UPPER ATOKA OUTCROP TO SUBSURFACE CORRELATION AND SEDIMENTATION HISTORY USING MAGNETIC SUSCEPTIBILITY

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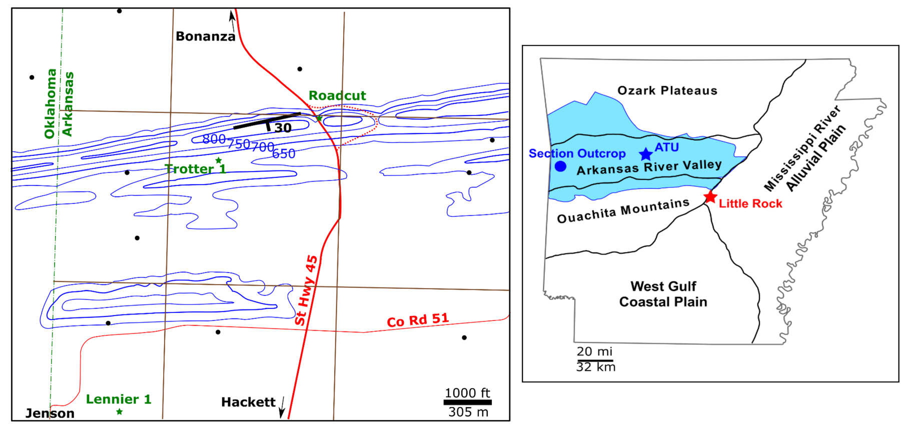
Introduction

The Upper Atoka Formation is Pennsylvanian in age and is shale-rich with interbedded sandstone units. It is interpreted to be shelf and prodelta sedimentary environments. A significant portion of one shale-rich unit is exposed in Hackett, AR in the western Arkansas River Valley region of the state.



Contour map modified from USGS Greenwood Quadrangle and Google Maps. Arkansas Physiographic map modified from Arkansas State Geological Survey physiographic and geological maps.

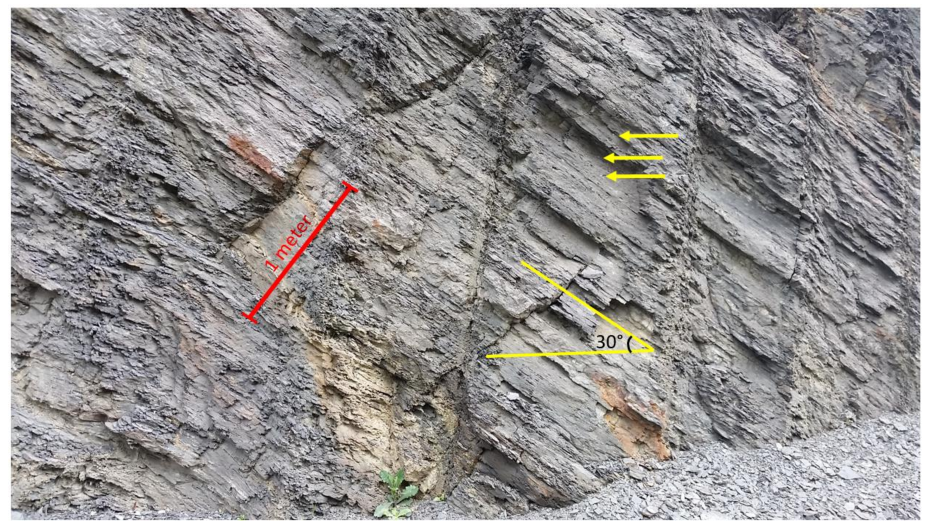
Map of outcrop and core locations and topography around the Backbone Anticline.

A correlation can be made to the Trotter #1 core and Lennier #1 core. Black dots are locations of other gas wells with well-log data.

Purpose

The purpose of this study was to determine the sedimentation history of the exposure using magnetic susceptibility properties of the shale-rich strata, and link these findings to the regional stratigraphy.

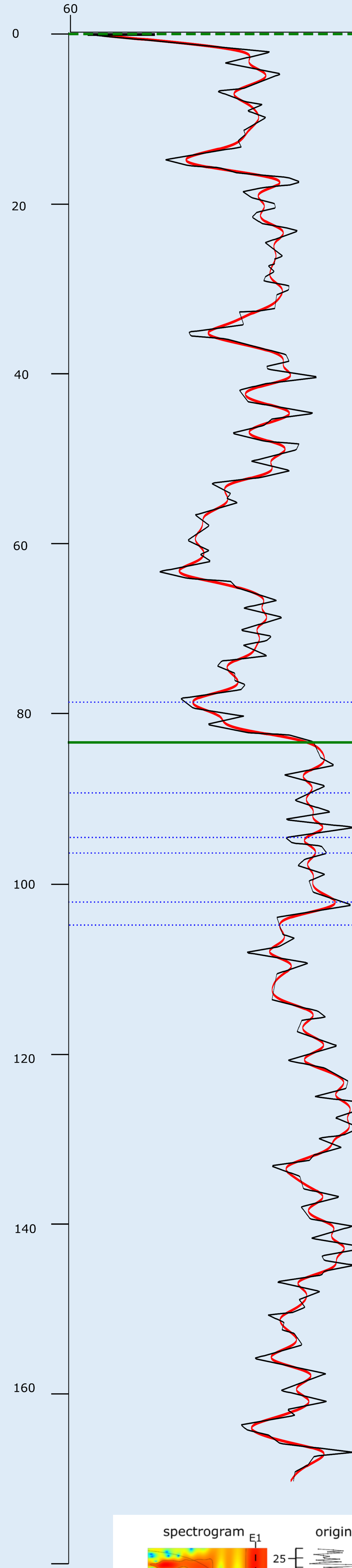
Methods



Field photo showing the bottom portion of the sampled area. The Atoka in this photo is comprised of shale. The tan to red areas are weathered sections that were avoided when sampling to preserve the unaltered nature of the bedding and its included minerals. Yellow arrows indicate positions of the samples taken. These reflect 0.10 m sampling interval, which was corrected for the 30 degree dip. A later trip collected samples at 0.10 m, but was offset from the original collection by 0.05 m, deriving a higher-resolution dataset. That portion of the section is not pictured here.

William's Magnetic Susceptibility Bridge at Louisiana State University. Photo by B. Ellwood.

At each interval, about 30 grams of material was collected and later pelletized in the lab to remove effects of anisotropy. 8-12 grams of material was placed in small sample bags and numbered continuously. The magnetic susceptibility values and mass were calculated using the Williams Magnetic Susceptibility Bridge at Louisiana State University.

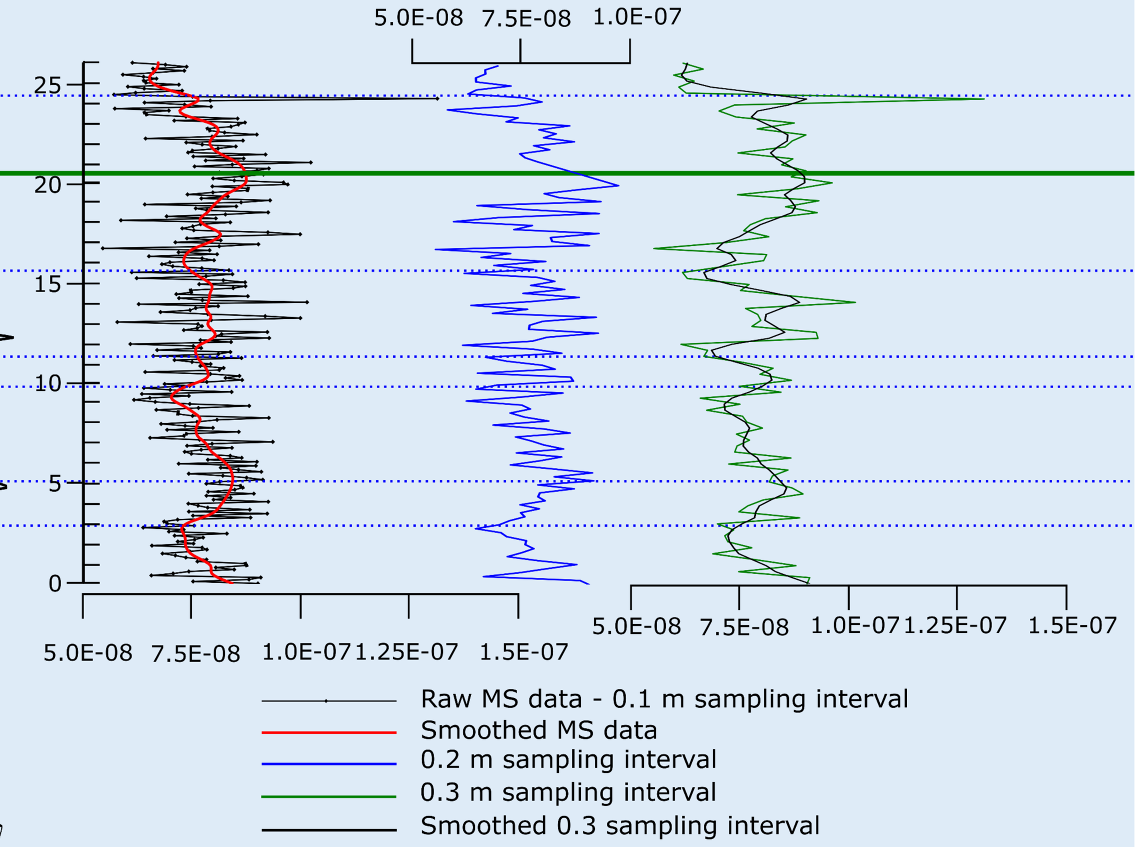


Linking to Regional Stratigraphy. Correlation between the magnetic susceptibility data and a gamma-ray curve from Lennier #1 well-log near the research area is shown here.

The gamma-ray log is in meters starting at the base of the Lower Carpenter sandstone unit. The gamma-ray log is smoothed with a cubic spline (red).

Parts to Note:

- The correlation to the magnetic susceptibility data from the exposure begins at approximately 80 m below the base of the Lower Carpenter. This was corroborated in the field along the exposure with a Jacob staff.
- The horizontal green line below represents a well-defined "kick" that serves as a hanging point for the correlation between datasets. The blue dotted lines represent additional correlations to the raw and smoothed magnetic susceptibility data.
- It is easier to distinguish hanging points for a gamma-ray log if the data are smoothed or the sampling interval is larger. Correlating with smoothed (splined) curves was used to correlate to well-logs.

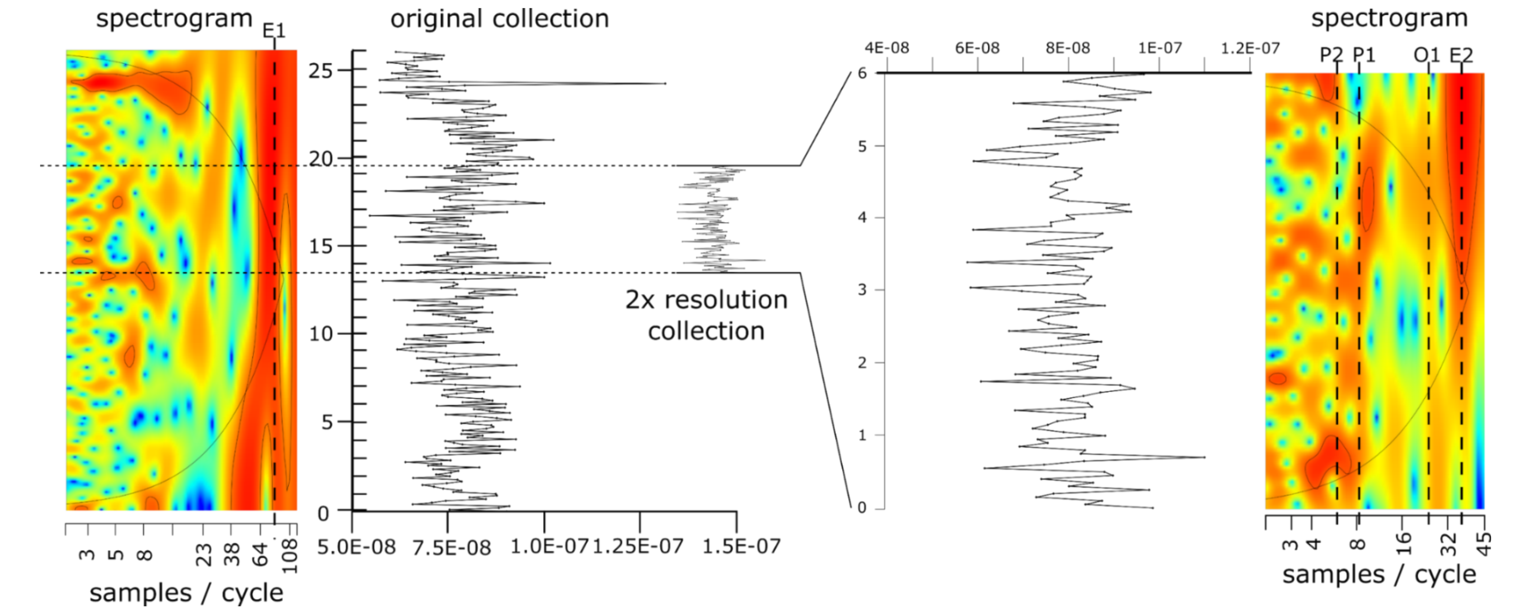


Magnetic susceptibility curves with sampling interval spacing at 0.10, 0.20, and 0.30 m and smoothed versions of these curves.

Correlation between smoothed raw data at 0.10 m sampling interval and the smoothed 0.30 m interval suggests that when looking to correlate MS data to a gamma-ray log, a coarser sampling interval is viable and efficient.

Spectrograms (below) depict cyclicity of data (x-axis) in samples through the height of the section (y-axis). Warm colors represent a cyclicity is present, cool colors absent. Powerful cycles present in the exposure are depicted by vertical warm bands. Some are highlighted, including the 0.129 f-value spectrogram from the original collection (left), and all detected in the second 0.05 m sampling (right).

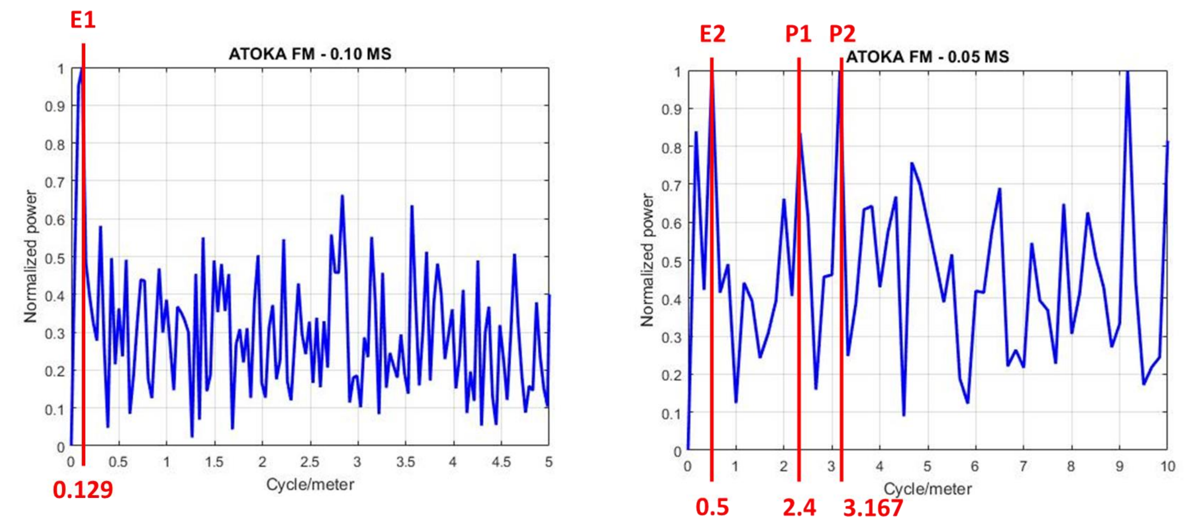
(Below) Spectrogram of raw magnetic susceptibility data from original collection (left), and the segment of that section sampled in a second collection and where it lies in that section (right).



Results and Interpretation

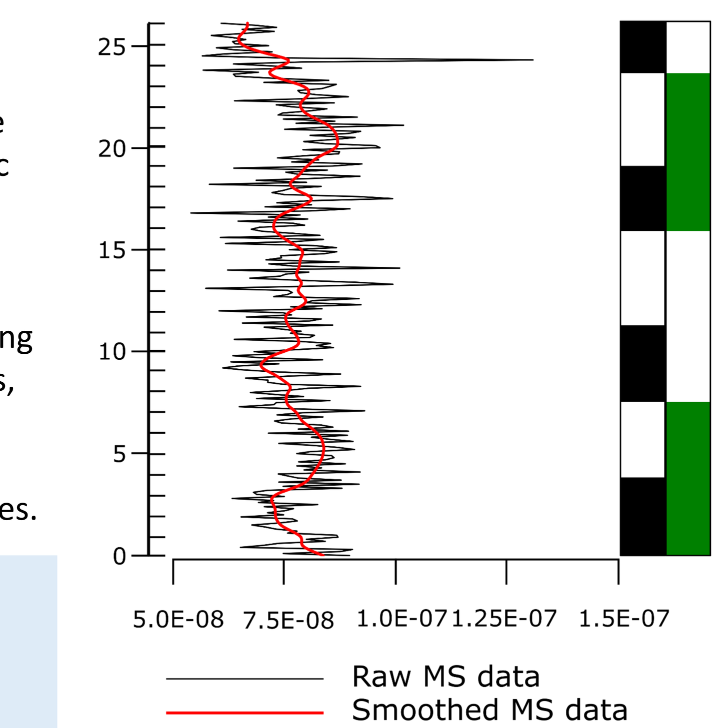
Sedimentation history. Fourier Transform signal analysis from initial collection, and at 2x the resolution for the targeted segment of the exposure.

Four powerful peaks, indicated by red lines, from the two datasets indicate Milankovitch-scale controls on sedimentation. Recorded are their interpreted Milankovitch bands.



Bar-logs help visualize cyclicity.

For each bar-log plot, the black line is raw magnetic susceptibility data. The colored line represents smoothed raw data. The black and white alternating bars represent half cycles, and colored alternating bars represent full cycles built from those half cycles.



E1 spline and bar-log depicting ~3 cycles over a section of about 26 m. Magnetic susceptibility data is from a continuous 26 m section sampled every 0.10 m. The number of cycles depicted in the bar-log coincide with Fourier Transform results. The 3 full cycles match the strong f-value at 0.129 cycles/m (7.75 m/cycle). E1 should complete a cycle about every 405,000 years.

Fourier transform results scaled to Milankovitch bands.

	E1	E2	O1	O2	P1	P2
duration (years)	405000	100000	42680	34070	20650	17360
pred. scaled difference compared to E2	0.2469	1	2.3430	2.9351	4.8426	5.7604
f-values (cycles/m)	0.129	0.5	-	-	2.4	3.167
actual f-values scaled to E2	0.258	1	-	-	4.8	6.334

Found in studies at 0.10 m and 0.05 m sampling interval

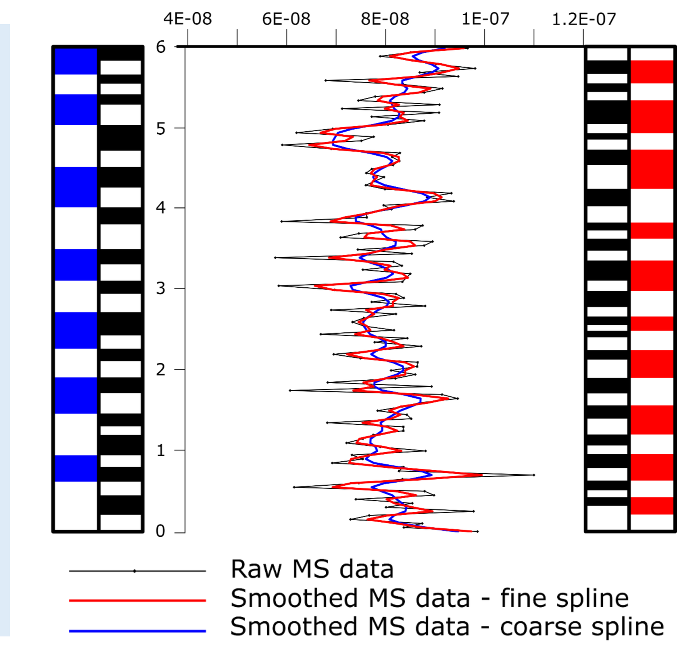
Close scaling of predicted scaled difference and f-value scaled difference.

Harmonic number (number of cycles in outcrop) for initial sampling and resampling for each Milankovitch band.

	E1	E2	O1	O2	P1	P2
duration (years)	405000	100000	42680	34070	20650	17360
f-values (cycles/m)	0.129	0.5	1.17	-	2.4	3.167
meters/cycle	7.75	2	0.85	-	0.417	0.316
number of cycles in 26.2 m	3.38	13.1	30.8	-	62.8	82.9
number of cycles in 6 m	0.77	2	7.02	-	14.4	19

Found in initial study at 0.10 m sampling interval

Found in study at 0.05 m sampling interval



Combined P1 and P2 cycles. P1 and P2 spline and bar-log depicting ~14 cycles and ~19 cycles respectively, over a section of about 6 m. Points plotted on the bar log are raw magnetic susceptibility data. The blue (P1) and red line (P2) are smoothed curves of the raw magnetic susceptibility values.

The number of cycles depicted in the bar-log coincide with Fourier Transform results. The 14 full cycles for P1 match the strong f-value at 2.4 cycles/m (0.417 m/cycle), giving a harmonic number of 14.4 for the 6 m and should complete a cycle about every 20,650 years. The 19 full cycles for P2 match the strong f-value at 3.167 cycles/meter (0.316 m/cycle) and should complete a cycle about every 17,630 years.

Acknowledgements

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Conclusions & Future Work

- Magnetic susceptibility data recorded from the shelfal and prodelta facies of the Upper Atoka can be correlated with gamma-ray logs.
- Using magnetic susceptibility data from shale-rich outcrops allows correlation to gamma ray logs, where marker beds are not present. Sampling at intervals of at least 0.3 m can derive a good correlation to well-log gamma-ray curves.
- Magnetic susceptibility analysis within the Upper Atoka can be used in detecting Milankovitch cycles. The optimal sampling interval for detected higher frequency cycles was 0.05 m while 0.1 m sampling intervals are more optimal for detecting lower frequency cycles
- Magnetic susceptibility is a vital tool in understanding and interpreting sedimentation history and stratigraphy when paired with numerous well-logs already present from Arkoma Basin oil and gas exploration.