Application of Remote Sensing In Two Southern Iranian Oil Fields

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Abstract

Geoscientists have long applied photographic cameras, radar, lasers, infrared (IR) scanners, radiometers, spectrometers, microwaves, and multi spectral scanners (MSS) in the search for hydrocarbons. With introduction of satellite remote sensing, basic techniques were then coupled with this new technology. This produced enhanced views of the Earth's surface. Although oil and gas reservoirs are deep below the surface, they have some indicators, which can be detected on the ground. To reduce the exploration costs for hydrocarbons during the reconnaissance stage of exploration, satellite images and available surface data by combining with other current conventional exploration techniques could be used. In recent years, geological reconnaissance has been augmented by sophisticated terrace data-gathering techniques, which have been categorized as remote sensors. GIS allows petroleum engineers or functional group within to communicate information and make spatial and temporal decisions about assets, activities and natural resources. The present paper deals with the study of two existing petroleum-rich reservoirs. The selected area contains thermally unprocessed VNIR, SWIR and TIR ASTER images for granule of the study area covering Ab-teymur and Darquin reservoirs. Each granule covers an area of 3600 Km^2 (60 km x 60 km) of land of onshore Iran. Besides the main geological units and the gas geological analysis within the boundary of these granules have been studied. For this work three layers of information are considered: geology, geochemistry and vegetation cover. The main geological units within the boundary of the granules have been discussed for both fields. The basis of gas geochemical prospecting methods is that no oil or gas reservoir cap rock is completely impermeable. Hydrocarbons and other compounds and elements escape from the reservoirs and the more volatile components migrate to the surface where they may be trapped in soils or diffuse in atmosphere or ocean. Vegetation cover within the boundaries of oil field influenced zones was taken into consideration as an individual layer of information which will complement the other layers of information by its corresponding statistical weight.

Keywords: *Remote Sensing; GIS; ASTER; Hydrocarbons; Exploration.*

Introduction

One of the important issues in determining the best solution to an engineering problem is the cost associated with the solution. In upstream engineering the cost of solution become more dominant due to high cost of project that can makes it unviable. Petroleum exploration is one of the costly phases in oil industry. Application of surface indicators is studied in this work. Among the surface data based methods geochemical, biogeochemical and geobotanical methods are more prominent. Although the cost of these surface exploration methods is lower compared to conventional geophysical surveys, they are not supported by the petroleum

industry due to their lack of success. The rate of success of these methods is low because they are not integrated with each other and only used individually for studies.
The following combination of surface data is used in this study: 1) Gas geochemistry. 2) Vegetation covers. 3) Land surface temperature (LST) derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
The use of fuzzy logic has been applied to analyze using statistical and fuzzy logic methods [1]. The patterns within each of these three main layers have been analyzed using statistical and fuzzy logic methods and their inter-correlations have been investigated.

Gas Geochemical Prospecting Method

The basis of gas geochemical prospecting methods is that no oil or gas reservoir cap rock is completely impermeable. Hydrocarbons and other compounds escape from the reservoir, and the more volatile components migrate to the surface where they may be trapped in soils, or diffuse into the atmosphere or ocean. Hydrocarbons that reach the surface can be detected directly in some cases or indirectly, through the geochemical changes they induce. Correlations between structural geology and geochemistry have established relationships between the presence of subsurface hydrocarbons and surface soil gas in moderately fractured and faulted areas. Oil and gas seepage is associated with many oil-producing regions. As early as 1940 it was claimed that the visible evidence of oil was responsible for the discovery of more oil than any other prospecting technique.
So hydrocarbon accumulations leak varying quantities of hydrocarbons to the near surface that are large enough, not only to be detected in the near surface, but also to be distinguished from the minute quantities of background hydrocarbons that commonly are present in most near-surface samples. Methane is not a reliable indicator for oil or gas because it is produced by microbiological processes occurring in soils and sediments. So the majority of gas prospecting techniques is based on the detection of ethane, propane, n- and iso-butane since they are not produced biologically in vast quantities and could be a good indicator of gas seepage from an underlying reservoir.
Migration of gases may be caused by difference in concentration (diffusion), pressure (effusion) or a combination of these two. Hydrocarbon gases can be trapped in soils in several different forms: a) As gas in the spaces between soil particles (Pore gas). b) Adsorbed onto particulate material (adsorbed gas). c) Dissolved in the groundwater (dissolved gas).
Pore gas analysis was the earliest method used in geochemical prospecting. The result from both Sokolov's and Laubmeyer's studies indicated that maximum concentration of hydrocarbon gases occur in soil air over productive zones, with minimum values over barren areas. It was also suggested that a high ratio of light fraction to the heavy fraction is indicative of a gas reservoir, while a low ratio was evidence for an oil deposit.

Geobotanical Prospecting Method

Geobotanical survey is also discussed in this study in which vegetation cover was examined to establish possible correlations to petroleum-rich areas. Some strong correlation was found between presence of special vegetation and subsurface hydrocarbons. The presence of aquifers, mineral deposits or hydrocarbons can lead to environmental heterogeneity, resulting in relatively higher humidity or heavy metal toxicity [2]. Geobotany has been used

extensively for mineral exploration but only applied in a limited way for hydrocarbon exploration.
In this study, once a relationship between the presences of plant indicators for limestone is established, then it can be related to the underlying hydrocarbons, since the majority of hydrocarbon reservoirs of the study area are all in the ASMARI limestone formation.

Remote Sensing Prospecting Method

In any petroleum exploration project in sedimentary basins, three main factors are taken into consideration: a) the petroleum system elements, such as source, reservoir, seal and overburden rocks, which are the product of sedimentation processes in a subsiding basin. b) Petroleum trapping mechanisms, the majority of which are the products of deformation. c) Heat kitchen to convert suitable organic matter into petroleum.
In this paper we try to find how thermal anomalies over petroleum reservoirs can be used to correlate with the presence of petroleum. The survey in the literature showed that the majority of published research about remote sensing and its application in petroleum exploration has been restricted to lineaments detection, since gas seepage takes place where lineaments and fractures are present. That research mainly focused on gas seepage detection with the help of lineaments derived from remotely sensed data rather than direct application of this methods have been complementary to the widely used geophysical methods for petroleum exploration.
The present studies have three main categories of surface phenomena, namely: surface temperature (TIR) derived from satellite data, soil gas (Rn, He) and vegetation covers and studies their correlation with the presence of oil and gas regardless of whether they can be explained or not. The objective of the research is to study if any correlation can be observed between these surface phenomena and petroleum existence in subsurface in the study area. Nasipuri and colleagues have been able to clearly establish a correlation between the presence of oil fields and thermal inertia [3,4] derived from ASTER images in a petroliferous pilot area in western India. The research benefits of present work are the costs associated with prospecting for new hydrocarbon resources will be dramatically decreased.

Methodology

1. Available Data

The main available data used in this paper are: 1.Satellite VNIR, SWIR and TIR ASTER ,2.data covering the study are 3.Geological data of the study area, 4.Geochemical data of the study area, 5. Geobotanical of the study area, 6. Meteorological data of the study, 7. Topographical data of the study are, 8. Geospatial data of the petroleum reservoirs of the study area.

2. Study Area

The region of study is in two southern Iranian oil fields namely: Ab-teymur and Darquin reservoirs.

3. Surface Data Processing Over Petroleum Reservoirs of the Study Area

This section discusses various data processing procedures employed for petroleum reservoirs within the granules of study area.

3.1 Thermal Anomaly Detection Using ASTER TIR Images

Thermal properties of material are directly a function of material's composition. Surface materials with varying thermo physical properties, such as thermal inertia, albedo, emissivity, and moisture content, respond differently to solar radiation, resulting in changing surface temperature during a 24-hour day [5].

3.2 Spatial location

Effect of spatial location of petroleum reservoirs, distance between petroleum volumes in place and the surface, should also be taken into consideration. This layer of information will reflect corresponding values for the distances between the surface layer of a specific petroleum reservoir and the land surface.

3.3 Geochemical Analysis

3.3.1. Alteration Zones

All the reported and mapped alteration zones were taken into consideration as an individual layer during the stage of data integration. Correlation matrixes analysis between the alteration zones and the oil fields influence radiuses were also a part of the Geochemistry layer data analysis. Based on the results obtained from these statistical analyses, fuzzy membership values were allocated to the corresponding locations of each of the individual alteration zones.

3.3.2. Gamma Ray and Soil Content in Thorium, Uranium and Helium

Geochemical data in terms of gamma ray spectrometry and Th, U and He content of the surface within the influence radius of oil fields was used as another individual layer with its corresponding fuzzy membership values. China-American Technology Corporation's scientific research revealed valuable information about a very high correlation between the presence of oil and gas and soil content of Helium and Thorium [6].

3.4 Vegetation Cover

Vegetation cover within the boundaries of oil field influence zones was taken into consideration as an individual layer of information which will complement the other layers of information by its corresponding statistical weight.

3.5 Analytical Semi-Variograms

Mean LST in different directions with respect to distance will be expressed by variograms. As the LST sample points do not necessarily fall all in one line and their intervals are not equal, the modified variogram formula will be defined as [7]:

$$\lambda(h) = \frac{\sum_{j=1}^{N} h_j[f(x_j) - f(x_j + h_j)]^2}{2\sum_{j=1}^{N}(h_j)}$$

where λ (h) is the variogram, N is the number of pairs whose distance from one another is equal to vector h, f(x) and f (x + h) are the LST values for points x and (x + h) whose distance are equal to vector h from each other and h_j is the class size which has been chosen to be the same as the spatial resolution of ASTER TIR (15m). The spherical variogram model is the best fit to the calculated empirical results.

Results of Surface Data Analysis Within ASTER Granules of the Study Area

The ASTER images of study area are represented in figure 1.

1. Geology

The main geological units within the boundaries of this granule is:

The brown to gray, feature forming sandstone and low weathering, gypsum-veined, red marl, siltstone of Aghajari formation of Zagros zone. The first sediment of this unit is sandstone and siltstone, lagoonal chemicals; gypsum evaporates present,

2. Gas Geochemistry

Results of gas geochemistry analysis within the boundaries of this granule:

- 62.3% of pixels of this granule, which are within the buffer zone of Ab-teymur reservoir, have radon concentration exceeding the background threshold value.
- 64.3% of pixels of this granule have helium concentration exceeding the background threshold value.

Radon concentration within the study area covering Ab-teymur and Darquain reservoirs is represented in figure 2.

3. Vegetation

Results of vegetation cover within the boundaries of this granule are:

- 9.4%, 18.3% and 26.4% of pixels, within the buffer zone of Ab-teymur reservoir, contain V4, V14, V15 forward vegetation species, respectively.
- 76.4%, 89.8%, 82.3% and 68.7% of pixels, within the buffer zone of Ab-teymur reservoir, contain V7, V12, V13 and V22 reverse vegetation species, respectively.
- 11.3%,2.8%12.4% of pixels, within the buffer zone of Darquain reservoir, contain V4, V14 and V15 forward vegetation species, respectively.
- 87.1%,77.6%, 90.1% and 88.7% of pixels, within the buffer zone of Darquain reservoir, contain V7, V12 , V13 and V22 reverse vegetation species, respectively.

4. Thermal Variogram

Thermal variation behaviors of 256 cells of this granule in respect to the buffer zones of Ab-teymur (top) and Darquin (bottom) reservoirs are represented in figure 3.

Information Integration and Correlation

Thermal anomalies and their orientation, radon and helium concentration and vegetation cover information are shown in table 1. Also table 2 shows the results of thermal map calculation carried out for the parts of granules which have been crossed with the location map of Ab-teymur and Darquin reservoirs.

Conclusions and Discussion

It was observed that by employing ASTER, thermal anomalies could be detected much easily than by previous conventional methods. Existence of a probable correlation between these detected thermal anomalies and the presence of oil has been partially confirmed by results of the studies so far. Thermal properties of surface was considered as a single factor reflected in an individual data layer among other data layers such as geology, geochemistry, geobotany, and local data layers which mutually influence one another. By employing fuzzy logic, complemented by GIS, a dynamic model has been partially produced during the course of current research allowing all the observed and measured surface properties to have their corresponding influences over the model. The directional variograms proved that the thermal inertia and emissivity of oil bearing surfaces fluctuates accordingly once the influence radius of oil field is crossed which recommends high spatial correlation between the presence of oil and thermal variations do exist. Innovative ASTER band combinations and ratios also do verify the correlation existence. Further studies are needed to be performed to develop the dynamic model in more details to an extent which can be employed in variety of geological conditions and situations.

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Table 1. Results of data integration for three main layers of thermal, gas and vegetation cover.

Reservoir Name	Thermally Anomalous pixels (%)	Rn Anomalous pixels (%)	He Anomalous pixels (%)	Forward Vegetation Cover (%)			Reverse Vegetation Cover (%)			
				V4	V14	V15	V7	V12	V13	V22
ABTEYMUR	49.8	62.3	64.3	9.4	18.3	26.4	76.4	89.8	82.3	68.7
ABTEYMUR	38.6	11.8	45.3	11.3	2.8	12.4	87.1	77.6	90.1	88.7

Table 2. Statistics of for thermal variogram direction for the cells of granule which are within the buffer zone of influence of Ab-teymur and DARQUIN reservoirs.

Reservoir Name	NW-SE	NE-SW	NS	EW
ABTEYMUR	29.1%	45.8%	29.1%	37.5%
ABTEYMUR	61.5%	61.5%	38.4%	15.4%

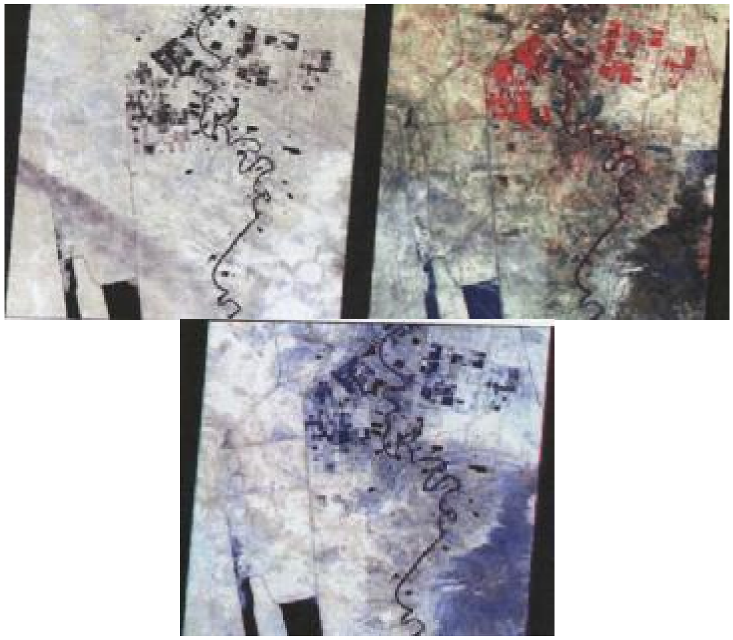

Figure 1. Thermally unprocessed VNIR, SWIR and TIR ASTER images (left to right) for the study area covering Ab-teymur and Darquin.

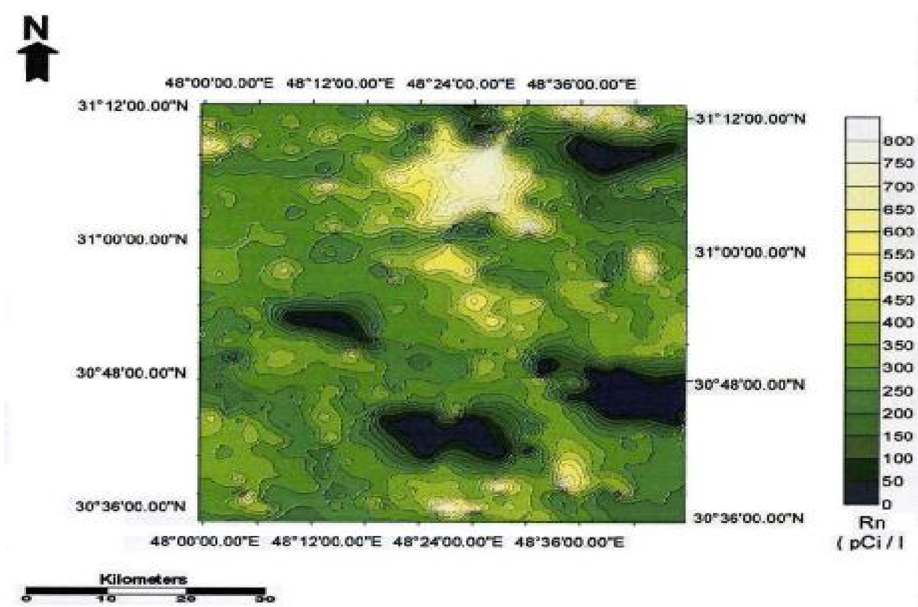

Figure 2. Radon concentration within the study area covering Abteymur and Darquin reservoirs.

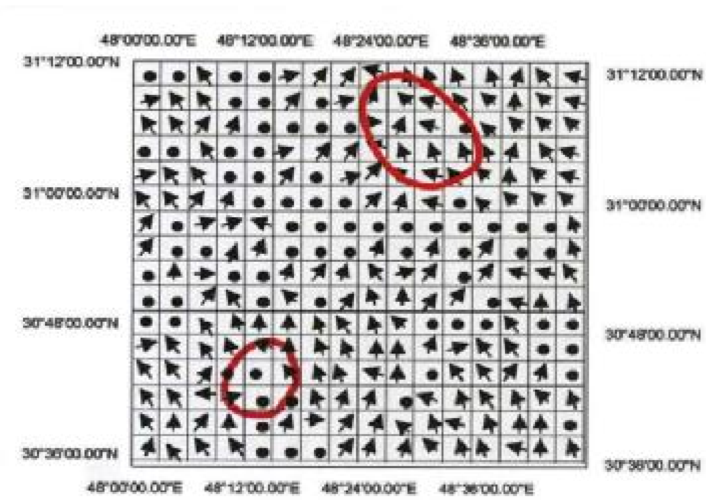

Figure 3. Thermal variation behaviors of 256 cells of this granule in respect to the buffer zones of Abteymur (top) and Darquin (bottom) reservoirs. The arrows indicate the dominant direction out of the four main directions for the given cell. Black spots indicate that there are either no thermal behavior variation in any specific direction or there is no thermal anomaly in place for that specific cell exceeding the threshold thermal value.