GEOTHERMAL RESOURCE ASSESSMENT FOR THE STATE OF TEXAS

Status of Progress, November 1980

Final Report

Appendices E through H

by

C. M. Woodruff, Jr.
Principal Investigator

and

S. Christopher Caran, Christine Gever, Christopher D. Henry,
G. L. Macpherson, and Mary W. McBride

Prepared for
U.S. Department of Energy, Division of Geothermal Energy

Under Contract No. DE-AS07-79ID12057

March 1982

Bureau of Economic Geology
W. L. Fisher, Director
The University of Texas at Austin

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APPENDIX E

Lineaments Seen on 51 Landsat Images of Texas
and Adjacent Areas

in

GEOTHERMAL RESOURCE ASSESSMENT

FOR THE STATE OF TEXAS--

STATUS OF PROGRESS,

NOVEMBER 1980

Prepared for
U.S. Department of Energy, Division of Geothermal Energy
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INTRODUCTION

This appendix is a folio of maps showing lineaments perceived by the three authors on each of 51 Landsat images. The maps represent the boundaries of the images viewed (fig. E-1), and each image has a project-specific number and name (table E-1) for reference to the identifying and qualifying information given in Appendix F.

The maps were reduced from an original image-scale of 1:250,000. The 51 maps that compose this folio show only the boundaries of the images viewed, the major latitude/longitude tics where they intersect the image borders, and three types of lines representing lineaments perceived by each of us (fig. E-2). No traditional cartographic representation of cultural or natural features is shown on these maps because of difficulties in registering the map projections of Landsat features onto base maps of standard projection (*see* Appendix F, table F-2). This registry problem is being solved, and a composite map of these lineaments is in preparation for presentation at a scale of 1:1,000,000.

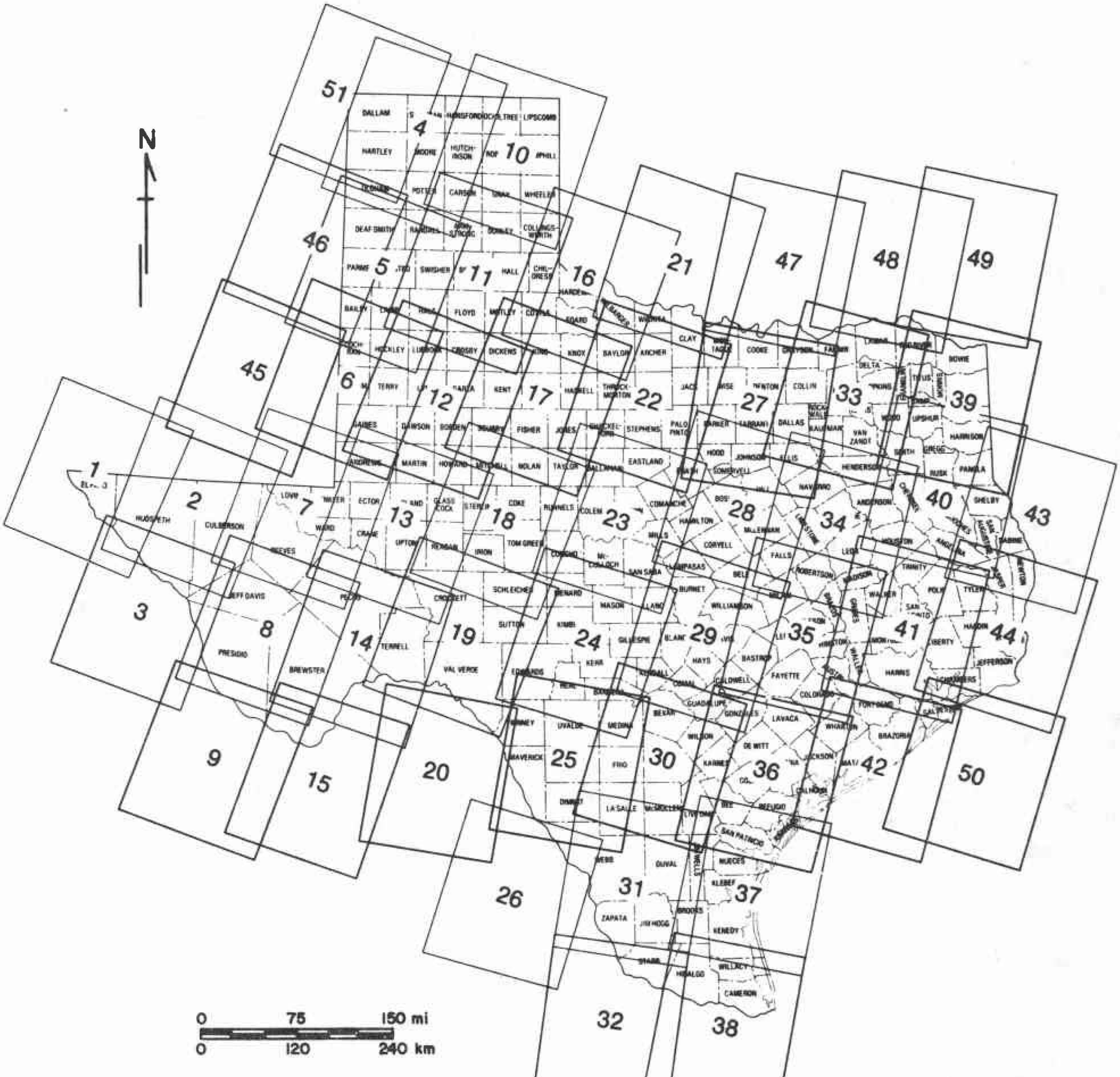


Figure E-1. Location map showing boundaries of the 51 Landsat images used in this study.

Table E-1. Project-specific identification numbers and names for Landsat scenes presented in folio and in Appendix F.

1	El Paso, Texas	27	Denton, Texas
2	Guadalupe Peak, Texas	28	Gatesville, Texas
3	Los Lamentos, Mexico	29	Marble Falls, Texas
4	Dalhart, Texas	30	Jourdanton, Texas
5	Muleshoe, Texas	31	Laredo, Texas
6	Hobbs, New Mexico	32	Rio Grande City, Texas
7	Pecos, Texas	33	Greenville, Texas
8	Alpine, Texas	34	Corsicana, Texas
9	Potrero del Llano, Mexico	35	Caldwell, Texas
10	Canadian, Texas	36	Victoria, Texas
11	Floydada, Texas	37	Corpus Christi, Texas
12	Post, Texas	38	Harlingen, Texas
13	Odessa, Texas	39	Texarkana, Texas
14	Sanderson, Texas	40	Lufkin, Texas
15	Santa Rosa, Mexico	41	Houston, Texas
16	Childress, Texas	42	Freeport, Texas
17	Aspermont, Texas	43	Natchitoches, Louisiana
18	San Angelo, Texas	44	Orange, Texas
19	Devil's River, Texas	45	Roswell, New Mexico
20	Nueva Rosita, Mexico	46	Fort Sumner, New Mexico
21	Lawton, Oklahoma	47	Ada, Oklahoma
22	Graham, Texas	48	Stanley, Oklahoma
23	Brownwood, Texas	49	Mena, Arkansas
24	Junction, Texas	50	Off Galveston (Gulf of Mexico)
25	Crystal City, Texas	51	Mosquero, New Mexico
26	Don Martin, Mexico		

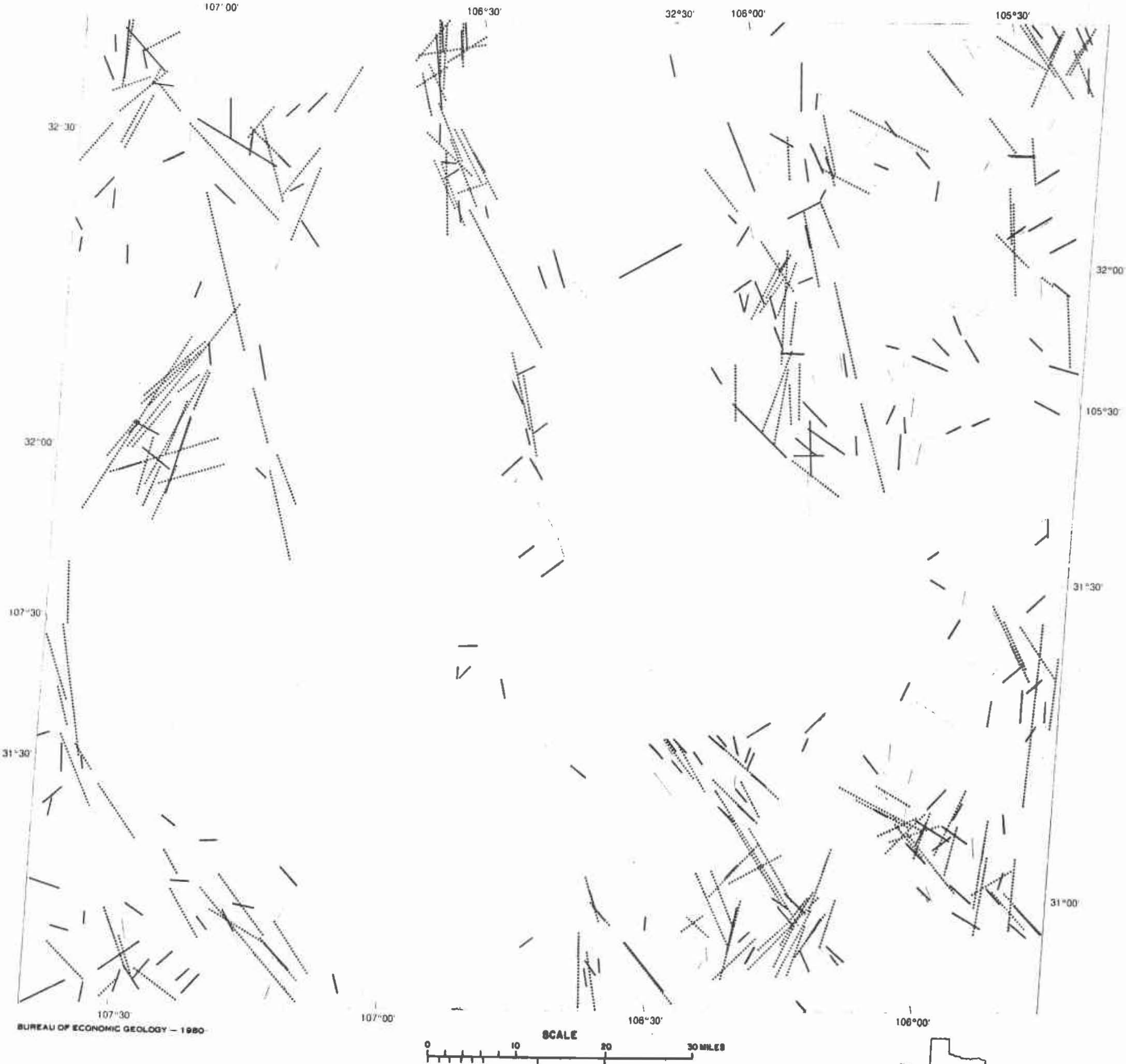
EXPLANATION

——— Person 1

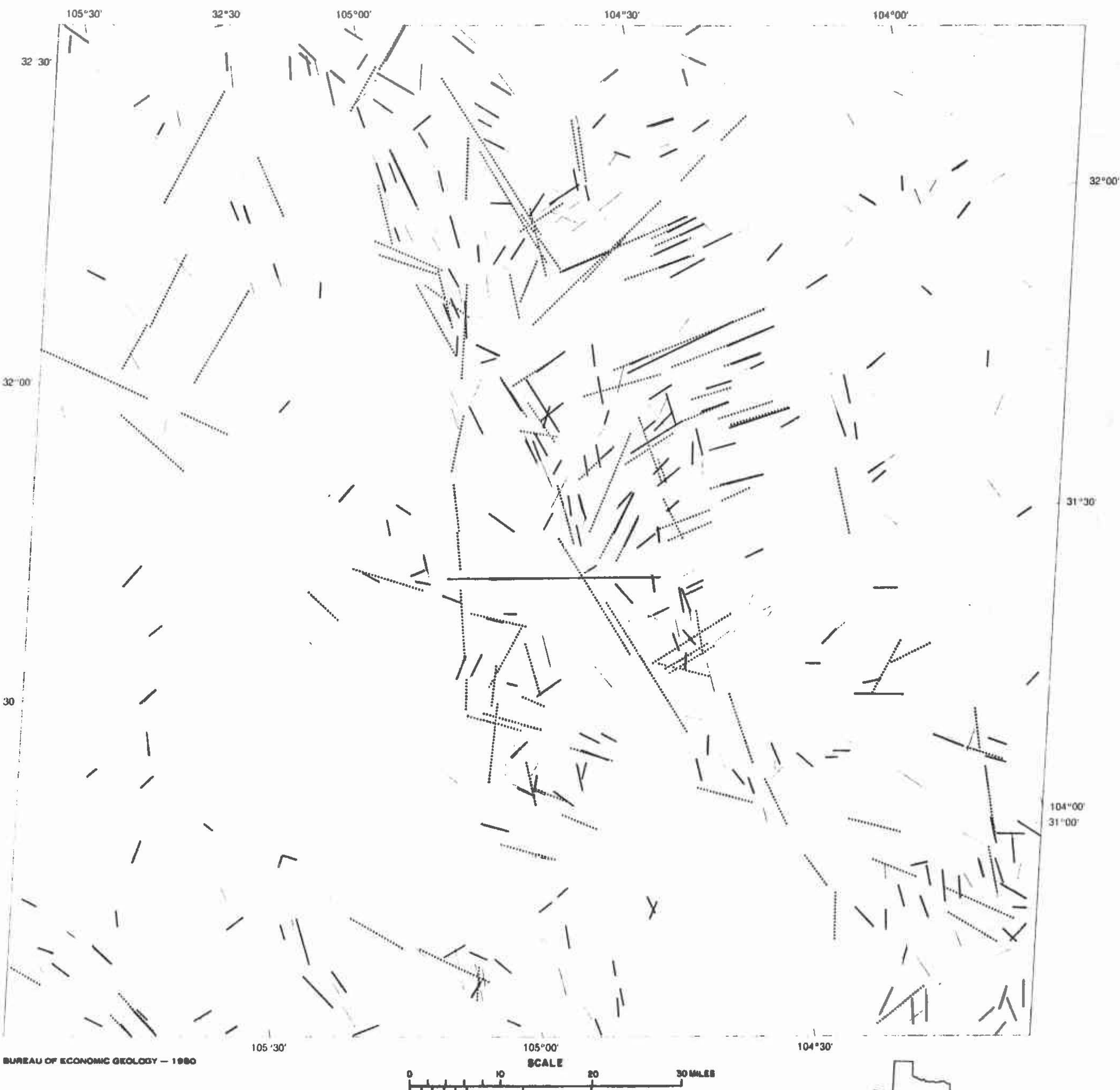
··········· Person 2

~~~~~~~~ Person 3

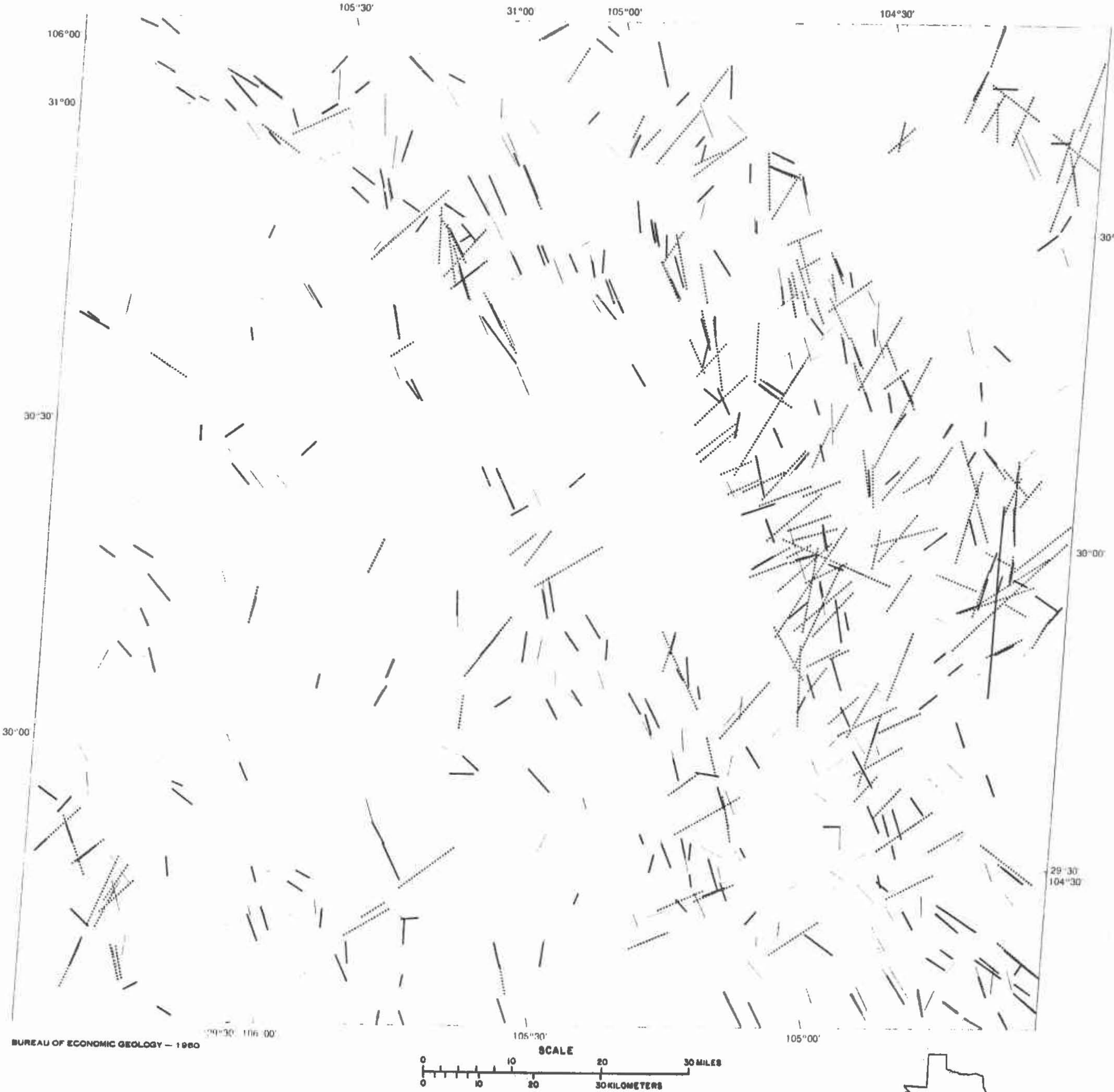
Figure E-2. "Signatures" denoting lineaments perceived by each of the three authors as shown on the 51 maps contained in this folio. "Person 1" is Woodruff; "Person 2" is Garan; "Person 3" is Thompson (except for scenes 23, 24, 25, 28, 29, and 30, in which "Person 3" is Gary E. Smith).
~~~~~~~~



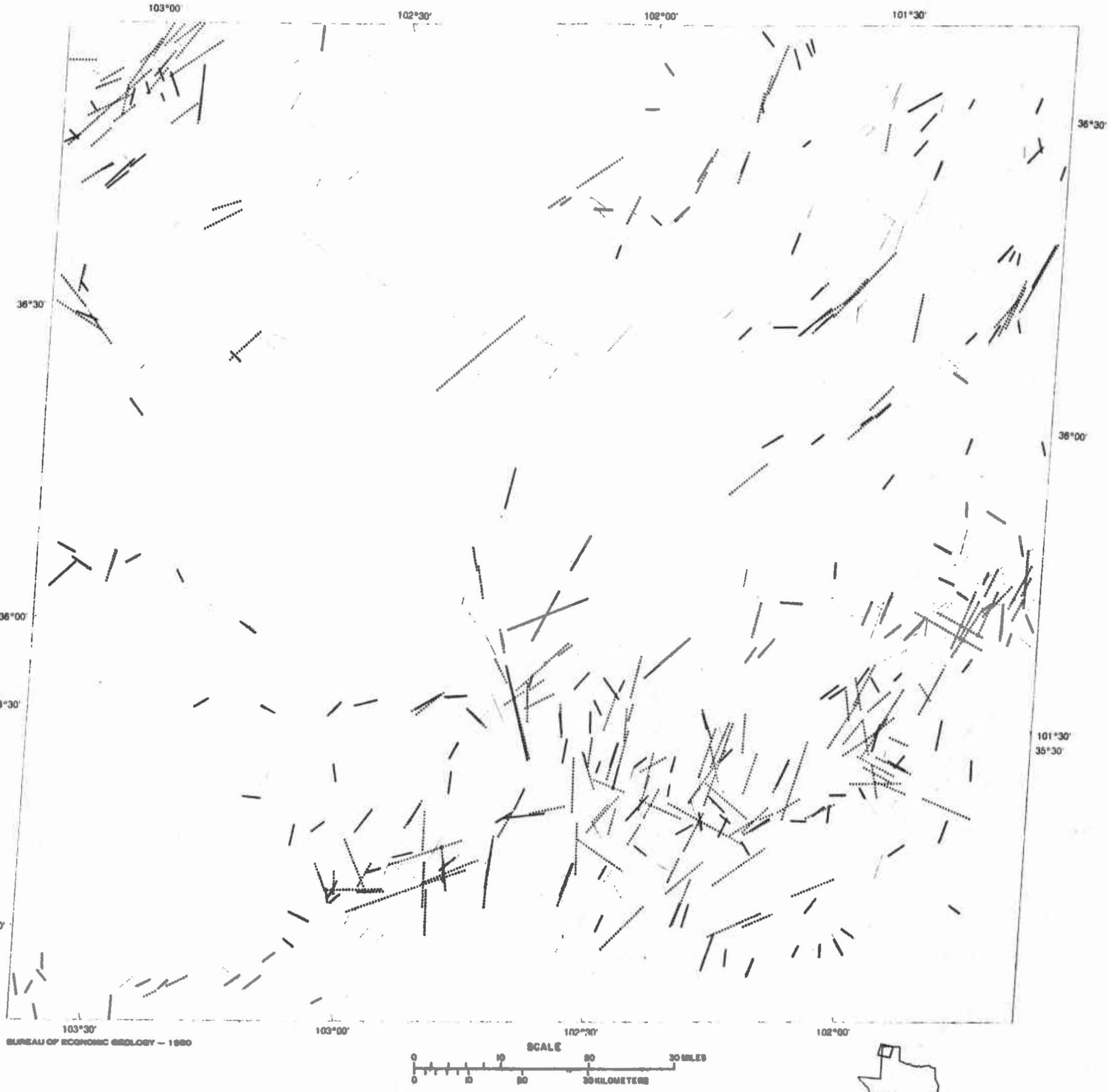
SHEET 1 — EL PASO, TEXAS



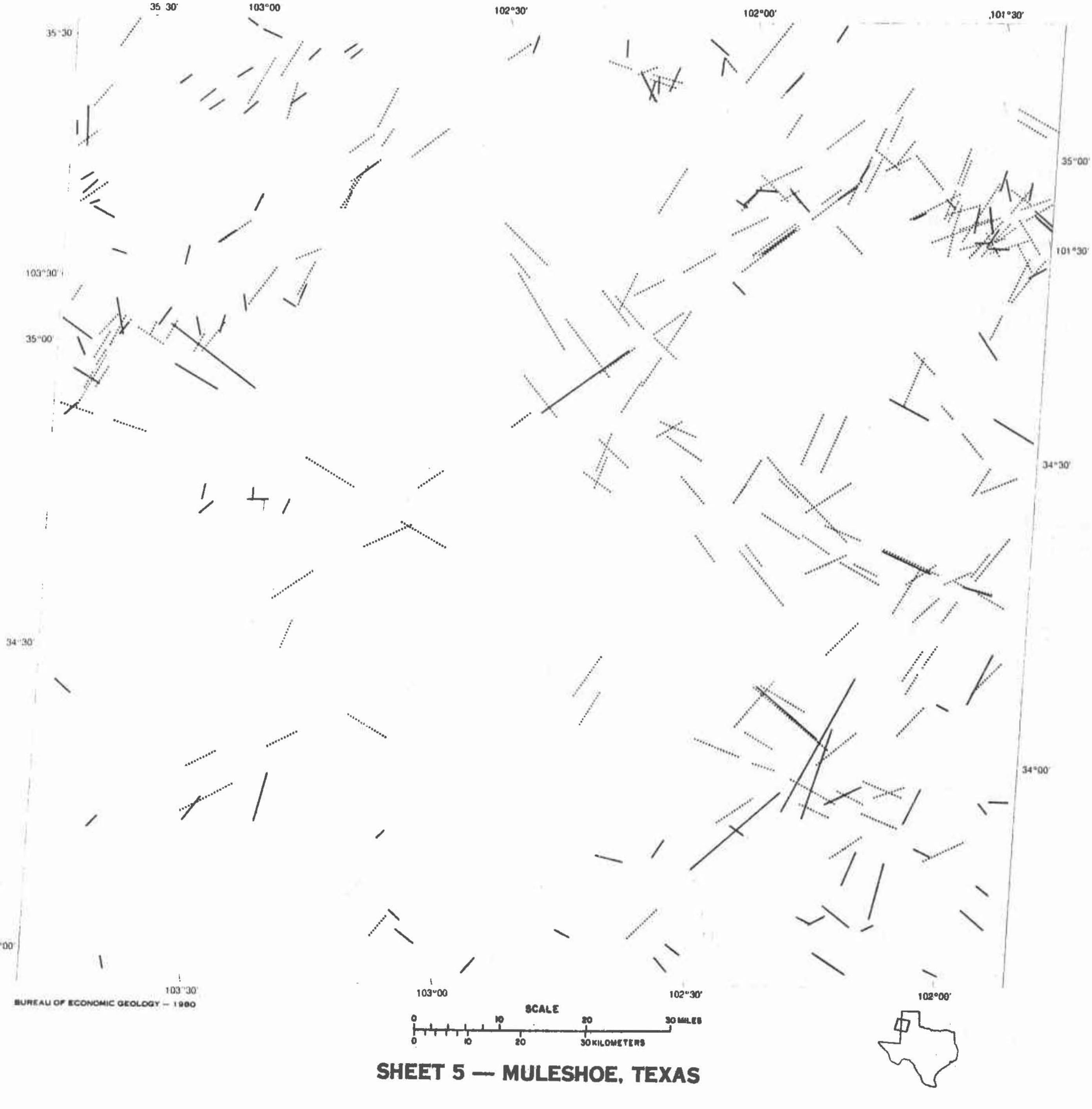
SHEET 2 — GUADALUPE PEAK, TEXAS



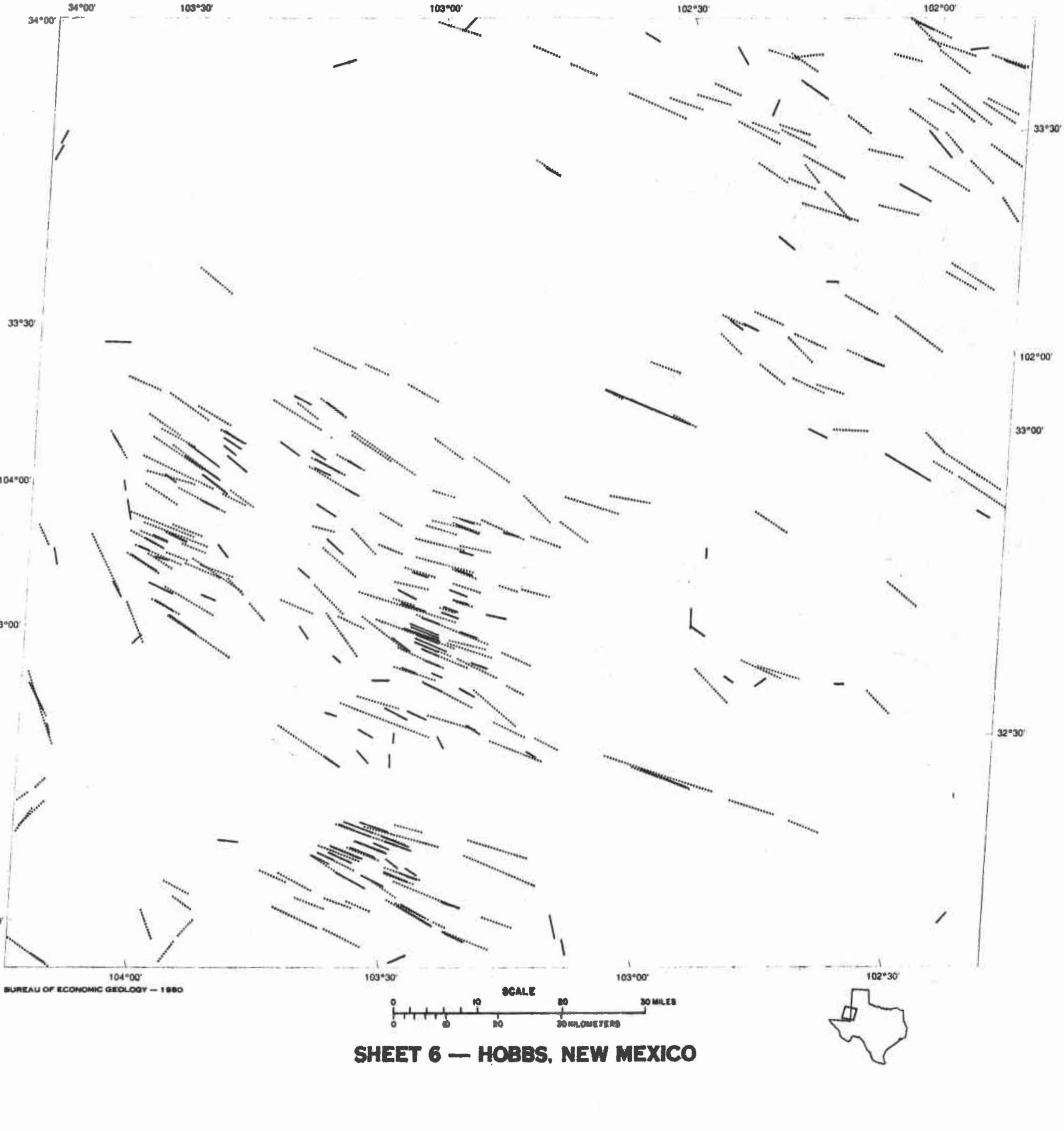
SHEET 3 — LOS LAMENTOS, MEXICO



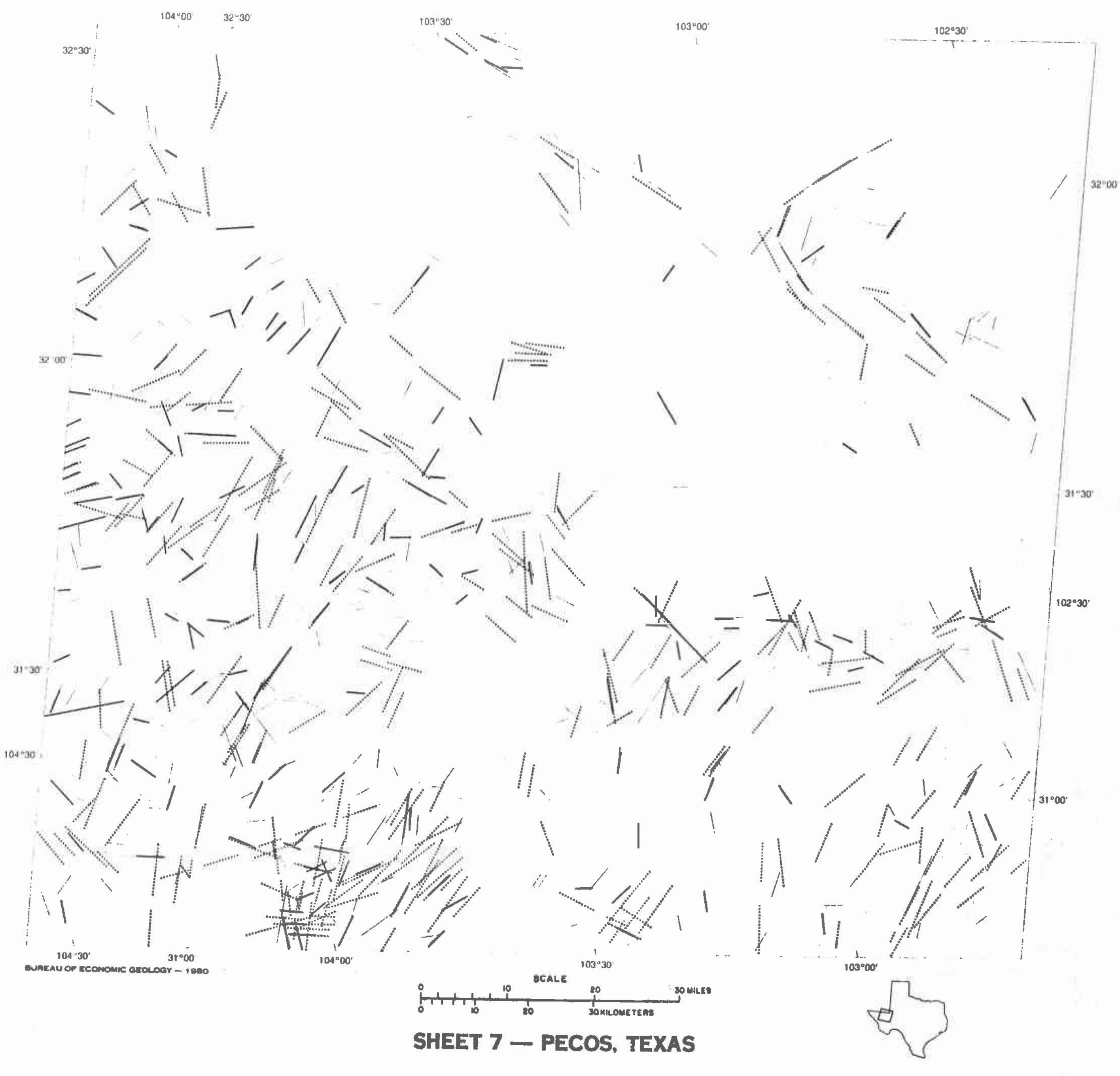
SHEET 4 — DALHART, TEXAS



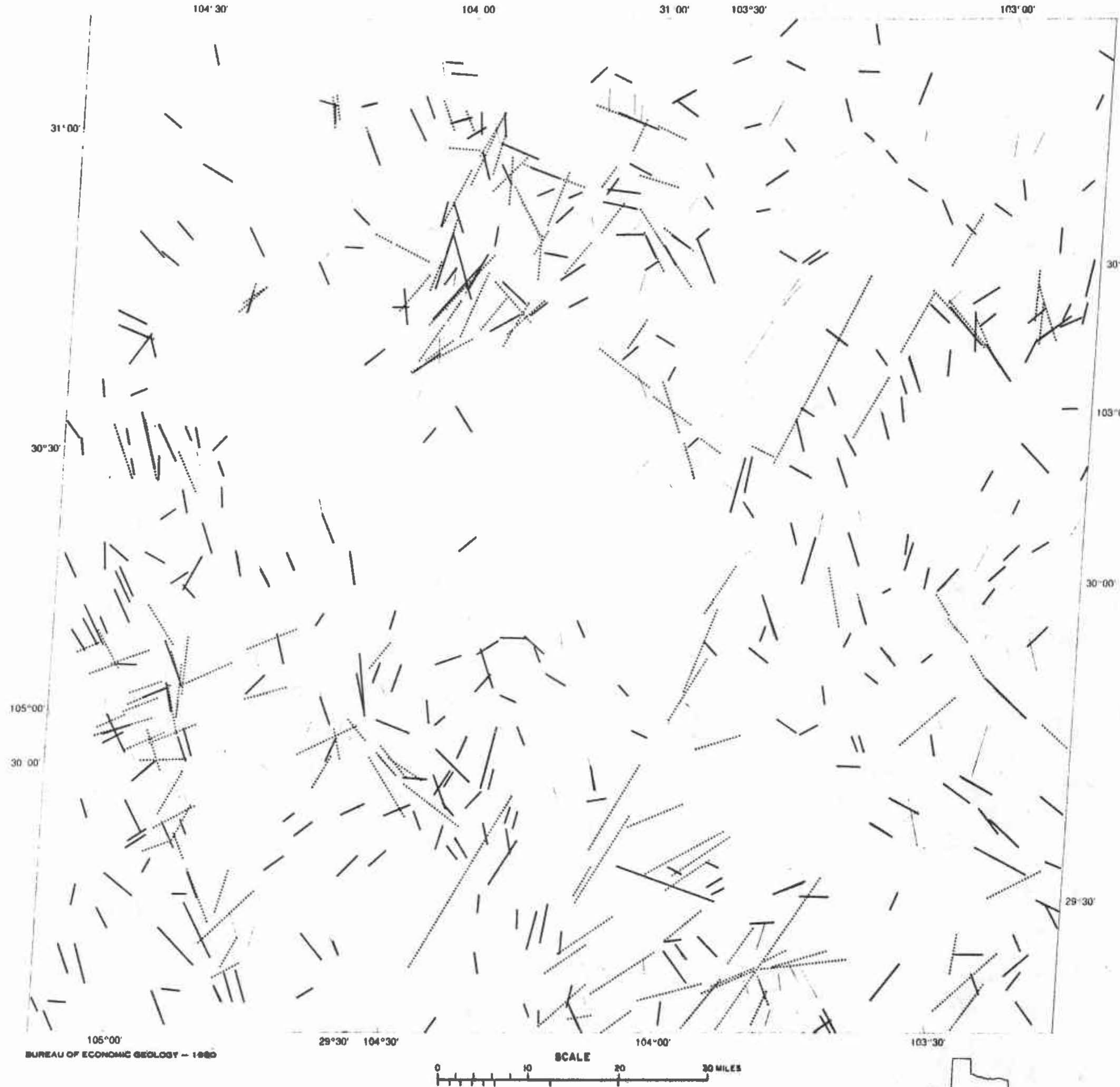
SHEET 5 — MULESHOE, TEXAS



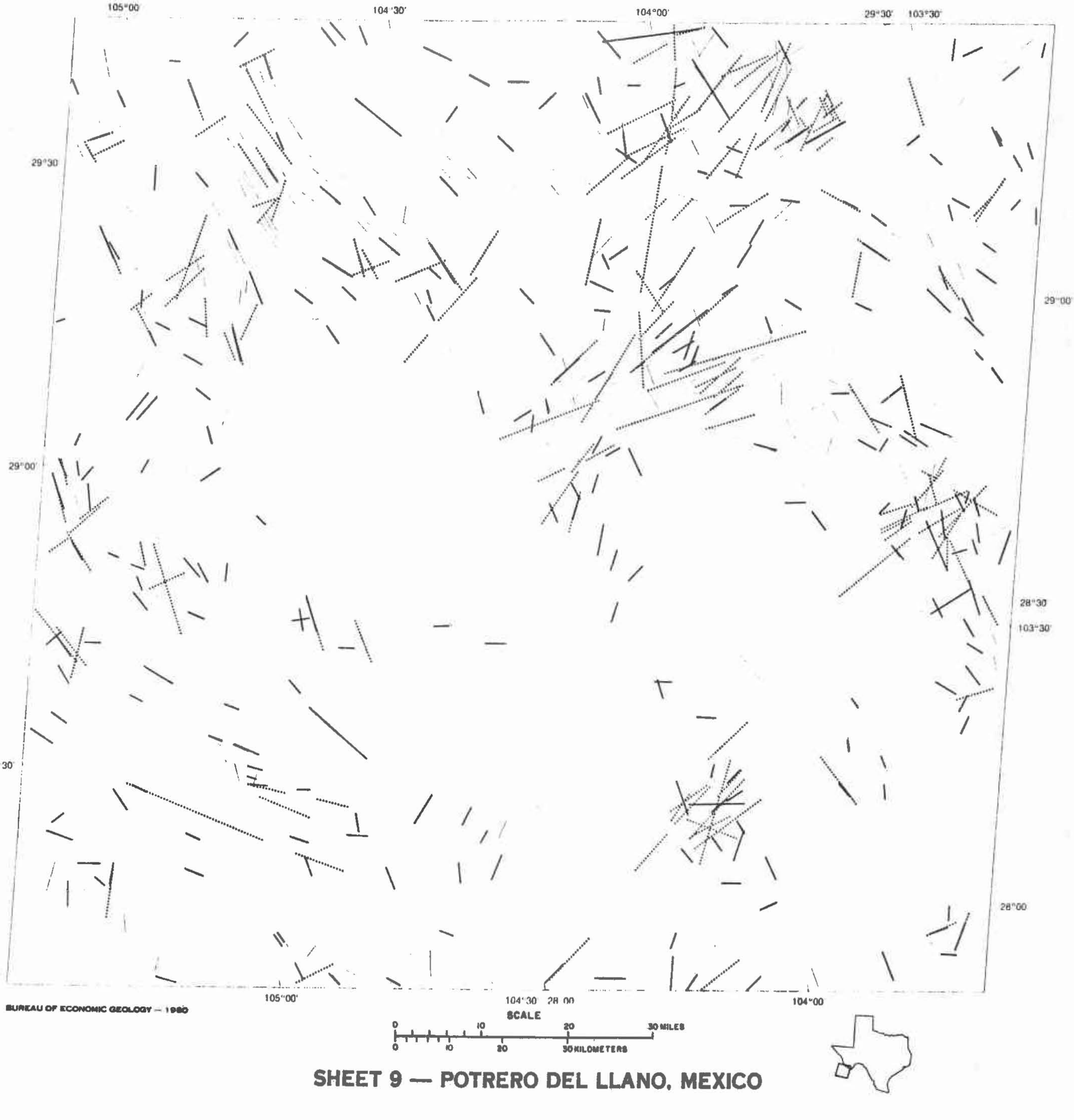
SHEET 6 — HOBBS, NEW MEXICO



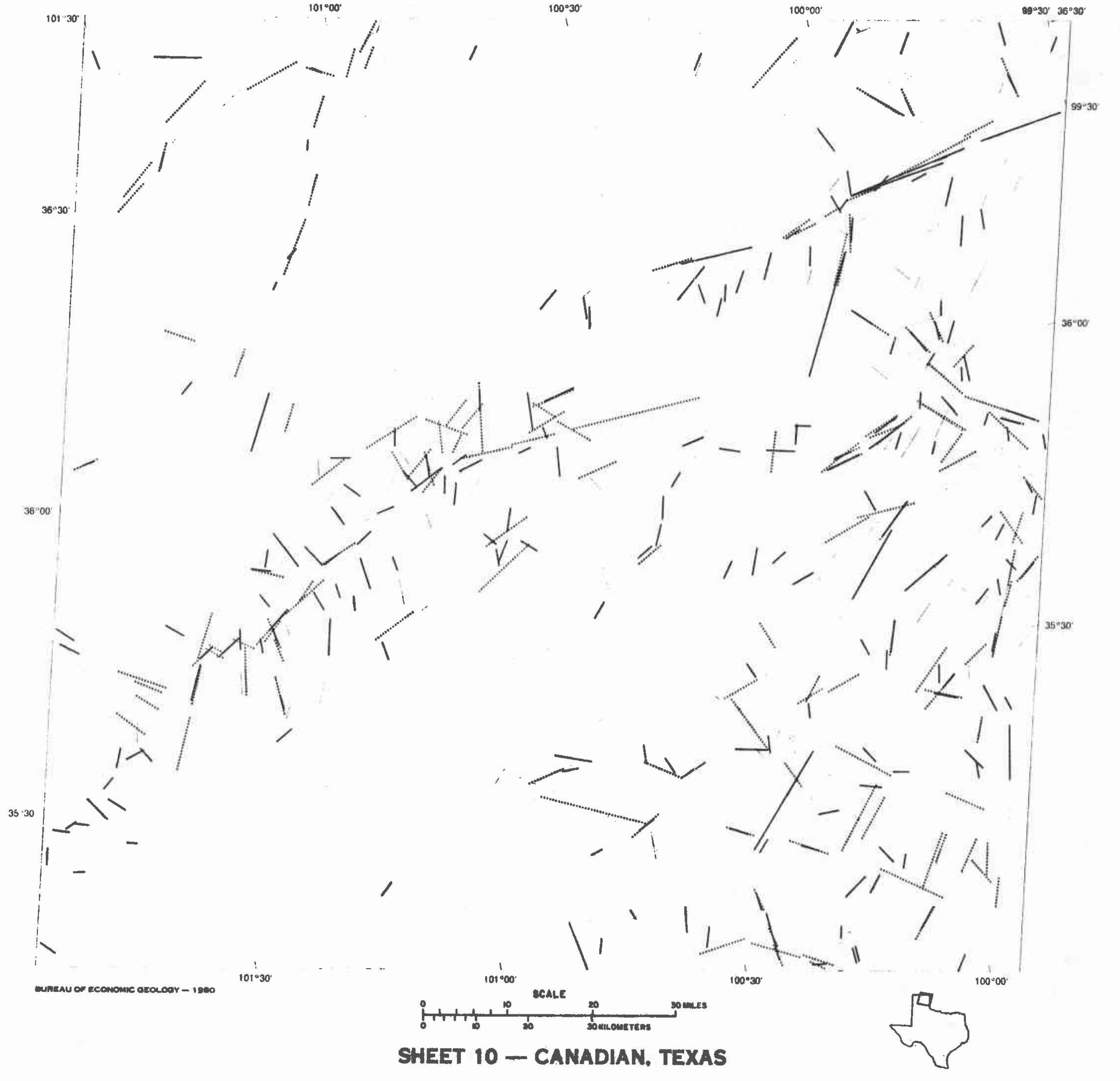
SHEET 7 — PECOS, TEXAS



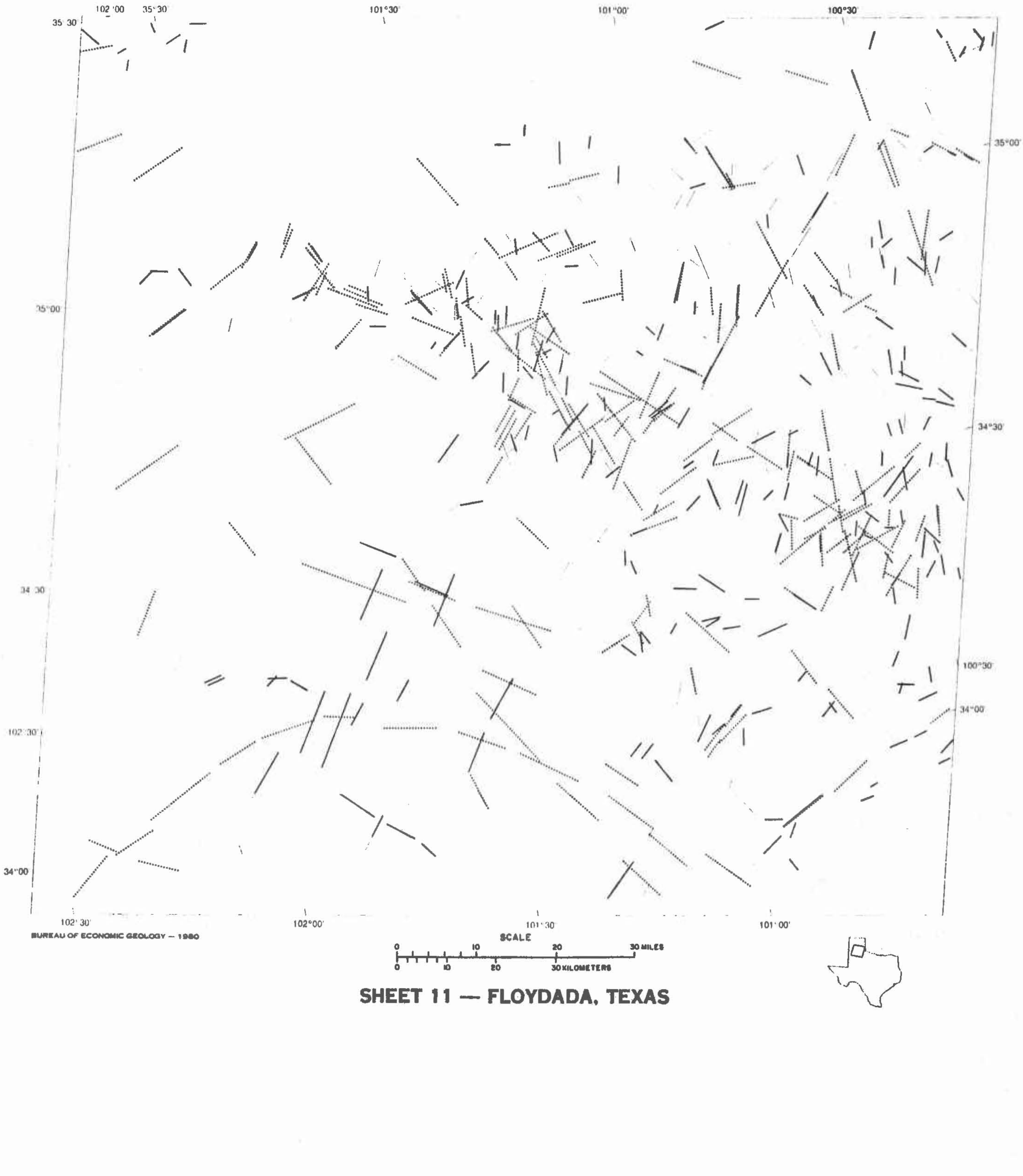
SHEET 8 — ALPINE, TEXAS



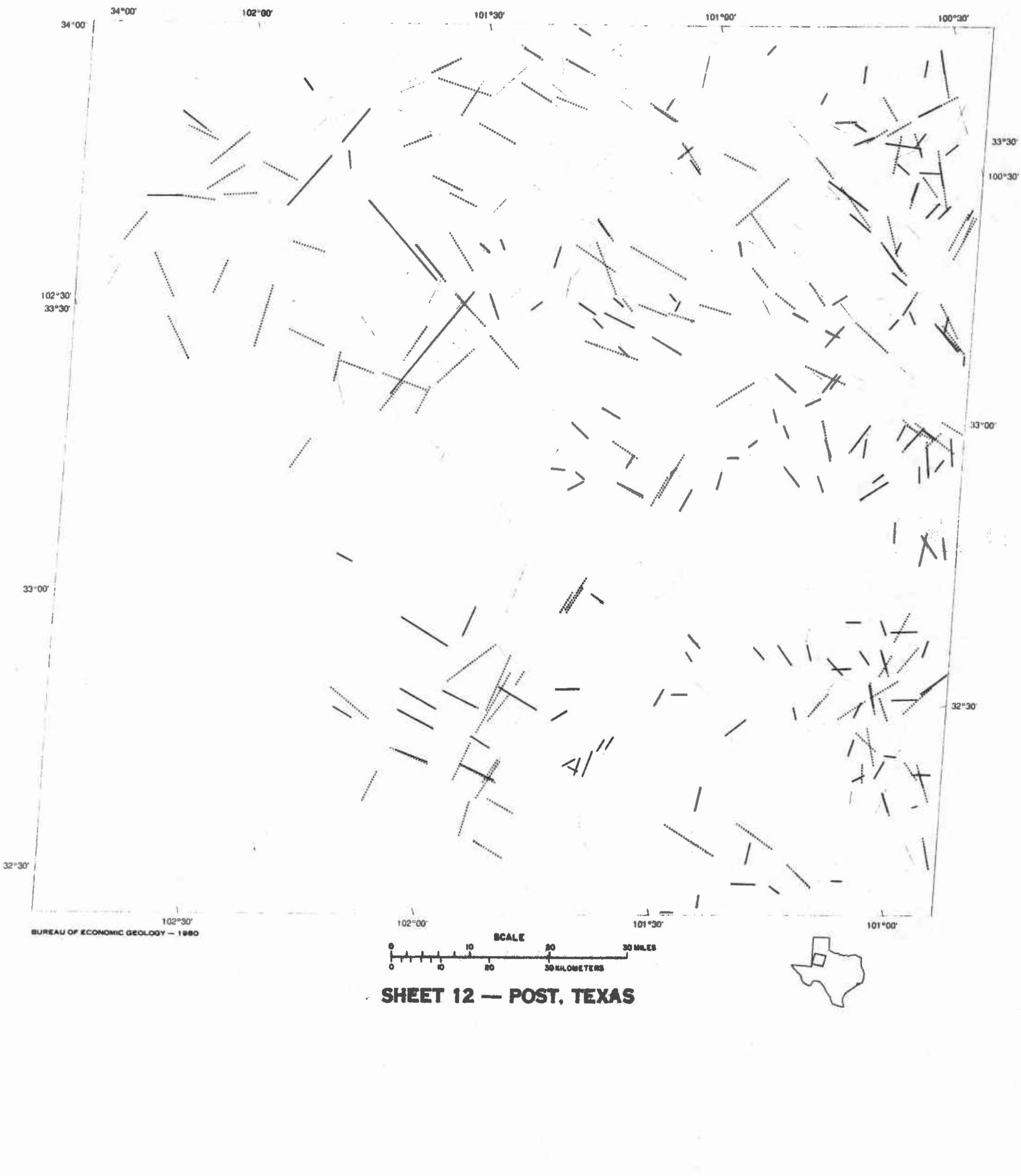
SHEET 9 — POTRERO DEL LLANO, MEXICO



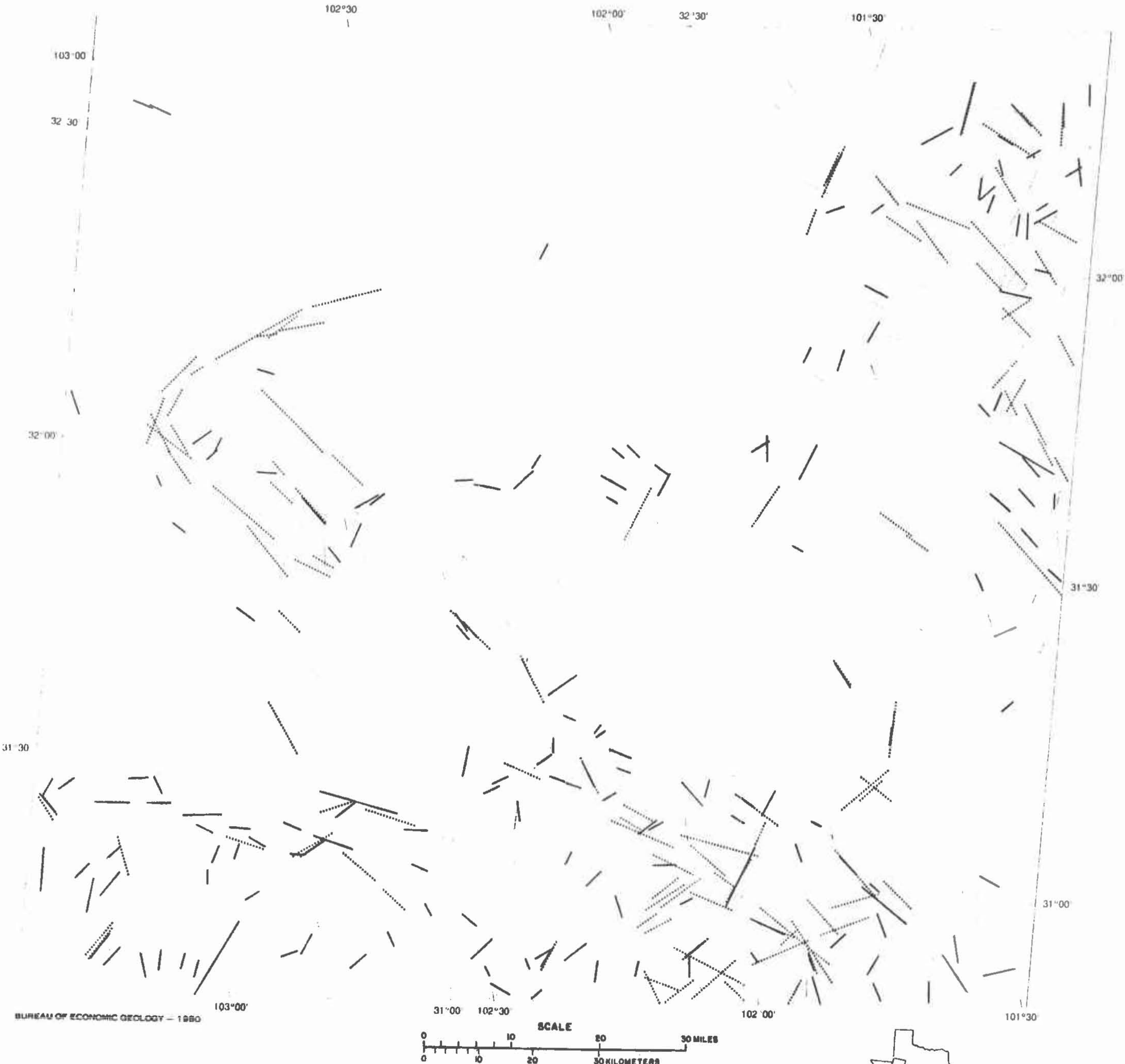
SHEET 10 — CANADIAN, TEXAS

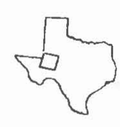


SHEET 11 — FLOYDADA, TEXAS

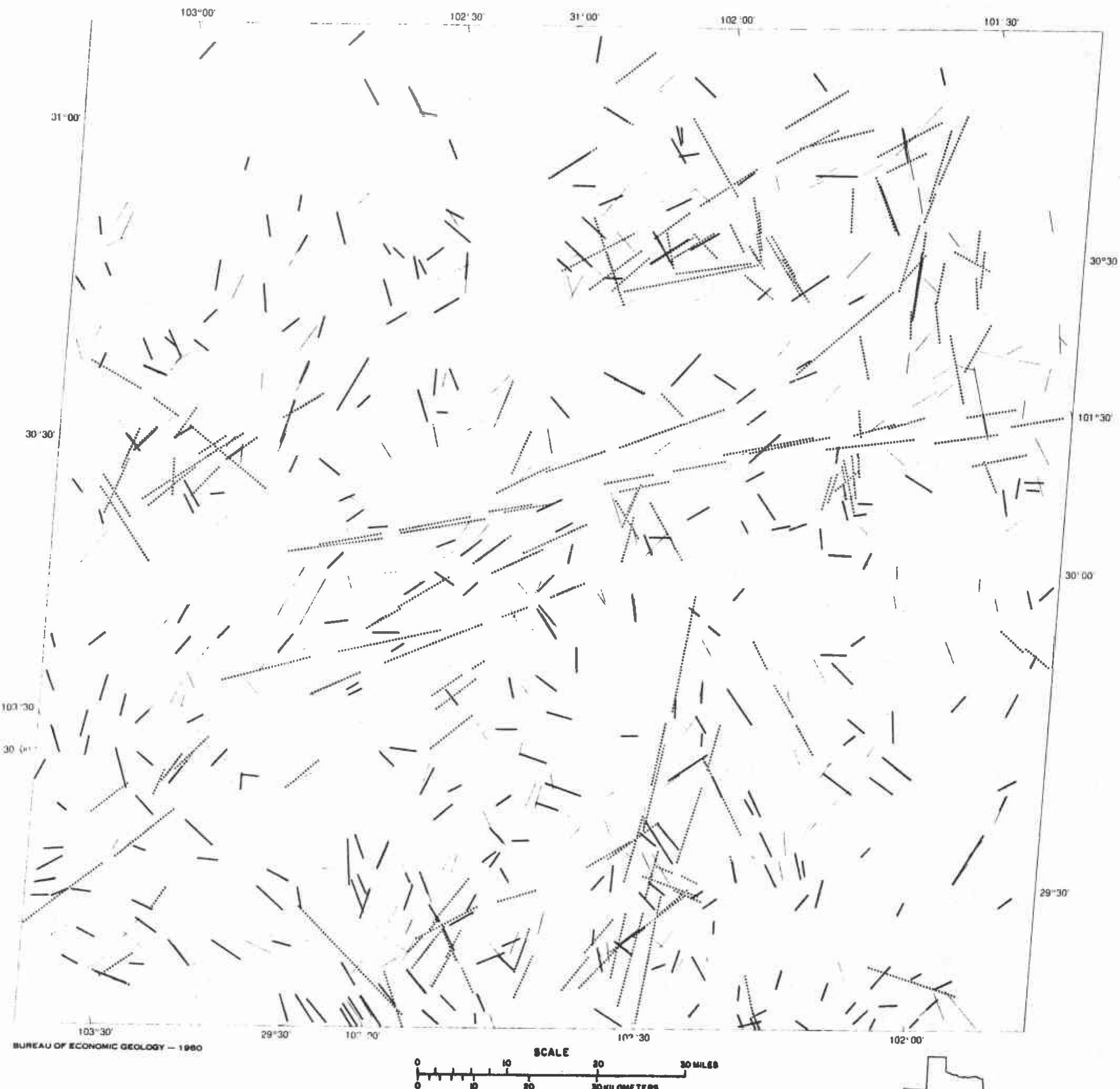


SHEET 12 — POST, TEXAS

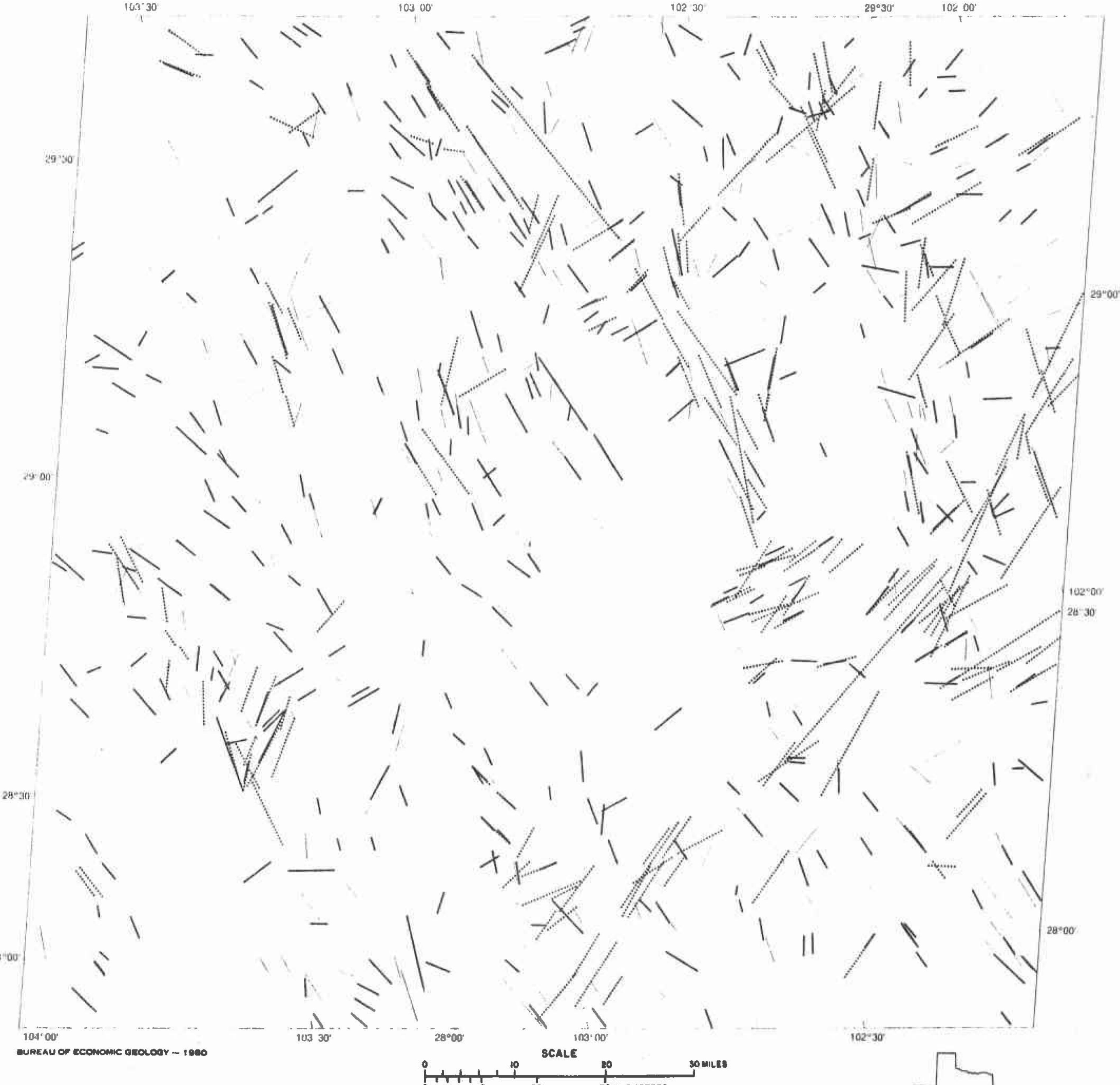




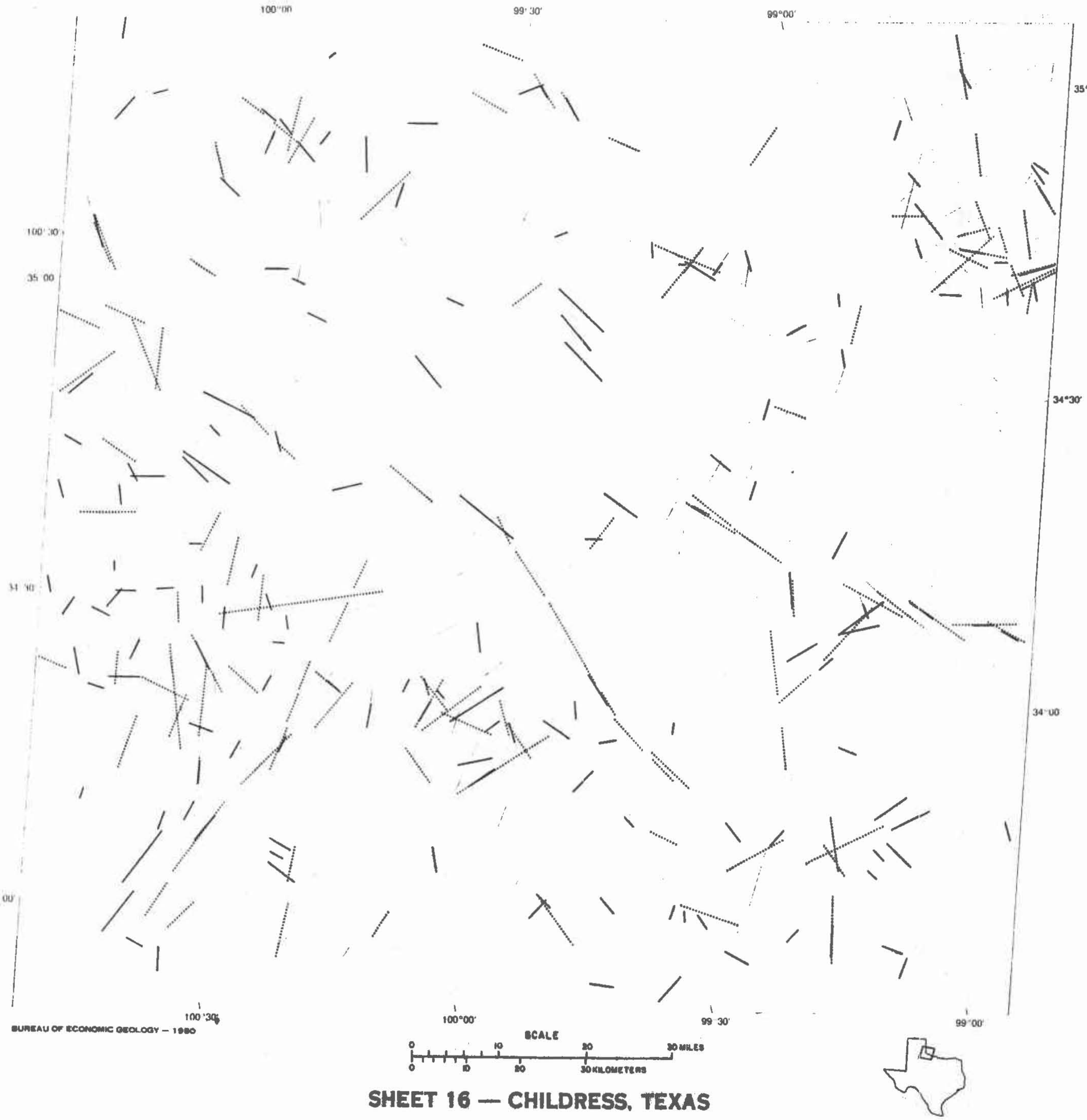
SHEET 13 — ODESSA, TEXAS



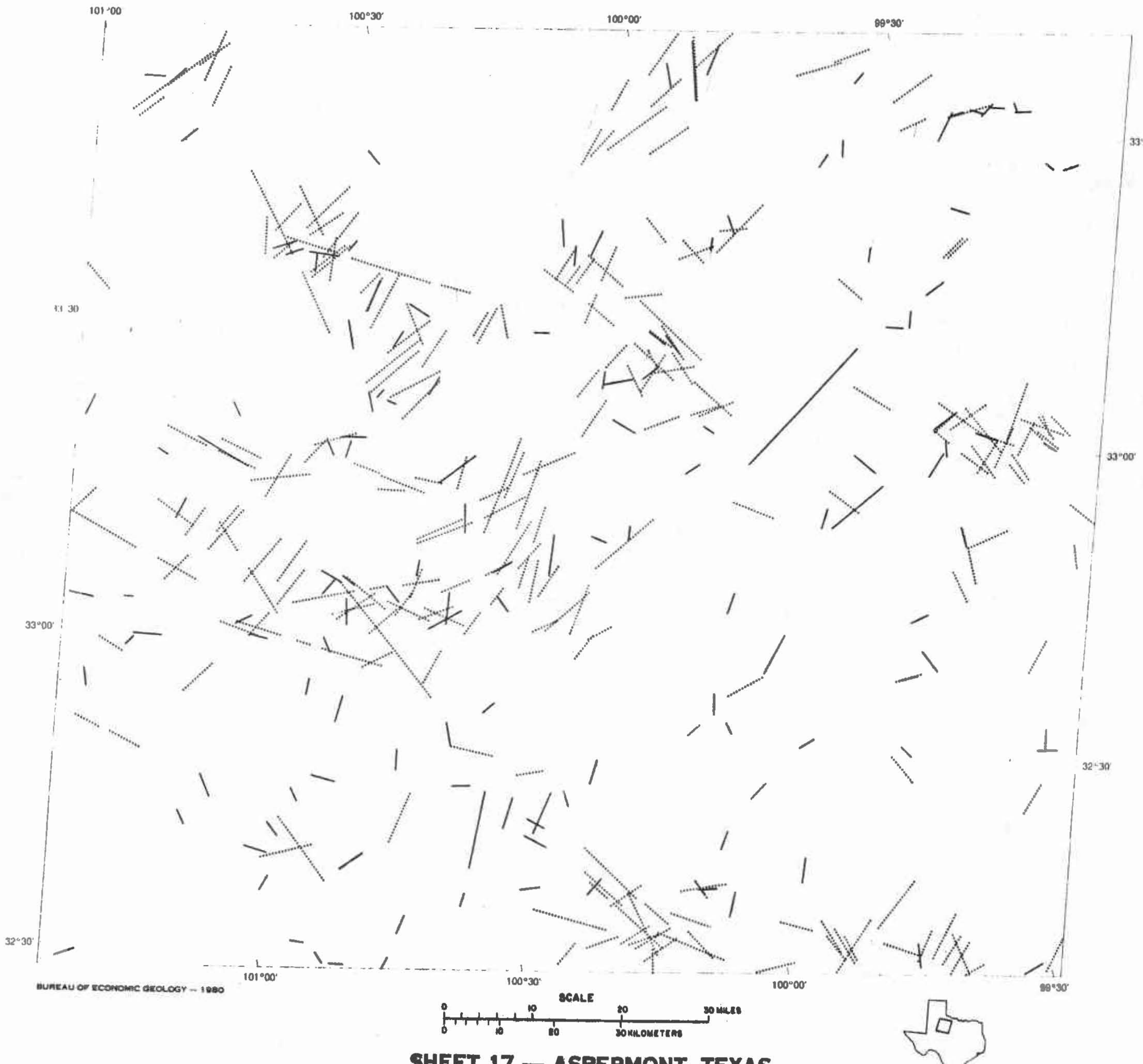
SHEET 14 — SANDERSON, TEXAS



SHEET 15 — SANTA ROSA, MEXICO



SHEET 16 — CHILDRESS, TEXAS



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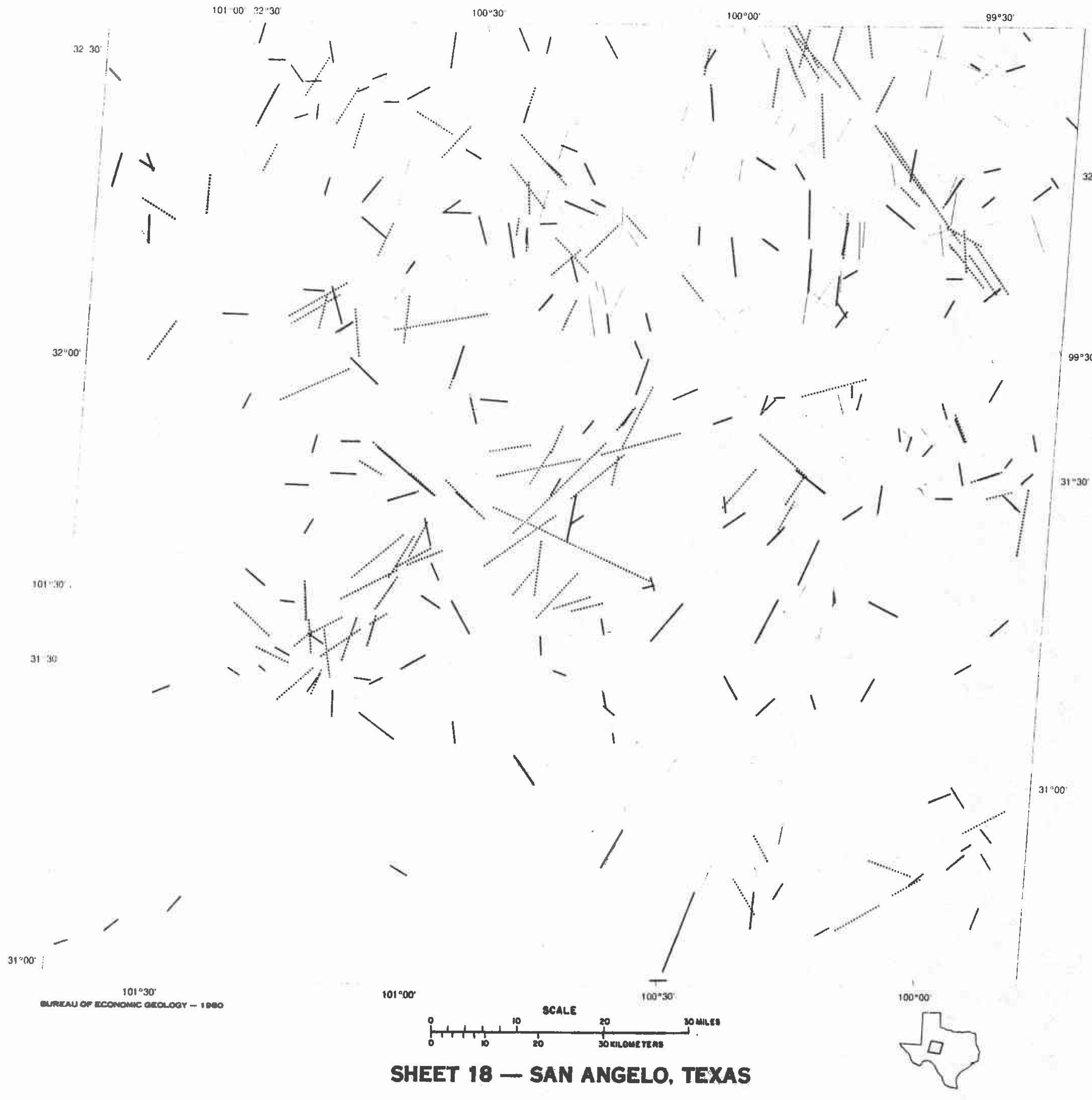
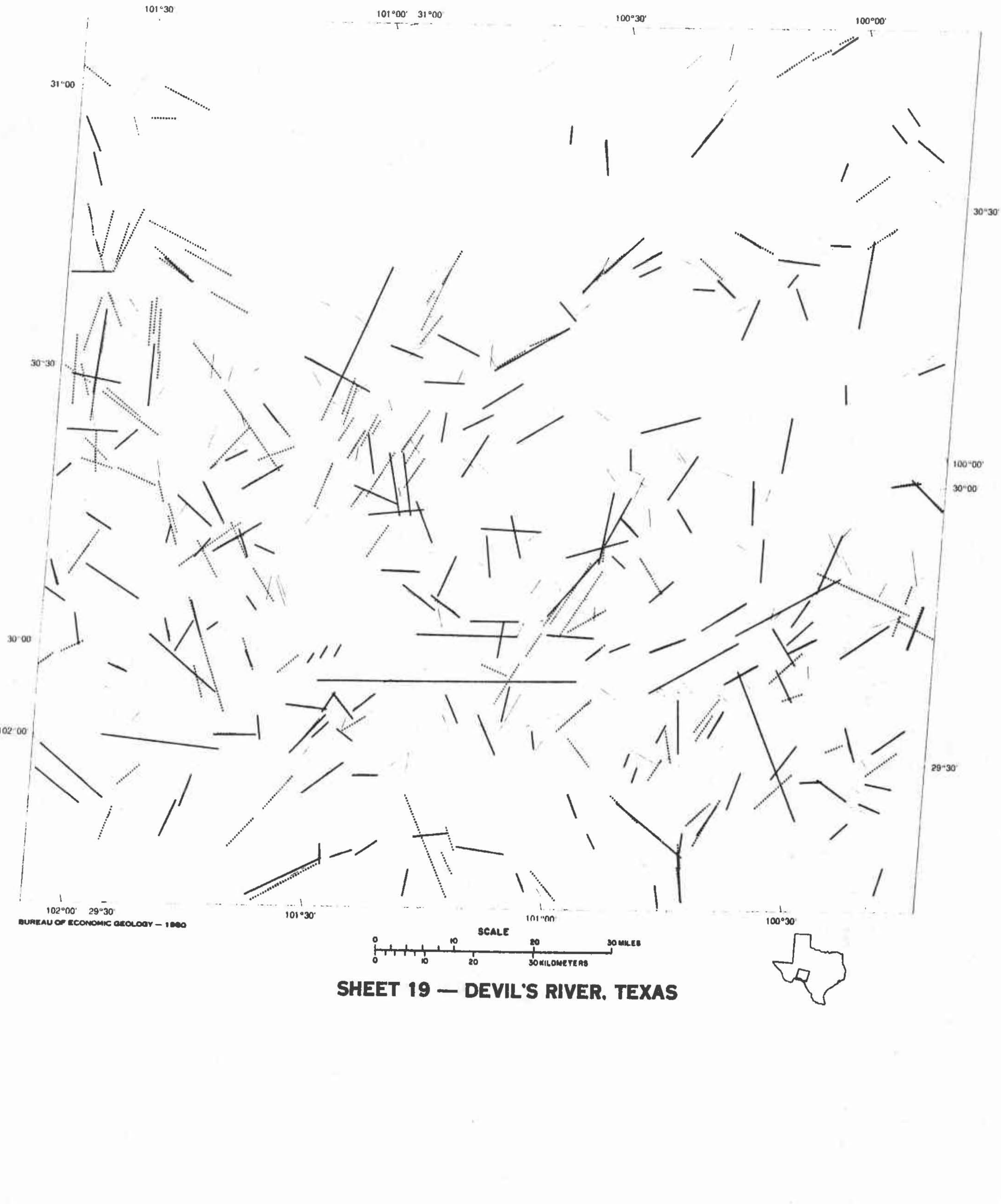
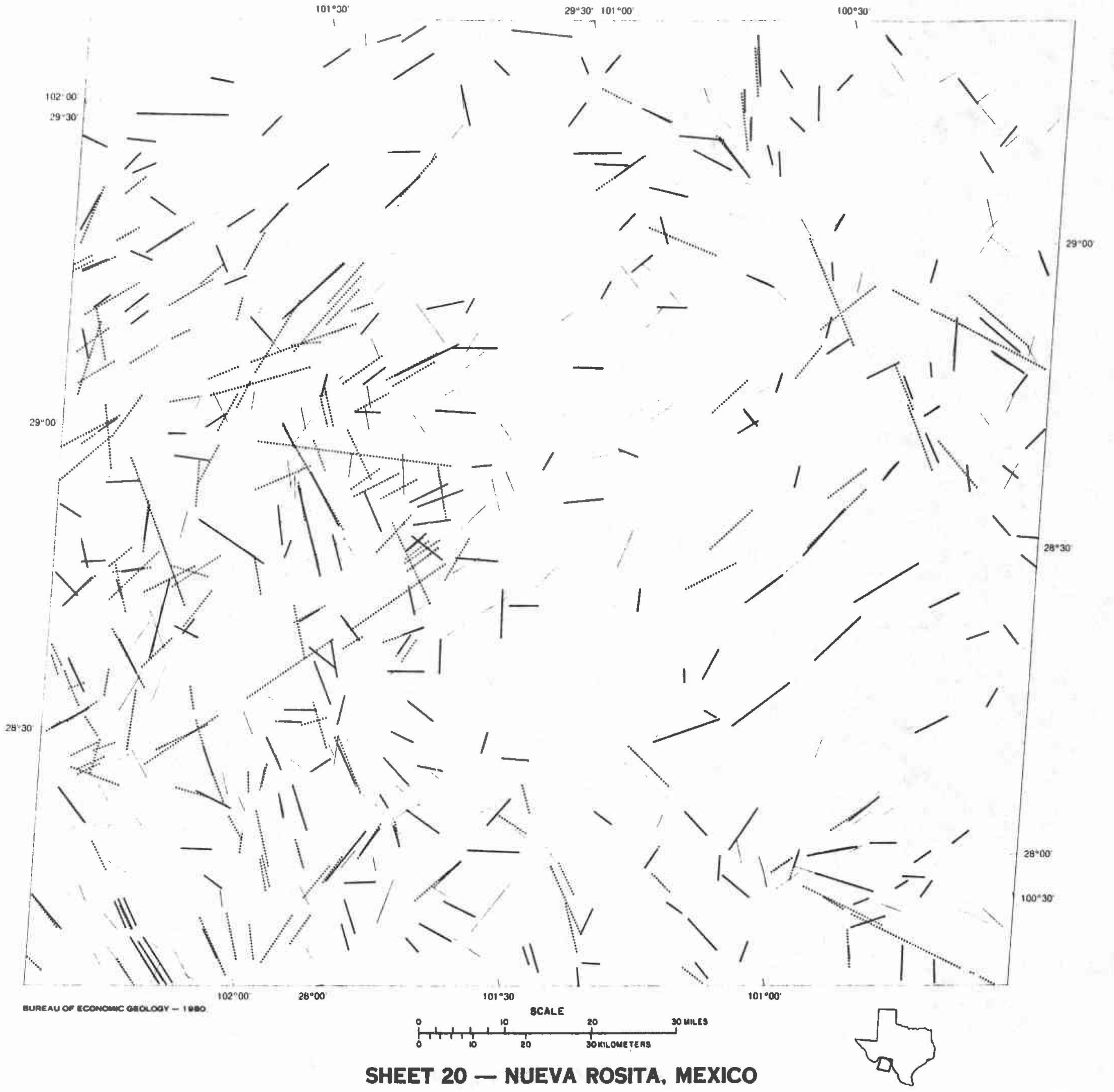


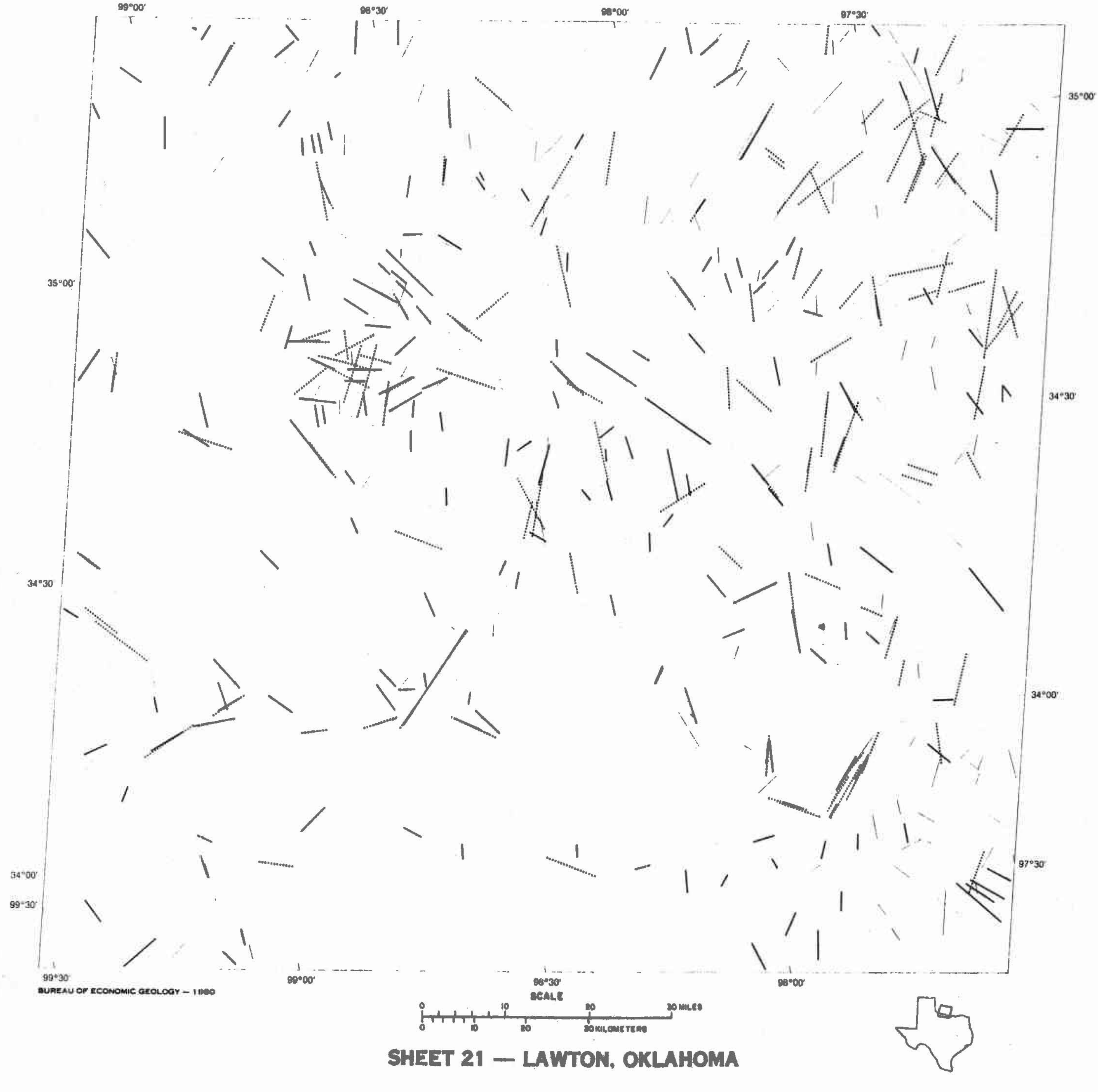
SHEET 18 — SAN ANGELO, TEXAS



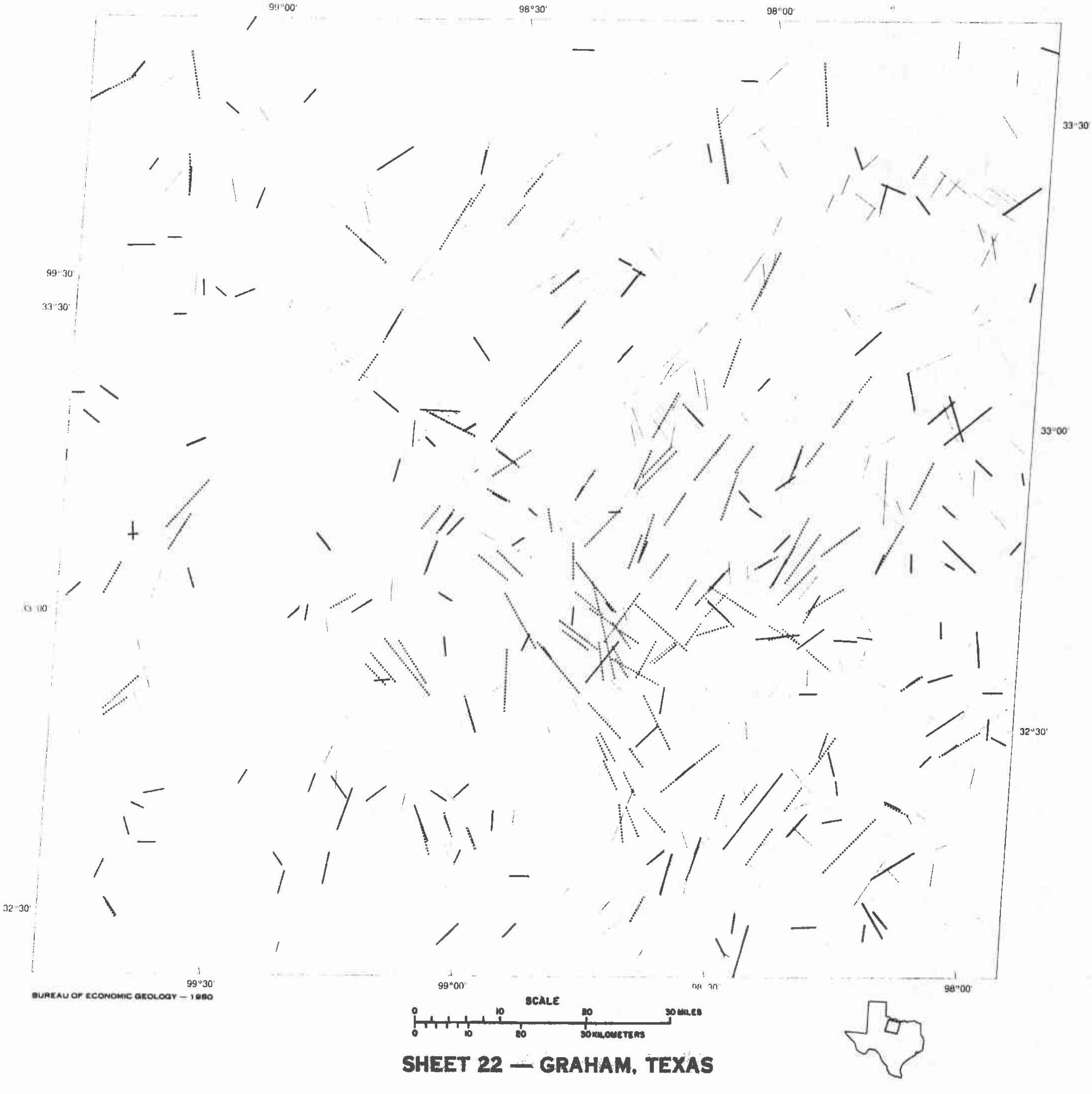
SHEET 19 — DEVIL'S RIVER, TEXAS



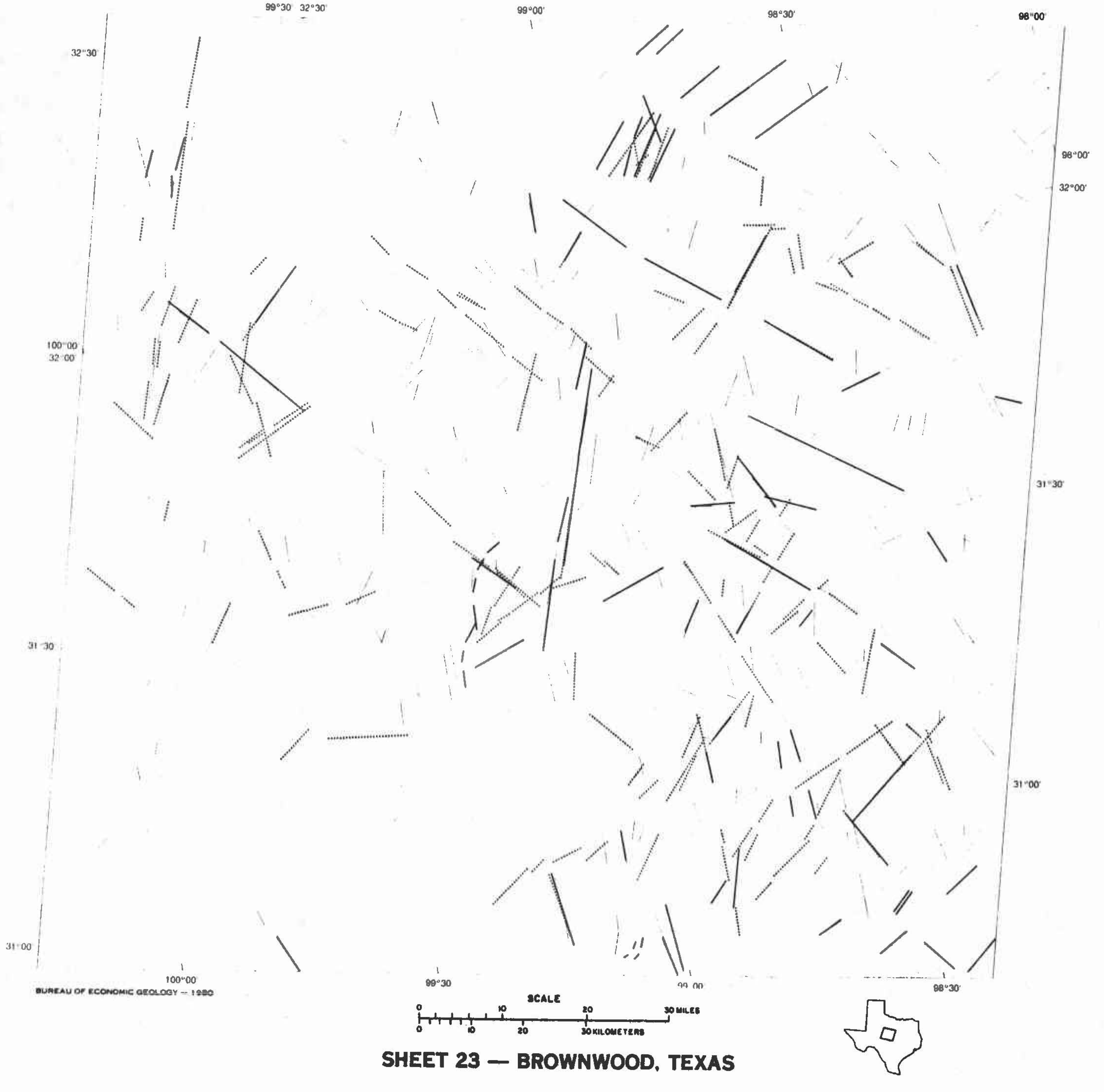
SHEET 20 — NUEVA ROSITA, MEXICO



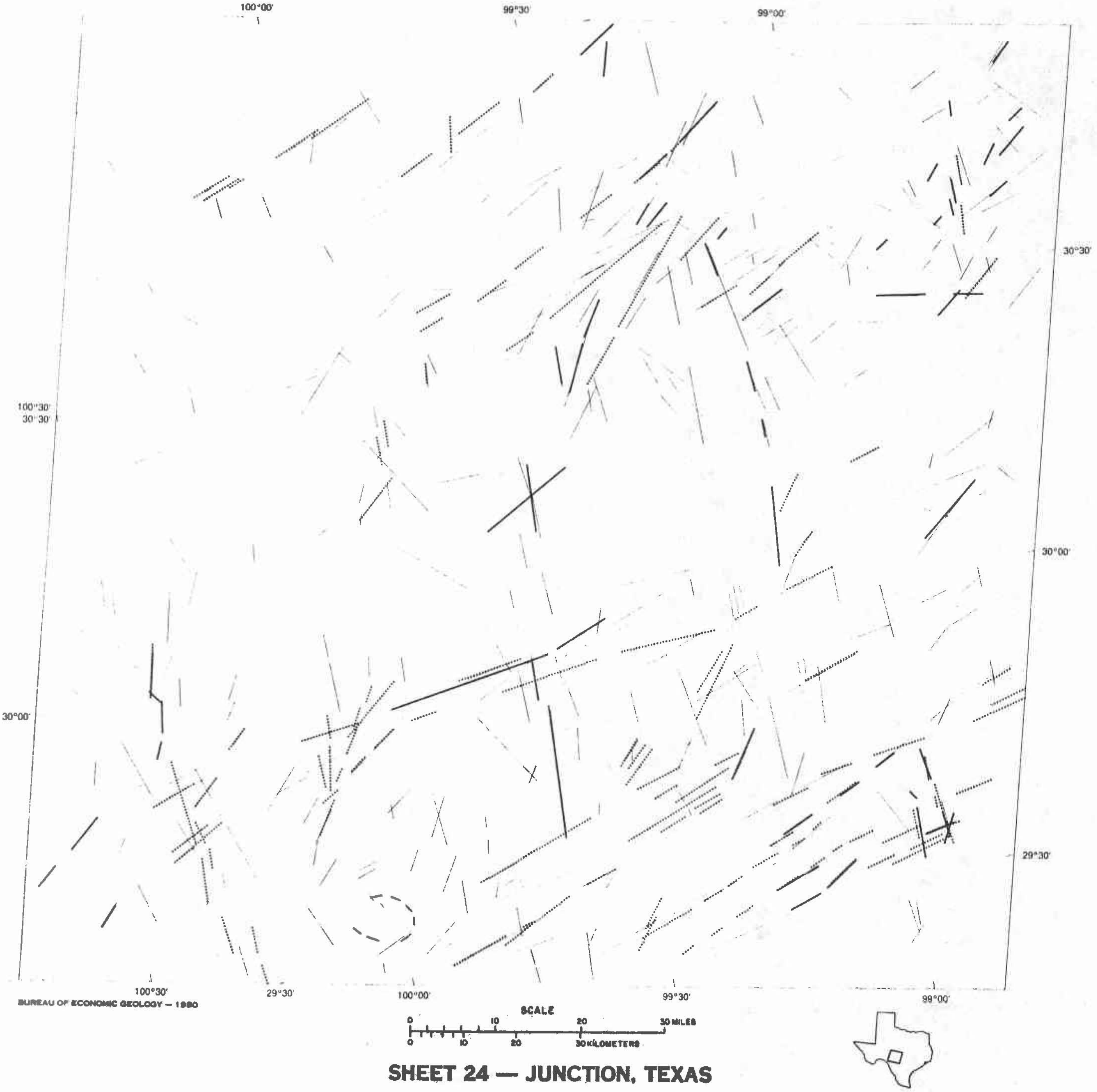
SHEET 21 — LAWTON, OKLAHOMA



SHEET 22 — GRAHAM, TEXAS



SHEET 23 — BROWNWOOD, TEXAS



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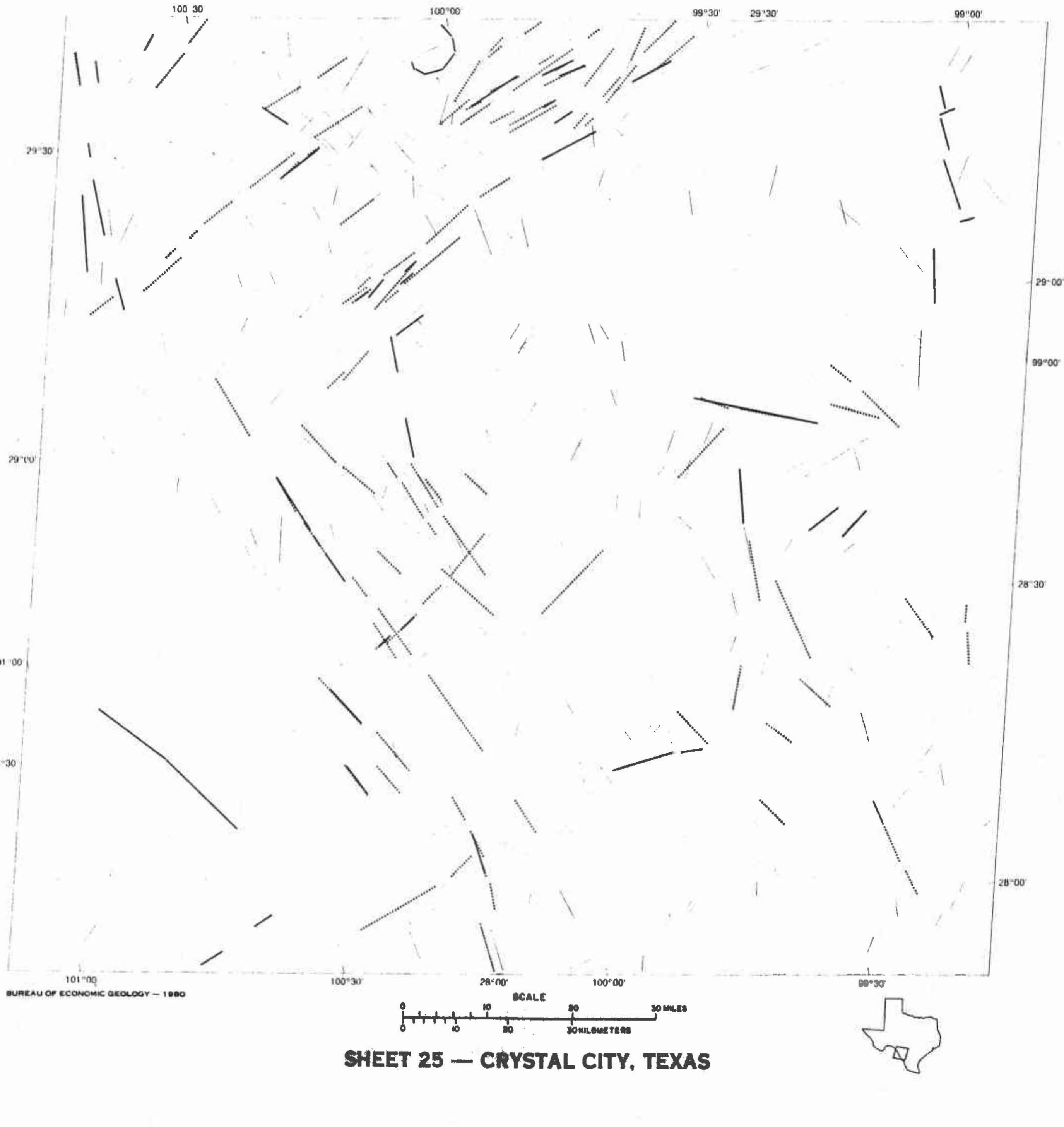
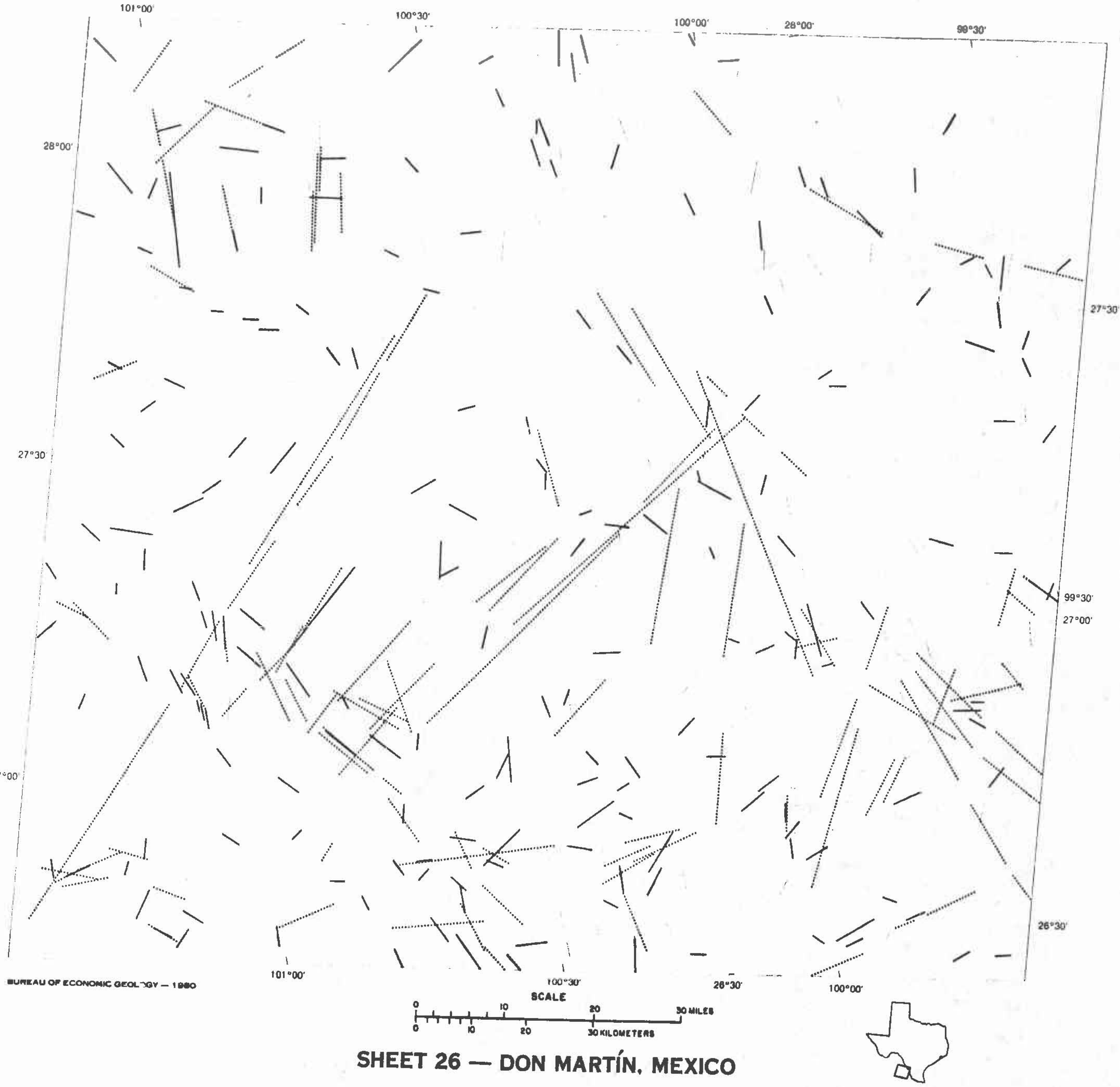
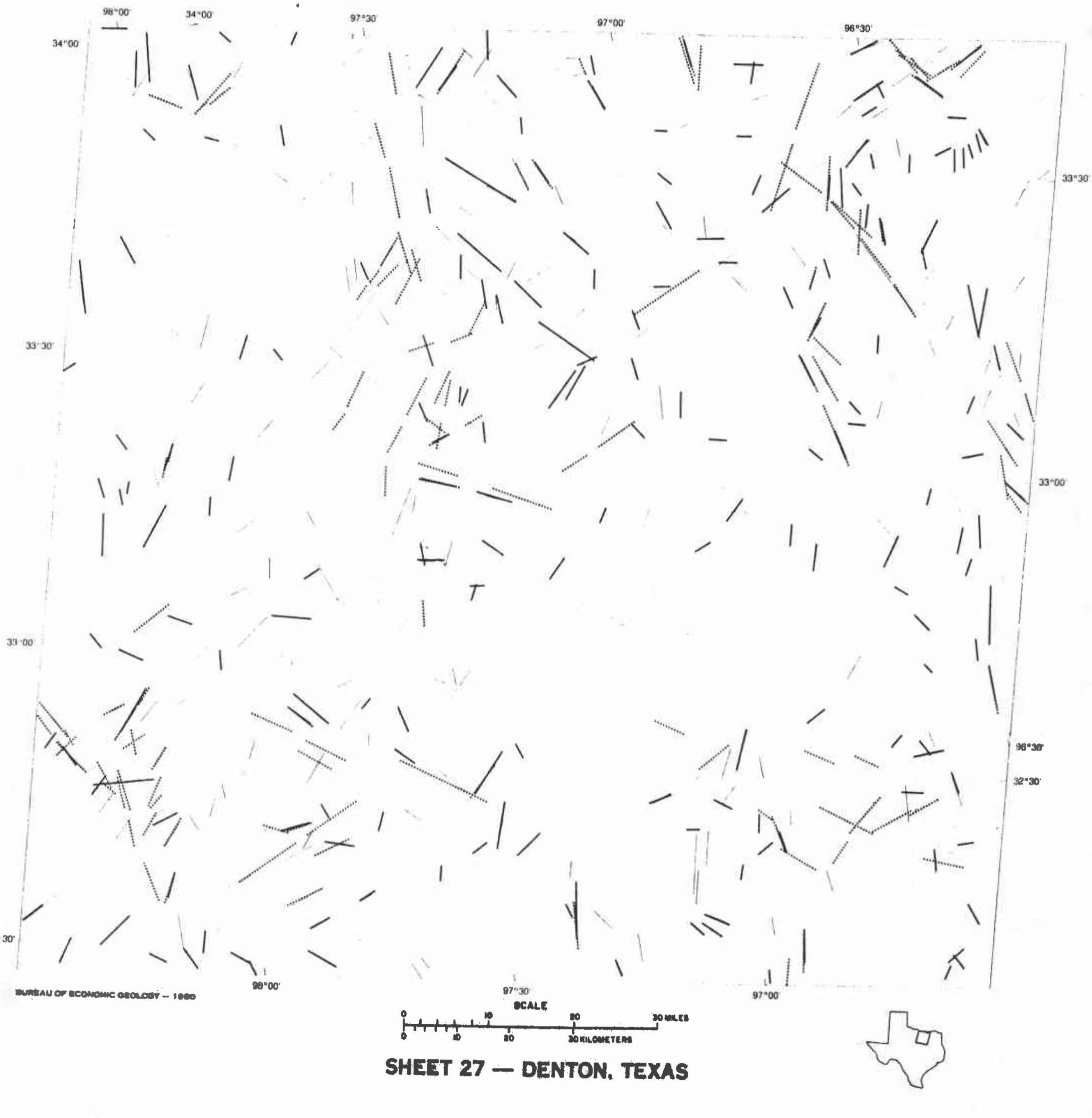


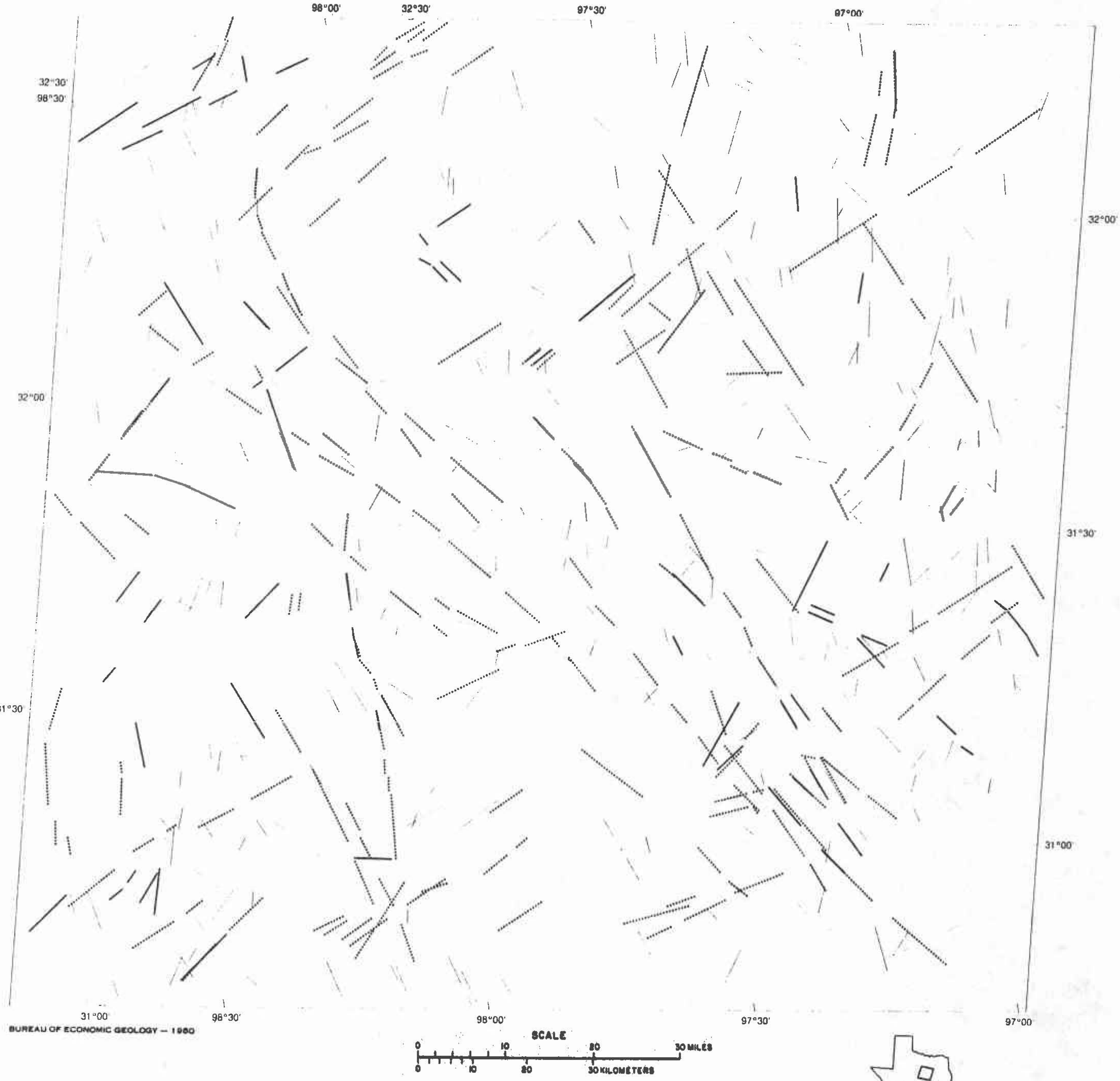
SHEET 25 — CRYSTAL CITY, TEXAS



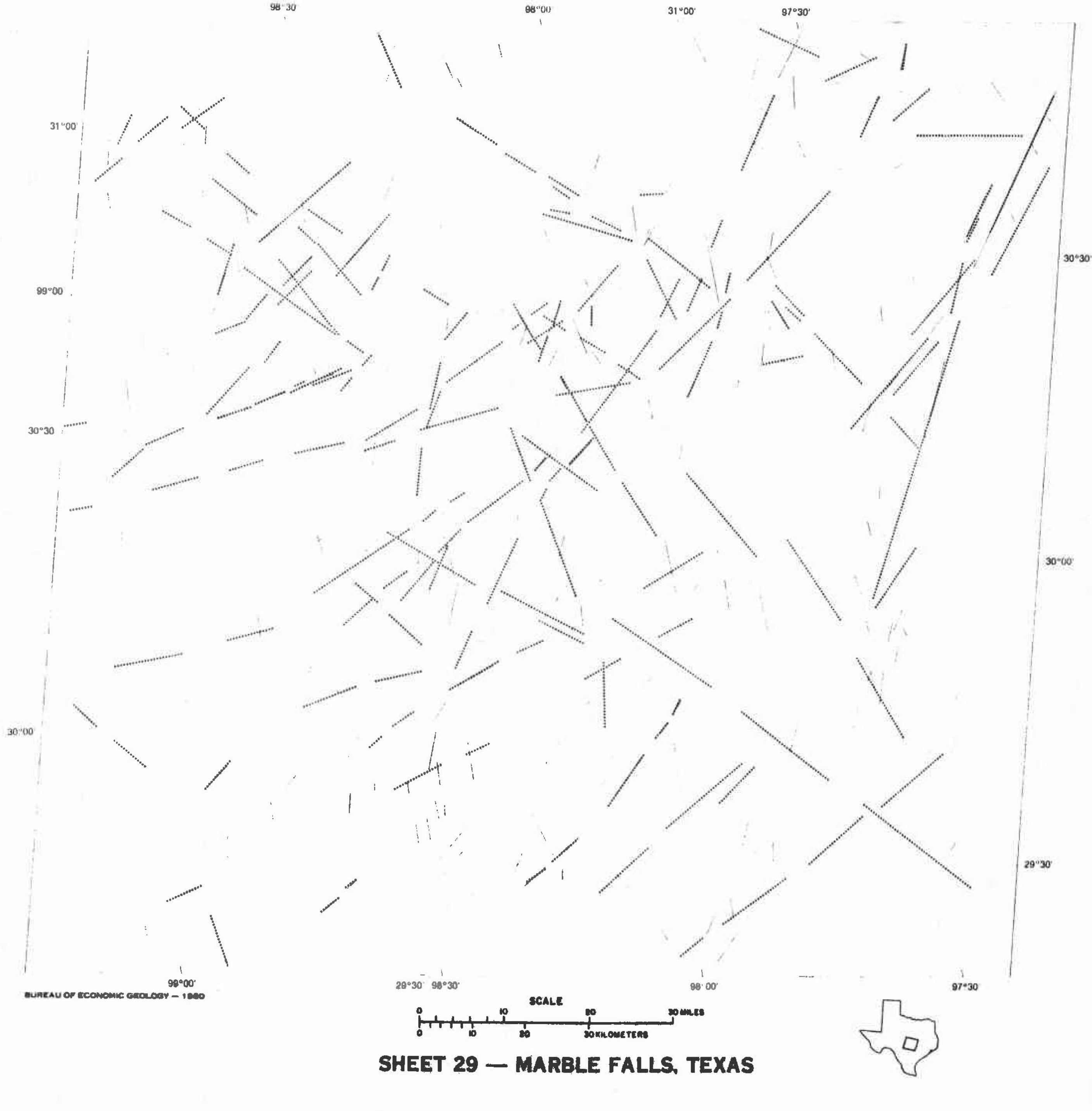
SHEET 26 — DON MARTÍN, MEXICO



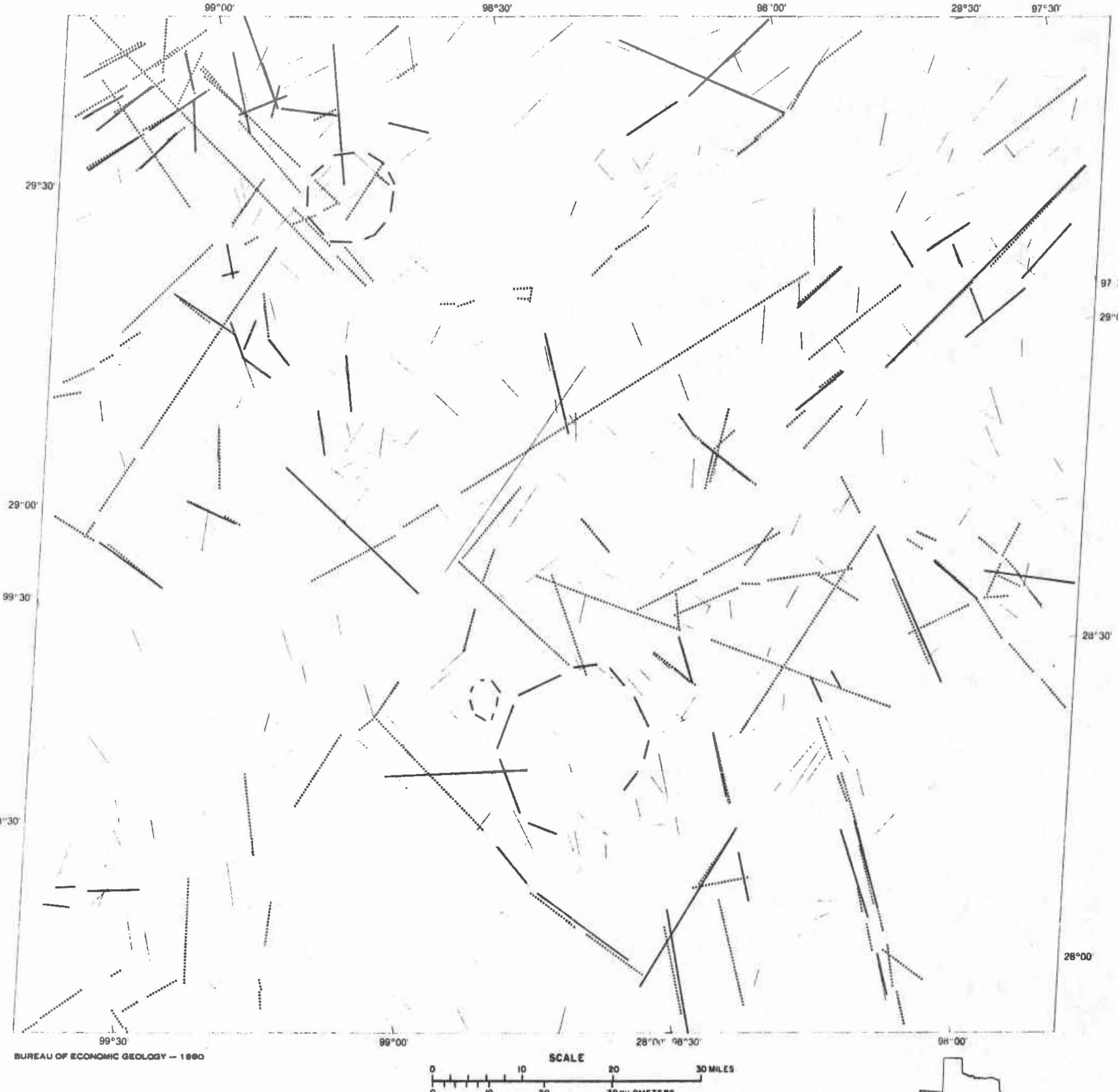
SHEET 27 — DENTON, TEXAS



SHEET 28 — GATESVILLE, TEXAS



SHEET 29 — MARBLE FALLS, TEXAS



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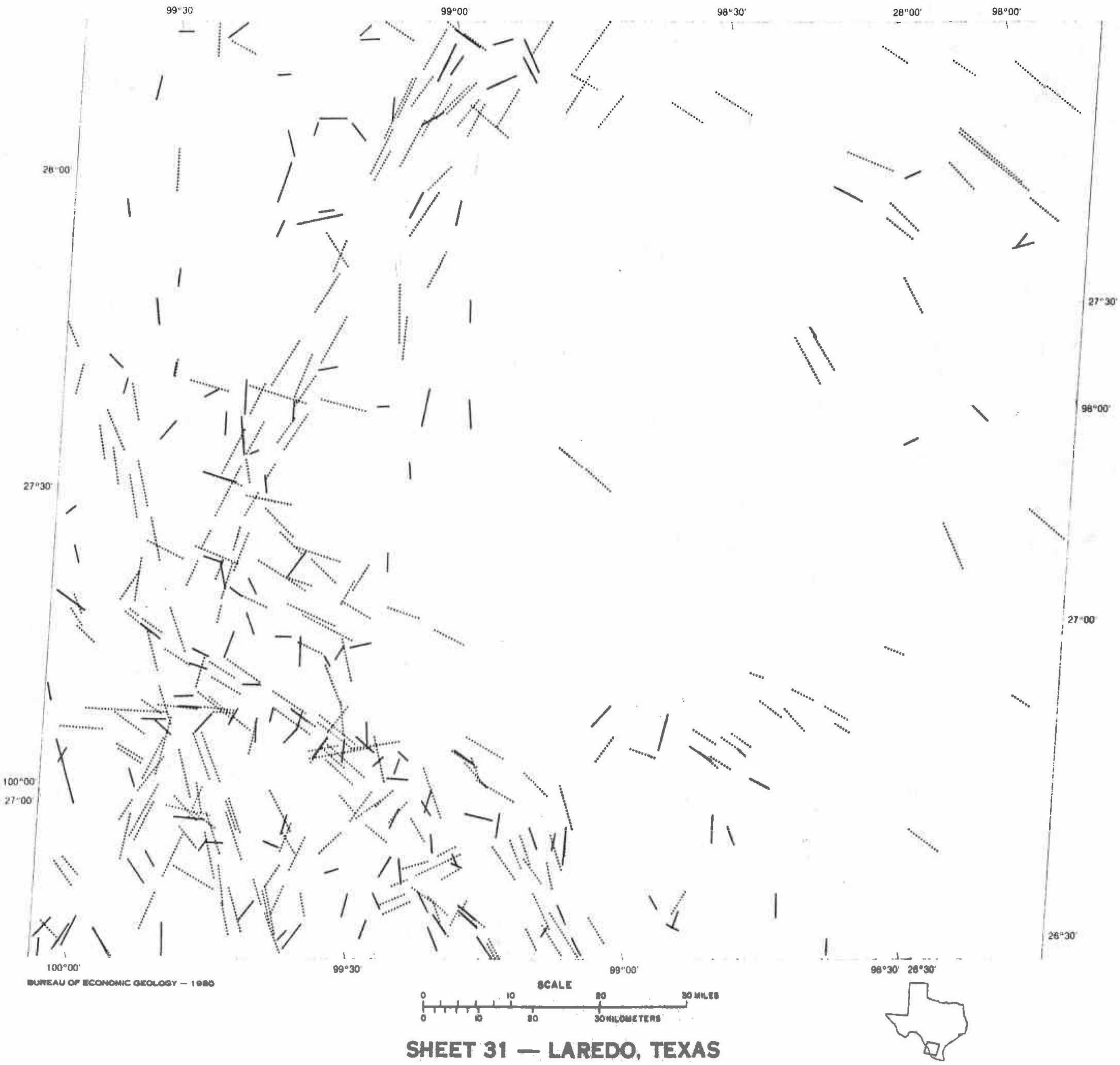

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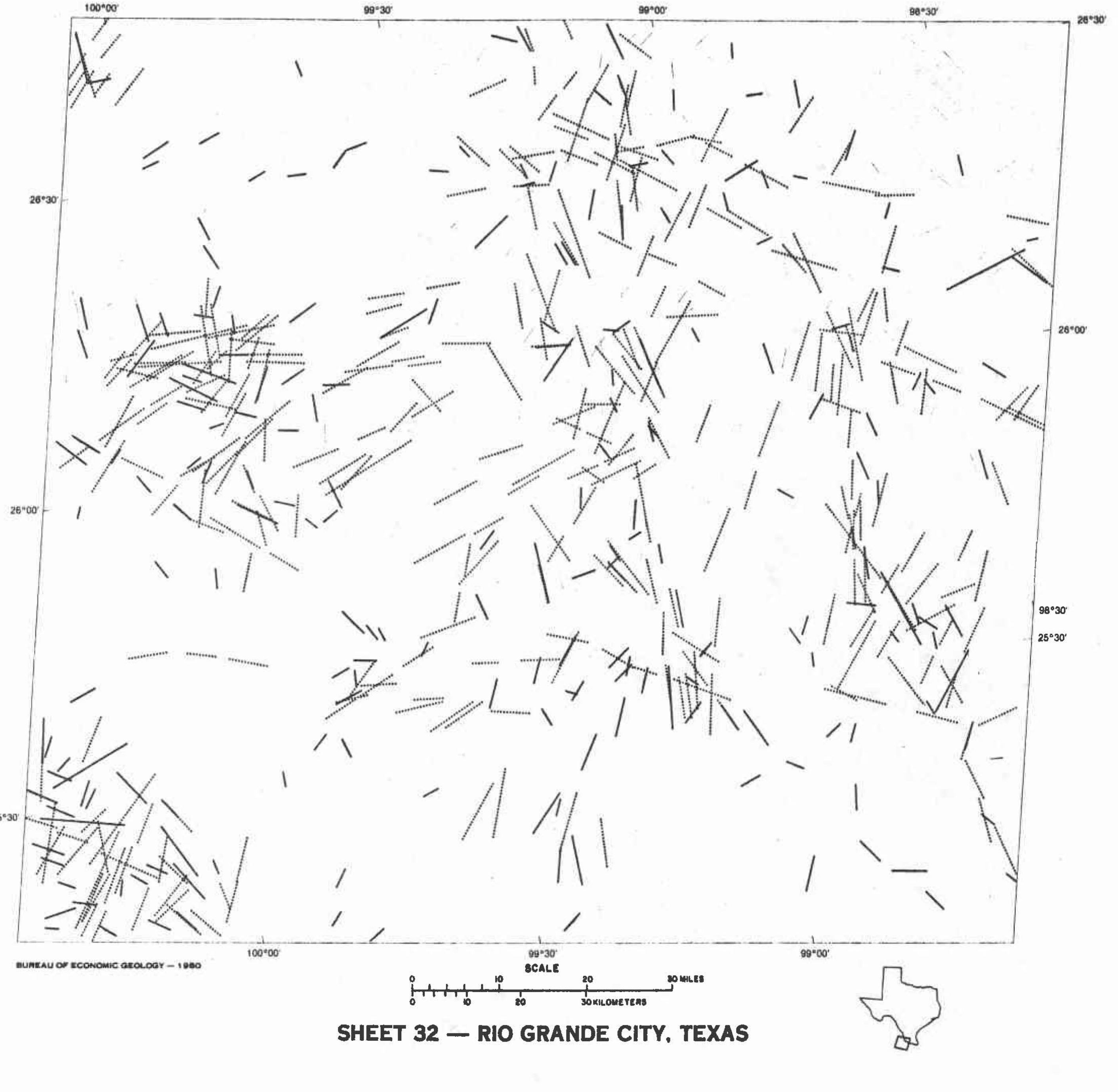

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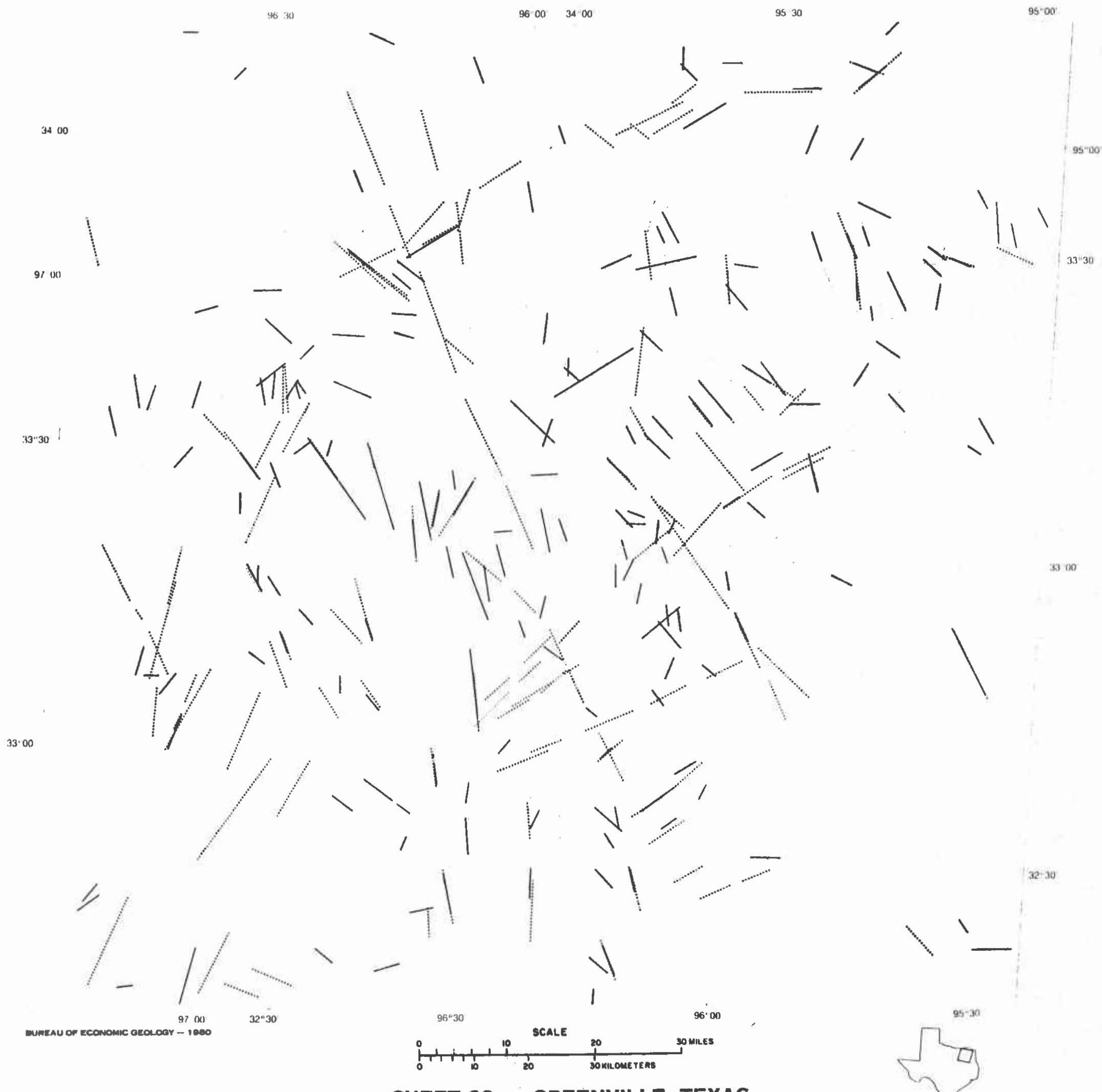
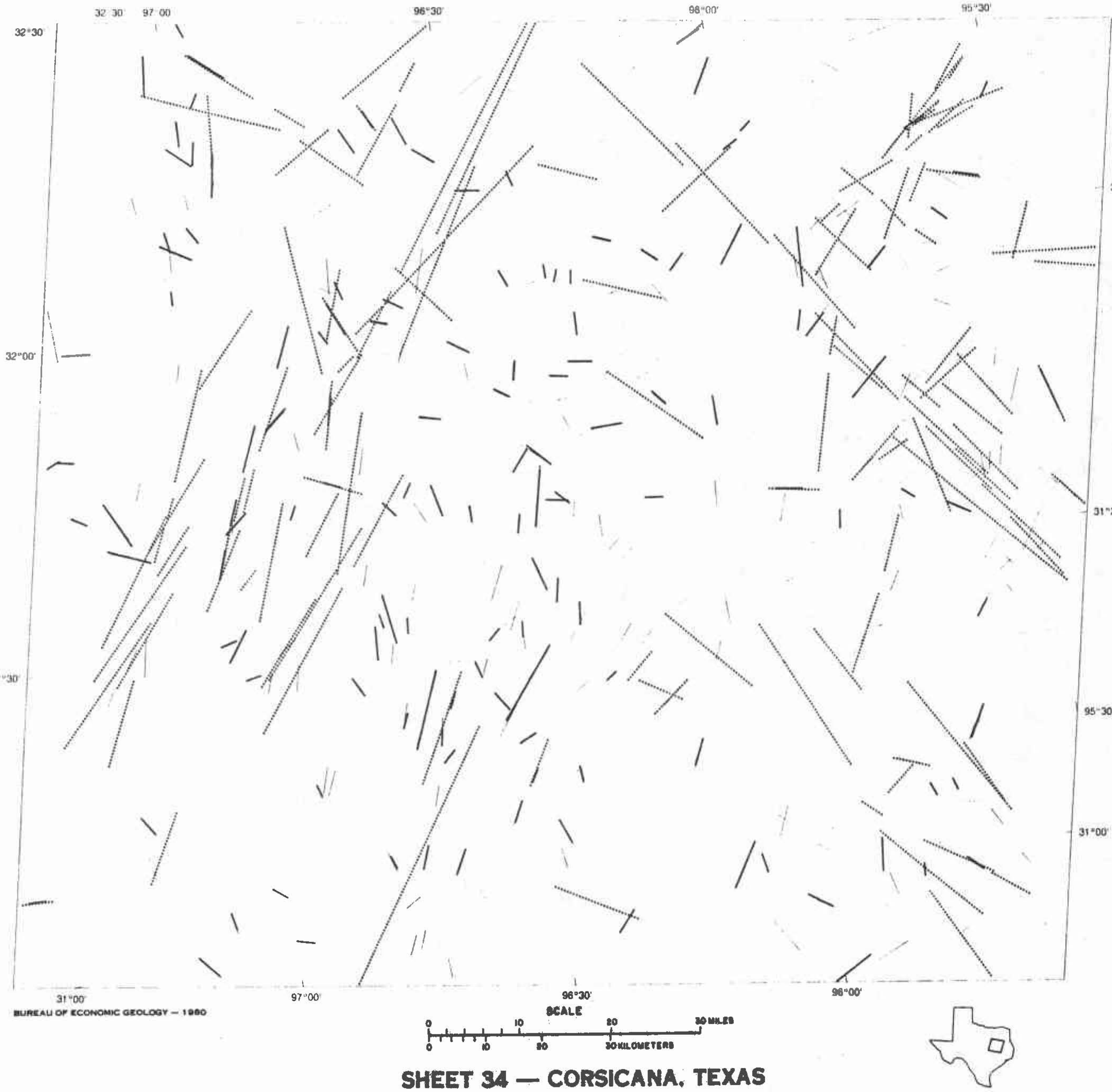
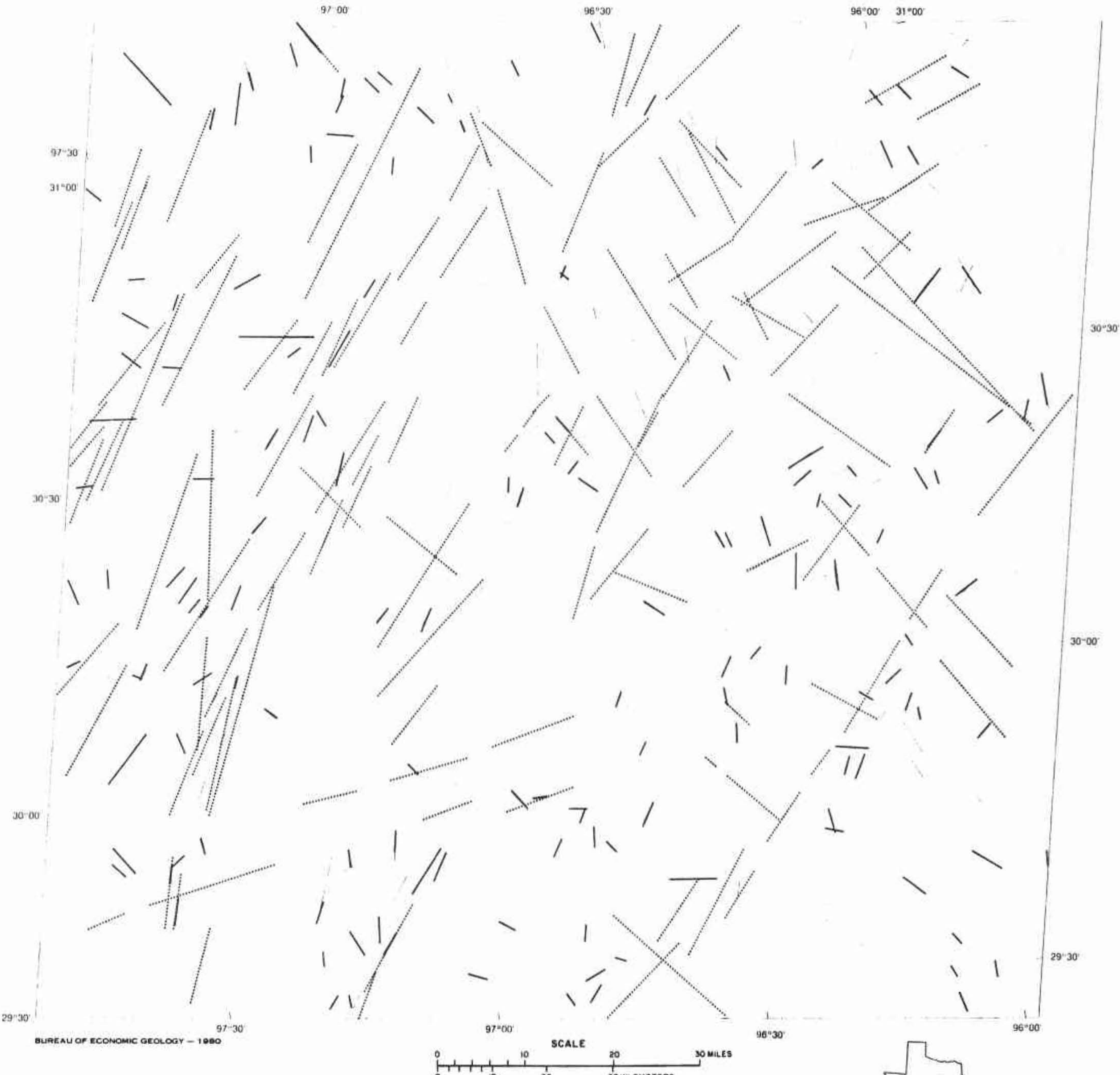


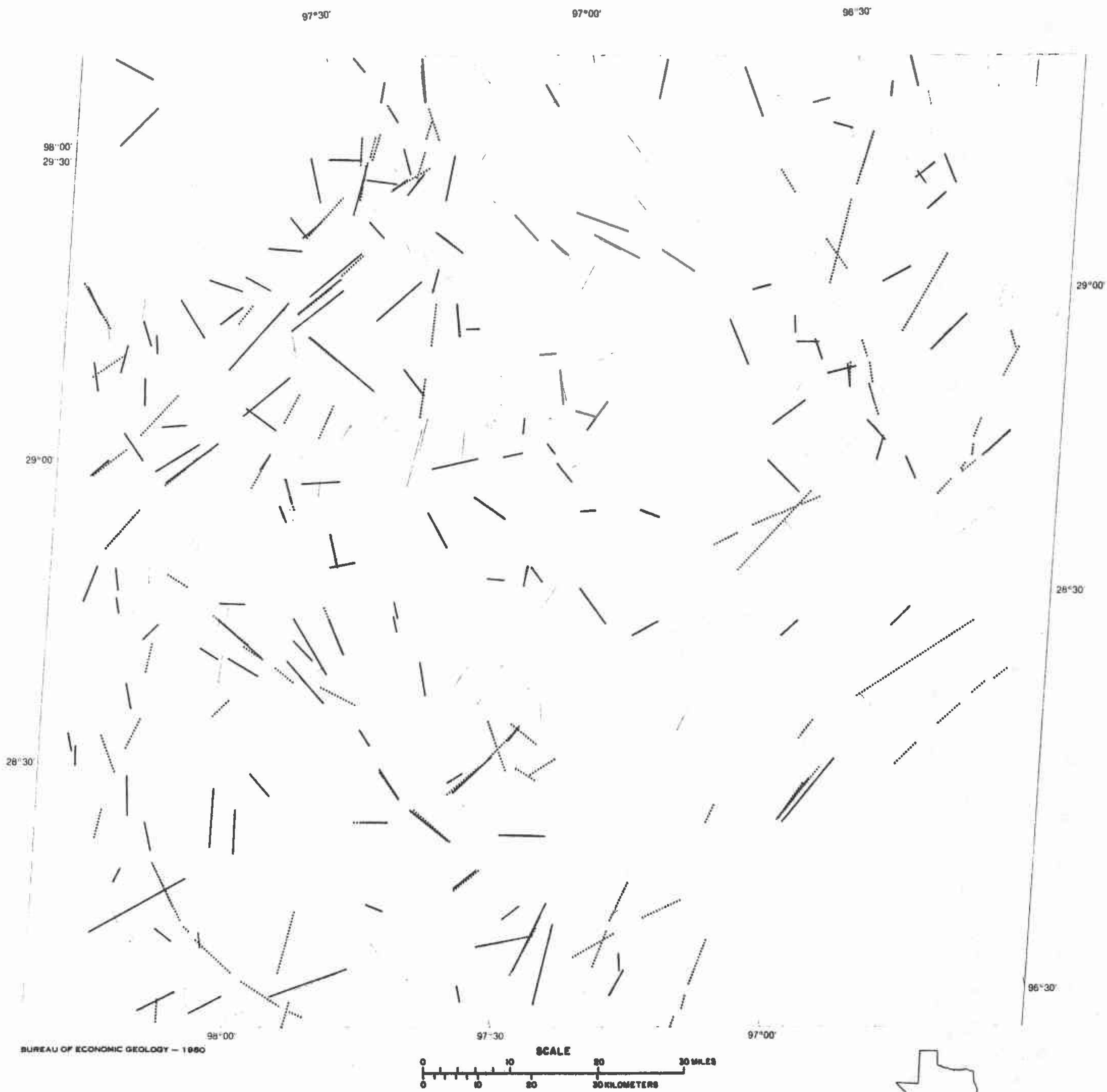
SHEET 33 — GREENVILLE, TEXAS



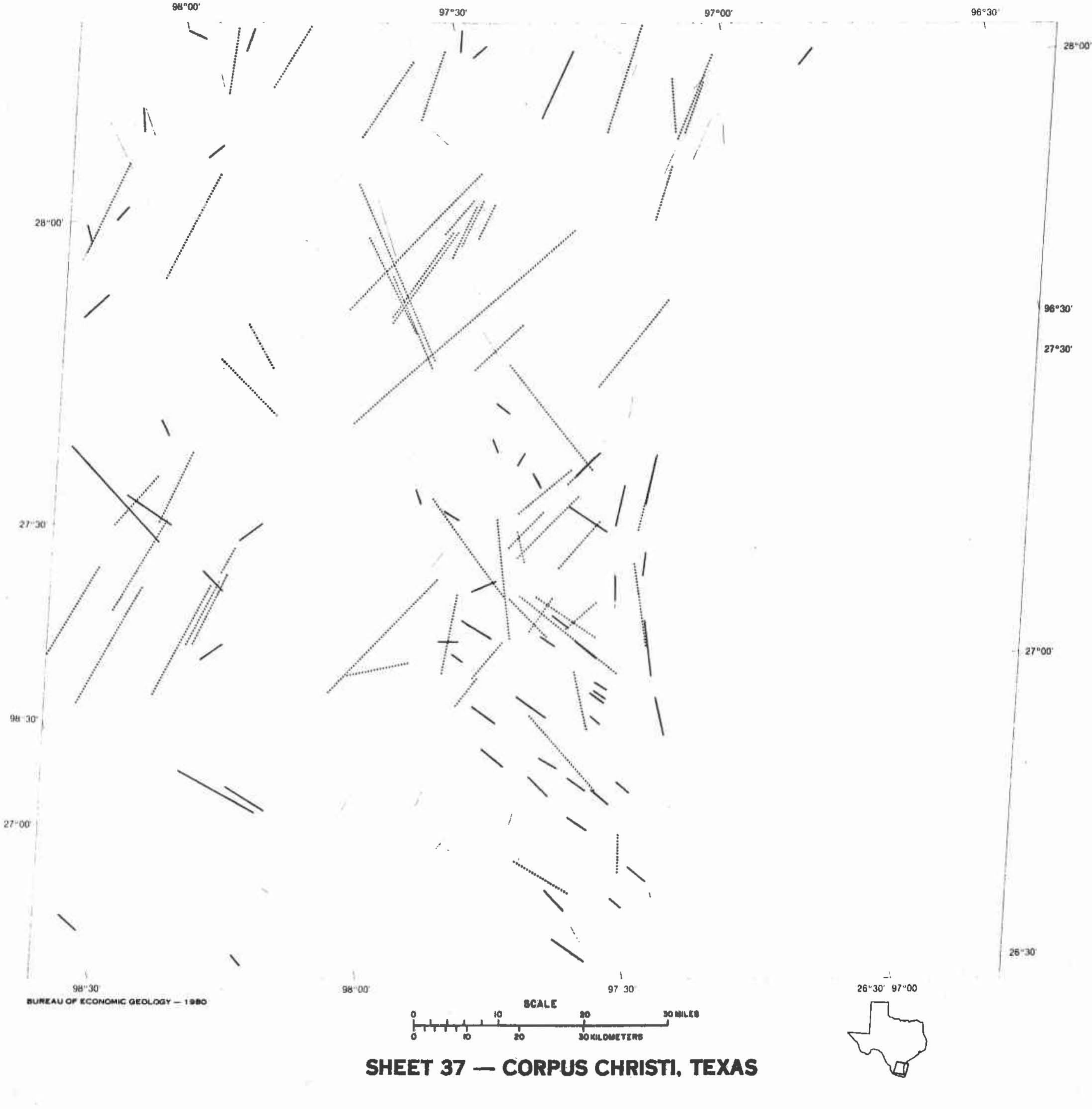
SHEET 34 — CORSICANA, TEXAS



SHEET 35 — CALDWELL, TEXAS



SHEET 36 — VICTORIA, TEXAS



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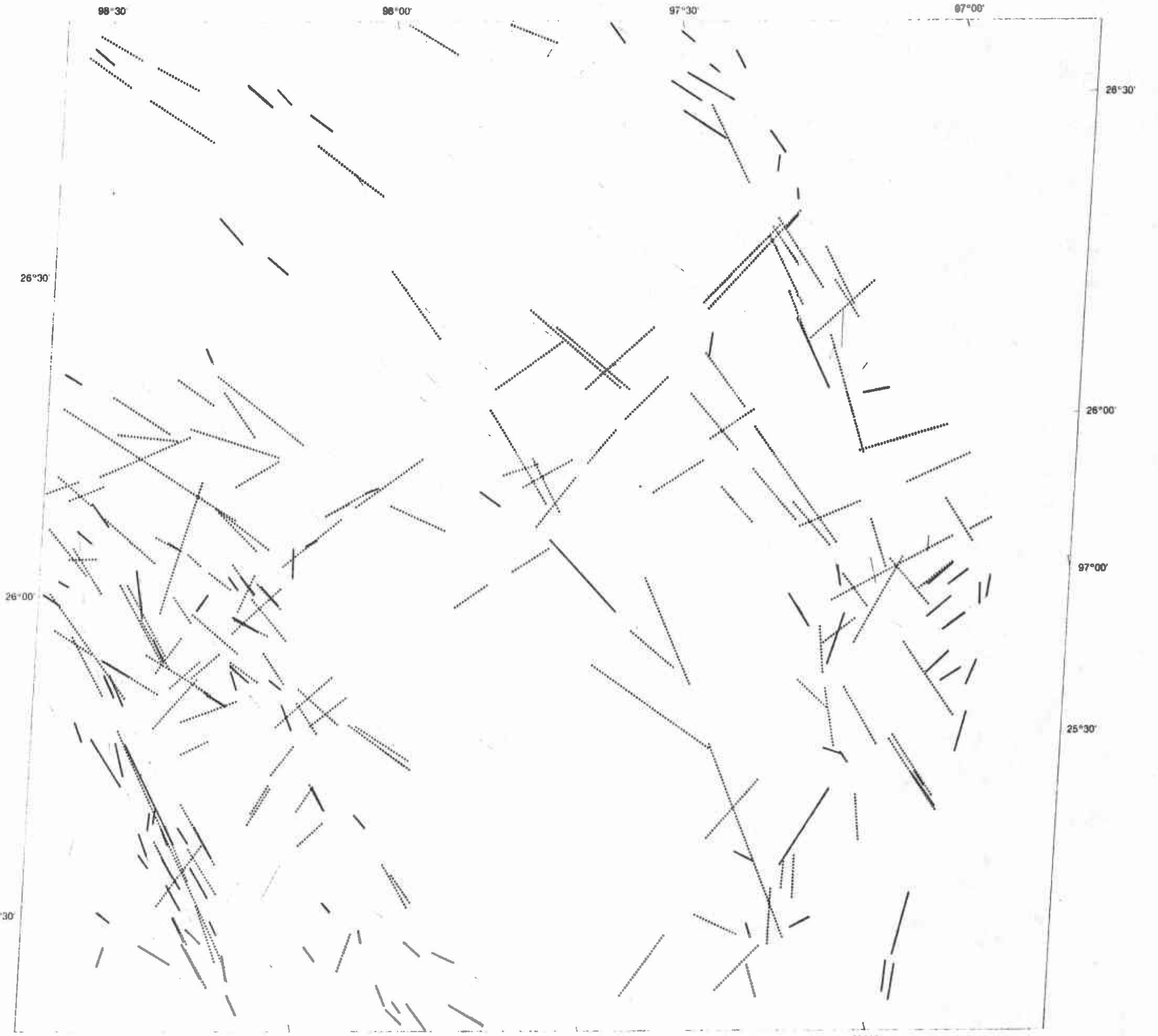
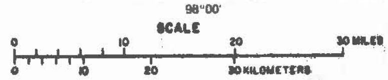
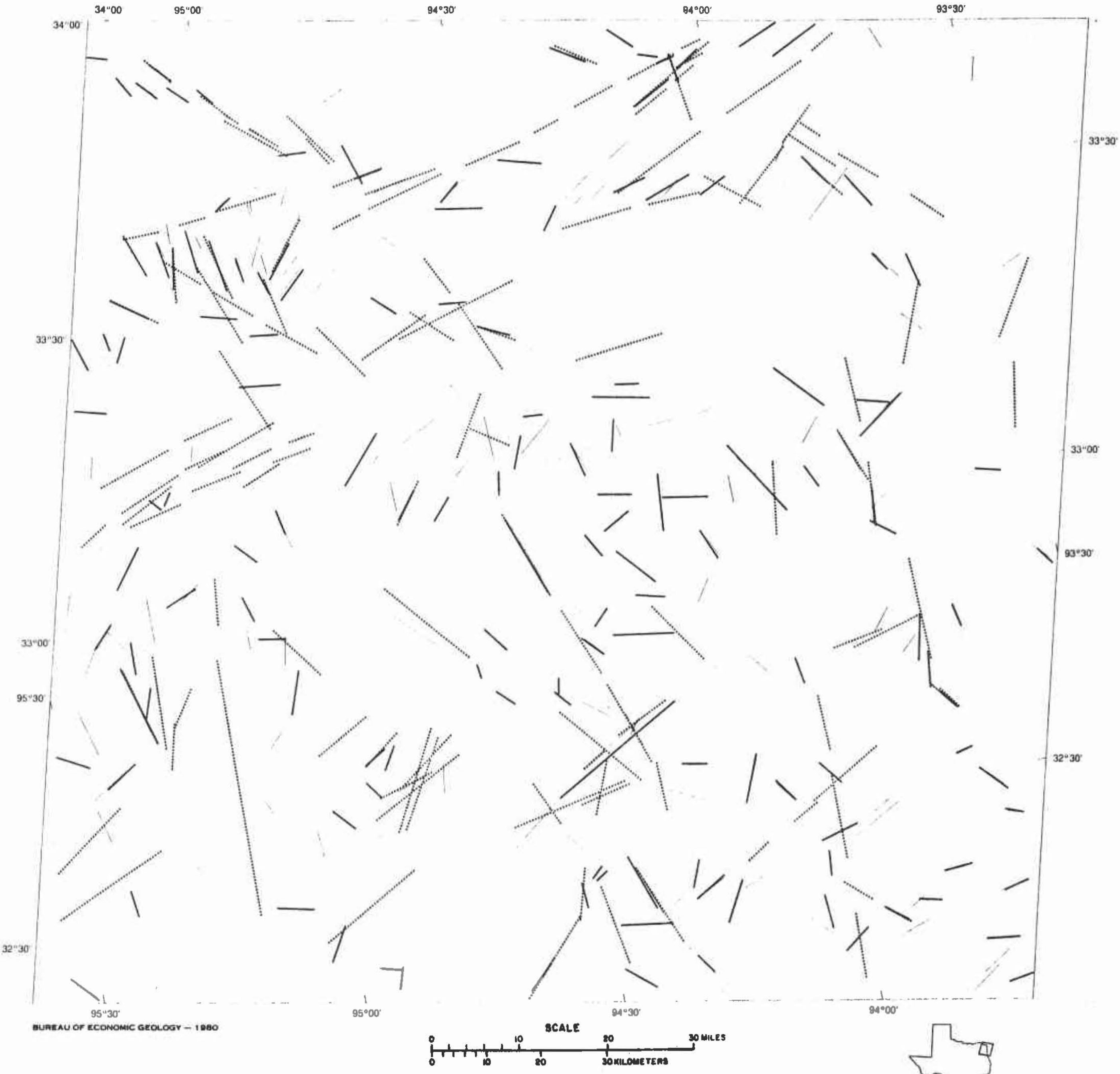


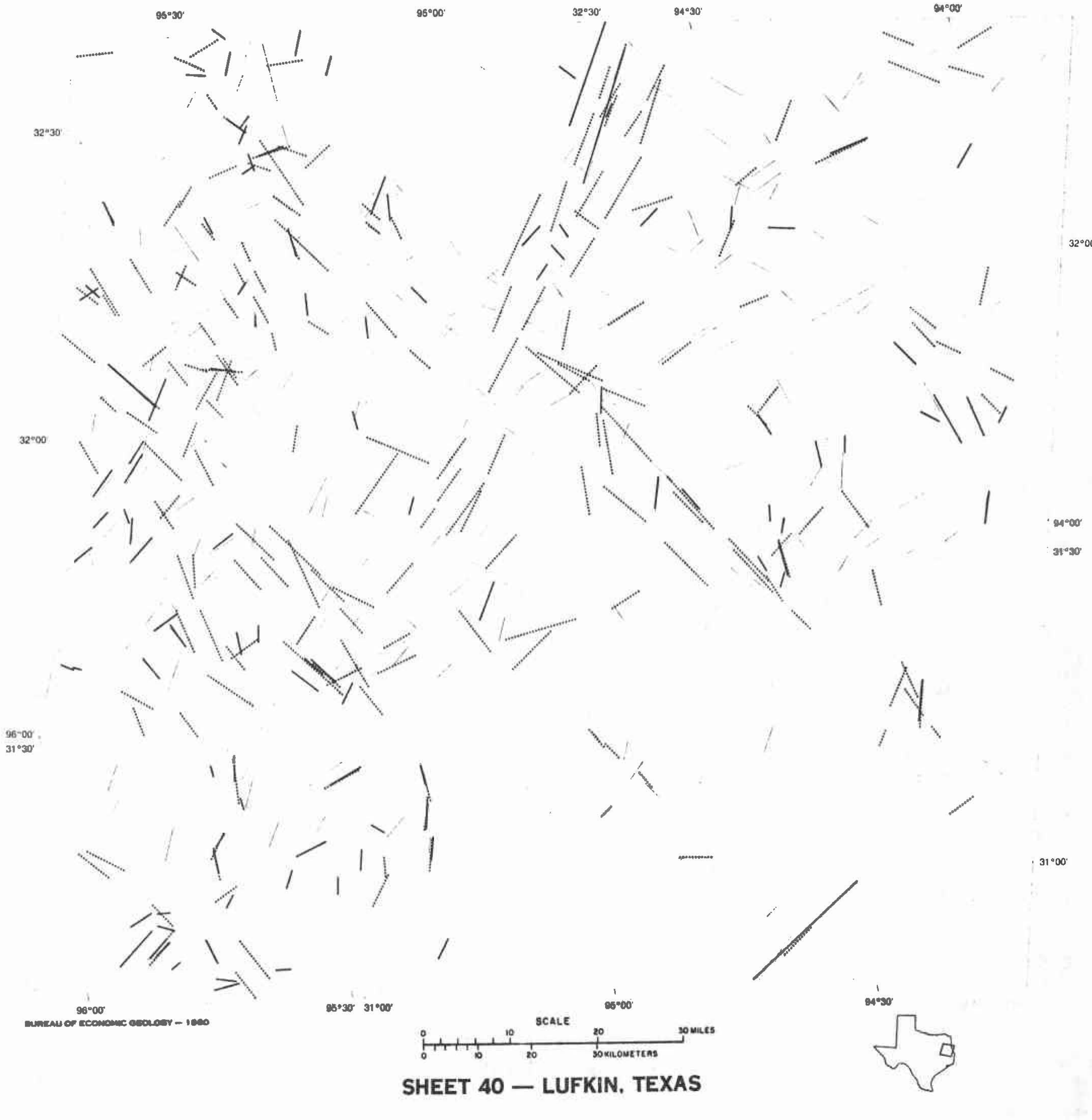
BUREAU OF ECONOMIC GEOLOGY — 1980



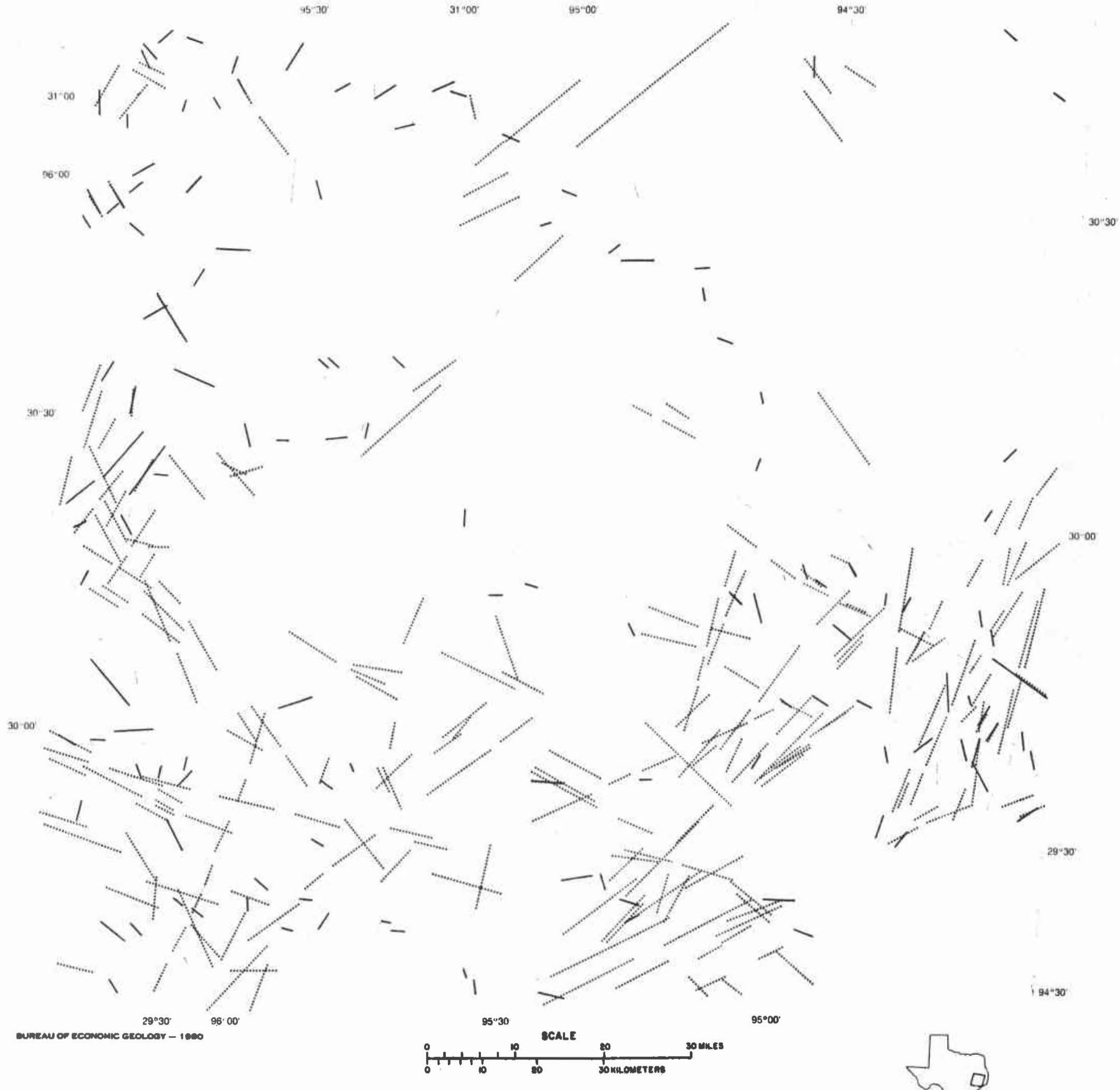
SHEET 38 — HARLINGEN, TEXAS



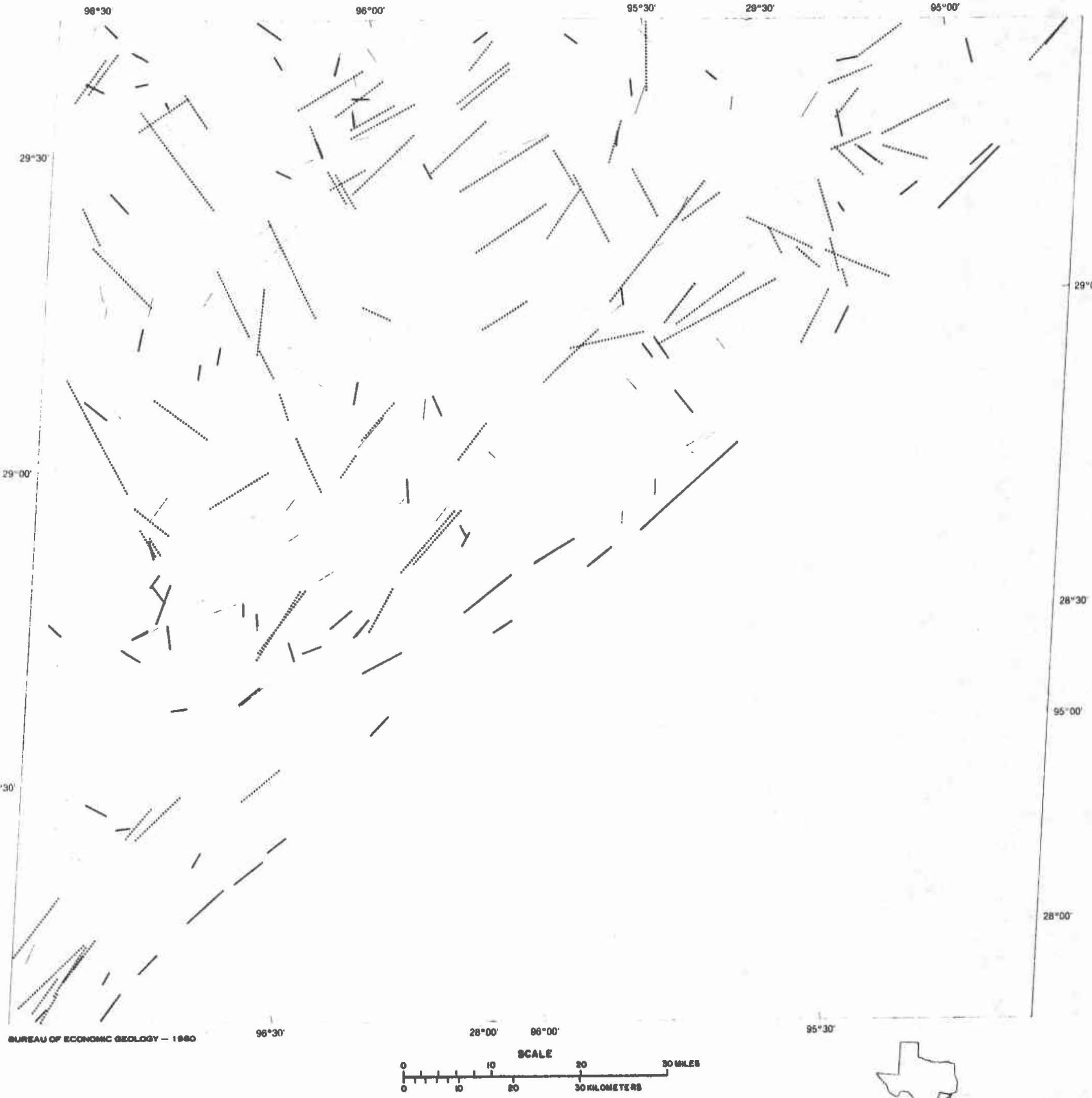
SHEET 39 — TEXARKANA, TEXAS



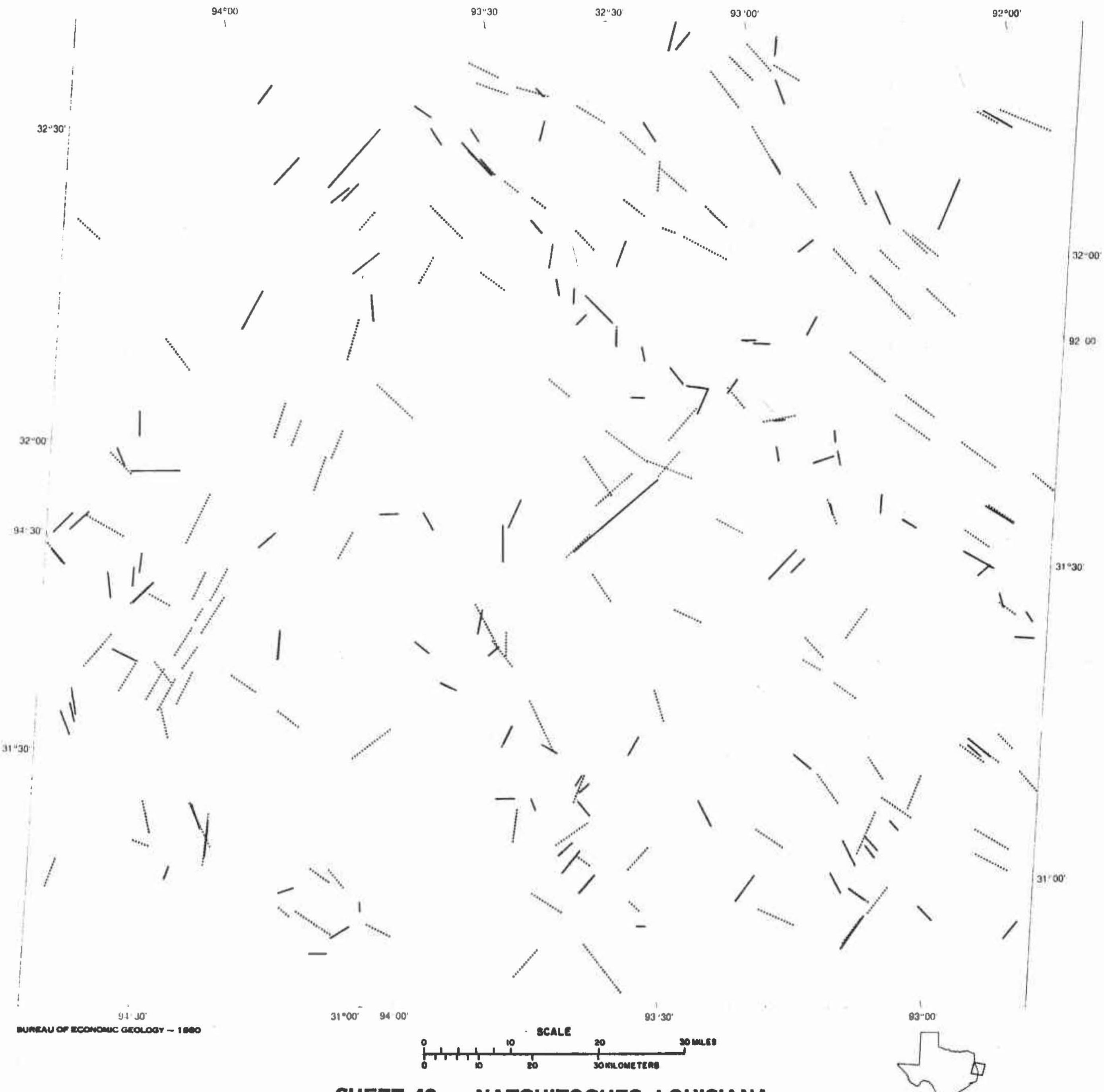
SHEET 40 — LUFKIN, TEXAS



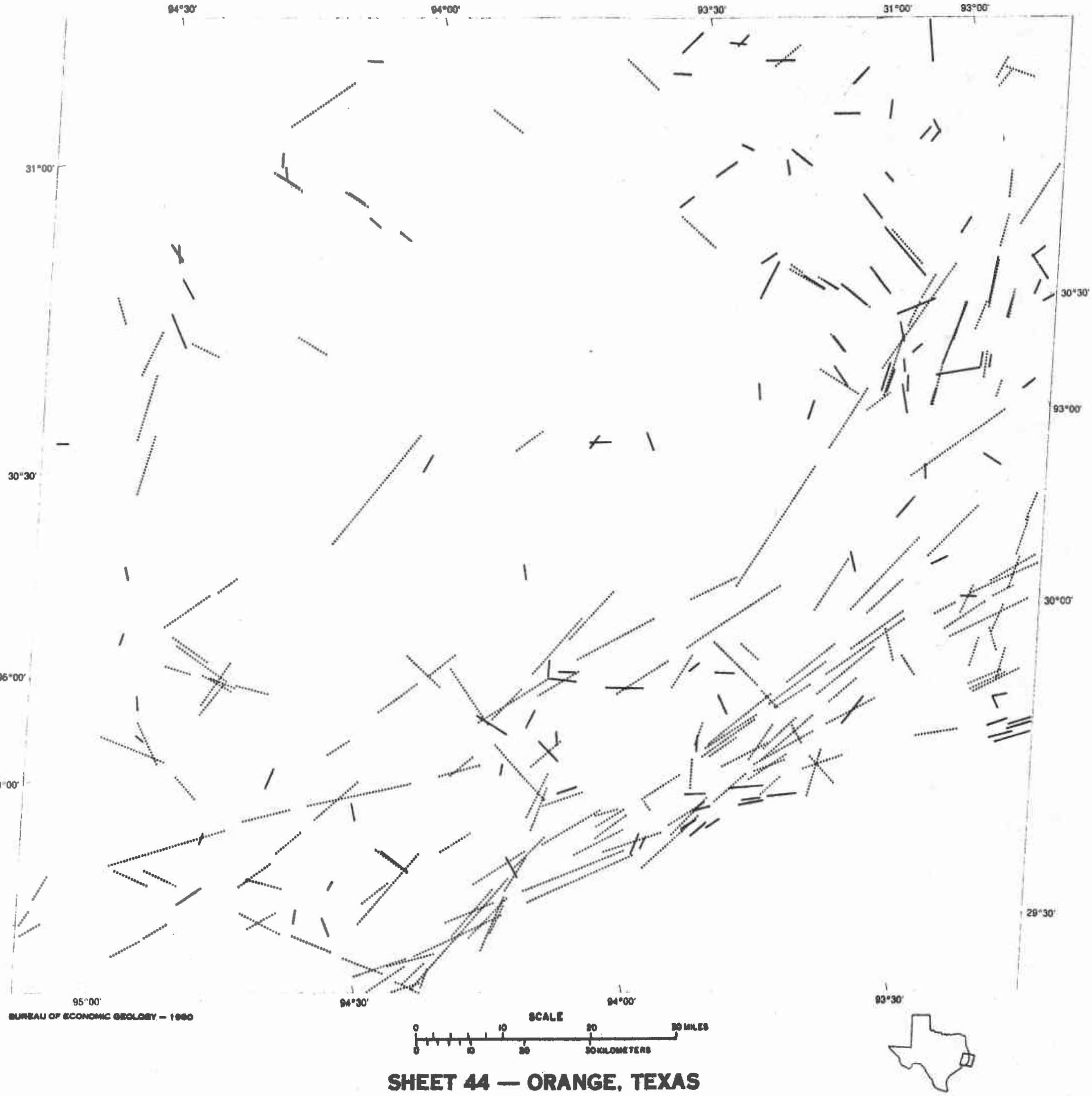
SHEET 41 — HOUSTON, TEXAS



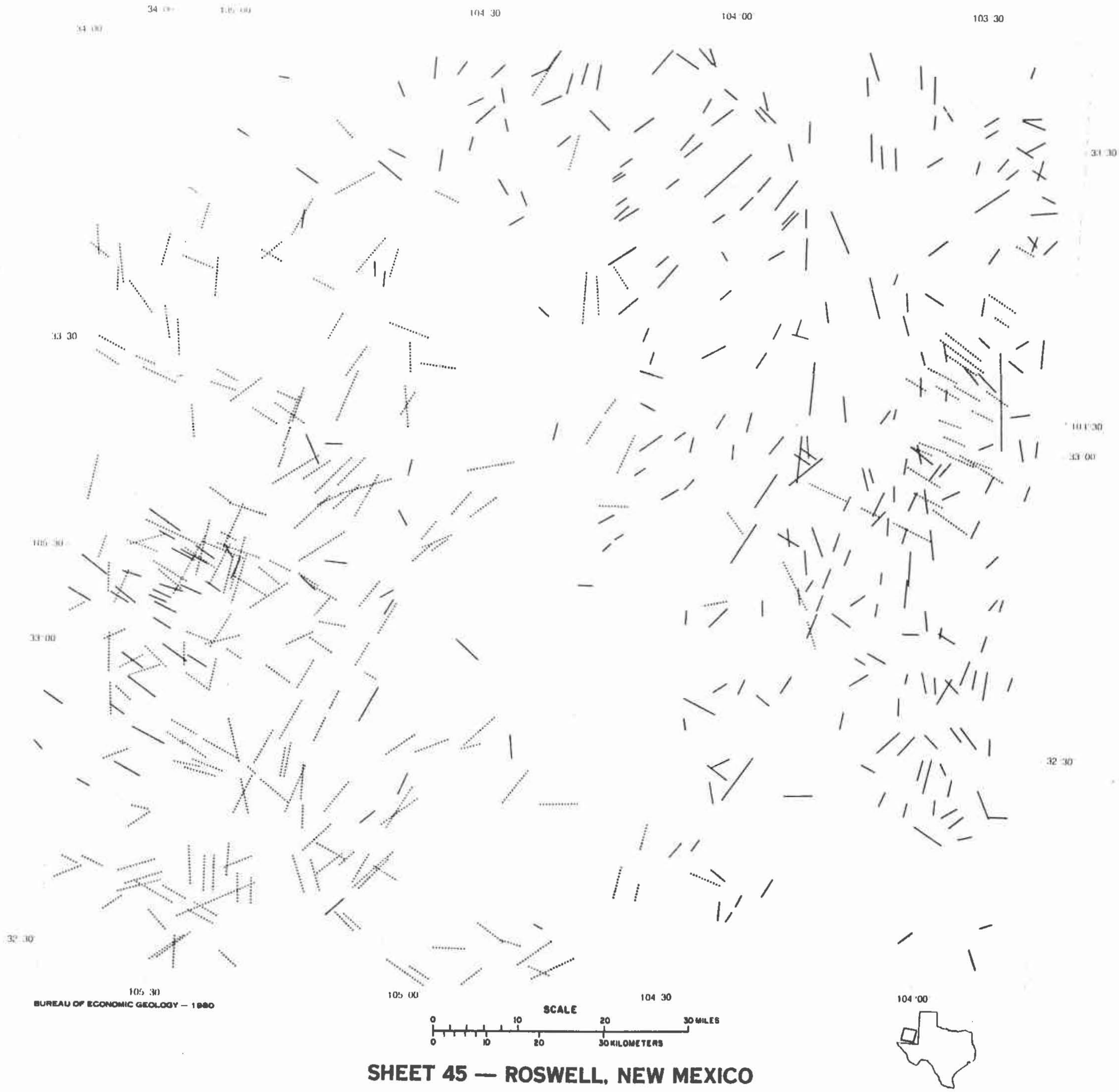
SHEET 42 — FREEPORT, TEXAS



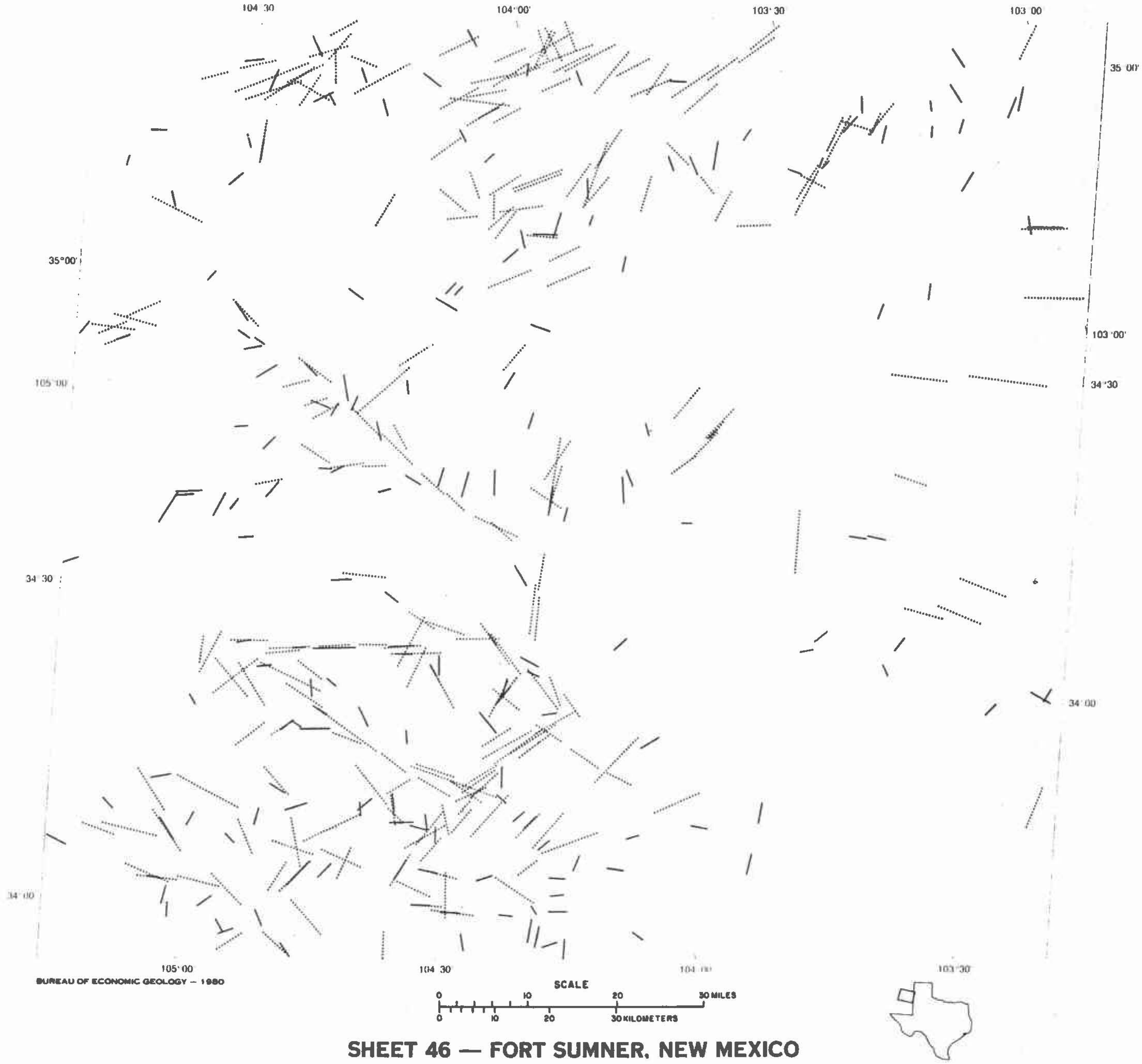
SHEET 43 — NATCHITOCHES, LOUISIANA



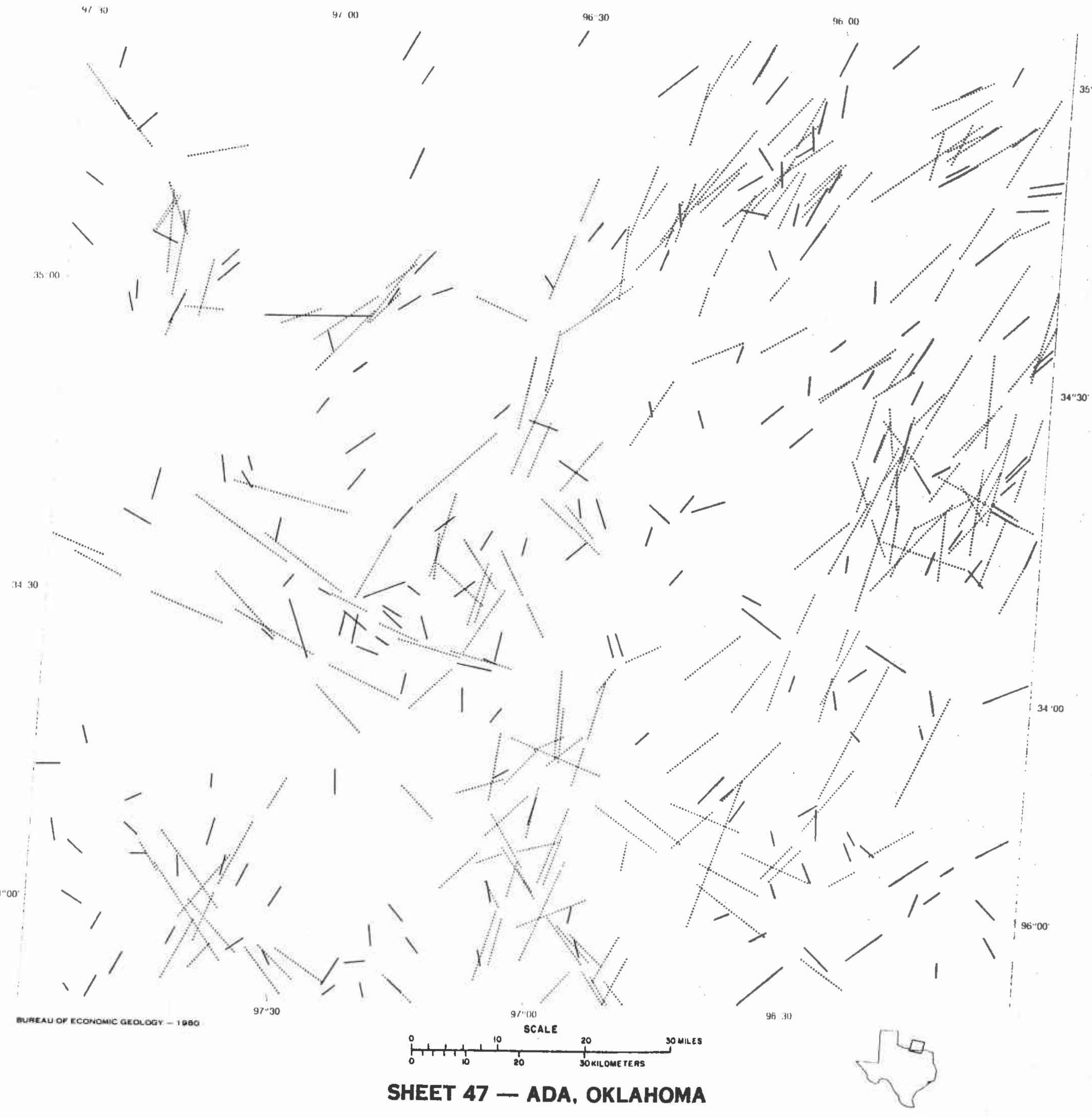
SHEET 44 — ORANGE, TEXAS



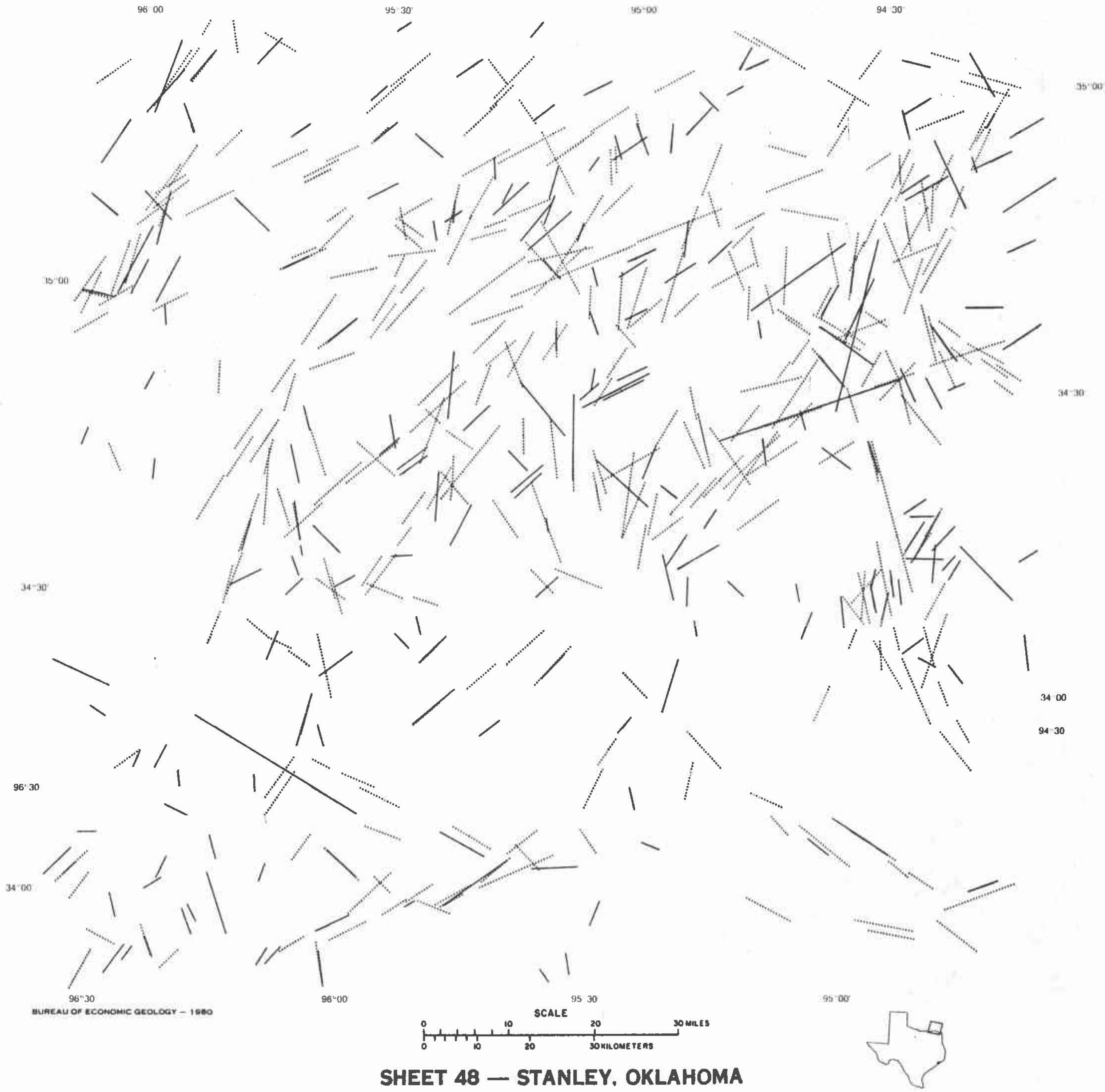
SHEET 45 — ROSWELL, NEW MEXICO



SHEET 46 — FORT SUMNER, NEW MEXICO

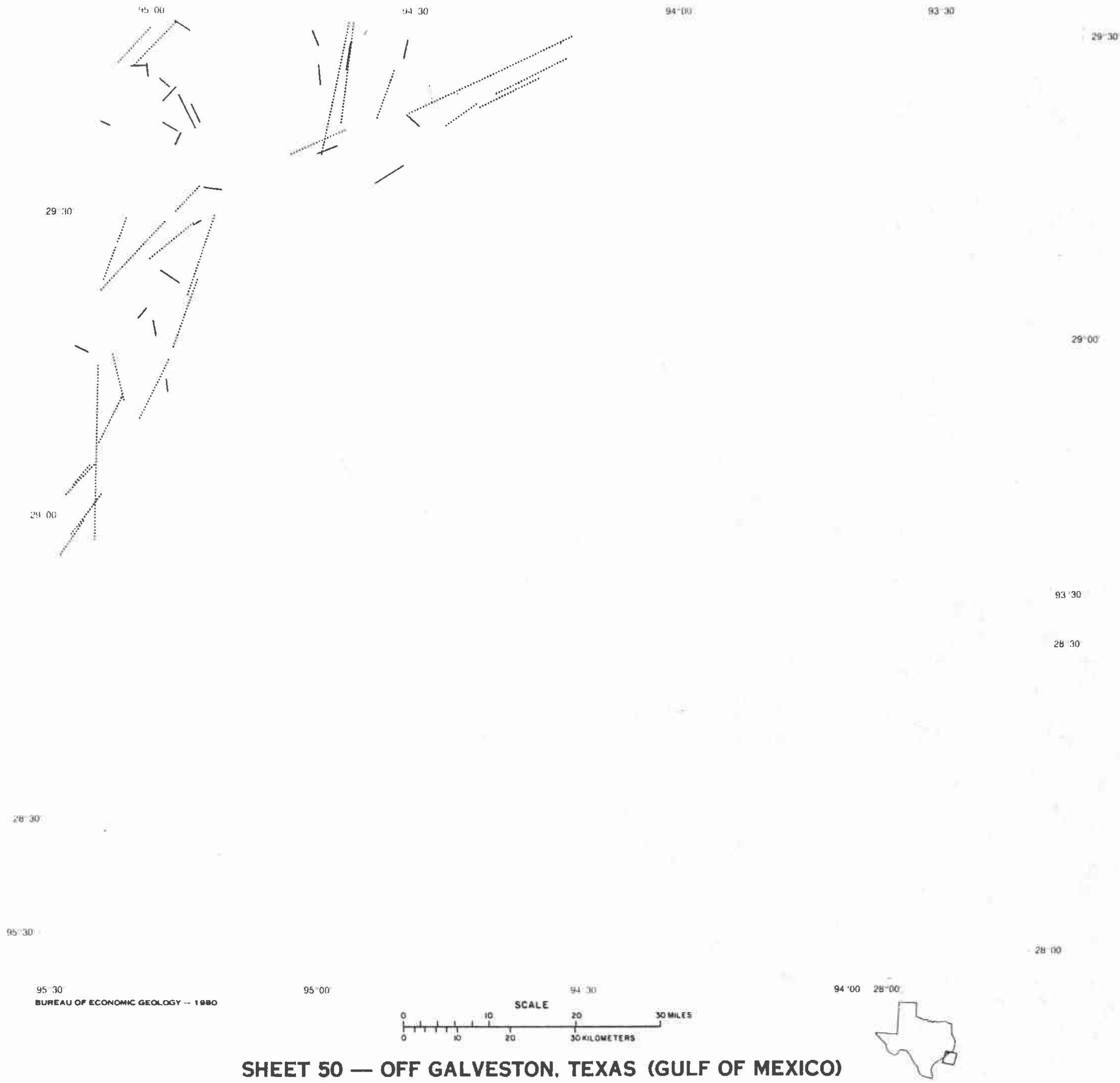


SHEET 47 — ADA, OKLAHOMA

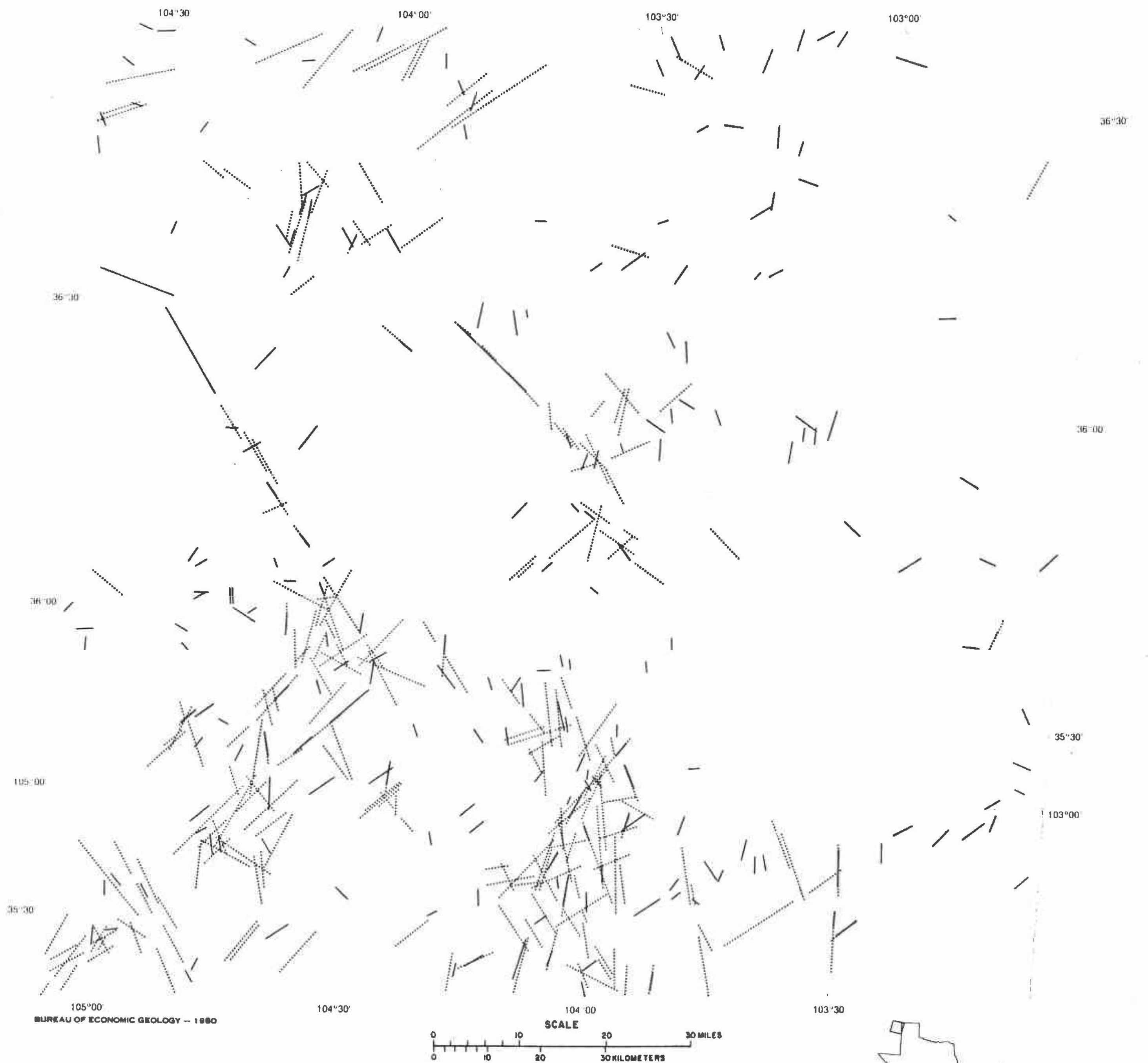


SHEET 48 — STANLEY, OKLAHOMA

SHEET 49 — MENA, ARKANSAS



SHEET 50 — OFF GALVESTON, TEXAS (GULF OF MEXICO)



SHEET 51 — MOSQUERO, NEW MEXICO

APPENDIX F

Index and Critique of Landsat Images Viewed in Compiling Folio of Lineaments in Texas

by

S. Christopher Caran and C. M. Woodruff, Jr.

in

GEOTHERMAL RESOURCE ASSESSMENT
FOR THE STATE OF TEXAS
Status of Progress,
November 1980

Prepared for
U.S. Department of Energy, Division of Geothermal Energy
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March 1982

Bureau of Economic Geology
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The University of Texas at Austin

CONTENTS--APPENDIX F

Figures

Tables

INTRODUCTION

This appendix contains a description of the Landsat system in general and a critique of the individual images that we used in our statewide evaluation of lineaments. This two-fold approach provides a means of assaying the external limitations imposed on our findings, that is, limitations owing to the system that produces the images, or to the peculiarities of particular images.

LANDSAT SYSTEM--A BRIEF DESCRIPTION

Landsat (formerly Earth Resources Technology Satellite, or ERTS) images consist of photographically reconstituted digital data collected either by multispectral scanner (MSS) or return-beam vidicon (RBV) sensors. The sensors are carried aboard unmanned Landsat orbital satellites that transmit all data to Earth for image processing. Three Landsat satellites have been placed in orbit, the first in 1972 (as ERTS 1), the second in 1975, and the third in 1978 (U.S. Geological Survey, 1979, p. 5-1). The satellites are now called Landsat 1, 2, and 3, respectively, but only satellites 2 and 3 are still transmitting. At least two additional Landsats, to be known as Landsat D and D', were scheduled for launch as of 1980 (EROS Data Center, 1980, p. 2).

The orbital pattern of each Landsat satellite is essentially fixed. A satellite passes the same location every 18 days, at approximately the same local time during each orbital "fly-by." Location of the satellite with respect to Earth's surface at any time can, therefore, be defined in terms of its numbered orbital "path" across the surface and its position along that path, corresponding to a preassigned "row" number (fig. F-1). This system of notation is called

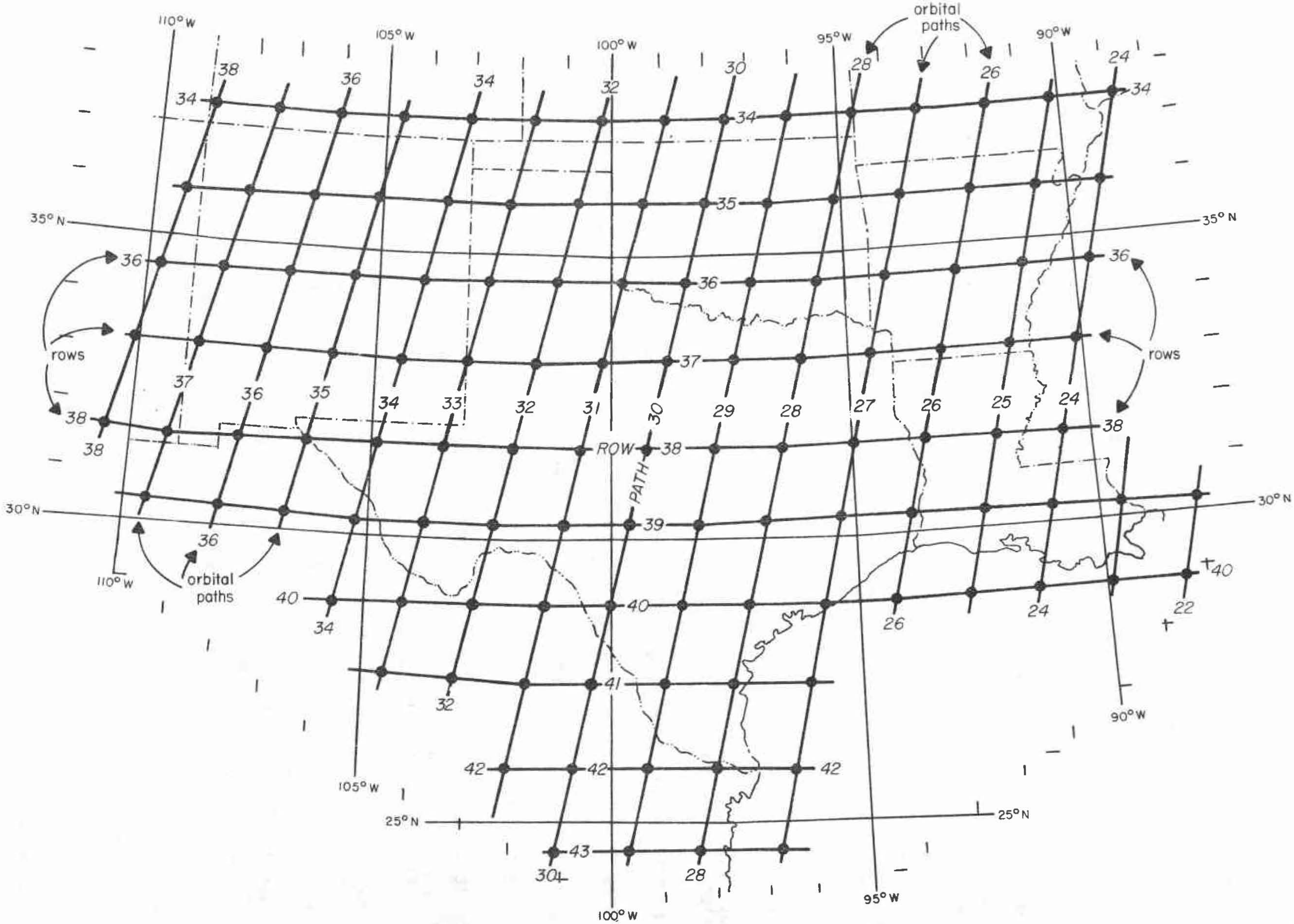


Figure F-1. Landsat path/row designations for Texas and adjacent areas.

the "Worldwide Reference System" (WRS). In the WRS, the intersection of a path and row marks the position of an imaging target for the Landsat sensors. The target location is, thus, the nominal center point of the area represented in each image; this area is called a "scene." Multiple images, representing satellite coverage on different dates, are generally available for any given scene; however, the boundaries of the area actually depicted in these repetitive images may vary. This variation is caused by essentially random oscillations in satellite attitude, small orbital perturbations, and minor adjustments in image processing. The locations of repetitive image center points are, in theory at least, held relatively constant, to within 37 km (23 mi) of the scene's nominal center point.

Images of scenes on adjacent paths normally overlap laterally, but since the paths converge toward the poles, the amount of lateral overlap or "sidelap" is variable. Sidelap represents approximately 26 percent of image width for scenes at 30° latitude, but ranges from 14 percent at lower latitudes to more than 85 percent near the poles. "Endlap," the overlap between successive images along an orbital path, is controlled through image processing and is generally held to 5 to 10 percent of the image area. Despite provisions to ensure normal endlap and sidelap, multiimage mosaics may contain gaps or "holidays" because of differences in the coverage afforded by individual images. Careful selection of images to be used in mosaics can reduce or eliminate this problem.

The multispectral scanner carried aboard each Landsat detects or "senses" electromagnetic energy having specified wavelengths. The scanner consists of either four or five optical elements, each of which is sensitive to a different "band" or segment of the electromagnetic spectrum (table F-1). Scanners on Landsats 1 and 2 respond to Earth-reflected sunlight in four discrete spectral

Table F-1. Spectral responses corresponding to Landsat multispectral scanner (MSS) bands.

Band	Spectral Response (wavelength, in micrometers)	Spectral Response (corresponding color)
4	0.5 - 0.6	green and yellow (blue/green transition to yellow/orange transition)
5	0.6 - 0.7	orange and red (yellow/orange transition to magenta)
6	0.7 - 0.8	magenta to near infrared
7	0.8 - 1.1	near infrared
8*	10.4 - 12.6	medium (thermal) infrared

*Landsat 3 only.

Spectral range of visible light: approximately 0.4 - 0.7 micrometer.

1 micrometer (μm) = 1×10^{-6} meter (m) = 1 micron (μ)
= 1×10^{-3} millimeter (mm)
= 1×10^{3} nanometer (nm) = 1×10^{-3} millimicron (mμ)
= 1×10^{4} Angstrom (Å)

bands in the visible and near infrared range, while the Landsat 3 MSS responds to these as well as to longer wavelength, thermal infrared emitted radiation. The "radiance" or relative intensity of the light reflected or emitted by the surface is measured and recorded for later processing into magnetic tape products and photographic images.

In this study, we are principally interested in "band 5" (0.6 to 0.7 micrometer), which is red spectral response. Thousands of measurements of band-5 reflectance are made during each scanner sweep, at approximately 10-microsecond intervals. Each measurement represents the aggregate reflectance from a finite area of the Earth's surface. In the Landsat system, the unit area for MSS radiance measurements is the effective "instantaneous field of view" (IFOV). The effective IFOV is an area measuring 79 x 56 m (259.2 x 183.7 ft) or 4,424 m^2 (1.09 acre).

Processing algorithms convert band-5 (and other) reflectance values measured by the satellite to the gray tones or colors of which photographic images are composed. The smallest tonal or chromal area within an image is the "picture element" or "pixel," which is the pictorial expression of reflectance from an effective IFOV. Pixels lie along lines in the scanning or cross-track direction; each line of pixels is called a "scan line." Pixels and scan lines are the fundamental components of Landsat images; they are the basis of spectral fidelity and image quality. Coherent images consist of well-ordered sets of valid pixels and scan lines.

After initial processing and correction of imagery data has been completed, the refined data must still be geometrically refitted before an image can be produced. Fitting presumably ensures proper geographic registration of data. The fit of MSS imagery data is controlled by Space Oblique Mercator (SOM) projection, an advanced system of mapping. Use of this system is made necessary because of the continuous mode of data collection employed by the multispectral scanner. The scanner moves continually across the satellite track. The satellite, in turn, is orbiting the rotating Earth along an orbital path that is approximately 15° east of geographic north, while at the same time experiencing minor but virtually random fluctuations in attitude and altitude.

Each of these positional variables can, in theory, be controlled under the SOM projection system, so that the finished Landsat image is presumably an accurate representation of the earth surface. The attainable accuracy has been claimed (U.S. Geological Survey, 1979) to be considerably greater than that of most conventional cartographic processes. However, we found this claim to be false. In certain areas, the latitude/longitude coordinates of a particular Landsat image were misaligned by as much as several minutes with reference to surveyed locations of easily recognized on-ground features. Direct comparison of Landsat images with corresponding maps of the same nominal scale also reveals measurable discrepancies. We compared regional topographic maps (of the Army Map Service [AMS] series) with a nominal scale of 1:250,000 and a Landsat band-5 image at 1:250,000 nominal scale (74.2-cm or 29.2-inch format) and found random deviations. In one example (table F-2) where we had good control, we noted a maximum difference of 0.4 cm (0.16 inch) of line length, which corresponds to 1.0 km (0.63 mi) on the ground. We also found angular (azimuth) deviations of as much as 0.7° between bearings measured on the Landsat image and on the corresponding AMS map. Elsewhere in the state the differences are even greater. We attribute these discrepancies to the different projections used in constructing Landsat images and AMS maps; they are essentially irreconcilable. Other sources of error, including differences in the relative stability of map and photographic base materials (owing to heat, humidity, aging, stretching, and processing defects), may also be important in some instances.

Table F-2. Two comparisons of length and azimuth measurements between specified points on Army Map Service (AMS) maps and a Landsat image.

Reference point	Latitude/ longitude coordinates[1]	AMS map[2] (nominally 1:250,000-scale)	Landsat image (nominally 1:250,000-scale)	(A) Distance on map cm (inch)	(B) Distance on Landsat image cm (inch)	A-B Difference cm (inch)	Difference on ground at 1:250,000 km (mi)	Azimuth, AMS map (degrees)	Azimuth, Landsat image (degrees)	Angular deviation (degrees)
COMPARISON 1										
Highway 290 at Highway 10	N30d17m34.69s, W099d31m05.15s	Llano	Junction	37.8 (14.9)	37.4 (14.7)	0.4 (0.16)	1.0 (0.63)	74.0	73.7	0.3
Coal Creek at Sandy Creek	N30d31m39.22s, W098d35m12.61s									
COMPARISON 2										
Verde Creek[3] at Guadalupe River	N29d56m08.75s, W099d00m20.54s	San Antonio	Junction	25.7 (10.1)	26.05 (10.3)	0.35 (0.14)	0.875 (0.54)	4.5	3.8	0.7
Verde Creek[3] at Hondo Creek	N29d21m16.16s, W099d03m23.41s									

[1] Coordinates measured from U.S. Geological Survey 7.5-minute quadrangle maps; d - degrees, m - minutes, s - seconds.
[2] Army Map Service topographic contour map.
[3] Coincidental homonyms; drainage systems not connected.

Landsat MSS images are extensively annotated with information pertaining to processing methods, sensor operation, scene location, date and time of data collection, and many other details of interest to data users. Each image is identified uniquely by a permanent identification number. Other information--including geodetic tic marks, center and corner point coordinates of the nominal scene, and, on later prints, the scene's path and row numbers--provides a basis for registering the image and for locating depicted surface features. In theory, these annotations enhance the usefulness of an image and (along with image quality data) constitute the primary basis for selecting images and evaluating interpretative bias. In practice, however, random errors, inconsistencies, and other such deficiencies severely limit the usefulness of this information.

LANDSAT IMAGES FOR LINEAMENT ASSESSMENT OF TEXAS

Image Selection

The process of selecting Landsat images that we used in the current study had profound consequences for the completion of our research objectives. Images had to meet several preliminary standards before being considered for selection. Each image had to:

(1) cover some part of the land area of Texas, including the bays and barrier islands;

(2) consist of a band-5, black-and-white print in 74.2-cm (29.2-inch), 1:250,000-scale format;

(3) be derived from data collected during periods of low sun-angle (October to April), while omitting images of extensively snow-covered scenes;

(4) bear a nominal quality rating of 8 (highest) and include no more than 10 percent cloud cover; and

(5) have good contrast and resolution, reduced or eliminated scan line stripes, and no other quality deficiencies.

Whenever possible, we examined full-size photographic "hard copies" of images prior to acquisition in order to determine or confirm suitability. In most instances, however, we had to rely on nominal quality ratings or examination of microfilms of images. The list of available images meeting our criteria was very limited for some scenes because of weather phenomena (clouds or snow cover); this was especially true for images depicting forested areas of East Texas and parts of the Coastal Plain, Coastal Zone, High Plains, and Red River Valley. The images selected were not entirely satisfactory, but at least one usable image was obtained for each of the 51 scenes that cover part of Texas.

The nominal quality ratings provided our main criteria for choosing specific images. Yet these ratings were markedly inconsistent in terms of actual image quality, and this subsequently affected the quality of our interpretations. Unfortunately, many factors can degrade Landsat image quality. The most common defect, particularly in images processed before 1979, is image striping. Striping occurs when spontaneous errors in sensor calibration cause all or most of the pixels along one or more scan lines to darken uniformly, usually to black. A similar effect is seen when one or more lines of reflectance data are lost or garbled, resulting in gaps or spotty pixels. The data-processing system currently used at EROS Data Center (the facility that produces Landsat images) has virtually eliminated these problems for newer images; also attempts are made there to lessen other common photographic defects including scratches, streaks, graininess, and improper print exposure, yet all these problems recur, presumably as a result of lapses in quality control at EROS Data Center. Hence, it was necessary for us to assess each image for its photographic quality (and other attributes), as these factors affected our perception of lineaments.

In order to assess each image consistently, we created a Landsat image inventory form that contains 15 categories (labeled "A" through "O") to include all relevant data, such as indices to the EROS file of images, geographical coordinates, subjective qualifiers, and the like (fig. F-2).

Categories Composing the Landsat Image Inventory Form

(A) Scene name

The scene name is the name that we assigned informally to refer to each Landsat scene (see Appendix E, table E-1). It is the name of the most readily identifiable community or geographic feature located at or near the actual center of the depicted scene. The named community or feature is restricted to that scene, not also depicted on the images of contiguous scenes.

(B) Scene number

The scene number is a number (from 1 to 51) that we assigned for referring to each Landsat scene (see Appendix E, table E-1). The numbering scheme is generally as follows: numbers increase from west to east (by path) and then from north to south (by row). This is based on, and is largely identical to, a convention employed by the Texas Natural Resources Information System (TNRIS). But gaps discovered in our original image coverage in the Panhandle, the Red River Valley, and the middle coastal regions resulted in our adding additional images (and numbers). Scene numbers are unrelated to the path/row numbers and image identification numbers.

LANDSAT IMAGE INVENTORY

(A) Scene name:

(C) Image identification number:

(G) Nominal center point coordinates:

(H) Nominal corner point coordinates:

(1)

(2)

(3)

(4)

(I) Image quality

Nominal (band 5):

Contrast:

Resolution:

Overall appearance:

(M) Biasing factors:

(N) Comments:

(B) Scene number:

(D) Image date:

(E) Path/row:

(F) Satellite:

(J) Cloud cover (percentage)

Nominal:

Actual (estimated):

(K) Obscured area (estimated percentage)

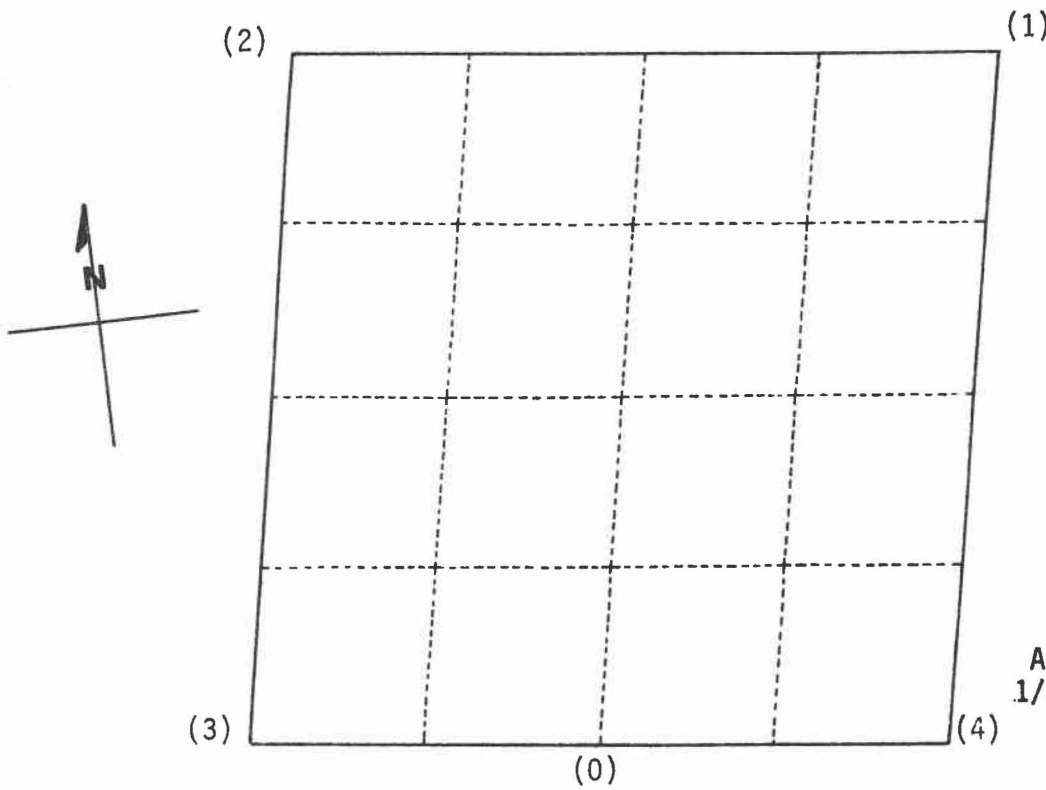
Water (coastal/lake):

Urban/built-up lands:

Agricultural lands:

Other:

(L) Viewing time:



Approximately 1/8 actual size.

Figure F-2. Landsat image inventory form. Each category ("A" through "O") is described in accompanying text.

(C) Image identification number

The image identification (ID) number normally consists of 13 digits and is assigned by EROS Data Center to every Landsat image. Each ID number is a unique and permanent identifier of an image; multiple images covering approximately the same scene area have different ID numbers. The numbers convey coded information about the image. Although the code has been changed several times since its introduction in 1972, the type of information generally includes: satellite number (Landsat 1, 2, or 3); day number (relative to satellite launch date) at the time of observation; hour, minute, and tens of seconds (Greenwich mean time) at moment of observation; type of image (MSS band or RBV subscene number); and image processing information (only on images dated February 17, 1977, and before). Both current and obsolete codes are discussed in the revised Landsat Data Users Handbook (U.S. Geological Survey, 1979) and in pamphlets issued periodically by the EROS Data Center.

There are, however, inconsistencies in this ID numbering system. For example, the ID numbers listed here differ slightly from those printed on the images. In our Landsat image inventory, we present the computer listings of these numbers from the EROS Data Center; these listings show the number by which a scene is retrieved from their files. The first character in the number as it appears on the image is a capital "E," signifying an encoded project identifier. This character is uniformly changed to an "8" in the computer listings. Other changes also occur between certain images and their corresponding computer ID. These are confined to the final two, or in some cases three, characters in the ID number; in the computer listings, these characters may even be omitted from the number as it was printed on the image. Changes in the last character are generally related to the band number, which is a part of the ID code. We could discern no reason for the other seemingly arbitrary discrepancies between the ID number printed on an image and that in the corresponding computer listing.

(D) Image date

Image date includes the calendar month, day, and year (numerical abbreviation), in that order, of data collection. It is the date on which Landsat passed over the scene and collected the data that were later used in image production. Dates that appear on images are presented in the following order: day, month, and year; this differs from the order in the EROS computer printout, whose convention (month, day, year) we employed.

(E) Path/Row

Path/row numbers are derived from the "World Reference System" orbital path and row number coordinates of satellite imaging "targets" (see fig. F-1). These targets generally correspond to the nominal center points of images. Path/row numbers are printed on images produced after early 1979 just to the left of the gray scale in the bottom margin of the image. From February 18, 1977 to early 1979, path/row numbers were printed in the annotation block above the gray scale (see U.S. Geological Survey, 1979, for more detailed explanation), and were not printed at all on images produced before February 18, 1977.

(F) Satellite

"Satellite" refers to the number (1, 2, or 3) of the Landsat satellite that procured the data used to produce an image. Landsat number is usually the second character in the image identification number, but other numbers inexplicably appear in this position on some images.

(G) Nominal center point coordinates

Nominal center point coordinates are intended to comprise the latitude and longitude of the "format center," the geometric extension of the spacecraft yaw axis to the earth's surface. However, accuracy of this value is cited by EROS Data Center as being both to the nearest minute and second; this contradiction clearly indicates the uncertainty with which these nominal center points may be identified. Satellite drift and wobble account for substantial deviations from the prescribed path/row "targets," so that the nominal center point coordinates are only a representative approximation of the image center. The computer printout of image data that was obtained from EROS Data Center frequently lists coordinates that are substantially different from those printed on the image margin, both of which are generally inaccurate. The coordinates cited here are those appearing in the computer listing; these have been included for reference only.

(H) Nominal corner point coordinates

Nominal corner point coordinates comprise the approximate latitude and longitude (nominally accurate to the nearest second) of the scene corners, that is, the points on the earth surface that correspond to each corner of the image. In fact, these coordinates are almost invariably inaccurate, in some instances differing by several minutes from the coordinates obtained by inspection of published 1:250,000- and larger-scale topographic maps. Reliance on these corner coordinates in some cases suggests that contiguous images either do or do not overlap when just the opposite is true. The coordinates cited here (which were obtained from EROS Data Center's computer listings) are included only to provide a gross indication of corner locations.

We numbered the corners of the images as follows: (1) northeast; (2) northwest; (3) southwest; and (4) southeast; to correspond to the respective latitude/longitude coordinates on the image critique forms. Note that the edges of each image are not oriented north-south, east-west, but instead have been rotated clockwise from north by approximately 15 to 20°.

(I) Image quality

Several measures of image quality have been included, such as "nominal," "contrast," "resolution," and "overall appearance." We used these to qualify the data obtained in the present study in concert with inventory items "J" through "O." Where image quality is poor, perception of lineaments may be hampered, obviously resulting in the perception of fewer, shorter, and less reliable figures.

Nominal (band 5)

The nominal quality rating of each band-5 image is assigned by personnel at EROS Data Center, on a scale consisting of "0" or "M" (missing data), "2" (poor), "5" (fair), or "8" (good). The rating is supposed to be a summation of data and image evaluations, but as mentioned, these ratings are often inconsistent. With few exceptions, we used only images with ratings of "8" in this study.

Contrast

We include here a brief subjective evaluation of the relative tonal contrast across each image. "Low" contrast implies little variation in tone across all or part of an image, whereas "moderate" to "high" ratings suggest greater degrees of contrast. We also used other modifiers with obvious connotations where appropriate. Higher image contrast is desirable because contrast is one of the ways in which variations in surface patterns within the scene can be represented.

Resolution

We include a brief, subjective evaluation of the comparative resolution of the image. "Sharp" resolution implies that finely detailed patterns within the image are clearly distinguishable. "Moderate" and "dull" ratings suggest lesser degrees of resolution. We also used other modifiers with obvious connotations where appropriate. Sharp image resolution is desirable because resolution is one of the ways in which surface patterns within the scene can be represented with precision. Resolution is closely related to contrast in Landsat images.

Overall appearance

We summarize our subjective evaluations with a critique of the general or overall appearance of the image. Contrast and resolution across the entire image are combined in each overall evaluation, which may range from "poor" to "fair," "good," or "excellent." We also considered variation in image quality over different parts of the image area in making this evaluation.

(J) Cloud cover (percentage)

We present the approximate percentage of the scene that is obscured by clouds and cloud shadows, both as "nominal values" (those presented on EROS computer files) or "actual" as we perceived the situation. Clouds and their shadows may either resemble or obscure surface features that would be depicted as lineaments; thus, only images with 10 percent or less (and, whenever possible, with 0 percent) nominal cloud cover were used in this study.

Nominal

The nominal percentage (from 0 to 100) of cloud and shadow cover in the image is a result of image evaluations made at EROS Data Center; these evaluations, as presented on the EROS printout, supposedly assess image quality for the prospective user.

Actual (estimated)

The ratings provided by EROS Data Center sometimes proved to be inaccurate; hence, we present our own estimated percentages (from 0 to 100) of cloud and shadow cover in the image.

(K) Obscured area (estimated percentage)

Certain types of ground cover interfere with the expression of geologic controls on landscapes. Since lineaments are, generally, depictions of features that are geologically controlled, fewer lineaments may be found in obscured areas. Moreover, certain ground features may be depicted as figures resembling lineaments, which is equally misleading. Particular care and attention is required when examining obscured areas in images, in order to perceive and interpret valid lineaments. Hence, we estimated percentages of our scenes that were obscured by several major types of cover, including water, urban development, agricultural patterns, and other types of obscuring features.

Water (coastal/lake)

We include our estimated percentage of each scene that consists of water bodies, including extensive lakes, bays, and open marine waters.

Urban/built-up lands

We also estimated percentage of the scene that is composed of urban or other built-up lands, including sparsely populated areas (other than agricultural lands) with numerous, well-marked roads (such as in oil fields), irrigation ditches, or transportation canals.

Agricultural lands

We estimated percentage of each scene that is composed of agricultural lands, particularly tilled croplands as well as pastures and brush-cleared rangelands. Tonal contrast between irrigated and nonirrigated areas was particularly troublesome in some areas.

Other

Finally, we tried to estimate percentages of scenes that are composed of other obscured areas. Also, we tried to categorize the type of obscuring feature; some of the common types of obscured areas are deforested lands, open-pit mines and quarries, and major transportation or utility corridors.

(L) Viewing time

Viewing time is the unit of time allotted for a single viewing period during which lineaments are perceived in an image. Our normal viewing period was 30 minutes, but this period was reduced to as little as 5 minutes for images of coastal scenes, where a significant percentage of the scene area is composed of coastal waters. The reduction in viewing time is roughly proportional to the percentage of the scene that is covered by water. The total viewing time for each image is viewing time ("L") times 6. This is because a single observer examines each image for two viewing periods (generally at least 3 hours apart) and, in all, three observers view each image.

(M) Biasing factors

This is a brief enumeration of factors that affected the perception and interpretation of linear figures in the image (thus constituting biasing factors) during the viewing period. Examples of biasing factors are prominent scan-line stripes; scratches, creases, or streaks in the image; and depictions of certain geomorphic features (such as some dunes, deltas, and eroded shorelines) that have at least questionable structural affinities.

(N) Comments

Under the "comments" section is space for remarks pertaining to any aspect of the inventory. Comments may consist of an elaboration of any of the other entries on the Landsat image inventory form, or any other relevant observation.

(O) (Diagram)

The diagram is a representation of the image outline at approximately 1/8 actual size. The north arrow indicates the general cardinal orientation of the image. The dashed lines, which do not appear on the image itself, are to assist the image evaluator in making percentage estimates (each parallelogram is 1/16 or 6.25 percent of the image area). The dashed lines also make it easier to sketch the locations of obscured areas, cloud-covered areas, parts of the image having poor quality, or any other area or figure that affects the interpretation of the image. The corners of the diagram are numbered in the sequence in which nominal corner point coordinates are listed. When any such feature is deemed important to our perception of lineaments we present a schematic drawing of the salient features.

REFERENCES

EROS Data Center, 1980, Transition to operational Landsat system being planned, in Landsat Data Users Notes: Sioux Falls, South Dakota, U.S. Geological Survey, issue 14, p. 1-4.

U.S. Geological Survey, 1979, Landsat data users handbook: Washington, D.C., U.S. Geological Survey, not paged consecutively.

ADDENDUM F-1

LANDSAT IMAGE INVENTORY

The following 51 pages present Landsat image inventory forms for each of the images that we chose for our statewide lineament assessment. The actual lineament traces are presented on maps in Appendix E.

LANDSAT IMAGE INVENTORY

Scene name: El Paso

Image identification number: 8591415400500

Nominal center point coordinates:

N31° 45' 00", W106° 29' 00"

Nominal corner point coordinates:

(1) N32° 22' 08", W105° 17' 54"

(2) N32° 38' 40", W107° 11' 29"

(3) N31° 07' 15", W107° 39' 12"

(4) N30° 51' 05", W105° 47' 24"

Image quality

Nominal (band 5): 8

Contrast: generally high*

Resolution: very sharp

Overall appearance: very good*

Biasing factors:

Scene number: 01

Image date: 10/19/77

Path/row: 35/38

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 1

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: negligible

Agricultural lands: >5**

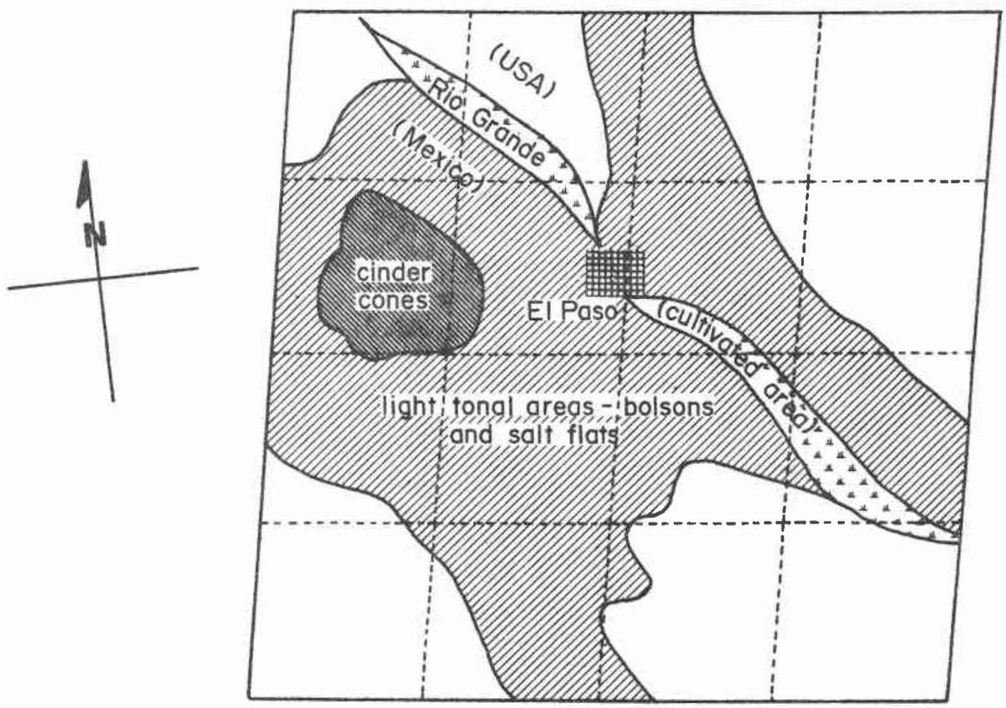
Other: 50* (salt flats, bolson)

Viewing time: 30 min

Comments:

*salt flats and bolsons highly reflective, virtually eliminating contrast in corresponding portions of the image; few lineaments perceived in these areas

**cultivation restricted to Rio Grande riparian area



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Guadalupe Peak

Image identification number: 83029716541X0

Nominal center point coordinates:
N31° 37' 01", W104° 48' 58"

Nominal corner point coordinates:

(1) N32° 12' 38", W103° 40' 20"

(2) N32° 30' 19", W105° 30' 52"

(3) N31° 01' 24", W105° 56' 40"

(4) N30° 43' 44", W104° 07' 53"

Image quality

Nominal (band 5): 8

Contrast: moderate to high

Resolution: moderate

Overall appearance: very good

Biasing factors:

obtrusive scan lines

Scene number: 02

Image date: 12/27/78

Path/row: 34/38

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

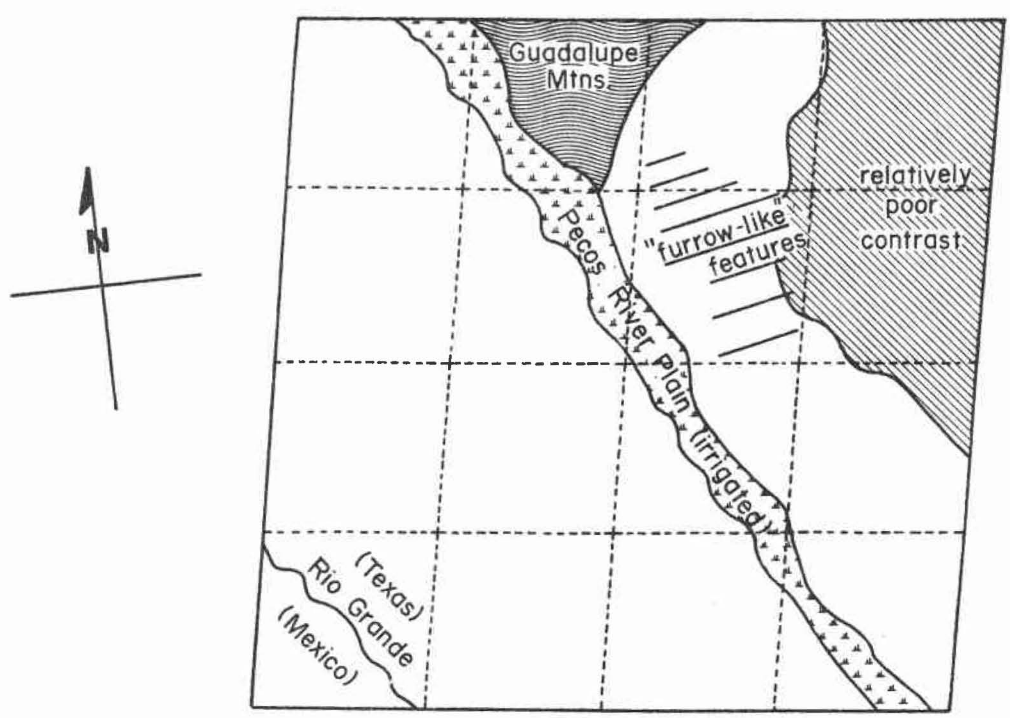
Agricultural lands: <5

Other:

Viewing time: 30 min

Comments:

moderate contrast owing to extensive salt flats and outcrops of other (light tonal) evaporites;
linear "furrow-like" features, first thought to be processing artifacts, later found to be real.



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Los Lamentos, Mexico

Image identification number: 83027916544X0

Nominal center point coordinates:

N30° 11' 56", W105° 16' 30"

Nominal corner point coordinates:

(1) N30° 47' 42", W104° 08' 59"

(2) N31° 05' 07", W105° 57' 54"

(3) N29° 36' 10", W106° 23' 10"

(4) N29° 18' 45", W104° 35' 53"

Image quality

Nominal (band 5): 8

Contrast: very high

Resolution: sharp

Overall appearance: excellent

Biasing factors:

prominent scan lines

Comments:

Scene number: 03

Image date: 12/09/78

Path/row: 34/39

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

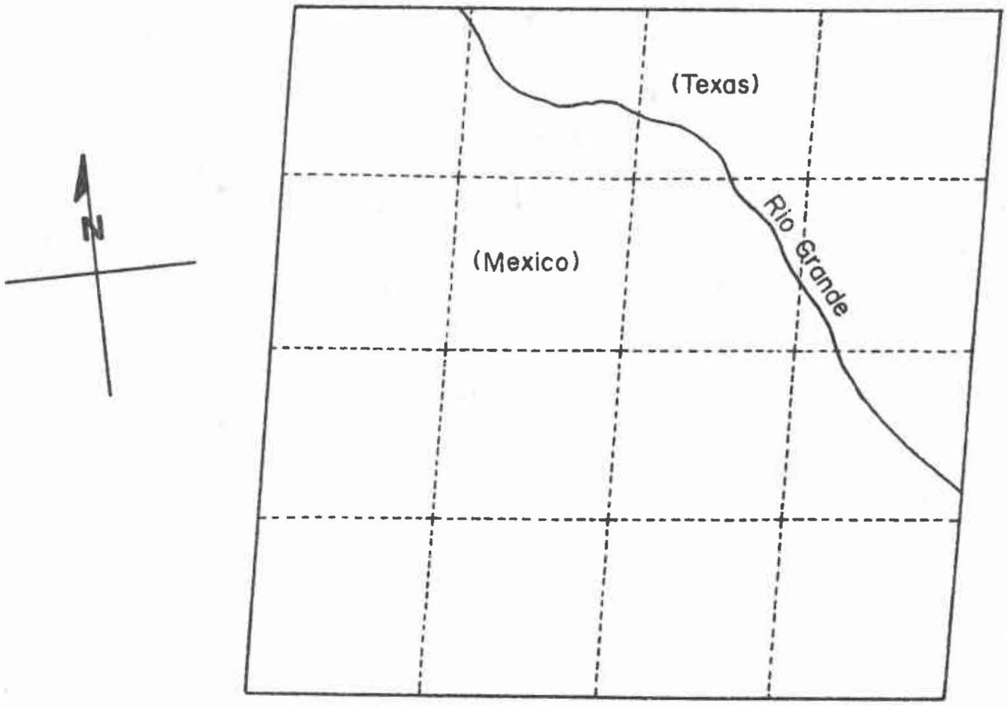
Water (coastal/lake): 0

Urban/built-up lands: 0

Agricultural lands: negligible

Other: desert (basin and range)

Viewing time: 30 min



Approximately 1/8 actual size.

Scene name: Dalhart

Image identification number: 8593015253500

Nominal center point coordinates:

N36° 00' 00", W102 24' 00"

Nominal corner point coordinates:

(1) N36° 37' 04", W101° 09' 00"

(2) N36° 54' 05", W103° 09' 04"

(3) N35° 22' 12", W103° 37' 53"

(4) N35° 05' 38", W101° 40' 02"

Image quality

Nominal (band 5): 8

Contrast: moderate to high

Resolution: moderate to dull

Overall appearance: good

Biasing factors:

Scene number: 04

Image date: 11/04/77

Path/row: 33/35

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): <5

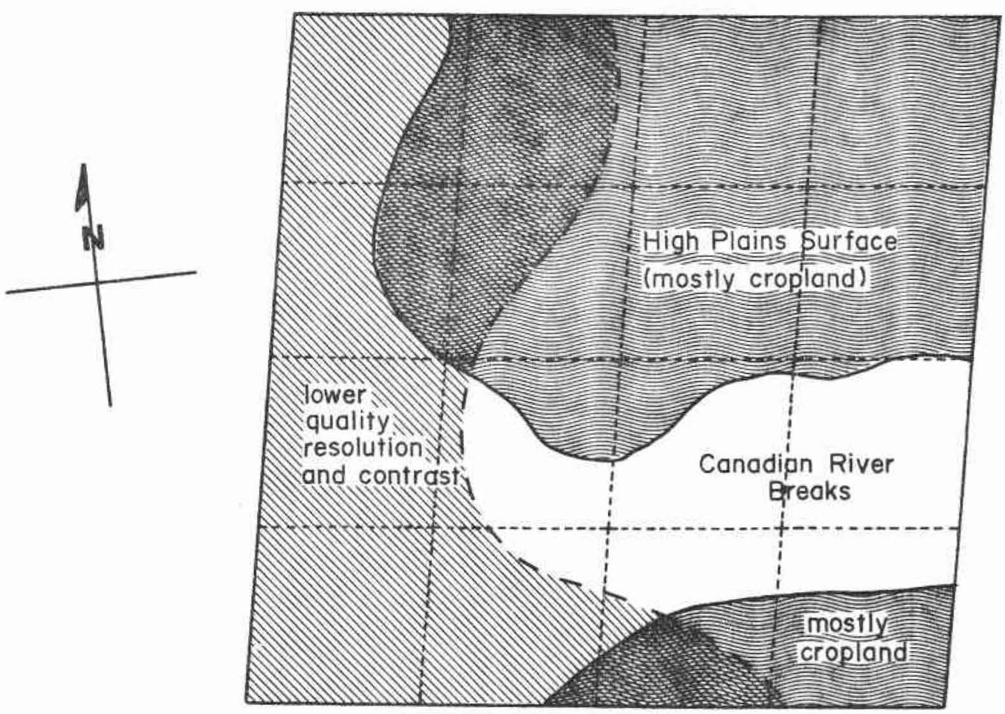
Urban/built-up lands: 0

Agricultural lands: 60

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Muleshoe

Image identification number: 8229116450500

Nominal center point coordinates:
N34° 35' 00", W102° 36' 00"

Nominal corner point coordinates:

(1) N35° 11' 05", W101° 21' 56"

(2) N35° 29' 21", W103° 19' 00"

(3) N33° 58' 13", W103° 49' 02"

(4) N33° 40' 23", W101° 54' 00"

Image quality

Nominal (band 5): 8

Contrast: moderate

Resolution: moderate to sharp

Overall appearance: good

Scene number: 05

Image date: 11/09/75

Path/row: 33/36

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): <1

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: <5

Agricultural lands: 90

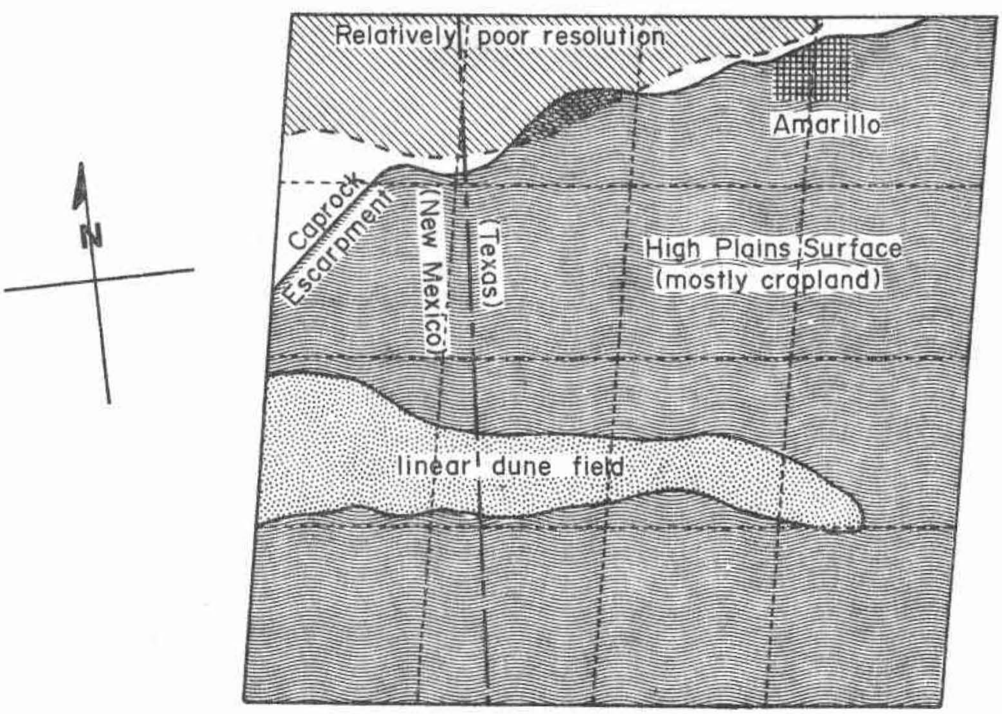
Other:

Viewing time: 30 min

Biasing factors:

obvious cultural overprint, especially roads, fencelines, and pipelines

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Hobbs, New Mexico

Image identification number: 83022416481X0

Nominal center point coordinates:

N33° 04' 08", W103° 01' 59"

Nominal corner point coordinates:

(1) N33° 39' 35", W101° 52' 09"

(2) N33° 57' 33", W103° 44' 27"

(3) N32° 28' 42", W104° 10' 50"

(4) N32° 10' 44", W102° 20' 24"

Image quality

Nominal (band 5): 8

Contrast: moderate (+)

Resolution: moderate (-)

Overall appearance: fair to good

Biasing factors:

oil fields, croplands impose "false lineaments"

Scene number: 06

Image date: 10/15/78

Path/row: 33/37

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: negligible

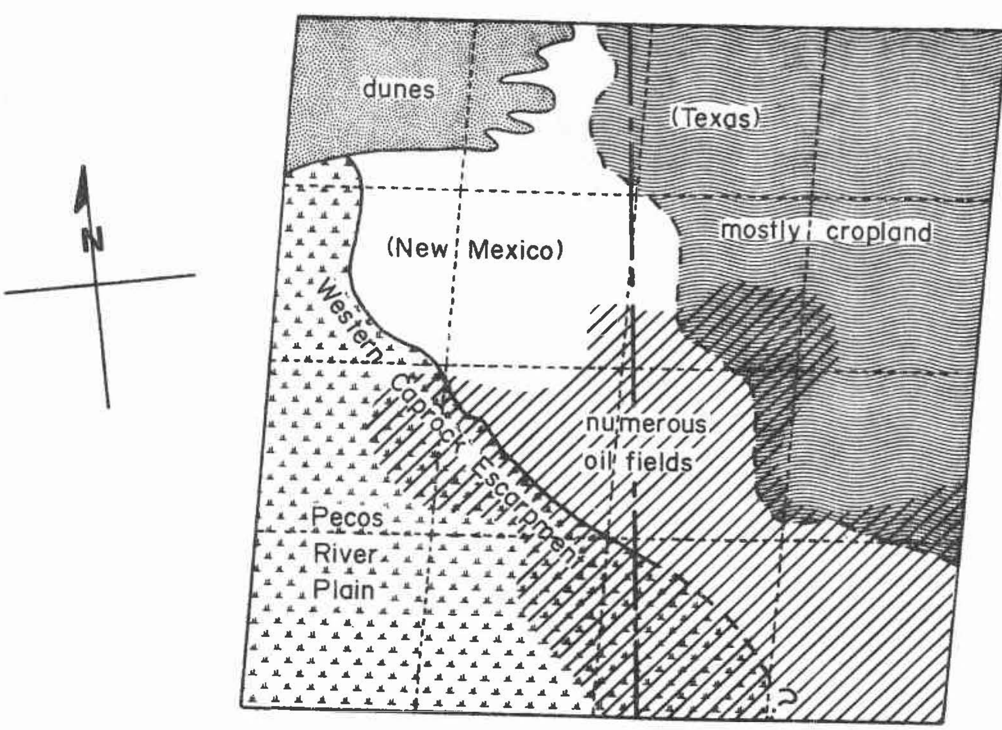
Agricultural lands: ≳50

Other:

Viewing time: 30 min

Comments:

eolian features may be confused with substrate control of lineaments; too, eolian features may be controlled by substrate



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Pecos

Image identification number: 82147916354X0

Nominal center point coordinates:

N31° 37' 00", W103° 24' 00"

Nominal corner point coordinates:

(1) N32° 10' 28", W102° 15' 53"

(2) N32° 28' 08", W104° 06' 23"

(3) N31° 03' 32", W104° 31' 16"

(4) N30° 45' 52", W102° 42' 26"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: generally sharp

Overall appearance: good to excellent

Scene number: 07

Image date: 02/09/79

Path/row: 33/38

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: minimal

Agricultural lands: ~20

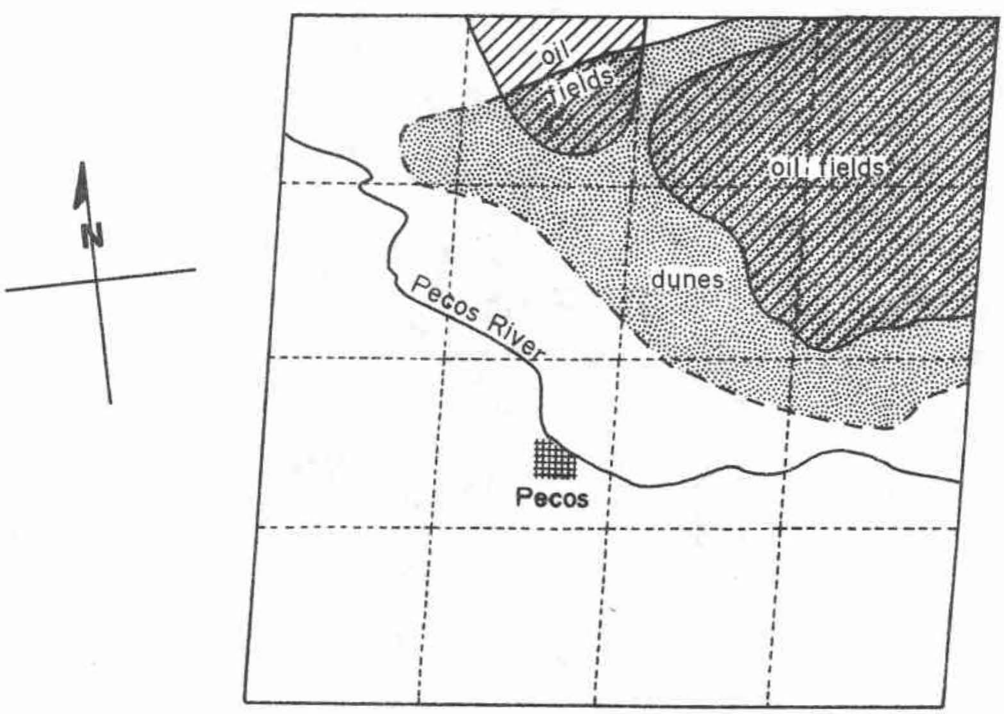
Other:

Viewing time: 30 min

Biasing factors:

influence (importance) of dunes; oil fields impose "false lineaments"

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Alpine

Image identification number: 82108316174X0

Nominal center point coordinates:
N30° 14' 17", W103° 58' 41"

Nominal corner point coordinates:
(1) N30° 48' 10", W102° 54' 43"
(2) N31° 04' 40", W104° 37' 52"
(3) N29° 40' 24", W105° 01' 54"
(4) N29° 23' 54", W103° 20' 09"

Image quality
Nominal (band 5): 8
Contrast: excellent
Resolution: very sharp
Overall appearance: very good

Biasing factors:

Scene number: 08

Image date: 01/09/78

Path/row: 33/39

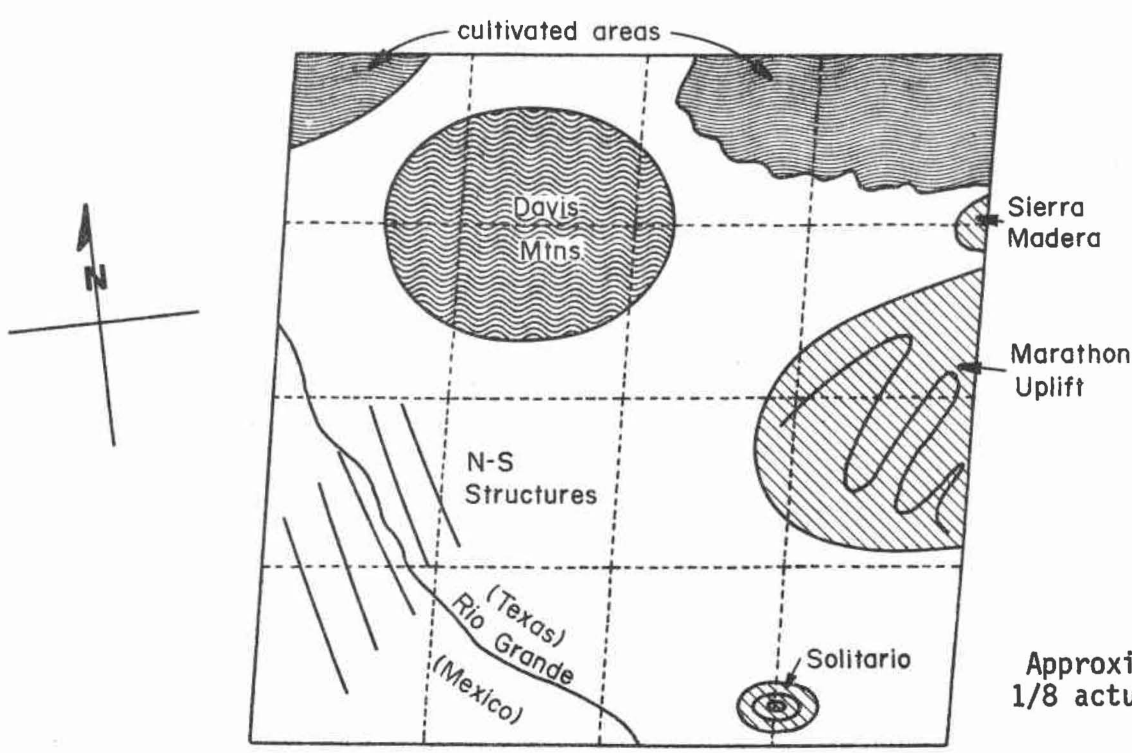
Satellite: Landsat 2

Cloud cover (percentage)
Nominal: 0
Actual (estimated): 0

Obscured area (estimated percentage)
Water (coastal/lake): 0
Urban/built-up lands: 0
Agricultural lands: minimal
Other:

Viewing time: 30 min

Comments:
mainly mountains and bolsons



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Potrero del Llano, Mexico

Image identification number: 82108316181X0

Nominal center point coordinates:

N28° 48' 07", W104° 22' 19"

Nominal corner point coordinates:

(1) N29° 22' 08", W103° 19' 21"

(2) N29° 38' 25", W105° 01' 03"

(3) N28° 14' 06", W105° 24' 37"

(4) N27° 57' 50', W103° 44' 13"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: mostly sharp

Overall appearance: excellent

Biasing factors:

Scene number: 09

Image date: 01/09/78

Path/row: 33/40

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

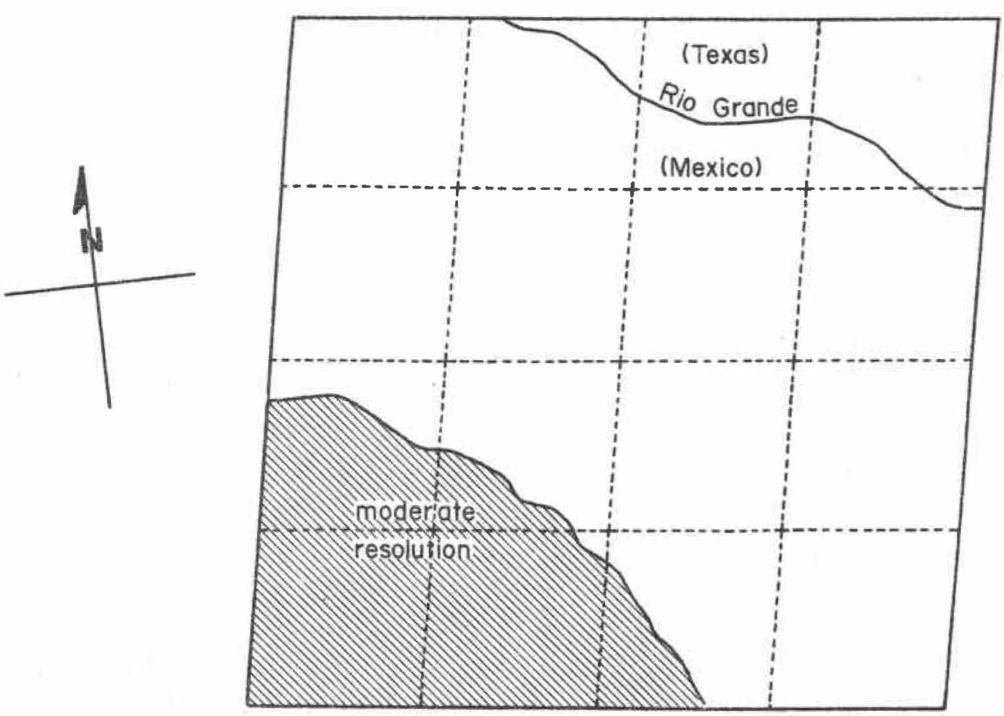
Agricultural lands: minimal

Other:

Viewing time: 30 min

Comments:

area entirely mountains and bolsons; higher density of lineaments in mountains



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Canadian

Image identification number: 8225416391500

Nominal center point coordinates:
N35° 52' 00", W100° 42' 00"

Nominal corner point coordinates:
(1) N36° 28' 05", W099° 25' 47"
(2) N36° 47' 10", W101° 25' 55"
(3) N35° 15' 09", W101° 57' 06"
(4) N34° 56' 34", W099° 59' 11"

Image quality
Nominal (band 5): 8
Contrast: high
Resolution: moderate to sharp
Overall appearance: excellent

Biasing factors:

Scene number: 10

Image date: 10/03/75

Path/row: 32/35

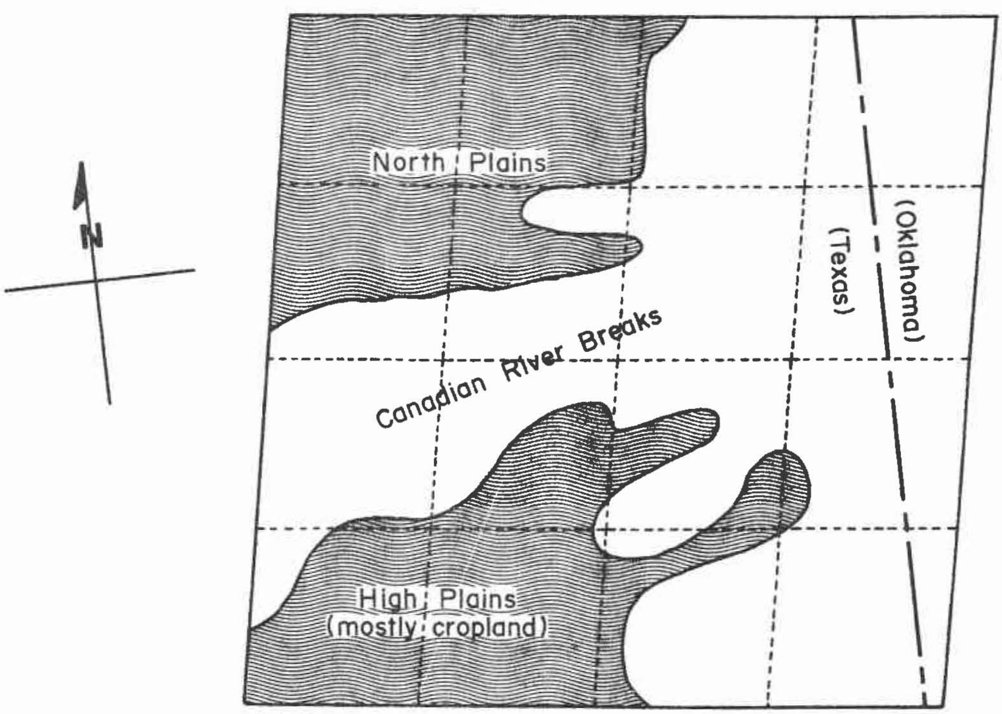
Satellite: Landsat 2

Cloud cover (percentage)
Nominal: 0
Actual (estimated): 0

Obscured area (estimated percentage)
Water (coastal/lake): <5
Urban/built-up lands: 0
Agricultural lands: ~20
Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Floydada

Image identification number: 8591115222500

Nominal center point coordinates:
N34° 34' 00", W101° 22' 00"

Nominal corner point coordinates:

(1) N35° 10' 49", W100° 08' 36"

(2) N35° 27' 49", W102° 05' 50"

(3) N33° 56' 29", W102° 34' 23"

(4) N33° 39' 55", W100° 39' 12"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: very sharp

Overall appearance: excellent

Scene number: 11

Image date: 10/16/77

Path/row: 32/36

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: negligible

Agricultural lands: 80

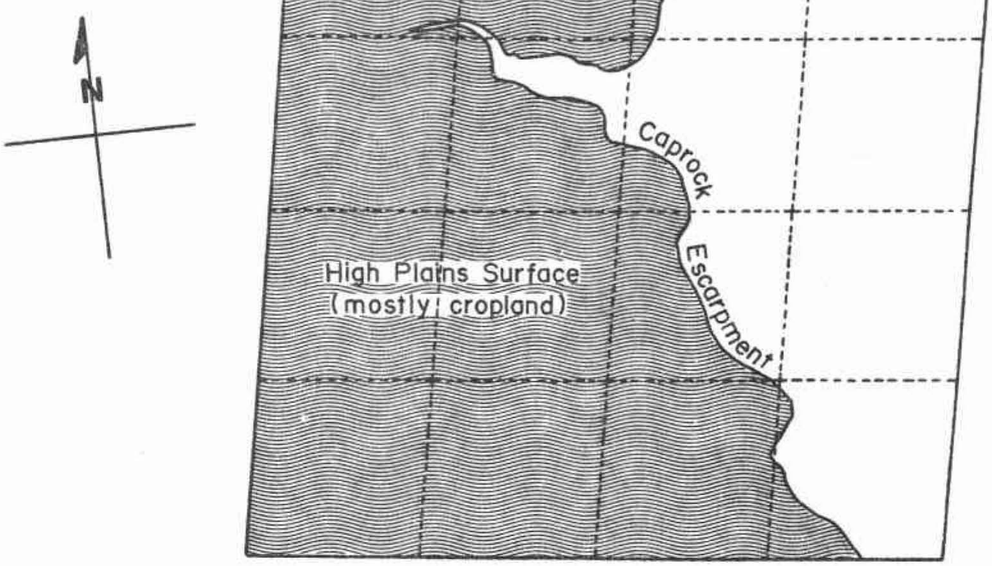
Other:

Viewing time: 30 min

Biasing factors:

intensive agricultural activity on High Plains surface (tableland) obscures features that might otherwise be depicted as lineaments; playas, which may reveal alinements, can be confused with center-pivot irrigation areas

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Post

Image identification number: 82111816123X0

Nominal center point coordinates:
N33° 04' 23", W101° 36' 50"

Nominal corner point coordinates:

(1) N33° 37' 57", W100° 30' 44"

(2) N33° 54' 58", W102° 17' 02"

(3) N32° 30' 48", W102° 42' 07"

(4) N32° 13' 47", W100° 57' 24"

Image quality

Nominal (band 5): 8

Contrast: moderate to low

Resolution: moderate to dull

Overall appearance:

Scene number: 12

Image date: 02/13/78

Path/row: 32/37

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

Agricultural lands: 75

Other:

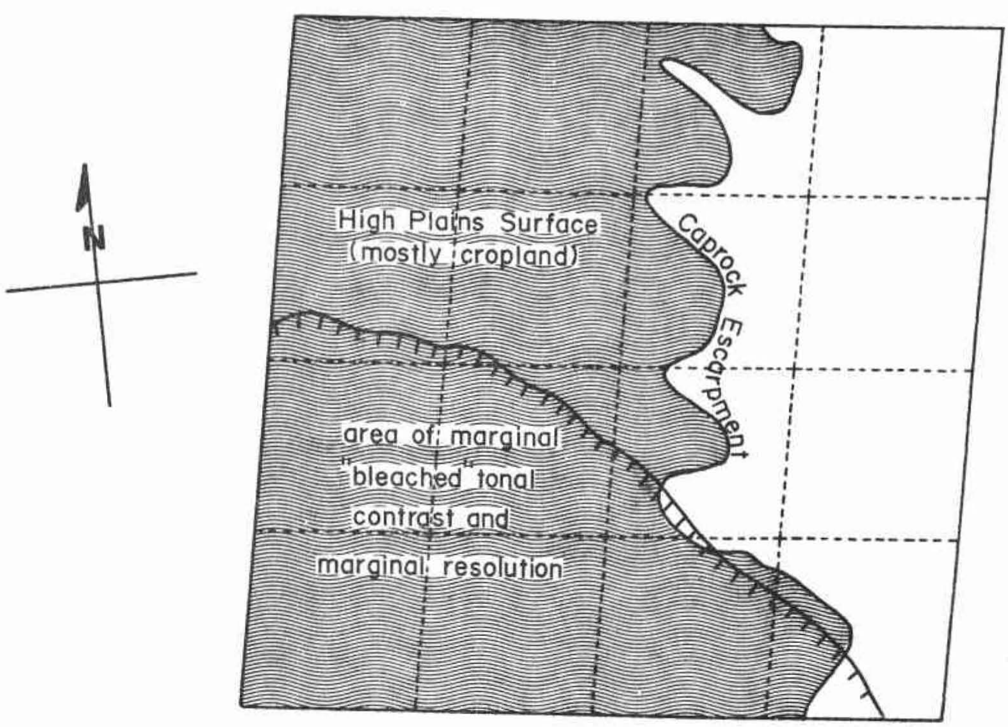
Viewing time: 30 min

Biasing factors:

intensive agricultural use of High Plains surface obscures possible lineaments; high relief at edge of Caprock results in perception of more lineaments

Comments:

playa alignment noted on this image



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Odessa

Image identification number: 8592915211500

Nominal center point coordinates: N31° 45' 00", W102° 13' 00"

Nominal corner point coordinates:

(1) N32° 22' 31", W101° 01' 46"

(2) N32° 38' 45", W102° 55' 55"

(3) N31° 06' 52", W103° 23' 19"

(4) N30° 51' 00", W101° 30' 59"

Image quality

Nominal (band 5): 8

Contrast: moderate (+)

Resolution: moderate (-)

Overall appearance:

Scene number: 13

Image date: 11/03/77

Path/row: 32/38

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: minimal

Agricultural lands: ~40

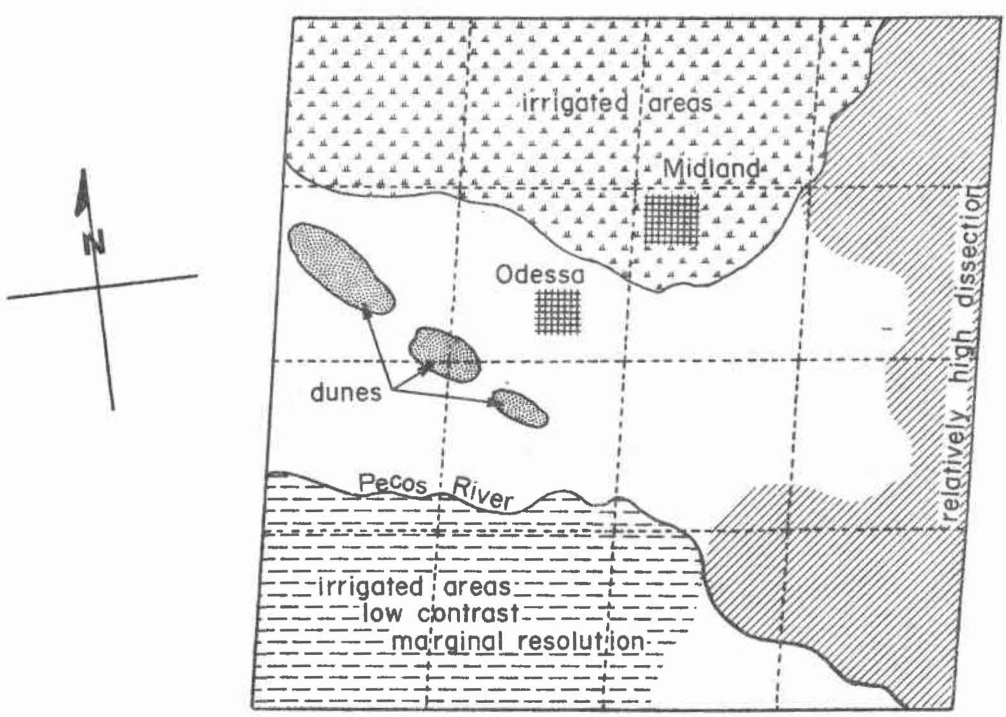
Other:

Viewing time: 30 min

Biasing factors:

oil fields in rectilinear grid and irrigated areas impart false lineaments; scan lines obtrusive

Comments: numerous oil fields throughout scene



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Sanderson

Image identification number: 82110016122X0

Nominal center point coordinates:

N30° 13' 08", W102° 28' 37"

Nominal corner point coordinates:

(1) N30° 47' 01", W101° 24' 41"

(2) N31° 03' 31", W103° 07' 48"

(3) N29° 39' 16", W103° 31' 50"

(4) N29° 22' 45", W101° 50' 06"

Image quality

Nominal (band 5): 8

Contrast: generally high

Resolution: generally sharp

Overall appearance: excellent

Biasing factors:

Scene number: 14

Image date: 01/26/78

Path/row: 32/39

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

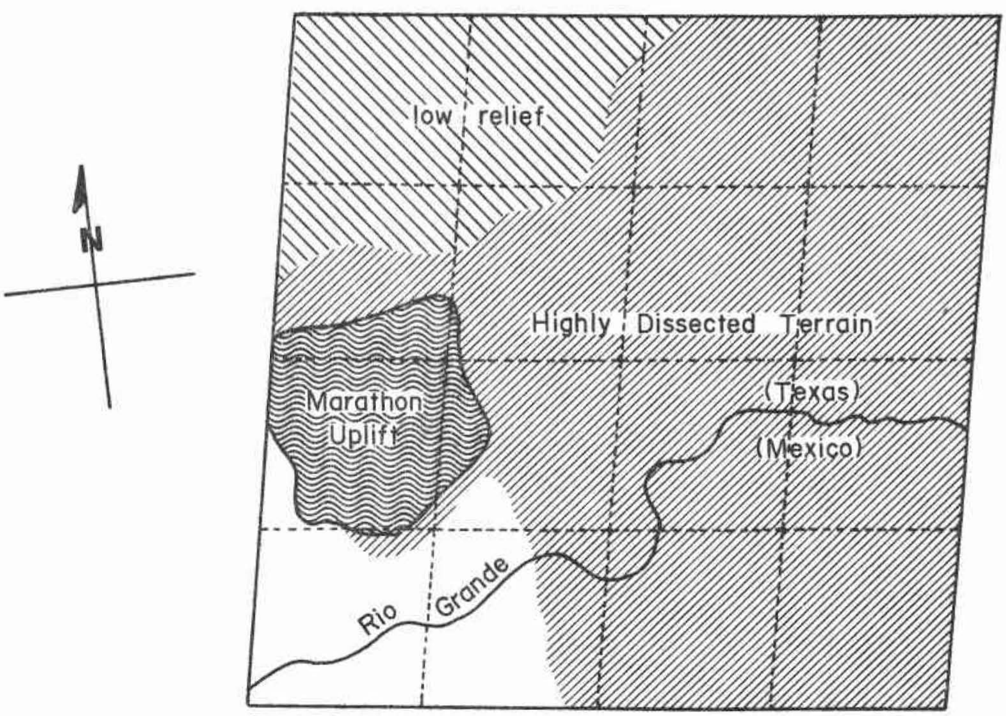
Urban/built-up lands: 0

Agricultural lands: minimal

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Santa Rosa, Mexico

Image identification number: 82110016125XO

Nominal center point coordinates:

N28° 47' 17", W102° 53' 06"

Nominal corner point coordinates:

(1) N29° 21' 18", W101° 50' 08"

(2) N29° 37' 34", W103° 31' 49"

(3) N28° 13' 16", W103° 55' 23"

(4) N27° 56' 59", W102° 15' 00"

Image quality

Nominal (band 5): 8

Contrast: excellent

Resolution: very sharp

Overall appearance: excellent

Biasing factors:

Scene number: 15

Image date: 01/26/78

Path/row: 32/40

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

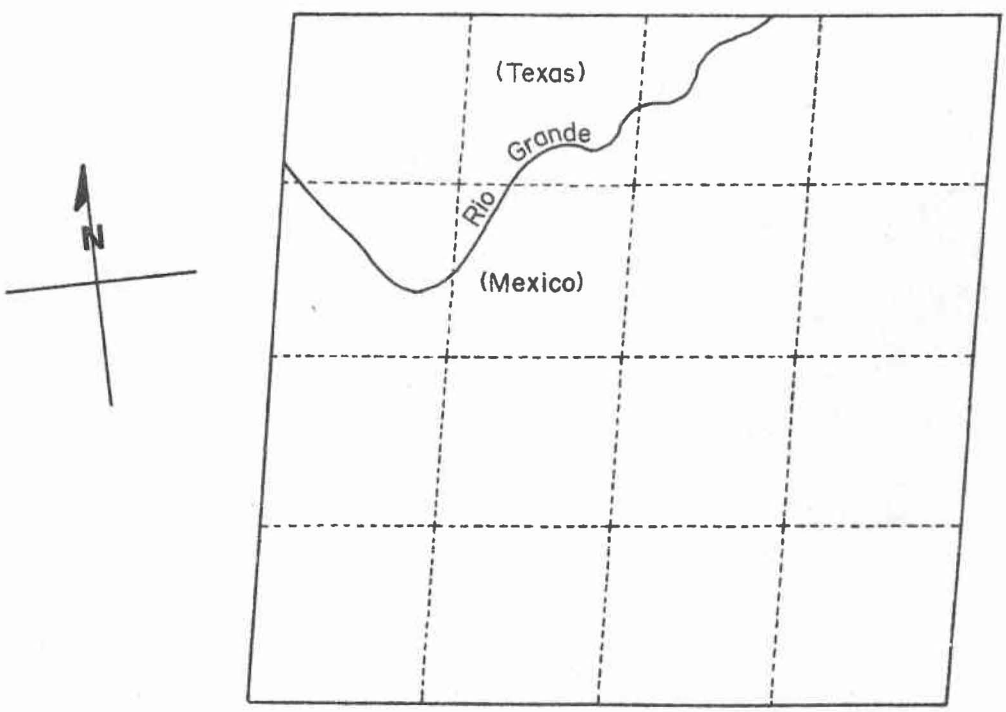
Agricultural lands: minimal

Other:

Viewing time: 30 min

Comments:

typical block faulted mountains and bolsons of Chihuahuan Desert; most lineaments expressed in mountains



Approximately 1/8 actual size.

Scene name: Childress

Image identification number: 82138716194X0

Nominal center point coordinates:
N34° 28' 19", W099° 38' 53"

Nominal corner point coordinates:
(1) N35° 03' 35", W098° 27' 47"
(2) N35° 21' 51", W100° 21' 56"
(3) N33° 53' 03", W100° 48' 56"
(4) N33° 34' 48", W098° 56' 47"

Image quality
Nominal (band 5): 8
Contrast: moderate
Resolution: moderate to sharp
Overall appearance: good

Biasing factors:
obtrusive scan lines

Scene number: 16

Image date: 11/09/78

Path/row: 31/36

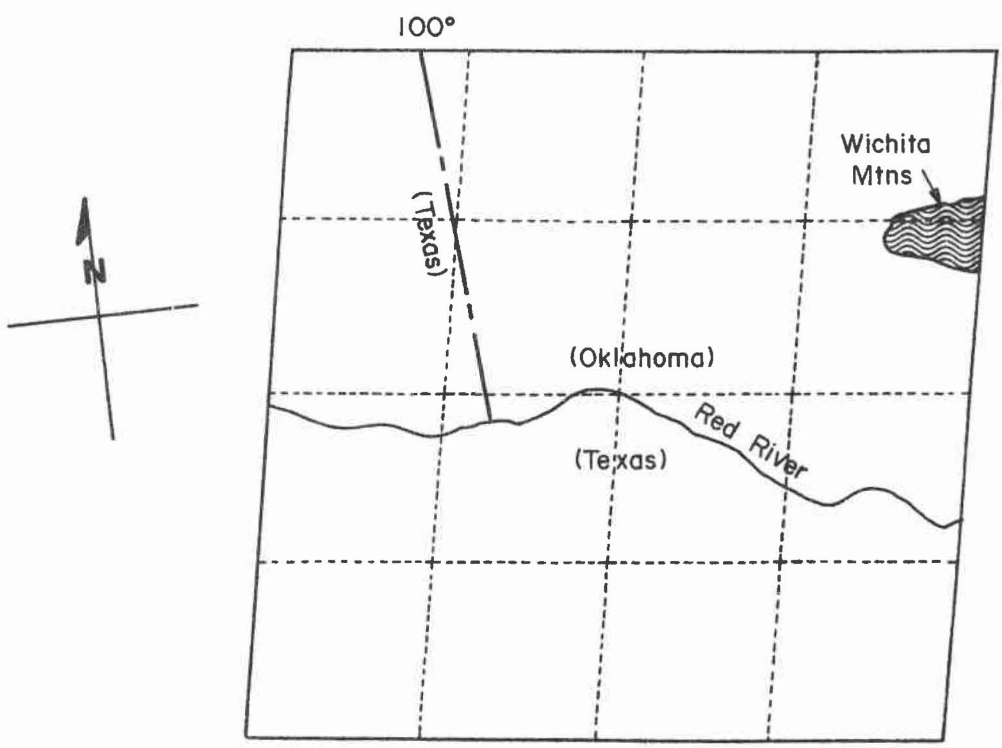
Satellite: Landsat 2

Cloud cover (percentage)
Nominal: 0
Actual (estimated): 0

Obscured area (estimated percentage)
Water (coastal/lake): negligible
Urban/built-up lands: negligible
Agricultural lands: 80
Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Aspermont

Image identification number: 83063616330X0

Nominal center point coordinates:
N33° 05' 00", W100 13' 00"

Nominal corner point coordinates:

(1) N33° 38' 18", W099° 03' 41"

(2) N33° 56' 16", W100° 55' 58"

(3) N32° 31' 42", W101° 21' 24"

(4) N32° 13' 44", W099° 30' 54"

Image quality

Nominal (band 5): 8

Contrast: moderate

Resolution: moderate (+)

Overall appearance: very good

Biasing factors:

Scene number: 17

Image date: 12/01/79

Path/row: 31/37

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

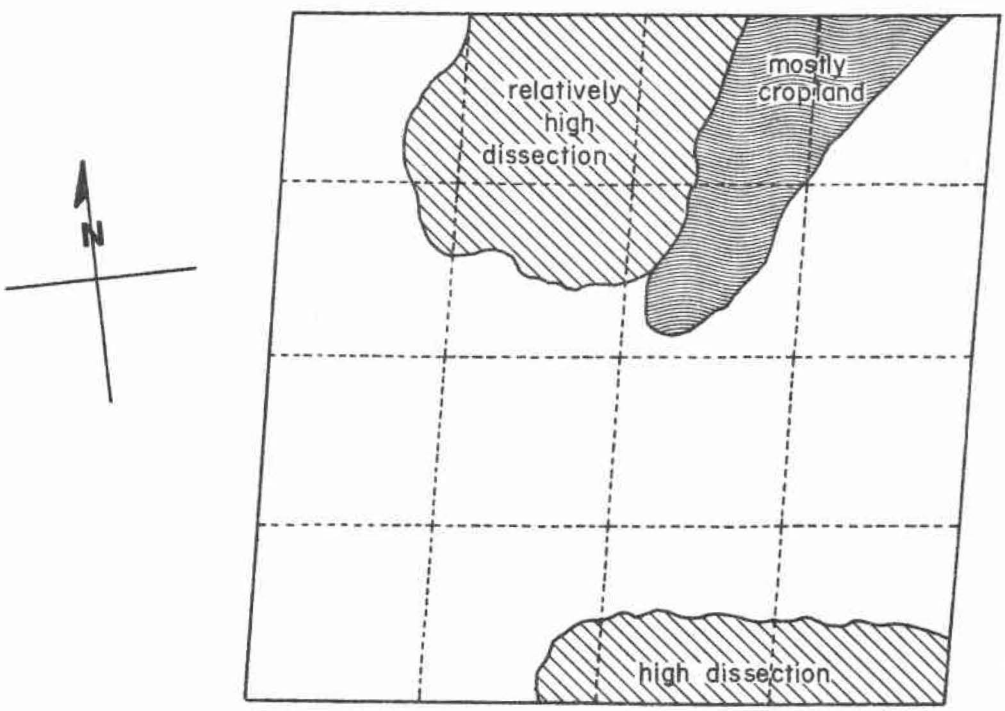
Agricultural lands: 40-60

Other:

Viewing time: 30 min

Comments:

"enhanced" quality—no scan lines visible



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: San Angelo

Image identification number: 82138716203X0

Nominal center point coordinates:

N31° 36' 54", W100° 30' 36"

Nominal corner point coordinates:

(1) N32° 12' 31", W099° 21' 59"

(2) N32° 30' 11", W101° 12' 31"

(3) N31° 01' 17", W101° 38' 18"

(4) N30° 43' 37", W099° 49' 31"

Image quality

Nominal (band 5): 8

Contrast: generally high

Resolution: moderate (locally dull)

Overall appearance: good

Biasing factors:

Scene number: 18

Image date: 11/09/78

Path/row: 31/38

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): negligible

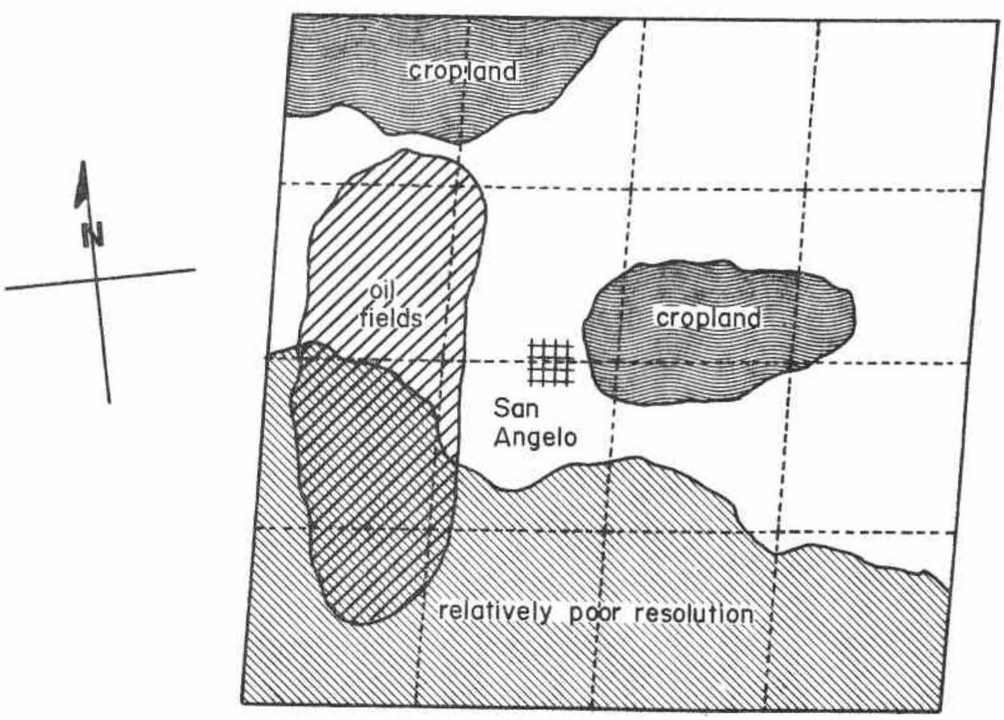
Urban/built-up lands: negligible

Agricultural lands: 30 +

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Devil's River

Image identification number: 82138716205X0

Nominal center point coordinates:

N30° 11' 10", W100° 55' 37"

Nominal corner point coordinates:

(1) N30° 46' 56", W099° 48' 06"

(2) N31° 04' 20", W101° 37' 01"

(3) N29° 35' 24", W101° 02' 17"

(4) N29° 17' 59", W100° 15' 00"

Image quality

Nominal (band 5): 8

Contrast: generally high

Resolution: generally sharp

Overall appearance: excellent

Scene number: 19

Image date: 11/09/78

Path/row: 31/39

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

Agricultural lands: <5

Other:

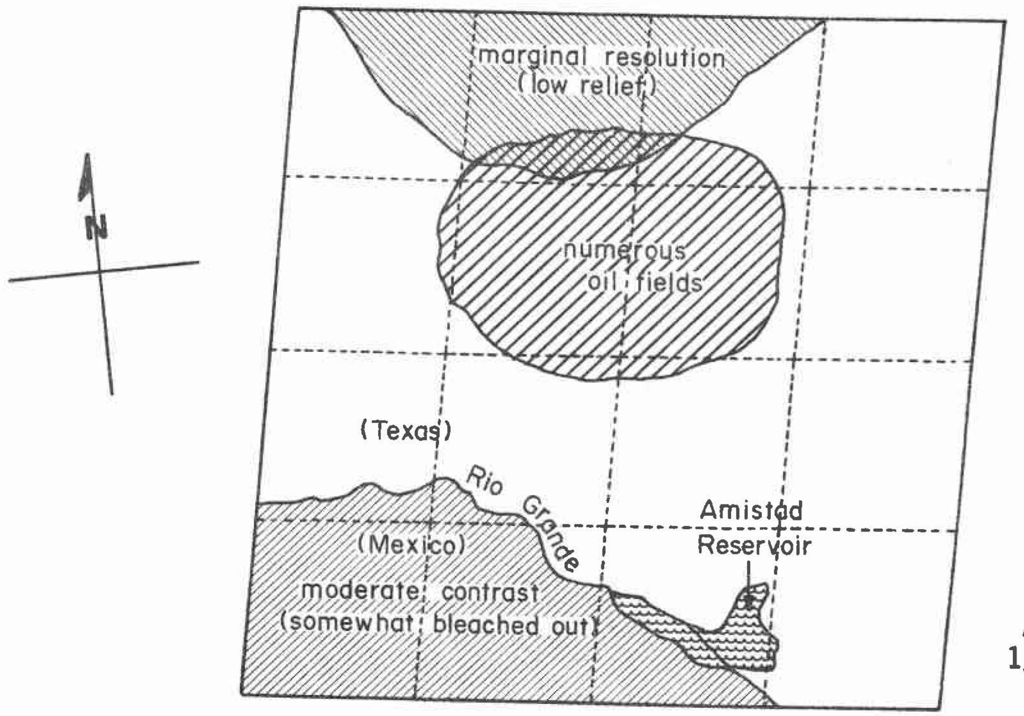
Viewing time: 30 min

Biasing factors:

rectilinear patterns of oil fields may be perceived as "false lineaments"

Comments:

most of image covers highly dissected terain



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

<u>Scene name</u>: Nueva Rosita, Mexico

<u>Image identification number</u>: 83000516345X0

<u>Nominal center point coordinates</u>:

N28° 43' 41", W101° 14' 28"

<u>Nominal corner point coordinates</u>:

(1) N29° 17' 42", W100° 11' 32"

(2) N29° 33' 58", W101° 53' 10"

(3) N28° 09' 39", W102° 16' 43"

(4) N27° 53' 24", W100° 36' 22"

<u>Image quality</u>

Nominal (band 5): 8

Contrast: high

Resolution: sharp

Overall appearance: very good

<u>Biasing factors</u>:

<u>Scene number</u>: 20

<u>Image date</u>: 03/10/78

<u>Path/row</u>: 31/40

<u>Satellite</u>: Landsat 3

<u>Cloud cover (percentage)</u>

Nominal: 0

Actual (estimated): 0

Obscured area (<u>estimated percentage</u>)

Water (coastal/lake): 0

Urban/built-up lands: 0

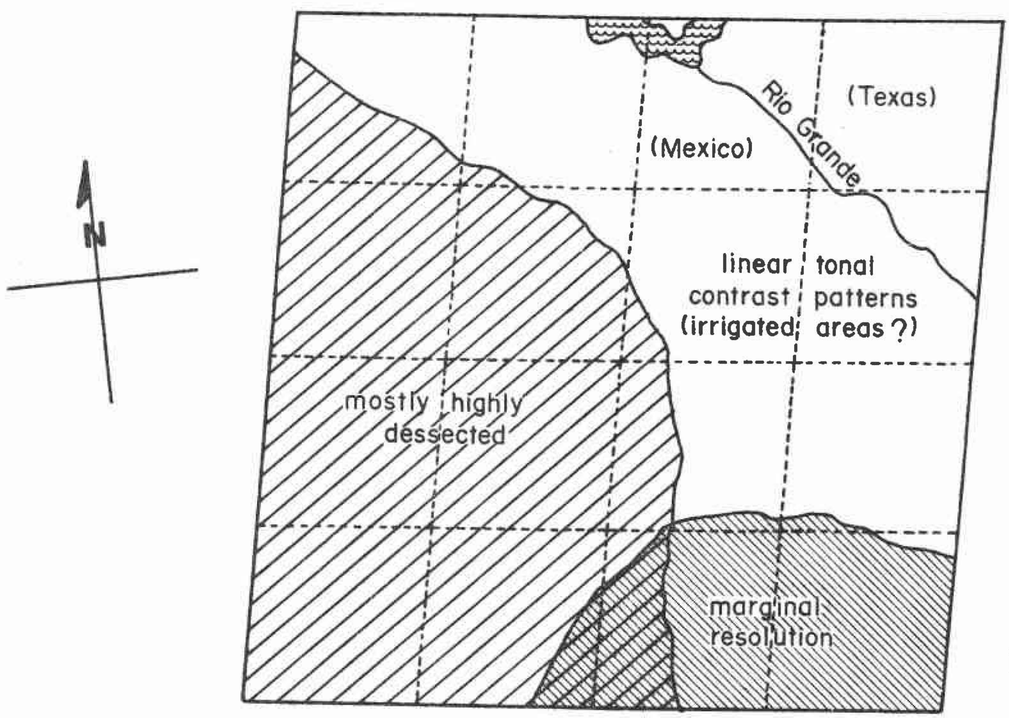
Agricultural lands: 30

Other:

<u>Viewing time</u>: 30 min

<u>Comments</u>:

broad areas of contrasting tone (irrigated land or processing artifact?) most prominent in Mexico; may result in local "false anomalies".



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Lawton, Oklahoma

Image identification number: 83023916304X0

Nominal center point coordinates:

N34° 29' 56", W098° 18' 00"

Nominal corner point coordinates:

(1) N35° 05' 12", W097° 06' 53"

(2) N35° 23' 28", W099° 01' 04"

(3) N33° 54' 41", W099° 28' 04"

(4) N33° 36' 25", W097° 35' 54"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: moderate

Overall appearance: fair to good

Biasing factors:

biases mainly due to prevalence of cropland

Scene number: 21

Image date: 10/31/78

Path/row: 30/36

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): negligible

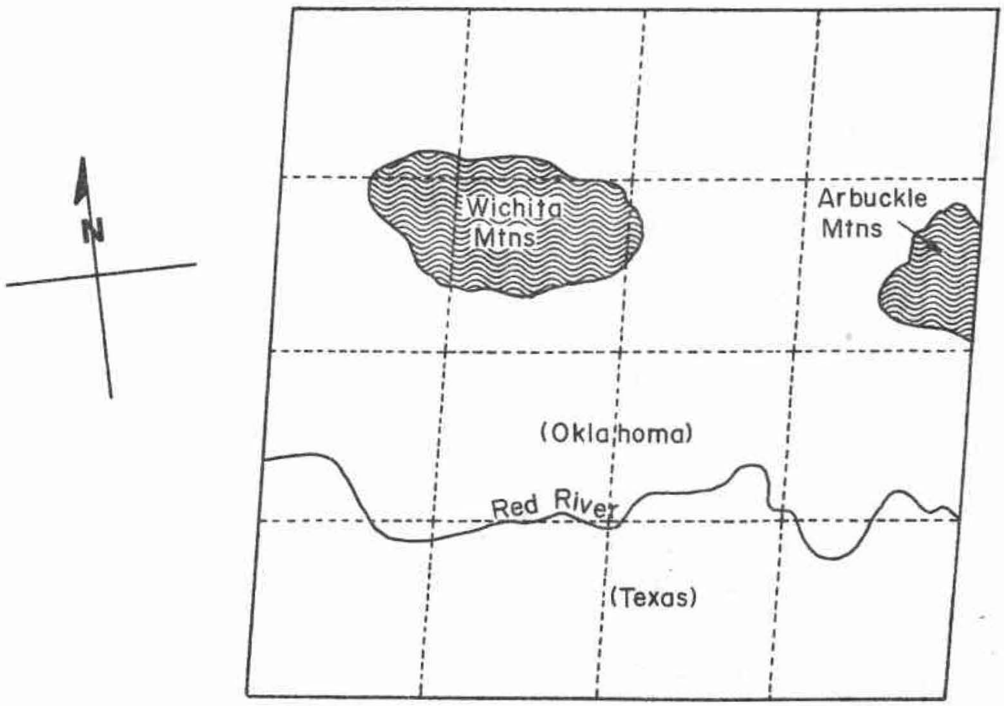
Urban/built-up lands: 0

Agricultural lands: 80 +

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Graham

Image identification number: 82138616142X0

Nominal center point coordinates:

N33° 02' 24", W098° 38' 06"

Nominal corner point coordinates:

(1) N33° 37' 51", W097° 28' 17"

(2) N33° 55' 48", W099° 20' 34"

(3) N32° 26' 57", W099° 46' 56"

(4) N32° 09' 00", W097° 56' 32"

Image quality

Nominal (band 5): 8

Contrast: moderate (+)

Resolution: moderate (-)

Overall appearance: very good

Scene number: 22

Image date: 11/08/78

Path/row: 30/37

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): negligible

Urban/built-up lands: negligible

Agricultural lands: ~40

Other:

Viewing time: 30 min

Biasing factors:

cropland masks true lineaments; may impart false ones

Comments:

Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Brownwood

Image identification number: 82136816140X0

Nominal center point coordinates:
N31° 37' 34", W099° 06' 40"

Nominal corner point coordinates:

(1) N32° 13' 10", W097° 58' 02"

(2) N32° 30" 51", W099° 48' 35"

(3) N31° 01' 57", W100° 14' 22"

(4) N30° 44' 16", W098° 25' 35"

Image quality

Nominal (band 5): 8

Contrast: moderate to low

Resolution: moderate (-)

Overall appearance: generally fair

Biasing factors:

Scene number: 23

Image date: 10/21/78

Path/row: 30/38

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): minimal (local)

Obscured area (estimated percentage)

Water (coastal/lake): negligible

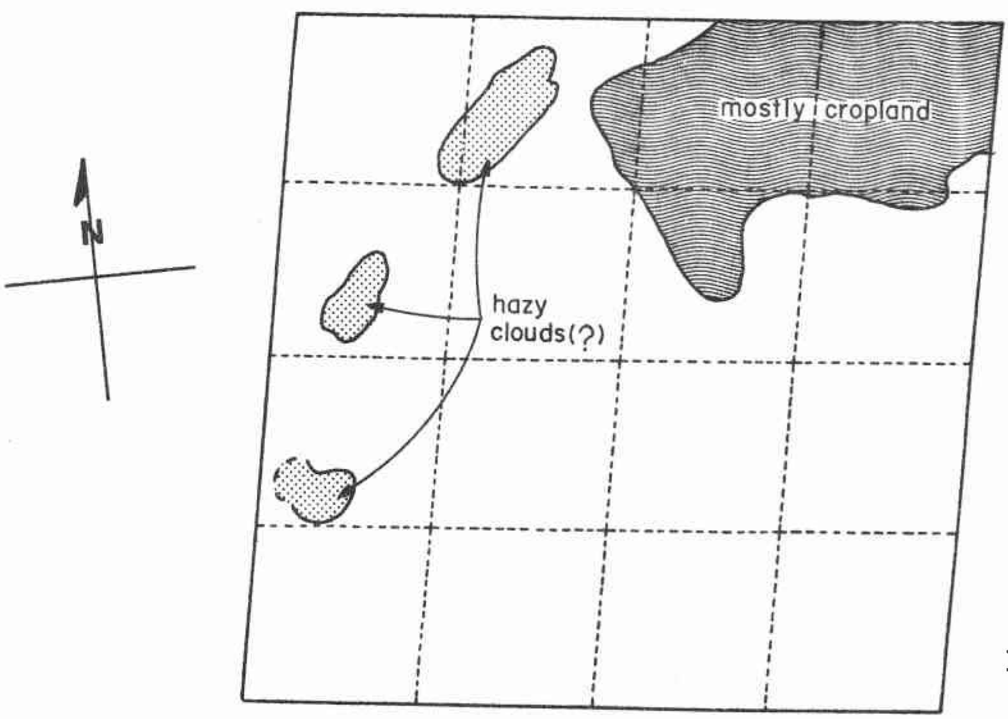
Urban/built-up lands: negligible

Agricultural lands: ~30

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Junction

Scene number: 24

Image identification number: 8227016292500

Image date: 10/19/75

Path/row: 30/39

Satellite: Landsat 2

Nominal center point coordinates:

N30° 13' 00", W099° 35' 00"

Nominal corner point coordinates:

(1) N30° 50' 03", W098° 24' 09"

(2) N31° 07' 20", W100° 16' 37"

(3) N29° 35' 21", W100° 45' 01"

(4) N29° 18' 26", W098° 54' 13"

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: minimal

Agricultural lands: ~30

Other:

Viewing time: 30 min

Image quality

Nominal (band 5): 5

Contrast: moderate

Resolution: moderate to dull

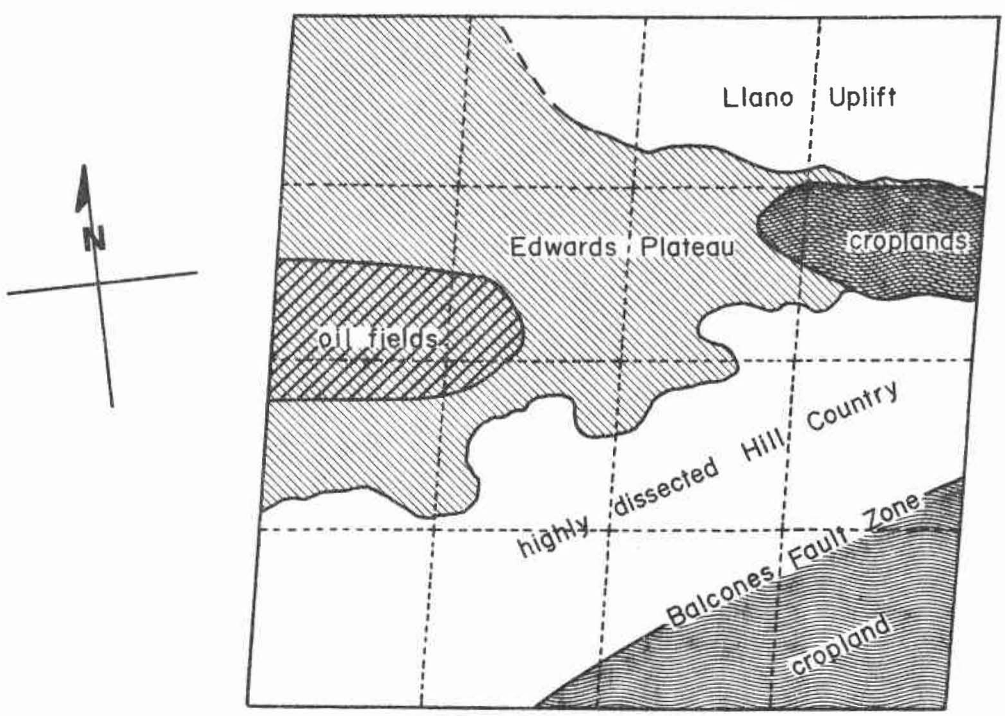
Overall appearance: fair

Biasing factors:

high dissection of Hill Country results in more lineaments being discerned; oil fields impart "false lineaments"

Comments:

relatively low relief plateau lands also areas of marginal resolution



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Crystal City

Image identification number: 8227016294500

Nominal center point coordinates:
N28° 47' 00", W099° 59' 00"

Nominal corner point coordinates:

(1) N29° 24' 10", W098° 49' 11"

(2) N29° 41' 14", W100° 40' 01"

(3) N28° 09' 17", W101° 08' 03"

(4) N27° 52' 33", W099° 18' 45"

Image quality

Nominal (band 5): 5

Contrast: moderate to high

Resolution: moderate

Overall appearance: good to very good

Scene number: 25

Image date: 10/19/75

Path/row: 30/40

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: ~0

Agricultural lands: ~15

Other:

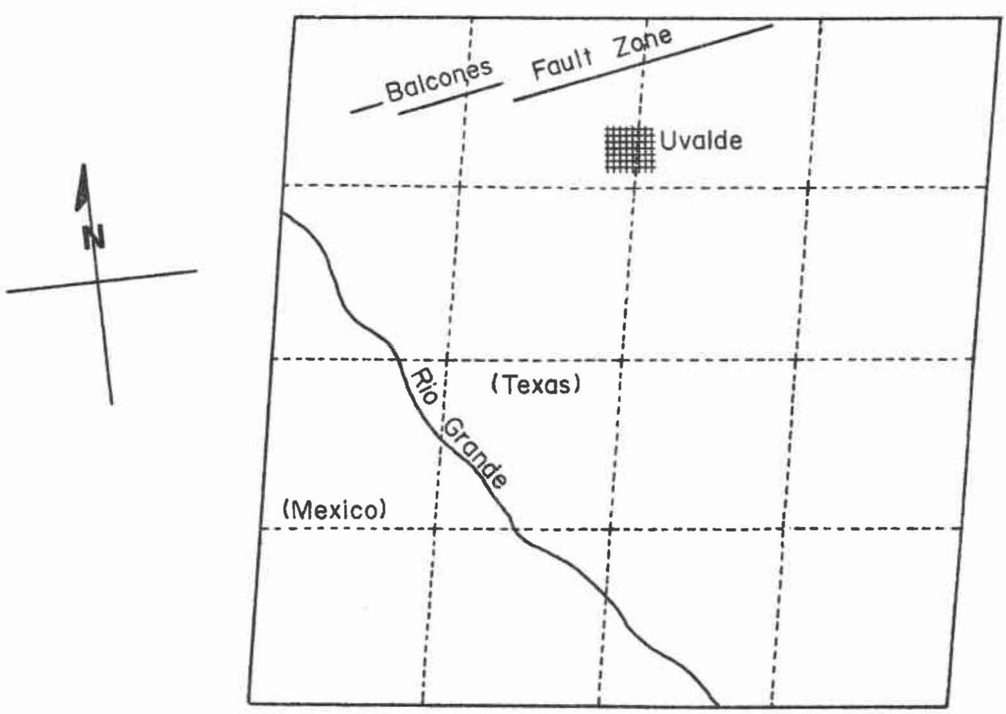
Viewing time: 30 min

Biasing factors:

agricultural activities and oil fields (including seismic survey lines?) impose long, man-made linear patterns

Comments:

broad linear areas of contrasting tones, presumably related to agricultural land use; these areas especially prominent in Mexico



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Don Martín, Mexico

Image identification number: 83067116275X0

Nominal center point coordinates:

N27° 20' 00", W100° 21' 00"

Nominal corner point coordinates:

(1) N27° 53' 54", W099° 15' 56"

(2) N28° 10' 50", W101° 01' 52"

(3) N26° 46' 06", W101° 25' 23"

(4) N26° 29' 10", W099° 40' 47"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: sharp

Overall appearance: very good

Biasing factors:

long linear features in Mexico (presumably roads?)

Scene number: 26

Image date: 01/05/80

Path/row: 30/41

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): minimal

Urban/built-up lands: 0

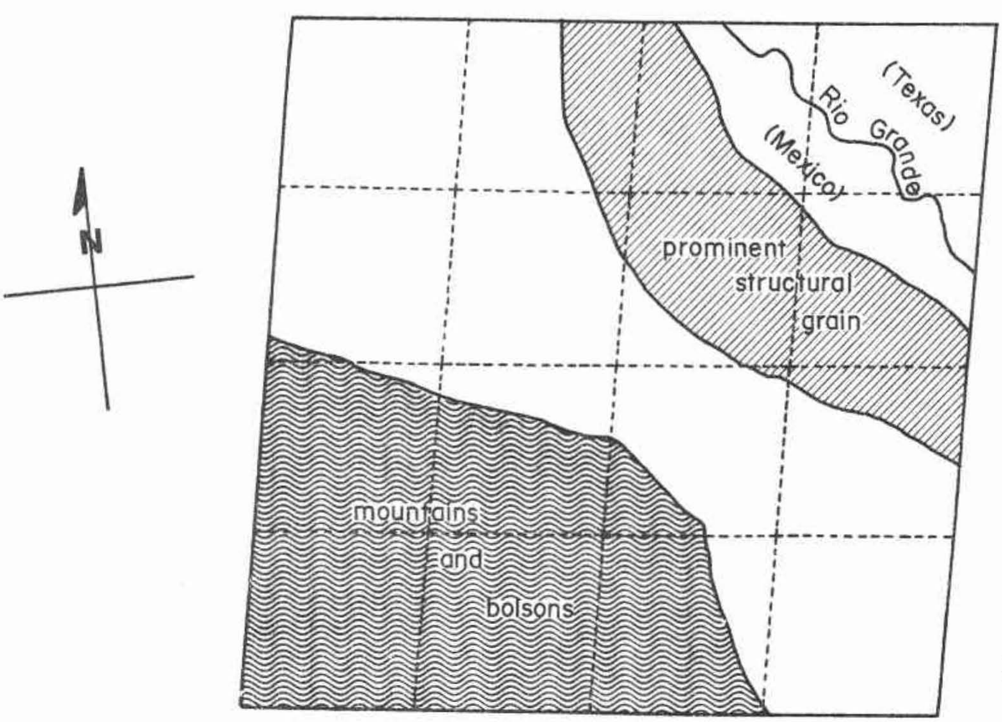
Agricultural lands: 10-30

Other:

Viewing time:

Comments:

no scan lines



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Denton

Scene number: 27

Image identification number: 8226916224500

Image date: 10/18/75

Path/row: 29/37

Satellite: Landsat 2

Nominal center point coordinates:

N33° 05' 00", W097° 17' 00"

Nominal corner point coordinates:

(1) N33° 41' 35", W096° 03' 39"

(2) N33° 59' 42", W097° 59' 42"

(3) N32° 27' 45", W098° 29' 23"

(4) N32° 10' 03", W096° 35' 15"

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): ≲ 5

Urban/built-up lands: ~10

Agricultural lands: ~70

Other:

Viewing time: 30 min

Image quality

Nominal (band 5): 5

Contrast: moderate

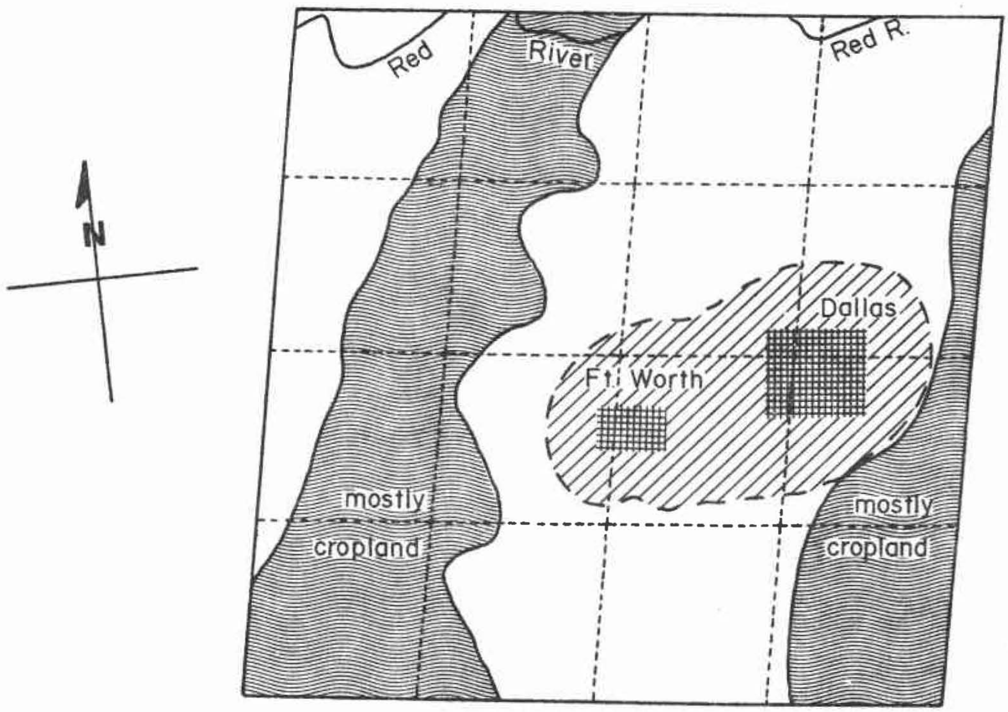
Resolution: moderate

Overall appearance: fair

Biasing factors:

Dallas-Ft. Worth urban area imposes major local negative bias; cropland masks real lineament and imparts possible "false lineaments"

Comments:



Approximately 1/8 actual size.

Scene name: Gatesville

Image identification number: 8226916231500

Nominal center point coordinates:

N31° 40' 00", W097° 42' 00"

Nominal corner point coordinates:

(1) N32° 16' 46", W096° 29' 53"

(2) N32° 34' 33", W098° 24' 06"

(3) N31° 02' 36", W098° 53' 13"

(4) N30° 45' 12", W097° 00' 48"

Image quality

Nominal (band 5): 8

Contrast: generally high

Resolution: moderate to sharp

Overall appearance: good

Scene number: 28

Image date: 10/18/75

Path/row: 29/38

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): minimal

Urban/built-up lands: <5

Agricultural lands: ~40

Other:

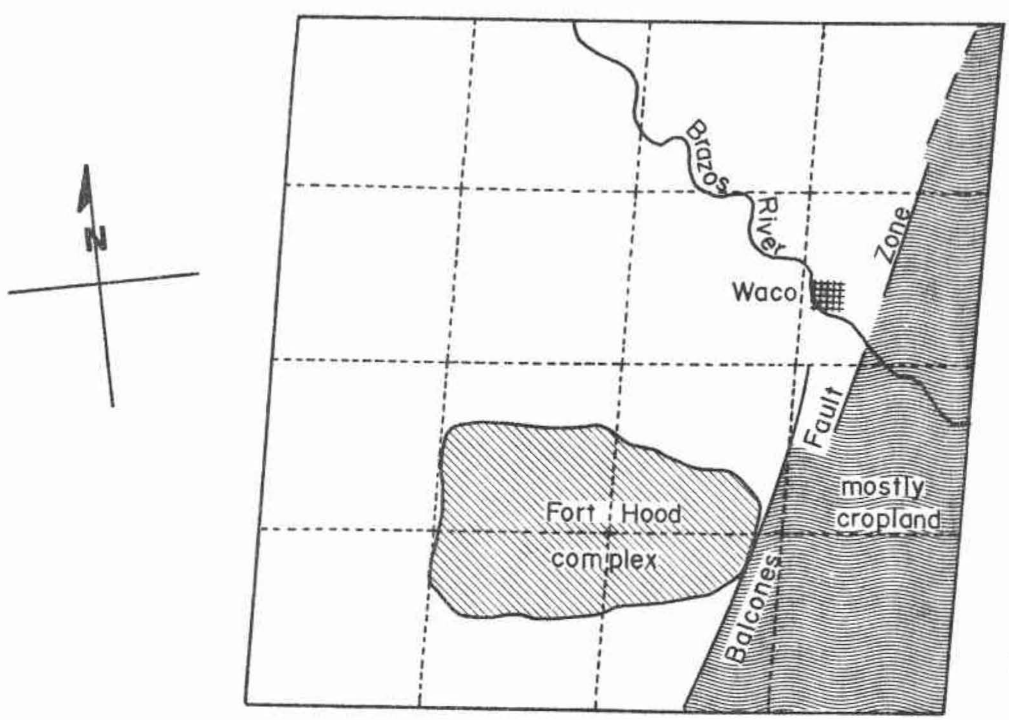
Viewing time: 30 min

Biasing factors:

roads and other facilities in Fort Hood area impart "false lineaments"

Comments:

cultural features align with geologic features along Balcones Fault Zone, resulting in ambiguous linear features



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Marble Falls

Image identification number: 8226916233500

Nominal center point coordinates:

N30° 15' 00", W098° 07' 00"

Nominal corner point coordinates:

(1) N30° 51' 58", W096° 56' 02"

(2) N31° 09' 24", W098° 48' 33"

(3) N29° 37' 26", W099° 17' 07"

(4) N29° 20' 22", W097° 26' 17"

Image quality

Nominal (band 5): 8

Contrast: moderate to high

Resolution: mostly sharp

Overall appearance: good to very good

Scene number: 29

Image date: 10/18/75

Path/row: 29/39

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): <5

Urban/built-up lands: ~5

Agricultural lands: ~40

Other:

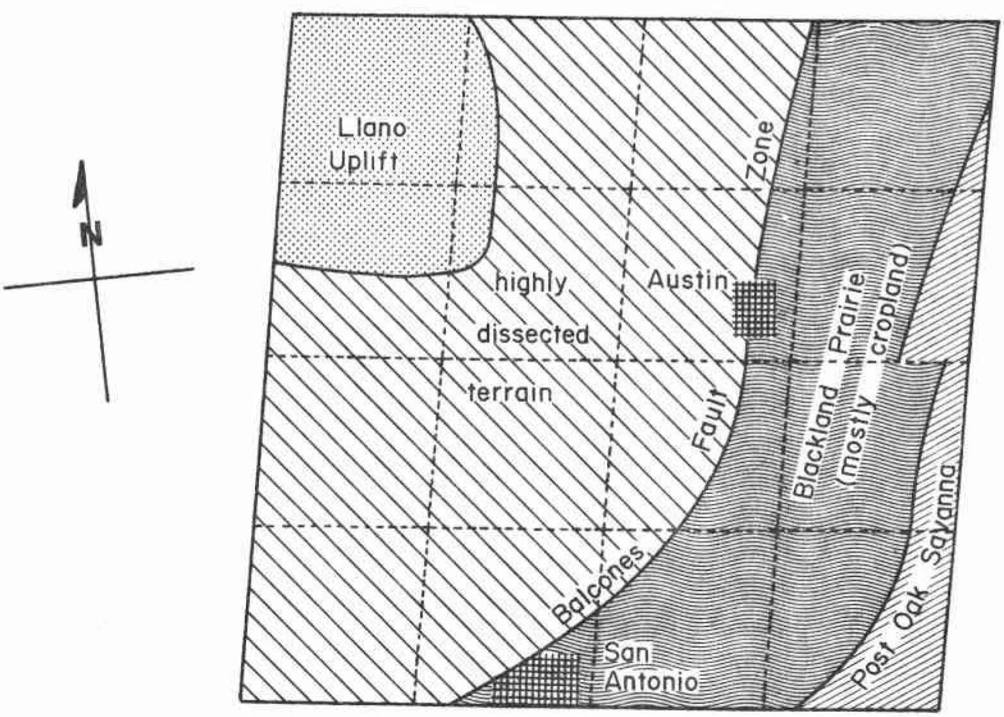
Viewing time: 30 min

Biasing factors:

cropland (especially along Blackland Prairie) imposes negative bias on denoting lineaments; high relief and dissection of terrain west of Balcones Fault Zone result in high density of lineaments

Comments:

cultural features align with strike of Balcones Fault Zone, thus obscuring possible lineaments



Approximately 1/8 actual size.

Scene name: Jourdanton

Image identification number: 8226916240500

Nominal center point coordinates:

N28° 49' 00", W098° 32' 00"

Nominal corner point coordinates:

(1) N29° 26' 06", W097° 22' 05"

(2) N29° 43' 17", W099° 12' 59"

(3) N28° 11' 20", W099° 41' 08"

(4) N27° 54' 30", W097° 51' 48"

Image quality

Nominal (band 5): 8

Contrast: moderate to high

Resolution: moderate to sharp

Overall appearance: good to very good

Scene number: 30

Image date: 10/18/75

Path/row: 29/40

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): ~0

Urban/built-up lands: ~5

Agricultural lands: 75

Other: ~20 (primarily flood plains)

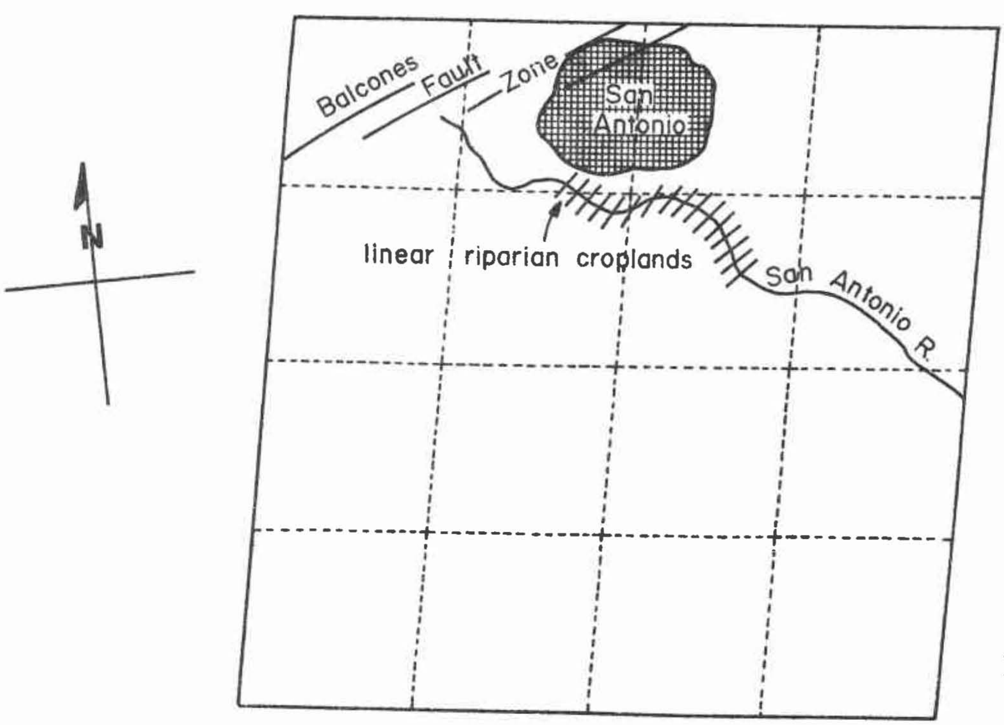
Viewing time: 30 min

Biasing factors:

along San Antonio River, riparian lands markedly linear perpendicular to the river

Comments:

major physiographic and structural trends define the patterns of land use; e.g., roads run along strike of Balcones Fault Zone



Approximately 1/8 actual size.

Scene name: Laredo

Image identification number: 83067016221X0

Nominal center point coordinates:
N27° 21' 00" W098° 56' 00"

Nominal corner point coordinates:

(1) N27° 54' 53", W097° 50' 55"

(2) N28° 11' 50', W099° 36' 53"

(3) N26° 47' 07", W100° 00' 23"

(4) N26° 30' 10", W098° 15' 46"

Image quality

Nominal (band 5): 8

Contrast: moderate (-)

Resolution: moderate (-)

Overall appearance: fair (grainy/fuzzy)

Scene number: 31

Image date: 01/04/80

Path/row: 29/41

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): minimal

Urban/built-up lands: negligible

Agricultural lands: ~20

Other:

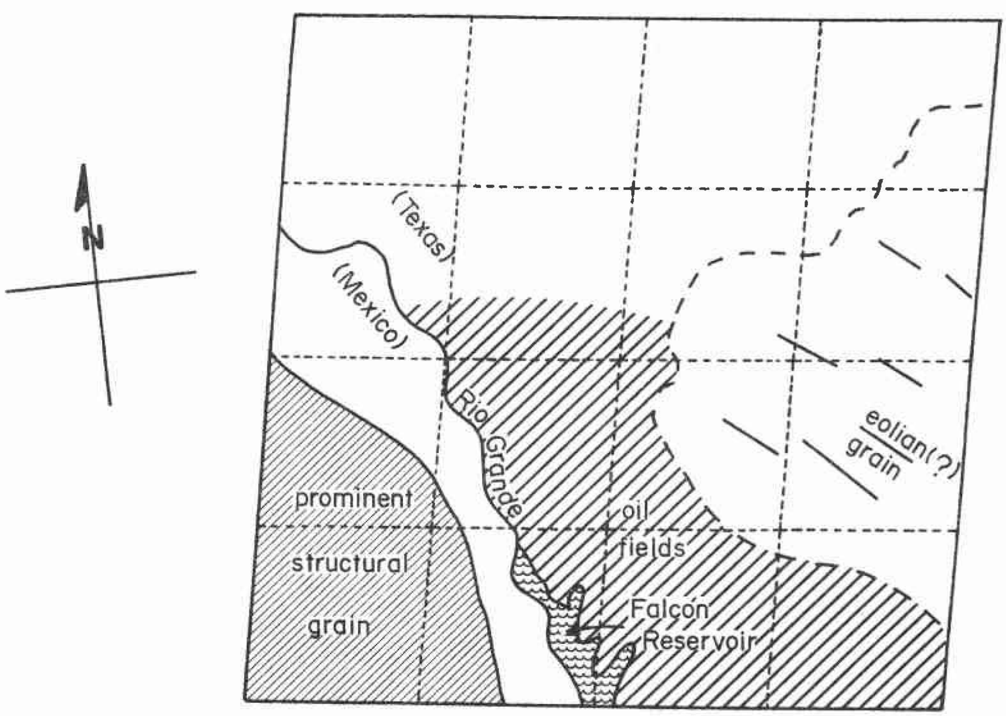
Viewing time: 30 min

Biasing factors:

confusion re: eolian grain-influenced by structure (?);
oil fields impose confusing patterns

Comments:

scan lines supposedly subdued; still obtrusive



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Rio Grande City

Image identification number: 83067016224X0

Nominal center point coordinates:
N25° 54' 00", W099° 20' 00"

Nominal corner point coordinates:
(1) N26° 28' 01", W098° 15' 48"
(2) N26° 44' 45", W100° 00' 26"
(3) N25° 19' 15", W100° 23' 33"
(4) N25° 03' 15", W098° 40' 10"

Image quality
Nominal (band 5): 8
Contrast: high
Resolution: sharp to very sharp
Overall appearance: good

Biasing factors:

Scene number: 32

Image date: 01/04/80

Path/row: 29/42

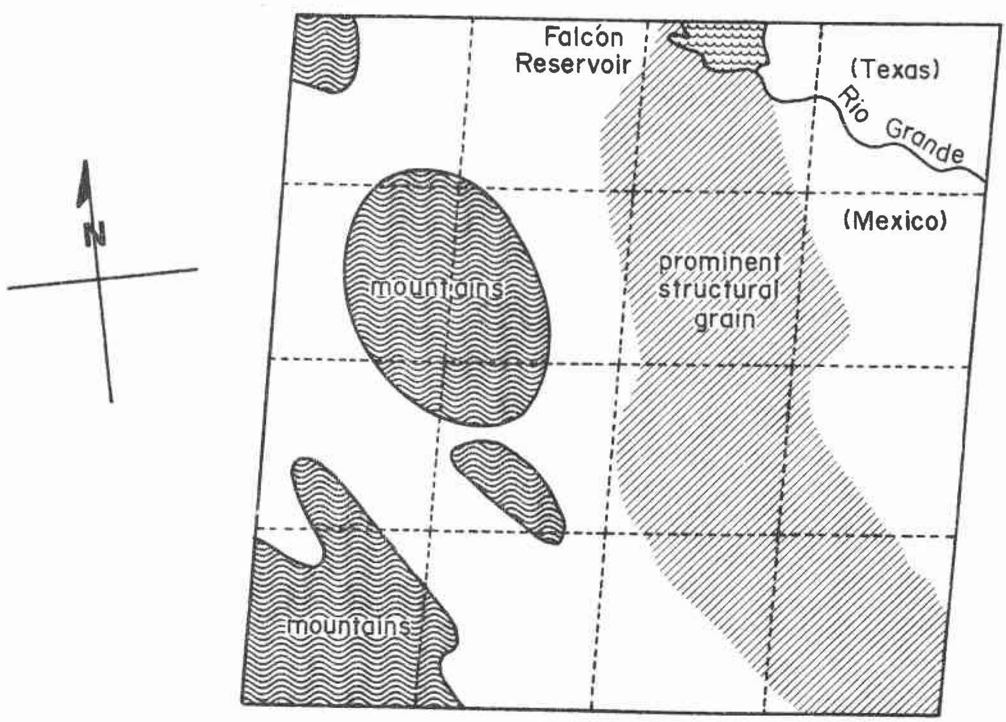
Satellite: Landsat 3

Cloud cover (percentage)
Nominal: 0
Actual (estimated): 0

Obscured area (estimated percentage)
Water (coastal/lake): <5 lakes
Urban/built-up lands: <5
Agricultural lands: 60
Other:

Viewing time: 30 min

Comments:
no scan lines



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Greenville

Image identification number: 8129016303500

Nominal center point coordinates:

N33 13' 48", W096 07' 56"

Nominal corner point coordinates:

(1) N33 50' 29", W094 55' 54"

(2) N34 07' 22", W096 50' 45"

(3) N32 36' 28", W097 19' 00"

(4) N32 19' 58", W095 26' 03"

Image quality

Nominal (band 5): 8

Contrast: fair

Resolution: dull

Overall appearance: fair

Biasing factors:

Scene number: 33

Image date: 05/09/73

Path/row: 28/37

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 10

Actual (estimated): ~5

Obscured area (estimated percentage)

Water (coastal/lake): 5 (lakes)

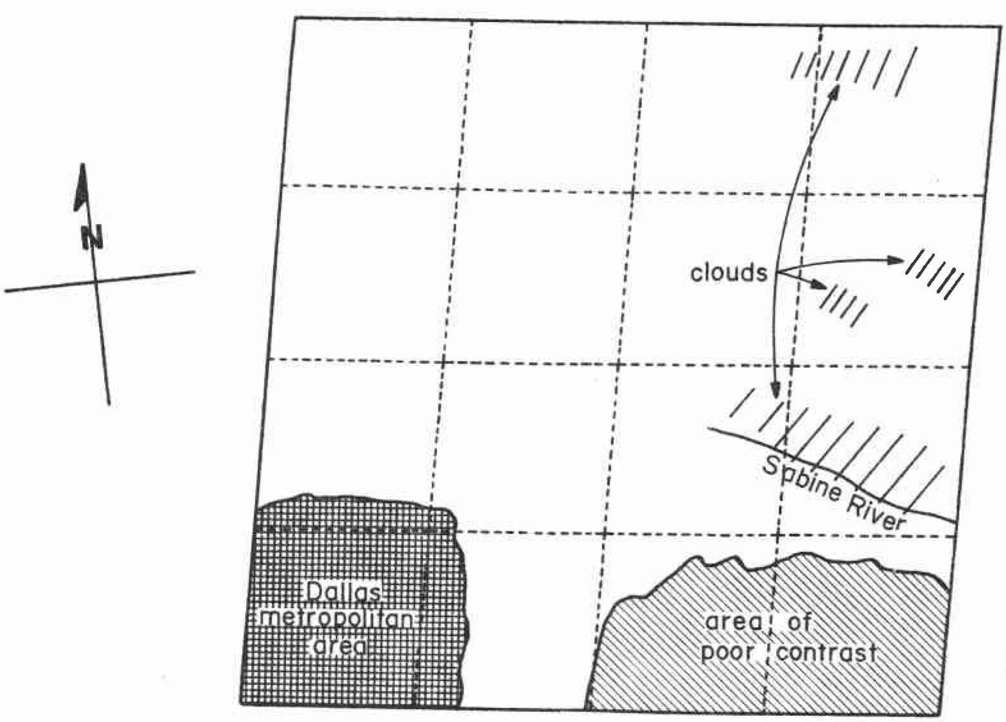
Urban/built-up lands: >5

Agricultural lands: ~75

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Corsicana

Image identification number: 83063316162X0

Nominal center point coordinates:
N31° 39' 00", W096° 22' 00"

Nominal corner point coordinates:
(1) N32° 12' 28", W095° 13' 52"
(2) N32° 30' 09", W097° 04' 24"
(3) N31° 05' 32", W097° 29' 17"
(4) N30° 47' 51", W095° 40' 25"

Image quality
Nominal (band 5): 8
Contrast: moderate to low
Resolution: moderate to dull
Overall appearance: fair to good

Scene number: 34

Image date: 11/28/79

Path/row: 28/38

Satellite: Landsat 3

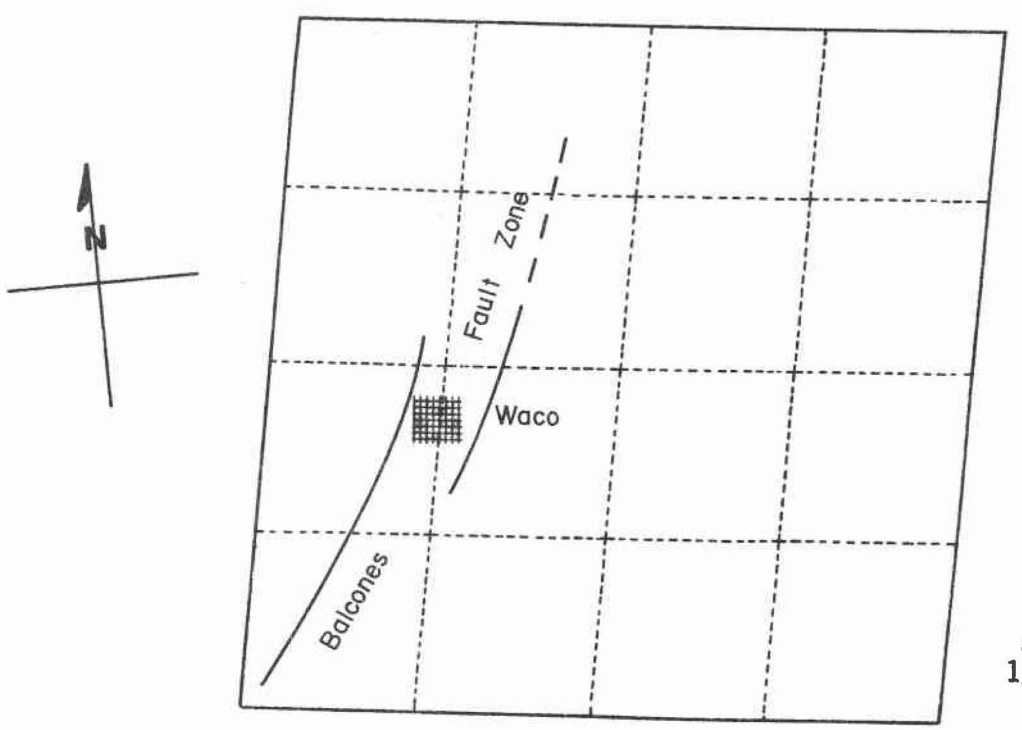
Cloud cover (percentage)
Nominal: 0
Actual (estimated): 0

Obscured area (estimated percentage)
Water (coastal/lake): 5 (lake)
Urban/built-up lands: <5
Agricultural lands: ~ 75
Other:

Viewing time: 30 min

Biasing factors:
cultural features align with geologic trends, such as along Balcones Fault Zone

Comments:
"enhanced" image (scan lines subdued)



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Caldwell

Image identification number: 8145216284500

Nominal center point coordinates:
N30° 20' 32", W096° 42' 50"

Nominal corner point coordinates:

(1) N30° 57' 19", W095° 33' 03"

(2) N31° 13' 56", W097° 24' 10"

(3) N29° 43' 10", W097° 51' 47"

(4) N29° 26' 54", W096° 02' 19"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: moderate to low

Overall appearance: fair

Scene number: 35

Image date: 10/18/73

Path/row: 28/39

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): <5 (lake)

Urban/built-up lands: <5*

Agricultural lands: >30 to 40

Other:

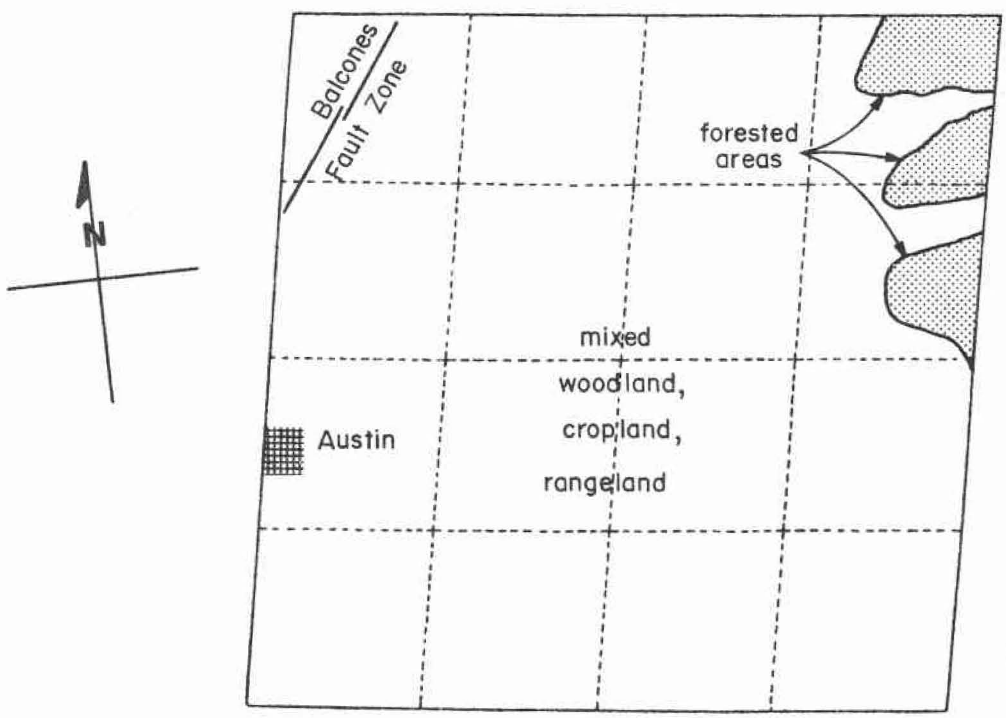
Viewing time: 30 min

Biasing factors:

roads, pipelines, fences, and other man-imposed "grids" may result in perception of "false lineaments"; too much contrast yields a disconcerting pattern of light and dark areas

Comments:

*urban areas evenly distributed across scene



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Victoria

Image identification number: 8111016313500

Nominal center point coordinates:

N28° 43' 40", W097° 13' 43"

Nominal corner point coordinates:

(1) N29° 21' 02", W096° 03' 57"

(2) N29° 37' 45", W097° 54' 46"

(3) N28° 05' 45", W098° 22' 24"

(4) N27° 49' 22", W096° 33' 08"

Image quality

Nominal (band 5): 8

Contrast: moderate to low

Resolution: moderate

Overall appearance: fair

Biasing factors:

Scene number: 36

Image date: 11/10/72

Path/row: 28/40

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 0

Actual (estimated): ~5

Obscured area (estimated percentage)

Water (coastal/lake): ~10

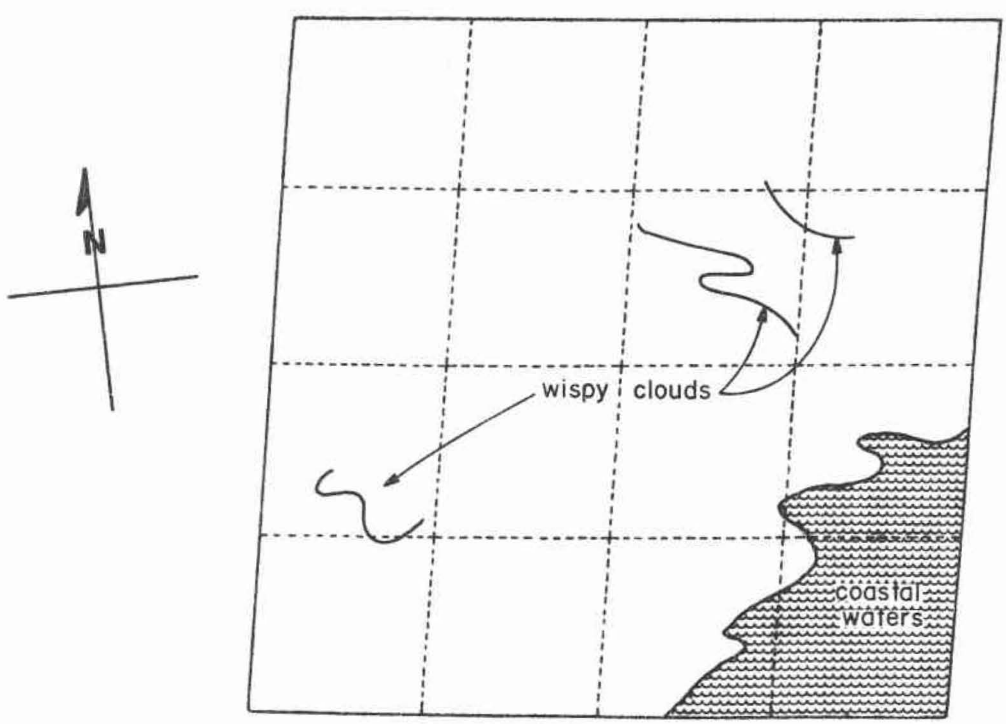
Urban/built-up lands: minimal

Agricultural lands: ~30 - 40

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Corpus Christi

Image identification number: 8203416202500

Nominal center point coordinates:
N27° 24' 00", W097° 27' 00"

Nominal corner point coordinates:

(1) N28° 00' 48", W096° 19' 17"

(2) N28° 17' 38", W098° 07' 17"

(3) N26° 46' 41", W098° 34' 01"

(4) N26° 30' 10", W096° 47' 26"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: sharp to moderate

Overall appearance:

Scene number: 37

Image date: 02/25/75

Path/row: 28/41

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): ~40

Urban/built-up lands: negligible

Agricultural lands: 20

Other:

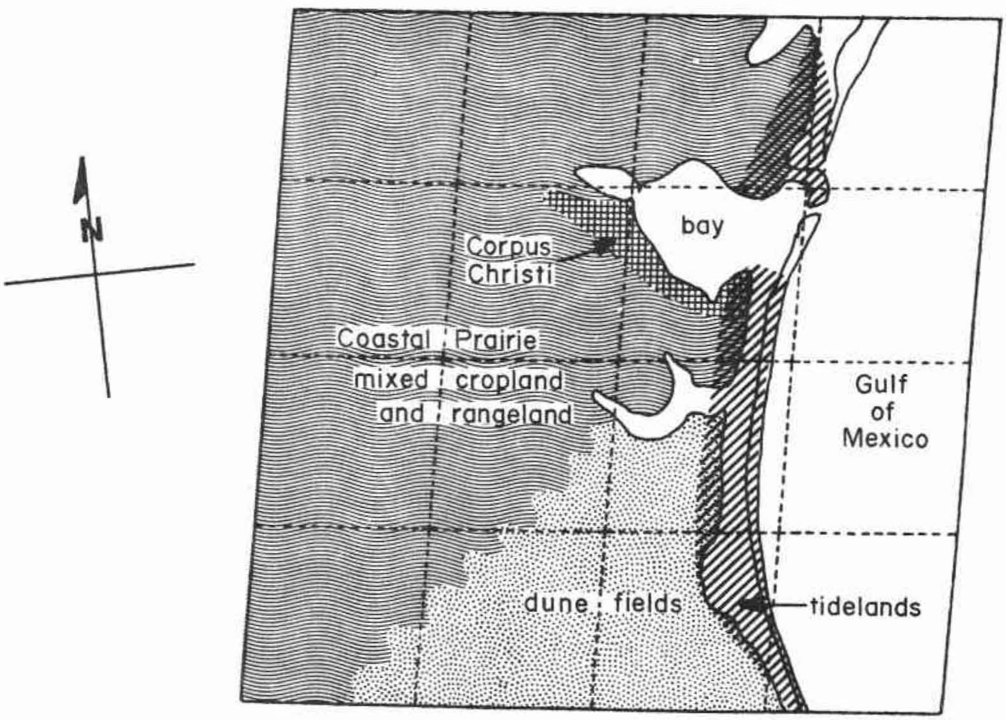
Viewing time: 20 min

Biasing factors:

upper part of coastal zone has numerous canals, roads, etc.; may result in perception of "false lineaments"

Comments:

banner dune complex and linear shoreline features result in uncertainty regarding bedrock-domination or climate and/or current-domination of features



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Harlingen

Image identification number: 8203416205500

Nominal center point coordinates:
N25° 58' 00", W097° 50' 00"

Nominal corner point coordinates:
(1) N26° 34' 53", W096° 43' 07"
(2) N26° 51' 32", W098° 29' 42"
(3) N25° 20' 38", W098° 56' 14"
(4) N25° 04' 17", W097° 10' 57"

Image quality
Nominal (band 5): 8
Contrast: moderate (+)
Resolution: moderate (-)
Overall appearance: good

Scene number: 38
Image date: 02/25/75
Path/row: 28/42
Satellite: Landsat 2

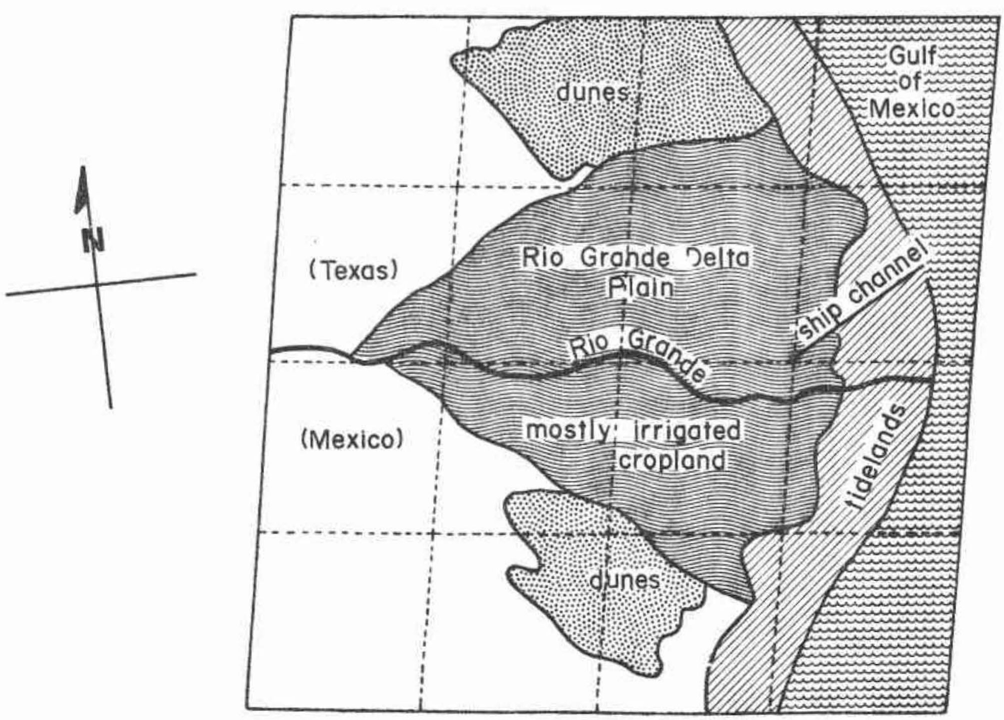
Cloud cover (percentage)
Nominal: 0
Actual (estimated): 0

Obscured area (estimated percentage)
Water (coastal/lake): ~30
Urban/built-up lands: <~5
Agricultural lands: ~50
Other:

Viewing time: 25 min

Biasing factors:
intensive agricultural use of Rio Grande delta plain obscures natural linear features; also, drainage ditches and canals impose problems with "false lineaments," especially in tidelands

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Texarkana

Image identification number: 82120315484X0

Nominal center point coordinates:

N33° 04' 19", W094° 26' 17"

Nominal corner point coordinates:

(1) N33° 37' 54", W093° 20' 10"

(2) N33° 54' 55", W095° 06' 29"

(3) N32° 30' 54", W095° 31' 33"

(4) N32° 13' 44", W093° 46' 51"

Image quality

Nominal (band 5): 8

Contrast: moderate to low

Resolution: moderate to dull

Overall appearance: fair to poor

Biasing factors:

Scene number: 39

Image date: 05/09/78

Path/row: 27/37

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): <5

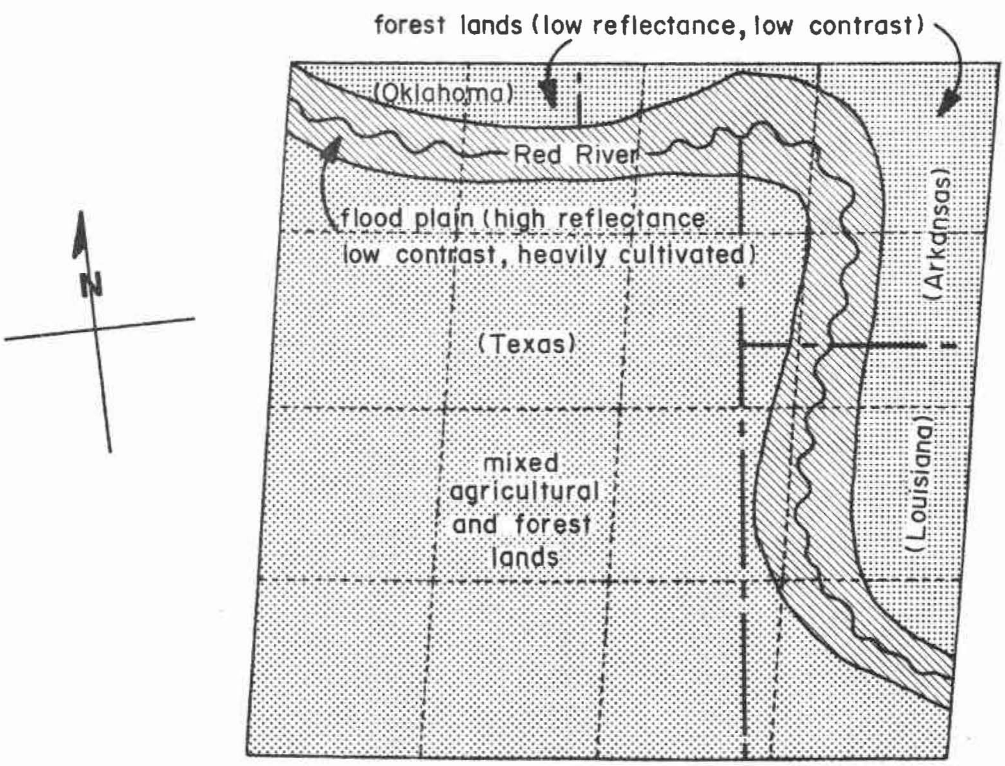
Urban/built-up lands: <5

Agricultural lands: 50

Other: 35 (forest lands)

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Lufkin

Image identification number: 8268116012500

Nominal center point coordinates:

N31° 44' 00", W094° 56' 00"

Nominal corner point coordinates:

(1) N32° 20' 25", W093° 44' 18"

(2) N32° 38' 13", W095° 37' 44"

(3) N31° 06' 57", W096° 06' 49"

(4) N30° 49' 33", W094° 15' 09"

Image quality

Nominal (band 5): 8

Contrast: moderate to low*

Resolution: moderate

Overall appearance: fair to poor

Scene number: 40

Image date: 12/03/76

Path/row: 27/38

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): < 5

Urban/built-up lands: ~5**

Agricultural lands: ~40 - 60

Other:

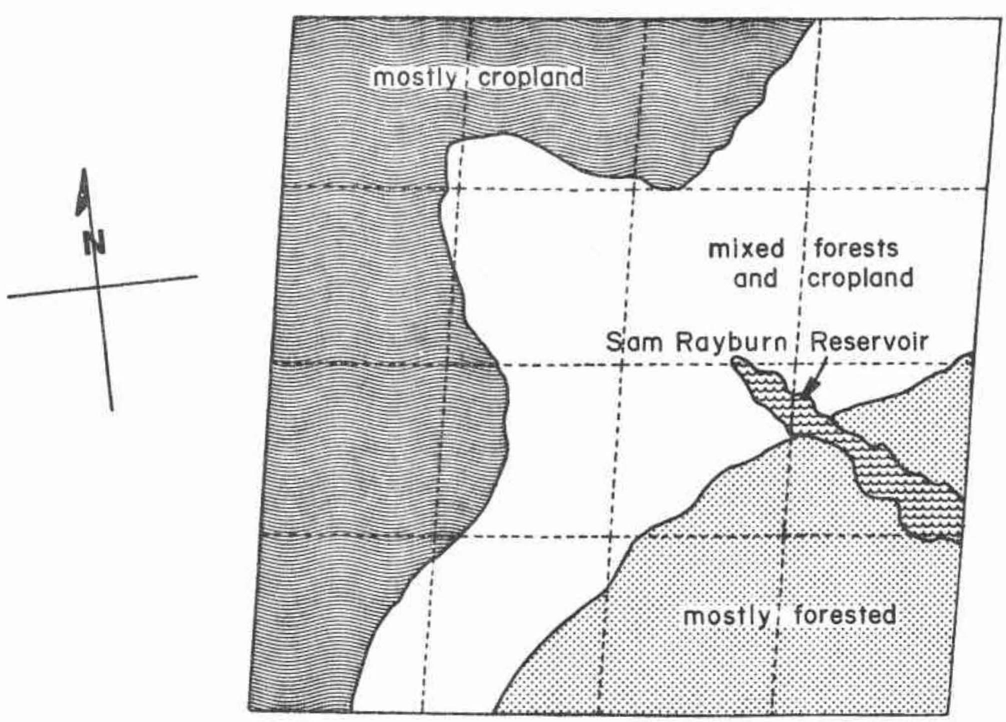
Viewing time: 30 min

Biasing factors:

*forest areas are dark, have poor contrast

**even distribution of cultural features (towns and roads) presents bias (confusion)

Comments:



Approximately 1/8 actual size.

Scene name: Houston

Image identification number: 82136515570X0

Nominal center point coordinates:

N30° 11' 24", W095° 24' 00"

Nominal corner point coordinates:

(1) N30° 47' 10", W094° 13' 18"

(2) N31° 04' 35", W095° 53' 45"

(3) N29° 35' 38", W096° 19' 01"

(4) N29° 18' 13", W094° 31' 45"

Image quality

Nominal (band 5): 8

Contrast: moderate to low*

Resolution: moderate

Overall appearance: fair

Scene number: 41

Image date: 10/18/78

Path/row: 27/39

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 10

Urban/built-up lands: ~10

Agricultural lands: ~30

Other: forests ~50*

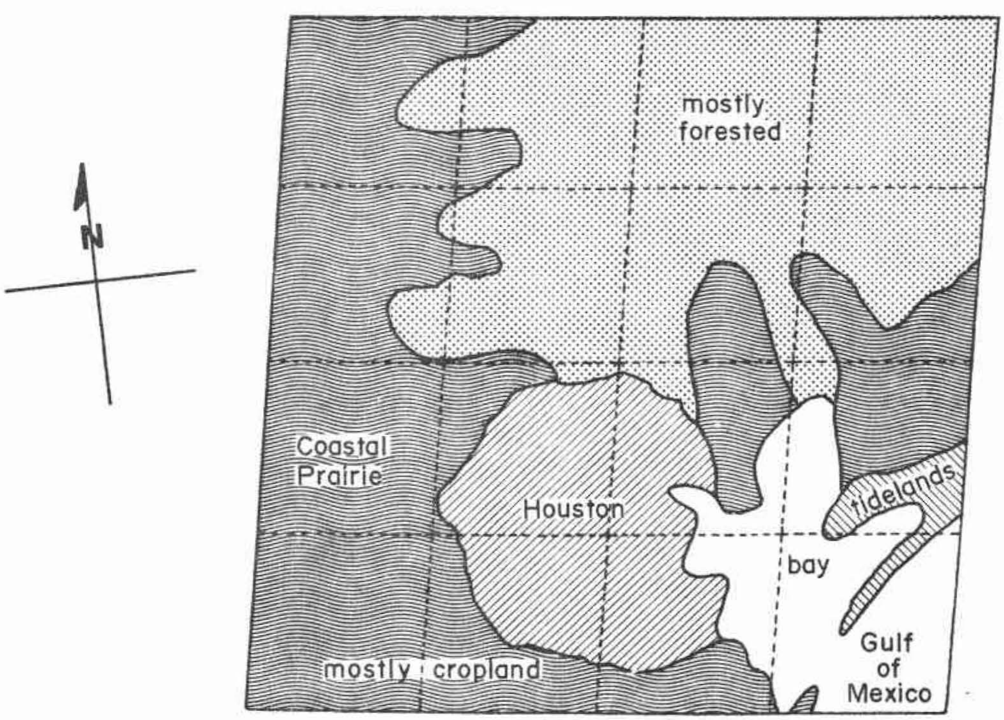
Viewing time: 30 min

Biasing factors:

low "veracity" image regarding lineaments:
coastal prairie biased owing to agricultural use; forests biased because of dark tone; also, prevalent urban overprint

Comments:

*forested areas very dark, have poor contrast



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Freeport

Image identification number: 8239316105500

Nominal center point coordinates:

N28° 46' 00", W095° 49' 00"

Nominal corner point coordinates:

(1) N29° 23' 15", W094° 39' 04"

(2) N29° 40' 19", W096° 30' 07"

(3) N28° 08' 11", W096° 58' 08"

(4) N27° 51' 28", W095° 08' 40"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: moderate to sharp

Overall appearance: good

Scene number: 42

Image date: 02/19/76

Path/row: 27/40

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 50 (coastal)

Urban/built-up lands: minimal

Agricultural lands: 40

Other:

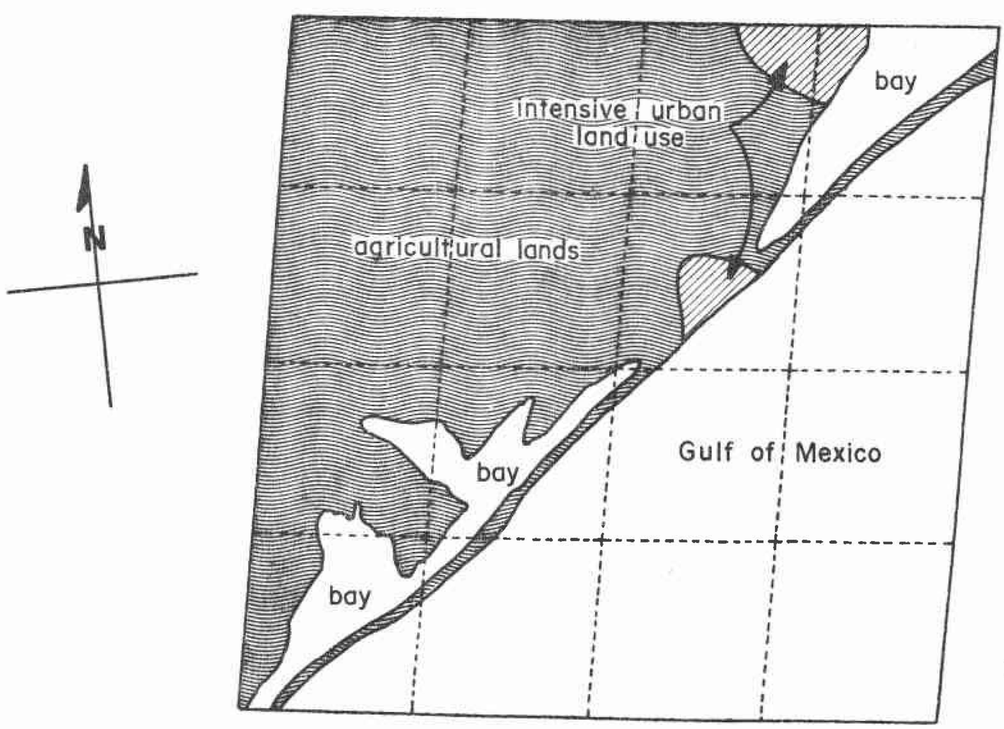
Viewing time: 15 min

Biasing factors:

canals, drainage ditches, pipelines, roads, etc. may result in "false lineaments"

Comments:

even distribution of towns, hence biasing factors uniformly spaced



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Natchitoches, Louisiana

Image identification number: 8268015553500

Nominal center point coordinates:
N31° 44' 00", W093° 31' 00"

Nominal corner point coordinates:
(1) N32° 20' 36", W092° 19' 22"
(2) N32° 38' 09", W094° 12' 56"
(3) N31° 06' 47", W094° 41' 45"
(4) N30° 49' 36", W092° 49' 58"

Image quality
Nominal (band 5): 8
Contrast: moderate (+)
Resolution: moderate to low
Overall appearance: fair

Biasing factors:
even distribution of cultural features

Scene number: 43

Image date: 12/02/76

Path/row: 26/38

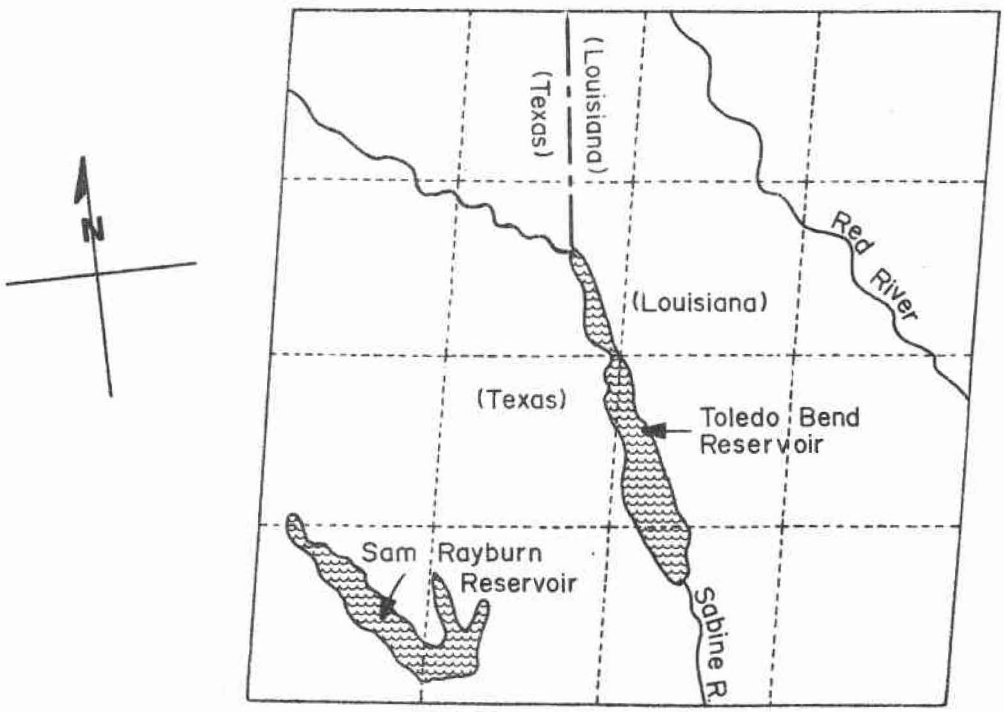
Satellite: Landsat 2

Cloud cover (percentage)
Nominal: 0
Actual (estimated): negligible

Obscured area (estimated percentage)
Water (coastal/lake): ~5
Urban/built-up lands: minimal (scattered)
Agricultural lands: *
Other: forested areas*

Viewing time: 30 min

Comments:
*image consists of mixed forested areas and cropland; difficult to assign individual percentage, but combined comprise <90% of scene



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Orange

Image identification number: 8280615504500

Nominal center point coordinates:

N30° 18' 00", W093° 58' 00"

Nominal corner point coordinates:

(1) N30° 54' 50", W092° 47' 20"

(2) N31° 12' 09", W094° 39' 25"

(3) N29° 40' 35", W095° 07' 49"

(4) N29° 23' 37", W093° 17' 25"

Image quality

Nominal (band 5): 8

Contrast: low to moderate

Resolution: moderate

Overall appearance: fair

Biasing factors:

Scene number: 44

Image date: 04/07/77

Path/row: 26/39

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated):

Obscured area (estimated percentage)

Water (coastal/lake): ~10

Urban/built-up lands: ~5

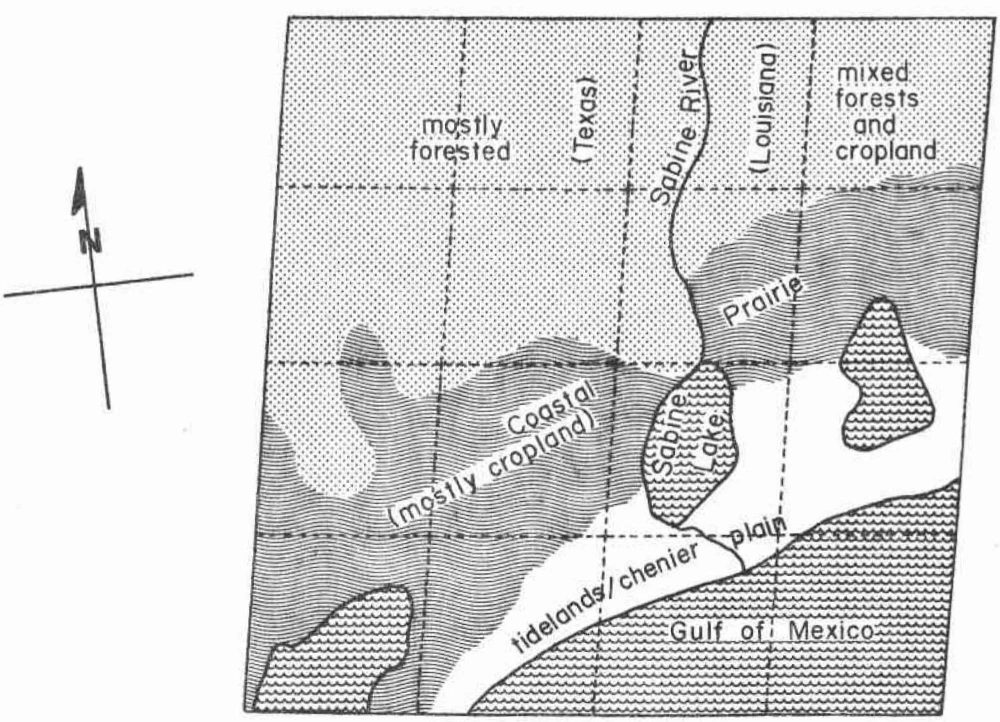
Agricultural lands: *

Other: forested lands*

Viewing time: 30 min

Comments:

*image consists of mixed forested areas and cropland; difficult to assign individual percentage, but combined comprise <80% of scene



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Roswell, New Mexico

Image identification number: 83022516540X0

Nominal center point coordinates:

N33° 04' 52", W104° 30' 14"

Nominal corner point coordinates:

(1) N33° 40' 18", W103° 20' 24"

(2) N33° 58' 16", W105° 12' 43"

(3) N32° 29' 25", W105° 39' 06"

(4) N32° 11' 27", W103° 48' 39"

Image quality

Nominal (band 5): 8

Contrast: moderate +

Resolution: moderate +

Overall appearance: good

Biasing factors:

oilwell sites visible as rectilinear grid

Scene number: 45

Image date: 10/16/78

Path/row: 34/37

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

Urban/built-up lands: 0

Agricultural lands: minimal*

Other:

Viewing time: 30 min

Comments:

*along Pecos

Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Fort Sumner, New Mexico

Image identification number: 82151616421X0

Nominal center point coordinates:
N34° 30' 00", W104° 03' 00"

Nominal corner point coordinates:
(1) N35° 03' 07", W102° 52' 25"
(2) N35° 21' 23", W104° 46' 34"
(3) N33° 56' 53", W105° 12' 36"
(4) N33° 38' 37", W103° 20' 22"

Image quality
Nominal (band 5): 8
Contrast: high
Resolution: sharp
Overall appearance: very good

Scene number: 46
Image date: 03/18/79
Path/row: 34/36
Satellite: Landsat 2

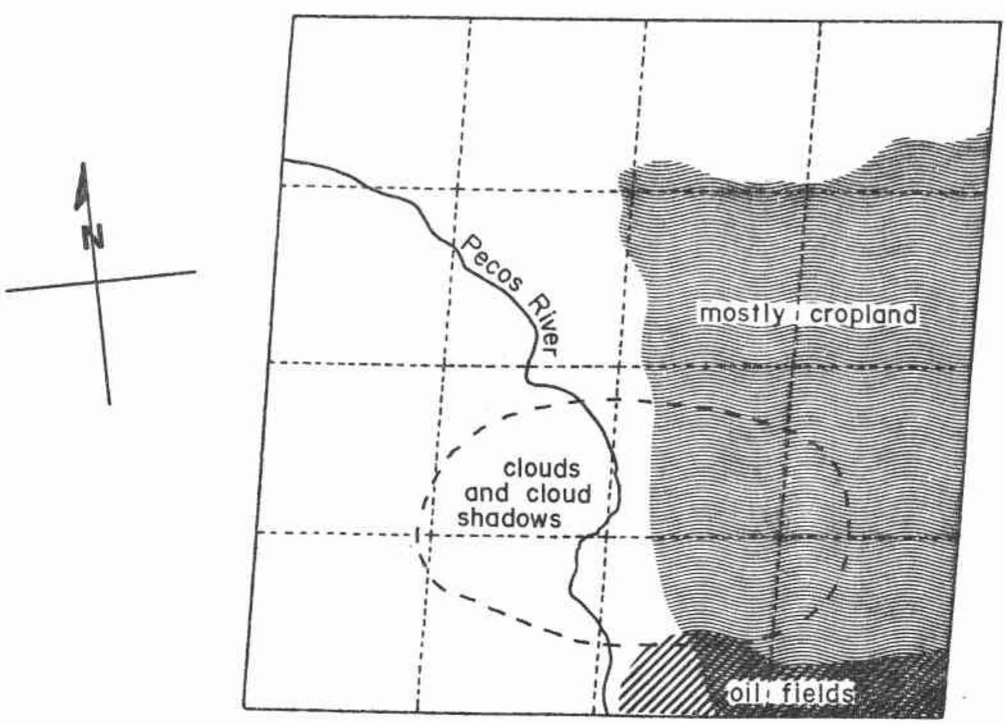
Cloud cover (percentage)
Nominal: 10*
Actual (estimated): >10*

Obscured area (estimated percentage)
Water (coastal/lake): >5
Urban/built-up lands: 5 to 10
Agricultural lands: 40
Other:

Viewing time: 30 min

Biasing factors:
*clouds and cloud shadows difficult to distinguish from ground patterns

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Ada, Oklahoma

Image identification number: 83029216244X0

Nominal center point coordinates:

N34° 28' 05", W096° 46' 08"

Nominal corner point coordinates:

(1) N35° 03' 21", W095° 35' 03"

(2) N35° 21' 36", W097° 29' 11"

(3) N33° 52' 49", W097° 56' 11"

(4) N33° 34' 33", W096° 04' 03"

Image quality

Nominal (band 5): 8

Contrast: moderate (-)

Resolution: dull

Overall appearance: fair to good (grainy)

Biasing factors:

Scene number: 47

Image date: 12/22/78

Path/row: 29/36

Satellite: Landsat 3

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): minimal

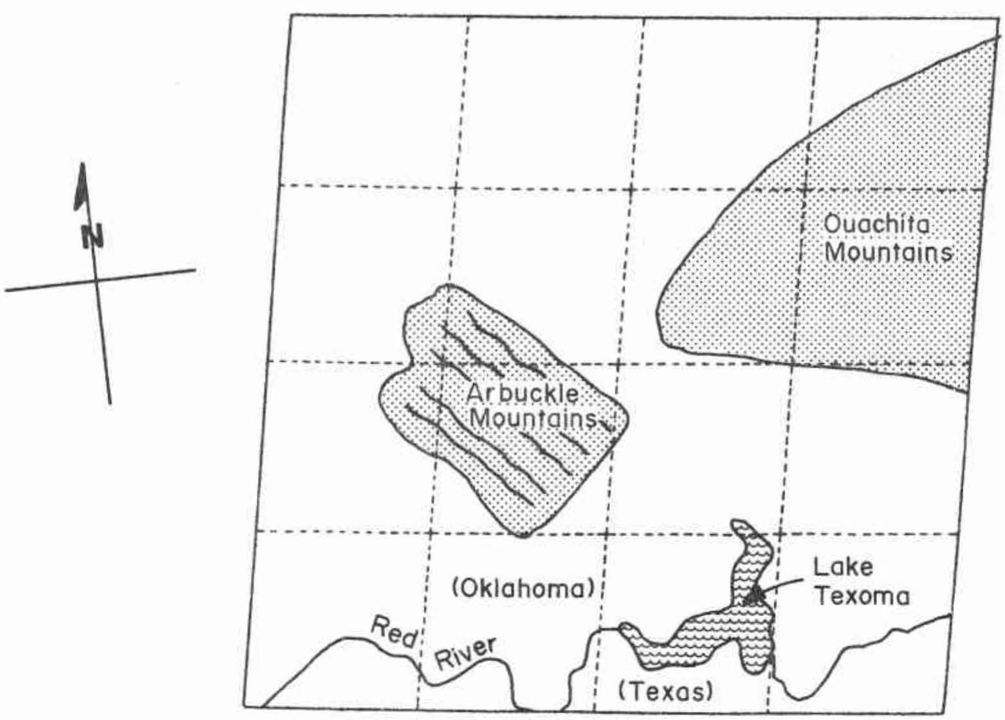
Urban/built-up lands: minimal

Agricultural lands: <70

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Stanley, Oklahoma

Image identification number: 82142016035X0

Nominal center point coordinates:

N34° 28' 48", W095° 22' 16"

Nominal corner point coordinates:

(1) N35° 04' 04", W094° 11' 10"

(2) N35° 22' 20", W096° 05' 19"

(3) N33° 53' 32", W096° 32' 19"

(4) N33° 35' 16", W094° 40' 10"

Image quality

Nominal (band 5): 8

Contrast: moderate to low

Resolution: dull

Overall appearance: good

Biasing factors:

"false lineaments" imparted by large rectilinear patches (logged areas) in Ouachita Mountains

Comments:

Scene number: 48

Image date: 12/12/78

Path/row: 28/36

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

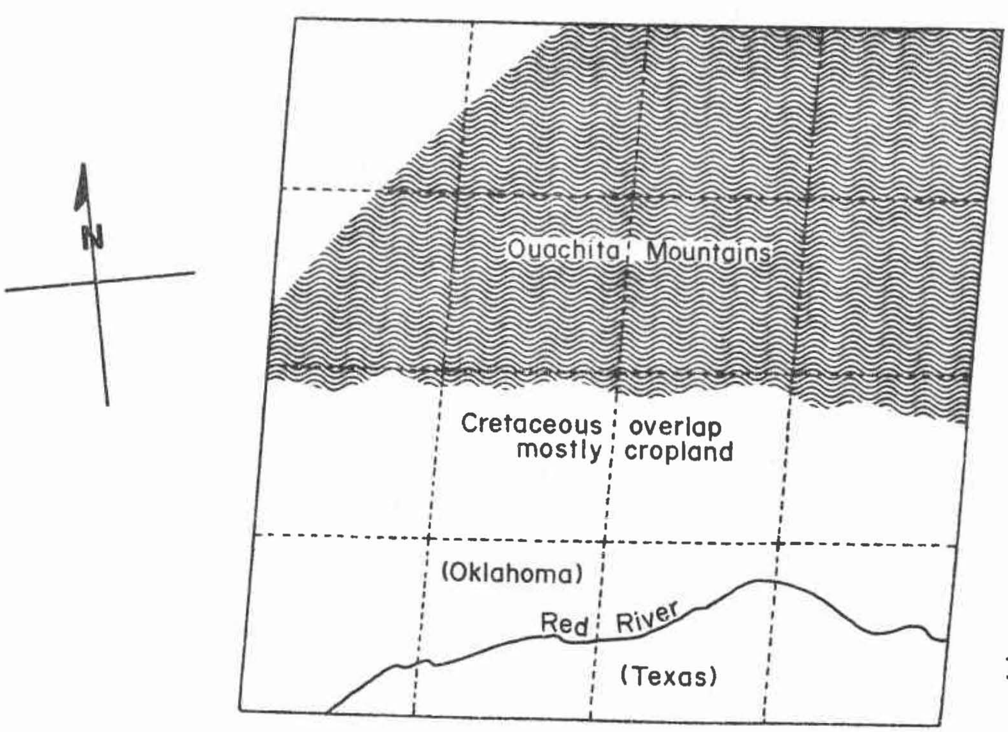
Water (coastal/lake): ~5

Urban/built-up lands: minimal

Agricultural lands: <40

Other: mountainous (forested) ~60

Viewing time: 30 min



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Mena, Arkansas

Image identification number: 8607715420500

Nominal center point coordinates:

N34° 32' 00", W094° 05' 00s"

Nominal corner point coordinates:

(1) N35° 08' 09", W092° 50' 49"

(2) N35° 26' 28", W094° 48' 05"

(3) N33° 55' 09", W095° 18' 09"

(4) N33° 37' 16", W093° 22' 56"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: generally sharp

Overall appearance: excellent

Scene number: 49

Image date: 01/03/78

Path/row: 27/36

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): minimal

Urban/built-up lands: negligible

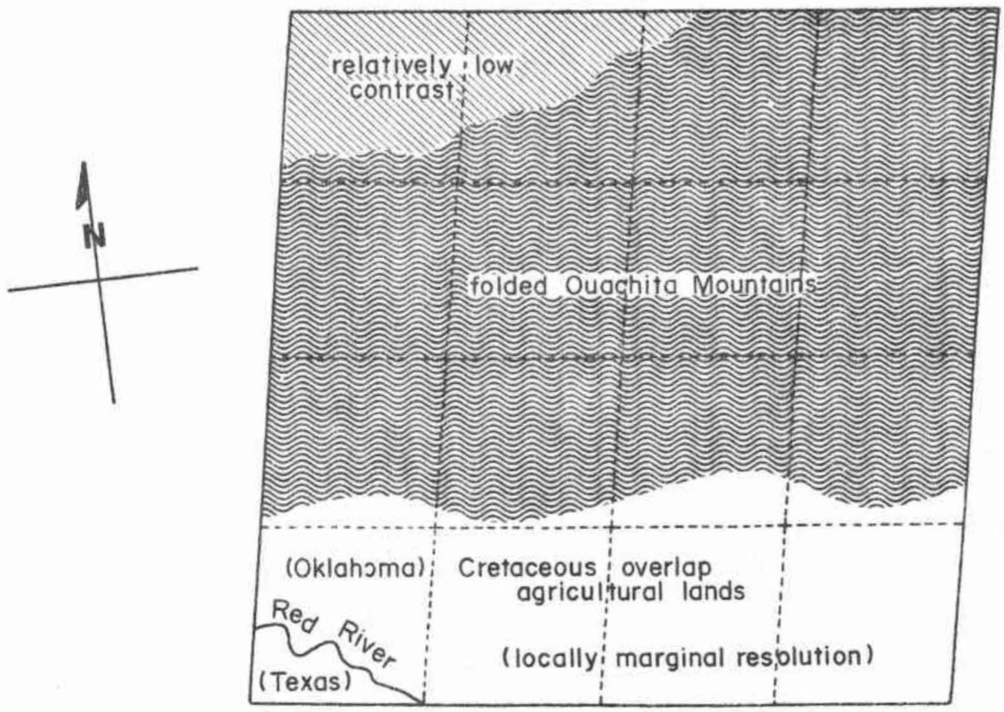
Agricultural lands: <40

Other: predominantly mountainous (forested) terrain

Viewing time: 30 min

Biasing factors:
areas (mainly in Ouachita Mountains) that have, apparently, been logged, impart a "patchwork" pattern; may result in "false lineaments" being noted

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Off Galveston (Gulf of Mexico)

Image identification number: 8280615511500

Nominal center point coordinates:
N28° 53' 00", W094° 22' 00"

Nominal corner point coordinates:

(1) N29° 29' 59", W093° 12' 25"

(2) N29° 47' 00", W095° 02' 53"

(3) N28° 15' 27", W095° 30' 48"

(4) N27° 58' 47", W093' 41' 54"

Image quality

Nominal (band 5): 8

Contrast: high

Resolution: sharp

Overall appearance: good

Scene number: 50

Image date: 04/07/77

Path/row: 26/40

Satellite: Landsat 2

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 80

Urban/built-up lands: ~10

Agricultural lands: ~10

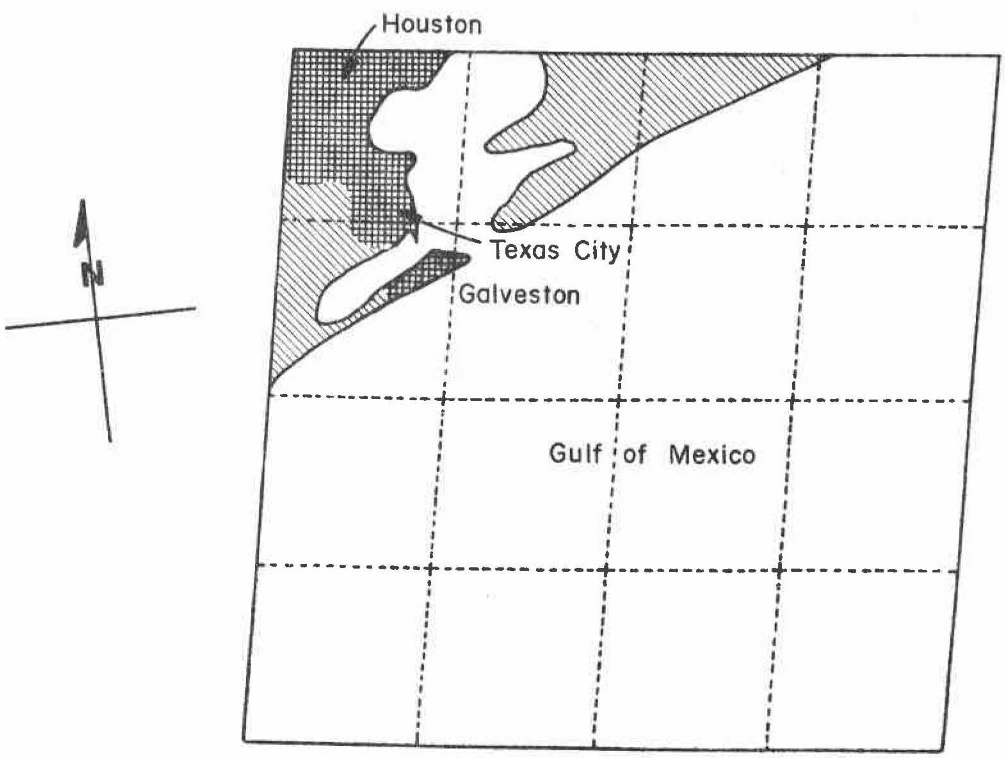
Other:

Viewing time: 5 min

Biasing factors:

almost entire land area "overprinted" with biasing cultural features (urban or agricultural)

Comments:



Approximately 1/8 actual size.

LANDSAT IMAGE INVENTORY

Scene name: Mosquero, New Mexico

Image identification number: 8593115311500

Nominal center point coordinates:

N36° 00' 00", W103° 51' 00"

Nominal corner point coordinates:

(1) N36° 37' 12", W102° 36' 05"

(2) N36° 54' 01", W104° 36' 13"

(3) N35° 22' 05", W105° 04' 48"

(4) N35° 05' 42", W103° 06' 54"

Image quality

Nominal (band 5): 8

Contrast: moderate (-)

Resolution: moderate to dull

Overall appearance: poor

Biasing factors:

Scene number: 51

Image date: 11/05/77

Path/row: 34/35

Satellite: Landsat 1

Cloud cover (percentage)

Nominal: 0

Actual (estimated): 0

Obscured area (estimated percentage)

Water (coastal/lake): 0

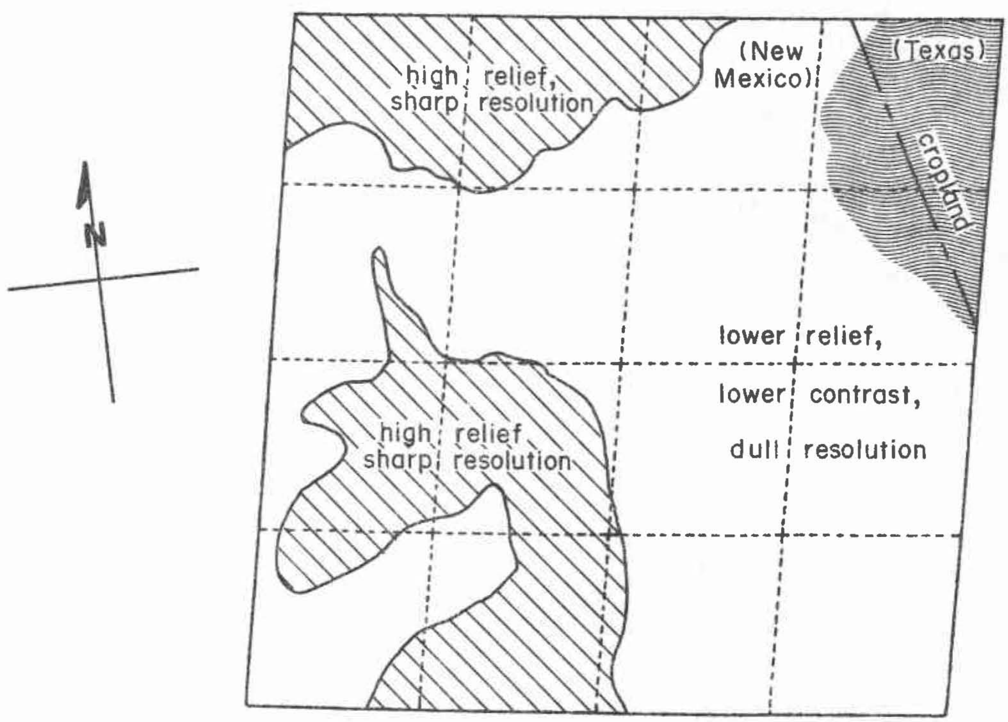
Urban/built-up lands: 0

Agricultural lands: ~30

Other:

Viewing time: 30 min

Comments:



Approximately 1/8 actual size.

APPENDIX G

Selected Bibliography of Lineaments and Related Structural Features, with Special Reference to Texas

Compiled by
Laura Caprio Dwyer and S. Christopher Caran

in

GEOTHERMAL RESOURCE ASSESSMENT

FOR THE STATE OF TEXAS--

Status of Progress,

November 1980

Prepared for
U.S. Department of Energy, Division of Geothermal Energy
Under Contract No. DE-AS07-79ID12057

March 1982

Bureau of Economic Geology
W. L. Fisher, Director
The University of Texas at Austin

CONTENTS

INTRODUCTION

Geologists have long been fascinated by linear planetary features, and this fascination is manifested in the enormous body of literature that pertains to lineaments. Hodgson (1976) traces the origin of geologic studies of anomalous linear surface-patterns to Britain during the early 19th century. Our research indicates that the term "lineament" was perhaps first used in print by Dana (1863) to refer to lines or alignments representing physiographic features on maps. From this early period of discovery to the present, interest in lineaments has continued to grow, suggesting a need for a bibliographic review of the associated literature. We have attempted to compile significant works pertaining to lineaments in general, although we accorded special attention to literature pertaining to lineaments perceived in Landsat images.

This bibliography is in three parts: (I) works concerned with detection, analysis, and interpretation of lineaments; (II) works concerned with lineaments and selected major structural features of Texas; and (III) works concerned with Cretaceous igneous features coincident with the Ouachita Structural Belt in Texas. The bibliography includes both early and modern writings on each subject. Some foreign- as well as English-language references are cited. Regrettably, inherent constraints of the project prevented a more complete review of the abundant foreign literature, treatment of which is necessarily minimal in this compilation.

We have aspired to make the bibliography comprehensive in scope if not in depth. In fact, the lists of citations on lineaments in Texas and on the igneous features along the Balcones/Ouachita trend are probably nearly exhaustive, based on comparison with the Bureau of Economic Geology's bibliographies of Texas geology:

(1) Sellards, E. H., Adkins, W. S., and Plummer, F. B., 1932, The geology of Texas, vol. 1, stratigraphy: University of Texas, Austin, Bureau of Economic Geology Bulletin 3232, 1007 p.

(2) Girard, R. M., 1959, Bibliography and index of Texas geology, 1933-1950: University of Texas, Austin, Bureau of Economic Geology Publication 5910, 238 p.

(3) Moore, E. T., and Brown, M. D., 1972, Bibliography and index of Texas geology, 1951-1960: The University of Texas at Austin, Bureau of Economic Geology Index Series, 575 p.

(4) Moore, E. T., 1976, Bibliography and index of Texas geology, 1961-1974: The University of Texas at Austin, Bureau of Economic Geology Index Series, 446 p.

(5) Masterson, A. R., 1981, Bibliography and index of Texas geology, 1975-1980: The University of Texas at Austin, Bureau of Economic Geology Index Series, 334 p.

In assembling the section on detection, analysis, and interpretation of lineaments (Part I), we compiled titles from many sources including various bibliographies, lists of references cited in related works, listings of publications by state and federal geological surveys, journal indexes, library catalogs, and computerized reference services. Computerized reference services from which we obtained citations are: Earth Resources Observation Systems (EROS) Data Center, Sioux Falls, South Dakota; Goddard Space Flight Center, Greenbelt, Maryland; and National Technical Information Service (NTIS), Springfield, Virginia. Whenever possible, we examined the works themselves to confirm or correct citations and to determine their relevance to the present research effort. We also made our own selected forays into the literature, particularly sources that address remote sensing, geomorphology, and structural geology.

We include references in Part I of this bibliography only if they deal with at least one of three main topics, the most important being the application of lineament data to geothermal resource exploration. The other topics are (1) explication of a method for detecting or perceiving lineaments, analyzing their properties statistically, or interpreting their significance in a geological context; and (2) discussion of lineaments perceived on photographic images obtained by satellites or aircraft, rather than on maps or through direct digital processing. These selection criteria focus attention on references most directly pertinent to our present inquiry and reduce to manageable proportions the total number of citations included.

In Part II of the bibliography, we apply a geographic criterion, distinguishing references on lineaments in Texas from all others. The list of more general references (Part I) and the list of those dealing with Texas (Part II) are mutually exclusive; that is, we did not duplicate citations that might otherwise appear in both sections of the bibliography. Thus, the general and Texas sections should be used conjointly. Among the primary sources of references included in this section of the bibliography were the Bureau of Economic Geology's bibliographies of Texas geology, cited above.

During the course of the current study we observed that some lineaments appear to correlate with the distribution of Cretaceous intrusive, extrusive, and pyroclastic igneous rocks that lie generally along the Balcones/Ouachita trend in Central Texas. These igneous features are found at the surface and in the subsurface and are distributed irregularly along most of this structural trend. We compiled references describing these features and the structural and tectonic history of the Ouachita System itself; these references compose the comprehensive Part III of the bibliography. As in the previous section, primary sources of literature citations were the several volumes of the Bureau of Economic Geology's bibliographies of Texas geology.

APPENDIX G, PART I

DETECTION, ANALYSIS, AND INTERPRETATION OF LINEAMENTS

Aarnisalo, Jussi, 1978, Use of satellite pictures for determining major shield fractures relevant for ore prospecting, northern Finland: Helsinki, Geological Survey of Finland Report of Investigation no. 21, 59 p.

Abdel-Gawad, Monem, and Tubbesing, Linda, 1975, Analysis of tectonic features in U.S. Southwest from Skylab photographs: Thousand Oaks, California, Rockwell International Science Center, 95 p.

Abdel-Gawad, Monem, and Tubbesing, Linda, 1975, Mineral target areas in Nevada from geological analysis of Landsat-1 imagery, in Proceedings of the NASA Earth resources survey symposium: Houston, NASA, v. 1-B, p. 1059-1078.

Abdel-Gawad, Monem, and Tubbesing, Linda, 1976, Transverse shear in southwestern North America--a tectonic analysis, in Hodgson, R. A., Gay, S. P., Jr., and Benjamins, J. Y., eds., Proceedings of the first international conference on the New Basement Tectonics: Salt Lake City, Utah Geological Association Publication no. 5, p. 61-80.

Abdel-Rahman, M. A., 1979, A statistical method for determining the orientational relationship between geological variables, in Podwysocki, M. H., and Earle, J. L., eds., Proceedings of the second international conference on Basement Tectonics: Denver, Basement Tectonics Committee, p. 486-490.

Abdel-Rahman, M. A., 1979, East-west pervasive lineaments in central and southeastern Spain, in El-Baz, Farouk, and Warner, D. M., eds., Earth Observations and Photography, v. 2 of the Apollo-Soyuz test project summary science report: Washington, D.C., NASA SP-412, p. 149-156.

Acker, L. L., Hatcher, R. D., Jr., 1970, Relationships between structure and topography in northwest South Carolina: South Carolina Division of Geology Geologic Notes, v. 14, no. 2, p. 35-48.

Allen, W. H., and others, 1973, First-look analysis of geologic ground patterns on ERTS-1 imagery of Missouri, in Symposium on significant results obtained from the ERTS-1: Washington, D.C., NASA, v. 1, sec. A, p. 371-378.

Anderson, A. T., and Smith, A. F., 1976, Application of Landsat imagery to metallic mineral exploration in Utah, in American Society of Photogrammetry and American Congress on Surveying and Mapping, Fall

Convention, Phoenix, Arizona, October 26-31, 1975, Proceedings: Falls Church, Virginia, American Society of Photogrammetry, p. 286-297.

Anderson, C. A., 1967, Precambrian wrench fault in Central Arizona: U.S. Geological Survey Professional Paper 575-C, p. C60-C65.

Anderson, H. V., 1960, Geology of Sabine Parish: State of Louisiana, Department of Conservation Geology Bulletin 100.34, 164 p.

Anuta, P. E., 1975, ERTS multispectral image transformations for geological lineament enhancement: Lafayette, Indiana, Purdue University, 22 p.

Baars, D. L., 1979, The Colorado Plateau Aulacogen--key to continental scale basement rifting, in Podwysocki, M. H., and Earle, J. L., eds., Proceedings of the second international conference on Basement Tectonics: Denver, Basement Tectonics Committee, p. 157-164.

Babcock, E. A., 1976, A statistical analysis of photo lineaments and joints, terrain parameters and lineament density near Lethbridge, Alberta, in Hodgson, R. A., Gay, S. P., Jr., and Benjamins, J. Y., eds., Proceedings of the first international conference on the New Basement Tectonics: Salt Lake City, Utah Geological Association Publication no. 5, p. 437-448.

Babcock, Elizabeth, Briggs, Phillip, Decook, Kenneth, and others, 1979, Geologic applications of Landsat images in northeastern Arizona to the location of water supplies for municipal and industrial uses; final report: Tempe, Arizona State University; Tucson, University of Arizona; and Phoenix, Arizona Water Commission, 103 p.

Badgley, P. C., 1962, Analysis of structural patterns in bedrock: American Institute of Mining and Metallurgic Engineers, Society of Mining Engineers Transactions, v. 223, no. 12, p. 381-389.

Bakliwasl, P. C., 1978, Tectonic interpretation from lineament analysis using photogeophysical techniques of Ranthambhor Fort area, Rajasthan, India, in Proceedings of third regional conference on geology of mineral resources of Southeast Asia: no. 3, p. 129-132.

Banks, N. G., Bennett, C. A., and Schmidt, J. M., 1978, Maps of photo lineaments and geomorphological features in the Spirit Lake quadrangle, Washington; A. Photo lineaments; B. Photo geomorphological features: U.S. Geological Survey, Open-File Report 78-505.

Barbier, E., and Fanelli, M., 1975, Attempt at correlating Italian long lineaments from Landsat-1 satellite images with some geological phenomena--possible use in geothermal energy research, in Proceedings of the NASA Earth Resources Survey Symposium: Houston, NASA, v. 1-B, p. 1079-1086.

Barosh, P. J., 1976, Lineament studies in New England and their tectonic implications, in Hodgson, R. A., Gay, S. P., Jr., and Benjamins, J. Y.,eds., Proceedings of the first international conference on the New Basement Tectonics: Salt Lake City, Utah Geological Association Publication no. 5, p. 218-235.

Bechtold, I. C., 1974, Evidence of fracturing of the deep basement from Nimbus, X-15, Apollo, ERTS-1 and Skylab images (abs.), in Proceedings of the first international conference on the New Basement Tectonics: Salt Lake City, Utah Geological Association Publication no. 5, p. 140.

Bechtold, I. C., and others, 1973, Remote sensing reconnaissance of faulting in alluvium, Lake Mead to Lake Havasu, California, Nevada and Arizona--an application of ERTS-1 Satellite: Newport Beach, California, Argus Exploration, 11 p.

Bench, B. M., Diamond, W. P., and McCulloch, C. M., 1977, Methods of determining the orientations of bedrock fracture systems in southwestern Pennsylvania and northern West Virginia: Washington, D.C., Bureau of Mines Report of Investigations no. 8217, 35 p.

Blackstone, D. L., Jr., 1973, Analysis of linear photo elements, Bighorn-Pryor Mountains, Montana and Wyoming: Springfield, Virginia, National Technical Information Service Report E73-10704, 14 p.

Blackstone, D. L., Jr., 1973, Analysis of photo linear elements, Laramie Mountains, Wyoming: Springfield, Virginia, National Technical Information Service Report E73-10663, 14 p.

Blackwelder, E., 1928, The recognition of fault scarps: Journal of Geology, v. 36, no. 4, p. 289-311.

Blanchet, P. H., 1957, Development of fracture analysis as exploration method: American Association of Petroleum Geologists Bulletin, v. 41, no. 8, p. 1748-1759.

Blom, C. J., 1955, Statistical consideration of linear geomorphological features of Guadalcanal (abs.): Geological Society of America Bulletin, v. 66, no. 12, pt. 2, p. 1644.

Boccaletti, M., and Coli, M., 1979, Sistimi di fratture nell'Appennino settentrionale da immagini Landsat; loro significato e problematiche (System of fractures in the Central Apennines seen by Landsat imagery; significance and problems): Universo, v. 59, no. 1, p. 123-134.

Braile, L. W., Hinze, W. J., Sexton, J. L., and others, 1979, An integrated geophysical and geological study of the tectonic framework of the 38th parallel lineament in the vicinity of its intersection with the extension of the New Madrid fault zone; annual progress report--fiscal year 1979: Washington, D. C., U. S. Nuclear Regulatory Commission, Division of Reactor Safety Research, Contract no. NRC-04-76-323, NRC FIN B5971, NUREG/CR-1014.

Brock, B. B., 1957, World patterns and lineaments, _in_ Transactions and Proceedings of the Geological Society of South Africa, v. 60, p. 127-175.

Brockmann, C. E., Fernandez, A., Ballon, R., Claure, H., 1977, Analysis of geological structures based on Landsat-1 images, _in_ Remote-sensing applications for mineral exploration: Stroudsburg, Pennsylvania, Dowden, Hutchinson, and Ross, p. 292-317.

Brosse, J. M, and Scanvic, J. Y., 1977, The contributing role of scale in remote sensing for structural geology, _in_ Workshop on remote sensing, Toulouse, France, October 26-28, 1976, Proceedings: v. 1, p. 99-117.

Brown, P. M., Brown, D. L., Shufflebarger, T. E., Jr., and Sampair, J. L., 1979, Wrench zone in the North Carolina coastal plain, _in_ Podwysocki, M. H., and Earle, J. L., eds., Proceedings of the second international conference on Basement Tectonics: Denver, Basement Tectonics Committee, p. 54-73.

Bucknam, R. C., 1978, Documentation for alinement arrays, Motagua fault, Guatemala: U.S. Geological Survey Open-File Report no. 78-880, 21 p.

Burns, K. L., 1973, Structural geology and ERTS-1 (abs.), _in_ ERTS-1 Investigators Symposium: Canberra, Australia, Bureau of Mineral Resources.

Burns, K. L., and Brown, G. H., 1978, The human perception of geological lineaments and other discrete features in remote sensing imagery--signal strengths, noise levels and quality: Remote Sensing of Environment, v. 7, p. 163-176.

Burns, K. L., and Shepherd, J., 1976, Satellite lineaments in southeast Australia, _in_ Hodgson, R. A., Gay, S. P., Jr., and Benjamins, J. Y., eds., Proceedings of the first conference on the New Basement Tectonics: Salt Lake City, Utah Geological Association Publication no. 5, p. 354-368.

Burns, K. L., Shepherd, J., and Berman, M., 1976, Reproducibility of geological lineaments and other discrete features interpreted from imagery--measurement by a coefficient of association: Remote Sensing of Environment, v. 5, no. 4, p. 267-301.

Buschbach, T. C., 1978, New Madrid seismotectonic study--activities during fiscal year 1978: Illingis State Geological Survey, prepared for the Division of Reactor Safety Research, Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission, Contract no. NRC 04-76-204, NUREG/CR-0450.

Cameron, H. L., 1953, Air photo interpretation in natural resources inventories: Photogrammetric Engineering, v. 19, no. 3, p. 481-486.

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APPENDIX G, PART II

LINEAMENTS OF TEXAS

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APPENDIX G, PART III

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APPENDIX H

Geothermal Resource Potential at Military Bases in Bexar, Travis, and Val Verde Counties, Texas

by

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in

GEOTHERMAL RESOURCE ASSESSMENT
FOR THE STATE OF TEXAS
Status of Progress,
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PREFACE

This study of geothermal potential at military bases in parts of Central Texas is a subset of our more extensive statewide resource-assessment efforts. The focus on military installations (and particularly U.S. Air Force Bases) reflects a growing desire on the part of the Federal Government to lessen the use of nonrenewable fuels. Use of geothermal waters for direct heating is a means to this end, and our study was conducted because of promising geothermal resources already delineated in Central Texas.

The study encompassed a six-month period and includes area-specific reevaluations of data from our other ongoing research. This appendix examines the geologic possibilities and constraints on using geothermal waters in selected areas. Our audience includes engineers, planners, and Air Force decision-makers, who will judge the economic and technical feasibilities of developing these resources. Insofar as possible, we have tried to simplify geologic jargon, but the report does presuppose a familiarity with technical matters related to water chemistry and general subsurface properties of the earth. Appendix H is designed to stand alone from the larger "Final Report," of which it is a part. However, complete understanding of the computer printouts of well data displayed in the "Addenda" to this Appendix requires reference to Appendix C, in which various printout codes are explained in detail.

EXECUTIVE SUMMARY

Varying amounts of evidence exist of potential geothermal resources beneath the military installations in Bexar, Travis, and Val Verde Counties. The degree of certainty with which this resource may be delineated or assayed is dependent on extant data, especially on ground-water data from any wells completed in the geologic horizons of interest. These data are not distributed evenly across any of the three areas of study. In fact, for certain areas (especially Val Verde County) there are no data pertaining to the potential geothermal aquifer, hence we cannot substantiate a resource.

The area having greatest apparent potential for geothermal resource development is Bexar County; there the Hosston Sand lies at sufficient depths to yield ground water having temperatures that may be in excess of 120°F and dissolved solids of probably less than 2,000 mg/l. However, no data on sustainable well yields are available for the Hosston in Bexar County. Possibly the optimal (high water temperature and low dissolved solids) location for well development in Bexar County is at Lackland or Kelly Air Force Bases (AFB). Brooks AFB is another likely site for Hosston well development, whereas Fort Sam Houston has a moderate potential for use of Hosston waters. Randolph AFB has slightly less potential. Fort Sam Houston has potential for tapping the fresh-water (77°F) Edwards aquifer for operating a ground-water heat pump system, but the resource questions involved in this use warrant a separate investigation.

Travis County has modest geothermal potential, also from the Hosston Sand. However, the Hosston well closest to Bergstrom AFB exhibits a temperature of only 94°F, though this may be a phenomenon that is due to slow artesian flow with a resulting cooling of the ground water from depth. Water quality from the Hosston beneath Bergstrom AFB presents no special problems, and the projected sustainable well yield seems adequate to support resource development on a scale similar to that at Marlin, Texas, where a hospital well requires a flow of 200 gallons per minute to meet peak heating demand.

Val Verde County is an area of intriguing structural anomalies and attendant geothermal manifestations, such as slightly warm springs from the Edwards Limestone. However, the main promising horizon beneath Laughlin AFB, the (Hosston-equivalent) "Basal Cretaceous Sands," are completely untested as a water resource. The Basal Cretaceous is deep enough that, given the prevailing geothermal gradient, water temperatures greater than 100°F may be expected.

INTRODUCTION

A major dislocation of the earth's crust bisects Texas from Del Rio east to the San Antonio vicinity and from there north to the Red River (fig. H-1). This zone of dislocation is denoted by the buried Ouachita Mountain Belt, which once stood tall throughout Central Texas, but which subsided approximately 225 million years ago when the Gulf of Mexico began to form. The buried mountain belt delineates a hinge zone that separates the stable continental interior from the downwarping Gulf Coast Basin. This hinge has repeatedly affected the geologic setting in Central Texas. It marked a persistent strandline during Cretaceous time when the formative Gulf extended into Central Texas. In this way, the hinge controlled the geometry and thickness of sandstone strata that eventually became important aquifers. It also affected porosity development in limestone aquifers during subsequent uplift and cavern development. The Ouachita hinge zone also marked a locus of volcanic activity and eventually controlled the location of Balcones faulting, which is so dramatically expressed by the landscape of South-Central Texas.

The Balcones/Ouachita trend has been demonstrated to be an area of geothermal anomalies (Woodruff and McBride, 1979; Woodruff, 1979; Woodruff, 1980). It is an area denoted by several aquifers that yield ground waters with temperatures in excess of 100°F. Heretofore, these warm, often slightly saline waters have generally been considered an oddity or a nuisance. They have provided domestic and municipal ground-water supplies where no other water is available, but mainly they have been used only for therapeutic purposes at local health resorts and spas. Now, however, increased costs of fossil fuels have focused attention on these ground-water resources as an energy supply--specifically, as a source of heat for such direct uses as space heating and hot water.

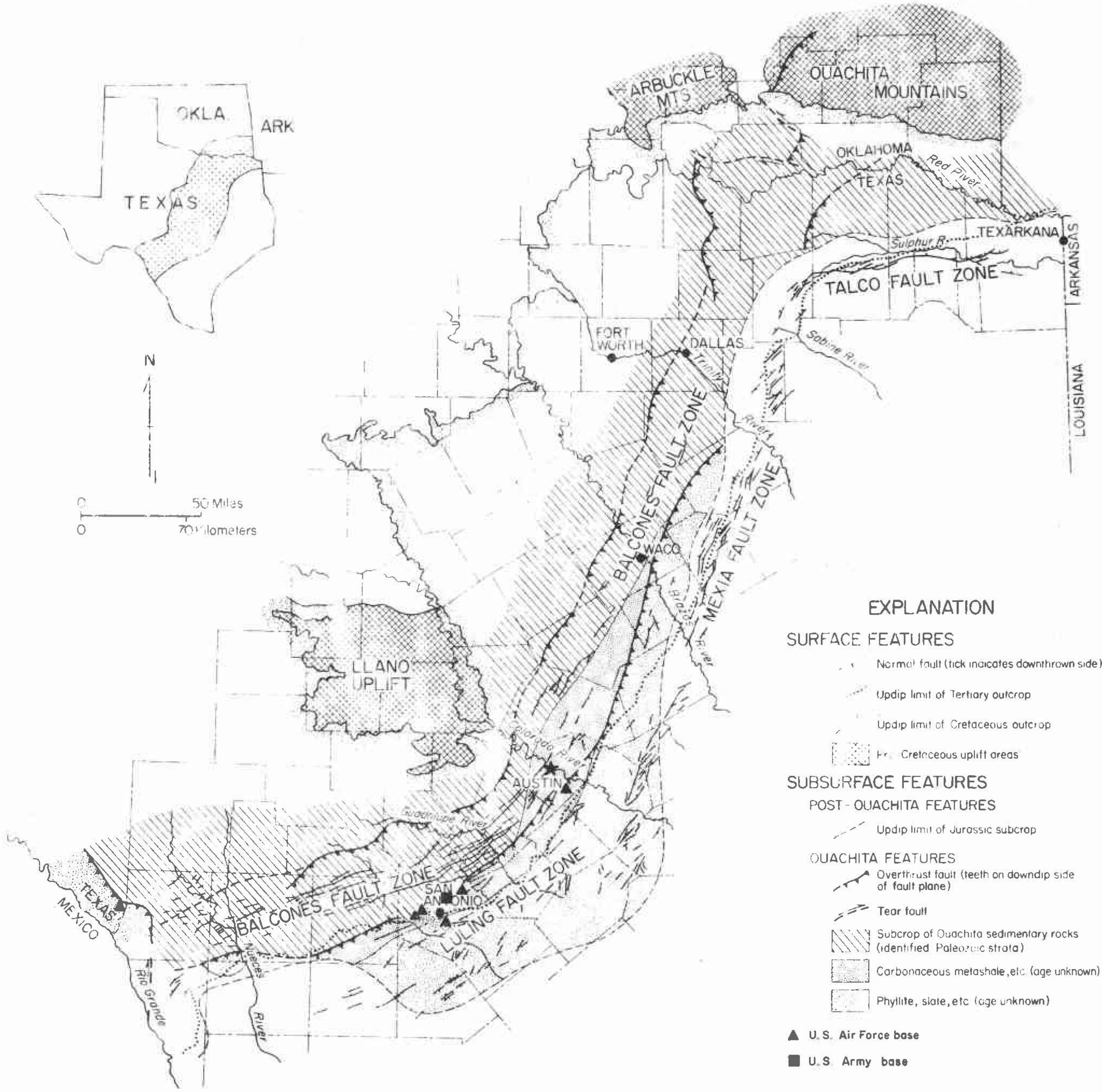

Figure H-1. Balcones/Ouachita structural trend in Central Texas showing locations of military facilities studied in Bexar, Travis, and Val Verde Counties.

The Balcones/Ouachita trend is a promising area for use of this kind of low-grade energy resource because the geologic dislocations have not only enhanced geothermal potential but have also affected human settlement patterns. In short, this trend includes many of the major cities of Texas, including Austin, Dallas, Fort Worth, San Antonio, and Waco. Geologic control on the location of cities is seen in the change from the Blackland belt and its cotton economy to the Edwards Plateau and its cattle economy. These Texas cities developed where they did because of this dual (cotton/cattle) resource base and an abundant water supply; they were established along a natural boundary, a line that is commonly considered to be "where the West begins."

Among the institutions and facilities that occupy this geologic-cultural break are numerous military bases. Bexar County, alone, is the home of four U.S. Air Force Bases--Randolph, Kelly, Brooks, and Lackland--and one U.S. Army installation--Fort Sam Houston. Besides these, Bergstrom AFB in Austin and Laughlin AFB near Del Rio also occur along the Balcones/Ouachita trend, and there are still other such facilities farther north along this trend. Installations of this kind are all potential users of low-temperature geothermal resources; they all have centralized facilities and year-round levels of use that are favorable for resource development at a scale large enough possibly to warrant drilling of geothermal production wells. However, before intensive efforts are begun to develop the resource, some fundamental issues must be addressed. Paramount among these is the question, what are the local characteristics of the resource? The answer involves assessments of (1) geographic location of the resource, which requires the evaluation of bedrock properties of the geothermal aquifers (depth, thickness, structural dislocations, and the like); (2) quality of the resource, including temperature and salinity of the water; and

(3) quantity of the resource, that is, sustainable well yield. These questions have defined our area-specific evaluations for the military bases in Bexar, Travis, and Val Verde Counties. However, we are constrained by the data at hand, in other words, by the location of wells and by the type and quality of information pertaining either to the bedrock penetrated by the wells or to the fluids contained therein. For several promising geologic horizons there simply are no data, and in these instances our assessments are largely conjectural. Ultimately, the true test of any subsurface resource is the drilling of a well.

Procedures

We attempted to obtain all information pertinent to geothermal resources near the military bases in Bexar, Travis, and Val Verde Counties. This entailed our obtaining two major types of data: (1) those pertaining to the lithic (bedrock) framework of the aquifers in question, and (2) those pertaining to their water attributes. The former consist for the most part of geophysical well logs and are mainly part of data bases employed in petroleum exploration activities; the latter occur mainly in reports and files of state and federal water-resource agencies. The two types of data often converge, and this created problems with map location, identification of wells, and consistency of tabular information. These problems have been discussed at length in the body of this report and will not be reiterated here. Suffice it to say, however, that the amount of water-well information available is a function of the quality and degree of use of the local ground-water resource. Yet since warm, mineralized ground water generally constitutes an undesirable table water resource, there are commonly few, if any, water wells (hence, data points on water quality or sustainable yield) in the thermal reaches of the aquifers investigated. Compounding the problem of economics, which dictates that people always drill for the cheapest (shallowest) and highest quality (lowest temperature and lowest salinity) water resource, there are also institutional rules that militate against a consistent geophysical log file for the aquifers in question. For example, the Texas Department of Water Resources (TDWR) requires the casing of petroleum exploration wells where they penetrate aquifer horizons, with the result that most electric logs begin below the casing level--below the very horizons that are of greatest interest to this study. Despite these difficulties, our data base is generally adequate for the necessary geologic interpretations, although our analyses of water attributes are based locally on sparse well control.

Of the three areas surveyed, Bexar County was accorded the most attention. This is partly because of the concentration of facilities there, but also because there are two presumed geothermal aquifers underlying the area. Of these, abundant data are available for the Edwards aquifer. In addition, hydrologic and geothermal complexities required extensive assessments that were not conducted elsewhere. For the other, deeper horizon, the Hosston Sand, little water data are available.

The findings presented herein are largely pictorial and graphical. For each county, we first depict structural and stratigraphic attributes of the aquifers in question; we then present water data insofar as they are available. We include a computer-derived tabulation of all control points in the counties surveyed, which is keyed to the various maps by unique numbers within each county. These data are presented as a series of computer-plotted maps showing the locations of wells and all 7.5-minute (latitude/longitude) intersections for each county. Two-page printouts of salient data on each county surveyed are included at the end of this report as addenda to this appendix.

For the most part, our data are limited to the three counties in which the military bases occur, but because Laughlin AFB lies close to the Val Verde - Kinney County line, Kinney County well data are included in their entirety. Elsewhere, we include only selected, pertinent data points from neighboring counties; this information is tabulated along with the data from the adjacent county where military installations occur.

GEOTHERMICS--A SIMPLIFIED OVERVIEW

Heat is generated in the earth's interior because of radioactive decay, and, in general, the deeper the penetration of the earth's crust, the higher the temperature. But deep-seated heat generation is not equally distributed, nor are the heat-conductive properties of earth materials everywhere the same. In short, there are some areas where earth materials constitute insulating layers, whereas elsewhere heat conduction is relatively more important. Also, there are "hot" spots owing to locally differing thermal properties of rock materials at depth. In general, this radiogenic heat powers the ongoing internal evolution of the earth's crust, and a marked correlation exists between areas of crustal activity denoted by earthquake belts and areas having abnormal geothermal manifestations such as volcanoes, hot springs, and geysers. The so-called mobile belts of the earth are the main areas for worldwide geothermal resource development and especially for localization of the high temperatures necessary for electric-power generation.

But what about tectonically quiescent areas? Central Texas, during recent geologic time, is certainly such a stable area. Yet there are thermal anomalies associated with the Balcones/Ouachita trend, which is a relict of a former mobile belt. What, if any, is the relation between the thermal anomalies in Central Texas and the long tectonic evolution that included the formation of a geosynclinal basin, deformation of the sediments formed in this basin into a thrust-faulted mountain range, subsidence of this mountain range, emplacement of volcanoes, and extensive normal faulting? There are two hypotheses that may contribute answers to this question: (1) the relict structural trend may still be more active than we think, thus there may still be anomalous amounts of heat flowing through this part of the crust; or (2) the thermal anomalies may actually be hydrologic phenomena, in which water circulates to considerable depth via faults and steeply dipping strata, absorbs heat, and then transmits this heat as it rises under favorable hydraulic conditions. In actuality, features of both models may occur in Central Texas, but a detailed assessment of these hypotheses is beyond the scope of this study. However, these two divergent mechanisms for geothermal heat transfer provide a basis for a summary discussion of conduction and convection, which are the two fundamental processes whereby heat is transferred from deep in the earth's interior.

Heat flow within the earth involves several variables, and it may have numerous causes. But, in general, it conforms to the heat-flow equation (Fourier's Law):

$$Q = - KA \frac{dt}{dx}$$

where: Q is heat flow;

K is thermal conductivity;

A is area traversed, generally assumed as unity;

and

$\frac{dt}{dx}$ is geothermal gradient, the change in earth temperature with depth.

The minus sign in the equation is simply a convention that implies that temperature <u>increases</u> with depth (if temperature is plotted on the abscissa, and depth on the ordinate, the line generally defined would have negative slope).

Geothermal gradient is the parameter generally available to geologists who are conducting subsurface studies. This is because when a petroleum exploration well is completed and logged, a bottom-hole temperature (BHT) is measured in order to calibrate log response (commonly an electrical phenomenon involving salinity [hence, resistivity] of fluids contained within pore spaces of the rocks penetrated). The purpose of BHT measurements, however, is only to obtain downhole temperatures of drilling muds for this calibration; it is not necessarily intended to be a measure of the earth's heat. Commonly, a log is taken immediately after drilling is completed, before the drilling fluids have equilibrated to the ambient rock temperatures. For very shallow wells this may mean that BHT is anomalously high, because frictional heat from drilling the well may not have dissipated. More commonly, however, the circulating drilling muds cool the bit so that the BHT reading is lower than that of the actual earth temperature at a given depth.

Despite the problems with BHT values, this information from the oil industry constitutes a valuable data base of subsurface earth temperatures. We employed these data to construct geothermal gradient maps, although we made no attempt to adjust BHT's for a presumed "equilibrium" (there are empirical methods for doing this). Instead, we present our gradient values as conservative, that is, as showing generally lower gradients than the probable equilibrated earth temperatures at the depths penetrated. Our computation of geothermal gradients entailed adjusting the BHT for local ground temperature prevailing at the earth's surface; this ground temperature is presumed to equal the long-term mean annual air temperature in the area of the well in question. This value is then subtracted from BHT, and the difference is divided by the depth to give a gradient commonly presented in the English units of °F/100 ft; the metric equivalent is °C/km.

Geothermal gradient is our most direct indication of deep-seated temperature conditions within the earth's interior, but Fourier's Law shows that it is a function of two independent variables. It is a direct function of heat flow and an inverse function of thermal conductivity. Thus, a high geothermal gradient may mean either a locally high heat flow or the presence of low thermal-conductivity properties (as commonly occur beneath a thick insulating blanket of sedimentary strata). Within a sedimentary basin, either of these conflicting parameters may locally be dominant, and because of the difficulties with assaying the meaning of geothermal gradient anomalies in terms of the data available, we view geothermal gradient only as a generalized, regional indicator of thermal regimes (fig. H-2). Those areas with significant anomalies warrant further consideration, but areas without such anomalous values should not be removed from consideration on the basis of gradient data alone.

The most important indicators of geothermal resources that are of use to military bases in Central Texas are quality, quantity, and temperature of the locally available ground water. Water is characterized by high thermal inertia; that is, once heated it tends to retain the heat for considerable periods of time. Moreover, water's mobility makes it an ideal conveyor of heat from one level to another within the earth. In short, ground water commonly acts as a natural heat storage and heat transfer medium. Near the earth's surface, solar energy is thus stored and conveyed; at depth, geothermal energy is likewise transferred.

Ground water flows underground in accordance with Darcy's Law, which may be simply expressed as an equation:

$$Q = - KA \frac{dh}{dl}$$

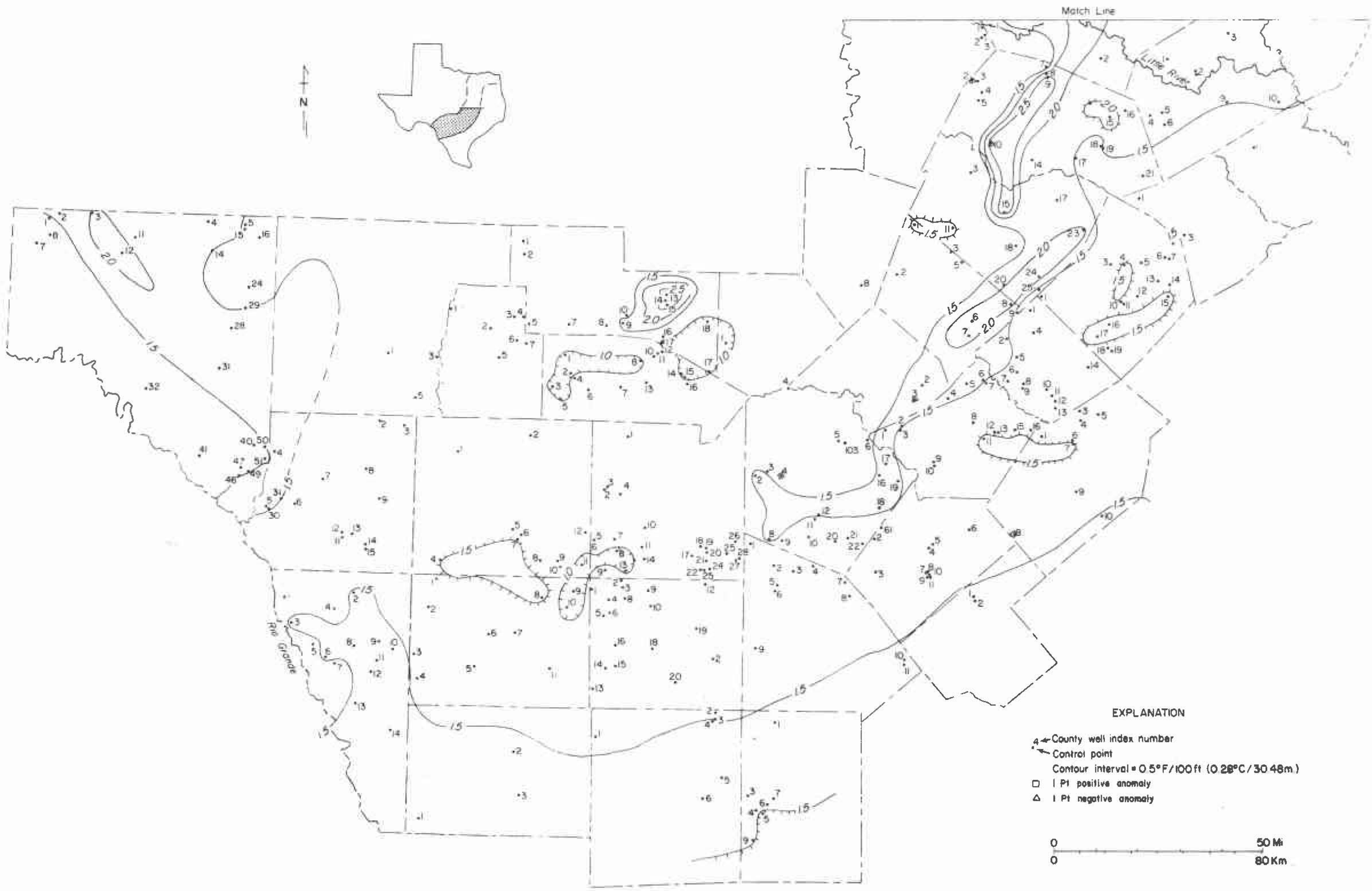

Figure H-2. Geothermal gradient map along southern part of Balcones/Ouachita trend.

where: Q is discharge of water;

K is hydraulic conductivity;

A is cross-sectional area of the part of the aquifer studied, commonly assumed to be unity; and

$\frac{dh}{dl}$ is hydraulic gradient, the change in pressure head with distance (depth).

As with the heat-flow equation, the minus sign is a convention implying that pressure increases with depth.

Darcy's Law and Fourier's Law are clearly analogous. Moreover, the factors included within one equation affect factors in the other. For example, hydraulic conductivity is defined assuming a water temperature of 60°F; but as temperature increases, water becomes less viscous (other factors remaining equal) and thus may move more rapidly through porous media. Conversely, water flowing upward alters both local heat-flow conditions and geothermal gradients, because of the influence of hydraulic conductivity. Yet, common misconceptions arise from Fourier's Law, because laboratory measurements of thermal properties of rocks are made with dry samples, whereas natural subsurface environments almost always consist of two phases--rock and water--having two markedly different thermal conductivity values. The values for rock are much higher than for water, but the water flows, and this is commonly the key factor in hydrothermal resources. Upward-flowing ground water generally results in high geothermal anomalies; downward-moving ground water commonly has an opposite effect, resulting in low geothermal anomalies.

In a practical sense, the convergence of Darcy's Law and Fourier's Law is illustrated by water-temperature attributes of typical aquifers. In very shallow, high-permeability aquifer systems, such as river alluvium, there is day-to-day interchange of water between the river and the ground-water body. This hydraulic continuity means that the ground-water temperatures will vary with those of the river, thus showing seasonal changes in a muted response to seasonal changes in air temperature. For deeper ground water that is recharged relatively rapidly (but which does not readily mix with surface water), the ground-water temperature approximates the average annual air temperature of the recharge zone. This is because (1) the ground water represents a mixed sample of rain that falls throughout the year, during all seasons, and (2) the shallow bedrock serves to insulate the waters contained therein and to aid in maintaining a constant temperature. For ground water that is deeper yet--below the depth directly affected by seasonal, recharging waters--the groundwater temperatures increase at a rate that is generally proportional to the local geothermal gradient. The depth at which this increase occurs depends on the permeability and, hence, on the ease of mixing of recharging waters with other ground water already in residence within the aquifer. Moreover, this simplified thermal setting may be radically altered by upwelling waters, which, as previously mentioned, would result in a hydrologically induced, abnormal geothermal gradient.

A complex assortment of processes occurs within the thermal reaches of a typical aquifer. With increasing temperature, the water tends to become more chemically reactive, so that the concentration of dissolved solids increases. This salinity increase is often related to ion exchange between the ground water and minerals composing the aquifer host rock. A common attribute of this process is the precipitation of secondary minerals in intergranular pore spaces, with an associated decrease in porosity and permeability. Thus, geothermal ground waters often exhibit increased salinity and occur in aquifers having decreased permeability. This process is exacerbated by the mixing of upwelling waters that are generally hot but more saline than downward-migrating meteoric waters; the mixing of waters of differing salinities commonly results in a worst-case situation: water temperature is mediated, salinity is maintained at a relatively high level, and porosity and permeability decrease markedly. Our focus is on areas that diverge from this tendency; that is, where temperature is high (with respect to local air temperature), but salinity is low, and hydraulic conductivity is maintained.

GEOTHERMOMETRY

From the preceding discussion on "Geothermics" it is evident that the hydrologic regime of geothermal waters affects our perception of the amount of heat available at any locality. Because of these hydrologic effects, water temperatures measured at the surface, either in flowing or pumped wells, may not indicate the maximum temperature of the water in the subsurface. For example, if thermal ground water rises to the surface slowly, either because it is pumped slowly or has a low rate of artesian flow, the water may cool significantly from its maximum temperature at depth. In some cases, however, this maximum temperature can still be determined from the chemical composition of the water. Hence, chemical analyses may allow one to use concentrations of certain ions as "geothermometers" to ascertain whether an apparently nonthermal ground-water source may have higher temperature values at depth. These geochemical indicators of deep-seated temperature regimes must be used with caution. Not only do the indicators depend on valid chemical analyses, but also the person analyzing these data must have a sophisticated view of the hydrogeochemical history of the water and must entertain a variety of hypotheses that might account for the concentrations of ions dissolved in a particular water. In short, these methods cannot be employed for all analyses, but only for those that meet certain analytical standards and can be presumed not to have been contaminated by mixing with other (shallower, hence cooler) waters.

Two chemical geothermometers are widely used: one is based on silica concentrations; the other is based on ratios among sodium, potassium, and calcium (Na/K/Ca) ions. Two assumptions must be satisfied for the chemical geothermometers to be used accurately: (1) water composition must be controlled by equilibrium with the appropriate chemical and mineralogic constituents at the reservoir temperatures, and (2) the composition must not change between the reservoir and the sampling and analysis procedures, either because of mixing or because of continued reaction with the wall rock at lower temperatures (Fournier and others, 1974). Geothermometers commonly work best on high-temperature waters, because equilibrium is more likely, and on high-discharge waters, because reequilibration is less likely.

GENERAL CHEMICAL CONSTRAINTS ON USE OF GEOTHERMAL GROUND WATER

Whether or not any geothermal ground water constitutes a usable resource depends on a number of additional factors that affect the economics of its production and disposal. One critical factor is water quality, which influences the likelihood for either corrosion or scale. Corrosion is related mainly to the acidity of the water; the higher the acidity (lower the pH), the greater the likelihood for corrosion to occur. The presence of hydrogen sulfide gas in solution is a key constituent that indicates low pH and thus the probability of corrosion. Scaling, on the other hand, results from the precipitation of a variety of minerals. Patton (1977) listed calcite, various forms of calcium sulfate, and iron compounds as the most common scales. Various forms of silica can also be problems in geothermal wells. Only calcite and possibly iron compounds should be problems for waters in Central Texas because of the temperatures encountered and the minerals constituting the aquifers.

Precipitation of calcite is likely to be the major source of scale in Central Texas limestone aquifers and could be a major adverse factor in water use. Calcite solubility increases with an increase in pCO_2 (partial pressure of CO_2) but, unlike most minerals, this variable decreases with increased temperature, so that--on the basis of pCO_2 alone--more calcite will be dissolved in cold water than in hot water. But the pressure and temperature regimes of a producing geothermal well counteract each other. Cooling of the saline water alone should not cause precipitation of calcite, but, in fact, should increase its solubility. However, in practice, a decrease in confining pressure (when water rises to the ground surface) results in a loss of CO_2 to the atmosphere and an increase in pH, greatly reducing calcite solubility, and causing calcite to precipitate. Maintenance of confining pressures, therefore, should prevent calcite scale from forming.

Silica precipitation should not be a problem in Central Texas geothermal aquifers. Silica solubility increases with an increase in temperature. Thus, lowering the temperature of a geothermal water can cause silica to precipitate (commonly as amorphous silica). However, silica precipitation occurs only when very high temperature water (>356°F) having a very high silica concentration (>200 mg/l) cools. Concentrations less than about 150 mg/l can remain in solution indefinitely without precipitation. The silica concentrations found in geothermal waters in Central Texas are generally less than 25 mg/l, and thus should cause no scaling problems.

BEXAR COUNTY

General

The Balcones/Ouachita trend is well expressed in the vicinity of Bexar County. This expression includes both surface and subsurface geologic attributes and attendant cultural responses. For example, downtown San Antonio is situated on a nearly flat plain bounded on the north by limestone hills and on the south by sand hills and chaparral terrain. These topographic changes reflect discontinuities in bedrock associated with the Balcones Fault Zone in the northern part of the county and its down-to-the-coast displacement of strata, and the Luling Fault Zone to the south, where younger strata are displaced up to the coast. The flat plain on which San Antonio was founded is a result of stream deposition on relatively erosive bedrock that lies between the two fault zones (fig. H-3). This alluvial plain (which, as it happens, is also ideal for the siting of airports, hence, of air force bases) is a topographic expression of what geologists term a graben, a downfaulted block between upthrown strata. The recognition of this kind of structural juxtaposition has bearing on the location of geothermal resources because: (1) a graben is commonly an indicator of steeply dipping rock or other such discontinuities in the underlying basement complex (the buried Ouachita Belt); and (2) the graben often causes a compartmentalization of strata, which for aquifers may result in retardation of downward flow of ground water.

Balcones faulting and associated features of the Central Texas landscape are responsible for localization of the prolific Edwards aquifer, which is the source of San Antonio's drinking water. However, it was recognized early that the fresh, artesian Edwards ground water extended only a few miles south of the limestone hills where springs issue forth at the edge of the alluvial plain. An abrupt discontinuity in water quality occurs in south San Antonio. This discontinuity is termed the "bad-water line" and is part of a regionwide change in the water quality of the Edwards aquifer. South of this "bad-water line," water produced from the Edwards Limestone is generally warm and saline.

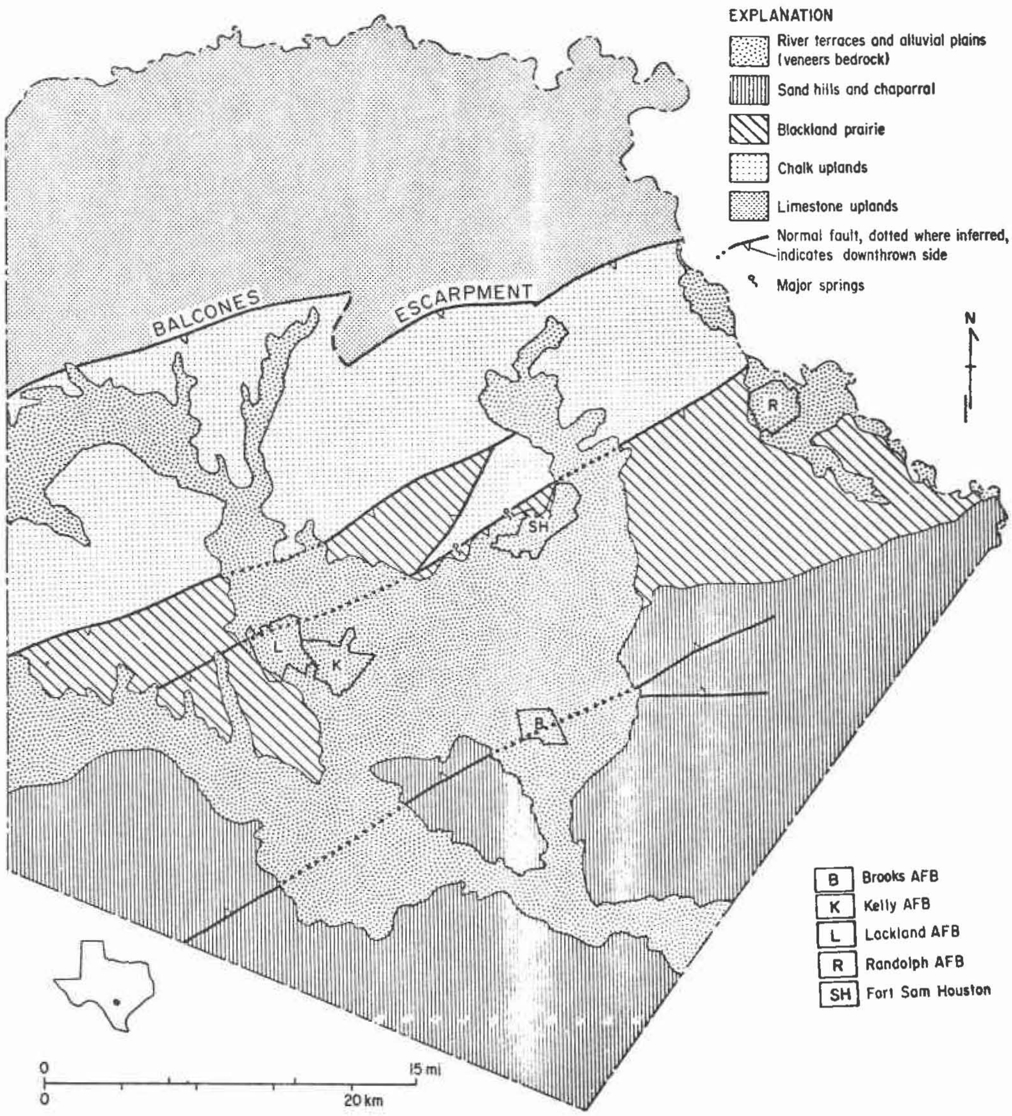

Figure H-3. Simplified map of geology and landforms of Bexar County.

In the San Antonio area, the contact between fresh and saline waters occurs within the aforementioned graben, although its exact limits disregard fault traces and structural contours. In short, although the origin of the "bad-water line" is problematical, it is no doubt ultimately controlled by the deep-seated structural disturbances associated with the Balcones/Ouachita trend. The saline-water zone constitutes one area of hydrothermal resources in the Bexar County vicinity; hence, it constitutes one target horizon that we surveyed for potential use by local military installations. A considerable amount of well data exists for the "bad-water" Edwards because of early attempts to locate potable water and subsequent petroleum exploration efforts.

We also propose that some geothermal potential exists within the Hosston Sand, a sandstone stratum resting directly on the Ouachita "basement." Our targeting of this deeper horizon (below the Edwards) is based on only a few water-temperature data, but we also note an analogy with areas farther north in Central Texas where these basal sands constitute a viable geothermal resource.

Data Base

San Antonio is the largest city in the United States for which ground water provides the entire municipal drinking water supply. Because of the importance of the Edwards aquifer there have been numerous detailed studies that assess the extent and quality of this resource (see, for example, Arnow, 1963; Klemt and others, 1979; Maclay and Small, 1976; and Pettit and George, 1956). However, even though extensive well development has delineated the "bad-water line," there has been little scientific attention accorded the saline waters south and east of this line.

Extensive historical well-drilling efforts have resulted in our having access to 89 thermal ground-water data points, including five wells in Atascosa

County. These data, however, are not evenly distributed, and there are few wells that sample either of our thermal horizons at distances greater than about 5 mi south of the "bad-water line." Moreover, there are only two wells that provide data on the thermal-water attributes of the deeper of the two geothermal aquifers, the Hosston Sand. Hence, for part of our assessment we depend on indirect methods, which generally involve evaluation of geophysical logs that provide a means of determining down-hole rock and fluid properties. For our Bexar County assessment, we obtained 24 data points of this kind and a few sample descriptions based on evaluation of rock cuttings obtained during the well-drilling process.

Findings

The aquifers having local geothermal resource potential in the San Antonio area include the "basal" Hosston Sand and the downdip reaches of the Edwards Limestone. For use by military installations, however, the Edwards Limestone is limited by the geographic extent of its thermal reaches and by adverse water quality. Simply put, it is a geothermal aquifer beneath only one (Brooks AFB) of the five major military bases in Bexar County. The Hosston Sand, on the other hand, is deep enough to provide warm ground water beneath all the military installations in the area, but our direct data on water attributes, including temperature, salinity, and well yield, are meager. Hence, our discussions of resource potential for both aquifers must be weighed in context of these limitations: for the Edwards, it is a documented limit of areal extent; for the Hosston, it is an uncertainty owing to sparse data.

Edwards Limestone

The geothermal reaches of the Edwards Limestone are delimited by the "bad-water line," where the aquifer changes from a cavernous system yielding vast quantities of cool, potable water, to one having porosity systems of more local extent yielding erratic quantities of waters that are generally warm and saline. The "bad-water line" extends obliquely along a southwest-to-northeast trend from near the juncture of Atascosa, Bexar, and Medina Counties to the Guadalupe County line near Randolph AFB. This abrupt change in aquifer properties has long been an enigma to geologists. It has been variously attributed to structural control and to facies changes (that is, changes in rock composition or texture because of differences in depositional environments), yet the line does not correspond to fault traces (fig. H-4) nor to clearly identified changes in original limestone environments (Abbott, 1974). Instead the "bad-water line" trends obliquely to the structure of the Edwards Limestone, and the fact that it is as shallow as 500 ft near Randolph AFB and as deep as 2,000 ft in southwestern Bexar County suggests that the line is a result of hydrologic evolution of the Edwards aquifer, as proposed by Woodruff and Abbott (1979). That is, the "bad-water" line may represent the lower (downdip) limit influenced by the discharge points (the major springs) that were instrumental in the geometrical and hydrologic development of the fresh-water Edwards artesian aquifer.

The "bad-water line" probably represents the boundary between two distinct hydrologic systems: one affected by recharge and discharge associated with modern river courses and springs, and the other associated with the deep basinal setting of the Edwards Limestone that includes oil and gas fields and their associated brines. Work by Lynton Land and Dennis Prezbindowski (oral communication, 1980) supports the deep-basin origin of the saline-water part of the Edwards aquifer. The regional plan view of the "bad-water line" also supports this hypothesis; the line converges toward the springs, as would be expected if these springs were potentiometric base levels. The analogy to surface drainage would be a series of coastal tributary systems (the fresh-water part of the Edwards) draining into major trunk streams (the mouth of these tributaries as

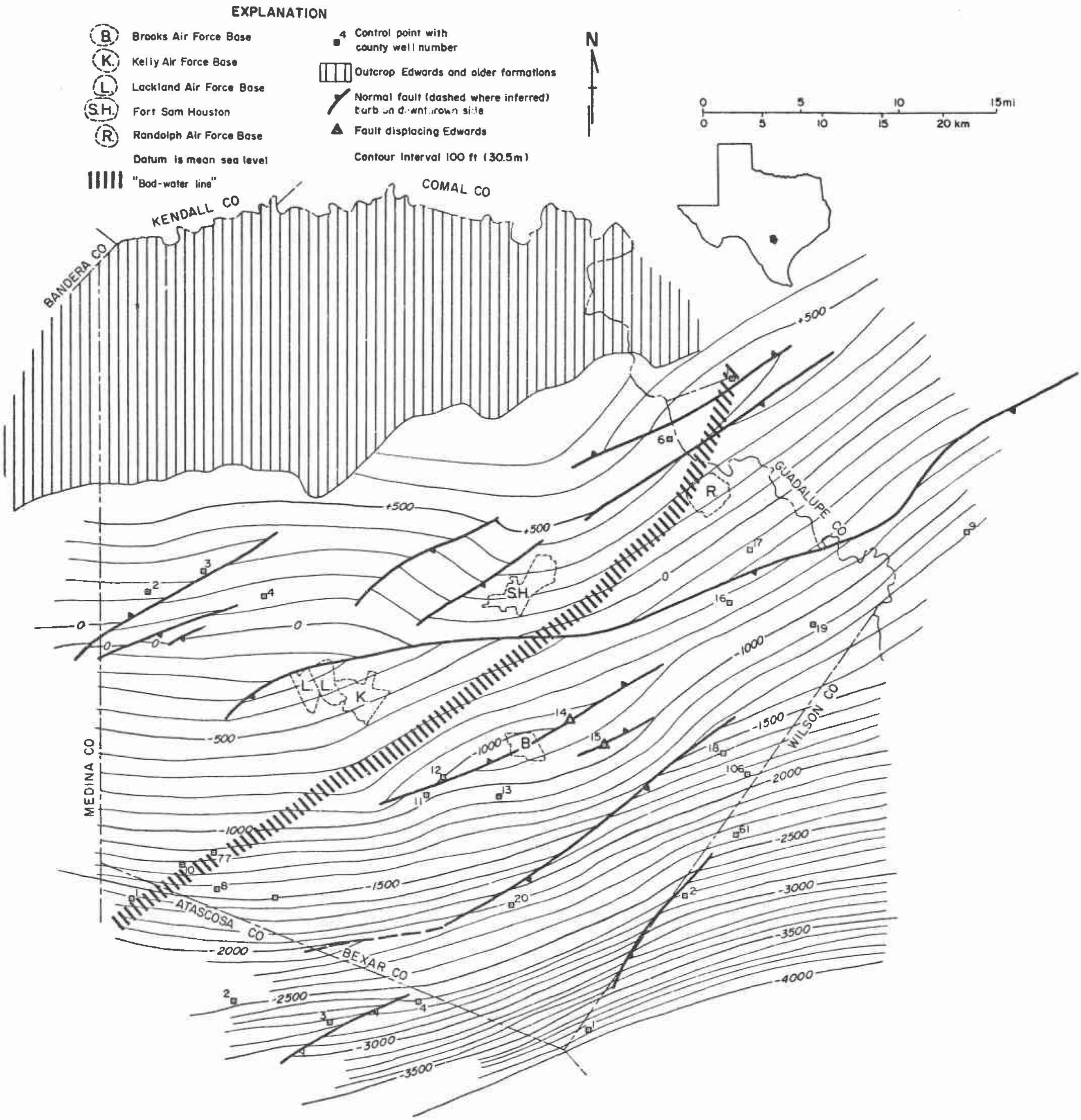

Figure H-4. "Bad-water line" of Edwards aquifer depicted on structural contours on top of the Edwards.

defined by the springs), adjacent to a vast saline-water system that fundamentally does not interact with the hydrology or chemistry of the fresh-water, underground "watersheds." In the analogy to surface water, the vast saline-water body would, of course, be the ocean.

The fact that the "bad-water line" is oblique to the structural contour lines projected on the top of the Edwards Limestone has important implications for the geothermal attributes along this line. In the areas where the springs impose a marked deflection of the "bad-water line" (where the line intersects the Edwards at a relatively shallow depth), the aquifer does not lie deep enough for there to be substantial increases in water temperature. Farther away from this "base-level" there is sufficient depth for elevated water temperatures, and along fault planes ground water may be warmer still owing to localized upward circulation along the faults. Such a situation exists near Brooks AFB, situated approximately 1,600 ft above the top of the Edwards, and located along the trace of one of the up-to-the-coast faults of the Luling Fault System. This area, then, is on the southern margin of the graben that delineates the alluvial plain on which downtown San Antonio is built.

Maps depicting the water attributes of the Edwards aquifer in the vicinity of the "bad-water line" show that only Brooks AFB lies in an area having geothermal promise from this limestone stratum (fig. H-5). Nearby wells exist at depths up to 2,215 ft and yield water temperatures of 104°F with salinities of more than 4,500 mg/l.

The influence of water as a conveyor of heat is illustrated by the computation of geothermal gradients based on ground-water temperatures. Even though some water temperatures (well 51, for example) near Randolph AFB are only mildly thermal (less than 85°F), their shallow depth results in a geothermal anomaly (a "gradient" of almost 2°F/100 ft). A similar anomaly occurs on the upthrown side

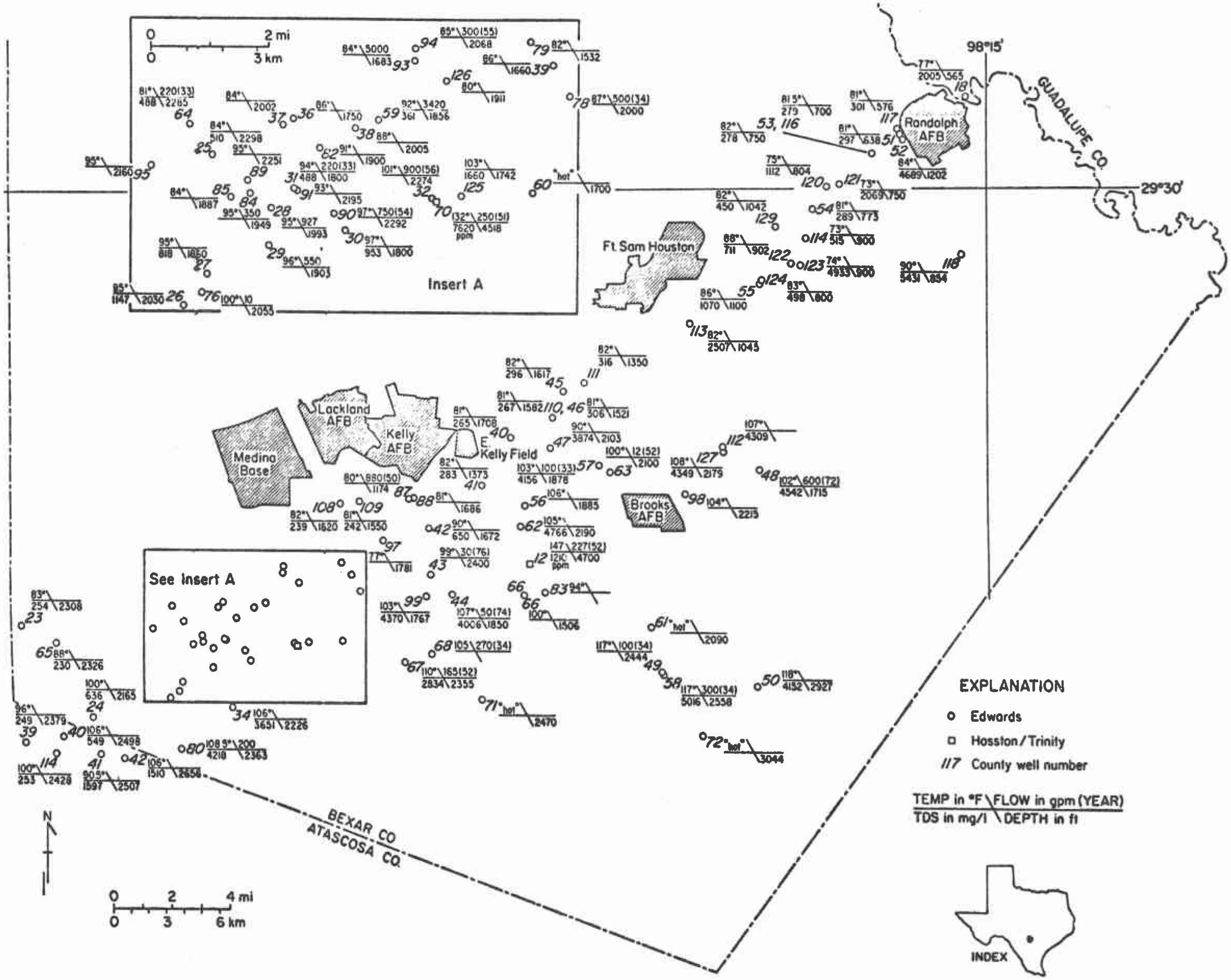

Figure H-5. Wells in Bexar County having elevated water temperatures.

of the fault beneath Brooks AFB. In both instances we are probably measuring the upward flow of warm water to an abnormally shallow depth, a phenomenon that does not necessarily indicate a more promising geothermal resource at greater depth. Comparison of geothermal gradients based on water temperatures to geothermal gradients based on deeper-seated earth temperatures using BHT values (fig. H-2) shows the magnitude and geographic distribution of these hydrologically induced "false anomalies."

In contrast, low thermal gradients in the fresh-water zone are due to rapid movement of cool recharging water into the subsurface (Garza, 1962). This hydrologic phenomenon results in an apparent depression of the region's thermal gradient, so that, if a correct value is to be recorded, wells must penetrate below any aquifer that is so readily influenced by surface temperatures.

Water Chemistry of the Edwards Aquifer

The chemical attributes of ground water in any geothermal aquifer are important for two reasons. The type and concentration of ions in solution may provide clues to the origin of the water, hence, to the heat content of the water. Also, chemical constituents commonly constrain use of geothermal waters because of problems with corrosion and scaling of materials with which the waters come in contact.

We compiled all available data on the chemistry of Edwards ground water in the vicinity of the "bad-water line." In addition, we conducted additional analyses for six previously unmeasured thermal wells. These two sets of analyses allowed us to evaluate the relations between the water chemistry and the thermal properties of the aquifer; these findings also led to refinements in the delineation of the "bad-water line." At minimum, our compiled chemical analyses include values for temperature, pH, and concentrations of sodium, calcium, magnesium, chloride, sulfate, and bicarbonate ions. Our own analyses contain these values plus values for potassium, lithium, strontium, fluoride, ammonia, nitrate, hydrogen sulfide, and silica.

We have used the computer program SOLMNEQ (Kharaka and Barnes, 1973) to evaluate all the available water analyses. SOLMNEQ calculates saturation indices for a variety of minerals as an aid to understanding the origin and controls of the chemical composition of water samples. These data allow us to determine whether the water from a given well is oversaturated with respect to a particular mineral, and thus we can predict whether the mineral is likely to precipitate. SOLMNEQ also calculates possible subsurface reservoir temperatures from the concentrations of silica or sodium, potassium, and calcium. Available analyses are also displayed graphically using Piper diagrams. On these diagrams each major cation or anion is plotted as a percentage of the total cations or anions expressed in milliequivalents per liter (figs. H-6, H-7, and H-8).

These chemical data show that the Edwards ground water comprises three geochemical suites: relatively fresh (generally less than 350 mg/l) Ca-Mg-HCO_3 water with temperatures less than 86°F; saline (up to approximately 5,000 mg/l) Na-Cl-SO_4 water with temperatures commonly greater than 100°F; and a transitional zone of intermediate composition, variable temperature, and TDS values ranging from 350 to 3,500 mg/l. Our work, although focusing on the generally higher temperature saline water, by necessity had to consider fresh waters in order to help define the distribution, characteristics, and origin of the warm waters. We have, then, mapped quality and temperature values throughout the study area to predict quality and temperature where data are sparse or unavailable.

The presence of the transitional zone is especially important in a geothermal context; in that area one may locally obtain Edwards ground water having temperatures up to 105°F and TDS values of less than 1,000 mg/l. This area may

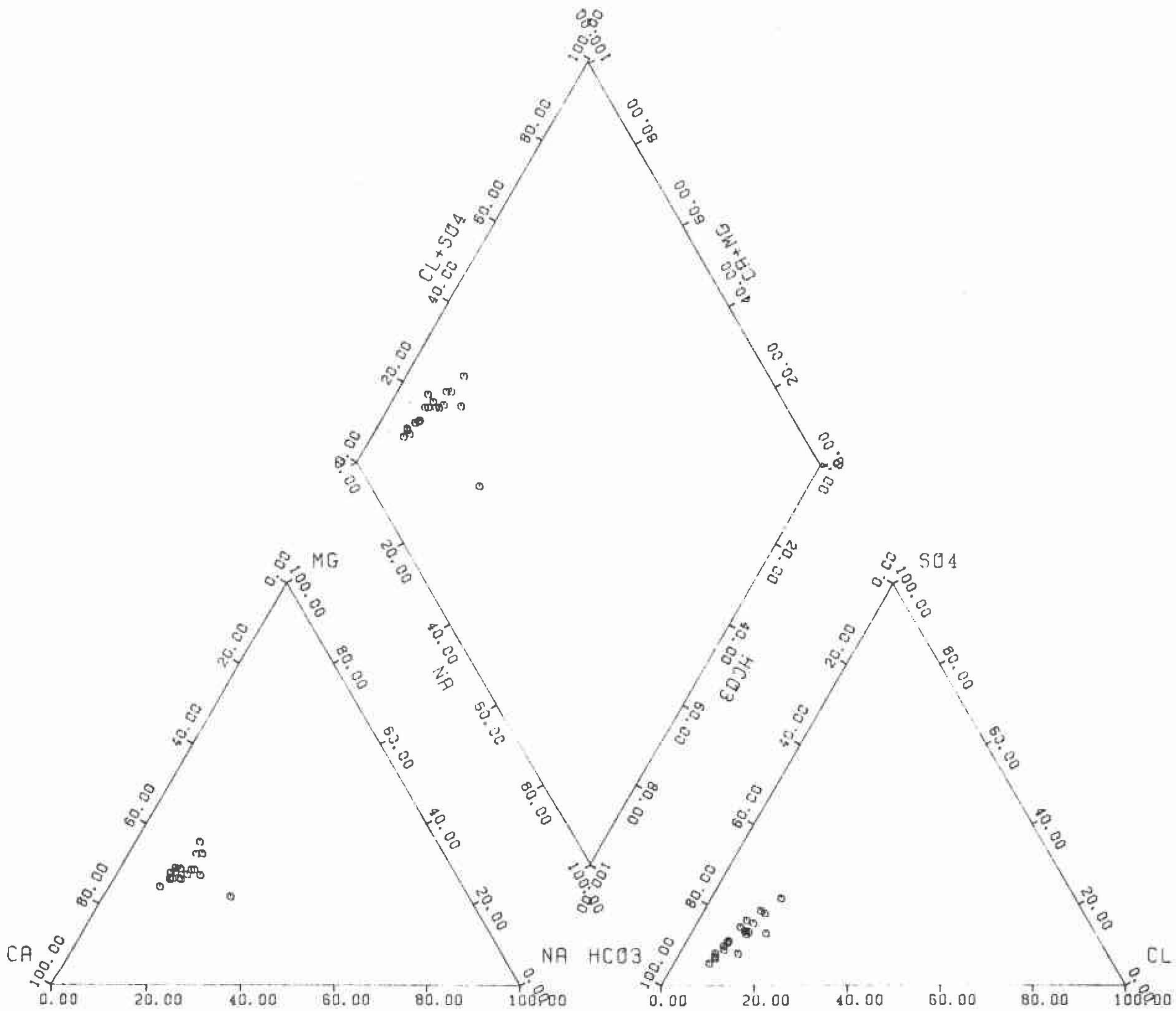

Figure H-6. Piper diagram for wells from the fresh-water zone, Bexar County.

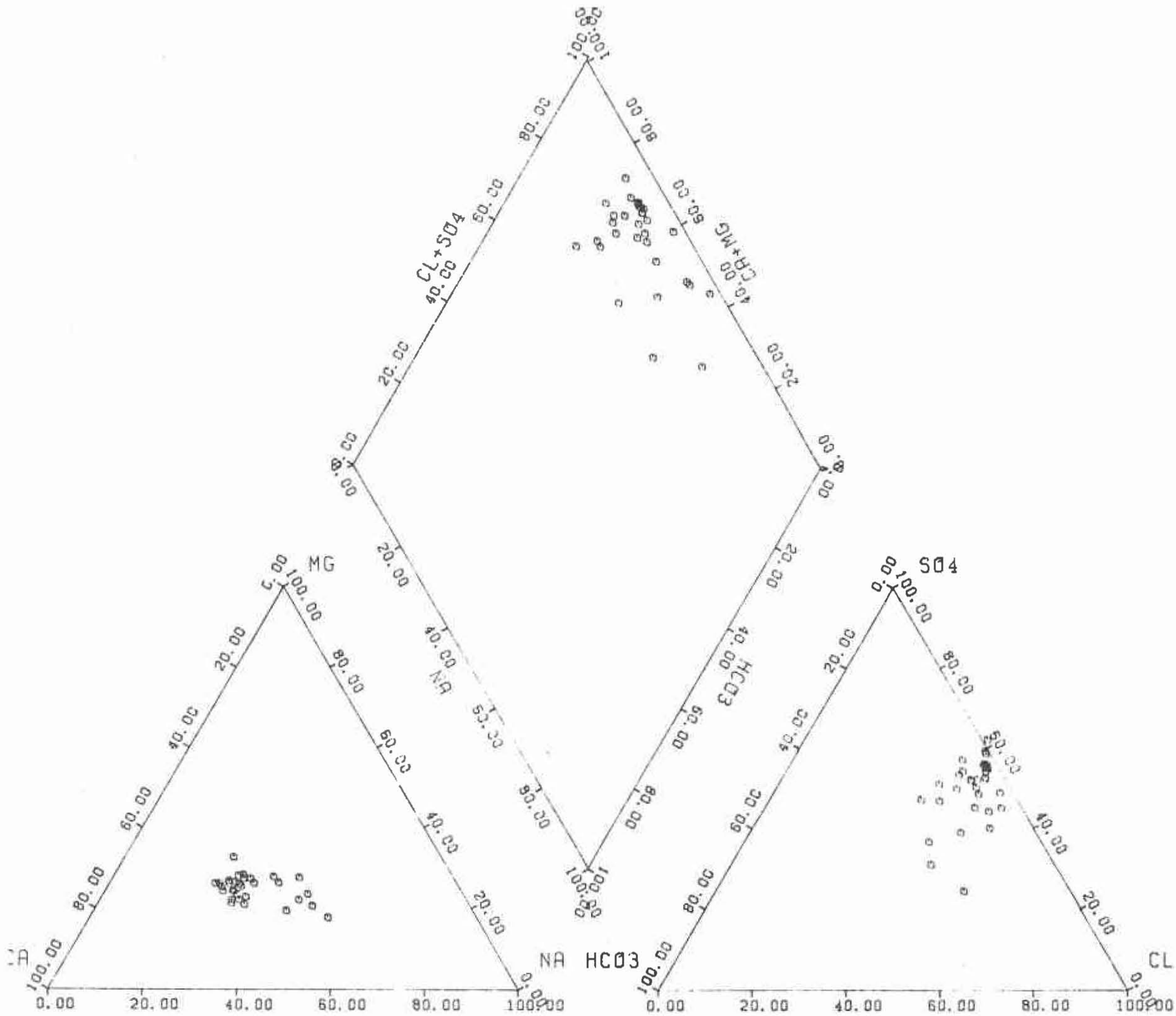

Figure H-7. Piper diagram for wells from the saline-water zone, Bexar County.

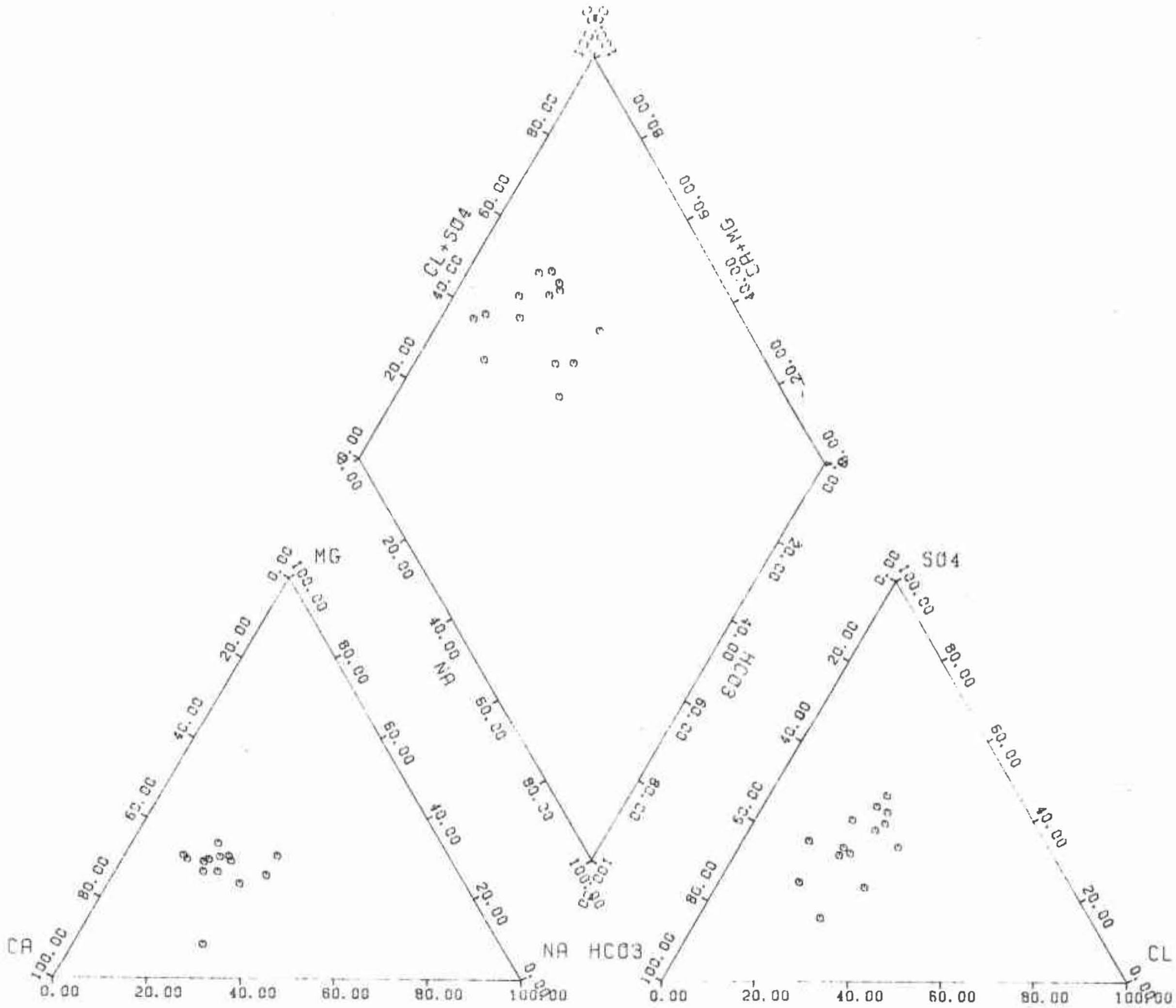

Figure H-8. Piper diagram for wells from the transitional zone, Bexar County.

have the highest promise for economic use of Edwards geothermal water; however, none of the military bases occur in this area.

In most places there is an abrupt contact between fresh and saline waters. Also, the change from fresh to saline water generally appears to occur along a vertical contact; adjacent wells of similar depth across the "bad-water line" commonly produce water with markedly different thermal and chemical attributes. This indicates that the Edwards Limestone is uniformly permeable throughout its thickness; that is, there is rapid intraformational hydrologic communication.

In the transitional zone, however, the boundary between fresh and saline waters is not fixed but has migrated with time. For example, the chemical composition of water in well 41 in Atascosa County (fig. H-5) changed dramatically from early 1957 to 1977. Total dissolved solids decreased from approximately 1,600 to 315 mg/l; the various dissolved components showed similar decreases. The change is probably related to the increase in hydraulic head in the fresh-water zone from drought times in the 1950's to more normal rainfall (and recharge) conditions later. During the drought, artesian pressure in the fresh-water part of the Edwards decreased, water levels in wells dropped, and saline water moved updip into parts of the Edwards that normally contained fresher water. When recharge increased in late 1957 the process reversed, and the saline water was pushed back coastward. Garza (1962) illustrated this process for several other wells near the "bad-water line."

Along with the abrupt increase in water temperature that generally characterizes the change from the fresh-water zone to saline water, there is also a gradual increase in temperature with increasing depth. However, some wells show locally discontinuous relations between depth and water temperatures. This may indicate the influence of faults, but faults may influence temperatures in essentially contrasting ways. Downward-flowing water along faults may result in anomalously low temperatures, whereas upwelling waters may be anomalously hot for a given depth. Because of these uncertainties and because of uneven distribution of data we did not contour temperature values, as a contour map implies a continuous set of variables. Instead we depicted individual temperature, depth, and salinity values for each water well within the saline-water zone of the Edwards as shown in figure H-5.

Geothermometry Applied to the Saline Waters of the Edwards

The Na/K/Ca geothermometer cannot be used to estimate maximum temperatures for the saline water zone of the Edwards Limestone for several reasons. The composition of the saline waters within the Edwards is clearly influenced by solution of evaporite minerals such as gypsum ($CaSO_4$) and possibly halite (NaCl); this alone negates the use of the Na/K/Ca geothermometer, because of the presence of sodium and calcium (and perhaps potassium) in a very soluble form. Moreover, the Na/K/Ca geothermometer assumes equilibrium with feldspars at the reservoir temperature, yet at the moderate temperatures involved, feldspar equilibrium is unlikely. A third, probably minor, problem is that the saline waters all precipitate calcite at the surface; calcium concentrations could be underestimated unless the samples are collected properly.

The silica geothermometer is probably more useful under the circumstances that we see in the vicinity of Bexar County. The greatest uncertainties in its use are whether or not equilibrium has occurred at the moderate temperatures of the saline-water zone, and if equilibrium has occurred, whether it is with quartz, chalcedony, or some other silica phase. We employed the SOLMNEQ program to compare temperatures to silica concentrations. Our comparisons (table H-1) show that almost all saline waters (and most transition and fresh waters) fall close to values predicted for chalcedony equilibrium, suggesting that the waters

Table H-1. Comparison of measured ground-water temperatures to computed (chalcedony) temperatures of selected wells, Bexar County.

Well	Measured Temperature (°F)	Chalcedony Temperature (°F)
18*	77.0	84.2
39	87.8	111.2
47	89.6	113.0
48	102.2	120.2
56	105.8	116.6
57	102.2	111.2
103	73.4	80.6
107	107.6	120.2
112	107.6	116.6
113	82.4	89.6
118	89.6	104.0
121	73.4	84.2
128	82.4	113.0

*Guadalupe County

are in equilibrium with chalcedony (a form of silica). Chalcedonic chert does occur in the Edwards in the saline-water zone, but because the chert formed in a previous environment, it may not be presently controlling silica concentrations in the saline water. Nevertheless, we assume that the saline waters are in equilibrium with chalcedony. If these waters actually are in equilibrium with chalcedony, our data imply that aquifer temperatures at depth are not significantly higher than measured temperatures of Edwards ground waters. The fact that both measured temperatures and those based on geothermometry agree is probably a good indication that these values represent subsurface thermal conditions. However, several analyses lie above the chalcedony equilibrium line, indicating that these waters are oversaturated with respect to chalcedony at the temperatures measured. The temperatures of these waters may be greater than their measured temperatures owing to cooling during slow rise of the waters or to some other reasons. To test this assumption we attempted to determine the discharge of the wells whose silica concentrations are farthest from a computed equilibrium. Wells with low discharge are more likely to have experienced significant cooling than are wells with high discharge. Unfortunately, only one well (no. 39, Bexar County) within this group is available for reexamination; the others are plugged or capped. Well 39 does have a very low flow rate, and thus, the water could have cooled significantly from depth. The temperature estimated from chalcedony equilibrium, 111.2°F, may be a better estimate of its true temperature at depth than its measured temperature of 87.8°F. A temperature of 111.2°F is slightly higher than that in most other wells in the same position relative to the "bad-water line."

Temperatures predicted from chalcedony equilibrium (table H-1) are mostly very close to the measured water temperatures. Where the measured and chalcedony temperatures differ, we tentatively conclude that the chalcedony temperatures are closer to the true reservoir temperatures; slight differences between the two temperatures are not significant, however, because small errors (1 to 2 mg/l) in estimation of the SiO_2 concentration can result in an uncertainty range of up to 9°F in the subsurface temperature estimate. Hence, the error in determining temperature from geothermometry is probably several degrees Celsius, so a discrepancy of a few degrees is not unreasonable.

Chemical Constraints on Use

Water with temperatures as high as 118°F can be obtained from the Edwards Limestone throughout much of southern Bexar County and into Atascosa County. These Edwards waters, however, have critical water quality problems, including higher than acceptable total dissolved solids and H_2S content, and potential scaling problems from precipitation of calcite or other minerals. An additional question not addressed here is the hydrologic effect of producing saline or transitional water. Overpumping may cause migration of the "bad-water line" and may thus adversely affect the water quality of fresh-water wells near the line.

The central part of the saline-water zone is not a favorable area for geothermal development, solely on the basis of water quality attributes. The temperature is sufficiently high, but total dissolved solids for all but one well range from 3,800 mg/l to 4,700 mg/l; the one well with lower total dissolved solids (well 67, Bexar County) contains 2,800 mg/l. The variation observed is probably not sufficiently great to favor one locality over another. Projected water quality from a geothermal production well at Brooks AFB could be expected to have these drawbacks.

All saline waters contain H_2S, with concentrations as high as 67 mg/l (Pearson and Rettman, 1976). Concentrations appear to increase with depth, although there are too few data to establish a clear trend. Also, the measured

H_2S concentrations may be lower than true concentrations because H_2S is volatile and difficult to preserve during sampling. For these reasons, it can only be said that H_2S is present in high concentrations in all saline waters. Hydrogen sulfide concentrations are an important factor in using the waters because of the corrosive effects of this gas, and also because of potential air quality problems associated with release of H_2S to the atmosphere. Moreover, Patton (1977) reported that H_2S and CO_2 can corrode more aggressively than H_2S alone. The saline waters all have very high CO_2 concentrations and the casings in most saline-water wells that we observed are highly corroded.

Precipitation of calcite should be the major source of scale for wells in the saline-water zone. As mentioned, calcite solubility increases with an increase in pCO_2, so that calcite precipitates when previously confined ground waters suddenly decrease in pressure. That this does happen with saline waters in the Edwards Limestone is shown by the chemical analyses and by the presence of abundant calcite precipitate around many saline-water wells we examined. Values of pCO_2 (in atmospheres) in saline waters calculated by SOLMNEQ range from 0.01 to 0.095. Atmospheric pCO_2 is 0.00032. The saline waters can maintain such high concentrations of CO_2 in the subsurface because of the pressure of overlying water. When these waters reach the surface, they rapidly lose CO_2 and precipitate calcite.

Most fresh ground waters in the San Antonio area also have pCO_2 values greater than the atmospheric concentration. However, the values are considerably less than those found in the saline waters, and Ca^{+2} concentrations are also lower. For these reasons, calcite is less likely to precipitate from fresh water than from saline water.

Other potential scale minerals are silica, gypsum, and iron compounds. Although the saline waters are only slightly undersaturated with respect to gypsum, the solubility of gypsum does not vary significantly between about 32°F and 140°F. Thus, cooling any of the saline waters to ambient air temperatures should not cause significant precipitation of gypsum. The importance of precipitation of iron compounds, on the other hand, is difficult to assess. Because the saline waters have high H_2S concentrations, iron concentrations should be extremely low; however, many saline waters reported by Pearson and Rettman (1976) contain low but measurable Fe^{+2} concentrations and are extremely oversaturated with respect to FeS_2 (pyrite). Some wells in the saline-water zone produce "black" water (Pettit and George, 1956) probably containing suspended iron sulfide. Also, corrosion of metal pipes by the saline waters could release additional iron to precipitate iron sulfides.

Chemical constraints on the use of transition-zone water should not be as critical as for saline-zone water. By definition, dissolved solids in the transition zone range from 350 to 3,500 mg/l, and in the favorable area of southwestern Bexar County, they are commonly about 500 to 600 mg/l. Disposal of this water should not be a problem because the water can be used for many other purposes. Most transition-zone waters contain H_2S, and some concentrations are as high as those found in the saline waters; thus, H_2S may be the greatest chemical constraint on use of the transition-zone waters. Precipitation of calcite should be a relatively minor problem, because pCO_2 and Ca^{+2} concentrations are much lower than in saline-zone waters. Precipitation of iron sulfide minerals could occur, but gypsum and silica precipitation should not be a problem either in the transitional-water zone or in the area having saline water.

Hosston Sand

Our stratigraphic control for the Hosston Sand consists of 24 wells in Bexar County and adjacent areas. Seventeen wells penetrate the entire Hosston thickness; these provide data for mapping the total thickness of the formation. These data adequately depict subsurface bedrock attributes; there are only two water wells, however, for which thermal data are available for the Hosston Sand aquifer. The disparity between our lithic data base and our water data base is due to the aforementioned dual purpose of the wells. Wells that provide stratigraphic and structural data are all petroleum exploration tests that have been drilled to a much deeper target horizon than the Hosston. Because of the presence of a shallow, dependable water supply in the Edwards aquifer, there has been no need to complete water wells into the Hosston.

The Hosston Sand is the basal Cretaceous rock unit in Central Texas. This means that in most places along the inner (landward) margin of the Balcones/Ouachita hinge zone, the Hosston comprises strata deposited directly on Ouachita "basement" rocks. In its updip, shallow reaches, the Hosston consists of ancient riverine and deltaic deposits, but across the hinge, a change in environment occurred, probably in response to continued adjustments (downwarping) of the underlying Ouachita complex. These adjustments resulted in marine conditions prevailing during Hosston time in southern Bexar County. The change from riverine to marine deposition has affected the aquifer properties because river deposits have dip-oriented sand trends (that is, the predominant trend is eastward into the Gulf Coast Basin). This allows ground water to migrate downward deep into the aquifer through the ancient river channel complexes and, in this way, to maintain relatively fresh water even at depths where geothermal effects are evident. Marine sands, on the other hand, are generally "strike-fed," that is, are parallel to the ancient shoreline, and thus have no avenues that allow easy transfer of ground water downdip. Moreover, marine sands commonly contain residues of their sea-water origin; the salinities of their ground waters are commonly higher than those of the river-deposited strata even within the same aquifer.

The sand geometries that indicate dip-oriented and strike-oriented parts of the Hosston are shown on a map of net sand thicknesses (fig. H-9). This map shows an evident dip-oriented sand trend, possibly an ancient channel course, that terminates in an area of thick sands directly beneath Lackland and Kelly Air Force Bases. The ancient strandline apparently curved inland from this sand-rich salient, which perhaps represents an ancient fan delta. From there the ancient strand apparently curved northward along the relatively thin sand areas beneath Brooks AFB and Fort Sam Houston. The moderately thick sand body beneath Randolph AFB probably represents marine barrier bars; their orientations are parallel to the ancient strand, which aligns with the strike of the Balcones/Ouachita trend in that area.

The overall geometry of the Hosston shows a thickening from north to south, as well as an abrupt increase in formation thickness along a line that runs roughly from Lackland AFB through Brooks AFB (fig. H-10). There, the formation increases from 400 ft thick to locally more than 500 ft thick. Elsewhere, near Randolph AFB and Fort Sam Houston, the Hosston is approximately 300 ft thick.

The structural contours on the top of the Hosston show that this datum ranges from as shallow as 1,600 ft below msl (a depth of 2,361 ft) below Randolph AFB to approximately 3,300 ft below msl (3,900 ft depth) below Brooks AFB (fig. H-11). With the Hosston formational thicknesses mapped as almost 300 ft beneath Randolph AFB and more than 500 ft beneath Lackland AFB, the equilibrated down-hole temperatures for the middle part of the Hosston should range from at least 94°F at Randolph AFB to more than 110°F beneath Brooks AFB, given prevailing geothermal gradients (1.5°F/100 ft). These values, however, do not necessarily indicate what the <u>actual</u> water temperatures will be at a given

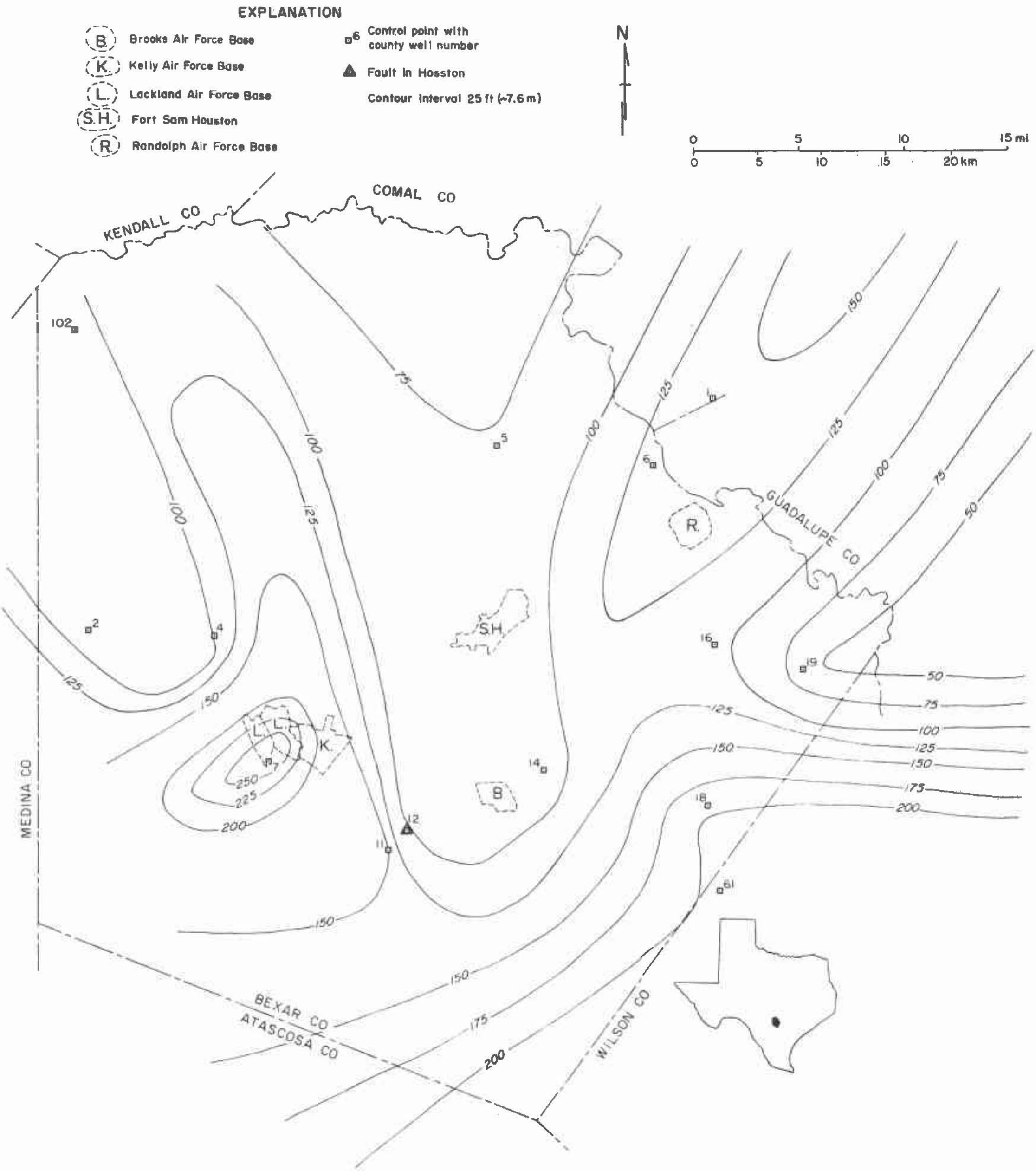

Figure H-9. Net sand geometry of the Hosston aquifer, Bexar County.

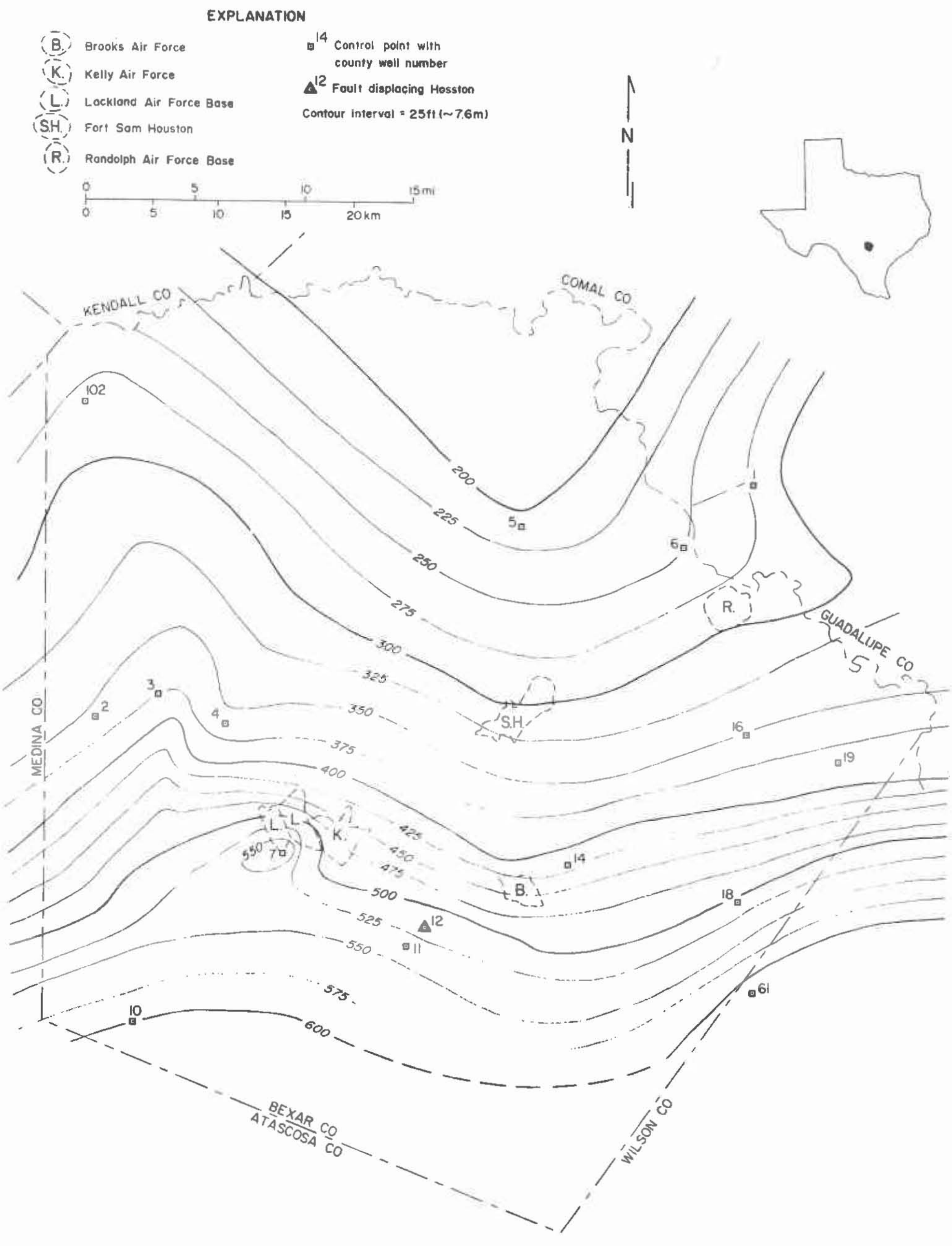

Figure H-10. Total formation thickness of the Hosston Sand, Bexar County.

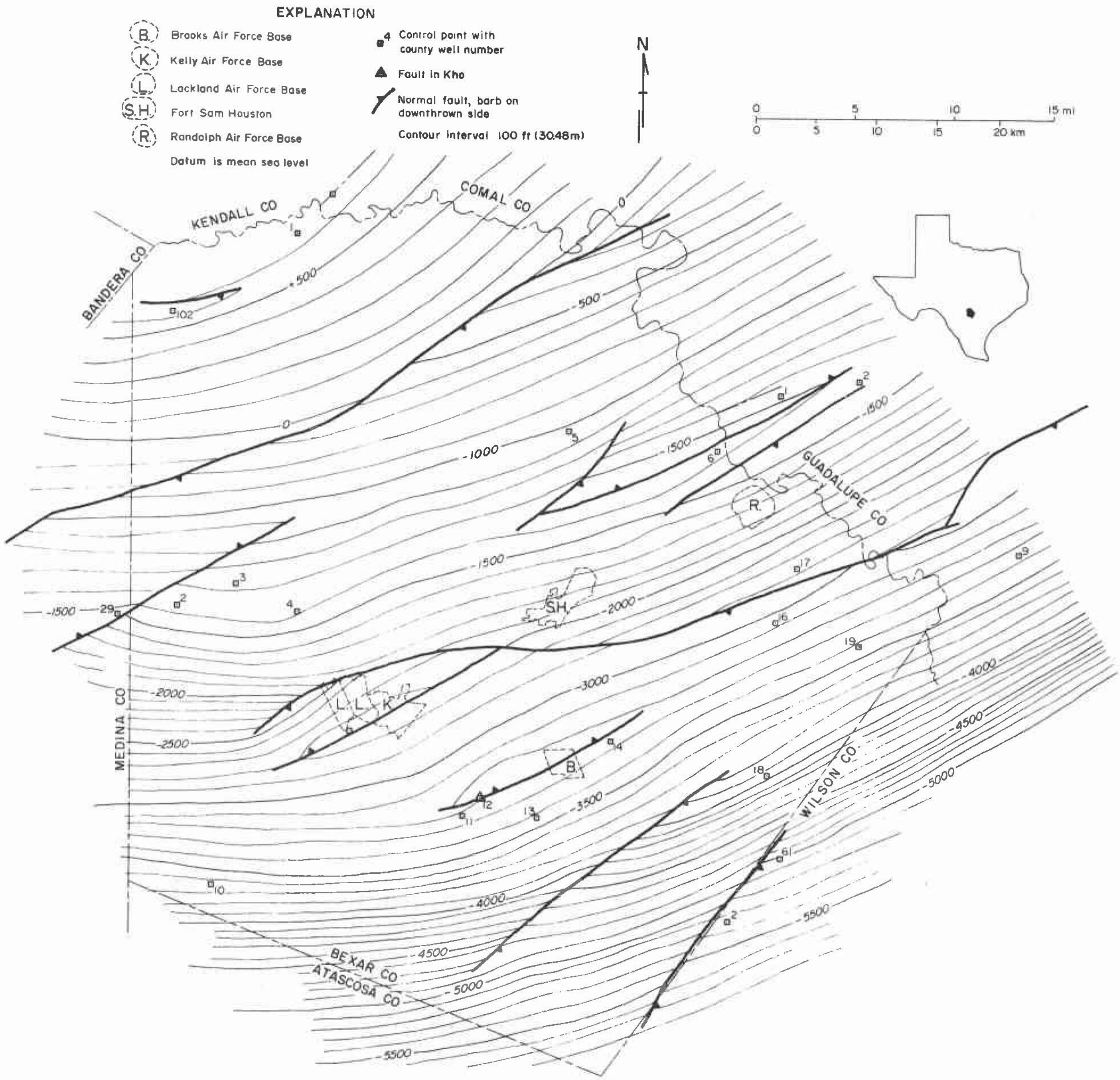

Figure H-11. Structural Contour Map on the Top of the Hosston Sand, Bexar County.

location, because of the local enhancement (or lessening) of geothermal potential owing to upward or downward movement of ground water. Well no. 12 in Bexar County, which lies along the fault that crosses beneath Brooks AFB, has a water temperature of 147°F, compared to a BHT of 144°F. This indicates that, at this locality, either the BHT does not represent an equilibrium temperature, or upwelling ground water has caused additional caloric value beyond what would be expected on the basis of geothermal gradient alone.

The localized graben that underlies Lackland AFB and Kelly AFB is especially noteworthy because the bounding faults are also shown by Flawn and others (1961) to affect the Ouachita "basement." There, an anomalously thick section of strata occurs within this downfaulted block, which means a greater aquifer section there than beneath other bases. It is probable that this faulting was contemporaneous with Hosston deposition, hence the dip-fed sands that terminate there may represent an alluvial fan system or fan-delta complexes similar to deposition presently occurring in Mexico along the structurally active Gulf of California.

Water Attributes of the Hosston

As mentioned previously, there are only two wells that have provided analyses of thermal ground water from the Hosston Sand in Bexar County (fig. H-5). These two data points provide markedly different readings, especially pertaining to water quality, and this makes extrapolation of these data difficult. Well no. 12 produced Hosston ground water from a depth of 4,700 ft with a temperature of 147°F and a TDS value of only 1,210, whereas well no. 70 produced from 4,518 ft with a temperature of 132°F and a TDS of 2,620. All five military bases are updip from these wells, thus the temperatures will be somewhat less, but the expected TDS values should also be lower. Given proper well completion procedures, and with special attention to isolating the water-producing sands from waters of the overlying Glen Rose Limestone (typically a saline water producer), we expect TDS values below 2,000 mg/l.

The projected water attributes within the graben beneath Lackland and Kelly Air Force Bases are especially difficult to project, because sand geometry and thickness within the graben have both positive and negative attributes. The increased sand thickness, which is presumed to be dip-fed, should be a locus of dependable (relatively high yield) ground-water supply having moderate to low salinity concentrations, all owing to the influence of recharging waters. However, the narrow, fault-bound basin may prevent adequate circulation of waters, and while this may maximize temperature values, salinities may also increase unacceptably.

These two Hosston water wells provide no data on sustainable well yield. Thus, a prime priority in developing this resource is the testing of the aquifer for its hydrologic performance.

Geothermal Prospectus--Bexar County

Geologic and hydrologic data show that the Hosston Sand constitutes the most promising target for providing geothermal waters for space heat and hot water at the military bases in Bexar County. There are, however, several unknown aspects of this resource, owing mainly to paucity of data on ground-water conditions (well yield and water quality) for the Hosston in its deep reaches. Therefore, developers of this resource should proceed cautiously. Existing data warrant drilling of exploratory wells, but at each stage of drilling, careful analysis of on-site geologic and hydrologic conditions should be conducted before proceeding to the next level of development (and expense).

The Hosston Sand lies deep enough beneath all five military installations to yield at least moderately thermal waters. Projected water temperatures beneath the various bases, assuming normal geothermal gradients, range from the low-90°F range to approximately 110°F. These temperature values, however, are probably lower than the actual ground-water temperatures because of thermal enhancement of upward-flowing ground water, especially along faults. This is markedly shown by one of our two Hosston ground-water data points (well no. 12), which has a bottom-hole temperature of 144°F, whereas it produced Hosston water recorded at 147°F. This well is cut by a fault, and thus there is a ready avenue for upwelling waters.

Given the combination of depth, sand thickness, and proximity to dip-oriented (ancient riverine?) sand trends, the area having highest geothermal potential in Bexar County is near Lackland and Kelly Air Force Bases. Brooks AFB probably would produce Hosston ground water having the highest temperature, but relatively thin, strike-oriented sands impose the possibility of diminished aquifer yield and perhaps problems with elevated concentrations of dissolved solids.

Fort Sam Houston and Randolph AFB both have only a moderate to low geothermal potential on the basis of depth and sand thickness relations. Of the two facilities, Fort Sam Houston warrants further consideration because of the greater depth to the top of the Hosston Sand and the higher formational thickness there as compared to Randolph.

The Edwards "bad-water zone" is probably not a viable geothermal resource because of adverse water-quality attributes. Only Brooks AFB would have water temperatures sufficiently high to be a prospective resource, but the TDS level, dissolved H_2S, and probable oversaturation with respect to calcite ensure continual problems with corrosion and scale.

Farther updip, north of the "bad-water line" where most facilities occur, temperatures are only slightly thermal (81°F near Kelly AFB, 84°F at Randolph AFB). Fort Sam Houston, which lies above the part of the Edwards having "normal" (nonthermal) temperatures, has water temperatures of about 77°F. This presents the possibility of obtaining a different sort of thermal energy from ground water. This method is the ground-water heat pump, which works on principles similar to central heating/cooling units that employ air heat pumps. In this way, the moderate temperature and thermal stability of the potable, artesian Edwards ground water might be used to reduce energy demands for heating during the winter and air conditioning during the summer. The assessment of local water resources to meet this demand is beyond the scope of this report, but the quantity of water should be adequate, and the water temperature should be in the mid-70°F range. Geothermal water appears to be a viable resource in selected areas.

TRAVIS COUNTY

General

As in Bexar County, the Balcones Fault Zone is a dominant aspect of the geologic setting of Travis County. The deep-seated structural dislocations of Ouachita basement rocks have affected surface faulting, emplacement of an ancient volcano (Pilot Knob), and evolution of the landscape resulting in a sharp break between the Hill Country and the innermost Gulf Coastal Plain along the main fault line.

There have also been hydrologic responses to the structural dislocations, similar to those in Bexar County. Barton Springs is a local discharge point for the Edwards aquifer, and the fresh-water and saline-water parts of the Edwards converge near the springs. However, unlike in Bexar County, there has been little testing of the Edwards saline waters in Travis County; hence there are no data indicating a thermal resource for these waters in the Austin area.

Historically, the Colorado River has provided Austin with a dependable water supply. However, local downtown institutions, for example, the Driskill Hotel, the Southern Pacific Railroad, and the State Capitol, have drilled deep wells for water supplies totally independent of the city's water distribution system. These wells generally penetrated the Hosston Sand and, commonly, thermal ground water was produced. As it happens, the Hosston constitutes the major potential geothermal resource for which there are data in Travis County. Our well control for this horizon is somewhat more complete in Travis County than in Bexar County, and these data indicate that the resource has only a moderate potential because of relatively low temperatures of Hosston ground water.

Data Base

The well control for assessing the structural and stratigraphic conditions of the Hosston Sand in the vicinity of Travis County consists of 36 data points. These include shallow wells where this stratum is tapped as a water resource near Lake Travis and elsewhere in the Hill Country. Most of our interpretations there are based on analyses of drillers' logs (that is, the description of cuttings--rock fragments--obtained while the well was being drilled). These descriptions are commonly in nontechnical parlance and require considerable translation for geologic application. Farther downdip (east of the main fault line that bisects the county), our data consist primarily of electric logs, although for some of the old water wells we again have only drillers' logs. Water data of use to this project are considerably more limited than are stratigraphic data. From the Hosston 11 wells produce thermal waters; one well also produces marginally thermal waters from the Glen Rose Limestone, which is about halfway between the Edwards above and the Hosston below.

Findings

Hosston Sand

The Hosston Sand is a continuation of the basal Cretaceous stratum lying directly on Ouachita basement rocks. As in Bexar County, the hinge zone related to subsidence of the Ouachita complex resulted in an abrupt change in geometry, composition, and thickness of overlying strata. In western Travis County these basal sand deposits crop out at the land surface; there the formation is called the Sycamore Sand. It represents ancient riverine, lagoonal, and strandline environments; these deposits suggest that rivers debouched from a highland area (the Llano Uplift) into a shallow sea. The Hosston Sand persisted throughout a vast amount of time, during which environmental conditions probably changed from marine to riverine and back again several times; but east of the Balcones/ Ouachita hinge line, marine conditions probably prevailed.

Our sand-thickness values, based on various types of data, are too inconsistent for us to construct a representative net-sand map for Travis County. An overall change occurs regionally (Woodruff and McBride, 1979), from predominantly dip-oriented sands to strike-dominated trends, reflecting a change from terrestrial to marine conditions.

The structural configuration of the Hosston largely follows that of the Ouachita complex, both of which show a markedly increased coastward dip east of the main fault line (fig. H-12). In the vicinity of Bergstrom AFB, the Hosston top is at a depth of 2,350 ft. Comparison of these data with the basement map (fig. H-13) indicates a net formational thickness of the Hosston there of approximately 900 ft.

Structural dislocations are evident in the vicinity of Bergstrom AFB. A down-to-the-coast fault extends onto the air base but does not completely

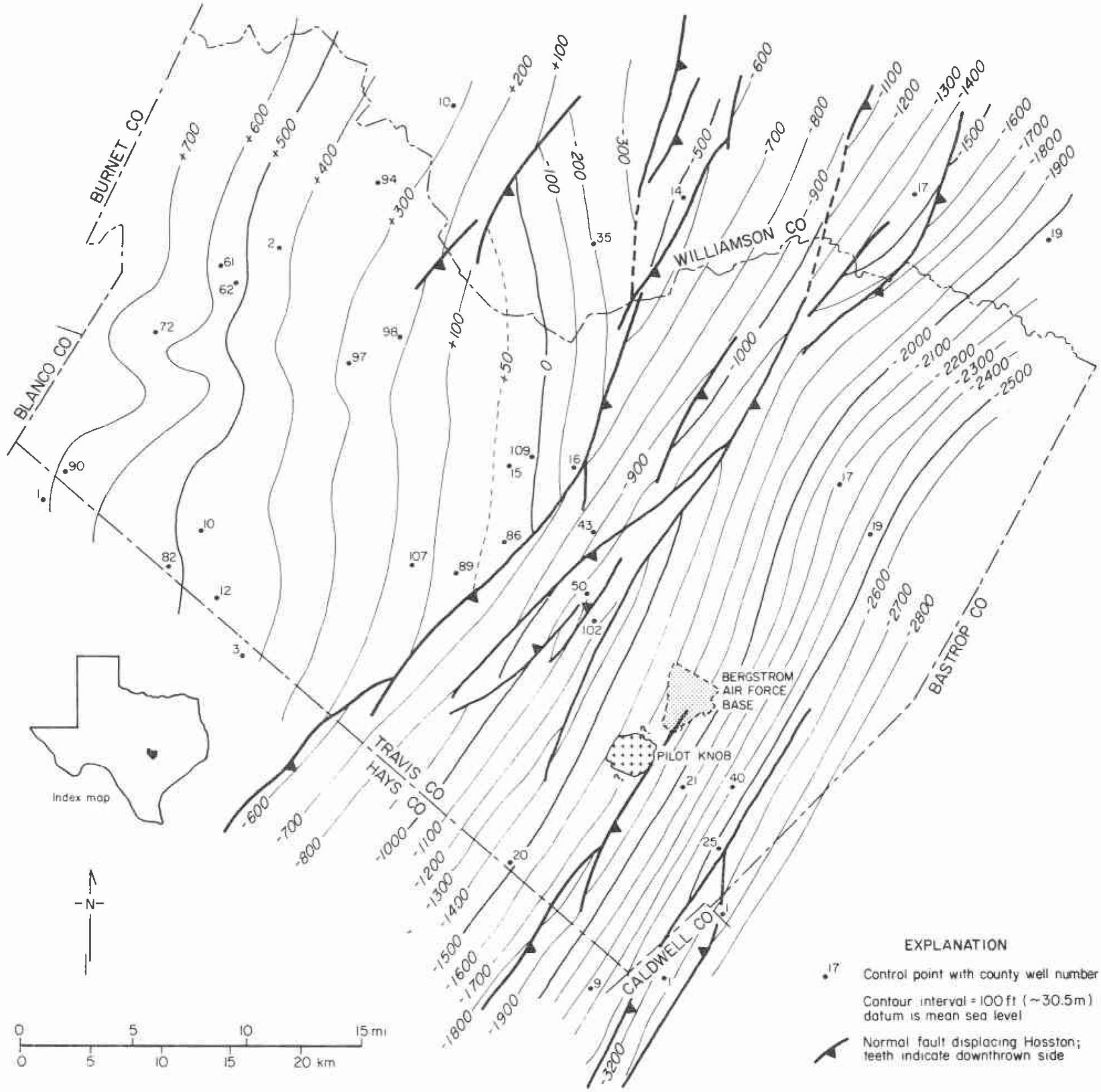

Figure H-12. Structural Contour Map on the Top of the Hosston Sand, Travis County.

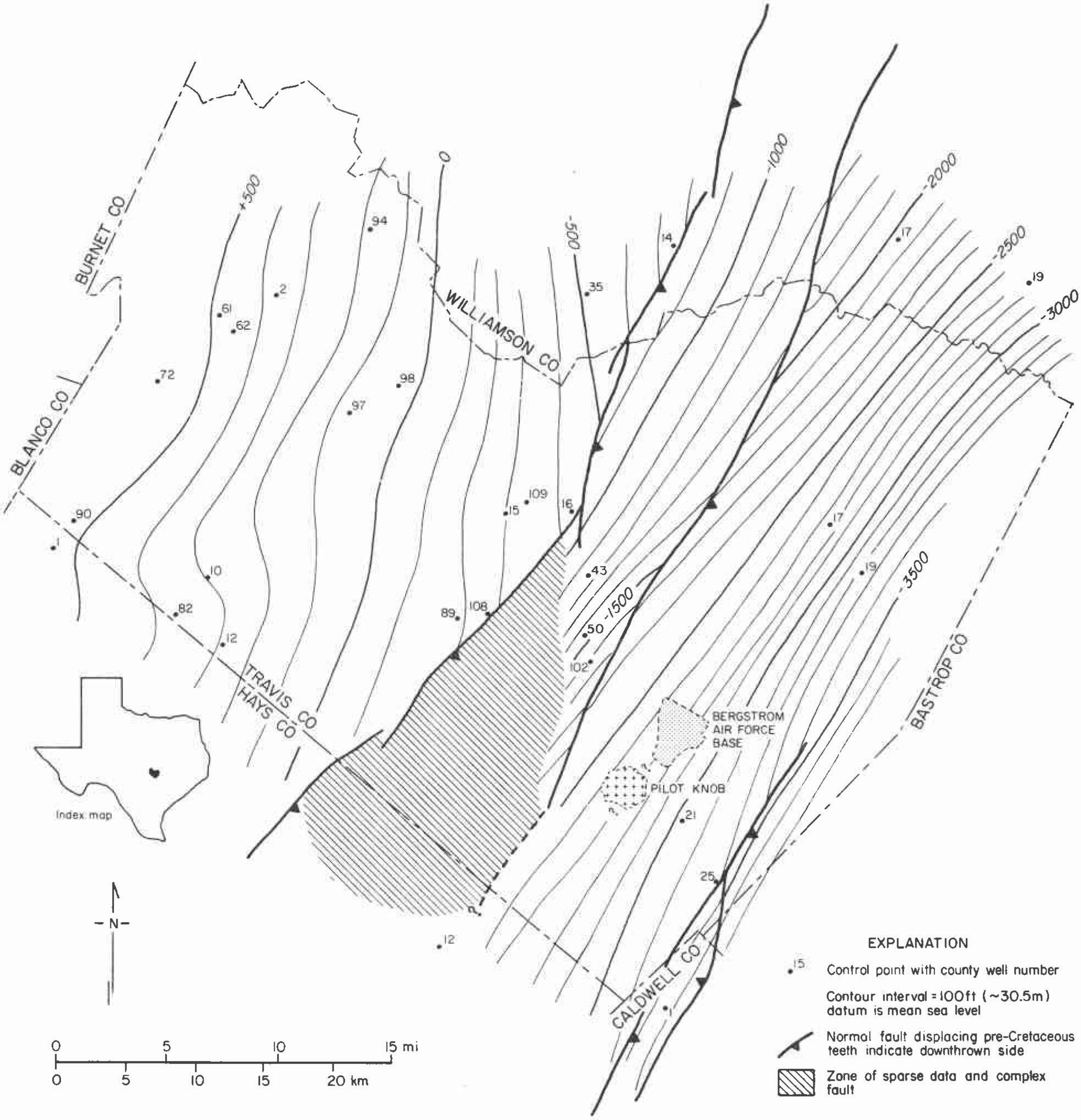

Figure H-13. Structural Contour Map on the Top of the Paleozoic (Ouachita) Basement Complex, Travis County.

transect it. In addition, Pilot Knob, an extinct volcanic plug, is only a few miles southeast of the base. The volcanic neck, emplaced during Late Cretaceous time, definitely caused more structural dislocations than are shown in figure H-12, but well control is not sufficient to show these additional faults. Faults associated with Pilot Knob might enhance the possibility of there being upward-flowing (thermal) ground waters. Elsewhere in Central Texas, buried igneous plugs have been the structural control for oil accumulation, which too is a phenomenon of upward migration of deep-seated fluids.

Water Attributes of the Hosston

Regional geothermal-gradient analysis shows an anomaly of up to 2°F/100 ft in eastern Travis County. On the basis of these data, one might expect water temperatures of approximately 120°F from the middle part of the Hosston (a depth of 2,220 ft) beneath Bergstrom AFB. Nearby water data, however, do not confirm this. A well adjacent to Pilot Knob (no. 56) drilled to a depth of 2,245 ft produces Hosston water at only 94°F (fig. H-14). However, this anomalously low temperature may be a result of the slow rate of artesian flow (the water seeps very slowly from the well at the ground surface, and we could lower a downhole temperature-measuring device only to a depth of 60 ft).

The Pilot Knob well has a TDS content of 2,202 mg/l. This analysis does not contain a value for H_2S, but during our field examination of this well we detected a faint odor of that gas. However, a relatively high nitrate concentration and a high pH probably indicates a moderate to low H_2S content, and thus only a slight problem with corrosion. Chemical analyses also indicate an apparent undersaturation with respect to minerals that generally precipitate scale; this fact indicates that scaling, like corrosion, will not be a major problem. In short, the geochemistry of this Hosston ground water indicates that

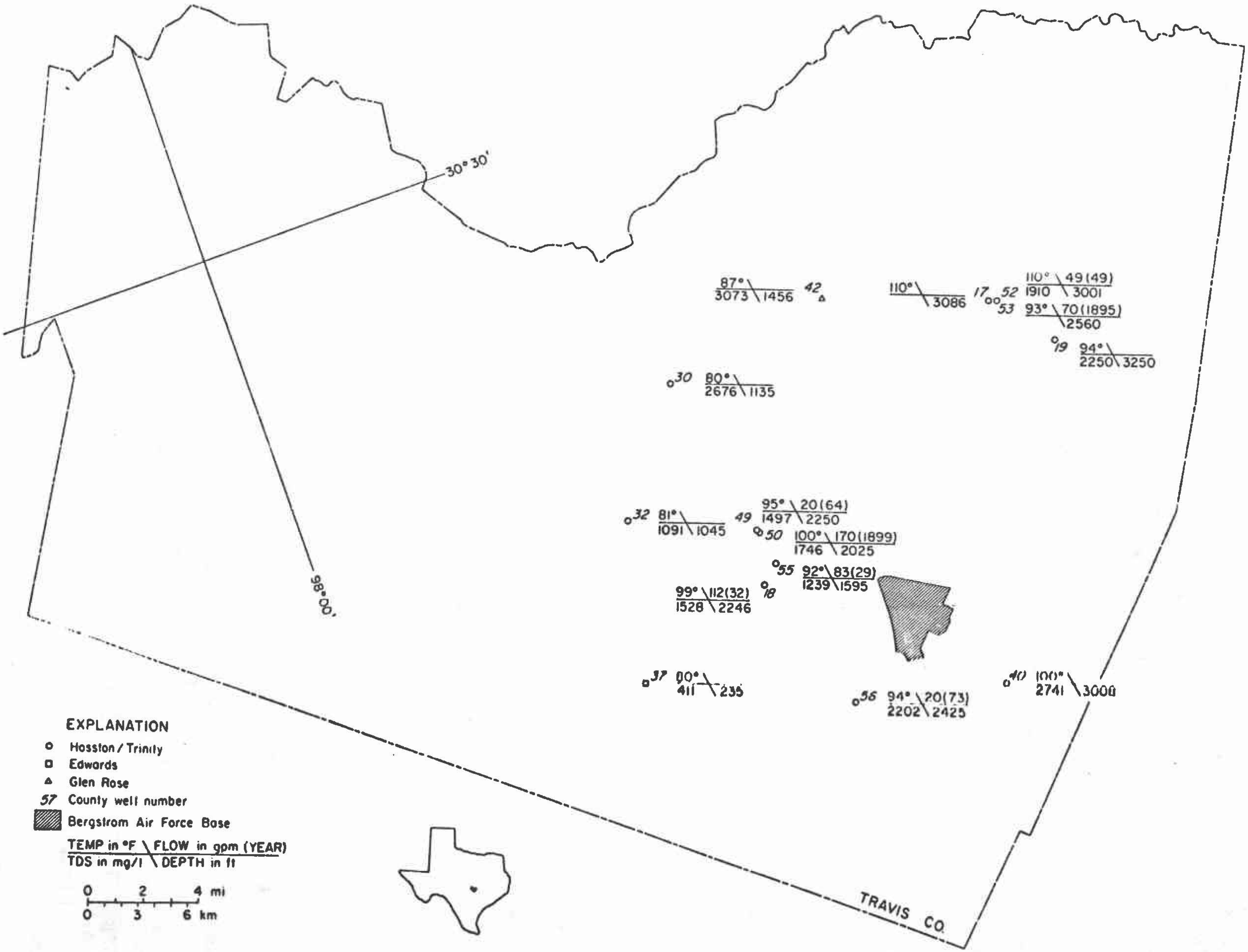

Figure H-14. Wells in Travis County having elevated water temperatures.

no major technical problems would be encountered in the use of the water. Moreover, the water flows under artesian pressure (at 20 gallons per minute or gpm); although there is no measurement of sustainable yield for that well, the expected transmissivity value for the Hosston in Travis County falls within the modest range of from 1,000 to 5,000 gallons per day per foot. Given these data, and the thickness of sand fraction of the aquifer near Bergstrom AFB, an estimate of safe, sustainable well yield is approximately 300 gpm. This estimate, however, is not founded on a recent pump test of the Pilot Knob well. If development of the resource is seriously considered, such a performance test should be conducted to refine this estimate.

Geothermal Prospectus--Travis County

The Hosston Sand in the Austin area constitutes a modest geothermal resource. The temperature of the well closest to Bergstrom AFB is probably somewhat cooler than may be expected, if we assume proper development of subsequent wells. This is corroborated by the shallower Hosston wells farther east that have higher water temperatures at shallower depths (see, for example, wells no. 18 and 50, fig. H-14). Even given the moderate temperature of the Pilot Knob well (no. 56) it may produce up to 4.1 x 10^8 Btu's during January. This value is computed on the basis of temperature differences between the well water and the mean minimum January temperature in Austin, given the artesian flow recorded in 1973 at 20 gpm.

VAL VERDE AND KINNEY COUNTIES

General Overview

The part of Val Verde County of interest to this study is the Del Rio vicinity near the Val Verde - Kinney County line. This area lies near the southwestern terminus of the Balcones Fault Zone, and it occurs near the head of the Rio Grande Embayment. The landscape near Del Rio and Laughlin AFB reflects changes similar to those in Bexar County; there is an abrupt change from locally dissected limestone terrane to a more gently sloping alluvial plain formed within the Rio Grande Embayment.

The limestone strata that underlie the uplands west and north of Laughlin AFB are mostly extensions of the Edwards Limestone. In the immediate vicinity of Laughlin AFB, the Edwards lies at depths of approximately 1,200 ft, and water is produced having temperatures in the 80°F-range, with TDS values in excess of 2,000 mg/l (fig. H-15). The "bad-water line" of the Edwards aquifer extends into Val Verde County, and Laughlin AFB lies slightly on the saline-water side of this line.

Data on the Edwards Limestone constitute the entire set of ground-water data that may be used to project the location and attributes of geothermal resources near Del Rio. These data show no particular promise for this type of resource, _if_ the Edwards is the only horizon considered. However, notwithstanding an absence of water data from deeper strata, there is a potential geothermal resource at a somewhat greater depth. This is the basal Cretaceous sand stratum --the southwestern equivalent of the Hosston Sand.

These "basal sands" lie at depths as great as 3,000 ft below Laughlin AFB, but depth varies markedly in only a short distance owing to the steep dip of underlying Paleozoic strata (fig. H-16). Log response of this sand appears favorable--a good "blocky" spontaneous potential deflection, and not too great a resistivity deflection. Thus, the basal sand unit may contain ample amounts of low-TDS water.

The deep-seated structural discontinuities are a complex variable that one must assay in correctly evaluating this resource. Not only does the Balcones Fault Zone converge with the Rio Grande Embayment, but also this area has an

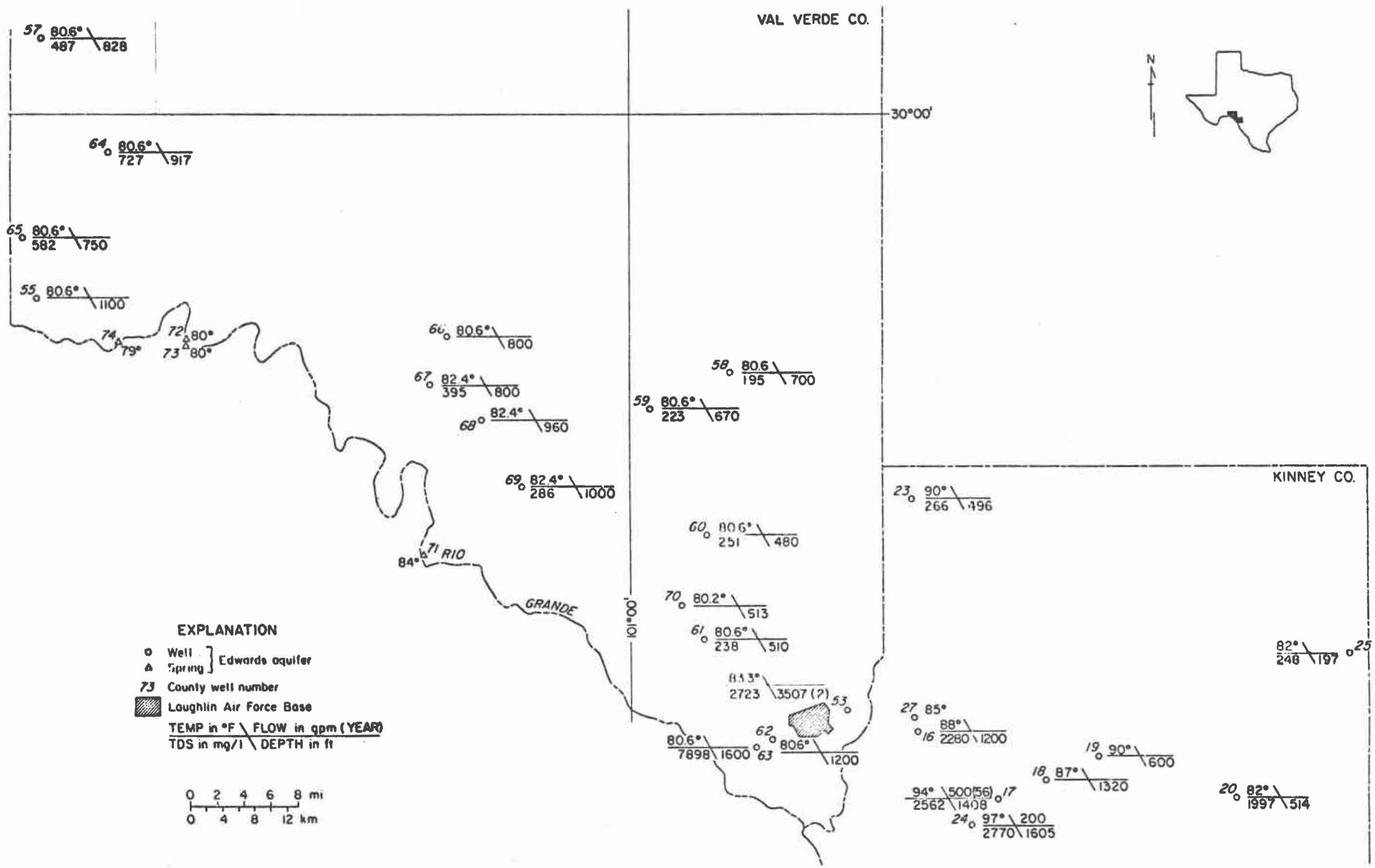

Figure H-15. Wells in Val Verde and Kinney Counties having elevated water temperatures.

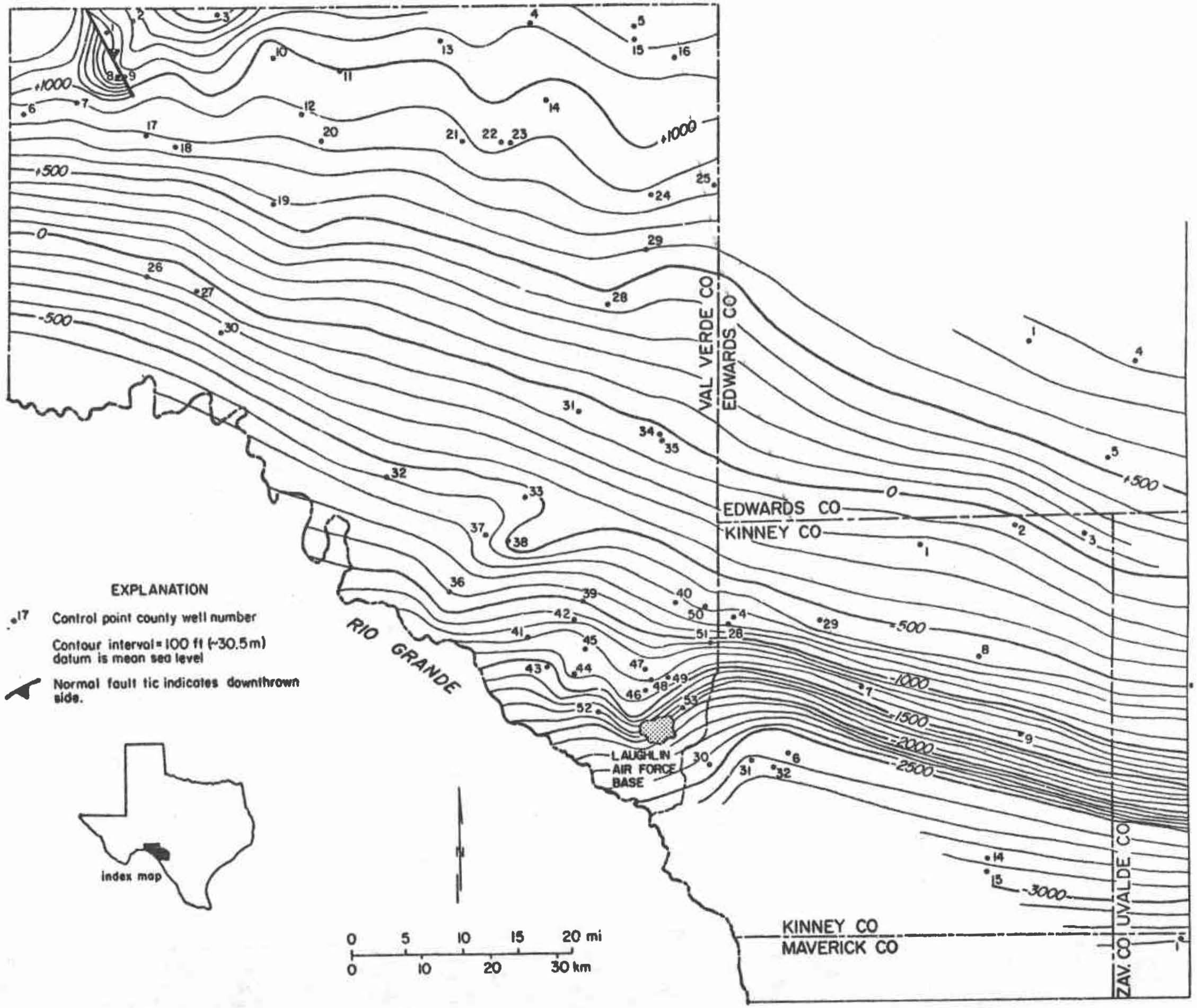

Figure H-16. Structure Contour Map on the Top of the Paleozoic Complex, Val Verde and Kinney Counties.

abrupt change in the trend direction of Ouachita deformation. There, the Ouachita thrust faults abruptly change from a northeast-southwest strike to a northwest-southeast orientation. The "basement rocks" of the Ouachita complex are thrust northeastward onto less deformed strata composing the Devils River Uplift.

This structural complexity augurs well for geothermal potential. The complex folding and faulting of strata beneath the Cretaceous sands provides the avenues for possible upwelling of ground waters that may have migrated to considerable depths. The quality and quantity of these waters are, however, purely conjectural. That the structural deformation in Val Verde County provides a proper environment for geothermal anomalies is borne out, though, by the presence of a few springs that issue from the Edwards-equivalent strata near Amistad Reservoir and that have temperatures of up to 84°F (no. 71, Val Verde County, fig. H-15).

In short, geothermal prospects in the Laughlin AFB area are not documented. But there are geologic relations that warrant continued interest, especially if any downhole data could be obtained for the "basal sands" at a depth of approximately 2,500 ft. Such data could quickly prove or disprove whether such a resource actually exists.

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ADDENDA TO APPENDIX H

Introduction

These addenda include the computer-plotted locations and print-outs of all well data for Bexar, Kinney, Travis, and Val Verde Counties. In addition, selected well data from adjacent counties were included if the corresponding well appeared on any of the maps.

This tabulation is presented by county in alphabetical order, and for each county wells are listed sequentially by the county unique number assigned for this project. For each data point we provide two pages of information, selected from computer files that compose our complete topical data base. The headings on these two pages are largely self-explanatory, but a detailed description of what constitutes each column of data may be found in Appendix C. The various codes that are presented in this tabulation are also explained in Appendix C. Where needed, summary explanations of these headings follow; for each heading we present the "address" of the data with respect to Appendix C.

Page 1 of Tabulation

Unique No.--This is the project-specific county unique number for each well. It is the identifying number that links the map-based data (Appendix A) to the topical information presented herein. This number is explained on CARD 1, Section "E."

State Well Number--This is the presentation of the state well number as assigned by TDWR. The numbering system is explained elsewhere in the text of this report (*see* fig. 2), and the individual components of the system are presented in Sections "A" through "C" of CARD 1, and Section "B" of CARD 7. The complete seven-digit number is presented only if the actual TDWR number has been substantiated. If no official number is known, then the last two digits are left blank. In this way we present all the locational information contained in a state well number without risking the establishment of a specious (unofficial) number.

Source Vera--This is short for veracity of source-map. It is based entirely on original map data from which the plot was digitized in Appendix A. The codes are explained in Appendix C, Section "I" of CARD 1.

Well Operator--See Appendix C, CARD 2, Section "B."

Well Number--See CARD 2, Section "C."

Well Owner--See CARD 2, Section "D."

Well Use Code--This code presents the most up-to-date reading on the status of the particular well in question. See CARD 2, Section "K."

Completion Date--See CARD 2, Sections "E" through "G."

Well Depth--See CARD 2, Section "I."

Ground Elevation--See Appendix C, CARD 3, Section "C."

Page 2 of Tabulation

Unique No.--Repeat unique number as done for page 1 for cross-referencing.

BHT (F)--This is the bottom-hole temperature for the deepest run as presented on the well heading. This value is given in degrees Fahrenheit. See Appendix C, CARD 3, Sections "K-L."

Depth at BHT (ft)--This is the depth in feet of the BHT measurement. See CARD 3, Section "I."

Date Logged--See CARD 3, Section "M."

Aquifer Code--This is the numeric aquifer code assigned by TDWR. The complete listing of these codes is given in Appendix C, Addendum C-4.

Wellhead H_2O Temp (F)--This is the water temperature in degrees Fahrenheit collected or compiled for the well in question. For collected data, see CARD 5, Section "K." For compiled data, SEE CARD 6, Section "B."

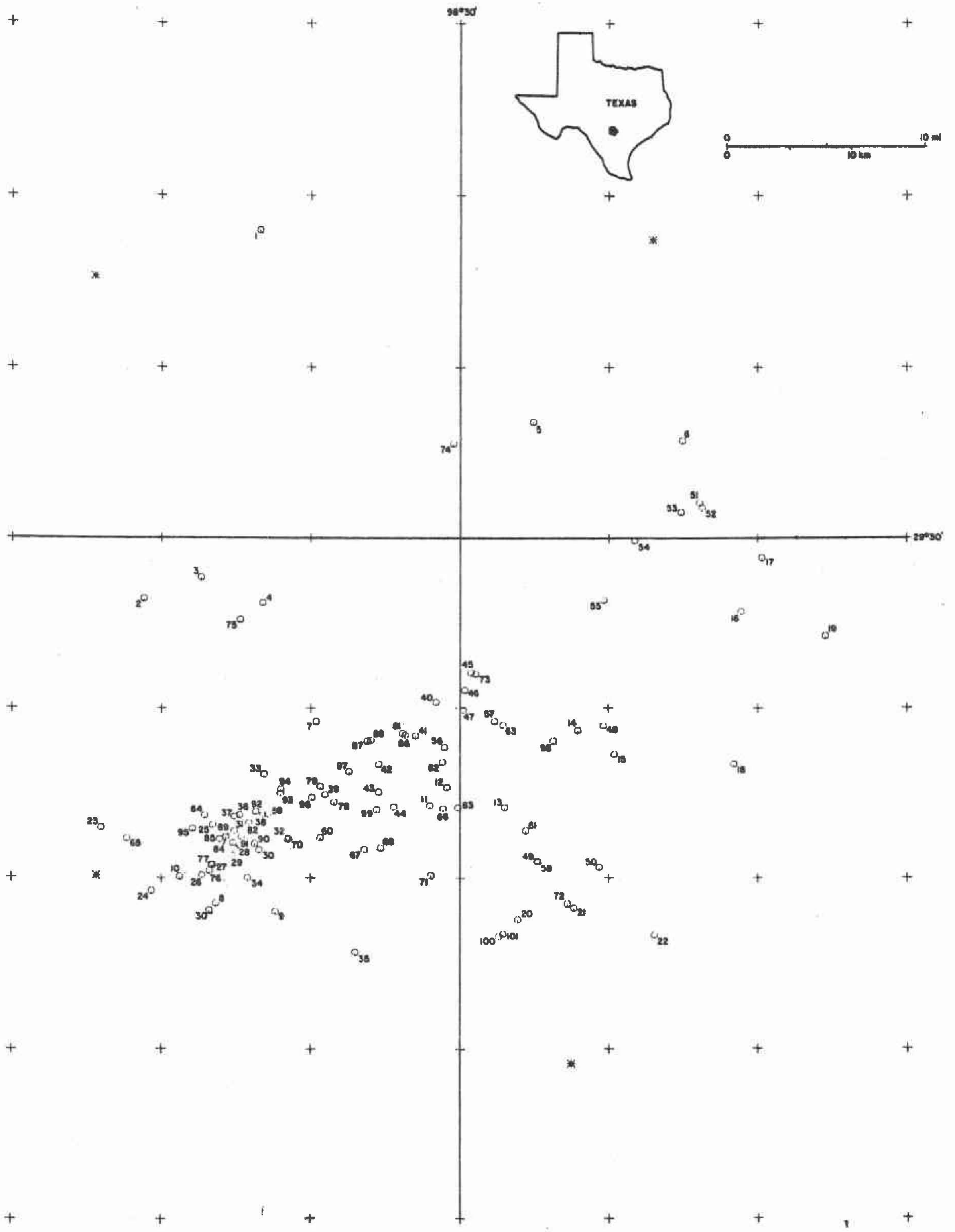
Date Measured--This is the date of cited temperature measurement. For collected data, see Appendix C, CARD 5, Section "C." For compiled data, see CARD 6, Section "D."

TDS (mg/1)--This value is almost always compiled; see CARD 6, Section "E."

TDS Date--This is the date of measurement for the TDS value cited. See CARD 6, Section "G."

TDS/Temp Source--For compiled data, the sources from which we obtained salinity and temperature values are given in summary form here. See CARD 6, Section "L."

BEXAR



COUNTY: AY:BEXAR

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	68-19-208	B	TWBD		TRINITY TEST		/ /	885.	1400.
2	68-34-6	D	GENERAL CRUDE	1	TALLEY	O	/ /	2622.	869.
3	68-35-1	D	HICKOCK-REYNOLDS	1	EWERT	ON	/ /	3002.	
4	68-35-6	A	GENERAL CRUDE	1	ROGERS RANCH	O	/ /	5896.	812.
5	68-29-2	D	RENLEE OIL	1	THEIS	O	/ /	2105.	800.
6	68-30-5	A	SECURITY DRILLING	2	ENGLEMANN	ON	/ /	2575.	850.
7	68-44-1	A	PAGENKOPF	1	BLUM	O	/ /	7028.	702.
8	68-51-2	D	JOHNSON DRLG	4	EVERGREEN NURSERY	W	/ /	2060.	621.
9	68-51-3	D	DRLG EXPLORATION	1	KURZ		/ /	4400.	599.
10	68-43-704	B	BUR-KAN STANOLIND	1	HUBBARD	OW	/ /	5138.	725.
11	68-44-6	A	UNION PRODUCING	1	MCKEAN	ON	/ /	4425.	595.
12	68-44-6	A	WEST PROD.	1	TIMBERLAKE	OW	/ /	4482.	573.
13	68-45-4	A	PARKER MCCUNE	1	GOAD	O	/ /	4400.	591.
14	68-45-3	A	ANDERSON PRICHARD	1	YTURRI	O	/ /	4301.	588.
15	68-46-1	D	SHUART	1	EICKERT		/ /	3400.	550.
16	68-38-6	A	THOMAS DRLG	1	SCHWENN	O	/ /	4046.	567.
17	68-39-1	D	BROWN	1	SCHROEDER	ON	/ /	3205.	734.
18	68-46-3	A	ARKANSAS FUEL	1	BURKHARDT	ON	/ /	5098.	563.
19	68-39-5	A	FAIR-WOODWARD ETAL	1	LYRO	ON	/ /	4607.	592.
20	68-53-2	D	TENNECO	1	HERRERA	ON	/ /	812.	535.
21	68-53-3	D	SECURITY DRGL	1	JUDSON	ON	/ /	2590.	
22	68-54-1	A	JACOBS	1	HARTL	ON	/ /	3028.	433.
23	68-42-804	C	J R JOHNSON DRLG		KOHLLEPPEL BROS	W	/ /1964	2308.	
24	68-50-304	C	J R JOHNSON DRLG		JOHN LOTT	W	02/17/1969	2165.	
25	68-43-811	C	J R JOHNSON DRLG	1	ATASCOSA RURAL WSC	WP	/ /1969	2298.	
26	68-43-703	C	BURKETT DRLG CO		FRANK JAMES	W	/ /1964	2030.	
27	68-43-810	C	BURKETT DRLG CO		K L HAGGARD	W	/ /1961	1860.	
28	68-43-816	A	PEGG BROS BURKETT C		ALDRIDGE NURSERY	W	/ /1951	1993.	
29	68-43-809	C	PEGG BROS		A J BALLARD	W	/ /1954	1903.	
30	68-43-813	A			A A GROTHUES	ON	/ /1933	1800.	
31	68-43-812	A	PEGG BROS		A A SELIGSON	O	/ /	1800.	
32	68-43-901	A	J R JOHNSON DRLG		EARL BAKER ESTATE	W	06/28/1956	2274.	
33	68-43-611	A			L F RIDDER	W	/ /	2911.	
34	68-51-201	C	J R JOHNSON DRLG		ASHLEY + ROSENSTEIN	W	04/ /1955	2226.	
35	68-52-405	C				W	/ /	408.	
36	68-43-504	C	WILL PEGG		J H SHELTON	W	/ /1956	1750.	
37	68-43-505	C	W F PEGG AND SONS		J W WATTS	W	/ /1956	2002.	
38	68-43-503	C	J R JOHNSON DRLG		R R JARVIS	W	/ /1955	2005.	
39	68-44-404	C	PEGG BROS		FELIPE VARGAS	W	/ /1955	1660.	
40	68-36-908	C	J R JOHNSON DRLG	2	BEXAR METRO WTR DST	WP	/ /1956	1708.	
41	68-44-301	C	J R JOHNSON DRLG		R J R FOODS INC	W	/ /1964	1373.	
42	68-44-210	C	J R JOHNSON DRLG		EDMOND PERSYN	W	/ /1955	1672.	
43	68-44-503	A			JAMES L NETTS	W	/ /1907	2400.	
44	68-44-502	A	JACOB WOLFF		J W AUSTIN	W	/ /1911	1850.	
45	68-37-704	C	J R JOHNSON		LONE STAR BREWING CO	WI	/ /1955	1617.	
46	68-37-706	C	J R JOHNSON	6	CITY WATER BOARD	WP	/ /1957	1521.	
47	68-45-102	A	J P BENKENDORFER		MORRILL ELEM SCHOOL	WP	/ /1910	2103.	
48	68-45-302	C	J R JOHNSON		R O HUNDLEY	WN	04/05/1955	1715.	
49	68-45-802	A	JACOB WOLFF		BLUE WING CLUB	W	/ /	2444.	
50	68-45-901	C	J R JOHNSON		CITY PUB SVC BOARD	W	/ /1962	2927.	

COUNTY: AY:BEXAR

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H20 TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1			/ /			/ /		/ /	
2	110.	2617.	11/20/1954			/ /		/ /	
3	110.	3002.	03/ /19			/ /		/ /	
4	123.	5895.	10/17/1954			/ /		/ /	
5	100.	2098.	09/23/1955			/ /		/ /	
6	96.	2581.	04/07/1955			/ /		/ /	
7		2919.	08/01/1941			/ /		/ /	
8	102.	2060.	07/13/1953			/ /		/ /	
9	131.	4402.	04/13/1963			/ /		/ /	
10		5140.	03/02/1948			/ /		/ /	
11	131.	4426.	01/20/1949			/ /		/ /	
12	144.	4482.	02/04/1948		120.	08/ /1952		/ /	TBWE B5608
13		4115.	11/08/1945			/ /		/ /	
14		4297.	06/17/1948			/ /		/ /	
15			/ /			/ /		/ /	
16	91.	4020.	06/24/1961			/ /		/ /	
17	118.	3205.	06/05/1965			/ /		/ /	
18	162.	5097.	11/30/1947			/ /		/ /	
19		4610.	12/14/1946			/ /		/ /	
20	70.	808.	12/03/1969			/ /		/ /	
21	106.	2589.	09/06/1954			/ /		/ /	
22	112.	3037.	05/06/1954			/ /		/ /	
23			/ /	066	28.5	06/13/1980	254	03/23/1972	TDWR R237
24			/ /	284	100.	07/14/1969	636	07/14/1969	TDWR R237
25			/ /	066	29.0	06/12/1980	510	02/06/1976	TDWR R237
26			/ /	066	95.	10/09/1968	1147	10/09/1968	TDWR R237
27			/ /	066	35.0	06/28/1980		/ /	TDWR R237
28			/ /	066	35.0	06/18/1980		/ /	TBWE B5608 VOL2 PART2
29			/ /	066	96.	/ /		/ /	TDWR R237
30			/ /	066	97.	/ /1953		/ /	TDWR R237
31			/ /	066	94.	/ /1949	488	03/04/1949	TBWE B5608
32			/ /	066	101.	/ /		/ /	TDWR R237 TDWR WS
33			/ /	066	27.0	06/10/1980		/ /	TDWR 237 TBWE B5608
34			/ /	066	106.	09/04/1973	3651	09/04/1973	TDWR R237
35			/ /	190	94.	07/26/1977	382	07/26/1977	
36			/ /	066	86.	/ /		/ /	TDWR R237
37			/ /	066	29.0	06/12/1980		/ /	TDWR R237
38			/ /	066	88.	/ /		/ /	TDWR R237
39			/ /	066	30.0	08/14/1980		/ /	TDWR R237
40			/ /	066	81.	12/07/1973	265	12/07/1973	TDWR R237
41			/ /	066	82.	12/04/1972	283	12/04/1972	TDWR R237
42			/ /	066	90.	06/17/1969	650	07/21/1971	TDWR R237
43			/ /	066	99.	/ /		/ /	TDWR R237 TBWE B5608
44			/ /	066	41.5	07/18/1980		/ /	TDWR R237 TBWE B5608
45			/ /	066	82.	12/07/1973	296	12/07/1973	TDWR R237
46			/ /	066	81.	12/07/1973	306	01/23/1974	TDWR R237
47			/ /	066	90.	07/17/1973	3874	07/17/1970	TDWR R237 TDWE B5608
48			/ /	066	102.	08/15/1972	4542	08/15/1972	TDWR R237
49			/ /	066	47.0	06/26/1980		/ /	TDWR R237 TDWR WS
50			/ /	066	118.	01/30/1973	4152	01/30/1973	TDWR R237

COUNTY: AY:BEXAR CONTINUED

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
51	68-30-803	C	OTTO MARCKWARDT		C W IVEY	W	/ /1951	638.	
52	68-30-807	C	TWDB		USGS	W	/ /1972	1202.	
53	68-30-802	C	MAX GERFERS		CITY OF CONVERSE	WP	/ /1954	750.	
54	68-38-107	C	J R JOHNSON DRLG		SOUTHWEST UTILITY CO	WP	/ /1970	773.	
55	68-37-602	C	HASKIN PUMP INC		LANDIS WILSON WA SYS	WN	/ /	1100.	
56	68-44-3	A			SAN JOSE BEACH	WD	/ /	1885.	
57	68-45-101	A			HOT WELLS TOURIST	WN	/ /	1878.	
58	68-45-803	A	DINGMAN DRLG CO		BLUE WING CLUB	W	/ /1929	2558.	
59	68-43-610	A	J R JOHNSON DRLG		L KNOWLTON	W	11/ /1956	1856.	
60	68-44-7	A	MID KANSAS DRLG CO		GEO N EVANS	ON	/ /1923	1700.	
61	68-45-8	A	WM H REYNOLDS		YTURRI NO 1	O	/ /	2090.	
62	68-44-3	A	ROHMER		SAN JOSE BEACH	W	/ /	2190.	
63	68-45-2	A			STATE HOSPITAL	W	/ /	2100.	
64	68-43-404	A	BURKETT DRLG CO		HENRY G NENTWICH	W	11/ /1955	2285.	
65	68-42-902	A	J R JOHNSON	2	ATASCOSA RURAL WSC	W	08/13/1969	2326.	
66	68-44-6	A	DINGMAN DRLG CO		CASSIN + DINGMAN	W	/ /1933	1506.	
67	68-44-8	A	HIGDON		CLINTON BROWN	WN	/ /	2355.	
68	68-44-8	A	HIGDON		PETTY ESTATE	WN	/ /	.	
70	68-43-9	A	ONION CREEK DRLG CO		EARL BAKER	WN	/ /1951	4518.	
71	68-44-9	C	BUCKEYE OIL CO	1	SEARINGEN	O	/ /	2470.	
72	68-53-3	C	T B SLICK		JOE LAMM	O	/ /	3044.	
73	68-37-7	A			CITY SAN ANTONIO	WP	/ /	.	
74	68-28-6	A	MID-TEX PRODUCTION	1	C G WALKER	O	10/12/1935	2132.	840.
75	68-35-5	A	GAS RIDGE SYNDICATE	1	PEPPER	O	/ /1921	3783.	935.
76	68-43-702	A	W B OSBORN (STOKES)	1	K L HAGGARD	W	/ /1958	2055.	647.
77	68-43-8	B	BLANCO OIL	1	HAGGARD	O	/ /	1783.	
78	68-44-405	A	PEGG BROS		MRS WM RIPPS	W	05/ /1934	2000.	
79	68-44-401	A	FRED BURKETT		C VERSTUYFT	W	/ /	1532.	
80	68-51-102	A	J R JOHNSON		FRANK WILLIS	W	07/16/1955	2363.	
81	68-44-214	A	J R JOHNSON		THURMAN BARRETT	W	06/08/1946	1285.	
82	68-43-814	A			FRITZ SCHNEIDER	W	/ /	1900.	
83	68-44-6	A			CITY OF SAN ANTONIO	WP	/ /	.	
84	68-43-817	A	PEGG BROS		TONY CONSTANZO JR	W	/ /1951	1949.	
85	68-43-806	A	BILL PEGG		TONY CONSTANZO JR	W	/ /1951	1887.	
86	68-44-2	A	J R JOHNSON		THURMAN BARRETT	W	/ /1949	1662.	
87	68-44-215	A	J R JOHNSON	1	CITY PUB SVC BOARD	W	/ /1947	1174.	
88	68-44-207	A	J R JOHNSON	4	CITY PUB SVC BOARD	WP	10/06/1956	1686.	
89	68-43-815	A	ARMSTRONG SUTTON		ALDRIDGE NURSERY INC	W	/ /1946	2251.	
90	68-43-807	A	J R JOHNSON		A A GROTHUES	W	07/ /1954	2292.	
91	68-43-805	A	J R JOHNSON		HENRY VERSTUYFT	W	06/30/1955	2195.	
92	68-43-5	A			R R JARVIS	WD	/ /	1850.	
93	68-43-608	A	J R JOHNSON	5	O R MITCHELL FARM	W	06/20/1955	1683.	
94	68-43-607	A	J R JOHNSON	3	O R MITCHELL FARM	W	04/08/1955	2068.	
95	68-43-7	A			ALDRIDGE NURSERY INC	W	/ /1979	2160.	
96	68-44-407	A	J R JOHNSON		O R MITCHELL RANCH	W	/ /1948	2040.	
97	68-44-403	A	J R JOHNSON		HENRY KRUEGER	W	03/ /1955	1781.	
98	68-45-2	A			MRS FRANCES DULLNIG	W	/ /1892	2215.	
99	68-44-5	A	J R JOHNSON		D SAENZ	W	/ /1944	1767.	
100	68-53-1	A	PARKS-BAILEY		J F BAILEY	W	/ /	2000.	
101	68-53-1	A			JOE LAMM	W	/ /	2873.	

COUNTY: AY:BEXAR CONTINUED

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
51			/ /	066	81.	10/04/1972	297	8/04/1972	TDWR R237
52			/ /	066	84.	11/21/1972	4685	11/21/1972	TDWR R237
53			/ /	066	82.	03/22/1972	278	01/09/1975	TDWR R237
54			/ /	066	81.	03/29/1971	289	03/29/1971	TDWR R237
55			/ /	066	86.	/ /	1070	01/30/1973	TDWR R237
56			/ /	066	106.	/ /		/ /	TBWE B5608
57			/ /	066	39.6	05/06/1980		/ /	TBWE B5608
58			/ /	066	47.0	06/26/1980		/ /	TDWR R237
59			/ /	066	33.5	06/10/1980		/ /	TDWR R237
60			/ /	066		/ /		/ /	TBWE B5608
61			/ /	066		/ /		/ /	TBWE B5608
62			/ /	066	40.5	07/10/1980		/ /	TBWE B5608
63			/ /		100.	/ /1952		/ /	TBWE B5608
64			/ /	066	27.0	06/26/1980	488	03/04/1949	TBWE B5608
65			/ /	066	31.0	06/13/1980	230	09/10/1970	CW
66			/ /	066	100.	/ /		/ /	TBWE B5608
67			/ /	066	43.5	07/22/1980		/ /	TBWE B5608
68			/ /	066	40.5	07/18/1980		/ /	TBWE B5608
70			/ /	178	132.	/ /1951	2620	/ /	TBWE B5608
71			/ /	066		/ /		/ /	TBWE B5608
72			/ /	066		/ /		/ /	TBWE B5608
73			/ /		26.5	05/06/1980		/ /	TBWE B5608
74		2132.	/ /			/ /		/ /	
75		3783.	/ /			/ /		/ /	
76	117.	1370.	07/28/1954	066	38.0	06/28/1980		/ /	TDWR 237
77		1774.	03/26/1961			/ /		/ /	
78			/ /	066	30.5	06/27/1980		/ /	TDWR 237 TBWE B5608
79			/ /	066	28.0	06/18/1980		/ /	TDWR 237
80			/ /	066	42.5	06/13/1980		/ /	TDWR 237
81			/ /	066		/ /		/ /	TDWR 237 TBWE B5608
82			/ /	066	33.0	06/28/1980		/ /	TDWR 237
83			/ /		34.5	06/27/1980		/ /	
84			/ /	066	35.	06/19/1980		/ /	TDWR 237 TBWE B5608
85			/ /	066	29.	06/19/1980		/ /	TDWR 237
86			/ /	066		/ /		/ /	TBWE B5608
87			/ /	066	26.5	06/27/1980		/ /	TBWE B5608 TDWR 237
88			/ /	066	27.0	06/27/1980		/ /	TDWR 237
89			/ /	066	35.0	06/12/1980		/ /	TBWE B5608
90			/ /	066	36.0	06/12/1980		/ /	TDWR 237
91			/ /	066	34.	06/18/1980		/ /	TDWR 237
92			/ /	066		/ /	630	03/04/1949	TBWE B5608
93			/ /	066	29.0	06/18/1980		/ /	TDWR 237
94			/ /	066	29.5	06/18/1980		/ /	TDWR 237
95			/ /	066	33.0	06/12/1980		/ /	
96			/ /	066		/ /		/ /	TDWR 237 TDWE B5608
97			/ /	066	24.8	07/22/1980		/ /	TDWR R237
98			/ /	066	104.	/ /		/ /	TBWE B5608 USGS WS
99			/ /	066	39.5	07/22/1980		/ /	TBWE B5608
100			/ /	066		/ /		/ /	TBWE B5608
101			/ /			/ /		/ /	

COUNTY: AL:ATASCOSA

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	68-50-3	D	TENNECO	1	P R SMITH	ON	/ /	4767.	663.5
2	68-51-8	D	TENNECO	1	J J SMITH	ON	/ /	5558.	649.
3	68-52-7	D	TENNECO	1	ROGERS	ON	/ /	5963.	590.
4	68-52-9	D	BAILEY,ESTES,COLE	1	SCHULTZE	ON	/ /	4006.	650.
39	68-50-201	A	JOHNSON DRLG + SUP		CITY OF LYTLE	WP	/ /1955	2379.	
40	68-50-302	C			TOUCHSTONE ESTATE	W	/ /1956	2498.	
41	68-50-301	C			C W MASK	W	/ /1956	2507.	
42	68-51-101	C			GIDLEY BUSH	W	/ /1956	2656.	
114	68-50-303	A			GIDLEY ESTATE	W	/ /1955	2428.	

COUNTY: ZL:WILSON

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	68-53-9	D	TENNECO-PENNZOIL	1	L.A. JASIK	ON	/ /	6600.	522.
2	68-54-2	D	GEN CRUDE OIL	1	TREVINO	ON	/ /	6423.	465.

COUNTY: KX:GUADALUPE

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	68-30-3	C	STANOLIND	1	SCHMIDT	O	/ /	2640.	805.
2	68-31-2	C	BLUMBERG	1	SANDERS	O	/ /	2500.	772.
9	68-40-2	C	WILSON	1	KUBELA	O	/ /	4012.	545.

COUNTY: TD:MEDINA

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
29	68-34-5	D	MOORE-UNION PROD	1	A WURZBACH	O	/ /	3183.	1011.

COUNTY: AL:ATASCOSA

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	125.	4764.	01/29/1968			/ /		/ /	
2	145.	5553.	02/10/1969			/ /		/ /	
3	150.	5962.	03/13/1968			/ /		/ /	
4	120.	4005.	04/06/1955			/ /		/ /	
39			/ /	066	96.	07/29/1977	249	07/29/1977	TWDB R210
40			/ /	066	41.0	06/28/1980	549	01/17/1956	TWDB R210
41			/ /	066	32.5	06/28/1980	1597	03/06/1957	TWDB R210
42			/ /	066	41.0	06/28/1980	1510	09/01/1977	TWDB R210
114			/ /	066	38.0	06/28/1980	253	10/26/1955	TWDB R032 CW

COUNTY: ZL:WILSON

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1		6670.	10/07/1969			/ /		/ /	
2	148.	6426.	11/26/1959			/ /		/ /	

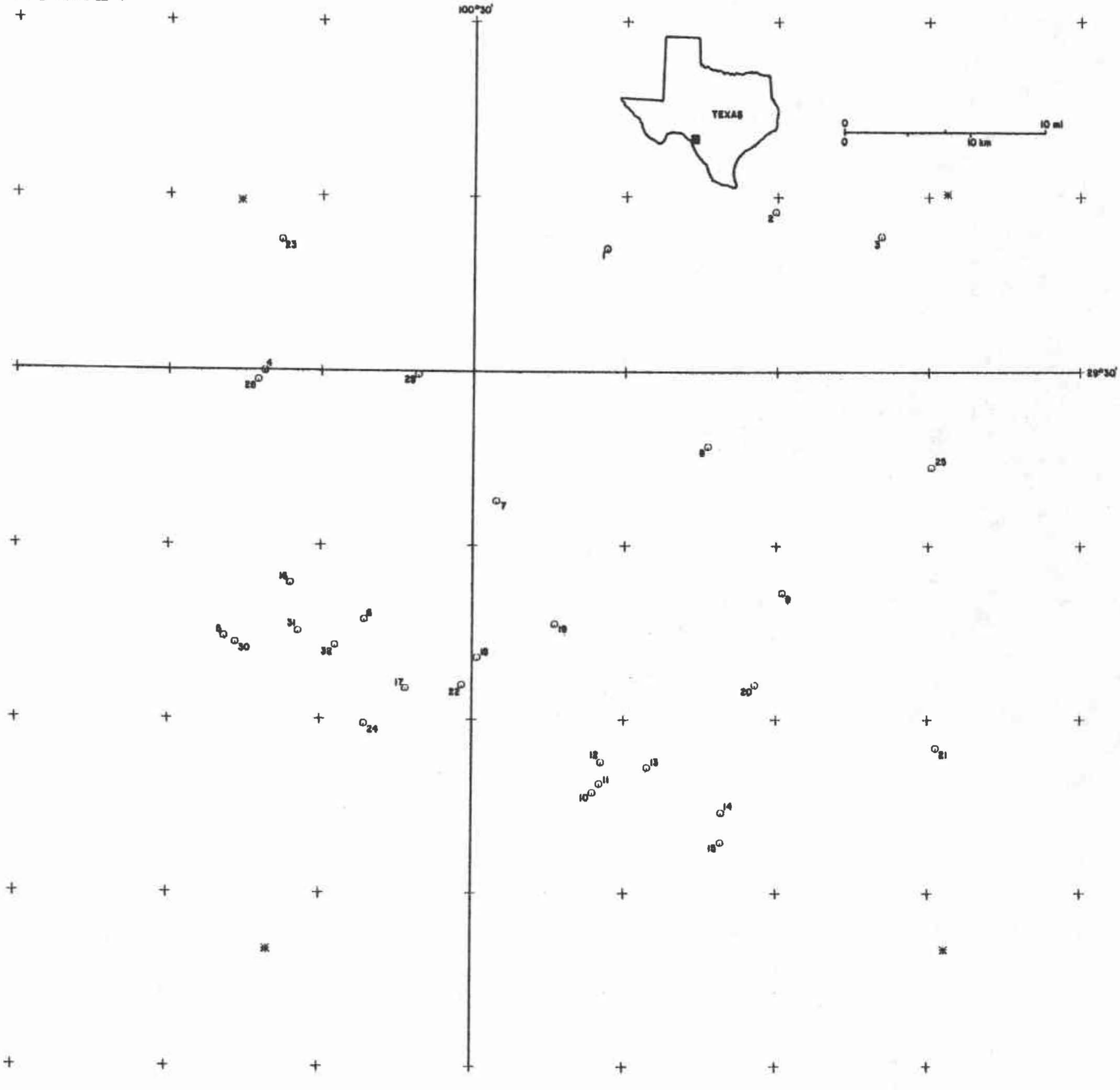
COUNTY: KX:GUADALUPE

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	110.	2639.	09/16/1954			/ /		/ /	
2	109.	2499.	05/16/1961			/ /		/ /	
9	120.	4011.	11/11/1954			/ /		/ /	

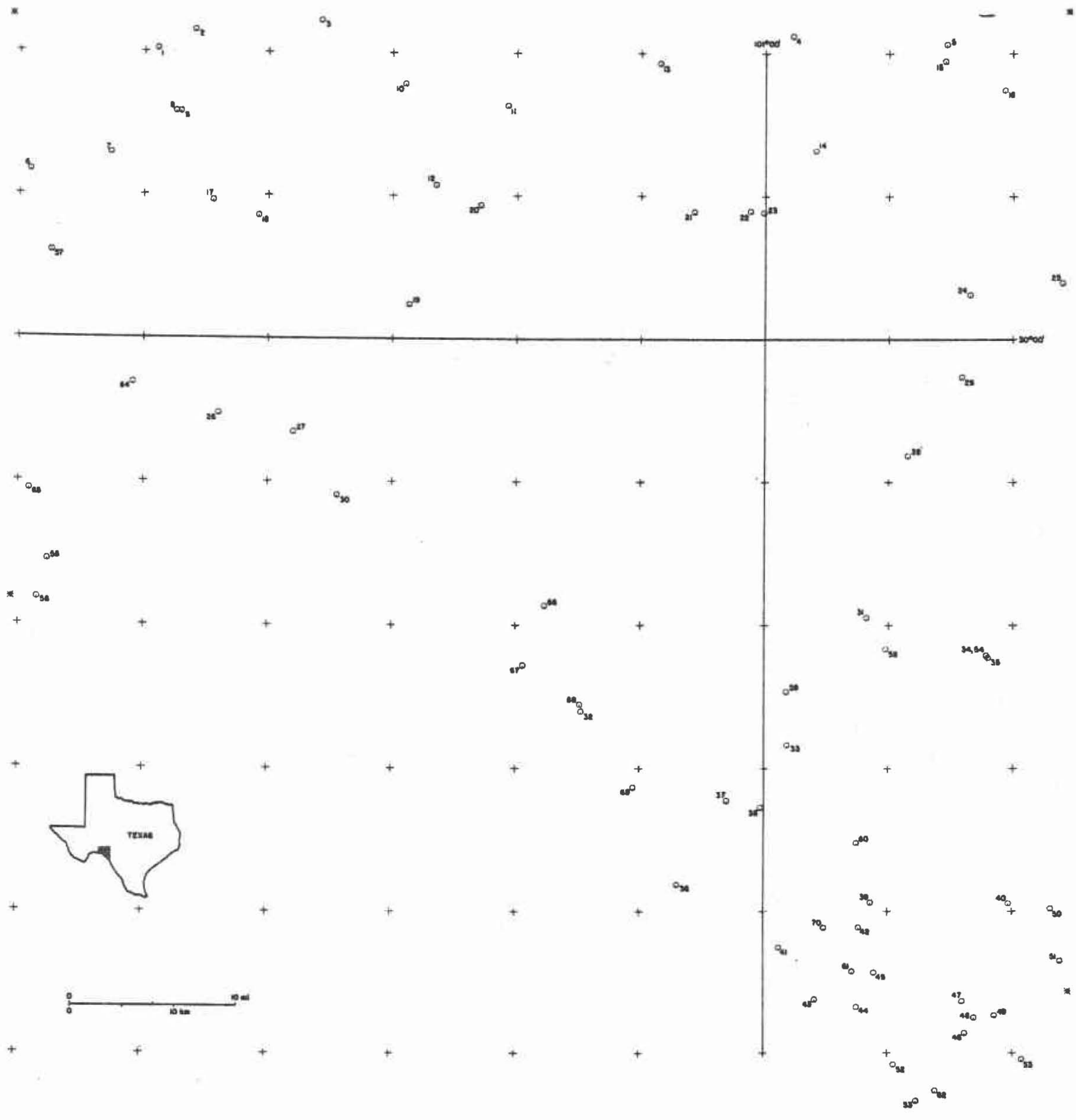
COUNTY: TD:MEDINA

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
29		3183.	4/24/1945			/ /		/ /	

KINNEY



VAL VERDE



COUNTY: RP:KINNEY

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	70-29-3	D	GULF OIL	1	G. SLATOR	O	/ /	5302.	1750.
2	70-30-3	D	J. FROST	1	MOODY RANCH	O	/ /	9874.	1671.
3	70-31-301	B	J. FROST	1	SILVER LAKES RCH	O	/ /	10513.	1892.
4	70-35-2	D	RICHARDSON OIL	1	M. ROSE	O	/ /	2591.	1215.
5	70-43-5	D	AUSTRAL OIL	1	C.B. WARDLAW	O	/ /	3500.	1043.2
6	70-44-4	D	L.M. JOSEY	1	A.F. BEIDLER	O	/ /	4006.	1036.
7	70-37-7	D	H.R. WHARTON	1	C.C. BELCHER	O	/ /	2970.	
8	70-38-5	D	FISH PROD CORP	1	POSTELL	O	/ /	5374.	1560.
9	70-47-1	D	SUTTON DRLG	1	HARRISON	O	/ /	4295.	1218.
10	70-53-6	D	ELTEX LTD	1	BEIDLER	O	/ /	5131.	1042.
11	70-53-6	D	PHILLIPS PETROL	1	HOBBS	O	/ /	4750.	1047.
12	70-53-3	D	USSRM COMPANY	1	L.E. HOBBS	O	/ /	4273.	1080.
13	70-54-1	D	STRITER OIL	1	TOFT	O	/ /	3040.	1071.
14	70-54-5	D	LEECO GAS + OIL	1	P. FRANKS	O	/ /	5262.	961.
15	70-54-8	D	GENERAL CRUDE OIL	1	W.C. HEDRICK	O	/ /	7924.	937.
16	70-43-3	D			J F BEIDLER	W	/ /	1200.	
17	70-44-8	D	J R JOHNSON		W A RICHARDS	W	/ /1952	1408.	
18	70-45-4	D	ARCHIE BUIE		LONNIE LANGSTON	W	/ /1954	1320.	
19	70-45-5	D			JOHN LOWRANCE	W	/ /1932	600.	
20	70-46-901	D	GEO CRYSTALL		GEO CRYSTALL	W	/ /1938	514.	
21	70-56-102	D			ETHEL WHITAKER	W	/ /	104.	
22	70-44-901	D				W	/ /	100.	
23	70-27-301	D				W	/ /	496.	
24	70-52-1	D	TYLER		GAEBLER BROS	W	/ /1915	1605.	
25	70-39-601	D				W	/ /	197.	
28	70-35-2	D	HAVOLINE OIL	1	PROSSER AND WALKER	OW	/ /1927	4381.	1220.
29	70-36-3	D	FISH PRODUCTION	1	ROY HENDERSON	O	/ /1951	2699.	1588.
30	70-43-5	D	MAGNOLIA	1	C B WARDLAW	O	/ /1931	5280.	998.
31	70-43-6	D	AUSTRAL OIL	1-A	WARDLAW-WHITEHEAD ES	O	/ /1953	4378.	1044.
32	70-44-5	D	GEORGE PROCTOR	1	WARDLAW-WHITEHEAD	O	/ /1948	4507.	1068.5

COUNTY: YR:VAL VERDE

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	54-44-701	C	SKELLY OIL	1	G L BUNGER	O	/ /	15500.	2224.
2	54-44-802	C	SHELL OIL	46UN1	MITCHELL-BUNGER	O	/ /	14643.	1816.
3	54-45-802	C	MAGNOLIA PETROLEUM	1	L M MORRISON	O	/ /	15144.	2213.
4	55-41-702	C	PURE OIL	1	T L DRISDALE	O	/ /	1285.	1864.
5	55-42-801	C	WESTERN NATURAL	2	ADAH CAUTHORNE	O	/ /	1510.	2095.
6	54-51-701	C	VAL VERT OIL	1	BASSETT RANCH	O	/ /	4010.	2069.
7	54-51-903	C	WESTERN NATURAL GAS	1	BASSETT	O	/ /	4787.	1875.
8	54-52-401	C	HUMBLE OIL	1	MILLS MINERAL TRUST	O	/ /	17051.	1800.
9	54-52-402	C	O O OWENS	1	MILLS RANCH	O	/ /1931	6790.	1860.
10	54-54-102	C	STANDARD OF TEXAS	1	ALMA OBERCAMPF	O	/ /1968	15490.	2173.

COUNTY: RP:KINNEY

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1		5299.	08/25/1963			/ /		/ /	
2	181.	9867.	06/14/1969			/ /		/ /	
3	200.	10512.	01/10/1967			/ /		/ /	
4	110.	2592.	08/01/1956			/ /		/ /	
5	135.	3502.	06/07/1954			/ /		/ /	
6	112.	3999.	08/08/1952			/ /		/ /	
7	100.	2966.	02/05/1966			/ /		/ /	
8	142.	5364.	01/23/1952			/ /		/ /	
9	120.	4290.	12/08/1961			/ /		/ /	
10			/ /			/ /		/ /	
11			/ /			/ /		/ /	
12	130.		05/13/1964			/ /		/ /	
13	115.	3036.	06/14/1962			/ /		/ /	
14	135.	5255.	08/14/1960			/ /		/ /	
15	152.	7923.	05/23/1961			/ /		/ /	
16			/ /	066	88.	/ /	2280	01/27/1948	TWDB B6216
17			/ /	066	94.	07/22/1977	2562	07/22/1977	TWDB B6216
18			/ /	066	87.	/ /		/ /	TWDB B6216
19			/ /	066	90.	/ /		/ /	TWDB B6216
20			/ /	066	82.	08/22/1977	1997	08/22/1977	TWDB B6216
21			/ /	004	83.	08/22/1977	451	08/22/1977	TWDB B6216
22			/ /	004	88.	08/22/1977	614	08/22/1977	TWDB B6216
23			/ /	066	90.	08/23/1971	266	08/21/1971	TWDB B6216
24			/ /	066	97.	/ /	2770	01/14/1943	TWDB B6216
25			/ /	066	82.	08/23/1977	248	08/23/1977	TWDB B6216
28			/ /			/ /		/ /	
29		2694.	07/10/1951			/ /		/ /	
30			/ /			/ /		/ /	
31	125.	4297.	10/13/1953			/ /		/ /	
32		4336.	09/15/1948			/ /		/ /	

COUNTY: YR:VAL VERDE

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	304.	15475.	01/24/1967			/ /		/ /	
2	300.	14654.	12/06/1967			/ /		/ /	
3	386.	15140.	12/17/1955			/ /		/ /	
4	294.	12179.	12/18/1956			/ /		/ /	
5	210.	10536.	07/02/1952			/ /		/ /	
6		4010.	/ /			/ /		/ /	
7	115.	4774.	04/04/1953			/ /		/ /	
8	281.	17525.	05/15/1957			/ /		/ /	
9		6790.	/ /			/ /		/ /	
10		2620.	/ /			/ /		/ /	

COUNTY: YR:VAL VERDE CONTINUED

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
11	54-54-603	C	STANOLIND OIL	1	W W WEST	O	/ /	2523.	1869.
12	54-54-803	C	PHILLIPS PETROLEUM	A-1	MAYFIELD	O	/ /	3250.	2037.
13	54-56-103	C	B E WILSON	4-A	WILSON HODGE	O	/ /	3006.	1896.
14	55-49-801	C	PHILLIPS/DELTA-GULF	1	B E WILSON	O	/ /	15265.	1883.
15	55-50-202	C	CARAWAY	1	GUIDA ROSE	O	/ /	11590.	1962.
16	55-50-304	C	CARAWAY R J	1	W B WHITEHEAD	O	/ /	10602.	2074.
17	54-60-202	C	O W KILLAM	1	EVERETT	O	03/29/1948	3001.	1563.
18	54-60-304	C	O W KILLAM	1	WALTER BABB	O	/ /	3100.	1559.
19	54-62-701	C	PRODUCERS OIL	1	BOB [DOC] EVERETT	O	08/10/1929	2530.	1929.
20	54-62-3	D	PHILLIPS PETROLEUM	1-A	GUINN	O	/ /	14730.	2054.
21	54-64-202	C	SHELL OIL-GULF OIL	1	R J CAUTHORN	O	/ /	17087.	1763.
22	54-64-301	C	SHELL OIL	1	B E WILSON	O	/ /	8904.	2096.
23	54-64-302	C	DYAR BROS	1	B W WILSON	O	/ /1929	3594.	2086.
24	55-58-801	C	HUMBLE OIL	1	EMMA WARDLAW	O	/ /	15045.	1984.
25	55-59-502	C	MAGNOLIA PETROLEUM	1	W E WHITEHEAD	O	04/22/1928	6725.	1779.
26	71-04-501	C	PHANTOM (BOVAIRD)	1	INGRAM		/ /	3035.	1494.
27	71-05-401	C	COCKBURN	1	INGRAM	O	/ /	1885.	1622.
28	70-02-706	C	SHELL OIL	1	TOMLINSON	O	/ /	1660.	1960.
29	70-02-204	C	GULF AND SHELL OIL	1	KATHERINE MUELLER	O	/ /	15846.	1729.
30	71-13-201	C	C A MAURER	1	JOHN W INGRAM	O	09/08/1947	2030.	1565.
31	70-09-901	C	SHELL OIL	1	MIERS	O	/ /	1838.	1708.
32	71-23-503	C	HUSKY OIL	1	ROSE-ROBERTSON	O	/ /	2408.	1567.
33	70-17-701	C	DOUGLAS OIL	1	J E SELLARS	O	11/09/1927	4192.	1288.
34	70-18-301	C	FENSLAND,ROSE	1	H H ROSE WW	W	/ /	2920.	1910.
35	70-18-302	C	FENSLAND	1	ABB ROSE	O	01/28/1923	2928.	1865.
36	71-32-701	C	E WILLIAMS (CARUSO)	1	W T O HOLMAN ESTATE	OW	/ /	3005.	1293.
37	71-32-302	C	JOINER OIL CO	1	SELLER BROS RANCH		/ /1940	2252.	1296.
38	71-32-303	C	HIWTHA/BENDUM-TREES	1	SELLERS	O	08/24/1927	3502.	1205.
39	70-25-902	C	HARRIS (BWC 665-13)	1	LONGLEY	OW	/ /	1560.	1110.
40	70-26-902	C	S E HURLBURT	1	E WALDROP	O	/ /	2745.	1210.
41	70-33-401	C	BUNN-JHNSTN + BRCKN	1-A	H B HORN/1 BRITE WW	OW	/ /	2616.	1199.
42	70-33-302	C	O W KILLIAM	1	MINTER PARKER	O	/ /	2676.	1184.8
43	70-33-803	C	D H WERBLOW + ASSOC	1	MAUDE S NEWTON	O	02/19/1955	7337.	1116.
44	70-33-901	C	TRNSCONTINENTAL OIL	1	W S STEVENSON	O	04/01/1927	4500.	1065.
45	70-33-603	C	RECLAMATION OIL	1	MOORE AND WHITEHEAD	O	06/ /1923	2550.	1050.
46	70-34-802	C	KARL HOBLITTZELLE	1	BLUFF CREEK RANCH	O	/ /	2334.	1120.
47	70-34-803	C	PETROCEL CORP	2	BLUFF CREEK RANCH	O	/ /	2790.	1207.
48	70-34-903	C	INDEPENDENT OPER	1	RUST	O	/ /	5430.	1175.
49	70-34-902	C	PETROCEL CORP	1	BLUFF CREEK RANCH	O	/ /	1973.	1100.
50	70-35-101	C	PETROCEL CORP	1	EDNA D WALDROP	O	/ /	2386.	1271.
51	70-35-501	C	HURLBUT	1	RUST	O	/ /	3485.	1180.
52	70-42-104	C	EAST DEL RIO CO	1	RUSSELL + WEATHERBY	O	/ /1928	3332.	953.
53	70-43-101	A	PLATEAU OIL CO	1	JOE YORK JR	OW	10/14/1926	3507.	1111.
54	70-18-301	C	ROY E KIMSEY JR	1	A F BROTHERTON		/ /	705.	915.
55	71-11-402	A	K B LOGAN		R FOSTER		/ . /1939	1100.	
56	71-11-7	A			R FOSTER		/ /	.	
57	54-59-401	C				W	/ /	828.	
58	70-17-301	C	KELTNER DRLG CO		H MIERS	W	/ /1965	700.	
59	70-17-401	C	KELTNER DRLG CO		C HINDS	W	/ /1965	670.	
60	70-25-601	C			E STEWART	W	/ /1910	480.	

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H20 TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
11	111.	2520.	01/17/1956			/ /		/ /	
12	135.	3252.	06/23/1960			/ /		/ /	
13		3006.	05/06/1957			/ /		/ /	
14	300.	15265.	04/23/1952			/ /		/ /	
15	208.	11594.	05/02/1951			/ /		/ /	
16	206.	10574.	04/23/1956			/ /		/ /	
17			/ /			/ /		/ /	
18			/ /			/ /		/ /	
19			/ /			/ /		/ /	
20	275.	14730.	07/04/1957			/ /		/ /	
21			/ /			/ /		/ /	
22		8906.	04/23/1959			/ /		/ /	
23		3594.	/ /			/ /		/ /	
24	274.	15296.	01/19/1957			/ /		/ /	
25		6725.	/ /			/ /		/ /	
26		3010.	/ /			/ /		/ /	
27			/ /			/ /		/ /	
28	94.	1653.	07/17/1965			/ /		/ /	
29	300.	15838.	09/29/1962			/ /		/ /	
30			/ /			/ /		/ /	
31	100.	1808.	08/05/1965			/ /		/ /	
32	98.	2402.	06/19/1951			/ /		/ /	
33		4192.	/ /			/ /		/ /	
34		825.	09/25/1968			/ /		/ /	
35		2928.	/ /			/ /		/ /	
36		2965.	/ /			/ /		/ /	
37			/ /			/ /		/ /	
38			/ /			/ /		/ /	
39		1490.	01/08/1965			/ /		/ /	
40	105.	2742.	03/19/1959			/ /		/ /	
41	90.	2615.	11/25/1963			/ /		/ /	
42		2676.	05/24/1949			/ /		/ /	
43	142.	7333.	02/12/1955			/ /		/ /	
44		4412.	/ /			/ /		/ /	
45		2550.	/ /			/ /		/ /	
46	104.	2333.	04/09/1955			/ /		/ /	
47	104.	2789.	03/30/1956			/ /		/ /	
48		5430.	/ /			/ /		/ /	
49	96.	1973.	05/07/1956			/ /		/ /	
50	104.	2378.	07/28/1952			/ /		/ /	
51	113.	3485.	03/30/1954			/ /		/ /	
52			/ /			/ /		/ /	
53		3507.	/ /	066	28.5	05/22/1980	2723	07/27/1939	TWDB R172
54		705.	09/17/1961			/ /		/ /	
55			/ /	066	80.6	08/12/1969		/ /	TWDB R172
56			/ /			/ /		/ /	
57			/ /	066	80.6	08/25/1969	487	08/25/1969	TWDB R172
58			/ /	066	80.6	/ /	195	04/28/1965	TWDB R172
59			/ /	066	80.6	/ /	223	05/04/1965	TWDB R172
60			/ /	066	80.6	/ /	251	09/05/1939	TWDB R172

COUNTY: YR:VAL VERDE . CONTINUED

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
61	70-33-601	C	HICKS+PUCKETT DRLG		S LONG	W	/ /1966	510.	
62	70-42-206	C			T R BRITE EST.	OW	/ /	1200.	
63	70-42-401	C			W L MOODY IV	W	/ /	1600.	
64	71-03-301	C			W A ARLEDGE	W	/ /	917.	
65	71-11-101	C	SNOW		J H FISHER	W	/ /1932	750.	
66	71-15-701	C	E BURCHETT		P W KELLY	W	/ /1910	800.	
67	71-23-102	C	WAGNER		MRS A F HABY	W	/ /1946	800.	
68	71-23-505	C	HICKS+PUCKETT DRLG		CITY OF COMSTOCK	WN	/ /1965	960.	
69	71-31-301	C	KELTNER DRLG CO		HOMER HOLMAN	W	/ /1965	1000.	
70	70-33-201	C	HICKS+PUCKETT DRLG		SAN PEDRO DEV CO	W	/ /1965	.	

COUNTY: JJ:EDWARDS

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	70-15-101	C	HUMBLE OIL	1	COLLINS	O	/ /	7329.	2264.
4	70-16-5	D	HUNT OIL	1	ALLISON	O	/ /	6512.	1893.
5	70-24-401	C	PHILLIPS PETROL.	1	CARSON	O	/ /	9776.	1673.

COUNTY: ZX:ZAVALA

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	70-64-6	D	PARK + PHILLIPS	1	FLOWERS-WARD 1-20	ON	/ /	7290.	823.

COUNTY: YR:VAL VERDE CONTINUED

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
61			/ /	066	80.6	/ /	238	06/02/1966	TWDB R172
62			/ /	066	80.6	/ /		/ /	TWDB R172
63			/ /	066	80.6	/ /	7898	06/25/1965	TWDB R172
64			/ /	066	80.6	08/12/1969	727	08/12/1969	TWDB R172
65			/ /	066	80.6	/ /	582	08/12/1969	TWDB R172
66			/ /	066	80.6	/ /		/ /	TWDB R172
67			/ /	066	82.4	/ /	395	04/19/1968	TWDB R172
68			/ /	066	82.4	/ /		/ /	TWDB R172
69			/ /	066	82.4	/ /	286	07/19/1965	TWDB R172
70			/ /		80.2	/ /		/ /	

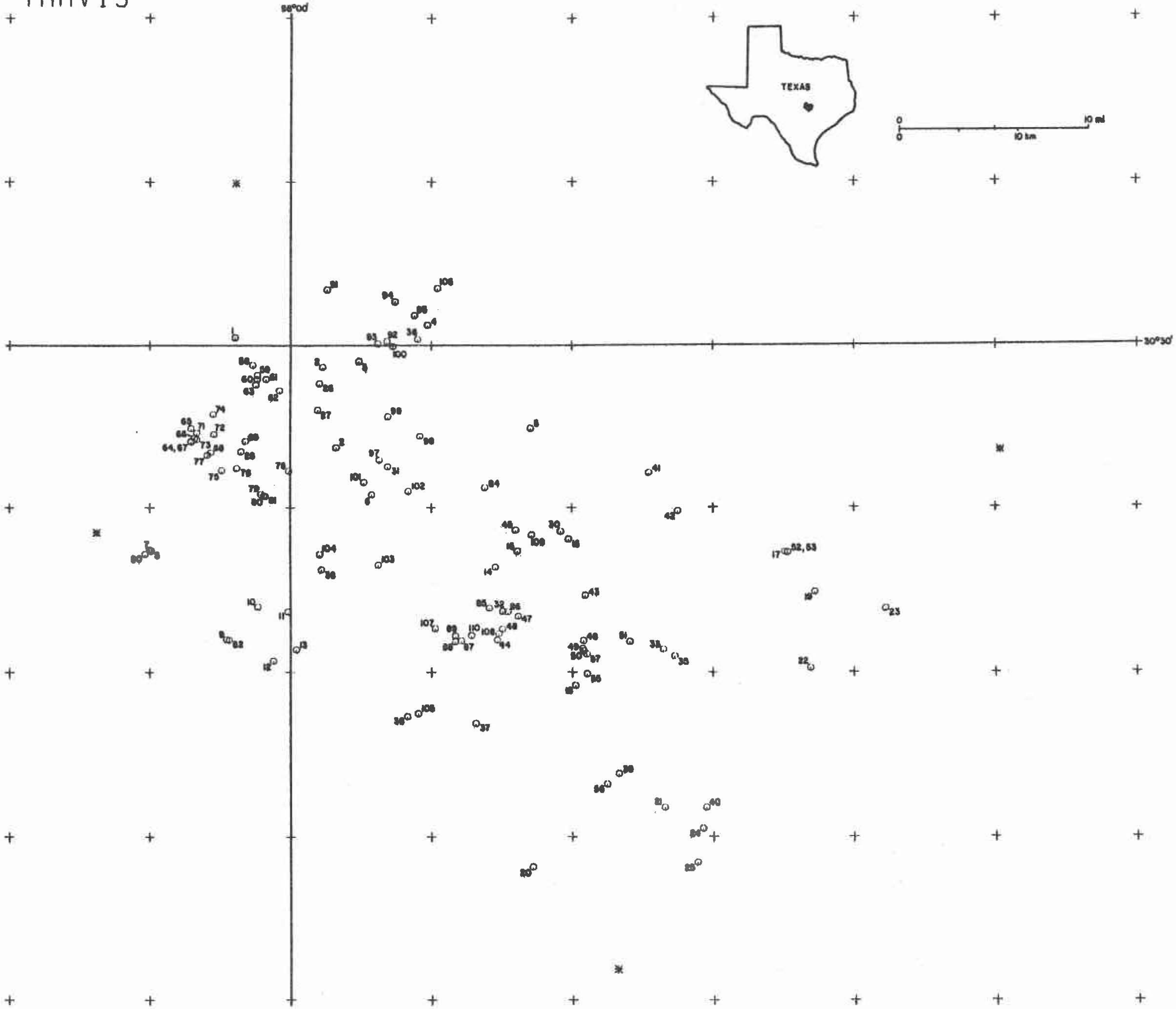
COUNTY: JJ:EDWARDS

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	141.	7318.	12/11/1952			/ /		/ /	
4		6512.	05/30/1948			/ /		/ /	
5	171.	9767.	07/02/1954			/ /		/ /	

COUNTY: ZX:ZAVALA

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	148.	7290.	01/04/1955			/ /		/ /	

TRAVIS



COUNTY: YD:TRAVIS

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	57-32-804	A	SHELL DEVEL		HENSEL RANCH	S	09/ /1953	214.	870.
2	58-33-103	B	STERZING DRLG CO	1	S WHELESS	W	09/20/1962	927.	1220.
3	58-33-201	B	POWERS PROD	1	E A JONES		07/09/1953	2999.	855.
4	58-25-911	B	CROUCH	1	TEJAS LAND + DEVL	WN	04/05/1972	940.	1080.
5	58-34-603	B	STERZING	1	BALCONES COUNTRY CLB	W	11/ /1960	1100.	940.
6	58-33-805	B	CENTRAL TEXAS DRLG		APACHE SHORES SUB	W	04/29/1968	720.	780.
7	57-48-102	A	SHELL MASON-JHNSTN	1	HMLTN POOL REIMERS	S	06/ /1953	152.	824.
8	57-48-103	A	SHELL DEVEL CO	2	HAMILTON POOL	W	08/ /1953	145.	928.
9	57-48-801	B	TWDB	2	JAMES KELLY		/ /	715.	1220.
10	57-48-601	B	SHELL DEVEL CO		TOM JOHNSON	OW	05/16/1973	1173.	1173.
11	57-48-601	B	KELLY	1	SHIELDS	WN	/ /1952	930.	1190.
12	57-48-901	B	STERZING	2	SHIELDS	WN	08/09/1954	960.	1060.
13	58-41-701	B	GEORGE SPRING	1	SHIELDS HQ	W	10/11/1967	628.	950.
14	58-42-502	B	LAYNE TEXAS CO	1	ST STEPHEN SCHOOL	WP	06/17/1949	1015.	753.
15	58-42-203	B	TX WATER WELLS INC	1	DAVENPORT	W	02/05/1951	1127.	600.
16	58-42-303	B	GLASS	1	TX CRUSHED STONE		01/11/1959	1290.	790.
17	58-44-204	A	SINGER-LAYNE TX	2	CITY OF MANOR	WP	06/26/1974	3258.	524.
18	58-51-102	A	LAYNE TEXAS		CITY OF AUSTIN STACY	WP	04/16/1969	2246.	530.
19	58-44-601	A	BREWSTER + BARTLE	1	E TUCKER	WN	12/12/1952	3250.	608.
20	58-58-3	D	MOBIL OIL	1	MINNIE BELL HEEP		03/24/1969	2606.	711.
21	58-51-801	B	G L REASOR	1	EZELL		12/19/1952	3389.	530.
22	58-44-901	A	TAMOL OIL	2	BURLESON		05/04/1949	1550.	410.
23	58-45-4	D	H E GOFF	1	J LOCKWOOD		10/10/1950	2035.	486.
24	58-51-9	D	ANDERSON-PRICHARD	5	F BLOMQUIST		08/03/1952	1519.	544.
25	58-59-301	B	WOODWARD ET AL	1	NELSON		01/26/1955	3772.	610.
26	58-33-102	C	SANDERS		C P HARRIS	WP	/ /	600.	
27	58-33-404	C				W	/ /	305.	
28	57-40-505	B	FARRER		WALLACE HARSCH	W	09/19/1963	207.	720.
29	58-33-403	B	SHEPLER		LAKE SHORE ACRES	W	/ /1965	462.	770.
30	58-42-302	C	JOHNSON DRLG + SPLY		M E HART	W	/ /	1135.	
31	58-33-808	B		2	TRAVIS LANDING SUBDI	W	/ /	.	750.
32	58-42-507	C	STERZING DRLG CO		R E JONES	W	/ /	1045.	
33	58-43-802	C				W	/ /	11.	
35	58-43-911	C				W	/ /	40.	
36	58-49-320	C				W	/ /	390.	
37	58-50-108	C				W	/ /	235.	
38	58-41-403	B		2	CHAS GLASS		/ /	816.	1180.
39	58-51-502	C				W	/ /	152.	
40	58-51-901	C	ALLEN + STOLLEY		C PHILQUIST	W	/ /	3008.	
41	58-35-803	A			A W COX	WN	/ /1900	1400.	
42	58-43-303	A	B F PAYTON		B F PAYTON	WN	/ /1940	1456.	645.
43	58-43-401	A	MCGILLVRAY		STATE OF TEXAS	WD	/ /1895	1975.	635.
44	58-42-803	B			R D JOHNSON	W	/ /	.	760.
45	58-42-207	B			JOE F GRAY	W	/ /	735.	930.
46	58-43-702	A			STATE OF TEXAS	WP	03/08/1890	1554.	
47	58-42-503	B	CHAS CALHOUN	2	FRED MORRIS	W	/ /	.	685.
48	58-42-805	B	S W GLASS		EANES SCHOOL	W	/ /1954	876.	
49	58-43-703	A			DRISKILL HOTEL	WN	/ /1900	2250.	
50	58-43-704	A	MCGILLVRAY		F B PERRY	WN	/ /1899	2025.	485.
51	58-43-801	A			S SMITH + MENKING	WN	/ /1916	1147.	

COUNTY: YD:TRAVIS

UNIQUE NO	BHT	DEPTH AT	DATE (MG/L)	AQUIFER	WELLHEAD	DATE		TDS	TDS/TEMP
1			/ /			/ /		/ /	
2		926.	09/05/1962			/ /		/ /	
3	100.	2999.	07/09/1953			/ /		/ /	
4		936.	04/05/1972			/ /		/ /	
5		1100.	07/05/1967			/ /		/ /	
6		692.	04/29/1968			/ /		/ /	
7			/ /			/ /		/ /	
8			/ /			/ /		/ /	
9		712.	/ /			/ /		/ /	
10		1130.	/ /			/ /		/ /	
11	96.	928.	/ /1952			/ /		/ /	
12		821.	/ /			/ /		/ /	
13		628.	/ /			/ /		/ /	
14		1015.	/ /			/ /		/ /	
15	99.	1127.	02/05/1951			/ /		/ /	
16		1250.	/ /			/ /		/ /	
17	120.	3251.	06/26/1974	269	43.3	01/25/1980		/ /	TDWR WS NURE
18	97.	1633.	04/16/1969	269	37.	01/29/1980	1528	08/18/1972	TDWR WELL SCHEDULE CW
19	130.	4507.	12/02/1952	269	94.	06/01/1966	2250	06/01/1966	TWDB R195
20	120.	2600.	03/24/1969			/ /		/ /	
21		3309.	/ /			/ /		/ /	
22		1550.	/ /1949	066		/ /		/ /	TBWE B5708
23	110.	2030.	10/10/1950			/ /		/ /	
24	103.	1585.	08/03/1952			/ /		/ /	
25	117.	3771.	01/26/1955			/ /		/ /	
26			/ /	082	84.	/ /		/ /	TWDB R195
27			/ /	080	80.	08/27/1970	518	08/27/1970	
28		207.	/ /	385	80.	10/08/1970	385	10/08/1970	
29		456.	05/08/1967			/ /		/ /	
30			/ /	385	80.	06/11/1971	2676	03/12/1974	TWDB R195
31	78.	686.	12/17/1970			/ /		/ /	
32			/ /	269	81.	/ /	1091	05/14/1955	TWDB R195
33			/ /	292	80.	03/22/1971	183	03/22/1971	
35			/ /	001	85.	03/22/1971	477	03/22/1971	
36			/ /	080	80.	03/11/1971	2864	03/11/1971	
37			/ /	066	80.	08/27/1970	411	08/27/1970	
38	78.	815.	05/21/1970			/ /		/ /	
39			/ /	396	80.	03/18/1971	246	03/18/1971	
40			/ /	269	100.	08/19/1937	2741	08/19/1937	TWDB R195
41			/ /	269		/ /	436	03/14/1974	CW
42		1456.	/ /	248	30.6	03/21/1980	3073	03/12/1940	CW
43		1975.	/ /	269		/ /	1388	10/01/1941	CW TWCP B5708
44		897.	05/11/1955			/ /		/ /	
45		723.	02/05/1971			/ /		/ /	
46			/ /	319	28.	02/05/1980	1539	10/02/1972	CW TWDB R195
47		935.	04/05/1955			/ /		/ /	
48		695.	/ /			/ /		/ /	
49			/ /	269	95.	05/17/1966	1497	05/17/1966	CW TWCPB5708 TWDBR195
50		2025.	/ /	385	100.	09/08/1937	1746	09/08/1937	CW TWCPB5708 TWDBR195
51			/ /	285	26.7	04/14/1980	4759	10/29/1964	CW TWCPB5708 TWDBR195

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
52	58-44-201	A	W B HINTON		CITY OF MANOR	WN	/ /1936	3001.	535.
53	58-44-202	A	EPPRIGHT/MCGILLVRAY		CITY OF MANOR	WD	/ /1895	2560.	
55	58-51-103	A	GARRICK		O O NORWOOD	WH	/ /1929	1595.	475.
56	58-51-701	A	E NALLE ET AL.		D COLLINS	WS	/ /1920	2425.	
57	58-43-708	A			SO PACIFIC TRANS CO	WN	/ /	.	
58	57-40-301	B	STERZING		V E GROVE	W	09/20/1965	425.	970.
59	57-40-302	B	FARRER		BRIDGEWATER	W	12/12/1963	180.	715.
60	57-40-303	B	STERZING		E BONE	W	/ /	210.	695.
61	57-40-304	B			GIRL SCOUTS OF AMER	W	03/04/1966	256.	720.
62	57-40-305	B	STERZING		HIGHLND LKS BAPTIST	W	/ /1957	362.	765.
63	57-40-308	B	POWELL		HAGEL PHILLIP	W	05/08/1974	192.	700.
64	57-40-401	B	STERZING		REID	W	01/14/1967	135.	700.
65	57-40-402	B	FARRER		I W MCELROY	W	03/08/1963	215.	740.
66	57-40-404	B	GLASS		G MARTIN	W	04/26/1970	176.	720.
67	57-40-405	B	GLASS		J ROYE	W	08/12/1969	175.	730.
68	57-40-503	B	FARRER		M B O'DELL	W	09/18/1963	180.	720.
69	57-40-601	B	FARRER		B BROWDER	W	05/16/1963	193.	700.
71	57-40-507	B	GLASS		GRIFFIN	W	04/28/1969	106.	750.
72	57-40-508	B	STERZING		REED	W	05/05/1966	170.	720.
73	57-40-509	B	MCDONALD		FORD	W	04/01/1975	234.	781.
74	57-40-510	B	BIBLE		FOSTER	W	06/ /1976	160.	720.
75	57-40-801	B	CENTRAL TEXAS		TINER	W	09/ /1967	305.	820.
76	57-40-802	B	CENTRAL TEXAS		BRIARCLIFF	W	06/26/1967	370.	850.
77	57-40-804	B	A+A		CLABAUGH	W	05/01/1969	155.	720.
78	57-40-904	B		2	ED GRAHAM	W	04/ /1970	277.	770.
79	57-40-909	B	A+A		NORMAN	W	07/20/1969	275.	720.
80	57-40-906	A	BONNETS		EVANS	W	03/23/1970	266.	715.
81	57-40-910	B	MCDONALD		DEALY	W	12/16/1971	279.	715.
82	57-48-801	B	CENTRAL TEXAS		KELLEY/DEER CK RANCH	D	/ /1968	870.	1220.
84	58-34-802	B	CROUCH		FEED LOT RESTAURANT	WN	06/ /1972	950.	1000.
85	58-42-501	B	FARRER		WESTLAKE WS CORP	N	04/14/1954	941.	990.
86	58-42-504	B	GLASS		SHELDON	WN	07/ /1954	786.	740.
87	58-42-702	A	GLASS/BIBLE		LOST CK GOLF CLUB	W	02/ /1972	560.	620.
88	58-42-705	A	BIBLE	2	LOST CK CNTRY CLB	W	03/ /1972	525.	525.
89	58-42-706	A	BIBLE	3	LOST CK CNTRY CLB	W	04/ /1972	530.	530.
90	57-47-301	B	SUMMEROW	1	REIMERS	ON	/ /1926	1274.	800.
91	58-25-402	A	GRIFFIN	1?	RODGERS(SUNSET RNCH)	ON	/ /1921	1500.	1024.
92	58-25-901	A	POWELL	A	BARNES-JONES	W	04/ /1966	643.	815.
93	58-25-804	A	POWELL		JONESTOWN HILLS	WP	07/ /1972	615.	925.
94	58-25-910	B	TRULL (GOFF?)	1	BASDALL GARDNER	ON	/ /1952	730.	880.
95	58-25-907	B	WRIGHT		BASDALL GARDNER	W	/ /	675.	775.
96	58-25-913	B	ARNOLD		DAVIS		/ /	840.	1050.
97	58-33-806	B	WRIGHT	1	TRAVIS LNDING SDIV#2	WP	12/ /1970	875.	860.
98	58-33-609	B	STERZING/WRIGHT		KRUEZ	W	07/ /1967	709.	730.
99	58-33-615	B	WRIGHT		POWELL	W	06/ /1967	675.	720.
100	58-33-303	A	STERZING		HORTON		04/30/1965	530.	720.
101	58-33-802	B	STERZING		CLARK	W	/ /1953	641.	820.
102	58-33-902	B	JOHNSON		BUREAU RECLAMATION	N	06/ /1937	716.	750.
103	58-41-513	A	SANDERS		RIVER BRIDGE WS	WP	02/ /1973	430.	600.
104	58-41-101	B	GLASS		DOULIE	W	10/16/1965	600.	920.

COUNTY: YD:TRAVIS CONTINUED

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H20 TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
52		3001.	/ /	269	110.	03/20/1941	1910	12/23/1946	TBWE B5708 TWDB R195
53			/ /	180	93.	/ /		/ /	TBWE B5708 TWDB R195
55		1595.	/ /		33.3	04/11/1980	1239	07/27/1961	TWDB R195
56			/ /	269	34.4	04/04/1980	2202	08/08/1949	TWDB R195 TDWR PO ACR
57			/ /			/ /	10100	09/05/1975	TDWR WS
58			/ /			/ /		/ /	
59		180.	/ /			/ /		/ /	
60			/ /			/ /		/ /	
61			/ /			/ /		/ /	
62			/ /			/ /		/ /	
63			/ /			/ /		/ /	
64			/ /			/ /		/ /	
65		215.	/ /			/ /		/ /	
66			/ /			/ /		/ /	
67			/ /			/ /		/ /	
68		180.	/ /			/ /		/ /	
69		193.	/ /			/ /		/ /	
71		106.	/ /			/ /		/ /	
72		170.	/ /			/ /		/ /	
73		234.	/ /			/ /		/ /	
74		160.	/ /			/ /		/ /	
75		305.	/ /			/ /		/ /	
76		370.	/ /			/ /		/ /	
77		155.	/ /			/ /		/ /	
78		277.	/ /			/ /		/ /	
79		275.	/ /			/ /		/ /	
80		266.	/ /			/ /		/ /	
81		279.	/ /			/ /		/ /	
82		870.	/ /			/ /		/ /	
84		950.	/ /			/ /		/ /	
85		931.	/ /			/ /		/ /	
86		786.	/ /			/ /		/ /	
87		543.	/ /			/ /		/ /	
88		525.	/ /			/ /		/ /	
89		530.	/ /			/ /		/ /	
90		1134.	/ /			/ /		/ /	
91			/ /			/ /		/ /	
92		557.	/ /			/ /		/ /	
93		615.	/ /			/ /		/ /	
94		730.	/ /			/ /		/ /	
95		675.	/ /			/ /		/ /	
96		843.	/ /			/ /		/ /	
97		840.	/ /			/ /		/ /	
98		663.	/ /			/ /		/ /	
99		575.	/ /			/ /		/ /	
100		530.	/ /			/ /		/ /	
101		641.	/ /			/ /		/ /	
102		716.	/ /			/ /		/ /	
103		430.	/ /			/ /		/ /	
104		577.	/ /			/ /		/ /	

COUNTY: YD:TRAVIS CONTINUED

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
105	58-49-304	B			JACK MANN		/ /	754.	930.
106	58-26-404	B			LEANDER LIMESTONE		/ /		1110.
107	58-42-701	B	SHELL?	1	COOK(E?) J-22	OW	/ /1931	1835.	775.
108	58-42-802	B	CLEMENTS/GLASS		BIRDWELL(CNTRY DAY)	WP	/ /1946	1043.	740.
109	58-42-301	B	JOHNSON		BOY SCOUTS OF AMER	WP	/ /	852.	520.
110	58-42-703	A	CENTRAL TEXAS		LOST CK DEVELOPMNT	WP	/ /1972	620.	680.

COUNTY: LR:HAYS

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	57-47-601	B	RUDMAN	1	HURLBUT	O	/ /	4620.	864.
3	58-49-114	B	TWDB	1	J C STANLEY	W	/ /	850.	1120.
9	58-58-902	B	WOODWARD	1	SCHUBERT	O	/ /	3297.	584.
12	58-58-4	D	BOB ANTIBUS	1	J HOWE		/ /1939	2380.	750.

COUNTY: BU:CALDWELL

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	58-59-801	D	WOODWARD	1	KING	O	/ /	4439.	585.

COUNTY: AT:BASTROP

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
1	58-59-602	B	SKELLY AND SUNRAY	1	RAY		/ /	3928.	595.

COUNTY: YD:TRAVIS CONTINUED

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
105		754.	/ /			/ /		/ /	
106		803.	09/13/1966			/ /		/ /	
107		1835.	/ /			/ /		/ /	
108		1043.	/ /			/ /		/ /	
109		842.	/ /			/ /		/ /	
110		620.	/ /			/ /		/ /	

COUNTY: LR:HAYS

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	138.	4624.	08/25/1970			/ /		/ /	
3	78.	847.	04/29/1970			/ /		/ /	
9	111.	3295.	02/10/1955			/ /		/ /	
12			/ /			/ /		/ /	

COUNTY: BU:CALDWELL

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	124.	4438.	04/20/1955			/ /		/ /	

COUNTY: AT:BASTROP

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
1	123.	3929.	11/14/1956			/ /		/ /	

COUNTY: ZK:WILLIAMSON

UNIQUE NO	STATE WELL NUMBER	SOURCE VERA.	WELL OPERATOR	WELL NUMBER	WELL OWNER	WELL USE CODE	COMPLETION DATE	WELL DEPTH (FT)	GROUND ELEV (FT)
10	58-26-1	D	J M WRIGHT	1	CITY OF LEANDER	W	/ /	688.	985.
14	58-27-8	D	L HENNA ET AL	2	ALSABROOK	O	/ /	2333.	750.
17	58-28-901	B	W M JARRELL	1	AVERY ET AL	O	/ /	2953.	657.
19	58-29-609	A		5	CITY OF TAYLOR	WP	/ /1971	3373.	550.

COUNTY: ZK:WILLIAMSON

UNIQUE NO	BHT (F)	DEPTH AT BHT (FT)	DATE LOGGED	AQUIFER CODE	WELLHEAD H2O TEMP (F)	DATE MEASURED	TDS (MG/L)	TDS DATE	TDS/TEMP SOURCE
10		675.	04/18/1969			/ /		/ /	
14	102.	2333.	03/04/1948			/ /		/ /	
17	110.	2953.	06/03/1950			/ /		/ /	
19	128.	3368.	06/19/1971	269	48.	04/28/1980		/ /	NURE