Appendix F

PHS-1 (Upper Mississipian Hinton Fm.)

PB1 and PB2 (2.6 and 2.7 m, respectively) are red muddy point-bar deposits with weakly developed soil structures. $\kappa$ and $\chi_{\text{lf}}$ (Figs. F-1 and F-2, respectively) are similar with PB2 having slightly higher values in both cases. Hysteresis data (Figs. F-3 a1 to b2) indicate that antiferromagnetic minerals occur in both samples and that ferrimagnetic minerals occur in sample PB2. Since these samples are clay based mudstones, paramagnetic contribution can be inferred however, the strong antiferromagnetic signature masks any paramagnetic influence below $\sim 0.8$ T. Antiferromagnetic signatures are inferred by broad open loops above $0.4$ T (Figs. F-3 a1 and b1), wasp-waisted loop characteristics (Fig. F-3 b2), and high $B_{\text{CR}}$ values (Figs. F-3 a2 and b2) indicative of high-coercivity minerals (e.g. hematite). Ferrimagnetic contribution is suggested in PB2 by the wasp-waisted characteristics seen in Figure F-3 b2. $M_S$ data (Fig. F-4) indicates that PB1 and PB2 are both associated with higher concentrations of paramagnetic minerals compared to antiferromagnetic and ferrimagnetic minerals. PB1 and PB2 $\chi_h$ values (Fig. F-5) indicate that paramagnetic and antiferromagnetic minerals are dominating the $\chi_{\text{lf}}$ signal; however since paramagnetic minerals have weaker $\kappa$ and $\chi_{\text{lf}}$ values pound-for-pound, antiferromagnetic minerals are probably controlling the bulk of $\chi_h$. Furthermore, the $\chi_{\text{ferri}}$ associated with PB2 indicates that ferrimagnetic minerals are much more prevalent in this sample as suggested by the wasp-waisted hysteresis characteristics (Fig. F-3 b2). In terms of magnetic grain-size, the Day Plot (Fig. F-6) indicates that PB2 is associated with larger magnetic grains compared to PB1. Overall, PB2 has slightly higher $\kappa$ and $\chi_{\text{lf}}$ values, compared to PB1. This is primarily due to an increase in the ferrimagnetic concentration and magnetic grain-size observed in PB2. Both samples are dominated by paramagnetic minerals, and since $\chi_h > \chi_{\text{ferri}}$, hematite is the dominant contributor to $\kappa$ and $\chi_{\text{lf}}$.

PC1 (3.0 m) is a sandy matrix supported basal point-bar platform conglomerate overlying a scour surface that truncates underlying red vertic paleosol facies. $\kappa$ and $\chi_{\text{lf}}$ values (Figs. F-1 and F-2, respectively) represent susceptibility lows compared to adjacent overlying and underlying samples. Hysteresis data (Figs. F-3 c1 and c2) indicate that paramagnetic and ferrimagnetic minerals occur in the sample. Paramagnetic minerals are inferred on the basis of
positive slope loop characteristics that remain closed at all fields (-1.2 to 1.2 T) prior to slope-correction. Ferrimagnetic minerals are inferred on the basis of a slope-corrected loop shape that reaches saturation at low fields (~ 0.2 T). Moderate $B_{CR}$ values (Fig. F-3 c2) suggest that higher coercivity mineral phases (e.g. hematite or SD magnetite) are present in the sample. However, due to low concentrations of this higher coercivity mineral, the slope corrected loop quality is poor and identifying any wasp-waisted characteristics is difficult. $M_S$ data (Fig. F-4) shows that the paramagnetic mineral concentration is significantly higher than the ferri/antiferromagnetic concentration. Figure F-5 shows a similar relationship where $\chi_h$ is much greater than $\chi_{ferri}$ suggesting that the paramagnetic and antiferromagnetic mineral phases have the greatest contribution to $\chi_{lf}$. The Day Plot (Fig. 5.6) shows that the magnetic grain-size associated with PC1 is complex due to high $B_{CR}/B_C$ values indicating that higher coercivity minerals are contributing to the samples remanence (Channel and McCabe, 1994). Overall, PC1 is associated with higher concentrations of paramagnetic minerals that likely dominate $\kappa$ and $\chi_{lf}$ values.

PV1 and PV2 (3.1 and 3.4 m, respectively) are red paleovertisols lying directly below the inclined lateral accretion deposits. Compared to PV1, $\kappa$ and $\chi_{lf}$ values (Figs. F-1 and F-2, respectively) are higher in PV2. Hysteresis data (Figs. F-3 d1 to e2) indicate that paramagnetic, antiferromagnetic, and ferrimagnetic minerals are present. Since these samples are clay based mudstones, paramagnetic contribution can be inferred, however, the strong antiferromagnetic signature masks any paramagnetic influence below ~ 0.8 T. Antiferromagnetic signatures are indicated by broad loops that are open above 0.4 T (Fig. F-3 d1 and e1), wasp-waisted loop characteristics (Fig. F-3 b2), and high $B_{CR}$ values (Figs. F-3 d2 and e2) all of which are indicative of high coercivity minerals. The slope-corrected loops (Figs. F-3 d2 and e2) show varying degrees of wasp-waistedness (indicating mixtures of antiferromagnetic and ferrimagnetic minerals) between the two samples, where PV2 displays strong wasp-waisted characteristics and PV1 displays very slight wasp-waisted characteristics. Figure F-4 shows that PV1 and PV2 have higher concentrations of paramagnetic minerals and lower concentrations of ferri/antiferromagnetic minerals. Figure F-5 shows that $\chi_{ferri}$ values are higher and $\chi_h$ values are lower PV1 and PV2, compared to PC1. This relationship indicates that PV1 and PV2 $\kappa$ and $\chi_{lf}$ values are higher than that of PC1 due to increased ferrimagnetic mineral concentration. The Day Plot (Fig. F-6) indicates that PV2 is associated with larger antiferromagnetic and/or ferrimagnetic grain-sizes compared to PV1. Grain-size discrepancies coupled with a higher
ferrimagnetic concentration (suggested by increased wasp-waistedness in Figure F-3 e2) and increased $\chi_{\text{ferri}}$ (Fig. F-5) for PV2, resulted in higher $\kappa$ and $\chi_{\text{lf}}$ values for PV2. Overall, PV1 and PV2 are associated with higher concentrations of paramagnetic minerals however, $\kappa$ and $\chi_{\text{lf}}$ values are likely being dominated by stronger antiferromagnetic mineral phases.

PV3 and PV4 (6.5 and 6.8 m, respectively) are red vertisols located at the base of a 4 m soil profile. $\kappa$ and $\chi_{\text{lf}}$ values (Figs. F-1 and F-2, respectively) are higher in PV3 compared to PV4. Hysteresis data (Figs. F-3 f1 to g2) indicate that paramagnetic, antiferromagnetic, and ferrimagnetic minerals occur in both samples. Antiferromagnetic signatures are indicated by broad loops that are open above 0.4 T (Fig. F-3 f1 and g1), wasp-waisted loop characteristics (Fig. F-3 b2), and high $B_{\text{CR}}$ values (Figs. F-3 d2 and e2) all-of-which are indicative of high coercivity minerals. The slope-corrected loops (Figs. F-3 f2 and g2) show varying degrees of wasp-waistedness (indicating mixtures of antiferromagnetic and ferrimagnetic minerals) between the two samples, where PV4 displays stronger wasp-waisted characteristics compared to PV3. These samples are clay based mudstones; therefore paramagnetic contribution can be inferred however, the strong antiferromagnetic signature masks any paramagnetic influence below ~1.0 T. Figure F-4 indicates that PV3 has a higher concentration of paramagnetic minerals and a lower concentration of ferri/antiferromagnetic minerals compared to PV4. The data in Figure F-5 indicates that the majority of the $\chi_{\text{lf}}$ signal is derived from $\chi_h$ for PV3 and PV4 with PV4 having the greater contribution to $\chi_{\text{lf}}$ from $\chi_h$. However, the $\chi_{\text{ferri}}$ values associated with PV3 and PV4 (Fig. F-5) suggest that PV3 has a greater ferrimagnetic contribution to $\chi_{\text{lf}}$ compared to PV4. The Day Plot (Fig. F-6) shows that PV3 is associated with larger magnetic grain-sizes compared to PV4. Therefore, PV3 has higher $\kappa$ and $\chi_{\text{lf}}$ values due to its greater proportion of ferri/antiferromagnetic minerals and larger magnetic grain-size. Overall, PV3 and PV4 are associated with higher concentrations of paramagnetic minerals that are likely dominating both $\kappa$ and $\chi_{\text{lf}}$ values.

MS1 (7.5 m) is a red mudstone located below a 0.4 m calcic paleosol and above a 1.5 m laccustrine limestone. $\kappa$ and $\chi_{\text{lf}}$ values for MS1 (Figs. F-1 and F-2, respectively) are the lowest for the PHS-1 core. Hysteresis data (Figs. F-3 h1 and h2) indicate that paramagnetic and antiferromagnetic minerals occur in the sample. Antiferromagnetic signatures are indicated by broad loops that are open above 0.4 T (Fig. F-3 h1 and h2), wasp-waisted loop characteristics
(Fig. F-3 h2), and high $B_{CR}$ values (Fig. F-3 h2) all-of-which are indicative of high-coercivity minerals. MS1 is a clay based mudstones; therefore paramagnetic contribution can be inferred however, the strong antiferromagnetic signature masks any paramagnetic influence below ~1.0 T. Figure F-4 shows that the concentration of paramagnetic minerals is greater than the concentration of ferri/antiferromagnetic minerals. However, Figure F-5 indicates that the greatest contribution to $\chi_{lf}$ is derived from antiferromagnetic and paramagnetic minerals. Furthermore, Figure F-5 shows that there is a ferrimagnetic contribution to $\chi_{lf}$ however; hysteresis data (Fig. F-3 h2) does not display identifiable wasp-waisted characteristics. The Day Plot (Fig. F-6) indicates that the magnetic grain-size associated with MS1 falls within the cluster of data for the majority of the PHS-1 samples. Decreases in the concentration of paramagnetic and/or antiferromagnetic minerals in MS1 may result in the $\kappa$ and $\chi_{lf}$ lows observed in Figures F-1 and F-2; however differences in magnetic minerals phases between MS1 and the other samples may also be responsible for these susceptibility lows. Overall, MS1 is associated with higher concentrations of paramagnetic minerals however, $\kappa$ and $\chi_{lf}$ are probably controlled by stronger antiferromagnetic mineral phases.

LL1, LL2, and LL3 (8.4, 8.6, and 9.5 m, respectively) are lacustrine limestones located at the base of the profile beneath the red mudstone. $\kappa$ and $\chi_{lf}$ values (Figs. F-1 and F-2, respectively) are closely related and vary systematically with respect to one another. Hysteresis data (Figs. F-3 i1 to k2) indicate that the magnetic mineralogy, and concentration are quite different between the samples. LL1 and LL3 hysteresis data (Figs. F-3 i1, i2, k1, and k2) shows that paramagnetic, antiferromagnetic, and ferrimagnetic minerals occur in the sample. In contrast, LL2 hysteresis data (Figs. F-3 j1 and j2) indicates that paramagnetic and ferrimagnetic minerals dominate the sample; however a higher coercivity mineral phase (e.g. hematite) may be present in low concentrations. Low $M_s$ and $B_C$ values associated with LL2 (Fig. F-3 j2) suggest that the ferrimagnetic mineral phase is magnetite. Paramagnetic signatures are indicated by closed loop characteristics below 0.4 T (LL2, Fig. F-3 j1) and inferred for the reason that these samples are clay-based mudstones. Antiferromagnetic signatures are indicated by broad loops that are open above 0.4 T (Fig. F-3 i1 and k1), wasp-waisted loop characteristics (Fig. F-3 i2 and k2), and high $B_{CR}$ values (Figs. F-3 i2 and k2) all-of-which are indicative of high-coercivity minerals (e.g. hematite). Ferrimagnetic mineral occurrences are inferred by the wasp-waisted loop characteristics observed in Figures F-3 i2 and k2, and by the loop shape and low $B_{CR}$ values.
seen in LL2 (Fig. F-3 j2). Figure F-4 indicates that these samples are dominated by paramagnetic minerals, with ferri/antiferromagnetic minerals occurring in lower concentrations. LL2 displays paramagnetic and ferrimagnetic concentration lows for the three samples. However, Figure F-4 shows that $\chi_{\text{ferri}} > \chi_h$ for LL2. This indicates that the majority of the $\chi_{\text{lf}}$ signal resides within the ferrimagnetic fraction for LL2, much different from that of LL1 and LL3. The majority of the $\chi_{\text{lf}}$ signal for LL1 and LL3 is derived from the antiferromagnetic and paramagnetic fraction ($\chi_h$, Fig. F-5). The Day Plot (Fig. F-6) indicates that LL1 is associated with a smaller magnetic grain-size than LL3. LL2, in contrast, is associated with a different magnetic mineralogy compared to LL1 and LL3 (ferrimagnetic for LL2 vs. antiferromagnetic for LL1 and LL3) therefore grain-size comparisons are meaningless. Despite having much lower paramagnetic and antiferromagnetic concentrations, LL2 $\kappa$ and $\chi_{\text{lf}}$ values vary little with respect to those of LL1 and LL3. Therefore, ferrimagnetic minerals are in high enough concentration to effectively raise the $\kappa$ and $\chi_{\text{lf}}$ for LL2. Overall, LL1, LL2, and LL3 are all associated with higher concentrations of paramagnetic minerals with respect to antiferromagnetic and ferrimagnetic minerals. In the case of LL1 and LL3, antiferromagnetic minerals are responsible for the bulk of $\kappa$ and $\chi_{\text{lf}}$. In contrast, ferrimagnetic minerals are responsible for the bulk of $\kappa$ and $\chi_{\text{lf}}$ in LL2.
Figure F-1

PHS 1 - K

Red Pointbar Vertisol

Red Vertisol

Red Lacustrine Carbonate

Depth (m)

K (SI x 10^-5)

PC1

PB1

PB2

PV1

PV2

PV3

PV4

MS1

LL1

LL2

LL3

Red Pointbar Vertisol

Red Vertisol

Red Lacustrine Carbonate
Figure F-3

(a1) PB1 Hysteresis - 2.6 m

\[
\begin{align*}
B_C &= 42.2 \text{ mT} \\
M_{RS} &= 4.35 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \\
M_S &= 108 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1}
\end{align*}
\]

(b1) PB2 Hysteresis - 2.7 m

\[
\begin{align*}
B_C &= 18.6 \text{ mT} \\
M_{RS} &= 1.57 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \\
M_S &= 82.8 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1}
\end{align*}
\]

(c1) PC1 Hysteresis - 3.0 m

\[
\begin{align*}
B_C &= 1.33 \text{ mT} \\
M_{RS} &= 0.14 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \\
M_S &= 94.6 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1}
\end{align*}
\]

(a2) PB1 Slope Corrected - 2.6 m

\[
\begin{align*}
B_C &= 267.8 \text{ mT} \\
M_{RS} &= 4.35 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \\
M_S &= 7.58 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1}
\end{align*}
\]

(b2) PB2 Slope Corrected - 2.7 m

\[
\begin{align*}
B_C &= 132 \text{ mT} \\
M_{RS} &= 1.57 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \\
M_S &= 3.72 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1}
\end{align*}
\]

(c2) PC1 Slope Corrected - 3.0 m

\[
\begin{align*}
B_C &= 8.81 \text{ mT} \\
M_{RS} &= 0.14 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \\
M_S &= 1.02 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1}
\end{align*}
\]
Figure F-3

(d1) PV1 Hysteresis - 3.1 m
- \( B_C = 21.0 \text{ mT} \)
- \( M_{RS} = 1.93 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_S = 94.6 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)

(d2) PV1 Slope Corrected - 3.1 m
- \( B_C = 154.5 \text{ mT} \)
- \( M_{RS} = 1.93 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_S = 4.73 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_{RS}/M_S = 0.41 \)
- \( B_{CR} = 440 \text{ mT} \)
- \( B_{CR}/B_C = 2.85 \)

(e1) PV2 Hysteresis - 3.4 m
- \( B_C = 21.8 \text{ mT} \)
- \( M_{RS} = 2.01 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_S = 94.5 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)

(e2) PV2 Slope Corrected - 3.4 m
- \( B_C = 221.2 \text{ mT} \)
- \( M_{RS} = 2.01 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_S = 3.42 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_{RS}/M_S = 0.59 \)
- \( B_{CR} = 497 \text{ mT} \)
- \( B_{CR}/B_C = 2.25 \)

(f1) PV3 Hysteresis - 6.5 m
- \( B_C = 48.6 \text{ mT} \)
- \( M_{RS} = 4.57 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_S = 100 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)

(f2) PV3 Slope Corrected - 6.5 m
- \( B_C = 343.6 \text{ mT} \)
- \( M_{RS} = 4.57 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_S = 6.93 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \)
- \( M_{RS}/M_S = 0.66 \)
- \( B_{CR} = 595 \text{ mT} \)
- \( B_{CR}/B_C = 1.73 \)
**Figure F-3**

(g1) PV4 Hysteresis - 6.8 m

- $B_C = 41.9$ mT
- $M_{RS} = 4.54 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_S = 117 \times 10^{-3}$ Am$^2$ kg$^{-1}$

(g2) PV4 Slope Corrected - 6.8 m

- $B_C = 422.0$ mT
- $M_{RS} = 4.54 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_S = 5.56 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_{RS}/M_S = 0.82$
- $B_{CR} = 592$ mT
- $B_{CR}/B_C = 1.40$

(h1) MS1 Hysteresis - 7.4 m

- $B_C = 51.3$ mT
- $M_{RS} = 4.19 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_S = 85.2 \times 10^{-3}$ Am$^2$ kg$^{-1}$

(h2) MS1 Slope Corrected - 7.4 m

- $B_C = 288.8$ mT
- $M_{RS} = 4.19 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_S = 6.53 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_{RS}/M_S = 0.64$
- $B_{CR} = 598$ mT
- $B_{CR}/B_C = 2.07$

(i1) LL1 Hysteresis - 8.4 m

- $B_C = 48.4$ mT
- $M_{RS} = 3.63 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_S = 66.0 \times 10^{-3}$ Am$^2$ kg$^{-1}$

(i2) LL1 Slope Corrected - 8.4 m

- $B_C = 164.6$ mT
- $M_{RS} = 3.63 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_S = 6.22 \times 10^{-3}$ Am$^2$ kg$^{-1}$
- $M_{RS}/M_S = 0.58$
- $B_{CR} = 343.2$ mT
- $B_{CR}/B_C = 2.09$
Figure F-3

(j1) LL2 Hysteresis - 8.6 m

\[ B_C = 5.71 \text{ mT} \]
\[ M_{RS} = 0.14 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]
\[ M_S = 23.7 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]

(j2) LL2 Slope Corrected - 8.6 m

\[ B_C = 29.5 \text{ mT} \]
\[ M_{RS} = 0.14 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]
\[ M_S = 0.44 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]
\[ M_{RS}/M_S = 0.32 \]
\[ B_{CR} = 185 \text{ mT} \]
\[ B_{CR}/B_C = 6.27 \]

(k1) LL3 Hysteresis - 9.5 m

\[ B_C = 52.8 \text{ mT} \]
\[ M_{RS} = 5.53 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]
\[ M_S = 102 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]

(k2) LL3 Slope Corrected - 9.5 m

\[ B_C = 258.7 \text{ mT} \]
\[ M_{RS} = 5.53 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]
\[ M_S = 7.84 \times 10^{-3} \text{ Am}^2 \text{ kg}^{-1} \]
\[ M_{RS}/M_S = 0.71 \]
\[ B_{CR} = 451 \text{ mT} \]
\[ B_{CR}/B_C = 1.74 \]
Figure F-6

PHS-1 Day Plot

$M_{RS}/M_S$ vs $B_{CR}/B_C$

- PV4
- LL3
- PV3
- MS1
- PV2
- PB1
- PV1
- PB2
- LL2
- PSD
- PC1

$S_D$

MD
Appendix F

PHS-1 Figure Captions

**Figure F-1** Volume susceptibility profile through the Upper Mississippian Lower Hinton Formation.

**Figure F-2** Low-frequency mass dependent susceptibility profile through the Upper Mississippian Lower Hinton Formation.

**Figure F-3** Hysteresis data. The Initial Loops pertains to the original hysteresis loop for all magnetic components. The Slope Corrected Loops pertain only to the ferrimagnetic components. B_C, M_RS, and M_S values are shown for each loop. B_CR data acquired from backfield experiments are also given for the slope corrected loops.

**Figure F-4** Saturation magnetization (M_S) data obtained from hysteresis measurements. Ferrimagnetic and paramagnetic M_S values reflect respective magnetic mineral concentrations.

**Figure F-5** Ferrimagnetic (χ_ferr) and high-field (χ_h) susceptibility obtained from hysteresis and magnetic susceptibility (χ_lf) measurements. χ_ferr and χ_h represent the respective ferrimagnetic and paramagnetic contributions to χ_lf.

**Figure F-6** PHS-1 Day Plot. Magnetite samples all fall in the PSD field according to the criteria of Dunlop and Ozdemir (1997). SD, PSD, and MD grain-size regions only apply to samples in which magnetite-titanomagnetite has been identified as the only remanence carrier.

**References**
