REMANENT MAGNETIZATION OF THE PERMIAN CUTLER FORMATION OF WESTERN COLORADO

by

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ABSTRACT

The early paleomagnetic observations from the Permian of the Western United States were not subjected to demagnetization studies. Observations on the Lower Permian Cutler Formation of western Colorado suggest that many of these older poles are in error by 10 or more degrees. The new pole from the Cutler Formation is at 42.7N 121.9E, is virtually identical with the demagnetized results from Eastern North America, and provides an excellent test of the dipolar hypothesis. The results of this study emphasize the need for additional study of the older paleomagnetic data for North America.

INTRODUCTION

Recently Farrell and May (1969) have reported on measurements made on samples of the Cutler Formation from the Monument Valley region of northern Arizona. Most of their samples proved to be unstable and only a few of those from the lowest member of the formation, the Halgaito Tongue, gave reliable results. Moreover, Farrell and May pointed out that all previous results (Graham, 1955; Runcorn, 1955, 1956; Doell, 1955; Collinson and Runcorn, 1960) from other Permian formations of the Colorado Plateau should be regarded as unreliable due to the lack of information regarding stability. Graham (1955) reported reconnaissance paleomagnetic observations of samples from the Cutler Formation of western Colorado and Utah. The pole positions calculated from these results have been cited extensively as being representative of Permian poles for North America; however, they are likely to be in considerable error for demagnetization studies were not done. Thus, it seems essential that rocks of Permian age from the western United States be studied so that a reliable point on the polar wander path for North America can be established.

With such a determination in mind two stratigraphic sequences within the Cutler Formation in western Colorado were sampled by means of a portable gasoline powered core drill (Helsley, 1967). All orientations were made by means of a magnetic compass. Upon return to the laboratory the 2.54 cm diameter field cores were cut to 2.54 cm long cylindrical samples and measured on an air-turbine spinner magnetometer (Helsley, 1967). Subsequent measurements made during the demagnetization studies were made on a PAR SM-1 magnetometer.

Regional Geology and Age

The samples used in this study come from the lower portion of the Cutler Formation exposed in the Gateway Quadrangle of western Colorado (Cater, 1955). Within this region the Cutler Formation thins abruptly against the Uncompahgre Uplift which seems to have been the source for much of the material in the formation. The Cutler Formation unconformably overlies the Hermosa Formation of Pennsylvanian age and is unconformably overlain in this region by the Lower Triassic Moenkopi Formation (Shoemaker and Newman, 1959). Based on regional correlations, this portion of the Cutler is equivalent to, or lies beneath, the Organ Rock Sandstone and may be in part equivalent to the Cedar Mesa Sandstone Member or the Halgaito Tongue of the Cutler in the Monument Valley region (Stewart, 1959). Thus, although the age of the formation cannot be stated precisely for lack of fossil control, it is certainly of Lower Permian age and most likely of lowest Permian age.

Within the sampling region the formation consists primarily of poorly sorted maroon to purple coarse sandstone with local conglomerate units. Bedding is generally massive and poorly developed. Local finer grained units consisting of poorly sorted, red-brown, medium to fine sandstones and sandy mudstone units are interbedded within the coarse clastic sequence. Three units consisting of these finer grained lithologies were sampled from two different areas. Each of the units covered 40 to 70 feet of section, with samples being taken at approximately 3 foot intervals. These three fine grained units have a total stratigraphic range of about 500 feet.

The regional strike of the Cutler in this region is uniformly to the northwest and the local dip varies between 4 and 5 degrees to the southwest. Some of the dip may be due to a sloping surface at the time of deposition. However the dip of the bedding in the siltstone units, is virtually identical with that in the conglomerate and sandstone units and thus it is thought that most of the dip was acquired structurally prior to the deposition of the overlying Moenkopi Formation.

Discussion of Results

The natural remanent magnetization (NRM) and thermal demagnetization results are summarized in Figure 1 and Table I. The NRM directions are initially quite scattered and have a tendency to streak toward the present earth's field. Most of the measurements lie in the SE quadrant in the lower hemisphere, although there are a few samples that have shallow negative inclinations to the SE. These few samples in the upper hemisphere are the only samples that show NRM directions which do not change on demagnetization.

Remeasurement of the NRM of a portion of the specimens over a year after initial measurement indicated that many of the samples have large viscous moments. Alternating current demagnetization techniques removed this viscous moment but were unsuccessful in removing all of the secondary magnetization for, although a better grouping resulted, the directions of magnetization still showed evidence of a streak toward the present field direction. Progressive thermal demagnetization experiments however resulted in a marked decrease in scatter, and thus heating experiments were performed on all samples. The results of these progressive heating experiments are shown in Figure 1 for 300°C, 400°C, 500°C and 600°C.

Most of the change in direction of magnetization occurred at temperatures below 300°C since the samples from both localities group well at both 300°C and 400°C and have approximately the same mean directions. This would suggest that all of the secondary component has been removed. Demagnetization at 500°C continued to move the mean direction away from the present field direction although the results are much more scattered. This increased scatter may be due to an error in the demagnetization technique for a small field was noted during the cooling of some of the samples. After correcting this error, a group of the suspect samples were reheated to 600°C. The directions for these samples after cooling were almost all in the upper hemisphere. Consequently all of the remaining samples also were heated to 600°C. The resulting directions are shown in the right hand plots in Figure 1. The directions from both localities are well grouped and have approximately the same dispersions (see Table I) as do the clusters for 300°C and 400°C, nevertheless the mean directions of magnetization are about 15° from those for the lower temperatures and are farther away from the present field direction.

It is thought that the results for 600°C represent the primary magnetization direction for they are not significantly different from the mean direction calculated for 500°C after removal of the three widely scattered samples (see Table I, Site 2). Since some of the samples were known to have been cooled in a small applied field this selection seems justified. Several samples from site 2 scattered widely after heating to 600°C and probably no longer provide reliable estimates of the Permian field direction. Four of these samples have been omitted in the calculation of the final mean direction and pole position (the omitted samples are marked by a minus sign in Figure 1).

Pole Positions

The pole positions derived from the 600°C thermally demagnetized data (see Table I) are in excellent agreement with previously published data from Prince Edward Island, West Virginia, and portions of the Colorado Plateau. Table II summarizes the Permian pole data for North America. The reliability assessment given in the last column is based upon the internal grouping of the data and upon whether or not demagnetization experiments have been performed. Obviously this is a somewhat subjective judgement, nevertheless all those marked "good" have similar pole positions while those marked "fair" or "poor" generally have pole positions similar to those found in the course of this study prior to or during demagnetization, thus suggesting that secondary components may be present. Farrell and May's data for the Toroweap and Hermit show similar disagreements and thus they may also contain a secondary component.

If one examines the "good" data from Table II, all of which are of Upper Carboniferous or Lower Permian age except for Farrell and May's Hoskinnini which may be as young as Lower Triassic, then one finds a remarkable similarity in pole position. The mean pole position for all of these "good" Lower Permian results is 42.3°N 123.5°E and has an α_{95} of 3.1 degrees. Since these data come from three widely separated regions of North America, their excellent agreement provides a very good confirmation of the dipolar nature of the field for Lower Permian time. Even if the "fair" data are included, the agreement is still very good (average pole position 41.6°N 121.5°E and α_{95} of 4.7 degrees).

The largest group of data judged to be of "poor" reliability is that of Graham (1955). No demagnetization experiments were performed on these samples, and Graham's primary purpose was not the determination of precise pole positions but instead was to show that indeed the pole position had been different in older times. Three of Graham's results give pole positions that are in good agreement with the demagnetized results of later investigators. Nevertheless, it is felt that one should accept Graham's view (personal communication) that his early non-demagnetized data should no longer be used for precise pole position determinations or comparisons. A similar statement can be made regarding the data from the Supai Formation (Runcorn, 1955; Doell, 1955; Graham, 1955).

The only other Permian data for North America is that of McMahon and Strangway (1968). Their study was done primarily to define the boundaries of the Kaiman reversed interval and no demagnetization studies are reported. Samples from the lower portion of the Maroon Formation are in good agreement with the demagnetized data from other localities in North America while those from the upper portions of the sampled sequence yield pole positions that are not in agreement with other Permian results. Despite the apparent agreement for samples from the lower Maroon Formation these have not been included in the average pole determination since they apparently have not been subjected to demagnetization studies.

Polar Wandering During the Permian

Using the data of Farrell and May (1969), Helsley (1969), Black (1964) and Helsley (1965), an estimate for the amount of polar wandering relative to North America for the Permian can be made.

The oldest data come from the Carboniferous to Permian red beds on Prince Edward Island (Black, 1964) and these poles are very similar to those of the Cutler found in this study (see Figure 2). The pole positions from the Lower Permian Dunkard Series of West Virginia (Helsley, 1965) are very similar to these but displaced a few degrees toward the Lower Triassic poles from the Moenkopi Formation (Helsley, 1969). The pole from the Halgaito Tongue of the Cutler Formation (Farrell and May, 1969) is even further displaced toward the Lower Triassic pole. The somewhat uncertain poles from the younger Permian units, the Hermit Shale and Toroweap Formation are similar to the Triassic position but are displaced to the south and east as would be expected if some secondary component of recent origin had not been removed. (Since these are reversely magnetized units for which the south rather than the north pole is plotted, the effect of adding a secondary component is to move the pole away from rather than toward the present pole. The demagnetization results shown in Figure 1 and Table I illustrate this point very well.) Helsley (1969) has argued that the results from the lowest portion of the Moenkopi Formation may well be representative of the uppermost Permian. The pole for this interval (labeled R1 in Figure 2) is slightly displaced toward the Lower Permian position from the rest of the Lower Triassic Moenkopi Formation results (labeled M). These results are then indicative of a systematic polar wandering of about 20° during the Permian period. This conclusion should be regarded as suggestive until additional data from rocks of Middle and Upper Permian age become available. It does seem certain however that approximately 20° of polar movement (continental drift?) occurred between Lower Permian and Lower Triassic time.

Age of the Hoskinnini Tongue

Farrell and May (1969) have described observations made on the Hoskinnini Tongue of the Cutler Formation in the Monument Valley region of the Colorado Plateau and have found results very similar to those of the Halgaito Tongue of the Cutler Formation. At first this seems reasonable. However, Stewart (1959) has demonstrated that the Hoskinnini can be shown to be physically equivalent to the lowest member of the Lower Triassic Moenkopi Formation while the Halgaito Tongue of the Cutler is the lowest member of the Permian sequence in the Monument Valley region. Moreover, the pole for the Hoskinnini found by Farrell and May is not at all similar to that for the lower Moenkopi found by Helsley (1969).

Assuming that Farrell and May did not make a mistake in identifying the Hoskinnini, this indicates that the Hoskinnini cannot be Triassic in age in the Monument Valley region and thus suggests that it may represent a facies that is markedly time transgressive. Until this difficulty in age assignment of this unit is resolved, Farrell and May's Hoskinnini result, despite its good appearance, should not be considered as reliable pole position for either the Permian or the Lower Triassic.

Conclusions

The results from this study support those of Farrell and May (1969), namely that most of the older Permian data from the western United States should not be regarded as reliable indicators of pole positions. Comparison of the pole positions found in this study, in which demagnetization was done, with those from the eastern part of North America provides more convincing evidence for the dipolar nature of the Permian field. It is suggested that more data is needed for rocks of Middle and Upper Permian age and that this data may be useful in unravelling some of the stratigraphic problems present in the Colorado Plateau region.

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Figure Captions

<u>Figure 1</u>

NRM of Cutler Formation before and after progressive heating experiments; Site 1 upper half, Site 2 lower half. The minus signs indicate samples not used in the statistical calculation.

<u>Figure 2</u>

Pole positions for Permian rocks from North America. 1 data from Cutler Formation; 1 Published data considered "good" (see Table II); 1 Published data considered "fair". R and M are poles from the Lower Triassic Moenkopi Foundation, Helsley, 1965.

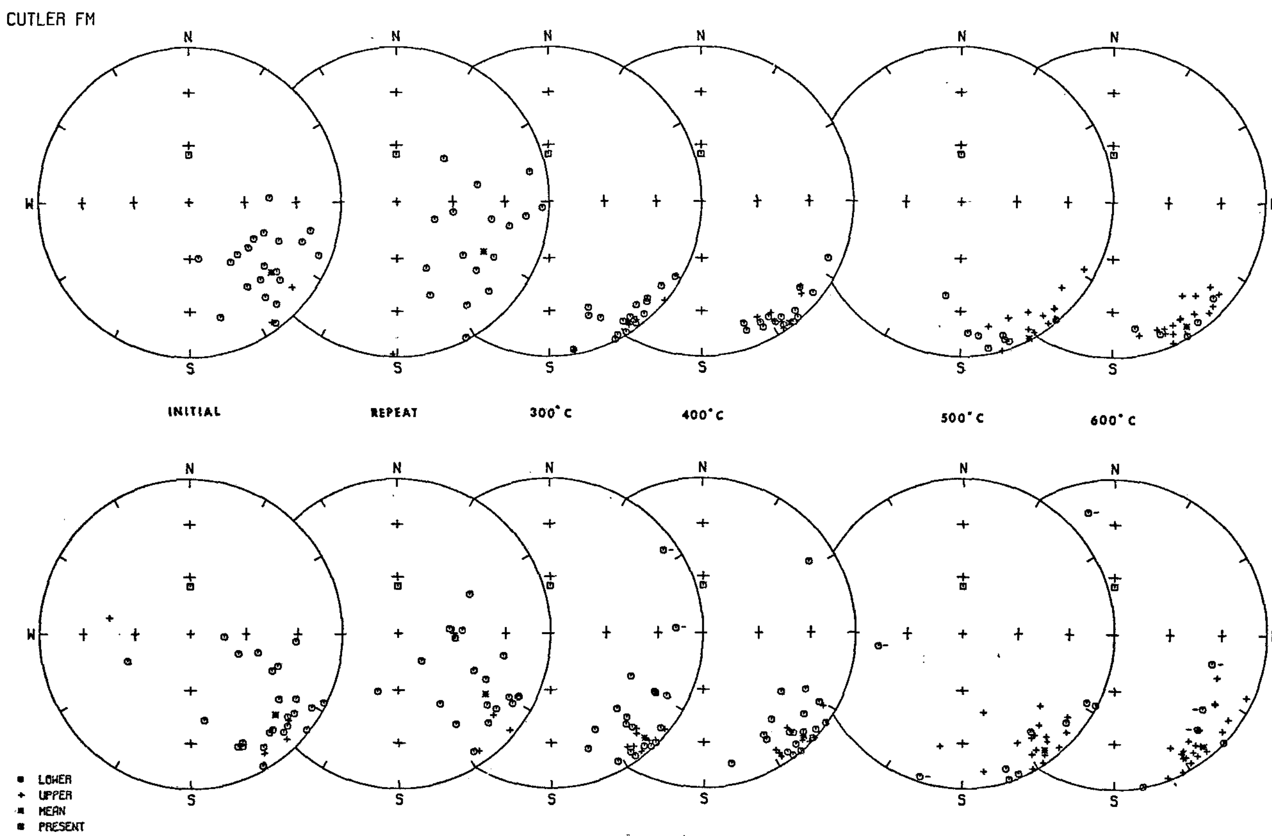
CUTLER FM
N
S
W
E
INITIAL
REPEAT
300°C
400°C
500°C
600°C
LOWER
UPPER
MEAN
PRESENT

Figure 1

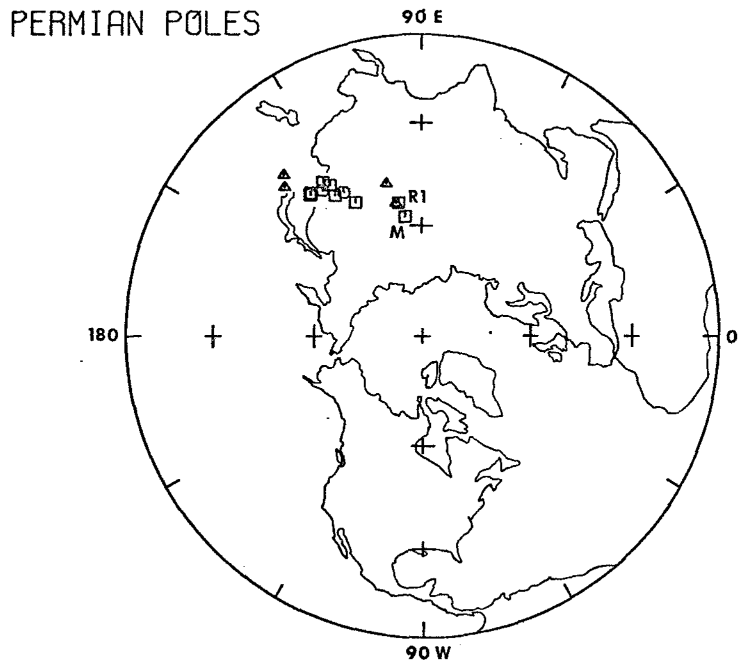

Figure 2

TABLE I

SAMPLE	DEC	INC	N	R	K	ALPHA	DEL	LONG	LAT	DP	DM
SITE 1	130.1	30.4	22	19.99	10.4	10.1	24.5	121.5	17.9	6.2	11.2
SITE 1 REMEASURED	119.8	35.1	18	15.02	5.7	15.9	33.0	128.1	9.2	10.6	18.4
SITE 1 300	146.0	7.0	21	20.27	27.4	6.2	15.1	115.8	37.4	3.1	6.2
SITE 1 400	143.8	2.7	21	20.22	25.5	6.4	15.7	119.6	38.0	3.2	6.4
SITE 1 500	152.8	-1.3	21	19.61	14.4	8.7	20.8	111.0	44.6	4.3	8.7
SITE 1 600	148.0	-7.4	21	20.21	25.2	6.5	15.8	118.0	44.6	3.3	6.5
SITE 2	133.2	24.8	28	24.29	7.3	10.9	29.5	121.3	22.4	6.3	11.7
SITE 2 REMEASURED	124.5	31.2	22	18.87	6.7	12.9	30.6	125.5	14.1	8.1	14.5
SITE 2 300	133.8	9.8	27	24.50	10.4	9.1	24.7	126.4	29.0	4.6	9.2
SITE 2 300 2 OMITTED	137.9	9.0	25	23.65	17.7	7.1	18.8	123.0	31.9	3.6	7.1
SITE 2 400	135.6	7.5	27	25.10	13.7	7.8	21.5	125.7	31.0	4.0	7.9
SITE 2 500	145.9	-10.5	27	24.31	9.7	9.4	25.6	122.7	44.6	4.8	9.6
SITE 2 500 3 OMITTED	143.9	-8.5	24	22.60	16.4	7.5	19.6	124.0	42.6	3.8	7.6
SITE 2 600	140.1	-6.4	27	25.35	15.7	7.2	20.0	127.0	39.3	3.7	7.3
SITE 2 600 4 OMITTED	142.4	-6.6	23	22.15	26.0	6.0	15.6	124.8	40.9	3.1	6.1

TABLE II

NORTH AMERICAN PERMIAN POLE DETERMINATIONS

SAMPLE		DEC	INC	N*	K	ALPHA	LONG'	LAT'	DP	DM	RELIABILITY
W VIRGINIA (HELSLEY,1965)											
DUNKARD SERIES	LP	163.5	7.7	9	176.8	3.9	122.3	44.1	2.0	3.9	GOOD
COLORADO (MCMAHON & STRANGWAY,1968)											
L MAROON FM	P	134.0	-2.0	8	30.0	10.0	133.0	33.0			FAIR
MAROON FM	P	132.0	4.0	22	17.0	8.0	131.0	30.0			FAIR
UTAH-ARIZONA (FARRELL & MAY,1969)											
HALGAITO		151.0	-11.0		54.0	6.0	117.0	49.0			GOOD
HOSKINNINI		150.0	-16.0		23.0	7.0	121.0	50.0			GOOD
TOROWEAP		157.0	3.0		36.0	7.0	103.0	47.0			FAIR
HERMIT		161.0	-7.0		76.0	8.0	101.0	53.0			FAIR
COLO.,UTAH,N.M. (GRAHAM,1955 IN IRVING,1964)											
ABO FM,NEW MEX.	LP	160.0	55.0	1	7.0	12.0	88.0	17.0	12.0	17.0	POOR
ABO FM,NEW MEX.	LP	149.0	8.0	1	5.0	18.0	117.0	42.0	9.0	18.0	POOR
CUTLER FM,COLO.	P	140.0	6.0	1			123.0	34.0			POOR
CUTLER FM,UTAH	P	161.0	33.0	1	96.0	10.0	92.0	33.0			POOR
SANGRE DE CRISTO	CP	175.0	31.0	1	9.0	11.0	81.0	38.0	7.0	11.0	POOR
YESO FM,NEW MEX.	LMP	143.0	-1.0	1	99.0	3.0	127.0	41.0	2.0	3.0	FAIR
ARIZ.(RUNCORN,DOELL,GRAHAM IN IRVING,1964)**											
SUPAI FM	CP	150.0	11.0	7	35.0	10.0	110.0	40.0	9.0	9.0	POOR
CAN., PRINCE EDWARD I. (BLACK,1964)											
RED BEDS E PEI	CP	176.8	5.5		12.5	5.5	121.7	40.9	2.7	5.5	GOOD
RED BEDS CEN PEI	CP	170.9	7.2		10.6	5.5	128.3	39.5	2.8	5.5	GOOD
RED BEDS NW PEI	CP	170.0	5.3		22.6	6.1	129.0	39.8	3.1	6.1	GOOD
CAN., PRINCE EDWARD I.(ROY,1963 IN BLACK,1964)											
RED BEDS	CP	174.7	8.1	17	-	7.0	123.2	39.0	3.7	7.4	GOOD
COLORADO (HELSLEY, THIS PAPER)											
CUTLER FM SITE 1	LP	148.0	-7.4	1	25.2	6.5	119.0	44.6	3.3	6.5	GOOD
CUTLER FM SITE 2	LP	142.4	-6.6	1	26.0	6.1	124.8	40.9	3.1	6.1	GOOD

* N = NUMBER OF SITES
** A COMBINED RESULT: RUNCORN, 1955, 1956; DOELL, 1955; GRAHAM, 1955 (IRV. 7.51)
' EAST LONGITUDE, NORTH LATITUDE