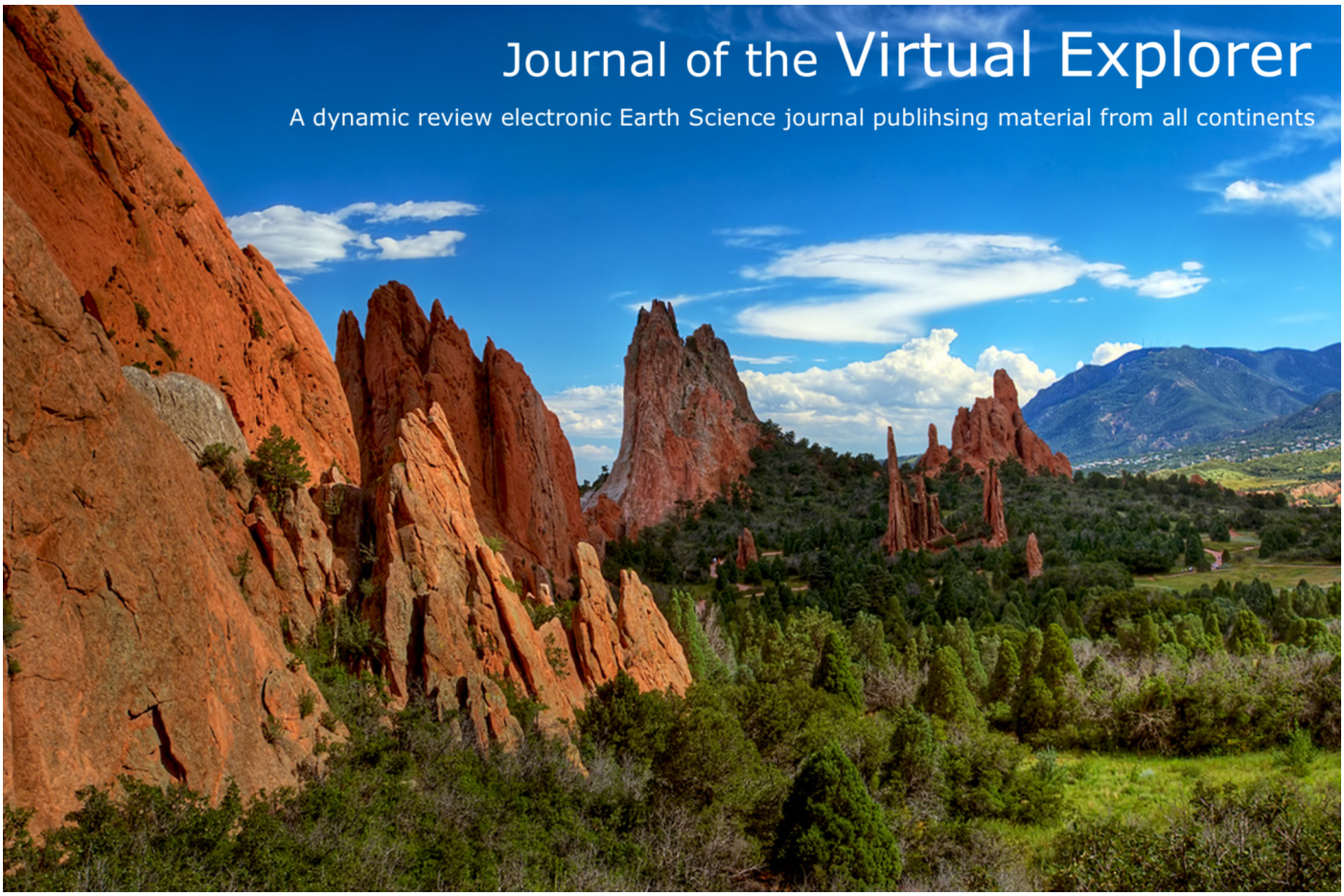


# Geographic Information System - An ultimate tool for Hydrocarbon Exploration and Exploitation

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Journal of the Virtual Explorer, Electronic Edition, ISSN 1441-8142, volume **23**, paper 2
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**Abstract:** The increasing popularity and advances in the development of GIS in recent years has increased its use manifold in almost all fields of life generally and in geosciences particularly, due to the robust integration of spatial features and tabular data, spatial analysis capability, intelligent maps, and a geographic user interface to the databases. This paper will present the case studies illustrating the benefits that can be derived from GIS and Remote Sensing technologies in the exploration and exploitation of hydrocarbons. Exploration Management System along with its front-end Geographic Information System, a graphical interface for quick analysis and decisions, was developed for upstream petroleum activities of Pakistan. It has not only helped to maintain its exploration monitoring data up-to-date for over a decade rather it has also proved useful in generating revenue through the services like data management and PPIS etc.

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## Introduction

This paper will present two promising technologies: Geographic Information System (GIS) and Remote Sensing (RS) along with several case studies illustrating the benefits that can be derived from these emerging technologies with special reference to the implementation of GIS in Pakistan for upstream petroleum activities. These technologies are being widely used nationally as well as internationally in almost all walks of life in general and in earth sciences particularly. The growth of GIS has been a marketing phenomenon of amazing breadth and depth and will remain so for many years to come. Clearly, GIS will integrate its way into our everyday life to such an extent that it will soon be impossible to imagine how we functioned before. Before discussing the applications of GIS and Remote Sensing in hydrocarbon exploration, their brief introduction is presented.

## Geographic Information System (GIS)

GIS is a computer-based software used for visualizing, manipulating, creating, analyzing and displaying the spatial data. Different definitions of a GIS have been evolved in different areas and disciplines (Clarke, 1995 and 2001; Burrough, 1986 and 1998; Duecker, 1979; Goodchild, 1992; and Star and Estes, 1990). According to Duecker (1979) geographic information system is a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A geographic information system manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses.

Clarke (2001) considered GIS as a toolbox, as an information system, as an approach to science and as a multi-billion dollar business. The geographic imaging capabilities of a GIS have been enhanced tremendously with the support of image analysis, which includes data visualization, data extraction/creation, and data analysis. Arcview Image Analysis leverages a broad range of readily available image data types including popular satellite imagery, aerial photography, orthoimagery, and other remotely sensed data, which supplements a wide variety of GIS applications. The main advantages obtained from a GIS include data analysis, modeling and prediction. Thus, GIS is a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986).

All definitions of GIS recognize that spatial data are unique because they are linked to maps. A GIS at least consists of a database, map information, and a computer-based link between them. GIS software lets the users to see, explore, and analyze data by location, revealing hidden patterns, relationships, and trends that are not readily apparent in spreadsheets or statistical packages.

## Remote Sensing (RS)

Digital Image Processing (DIP) involves the manipulation and interpretation of digital images with the aid of a computer. This form of remote sensing may include seven broad types of computer-assisted operations including Image Rectification and Restoration, Image Enhancement, Image Classification, Data Merging and GIS Integration, Hyper-spectral Image Analysis, Biophysical Modeling, and Image Transmission and Compression.

According to Lillesand and Kiefer (2003), Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. Digital remotely sensed data are an ever-increasing input to GIS databases especially where large areas must be analyzed and repeat coverage is necessary because of rapidly changing conditions. Remote Sensing is the technology that is now used vastly, by which the Earth's surface and atmosphere, the planets, and the entire universe are being observed, measured, and interpreted from such vantage points as the terrestrial surface, earth-orbit and outer space.

Geographic Information System and Remote Sensing together helps in taking care of business by leveraging technology that facilitates to see the big picture, make the best decisions, and capitalize on the organization's investment both in terms of data and resources. The GIS software offers an innovative solution that helps to create, visualize, analysis and present information better and more effectively.

## Application of GIS and Remote Sensing in Hydrocarbon Exploration

GIS is built upon knowledge from geography, cartography, computer science and mathematics and can be applied in any field, directly or indirectly. The use of GIS in

the natural resource industry is widely recognized and has been used extensively for the exploration of groundwater resources and hyrdogeological investigations (Nath et al., 2000; Chi and Lee, 1994; Laurent et al., 1998; Gardino and Tonelli, 1983; and Gustafsson, 1993), mineral exploration (Ramadan et al., 1999 and 2003), and hydrocarbon exploration (Williams, 2000; Porter et al., 2000; Shah, 2003 and Iqbal, 2004).

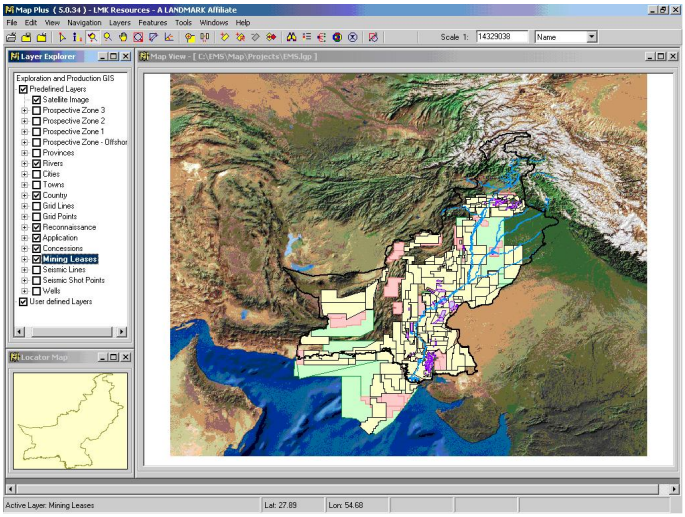
Williams (2000) used satellite remote sensing technology in the search for new petroleum reservoirs in South Asia both onshore and offshore. Onshore, the arid terrain and superb exposures were found in the Makran, Kirthar and Suleiman Ranges that provided classic areas for geological and structural interpretation from space. Offshore, several oil seeps were detected in the frontier basins of the Indus deep water by satellite radar. The study also presented numerous examples of the increasing range of remote sensing techniques now available to the modern explorer with special concentration on offshore seep detection.

Seismic operations are becoming more difficult to conduct due to culture, permits, restrictions, divided interests, and complex acquisition methods used to improve quality of the final seismic product. Valuable information is gathered and compiled during feasibility, evaluation and design stages. Minerals, permitting, and pre-survey / hazard mapping information is provided prior to, and during the advance, survey and drilling operations. As 3D seismic surveys continue to grow in size and complexity, logistics and planning play a vital role in determining the efficiency and profitability of a seismic operation. The seismic metadata (information describing the seismic data) associated with these surveys is also rapidly increasing in volume and variety, yet is still stored in disparate locations such as trace headers, co-ordinate files and paper and electronic observer logs. With the increasing popularity of time lapse seismic, this metadata can be considered to be used for the pre-plan information of a repeat seismic survey, and it is consequently more important than ever that it be efficiently gathered, stored, analyzed and archived.

Porter, et al. (2000) optimized the seismic metadata with MATRIX®, a system with effective implementation of GIS for managing today's complex 3D seismic projects as mentioned above. This GIS-based system along with the open database architecture, data connection and load wizards, report and analysis builder, and web-enabling technology helped in managing, analyzing, and presenting information from inception to completion and provide benefit to a wide verity of user groups involved in the project ranging from crew clerk to field geophysicist, seismic processor to operations manager, or drill push to safety auditor, and would enabled these users to enter, access, report, and perform analysis to support decision making.

As mentioned earlier, the increasing demand of GIS and Remote Sensing revealed many projects locally as well as internationally. LMK Resources (formerly: Mathtech Pakistan (Pvt.) Ltd.), a petroleum information technology company, implemented GIS-based Exploration Management System (EMS) in Directorate General of Petroleum Concessions (DGPC), Ministry of Petroleum and Natural Resources, Islamabad (Shah, 2003). They are the custodians of all Exploration & Production (E&P), Geological and Geophysical (G&G) data for Pakistan on the behalf of DGPC. The data submitted by various companies was previously managed manually and it was very difficult to find any desired data within a reasonable amount of time. Many other problems and issues were data redundancy, manual work, heterogeneous data formats, no standard nomenclature for data labeling, hard to retrieve required information, much efforts required even for simple reports, more personals required for record management, difficult data mobilization, data ownership and responsibility not clearly defined, etc. These problems were studied extensively and an integrated digital POSC (Petrotechnical Open Standards Consortium) compliant database, Exploration Management System (EMS) was developed. It not only became one of the most popular information and management tool for exploration companies in Pakistan as well as abroad but it also helped the country to have the second most organized E&P database in the world after Norway (Shah, 2003). Major domains covered in it include lease information, wells information, production information, seismic surveys and technical library data along with its front-end GIS MapPlus© (Figure 1).

**Figure 1. MapPlus**

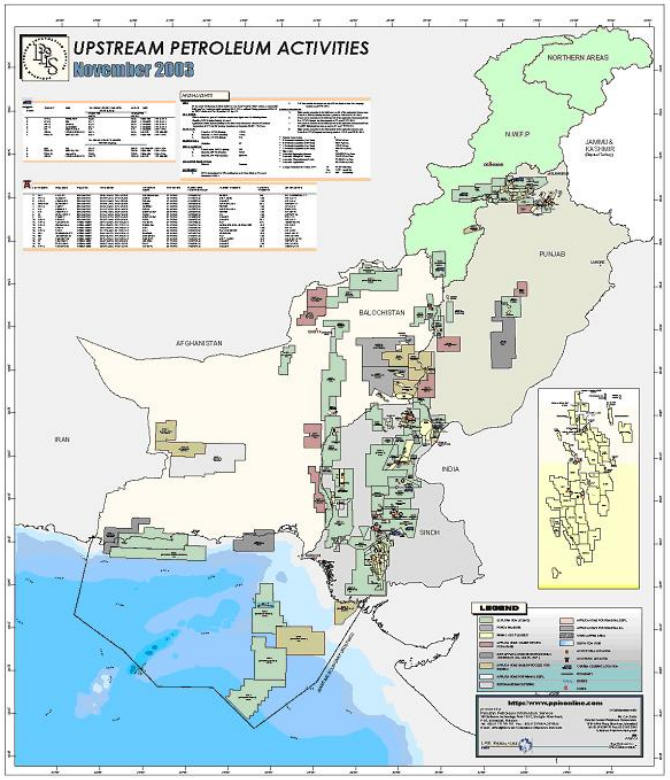


The Geographic Information System presenting selected E&P blocks data with satellite image in the background (After Shah, 2003).

MapPlus© is an interactive E&P data management tool with advanced capabilities to browse and manage spatial and tabular data, which helps geoscientists to visualize all updated oil and gas related activities on an interactive and customized GIS for quick analysis and decisions. It is specifically tailored to meet the needs of data managers, technicians, data operators, geophysicists, geologists and engineers. Some highlighted features of the GIS include; ESRI shape files based multi-layers map display, provides up-to-date base map for E&P activities, user-friendly and menu-driven interfaces, enhanced annotation and layer management, overlay high-resolution satellite image, run-time shape files generation from the underlying database, object identification, customized legend editors, generation of seismic base maps, basic and advanced navigational features, spatial search and selection, XML based project handling, comprehensive projection, query, threshold, and grid managers, thematic mapping, document hyper-linking, to-the-scale map printing, data export, generation of web pages and many more. It is so comprehensive and customizable that users directly or indirectly related to oil and gas sector can benefit from it very conveniently.

Implementation of Geographic Information System has not only helped the organization to maintain its exploration monitoring data up-to-date for over a decade rather it has also proved useful in generating self-revenue through the services like data management packages and PPIS (Pakistan Petroleum Information Service) etc. The PPIS is a unique information service that provides updates on Pakistan's upstream exploration activities. It has a history of providing vital information to the E & P industry. The service also includes digital and hardcopy versions consisting of monthly reports and attractive large scale Maps. It also provides a standard base map that is being currently used by all E&P companies for upstream petroleum activities (Figure 2).

**Figure 2. PPIS**




A typical PPIS map showing upstream petroleum activities (After Shah, 2003).

## Conclusions

Geographic Information System and Remote Sensing has become a widely accepted tool in all fields of life and particularly in hydrocarbon exploration and exploitation. In building a GIS database for comprehensive analysis, all avenues of data collection should be perused including literature survey, public and private organizations and computer networks. The integration of remote sensing with GIS provides a greater understanding by combining remotely acquired spectral information with other data including physiographical, geological, geophysical,

hydrogeological, geochemical and positional data. The use of GIS in natural resources evaluation has recently expanded with increasing emphasis in surface and subsurface applications. GIS and Remote Sensing helps in monitoring and managing earth resources accurately and reliably at a cost-effective and short turnaround time, and thus, led to the acceptance of this as technology by the scientific community.

Implementation of GIS in DGPC resulted in data normalization, control redundancy and enforced data integrity, timely access to information, cost effective solution and self-revenue generating model, ensures data validation and security, easy data management and maintenance, on-line available E&P data, easy data duplication and format conversion, easy generation of interactive and fully customized maps, provided updated data and maps, provided standard base map for upstream petroleum activities. Currently, the industry has numerous powerful geological and geophysical planning, evaluation, processing, analysis, and interpretation tools. These requirements can be effectively addressed with an effective implementation of GIS and Remote sensing technology. The net gains are improved efficiency and quality through effective information management, analysis, and dissemination.

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