Fluid flow through Jurassic sandstones in the Paradox Basin, Colorado: Syndepositional, diagenetic or later?

John I. Ejembi[1], Sara Satolli[2], Sarah A. Friedman[3], Sally L. Potter-McIntyre[1], and Eric C. Ferré[4]

[1]Dept. of Geology, Southern Illinois University, Carbondale, Illinois 62901, USA; [2]Dept. of Engineering and Geology, University "G. d'Annunzio," Chieti-Pescara 66100, Italy;
[3]Dept. of Biological & Physical Sciences, Montana State University Billings, Montana 59101, USA; [4]School of Geosciences, University of Louisiana at Lafayette, Lafayette, Louisiana 70504, USA

GSA 2018
4-7 November
Indianapolis, Indiana, USA

Session # 121 T168
Sedimentary Geology Division/SEPM
Student Research Compeition: Dynamics of Stratigraphy and Sedimentation (Posters)
Poster Booth # 355

1. Introduction

The Entrada Sandstone, Wanakah Formation, and the Tidwell Member of the Morrison Formation were Middle-Late Jurassic deposition in the Paradox Basin in southwest Laurentia.

The anisotropy of magnetic susceptibility (AMS) in sandstones from these units in modern western Colorado (**Fig. 1**) show some interesting directional characteristics that are surprisingly oblique (average tilt of ~ 50° SE) to the sub-horizontal, sedimentary bedding and is consistent across two study sites.

Observations at the outcrop scale and macroscopic specimens show that the AMS fabrics in these rocks are not primary (i.e., syndepositional) but might have been acquired due to secondary alterations by Fe-rich fluids.

This study utilizes low field AMS in sandstones, magnetic hysteresis measurements, isothermal remanent magnetization (IRM) acquisition, and thermal demagnetization of the natural remanent magnetization (NRM) to characterize the magnetic behavior and phases in these rocks. We investigate the presence of ferromagnetic minerals in pores spaces and along grain boundaries using SEM-BSE images and X-ray energy dispersive analysis (EDAX).

2. Project Goal

To determine the significance of the AMS fabric and the origin of the ferruginous fluids that percolated through these rocks.

3. Geologic, Tectonic, and Sedimentary Framework of Study Area

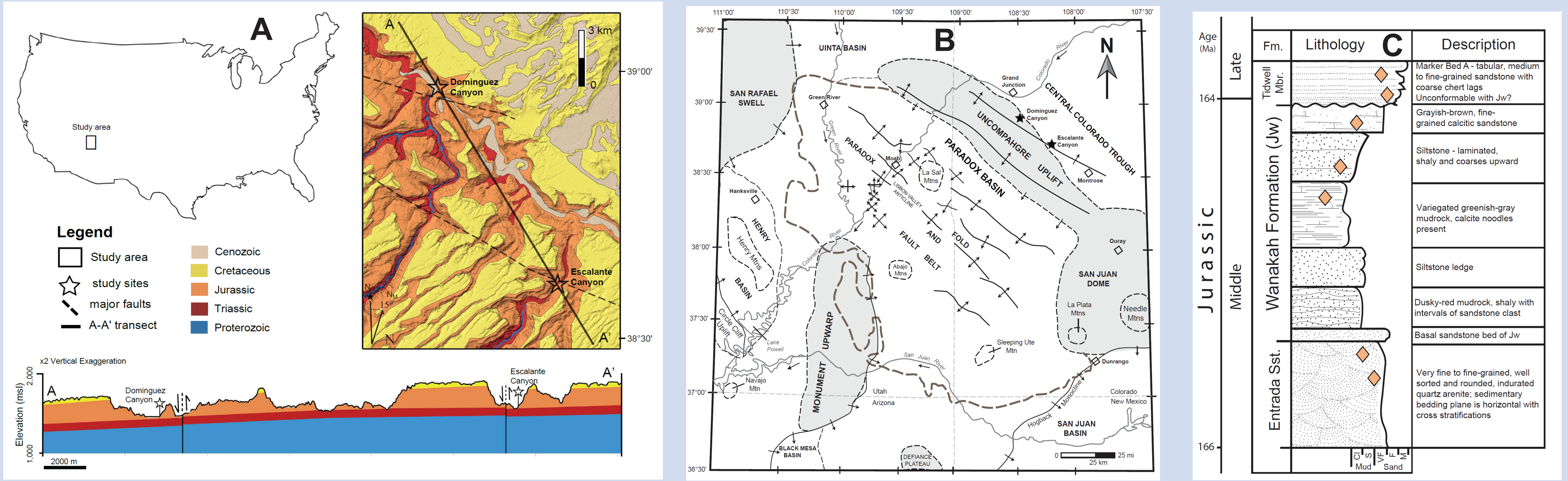


Fig. 1.A. Geologic of study area in western Colorado (after Tweto 1979) showing a northwest to southeast trending geologic cross-section of study area. The depth profile across section according to USGS DEM maps of the area **B.** Tectonic setting of the Paradox Basin and adjacent areas (after Kelly, 1958). **C.** Generalized stratigraphy of the Middle to early Late Jurassic in the study areas. Diamond symbols denote sampling horizons.

4. Methods and Principles of AMS

AMS Parameters

Induced magnetization, $\boldsymbol{J} \propto$ Mag. field, $\boldsymbol{H}$

$$\boldsymbol{J} = K\boldsymbol{H} \; ; \; \boldsymbol{K} = \frac{J}{H}$$

Mean Magnetic Susceptibility (K_m)

$$K_m = \frac{K_1 + K_2 + K_3}{3}$$

Shape Factor (T)

$$Prolate = -T; Oblate = +T$$

Degree of Magnetic Susceptibility (P')

$$P' = \frac{K_1}{K_3}$$

An undeformed sedimentary rock with primary magnetic fabric should have a positive $+T$ and a moderate P'

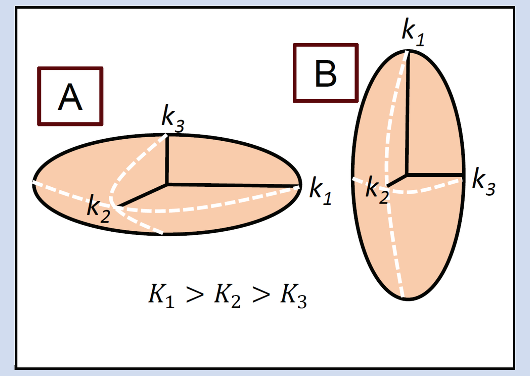
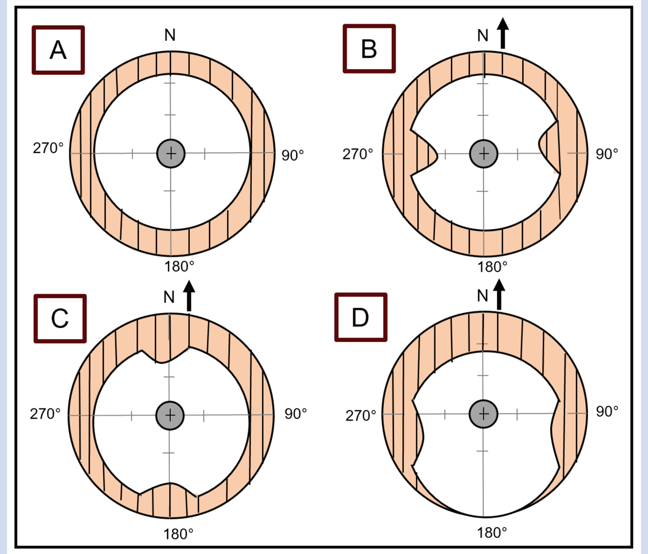


Fig. 2. Tri-axial representation of the shapes of the AMS ellipsoid. **A.** Shape is oblate and depicts planar fabric. **B.** Shape is prolate and depicts linear



After Tarling and Hrouda, 1993

Fig. 3. Depositional fabrics with zero flow on **A.** a horizontal plane and **B.** shallowly sloping plane. Horizontal plane deposition by **C.** a Weak current (<1 cm/s) and **D.** a strong current (>1 cm/s). The shaded, gray circle and hatched areas depict the orientations of the K_3 and K_1 axes, respectively. Arrow in **B** points to the slope direction while those in **C** and **D** indicate the flow directions.

5. Results

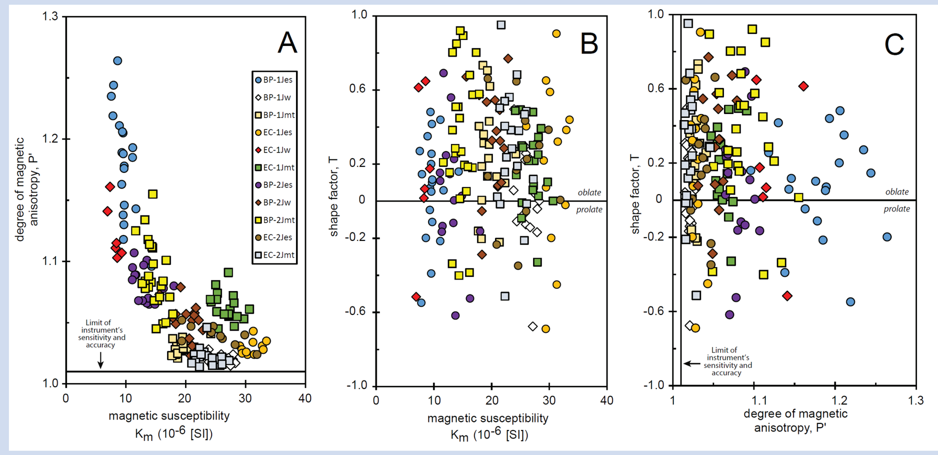


Fig. 4. Plots of the AMS parameters in samples from the two study sites. **A.** P' vs K_m **B.** T vs K_m and **C.** T vs P'

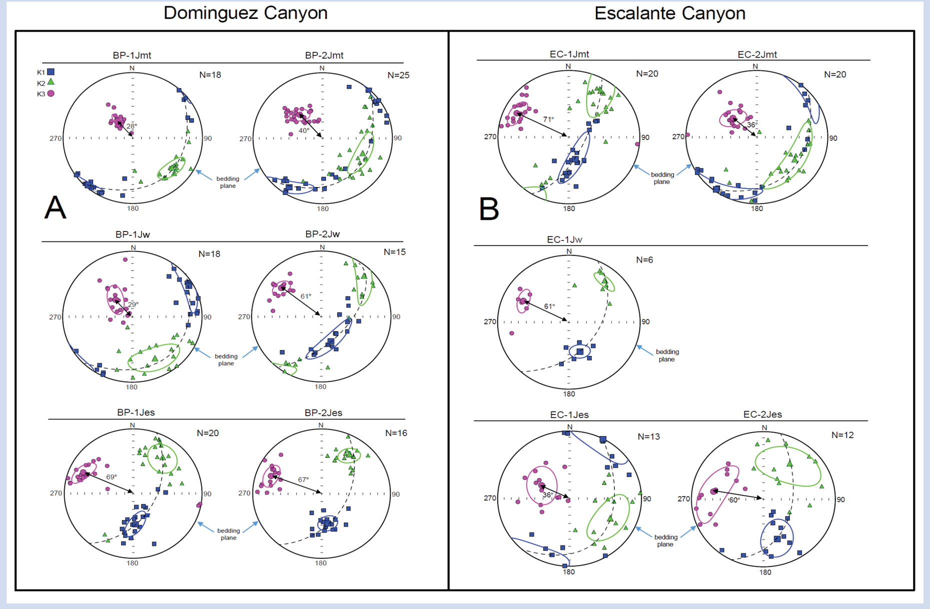


Fig. 5. Equal area lower hemisphere stereographic projections of the three principal magnetic susceptibility axes.

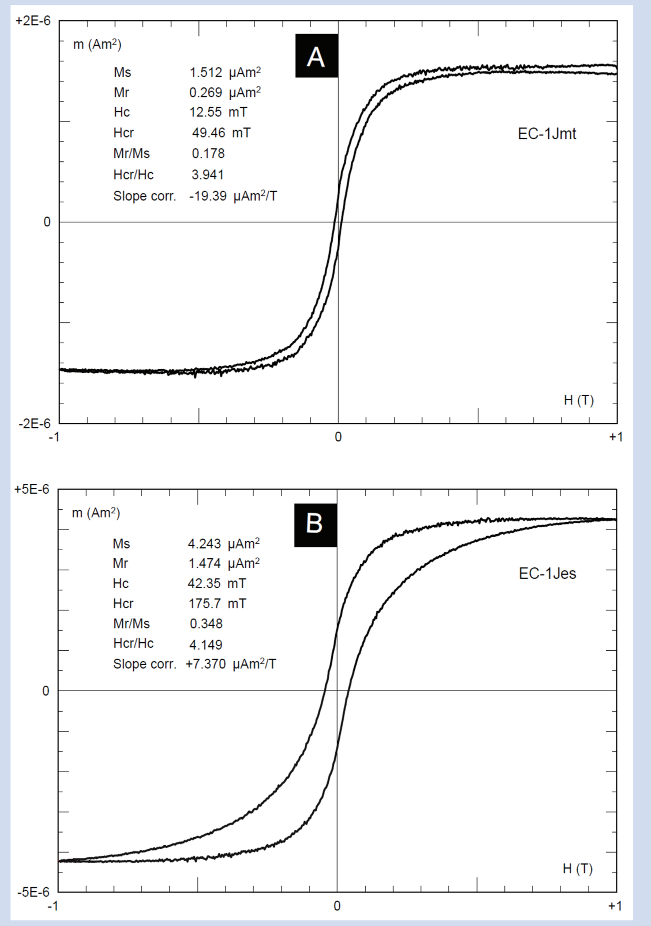


Fig. 6. Representative magnetic hysteresis curves (magnetic moment, m versus applied field, H) observed in all the sandstone samples. Both samples exhibit low paramagnetic susceptibility behavior, with EC-1Jmt showing a single component magnetic hysteresis behavior (**A**) and EC-1Jes showing at least two components magnetic hysteresis behavior (**B**).

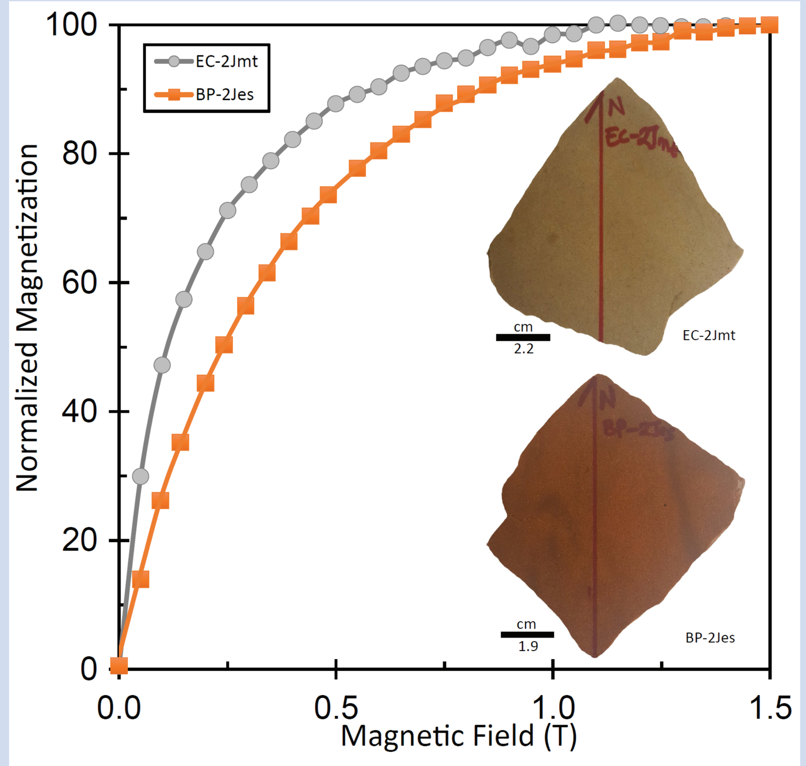


Fig. 7. Isothermal Remanent Magnetization (IRM) acquisition plot of two samples (BP-2Jes and EC-2Jmt) from the Middle and Late Jurassic, respectively. The two samples are remarkably different lithologically. Insets are photographs of a freshly cut slab of both samples taken during the AMS sample preparation stage. The marker on the sample surface shows the in situ geographic orientation.

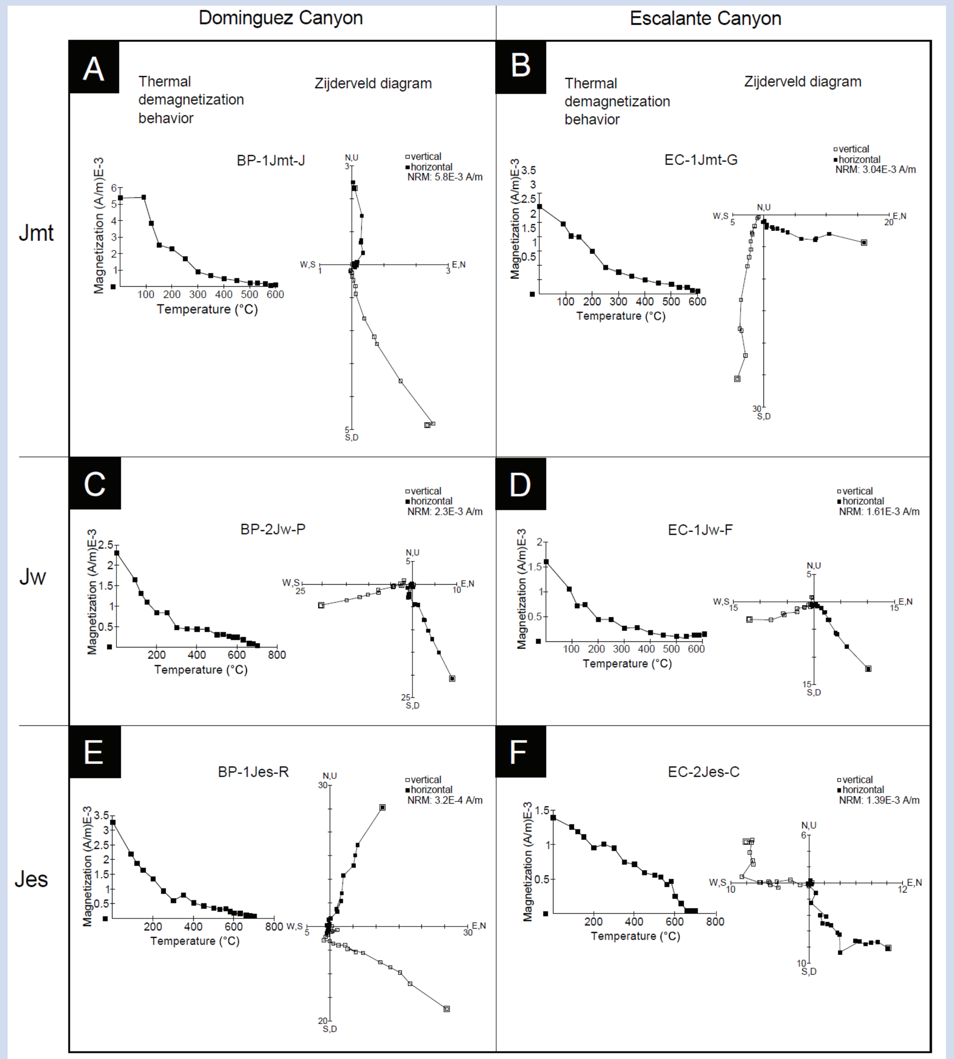


Fig. 8. Stepwise thermal demagnetization of the natural remanent magnetization (NRM) behavior and corresponding Zijderveld diagram of representative samples from the two study localities.

1. AMS fabrics are homogeneously distributed and are consistent between samples and across study sites (**Fig. 4**).

Results Continued

2. AMS petrofabrics (**Fig. 4BC**) are predominantly planar (**Fig. 2**) due to strong magnetic foliation.
3. The AMS fabrics tilt ~ 50° from the sedimentary pole toward the SE for both localities (**Fig. 5**).
4. Hysteresis behaviors (**Fig. 6**) show dominance of ferromagnetic phases.
5. The IRM acquistion (**Fig. 7**) shows the Entrada host a mixture of magnetically high (hematite) and low (magnetite) coercitive phases than the Tidwell sample.
6. The NRM shows (**Fig 8**) a directionally stable single-component behavior and a relatively straight demagnetization path toward the origin. Most sample demagnetizes at <150°C suggesting the presence of low stability phases – goethite.
7. The SEM and EDAX analyses confirm presence of detrital magnetite (**Fig. 9**).

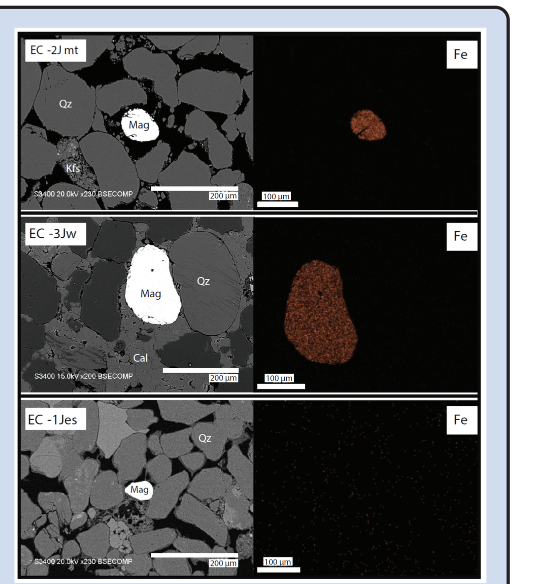


Fig. 9. SEM images and elemental maps from polished thin sections of three representative samples from Escalante Canyon (EC)

6. Discussion

The AMS fabric is not a sedimentary magnetic fabric (**Fig. 3; 10A**).

Petrographic and macroscopic observations show AMS is not a tectonic fabric (**Fig. 9**).

Rock color (i.e., red, tan and gray) suggests various degree of diagenetic alterations (high to very low iron solutions) reflecting changes in redox conditions.

Two hypotheses for origin of AMS are tested based on the magnetic assemblages in the rock samples:

1. Competition between inverse (goethite) with normal (magnetite + hematite) fabrics
2. Percolation of ferruginous fluids and subsequent secondary mineralization

The first hypothesis does not explain the remarkable consistency of AMS fabrics between sites 12 km-apart (**Fig. 5**).

The magnetic (**Figs. 6** and **7**) and thermal demagnetization behaviors (**Fig. 8**) of the specimens indicate that the proportion of magnetite, hematite, and goethite varies from sample to sample.

The second hypothesis is consistent with most of the results and observations at the study area. The origin of AMS is linked to unidirectional percolation of Fe-rich fluids driven by the Uncompahgre Uplift in the Cretaceous (**Fig. 11**).

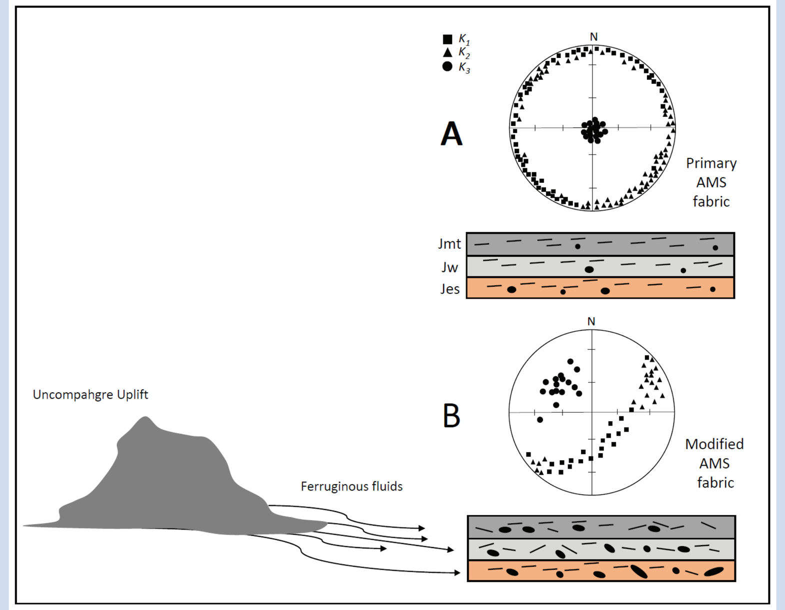


Figure 10. A. Primary sedimentary AMS fabric **B.** Model showing the origin of ferruginous fluids in the Uncompahgre Uplift and subsequent acquisition of secondary AMS fabric following percolation and precipitation of ferromagnetic minerals.

7. Conclusion

This study demonstrates the utility of magnetic methods in tracking fluids in porous sandstones

Future AMS studies on sedimentary rocks need to consider that regional hydraulic systems may ultimately modify primary AMS fabrics, therefore caution should be exerted in the interpretation of magnetic fabrics.

8. Acknowledgments

This research was funded by the American Chemical Society-Petroleum Research Fund (ACS-PRF) Grant No. 55161 (to Potter-McIntyre).
The Geological Society of America (GSA) Graduate Research Grant and the National Association of Black Geoscientists (NABG) Scholarship Award (to JIE) benefitted this research as well. Joe Krienert helped to digitize and compile the geologic map of the study area.