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A Study of the Relationship between Hydrocarbon Migration and Magnetic Alteration of the Michigan Basin Soils and Sediments

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Oil and gas reservoirs may be associated with significant magnetic anomalies arguably caused by diagenetic alteration of iron-bearing minerals in hydrocarbon seepage environments. However, complete understanding of the physical mechanisms and pathways of hydrocarbon-induced magnetic alteration requires a robust and representative observational database. In order to facilitate the fundamental understanding of the magnetic signature of hydrocarbons, we conducted a rigorous investigation of the genetic relationship between the hydrocarbon migration and magnetic properties of sediments overlaying the oil-bearing formations of the Silurian northern pinnacle reef belt of the Michigan Basin. Several hundreds of near-surface soil and sediment samples were collected across several long transects across the trend of the Niagaran Reef System and represented areas both over and away from known hydrocarbon sources. The samples were investigated by a variety of microscopy and rock magnetic methods (such as bulk magnetic susceptibility, frequency-and field-dependent magnetic susceptibility, first-order reversal curve analyses, and others). The obtained results indicate a well-defined correlation between the location of the hydrocarbon-producing Niagaran Reef System and high magnetic susceptibility values. The observed correlation suggests that magnetic anomalies associated with hydrocarbon seepage within these soils and sediments are essentially vertical and not subject to the diffusion one might expect in a loose, sandy matrix characteristic for the sampling area. The rock magnetic data indicate that the magnetic enhancement of soils is due to the appearance of nearly single-domain magnetite most likely formed by reduction of iron oxyhydroxides by light hydrocarbons. The samples representing the areas outside the Niagaran Reef System contain largely multidomain magnetite of detrital origin as well as hematite and goethite. In addition to new data on magnetic mineral diagenesis, our results support the use of magnetic susceptibility as a useful tool for first-order contouring of hydrocarbon reservoirs and for environmental monitoring.