Utilizing Magnetic Signatures Related to Hydrocarbons

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Summary

The demand for hydrocarbons is growing exponentially and to meet this demand an integrated approach is required for hydrocarbon exploration. Magnetic techniques have long been used in this regard. However, over the past two decades, the application of aeromagnetic data to hydrocarbon exploration has moved from primarily mapping basement structures and lithologies to mapping structures within the sedimentary section. Geochemical studies have shown that magnetic mineralisation may be associated with hydrocarbon seepage and migration that could result in miniscule magnetic signatures. It is the advancement in technology, over the past two decades that have resulted in high-resolution magnetometers, better aircraft positioning using GPS, gradiometers measuring horizontal and vertical gradients in the total magnetic field, compensation software / hardware for suppressing airplane noise and this has brought about a marked improvement in the data acquisition quality and resolution. This coupled with sophisticated computers and data processing and imaging techniques has made it possible to identify and interpret these miniscule magnetic signatures associated with hydrocarbons. Airborne magnetic surveys have come a long way from the collection of aeromagnetic data at reconnaissance scale, to High Resolution Aeromagnetic (HRAM) surveys and now the collection of Super HRAM with helicopters. Global examples of such surveys and the resultant improvement in magnetic data interpretation related to hydrocarbon exploration will be presented.

Introduction

The time has come to keep pace with the technology to identify, on a global scale, the dwindling hydrocarbon resources. No single method can achieve 100% success rates in finding oil. This necessitates that all possible technological advances be channelised in a systematic manner to offer a more cost effective way of reducing finding costs and improving discovery rates.

Exploration of the subsurface requires innovative techniques and the magnetic method offers an excellent opportunity to map the structure and lithology of the subsurface. The magnetic fields change when the physical properties, like susceptibility, of the subterranean rocks change and this method has, for a long time, played a secondary role in oil exploration, such as helping to define the basement structures that control emplacement of hydrocarbon in overlying sedimentary basins. However, technological advancement in the recent past and better understanding of magnetic mineralogy has promoted the magnetic method from a secondary, reconnaissance tool to a method that a specialist needs to consider seriously for the purpose of hydrocarbon exploration.

Rise of the Magnetic Method

Over the last two decades, major strides have been made in the acquisition, processing and interpretation of aeromagnetic data. Improvement in the instrumentation technology have led to the development of accurate magnetometers, with gradiometers measuring horizontal and vertical gradients in the total magnetic field; this coupled with precise aircraft positioning using GPS and software / hardware for suppressing airplane noise has resulted in marked improvement in the data acquisition quality and resolution. Modern high-resolution magnetometers are able to measure magnetic signal reflecting magnetic variations in sediments. Information about magnetic properties of sedimentary cover, lead to mapping geological structures prospective for hydrocarbon exploration. One of the major problem in the application of magnetic methods is the isolation of weak magnetic anomalies caused by low concentrations of the magnetic minerals in sediments. These weak anomalies are often masked by much stronger magnetic anomalies caused by underlying magnetic rocks and/or by rocks in the sedimentary basin. The weak anomalies can be efficiently isolated using selective filtering techniques. With the availability of sophisticated computers and data processing and imaging techniques, the interpretations have improved manifold and have contributed to a quantum jump in the application of aeromagnetic data to hydrocarbon exploration, from primarily mapping basement structures and lithologies to mapping structures within the sedimentary section. The data quality and resolution of high resolution aeromagnetic (HRAM) surveys now provide levels of detail that are compatible to those derived from seismic, well and surface geological data. HRAM data for petroleum
exploration are commonly defined as data collected at a flight line spacing of 800m or less at flight heights of 150m or less, at 15 m or less sample spacing along the flight line and at better than 0.1nT accuracy (Glenn and Badgery, 1998).

Helicopter mounted system can be used in areas with strong topographic effects as these can be flown while draping the landscape, and as such, minimize the effect of topography. Super HRAM data is collected from a helicopter platform; according to Image Interpretation Technologies Inc. (2005), for SHRAM, typically the data is flown 30 – 50 m above the ground and with 50 – 200 m flight line spacing. By flying closer to the ground with decreasing flight line spacing, there is a dramatic increase in resolution; the helicopter-borne SHRAM data can detect even the subtlest sedimentary magnetic anomalies that are created in the shallow sedimentary section.

An important aspect of identifying hydrocarbon reservoirs is the production or enhancement of magnetic minerals in the shallow sediments above the trapped hydrocarbons. The hydrocarbons leak in varying quantities to the surface and produce, through geochemical interaction, magnetic minerals in the sediments. It is found that microseeping hydrocarbon reservoirs exhibit distinctive magnetic signatures resulting in characteristic “magnetically enhanced zones” which have proven invaluable in hydrocarbon exploration. In China, soil magnetic measurements and soil hydrocarbon analysis were conducted near the Jingbian gas field and their results provide strong evidences for the formation of highly magnetic minerals in close association with hydrocarbon seepage (Liu et al, 2004). Recognition of such seepage induced magnetic anomalies can be used to facilitate the exploration of oil and gas. Enrichment of magnetic mineralization due to hydrocarbon migration is also a well known phenomenon (see articles in Schumacher and Abrams, 1996).

Urquhart (2004) states that “Bacteria and other microbes play a profound role in the oxidation of migrating hydrocarbons. Their activities are directly or indirectly responsible for many of the diverse surface manifestations of petroleum seepage. These activities, coupled with long-term migration of hydrocarbons, lead to the development of near-surface oxidation-reduction zones that favor the formation of hydrocarbon-induced chemical and mineralogical changes. This seep-induced alteration effect has led to the development of a varied number of geochemical exploration techniques. Some detect hydrocarbons directly in surface and seafloor samples, others detect seep-related microbial activity, and still others measure the secondary effects of hydrocarbon-induced alteration using magnetic techniques “. He discusses the Sedimentary residual magnetic (SRM) anomaly method which depends on the magnetic properties of the rocks in the sedimentary section being changed by the presence of hydrocarbons at depth; these changes produce magnetic anomalies that are distinguishable from anomalies produced by the magnetic basement and other effects. The test studies show that in practice the method will enhance the success rate of an exploration program where the SRM method is incorporated into the methodology.

**Examples**

Magnetic surveys of the Western Canada Sedimentary Basin (WSCB) have been carried out extensively, at different resolutions. Hassan (2003) of GEDCO, has made a comparison of the HRAM data and Geological Survey of Canada (GSC) data collected over the WSCB and finds that the GSC data does not have adequate frequency content to solve structural problems except on very regional scale while the HRAM data could resolve faults both in the basement and in the sedimentary section and allow one to map the basement. Further, selected areas of WSCB were re-flown using helicopter to collect SHRAM data. Image Interpretation Technologies Inc. (IITech, June 2005) have compared the HRAM and SHRAM data sets; a thrust fault identified in the HRAM data appeared to be offset in a sinistral sense suggesting a tear fault in the sedimentary section. However, the better resolution of the SHRAM data suggested a lateral ramp in the hangingwall of the thrust, rather than a tear fault.

Results from several examples like the Northern Mackenzie Corridor project of IITech Ltd and others will be presented to demonstrate the utility of magnetic signatures in hydrocarbon exploration.

**Conclusions**

The Magnetic Method has come a long way in resolving the magnetic sources and with decreasing hydrocarbon resources and increasing cost of find, it is going to be “a method to reckon with”

**References**

Hassan H.H. 2003. Why is HRAM data better for exploration purposes than the magnetic data available from the GSC? GEDCO publication