Using of ArcGIS in Oil and Gas Exploration

Term Paper

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Abstract

Discovering new sources of oil and gas is the core competence to be successful in the petroleum industry. GIS can help to evaluate the potentiality of oil and gas. Classical petroleum geology applications are basically based on making paper maps to find out geologic features of subject area. In oil industry the dealing of data is main issues, so that updating you data base, evaluation and using all available data are very important to produce the drillable lead and prospect. In this paper we will go through the uses of GIS-based (ArcGIS) portfolio management tools to solve the problems of dealing with data. These tools uses by Petroleum Development Oman's company to support the exploration workflow (we will address it at the first part of this paper). GIS also can help in data integration for example the geological maps had been developed using various data types like topographical map, Digital Elevation Model (DEM), satellite images, cultural data, leads and prospects map to identify the best prospect to find oil and gas. The second case study of this term paper will provide an overview of how GIS is being utilized for oil and gas exploration work in the Ethiopian project. The critical success factor of GIS tools is the close link between multi-discipline evaluation teams and the portfolio managers. The main objective for the use of GIS environment is to use as an effective data and knowledge management system throughout oil and gas exploration phase. Petroleum exploration is a very complicated field dependent on a multitude of variables; because of this the analysis capabilities of GIS programs will be able to lower the cost of petroleum exploration by analyzing the potential of petroleum being found at a potential location and also the potential yield of an oil field.

1. Introduction

GIS is very good tool to evaluate the potential for oil in promising locations. Usually oil exploration need analysis of satellite imagery, digital aerial photomosaics, seismic surveys, surface geology studies, subsurface and cross section interpretations and images, well locations, and existing infrastructure information *(see Figure1)*. GIS can allow us to overlay, view, and manipulate the data to analyze and understand the possibility to find oil and gas.

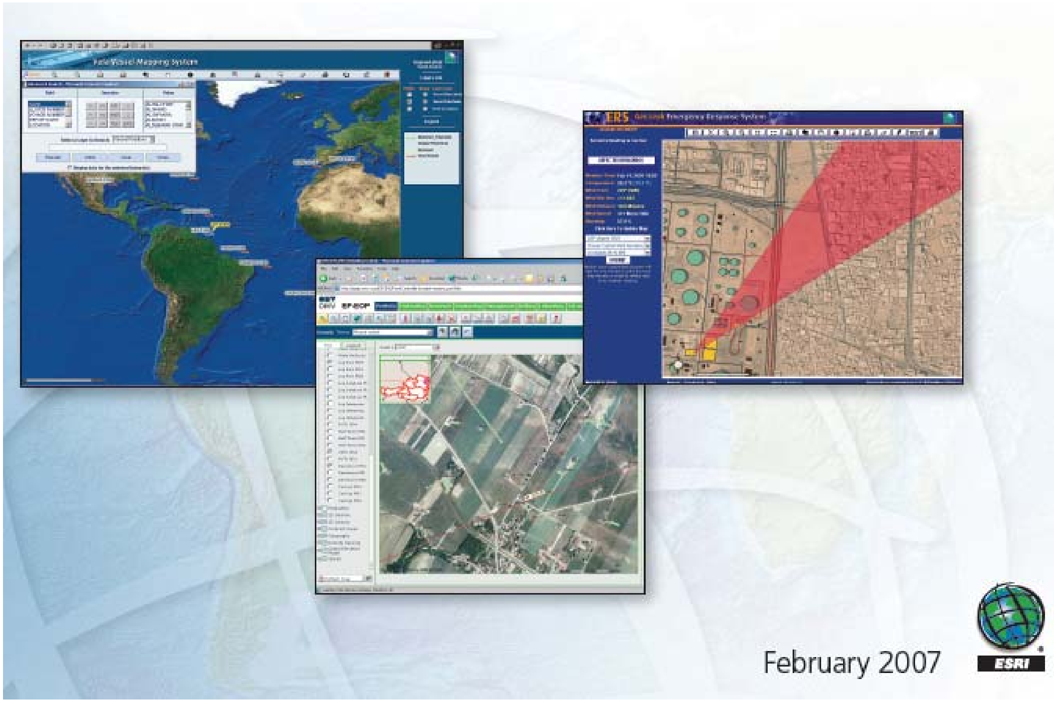


Figure.1: Uses of GIS in oil and gas exploration (Take from GIS Best Practices Poster, GIS for Petroleum by ESRI, Feb 2007)

2. Problem Statement

Oil and gas exploration portfolio contains a multitude of data on potential hydrocarbon accumulations (leads and prospects). Major challenges in managing such a portfolio are: data updating, a consistent evaluation applied throughout all available data ongoing lead/prospect evaluation process.

3. Objective

The main objective of this paper is to give an idea and workflow of the applications of the GIS technology in oil and gas exploration and mention how the GIS technology can help to evaluate the potential for oil and gas in promising locations and taking the appropriate decisions. Basically the advantages of GIS for petroleum exploration are to:

- Provides better way of viewing and exploring geological data.
- Links both tables and graphical data into "intelligent" maps.
- Makes analysis and queries easier.

4. Motivation

Classical petroleum exploration applications are basically based on making paper maps to find out geologic features of subject area. Mapping petroleum geology related maps is quite difficult and time consuming.

5. Methodology

GIS-based (ArcGIS) portfolio management tools can apply in the exploration workflow and it represented be a funnel, starting from play mapping through early lead identification, maturation into prospects, subsequent drilling and discovery with finally booking and handover to production (Kevin McLay, July 2003). Each phase of the funnel feeds the next stage and must be supported by the portfolio. Key datasets stored via ArcGIS or made available within it. This data includes play, lead and prospect, well, geophysical and geological data. A play is a group of reservoirs genetically related by depositional origin, structural style or trap type, source rocks, and seals. Plays are determined on the basis of correlation of chronozones, identification of structural and depositional styles, construction of composite type logs of fields, organization of geological data (such as maps and cross sections of type reservoirs), and compilation of geologic and reservoir attribute data on all reservoirs.

6. Literature Review

6.1. GIS Use in the Petroleum Industry

Exploration, Productions and Refining are involves the process of exploring new locations as petroleum reserves, managing the production of crude petroleum from earth strata, managing the pipeline network to transfer crude sources to refining plant and facility management of various resources connected to such a huge industry. (Dean E. Gaddy, 2003).

6.2. GIS Applications in Petroleum Exploration

Exploration requires the analysis of a lot of different types of data such as satellite imagery, digital aerial photo mosaics, seismic surveys, surface geology studies, subsurface and cross section interpretations and images, well locations, and existing infrastructure information. A GIS can tie these data together to the location in question and allow you to overlay, view, and manipulate the data in the form of a map to thoroughly analyze the potential for finding new or extending play potential. Geologists, geophysicists, engineers and petro-physicists usually perform exploration evaluation.

6.3. Benefits of GIS

- Saving time for designing seismic survey by low safety risk by selecting the best routes for seismic acquisition by using topographical evaluation from satellite images and topographical maps.
- Saving costs.
- Use input data from different software’s by different formats.

- Use the web- base GIS software and computer networks for sharing the data and information through united database
- Cross discipline interpretation using the Arc-GIS software capabilities by integration of the contribution of different team members.
- Data visualization through the use of symbology.
- Mapping of digital databases.
- Data representation in different forms such as maps, charts, data tables and query results.

7. Exploration Workflow Overview: Oman Case study

Petroleum Development Oman's (PDO) is the main oil and Gas company in the Sultanate of Oman. (*Kevin McLay, July 2003*). The majority of the shares (60%) are owned by the Government of the Sultanate of Oman. The remainder are held by Shell International Exploration and Production (34%), which also acts as the operator, TotalFinaElf (4%) an Partex (Oman) Corporation (2%) (*See Figure.2*).

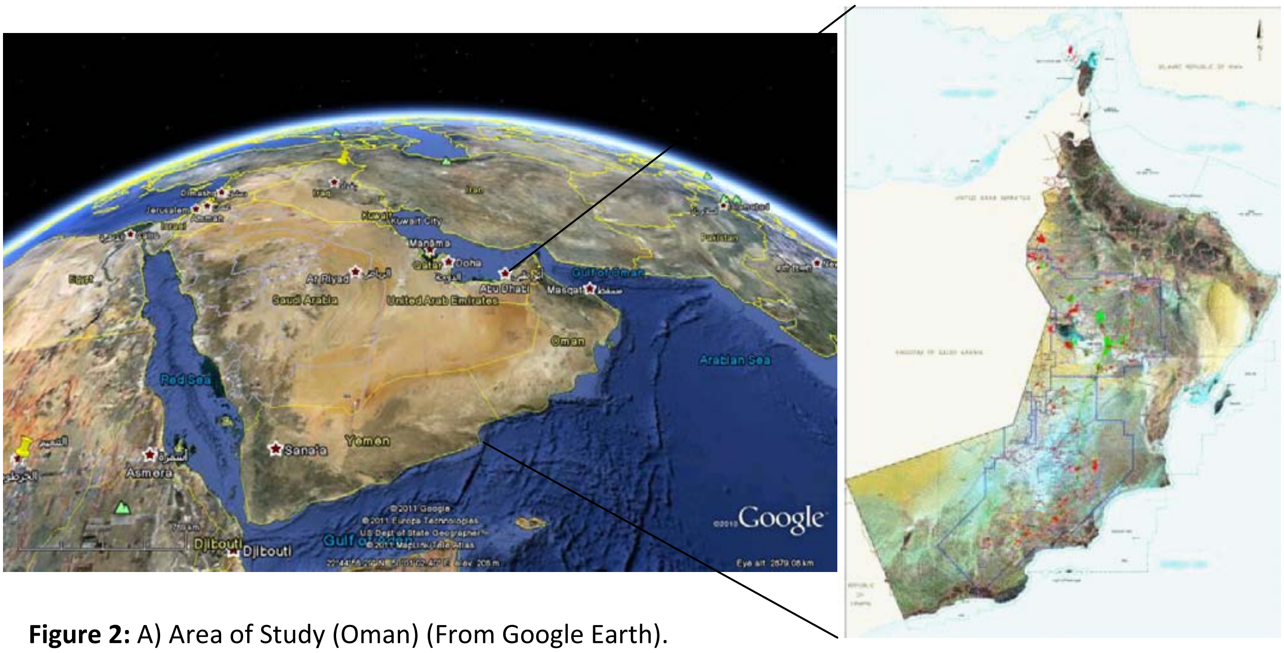


Figure 2: A) Area of Study (Oman) (From Google Earth).

B) PDO's Concessions Maps (Kevin McLay, July 2003)

7.1. Effectiveness of Turning Undefined to Defined

The exploration work flow start from turning the undefined resources to define. The defined resources represented by approved leads and prospects while the undefined resources are the remaining unidentified hydrocarbon potential within the concession. Play analysis is undertaken to best identify this undefined potential. A fundamental part of play analysis is data integration and analysis. Data collected and created in this stage is fed into the formal processes for identifying the remaining potential of particular plays.

7.1.1. Well Data Integration

The source data for mapping and play analysis, is that of well data. Making this data dynamically available within ArcGIS has been a major goal for the ongoing success of ArcGIS. A module within ArcGIS has been built that allows predefined queries to be run directly against the well database with results returned into a local geodatabase. Explorationists can quickly and easily produce maps of the following:

- Stratigraphic intervals
- Location of core samples
- Location and presence of hydrocarbon shows and tests
- Porosity distributions
- Gravity variations

Results can be displayed in their correct location along the well track or brought to the surface location of the well for general analysis (*see Figure.3*).

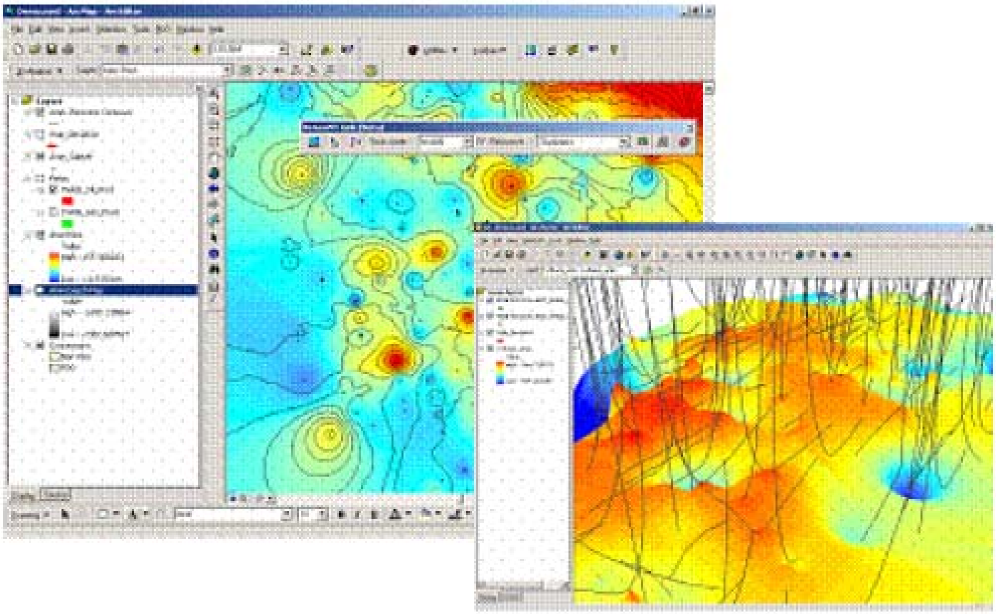


Figure 3: Well Database Module (ArcMap) and a 3D view of well with stratigraphic depth map. (*Kevin McLay, July 2003*)

Previous to this application, well data was first selected in the well database interface and exported to Excel prior to importing to ArcGIS. This had many disadvantages, such as the generation of multiple data copies and also it being a very time consuming process for skilled staff. Future plans for this module include the remote launching of individual components within the well database application, such as a well log viewer. This will further integrate well data within ArcGIS.

7.1.2. Geological Mapping

The benefits of using ArcGIS are:

7.1.2.1 Play Fairway Mapping

Mapping top reservoir and seal formation it was possible to enhance the interpretation of potential play fairways. Although relatively simple in GIS terms, the real power of this is in the new ways of working and utilising GIS in the exploration workflow. The ability to easily do this was facilitated by (*see Figure.4*):

- Eextract and display horizon information from the well database.
- Ddefine and create user-defined data.
- Overlay multiple data types.

Figure 4: Play Fairway Mapping. Cross section illustrates formation structure (*Kevin McLay, July 2003*)

7.1.2.2. Mapping and Analysis of Trapping Configurations

Identification of potential trapping structures can be done using ArcGIS. The following example illustrates mapping and analysis of these structures in ArcGIS. As before, one of the key datasets is that of well data. The horizons representing the bottom and top of the seals were extracted from the well database (*see Figure.5*).

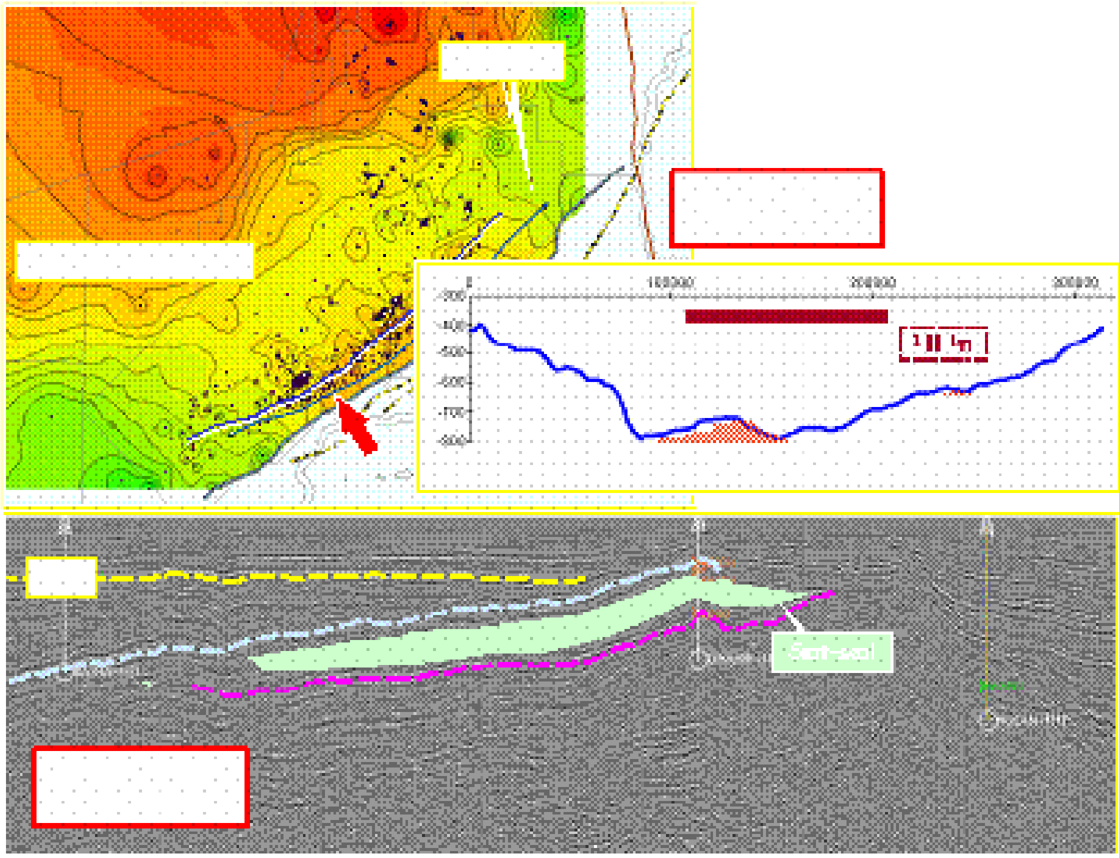


Figure 5: Mapping and analysis of trapping configurations. (*Kevin McLay, July 2003)*

7.1.3. Play Analysis

ArcGIS have Play analysis module. Play data is now consistently managed, readily accessible for a wide range of additional processes and most importantly, fully auditable (*see Figure.6*).

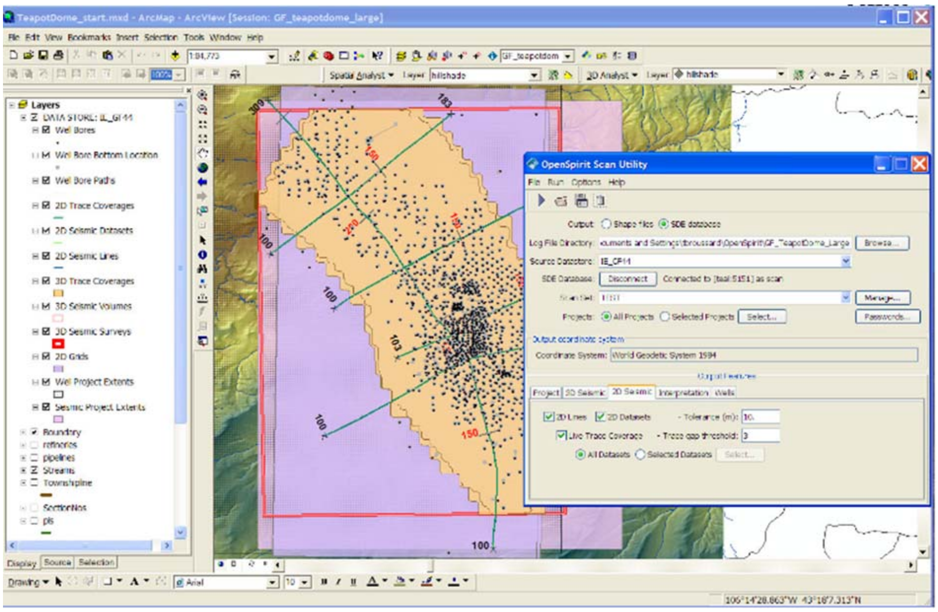


Figure 6: Play Analysis System within ArcGIS. (*Kevin McLay, July 2003)*

The basis of this approach is in the interpreter interactively defining Common Risk Segment (CRS) Maps. These CRS maps are polygons with associated Possibility Of Success (POS) factors. CRS maps are commonly defined for chance of seal, charge, reservoir and recovery. These maps are then intersected and further combined with lead density maps to produce final maps that depict statistically generated unidentified hydrocarbon volumes. The data model is versioned thus allowing play analysis runs from previous years to be stored and subsequently retrieved. In conjunction with the play data, specific audit information is also maintained. This includes user details, time stamps and any calibration data used in the process.

7.2. Defined Portfolio Leads & Prospects

Detailed prospect data, such as risks and resource characteristics, can be directly accessed, visualised and analysed within ArcGIS. This approach ensures outlines are kept in step with Fastrack entries and facilitates cross portfolio display and analysis.

The prospect module provides the following functionality:

- Management Tool.
- QC and Reporting.
- Filter Tool.

7.3. Portfolio Management

With the lead and prospect outlines now consistently managed, portfolio status maps can be produced with a high degree of confidence. These maps are produced quarterly and distributed to all exploration users. To promote consistency, a standard look and feel has been implemented. The portfolio maps depict the current state of the portfolio along with the major relevant geological elements. They are frequently used in planning and strategy meetings and for reporting to shareholders. The maps are an excellent tool to promote and facilitate knowledge sharing (*see Figure.7*).

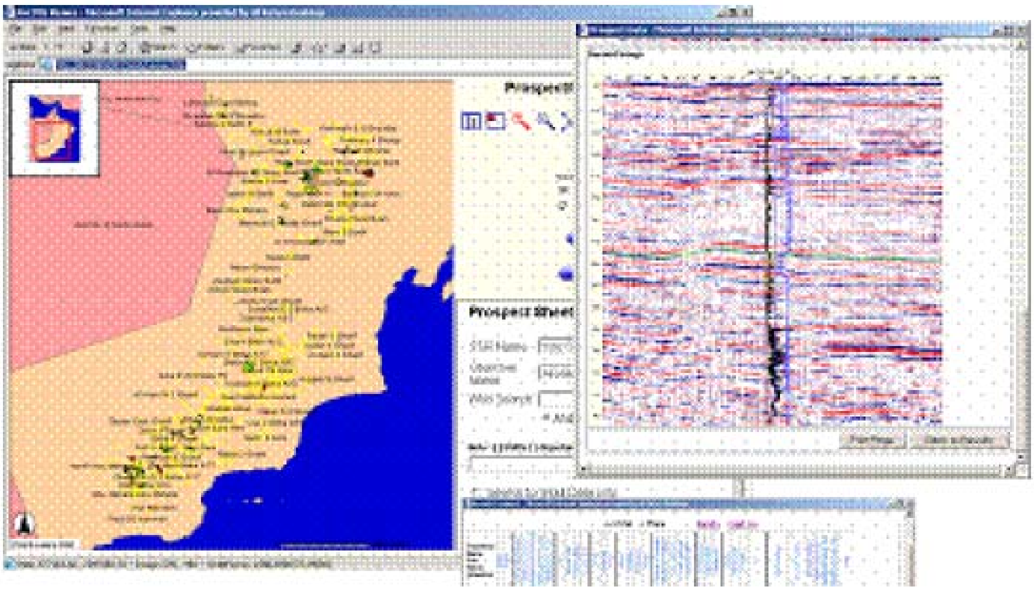


Figure.7: web based prospect data capture tool (*Kevin McLay, July 2003)*

8. Oil and Gas Exploration using GIS: Ethiopia Case Study

8.1 Introduction

PETRONAS Carigali Overseas Operations (PCOSB) has been in operation in Ethiopia since 2003 (*See Figure.8*). The Ethiopia project team utilized ArcGIS as a mapping tool to integrate geological data in generating complex geological structures of Ethiopia blocks. Such optimized seismic survey planning has resulted in reducing cost and time in determining the best routes and other factors during operations survey.

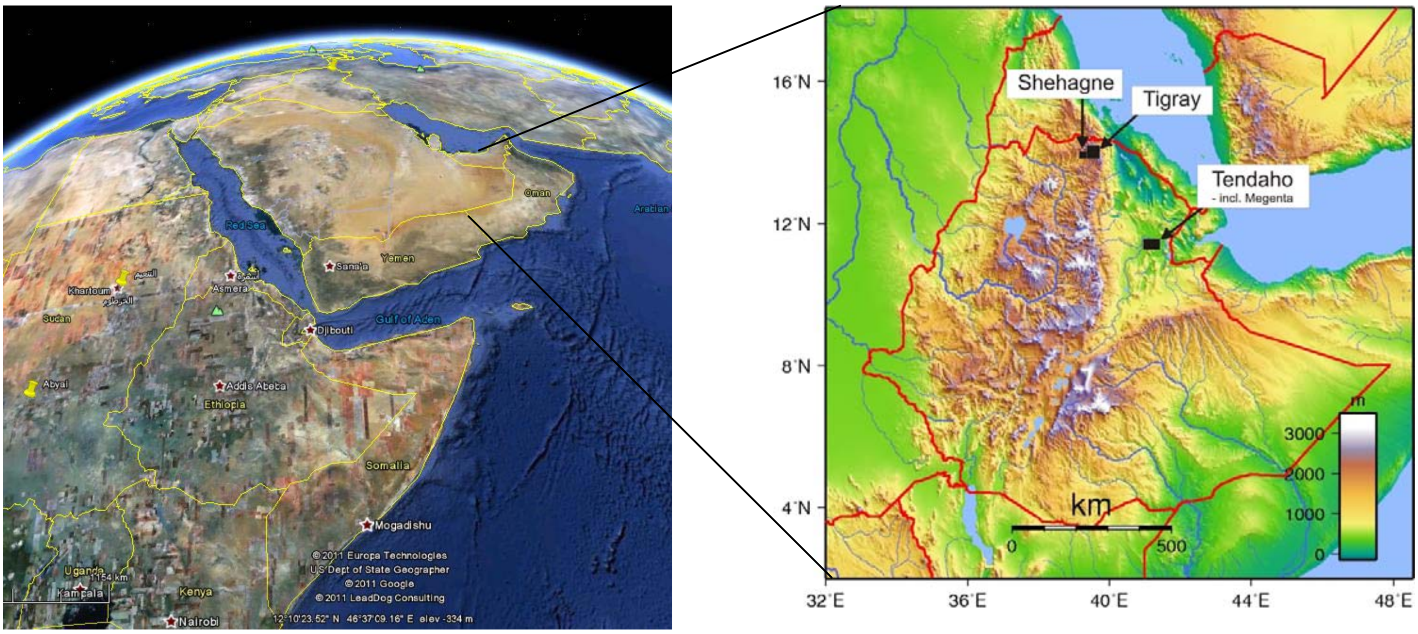


Figure 8: A) Area of Study, Ethipoia (Google Earth).

B) PCOSB Blocks in Ethiopia (Source: IHS Energy, 2007)

8.2. Geological Background

Ethiopia is located in eastern Africa in the southern Red Sea region (*See Figure.8*). It borders Sudan on the west, Eritrea on the north, Djibouti and Somalia on the east, and Kenya on the south (Mohd. Zukhairi, 2008). The topography of Ethiopia consists of a central high plateau bisected by the Ethiopian segment of the Great Rift Valley into northern and southern highlands and surrounded by lowlands, more extensive on the east, where PCOSB blocks are located and southeast than on the south and west.

The first steps in exploration project, is the creation of reconnaissance maps. It is produced relative to the available datasets from previous geological and geophysical study integrated with latest datasets, which can present distinct trends, patterns and anomalies of surface and subsurface structures and which can then be used to evaluate and determine the seismic routes. ArcGIS was then utilized to map the study area by integrating various datasets to develop a better picture especially in topographical surfaces.

8.3. Geophysical Methods in oil & Gas Exploration

Geophysical applications like seismic methods, gravitational methods and magnetic methods are used for determine and locate the geological structures suitable for the accumulation of oil. These methods were used during exploration and appraisal study of Ethiopia project. The project commenced from regional framework of the area through basin study, to determine the potential play (possible hydrocarbon accumulation), until the seismic 2D and 3D design to understand the subsurface of the targeted areas (*see Figure 9*).

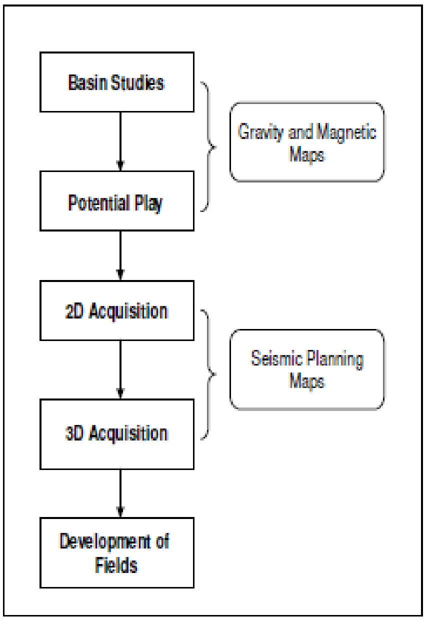


Figure.9: Exploration Workflow (*Mohd. Zukhairi, 2008)*

8.4. Regional Mapping Using GIS

During the evaluating of geological structures of the areas, integrated geological maps were generated. This comprises the gravity and magnetic with DEM and topography overlays. The maps were to picture the shape of the basin, play, prospects and leads (*See Figure.10*).

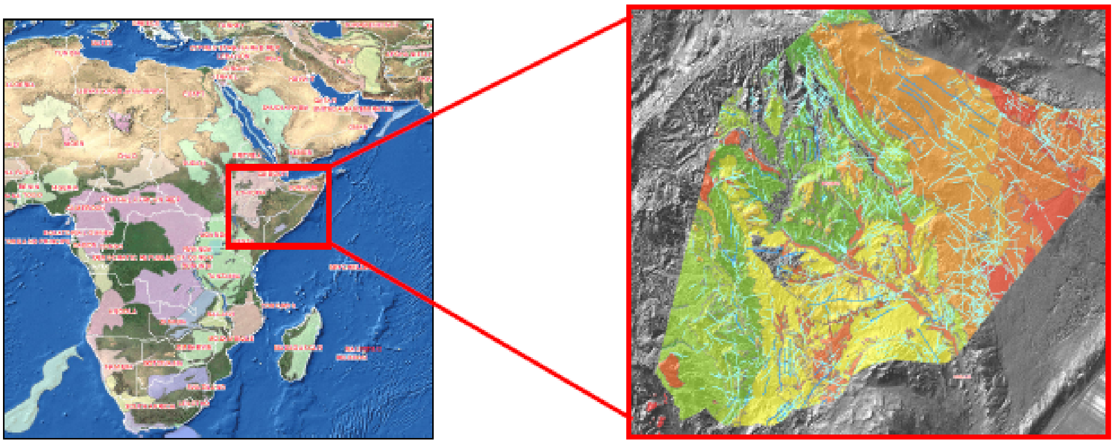


Figure.10: Regional Mapping using GIS (*Mohd. Zukhairi, 2008*)

8.5. Seismic Survey Planning

Careful planning can result in more cost-effective acquisition and processing, and in data of sufficient quality to benefit the most advanced processing. Before the first shot is fired or the first traced recorded, geophysicists must determine the best route to reveal the subsurface target (*Mohd. Zukhairi, 2008*). Generally, they would also consider locations and types of sources and receivers and the time and labor required for acquisition. Many additional factors, including HSE issues, must be taken into account such as:

- Topography: seismic line must be as straight as possible for better data acquisition- how flat is the topography (*see Figure.11*).
- HSE matters: access due to political situations, safety, etc.

- Subsurface structures: Inline seismic basically must follow the dipping topographical structures and crossline seismic must follow the strike of the topographical structures for accurate.

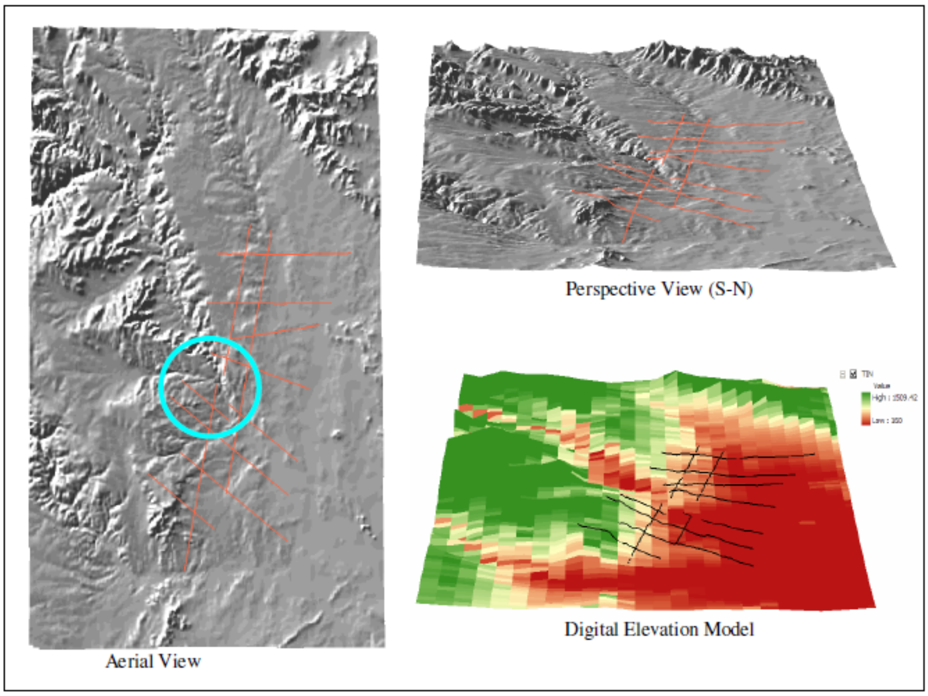
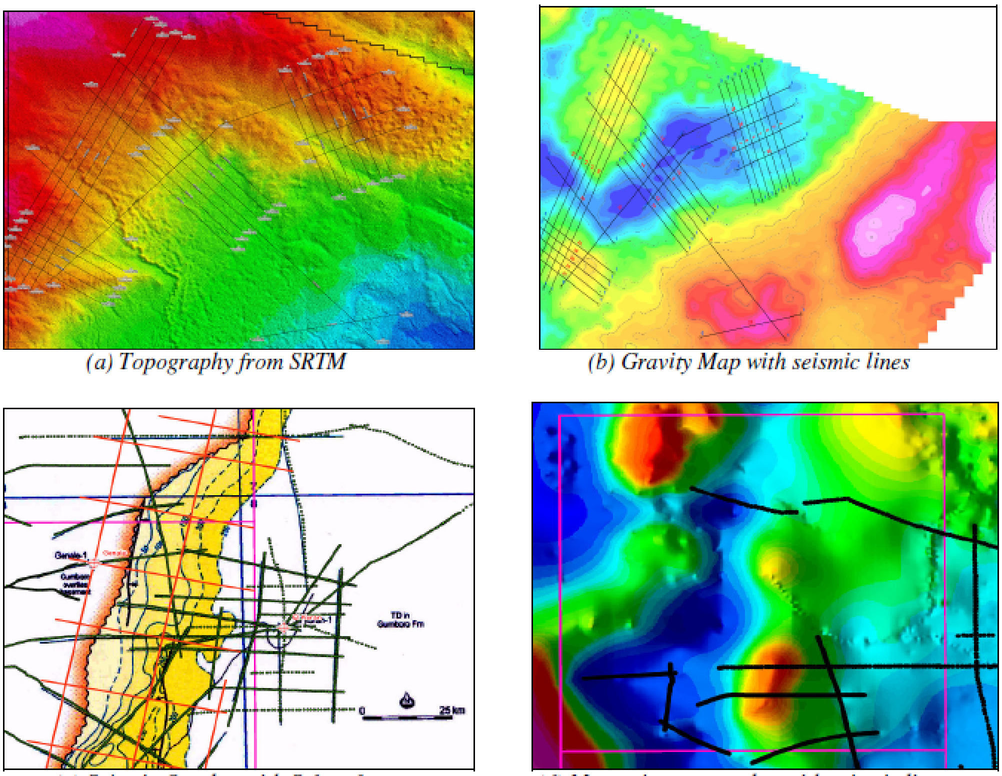


Figure.11: Topographical Analysis using ArcGIS 3D (Mohd. Zukhairi, 2008)

8.6. Integrated Geological Maps

Different types of data such as satellite imagery, digital elevation model (DEM), seismic surveys, surface geology studies, subsurface and crosssection interpretations and images, well locations and existing infrastructures information are used for analysis and integration (Mohd. Zukhairi, 2008). GIS can tie these data together to the location in question and allow us to overlay, view and manipulate the data in the form of a map to thoroughly analyze the potential of seismic survey lines locations. Initially, multi-disciplinary geosciences survey was conducted of the country. Multiple potential study locations were selected by: Study of surface lineaments, fractures and circular and accurate anomalies identified from satellite images and aerial photographs. Analysis and graphical representations of fracture orientations, lengths and density. The fundamental fracture characteristics used for structural interpretation were characterized with hybrid geosciences workstation. Investigation of regional geology and geophysical elements. Mapping and analysis for area. Through the integrated datasets using GIS, raster data, such as aerial photos or satellite imagery, can be incorporated with vector data, and surface culture, such as contours, topographic landmarks, digital elevation model or points of interest can be presented. Maps of the following features and characteristics were created in the first phase of exploration reconnaissance mapping program (*see Figure.12*):



(a) Topography from SRTM

(b) Gravity Map with seismic lines

(c) Seismic Overlay with Subsurface

(d) Magnetic map overlay with seismic lines

Figure.12: (a) Topography from SRTM, (b) Gravity Map with seismic lines, (c) Seismic Overlay with Subsurface, (d) Magnetic map overlay with seismic lines *(Mohd. Zukhairi, 2008)*

9. Discussion and Analysis

Classical petroleum exploration applications banded on producing paper maps to research geologic interest area. Mapping petroleum geology related maps is quite difficult and time consuming. Recently Geographic Information Systems (GIS) provides a better way of viewing and exploring data by linking both graphic and tables data into a graphically "intelligent" map with supportive tabular information. The GIS environment offers the exploration geologist a wide variety of options for integrating regionalized geodata. The full power of the methodology of Characteristic Analysis introduced in the eighties can now be exploited by means of GIS support. GIS not only improves the speed, efficiency and accuracy of our maps but also provides the ability to make analyses that were never before possible. Such computational power will lead all disciplines within the business to learn different things much more rapidly, leading to greater insights.

10. Conclusion and Recommendation

Applying ArcGIS within the exploration workflow is an ongoing process. Tools developed, although important, are not the critical items. Data is the fundamental component as over time tools will come and go, while data remains a common factor. It is important to note that no matter how technically good the tools are, they are only as good as the users who have the discipline to utilise them and populate the databases.

"GIS allows the integration of technologies and interpretations - a whole range of ideas, data and analyses can be brought to problem solving that we have not seen before."

Everyone can input their data into the system and people will see things they never had the opportunity to see before and make calculations that they never made before, simply because it was too difficult.

Even though major oil companies have been moving data into GIS systems for several years, scientific and professional organizations have been slower to build GIS systems because of the expense.

ArcGIS is a key enabler due to its power to integrate data and its flexibility in allowing users to develop their own workflows. It is the best practice from these workflows, as they develop over time that must be captured and embedded in the formal processes to ensure the initiatives do not die over time.

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Glossary

Chance Factor: Probability that an event will materialise; (oil exploration) Probability of finding some hydrocarbons (but not necessarily in commercial quantities). Chance factor = 1 - Risk. See also POS.

Charge chance factor: Probability that hydrocarbon charge generation and migration took place and that the hydrocarbons reached the prospect.

CRS: Common Risk Segment.

Fastrack: A Shell prospect appraisal programme that introduces the capability of handling alternative models of the sub-surface as well as the uncertainty in each model.

Identified Potential: All identified approved leads and prospects.

Lead: Subsurface feature with the potential to have entrapped oil or gas, and which is constrained by at least two intersecting traverses (e.g.seismic lines).

Lead Density Map: Map consisting of polygons representing the lead density within a given area. Lead Density is commonly defined as the number of expected leads per 1000 square kilometres.

Play: A set of common ingredients related to trap, charge, reservoir, seal, and timing that conspire to form similar types of hydrocarbon accumulation.

Portfolio Management: Process by which the (exploration) portfolio is managed to achieve multiple and conflicting objectives. Involves continually testing scenarios for future production growth whilst trying to balance long term and short term requirements, the need to deliver both value and volume, meet cost targets, deliver robust projects with a suitable balance of risk and reward whilst keeping within spending limits.

POS: Probability of Success. POS = 1 - total of all risks.

Prospect: Subsurface feature with the potential to have entrapped oil or gas, and which has a relatively well-defined geometry from available data based on several traverses (e.g. seismic lines).

Recovery chance factor: Probability of recovering hydrocarbons at commercial rates (irrespectively of the size of the accumulation).

Reservoir (presence) chance factor: Probability of the reservoir being present in the prospect area. Reservoir formation: Vertical subdivision of the total reservoir interval between the top seal and the seat seal.

Seal: Rock layer impermeable to hydrocarbons which either overlies (top seal) or underlies (seat seal) or laterally seals (sealing fault, salt diapir) a reservoir rock.

Seal chance factor: Probability that an effective sealing lithology is present over the structure since the latest charge phase. Seal presence (play), expressing the probability of the seal having been deposited and preserved in the crestal area of the prospect.

Trap: Structure composed of reservoir rock enclosed in sealing rock capable of retaining hydrocarbons

Unidentified Potential: Estimated Undiscovered Resources (play potential) beyond identified prospects and leads.

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Appendix 1

GIS for Petroleum, ESRI Paper

Appendix 2
Oman Case Study Paper

Appendix 3
Ethiopia Case Study Paper

Appendix 4

PPT Presentation