DOLORES ARCHAEOLOGICAL PROGRAM

TECHNICAL REPORTS

Volume VI, Chapter 11

Archaeomagnetic Dating - 1979

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Prepared For

Cultural Resources Mitigation Program: Dolores Project

Bureau of Reclamation, Upper Colorado Region

Contract 8-07-40-S0562

Under The Supervision Of

David A. Breternitz, Senior Principal Investigator

Final Submission

22 March 1982

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. DAP-VI(11)	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Dolores Archaeological Program Technical Reports: Archeomagnetic Dating - 1979		5. Report Date March 1982 (Submitted)
		6. Performing Organization Code
7. Author(s) J. Holly Hathaway and Jeffrey L. Eighmy		8. Performing Organization Report No.
9. Performing Organization Name and Address University of Colorado - DAP Rural Route 1, 17219 CR 26 Dolores, Colorado 81323		10. Work Unit No.
		11. Contract or Grant No. 8-07-40-S0562
12. Sponsoring Agency Name and Address U.S. Bureau of Reclamation P.O. Box 11568 Salt Lake City, Utah 84147		13. Type of Report and Period Covered Contractual FY 1979
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The 1979 archaeomagnetic sampling program involved the recovery of 61 archaeomagnetic samples from 17 Dolores Archaeological Program (D.A.P.) area sites. Results from analysis of these samples were used not only to aid in the chronological interpretation of the excavated sites, but also to refine the field and laboratory methodology employed by the sampling program. An attempt was made to refine the current Southwest master curve (Weaver [1], Dubois [2]) in order to increase its usefulness and applicability in the project area. Auxiliary studies conducted during the 1979 season included soil analyses, intended to demonstrate the relationship between soil characteristics and archaeomagnetic sample quality; and experimental kiln firings, intended to provide temperature and date controls for other samples recovered from a variety of contexts in the D.A.P. area.

17. Key Words Dolores Archaeological Program, SW Colorado, Anasazi, Archaeology, Archeomagnetic Dating		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 126	22. Price

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ABSTRACT

The 1979 archaeomagnetic sampling program involved the recovery of 61 archaeomagnetic samples from 17 Dolores Archaeological Program (D.A.P.) area sites. Results from analysis of these samples were used not only to aid in the chronological interpretation of the excavated sites, but also to refine the field and laboratory methodology employed by the sampling program. An attempt was made to refine the current Southwest master curve (Weaver [1], Dubois [2]) in order to increase its usefulness and applicability in the project area. Auxiliary studies conducted during the 1979 season included soil analyses, intended to demonstrate the relationship between soil characteristics and archaeomagnetic sample quality; and experimental kiln firings, intended to provide temperature and date controls for other samples recovered from a variety of contexts in the D.A.P. area.

INTRODUCTION

Research Orientation

The archaeomagnetic sampling program initiated in 1978, the first year of field operations of the Dolores Archaeological Program (D.A.P.), was continued during the 1979 field season. Due to the intensified mitigation program during the 1979 season, archaeomagnetic collections increased to nearly twice as many samples as were collected in 1978.

The immediate goal of the program was to obtain a representative collection of favorable samples from cultural contexts excavated by D.A.P. personnel. The archaeomagnetic assemblage would then serve two purposes. First, when used with other dating methods (dendrochronology, C-14, and ceramic and architectural seriations), archaeomagnetism would provide the archaeologist with a refined chronological base for past cultural behavior; it would also aid in temporal assessment when other dating methods are absent.

Secondly, the collection could be used to verify and refine DuBois' [2] master curve of the Southwest. This curve was proposed by Dr. D. L. DuBois of the University of Oklahoma (Weaver [1], DuBois [2]), and later substantiated by Wolfman [3] and Eighmy et al. [4]. Independently dated samples of similar age assignments (within 25 years) were grouped together and a mean virtual geomagnetic pole (VGP) position was determined for various age groups. Each VGP position indicates the estimated, directional plot of the geomagnetic pole at that locality at a point in time. When consecutively dated VGP positions are documented for a given locality or region, a VGP curve may be established. The trends noticed in the D.A.P. material could then be compared with corresponding chronolog-

ical segments of the Southwest curve as reported by DuBois. Because a large proportion of Dolores material dates from A.D. 600-1000, the early portion of the DuBois curve was examined more thoroughly. With a more accurately defined master curve, better dates may be provided for D.A.P. and southwestern collections.

Secondary goals of the archaeomagnetic program involved improving the technical accuracy of collection procedures and laboratory analyses. Advancements in these areas will ultimately affect the reliability of dates provided by archaeomagnetism. Because archaeomagnetism is a relatively recent development (within the last 10-20 years), processes involved in producing and retaining magnetic orientation resulting from ancient firings (called "remanent magnetizations") are not completely understood. Similarly, laboratory and field procedures measuring this remanent magnetization are continually being refined as knowledge increases. The D.A.P. archaeomagnetic studies have initiated several important and innovative methods in these areas.

SUMMARY OF WORK

Archaeomagnetic sampling was one of the primary tasks of the D.A.P. Special Studies crew, supervised by J. Holly Hathaway. The field season began on 1 June 1979 and operations were completed on 19 November 1979. Helen Hoy was acting supervisor of archaeomagnetic collections from 1 September 1979 through 19 November 1979.

Seven crew members (K. Bauman, R. Beaty, J. Jones-Brooks, L. Childs, H. Hoy, M. Kennedy, and B. King) were trained in archaeomagnetic collection procedures and briefed on basic underlying principles involved with archaeomagnetic dating. Each locality tested by D.A.P. personnel (Grass Mesa, Sagehen Flats, North Sagehen, and House Creek) had at least one crew member who assisted Hathaway in collecting archaeomagnetic samples from sites in that area. When not involved with archaeomagnetic collections, these crew members assisted on the excavation crews.

Archaeomagnetic samples were collected from 17 prehistoric sites. Two of these sites, Site 5MT2151 and Site 5MT2193, had been previously excavated in 1978, but they required further mitigation and produced additional archaeomagnetic samples. Excavations at 13 sites did not provide features or contexts of sufficient incineration to warrant archaeomagnetic samples. A total of 61 archaeomagnetic samples was collected from prehistoric firings at sites excavated during the 1979 field season. Various prehistoric features were sampled in the D.A.P. archaeomagnetic program including burned pitstructure walls and floors, hearths, firepits, and burned house walls and floors.

Additionally, three mock kilns from Site 5MT2192 were sampled. The kilns were prepared and fired by D.A.P. ceramic laboratory personnel

in order to reproduce a prehistoric kiln firing (Lucius [5]). Samples from these experimental firings provided controls for two important variables: firing temperature and date. Results from these experiments were then compared with the actual VGP position calculated from current declination and inclination estimates of Dolores, Colorado.

Archaeomagnetic sampling collections totaled approximately 100 person-days of field work (collecting samples, site visitation, feature assessment, etc.) and 18 person-days of laboratory work (recording, processing, and monthly reports). Laboratory analysis was conducted by Dr. J.L. Eighmy (Colorado State University) who was assisted by J.H. Hathaway (Colorado State Universtiy). Samples were analyzed at University of Colorado's paleomagnetic laboratory under the direction of Dr. E. E. Larson.

METHODOLOGY[1]

Laboratory Methods

To more fully evaluate the archaeomagnetic results from samples collected at the D.A.P., a brief outline of archaeomagnetic theory and method may be helpful (for a detailed discussion see Eighmy [6]). An understanding of archaeomagnetism is based on two facts: (1) burned clay records the direction and intensity of the earth's field at the time of the incineration at that location, and (2) the direction of the geomagnetic field wanders at a rate of approximately 0.1° per year.

Thermal Remanent Magnetism

The direction and intensity of ancient magnetic fields can be determined from burned clay due to the property called thermoremanent magnetism (TRM). A total TRM originates when clay is heated to temperatures above 570°C in the presence of the earth's field. The electrons of magnetic particles in the clay, primarily hematite and magnetite, spin randomly at high temperatures due to thermal agitation. As the temperature of the clay falls, the orientation of many of the electron orbits will parallel the earth's field at that place and time. Further cooling "locks" the oribital paths indefinitely, thus preserving a record of field direction and intensity as long as the fired clay is not disturbed. However, repeated high temperature refiring of a feature will "erase" all previous TRM and realign the orbital paths to the ambient fields, thus recording the magnetic field of the last high firing. Many burned archaeological features are subjected to the above-mentioned thermal alterations and thus may exhibit TRM.

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[1] Portions of the text in this section also appear, in slightly different form, in Eighmay [6].

Remanent magnetization can also be caused by partial thermal magnetization (PTRM) or by chemical magnetization (CRM) of an archaeological feature. PTRM occurs when temperatures less than 570°C are attained during the firing of an archaeological feature. Thermal remanence is acquired in a nonlinear fashion; most (about 75 percent) of the magnetism is acquired at high (more than 525°C) temperatures. Therefore a PTRM results from low temperature firings.

CRM can also occur from low temperature firings (below 400°C). CRM is characterized by the alteration of one magnetic mineral to another which is often associated with oxidation processes. CRM produces a remanent magnetization maintained indefinitely, unless subsequent firings attain temperatures sufficient to produce a TRM. Since CRM and TRM are distinquished by representing different firing occurrences, they may represent different occupational activities. TRM dates the last firing occurrence above 570°C. It is assumed that the last firing is the hottest firing; subsequently, archaeomagnetic dates are judged to represent the abandonment of the structure at archaeological sites. CRM is associated with the first firing occurrence or the original occupation or use of a structure or feature. At present, archaeomagnetists are not absolutely sure which of these processes is most important when dating archaeomangetic samples (Michels [7]). Preliminary results from the experimental firing of hearths indicate that heating clay to temperatures above 600°C may be uncommon in archaeological contexts. Krause [8] has fired three hearths (0.5 m in diameter, between 35 and 40 pounds of pine) and has achieved maximum temperatures of only 450°C. Even at these low temperatures, the three hearths produced good archaeomagnetic results (i.e., low alpha 95 values), suggesting that PTRM and/or CRM may be as important as total TRM.

Unfortunately, TRM, PTRM, and CRM, once acquired, can be obscured or erased by several different processes. Viscous remanent magnetization (VRM) and isothermal remanent magnetization (IRM) are the most common in archaeological samples. VRM results from the influence of the earth's field over a long period of time. The earth's field causes some magnetic grains to align with the field at normal (room) temperatures and thus additively contributes to the total remanence (or natural remanent magnetization [NRM]). The amount of VRM depends largely on the amount of time the sample is exposed to the earth's changing field. IRM can occur when a large magnetic field or electrical charge (such as lightning) is applied near a magnetized area, permanently erasing the magnetic orientation produced by the thermal event.

Demagnetization

Secondary components of magnetization (VRM) are removed by a process called demagnetization. The object in a demagnetization procedure is to randomize the oribital paths of electrons aligned by viscous, very low-temperature thermoremanence sources. This can be accomplished in two ways. First, the clay sample can be subjected to a sinusoidally oscillating field with decreasing amplitude, while being shielded from the earth's and all other fields (AF demagnetization). Second, the sample can be reheated to low temperatures while shielding it from magnetic fields (thermal demagnetization). Shielding the sample prohibits realignment with the ambient field. Low levels of AF and thermal demagnetization usually reduce effects of secondary components (i.e., VRM) while retaining most of the primary remanence; however, as higher levels of demagnetization are reached, more primary remanence is "erased." Both methods can effectively neutralize effects from secondary components;

however, thermal demagnetization is more frequently used for detecting CRM and PTRM, and AF demagnetization is more frequently used for magnetic "cleaning" (randomizing effects from VRM) of archaeomagnetic samples. Since demagnetization permanently alters a sample's remanent magnetization, extreme care is taken during demagnetization to record all sample treatments and results. Therefore, with demagnetized results, the archaeologists or geophysicists should have a good record of the magnetic remanence produced by the ancient firing.

Archaeomagnetic Curves

In the past 10 years considerable archaeomagnetic research has been conducted throughout the world. Some of this research has resulted in records of past geomagnetic secular variation. The resultant reconstructions are of variable precision. Most of the imprecision results from inadequate temporal control of the archaeological context. Field collection and laboratory measurement of the magnetic properties of samples have been refined to the point where most of the remaining uncertainty in archaeomagnetic curves can be attributed to determining the temporal contexts of ancient directions.

The construction of archaeomagnetic curves can be illustrated by the following hypothetical example. If an ancient pueblo in the Southwest had numerous carbon-14-dated rooms and a number of firepits in each house, it might be possible to construct a record of past magnetic change. If the carbon-14 dates place the construction of 10 of the rooms at equidistant intervals of approximately 10 years over a span of 100 years between A.D. 1250-1350, and if it is assumed that rooms were used for about 50 years, then the hearths in those rooms would "probably" have been last fired between A.D. 1300-1400. If each of these rooms contained a sampled

hearth, then the resultant magnetic directions should plot in a spatiotemporal trend. Each magnetic plot from the hearths in the village records a pole position at that locality at a point in time. The A.D. 1300-1400 master curve of secular variation is, thus, a path through the VGPs calculated from directions of remanent magnetization.

Archaeomagnetic Dating

Archaeomagnetic dating depends then, on independently dated master records of changing VGPs. With such data an undated burned feature can be measured for its fossilized magnetic direction. This direction is then compared to the master record and an age is assigned to the feature. Before archaeomagnetic dating can be relied upon, the archaeologist must know: (1) how the master record was independently dated; and (2) whether or not a master record developed in one area can be applied in others, since the changes depicted by the master records are regionally specific. The first consideration, although important, is largely out of the hands of the individual archaeologist. Independent dating of ancient VGPs in the southwestern portion of the United States depends on tree-ring dating. Assuming careful application, dendrochronology seems capable of precisely dating ($\pm$ 10 years) old VGP positions.

The second consideration, the regional specificity of master curves, remains unsolved. In North America, the only published record of secular variation is a VGP path for the Southwest developed by DuBois [2] at the Paleomagnetic Laboratory, University of Oklahoma. Dated VGPs were collected from Arizona, New Mexico, southern Colorado, and southern Utah. Within this area, DuBois [2:140] has found that the ancient VGP positions of similar ages at two sites separated by 592 km do not differ significantly. Thus, there is some hope that fairly large regions can rely on a

master curve, but just how large an area is less certain. Dubois and Daniel Wolfman of the Arkansas Archaeological Survey, University of Arkansas (Wolfman [9]), are collecting data from the midwestern portion of the United States to determine the nature of secular variation there. Wolfman [9] reports that the midcontinent curve differs little from that developed for the Southwest, indicating that areas as large as the North American continent may rely on slight variations of a single master curve.

It should be recognized, however, that significant spatiotemporal differences have been observed even within the Southwest (Svenson [10]). Therefore, accurate reports of archaeomagnetic sample directions and any independent dating are important considerations in allowing the further refinement of archaeomagnetic master curves. Additional refinement and regional specificity are always possible in archaeomagnetism. Some archaeomagnetic results which appear unusual today may be explained as further improvements in archaeomagnetic master curves are made. Thus, it is important to report not only the archaeomagnetic dates of good samples which conform to current archaeomagnetic expectations, but also to give a complete account of each good sample's direction, accuracy, and archaeological/temporal context.

Laboratory Measurements and Results

Samples were measured on a Schonstedt Spinner Magnetometer in the Paleomagnetic Laboratory, University of Colorado. All specimens were measured for their NRM, then demagnetized. For dating a thermal event, the archaeomagnetist is interested in the stable thermoremanent magnetism. To measure this component of the total magnetization of a sample, it is best to filter out secondary, less stable magnetizations. The problem

with demagnetization is randomizing as much secondary magnetization (VRM) as possible without unnecessarily randomizing any of the primary thermal component. To determine the best level, several D.A.P. specimens were AF demagnetized and measured at successive 25 or 50 oersted levels. The relative movement of the specimen's directions and the level of intensity were examined. It was theorized that the best level for the two demagnetized samples was one which showed a marked change in intensity and at which the specimen directions tended to converge. Based on these experiments and previous experience (Eighmy et al. [4]), 25 oersteds appeared to be the optimum level (Figures 11.1 and 11.2). It was felt that, at this level, most secondary magnetization was removed without needlessly removing primary TRM.

After each demagnetization, the direction of the remanent magnetism of a specimen was measured in terms of three dimensional space with x, y, and z coordinates or components of the magnetic moment. In processing samples, the magnitude of x, y, and z components is measured four times, and the set of values, plus the field orientation of the specimen, are used to calculate the declination (D) and inclination (I) for each specimen. The x, y, and z components of all specimens of a sample are also combined to calculate a mean I and D for the sample. Latitude and longitude values for the sample can then be easily substituted for the mean I and D.

Fisherian statistics (Irving [11:58]) are used to estimate the precision parameter, K:

$$K = \frac{N-1}{N-R} \qquad \text{where } N = \text{number of directions}, \quad R = \text{average vector}$$

The precision parameter refers to the reliability of the observed mean

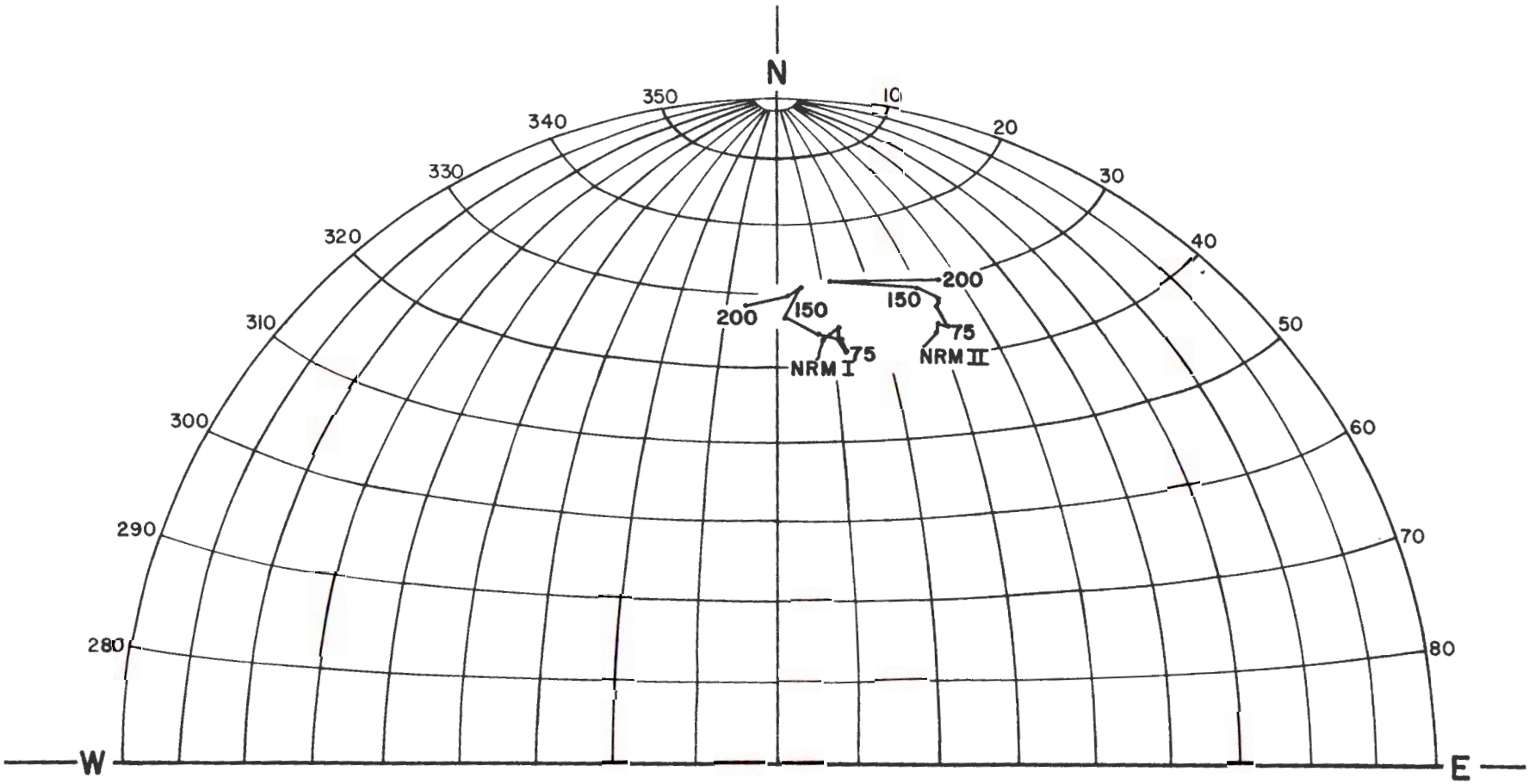

Figure 11.1 Stereonet projection of step demagnetization Sample 5MT4544-4, Specimens 1 and 2.

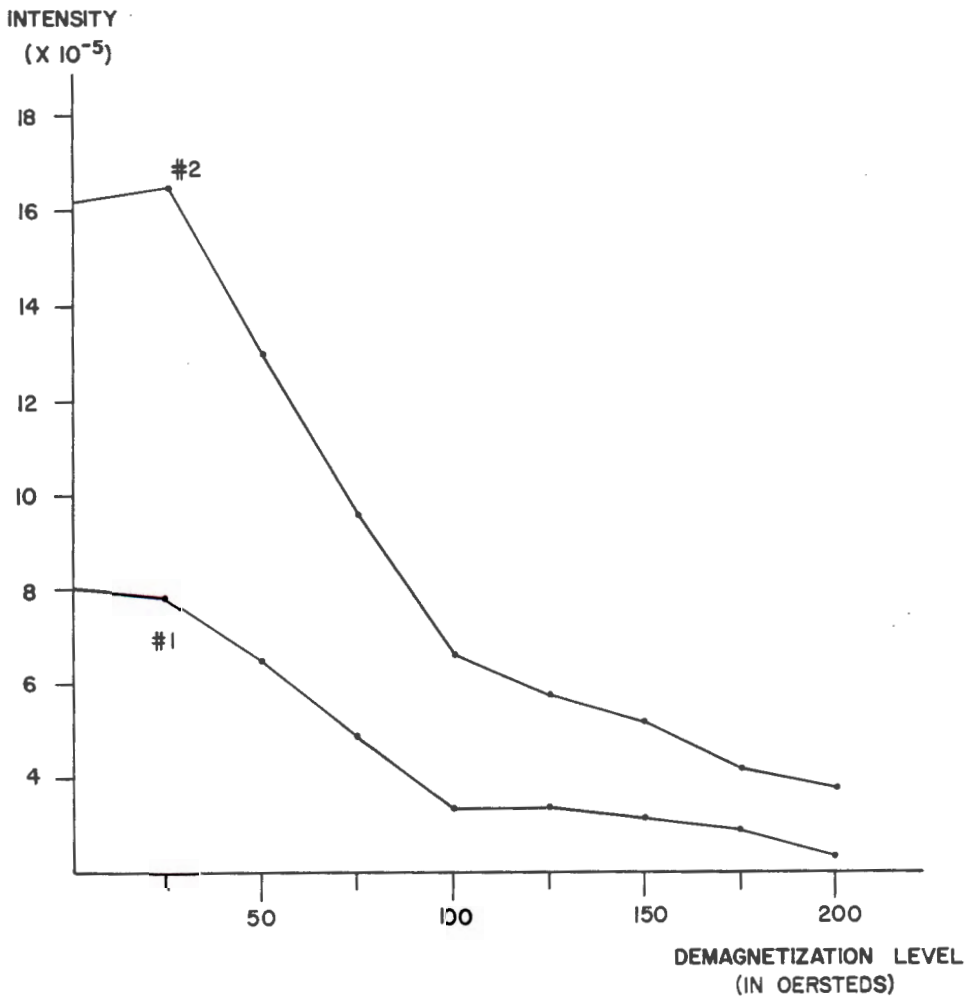

Figure 11.2 Intensity levels of step demagnetization of Specimens 1 and 2, Sample 4 at Site 5MT4545.

directions. The reliability of an archaeomagnetic collection may also be defined as the radius (alpha) of a circle centered on the observed mean direction within which the true mean will fall 95 percent of the time. Thus, a small alpha 95 indicates a sample composed of specimens which point in a tight cluster of directions and a large alpha 95 indicates a scattered collection. The alpha was calculated according to the following formula (Irving [11:62]):

$$\text{alpha} = \text{Cos}^{-1}\left(1 - \frac{N-R}{R}\left[\left(\frac{1}{.05}\right)^{1/N-1} - 1\right]\right)$$

In some cases the calculated alpha 95 can be improved. Carefully recorded field notes are important for this stage of analysis because if, in the course of laboratory processing, it becomes obvious to laboratory personnel that some specimen(s) is inconsistent with the others, and field notes indicate that the specimen was unstable, unfired, etc., then such an "outlier" can safely be discarded. A better, truer representation of the actual direction of the remanent magnetism will be provided by the results of the remaining specimens.

The problem with outliers is even more involved. Extreme outliers often become evident in the laboratory but the reasons for their inconsistency are not evident in field notes. It appears that for some obscure reason one or more specimens may not record the ancient direction indicated by the other specimens in the set. In an attempt to salvage the sample, the archaeomagnetic analyst can arbitrarily discard the outlying specimen(s), but without a good independent reason, such discard is discouraged. Still, with some specimen sets, obvious outliers exist and the data are too important to ignore due to a large alpha 95 from one or more outliers. No satisfactory solution exists at present for handling

the outlier problem. One solution which is not biased in terms of a preferred direction is to set some arbitrary limit, for example, two angular standard deviations, beyond which only outliers exist. If a specimen lies beyond the second angular standard deviation of the distribution of remaining specimens, then it is an "outlier" and can be discarded. In any case, careful documentation of what was done to the set should be provided by the laboratory.

Field Methods

Several amendments in conjunction with the basic archaeomagnetic sampling procedures outlined in the 1978 archaeomagnetic dating report (Hathaway [12]) were followed during the 1979 field season. These amended procedures were implemented to improve the program's effectiveness and reliability.

First, a priority system was established to consider the physical properties of the sampling context, to enable ranking for more effective sample analysis, and eventually to improve the program's productivity. Second, an alternative method of measuring sampling cube orientations in the field was examined. Tarling [13:59] suggests that magnetic-compass measurements may be inaccurate representations of the cube's orientation to the geomagnetic pole due to interferences by localized anomalies. Therefore, the D.A.P. archaeomagnetic program implemented a procedure utilizing sun-compass orientations (Krause [14]) in conjunction with Brunton-compass orientations for each sampling cube. It was felt that the sun compass would provide a more accurate representation of the cube's declination from which to compute a paleopole position.

Third, the program required a soil collection from areas which were

archaeomagnetically sampled. These samples provided analysts with a control of the physical characteristics of a sample area. A selected proportion of this collection could then be analyzed for relative amounts of clay, silt, sand, and iron. From these soil analyses, a model could be devised by synthesizing these results with the archaeomagnetic results. The model would provide a continuum of attributes indentifying the ones necessary for productive archaeomagnetic samples. Consideration of these attributes could then be applied to the field situation to provide better selectivity of sampling matrices and consequently increase the program's efficiency and productivity.

Priority System

A priority system was adapted to the 1979 archaeomagnetic program and was employed for all samples. The purpose of this system was to provide a quantitative evaluation of the sampling context, quality, and procedure. This preliminary evaluation of sample areas would then be used by laboratory analysts to (1) prioritize analyses of samples, (2) enable assessment of predictability of archaeomagnetic conditions in the field situation, and (3) validate the importance of the various characteristics of archaeomagnetism. Field notes were instrumental to this system by providing detailed descriptions and qualitative evaluations of the sample conditions.

The priority system was established upon five levels corresponding to the likelihood of archaeomagnetic success. The appropriate level was subjectively determined from the consideration of six interactive variables: oxidation, hardness/preparation, texture, intrusions, erosion/weathering, and collection quality.

Oxidation is related to the amount and intensity of heating that has

occurred in a particular area. Tarling [15:186] indicates that temperatures exceeding the Curie point of ferromagnetic materials (580-675°C) are necessary to produce strong TRM. However, recent experiments (Krause [8]) suggest that lower temperatures will produce partial thermoremanence yielding good archaeomagnetic results. Hardness and preparation reflect the degree of stability of the sampling area. These factors may also indicate the amount of clay present, since clay has a tendency to harden upon repeated high-temperature firings. Texture is a measure of particle size and of relative proportions of sand, silt, and clay. When the clay content is proportionately high, ferromagnetic minerals may be present. These three factors (oxidation, hardness/preparation, and texture) are the most important factors in determinating sample priority.

Intrusions are considered by amount per volume and include any extratextural elements such as pebbles, charcoal, or organic materials. Erosion is the amount of material removed by natural processes over time. Only if intrusive and erosive qualitites were excessive did they affect prioritization.

Collection quality refers to the degree of ease in obtaining the individual specimens and the relative stability of the earthen pedestals. Since a poorly collected sample will affect archaeomagnetic results, this factor is extremely important in the final designation but should be less variable than the other factors.

Table 11.1 provides a summary of the characteristics reviewed for each variable and the level of prioritization assigned. The final designation (Priorities 1-5) is determined from a combination of the various evaluations from the six factors.

Table 11.1 Priority System for Archaeomagnetic Samples

Factors	Priority 1	2	3	4	5
Oxidation	red/orange 1 cm+ thick		spotty orange 0.5 cm thick		no oxidation, blackened
Hardness/ preparation	hard, solid; surface well prepared, i.e., coping-plaster		hard, but unprepared surface		soft, no preparation, surface is not smooth
Erosion/ weathering	very little apparent weathering, uncracked	INTERMEDIATE	some cracking, erosion of sample area	INTERMEDIATE	cracked and hard, slumped or eroded
Texture (clay/sand/ silt)	20% or better clay content		granular/ sandy, but some clay content (10-20%)		very sandy, little to no clay (0-10%) content
Intrusions	none to very few intrusions		some intrusions		excessive intrusions
Collection quality	good solid pedestals, no unstable specimens		some unstable specimens		friable situation, specimens are all a little unstable due to soil conditions

Cube Orientation Methods

A magnetic compass (such as those manufactured by the Brunton Instrument Company) is commonly used to measure cube orientation in archaeomagnetism. Because this instrument is sensitive to magnetic forces, including localized anomalous behavior, a method independent of magnetic perturbations may better represent the cube's relation to the geographic or magnetic pole. Tarling [13:59] suggests that magnetic-compass readings may vary as much as 30° in certain terrains (i.e., igneous terrain) when compared with gyro-compass and sun-compass readings. Certain archaeological conditions may also produce a magnetic influence sufficient to obscure the magnetic directions. Measurements taken from features located inside large conflagrated areas, or nearby buried historic trash (often metallic), may be affected by the fields produced by these areas. Therefore, sun-compass orientations were utilized to improve the archaeomagnetic program by providing an accurate representation of the true orientation of each cube, irrespective of magnetic deflections.

The sun compass used by project personnel was designed and manufactured by Krause [14] and Eighmy (Colorado State University). The compass consists of a base with two sides constructed of angle aluminum (at 90°) which fit flush with the southeast corner of the mold. The face consists of a 360° protractor calibrated to the four corners of the base. A perpendicular post protrudes from the center of the protractor. The angular orientation for each cube was obtained from the observed angle of the sun's shadow cast by the post. Computation of the cube's azimuth to true north was then calculated using the following formula (Tarling [13:59]):

$$180 + \tan^{-1} \left(- \frac{\sin LHA}{\cos \lambda \tan SD - \sin \lambda \cos LHA} \right)$$

where LHA = local hour angle
λ = site latitude
SD = sun's declination

The difference between this calculation and the Brunton-compass orientation for a corresponding cube should be equal to the local magnetic declination (13.5°E in the Dolores, Colorado area). Where the anomalous magnetic behavior affects the Brunton reading, the difference should vary proportionally to the influence produced by the anomaly.

The sun compass was employed whenever possible, but because the presence of the sun is necessary to procure the reading, the sun compass could not be used at all times. A total of 30 samples was measured by both orientation methods during the 1979 field season.

Soil Sampling

As previously mentioned, the textural qualities of a medium are important considerations for obtaining a remanent magnetization produced by a prehistoric firing. Although qualitative descriptions aid the analyst in evaluating and considering the characteristics of the sampling medium, it is best to retain a portion of the sampling matrix for laboratory study. Subsequently, a 1-L soil sample was collected from the matrices of all archaeomagnetically sampled areas in the project area. These samples serve two purposes: (1) they enable analysts to review the sampling medium without site visitation, and (2) they provide for a quantitative analysis relating archaeomagnetic results with soil qualities.

Twenty-three samples (35 percent) were collected for quantitative analysis at the Colorado State University Soils Laboratory. Soil texture

analysis consisted of a hydrometer test of the soil fraction representing particles of 2 mm or less for percent of sand, silt, and clay. Of the soil types represented, clay-based soils provide the most stable medium for retention of remanent magnetization. Therefore, it was expected that a positive correlation between percent clay and superiority of archaeomagnetic results would be evident in the data (i.e., as percent clay declines, the alpha 95 values increase).

The soils laboratory also conducted an analysis of the total ferric content for samples. This test included all the iron-bearing minerals present in the matrix and is considered to be a measure of the ferromagnetic minerals in the substance. The presence of ferromagnetic minerals (commonly magnetite and hematite) is crucial to the production of a remanent magnetization. These particles are the carriers of a magnetic moment measured in laboratory analyses for direction and intensity. The sample direction and intensity reflect the earth's magnetic field at the time of firing, thus allowing dating of the incineration. Axiomatically, the more particles present, the greater the likelihood of acquisition of a strong remanence. Therefore, it was felt that percent ferric content would correlate with sample strength and variability.

Because soil considerations are not the only factors affecting remanent magnetization, samples were carefully selected by degrees of oxidation, coloration, change, etc., based on the priority system mentioned previously. A selection of 23 samples included 8 priority 1 samples, 7 priority 2 samples, 4 priority 3 samples, and 4 priority 4 samples.

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RESULTS OF 1979 ARCHAEOMAGNETIC SAMPLING PROGRAM

Archaeomagnetic samples were collected at sites excavated during the 1979 D.A.P. field season from all fire-hardened features judged by a preliminary evaluation to be adequate for analysis. The analyses of these samples provided information on temporal placement and intrasite relationships of major structural features and of minor features within sites. A site-specific description of archaeomagnetic operations conducted during the 1979 field season is presented below. Appendix A contains a site-by-site summary of samples. The archaeomagnetic results for each site are summarized following the archaeomagnetic operations discussion. Appendix B contains site-by-site paleopole plots of the productive samples (see specific site archaeomagnetic appendixes for a complete discussion of sample results.)

Site 5MT0023 (Grass Mesa Village)

Site 5MT0023 (Breternitz and Campbell [16]) is located on a large bench 30 m above the Dolores River flood plain. The site is located in the Grass Mesa Locality and probably was occupied by prehistoric peoples on a permanent basis for 150 years during the McPhee Phase (A.D. 850-970). The architectural remains at the site consist of multiple pitstructures, often superimposed, causing complex interpretations of intrasite patterning. Roomblocks are located north of the pitstructures and trash middens are found south of the village area. A large pitstructure is located at the northwest edge of the village.

The Archaeomagnetic Samples

Eleven archaeomagnetic samples associated with features or contexts

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dating from early to middle McPhee Phase occupations, were collected from Site 5MT0023.

Four samples were collected from Pitstructures 1, 3, and 5 (superimposed structures in the same horizontal location). Two of these samples were collected from Pitstructure 1 (one from the central hearth and one from a burned area on the west wall). These samples should date the last use and abandonment of Pitstructure 1. Two samples were recovered from the burned structural areas in the remaining two superimposed pitstructures. One sample was collected from a burned area on the north wall of Pitstructure 3 and another was collected from a burned area on the east wall of Pitstructure 5. These samples should date the abandonment of these two structures. Architectural, ceramic, and stratigraphic evidence date Pitstructure 3 to A.D. 750; Pitstructures 1 and 5 date to around A.D. 850.

Three samples were recovered from the central hearths of three spatially distinct pitstructures. One sample was obtained from Pitstructure 2, one from Pitstructure 4, and one from Pitstructure 6. Construction of these structures is temporally placed by dendrochronological dates to the mid-A.D. 800s; stratigraphic evidence indicates 10-15 years of prehistoric occupation.

Two samples were obtained from temporary hearths located inside surface structures. Stratigraphic analysis temporally places occupations near A.D. 850.

Two samples were recovered from exterior hearths, probably used minimally according to depositional remains and presampling excavations. Dating of these features is tenuous, but architectural association indicates an occupation around A.D. 750-800.

The Archaeomagnetic Results

All but one sample from Site 5MT0023 yielded material considered by researchers to be adequately consistent to provide mean paleopole locations for dating. The paleopole plots for Site 5MT0023 samples are projected on the master Southwest curve in Appendix B. It is apparent from these results that the VGP positions of Samples 2 and 4-9 indicate overlapping dates from A.D. 700-775. The paleopole plots of Samples 7 and 8 are nearly identical in position and probably represent close temporality of these incinerations. The VGP positions of Samples 3, 10, and 11 are quite variable from the results of the above-mentioned samples. Sample 3 plots much later on DuBois' Southwest curve at A.D. 1030 $\pm$ 30 years. Sample 11 also plots later at around A.D. 910 $\pm$ 45 years and Sample 10 plots much earlier at A.D. 640 $\pm$ 50 years.

Compilation of all the archaeomagnetic information from Site 5MT0023 indicates a 350-400 year (A.D. 640-1030) occupation of the site. However, this estimate is not substantiated by the archaeological evidence, which indicates a 150-200 year occupation at the site.

Site 5MT2151 (LeMoc Shelter)

Site 5MT2151 (Hogan et al. [17]) is located in a south-facing rock shelter on the north slope of the Dolores River canyon. The site is situated in the Grass Mesa Locality and probably was occupied continuously by prehistoric populations on a temporary or permanent basis for at least 400-500 years (A.D. 600-1050). The site is stratigraphically complex. During the earliest documented use of the shelter, from Basketmaker III and early Pueblo I periods (about A.D. 600-800), the site was a small hamlet with one or two households. Later, during the late Pueblo I and

periods (A.D. 800-1050), the site was used as a seasonsal camp and processing area. Archaeomagnetic sampling at LeMoc Shelter during the second field season was directed toward temporal documentation of the later occupations of the shelter. A total of three samples was collected from Site 5MT2151.

The Archaeomagnetic Samples

Two samples were recovered from burned areas associated with Surface Structure 11; one was obtained from a temporary hearth located at Surface 2 and the other was collected from a burned area on the west wall of the room. These samples should yield the last use of Surface 2 and the abandonment of the room. However, the latter sample may represent a more recent burn associated with a much later time period.

One sample was obtained from the central hearth of Pitstructure 2. Archaeomagnetic results are expected to temporally date the last use of the pitstructure.

The Archaeomagnetic Results

Archaeomagnetic samples recovered from the wall of Surface Structure 11 and the central hearth of Pitstructure 2 provide data sufficient for dating. The paleopole plot from the sample representing the surface structure burn falls nearest the A.D. 1325 portion of the curve; however, dates of A.D. 1050 and A.D. 1440 may also be interpreted with an error bar of $\pm$ 55 years. The A.D. 1050 interpretation is more consistent with other archaeological data, such as tree-ring, architectural, and stratigraphic analyses. The sample collected from the hearth of Pitstructure 2 plots near the A.D. 920 portion of the Southwest curve; however, an A.D. 790 interpretation may also be possible with an error bar of $\pm$ 30 years. The second alternative is comparable with dates estimated from other archaeological methods.

Site 5MT2192 (Pheasant View Hamlet)

Site 5MT2192 (Yarnell [18]), situated approximately 2.5 km west of the Dolores River, is a small habitation in the Sagehen Flats Locality. The site served as a small permanent habitation or hamlet for about 20 years and was probably occupied during the Dos Casas Subphase (about A.D. 750-825). Major architectural remains investigated at the site include a roomblock of four to five slab-lined rooms and a pitstructure located to the south of the roomblock.

The Archaeomagnetic Samples

Four prehistoric features were archaeomagnetically sampled during the 1979 field season. Three additional samples were recovered from recently fired kilns; the results from these samples are discussed later.

Of the four samples from prehistoric features, two were recovered from surface hearths (one located in the roomblock and one in an exterior use area); these will be used to date the latest prehistoric use of these areas. The third sample was collected from a large fire-hardened pit located northwest of the pitstructure. The fourth sample was recovered from the central hearth of Pitstructure 1; this sample should date the last occupation of the structure.

The Archaeomagnetic Results

Results from one sample (obtained from a surface hearth in Room 1) provided a relatively strong and consistent magnetic direction which was plotted relative to the Southwest curve. No temporal interpretation is possible from this paleopole plot except within a modern time frame. Apparently the magnetic direction noted in this sample was disturbed in some manner, resulting in a location uncharacteristic of the temporal plot expected.

Site 5MT2193 (Dos Casas Hamlet)

Site 5MT2193 (Brisbin et al. [19]) is a small, permanent habitation or hamlet in the Sagehen Flats Locality; it is situated about 3 km west of the Dolores River. Major architectural remains investigated at the site include a crescent-shaped roomblock and two pitstructures in an outside use area to the south of the roomblock. The two pitstructures were not contemporaneous; Pitstructure 2 was built after Pitstructure 1 had burned and is located about 10 m closer to the roomblock. Tree-ring analysis conducted on samples recovered from the pitstructures indicates that Pitstructure 1 was constructed about A.D. 760 and Pitstructure 2 about A.D. 770. The site was probably occupied by a single family and can be temporally assigned to the Sagehen Phase. Archaeomagnetic sampling was directed at the collection of burned matrices associated with the two pitstructures.

The Archaeomagnetic Samples

A total of 14 samples was recovered from cultural contexts of the roomblock and pitstructures; 8 were obtained during the 1979 field season and the other 6 were collected during the 1978 field season (see Hathaway [12] for report of 1978 field season samples).

During 1979, four samples were collected from burned contexts in Pitstructure 1; three were from the central hearth and one was from a burned area on the south wall. The samples were expected to yield temporal information on the abandonment and last use of the structure. The purpose of recovering three samples from the central hearth was to distinguish temporal occurrences of the various remodeling which was apparent from the archaeological record.

Three samples were obtained from burned contexts in Pitstructure 2: one was from the central hearth; one was from a fire-hardened area on Surface 1, just north of the hearth; and the last was from a burned area on the west bench wall. These samples should provide a sequence of last use and abandonment of Pitstructure 2. Tree-ring and stratigraphic analyses indicate abandonment at around A.D. 780.

One sample was collected from a hearth located in an exterior use area about 10 m east of Pitstructure 2. The feature is contemporaneous with the roomblock and should date near A.D. 780.

The Archaeomagnetic Results

Only one of the eight samples collected, Sample 18, produced a remanent direction sufficient for archaeomagnetic dating. This sample is from the fire-hardened area on the south wall of Pitstructure 1. The paleopole plot of Sample 18 falls near the A.D. 750, 960, and 1500 portions of the curve with an error of ± 50 years. The upper range of the A.D. 750 date would appear to be most consistent with the archaeological record.

Site 5MT2194 (Casa Bodega Hamlet)

Site 5MT2194 (Brown [20]) is a small hamlet in the Sagehen Flats Locality, situated west of the Dolores River. The site was probably occupied by a single family unit during the Sagehen Phase. The major architectural remains consist of a single pitstructure located south of jacal-constructed storage areas. The site was probably occupied permanently for about 15-20 years around A.D. 675-750.

The Archaeomagnetic Samples

One archaeomagnetic sample, Sample 1, was recovered from the

central hearth of Pitstructure 1. As the structure was unburned, no samples were obtained from the walls of the structure. The sample should temporally place the last use of the pitstructure.

The Archaeomagnetic Results

The sample recovered proved inadequate for archaeomagnetic dating; no paleopole position was plotted on the Southwest curve.

Site 5MT2199 (Horse Bone Camp)

Site 5MT2199 (Brown [21]) is located about 3 km west of the Dolores River and 0.5 km north of the Sagehen Marsh, in the Sagehen Flats Locality. The site probably functioned as a limited activity or seasonal locus during late Pueblo I and early Pueblo II periods and possibly during the Archaic period (3000 B.C.-A.D. 500). No architectural remains were located through archaeological investigations; the site is composed of several activity areas, including a fire-hardened hearth.

The Archaeomagnetic Samples

One feature was archaeomagnetically sampled from Site 5MT2199 (Sample 1). The feature consisted of a moderately burned hearth expected to date to the Archaic period.

The Archaeomagnetic Results

Archaeomagnetic results from the sample could not be accurately dated due to the large degree of internal scatter in the magnetic directions.

Site 5MT2203 (Casa Roca)

Site 5MT2203 (Brisbin [22]) is a small surface site located 2.5 km

west of the Dolores River in the Sagehen Flats Locality. The site served as a small field house during the McPhee Phase (about A.D. 875-950). The site is situated 2 km west of the contemporaneous McPhee Village and might have been utilized by family groups living there.

The Archaeomagnetic Samples

One archaeomagnetic sample, Sample 1, was collected from a moderately burned hearth located in an activity area northeast of the main field house.

The Archaeomagnetic Results

The internal homogeneity of the sample was inadequate to provide accurate results; thus, the sample was not plotted on the Southwest curve.

Site 5MT2236 (Horsefly Hamlet)

Site 5MT2236 (Chenault [23]) is located 2 km west of the Dolores River in the Sagehen Flats Locality. The site possibly served as a camp during the Great Cút Phase (3000 B.C.-A.D. 500) and was later used as a unit hamlet (around A.D. 780-800). Investigations on the site partially exposed a Pueblo II pithouse south of a roomblock area. Tree-ring analysis dates construction of the pitstructure to A.D. 775. The structure was probably occupied for 15-20 years.

The Archaeomagnetic Samples

Two samples were recovered from Site 5MT2236. Sample 1 was taken from a large slab-lined pit in an exterior use area; Sample 2 was recovered from the central hearth of the pitstructure. Results from Sample 2 should provide temporal information on the last use of Pitstructure 1. Sample 1 may yield results corresponding to the earliest use of the site (3000 B.C.-A.D. 500).

The Archaeomagnetic Results

The archaeomagnetic VGP plot for Sample 1 falls in the southwest quadrant of the polar region. Prehistoric use of this feature is interpreted from the Southwest curve at A.D. 1085-1215. Because Archaic dates for the Southwest curve have not been determined, evaluation of this sample as an Archaic incineration is not possible at the present time. The results from Sample 2 were plotted and may be interpreted as either A.D. 740 $\pm$ 35 or A.D. 1475 $\pm$ 35. The upper limit of the A.D. 740 date, A.D. 775, is consistent with dendrochronological estimates.

Site 5MT2320 (House Creek Village)

Site 5MT2320 (Robinson [24]) is a large multicomponent habitation possibly incorporating intersite integrative architecture and functions. The site is located 1.5 km east of the Dolores River and just above and on the south slope of House Creek drainage, in the House Creek Locality. The site is considered part of a larger village complex dating to the McPhee Phase in the D.A.P. typological system. During the McPhee Phase this habitation and other large villages (McPhee Pueblo, Cline Crest Pueblo, etc.) in the Escalante Sector might have formed the first tier of a central place-type settlement pattern.

The Archaeomagnetic Samples

Archaeomagnetic sampling was very moderate on Site 5MT2320 due to the lack of adequately incincerated features excavated. One sample, Sample 1, was recovered from the central hearth of Pitstructure 1, which should temporally place the last use of the structure. Architectual and stratigraphic analyses place the occupation to late Pueblo I-early Pueblo II times.

The Archaeomagnetic Results

Results from Sample 1 indicate an earlier abandonment of the structure than expected from the archaeological material. The VGP position plots near the A.D. 720 or alternatively A.D. 1460 portion of the Southwest curve with a ± 25 year range of error.

Site 5MT2848 (Rusty Ridge Hamlet)

Site 5MT2848 (Greenwald [25]) is located 2.25 km west of the Dolores River in the Sagehen Flats Locality. The site consists of a unit hamlet; investigations concentrated on partial exposure of two pitstructures. The structures were not contemporaneous, Pitstructure 1 having been constructed after the abandonment of Pitstructure 2. Tree-ring analysis of beams from Pitstructure 1 indicates an A.D. 780 construction; the structure was occupied for about 20 years.

The Archaeomagnetic Samples

Three archaeomagnetic samples were collected from fire-hardened matrices at Site 5MT2848. Two samples were recovered from Pitstructure 1, one from the central hearth (Sample 3) and one from a fire-hardened area on the floor (Sample 2). These samples should yield the last use and abandonment of Pitstructure 1. The third sample was obtained from the central hearth of Pitstructure 2 (Sample 1). Results from this sample should provide information on temporal placement of the last use of Pitstructure 2.

The Archaeomagnetic Results

Archaeomagnetic results recorded VGP positions for each sample. Sample 1 plots early on the Southwest curve, dating between A.D. 615-705. Sample 2 falls near the A.D. 915 region of the curve with a ± 20 year

range of error. The paleopole plot of Sample 3 is hard to interpret because of the large error bar (+ 40 years) and its location near several portions of the curve; temporal estimates include A.D. 775, A.D. 935, and A.D. 1515. Archaeomagnetic results indicate a long abandonment of the site prior to reoccupation. The two samples collected from Pitstructure 1 indicate abandonment was prior to incineration of the structure.

Site 5MT2853 (Deer Hunter Hamlet)

Site 5MT2853 (Greenwald [26]) consists of a small hamlet located 2.25 km west of the Dolores River. The site is situated in the Sagehen Flats Locality and is part of a household cluster dated to the Dos Casas Subphase of the D.A.P. chronological sequence. Archaeological investigations included the partial excavation of a Pueblo I pitstructure.

The Archaeomagnetic Samples

One archaeomagnetic sample, Sample 1, was recovered from Site 5MT2853. The sample was collected from the central hearth of Pitstructure 1 and should temporally place the last use of the structure. Architectural and ceramic analyses of the site indicate an occupation between A.D. 700-800.

The Archaeomagnetic Results

Archaeomagnetic results date the last use of the hearth to A.D. 870 + 25 years, suggesting a later occupation than indicated by other cultural remains.

Site 5MT2854 (Aldea Sierritas)

Site 5MT2854 (Kuckelman [27]) consists of a small hamlet located 2 km west of the Dolores River in the Sagehen Flats Locality. Major

architectural remains include a south-facing roomblock, two pitstructures, and various exterior use areas. The pitstructures were not contemporaneous; Pitstructure 1 was occupied prior to construction of Pitstructure 2.

The Archaeomagnetic Samples

Two archaeomagnetic samples were recovered from cultural contexts at Site 5MT2854. These samples represent matrices from the later use of the site; additional sampling is scheduled for the 1980 field season.

Sample 1 was obtained from a temporary hearth located in an exterior use area west of the pitstructures. The last use of the feature is expected to date to A.D. 750. Sample 2 was collected from the central hearth of Pitstructure 2. This sample should date the last use of Pitstructure 2, which was believed to have been occupied during A.D. 775.

The Archaeomagnetic Results

Archaeomagnetic analysis of these features indicates dates earlier than expected from archaeological estimates. Sample 1 plots near the A.D. 660 portion of the curve with a large range of error (+ 40 years). Sample 2 plots slightly later at A.D. 735 with a + 40 year error bar.

Site 5MT2858 (Apricot Hamlet)

Site 5MT2858 (Montgomery [28]) is a small habitation located in the Sagehen Flats Locality. The site served as a unit hamlet occupied for an estimated 20 years during the Sagehen Phase (about A.D. 700-760). The site consists of a jacal roomblock located north of an early Pueblo I pitstructure.

The Archaeomagnetic Samples

Four archaeomagnetic samples were recovered from Site 5MT2858.

These samples represent occupations from Pitstructure 1, temporary use of Pitstructure 2, and an exterior use area associated with the roomblock. Two samples were collected from Pitstructure 1; one from the central hearth (Sample 2) and one from a fire-hardened area on the floor northeast of the hearth (Sample 3). These samples should date the last use and abandonment of the pitstructure.

One sample was obtained from a hearth at the surface of Pitstructure 2 (Sample 4) and probably represents a later use of the site (around A.D. 750).

One other sample was obtained from a surface hearth located due north of Pitstructure 1 at Occupation Surface 1 (Sample 1).

The Archaeomagnetic Results

Samples 1 and 2 yielded magnetic directions sufficient for dating. The paleopole plot of Sample 1 falls near the A.D. 650 portion of the curve with a ± 45 year error bar. The upper limit of this sample is slightly earlier than the expected date estimated from archaeological material. Sample 2 plots near the A.D. 710 portion of the curve with a small range of error (+ 25 years). The upper limit of this sample is also earlier than expected estimates for the last use of the structure (A.D. 750).

Site 5MT4512 (Cascade House)

Site 5MT4512 (Wilshusen [29]) is located 2.5 km west of the Dolores River in the Sagehen Flats Locality. The site probably served as a field house during the McPhee Phase (about A.D. 800-900). The site is situated 2 km west-southwest of the contemporaneous McPhee Village and might have been used by family groups living there. Architectural remains at this

site consist of a small roomblock containing several slab-lined and jacal rooms, and a pitstructure in an exterior use area south of the roomblock.

The Archaeomagnetic Samples

Three archaeomagnetic samples were recovered from burned cultural contexts at Site 5MT4512. One sample was obtained from a temporary hearth located in Pitstructure 1 (Sample 1) and is expected to date the last use of the structure. Ceramic and architectural estimates indicate the site was probably abandoned by A.D. 875. Two samples were collected from burned features in exterior use areas of the site. One sample represents a burned matrix from a large slab-lined pit, possibly used for roasting (Sample 2). The other sample was obtained from a shallow hearth located in a northern peripheral area (Sample 3). Both samples should temporally place the last use of the primary occupation of the site.

The Archaeomagnetic Results

Paleopole positions were retained from archaeomagnetic analyses of Samples 2 and 3. Sample 2 indicates a last use of Feature 37 (slab-lined pit) at A.D. 660 $\pm$ 60 years. Sample 3 falls in the southernmost area of the polar region and cannot be temporally interpreted given the present limitations of the Southwestern curve (see Appendix C for an evaluation of the present prehistoric limitations of the Southwestern curve).

Site 5MT4545 (Tres Bobos Hamlet)

Site 5MT4545 (Brisbin [30]) is a Basketmaker III hamlet located 3 km west of the Dolores River in the Sagehen Flats Locality. Architectural remains consist of a roomblock of 13 south-facing jacal rooms and a pitstructure in an exterior use area south of the roomblock. Tree-ring

analysis indicates a construction date of A.D. 600 for the roomblock. The site was probably occupied by a single family and dates to the Sagehen Phase.

The Archaeomagnetic Samples

Seven archaeomagnetic samples were recovered from Site 5MT4545 during the 1979 field season. The samples represent burned matrices from the roomblock and pitstructures.

Two samples were collected from the pitstructures, one from the central hearth of the main chamber (Sample 4) and one from the north wall of the antechamber (ventilator shaft) (Sample 3). Two samples were obtained from burned matrices of the roomblock, one from a fire-hardened area on the north wall of Surface Structure 1 (Sample 2) and one from an incinerated floor surface of Surface Structure 3 (Sample 6). One sample was collected from the third stratum of a large pit which had been temporarily used as a firepit (Sample 1). Two samples were obtained from exterior hearths; one was located west of the roomblock (Sample 5) and the other was north of the pitstructure (Sample 7). These samples should date the last use of the pitstructure and roomblock and subsequent incinceration of the architectural remains.

The Archaeomagnetic Results

Samples 2-6 provided magnetic information adequate for plotting. Samples 2 and 6 fell in the southwestern quadrant of the polar region and archaeomagnetic interpretations date these features to A.D. 1375, with a relatively small range of error ($\pm$ 30 and $\pm$ 25 years respectively). A second interpretation of Sample 6 includes a date of A.D. 1100. These dates are clearly too late, given other archaeological evidence. This discrepancy is evaluated in Appendix C of this report. Samples 3-5 are

associated with large error bars (± 50 years). Sample 3 falls near several portions of the Southwest curve, A.D. 760, A.D. 985, and A.D. 1460. Sample 4 dates to about A.D. 700, and Sample 5 is slightly earlier at A.D. 670. The lower limits of the latter two samples are consistent with the archaeological record; however, the archaeomagnetic results from Sample 3 are substantially later than expected dates.

Site 5MT4614 (Prairie Dog Hamlet)

Site 5MT4614 (Yarnell [31]) is located 2.5 km west of the Dolores River in the Sagehen Flats Locality. The site served as a small hamlet during the Sagehen Phase (around A.D. 700-750) for an estimated 30 years. Architectural remains include a south-facing roomblock of five to six jacal rooms, ancillary-use areas, and two pitstructures located south of the roomblock. The two structures are not contemporaneous. Pitstructure 2 was constructed after abandonment of Pitstructure 1. Stratigraphic and ceramic analyses indicate an occupation for Pitstructure 1 at A.D. 730 and for Pitstructure 2 at A.D. 750.

The Archaeomagnetic Samples

Three archaeomagnetic samples were recovered from features associated with occupation of the pitstructures and the roomblock. Sample 1 was collected from the central hearth of Pitstructure 1 and Sample 2 was collected from the central hearth of Pitstructure 2. These samples should provide temporal control for the last uses of the structures. Sample 3 was collected from a surface hearth located in Surface Structure 3 and should date the last use of the roomblock.

The Archaeomagnetic Results

The paleopole plots of Samples 1 and 2 date to A.D. 750 ± 25 years and A.D. 790 ± 35 years, respectively. Alternative dates for the samples are included in Appendix A. These dates are less probable when considering the archaeological interpretations; the archaeomagnetic information indicates an earlier occupation of Pitstructure 1 by 10-40 years. Sample 3 was discarded.

Site 5MT4644 (Windy Wheat Hamlet)

Site 5MT4644 (Brisbin [32]) is a large hamlet located 1.5 km west of the Dolores River in the Sagehen Flats Locality. The site was occupied during the Sagehen Phase for an estimated 40 years. Major architectural remains consist of a south-facing roomblock of five or six rooms and three pitstructures in an exterior use area to the south of the roomblock. The structures were not contemporaneous. Pitstructure 3 was occupied earliest, Pitstructure 2 was occupied after abandonmnet of Pitstructure 3, and Pitstructure 1 was constructed after Pitstructure 2 had burned. Tree-ring analysis for Pitstructures 1 and 2 date construction to A.D. 795 and A.D. 776, respectively. The roomblock was utilized during occupation of Pitstructure 1.

The Archaeomagnetic Samples

Six archaeomagnetic samples were recovered from cultural contexts representing the later two occupations of the site. Continued investigation at Site 5MT4666, including additional archaeomagnetic sampling, is scheduled for the 1980 field season. Samples will be recovered from cultural contexts associated with the first occupation and should temporally place the last use of Pitstructure 3.

Three samples were collected from fire-hardened matrices of Pitstructure 1; two samples were from the west and north walls (Samples 1 and 5, respectively), and one was from the central hearth (Sample 4). Three samples were collected from Pitstructure 2; two were from the central hearth (Samples 2 and 6) and one was from the north wall (Sample 3).

The Archaeomagnetic Results

The paleopole plots of Samples 1 and 5 coincide and date to A.D. 915 ± 30 years. The plot of Sample 2 falls near the A.D. 925 portion of the curve with a very small error range of ± 20 years. These estimates are 100 years later than estimates provided by tree-ring analyses. The paleopole positions recorded by the ancient conflagration are presumed to be accurate; the discrepancy may be attributed to the inaccurate temporal calibration of the Southwest curve (Appendix C). Samples 2 and 6 were collected from the rim and bottom, respectively, of the central hearth in Pitstructure 2. However, the paleopole plots are discordant; the rim sample plots near the A.D. 925 portion of the curve with a very small error range of ± 20 years, and the basal sample plots much earlier, at A.D. 625 ± 50 years. According to experiments conducted by Krause [8], samples collected from the base of a hearth are more often an inaccurate representation of the ambient field than samples collected from the rim. Therefore, the paleopole plot from Sample 2 is regarded as a better representation of the magnetic direction at the time of incineration. The paleopole plot of Sample 3 falls near the A.D. 900 portion of the curve with a ± 35 year error bar.

INTENSIVE ANALYSES

Investigations concerning several aspects of archaeomagnetism were conducted during the 1979 season. It was felt that better understanding of the study areas would contribute valuable information in understanding, interpreting, and dating archaeomagnetic samples.

First, the evaluation system of sample matrices used by program personnel was analyzed. The effectiveness of this program was estimated by the relative productivity of the various priority levels (discussed previously).

The second analysis involved estimating the observed difference in cube orientation by two methods, one dependent upon magnetic influences and the other dependent upon angular declinations from the sun. Differences between the two methods were then evaluated through the measurements obtained from three samples of recent firings. The differences between the sun-compass mean pole plots and Brunton-compass mean pole plots of corresponding samples were then compared to the reference location determined from known declination and inclination values of the Dolores area during 1979.

A third analysis consisted of a quantitative study of various soil conditions and the relative productivity noted in the Dolores material. A correlation study was conducted on the known textural and ferric percentages with respect to alpha 95 values (i.e., sample clustering).

The fourth study entailed sampling and analyzing the three kilns of recent manufacture and firing. The TRM recorded in the kiln matrices was then compared to the known magnetic direction for Dolores during 1979.

Finally, an evaluation of the Southwest master curve was conducted. Independently dated samples were compiled from the Dolores material to redefine the present VGP curve for the time span A.D. 600-900. This material is presented in Appendix C.

Priority System

As previously mentioned and described, a priority system was initiated for archaeomagnetic collections during the 1979 field season. The ultimate goal of this program is to eliminate costly collection and analysis of unproductive samples. The following analysis provides a correlation between the field-assigned priority designations and the final laboratory results. The productivity of particular sampling media is also reviewed.

During the 1979 field season a total of 61 samples was recovered from prehistoric contexts. Sixty-four percent of these samples provided archaeologists with temporal assessments of incinerated cultural mediums. Priority numbers were assigned to all samples based on the previously mentioned characteristics. Table 11.2 summarizes the samples collected in the various priority levels and the productivity of those samples.

Samples designated Priority 1 represent 38 percent of the total population of collected samples for the 1979 field season. This category was only 57 percent productive, which is below the expected successfulness of this group. In order to better understand the discrepancy between the observed and expected values, the group was subdivided into contextual types (Table 11.3). This division clearly shows that samples collected from central pitstructure hearths contributed disproportionately to the undateable samples. When compared to the productivity of samples

Table 11.2 Comparison between Priority Level and Productivity of Samples

Priority Level	Dated Samples	Undated Samples	Total	% of 1979 Collections	Category to Collection (%)*	C. Prod. (%)**
1	13	10	23	38	34	57
2	11	2	13	21	28	87
3	9	4	13	21	23	69
4	6	4	10	17	15	60
5	0	2	2	3	0	0

*Category productivity to collection productivity.
**Category productivity.

Table 11.3 Comparison between Priority 1 Contexts and Productivity of Samples

Cultural Context	Dated Samples	Undated Samples	Total	% of Priority 1	Context to Priority 1 (%)*	C. Prod. (%)**
Fire-hardened walls	5	0	5	22	39	100
Central pitstructure hearths	8	7	15	65	61	53
Exterior hearths	0	2	2	9	0	0
Fire-hardened floors	0	1	1	4	0	0

*Context productivity to Priority 1 productivity.
**Context productivity.

recovered from fire-hardened structural walls, the samples collected from the central hearths were about one-half as likely to produce satisfactory results for dating. It is possible that although these matrices exhibit characteristics of a well-burned nature, temperatures during prehistoric use did not attain the "Curie temperature" of ferromagnetic minerals (580-670°C), and thus a good direction was not produced in the clay. It is apparent from this evidence that the criteria for choosing the most productive samples from central hearths need to be revised for the 1980 field season.

The Priority 2 designated samples constitute 21 percent of the 1979 collections; 84 percent of these samples produced good archaeomagnetic results. The successful samples in this category contributed to more than one-fourth of the collection productivity.

The Priority 3 group represents 21 percent of the total collection and the successful samples consist of less than one-quarter of the collection productivity. Two-thirds of the category provide magnetic information sufficient for dating.

Seventeen percent of the 1979 collections were designated as Priority 4, which yielded 15 percent of the successful samples in the collection. The Priority 4 category produced a slightly higher-than-expected success rate of 60 percent.

Priority 5 represents 3 percent of the collections, none of which provided adequate results for dating. These samples were not expected to yield good archaeomagnetic results and were collected only in situations where other dating methods were absent.

Table 11.4 provides an evaluation of the productivity of certain archaeological contexts. It is evident from this table that fire-hardened

Table 11.4 Comparison between All Sampled Contexts and Productivity of Samples

Cultural Context	Dated Samples	Undated Samples	Total	% of 1979 Collection	Context to Collect. (%)*	C. Prod. (%)**
Fire-hardened walls	10	1	11	18	26	91
Central Pitstructure Hearths	17	7	24	39	44	71
Exterior Hearths	10	12	22	36	25	46
Fire-hardened Floors	2	2	4	7	5	50

*Context productivity to collection productivity.
**Context productivity.

structural walls provide the most consistent magnetic records of the ancient VGP position.

Central hearths of pitstructures carry remanent magnetism capable of dating in the majority of cases (71 percent); however, results from Table 11.3 indicate a much lower productivity for the Priority 1 category. A comparison of Tables 11.3 and 11.4 reveals that all central hearths which did not provide dates fell in the Priority 1 category. To better-evaluate this occurrence, the categories used for designation of priority levels (see above) were considered. All other factors being equal, matrices which were classed in the Priority 1 level consisted of better-prepared mediums, while those hearths of ambient matrices were classed lower. Although it is felt that preparation provides a better medium capable of acquiring and retaining TRM, preparation may be an inadequate indicator of potential archaeomagnetic samples. Provided prepared hearths were continually or occasionally remodeled, TRM from previous incinerations would be slowly displaced by the new medium. In turn, this displacement would thus remove an oriented matrix from the collection population and replace it with a nonoriented or randomly magnetized medium. This effect would be compounded if subsequent firings did not reach a sufficient temperature to magnetize the newly added material. A good direction may be produced with sufficient temperatures but researchers are uncertain as to the lower limits of sufficiency. The archaeomagnetic collector is cautioned to carefully evaluate hearths which show evidence of remodeling or are prepared along the rim to ensure that the added medium has been subjected to intensive firing.

Samples obtained from exterior or surface hearths and structural floors were about 50 percent successful in the laboratory. Due to

the nature of archaeological investigations, floors are often exposed for a month or more before the archaeomagnetist can obtain a sample. During this time foot traffic and weather have altered the matrix, thus disturbing the orientation representative of the past magnetic field. Provided an area can be kept undisturbed until collection, a good direction can often be obtained.

Surface hearths are quite variable with respect to archaeomagnetic characteristics and often present a problem in dating. Hearths with oxidized or extensively blackened matrices are superior for archaeomagnetic dating.

Soil Analysis

Soil analyses performed on matrices of 23 archaeomagnetically sampled features and burned contexts consisted of a textural analysis and a total ferric-content analysis. Included in this group were eight Priority 1 samples, seven Priority 2 samples, and four samples each of Priorities 3 and 4. Fifteen of the samples were successfully dated by archaeomagnetic procedures: three were in the Priority 1 category, six were in the Priority 2 category, four were in the Priority 3 category, and two were in the Priority 4 category. Table 11.5 summarizes the results of soil and archaeomagnetic analyses for the selected samples.

The correlation between these variables (priority level, soil texture, and archaeomagnetic analysis) was then calculated. Correlations of a negative direction indicate increasing values of one variable with decreasing values in the other variable. Positive correlations show an increase in the values of both variables. The r^2 value exhibits the amount of the total variation in one variable which can be explained in

Table 11.5 Soil Analysis and Archaeomagnetic Results (Page 1 of 2)

Archaeomagnetic Designation Site Sample	Soil Results*	Soil Textural Classification	Total Ferric Content	Priority Level	Alpha 95
5MT0023-3	38-41-21	loam	1.74	1	1.56
5MT0023-6	45-35-20	loam	1.83	3	2.98
5MT0023-7	32-42-26	loam	2.23	2	1.99
5MT2151-13	64-15-21	sandy clay	1.29	4	2.03
5MT2192-1	46-30-24	loam	1.56	1	4.02
5MT2192-7	45-30-25	loam	1.78	2	1.75
5MT2193-17	56-21-23	sandy clay	1.31	1	25.54
5MT2193-18	45-31-24	loam	1.74	2	3.46
5MT2193-20	44-39-17	loam	1.55	1	5.42
5MT2194-1	41-28-31	clay	1.95	1	5.01
5MT2199-1	42-28-30	clay	1.91	2	3.53
5MT2236-1	32-39-29	clay	1.97	3	2.73
5MT2320-1	33-36-31	clay	1.95	2	1.44
5MT2848-2	40-35-25	loam	1.92	2	1.35
5MT2858-1	32-38-30	clay	2.22	3	2.95

Table 11.5 Soil Analysis and Archaeomagnetic Results (Page 2 of 2)

Archaeomagnetic Designation Site Sample	Soil Results*	Soil Textural Classification	Total Ferric Content	Priority Level	Alpha 95
5MT2858-4	33-38-29	clay	2.09	1	2.14
5MT4512-3	51-25-24	sandy clay	1.68	4	2.27
5MT4545-3	29-37-34	clay	2.20	1	3.69
5MT4545-5	29-33-38	clay	2.32	3	2.98
5MT4545-6	33-34-33	clay	2.30	2	1.64
5MT4614-1	49-32-19	loam	1.34	1	1.72
5MT4614-3	51-28-21	sandy clay/loam	1.56	4	5.18
5MT4644-6	39-34-27	clay/loam	1.71	4	3.35

* sand-silt-clay percentages

variation of the other variable. Due to the sensitivity of correlation measures to outliers, Sample 17 at Site 5MT2193 was omitted in the calculations because of an exceptionally high alpha 95 value. However, it should be noted that Sample 17 falls into the expected mode with high alpha 95 values and sand percentages, and low silt, clay, and ferric percentages. Scattergrams for percent sand to alpha 95 values, percent silt to alpha 95 values, percent clay to Alpha 95 values, and ferric content to alpha 95 values, are presented in Figures 11.3, 11.4, 11.5, and 11.6.

The correlation between percent sand and alpha 95 values was determined as +.1317 with an r^2 score of .0173. These values indicate a low degree of positive correlation between sand and alpha 95 values. However, if this group is divided into priority groups, different relationships are noted:

Priority 1	$r = + 0.1121$	$r^2 = .0126$
Priority 2	$r = + 0.5333$	$r^2 = .2844$
Priority 3	$r = + 0.2704$	$r^2 = .0731$
Priority 4	$r = - 0.3872$	$r^2 - .1499$

The highest degree of positive correlation (low alpha 95 values corresponding to low sand percentages) is observed in the Priority 2 category. The Priority 4 category exhibits a negative correlation between alpha 95 values and sand percentages. As shown in a previous section, the Priority 1 category is an anomalous group (from the expected successfulness of the category). Whereas this group was expected to show the greatest amount of correlation between textures and alpha 95 values (due to the fact that other factors involved in producing TRM were evaluated at a high estimation), the least amount of correlation is noted (only 1.3

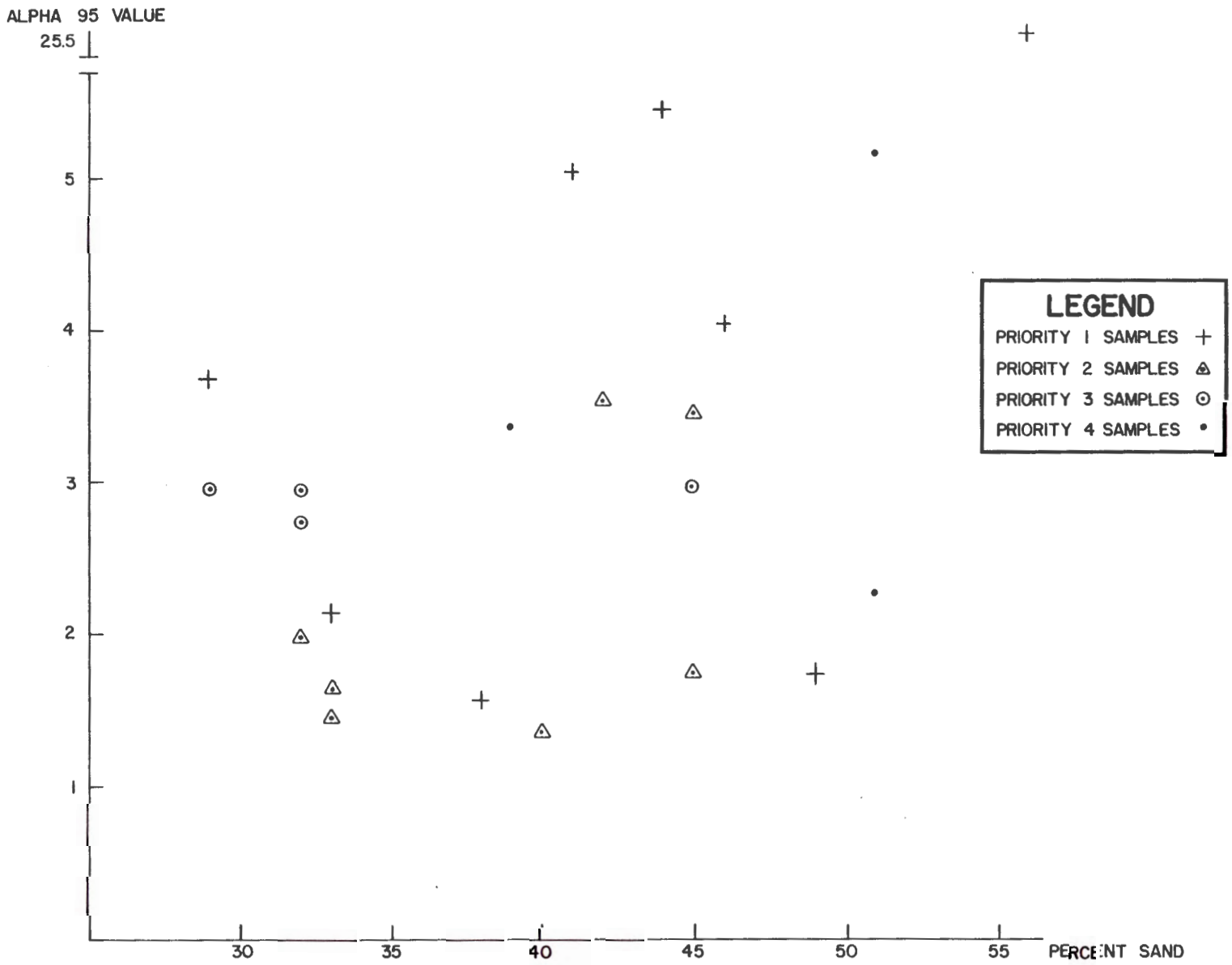


Figure 11.3 Correlation between alpha 95 values and percent sand in matrix.

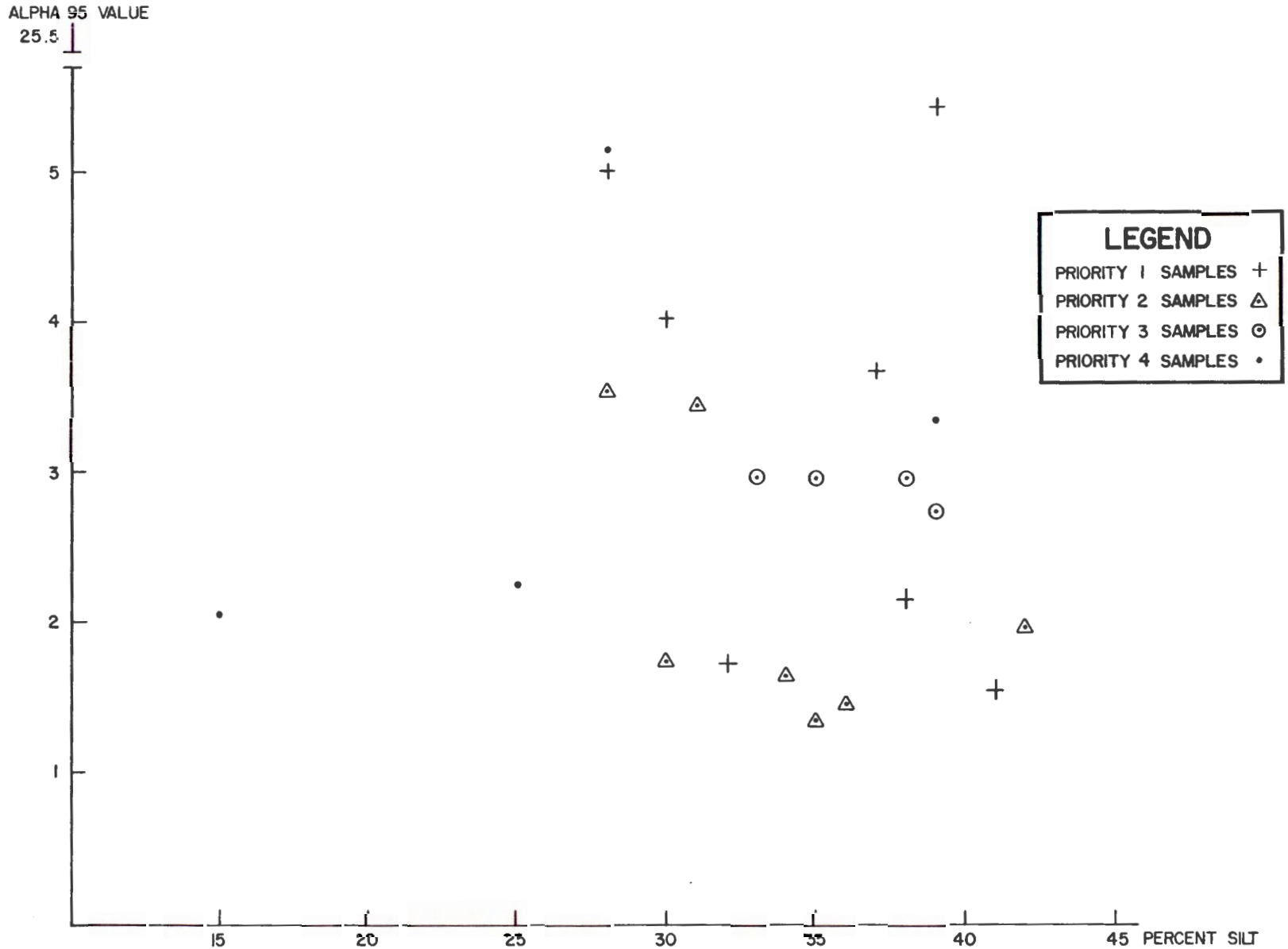


Figure 11.4 Correlation between alpha 95 values and percent silt in matrix.

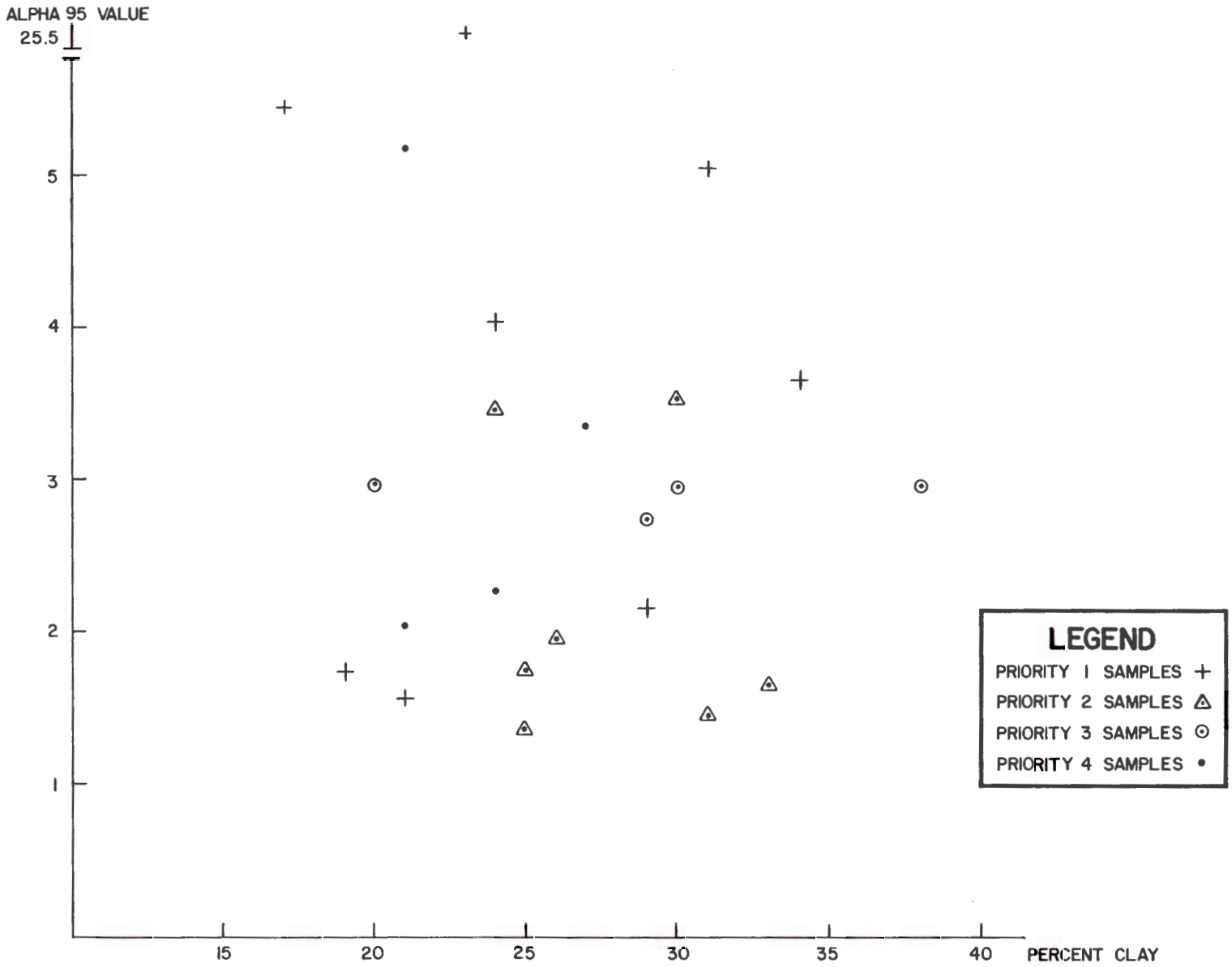


Figure 11.5 Correlation between alpha 95 values and percent clay in matrix.

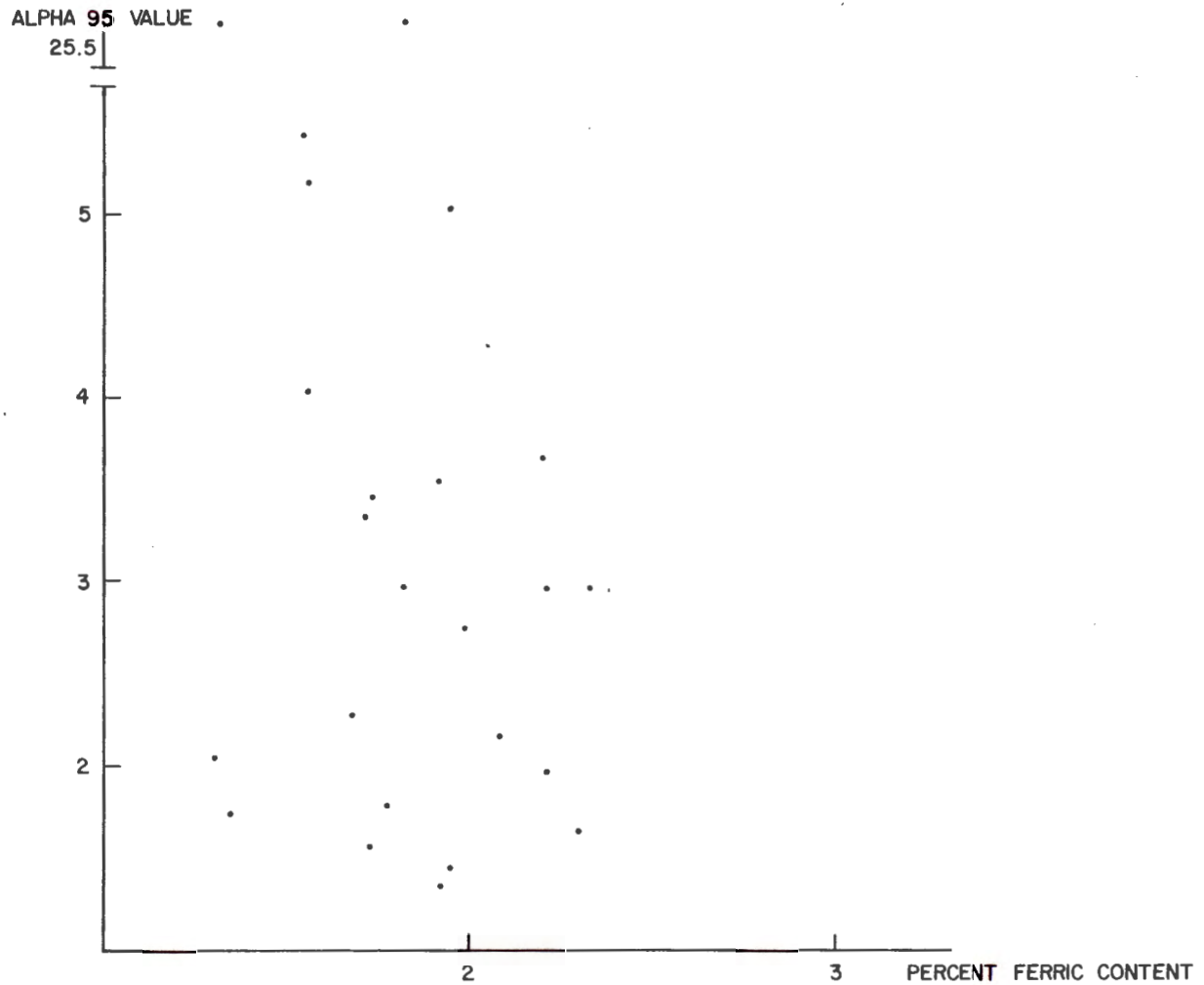


Figure 11.6 Correlation between alpha 95 values and ferric content in matrix.

percent of the total variation in alpha 95 values can be explained by variation in sand).

The correlation between percent silt and alpha 95 values was calculated to be -0.0998 with a r^2 = 0.0100. These values imply a very slight negative correlation between percent silt and alpha 95 values. Again, the total collection was divided according to priorities and the following values were determined:

Priority 1	r = - 0.3295	r^2 = 0.1086
Priority 2	r = - 0.5422	r^2 = 0.2940
Priority 3	r = + 0.4007	r^2 = 0.1606
Priority 4	r = + 0.5554	r^2 - 0.3084

An interesting pattern emerges in these calculations. The two higher priorities show a negative correlation between percent silt and alpha 95 values, whereas the lower priorities exhibit positive correlations of percent silt and alpha 95 values. This tendency has resulted in the offsetting of the total correlation values to a very small index. Note that the Priority 2 and Priority 4 categories have the highest degree of correlation at 0.2940 and 0.3084, respectively.

The correlations between percent clay and alpha 95 values were quite marginal and not as predictive as expected. The total collection exhibited a correlation of -0.0887 with an r^2 value of 0.0078. The various priorities were correlated in the following directions and degrees:

Priority 1	r = + 0.1292	r^2 = 0.0167
Priority 2	r = - 0.1688	r^2 = 0.0262
Priority 3	r = + 0.0150	r^2 = 0.0002
Priority 4	r = - 0.1583	r^2 - 0.0251

In this group, the expected negative correlations are evident only in Priorities 2 and 4, and the degree of correlation is quite low (especially when compared with the percent silt and alpha 95 value correlation).

In summary, it appears from this data that percent sand (positively correlated) and percent silt (negatively correlated) are better predictors of successful archaeomagnetic samples. The Priority 1 group appears anomalous especially in relation to percent clay and alpha 95 value correlations; exactly the opposite correlation is exhibited between these two variables (as percent clay decreases, alpha 95 values decrease).

The correlation between total ferric content and alpha 95 values was found to be -0.1603 with an r^2 value of 0.0257. This implies a small degree of negative correlation between ferric content and alpha 95 values. It appears that soils containing ferric contents as low as 1.29 percent are capable of producing good archaeomagnetic results under the proper conditions.

Ferric content of 1.75+ is associated with clay soils and loams of a higher clay content. Other soil types (sandy clays, sandy clay loams) tend to contain fewer amounts of ferrous material. The degree to which this measurement reflects ferromagnetic minerals has not yet been determined. Studies involving these aspects are projected for the 1981 field season and will be included in a report following completion of the analysis.

Cube Orientation Methods

An intensive analysis of two orientational methods for obtaining archaeomagnetic specimen declination was conducted. Thirty samples

collected during the 1979 field season served as an experimental group for which two instruments were employed in determining specimen orientation.

The Brunton compass (used on all samples collected during 1979) is a magnetically sensitive instrument which orients to the current magnetic field lines within an area. However, localized anomalous perturbations may influence the magnetic direction measured by the compass, obscuring true magnetic declination. In such an instance, specimen orientation would reflect this deviation, and thus be an inaccurate representation of the cube's relation to magnetic north. The sun compass, conversely, operates independently of magnetic influences. This instrument detects the angular relationship between a specimen and the sun's position in the sky. For a known location and time this relationship may be converted to the specimen's orientation to true north.

Several analyses were performed on the data obtained from measurements of samples using the two instruments. The analyses were directed toward determining mean sample orientation differences, relative sample clustering, and accuracy in paleopole positions.

The first study entailed computing the mean sample declination difference between the sun-compass and the Brunton-compass measurements. The difference between the two measurements should equal 13.5°E (magnetic declination for Dolores, Colorado).

The mean sample declination was obtained in the following manner. Sun-compass values were converted by Tarling's formula [13:59] to a declination representing the cube's orientation to true north. Differences between this value and Brunton-compass declinations were then calculated. A sample mean difference and standard deviation were calculated. Specimens which were exceedingly divergent from the mean

value (i.e., if they fell beyond two standard deviations) were excluded. A new mean standard deviation was then calculated. Table 11.6 summarizes the mean sample differences in sun- and Brunton-compass declinations of corresponding samples. The average value of the sample differences for the collection is 10.38° or 3.12°W of the known magnetic declination of the Dolores area. A test of significance performed on these data indicates that there is a statistically significant difference between the observed difference (10.38°) and magnetic declination for Dolores (13.5°W). The statistical test of:

$$t = \frac{x - \mu_0}{s} \quad n$$

where x = mean sample differences
μ_0 = 13.5° (magnetic declination)
s = standard deviation of sample differences
n = number of observations (30)

yielded a value of -12.56 which has an associated p value (estimation of confidence) of less than 0.005.

The discrepancy between magnetic declination and sun- and Brunton-compass differences might be explained by several factors:

1. consistent instrumental error in Brunton compass
2. consistent instrumental error in sun compass
3. magnetic declination is not 13.5°W in the Dolores valley.

The identical sun compass used in this study was used in a similar study performed by Krause in the Fort Collins area. No statistically significant difference was observed between magnetic declination from the sun and Brunton compass in the Fort Collins area (Krause [14]). This suggests that the deviation in the Dolores materials is not due to an inherent error in the sun compass instrument.

Table 11.6 Sun Compass-Brunton Compass Differences in Declination (Page 1 of 3)

Archaeomagnetic Designation Site Sample	Mean Sample Sun Compass-Brunton Compass Azimuth Differences(°)	Standard Deviation of Mean Sample Differences	Comments
5MT0023-2	7.15	2.56	Large standard deviation reflects two distinct means from sample corresponding to two different times of collection.
5MT0023-3	7.98	3.95	Large standard deviation reflects two distinct means from sample corresponding to two different times of collection.
5MT0023-4	11.72	1.03	2 specimens defined as outliers.*
5MT0023-5	10.96	1.59	--
5MT0023-6	10.27	.95	1 specimen defined as outlier.
5MT2151-13	11.38	.80	1 specimen defined as outlier.
5MT2192-5	10.88	.92	17 specimens collected for sample, 1 specimen defined as outlier.
5MT2192-6	8.93	1.72	3 specimens defined as outliers.
5MT2192-7	11.54	1.55	1 specimen defined as outlier.
5MT2320-1	10.19	1.08	2 specimens defined as outliers.
5MT2854-2	10.34	.71	Based on 6 specimens due to inability in field to collect a full suite of sun-compass azimuths.
5MT2858-2	11.44	1.35	1 specimen defined as outlier.

Table 11.6 Sun Compass-Brunton Compass Differences in Declination (Page 2 of 3)

Archaeomagnetic Designation Site Sample	Mean Sample Sun Compass-Brunton Compass Azimuth Differences(°)	Standard Deviation of Mean Sample Differences	Comments
5MT2858-3	9.72	1.23	1 specimen defined as outlier.
5MT2858-4	11.02	.79	3 specimens defined as outliers.
5MT4512-2	10.37	1.73	Based on 10 specimens due to inability in field to collect a full suite of sun-compass azimuths and recognition of 1 outlier.
5MT4512-3	7.50	3.63	Large standard deviation reflects two distinct means from sample corresponding to two different times of collection.
5MT4545-1	11.84	.99	--
5MT4545-2	11.77	.68	--
5MT4545-3	10.49	.95	Based on 6 specimens due to inability in field to collect a full suite of sun-compass azimuths.
5MT4545-5	10.19	.48	--
5MT4545-6	10.25	.66	2 specimens defined as outliers.
5MT4545-7	12.08	1.50	--
5MT4614-1	10.83	1.15	1 specimen defined as outlier.

Table 11.6 Sun Compass-Brunton Compass Differences in Declination (Page 3 of 3)

Archaeomagnetic Designation Site Sample	Mean Sample Sun Compass-Brunton Compass Azimuth Differences(°)	Standard Deviation of Mean Sample Differences	Comments
5MT4614-2	9.56	2.07	Based on 8 specimens due to inability in field to collect a full suite of sun-compass azimuths and recognition of 3 outliers.
5MT4614-3	11.56	.67	Based on 6 specimens due to inability in field to collect a full suite of sun-compass azimuths.
5MT4644-1	7.18	1.28	Based on 9 specimens due to inability in field to collect a full suite of sun-compass azimuths and recognition of 2 outliers.
5MT4644-2	11.28	1.65	3 specimens defined as outliers.
5MT4644-3	10.82	1.13	1 specimen defined as outlier.
5MT4644-4	11.47	1.05	1 specimen defined as outlier.
5MT4644-5	10.82	1.61	2 specimens defined as outliers.

*Outliers were defined in the following manner: A sample mean and standard deviation were calculated from the full complement of specimens. Specimens which fell two standard deviations from the mean were defined as outliers and excluded. A new mean and standard deviation were then calculated.

To control for current magnetic declination, the north star was sighted in the project area on 2 September 1978. The average observed magnetic declination was 13.5°W, one-half of one degree different than the U.S.G.S. 1965 Geological Map (Trimble Point Quadrangle) and in substantial agreement with expected values calculated from the National Oceanic Atmospheric Administration Map, "Magnetic Declination in the United States - Epoch 1975.0." These data suggest strongly that the true magnetic declination of the Dolores valley is 13.5°W.

Studies testing the Brunton compass accuracies are scheduled for the 1980 field season. Two factors may contribute to deviant behavior: an instrumental error causing consistent westward deflection of the needle or subtle anomalous behavior in the area which is strong enough to influence the Brunton compass.

Figure 11.7 represents the proportional distribution of declination differences of three populations: (a) the complete experimental collection, (b) all samples associated with intensely burned areas, and (c) all samples isolated from intensely burned areas. It was felt that the magnetic fields of features and burned contexts located near intensely burned areas (i.e., burned pitstructures) were affected by the field surrounding the anomaly in addition to the earth's magnetic field, thus deflecting the observed magnetic declination of the sample specimens.

Analysis of the two sets of samples does not support this hypothesis. The mean declination difference noted for samples collected near intensely burned areas was 9.8°, and for samples isolated from intensely burned areas the difference was 10.7°. A test of significance conducted on these two means proved statistically insignificant at the .05 level.

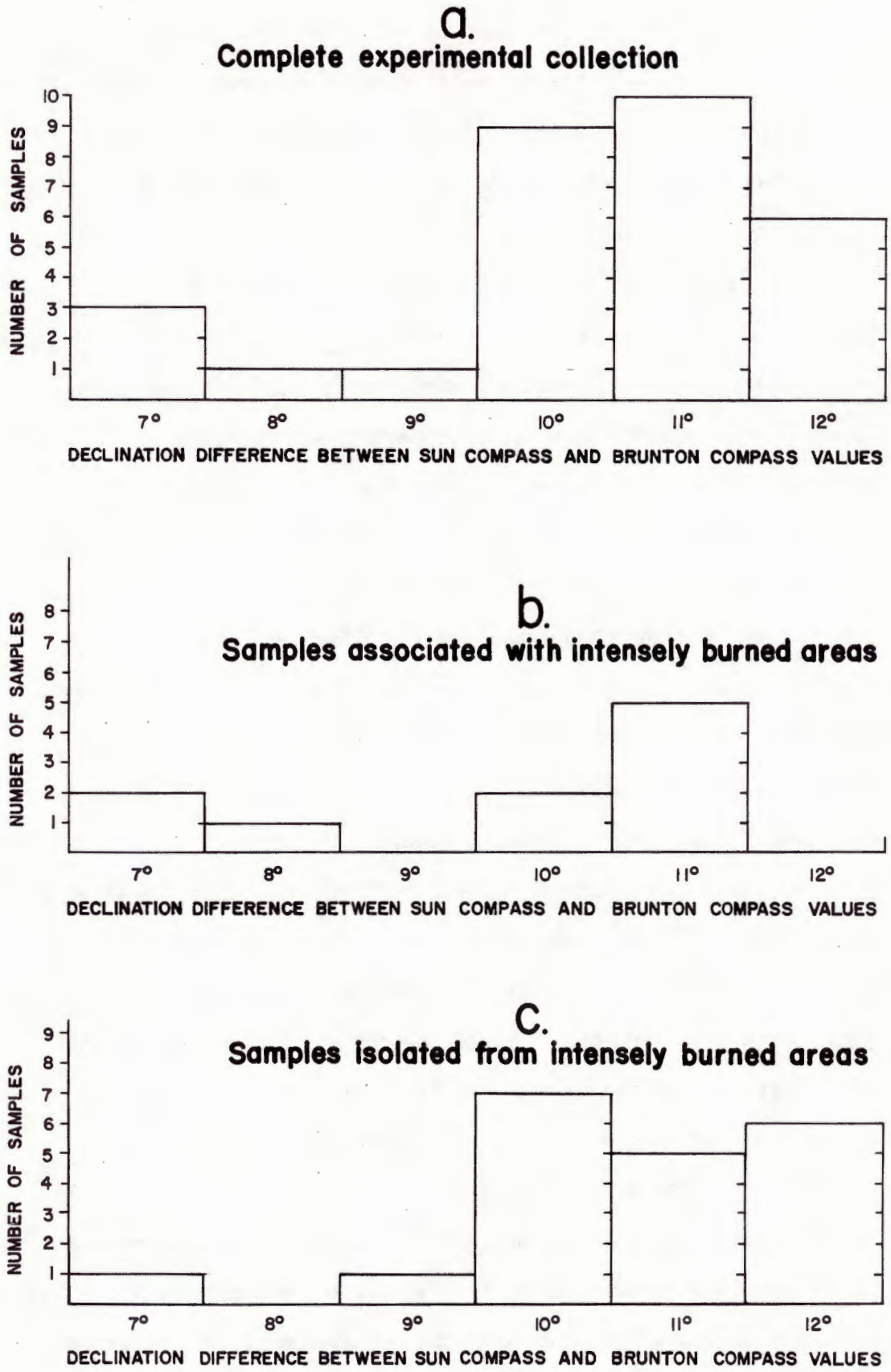


Figure 11.7 Histogram of declination differences of two methods of sun and Brunton compass.

The final analysis consisted of inserting the sun compass specimen declination into the archaeomagnetic computer program to obtain VGP positions and alpha 95 values. This information was then compared with corresponding data computed from the computer program for Brunton-compass declinations.

Table 11.7 represents the alpha 95 values obtained for the sun- and Brunton-compass orientations for corresponding samples. The average alpha 95 value for the sun compass orientations is 2.93°, whereas alpha 95 values for the Brunton compass orientations average 2.89°. The differences between these values were found to be statistically insignificant at the .05 level.

The calculated paleopole locations for the Brunton- and sun-compass orientations are included in Table 11.8. Evaluation of the accuracy in the VGP positions of prehistoric samples is complicated by several factors: accuracy of the currently accepted paleopole curve, accuracy of representation of a pole position in a given sample, and errors in independent dating of a feature. However, three samples (Site 5MT2192, Samples 5, 6, and 7) were collected from incinerations of a known date (August 1979). These features were part of a study conducted by the D.A.P. additive analysis laboratory personnel in an attempt to reproduce prehistoric kiln firings. The declination and inclination during 1979 in the Dolores region can be obtained from calculations of expected values of the National Oceanic and Atmospheric Administration maps, "Magnetic Declination in the United States-Epoch 1975.0" and "Magnetic Inclination in the United States-Epoch 1975.0." These values were determined to be 13.5°E and 64.4° (down), respectively. By inserting these values and the known latitude and longitude into the archaeomagnetic calculations, a VGP

Table 11.7 Alpha 95 Values for Corresponding Samples for Brunton- and Sun-Compass Orientations (Page 1 of 2)

Archaeomagnetic Declination Site Sample	Alpha 95 Values* for Sun-Compass Orientations (°)	Alpha 95 Values* for Brunton-Compass Orientations (°)
5MT0023-2	2.87	2.85
5MT0023-3	2.32	1.56
5MT0023-4	2.35	2.23
5MT0023-5	1.35	3.07
5MT0023-6	4.35	2.98
5MT2151-13	2.04	2.03
5MT2192-5	3.24	2.68
5MT2192-6	2.99	2.72
5MT2192-7	1.67	1.75
5MT2320-1	1.41	1.44
5MT2854-2	18.05**	2.68
5MT2858-2	1.58	1.46
5MT2858-3	6.88	11.39
5MT2858-4	5.38	2.14
5MT4512-2	4.58	3.61
5MT4512-3	2.45	2.23
5MT4545-1	4.07	4.02
5MT4545-2	1.84	1.96
5MT4545-3	13.32**	3.69
5MT4545-5	3.01	2.98
5MT4545-6	2.30	1.64
5MT4545-7	4.22	4.27
5MT4614-1	1.46	1.72

Table 11.7 Alpha 95 Values for Corresponding Samples for Brunton- and Sun-Compass Orientations (Page 2 of 2)

Archaeomagnetic Declination Site Sample	Alpha 95 Values* for Sun-Compass Orientations (°)	Alpha 95 Values* for Brunton-Compass Orientations (°)
5MT4614-2	2.63	2.38
5MT4614-3	5.55**	4.93
5MT4644-1	1.55	1.80
5MT4644-2	1.46	1.45
5MT4644-3	2.45	2.70
5MT4644-4	7.16	7.71
5MT4644-5	1.45	1.25

*Alpha 95 values reported for Brunton- and sun-compass orientations were independently "cleaned." The values reflect the smallest value obtained from cleaning processes, thus Brunton- and sun-compass alpha 95 values from a single sample set are not necessarily based on identical specimens or on the same number of specimens.

**Because only 6 sun compass azimuths were obtained in the field, the alpha 95 values are based on 6 specimens instead of 12. Thus, a larger alpha 95 value is inherent in these samples. These samples were excluded for determination of the average of all alpha 95 values for the two categories.

Table 11.8 Mean Paleopole Direction for Corresponding Brunton- and Sun-Compass Orientations (Page 1 of 2)

Archaeomagnetic Declination Site Sample	Brunton-Compass Orientations* Paleolatitude	Brunton-Compass Orientations* Paleolongitude	Sun-Compass Orientations* Paleolatitude	Sun-Compass Orientations* Paleolongitude
5MT0023-2	87.9	296.2	86.3	186.5
5MT0023-3	87.5	137.3	83.5	155.7
5MT0023-4	85.3	3.0	86.6	13.2
5MT0023-5	81.9	357.4	83.8	17.3
5MT0023-6	83.4	335.7	84.3	309.8
5MT2151-13	82.3	40.2	83.1	57.3
5MT2192-5	74.2	292.4	74.0	281.7
5MT2192-6	73.7	289.3	75.3	275.5
5MT2192-7	75.7	281.2	76.5	276.7
5MT2320-1	85.7	326.1	87.6	316.0
5MT2854-2	84.0	356.8	78.2	158.4
5MT2858-2	85.3	321.6	87.8	299.4
5MT2858-3	84.0	291.1	56.1	289.7
5MT2858-4	52.9	255.9	65.0	257.7
5MT4512-2	65.3	291.3	81.1	276.4
5MT4512-3	85.2	267.2	76.0	247.7
5MT4545-1	78.8	10.4	89.4	81.2
5MT4545-2	82.2	246.6	82.0	238.2
5MT4545-3	86.8	44.2	75.0	157.1
5MT4545-5	81.7	270.6	82.2	254.3
5MT4545-6	83.8	213.7	81.4	209.2
5MT4545-7	80.5	127.2	79.2	132.8
5MT4614-1	86.7	18.7	88.5	54.4

Table 11.8 Mean Paleopole Direction for Corresponding Brunton- and Sun-Compass Orientations (Page 2 of 2)

Archaeomagnetic Declination		Brunton-Compass Orientations*		Sun-Compass Orientations*	
Site	Sample	Paleolatitude	Paleolongitude	Paleolatitude	Paleolongitude
5MT4614-2		82.8	41.6	84.1	73.2
5MT4614-3		76.1	234.3	62.4	206.9
5MT4644-1		77.0	45.8	78.5	74.9
5MT4644-2		80.0	32.8	80.9	36.8
5MT4644-3		80.5	43.2	81.4	60.3
5MT4644-4		84.3	22.3	84.0	20.0
5MT4644-5		76.1	51.2	76.5	61.5

*The paleopole positions noted are based on "cleaned" samples. Alpha 95 values for these positions are represented for corresponding sample and orientation method in Table 11.7.

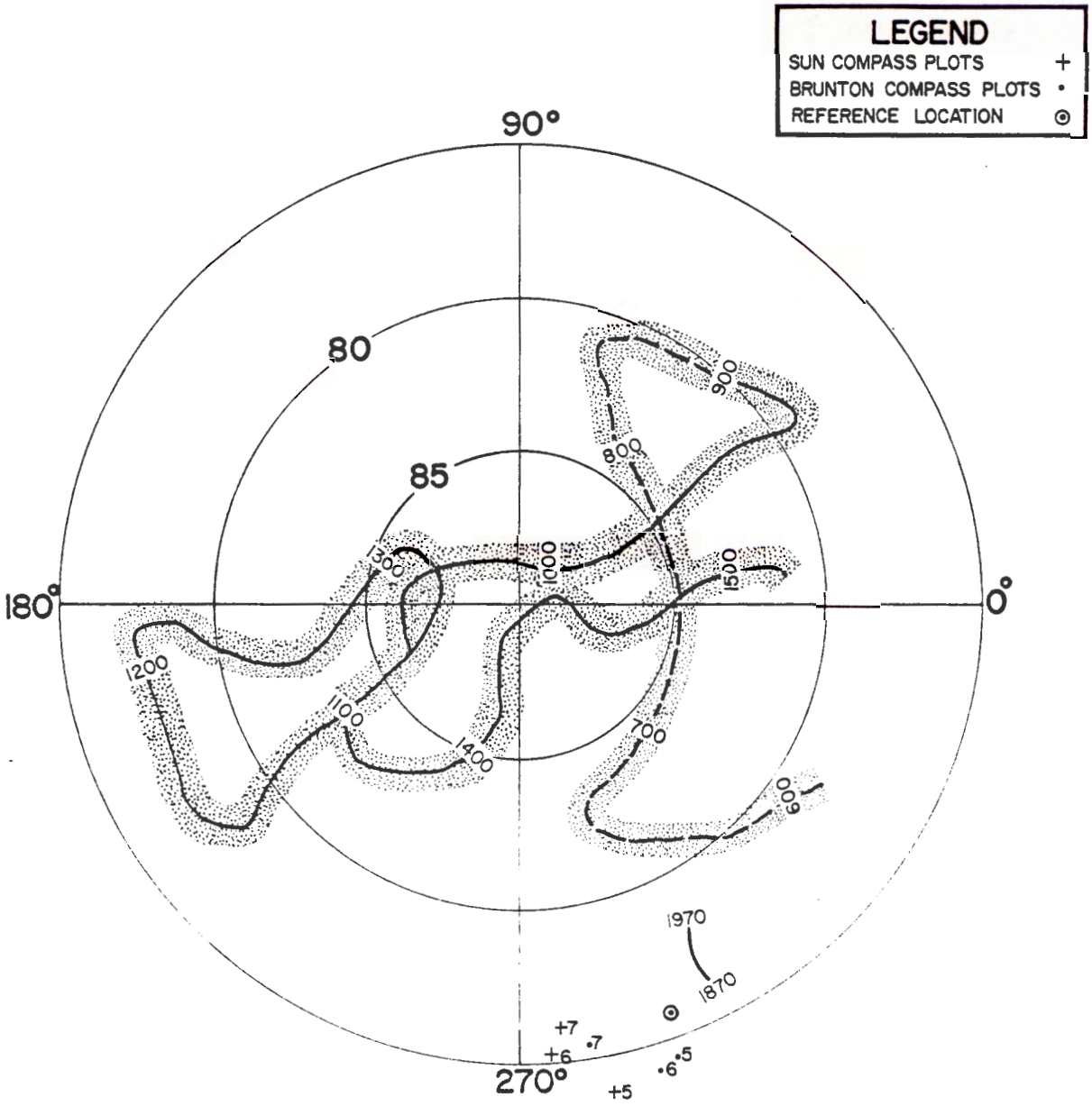
NOTE: Those samples with alpha 95 values larger than 3.5° represent increasing degrees of sample scatter (as the value increases) and are less likely to be a true representation of the paleopole position at the time of firing.

position of 76.4°N latitude and 295.2°E longitude were established. This VGP position was then plotted with VGP locations determined from Brunton- and sun-compass orientations of Samples 5, 6, and 7 from Site 5MT2192 (Figure 11.8). It is evident from this illustration that the sun-compass plots are consistently west of the Brunton-compass plots and also the reference location. Although this information is far from conclusive, it indicates that the Brunton-compass plots orient the samples more accurately towards the reference location than do the sun-compass plots. Additional studies are projected for the 1980 field season in an attempt to substantiate the results from this study.

Archaeomagnetic Sampling of Kiln Simulations

The D.A.P. additive analysis laboratory personnel conducted several firing simulations of ancient kilns during August 1979. Kiln 1 utilized an existing prehistoric feature excavated by program personnel earlier in the field season. Kilns 2-4 were excavated specifically for purposes of this study. Maximum temperatures for Kiln 1 were measured by a pyrometer to 800°C. Kiln 2 was fired on two occasions with estimated maximum temperatures of 450°C. Kilns 3 and 4 were estimated to attain temperatures of 650°C. These temperatures are sufficient for producing TRM in the matrix (Tarling [15:169]), and thus the kilns were considered adequate for archaeomagnetic sampling.

These simulations represent a special circumstance for archaeomagnetic researchers. Analysis of prehistoric samples entails projection of a mean VGP position on the master Southwest curve. Dating of samples is based on the proximity of the mean position of the sample with the master curve. However, archaeomagnetists are uncertain as to how



Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.8 Sun compass and Brunton compass VGP plots for Samples 5, 6, and 7 at Site 5MT2192.

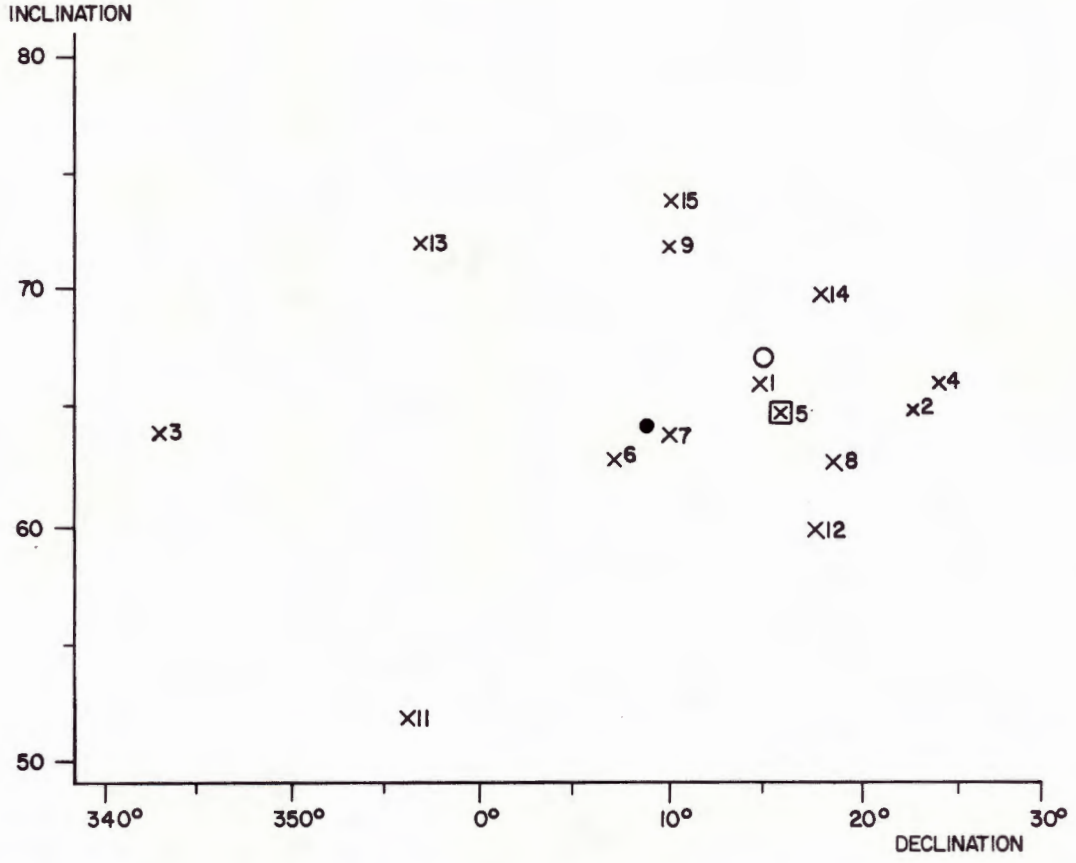
well the remanent magnetization reflects the VGP location at the time and place of firing. Because the firing of these kilns took place at a known place and time, the apparent pole position can be determined from the known declination and inclination for the Dolores area during 1979. The mean direction of samples collected from these kilns can then be compared to the calculated pole position.

Kilns 1-3 were archaeomagnetically sampled (archaeomagnetic samples 5, 6, and 7, respectively, at Site 5MT2192). Sixteen specimens were obtained from Kiln 1, which included eight specimens from the rim and eight from the base. Twelve specimens were collected from the rims of Kilns 2 and 3. Archaeomagnetic results from Sample 5 at Site 5MT2192 were analyzed as a whole unit and then divided into two groups representing the rim specimens (designated as Site 5MT2192-5a) and the basal specimens (designated as Site 5MT2192-5b). Results from Sample 5a yielded the lowest alpha 95 value with the closest approximation of the calculated pole position for Dolores. Results from the basal specimens, 5b, did not provide sufficiently clustered specimens for plotting a mean pole position. Samples 6 and 7 both produced sufficient specimen clustering for archaeomagnetic analysis. Archaeomagnetic results for Samples 5, 5a, 5b, 6, and 7 are reported in Table 11.9. Figures 11.9 and 11.10 are scattergrams representing the individual magnetic directions for Samples 5-7 at Site 5MT2192. The present magnetic direction for Dolores was determined from expected values of the National Oceanic and Atmospheric Administration maps. Magnetic declination and inclination were found to be 13.5°E and 64.4° (down) for Dolores during 1979. This position is located on Figures 11.9 and 11.10 as a reference point for comparison with the mean directions of Samples 5-7.

Table 11.9 Archaeomagnetic Results from Samples 5, 5a, 5b, 6, and 7 at Site 5MT2192

ARCHAEOMAGNETIC DESIGNATION	SAMPLE NUMBER				
	5	5a	5b	6	7
Feature and provenience	Ceramic kiln firing 1	Ceramic kiln firing 1	Ceramic kiln firing 1	Ceramic kiln firing 2	Ceramic kiln firing 3
Specimens used in final analysis/ total collected	11/16	7/8	8/8	9/12	11/12
Degauss level	25 Oe*	25 Oe*	25 Oe*	25 Oe*	25 Oe*
Mean inclination	66.16	64.59	70.22	66.88	66.86
Mean declination	15.64	16.13	11.58	15.43	10.87
Mean intensity	$.626 \times 10^{-3}$	$.133 \times 10^{-2}$	$.163 \times 10^{-3}$	$.134 \times 10^{-2}$	$.322 \times 10^{-3}$
Mean sample vector	10.97	6.99	7.88	8.98	10.99
Precision parameter (k)	290.96	747.54	47.78	359.50	683.15
Alpha 95	2.68	2.21	7.35	2.79	1.75
Paleolatitude	74.18	75.09	71.46	73.67	75.71
Paleolongitude	292.36	299.49	273.06	289.34	281.17
Error along great circle (EP)	3.60	2.85	10.94	3.72	2.39
Error perpendicular to great circle (EM)	4.39	3.55	12.68	4.50	2.89

*Oe - oersteds



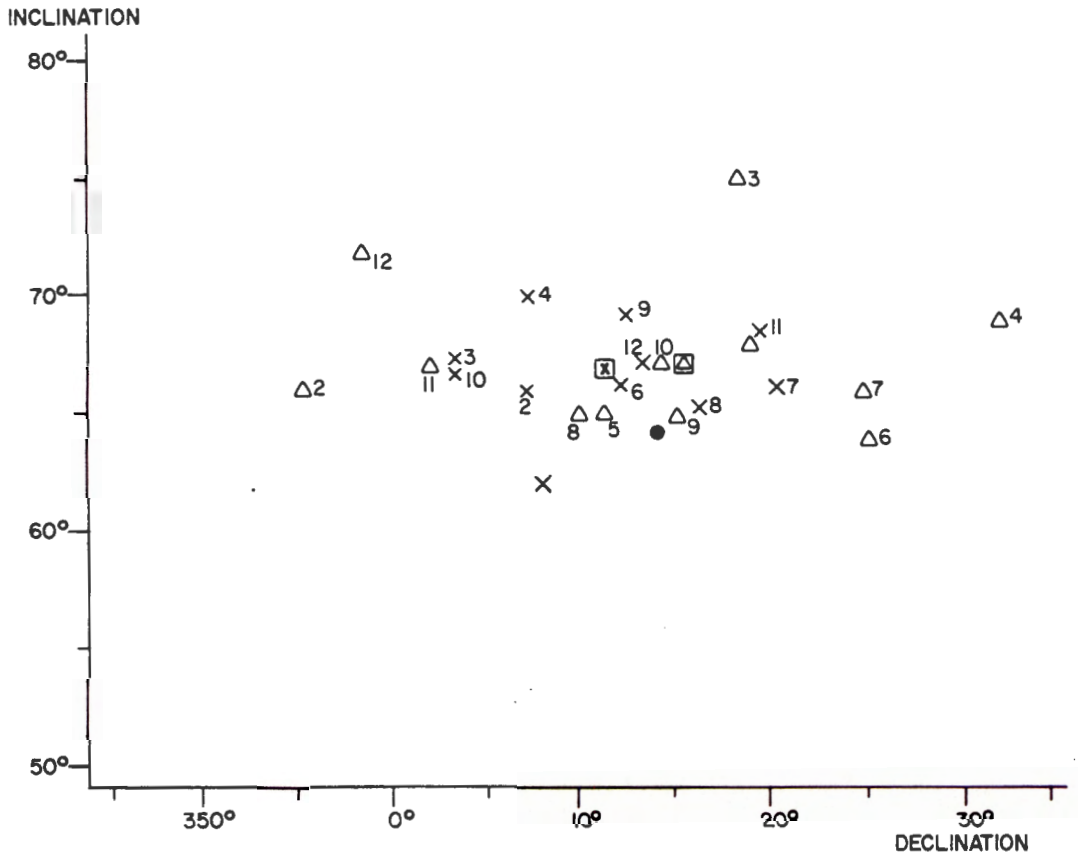
X - 5MT2192-5, comprised of Specimens 1-16. Specimens 10 and 16 fall outside of plotting surface. Specimens 3, 10, 11, 13, and 16 defined as outliers. O indicates mean sample direction, excluding outliers.

5MT2192-5a, comprised of Specimens 1-8. Specimen 3 defined as outlier. □ indicates mean sample direction of Sample 5a, excluding outlier.

5MT2192-5b, comprised of Specimens 9-16. Too scattered to report mean sample direction.

• Reference location. Magnetic direction for Dolores area, 1979. Determined from expected values of the National Oceanic and Atmospheric Administration maps; "Magnetic Declination in the United States - Epoch 1975.0" and "Magnetic Inclination in the United States - Epoch 1975.0."

Figure 11.9 Individual magnetic directions for Samples 5, 5a, and 5b at Site 5MT2192, and current observed magnetic directionof Dolores, Colorado.



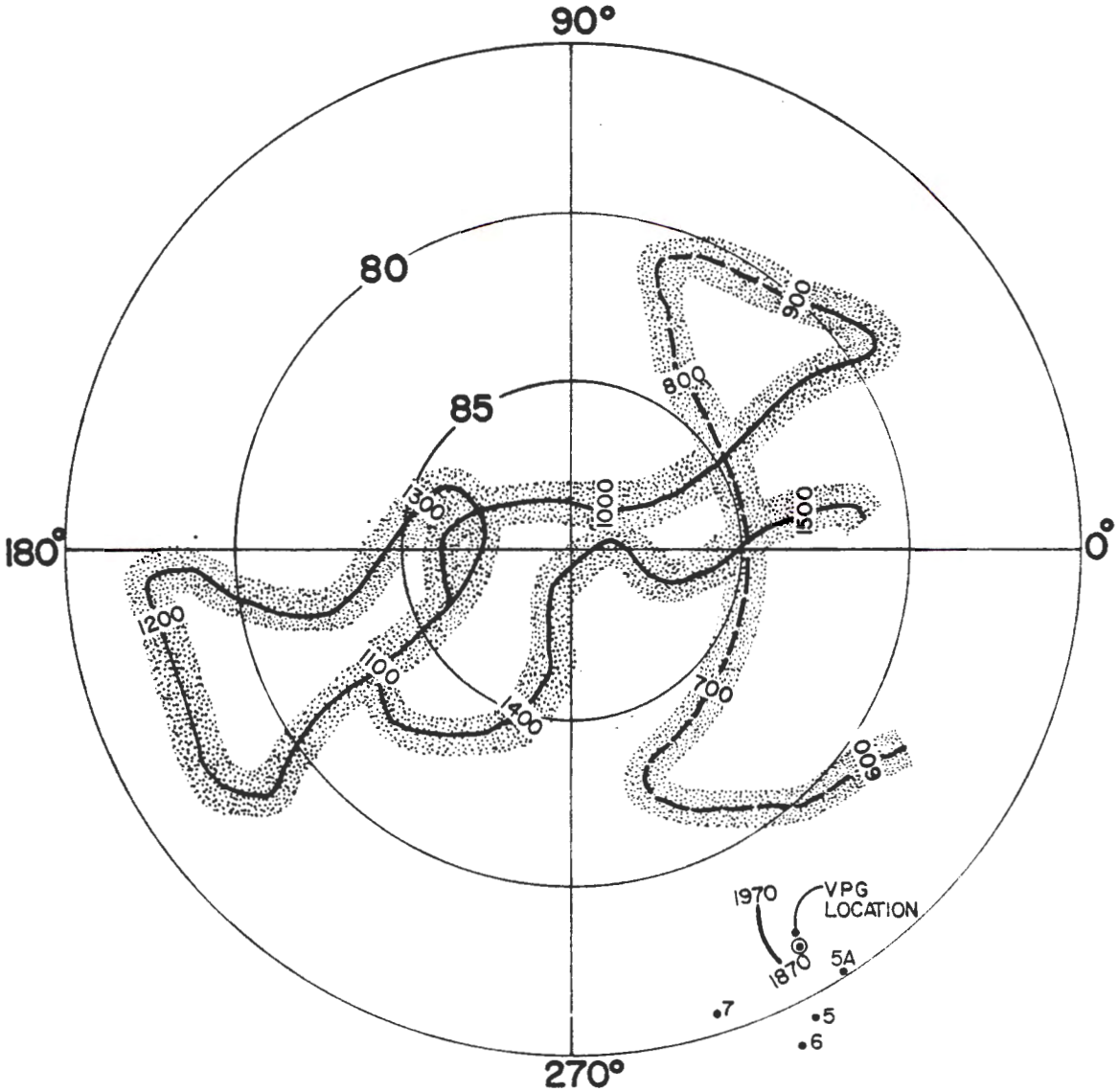
△ 5MT2192-6; Specimens 2, 4, and 12 defined as outliers. ⊠ indicates mean sample direction, excluding outliers.

x 5MT2192-7; Specimen 5 falls outside plotting surface and defined as outlier. ⊠ indicates mean sample direction, excluding outliers.

Reference location. Magnetic direction for Dolores area, 1979. Determined from expected values of the National Oceanic and Atmospheric Administration maps; "Magnetic Declination in the United States - Epoch 1975.0" and "Magnetic Inclination in the United States - Epoch 1975.0."

Figure 11.10 Individual directions for Samples 6 and 7 at Site 5MT2192, and current observed magnetic direction of Dolores, Colorado.

VGP locations were then calculated for Samples 5, 5a, 6, and 7 and the reference direction. These positions were then plotted on the polar (Figure 11.11). The samples approximate the reference location fairly well, especially when the elliptically inclusive area of the alpha 95 is considered. Sample 5a is the closest representation of the reference location and Sample 7 is the farthest from the reference point. This observation is noteworthy when considering that Sample 7 retained the smallest alpha 95 value.



Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.11 VGP locations of Samples 5, 5a, 6, and 7 at Site 5MT2192 with the current observed VGP location for Dolores, Colorado.

SUMMARY AND CONCLUSIONS

A total of 64 archaeomagnetic samples was collected from 17 prehistoric sites during the D.A.P. 1979 field season; actual labor expenditure in the field portion of the collecting program amounted to 100 person-days.

The sampling program was expected to yield a wide range of dates (A.D. 600-950) reflecting the long sequence of occupation in the study area. However, discrepancies between archaeomagnetic results and corresponding samples from other independent dating methods are apparent in a portion of the data. Resolution of this problem included an evaluation of the master Southwest curve originally proposed by Dubois [2] based on the Dolores material. The results from this study (Appendix 3) indicate that several refinements would provide a more accurate estimation of the VGP curve for the period A.D. 750-900 in the Southwest region.

Intensive analysis of archaeomagnetic sample prioritization for the 1979 field season revealed an unusually low correlation of the productivity of central pitstructure hearths. Structural walls appear consistently to provide the best results for archaeomagnetic dating. These results suggest a revision for the 1980 archaeomagnetic sample prioritization for more rigorous criteria for central hearth sampling.

Analysis of the sun-compass and Brunton-compass results suggests a strong possibility that cube orientation is best represented by the Brunton compass. Continued research in this area is scheduled for the 1980 field season to better substantiate the conclusions from these results.

Soil analyses indicate a large range of variability in sand-silt-

clay percentages that may produce measurable thermoremanent magnetizations in optimum conditions. The trend noticed, however, is indicative of a slight negative correlation between alpha 95 values and percent sand, and a slight positive correlation between alpha 95 values and percent silt and percent clay. Sand and silt appear to be better indicators of productive samples than clay.

Analysis of archaeomagnetic samples of three kiln firings suggests that the observed ambient field falls within the 95 percent circle of confidence (alpha 95) of the measured sample directions. Because a majority of the prehistoric samples collected in the project area probably do not reach such extreme temperatures (450-800°C), a controlled study of the effects of different soil and temperature conditions on the accuracy of recording the observed ambient field from measured sample remanence is scheduled for the 1980 field season. This study will ultimately provide important information assisting evaluation of prehistoric remanence.

The priorities and goals for the 1980 D.A.P. archaeomagnetic sampling program are as follows:

1. To employ the sampling program to achieve temporal control at Grass Mesa Village (Site 5MT0023) and McPhee Pueblo (Site 5MT4475), two large, stratigraphically complex sites.

2. To employ the sampling program to assist in dating other smaller sites scheduled for excavation in 1980.

3. To use the sampling collection in further evaluating and revising the master Southwest curve.

APPENDIX A

SITE-BY-SITE SUMMARY OF ARCHEOMAGNETIC SAMPLES

by

J. Holly Hathaway

Key for Tables 11.A.1 - 11.A.17

Provenience description:

Feat - feature

Pitstr - pitstructure

Surstr - surface structure

Nonstr - nonstructure

Table 11.A.1 Summary of Archaeomagnetic Samples from Site 5MT0023

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 3, Level 4	exterior hearth	900±30	2	sample discarded
2	Feat 16, Pitstr 1	central hearth	880±20	1	700±50 1275±50 1425±50
3	W wall, Pitstr 1	fire-hardened wall	880±20	1	1030±30 1320±30
4	Feat 50, Surstr 12	temporary hearth	850±30	3	750±35 980±35 1480±35
5	Feat 64, Surstr 6	temporary hearth	850±30	3	750±45 1500±45
6	Feat 11, Nonstr 4	exterior hearth	750±100	3	725±45 1475±45
7	Feat 104, Pitstr 6	central hearth	880±20	2	725±30 1460±30
8	Feat 119, Pitstr 4	central hearth	880±20	2	740±25 1460±25
9	Feat 114, Pitstr 2	central hearth	880±20	1	775±35 975±35 1480±35
10	N wall, Pitstr 3	fire-hardened wall	850±30	2	640±50
11	E wall, Pitstr 5	fire-hardened wall	880±30	2	910±45

Table 11.A.2 Summary of Archaeomagnetic Samples from Site 5MT2151

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
11	Feat 78, Surstr 11	temporary hearth	875±25	4	sample discarded
12	W wall, Surstr 11	fire-hardened wall	875±25	4	1050±55 1325±55 1440+55
13	Feat 88, Pitstr 2	fire-hardened wall	1000±50	4	790+30

*Samples 1-10 were collected during the 1978 field season.

Table 11.A.3 Summary of Archaeomagnetic Samples from Site 5MT2192

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 13, Pitstr 1	central hearth	850±25	1	sample discarded
2	Feat 25, Occupation Area 2	fire-hardened pit	850±25	3	sample discarded
3	Feat 7, Area 5	temporary hearth	850±25	5	sample discarded
4	Feat 33, Surstr 1	exterior hearth	850±25	4	modern??

Table 11.A.4 Summary of Archaeomagnetic Samples from Site 5MT2193

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
15	Feat 26, Pitstr 1	bottom of central hearth	765±5	1	sample discarded
16	Feat 26, Pitstr 1	remodeled sides central hearth	765+5	1	sample discarded
17	Feat 26, Pitstr 1	beneath remodeled central hearth	765±5	1	sample discarded
18	S wall, Pitstr 1	fire-hardened wall	765±5	2	750±50 960±50 1500±50
19	Feat 83, Subarea 5	exterior hearth	770±30	4	sample discarded
20	Feat 84, Pitstr 2	central hearth	780±10	1	sample discarded
21	E bench wll, Pitstr 2	fire-hardened wall	780±10	2	sample discarded
22	Surface 1 Pitstr 1	fire-hardened floor	780±10	1	sample discarded

*Samples 1-6 were collected during the 1978 field season; sample numbers 7-14 were not assigned.

Table 11.A.5 Summary of Archaeomagnetic Samples from Site 5MT2194

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 24, Pitstr 1	central hearth	650±50	1	sample discarded

Table 11.A.6 Summary of Archaeomagnetic Samples from Site 5MT2199

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date	Priority	Archaeomagnetic Date (A.D.)
1	Feat 3	temporary hearth	2000 B.C.±1000	1	sample discarded

Table 11.A.7 Summary of Archaeomagnetic Samples from Site 5MT2203

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 3, Occupation Area 2	exterior hearth	960-20	5	sample discarded

Table 11.A.8 Summary of Archaeomagnetic Samples from Site 5MT2236

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 4, Area 3	slab-lined pit	790±10 or 1000 B.C.±1000	3	1150±65?
2	Feat 5, Pitstr 1	central hearth	790±10	2	740+35 1475+35

Table 11.A.9 Summary of Archaeomagnetic Samples from Site 5MT2320

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 3, Pitstr 1	central hearth	880±20	2	720±25 1460±25

Table 11.A.10 Summary of Archaeomagnetic Samples from Site 5MT2848

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 3, Pitstr 2	central hearth	800±10	2	660±45 1400±45
2	Surface 1, Pitstr 1	fire-hardened floor	800±10	2	915±20
3	Feat 19, Pitstr 1	central hearth	800±10	1	775±40 935±40 1515±40

Table 11.A.11 Summary of Archaeomagnetic Samples from Site 5MT2853

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 5, Pitstr 1	central hearth	750±50	1	870±25

Table 11.A.12 Summary of Archaeomagnetic Samples from Site 5MT2854

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 2,	temporary hearth	750±50	4	660±40 1400±40
2	Feat 5, Pitstr 1	central hearth	790±10	1	735±40 1490±40

Table 11.A.13 Summary of Archaeomagnetic Samples from Site 5MT2858

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 1	temporary hearth	800±30	3	650±45
2	Feat 2, Pitstr 1	central hearth	800+30	2	710±25
3	Surface 1, Pitstr 1	fire-hardened floor	800±30	3	sample discarded
4	Feat 33, Pitstr 2	temporary hearth	800±30	1	sample discarded

Table 11.A.14 Summary of Archaeomagnetic Samples from Site 5MT4512

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 12, Pitstr 1	temporary hearth	850±20	3	sample discarded
2	Feat 37	slab-lined fireplace	850±20	3	680±60 1450±60
3	Feat 45	exterior hearth	850±20	4	no date assigned*

*Results were consistent, but fell away from the current Southwest curve.

Table 11.A.15 Summary of Archaeomagnetic Samples from Site 5MT4545

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 27	pit with burning	620±25	3	sample discarded
2	N wall, Surstr 1	fire-hardened wall	620±25	3	1375±30
3	NW wall, Pitstr 2	fire-hardened wall	620±25	1	760±50 985±50 1460±50
4	Feat 17, Pitstr 1	central hearth	620±25	1	700±50
5	Feat 5, Surface 1	exterior hearth	620±25	3	670+50
6	Surface 1, Surstr 3	fire-hardened floor	620±25	2	1375±25 1100±25
7	Feat 68	exterior hearth	620±25	4	sample discarded

Table 11.A.16 Summary of Archaeomagnetic Samples from Site 5MT4614

Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	Feat 17, Pitstr 1	central hearth	750±30	1	750+25 925±25 1460±25
2	Feat 39, Pitstr 2	central hearth	750±30	3	790+35 940±35
3	Feat 134, Surstr 3	slab-lined hearth	750±30	4	sample discarded

Table 11.A.17 Summary of Archaeomagnetic Samples from Site 5MT4644

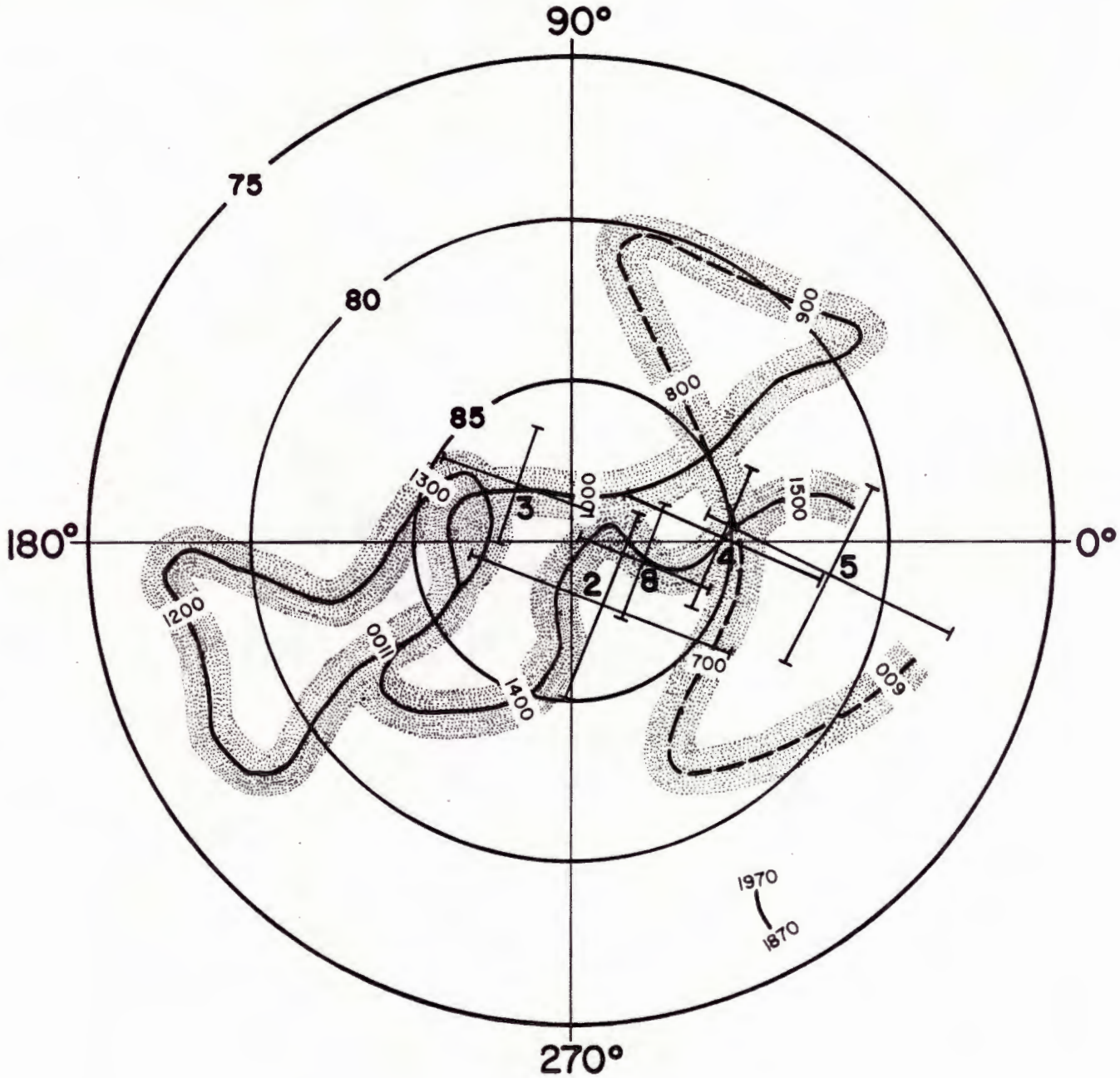
Sample Number	Provenience	Cultural Context	Archaeologically Inferred Date (A.D.)	Priority	Archaeomagnetic Date (A.D.)
1	W wall, Pitstr 1	fire-hardened wall	810±10	1	915±30
2	Feat 21, Pitstr 2	central hearth (rim)	790±10	1	925±20
3	N wall, Pitstr 2	fire-hardened wall	790±10	1	900±35 1460±55
4	Feat 16, Pitstr 1	central hearth	810±10	1	sample discarded
5	N wall, Pitstr 1	fire-hardened wall	810±10	1	915±30
6	Feat 21, Pitstr 2	central hearth (bottom)	790±10	4	625±50 700±50

APPENDIX B

PALEOPOLE REPRESENTATIONS OF SUCCESSFUL ARCHAEOMAGNETIC SAMPLES DURING THE 1979 FIELD SEASON AT THE DOLORES ARCHAEOLOGICAL PROGRAM

by

J. Holly Hathaway

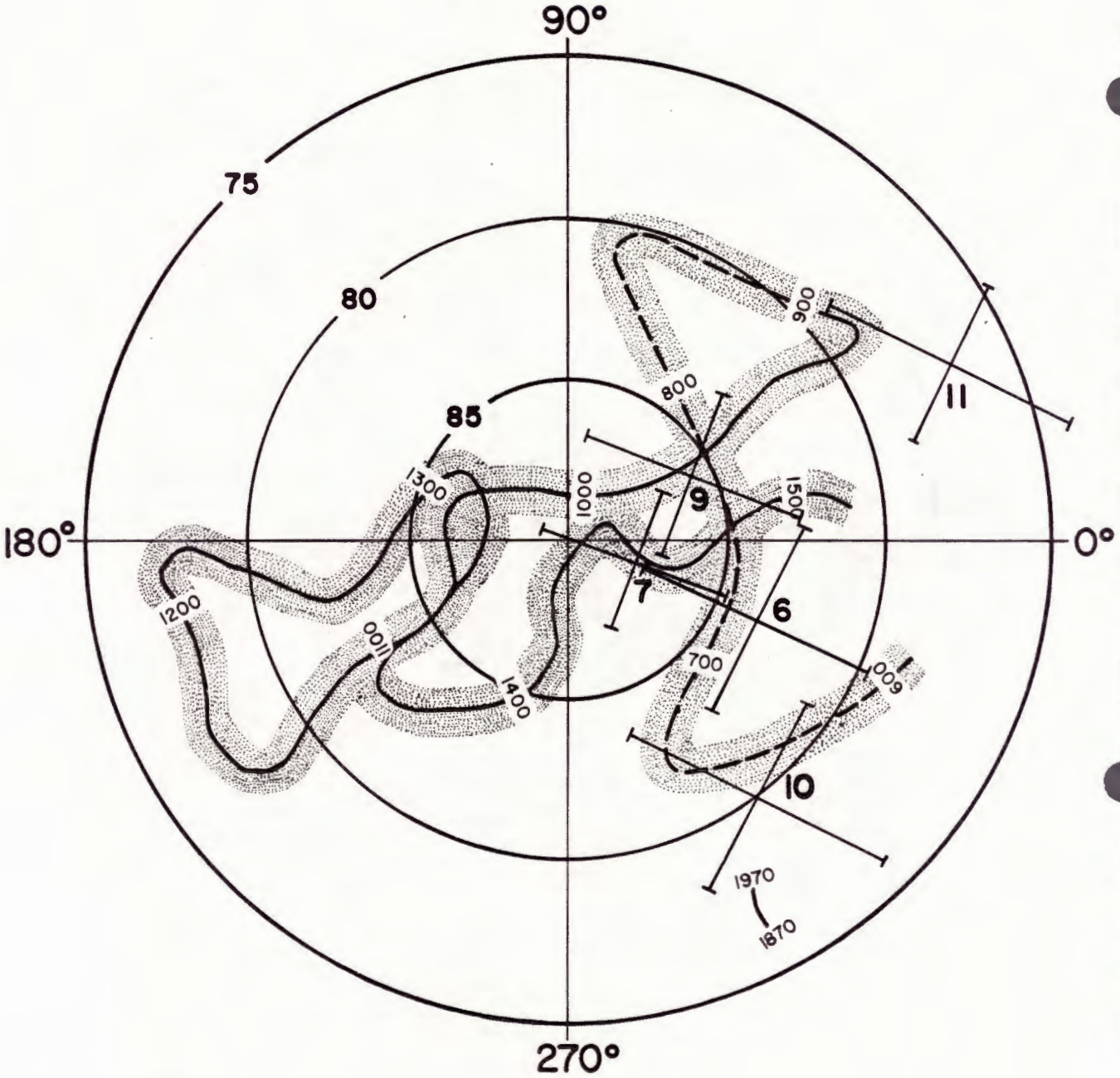


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.1 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT0023, Samples 2-5, and 8.

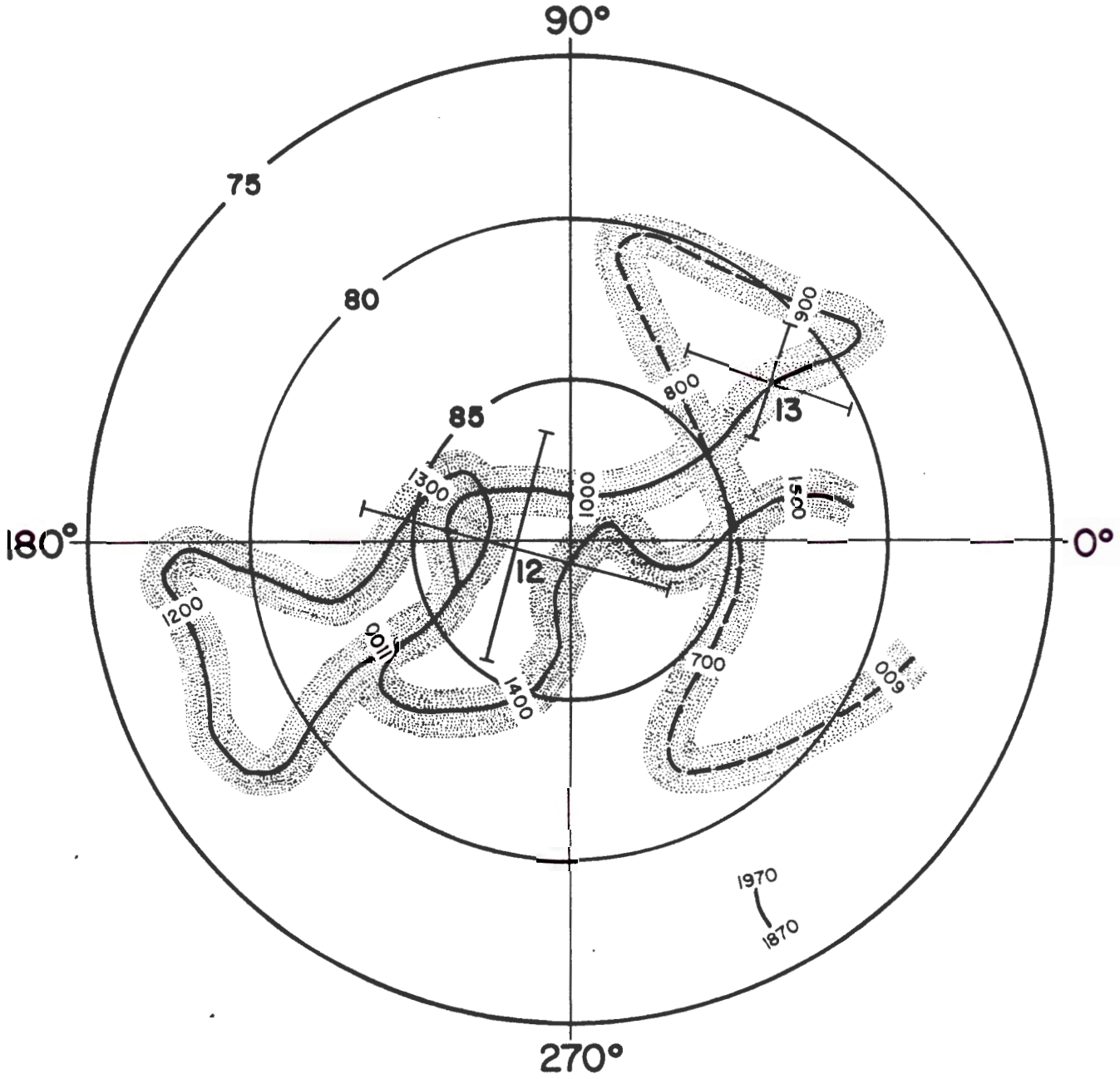


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.2 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT0023, Samples 6, 7, and 9-11.

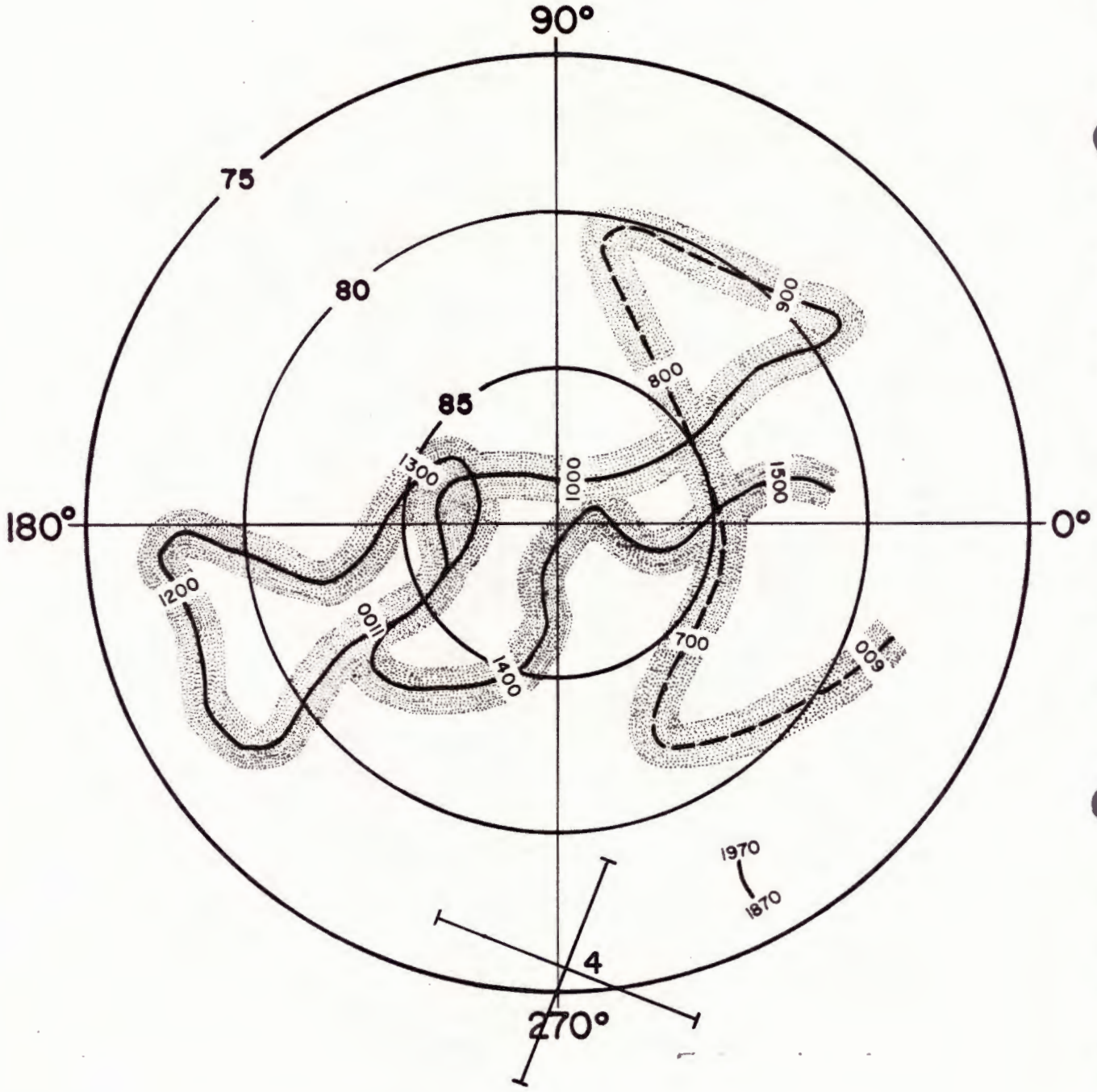


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.3 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2151, Samples 12 and 13.

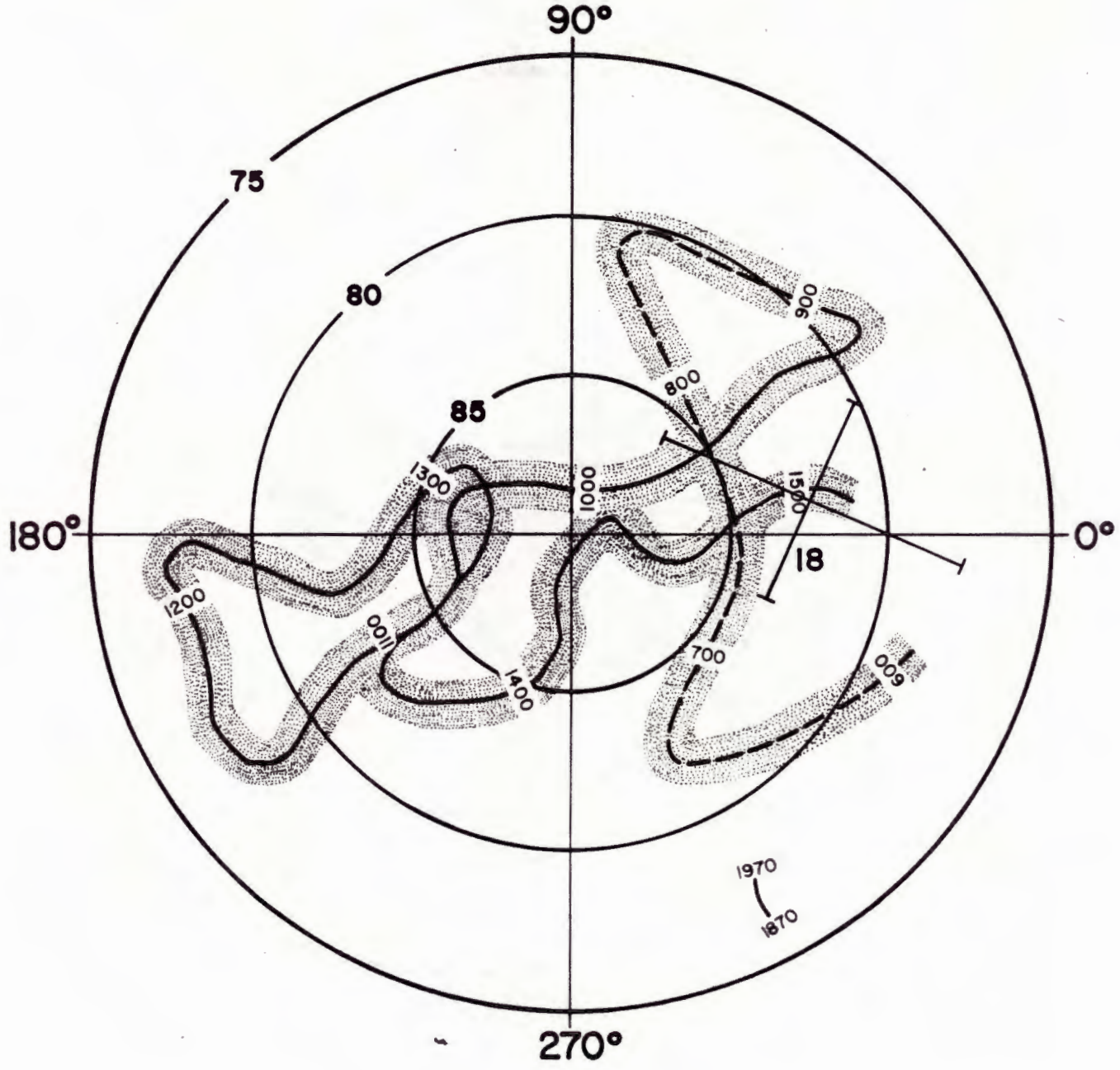


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.4 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2192, Sample 4.

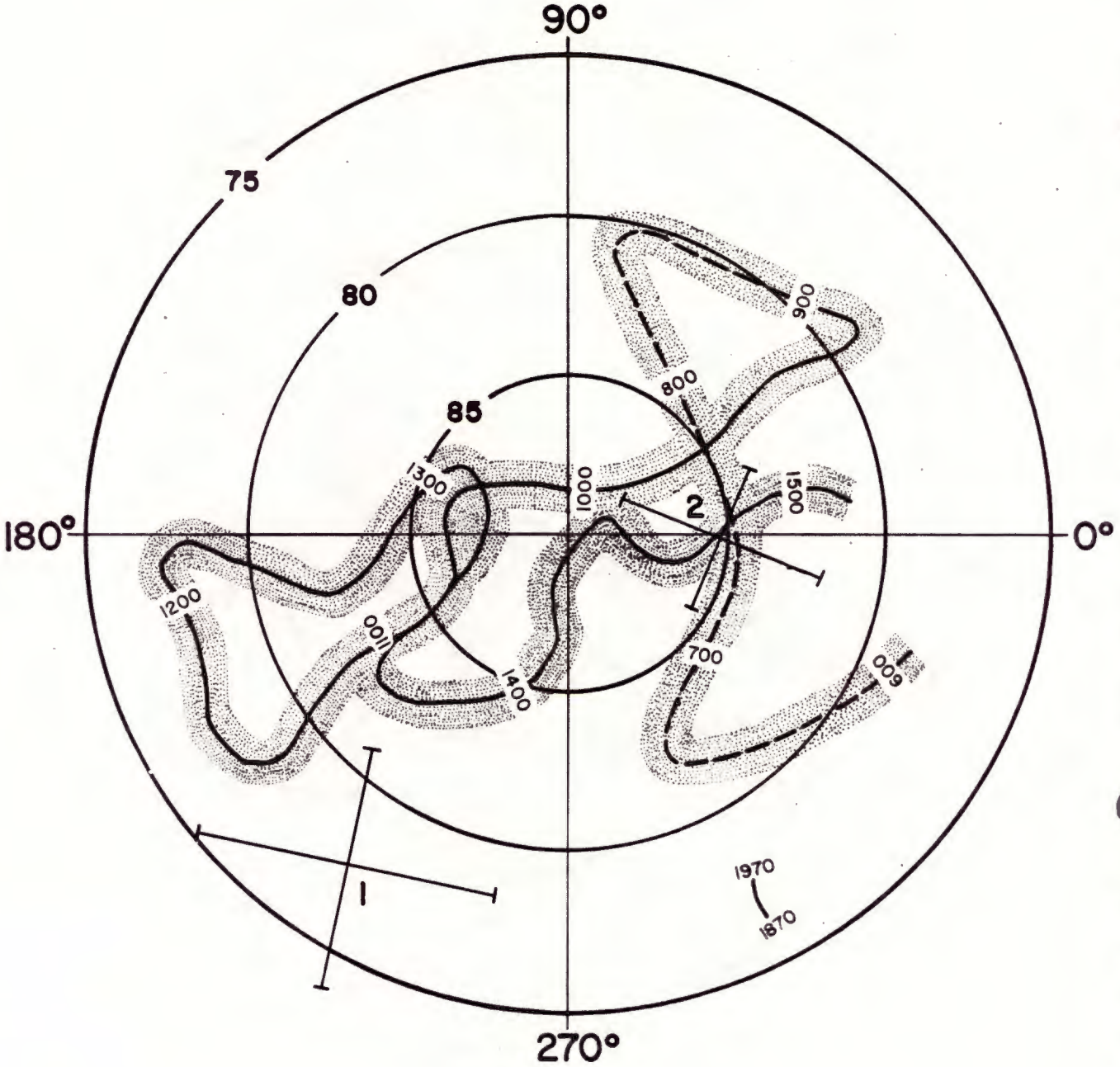


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.5 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2193, Sample 18.

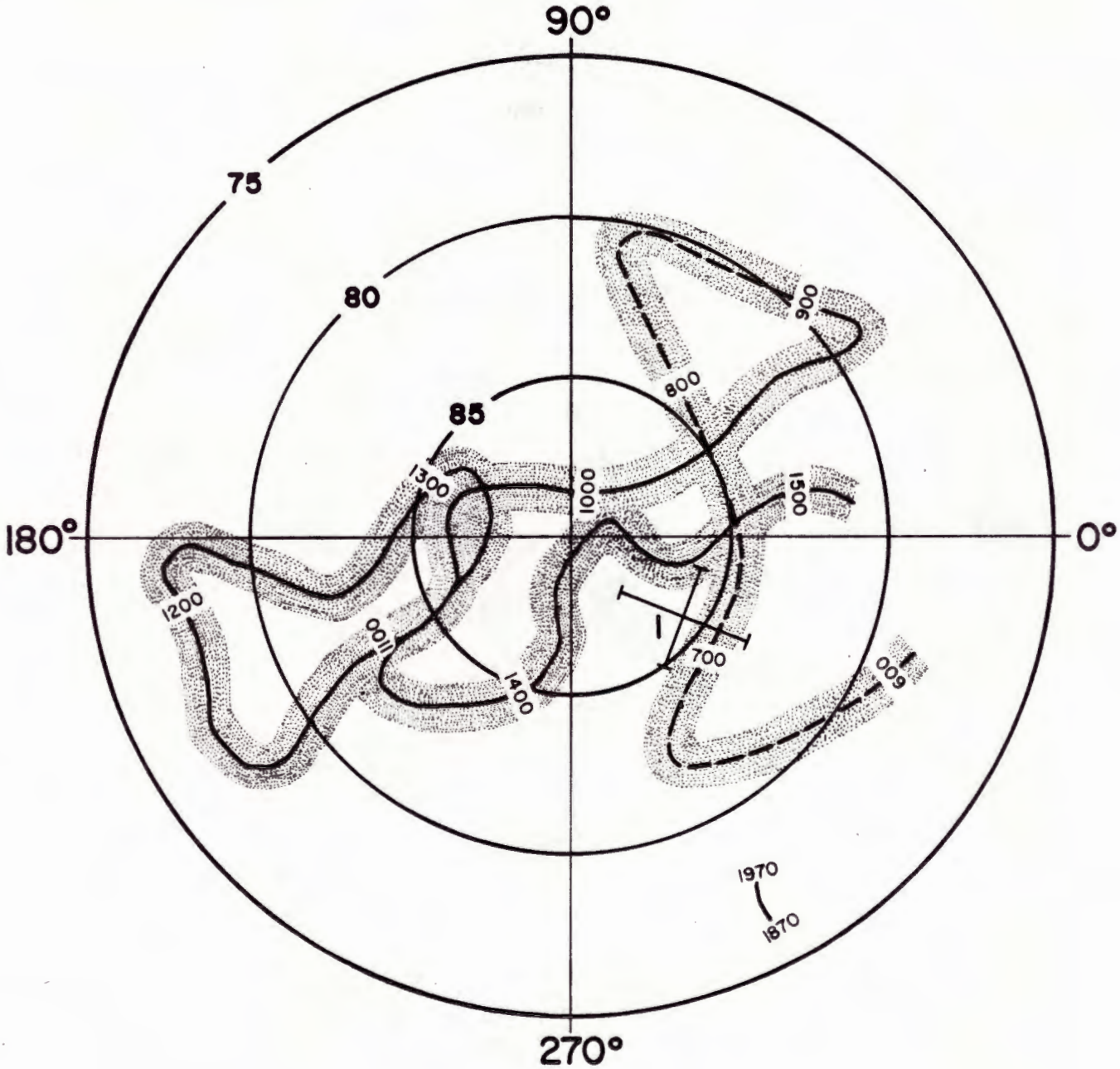


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.6 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2236, Samples 1 and 2.

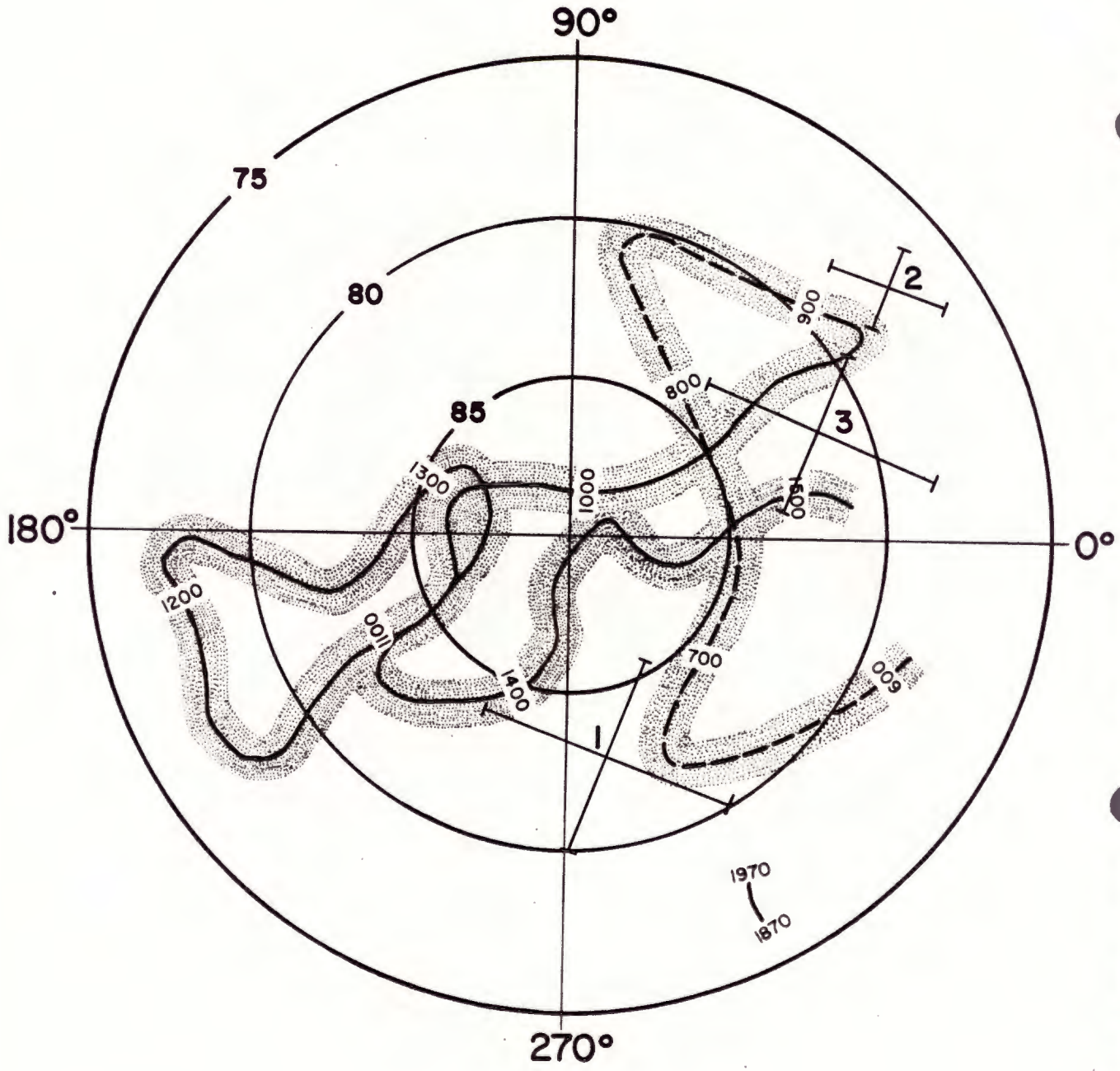


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.7 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2320, Sample 1.

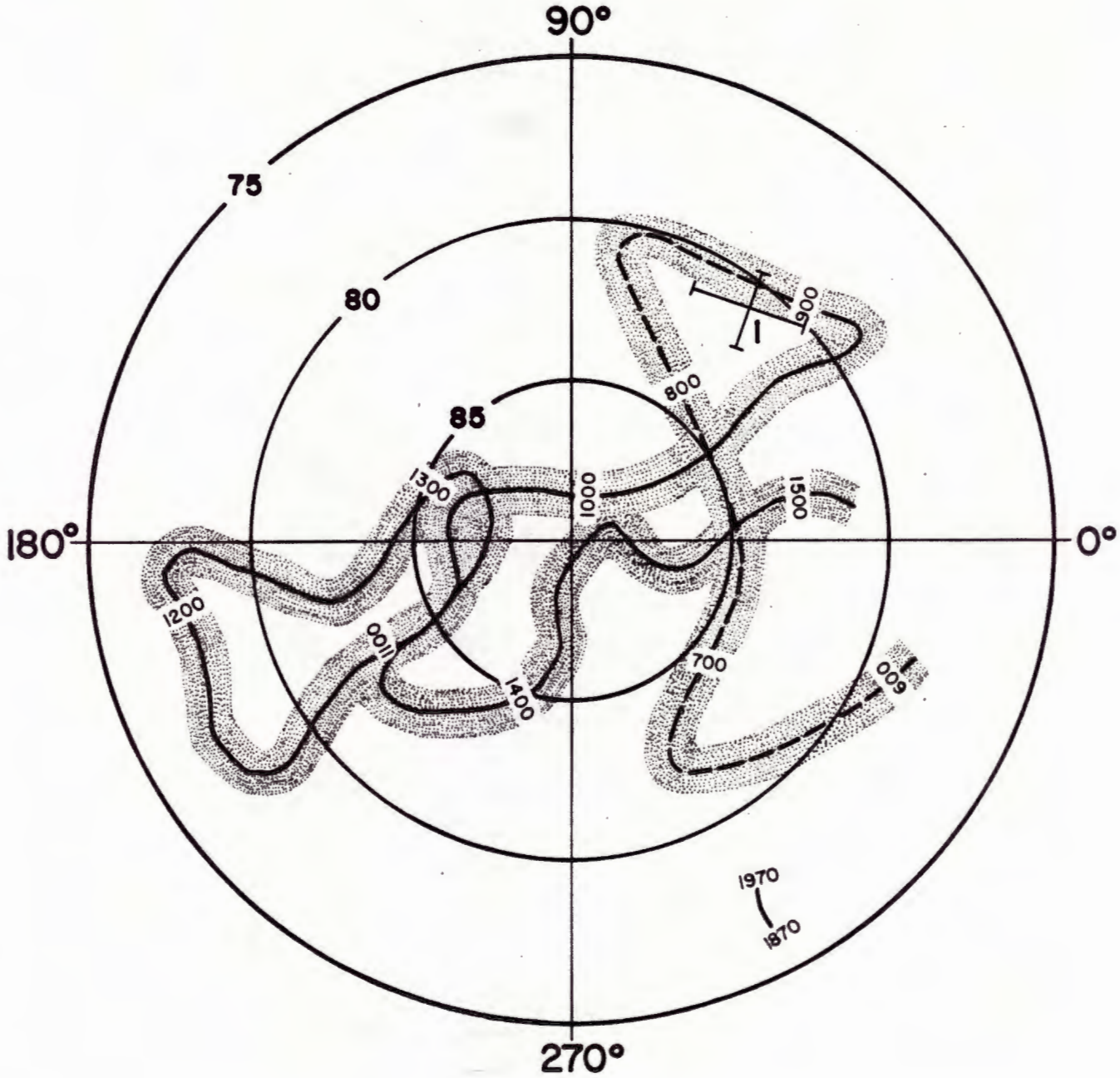


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.8. Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2848, Samples 1-3.

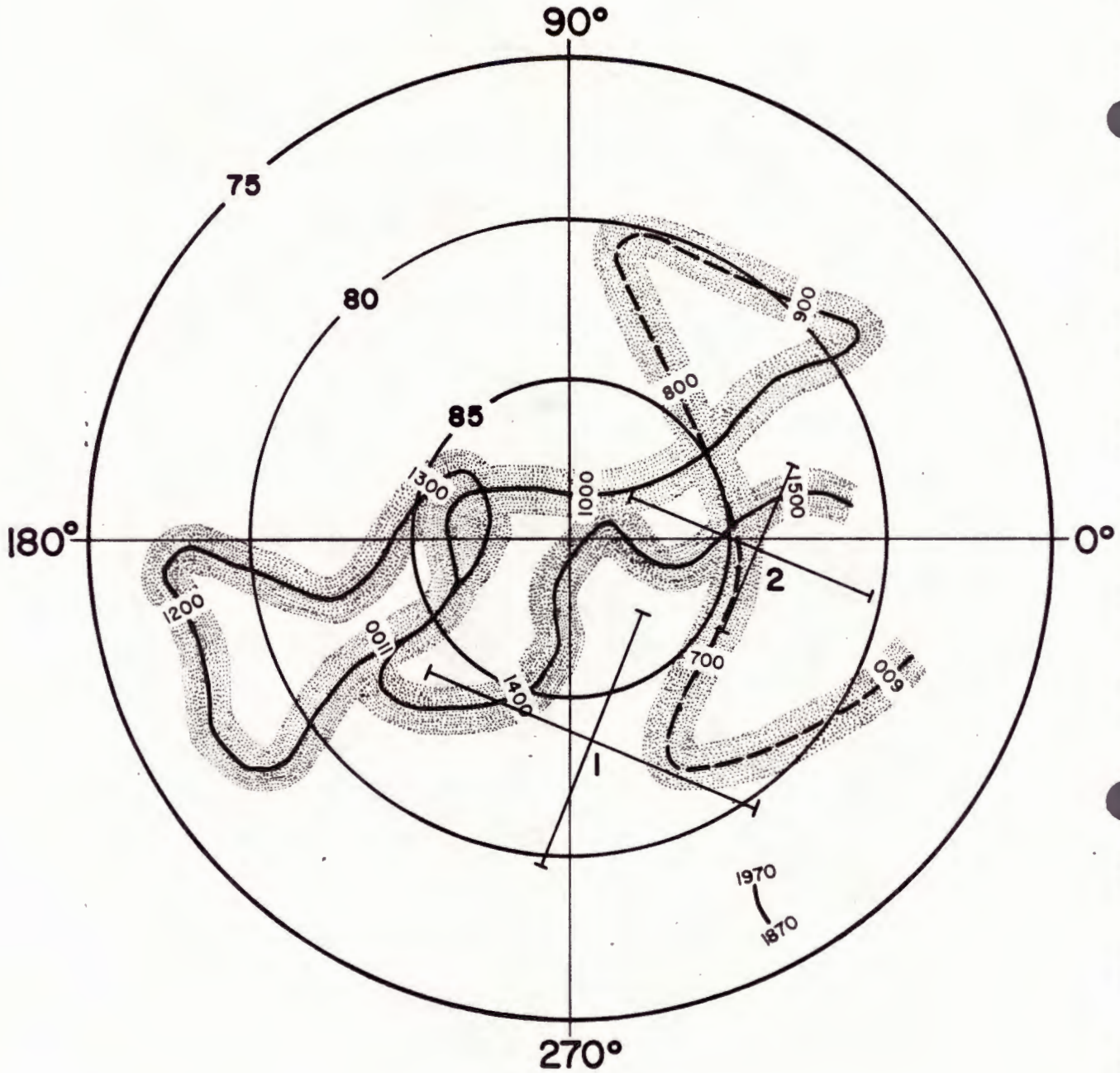


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.9 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2853, Sample 1.

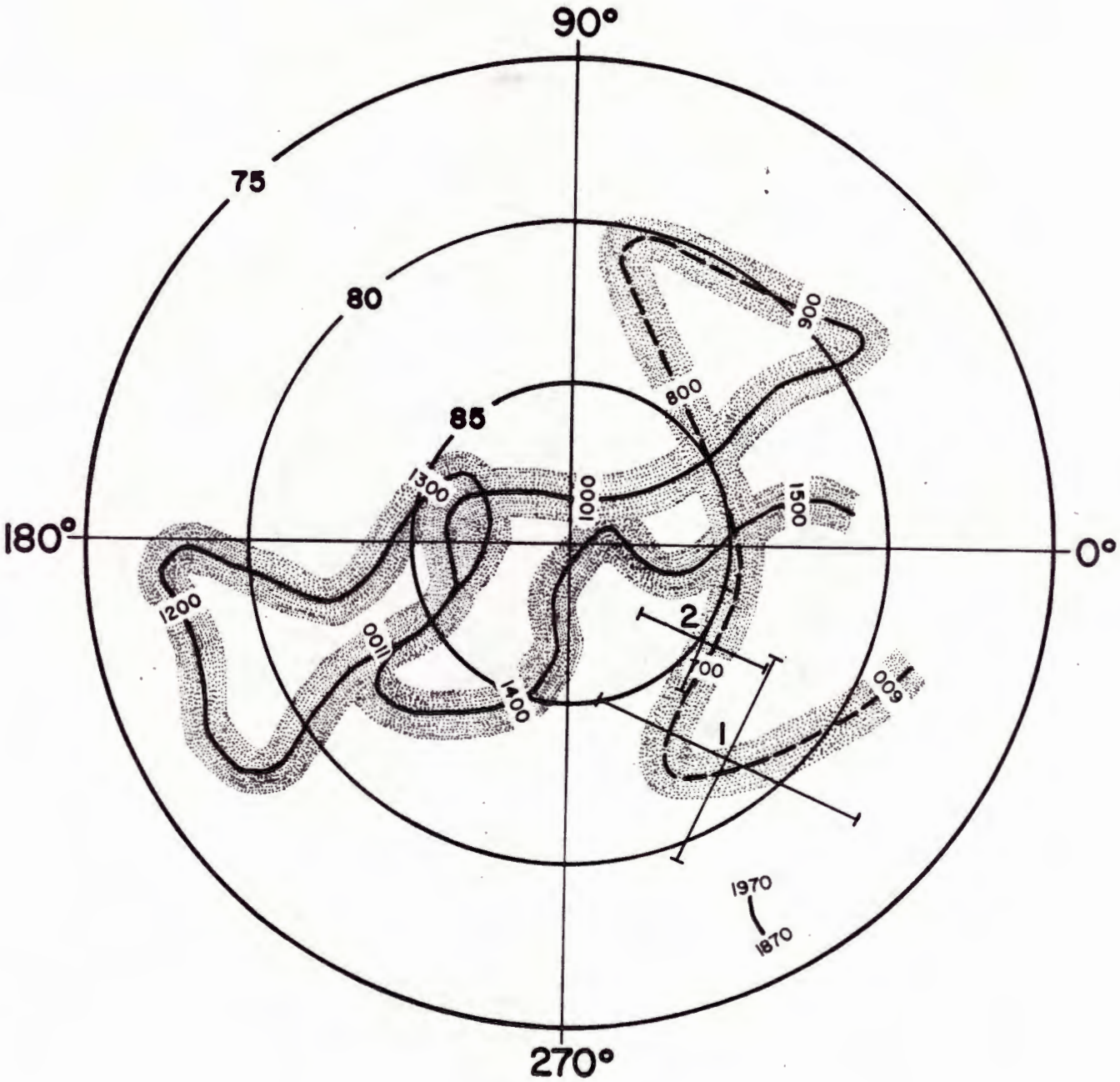


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.10 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2854, Samples 1 and 2.

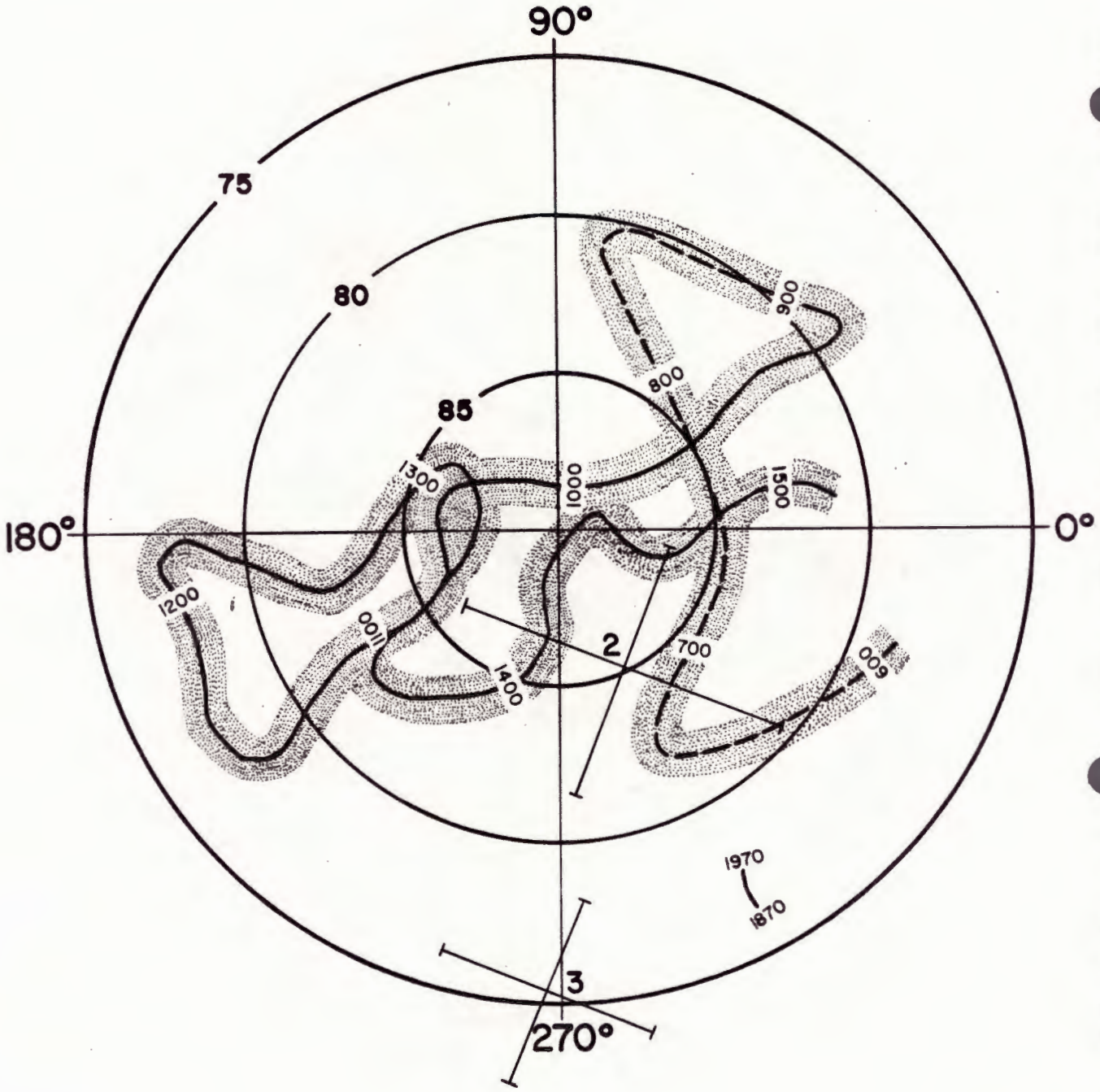


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.11 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT2858, Samples 1 and 2.

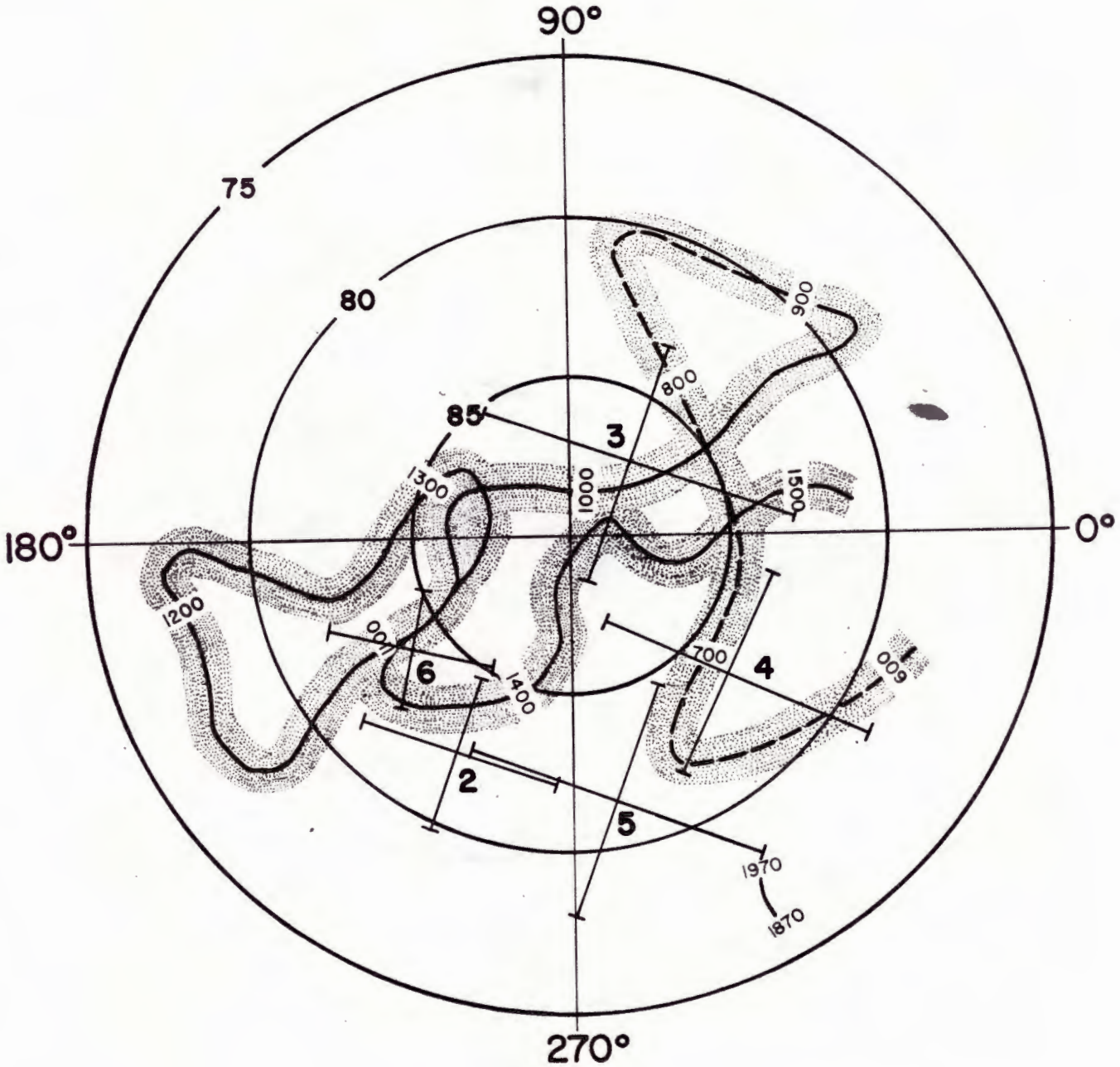


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.12 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT4512, Samples 2 and 3.

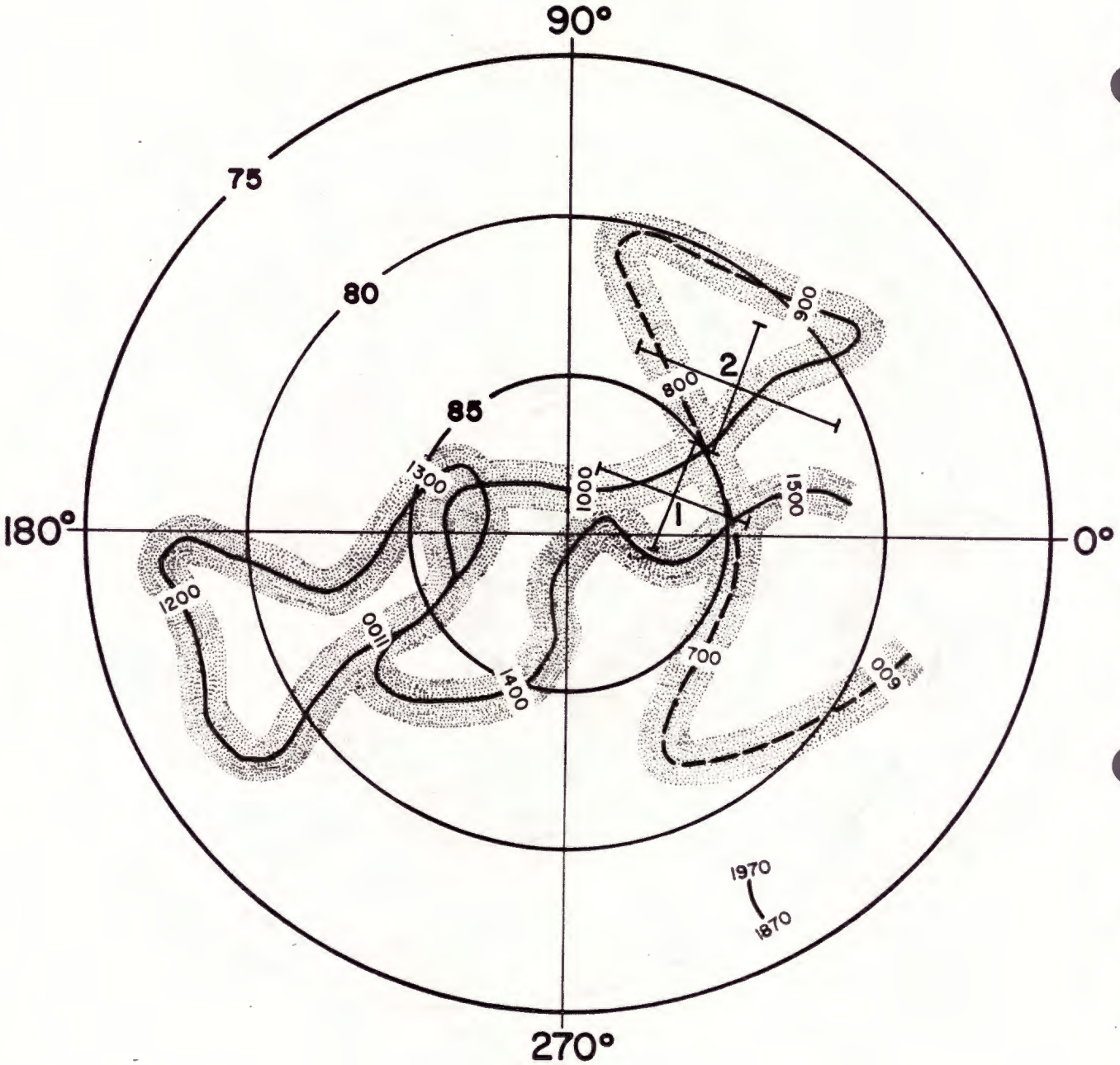


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.13 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT4545, Samples 2-6.

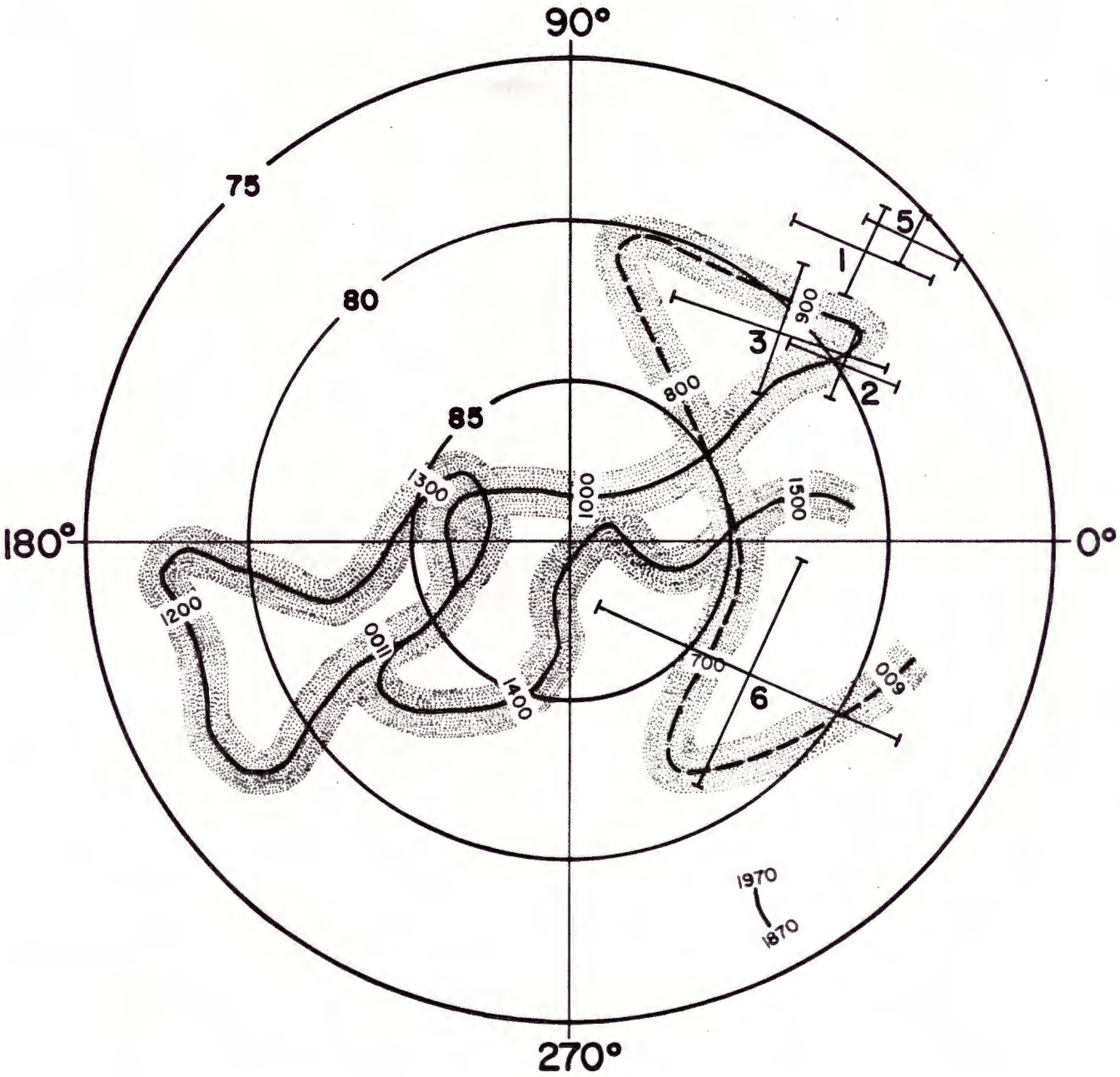


Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.14 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT4614, Samples 1 and 2.



Solid portion based on Dubois [2].

Dashed portion is based primarily on Wolfman [3].

Modern portion is calculated from U.S.G.S. magnetic declination and inclination maps for the United States - Epoch and from Svendsen [10].

Figure 11.B.15 Paleopole representations of successful archaeomagnetic samples during the 1979 field season at the D.A.P. for Site 5MT4644, Samples 1-3, 5, and 6.

APPENDIX C

MODIFICATION OF THE SOUTHWEST ARCHAEOMAGNETIC CURVE A.D. 700 TO A.D. 900: DOLORES ARCHAEOLOGICAL PROGRAM RESULTS

by

J. Holly Hathaway, Jeffrey L. Eighmy, and Allen E. Kane

ANASAZI HERITAGE CENTER
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INTRODUCTION[1]

Archaeomagnetic dating depends ultimately on a large set of independently dated samples representing ancient pole positions (or virtual geomagnetic poles--VGPS) from which a composite record of the apparent ancient polar wandering can be constructed for a region. Therefore, the collection of well-dated samples yielding accurate pole positions is an important concern of archaeomagnetists. For the Southwest, the apparent polar wandering is fairly well documented between A.D. 1000 and A.D. 1500 (Dubois [2] and Eighmy et al. [4]); therefore, current archaeomagnetic research interest in the Southwest focuses on extending documentation of VGP variation to earlier periods. Opportunities in this regard have become available through research activity conducted by the Dolores Archaeological Program in southwestern Colorado. During the 1978, 1979, and 1980 field seasons, program field personnel collected 163 archaeomagnetic samples, almost all of which, based on preliminary interpretations of archaeological survey data, date to the seventh, eighth, ninth, and tenth centuries A.D.

Archaeomagnetic samples were recovered from 31 prehistoric "permanent-habitations" sites in the project area. Twenty-seven of the sites (termed "hamlets") were probably occupied for a short span (20-30 years) by a few family groups, while the other four are larger "villages," perhaps continually occupied by 10-30 families for 100 or 150

[1]Thanks are due Dr. Edwin E. Larson, Department of Geological Sciences, University of Colorado, for facilitating measurement of this large data set in his paleomagnetic laboratory, and for his help in providing insights in analysis of the data.

years. Most samples were recovered from hearths in surface rooms or subterranean dwellings (pithouses); a minority was collected from burned earthen walls constituting pithouse structural remains. Approximately 30 percent of the samples were from media (hearths, pits, and walls) with remanent magnetisms that consistently produced sample directions with alpha 95 values of less than 2.6°. As comparable temporal data from independent sources are available for most of the sites, efforts to evaluate the Southwest master curve focused on these data.

Independently Dating the Archaeomagnetic Samples

Based on independent lines of evidence (ceramic and architectural seriation, and dendrochronological and radiocarbon dating) the Dolores Archaeological Project could assign occupation periods for 13 sites (Table 11.C.1). It should be noted that the dates given are estimates and represent the range within which the actual span of prehistoric occupation probably occurred. Within these sites the ages of the specific sampling media were estimated by the excavation crews. Subsequent laboratory analysis has resulted in reevaluation and more precise determination of these field estimates. The original "guess dates," associated radiocarbon and dendrochronological dates, and the final (revised) estimates of feature ages are represented in Table 11.C.2. In those cases where associated dates from other sources were not available, the field guess date and the estimated occupational span were considered in arriving at a final estimated date of when the sample media were burned or last burned. The ambiguity in such cases is exemplified by the assignment of a larger uncertainty factor.

Table 11.C.1 Occupation Periods for Sites with Archaeomagnetic Samples

Site	Occupation Period (years A.D.)*
5MT0023	800-950
5MT2181	775-825
5MT2182	775-875
5MT2320	800-900
5MT2848	675-725, 775-825
5MT4475	800-975
5MT4477	850-950
5MT4480	850-925
5MT4545	600-650
5MT4614	700-775
5MT4644	750-825
5MT4684	650-725
5MT4725	825-900

*Estimates based on architectural, dendrochronological, carbon-14, and ceramic evidence. The occupation period is the time during which the occupation of the site occurred. The actual span of occupation within this period was probably somewhat shorter, but cannot be specified exactly.

Table 11.C.2 Independent Dating of Features with Archaeomagnetic Samples

Sample (Site plus sample number)	Location of Archaeomagnetic Sample	Independent Dating (tree-ring cutting date, A.D.)*	Final Estimate (A.D.)**
5MT0023-3			
5MT0023-7	Pithouse 6, hearth	798vv,828vv	880±20
5MT0023-8	Pithouse 4, hearth	858+vv	880±20
5MT0023-9	Pithouse 2, hearth	699vv,722+vv	890±20
5MT0023-13	Pithouse 3, hearth (Feature 100)	852r	870±10
5MT0023-14	Pithouse 3, hearth (Feature 312)	852r	865±10
5MT0023-15	Pithouse 13, floor (Surface 2)	795+vv,850vv	880±20
5MT0023-19	Pithouse 17, west wall	882++vv	900±20
5MT0023-21	Pithouse 10, north wall	867+r	880±10
5MT2151-13	Pithouse 2, hearth	700++vv,482vv	750±30
5 MT2181-1	Pithouse 1, hearth	779vv,780v	790±10
5MT2182-3	Pithouse 1, east bench	790r,793r	800±10
5MT2192-2	Room 1, floor		780±20
5MT2236-2	Pithouse 1, hearth	758v-765v (7 samples), 765r (1 sample)	780±10
5MT2320-1	Pithouse 1, hearth		880±30
5MT2848-2	Pithouse 1, floor	783vv,784r	800±10
5MT4475-14	Pithouse 3, hearth (remodeled area)	875v,874v,874r	890±10
5MT4475-15	Pithouse 3, hearth	875v,874v,874r	890±10
5MT4475-16	Pithouse 3, east wingwall	875v,874v,874r	890±10
5MT4475-18	Pithouse 3, north wall	875v,874v,874r	890±10
5MT4475-20	Pithouse 5, hearth	825vv	880±15
5MT4477-2	Pithouse 2, west wall	871r,871r,871B	890±10
5MT4480-1	Pithouse 4, hearth	864B,874vv	880±15
5MT4545-2	Pithouse 1, north-northwest wall	598vv,552vv	650±30
5MT4545-6	Room 1, floor		650±30
5MT4614-1	Pithouse 1, hearth		725±30
5MT4614-2	Pithouse 2, hearth		750±30
5MT4644-1	Pithouse 1, west wall	787vv,793vv	820±20
5MT4644-2	Pithouse 2, hearth	776r	790±10
5MT4644-3	Pithouse 3, north wall	776r	790±10
5MT4644-5	Pithouse 1, north wall	787vv,793vv	820±20
5MT4644-8	Pithouse 3, hearth		760±30
5MT4684-1	Pithouse 1, hearth	559vv,669v	690±15
5MT4684-5	Pithouse 5, hearth		700±30
5MT4725-2	Pithouse 1, hearth	845r (3 samples), 845v (1 sample)	860±15
5MT4725-6	Pithouse 5, hearth		880±25

Key for Table 11.C.2

*Letter abbreviations after dates are as follows:

B - part of original bark is present.

r - less than a full section is present, but the outermost ring is continuous around available circumference.

vv - a subjective judgment that, although there is no direct evidence of the true outside on the specimen, the date is within a very few years of being a current date.

v - there is no way of estimating how far the last ring is from the true outside.

+ - one or more rings may be missing near the end of the ring series whose presence or absence cannot be determined because the specimen does not extend far enough to provide an adequate check.

++ - a ring count is necessary due to the fact that beyond a certain point the specimen could not be dated.

**Final estimate is best approximation of last prehistoric use of sampling medium based on occupation period (Table 11.C.1) and specific reconstruction of use history of structures and features and samples. The confidence interval is based on the precision of the dating methods used to arrive at the estimate.

Sampling and Laboratory Procedure

Twelve separate 1 in^3 specimens were recovered when sampling a burned feature. The collection procedure followed standard archaeomagnetic practices in the U.S. (Windes [33], Eighmy [6], Hathaway [12]). The natural remanent magnetism (NRM) of each specimen was first measured in the laboratory on a Schonstedt Spinner magnetometer; then selected specimens were demagnetized at 25 oersted intervals using the alternating field method. After this process, determination of the optimum demagnetization level for a sample was made from the level at which the pilot specimens' directions converged and stabilized. Generally, samples characterized both by minimal scatter of the NRM directions and high intensities changed little in direction during demagnetization. In contrast, weakly magnetized samples had large alpha 95 values and demagnetization did little to reduce these values while directions changed more radically.

Occasionally, samples contained specimens which were directionally inconsistent with a majority of the sample directions. These specimens were defined as "outliers" if they lay more than two angular deviations away from the mean of the remaining specimen set (methods for calculating angular deviations of samples are presented by Irving [11:68]). Due to statistical reliance on measurements of squared distances, outliers affect the sample mean and measures of confidence disproportionately. Therefore, it is felt that omitting outliers results in a better representation of the true direction created by the ancient firing, as well as improving statistical measures of confidence (i.e., alpha 95, precision (k) parameter, and R vector). Samples in which more than a quarter of the specimens were identified as outliers were not used in the subsequent

analysis. Further, only samples with excellent magnetization were used, i.e., those with alpha 95 < 2.6°.

Results

The distribution of declinations (D) and inclinations (I) (Table 11.C.3) are fairly consistent internally with the exception of a low westerly declination value at A.D. 800 (Sample 5MT2182-3). Due to the extreme position of this sample relative to other samples dated to this age, this sample was deleted from the subsequent analysis. The scatter in D and I at a given time (generally less than + 4°) may be attributed to several factors: degree of accuracy of the independent age assessments and possible mechanical shifting of burned matrices prior to collection. Another factor which may contribute to the ambiguity of these directions is the difficulty in discriminating at what time the remanent magnetization was attained and, accordingly, what physical process produced this remanence (i.e., thermoremanent magnetization (TRM), partial thermoremanent magentization (PTRM), chemical remanent magentization (CRM), or a combination of these in the past. The temporal variance between these occurrences (TRM, PTRM, CRM) may be as large as 10-20 years, especially in samples recovered from features repeatedly heated over long periods of time (+ 10 years).

The D and I trends apparent from the Dolores material indicate very little fluctuation in declination values from A.D. 700-900 (less than ± 4°) (Figure 11.C.1) while inclination changes more measurably (Figure 11.C.2). Several inclination minima are apparent from the Dolores data: one at A.D. 690 (documented only by one data point), another at A.D. 820, and a trend toward minimum inclination noted at A.D. 890. Similar

Table 11.C.3 Archaeomagnetic Results from the Dolores Archaeological Program

Sample ID	Site Latitude	Site Longitude (E)	No. of Specimens	Demagnetization level (oersteds)	Declination	Inclination	Alpha 95	k
5MT0023-3	37.57	251.46	12	125	356.14	55.20	1.48	858.38
5MT0023-7	37.57	251.46	12	25	2.28	56.85	2.34	344.00
5MT0023-8	37.57	251.46	12	25	0.84	57.10	1.48	861.73
5MT0023-9	37.57	251.46	10	25	1.70	54.06	2.54	363.93
5MT0023-13	37.57	251.46	11	50	2.85	56.02	2.21	429.53
5MT0023-14	37.57	251.46	10	50	1.83	58.08	1.82	704.23
5MT0023-15	37.57	251.46	12	50	4.13	53.37	1.00	1871.82
5MT0023-19	37.57	251.46	12	100	353.19	59.94	2.34	345.29
5MT0023-21	37.57	251.46	12	50	2.67	49.54	1.39	971.16
5MT2151-13	37.63	251.43	12	25	2.72	50.16	2.03	457.71
5MT2181-1	37.54	251.46	12	50	1.10	47.46	1.88	532.78
5MT2182-3	37.54	251.46	12	50	353.99	43.68	2.02	464.82
5MT2193-2	37.52	251.43	11	150	0.50	53.25	2.00	520.94
5MT2236-2	37.51	251.43	12	25	2.98	55.68	2.25	373.70
5MT2320-1	37.52	251.47	9	25	3.31	57.88	1.44	1280.05
5MT2848-2	37.52	251.43	12	75	5.91	45.12	1.28	1156.42
5MT4475-14	37.52	251.45	9	50	3.98	55.17	2.33	490.45
5MT4475-15	37.52	251.45	10	100	2.87	54.06	1.12	1850.42
5MT4475-16	37.52	251.45	12	150	9.30	47.57	1.73	627.43
5MT4475-18	37.52	251.45	11	50	6.05	49.73	1.43	1019.44
5MT4475-20	37.52	251.45	11	50	4.69	52.31	1.71	709.97
5MT4477-2	37.52	251.45	12	75	6.63	52.16	1.72	637.08
5MT4480-1	37.53	251.45	11	50	3.96	53.43	2.54	325.12
5MT4545-2	37.51	251.42	9	25	358.75	63.56	2.21	543.06
5MT4545-6	37.51	251.42	12	100	349.94	58.94	1.92	511.91
5MT4614-1	37.52	251.42	12	25	1.26	54.96	1.72	635.97
5MT4614-2	37.52	251.42	9	25	2.23	50.47	2.38	469.05
5MT4644-1	37.53	251.45	12	75	4.54	42.52	1.40	960.98
5MT4644-2	37.53	251.45	11	100	6.04	46.45	1.32	1200.33
5MT4644-3	37.53	251.45	12	100	2.91	44.64	2.55	290.74
5MT4644-5	37.53	251.45	12	75	3.89	40.59	1.65	691.40
5MT4644-8	37.53	251.45	10	50	1.87	46.32	2.20	482.96
5MT4684-1	37.52	251.45	12	125	4.84	50.87	1.96	489.70
5MT4684-5	37.52	251.45	11	50	4.84	55.92	1.93	558.51
5MT4725-2	37.52	251.45	12	50	3.66	52.22	2.19	393.76
5MT4725-6	37.53	251.45	11	50	4.45	55.65	2.28	403.17

*Paleolatitude and paleolongitude, R vector, EM and EP can be calculated from table values. All samples consisted of 12 specimens originally. Local magnetic declination is 11.55.

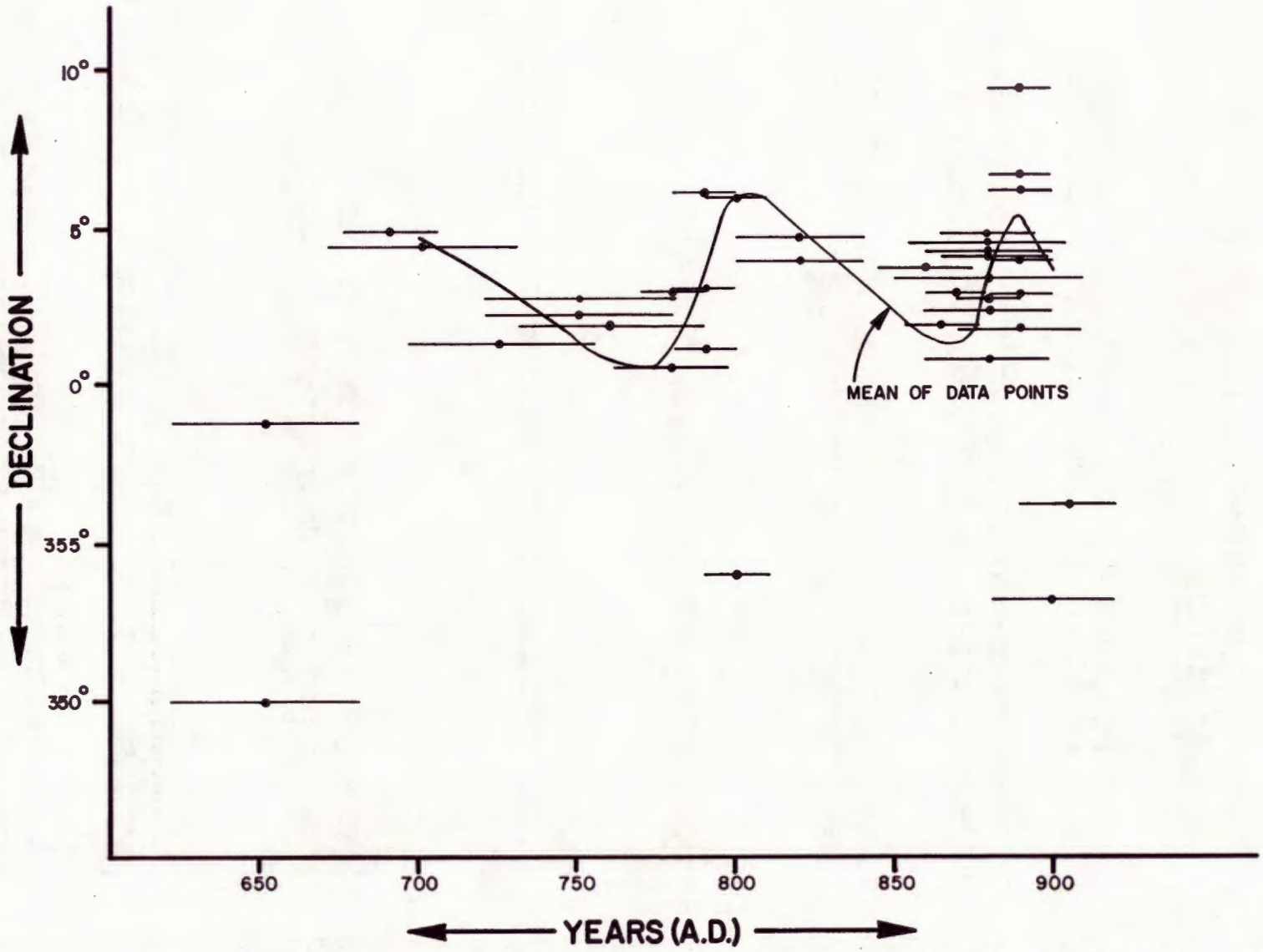

Figure 11.C.1 Declination of archaeomagnetic samples dated to the seventh, eighth, ninth, and tenth centuries A.D. in southwest Colorado. Uncertainty in the independent dating of the samples is illustrated as a bar either side of the estimated age. Declination error (alpha 95) is omitted for clarity but can be obtained from Table 11.C.3. The trend line represents a free-hand interpretation of declination change.

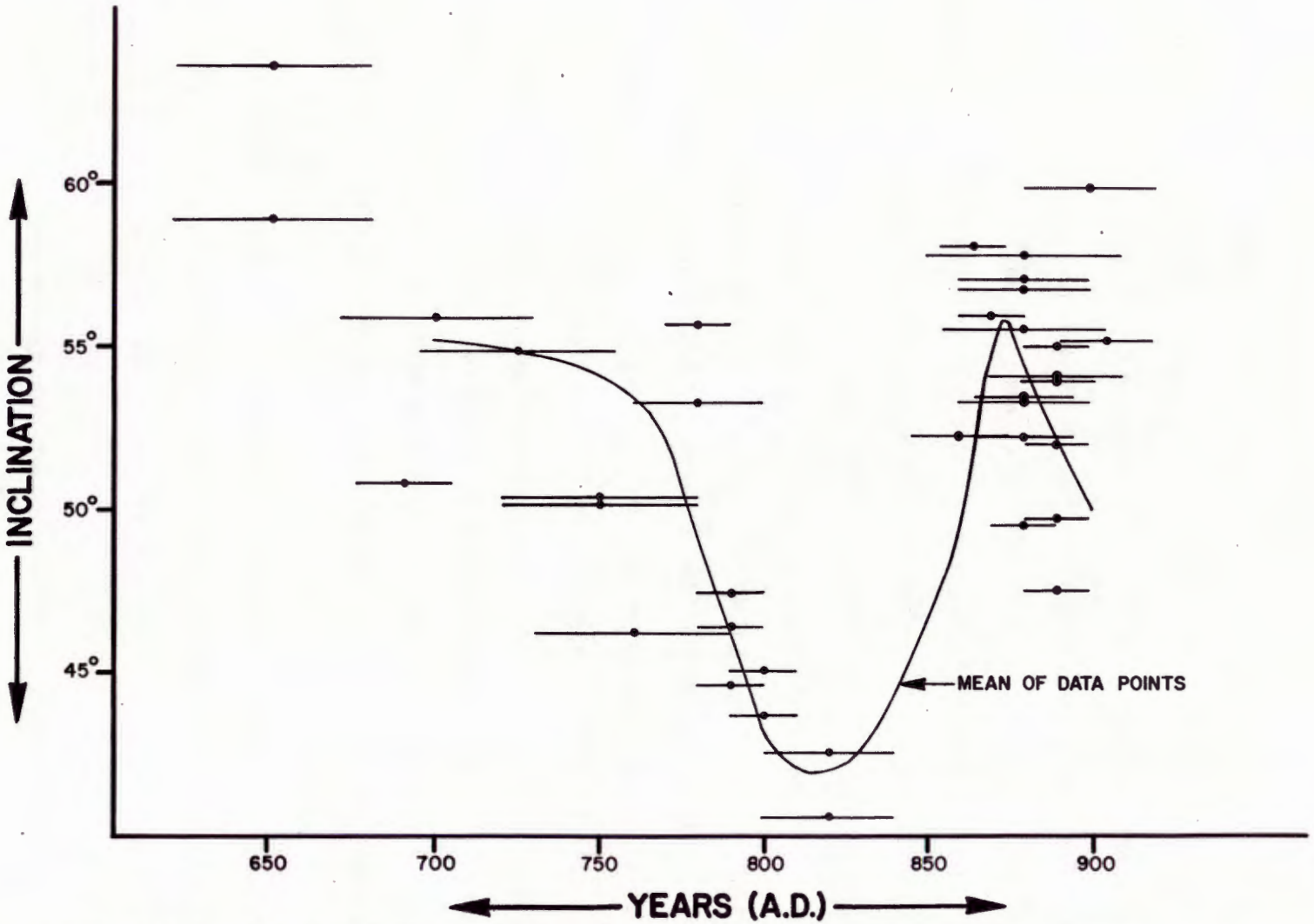

Figure 11.C.2 Inclination of archaeomagnetic samples dated to the seventh, eighth, ninth, and tenth centuries A.D. in southwest Colorado. Uncertainty in the independent dating of the samples is illustrated as a bar either side of the estimated age. Inclination error (alpha 95) is omitted for clarity but can be obtained from Table 11.C.3. The trend line represents a free-hand interpretation of inclination change.

inclination values were reported for the Southwest by Watanabe and DuBois [34] and later by DuBois [2] (for the latter minimum only). Maximum inclinations are noted at A.D. 650, A.D. 700, and A.D. 870.

In order to provide an impression of apparent paleopole movement for the Dolores area, two methods can be used. First, the D and I values for samples with similar age assignments can be averaged and measures of confidence calculated. Because samples within a particular age group are occasionally from different archaeological sites, the site latitudes and longitudes are also averaged; however, variation between sites was seldom greater than 0.05° in latitude or longitude.

The averaging is based on the mean declination and inclination values of each sample; these values are then converted to a paleopole location. Giving unit weight to the mean directions of each sample, confidence measures can be calculated according to Fischer [35]. Error along the great circle (EP) and perpendicular to the great circle (EM) constitute the axes of the ellipse describing the 95 percent confidence interval (alpha 95) about the mean paleopole direction. Consideration of these parameters relative to the mean paleopole positions will more accurately represent the scatter inherent in sample sets used for calibration of the curve. Only dates with more than three samples were used in this averaging procedure. Three groups were thus identified at A.D. 790, A.D. 800, and A.D. 890. The mean pole positions and confidence measures are presented in Table 11.C.4, and represented on the polar stereographic projection map in Figure 11.C.3.

It is evident from this representation that the scatter inherent in the A.D. 890 data are more variable than the A.D. 790 or A.D. 880 material.

Table 11.C.4 Mean Virtual Geomagnetic Pole Positions of Samples from the Dolores Area* for Selected Dates

Year (A.D.)	Number of Specimens	Apparent Mean Paleo-direction: Dolores Area Samples		Mean Paleopole Location		Statistical Measure of Confidence		
		Declin-ation	Inclin-ation	Lati-tude	Longi-tude	Alpha 95	EM†	EP††
790	3	3.36	46.20	79.61	54.70	3.86	4.95	3.17
880	8	3.32	54.52	86.34	23.49	2.01	2.67	2.00
890	6	5.22	51.15	83.59	28.19	5.81	7.96	5.46

*The center of the Dolores area sites with archaeomagnetic samples was taken to be 37.54° Latitude (N) and 251.45° Longitude (E). Local magnetic declination (1980) is 11.55°.

†Error perpendicular to the great circle.

††Error along the great circle.

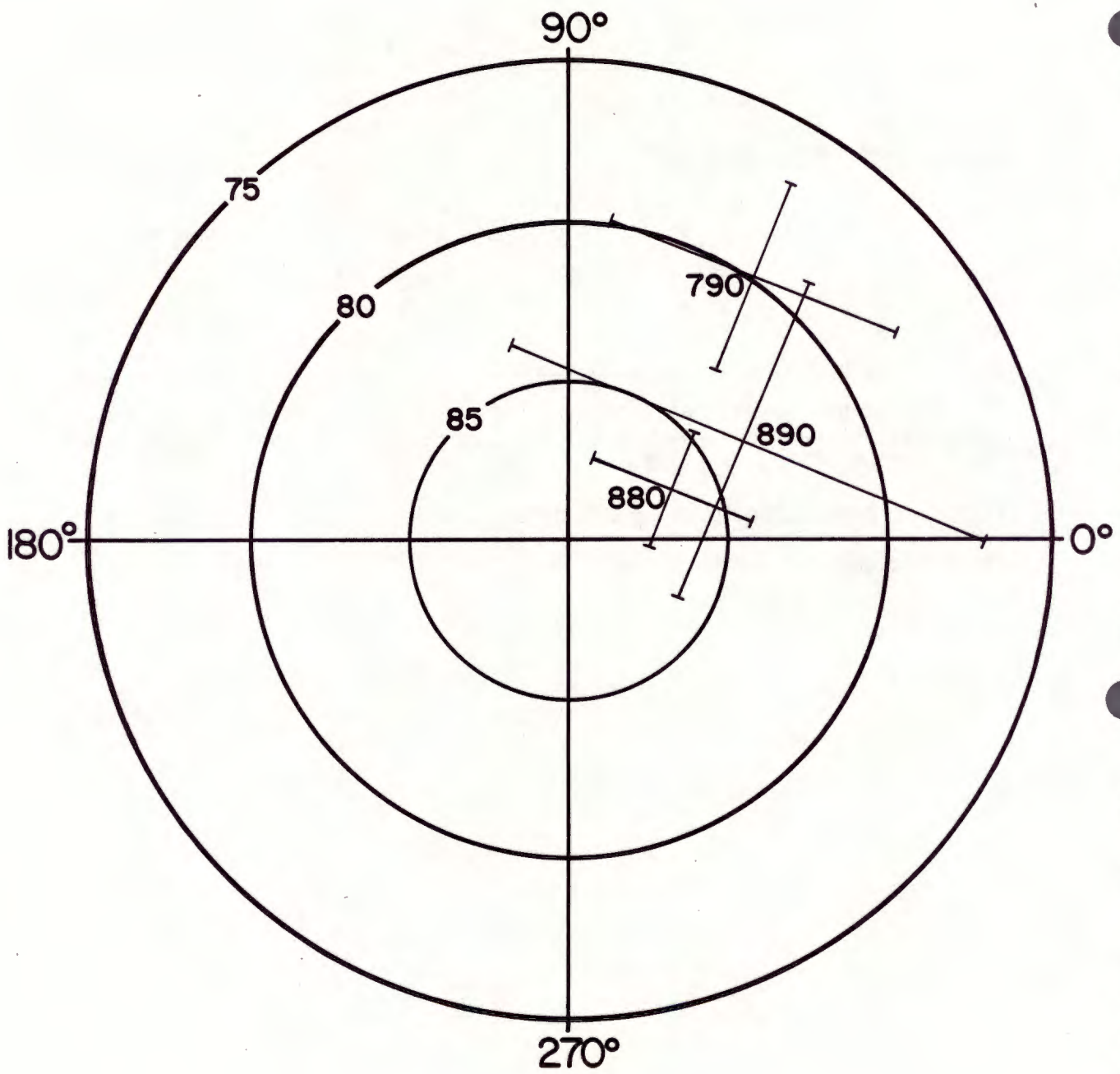

Figure 11.C.3 Polar representation of Dolores Archaeological Program averaged VGP mean positions and respective ovals of confidence (alpha 95s) for A.D. 790, 880, and 890.

The second method uses declination and inclination trend values to reconstruct a VGP path. Fourteen data points were selected from the trends in declination (Figure 11.C.1) and inclination (Figure 11.C.2) between A.D. 700 and A.D. 900 in addition to the three averaged D and I values determined in the previous method (Table 11.C.4). The D and I values for each selected point were then converted to paleopole locations; these are presented in Table 11.C.5. For ease of visualization and comparison with previous reconstructions, the VGP path described by this data was then plotted (Figure 11.C.4). This path can be used to compare Dolores results with the other available VGP paths for the Southwest during this time period (Wolfman [3:528]).

Discussion

The available data suggest that the A.D. 700-900 trend in the north magnetic pole as apparent from Dolores went, first, through a clockwise ellipse and then through a counterclockwise oval. Further, the rate of change in the VGP path motion seems to slow slightly during curves and to speed up during periods of linear travel. When compared with the early segment of the Southwest master curve described by Weaver [1] and Wolfman [3], the Dolores data suggest a substantial modification of the A.D. 700 to A.D. 900 segment. This modification is due largely to lower inclination values for A.D. 790 to A.D. 825 and higher inclination values for A.D. 865 to A.D. 890.

There is an urgent need for more data in order to better define and to routinely refine secular variation. With respect to the A.D. 700 to A.D. 900 period, two important problems can be specified: (1) a significant gap in information exists between A.D. 825 and A.D. 860 which

Table 11.C.5 Data Used to Reconstruct the A.D. 700-900 Path of the Apparent Polar Wandering for the Dolores Area*

Year (A.D.)	Apparent Paleo-direction: Dolores Area Samples		Apparent Virtual Geomagnetic Pole Location: Dolores Area Samples	
	Declination	Inclination	Paleolatitude	Paleolongitude
700	4.60	55.20	85.89	6.19
725	3.05	54.80	86.70	22.50
735	2.40	54.50	86.83	33.13
750	1.40	54.00	86.79	50.38
775	0.50	50.50	83.69	67.56
780	1.00	48.70	82.06	65.15
790	3.40	46.20	79.60	54.70
800	5.80	42.90	76.45	48.42
810	5.80	42.00	75.80	49.38
815	5.40	41.80	75.78	50.98
825	4.50	42.20	76.30	53.89
850	2.20	46.40	80.00	60.16
865	1.20	51.90	84.88	60.03
875	1.40	55.80	88.03	36.53
880	3.30	54.50	86.30	23.50
890	5.20	52.20	83.60	28.20
900	3.60	50.00	82.62	46.62

*The center of the Dolores area sites with archaeomagnetic samples was taken to be 37.54° Latitude (N) and 251.45° Longitude (E). Local magnetic declination (1980) is 11.55°.

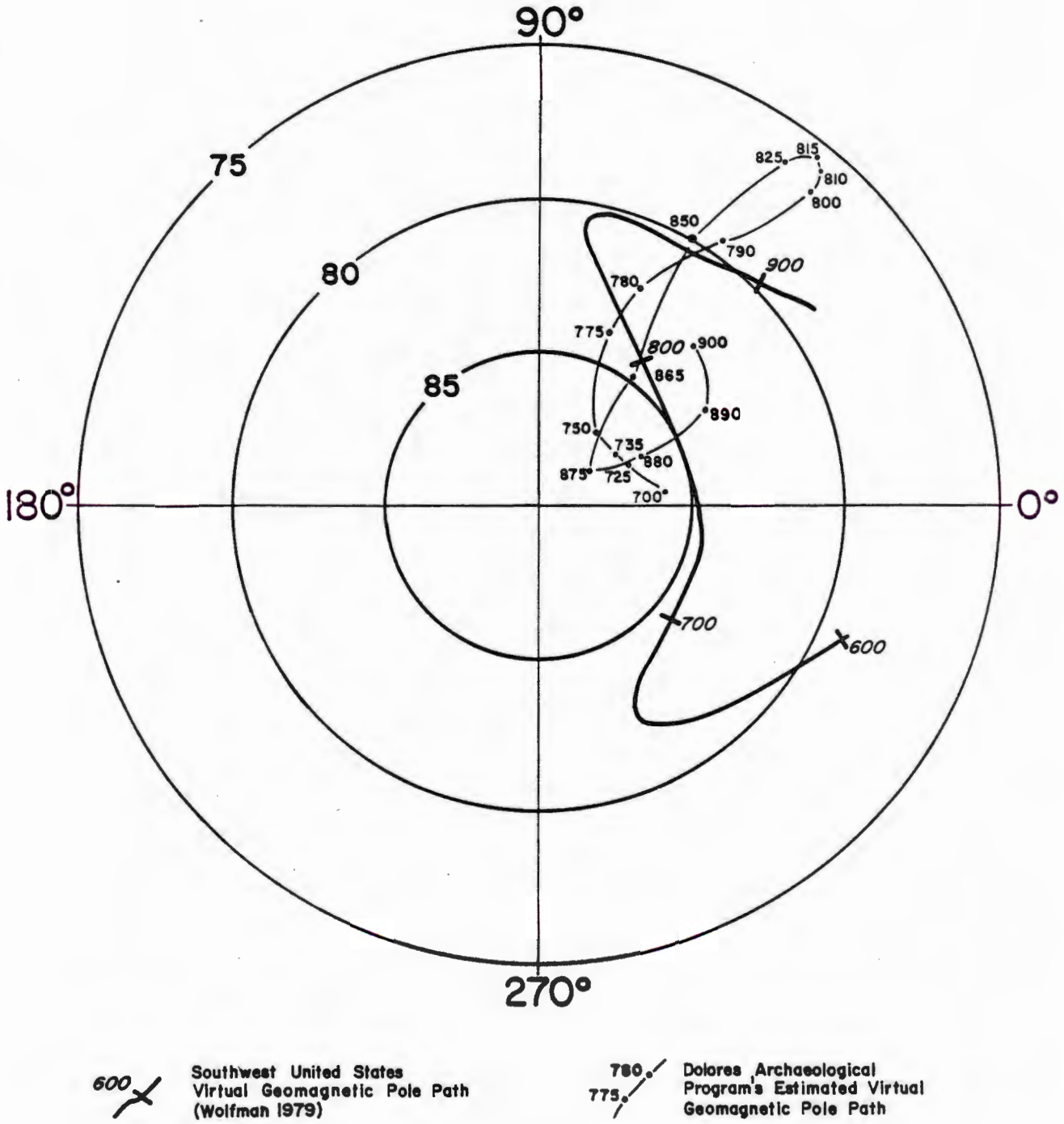

Figure 11.C.4 Comparison of D.A.P. results with the Dubois Southwest master curve.

needs to be filled, and (2) the characteristics of the curve for this 200 year segment appear more complex than for later portions of the Southwest master curve.

Still, it is reassuring to note general and some specific congruence between the available versions of this portion of the curve. First, declination changes are slight by all accounts. Second, between A.D. 700 and A.D. 800 all reconstructions evidence declining inclination. Third, the Dolores reconstruction links fairly well with the early end of the A.D. 1000 to A.D. 1500 portion of the Southwest master curve. And, fourth, specific similarities with the early Weaver [1] version and the Dolores material is evident at A.D. 790 and A.D. 900.

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