Andean Past

Volume 5 Article 20

1998

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Introduction

In recent years considerable progress has been made in the reconstruction of records of the changes in geomagnetic direction using the archaeomagnetic method. While numerous results have been reported for the northern hemisphere, until recently few measurements have been made on samples collected in the southern hemisphere. During the summers of 1982 and 1983, a total of 134 archaeomagnetic samples, each consisting of approximately eight individually oriented specimens were collected at 37 archaeological sites in Peru (Dodson and Wolfman 1983; Wolfman and Dodson 1986). The majority (103) of these samples were collected at 22 sites on the North Coast between the Casma and Lambayeque River valleys. The largest collections were obtained at the sites of Manchan (in the Casma valley), Chan Chan (in the Moche Valley), and Huaca del Pueblo Batán Grande (in the La Leche Valley). The 24 samples in stratigraphic superposition collected at Huaca del Pueblo Batán Grande were especially critical to the construction of the archaeomagnetic record for the period *ca*. AD 675 - 1450. Nineteen specimens were collected at eight sites in the Rímac and Lurín drainages near Lima, ten were from six sites scattered in the highlands, and two were from a single site on the south coast. Most of the samples were collected from baked features which date from the time period *ca*. A.D. 550 - 1550. Consequently, the work thus far accomplished has led to the construction of an archaeomagnetic polar curve for most of this time period which is valid for at least a 500 mile diameter circle centered at about 10° S and 78° W (North Central coast of Peru).

Archaeomagnetism in Geophysics and Archaeology

The importance of archaeomagnetic data to several disciplines has been emphasized in a number of recent publications (Schurr *et al.* 1984; Thellier 1981). In geophysics these data provide the most exact information obtainable about the past changes in the direction, magnitude, and variability of the geomagnetic field prior to direct measurements. This information in turn provides constraints on models of the manner in which the field is generated. A great deal of work has been done to develop geomagnetic records from lacustrine and marine sediments. However, the magnetic data obtained from these sources are poor in comparison to those obtained from baked clays in archaeomagnetic studies. In addition, whereas baked clay samples from archaeological sites can often be readily dated by one or more methods, sediments are very difficult to date reliably. Of equal importance, archaeomagnetic data (particularly directional data) obtained from baked clay provide the basis for an archaeological dating method whose precision in many situations is on the order of ± 20 to ± 50 years at the 95% confidence level. This high precision allows archaeologists to make inferences concerning culture history and processes that are not possible using other chronometric methods with the exception of dendrochronology. This latter method unfortunately is of limited applicability, whereas archaeomagnetic dating can be applied in most areas around the globe. The accuracy of the archaeomagnetic method (*i.e.,* the calibration of the reference curves) is dependent on a variety of factors, including the independent dating methods used in the area (*e.g.*, dendrochronology, radiocarbon), the refinement of the local cultural chronology, and the number of archaeomagnetic samples collected.

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Paleointensity measurements from baked clays and ceramics have been of considerable interest to geophysicists, but, thus far, have been of far less importance in archaeological dating. Some attempts have been made to obtain paleointensity data from sediments, but the validity of these results is somewhat more dubious than the directional data.

The greatest disadvantage of archaeomagnetic directional measurements is the length of time required to collect enough samples to develop records of useful length. In contrast, millennia long cores can often be collected from lacustrine and marine sediments in a few hours. However, the time spent to collect samples which yield high quality archaeomagnetic data is worth the effort. Recently, archaeomagnetic data have been used as the standard against which those obtained from sediments are compared and, to some extent, verified (Verosub and Mehringer 1984; Wolfman *et al*. 1982). During the past decade, books and articles have reviewed these topics including lengthy discussions of the history of the method and the theory of the origin of the geomagnetic secular variation (Creer *et al*. 1990; Merrill and McElhinney 1983). These reviews and other recent developments, including the reporting of basic data, indicate that archaeomagnetic studies, which were formerly of central importance in paleomagnetism (*e.g*., Thellier and Thellier 1959), have recently undergone a resurgence.

Field and Laboratory Procedures

Field and laboratory procedures, including configuring and calibrating the curve, with minor modifications follow those discussed by Wolfman (1984, 1990).

Most samples were collected from ongoing excavations or from sites that had been excavated in the previous one or two years. A few samples were collected from baked features visible on the surface of several archaeological sites (particularly Chan Chan) and, finally, a very few were collected from the sidewalls of looters' excavations. All samples from excavated sites were collected with the cooperation of either the archaeologists in charge of the work at the site or others who were familiar with the excavations at the site. These archaeologists were able, in most cases, to provide important information about the approximate age of the collected samples based on radiocarbon results as well as ceramic and architectural styles.

Each archaeomagnetic sample consists of six to ten (but usually eight) oriented specimens encased in a plaster cube 1.062 inches on an edge. The specimens were transported to the University of California, Santa Barbara, where each specimen was measured in six orientations in a horizontal three axis SCT cryogenic magnetometer. The specimen mean direction was computed as the mean of the six measurements. Although the average magnetic moments of the individual samples are not reported on the accompanying table, the specimens are usually strong, with typical remanent magnetizations as large as 1×10^{-3} emu/cm^3, with approximately half the remanent magnetization remaining after demagnetization in a 100 Oersted (Oe) alternating magnetic field. Following measurement of the Natural Remanent Magnetism (NRM), each specimen was remeasured after "cleaning" in alternating demagnetization fields of 50, 100, and 150 Oe. The direction of magnetization of most samples did not change significantly with demagnetization beyond 50 Oe. Normally, the mean direction reported for a sample (see Table 1) is at the demagnetization level at which its angular dispersion is smallest. In a few instances where the direction continued to change significantly with increasing demagnetization, the mean direction for a higher demagnetization level than that of the minimum dispersion is reported. The sample mean direction is computed as the mean of all the specimens in the sample unless a specimen direction differs from the sample mean by more than two angular standard deviations. Such "anomalous" specimens are deleted. In addition, experience has shown that samples with alpha-95 (α_{95}) $\geq 4.0°$ often have aberrant directions. For this reason, the results from such samples are not used in curve construction or for archaeological dating. Of the total of 134 samples collected 68 (or 51%) have α_{95} values of less than four degrees. A high proportion, 56 samples (or 42%) of the samples collected, have an $\alpha_{95} \leq 2.0°$.

North and Central Coast results: A.D. 550 - 1550

The cultural and historical setting of prehispanic Peru as a whole, and of the North Coast in particular, from *ca.* 2000 BC to the Spanish conquest is fairly well understood. Throughout much of this century, considerable effort has been made to seriate the successive ceramic styles dating from this time. Radiocarbon dating has provided a framework of absolute dates. However, despite the general understanding of the chronological picture, major differences of opinion still exist concerning the absolute dating of major cultural developments on the north coast of Peru from A.D. 900 to 1500 (*e.g.,* Moseley and Cordy-Colllins 1990; Schaedel 1993). One group of archaeologists, basing their chronology in part on ethnohistorical documents, has argued that the Late Intermediate Period began in this region *ca.* AD 1200 (Cavallaro 1988, 1997; Conrad 1982; Kosok 1965; Rowe 1945, 1948; Schaedel 1993; Watson 1986). By this reconstruction, the site of Chan Chan (the capital of the Kingdom of Chimor) was established at this time. Others, particularly those involved in excavations at this site, date its founding at *ca.* AD 900 (Kolata 1982, 1990; Moseley 1975; Topic and Moseley 1983). This controversy continues to be a major stumbling block to cultural understanding on the north coast as illustrated in the proceedings of a recently published Dumbarton Oaks symposium (Moseley and Cordy-Collins 1990). A major goal of the research discussed in this article is to establish a geomagnetic record for Peru which eventually may help to settle this and other controversies.

Previous archaeomagnetic work and analysis of the modern geomagnetic field indicates that archaeomagnetic chronologies can be developed that are valid for areas *ca.* 500 miles in diameter. Although samples were collected in a wider area in this study, the great majority of them came from the north and central coasts from the Lurín Valley in the south to the Lambayeque Valley in the north, a distance of approximately 400 miles. The great majority of these samples dated between A.D. 550 and A.D. 1550. Fortunately, the samples were fairly well spread out in this time period and consequently, a curve for most of the time period A.D. 550 - 1550 has been constructed using selected results from 124 samples from 29 sites collected on the north and central coasts of Peru as well as 10 samples from 6 sites in the North Highlands. Because the samples for archaeomagnetic dating are collected from baked clay features, it is not surprising that sites on the coast, where many structures were made of adobe, produced far more samples than the highlands where stone was the principal construction material. Determination of the configuration of the curve has been greatly assisted by many stratigraphic sequences of samples, particularly 24 collected at the site of Huaca del Pueblo Batán Grande. Radiocarbon dating provided the primary basis for calibration of the curve. The many radiocarbon results from stratigraphic contexts at Huaca del Pueblo Batán Grande were crucial in this phase of the work. In addition, calibration was assisted by knowledge of the end date of the prehistoric period (A.D. 1532) and the generally accepted date of the conquest of the Chimú Empire by the Inca around 1460-1470. Of the 134 samples collected during the two field seasons, 60 were used for the construction of the current curve. Some points may be found on more than one section of the curve, as they may date to more than one time range. Finally, the length of the curve between A.D. 675 and *ca.* 1500 is *ca.* 50°, suggesting an average rate of secular variation of *ca.* 1°/10 years, which is in very good agreement with the rate found in other parts of the world. While it is a little premature to assign exact dates to the results, a few approximate dates using the curve as constructed are offered here. Encouragingly, they are in very good agreement with information suggested by other dating methods.

For convenience the curve has been divided into three sections:

1. A.D. 675 - 1300. This section of curve starts with two samples (109 and 110) col-

lected at Pampa Grande (Table 1). Shimada (1994) and others (*e.g.,* Haas 1985) have suggested that a major conflagration took place at the end of the Moche V occupation of this site at the neck of the Lambayeque Valley. The results from the two archaeomagnetic samples collected from widely separated baked features, which have almost identical pole positions, support this. The radiocarbon dates from this site (see Appendix in Shimada 1990:372-382; table 2 in Shimada 1994:4-5) suggest a date of *ca.* A.D. 675 for this great fire. The configuration of the rest of this section of curve is essentially defined, as noted above, by 24 stratigraphically superimposed samples from Huaca del Pueblo Batán Grande. Thirty-one radiocarbon results (see table 3 in Shimada 1995:183-187), which are in excellent agreement with the stratigraphy at this site and associated ceramic material, provided information for the calibration of the curve. Of particular interest, two samples (131 and 132) from the lowest levels of Huaca del Pueblo Batán Grande, associated with Moche V material, appear to date at *ca.* A.D. 700. In those cases where there is some independent chronometric information for samples collected at other sites, the archaeomagnetic results provide confirmation. For example, two Middle Horizon samples (125 and 126) were collected from the Huaca La Pintada section of Pachacamac in the Lurín Valley. Based on the chronology inferred from the Huaca del Pueblo Batán Grande samples, an archaeomagnetic date of *ca.* A.D. 800 is indicated. This is within the accepted time range of the Middle Horizon, and furthermore, is in reasonably good agreement with a recent radiocarbon date of 1180 ± 70 B.P. (PUCP-83) for this period at this site (Paredes and Franco 1985:80; Shimada 1991:xxvii-xxx).

Three samples (35, 107, and 108) from the site of Huaca El Corte, 15 km northwest of Huaca del Pueblo Batán Grande, are thought to date to the early part of the Late Intermediate Period (LIP) based on associated cultural material and radiocarbon dates (see table 3 in Shimada 1995:190). The archaeomagnetic results from these samples suggest a date in the A.D. 1000-1050 range. In addition, two samples collected at Pacatnamú (91 and 92) which are thought to date between A.D. 1200 and 1300 have pole positions within the expected interval (Figure 2). Finally, one sample (30) from the site of Sur Chayuac at Chan Chan illustrates the problems often encountered in archaeomagnetic dating. This sample, because it was associated with a few sherds of the Black-white-red style, which dates to the final phase of the Middle Horizon on the north coast (Collier 1955; Mackey 1983; Proulx 1973; Schaedel 1966), had the potential to shed light on the differences of opinion about the beginning of the LIP in the Moche Valley which is thought to be contemporaneous with the founding of Chan Chan. Unfortunately, due to the fact that the curve loops back over itself, archaeomagnetic dates of both *ca.* A.D. 875 (Figure 1), which would favor a long occupation for Chan Chan (see *e.g.,* Kolata 1982, 1990; Moseley 1975; Topic and Moseley 1983), and *ca.* A.D. 1150, which would favor a short occupation (*e.g.* Cavallaro 1988, 1997; Kosok 1965; Rowe 1945, 1948; Schadel 1993; Watson 1986) are possible.

2. A.D. 1300 - 1500. The great majority of samples from Chan Chan, Manchan, and Túcume have pole positions in what appears to be the A.D. 1300 - 1500 range. However, due to the paucity of samples collected from stratigraphically superimposed baked features at these sites, the exact configuration of the curve in this time period and its calibration is not entirely clear. Examination of Figure 3 indicates that there are two sets of points in this time period. The earlier set includes samples from Túcume, Cerro de los Cementarios, one from Manchan, and the Ciudadelas and Units S, AT, and AW at Chan Chan. The Unit AW sample (29) is under a wall and therefore earlier than the final construction phase in this unit (as represented by samples 26 and 27, which are included in the second group). The second group of samples includes four from Manchan, two from the final construction phase of Unit AW at Chan Chan, and one from Site 38 in the Casma Valley. The close temporal association of the Manchan and the Unit AW samples is in good agreement with the archaeological evidence. While a variety of configurations could be made to fit the data points, at this time the two loops shown in Ta-

ble 1 seem to best fit the data. However, this could change as more archaeomagnetic results are obtained. The exact end date of this section of curve is not entirely clear. The calibration shown on Figure 3 was developed assuming that all the samples from Chan Chan (including hearths in Unit AW) and nearly all the Manchan samples predate the Inca conquest of the Chimú kingdom, thought to date to A.D. 1460-1470, based on historic documents. Unfortunately, independent archaeological dating for the abandonment of Chan Chan is lacking.

3. Post A.D. 1500. Only four samples which apparently date later than A.D. 1500 have been collected (Figure 3). Based on associated cultural material, one (from Manchan) is Late Horizon in age and one (also from Manchan) dates to the early Colonial Period. The third (also from Manchan) was thought to date to the LIP and it is not clear whether the archaeomagnetic result is aberrant or the estimated date a little too early. While it is conceivable that the post A.D. 1500 curve is as shown in part by the dotted line on Figure 4, it is also quite possible that a more complex pattern will emerge. The fourth sample was obtained at Chinchero (in the highlands) and is almost certainly Colonial in age.

Concluding Remarks

The work described above has led to the development of the first archaeomagnetic curve anywhere in South America. For the field of archaeology this provides a basis for archaeomagnetic dating in the A.D. 675 - 1550 time period for the Central and North Coast regions and adjacent highlands of Peru. For geophysics, these important new data for the southern hemisphere should provide further constraints on models of the geomagnetic field. In addition, the curve can be used to test the reliability of geomagnetic direction data obtained from lake sediments from the same area.

Future archaeomagnetic work in Peru will be directed at extending and refining the curve developed for the north and central coasts and adjacent highlands as well as augmenting the limited number of archaeomagnetic samples thus far collected from southern Peru.

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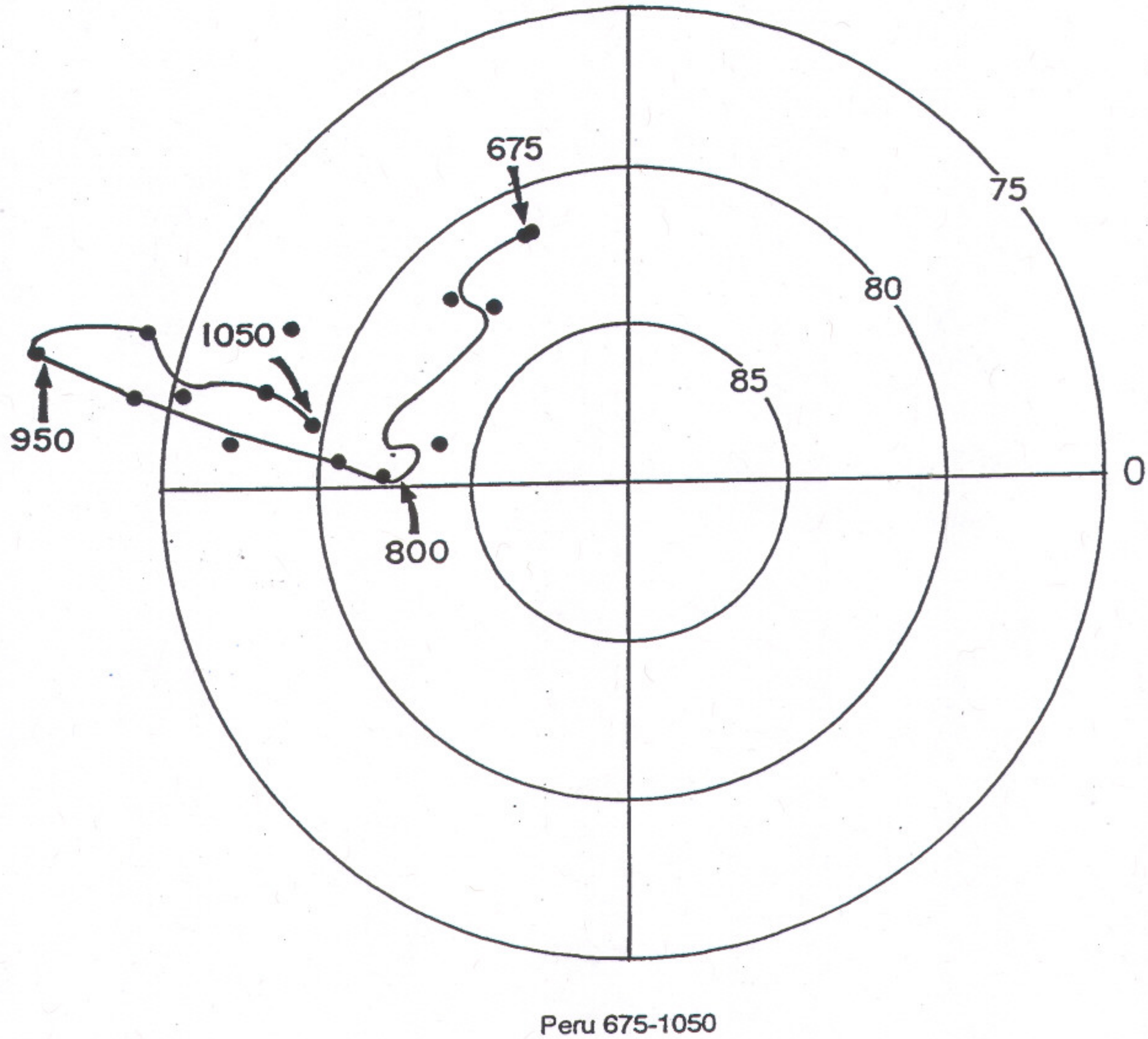

Figure 1. Archaeomagnetic curve for Peru, A.D. 675-1050.

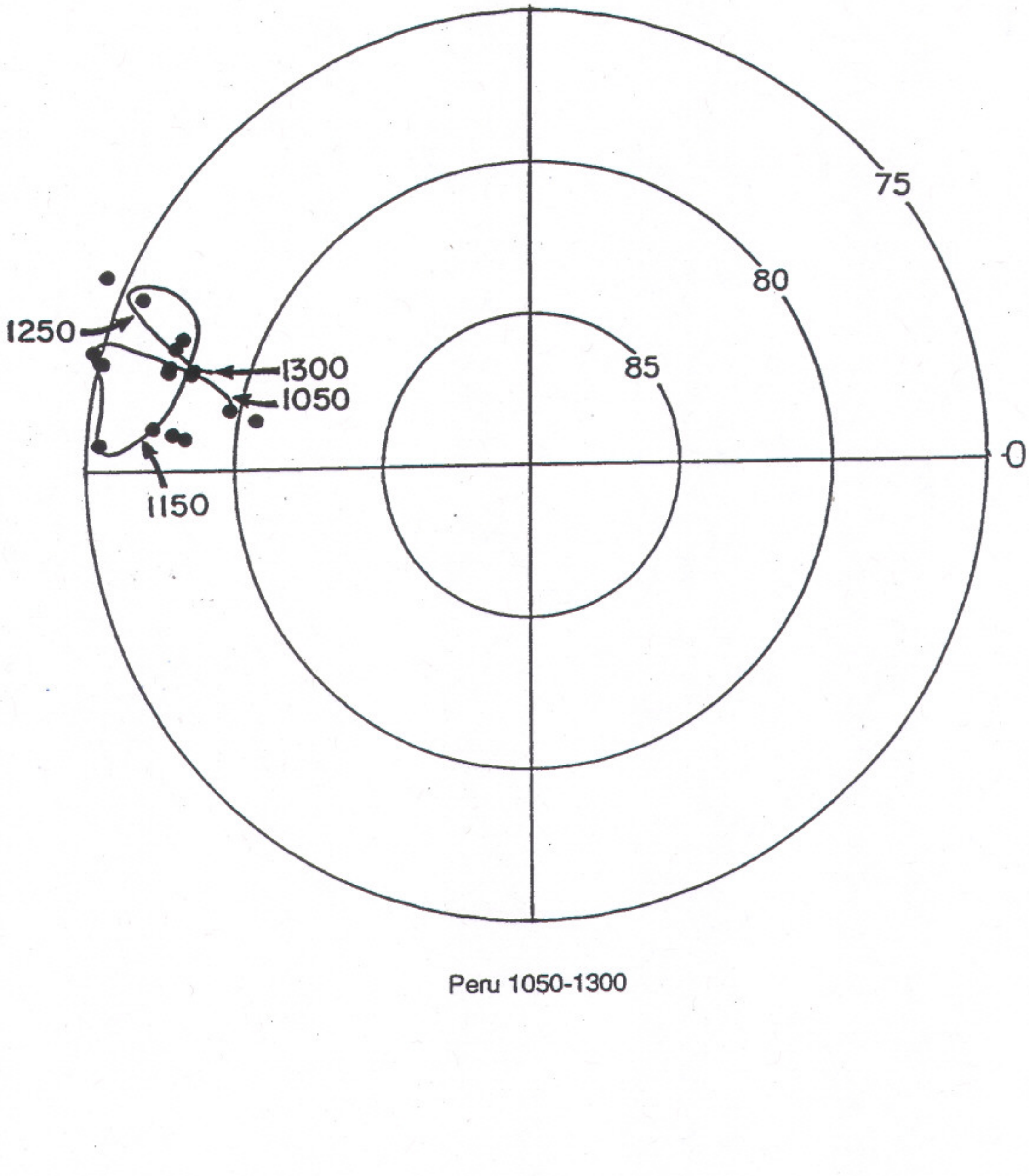

Figure 2. Archaeomagnetic curve for Peru, A.D. 1050-1300.

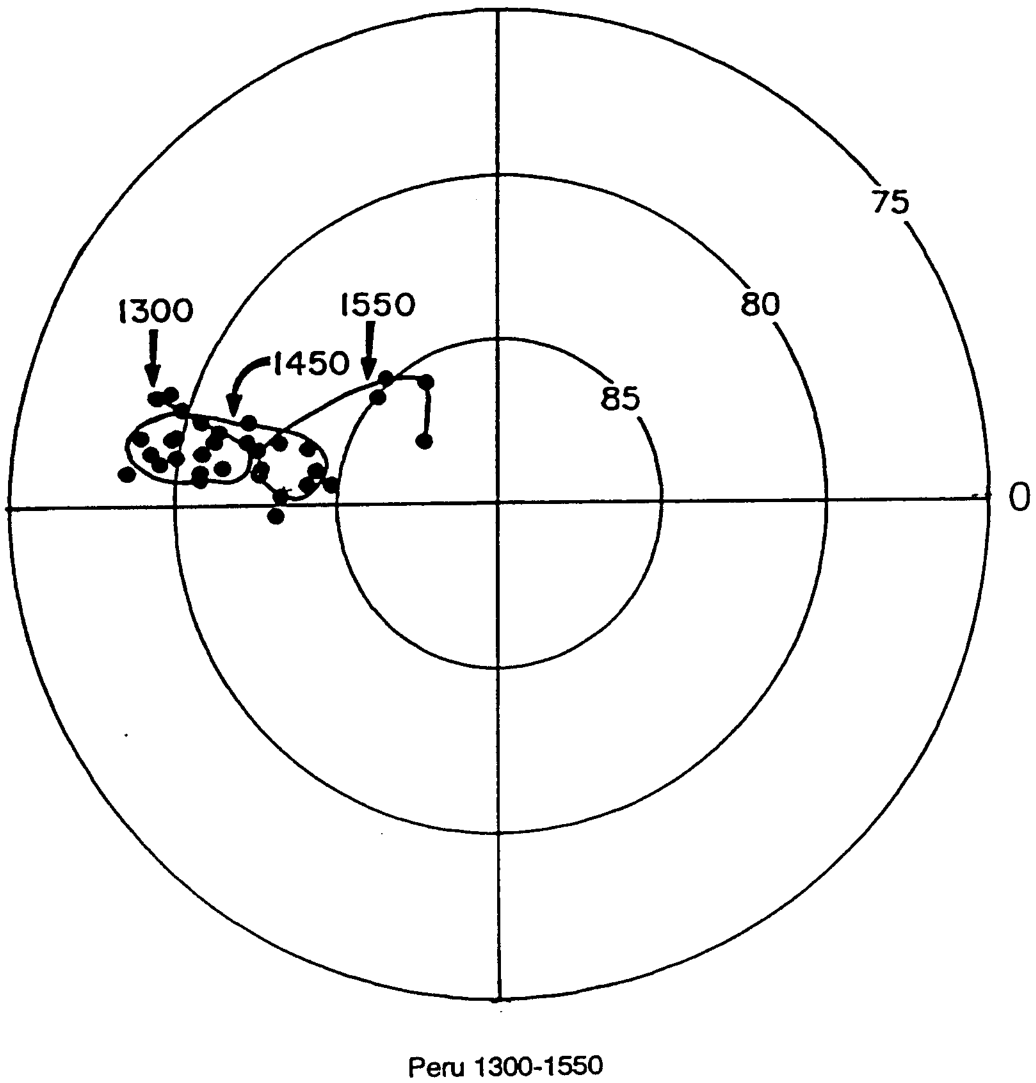

Figure 3. Archaeomagnetic curve for Peru, A.D. 1300-1550.

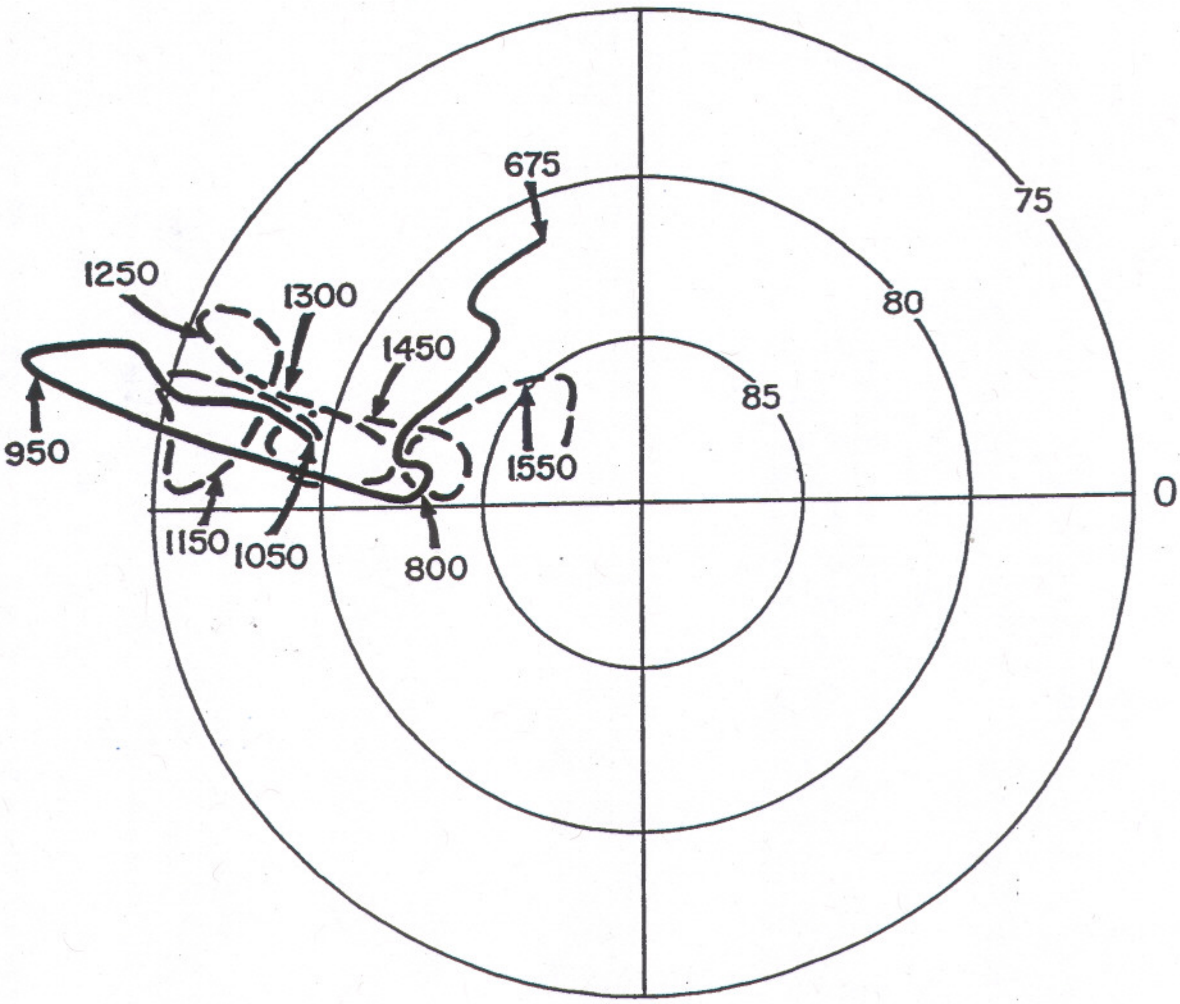

Figure 4. Summary of archaeomagnetic curves for Peru, A.D. 675-1550.

Table 1. Archaeomagnetic Results for Peruvian Samples *(continued on following page)*

#	Site	Feature	Horizon	n/N	H	α_{95}	Lat	Long
110	Pampa Grande	floor 1, s B, m 2	MH (~ 650)	8/8	50	1.2	81.5	111.2
109	Pampa Grande	floor, s 16	MH (c 650)	8/8	100	1.5	81.5	113.1
132	Batán Grande	floor 5, r 40, q 72	MH (c 650)	8/8	0	1.7	81.9	133.8
131	Batán Grande	floor 3, r 40, q 28A	MH	8/8	0	2.2	83.0	127.4
125	Pachacamac	floor (courtyard La Pintada)	MH (?)	8/8	100	0.9	83.9	167.9
126	Pachacamac	floor 5 cm below 125	MH (?)	8/8	100	1.0	82.2	177.8
134	Batán Grande	oven, f 7, r 34, q 48	MH	8/8	100	1.8	70.7	167.0
129	Batán Grande	oven, f 5, r 33, q 78 85	MH	7/8	50	2.8	78.1	155.2
128	Batán Grande	floor 3, r 35, q 90	MH	8/8	100	1.8	80.7	175.0
133	Batán Grande	floor 3, r 39, q 67	MH	8/8	0	1.3	73.9	162.2
116	Las Ventanas	floor, huaquero pit	LIP (~ 900)	8/8	50	1.7	74.0	169.7
35	Huaca Corte	floor, platform mound 1	LIP (~ 950)	7/8	100	1.1	78.0	165.5
107	Huaca Corte	floor 1, huaquero pit, m 2	LIP (~ 1050)	9/9	50	2.6	75.5	168.5
119	Batán Grande	floor 9, r 29, q 76B	LIP (~ 1150)	8/8	50	2.8	79.7	169.0
117	Batán Grande	floor 8A, r 29, q 76A	LIP (~ 1150)	8/8	50	1.4	77.4	164.4
118	Batán Grande	floor 7, r 29, q 71	LIP (~ 1150)	7/8	100	2.3	75.2	166.1
114	Batán Grande	floor 7, r 29, q 76D	LIP (c 1075)	8/8	100	1.5	74.8	165.0
97	C. Cementerios	pit, NE corner p 2, m T	LIP (~ 1150)	8/8	50	2.2	80.6	170.2
115	Batán Grande	floor 5, r 29, q 62-73	LIP	7/8	50	1.9	75.5	176.7
30	Chan Chan (SC)	pit N1-E96.98, u 2	LIP	8/8	100	2.7	77.2	173.8
37	Batán Grande	pit, t 3, r 14, F 49	LIP (~ 1250)	6/6	150	2.0	77.9	174.4
32	C Cementerios	oven, s III, a 1, su Q, F 25	LIP (~ 1400)	8/8	50	3.0	78.3	175.0
92	Pacatnamú	floor, H-1, F 35	LIP	8/8	50	2.7	78.2	163.9
91	Pacatnamú	wall, H-1, F 36	LIP	8/8	50	1.3	77.5	159.7
106	Batán Grande	floor 5, r 29, q 62	LIP (~ 1400)	7/7	50	2.6	77.4	161.4
113	Batán Grande	floor 2 & wall, r 31, q 68	LIP	8/8	50	1.8	75.8	156.4
105	Batán Grande	floor 2 & wall, r 31, q 67	LIP	8/8	100	3.5	74.4	155.7
103	Batán Grande	floor 13, r 19, q 43	LIP	8/8	50	1.9	78.1	164.5
98	Batán Grande	pit, f 2, r 28, q 48	LIP	8/8	50	2.6	77.4	165.1
84	Batán Grande	wall 87, f 10, r 19, F 91	LIP	8/8	50	1.3	78.8	162.9
102	Túcume (HM)	floor (top), N side of huaca	LIP	8/8	100	1.8	78.6	169.5
101	Túcume (HM)	floor 2 (S side of huaca)	LIP	7/7	100	2.6	79.2	161.6
33	C. Cementerios	oven, F 27, s III, a 1, su Q	LIP (~ 1500)	8/8	100	2.4	79.7	163.7
36	C. Cementerios	oven, F 31, s III, a 5	LIP (~ 1500)	7/8	50	1.0	81.9	166.2
19	Chan Chan (GC)	floor 3, entranceway u D	LIP	7/8	50	2.2	81.3	172.5
100	Túcume	floor	LIP	8/8	50	1.5	80.6	175.2
99	Túcume	floor, 60 cm below surface	LIP	8/8	50	2.0	79.3	173.0
89	Huaca Campos	floor, q VIII-C-56	LIP	7/8	0	3.7	83.0	182.7
83	Batán Grande	wall 90, f 7-7A, r 24 (SE corner)	LIP	8/8	50	1.4	79.0	171.5
82	Batán Grande	floor 5-5A, w 78, r 19 (SE corner)	LIP	8/8	50	1.9	79.6	168.7
5	Manchan	pit 80010, u 024, l 7	LIP	8/8	50	1.4	84.0	174.5
120	Santa Ana	pit, site 38 (Collier & Thompson)	LIP	9/9	100	2.4	82.5	173.3
26	Chan Chan	pit (south), u S, b 2	LIP / LH	8/8	50	3.0	80.9	167.7
29	Chan Chan (CP)	pit, u AW, F 3 (under wall)	LIP / LH	8/8	50	3.4	79.8	171.6
58	Chan Chan	wall (SW), u AT,	LIP / LH	9/9	200	1.9	79.7	168.2
21	Chan Chan	wall, u Q, F 1	LIP / LH	10/10	100	1.3	80.4	164.8
28	Chan Chan (R)	bricks, burnt post hole (NE corner)	LIP / LH	6/8	50	3.0	81.0	165.9
27	Chan Chan	pit (NE), u S, b 2	LIP / LH	8/8	100	3.4	81.8	162.4

Table 1. Archaeomagnetic Results for Peruvian Samples *(continued from previous page)*

#	Site	Feature	Horizon	n/N	H	α_{95}	Lat	Long
22	Chan Chan	pit, u AW, F 2	LIP / LH	6/8	50	1.7	84.2	170.2
23	Chan Chan	pit, u AW, F 3	LIP / LH	8/8	50	2.7	83.2	178.0
20	Chan Chan (GC)	floor, u H75-P4	LIP / LH	7/8	50	2.3	82.3	167.8
6	Manchan	pit 00820, u 221, l 3	LH	9/9	50	1.4	80.6	173.7
9	Manchan	pit 60020/21 (B), u 213, l 2	LH	9/9	50	1.1	83.8	164.5
7	Manchan	pit 00000 , u 250 (surface)	LH	9/9	50	2.8	84.7	173.7
12	Manchan	pit 60081/82/83/84, u 211, l 3	LH	8/9	50	0.5	82.5	171.7
8	Manchan	pit 60020/21 (A), u 213, l 2	LH	9/9	100	1.9	85.0	140.1
59	Ollantaitambo	floor, s I, q D/11, l 4D	LH	7/8	100	1.8	84.8	133.6
127	Huaca de Lurín	wall	LH	7/7	50	2.7	85.7	122.5
63	Chincheros	floor, structure 1	C	7/7	100	1.1	82.9	164.8
10	Manchan	floor, u 022, (surface)	C	6/8	50	2.8	87.0	141.8

Key:

#	= Our sample number.
Site	= Archaeological site from which the sample was taken.
Horizon	= Age of feature from which sample was taken (approximate dates A.D. are listed if available, a "c" indicates that the feature has been radiocarbon dated).
n	= Number of specimens used to calculate the mean magnetic direction of the sample.
N	= Total number of specimens in the sample ($n \leq N$).
H	= Peak alternating field (in Oersteds) used to "clean" the specimens.
α_{95}	= Radius of the circle of 95% confidence (in degrees) about the mean magnetic direction of the sample.
Lat	= Latitude of the "virtual" geomagnetic pole position corresponding to the magnetic direction
Long	= East longitude of the "virtual" geomagnetic pole position