

# The magnetic polarity stratigraphy of the Mauch Chunk Formation, Pennsylvania

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Three sections of Chesterian Mauch Chunk Formation in Pennsylvania have been studied paleomagnetically to determine a Late Mississippian magnetic polarity stratigraphy. The upper section at Lavelle includes a conglomerate with abundant red siltstone rip-up clasts that yielded a positive conglomerate test. All samples were subjected to progressive thermal demagnetization to temperatures as high as 700°C. Two components of magnetization were isolated: a synfolding "B" component and the prefolding "C" component. The conglomerate test is positive, indicating that the C component was acquired very early in the history of the sediment. A coherent pattern of magnetic polarity reversals was identified. Five magnetozones were identified in the upper Lavelle section, which yields a pattern that is an excellent match with the pattern of reversals obtained from the upper Mauch Chunk at the original type section of the Mississippian/Pennsylvanian boundary at Pottsville, PA. The frequency of reversals in the upper Mississippian, as identified in the Mauch Chunk Formation, is approximately one to two per million years, which is an average for field reversal through time.

The paleomagnetic study of the Mauch Chunk Formation (Fm) has a long history (1–6). DiVenere and Opdyke (7) were able to obtain an excellent magnetostratigraphic record from the upper part of the Mauch Chunk Fm at Pottsville, PA, over a stratigraphic thickness of 340 m immediately beneath the contact of the basal Pennsylvanian Pottsville Fm. The widespread Mauch Chunk Fm is a monotonous sequence of red and gray siltstones, fine sandstone, and shale. It has been divided informally by Wood *et al.* (8) into three members. The upper member of the Mauch Chunk Fm intertongues with the overlying Pottsville Fm, and the lower member intertongues with the underlying Pocono Fm. Fossils are very scarce in the Mauch Chunk Fm. In the central Pennsylvania folded Appalachians (Fig. 1) the Mauch Chunk Fm forms many of the slopes and is often covered by vegetation. Long sections were available for study at the type section at Jim Thorpe, PA, and at Lavelle, PA. The purpose of this study is to attempt to extend magnetic polarity stratigraphy to a greater portion of the Mauch Chunk Fm.

## Sampling

The lowermost 445 m of the Mauch Chunk, above the intertonguing contact with the Pocono Fm, were sampled at the Mauch Chunk type section along Route 209 and the Lehigh Valley Railroad Tracks. Samples were taken at 1- to 2-m intervals where possible. The base of the section was situated at the railway station where the Pocono Fm intertongues with the Mauch Chunk Fm. Exposures are excellent, except for the top of the section; therefore, the upper part of the section was not sampled at Jim Thorpe.

The second section studied was taken along Route 901 South of Lavelle, between Mahanoy Creek and Interstate 81 on the south limb of the Frackville anticline. The measured section begins in or just above sandstones of the Pocono Fm. Three hundred and twenty meters of section were sampled above the contact with the Pocono, which unfortunately includes a covered interval at 40–60 m above the base of the section, the middle of

the formation is not exposed. The upper part of the section was sampled in a new road cut, which beautifully exposed most of the upper Mauch Chunk, the section beginning at the intersection of Beury Lake Road.

The upper Mauch Chunk at Lavelle is composed of >200 m of section, the lower 120 m of which is monotonous red siltstones and mudstones of the middle Mauch Chunk facies. At ≈120 m from the bottom of the measured section coarse sandstones and conglomerate of Pottsville facies begin to appear in the sequence. Some of these channel sands contain rip-up clasts of the Mauch Chunk facies. The sandstone units are separated from each other by typical Mauch Chunk lithologies. The upper boundary of the red facies is usually taken as the top of Mauch Chunk Fm. The uppermost red bed is above our measured section, which we were unable to sample because of poor exposure. All samples were drilled with a handheld diamond coring drill, which was 2.54 cm in diameter and oriented with a magnetic compass.

## Laboratory Methods

The samples were returned to the laboratory and sliced into cylinders 1.5 cm in length. The samples were progressively demagnetized thermally in 12 or more incremental steps to temperatures as high as 690°C (Fig. 2). All components of magnetization were determined by using line-fitting techniques given by Kirschvink (9). Previous work has shown that at least three components are present in these rocks (3), which were designated components A, B, and C. It has been shown that component A is a recently acquired component of magnetization and unblocks at low temperatures <200°C. Component B in this study, as in previous studies, dominates the orthogonal plots to temperatures >650°C. Component C in this study unblocks at very high temperatures, in most cases, >660°C. This component has dual polarity, normal, northwest and up, and reversed, southeast and down, directions (Figs. 2 and 3). A tilt test was performed in this study comparing the results from Jim Thorpe to the results from the south dipping limb of the Frackville anticline. In this study component B groups best at 70% unfolding (Fig. 4) and is therefore of Permian age. Previously, Kent and Opdyke (3) obtained the best grouping of the "B" component at 50% of unfolding. The mean directions of magnetization of the "C" component from the two localities are not significantly different from each other and are similar to other results from the northeast part of the Pennsylvania salient. However, the inclination is shallower than reported in the study by Kent (4) by ≈10° (Table 1). The reason for this may be due to the incomplete removal of the B component in the reversed C component vectors. However, Stamatakis and Kodama (5) have argued for inclination shallowing in the Mauch Chunk due to strain. The C component passes the fold test and has its maximum concen-

Abbreviation: Fm, formation.

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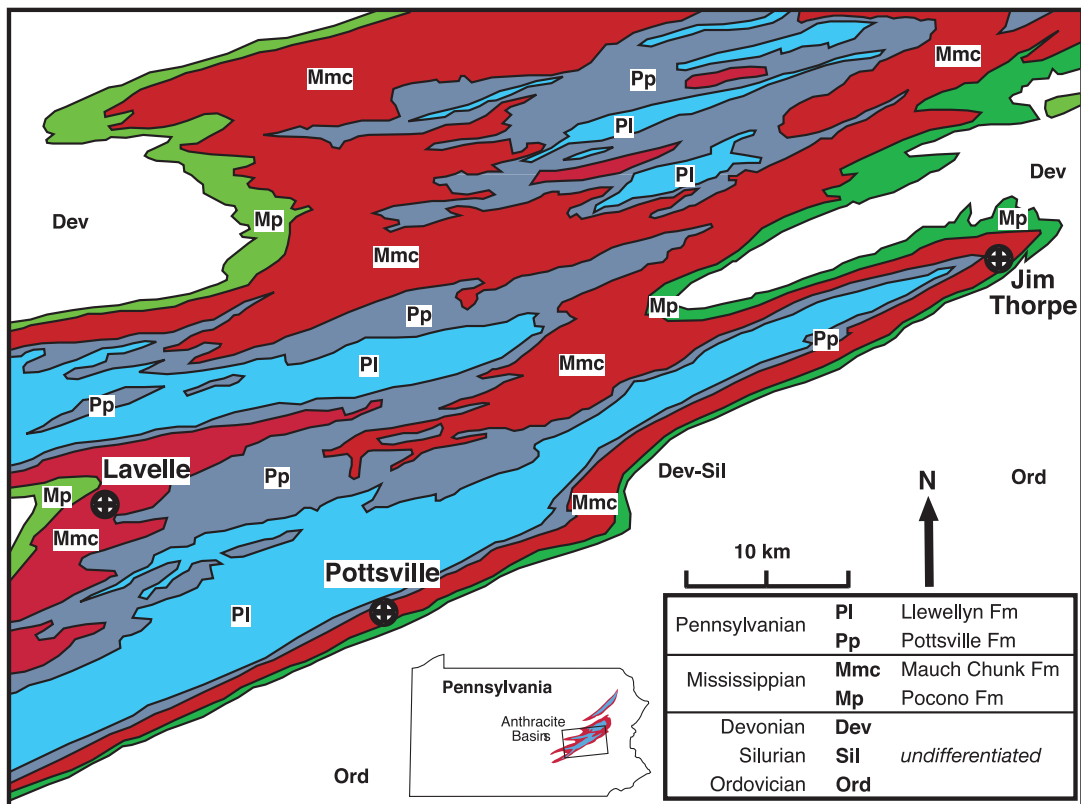


Fig. 1. Sampling localities of the Mauch Chunk Fm, Pennsylvania

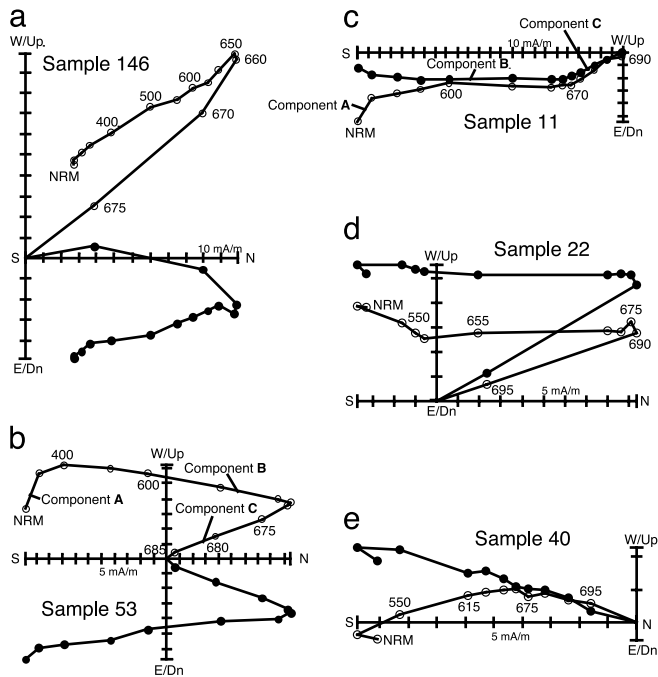


Fig. 2. Orthogonal plots of normal and reversed samples from the Mauch Chunk Fm from Lavelle, PA (a–c), and Jim Thorpe, PA (d and e). The magnetization vectors after the heat treatment specified are plotted on two of the three possible orthogonal planes, normal remanent magnetization (NRM) is the initial magnetization. Solid dots are on the horizontal plane, and the open circles are on one of the two vertical planes as indicated. Straight line segments are indicated as components A, B, and C, as shown for samples 11 and 53 from Lavelle.

tration “K” at 100% unfolding and therefore is older than the Permian folding.

A fold test was performed on the Mauch Chunk Fm exposed in the Frackville anticline by Stamatakos and Kodama (5). They found that the B component grouped best at 80% unfolding, a value similar to that found in this study. Their study consisted of 10 sites, six on the north dipping limb and four on the south dipping limb in sediments of varying lithology ranging from coarse sandstones to shales. They analyzed the strain in the sediments and concluded that the C direction had been affected so that this component was rotated to shallower inclinations on the south flank of the anticline and to steeper inclinations on the north flank. The resulting C component appears to be synfolding. The effect of penetrative strain might help to account for the shallower-than-expected C component observed in this study. It should be noted that in this study siltstones were preferentially sampled and that no shales or coarse sandstones were drilled. We observed that siltstones yield the best results. However, even if the inclination has been affected by strain, the magnetic stratigraphy would be unaffected.

### Conglomerate Test

An opportunity to test the hypothesis of early remanence acquisition is possible since abundant rip-up clasts are present in the Upper Mauch Chunk Fm south of Lavelle along the new road cut for state Route 901 north of the exit from Interstate 81. These clasts are clearly of Mauch Chunk Fm red siltstone and mudstone lithology incorporated into Pottsville facies conglomerates and coarse sandstones during the meandering of the Pottsville streams. The intertonguing of the Pottsville facies with the Mauch Chunk facies provides a nearby source for the clasts. These clasts are large enough to drill, and 20 samples were taken.



**Table 1. Locality statistics**

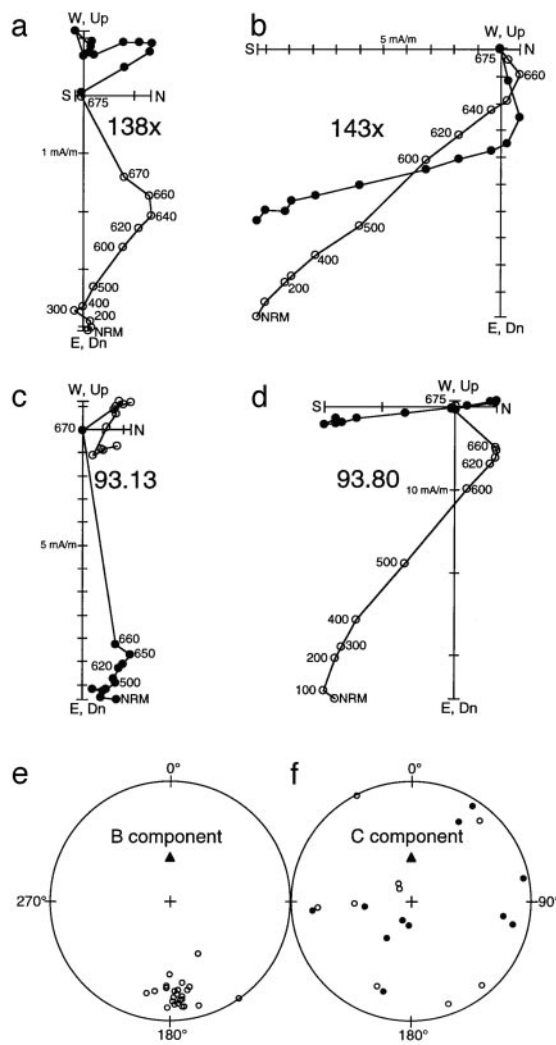
Locality	Long, °E	Lat, °N	n/N	Cmp	<i>In situ</i>			Tilt corrected			
					D, °	I, °	$\kappa$	D, °	I, °	$\kappa$	$\alpha_{95}$
Upper Lavelle	283.6	40.7	34/46	B	174.8	-32.4	61	175.3	26.1	50	4.0
			39/46	C	170.1	-33.1	10	170.9	25.0	10	7.7
Lower Lavelle	283.6	40.7	98/114	B	177.3	24.2	43	175.6	-7.5	42	2.2
			99/114	C	176.6	44.9	6	167.4	17.1	11	4.6
Jim Thorpe	284.3	40.9	150/186	B	182.5	-37.1	26	175.1	9.8	27	2.3
			275/362	B*	179.7	-15.4	7	175.1	-1.0	32	1.5
			141/186	C	175.3	-31.0	12	172.6	18.0	14	3.3
MC			3	B	178.1	-16.0	6	175.3	9.5	23	26.1
			3	C	173.9	-8.4	4	170.3	20.0	263	7.6

MC, global mean for Mauch Chunk Fm; Long, longitude; Lat, latitude; n/N, number of samples used/measured; Cmp, component designation; D, declination; I, inclination;  $\kappa$ , precision parameter;  $\alpha_{95}$ , radius of 95% confidence circle about the mean direction.

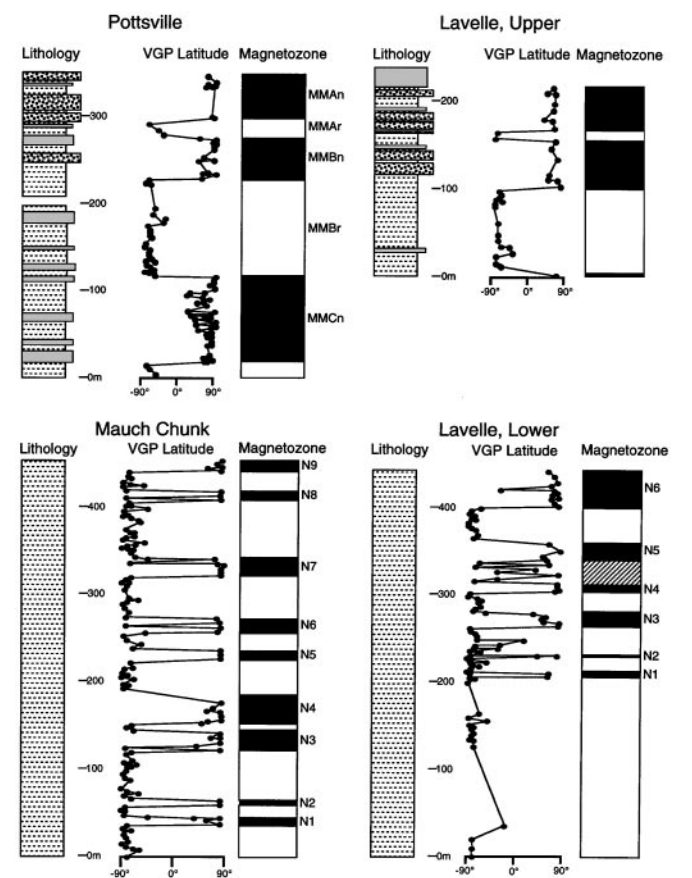
\*B component direction after 70% unfolding.

A short reversed interval begins at 150 m above the base of the section and is  $\approx 12$  m thick. The section terminates in normally magnetized sediment at the base of the Pottsville Fm. The

correlation of the upper sequence magnetic polarity stratigraphy at Lavelle to that previously described at Pottsville (7) is very straightforward. The top of each section at the contact with the Pottsville Fm is dominated by normal polarity with a short reversed magnetozone above the first appearance of sediments of Pottsville lithology. This normal magnetozone is preceded by a long reversed magnetozone in each section of  $\approx 100$  m. The pattern match between the two sections is excellent, and rates of sedimentation appear to be similar. Since the two sections have such matching polarity stratigraphies, a slightly more formal



**Fig. 5.** Orthogonal plots of samples from clasts in the upper Mauch Chunk from Lavelle, PA, plotted as in Fig. 2 with stereoplots of the clast B and C directions corrected for bedding tilt. Directions that plot in the lower hemisphere are represented by solid circles, and directions that plot in the upper hemisphere are represented by open circles.



**Fig. 6.** Litho and magnetic polarity stratigraphy of the Mauch Chunk Fm at Lavelle, Mauch Chunk, and Pottsville. The virtual geomagnetic pole (VGP) latitude is plotted with respect to the section mean paleomagnetic pole against the sample position in the measured section.

designations has been given these magnetozones. We designate them Mississippian Mauch Chunk magnetozones MM An through MM Cn. Time cannot be estimated except very crudely; therefore, the establishment of chrons is inappropriate at this time.

The lower Mauch Chunk Fm was sampled at Jim Thorpe along the section measured by Sevon in the study by Epstein *et al.* (12). The section begins in the transition zone at the top of the Pocono Fm and follows Route 209, then transitions to the Lehigh Valley Railroad. This is the type section of the Mauch Chunk Fm. The section is well exposed and 445 m of section were sampled. Eighteen magnetozones were delineated based on two or more consecutive sites with the same polarity. The base of the section at the contact with the Pocono Sandstone is reversely magnetized. The first 110 m of section contains two normal magnetozones of short duration, and reversed magnetization dominates this interval. The interval from 100 to 200 m is characterized by the presence of two prominent normal magnetozones, N3 and N4, which terminate in a sampling hiatus, making the upper limit of N4 uncertain. The section between 200 and 300 m is again characterized by two normal magnetozones, N5 and N6, and these are followed by another normal interval at 325 m (N7). The upper part of the section has two normal magnetozones, N8 at 410 m with the section terminating in normal zone N9. Reversed polarity dominates the section, 64% of the sediments being of this polarity.

The magnetic polarity stratigraphy of the lower part of the Mauch Chunk Fm at Lavelle is complicated by the presence of two long covered intervals in the lower 200 m, which represent 75% of the section, probably caused by the presence of the Higgins fault (8) that undoubtedly has led to the apparent thickening of the lower reversed magnetozones. Three normal magnetozones occur between 200 and 300 m. The first normal magnetozone (N1) occurs at 206 m, the second occurs at 225 m (N2), and the third occurs at 268 m (N3). The polarity record is very noisy between 300 and 360 m; however, at least two normal magnetozones are present in this interval. The top of the section terminates in normally magnetized sediments of N6. Fifty-six percent of the sediments above N1 are reversely magnetized.

The correlation of the lower Mauch Chunk Fm between Mauch Chunk and the section along Route 901 south of Lavelle is not certain. However, the lowest part of the formation

immediately above the contact with the Pocono Fm is reversely magnetized in each section. The covered interval in the lower part of the section at Lavelle of 80 m may well mark the presence of the Higgins fault and may cause repetition of strata. This faulting makes a one-to-one correlation between the two sections difficult; however, correlating N1 in each section and N7 at Jim Thorpe to N6 at Lavelle leads to a reasonable correlation between the two sections. Other correlations are possible, but none are compelling.

## Conclusions

The successful conglomerate test on rip-up clasts has shown that Paleozoic red beds can preserve syndepositional or early post-depositional magnetic components that can be used in determining the polarity history of the earth's magnetic field at the time the sediments formed.

The magnetic polarity stratigraphy of the late Mississippian upper Mauch Chunk Fm that was first delineated at Pottsville has been confirmed at Lavelle and has been given a formal designation. Eighteen magnetozones have been established in lower and middle Mauch Chunk Fm sediments at Jim Thorpe and tentatively correlated to Lavelle.

The rate of reversal of the earth's field in the Mississippian appears to be similar to later times in the earth's history. The length of time covered by the Mauch Chunk Fm can be estimated by using standard timescales (13), and it is probably on the order of 16 million years. We have detected at least 22 reversals of the earth's magnetic field and, since the formation has not been sampled in its entirety, more reversals undoubtedly exist. The rate of reversal will exceed one per million years and may be close to the average rate of reversal of two per million years suggested by Opdyke and Channell (14).

Magnetic polarity stratigraphy may be used to zone the Mauch Chunk Fm that, because of its monotonous succession of red siltstones and mudstone and paucity of fossils, is historically difficult to correlate. A bore core through the formation would be very useful in this effort.

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