Multiple data set integration for structural and stratigraphic analysis of Oil and Gas bearing formation using GIS.

K.M.Mohamed Elias

Cauvery Basin, Tamilnadu, India.

Introduction:

Exploration for oil and gas has always depended on surface maps of rock types and structures that point directly to, or at least hint at, subsurface conditions favorable for generation and accumulation of oil and gas. Mapping begins with reconnaissance, and if that indicates favorable condition for generation of hydrocarbons, then detailed mapping begins. Originally, both of these give 3-D constructions of subsurface structural and stratigraphic traps for the hydrocarbons. Then, they are sampled by drilling and their properties measured.

IRS, Land sat, Spot and other space imaging systems, serve as mega-photos that depict large areas, within which clues to subsurface conditions may be evident. The advent of higher-resolution space imagery proved a boon to energy sector seeking new sources of fossil fuels. Sometimes the imagery proved especially sensitive to subtle indications of interior structures. For instance, fractures around structures in known oil/gas fields may extend further, as seen in the coherent space images, than suspected from groundwork. Also, drainage patterns at broader scales may reflect control by underlying rocks involved in suitable traps. And even vegetation distribution may disclose signs of structure. These and other indicators discernible in space imagery appealed to exploration geologists as another means to survey large areas

Lineament Analysis in Geology:

Lineament investigations for geological structural analysis have oftentimes been viewed as untrustworthy. This view perhaps may be caused by the subjectivity of the lineament identification process. Geologists conducting lineament analysis have generally considered all lineaments as equal regardless of their appearances in the data set(s) being used, or else used subjective processes in an attempt to identify major trends. Also, the utilization of multiple data sets in the identification and analysis of lineaments has rarely been employed. This is rather unfortunate, as it appears that surficial data sets, such as satellite imagery, aerial photo, digital elevation models (DEMs), and geological maps integrated with subsurface information such as seismic reflection geophysics and formation structure maps, provide very powerful capabilities in lineament analysis. One of the major capabilities in lineament identification made possible using data set integration is the ability to identify lineaments based on their characteristics. This is an important issue as combining data may help lend credibility to certain types of lineaments. Geographic Information Systems (GIS) functionality, such as vector and raster spatial analysis and overlay, can be employed for structural analysis and evaluation of significance, using powerful software programs such as Arc View, Arc/Info, Erdas *Imagine,* and Ilwis

Lineaments on Remote Sensing Imagery:

All the lineaments observed and identified on remote-sensing data of various types and scales and on topographic maps, constitute a definite expression of the structure of the earths in the form of linearly organized elements of the landscape.

Lineaments are manifested as natural formations in different forms of planar geometrical figures; continuous straight lines or broken lines occurring on the extensions of one another or as point formations situated on a single straight line. It needs to be emphasized that continuous extended lineaments as well as broken chains of lineaments, traceable without change in orientation through different landscapes, geomorphological and litho facial units, usually represent different elements of the landscape.

The Cavery Basin in Tamilnadu provides an excellent study area for such an analysis. Many geological features in this basin are linearly arranged, including major uplifts, faults, and fractures

Mesofracture zones:

The study of mesofracture zones deserves special attention in view of the importance of locating dilatation and fissure zones in the productive horizons for solving petroleum geological problems.

Mesofracture zones are identified in large scale satellite imagery and high altitude aerial photos as high density lineament zones with a width of up to a few kilometres and a length up to several tens of kilometres, consisting of numerous relatively short (1-4 km) and near parallel lineaments. The genetic nature of these zones is determined by their relations to plicate and disjunctive structures.

Mesofracture zones have the following characteristic features: they are organized systems of individual lineaments with consistent orientations; They independently intersect different types of relief, litho facial and stratigraphic associations of rocks, without change in direction; They are essentially independent (discordant) from plicated tectonics, i.e., they intersect, without change in strike, fold structures at different angles to their axes; further, the orientations of individual elements of mesofracture zones are usually not dependent on the direction and morphology of the anticlines and other elements of the folds; They have different widths and predominantly contain fractures with lengths of many kilometres, usually exceeding the dimensions of the folds; the intensity of fractures (fracture density) does not increase within the fold structure; They have complex and diverse relations with known faults, which coincide with mesofracture zones only in isolated cases and in limited areas; faults in local structures of sedimentary rocks, confirmed by drilling, are rarely reflected on satellite imagery; The internal structure of mesofracture zones, even in shield area, is often represented by different combinations of lineament complexes reflecting diverse morphologies(step type, linked on echelon etc); Often, the large mesofracture zones are accompanied by 'dependent' satellite fracture systems.

Remote Sensing Data Processing and Analysis:

Image Enhancement:

a) Spatial Filtering:

The IRS LissII image was digitally enhanced in order to facilitate the process of identifying lineaments. After experimenting with different filter kernels, the best enhancement was found to be a 5 X 5 modified Laplacian edge enhancement filter with the following matrix:

-1 -1 -1 -1 -1
-1 -1 -1 -1 -1
-1 -1 49 -1-1
-1 -1 -1 -1 -1
-1 -1 -1 -1 -1

b) False Colour Composition:

The band combination found to be most useful was a standard false colour composite with Band1 (blue) Band 2 (green) displayed on the blue gun, Band 3 (red) displayed on the green gun, and Band 4 (near-IR) displayed on the red gun. This band combination made it easier to identify linear patterns of vegetation, which represent paleo channels and deeper soils associated with geological zones of weakness and erosion susceptibility.

c) Principal Component Analysis and Laterite Index Map:

The first principal component (pc1) includes the larger percentage of the total scene variance and succeeding components (pc2, pc3, pcn) each contain a decreasing percentage of the scene variance. Vegetation and laterite are high in NDVI value because of their high reflectance in NIR and absorption in red spectral range. But vegetation gives high reflection in green spectral region also, in which laterite does not give. Considering the particular spectral properties of laterite and vegetation a normalized index is designed in the study. Which is useful in differentiating laterite from vegetation. It is understood that the value of proposed index will be higher in case of laterite than in vegetation cover. In many places the value of proposed index is high in both the maps, which perhaps indicated the occurrence of laterite in densely vegetated area in some case the value of proposed index laterite with traces of vegetation

Digital Basement Terrain Model (DBTM):

DBTM had been created from Time Structural Basement Map (TSBM). The TSBM is georeferenced with coordinates calculated using UTM projection. Than the contours of TSBM has been digitised to obtain contour segment map in which the value of individual contours are incorporated. The specified value of the segment contour map has been converted into raster format in order to assign value for each and every pixels of the study area by moving average program in Ilwis. As a result Interpolated Time Map had been created. Basement Depth value of 10 wells in the study area has been taken as a control point to calculate the velocity of entire study area. Well Depth Data obtained from 10 wells are divided by the One Way Time of the respective wells. Than the Point Velocity Map is created and manipulated using moving average to assign velocity value for every pixels. As a result Velocity Structural Basement Map had been generated. In which the each and every pixels has assigned velocity of the adjacent well. Interpolated Time Map shows two way time (i.e., the time taken by the wave to propagate down the earth and reflected back to surface) so the Interpolated Time Map has been multiplied by .5 to obtain one-way Time Map. Than the One Way Interpolated Time Map is multiplied with Velocity Structural Basement Map as a result Digital Basement Terrain Model had been created. DBTM is density sliced for every 50 mts intervals and ultimately results in depth sliced DBTM which can be altered by changing the georeference, viewing angle, scale height, view point, horizontal rotation, vertical rotation, distance, location point, location height.

Digital Basement Terrain Model exposes the three-dimensional configuration of the basement, reservoir rock top layer and cap rock top layer. High values of contours favour horst structures while the low values of contours favour graben Structures. The boundaries of horst and graben are drawn to extract normal or dip slip fault. Slip in the antiform axis and synform axis indicates strike slip or transcurrent fault. Event termination also favours the fault zones. Cross faults has also been detected from DBTM. The DBTM interpreted from different direction by altering viewing angle. The DBTM is enhanced which is boon to our study and product of enhancement is Slope Map, Shape Map, Shaded Basement Relief Map, Colour Shaded Basement Depth Map, Colour Shaded Seismic one way Time Map, Colour Shaded Seismic Velocity Map. Slope Map expose the Gentle, Moderate and steep slope where as the Shape Map gives the Convex, Flat and Concave Terrain. The Slope Map and Shape Map Integrated using Union command in Arc Info. Which gives convex gentle slope, convex moderate slope, and convex steep slope classes. The obtained class is integrated with Depth Map, which consists of topographic very high, topographic moderate high and topographic low classes. First priority is given to convex steep slope with topographic very high and convex steep slope with topographic moderate high. Second priority is given to convex moderate slope with topographic very high and convex moderate slope with topographic moderate high, third priority is given to convex gentle slope with topographic very high and convex gentle slope with topographic moderate high. From the inferred map the Basement Fault Map and Surface Lineaments Maps are superimposed and Oil Prospect Map had been generated. Which in turn gives the favourable site for oil.

Rose diagram:

Lineaments patterns have been summarized using rose diagram, when lineament processing is completed, the final "Geological" lineament file is also converted back to a vector format. Than the vector mean calculated for surface lineaments as well as subsurface faults. The vector means direction of major surface lineament is 47°. The vector means direction of minor lineament is 275° as there is bi-model distribution at an angle of 90°. The vector means direction of subsurface faults is 57°

3.6 Fence Diagram:

Fence Diagram had been generated using Surfer and Arc View Lithology Stick Diagram Extension. In Surfer the x, y coordinates of the wells entered to get two-dimensional view of the well point. Data Base File and Index File are generated and incorporated in Lithology Stick Diagram Extension. Than the two wells that intend to serve as end points were chosen. Arc View generated the LithoStick along that profile. The Litho Stick are rectified and enhanced for better view. Using Arc View tools the pattern had been assigned to each and every Formation. As the Litho Stick is in profile direction it has been transferred to surfer well location point file. Than the same formation are correlated by digitization which gives pinch out of formation and 3 D view of sub surface.

GIS Functionality in Analysis of Geological Structure

Geographical Information Systems (GIS) have become increasingly powerful due to improvements in both hardware and software. With this increase in the power of GIS, many fields in both geography and geology have found new uses for GIS. One of the geological fields that have recently benefited from GIS input is structural geology. Many of the recent technological advances in structural geology involving GIS on the construction of large databases containing structural information about features such as faults, folds and fractures. This information can then be used in the construction of geological structure maps. Once data about these structural features is entered into a GIS package, data manipulation for detailed analysis can take place. Different thematic maps specified above are integrated using GIS softwares.

.

3.7 Integrated analysis of Geological, Geophysical and Remote sensing Data in Identification of Fracture Zones:

Large divisions of the earth's crust are indicated by diverse tectonic contacts represented as individual disjunctive structures with apparent displacements, or (often as extensive fracture zones. Usually, they determine the outer boundaries of large oil- and gas- bearing regions (e.g., basins), in which petroleum districts and zones of accumulation are located. Intrabasin mega fractures mainly determine the stratigraphic altitude of oil-bearing layers and the formation of various types of oil and gas traps. Interpretation of this type of fracture, particularly if it is still active today, is quiet feasible. In such cases satellite imagery of different scales can be used for detailed studies of oil and gas bearing regions. The results of lineament analysis of satellite imagery can be fragmentarily verified by conventional geological and geophysical methods.

All the surface geophysical and geomorphological methods are in essence remote- sensing techniques, which give only qualitative parameters of the target. The major limitation of field geophysical methods for fracture studies is their ambiguity of interpretation, since the geophysical methods for fracture studies is their ambiguity of interpretation, since the geophysical anomalies may also be caused by variations in lithology, porosity or caverns of rocks. Nevertheless, they have a definite advantage as they provide in the initial stage itself the approximate picture of the distribution and some parameters of the fracture zones at the level of oil and gas prospects. In turn, these results can be very useful in planning further detailed surveys. Interpretation of satellite imagery and aerial photos can be valuable in selecting targets for such work.

The increasing application and improvements in geophysical mainly seismic methods in petroleum exploration, have confirmed their exclusive role in locating oil and gas structures. A large amount of geophysical data (particularly those that cannot be interpreted definitively) to be revised using remote- sensing data. Since the linear (fault) structures are more readily interpretable, the integration of remote- sensing and geophysical data should be given priority in the study of fracturing in sedimentary formations, mainly the disjunctive structures and fissure zones of various magnitudes.

5.0 Conclusion & Suggestion:

The ethics of this study is to demonstrate the information interpreted from remotely sensed imagery combined with conventional field and other data can improve the exploration process in terms of cost, accuracy and time. The Present Study has demonstrated this by compiling, registering, and analysing data obtained from various methods (Remote Sensing, Geophysics etc) in GIS for the part of Cauvery Basin and utilizing exploration critical information of the Study Area. The ability to compare various data sets, individually or in combination, enables the exploration geologist to extract the maximum information possible and apply it to the exploration problem. While the synergistic effect of registered multiple data sets is a major improvement in the analysis of data for oil and gas exploration. Satellite Data Play a vital role in identifying structures in Frontier Basin as structure is easily readable from Satellite Image. Therefore, lineament analysis of remote sensing data together with conventional geological and geophysical investigations enables obtaining new additional information about oil- and gas-bearing objects at different stages of their investigation.