Paper G 17

AN EVALUATION OF THE SUITABILITY OF ERTS DATA FOR THE PURPOSES OF PETROLEUM EXPLORATION

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I. INTRODUCTION

- The overall objective of this experiment is to determine the types and amounts of information valuable to petroleum exploration extractable from ERTS data and the cost of obtaining the information using traditional or conventional means.

  In particular, we wanted to evaluate this new petroleum exploration tool in a geologically well known area in order to assess its usefulness in an unknown area. In light of the current energy situation, we feel that such an evaluation is important in an effort to:

  - Best utilize technical effort with customary exploration tools by rapidly focusing attention on the most promising areas;
  - Reduce the time required to go through the exploration cycle;
  - Maximize the cost savings in both of these.

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II. DESCRIPTION OF TEST SITE

- The Anadarko Basin lies in western Oklahoma and the panhandle of Texas. It was chosen as a test site because there is a great deal of published information available on the surface and subsurface geology of the area; there are many known structures that act as traps for hydrocarbons. The Anadarko Basin is similar to several other large epicontinental sedimentary basins. Eason's geologists know the area well, and it is convenient for our offices in Oklahoma City. •

Climate, Vegetation and Terrain

- As a result of climatic variation across the site, native vegetation ranges from scrub oak in the east, seen in this slide, to short prairie grass and sage in the west.

- The entire area is extensively farmed and ranched, and divided along township and range survey lines. This imposes a north-south and east-west cultural and vegetation pattern over the area.

- The eastern part of the area is characterized by gently rolling hills with a local relief of 60 meters. • In the west, the topography consists of mesas and undissected uplands with sharply incised canyons producing local relief of up to 400 meters.

Geology

- The basin is a large west-northwest trending asymmetrical syncline with the south flank much steeper than the north flank. The axis of the basin where the Kodachrome was taken lies about 40 kilometers north of the Wichita Mountains, seen in the distance, which exposes early Cambrian crystalline rocks. • The basin is filled with approximately 7,000 meters of late Pre-Cambrian and early Cambrian sedimentary and layered igneous rocks. The Paleozoic rocks include approximately 5,000 meters of Pre-Pennsylvanian limestone, shale and sandstone, approximately 5,000 meters of Pennsylvanian clastic sedimentary rocks deposited during rapid subsidence and orogenic deformation, and approximately 1,000 meters of Permian rocks, mostly red beds and evaporites accumulated during late gentle subsidence marked by periods of restricted circulation.

- Rocks at the surface include gently dipping Permian red beds and evaporites in the eastern half of the area. Tertiary continental clastic rocks of the Ogallala formation cover the western part. Quaternary deposits occur along major rivers and in large areas of wind-borne sand on the uplands.

- Most of the structures that trap hydrocarbons (marked by colored dots) were created during the intermittent tectonism that began in earliest Pennsylvanian time and continued into earliest Permian time. Many of these traps are located in the highly deformed frontal zone north of the Wichita-Amarillo Mountain trend.

Exploration for structurally trapped hydrocarbons in the basin is exceedingly difficult because the important structures are buried by 300 to 1,000 meters of essentially undeformed Permian and younger rocks. Surface features that reflect the deeply buried structures are extremely subtle and may be interrupted by much younger solution collapse structures.

Our hypothesis was that the synoptic view provided by ERTS imagery might allow integration of a sufficient number of these subtle features so as to, in effect, see the deeply buried structures through the overlying rocks.

- Intensive petroleum exploration in the basin began in 1917. However, it is only during the past 5 years that the deeper portions of the basin have received extensive exploration attention. The deepest well in the world, the Lone Star #1, Baden,with a total depth of 30,050 feet, completed drilling last year west of the Elk City field. It is a $5 million dry hole.

III. TECHNICAL ANALYSIS

From a total of 49 ERTS scenes received, we interpreted 16 scenes in black and white and color composite form. The remaining 33 scenes are of limited use because they are peripheral to our test site or they contain a high percentage of cloud cover. • We interpreted paper prints, transparencies, mosaics, and digitally-enhanced imagery. This is an optical enhancement, color combining Bands 5, 6, and 7. It brings out closed anomalies such as these.... and linears like these. • This frame combines and offsets a negative of Band 6 and a positive of Band 7, emphasizing linears like these... • The MSS imagery was interpreted for a variety of features. These include linear features, • lithology, • tonal, textural and closed anomalies, and a variety of other features such as drainage and topography. We interpreted all four MSS bands and color composites. This has resulted in more than 120 individual interpretations.

From these frame-by-frame studies, we went in two directions. One approach was to focus our attention on small areas selected by ERTS interpretation and on the basis of known oil and gas exploration interest. The second approach was to compile the various interpretations into regional overlays.

The regional compilations, selected site studies, and interpretations of individual frames were analyzed and compared to existing information. The information included published maps and reports, auxiliary imagery, and interviews with geologists in Oklahoma.

IV. RESULTS AND CONCLUSIONS

Evaluation of Imagery

- Bands 5 and 7 together have the greatest versatility and widest range of easily extractable information. Bands 5 and 7 are generally of high overall contrast and, in fact, the contrasts are frequently reversed between the two.

  However, all bands must be carefully interpreted in order to derive the maximum amount and kinds of geologic information. Each band contains different features which are more easily detectable than on the other bands. On this illustration you can see linears interpreted from Band 7 of this scene. • Combining this successively with Bands 5 and 4, you can see Band 5 linears such as A and B which were added to the interpretation previously done from Band 7. Linears C and D were visible on Band 4, but not on Band 5 or Band 7.

- Seasonal differences increase the amount of information available from ERTS. We have found that imagery of extremes of vegetation growth, that is, maximum vigor and maximum die-back, to be most useful. However, so many subtle but important differences appear throughout the year that study of imagery from an entire year or even several years is necessary for optimum results. We will next look at interpretation of the area shown here ..... • and in this view. This is the Cimmaron River, North and South Canadian, a badlands area, and a gently rolling upland. • This illustration compares our interpretation of inferred lithologies made from spring and from fall imagery.

Area A demonstrates the great amount of detail frequently obtained from spring imagery which is near-absent in the fall. Points B and C locate boundaries interpreted from fall imagery, but not seen in the spring. At D you will note more detailed and precise location of a lithologic boundary on spring coverage. Boundary E, while noted on both images, is more confidently drawn from fall imagery.

Summary of ERTS-1 Interpretation

Using ERTS-1 imagery, we have defined the major features of the Anadarko Basin and refined our understanding of many smaller areas within our test site.

- Regional analysis of the inferred lithologic distribution defines the general features of the basin. This map was compiled from interpretation of ERTS Band 7 imagery without reference to existing maps. • Here is a generalized geologic map for comparison.

    - Analysis indicates a gentle south dip on the north flank of the basin. The dip becomes southwesterly as one moves east, indicating a plunging basin.

- Outcrop width on two sides of the basin shows asymmetry.
- Horizontal rocks cover the west end unconformably.
- Basement rock outcrops and alignments define the Wichita Uplift on the south.

- Our study defined several regional sets of linears. Field checks indicate these linears represent fractures. The sets trending approximately N 40 W (yellow) and N 80 W (green), in particular, are associated with or control many of the structural hydrocarbon fields. • A few fields are located by the dots. The N 30 E set (blue) coincides with the edges of solution collapse areas and with the edges of a large thin area shown in a thickness map of Middle-Pennsylvanian rocks on the north flank of the basin. The north to N 10 W set of linears (brown) is associated with the Amarillo-Wichita Uplift on the south side of the site. These associations suggest that the regional linears are either faults or fault-related features which have been active in the past and control the location of many structural hydrocarbon traps.

- This diagram locates known and hypothesized faults and linears within the basin. • Here, we have overlaid our working interpretation of linears made on fall imagery and have marked in red the places where our interpretations match or extend the diagrammed linears.

The regional map of anomalies also was compared to other pertinent information. We were able to locate most known structures of interest on ERTS imagery prior to referring to existing data. • On one composite overlay of fall imagery we counted 76 anomalous features. We classified these as geomorphic, tonal, and "hazy" areas. These "hazy" areas appear on the imagery as if image detail had been smudged or partially erased. They are not artifacts. Of 76 anomalies, 59 correlate with producing oil and gas fields, 11 are on known but non-producing structures, and the remaining 6 could not be correlated with known features. Of 35 "hazy" anomalies, 33 correlate with producing fields or drilled structures. On a recent compilation, 42 of a total of 57 "hazy" areas occur where producing fields exist. Six additional areas correlate with known but non-productive structures. • Several "hazy" anomalies are shown on this illustration along with a few tonal, textural and geomorphic anomalies. • Here is the same scene without the overlay.

Next, we will look at an air photo of this area. • This is a color infrared photo taken from 60,000 feet; it is 15 miles across. The ERTS "hazy" area is outlined. After study of all air photographs taken over the "hazy" areas, we conclude they cannot be recognized except on ERTS imagery.

We have studied small areas selected from the anomaly maps, from published reports, and at the suggestion of our petroleum geologists. In every instance, we find that focusing our attention in this fashion increases the detail we perceive in an area. Our interpretations occasionally differ somewhat from suggested or published analyses. In a few instances, notably over the Cement-Chickasha fields, we can add details to the known structure but have not been able to confidently define these large features, which are fairly shallow, strongly folded and faulted structures.

- Some of our interpretations closely match conventional interpretations as at the Mobeetie field. Its closed structure and faulted nature can be seen here,
- as well as in our ERTS interpretation. In sum, interpretation of ERTS imagery enables us to locate areas for more detailed analysis on ERTS and for aerial photographic and geophysical studies.

Auxiliary Imagery

Auxiliary imagery, particularly high altitude aerial photography, is exceedingly valuable to studies of ERTS data. The side-looking, airborne radar and thermal infrared imagery we used, despite their generally poor quality, proved of value in defining, locating and understanding linear and geomorphic features. High altitude, small-scale, multiband, aerial photography provides a means of understanding local image responses and patterns seen on ERTS imagery. It provides a means of verifying and refining interpretations and relating field observations to ERTS imagery. The photography provides details on features which are best interpreted in the regional context provided by ERTS.

V. APPLICATION TO PETROLEUM EXPLORATION AND COSTS

We have found that the ERTS imagery is an excellent tool for reconnaissance exploration of large sedimentary basins or new exploration provinces. The imagery allows rapid interpretation of large features and quickly focuses attention on anomalous areas. For the first time, small and medium size oil companies can rapidly and effectively analyze exploration provinces as a whole.

- Let me list specific types of information derived from ERTS that are useful for petroleum exploration:

  - There is a vast quantity of information on linear features -- much more than is generally available, even on large-scale maps.

- Many of the general lithologic relationships that are known to exist in the basin are visible on the imagery.

- A large number of closed anomalies of various types appear on the imagery. The majority of these correlated with known structural features or oil and gas fields.

- Many of the details of the structures controlling hydrocarbon accumulation are visible in the imagery, once one's attention is directed to a particular area.

- The overall structure of the basin and many of the major internal structures are visible on the imagery.

- The imagery provides overall geologic context of the exploration province.

Cost Analysis

So much for ERTS data and information itself. How does the cost of a petroleum exploration program employing ERTS compare to a standard program? Because of a variety of options available for obtaining reconnaissance geological and geophysical data, cost comparisons are difficult.

Moreover, the types of data obtained by the two approaches are not precisely comparable.

Savings produced by incorporating ERTS into an exploration program might be 20% to 50% of the cost of a standard survey. The savings would be made primarily by reducing the amount of seismic and other geophysical surveys needed.

The ERTS approach would also greatly reduce the time required for regional reconnaissance and analysis of the basin and would conserve technical manpower. It is difficult to assign a dollar figure to either of these types of savings.

- In conclusion, we should mention several questions which require more study. We need to determine the exact nature and source of several anomaly types, particularly "hazy" areas. Are the anomalies man-made or man-induced? Are they geochemically-induced soil or vegetation effects, or merely fortuitous? Are the "hazy" anomalies characteristic of hydrocarbon provinces, unique, or ubiquitous? What anomalies are related to stratigraphic oil and gas traps? Which to structural traps? What aspects of this study apply to other deformed sedimentary basins? And, finally, what savings will result from incorporation of Earth Resources Satellite data into an actual exploration program?

Thank you.