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GEOLOGIC ANALYSIS OF A MULTISPECTRALLY PROCESSED APOLLO SPACE PHOTOGRAPH*

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*Work done in cooperation with the National Aeronautics and Space Administration

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ABSTRACT

Apollo photograph AS-6-1452 of the Carlsbad-Hobbs area in New Mexico was selected for experimental processing because of its apparently subdued topography and simple geologic structure. An RCA two inch return beam, high-resolution vidicon camera, colored glass filters, and a laser image reproducer were used to scan the photograph and to produce three dye-transfer images representing the red, green, and blue parts of the visible spectrum. These images were evaluated for their geologic content.

The green dye-transfer print representing the exposed blue (400-500mμ) and red (600-700mμ) parts of the visible spectrum was found to convey the most information. Geologic, vegetative, and cultural features were classified on the basis of their relative reflectance or degree of "brightness."

The most significant geologic feature seen in the green dye-transfer print is a major northeast-trending lineament, not shown on the most recent geologic map of New Mexico. The lineament is believed to correspond to a structural depression or "channel" in the Precambrian basement that projects northeastward from the Delaware basin. Stratigraphic information indicates that the lineament may represent a zone of weakness that was active periodically throughout geologic time and along which coral reefs developed in Permian time.

INTRODUCTION

The Apollo-Saturn 6 spacecraft was launched on April 4, 1968, at 12:00:01 Greenwich time from Complex 39-A, Kennedy Space Center, Florida. A Maurer camera, Model 220 G, having a Kodak Ektar 76 mm lens (f/2.8) was mounted in the hatch window. It contained 70 mm Kodak Ektachrome, high resolution aerial film (SO-121) and the lens was set at f/5.6 and 1/500 second. The camera system was armed with a gravity switch set for G=2.5 (ambient = 1.5 G) which activated the system at Ground Elapsed Time (GET) equal to 00:0;:30 after lift-off. The first exposure was taken at 1:29:51 GET and every 8.64 seconds thereafter. The camera operated continually through the second orbit of the spacecraft, taking near-vertical daylight photographs from the Georgia coast across the Atlantic to Senegal, North Africa, and finally, the east coast of South Africa. The spacecraft flew in darkness from Madagascar to the central Pacific. The second daylight sequence of land features extends from the Pacific coast of Baja California to the Georgia coast south of the Savannah River and into the Atlantic.

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Frame AS-6-1452 of the Carlsbad-Hobbs, New Mexico area, covering an area of about 10,000 square miles, was taken at GET 3:10:03 hours or 8:10 am. MST time from an altitude of 125 nautical miles. Adjacent vertical space photography, having about 60 percent overlap, provides excellent stereoscopic coverage of the area.

These data, provided in the form of 9 x 9 inch second generation color prints and transparencies, served as basic materials for the data processing experiment described in this report. Partial analyses of the processed data and geologic implications of interpretation are presented.

EXPERIMENT PROFILE

The purpose of this experiment was to simulate photography to be acquired from a three-camera multispectral television system that has been proposed by the Departments of the Interior and Agriculture to NASA for the first Earth Resources Technology Satellite (ERTS). Each ERTS camera will be photo-sensitive in a distinct part of the visible and near-infrared spectrum. Camera A, for example, will photograph in the blue-green region (475-575 millimicrons); camera B, the red region (580-680mμ); and camera C, the near-infrared region (690-830mμ). The experiment was also designed to test the capabilities of the RCA 4500 line two inch return beam vidicon camera and laser image reproducer, prime candidates for the satellite and supporting data handling system. In addition, it was hoped that the experiment would help determine the potential data needs and processing requirements that will facilitate the distribution and use of satellite data in a timely fashion.

System Design: A nine by nine inch color transparency of Apollo-Saturn 6 - 1452 photograph of Carlsbad, New Mexico, was mounted on a light box producing 1000 ft-Lamberts (± 5 percent) at a color temperature of 3200°K. The scene was photographed four times: 1) with a 1.0 neutral density filter to produce a normal black and white negative at an exposure time of 180 milliseconds; 2) red filter (Wratten 29) for 90 milliseconds; 3) blue (CS5-61) filter for 180 milliseconds; and 4) a green filter (Wratten 61) for 140 milliseconds. The photo conductor was exposed to peak at approximately 0.15 foot candles per second.

The scene was transferred through the filters and return beam vidicon (RBV) camera to a face plate which was rapidly scanned and transferred by a laser beam image reproducer (LBIR) to negative film. The LBIR negatives were enlarged and reproduced on matrix film to which dye solutions of subtractive primary colors (cyan, yellow, and magenta) were added to produce a color print which closely corresponds to the original. Color separation prints (blue, green and red), corresponding to the filters used, were also produced for evaluation.

Method of Evaluation of Data: The prints were evaluated visually by incremental comparisons of parts of the scene in each color separation with that of the original color transparency. The prints were also evaluated on the basis of the total scene. Magnification was used where necessary to determine the loss of resolution and detail.

As might be expected the color transparency had the greatest information content; cultural detail dominated the scene. Some of the finest cultural detail was seen in the area of the Central Basin platform where a quarter mile grid of roads and clearings represents individual well sites in the oil fields of eastern New Mexico. Oil wells cover a large part of the area south and west of Hobbs and Lovington (Figure 1). The shape and margins of the oil fields correspond closely to those shown by Montgomery (1965, fig. 20).

Much of the area is underlain by the Tertiary Ogallala Formation at the surface in the northeastern part of the photograph. This formation is darker than the older rocks and alluvium to the west and, consequently, cultural activity which disturbs the surface stands out in marked contrast. West of the Mescalero Ridge there is less contrast and the oil activity is less distinguishable.

Of the multispectral prints provided, the green print presented the greatest amount of usable information. This is probably because this spectral band represents data derived from the blue and red portions (i.e., widest range) of the visible spectrum. The features detected on basis of relative brightness and form are listed below in order from brightest to darkest:

Brightest	Salt lakes
	Playas
	Older rocks and weathered surfaces
	Towns, small cities
	Ogallala Formation
	Cultivated fields
	Lineaments due to fractures and faults
	Karst features
	Smoke plume (shadow)
	Reservoirs
Darkest	Vegetation

A northeast-trending lineament west of Hobbs, is expressed by a slight change in tone on either side, both in the area of older rocks and the area underlain by the Ogallala Formation. Part of the difference in tonal density appears to be due to clearing related to development of the Vacuum oil field on the north side of the lineament. The clearing terminates on the south as a relatively sharp line along the northeast portion of the lineament. A second linear feature appears to parallel the first, a few miles to the northwest. Neither of the lineaments seen in the photograph, however, are shown on the latest geologic map of New Mexico, (Dane and Bachman, 1965).

Preliminary field observations were made to determine whether the lineament represented a fault, fracture, or other geologic structure or a man-made feature such as a pipeline.

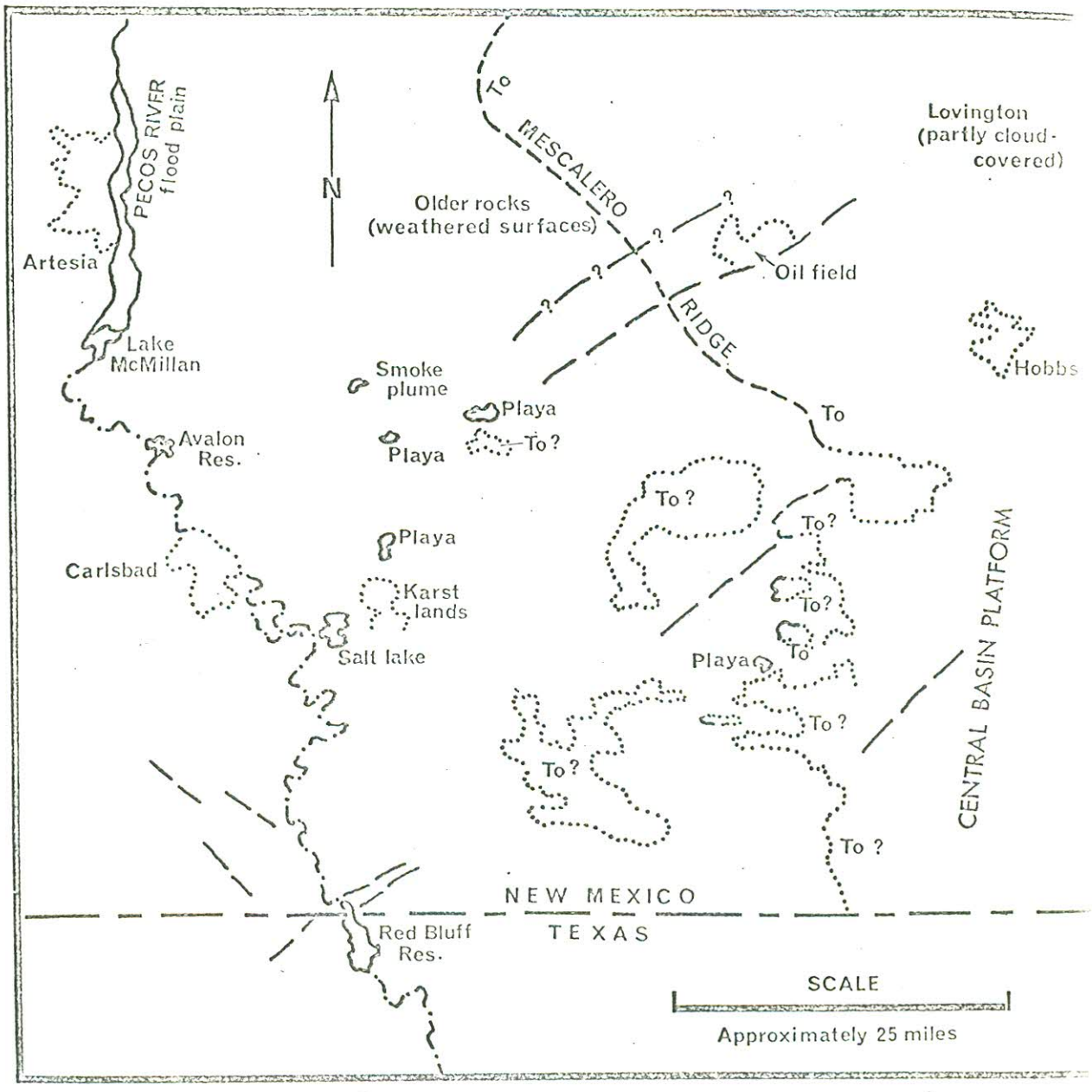

Figure 1. Sketch map showing the area covered by Apollo 6 photograph, AS-6-1452, and identified features. Tertiary Ogallala Formation (To) crops out in the east half of the area. Lines indicating the base of the formation are dashed where clearly visible and dotted where suspected. Linear features, shown as heavy dashed lines, may be of geologic origin.

No evidence of faulting was observed on the ground within the zone defined for the lineament east of Mescalero Ridge. Pipelines crossed the zone in many places but nowhere were they seen to parallel it. In general, oil wells north of the lineament were closely spaced and actively pumping. To the south, the spacing was random and more widespread; the pumps were idle when the area was visited in November 1968.

The red and blue dye-transfer prints show some of the features described above but in general were too dark in tone to be readily useable. The darkness may be due in part to processing.

Geologic Implications of a Linear Feature: The linear feature or "lineament" described above, may be the surface expression of the north edge of the San Simon syncline, the site of an ancient channel which connected the Midland basin in west Texas with the Delaware basin in New Mexico during Permian time. South of the channel lies the Central Basin platform, a large positive area or topographic high in the central part of the Permian basin. The channel coincides with the -11,000 and -12,000 foot structure contours drawn on the Precambrian surface by Foster and Stipp (1961), who show a northeast-trending depression extending from the Delaware basin. North of the channel is an area known as the Northwestern shelf, a relatively stable area north of the Delaware basin. Along the hinge line or transitional zone between the Northwestern shelf and the Delaware basin extensive limestone and reefs, banks grew intermittently during part of Pennsylvanian and most of Permian time (Montgomery, 1965, p. 77). Major oil fields exploiting such ancient reefs include the Vacuum, Empire and Lovington fields, all producing from Permian reefs.

Detailed stratigraphic sections and paleogeology based on drill hole information have been described by Meyer (1966) who clearly shows transition zones of the Abo Reef and bordering the Northwestern shelf and the Central Basin platform during the Wolfcamp time of early Permian age. The transition zones, marked by sharp changes in facies and reef structure, directly overlie the margins of the Precambrian depression. Sedimentation in the transition zones consisted of fine grained black siltstones and black massive limestones with fusilinid fauna assigned to the Bone Spring Limestone of the Leonard Series (Meyer, 1966, p. 71).

The synoptic view provided by the Apollo 6 photograph and subsequent special processing have made it possible to detect a major linear feature that cannot otherwise be seen. The linear feature appears to be the surface expression of a structural zone of weakness in the earth's crust that has been intermittently active, at least since post-Precambrian geologic time.

Similar observations have been made by Trollinger (1968a and b) who recognized major deep structures in the Delaware basin directly from Ektachrome prints of Gemini and Apollo photography. He believed that he could do so with confidence because of his knowledge of the subsurface geology. The study described herein, however, is unique at this time in that the structures observed were enhanced by data processing techniques which attempted to duplicate spectral bands that will be used in forthcoming multispectral television satellites. This paper is provided for the record with the hope that it will help determine whether such observations can be repeated by successive multispectral views from space. Studies such as this

may eventually help to determine the conditions of weather, season, sun angle, spectral region, and other variables that affect recognition of geologic features. As such records grow it will be possible to better define optimum data gathering and processing systems; these will be an aid in the ever increasing task of discovering, managing and conserving earth resources.

CONCLUSIONS

Image enhancement techniques applied to an Apollo 6 photograph of the Carlsbad-Hobbs, New Mexico, area were successful in depicting a lineament more than 25 miles in length. The lineament may be of substantial significance to the interpretation of geologic structure along the northern margin of the Delaware basin. The lineament does not appear on regional geologic maps of the region but can be correlated with subsurface well and geophysical data.

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