Table 1. Periods of normal geomagnetic polarity during the last 10 million years; intervening periods were of reversed polarity.

Millions of years ago		
0.00– 0.70	4.32– 4.47	7.08– 7.12
.90– .95	4.63– 4.74	7.20– 7.51
1.80– 1.95	4.80– 4.95	7.60– 7.66
2.40– 3.00	5.74– 5.92	7.95– 8.33
3.20– 3.40	6.03– 6.27	8.42– 8.55
4.00– 4.16	6.60– 6.74	8.84–10.00

While an isolated ridge segment may or may not change its spreading rate with time, the rate may change with geographic position; the rates of 1, 3, and 4.5 cm/yr quoted for Reykjanes, Juan de Fuca, and Pacific-Antarctic ridges, respectively, illustrate this point. The variation in relative position with respect to the ridge axis of the magnetic anomalies (Fig. 2) indicates the possibility that the spreading rate can change noticeably over the relatively small geographic distance between profiles; this fact allows interpretation of the anomaly patterns in the northeast Pacific. Figure 5 shows types of magnetic patterns that might result from a spreading rate that changed with geographic position along the axis of a ridge but not with time.

Figure 5a shows that a minor variation in spreading rate could create two adjacent anomalies that, although essentially parallel with each other, would not strike parallel with the ridge axis; this condition would exist far from the ridge axis, since near the axis the anomalies would appear parallel not only with each other but also with the axis. If the variation in spreading rate were great enough, anomalies adjacent to the axis would be distinctly nonparallel with the ridge axis (Fig. 5b); this effect could account for the pattern on the eastern side of Gorda Ridge (*14*). Figure 5c shows a discontinuity of spreading rate at a fracture zone; the offset in anomalies across the fracture zone is greatest for the older anomalies and less for the younger. An offset ridge axis, with a discontinuity in spreading rate across a fracture zone, would create similar patterns; such patterns could explain the small variation in offset of the magnetic anomalies across the Mendicino and Pioneer fracture zones.

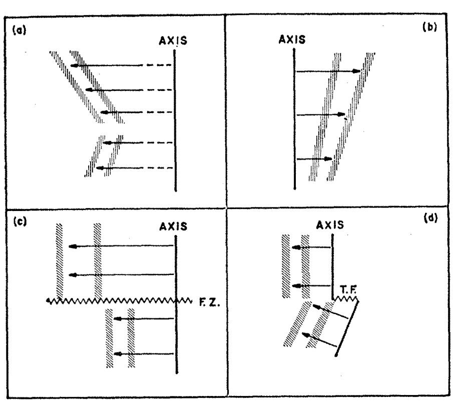

Fig. 5. (a) Shows how a minor variation in spreading rate could create adjacent anomalies (shaded), at a distance from the ridge axis, that are essentially parallel with each other but not parallel with the ridge axis. (b) A large variation in spreading rate close to the ridge axis creates nonparallel anomalies. (c) A difference in spreading rate across a fracture zone (*F.Z.*) creates differences in apparent offset of the anomaly pattern along the fracture zone. (d) Shows how spreading from nonparallel axes of a ridge can produce a disturbed area; the line between the two axial segments is a transform fault (*T.F.*).

Figure 5d shows a constant spreading rate along the axis, but with nonparallel segments of the axis. The juncture of the Juan de Fuca and Gorda ridges (*14*) is reminiscent of this pattern, with epicenters in great density along the transform fault between the offset axes (*14, 15*). Certainly other patterns of magnetic anomalies may be derived by various combinations of axial positions and spreading rates.

Thus the spreading rate of 3 cm/yr found by Vine (*12*) for the Juan de Fuca Ridge is not, we feel, necessarily indicative of the rate for all the northeast Pacific; rather one would expect to find a broken pattern in most areas, like the pattern in the northeast Pacific.

We feel that these results strongly support the essential features of the Vine and Matthews hypothesis and of ocean-floor spreading as postulated by Dietz (*16*) and Hess (*17*). The very rapid apparent-spreading rate in the South Pacific permits one (using a constant spreading rate) to date reversals of the geomagnetic field back to 10 million years ago.

The bodies of the Pacific-Antarctic, when adjusted for slower spreading rate, fit well with magnetic anomalies observed over Reykjanes Ridge in the North Atlantic. Preliminary examination of magnetic data from Gorda Ridge in the northeast Pacific shows (especially on the western side) great similarity to the *Eltanin*-19 profile. Magnetic profiles over the Pacific-Antarctic Ridge in areas other than those discussed by us demonstrate the same similarity. Other magnetic profiles from over the Pacific-Antarctic Ridge, the Indian-Antarctic Ridge (south and southwest of Australia), and the Mid-Atlantic Ridge in the South Atlantic indicate the possible application of this model to those areas.

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Copper Artifacts from Prehistoric Archeological Sites in the Dakotas

Abstract. *Thirteen archeological specimens were analyzed spectrographically, and within defined limits they were determined to be native copper. Twelve of the specimens show close elemental homogeneity and are believed to be of Lake Superior ore; the origin of the other specimen is devious.*

Although numerous stone, bone, shell, and vegetal remains from archeological sites on the Northern Plains have been analyzed and identified, only two brief statements have been published which are relative to native copper artifacts from prehistoric sites in

Table 1. Spectrographic analysis of selected trace and minor element components of 13 small copper artifacts*. Numbers in parentheses indicate wavelength in angstroms.

Sample	Concentration in parts per million										
	Ca (3968)	Mg (2852)	Fe (3020)	Ni (3414)	Ag (3382)	Al (3961)	V (3185)	As† (2780)	Zn (3282)	Pb (3683)	Sn (3262)
Side Hill	28	5	23		70						
Sitting Crow	33	28	40		100	70	100	3000			
Kropp	7	3	13		85		25				
Kropp	< 1	< 1	10		440						
Kropp	28	3	14		390			2500			
Kropp	< 1	1	25		230						
Kropp	< 1	1	40		570						
Kropp	< 1	< 1	22		85			700			
Kropp	< 1	< 1	19		90						
Langdeau	4	4	100		17						
Langdeau	< 1	< 1	17		220						
Calamity	6	< 1	18		250						
McClure	2	< 1	75	18	150			900	> 10,000	> 10,000	> 10,000
Lake Superior	27	< 1	27		< 1000		15				

* Boron and silicon were the only recorded trace elements not determined. † Lower detection limit of arsenic using this method is 500 ppm.

the area (*1*, *2*). Inasmuch as neither of the articles provides detailed qualitative or quantitative data, the present authors thought it worthwhile to analyze a group of metal specimens, and to report the results in a more substantive manner.

These particular thirteen specimens were selected for analysis because they are from three very widespread and well-researched archeological horizons on the Northern Plains. The earliest of these horizons, beginning about 500 B.C., is best known by the name Plains Woodland. Available evidence indicates that the culture consisted of small, hunting–gathering groups who occupied temporary campsites along streams, and constructed burial mounds for the interment of their dead. The next horizon, appearing around A.D. 800, is the Early Period of the Mississippi Phase. Here we have horticultural populations dwelling in large, distinctive villages with rectangular houses which are characteristically fortified with a moat and stockade system. The third horizon began about A.D. 1450 and continues on into historic times. This is the Late Period of the Mississippi Phase and it is manifested by the remains of large, circular earth lodges—sites once inhabited by peoples whose culture was basically similar to early ethnographic descriptions of Arikara, Mandan, and Hidatsa communities. All the sites under discussion were excavated by field parties of the Smithsonian Institution, River Basin Surveys, as part of a nation-wide archeological salvage program (*3*).

The first specimen (39BF233-38) from Mound 1 at the Side Hill Site in Buffalo County, South Dakota, is a tubular bead 27 mm long and 5 mm in diameter. This Woodland burial mound has been radiocarbon dated at A.D. 750 ± 90 years. The second object (39BF225-502) is from Mound 2 at the Sitting Crow Site, also in Buffalo County. The object is a bipointed awl 68 mm long and 7 mm in maximum diameter. On the basis of archeological evidence, we assign this tumulus to the Woodland Period at a date of about A.D. 700. The next seven specimens (32SN8-32, -33, -36A, -85, -91, -168, and -295) are from the Kropp Mound, an elaborate Woodland tumulus in Stutsman County, North Dakota. These specimens consist of entire or fragmented tubular beads ranging up to 49 mm long and 7 mm in diameter. The Kropp Mound has a radiocarbon date of A.D. 1000 ± 85 years.

The next two specimens (39LM209-880 and 1117) are from the Langdeau Village, a settlement of rectangular houses in Lyman County, South Dakota. The first piece is but a jagged fragment of sheet copper 19 mm by 19 mm; the second is a tubular bead 32 mm long and 4 mm in diameter. Three radiocarbon assays from the Langdeau Village range from A.D. 1000 ± 65 years to A.D. 1140 ± 70 years. Another village of rectangular houses is the Calamity Site in Dewey County, South Dakota. The metal specimen (39DW231-957) from this site is a thin, triangular sheet 40 mm long and 19 mm wide at the base. Archeological evidence suggests that this village was occupied no later than A.D. 1400.

The last sample under discussion (from the latest archeological occupation) is a tubular bead (39HU7-285) from the circular earth lodge, McClure Site in Hughes County, South Dakota. The specimen measures 51 mm long and 4 mm in diameter. From a preliminary analysis of the archeological remains, McClure is thought to have a date of about A.D. 1650.

Small samples (30 to 50 mg) were removed from the edge of each artifact and placed in numbered beakers. Corrosion products and any surficial contamination of the metallic copper was removed by filling the beakers with a 1.0*N* solution of sodium ethylenediaminetetraacetic acid at *p*H 8. The samples were agitated with a needle to free them of air bubbles, and left in the solution for twelve hours after which the solution was discarded and the samples were carefully washed in distilled water. They were then clipped to a uniform 10 mg in order to achieve a relatively uniform sample weight for spectrographic excitation.

A 1.5-m emission spectrograph (with a 24,000 line concave grating in an Abney mount giving a dispersion of 6.05 Å/mm at the film plane) was used with a standard ARL DC Arc Source. The spectrograms were recorded on Kodak SA-1 film processed in Kodak D-19 developer and later read on a ARL comparitor-densitometer for elements present and line density.

Several samples of natural copper ore from the Lake Superior region were obtained from the Department of Geology, University of Kansas. These were analyzed quantitatively and used as probable indicators of elements present, and as relative concentrations of those elements. The native copper samples were also used to determine the optimum spectrographic excitation parameters for the artifact samples.

Native copper from the Lake Superior area is very pure, usually > 99 percent pure copper. Many elements of the common rock-forming minerals are found in small traces in the copper; these include silicon, calcium, magnesium, vanadium, iron, aluminum, and boron. The more characteristic elements include silver, usually less than 1000 ppm but occasionally occurring in larger amounts. There is also the occasional presence of arsenic and nickel. No trace of bismuth, antimony, or gold was found in the Lake Superior native copper samples (*4*). The results of trace element analysis of the thirteen artifacts and one sample of native copper are presented in Table 1. These results show that twelve samples fall within the defined compositional limits of native copper from the Lake Superior area. The McClure Site sample is anomalous because of the relatively large quantities of lead, tin, and zinc, and a trace of nickel. However, it cannot be definitely stated at this time that it is not native copper (*5*). It should also be noted that our test results agree very closely with those previously conducted on copper artifacts from archeological sites in Iowa (*4*).

Within the limits of our research and laboratory techniques, we feel that we have shown that native copper artifacts occur in various archeological contexts dating between A.D. 700 and A.D. 1650 in the Dakotas, and that these artifacts were manufactured from ore obtained in the Lake Superior area. Anthropological implications of trade and diffusion, as well as more refined laboratory analyses, need further research and collaboration.

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Lithology and Paleontology of the Reflective Layer Horizon A

Abstract. *Cores recovered from horizon A are Late Cretaceous (Maestrichtian) in age and consist of alternating layers of calcareous turbidites and "red clay." The presence of red clay suggests that the water depth in this area during Cretaceous time was at least as great as at present—more than 5100 meters. A middle Cretaceous (Cenomanian) core consisting of interbedded sand and gravel and light-to-dark-gray lutite was taken in the same area from a layer stratigraphically below the horizon; the presence of hydrogen sulfide and iron sulfide may indicate anaerobic conditions that may be attributable to local ponding of sediment in Cenomanian time.*

The geophysical evidence and the significance of the reflective layer horizon A has been discussed (*1*). We now report its lithology and the paleontologic evidence of its Cretaceous (Maestrichtian) age.

Eight Cretaceous cores have been recovered from the outcrop area (Fig. 1): seven are Maestrichtian and appeared to be outcrops of horizon A on the seismic-profile records (*1*). All Cretaceous cores were taken in water depths exceeding 5100 m (Table 1).

In general, the seven cores consist of red clay overlying alternating layers of turbidites and normal pelagic (red-clay) sediments. The turbidites range in thickness from less than 10 cm to more than 2 m; they usually show a typical graded bedding, with coarse-grained sand or gravel at the base of each cycle. In most cases, coarser fractions of the turbidites consist of shallow-water foraminifers, corals, gastropods, pelecypods, and fish bones. In two of the cores, volcanic ash occurs in some of the turbidites. Some turbidites in the cores are comprised almost entirely of clay-size particles composed largely of coccolith plates.

Core V 21-236 consists of a moderate-yellowish-brown to grayish-orange lutite overlying alternating layers of white calcilutite, fine-grained foraminiferal sand, and yellowish-gray lutite; the Cretaceous portion begins at 260 cm. Core V 21-237 consists of pale-yellowish-brown and grayish-brown lutite overlying a layer of laminated lutite and manganese oxide and alternating layers of light-olive-gray lutite and foraminiferal sands; the Cretaceous portion is believed to begin at a depth of 48 cm.

Core V 21-238 is composed of a dark-yellowish-brown, burrow-mottled lutite overlying alternating layers of turbidites and moderate-yellowish-brown lutite; the Cretaceous portion begins around 26 cm. Core 239 consists of a pale-brown and olive-to-dark-gray lutite and silty lutite overlying interbedded layers of sand, turbidites, and dark-brown lutite; the Cretaceous portion begins around 700 cm.

Core V 21-241 consists of a moderate-to-dark-yellowish-brown lutite overlying alternating layers of foraminiferal sand and mostly brownish lutite containing many coccoliths and a few foraminifers; the Cretaceous portion begins at 340 cm. Core V 22-12 comprises a pale-brown-to-dusty-yellow silty lutite overlying an olive-gray lutite, dark-yellowish-brown lutite, and quartzose and calcareous silt. Core V 22-16 consists of a pale-to-moderate-yellowish-brown and gray lutite overlying interbedded layers of reddish-brown lutite and yellowish-gray-to-light-gray sand; the Cretaceous portion begins at 60 cm.

As we have mentioned, no fossils younger than Cretaceous have been found in the turbidite sections of the cores described; Foraminifera indicating Maestrichtian age are *Globotruncana calciformis* Vogler, *G. gagnebini* Tirev, *G. gansseri* Bolli, and *G. stuarti stuartiformis* Dalbiez; other longer-ranging foraminifers include *Schackoina multispinata* (Cushman and Wickenden), *Globotruncana fornicata* Plummer, *G. havanensis* Voorwijk, *G. nothi* (Bronniman and Brown), *Globigerinelloides aspera* (Ehrenberg), *Rugoglobigerina rugosa* (Plummer), *Planoglobulina glabrata* (Cushman), *Pseudotextularia elegans* (Rzehak), and *Racemiguembelina fructicosa* (Egger).

Foraminifers indicating Cretaceous age are found not only in the turbidites but also, much less abundantly, in the normal pelagic sediment between the turbidites. Foraminifers found in the normal pelagic sediments are predominantly planktonic; their tests show evidence of corrosion, in contrast with the fresh appearance of foraminiferal tests found in the turbidites, indicating that they were deposited in place rather than being contaminants from the interbedded turbidites. The presence of these indicators in the pelagic sediment establishes the Maestrichtian age of these cores.

One other Cretaceous core (V 22-8) was taken from a layer that outcrops stratigraphically below horizon A on the seismic-profile records; it consists of medium-olive-gray-to-dark-gray lutite and silty lutite overlying interbedded carbonate sands and gravels, light-green-olive-gray lutite, and dark-greenish-gray-to-medium-dark-gray lutite. Iron sulfide is present in the medium-dark-gray layer, and the odor of hydrogen sulfide was noted in this layer when the core was opened.

The upper 90 cm of this core con-