

## Using Remote Sensing and GIS technologies as an Aid for Hydrocarbon Exploration in the Assam-Arakan Fold-Thrust belt

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### Abstract

Hydrocarbon exploration in geologically complex and highly rugged terrains, like the Assam-Arakan fold-thrust belt (FTB), is always faced with difficulties. In such cases, it is imperative that such exploration technologies be used, which are cost effective and provide greater accuracy. An integrated approach of remote sensing and Geographic Information System (GIS) technologies can just suffice these requirements during exploratory efforts in such difficult terrains. Besides, a geodatabase generated using remote sensing and GIS technologies can also be used for operation and maintenance, production, environmental monitoring, land lease management and data base management. The present study is an example of how remote sensing and GIS technologies can be used in a petroleum venture in a geologically complex and difficult terrain like the Assam-Arakan fold-thrust belt.

### Introduction

The Assam-Arakan FTB extends all along the India-Myanmar border from the Himalayas in the north to the Bay of Bengal in the south. Petroliferous Tertiary non-marine sedimentary rocks essentially dominate the stratigraphy within the foreland FTB. Like the Himalayan orogenic belt, several fault-bound, stacked-up and longitudinally continuous litho-tectonic zones characterize the Assam-Arakan FTB. Since the late 19<sup>th</sup> century, workers have adopted various techniques and methods

to understand the structures in the FTB, which, in turn, aid in developing hydrocarbon exploration leads. The present work is a consequence of such an activity in the area, undertaken by Hindustan Oil Exploration Company Limited and its Joint Venture partners (Block AAP-ON-94/1, Assam-Arunachal Pradesh, India; Eighth round of exploration bidding announced by Government of India in 1994).

An integrated approach of remote sensing and GIS technologies provides better opportunities not only for geological mapping, but also for geological interpretation and implementation of exploration programs in difficult terrains with greater accuracy and in a cost-effective manner (Everett et al. 2002; Harris and Cooper 2002; Saraf et al. 2002). In assistance with ESRI India (NIIT GIS Ltd.), an extensive GIS database has been build up for the study area through standard procedures, so as to utilize the data not only to generate map outputs, but for various analysis as well. Thematic layers generated by digitization include, settlements, roads, railway network, drainage, topographic contours, geological information, well locations, seismic line locations, oil and gas pipelines, time contours of stratigraphic horizons and depth contours of stratigraphic horizons.

The GIS database generated is currently being used, besides for integration into sophisticated, quantitative structural models, for implementing, documenting and monitoring exploration programs like geochemical prospecting, seismic acquisition and well drilling, besides the environmental impact assessment being carried out for each exploration program.

### **Data Used**

The following data sets from different sources were used in the present study:

1. Remote sensing data digital data of IRS-1D LISS-III and IRS-ID PAN.
2. Existing geological maps, structure contour maps, and topographical maps (1:50,000 scale).
3. Field survey data of existing well and seismic line locations, as well as GPS survey points (used as GCPs during georeferencing).

## Methodology

Figure 1 depicts the various steps undertaken to build up the geo-database. The flowchart also shows how the geo-database is being currently used for various exploration programs.

First, the topographical maps were scanned and then georeferenced in ERDAS Imagine 8.4 to a Lambert Conformal Conic projection system, as had been used for the previous geophysical surveys during seismic acquisition. Then a mosaic of the topographical maps was generated. Settlements, roads, drainage, topographic contours and other geographic information were then digitized from this mosaic of topographical maps. The geological atlas was then scanned and georeferenced in ERDAS Imagine 8.4, also to the appropriate projection system. Reference points were selected from the same maps.

The IRS 1-D PAN and LISS-III images, both obtained from NRSA, Hyderabad, were then also georeferenced to the appropriate projection system in ERDAS Imagine 8.4. Ground Control Points (GCPs) were selected from the mosaic of georeferenced topographical maps and GPS surveys in the field, after the GPS GCPs were matched with the GCPs obtained from the topographical map. By combining Bands 4, 3 and 2 of the LISS-III image, a false colour composite (FCC) was generated. Spatial enhancement was also done to the IRS 1-D PAN and LISS-III images. To take advantage of the spatial resolution and spectral resolution of the IRS 1-D PAN and LISS III images, respectively, both the images were "resolution merged" together to obtain a multi-spectral image having higher spatial resolution. Digital Image Processing was carried out in ERDAS Imagine 8.4. A modified geological atlas (Figure 2) was generated based on interpretations from the multi-spectral image having higher spatial resolution, following image radiometric enhancements. All the information in the georeferenced geological atlas (lithological boundaries as polygon features, faults and axial traces of folds as polyline features and bedding plane dip-strike data as point features) were digitized in ArcGIS 8.1. The road and railway network, settlement, drainage of the region was also updated using the merged satellite image. A land use map was also generated from the merged image following image classification.

The topographic contours and elevation points were interpolated using the Triangulated Irregular Network (TIN) method to generate the Digital Elevation Model (DEM) (Figure 3a), slope map (Figure 3b) and aspect map of the study area. In order to generate Digital Terrain Models (DTMs), the LISS-III, PAN and merged images were draped over the DEM. Figure 3c is a DTM generated by combining the LISS-III image with the DEM. These analyses were carried out in ArcGIS 8.1 using the 3-d Analyst module.

Similarly, all the time and depth structure contour maps of various stratigraphic horizons were interpolated using TIN to produce digital models for better 3-dimensional visualization (Figures 4a and b). A structural dip domain map was also created by IDW (Inverse Distance Weighted) interpolation technique using fault traces and fold axial traces as barriers (Mishra et al. 2002). Based on the X-Y coordinates, well locations and seismic lines were constructed and overlaid on top of all the layers. These steps were also carried out in ArcGIS 8.1.

## **Results and Discussion**

Besides the digitization of settlements, roads, railway network, drainage, topographic contours, well locations, seismic line locations, oil and gas pipelines, etc., the following outputs have been generated using the various data sets and methods described above:

1. Merged multi-spectral higher resolution remote sensing data
2. Modified geological map
3. Structural dip domain map
4. Land use map
5. Digital Elevation Model, slope map and aspect map
6. Digital Terrain Models
7. Pseudo 3-dimensional models of stratigraphic horizons

The geo-database was finally developed after a series of steps that included georeferencing, digitization, digital image processing, analysis and interpretation, etc. Once the geo-database was developed, the primary task of exploring hydrocarbons in the FTB was initiated. The study area being at early stages of hydrocarbon exploration, sub-surface data is scanty. Consequently, geological modelling using structural techniques was adopted first. Incorporating into the geo-database, the enormous sub-surface data available outside the study area, enhanced the interpretations. The structural trends and hydrocarbon play concepts established outside the study area were then extrapolated into the study area.

The surface geological data (consisting of the modified geological map and the structural dip domain map) was integrated with the topographic, well and seismic data using standard structural methods. A series of structural cross-sections that are geometrically and kinematically tenable, as well as retrodeformable (Figure 4c is one such example), was then constructed using the technique of “*cross section balancing*”. The technique includes both extrapolation and interpolation of surface and sub-surface data to decipher the sub-surface structural and stratigraphic disposition of rock units to generate a cross-section that can be validated both by inverse and forward modelling strategies. Following the interpretation of the “*serial balanced cross sections*” and the pseudo 3-dimensional models of stratigraphic horizons, a number of possible hydrocarbon leads and prospects have been identified. Combining these interpretations with interpretations from well log and seismic reflection data, the hydrocarbon potential and prospect is now being quantitatively worked out, based on the existing geo-database.

The geo-database and interpretations made thereof are also being currently used for further exploratory efforts. During geochemical prospecting, the geo-database was successfully used for planning the survey, realizing the logistic requirements and operation documentation and monitoring. The geo-database has also been used for the planning of a new seismic survey. The topographic profile along each line of the seismic grid has been extracted from the DEM, directly indicating the nature of the terrain. The land use pattern in the area of the proposed seismic survey has been deduced from the classified satellite imageries. The land use map would also be

used during the survey. The geo-database also gives an indication of the logistics required in the area of the proposed seismic survey. During the seismic surveys, the geo-database would also be used for operation documentation and monitoring. The same geo-database would also be used for planning the location of well drilling, based on a proper understanding of the hydrocarbon potential of the area, the logistics required and the land use pattern in the area. The management of the leased land, and also the operation documentation, monitoring and maintenance of the well would be carried out on the basis of the geo-database. A rapid environmental impact assessment has already been carried out based on the geo-database and field studies *before* the beginning of the seismic survey. *During* the seismic survey and also during the drilling of well(s), the geo-database would be used for environmental monitoring.

## **Conclusion**

Orogenic belts, like the Assam-Arakan FTB, are often characterized by complex structures, poor logistics and terrain inaccessibility. Consequently, the surface and sub-surface geological and geophysical data are of poor quality, being discontinuous and scanty. In such areas, it is imperative that proper interpretation techniques be applied for any exploratory effort. The GIS database generated can be used not only for geological interpretations, but also for exploration programs like geochemical prospecting, seismic acquisition and well drilling, besides the environmental impact assessment being carried out for each exploration program.

Remote sensing and GIS technologies are gradually proving to be valuable tools for creating and developing exploration information. Remote sensing and GIS technologies are currently being used by 90 percent of upstream exploration departments across asset teams worldwide (Zolnai, 2002). In fact, from initial exploration through acquisition and production to final divestiture, spatial information is key to any hydrocarbon venture. An integrated approach of remote sensing and GIS can also benefit the entire petroleum enterprise:

- Exploration

- Operation and maintenance
- Production
- Land lease management
- Data management

The advantage of GIS tools is truly represented in building a geo-database. The layers hierarchy has been built using ArcGIS such that the geo-database can accommodate smooth growth scale from single user to a very large enterprise wide multi-user database.

### References

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### LIST OF FIGURES

**Figure 1** Flowchart depicting the use of remote sensing and GIS in petroleum ventures.

**Figure 2** The modified geological map of the study area. The original geological atlas was published in 1956.

**Figure 3 (a)** The Digital Elevation Model of the study area (top view with colour coding values). **(b)** The slope map of the study area (top view with colour

coding values). **(c)** Digital Terrain Model or 3-D surface model of the study area created by combining DEM and IRS-1D LISS-III satellite image.

**Figure 4 (a)** Time structure contour map of the top of a stratigraphic horizon in and around the study area. **(b)** Pseudo 3-D model of the stratigraphic horizon in **(a)**, created by the interpolation of the time contours using TIN method. **(c)** A *balanced cross section* constructed using the geo-database, by integrating surface and sub-surface data.