United States Department of the Interior

GEOLOGICAL SURVEY
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IN REPLY REFER TO

Office of Energy Resources
Branch of Oil and Gas Resources

November 7, 1975

Memorandum

To: James Broderick, NASA/GSFC

From: T. J. Donovan, U.S. Geological Survey

Subject: Progress report on LANDSAT study of alteration aureoles in surface rocks overlying petroleum deposits

A. Problems: Localized reducing conditions in the near-surface and surface rocks resulting from leakage of hydrocarbons at the Cement Field, Oklahoma, have caused a discoloration of the surface rocks there resulting from reduction, dissolution, and removal of iron. These discolorations vary in areal intensity and are often manifested as patches and streaks too small and variable for the resolving power of the imaging system. Additionally, an extensive vegetative cover of non-uniform density complicates the problem. Thus, virtually all of our early attempts to delineate the alteration zone over the Cement Oil Field through enhanced imagery (linear stretching and band ratioing) failed. These problems were compounded by the late arrival of NASA funding to JPL.

B. Accomplishments and Significant Results: A series of low-altitude underflight remote-sensing experiments were flown at Cement and Davenport Oil Fields, Oklahoma. These were designed to gather complimentary and supporting data for the LANDSAT analysis as well as to provide a broad database for integrated studies. Preliminary results were presented at the Society of Exploration Geophysicists Annual Meeting in Denver on October 15. (See section C of this report and attachments.)

Because of the delay in receipt of NASA contract funding by JPL computer enhancement of LANDSAT data were necessarily curtailed. However, a limited amount of experimental work was funded by USGS and carried out at the USGS Image Processing Facility in Flagstaff. An experimental algorithm which employes a sinusoidal stretch of

brightness values (DN) was developed by Dr. L. Soderblom of USGS and applied to a January, 1973 scene (Bands 4, 5, and 6) of cement. The results, although not spectacular, are extremely encouraging and for the first time demonstrate that the alteration anomaly at Cement may be defined through enhanced LANDSAT images. These preliminary results were reported at the First Annual Pecora Conference, Sioux Falls, South Dakota on October 30. (See section C of this report and attachments.)

C. Publications (copies attached):

1) Donovan, T. J., Barringer, A. R., Foote, R. S., Watson, R. D., 1975, Low-altitude Remote Sensing Experiments at Cement and Davenport Oil Fields, Oklahoma [abs.]: Soc. Explor. Geophysicists, 45th. Ann. Mtg., Denver, Colo., 1975, Abstracts, p. 68-69.

2) Donovan, T. J., 1975, LANDSAT Data Contributions to Project BIRDDOG [abs.]: Amer. Mining Congress, 1st. Ann. Pecora Conference, Sioux Falls, S. D., 1975.

D. Recommendations: Work in the Cement area will continue but it is recommended that part of the effort be applied to new study areas in Texas and Wyoming where some of the problems discussed in section A of this report are minimized.

E. Funds Expended:

1)	Funds appropriated directly to USGS	$13,000
	Funds expended for OE and co-investigators salary	13,000
2)	Funds deposited at EDC by NASA	2,600
	Balance as of 092575	1,800
	All data products received in good order.	
3)	Funds received by JPL (These monies were received too late to provide any accounting.)	77,000
4)	USGS appropriated expenditures	$58,550.85

The Society of
Exploration Geophysicists

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Abstracts

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obtained in the field indicates that the altered and unaltered rocks should be seperable in a three-image color-ratio composite, all six spectral bands being in the near-infrared. However, in the response range of the Landsat Multispectral Scanner (MSS), discrimination of the altered and unaltered rocks is achieved best by using the following diazo color and stretched-ratio image combinations: blue for MSS 4/5, yellow for MSS 5/6, and magenta for MSS 6/7. Altered areas appear green in this combination. In the Silver Bell, Ariz., mining district, preliminary evaluation indicates that the most useful color-ratio composite for mapping the alteration zone consists of blue for MSS 4/5, yellow for MSS 4/6, and magenta for MSS 4/7. In these composites, altered areas also appear as distinctive green patterns. In south-central Navada, two rock types that are not altered appear green in the color-ratio composite. Discrimination of these unaltered rock types may be possible at longer wavelengths than those recorded by the MSS, as discussed above.

Low-altitude Remote Sensing Experiments at Cement and Davenport Oil Fields, Oklahoma

SS-12

Terrence J. Donovan, Anthony R. Barringer, Robert S. Foote, and Robert D. Watson

Geologic and geochemical field studies over petroleum deposits have isolated systematic areal mineralogic and chemical variations in surface rocks which are byproducts of petroleum microseepage. These diagenetic anomalies and their attendant geomorphic effects signal the presence of buried petroleum or natural gas. An understanding of the general geochemical processes, pathways, and manifestations, provides a base from which an experimental remote sensing program, using a variety of sensors, can be evaluated. The primary objective is to develop exploration techniques geared to surface manifestations of buried hydrocarbons that can rapidly cover relatively large areas at low cost per unit area.

At Cement and Davenport oil fields, Oklahoma, a series of remote sensing experiments are being carried out which are closely tied to, and correlated with, detailed ground-truth control. The airborne techniques include: (apparent) resistivity mapping utilizing electric field components of low-frequency radio waves; geochemical sampling and real-time elemental analysis of particulate matter wafted into the air; measurement of the natural gamma-radiation flux furnished by ^{214}Bi (uranium series), ^{208}Tl (thorium series), and ^{40}K (potassium); measurement of the variation in luminescence of carbonate rock cements as a function of trace metals content using a Fraunhofer line-depth method; aeromagnetic profiling; and low-altitude special-purpose photography and thematic mapping. Both fixed- and rotary-wing platforms are employed.

These and other experiments are continuing, and preliminary results are encouraging. For example, traverses carried out with the AIRTRACE® system, an airborne geochemical technique for collecting and analyzing atmospheric particulates, indicate anomalies in the Mn/Fe ratio which correlate with ground measurements for Fe and Mn over the Cement Field. Repeat flights confirmed the reproducibility of the anomaly. Similarly, gamma-radiation measurements corrected for cosmic-radiation and atmospheric gamma-ray contributions, show reproducible anomalous ^{214}Bi/^{208}Tl, ^{214}Bi/^{40}K, and ^{208}Tl/^{40}K ratios; and aeromagnetic profiles show a marked magnetic discontinuity. These geophysical perturbations correlate with structure and/or areal

variations in secondary mineralization and bleaching (iron loss) of red beds at the surface, which have been traced to petroleum microseepage.

Remote Sensor Applications to Tectonism and Seismicity in the Northern Part of the Mississippi Embayment

SS-13

Dennis W. O'Leary and Shirley L. Simpson

A comparative study of ERTS images, SLAR image strips, and Skylab photographs was made to help develop a regional tectonic model and to evaluate the seismic hazards of the northern part of the Mississippi embayment as far south as the Ouachita front.

Statistical analysis of the lineaments indicates frequency variations according to tectonic province. The geomorphic character of the features and the fairly consistent northwest trend groupings throughout the area suggest the influence of jointing, whereas the widely variable north and northeast-trending groups suggest a variety of influences including faulting and surficial factors which control stream orientation. Nearly all mapped faults trend at an oblique angle to lineaments; those with notable correspondence strike in a north-northeast direction. Certain faults, as mapped, appear as direct extensions or connecting segments of certain lineaments. This suggests that faults trending in a northeasterly direction have more topographic expression than those trending northwest, hence such faults appear to be more recent, as they disrupt slopes in equilibrium with drainage courses. Preliminary seismic data from the area indicate a well-defined trend of epicenters strending N16E from Lone Star, Mo., to Sikeston, Mo., and a trend striking N40W from Lone Star to Gratio, Tenn. Lineaments mapped in this region closely parallel these trends. Gravity and magnetic data for the area are incomplete at this time. However, for a small area near New Madrid, Mo., a trend analysis was made of the totals of length-width ratios of the magnetic anomalies, grouped in 10° intervals. Except for a trend at NO°-10°E, anomaly trends correlate closely with the azimuth-frequency rose diagram of lineaments from ERTS images covering the entire study area. These data strongly indicate basement control, involving gradients of magnetic anomalies, along trends parallel to the mapped lineaments.

Application of the Remote Sensing of Terrestrial Gamma Rays

SS-14

Joseph S. Duval

Over the past 15-25 years the remote sensing of terrestrial gamma rays has been applied in the search for the radioactive elements, potassium, uranium, and thorium. Today the search for these elements remains the single largest application of the method. This paper reviews the state of the art and some applications of the technique.

The current method can be broadly described as a system based on a multichannel analyzer with a large volume of NaI(Tl) detectors. One or more of the detectors may be shielded from the terrestrial gamma rays by a lead plate so as to obtain a continuous measurement of the background due to cosmic rays and airborne uranium daughters at and above the level of the aircraft. The data are still generally presented in the form of counts per unit time even though recent work has shown that it is feasible to present the data as apparent concentrations of the three elements. Extensive use is being made of

LANDSAT Data Contributions to Project BIRDDOG

By

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Abstract

The U.S. Geological Survey's Project BIRDDOG (Basic Investigation of Remotely Detectable Deposits of Oil and Gas) is an outgrowth of investigations which have shown that imperfect rock seals capping petroleum and natural gas deposits can allow a large volume of low-molecular-weight hydrocarbons to escape slowly to the surface over long periods of time. Reactions and interactions among the hydrocarbons, ground-water solutes, and mineral constituents of porous rocks may produce, at the surface, mineralogical and chemical evidence for buried hydrocarbon deposits. BIRDDOG'S current experimental activities include underflight verification, reconnaissance, and aerial mapping of significant but commonly subtle surface manifestations of subsurface hydrocarbons, which are expressed as variations in tone, color, and geomorphology. These variations may be detected initially using computer-enhanced LANDSAT (formerly Earth Resource and Technology Satellite or ERTS) images. These multispectral scanner images of the Earth's surface are telemetered through ground stations to a central data-processing facility where they are converted to computer-compatible tapes. Enhanced black and white or color photographs are then derived from these tapes. This process provides a set of data useful in exploration programs for mineral and fuel resources, especially oil and gas. The ultimate goal is to determine if remote-sensing exploration techniques geared to surface manifestations of buried hydrocarbons can be incorporated into conventional exploration programs with cost-saving benefits.