THE PALEOMAGNETISM OF THE UPPER ORDOVICIAN FAIRVIEW FORMATION

A Thesis

Presented in Partial Fulfillment of the Requirements
for the Degree of Bachelor of Science

by

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1977

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ACKNOWLEDGEMENTS

I wish to acknowledge the helpful comments and criticism of my adviser, Dr. Hallan C. Noltimier. In addition, I wish to thank Dr. Walter C. Sweet for all information, material and data so generously supplied. I also wish to acknowledge the valuable assistance of Dr. Brooks Elwood who wrote the computer program specifically for this thesis. Last, but not least, I wish to express my thanks to my colleague Cathy Musser whose help was always greatly appreciated.

ABSTRACT

A paleomagnetic study was conducted involving the Upper Fairview (Upper Ordovician, Maysvillian) Formation and Lower Fairview Formation. The purpose of this study was to determine the possibility of measuring the geomagnetic polarity reversals occurring in paleozoic limestones. This thesis is primarily concerned with, and concentrates on, the latter twenty one feet and its results. For information concerning the remaining section, see Musser (1977).

CHAPTER I

INTRODUCTION

The type section on which this thesis is based was obtained from a 1,200 foot section of standard BX core. The core was drilled in July 1970 and boxed by Cominco American, Inc. and designated as CA-38. The location of the drill site was approximately 1,800 feet east of Minerva, Mason County Kentucky. Shortly thereafter the core was obtained by the Geology and Mineralogy Department at Ohio State University and stored in the Micropaleontological Laboratory (basement of Orton Hall). This core represents nearly a complete section beginning near the top of the Fairview Formation (core depth of 20 feet) and extends through the Lower Fairview (core depth of 98 feet) to the High Bridge Group (Middle Ordovician).

In 1906 Bassler introduced the name Fairview for a Formation unit in the type section of the Upper Ordovician Cincinnatian Series. Bassler in defining the Fairview combined two previously named beds, the Fairmount and underlying Mount Hope. Justification for this combination was on the basis of almost identical faunal characteristics. More recently Ford (1965) mapped and redefined the Fairview Formation as a rock-stratigraphic unit in the Cincinnati area. In the Maysville region of Kentucky rocks of similar lithology and faunal conformance are designated in Ford's classification as the Fairview Formation within the Maysville group or stage.

Briefly the Fairview consists of interbedded blue-gray limestones, siltstones, shales and mudstones. It also contains an abundance of Upper Ordovician fossils including several species of conodonts such as PLECTODINA FURCATA and OULODUS OREGONIS VELICUSPIS (Sweet, Harper, Zlatkin, 1974).

The Fairview as represented by core CA-38 was divided into three seperate lithologies; Upper, Middle and Lower. The Upper Fairview (27 feet thick) consist of fossiliferous limestones interbedded with siltstones and shales. The Middle Fairview (9 feet thick) tends to be dominated by shales which are very similer to the Miamitown Shale of Southwestern Ohio (Ford, 1967; Osborne, 1968). Because of these similarities the Middle Fairview is considered a part of the Miamitown Shale. The Lower Fairview (42 feet thick) is composed of limestones interbedded with shales in approximately equal ratios (Sweet, Harper, Zlatkin, 1974).

A shale percentage log has been included in Appendix A, analyzing the bulk properties (lithologies, ratio of shale to limestone) of the lower 21 feet, core depth of 40-52 feet. This log represents a record of shale thickness stated as a percentage of the total thicknesses of successive one foot intervals.

CHAPTER II

PROCEDURE

On obtaining a box of BX core from the Micropaleontological Laboratory several precautionary procedures were necessary before subsampling could commence. These precautions were required because each box contained ten feet of fragmented core segments representing arbitrary lengths. There was, however, a maximum length of 0.83 feet per segment which was never exceeded. Figure 1 illustrates a typical section of fragmented core.

The Cominco personnel initially designated on the exterior of each box the core depth for a particular ten foot interval such as 41-51 feet, plus an arrow indicating top or (in this case) the 41 foot level. This labeling is the only orientation known concerning the core segments and is the only control in the sense of the up-hole direction for each segment. Azimuth alignments have been totally randomized by rotation of the core about its long axis during drilling, recovery and boxing. Within each box the writer proceeded to measure, number and inspect each individual core segment. This inspection hopefully minimized the probability of an improperly oriented (inverted) core segment. The core segments were then labelled with a code number and the up-core

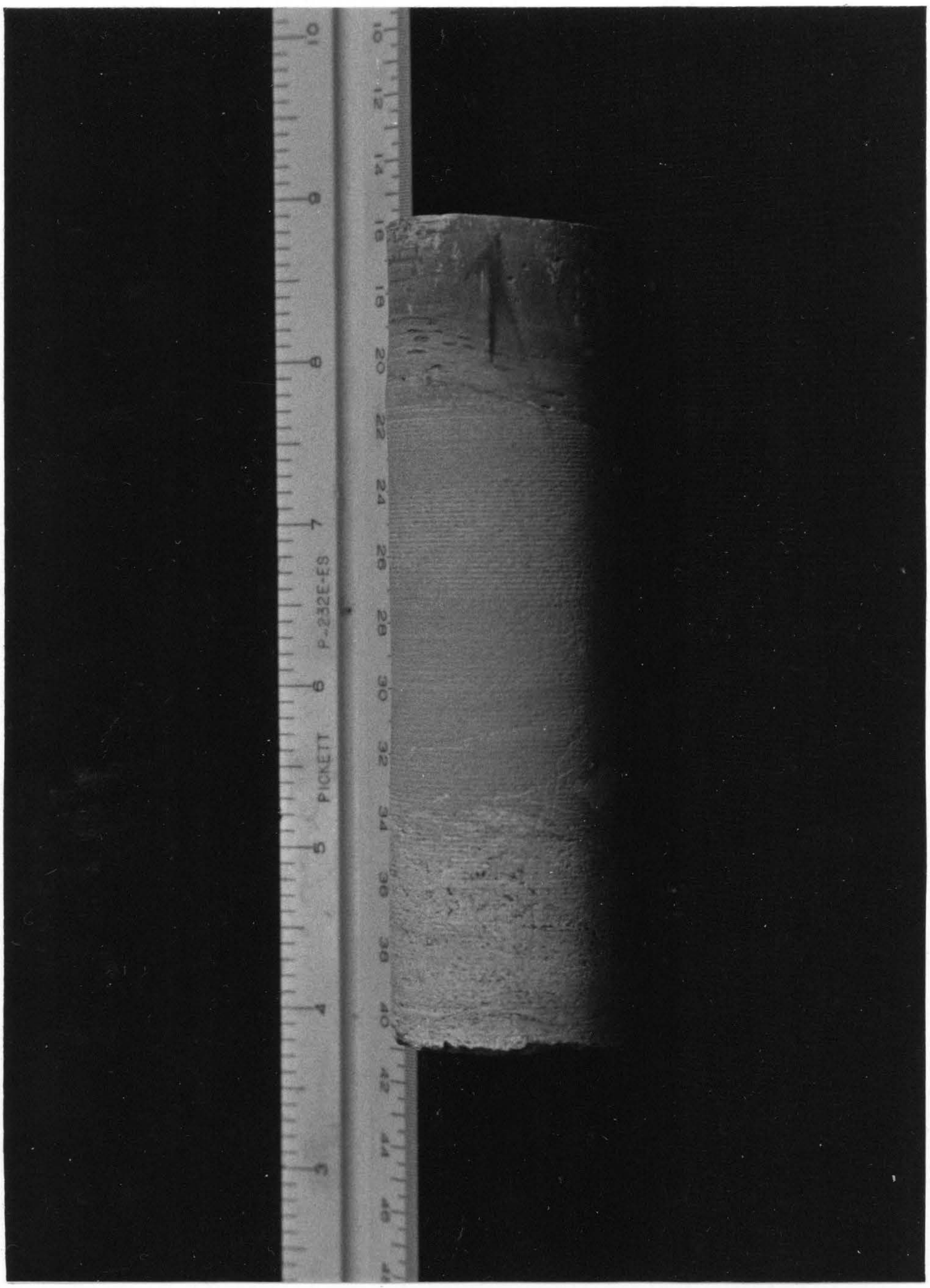


FIGURE-1

direction of each segment was clearly marked by use of a barbed arrow.

Before paleomagnetic study could commence, it was necessary to construct a jig that would securely hold a variety of core lengths in which subsampling could be conducted. Dr. Noltimier and I designed and I constructed a tray and guide plate which would accomodate a length of BX core up to 0.83 feet. Figures 2 and 3 illustrate both devices. Subsampling proceeded by drilling normal to the core axis with a drill press adapted to produce cores approximately one inch in diameter using a diamond tipped drill. Ideally, five subcores could be drilled from an 0.83 foot section of core. In reality, I never obtained over three subcores per given length of BX core. Each core was then marked with a line on the up side and labelled indicating the box and coded core segment from which the core was taken. A standardized code name designated as 70ZA preceded both box and core segment number. Using a double-bladed rock saw the cores were trimmed into specimens 0. 87 inches in length.

The NRM (natural remanent magnetization) of each sample was measured using a SRM (superconducting rock magnetometer). This device measures the total magnetization in emu (gauss • cubic centimeters) in terms of three orthogonal magnetic components

FIGURE - 2

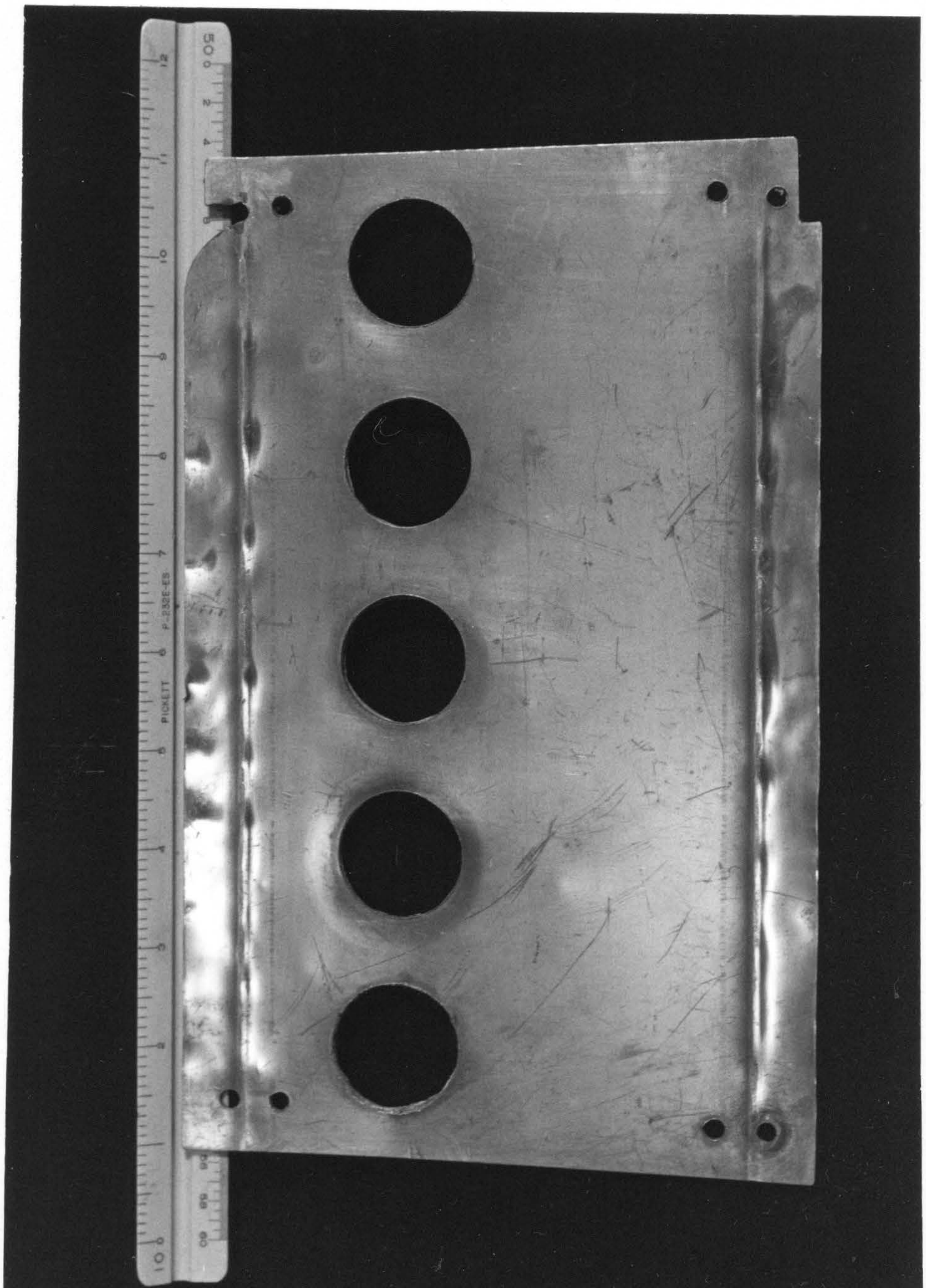


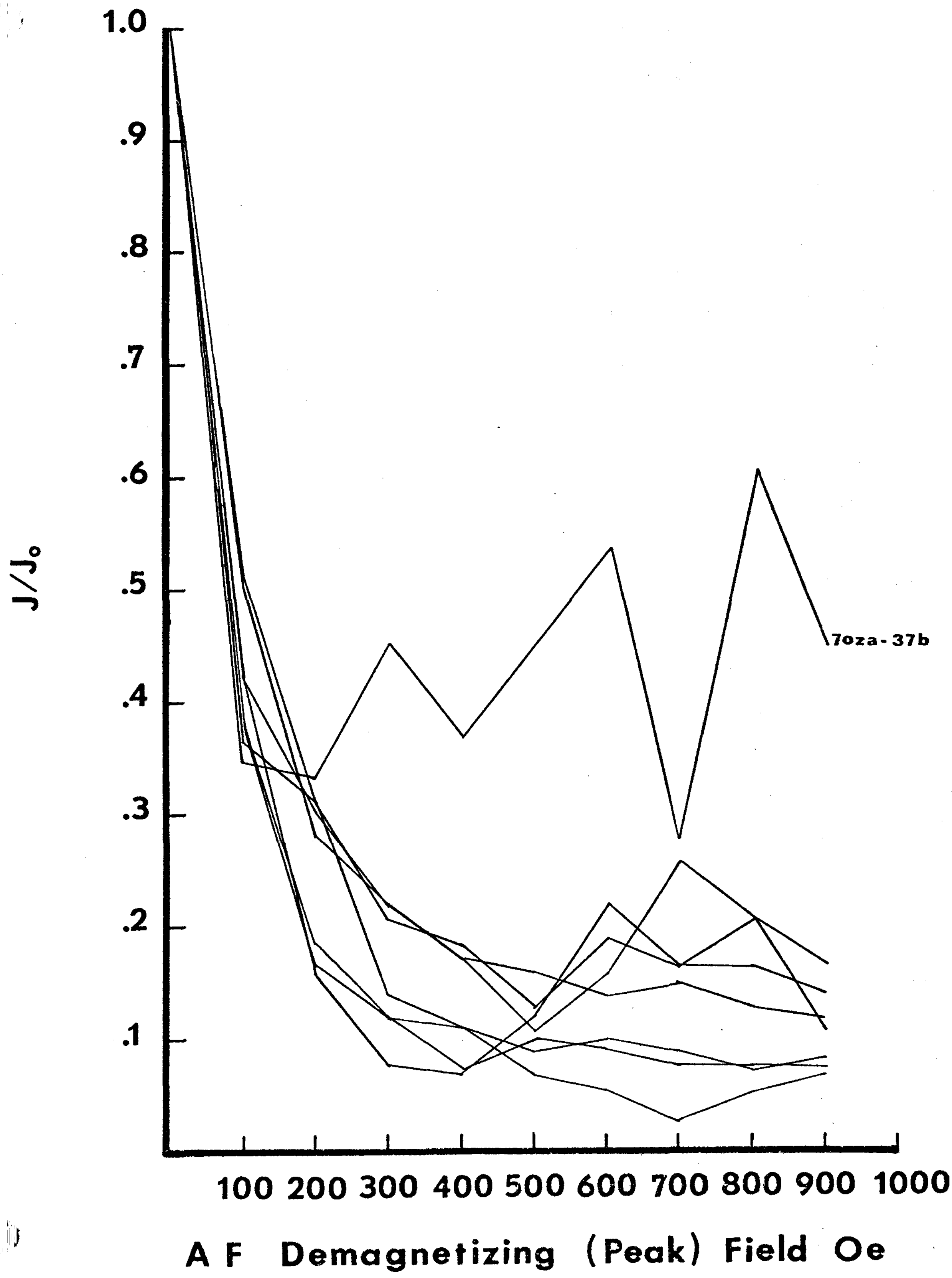
FIGURE - 3

along the X, Y and Z axes of each sample (the volume of each sample is in fact very nearly constant at eleven cubic centimeters). The SRM output is displayed simultaneously in the form of a digital readout for recording purposes. Due to instrumental drift, three measurements were necessary to obtain accurate values for the respective axes. Initial values were recorded before the sample was inserted into the magnetometer. Second measurements were obtained with the sample within the SRM and a third set was recorded after the sample was withdrawn.

Paleomagnetic stability tests were conducted with a Schonstedt GSD-1 AC Geophysical Specimen Demagnetizer. All specimens were first measured as is to determine the NRM. They were then demagnetized along three mutually perpendicular axes (X, Y, Z) in steps of 100 oersteds up to a peak magnetic field of 600 oersteds, or in some instances 900 oersteds. By this method all magnetic domains of ferromagnetic minerals carrying the natural magnetic remanence with short relaxation times were randomized leaving only those domains (stable single domains) capable of retaining magnetic moments over long periods of geologic time. The peak magnetic field at which the residual intensities stabilized was determined from those cores demagnetized up to 900 oersteds. The demagnetized values were plotted as J/Jo (intensity after demagnetization / original NRM intensity) versus the peak alternating field (H). From the graph, figure 4, the peak magnetic field at which a stable magnetic component is revealled was found to be approximately 450 oersteds. The reader may notice the decay curve labelled 70ZA-37B. This curve is atypical in that it increases in magnetization rather than the normal decrease as represented by the majority of the decay curves. Several factors could cause this anomalous behavior; one of which is measurement error. Contamination of the sample due to handling between demagnetization steps could also account for the increase in magnetization.

After completion of the paleomagnetic measurements the data was processed using a program written by Dr. Brooks Elwood and modified by the author. The program was designed to calculate the X component of magnetization in the subsample which is parallel to the up-core direction of the original core and J, the total magnetic moment of each core. This was completed for all NRM (H=NRM) and subsequent demagnetization measurements (H=300, 400-450, 600). The sample code and its X and J values is printed adjacent to the NRM column. Appendix B illustrates this data. Within the H=300 oersted column, two samples are represented by asterisks and corresponding arbitrary J's. Due to operator error, measurements in

FIGURE-4


1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
J/Jo
7oza-37b
100 200 300 400 500 600 700 800 900 1000
A F Demagnetizing (Peak) Field Oe

this field were not obtained. To insure consistant visual alignment of the data, two dummy values were incorporated into the programs data deck to replace these missing results.

CHAPTER III

PALEOMAGNETIC RESULTS

In this study the up, or X, direction of magnetization was the only known orientation. Rotation of the BX core about its vertical axis rendered Y and Z directions useless except in calculating J (total magnetic moment) and the magnetic inclination from which the paleolatitude may be calculated. Because of this limitation the data was not amenable to standard Fisher Statistical Analysis or the calculation of a virtual geomagnetic pole (VGP). However, the data lent itself useful in the discovery of geomagnetic polarity reversals. For this sequence of cores, the majority of negative signs preceding the X moments indicates a reversed geomagnetic field orientation. Essentially this means that the magnetic flux lines that surround the Earth normally eminate from the southern geomagnetic pole and converge in the northern geomagnetic pole. During a reversal, the intensity of the geomagnetic field drops to zero, reverses direction, and then increases in field strength. Once the reversing process begins, it proceeds rather quickly taking 100 to 1000 years for completion. The cores that display a positive X moment after a 600 oersted cleaning, represent a time during the Upper Ordovician when the geomagnetic field assumed a normal polarity. McElhinny

(1973) reports the paleomagnetic data for the Ordovician, indicating that the polarities were roughly 50% normal and 50% reversed. The polarities in this data are predominantly reversed.

In evaluating the paleomagnetic data from the computer output, geomagnetic reversals can be grouped in two categories; probable and possible reversals.

Probable reversals can be exemplified by those cores displaying negative to positive sign changes upon demagnetization. This characteristic would imply that the initial X component of the NRM had become masked by additional magnetization such as isothermal remanent magnetism (IRM) and / or viscous remanent magnetism (VRM). This secondary magnetization would have been acquired after the deposition of the sediment and probably in geologically recent times. After a several hundred oersted cleaning, the additional components were destroyed leaving the stable residual positive moment. Cores ZA3-59A through ZA4-2A exhibit this phenomenon.

A possible reversal implies a certain degree of uncertainly surrounding the result. The reason for this doubt can be traced back to the boxing of the BX core fragments. If, for example, a reversely magnetized segment had been inverted in the box, then subsampling of the segment would produce a core displaying a positive X (NRM) moment. Those isolated cores that display this characteristic reversal in polarity can only be considered possible reversals unless supported by other factors. One such factor is exhibited by cores ZA4-9A through ZA4-12A which represent a group of positive X moments under the NRM column. This series of cores drilled from several adjacent BX segments tends to lower the probability of an accidental reversal in view of the fact that several adjoining cores display a positive polarity.

The computer output in Appendix B represents a total of twenty one feet of the Fairview Formation. The three upper most cores (ZA2-49A through ZA2-53A) are approximately a one foot overlap into the upper nineteen feet. Within this twenty one feet there exist five probable reversals, one of which is a group of three cores within the Miamitown Shale (ZA3-59A through ZA4-2A). Three single and three groups of possible reversals are also evident within this section of the Fairview. The time span indicated by this stratigraphic interval of core is uncertain.

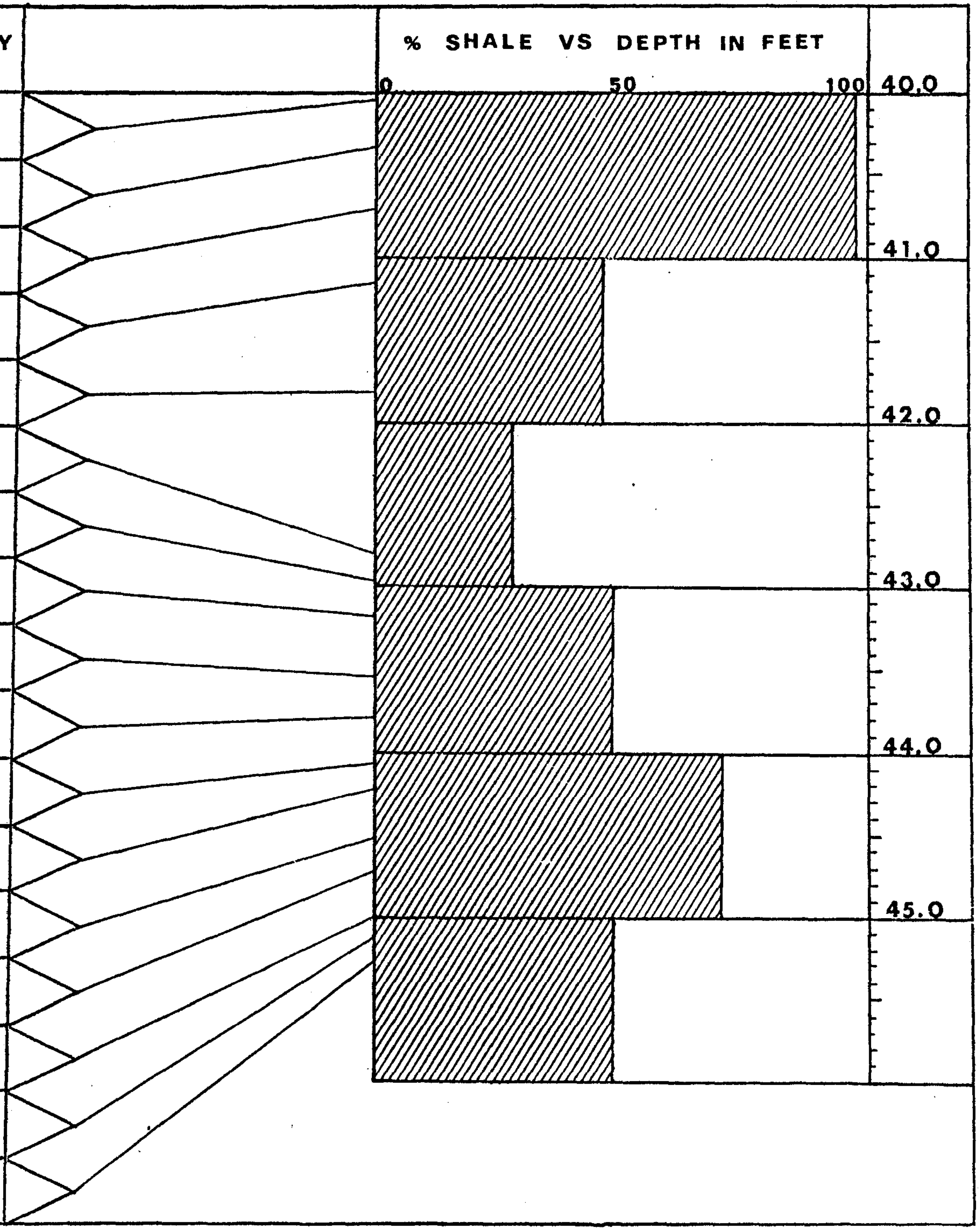
In Appendix A a correlation between polarity (R denoting reversed polarity, N representing normal polarity) and depth of sample can be seen. A question mark adjacent to the letter N indicates a possible reversal to normal polarity.

As previously mentioned, a value for the paleolatitude can be calculated from existing data. The X, Y and Z moments were selected from the 600 oersted demagnetizations for thirteen samples. Four cores were chosen from the top and middle and five cores from the lower section of the twenty one foot CA-38 interval. This procedure was adopted in order to obtain a more representative value for the paleolatitude. An average inclination, I, was calculated and inserted into the dipole formula, $\tan l = 0.5 \tan I$, (l) representing the paleolatitude, (I) the average magnetic inclination of the stable remanence in the sample. A value of twenty two degrees south of the equator was obtained. To determine the validity of this calculation paleozoic pole positions for the Middle Ordovician Trenton Limestone (36°S., 66°W.) and Lower Silurian Castanea Formation (21°S., 78°W.) for North America were obtained from McElhinny and Opdyke (1973). These pole positions were plotted using a polar stereographic projection and their paleoequators determined. The estimated paleolatitude was also plotted and found to fall approximately in between both paleoequators. From this information, a virtual geomagnetic pole for the Upper Ordovician Fairview Formation was interpolated. A value of 118° East and 30° North was obtained for the North VGP and 64° West, 30° South was estimated for the South VGP.

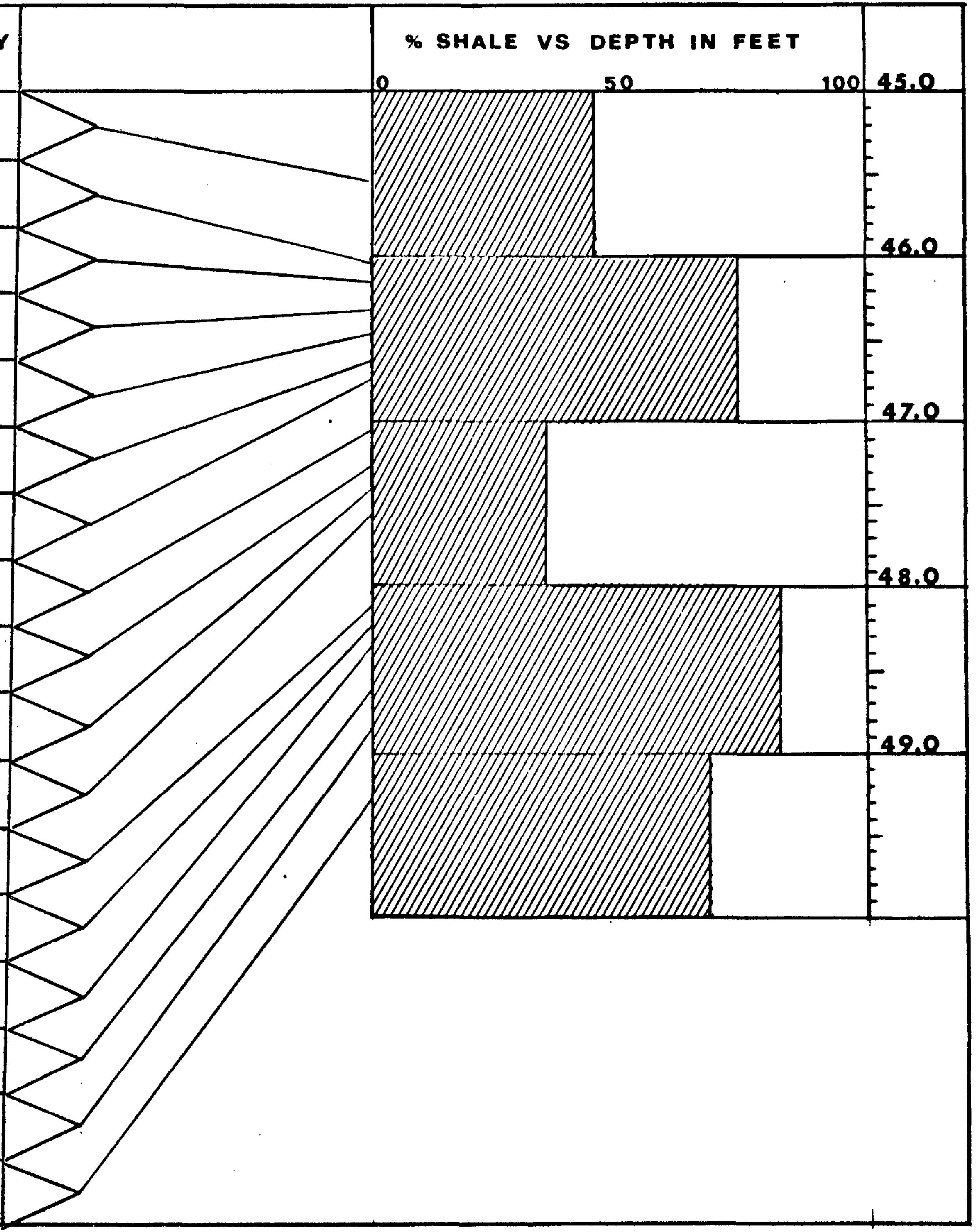
APPENDIX A

PALEOMAGNETIC TABLES

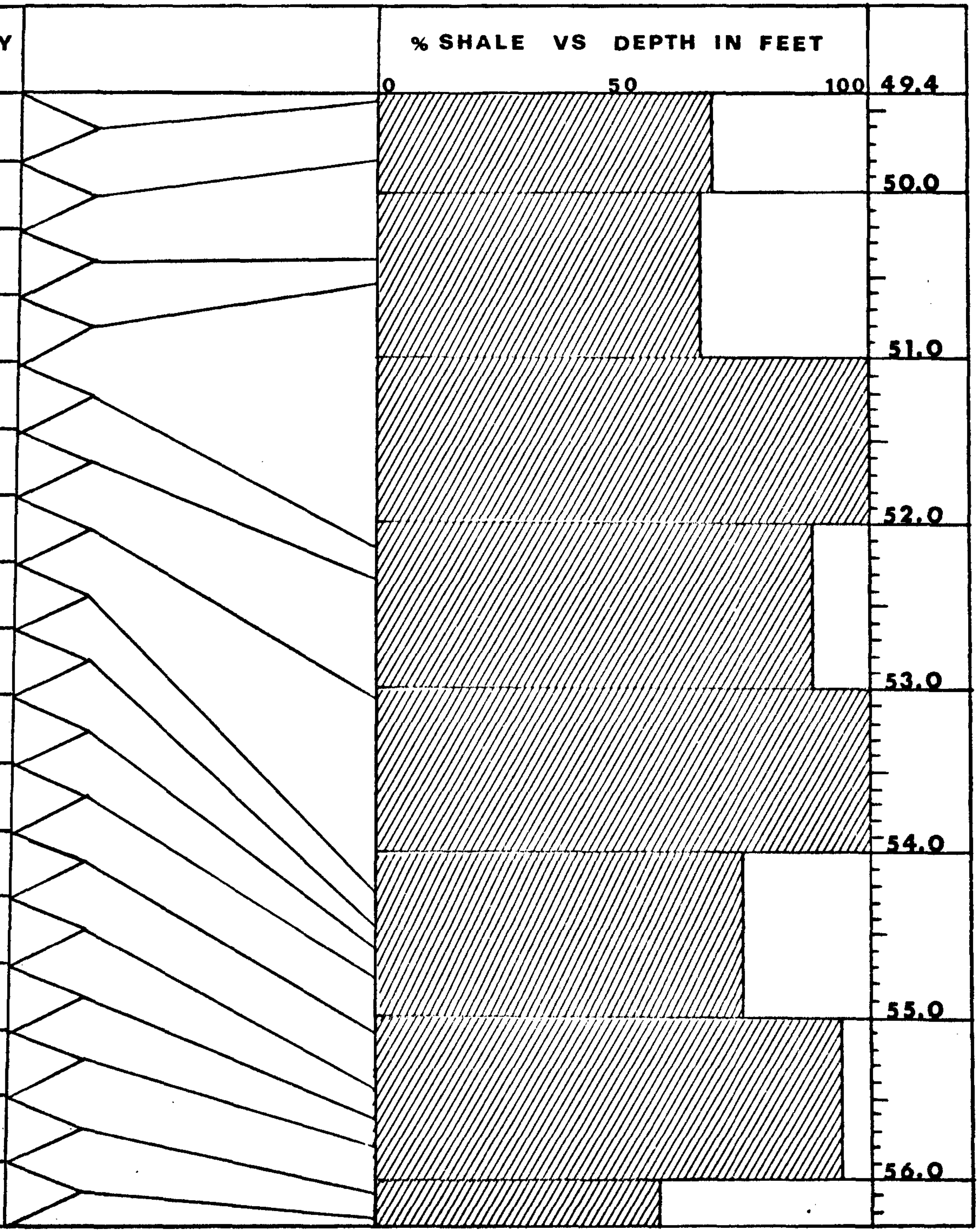
CORE 70ZA BOX NUM.	CORE 70ZA SUBSAMPLE	PALEOMAGNETIC SUBSAMP. DEPTH (ft)	POLARITY
2	49A	40.02	R
2	50A	40.31	R
2	53A	40.70	R
3	1A	41.17	R
3	5A	41.83	R
3	12A	42.80	N
3	14A	42.97	R
3	15A	43.20	N
3	20A	43.58	R
3	22A	43.81	R
3	23A	44.06	R
3	24A	44.23	N?
3	26A	44.53	N?
3	27A	44.73	R
3	29A	45.00	N
3	31A	45.14	R
3	31B	45.30	R



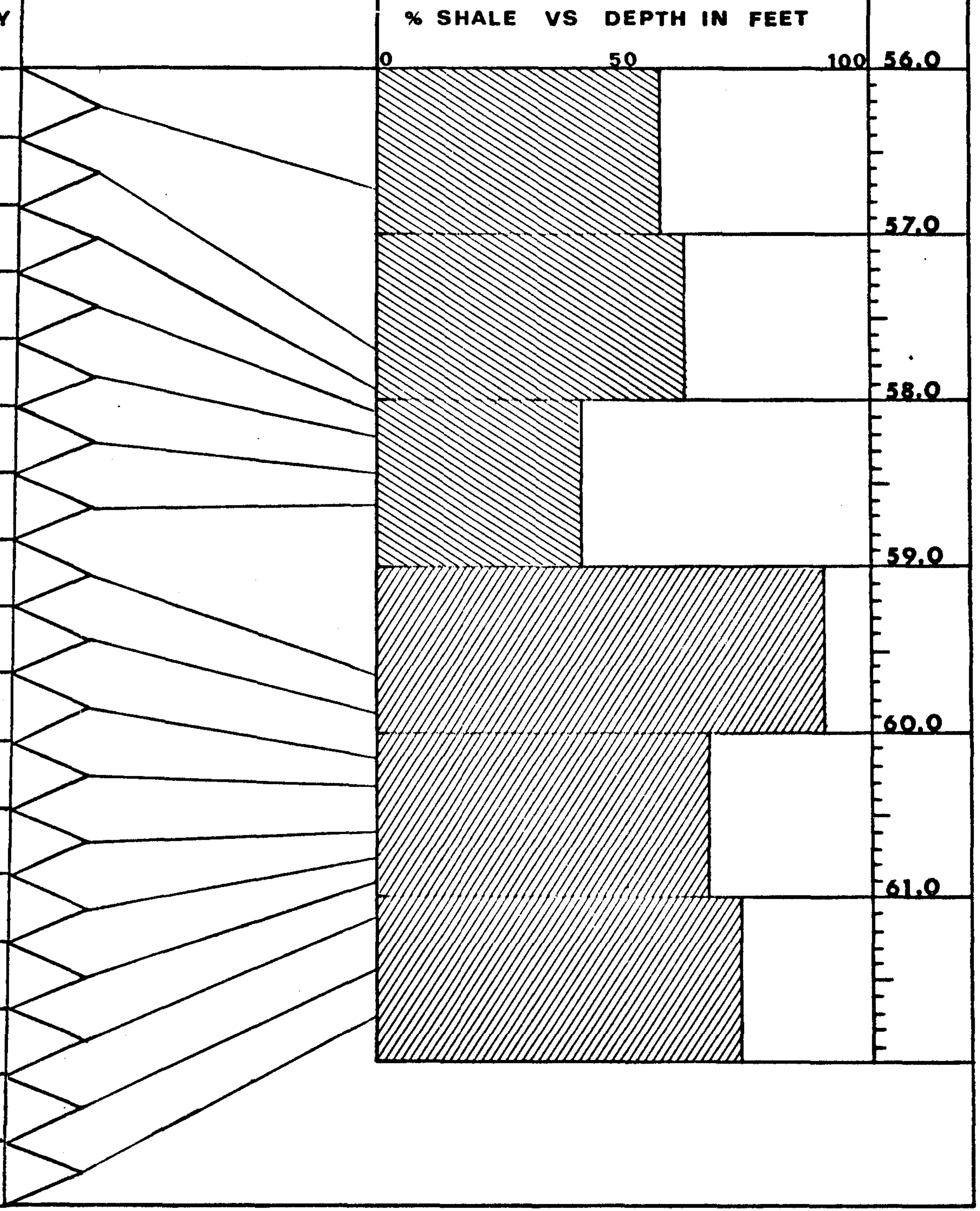
CORE 70ZA BOX NUM.	CORE 70ZA SUBSAMPLE	PALEOMAGNETIC SUBSAMP. DEPTH (ft)	POLARITY
3	32A	45.45	R
3	35A	46.02	R
3	36A	46.14	R
3	37A	46.32	R
3	37B	46.48	R
3	38A	46.63	N?
3	39A	46.74	N?
3	43A	47.06	R
3	44A	47.29	R
3	45A	47.40	R
3	45B	47.56	R
3	48A	48.11	N?
3	49A	48.24	R
3	50A	48.36	R
3	52A	48.63	R
3	53A	48.86	R
3	55B	49.29	R



CORE 70ZA BOX NUM.	CORE 70ZA SUBSAMPLE	PALEOMAGNETIC SUBSAMP. DEPTH (ft)	POLARITY
3	56A	49.43	R
3	58A	49.80	R
3	59A	50.40	N
3	59B	50.56	N
4	2A	52.15	N
4	3A	52.34	R
4	4A	53.06	N?
4	7A	54.22	N
4	9A	54.43	N?
4	9B	54.59	N?
4	10A	54.78	N?
4	12A	55.12	N?
4	15A	55.49	R
4	15B	55.65	R
4	16A	55.81	R
4	17A	56.10	R
4	17B	56.26	R



CORE 70ZA BOX NUM.	CORE 70ZA SUBSAMPLE	PALEOMAGNETIC SUBSAMP. DEPTH(ft)	POLARITY
4	20A	56.72	R
4	26A	57.70	R
4	27A	57.93	N?
4	28A	58.08	R
4	29A	58.22	R
4	32A	58.45	R
4	33A	58.65	R
4	43A	59.65	R
4	45A	59.89	R
4	46A	60.15	R
4	46B	60.31	R
4	48A	60.60	R
4	48B	60.76	R
4	48C	60.92	R
4	49A	61.13	R
4	50A	61.44	R
4	52A	61.72	N



APPENDIX B

COMPUTER OUTPUT

CRYOGENIC MAGNETOMETER OUTPUT

SAMPLE	H=NRM X	H=NRM J	H=300 X	H=300 J	H=400-450 X	H=400-450 J	H=600 X	H=600 J
ZA2-49A	-0.0135	0.162E-06	-0.0020	0.502E-07	-0.0030	0.391E-07	-0.0020	0.391E-07
ZA2-50A	-0.0240	0.416E-06	-0.0030	0.678E-07	-0.0040	0.600E-07	-0.0040	0.539E-07
ZA2-53A	-0.0240	0.320E-06	-0.0045	0.797E-07	-0.0045	0.680E-07	-0.0025	0.750E-07
ZA3-1A	-0.0310	0.382E-06	-0.0060	0.851E-07	-0.0060	0.687E-07	-0.0045	0.579E-07
ZA3-5A	-0.0285	0.508E-06	-0.0030	0.700E-07	-0.0025	0.552E-07	-0.0005	0.606E-07
ZA3-12A	-0.0030	0.332E-07	0.0015	0.296E-07	0.0015	0.250E-07	0.0005	0.707E-08
ZA3-14A	-0.0390	0.496E-06	-0.0040	0.640E-07	-0.0010	0.482E-07	-0.0020	0.412E-07
ZA3-15A	0.0025	0.478E-06	-0.0005	0.682E-07	0.0010	0.110E-06	0.0020	0.115E-06
ZA3-20A	-0.0005	0.427E-07	0.0005	0.450E-07	0.0	0.320E-07	-0.0010	0.335E-07
ZA3-22A	-0.0375	0.764E-06	-0.0085	0.155E-06	-0.0055	0.132E-06	-0.0070	0.123E-06
ZA3-23A	-0.0065	0.743E-07	-0.0005	0.707E-08	0.0005	0.112E-07	-0.0010	0.141E-07
ZA3-24A	0.0600	0.777E-06	0.0095	0.124E-06	0.0065	0.957E-07	0.0070	0.923E-07
ZA3-26A	0.0065	0.682E-07	0.0015	0.187E-07	0.0010	0.141E-07	0.0	0.150E-07
ZA3-27A	-0.0305	0.415E-06	-0.0060	0.652E-07	-0.0050	0.585E-07	-0.0020	0.559E-07
ZA3-29A	-0.0035	0.642E-07	0.0020	0.269E-07	0.0010	0.187E-07	0.0020	0.250E-07
ZA3-31A	-0.0390	0.394E-06	-0.0045	0.517E-07	-0.0030	0.439E-07	-0.0025	0.308E-07
ZA3-31B	-0.0080	0.802E-07	-0.0015	0.166E-07	-0.0010	0.112E-07	-0.0010	0.269E-07
ZA3-32A	-0.0650	0.787E-06	-0.0100	0.122E-06	-0.0070	0.896E-07	-0.0075	0.829E-07
ZA3-35A	-0.0500	0.696E-06	-0.0075	0.133E-06	-0.0050	0.117E-06	-0.0075	0.963E-07
ZA3-36A	-0.0495	0.607E-06	-0.0060	0.802E-07	-0.0045	0.718E-07	-0.0020	0.320E-07
ZA3-37A	-0.0430	0.596E-06	-0.0040	0.765E-07	-0.0035	0.502E-07	-0.0030	0.510E-07
ZA3-37B	-0.0070	0.127E-06	0.0	0.566E-07	-0.0030	0.469E-07	-0.0030	0.687E-07
ZA3-38A	0.0210	0.240E-06	0.0050	0.673E-07	0.0050	0.510E-07	0.0050	0.548E-07
ZA3-39A	0.0690	0.723E-06	0.0105	0.113E-06	0.0080	0.890E-07	0.0080	0.886E-07
ZA3-43A	-0.0230	0.311E-06	-0.0060	0.687E-07	-0.0045	0.456E-07	-0.0050	0.502E-07
ZA3-44A	-0.0140	0.254E-06	-0.0040	0.510E-07	-0.0020	0.300E-07	-0.0020	0.346E-07
ZA3-45A	-0.0420	0.536E-06	-0.0070	0.883E-07	-0.0045	0.673E-07	-0.0040	0.500E-07
ZA3-45B	-0.0315	0.420E-06	-0.0040	0.534E-07	-0.0040	0.559E-07	-0.0040	0.458E-07
ZA3-48A	0.0485	0.620E-06	0.0060	0.781E-07	0.0040	0.574E-07	0.0040	0.500E-07
ZA3-49A	-0.0400	0.424E-06	-0.0040	0.447E-07	-0.0050	0.585E-07	-0.0050	0.548E-07
ZA3-50A	-0.0505	0.692E-06	-0.0085	0.125E-06	-0.0090	0.121E-06	-0.0025	0.997E-07
ZA3-52A	-0.0325	0.402E-06	-0.0040	0.500E-07	-0.0040	0.721E-07	-0.0055	0.587E-07
ZA3-53A	-0.0325	0.387E-06	-0.0050	0.561E-07	-0.0025	0.269E-07	-0.0035	0.442E-07
ZA3-55B	-0.0200	0.341E-06	-0.0040	0.696E-07	-0.0020	0.430E-07	-0.0020	0.324E-07

CRYOGENIC MAGNETOMETER OUTPUT

SAMPLE	H=NRM X	H=NRM J	H=300 X	H=300 J	H=400-450 X	H=400-450 J	H=600 X	H=600 J
ZA3-56A	-0.0305	0.381E-06	*******	0.173E+02	-0.0055	0.594E-07	-0.0050	0.568E-07
ZA3-58A	-0.0120	0.172E-06	-0.0030	0.510E-07	-0.0030	0.300E-07	-0.0020	0.224E-07
ZA3-59A	-0.0030	0.335E-07	0.0030	0.361E-07	0.0030	0.403E-07	0.0025	0.335E-07
ZA3-59B	-0.0035	0.442E-07	0.0	0.141E-07	-0.0005	0.150E-07	0.0	0.112E-07
ZA4-2A	-0.0030	0.436E-07	0.0	0.158E-07	0.0005	0.112E-07	0.0005	0.707E-08
ZA4-3A	-0.0230	0.403E-06	-0.0030	0.510E-07	0.0	0.502E-07	-0.0015	0.559E-07
ZA4-4A	0.0400	0.439E-06	0.0055	0.594E-07	0.0090	0.911E-07	0.0040	0.510E-07
ZA4-7A	-0.0040	0.131E-06	-0.0010	0.269E-07	0.0	0.150E-07	0.0	0.100E-07
ZA4-9A	0.0405	0.549E-06	0.0060	0.723E-07	0.0035	0.464E-07	0.0040	0.490E-07
ZA4-9B	0.0235	0.391E-06	0.0050	0.520E-07	0.0065	0.907E-07	0.0060	0.872E-07
ZA4-10A	0.0410	0.526E-06	0.0075	0.103E-06	0.0050	0.687E-07	0.0060	0.678E-07
ZA4-12A	0.0375	0.547E-06	0.0080	0.109E-06	0.0055	0.784E-07	0.0040	0.721E-07
ZA4-15A	-0.0270	0.490E-06	-0.0030	0.618E-07	-0.0030	0.350E-07	-0.0020	0.245E-07
ZA4-15B	-0.0100	0.211E-06	-0.0040	0.707E-07	-0.0050	0.559E-07	-0.0040	0.450E-07
ZA4-16A	-0.0450	0.546E-06	*******	0.173E+02	-0.0045	0.696E-07	-0.0050	0.844E-07
ZA4-17A	-0.0300	0.520E-06	-0.0050	0.642E-07	-0.0035	0.589E-07	-0.0020	0.320E-07
ZA4-17B	-0.0210	0.350E-06	-0.0045	0.673E-07	-0.0045	0.456E-07	-0.0030	0.320E-07
ZA4-20A	-0.0330	0.526E-06	-0.0040	0.860E-07	-0.0045	0.689E-07	-0.0045	0.758E-07
ZA4-26A	-0.0410	0.837E-06	-0.0045	0.216E-06	-0.0050	0.177E-06	-0.0055	0.164E-06
ZA4-27A	0.0550	0.681E-06	0.0100	0.142E-06	0.0070	0.943E-07	0.0080	0.101E-06
ZA4-28A	-0.0025	0.308E-07	-0.0005	0.255E-07	-0.0005	0.652E-07	-0.0010	0.594E-07
ZA4-29A	-0.0095	0.637E-06	-0.0040	0.184E-06	-0.0030	0.121E-06	-0.0045	0.887E-07
ZA4-32A	-0.0250	0.526E-06	-0.0050	0.826E-07	-0.0050	0.642E-07	-0.0035	0.572E-07
ZA4-33A	-0.0035	0.669E-07	-0.0010	0.206E-07	-0.0010	0.187E-07	-0.0010	0.122E-07
ZA4-43A	-0.0460	0.785E-06	-0.0065	0.161E-06	-0.0040	0.122E-06	-0.0050	0.121E-06
ZA4-45A	-0.0450	0.663E-06	-0.0050	0.122E-06	-0.0040	0.108E-06	-0.0045	0.702E-07
ZA4-46A	-0.0315	0.363E-06	-0.0080	0.820E-07	-0.0065	0.696E-07	-0.0040	0.482E-07
ZA4-46B	-0.0360	0.372E-06	-0.0085	0.863E-07	-0.0060	0.640E-07	-0.0050	0.592E-07
ZA4-48A	-0.0300	0.372E-06	-0.0050	0.795E-07	-0.0045	0.667E-07	-0.0040	0.696E-07
ZA4-48B	-0.0450	0.629E-06	-0.0070	0.885E-07	-0.0060	0.781E-07	-0.0050	0.602E-07
ZA4-48C	-0.0050	0.144E-06	-0.0010	0.112E-07	0.0	0.100E-07	-0.0030	0.320E-07
ZA4-49A	-0.0390	0.819E-06	-0.0060	0.186E-06	-0.0040	0.141E-06	-0.0040	0.113E-06
ZA4-50A	-0.0315	0.101E-05	-0.0050	0.245E-06	-0.0055	0.184E-06	-0.0050	0.157E-06
ZA4-52A	-0.0090	0.107E-06	0.0010	0.678E-07	0.0020	0.616E-07	0.0005	0.324E-07

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