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Magnetic Fabric of Prominent Unconventional Resource Plays in North America: Implications for decrypting key Burial events in Mudrocks

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Unconventional resource production across North America has provided unprecedented access to samples from the Antrim, Haynesville, Marcellus, Wolfcamp and Woodford units. This study investigates the nature and character of magnetic fabrics under various tectonic, depositional and burial conditions. Composite sedimentary/tectonic fabrics are observed in the Wolfcamp, Marcellus and Woodford units and likely indicate compaction followed by layer parallel shortening during foreland basin development. Imbricated magnetic fabrics occur in the Antrim and likely reflect paleocurrents related to a prograding prodeltaic system. The Haynesville displays a classic sedimentary, compaction driven fabric consistent with tectonically quiescent conditions. Anomalous prolate, high inclination (>60°) fabrics occur in discrete intervals across all units. Low-temperature AMS and rock magnetic observations suggest that these fabrics result from increased concentrations of inverse magnetic carrier minerals (e.g. ferroan carbonates and single-domain magnetite). Other anomalous fabrics are attributed to pervasive mineralized fractures, localized brecciation and preserved debris flow microstructures. High-field and x-ray diffraction data suggests that clays, specifically illite/smectite and chlorite control the magnetic susceptibility. Preliminary hysteresis data from the Antrim shows low coercivity magnetite bearing samples near the basin margin and a complex magnetic mixture in the deeper core. The geographic variability of magnetic mineralogy may be associated with unique diagenetic histories across the basin although additional investigation is required.
Interesting relationships exist between organic/inorganic geochemistry and magnetic fabric parameters. TOC data shows a positive correlation with the degree of magnetic anisotropy and oblateness whereas elevated S1/TOC values generally correspond to low degrees of anisotropy and prolateness. This relationship may demonstrate a first-order control of clay microstructure on hydrocarbon distributions. The relationship between TOC and degree of anisotropy also show ascending linear regression gradients with increasing levels of thermal maturity. This relationship could indicate changing clay crystal anisotropy related to illitization of smectite. Redox sensitive elements such as Ni, Mo and V show a positive correlation magnetic anisotropy. Additionally, Al and Fe concentrations correlate well with bulk magnetic susceptibility.
Overall, magnetic fabrics orientations largely reflect compaction and the tectonic style of the sedimentary basin however, the presence of discrete anomalous fabric horizons suggests that diagenetic process can overprint precursor fabrics. Lastly, comparison of AMS to organic/inorganic geochemistry can provide valuable insights about the role of clay fabrics on hydrocarbon residence and migration and possibly indicate degrees of thermal maturity.