FINAL REPORT

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DRA

Study to Define Points of Entry for Potential Contaminants in Limestone Aquifers

School of
Graduate Studies
And Research

The University
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PRINCIPAL INVESTIGATOR: DR. F. L. DOYLE

The University of Alabama in Huntsville

Center for Environmental Studies

Box 1247

Huntsville, Alabama 35807

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F. L. Doyle
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Principal Investigator

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Final Report

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Defining Point of Entry for Potential Contaminants in Limestone Aquifers

Purpose

Remotely sensed data may help in defining possible points of entry of potential contaminants into the limestone aquifer in Madison County, Alabama, consequently, imagery generated by the first Earth Resources Technology Satellite (ERTS-1), and thermal data recorded by an RS-7 scanner on board a U-2 aircraft were examined with this in mind.

Knowledge of the locations at which contaminants could enter the aquifer is an important consideration in water quality management. Regions that depend at least partially on ground water for their water supply are particularly aided by knowing this inasmuch as site selection of monitor wells which is based on knowledge of the geologic framework of the area is much preferable to selection at random.

Investigators

Principal investigator was Dr. F. L. Doyle of The University of Alabama in Huntsville and the Geological Survey of Alabama. Mr. Herman G. Hamby of NASA's Environmental Applications Section, Marshall Space Flight Center, was project manager. Mr. David Browning, Mrs. Wanda Hardison, and Mrs. Betty Spillman, provided technical and secretarial support.

Materials

ERTS-1 imagery recorded on 28 December 1972 in the Multi-Spectral Scanner-5 (MSS-5) and MSS-7 bands, and a false-color composite of the MSS-4 (green), MSS-5 (red) and MSS-7 (near infrared) bands were the principal materials used. Thermography recorded in daylight hours at about 60,000 feet altitude by an RS-7 infrared scanner on board a U-2 aircraft was supplementary. The DataColor 703-32 color densitometer was an aid in interpretation.

Area Covered

The target area of investigation was the western two-thirds of Madison County, Alabama, along with parts of adjoining counties. Regional perspective was necessary, however, and mosaics of ERTS-1 imagery covering all of North Alabama and the adjoining regions provided this. Final results include most of Madison County, and parts of Limestone, Morgan, and Marshall Counties, Alabama.

General Geology and Hydrology of the Area

The area is mainly underlaid by limestone bedrock, usually covered by up to several ten's of feet of regolith (insoluble residue and other weathering products). Sandstone usually caps the higher elevations, and shale is present locally.

Ground water occurs in the regolith and in pore spaces in bedrock. Porosity in the limestone bedrock is usually in the form of cavities which are caused by the reaction of the limestone with water charged with carbon dioxide. Soluble products are formed, carried away in water, and a solution cavity develops.

Techniques

Visual examination of the imagery (both prints and transparencies) for natural lineations was the primary method of study. The color densitometer converted shades of gray into combinations of 32 colors plus black. By selecting the most advantageous color combinations, this density slicing enhanced the imagery and allowed lineations to be recognized more readily. Furthermore, it allowed selection of what are assumed to be major lineations inasmuch as not all lineations interpreted on the original imagery were emphasized on the color-enhanced products.

Results

1) The most prominent lineations are on the density-sliced imagery and have a bearing of North 50° to 56° West (N 50° to 56° W) and cross the Tennessee River at the southern edge of Madison County (Figure 1). This trend is recognizable on the false-color composite imagery (Figure 2) also, but the most noticeable lineation on that imagery are ones with a bearing of N 40° to 46° W. The fact that this latter trend is not well-defined on the density-sliced imagery suggests that it is of secondary importance to the first.

These lineations probably reflect fractures in bedrock which cause differences in soil moisture, vegetation, and other natural parameters, and which then are made visible on the imagery. Solution of limestone by water descending along the postulated bedrock fractures can enlarge the openings and allow penetration of potential contaminants into the limestone aquifer.

2) Besides the major lineations noted in 1), similar features with other bearings have been identified during the study. These are also shown on Figures 1 and 2 and may be equally important with the major lineations in terms of practical application in ground water hydrology.

3) These major trends of lineation are in the proximity of high-yield water wells in the southwestern part of Madison County, and solution along the major fractures, or associated fractures, probably explain the development of the permeability required for these wells.

4) These major fracture trends may be related to deeper fractures such as those which might occur in the crystalline rock underlying the veneer of sedimentary rocks deposited in Paleozoic time. The major lineation noted on the density-sliced imagery makes an angle of 88° to 94° with the trend of structures of the Appalachian Mountains, as measured where the Tennessee River follows the Sequatchie anticline (upfold) to the east in Jackson County. This near-right angle relationship may be of considerable significance in terms of structural geology.

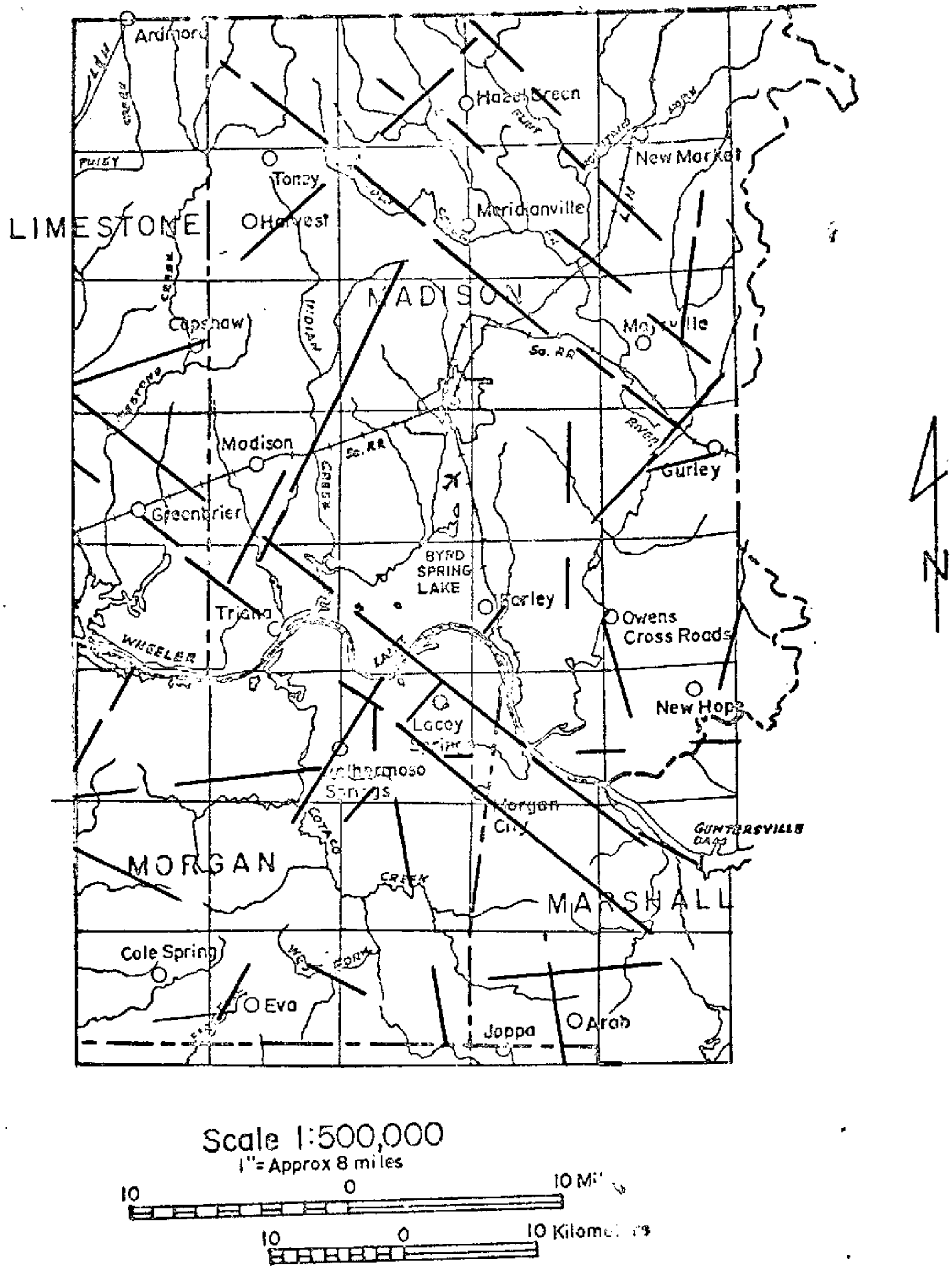

Figure 1

Lineations observed on
Density-Sliced Imagery
Recorded by ERTS-1 on
28 December 1972.

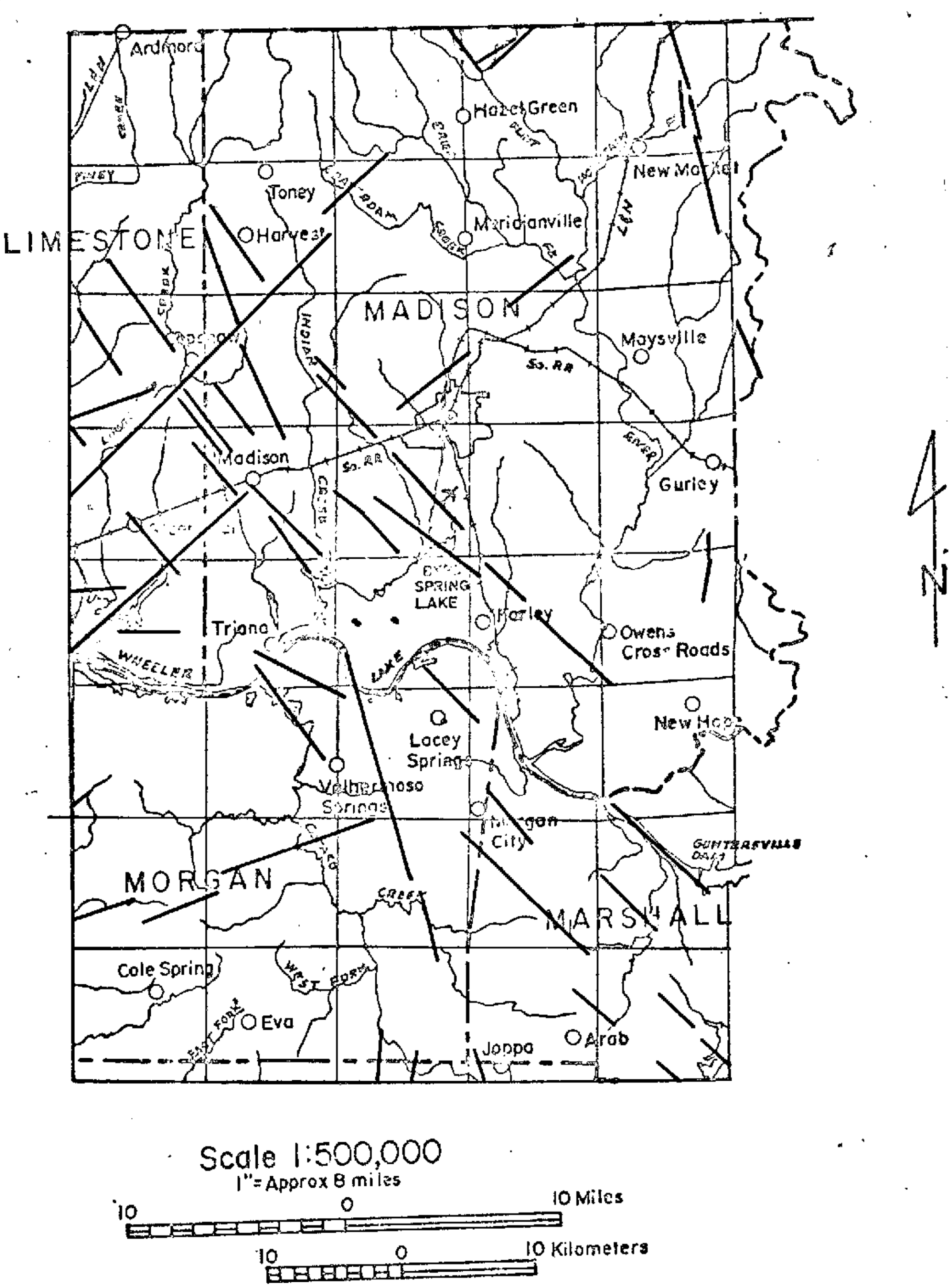

Figure 2

Lineations interpreted on False Color Composite of ERTS-1 Imagery in MSS-4, -5, and -7 bands recorded 28 December 1972.

5) The relationship of the major lineations to earthquake epicenters known in Alabama is obscure.

6) Information from this imagery can be used in selecting ground truth stations prior to low-altitude overflights collecting thermal data.

Conclusions

Imagery from satellites and high-altitude air-borne platforms are effective materials for interpretation of natural lineations. If these lineations are assumed to be caused by fractures in the bedrock, which are reflected at the surface by differences in parameters such as soil moisture and vegetation, then the location of fractures is possible from these materials. Given bedrock of limestone, or other soluble rock, location of fractures is helpful in establishing potential points of entry of contaminants, consequently, the imagery studied is a valuable tool in ground water hydrology.

Image enhancement by color densitrometry emphasizes the major lineations and is consequently an important aid in using the imagery.

The composite image of MSS bands -4, -5, and -7, as printed in false color, is the most helpful. On the other hand, each band shows some lineations better than others, consequently, a combination of several bands, composites, and density-sliced imagery is desirable.

Ground truth collection stations can be best selected prior to low-level collection of thermal data by using results from the interpretation of satellite imagery.

Thermal imagery recorded during the daylight hours and from high altitude can be somewhat helpful for recognizing areas of presumed higher soil moisture content. Low-altitude, pre-dawn imagery will probably prove to be most effective, and should be recorded and evaluated when possible.

Data collected by the Earth Resources Experimental Package (EREP) on board Skylab should be evaluated in the same manner as that from ERTS-1.

Future Activities

Image enhancement by a horizontal bar filter will be compared with that done by density slicing. Lineations, which must be recognized subjectively when using original imagery or density-sliced imagery, can be delineated directly by means of the horizontal bar filter, thus reducing subjective judgment to a minimum.

Low-altitude aircraft will overfly parts of Madison, Limestone, and bordering counties at optimum time for recording thermal infrared imagery in the 8 - 14 micron range. Ultraviolet and SLAR imagery may be recorded also. Color photographs (in sterographic coverage) and mosaics made from them will provide a base on which data and interpretations can be plotted.

Having affirmed the existence of the lineations and having identified their approximate locations, stations for collecting ground truth data can then be established so that field observations can be made at, or near, the time of the proposed overflights. Soil moisture is assumed to be correlative with the relative differences in temperature recorded on thermal infrared imagery, accordingly data on soil moisture, and related parameters, will be chosen for ground truth measurements.