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Satellite Imagery - A Tool of Diversified Applications in Exploration and Development of Oil and Gas Fields

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ABSTRACT: *Pakistan Petroleum Ltd (PPL), amongst the pioneers for exploration and development of oil and gas fields in Pakistan have an extensive/historical data-base. The off-the-shelf availability of satellite imagery, since late seventies, not only expanded our data-base quickly but provided a powerful tool of diversified applications. The spectral, spatial and temporal resolution of satellite imagery has since been used for applications as diversified as:*

i. Geological mapping in exposed areas and anticipated subsurface structures.

ii. Lineaments/topographic anomalies in plains.

iii. Identification of suitable geological sections and their approach for stratigraphic measurements.

iv. Monitoring of river channels/water bodies for carrying out field development/ drilling operations.

v. Planning of geophysical surveys and layout of the seismic lines to be recorded.

vi. Mosaic of the entire country for better understanding of geology/tectonics etc. and the spatial relationship of different sedimentary basins in Pakistan.

i. Geological mapping in exposed areas and anticipated subsurface structures

Pakistan, a predominantly arid and semi-arid country, consists of plains, deserts and largely barren rock outcrops devoid of vegetation cover, hence geological mapping can be carried out effectively using satellite imagery.

Large scale (1:100,000) geological mapping on geometrically corrected images is found to be fast, accurate and very useful. Existing field maps help in identification of the stratigraphic horizons and their contacts on the imagery. The images themselves provide a powerful tool for interpreting/extending the geological contacts and the structural trends regionally with a higher level of accuracy.

The interpreted overlays of adjacent images, prepared independent of each other show remarkable continuity when spliced together. This approach increases the level of confidence on the interpretation and the use of satellite imagery for geological mapping. An example of geological mapping, based on the interpretation of a geometrically corrected LANDSAT image (false coloured composite) is shown as Fig 1.

Projection of structural trends into the areas where surface expressions are not pronounced can be done on a satellite imagery. The subtle indications of continuation of a trend are much better identifiable on an imagery than on a simple geological map.

ii. Lineaments/Topographic Anomalies in plains

Satellite imagery allows detection of large but subtle features that may escape ground

investigation or even aerial survey. This is because of the high altitude view point of different generations of earth resources satellites. A high altitude view point eliminates superfluous, confusing details and the continuity of regional but subtle geomorphic features is enhanced. Such regional features like lineaments, major faults and folds can be detected easily on imagery. The size of these features, particularly the lineaments, is sometimes so big that their significance may not emerge from a single scene, although it covers several hundred square kilometers of area. A mosaic of adjacent scenes is very useful in identifying features of such a regional extent.

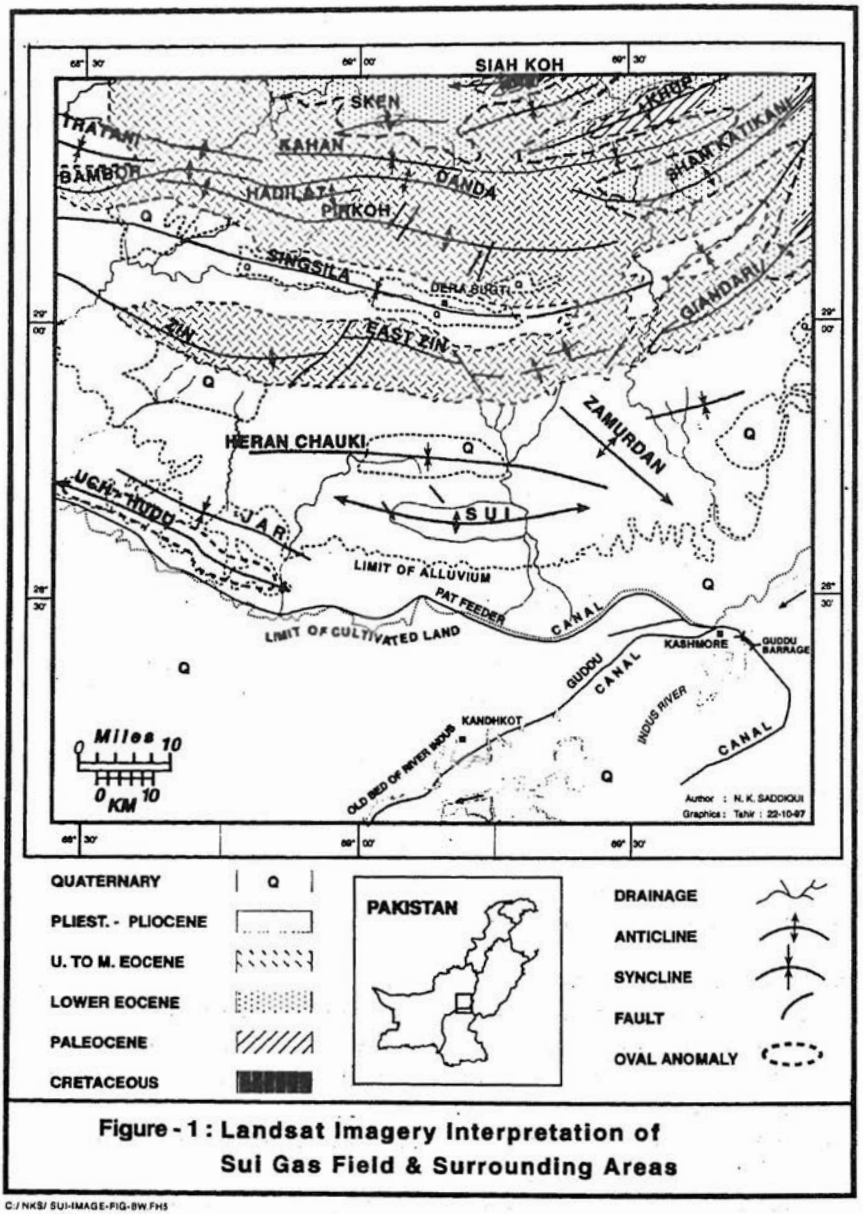

Fig. 1. Satellite imagery interpretation of Sui Gas Field and surrounding areas.

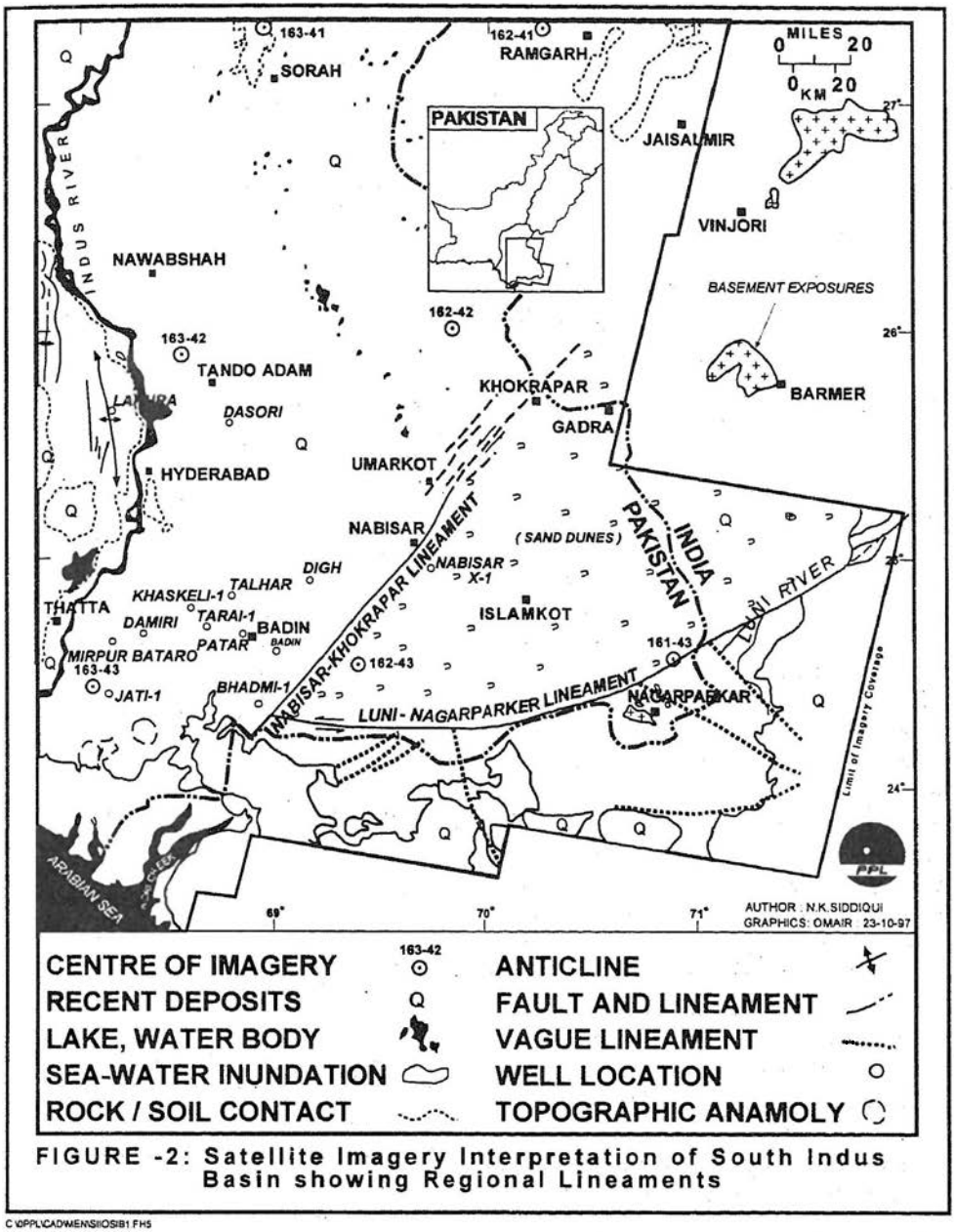

FIGURE -2: Satellite Imagery Interpretation of South Indus Basin showing Regional Lineaments

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Fig. 2. Satellite imagery interpretation of south Indus basin showing regional lineaments.

A mesh of lines can be drawn while interpreting linear features on an imagery but extreme care should be taken while drawing any line on the overlay. A comparative study of imagery in different bands and a look at the geographical map of the area eliminates the possibility of confusing man-made linear features with a lineament. A few large lineaments, particularly in south eastern corner of Pakistan have been identified (Fig 2). The

size and continuity of these lineaments indicate that they may be a manifestation of basement zones of weakness. Their reactivation, probably due to the continuous northward movement of the Indian plate, has caused the subtle break in the overlying recent sediments. The significance of these lineaments with reference to hydrocarbon generation/entrapment is yet to be explored.

The subsurface geology in Pakistan, particularly in plains and deserts, is not conducive for the development of topographic anomalies. Even the large Khairpur-Jacobabad High has no surface expression, except where the Eocene Limestone itself exposes, near Khairpur. The reason being the monoclinal platform nature of sedimentary rocks in eastern part of Pakistan, under the plains and deserts. The two main gravity Highs namely Khairpur-Jacobabad and Mari-Jaisalmer High, underlying thick Siwaliks are predominantly dormant since the post-Eocene uplift about 37 million year ago (Ma). The post-Siwalik uplift, however, resulted in the present day structural configuration of the Axial Belt with rapidly diminishing effects away from the mountain ranges i.e. on the rocks underlying the plains and deserts. In deserts the subsurface rocks substantially close to the ground result in a thinner accumulation of aeolian sand. Depending upon the type of soil, vegetation cover and the moisture content the spectral signature will be different compared to the surrounding area which can also be affected by the reduced thickness of soil cover and results in a tonal anomaly. Due to the lack of shallow rock occurrences in the deserts and plains of Pakistan the tonal anomalies are difficult to identify, if at all these are present.

iii. Identification of suitable Geological Sections and their approach for Stratigraphic measurements

The rock outcrops in Pakistan are largely devoid of vegetation cover. The satellite images and their mosaics, particularly on 1:1,000,000 scale, provide a synoptic geological picture of Pakistan in terms of stratigraphy, structural style and topographic characteristics. The existing geological maps or field visits help in recognising the age and lithology of different rock types on the imagery. The streams which cut across the rocks not only provide best exposures but an easy approach to stratigraphic sections. The measurement of stratigraphic sections, particularly in sedimentary rocks, provide the vital subsurface information about the thicknesses of rocks which could be encountered in adjacent alluvium covered areas by projecting surface rocks into the basin depth. The thicknesses of different rock types, thus measured, is the basis for determining the depth of wells to be drilled for exploration. Satellite imagery provides an extremely handy tool for identifying the deep-cut streams which expose maximum number of different rock types and the updated access to sections compared to the out-dated toposheets. This allows a compilation of maximum field data in a minimum possible time. A quick-look idea about the rock thicknesses can also be made by making measurements on the image itself.

iv. Monitoring of River Channels/Water Bodies for carrying out Field Development/Drilling Operations

PPL's Kandhkot gas field (Fig-1) is located within the flood plains of River Indus, with part of the subsurface gas-bearing structure extending below the main river course. Protective earth-fill embankments are present on the river sides to restrict the water encroachment. But several gas wells, drilled close to the main river channel, are prone to seasonal flooding. The annual floods also change the configuration of channels, inundating large areas and hampering round the year field operations. The excessive erosion along the banks of the river channels, at times, bring them dangerously close to the existing wells. The dynamic surface conditions make it imperative to monitor the changes in River Indus course and its flooding pattern in order to take preventive measures for execution of field operations.

The toposheets of the area were found to be out-dated (1965) and the available aerial photographs provided the river configuration as existed at the time of aerial survey (1976). On the other hand, satellite imagery was available from almost every year for pre- , post-and maximum flooding period. Comparison of these multi-dated images, the so called "Change Pair", highlighted the changes and the direction in which the river was expected to shift its main course in future. The satellite imagery, thus, provided the cheapest and quickest means to plan and execute the project of such a dynamic nature. For that matter any dynamic phenomena like desertification, crops/forests, land-use planning, natural disasters, even the movement of troops and armaments, animal herds etc. can be effectively monitored, and remedial measures taken/planned in time.

v. Planning of Seismic Surveys and the layout of lines to be recorded

Petroleum exploration, particularly in alluvium covered areas, starts with seismic surveys. Surface layout of the recording lines is controlled by the regional subsurface geology. The position and orientation of the recording lines, therefore, can not be changed much. The latest information regarding topography and presence of man-made features like residential areas, road, canals, agriculture and forestation etc. is important for planning the surveys. The toposheets are generally outdated but a satellite image provides the latest information about the surface constraints which have to be overcome or avoided for carrying out the surveys. SPOT images in particular, because of their better resolution, have been used for effective planning of the surveys.

vi. Mosaic of the entire country

The 2D satellite images do have some 3D effect, particularly in areas where the rock outcrops and other topographic features trend in a dominantly north-south orientation. Depending upon the relief, the shadows which form on the western side, are probably the main cause which impart 3D effect even in a single image. In Pakistan the mountain ranges are predominantly oriented in a north-south direction resulting in a helpful 3D effect for understanding the geology and structural characteristics. A mosaic of the entire country, preferably on a million scale, has proved to be of much greater use than a simple geological map.

The mosaic of Pakistan, which can be prepared by using about fifty two (52) LANDSAT images on a million scale, provides a synoptic view of the entire country and adjacent areas across the border. Having a subtle 3D effect, it enables one to understand in a much better way the spatial distribution of tectonic and structural features, their regional setting and inter-relationship at one glance, compared to a geological map.

REFERENCES

Abid, M. S. & Siddiqui, N. K., 1982. Satellite Imagery and its use in petroleum Exploration in Pakistan. Petroleum Institute of Pakistan Seminar on Petroleum Exploration in Pakistan, Karachi.

Siddiqui, N. K., 1991. Monitoring the changes in the Indus River course through Satellite Imagery. Report on the Regional Seminar on the Applications of Remote Sensing Techniques to Land-use planning and Environment Surveying (SUPARCO-ESCAP/UNDP), Karachi, Pakistan, 81-87.