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Airborne GammaSense Surveys For Hydrocarbon Exploration

Perhaps the least used set of tools are those associated with the geochemical "plume" of altered material that can exist above a hydrocarbon accumulation. These are perhaps more correctly considered geochemical anomaly targets, with some physical property change that can be practically measured and mapped using geophysical tools. Gamma-ray spectrometry (GammaSense) is probably the most commonly used tool in plume detection and mapping, with magnetics, used on occasions where the area is sufficiently clear of disturbing cultural features (Morse & Zinke 1995, Zinke & Morse 1996, Foote 1995, Schumacher 1996, Donovan 1984).

The GammaSense method is based on the observation that the presence of hydrocarbon micro-seeps alters the redox equilibrium in the rocks and soils above a hydrocarbon accumulation, and creates an environment which is locally predominantly reducing. This can alter the solubility of minerals which are composed of one or more elements detectable using gamma-ray spectrometry. Minerals of Uranium can have a dramatic change from being readily soluble in the oxidized hexavalent state to being generally insoluble in the reduced tetravalent state (Foote 1995 and Morse & Zinke 1995). Potassium has a similar behavior in the presence of hydrocarbon micro-seeps, but with a more complex chemistry.

The local changes in solubility disturbs the normal (often random) distribution of particularly Potassium (K) and Uranium (U) in the presence of circulating meteoric and ground waters. A geochemical "halo", detectable through detailed mapping of the gamma-ray radiation patterns, can exist over hydrocarbon accumulations (Foote 1995, Morse & Zinke 1995 and Zinke & Morse 1996).

Similarly Iron (Fe) minerals can also be redistributed in a changing geochemical environment and have magnetic minerals formed and accumulated (Donovan et al 1984, Foot 1996 and Machel 1996) that can be detected using the information from high resolution airborne magnetic surveying (ISMAP). These features can be circular features sometimes with anomalies resembling ring-fractures with amplitudes of 1 to 5 nT.

The objective of surveying with a multi-channel, gamma-ray spectrometer system and a large volume gamma-ray sensor is to detect subtle characteristic radiation patterns as indicators of subsurface hydrocarbon accumulations over petroliferous terrane. ISMAP and GammaSense techniques may be applied independently of each other, however, it is practical and cost effective to combine them in one multi-sensor, multi-method survey.

It is a fact that hydrocarbon anomalies can be qualitatively and directly identified from airborne GammaSense measurements. It has been repeatedly observed that the subtle anomalous patterns of radiation flux detected over petroleum basins exists over subsurface hydrocarbon accumulations. (*This we have also determined from GammaSense surveys we have conducted in Latin America, in both tropical and desert areas, and in various locations in the USA.)*

HOW DOES GAMMASENSE WORK?

The earth's crust contains uranium, thorium, and potassium. These primordial radionuclides were randomly laid down during the planet's formation. They and their progeny emit highly energetic gammarays in the course of radioactive decay. As their half-lives approximate the age of the earth, it is to be expected that all three elements contribute measurably to our natural radiation background. Hundreds of millions of years after the laying down of the radionuclides, hydrocarbon deposits formed.

Uranium is the most mobile of the three radionuclides. Subsurface hydrocarbons, however, through recognized geochemical processes, alters uranium's mobility above hydrocarbon deposits (*in its fully oxidized state, the uranium ion is water-soluble, highly mobile, and easily transported by ground water, however, on entering an environment containing organic matter, the ion is reduced becoming insoluble and immobile*). Potassium also shows similar characteristic mobility changes. As a consequence, the gamma radiation flux detected over hydrocarbon deposits is noticeably altered by the contributions from uranium and potassium. In addition, the random radiation pattern normally observed has now changed into a *characteristic radiation pattern,* thereby creating a readily identifiable pathfinder in potentially productive basins.

If you wish to know more about the GammaSense method, please contact us. A bibliography of Technical Papers and Case Histories is available (in some instances we can provide a copy of some papers).

Piper PA-31 Navajo Survey Aircraft in ISMAP/GammaSense configuration

GammaSense detector packages installed in the cabin of a Piper PA-31 Navajo survey aircraft

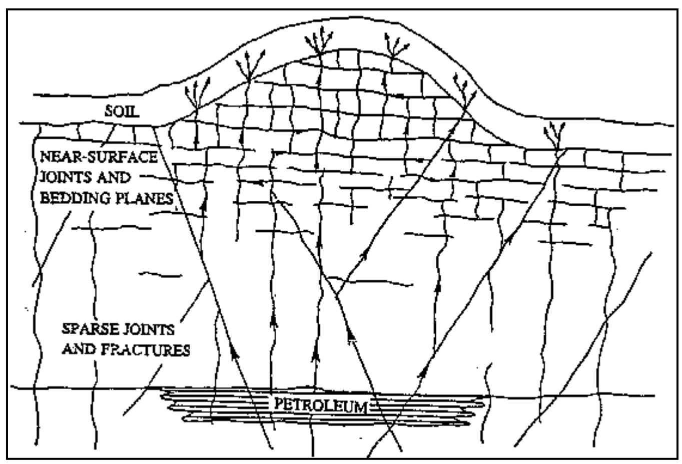
The following is an abstract of a paper written by Donald F. Saunders and published in Special Publication #3, December 1995 by the Association of Petroleum Explorationists. The paper is entitled "Overview of Radiometrics and Related Surface Methods for Petroleum Exploration" and sums up in few words the GammaSense method of hydrocarbon exploration.

Abstract

Over the past 25 years there has been progressive development in understanding the relation of aerial and surface radiometric measurements to subsurface petroleum accumulations. The data from many recent gamma-ray spectral surveys have confirmed the presence of characteristic anomalously low potassium and higher uranium gamma-ray levels over a majority of oil and gas fields tested. Similar surveys by the author as parts of integrated exploration programs have yielded several new prospects and at least four new field discoveries.

A single model involving: 1) light hydrocarbons seeping to the surface from petroleum accumulations and 2) the effects of their bacterial consumption and degradation may account for surface and near-surface radiometric, shallow source magnetic, geomorphic and light-hydrocarbon anomalies. The degradation process creates carbon dioxide which forms carbonic acid in groundwater. This can leach potassium from soils to create low-potassium gamma-ray spectral anomalies. The carbonic acid may also react with calcium silicates to form secondary calcium carbonate mineralization which may result in geomorphic tonal or stream drainage anomalies or seismic velocity anomalies.

Hydrogen sulfide is also created by anaerobic bacterial degradation of hydrocarbons and causes a chemically reducing environment, which can concentrate uranium in the region over petroleum. Thus, low-potassium anomalies with simultaneous uranium anomalies higher than those shown by potassium are considered favorable indicators of petroleum. The reducing environment may also convert nonmagnetic iron minerals to magnetic ones to produce shallow surface aeromagnetic anomalies and soil or drill cuttings magnetic susceptibility anomalies.



Possible microseepage paths up through the network of fractures, joints and bedding planes

Surface soil type or lithology, soil moisture content, variable vegetation shielding and topographic variations in counting geometry are known to cause serious errors in the use of total count radiometrics and single channel gamma-ray spectral potassium measurements in petroleum prospecting. These effects may all be surpressed by measuring the natural radioelements individually by multi-channel gamma-ray spectrometry and using methods of thorium normalization.

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