | 9½N | 64-47-50 | 45-05-11 | 8.3 | 35½ | 4.5 | 346½ | 74½ |
| NS8* | 5/16 | " " | 74 | 9½N | 64-45-50 | 45-05-52 | 6.8 | 16 | 29 | 119½ | 77½ |
| NS9 | 7/14 | " " | 68 | 5 S | 65-04-24 | 45-02-26 | 3.9 | 9½ | 42 | 26 | 71 |
| NS10 | 7/17 | " " | Approx. | Flat | 65-13-40 | 44-54-40 | 15 | 3 | 345 | 40½ | 68½ |
| NS11* | 7/15 | " " | 23 | 6 E | 65-19-05 | 44-52-36 | 12 | 8 | 59 | 22½ | 67 |
| NS12* | 7/12 | " " | Approx. | Flat | 65-52-35 | 44-37-07 | 12 | 12½ | 24 | 174½ | 75½ |
| NS13 | 8/15 | " " | Approx. | Flat | 65-55-30 | 44-36-44 | 5.8 | 2 | 667 | 51½ | 61½ |
| M6* | 8/16 | Deerfield | 67 | 37 S | 72-33-06 | 42-36-51 | 12 | 5½ | 105 | 50½ | 43 |
| M7 | 4/6 | " | 52 | 34 S | 72-33-18 | 42-36-50 | 9.8 | 27 | 13 | 7 | 58½ |
| M8 | 7/9 | " | 180 | 20 E | 72-35-05 | 42-32-20 | 15 | 80½ | 1.5 | 330½ | 64 |
| M9* | 8/13 | " | 175 | 10 E | 72-34-01 | 42-29-03 | 8.3 | 11½ | 24 | 48½ | 46 |
| C1* | 8/12 | Hampden | 179 | 20 E | 72-45-03 | 41-53-53 | 18 | 6½ | 72 | 44 | 58 |
| C2 | 6/7 | Talcott | 25 | 10 S | 72-43-00 | 41-26-18 | 8.1 | 9 | 57 | 71 | 58 |
| C3* | 6/8 | " | 170½ | 9½E | 72-50-04 | 41-42-40 | 7.6 | 15 | 22 | 347 | 75 |
| C4* | 3/5 | Holyoke | 170½ | 9½E | 72-49-00 | 41-42-27 | 4.4 | 5 | 625 | 77½ | 52½ |

## TABLE I-1 (cont.)

|  |  |  | Geologic Attitude |  | Location |  |  |  |  | Pole Position |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | C/S | Formation | Stk. E | Dip | Long. W ° ' " | Lat. N ° ' " | Ix10$^4$ cgsu/ss | $\theta_{95}$ | k | Long. E | Lat. N |
| P3 | 8/12 | diabase | 34 | 25 W | 77-05-21 | 39-58-41 | 7.4 | 4 | 176 | 93 | 68 |
| P6 | 6/7 | " | 65 | 12 N | 76-54-50 | 40-03-29 | 27 | 3½ | 394 | 120 | 62½ |
| P9* | 8/8 | " | 75 | 15 N | 75-32-13 | 40-20-36 | 11 | 8 | 48 | 131½ | 66½ |
| P10* | 9/15 | " | 75 | 15 N | 75-32-19 | 40-21-10 | 6.3 | 2½ | 396 | 117 | 63½ |
| P11 | 8/10 | " | 70 | 15 N | 75-28-01 | 40-16-02 | 3.8 | 3 | 389 | 136½ | 71½ |
| P14 | 8/19 | " | 55 | 15 N | 75-19-36 | 40-23-31 | 2.7 | 3 | 327 | 102 | 62½ |
| P16 | 6/6 | " | 80 | 30 N | 74-57-50 | 40-20-18 | 15 | 10 | 48 | 151 | 52½ |
|  |  |  |  |  |  |  |  |  |  |  |  |
| V1* | 15/24 | " | 25 | 30 W | 77-31-01 | 39-04-07 | 12 | 4½ | 77 | 125 | 62 |
| V5* | 8/14 | " | 15 | 10 W | 77-34-25? | 38-44-59? | 4 | 11 | 26 | 172½ | 58½ |
| V6* | 8/16 | " | 13 | 15 W | 77-48-48 | 38-31-45 | 7.4 | 12½ | 20 | 353½ | 88 |

---

| | |
|---|---|
| * | Samples required a.c. demagnetization treatment |
| C/S | Cores/Samples |
| $\theta_{95}$ | Angular radius of Fisher circle of confidence (95% probability) |
| k | Precision factor |
| ? | Location questionable |

## TABLE I-2

## SEDIMENTARY ROCK DATA

| | | | Geologic Attitude | | Location | | | | | Pole Position | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | C/S | Formation | Stk. E | Dip | Long. W ° ' " | Lat. N ° ' " | $\mathrm{Ix10}^5$ cgsu/cc | $\theta_{95}$ | k | Long. E | Lat. N | Remarks |
| M1 | 7/7 | Turners Falls | 71 | 27 S | 72-31-41 | 42-36-22 | 1.8 | | | | | |
| M2 | 4/4 | " " | 73 | 35 S | 72-31-39 | 42-36-20 | 2.7 | | | | | |
| M3 | 9/9 | " " | 76 | 30 S | 72-31-25 | 42-36-23 | 1.4 | | | | | |
| M4 | 8/11 | " " | 45 | 33½ S | 72-33-05 | 42-36-48 | 3.0 | | | | | |
| M5* | 8/28 | " " | 65½ | 39 S | 72-31-46 | 42-37-21 | 1.5 | | | | | |
| M11* | 4/8 | Longmeadow | 99 | 15 S | 72-31-44 | 42-17-08 | 1.1 | | | | | |
| NJ1 | 7/7 | Lockatong | 65 | 7 N | 74-55-07 | 40-30-46 | 3.9 | 4½ | 168 | 107½ | 63½ | N |
| NJ2 | 11/13 | Brunswick | 70 | 7 N | 75-04-08 | 40-27-29 | 2.6 | 7½ | 43 | 66 | 65 | N |
| NJ3 | 8/11 | " | 62 | 10 N | 75-04-06 | 40-27-07 | 3.5 | 10 | 36 | 81½ | 73½ | N |
| NJ4 | 6/9 | Lockatong | 75 | 15 N | 75-03-45 | 40-25-58 | 2.6 | 16½ | 18 | 139½ | 61½ | N |
| P1* | 8/10 | Gettysburg | 44 | 21 W | 77-16-46 | 39-49-11 | 1.4 | 6½ | 69 | 105½ | 69 | N |
| P2 | 9/11 | New Oxford | 19 | 10 W | 77-07-59 | 39-45-40 | 0.51 | 7½ | 46 | 122 | 73½ | N |
| P4 | 8/8 | " " | 55 | 36 N | 76-58-13 | 39-58-02 | $1x10^{-6}$ | | | | | |
| P5 | 10/14 | Gettysburg | 48 | 40 N | 77-01-30 | 40-02-05 | 1.6 | 6½ | 58 | 113½ | 61½ | N |
| P7 | 5/5 | New Oxford | 25 | 24 W | 76-52-48 | 40-01-43 | 0.18 | 54½ | 2.9 | 196 | 34½ | R |
| P8 | 10/14 | " " | 43 | 20 W | 76-45-56 | 40-02-55 | 0.47 | 35 | 2.8 | 216½ | 14½ | R |
| P12 | 7/7 | Brunswick | 70 | 14 N | 75-27-03 | 40-11-30 | 1.6 | 40 | 3.3 | 219 | - 8 | R |
| P13 | 2/2 | " | 72 | 15 N | 75-27-33 | 40-14-57 | 1.4 | 23½ | 227 | 139 | 70 | N |
| P15 | 13/16 | Lockatong | 30 | 7 W | 75-09-40 | 40-28-40 | 1.2 | 43 | 1.9 | 138½ | 37½ | R |
| Md1 | 9/12 | Gettysburg | 101 | 31 N | 77-20-00 | 39-40-53 | 2.3 | 6 | 71 | 104 | 62½ | N |
| Md2 | 15/20 | " | 57 | 10 N | 77-13-49 | 39-40-55 | 2.6 | 3 | 161 | 91 | 61½ | N |
| Md3 | 6/6 | " | 74 | 30 N | 77-18-23 | 39-43-13 | 1.7 | 19½ | 13 | 115 | 52½ | N |

TABLE I-2 (cont.)

|  |  |  | Geologic Attitude |  | Location |  |  |  |  | Pole Position |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | C/S | Formation | Stk. E | Dip | Long. W ° ' " | Lat. N ° ' " | $I \times 10^5$ cgsu/cc | $\theta_{95}$ | k | Long. E | Lat. N | Remarks |
| V2 | 6/7 | sediments | 29 | 31 W | 77-37-18 | 39-01-36 | 5.1 | 4½ | 202 | 125 | 59 | N |
| V3 | 8/14 | " | 5 | 27 W | 77-38-28 | 38-49-32 | 0.8 | 15 | 15 | 242 | -25 | R |
| V4 | 8/13 | " | 14 | 22 W | 77-36-26 | 38-47-06 | 1.6 | 32½ | 3.9 | 242 | 82 | N |
| V7 | 7/7 | " | 7 | 6½W | 78-04-04 | 38-18-30 | 4.8 | 7 | 81 | 91½ | 70½ | N |
| V8 | 9/12 | " | 51 | 14 N | 78-15-18 | 38-11-03 | 0.59 | 21½ | 6.7 | 7 | 67 | N |
| V9 | 9/21 | " | 86 | 9 N | 78-16-01 | 38-10-34 | 1.2 | 44½ | 2.4 | 312 | 72 | N |
| V10 | 2/2 | " | 15 | 19 W | 78-31-21 | 37-49-22 | 1.4 | 78½ | 12 | 152 | 72 | N |
| V11 | 11/16 | " | 40 | 11 W | 78-37-46 | 37-44-46 | 4.2 | 6 | 63 | 74½ | 62 | N |
| V12 | 3/5 | Border Congl. | 149 | 19 W | 79-08-23 | 36-57-24 | 2.3 |  | 1.3 | 216½ | 40 | R |
| V13 | 4/4 | " " | 31 | 23 W | 79-10-43 | 36-54-38 | $1 \times 10^{-6}$ |  |  |  |  |  |
| V14 | 4.7 | sediments | 45 | 45 N | 79-18-15 | 36-49-43 | 1.4 | 12½ | 57 | 140 | 61½ | N |
| V16 | 10/12 | " | 41 | 28 W | 79-41-10 | 36-37-45 | 3.0 | 9½ | 28 | 134½ | 70 | N |
| V17 | 9/12 | " | 46 | 32 N | 79-41-32 | 36-37-46 | 3.6 | 37 | 2.9 | 159 | 71½ | N |
| V18 | 8/10 | " | 49 | 30 N | 79-41-36 | 36-38-10 | 2.1 | 77 | 1.5 | 227 | 33½ | R |
| NC1 | 8/14 | Pekin | 15 | 10 E | 79-29-10 | 35-23-00 | 1.3 | 25 | 5.9 | 282½ | -38 | R |
| NC2 | 8/12 | " | 44 | 10 E | 79-25-55 | 35-26-45 | 6.6 | 14 | 16 | 73 | 53½ | N |
| NC3 | 6/12 | Sanford | 25 | 20 E | 79-22-09 | 35-27-27 | 4.4 | 65 | 1.5 | 16½ | 8 | N |
| NC4 | 14/28 | " | 68 | 7 S | 79-15-45 | 35-27-31 | 1.5 | 54 | 1.5 | 297½ | 12½ | N |
| NC5 | 12/24 | " | 99 | 12 S | 79-14-38 | 35-32-28 | 0.98 | 15 | 9.4 | 265½ | -23 | R |
| NC6 | 8/9 | Cumnock | 70 | 18 S | 79-14-40 | 35-34-13 | 4.8 | 3 | 330 | 97½ | 58 | N |
| NC7 | 8/16 | Sanford | 74 | 17 S | 79-12-20? | 35-27-50? | 0.92 | 42 | 2.7 | 249 | -13½ | R |
| NC8* | 9/18 | " | 105 | 15 S | 79-12-10? | 35-28-20? | 0.79 | 19½ | 3.3 | 279 | -33½ | R |
| NC9 | 7/9 | Pekin | 25 | 14 E | 79-00-10 | 35-37-45 | 1.5 | 10½ | 34 | 92½ | 59½ | N |

N Normal

R Reversed

# PART II

## PART II: PALEOMAGNETIC RESULTS

It is assumed in this analysis that the geomagnetic field acting during Triassic time approximated on average to that of a dipole field oriented along the earth's axis of rotation. Runcorn (1959) has shown that the relative rotation of the core and mantle infers that even if a permanent non-dipole field could be generated in the core, the non-axial parts would be averaged out by observations over a long time at the earth's surface. Since the deposition period of sedimentary rocks is relatively long, the average remanent magnetization of samples collected through a considerable thickness of one rock formation should represent the axial magnetic field (provided, of course, that the magnetization is stable). It is, however, also expected that the remanent magnetization of the igneous rocks may show the influence of secular variations of the magnetic field.

The location of the north-seeking pole of the dipole field, which would have produced the remanent magnetization in a given core, has been obtained for each core. The magnetic inclination (I) and the latitude ($\lambda$) are related by:

$$\text{Tan } I = 2 \text{ Tan } \lambda$$

where $\lambda$ is the latitude of the site location with respect to the pole position. By the method of Fisher (1953), the circle of confidence (for 95% probability) was calculated for the pole positions of each outcrop. The data is given in Table I-1 and Table I-2.

The circles of confidence are also plotted on an equal-area polar projection of the northern hemisphere of the globe. Since the latitudes of most pole positions are greater than 60 degrees north, the circles of confidence are actually plotted as circles. The error introduced is very small and should in no way affect an interpretation. When the pole position occurs in the southern hemisphere, the corresponding south pole is plotted. South poles are indicated by open circle plots with dashed circles of confidence.

The pole positions for the igneous rocks are plotted in Fig. II-1, Fig. II-2, and Fig. II-3. The only agreement among the three areas seems to be those pole positions which reflect the influence of the present magnetic field.

Fig. II-4 shows the pole positions before and after bedding corrections for some of the more stable outcrops in the Connecticut Valley and Pennsylvania - Virginia areas. They are shown by open and closed points respectively, and are joined by straight lines. It is possible then that the magnetization of these two areas has been stable since deformation. The bedding correction for the Nova Scotia samples was too small to be of any significance.

Fig. II-5, Fig. II-6, and Fig. II-7 give the pole positions for the sedimentary rocks. Fig. II-8, like Fig. II-4, shows the influence of the bedding correction and indicates that the magnetization in most of the sediments may have been stable since deformation. Except for the Maryland area, the geologic corrections made in local areas, such as New Jersey, Virginia, and North Carolina, do not show conclusively that the magnetizations are stable. When the areas are considered as a whole, however, the evidence is much more convincing.

Since all of the igneous rocks were given an a.c. demagnetization test, the author did not feel justified in eliminating any of

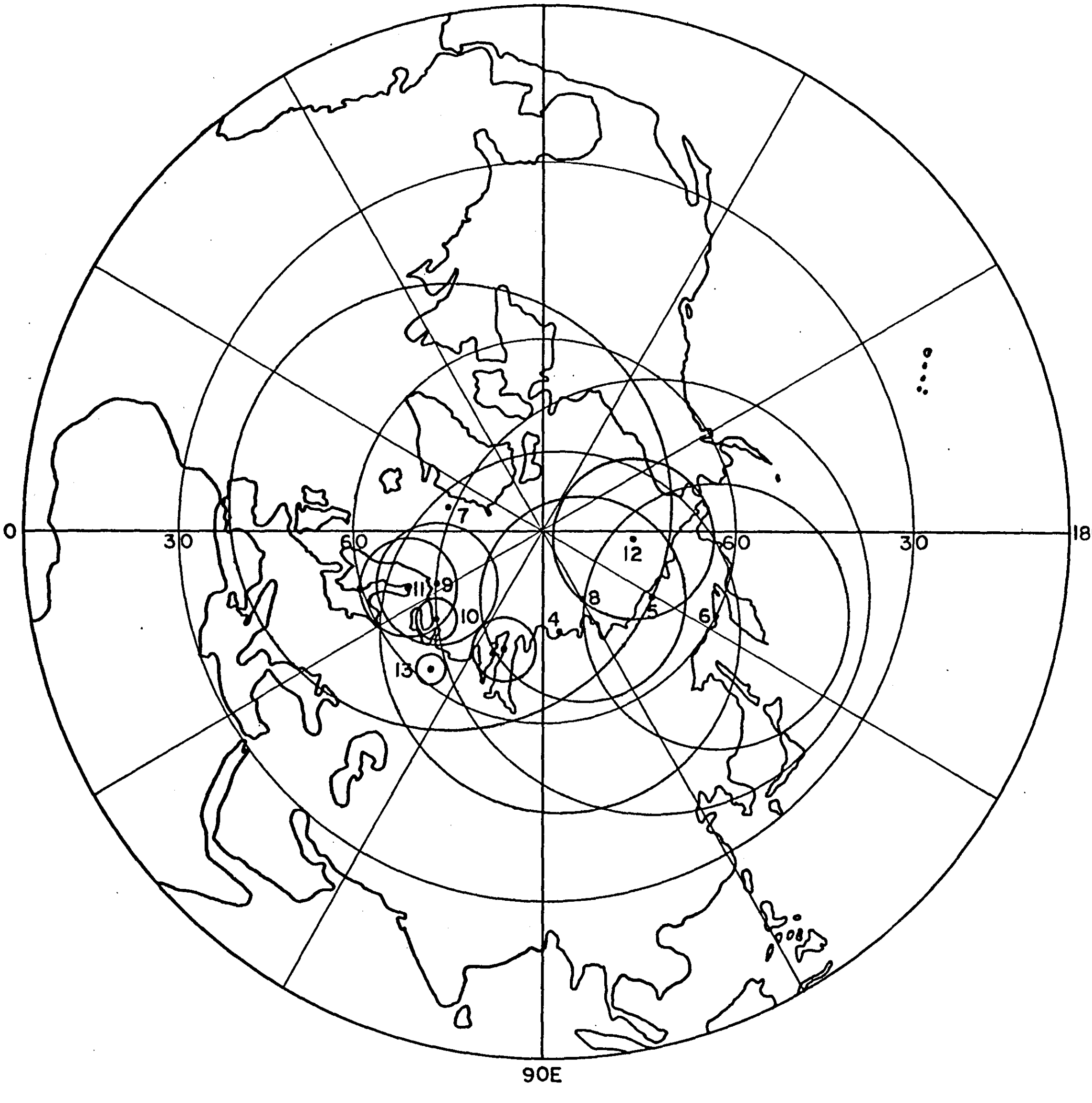


FIG. II-1 NOVA SCOTIA POLE POSITIONS - IGNEOUS

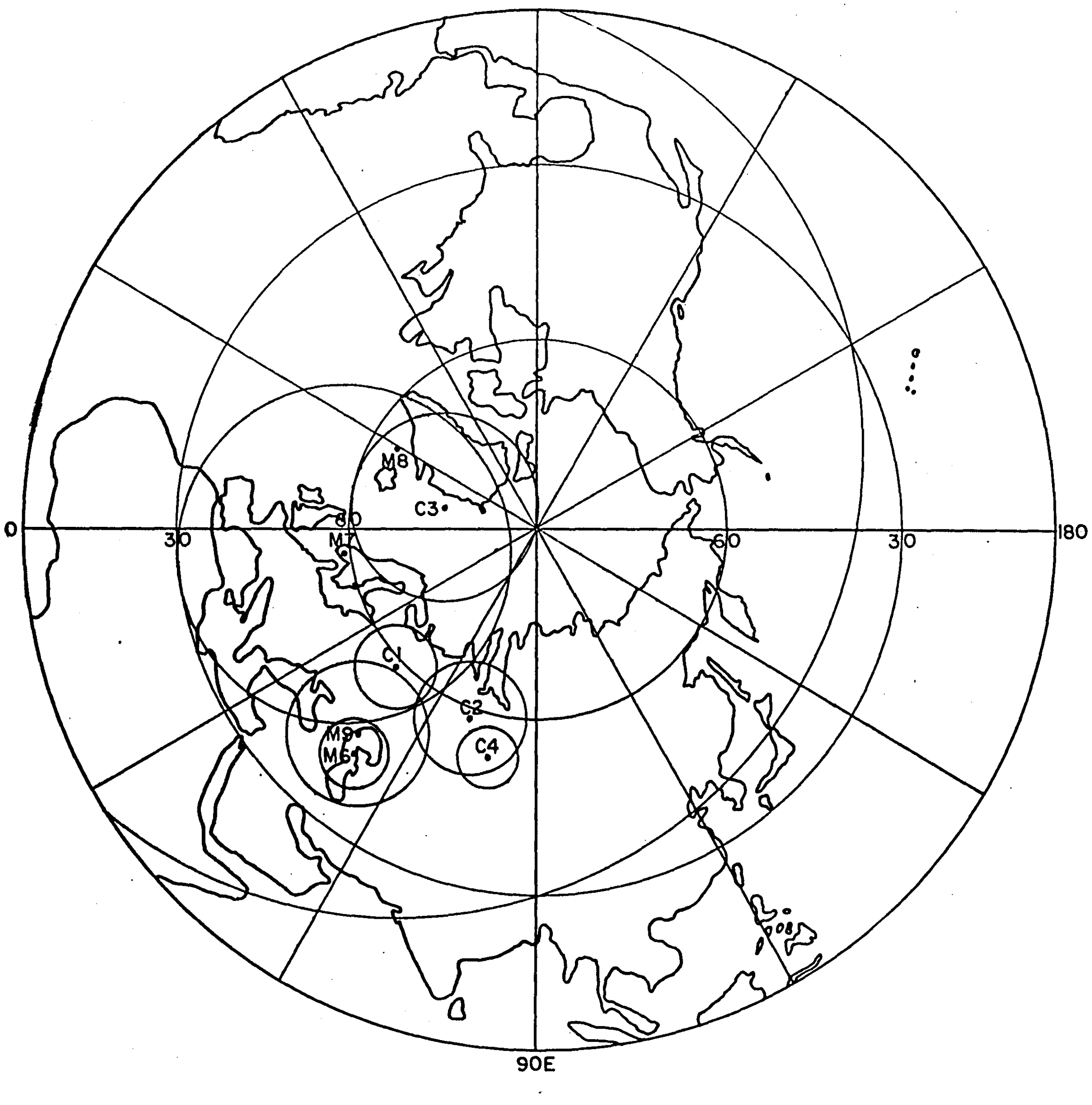


FIG. II-2 MASS. AND CONN. POLE POSITIONS - IGNEOUS

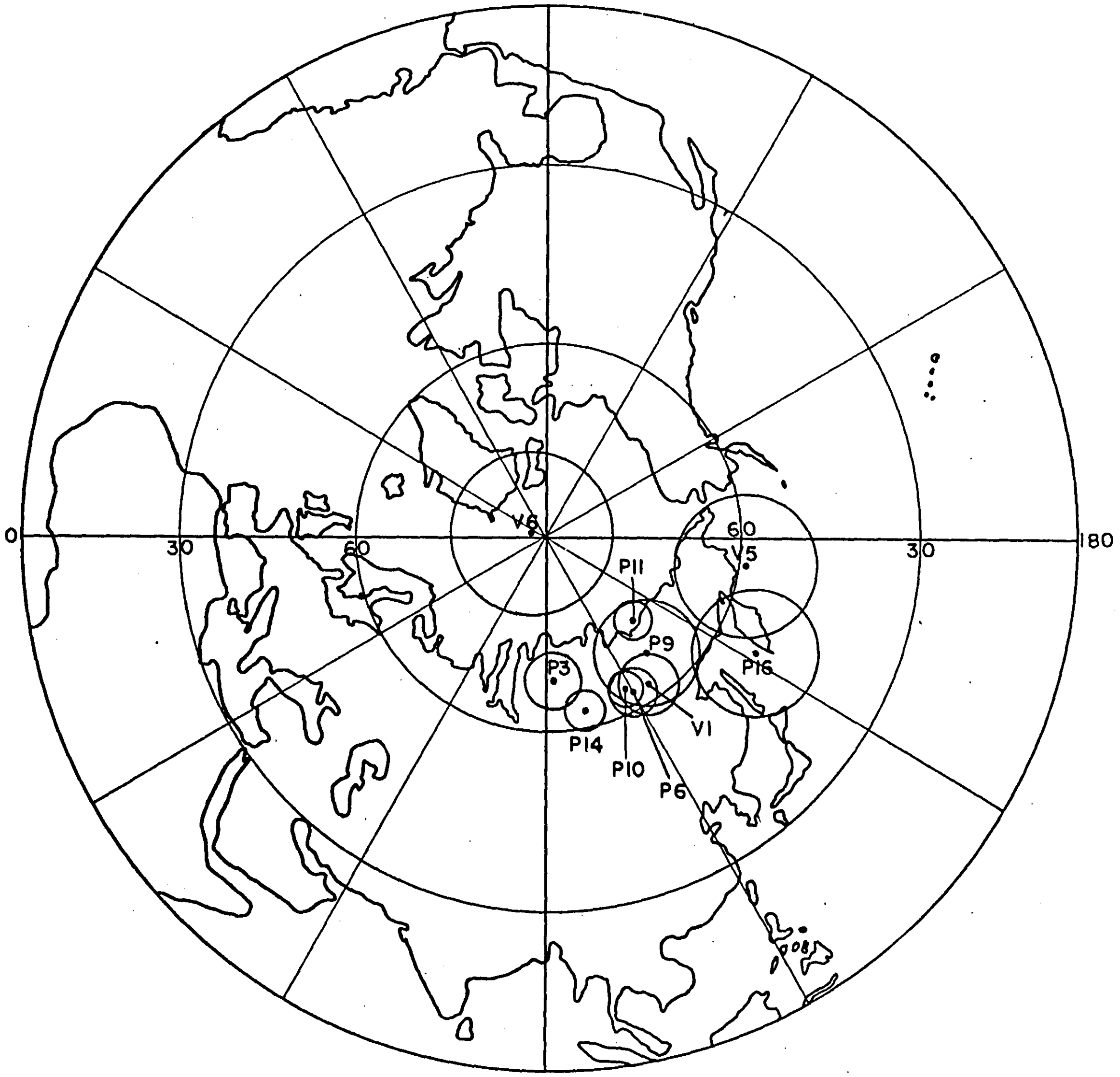


FIG. II-3 PA. AND VA. POLE POSITIONS - IGNEOUS

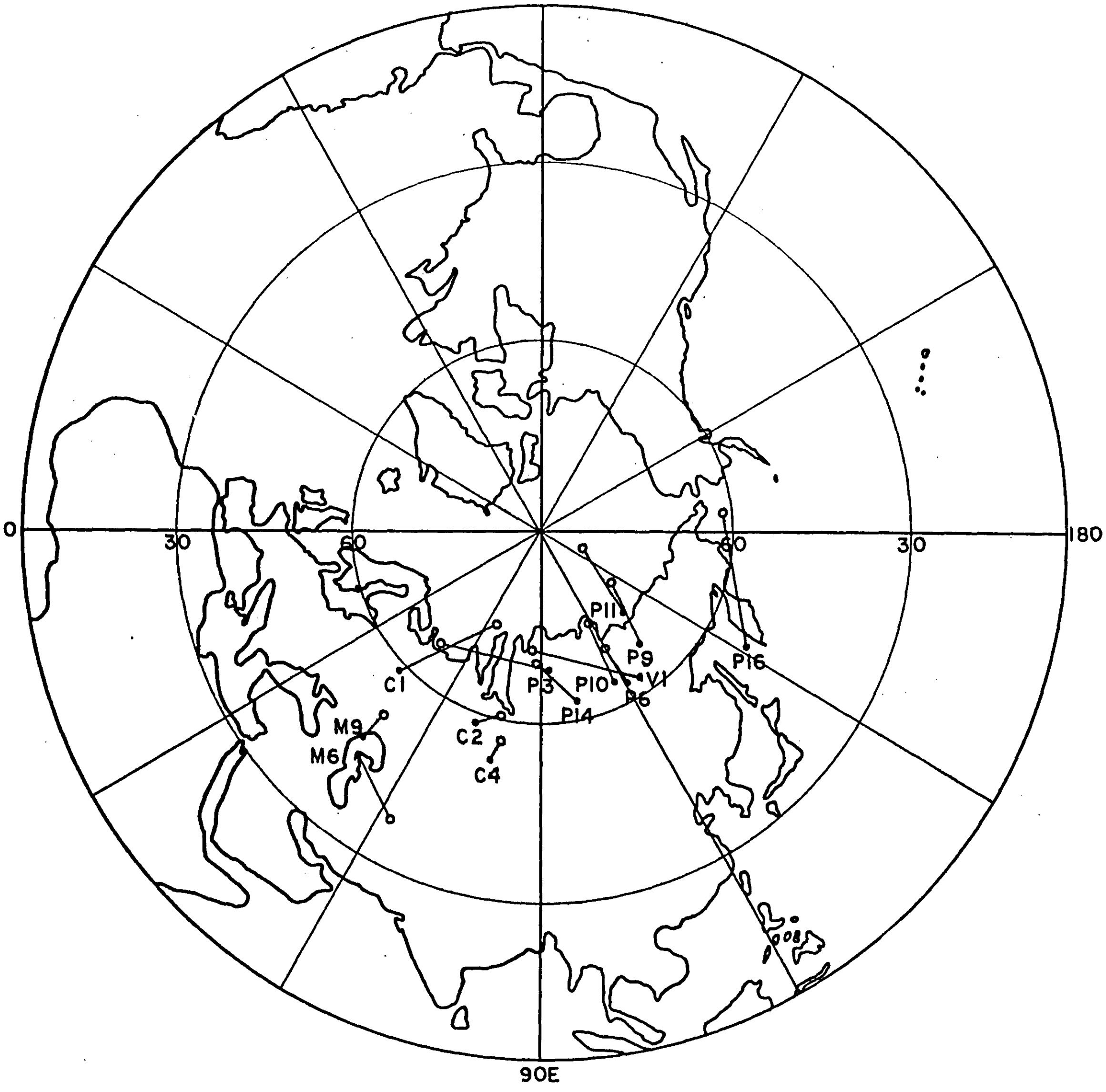


FIG. II-4 INFLUENCE OF BEDDING ON POLE POSITIONS - IGNEOUS

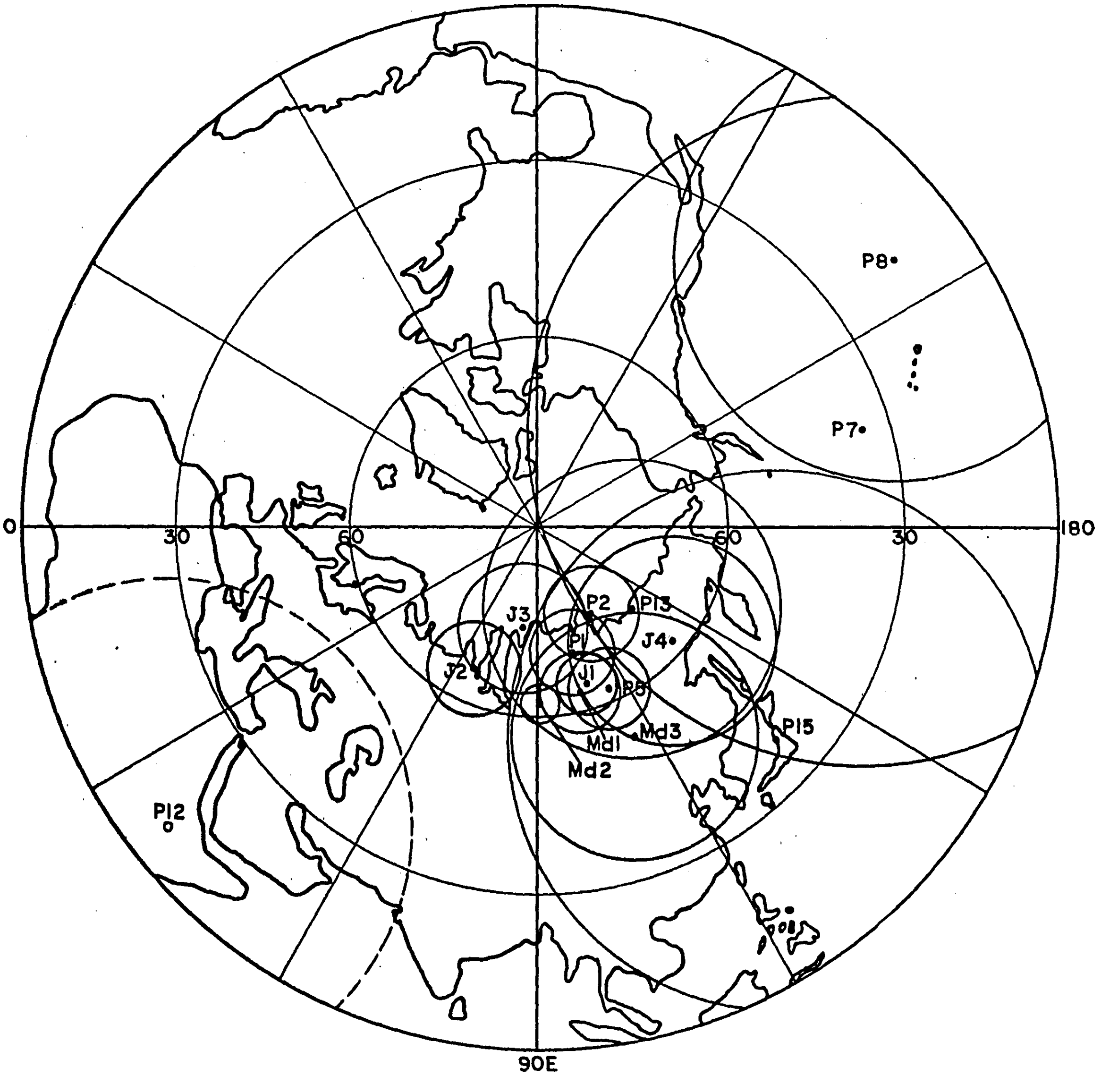


FIG. II-5 N. J., PA. AND MD. POLE POSITIONS - SEDIMENTARY

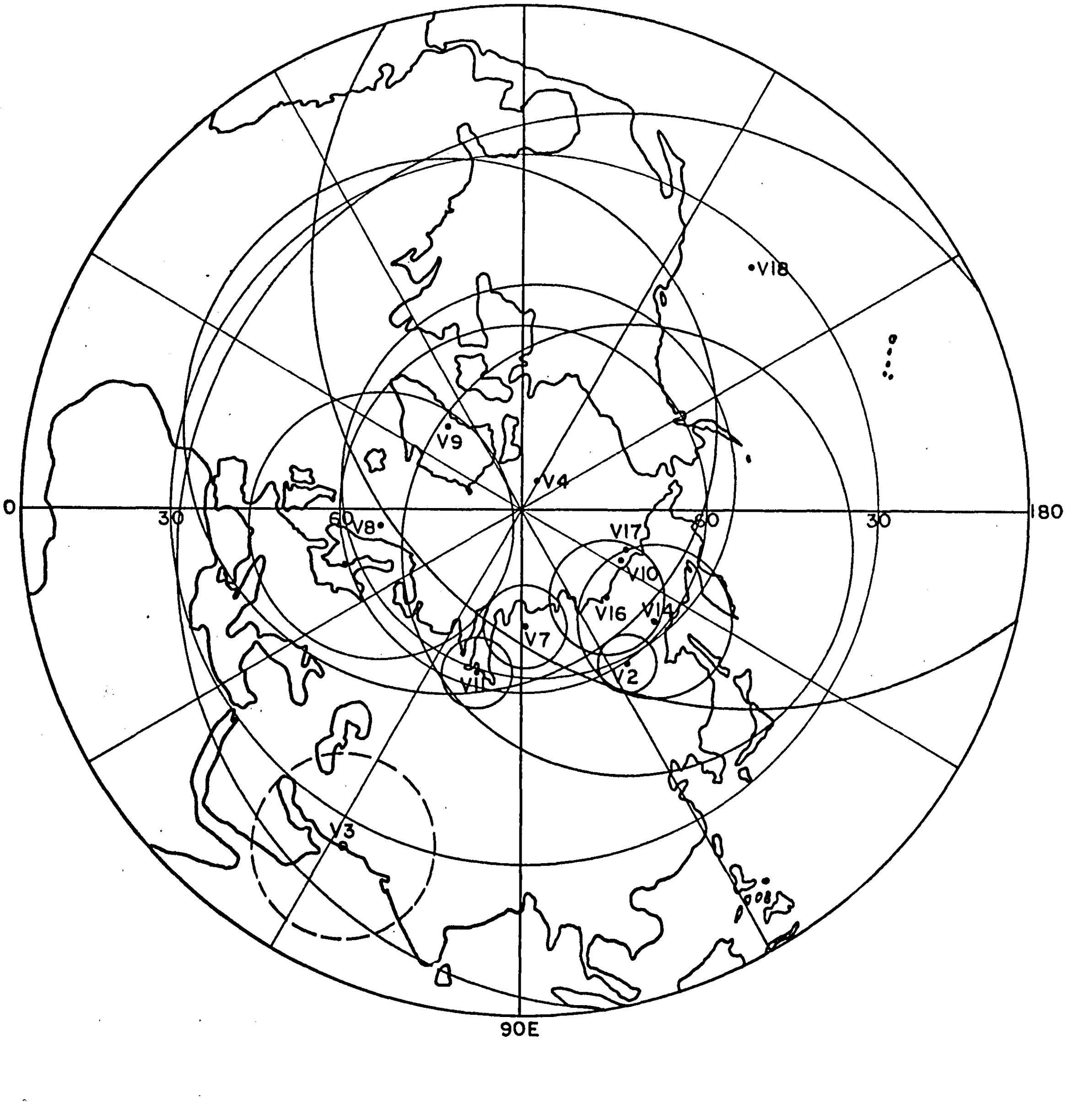


FIG. II-6 VA. POLE POSITIONS - SEDIMENTARY

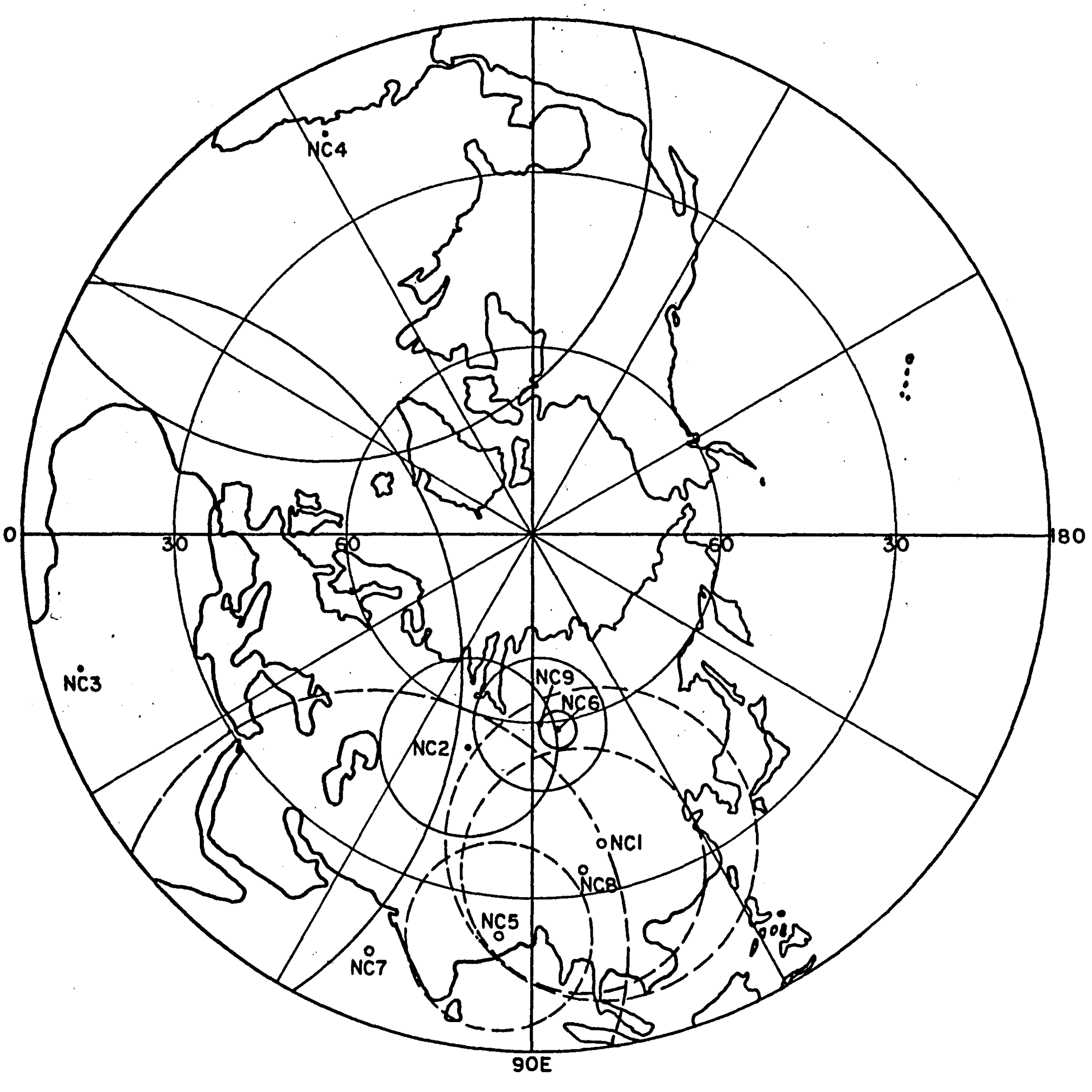


FIG. II-7 N.C. POLE POSITIONS - SEDIMENTARY

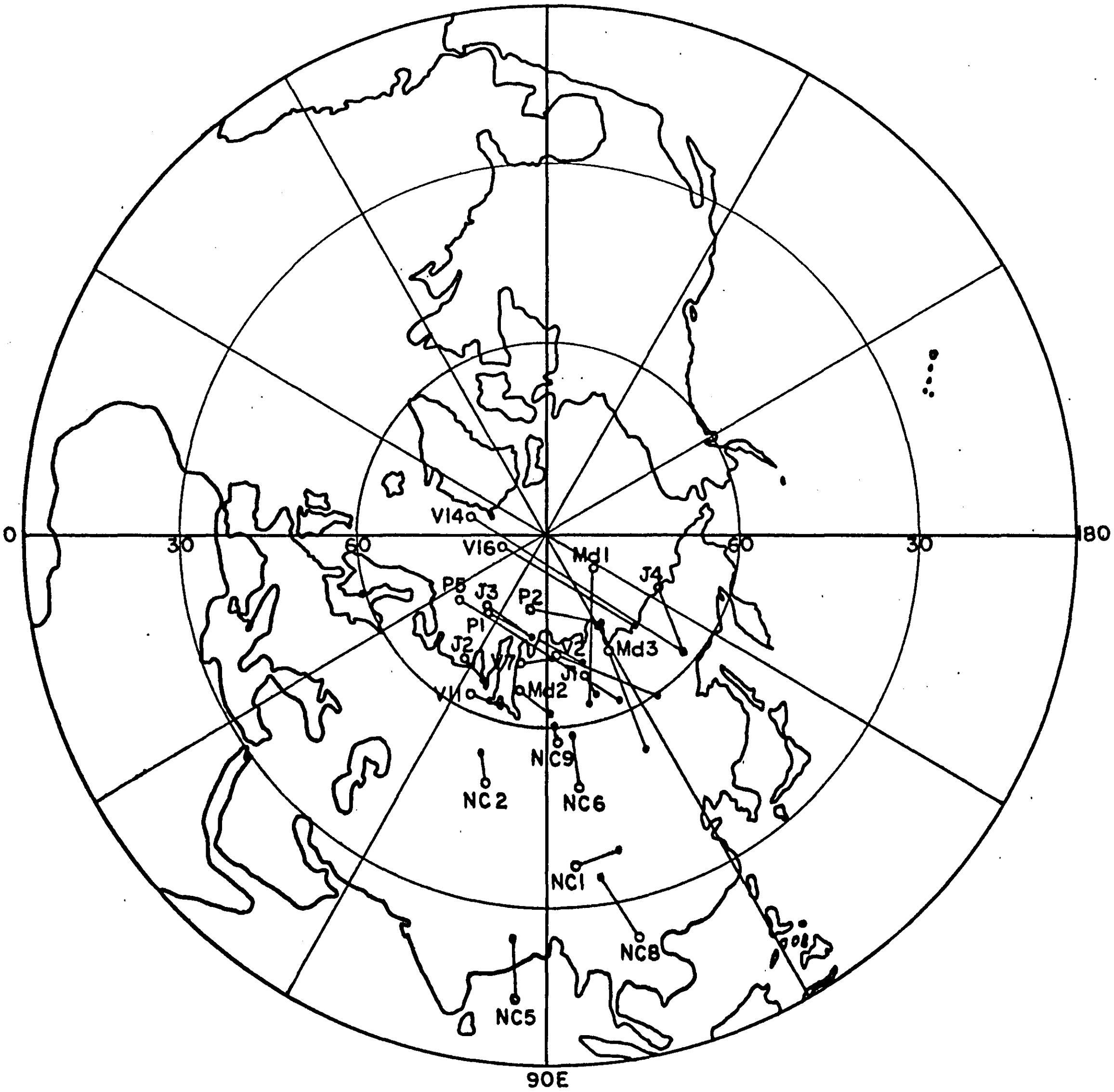


FIG. II-8 INFLUENCE OF BEDDING ON POLE POSITIONS - SEDIMENTARY the results in the final analysis. To obtain the final circle of confidence, the Fisher statistical treatment was applied to the pole positions of the outcrops. This was done for each of the igneous areas because of the basic differences in their pole positions. The results are given in Table II-1.

The tendency of pole positions with small circles of confidence to group together suggests that the results may be unduly influenced by non-Triassic pole positions (i.e., the remanent magnetization of some outcrops is unstable). Any selection of pole positions according to the size of the circle of confidence will, of course, be arbitrary.

Many of the sedimentary outcrops were eliminated from the final analysis for one of the following two reasons:

1. The remanent magnetization was partially reversed.
2. The remanent magnetization contained unstable components that might have been removed by partial a.c. demagnetization.

Eliminations based on the second reason were somewhat arbitrary and only the more obvious cases have been excluded. The final analysis was made on the following outcrops: NJ1, 2, 3, and 4; P1, 2, 5, and 13; Md1, 2, and 3; V2, 7, 11, 14, and 16; NC2, 6, and 9. The final data is given in Table II-1. The average pole positions are plotted in Fig. II-9.

Triassic pole positions based on measurements by other investigators are given in Table II-2 and Fig. II-10 for comparison. This data is reproduced from an analysis by Irving (1959).

TABLE II-1

AVERAGE POLE POSITIONS

| No. | Area | Type | No. of outcrops | $\theta_{95}$ | k | Pole Positions Long. E | Pole Positions Lat. N |
|---|---|---|---|---|---|---|---|
| 1 | N.S. | Igneous | 11 | 10 1/2 | 20 | 77 1/2 | 78 1/2 |
| 2 | Conn. Valley | " | 8 | 15 | 15 | 40 | 61 1/2 |
| 3 | Pa-Va | " | 10 | 8 1/2 | 33 | 129 | 67 1/2 |
| 4 | NJ-NC | Sediments | 19 | 5 | 47 | 105 1/2 | 65 1/2 |

Before a final opinion can be expressed about the geomagnetic field in the eastern United States during Tirassic time, several explanations for the differences in the sedimentary and igneous results must be considered. Four possible reasons for the differences follow:

1. Igneous rocks represent a small interval of time and hence were influenced by the local magnetic field more so than by the average dipole field.
2. The igneous poles represent random walk positions of the geomagnetic field (see Green, 1958), which are averaged out in the sedimentary results.
3. The igneous rocks were not magnetized originally in the direction of the earth's magnetic field.
4. The igneous rocks (and perhaps the sediments) are magnetically unstable.

## TABLE II-2

## TRIASSIC POLE POSITIONS

| | | | Pole Positions | | | | |
|---|---|---|---|---|---|---|---|
| No. | Country | Rock Unit | Long. | Lat. N | $d\chi$ | $d\psi$ | Remarks |
| 46 | England | New Red Sandstone | 131 E | 43 | 7 | 12 | N & R |
| 47 | France | Red sst. of the Vosges | 143 E | 28 | 6 | 12 | R |
| 48 | U.S.A. | Lavas and sediments Connecticut Valley | 88 E | 55 | 8 | 15 | N & R |
| 49 | " | Lavas Connecticut Valley | 90 E | 54 | 6 | 11 | N |
| 50 | " | Brunswickian formation of Newark Series | 93 E | 63 | 3 | 6 | N |
| 51 | " | Springdale sst. | 107 E | 55 | - | -- | N |
| 52 | Bechuanaland | Kgoma Series | 44 W | 54 | 5 | 10 | N |
| 53 | Australia | Brisbane tuff. | 37 W | 39 | - | -- | N & R |

$d\chi$ and $d\psi$ are the semi-axes of the ovals of confidence of the poles, in the direction of and perpendicular to the great circle joining the pole and the site.

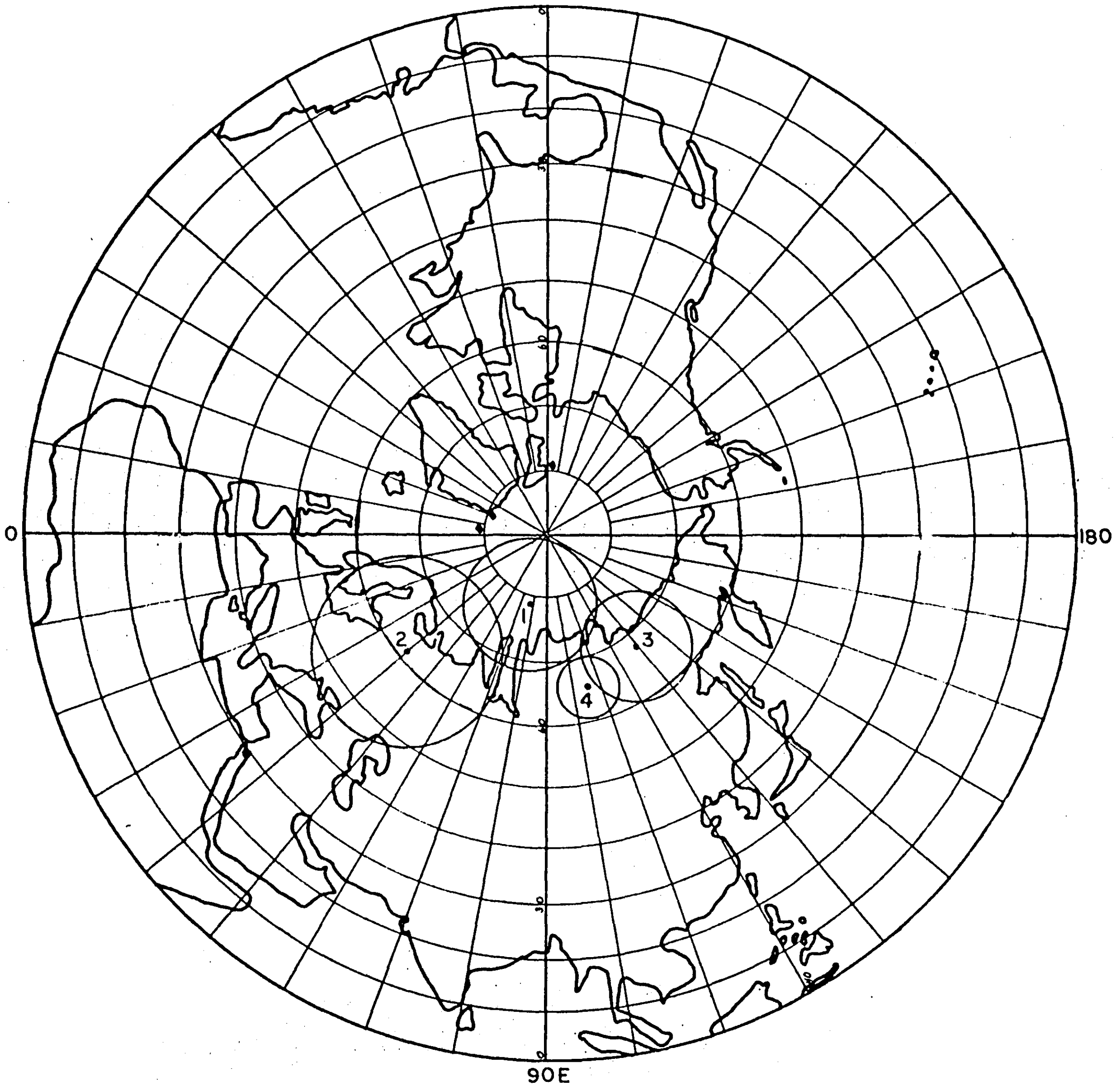


FIG. II - 9 AVERAGE POLE POSITIONS

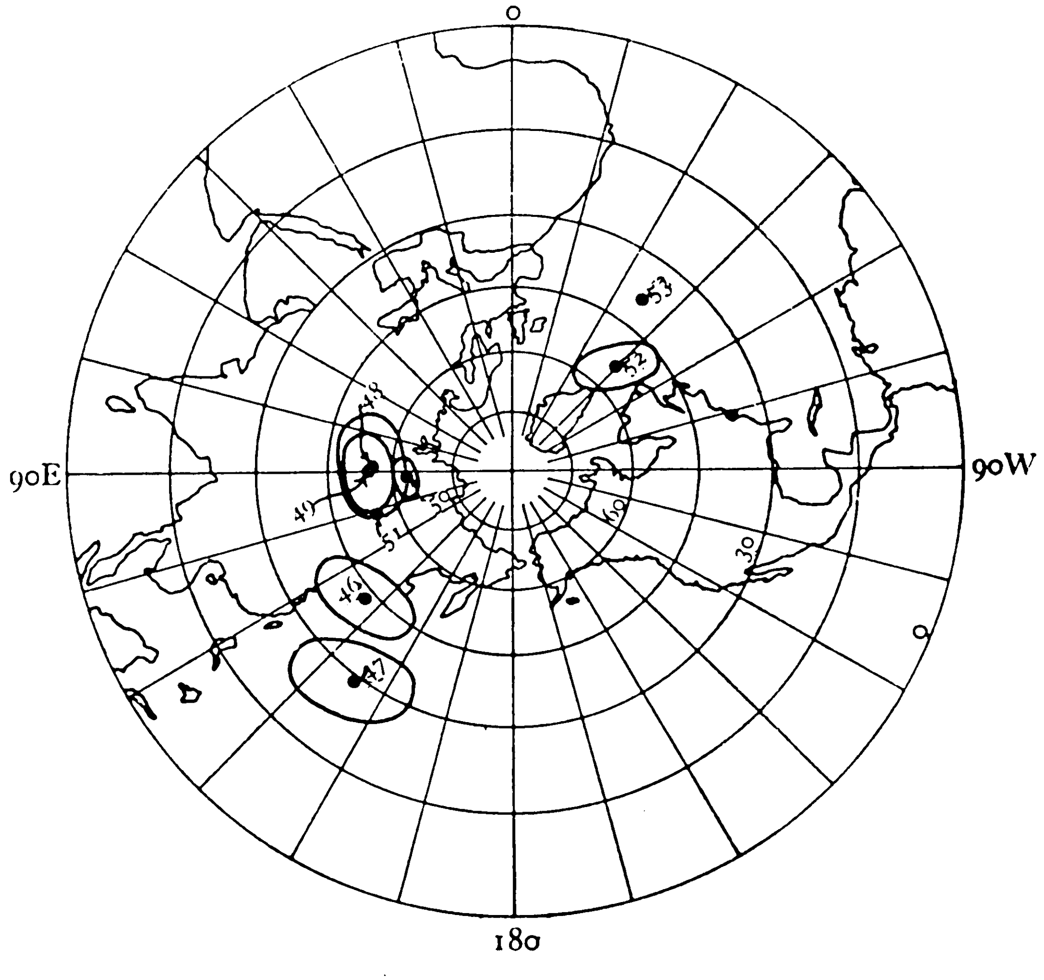


FIG.II-10 —*Triassic pole positions.*(after IRVING)

A discussion of the above four points follows:

1. It is not possible to set a time limit on the formation period of the igneous rocks. However, since the three Connecticut lava flows are separated by several hundred feet of sediments (see Krynine, 1950), it seems likely that the deposition period required at least several thousand years. If this is true, and if the magnitude of the geomagnetic secular variations resembles that of more recent times (see Johnson, 1948), then it is probably that the average pole position of the Connecticut Valley lavas represents the axial dipole field (of course, this is based on just a few samples in time). Further, the pole position of the Connecticut lavas and sediments, No. 48 in Fig. II-10, indicates that the sediments are in fair agreement with those from other areas, whereas they should agree more closely with the lavas. If the magnetization of the sediments was caused by a long-term, post-depositional chemical process, differences in the polar plots of the various sedimentary formations may be smoothed out.
2. Although the random walk theory is a possibility, it seems that there should be some evidence of it in the sedimentary formations, particularly since continental deposition can be quite rapid. Chemical magnetization may have the same effect as that mentioned above.

3. At first this seemed an attractive hypothesis, but the heating experiments described in Part I ruled it out. It is unlikely, moreover, that any physical mechanism, such as anisotropy of magnetization (Grabovsky, 1959) could be so uniform as to give consistent results over large areas. If the rocks possess considerable susceptibility the remanent magnetization may be distorted slightly (Kalashinikov, 1959). Such distortion should, however, be averaged out by samples collected over large areas.

4. Although corrections for geologic attitude indicate that some of the igneous rocks have been stable since deformation (see Fig. II-4), there is still the possibility that they were unstable before deformation. The close agreement between the pole positions of most sediments with those of the Pennsylvania - Virginia igneous rocks further suggests that intrusive rocks may be more stable than extrusive rocks.

From the above discussion then, it appears that point 3 is the least valid, whereas points 1, 2, and 4 are still quite possible. It must also be remembered that the a.c. demagnetization tests reveal a basic difference in the magnetic stability of the igneous rocks. The direction of remanent magnetization in most Nova Scotia and Connecticut Valley igneous samples can be changed appreciably by applying a.c. fields of less than 100-200 Oe., whereas this cannot be done with the Pennsylvania - Virginia igneous samples. Thus, point 4 may be better taken.

## Proposals for Future Sampling

Although this survey has been quite extensive and has revealed several hitherto unknown features of the remanent magnetization of the East Coast Triassic rocks, there are still several areas of sufficient interest to warrant further sampling. Because the northern New Jersey lavas and sediments are similar to those in Connecticut, they may be the same age. An investigation of these, as well as a more complete survey of the Meriden Formation of Connecticut, may be very enlightening.

Since the igneous rocks of Nova Scotia give pole positions that are different from those of the sedimentary formations, a survey of the sediments in this area will also be important.

Although it is doubtful that findings from any of the smaller basins, such as the Dan River and Richmond basins, will alter the final results, it will never the less be worth while to make comparative measurements on the rocks in these areas.

## Conclusions

Several important conclusions, some of which are very tentative, may be drawn from this survey, based on findings from the East Coast Triassic rocks and not necessarily applicable to other areas. They include the following:

1. Results of sedimentary rock measurements from several basins are in close agreement and indicate that factors which might introduce errors into magnetic

studies are either negligible or consistent in their influence.

2. Igneous rocks may not be as reliable as sedimentary rocks for paleomegnetic interpretations.
3. A.c. demagnetization tests can improve the results from both igneous and sedimentary rocks.
4. Results from small numbers of samples may be indicative (i.e., the data given in Table II-2), but extensive sampling is certainly more valid.
5. It seems evident that during the Upper Triassic the geomagnetic field over the eastern United States approximated on average that of a dipole. The axis of this dipole intercepted the earth's surface in the vicinity of Long. 105 1/2 E and Lat. 65 1/2 N.

# APPENDICES

# APPENDIX A: INSTRUMENTATION

## 1. General

The apparatus is of the "rock generator" type (Johnson, 1938; Nugata, 1943; Bruckshaw, 1948; Graham, 1955; Doell, 1955; Hood, 1956) in which the specimen, in the form of a one-inch diameter cylinder one-inch long, is rotated near a coil. The magnetic moment of the rock sample generates an alternating voltage in the coil which is analyzed for phase and amplitude to determine the direction of magnetization and the intensity of magnetization, respectively, of the specimen.

A block diagram of the apparatus is shown in Fig. A-1. The signal generated in the specimen coil is fed into the attenuator and then into the battery-operated General Radio amplifier. From here the signal is sent through a filter and into the phase detector unit.

The photocell and light chopper located at the base of the spinner generate another alternating voltage, referred to as the reference signal. The photocell may be rotated about the spinner and in this way the phase difference between the specimen signal and the reference signal can be varied. This signal is fed into the reference aplifier and phase detector unit which contains a filter that is matched to the one in the circuit associated with the specimen signal.

Various methods for generating the reference signal and measuring the phase have been described in the literature. The spinner arrangement described by Graham (1956), is similar to the apparatus here, while the detector circuit is similar to that

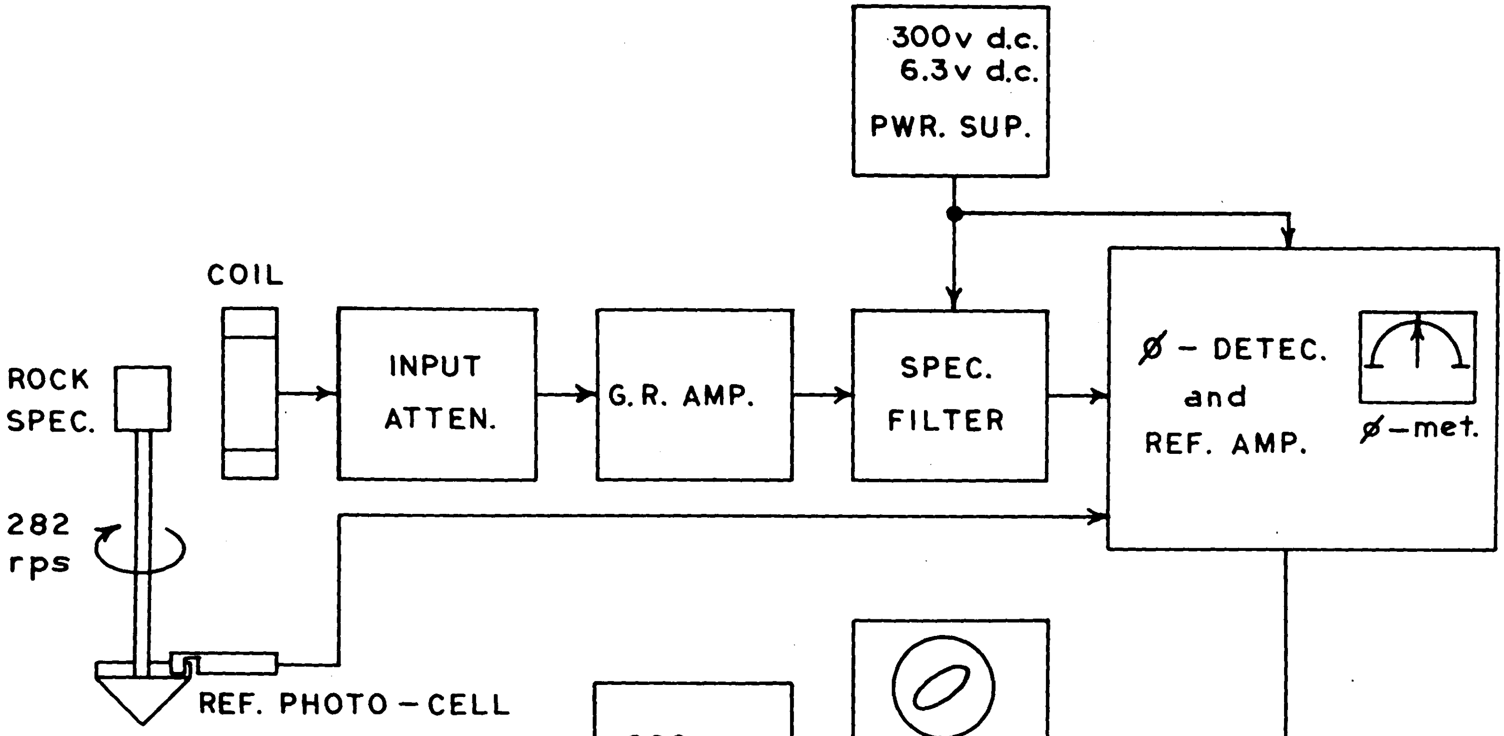


FIG. A-1 BLOCK DIAGRAM OF APPARATUS

described by Hood (1956). Fig. A-2 is a photograph of the measuring apparatus in which the components are as follows:

A. Spinner assembly
B. Decade attenuator
C. General Radio amplifier
D. Calibrated attenuator and filter
E. Reference amplifier and detector unit
F. Oscilloscope
G. Air pressure regulator and on-off control
H. 300 volt power supply
I. 6.3 volt filament supply
J. Reference lamp power supply

## 2. Specimen and Reference Generator

The spinner and coil assemply are shown in Fig. A-3, in which the components are as follows:

A. Specimen pick-up coils
B. Specimen holder
C. Reference light chopper
D. Reference photocell assembly
E. Spinner base
F. Phase dial

Fig. A-4 is a cut-away drawing of the spinner assembly, and shows details of the various parts.

The specimen coils actually consist of two coils each, connected in such a manner that the current flow induced in the inner coil is opposite to that induced in the outer coil. The radii and number of

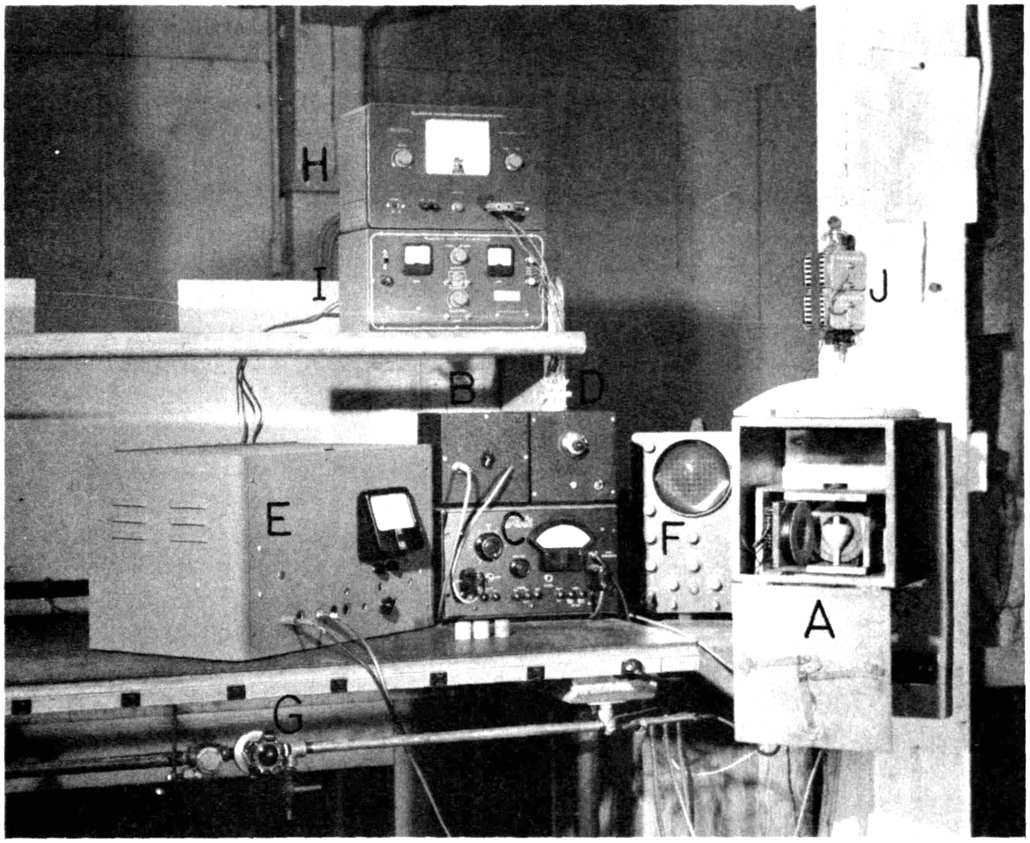


FIG. A-2 VIEW OF APPARATUS

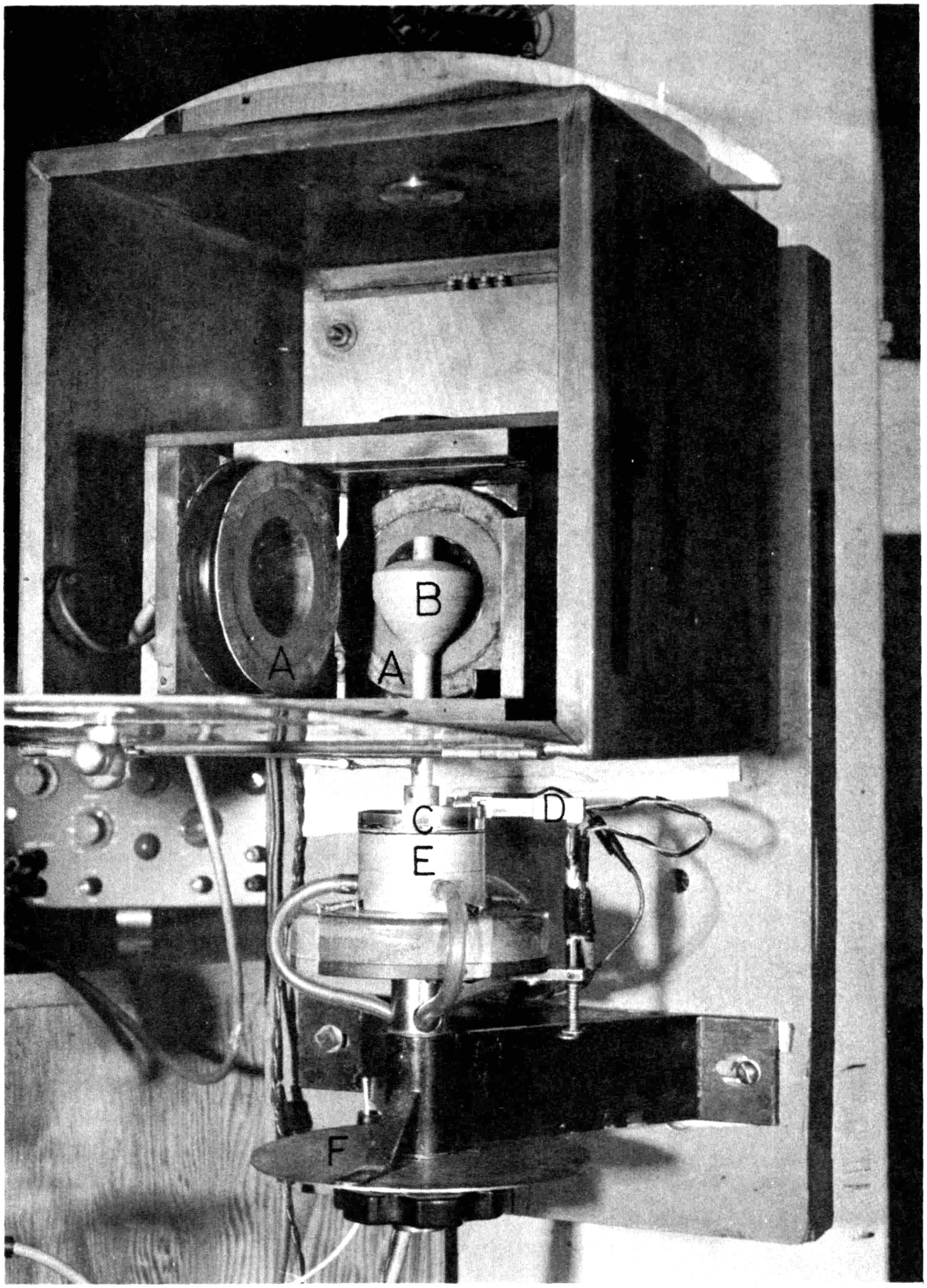


FIG. A-3 COILS AND SPINNER ASSEMBLY

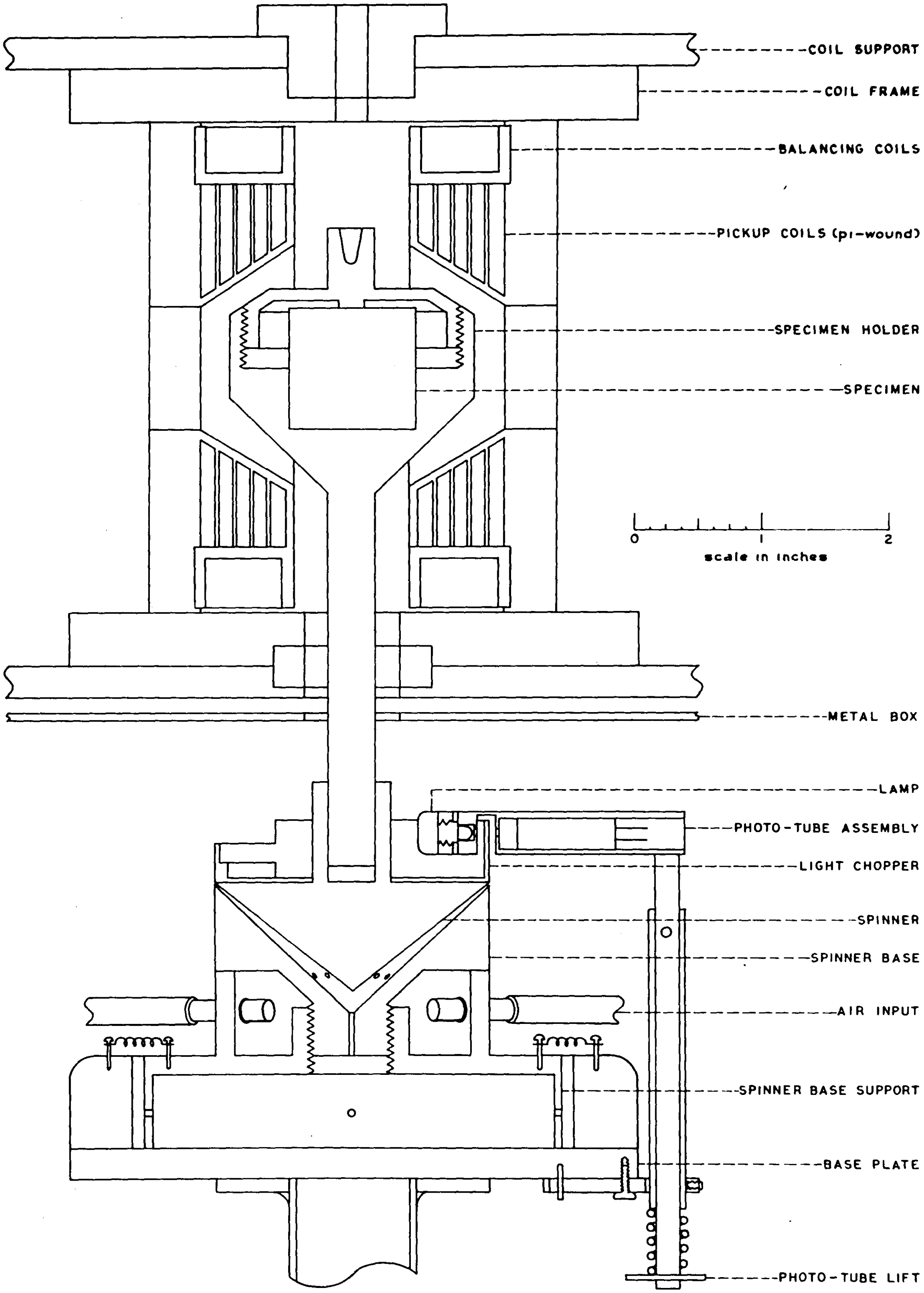


FIG. A-4 SPINNER ASSEMBLY CROSS-SECTION

turns of the coils are designed to give zero flux linkages through the double coil system.

Considering a concentric pair of coils with rectangular cross-section, when H is not a function of r, it can be shown that the current induced in the coils is proportional to the quantity $(r_2^3 + r_3^3 - r_1^3 - r_4^3)$, where $r_1$ and $r_2$ are the inner and outer radii of the inner coil respectively, and $r_3$ and $r_4$ are the inner and outer radii of the outer coil, respectively. (Although the coils used do not have rectangular cross-sections, they can be divided into several smaller units for the purpose of meeting the above requirements.)

Thus, if this quantity is made to equal zero, there will be no currents induced in the coil system by a uniform field H. This is very convenient for eliminating the effects of stray 60 cycle fields in the laboratory and also for removing any signals that may be induced by the coils vibrating in the earth's field. The coils were balanced for this condition by experimentally determining the number of turns that were required on the outer coil.

This condition does not exist for curved fields, however, so the coils are made as small as conveniently possible. Since the current induced in the coils is a function of R (the distance from the magnetic source to the windings) it is apparent that the signal induced in the coils by the rotating specimen is not made zero by the two opposing coils because there are many more flux linkages in the inner coil system than in the outer one. The e.m.f. of this double coil, due to the rotating specimen, is more than 50 per cent of that which is produced by the inner coil alone.

The inner coil has been p i-wound to decrease the distributed capacitance between the windings and thus to increase the natural resonant frequency of the coil. This eliminates the possibility that there may be undesirable amplitude and phase versus frequency effects near the operating frequency.

A consideration of the signal to noise ratio will necessarily involve the input tube in the amplifier. The statistical voltage produced in the input of an amplifier of bandwidth W is:

$$E_n = 12.7 \times 10^{-11} \sqrt{W(R_t + R_c)}$$

where $R_t$ is the equivalent noise-resistance of the first tube and $R_c$ is the grid resistance in the first grid (the coil resistance). For a rectangular cross section coil, assuming that the windings are symmetrically placed in horizontal and vertical rows, the coil resistance $R_c$ is given by:

$$R_c = (\pi^2 \ell \rho / 4a^2)(r_2^2 - r_1^2)$$

where $\ell$ is the width of the coil and $\rho$ and a are the conductivity and circular area, respectively, of the wire used in the winding. For a given coil size the voltage induced in the coil by the rotating specimen is proportional to the number of turns in the coil, or inversely proportional to a. Therefore, the signal to noise ratio is proportional to:

$$\frac{1}{a\sqrt{W(R_t + R_c)}}$$

or

$$\frac{1}{\sqrt{W(R_t a^2 + (\pi^2 \ell \rho / 4)(r_2^2 - r_1^2))}}$$

Once $r_2$ and $r_1$ have been chosen, (which is, of course, arbitrary) it is clear that the signal to noise ratio increases with a decrease in a.

The inner coil was wound with number 40 gauge wire and contains approximately 25 thousand turns, whereas the outer coil was wound with number 38 gauge wire and contains about 8 thousand turns. The total resistance of these two coils is 24 thousand ohms. Since there are two sets of coils, the combined resistance of the system is 48 thousand ohms. Obviously the voltage induced in the over-all system is twice that induced in either coil pair alone. The reason for two pairs of coils is to increase the input signal to the amplifier and also to reduce the effect of the position of the spinner on the voltage output.

The reference signal generator consists of a Clairex type Cl - 2 photocell, a 3 volt "grain of wheat" lamp, and a light chopper. The photocell and lamp assembly may be raised and turned at right angles to facilitate starting and stopping the spinner. The photocell mount is attached to the base plate which supports the spinner base. The entire assemply can be rotated through 360°, permitting the phase difference between the reference and specimen signals to be varied.

The spinner is of the Beams (1930) type, in which the specimen holder spins freely in air without bearings. This type of mechanism permits high speeds that otherwise would have been difficult to attain. The spinner and spinner base are cone-chaped; the spinner has an angle $\alpha$ of 101.5 degrees and the base has an angle $\beta$ of 91.5 degrees. Air holes inside the base are oriented at an angle and create a vortex of air which causes rotation of the spinner. The result of the Bernoulli effect, produced by the narrowing of the air passage near the edge of the spinner and spinner base, keeps the spinner in its place.

The specimen holder stands on a shaft about 6 inches long and is attached to the spinner. This permits the coils to be shielded from the air blast at the base of the spinner, which may cause an undesirable vibration of the coils. It also helps to minimize coupling between the coils and the reference generator and allows the photocell to be rotated a full 360 degrees. Of course, it also allows the specimen holder to be much closer to the coils.

The spinner is usually steadied by hand until it is brought up to about half speed, at which time it stabilizes and spins freely without supports. It was found that the spinner would also perform quite satisfactorily with a cloth bearing located near its center of gravity (approximately the middle of the shaft.) With this cloth bearing the spinner may be started and stopped without having to be supported.

The spinner base is held in place by four springs. The friction between the spinner base and the bottom plate, and the three tygon tubes which feed air to the spinner base tend to damp out any oscillatory motion that may be initiated during the starting procedure.

Several different materials were used for the specimen holder, but most of these proved unsatisfactory. Materials such as linen and paper bakelite, lucite, and fiberglass could not withstand the added impact that occurred when a rock specimen broke during the spinning operation.

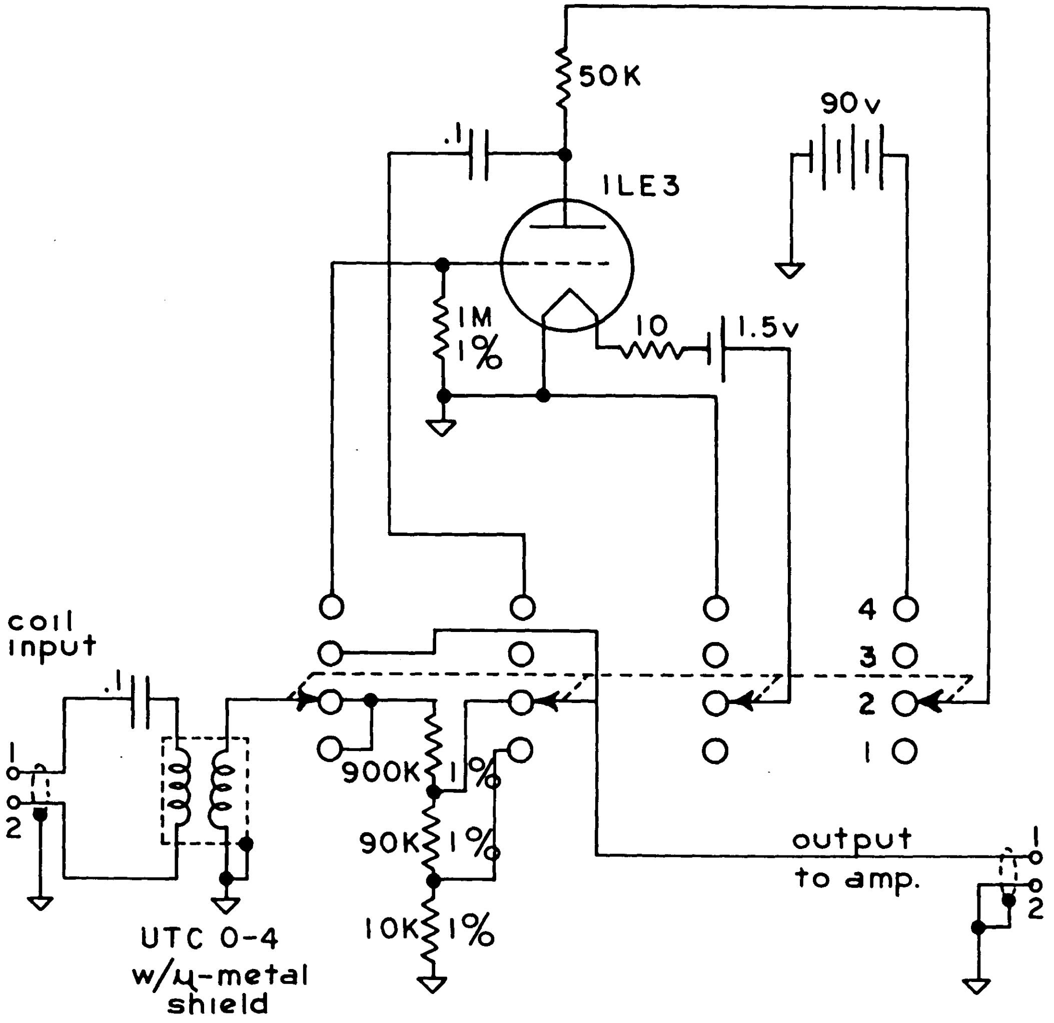
The most satisfactory material used was laminated West African mahogany, which was chosen in preference to other woods because of its high strength to weight ratio. The cap of the specimen holder was made from Du Pont nylon or Du Pont delrin. Another holder was constructed entirely of delrin, and preliminary tests indicate that it is quite satisfactory.

### 3. Input Attenuator and G. R. Amplifier

A circuit schematic of the input attenuator is shown in Fig. A-5. The output terminals of the coil are connected to the primary of the input transformer, a UTC type 0 - 4, via a 6 foot shielded cable. The transformer eliminates the necessity for grounding one side of the coil to the attenuator chassis and helps to reduce the effects of undesirable electrostatic signals generated by the spinner. The secondary of the transformer is connected to the attenuator selector which has two positions for attenuation, one position direct coupled and one position for amplification. The multiplication factors for positions 1 through 4 are approximately x 1/100, x 1/10, x 1, and x 10 respectively.

An amplication of x 10 on position 4 is supplied by a battery-powered type 1LE3 vacuum tube. The input signal is applied directly to the grid and the output is capacitive coupled from the plate. The signal experiences a phase change of 180 degrees when this amplifier is used, which must be taken into consideration.

The output signal from the attenuator circuit is then applied to a General Radio type 1231-B battery-operated amplifier. The



Cap. in micro-farads

FIG. A-5 INPUT ATTENUATOR

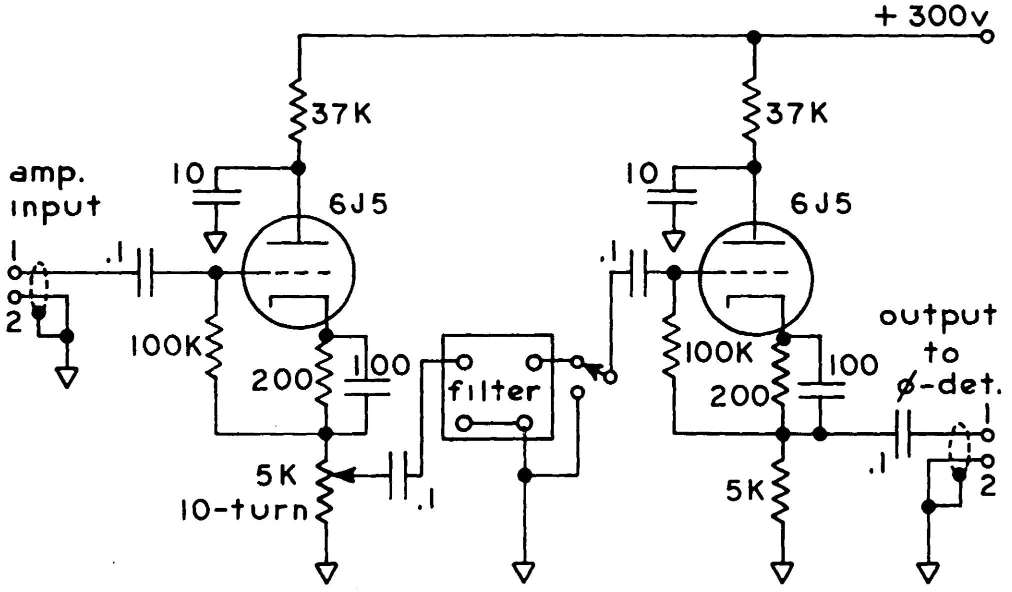
maximum gain of the amplifier is 86 db and there are two attenuators built into the unit. One of these is a variable gain control and is always set for maximum gain during the operating procedure. The other has two settings, labeled $< 0.03$ volt and $< 1$ volt on the front panel. These two settings are referred to as position A and position B, respectively, on the calibration curve (see Fig. B-2). The output of the G. R. amplifier is applied to the specimen signal filter circuit.

## 4. Specimen Signal Filter

Fig. A-6 is a schematic of the specimen signal filter circuit. The basic components of the circuit are a cathode-follower input with a variable attenuator, a bandpass filter, an on-off switch, and a cathode-follower output.

Both cathode followers are of the biased type, employing 6J5 vacuum tubes with decoupled plate circuits to minimize the influence of 60 cycle ripple in the power supply voltage. The load resistor in the cathode circuit of the input tube is a 5K ohm, 10 turn, 0.1% linearity potentiometer which serves as a variable attenuator. The dial on this control is linearly divided into 1000 divisions, each turn representing 100 divisions. Thus, there are three attenuators in the specimen amplifier circuits; a 4 step attenuator in the input circuit, a 2 step attenuator in the G. R. amplifier, and a variable attenuator in the filter circuit.

The filter is used to improve the signal to noise ratio of the specimen signal and hence to increase the sensitivity of the phase detector. Since the filter introduces a phase shift versus frequency dependence, it is necessary to incorporate a matched filter in the



Cap. in micro-farads

Filter — Burnell Co. type BIF Bandpass

FIG. A-6 FILTER CIRCUIT

reference amplifier. The filters were supplied by the Burnell Company (type BIF bandpass filters with a 6 db grain) according to the following specifications:

1. Center frequency 287.5 cycles
2. Less than 0.5 degrees relative phase shift within 5 cycles either side of the center frequency
3. Stable within a 60 - 100 degree temperature range

Considering amplitude variations as well as phase variations, the best operating frequency for the filters was found to be about 282 cycles.

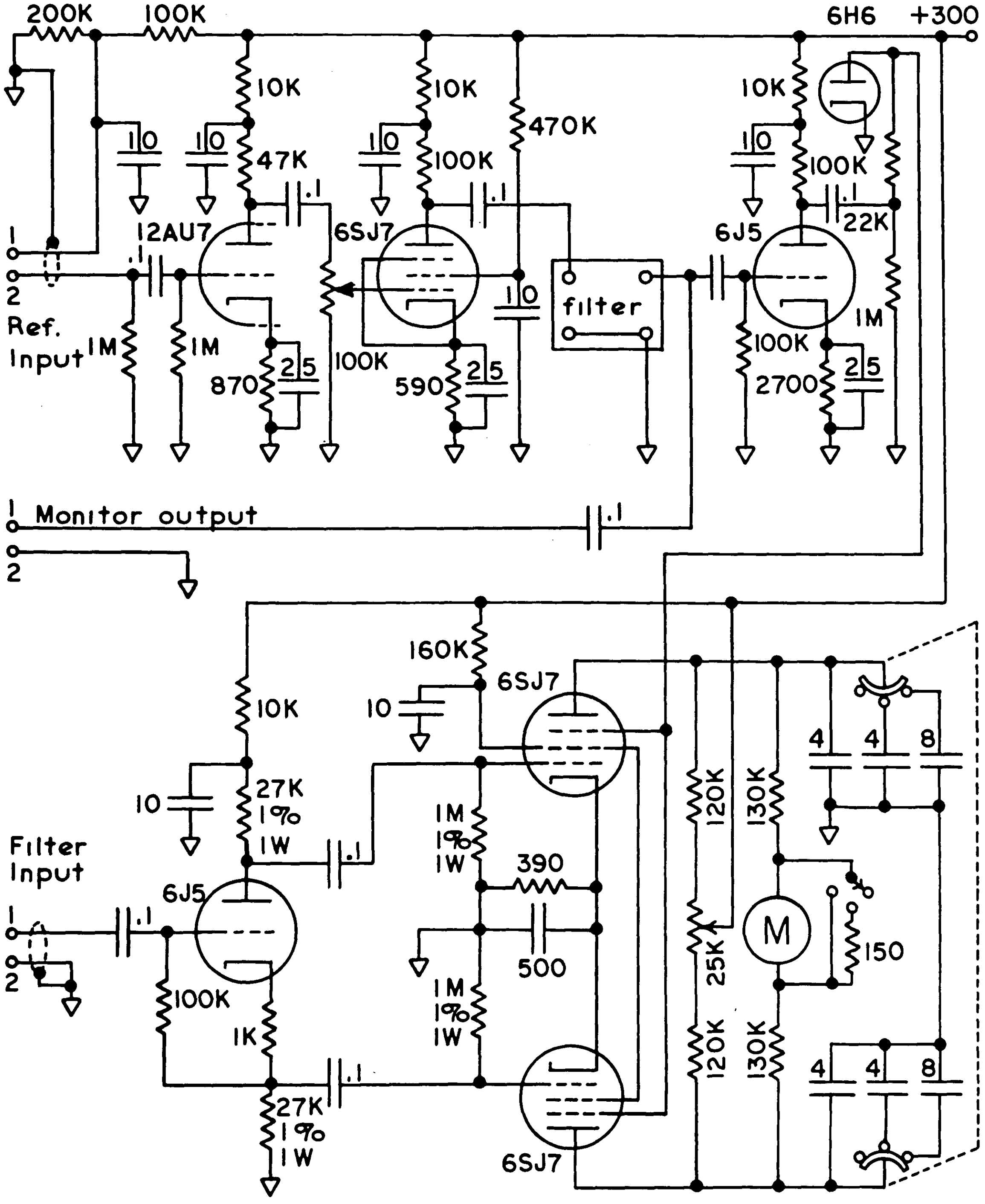
The on-off switch removes the specimen signal from the grids of the detector tubes while the phase meter is being adjusted for zero-signal condition. The switch is left in the on position during the operating procedure.

The output cathode-follower couples the signal to the phase-splitter located on the chassis A in Fig. A-2.

### 5. Reference Amplifier and Filter

The reference amplifier and phase detector circuits are on the same chassis; a schematic of this unit is shown in Fig. A-7. The output signal from the photocell is applied to the input of the reference amplifier where it is converted into a symmetrical square wave and then applied to the suppressor grids of the 6SJ7 detector tubes.

The main components of the reference amplifier are a 12AU7 low gain input amplifier (approx. x 10), a bandpass filter, a variable gain control, a 6SJ7 high gain amplifier (approx. x 100), an overdriven 6J5 amplifier and a 6H6 clipper. The clipper eliminates the positive



Cap. in micro-farads
Filter — Burnell Co. type BIF bandpass

FIG. A-7 REFERENCE AMPLIFIER AND Ø-DETECTOR part of the output voltage which otherwise would drive the suppressor grids of the detector tubes into the conduction region.

All the amplifiers are of the RC type, and each plate circuit is decoupled from the B+ line in order to eliminate 60 cycle ripple. The gain control permits the symmetry of the square wave output to be varied slightly, but other than this it serves only to prevent the voltage on the grid of the 6J5 from becoming too large.

The bandpass filter, as mentioned previously, is matched to the specimen amplifier filter so that the phase vs. frequency response of the two units will be identical.

## 6. Phase Detector

The phase detector circuit includes the 6J5 phase-splitter and the two 6SJ7 detector tubes shown in Fig. A-7. The specimen input signal is converted by the phase-splitter into two signals of equal amplitude, but differing in phase by 180 degrees. The amplitudes of these two signals are balanced by the two 27K ohm, 1% wire-wound resistors; (it was not found necessary to match these signals better than 1%). The outputs from the phase-splitter are then applied to the control grids of the detector tubes.

The two 6SJ7's were selected beforehand for similar characteristics so as to minimize balancing problems. The cathode circuits have a common resistor, shunted by a 500 micro-farad capacitor, which biases the tubes for class A operation. The screen grids also have a common connection. A 25K ohm potentiometer connected to the 300 volt lead varies the plate load resistance of each tube and thus permits the two plate voltages to be equalized. In this way the phase meter (a Simpson 25 micro-amp, zero-center meter), which is connected through two 130K ohm resistors to the plates, can be balanced for zero-signal condition. The meter sensitivity switch is used to short the meter when the equipment is being turned on or off and also to lower the sensitivity when the incoming specimen signal amplitude is unknown.

The reference signal applied to the suppressor grids serves to turn the tubes on and off at regular intervals. In other words, during the half cycle when the reference signal has zero voltage amplitude, the detector tubes behave as class A amplifiers, and any signal applied to the control grid will be amplified in the plate circuit. However, during the half cycle when the reference signal has a negative voltage amplitude, there will be no conduction through the tube, and the plate voltage will rise to the full B+ value (300 volts).

A complete mathematical analysis given by Hood (1956) involves the capacitors connected between the plates and ground. The circuit actually acts as a biased commutator, however, and a simple analysis is given by Nagata (1943).

The phase sensing action of this circuit may be best understood by considering the action of only one of the detector tubes. Fig. A-8 is a diagram of the voltage appearing at the plate of the tube during one cycle of operation. Assuming that the phase meter has been balanced for zero current flow when no signal is applied to the control grid, the plate voltage during the on-time will be some steady d. c. value, say 150 volts (case I). Now, if a pure sine wave is applied to the control grid, and it is in phase with the reference signal, the

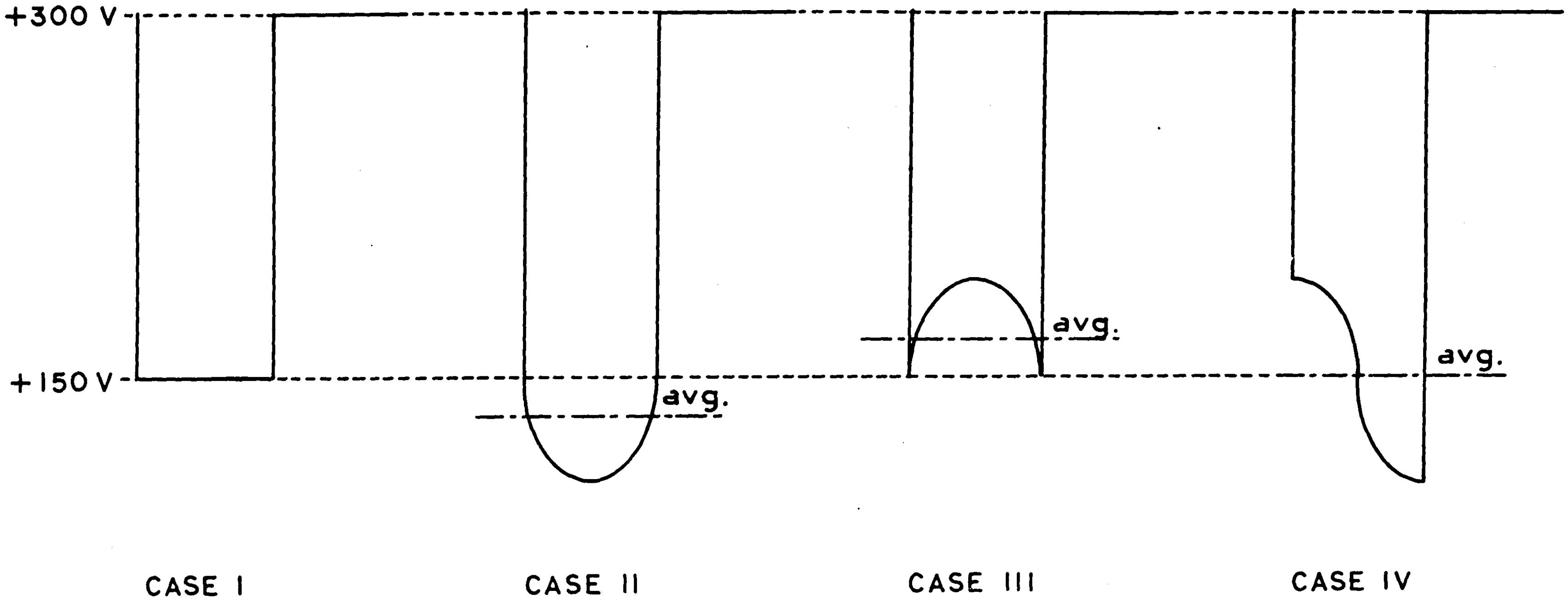


FIG. A-8 PHASE RELATIONS

average plate voltage during the on-time will become less positive (case II). Conversely, if there is a 180 degree phase difference between the two signals, the average plate voltage will become more positive (case III), and if the phase difference is 90 degrees, the average plate voltage will be unchanged (case IV), i.e., 150 volts.

Variation of the average plate voltage about the zero signal reference line is therefore proportional to cos $\theta$, where $\theta$ is the phase difference between the control grid and the suppressor grid signals. The current flow through the phase meter will also be proportional to cos $\theta$.

The sensitivity of this circuit can be doubled by simply applying a second signal, 180 degrees out of phase with the first signal, to the control grid of a second tube and connecting the meter between the two plate circuits. When the plate voltage of one tube becomes more positive, the other plate voltage becomes less positive and the phase meter current will be twice that produced by one tube alone. The use of two detector tubes has the added advantage that variations in the B+ voltage, the filament voltage, etc., have a minimum effect on the stability of the circuit. The deflection of the phase meter is obviously dependent upon the amplitude of the specimen signal, but independent of the amplitude of the reference signal.

The capacitors connected between the plate circuits and ground cause the plate voltage to assume a d. c. value approximately equal to the average plate voltage during the on-time of the tube. This changes the phase meter current from a pulsating d. c. to a steady d. c. current. By varying the amount of capacitance the response time of the meter can be varied; that is, the time required for the meter to indicate a change of phase. Except for the 4 micro-farad capacitors permanently in the circuit, the capacitors are used only when the noise level becomes large enough to make the meter indications unstable.

Any control grid signal which is not a harmonic of the reference signal will cause the plate voltage to vary alternately more positive and more negative, the average variation being zero. Also, even harmonics will be averaged to zero since there are an equal number of positive and negative half cycles during the on-time of the tube. However, it is clear that odd harmonics will not be averaged to zero, and will therefore interfere with the phase detection of the fundamental frequency.

The specimen signal bandpass filter reduces the amplitude of the odd harmonics so that they do not disturb the operation of the phase detector. The filter also minimizes the noise level which could have driven the detector tubes into the cut-off or saturation regions, limiting the phase sensing action of the circuit. Obviously, the control grids must be well shielded from the reference signal to prevent interference.

### 7. Power Supplies

A Heathkit model PS-3 power supply delivers a regulated 300 volts at 30 milliamps to the amplifier and detector units. The filaments require 6.3 volts d. v. at 3 amps and are supplied by a Heathkit model BE-4 battery eliminator.

As mentioned previously, the G. R. amplifier and the input amplifier have their own battery power supplies. The G. R. uses a type 6TA60 Battery while the input amplifier uses two type C batteries and one type N60 battery.

## 8. Accessory Equipment

Rotation of the specimen is controlled by a Watts air pressure regulator, shown in Fig. A-2. The frequency is monitored by observing the Lissajous figures produced on an oscilloscope by the reference signal and a 282 c.p.s. signal from the audio oscillator. When the two signals have the same frequency, the Lissajous figure consists of one stationary loop.

Fig. A-9 is a photograph of the Fanslau coil used for attaining a magnetic field-free region. The diameter of the larger coil is 4 feet and each coil contains 20 turns of wire. A 6 volt battery eliminator supplies approximately 1 amp of current to the coil, an amount sufficient to null the earth's magnetic field. A discussion of the design of a Fanslau coil is given by Chapman and Bartels (1940).

The furnace, located inside the Fanslau coil, has non-inductively wound heating coils and is powered by a 110 volt variac. Temperature in the oven is controlled by a Foxboro potentiometer controller (using a thermocouple) which turns the variac voltage on and off. The variac is adjusted for minimum power requirements at the desired temperature and thus tends to minimize temperature variations as the thermocouple turns the current on and off.

The magnetic field inside the Fanslau coil is measured by a flux-gate type zero-field magnetometer (Serson, 1956). The magnetometer and the flux-gate detector unit are labeled A in Fig. A-9, and a

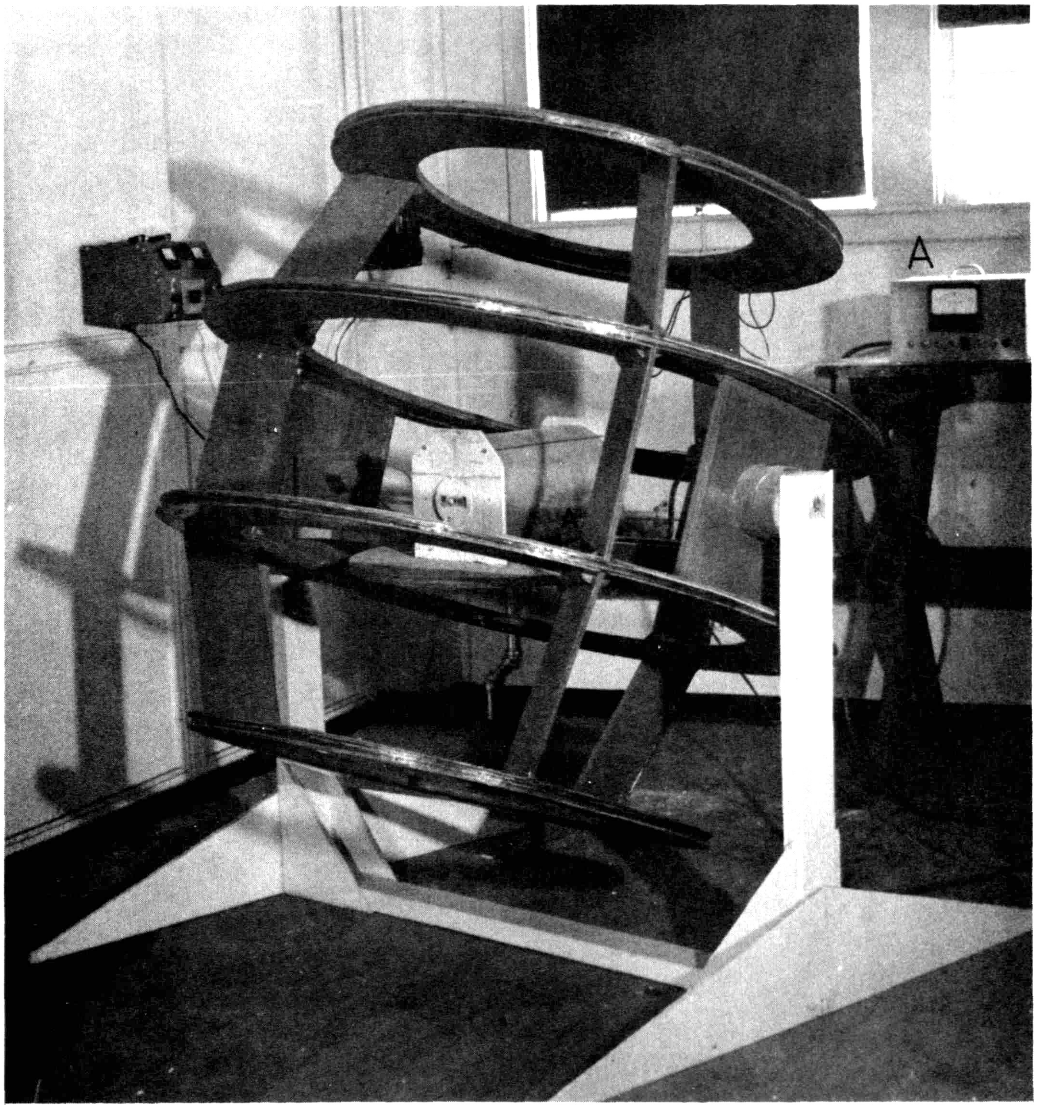


FIG. A-9 FANSLAU COIL AND OVEN

transistorized schematic of the circuit (supplied by Serson) is shown in Fig. A-10.

This unit is capable of measuring fields of less than 1 gamma and is more than adequate for its intended use.

It was found that the magnetic field in the laboratory often varied as much as 1000 gammas, and it was necessary to periodically adjust the current in the Fanslau coil. To reduce the effects of these field variations on cooling rock samples, a rock tumbler was used, (see Fig. A-11). The holder holds six samples and will just fit inside the oven. When the rocks are ready to be cooled the holder is placed on the table of the tumbler, one end resting on a bearing and the other end resting directly on the table. When the bearing supports are turned, the holder also rolls on the table, thus producing rotation about two axes. From the point of view of the rock specimen, a d. c. field appears as an a. c. field, the frequency being determined by the rate of rotation. The radius of the largest end plate on the holder was made to differ from the radius about the vertical axis of rotation in such a way that the holder seldom repeats any of its positions. An air turbine is used to rotate the unit at several turns per second.

For the a. c. demagnetization experiments a one-sample tumbler was used inside a small Helmholtz coil (see Fig. A-12). The cross section of the coils is approximately 3/4 inches square and the mean radius is 2.5 inches. Each coil contains 250 turns of No. 16 nyclad wire and they are connected in series. The current is supplied by a variac capable of delivering over 10 amperes. At maximum current the field inside the coils is about 550 Oersted. The heat generated by

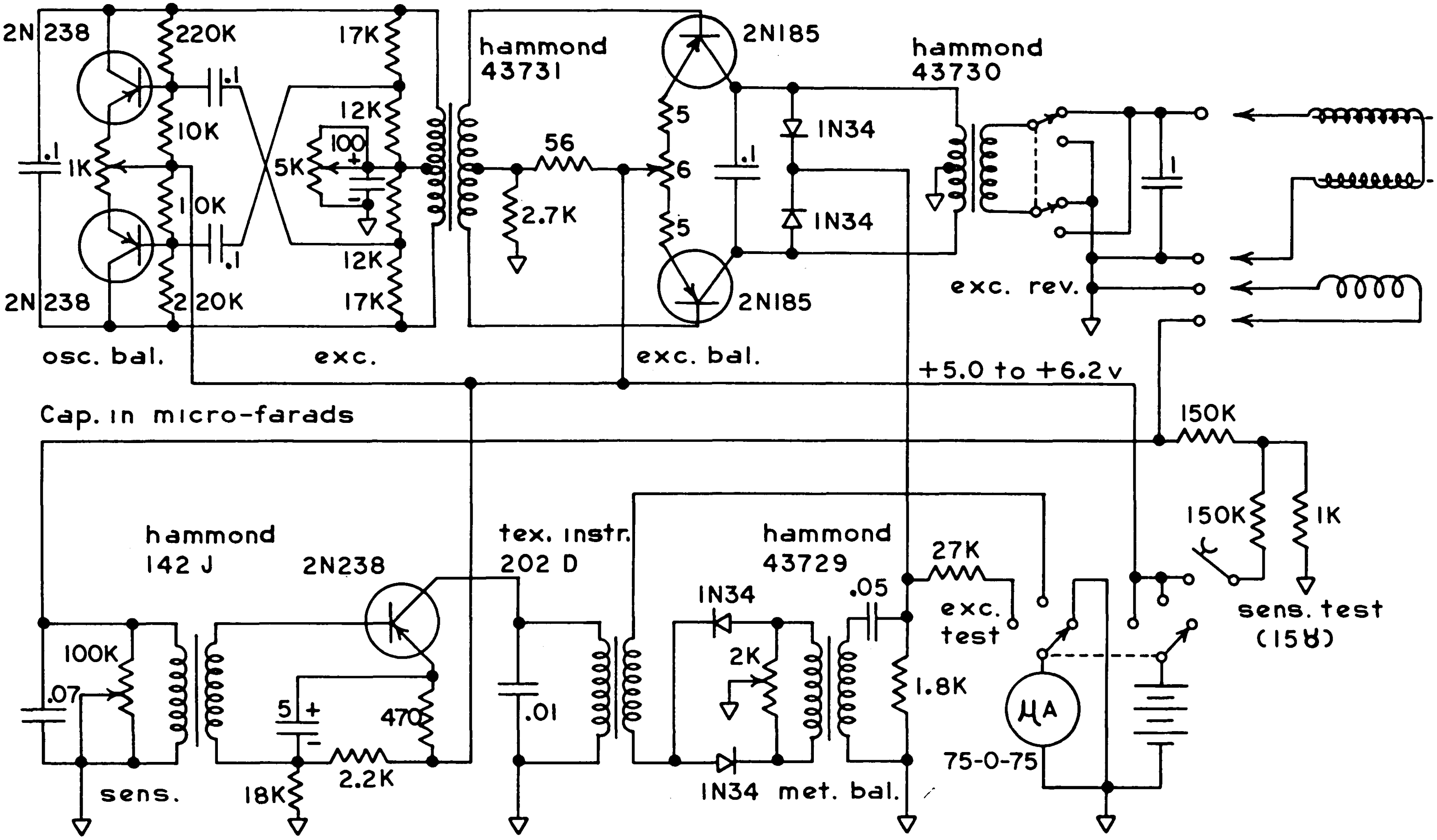


FIG. A-10 PORTABLE MAGNETOMETER (SERSON - 1957)

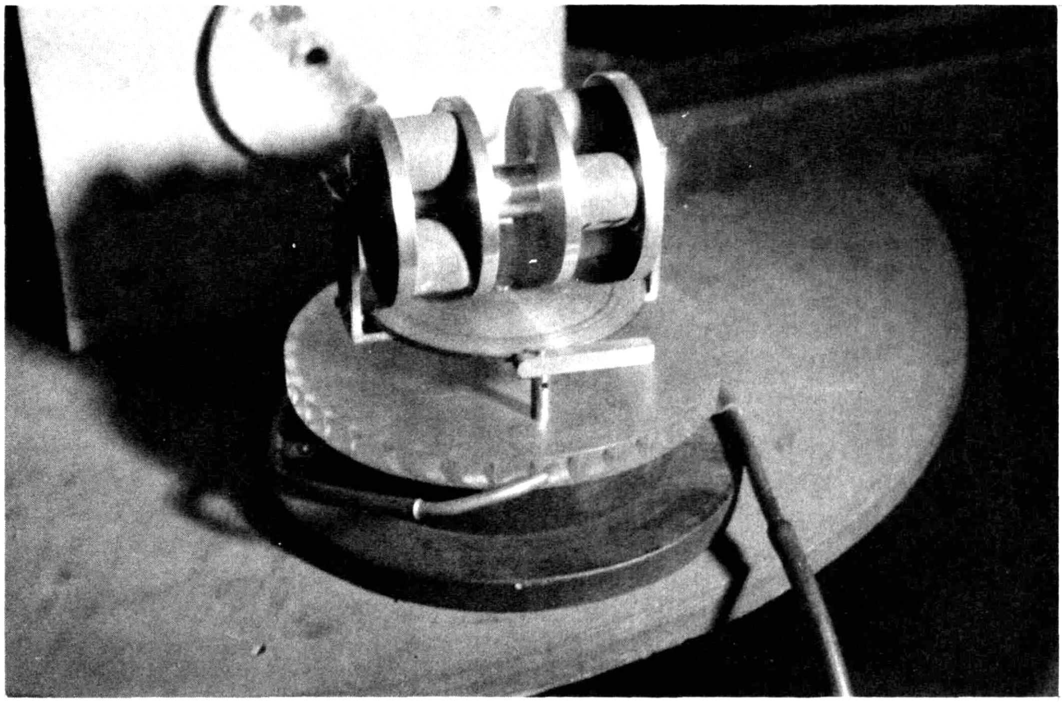


FIG. A-11 ROCK TUMBLER

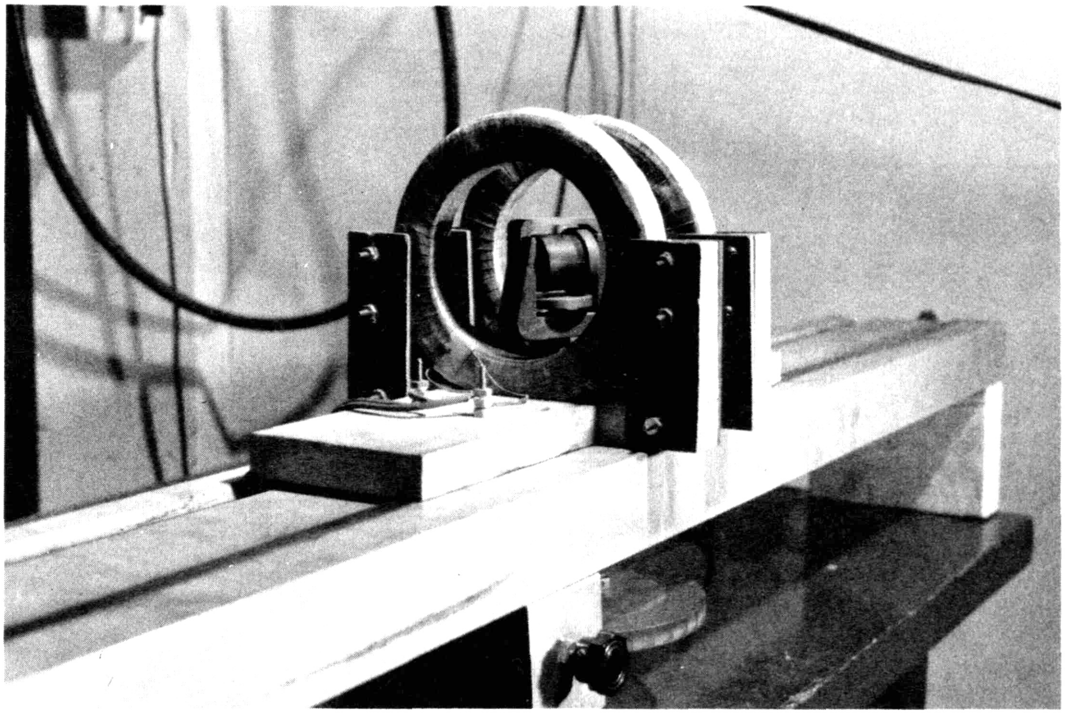


FIG. A-12 DEMAGNETIZATION COILS

the resistance in the windings limits the maximum field that can be produced. The coils were originally designed to slide apart on runners so as to produce a continuous decrease in the field intensity between the coils. This was found to be unnecessary however, so they were set apart at the proper distance, and the variac was used to raise and lower the field intensity.

The tumbler is turned by a small a. c. motor that applies power to the outer rim of a large disk. The motor speed is varied by an adjustable rheostat, which is usually set to rotate the tumbler from five to ten revolutions per second.

# APPENDIX B: OPERATION

## 1. Circuit Adjustments

The electronic units are allowed to warm up for some time until their tube characteristics have stabilized. This is particularly important with regard to the audio-oscillator since it sets the frequency standard for the frequency-sensitive apparatus. After the spinner has been brought up to speed, the oscilloscope is used to observe the output of the reference amplifier. The reference amplifier gain control is first turned to its minimum position, then it is slowly increased until the output becomes a symmetrical square wave.

The specimen signal is next removed from the detector tubes by the on-off switch in the specimen filter circuit. The meter switch is then set for maximum sensitivity and the meter balance control is used to zero-center the phase meter. It is usually necessary to check the meter balance periodically during the initial measurements until the instrument has become completely stable. If at any time the meter can not be balanced to zero, a better selection of detecting tubes has to be made.

## 2. Calibration

### a. Phase Angle

The relative phase angle of the circuits is determined by measurement of a one-inch wooden cylinder containing a piece of magnetized drill rod mounted parallel to and centrally located between the ends of the cylinder. This simulated specimen is oriented in the holder so that the north-seeking pole of the magnet points toward the

"O" reference mark inscribed inside the holder. When the circuit alignments have been made, and the spinner is brought up to the correct speed, the phase meter will show a deflection. The maximum amount of deflection can be controlled by the specimen amplifier attenuators. The phase dial is then rotated until the meter indicates a null reading. Since there are two positions 180 degrees apart on the graduated phase dial which give a null reading, it is necessary to establish a convention whereby it is apparent which pole is being observed. This is accomplished by having the needle of the meter move from left to right, as the null position is approached, when the angle indicated by the phase dial pointer is increased.

When the meter indicates the correct null position, the phase dial is loosened from its holder and rotated until 0 degrees comes opposite the pointer. The dial is then secured in place.

In order to minimize errors such as phase-dial shifts, incorrect orientations of the specimens in the holder, etc., it is best to make two measurements for each component of magnetization. The second measurement is made with the specimen rotated 180 degrees about the axis directed toward the "O" reference mark. The angle between the direction of the component of magnetization in the plane of rotation and the reference mark is then 360 degrees minus the phase dial reading. This technique is used during the calibration procedure as well as during the specimen measurements.

### b. Intensity of Magnetization

Nagata (1943) has shown that the magnetization of a rock specimen can be approximated by a small dipole located at the center of the specimen. In order to calibrate the intensity of magnetization indicated by the attenuator settings in the specimen amplifier circuits at a given maximum meter deflection, a small coil of known radius and number of turns takes the place of the specimen. A known alternating current passing through the coil will simulate in the pick-up coil the effect of the rotating dipole. A block diagram of the calibration equipment is shown in Fig. B-1.

The maximum induced magnetic moment of the test coil, i.e., when the current is maximum, will be equal to the moment of the rotating dipole which produces the same effect in the pick-up coil. This is given by:

$$M = \frac{\sqrt{2}\,\pi r^2 NE}{10\,R} \qquad \text{c.g.s. units}$$

where: r = radius of coil

E = r.m.s. voltage across coil and attenuator

R = total resistance of coil and attenuator

N = number of turns in coil

If a cylindrical specimen, which is 1 inch long and 31/32 inches wide, produces the same signal in the pick-up coil as does the test coil, then the component of magnetization of this specimen is:

$$M_s = \frac{\sqrt{2}\,\pi r^2 NE}{10(12.04)R} \qquad \text{c.g.s. units/c.c.}$$

The calibration curves, shown in Fig. B-2, represent the intensity of magnetization required to deflect the phase meter full scale to the right for the given attenuator settings, assuming that the phase dial is adjusted to read the proper maximum.

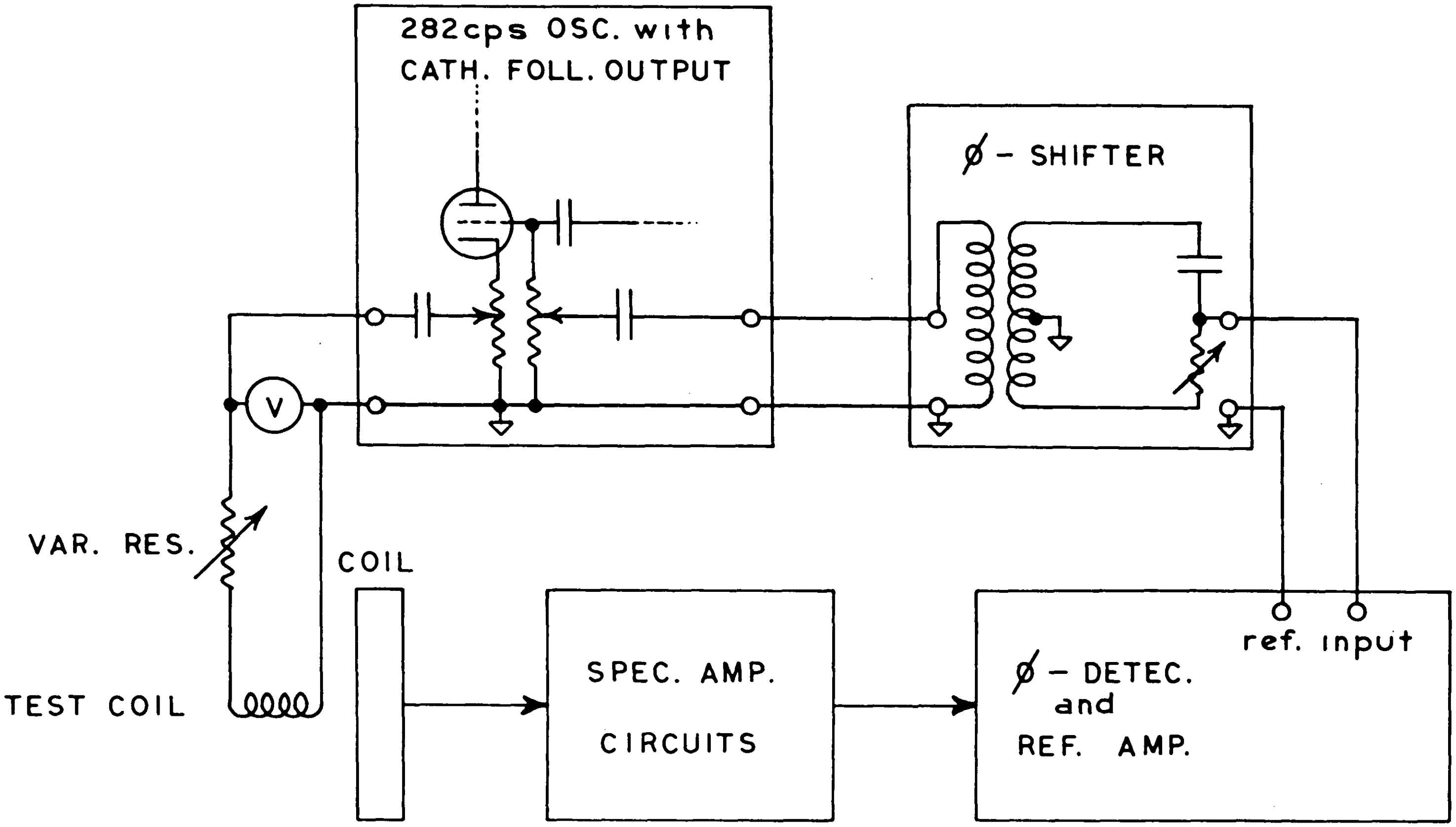


FIG. B-1 CALIBRATION PROCEDURE

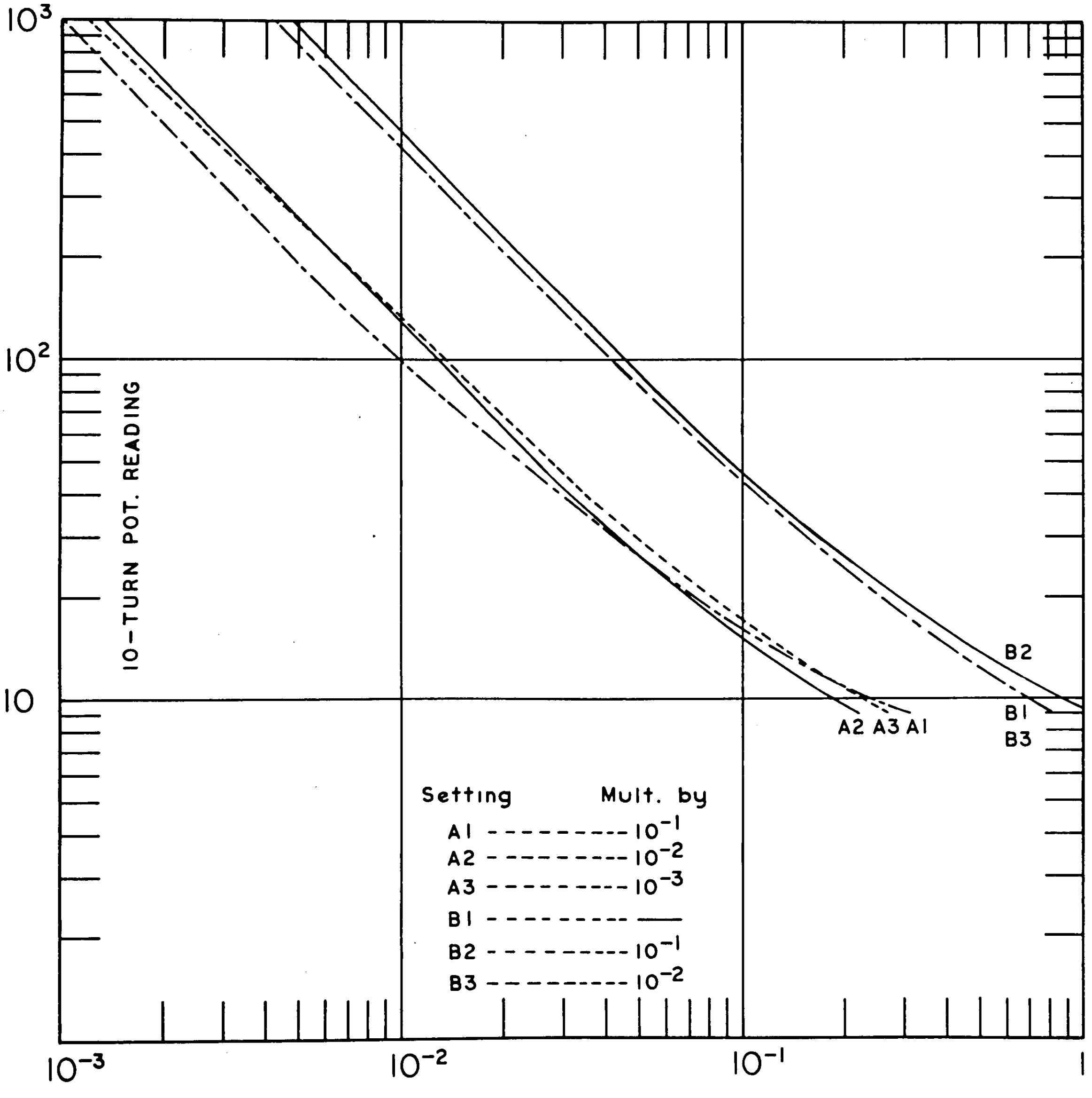


FIG. B-2 INTENSITY OF MAGNETIZATION

It may be noticed in Fig. B-1 that the reference voltage is not taken from a point that may vary in amplitude during the calibration. Also the phase shift network should be adjusted periodically for maximum deflection.

### 3. Measuring Procedure

When the spinner is rotating at the proper frequency and the phase meter has been zero-balanced, the method of measurement is as follows:

1. The specimen signal attenuators are set for low sensitivity and then the on-off switch is turned on.
2. The phase dial is rotated until the meter shows a maximum deflection to the right.
3. The attenuators are then adjusted until the meter reads full scale.
4. The phase-dial is rotated until the meter is nulled. When the phase-dial pointer indicates an increase in angle, the meter deflection should move from left to right, insuring that the proper pole is being measured.

The frequency will have to be monitored carefully during the full scale and null readings of the meter. The data obtained is:

1. The attenuator settings are converted by Fig. B-2 into the intensity of magnetization of the component in the plane of rotation.
2. The phase-dial reading gives the angle, about the spinner axis and in the plane of rotation, between the "0" reference

mark and the component of magnetization in this plane. This angle is measured counter-clockwise when looking into the holder.

## 4. Sensitivity

The sensitivity of the instrument is limited by the electrostatic signal generated when the spinner rotates in air. In order to minimize this signal, the spinner is coated with silver circuit paint and a wire brush is connected to ground and allowed to rub against the shaft. In this manner the amplitude of the signal can be kept below $5 \times 10^{-7}$ c.g.s. units. This means that measurements of moments of $2.5 \times 10^{-6}$ c.g.s. units/cc can be made with errors in direction of less than 10 degrees.

The amplitude and phase of the electrostatic signal usually remained constant during the time required to measure a specimen completely. Hence it is possible to remove this component from the measurements and further increase the sensitivity. This was seldom done, however, since most of the rock specimens had a relatively high intensity of magnetization.

When there is no electrostatic signal present, and this is indeed a rare occurrence, the background signal is $1 \times 10^{-7}$ c.g.s. units. Occasionally, neighboring laboratories create frequencies at or near the operating frequency, and cause the phase meter needle to move slowly from one side to the other, the rate depending upon the difference between the two frequencies. When this happens the variable attenuator is used at as low a setting as possible so as to increase the signal to noise ratio, since most of the stray signal is induced in the circuitry and not in the pick-up coil. Of course, when this effect becomes too large, the equipment can not be operated.

# APPENDIX C: COLLECTION AND PREPARATION OF SPECIMENS

## 1. Collection

One-inch diameter rock cores are drilled *in situ* using a twelve-inch portable diamond coring drill powered by a small McCullough chain-saw engine. The engine, originally equipped with a gear reduction unit, has been converted to direct drive because the diamond core drills much better at higher speeds, and also because the reduction in weight is significant. The water required to cool the drill is supplied by a three gallon garden-spray tank. Depending on the length of the cores, which vary from two to ten inches, anywhere from one to three tanks of water are required to collect eight cores. This method of collecting specimens was first described by Graham and Hales (1957).

Fig. C-1 is a photograph of the engine and the orientation device. The orienter slides into the hole, with the core still intact, and then the compass is leveled by rotating the barrel and by adjusting the dip indicator. The top side of the core is marked by running a brass rod along the slot in the barrel of the orienter. The azimuth of the down dip direction of the line is recorded, as well as the dip of the core, and then the core is broken loose and the top and bottom are carefully marked. The cores are designated according to state and number of core.

When the rocks are too friable to permit drilling, or when the engine becomes inoperative, samples are collected by hand according to the technique given by Doell (1956).

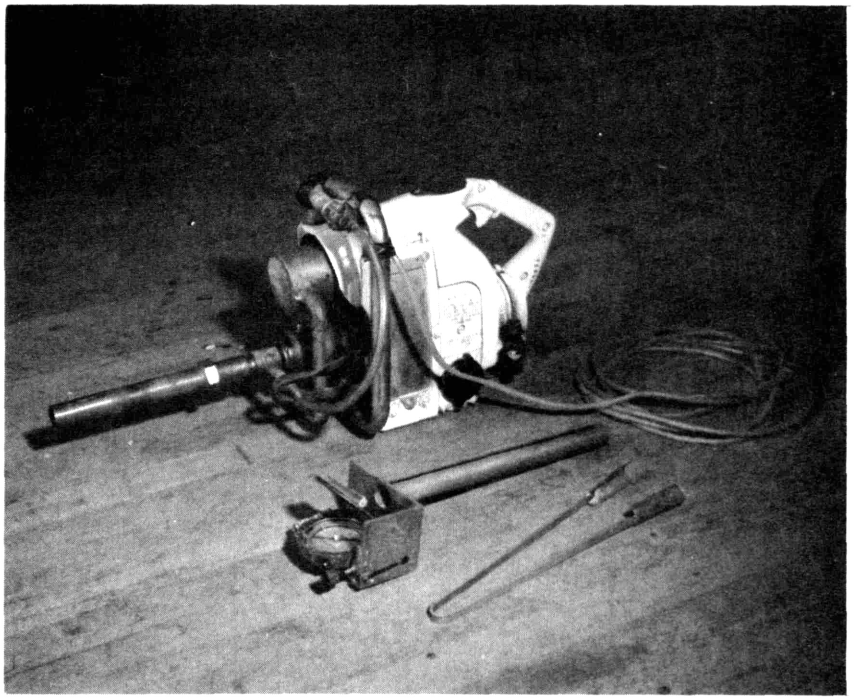


FIG. C-1 PORTABLE DRILL

## 2. Preparation

The cores are cut into one-inch lengths, starting at the bottom, and are numbered consecutively. Each specimen then has two orientation marks: a vertical line along the side and a mark identifying the top. The coordinates of the specimen (see Fig. C-2) are designated as follows:

1. The z axis is parallel to the cylinder axis and is directed positive upwards.
2. The x axis is perpendicular to the cylinder axis and is directed positive toward the reference line.
3. The y axis is directed positive so that the system is right-handed and orthogonal.

Samples collected by hand are drilled in the laboratory so that the core is perpendicular to the surface of the sample, the orientation line being scribed on the up-dip side of the core. Hence the dip of the core is the complement of the dip of the sample.

The errors in orientation of the cores are probably no greater than one or two degrees. However, errors in orientation of hand samples are much larger, perhaps more than five degrees. Thus, the core-drilling technique is not only much faster than hand sampling, but is also much more accurate.

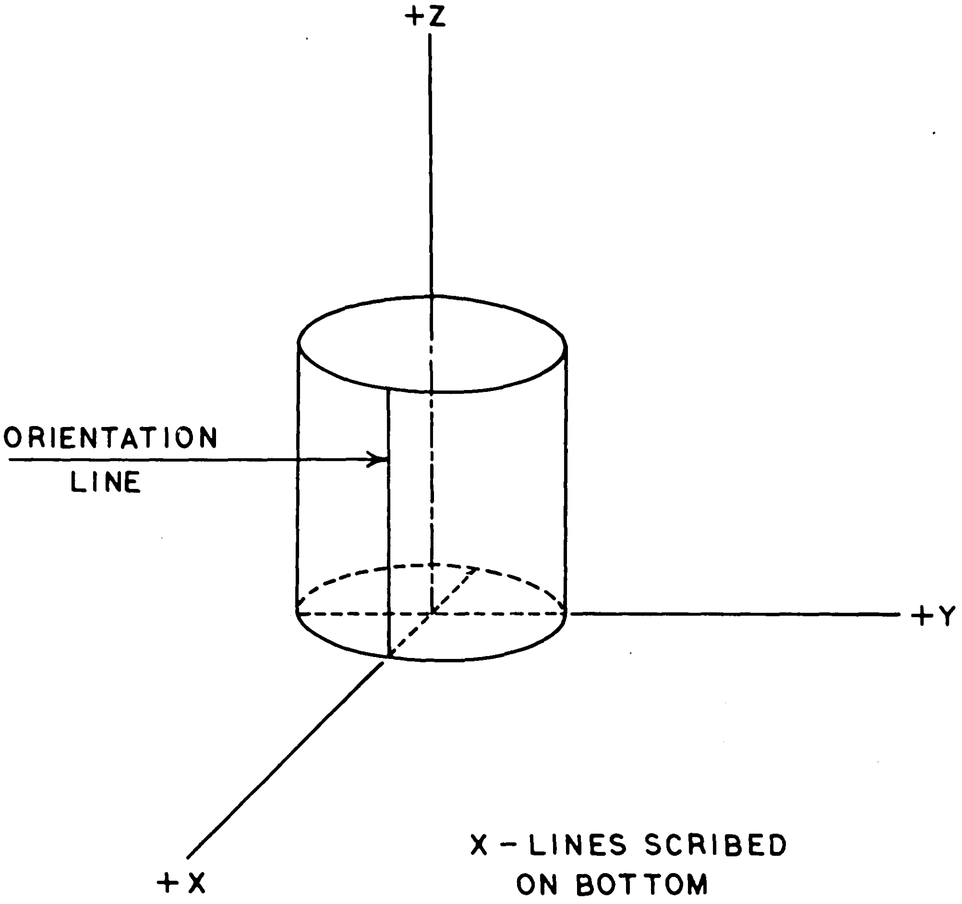


FIG. C-2 SPECIMEN DESIGNATION

# APPENDIX D: DERIVATION OF THE MAGNETIC VECTOR

Only three orientations of the specimen in the specimen holder are required to obtain the direction and magnitude of the magnetic vector. For increased accuracy, however, six different orientations are measured and the twelve data obtained are averaged to yield three angles and three intensities. Each specimen orientation gives the following two data:

1. The angle between the component of magnetication in the plane of rotation and some reference axis of the specimen.
2. The magnitude of this component of magnetization.

The orientation of the axes with respect to the specimen has been shown in Fig. C-2. The system used to describe the magnetic measurements is given in Fig. D-1, where M is the magnetic vector and is, of course, directed toward the north-seeking end. A, B, and C are the components of M, lying in the planes normal to the x, y, and z axes, respectively. X, Y, and Z are the components of M lying along the x, y, and z axes, respectively. $\alpha x$ is the angle measured from the +y axis to the component A in a right-handed sense. Similarly, $\alpha y$ is measured from the +x axis to the component B, and $\alpha z$ is measured from the +x axis to the component C.

For the first measurement the specimen is oriented with +x directed toward the "0" reference mark on the holder and +y directed upward, parallel to the axis of rotation. The z axis is in the "90" direction (90° from "0"). The data obtained are the component B and the angle $\alpha y$. The specimen is then rotated until -y is directed

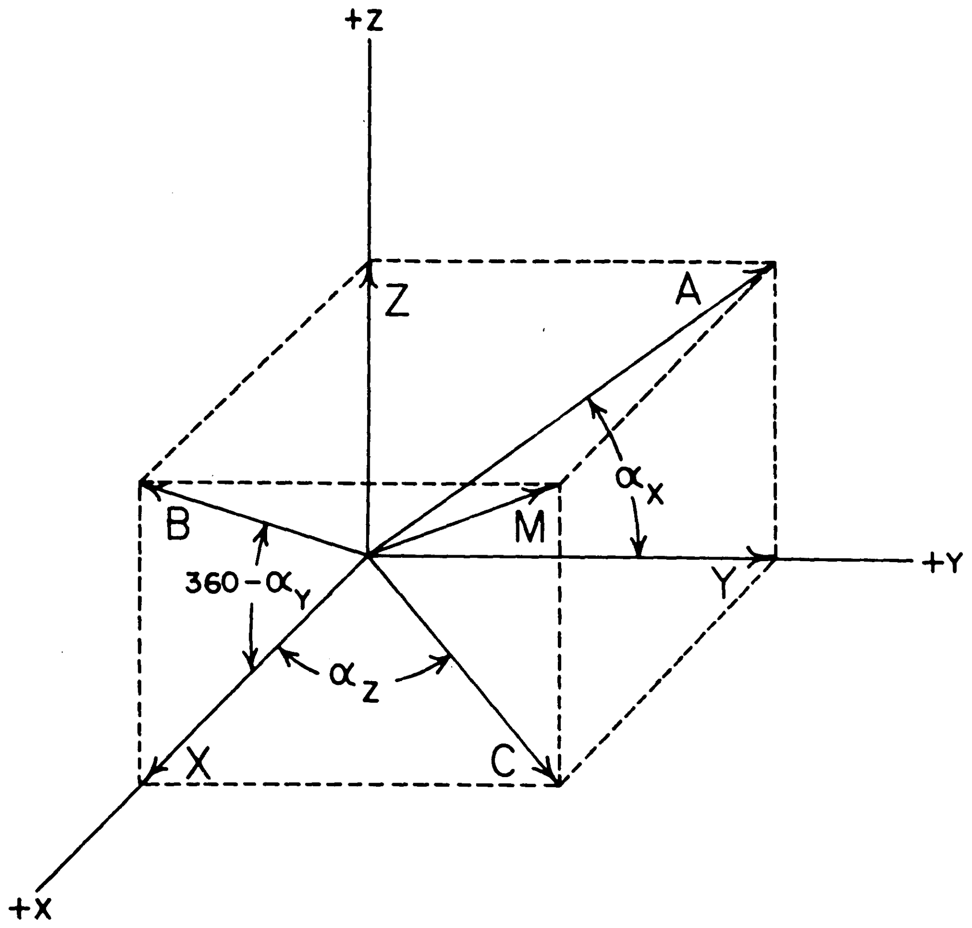


FIG. D-1 VECTOR ORIENTATIONS

upward and +z is directed toward "90"; +x remains in the original position. Thus, B is once more measured, but the angle obtained is 360 minus $\alpha y$. The two measurements are averaged to give the final value for B and $\alpha y$.

Accordingly, average values for A, C, $\alpha x$, and $\alpha z$ are obtained following the procedure given in Table D-1.

| "0" pos. | Upward | "90" pos. | Angle measured | Component measured |
|---|---|---|---|---|
| +x | +y | -z | $\alpha y$ | B |
| +x | -y | +z | $360 - \alpha y$ | B |
| +y | +x | +z | $\alpha x$ | A |
| +y | -x | -z | $360 - \alpha x$ | A |
| +x | +z | +y | $\alpha z$ | C |
| +x | -z | -y | $360 - \alpha z$ | C |

Table D-1

Since

$$A^2 = y^2 + z^2$$

$$B^2 = x^2 + z^2$$

$$C^2 = x^2 + y^2$$

$$M^2 = x^2 + y^2 + z^2$$

it follows that

$$M = \left[ 1/2(A^2 + B^2 + C^2) \right]^{1/2}$$

Thus the amplitude of the vector M can be obtained from the measurements A, B, and C.

Finally, the direction of the vector M with respect to the axes and with respect to the geographical coordinates is obtained graphically

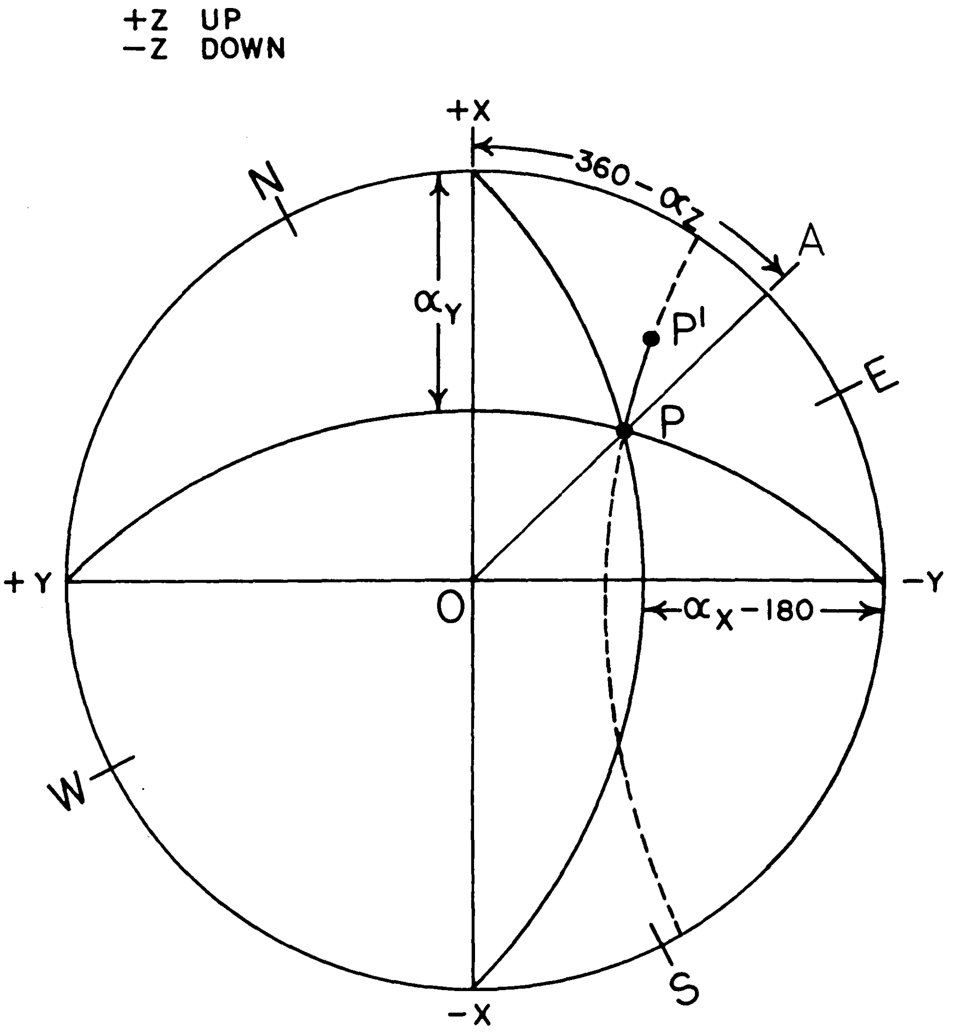


FIG. D-2 SCHMIDT-NET EXAMPLE

with the aid of the Schmidt equal-area projection. The Schmidt projection is preferred to the stereographic projection since a unit area on the sphere remains nearly constant after projection. This feature is desirable in the application of the statistical methods described in appendix E.

The plotting procedure used here followed that of Doell (1955). In contrast to the technique of Graham (1949), whereby only one hemisphere is used for plotting, both hemispheres are used. To distinguish between the two, solid circles and solid lines were used for plots on the lower hemisphere, and open circles and dashed lines for plots on the upper hemisphere.

The orientation of the axes on the Schmidt-net are shown in Fig. D-2, where the x and y axes are in the plane of projection and the +z axis is up.

The angle $\alpha z$ defines the plane containing the z axis and the vector M, represented by line OA, which intersects both the upper and the lower hemispheres. The angles $\alpha x$ and $\alpha y$ define two more planes which should intersect at a common point along OA. In this illustration the projected point P obviously lies on the lower hemisphere. This gives the direction of the magnetic vector M with respect to the specimen coordinates.

However, the projections do not always meet at a common point. When a small triangle is formed, giving an estimate of the error in the measurements, the mean direction is taken as the center of the largest circle than can be inscribed inside the triangle. For all of the measurements reported in the survey the error was less than 10 - 15° and in most measurements it was less than 1°.

In order to obtain the direction of M *in situ*, the specimen coordinates have to be oriented in the position they had in the field. For this the N-S geographic axis is marked so that the +x axis assumes the correct declination; i.e., the angle between the down-dip direction of the specimen core and geographic north. The z axis is then rotated about the y axis until it has the proper inclination, moving point P into P'. The original bearing of the magnetic vector is now represented by point P', with respect to the N-S axis. The dip of the vector is referred to as positive when directed downward and negative when directed upward. The angle of declination reads clockwise from north.

Corrections for bedding orientations which restore the specimen to its pre-deformation position can be made in a similar manner. The strike of the bedding plane is marked with respect to the N-S axis, and then the strike axis is moved into alignment with the axis of the Schmidt-net. When the z axis is rotated about the strike axis, by an amount equal to the dip of the bed, point P' will move into the position of the magnetic vector before the deformation (not shown in Fig. D-2)

For a more complete account of the use of the Schmidt-net for rock-magnetic problems, the reader is referred to Doell (1955).

# APPENDIX E: METHOD OF STATISTICAL TREATMENT

A certain amount of scatter is usually present in the direction of remanent magnetization which is determined from the different samples taken from any given body of rocks. Since the magnetization of such rocks may reflect the influence of the geomagnetic field present during the time of formation, it is of interest to determine the average direction of magnetization calculated from the several samples, and also an estimate of the probable error of this average direction. A statistical treatment for the solution of this problem was developed by Fisher (1953), and has been used throughout this report. An outline of this treatment is given below.

Before Fisher's treatment is applied, however, the average direction of magnetization for each core is used to locate the geographic position of the north-seeking pole of a geocentric dipole field that would have produced this direction of magnetization in the core. The pole position of this dipole field lies in the direction of the horizontal component of the remanent vector, and the relative latitude ($\lambda$) is given by

$$\text{Tan } I = 2 \text{ Tan } \lambda$$

where I is the inclination of the magnetic vector and $\lambda$ is the latitude of the outcrop location with respect to the pole position. The stereographic or Schmidt equal-area projection can be used in the determination of the pole positions (see Graham, 1955).

Thus, for each outcrop, there is a set of N pole positions, where N is equal to the number of cores taken from the outcrop. In.

practice, these pole positions are plotted on a projection of the unit sphere such as the Schmidt equal-area projection. If it is assumed that the Schmidt net represents a north polar projection of the earth, the longitude and latitude of the pole position can be read directly from the projection (for instance, the polar plots in Part II are equal-area projections).

The pole positions therefore define a set of unit vectors, directed from the center of the unit sphere to the points in question. Fisher has shown that the average direction of a set of N such unit vectors, represented by the points $P_i$ on a unit sphere ($i = 1, 2, .. N$), is given by the direction in space of the resultant, $\overline{R}$, of the N unit vectors. Let $l_i$ and $m_i$ be the longitude and latitude, respectively, of the $i^{th}$ unit vector, $v_i$. Then

$$z_i = \sin m_i ,$$
$$x_i = \cos m_i \cos l_i, \text{ and}$$
$$y_i = \cos m_i \sin l_i$$

where $z_i$ is the vertical component of $v_i$ (reckoned positive upwards), $x_i$ is horizontal component of $v_i$ directed toward longitude zero (positive toward longitude zero), and $y_i$ is the horizontal component of $v_i$ directed toward longitude 90 E (positive toward longitude 90 E). The magnitude of R, $|R|$, the longitude of R, L, and the latitude of R, M, can be calculated from $x_i$, $y_i$, and $z_i$, by the use of the following equations:

$$|R| = \left\{ \left(\sum_{i=1}^{N} z_i\right)^2 + \left(\sum_{i=1}^{N} x_i\right)^2 + \left(\sum_{i=1}^{N} y_i\right)^2 \right\}^{1/2}$$

$$L = \mathrm{Tan}^{-1} \left\{ \sum_{i=1}^{N} y_i \Big/ \sum_{i=1}^{N} x_i \right\}$$

$$M = \mathrm{Sin}^{-1} \left\{ \sum_{i=1}^{N} z_i \Big/ \left[ \left(\sum_{i=1}^{N} x_i\right)^2 + \left(\sum_{i=1}^{N} y_i\right)^2 + \left(\sum_{i=1}^{N} z_i\right)^2 \right]^{1/2} \right\}$$

The confidence of this average direction can then be determined from

$$1 - \mathrm{Cos}\,\theta = \frac{N - |R|}{|R|} \left\{ \left(\frac{1}{P}\right)^{1/n-1} - 1 \right\} \qquad \text{Fisher (1953)}$$

where P is the desired probability level (P is taken as 5 percent throughout this report). The "radius of the circle of confidence," $\theta$, can be calculated from the above equation. For P = 5 percent, $\theta$ is the semi-angle of a cone whose apex lies at the center of the unit sphere and whose axis is the vector $\bar{R}$, within which the true direction lies for 95 percent of such determinations. There is no limitation on the size of N in this equation, but theoretically the size of N - R should not exceed 2. However, if N is moderately large this restriction need not apply, since the error introduced is of negligible importance.

An estimate of the precision of the directions of $v_i$, k, can be calculated from

$$k = \frac{N - 1}{N - R} \qquad \text{Fisher (1953)}$$

For a uniform distribution k is nearly one, and approaches high numbers as the precision increases. Although $\theta$ gives a direct estimate of the precision, k has been included in the results.

If reversals are present in any of the measurements, it is more feasible to consider the probability that the average direction

R lies along an axis, and not only in one direction. In other words, all of the unit vectors, $v_i$, can be considered positive. Although some of the samples in this report definitely indicate reversals, there are no clear cases where both reversals and normal directions of magnetization are contained within the same outcrop. Thus, this point is not applicable to any of the results.

# APPENDIX F: DISCUSSION OF PROCEDURE AND RESULTS

## 1. Collection

All samples from Nova Scotia and some from Massachusetts were collected during the summer of 1956. All other samples were collected during the following summer. Most of the samples were taken from road-cuts and quarries because the equipment limited the survey to easily accessible areas, and also because these outcrops were relatively unweathered. Anywhere from 2 to 14 cores were collected from each site, depending on the extent of the exposure and the ease of coring. Although Nova Scotia sediments were originally to be included in the survey, they were found to be too friable and the coring technique could not be used.

To test for stability of the remanent magnetization in rocks it is desirable to collect samples from several sites within the same formation which have significantly different bedding attitudes. Since the beds of most Triassic basins generally dip toward one side of the basin, selection of sites with large differences of strike and dip was somewhat difficult. Furthermore, the number of sites available along road sides was limited. From collections made over large areas, however, it is possible to infer that the magnetization has been stable since the beds were deformed.

## 2. Measurement

The interval of time between the collection and measurement of the specimens ranged from several months to a year. This was not important, however, since most of the specimens were given an a.c. demagnetization test. Any isothermal components of magnetization that may have been imparted to the specimen during this interval were thus removed.

All of the measurements were made with a "rock-generator" type apparatus. To test the accuracy of this instrument, several specimens were measured by A. Cox at the University of California, Berkeley. A comparison of results indicated that the direction of magnetization determinations were within a half degree, and the intensity determinations were within one per cent. Due to slight variations in the amplifier gain, caused by battery and tube replacements, errors in the intensity may vary as much as five per cent.

Although the sensitivity of the instrument was adequate for the original measurements of the specimens, it set a limit on the maximum value of the a.c. demagnetizing field that could be used in treating some of the weak sediments. For specimens with magnetization intensities of less than 2.5 x $10^{-6}$ cgsu/cc, the error in the direction of magnetization measurements might be greater than 10 degrees, and therefore the specimens could not be demagnetized much below this level.

### 3. A.C. Demagnetization

Creer (1959) and As (1958) have demonstrated that it is possible to reduce the scatter in remanent magnetization results, and also to bring the results into better agreement with those determined from other sites, by treating the samples in an a.c. demagnetizing field. The influence of a.c. fields on isothermal-remanent magnetization (IRM) and on thermo-remanent magnetization (TRM) has been studied by Rimbert (1958). IRM components can usually be removed from most rocks by treatment in relatively low intensity a.c. fields. TRM, however, is much more difficult to remove by a.c. demagnetization. In this respect, the relative stability of chemical magnetization is not too well known, although in some cases its behavior is not unlike a TRM (see Haigh, 1958).

If a rock specimen contains a "soft" component of magnetization, whose direction can be easily changed, it is necessary to remove this component before the original direction of remanent magnetization can be determined. Many of the specimens examined in this report are known to have acquired an IRM component while in the laboratory. Thus, it is probable that many of these specimens acquired an IRM component in the field.

During the demagnetization procedure the intensity of the a.c. field was controlled by a variable auto-transformer. Since the field was varied in finite steps, and not continuously, several experiments were performed to determine whether this affected the results of the demagnetization tests. Several specimens from the same core were treated. In one case the a.c. field was reduced by the transformer, in the next case the field was reduced by sliding the demagnetizing coils apart very slowly. The specimens gave similar results. Also, for one specimen, the field was increased in steps of 10 Oe., and then reduced alternately by one of the two methods. There was no related variation in the demagnetization path of the specimen. Hence, it is assumed that the demagnetizing apparatus does not bias the results.

Fig. I-19, Fig. I-20, and Fig. I-21 show some results of the demagnetization tests that were made on igneous specimens. They are representative of many of the specimens, but not all. The behavior of the remanent magnetization in the Nova Scotia and Pa - Va rocks, when subjected to a.c. fields, is a point of considerable interest. Specimens from the Pa - Va area gave similar results, whereas specimens from Nova Scotia responded in a variety of ways to the a.c. field treatment.

In general, the remanent magnetization of the Pa - Va igneous rocks was quite stable in a.c. fields above 20 - 100 Oe. The initial deflection of the remanent vector was probably due to the removal of a "soft" IRM component. Some of the specimens experienced a change in the direction of remanent magnetization when left in the laboratory for long periods, but after a.c. field tests the resultant direction was always the same. After the initial demagnetization in low intensity fields, the remanent vector remained within about 5 degrees of an average direction during further demagnetization.

Specimens from several Nova Scotia outcrops, such as NS 13, responded to the a.c. field tests in a similar manner. The variations of the remanent vectors about an average direction were, however, slightly larger than those for the Pa - Va specimens. As a rule, the smaller the circle of confidence for a given outcrop, the more stable the remanent magnetization in the presence of a.c. fields.

Many of the Nova Scotia specimens were relatively unstable in a.c. fields, as is shown in Fig. I-20. Except for the removal of the "soft" component, a.c. field intensities of 100 - 200 Oe. were usually required to displace the remanent vector by large amounts. For instance, the remanent vector of specimen number NS 18-3 remained within 10 degrees of its original direction for field intensities below 100 Oe. Above this value the vector was deflected more than 180 degrees.

There is a possibility that the change in the direction of magnetization, resulting from the a.c. field tests, was a random phenomenon. To test this hypothesis, the demagnetization procedure was repeated several times at the same field intensity for a number of specimens. In most cases the remanent vector remained within a few degrees of an average value. When the field intensity was increased the remanent vectors continued to change in the same direction as before the test.

The variation in the direction of the remanent vector was often confined to a plane, such as that in Fig. I-20. It was not possible to relate this plane with the geologic attitude of the beds. An analysis of the physical properties of the rocks may lead to a better understanding of this phenomenon.

Judging by the a.c. field tests the Connecticut Valley igneous rocks are more closely related to the Nova Scotia rocks. Some of the variations in the direction of remanent magnetization resulting from the a.c. test were quite large, although there was no obvious tendency for this variation to be confined to a plane.

Belshé has experienced similar results in a.c. demagnetizing tests performed on igneous rocks. This pattern of behavior is therefore not unique in the Nova Scotia and Connecticut Valley Triassic lavas.

## 4. Accepted Demagnetization Results

There are several ways to proceed with the a.c. field tests for a given outcrop. They are:

1. Select one specimen from each core, subject them to an a.c. demagnetizing field, and increase the a.c. field intensity by regular intervals. Determine the Fisher circle of confidence for the average direction of magnetization after each successive a.c. test. When the circle of confidence is reduced to a minimum value, proceed with the demagnetization of the remaining specimens at the same field intensity.

2. Proceed as above, treating each core independently, however. When the remanent vector begins to vary about an average direction, treat the remaining specimens with the same field intensity. The circle of confidence does not have to be determined.

3. Select only a few representative specimens and determine the average a.c. field intensity required.

The labor involved in the first method is, obviously, considerable.

If the outcrop is not homogeneous, i.e., contains several flows, etc., it is possible also that the cores require different intensity demagnetizing fields, and it is apparent in the case of the Nova Scotia specimens that too-large a.c. fields will produce instability in some specimens. The second method is more reliable for the Nova Scotia and Connecticut Valley specimens. The greater stability of the

Pa - Va igneous rocks makes it possible to determine the demagnetization pattern for only a few specimens. The remaining specimens are then subjected to a demagnetizing field of the accepted intensity.

It may be possible to improve the results slightly by a more careful treatment of the samples, although it seems very improbable that the improvement will be significant.

### 5. Method of Averaging Data

It has been the practice of many investigators to let each specimen represent one unit of data in the final analysis. For instance, pole position number 50 in Fig. II-10 was determined from the remanent magnetization results of 71 specimens taken from 21 samples.

If the specimens are taken along a direction perpendicular to the bedding plane there is some justification in having each specimen represent a different interval of time during deposition of the sediments. If the specimens are taken along the bedding plane, then this is probably not the case. With the igneous rocks, an interval of time may be represented by each flow.

For many of the outcrops sampled during this survey, specimens from the same core had remanent magnetization directions that agreed very well, yet the average directions for the cores were significantly different. Thus, if each specimen is given the same weight in the statistical treatment, the average direction of magnetization for the outcrop will be displaced in favor of the core containing the most specimens.

In this report the author prefers to let the cores represent the basic sampling unit. Thus the specimen magnetizations were averaged to obtain one direction of remanent magnetization for each core.

## 6. Geologic Corrections

For the sedimentary beds, a strike and dip determination was made at, or near, each core. The bedding plane of each core was then corrected to a horizontal position, presumably orienting the core in the same position it had before the bed was deformed.

It was found that the average direction of remanent magnetization was about the same, whether the cores were corrected individually or an average correction was applied to the entire outcrop. Since an average strike and dip determination was believed to be more reliable, this method was used on all the outcrops. The geologic attitude of the beds at each outcrop is given in Table I-1 and Table I-2.

Corrections for the igneous rocks were more difficult because the geologic attitudes were not always obvious. In many instances the strike and dip had to be inferred from near by sediments.

There is a possibility that the outcrop may have been rotated about an axis perpendicular to the bedding plane. If this is so, the results will contain an error which is difficult to evaluate. It seems improbably, however, that this type of deformation is very prominent in the eastern United States Triassic rocks. Most of the beds have dips of less than 35 degrees and folding is not very extensive.

It is hoped that any errors caused by inaccurate geologic corrections are averaged out by the large number of observations made over an extensive area.

## 7. Pole Position

The dipole formula was used to obtain the pole position of a geocentric dipole field that would account for the direction of the remanent magnetization in a given core. The respective pole positions were determined for each core within an outcrop, and then Fisher's statistical treatment was applied to obtain the average pole position and the circle of confidence at the 95% probability level (see Appendix E). This data is given in Table I-1 and Table I-2, and the pole plots are given in Part II.

The average pole position for each of the three igneous areas, and for the sediments, was determined by averaging the pole positions for the outcrop. The fact that poles with small circles of confidence lie close together, whereas the poles with larger circles of confidence are generally scattered toward the present geographic pole, suggests that the final results may be in error. Any selection of poles based on the angle $\theta_{95}$, or based on the relative stability of the respective specimens when subjected to a.c. fields, will, of course, be arbitrary. Since all of the igneous rocks were given the same treatment, the author feels that none of the results can be eliminated from the final analysis.

This was not the case with the sedimentary rocks because the a.c. tests could not be completed. Many outcrops which appeared to contain "soft" components of remanent magnetization were not included in the final results. It is believed that more complete a.c. tests will bring the results of such outcrops into better agreement with the final average.

### 8. Heat Treatment

It is possible to remove "soft" components of remanent magnetization from rocks by applying heat and then allowing the rocks to cool in a zero-field region (Doell, 1956). This test was applied to one specimen from each core of outcrop number NS 4 in order to determine the relative merits of the a.c. field vs. heat treatments. The specimens were heated to successively higher temperatures (25 °C intervals) and allowed to cool inside the Fanslau coil. The remanent magnetization was determined after each application of heat. The tests were continued beyond 600 °C, above the curie temperature of magnetite. The intensity of magnetization was reduced almost to zero at this temperature. (The rock tumbler was not available at this time, and it was not possible to keep the field inside the Fanslau coil at a zero level.)

The a.c. field test was applied to the remaining specimens. The results of both tests were essentially alike, with a 20 Oe. a.c. field roughly corresponding to 300 °C.

Although the tests may be equally valid, there are several reasons for preferring the a.c. method. The heat test requires approximately two hours to heat and cool a group of specimens. During this time the earth's field has to be critically nulled out. The a.c. test requires only a minute or so per specimen, and the earth's field is of no consequence. Furthermore, it is possible that heat applications may induce chemical changes in the specimens, either destroying or altering the remanent magnetization.

The basic difference in the pole positions for the three igneous areas suggests that the rocks may not have acquired a remanent magnetization in the direction of the earth's field at the time they were cooled. Kalashinkov (1959) and Grabovsky (1959) have shown that the magnetic susceptibility of the rock may account for the divergence between the vector of the remanence and the earth's magnetic field which has caused this remanence.

To test the significance of this hypothesis, two specimens from each of the igneous areas were randomly oriented inside the oven, heated to approximately 650 °C, and then allowed to cool in the presence of the earth's field. The declination of the field inside the oven was accurately determined. The dip and the intensity of the field could not be determined at the exact site of the specimens.

The results showed that each specimen acquired a remanent vector in approximately the same direction. A discrepancy of about 2 degrees could be accounted for by the orientation error. Thus it seems unlikely that the magnetic susceptibility is responsible for the difference in the pole positions.

The intensities of magnetization acquired by the above specimens were slightly different. The intensity of the Nova Scotia specimens was about 20% less than the original value, whereas the intensity of the Massachusetts specimens was increased about 200%. The intensity of the Pennsylvania and Virginia specimens was increased about 100%. Since the intensity of the applied field was not known, it is not possible to make any inferences about the intensity of the geomagnetic field during Triassic times. The interested reader is referred to an article by Thellier (1959) for an account of the intensity of the earth's magnetic field during the geologic and historic past.

## 9. Laboratory Deposition Tests

In order to obtain some indication of the magnetization that the sediments may have acquired in deposition, several specimens of North Carolina sandstone were powdered and redeposited in the laboratory. This work was performed by D. Greenewalt of the Department. The remanent magnetization was measured with an astatic type magnetometer. A brief description of the procedure and the results are outlined below.

Several specimens were ground to a powder. Then the powder was allowed to fall through water to separate those grains which remained in suspension for more than 5 seconds and less than 30 seconds. The grain size was found to vary from 0.1 to 0.02 mms. in diameter. The powder was redeposited in still water in the earth's magnetic field. The water was then drained away gradually and the sediment was allowed to dry. Specimens taken from this deposit were found to have a magnetization which roughly coincided in declination with the earth's magnetic field, but which had a dip some 10 to 30 degrees less than the magnetic inclination. The intensity of magnetization was several times greater than that of the original rock before powdering.

Similar experiments performed with Triassic sediments from England have been reported by Clegg, et al (1954). In their results the variation in the dip was about 8 degrees and the intensity was about three times as great as that of the original rock. They suggest that the lower magnetic intensity of the natural specimen may be accounted for by turbulence during deposition or by a rise in the intensity of the earth's field since Triassic time, or it may also be due to the decay of the remanent magnetism with time. Nagata (1943) has found decay times comparable to this in the remanent magnetism of igneous rocks.

## 10. Origin of Remanent Magnetization

The information acquired from the deposition tests indicates that the sediments may well have become magnetized before cementation. In some cases this could have occurred on deposition.

The primary magnetic materials in the sediments were magnetite and hematite. The magnetite occurred as detrital fragments whereas the hematite was more often present in the form of a pigment. Evidence that this form of hematite may be magnetic and can be reliable for paleomagnetic work is given by Hargrave and Fischer (1959). Their investigation of Jurassic red limestones and radiolarites from the Alps indicated that hematite was the only magnetic material present.

Howell, et al (1958) experimented with Triassic rocks from Arizona and their results suggested that part of the remanent magnetization may have been due to the presence of hematite; when hematite is cooled below -20 °C it loses part of its remanent magnetization. Since it is difficult to measure specimens with such low temperatures on the rock-generator type megnetometer (because the specimens become heated quite easily), similar experiments have not been performed with the Triassic rocks included in this report. Tests made by D. Greenewalt, using the astatic magnetometer, indicated that the hematite may have been contributing to the remanent magnetization.

Krynine (1950) regarded the Triassic red beds as sediments derived mainly from red soils produced by weathering of the silicate rocks in the source area. Thus, the red color is of primary origin and represents physical and (or) chemical deposition. Reinemund (1955) found these conclusions to be in general agreement with conditions observed in the Deep River basin of North Carolina.

## 11. Stability of Magnetization

The fact that many of the rocks show a uniformity in direction of magnetization indicates some degree of magnetic stability over a long period of time. Of course, the geologic corrections gave evidence that most of the rocks have been stable since deformation. That the magnetization remains stable over short periods of time was confirmed by repeated measurements of some of the specimens which had been stored with their magnetic axes oriented in random directions.

Some of the rocks were unstable in the presence of the earth's field. In most cases the unstable components could be removed by a.c. field treatment; some specimens acquired IRM components in times comparable to the measurement time (10 min.) and, therefore, it was not possible to obtain accurate results. These samples represented a minority however and in most cases they were not included in the final results.

The relative instability of the Nova Scotia and Connecticut Valley igneous rocks, when subjected to a.c. fields, suggested that these results may not be reliable. In contrast, the Pa - Va igneous rocks were very stable and their results were in good agreement with the results of the sedimentary rocks.

## 12. Magnetic Reversals

Many of the sedimentary rocks were magnetized in a Northerly direction with a mean downward dip. Considerable scatter was present in the remanent magnetization of some rocks, however. In general, the scatter was downward and confined to a plane which contained the direction of magnetization of the stable rocks and the direction of the present earth's field. When given an a.c. field test many of the scattered remanent vectors moved toward a reversed direction. Although the tests were not conclusive, due to the upper limit of the a.c. field intensity, the reversals appeared to be slightly less than 180 degrees.

Reversals were found in most of the sedimentary formations, but there were no cases where both normal and reversely magnetized specimens were found within the same outcrop. During the a.c. tests the remanent vectors of some specimens were deflected in a direction perpendicular to the plane of scatter; in this case the magnetization was considered to be normal.

There are several reasons for believing that the reversals were caused by a physical or chemical effect of the type envisaged by Neel (1949, 1952), and were not due to a reversal in the main geomagnetic field.

1. The reversals occured throughout the Triassic rocks, but there was no evidence of rocks with a stable, reversed magnetization. Many of the normally magnetized rocks showed no influence of the present earth's field and were quite stable in a.c. fields; i.e., some of the New Jersey sediments.

2. Many of the rocks with normal magnetizations were scattered in a nearly reversed direction. Conversely, many of the reversed rocks were scattered toward the normal direction. Thus, the earth's field was not the only factor influencing the scatter; the reversal mechanism seemed to have some influence, also.

3. Two minor points, which may or may not have a bearing on the issue, are:
    a. Reversed rocks generally had a weaker intensity of magnetization. Why should the reversed field always be weaker than the normal geomagnetic field?
    b. No reversed and normally magnetized specimens were found within the same outcrop.

Clegg, et al, found the same pattern of scatter in the English Triassic rocks, and apparently there was no physical difference in the reversely or normally magnetized specimens. For the most part they were non-committal on the reversal issue.

Although the above points suggest a reversal in the rock itself, the evidence is certainly far from being conclusive. At present, the issue is still open to further criticism.

### 13. Comparison of Pole Positions

Fig. II-10 shows the Triassic pole positions that have been determined by other investigators. The pole positions determined from United States rocks are slightly southwest of the final pole position given in this report.

Poles No. 48 and 49 include results from the igneous rocks of the Connecticut Valley. Since these rocks are considered to be unreliable, it is safe to assume that these poles are unreliable. Pole No. 50, determined from the Brunswickian formation in New Jersey, is in good agreement with the results reported here for the same formation. Pole No. 51 (Springdale sandstone) has the same longitude as the pole position given in this report; the latitudes differ by about 10 degrees.

With respect to the Triassic pole positions as determined from English and United States sedimentary rocks, the longitude difference is somewhat less and the latitude difference is somewhat more than than previously thought to exist. For a comprehensive discussion on the relative significance of the pole positions, as regards continental drift and polar wandering, the reader is referred to an analysis by Irving (1959).

## 14. Conclusions

One very important result that became evident by this survey concerned the relative values of the igneous and sedimentary rocks for paleomagnetic determinations. The sediments gave fairly consistent results whereas the igneous rocks did not. For the reasons given in Part II, it was assumed that the igneous rocks were not as stable as the sediments, and hence their results were not included in the final analysis.

The pole positions given in Fig. II-10 led Du Bois, et al (1957) to conclude that (1) small samplings can be quite reliable, and (2) results from both igneous and sedimentary rocks laid down at the same time are in agreement. Concerning point (1), it is noticed that the difference between the pole position (determined from United States rocks) given in Fig. II-10 and the pole position determined from this survey, is about half the difference between the English and the United States pole positions. For this reason the author feels that small samplings can also be misleading. That point (2) is in error is obvious from the pole positions given in Fig. II-9.

# APPENDIX G: IGNEOUS AND SEDIMENTARY ROCK DATA

The remanent magnetization data for the igneous and sedimentary rocks is contained in Table G-1 and Table G-2. The following information is given:

Outcrop No./ average intensity of a.c. demagnetizing field, when used, e.g., NS 4/20 Oe.

No. - specimen designation; core-specimen

D.M. - Direction of magnetization; declination is east of north, dip is positive downward. Where two directions are given for one specimen, the first is the original direction of remanent magnetization and the second is the direction after a.c. demagnetization.

I - Intensity of remanent magnetization to two significant figures (cgsu/cc).

N. Pole - North seeking pole of a dipole field that would produce the average direction of magnetization in each core. The longitude is east and the latitude is positive north.

TABLE G-1

## IGNEOUS ROCK DATA

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| NS 2&3 | | | | | |
| 2 | 27 | 52½ | 28.0 | 69½ | 71½ |
| 3-1 | 22½ | 40½ | 7.5 | 83 | 65 |
| 2 | 22½ | 40½ | 9.3 | | |
| 3 | 22½ | 45 | 8.1 | | |
| 4 | 23½ | 48 | 8.1 | | |
| 4-1 | 35 | 57½ | 10.0 | 47 | 73½ |
| 2 | 34½ | 58 | 9.2 | | |
| 5-1 | 37 | 50 | 11.0 | 52 | 66 |
| 2 | 37 | 50½ | 11.0 | | |
| 3 | 37 | 51 | 11.0 | | |
| 4 | 38½ | 53 | 10.0 | | |
| 6-1 | 14½ | 44 | 7.8 | 99 | 68 |
| 2 | 14½ | 45½ | 7.7 | | |
| 3 | 16 | 45½ | 9.3 | | |
| 7-1 | 34½ | 60 | 5.5 | 57 | 75½ |
| 2 | 27½ | 56 | 6.0 | | |
| 3 | 29½ | 53 | 6.0 | | |
| 4 | 27½ | 60 | 5.1 | | |
| 8-1 | 20½ | 47½ | 6.9 | 86½ | 69 |
| 9-1 | 29 | 51½ | 4.2 | 68 | 70 |
| 2 | 26½ | 51 | 4.6 | | |
| NS 4/20 Oe. | | | | | |
| 10-1 | 26 | 45 | 6.6 | 152½ | 64½ |
| | 351½ | 39 | 4.6 | | |
| 2 | 23½ | 45 | 6.5 | | |
| | 335½ | 31 | 4.6 | | |
| 3 | 24½ | 42 | 6.7 | | |
| | 351 | 34 | 4.3 | | |
| 11-1 | 328½ | 53½ | 5.6 | 132 | 70 |
| | 6½ | 43 | 2.8 | | |
| 2 | 310 | 61 | 6.1 | | |
| | 341 | 26 | 4.7 | | |
| 3 | 6½ | 44 | 6.3 | | |
| | 13 | 40 | 2.6 | | |
| 12-1 | 90½ | 65 | 5.6 | 265 | 74½ |
| | 7½ | 67½ | 0.48 | | |
| 2 | 51½ | 60½ | 5.7 | | |
| | 357½ | 63 | 1.8 | | |
| 13-1 | 99½ | -28 | 6.7 | 34 | -10½ |
| 2 | 103 | -27 | 6.7 | | |
| 3 | 100 | -21 | 6.5 | | |
| | 96 | -30 | 4.9 | | |

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 14-1 | 244½ | 65½ | 3.4 | 198 | 83½ |
| | 25½ | 71 | 1.3 | | |
| 2 | 16½ | 46 | 4.9 | | |
| | 2½ | 46½ | 1.5 | | |
| 3 | 16½ | 47 | 4.5 | | |
| | 338 | 44½ | 1.1 | | |
| 15-1 | 9½ | 41 | 3.5 | 168 | 77½ |
| | 352½ | 52 | 1.8 | | |
| 2 | 10 | 47½ | 3.8 | | |
| | 360 | 47 | 1.1 | | |
| 3 | 340½ | 55 | 4.2 | | |
| | 338½ | 50 | 0.84 | | |
| 4 | 34½ | 84 | 3.9 | | |
| | 13 | 43½ | 1.0 | | |
| 16-1 | 71 | 46½ | 5.2 | 7½ | 55½ |
| | 46½ | 61 | 3.1 | | |
| 2 | 51 | 42 | 5.0 | | |
| | 41½ | 48 | 1.4 | | |
| 17-1 | 346½ | 35½ | 7.2 | 156½ | 59½ |
| | 346 | 31 | 6.4 | | |
| 2 | 346½ | 36 | 7.2 | | |
| | 346 | 27 | 5.6 | | |
| 3 | 350½ | 38½ | 7.7 | | |
| | 354 | 30 | 5.8 | | |
| 4 | 346 | 36½ | 7.3 | | |
| | 344½ | 31½ | 5.5 | | |
| NS 5/20 Oe. | | | | | |
| 18-1 | 356½ | 56 | 22.0 | 126 | 70 |
| 2 | 9½ | 47 | 25.0 | | |
| 3 | 0½ | 51 | 24.0 | | |
| 4 | 359 | 49 | 24.0 | | |
| 19-1 | 300½ | 31 | 16.0 | 194 | 30 |
| 2 | 297 | 34 | 13.0 | | |
| 20-1 | 280½ | 55½ | 17.0 | 213½ | 26 |
| 2 | 288½ | 57 | 21.0 | | |
| 3 | 288 | 56 | 20.0 | | |
| 4 | 285½ | 56 | 22.0 | | |
| 5 | 282 | 56 | 22.0 | | |
| 6 | 284½ | 58 | 20.0 | | |
| 7 | 287½ | 56 | 22.0 | | |
| 8 | 281½ | 57½ | 21.0 | | |

| No. | D. | M. | Ix$10^4$ | N. | Pole |
|---|---|---|---|---|---|
| 21-1 | 347½ | -27 | 11.0 | 132 | 44 |
| | 350½ | 13 | 7.1 | | |
| 2 | 358½ | -69 | 26.0 | | |
| | 348½ | 4 | 7.3 | | |
| 3 | 328 | -64 | 39.0 | | |
| | 345½ | 8 | 6.6 | | |
| 22-1 | 358½ | 53 | 14.0 | 105 | 68 |
| | 12½ | 48½ | 7.7 | | |
| 2 | 353 | 48½ | 16.0 | | |
| | 10½ | 46 | 8.5 | | |
| 23-1 | 36½ | 35 | 18.0 | 71 | 48½ |
| 2 | 25½ | 37 | 14.0 | | |
| 24-1 | 24½ | 60 | 9.1 | 87 | 66 |
| | 23 | 44 | 6.3 | | |
| 2 | 23 | 57 | 7.9 | | |
| | 25½ | 47 | 6.1 | | |
| 3 | 18 | 59 | 9.1 | | |
| 4 | 15 | 54 | 11.0 | | |
| 5 | 8½ | 51½ | 13.0 | | |
| | 15½ | 48 | 8.4 | | |
| 6 | 10 | 52 | 13.0 | | |
| | 13½ | 43½ | 8.0 | | |
| 25-1 | 315½ | 34 | 16.0 | 181 | 41½ |
| | 314 | 33 | 14.0 | | |
| 2 | 321 | 27½ | 15.0 | | |
| | 317½ | 36 | 18.0 | | |
| 3 | 314 | 33 | 19.0 | | |
| | 313 | 37 | 17.0 | | |
| 26-1 | 353 | 59 | 50.0 | 92 | 74½ |
| | 352 | 57 | 15.0 | | |
| 2 | 355½ | 57½ | 63.0 | | |
| | 355½ | 54½ | 14.0 | | |

NS 6

| No. | D. | M. | Ix$10^4$ | N. | Pole |
|---|---|---|---|---|---|
| 27-1 | 339 | 55 | 8.9 | 164 | 65 |
| 2 | 330½ | 57 | 8.6 | | |
| 3 | 331½ | 56 | 9.2 | | |
| 4 | 337½ | 60 | 9.8 | | |
| 5 | 331 | 59 | 9.0 | | |
| 6 | 352 | 61½ | 8.5 | | |
| 7 | 347 | 57½ | 8.8 | | |
| 28-1 | 16½ | 59 | 7.3 | 125 | 73 |
| 2 | 15½ | 55½ | 8.7 | | |
| 3 | 9 | 57 | 8.9 | | |
| 4 | 348½ | 60 | 8.3 | | |
| 5 | 343½ | 65 | 8.9 | | |

NS 7/10 Oe.

| No. | D. | M. | Ix$10^4$ | N. | Pole |
|---|---|---|---|---|---|
| 29-1 | 69½ | 66 | 8.2 | 30 | 62 |
| | 60½ | 58 | 6.3 | | |
| 2 | 70½ | 63 | 7.3 | | |
| | 50½ | 59 | 6.5 | | |
| 3 | 29½ | 65½ | 12.0 | | |
| | 33½ | 64 | 9.4 | | |
| 4 | 44½ | 71 | 7.2 | | |
| | 48½ | 65½ | 6.1 | | |
| 5 | 51½ | 56 | 8.6 | | |
| | 51½ | 53½ | 6.0 | | |
| 6 | 39½ | 61 | 8.0 | | |
| | 44½ | 63 | 5.7 | | |
| 7 | 50½ | 64½ | 8.1 | | |
| | 45½ | 61 | 5.5 | | |
| 8 | 50½ | 67 | 7.9 | | |
| 30-1 | 344½ | 66½ | 6.6 | 181½ | 74 |
| | 344 | 61½ | 5.3 | | |
| 2 | 325½ | 66 | 6.2 | | |
| | 349½ | 63½ | 5.8 | | |
| 3 | 332½ | 74 | 7.0 | | |
| | 336½ | 67½ | 5.4 | | |
| 31-1 | 61½ | 74 | 4.4 | 282 | 80 |
| | 307½ | 83 | 3.2 | | |
| 2 | 50½ | 78 | 7.3 | | |
| | 36½ | 77½ | 1.4 | | |
| 3 | 87½ | 76 | 8.3 | | |
| | 42½ | 69½ | 3.4 | | |
| 4 | 9½ | 78 | 8.2 | | |
| | 144½ | 83 | 4.1 | | |
| 5 | 99½ | 73 | 7.9 | | |
| 6 | 89½ | 84½ | 8.1 | | |
| 7 | 322 | -15 | 7.8 | | |
| | 321½ | 66 | 3.4 | | |
| 32-1 | 48½ | 57 | 6.4 | 23 | 55 |
| | 69½ | 57 | 5.4 | | |
| 2 | 44½ | 61 | 7.1 | | |
| | 56½ | 51½ | 5.3 | | |
| 3 | 47½ | 66 | 9.5 | | |
| | 41½ | 64½ | 6.8 | | |
| 4 | 64½ | 65 | 8.3 | | |
| | 57 | 64 | 5.9 | | |
| 5 | 69½ | 65 | 6.8 | | |
| | 64½ | 65 | 5.2 | | |
| 6 | 51½ | 66 | 6.8 | | |
| 7 | 59½ | 64½ | 6.1 | | |
| 8 | 73½ | 66 | 6.5 | | |
| 33-1 | 33 | 75 | 8.6 | 96 | 80½ |
| | 7½ | 59½ | 9.1 | | |
| 2 | 63½ | 74 | 9.2 | | |
| | 9½ | 65 | 7.3 | | |

| No. | D. M. | | Ix$10^4$ | N. Pole | |
|---|---|---|---|---|---|
| 33-3 | 102 | 76 | 11.0 | | |
| | 352½ | 64 | 7.9 | | |
| 4 | 111½ | 75 | 9.7 | | |
| | 9½ | 61 | 7.2 | | |
| 5 | 102½ | 68 | 9.5 | | |
| | 31 | 64½ | 6.3 | | |
| 6 | 121½ | 77 | 8.9 | | |
| 7 | 74½ | 73 | 9.0 | | |
| 34-1 | 182½ | 64 | 15.0 | 307 | 4 |
| | 174 | 44 | 2.9 | | |
| 2 | 172½ | 48 | 16.0 | | |
| | 154 | 66 | 2.9 | | |
| 3 | 210½ | 52 | 12.0 | | |
| | 170 | 51 | 3.6 | | |
| 4 | 174½ | 33 | 5.5 | | |
| | 155 | 51 | 6.3 | | |
| 5 | 169½ | 72½ | 5.9 | | |
| | 150½ | 68 | 1.9 | | |
| NS 8/100 Oe. | | | | | |
| 35-1 | 131 | -11 | 11.0 | 60 | 63 |
| | 30½ | 60 | 1.6 | | |
| 2 | 346½ | 45 | 3.4 | | |
| | 32 | 44 | 0.83 | | |
| 36-1 | 265 | 17½ | 12.0 | 144½ | 68½ |
| | 0½ | 70½ | 1.3 | | |
| 2 | 261½ | 18 | 13.0 | | |
| | 344 | 51 | 0.95 | | |
| 3 | 259½ | 19 | 12.0 | | |
| | 207 | 54 | 0.88 | | |
| 4 | 262 | 18½ | 13.0 | | |
| | 357 | 35 | 0.70 | | |
| 5 | 249½ | 18 | 15.0 | | |
| 37-1 | 241½ | 81 | 2.1 | 66 | 82½ |
| | 8 | 68 | 0.47 | | |
| 2 | 271½ | 80 | 1.8 | | |
| | 23½ | 68½ | 0.42 | | |
| 3 | 177½ | 76½ | 1.2 | | |
| | 15 | 66½ | 0.29 | | |
| 38-1 | 327½ | 73½ | 4.0 | 197 | 77 |
| | 342 | 62½ | 1.6 | | |
| 2 | 335½ | 78 | 3.7 | | |
| | 323 | 83½ | 1.1 | | |
| 3 | 312½ | 71 | 5.5 | | |
| | 351½ | 64 | 1.5 | | |
| 39-1 | 322½ | 51 | 3.9 | 138 | 67½ |
| | 355½ | 52 | 1.7 | | |
| 2 | 322½ | 63 | 4.1 | | |
| | 349 | 48 | 1.8 | | |
| 3 | 318½ | 64 | 3.7 | | |
| | 347 | 52 | 1.6 | | |

| No. | D. M. | | Ix$10^4$ | N. Pole | |
|---|---|---|---|---|---|
| NS 9 | | | | | |
| 40-1 | 33½ | 48 | 8.2 | 36½ | 57½ |
| 41-1 | 27½ | 54½ | 1.4 | 29½ | 66½ |
| 2 | 24½ | 53½ | 1.4 | | |
| 3 | 20½ | 56 | 1.6 | | |
| 42-1 | 16½ | 51½ | 4.3 | 45½ | 70½ |
| 2 | 20½ | 50 | 3.7 | | |
| 43-1 | 21 | 52 | 3.2 | 40½ | 68½ |
| 44-1 | 10½ | 60 | 5.4 | 355½ | 81½ |
| 2 | 2½ | 62 | 5.3 | | |
| 45-1 | 359½ | 65 | 5.5 | 316 | 85 |
| 2 | 358 | 59 | 6.0 | | |
| 46-1 | 37½ | 61½ | 2.7 | 6 | 61 |
| 2 | 41½ | 64½ | 2.9 | | |
| 3 | 22½ | 61 | 3.4 | | |
| NS 10 | | | | | |
| 47-1 | 30 | 53 | 19.0 | 42½ | 64½ |
| 2 | 28 | 52 | 16.0 | | |
| 48-1 | 30 | 54½ | 12.0 | 40 | 68 |
| 2 | 24 | 55½ | 12.0 | | |
| 49-1 | 33 | 51 | 19.0 | 41½ | 63½ |
| 2 | 28½ | 51½ | 18.0 | | |
| 3 | 31 | 54 | 18.0 | | |
| 4 | 29½ | 52½ | 15.0 | | |
| 5 | 28½ | 53 | 15.0 | | |
| 50-1 | 26 | 61 | 12.0 | 49 | 73½ |
| 2 | 17½ | 50½ | 17.0 | | |
| 3 | 21½ | 53 | 14.0 | | |
| 4 | 10 | 58 | 16.0 | | |
| 51-1 | 20½ | 55½ | 15.0 | 47 | 72 |
| 52-1 | 25 | 58 | 12.0 | 35½ | 70½ |
| 53-1 | 30½ | 57½ | 15.0 | 31 | 67 |
| 2 | 28½ | 59 | 16.0 | | |
| NS 11/15 Oe. | | | | | |
| 54-1 | 7½ | 68½ | 19.0 | 19 | 47 |
| | 50 | 56 | 11.0 | | |
| 2 | 359 | 66 | 18.0 | | |
| | 44 | 57 | 11.0 | | |
| 3 | 7½ | 62 | 17.0 | | |
| | 50 | 55 | 10.0 | | |
| 55-1 | 17 | 64½ | 14.0 | 34 | 62 |
| | 26 | 55 | 10.0 | | |
| 56-1 | 8 | 66 | 11.0 | 20 | 68 |
| | 16 | 62 | 5.8 | | |
| 2 | 11 | 70 | 13.0 | | |
| | 18½ | 59½ | 5.5 | | |

| No. | D. | M. | Ix10$^4$ | N. | Pole |
|---|---|---|---|---|---|
| 56-3 | 354 | 68½ | 9.6 | | |
| | 18½ | 64½ | 5.6 | | |
| 57-1 | 8 | 68½ | 9.7 | 19½ | 78 |
| | 9 | 64½ | 5.2 | | |
| 2 | 11 | 71 | 8.8 | | |
| | 6 | 58½ | 5.1 | | |
| 58-1 | 352 | 69½ | 8.2 | 11 | 75 |
| | 9 | 63½ | 5.0 | | |
| 59-1 | 318½ | 48½ | 11.0 | 32 | 69½ |
| | 18½ | 54 | 3.0 | | |
| 2 | 322 | 64½ | 8.6 | | |
| | 16 | 62 | 3.0 | | |
| 60-1 | 43 | 64½ | 8.2 | 17 | 67 |
| | 32 | 62 | 3.6 | | |
| 2 | 26 | 67 | 11.0 | | |
| | 14½ | 64½ | 5.4 | | |
| 3 | 17½ | 70 | 8.5 | | |
| | 23½ | 59½ | 4.5 | | |

NS 12/20 Oe.

| | | | | | |
|---|---|---|---|---|---|
| 61-1 | 344 | 44 | 18.0 | 151½ | 67 |
| 2 | 345½ | 43½ | 20.0 | | |
| 62-1 | 337 | 52½ | 10.0 | 174 | 68½ |
| 2 | 338 | 52 | 11.0 | | |
| 63-1 | 334½ | 47 | 5.2 | 171 | 63½ |
| 64-1 | 224 | 34 | 6.7 | 310 | 81 |
| | 331 | 69 | 2.4 | | |
| 2 | 137 | 69½ | 6.5 | | |
| | 33 | 66 | 2.1 | | |
| 65-1 | 302½ | 62 | 8.2 | 213½ | 67 |
| | 324 | 64½ | 4.0 | | |
| 2 | 298 | 52 | 6.5 | | |
| | 329 | 62 | 4.0 | | |
| 66-1 | 349 | 52½ | 22.0 | 173 | 67 |
| | 336 | 50½ | 6.6 | | |
| 67-1 | 352 | 64½ | 14.0 | 157 | 73 |
| | 349 | 52½ | 4.6 | | |
| 2 | 357 | 62 | 14.0 | | |
| | 343½ | 50 | 4.1 | | |

NS 13

| | | | | | |
|---|---|---|---|---|---|
| 68-1 | 26 | 49 | 3.3 | 50 | 64½ |
| 69-1 | 30½ | 45 | 3.1 | 50 | 60 |
| 70-1 | 26½ | 45 | 4.4 | 54½ | 62½ |
| 71-1 | 30 | 44 | 6.7 | 50 | 58 |
| 2 | 31½ | 42 | 6.5 | | |

| No. | D. | M. | Ix10$^4$ | N. | Pole |
|---|---|---|---|---|---|
| 72-1 | 30½ | 43 | 5.0 | 51 | 60 |
| 2 | 30½ | 42 | 5.1 | | |
| 3 | 28 | 46 | 5.3 | | |
| 73-1 | 26½ | 44½ | 6.5 | 55 | 61½ |
| 74-1 | 34 | 43 | 7.7 | 48½ | 58 |
| 2 | 30½ | 45 | 7.7 | | |
| 3 | 29½ | 44 | 7.4 | | |
| 75-1 | 25 | 49 | 6.3 | 52½ | 66 |
| 2 | 28½ | 50 | 5.8 | | |
| 3 | 24½ | 48 | 6.3 | | |

M 6/10 Oe.

| | | | | | |
|---|---|---|---|---|---|
| 39-1 | 19½ | 11 | 9.0 | 45½ | 43½ |
| | 18 | 3½ | 8.0 | | |
| 2 | 16½ | 12 | 9.7 | | |
| | 19½ | 5 | 8.9 | | |
| 40-1 | 16½ | 18 | 8.2 | 41 | 45 |
| | 17 | 10 | 6.9 | | |
| 2 | 18 | 19 | 9.1 | | |
| | 17 | 8 | 8.0 | | |
| 41-1 | 27 | 6 | 11.0 | 50½ | 40 |
| | 23½ | - 3 | 8.7 | | |
| 2 | 22½ | 8½ | 9.2 | | |
| | 25½ | - 7 | 9.0 | | |
| 3 | 24 | 5½ | 10.0 | | |
| | 24½ | - 4½ | 9.3 | | |
| 42-1 | 14 | 11 | 14.0 | 58½ | 49 |
| | 15 | -11 | 14.0 | | |
| 2 | 12½ | 10½ | 16.0 | | |
| | 11 | 2 | 12.0 | | |
| 43-1 | 22 | 5½ | 9.7 | 51 | 40½ |
| | 21 | - 4 | 9.1 | | |
| 2 | 26½ | 6½ | 10.0 | | |
| | 27 | - 5 | 8.3 | | |
| 44-1 | 19½ | - 3½ | 15.0 | 64 | 41 |
| | 20 | -14 | 12.0 | | |
| 2 | 21 | - 5½ | 15.0 | | |
| | 22 | -17 | 12.0 | | |
| 45-1 | 18 | 1½ | 7.2 | 59 | 43 |
| | 16½ | - 8 | 5.4 | | |
| 2 | 28 | - 6 | 8.2 | | |
| | 21½ | -10 | 6.4 | | |
| 46-1 | 26 | 38½ | 27.0 | 33½ | 45 |
| | 15½ | 17½ | 9.6 | | |

M 7

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 47-1 | 10 | 28½ | 10.0 | 33½ | 54½ |
| 2 | 19½ | 30½ | 9.1 | | |
| 48-1 | 358 | 53 | 11.0 | 242½ | 50½ |
| 49-1 | 4 | 25 | 7.9 | 62 | 66½ |
| 2 | 1 | 13 | 5.9 | | |
| 50-1 | 359 | 56 | 15.0 | 340 | 45 |

M 8

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 51-1 | 196 | 13 | 4.2 | 275 | -38 |
| 52-1 | 269 | -18 | 18.0 | 198½ | 0 |
| 53-1 | 23½ | 33 | 4.2 | 53 | 46½ |
| 2 | 30 | 29 | 5.0 | | |
| 54-1 | 12 | 33 | 8.6 | 65 | 55½ |
| 55-1 | 338½ | 52 | 10.0 | 73 | 81 |
| 56-1 | 81½ | 73½ | 0.60 | 355 | 12½ |
| 2 | 106 | 52 | 1.2 | | |
| 57-1 | 97 | 74 | 99.0 | 298½ | 38 |

M 9/50 Oe.

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 58-1 | 26 | 40 | 6.3 | 59½ | 48½ |
| | 27 | 25 | 3.9 | | |
| 59-1 | 22½ | 31 | 7.9 | 75 | 49 |
| | 18 | 27½ | 6.2 | | |
| 2 | 34½ | 18½ | 8.9 | | |
| | 24 | 8 | 6.2 | | |
| 60-1 | 30 | 27 | 8.0 | 63 | 44 |
| | 29 | 14½ | 6.8 | | |
| 61-1 | 87½ | 40 | 4.2 | 66 | 39½ |
| | 29 | 9 | 3.4 | | |
| 2 | 87 | 25½ | 3.7 | | |
| | 31½ | 5½ | 3.4 | | |
| 62-1 | 22 | 66½ | 9.0 | 31 | 64 |
| | 17½ | 56 | 6.1 | | |
| 63-1 | 95 | 57½ | 7.8 | 31 | 37½ |
| | 36 | 48 | 3.4 | | |
| 2 | 106 | 41½ | 8.6 | | |
| | 60 | 26 | 2.9 | | |
| 64-1 | 68 | 37 | 8.4 | 38½ | 37½ |
| | 46 | 24 | 3.1 | | |
| 2 | 72 | 40 | 8.0 | | |
| | 48 | 34 | 2.9 | | |
| 65-1 | 73 | 59 | 14.0 | 23 | 36½ |
| | 56 | 46 | 4.7 | | |
| 2 | 65 | 57½ | 13.0 | | |
| | 53½ | 44½ | 3.7 | | |

C 1/50 Oe.

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 1-1 | 20 | 67 | 20.0 | 34 | 64½ |
| | 4½ | 56½ | 6.7 | | |
| 2 | 12 | 61 | 17.0 | | |
| | 2 | 54 | 4.4 | | |
| 2-1 | 28 | 51 | 18.0 | 59 | 57½ |
| | 17 | 39½ | 4.5 | | |
| 2 | 39 | 49½ | 19.0 | | |
| | 5½ | 38½ | 5.0 | | |
| 3-1 | 52 | 44 | 15.0 | 41½ | 46 |
| | 5 | 33½ | 2.0 | | |
| 2 | 57 | 43 | 14.0 | | |
| | 57 | 43 | 3.3 | | |
| 4-1 | 24 | 57½ | 17.0 | 35½ | 50 |
| | 22½ | 51 | 2.0 | | |
| 2 | 28½ | 48 | 19.0 | | |
| | 28½ | 48 | 2.6 | | |
| 5-1 | 276½ | 51½ | 34.0 | 33½ | 53½ |
| | 19 | 53 | 3.2 | | |
| 6-1 | 22 | 56 | 19.0 | 60 | 59 |
| | 9 | 40 | 2.4 | | |
| 7-1 | 324 | 62 | 9.8 | 58 | 63½ |
| | 4 | 44 | 5.6 | | |
| 8-1 | 23 | 46 | 20.0 | 34½ | 65½ |
| | 2 | 56 | 6.9 | | |

C 2

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 9-1 | 7½ | 19 | 6.5 | 81 | 51½ |
| 2 | 20½ | 7 | 12.0 | | |
| 10-1 | 15 | 16 | 2.4 | 78½ | 53 |
| 11-1 | 25 | 24 | 5.3 | 59 | 50 |
| 12-1 | 1 | 46 | 6.8 | 68 | 73 |
| 13-1 | 13½ | 39 | 7.8 | 60½ | 63½ |
| 14-1 | 17 | 25 | 16.0 | 70 | 55½ |

C 3/150 Oe.

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 15-1 | 350½ | 22½ | 5.6 | 153 | 79 |
| | 338 | 52 | 4.7 | | |
| 16-1 | 67 | -29 | 11.0 | 21 | 63½ |
| | 23 | 59 | 3.1 | | |
| 2 | 20 | 74 | 2.2 | | |
| | 19 | 60 | 3.1 | | |
| 17-1 | 173 | 73 | 4.5 | 338 | 72 |
| | 358½ | 71 | 4.2 | | |
| 18-1 | 7 | 69 | 12.0 | 319½ | 54 |
| | 5 | 83 | 5.1 | | |

| No. | D. | M. | Ix10$^{4}$ | N. Pole | |
|---|---|---|---|---|---|
| 19-1 | 175 | 50 | 6.2 | 9 | 78 |
| | 158 | 64 | 2.7 | | |
| 20-1 | 274 | 47 | 9.6 | 337 | 74 |
| | 358 | 71 | 3.4 | | |
| 2 | 273 | 58 | 10.0 | | |
| | 354 | 70 | 3.8 | | |
| C 4/100 Oe. | | | | | |
| 22-1 | 8 | 24½ | 4.1 | 75 | 50½ |
| | 14 | 15 | 3.3 | | |
| 2 | 12 | 23 | 4.1 | | |
| | 17½ | 18½ | 3.0 | | |
| 3 | 12 | 26 | 4.2 | | |
| | 19 | 16½ | 3.0 | | |
| 23-1 | 12½ | 37 | 3.9 | 81 | 55½ |
| | 11 | 22 | 2.5 | | |
| 24-1 | 10 | 43½ | 3.9 | 76½ | 51½ |
| | 17 | 19 | 2.2 | | |
| P 3 | | | | | |
| 21-1 | 11 | 39 | 9.2 | 110 | 63½ |
| 22-1 | 12 | 46 | 7.0 | 118 | 67 |
| 23-1 | 26 | 42 | 7.1 | 86 | 69 |
| 2 | 25 | 44½ | 6.3 | | |
| 24-1 | 26 | 46½ | 5.0 | 91 | 71 |
| 25-1 | 24 | 45 | 8.9 | 100 | 70½ |
| 2 | 18½ | 47 | 7.8 | | |
| 26-1 | 22 | 42 | 8.3 | 93½ | 66 |
| 2 | 20 | 42½ | 7.8 | | |
| 27-1 | 26 | 37 | 6.9 | 82 | 64½ |
| 28-1 | 28 | 40½ | 7.3 | 82½ | 67 |
| 2 | 25 | 40½ | 6.9 | | |
| P 6 | | | | | |
| 47-1 | 354 | 35 | 60.0 | 115 | 61½ |
| 2 | 359 | 33 | 55.0 | | |
| 48-1 | 354 | 36 | 52.0 | 120 | 62½ |
| 49-1 | 358½ | 38 | 14.0 | 112 | 64 |
| 50-1 | 350 | 32 | 0.22 | 125 | 58½ |
| 51-1 | 350 | 35 | 0.36 | 126 | 60 |
| 52-1 | 356 | 45 | 6.3 | 121½ | 67½ |

| No. | D. | M. | Ix10$^{4}$ | N. Pole | |
|---|---|---|---|---|---|
| P 9/50 Oe. | | | | | |
| 68-1 | 27 | 59½ | 9.7 | 53 | 67½ |
| | 30½ | 54 | 6.3 | | |
| 69-1 | 352 | 57 | 16.0 | 144½ | 63½ |
| | 342 | 49 | 9.4 | | |
| 70-1 | 350 | 56½ | 12.0 | 138½ | 62 |
| | 344 | 44½ | 6.2 | | |
| 71-1 | 305 | 78½ | 18.0 | 134½ | 67 |
| | 349½ | 51 | 6.8 | | |
| 72-1 | 332 | 58½ | 8.9 | 138 | 63½ |
| | 345 | 47 | 5.8 | | |
| 73-1 | 348 | 51 | 11.0 | 133 | 62½ |
| | 347½ | 43 | 6.8 | | |
| 74-1 | 338 | 51 | 10.0 | 138½ | 62 |
| | 344 | 44½ | 5.9 | | |
| 75-1 | 350 | 54½ | 5.4 | 144 | 67½ |
| | 345 | 54½ | 4.6 | | |
| P 10/50 Oe. | | | | | |
| 76-1 | 0½ | 40½ | 5.8 | 111 | 63 |
| | 359 | 41 | 4.8 | | |
| 2 | 359 | 40½ | 5.2 | | |
| | 358½ | 41 | 4.6 | | |
| 77-1 | 356 | 43½ | 4.0 | 114½ | 63½ |
| | 357 | 42 | 3.4 | | |
| 2 | 357½ | 44 | 3.2 | | |
| | 357½ | 42 | 2.9 | | |
| 78-1 | 354 | 35½ | 7.4 | 115 | 59½ |
| | 356½ | 34½ | 6.4 | | |
| 2 | 354½ | 35½ | 6.8 | | |
| | 356 | 34½ | 6.1 | | |
| 79-1 | 354 | 40½ | 2.9 | 113 | 62 |
| | 357 | 40 | 2.6 | | |
| 2 | 358 | 40½ | 3.7 | | |
| | 359 | 40½ | 3.4 | | |
| 80-1 | 341 | 37 | 6.5 | 113 | 64 |
| | 357 | 41 | 6.1 | | |
| 2 | 346½ | 40½ | 5.8 | | |
| | 358½ | 42½ | 5.1 | | |
| 81-1 | 338 | 41 | 9.3 | 122 | 63 |
| | 353 | 41 | 6.3 | | |
| 82-1 | 326½ | 40½ | 7.9 | 135 | 63 |
| | 349 | 44 | 5.6 | | |
| 2 | 333 | 44 | 7.7 | | |
| | 343 | 46 | 5.7 | | |
| 83-1 | 338½ | 50 | 11.0 | 109 | 67 |
| | 1½ | 46 | 6.0 | | |
| 84-1 | 353½ | 49 | 6.6 | 118 | 65 |
| | 356½ | 44 | 5.1 | | |

| No. | D. M. | | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| P 11 | | | | | |
| 85-1 | 353½ | 54½ | 3.9 | 132½ | 71 |
| 86-1 | 348 | 58 | 2.5 | 143 | 69½ |
| 2 | 348 | 53½ | 3.6 | | |
| 87-1 | 354 | 52½ | 4.4 | 129½ | 69½ |
| 88-1 | 360 | 53½ | 2.1 | 117½ | 71½ |
| 89-1 | 343 | 61½ | 3.7 | 159 | 71 |
| 90-1 | 352½ | 57½ | 3.8 | 137 | 72 |
| 91-1 | 355 | 53½ | 5.0 | 132 | 72 |
| 2 | 354 | 59 | 4.3 | | |
| 92-1 | 353 | 60½ | 5.0 | 142 | 74 |
| P 14/50 Oe. | | | | | |
| 103-1 | 16 | 37 | 2.5 | 97 | 63 |
| | 8½ | 40 | 2.9 | | |
| 2 | 13 | 34 | 3.0 | | |
| | 9½ | 35½ | 2.6 | | |
| 3 | 12½ | 33½ | 2.9 | | |
| | 10 | 40 | 2.6 | | |
| 104-1 | 360 | 38½ | 2.1 | 111 | 63 |
| | 2 | 38½ | 2.2 | | |
| 2 | 358½ | 35 | 2.6 | | |
| | 2 | 37 | 2.9 | | |
| 105-1 | 19½ | 44½ | 2.4 | 91½ | 65 |
| | 20 | 43 | 2.4 | | |
| 2 | 27½ | 39½ | 2.6 | | |
| | 6½ | 38 | 2.3 | | |
| 106-1 | 2½ | 32 | 2.3 | 110½ | 61½ |
| | 358½ | 35 | 2.5 | | |
| 2 | 1 | 31 | 3.0 | | |
| | 3½ | 31½ | 2.5 | | |
| 107-1 | 9 | 40 | 2.4 | 95½ | 63 |
| | 14 | 39 | 2.3 | | |
| 2 | 17½ | 34½ | 2.7 | | |
| | 12½ | 38 | 2.4 | | |
| 3 | 8½ | 33½ | 2.9 | | |
| | 10 | 33½ | 2.4 | | |
| 108-1 | 7½ | 30½ | 2.4 | 101 | 60 |
| | 6½ | 32½ | 2.4 | | |
| 109-1 | 7½ | 35 | 2.7 | 112½ | 59 |
| | 358½ | 33½ | 2.5 | | |
| 2 | 356½ | 30½ | 3.1 | | |
| | 354 | 31 | 2.5 | | |
| 3 | 3 | 34½ | 3.2 | | |
| | 6 | 31 | 3.5 | | |
| 110-1 | 16 | 37½ | 2.3 | 93 | 63½ |
| | 10½ | 37½ | 2.2 | | |
| 2 | 12½ | 34 | 2.6 | | |
| | 12½ | 37½ | 2.2 | | |
| 3 | 15 | 45½ | 3.1 | | |
| | 9½ | 37½ | 2.4 | | |

| No. | D. M. | | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| P 16 | | | | | |
| 125-1 | 322½ | 42 | 13.0 | 153 | 47½ |
| 126-1 | 312 | 44½ | 18.0 | 163 | 45 |
| 127-1 | 330 | 44 | 16.0 | 145½ | 51 |
| 128-1 | 316 | 43½ | 18.0 | 160 | 46 |
| 129-1 | 338½ | 44 | 11.0 | 137 | 53 |
| 130-1 | 348 | 71½ | 12.0 | 136 | 71 |
| V 1/20 Oe. | | | | | |
| 1-1 | 351 | 39½ | 6.4 | 122 | 61 |
| | 7 | 38 | 4.2 | | |
| 2-1 | 23½ | 50 | 14.0 | 122 | 66½ |
| | 15 | 41 | 11.0 | | |
| 2 | 19½ | 47 | 12.0 | | |
| | 10½ | 43 | 10.0 | | |
| 3-1 | 41 | 35 | 15.0 | 83 | 66 |
| | 28 | 34½ | 6.4 | | |
| 4-1 | 6 | 36 | 2.8 | 115 | 56½ |
| | 3½ | 27½ | 2.5 | | |
| 5-1 | 7 | 30 | 26.0 | 107 | 61 |
| | 10½ | 31 | 16.0 | | |
| 2 | 7 | 28 | 24.0 | | |
| | 12 | 29½ | 16.0 | | |
| 6-1 | 359½ | 42½ | 6.3 | 125 | 62½ |
| | 9 | 38 | 4.2 | | |
| 2 | 352½ | 48 | 8.2 | | |
| | 4 | 40½ | 4.4 | | |
| 7-1 | 1 | 42½ | 10.0 | 120½ | 61 |
| | 6½ | 32 | 5.7 | | |
| 2 | 352½ | 46½ | 8.7 | | |
| | 5 | 38 | 4.7 | | |
| 8-1 | 360 | 47½ | 11.0 | 117 | 63½ |
| | 10 | 36½ | 6.8 | | |
| 9-1 | 349 | 47 | 8.9 | 147 | 59 |
| | 0½ | 44 | 4.8 | | |
| 2 | 355 | 45 | 8.2 | | |
| | 352 | 47 | 5.2 | | |
| 10-1 | 10 | 38 | 7.4 | 115 | 61½ |
| | 7 | 34½ | 4.8 | | |
| 2 | 6 | 37½ | 7.9 | | |
| | 11 | 32½ | 4.2 | | |
| 11-1 | 339½ | 50 | 12.0 | 152 | 49½ |
| | 336½ | 40 | 6.6 | | |
| 2 | 337 | 46 | 12.0 | | |
| | 343½ | 40½ | 6.6 | | |
| 12-1 | 332 | 51 | 10.0 | 144½ | 57 |
| | 353½ | 43 | 5.4 | | |
| 13-1 | 0½ | 53½ | 11.0 | 134½ | 65 |
| | 8 | 46 | 64.0 | | |

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 14-1 | 2½ | 38 | 25.0 | 119 | 62 |
| | 7 | 33 | 21.0 | | |
| 2 | 328 | 44 | 28.0 | | |
| | 8 | 38½ | 11.0 | | |
| 15-1 | 359 | 43 | 11.0 | 129 | 62 |
| | 4 | 41½ | 5.8 | | |
| 2 | 358 | 44½ | 8.6 | | |
| | 4½ | 39 | 5.1 | | |

V 5/20 Oe.

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 38-1 | 351 | 28½ | 5.9 | 125 | 58 |
| | 351 | 21½ | 3.8 | | |
| 39-1 | 3 | 40 | 4.3 | 127½ | 72½ |
| | 355 | 44½ | 3.3 | | |
| 2 | 4½ | 38½ | 5.0 | | |
| | 5 | 40½ | 4.2 | | |
| 40-1 | 325 | 53½ | 4.2 | 182 | 52 |
| | 320½ | 47 | 2.6 | | |
| 2 | 329 | 55 | 4.3 | | |
| | 327 | 52½ | 3.0 | | |
| 41-1 | 332½ | 36 | 4.5 | 157½ | 57 |
| | 334 | 31½ | 3.4 | | |
| 2 | 339 | 45 | 4.1 | | |
| | 339½ | 41 | 3.5 | | |
| 42-1 | 341 | 51 | 3.9 | 183 | 55 |
| | 328 | 51½ | 3.4 | | |
| 43-1 | 298 | 58½ | 3.6 | 187½ | 56 |
| | 316 | 51½ | 2.7 | | |
| 2 | 300½ | 55 | 3.2 | | |
| | 341½ | 58½ | 2.8 | | |
| 44-1 | 320 | 44 | 1.8 | 184 | 51 |
| | 328 | 46½ | 1.8 | | |
| 2 | 322 | 45 | 3.9 | | |
| | 318½ | 53½ | 3.9 | | |
| 45-1 | 312 | 60 | 4.1 | 195½ | 47½ |
| | 321 | 53 | 4.1 | | |
| 2 | 304 | 60 | 2.6 | | |
| | 310 | 59½ | 2.6 | | |

V 6/20 Oe.

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 46-1 | 349½ | 59 | 7.9 | 130 | 78 |
| | 355½ | 55 | 5.5 | | |
| 2 | 16 | 56 | 5.6 | | |
| | 21½ | 42½ | 5.0 | | |
| 47-1 | 20½ | 61½ | 6.6 | 71 | 85 |
| | 24 | 55½ | 3.9 | | |
| 2 | 6 | 63 | 8.5 | | |
| | 23½ | 52½ | 5.5 | | |
| 48-1 | 339½ | 62 | 11.0 | 156 | 76½ |
| | 352 | 56½ | 6.5 | | |
| 2 | 355 | 65 | 7.8 | | |
| | 2½ | 50 | 4.5 | | |
| 49-1 | 46 | 49 | 8.9 | 65 | 80½ |
| | 26 | 49 | 4.5 | | |
| 2 | 42 | 51 | 8.6 | | |
| | 24½ | 50½ | 4.7 | | |
| 50-1 | 12½ | 72½ | 5.1 | 188 | 85 |
| | 19½ | 60 | 4.5 | | |
| 51-1 | 101 | 75 | 7.1 | 268 | 60½ |
| | 81 | 75 | 4.6 | | |
| 2 | 46 | 76½ | 8.3 | | |
| | 28 | 73 | 5.4 | | |
| 52-1 | 99 | 66 | 7.3 | 350 | 82 |
| | 38 | 59 | 4.7 | | |
| 2 | 76 | 69½ | 6.7 | | |
| | 31 | 56½ | 4.6 | | |
| 53-1 | 66 | 43½ | 5.7 | 1 | 59½ |
| | 50½ | 39 | 5.4 | | |
| 2 | 75½ | 51½ | 7.0 | | |
| | 71 | 53½ | 5.3 | | |
| 3 | 68 | 51½ | 6.0 | | |
| | 50½ | 52 | 5.2 | | |

½V 12

| No. | D. | M. | Ix10$^4$ | N. Pole | |
|---|---|---|---|---|---|
| 91-1 | 143 | 53 | 1.4 | very unstable | |
| 92-1 | 148 | 7 | 0.62 | | |
| 2 | 308 | 25 | 2.4 | | |
| 93-1 | 334 | 28 | 1.9 | | |

## TABLE G-2

## SEDIMENTARY ROCK DATA

| No. | D. | M. | Ix10$^5$ | N. Pole |
|---|---|---|---|---|
| M 1 | | | | |
| 1 | broken | | | |
| 2 | 360 | 43 | 1.1 | |
| 3 | 12½ | 40 | 1.7 | |
| 4 | 2½ | 48½ | 1.7 | |
| 5 | 2½ | 50 | 1.7 | |
| 6 | 354 | 51½ | 2.4 | |
| 7 | 4½ | 40 | 1.7 | |
| 8 | 7 | 50 | 2.0 | |
| M 2 | | | | |
| 9 | 3½ | 39½ | 2.6 | |
| 10 | 354 | 53 | 2.1 | |
| 11 | 359½ | 48 | 3.5 | |
| 12 | broken | | | |
| 13 | 7½ | 56 | 2.4 | |
| M 3 | | | | |
| 14 | 355 | 30 | 1.5 | |
| 15 | 345 | 48 | 0.87 | |
| 16 | 342 | 59 | 0.96 | |
| 17 | 348 | 52 | 1.2 | |
| 18 | 351 | 44½ | 1.5 | |
| 19 | 1 | 50 | 1.3 | |
| 20 | 358 | 52½ | 2.1 | |
| 21 | 351 | 58 | 1.2 | |
| 22 | 351 | 47½ | 2.0 | |
| M 4 | | | | |
| 23 | 332 | 64 | 3.4 | |
| 24 | 347½ | 55 | 1.8 | |
| 25a | 340½ | 59½ | 2.3 | |
| 25b | 334½ | 59 | 2.2 | |
| 25c | 343 | 60 | 2.3 | |
| 25d | 345½ | 58 | 2.3 | |
| 26 | 349½ | 45½ | 1.5 | |
| 27 | 342 | 65½ | 2.2 | |
| 28 | 330 | 68½ | 1.9 | |
| 29 | 350 | 70 | 5.0 | |
| 30 | 71 | 56½ | 7.6 | |
| M 5/20 Oe. | | | | |
| 31-1 | 339½ | 55 | 0.64 | |
| | 5 | 45 | 0.57 | |
| 2 | 354 | 54½ | 0.62 | |
| | 0 | 42½ | 0.61 | |
| 3 | 8 | 55 | 0.59 | |
| | 358 | 49½ | 0.57 | |
| 32-1 | 357 | 52 | 0.57 | |
| 2 | 356 | 46½ | 0.54 | |
| 33-1 | 10½ | 50 | 1.4 | |
| | 6 | 53½ | 1.2 | |
| 2 | 6½ | 52½ | 1.3 | |
| | 6½ | 55½ | 1.0 | |
| 3 | 352 | 72 | 1.7 | |
| | 344 | 63 | 1.1 | |
| 4 | 17 | 50½ | 1.2 | |
| | 5½ | 51 | 1.1 | |
| 34-1 | 4 | 55 | 1.6 | |
| 2 | 0½ | 50 | 2.0 | |
| 3 | 1 | 56½ | 1.7 | |
| 4 | 358 | 56½ | 1.8 | |
| 35-1 | 350 | 57½ | 1.6 | |
| 2 | 347½ | 56½ | 1.7 | |
| 3 | 354 | 56 | 1.8 | |
| 36-1 | 346 | 58 | 1.7 | |
| | 344 | 59 | 1.6 | |
| 2 | 6 | 59½ | 1.5 | |
| | 346 | 60 | 1.6 | |
| 3 | 354 | 61 | 1.7 | |
| | 342 | 59 | 1.6 | |
| 37-1 | 358½ | 63½ | 2.4 | |
| 2 | 360 | 66½ | 2.0 | |
| 3 | 1½ | 61 | 1.7 | |
| 4 | 8 | 61 | 1.9 | |
| 5 | 7½ | 60 | 1.6 | |
| 38-1 | 359½ | 54 | 1.6 | |
| | 357 | 56 | 2.1 | |
| 2 | 14 | 55½ | 1.6 | |
| | 4 | 53 | 1.8 | |
| 3 | 7½ | 50½ | 1.9 | |
| | 2 | 53 | 2.2 | |
| 4 | 10 | 65½ | 1.7 | |
| | 2 | 59 | 2.2 | |

| No. | D. | M. | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| M 11/50 Oe. | | | | | |
| 74 | 15½ | 67 | 1.1 | | |
| | 6 | 54 | 0.79 | | |
| 75 | 40 | 28½ | 1.6 | | |
| | 1½ | 57 | 0.91 | | |
| 76 | 14 | 39½ | 1.8 | | |
| | 2 | 54½ | 1.3 | | |
| 77 | 15 | 64 | 0.85 | | |
| | 16 | 62 | 0.62 | | |
| J 1 | | | | | |
| 1 | 350 | 40 | 7.4 | 131 | 65½ |
| 2 | 4 | 35 | 3.9 | 100½ | 65 |
| 3 | 4 | 34 | 2.4 | 100½ | 64½ |
| 4 | 359 | 22 | 5.9 | 108½ | 57 |
| 5 | 358½ | 33½ | 3.0 | 111 | 62 |
| 6 | 7½ | 28½ | 2.6 | 93½ | 60½ |
| 7 | 360 | 38½ | 1.8 | 109 | 66½ |
| J 2 | | | | | |
| 8-1 | 32 | 40 | 3.0 | 63 | 65 |
| 2 | 10 | 43½ | 2.4 | | |
| 9 | 28 | 44½ | 2.8 | 51 | 64 |
| 10 | 7 | 53 | 2.6 | 90 | 77 |
| 11 | 43 | 42½ | 2.9 | 34½ | 54 |
| 12 | 17 | 29½ | 2.9 | 76 | 59 |
| 13-1 | 28 | 39 | 2.5 | 56 | 59½ |
| 2 | 28 | 36 | 2.8 | | |
| 14 | 2½ | 29½ | 2.1 | 102 | 61½ |
| 15 | 9 | 39 | 2.3 | 89 | 66 |
| 16 | 8½ | 42 | 2.2 | 89½ | 69 |
| 17 | 36½ | 40 | 3.1 | 43 | 56 |
| 18 | broken | | | | |
| J 3 | | | | | |
| 19 | 28 | 47 | 4.0 | 55½ | 66 |
| 20 | 35 | 45½ | 3.8 | 45½ | 61½ |
| 21 | 355½ | 46 | 5.0 | 124 | 70 |
| 22-1 | broken | | | | |
| 2 | " | | | | |
| 23 | 355 | 49½ | 3.2 | 130 | 71½ |
| 24-1 | 11½ | 65 | 2.6 | 70 | 87 |
| 2 | 15 | 66½ | 2.6 | | |

| No. | D. | M. | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| 25-1 | 15½ | 46½ | 3.1 | 80 | 65 |
| 2 | 17 | 33 | 4.2 | | |
| 26 | 12 | 52½ | 2.7 | 85 | 75 |
| J 4 | | | | | |
| 27-1 | 347 | 44 | 0.71 | 168 | 53½ |
| 2 | 295 | 45 | 0.94 | | |
| 28 | 333 | 31 | 16.0 | 147 | 50½ |
| 29-1 | 336 | 21½ | 0.49 | 140 | 44 |
| 2 | 335 | 8½ | 0.49 | | |
| 30-1 | 335 | 42 | 0.65 | 136 | 52 |
| 2 | 346 | 14 | 0.53 | | |
| 31 | 26 | 66 | 1.3 | 49½ | 79 |
| 32 | 18 | 67 | 3.0 | 66 | 81½ |
| P 1/50 Oe | | | | | |
| 1 | 12 | 36 | 2.2 | 113½ | 65 |
| | 6 | 42½ | 1.7 | | |
| 2 | 356 | 43 | 1.7 | 130 | 68 |
| | 3½ | 52 | 1.8 | | |
| 3 | 16 | 38½ | 2.1 | 119½ | 64½ |
| | 3½ | 43½ | 1.8 | | |
| 4 | 357½ | 49½ | 0.94 | 122 | 63½ |
| | 1½ | 43 | 0.87 | | |
| 5-1 | 5½ | 38½ | 1.3 | 91 | 58 |
| | 13 | 30 | 1.5 | | |
| 2 | 8 | 41 | 1.4 | | |
| | 13½ | 29 | 1.6 | | |
| 6-1 | 31 | 63 | 1.3 | 80 | 75½ |
| | 30½ | 45½ | 1.1 | | |
| 2 | 35 | 58 | 1.5 | | |
| | 27 | 63 | 1.4 | | |
| 7 | 50 | 67½ | 0.61 | 88 | 77½ |
| | 28 | 57 | 0.35 | | |
| 8 | 44 | 67 | 0.63 | 83½ | 72½ |
| | 26 | 51 | 0.33 | | |
| P 2 | | | | | |
| 9 | 17 | 33 | 0.57 | 83 | 66 |
| 10-1 | 19 | 43 | 0.58 | 104 | 69 |
| 2 | 359½ | 32 | 0.51 | | |
| 11-1 | 349½ | 42½ | 0.56 | 119½ | 70 |
| 2 | 17 | 39 | 0.63 | | |

| No. | D. M. | | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| 12-1 | too weak and unstable | | | | |
| 2 | " | " | " | " | |
| 13 | " | " | " | " | |
| 14 | " | " | " | " | |
| 15 | 5½ | 47½ | 0.27 | 127 | 74 |
| 16 | 20½ | 56 | 0.28 | 90 | 84 |
| 17 | 339 | 53 | 0.20 | 172½ | 60 |
| 18 | 13 | 53 | 0.54 | 118 | 81 |
| 19 | 12½ | 46 | 0.58 | 103 | 75 |
| 20 | 353 | 41 | 0.88 | 140 | 65 |
| P 4 | | | | | |
| 29 | | | | | |
| 30 | | | | | |
| 31 | | | | | |
| 32 | too weak and unstable | | | | |
| 33 | $<1 \times 10^{-6}$ | | | | |
| 34 | | | | | |
| 35 | | | | | |
| 36 | | | | | |
| P 5 | | | | | |
| 37 | 353 | 61½ | 1.5 | 148 | 55½ |
| 38 | 354 | 49 | 1.2 | 135½ | 52½ |
| 39-1 | 13 | 41½ | 2.1 | 109 | 57 |
| 2 | 13 | 43 | 2.7 | | |
| 40-1 | 20½ | 38 | 1.5 | 94½ | 58 |
| 2 | 27 | 41½ | 1.8 | | |
| 41 | 15 | 59½ | 1.4 | 131½ | 63 |
| 42 | 30½ | 52 | 1.5 | 103 | 66 |
| 43-1 | 31½ | 45 | 1.6 | 95½ | 64 |
| 2 | 31 | 52 | 1.8 | | |
| 44 | 31½ | 50 | 1.9 | 99 | 65 |
| 45-1 | 32 | 46½ | 1.3 | 95½ | 64 |
| 2 | 30 | 50 | 1.4 | | |
| 46 | 13½ | 44½ | 1.3 | 110½ | 58 |
| P 7 | | | | | |
| 53 | 270 | 58 | 0.17 | 203½ | 18½ |
| 54 | 248 | 42 | 0.28 | 210 | 0 |
| 55 | 310 | 58 | 0.17 | 187 | 38 |
| 56 | 274 | 42 | 0.10 | 196 | 13 |
| 57 | 17 | 34 | 0.18 | 96½ | 65 |

| No. | D. M. | | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| P 8 | | | | | |
| 58 | 217½ | 13½ | 0.52 | 234 | -28½ |
| 59-1 | 193½ | 8 | 0.41 | 255 | -33½ |
| 2 | 198 | 24 | 0.36 | | |
| 60-1 | 213 | 17 | 0.59 | 237 | -29 |
| 2 | 214 | 12 | 0.57 | | |
| 61 | 283 | 39½ | 0.45 | 191 | 20½ |
| 62-1 | 335 | 60 | 0.45 | 182 | 49½ |
| 2 | 304 | 56 | 0.51 | | |
| 63 | 322½ | 73½ | 0.56 | 196½ | 56 |
| 64 | 276 | 47 | 0.56 | 197 | 21 |
| 65 | 205 | 3 | 0.33 | 248 | -38 |
| 66-1 | 272 | 61½ | 0.39 | 205 | 31 |
| 2 | 278 | 66 | 0.57 | | |
| 67 | 35 | 68 | 0.35 | 146 | 88 |
| P 12 | | | | | |
| 93 | 208 | - 6 | 2.0 | 246½ | -41 |
| 94 | 228 | -10½ | 2.7 | 223½ | -33½ |
| 95 | 346 | 69 | 0.58 | 179½ | 77 |
| 96 | 247 | 66 | 0.76 | 245 | 16 |
| 97 | broken | | | | |
| 98 | 238 | - 3 | 1.2 | 217 | -24 |
| 99 | 238 | -22 | 1.4 | 209 | -31 |
| 100 | 284½ | 6 | 2.8 | 184 | 10 |
| P 13 | | | | | |
| 101 | 352 | 59 | 1.4 | 140 | 73½ |
| 102 | 347 | 40 | 1.3 | 138 | 66 |
| P 15 | | | | | |
| 111 | too weak | | | | |
| 112 | 6 | 64 | 0.50 | 212 | 86 |
| 113 | 47 | 42 | 0.21 | 26 | 53 |
| 114 | 333½ | 65 | 0.23 | 207½ | 65 |
| 115 | 265 | 33 | 0.14 | 208½ | 7 |
| 116 | 250 | 59½ | 1.5 | 230 | 14 |
| 117 | 34 | 45 | 0.23 | 40 | 64 |
| 118-1 | 354 | 68 | 0.63 | 239½ | 64 |
| 2 | 305 | 81½ | 0.75 | | |
| 119-1 | 215 | 8½ | 1.0 | 224 | 5½ |
| 2 | 296 | 66 | 1.4 | | |
| 3 | 281 | 55 | 1.2 | | |

| No. | D. M. | | $Ix10^5$ | N. Pole | |
|---|---|---|---|---|---|
| 120 | 346 | 54½ | 2.0 | 171 | 71 |
| 121 | 264 | 58 | 2.5 | 222 | 20 |
| 122 | 200 | -22 | 3.6 | 253½ | -56 |
| 123 | 169 | 11½ | 2.0 | 298 | -41 |
| 124 | 187 | 8 | 2.1 | 274 | -44 |
| Md 1 | | | | | |
| 1-1 | 343 | 62 | 1.0 | 110½ | 69½ |
| 2 | 343 | 65 | 1.0 | | |
| 3 | 343 | 66 | 1.1 | | |
| 2 | 353 | 54 | 3.9 | 104 | 63½ |
| 3-1 | 327 | 50 | 3.0 | 130 | 62½ |
| 2 | 342 | 56 | 2.9 | | |
| 4 | 352½ | 42 | 2.5 | 108 | 57 |
| 5 | 346 | 54½ | 2.0 | 113½ | 63½ |
| 6 | 352½ | 31½ | 3.7 | 110 | 51 |
| 7 | 359 | 48 | 3.5 | 98 | 59½ |
| 8 | 21 | 65 | 1.0 | 63½ | 65½ |
| 9 | 0½ | 54 | 1.9 | 94 | 62½ |
| Md 2 | | | | | |
| 10 | 18 | 32 | 2.9 | 75 | 61½ |
| 11 | 9 | 24½ | 3.2 | 91 | 58½ |
| 12-1 | 7½ | 16 | 2.9 | 95 | 58 |
| 2 | 6 | 30 | 2.7 | | |
| 13 | 359½ | 37½ | 2.5 | 111½ | 63½ |
| 14 | 1½ | 20 | 3.0 | 113 | 56½ |
| 15-1 | 16½ | 31½ | 1.8 | 75½ | 60½ |
| 2 | 18½ | 29 | 1.9 | | |
| 16 | broken | | | | |
| 17 | 13 | 26 | 6.1 | 85 | 58½ |
| 18-1 | 5½ | 31 | 2.1 | 93½ | 63 |
| 2 | 11 | 33 | 2.1 | | |
| 19 | 9½ | 32 | 1.9 | 90 | 63 |
| 20 | 14½ | 37½ | 1.9 | 81 | 65½ |
| 21 | 5 | 34 | 1.8 | 100 | 63 |
| 22-1 | 13 | 29½ | 2.3 | 86 | 60½ |
| 2 | 11 | 27½ | 2.5 | | |
| 23-1 | 20½ | 36½ | 2.1 | 73½ | 63 |
| 2 | 18 | 35½ | 2.5 | | |
| 24 | 4 | 25 | 3.1 | 99½ | 59 |
| 25 | 8 | 25 | 2.8 | 93½ | 59 |

| No. | D. M. | | $Ix10^5$ | N. Pole | |
|---|---|---|---|---|---|
| Md 3 | | | | | |
| 26 | 19½ | 58½ | 0.42 | 89½ | 67½ |
| 27 | 360 | 57½ | 0.46 | 117 | 65 |
| 28 | 333 | -24 | 0.46 | 130 | 10½ |
| 29 | 344½ | 29½ | 3.5 | 112 | 51 |
| 30 | 7½ | 49½ | 3.0 | 102 | 61½ |
| 31 | 352 | 37½ | 2.3 | 119½ | 53 |
| V 2 | | | | | |
| 16-1 | 359 | 38½ | 3.5 | 132 | 58 |
| 2 | 359½ | 40 | 3.9 | | |
| 17 | 360 | 36½ | 4.5 | 128 | 58 |
| 18 | 8 | 35½ | 4.0 | 117 | 61 |
| 19 | 2 | 27 | 6.7 | 115½ | 55 |
| 20 | 2 | 48 | 7.8 | 140½ | 61½ |
| 21 | 4 | 32 | 5.3 | 117½ | 58 |
| V 3 | | | | | |
| 22-1 | 203 | 54½ | 0.34 | 250 | -25 |
| 2 | 184 | 29 | 0.39 | | |
| 23 | 198½ | 23 | 0.57 | 248 | -37 |
| 24-1 | 175½ | 12 | 1.0 | 270 | -42 |
| 2 | 174 | 14 | 1.1 | | |
| 25 | 195 | 74 | 0.33 | 236 | 7½ |
| 26-1 | 189 | 28 | 0.94 | 254 | -37 |
| 2 | 194½ | 22½ | 1.2 | | |
| 27-1 | 243½ | 41 | 0.41 | 217 | -13 |
| 2 | 228 | 38½ | 0.45 | | |
| 28-1 | 195 | 51½ | 1.1 | 242 | -22½ |
| 2 | 202½ | 32½ | 0.83 | | |
| 29-1 | 217½ | 27 | 1.4 | 230 | -25 |
| 2 | 216 | 41 | 1.2 | | |
| V 4 | | | | | |
| 30 | 71 | 68½ | 0.82 | 279½ | 62 |
| 31 | 205 | 20 | 2.2 | 242½ | -34 |
| 32-1 | 88 | 55 | 1.8 | 323 | 65 |
| 2 | 45 | 57 | 1.5 | | |
| 33-1 | 17½ | 46 | 1.5 | 115 | 77½ |
| 2 | 24 | 50½ | 1.6 | | |
| 34-1 | 37½ | 52 | 1.2 | 115½ | 83 |
| 2 | 17 | 51 | 1.1 | | |

| No. | D. | M. | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| 35-1 | 358 | 67½ | 0.70 | 144 | 77 |
| 2 | 26 | 38½ | 1.1 | | |
| 36 | 20 | 53½ | 1.5 | 147 | 79 |
| 37-1 | 34 | 48 | 2.6 | 66 | 80½ |
| 2 | 32½ | 49 | 2.8 | | |
| V 7 | | | | | |
| 54 | 7½ | 32½ | 5.3 | 94 | 69 |
| 55 | 3 | 27 | 9.1 | 103 | 65 |
| 56 | 357½ | 33 | 5.5 | 118 | 68 |
| 57 | 18 | 31 | 2.7 | 68 | 66 |
| 58 | 12 | 49 | 3.4 | 76½ | 80½ |
| 59 | 3 | 27 | 4.7 | 103 | 65 |
| 60 | 18 | 42 | 3.2 | 62 | 73 |
| V 8 | | | | | |
| 61 | 67½ | 56 | 0.70 | 357 | 54½ |
| 62-1 | 43 | 47 | 0.56 | 30½ | 59½ |
| 2 | 45 | 42½ | 0.63 | | |
| 63-1 | 36½ | 36½ | 1.0 | 48 | 59 |
| 2 | 33 | 34 | 0.73 | | |
| 64 | 154 | 49½ | 0.50 | 296 | - 5 |
| 65 | 40½ | 49 | 0.55 | 34 | 65 |
| 66 | 36 | 57½ | 0.55 | 27 | 74½ |
| 67 | 36 | 53 | 0.53 | 34½ | 70 |
| 68-1 | 14½ | 52½ | 0.67 | 66½ | 76 |
| 2 | 29 | 51½ | 0.32 | | |
| 69 | 69 | 67 | 0.39 | 336 | 62 |
| V 9 | | | | | |
| 70-1 | 38½ | 53½ | 0.74 | 22 | 67½ |
| 2 | 39½ | 60 | 0.72 | | |
| 71-1 | 281½ | 45 | 0.41 | 207½ | 35 |
| 2 | 285 | 53½ | 0.44 | | |
| 3 | 303 | 66 | 0.59 | | |
| 72-1 | 21 | 53 | 1.1 | 68 | 79 |
| 2 | 20 | 57 | 1.0 | | |
| 3 | 5 | 56 | 0.96 | | |
| 73-1 | 358 | 52½ | 1.3 | 97 | 83 |
| 2 | 8 | 56½ | 1.5 | | |
| 3 | 24½ | 65½ | 1.8 | | |
| 74-1 | 344½ | 41½ | 1.6 | 140½ | 65 |
| 2 | 350½ | 39 | 1.7 | | |

| No. | D. | M. | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| 75-1 | 16½ | 3 | 2.0 | 80 | 48½ |
| 2 | 11 | 9 | 1.6 | | |
| 76-1 | 156 | 38 | 1.6 | 313½ | -15 |
| 2 | 140 | 43 | 1.4 | | |
| 77-1 | 104 | 72 | 0.55 | 330 | 41½ |
| 2 | 85 | 69½ | 0.71 | | |
| 77a-1 | 110 | 14½ | 0.78 | 355½ | - 5 |
| 2 | 107 | 16 | 0.74 | | |
| V 10 | | | | | |
| 78 | 348 | 60 | 1.0 | 98½ | 71½ |
| 79 | 15 | 37 | 1.8 | 184 | 61 |
| V 11 | | | | | |
| 80-1 | 28 | 36 | 2.3 | 56½ | 63 |
| 2 | 24½ | 35 | 1.9 | | |
| 3 | 27½ | 31 | 4.3 | | |
| 81 | 24 | 28 | 5.7 | 64 | 60½ |
| 82 | 17½ | 25 | 1.9 | 75 | 60 |
| 83 | 19 | 8 | 6.5 | 73 | 51 |
| 84 | 352 | 31 | 6.7 | 127 | 62 |
| 85 | 10½ | 15½ | 5.1 | 87 | 57 |
| 86 | 14 | 30 | 5.3 | 81 | 64 |
| 87-1 | 22 | 22 | 7.1 | 67 | 58 |
| 2 | 22½ | 23 | 6.9 | | |
| 88-1 | 22 | 35 | 4.1 | 55 | 62½ |
| 2 | 32 | 31 | 4.2 | | |
| 89-1 | 16 | 30 | 1.7 | 81 | 64 |
| 2 | 12 | 21½ | 1.5 | | |
| 90 | 24 | 36 | 2.0 | 60 | 65 |
| ½V 12 | | | | | |
| 94-1 | 282 | - 2 | 1.5 | 180 | - 1½ |
| 2 | 286 | - 4 | 1.8 | | |
| 95-1 | 119 | 20 | 3.7 | 197½ | 37½ |
| 2 | 126 | 31½ | 2.7 | | |
| 96 | 316 | 50½ | 1.8 | 331 | -19½ |
| V 13 | | | | | |
| 97 | | | | | |
| 98 | weak and unstable | | | | |
| 99 | | | | | |
| 100 | | | | | |

| No. | D. M. | | $I \times 10^5$ | N. Pole | |
|---|---|---|---|---|---|
| V 14 | | | | | |
| 101 | 360 | 49 | 0.74 | 130½ | 55½ |
| 102-1 | 1 | 42½ | 1.6 | 124 | 57 |
| 2 | 12 | 52½ | 1.7 | | |
| 103-1 | 7 | 82½ | 1.1 | 164 | 60½ |
| 2 | 21 | 67 | 1.7 | | |
| 104-1 | 45 | 68½ | 1.4 | 147½ | 69 |
| 2 | 28 | 66½ | 1.4 | | |
| V 15 | | | | | |
| 105<br>106 | broken | | | | |
| V 16 | | | | | |
| 107 | 26 | 53 | 1.9 | 103 | 76 |
| 108-1 | 21½ | 60 | 2.7 | 141½ | 75 |
| 2 | 15½ | 62 | 3.1 | | |
| 109-1 | 13 | 59 | 2.4 | 154 | 70½ |
| 2 | 11½ | 63½ | 2.8 | | |
| 110 | 19½ | 59 | 3.1 | 134 | 75 |
| 111 | 340½ | 56 | 5.3 | 161 | 57 |
| 112 | 16½ | 37 | 2.5 | 93½ | 64 |
| 113 | 358½ | 61½ | 3.0 | 158½ | 65½ |
| 114 | 11 | 7 | 3.7 | 84 | 49½ |
| 115 | 3½ | 58 | 3.3 | 147½ | 68½ |
| 116 | 354½ | 68½ | 2.5 | 173½ | 64½ |
| V 17 | | | | | |
| 117 | 352 | 47 | 4.6 | 138½ | 58 |
| 118 | 340½ | 47 | 2.4 | 148 | 52½ |
| 119-1 | 189½ | 38½ | 4.3 | 249 | - 6 |
| 2 | 177½ | 48 | 5.1 | | |
| 120 | 170½ | 48 | 2.8 | 257½ | 2½ |
| 121 | 12½ | 46 | 1.3 | 113 | 65½ |
| 122-1 | 40½ | 16 | 4.9 | 46 | 44½ |
| 2 | 44½ | 13 | 5.3 | | |
| 123-1 | 3 | 44½ | 3.2 | 120 | 62 |
| 2 | 6 | 41 | 3.4 | | |
| 124 | 1½ | 53 | 1.6 | 136½ | 63½ |
| 125 | 20½ | 52 | 3.8 | 110 | 70½ |

| No. | D. M. | | $I \times 10^5$ | N. Pole | |
|---|---|---|---|---|---|
| V 18 | | | | | |
| 126 | 122½ | 36 | 0.51 | 324½ | 14½ |
| 127 | 150 | -13 | 2.8 | 319½ | -37½ |
| 128 | 346 | 27 | 0.72 | 128 | 51 |
| 129-1 | 200½ | 11 | 2.7 | 249 | -41 |
| 2 | 201½ | -13 | 6.3 | | |
| 130 | 359 | 66 | 1.9 | 160 | 67½ |
| 131 | 272 | 60½ | 1.7 | 195 | 29 |
| 132-1 | 239 | 32 | 2.3 | 217½ | - 9 |
| 2 | 219 | 31 | 0.80 | | |
| 133 | 319 | 70 | 1.6 | 181 | 52½ |
| NC 1 | | | | | |
| 1-1 | 187½ | 35 | 1.7 | 276 | -47 |
| 2 | 197 | 38 | 1.5 | | |
| 2-1 | 189½ | 16½ | 1.8 | 269 | -38½ |
| 2 | 201 | 41 | 1.2 | | |
| 3 | 71½ | 55 | 1.0 | 353½ | 26 |
| 4-1 | 196 | 17½ | 1.3 | 263 | -42 |
| 2 | 195½ | 22 | 1.0 | | |
| 5 | 199½ | 17½ | 1.4 | 260 | -40½ |
| 6-1 | 183 | 27½ | 0.97 | 278 | -41 |
| 2 | 189½ | 25 | 1.3 | | |
| 7-1 | 185 | 16 | 1.3 | 277 | -35 |
| 2 | 186½ | 18 | 1.2 | | |
| 8-1 | 174 | 15½ | 1.6 | 290 | -47 |
| 2 | 179 | 18 | 1.1 | | |
| NC 2 | | | | | |
| 9-1 | 48 | 7½ | 16.0 | 35 | 34½ |
| 2 | 46 | 7 | 15.0 | | |
| 10 | 7½ | - 4 | 5.2 | 87 | 57 |
| 11-1 | 356½ | 2½ | 4.7 | 102½ | 63 |
| 2 | 358 | 4 | 4.9 | | |
| 12 | 29 | -10 | 6.2 | 61½ | 45 |
| 13 | 346 | 11½ | 0.61 | 128 | 67 |
| 14 | 22½ | -10 | 4.3 | 74 | 40 |
| 15-1 | 31 | - 3 | 3.1 | 57½ | 46 |
| 2 | 26 | - 7½ | 3.8 | | |
| 16-1 | 10 | - 9 | 7.7 | 88 | 54 |
| 2 | 8 | -11 | 7.8 | | |

| No. | D. | M. | $I \times 10^5$ | N. | Pole |
|---|---|---|---|---|---|
| NC 3 | | | | | |
| 17-1 | 332½ | - 6 | 6.1 | 120 | 59½ |
| 2 | 3½ | 9½ | 6.3 | | |
| 18-1 | 154½ | - 3 | 3.9 | 326 | -57½ |
| 2 | 155 | - 5 | 4.5 | | |
| 19-1 | 153½ | - 3½ | 3.5 | 328½ | -57 |
| 2 | 152 | - 6 | 3.3 | | |
| 20-1 | 102 | 17 | 3.9 | 5 | - 6½ |
| 2 | 95 | 23 | 3.7 | | |
| 21-1 | 51 | 35 | 4.4 | 18½ | 32 |
| 2 | 48 | 33½ | 2.7 | | |
| 22-1 | 16 | - 4 | 5.3 | 73 | 53 |
| 2 | 14½ | 3 | 5.6 | | |
| NC 4 | | | | | |
| 23-1 | 37 | 55½ | 0.40 | 348 | 66½ |
| 2 | 6 | 52½ | 0.40 | | |
| 24-1 | 43½ | 20½ | 1.0 | 31 | 45 |
| 2 | 36 | 21 | 1.6 | | |
| 25-1 | 129 | 9 | 5.4 | 345½ | -30½ |
| 2 | 129 | 5 | 5.0 | | |
| 26-1 | 105 | 23 | 0.89 | 353½ | - 3½ |
| 2 | 98 | 28 | 0.92 | | |
| 27-1 | 279 | 8 | 4.2 | 191 | 9 |
| 2 | 277 | 6 | 4.4 | | |
| 28-1 | 54 | 26 | 0.84 | 8 | 44½ |
| 2 | 40 | 55 | 0.67 | | |
| 29-1 | 319½ | 51½ | 0.33 | 201½ | 70 |
| 2 | 348 | 41 | 0.62 | | |
| 30-1 | 172 | 14 | 0.91 | 292 | -50½ |
| 2 | 173 | 11½ | 0.72 | | |
| 31-1 | 177½ | 29 | 0.88 | 279 | -37½ |
| 2 | 194 | 50 | 0.77 | | |
| 32-1 | 289 | 41 | 0.63 | 233½ | -17½ |
| 2 | 193 | 16 | 1.0 | | |
| 33-1 | 302 | 43 | 0.82 | 181½ | 56 |
| 2 | 340 | 25 | 1.0 | | |
| 34-1 | 227 | 75 | 0.74 | 285 | -13 |
| 2 | 143 | 70½ | 0.89 | | |
| 35-1 | 176½ | 2 | 3.1 | 290½ | -58 |
| 2 | 172½ | 4 | 2.7 | | |
| 36-1 | 65 | 76 | 0.94 | 303½ | 13 |
| 2 | 158 | 73½ | 0.65 | | |

| No. | D. | M. | $I \times 10^5$ | N. | Pole |
|---|---|---|---|---|---|
| NC 5 | | | | | |
| 37-1 | 162½ | 60½ | 1.1 | 274 | -37 |
| 2 | 197 | 27½ | 1.1 | | |
| 38-1 | 205 | 33 | 2.1 | 271½ | -40 |
| 2 | 164 | 44½ | 2.1 | | |
| 39-1 | 160 | 49½ | 1.3 | 288½ | -33 |
| 2 | 178½ | 49 | 1.7 | | |
| 40-1 | 176 | 39½ | 2.3 | 274 | -40 |
| 2 | 194 | 40 | 1.8 | | |
| 41-1 | 219 | 32½ | 0.69 | 241 | -31 |
| 2 | 215 | 41½ | 0.66 | | |
| 42-1 | 241 | 75 | 0.38 | 245½ | 6 |
| 2 | 274 | 67 | 0.50 | | |
| 43-1 | 178½ | 52½ | 0.70 | 273 | -15 |
| 2 | 276 | 83 | 0.73 | | |
| 44-1 | 53 | 59½ | 0.48 | 300 | -10½ |
| 2 | 181 | 43 | 0.90 | | |
| 45-1 | 224 | 56 | 0.45 | 251 | -13 |
| 2 | 229½ | 69½ | 0.33 | | |
| 46-1 | 174 | 28½ | 0.88 | 279½ | -42 |
| 2 | 187 | 45 | 1.1 | | |
| 47-1 | 202 | 34 | 0.90 | 245½ | -25 |
| 2 | 247½ | 59 | 0.57 | | |
| 48-1 | 7 | 69 | 0.36 | 248 | 21 |
| 2 | 289 | 55 | 0.50 | | |
| NC 6 | | | | | |
| 49 | 6½ | -14 | 5.4 | 90½ | 55½ |
| 50 | 6½ | -16½ | 4.6 | 92 | 54 |
| 51 | 4 | -11½ | 5.3 | 94½ | 57½ |
| 52 | 4 | - 9 | 6.1 | 93½ | 58 |
| 53 | 3 | - 8 | 5.3 | 95½ | 58½ |
| 54 | 1½ | - 9½ | 5.3 | 98½ | 58½ |
| 55-1 | 357 | - 7½ | 5.2 | 106½ | 60½ |
| 2 | 357 | - 4 | 3.6 | | |
| 56 | 355 | - 4 | 2.6 | 111 | 61 |
| NC 7 | | | | | |
| 57-1 | 220 | 20 | 0.63 | 234 | -11 |
| 2 | 308 | 56½ | 0.53 | | |
| 58-1 | 51½ | -49 | 0.95 | 15 | -51 |
| 2 | 67 | -49 | 0.90 | | |
| 59-1 | 303 | 87 | 0.50 | 262 | 0½ |
| 2 | 255 | 60 | 0.71 | | |
| 60-1 | 248½ | 38½ | 1.7 | 226½ | - 9 |
| 2 | 260 | 41 | 1.3 | | |

| No. | D. | M. | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| 61-1 | 259 | 50½ | 0.43 | 228½ | - 1 |
| 2 | 265 | 45 | 0.65 | | |
| 62-1 | 205½ | 21½ | 2.2 | 246½ | -45 |
| 2 | 208 | 16½ | 1.8 | | |
| 63-1 | 303 | 37½ | 0.94 | 206½ | 28 |
| 2 | 314 | 34 | 0.73 | | |
| 64-1 | 29 | 72 | 0.42 | 310 | 7½ |
| 2 | 126 | 70 | 0.33 | | |
| NC 8/550 Oe. | | | | | |
| 65-1 | 142 | 29½ | 1.3 | 268½ | -46 |
| | 178 | 29½ | 0.98 | | |
| 2 | 141 | 38½ | 1.3 | | |
| | 198 | 29 | 1.1 | | |
| 66-1 | 5½ | 55 | 0.75 | 267 | -32½ |
| | 208½ | 36 | 0.58 | | |
| 2 | 1 | 62 | 0.98 | | |
| | 161½ | 63 | 0.39 | | |
| 67-1 | 214 | 74½ | 1.0 | 255 | -45 |
| | 138 | 57 | 0.18 | | |
| 2 | 202 | 62 | 1.1 | | |
| | 228½ | 13½ | 0.66 | | |
| 68-1 | 26½ | 39½ | 0.84 | 284 | -37½ |
| | 177 | 21 | 0.28 | | |
| 2 | 29½ | 50½ | 0.96 | | |
| | 164 | 72½ | 0.35 | | |
| 69-1 | 303 | 78½ | 0.46 | 323 | -25 |
| | 110½ | 32 | 0.69 | | |
| 2 | 343 | 55 | 0.67 | | |
| | 155 | 47½ | 0.52 | | |
| 70-1 | 352½ | 22½ | 0.88 | 267 | -26 |
| | 332 | 74½ | 0.18 | | |
| 2 | 337½ | 38 | 0.59 | | |
| | 182 | 20 | 0.64 | | |
| 71-1 | 21 | 46½ | 0.53 | 294½ | 25 |
| | 110 | 54 | 0.21 | | |
| 2 | 17½ | 36 | 0.55 | | |
| | 332 | 57½ | 0.38 | | |
| 72-1 | 175 | 48½ | 0.56 | 259½ | -48½ |
| | 200 | 32 | 0.57 | | |
| 2 | 200½ | 50 | 0.44 | | |
| | 189 | 20 | 0.51 | | |
| 73-1 | 320 | 73½ | 0.76 | 303 | -40½ |
| | 165 | 28 | 0.17 | | |
| 2 | 250 | 74 | 0.59 | | |
| | 151 | 42½ | 0.39 | | |

| No. | D. | M. | Ix10$^5$ | N. Pole | |
|---|---|---|---|---|---|
| NC 9 | | | | | |
| 74-1 | 357 | - 3 | 1.3 | 92 | 57 |
| 2 | 12½ | 4½ | 1.4 | | |
| 75-1 | 333½ | 2½ | 2.3 | 141 | 55 |
| 2 | 329 | 4 | 2.1 | | |
| 76 | 5 | - 3 | 1.3 | 92½ | 55 |
| 77 | 16½ | 14½ | 1.1 | 64 | 57 |
| 78 | 355 | 2 | 1.2 | 109 | 59 |
| 79 | broken | | | | |
| 80 | 9 | 10½ | 1.4 | 77 | 59½ |
| 81 | 10 | 11 | 1.5 | 72½ | 59 |

## APPENDIX H: COMMENTS ON PROCEDURE AND CONCLUSIONS

### 1. Rejection Criteria for Sedimentary Outcrops

The final analysis of the sedimentary pole positions did not include the data from many of the outcrops. These outcrops were rejected on the basis that they contained unstable components of remanent magnetization which could not be removed with demagnetizing fields as high as 550 Oe. Several of the magnetic vector demagnetization paths for some of the igneous rocks are shown in Part I. It is noticed that the magnetic vector generally moves in a given direction during the demagnetization procedure until the unstable component has been removed. Further demagnetization causes the magnetic vector to vary randomly about an average direction. The magnetic vectors of many sedimentary outcrops also moved in a constant direction during the demagnetization procedure. However, after demagnetization in fields as high as 550 Oe, many of these showed no tendency to vary randomly, indicating that part of the unstable component still remained.

As an example of this behavior several of the magnetic vector paths for outcrop number NC 8 are plotted in Fig. H-1. The initial direction is given, as well as the directions after demagnetization in fields of 250 Oe and 550 Oe. Intermediate values of the demagnetizing field fell along these paths. Although the vectors seem to be moving toward the same area it is clear that further demagnetization is required. Hence, when the magnetic vector continued to move in a given direction after the application of 550 Oe demagnetizing fields, the outcrop was rejected.

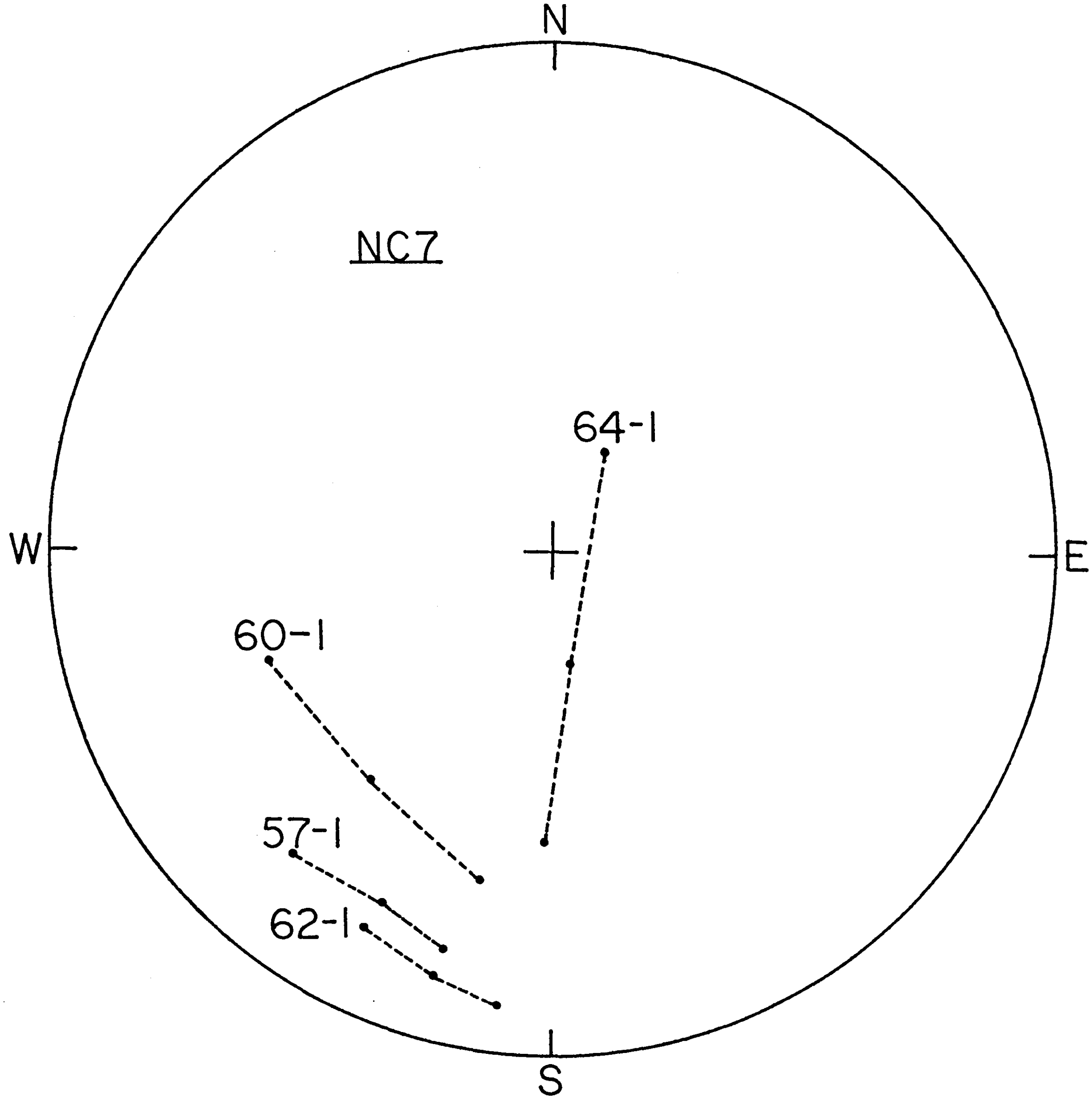


FIG. H-1 MAGNETIC VECTOR DEMAGNETIZATION PATHS

Even if larger demagnetizing fields had been available it still may not have been possible to remove the unstable components because the magnetic intensity was approaching the limit of the instrument ($2.5 \times 10^{-6}$ cgsu/cc for 10° accuracy). Also, in the $10^{-7}$ cgsu/cc range, the magnetization may not be meaningful (see Nagata, 1953).

Table H-1 contains the original direction of magnetization and the direction after demagnetizing in 250 Oe and 550 Oe fields, respectively, for several samples from each outcrop. Those outcrops which were rejected because of the above criteria are marked with an asterisk (*).

## 2. Influence of Earth's Field

The average direction of magnetization for each outcrop is shown in Part I. It is possible that the present earth's field (or axial dipole field) has influenced the direction of magnetization of some of the outcrops. This is evident in Part II where it is noticed that several of the circles of confidence include the magnetic dipole axis. It is doubtful, however, that this influence has affected the results to any extent.

The geologic attitude of the beds unfortunately displaces the original average magnetic vector of many outcrops toward the earth's field. However, there is no general tendency for any one geologic formation to show consistent influence of the present earth's field. Fig. II-8 indicates that the geologic correction has brought the average directions of magnetization together. Many of the circles of confidence that included the earth's field before correction did not do so after correction.

The rejection of several outcrops from the final analysis eliminated most of the earth's field influence, although perhaps not all.

# Table H-1

## SEDIMENTARY DEMAGNETIZATION VALUES

| No. | D. | M. |
|---|---|---|
| M 5 | | |
| 33-3 | 352 | 72 |
| | 10 | 69 |
| | 354 | 73 |
| 35-3 | 354 | 56 |
| | 12 | 49 |
| | 5 | 52 |
| 38-4 | 10 | 65 1/2 |
| | 23 | 56 |
| | 9 | 60 1/2 |
| J 1 | | |
| 1 | 350 | 40 |
| | 352 | 47 |
| | 328 | 39 |
| 4 | 359 | 22 |
| | 355 | 20 |
| | 1 | 22 |
| J 2 | | |
| 11 | 43 | 42 1/2 |
| | 44 | 44 |
| | 39 1/2 | 42 |
| 13-2 | 28 | 36 |
| | 26 | 32 |
| | 21 | 34 1/2 |
| 14 | 2 1/2 | 29 1/2 |
| | 7 | 24 |
| | 11 | 27 1/2 |
| J 3 | | |
| 21 | 355 1/2 | 46 |
| | 354 | 42 |
| | 359 | 47 |
| 26 | 12 | 52 1/2 |
| | 15 | 56 |
| | 13 | 50 |
| J 4 | | |
| 27-1 | 347 | 44 |
| | 350 | 40 |
| | 348 | 45 |
| 29-1 | 336 | 21 1/2 |
| | 345 | 25 |
| | 342 | 27 |
| 30-1 | 335 | 42 |
| | 340 | 45 |
| | 330 | 41 |
| P 1 | | |
| 1 | 12 | 36 |
| | 2 | 44 |
| | 11 | 32 |
| 2 | 356 | 43 |
| | 359 | 40 |
| | 5 | 45 |
| 7 | 50 | 67 1/2 |
| | 48 | 60 |
| | 44 | 70 |
| P 2 | | |
| 9 | 17 | 33 |
| | 13 | 29 |
| | 16 | 35 |
| 16 | 20 1/2 | 56 |
| | 2 | 60 |
| | 15 | 49 |
| 20 | 353 | 41 |
| | 349 | 47 |
| | 354 | 42 |
| P 5 | | |
| 37 | 353 | 61 1/2 |
| | 10 | 59 |
| | 2 1/2 | 58 |
| 41 | 15 | 59 1/2 |
| | 28 | 51 |
| | 23 | 44 |
| 44 | 31 1/2 | 50 |
| | 25 | 45 |
| | 27 | 52 |
| 46 | 13 1/2 | 44 1/2 |
| | 14 | 50 |
| | 15 | 42 |
| P 7* | | |
| 53 | 270 | 58 |
| | 232 | 55 |
| | 205 | 40 |
| 54 | 248 | 42 |
| | 221 | 35 |
| | 206 | 25 |
| 56 | 274 | 42 |
| | 246 | 34 |
| | 228 | 17 |
| P 8* | | |
| 62-1 | 335 | 60 |
| | 273 | 28 |
| | 266 | - 8 |
| 64 | 276 | 47 |
| | 263 | 27 |
| | 256 | 2 |
| 67 | 35 | 68 |
| | 346 | 79 |
| | 271 | 64 |
| P 12* | | |
| 95 | 346 | 69 |
| | 297 | 55 |
| | 280 | 26 |
| 96 | 247 | 66 |
| | 251 | 43 |
| | 254 | 10 |
| 100 | 284 1/2 | 6 |
| | 283 | -13 |
| | 288 | -36 |
| P 13 | | |
| 101 | 352 | 59 |
| | 358 | 54 |
| | 334 | 47 |
| 102 | 347 | 40 |
| | 345 | 32 |
| | 359 | 33 |

| No. | D. | M. |
|---|---|---|
| P 15* | | |
| 116 | 250 | 59 1/2 |
| | 258 | 50 |
| | 263 | 35 |
| 119-1 | 215 | 8 1/2 |
| | 208 | - 8 |
| | 194 | -22 |
| 120 | 346 | 54 1/2 |
| | 343 | 54 |
| | 339 1/2 | 55 1/2 |
| Md 1 | | |
| 2 | 353 | 54 |
| | 359 | 56 |
| | 355 | 45 |
| 4 | 352 1/2 | 42 |
| | 2 | 47 |
| | 356 | 41 |
| 6 | 352 1/2 | 31 1/2 |
| | 358 | 40 |
| | 357 | 29 |
| Md 2 | | |
| 10 | 18 | 32 |
| | 15 | 35 |
| | 17 | 29 |
| 14 | 1 1/2 | 20 |
| | 358 | 19 |
| | 3 | 22 |
| 17 | 13 | 26 |
| | 14 | 24 |
| | 11 | 32 |
| Md 3 | | |
| 26 | 19 1/2 | 58 1/2 |
| | 16 | 64 |
| | 17 | 56 |
| 29 | 344 1/2 | 29 1/2 |
| | 350 | 27 |
| | 351 | 34 |
| 31 | 352 | 37 1/2 |
| | 348 | 42 |
| | 355 | 39 |
| V 2 | | |
| 18 | 8 | 35 1/2 |
| | 10 | 40 |
| | 7 | 38 |
| 19 | 2 | 27 |
| | 358 | 25 |
| | 3 | 29 |
| 21 | 4 | 32 |
| | 10 | 33 |
| | 2 | 39 |
| V 3* | | |
| 22-1 | 203 | 54 1/2 |
| | 191 | 38 |
| | 186 | 20 |
| 26-1 | 189 | 28 |
| | 186 | 13 |
| | 185 | 1 |
| 29-1 | 217 1/2 | 27 |
| | 196 | 28 |
| | 178 | 20 |
| V 4* | | |
| 31 | 205 | 20 |
| | 208 | 61 |
| | 5 | 79 |
| 32-2 | 45 | 57 |
| | 62 | 56 |
| | 42 | 51 |
| 35-1 | 358 | 67 1/2 |
| | 6 | 55 |
| | 14 | 42 |
| V 7 | | |
| 54 | 7 1/2 | 32 1/2 |
| | 358 | 35 |
| | 16 | 27 |
| 57 | 18 | 31 |
| | 21 | 40 |
| | 15 | 39 |
| 59 | 3 | 27 |
| | 1 | 22 |
| | 9 | 28 |
| V 8* | | |
| 61 | 67 1/2 | 56 |
| | 50 | 47 |
| | 38 | 31 |
| 64 | 154 | 49 1/2 |
| | 138 | 49 |
| | 107 | 42 |
| 69 | 69 | 67 |
| | 50 | 56 |
| | 39 | 40 |
| V 9* | | |
| 71-1 | 281 1/2 | 45 |
| | 302 | 54 |
| | 332 | 55 |
| 73-1 | 358 | 52 1/2 |
| | 358 | 42 |
| | 359 | 31 |
| 76-1 | 156 | 38 |
| | 126 | 65 |
| | 54 | 66 |
| V 10* | | |
| 78 | 348 | 60 |
| | 319 | 53 |
| | 282 | 40 |
| 79 | 15 | 37 |
| | 359 | 40 |
| | 336 | 39 |
| V 11 | | |
| 81 | 24 | 28 |
| | 20 | 32 |
| | 23 | 34 |
| 84 | 352 | 31 |
| | 2 | 34 |
| | 1 | 29 |
| 88-1 | 22 | 35 |
| | 19 | 40 |
| | 20 | 32 |
| V 12* | | |
| 94-1 | 282 | - 2 |
| | 260 | -22 |
| | 234 | -24 |
| 96 | 316 | 50 1/2 |
| | 270 | 66 |
| | 216 | 54 |
| V 14 | | |
| 101 | 360 | 49 |
| | 15 | 47 |
| | 2 | 54 |
| 103-1 | 7 | 82 1/2 |
| | 24 | 61 |
| | 5 | 57 |

| No. | D. | M. |
|---|---|---|
| V 16 | | |
| 107 | 26 | 53 |
| | 34 | 58 |
| | 27 | 54 |
| 111 | 340 1/2 | 56 |
| | 2 | 43 |
| | 2 | 49 |
| 114 | 11 | 7 |
| | 15 | 34 |
| | 2 | 37 |
| V 17* | | |
| 117 | 352 | 47 |
| | 359 | 40 |
| | 3 | 31 |
| 121 | 12 1/2 | 46 |
| | 12 | 35 |
| | 10 | 24 |
| 124 | 1 1/2 | 53 |
| | 7 | 44 |
| | 10 | 36 |
| V 18* | | |
| 126 | 122 1/2 | 36 |
| | 148 | 27 |
| | 172 | 19 |
| 128 | 346 | 27 |
| | 336 | 67 |
| | 194 | 69 |
| 131 | 272 | 60 1/2 |
| | 222 | 60 |
| | 189 | 40 |
| NC 1* | | |
| 1-1 | 187 1/2 | 35 |
| | 189 | 29 |
| | 184 | 16 |
| 3 | 71 1/2 | 55 |
| | 110 | 62 |
| | 162 | 46 |
| 6-1 | 183 | 27 1/2 |
| | 184 | 19 |
| | 187 | 6 |
| NC 2 | | |
| 10 | 7 1/2 | - 4 |
| | 348 | -10 |
| | 2 | -12 |

| No. | D. | M. |
|---|---|---|
| 12 | 29 | -10 |
| | 34 | - 6 |
| | 15 | 2 |
| 14 | 22 1/2 | -10 |
| | 24 | -15 |
| | 17 | - 4 |
| NC 3* | | |
| 18-1 | 154 1/2 | - 3 |
| | 118 | 2 |
| | 85 | 7 |
| 20-1 | 102 | 17 |
| | 81 | 28 |
| | 60 | 28 |
| 22-1 | 16 | - 4 |
| | 13 | 8 |
| | 11 | 22 |
| NC 4* | | |
| 23-1 | 37 | 55 1/2 |
| | 22 | 46 |
| | 12 | 32 |
| 32-1 | 289 | 41 |
| | 298 | 12 |
| | 309 | - 8 |
| 34-1 | 227 | 75 |
| | 208 | 68 |
| | 229 | 48 |
| 36-1 | 65 | 76 |
| | 12 | 64 |
| | 358 | 42 |
| NC 5* | | |
| 38-1 | 205 | 33 |
| | 198 | 28 |
| | 189 | 26 |
| 40-1 | 176 | 39 1/2 |
| | 180 | 31 |
| | 183 | 19 |
| 47-2 | 247 1/2 | 59 |
| | 216 | 52 |
| | 200 | 39 |
| NC 6 | | |
| 49 | 6 1/2 | -14 |
| | 8 | -15 |
| | 5 | - 4 |
| 52 | 4 | - 9 |
| | 6 | - 5 |
| | 7 | -15 |

| No. | D. | M. |
|---|---|---|
| 56 | 355 | - 4 |
| | 356 | -10 |
| | 358 | - 2 |
| NC 7* | | |
| 57-1 | 220 | 20 |
| | 206 | 16 |
| | 195 | 12 |
| 60-1 | 248 1/2 | 38 1/2 |
| | 218 | 41 |
| | 192 | 32 |
| 62-1 | 205 1/2 | 21 1/2 |
| | 195 | 18 |
| | 187 | 10 |
| 64-1 | 29 | 72 |
| | 171 | 70 |
| | 182 | 40 |
| NC 8* | | |
| 65-2 | 141 | 38 1/2 |
| | 161 | 32 |
| | 178 | 29 1/2 |
| 68-2 | 29 1/2 | 50 1/2 |
| | 52 | 70 |
| | 135 | 72 1/2 |
| 72-1 | 175 | 48 1/2 |
| | 190 | 42 |
| | 200 | 33 |
| NC 9 | | |
| 75-1 | 333 1/2 | 2 1/2 |
| | 340 | 5 |
| | 342 1/2 | -19 |
| 77 | 16 1/2 | 14 1/2 |
| | 14 | 19 |
| | 19 1/2 | 20 |
| 81 | 10 | 11 |
| | 5 | 6 |
| | 9 | 15 |

* Rejected from final analysis

With the Massachusetts sandstones the situation is very different. All of the outcrops seem to have been influenced by the earth's field. Also, the geologic correction displaces the magnetic vector directly away from the average direction of the other formations. Finally, the probability that the iron in the sandstone was derived from the Deerfield Diabase further suggest that the magnetization may be later than Triassic.

### 3. <u>Reduction of Scatter by Geologic Correction</u>

It has been stated in Parts I and II that the geologic correction has reduced the scatter among the average outcrop directions within most of the areas. As evidence of this, the circle of confidence for 95% probability has been calculated for the average direction of magnetization of the outcrops before and after geologic correction. Only those outcrops which were included in the final analysis have been used. This data is given in Table H-2.

The lack of significant variations in the strike and dips within the area tends to minimize the influence of the corrections on the scatter. It is noticed, however, that the outcrops with the smallest circles of confidence show a better reduction in scatter than those with large circles of confidence. This point is not demonstrated with statistics but can be inferred from the illustrations in Part II.

In the igneous areas, only Nova Scotia showed an increase in scatter with correction. So was the case with the Maryland-West Pennsylvania sediments. However, both of these increases of scatter were less than the corresponding decreases of scatter in the other areas. Also, note that the overall influence on the sediments from the four areas was a significant reduction in scatter.

## Table H-2

## INFLUENCE OF GEOLOGIC CORRECTION

| | Area | $\theta^{95}$ (Original) | $\theta^{95}$ (Corrected) |
|---|---|---|---|
| Igneous | N. S. | 8° | 8 3/4° |
| | Mass. - Conn. | 18 1/2° | 16 1/4° |
| | Pa. - Va. | 8 1/2° | 7 1/2° |
| Sed. | N. J. - E. Pa | 13 1/2° | 9° |
| | Md. - W. Pa. | 8 3/4° | 10 1/2° |
| | Va. | 14 1/2° | 13° |
| | N. C. | 17° | 12 1/2° |
| | Avg. (sed.) | 9° | 6 1/2° |

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Since most literature on rock magnetism is relatively easy to find, the bibliography includes only those articles which are directly concerned with this report. Several selections are particularly worthy of mention, however, because of their extensive coverage of a topic or because of their comprehensive bibliographies. They are: Nagata (1953), Watson and Irving (1957), Rimbert (1958), Irving (1959), and Thellier (1959).

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