

**Mapping of Soils and  
Geologic Features with  
Data from Satellite-  
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Scanners**

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Mapping of Soils and Geologic Features with Data from  
Satellite-Borne Multispectral Scanners<sup>1</sup>

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Abstract

The ERTS-1 satellite provides opportunity for quick inventory and assessment of geologic, soils, and vegetative cover aspects of large-scale areas of the Earth's surface. Collin County, Texas, U.S.A., a 2270 Km<sup>2</sup> area of relatively simple geology and soil associations was chosen for initial study, using ERTS-1 4-channel multispectral scanner data. These data were analyzed by computer-implemented pattern recognition techniques developed at the Purdue University Laboratory for Applications of Remote Sensing (LARS). The results indicate excellent visual correlation, on a gross scale, between automatically produced maps and existing geologic and soils maps and field information.

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## Introduction

Today, little is known about the geologic, soils, and vegetation resources of vast areas on the surface of the earth. If these areas are to be developed, managed, and conserved for the benefit and enjoyment of man, there is need to obtain as quickly as possible an inventory of the resources of these areas.

Within the past decade, significant advances have been made in the development of airborne and space-borne sensor systems which make it possible to obtain vast quantities of earth resources data over large geographical areas within a very short time. Such data acquisition systems, coupled with computer-implemented analysis programs, provide a new, rapid reconnaissance capability for inventorying and managing earth resources (2).

The objective of this paper is to present the preliminary analysis results and interpretations of multispectral scanner data obtained on the first data-acquisition pass over the Central United States of the Earth Resources Technology Satellite (ERTS-1) launched by the National Aeronautics and Space Administration on July 23, 1972.

The area chosen for this study is Collin County, Texas.

## Physical Setting

Collin County, an area of 2270 km<sup>2</sup>, is near the northern boundary of the Gulf Coastal Plain of Texas. It is in the second tier of counties south of Red River, the boundary of the Coastal Plain physiographic province. The county may be classified as dissected, Coastal Plain upland. Drainage is southward into the Trinity River system. Elevations range from a maximum of about 250 m above sea level on the Austin scarp in the western part of the county to a low of about 150 m at Lavon Reservoir. The average elevation is about 225 m.

Geology. The geology is relatively simple. The county is underlain by an eastward and southeastward-dipping series of Upper Cretaceous marine sedimentary rocks, overlain locally by Pleistocene fluvial terrace deposits or recent floodplain alluvium. Change in strike of beds from north to east

across the county may be in response to deposition of Cretaceous units over now buried, plunging folds of the Ouachita or Arbuckle mountain systems (1).

Description of the soil-forming rock units follows (Table 1 and geologic map of Collin County, Figure 1).

Soils. Six soil associations have been identified and mapped in Collin County (Figure 2). Soils of the Houston Black-Austin association occur primarily on rocks of the Austin group. These deep, clayey soils are found on gently sloping to sloping uplands over argillaceous marl and chalk (4). The Houston Black-Houston soils are associated with the Ozan and Marlbrook formations. These deep, clayey soils occur on gently sloping to sloping uplands over calcareous clays and minor limestone units. Soils formed on the Pleistocene fluviatile terrace deposits belong to the Houston Black-Burleson association. These deep, clayey soils occur on nearly level to gently sloping stream terraces.

The deep clayey and loamy soils of the nearly level flood plains belong to the Trinity-Frio Association and are developed on Recent alluvium. The eroded, deep, clayey soils of the Ferris-Houston Association occur on sloping to strongly sloping uplands. These soils were developed on Pecan Gap Chalk and Wolfe City Formation, consisting of fine grained, calcareous sand, silt, and chalky limestone. The Wilson-Burleson soils are associated with the Eagle Ford Formation. These deep, loamy and clayey soils occur on nearly level to gently sloping uplands and are underlain by gypsum-bearing shale.

### Procedures

Some of the first ERTS-1 multispectral data were obtained by the satellite sensor system on July 25, 1972 over a swath 185 kilometers in width along a path between Duluth, Minnesota and Corpus Christi, Texas. Within this swath an area of approximately 34,000 km<sup>2</sup> (185 km x 185 km) centering around the Lake Texoma Region between the states of Texas and Oklahoma was chosen for analysis by the Laboratory for Applications of Remote Sensing (LARS) at Purdue University.

Digital data from the ERTS 4-channel multispectral scanner (3) were analyzed by computer-implemented pattern recognition techniques developed at

Table 1. Geologic Column of Collin County, Texas

<u>Geologic Age</u>	<u>Thickness (m)</u>	<u>Description</u>
Recent (Qal)	3±	Stream Alluvium
Pleistocene (Qt)	10±	Terrace deposits, dominantly gravel, sand, and silt; some clay or silty clay.
Upper Cretaceous (Santonian-Coniacian-Turonian)		
Marlbrook Marl (Kmb)	100	Calcareous, silty, glauconitic clay; in southern Collin County contains scarp-forming light gray limestone.
Pecan Gap Chalk (Kpg)	15	Alternating units of olive-gray, sandy lime and hard, granular, dark blue-gray limestone. Glauconite abundant. Sandy chalk and marl toward base.
Wolfe City Formation (Kwc)	25	Calcareous, fine-grained sand and silt, with concretions; calcareous, dark gray mudstone at base.
Ozan Formation (Ko)	140	Dark gray calcareous clay; variable amounts of silt and glauconite.
Austin Group (Kau)	140-150	Regionally divided into 7 units, undifferentiated in Collin County. Dominant units are <u>Gober Chalk</u> (kg), and argillaceous, blue-gray, massive chalk (130 m thick); and <u>Ector Chalk</u> (Kec), 10 m thick, brittle, light gray, argillaceous chalk.
Eagle Ford Formation (Kef)	100-130	Blue-gray to black, bypassiferous shale. Local sand units in outcrop give rise to sand dune topography.

The contact of the Eagle Ford with the Austin group is commonly marked by a prominent, west facing topographic scarp, 40 m high locally, developed on chalk with the scarp overlooking rolling prairie or plains on Eagle Ford shales lying to the west.

LARS (2). Of the four spectral channels or wavelengths, two are in the visible region and two are in the reflective infrared region of the spectrum (Table 2).

Table 2. Electromagnetic spectral ranges measured by the 4-Channel Scanner of ERTS-1.

<u>Channel No.</u>	<u>Spectral Range</u>	<u>Description</u>
1	0.5 - 0.6 $\mu\text{m}$	green
2	0.6 - 0.7 $\mu\text{m}$	red
3	0.7 - 0.8 $\mu\text{m}$	near infrared
4	0.8 - 1.1 $\mu\text{m}$	near infrared

### Results and Discussion

The use of multispectral scanner data enables production of quantitative reflectance measurements from each spectral channel, and for each resolution element or instantaneous field of view of the scanner system. The resolution of the ERTS-1 scanner is approximately 80 meters for elements in a scene having a contrast ration of 1:1.2. This means that the scanner at an altitude of approximately 900 km can detect, separate, or measure an area of two-thirds of a hectare if appropriate contrast exists. Where contrasts are extreme, even much smaller areas can be detected on scanner data.

By computer analysis of spectral data from Collin County, it was possible to map the gross natural drainage patterns of the County. In many cases, these spectral patterns also correspond closely to differences in soil associations and geologic parent materials (Figure 3). From spectral maps a prominent escarpment is readily identified in the western part of the county. This escarpment represents a division between soil associations, geologic materials, and types of agriculture. To the west of the escarpment, the average reflectance is considerably higher than east of the escarpment. Causes for these differences may be related to two factors for this particular set of data (Figure 4). First, the surface soils are lighter in color west of the escarpment. Second, wheat and grassland are the predominant cover west of the escarpment. Most of the vegetation on the heavier, darker soils east of the escarpment is cotton, grain sorghum, and wooded areas. At the

time these spectral data were obtained, these areas were green, producing a relatively low spectral response. Grass pastures and wheat stubble west of the escarpment produced relatively high reflectance.

A very useful technique for interpreting multispectral data is to calculate the ratio between the relative reflectance in the visible channels and the relative reflectance from the reflective infrared. In this study the following ratio was used:

$$R = \frac{A + B}{D}$$

where A = relative reflectance in channel 1 (0.5-0.6 $\mu$ m)

B = relative reflectance in channel 2 (0.6-0.7 $\mu$ m)

C = relative reflectance in channel 4 (0.8-1.1 $\mu$ m)

In general, for this set of data, low ratio values (<1) may be interpreted as green vegetation; values between 1.5 and 2.5 may be bare soil and/or plant residues. Water will produce yet higher ratio values. Different densities of green vegetative cover and percentages of exposed soil will produce intermediate ratio values between 1 and 2.

Although these results are preliminary, and the analysis of data was accomplished without benefit of ground observation data, quantitative spectral data from ERTS were very useful in separating and mapping gross surface features. The scene represented by the computer printout in Figure 4 is divided into eleven spectrally separable classes. One of the spectral classes is represented by the symbol "Q". This corresponds to the low reflectance areas of the drainageways. In general, these areas are covered with dense vegetation, trees, and bushes. The average R value for all Q's in the scene is 0.88. Within the drainageways interspersed with the symbol "Q" are individual "M's" or clumps of "M's". The average R value of M's in the scene is 1.79. This is indicative of bare soil or yellow, grassy spots in the drainageways. In the extreme northwest corner of this scene (Figure 4) is a concentration of "+"s" with an average ratio value of 1.40. This represents a rangeland area covered with coastal Bermuda grass (Cynodan dactylon) which was yellow at the time of the ERTS pass.

These are examples of how quantitative spectral data may be used. Such data will become much more applicable when adequate ground observations provide for more complete interpretation.

### Summary and Conclusions

An initial, rapid computer analysis of multispectral scanner data obtained from 900 km above the surface of the earth was used to delineate and map an area of  $2,000 + \text{km}^2$  into 12 spectrally separable classes. These classes were related to natural surface drainage patterns, soil associations, parent materials, and cultivated and natural vegetation.

These initial results were obtained with the analysis of data from only one overpass of ERTS-1. With the capability of obtaining multispectral data every eighteen days over the same study area, computer-implemented analysis of such sequential data should make it possible to delineate and map many soils and geologic features which are impossible to detect spectrally with satellite data obtained during the season of maximum vegetative cover.



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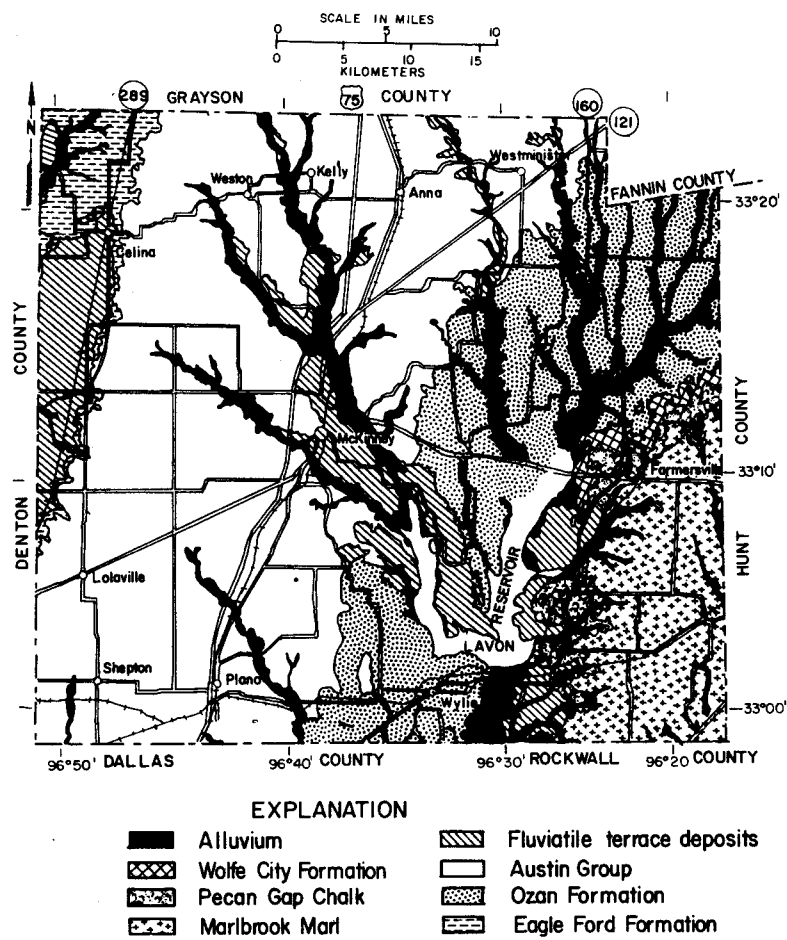


Figure 1. Generalized geologic map of Collin County, Texas, U.S.A.

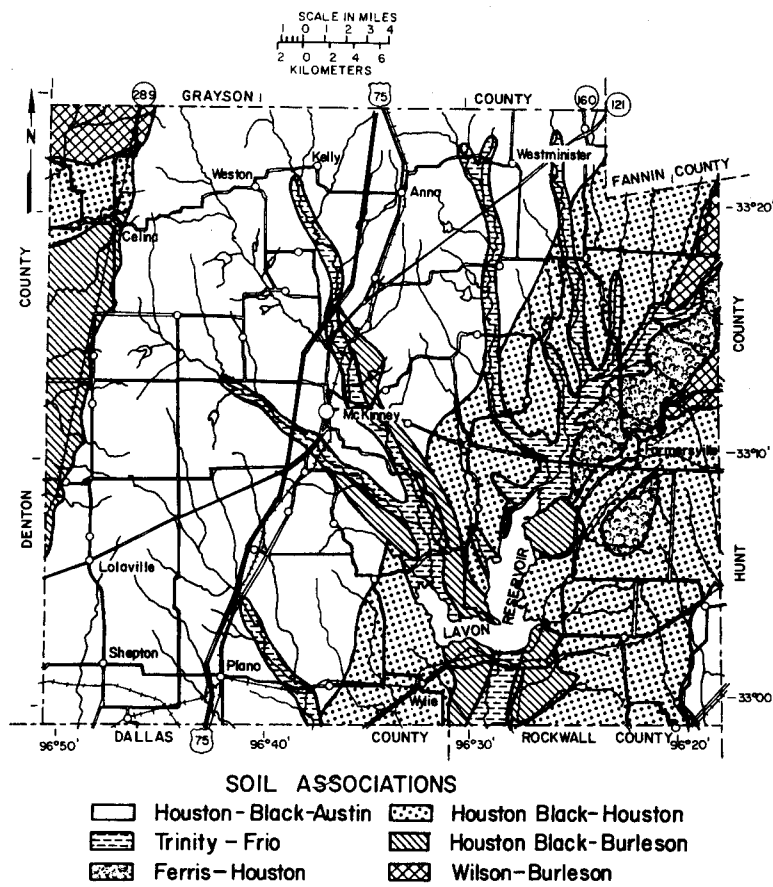
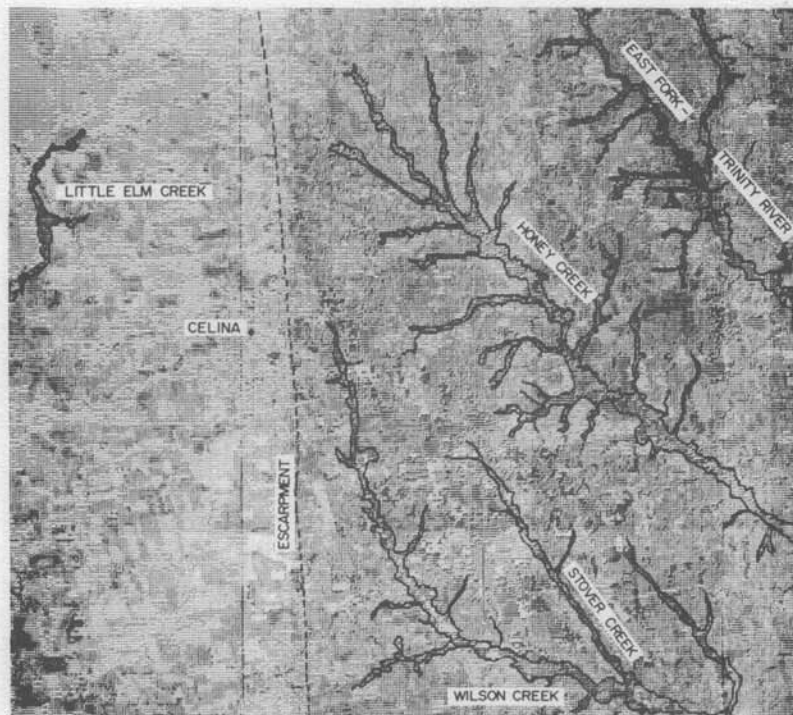
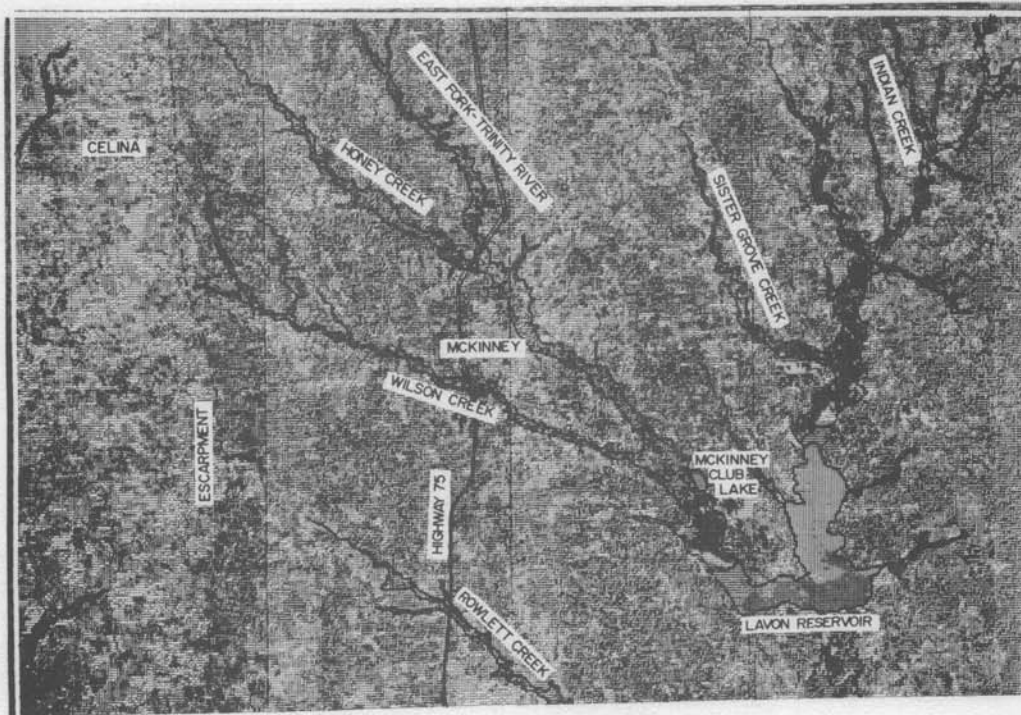


Figure 2. Generalized soil associations map of Collin County, Texas, U.S.A.



Figures 3 and 4. Gray-scale computer printouts, photographically reduced, showing classification of spectrally separable surficial features, such as drainage lines, vegetative cover types, and approximate position of Austin Chalk escarpment. Note increased detail at scale used in Figure 4.