Integration of Surface and Subsurface Data Optimizes Hydrocarbon Exploration

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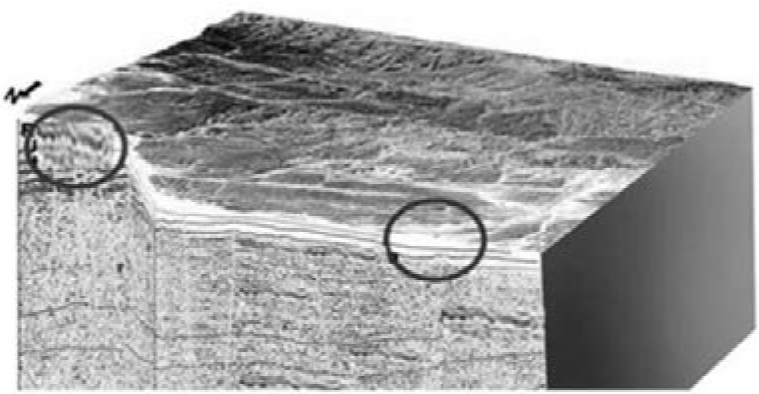


The selection of effective exploration targets is an important step in achieving success in hydrocarbon exploration. As a common practice, remote sensing and GIS technology are used to prepare baseline information like geological maps, structural maps, geological cross sections, thermal anomaly detection, hydrocarbon micro-seepage identification etc. to shortlist target exploration locations. Integrating geological cross-sections with the sub-surface structural trends leads to the identification of prospect areas.

The selection of effective exploration targets is an important step in achieving success in hydrocarbon exploration. These selections are primarily based on studies of basic geological conditions. Petroleum geologists usually consider basins to be a basic geological unit of petroleum exploration and their main objective is to locate various sedimentary basins. Remote sensing, geological and geophysical data integration provide accurate geometric shapes of sedimentary basins.

As a common practice, remote sensing and GIS technology, are used to prepare baseline information like geological maps, structural maps, geological cross sections, thermal anomaly detection, hydrocarbon micro-seepage identification etc. to shortlist the target locations. These help in providing information on the regional geological settings of petroliferous basins and their analysis using remote sensing satellite sensors help in identifying surface anomaly which indicate the presence of hydrocarbon reservoirs.

On the other hand, using sub-surface information like gravity, magnetic and 2D seismic data provide relative subsurface information for oil and gas exploration which, when integrated with the surface geological, structural, thermal anomaly and hydrocarbon micro-seepage information, provides valuable information about the lead or prospect areas to be surveyed for 3D seismic studies. The geological cross-sections made along with the 2D seismic lines also provide the sub-surface structural trends and leads to the identification of prospect areas.

Following this process not only saves time and costs but it also makes it easier to identify and select target areas for 3D seismic data acquisition. Application of this modern day space technology in conjunction with other ground information, can help exploration and production companies in data modeling prior to their 3D seismic data acquisition.

The Integrated Exploration System

Satellite imagery has evolved into a very useful tool for geologists and geophysicists, surveyors and environmental planners. The selection of effective exploration targets is an important step to achieve success in hydrocarbon exploration. The selections are dependent on studies of basic petroleum geological conditions. Petroleum geologists generally consider basins to be a basic geological unit of petroleum exploration and their main tasks is to find and determine various sedimentary basins. Remote sensing images provide accurate and visual data for directly determining geometric shapes of sedimentary basins.

Remote sensing and GIS techniques are increasingly being used to prepare baseline information like geological maps, structural map, geological cross sections, thermal anomaly detection, hydrocarbon micro-seepage identification etc. to shortlist the target locations. It provides information on the regional geological settings of petroliferous basins, host rock, petroleum geological conditions etc. Additionally, analytical capability of remote sensing satellite sensors further help in identifying the surface anomaly that are indicators of presence of oil and gas traps.

With rapid advancements in sensing equipment since ASTER became operational, extraction of potential indicators such as, surface emissivity, surface temperature, brightness temperature and surface radiance is used increasingly in the context of petroleum exploration. ASTER satellite data is useful for locating major fracture zones and detecting subtle differences in vegetation, soils and rocks related to the presence of hydrocarbons.

In the first phase of the integrated exploration system, remote sensing can assist geologists in the selection of exploration regions by defining the existence of sedimentary basins. Remote sensing methods can generate a wealth of information useful in determining the value of exploratory prospecting. In the second phase of appraisal, remote sensing data are merged with other available information such as Aeromagnetic, gravity, geochemical surveys and 2D seismic surveys. The result of this phase is to estimate the outcome of oil discovery probabilities for locating oil prospects.

To reduce the exploration costs for oil exploration during the reconnaissance stage, remote sensing and GIS studies play a major role for surface data collection and 3D integration of surface and sub-surface data. Remote sensing data most widely used in hydrocarbon exploration are aerial photography, radar, Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) and airborne multispectral scanner data.

The rapid development of remote sensing technology has also made it possible to carry out "direct detection" of oil resources by identifying the tonal anomaly that is the manifestation of hydrocarbon micro seepage. Remote sensing of hydrocarbon-induced alteration holds great promise as a rapid, cost-effective means of detecting anomalous digenesis in surface soils, rocks and related vegetation. The most extensive studies were about reduction of ferric iron (red bed bleaching), conversion of mixed-layer clays and feldspars to kaolinite, increase of carbonate content, and anomalous spectral reflectance of vegetation.

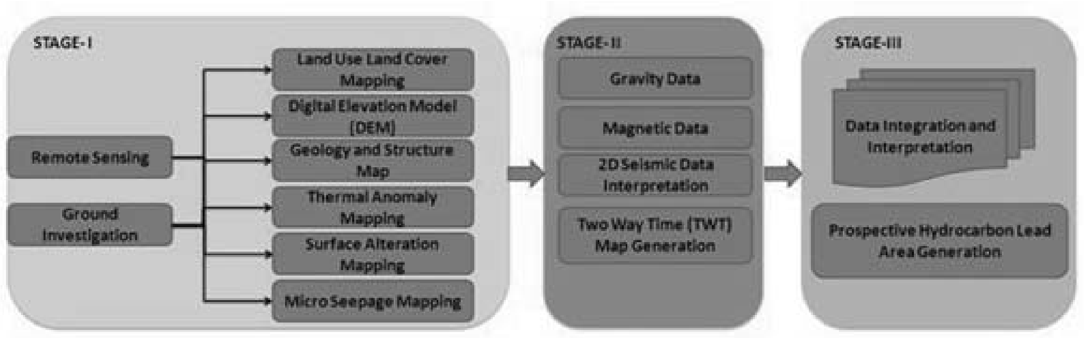
Scope of Work

The methodology used to identify the probable hydrocarbon lead areas for further 3D seismic data acquisition proceeded along the following pattern with the objective of studying and assessing the locales of hydrocarbon potential..

- Ortho-rectification of IRS LISS-III (MSS), PAN satellite image and PAN sharpening with LISS III imageries
- Geological and structural mapping using Remote Sensing technique and Ground Investigation
- Generation of Digital Elevation Model (DEM) at 15m resolution
- Alteration and thermal anomaly mapping using Remote Sensing technique
- Identification of Micro seepage mapping using Remote sensing
- Integration of existing Gravity, Magnetic and Seismic data and establishing correlation between subsurface structures and surface geology
- Delineate the probable potential/lead area in the selected blocks in Yemen

The study involved mainly three steps of visualisation.

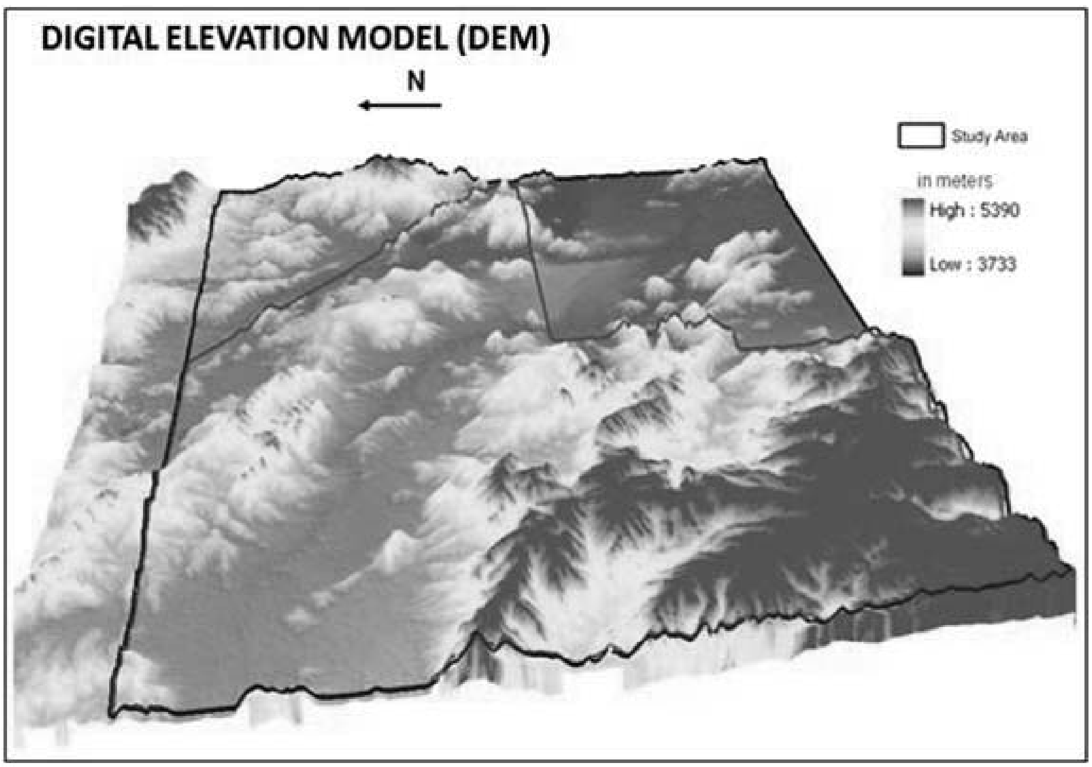
Step-1: Remote Sensing & GIS and Ground Investigation based input thematic layers preparation
Step-2: Gravity & Magnetic and Seismic Data interpretation and integration, TWT map preparation and
Step-3: Surface and Sub-surface data integration for identification of hydrocarbon lead areas. The brief descriptions of the methodological steps are illustrated in the below given flow chart.



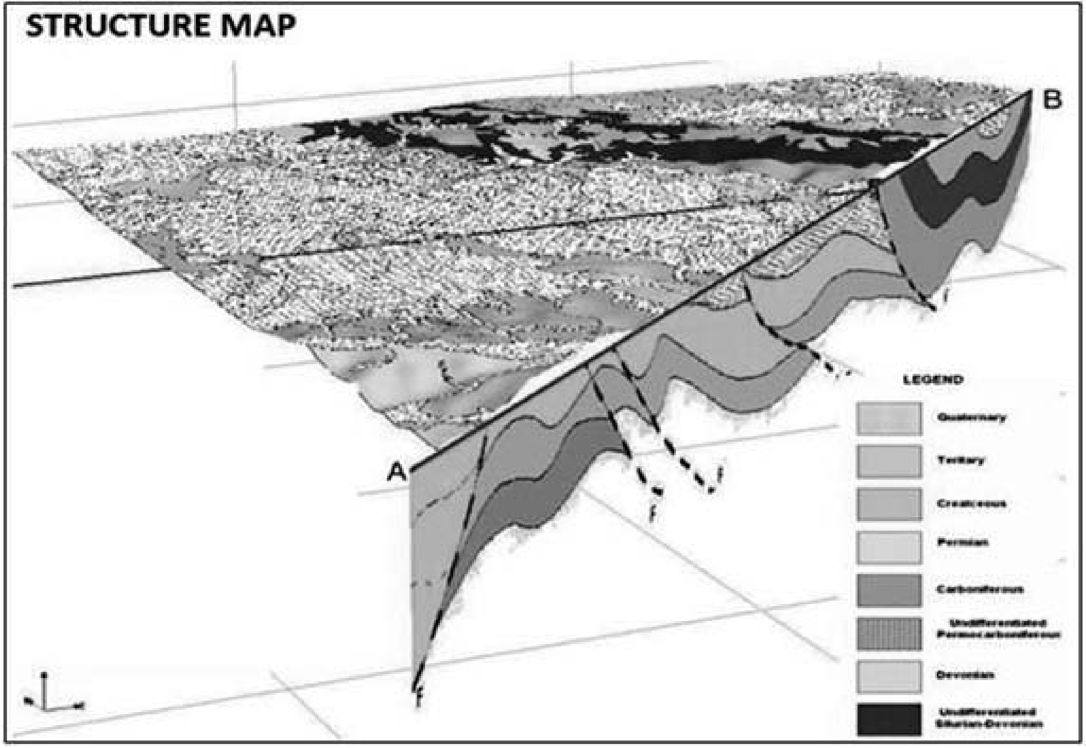
This flowchard illustrates the methodology.

Results

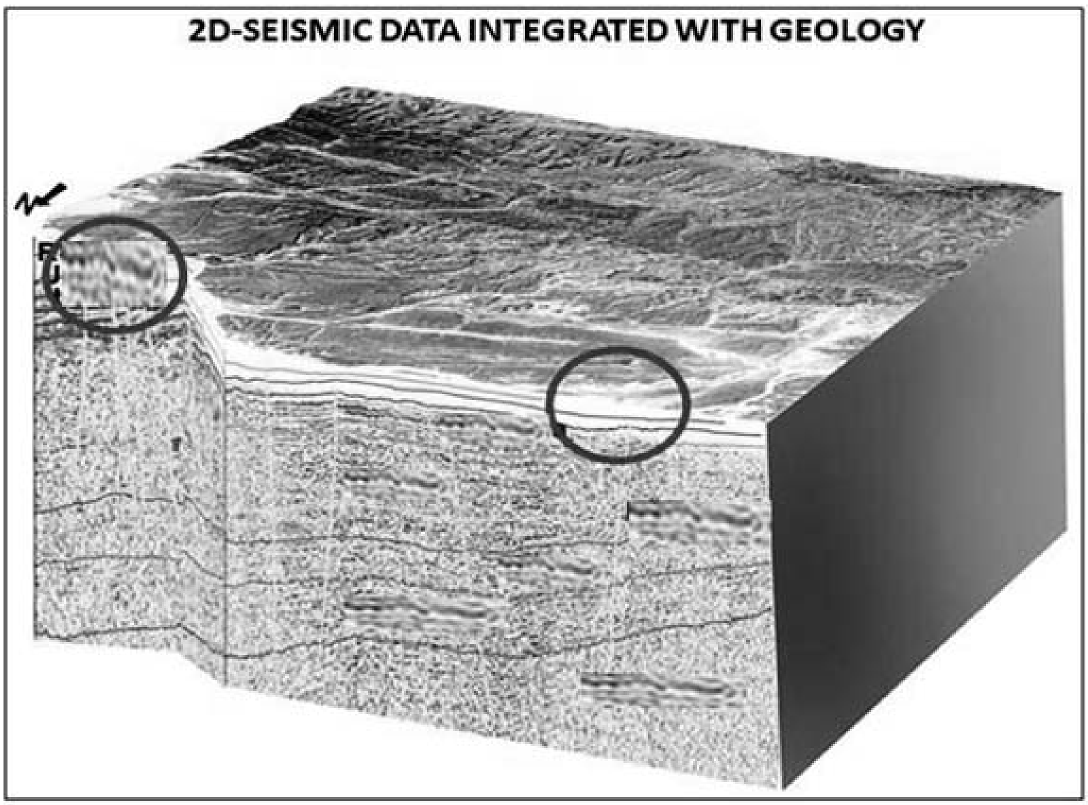
The results of various intepretations, analyses, and data integration are presented below.



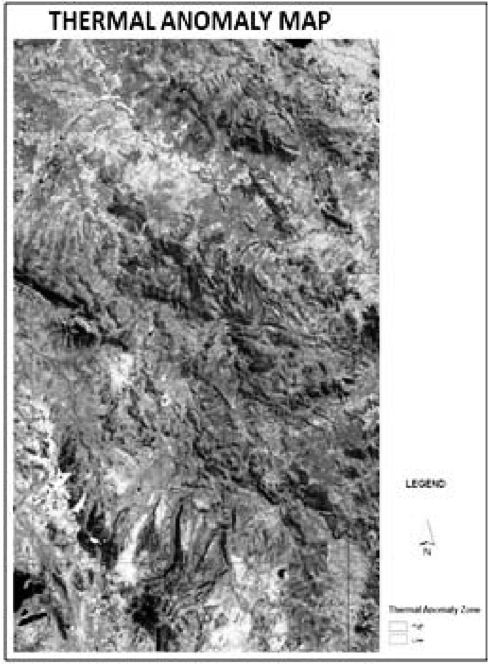
A Digital Elevation Model (DEM) was generated at 15m resolution.



Geological and structural mapping used remote sensing techniques as well as ground investigation.

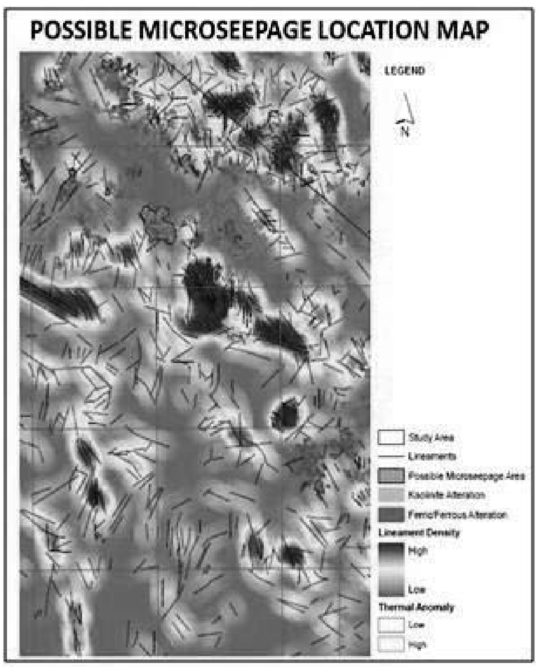


Integrating the 2D seismic data with geology provide relative subsurface information for oil and gas exploration.

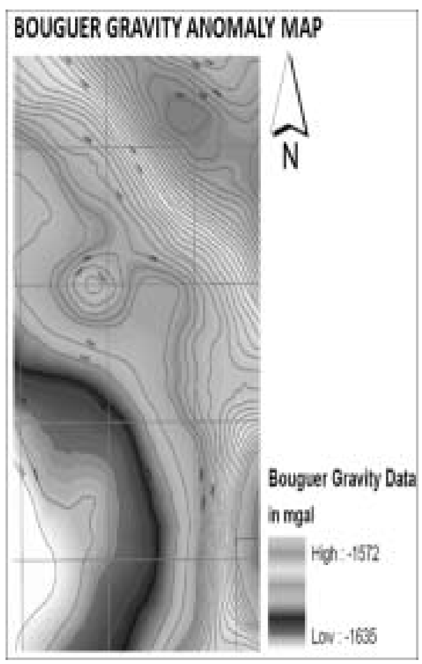


Thermal data comes from the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) and airborne multispectral scanner data.

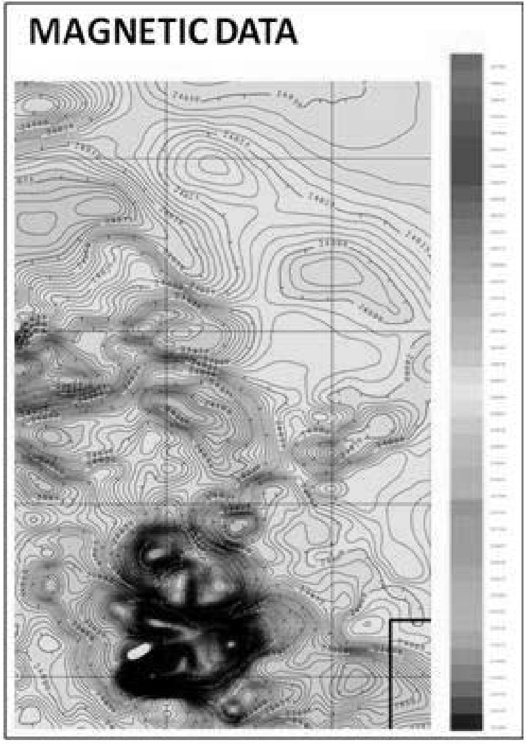
Remote sensing helped detect hydrocarbon-induced alteration of soils and sediments.



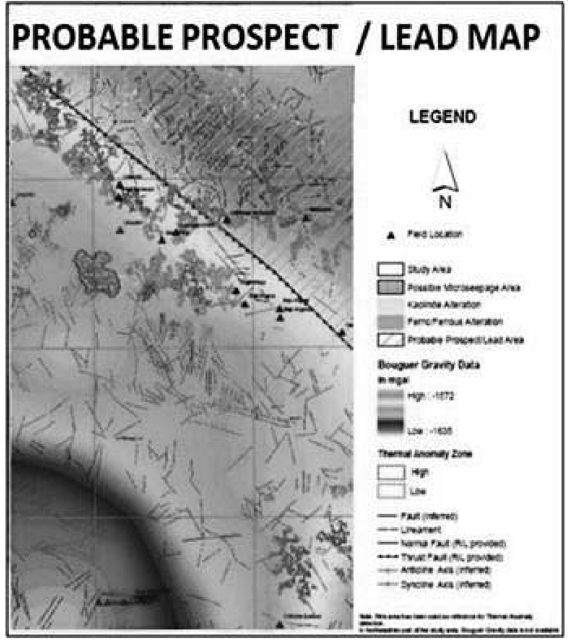
Hyperspectral classification and neural network analysis of ASTER data helped determine possible microseepage locations.



The gravity anomolies that are corrected for terrain provide understanding of the different rock densities in the subsurface.



Magentic surveys provide a visualization of the geological structure of the upper crust in the subsurface.



The derived map of probable leads help determine the areas for 3D seismic data acquisition on the ground.

The above generated outputs aimed at integration of geological, geophysical, geo-technical and remote sensing based indicators of hydrocarbon micro seepage to identify the probable lead area for further 3D seismic data acquisition. Considering the large investment in 3D seismic data acquisition; this study will result in optimizing the task along with and monetary gains.

Conclusions

Following conclusions are drawn based on the above study:

Remote sensing data helped in geological, structural interpretation, demarcation of geomorphology, identification of alteration thermal anomaly and identification of micro-seepage mapping.

Through geological and geophysical seismic interpretation and the use of orthorectified satellite images, it provided insights on the selection of areas to plan 3D seismic surveys for further exploration programs.

The Two Way Time Maps clearly brought out the Lead area. This was further validated by the Lineament trend evaluated through Satellite Imagery studies/analysis.

The presence of high thermal anomaly spots within the Lead area was a further validation of hydrocarbon accumulation.

The Time Geologic sections drawn across the Lead area corroborated the presence of good structural lead in this part.

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About Matt Ball

Matt has been promoting the application of sensors, systems, models and simulation for the better stewardship of our planet for the past fifteen years. The first ten years of that span were as editor of *GeoWorld* magazine and show manager of the GeoTec Event. The past five have been as a founder of Vector1 Media, with publications *Sensors & Systems, Informed Infrastructure* and *Asia Surveying & Mapping*. E-mail: mattball at vector1media.com