Concept of natural hydrogen accumulations identification by remote sensing technology

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Naaman's Building, Suite 206, 3501 Silverside Road, Wilmington, New Castle County Delaware, 19810, USA
Michelfriedman@fands-llc.biz Voip + 1 786 352 8843
Home: Bolivia land line +591 3 3330971 Mobile +591 71696657

1. Hydrogen anomalies identification principles

Hydrogen is a gas found in the atmosphere at trace levels which cannot sustain life. It is synthesized from hydrocarbons and water. Hydrogen gas makes up the lightest fraction of the H2O molecule. Hydrogen is both the lightest and most basic of all elements. It is a fairly reactive gas, which enters into chemical combination with most of the elements and is feebly repelled by magnetic forces.

Naturally occurring hydrogen can be found in underground deposits and typically extracted in a manner similar to natural gas.

A large section of physics is devoted to the study of the effects produced within various materials by the application of a magnetic field. In the hydrogen atom, a nucleus with a single positively charged proton, which remains stationary, is orbited by a single negatively charged electron. Such a configuration may give the impression that hydrogen has a powerful magnetic attraction, but this is not the case. Hydrogen gas is, in effect, only very weakly magnetic. The reason for this is that hydrogen atoms are not found in isolation. They are bonded together to form a molecule, which has a lower chemical energy than separate atoms. Within this molecule, the momentum of one electron travels in the opposite direction to that of its neighbor. Due to this phenomenon, the molecule is only weakly magnetic and is considered to lack a permanent magnetic moment.

Hydrogen is a diamagnetic substance. Diamagnetism occurs in materials whose atoms have paired electrons. According to Faraday's Law, when a hydrogen molecule is exposed to a magnetic field its electrons which are in orbit, alter their momentum slightly. As the magnetic field increases, an induced field is created, which the molecule's electrons experience as a force. Through this principle of physics, the hydrogen molecule acquires an induced magnetic moment.

The photoelectric effect provided indisputable evidence for the existence of the photon and thus the particle-like behavior of electromagnetic radiation. The concept of the photon, however, emerged from experimentation with *thermal radiation*, electromagnetic radiation emitted as the result of a source's temperature, which produces a continuous spectrum of energies. More direct evidence was needed to verify the quantized nature of electromagnetic radiation. In this section, we describe how experimentation with visible light provided this evidence.

Although objects at high temperature emit a continuous spectrum of electromagnetic radiation, a different kind of spectrum is observed when pure samples of individual elements are heated. For example, when a high-voltage electrical discharge is passed through a sample of hydrogen gas at low pressure, the resulting individual isolated hydrogen atoms caused by the dissociation of H_2 emit a red light. Unlike blackbody radiation, the color of the light emitted by the hydrogen atoms does not depend greatly on the temperature of the gas in the tube. When the emitted light is passed through a prism, only a few narrow lines, called a line spectrum, which is a spectrum in which light of only a certain wavelength is emitted or absorbed, rather than a continuous range of wavelengths, rather than a continuous range of colors. The light emitted by hydrogen atoms is red because, of its four characteristic lines, the most intense line in its spectrum is in the red portion of the visible spectrum, at 656 nm.

The hydrogen properties described above are behind the principles of the natural hydrogen manifestations on the Earth surface and their subsequent identification and delineation as anomalies.

2. Remote sensing approach for hydrogen anomalies identification

We use the patented remote sensing survey processing technique to accurately identify and map anomalies associated with various minerals and substances (oil, gas, gold, uranium, copper, water, hydrogen etc.).

Remote sensing has been used for many years to explore for minerals. It involves gathering information about the physical world by measuring the electromagnetic radiation, particle and field signals that emanate from objects. To date, satellite imaging is widely used as an exploration tool. Remote sensing makes use of spectral signatures. For any given material, the amount of solar radiation that it reflects, absorbs, transmits and emits varies with wavelength. When the amount of radiation or electromagnetic energy from an object is plotted over a range of wavelengths, the connected points produce a curve called the material's spectral signature. More than 4,000 natural minerals can be found on the earth, and each has its own unique chemical composition and inherent frequency. The amount of solar radiation that a mineral or substance reflects, transmits, and emits due to its chemical composition is like a fingerprint, or what is called a spectral signature. By measuring the tiny wavelength variations with remote sensing, a mineral's or substance's spectral signature can often be identified from space.

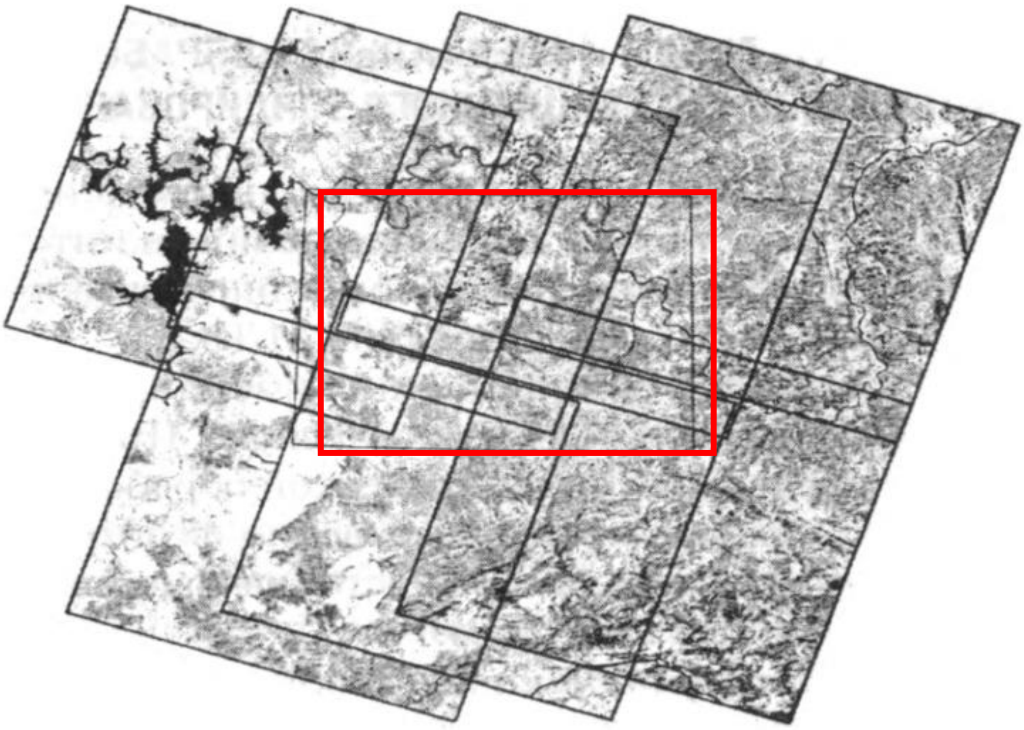
All objects have a unique spectral signature, and similar objects share a spectral signature. Once we have identified the spectral signature of an object, the same signature can be searched for in other data sets to find patterns and similar objects. The inherent electromagnetic fields (spectra) exist over each type of accumulation (oil, gas, water, hydrogen) or deposits (gold, uranium, copper etc.). These electromagnetic fields (of a specific frequency) are formed over the accumulations or deposit, and manifested on the ground surface due to various chemical, thermal and electrochemical processes in rocks with prolonged migration of oil, gases (other metals in ores) from great depths to the ground surface. The accumulations and ore deposits and their constituent minerals/substances have characteristic properties that are visible using different wavelengths of light beyond the visible range. Those unique properties can be evaluated to map the distribution of specific minerals.

We analyze the spectral imagery obtained from earth observation satellites to identify and map mineral signatures (electromagnetic fields). Certain satellite has such high spectral and radiometric quality that we can measure gas leakage in the atmosphere after the proper atmospheric corrections have been applied to the data.

Satellite images processing is a well-established procedure which has been used by many companies. We use both digital and analogue types of satellite images, the latter being prerequisite since the wavelengths are preserved on them. *In addition to the standard* *processing procedure of satellite images in visible range, IR and UV spectra, we use the patented innovative image processing in the invisible range of electromagnetic radiation. The invisible spectra of characteristic electromagnetic fields are "visualized" in the form of "high-brightness zones" on high-resolution analog satellite images. The processing includes application of special chemical reagents (nanogels), phosphors, sensitizers, which are selected for each type of accumulation (deposit) followed by treatment in the small-size nuclear reactor. It enhances the identified anomalies and make them visible and geologically interpretable. The nuclear reactor helps to enhance visualization of the identified anomalies by setting resonance of the frequencies of reference elements in nanogels and satellite images.*

3. Occurrence depth estimation

The method of predicting the depth is based on a change in the position of the boundaries of anomalies (displacement of the boundary of the maximum signal energy) with different inclinations of the orbits of satellites and geometric parameters of the location of satellites relative to the anomaly.
The depth of occurrence at step 1 is estimated using no less than two satellite images that are taken from 2 satellites, but with different orbital inclinations. From the analysis of these images, the “shift value” of the anomaly boundary is determined. Knowing the angles of inclination of the orbits (i.e., the angle under which the anomaly is recorded) and one leg (“shift value” of the anomaly boundaries), then the second leg (i.e., the depth of occurrence) is estimated. See below
In the process of evaluating the site, the Poisk Group processes a certain number of satellite images taken from different angles (Fig.1).



Pic.1. Example of satellite images covering a research area (shown with a red outline in the center)

Knowing the angle at which a satellite image was taken (supplied by a satellite imaging company), the depth of occurrence can be calculated (Fig.2) as follows.

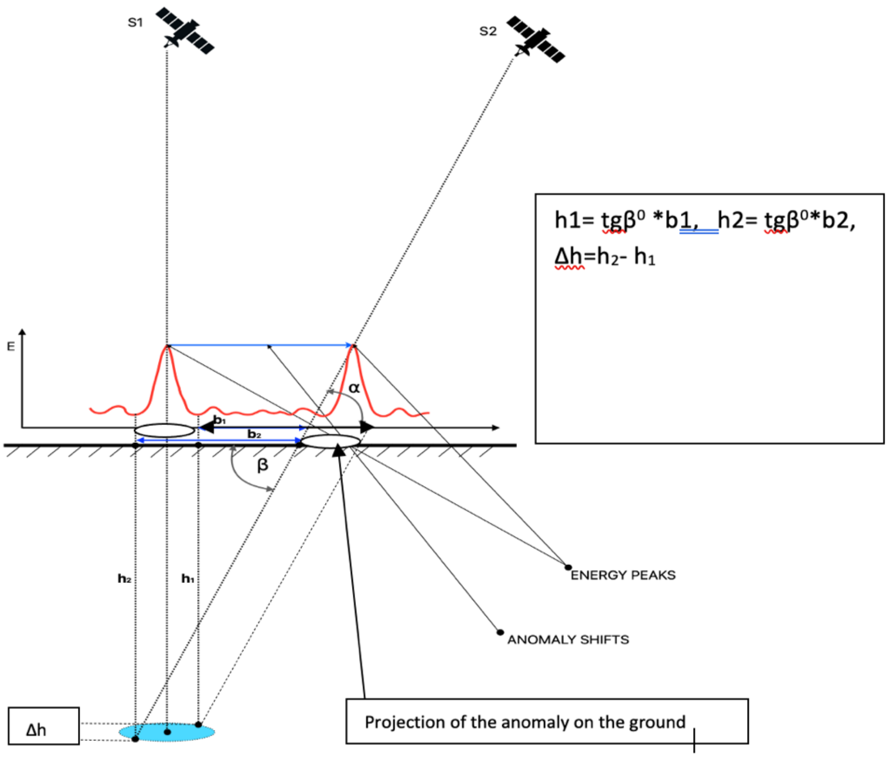


Fig. 2. Depth estimation

By analyzing several images, the magnitude of the displacement of the boundaries of the anomaly is determined, the tangent of the satellite inclination angle is calculated for each image, the height of the satellite is taken into account, and then the depth of the top and bottom of the geological body are estimated:

1) h1= tgß0 *b1,
2) h2= tgß0*b2,
3) Δh= h2- h1

Where

- h1 – depth of top of the mineralization
- h2- bottom of the mineralization
- Δh is the thickness of the mineralization
- β0 - the angle of inclination of the axis of the orbit of the satellite S2
- b is the distance from the initial point of increasing (b1) and decreasing (b2) of the maximum value of the signal amplitude to the intersection with the satellite observation line of the anomaly boundary registered by the satellite S2.
- S1 is a satellite located as close as possible to the vertical line of observation over the anomalous area

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4. Geological prerequisites

The most promising geological environments where deposits of natural hydrogen are most likely to be found

1. Igneous rocks create a wide range of environments with hydrogen-rich gas in the form of free gas, dissolved gas and trapped fluid inclusions in ophiolites, rift zones, faults and atmospheric degassing in volcanic gases, geysers, hot springs and surface gas outlets.
2. Kimberlite pipes are rarely associated with hydrogen–rich gas, but it is in them that the record flow rates of natural hydrogen are found today in the kimberlite pipe in Russia, where the flow rate was 100,000 m3 per day.
3. Ore bodies are often a place of accumulation, both in igneous and sedimentary rocks.
4. Coal seams and/or carbonates have a high potential for hydrogen accumulation.
5. Inside gaseous fluid inclusions; the older the rock, the higher the H2 content, because time is the main factor.
6. Evaporite sulfates can store large amounts of H2 (up to 20-30% by volume), and halite with a high potassium content (for example, K-potassium deposits) also provides a radiogenic hydrolytic source of H2 through an intermediate compound of calcium metal, which together with salt is a good shield for hydrogen accumulation.
7. Oil and gas fields usually do not contain large amounts of H2, however, for fields with a high content of H2, H2 production can be profitable, especially when producing liquefied gas.

The high reactivity of H2 affects the structure and chemical composition of the rock it crosses, for example, the mechanical strength of carbonates decreases, potentially accelerates the development of faults under stress conditions with the creation of additional migration routes. The H2 content in wells usually increases with depth.

So far, only three types of seals for the H2 accumulations are possible: sills of basic rocks (found in Mali, where the only natural hydrogen generation for today is found under a dolerite rock), salt, and shales.

The following criteria could be the most important in terms of H2 accumulations:

- The presence of iron-rich ultramafic and basic rocks, especially the Archean basement, which can be potential sources of both radiolytic and hydrolytic H2.
- Deep faults that provide migration and concentration of diffuse sources of H2.
- A reservoir potential at depth at the boundary between the basement and sedimentary rocks. For example, natural gas from the Mt Kitty 1 well (Amadeus basin) contains 11 moles % H2 in a fractured igneous basement directly overlain by sedimentary rocks.
- Areas with closed isometric depressions, which by themselves cannot be concentrators of natural hydrogen accumulations, but indicate that natural hydrogen degassing occurs in this area

Knowing the environment and geological setting of the area-of- interest would be helpful to preliminary estimate its hydrogen potential and work out a most effective RS survey procedure.

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