WM r/f (106)
WMGT r/f
NMSS r/f
REBrowning
MBell
HMiller
TVerma
JLinehan, WMRP
RJohnson
JKennedy
SBillhorn
MRKnapp
PSJustus
MFliegel
JTrapp & r/f
RLee
AIbrahim
FRoss
JGreeves
MTokar
JPearring
PDR

JAN 15 1986

STRUCTURE TRIP REPORT

MEMORANDUM FOR: Malcolm Knapp, Chief
WMGT

FROM: John Trapp, Richard Lee, Abou-Bakr Ibrahim, and Fred Ross, WMGT

SUBJECT: TRIP REPORT - STRUCTURE AND TECTONICS OF THE PALO DURO BASIN: MEETING WITH DOE AND THEIR CONTRACTORS

On November 19-21, 1985, members of WMGT staff and their technical assistance contractors met with DOE and their contractors at the Parke University Motel in Columbus, Ohio to discuss the geologic structure of the Palo Duro Basin, Texas.

The purpose of the meeting was to examine the existing data that serves as the basis for interpretations of structural features in the Palo Duro Basin as presented in DOE contractor reports. The emphasis of the meeting was to evaluate the structural configuration and tectonic history of the basin. Principle meeting objectives were to determine the availability of data for structural interpretations, the differences in published interpretations, the significance of these differing interpretations, and methods for resolving these differences.

Enclosed are copies of the list of meeting attendees (Enclosure 1), the meeting agenda (Enclosure 2), the signed meeting summary (Enclosure 3), and copies of all presentation materials (Enclosure 4). Since these enclosures are quite extensive, they have only been provided to Mr. Browning and the DCC. Additional copies are available in the offices of Robert Johnson and John Trapp.

/S/
John Trapp, WMGT

/S/
Richard Lee, WMGT

/S/
Abou-Bakr Ibrahim, WMGT

/S/
Fred Ross, WMGT

8606160002 860115
PDR WASTE
WM-16 PDR

WM Record File: 106
WM Project: 16
Docket No.
PDR ✓
LPDR ✓
Distribution:
(Return to WM, 623-SS)

Enclosures:
As Stated

:WMGT	:WMGT	:WMGT	:WMGT	:	:	:
:JTrapp;mt	:RLee	:AIbrahim	:FRoss	:	:	:
:86/01/14	:86/01/14	:86/01/14	:86/01/	:	:	:

1323

See memo to Knapp fm. Kapp 1/15/86

SUMMARY OF NRC/DOE MEETING
ON THE
STRUCTURE AND TECTONICS OF THE PALO DURO BASIN

106

Date/Location
November 18-21, 1985
Park University Hotel
Columbus, OH

Attendees/Organizational Affiliation
A list of attendees and their organizational affiliations is attached as Enclosure 1.

Background/Facts
The meeting agenda (Enclosure 2) gives the meeting objectives and the topics discussed and the name and affiliation of the presentors. Enclosure 3 consists of all of the handouts and copies of the viewgraphs presented; each package is identified by the person making the presentation and a number which is shown on Enclosure 2. During the course of the meeting proprietary and DOE aquired seismic reflection data were made available for review. Enclosure 4 lists which portions of this data were reviewed by NRC staff and contractors.

Observations

The NRC had the following observations:

1. A significant amount of data available for structural interpretations of the Palo Duro Basin consists of boring logs of oil exploration wells and seismic surveys conducted for oil exploration. As part of site screening activities of the entire basin, project specific seismic data were obtained utilizing acquisition parameters which emphasize resolution in the approximate 2000 to 6000 ft. depth range. As such, the inherent uncertainty and limitations of these data for detailed structural analysis are recognized particularly with respect to near-surface strata.

2. The nature and distribution of the seismic and boring data are such that some variations in interpretations are possible for both the data and the resultant structural features.

3. Some available seismic data and remote sensing imagery, such as landsat and aerial photographs, do not appear to have been fully utilized. Much seismic data are proprietary in nature, and when approached by DOE contractors, the oil companies have refused to release the data. Other seismic data are known by DOE to be available from brokers; however, the quality and usefulness of this data is not well known. DOE should consider evaluating the availability and usefulness of all seismic data to determine if they can be obtained and if they are worth obtaining to assist in structural interpretations. It should be recognized that NRC has defined procedures for dealing with proprietary data. DOE may also wish to consider obtaining and evaluating other available remote sensing data such as various types and scales of aerial photography and radar imagery.

4. In the development of their site characterization plans DOE should consider developing a comprehensive integration of the available data. The following data elements have been addressed to some degree; however, NRC considers the integration effort should include:

   a. Development of a conceptual regional tectonic model(s) to evaluate various structural interpretations.

   b. Evaluations of the possible effects of strike-slip faulting including both the ability to recognize such features and their effect on structural interpretations.

   c. Evaluations of the role of the Matador Arch and Oldham Nose in the regional tectonic setting.

   d. Evaluations of the relationship between fracture patterns observed in boreholes, outcrops, and remote sensing data including the limitations of the various methods in recognizing these features.

   e. Modelling of gravity and magnetic data.

   f. Evaluations of potential reactivation of structural features through geologic time including the upward change in structural expression such as progression from faulting to folding to fracturing which may be expected and variations in fracture density and orientations over areas of deep faults in comparison with unfaulted areas.

   g. Providing more emphasis on evaluating the presence or absence of folds and their role in the tectonic history of the area.

   h. Resolving difficulties in identifying basement.

   i. Reevaluation of the boundaries and the resultant effect of the regional stress field between the approximately N 70^{o} E maximum horizontal stress field of the mid continent to the approximately N-S stress field of the Rio Grande rift.

5. It appears that DOE's contractors have made significant progress in developing and implementing a viable QA program; however, NRC questions if traceability of information from study to study can yet be demonstrated. From the meeting presentations, it is NRC's impression that each study is providing some checks and documentation; however, there appears to be little to no effort to cross-check from one study to another. Examples that arose during the meeting include: criteria used to identify faults on seismic lines, criteria used to eliminate or modify faults presented in the published literature and subcontractor reports and criteria to select stratigraphic "picks" from borehole logs. DOE may wish to have its QA personnel consider this concern.

6. When planning for seismic reflection surveys NRC believes that:

   a. Expanded coverage with seismic refraction profiling may provide much useful information concerning lateral and vertical variations of velocity values. Such information could be useful for 1) drill hole location optimization, 2) geohydrology characterization, and 3) planning of seismic reflections lines and evaluation of shallow reflection anomalies.

   b. Dual programs may be desirable in certain areas to provide both shallow and deep structural data.

   c. Shallow (less than 2000 feet) surveys should be considered in selected areas where the Alibates Fm is known to be faulted.

7. DOE should consider the usefulness and applicability of electrical and electromagnetic surveys in resolving structural and geohydrologic concerns.

8. Based on the DOE presentations of general types of planned site characterization studies, it appears to the NRC that current planning is focusing on developing site specific studies. It is not as apparent that the same attention has been given to also developing regional investigations important to understanding site performance. During future meetings in which proposed studies are discussed this subject needs additional clarification. This subject should be evaluated in light of the performance objectives of 10 CFR 60.

9. The NRC staff appreciates the effort of DOE in making available at this meeting the key personnel involved in the structural evaluation of the Palo Duro Basin. The knowledge and candor of the presentors helped assure the success of the meeting in accomplishing its objectives. The NRC staff wishes to thank all DOE participants for their effort.

The DOE had the following observations:

1. A common data base has been available to all SRP investigators for use in structural and stratigraphic interpretation; each study has utilized selected portions of the data base. The regional nature of the currently available borehole information and seismic surveys permit conflicting structural interpretations.

2. SRP recognizes a need to develop a uniform approach to evaluation and interpretation of geotechnical data (i.e., criteria for (1) picking formation "tops" from geophysical logs, (2) picking faults on Palo Duro seismic sections, (3) assigning geologic horizons to seismic data, and (4) "time to depth" conversions.)

3. It is important to obtain seismic data optimized for both basement structure and shallow structures (repository horizon and above). These two needs lead to conflicting requirements for data acquisition parameters if a single seismic survey is to be used. Consideration should be given to separate surveys for deep and shallow data.

4. The exploration geophysics industry (particularly seismic), is needed by the program because of their expertise, capital equipment, and software. However, the industry's procedures and software are largely proprietary and do not fully comply with the program's general requirements for QA. Nor can the industry be expected to comply by revealing their proprietary programs. Some agreement between NRC and SRP is desirable before site characterization activities to identify the acceptable applications of industry data.

5. The uncertainty in structural maps should be explicitly stated rather than relying solely on the indicated distribution of data points to suggest areas of greater or lesser control.

6. DOE needs to resolve the level of detail needed in structural tectonic models necessary at different phases prior of pre-licensing studies. Specifically, the interpretation of structures within the tectonic framework and the evaluation of performance objectives must be related to uncertainties inherent in the model.

7. There is the need to clearly define the implications to site performance of tectonism during various geologic periods.

8. Site studies require integration to achieve consistent conceptual models of geology, structure, and hydrology (e.g., structural control of geomorphic processes and depositional patterns, and interrelationship of the geologic framework to hydrogeologic processes.

9. Available remote sensing data have not been utilized and completely evaluated.

10. This meeting demonstrates the desireability of early technical interchanges between DOE and NRC to discuss existing data and uncertainties in interpretations. Such discussions are valuable to expedite the later review of the SCP.

11. It was noted that relatively little information exists concerning the Dockum Formation across the entire panhandle. Some approaches to enhancing our understanding of this unit include geological and structural mapping in areas of exposure (e.g., Canadian River Valley), and shallow reflection/refraction seismic surveys.

SUMMARY OF NRC/DOE MEETING
ON THE
STRUCTURE AND TECTONICS OF THE PALO DURO BASIN

Observations

The NRC had the following observations:

1. A significant amount of data available for structural interpretations of the Palo Duro Basin consists of boring logs of oil exploration wells and seismic surveys conducted for oil exploration. As part of site screening activities of the entire basin, project specific seismic data were obtained utilizing acquisition parameters which emphasize resolution in the approximate 2000 to 6000 ft. depth range. As such, the inherent uncertainty and limitations of these data for detailed structural analysis are recognized particularly with respect to near-surface strata.

   Response: DOE recognizes the inherent limitations of existing seismic data. The regional database was intended to provide a basis for screening large land areas to define preferred study sites for detailed characterization and as such, are reconnaissance in nature. As indicated in DOE Observation 3, it is important, during site characterization, to obtain seismic data optimized for both basement structure and shallow structures (repository horizon and above). These considerations are currently being addressed in the planning of site characterization seismic data acquisition.

2. The nature and distribution of the seismic and boring data are such that some variations in interpretations are possible for both the data and the resultant structural features.

   Response: This point is raised as DOE's Observation 1. The issue of greatest importance is the impact of any reasonable alternative interpretation on expected site performance. Site Characterization studies of local and regional structural elements will be based on overall site performance considerations (to be discussed in the SCP), not on questions of strictly academic interest. It may well turn out that the differing interpretations of regional structure based upon screening data have no impact on demonstrated release rates (and probabilities) from the candidate site.

3. Some available seismic data and remote sensing imagery, such as landsat and aerial photographs, do not appear to have been fully utilized. Much seismic data are proprietary in nature, and when approached by DOE contractors, the oil companies have refused to release the data. Other seismic data are known by DOE to be available from brokers; however, the quality and usefulness of this data is not well known. DOE should consider evaluating the availability and usefulness of all seismic data to determine if they can be obtained and if they are worth obtaining to assist in structural interpretations. It should be recognized that NRC has defined procedures for dealing with proprietary data. DOE may also wish to consider obtaining and evaluating other available remote sensing data such as various types and scales of aerial photography and radar imagery.

Response:

a. Available Seismic Data - DOE has obtained representative, good quality seismic data of the site and region. It is recognized that additional brokered data exists and is desirable, particularly north of the site and over the Amarillo uplift. Further significant data at the site do not seem available through open channels with oil companies. Also, much of the available data is not of a quality (resolution at depths of interest) to be very useful to the program. Regarding seismic data owned by oil and gas exploration firms, it may be possible, on a case by case basis, to examine either the raw data or interpretations, but it is unclear how these proprietary lines can be used in an open, public program. DOE will continue to pursue this matter with NRC staff.

b. Remote Sensing Imagery - Some investigation of both satellite imagery and aerial photography of the Palo Duro Basin region has already occurred. The site has been flown at a detailed scale to permit construction of topographic maps for engineering design. DOE has recently received a subcontractor evaluation of landsat imagery of the Palo Duro region, and is performing a technical review of this study. As a result of this review, it is anticipated that additional remote sensing imagery analyses can be recommended which will be of use to the Salt Repository Project. A recent flyover was made of the Deaf Smith site using Side-Looking Airborne Radar (SLAR). This imagery, when available, will be evaluted to further utilize remote sensing within the Salt Repository Project.

4. In the development of their site characterization plans DOE should consider developing a comprehensive integration of the available data. The following data elements have been addressed to some degree; however, NRC considers the integration effort should include:

   a. Development of a conceptual regional tectonic model(s) to evaluate various structural interpretations.

   b. Evaluations of the possible effects of strick-slip faulting including both the ability to recognize such features and their effect on structural interpretations.

   c. Evaluations of the role of the Matador Arch and Oldham Nose in the regional tectonic setting.

   d. Evaluations of the relationship between fracture patterns observed in boreholes, outcrops, and remote sensing data including the limitations of the various methods in recognizing these features.

   e. Modelling of gravity and magnetic data.

   f. Evaluations of potential reactivation of structural features through geologic time including the upward change in structural expression such as progression from faulting to folding to fracturing which may be expected and variations in fracture density and orientations over areas of deep faults in comparison with unfaulted areas.

g. Providing more emphasis on evaluating the presence or absence of folds and their role in the tectonic history of the area.

h. Resolving difficulties in identifying basement.

i. Reevaluation of the boundaries and the resultant effect of the regional stress field between the approximately N 70° E maximum horizontal stress field of the mid continent to the approximately N-S stress field of the Rio Grande rift.

Response: DOE agrees that it is desirable to provide an integrated geological analysis with the site description in the Chapters 1 through 4 of the Site Characterization Plan (SCP). The points raised in this observation will be considered to the extent possible in the SCP.

5. It appears that DOE's contractors have made significant progress in developing and implementing a viable QA program; however, NRC questions if traceability of information from study to study can yet be demonstrated. From the meeting presentations, it is NRC's impression that each study is providing some checks and documentation; however, there appears to be little to no effort to cross-check from one study to another. Examples that arose during the meeting include: criteria used to identify faults on seismic lines, criteria used to eliminate or modify faults presented in the published literature and subcontractor reports and criteria to select stratigraphic "picks" from borehole logs. DOE may wish to have its QA personnel consider this concern.

Response: DOE has expended considerable effort over the past serveral years to develop a consistent and coordinated Quality Assurance (QA) program which meets the requirements of NQA-1 and 10 CFR 50, Appendix B. QA provides the means of documenting how an activity was conducted, i.e., the steps taken in each analysis leading to a specific interpretation. The key is to understand how varying the data reduction method changes the overall interpretation. It is recognized that as the program enters the site characterization phase to collect licensing information, it will be necessary to focus on a single approach to data interpretation (e.g., defined criteria for selecting formation tops from E-logs) by all contract research groups. Appropriate procedures will be developed for site characterization analytical work. However, some flexibility will still need to be provided to allow alternative approaches to be considered.

6. When planning for seismic surveys NRC believes that:

a. Expanded coverage with seismic refraction profiling may provide much useful information concerning lateral and vertical variations of velocity values. Such information could be useful for 1) drill hole location optimization, 2) geohydrology characterization, and 3) planning of seismic reflections lines and evaluation of shallow reflection anomalies.

b. Dual programs may be desirable in certain areas to provide both shallow and deep structural data.

c. Shallow (less than 2000 feet) surveys should be considered in selected areas where the Alibates Fm is known to be faulted.

Response:

a. Cost-benefit considerations are a mandated part of the repository program. Both reflection and refraction programs are planned to address either specific issues or to provide needed support for other studies.

   (1) Lateral and vertical variations of seismic velocity are probably insufficient to have any influence on optimizing the siting of drill holes. Sites will be selected to optimize the intended purpose for each hole, such as stratigraphic or hydrologic studies. Limited seismic work will be used to indicate that anamolous conditions are not present. Targeting an anomaly would be an exception.

   (2) Hydrologists have indicated that the upper aquifer studies will require: elevations for the water table (available from existing water wells), the Ogallala-Dockum contact, and the base of the Dockum on about a 1/8-mile, or larger, grid. Variations in seismic velocity within the aquifer are not readily correlated with hydrologic parameters. The means to provide the desired data points will be considered in preparing the SCP.

   (3) The reflection work will desire datum statics from refraction arrivals as an integral part of the reflection program, or will use a specialized refraction program to address datum statics only.

b. Agree with NRC.

c. Agree with NRC.

Plans and rationale will be provided in the SCP and subject to NRC review.

7. DOE should consider the usefulness and applicability of electrical and electromagnetic surveys in resolving structural and geohydrologic concerns.

   Response: The type of investigations to be conducted during site characterization will be matched to the issues to be resolved and overall site performance objectives. The SRP Issue Resolution Strategy, which will be presented in Section 8.2 of the SCP, will describe the type of information necessary to address questions of site performance. Associated field study plans will present the approach to collecting that information. All available geophysical survey techniques will be considered, as appropriate.

8. Based on the DOE presentations of general types of planned site characterization studies, it appears to the NRC that current planning is focusing on developing site specific studies. It is not as apparent that the same attention has been given to also developing regional investigations important to understanding site performance. During future meetings in which proposed studies are discussed this subject needs additional clarification. This subject should be evaluated in light of the performance objectives of 10 CFR 60.

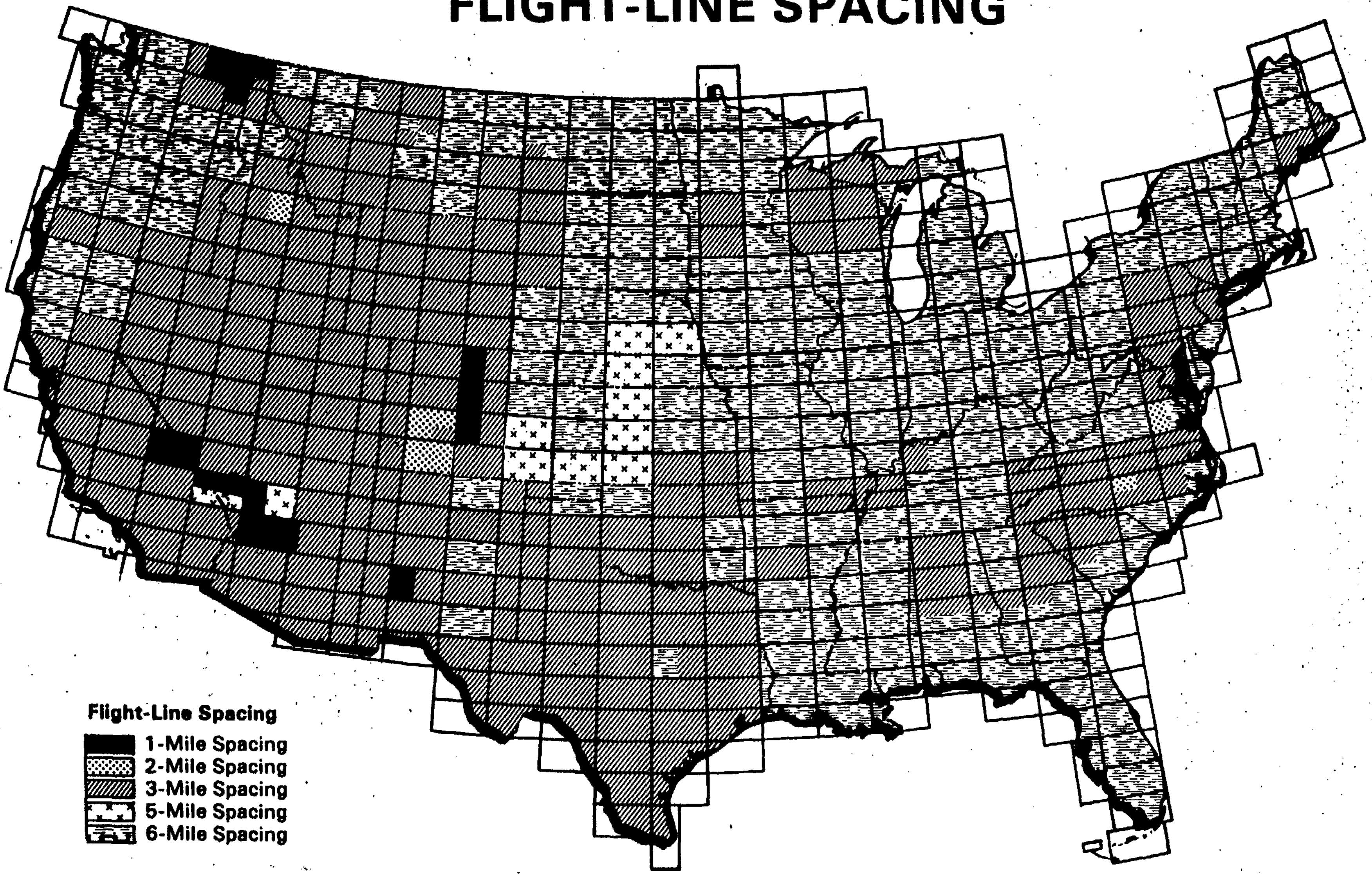
   Response: SRP agrees with the need to evaluate site performance within a regional geologic context. However, the necessary level of detail for regional understanding is not well defined at this time. The SCP for the candidate salt site will describe what is known of the regional geology and important alternative interpretations. Chapter 8 of the SCP will define site performance objectives, and list the issues to be resolved through site characterization studies in order to demonstrate a level of site performance. Additionally, Chapter 8 will present what is believed to be a reasonable set of activities, including regional studies, to assure issue resolution. We look forward to further interactions with the NRC on this subject to assure that all substantive concerns and recommendations are accomodated.

9. The NRC staff appreciates that effort of DOE in making available at this meeting the key personnel involved in the structural evaluation of the Palo Duro Basin. The knowledge and candor of the presentors helped assure the success of the meeting in accomplishing its objectives. The NRC staff wishes to thank all DOE participants for their effort.

   Response: SRPO concurs with the observation on the usefulness of this type of working meeting where all participants have an opportunity to discuss ideas in an open, professional environment. We would like to maintain this format for future discussions.

1. Contractor Supplied Data
2. Spike Filter
3. Critical Point Selection [GJBX 177(81)]
4. Line Adjust
5. Leveling
6. Coordinate Conversion
7. Gridding
8. Smoothing
9. Contouring
10. Drafting

NURE AERIAL RADIOMETRIC SURVEYS: FLIGHT-LINE SPACING



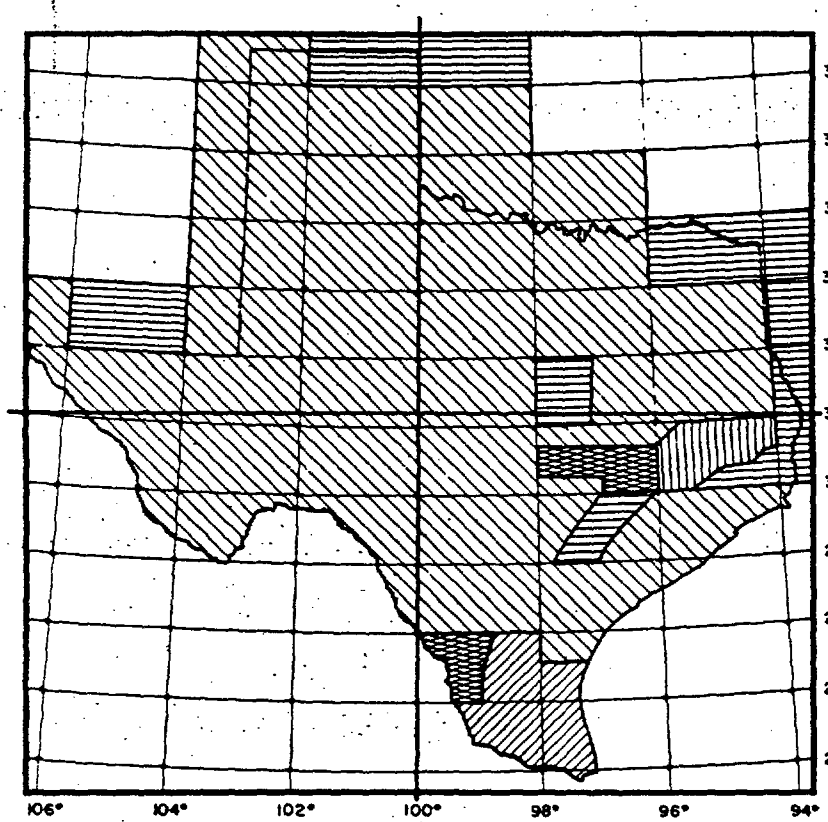
1293-10/83

28°

27°

26°

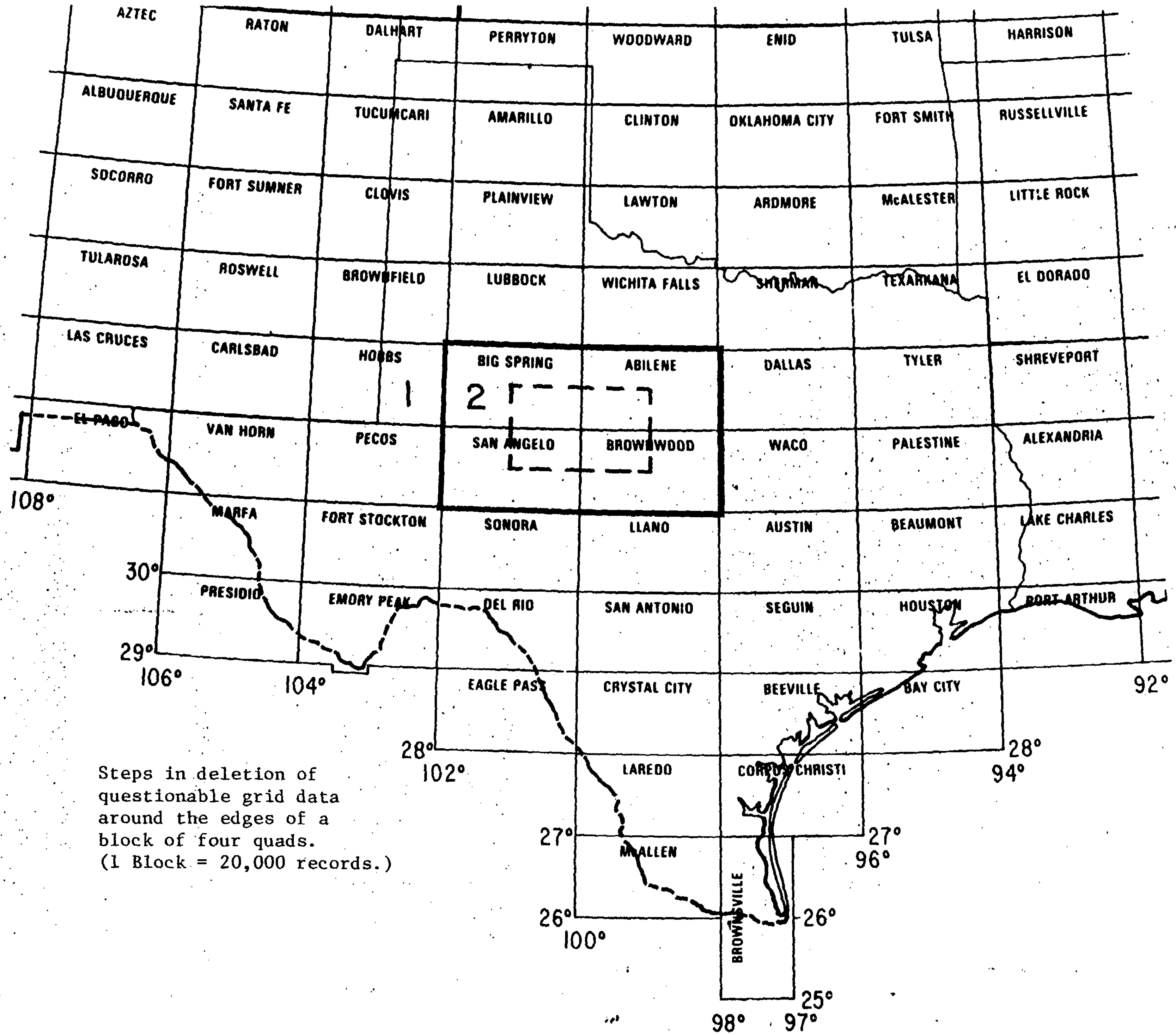
INDEX TO SOURCES OF DATA



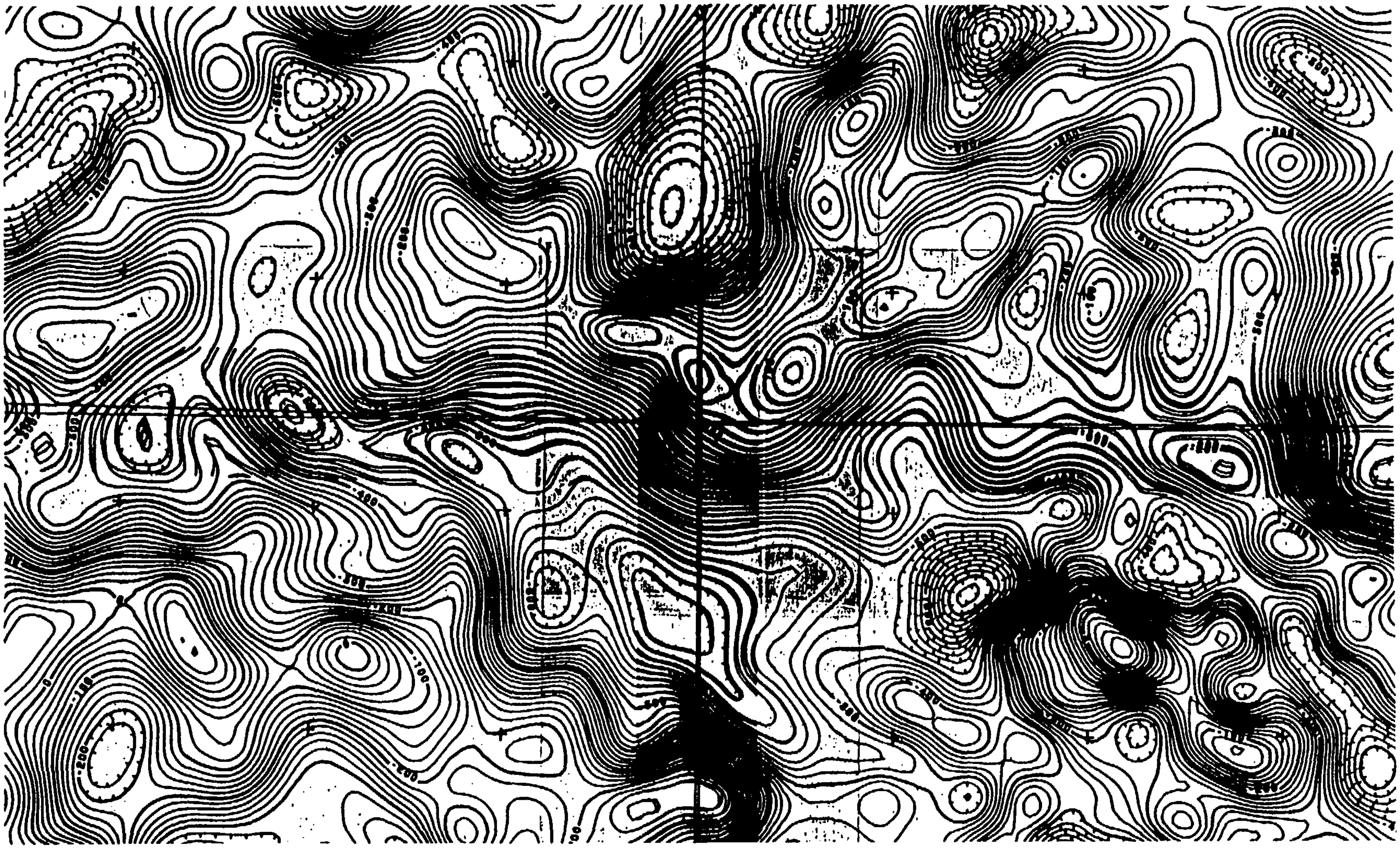
- U.S. Department of Energy, National Uranium Resource Evaluation Aeromagnetic Data—3 mile line spacing
- U.S. Department of Energy, National Uranium Resource Evaluation Aeromagnetic Data—5 or 6 mile line spacing
- U.S. Department of Energy, National Uranium Resource Evaluation Aeromagnetic Data—12 to 20 mile line spacing
- U.S. Atomic Energy Commission Aeromagnetic Data—5 mile line spacing
- Bureau of Economic Geology, University of Texas at Austin Aeromagnetic Data

96° 95° 94°

OMAGNETIC MAP OF TEXAS—SOUTHEAST SHEET



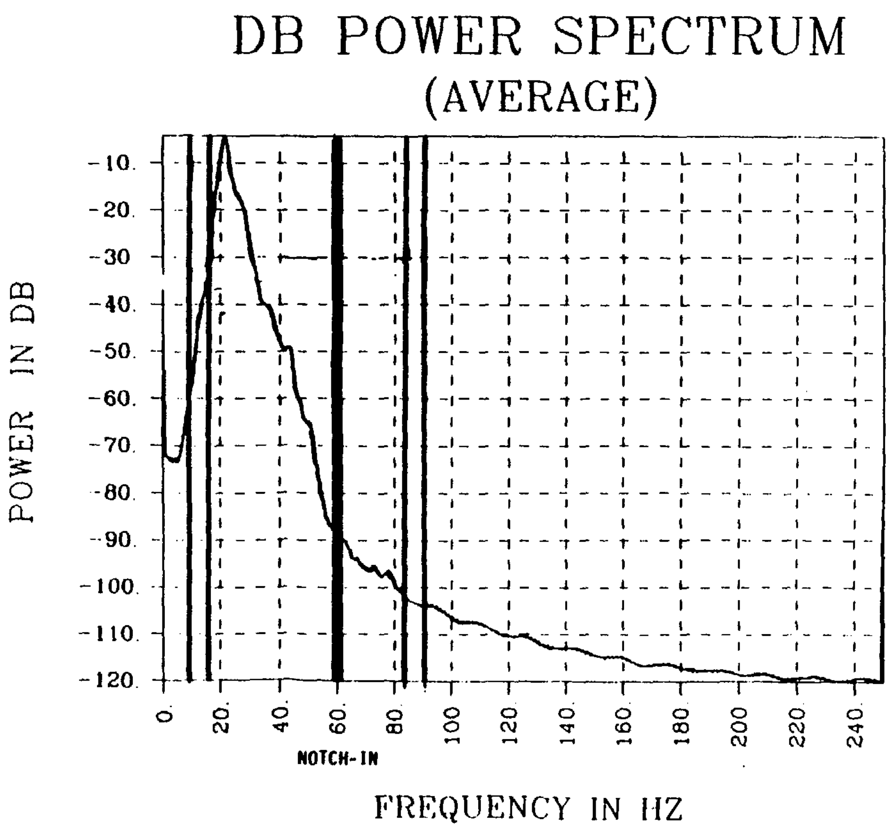
Steps in deletion of
questionable grid data
around the edges of a
block of four quads.
(1 Block = 20,000 records.)



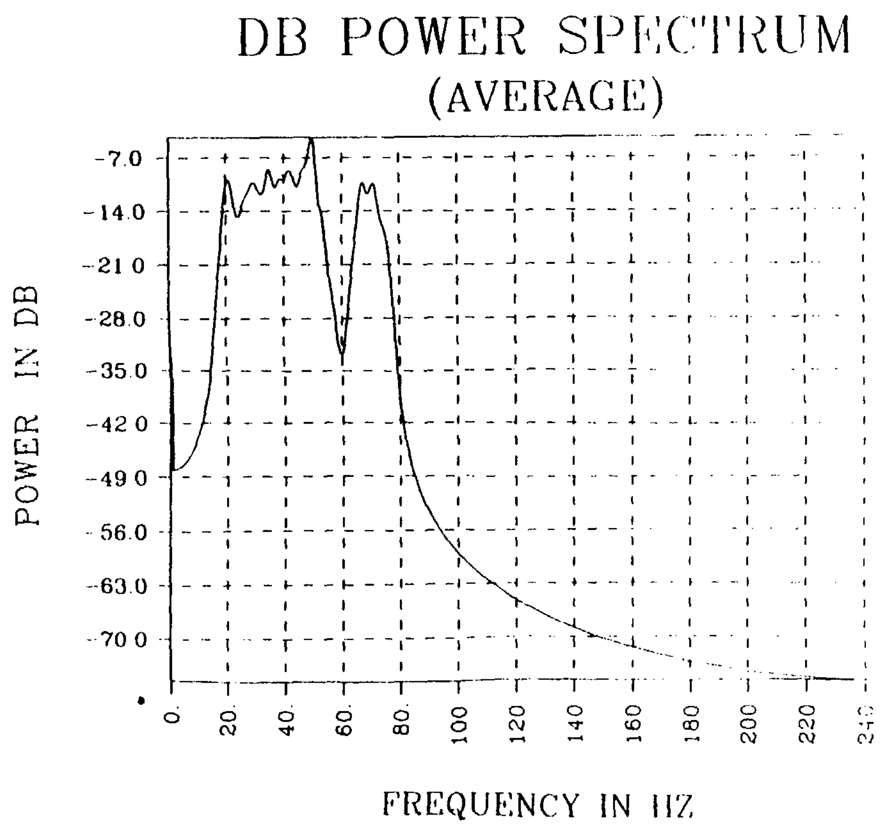
Demonstration of the ability of Bendix software to make separate maps that fit together. Shown are the portions of the four map sheets of the Texas map at their common corner.

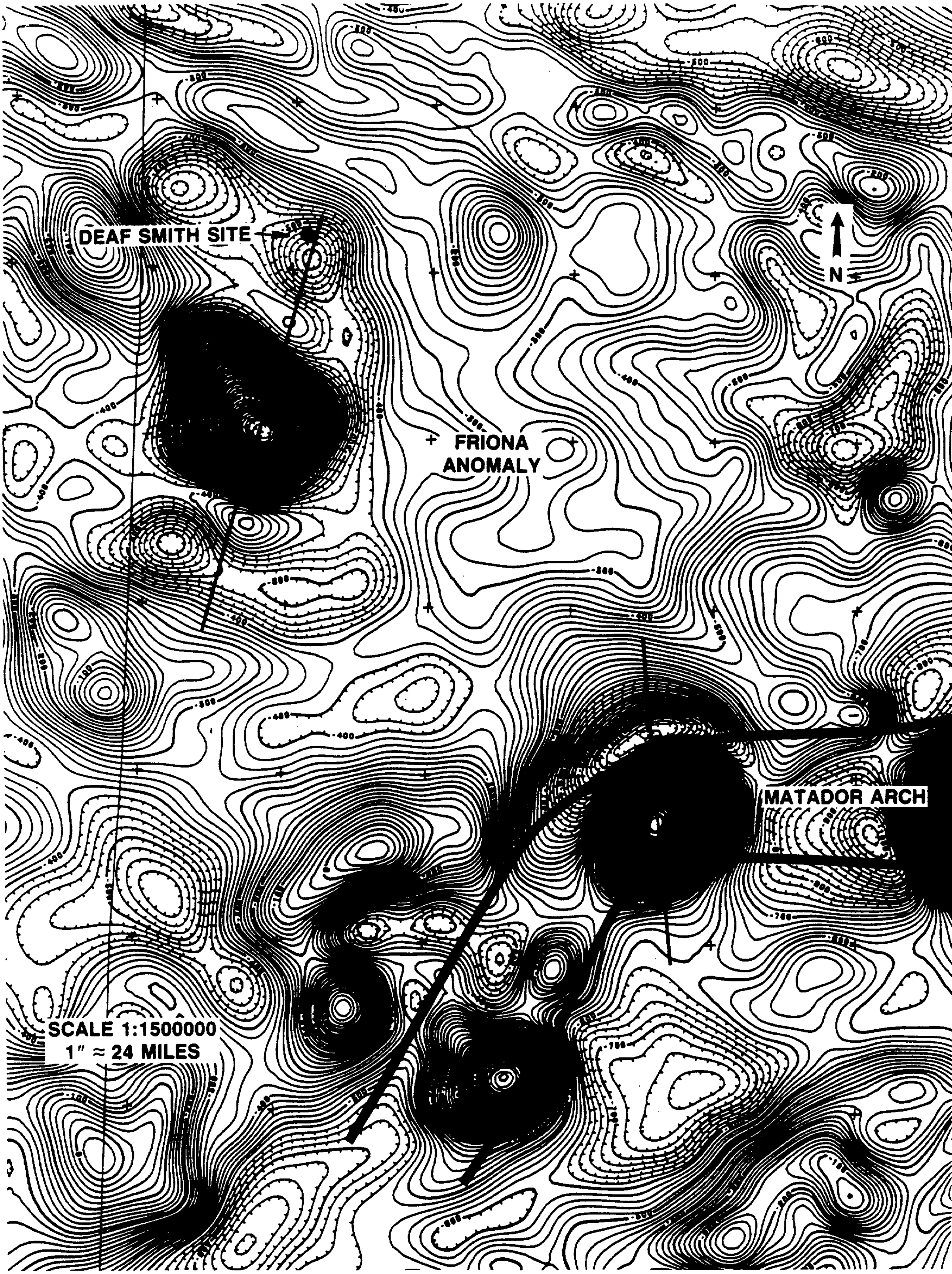
Turner (6)

LINE 0 BEFORE REPROCESSING



LINE 0 AFTER REPROCESSING



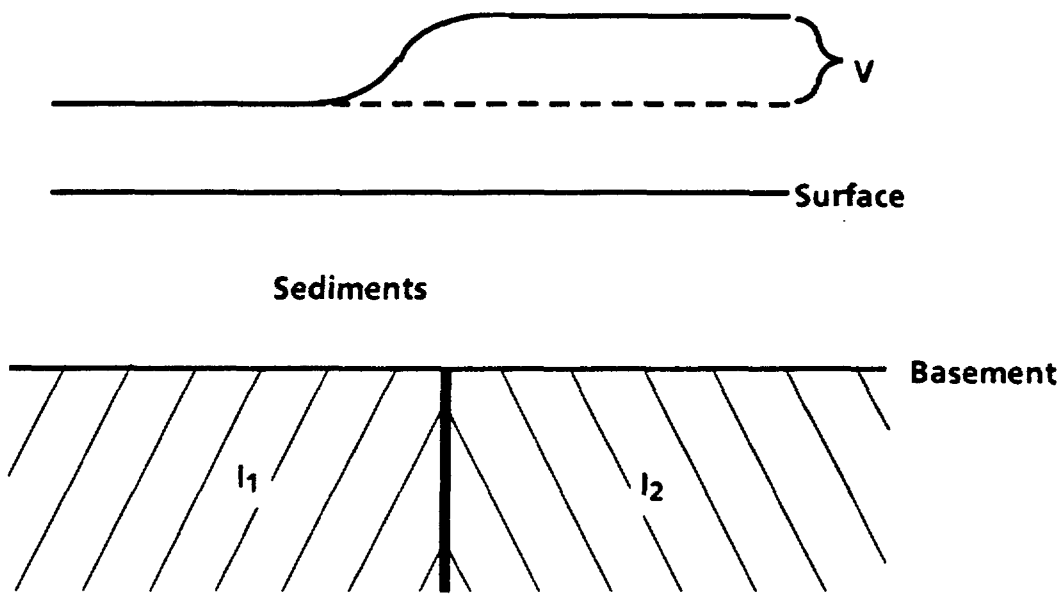

DEAF SMITH SITE
N
FRIONA
ANOMALY
MATADOR ARCH
SCALE 1:1500000
1″ ≈ 24 MILES

MAGNETIC ANOMALY CALCULATIONS

Types: (1) Intrabasement
(2) Suprabasement
(3) Vertical Sheet

(1) INTRABASEMENT ANOMALY

Model:

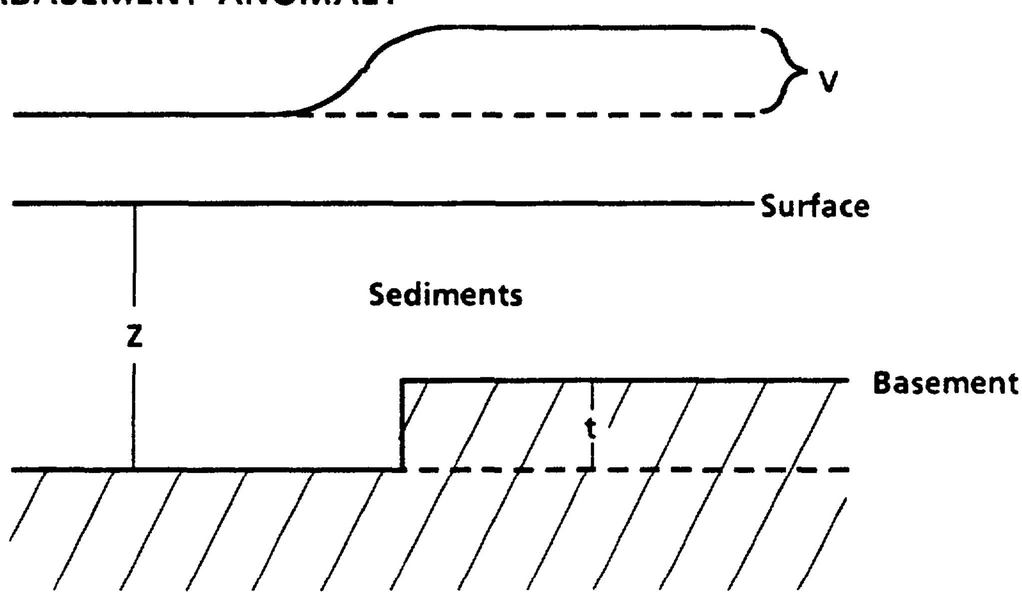


$V = 2\pi(I_1 - I_2)$ (Nettleton, 1976)
$= 2\pi(0.002)$ (Nettleton, 1976)
$= 0.1256$ gauss $= 1256$ gammas

Intrabasement anomaly is for vertical polarization and the vertical field component.

(2) SUPRABASEMENT ANOMALY

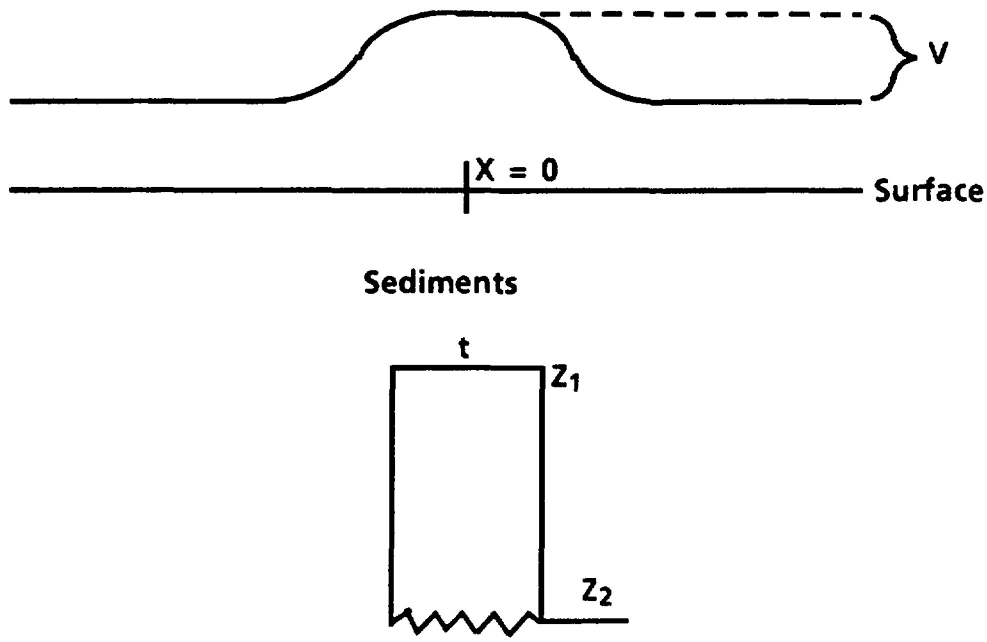
Model:



$V = 2It/Z$ (Nettleton, 1976)
$= 2(0.002)(1000)/8000 \times 10^5$
$= 50$ gammas for $t = 1000$ feet
$= 100$ gammas for $t = 2000$ feet

(3) VERTICAL SHEET ANOMALY

Model:

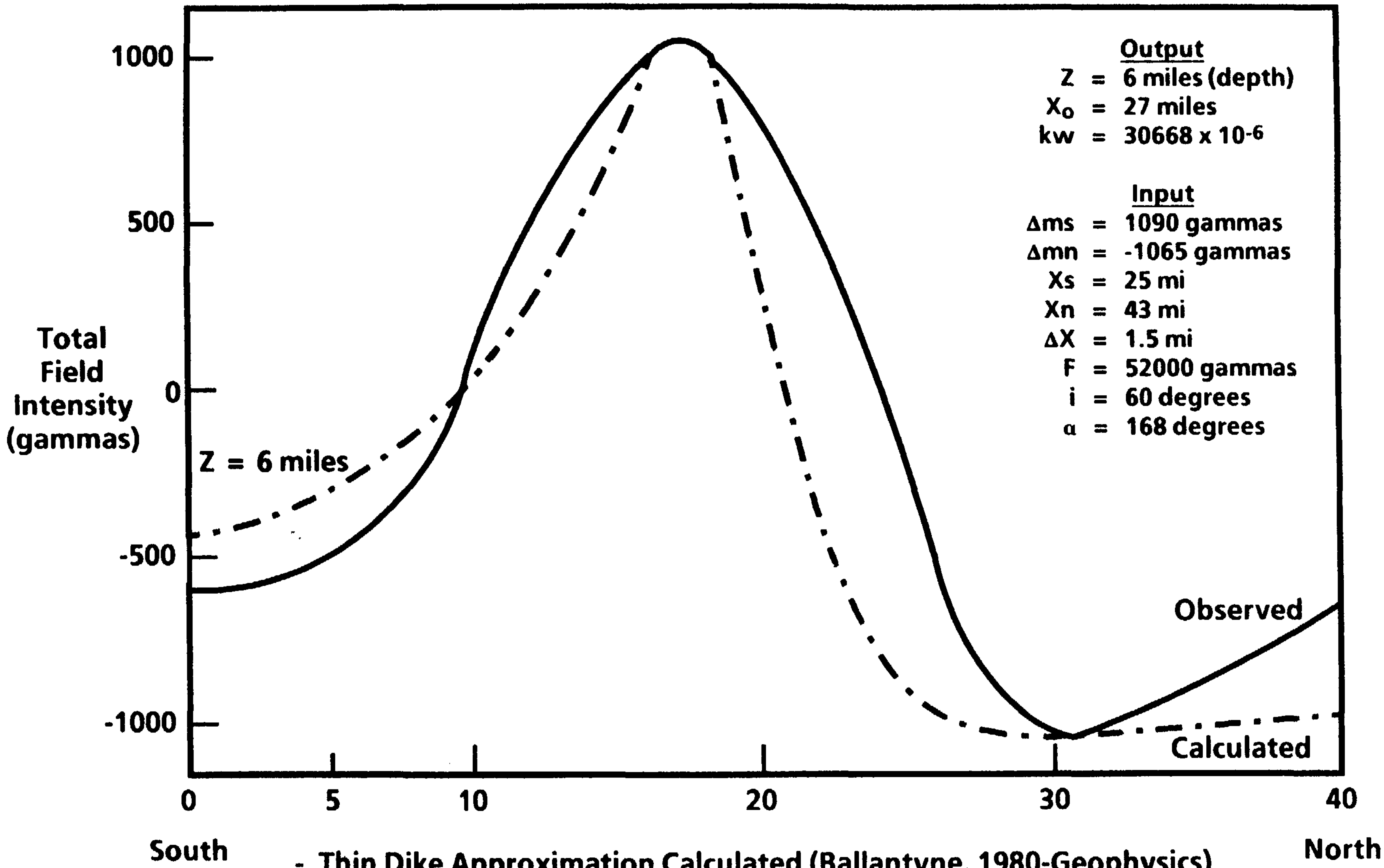


$$
\begin{aligned}
V &= 2It/Z[(Z_1/Z^2{}_1 + X^2) - (Z_2/Z^2{}_1 + X^2)] \quad \text{(Dobrin, 1976)} \\
&= 2(0.0015)(9 \times 5280)(1/8000 - 1/28000) \times 10^5 \\
&= 1273 \text{ gammas}
\end{aligned}
$$

This is for $t = 9$ miles, $X = 0$, $I = 0.0015$, $Z_1 = 8000$ feet, $Z_2 = 28000$ feet.

As for (1), anomalies calculated for (2) and (3) are for vertical polarization and for the vertical field component.

MATADOR ARCH TOTAL FIELD MAGNETIC ANOMALY



- Thin Dike Approximation Calculated (Ballantyne, 1980-Geophysics)
- Profile is Perpendicular to Strike
- No IGRF Removed

Material	Magnetite Content and Susceptibility, cgs units						Ilmenite, average	
	Minimum		Maximum		Average			
	%	$k \times 10^6$	%	$k \times 10^6$	%	$k \times 10^6$	%	$k \times 10^6$
Quartz porphyries	0.0	0	1.4	4,200	0.82	2,500	0.3	410
Rhyolites	0.2	600	1.9	5,700	1.00	3,000	0.45	610
Granites	0.2	600	1.9	5,700	0.90	2,700	0.7	1000
Trachyte-syenites	0.0	0	4.6	14,000	2.04	6,100	0.7	1000
Eruptive nephelites	0.0	0	4.9	15,000	1.51	4,530	1.24	1700
Abyssal nephelites	0.0	0	6.6	20,000	2.71	8,100	0.85	1100
Pyroxenites	0.9	3000	8.4	25,000	3.51	10,500	0.40	5400
Gabbros	0.9	3000	3.9	12,000	2.40	7,200	1.76	2400
Monzonite-latites	1.4	4200	5.6	17,000	3.58	10,700	1.60	2200
Leucite rocks	0.0	0	7.4	22,000	3.27	9,800	1.94	2600
Dacite-quartz-diorite	1.6	4800	8.0	24,000	3.48	10,400	1.94	2600
Andesites	2.6	7800	5.8	17,000	4.50	13,500	1.16	1600
Diorites	1.2	3600	7.4	22,000	3.45	10,400	2.44	4200
Peridotites	1.6	4800	7.2	22,000	4.60	13,800	1.31	1800
Basalts	2.3	6900	8.6	26,000	4.76	14,300	1.91	2600
Diabases	2.3	6900	6.3	19,000	4.35	13,100	2.70	3600

SOURCE: L. B. Slichter and H. H. Stearn, "Geophysical Prospecting," *Am. Inst. Mining Met. Engrs., Trans.*, 1929.

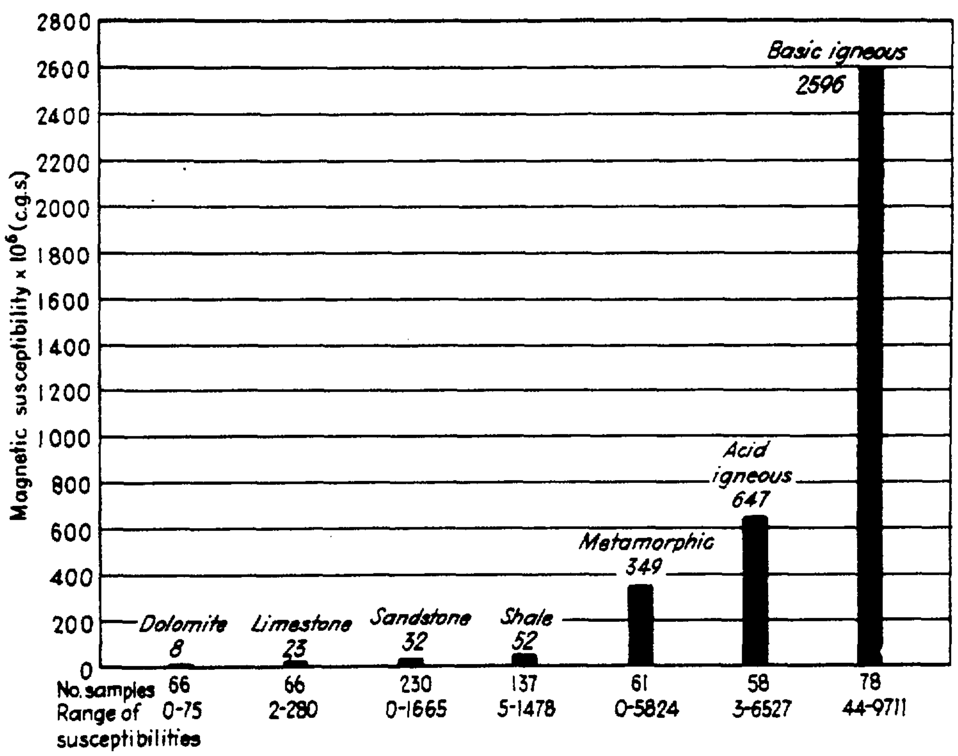


FIGURE 14-14
Average magnetic susceptibilities of surface samples and cores as measured in the laboratory. (*Compiled by J. W. Peters, Mobil Oil Corp.*)

FIGURES FROM DOBRIN, 1976

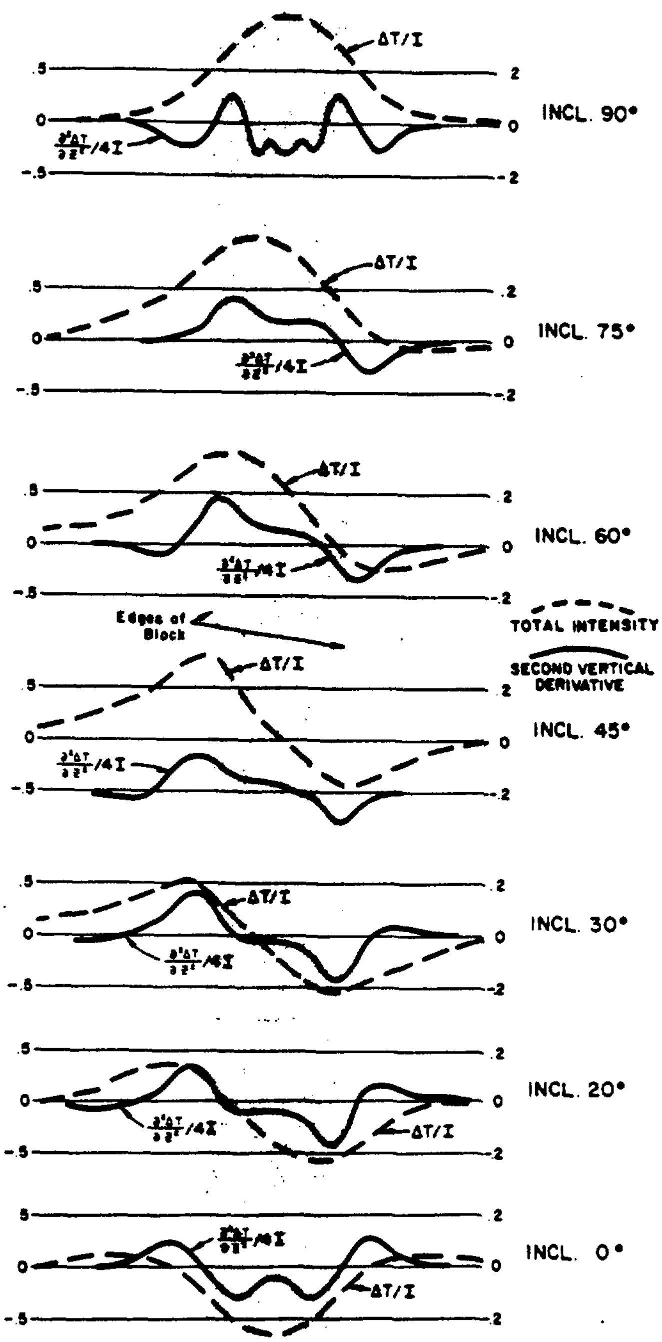
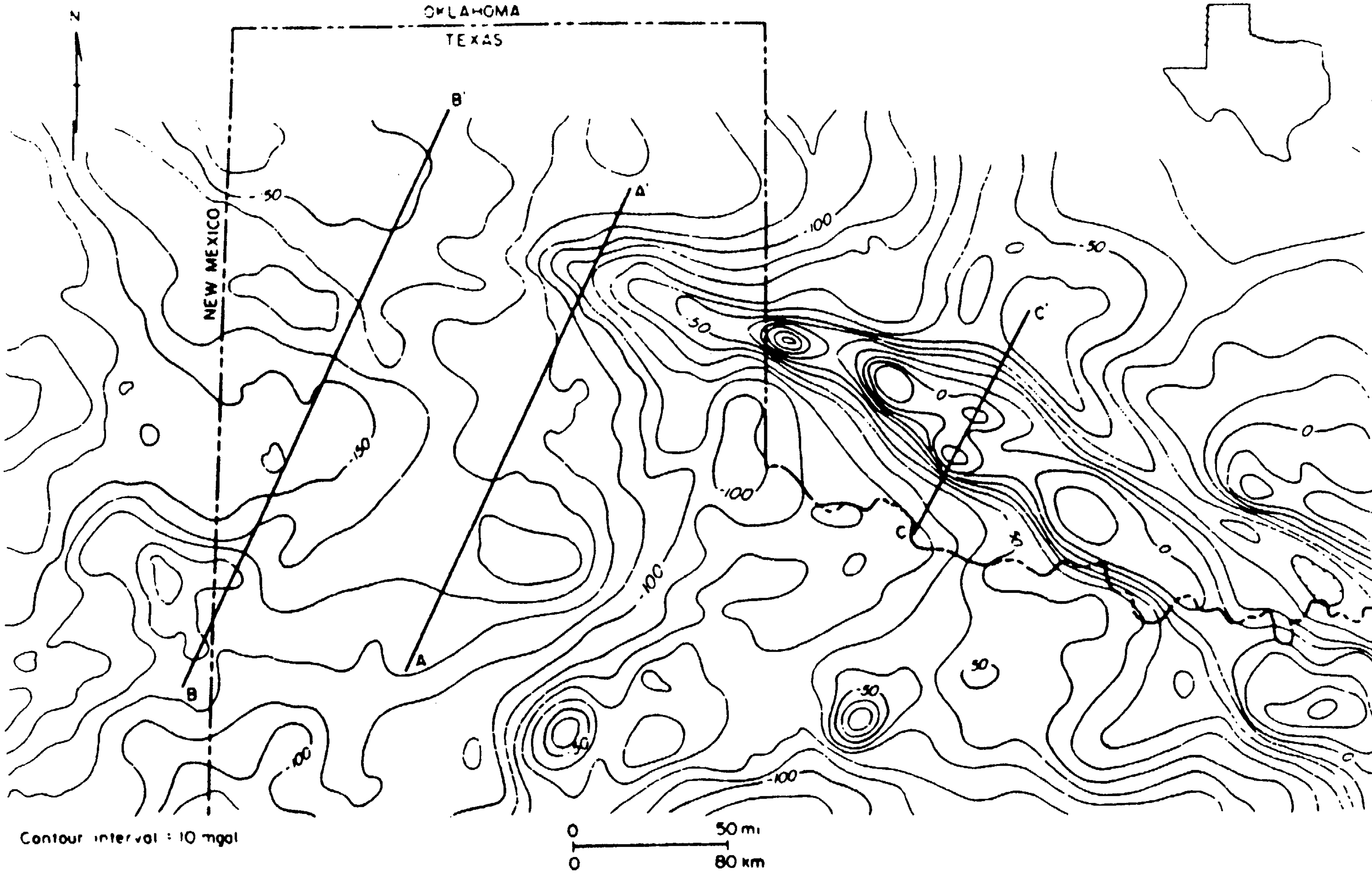


FIGURE 14-9
Profiles of magnetic and vertical derivative (curvature) fields on a north-south line across a prism with top at 1 unit depth, bottom at infinity, and for the various angles of inclination shown. All curves are for a body 8 depth units long (represented by the shaded area) and 6 units wide north to south. (*From Vacquier et al., 1951.*)


N
OKLAHOMA
TEXAS
NEW MEXICO
B'
B
A'
A
C'
C
-50
-100
-150
0
50
-40
Contour interval : 10 mgal
0
50 mi
0
80 km

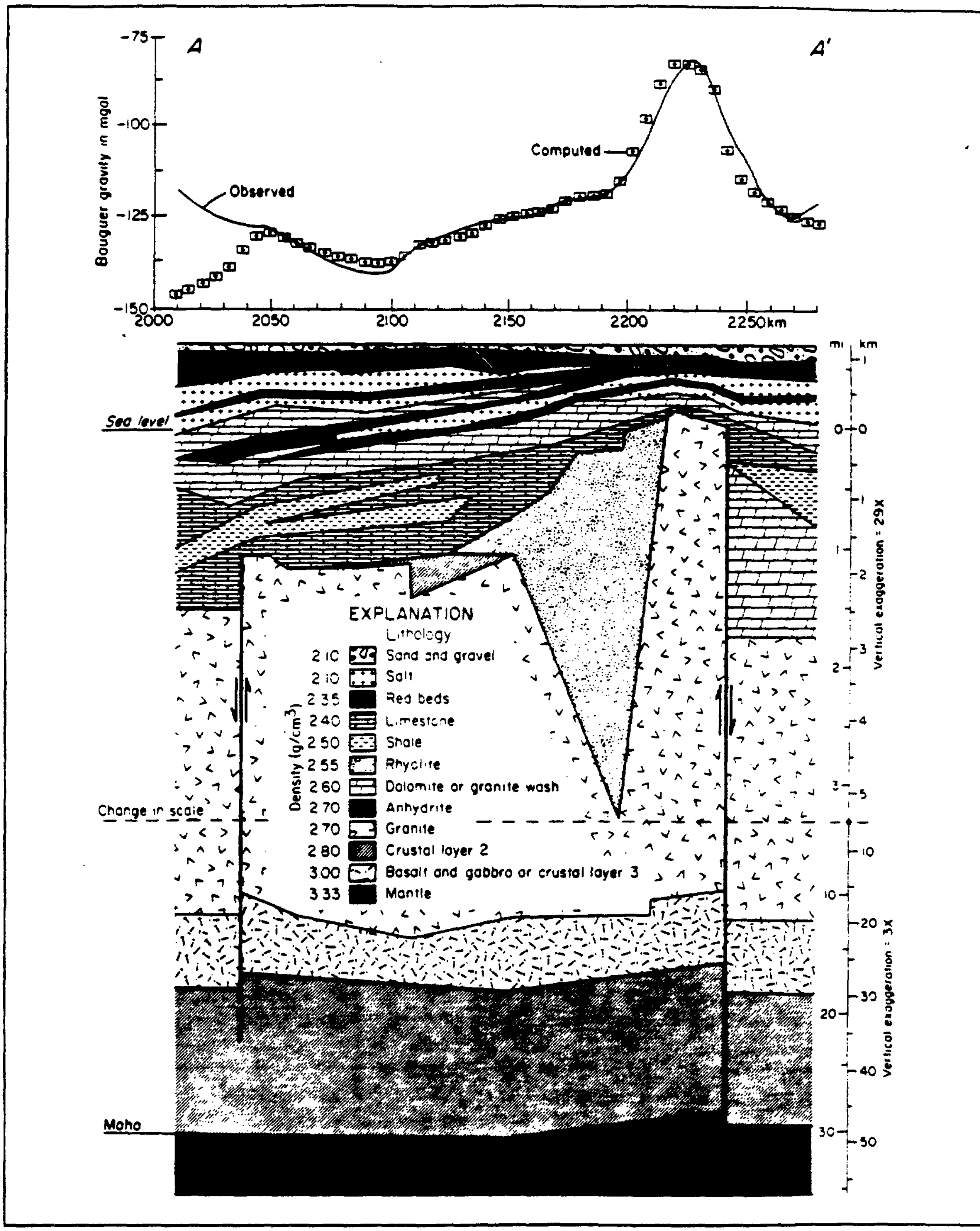


Figure 43. Gravity model A-A'. Cover-rock geometry is simplified from cross section D-D'; crustal layering and depth to Moho are taken from Stewart and Pakiser (1962), and the basement lithology is taken from Muehlberger and others (1967). See figure 42 for location.

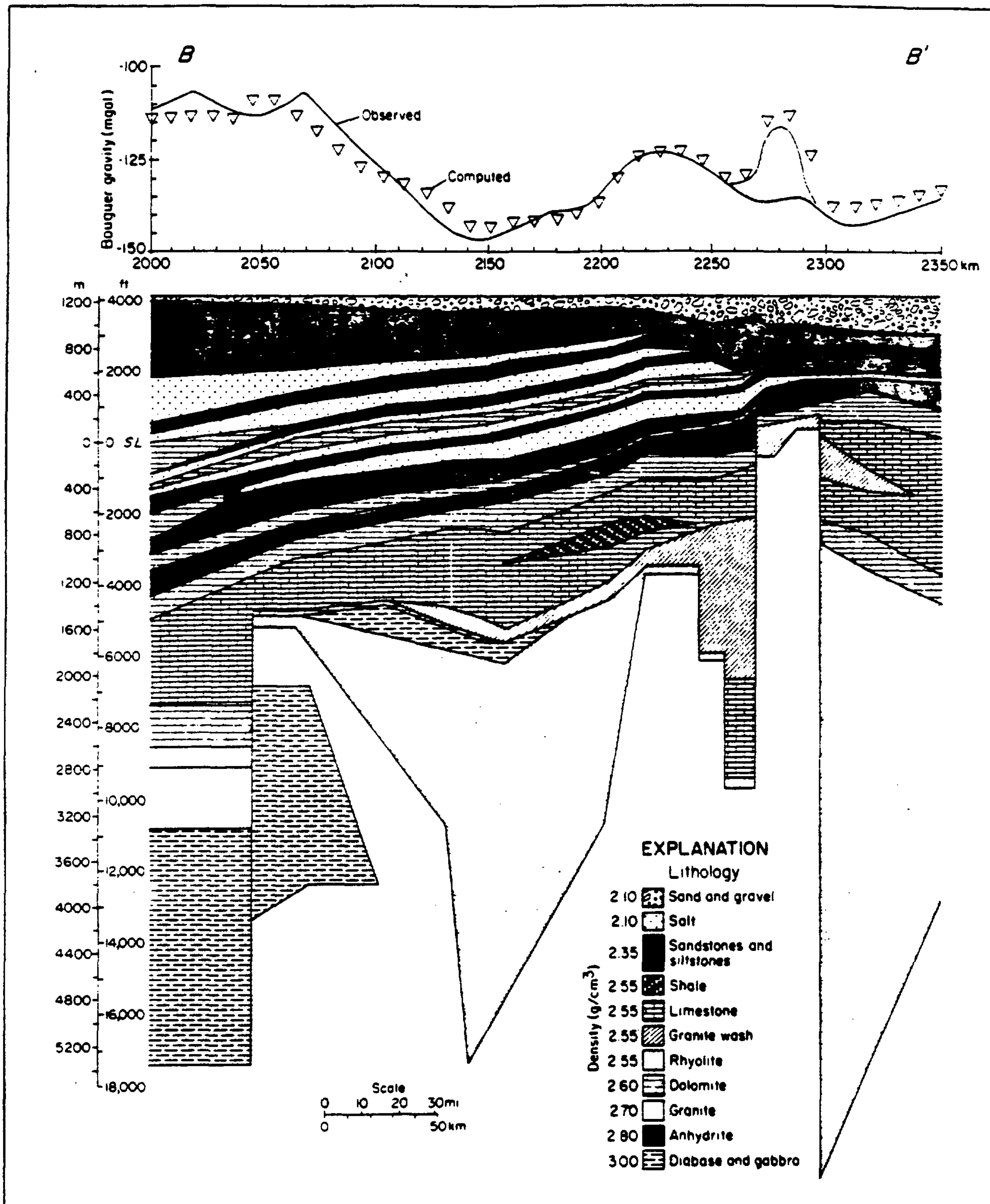


Figure 44. Gravity model B-B', modified from cross section B-B'. Shaded area on computed curve is a positive anomaly predicted from the model, which does not appear in the observed gravity. This requires that granites in this region be thin sills intruded into a deep rhyolite basin. See figure 42 for location.

Budnik (2)

Structural geology and tectonic history of the Palo Duro Basin and adjoining areas.

I. Introduction

The structural geology and tectonic history of the Palo Duro Basin is closely related to that of the adjoining areas. Therefore, to fully understand the structural development of the Palo Duro Basin it has been necessary to examine the history of deformation of not only of the basin and adjoining areas, but the entire region as well.

II. Structural geology of areas marginal to the Palo Duro Basin.

A. Amarillo Uplift -- a major positive structural element of the Ancestral Rocky Mountains; has been internally deformed into a series of horsts and grabens;

B. Whittenburg Trough -- deep pull-apart graben along south side of Amarillo Uplift;

C. Oldham-Harmon structural trend -- northwest-trending series of en echelon basement blocks that lie along the northern margin of the Palo Duro Basin;

D. Matador Arch -- east-west trending series of en echelon basement blocks that separate the Palo Duro and Midland Basins;

E. Roosevelt positive -- broad positive area that separates the Palo Duro and Tucumcari Basins.

III. Structural geology of the Palo Duro Basin.

A. The Palo Duro Basin is a structural low that occupies the southern part of the Texas Panhandle. It was a discrete depositional basin only during the Late Pennsylvanian.

B. Deformation appears to decrease southward from the Oldham-Harmon trend;

C. Structures within the basin are generally isolated positives and poorly defined lows:

1) Castro Trough -- northwest-trending low extending from Swisher County to Deaf Smith County;

2) Central Randall positive -- fault-bounded structure that probably typifies structures within the basin;

3) Deaf Smith County -- poor control, but there appear to be northwest- and northeast-trending faults.

D. Dominent structural grain is northwest-southeast, although northeast-southwest trending structures are locally important.

IV. Tectonic history of the Palo Duro Basin and surrounding region.

A. Tectonic history of the basin was defined using structural and stratigraphic data; information for the surrounding areas came primarily from published sources.

B. Deformation has been episodic; timing coincident with deformation of adjoining areas to east and west:

1. Proterozoic -- volcanism (1400 Ma), primarily rhyolite with related granite, similar rocks extend northeastward to Missouri.

2. Cambrian -- rifting associated with opening of the Southern Oklahoma Aulacogen.

3. Cambrian to Early Devonian -- carbonate shelf.

4. Middle Devonian -- folding of the Texas Arch and Anadarko Basin; formation of regional unconformity.

5. Mississippian -- carbonate shelf.

6. Pennsylvanian -- Ancestral Rocky Mountain orogeny, formation of Palo Duro depositional basin; 75 miles left-lateral strike-slip faulting along Amarillo Uplift.

7. Permian -- regional subsidence associated with formation of the Permian Basin, transition from normal marine to restricted depositional conditions during Early Permian.

8. Triassic -- non-marine deposition during subsidence that was possibly associated with rifting in Gulf of Mexico.

9. Cretaceous -- very shallow marine to non-marine environments. No evidence of Laramide deformation.

10. Tertiary -- reactivation of basement structures during deposition of the Ogallala Formation in Late Miocene, coincident with Basin and Range deformation to the west.

11. Quaternary -- tectonic activity along Amarillo-Wichita Uplift, as indicated by seismicity in Whittenburg Trough; movement along Meers Fault in Oklahoma.

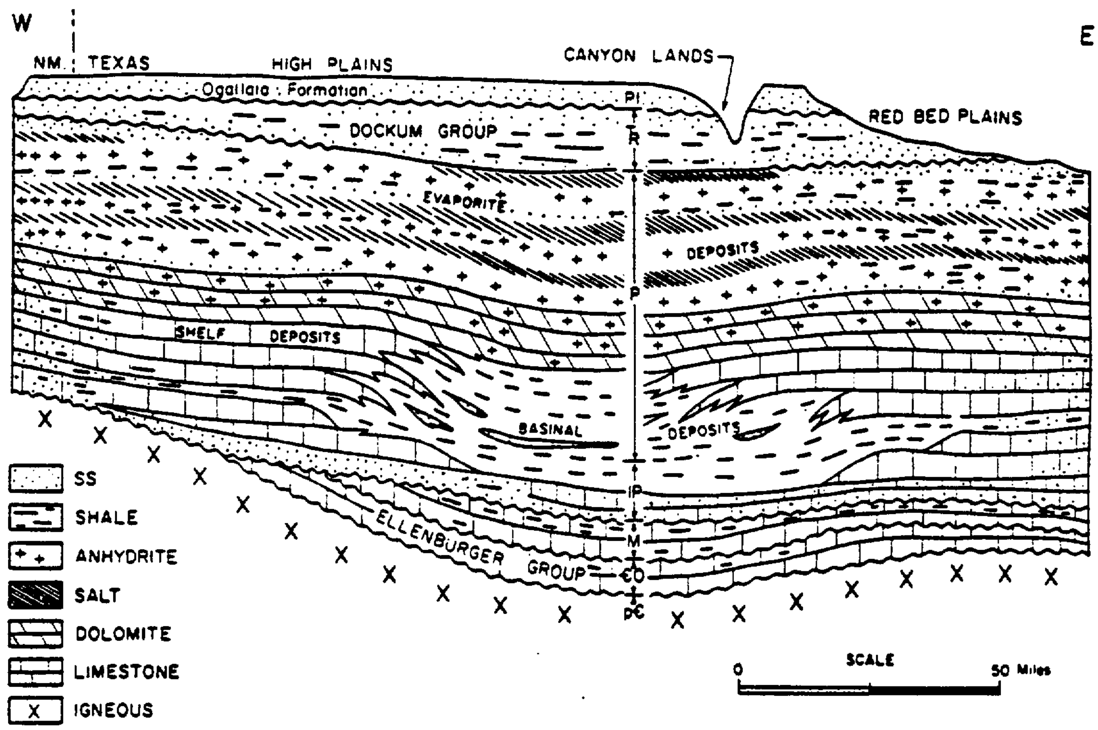


Figure 7. Schematic east-west section across Palo Duro Basin, Texas Panhandle.

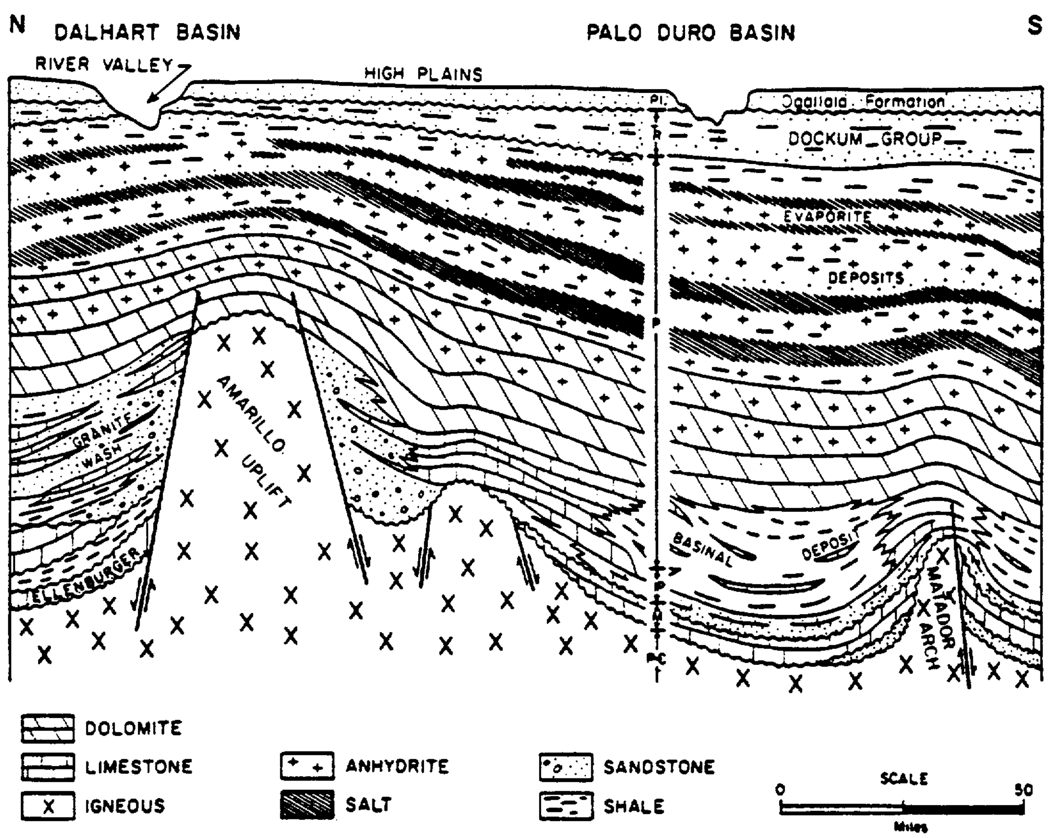
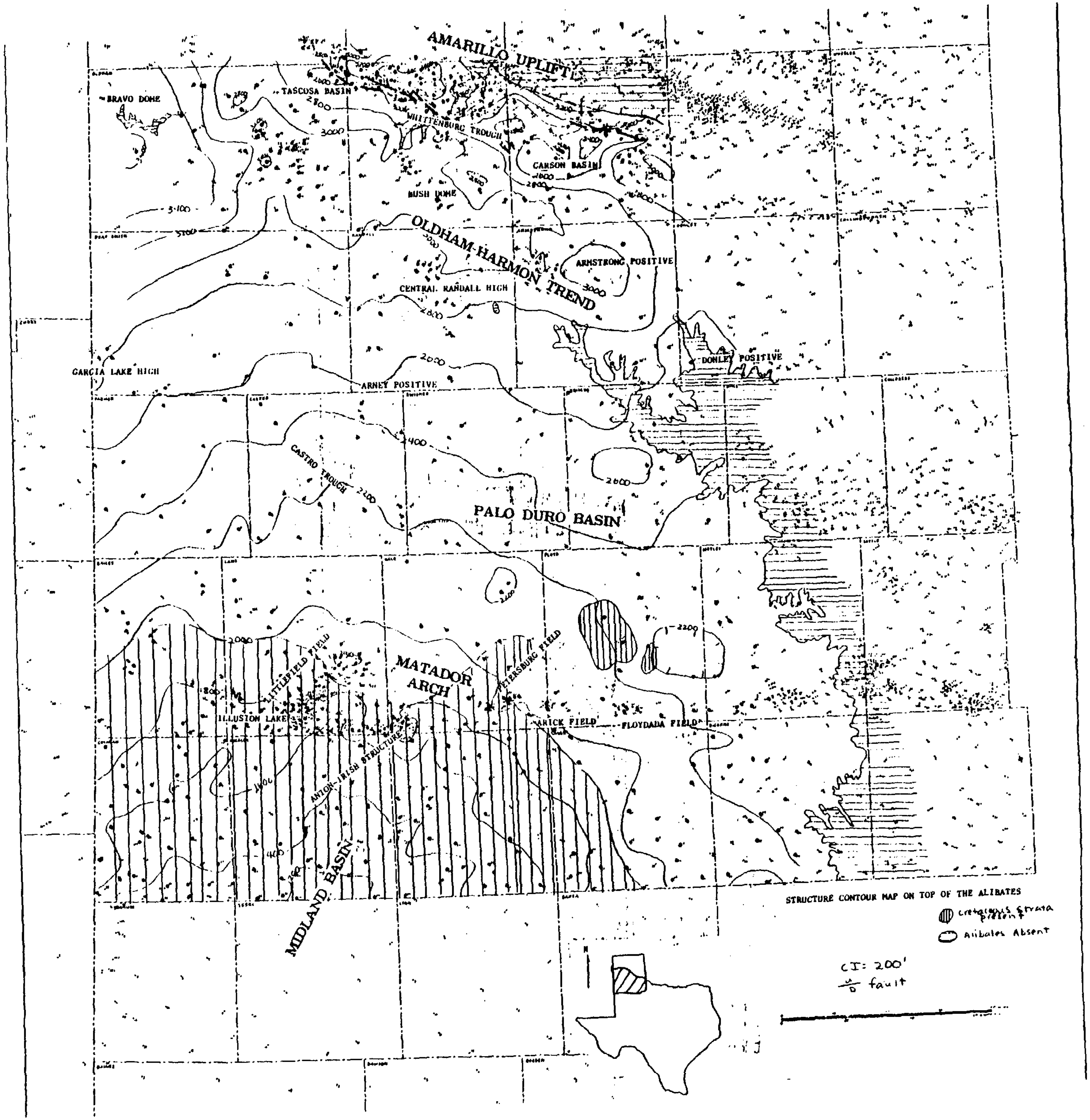


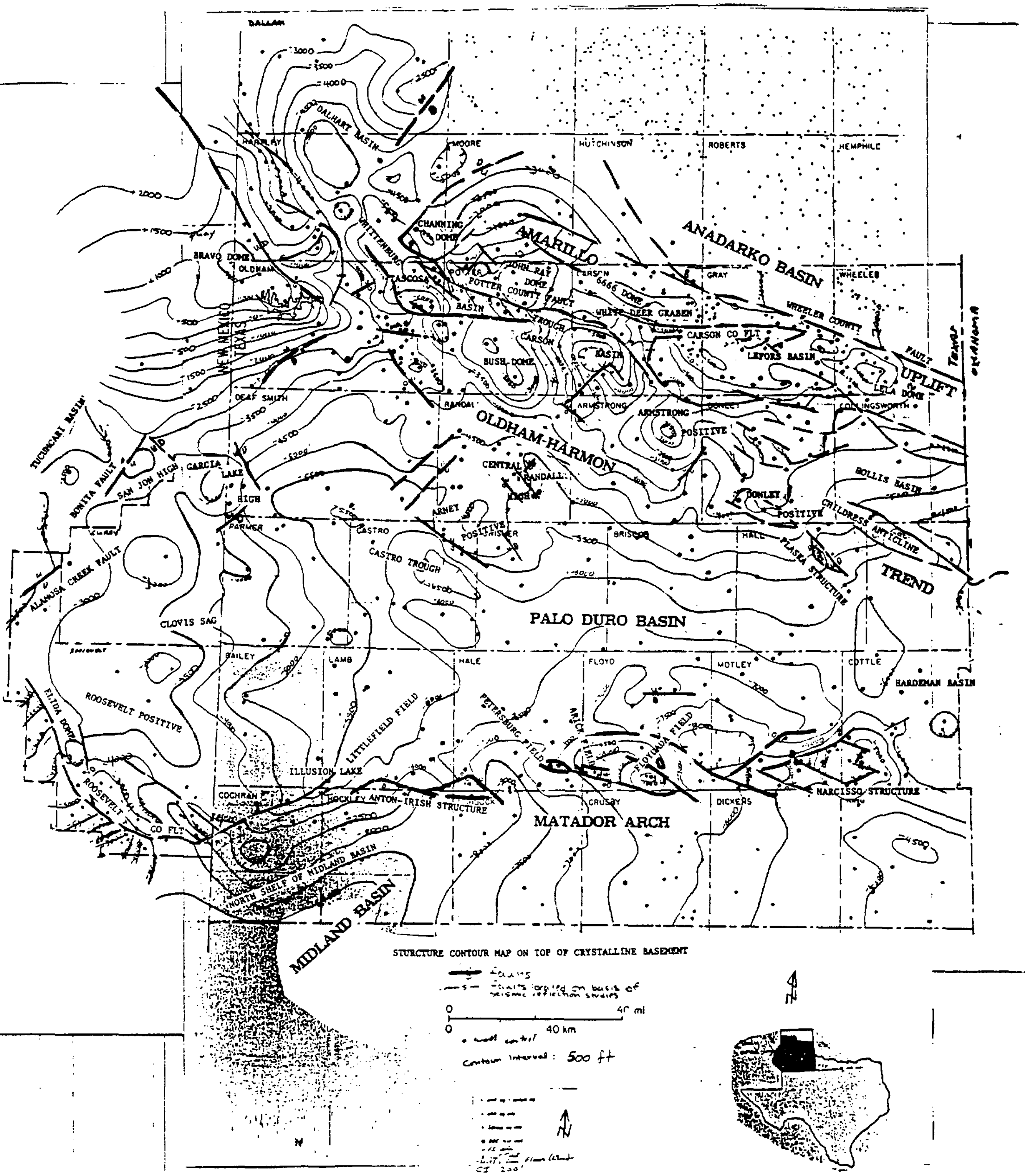
Figure 8. Schematic north-south section across Dalhart Basin, Amarillo Uplift, Palo Duro Basin, and Matador Arch, Texas Panhandle.

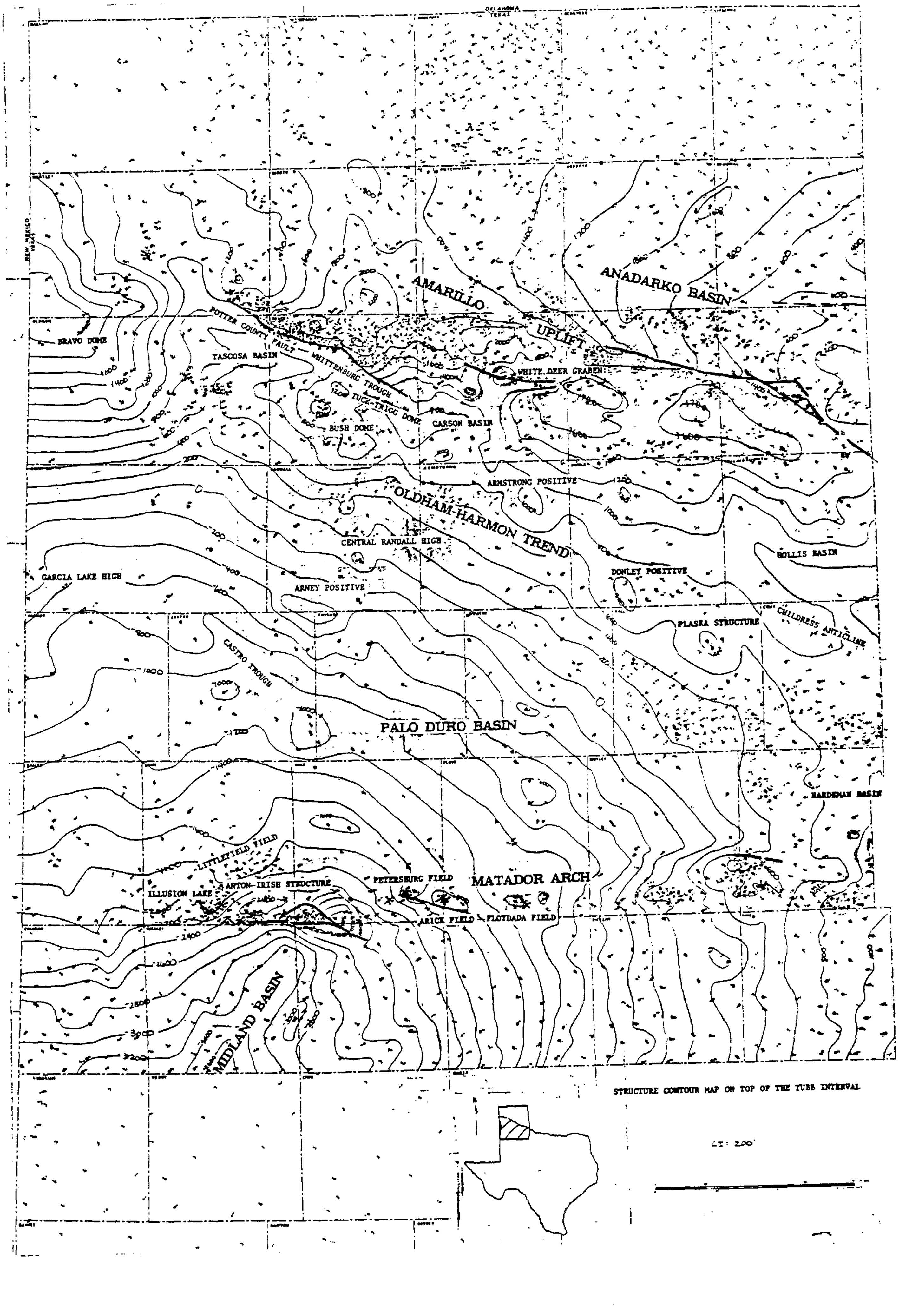
SYSTEM	SERIES	GROUP	Palo Duro Basin FORMATION	Dalhart Basin FORMATION	General Lithology and depositional setting
QUATERNARY	HOLOCENE		alluvium, dune sand Playa	alluvium, dune sand Playa	
	PLEISTOCENE		Tahoka "cover sands" Tule / "Playa" Blanco	"cover sands" "Playa"	Lacustrine clastics and windblown deposits
TERTIARY	NEOGENE		Ogallala	Ogallala	Fluvial and lacustrine clastics
CRETACEOUS			undifferentiated	undifferentiated	Marine shales and limestone
TRIASSIC		DOCKUM			Fluvial-deltaic and lacustrine clastics
PERMIAN	OCHOA		Dewey Lake	Dewey Lake	Sabkha salt, anhydrite, red beds, and peritidal dolomite
			Alibates	Alibates	
	GUADALUPE	ARTESIA	Salado/Tansill	Artesia Group undifferentiated	
			Yates		
			Seven Rivers		
			Queen/Grayburg		
			San Andres	Blaine	
	LEONARD	CLEAR FORK	Glorieta	Glorieta	
			Upper Clear Fork	Clear Fork	
			Tubb	undifferentiated Tubb-Wichita Red Beds	
			Lower Clear Fork		
			Red Cave		
		WICHITA			
	WOLFCAMP				Shelf and shelf-margin carbonate, basinal shale, and deltaic sandstone
?			?	?	
PENNSYLVANIAN	VIRGIL	CISCO			
	MISSOURI	CANYON			
	DES MOINES	STRAWN			
	ATOKA	BEND			
	MORROW				
MISSISSIPPIAN	CHESTER				Shelf carbonate and chert
	MERAMEC				
	OSAGE				
ORDOVICIAN		ELLENBURGER			Shelf dolomite
CAMBRIAN ?					Shallow marine(?) sandstone
PRECAMBRIAN					Igneous and metamorphic

Figure 26. Stratigraphic column and general lithology of the Palo Duro and Dalhart Basins. After Handford and Dutton (1980).



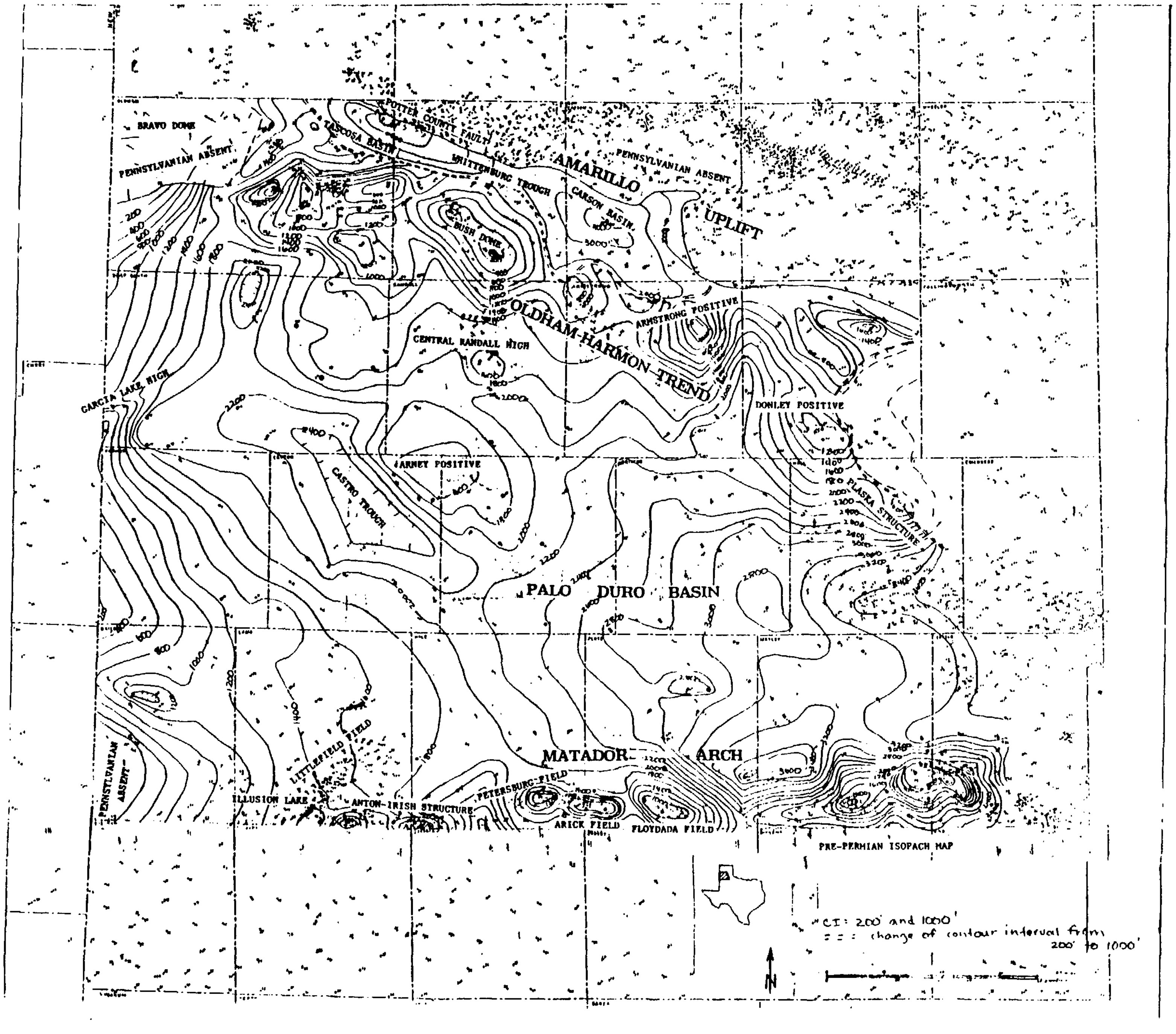
STRUCTURE CONTOUR MAP ON TOP OF THE ALIBATES


DALLAM
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
DALHART BASIN
CHANNING DOME
AMARILLO
ANADARKO BASIN
BRAVO DOME
OLDHAM
TASCOSA
POTTER COUNTY FAULT
JOHN RAY DOME
CARSON
GRAY
WHEELER
WHEELER COUNTY FAULT
WHITE DEER GRABEN
CARSON CO FLT
LEFORS BASIN
UPLIFT
LELA DOME
BUSH DOME
NEW MEXICO
TEXAS
DEAF SMITH
RANDALL
ARMSTRONG
ARMSTRONG POSITIVE
DONLEY
COLLINGSWORTH
OLDHAM-HARMON
TUCUMCARI BASIN
BONITA FAULT
SAN JON HIGH
GARCIA LAKE HIGH
CENTRAL RANDALL HIGH
BOLLIS BASIN
DONLEY POSITIVE
CHILDRESS ANTICLINE
PARMER
ARNEY POSITIVE
CASTRO
SWISHER
BRISCOE
HALL
FLASKA STRUCTURE
TREND
ALAMOSA CREEK FAULT
CASTRO TROUGH
CLOVIS SAG
PALO DURO BASIN
BAILEY
LAMB
HALE
FLOYD
MOTLEY
COTTLE
HARDEMAN BASIN
ELIDA DOME
ROOSEVELT POSITIVE
LITTLEFIELD FIELD
PETERSBURG FIELD
FLOYDADA FIELD
ILLUSION LAKE
COCHRAN
HOCKLEY
ANTON-IRISH STRUCTURE
CROSBY
DICKENS
NARCISSO STRUCTURE
MATADOR ARCH
ROOSEVELT CO FLT
NORTH SHELF OF MIDLAND BASIN
MIDLAND BASIN
STRUCTURE CONTOUR MAP ON TOP OF CRYSTALLINE BASEMENT
faults
faults located on basis of seismic reflection studies
0 40 mi
0 40 km
well control
Contour Interval: 500 ft

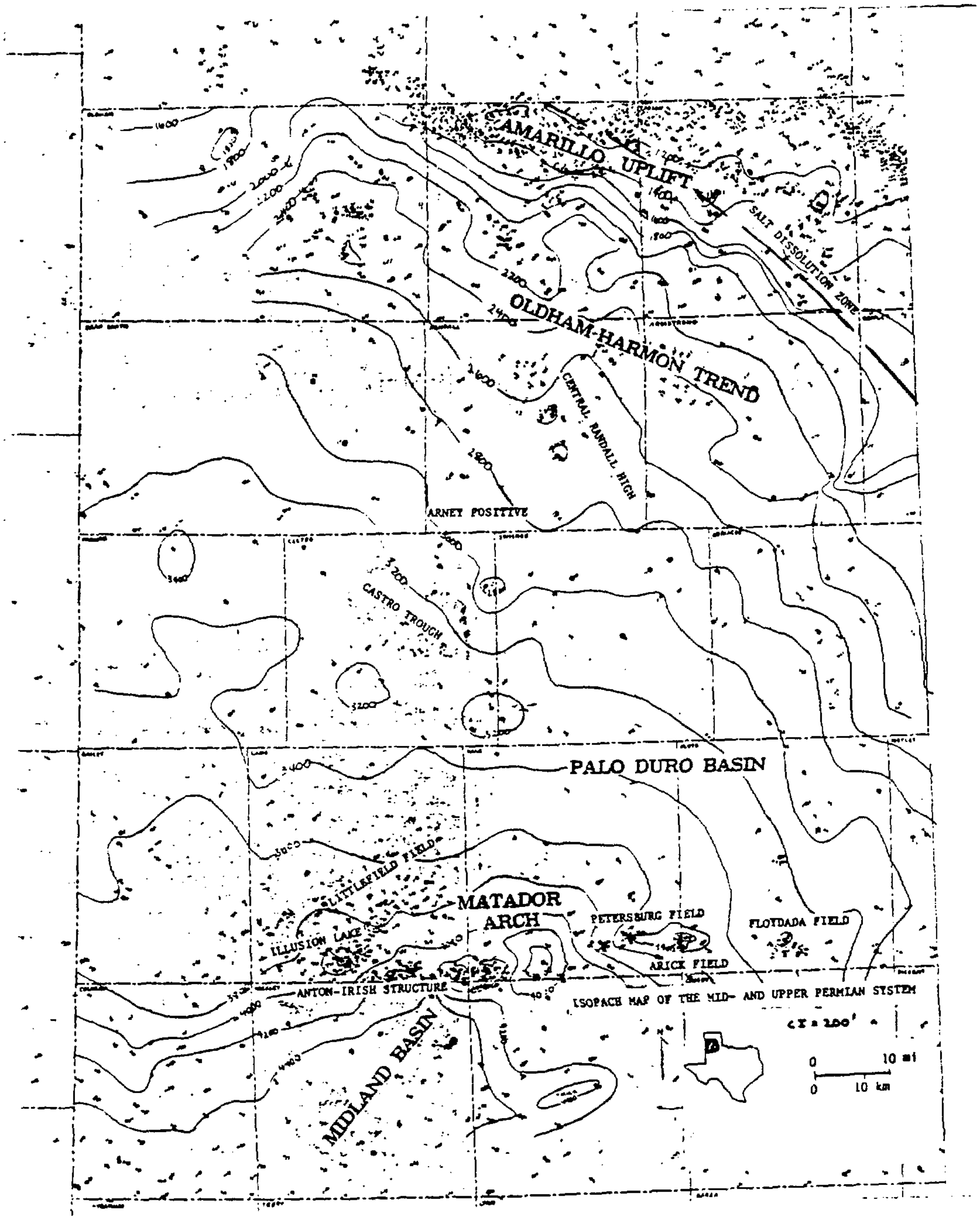


STRUCTURE CONTOUR MAP ON TOP OF THE TUBB INTERVAL

CI: 200'

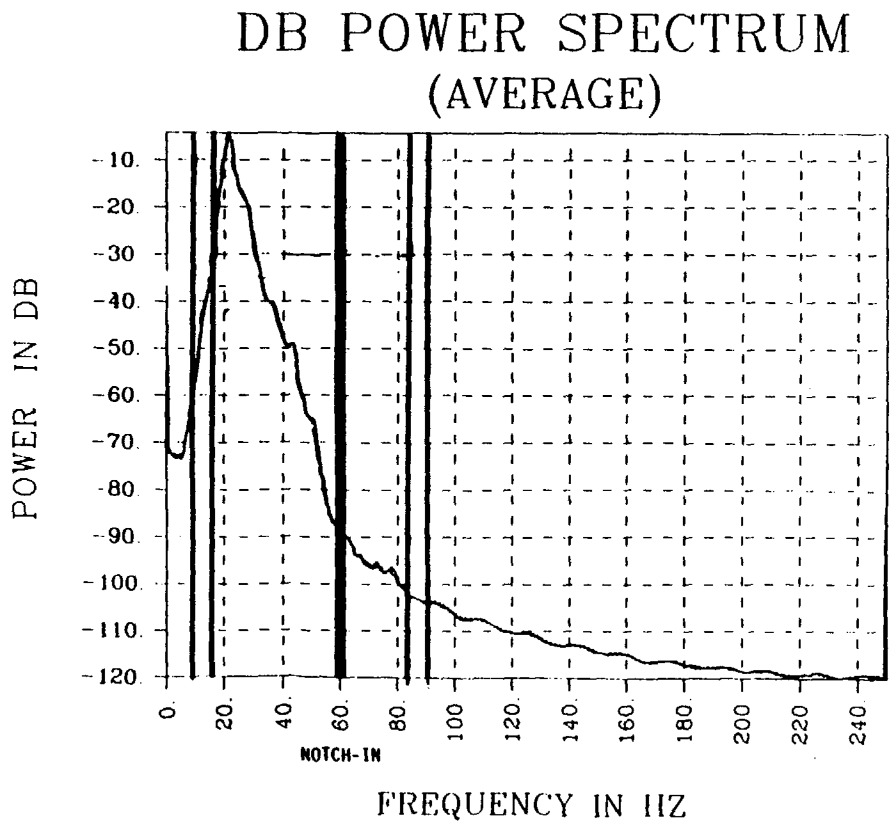


BRAVO DOME
PENNSYLVANIAN ABSENT
POTTER COUNTY FAULT
TASCOSA BASIN
BRITTENBURG TROUGH
AMARILLO
UPLIFT
PENNSYLVANIAN ABSENT
CARSON BASIN
BUSH DOME
OLDHAM-HARMON TREND
ARMSTRONG POSITIVE
CENTRAL RANDALL HIGH
GARCIA LAKE HIGH
DONLEY POSITIVE
FARNEY POSITIVE
CASTRO TROUGH
PLASKA STRUCTURE
PALO DURO BASIN
MATADOR ARCH
PENNSYLVANIAN ABSENT
LITTLEFIELD FIELD
ILLUSION LAKE
ANTON-IRISH STRUCTURE
PETERSBURG FIELD
ARICK FIELD
FLOYDADA FIELD
PRE-PERMIAN ISOPACH MAP
CI: 200' and 1000'
change of contour interval from 200' to 1000'
N

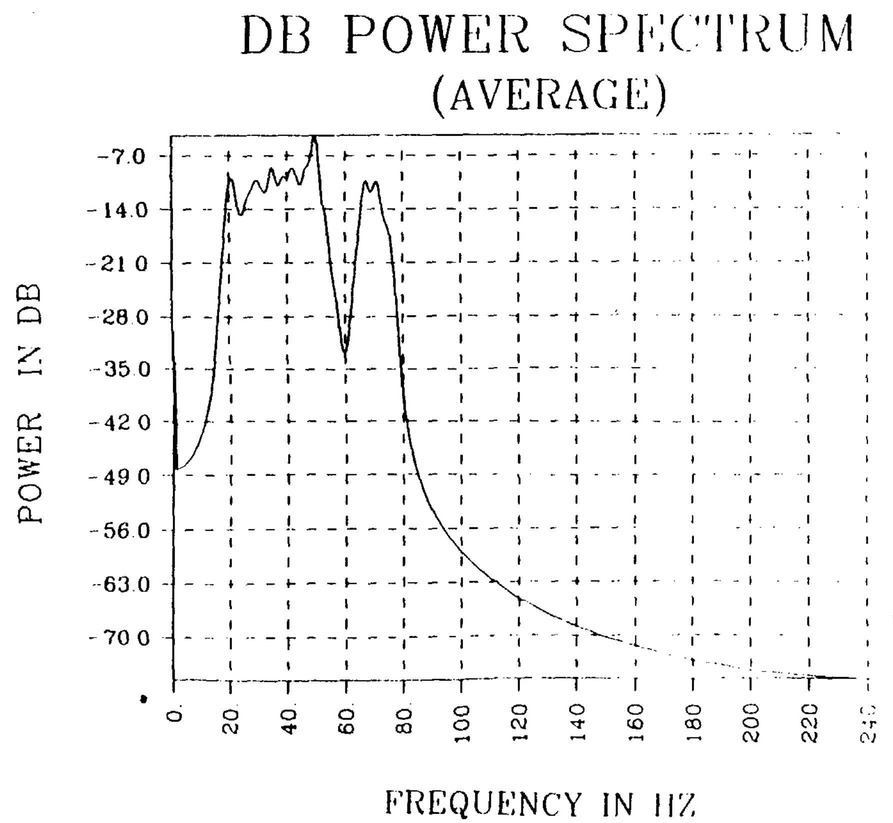

AMARILLO UPLIFT
SALT DISSOLUTION ZONE
OLDHAM-HARMON TREND
CENTRAL RANDALL HIGH
ARNEY POSITIVE
CASTRO TROUGH
PALO DURO BASIN
LITTLEFIELD FIELD
MATADOR ARCH
ILLUSION LAKE
PETERSBURG FIELD
FLOYDADA FIELD
ARICK FIELD
ANTON-IRISH STRUCTURE
MIDLAND BASIN
ISOPACH MAP OF THE MID- AND UPPER PERMIAN SYSTEM
0 10 mi
0 10 km

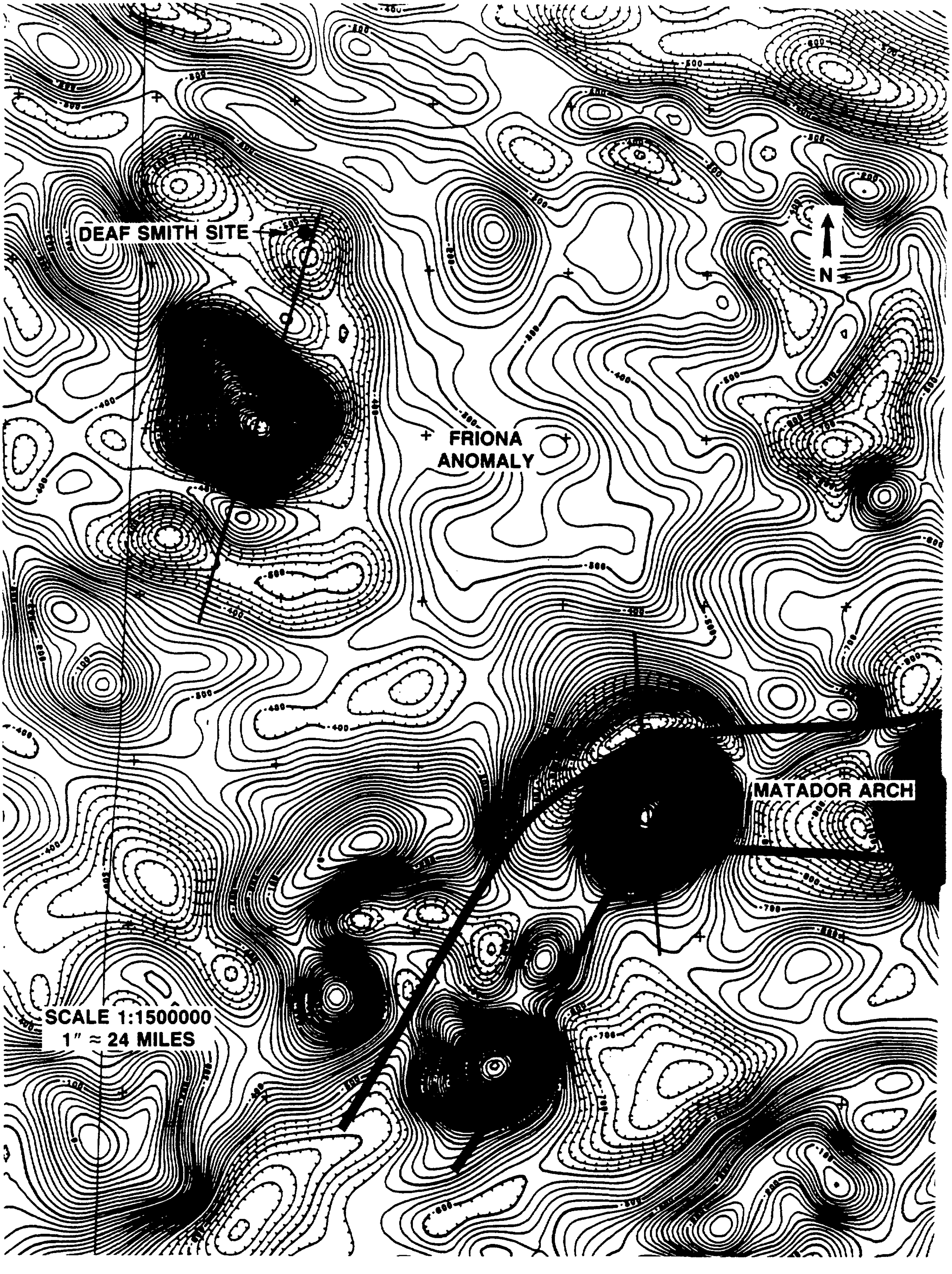
Turner (6)

LINE 0 BEFORE REPROCESSING



LINE 0 AFTER REPROCESSING



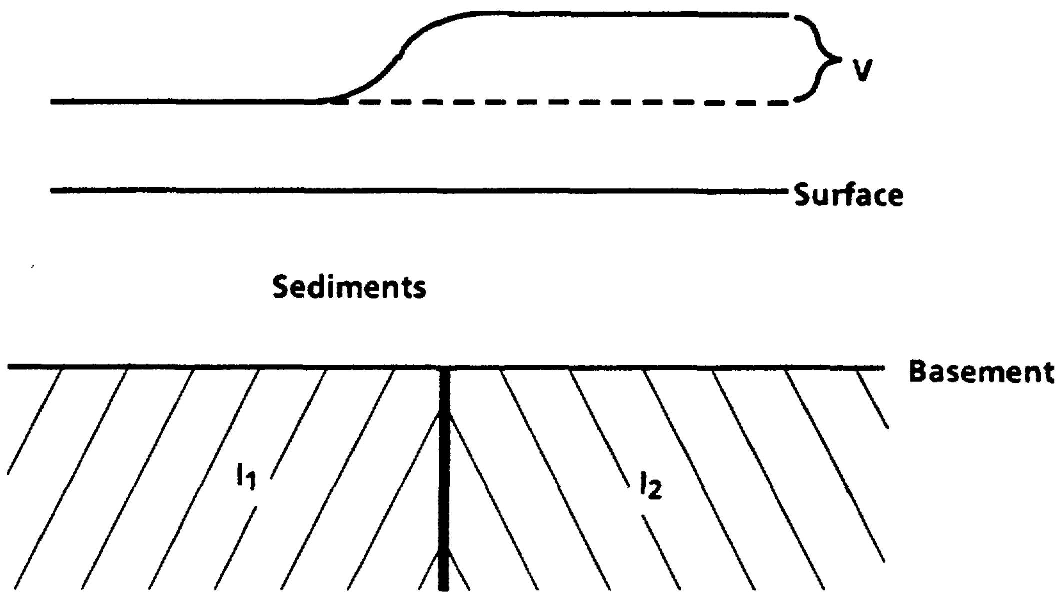

DEAF SMITH SITE
FRIONA ANOMALY
MATADOR ARCH
N
SCALE 1:1500000
1″ ≈ 24 MILES

MAGNETIC ANOMALY CALCULATIONS

Types: (1) Intrabasement
(2) Suprabasement
(3) Vertical Sheet

(1) INTRABASEMENT ANOMALY

Model:

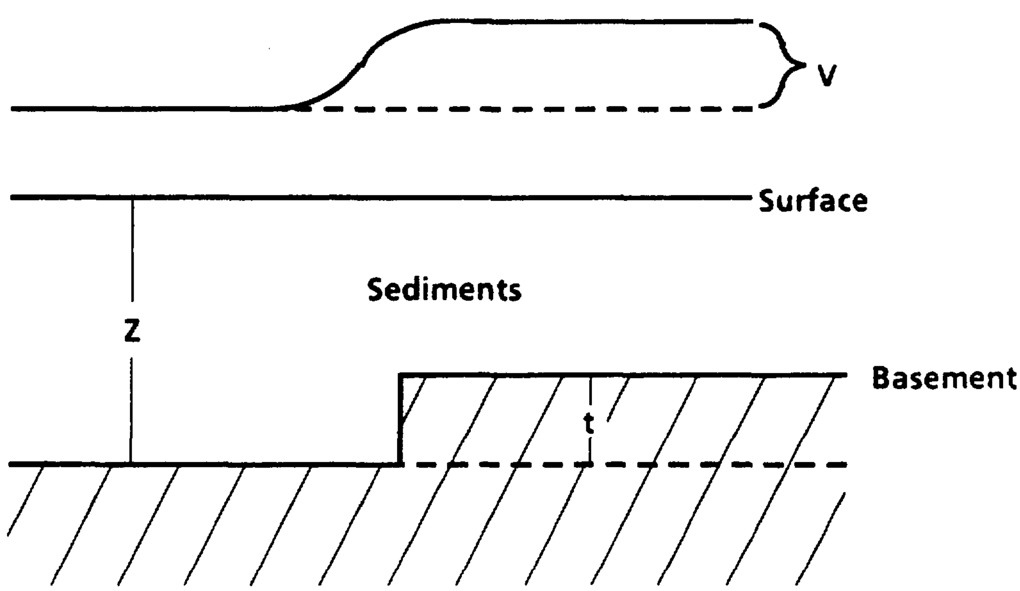


$V = 2\pi(I_1 - I_2)$ (Nettleton, 1976)
$= 2\pi(0.002)$ (Nettleton, 1976)
$= 0.1256$ gauss $= 1256$ gammas

Intrabasement anomaly is for vertical polarization and the vertical field component.

(2) SUPRABASEMENT ANOMALY

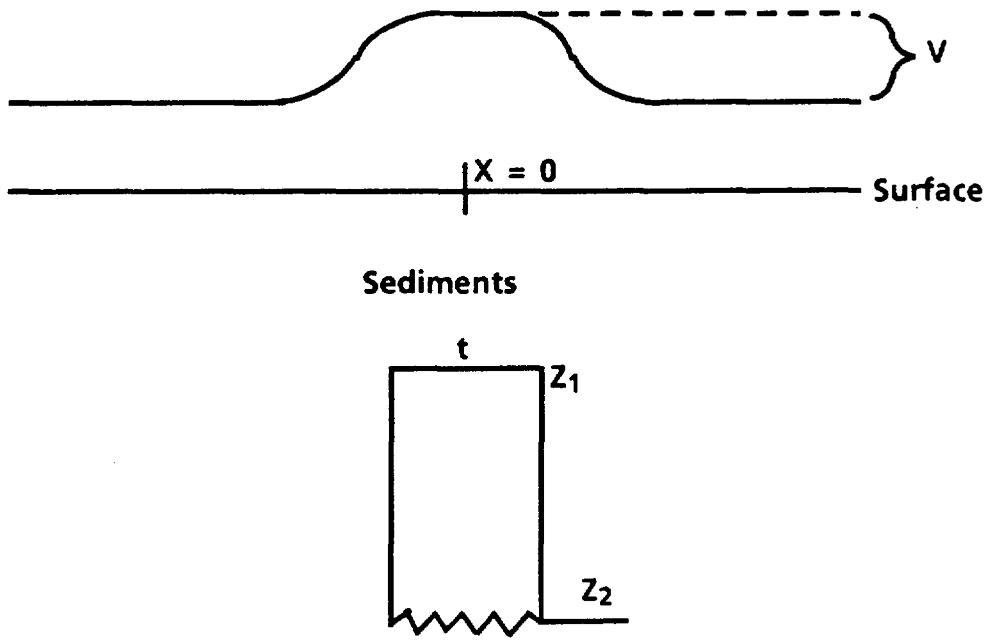
Model:



$V = 2It/Z$ (Nettleton, 1976)
$= 2(0.002)(1000)/8000 \times 10^5$
$= 50$ gammas for $t = 1000$ feet
$= 100$ gammas for $t = 2000$ feet

(3) VERTICAL SHEET ANOMALY

Model:

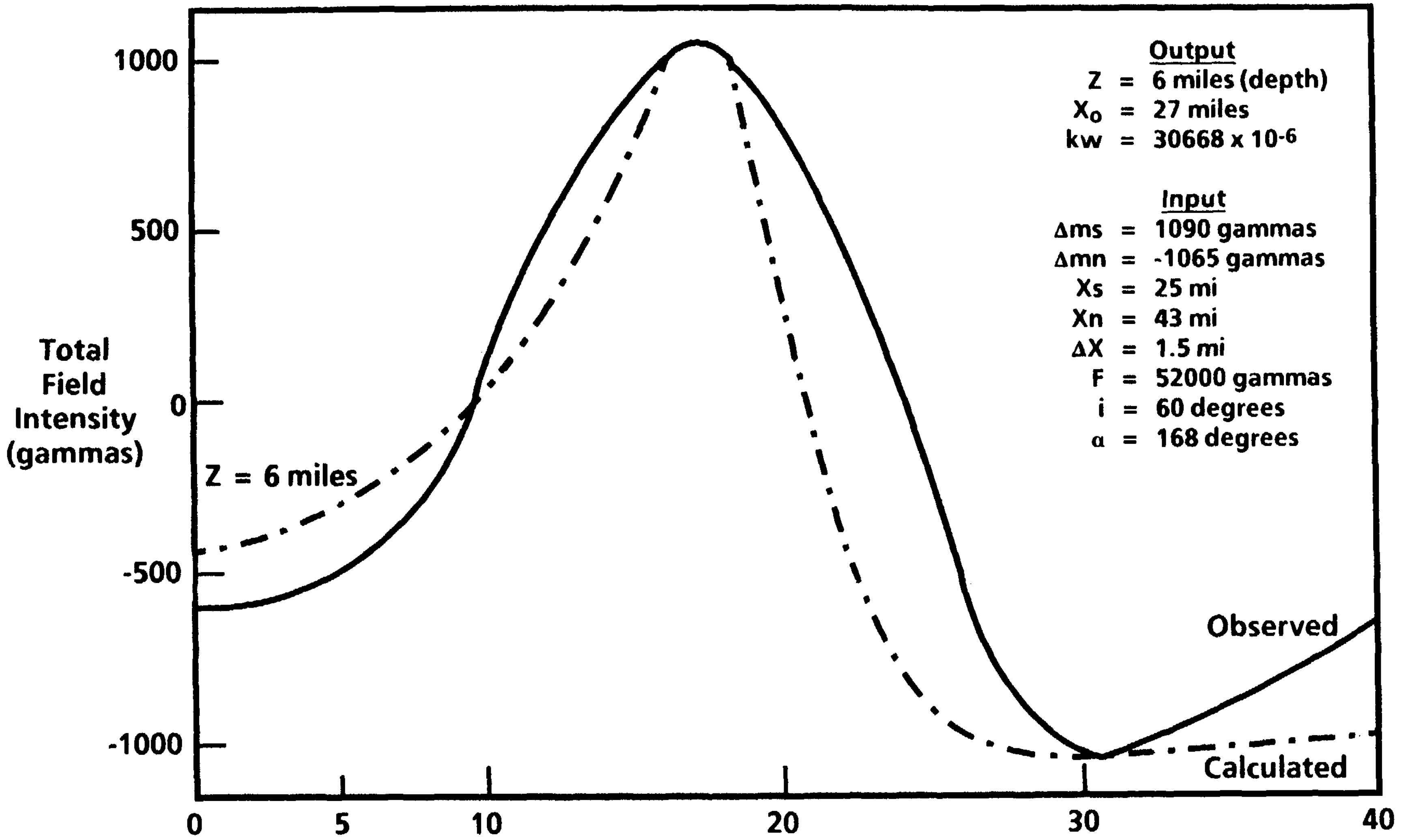


$$V = 2It/Z[(Z_1/Z^2{}_1 + X^2) - (Z_2/Z^2{}_1 + X^2)] \quad \text{(Dobrin, 1976)}$$
$$= 2(0.0015)(9 \times 5280)(1/8000 - 1/28000) \times 10^5$$
$$= 1273 \text{ gammas}$$

This is for $t = 9$ miles, $X = 0$, $I = 0.0015$, $Z_1 = 8000$ feet, $Z_2 = 28000$ feet.

As for (1), anomalies calculated for (2) and (3) are for vertical polarization and for the vertical field component.

MATADOR ARCH TOTAL FIELD MAGNETIC ANOMALY



- Thin Dike Approximation Calculated (Ballantyne, 1980-Geophysics)
- Profile is Perpendicular to Strike
- No IGRF Removed

Material	Magnetite Content and Susceptibility, cgs units						Ilmenite, average	
	Minimum		Maximum		Average			
	%	$k \times 10^6$	%	$k \times 10^6$	%	$k \times 10^6$	%	$k \times 10^6$
Quartz porphyries	0.0	0	1.4	4,200	0.82	2,500	0.3	410
Rhyolites	0.2	600	1.9	5,700	1.00	3,000	0.45	610
Granites	0.2	600	1.9	5,700	0.90	2,700	0.7	1000
Trachyte-syenites	0.0	0	4.6	14,000	2.04	6,100	0.7	1000
Eruptive nephelites	0.0	0	4.9	15,000	1.51	4,530	1.24	1700
Abyssal nephelites	0.0	0	6.6	20,000	2.71	8,100	0.85	1100
Pyroxenites	0.9	3000	8.4	25,000	3,51	10,500	0.40	5400
Gabbros	0.9	3000	3.9	12,000	2.40	7,200	1.76	2400
Monzonite-latites	1.4	4200	5.6	17,000	3.58	10,700	1.60	2200
Leucite rocks	0.0	0	7.4	22,000	3.27	9,800	1.94	2600
Dacite-quartz-diorite	1.6	4800	8.0	24,000	3.48	10,400	1.94	2600
Andesites	2.6	7800	5.8	17,000	4.50	13,500	1.16	1600
Diorites	1.2	3600	7.4	22,000	3.45	10,400	2.44	4200
Peridotites	1.6	4800	7.2	22,000	4.60	13,800	1.31	1800
Basalts	2.3	6900	8.6	26,000	4.76	14,300	1.91	2600
Diabases	2.3	6900	6.3	19,000	4.35	13,100	2.70	3600

SOURCE: L. B. Slichter and H. H. Stearn, "Geophysical Prospecting," *Am. Inst. Mining Met. Engrs., Trans.*, 1929.

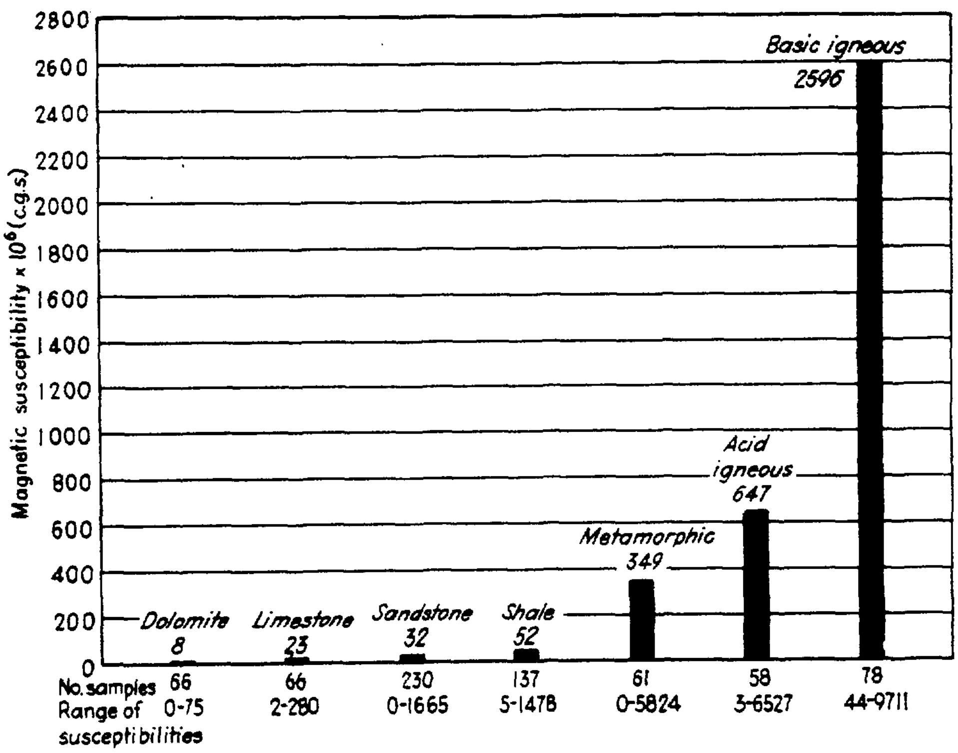


FIGURE 14-14
Average magnetic susceptibilities of surface samples and cores as measured in the laboratory. (*Compiled by J. W. Peters, Mobil Oil Corp.*)

FIGURES FROM DOBRIN, 1976

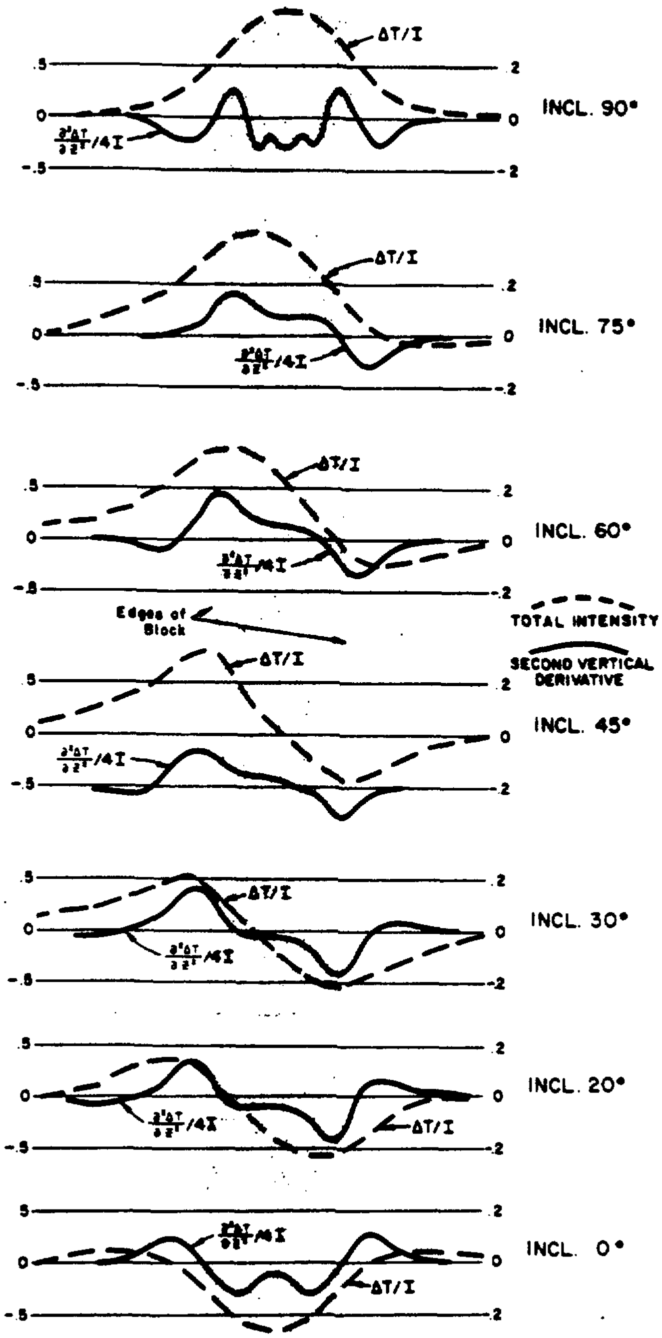
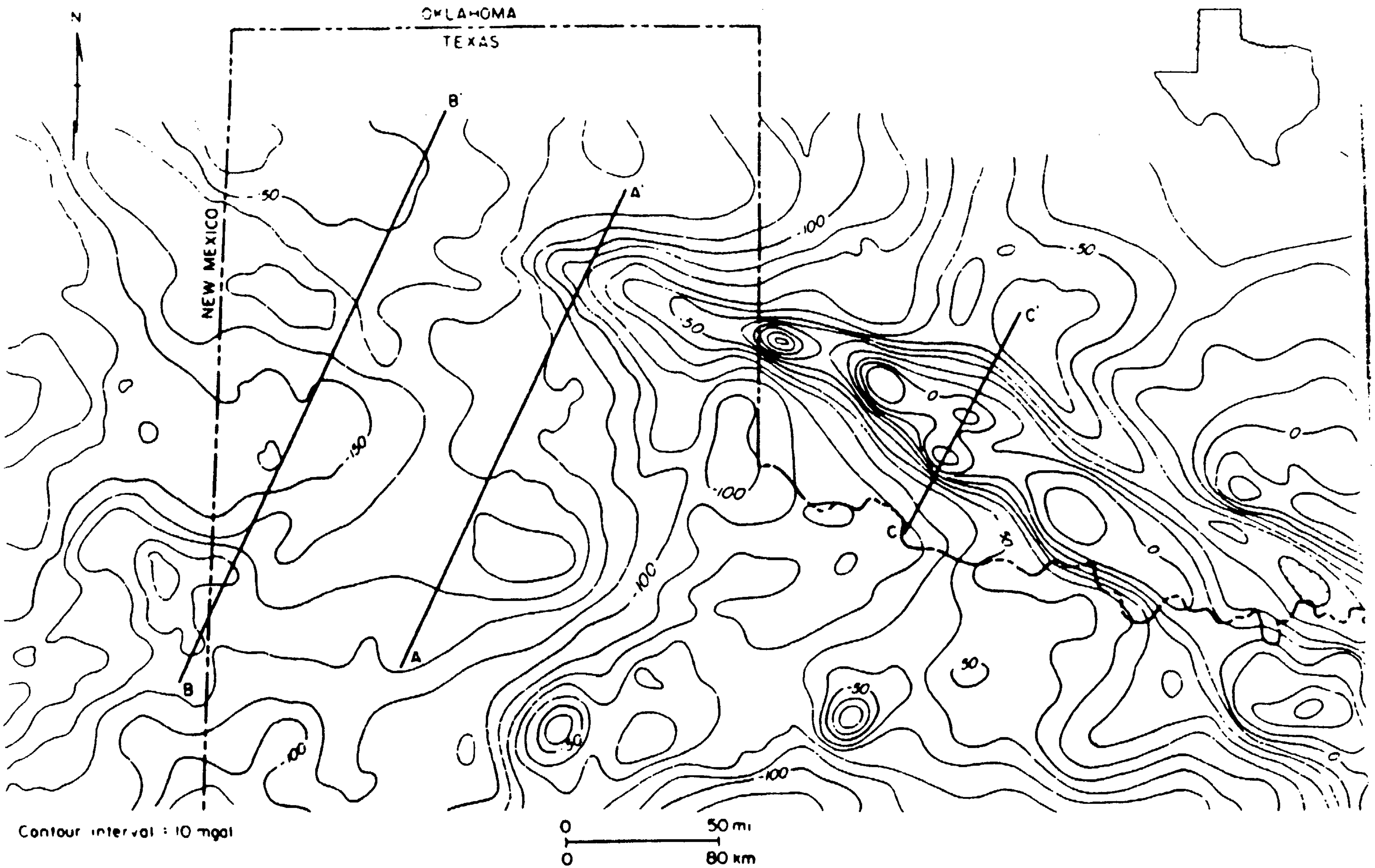


FIGURE 14-9
Profiles of magnetic and vertical derivative (curvature) fields on a north-south line across a prism with top at 1 unit depth, bottom at infinity, and for the various angles of inclination shown. All curves are for a body 8 depth units long (represented by the shaded area) and 6 units wide north to south. (*From Vacquier et al., 1951.*)


N
OKLAHOMA
TEXAS
NEW MEXICO
B'
B
A'
A
C'
C
-50
-100
-150
0
Contour interval : 10 mgal
0
50 mi
0
80 km

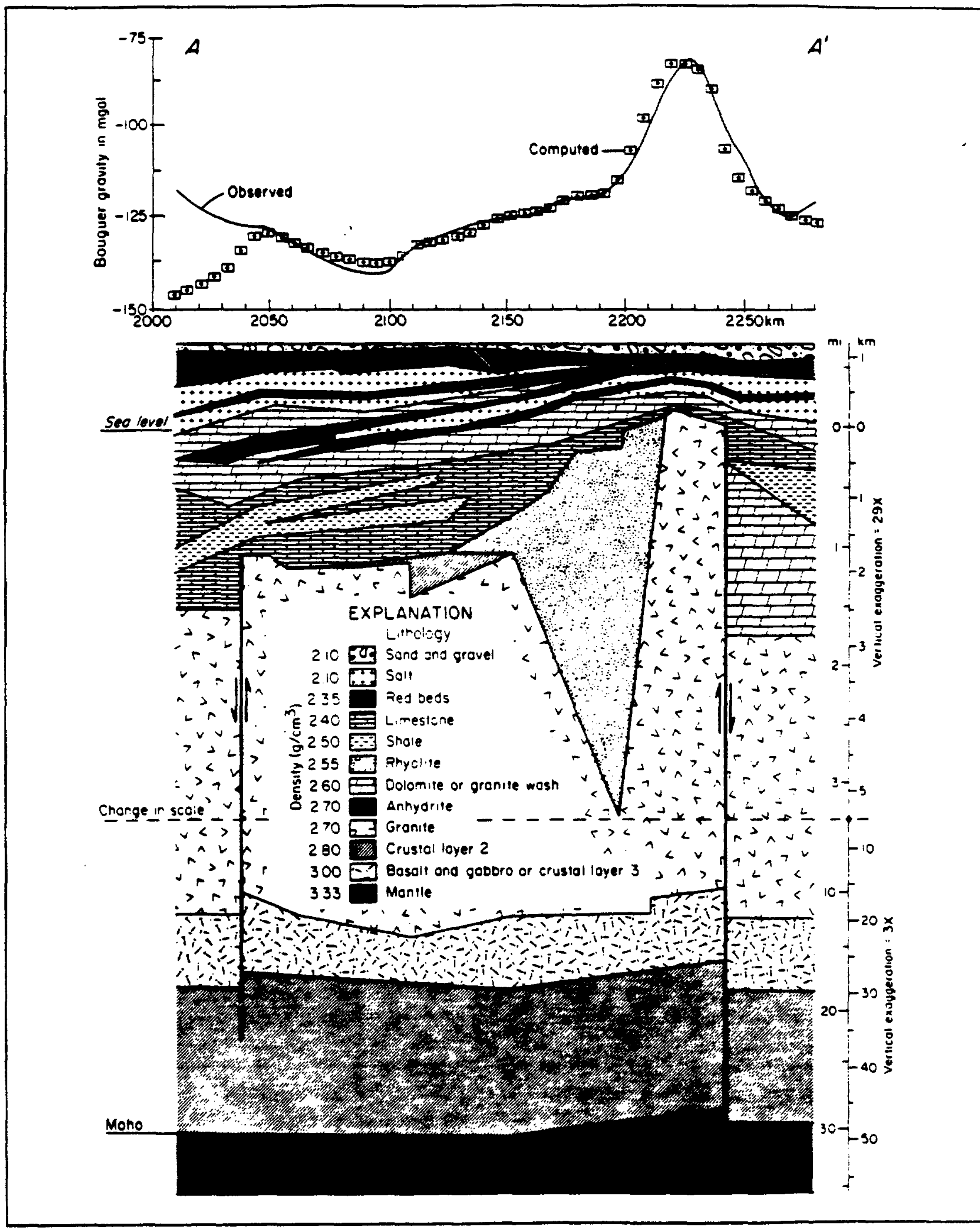


Figure 43. Gravity model A-A'. Cover-rock geometry is simplified from cross section D-D'; crustal layering and depth to Moho are taken from Stewart and Pakiser (1962), and the basement lithology is taken from Muehlberger and others (1967). See figure 42 for location.

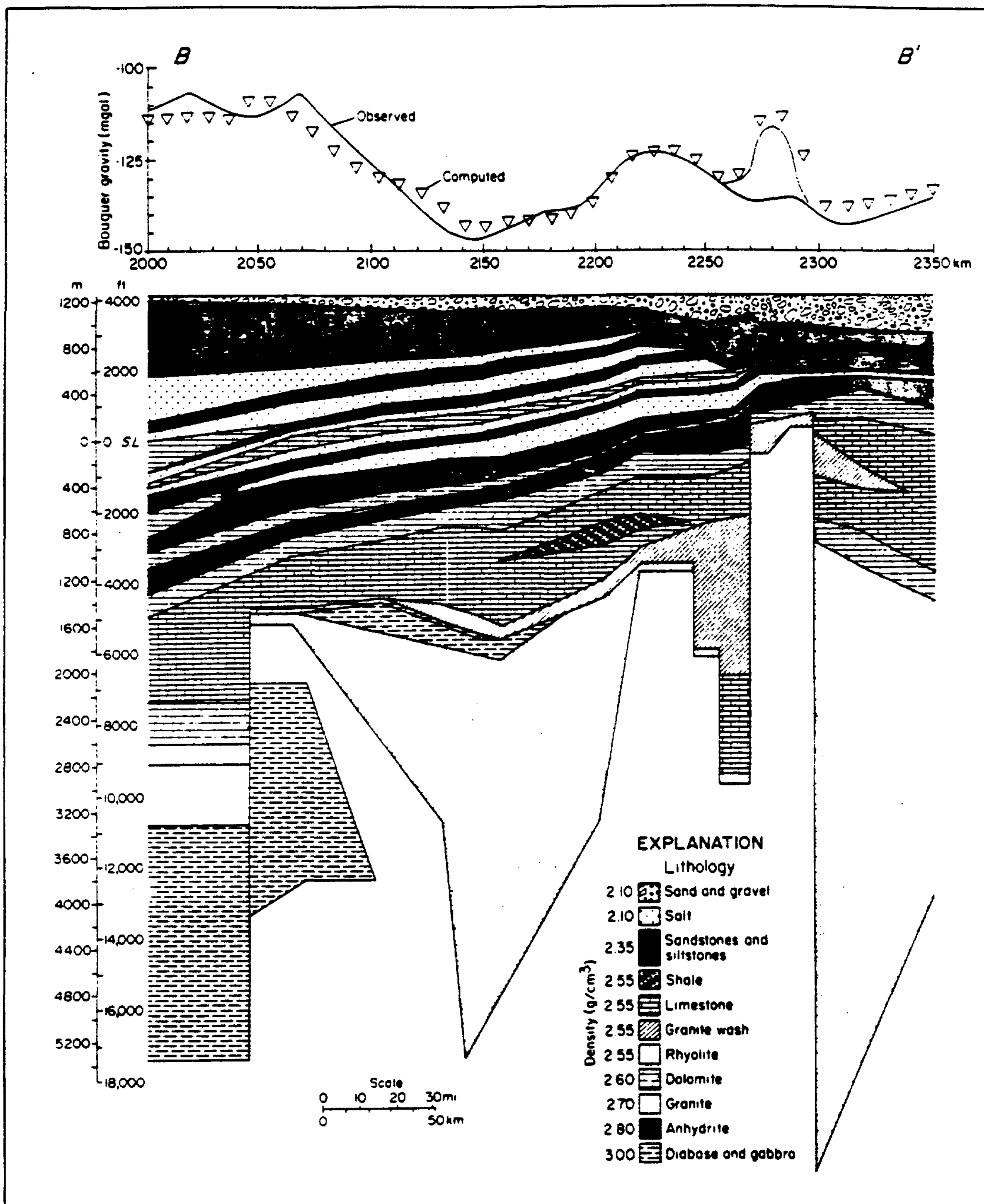


Figure 44. Gravity model B-B', modified from cross section B-B'. Shaded area on computed curve is a positive anomaly predicted from the model, which does not appear in the observed gravity. This requires that granites in this region be thin sills intruded into a deep rhyolite basin. See figure 42 for location.

Long (4)

SWEC SEISMIC DATA RECORDING AND PROCESSING PARAMETERS

The RFP issued in June, 1982, requested bidders to provide price per mile quotations as follows:

A. Recording
   1. Spread: split/straddle using 24 phones (14 or 28 Hz dampened 60% of critical) per trace.

   2. Vibrators: three available with not less than two operating to employ 20 (2 x 10) 7 second sweeps at 20 to 120 Hz input for 11 seconds.

   3. Recording: 2 ms sample rate at 18-120 Hz band pass. Quote price per mile for each of the following configurations:
      a. 96 trace - 48 fold - 55' group interval - 55' sweep interval
      b. 96 trace - 24 fold - 55' group interval - 110' sweep interval
      c. 48 trace - 24 fold - 110' group interval - 110' sweep interval

B. Processing

   1. Specify and quote a processing sequence of operations utilizing state of the art production techniques at a 2 ms sample rate.
   2. Provide full scale and half scale sections - three second length, full scale sections to be 20 traces per inch horizontally at 55' group and sweep intervals and 10" per second of reflection time vertically.

Western Geophysical Company was the successful bidder. Field experimentation designed to establish recording parameters were conducted on July 7 and 8, 1982.

C. The following Recording Parameters were selected:
   1. Geophones: 16 per group - 10 Hz - dampened 70% of critical; changed to 24 per group on April 6, 1983
   2. Group length: 165'
   3. Group interval: 55'
   4. Spread: 2805' - 220' - 0 - 220' - 2805'
   5. Source: Sweep frequency 17 to 85 Hz - 3 vibrators - 30 (3 x 10) 9 sec. sweeps
   6. 13 sec. record length - 2 ms sample rate
   7. Filter: 12 - 90 Hz - Notch 60

D. Processing Parameters were essentially as specified and quoted by WGC. These included: Edit/Demultiplex, correlation and vertical sum; digital filtering, datum statics and trace balance; zero phase deconvolution; CDP gathers; velocity analysis; automatic statics; NMO; coherency stack; gain and time variant filtering. A 3.0 second record length for processing was selected to minimize cost. Comparisons between 24 fold and 48 fold processing failed to justify the increased cost of 48 fold processing.

Budnik 5

Reprocessing of Seismic Reflection Data

I. Introduction

Difficulty in interpretation of the DOE seismic reflection profiles collected in 1982 and 1983 prompted the reprocessing of the data by the Bureau and the University of Texas. Institute for Geophysics. Specific problems with the original stacked data included:

1. the discontinuous nature of the Alibates reflector. possibly as a result of salt dissolution;

2. the variation in strength of reflectors associated with the San Andres Formation along the profiles; and

3. the lack of good resolution of the basement surface. in part because the seismic acquistion parameters were set to maximize resolution at the level of the San Andres Formation.

The three primary objectives of the reprocessing program were to:

1) study the near surface data to identify acquision and/or processing problems that may have affected the continuity of reflectors;

2) examine the data in the vicinity of the San Andres Formation to determine the nature of lateral variability in the reflectors: and

3) better delineate the location of the basement surface. if possible. with the available data.

II. Procedures

A. Near surface reflectors were examined in a small-fold study of the field data using near traces. In addition. velocity studies were made to insure that the data were properly stacked.

B. Complex attributes of the data (instanteous frequency and amplitude) were determined from the stacked data to more precisely identify events associated with the San Andres Formation and the basement surface.

III. Conclusions

A. In the cases studied. the disruption of near surface reflectors was related to loss of fold in the vicinity of "no permit" areas. Incorrect stacking velocities and the presence of a strong airwave also contributed to the lack of continuity. A study of each line would be necessary determine if all apparent disruptions are artifacts of acquision and/or processing techniques.

B. Lateral variations in the San Andres Formation are. in part. related to variation in quality of data. and. in part. appear to be related to horizonal variations in bulk rock characteristics. However. there are insufficent geologic data at the present time to fully interpret the results.

C. Although complex attributes differ for the basement and overlying sedimentary section. no unique seismic signature was noted for the basement surface.

AVAILABLE GEOPHYSICAL DATA IN THE TEXAS PANHANDLE

SEISMIC REFLECTION DATA

GRAVITY DATA

AEROMAGNETIC DATA

85-45,788

Acharya (3)

SEISMIC REFLECTION DATA

PROPRIETARY DATA

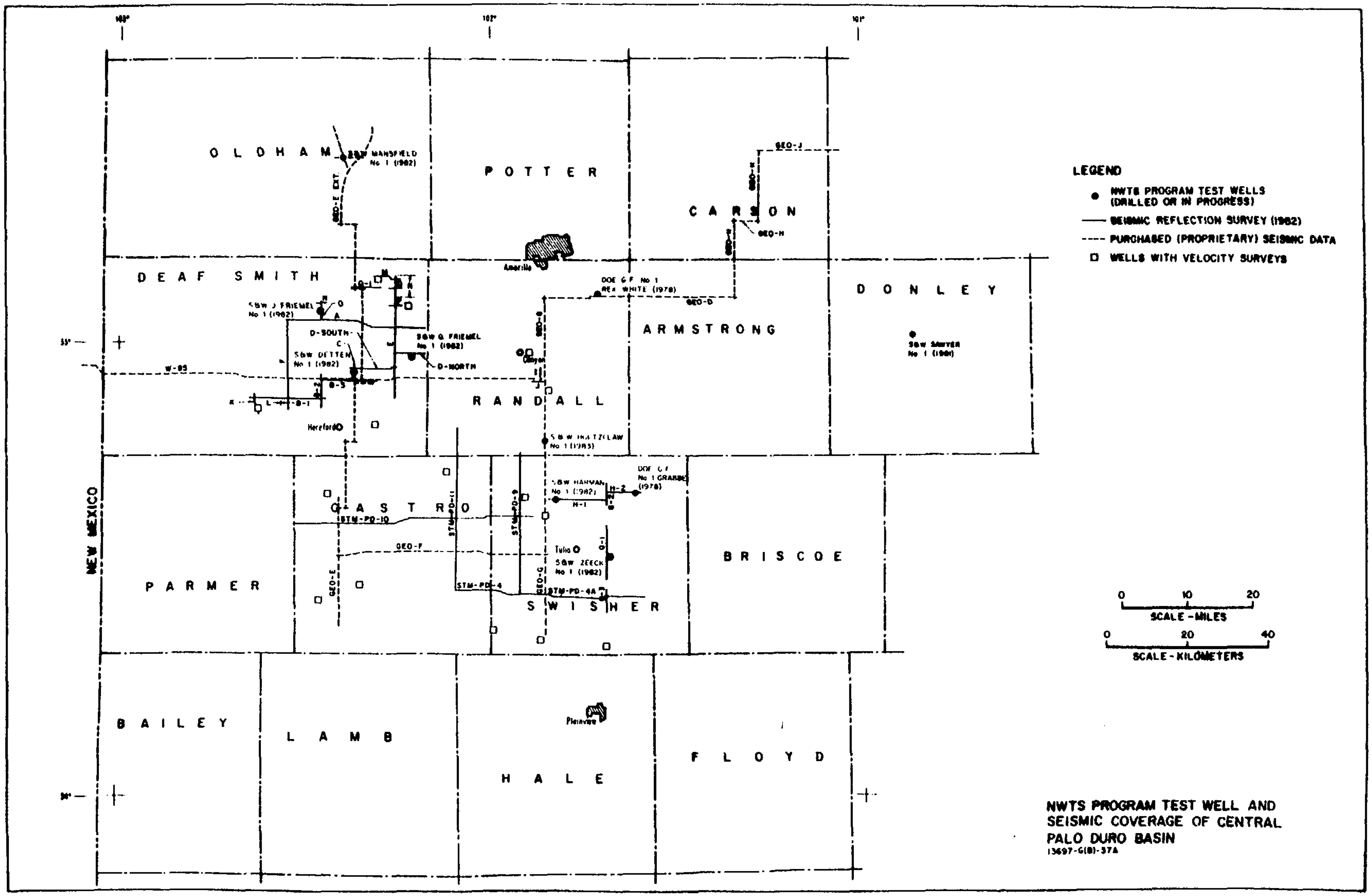
SWEC SURVEYS

VELOCITY SURVEY DATA

VERTICAL SEISMIC PROFILES

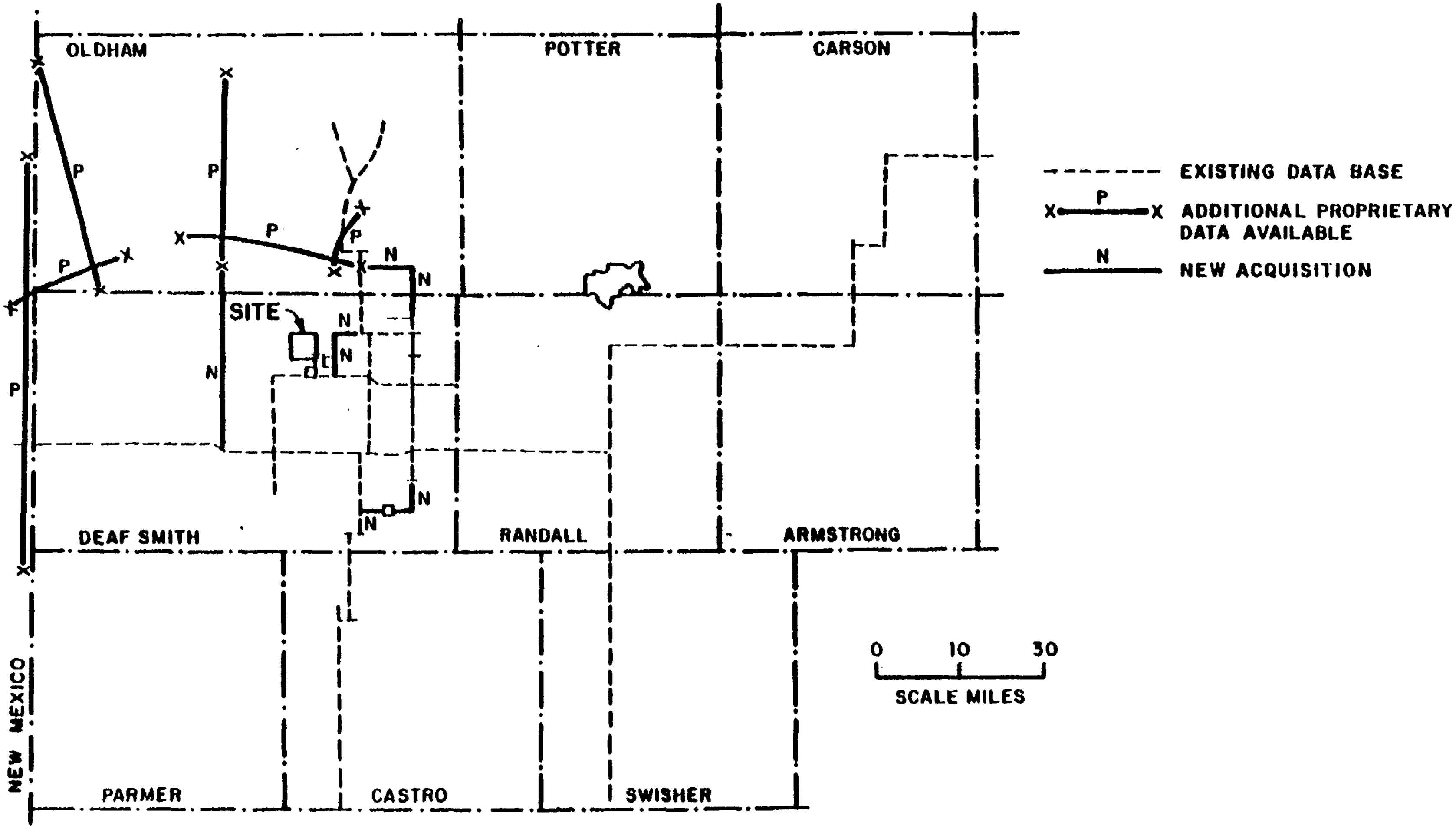
SYNTHETIC SEISMOGRAMS

85·45,789

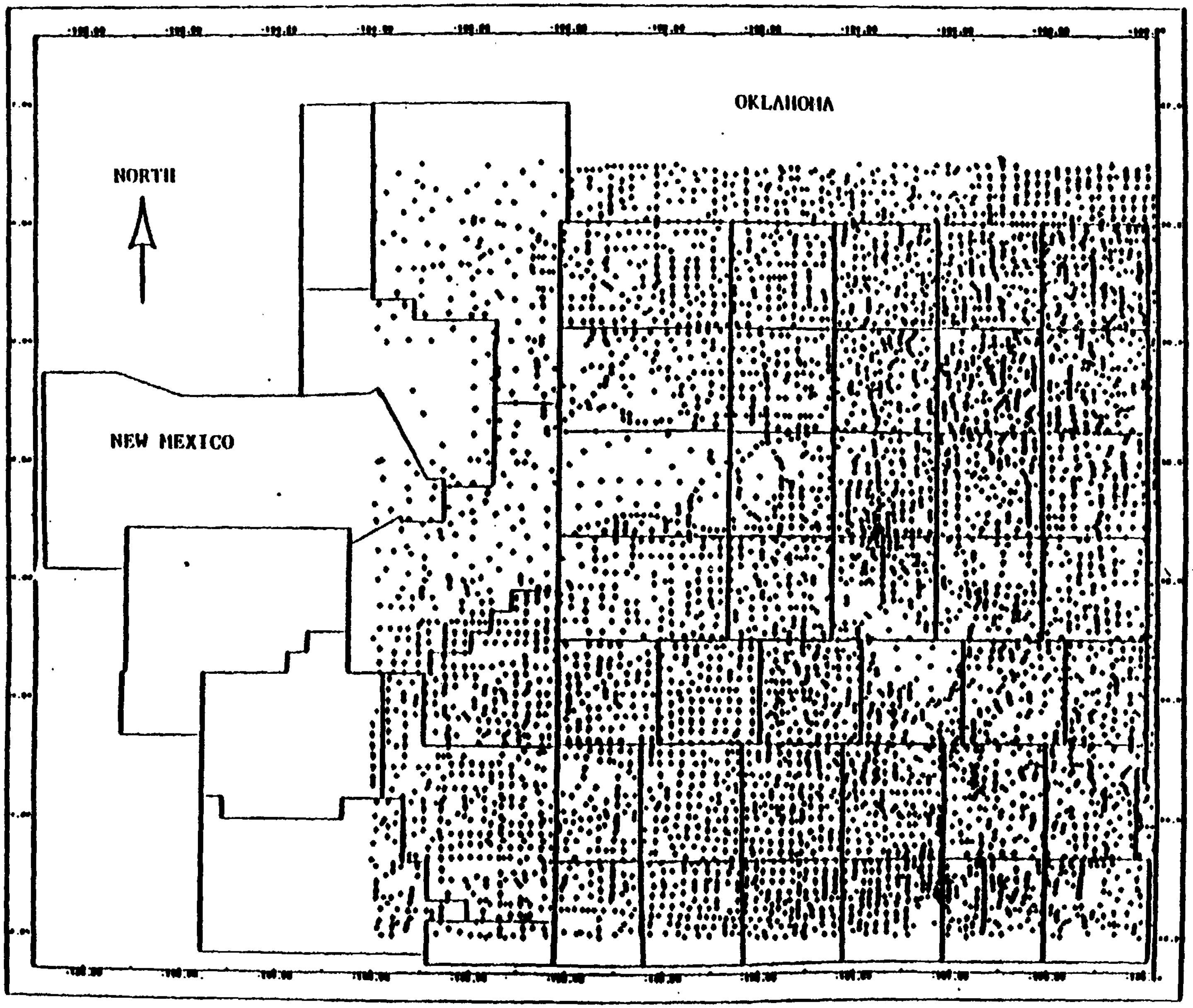


NWTS PROGRAM TEST WELL AND SEISMIC COVERAGE OF CENTRAL PALO DURO BASIN

13697-G(8)-37A

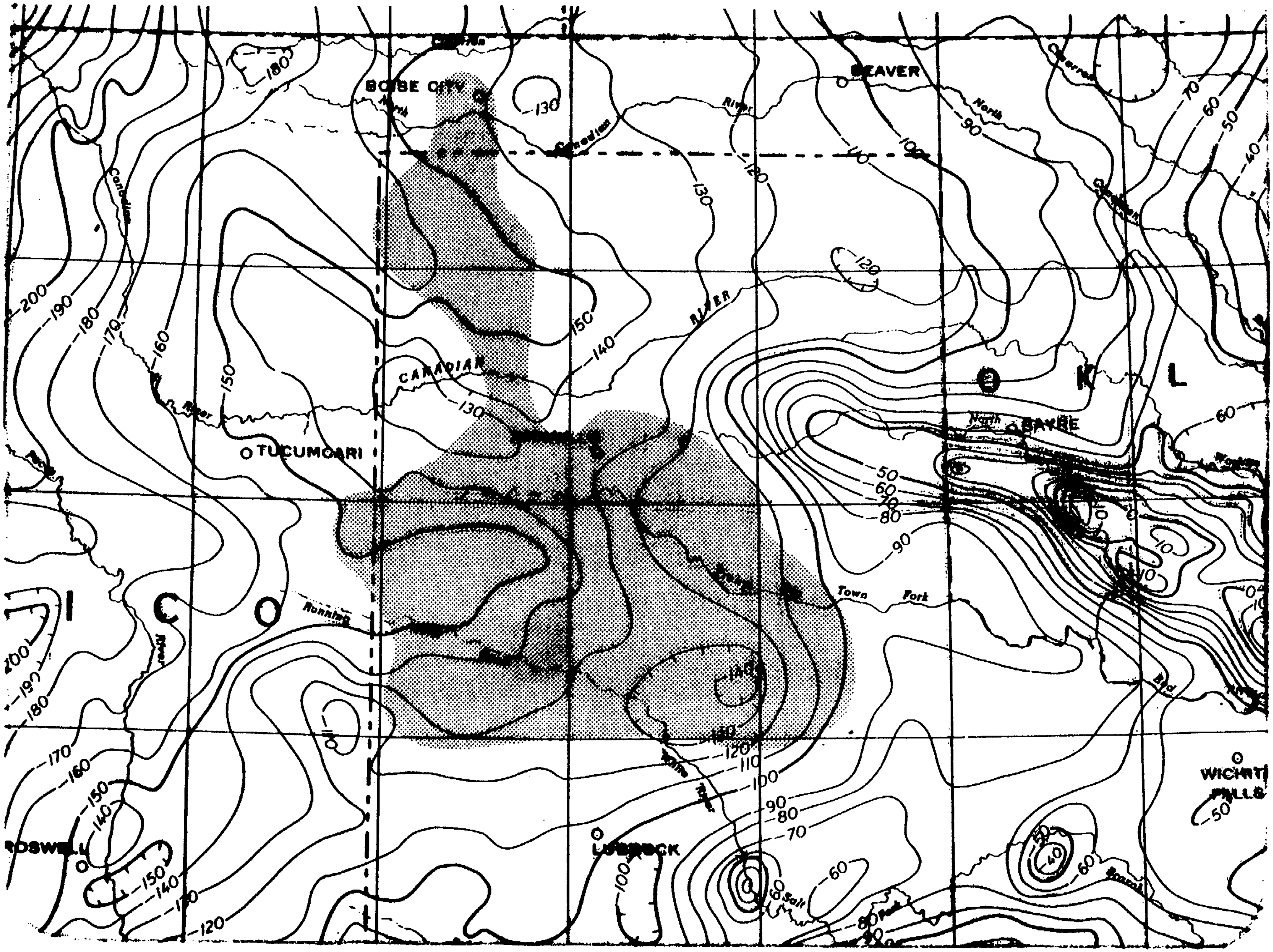


ATTACHMENT-2
CDP SEISMIC COVERAGE
ACTIVITY PLAN 13697-37



GEOPHYSICAL SURVEYS
ATTACHMENT 3-0
LOCATION MAP OF
GRAVITY VALUES

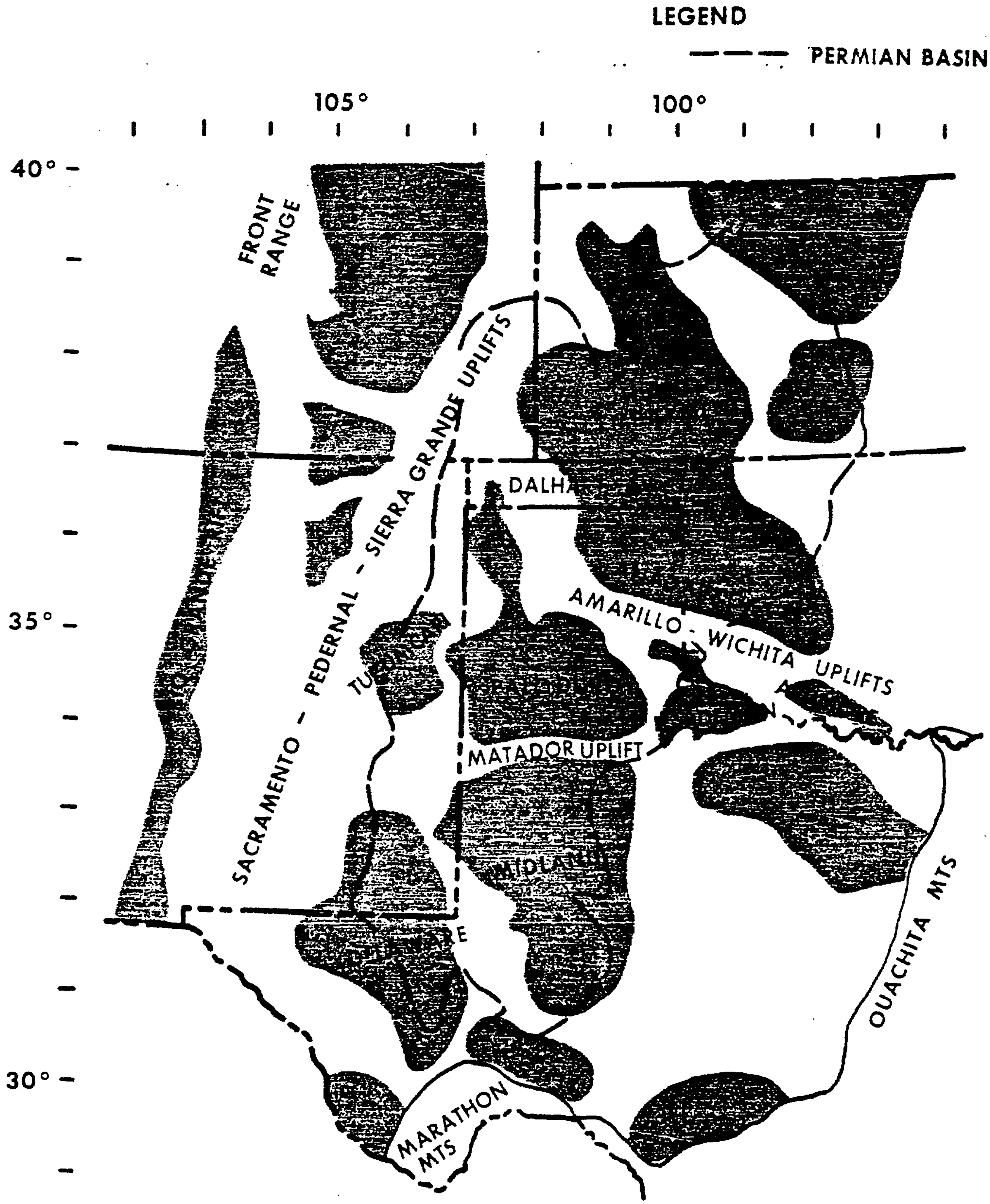
BOUGUER GRAVITY ANOMALY MAP



82-23668

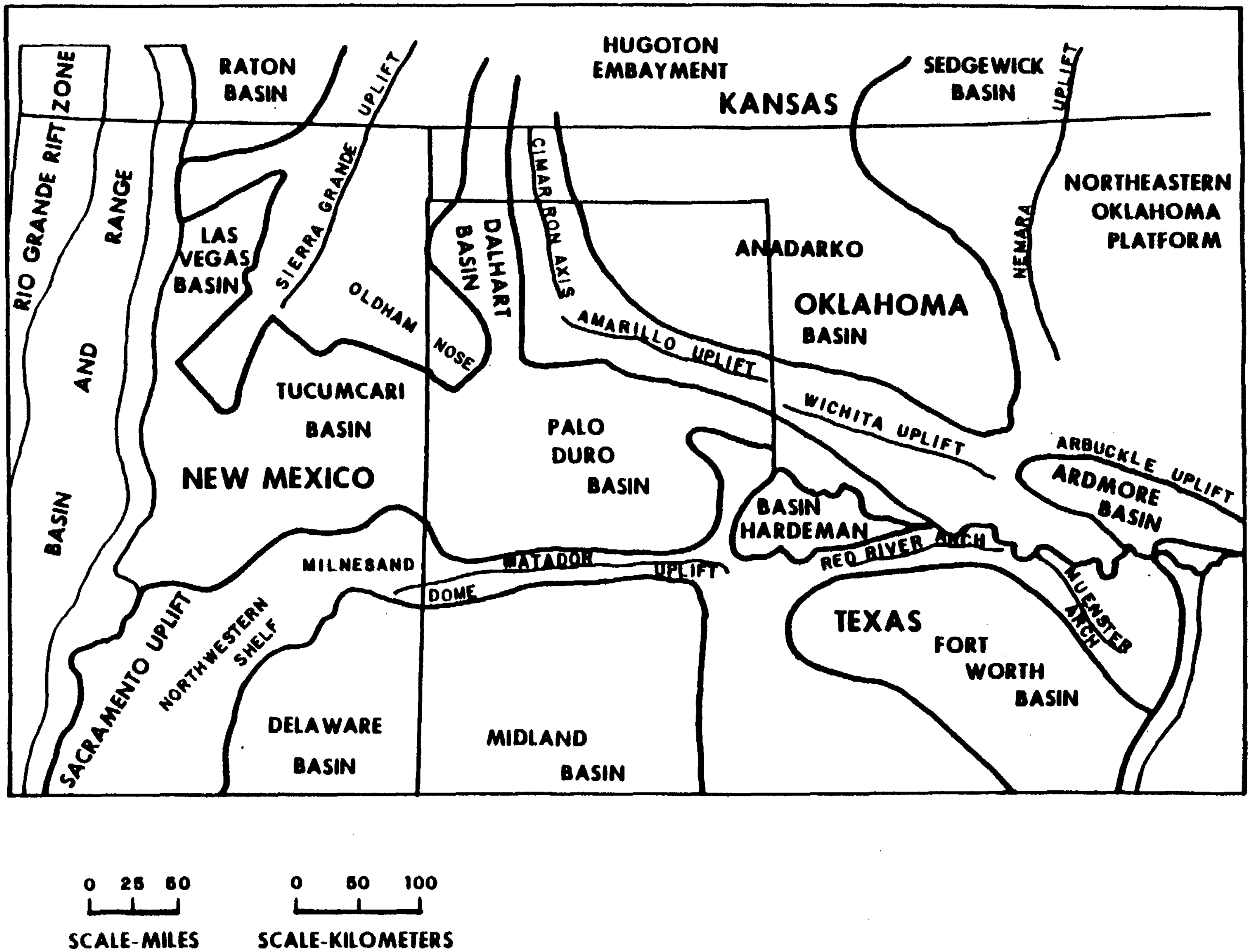
Peck (1)

REGIONAL TECTONIC MAP



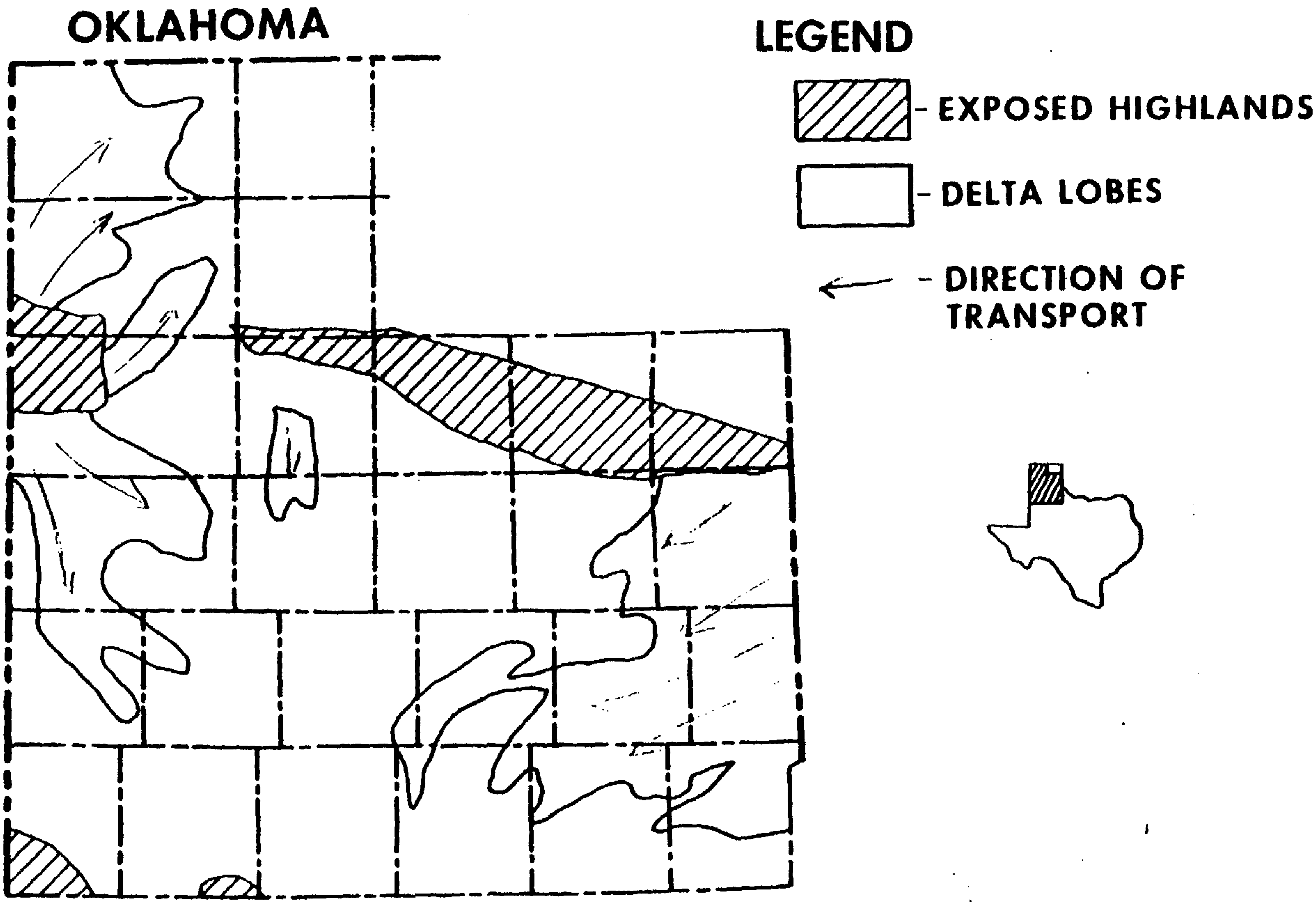
OH-2

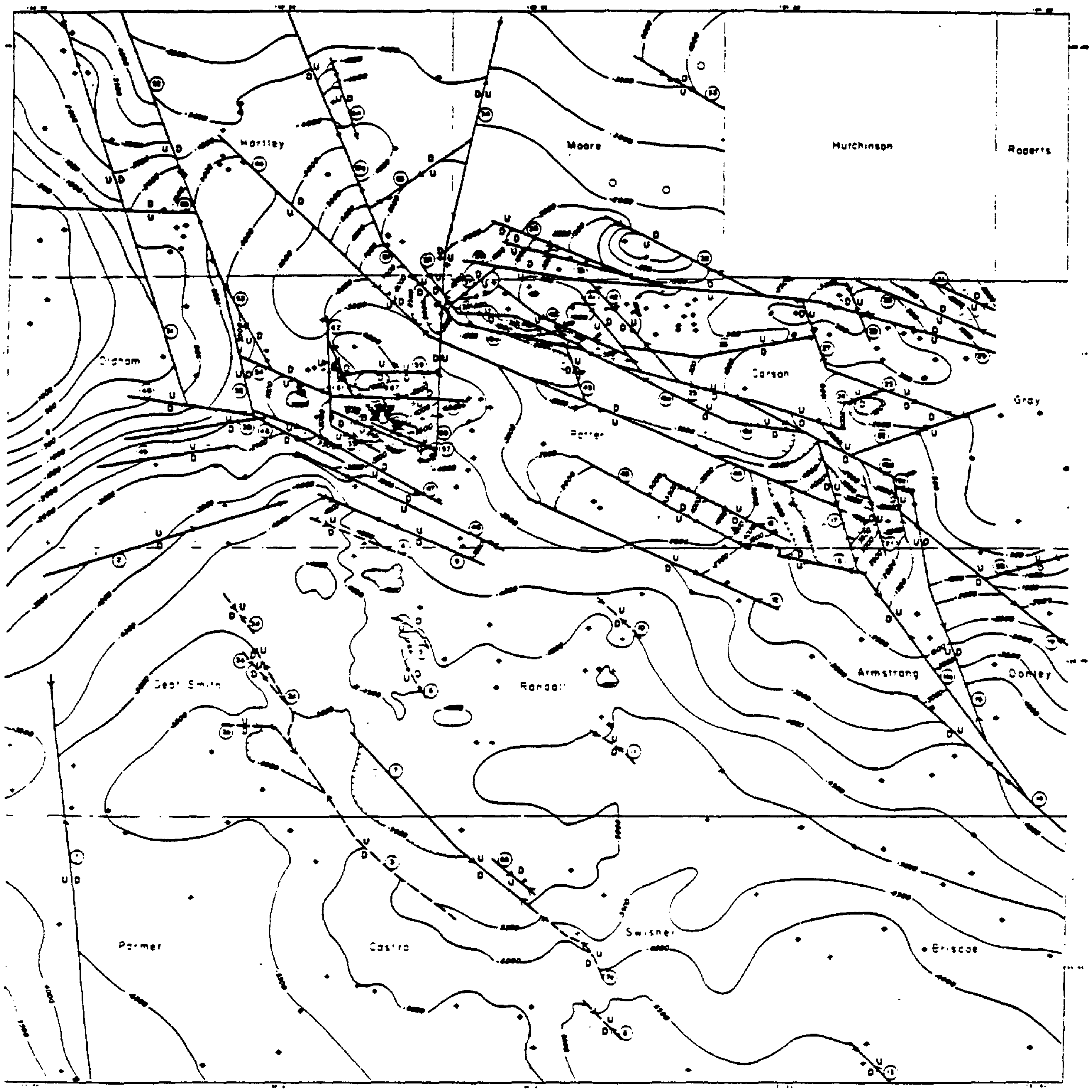
REGIONAL TECTONIC FEATURES



5-44,009

PENNSYLVANIAN DELTAS





Explanation

Datum is Mean Sea Level

Numbers Identifying Faults Refer to Tables 1 and 2

Fault Interpreted From Geophysical Well Log Data (U-Upthrown D-Downthrown) Arrows Indicate Areas of Maximum Observed Displacement

Fault Interpreted by Long, 1983 (U-Upthrown D-Downthrown) Arrows Indicate Areas of Maximum Observed Displacement

Structure Contour-Interval 500 Feet.

Well Control

Well Not Penetrating Precambrian But Used to Confine Maximum Elevation

Fault Identification Number

0 5 10 15 20

Scale - Miles

0 5 10 15 20

Scale - Kilometers

Source: SWEC Search 1982-84 ... Data From Long 1983

Elevation of Precambrian

Figure 4

WELL LOG SUITE

Description

Gamma Ray Log
Caliper Log (4-Arm)
Spontaneous Potential Log (fresh water mud only)
Dual Induction Electric Log (fresh water mud only) or
Dual Laterolog (salt mud only)
Microresistivity Log
Borehole Compensated Sonic Velocity Log
- Sonic Waveform
- Integrated Travel Time
- Digitized Waveform

Long Spaced Sonic Log
- Sonic Waveform
- Digitized Waveform

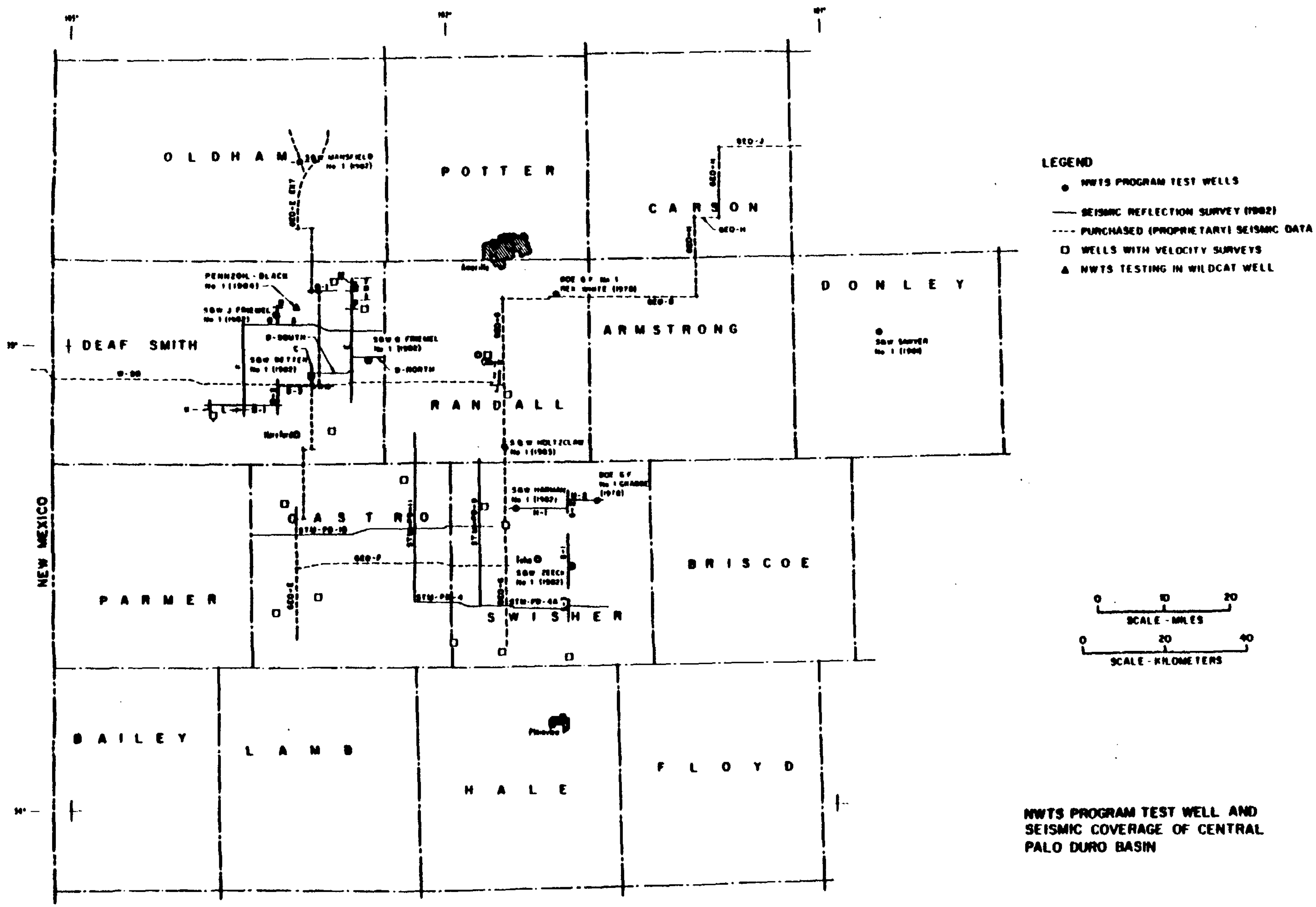
Well Seismic Log
Density Log with photoelectric absorption curve
Gamma Ray Spectrometry Log
Compensated Neutron Log
High Resolution Continuous Dipmeter Logs (including fracture identification, continuous directional survey, and arrow plots)
Continuous Directional Survey
Electromagnetic Propagation Log
Temperature Log
Repeat Formation Tester (run separately at selected intervals)
Thermal Decay Time
Digital Sonic Log

Synthetic logs derived from computer processing of the above logs will be obtained to provide calculated information on rock porosity/permeability and mechanical properties.

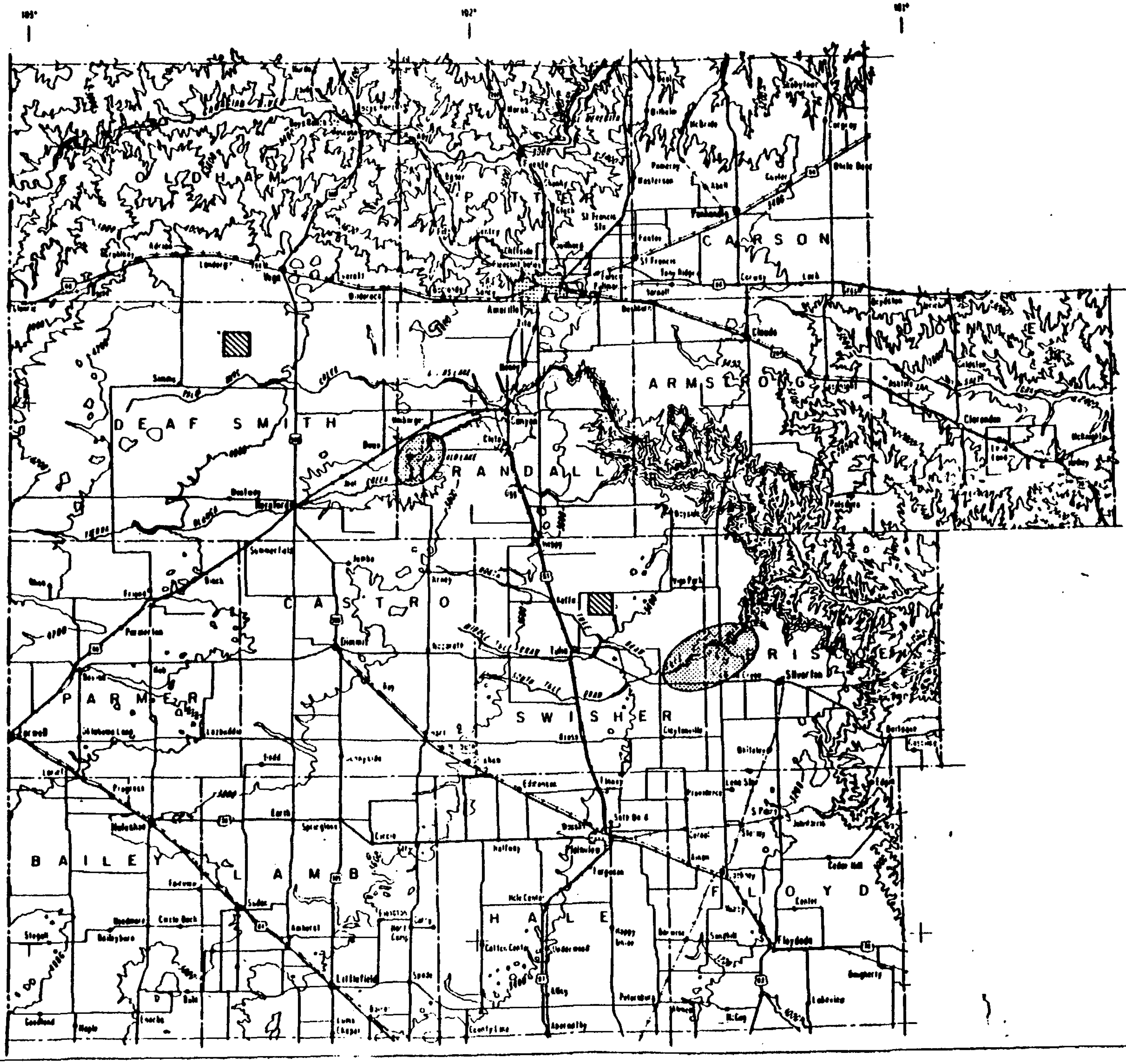
A Cement Bond Log, Variable Density Log, and Casing Potential Log will be run within the cased portion of the well. A Gamma Ray Log and Casing Collar Locator log will be run simultaneously with these logs for depth control and correlation with the logs run in the open hole.

As required, a partial suite of logs will be performed to identify potentially porous zones, and to locate good packer seats prior to running drill stem tests. This partial suite will consist of:

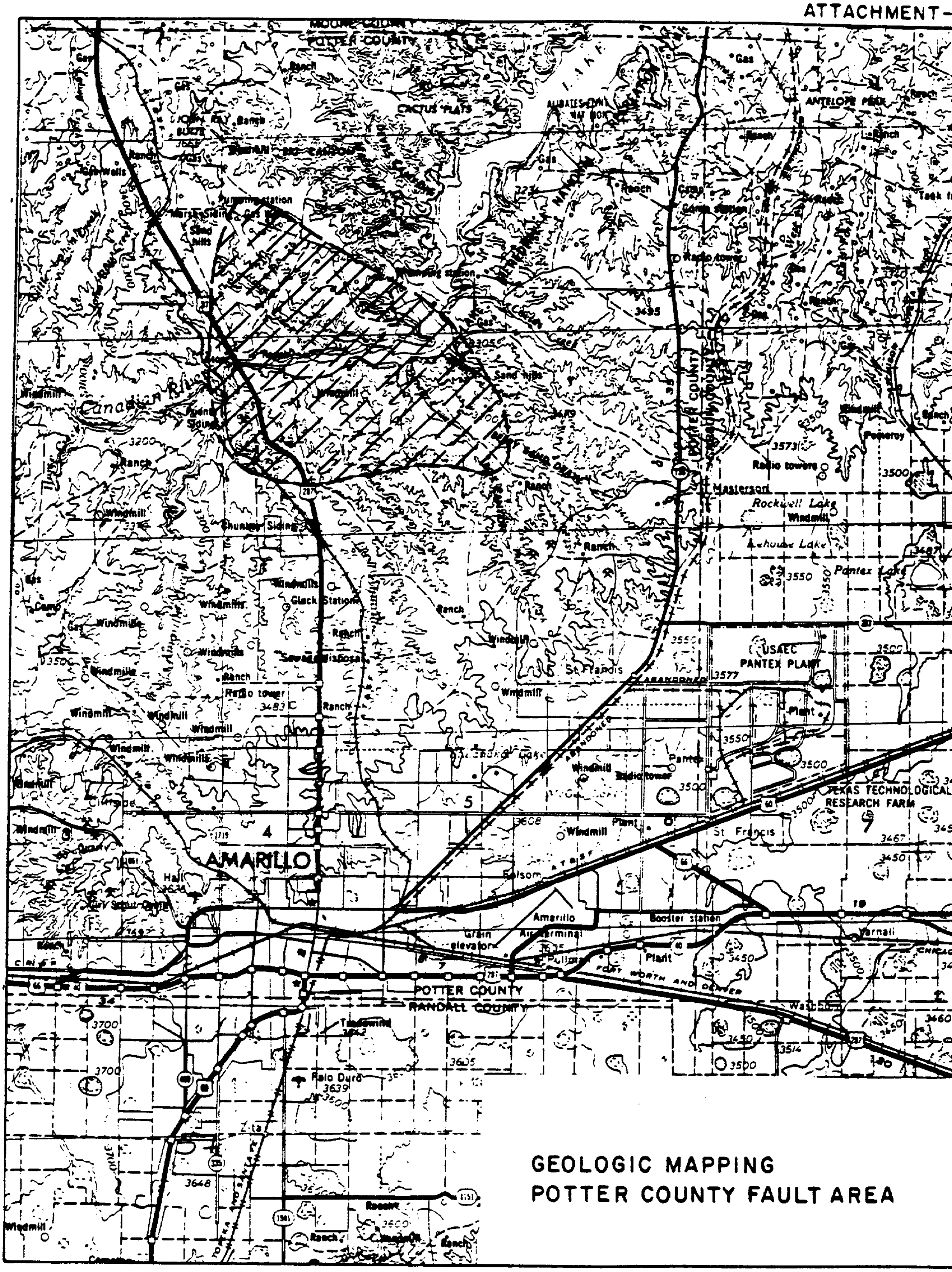
Gamma Ray Log
Compensated Neutron Log
Dual Induction or Dual Laterolog
4-Arm Caliper Log



NWTS PROGRAM TEST WELL AND SEISMIC COVERAGE OF CENTRAL PALO DURO BASIN



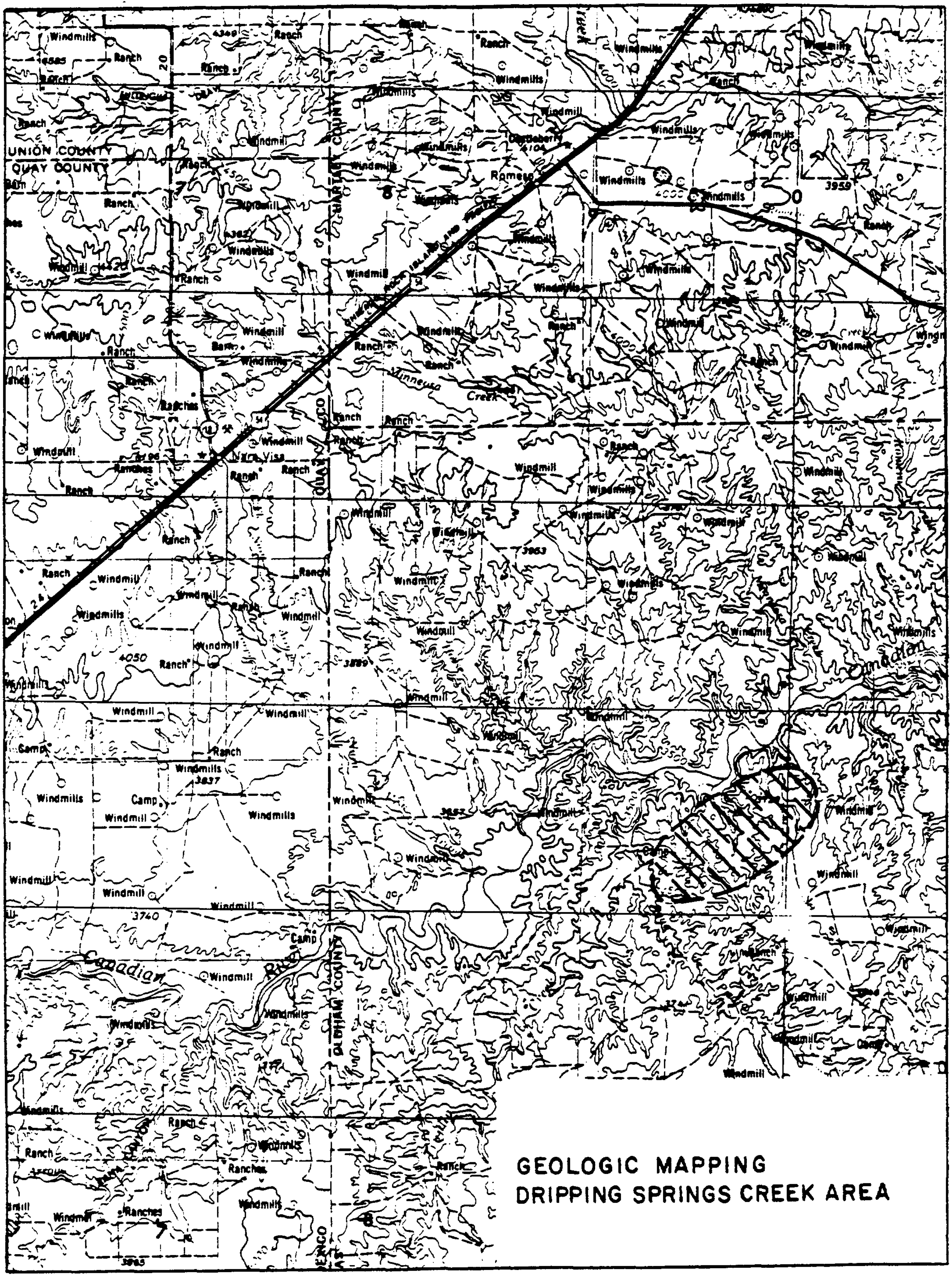
AP 13697-23
ATTACHMENT I
LOCATION OF AREAS OF STUDY
STONE & WEBSTER ENGINEERING CORPORAT



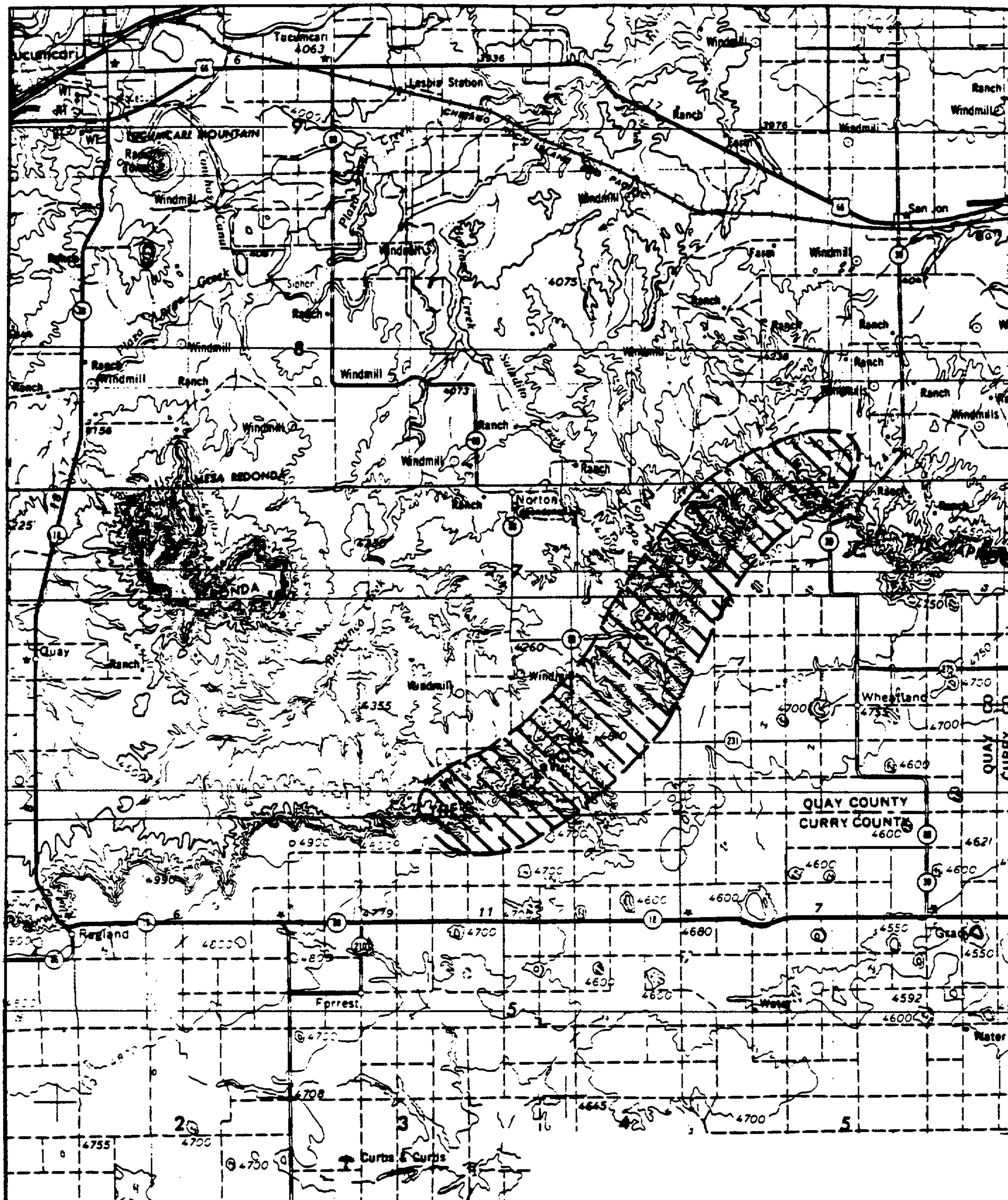
GEOLOGIC MAPPING
POTTER COUNTY FAULT AREA

AP 13697-36-0
ATTACHMENT-3

GEOLOGIC MAPPING
PUNTA de AQUA CREEK AND
BILLYS CREEK AREA



GEOLOGIC MAPPING
DRIPPING SPRINGS CREEK AREA



GEOLOGIC MAPPING
BONITA FAULT AREA

Enclosure 2

Agenda
Joint NRC/SRP Workshop
November 19-21, 1985, Parke University Hotel, Columbus, Ohio

STRUCTURE AND TECTONICS OF THE PALO DURO BASIN

Objective: Participants at this workshop will obtain an understanding of the current state of knowledge of the structural features of the Palo Duro Basin. The focus will be on evaluating the present structural configuration of the basin and its tectonic history and setting. Current seismicity and active tectonic processes in the region will not be discussed.

The data base from which structural interpretations have been made will be examined. The workshop will identify areas where contractor interpretations of existing data differ, and consider methods to resolve those differences.

November 19, 1985

8:30 - 9:00	INTRODUCTIONS	
9:00 - 10:00	OVERVIEW OF THE PALO DURO BASIN	SRPO, NRC
	- Current basis for definition and tectonic history.	J. Peck (SWEC) (1) R. Budnik (TBEG) (2)
10:00 - 12:00	DESCRIPTION OF DATA USED IN SRP's STRUCTURAL STUDIES	
	- Seismic Lines. Includes: location of DOE-run and purchased lines, the quality of the data (resolution at depths of interest), the rationale for selection of specific lines, and the proprietary status of the information.	H. Acharya (SWEC) (3)
	- Types of processing of seismic information, including reasons for selecting specific processing techniques.	G.J. Long (G.J. Long) (4 R. Budnik (TBEG) (5) D. Turner (ONWI) (6)
	- Other geophysical data (gravity, aeromagnetic) used to define structures.	TBD (SWEC) W. Bennett (Bendix) (7)
12:00 - 1:00	--- LUNCH ---	

1:00 - 5:00	-	Non-DOE wells. Includes: number and location of wells, lithologic and geophysical logs available, quality of the data, rationale for selection of wells to be included in the data base, and availability of the data for review by third parties.	P. Murphy (SWEC) (8)
	-	Summary of the borehole database.	P. Murphy (SWEC)
	-	DOE Wells. Includes: lithologic logs and geophysical logs available, stratigraphic correlations made, and application of well information to other studies (e.g. use of sonic logs to establish parameters for seismic processing).	J. Peck (SWEC) (9)
	-	Remote-sensed Imagery. Includes: types of imagery analyzed, application of remote-sensing to structural interpretation (e.g. lineament analysis), and "ground checking" of interpreted features.	T. Gustavson (TBEG) (10)
	-	Geologic Analysis. Includes: field mapping, joint/fracture analysis (outcrop and borehole), relation of mapped features to regional structures, (including recent interpretations of Pleistocene units).	~~R. Gillespie (SWEC)~~ ~~J. Peck (SWEC)~~ E. Collins (TBEG) ~~T. Gustavson (TBEG~~) D. Pierce (SWEC) (12)
	-	Quality Assurance. Procedures for data collection/interpretation of seismic, borehole, and other data applicable to structural analyses.	E. Washer (SWEC) (13) D. Davidson (TBEG) (14)

November 20, 1985

8:30 - 11:00		INTERPRETATION AND SYNTHESIS OF STRUCTURAL DATA	
	-	Stratigraphic Correlations. Includes: development of structure contour maps of major units (include younger units such as the Dockum), development of isopach maps, and the types of data utilized in these studies.	P. Murphy (SWEC) (15) T. Gustavson (TBEG) S. Hovorka (TBEG) R. Budnick (TBEG)

	- <u>Detailed Correlations</u>. This will be a brief synopsis of material presented at the August 5-9 workshop in question.	T. Gustavson (16)
11:00 - 12:00	PARTS OF THE AVAILABLE DATA BASE NOT UTILIZED AND RATIONALE FOR EXCLUSION	
	- Summary of all available borehole and proprietary geophysical data and selection criteria for access by the program.	E. Washer (SWEC)
	- Summary of available literature sources for structural interpretations of the Palo Duro Basin.	E. Washer (SWEC) E. Bingler (TBEG) R. Budnik (TBEG)
12:00 - 1:00	--- LUNCH ---	
1:00 - 5:00	INTERPRETATIONS OF THE STRUCTURAL GEOLOGY DATA BASE	
	- Computer mapping abilities from geologic data base.	T. Bruno (SWEC) (19)
	- Methods/Procedures for interpreting seismic data.	G.J. Long (G.J. Long)(1 R. Budnik (TBEG)(17)
	- Magnetic anomalies	D. Turner (ONWI) (6)
	- Extent to which available data (bore-hole stratigraphic information, surface mapping, seismic information published studies) has been integrated into a structural interpretation.	R. Budnik (TBEG) T. Gustavson (TBEG) P. Murphy (SWEC) J. Peck (SWEC) T. Regan (SWEC)
	- Effects of differing data interpretations or different data bases on structure/tectonic evaluations of the Palo Duro Basin, including methods, data base and results.	TBD (TBEG) D. Pierce (SWEC)
November 21, 1985		
8:30 - end	SUMMARY AND CONCLUSIONS	
	- General types of additional studies necessary to resolve differing structural interpretations/hypotheses.	All D. Ballmann (20)
	- Meeting summary and agreements.	SRPO, NRC

EXPECTED ATTENDEES

SRPO

J. Sherwin
T. Baillieul
M. Ferrigan
A. Avel

ONWI

W. Newcomb
J. Hileman
A. Funk
D. Ballman
O. Swanson
C. Kuntz
D. Turner
S. Adams
S. Nelson
K. Johnson

SWEC

J. Peck
E. Washer
D. Pierce
P. Murphy
T. Regan
H. Acharya
T. Bruno
G.J. Long *

TBEG

E. Bingler
J. Raney
T. Gustavson
R. Budnik
E. Collins
S. Hovorka
C. Kreitler

NRC

J. Trapp
R. Johnson
P. Justus
M. Blackford
A. Ibrahim
R. Lee
F. Ross
E. Zurflueh
J. Pearring
E. Levine **
V. Murphy **
D. Carpenter ***
H. Mckaque ***
R. Berry ***
C. Purcell ***

GLYN JONES

BENDIX

W. Bennett

* (G.J. Long & Associates)
** (Weston Geophysical)
*** (LLL)

ENCLOSURE 3

Budnik (17)

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Budnik (17)

Interpretation of seismic reflection data

I. Introduction

Seismic reflection data were examined as an aid to structural and stratigraphic studies within the basin. All available stratigraphic and velocity data were integrated to interpret the seismic data.

II. Procedures used in the identification of reflectors:

1. Compared of synthetic seismograms and VSP data from DOE wells with adjacent seismic reflection profiles.

2. Constructed time/depth plots using check shot data from petroleum exploration wells, in areas without synthetic seismograms.

3. Used regional isopach and structural data as aid to interpreting basement reflector.

III. Problems

1. Acquisition parameters were inappropriate for resolving deep structure.

2. "No-permit" areas resulted in degraded data.

3. Problems with statics corrections and velocity determinations produced mis-ties with well data.

4. SWEC lines did not tie well to each other nor to lines from other surveys.

5. Poor velocity control reduced reliability of structure maps produced from seismic data.

6. Variablility in quality of data made it difficult to trace structures from line to line.

IV. Conclusions

1. The available seismic reflection data have been useful for examining the gross structural continuity of Permian strata within the Palo Duro Basin. However, details of faulting are still unresolved.

2. The accuracy of structure contour maps developed from the seismic data is probably low because of poor velocity control, both regionally and along individual lines.

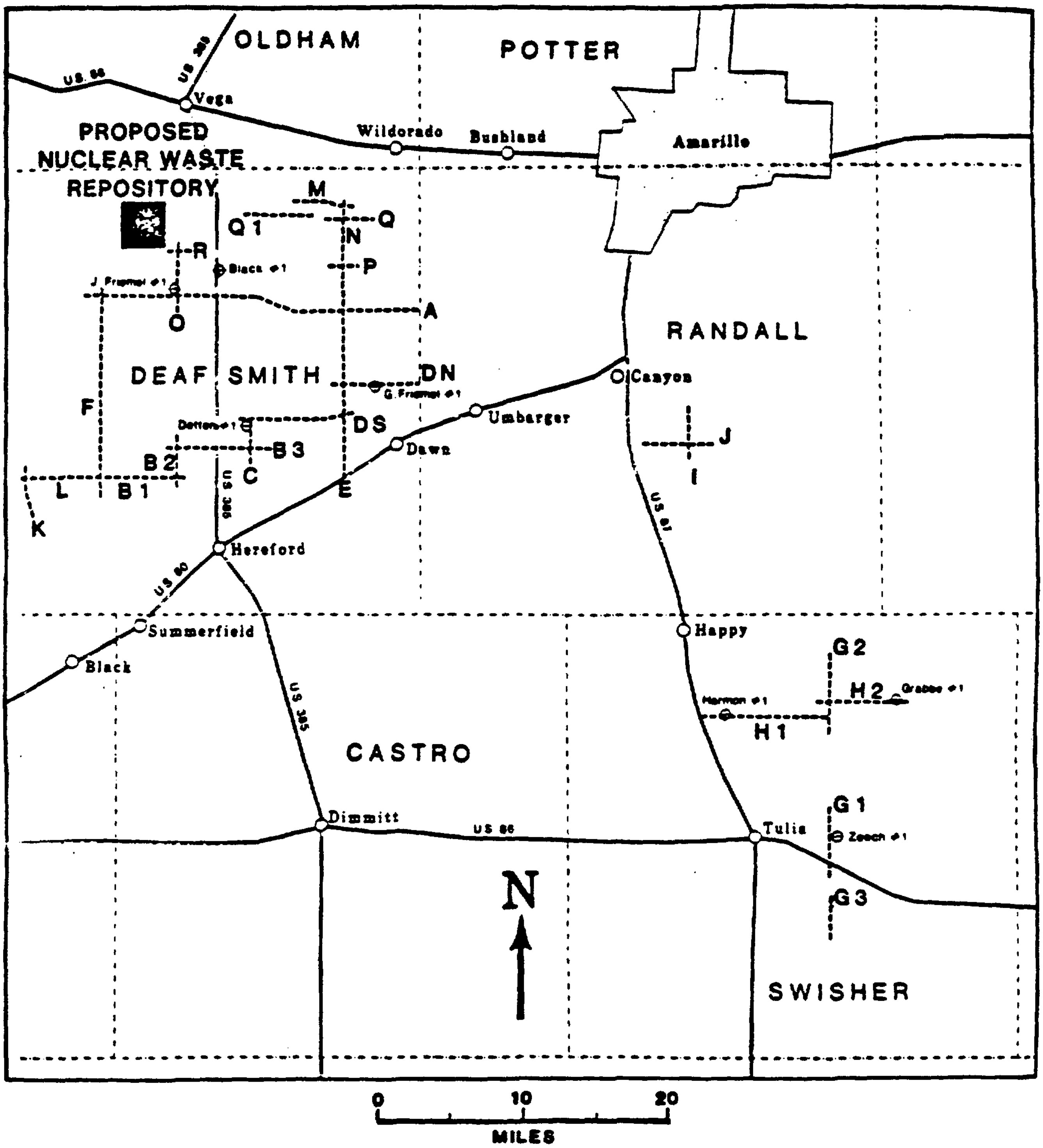

OLDHAM
POTTER
US 66
US 385
Vega
Wildorado
Bushland
Amarillo
PROPOSED
NUCLEAR WASTE
REPOSITORY
M
Q 1
Q
N
R
P
Black #1
J. Friemel #1
O
A
RANDALL
DEAF SMITH
DN
G. Friemel #1
Canyon
F
Detten #1
DS
Umbarger
J
Dawn
B 3
B 2
C
I
L
B 1
E
US 87
K
Hereford
US 60
Summerfield
Happy
Black
G 2
H 2
Grabbe #1
Harmon #1
H 1
CASTRO
US 385
G 1
Dimmitt
US 86
Tulia
Zeech #1
G 3
N
SWISHER
0
10
20
MILES

FIGURE 001

TABLE 1

LINE NUMBER	SHOT BY.	ENERGY SOURCE	FOLD % MSC	FREQUENCY* Hz	SPREAD feet	SOURCE SPACING FT
SWEC-A to B-3. D-I	Western	Vibroseis	24	12-90	2860-220-0-220-2860	110
SWEC-C #	Western	Vibroseis	24	18-128	2860-275-0-275-2860	110
SWEC-C +	Western	Vibroseis	48	18-128	2860-275-0-275-2860	55
SWEC-C @	Western	Vibroseis	48	18-128	5720-550-0-550-5720	110
SWEC-J	Western	Vibroseis	48	8-64	11220-880-0-880-11220	220
SWEC-K to R	Western	Vibroseis	24	12-90	2805-220-0-220-2805	110
BENDIX-D, F to H, J	Bendix-United	Vibroseis	12	12-40	4620-990-0-990-4620	330
BENDIX-E	Bendix-United	Vibroseis	12	12-40	4620-990-0-990-4620	330
75-2	Sundance	Dynamite	8	16-125	6600-220-0-220-6600	660
10-120	Sundance	Dynamite	12	16-125	5280-220-0-220-5280	440
PD-4, 4A, 9, 10, 11	STM	Vibroseis	24	15-75	8250-495-0-495-8250	330
W-95	Western	Vibroseis	24	8-64	7150-825-0-825-7150	275

Configuration A & B
+ Configuration C
@ Configuration D
in Figure 2

* notch @ 60

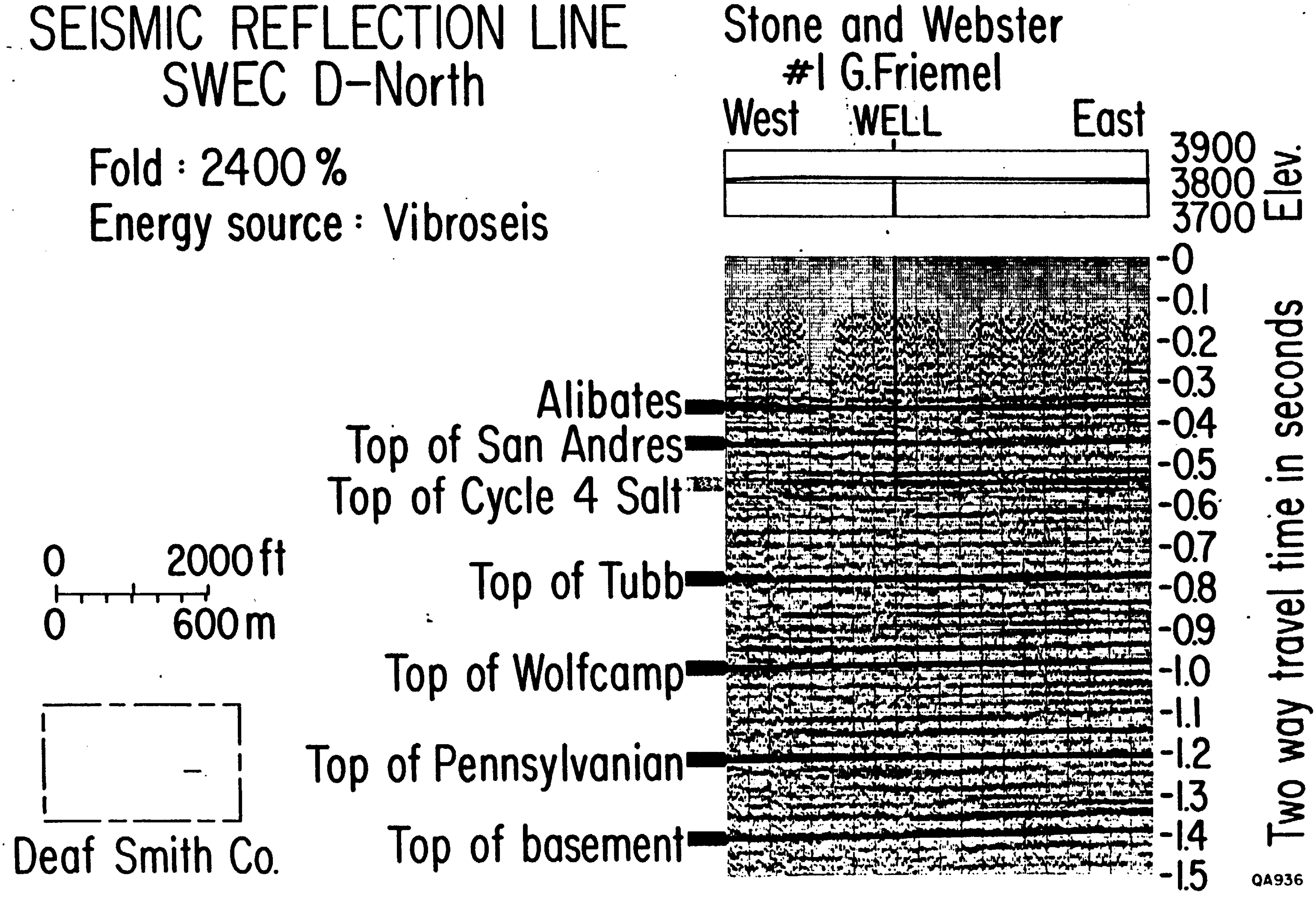
TABLE 2

List of DOE Test Wells

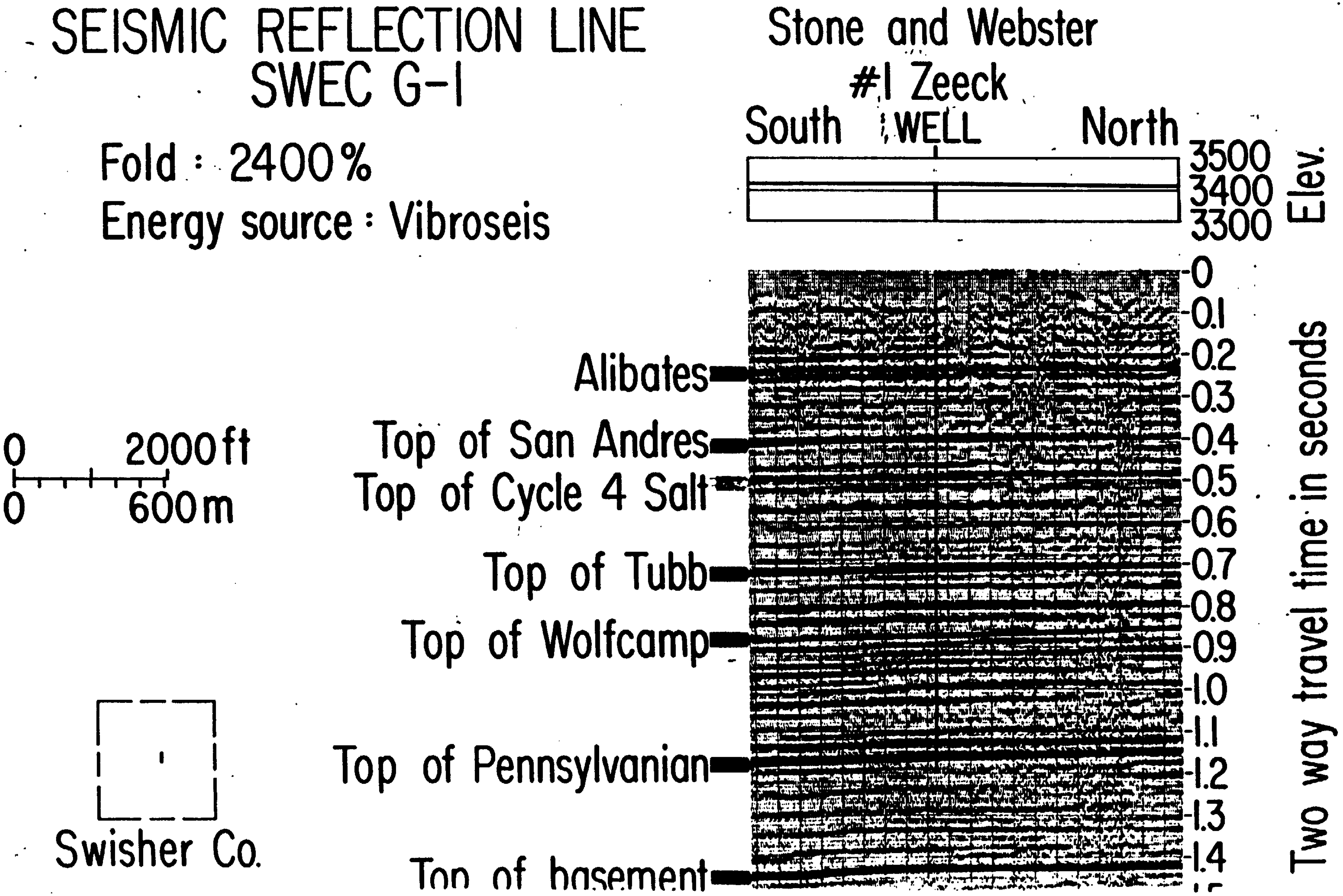
Well Name		County	Velocity Data*
GRUY-FEDERAL	#1 Rex White	Randall	ISL
SWEC	#1 Mansfield	Oldham	ISL
SWEC	#1 Sawyer	Donley	ISL
GRUY-FEDERAL	#1 Grabbe	Swisher	ISL, SS
SWEC	#1 Detten	Deaf Smith	ISL, SS
SWEC	#1 G. Friemel	Deaf Smith	ISL, SS
SWEC	#1 Harman	Swisher	ISL, SS, VS
SWEC	#1 Holtzclaw	Randall	ISL, SS, VS
SWEC	#1 J. Friemel	Deaf Smith	ISL, SS, VS, VSP
SWEC	#1 Zeeck	Swisher	ISL, SS, VS, VSP

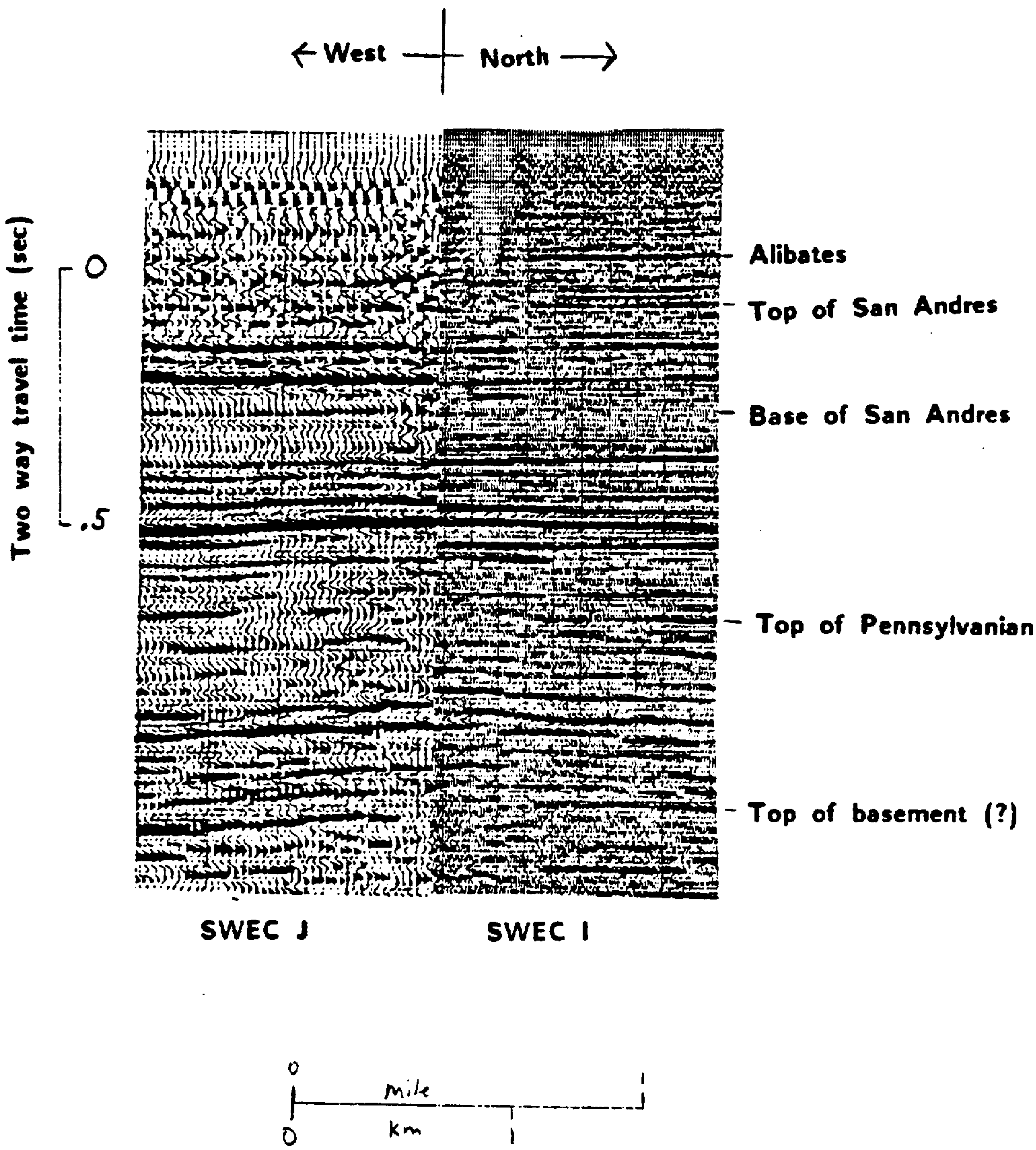
Velocity Data

ISL	Integrated sonic log
SS	Synthetic seismogram (geogram)
VS	Velocity survey
VSP	Vertical seismic profile

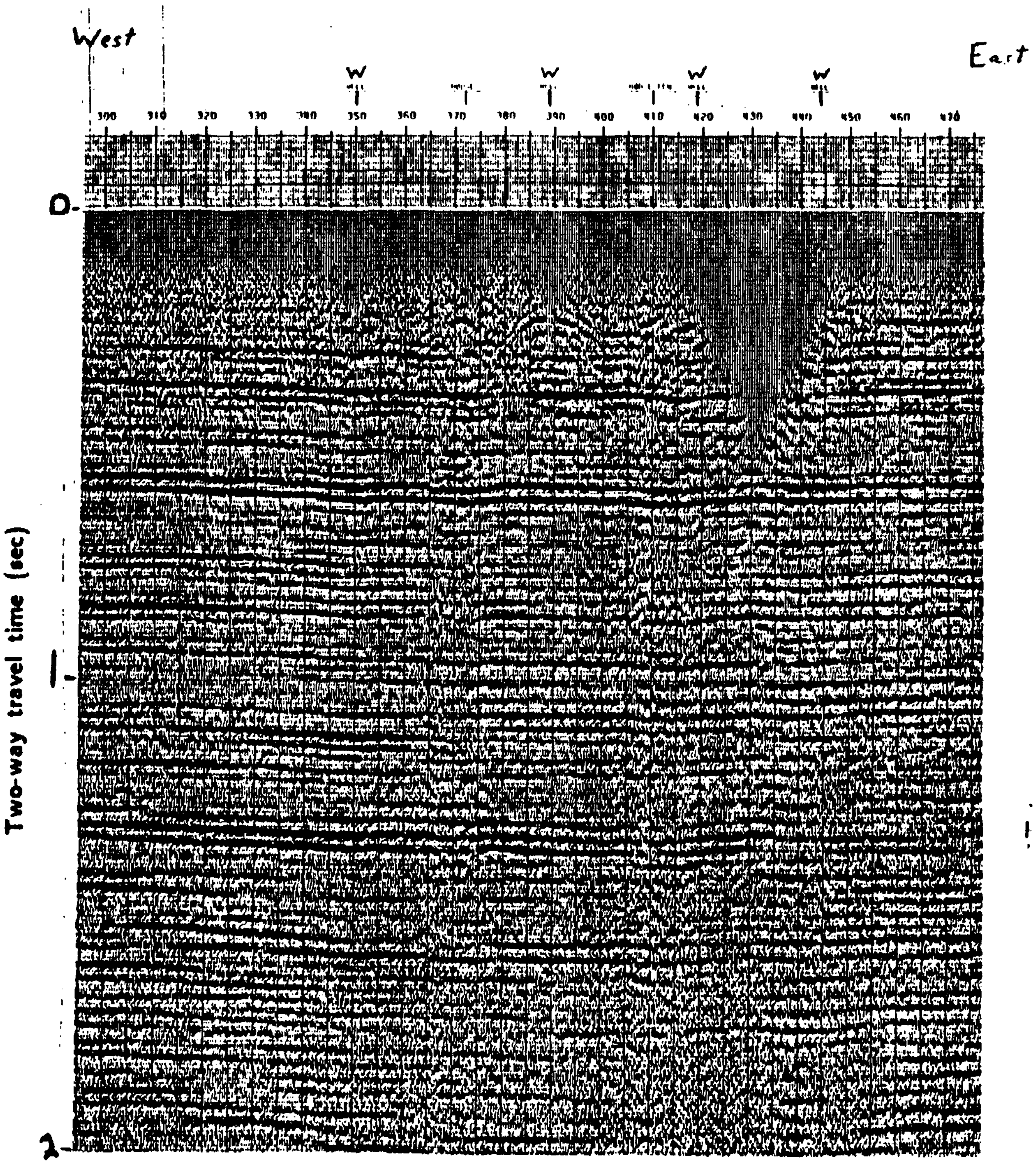


SEISMIC REFLECTION LINE
SWEC D-North
Fold : 2400 %
Energy source : Vibroseis
Stone and Webster
#1 G.Friemel
West
WELL
East
3900
3800
3700
Elev.
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
Two way travel time in seconds
Alibates
Top of San Andres
Top of Cycle 4 Salt
Top of Tubb
Top of Wolfcamp
Top of Pennsylvanian
Top of basement
0
2000 ft
0
600 m
Deaf Smith Co.
QA936


SEISMIC REFLECTION LINE
SWEC G-1
Fold : 2400%
Energy source : Vibroseis
Stone and Webster
#1 Zeeck
South
WELL
North
3500
3400
3300
Elev.
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Two way travel time in seconds
Alibates
Top of San Andres
Top of Cycle 4 Salt
Top of Tubb
Top of Wolfcamp
Top of Pennsylvanian
Top of basement
0 2000 ft
0 600 m
Swisher Co.



← West
North →
Two way travel time (sec)
0
.5
Alibates
Top of San Andres
Base of San Andres
Top of Pennsylvanian
Top of basement (?)
SWEC J
SWEC I
0
mile
1
0
km
1



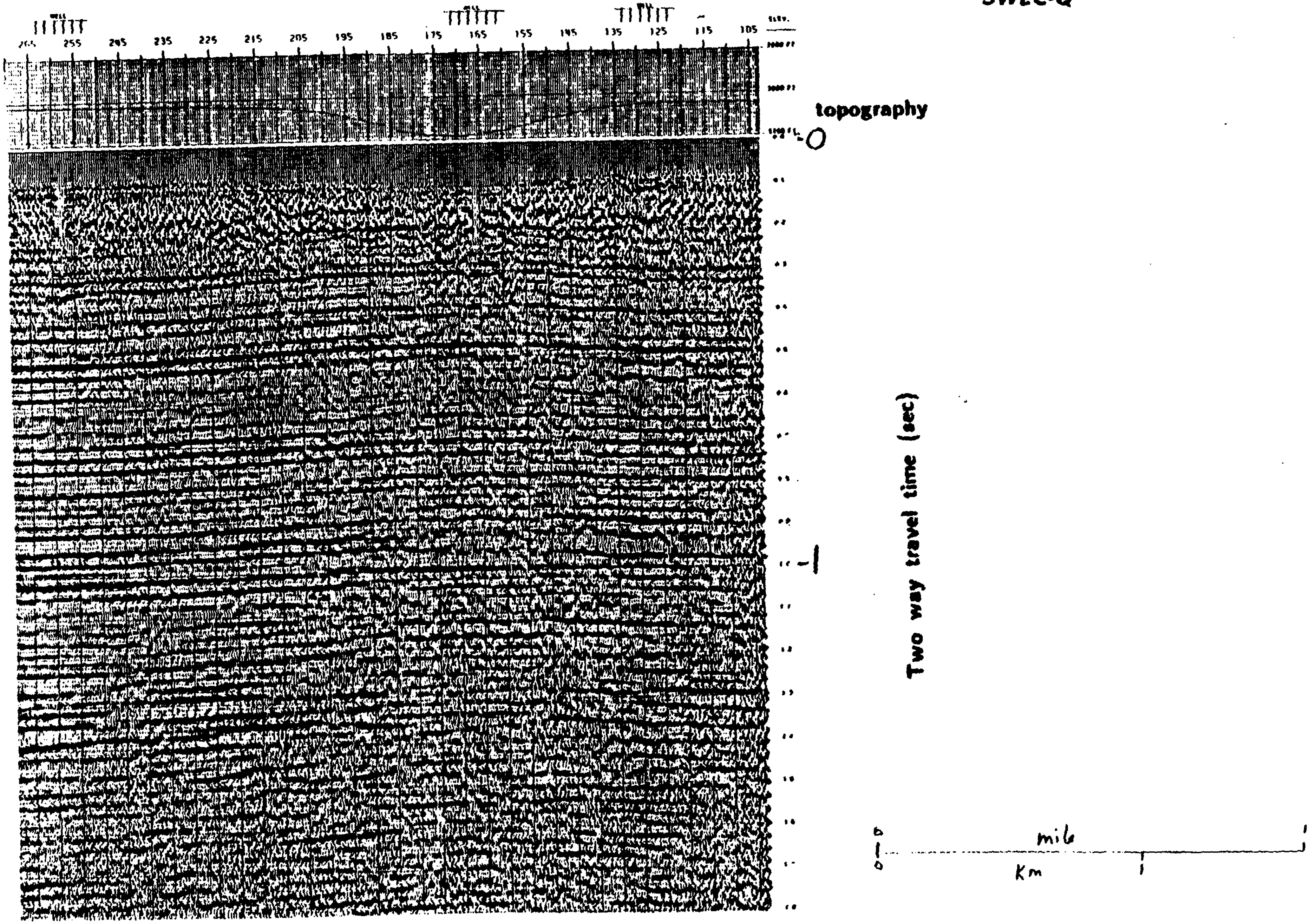
SWEC B-3

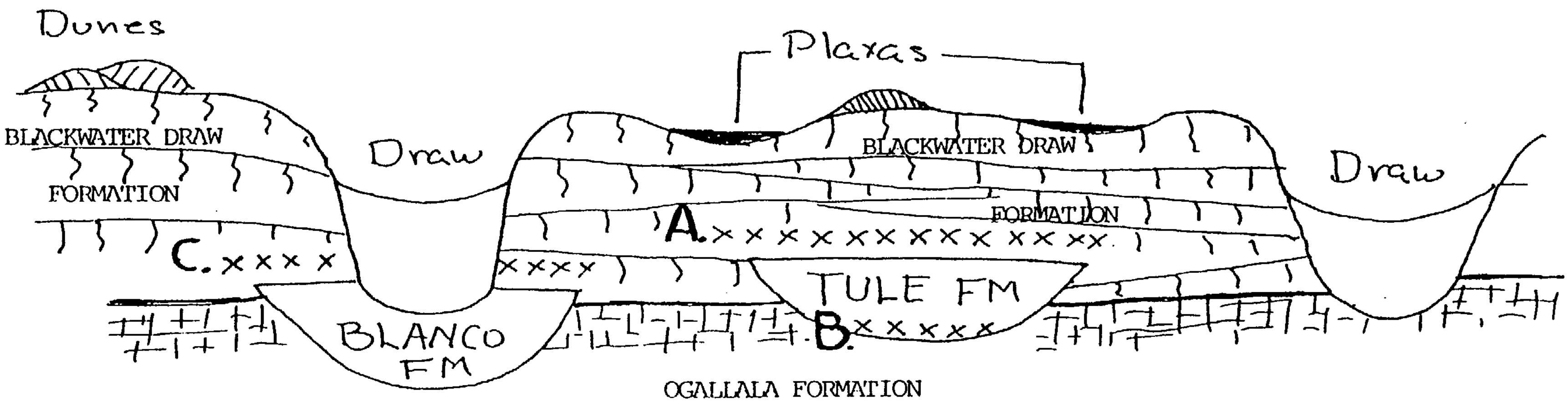
Distortion of data in vicinity of irrigation wells

mile

km

SWEC-Q

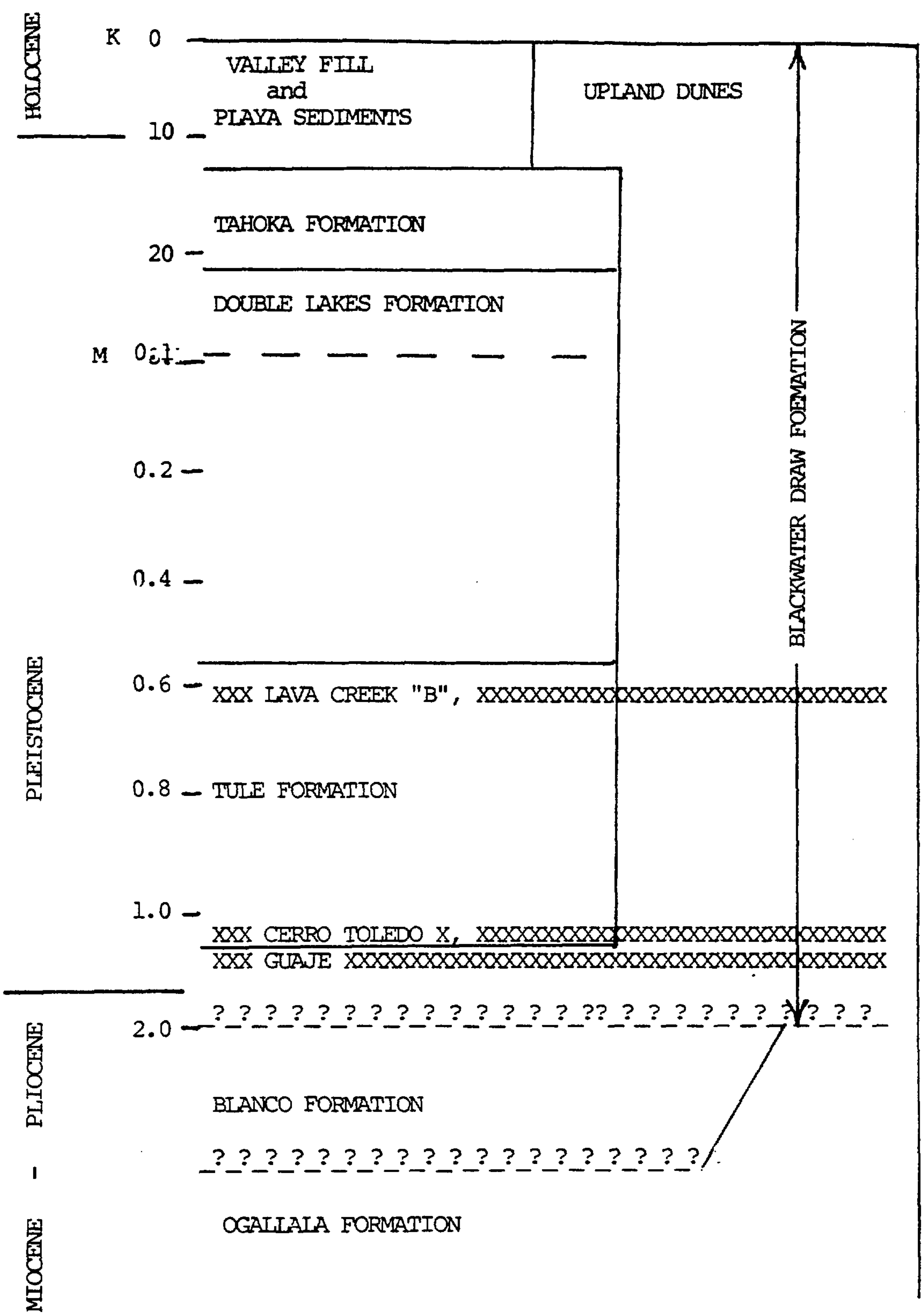




SOIL HORIZON

Ogallala Caprock calcrete

TEPHRA
A. Lava Creek "B", 600,000 yrs.
B. Cerro Toledo X, 1,300,000 yrs.
C. Guaje 1,400,000 yrs.



HOLOCENE
K 0
VALLEY FILL
and
PLAYA SEDIMENTS
UPLAND DUNES
10
TAHOKA FORMATION
20
DOUBLE LAKES FORMATION
M 0.1
0.2
0.4
0.6
XXX LAVA CREEK "B", XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.8
TULE FORMATION
PLEISTOCENE
1.0
XXX CERRO TOLEDO X, XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXX GUAJE XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.0
BLACKWATER DRAW FORMATION
BLANCO FORMATION
OGALLALA FORMATION
MIOCENE - PLIOCENE

Gustavson (16)

1. GUSTAVSON, T.C., IN PRESS, GEOMORPHIC DEVELOPMENT OF THE CANADIAN RIVER VALLEY, TEXAS PANHANDLE: AN EXAMPLE OF REGIONAL SALT DISSOLUTION AND SUBSIDENCE: GEOLOGICAL SOCIETY OF AMERICA BULLETIN.

CONTENTS:

PRESENTS REGIONAL STRUCTURAL AND STRATIGRAPHIC ARGUMENTS THAT THE CANADIAN RIVER VALLEY FORMED AS A RESULT OF DISSOLUTION-INDUCED SUBSIDENCE FOLLOWING THE DEPOSITION OF OGALLALA FLUVIAL SEDIMENTS (PLIOCENE?). FIGURES 1-9. TIMING OF DISSOLUTION RANGES FROM PLIOCENE TO RECENT.

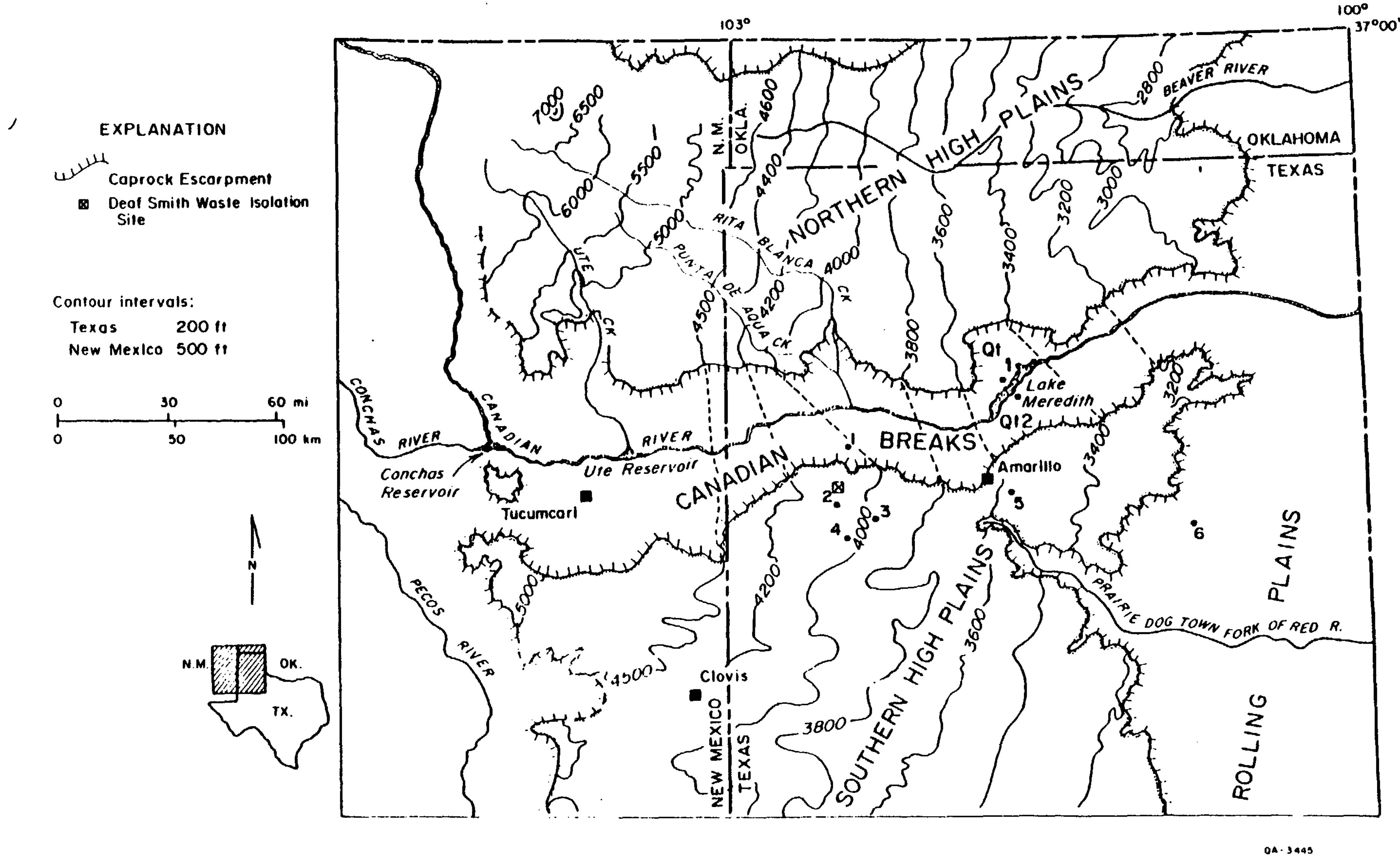


FIGURE 1. Study location, regional topography and physiography

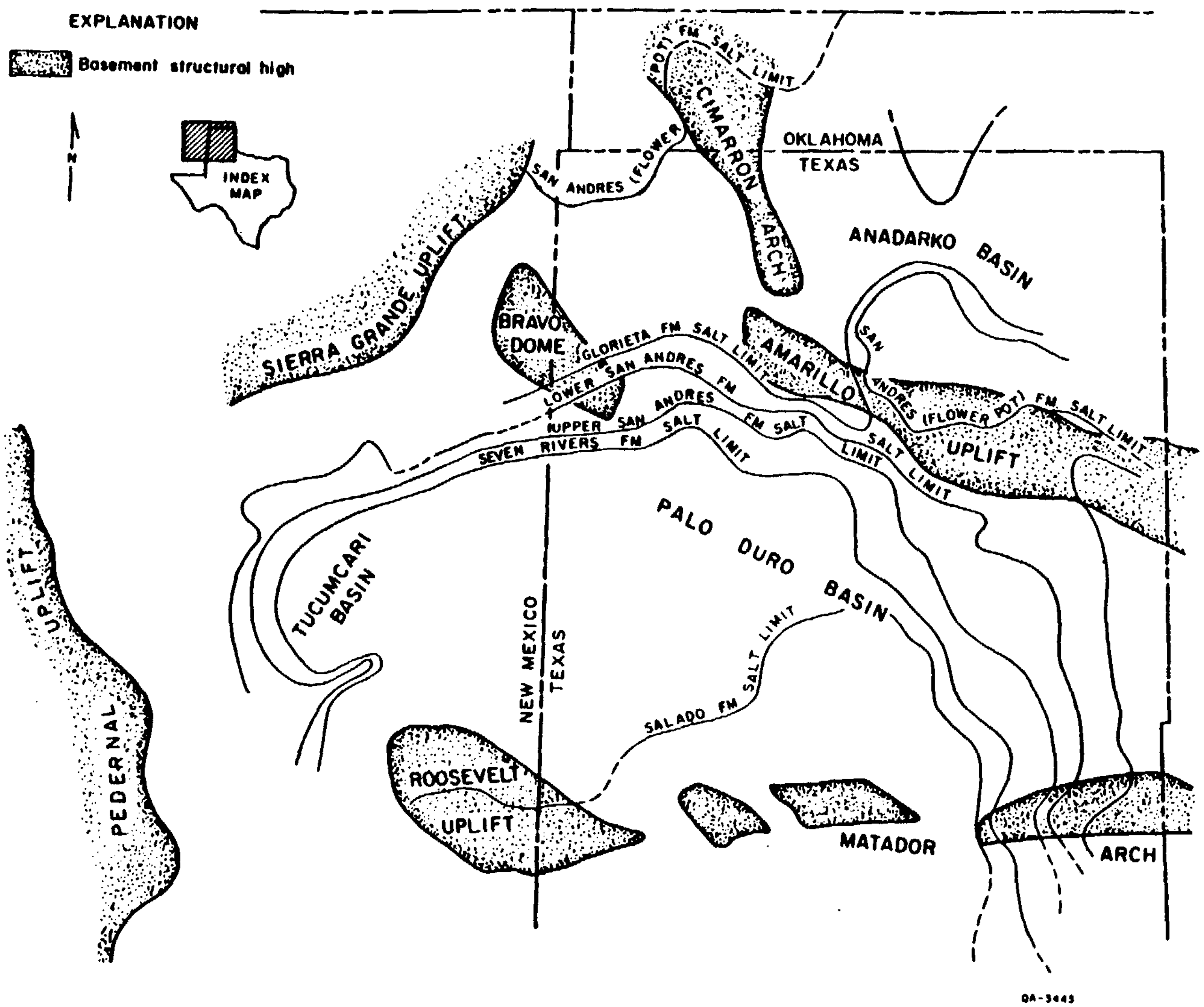


FIGURE 2. Regional structural elements.

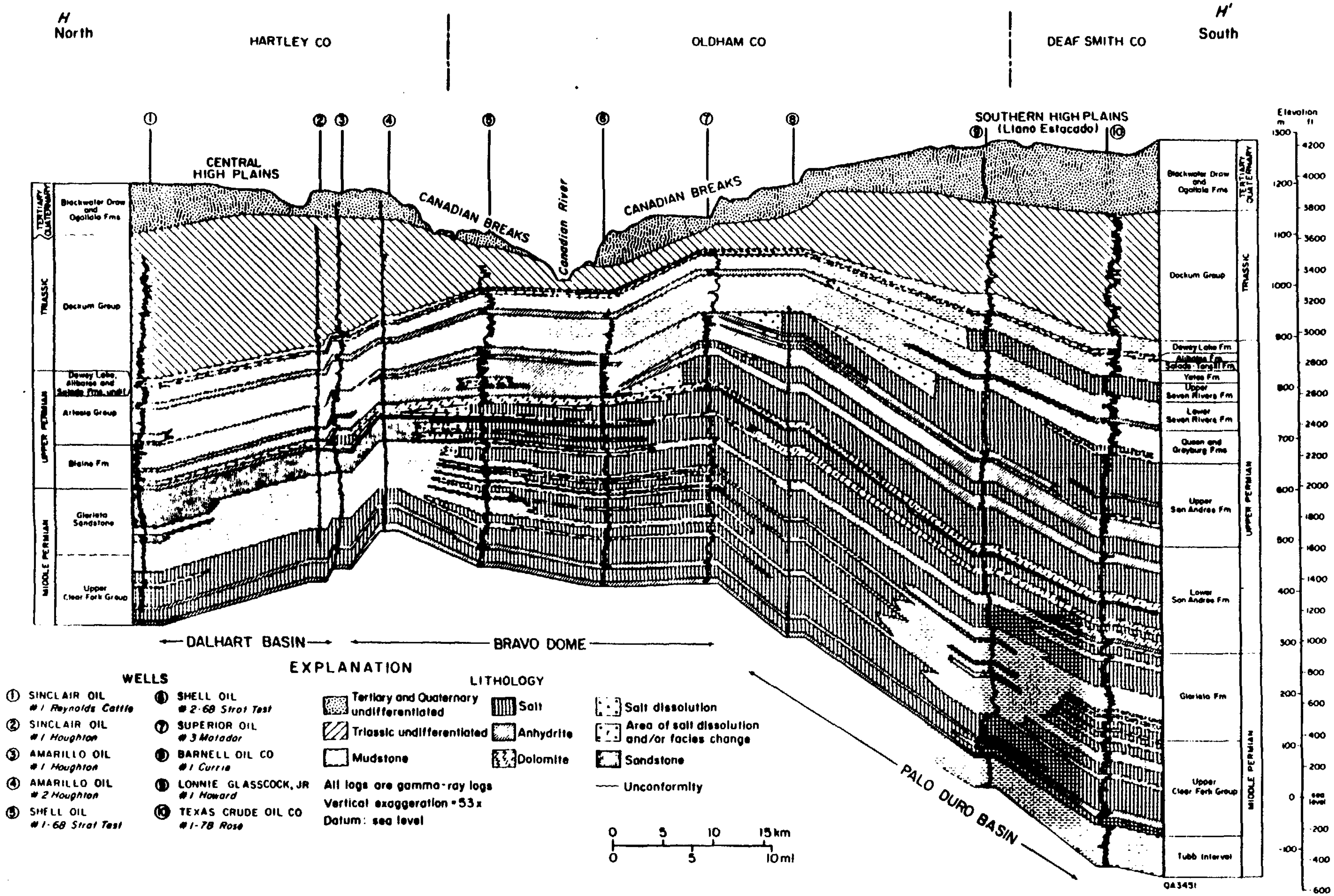


Figure 3. Stratigraphic cross section.

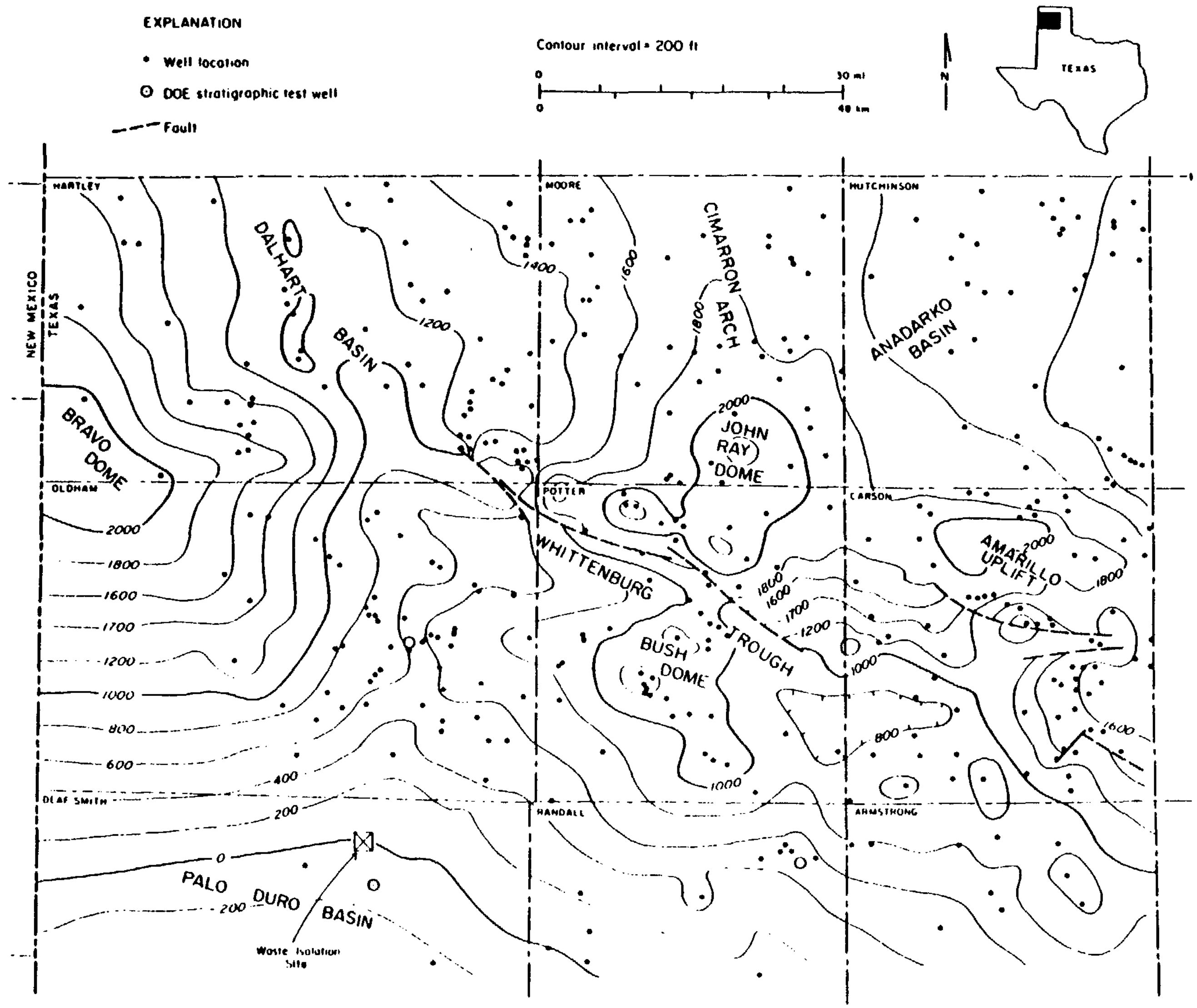


FIGURE 4. Structure-contour map on the Tubb Formation

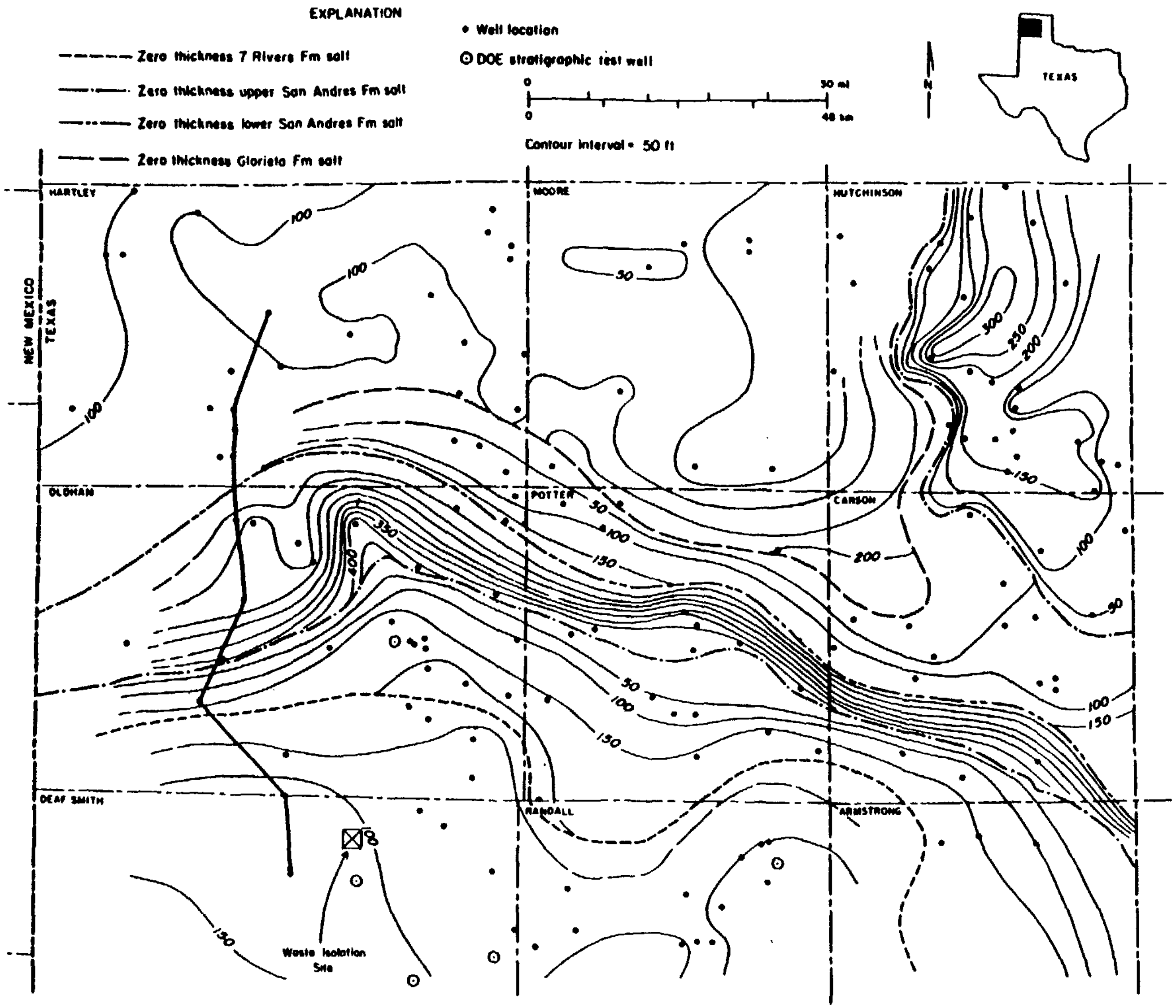


FIGURE 5. Salt thickness slice map for Permian bedded salts.

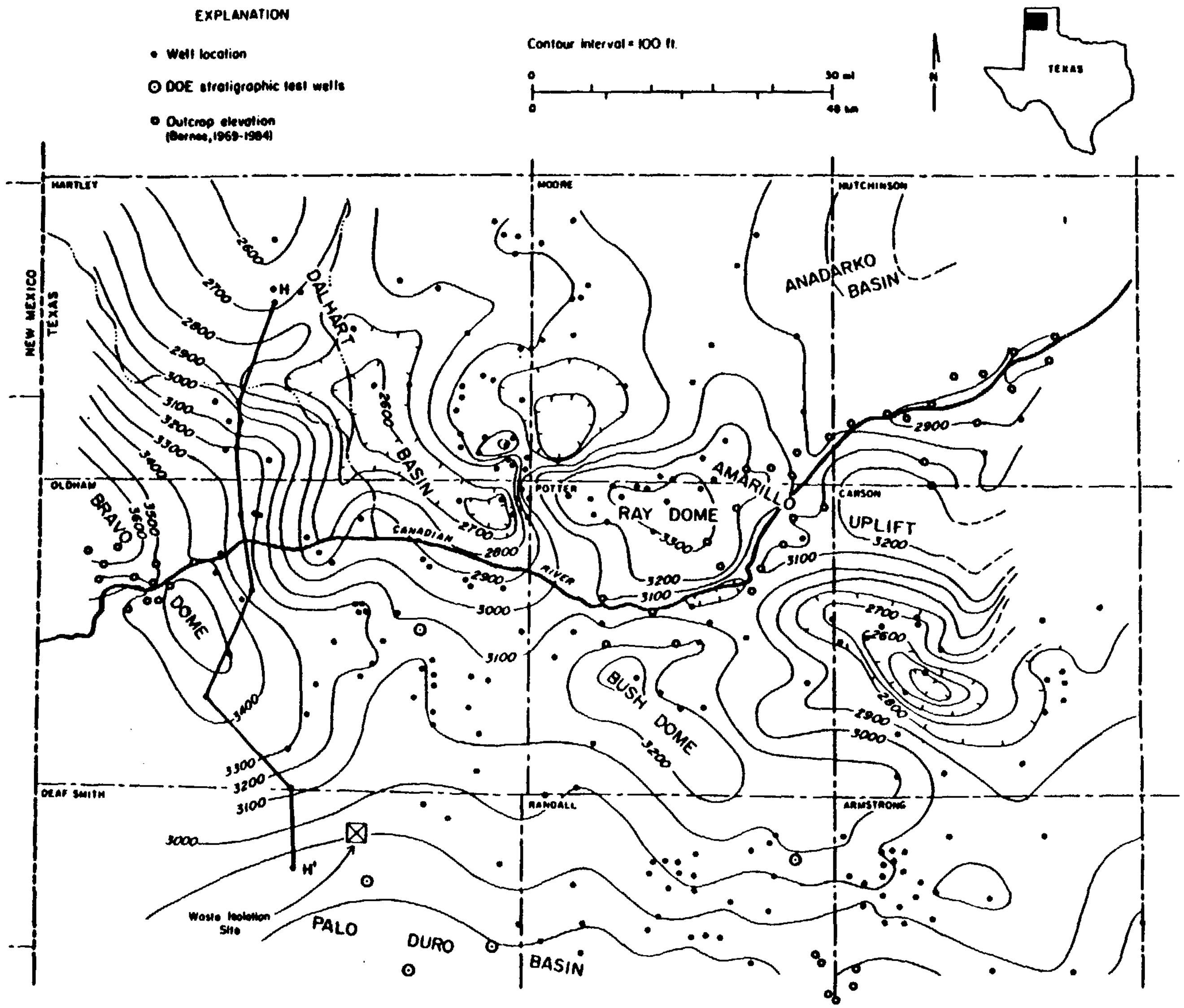


Figure 6 Structure on the Alibates Formation

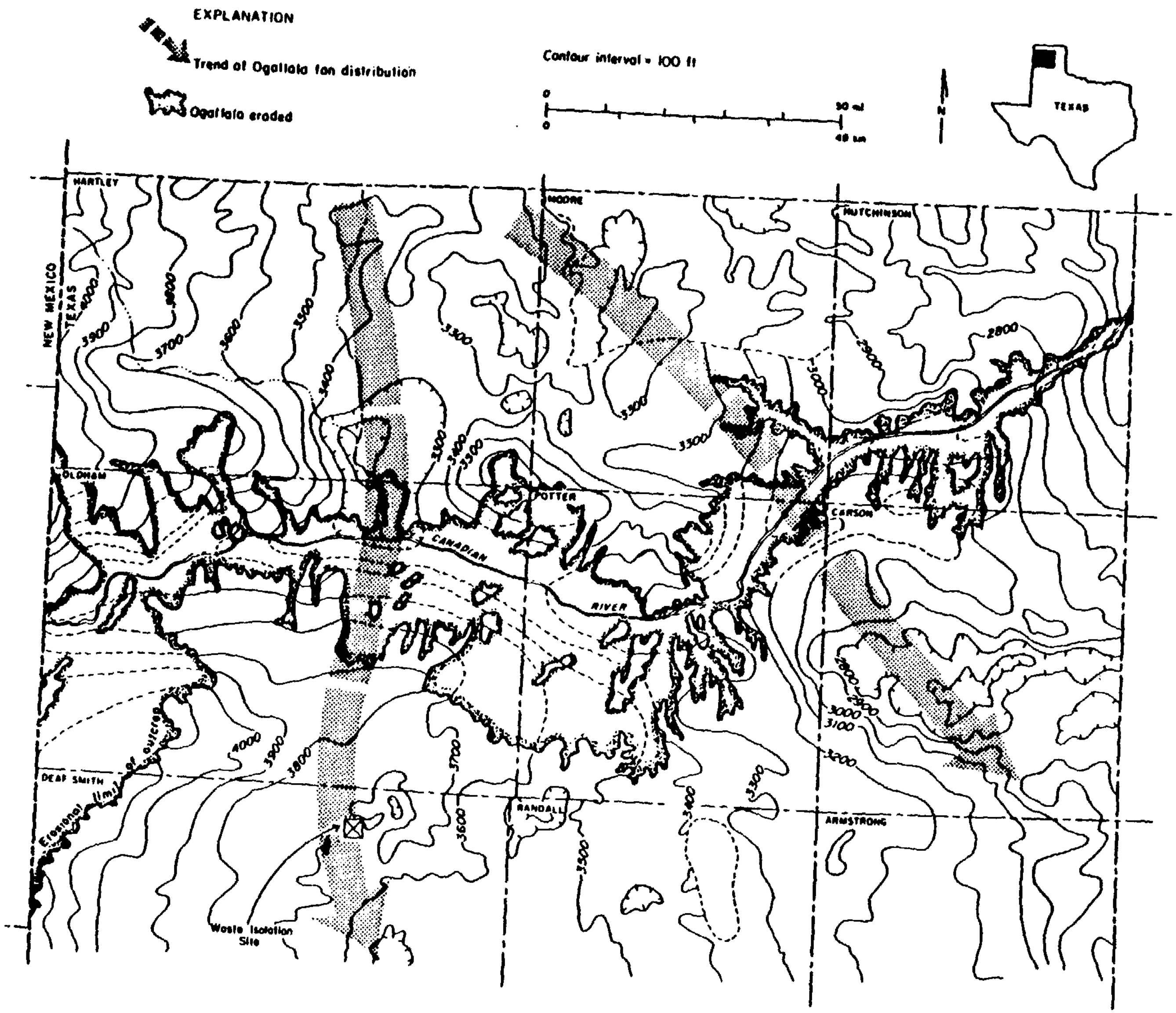


FIGURE 7. Structure-contour map on the base of the Ogallala Formation

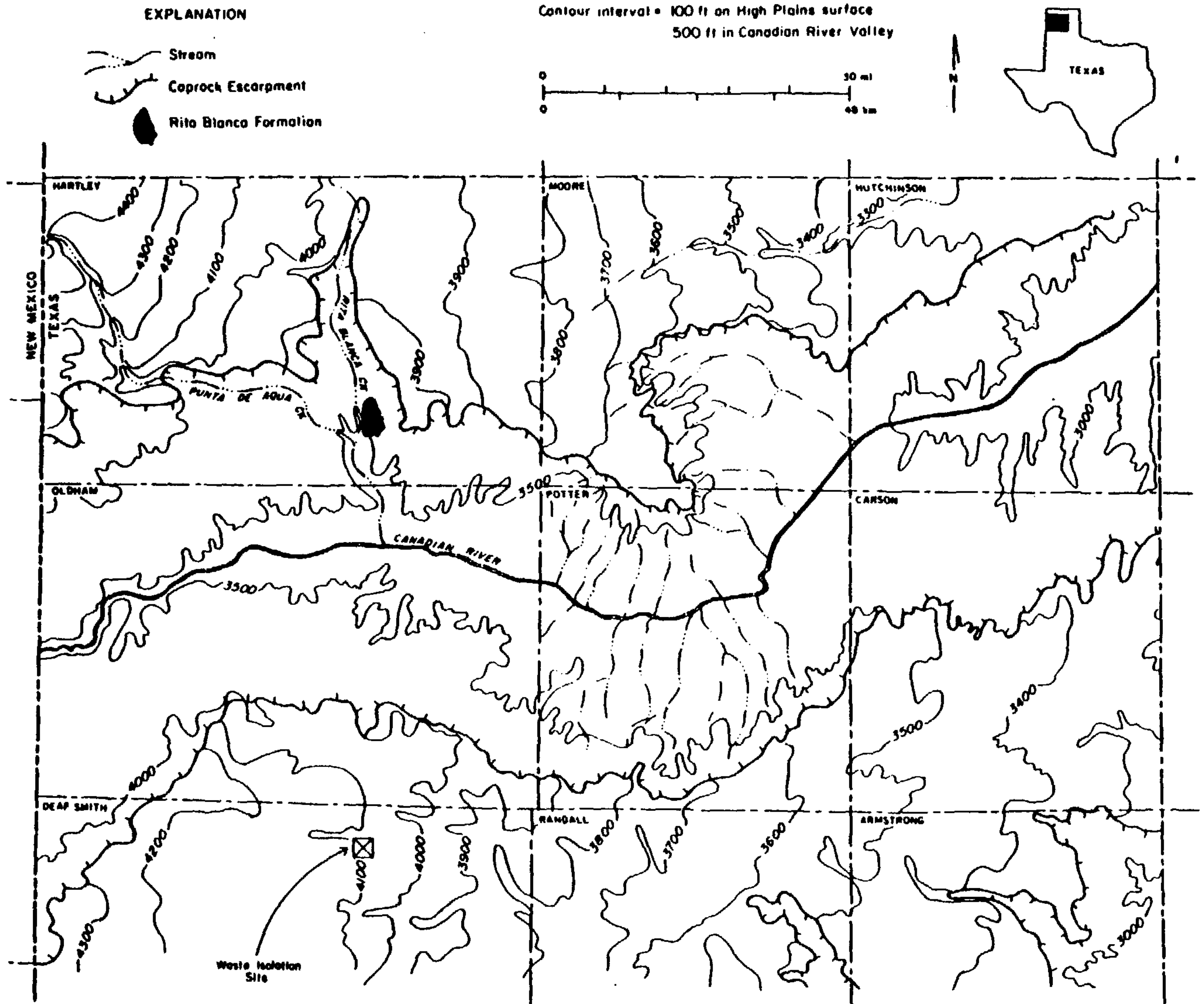


FIGURE 8. Topography.

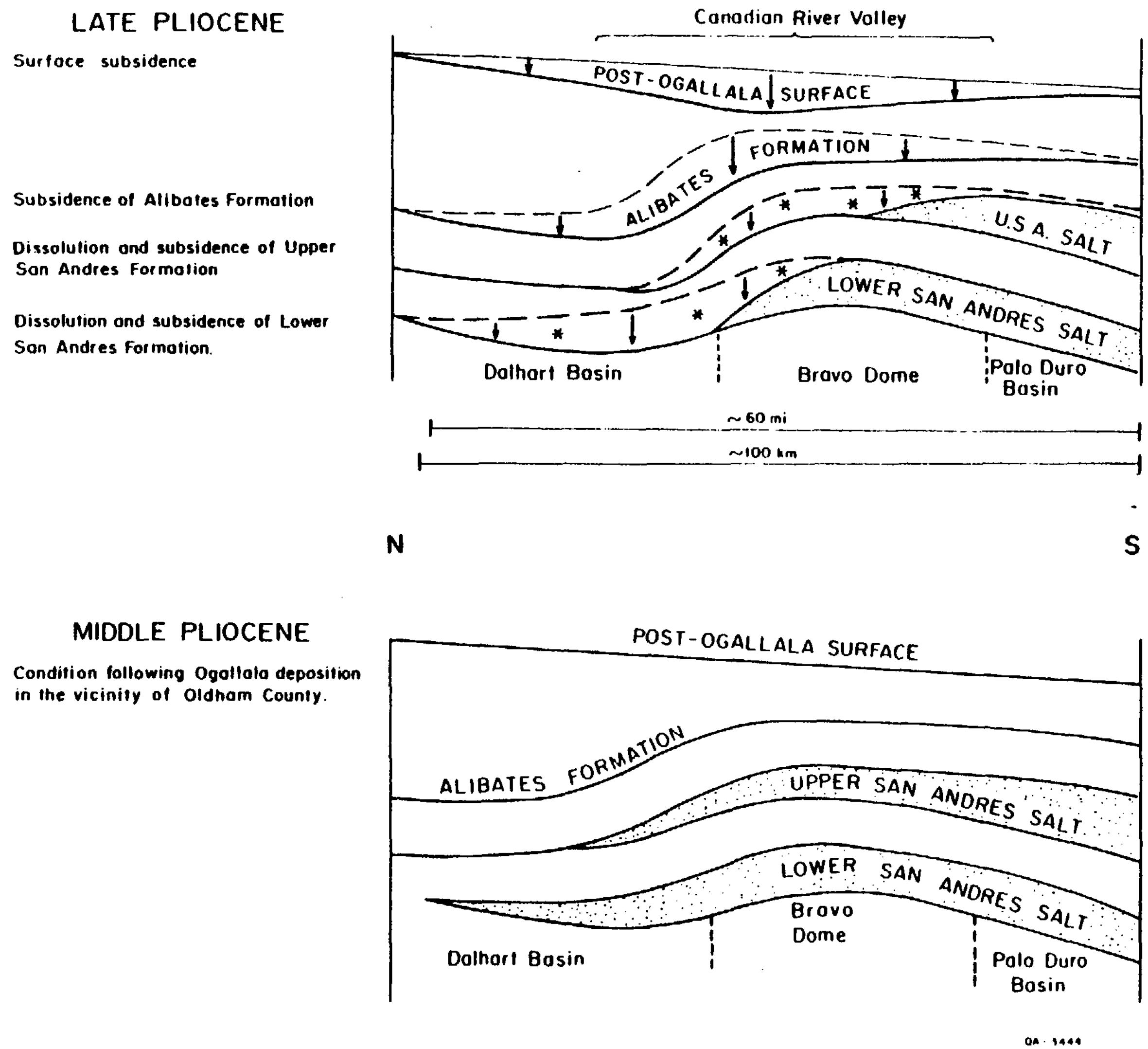


Figure 9. Process model for the formation of the Canadian River Valley

Elevation of Precambrian

PRELIMINARY

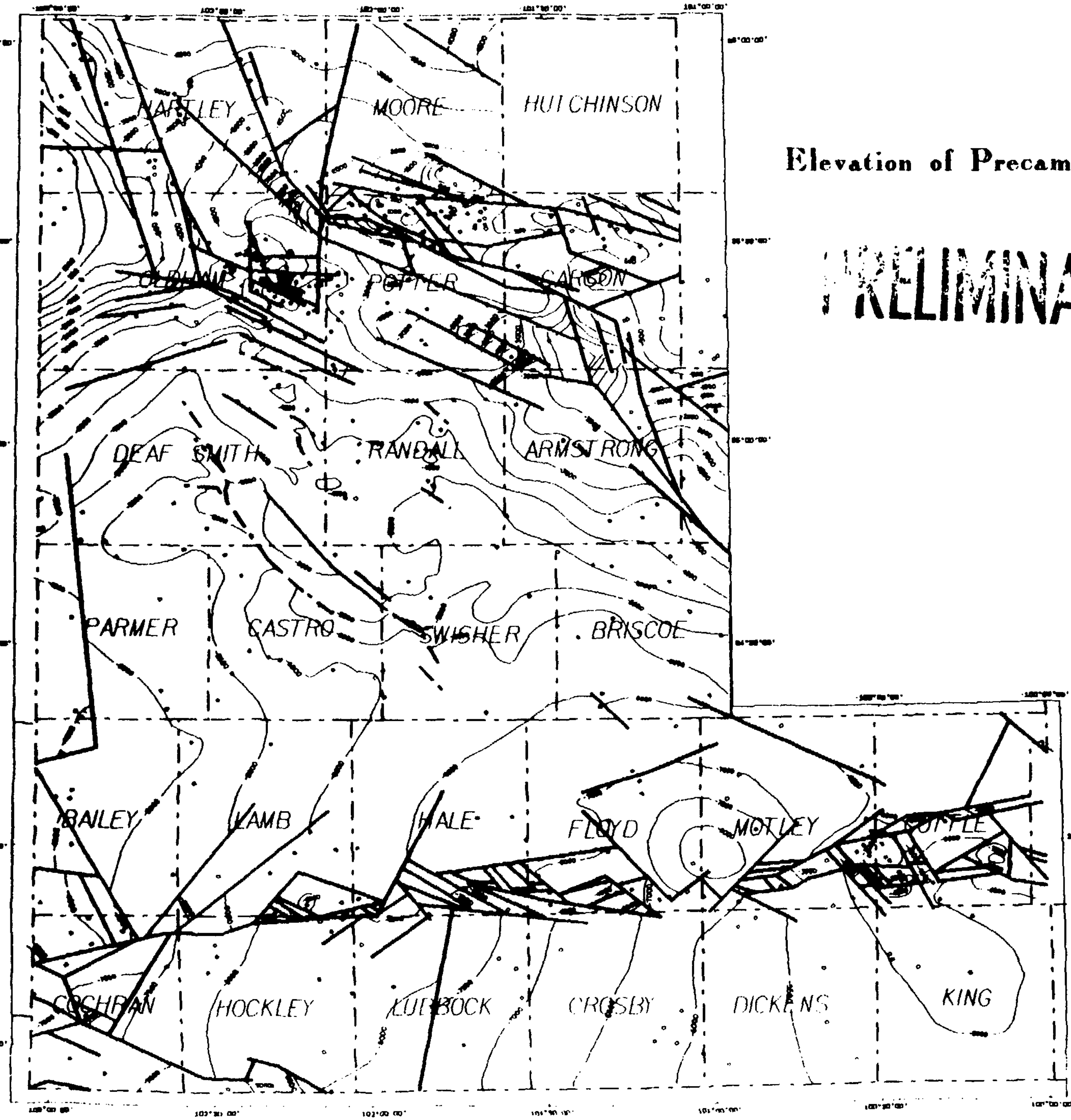
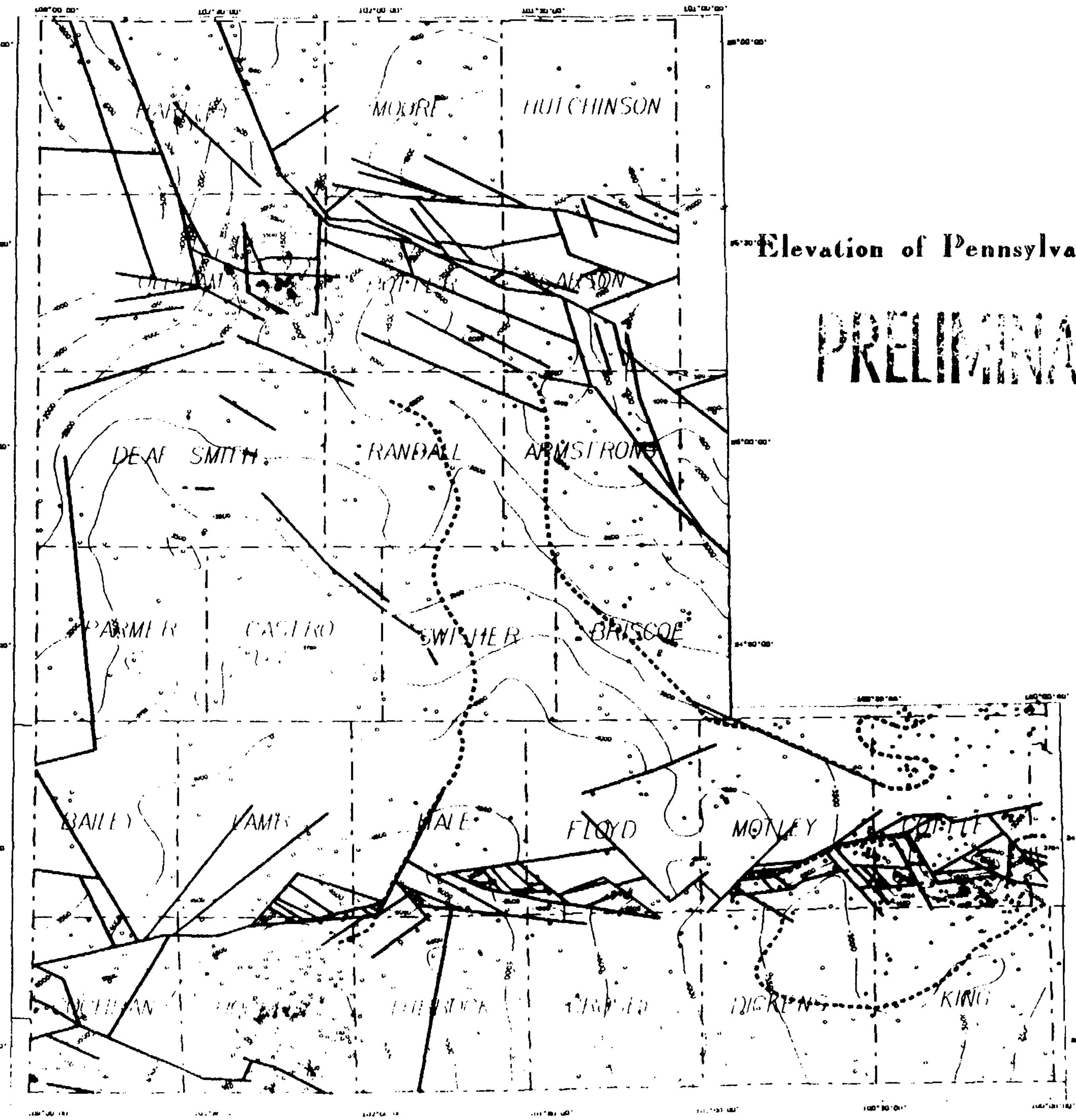


FIGURE 10

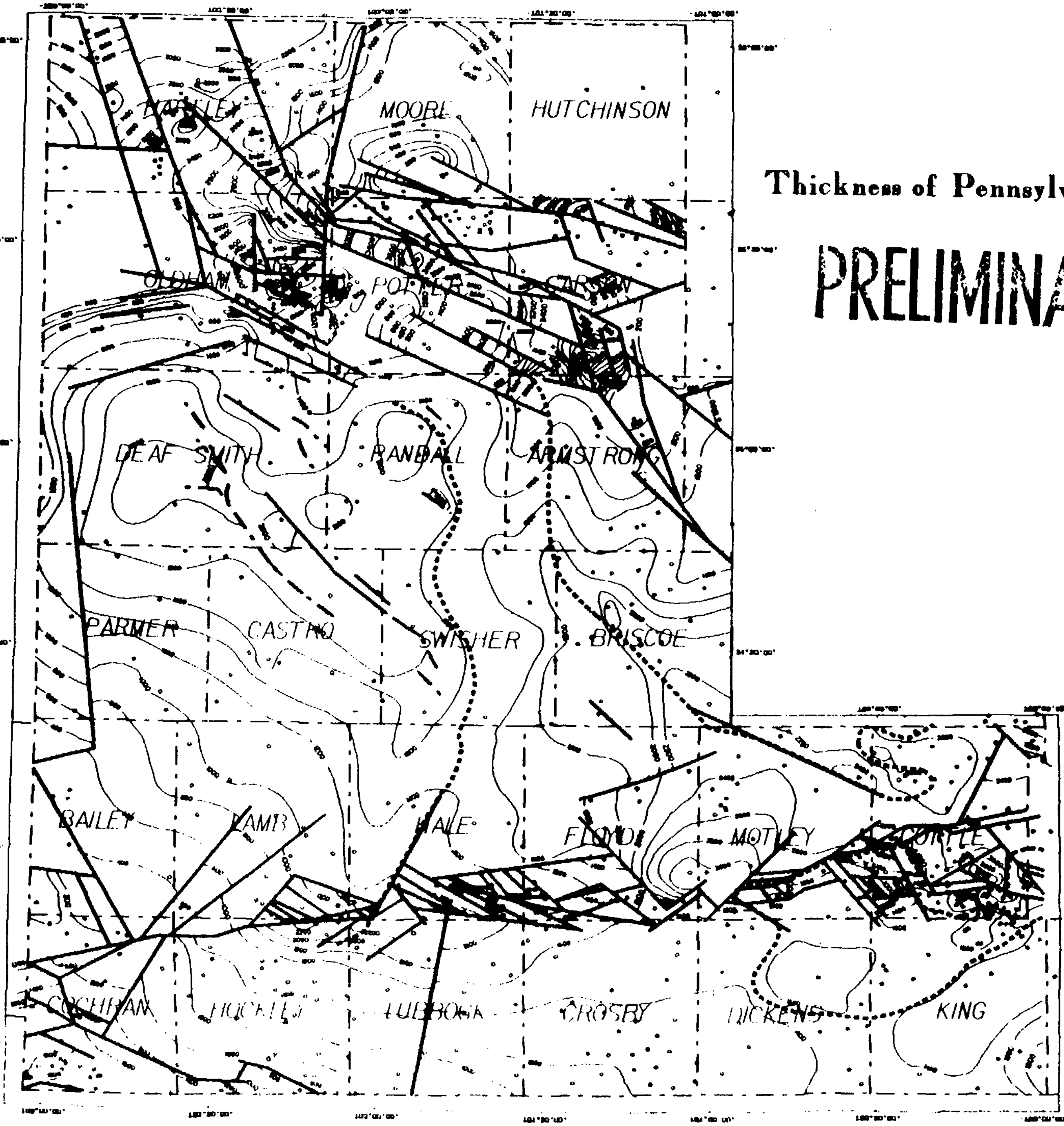
Murphy (15)



Elevation of Pennsylvanian

PRELIMINARY

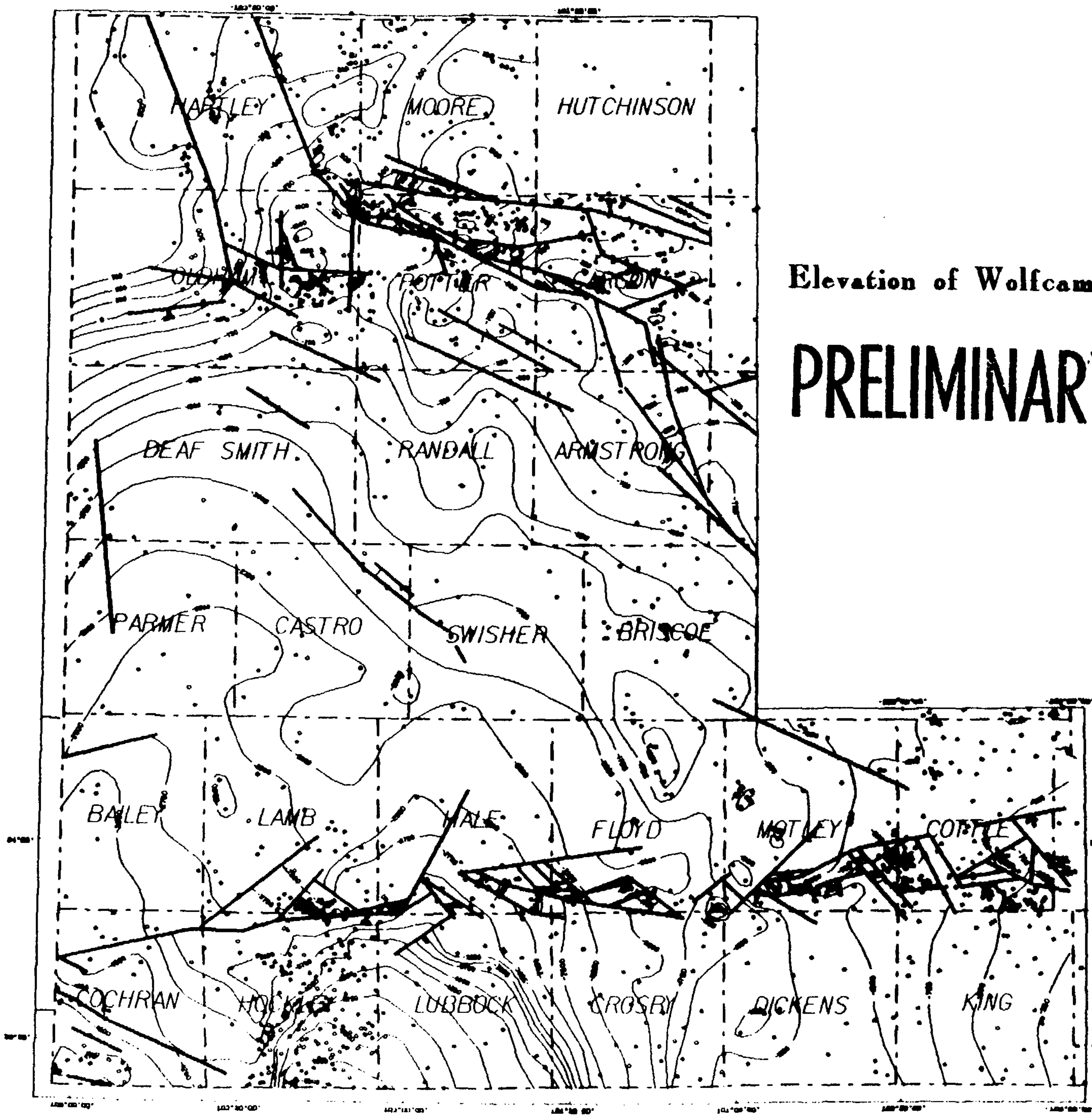
FIGURE 11



Thickness of Pennsylvanian

PRELIMINARY

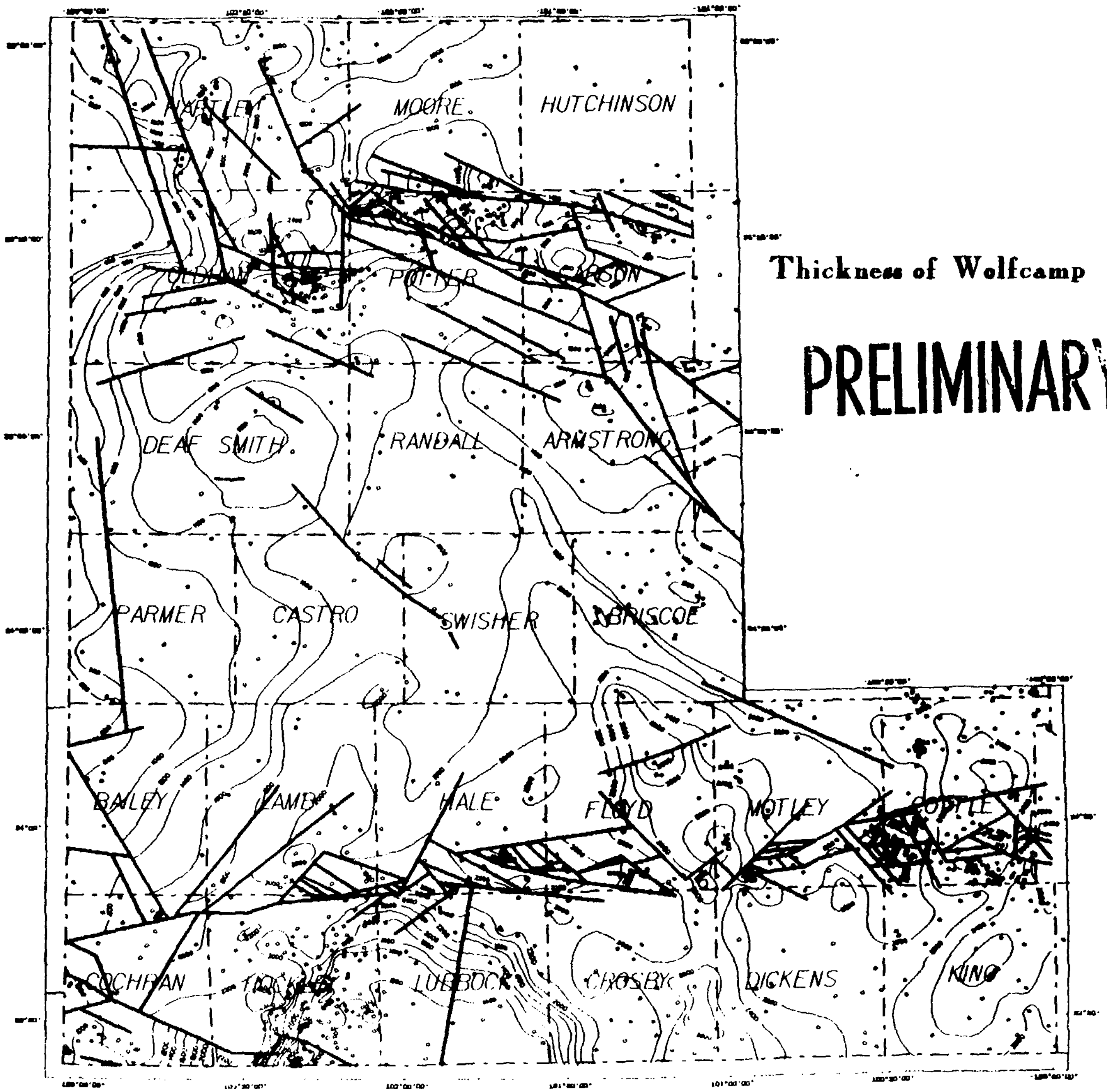
FIGURE 12



Elevation of Wolfcamp

PRELIMINARY

FIGURE 13



Thickness of Wolfcamp

PRELIMINARY

FIGURE 14

Elevation of Tubb

PRELIMINARY

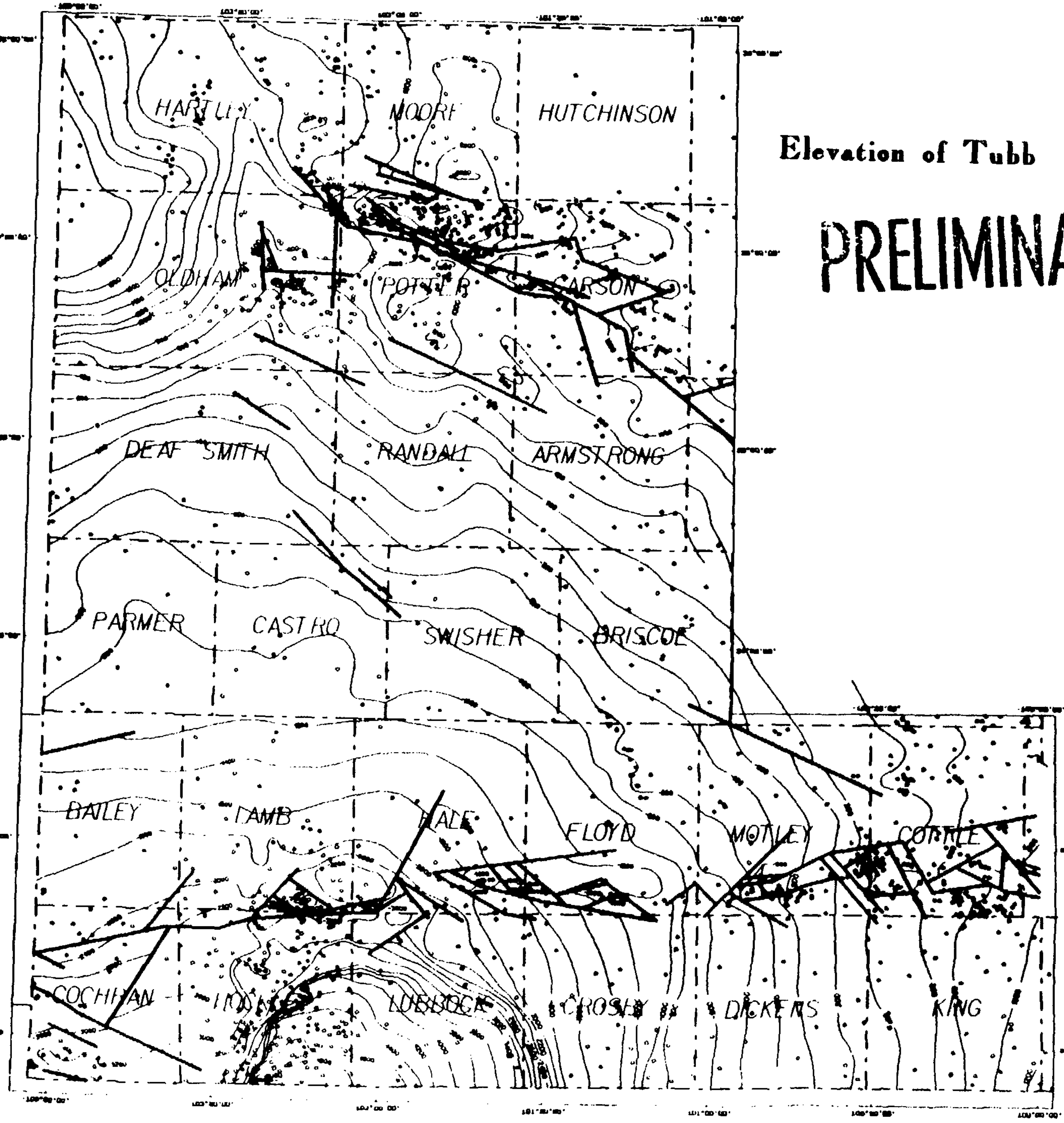


FIGURE 15

Elevation of Glorieta

PRELIMINARY

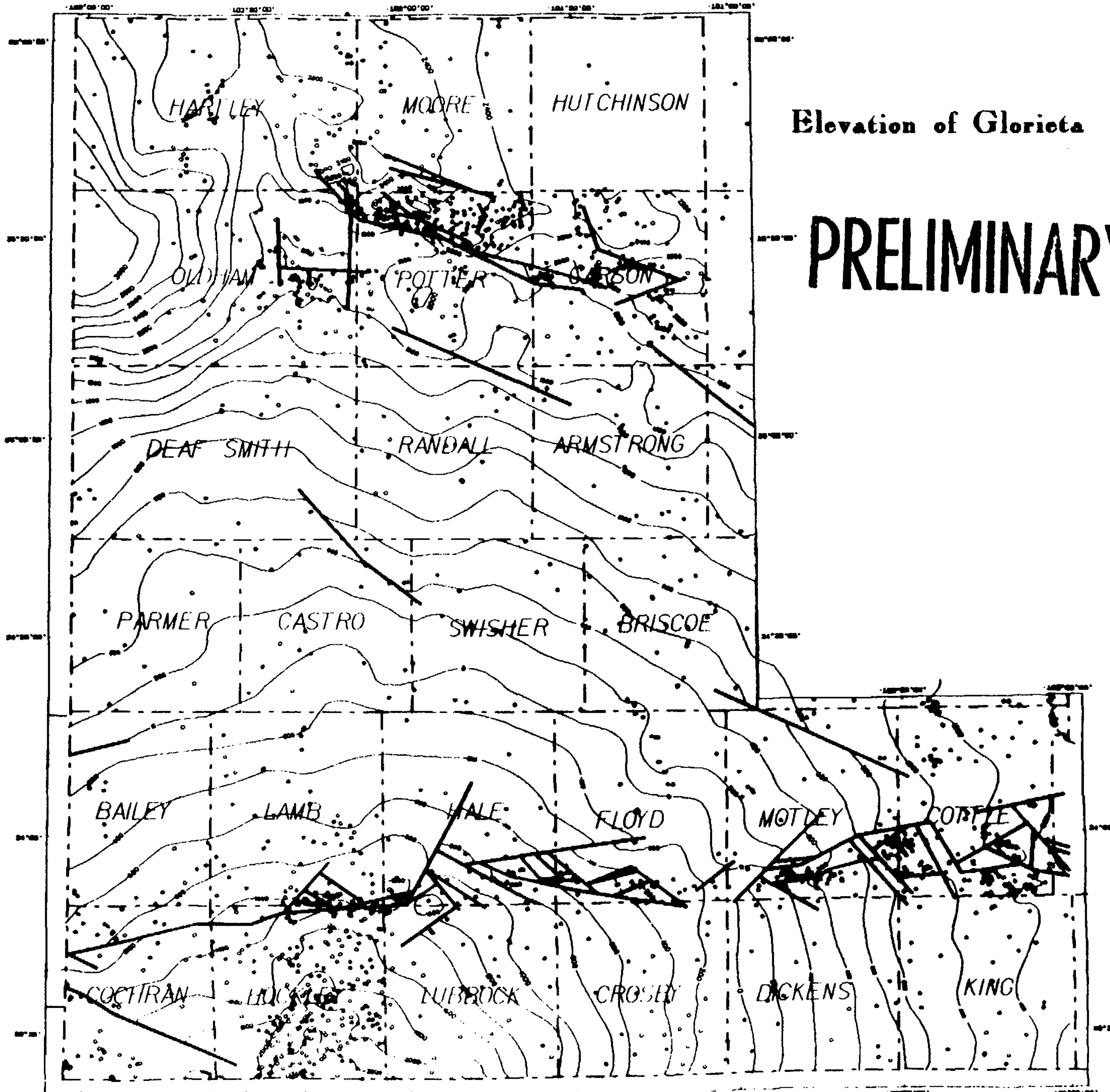


FIGURE 16

Elevation of LSA

PRELIMINARY

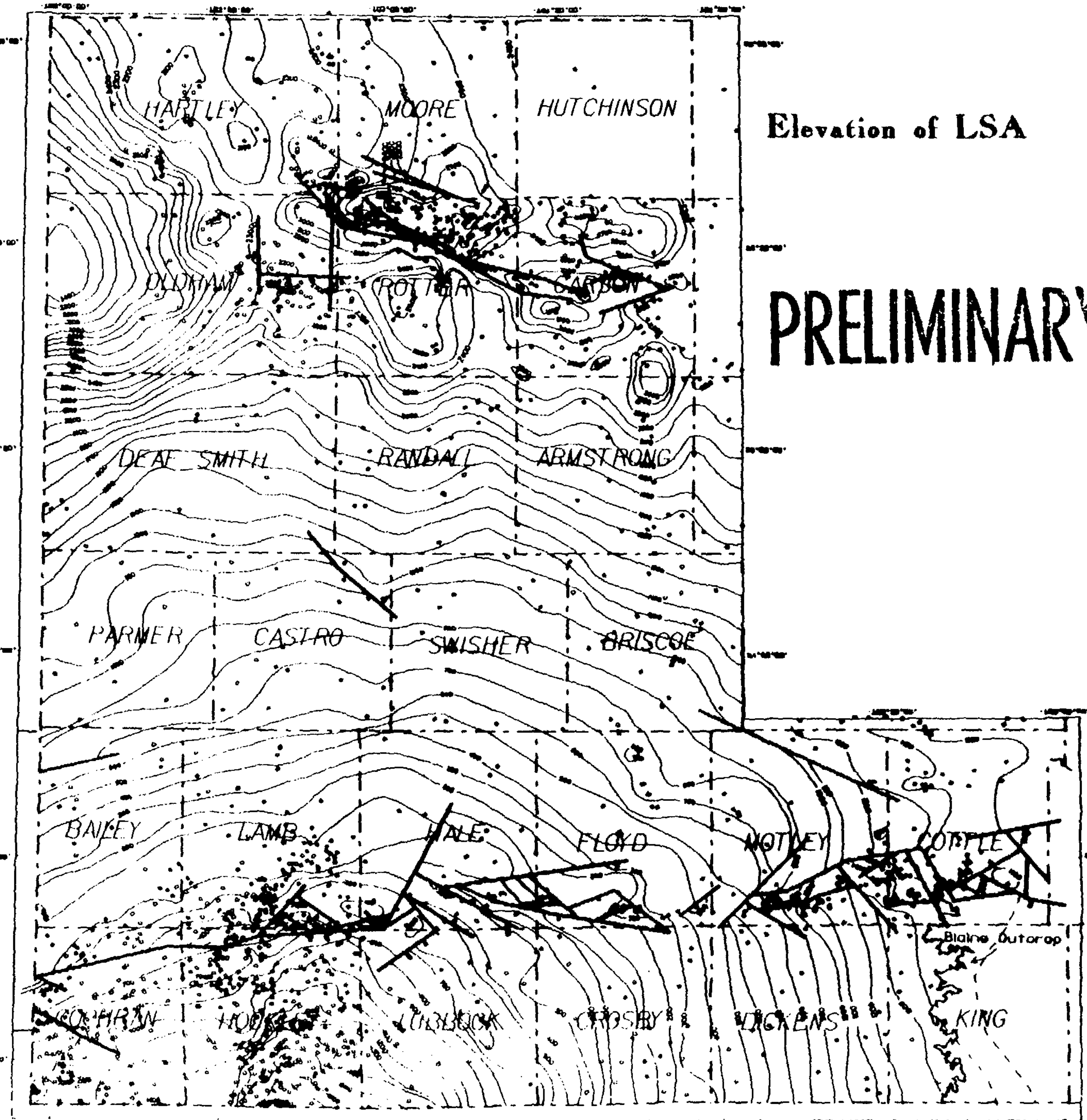
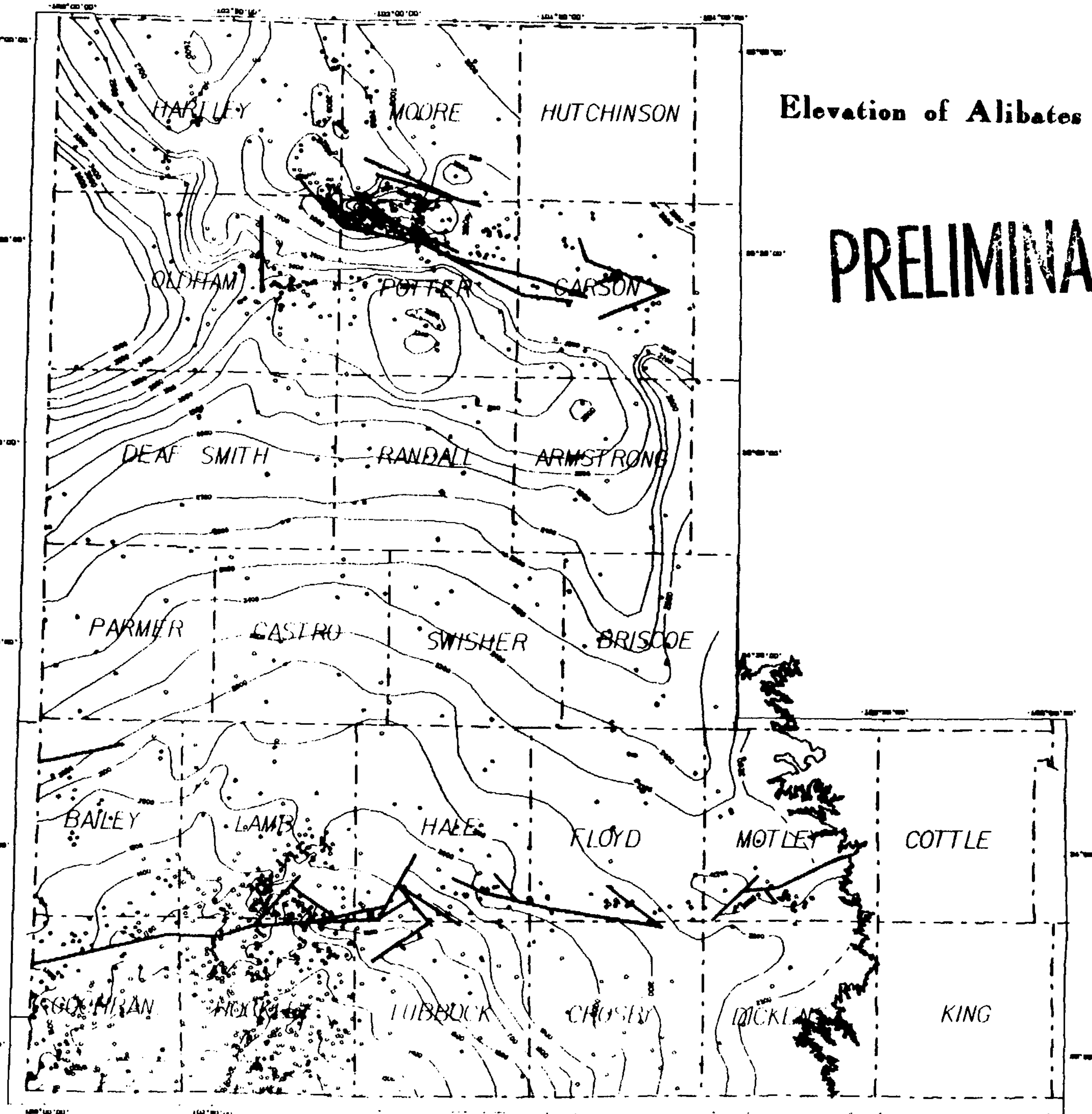


FIGURE 17

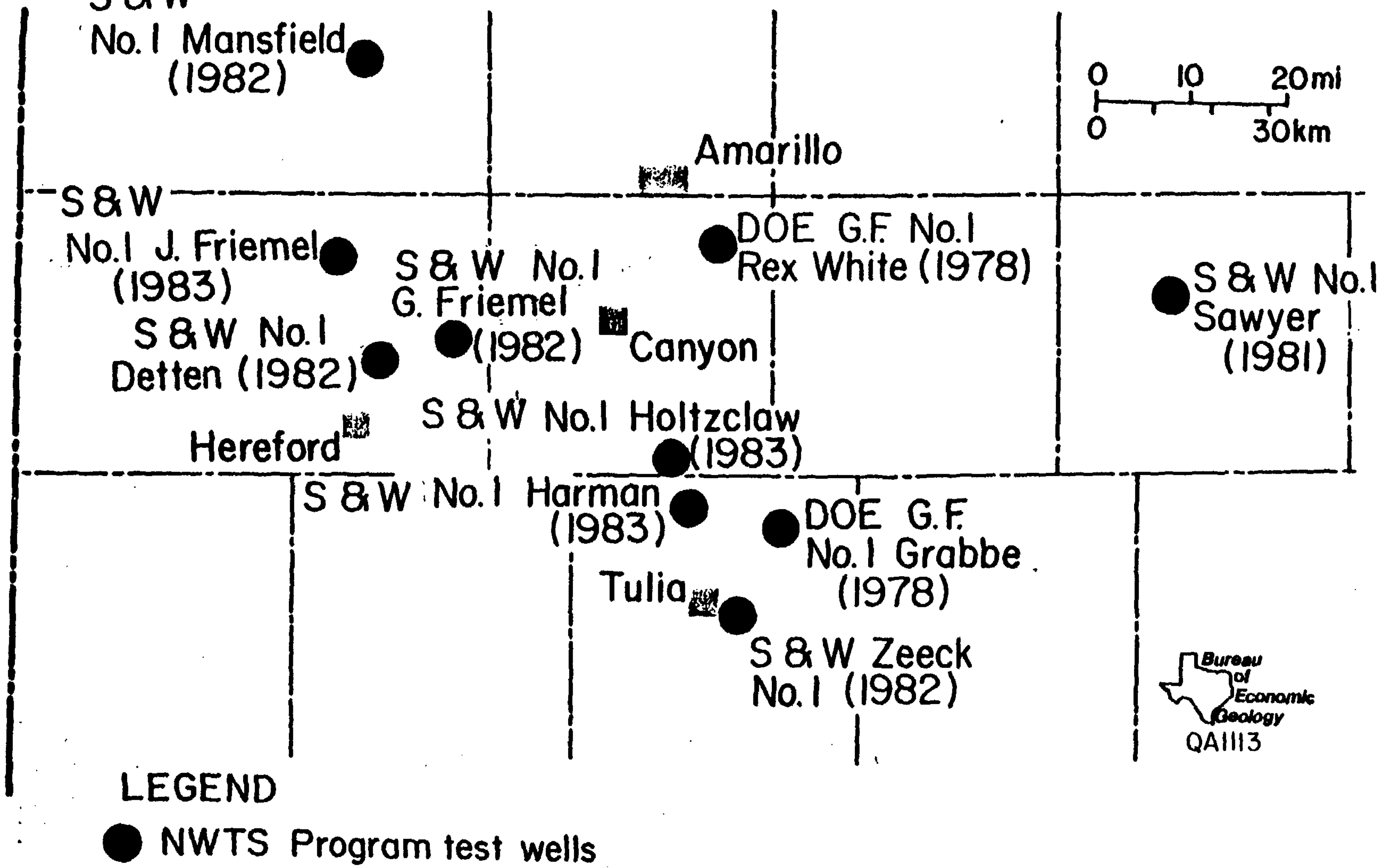


Elevation of Alibates

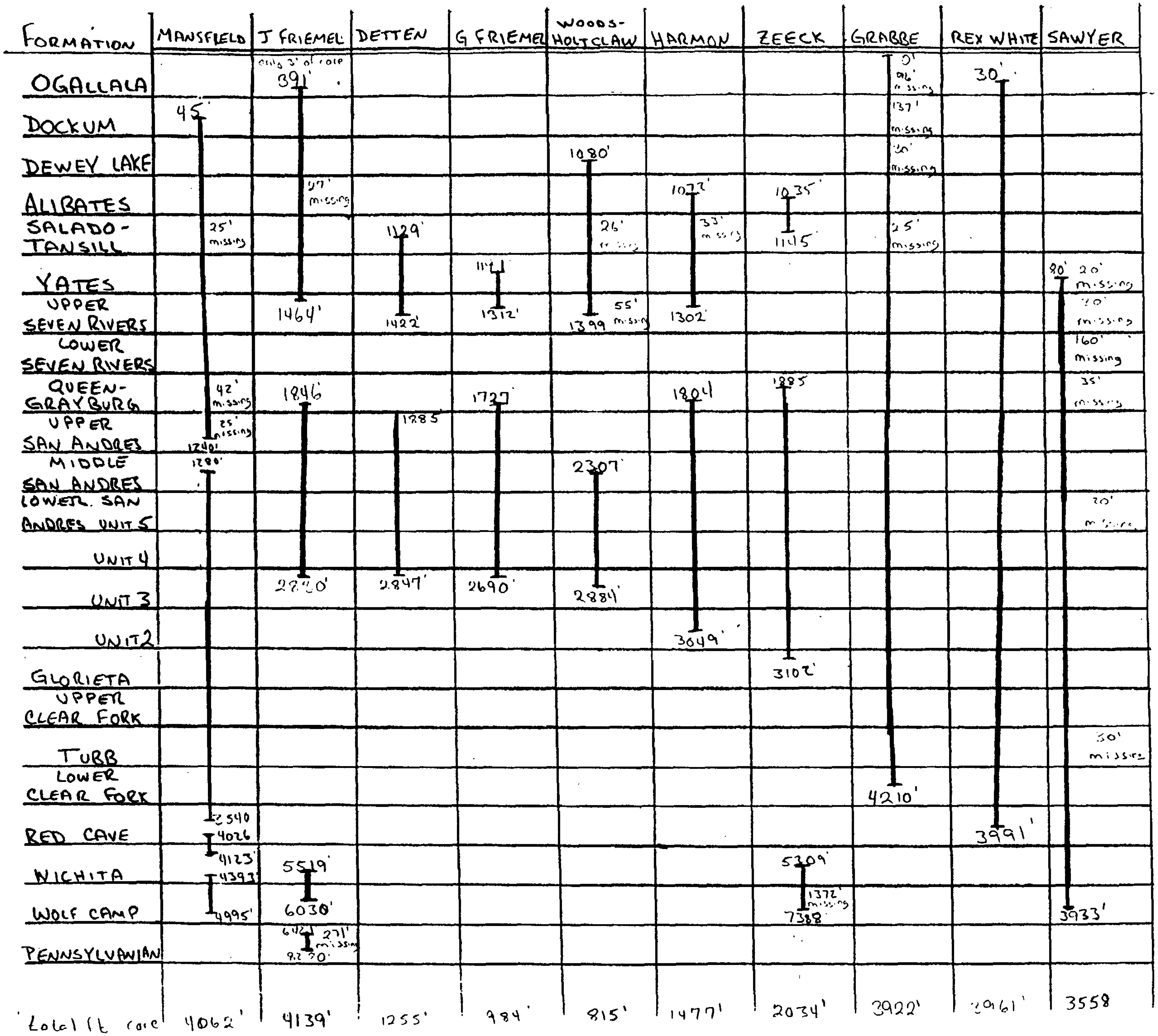
PRELIMINARY

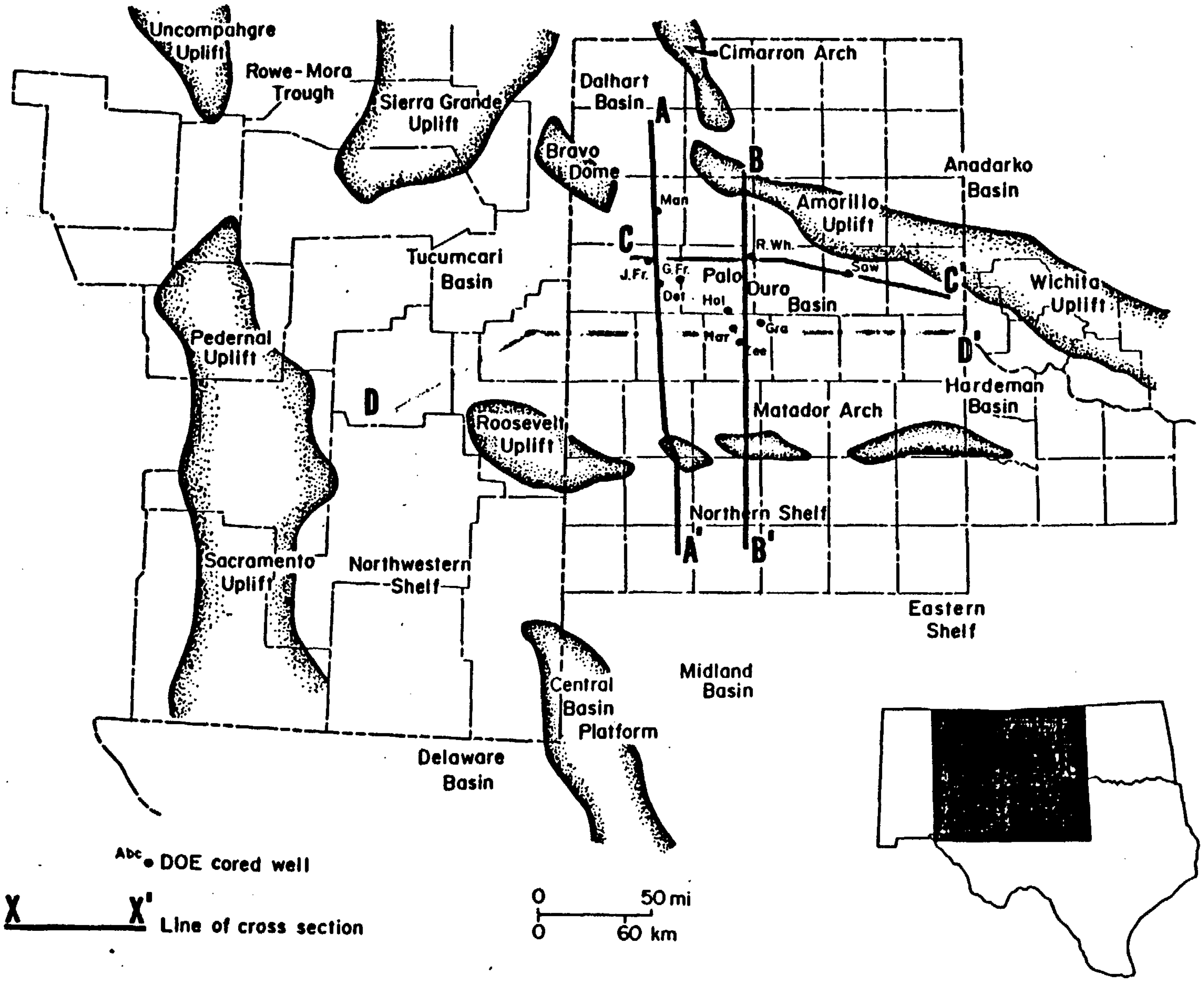
Figure 18

NWTS TEST WELLS



CORED INTERVALS




Uncompahgre Uplift
Rowe-Mora Trough
Sierra Grande Uplift
Cimarron Arch
Dalhart Basin
Bravo Dome
Anadarko Basin
Amarillo Uplift
Tucumcari Basin
Palo Duro Basin
Wichita Uplift
Pedernal Uplift
Hardeman Basin
Matador Arch
Roosevelt Uplift
Northern Shelf
Sacramento Uplift
Northwestern Shelf
Eastern Shelf
Midland Basin
Central Basin Platform
Delaware Basin
Man
J.Fr.
G.Fr.
Def
Hol
R.Wh.
Saw
Mar
Gra
Zee
A
A'
B
B'
C
C'
D
D'
Abc • DOE cored well
X X' Line of cross section
0 50 mi
0 60 km

SYSTEM	SERIES	GROUP	Palo Duro Basin FORMATION	Dalhart Basin FORMATION	General Lithology and depositional setting
QUATERNARY	HOLOCENE		alluvium, dune sand Playa	alluvium, dune sand Playa	
	PLEISTOCENE		Tahoka "cover sands" Tule Blanco	"cover sands"	Lacustrine clastics and windblown deposits
TERTIARY	NEOGENE		Ogallala	Ogallala	Fluvial and lacustrine clastics
CRETACEOUS			undifferentiated	undifferentiated	Marine shales and limestone
TRIASSIC		DOCKUM			Fluvial-deltaic and lacustrine clastics
PERMIAN	OCHOA		Dewey Lake	Dewey Lake	Cyclic sequences: shallow-marine carbonates; hypersaline- shelf anhydrite, halite; continental red beds
			Alibates	Alibates	
	GUADALUPE	ARTESIA	Salado/Tansill	Artesia Group undifferentiated	
			Yates		
			Seven Rivers		
			Queen/Grayburg		
			San Andres	Blaine	
	LEONARD	CLEAR FORK	Glorieta	Glorieta	
			Upper Clear Fork	Clear Fork	
			Tubb	undifferentiated Tubb-Wichita Red Beds	
			Lower Clear Fork		
			Red Cave		
		WICHITA			
	WOLFCAMP				Shelf and shelf-margin carbonate, basinal shale, and deltaic sandstone
?			?	?	
PENNSYLVANIAN	VIRGIL	CISCO			
	MISSOURI	CANYON			
	DES MOINES	STRAWN			
	ATOKA	BEND			
	MORROW				
MISSISSIPPIAN	CHESTER				Shelf carbonate and chert
	MERAMEC				
	OSAGE				
ORDOVICIAN		ELLEN-BURGER			Shelf dolomite
CAMBRIAN ?					Shallow marine(?) sandstone
PRECAMBRIAN					Igneous and metamorphic

TYPICAL SAN ANDRES CYCLE

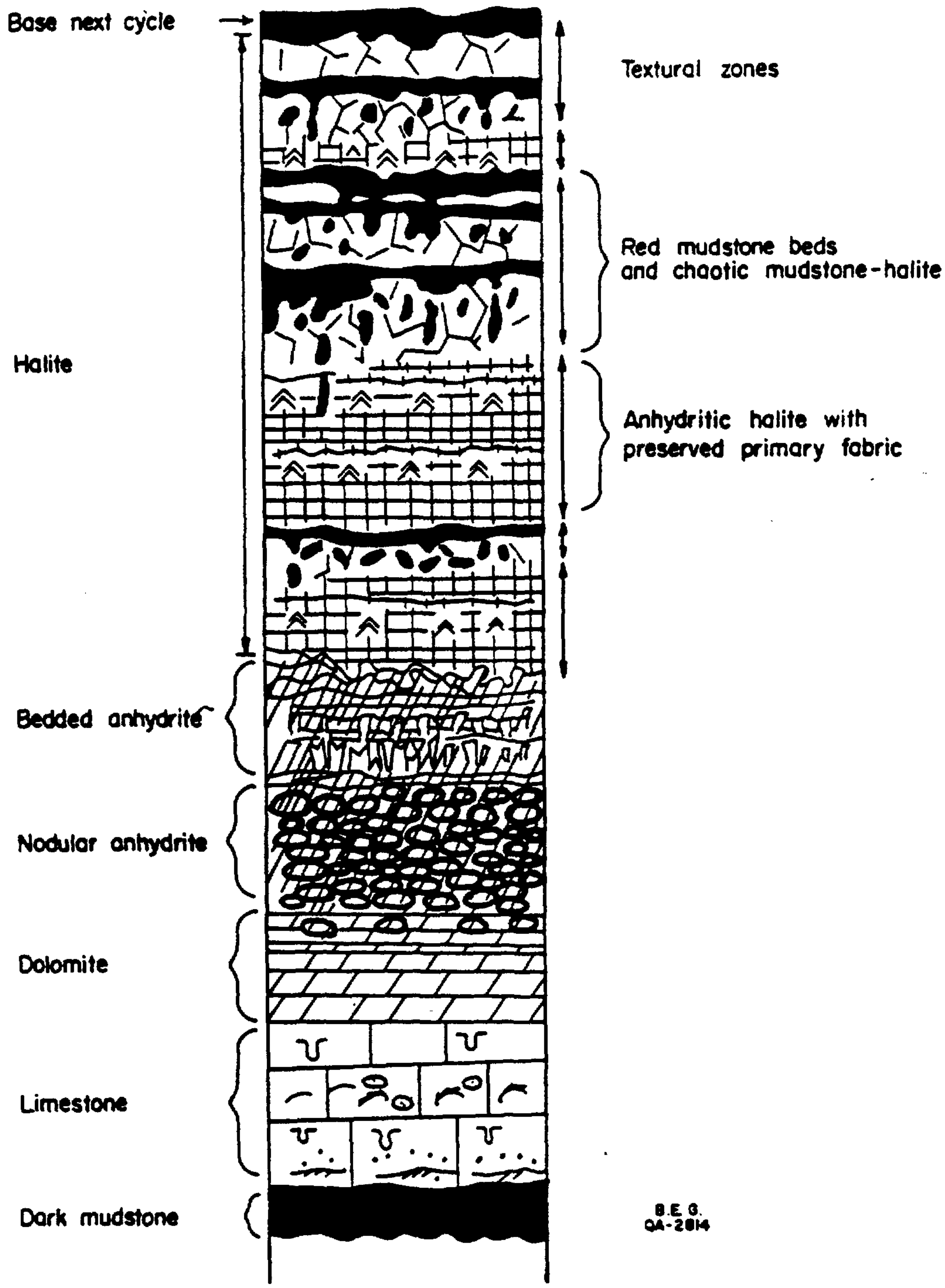
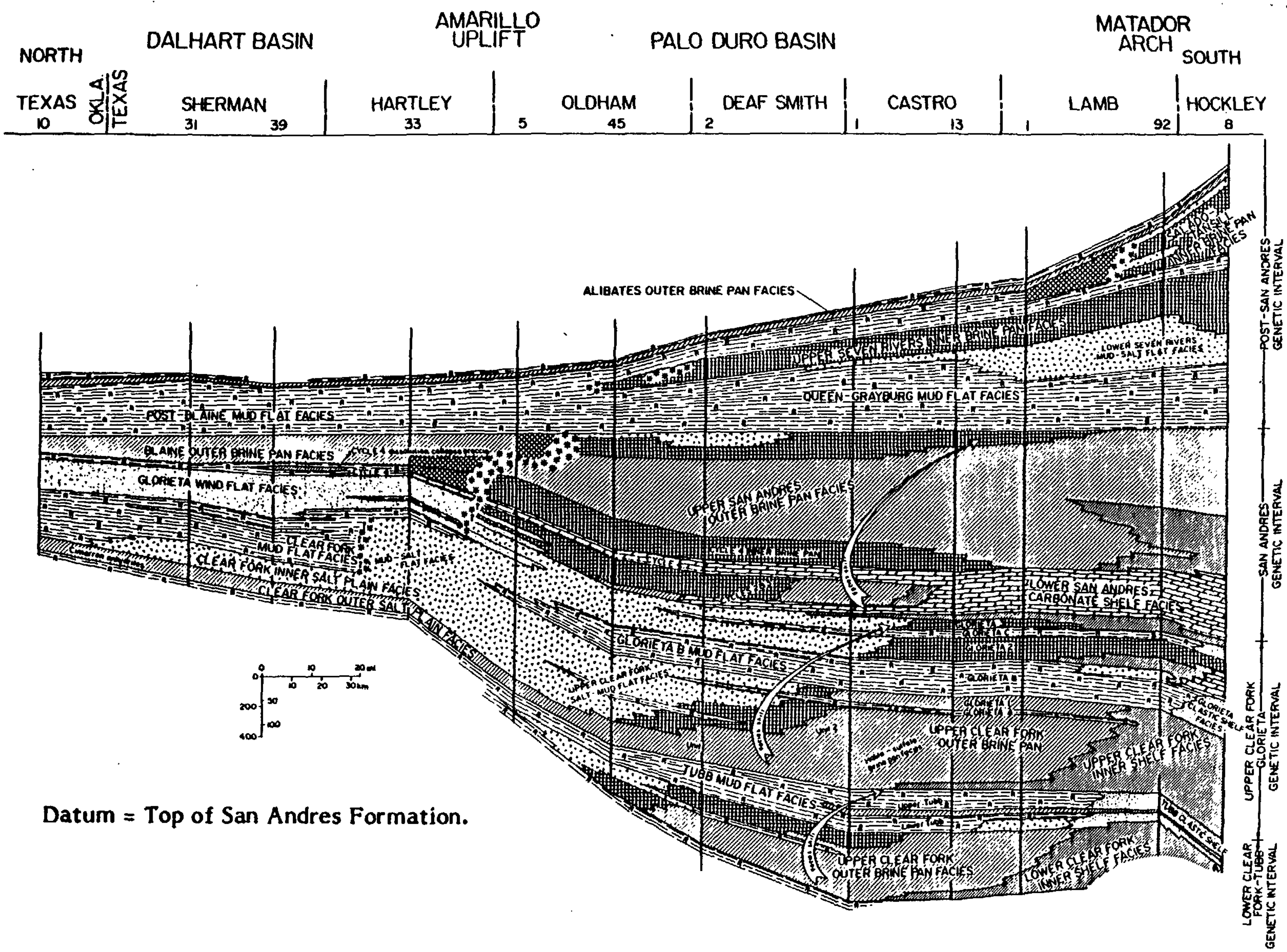


figure 2



Datum = Top of San Andres Formation.

Table 3 Textural classification of halite with genetic significance.

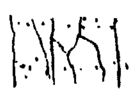
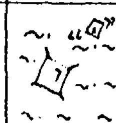
Symbol		A	B	C	D	E	F	G	H	I
halite type		chevron halite rock	color banded/ vertically oriented halite rock	C reserved for another primary fabric not yet recognized	chaotic mud-stone-halite rock	equant muddy halite rock	equant anhydritic halite rock	displacive halite in other sediments	halite cavity-filling cement	fibrous fracture-filling halite cement
halite crystal size		0.5-5 cm tall	0.5-5cm tall		0.3 to 3 cm	1-5 cm	1-5 cm	0.5-3 cm	1 to 20+ cm	.3 to 1 cm
halite crystal shape		subvertical mosaic; L:W= 3:2 to 4:1	subvertical mosaic; L:W= 3:2 to 4:1		equant anhedral to euhedral crystals	equant mosaic	equant mosaic	euhedral cubes or hopper shapes	equant mosaic	fibrous
impurities	composition	anhydrite common; mudstone possible	anhydrite, mudstone, organics		mudstone, minor anhydrite	mudstone, minor anhydrite	anhydrite	mudstone; also dolomite, anhydrite	cavity filling halite is clean but is associ-ated with mud-stone and anhydrite insoluble residues	trace of hema-tite present as coloring agent, otherwise pure halite
	%	<1%-5%	1%-5%		10-50%	1-10%	1-25%	50-99%		
	location	anhydrite on grain bound-aries, part-ings, mud-stone only in pipe fills	within and between grains, along partings, in pipes		in masses between halite crystals, some also within grains	within grains, minor between grains	along part-ings, grain boundaries	matrix for halite		
fluid inclusions		abundant,small define relict growth faces	varied		few	varied	varied	few	large and abundant	?
associated with halite types		F along crystal boundaries and pipes, H and/or D in pipes	F & E, H and/ or D in pipes		mudstone beds typically includes remnant B halite	may contain remnant A,B, possible H	may contain remnant A,B possible H	non-halite rocks	all halite types	in non-halite rocks
identifying characteristics		minute fluid inclusions along relict halite growth faces	bedding and/ or vertical orientation of crystals		10-50% mudstone in inter-crystalline masses,chaot-ic texture	halite colored red brown or black by 1-10% impurities, no bedding	halite with 1-25% anhy-drite, no bedding	euhedral to sub-hedral halite crystals in sediments	exceptionally coarse clear crystals, fill cavity in other salt type	fibrous halite in fracture, many examples red colored
sketch										

fig 6a

Key to detailed logs, San Andres units 4 and 5 halite

Column 1 — Depths in feet below kelly bushing

PC indicates point count of 100 points over 1 foot interval of slabbed core to check estimated percent lithology.

+ and * indicate sampled interval, core not available during detailed logging and checking.

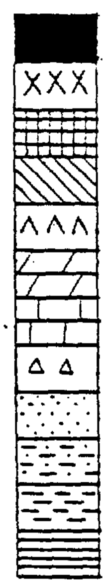
* indicates sample logged by BEG and a detailed description available in BEG files.

+ indicates sample logged, but no detailed description.

Intervals sampled before BEG logging are labeled as "sampled" in column 2

Column 2 — Estimated percent lithology

Mineral Composition



Porosity
Potash Salt
Halite
Anhydrite
Gypsum
Dolostone
Limestone
Chert
Sandstone
Siltstone
Mudstone
Claystone

Carbonate Components

G Grainstone
P Packstone
W Wackestone
M Mudstone

Carbonate Components (continued)

- o oolites or coated grains
- intraclasts
- fossiliferous (general)
- molluscs
- crinoids
- forams
- brachiopods
- A phylloid algae
- coral

Column 3 Structures

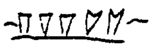
Sketch of structures in left half of column; interbeds of one lithology in another extend 3/4 of column width; boundaries between lithologies drawn across entire column width.

Halite

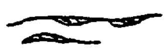
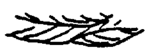
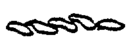
- chevrons
- vertically oriented crystals
- dark bands
- pipe, pits (show residue at bottom)
- anhydrite
- chaotic mud salt
- recrystallized halite
- exceptionally coarse halite
- mudstone interbed
- anhydrite interbed
- discontinuous mudstone interbed
- discontinuous anhydrite interbed
- nonhorizontal bedding

Column 3 Structures (continued)

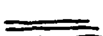
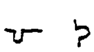
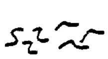
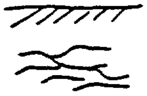
Anhydrite

	gypsum pseudomorphs
	bedding (schematic)
	contorted bedding
	nodular
*	crystallotopic

Carbonates

	bedding, scour surface
	wispy lamination
	ripple lamination
	cross beds
	intraclasts
	coarse grainstone
	burrows
	stylolites

Clastics

	lamination
	burrows
	ripple lamination
	disturbed intraclastic fabric
	more disturbed
	cross bedding
	dissipation structures

cd

Column 3 Structures (continued)

General

- boudinage
- mudcracks
- clasts
- faulting
- fractures
- birdseye-fabric
- contorted alminae.
- displacive halite hoppers
- skeletal displacive halite
- filled fracture
- nodules (note composition)
- crystallotopic anhydrite in other lithologies

Column 4 Comments

A. At left edge letters A through F indicate halite rock types.

Halite Types

A bedded halite with chevron fluid inclusions

B bedded halite with vertically oriented crystals

D chaotic mudsalt

E recrystallized muddy halite

F recrystallized halite with interstitial anhydrite

G displacive halite in sediment

H coarse recrystallized cavity fill halite

I fibrous fracture fill

See table and text for description of halite classification.

B. Location, irregularity and estimated continuity of mudstone and anhydrite interbeds in halite.

mudstone

anhydrite

irregular base, flat top

discontinuous beds

C. Comments on interbeds

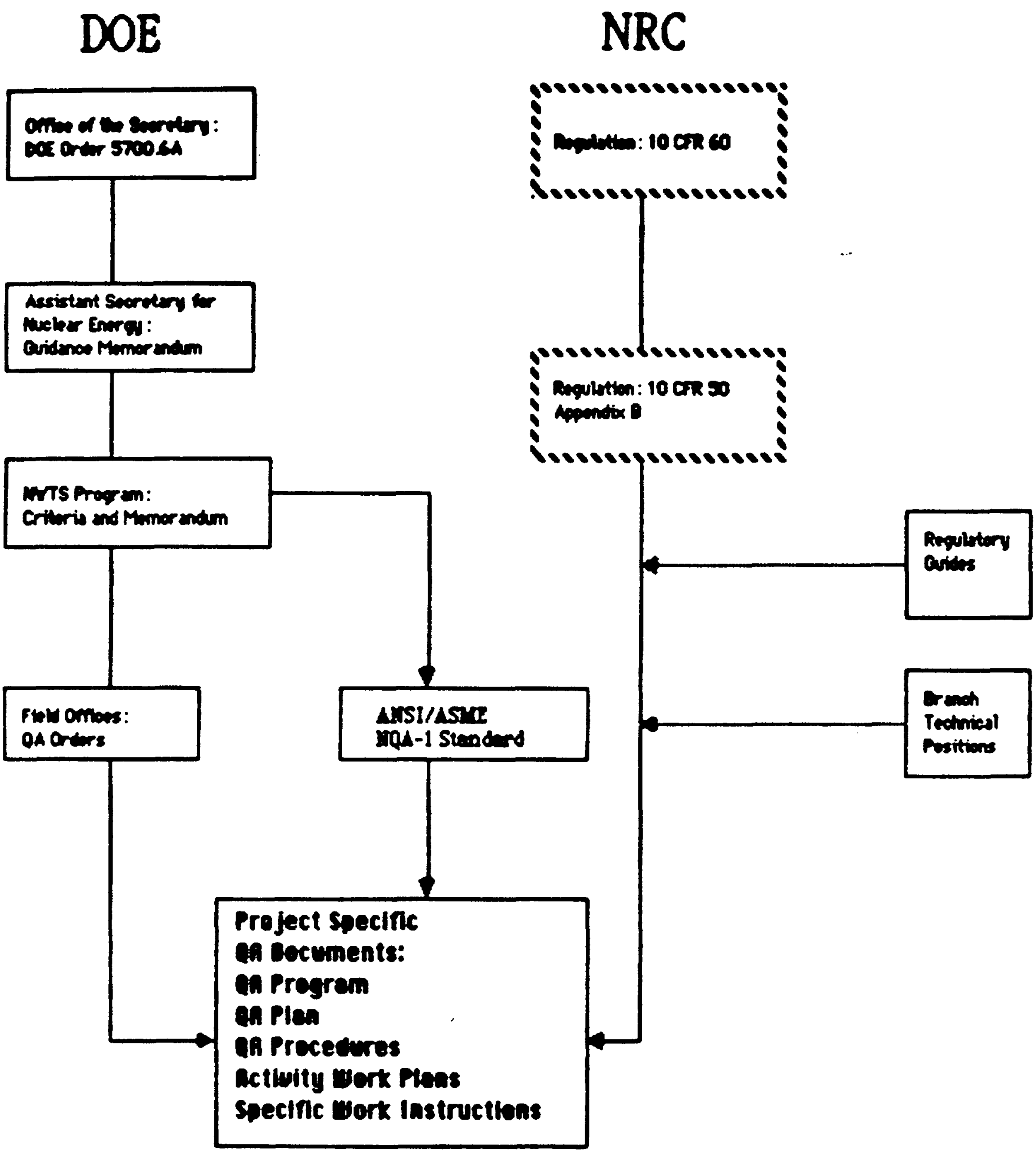
M indicates mudstone

A indicates anhydrite Z indicates siltstone

bed thickness shown

5A indicates 5 anhydrite interbeds too closely spaced to show individually, estimated percent impurities shown.

Davidson (14)



Hierarchy of Documents Affecting BEG QA Program

DOE WELLS

BUREAU OF ECONOMIC GEOLOGY
QUALITY ASSURANCE PROCEDURES
FOR DATA COLLECTION/INTERPRETATION OF BOREHOLE INFORMATION

STEP ONE

Assuring the integrity of sample materials

- WSCL 001: The Basic Procedures of the Well Sample And Core Library
- QAP C 1.1.10: Inspection Procedures for Geologic Material Processing
- TS 001: Instructions for Petrographic Thin Section Production
- TS 002: Operation Instructions for the Petrographic Thin Section Impregnation Machines
- MSL 001: Methods for Collecting and Handling Samples for Macrochemical and Trace Chemical Analyses
- QAP C 1.1.13: Procedures for Handling, Shipping and Storage

STEP TWO

Assuring the Validity of the Data Collection/ Interpretation Process

- MSL 001: Methods for Collecting and Handling Samples for Macrochemical and Trace Chemical Analyses
- WTWI-4A: Instructions for Host Rock Analysis

DOE WELLS

Quality Assurance Procedures for Data Collection/ Interpretation of Borehole Information

As we have seen there are a wide range of very useful data that are derived from the DOE boreholes. The reliability of the physical and chemical characteristics determined for each type of material rests on the validity of the processes used to analyze those materials. Even more important is the integrity of the samples from which thoses results were obtained. Therefore the Bureau places great importance on ensuring the quality of the samples that are to be analysed. **Analytical results are no better than the samples from which those results were obtained.** The integrity of the samples (in our case primarily well cores) is controlled by quality assurance procedures. ***The quality of the samples is the first concern of the data collection and interpretation system.*** These written documents describe in detail how cores and associated samples are identified, handled, sampled, and shipped. They are:

1. WSCL 001: The Basic Procedures of the Well Sample and Core Library

2. QAP C1.1.10: Inspection Procedures for Geologic Material Processing

3. TS 001: Instructions for Petrographic Thin Section Production

4. TS 002: Operation Instructions for the Petrographic Thin Section Impregnation Machines

5. MSL 001: Methods for Collecting and Handling Samples for Macrochemical and Trace Chemical Analyses

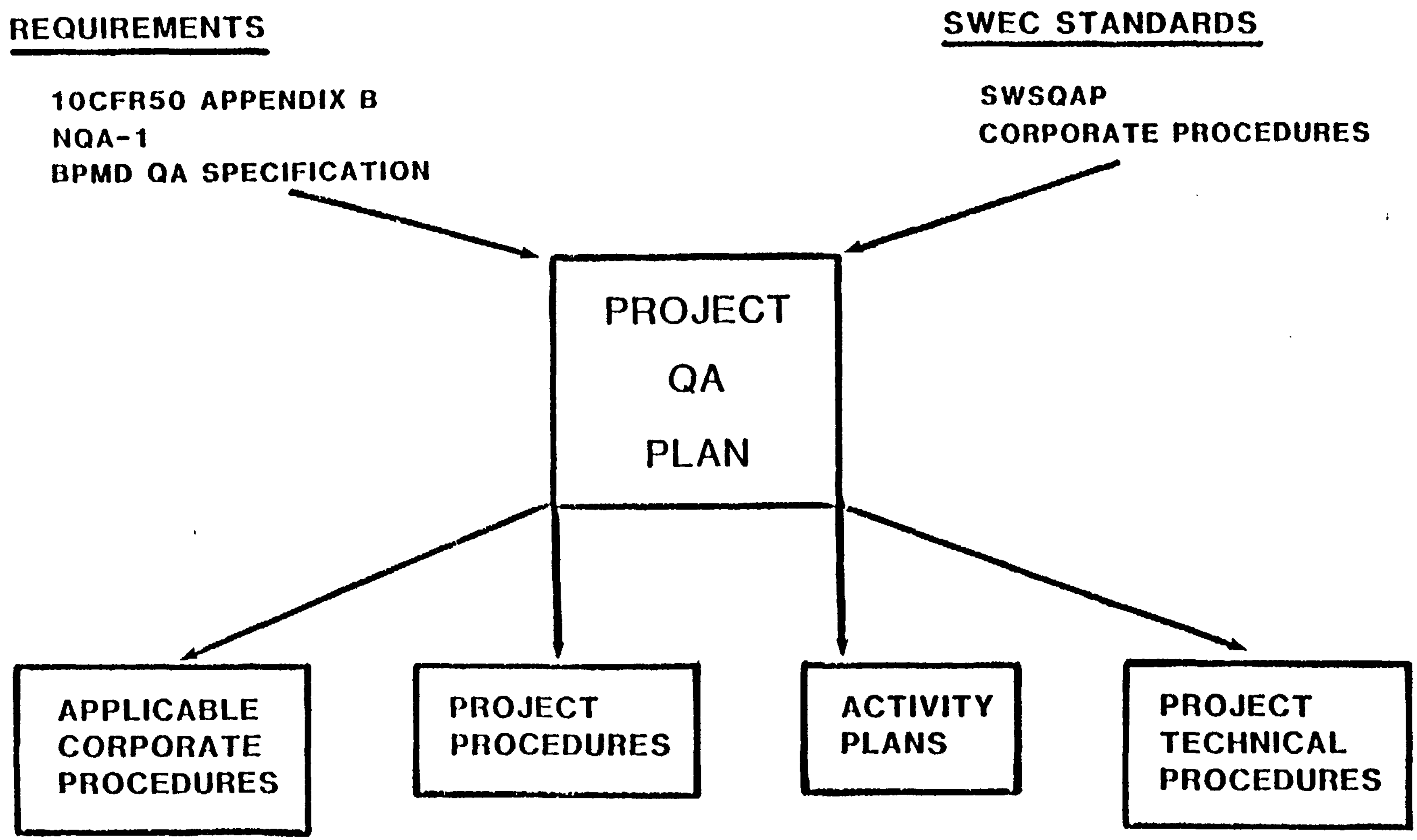
6. QAP C 1.1.13: Procedures for Handling, Shipping and Storage

The ***second*** area of control through our quality assurance procedures is in the interpretertation of the analytical data from the samples. The following procedures are relevent to the Bureau's interpretation of borehole derived data:

ANALYTICAL TYPES AND PRIMARY QA PROCEDURES ASSOCIATED WITH DOE BOREHOLES

TYPE	QA PROCEDURE
Lithologic Logging of Well Core	WTWI-4A: Instructions for Host Rock Analysis
Pertographic Descriptions	WTWI-4A: Instructions for Host Rock Analysis
Geochemical Testing	MSL 001: Methods for Collecting and Handling Samples for Macrochemical and Trace Chemical Analyses

QA PROGRAM


REQUIREMENTS
10CFR50 APPENDIX B
NQA-1
BPMD QA SPECIFICATION
SWEC STANDARDS
SWSQAP
CORPORATE PROCEDURES
PROJECT QA PLAN
APPLICABLE CORPORATE PROCEDURES
PROJECT PROCEDURES
ACTIVITY PLANS
PROJECT TECHNICAL PROCEDURES

STONE & WEBSTER CORPORATE PROCEDURES

- TECHNICAL AND ADMINISTRATIVE PROCEDURES AND GUIDELINES WITH GENERAL APPLICABILITY TO THE COMPANY'S WORK

- ISSUED BY THE VARIOUS DEPARTMENTS / DIVISIONS FOR THEIR AREAS OF RESPONSIBILITY, E.G.:

  ENGINEERING DEPARTMENT

  GEOTECHNICAL DIVISION

  ENGINEERING ASSURANCE DIVISION

85-45790

PROJECT PROCEDURES

- TECHNICAL AND ADMINISTRATIVE PROCEDURES ISSUED BY THE PERMIAN BASIN PROJECT (PROJECT MANUAL AND PROJECT Q.A. PLAN)
- OFTEN BASED ON MORE GENERAL CORPORATE PROCEDURES
- PROJECT SPECIFIC AND GENERALLY APPLICABLE TO ALL PROJECT WORK

85-45791

PROJECT TECHNICAL PROCEDURES (PTPs)

- TECHNICAL PROCEDURES ISSUED BY THE PERMIAN BASIN PROJECT
- APPLICABLE TO WORK PERFORMED BY STONE & WEBSTER PERSONNEL
- GUIDELINES AND REQUIREMENTS FOR PERFORMING A SPECIFIC TASK OR STUDY
- PREPARED WHEN NO APPLICABLE CORPORATE TECHNICAL PROCEDURE OR GUIDELINE IS AVAILABLE

ACTIVITY PLANS

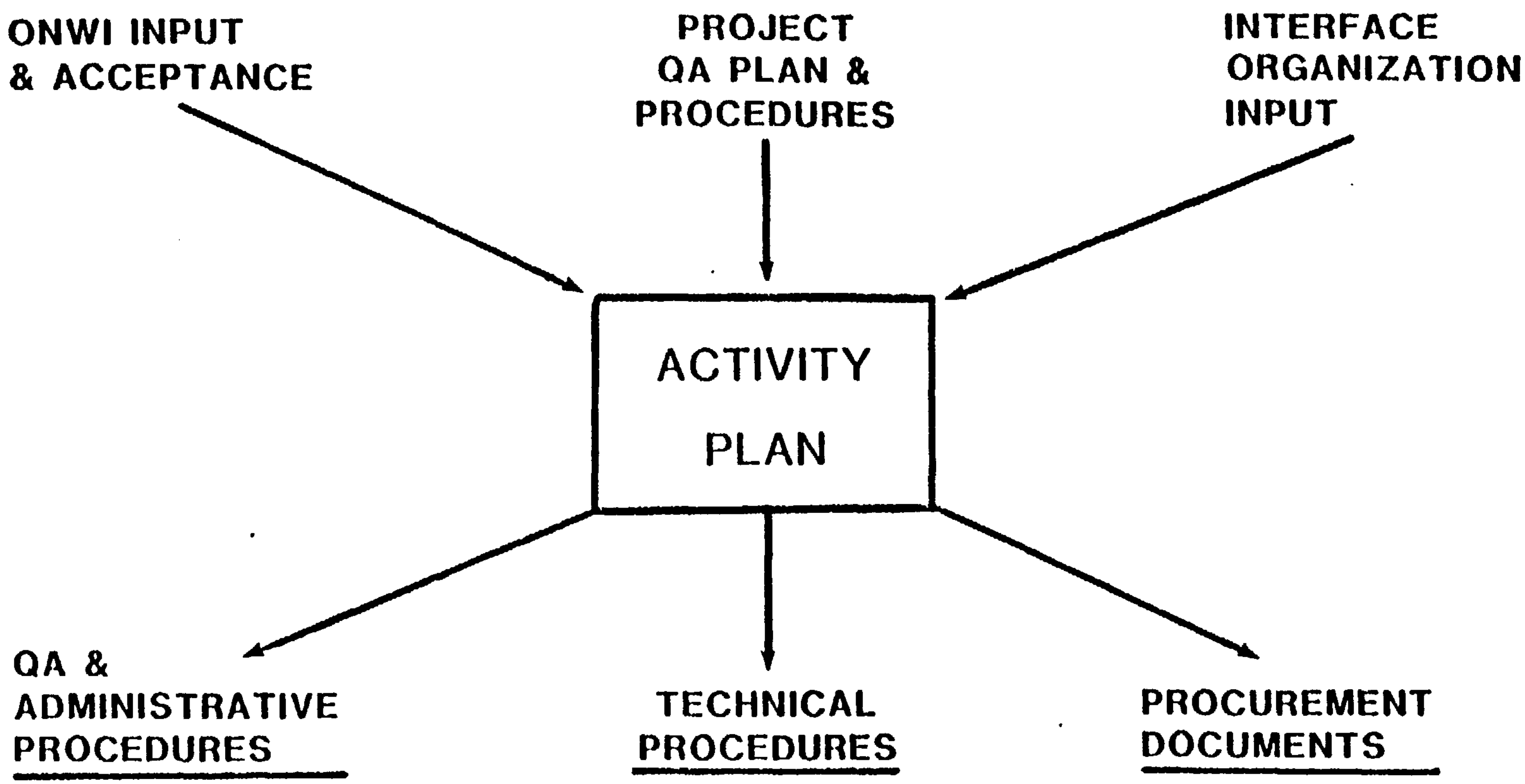
- SUMMARY PLANS FOR A COMPLEX PROJECT STUDY (USUALLY A FIELD INVESTIGATION WITH SEVERAL COMPONENTS)
- OBJECTIVES
- SCOPE OF WORK
- PARTICIPANTS
- QUALITY ASSURANCE
- EVALUATION
- REPORTS
- SCHEDULE

ENGINEERING SERVICE SCOPES OF WORK (ESSOWS)

- TECHNICAL AND QUALITY ASSURANCE REQUIREMENTS FOR SUBCONTRACTORS

85-45792

ACTIVITY CONTROL DOCUMENTS



QA & ADMINISTRATIVE PROCEDURES

ENGINEERING ASSURANCE (EAP)

ENGINEERING DEPARTMENT (EDPP)

PROJECT (PP)

TECHNICAL PROCEDURES

GEOTECHNICAL DIVISION (GTP)

ENVIRONMENTAL DIVISION (ETP)

PROJECT (PTP)

PROCUREMENT DOCUMENTS

ENGINEERING SERVICE SCOPE OF WORK (ESSOW)

PURCHASE REQUISITION (PR)

ACTIVITY PLANS (APs) (Formerly Field Test Plans, FTPs)

	TITLE	REVISION NO.	REVISION DATE
FTP 13697-1-2	Texas BEG Exploratory Wells • DOE - SWEC Sawyer No. 1 Donley County Texas • DOE - SWEC Mansfield No. 1 Oldham County Texas	2	12/10/81
AP 13697-2-1	Stratigraphic Test Wells • SWEC Detten No.1 Friemel No.1 Harman No.1	1	6/11/82
AP 13697-3-2	Hydrologic Test Wells • SWEC - Zeeck No. 1 • SWEC Detten No. 1 (Deepened Stratigraphic Test Well)	2	6/15/82
FTP 13697-4-1	Engineering Design Boreholes	1	4/4/85
AP 13697-5-1	Laboratory Testing	1	1/25/84
AP 13697-6-0	Hydrogeologic Test Well • SWEC - Zeeck No. 1 Well Pump Testing and Fluid Sampling	0	7/22/82
AP 13697-7-0	SWEC Mansfield No.1 Well Pump Testing and Fluid Sampling	0	6/30/82
AP 13697-8-0	Water Well Drilling For Fluid Sampling of the Dissolution Zone	0	9/22/82
AP 13697-9-0	Hydrologic Test Well • SWEC - J. Friemel No. 1	0	10/04/82

		TITLE	REVISION NO.	REVISION DATE
AP	13697-10-0	Testing at the Pennzoil No. 1 Black Wildcat Well	0	7/23/84
AP	13697-11	Reserved	-	-
AP	13697-12-0	Statigraphic Test Well • SWEC - Holtzclaw No. 1	0	12/23/82
AP	13697-13-1	Microearthquake Network	1	5/31/84
AP	13697-14-0	Stratigraphic Test Well • SWEC - Oschner No. 1	0	3/25/83
AP	13697-15-1	Geophysical Surveys	1	6/21/83
AP	13697-16-0	Seismic Reflection Surveys	0	7/16/82
AP	13697-17-0	Hydrogeologic Test Well • SWEC - J. Fremel No. 1 Pump Testing and Fluid Sampling	0	4/12/82
AP	13697-18-2	Geotechnical Borehole Testing	2	9/19/84
AP	13697-19-0	Engineering Design Borehole - Geotechnical Field Testing	0	9/9/83
AP	13697-20-1	Hydrologic Test Well - Western Deat Smith No. 1 (PD-14)	1	7/5/85
AP	13697-21	Reserved		
AP	13697-22-0	Dockum - Upper Permian Test Wells	0	8/9/84
AP	13697-23-0	Geologic Mapping and Field Reconnaissance - MacKenzie Lake and Buffalo Lake Areas	0	6/29/84

AP - 9 HYDROLOGIC TEST WELL - J. FRIEMEL NO. 1

TABLE OF CONTENTS

AP - 9 HYDROLOGIC TEST WELL J. FRIEMEL NO. 1

ATTACHMENT 4-0
HYDROLOGIC TEST WELL

SWEC SUBCONTRACTORS

Name	General Description	Contract ESSOW or P.O. No.
Baker & Taylor	Drill Rig & Crew	G103A
Schlumberger	Geophysical Logging & Perforating Services	G103B
Hycalog	Rock Coring Equipment & Coring Engineer	G103C
Dresser-Magcobar	Mud Program - Drilling Fluids & Mud Engineer	G103D
Field Call-out	Cementing Supplies & Services	*
Field Call-out	Casing and Tubing	
Johnston - Macco	Drill Stem Testing	G103G
FMC	Well Head Assembly	G103H
Field Call-out	Casing Installation Crew	*
Field Call-out	Fuel-Drill Rig, Other Onsite Equipment	*
Field Call-out	Water for Drilling	*
Exploration Logging	Mud Logging Services	G103Q
John Nicholson Amarillo, Texas	Drilling Consultant Petroleum Geologist	G112A
P. Cameron, Jr, Inc.	Consultant-Petroleum Engineer. Drill Rig Engineers	G112F
Glen Thompson Tucson, Arizona	Mud Tracer Consultant	G112D

*Field Purchase Orders

AP - 9 HYDROLOGIC TEST WELL - J. FRIEMEL NO. 1

ATTACHMENT 5-0
HYDROLOGIC TEST WELLS

SWEC PROJECT TECHNICAL PROCEDURES (PTPs)
AND PROJECT PROCEDURES (PPs)

Number	Title/Description
PTP 13697-7	Cementing and Casing Installation
PTP 13697-8	Logging, Packaging, and Transport of Core
PTP 13697-11	Transport, Logging, Photographing, and Storage of Core at SWEC Field Office
PP 9-1	Responsibilities of SWEC Site Geologist
PP 9-2	Receiving Equipment and Materials

PROJECT TECHNICAL PROCEDURES ((PTPs)

NO.	TITLE	REVISION NO.	REVISION DATE
PTP 13697-1-4	Logging, Packaging, and Transport of Core - Donley and Oldham County Wells	4	4/6/83
PTP 13697-2	Cancelled		
PTP 13697-3-2	Casing Installation and Cementing - Donley and Oldham County Wells	2	4/22/81
PTP 13697-4-3	Pump Testing and Fluid Sampling Sawyer and Mansfield Wells	3	9/14/82
PTP 13697-5-1	Handling and Transport of Formation Fluid Samples - Donley and Oldham County Wells	1	6/2/81
PTP 13697-6-0	Preparation, Loading, and Preservation of Smoked Seismic Paper Records for Sprengnether MEQ-800 Portable Seismic Recorder	0	2/9/83
→ PTP 13697-7-1	Casing Installation and Cementing and Plugging Test Wells	1	8/15/83
→ PTP 13697-8-2	Field Logging, Packaging, and Transport of Core - Stratigraphic and Hydrologic Test Wells and Engineering Design Borehole	2	4/27/83
PTP 13697-9-1	Laboratory Testing of Rock and Salt Samples at SWEC Geotechnical Laboratory	1	8/27/84

QUALITY ASSURANCE PLAN

GEOLOGIC PROJECT MANAGER-

PERMIAN BASIN

PROJECT TECHNICAL PROCEDURES ((PTPs)

NO.	TITLE	REVISION NO.	REVISION DATE
PTP 13697-10-1	Handling and Transport of Formation Fluid Samples From DST and RFT Tests in Stratigraphic and Hydrologic Test Wells and Engineering Design Borehole	1	1/24/83
→ PTP 13697-11-2	Transport, Logging, Photographing and Storage of Core at SWEC Field Office	2	5/2/83
PTP 13697-12-2	Determination of Point Load Strength Index on Rock Cores	2	3/21/84
PTP 13697-13-2	Pump Testing and Fluid Sampling SWEC Test Wells	2	7/1/83
PTP 13697-14-1	Microearthquake Seismic Network for Seismic Data Collection, Reporting Seismic Events, Reporting Equipment Failure, and Data Transfer	1	6/12/84
PTP 13697-15-0	Logging, Photographing, Packaging, and Transport of Core - Deep Test Wells	0	8/11/83
PTP 13697-16-0	Confirmation of Geophysical Well Log Data Recorded on Magnetic Tape	0	4/27/84
PTP 13697-17-0	Maintenance of Geophysical Well Log Tapes	0	7/13/84
PTP 13697-18-1	Creating and Amending Project Computerized Geologic Data Base	1	2/5/85
PTP 13697-19-0	Hydraulic Fracture Orientation Determination	0	5/29/84

PROJECT PROCEDURES (PPs)

TABLE OF CONTENTS*

*These procedures are maintained in the Project Manual and reflect prime quality assurance program compliance. Other procedures exist in the Project Manual that reflect basic project administration.

PROJECT PROCEDURES (PPs) (CONT'D)

TABLE OF CONTENTS* (CONT'D)

*These procedures are maintained in the Project Manual and reflect prime quality assurance program compliance. Other procedures exist in the Project Manual that reflect basic project administration.

PROJECT PROCEDURES (PPs) (CONT'D)

TABLE OF CONTENTS* (CONT'D)

*These procedures are maintained in the Project Manual and reflect prime quality assurance program compliance. Other procedures exist in the Project Manual that reflect basic project administration.

**Project Administrative Directive (PAD) (PP 2-1)

PROJECT PROCEDURES (PPs) (CONT'D)

TABLE OF CONTENTS* (CONT'D)

*These procedures are maintained in the Project Manual and reflect prime quality assurance program compliance. Other procedures exist in the Project Manual that reflect basic project administration.

**Project Administrative Directive (PAD) (PP 2-1)

Collins (11)

FRACTURE INVESTIGATIONS OF THE PALO DURO BASIN AREA

Eddie Collins, BEG

1. Regional fracture orientations -- figs. 2,3
   - data collected in Permian and Triassic strata
   - data includes joint strikes measured in outcrop and fracture orientations measured from fracture identification logs
   - data for each one degree by one degree quadrant has been plotted together
   - have plotted general fracture orientations and fracture orientations that are significant at a 95% confidence level
   - regionally, west-east striking fractures are signifcant in Permian strata
   - Deaf Smith Co. also has NE striking fractures

2. Vertical and lateral continuity of fractures

2.1 Faults, folds, joints - figs. 4-6
   - at western part of study area one signifcant joint set strikes NE, parallel to the strike of the Alamosa Creek and Bonita Faults
   - northeast of Deaf Smith Co., joints were studied in Permian, Triassic and Tertiary rocks at a flexure off the southwest flank of John Ray Dome; at intervals along a traverse in the different age

strata. strikes of a representative joint from each set were measured; data has been plotted in azimuth vs traverse distance plots and rose diagrams; data show a well defined NW striking joint set in the overlying strata. parallel to the flexure axis; fracture spacing is closely spaced in Permian and Triassic sandstones (5-8 joints across 1 m in 1-2 m beds); Tertiary Ogallala strata also have a well defined NE striking joint set

2.2 Joint zones - fig. 7

- in relatively undeformed strata. zones of closely spaced joints extend vertically through Permian and Triassic strata; these joint zones range in width from 10 to 40 m and have been traced laterally up to 1 km

2.3 Joint spacing vs bed thickness - fig. 8

- the number of joints across two meters were measured for sandstone beds of different thicknesses; figure 8 shows plotted data

2.4 Lateral variability of joint orientations - figs. 9, 10

- strikes of vertical gypsum-filled joints in Permian strata were measured along three traverses at Palo Duro Canyon State Park; data are plotted in azimuth vs traverse distance plots and rose diagrams
- data show well defined E-W striking joints throughout the area; most of the joints strike NNW at the northern traverse (fig. 10);

the middle traverse (traverse 2) shows the strikes of the NNW oriented joints drift northwestward and NW striking joints become most common

3. Preliminary evaluations of fractures and veins in the core

3.1 General occurrance of fractures and veins - figs. 11-13

- core show that Permian strata are cut by gypsum. halite. anhydrite. and calcite veins. as well as fractures with no mineral filling: most of the fractures without mineral fillings are the result of drilling coring. however some are thought to be natural
- for this study the strata has been grouped into three categories based on lithology and stratigraphic sequence: the categories are (1) strata below salt units. (2) strata that contain bedded halite. and (3) deformed strata above the salt units (salt dissolution zone)
- based on the core descriptions. the percentage of fractured core for each category has been determined by dividing the number of one foot core intervals containing fractures by the total core footage
- data show that strata above the bedded halite units are more fractured than the salt zone units: the salt zone unit category contains the lowest percentages of fractured core: for strata below the bedded halite units. core from the Mansfield well located on the Bravo Dome has the greatest percentage of fractured core

3.2 Gypsum veins (core and outcrop) - figs. 14- 27

- strata overlying salt units commonly have vein fillings of gypsum
- core and outcrop studies show gypsum veins are common in a deformed strata zone
- veins are composed of fibrous gypsum bisected by a medial scar; they are thought to be antitaxial crack-seal veins (Ramsay and Huber, 1983); the medial scar marks the site of earliest mineralization with new material added at the vein - wall rock contact; the mineral fibers indicate the direction of maximum principal extension at the time they were added to the vein
- gentle subsidence and collapse is thought to have opened the gypsum filled fractures

3.3 Halite veins - figs. 28-32

- fibrous halite veins fill fractures in bedded units
- veins occur within mudstone, siltstone, and carbonate interbeds
- some veins exhibit a subpolygonal pattern on bedding planes; these may have a desiccation or synaeresis related origin
- some veins exhibit a postcompactional origin; they are eliptical in shape and do not exclusively "V" downwards; fracture filling is not zoned and contains no silt or mud filling; crosscutting relationships show that many veins postdate compaction and cementation

3.4 Veins and fractures below halite units - fig. 33

- calcite and anhydrite veins are present as well as fractures without mineral fillings

3.5 Fracture orientations in Deaf Smith Co. - fig. 34

- fracture orientations have been interpreted using fracture identification logs; these logs have limitations; data show westward and northeastward fracture orientations

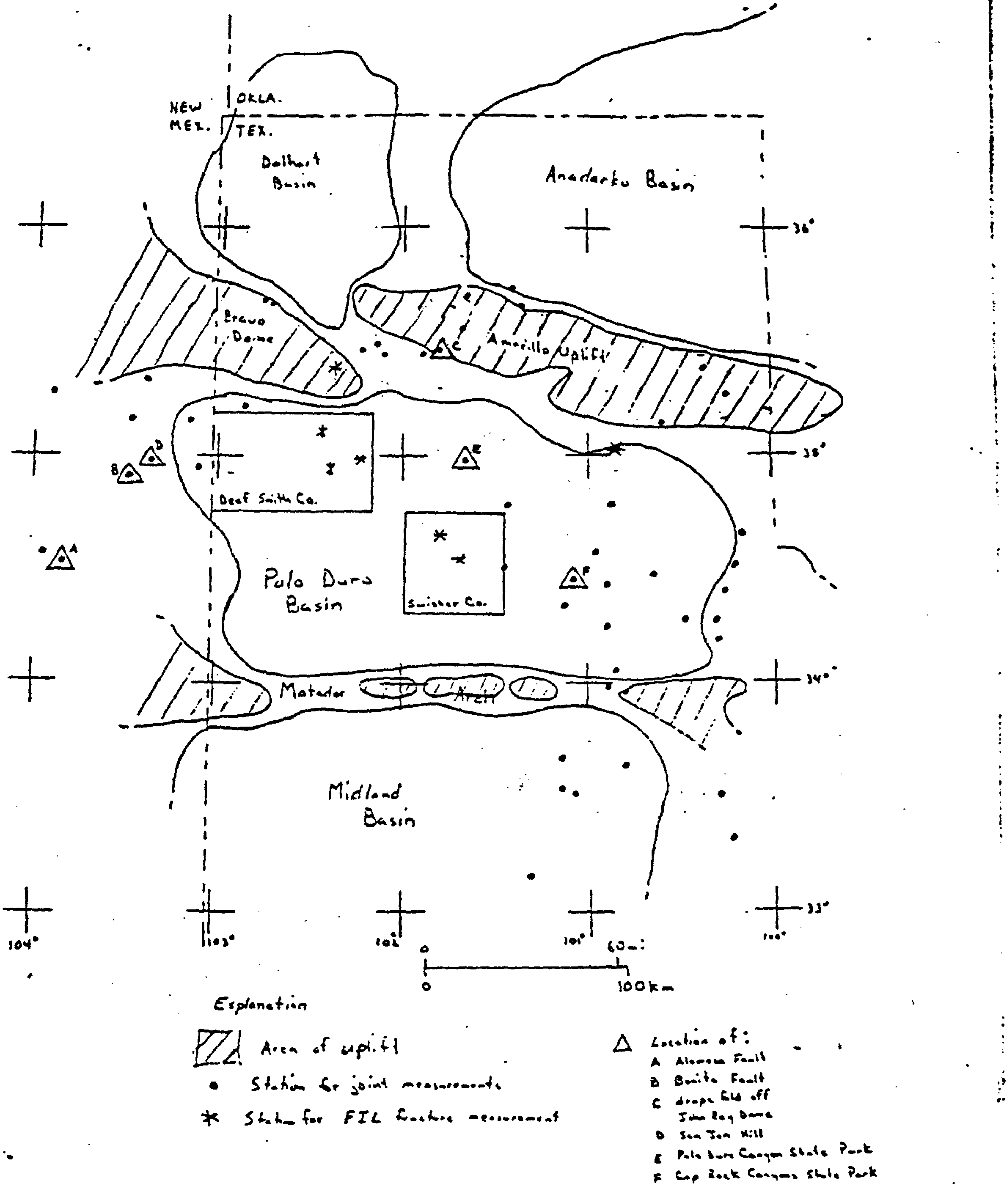


Figure 2 Structural setting of the Palo Duro Basin area showing the location of (1) stations for the regional joint and Fracture Identification Log (FIL) fracture measurements and (2) areas for detailed field studies.

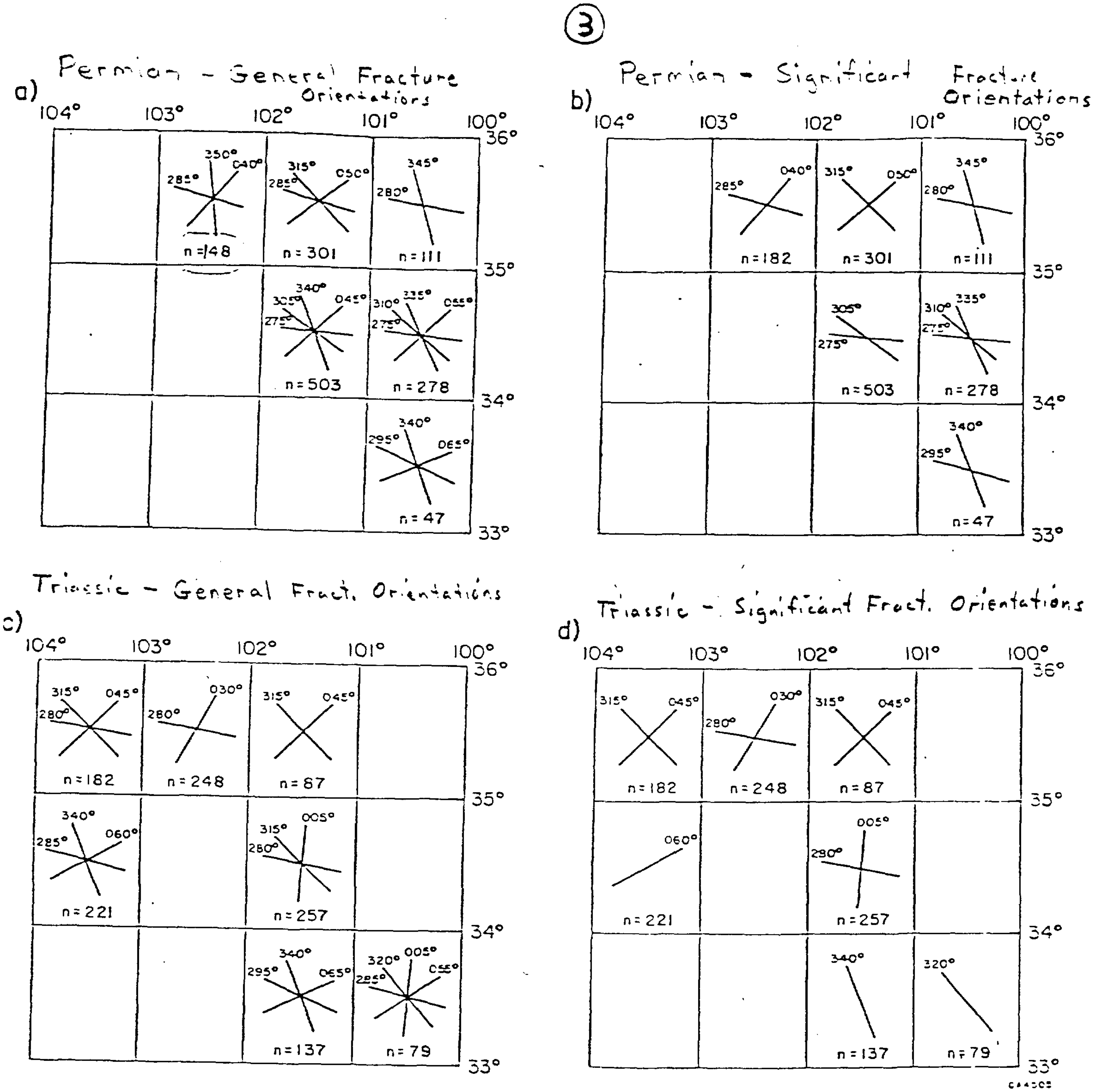


Figure 3 Fracture maps of the Texas Panhandle and eastern New Mexico region showing (a) mean fracture strikes for Permian strata, (b) mean fracture strikes that are significant at 95% confidence for Permian strata, (c) mean fracture strikes for Triassic strata and (d) mean fracture strikes that are significant at 95% confidence. Stations for fracture measurements and structural setting are shown in figure 1. n = the number of measurements in each quadrant.

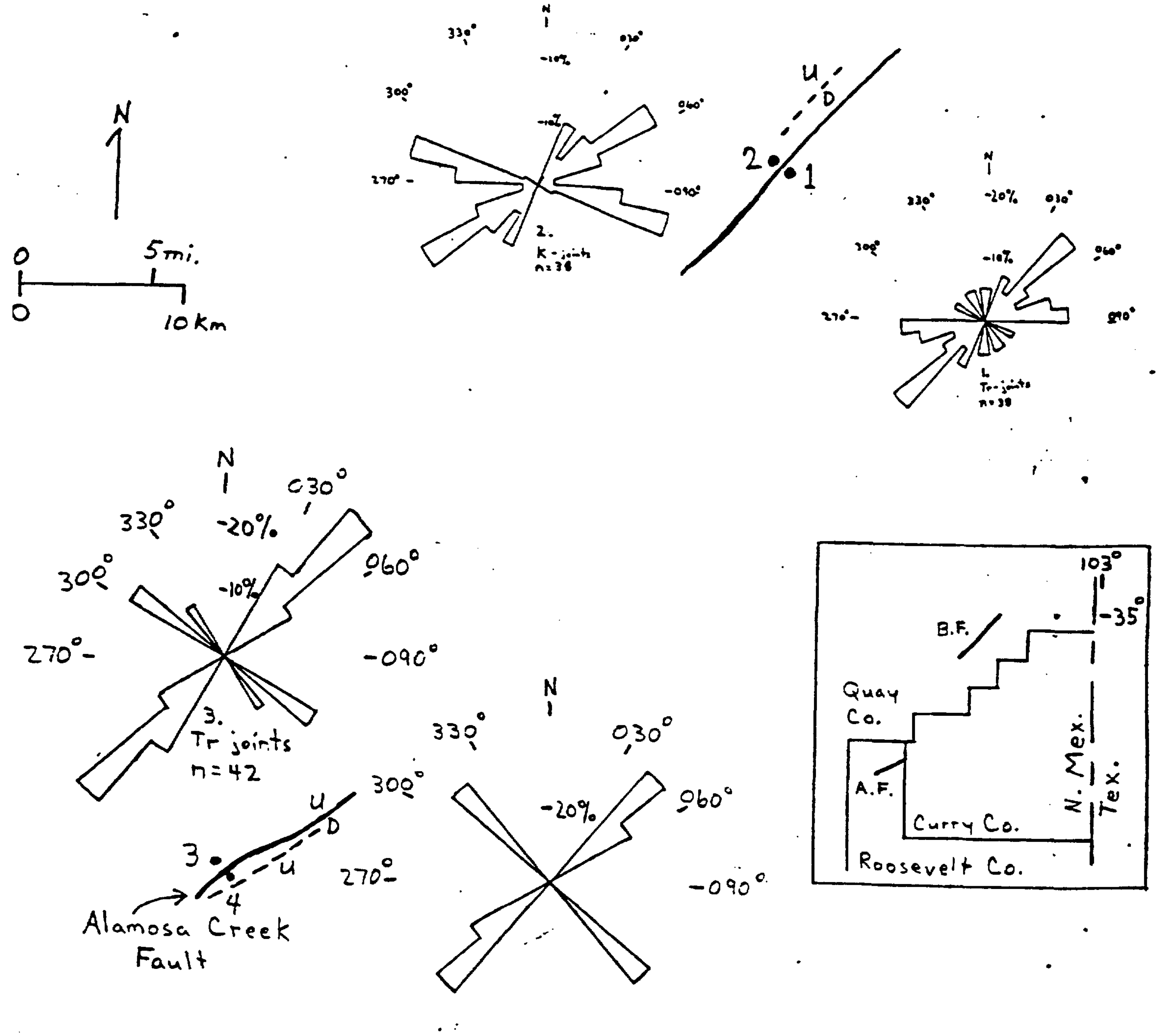


Figure 4 **(a) Strikes of faults and joints at the western margin of the Palo Duro Basin in eastern New Mexico. Rose diagram data are plotted as percentages of total number of measurements (n) for 10° intervals.**

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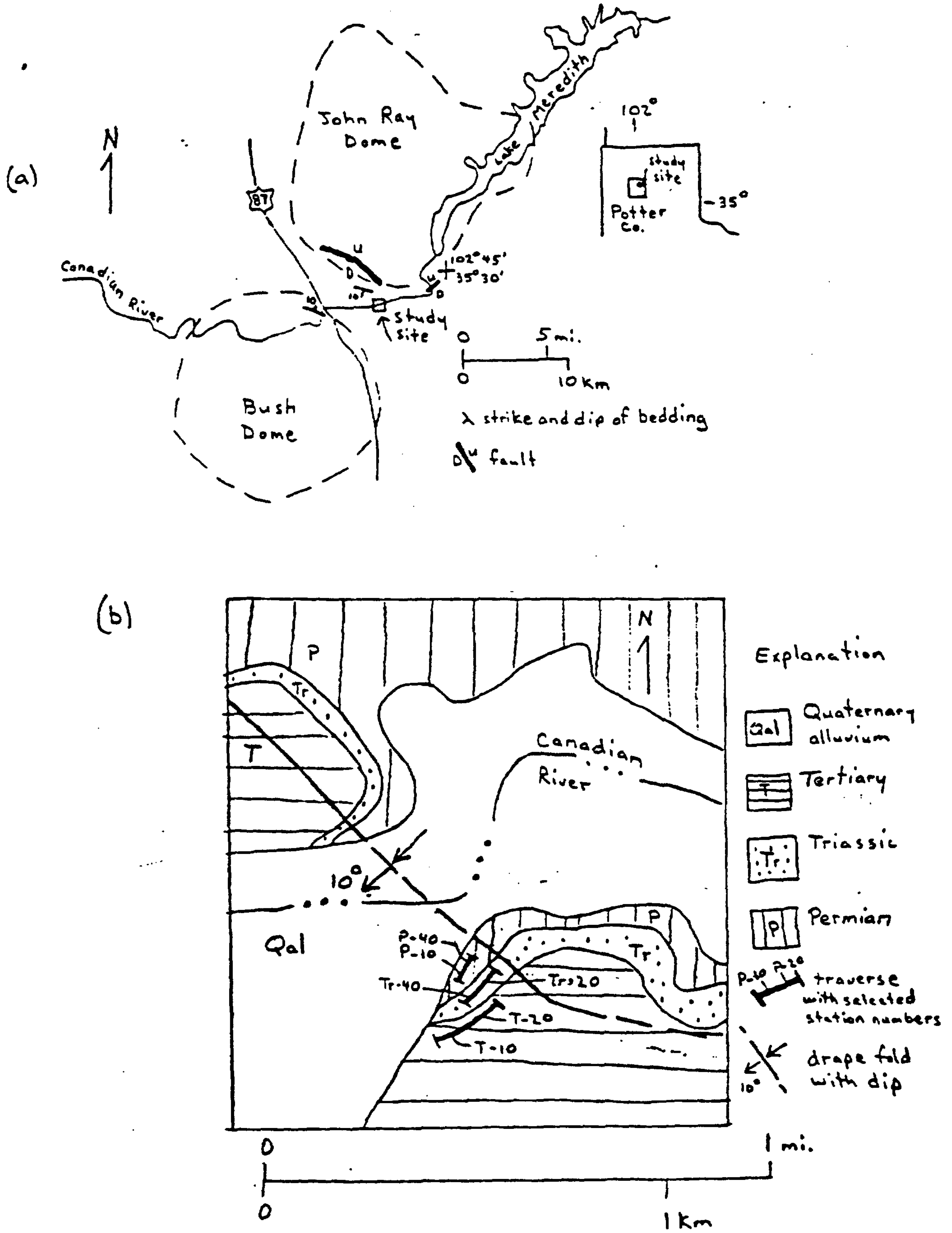


Fig. 5 (a) Location of study area at flank of John Ray Dome. (b) Location of traverses in Permian strata (P), Triassic strata (Tr), and Tertiary strata (T).

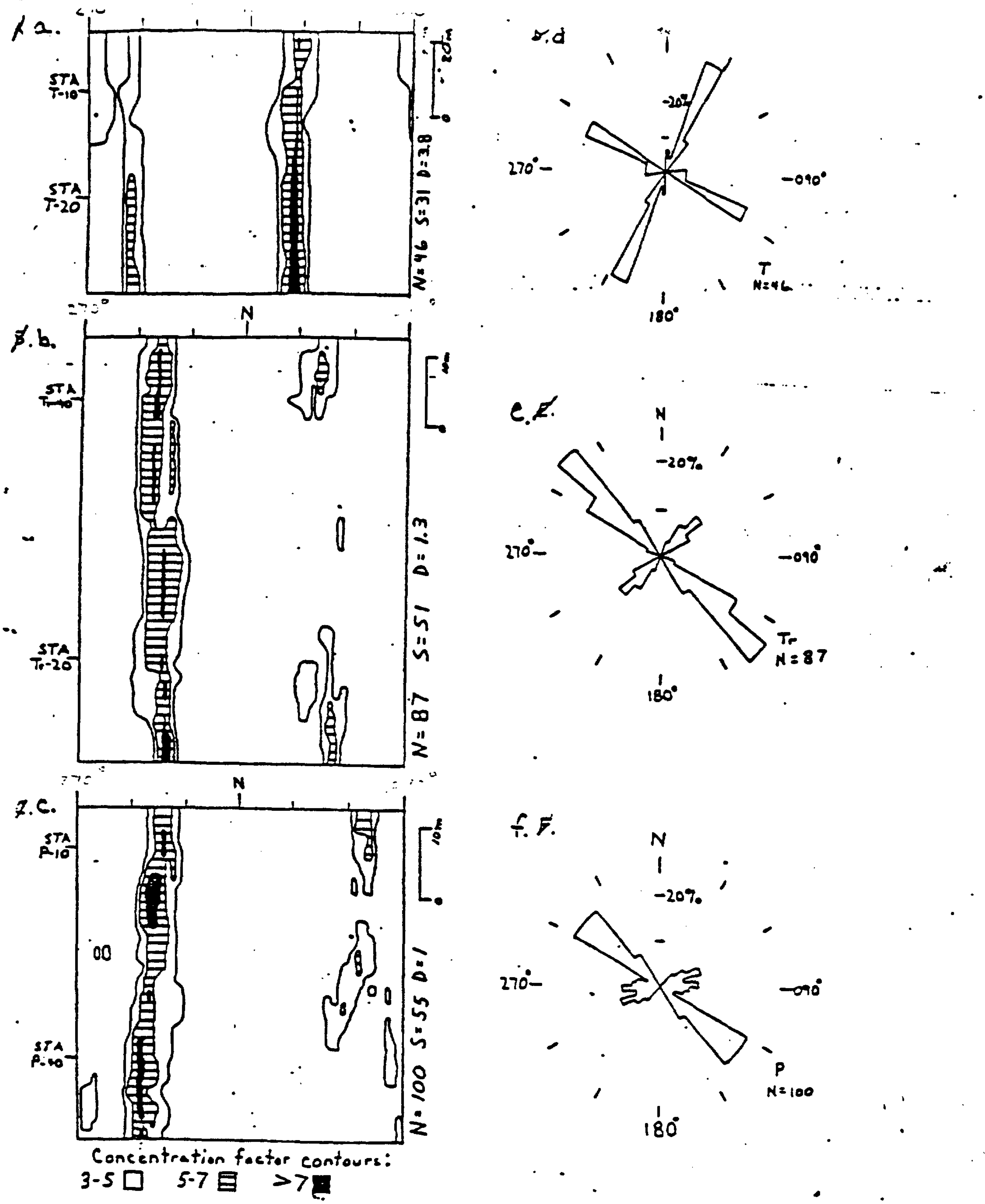


Figure 6 Azimuth-versus-traverse-distance plots are for joints in (a) Tertiary, (b) Triassic, (c) Permian strata. N = number of measurements, S = number of stations, STA = selected station number, and D = average distance between the stations. Contours are in concentration of data within 10° intervals across every 2° of azimuth (Wise and McCrory, 1982). Corresponding rose diagram plots are of joints in (d) Tertiary, (e) Triassic, and (f) Permian strata. Data are plotted as percentages of total number of measurements (N) for 10° intervals.

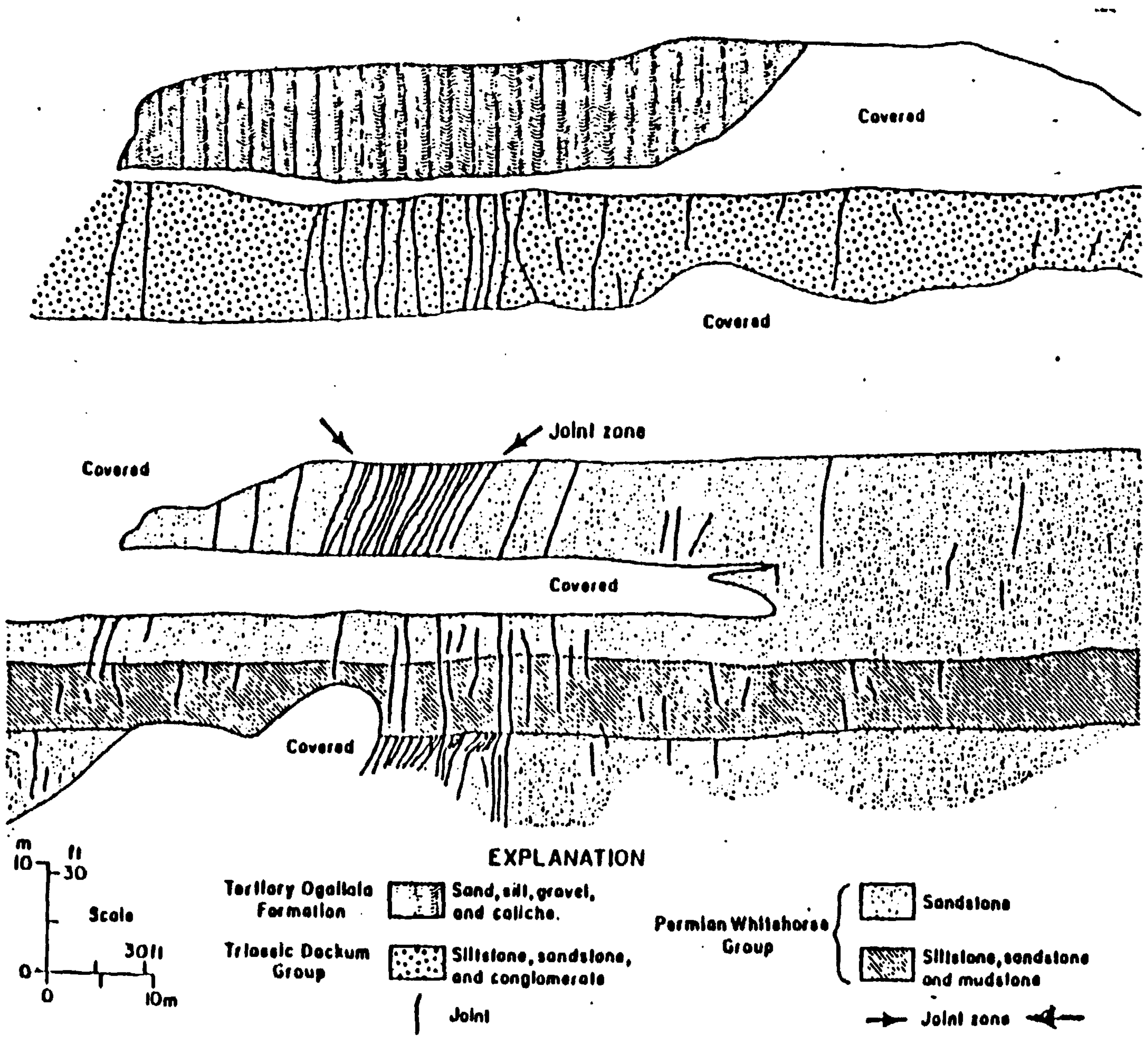
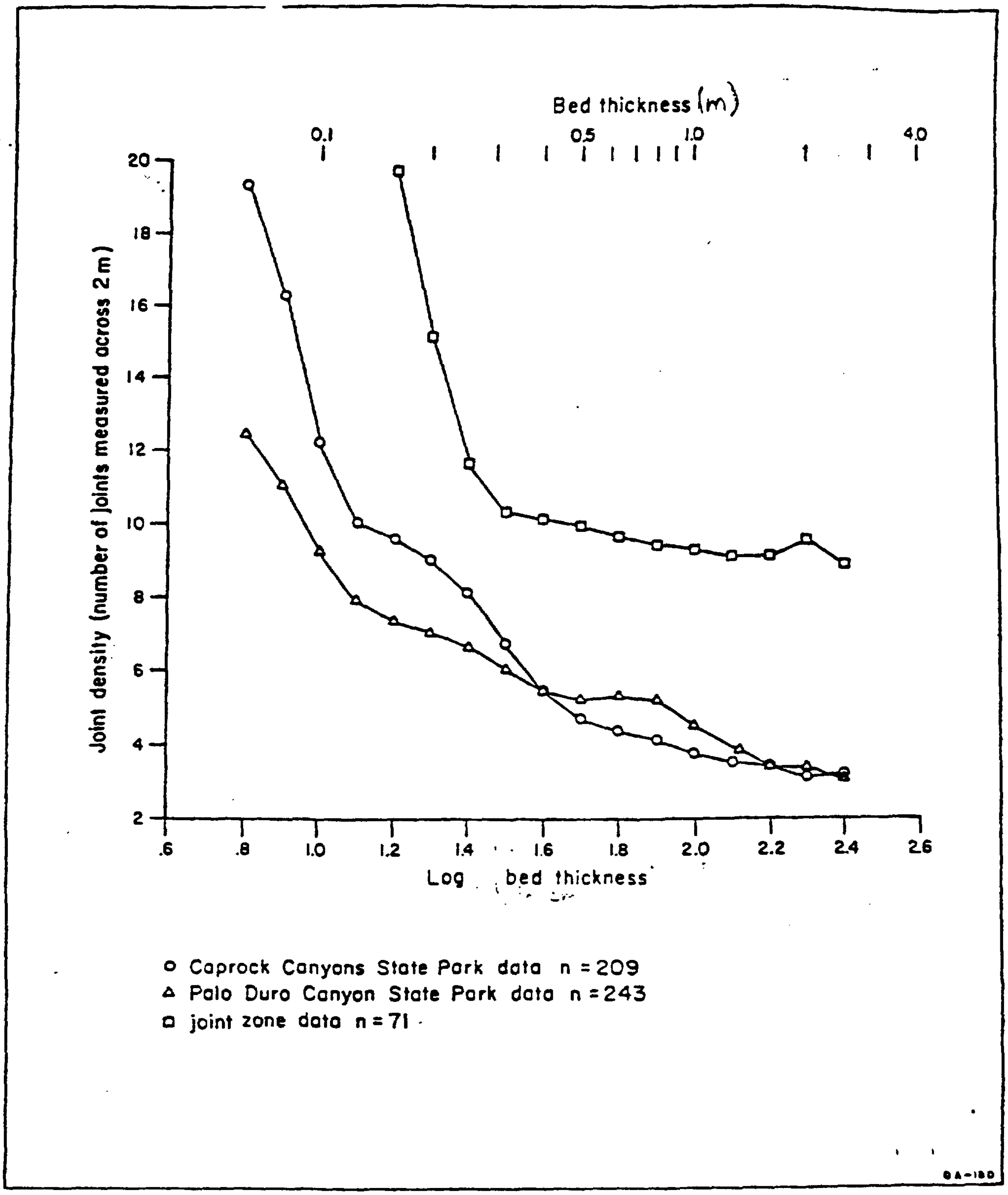


Figure 7 Cross-section view of a joint zone extending through Permian and Triassic rocks at Caprock Canyons State Park in Briscoe County. Overlying Tertiary Ogallala sediments are also fractured, although it is uncertain if the Ogallala fractures are actually systematic joints that are part of the joint zone.



gure 8 Graph showing weighted joint density versus log of bed thickness for data from aprock Canyons State Park, Palo Duro Canyon State Park, and joint zones at both parks.

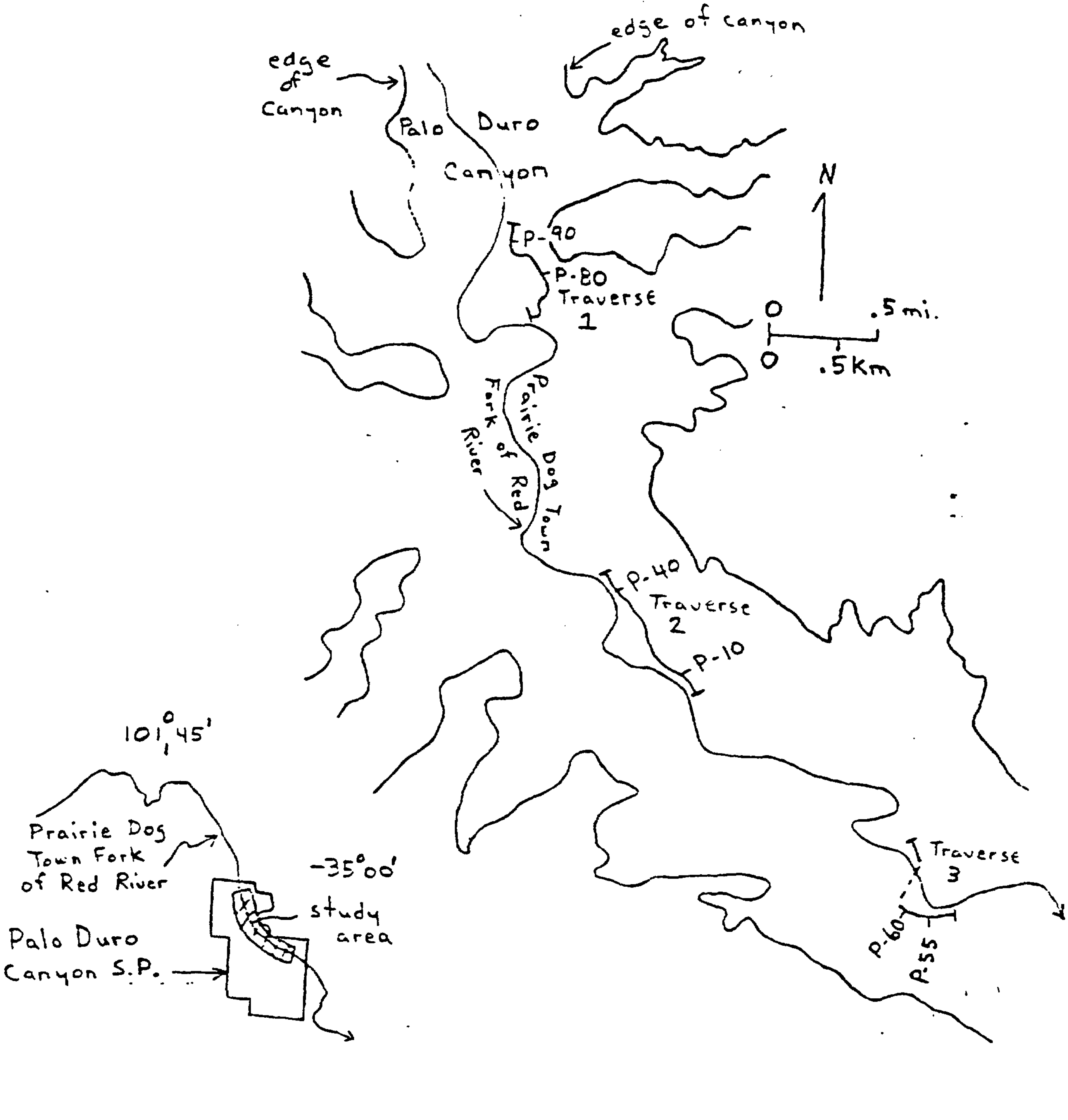


Figure 9 Location of traverses in Permian strata at Palo Duro Canyon State Park. AVTD plots for the traverses are shown in figure 19.

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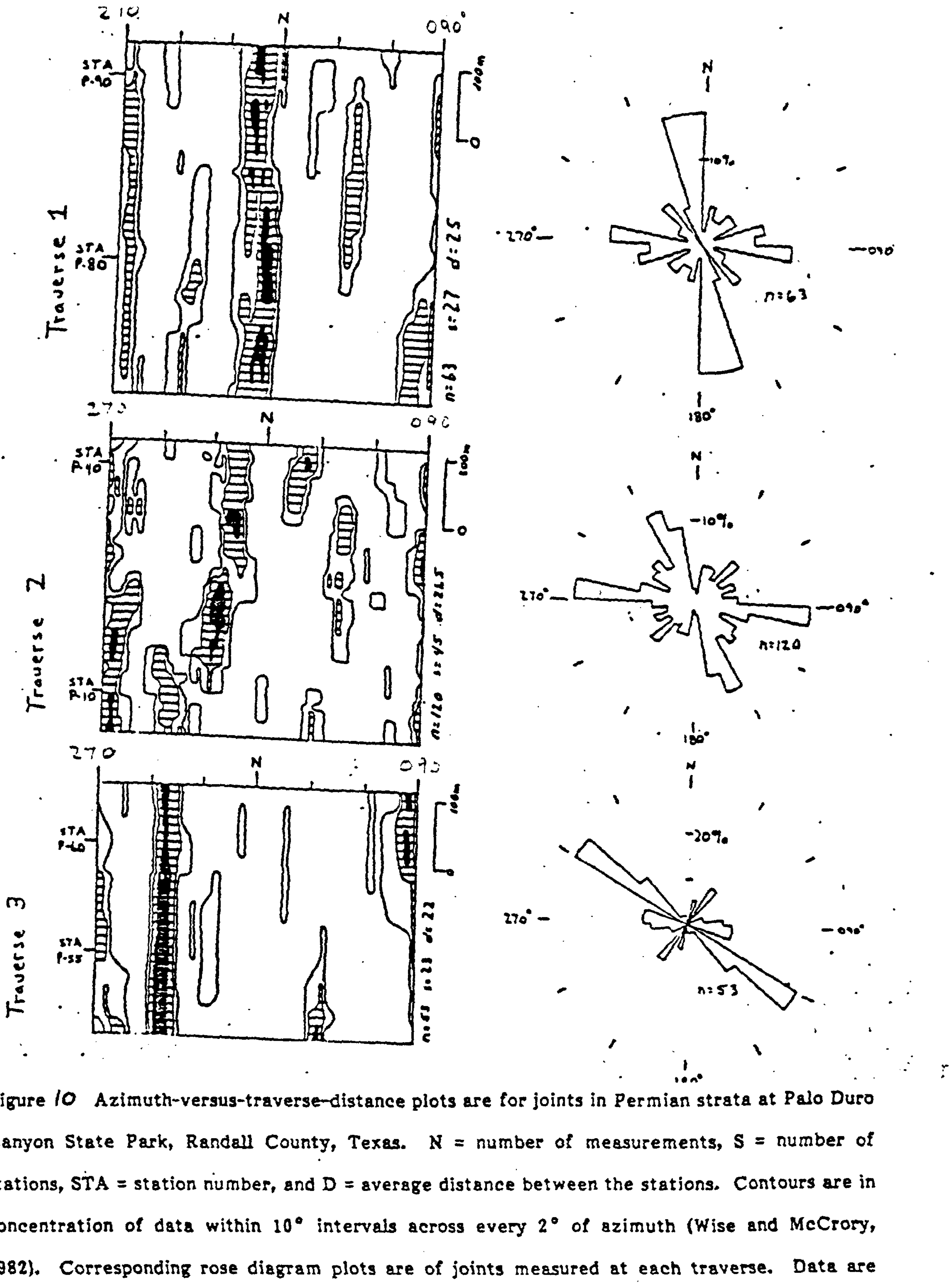

Figure 10 Azimuth-versus-traverse-distance plots are for joints in Permian strata at Palo Duro Canyon State Park, Randall County, Texas. N = number of measurements, S = number of stations, STA = station number, and D = average distance between the stations. Contours are in concentration of data within 10° intervals across every 2° of azimuth (Wise and McCrory, 1982). Corresponding rose diagram plots are of joints measured at each traverse. Data are plotted as percentages of total number of measurements (N) for 10° intervals.

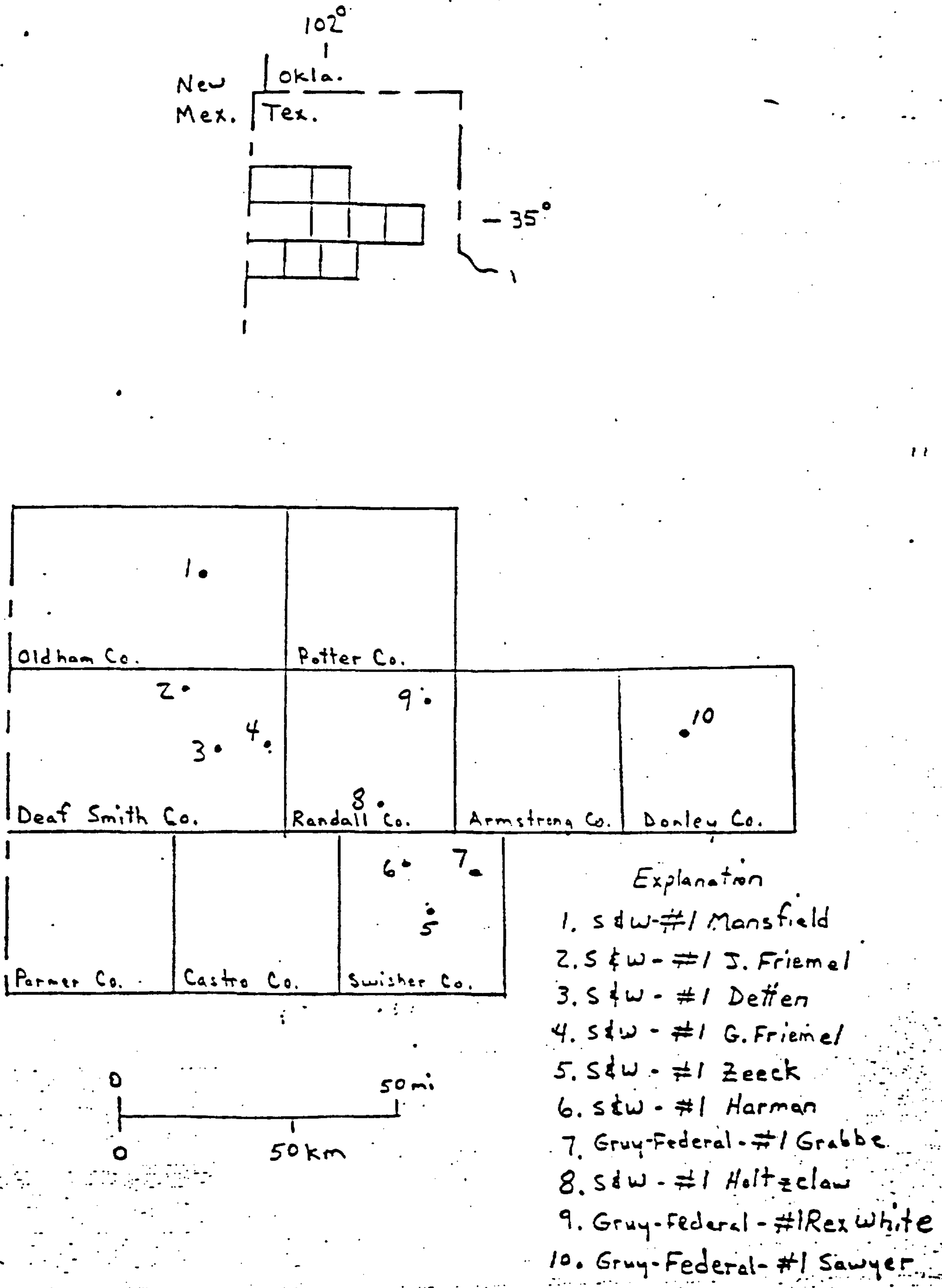

Figure 11 Location of boreholes used for fracture studies in the Palo Duro Basin area.

Deformed [illegible] Zone Units ([illegible] Zone)

Salt Zone Units

Units below salt

System	Series	Group	Palo Duro Basin Formation	Dalhart Basin Formation	General Lithology and depositional setting
QUATERNARY	HOLOCENE		alluvium, dune sand Playa	alluvium, dune sand Playa	
	PLEISTOCENE		Tahoka "cover sands" Tule Blanco	"cover sands"	Lacustrine clastics and windblown deposits
TERTIARY	NEOGENE		Ogallala	Ogallala	Fluvial and lacustrine clastics
CRETACEOUS			undifferentiated	undifferentiated	Marine shales and limestone
TRIASSIC		DOCKUM			Fluvial-deltaic and lacustrine clastics
PERMIAN	OCHOA		Dewey Lake	Dewey Lake	Cyclic sequences: shallow-marine carbonates; hypersaline-shelf anhydrite, halite; continental red beds
			Alibates	Alibates	
	GUADALUPE	ARTESIA	Salado/Tansill	Artesia Group undifferentiated	
			Yates		
			Seven Rivers		
			Queen/Grayburg		
			San Andres	Blaine	
	LEONARD	CLEAR FORK	Glorieta	Glorieta	
			Upper Clear Fork	Clear Fork	
			Tubb	undifferentiated Tubb-Wichita Red Beds	
			Lower Clear Fork		
			Red Cave		
		WICHITA			
	WOLFCAMP				Shelf and shelf-margin carbonate, basinal shale, and deltaic sandstone
? PENNSYLVANIAN	VIRGIL	CISCO	?	?	
	MISSOURI	CANYON			
	DES MOINES	STRAWN			
	ATOKA	BEND			
	MORROW				
MISSISSIPPIAN	CHESTER				Shelf carbonate and chert
	MERAMEC				
	OSAGE				
ORDOVICIAN		ELLENBURGER			Shelf dolomite
CAMBRIAN ?					Shallow marine(?) sandstone
PRECAMBRIAN					Igneous and metamorphic

Figure 12 Generalized stratigraphic column, Palo Duro Basin, modified from Budnik and Smith (1982).

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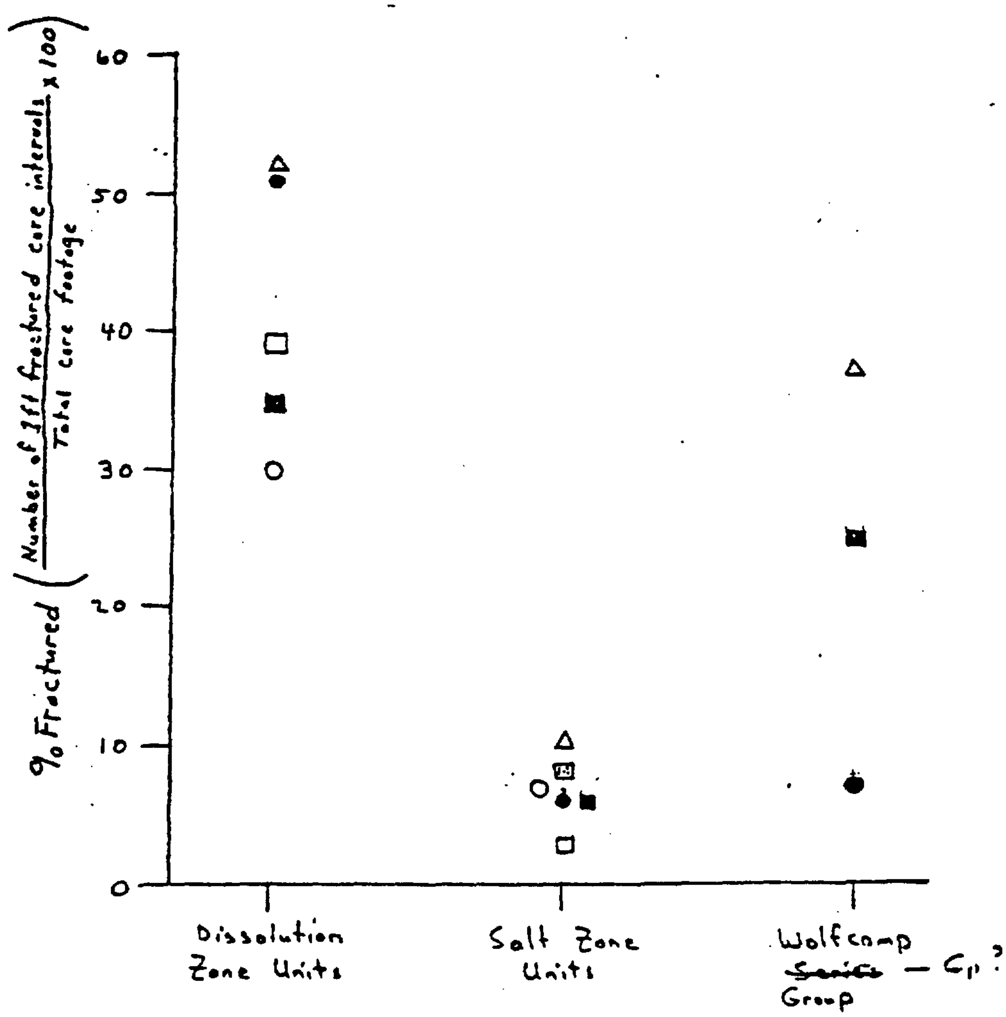


EXPLANATION

Well	Dissolution Zone Units	Salt Zone Units
△ S&W - Mansfield #1	A, S/T, Y, SR	QG, SA, G, uCF, T, lCF
▩ S&W - J. Freimel #1	A, S/T, Y, SR	SR, SA
□ S&W - Detten #1	A, S/T, Y	SA
⊡ S&W - G. Freimel #1		SR, QG, SA
● S&W - Zeeck #1	S/T	SA
○ S&W - Harmon #1	A, S/T, Y	QG, SA

Figure 13 Percentage of fractured Permian core from boreholes in Oldham, Deaf Smith, and Randall Counties, Texas. Abbreviations of Permian formations are as follows: A - Alibates; S/T - Salado-Tansill; Y - Yates; SR - Seven Rivers; QG - Queen Grayburg; SA - San Andres; G - Glorieta; uCF - upper Clear Fork; T - Tubb; lCF - lower Clear Fork.

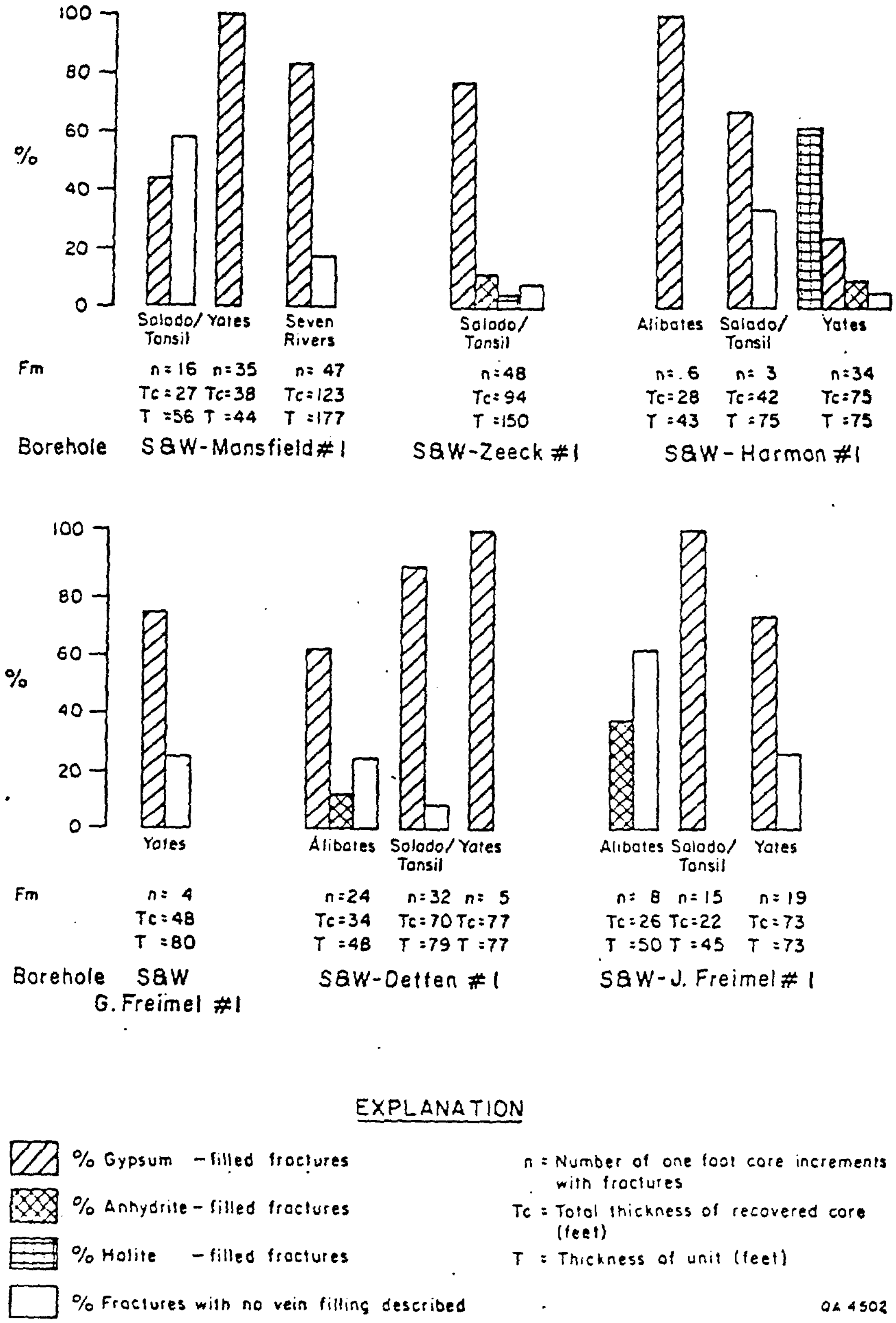
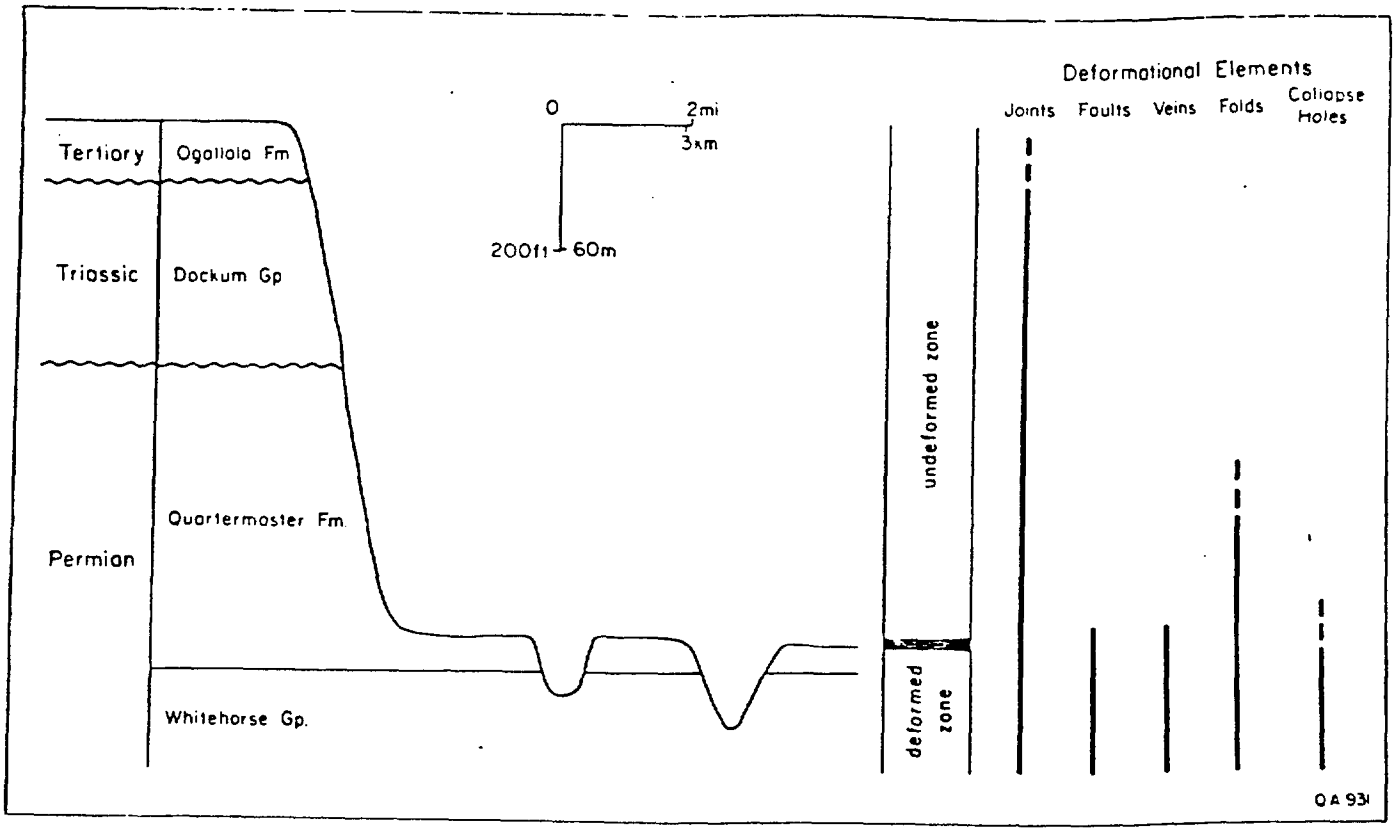
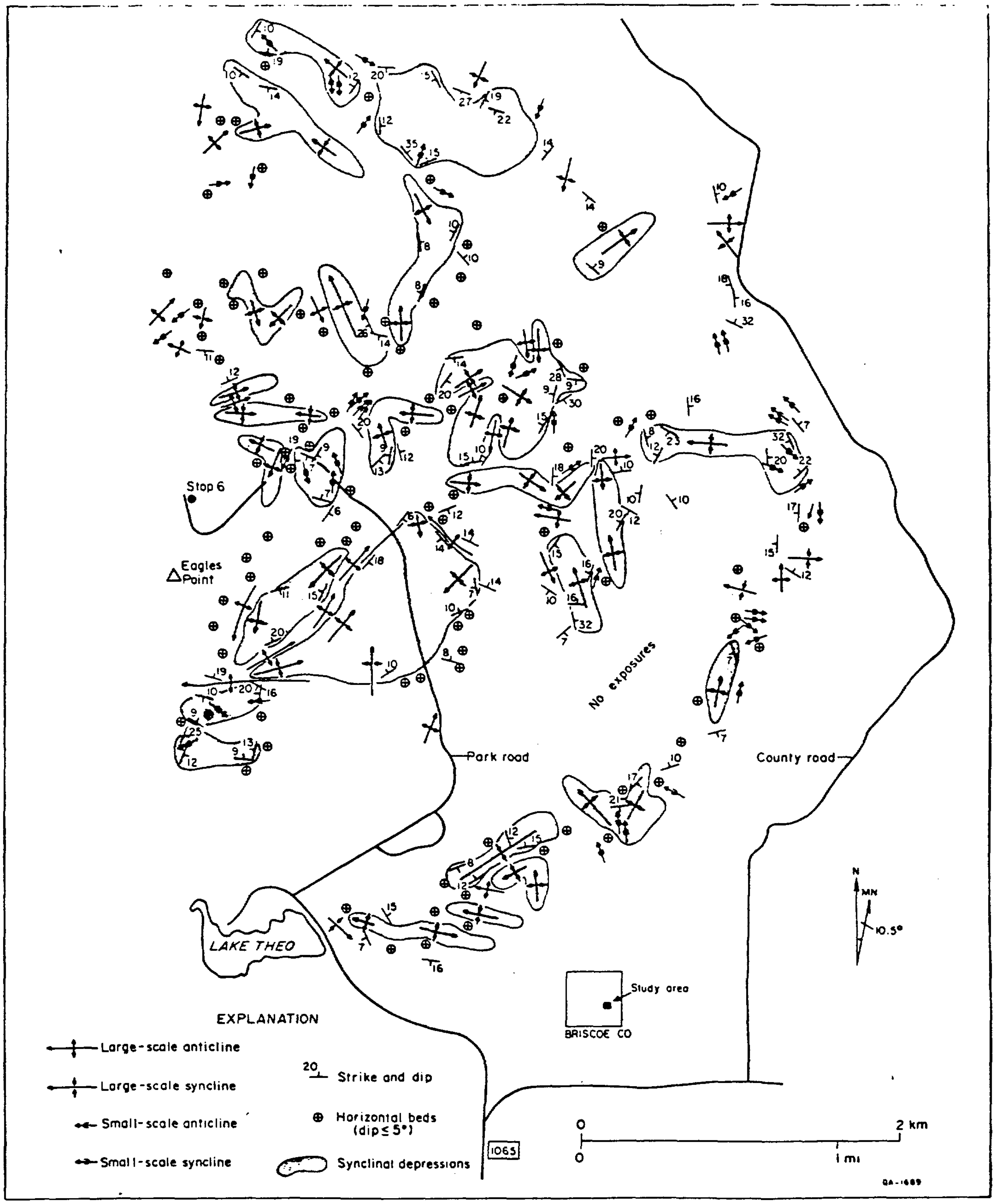


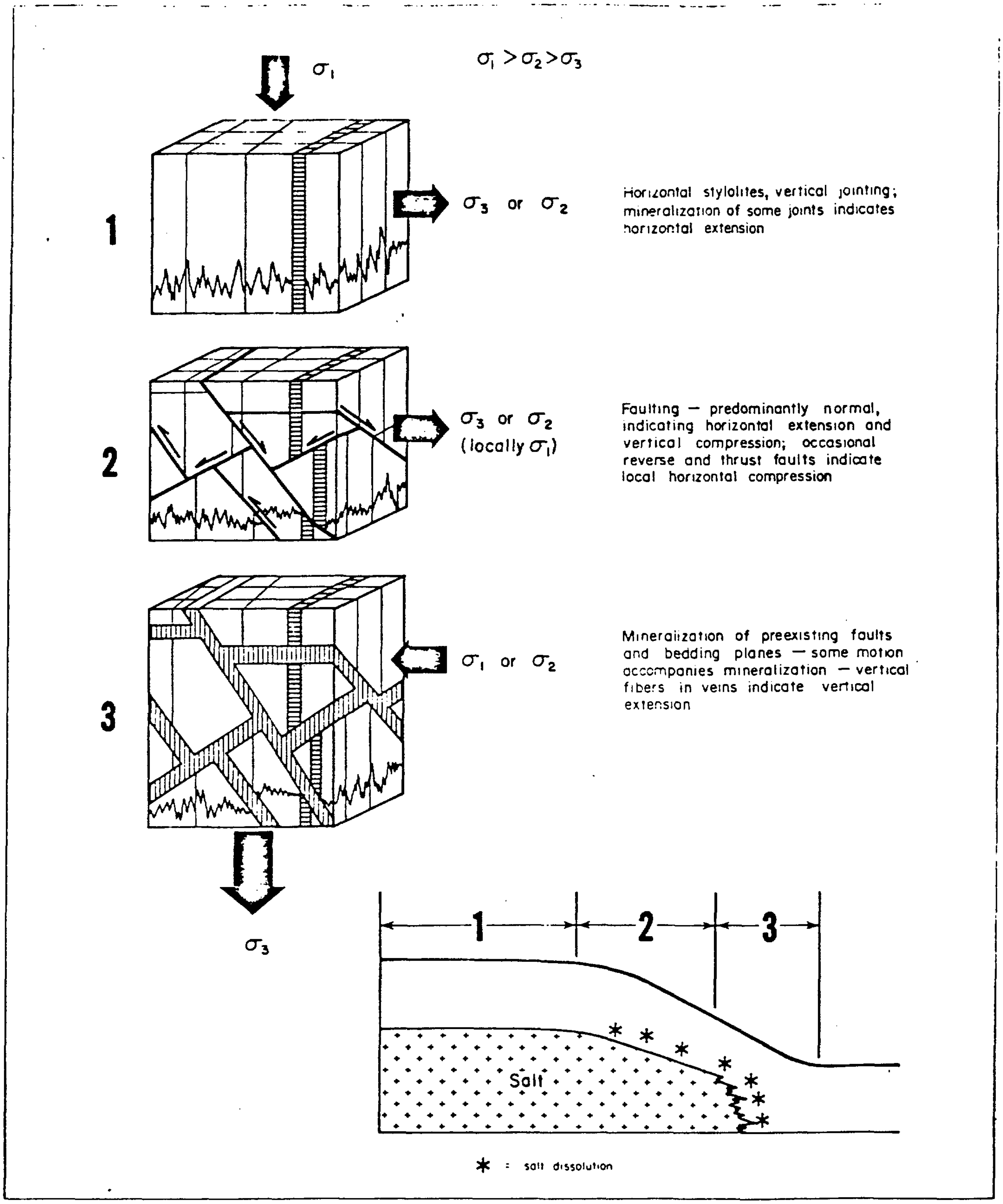
Figure 14 Composition of veins in core of Permian strata from salt dissolution zone/ deformed strata zone.



18 Stratigraphy and deformational elements at Caprock Canyons State Park.



Slide 26. Structural elements in the lower Quartermaster Formation and upper Whitehorse Group within part of Caprock Canyons State Park. Folds are characterized by synclinal depressions of various shapes (from Collins, 1983b).



Slide 27 . Conceptual model of brittle deformation above dissolution zones. Stage 1 represents normal burial; Stage 2 represents horizontal extension as a precursor to dissolution collapse; Stage 3 represents collapse (from Goldstein, 1982).

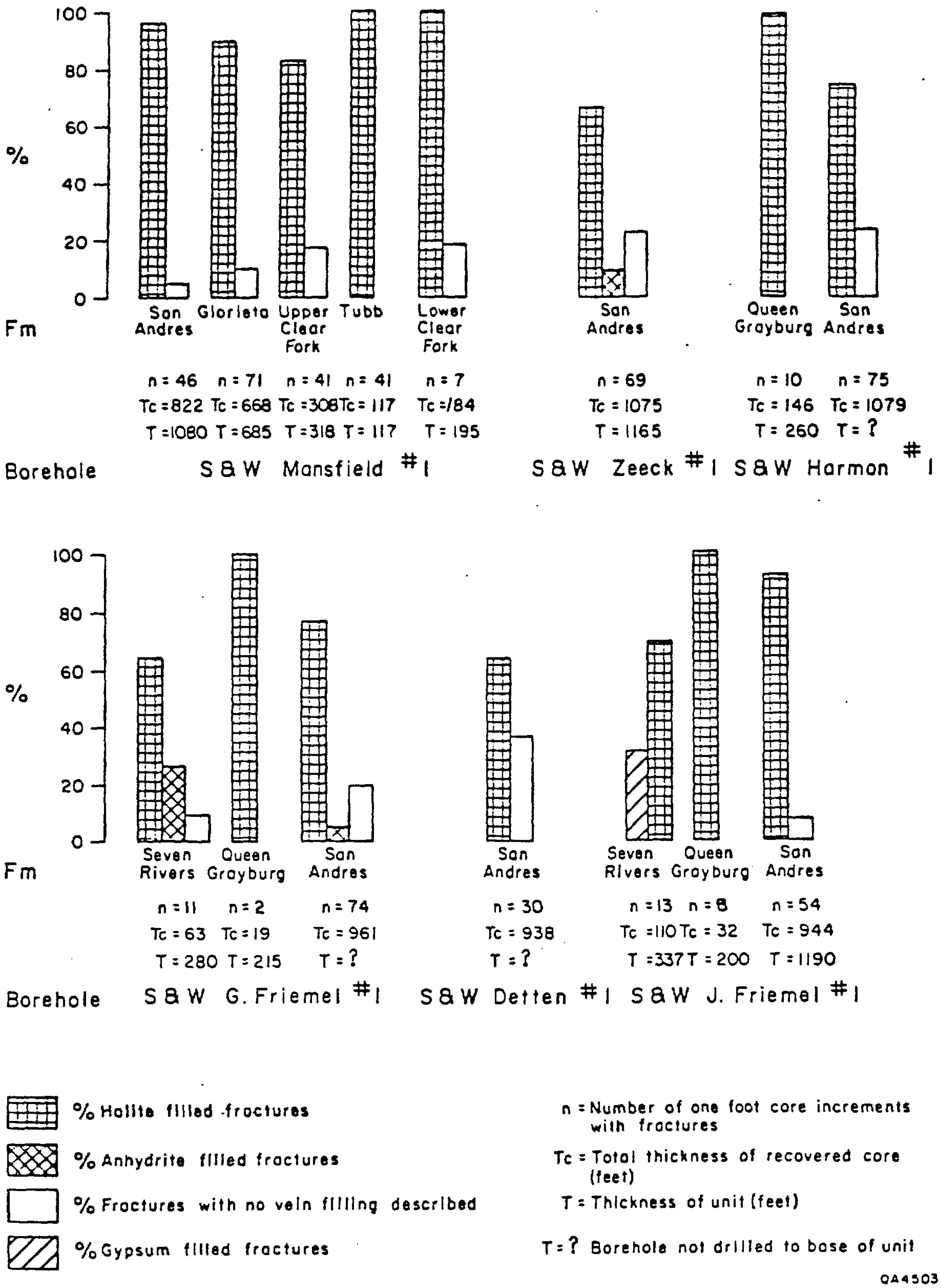


Figure 28 Composition of veins in core of Permian salt-bearing strata.

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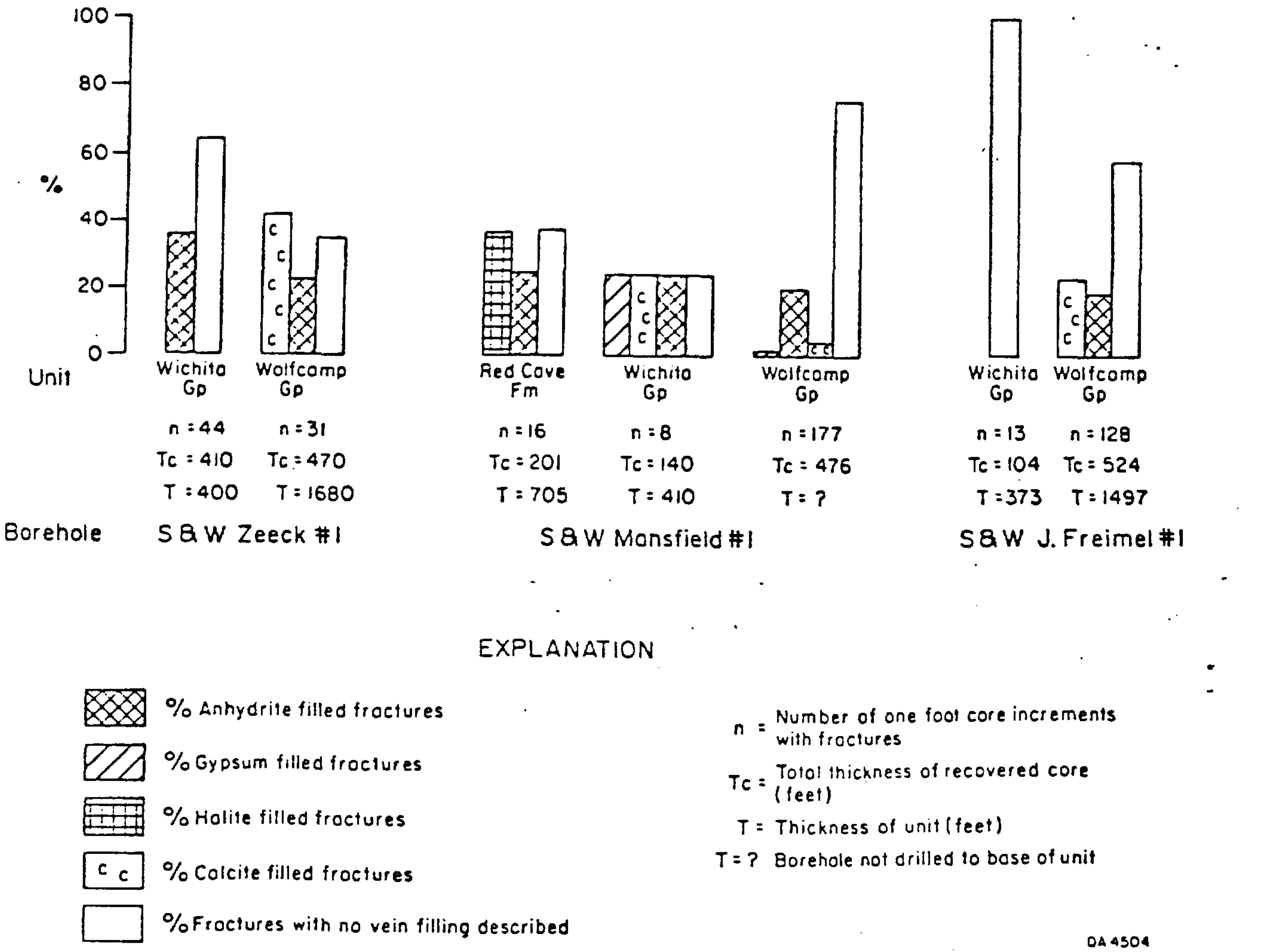


Figure 33 Composition of veins in core of the Red Cave Formation and Wichita and Wolfcamp Groups. These units are stratigraphically below the Permian salt-bearing units.

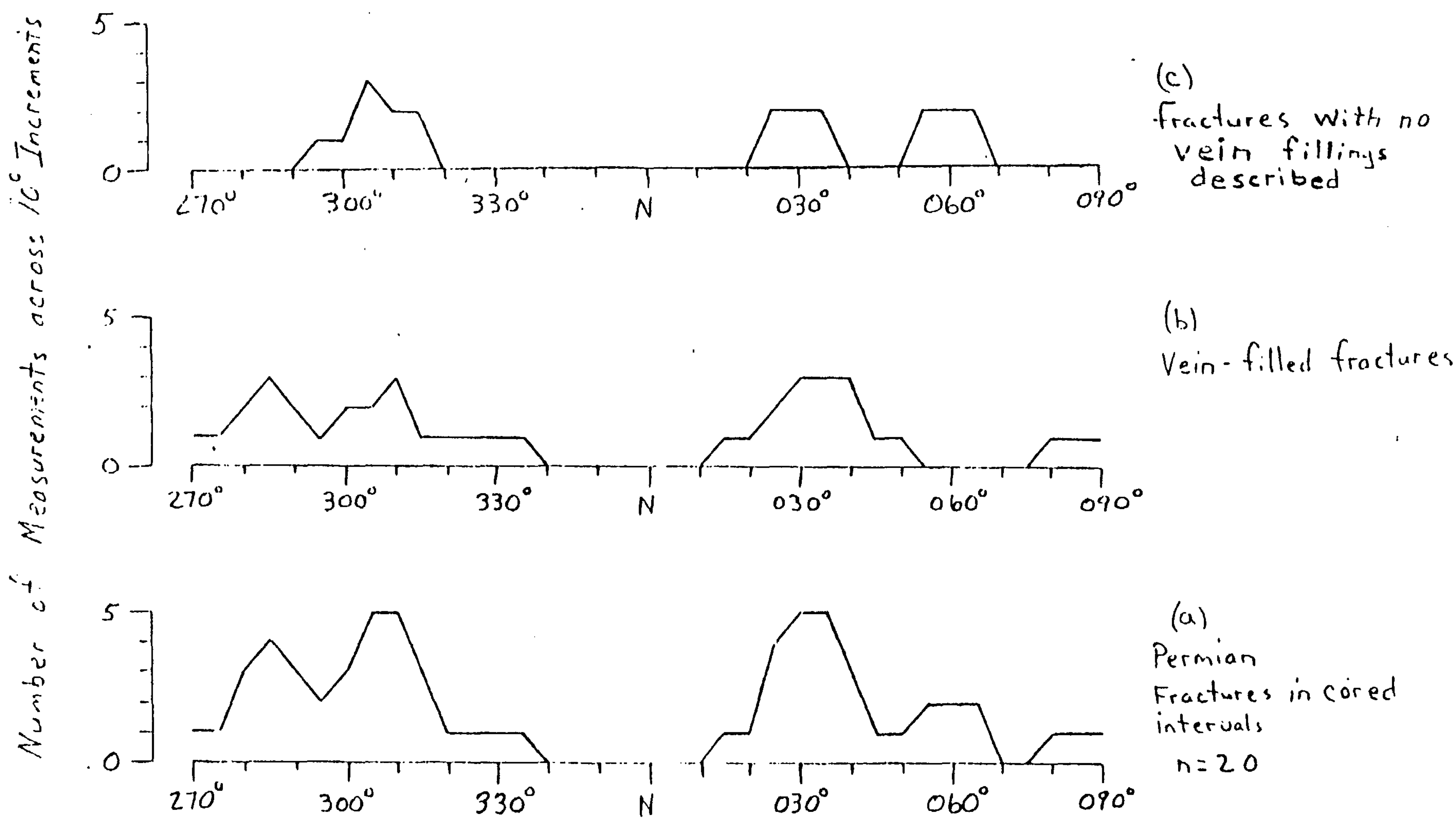


Figure 34 - Frequency distributions showing fracture orientations (a) in cored intervals of Permian strata in Deaf Smith County, (b) of vein-filled fractures, and (c) of fractures with no vein fillings. Data have been smoothed by 10° running average every 2° of azimuth (Wise and McCrory, 1982, p. 893).

FREQUENCY OF FRACTURE* AZIMUTHS FROM FILS
SWEC/J. FRIEMEL NO. 1

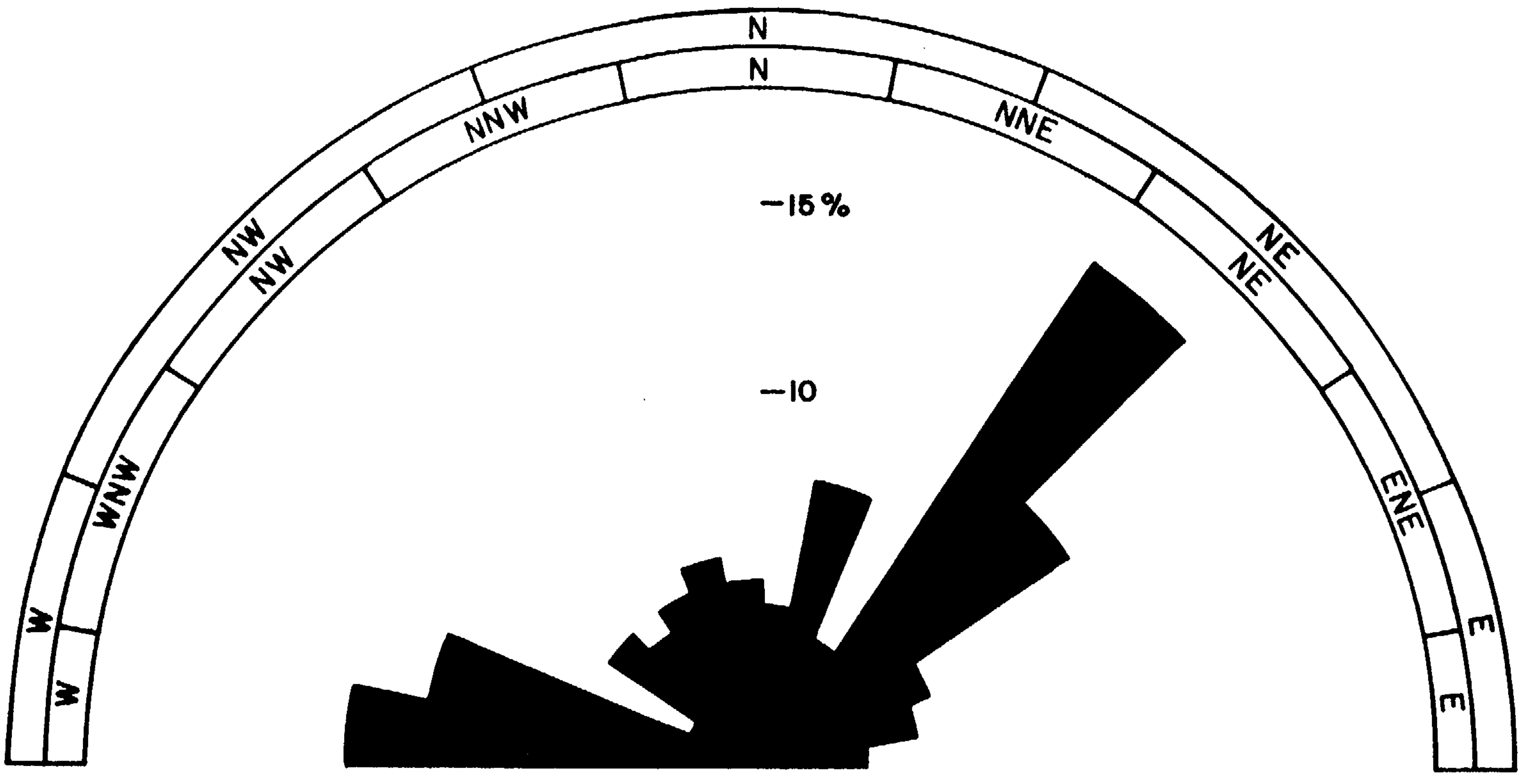
FORMATION	AZIMUTH																TOTAL
	W		NW				N				NE				E		
	W	WNW		NW		NNW		N		NNE		NE		ENE		E	
OGALLALA																	
DOCKUM	1						1			1							3
DEWEY LAKE																	
ALIBATES							1										1
SALADO							1										1
YATES				1		1	1	1									4
U. SEVEN RIVERS						1				1							2
L. SEVEN RIVERS				1						2						1	4
QUEEN - GRAYBURG									2	1							3
U. SAN ANDRES										1							1
L. SAN ANDRES								2									2
GLORIETA		3		1	1		1	2	1	1		1	1				12
U. CLEAR FORK				1	2		2		1		1			1			8
TUBB												1	1	2			4
L. CLEAR FORK			1										1				2
RED CAVE				2	1					1	1	19	10	1			35
WICHITA																1	1
WOLFCAMP	13	10	2	1	1	2	1		1	2	1		1		2	2	39
PENNSYLVANIAN	2				1	3		2	1	1	2	2		3	4		21
TOTAL	16	13	3	7	6	7	8	7	6	11	5	23	14	7	6	4	143

*VERTICAL FRACTURES ONLY

PRELIMINARY

85-45,709

Pierce (12)



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SWEC/J. FRIEMEL NO. 1

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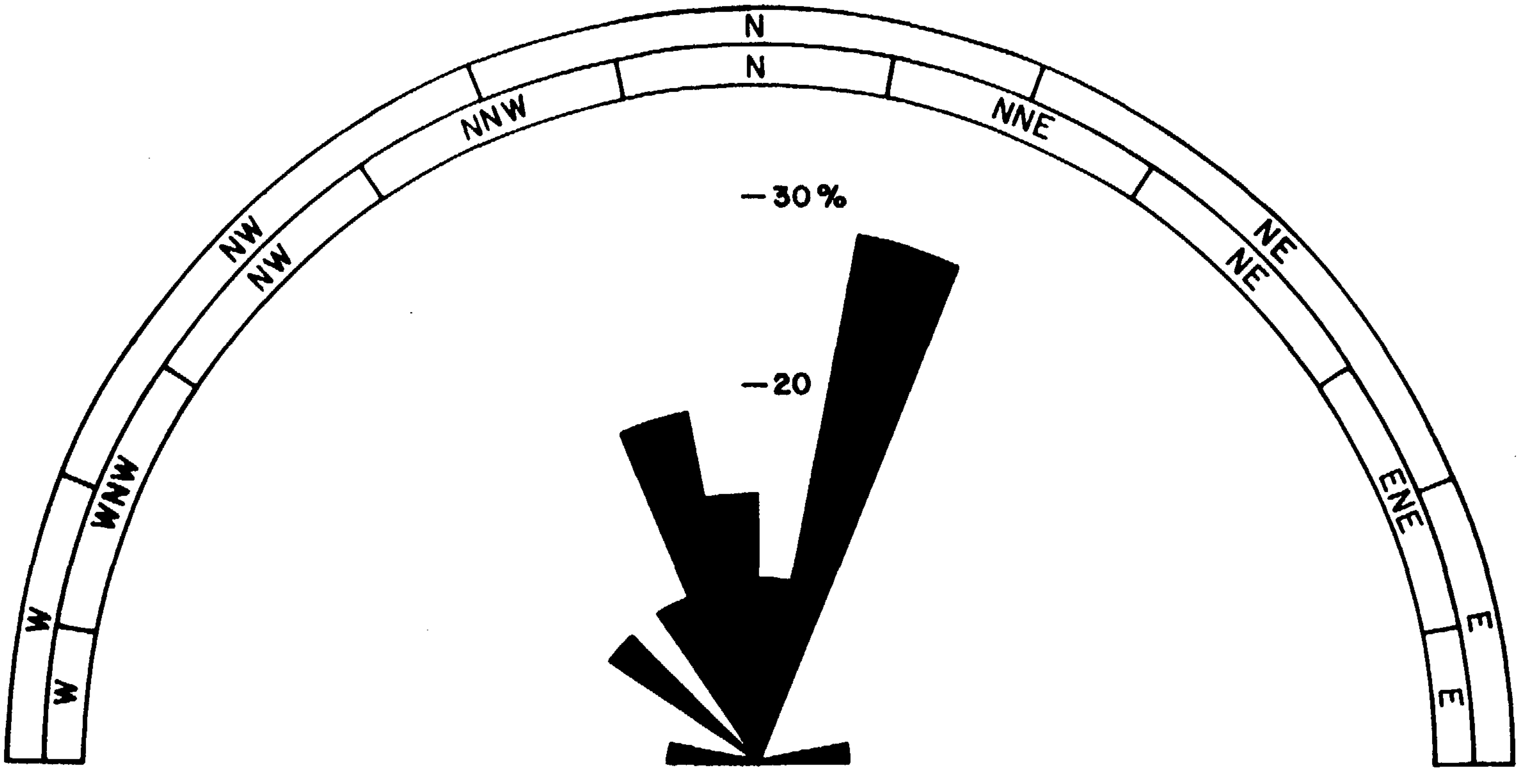
OGALLALA - PENNSYLVANIAN

T.D. = 8,283 FT.

PRELIMINARY

85-45,705



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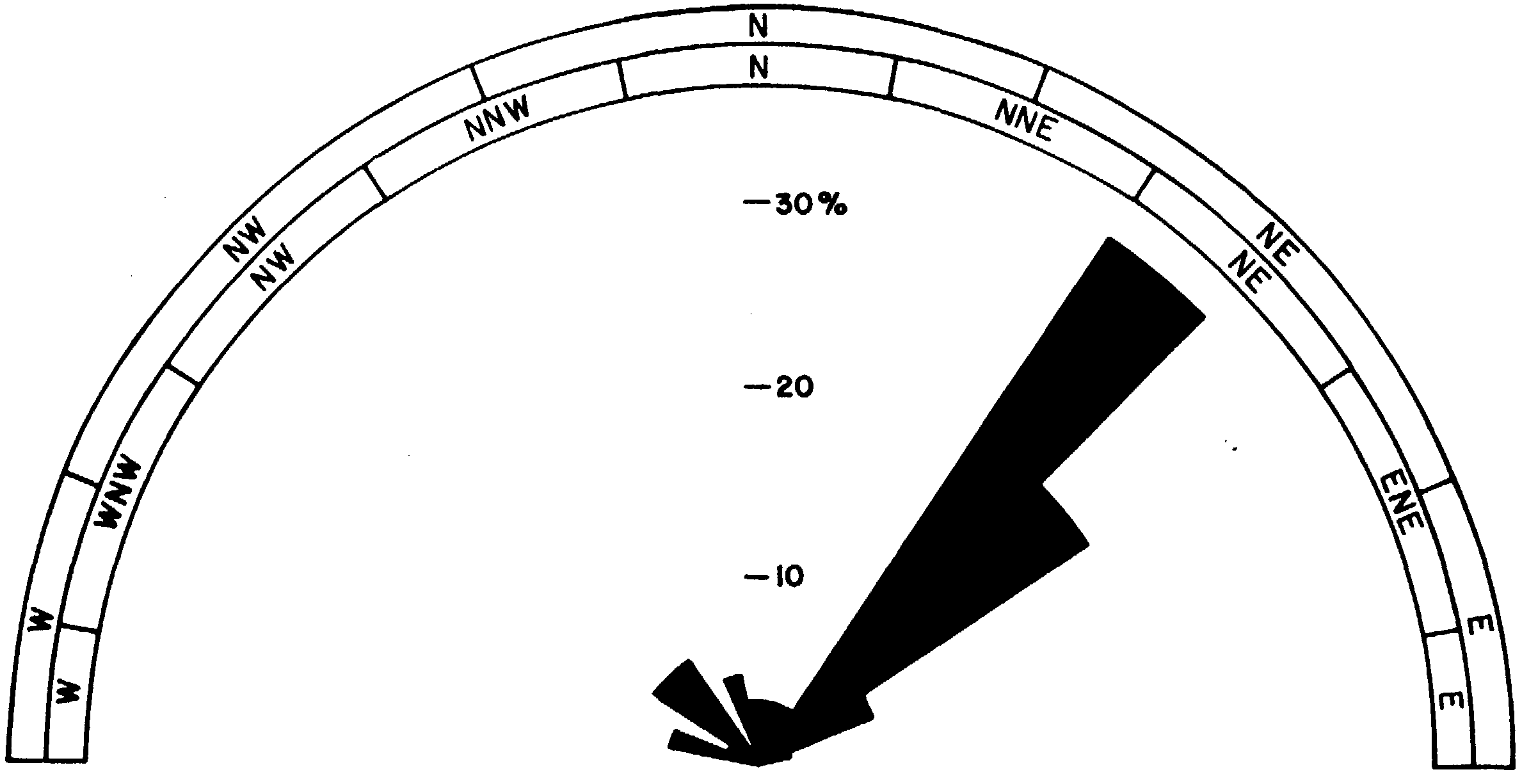
SWEC/J. FRIEMEL NO. 1

FRACTURE AZIMUTHS FROM FILS

OGALLALA - LOWER SAN ANDRES

PRELIMINARY

85-45,704



n = 62

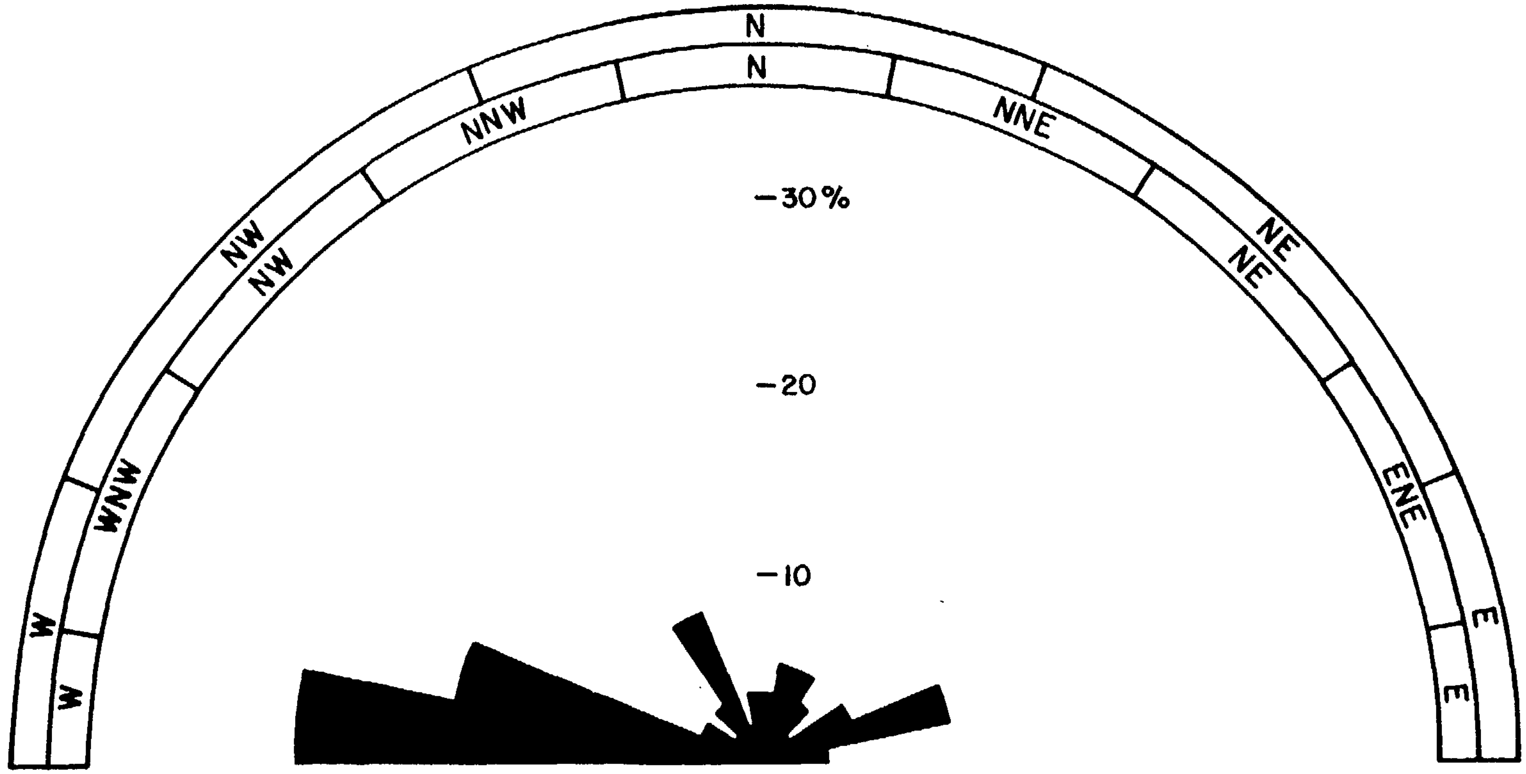
SWEC/J. FRIEMEL NO. 1

FRACTURE AZIMUTHS FROM FILS

GLORIETA - WICHITA

PRELIMINARY

85-45,705



n = 60

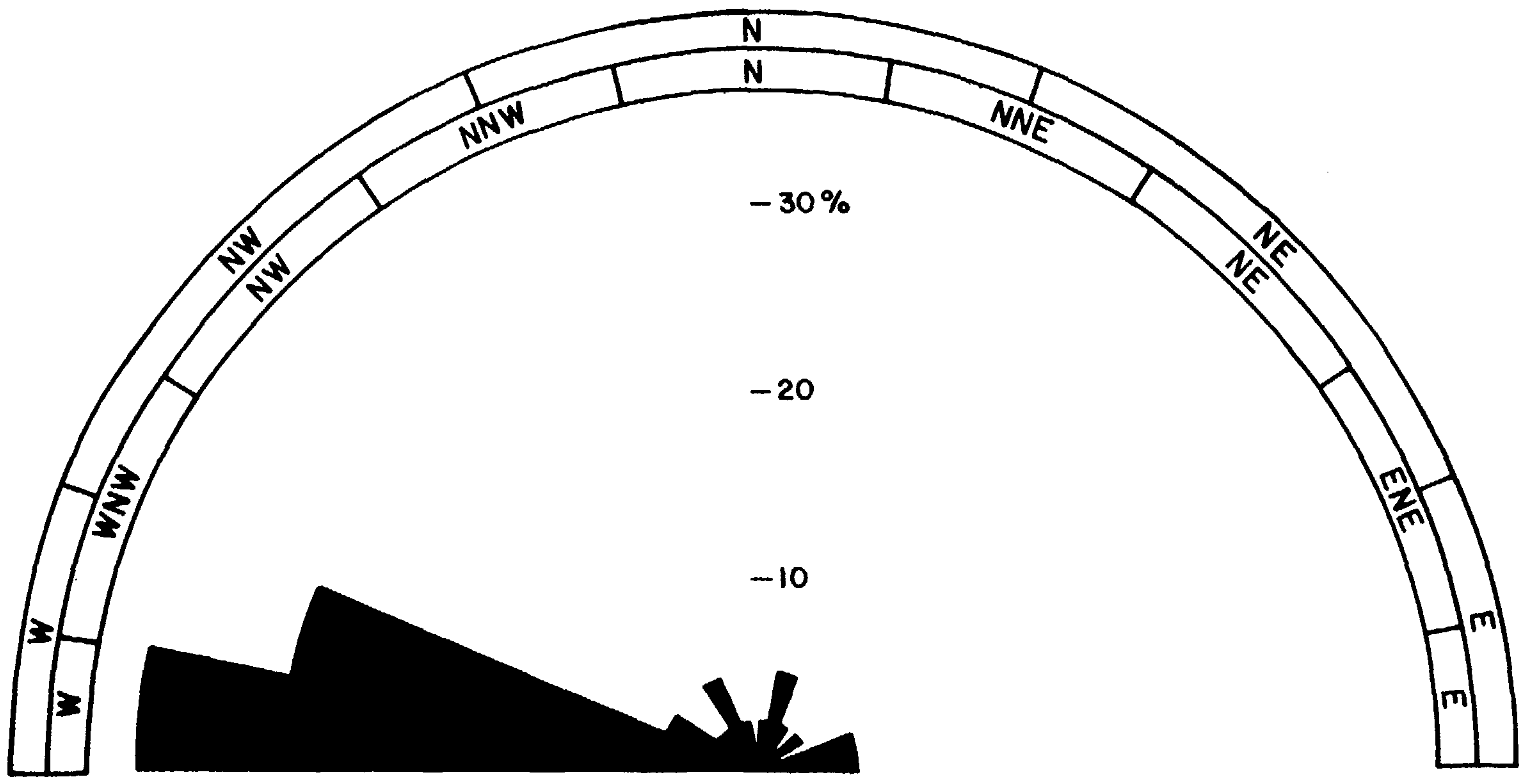
SWEC/J. FRIEMEL NO. 1

FRACTURE AZIMUTHS FROM FILS

WOLFCAMP - PENNSYLVANIAN

PRELIMINARY

85 - 45, 706



n = 39

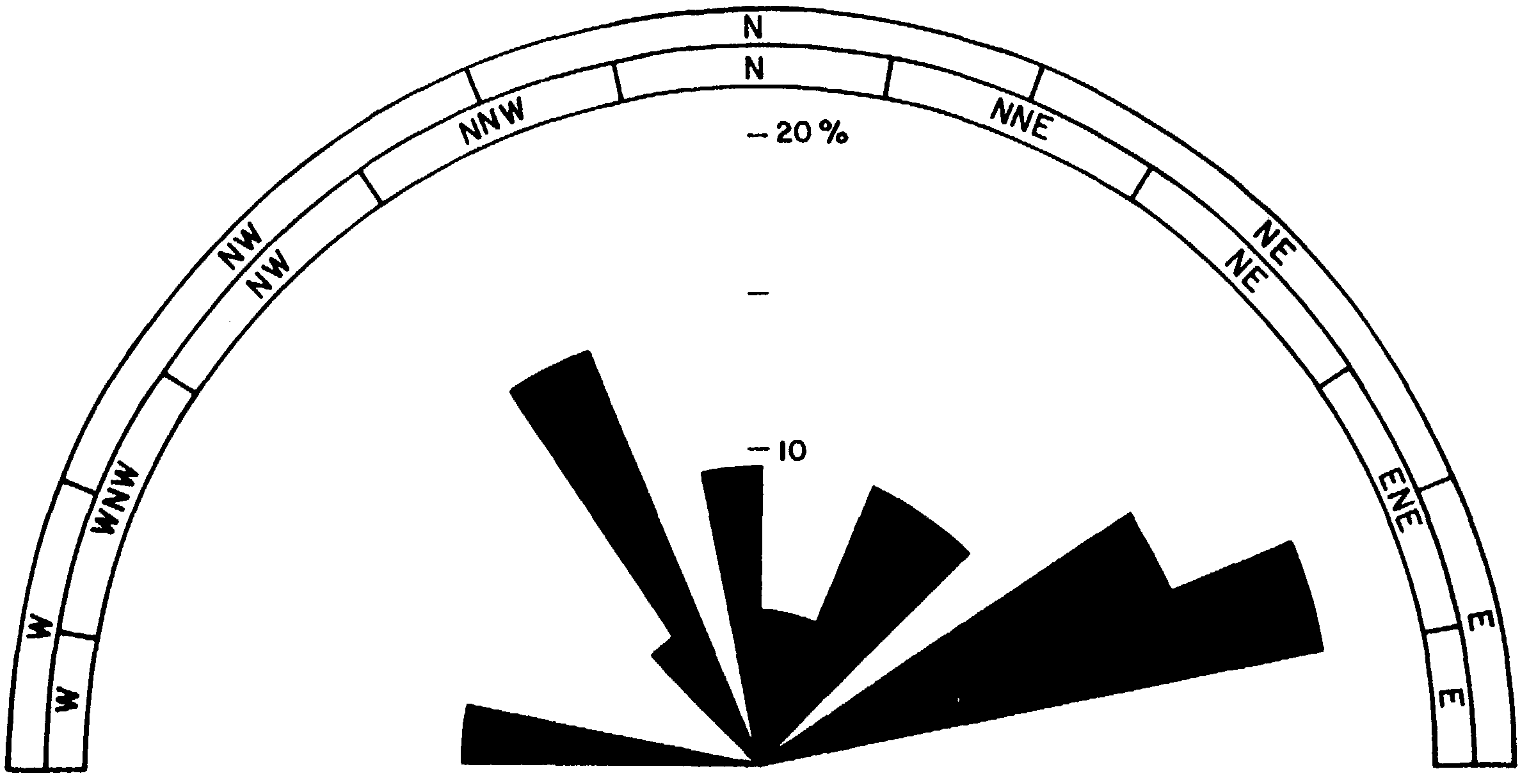
SWEC/J. FRIEMEL NO. 1

FRACTURE AZIMUTHS FROM FILS

WOLFCAMP

PRELIMINARY

85-45,707



n = 21

SWEC/J. FRIEMEL NO. 1

FRACTURE AZIMUTHS FROM FILS

PENNSYLVANIAN

PRELIMINARY

85-45,708

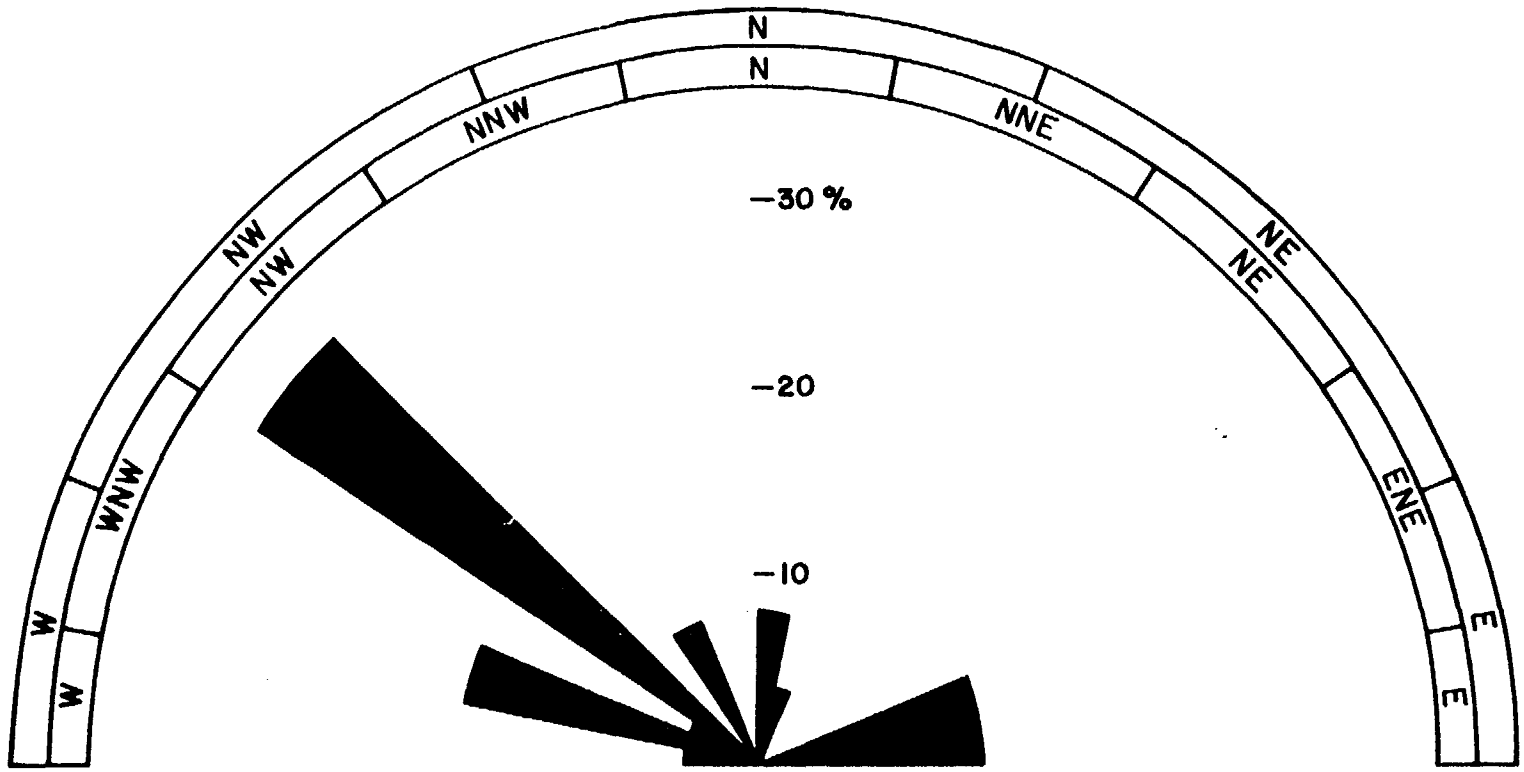
FREQUENCY OF FRACTURE* AZIMUTHS FROM FILS
SWEC/DETTEN NO. 1

FORMATION	AZIMUTH																TOTAL
	W		NW				N				NE				E		
	W	WNW		NW		NNW		N		NNE		NE		ENE		E	
OGALLALA				1						1							2
DOCKUM						2											2
DEWEY LAKE																	
ALIBATES																	
SALADO																	
YATES				1													1
U. SEVEN RIVERS																1	1
L. SEVEN RIVERS		4	1	5													10
QUEEN - GRAYBURG	1			1					2						3	2	9
U. SAN ANDRES																	
L. SAN ANDRES																	
TOTAL	1	4	1	8		2			2	1					3	3	25

*VERTICAL FRACTURES ONLY

PRELIMINARY

85-45,710



n = 25
SWEC/DETTEN NO. 1
FRACTURE AZIMUTHS FROM FILS
OGALLALA - LOWER SAN ANDRES
T.D. = 2,839 FT.

PRELIMINARY

85-45,702

FREQUENCY OF FRACTURE* AZIMUTHS FROM FILS
SWEC/G. FRIEMEL NO. 1

FORMATION	AZIMUTH: W	NW			N		NE		E	TOTAL
	W	WNW	NW	NNW	N	NNE	NE	ENE	E	
OGALLALA										
DOCKUM										
DEWEY LAKE										
ALIBATES										
SALADO						1				1
YATES										
U. SEVEN RIVERS					1			1		2
L. SEVEN RIVERS										
QUEEN - GRAYBURG										
U. SAN ANDRES						1				1
L. SAN ANDRES										
TOTAL					1	2		1		4

*VERTICAL FRACTURES ONLY

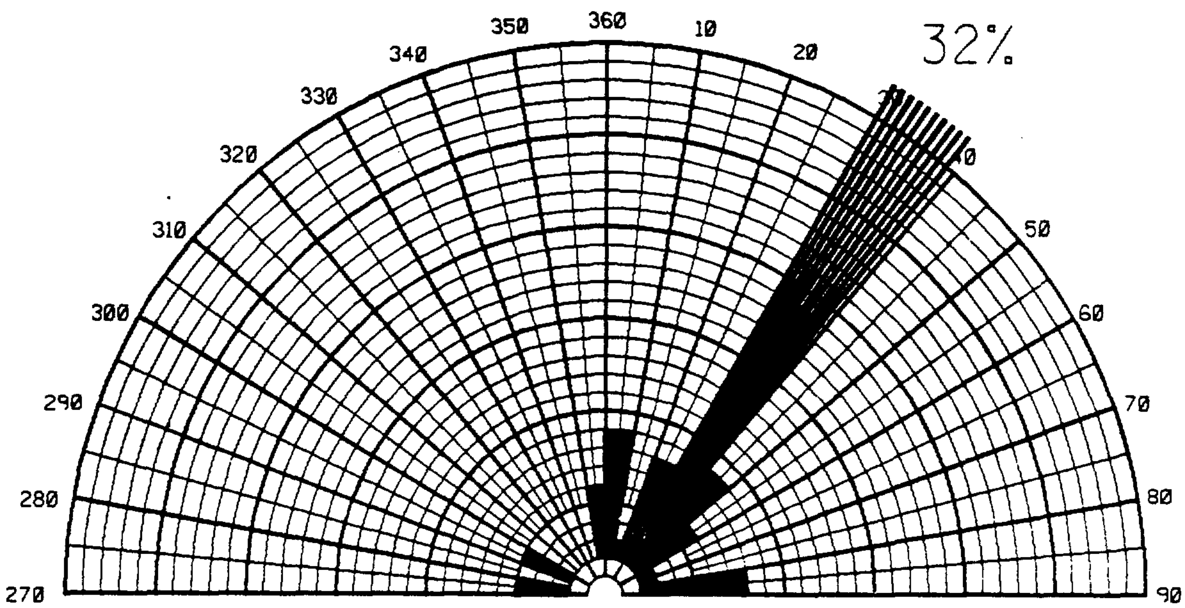
PRELIMINARY

85-45, 711

SWEC / Mansfield No. 1

FORMATION	AZIMUTH																		TOTAL
	W			NW					N					NE			E		
	W	WNW			NW		NNW		N		NNE		NE			ENE		E	
OGALLALA																			
DOCKUM	1									1					1			2	5
DEWEY LAKE																			
ALIBATES																			
SALADO																			
YATES																			
U. SEVEN RIVERS									1										1
L. SEVEN RIVERS												1					1	2	4
QUEEN-GRAYBURG																			
U. SAN ANDRES										1									1
L. SAN ANDRES																			
GLORIETA									1	1	1							1	4
U. CLEAR FORK	1								1	1			1						4
TUBB	1														1				2
L. CLEAR FORK																			
RED CAVE				1		1			1	2		4	18	5	2	2	1		37
WICHITA											1		2	1					4
WOLFCAMP		1	3																4
PENNSYLVANIAN																			
TOTAL	3	1	3	1		1			4	6	2	5	21	6	4	2	2	5	66

PRELIMINARY



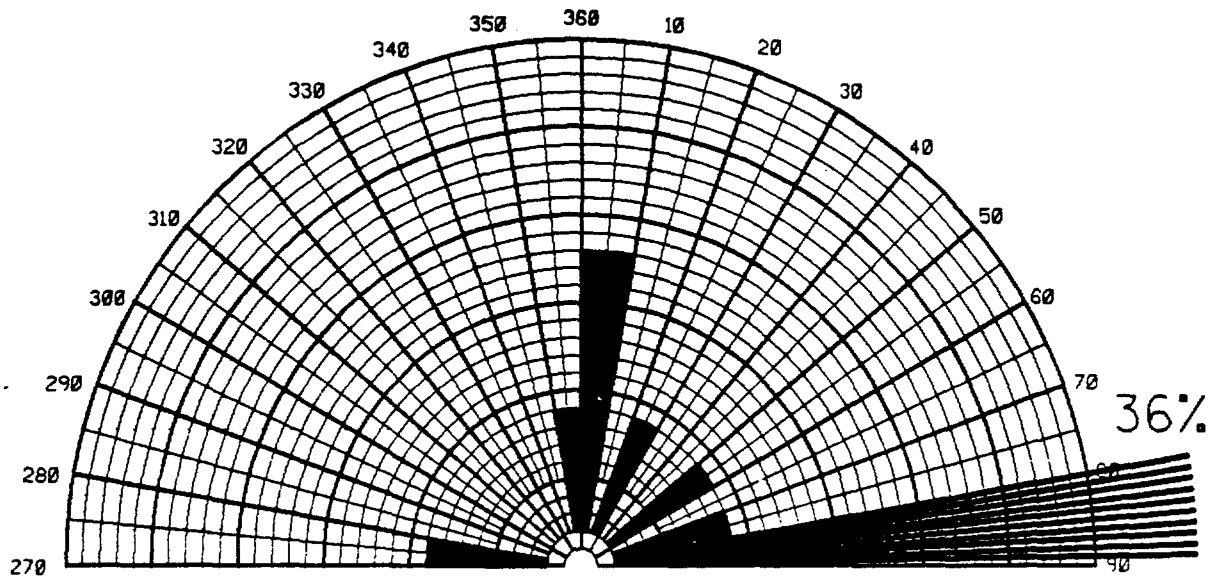
FIL Fractures

Mansfield No. 1

n=66

AZIMUTH FREQUENCY SCALE - FROM CENTER TO EDGE 0 TO 30 PERCENT

PRELIMINARY



FIL Fractures

Upper San Andres-Dockum

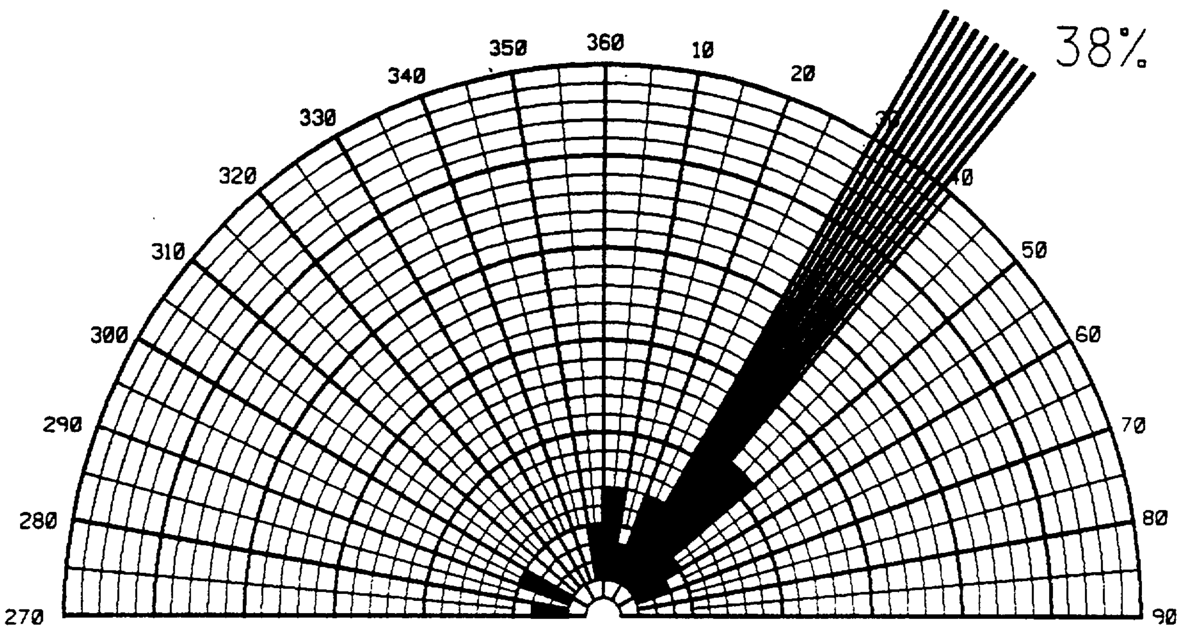
Mansfield No. 1

n=11

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE Ø TO 3Ø PERCENT

PRELIMINARY



FIL Fractures

Wolfcamp-Glorieta

Mansfield No 1.

n=55

AZIMUTH FREQUENCY SCALE - FROM CENTER

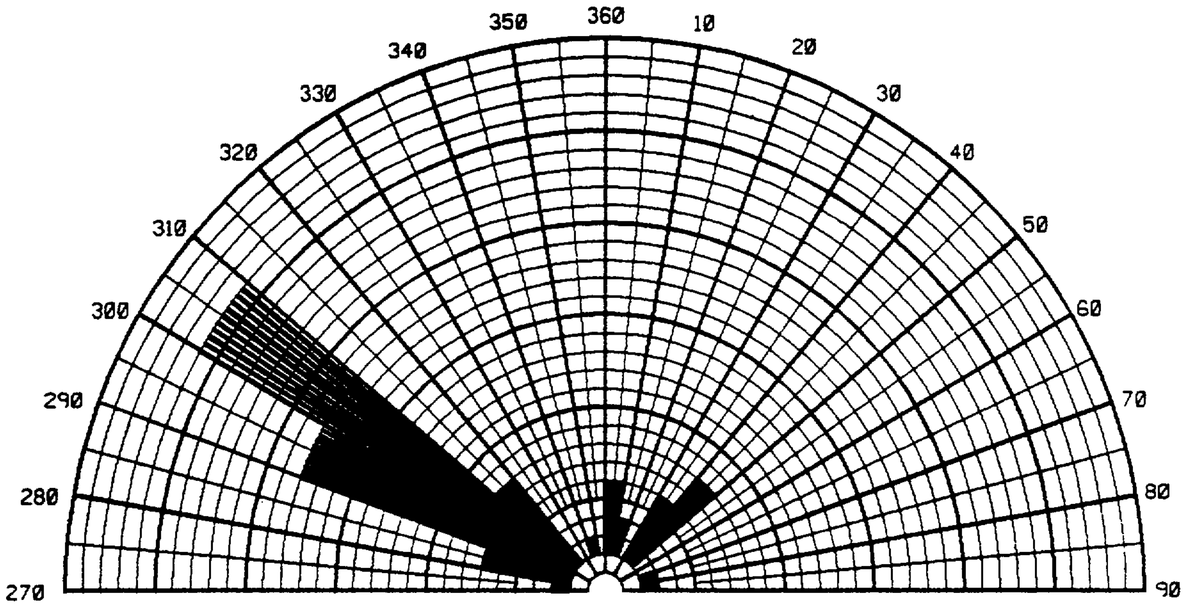
TO EDGE Ø TO 30 PERCENT

PRELIMINARY

SWEC / Zeeck No. 1

FORMATION	AZIMUTH																		TOTAL
	W				NW				N					NE			E		
	W	WNW			NW		NNW		N			NNE		NE		ENE		E	
OGALLALA																			
DOCKUM																			
DEWEY LAKE																			
ALIBATES																			
SALADO													1		1				2
YATES	1																	1	2
U. SEVEN RIVERS								1						1					2
L. SEVEN RIVERS								1						1					2
QUEEN-GRAYBURG																			
U. SAN ANDRES		1											1				1		3
L. SAN ANDRES																		1	1
GLORIETA		1	1							1	2			1					6
U. CLEAR FORK							1			1			1	1					4
TUBB								1					1	1		1			4
L. CLEAR FORK																			
RED CAVE																			
WICHITA																			
WOLFCAMP	1	3	9	14	6					2	1			1			1		38
PENNSYLVANIAN			3	5															8
TOTAL	2	5	13	19	6		1	3		4	3		4	6	1	1	2	2	72

PRELIMINARY



FIL Fractures

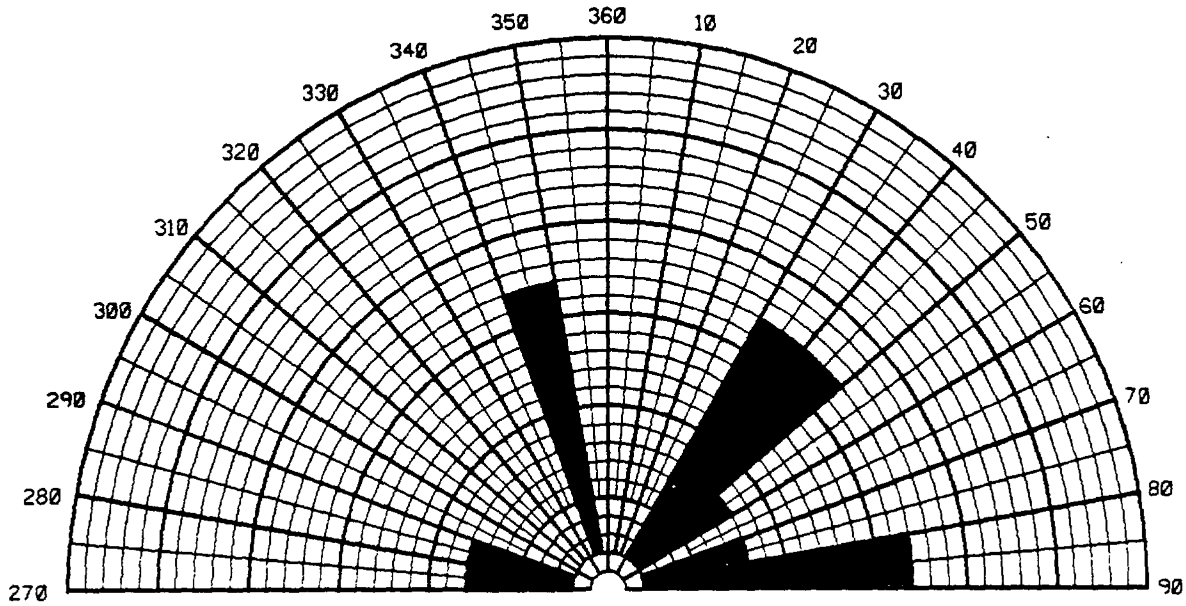
Zeeck No. 1

n=72

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE 0 TO 30 PERCENT

PRELIMINARY



FIL Fractures

Lower San Andres-Salado

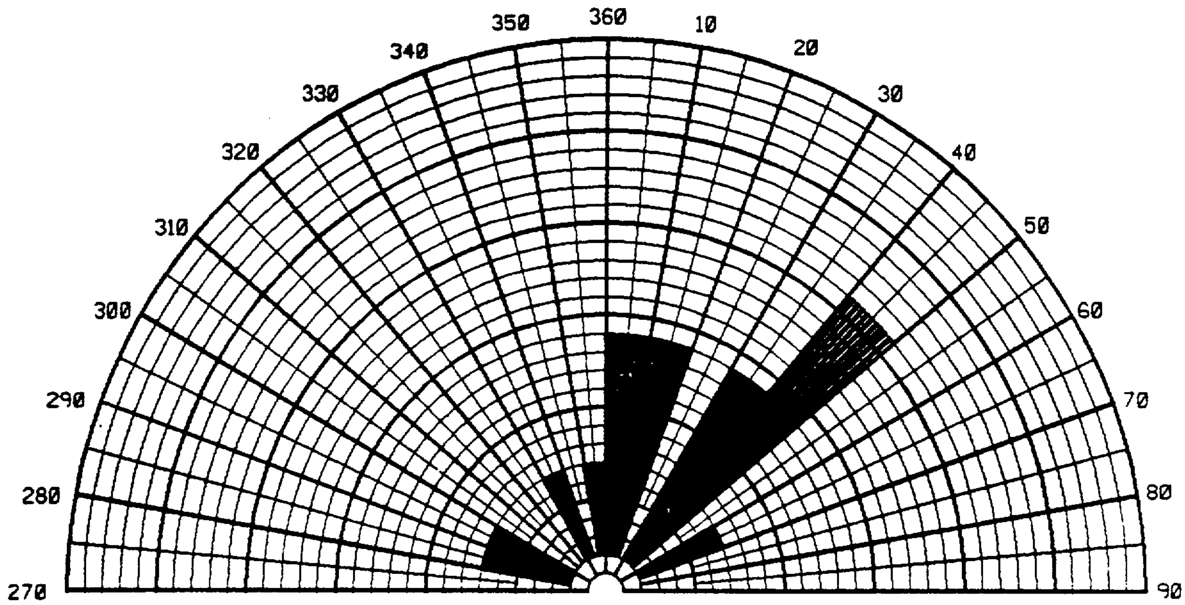
Zeeck No. 1

n=12

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE 0 TO 30 PERCENT

PRELIMINARY



FIL Fractures

Tubb-Glorieta

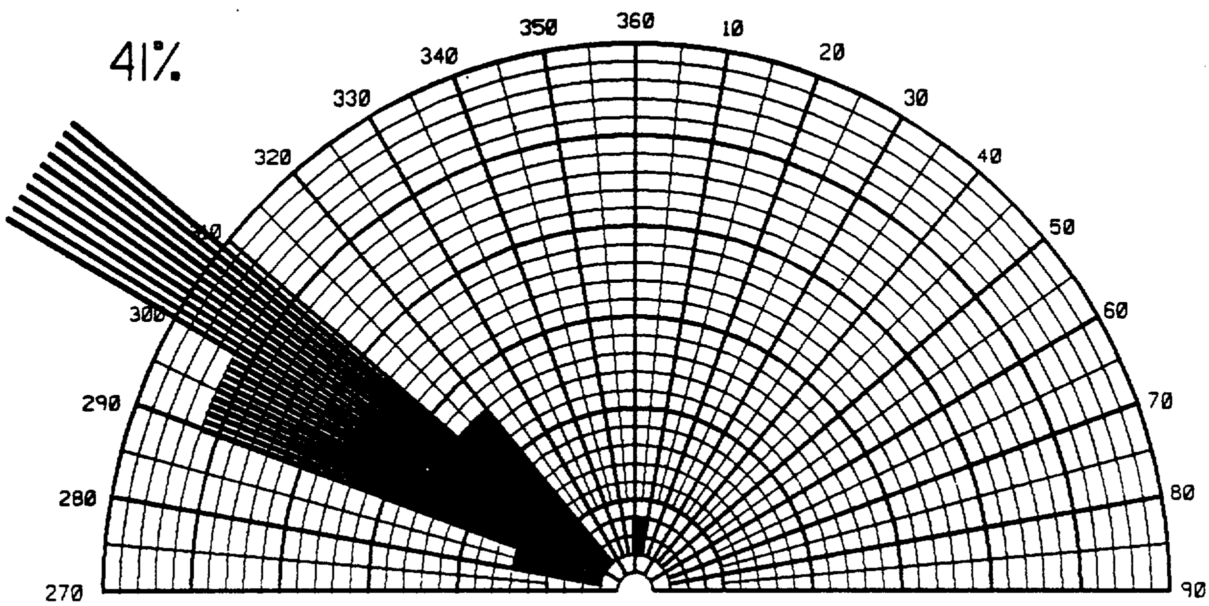
Zeeck No. 1

n=14

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE Ø TO 30 PERCENT

PRELIMINARY



FIL Fractures

Pennsylvanian and Wolfcamp

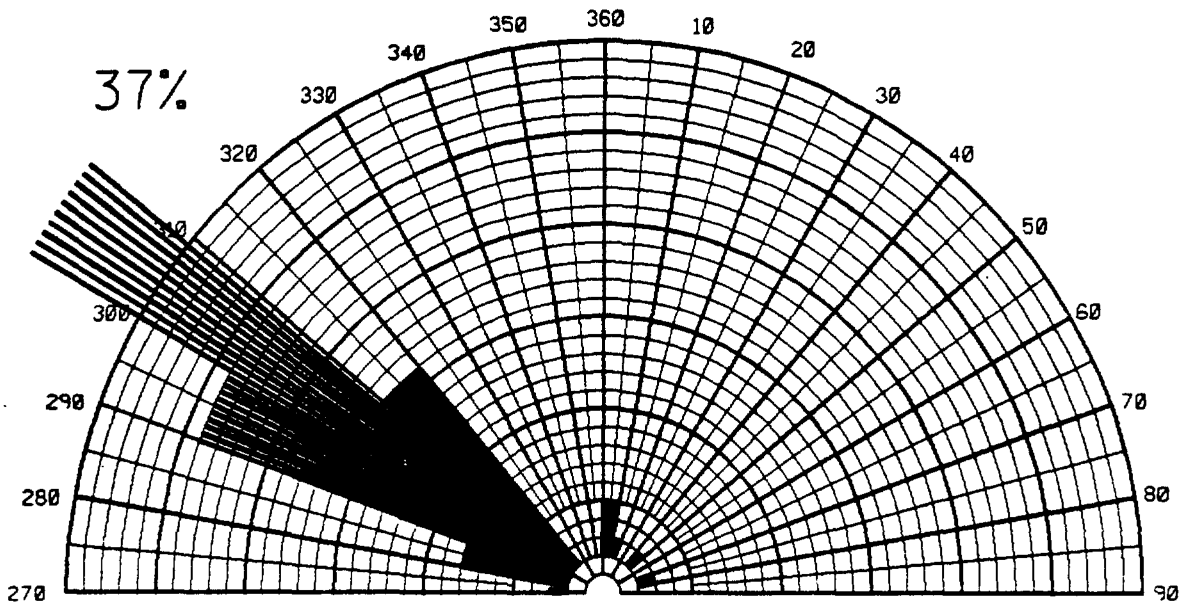
Zeeck No.1

n=46

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE Ø TO 3Ø PERCENT

PRELIMINARY



FIL Fractures

Wolfcamp

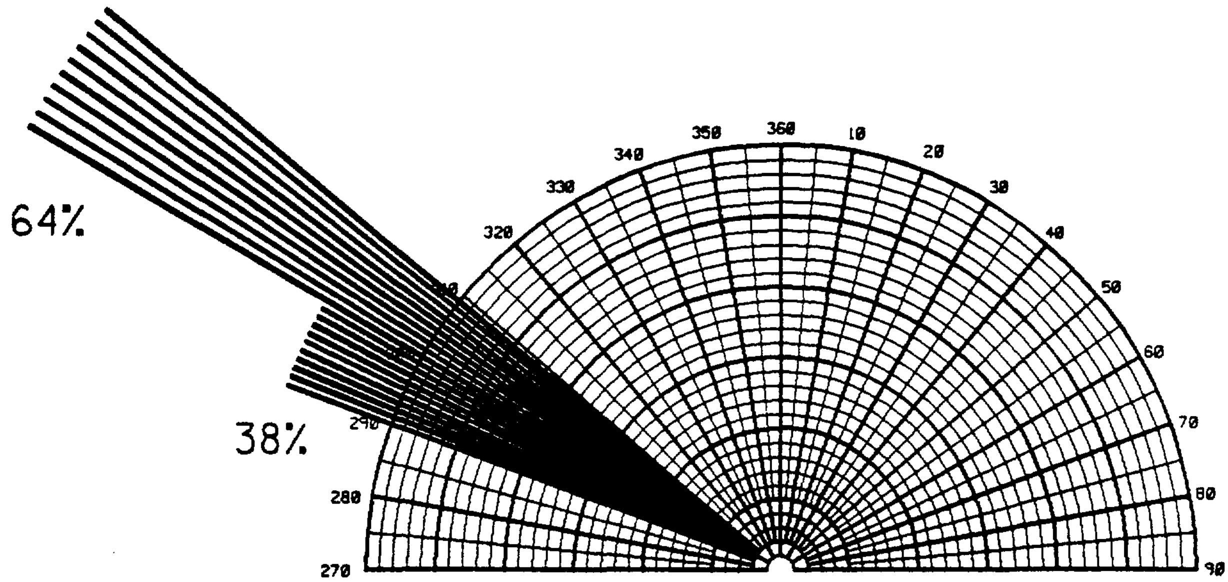
Zeeck No. 1

n=38

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE Ø TO 30 PERCENT

PRELIMINARY



FIL Fractures

Pennsylvanian

Zeeck No. I

n=8

AZIMUTH FREQUENCY SCALE - FROM CENTER

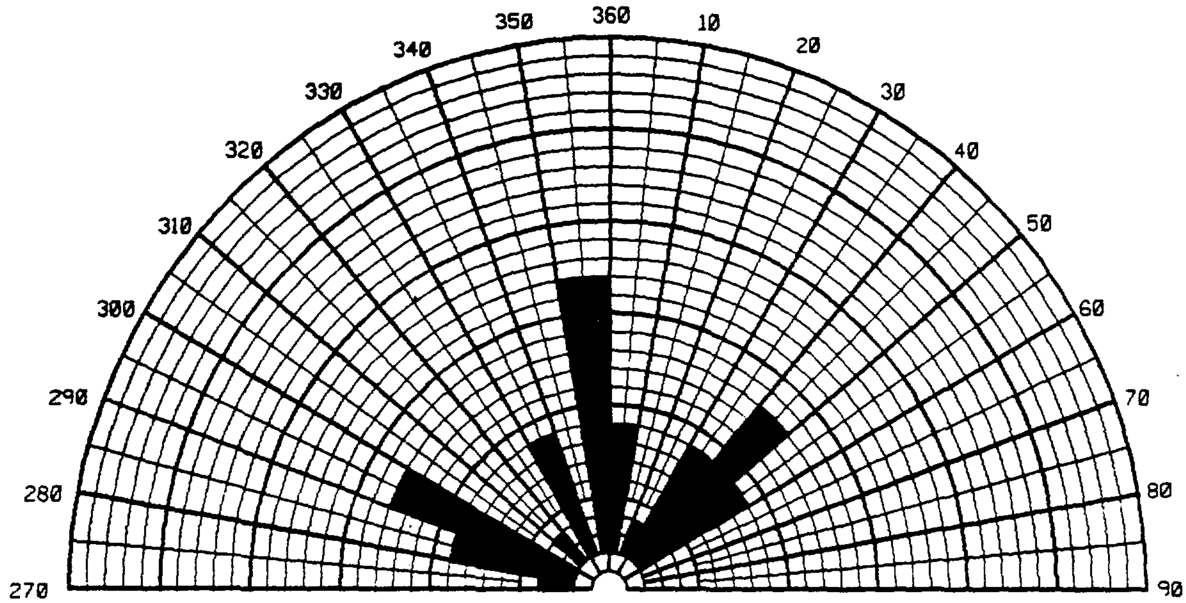
TO EDGE Ø TO 30 PERCENT

PRELIMINARY

SWEC / Harman No. 1

FORMATION	AZIMUTH																		TOTAL
	W	NW						N				NE				E			
	W	WNW			NW		NNW		N		NNE		NE			ENE		E	
OGALLALA													1						1
DOCKUM		2	2						1			1	1	3	1				11
DEWEY LAKE																			
ALIBATES									1	1									2
SALADO																			
YATES																			
U. SEVEN RIVERS			1				1	1		1									4
L. SEVEN RIVERS																			
QUEEN-GRAYBURG					1														1
U. SAN ANDRES	1																		1
L. SAN ANDRES									2						1				3
GLORIETA																			
U. CLEAR FORK																			
TUBB																			
L. CLEAR FORK																			
RED CAVE																			
WICHITA																			
WOLFCAMP																			
PENNSYLVANIAN																			
TOTAL	1	2	3		1		1	1	4	2		1	1	4	2				23

PRELIMINARY



FIL Fractures

Harman No. I

n=23

AZIMUTH FREQUENCY SCALE - FROM CENTER

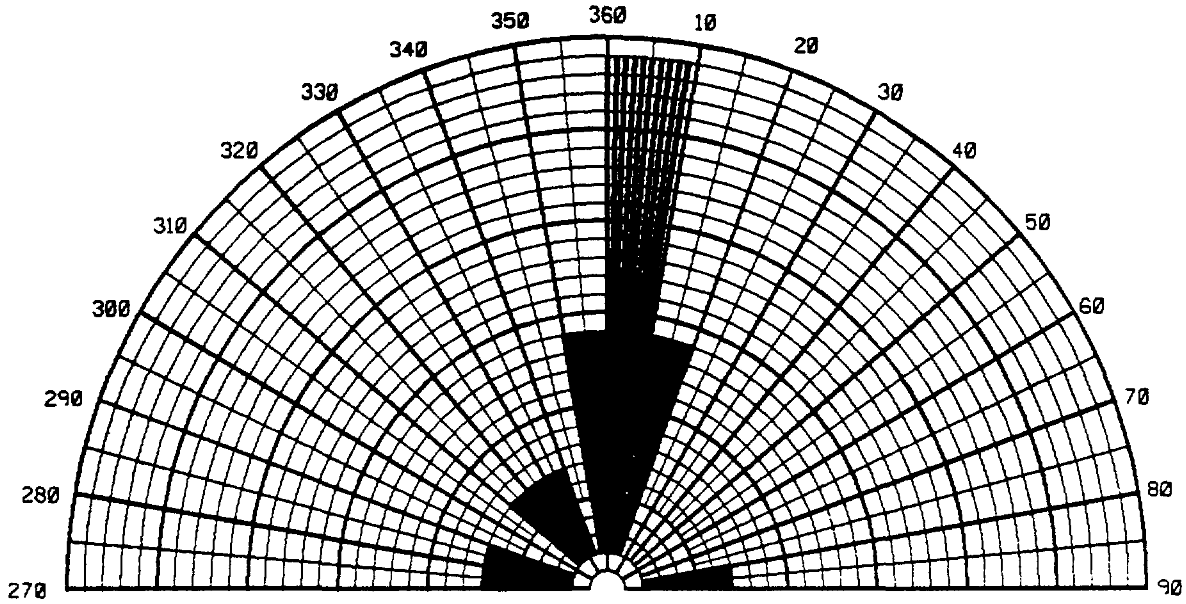
TO EDGE 0 TO 30 PERCENT

PRELIMINARY

SWEC / Sawyer No. 1

FORMATION	AZIMUTH																		TOTAL
	W				NW				N					NE			E		
	W		WNW		NW		NNW		N			NNE		NE		ENE		E	
OGALLALA																			
DOCKUM																			
DEWEY LAKE																			
ALIBATES																			
SALADO																			
YATES																			
U. SEVEN RIVERS																			
L. SEVEN RIVERS	1																		1
QUEEN-GRAYBURG																			
U. SAN ANDRES																			
L. SAN ANDRES																		1	1
GLORIETA		1			1						1								3
U. CLEAR FORK					1	1													2
TUBB									1										1
L. CLEAR FORK									1		1								2
RED CAVE										2									2
WICHITA																			
WOLFCAMP										2									2
PENNSYLVANIAN																			
TOTAL	1	1			2	1			2	4	2							1	14

PRELIMINARY



FIL Fractures

Sawyer No. 1

n=14

AZIMUTH FREQUENCY SCALE - FROM CENTER

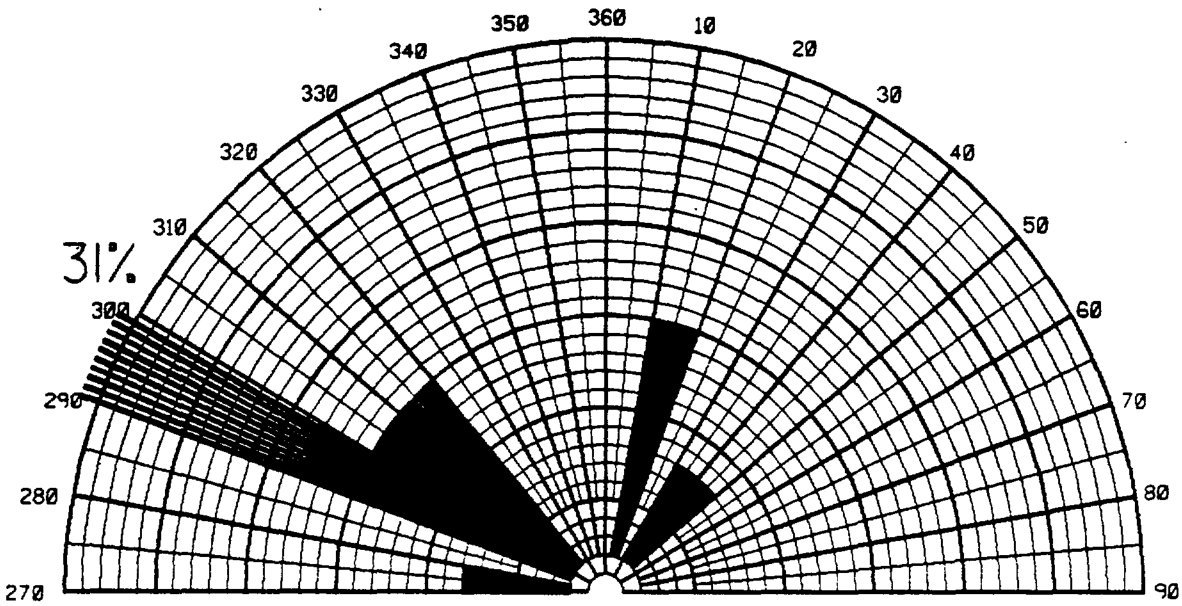
TO EDGE 0 TO 30 PERCENT

PRELIMINARY

SWEC / Holtzclaw No. 1

FORMATION	AZIMUTH																		TOTAL
	W				NW				N					NE			E		
	W		WNW		NW		NNW		N			NNE		NE		ENE		E	
OGALLALA																			
DOCKUM													1	1					2
DEWEY LAKE																			
ALIBATES																			
SALADO																			
YATES																			
U. SEVEN RIVERS																			
L. SEVEN RIVERS			3		1						1								5
QUEEN-GRAYBURG	1		1	2	1														5
U. SAN ANDRES															1				1
L. SAN ANDRES																			
GLORIETA																			
U. CLEAR FORK																			
TUBB																			
L. CLEAR FORK																			
RED CAVE																			
WICHITA																			
WOLFCAMP																			
PENNSYLVANIAN																			
TOTAL	1		4	2	2						1		1	1	1				13

PRELIMINARY



FIL Fractures

Holtzclaw No. 1

n=13

AZIMUTH FREQUENCY SCALE - FROM CENTER

TO EDGE Ø TO 3Ø PERCENT

PRELIMINARY

Gustavson (10)

REMOTE-SENSED IMAGERY

TYPE OF IMAGERY	SOURCE	DATA
1. LANDSAT/ERTS	EROS DATA CENTER SIOUX FALLS, IA	BLACK AND WHITE AND FALSE COLOR IMAGES, DIGITAL TAPE, ALL PANHANDLE
2. SLAR	USGS	IMAGES OR DIGITAL TAPE, PLAINVIEW AND CLOVIS QUADS
3. HIGH-ALTITUDE, QUAD-CENTERED, COLOR INFRARED	BEG	1:80,000 ALL PANHANDLE
4. LOW-ALTITUDE, BLACK AND WHITE, AERIAL PHOTOGRAPHY	USDA	VARIOUS SCALES AND VINTAGES, ALL PAN-HANDLE
5. LOW-ALTITUDE, BLACK AND WHITE MOSAICS	TOBIN AERIAL SURVEYS SAN ANTONIO, TX	1:24,000 ALL PANHANDLE

TYPE OF IMAGERY	SOURCE	DATA
6. SHUTTLE IMAGING RADAR	GODDARD SPACE FLIGHT CENTER GREENBELT, MD	1:500,000 SELECTED AREAS
7. LOW-ALTITUDE, COLOR INFRARED	TEXAS NATURAL RESOURCE INFORMATION SYSTEM, AUSTIN, TX	1:20,000, SELECTED AREAS
8. LOW-ALTITUDE COLOR OBLIQUE SLIDES	BEG	SELECTED AREAS

REMOTE-SENSED IMAGERY

REGIONAL STUDY

1. FINLEY AND GUSTAVSON. 1981. LINEAMENT ANALYSIS BASED ON LANDSAT IMAGERY, TEXAS PANHANDLE: GEOLOGIC CIRCULAR 81-5.

CONTENT:

LINEAMENTS, ALIGNED PLAYAS, SCARPS AND DRAINAGE SEGMENTS WERE MAPPED FROM LANDSAT IMAGES AND COMPARED TO REGIONAL FRACTURE TRENDS. FIGURES 1-5.

GROUND CHECK:

MOST LINEAMENTS CAN BE RECOGNIZED ON THE GROUND; HOWEVER, THE CAUSE OF THE LINEAMENTS SUCH AS A SYSTEM OF FRACTURES AT THE SURFACE, REMAINS ELUSIVE. FRACTURES ARE GENERALLY ABSENT FROM THE BLACKWATER DRAW AND OGALLALA FORMATIONS.

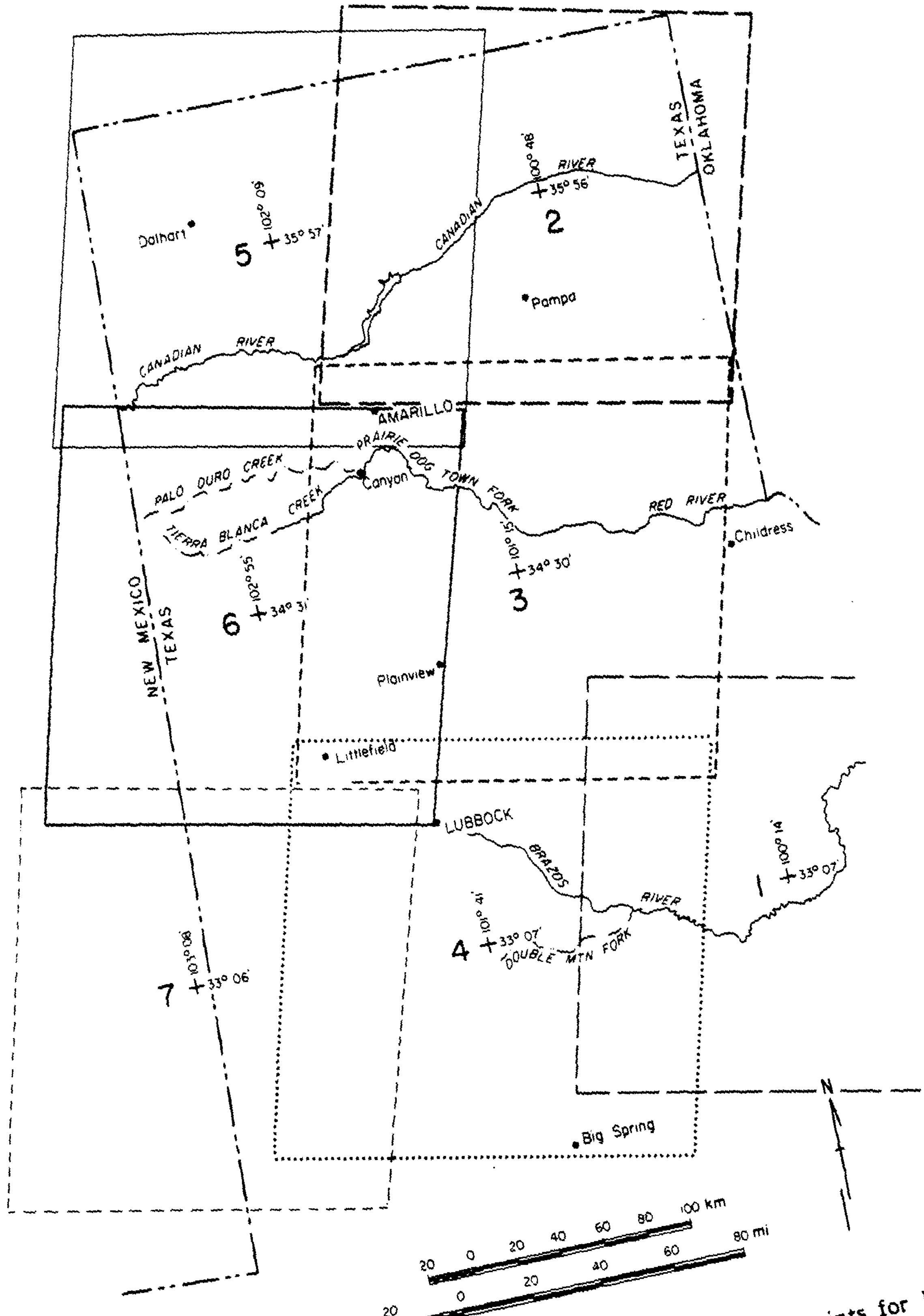


Figure 1. Generalized frame boundaries and approximate center points for Landsat coverage of the Texas Panhandle.

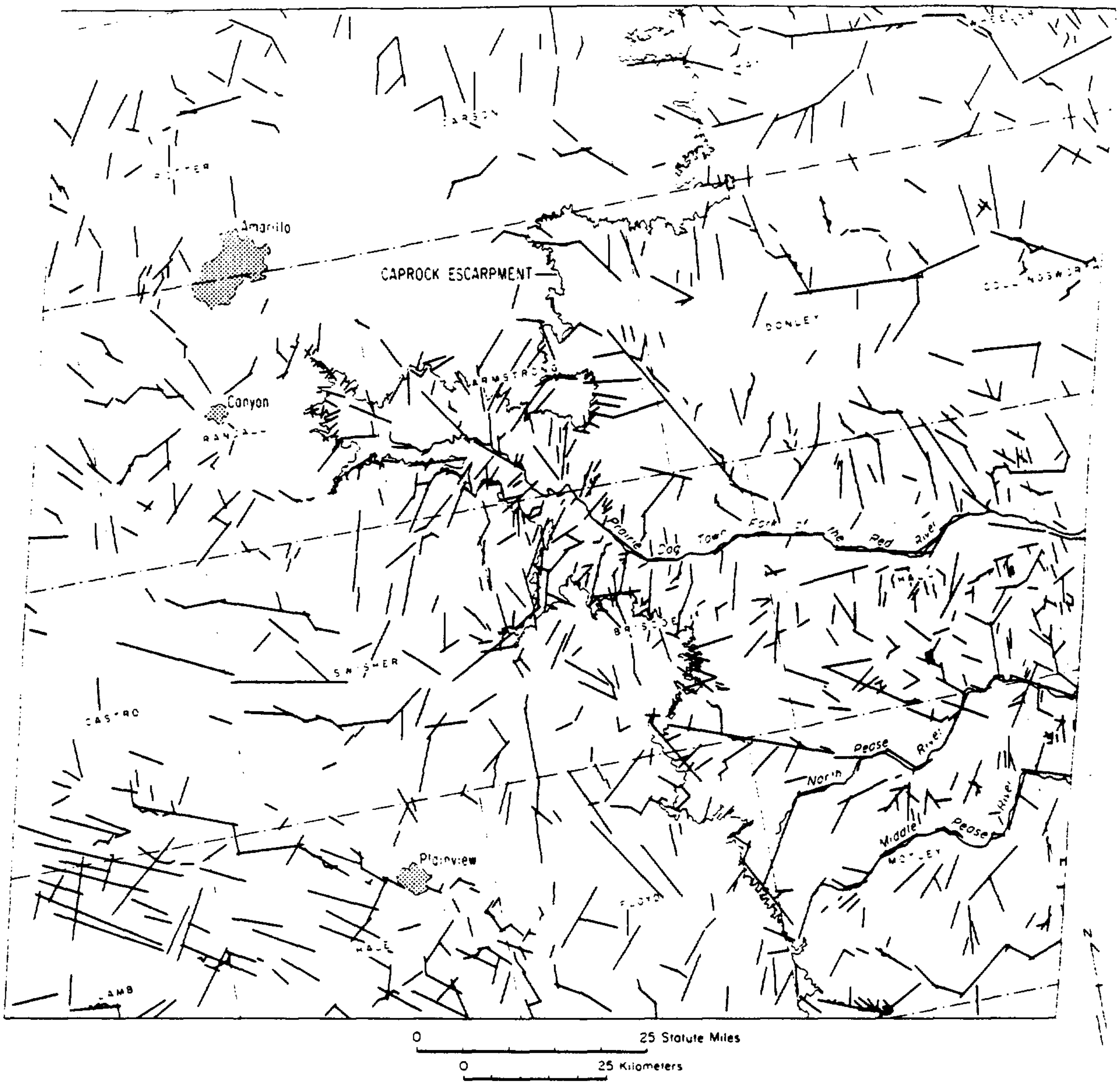


Figure 2. Lineaments derived from Landsat imagery, block 3 (fig.1), Texas Panhandle region (Scene 1672-16455, May 26, 1974). Original imagery is at a scale of 1:250,000.

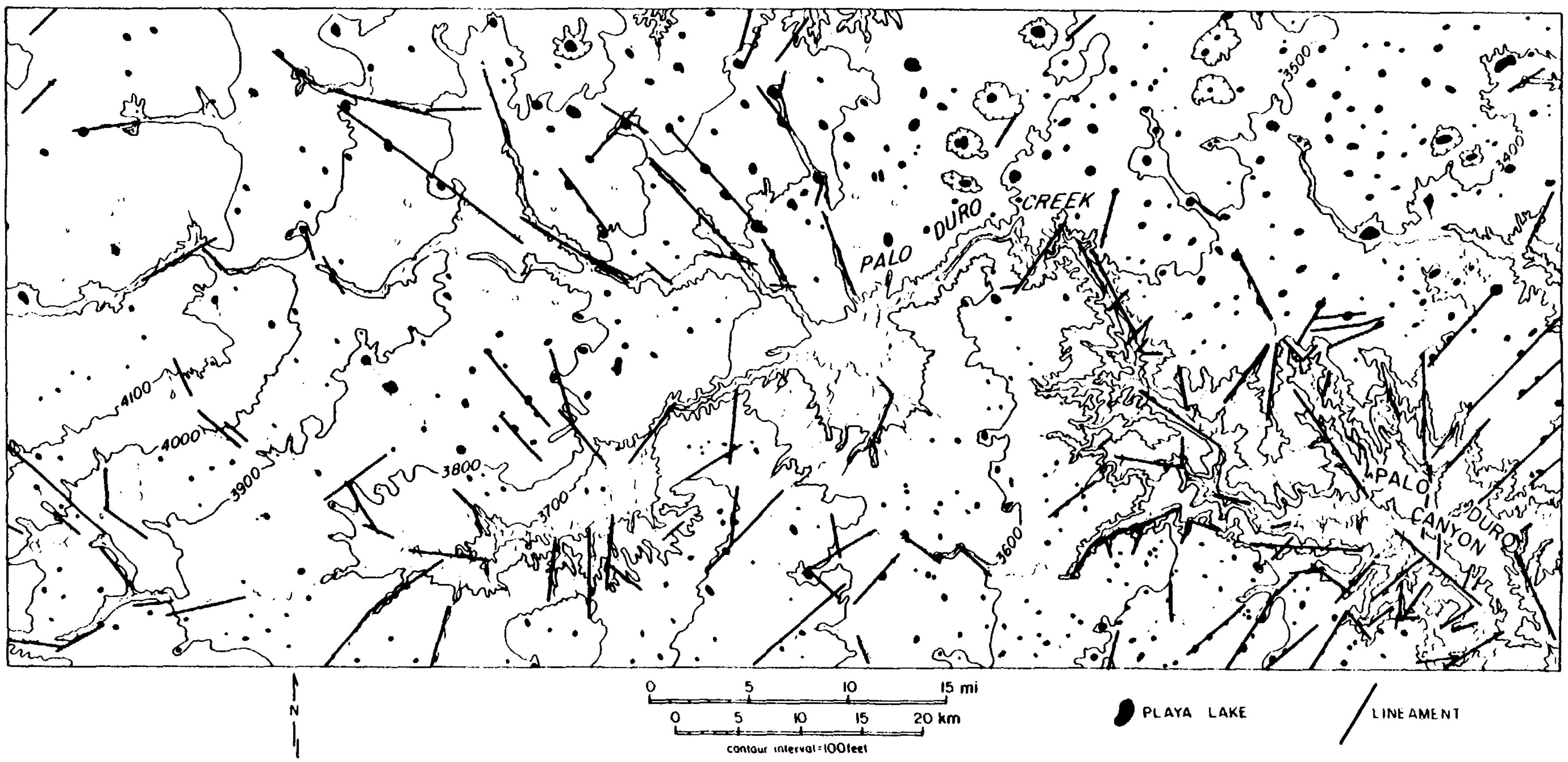


Figure 3. Detail of lineaments mapped on Landsat imagery in the vicinity of Palo Duro Creek and Palo Duro Canyon. Linear stream segments and escarpments form many of the lineaments. Area shown is A in figure 4. Original imagery is at a scale of 1:250,000.

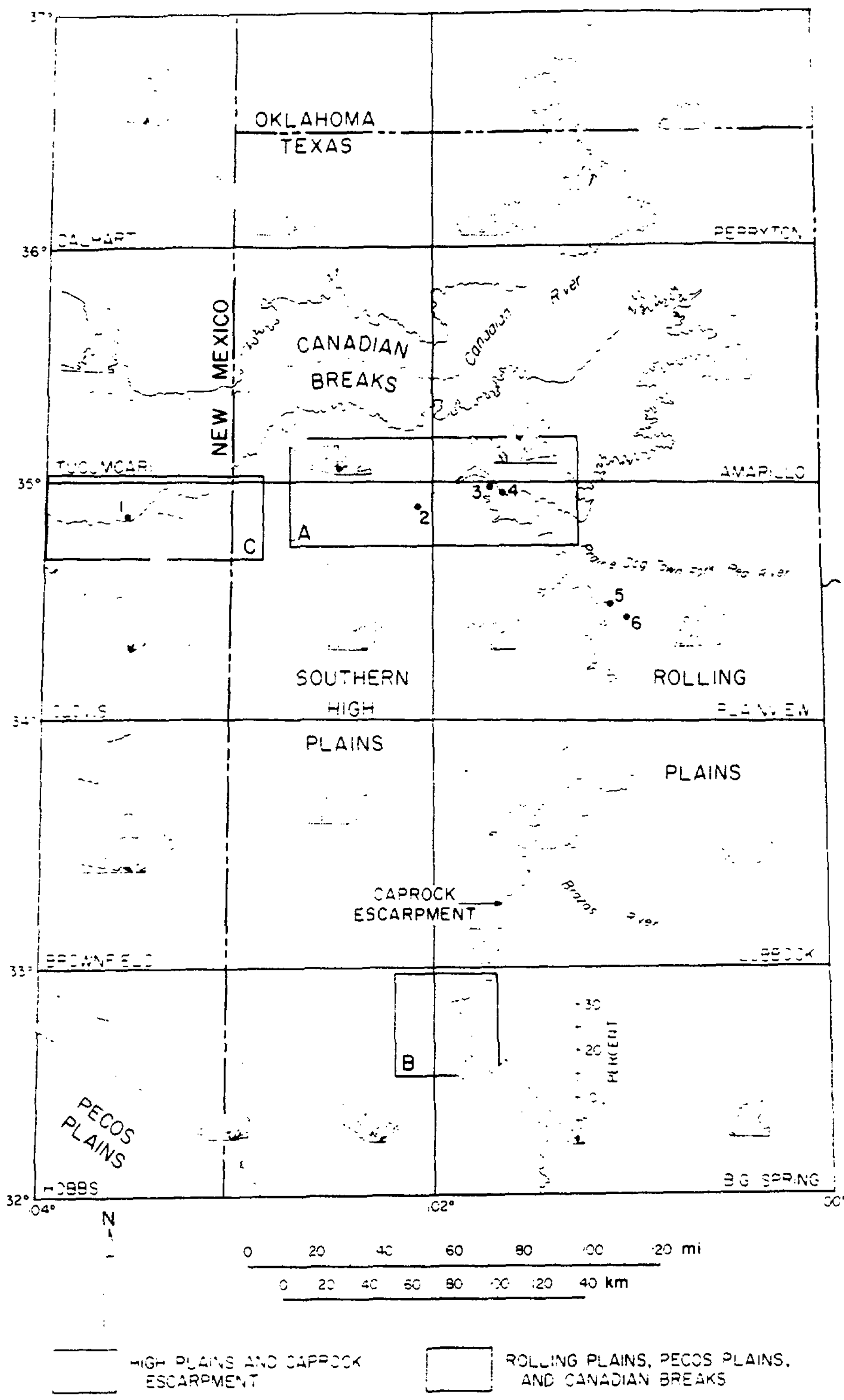


Figure 4. Summary of lineament length by 10° azimuth category within each named 1° x 2° National Map Series sheet. Area A, corresponds to figure 3. Localities 1 through 6 are sources of joint data for figure 5.

LOCAL STUDY

1. GUSTAVSON, T.C. AND OTHERS. 1982. EVAPORITE DISSOLUTION AND DEVELOPMENT OF KARST FEATURES ON THE ROLLING PLAINS OF THE TEXAS PANHANDLE: JOURNAL OF EARTH SURFACE PROCESSES AND LANDFORMS, VOL. 7, P. 545-563.

CONTENT:

COMPARES ORIENTED SUBSIDENCE/COLLAPSE FEATURES, IDENTIFIED FROM FIVE VINTAGES OF BLACK AND WHITE AERIAL PHOTOGRAPHY, TO LINEAR DRAINAGE ELEMENTS, OPEN EARTH FRACTURES, AND FRACTURES IN HALL COUNTY, TEXAS. FIGURES 1-4.

GROUND CHECK:

SUBSIDENCE FEATURES, MOSTLY DOLINES, ARE EASILY RECOGNIZED ON THE GROUND. DOLINE AXES AND THE ALIGNMENT OF A GROUP OF DOLINES ARE LOCALLY PARALLEL TO A SERIES OF OPEN EARTH FRACTURES.

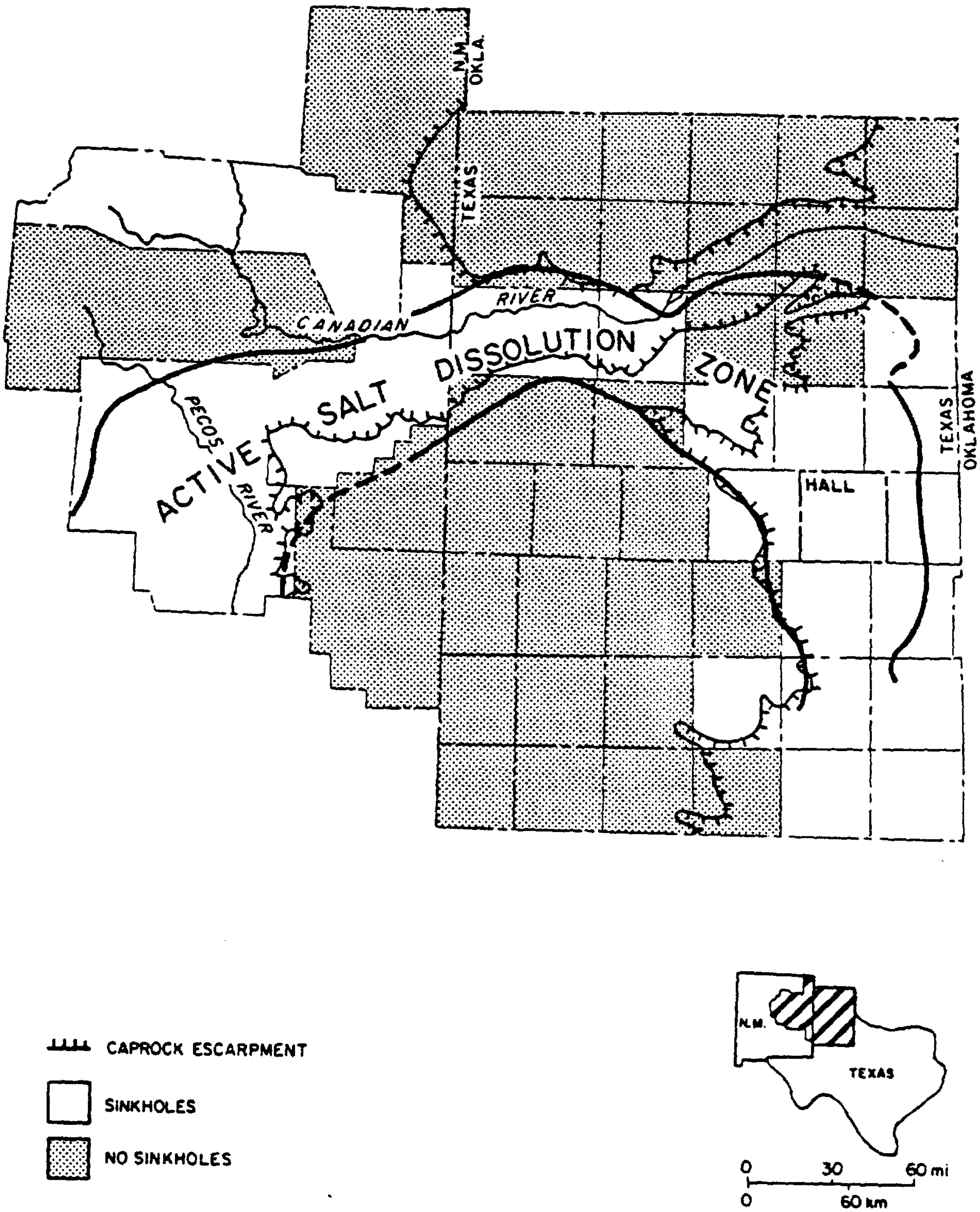


Figure 1. Study location and distribution of sinkholes in the Texas Panhandle.

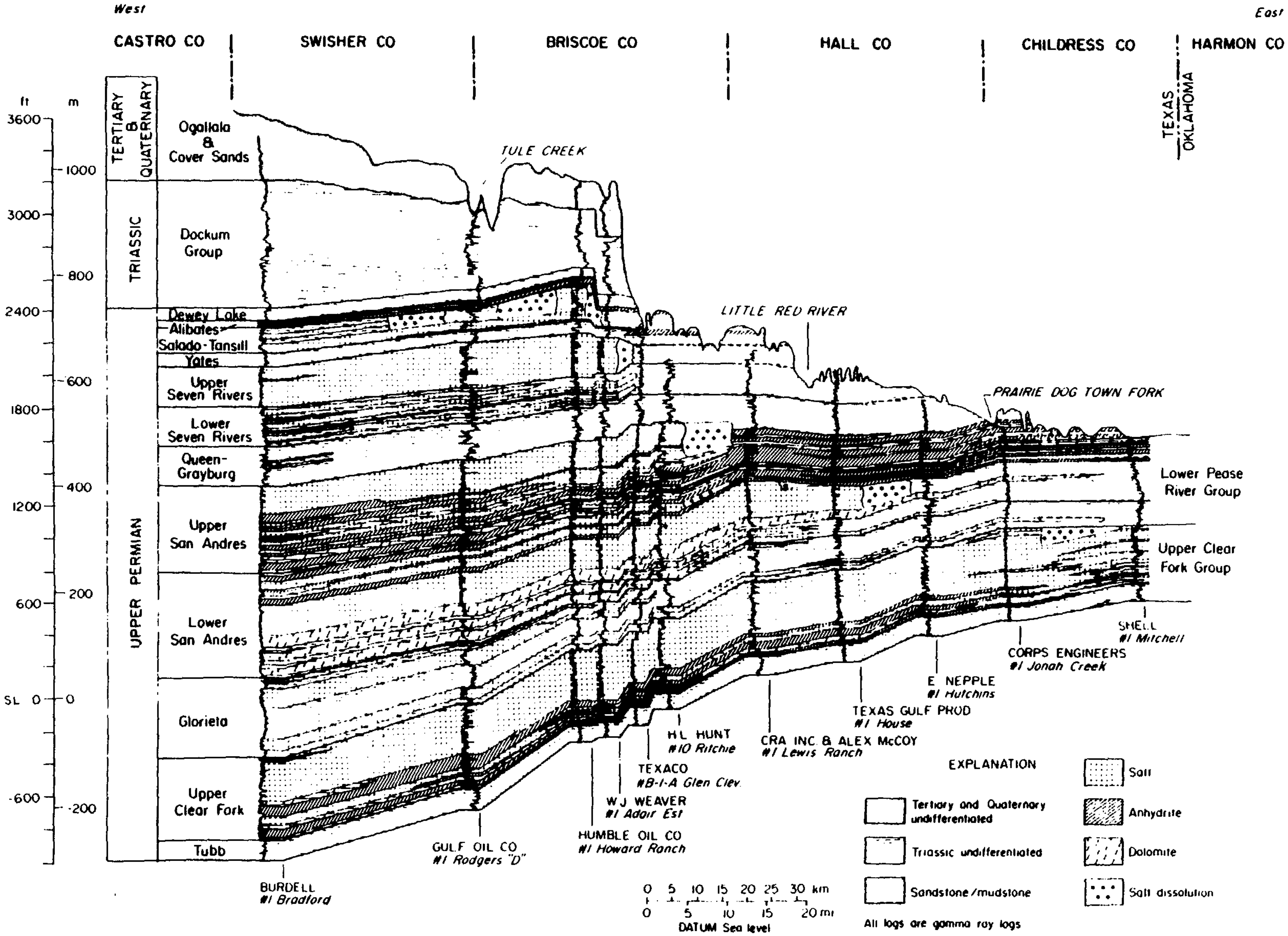


Figure 2. Structure and stratigraphic cross-section on the northeast flank of the Palo Duro Basin.

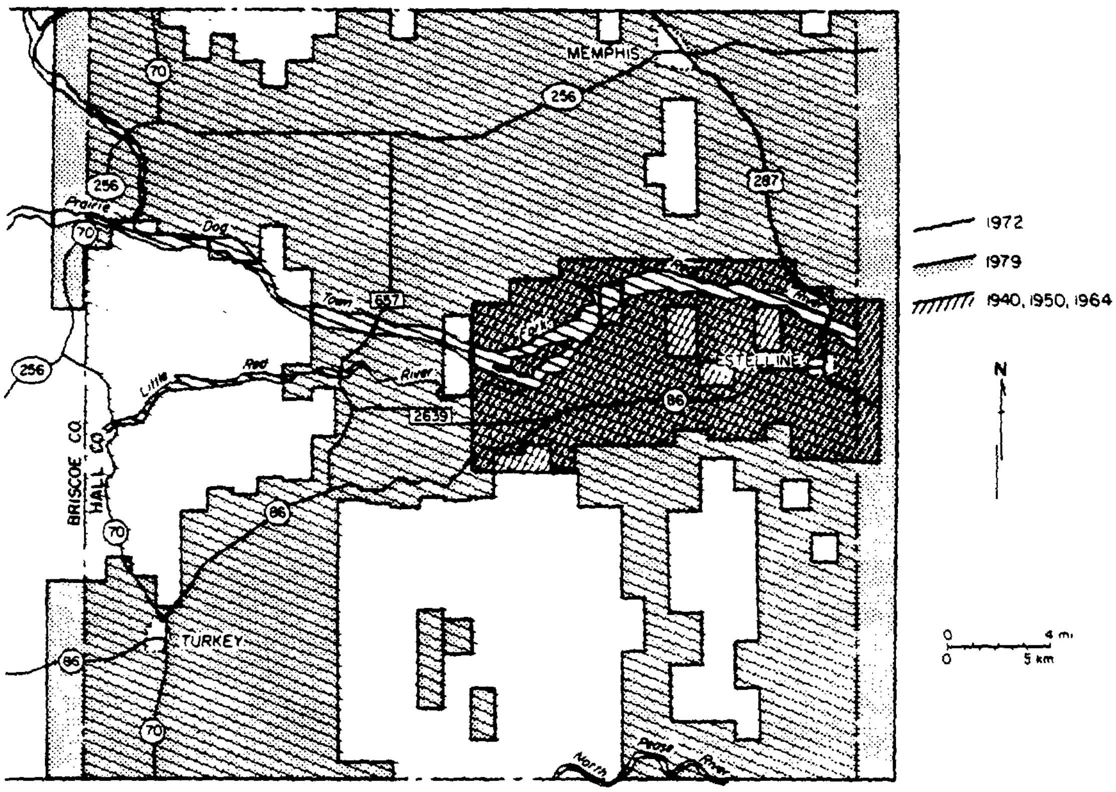


Figure 3. Distribution of photographic data that were analysed. Colour slides, 1979; black-and-white stereographic photography, 1940, 1950, 1964, and 1972

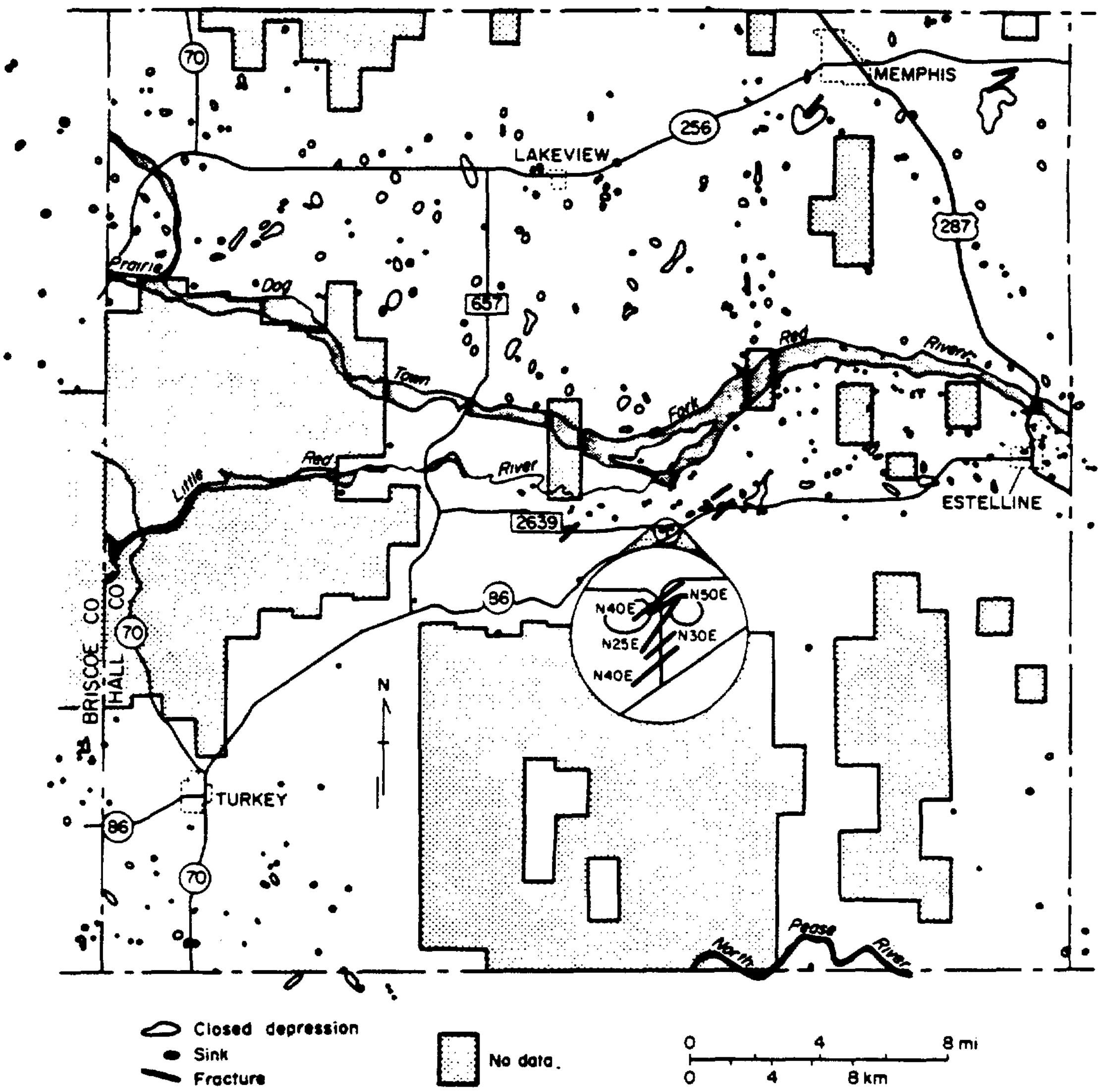


Figure 4. Location of sinkholes, closed depressions, and fractures in Hall and eastern Briscoe Counties. Closed depressions are drawn to scale, sinkholes which are much smaller are not drawn to scale. Areas of no data are those areas for which coloured slides were not available. These areas are relatively highly dissected and closed depressions do not occur there

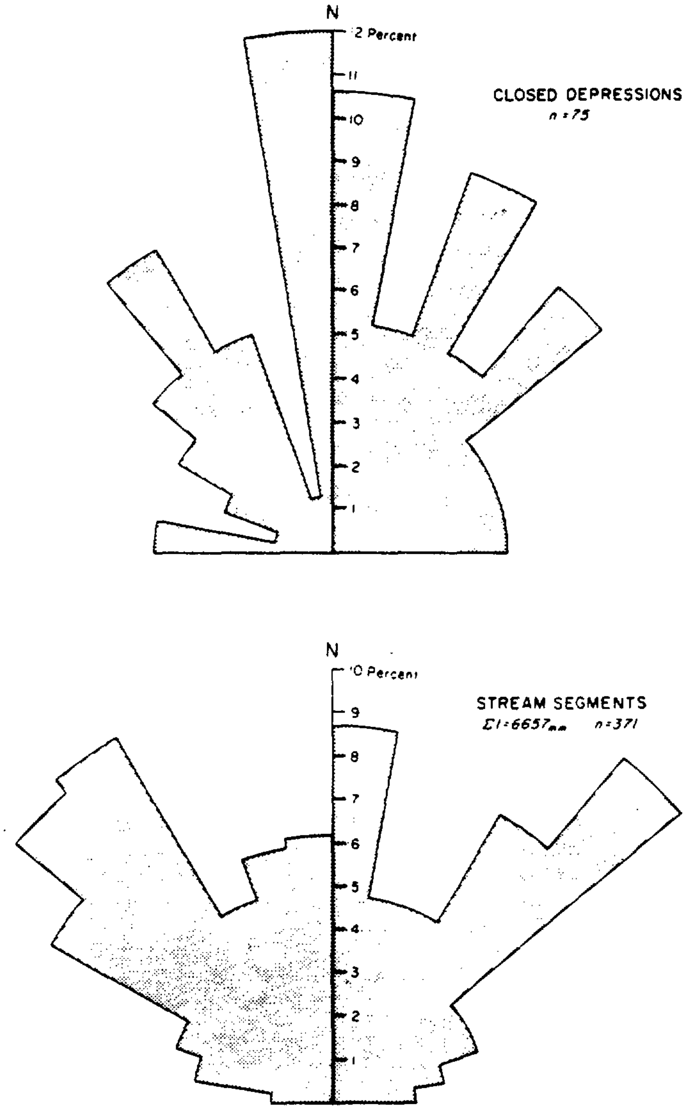


Figure 5. Diagrams indicate orientations of closed depressions and linear stream elements in Hall County. For each 10° sector, linear data are plotted as a percentage of total number of closed depressions and as a percentage of total length of linear stream segments, respectively

Peck (9)

SUMMARY OF WELLS DRILLED AND TESTED BY SWEC

1. Sawyer No. 1; Donley County, started June 23, 1981, completed October 15, 1981. T.D.: 4806 ft. Present status: Final plugged.

a. Casing Program - 13 3/8 in. conductor to 66 ft, 9 5/8 in. surface to 337 ft, 5 1/2 in. production to 3938 ft, 4 in. liner from 3938 ft to 4806 ft.

b. Rock Coring (all 4 in. OD core) - Total of 3872 ft, from 66 ft to 3938 ft, Yates through Pennsylvanian.

MAJOR SALT SECTION

- Upper San Andres 438 ft to 652 ft, thickness 214 ft
- LSA - Unit 5 652 ft to 756 ft, thickness 104 ft
- LSA - Unit 4 756 ft to 840 ft, thickness 84 ft
- LSA - Unit 3 840 ft to 894 ft, thickness 54 ft
- LEA - Unit 2 894 ft to 947 ft, thickness 53 ft

Unusual features - Fault zone at 756-762 ft - 155 of missing section.

c. Drill Stem Tests (DSTs)

No. 1 2950 ft to 3123 ft - Wolfcamp, PI = 816 psi, K = 0.15 md

d. Geophysical Logging - Complete suites of cased and open hole logs.

e. Long-Term Pump Testing and Fluid Sampling

Zone 1 - Ellenburger Sand, 4716 ft - 4746 ft, unable to obtain data to determine PI or K, 4 downhole and 2 surface samples.

Zone 2 - Ellenburger Top, 4604 ft - 4640 ft, PI = 1390 psi, K = 0.3 md., 4 surface samples.

Zone 3 - Penn. Limestone, 4500 ft - 4535 ft, PI = 1531 psi, K = 5.4 md., 4 downhole and 2 surface samples

Zone 4 - Penn. Limestone, 4258 ft-4342 ft, PI = 1350 psi, K = 2.7 md., 7 downhole and 10 surface samples.

Zone 5 - Wolfcamp, 3189 ft - 3172 ft, PI = 977 psi, K = 2.7 md., 3 downhole and 20 surface samples.

f. Dissolution Zone water Well

Sawyer No. 2, 784 ft, 20 ft screen section at bottom of hole in LSA Unit 4. Testing by TBEG began April, 1983.

2. Mansfield No. 1, Oldham County, started October 19, 1981, completed December 19, 1982. T.D. 4995 ft by SWEC, 7409 ft by Baker & Taylor (dry hole). Present status: Final plugged.

a. Casing Program - 13 3/8 in. conductor to 41 ft, 9 5/8 in. surface to 1212 ft, 5 1/2 in. tubing to 5180 ft.

b. Rock Coring (All 4 in. OD core) - Total of 4196 ft.

- 46 ft to 3540 ft - Dockum to Red Cave
- 4023 ft to 4123 ft - Wichita
- 4393 ft to 4995 ft - Wichita and Wolfcamp

MAJOR SALT SECTION

o Upper San Andres	985 ft to 1373 ft,	thickness 388 ft
o LSA - Unit 5	1373 ft to 1546 ft,	thickness 173 ft
o LSA - Unit 4	1546 ft to 1815 ft,	thickness 269 ft
o LSA - Unit 3	1815 ft to 1940 ft,	thickness 125 ft
o LSA - Unit 2	1940 ft to 1978 ft,	thickness 38 ft
o LSA - Unit 1	1978 ft to 2001 ft,	thickness 23 ft

c. Drill Stem Tests (DSTs)

No. 1 4800 ft - 4996 ft - Wolfcamp PI = 1322 psi K= 26.6 md.
No. 2 4550 ft - 4650 ft - Wolfcamp - Did not produce sufficient fluid.
No. 3 4550 ft - 4650 ft - Wolfcamp - Did not produce sufficient fluid
No. 4 4550 ft - 4650 ft - Wolfcamp - Unable to set packers.
No. 5 6994 ft - 7409 ft - Granite Wash - Did not produce sufficient fluid.
No. 6 6612 ft - 6640 ft - Penn. Carbonates, PI = 2230, K = 21.4 md.
No. 7 4812 ft - 4840 ft - Wolfcamp, PI = 1404, K = 30.22 md.

d. Geo;hysical Logging - Complete suites of cased and open hole logs.

e. Long-Term Pump Testing and Fluid Sampling

Zone 1 - Wolfcamp, 4818-4890, PI = 1470 psi, K = 3.3 md., 8 downhole and 24 surface samples
Zone 2 - Wolfcamp, 4514-4638, PI = 1150 psi, K = 0.6 md., 9 downhole and 8 surface samples.

f. Dissolution Zone Water Well

Mansfield No. 2, 780 ft, 30 ft screen at bottom in Queen/Grayburg. Testing by TBEG began June, 1983.

3. Detten No. 1 - Deaf Smith County, started February 26, 1982, completed May 5, 1982. T.D. 2839.3 ft. Present Status: Final plugged.

a. Casing Program - 13 3/8 in. conductor to 53 ft, 9 5/8 in. surface to 1122 ft.

b. Rock Coring (all 4 in. OD core) - Total of 1249 ft

- 1129.2 ft to 1423.0 ft - Salado, Yates, Upper Seven Rivers
- 1884 ft to 2839.3 ft - Upper San Andres, Lower San Andres to Unit 3

MAJOR SALT SECTION

- Upper San Andres 1866 ft to 2374 ft, thickness 508 ft
- LSA - Unit 5 2374 ft to 2575 ft, thickness 201 ft
- LSA - Unit 4 2575 ft to 2830 ft, thickness 255 ft

c. Drill Stem Tests (DSTs)

No. 1 1160 ft - 1360 ft - Upper Seven Rivers - Unsuccessful - Poor packer seat.
No. 2 1299 ft - 1366 ft - Upper Seven Rivers - Unsuccessful - Poor packer seat.
No. 3 2749 ft - 2839 ft - LSA Unit 4 Dolomite, P.I. = 1150 psi, K = 0.16 md.

d. Geophysical Logging - Complete suites of open hole logs.

e. Long-Term Pump Testing and Fluid sampling - None.

f. Dissolution Zone water Well

Detten No. 2, 1325 ft, 20 ft of screen at bottom in Yates. The well was completed in March, 1933. Testing, monitoring, and sampling by TBEG continues.

4. G. Friemel No. 1 - Deaf Smith County, started February 23, 1982, completed March 31, 1982. T.D. 2710 ft. Present Status: Final plugged.

a. Casing Program - 13 3/8 in. conductor to 50 ft, 9 5/8 in. surface to 1058 ft.

b. Rock Coring (all 4 in. OD core) - Total of 1121.7 ft

- 1191.5 ft to 1312.0 ft - Yates, Upper Seven Rivers
- 1709.0 ft to 2710.2 ft - Queen/Grayburg, Upper San Andres, and Lower San Andres to Unit 3

MAJOR SALT SECTION

- Upper San Andres 1742 ft to 2331 ft, thickness 589 ft
- LSA - Unit 5 2331 ft to 2435 ft, thickness 104 ft
- LSA - Unit 4 2435 ft to 2688 ft, thickness 253 ft

c. Drill Stem Tests (DSTs)

No. 1 2600 ft - 2710 ft, LSA Unit 4 Dolomite, P.I. = 975 psi, K = 0.07 md.

d. Geophysical Logging - Complete suites of open hole logs.

e. Long-term Pump Testing and Fluid Sampling - None.

f. Dissolution Zone water Well - None.

5. Zeeck No. 1 - Swisher County, started April 9, 1982, completed August 17, 1982. T.D. 7652 ft. Pump testing started September 22, 1983, completed May 2, 1984. Present Status: Final plugged.

a. Casing Program - 13 3/8 in. conductor to 26 ft, 9 5/8 in. surface at 1024 ft, 5 1/2 in. to 7421 ft.

b. Coring (all 4 in. OD core) - Total of 1993 ft

- 1035 ft to 1144 ft - Salado
- 1885 ft to 3102 ft - Queen/Grayburg, Upper San Andres, Lower San Andres Units 5, 4, 3, and Upper Section of Unit 2.
- 5309 ft to 5780 ft - Wichita/Wolfcamp Contact and Upper Wolfcamp
- 5910 ft to 6058 ft - Wolfcamp
- 7300 ft to 7387 ft - Pennsylvanian Carbonates

MAJOR SALT SECTION

- Upper San Andres 2014 ft to 2574 ft, thickness 560 ft
- LSA - Unit 5 2574 ft to 2732 ft, thickness 158 ft
- LSA - Unit 4 2732 ft to 3014 ft, thickness 282 ft
- LSA - Units 3,2,&1 3014 ft to 3188 ft, thickness 174 ft

c. Drill Stem Tests (DSTs)

No. 1 1019 ft - 1044 ft - Salado, Unsuccessful.
No. 2 1019 ft - 1044 ft - Salado, Did not produce sufficient fluid.
No. 3 3035 ft - 3103 ft - LSA, Unit 3, Did not produce sufficient Fluid.
No. 4 2932 ft - 3103 ft - LSA Unit 3, Unsuccessful.
No. 5 2927 ft - 3103 ft - LSA Unit 4 Dolomite, P.I. = 1250 psi, K = 0.25 md.
No. 6 5365 ft - 5542 ft - Upper Wolfcamp, PI = 1875 psi, K = 6.77 md.
No. 7 7146 ft - 7225 ft - Pennsylvanian, PI = 2559 psi, K = 2.83 md.

d. Geophysical Logging - Complete suites of open and cased hole logs.

e. Long-Term Pump Testing and Fluid Sampling

Zone 1 - Penn. Carbonates, 7140 ft - 7230 ft, P.I. = 2400 psi, K - 15 md., 10 downhole and 48 surface samples

Zone 2 - Wolfcamp, 5603 ft - 5640 ft, P.I. = 1960 psi, K = 1 md., 6 downhole and 9 surface samples.

Zone 3 - Wolfcamp, 5470 ft - 5550 ft, P.I. = 1890 psi, K = 7 md., 3 downhole and 34 surface samples.

Zone 4 - LSA Unit 4 Dolomite, 2930 ft - 2970 ft, P.I. = 1300 psi, 25 surface samples

f. Dissolution Zone water Well - None.

6. Harman No. 1 - Swisher County, started July 29, 1982, completed September 7, 1982. T.D. 3052 ft, hole completed as Shallow Dissolution Zone Water Well (see below)

a. Casing Program - 13 3/8 in. conductor to 40 ft, 9 5/8 in. surface to 1063, cement to plug 1220 ft ± to 1400 ft ±.

b. Rock Coring (all 4 in. OD core) - Total of 1481 ft

- 1070 ft to 1303 ft - Alibates, Salado, Yates, and Upper Seven Rivers
- 1804 ft to 3052 ft (T.D.) - Queen/Grayburg, Upper San Andres, and Lower San Andres into Unit 2.

MAJOR SALT SECTION

- Upper San Andres 1949 ft to 2466 ft, thickness 517 ft
- LSA - Unit 5 2466 ft to 2651 ft, thickness 185 ft
- LSA - Unit 4 2651 ft to 2931 ft, thickness 280 ft
- LSA - Unit 3 2931 ft to 3012 ft, thickness 81 ft

c. Drill Stem Tests (DSTs)

No. 1 2840 ft - 3050 ft - Unit 4 Dolomite, P.I. = 1203 psi K = 0.011 md., minor leakage noted around packers.

No. 2 2830 ft - 3050 ft - (T.D.) - Unit 4 Dolomite, P.I. 1315, K = 0.186 md.

d. Geophysical Logging - Complete suites of open hole logs.

e. Long-Term Pump Testing and Fluid Sampling - None.

f. Dissolution Zone water Well

Installed in existing borehole with open hole section from bottom of surface casing at 1064 ft to top of cement plug at 1220 ft ±. Gravel packed screen (30 ft long) set in Yates. The well was completed in March 1983; Testing, monitoring, and sampling by TBEG continues.

7. Friemel No. 1 - Deaf Smith County, started October 15, 1982, completed March 18, 1983. T.D. 8283 ft, pump testing started May 3, 1983 completed September 19, 1984. Present status: Final plugged.

a. Casing Program - 22 in.. conductor to 48 ft, 16 in. surface to 1210 ft, 10 3/4 in. intermediate salt string to 4695 ft, 5 1/2 in. to 8283 ft.

b. Rock Coring (all 4 in. OD core) - Total of 3041 ft

o 352 ft to 1464 ft -	Dockum, Dewey Lake, Alibates, Salado, Yates, and Upper Seven Rivers
o 1846 ft to 2830 ft -	Upper San Andres, LSA Units 5, 4, and Upper Section of Unit 3
o 5519 ft to 6032 ft -	Wolfcamp
o 6421 ft to 6537 ft -	Penn. Carbonates
o 7698 ft to 7780 ft -	Granite Wash
o 8047 ft to 8283 ft (T.D.) -	Granite Wash

MAJOR SALT SECTION

o Upper San Andres	1880 ft to 2372 ft, thickness 492 ft
o LSA - Unit 5	3372 ft to 2560 ft, thickness 188 ft
o LSA - Unit 4	2560 ft to 2822 ft, thickness 262 ft
o LSA - Units 3,2,&1	2822 ft to 3018 ft, thickness 196 ft

c. Drill Stem Tests (DSTs)

No. 1	958 ft - 1216 ft -	Santa Rosa - Too High Producer.
No. 2	787 ft - 850 ft -	Santa Rosa - Unsuccessful.
No. 3	1279 ft - 1464 ft -	Upper Seven Rivers - Did not produce sufficient fluid.
No. 4	1279 ft - 1464 ft -	Upper Seven Rivers - Did not produce sufficient fluid.
No. 5	2753 ft - 2830 ft -	LSA Unit 4 Dolomite - Did not produce sufficient fluid.
No. 6	5630 ft - 5909 ft -	Wolfcamp, P.I. = 1756 psi, K = 10.3 md.
No. 7	7692 ft - 8283 ft -	Penn. Carbonates and Granite Wash -Unsuccessful, Tool stuck.

d. Geophysical Logging - Complete suites of open and cased hole logs.

e. Long-Term Pump Testing and fluid sampling

Zone 1 - Penn. Granite Wash, 8168 - 8804 ft, Formation press = 2840 psi, K = 29 md., 12 downhole and 54 surface samples.

Zone 2 - Penn. Granite Wash, 8122-8132 ft, Formation Press = 2809 psi, K = 131 md., 23 surface samples.

Zone 3 - Penn. Granite Wash, 8040-8050 ft, formation press = 2766 psi, K = 152 md., 21 surface samples.

Zone 4 - Penn. Granite Wash, 7890-7904 ft, Formation press. = 2684 psi, K = 3.3 md., 10 downhole and 52 surface samples.

Zone 5 - Penn. Granite wash, 7707-7711 and 7729-7734 ft, Formation press. = 2615 psi, K= 1000 md., 15 surface samples.

Zone 6 - Penn. Carbonate, 7300-7326 ft, Formation press. = 2428 psi, K = 92 md., 11 downhole and 47 surface samples.

Zone 7 - Wolfcamp, 5825-5926 ft, Formation press = 1721 psi, K = 1.3 md., 17 downhole and 89 surface samples.

Zone 8 - LSA Unit 4, 2754-2798 ft, Formation press. = 957 psi, K = 0.04 md., 25 surface samples.

Zone 9 - Queen/Grayburg, 1690-1770 ft, Formation press. = 510 psi, K = 1.2 md., 13 downhole and 23 surface samples.

f. Seismometer - seismometer installed at a depth of 480 ft in the well. Surface facility expected to be constructed and system operational by December, 1985.

8. Holtzclaw No. 1 - Randall County, started February 28, 1983, completed March 24, 1983. T.D. 2884 ft. Hydro fracture testing performed in December, 1983 (see below). Present status: Final plugged.

a. Casing Program - 20 in. conductor to 41 ft, 10 3/4 in. surface to 1125 ft.

b. Rock Coring (all 4 in. OD) Total of 901 ft

1080 ft - 1401 ft - Dewey Lake, Albates, Salado, Yates and Upper Seven Rivers

2304 ft - 2884 ft - Upper San Andres, Lower San Andres Unit 5, 4 & into 3.

MAJOR SALT SECTION

- Upper San Andres 1878-2369 ft, total salt thickness 160 ft
- LSA - Unit 3 2369-2562 ft, total salt thickness 75 ft
- LSA - Unit 4 2562-2822 ft, total salt thickness 124 ft

c. Drill Stem Tests (DSTs)

No. 1 1276 ft - 1322 ft - Upper Seven Rivers - did not produce sufficient fluid.
No. 2 1140 ft - 1186 ft - Salado - did not produce sufficient fluid.
No. 3 702 ft - 748 ft - Santa Rosa - did not produce sufficient fluid.
No. 4 1718 ft - 1764 ft - Queen/Grayburg - Formation press = 694 psi, K = 1.56 md.
No. 5 2745 ft - 2792 ft - LSA - 4 - did not produce sufficient fluid.

d. Geophysical Logging - Complete suites of open hole logs.

e. Long-Term Pump Tsting and Fluid sampling - None.

f. Dissolution Zone water Well - None.

g. Hydrofracture Testing

Queen/Grayburg	1850-1858.5, Max. Horiz Stress = 1260 psi, Min. Horiz Stress = 1110 psi, orientation of fracture developed = N30°E
USA	2330-2338.5, fracture broke around packers, orienttion of fractures developed = N40°E and N80°W
LSA - Unit 5	2430-2438.5, Min horiz Stress = 2915 psi, Vert. stress = 2780 psi, orientation of fracture developed = N60°E
LSA - Unit 4	2581-2589.5, Min horiz stress = 3500 psi, Vert stress = 2950 psi, orientation of fracture developed = N60°E
LSA - Unit 4	2790-2798.5, Max horiz stress = 2550 psi, Min horiz stress = 1900 psi orientation of fracture developed = N45°E

Murphy (8)

NRC WORKSHOP
November 19 - 21, 1985

A.) Number and Location of Wells

Figure 1 - Study Area

Figure 2 - Distribution of Well Selection

Figure 3 - Well Locations

Figure 4 - County Distribution of Wells

B.) Lithologic Data

1) Largest source are geophysical logs specifically Density-Neutron - Sonic

2) Sample logs & Mud Logs

3) Core - limited core from exploration wells taken in producing horizons and occasionally basement. The program wells are our only source of core throughout the stratigraphic section.

C.) Availability

1) Geophysical Logs & Mud Logs

Panhandle Electric Well Log Service

West Texas Electric Well Log Service

North Texas Electric Well Log Service

Rocky Mountain Electric Well Log Service

500 N. Baird Street
Midland, TX 79701

State Agencies

2) Sample Logs

Panhandle Sample Log Service
1011 W. Ninth Street
Amarillo, TX 79109

American Stratigraphic Co.
6280 E. 39th Avenue
Denver, Co. 80207

Permian Basin Sample Laboratory
401 N. Colorado
Midland, TX 79701

Ardmore Geological Society
P.O. Box 1552
Ardmore, OK 73401

D.) Quality of Data

Generally, the older the log the poorer the quality. The oldest log in our data base dates from 1931. These older logs were resistivity and were types run in holes using poor drilling techniques, poor mud programs, and crude instruments which were not serviced regularly. Technological advances over the years have improved the quality of logs and their interpretation immensely. Quality also varies with each logging service.

The following compares the type of geophysical log vs. use.

	Percentage of file (est.)	Used for Correlation	Used for Lithology
Resistivity Logs (all forms)	40%	Fair	Poor
Gamma Ray - Neutron (all forms)	25%	Fair	Poor
Gamma Ray - Density (all forms)	15%	Good	Good
Gamma Ray - Sonic (all forms)	15%	Good	Good
Neutron, Density, Sonic (no gamma-ray)	1%	Poor	Poor
All logs	4%	Excellent	Excellent

All of the data is available for purchase from commercial sources listed earlier. All of the interpretations regarding formations, major salt beds, and porosity determinations are on computer tape.

E.) Organization

1) All information from each well are in folders arranged by state, alphabetically by county, and by number.

2) SWEC identification numbers match Bureau numbers up to July, 1980 Those numbers assigned to wells afterwards are followed by the letter "s" (not included in computer file). The original set of numbers were assigned from West to East and North to South. Later numbers were assigned to wells based on order of acquisition. Each county has numbers begining with No. 1. The county codes are listed on Attachment 2.

3) Each Folder contains:

- Geophysical Logs (if any)
- Sample Logs (if any)
- Mud Logs (if any)
- State Records (if any)

  Applications to drill

  Plats

  Completion Reports

(used to check elevation, verify location, type and location of production and yields, driller's logs)

- Well Record Sheet

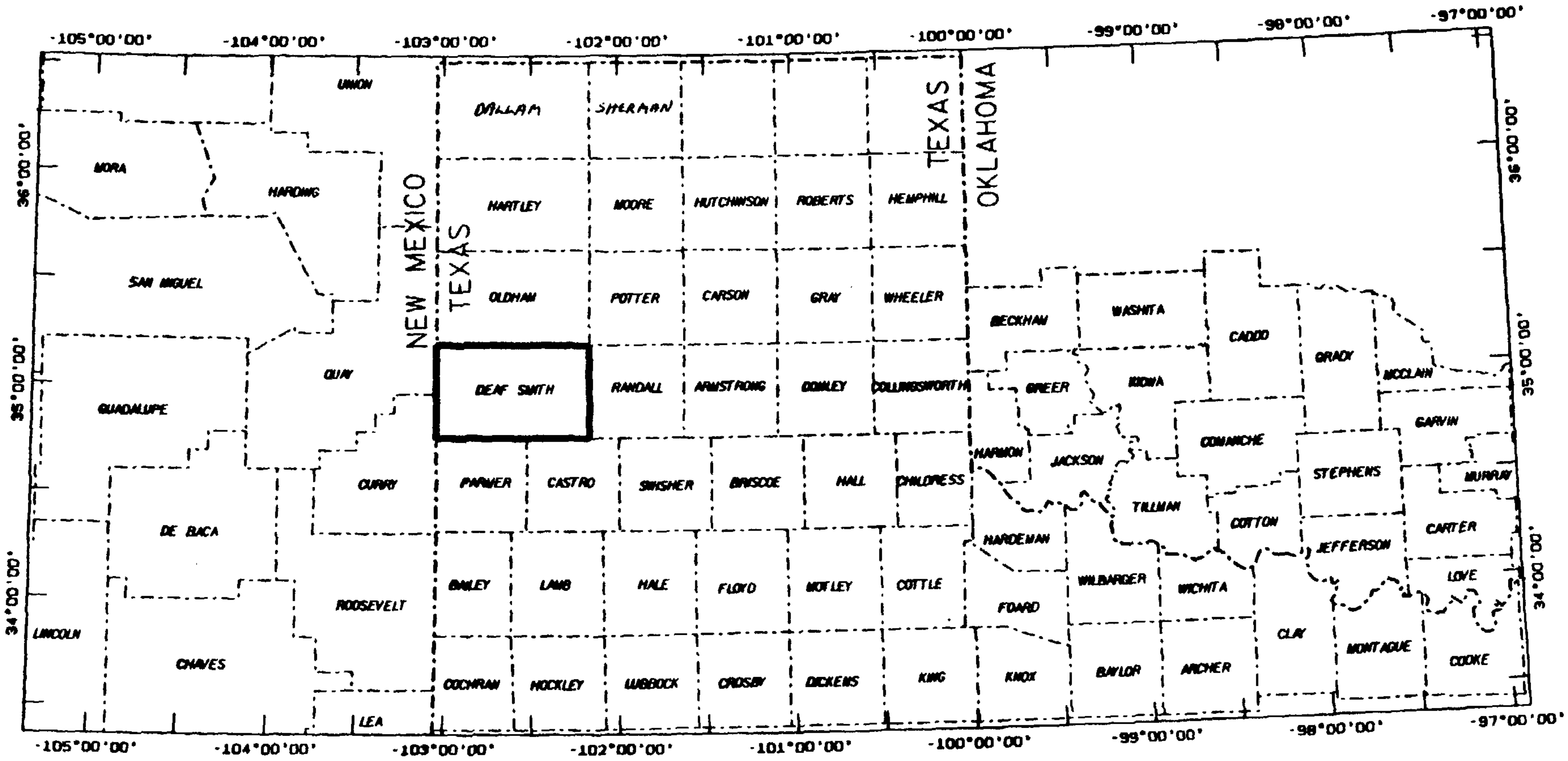
  Lists Formation tops and salt beds

4) Computer file

   - Entered from well record sheet, salt information listed separately on Attachment 5, p. 2
   - changes to file made on change sheets, stamped by originator, Project Geologist when checked, and when change is verified and transferred to master file.
   - change sheets organized by state, alphabetically by county, by number, chronologically.

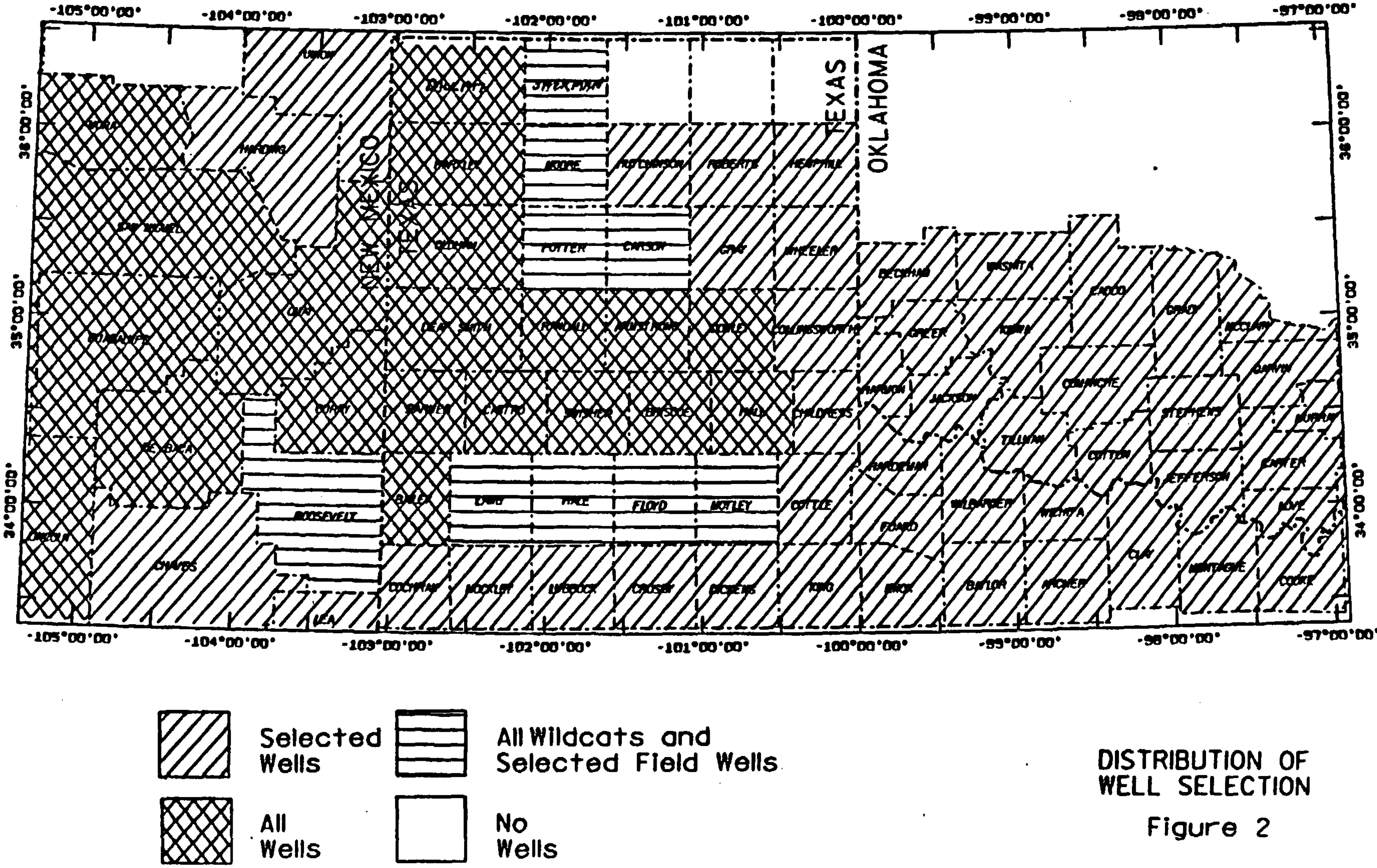
5) Maps

   - Postings of Formation tops or thicknesses with and/or without contours.
   - Posting of elevations at a 1:250,000 scale and checked against 2 degree USGS Topographic Map.
   - check of anomalous values for possible errors.



STUDY AREA

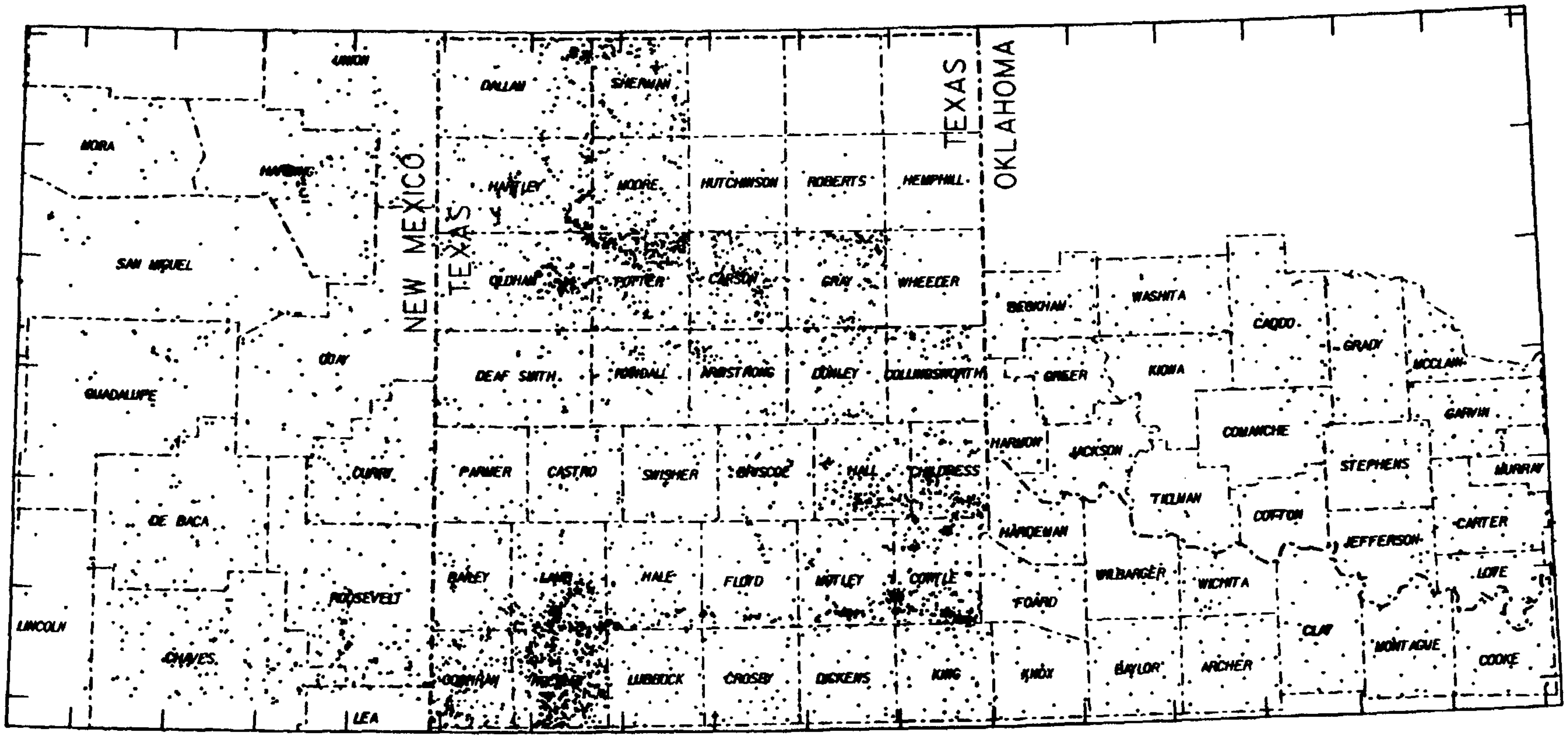
Figure 1



NOTE: Wells were selected based on depth, location, and year drilled.

DISTRIBUTION OF WELL SELECTION

Figure 2

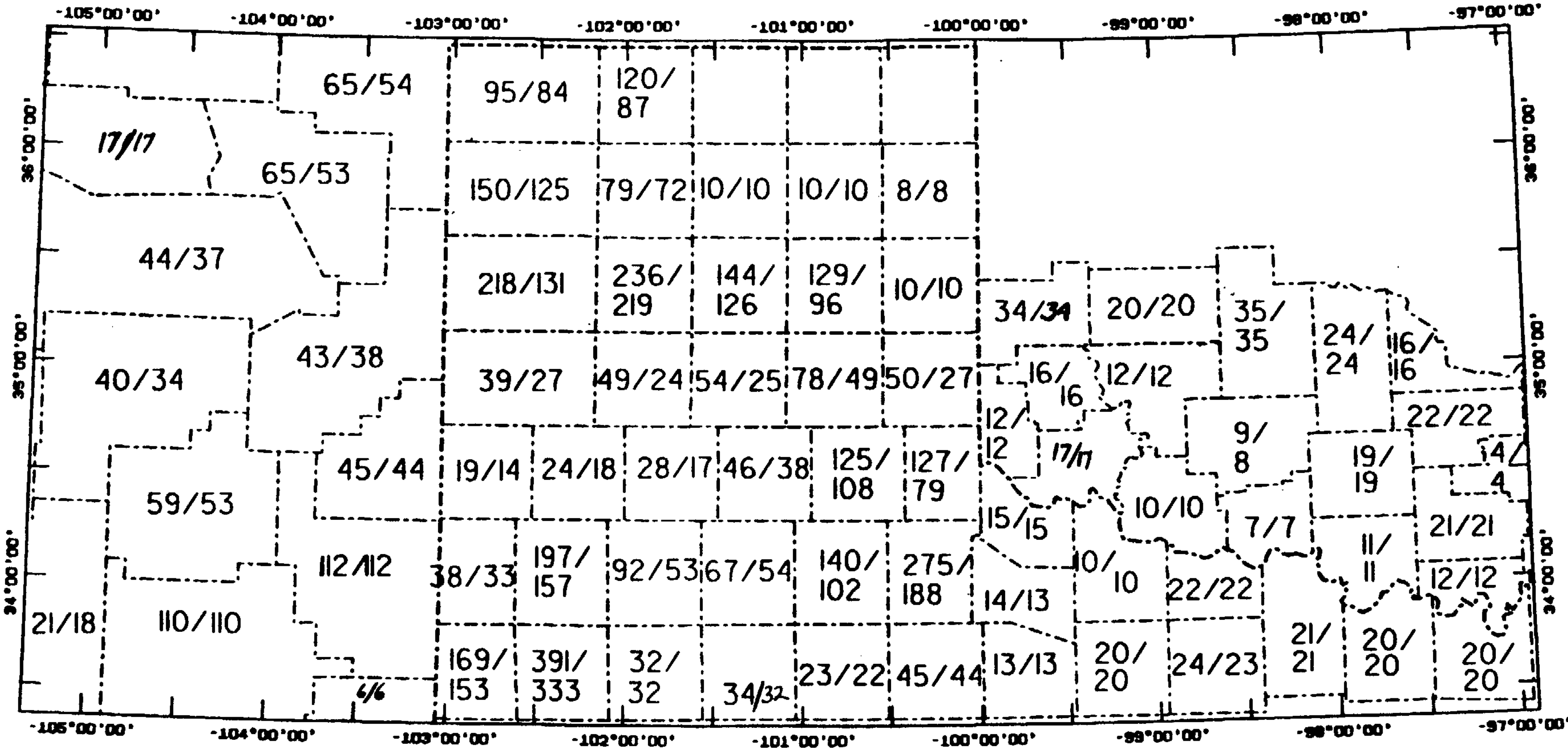


Texas : 3525
Oklahoma : 480
New Mexico : 659

TOTAL : 4624

LOCATION OF WELLS
IN DATA BASE

Figure 3



Number of wells with records/
Number of wells with geophysicallogs
4624/3849 in Data Base

COUNTY DISTRIBUTION
OF WELLS
Figure 4

SCHLUMBERGER

GAMMA RAY · NEUTRON

SCHLUMBERGER WELL SURVEYING CORPORATION

Houston, Texas

COMPANY SOCONY MOBIL OIL CO., INC.

WELL R. S. COON #6-M

FIELD PANHANDLE

COUNTY MOORE STATE TEXAS

Location (2) 1320' FR S & E/L

Sec. 106 BLK. 44 SURVEY H&TC

Other Services: S-GR-C (6) ML

Permanent Datum: GL (5) Elev. 3455.5

Log Measured From KB 8.5 Ft. Above Perm. Datum

Drilling Measured From KB

Elev.: K.B. 3464 D.F. 3463 G.L. 3455.5 (5)

Date	1-31-65 (3)
Run No.	ONE
Type Log	SCINT. - G-N
Depth—Driller	3500
Depth—Logger (4)	3506
Bottom logged interval	3501
Top logged interval	20
Type fluid in hole	STARCH
Salinity, PPM Cl	
Density	9.3
Level	FULL
Max rec. temp., deg F.	100°
Operating rig time	2 HRS
Recorded by	CARRELL
Witnessed by	BROWN & SIKMAN

BORE HOLE RECORD / CASING RECORD

Run No.	Bit	From	To	Size	Wgt.	From	To
1	8-1/4	3180	3500	7		3615	3165

Panhandle Electrical Log Service

Dallas & Texas

REFERENCE P8555E

IC COMPLETION RECORD

SPUD DATE

COMP DATE

DST RECORD

(1) 42-341-13997

PERMIAN BASIN GPM

ONWI

PTP No. 13697

P.O. No. L55921

Document I.D. M00-33

NOTES: (NUMBERS CROSS-REFERENCED TO WELL RECORD FORM - ATTACHMENT 4)

1. API NUMBER. NORMALLY FOUND BELOW DST RECORD OR ON STATE RRC RECORDS. USUALLY INCLUDES TWO DIGIT STATE NO. (TEXAS-42), THREE DIGIT COUNTY NO. (MOORE-341) AND FIVE DIGIT WELL NUMBER.
2. EXACT LOCATION OF WELL WITHIN A SECTION. 1320 FR S&E/L TRANSLATES TO 1320 FT FROM SOUTH LINE AND 1320 FT FROM EAST LINE. "SOUTH" AND "EAST" ARE CROSSED OUT ON THE WELL RECORD FORM.
3. DATE OF LOGGING RUNS, EXCLUDING COMPUTED LOGS SUCH AS CORIBAND OR CYBERLOOK. DO NOT ENTER DATE DRILLED.
4. DEPTH OF WELL MEASURED BY LOGGER - NOT BY DRILLER UNLESS THE DIFFERENCE IS MORE THAN 50 FT OR THE COMPLETION REPORT (W-3) INDICATES A DEEPER DEPTH AND/OR WELL WAS PLUGGED BACK (p.b.) BEFORE LOGGING.
5. REFERENCE ELEVATION FOR LOGS (NOTE K.B.-KELLEY BUSHING, D.F.-DECK FLOOR OR GL-GROUND LEVEL).
6. INDICATE OTHER LOGS RUN BUT NOT IN WELL FILE (USE ABBREVIATIONS ON ATTACHMENT 6)

State and County Abbreviations used for Well Identification Numbers

County Name	Abbreviations State	Abbreviations County
ARCHER	TX	ARC
ARMSTRONG	TX	ARM
BAILEY	TX	BAI
BAYLOR	TX	BAY
BRISCOE	TX	BRI
CARSON	TX	CAR
CASTRO	TX	CAS
CHILDRESS	TX	CHI
CLAY	TX	CLA
COCHRAN	TX	COC
COLLINGSWORTH	TX	COL
COOKE	TX	COO
COTTLE	TX	COT
CROSBY	TX	CRO
DALLAM	TX	DAL
DEAF SMITH	TX	DEA
DICKENS	TX	DIC
DONLEY	TX	DON
FLOYD	TX	FLO
FOARD	TX	FOA
GRAY	TX	GRA
HALE	TX	HAE
HALL	TX	HAL
HANSFORD	TX	HAN
HARDEMAN	TX	HDM
HARTLEY	TX	HAR
HEMPHILL	TX	HEM
HOCKLEY	TX	HOC
HUTCHINSON	TX	HUT
KING	TX	KIN
KNOX	TX	KNO
LAMB	TX	LAM
LIPSCOMB	TX	LIP
LUBBOCK	TX	LUB
MONTAGUE	TX	MON
MOORE	TX	MOO
MOTLEY	TX	MOT
OCHILTREE	TX	OCH
OLDHAM	TX	OLD
PARMER	TX	PAR
POTTER	TX	POT
RANDALL	TX	RAN
ROBERTS	TX	ROB
SHERMAN	TX	SHE
SWISHER	TX	SWI
WHEELER	TX	WHE
WICHITA	TX	WIC
WILBARGER	TX	WIL

County Name	Abbreviations State	Abbreviations County
CHAVES	NM	CHA
COLFAX	NM	CFX
CURRY	NM	CUR
DE BACA	NM	DEB
GUADALUPE	NM	GUA
HARDING	NM	HRD
LEA	NM	LEA
LINCOLN	NM	LIN
MORA	NM	MOR
QUAY	NM	QUA
ROOSEVELT	NM	ROO
SAN MIGUEL	NM	SAN
TORRANCE	NM	TOR
UNION	NM	UNI
BECKHAM	OK	BEC
CADDO	OK	CAD
CARTER	OK	CRT
COMANCHE	OK	COM
COTTON	OK	CTT
CUSTER	OK	CUS
GARVIN	OK	GAR
GRADY	OK	GDY
GREER	OK	GRE
HARMON	OK	HRM
JACKSON	OK	JAC
JEFFERSON	OK	JEF
JOHNSTON	OK	JOH
KIOWA	OK	KIO
LOVE	OK	LOV
MARSHALL	OK	MAR
MCCLAIN	OK	MCC
MURRAY	OK	MUR
STEPHENS	OK	STE
TILMAN	OK	TIL
WASHITA	OK	WAS

FILE CHECKLIST

PROJECT: Permian Basin JOB#: 13697 (1) DATE: FEB 24, 1984

STATE: TEXAS COUNTY: MOORE (2) LOCATION: 106, 44, H&TC

WELL#: (3) MOO-33 (4) WELL NAME: SOCONY-MOBIL R.S. COON #6M

☐	Sample Log # (5) ______	(10) Type of Log	Order #
☐	(6) Scout Ticket	GRN	P8555E
☐	(7) State Permits	SONIC-GR	P8555D
☐	(8) ______		
☐	______		
☐	(9) Completed Record Form		

NOTES:

1. DATE OF INVENTORY.
2. INCLUDE SECTION, BLOCK, TOWNSHIP, RANGE AND SURVEY.
3. SWEC WELL IDENTIFICATION NUMBER.
4. INCLUDE OPERATOR AND LEASE NAME.
5. CHECK IF LOG INCLUDED AND ITS SAMPLE NO.
6. CHECK IF SCOUT TICKETS ARE INCLUDED IN FILE.
7. CHECK IF STATE PERMIT OR APPLICATION FOR PERMIT IS INCLUDED (FORM 1, W-1).
8. OTHER STATE INFORMATION: INDICATE TYPE - PLAT, WR (WELL RECORD), DL (DRILLERS LOG) PR (PLUGGING RECORD), W-2, W-3, G-1.
9. CHECK IF SWEC WELL RECORD FORM GP-013081-2A IS INCLUDED.
10. TYPE OF LOG AND REFERENCE ORDER NO. USE ABBREVIATIONS SHOWN ON ATTACHMENT 6.

WELL RECORD
STONE & WEBSTER ENGINEERING CORP.
FORM GP-013081-2A

STATE: TEXAS
COUNTY: MOORE
PERMIT NO. (1) 42-341-19997
OPERATOR: MOBIL OIL
LEASE: R.S. COON #6-M
(2) 1320 FEET NORTH/~~SOUTH~~
1320 FEET ~~EAST~~/ WEST
DATE DRILLED (3) 1-31-65
TOP OF ROCK (EL.):
DEPTH OF WELL (4) 3504
ELEVATION/REFERENCE (DF, GL, ETC) (5) 3452 KB

RECORDS / LOGS AVAILABLE: IIL (6)
LOGS IN HOUSE: BL-GR-C, GRN

SALT FROM (7) GRN
LOG QUALITY (8) POOR
(9) LOGS INTERPRETED BY BJM 2-24-83
LOGS CHECKED (10)
RECHECKED
LOCATION CHECKED (10)
RECHECKED

SECTION: 106 AGGREGATE SALT (11) 87' WELL NO. MOO-33
BLOCK/~~TWP~~: 44 DEEPEST FORMATION PENETRATED: WOLFCAMP
SURVEY/~~RANGE~~: H & TC LATITUDE 035.1467 LONGITUDE -101.6328

FORMATION RECORD

FORMATION	DEPTH (TOP-BOT)	TOP EL	FORMATION	DEPTH (TOP-BOT)	TOP EL
			CLEAR FORK GP.		
			GLORIETA	1048-1303?	
OGALLALA	S-327		U. CLEAR FORK	1303?-1562	
DAKOTA GROUP			TUBB	1562-1689	
			L. CLEAR FORK	1689-1812	
FREDRICKSBURG			RED CAVE	1812-2337	
TRINITY					
			WICHITA	2337-2678	
MORRISON			WOLFCAMP	2678-T.D.	
EXETER			PENNSYLVANIAN		
			MISSISSIPPIAN		
DOCKUM			ELLENBURGER		
TRUJILLO			CAMBRIAN SS.		
TECOVAS			PRECAMBRIAN		
SANTA ROSA					
DEWEY LAKE	327-368				
ALIBATES	368-390				
WHITEHORSE GP.					
SALADO	390-417				
YATES	417-448				
U. SEVEN RIVERS	448-474				
L. SEVEN RIVERS	474-616				
QUEEN/GRAYBURG	616-745				
U. SAN ANDRES	745-910				
L. SAN ANDRES	910-1048				

AGGREGATE SALT THICKNESS	87'
NUMBER OF LAYERS	3
THICKER THAN 5 FEET	3
THICKER THAN 20 FEET	2
DEPTH TO THICKEST LAYER	1450
THICKNESS OF THICKEST LAYER	52
ELEVATION OF THICKEST LAYER	

SEE PAGE 2 FOR NOTES.

SALT INFORMATION

FORMATION	SALT ELEV.	SALT DEPTH	SALT THICK
U. CLEAR FORK		1450-1502	52'
		1552-1562	10'
L. CLEAR FORK		1787-1812	25'

TOTAL SALT

FORMATION	THICKNESS	FORMATION	THICKNESS
SALADO	0		
SEVEN RIVERS	0		
U. SAN ANDRES	0		
L. SAN ANDRES	0		
GLORIETA	0		
U. CLEAR FORK	62'		
TUBB	0		
L. CLEAR FORK	25'		

N=310, F= LSA 5, FTOP= 910, FBOT= 983
N=330, F= LSA 4, FTOP= 983, FBOT= 1048
N=350, F= LSA 3, FTOP= 1048, FBOT= 1048 A
N=370, F= LSA 2, FTOP= 1048, FBOT= 1048 A
N=390, F= LSA 1, FTOP= 1048, FBOT= 1048 A

ADDITIONAL INFORMATION

NOTES:

1 THRU 6 - SEE ATTACHMENT 1
7. INDICATE LOG(S) FROM WHICH SALT BEDS WERE DETERMINED.
8. INDICATE GOOD, FAIR OR POOR.
9. INITIALS OF INTERPRETER AND DATE.
10. DATE AND INITIALS OF INDIVIDUAL WHO CHECKS THE INTERPRETATION AND LOCATION (ONLY WHEN RRC RECORDS ARE AVAILABLE).
11. FILLED IN ONLY IF INTERPRETER IS CERTAIN THAT THE GEOPHYSICAL LOG COVERS THE ENTIRE SALT SECTION. NUMBER OBTAINED FROM "SALT INFORMATION" SECTION OF FORM.

GP-122982-2 (FRONT)

NOTIFICATION OF CHANGES TO THE OIL & GAS WELLFILE

NEW ELEV AND REF		WELL #	(1)
NEW LATITUDE	(2)	COUNTY	
NEW LONGITUDE		STATE	
TOTAL AGGREGATE SALT		OLD WELL # (IF CHANGED)	(1)

1. CHANGES OR ADDITIONS TO FORMATION PICKS (4)

NO.	FORMATION	NAME? (3)	TOP	A/S/?	BOTTOM (5)	T/?
0	SURFACE					
5	COLORADO	NOTES:				
10	DAKOTA					
25	TRINITY	1.	FOR CHANGES TO WELL NUMBERS, BOTH OLD AND NEW NUMBERS			
40	MORRISON		MUST BE ENTERED. FOR NEW WELLS, ATTACH A COPY OF THE			
50	EXETER		WELL RECORD FORM. (SEE SECTION 3.3).			
55	CHINLE	2.	LATITUDE MUST BE PREFACED WITH AN "0" AND LONGITUDE			
60	DOCKUM		WITH A (-), I.E., 035.1467 AND -101.6328.			
75	SANTA ROSA	3.	IF THE FORMATION IS A NEW LISTING, THE "NAME" COLUMN			
100	DEWEY LAKE		SHOULD BE CHECKED.			
110	ALIBATES	4.	USE "S" IF THE TOP OF THE FORMATION IS AT THE SURFACE.			
120	SALADO		ABSENT FORMATIONS ARE ASSIGNED THE SAME TOP AND BOTTOM			
130	YATES		DEPTHS AND ANNOTATED WITH AN "A". A QUESTIONABLE OR			
140	U SEVEN RIVER		INDETERMINATE BOTTOM/TOP PICK SHOULD BE ANNOTATED WITH			
150	L SEVEN RIVER		A QUESTION MARK IN THE APPROPRIATE COLUMN.			
160	QUEEN/GRAY	5.	FORMATIONS THAT ARE NOT FULLY PENETRATED SHOULD BE LEFT			
170	U SAN ANDRES		BLANK FOR THE BOTTOM DEPTH AND ANNOTATED BY A "T".			
200	L SAN ANDRES	6.	SWEC DEFINITION OF TARGET SALT BED IS A SALT BED THAT			
310	LSA 5		IS AT LEAST 75 FT THICK, WITH NONSALT INTERBEDS IN-			
330	LSA 4		DIVIDUALLY NOT EXCEEDING 10 FT THICK, AND CUMULATIVELY			
350	LSA 3		NOT EXCEEDING 15 PERCENT OF THE TOTAL BED THICKNESS.			
370	LSA 2		FOR FORMATIONS LACKING TARGET SALT, THE FORMATION			
390	LSA 1		TOP DEPTH SHOULD BE ENTERED IN BOTH THE "TOP" AND			
395	FLOWERPOT		"BOTTOM" COLUMNS.			
410	GLORIETA	7.	THE NAME COLUMN SHOULD BE CHECKED IF THE FORMATION IS A			
420	U CLEAR FORK		NEW LISTING.			
430	TUBB	8.	TOTAL SALT THICKNESS DOES NOT INCLUDE ANY NONSALT			
440	L CLEAR FORK		INTERBEDS.			
450	RED CAVE	9.	AGGREGATE SALT THICKNESS OF EACH SALTBEARING FORMATION.			
451	MATADOR		THE TOTAL OF ALL SALT THICKNESSES IS ENTERED ON THE			
452	U SPRAYBERRY		FRONT PAGE OF THIS FORM.			
453	SPRAYBERRY	10.	TO DELETE A FORMATION, SALT DEPTH, OR OTHER DATA, PUT A			
454	L SPRAYBERRY		CENT SIGN "¢" IN THE APPROPRIATE COLUMN.			
456	DEAN					
460	WICHITA					
470	WOLFCAMP					
500	PENNSYLVANIAN					
600	MISSISSIPPIAN					
603	KINDERHOOK					
605	WOODFORD					
610	FUSSELMAN					
612	HUNTON					
614	SYLVAN					
615	MONTOYA					
620	VIOLA					
640	SIMPSON					
700	ELLENBURGER		(10) ¢		(10) ¢	
730	DEVONIAN					
760	SILURIAN					
790	ORDOVICIAN					
800	CAMBRIAN					
900	PRECAMBRIAN					

OP-112981-2 (BACK)

2. CHANGES OR ADDITIONS TO TARGET SALT PICKS ⑥ WELL #

NO.	FORMATION		NAME?	TOP	A/?	BOTTOM	?	SALT= ⑧
125	SALADO	TGT	⑦					
145	U7R	TGT						
175	USA	TGT						
315	LSA 5	TGT						
335	LSA 4	TGT						
355	LSA 3	TGT						
375	LSA 2	TGT						
415	GLORIETA	TGT						
425	U CLEAR FK	TGT						
445	L CLEAR FK	TGT						

3. CHANGES OR ADDITIONS TO 85% PURE SALT PICKS

NO.	FORMATION		NAME?	TOP	A/?	BOTTOM	?	SALT=
901	USA	TK						
902	SALADO	TK						
904	U7R	TK						
906	USA	TK						
908	LSA 5	TK						
910	LSA 4	TK						
912	LSA 3	TK						
914	LSA 2	TK						
916	LSA 1	TK						
918	GLORIETA	TK						
920	UCF	TK						
922	LCF	TK						
930	YATES	TK						
932	Q/G	TK						
934	TUBB	TK						

4. CHANGES OR ADDITIONS TO AGGREGATE SALT THICKNESSES

NO.	FORMATION		NAME?		THICKNESS
214	SALADO	SALT		0	⑨
215	U7R	SALT		0	
216	L7R	SALT		0	
217	USA	SALT		0	
218	LSA	SALT		0	
219	GLOR	SALT		0	
220	UCF	SALT		0	
221	TUBB	SALT		0	
222	LCF	SALT		0	
223	YATES	SALT		0	
224	Q/G	SALT		0	

5. CHANGES OR ADDITIONS TO FIRST SALT DEPTHS

NO.	FORMATION	NAME?	DEPTH TO FIRST SALT
240	USA FIRST		
241	LSA 5 FIRST		
242	LSA 4 FIRST		

6. CHANGES OR ADDITIONS TO EVAPORITE SEQUENCES ABOVE AND BELOW TARGET SALT

NO.	FORMATION	NAME?	TOP	BOTTOM
1	ABOVE			
999	BELOW			

7. ADDITIONAL CHANGES

NO.	FORMATION	NAME?					

GEOPHYSICAL WELL LOG ABBREVIATIONS

SCHLUMBERGER

INDUCTION-ELECTRICAL SURVEY	IES
INDUCTION-SPHERICALLY FOCUSED LOG	ISF*
DUAL INDUCTION-LATEROLOG*	DIL
DUAL INDUCTION-SPHERICALLY FOCUSED LOG	DISF
DUAL LATEROLOG*	DLL*
MICROLOG*	ML
MICROLATEROLOG*	MLL
PROXIMITY* LOG	PL
MICRO-SPHERICALLY FOCUSED LOG	MICROSFL*
FORMATION DENSITY LOG	FDC*
COMPENSATED NEUTRON LOG	CNL*
SIDEWALL NEUTRON POROSITY LOG	SNP*
BOREHOLE COMPENSATED SONIC LOG	BHC*
LONG-SPACED SONIC	LSS*
NATURAL GAMMA RAY SPECTROMETRY	NGS*
ELECTROMAGNETIC PROPAGATION LOG	EPT*
HIGH RESOLUTION DIPMETER	HDT*
CONTINUOUS DIRECTIONAL SURVEY	CDR
WELL SEISMIC TOOL	WST*
FORMATION INTERVAL TESTER	FIT*
REPEAT FORMATION TESTER	RFT*
SIDEWALL SAMPLER	CST

WELLEX-DRESSER ATLAS

GAMMA-GUARD	G/G
INDUCTION-ELECTRIC LOG	IEL
COMPENSATED ACOUSTIC VELOCITY (WITH GAMMA RAY)	C/AUL/(GR)
COMPENSATED DENSITY LOG (WITH GAMMA RAY)	CDL/(GR)
FORXO	FORXO
RADIOACTIVITY	GRN
DENSITY (WITH GAMMA RAY)	DEN/(GR)
COMPENSATED DENSITY-NEUTRON LOG (WITH GAMMA RAY)	CDL/N/(GR)
SIDEWALL NEUTRON (WITH GAMMA RAY)	SWN(-GR)
COMPENSATED DENSITY, DUAL SPACED NEUTRON (WITH GAMMA RAY)	CD-DSN(-GR)
BOREHOLE COMPENSATED ACOUSTIC LOG (WITH GAMMA RAY)	BHC-AL/(GR)

FRONTIER

GAMMA RAY-NEUTRON	GRN
DENSITY (WITH GAMMA RAY)	DEN(-GR)
TEMPERATURE (WITH GAMMA RAY)	TEMP(-GR)

LANE

DENSILOG (WITH GAMMA RAY)	GDC
GAMMA RAY-NEUTRON	GR/NN
RADIOACTIVITY	GR/NN
DIFFERENTIAL TEMPERATURE	DIFF-TEMP

NOTES:

(1) SPECIAL LOGS, SUCH AS CORIBAND, CYBERLOOK, AND SPECTRALOG, SHOULD BE SPELLED OUT (NO ABBREVIATION).

(2) VARIOUS CEMENT BOND LOGS EXIST. SUCH ABBREVIATIONS WOULD BE:

CEMENT BOND	CB
CEMENT BOND EVALUATION	CBE
ACOUSTIC CEMENT BOND EVALUATION	ACCBE
ACOUSTIC CEMENT BOND	ACCB

(3) MOST OF SCHLUMBERGER LOGS ARE RUN IN COMBINATION. FOR EXAMPLE:

DUAL LATERLOG_MICRO SFL_MICROLATERLOG	DLL-MSFL-MLL
COMPENSATED NEUTRON-FORMATION DENSITY (WITH GAMMA RAY)	CNL-FDC(-GR)

(4) HYDROCARBON MUD LOG — HC

(5) GAMMA RAY — GR

* MARK OF SCHLUMBERGER

Long (18)

PALO DURO BASIN PROJECT

INTERPRETATION OF SEISMIC DATA

1. VELOCITY DATA - Assemble, classify and integrate vertical velocity data with subsurface data. Reduce velocity data to a common reference datum. Determine reflection times for subsurface geologic markers at points of control.
2. MAPPING HORIZONS - Identify and select the reflections/subsurface horizons to be mapped. (USA, LSA1, Wc and PreC)
3. SUBSURFACE REFLECTION TRAVERSES - Identify and mark the reflection horizons to be mapped on the seismic sections. Close all seismic subsurface traverses by adjusting to compensate for loop misclosures. Revise seismic time horizons as required to tie at points where velocity and electric log data are available. Time the seismic horizons at appropriate intervals and post the times to a base map.
4. STRUCTURAL CONFIGURATION - Contour time maps.
5. SECONDARY ADJUSTMENTS - Utilizing the horizon dip attitudes indicated by the time structure maps, project and tie the horizons to offline points of velocity/subsurface control making adjustments to the seismic horizons and contour maps as required.
6. APPARENT AVERAGE VELOCITY MAPS - Determine the apparent average velocity to each mapped horizon at each well within the survey from the contoured time value of the horizon at the well and the depth of the corresponding subsurface marker. Post these values to a base map and contour the apparent average velocity configuration for each mapped horizon. The differences in apparent average velocity observed over the area represent a combination of lateral changes in the vertical velocity gradient and unresolved near surface corrections.
7. TIME-DEPTH CONVERSION - For each mapped horizon compare the time map postings with the apparent average vertical velocity configuration, determine the average velocity at that station, and convert reflection times to depths. Post these values to the base map. Prepare isopach maps and depth maps for each horizon.

Bruno (19)

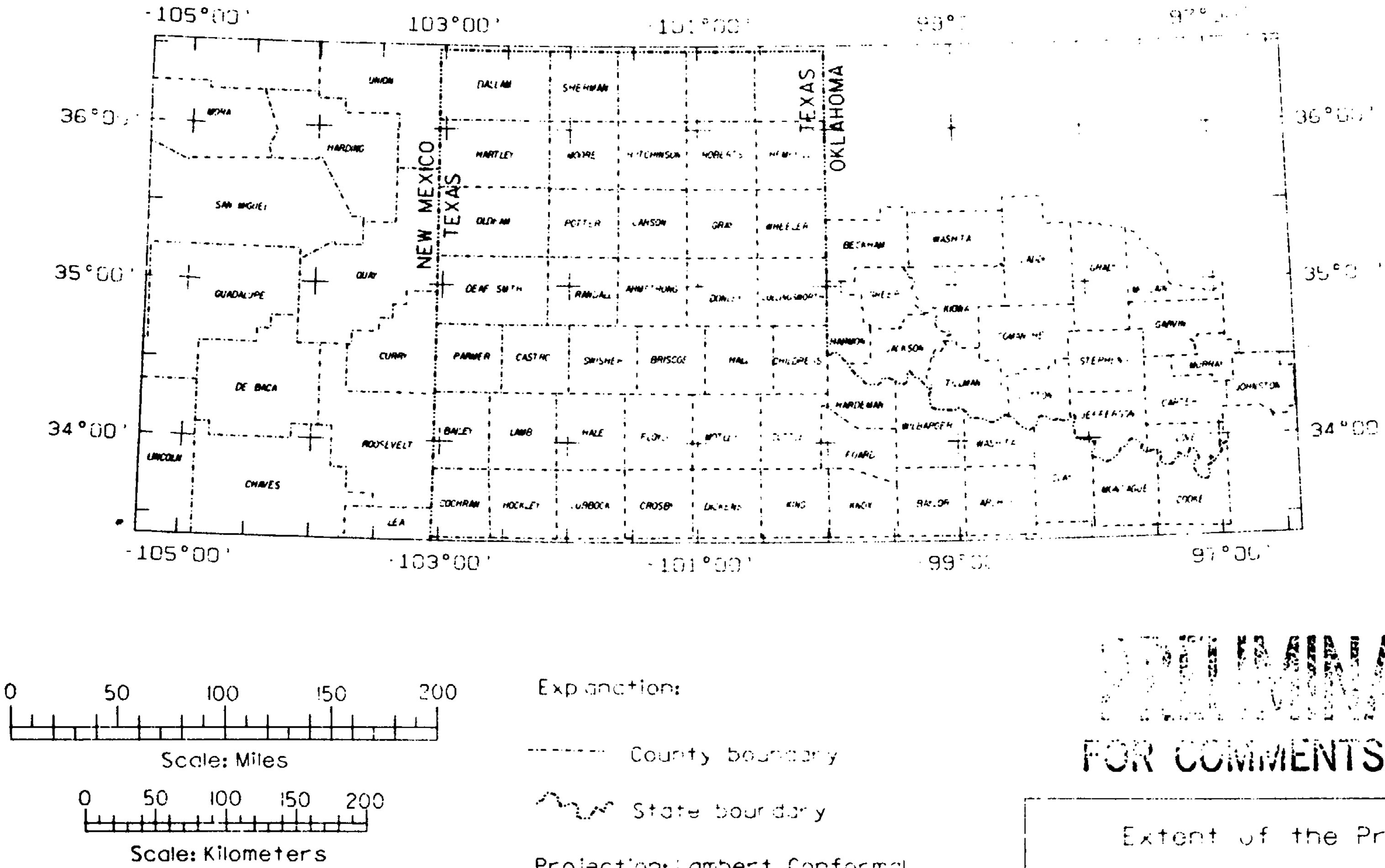
NRC WORKSHOP
November 19 - 21, 1985
Mapping from Geologic Data Base

I. Figures from previous reports

* Study Area
* X - Sections
* Block Diagrams
* Fence Diagrams

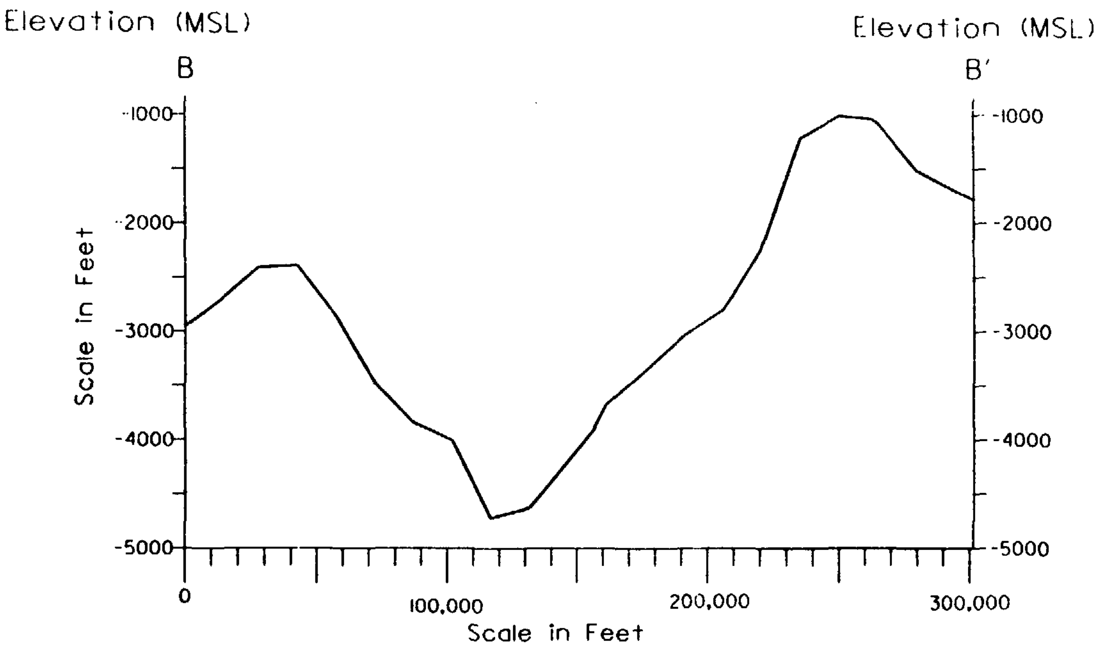
II. How these figures are made

* Data base
  - Geologic Interpretation
  - Procedures for Verification
* Preliminary Maps
  - Surface II Postings of data values
  - Surface II contours (thickness and elevation)
  - X-sections
* Hand drawn maps and sections
* finalized maps
  - Checking procedures



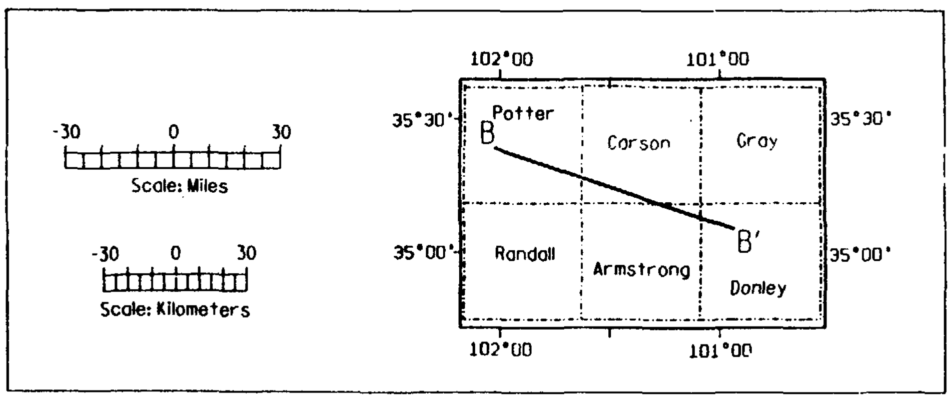
FOR COMMENTS ONLY

Extent of the Project Study Area



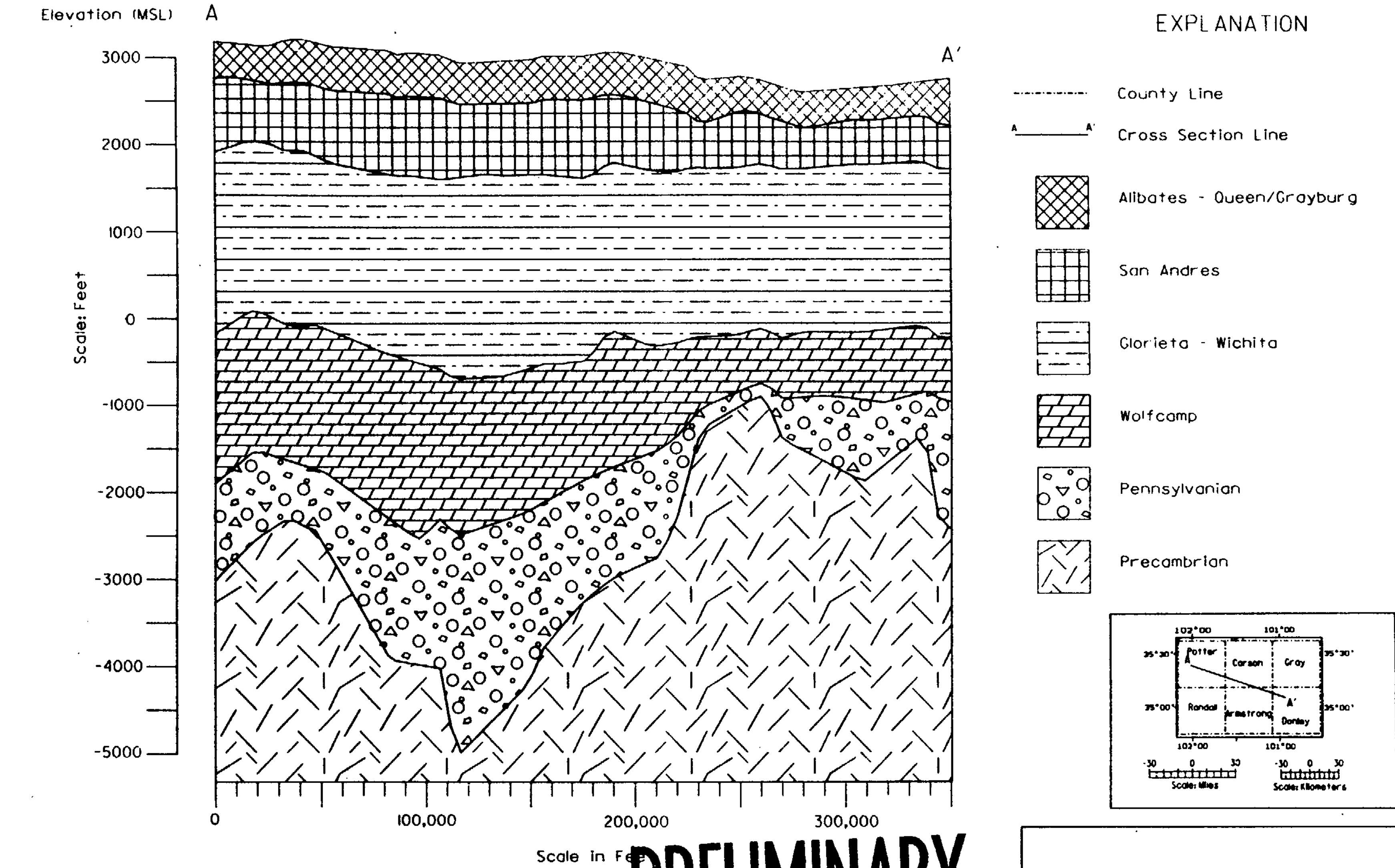
Note:

Vertical Exaggeration: 500x

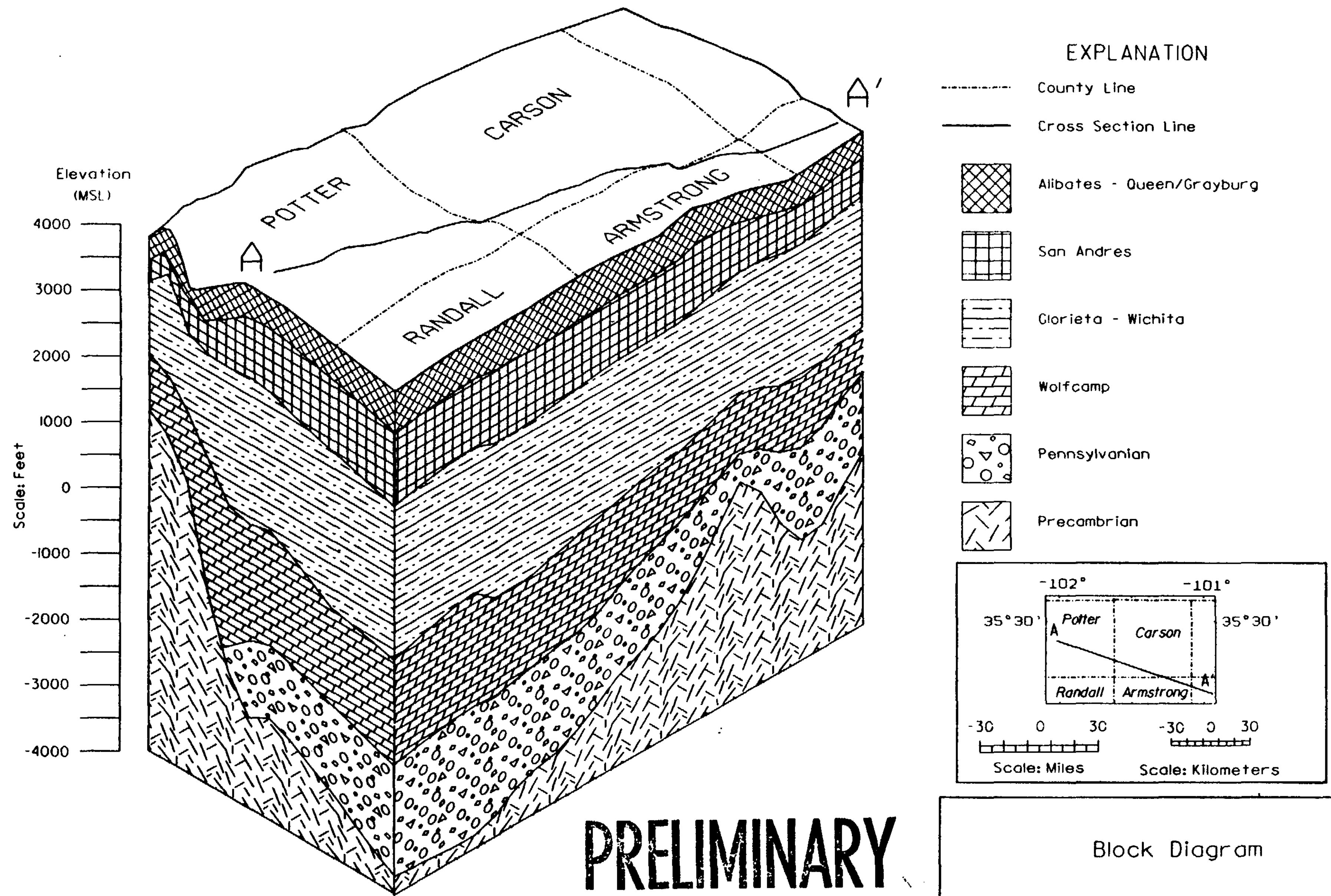


PRELIMINARY
COMMENTS ONLY

Cross Section of
a Single Horizon

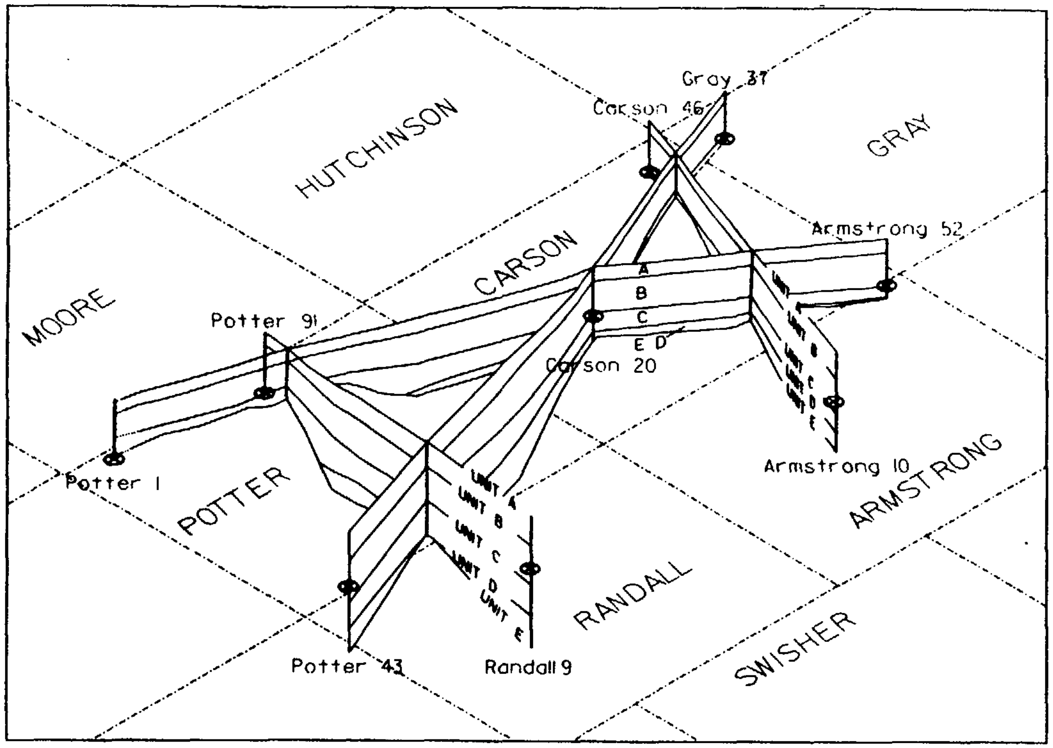


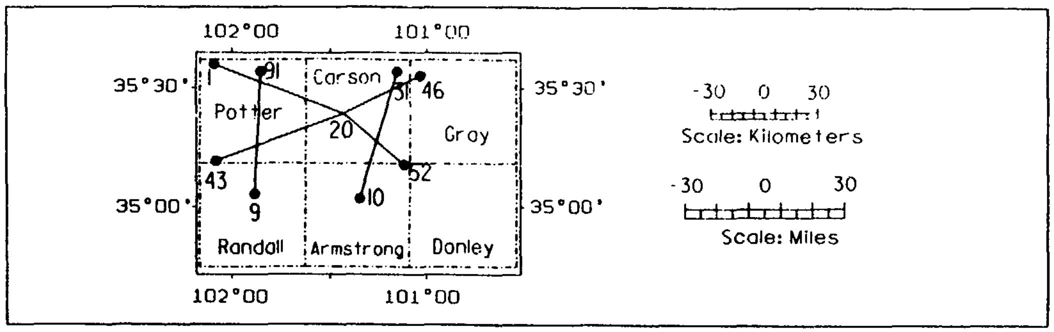
Patterned Cross Section



PRELIMINARY
FOR COMMENTS ONLY

Block Diagram





EXPLANATION

UNIT A: Alibates - San Andres

UNIT B: Glorieta - Wichita

UNIT C: Wolfcamp

UNIT D: Pennsylvanian

UNIT E: Precambrian

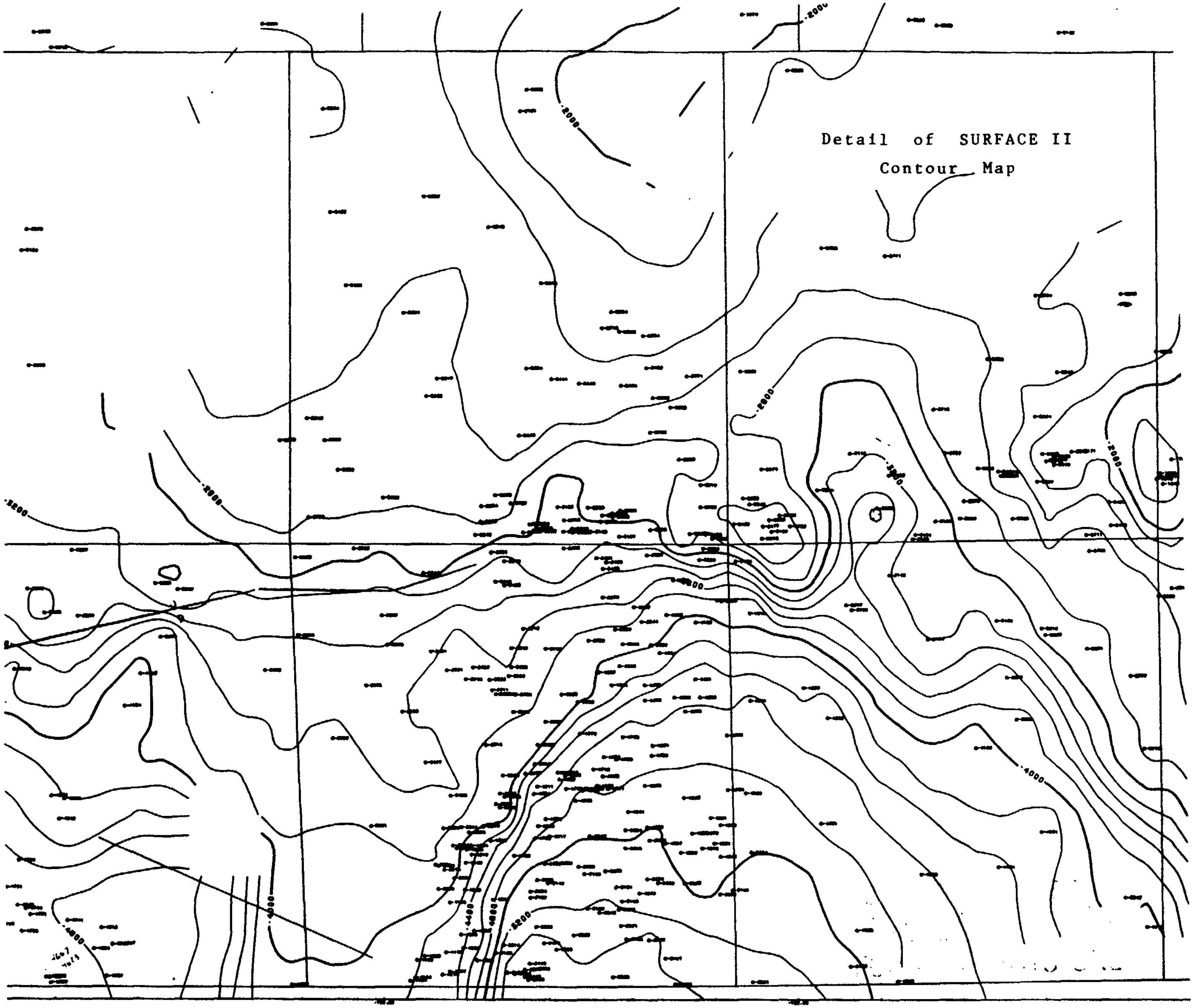
⊕ Well Symbol

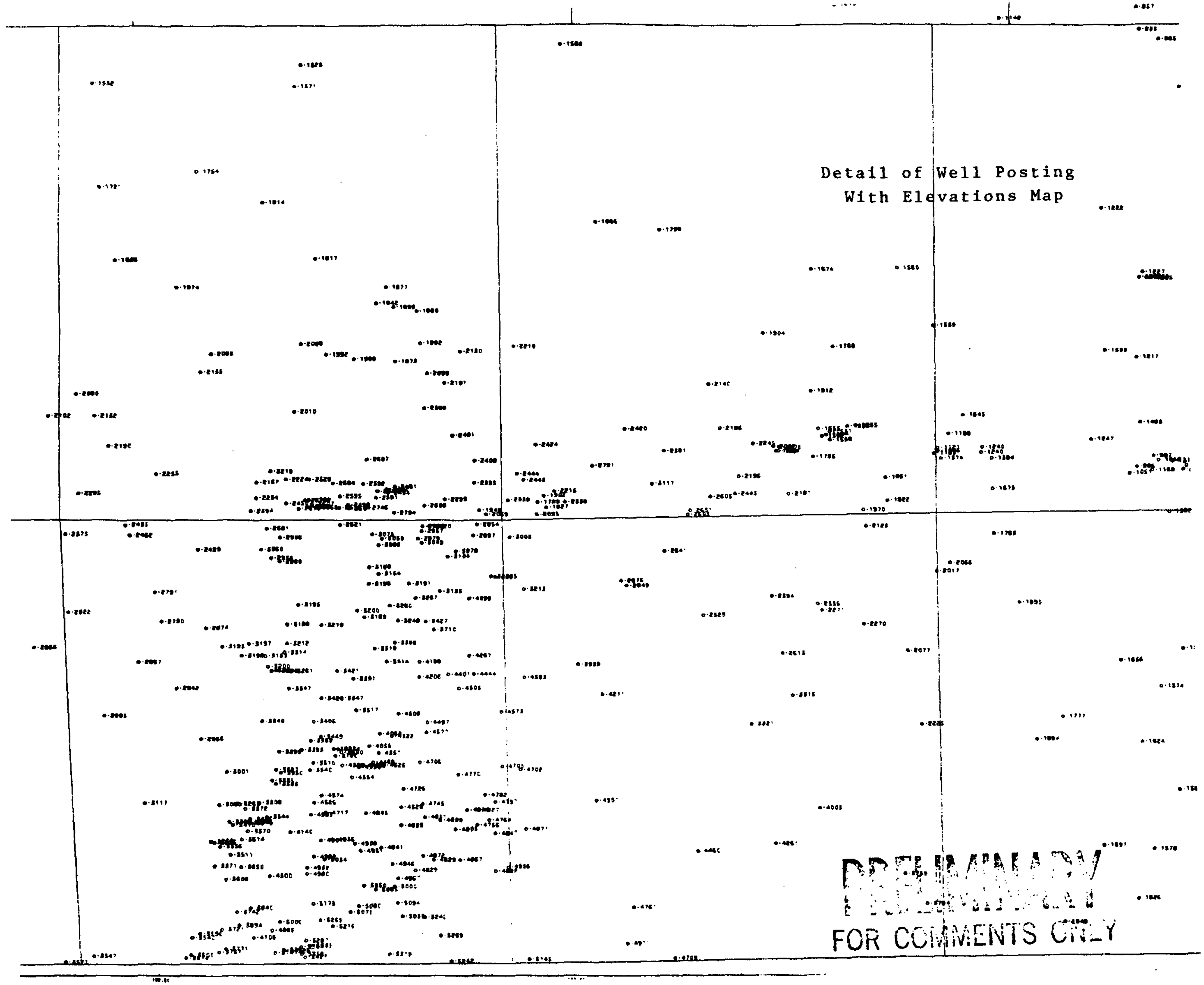
Note: Well symbols are at elevation 0 (MSL).

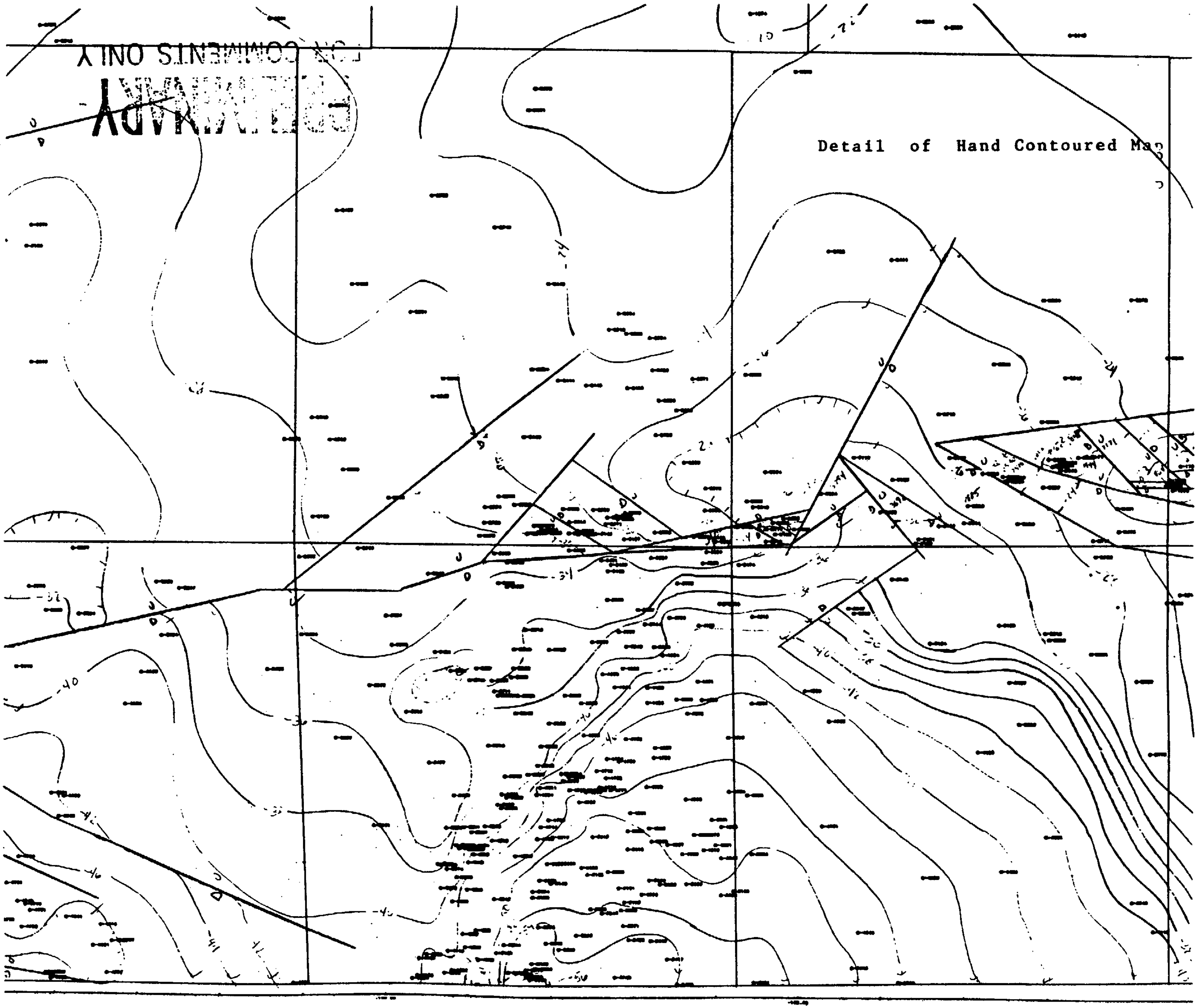
PRELIMINARY
FOR COMMENTS ONLY

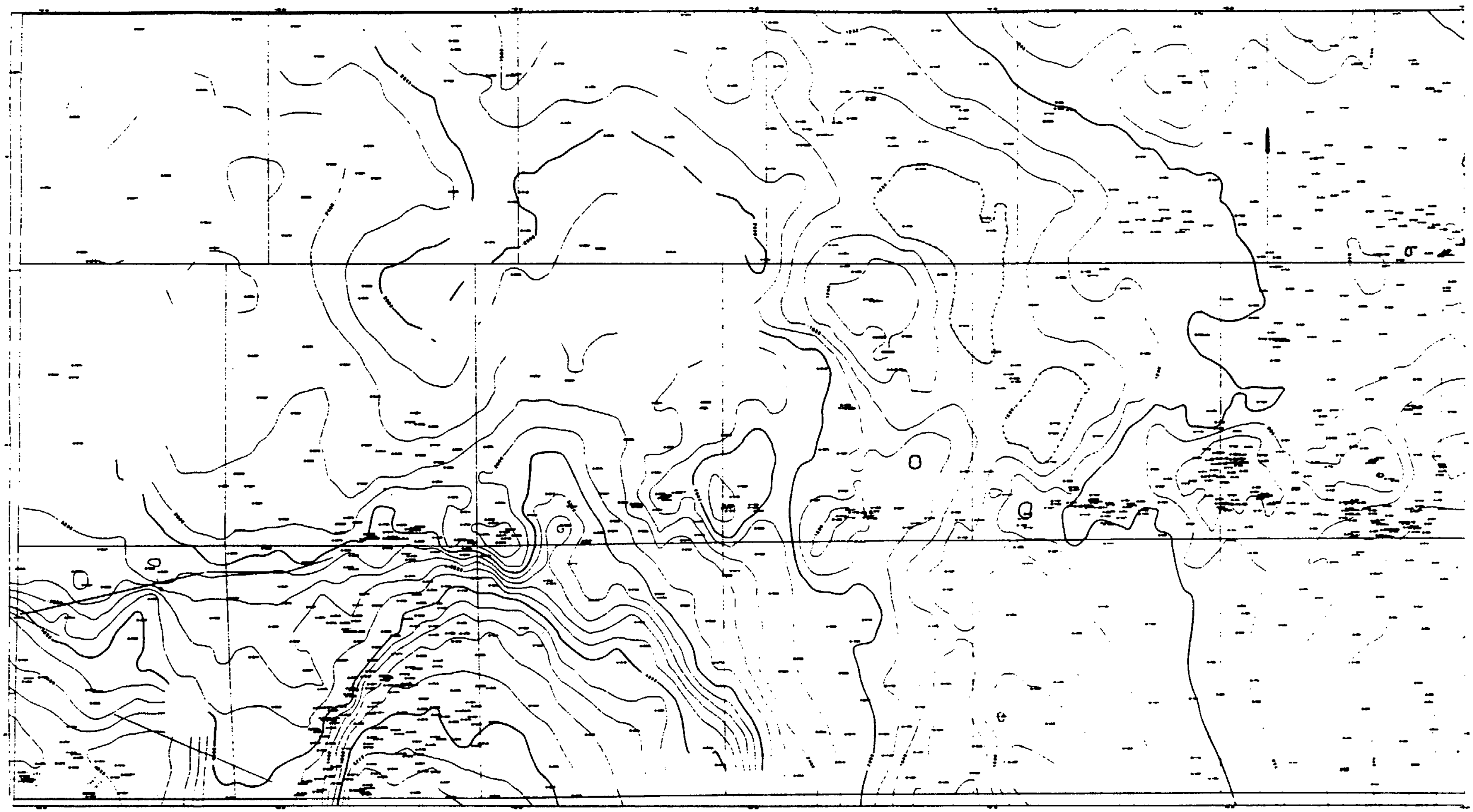
Fence Diagram

Detail of SURFACE II
Contour Map

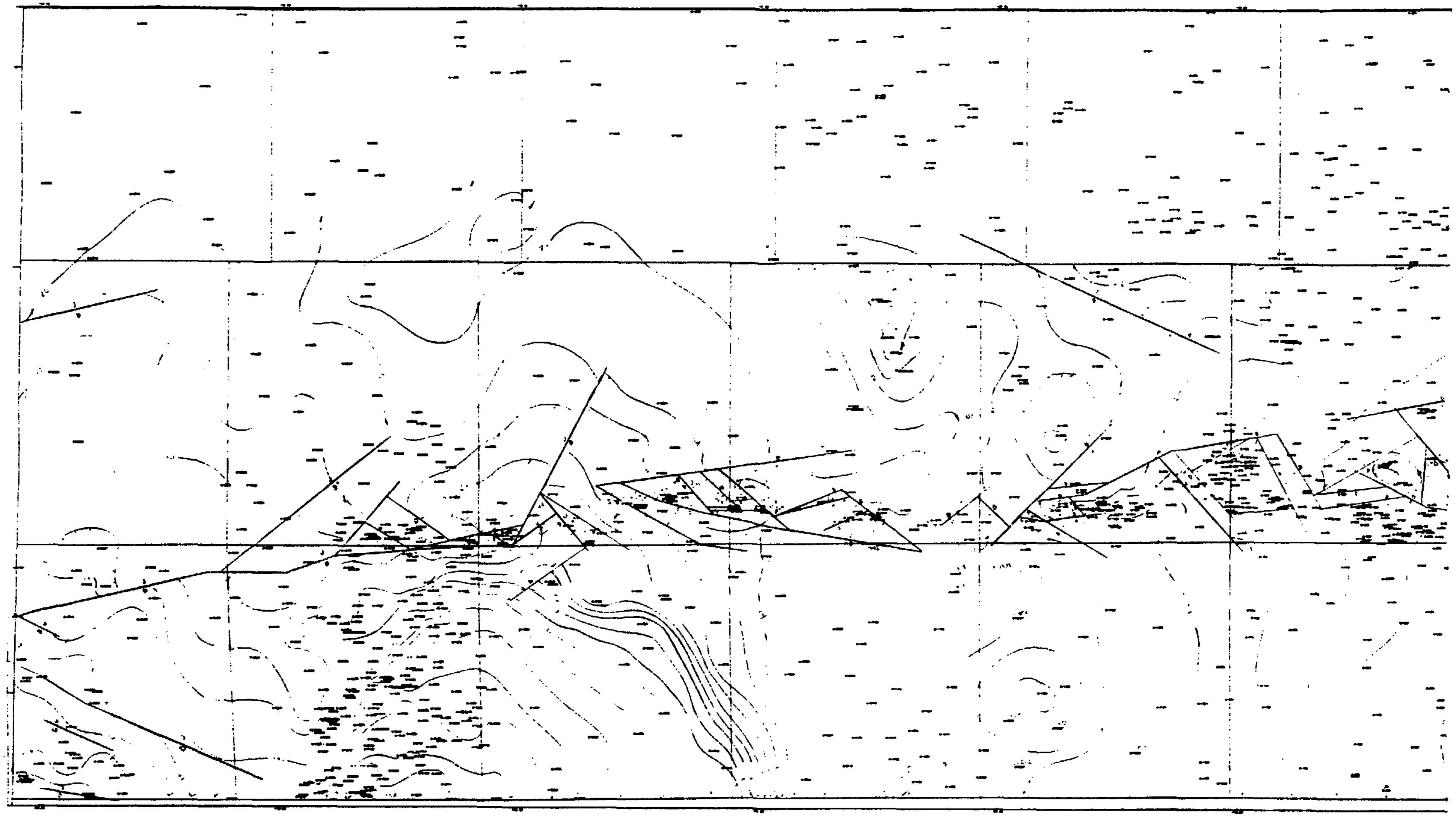



Detail of Well Posting
With Elevations Map
FOR COMMENTS ONLY


Detail of Hand Contoured Map
PRELIMINARY
FOR COMMENTS ONLY

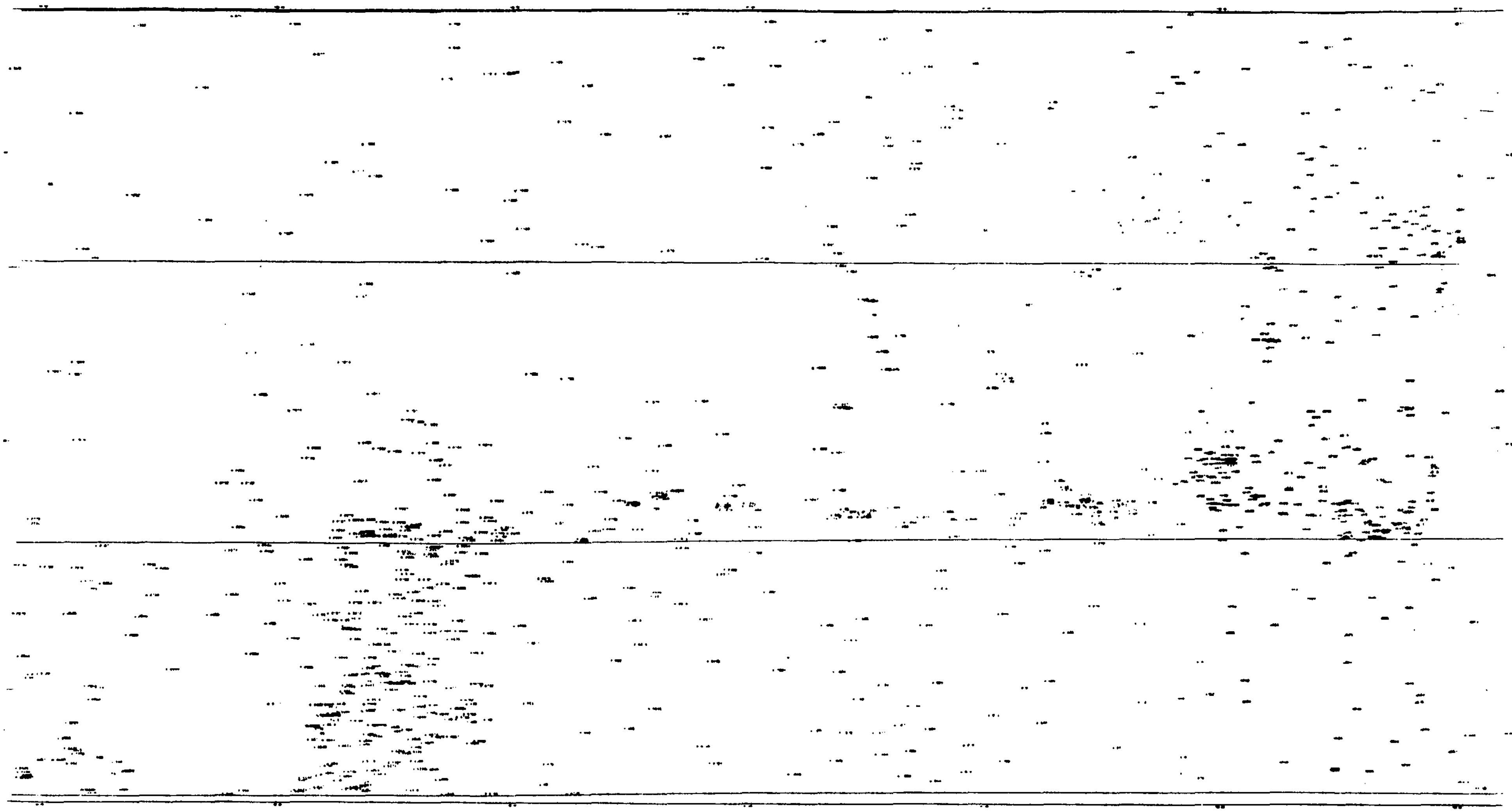


SURFACE II Contour Map

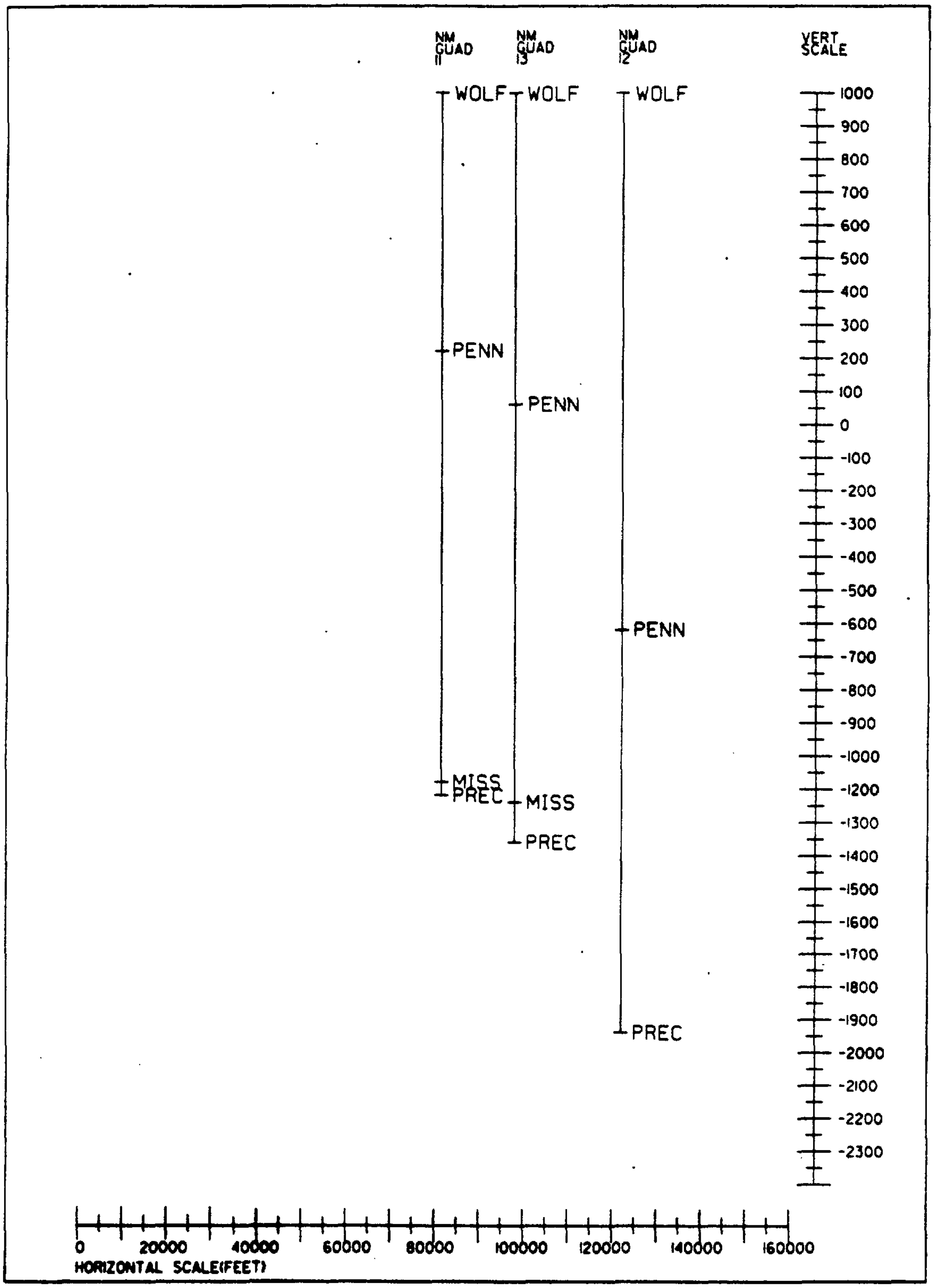


Hand Drawn Contour Map
Based on SURFACE II Map

PRELIMINARY
FOR COMMENTS ONLY

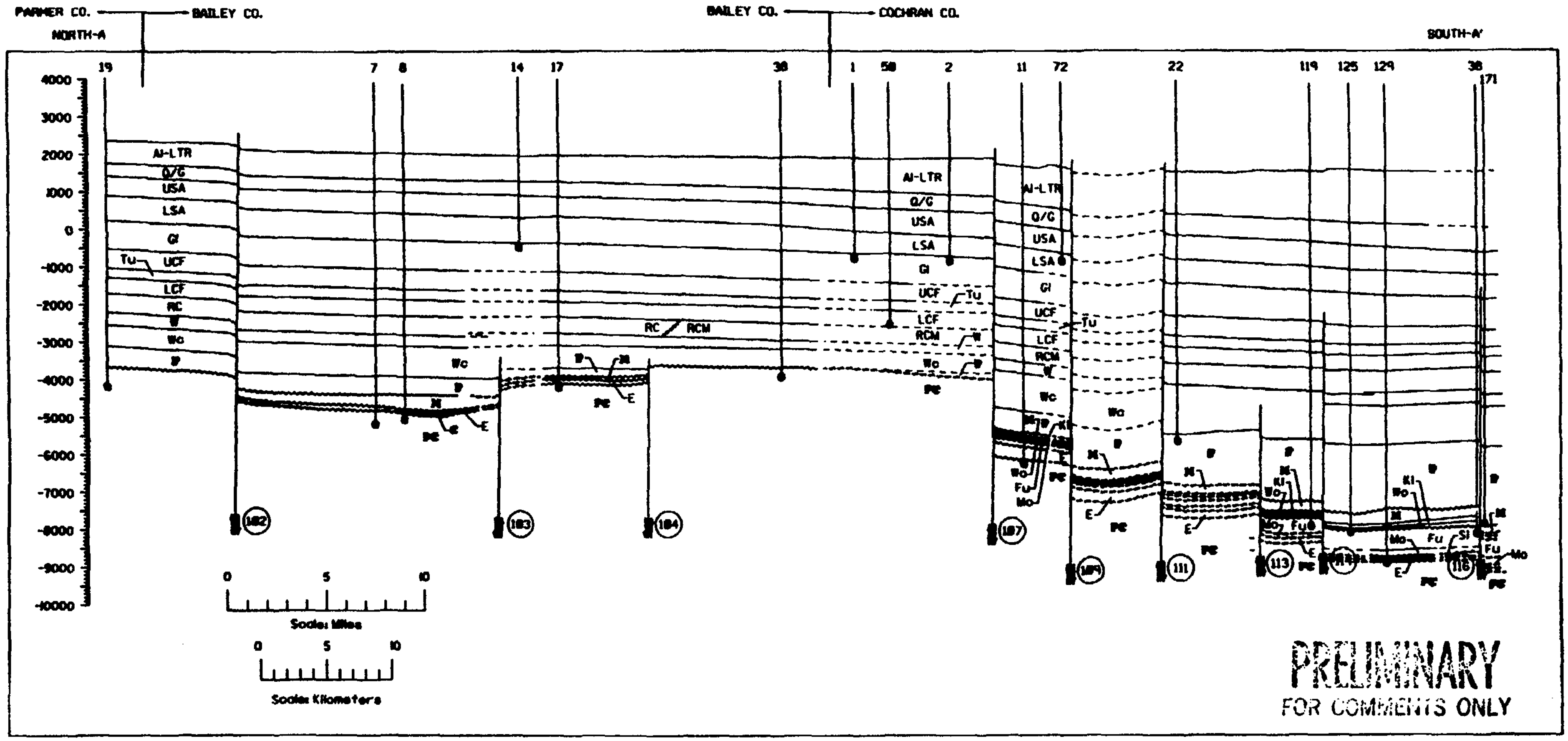


Well Posting Map with Z Values



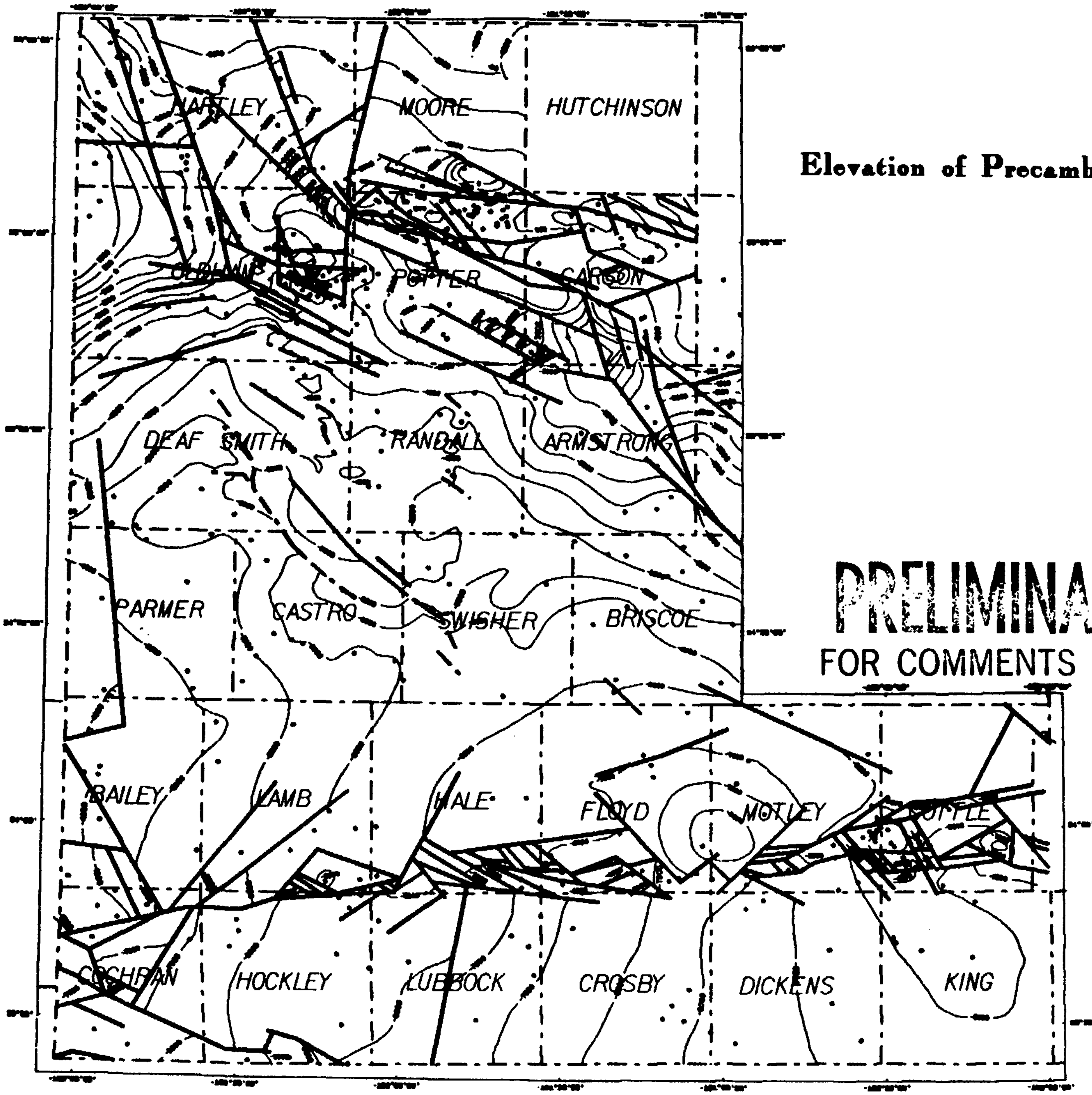
PRELIMINARY
FOR COMMENTS ONLY

Example of WELLMAP
Cross Section

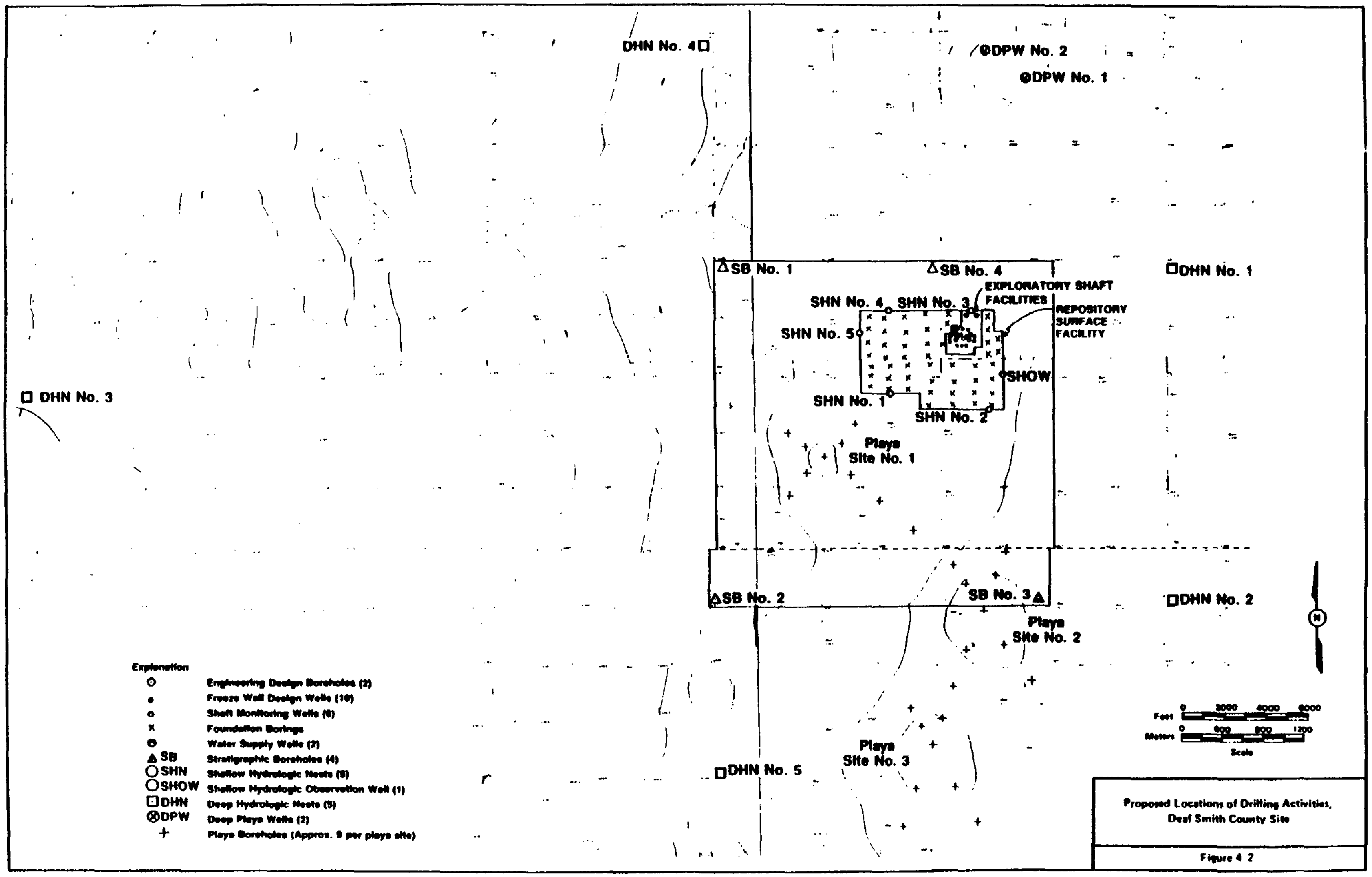


PARMER CO.
BAILEY CO.
NORTH-A
BAILEY CO.
COCHRAN CO.
SOUTH-A'
19
7
8
14
17
38
1
58
2
11
72
22
119
125
129
38
171
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
Al-LTR
Q/G
USA
LSA
Gl
UCF
LCF
RC
RCM
Tu
Wc
E
Fu
Mo
Kl
Sl
182
183
184
187
109
111
113
114
116
0
5
10
Scale: Miles
Scale: Kilometers
PRELIMINARY
FOR COMMENTS ONLY

Elevation of Precambrian



PRELIMINARY
FOR COMMENTS ONLY



Proposed Locations of Drilling Activities, Deaf Smith County Site

Figure 4 2

A larger reproduction of this figure appears at the back of this volume.

Ballmann (20)

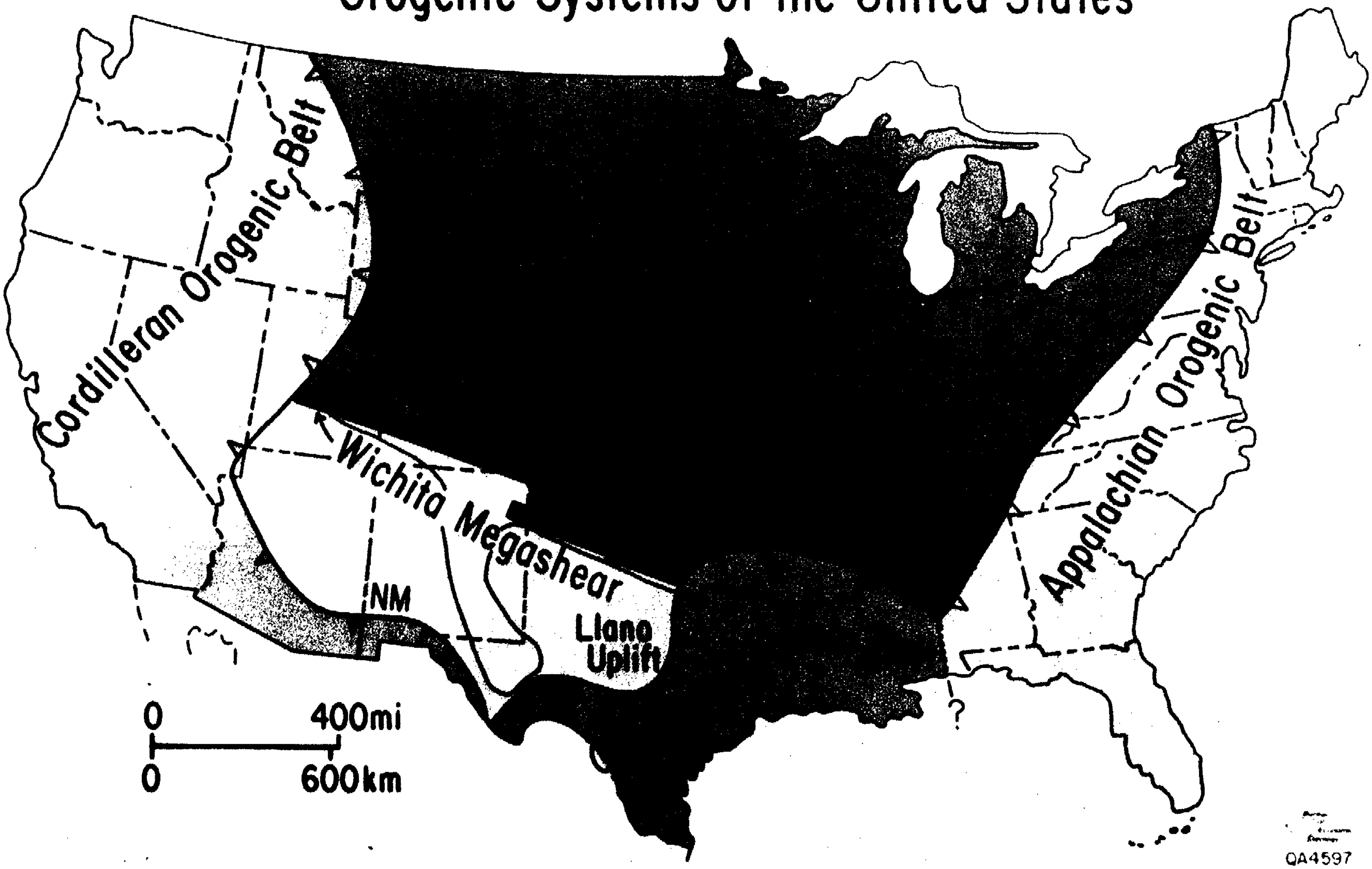
Enclosure 4

Seismic Reflection Survey Data
Reviewed by NRC

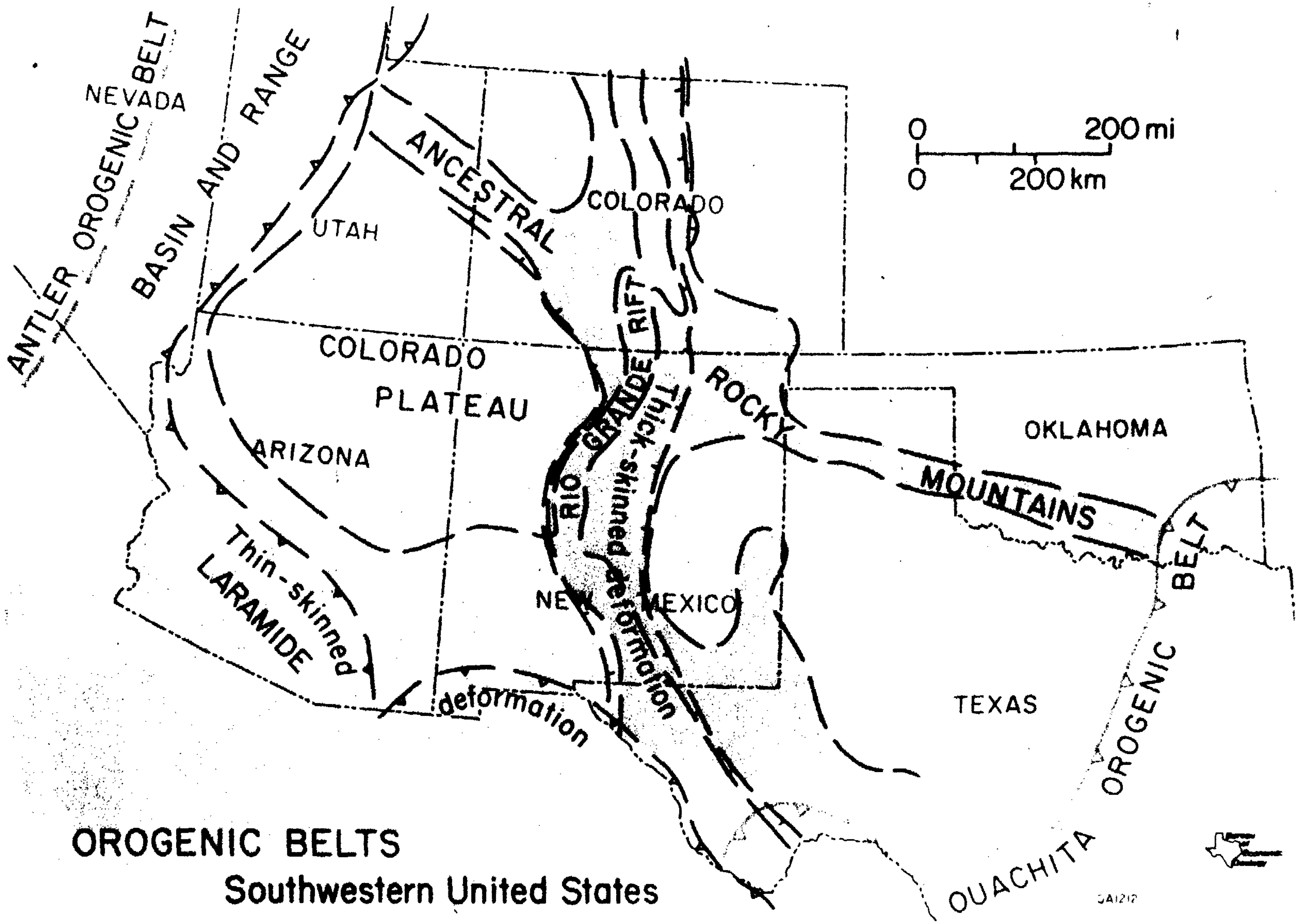
Seismic survey data of a proprietary nature were reviewed by the NRC staff and contractors. These consisted of the following lines designated on SWEC drawing "Sketch No. 13697-44-A-1":

STM-PD-10
STM-PD-11
STM-PD-9
GEO-E
W-95

Orogenic Systems of the United States



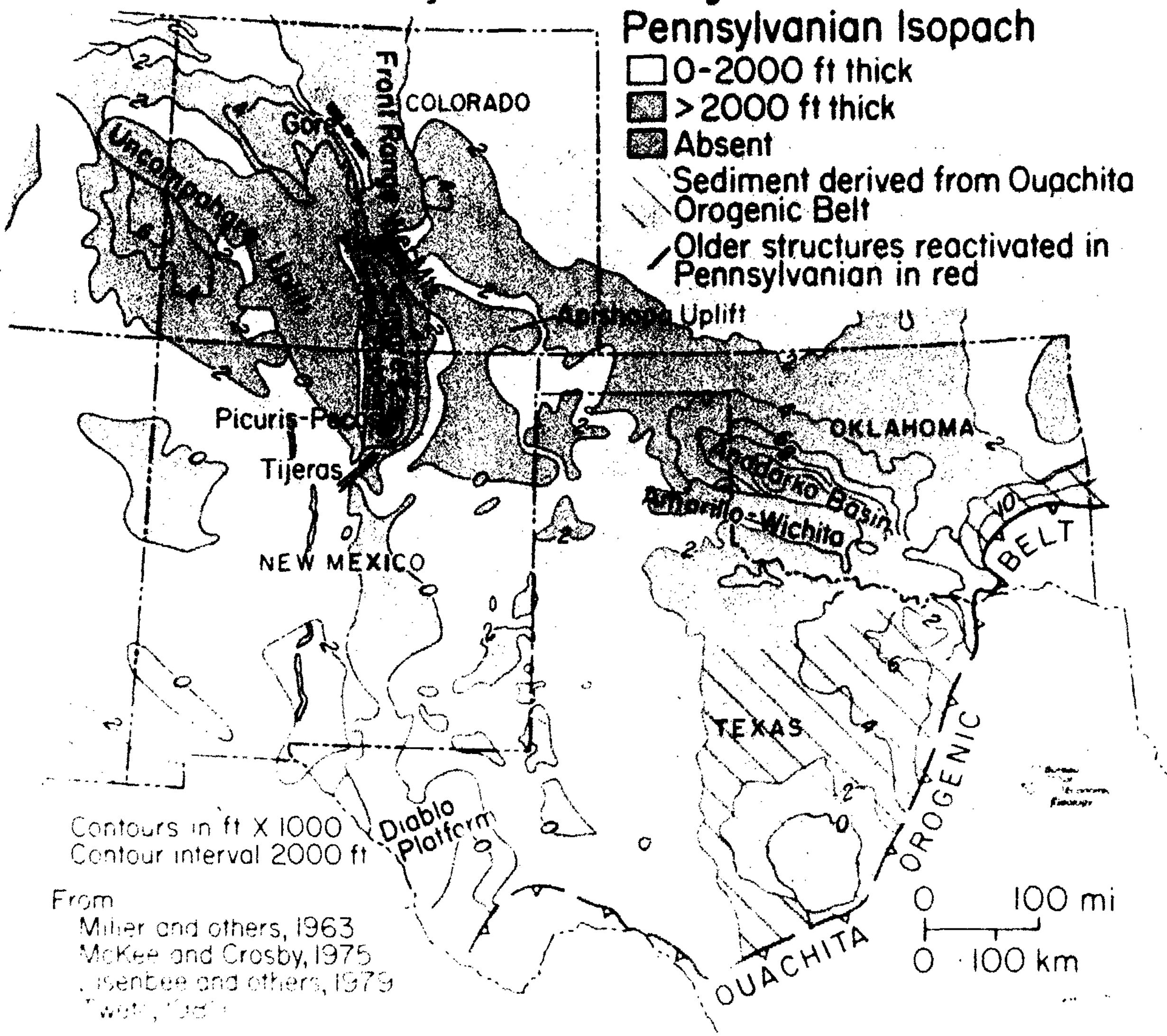
QA4597

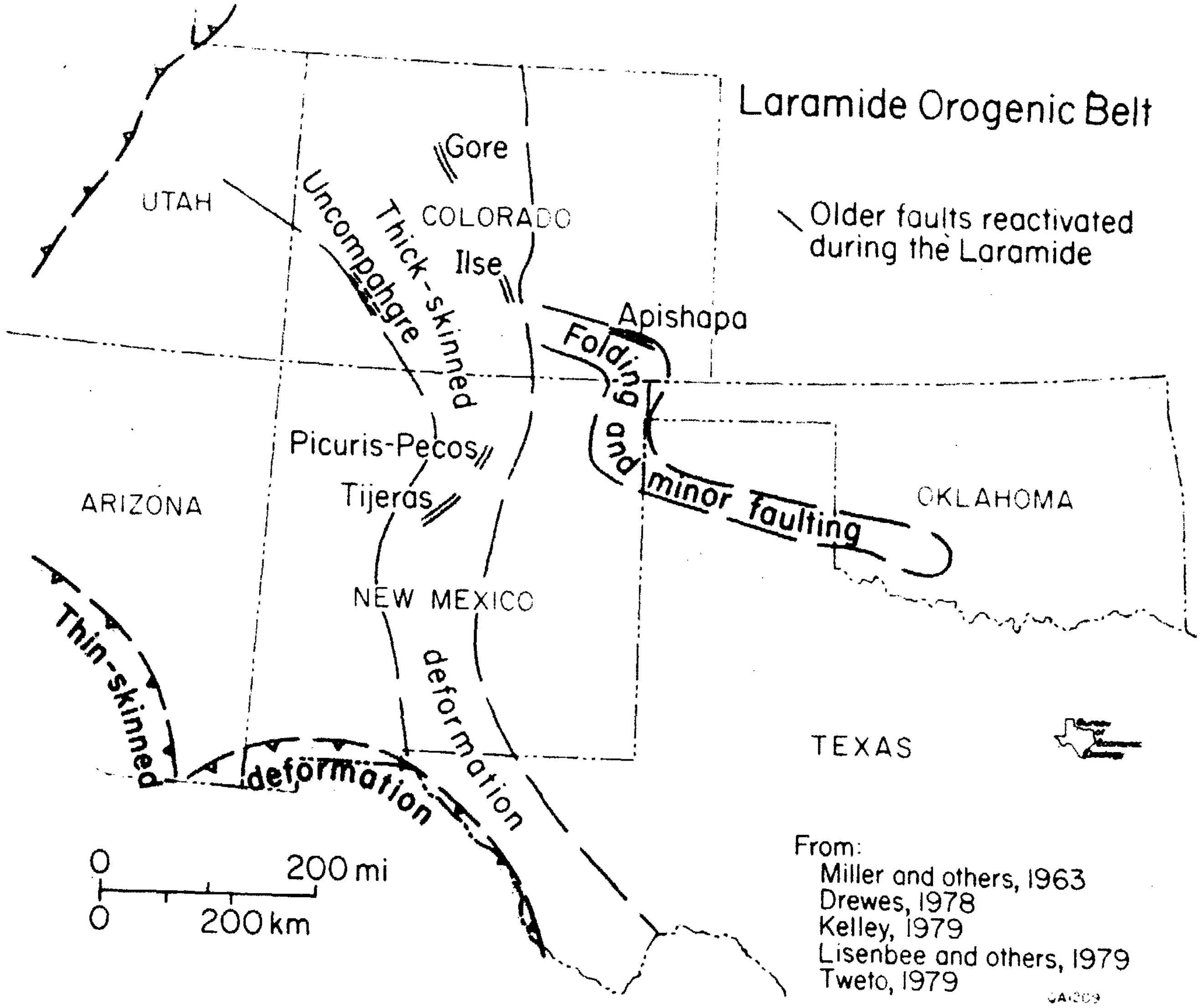


OROGENIC BELTS

Southwestern United States

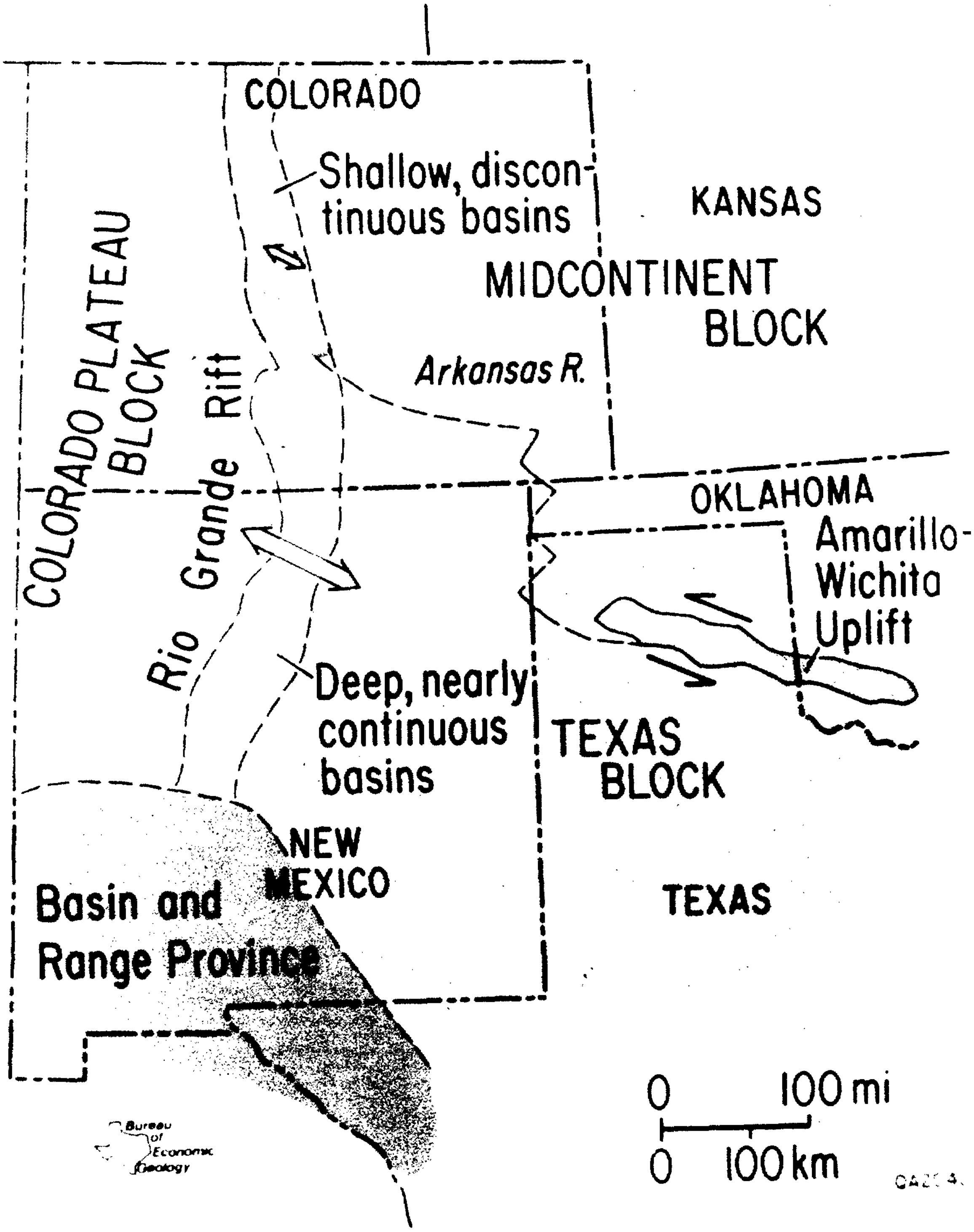
Ancestral Rocky Mountain Orogenic Belt / Pennsylvanian Isopach

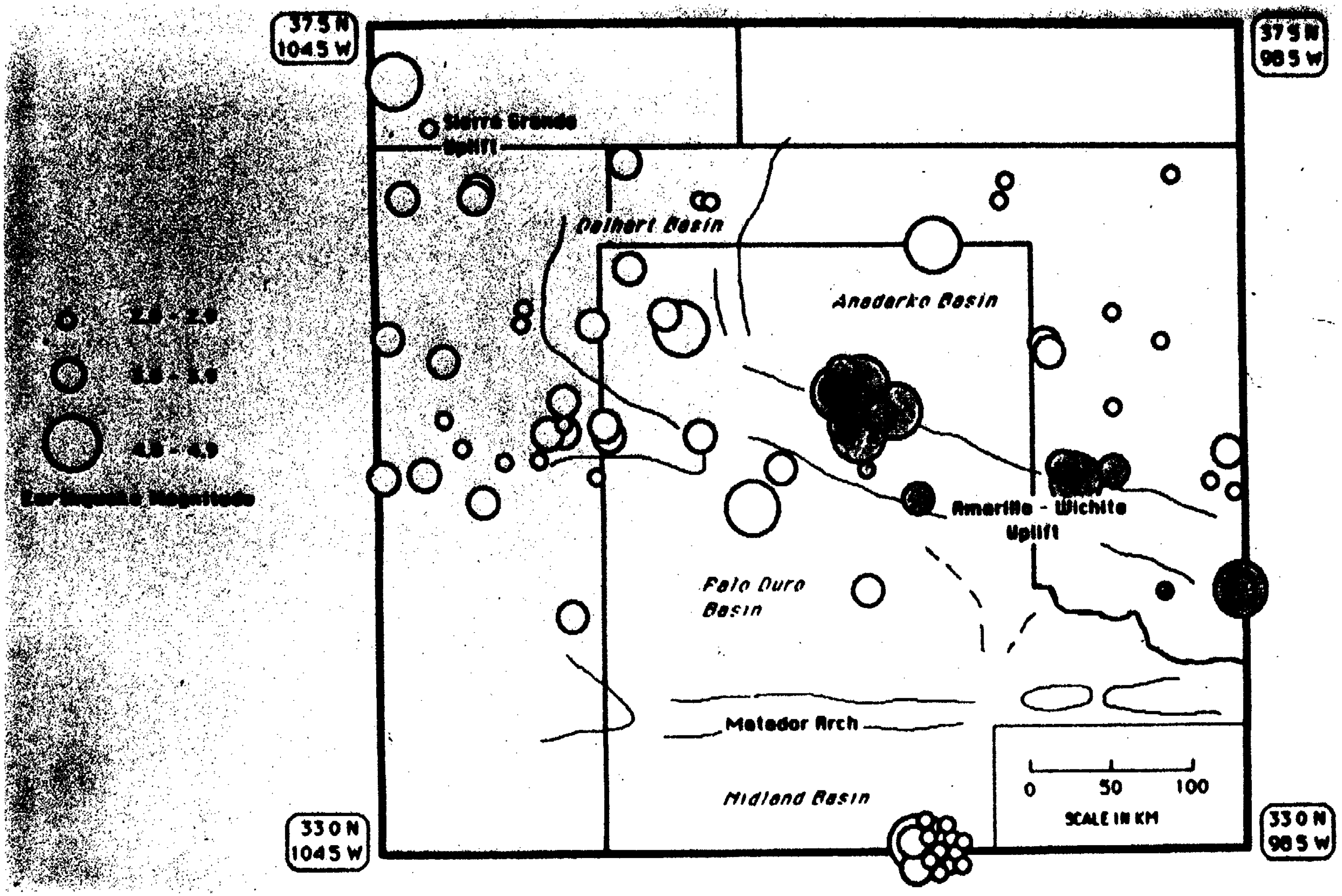




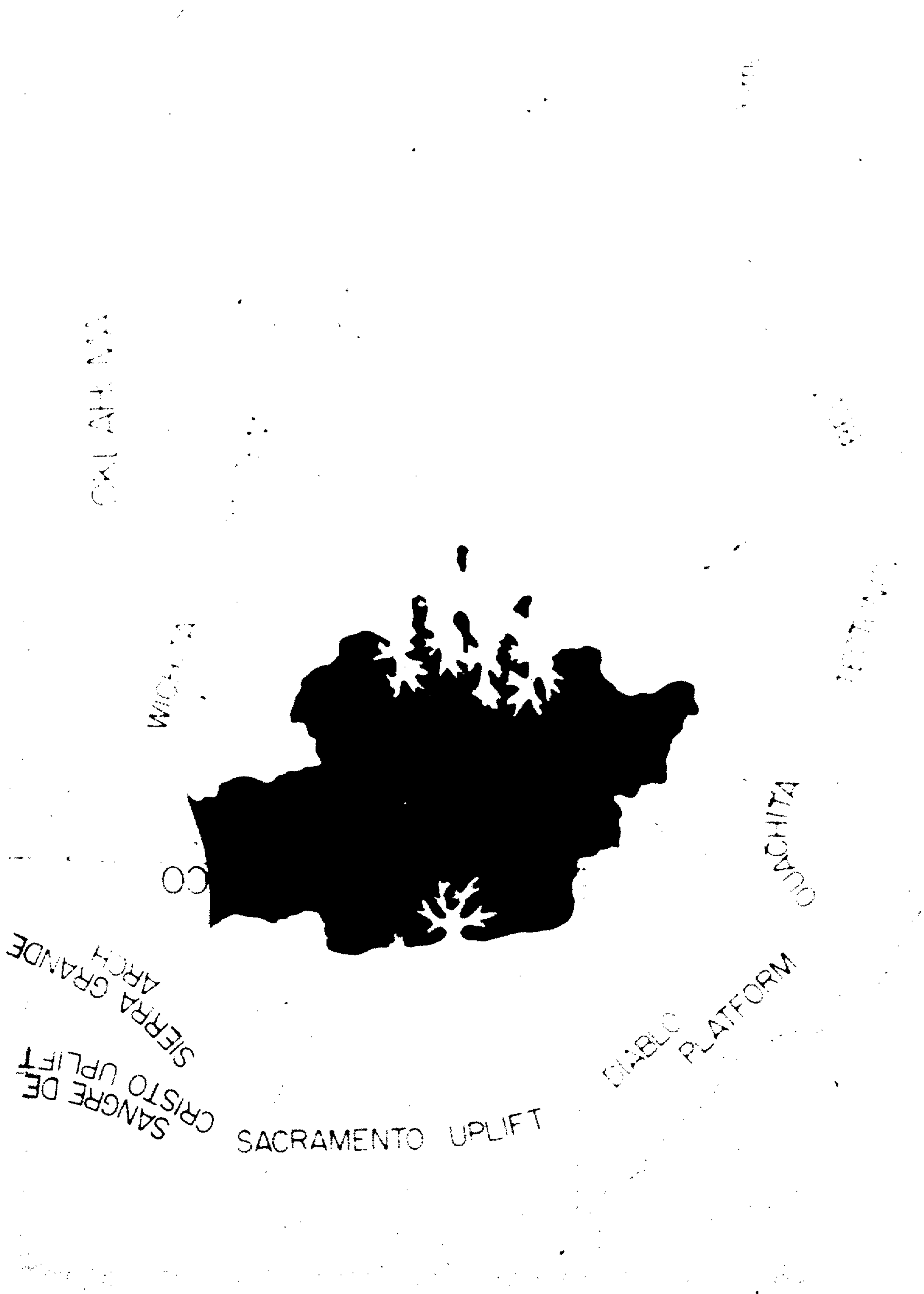
Laramide Orogenic Belt
Older faults reactivated during the Laramide
UTAH
COLORADO
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
Gore
Ilse
Apishapa
Uncompahgre
Thick-skinned deformation
Picuris-Pecos
Tijeras
Folding and minor faulting
Thin-skinned deformation
0 200 mi
0 200 km
From:
Miller and others, 1963
Drewes, 1978
Kelley, 1979
Lisenbee and others, 1979
Tweto, 1979

NEOGENE TECTONIC SETTING

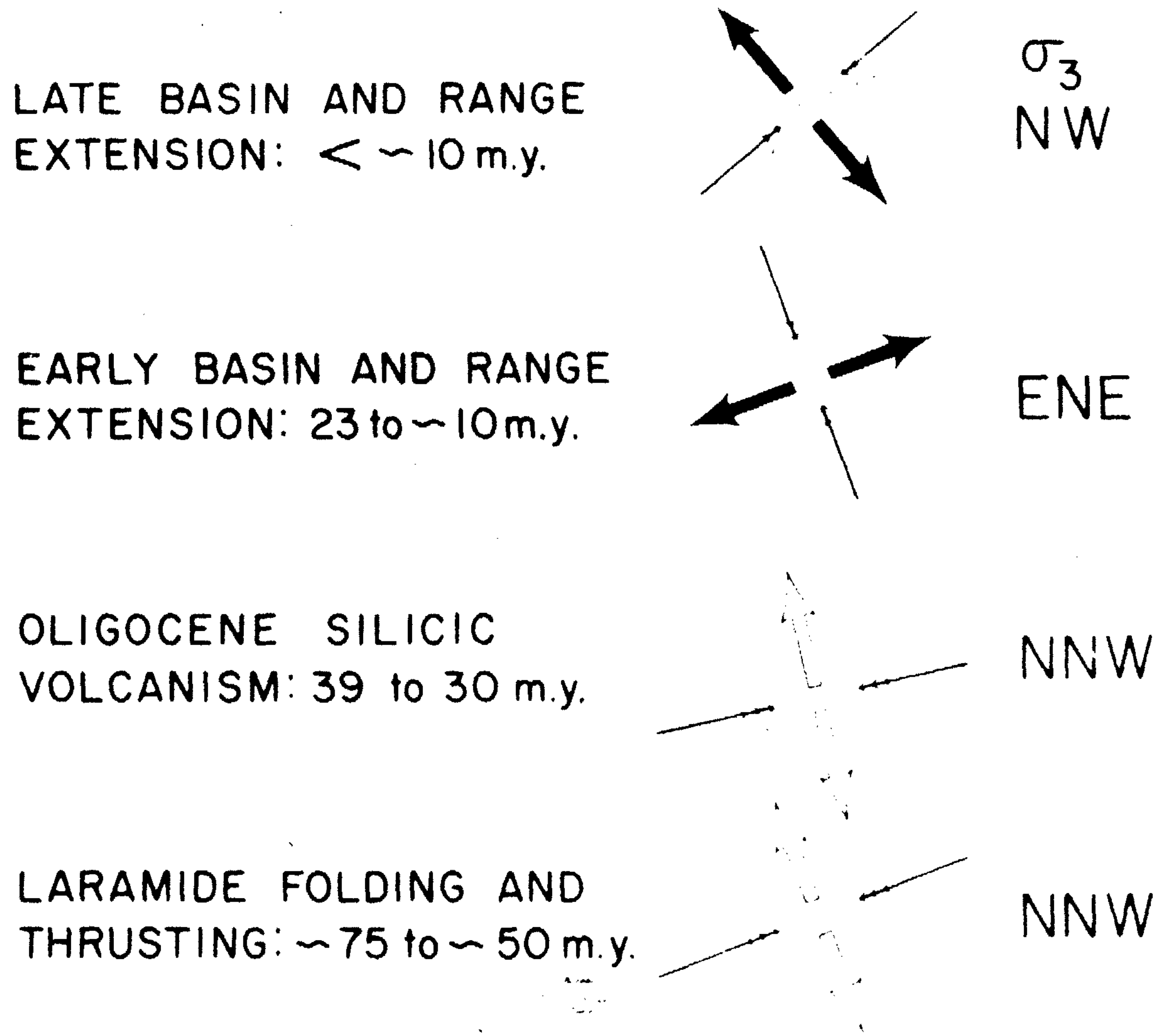




37.5 N
104.5 W
37.5 N
98.5 W
Sierra Grande
Uplift
Dalhart Basin
Anadarko Basin
Amarillo - Wichita
Uplift
Palo Duro
Basin
Matador Arch
Midland Basin
0
50
100
SCALE IN KM
33.0 N
104.5 W
33.0 N
98.5 W

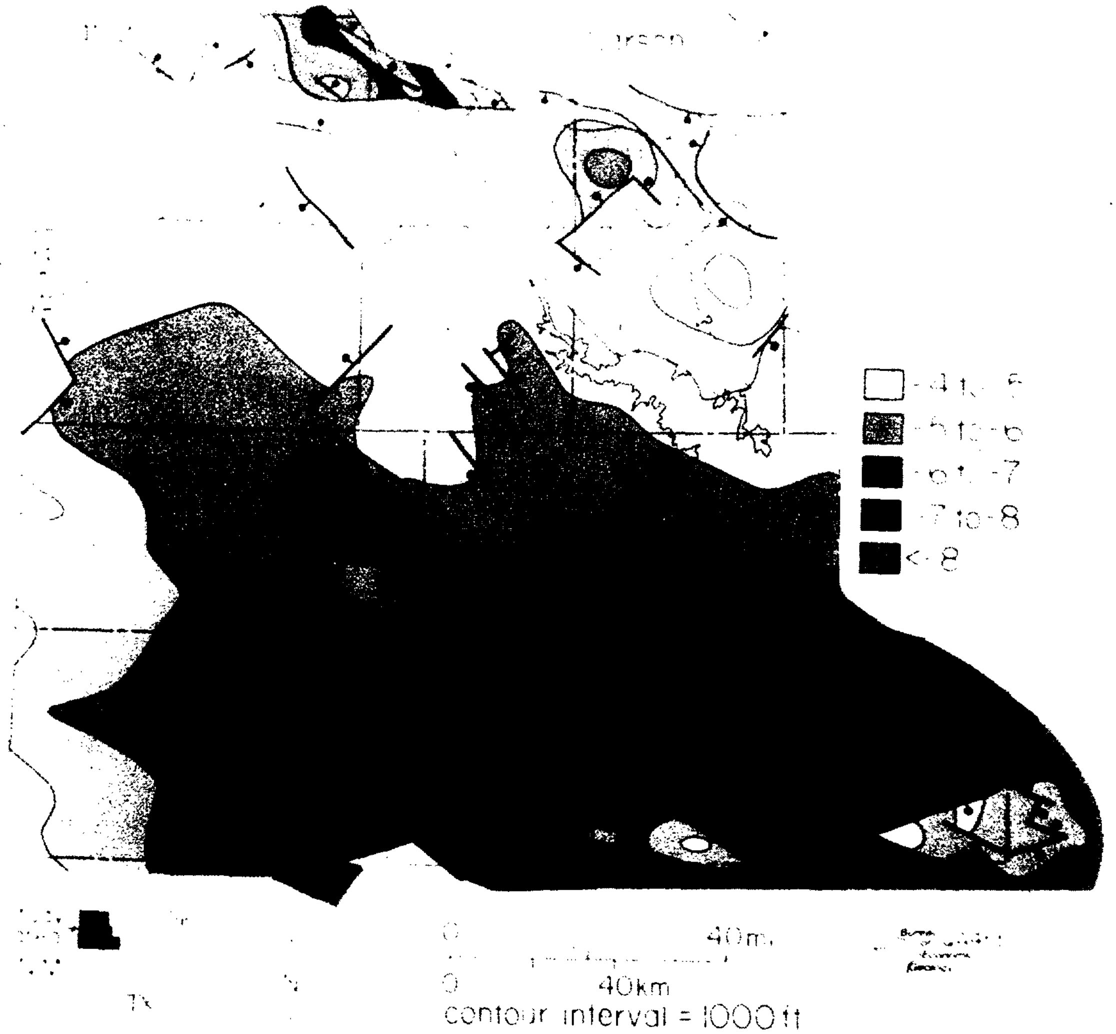


OUACHITA
SIERRA GRANDE ARCH
SANGRE DE CRISTO UPLIFT
SACRAMENTO UPLIFT
DIABLO PLATFORM



σ_3
LATE BASIN AND RANGE EXTENSION: < ~10 m.y.
NW
EARLY BASIN AND RANGE EXTENSION: 23 to ~10 m.y.
ENE
OLIGOCENE SILICIC VOLCANISM: 39 to 30 m.y.
NNW
LARAMIDE FOLDING AND THRUSTING: ~75 to ~50 m.y.
NNW

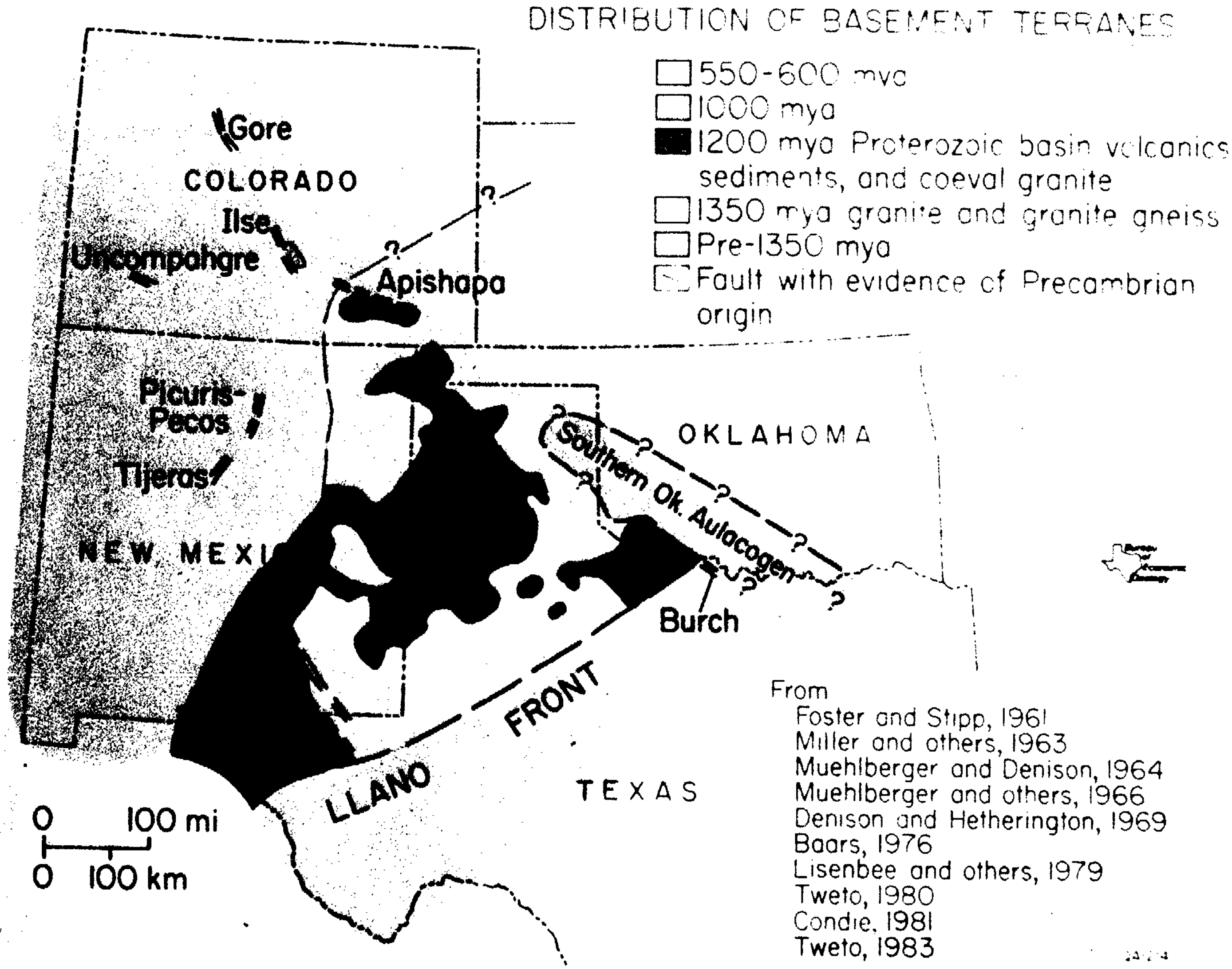
SIMPLIFIED BASEMENT STRUCTURE



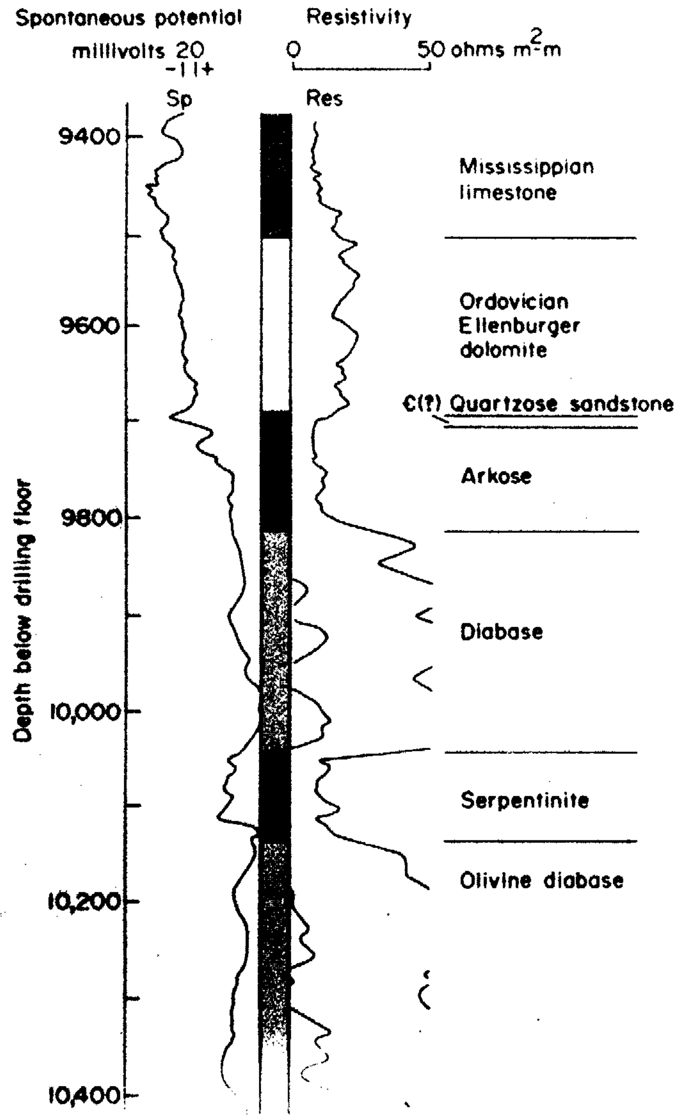
EXPLANATION (ft X 1000)

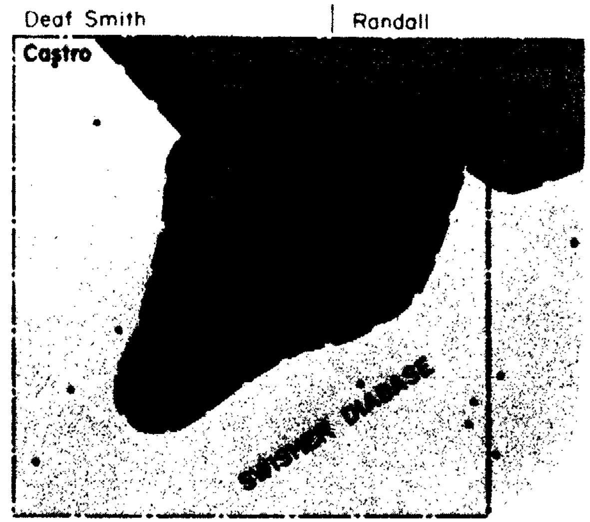
(from Budnik, 1984)

>1	0 to -1	-2 to -3
1 to 0	-1 to -2	-3 to -4


DISTRIBUTION OF BASEMENT TERRANES
550-600 mya
1000 mya
1200 mya Proterozoic basin volcanics, sediments, and coeval granite
1350 mya granite and granite gneiss
Pre-1350 mya
Fault with evidence of Precambrian origin
Gore
COLORADO
Ilse
Uncompahgre
Apishapa
Picuris-Pecos
Tijeras
NEW MEXI
OKLAHOMA
Southern Ok. Aulacogen
Burch
LLANO FRONT
TEXAS
0 100 mi
0 100 km
From
Foster and Stipp, 1961
Miller and others, 1963
Muehlberger and Denison, 1964
Muehlberger and others, 1966
Denison and Hetherington, 1969
Baars, 1976
Lisenbee and others, 1979
Tweto, 1980
Condie, 1981
Tweto, 1983

SUN OIL COMPANY *#1 Herring*, Castro County





Distribution of pre-Ellenburger Group arkose in Castro Trough

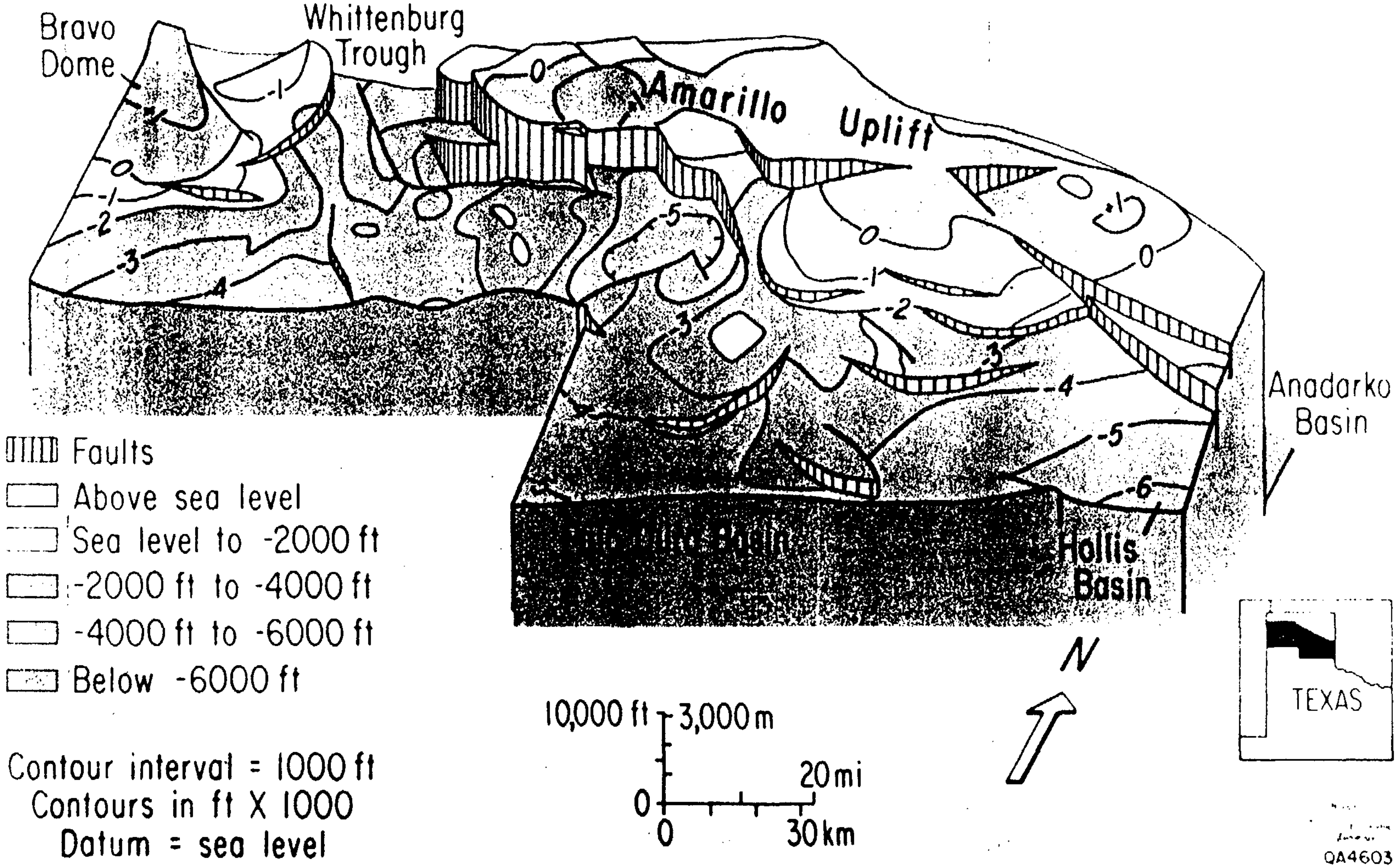
• Well control

⊙ Wells penetrating pre-Ellenburger arkose

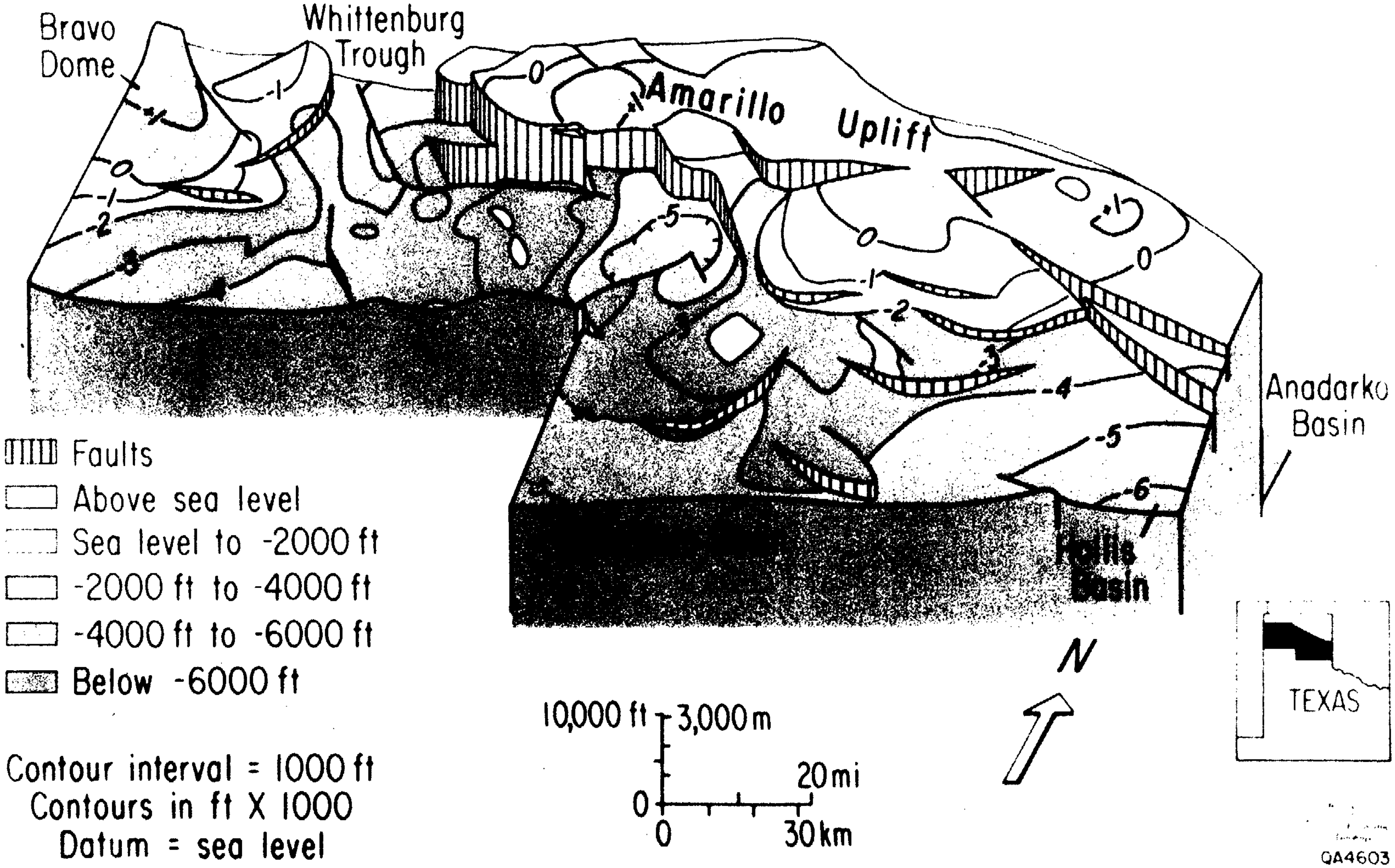
0 10 mi

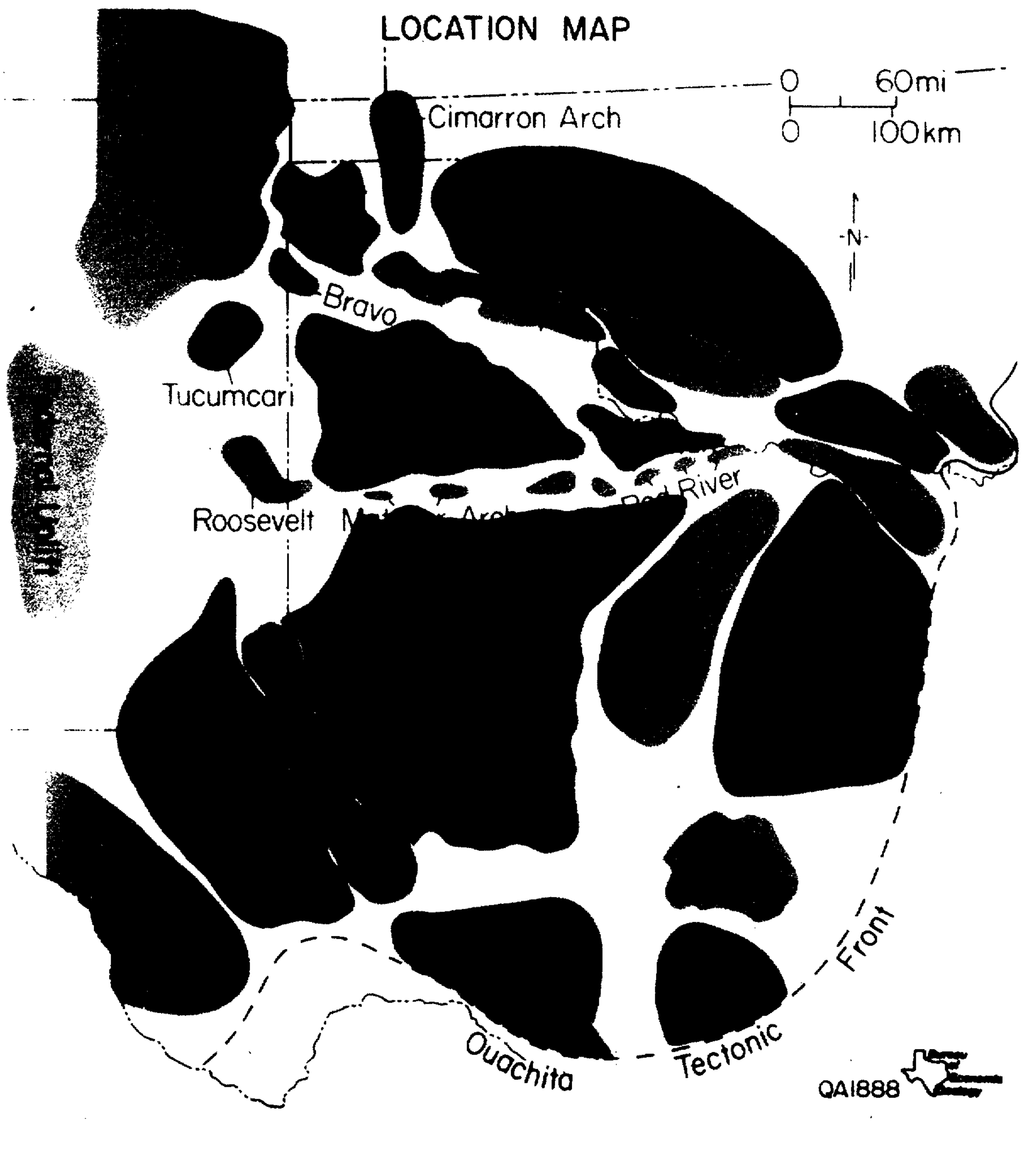
0 10 km

Block diagram of basement surface of Amarillo Uplift

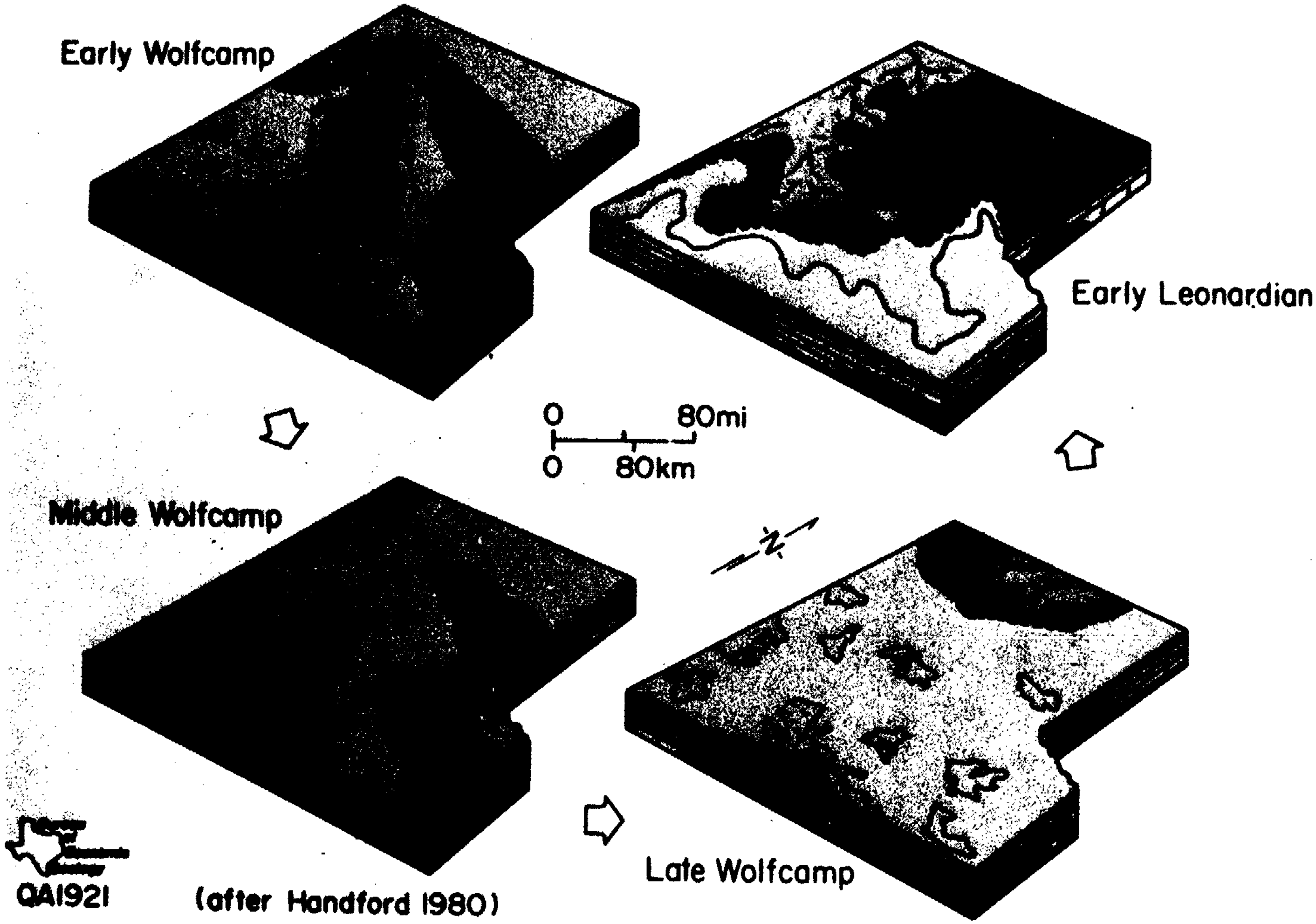


Block diagram of basement surface of Amarillo Uplift



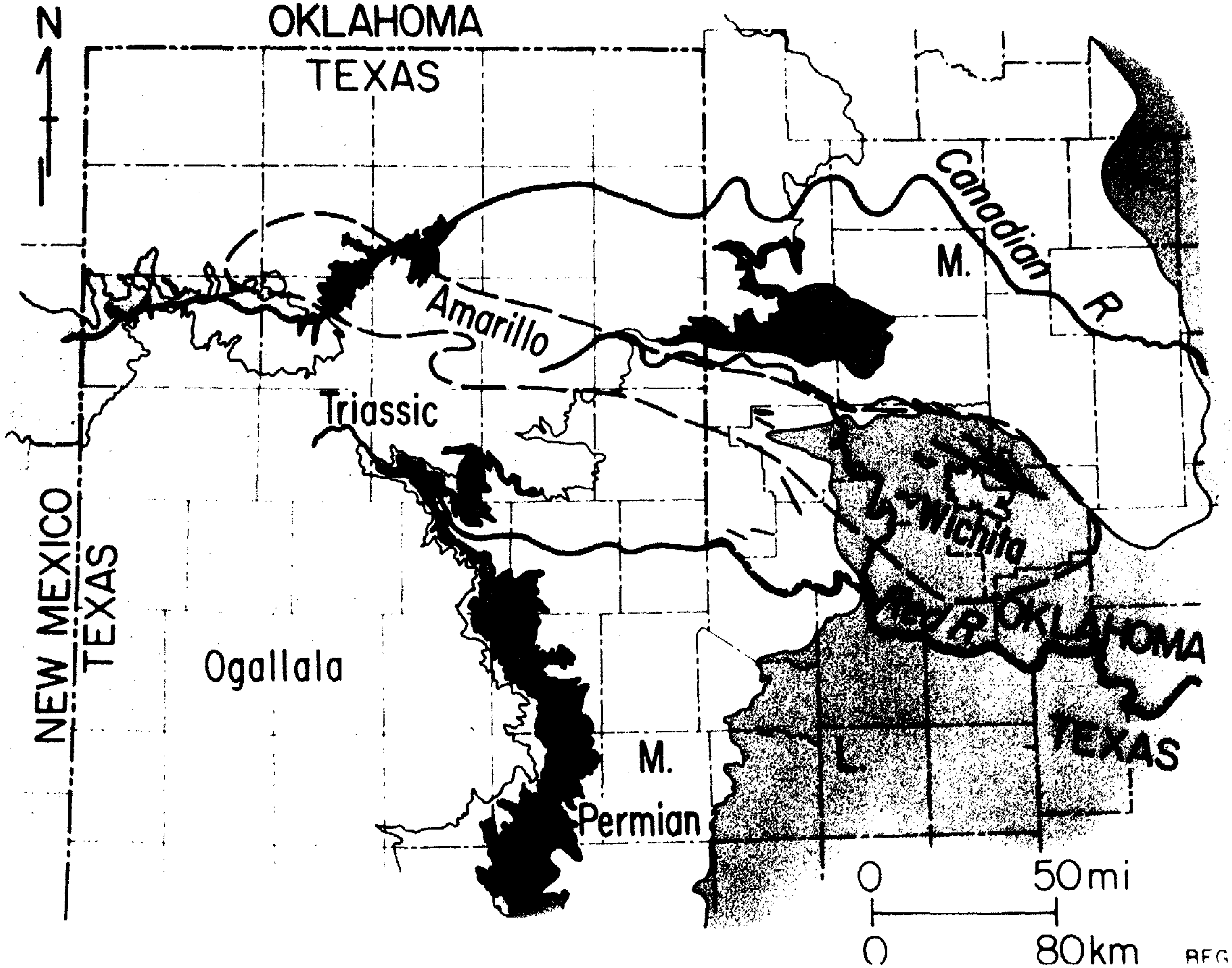

LOCATION MAP
0 60mi
0 100km
N
Cimarron Arch
Bravo
Tucumcari
Roosevelt
River
Ouachita
Tectonic
Front
QA1888

PALEOGEOGRAPHIC EVOLUTION OF PALO DURO BASIN

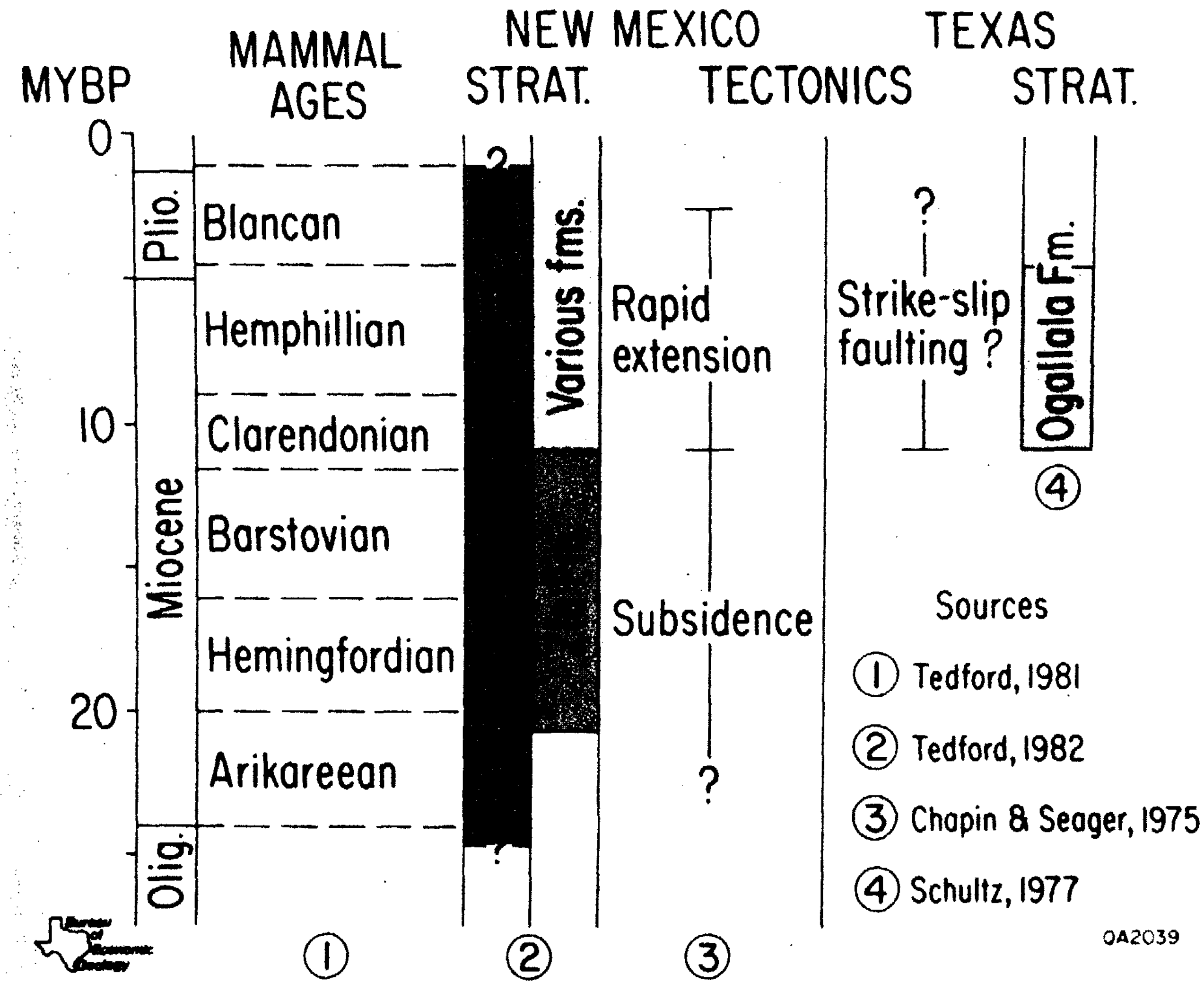


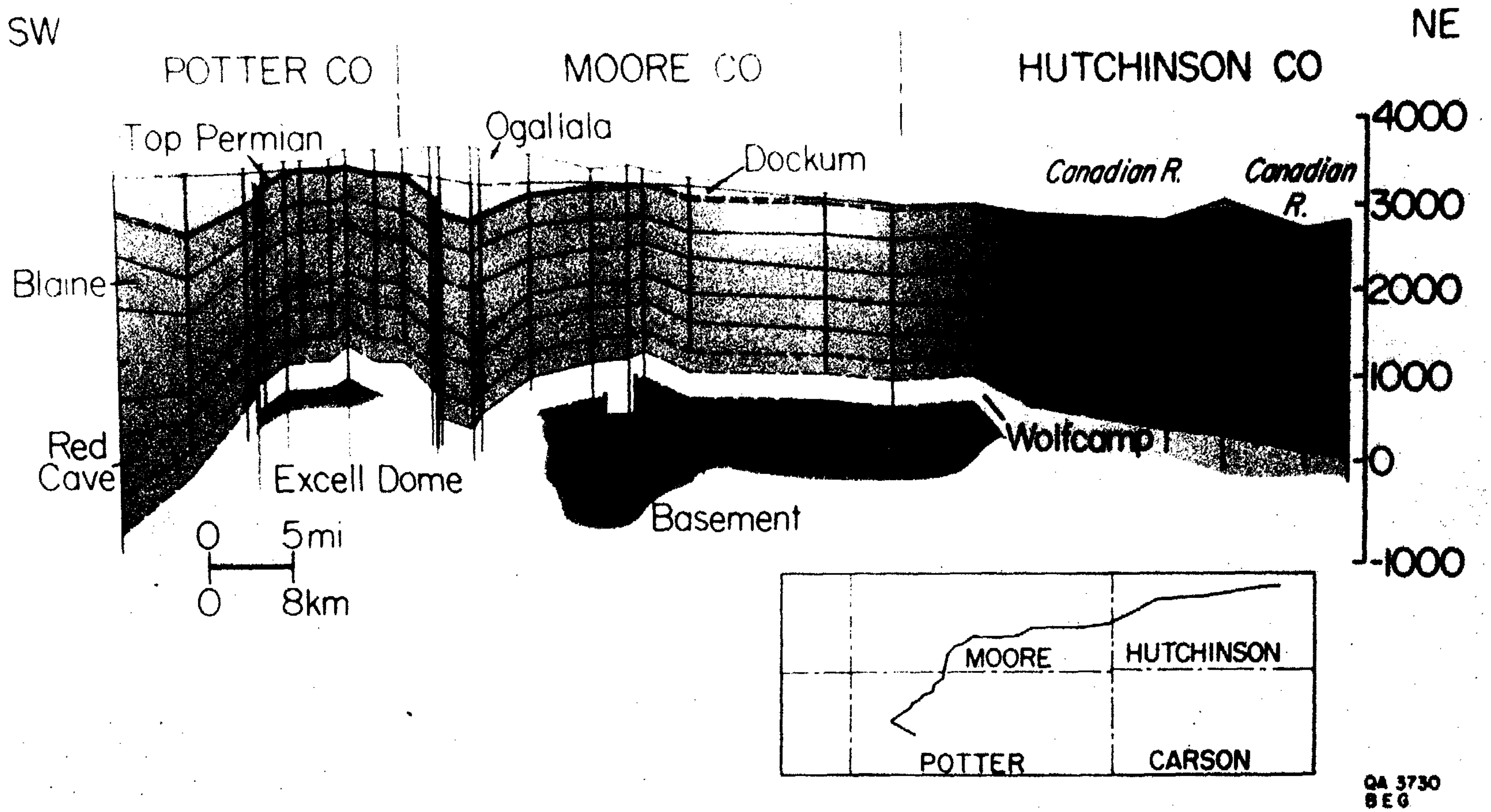
QA1921

(after Handford 1980)

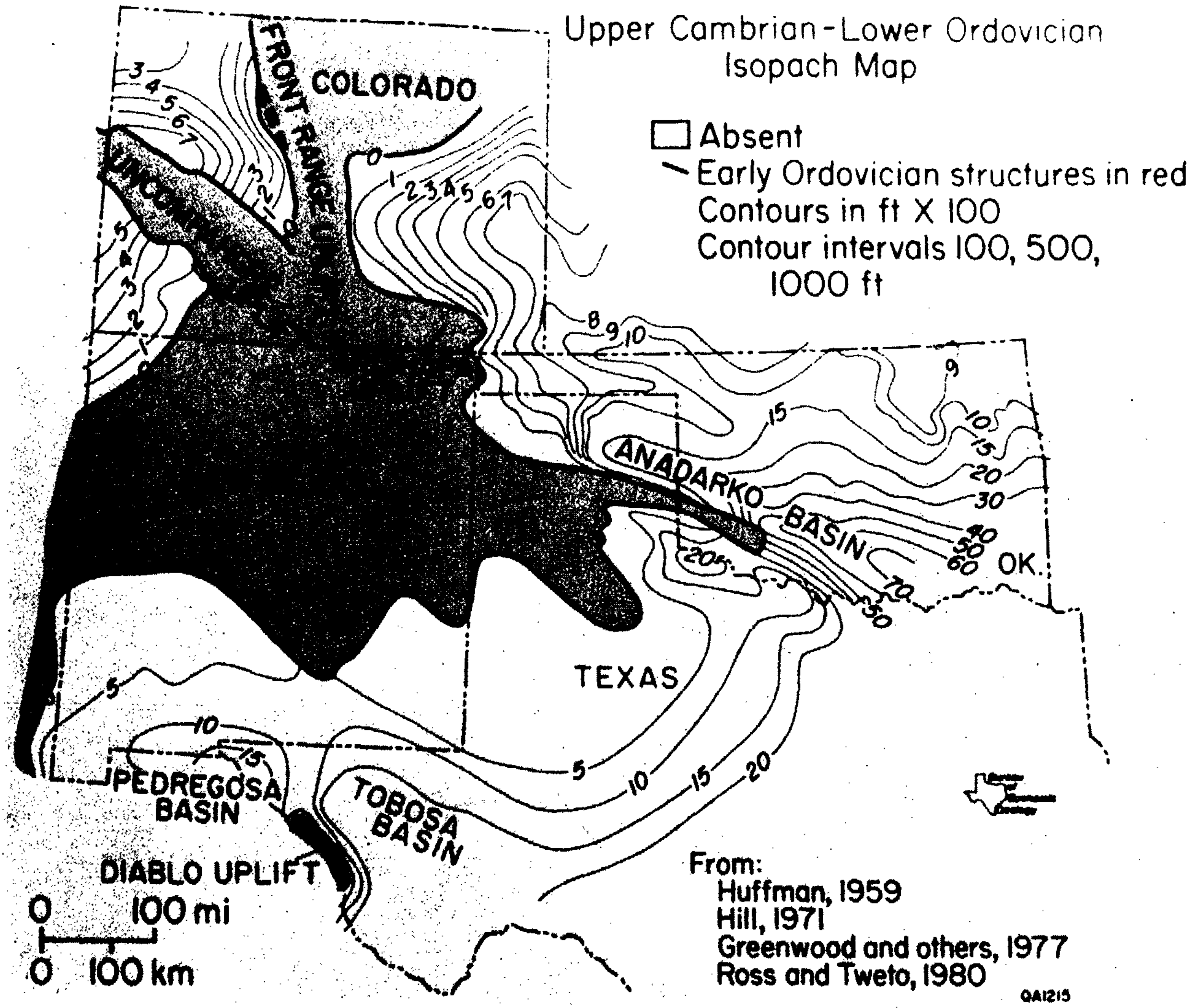

N
OKLAHOMA
TEXAS
Canadian
R.
M.
Amarillo
Triassic
Wichita
Red R.
OKLAHOMA
TEXAS
NEW MEXICO
TEXAS
Ogallala
M.
Permian
L.
0
50mi
0
80km
BEG

CORRELATION CHART

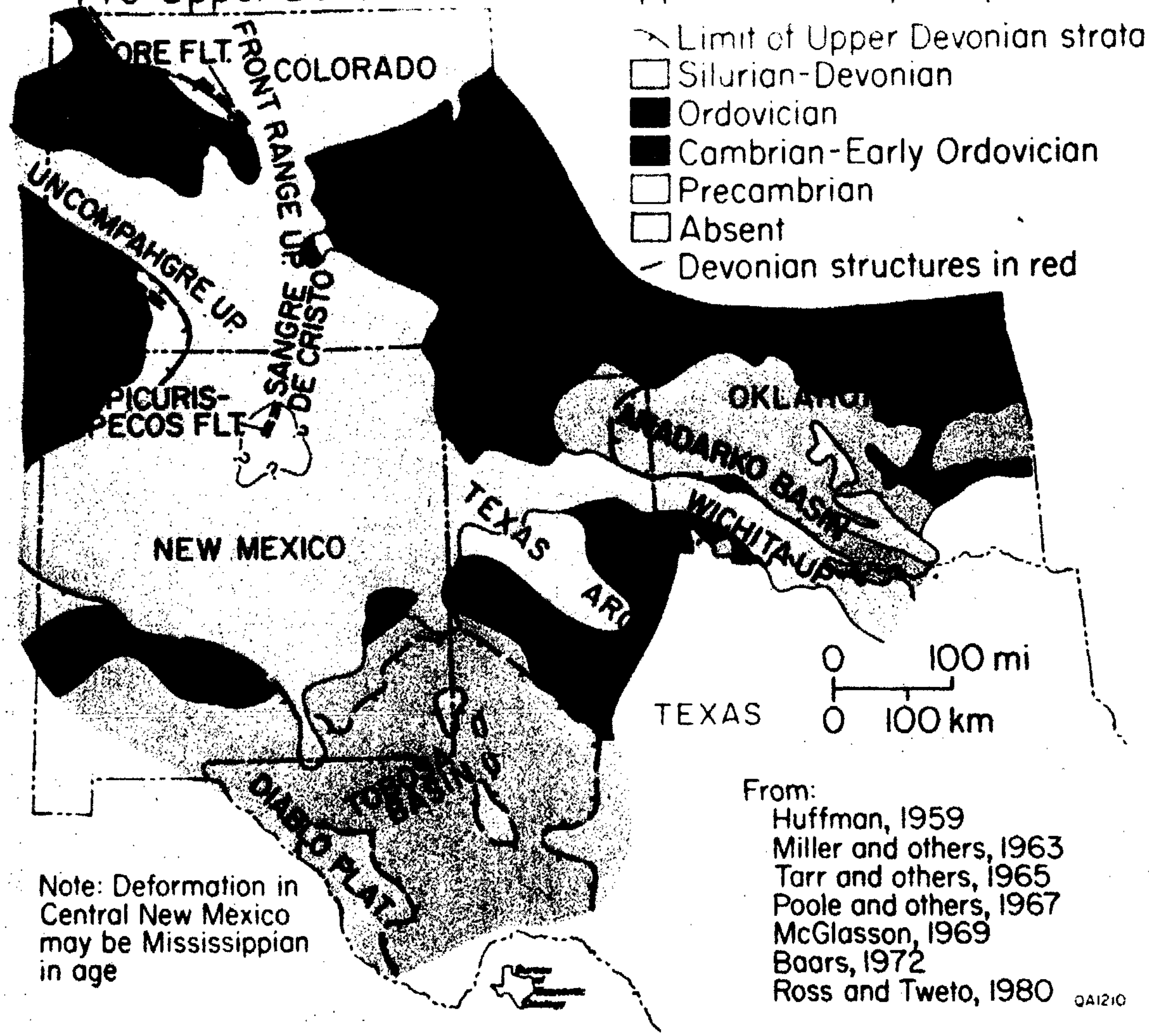




SW
NE
POTTER CO
MOORE CO
HUTCHINSON CO
Top Permian
Ogaliala
Dockum
Canadian R.
Canadian R.
4000
3000
2000
1000
0
-1000
Blaine
Red Cave
Excell Dome
Basement
Wolfcamp 1
0 5mi
0 8km
MOORE
HUTCHINSON
POTTER
CARSON
QA 3730
BEG


Upper Cambrian-Lower Ordovician
Isopach Map
Absent
Early Ordovician structures in red
Contours in ft X 100
Contour intervals 100, 500, 1000 ft
COLORADO
FRONT RANGE
ANADARKO BASIN
OK.
TEXAS
PEDREGOSA BASIN
TOBOSA BASIN
DIABLO UPLIFT
0 100 mi
0 100 km
From:
Huffman, 1959
Hill, 1971
Greenwood and others, 1977
Ross and Tweto, 1980
QA1215

Pre-Upper Devonian/Mississippian Subcrop Map

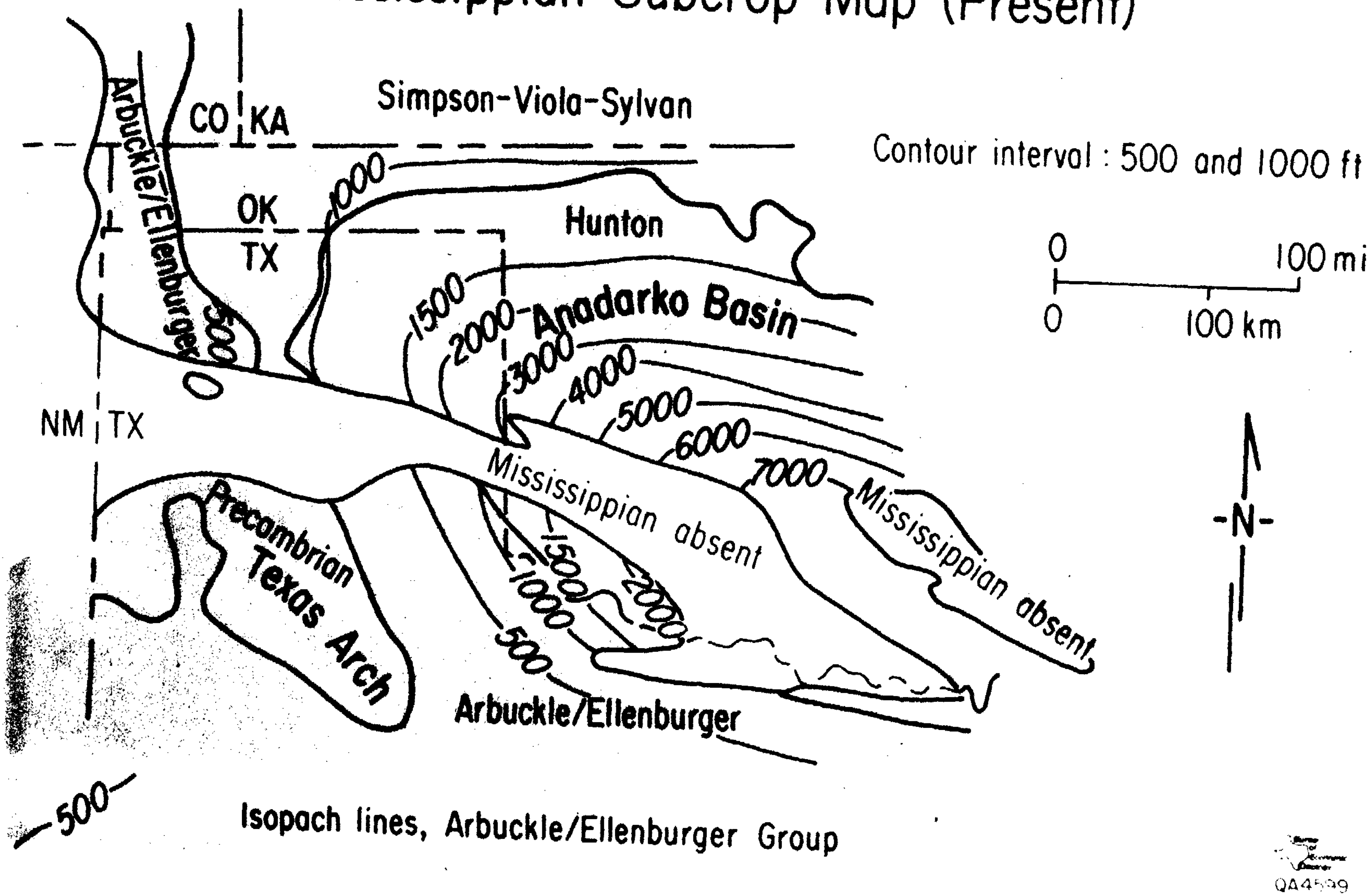


Note: Deformation in Central New Mexico may be Mississippian in age

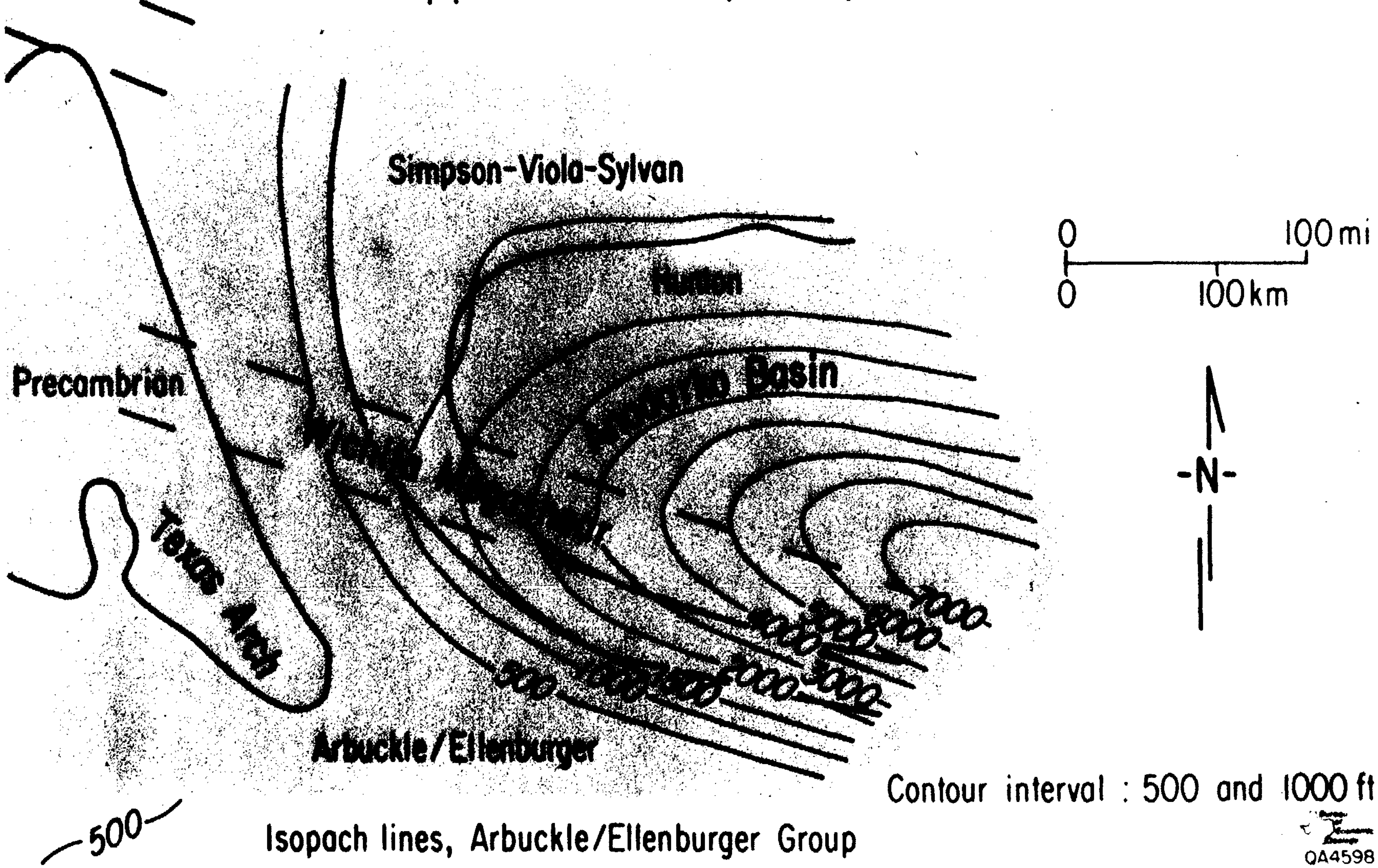
From:
Huffman, 1959
Miller and others, 1963
Tarr and others, 1965
Poole and others, 1967
McGlasson, 1969
Baars, 1972
Ross and Tweto, 1980

QA1210

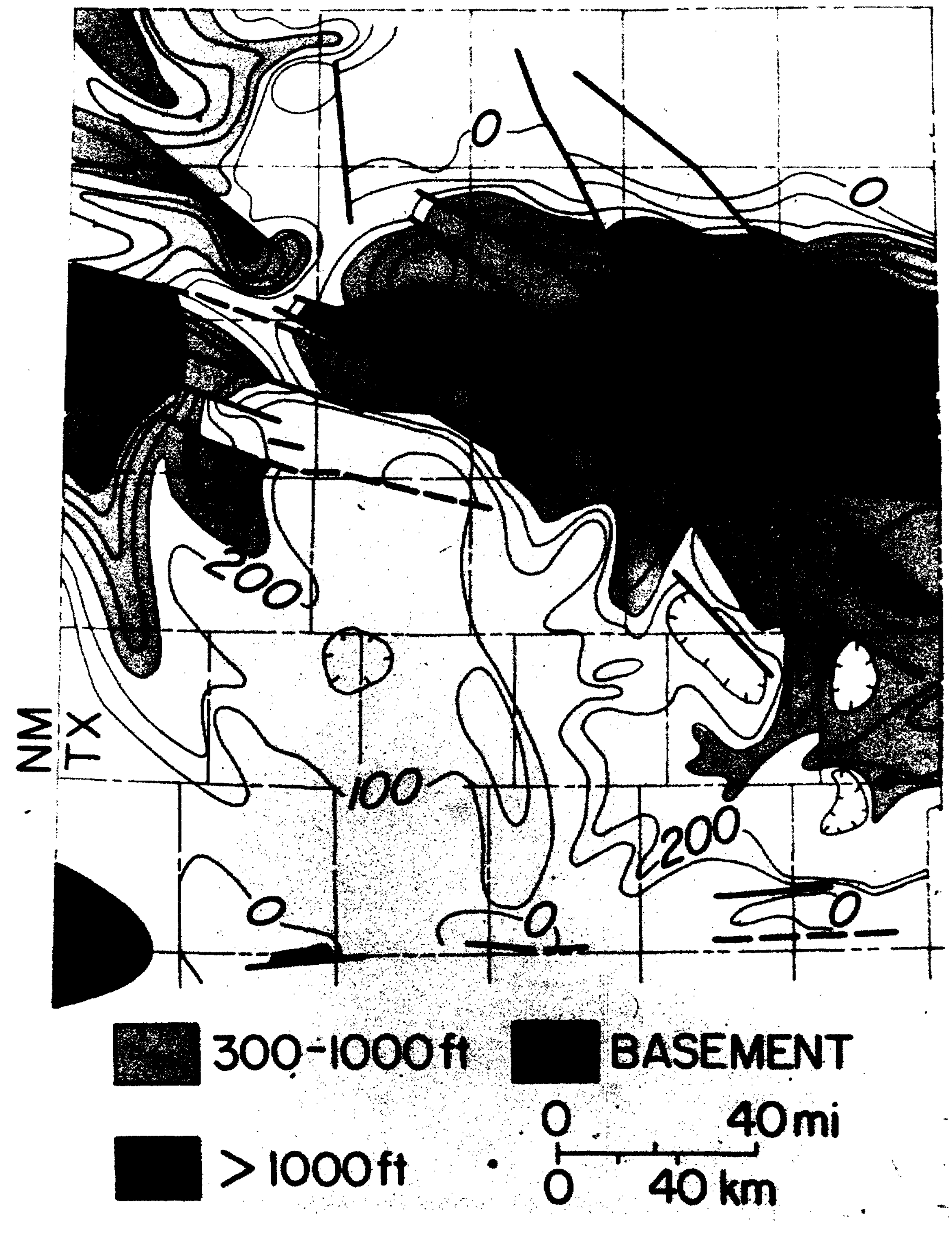
Mississippian Subcrop Map (Present)

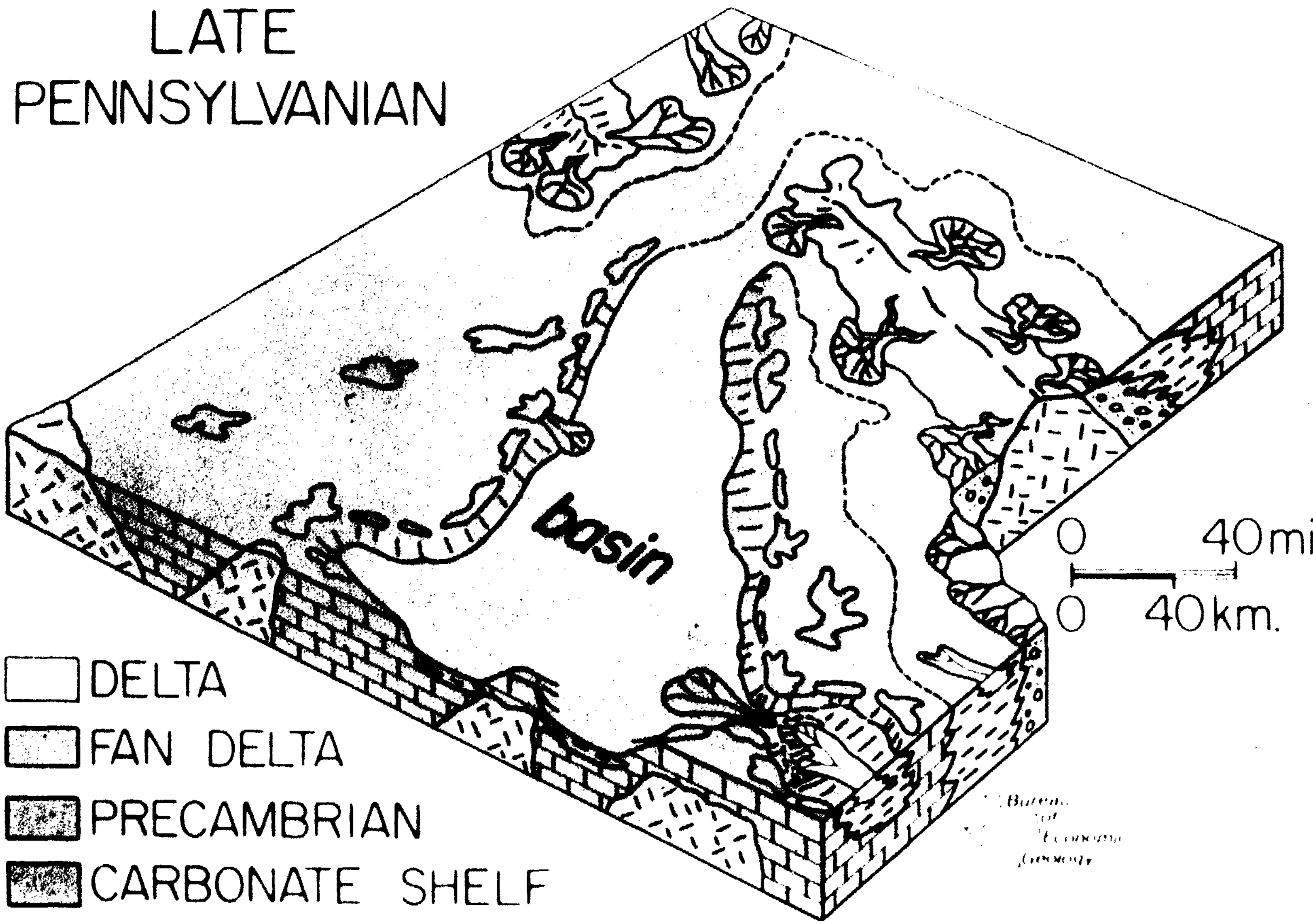


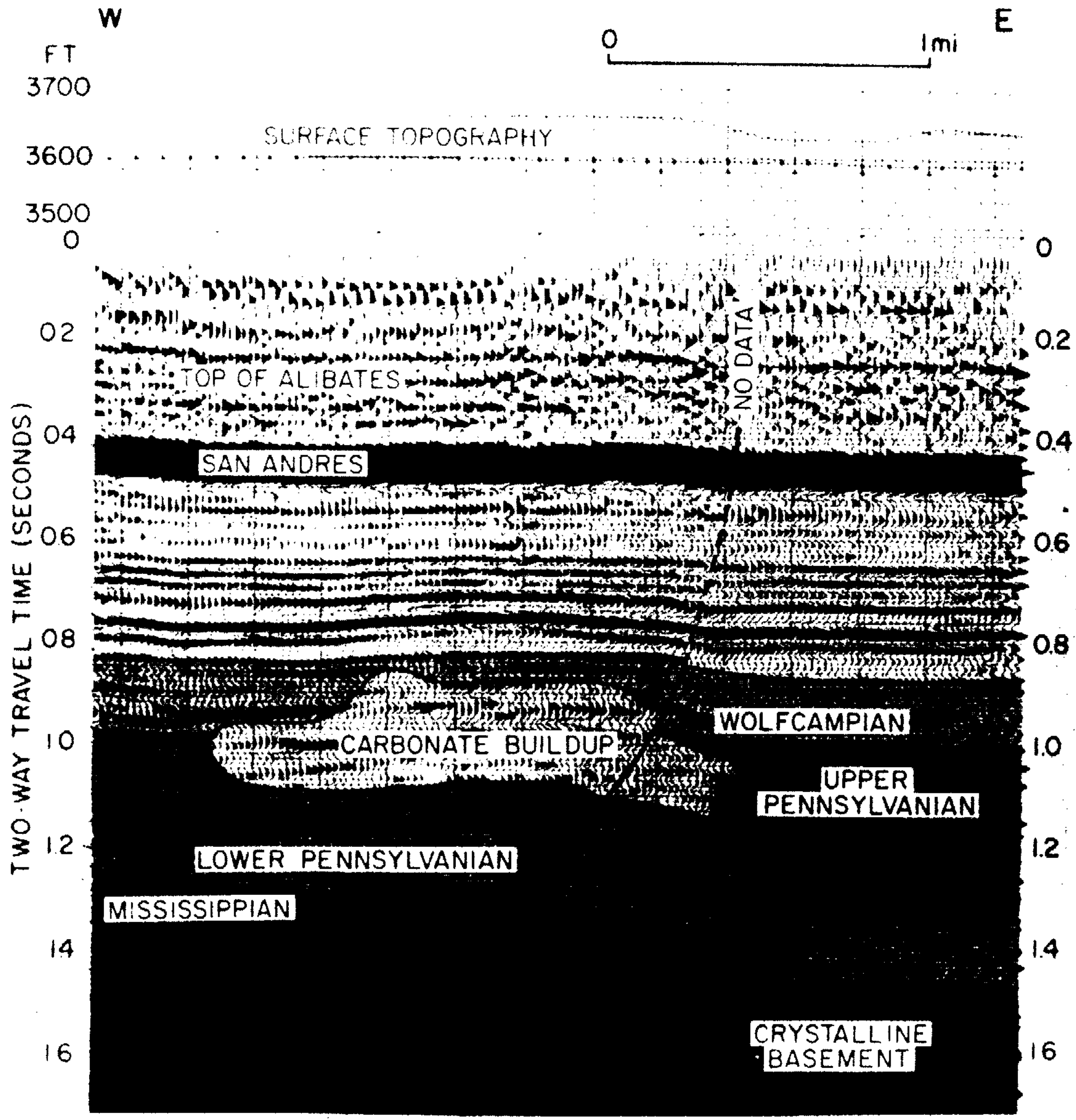
Mississippian Subcrop Map (Restored)



NET GRANITE WASH




LATE
PENNSYLVANIAN
basin
0 40mi
0 40km.
DELTA
FAN DELTA
PRECAMBRIAN
CARBONATE SHELF


W
E
0
1 mi
FT
3700
3600
3500
SURFACE TOPOGRAPHY
0
02
04
06
08
10
12
14
16
TWO-WAY TRAVEL TIME (SECONDS)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
16
NO DATA
TOP OF ALIBATES
SAN ANDRES
CARBONATE BUILDUP
WOLFCAMPIAN
UPPER PENNSYLVANIAN
LOWER PENNSYLVANIAN
MISSISSIPPIAN
CRYSTALLINE BASEMENT

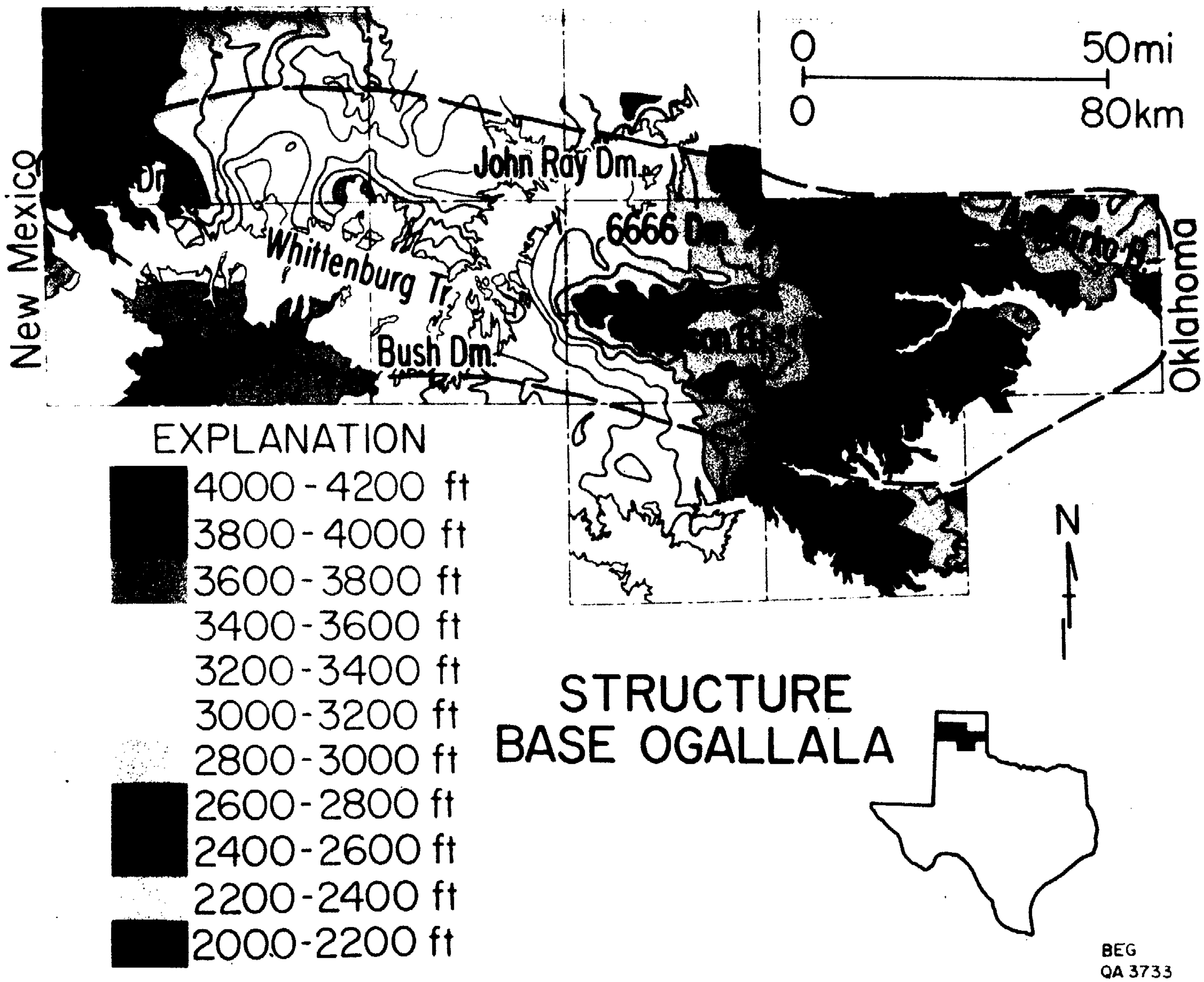
STRATIGRAPHIC COLUMN

SYSTEM	GROUP	FORMATION
QUATERNARY		RECENT FLUVIAL & LUCUSTRINE DEPOSITS
TERTIARY		OGALLALA
CRETACEOUS	DAKOTA	
		FREDRICKSBURG
		TRINITY
JURASSIC		MORRISON
		EXETER
TRIASSIC	DOCKUM	
PERMIAN		DEWEY LAKE
		ALIBATES
	ARTESIA/WHITEHORSE	
		YATES
		QUEEN/GRAYBURG
	CLEAR FORK	
		TUBB
		RED CAVE
	WICHITA	
	WOLFCAMP	
PENNSYLVANIAN	UNNAMED SANDSTONE, CARBONATE, AND SHALE	
MISSISSIPPIAN	UNNAMED	CARBONATE
ORDOVICIAN	ELLENBURGER	
CAMBRIAN	UNNAMED	SANDSTONES
PRECAMBRIAN		

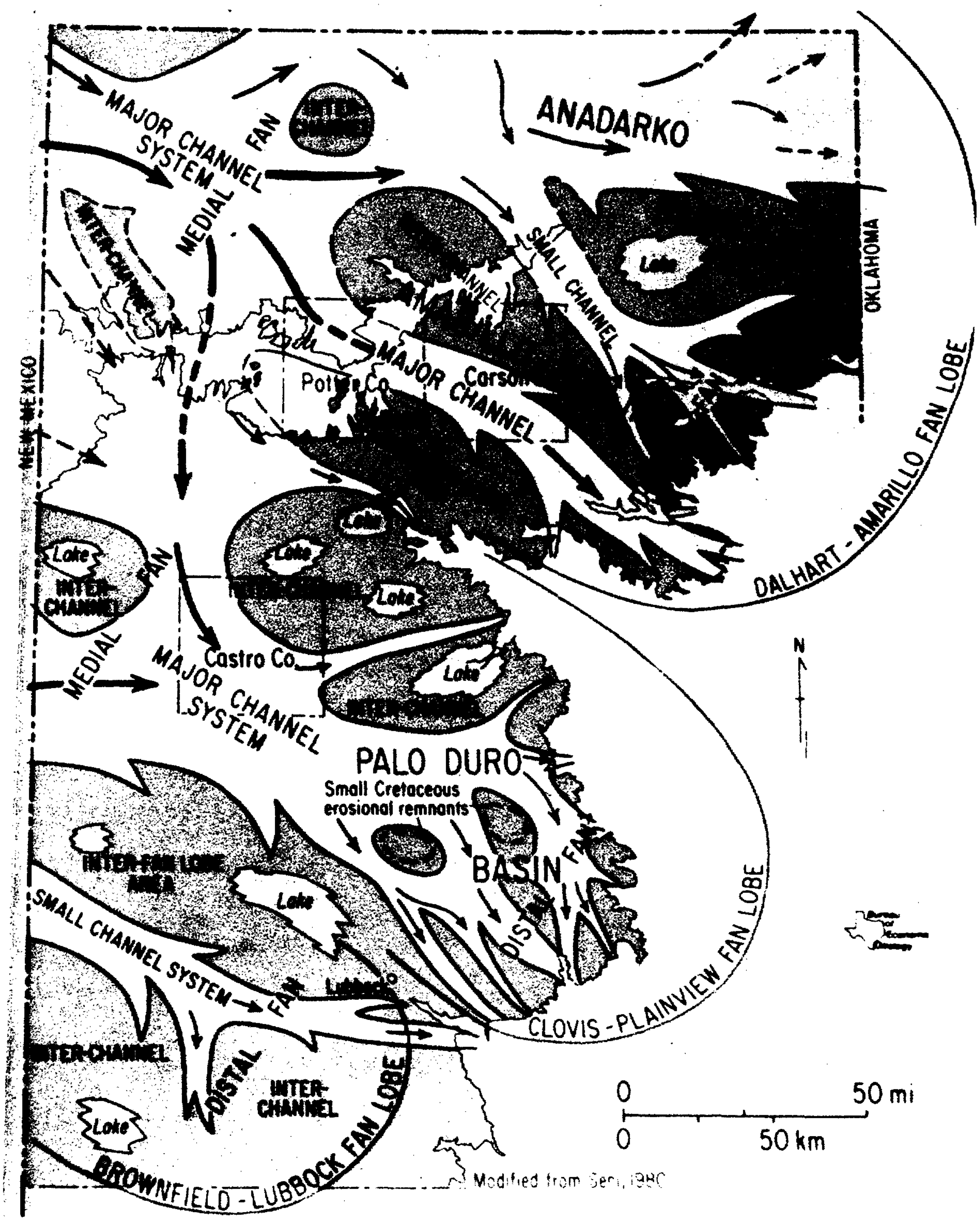
SALT BEARING

ISOPACH
PERMIAN post Wolfcamp

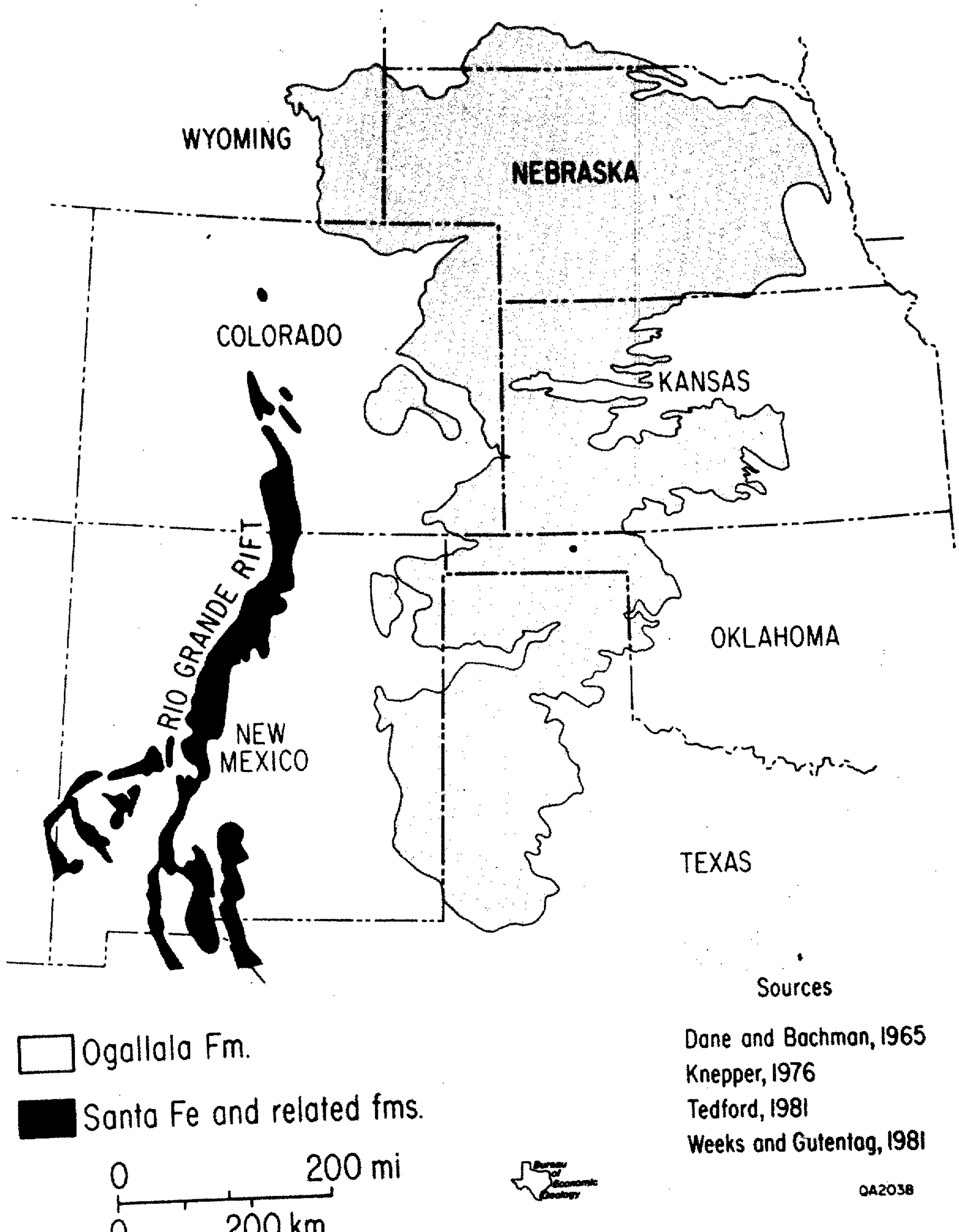
BEG
QA-3223


New Mexico
John Ray Dm.
6666 Dm.
Whittenburg Tr.
Bush Dm.
Oklahoma
0 50mi
0 80km
EXPLANATION
4000-4200 ft
3800-4000 ft
3600-3800 ft
3400-3600 ft
3200-3400 ft
3000-3200 ft
2800-3000 ft
2600-2800 ft
2400-2600 ft
2200-2400 ft
2000-2200 ft
N
STRUCTURE
BASE OGALLALA
BEG
QA 3733

DEPOSITIONAL PATTERNS OF OGALLALA FM.



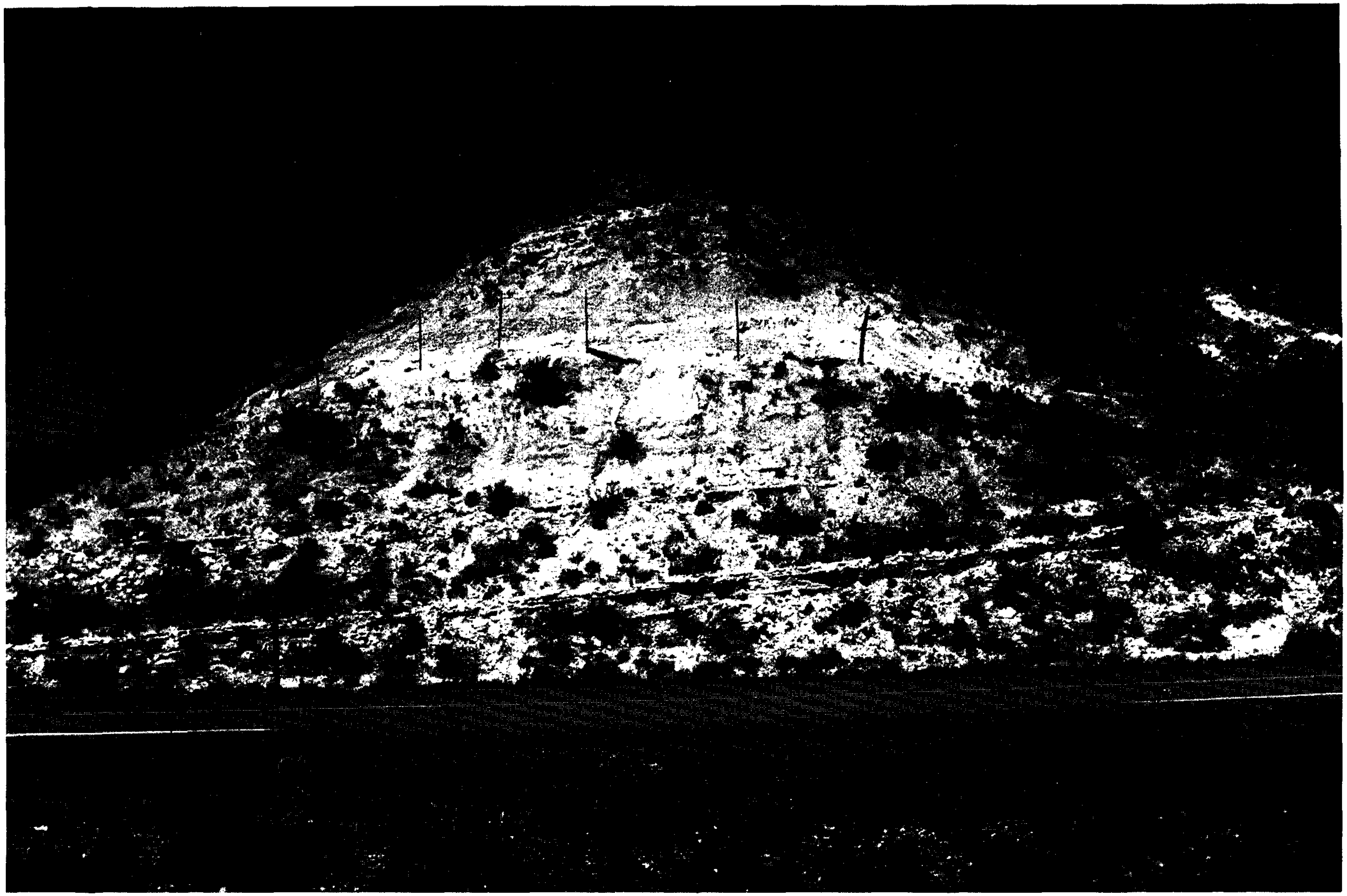
DISTRIBUTION OF NEOGENE SEDIMENTS

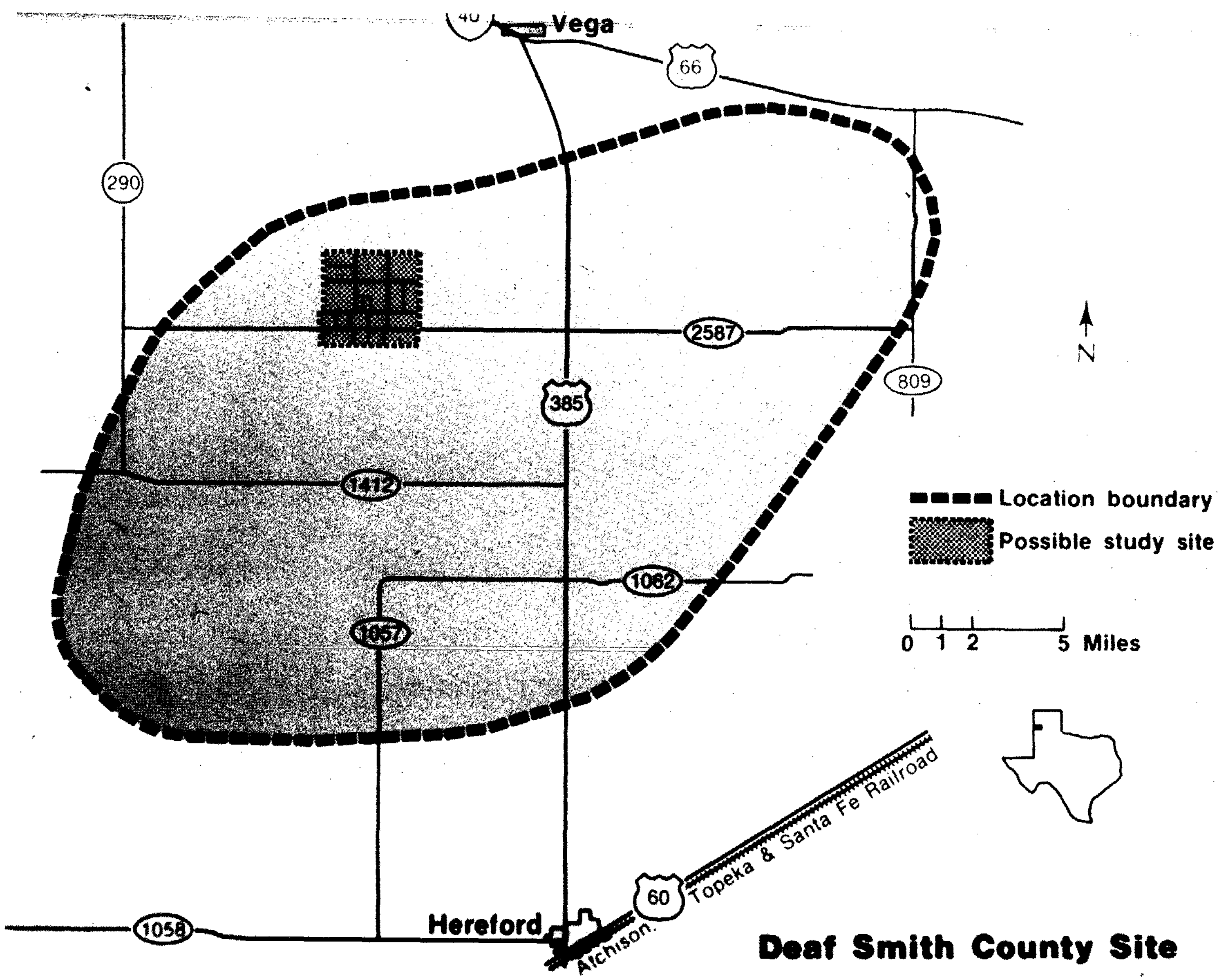


Sources

Dane and Bachman, 1965
Knepper, 1976
Tedford, 1981
Weeks and Gutentag, 1981

QA2038

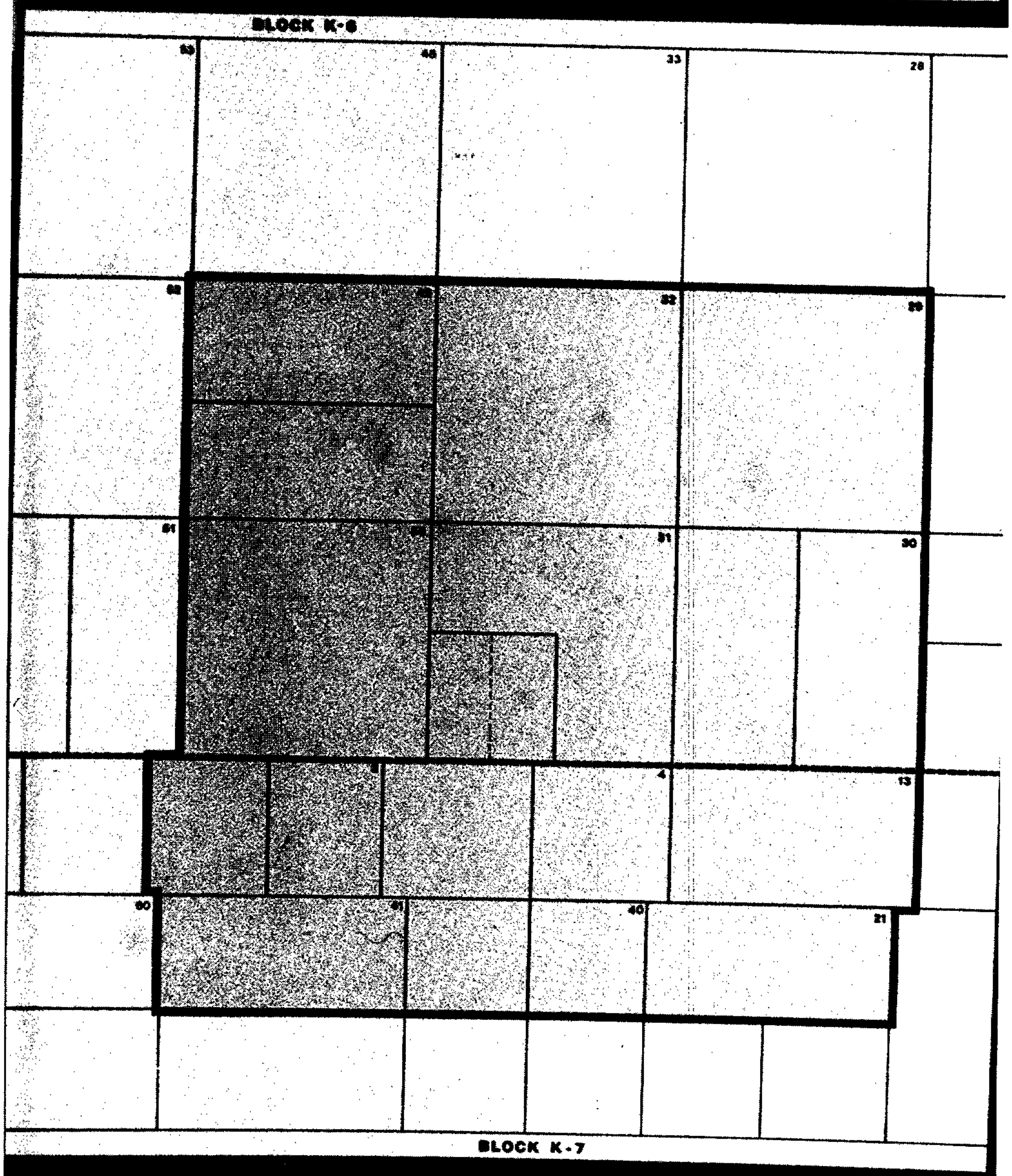




Deaf Smith County Site

Possible 9-Square-Mile Study Site
Deaf Smith County, Texas

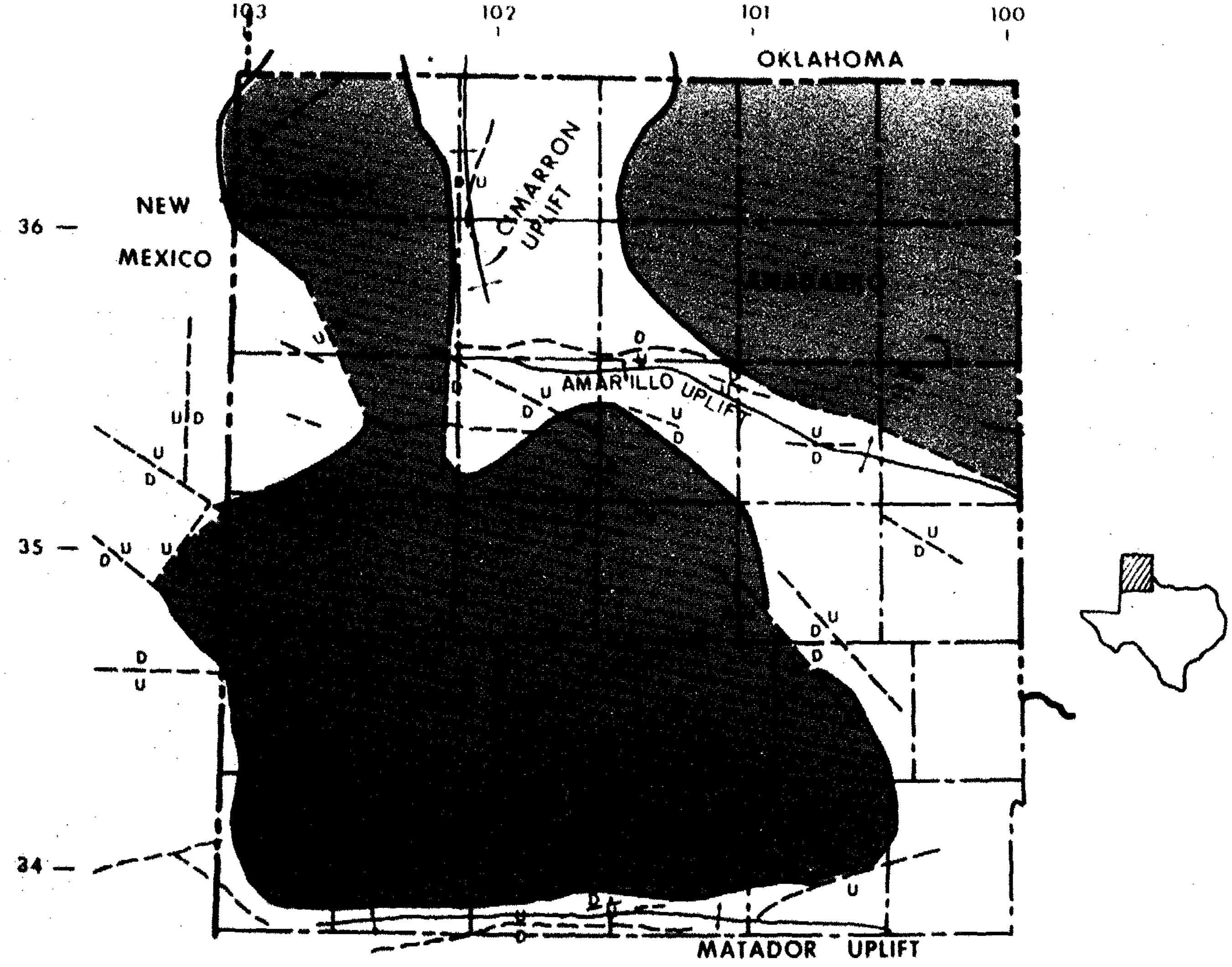
G.B.&C.N.G. RR

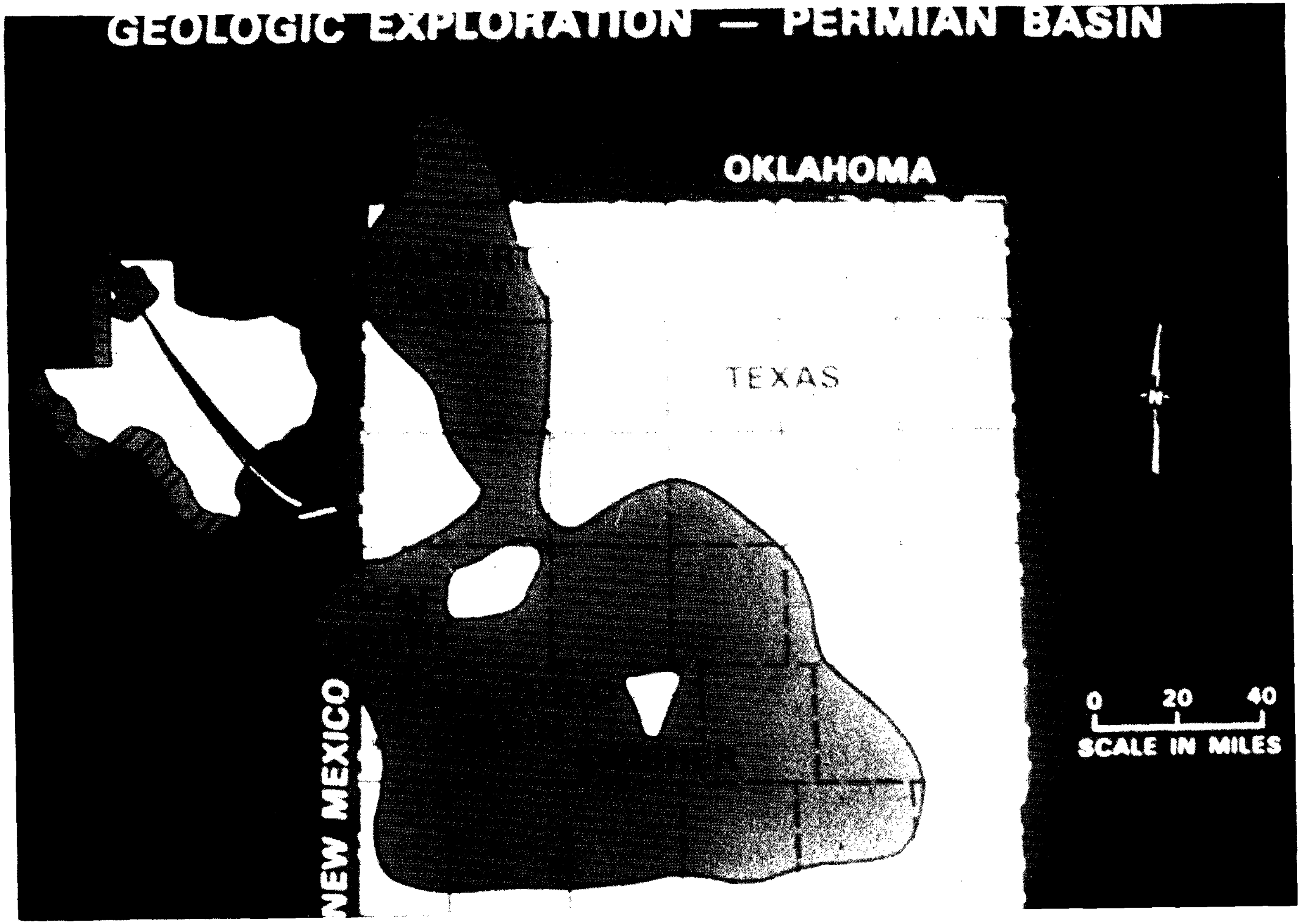


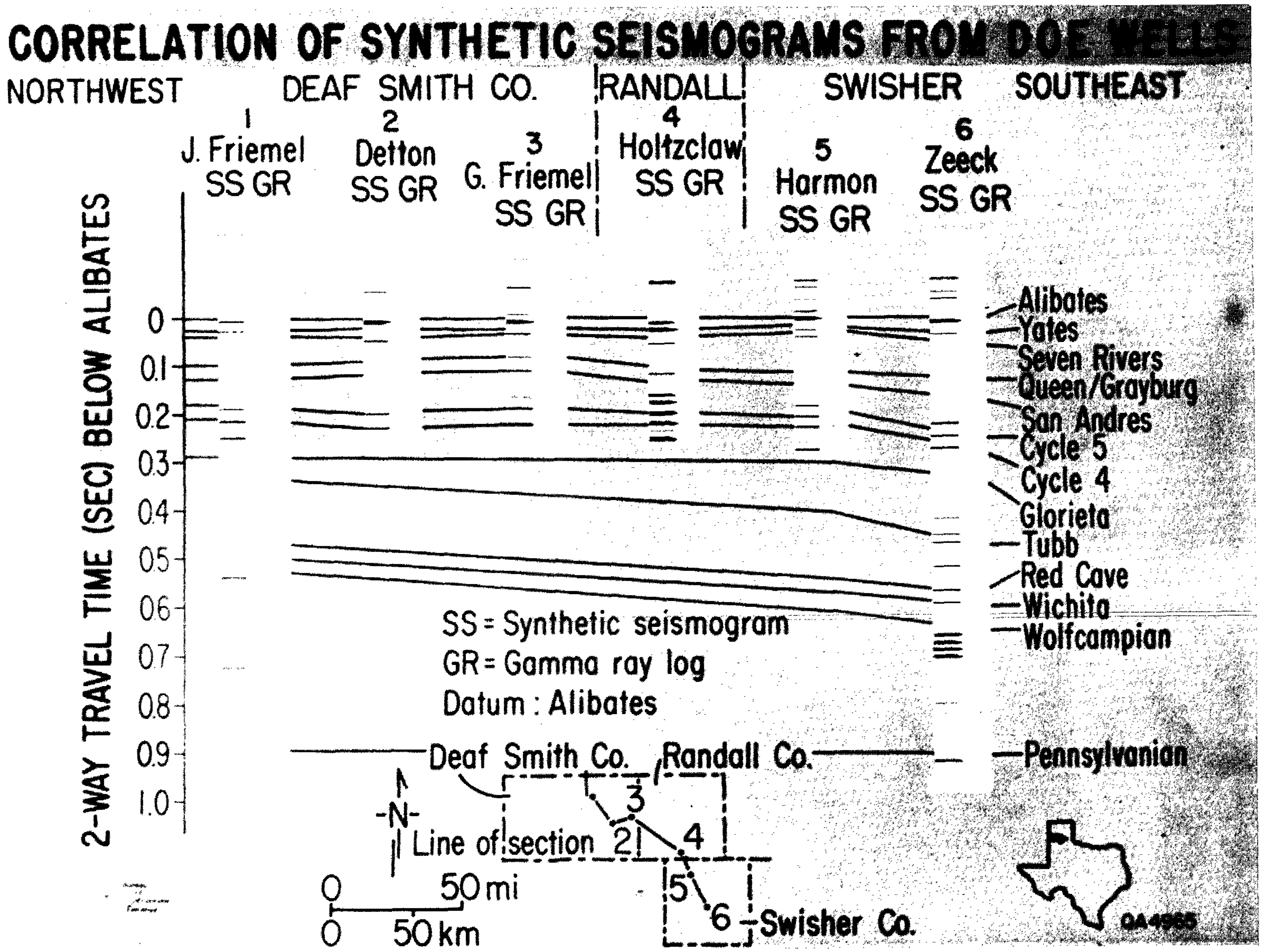
Possible study site boundary

Block boundary

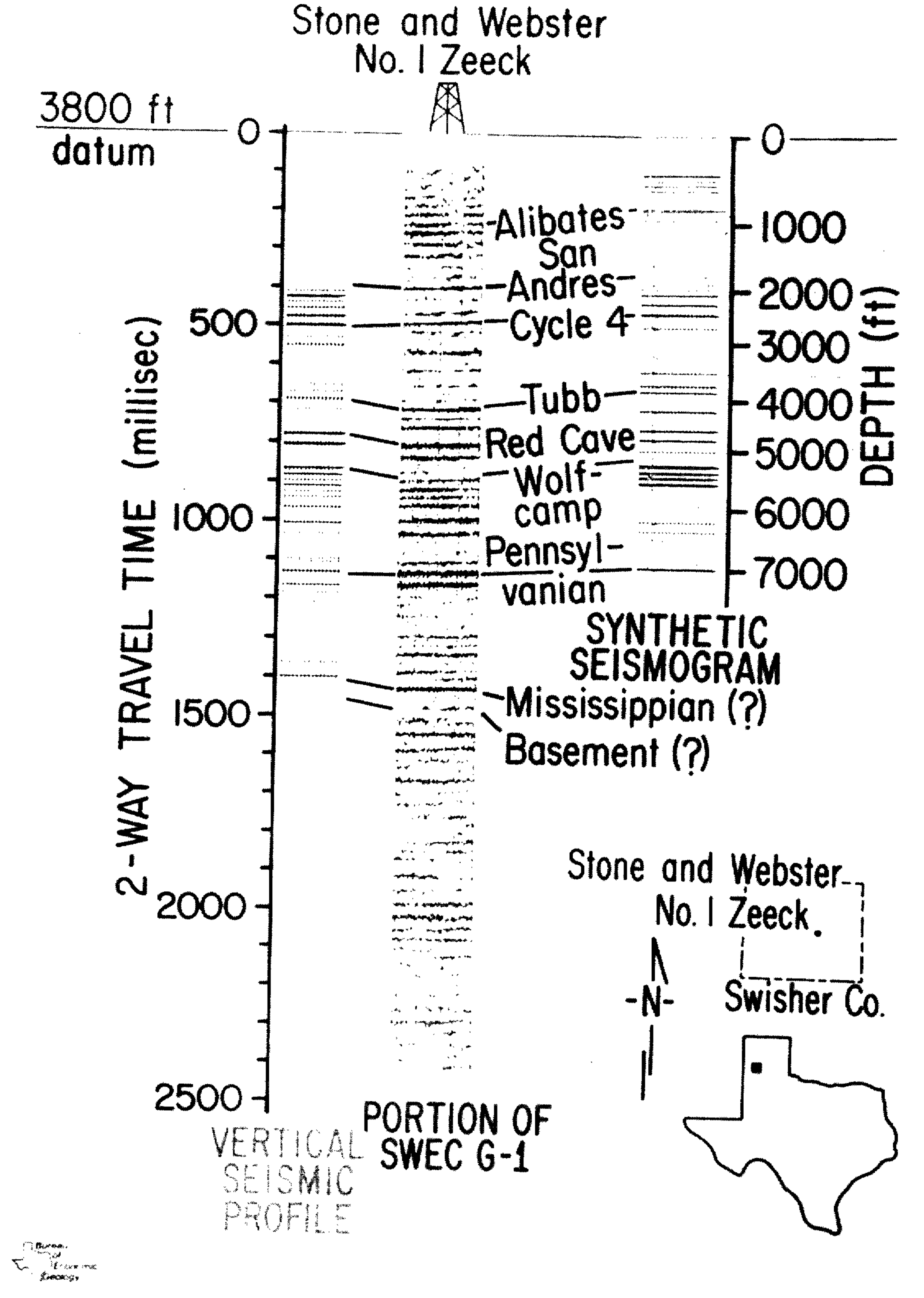
TECTONIC MAP

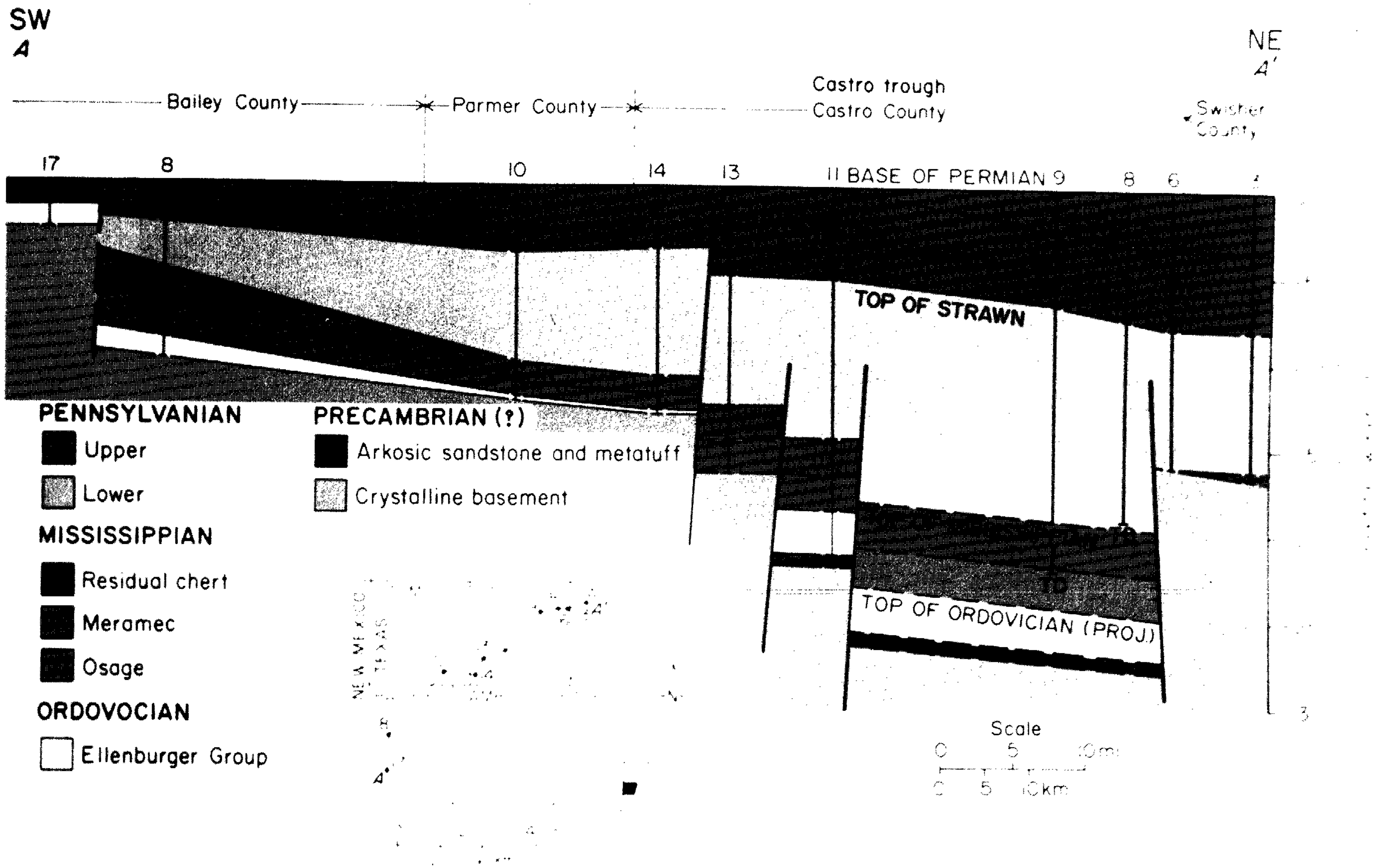



GEOLOGIC EXPLORATION — PERMIAN BASIN
OKLAHOMA
TEXAS
NEW MEXICO
N
0 20 40
SCALE IN MILES


CORRELATION OF SYNTHETIC SEISMOGRAMS FROM DOE WELLS
NORTHWEST
DEAF SMITH CO.
RANDALL
SWISHER
SOUTHEAST
1 J. Friemel SS GR
2 Detton SS GR
3 G. Friemel SS GR
4 Holtzclaw SS GR
5 Harmon SS GR
6 Zeeck SS GR
2-WAY TRAVEL TIME (SEC) BELOW ALIBATES
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Alibates
Yates
Seven Rivers
Queen/Grayburg
San Andres
Cycle 5
Cycle 4
Glorieta
Tubb
Red Cave
Wichita
Wolfcampian
Pennsylvanian
SS = Synthetic seismogram
GR = Gamma ray log
Datum : Alibates
Deaf Smith Co.
Randall Co.
Swisher Co.
N
Line of section
0 50 mi
0 50 km
QA4965

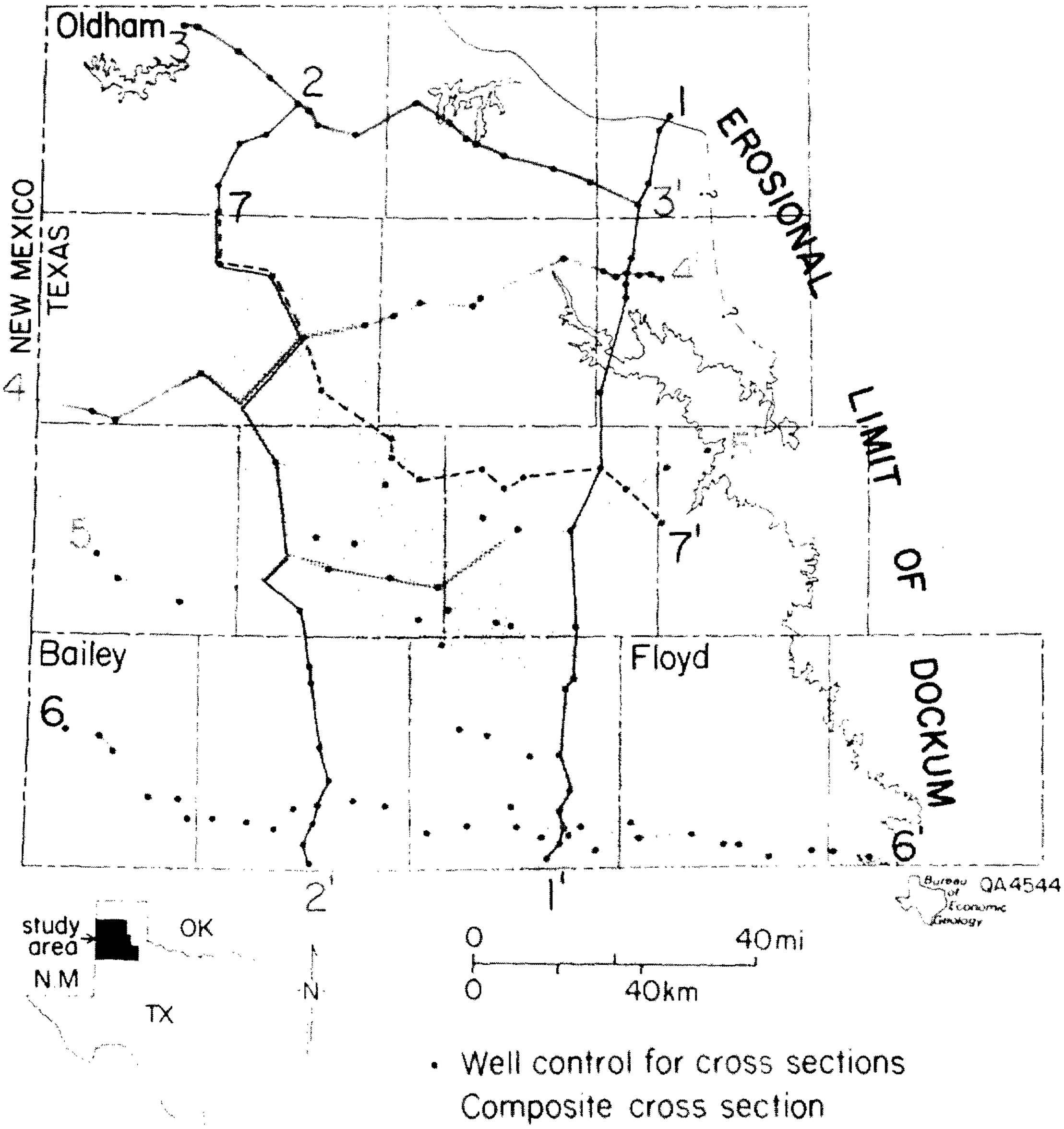
CORRELATION OF VSP, SYNTHETIC SEISMOGRAMS, & SEISMIC DATA

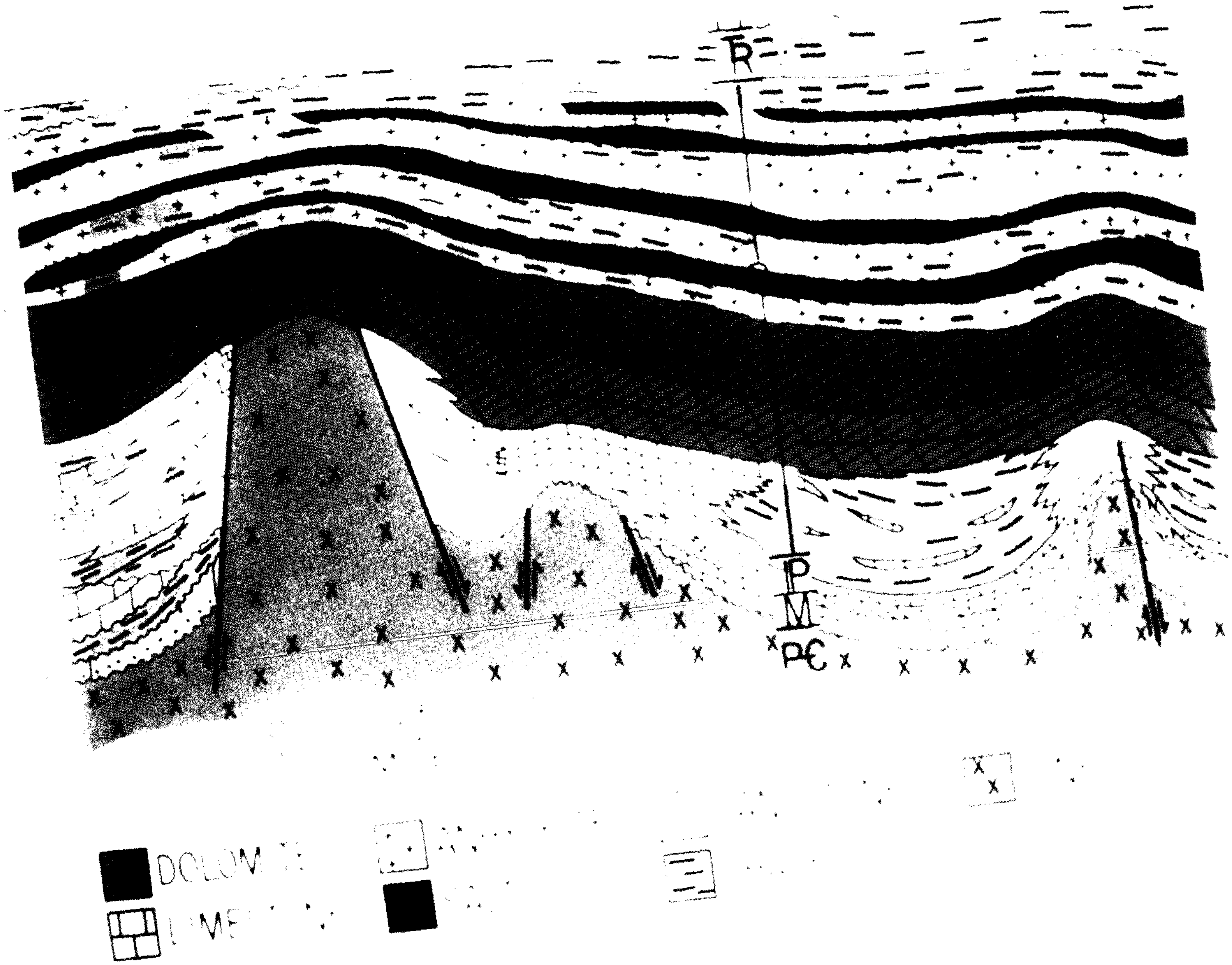


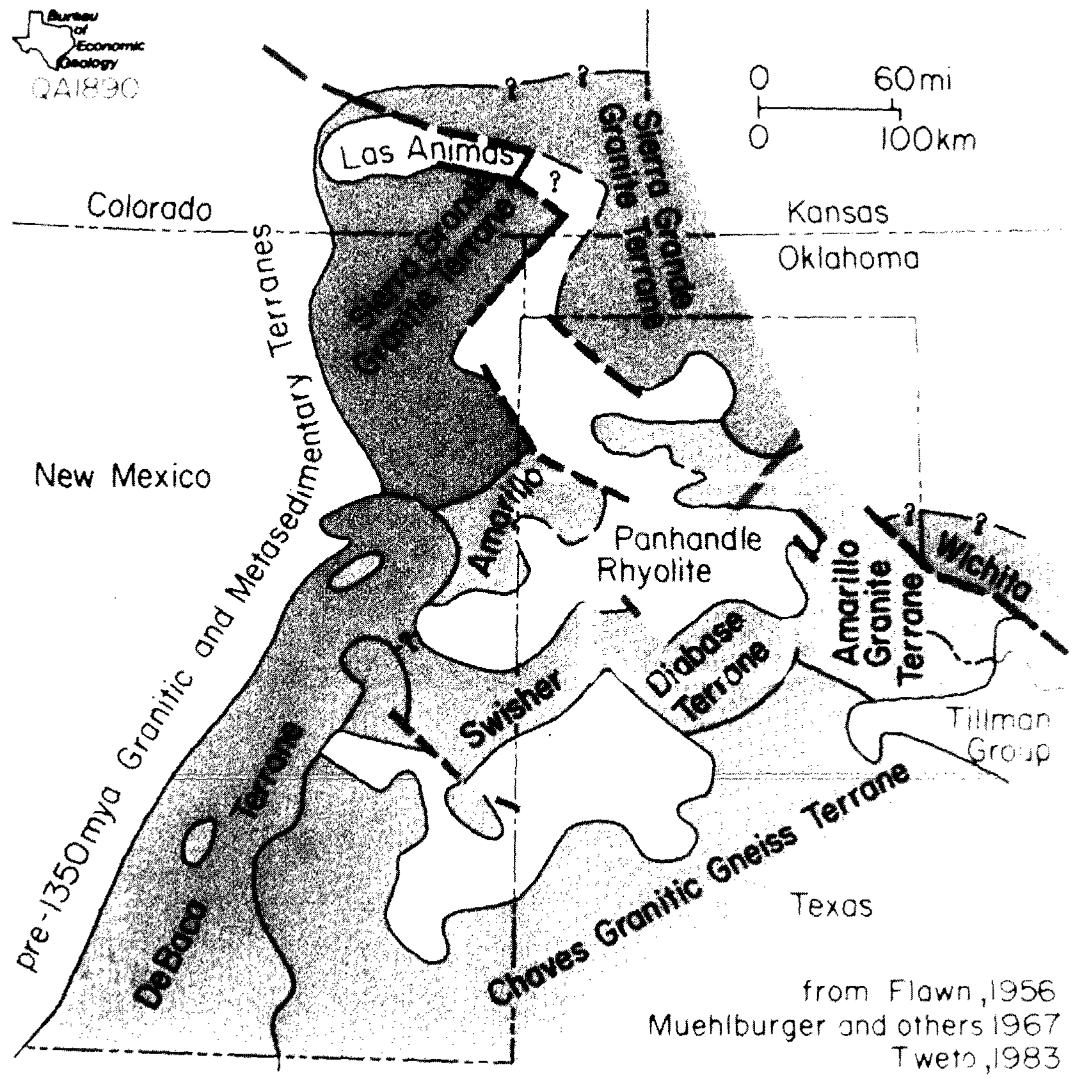


SW
A
NE
A'
Bailey County
Parmer County
Castro trough
Castro County
Swisher County
17
8
10
14
13
11 BASE OF PERMIAN 9
8
6
TOP OF STRAWN
TOP OF ORDOVICIAN (PROJ.)
PENNSYLVANIAN
Upper
Lower
MISSISSIPPIAN
Residual chert
Meramec
Osage
ORDOVOCIAN
Ellenburger Group
PRECAMBRIAN (?)
Arkosic sandstone and metatuff
Crystalline basement
Scale
0
5
10 mi
0
5
10 km

INDEX MAP

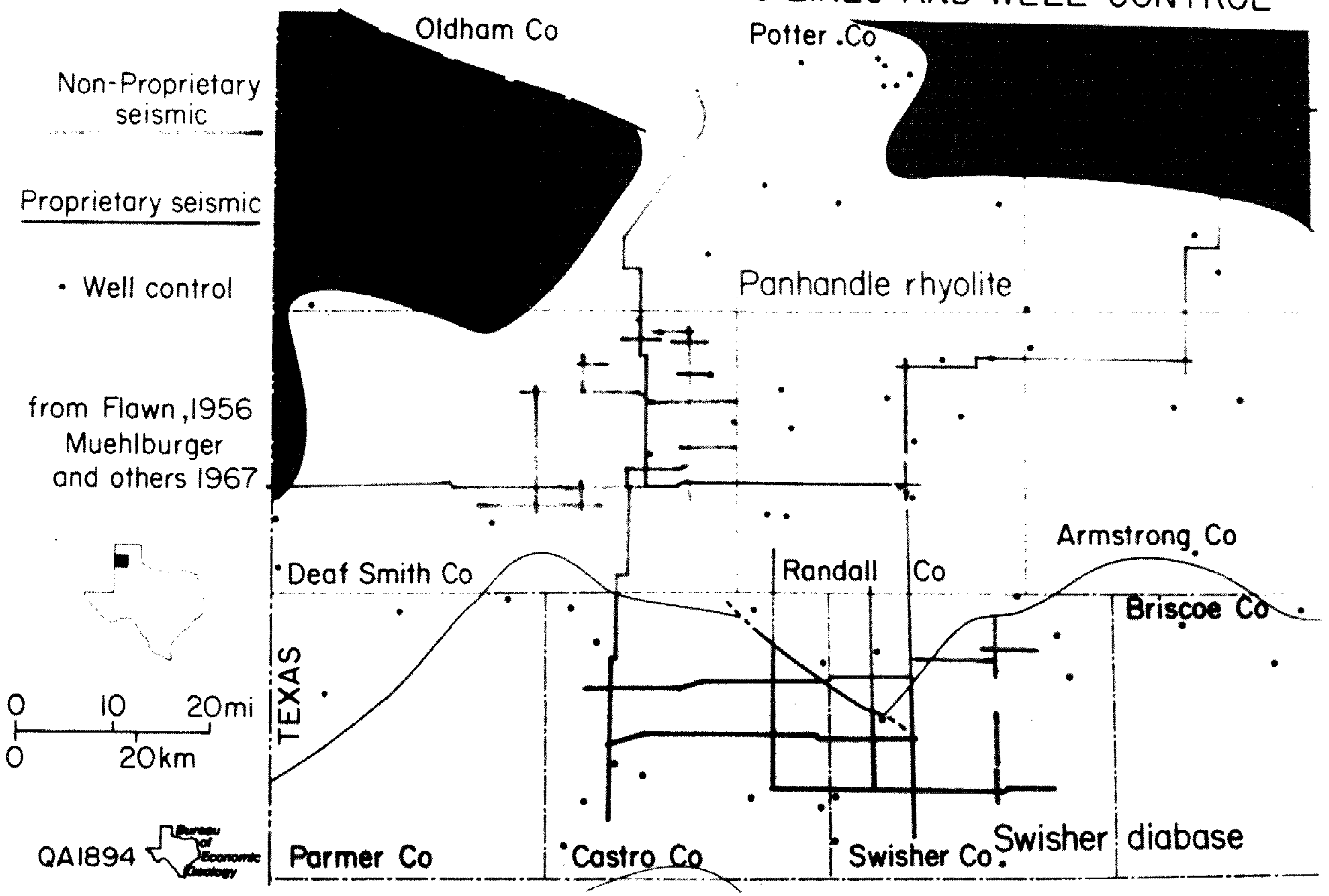

Oldham
NEW MEXICO
TEXAS
EROSIONAL LIMIT OF DOCKUM
Bailey
Floyd
1
1'
2
2'
3
3'
4
4'
5
6
6'
7
7'
QA4544
Bureau of Economic Geology
study area
OK
N.M
TX
N
0
40mi
0
40km
• Well control for cross sections
Composite cross section

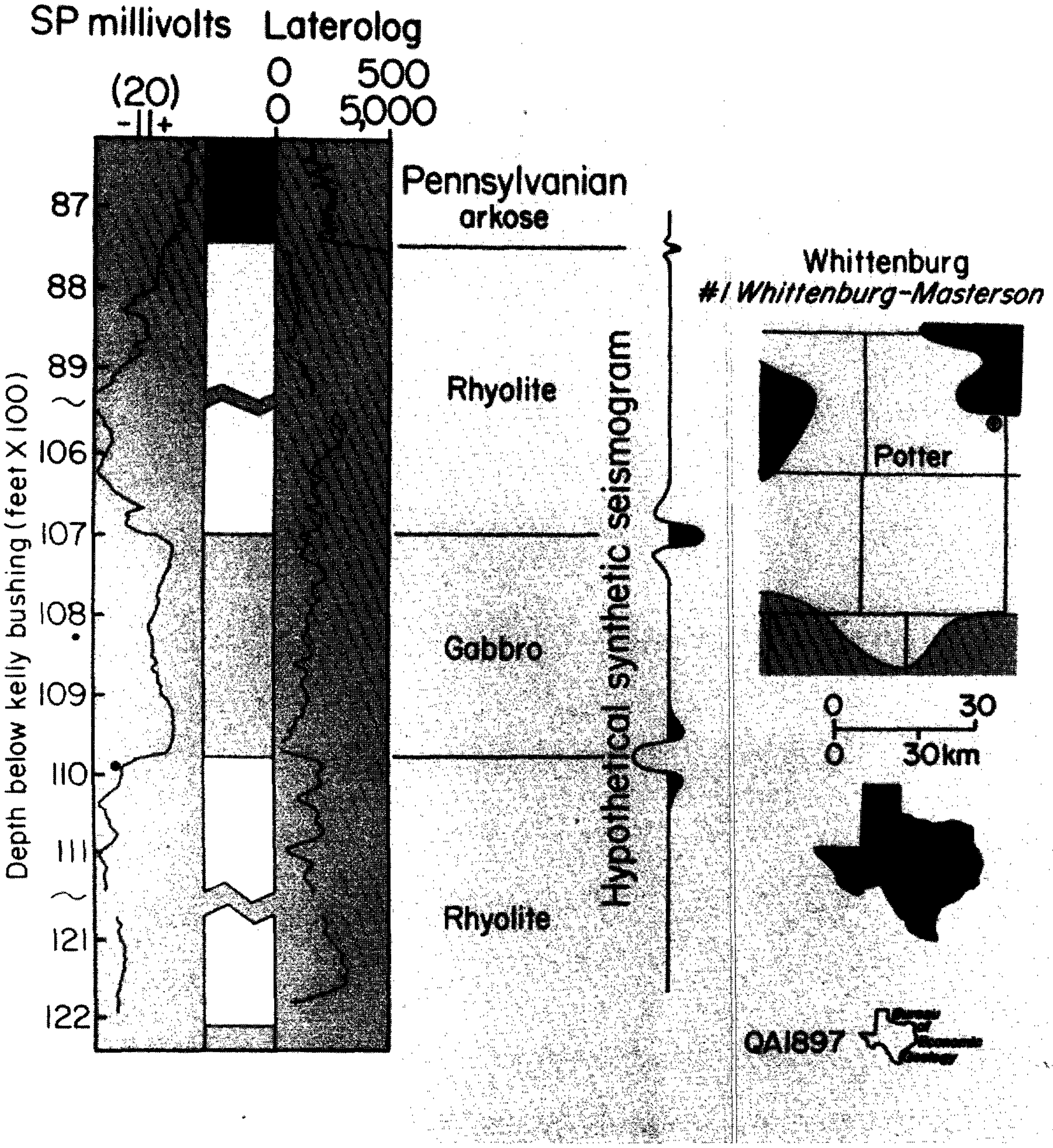

R
P
M
PЄ

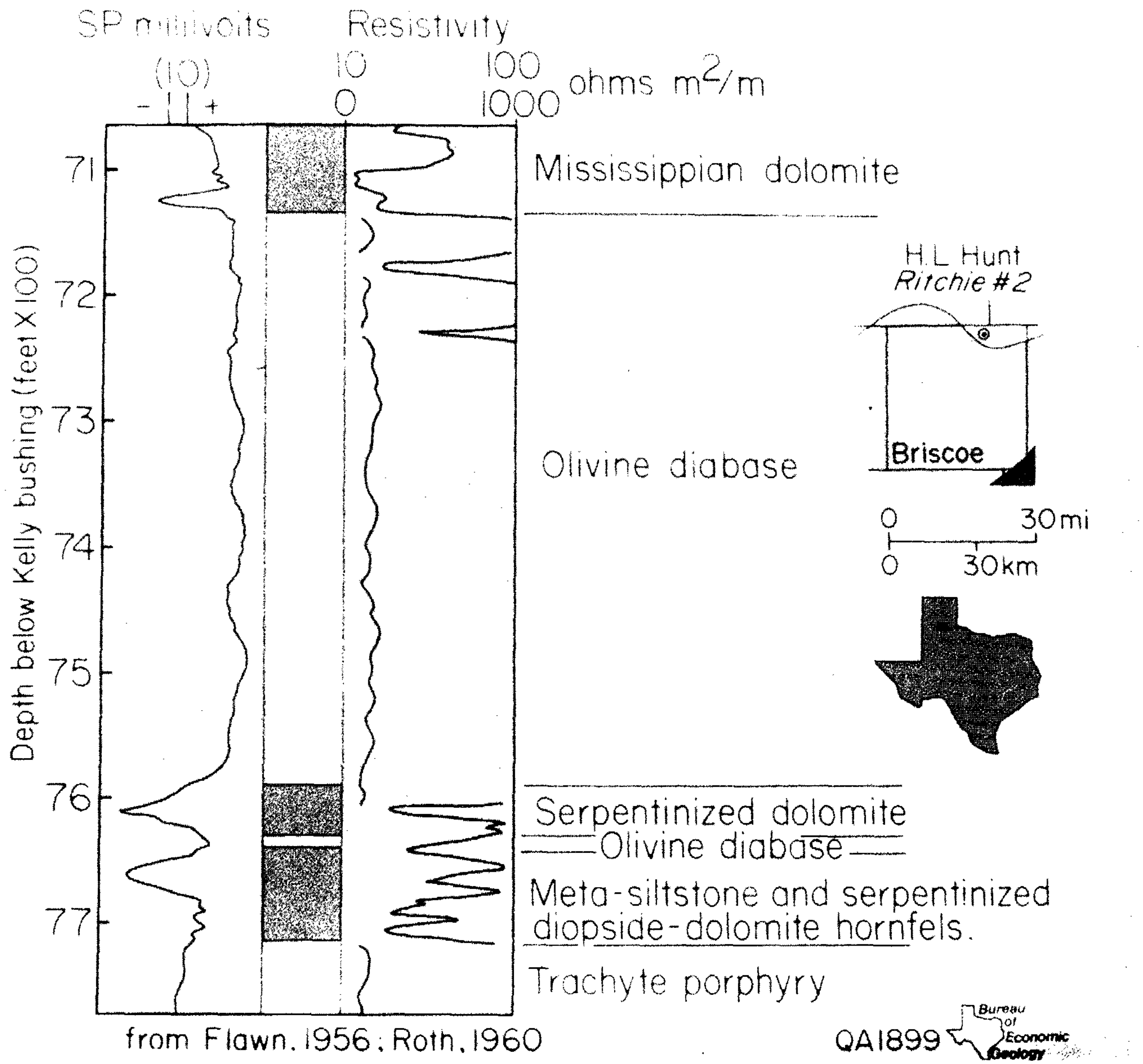


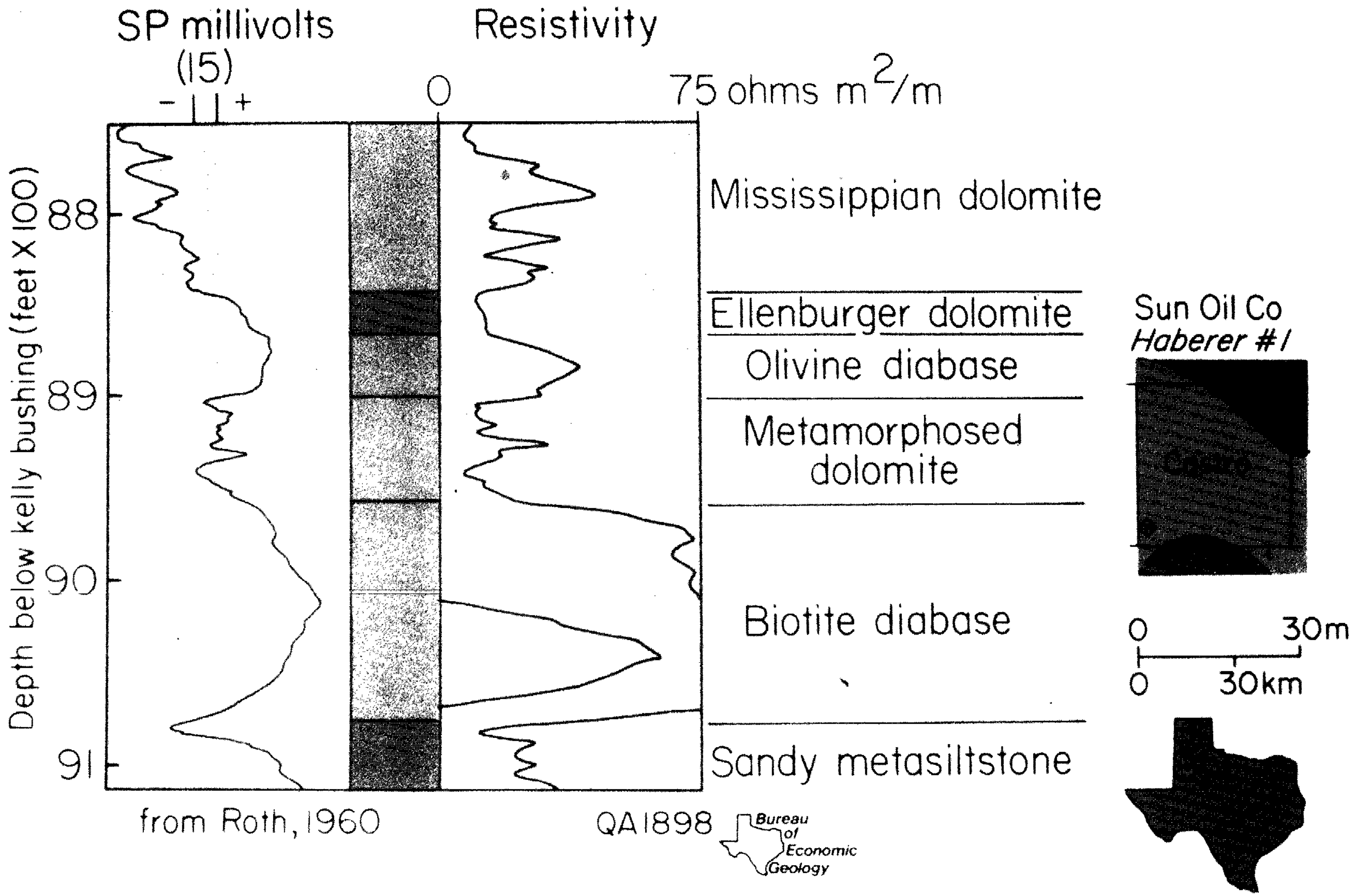
DISTRIBUTION OF BASEMENT TERRANES

DISTRIBUTION OF SEISMIC LINES AND WELL CONTROL



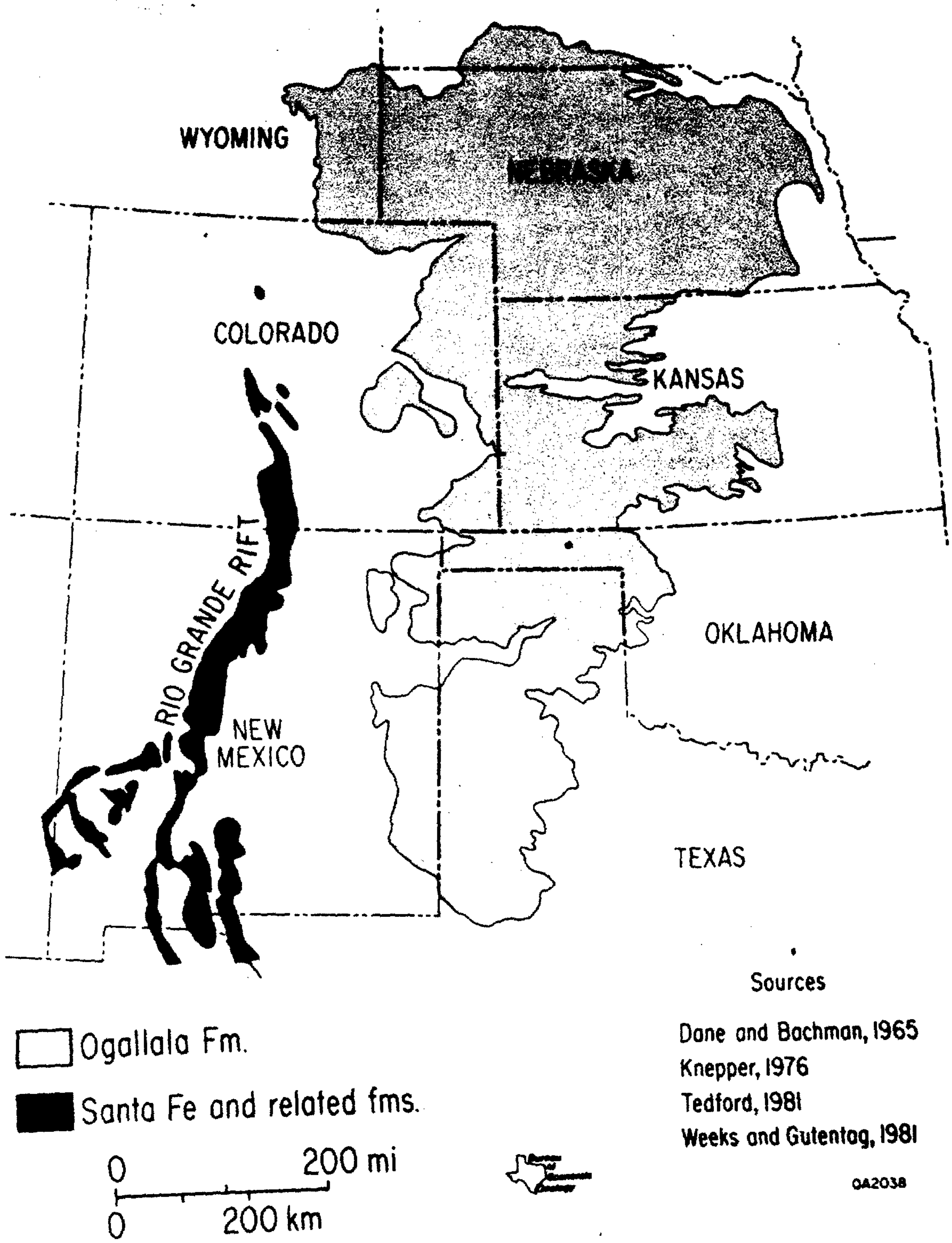

SP millivolts
Laterolog
(20)
0 500
0 5,000
Pennsylvanian
arkose
Rhyolite
Gabbro
Rhyolite
Depth below kelly bushing (feet X 100)
87
88
89
106
107
108
109
110
111
121
122
Hypothetical synthetic seismogram
Whittenburg
#1 Whittenburg-Masterson
Potter
0 30
0 30km
QA1897

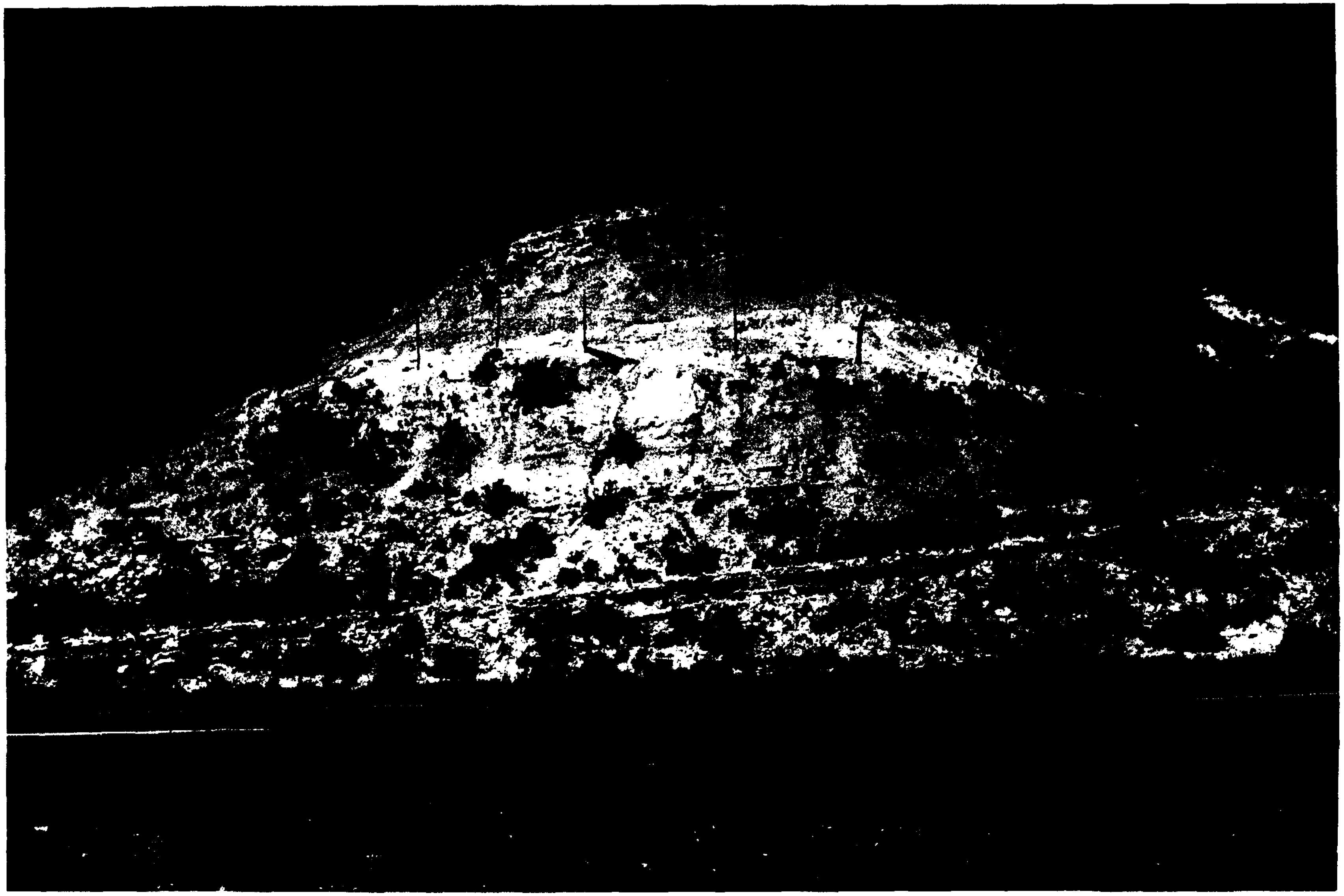

SP millivolts
(10)
- +
Resistivity
10
0
100
1000
ohms m2/m
Depth below Kelly bushing (feet X 100)
71
72
73
74
75
76
77
Mississippian dolomite
Olivine diabase
Serpentinized dolomite
Olivine diabase
Meta-siltstone and serpentinized
diopside-dolomite hornfels.
Trachyte porphyry
H.L Hunt
Ritchie #2
Briscoe
0
30 mi
0
30 km
from Flawn, 1956; Roth, 1960
QA1899
Bureau of Economic Geology

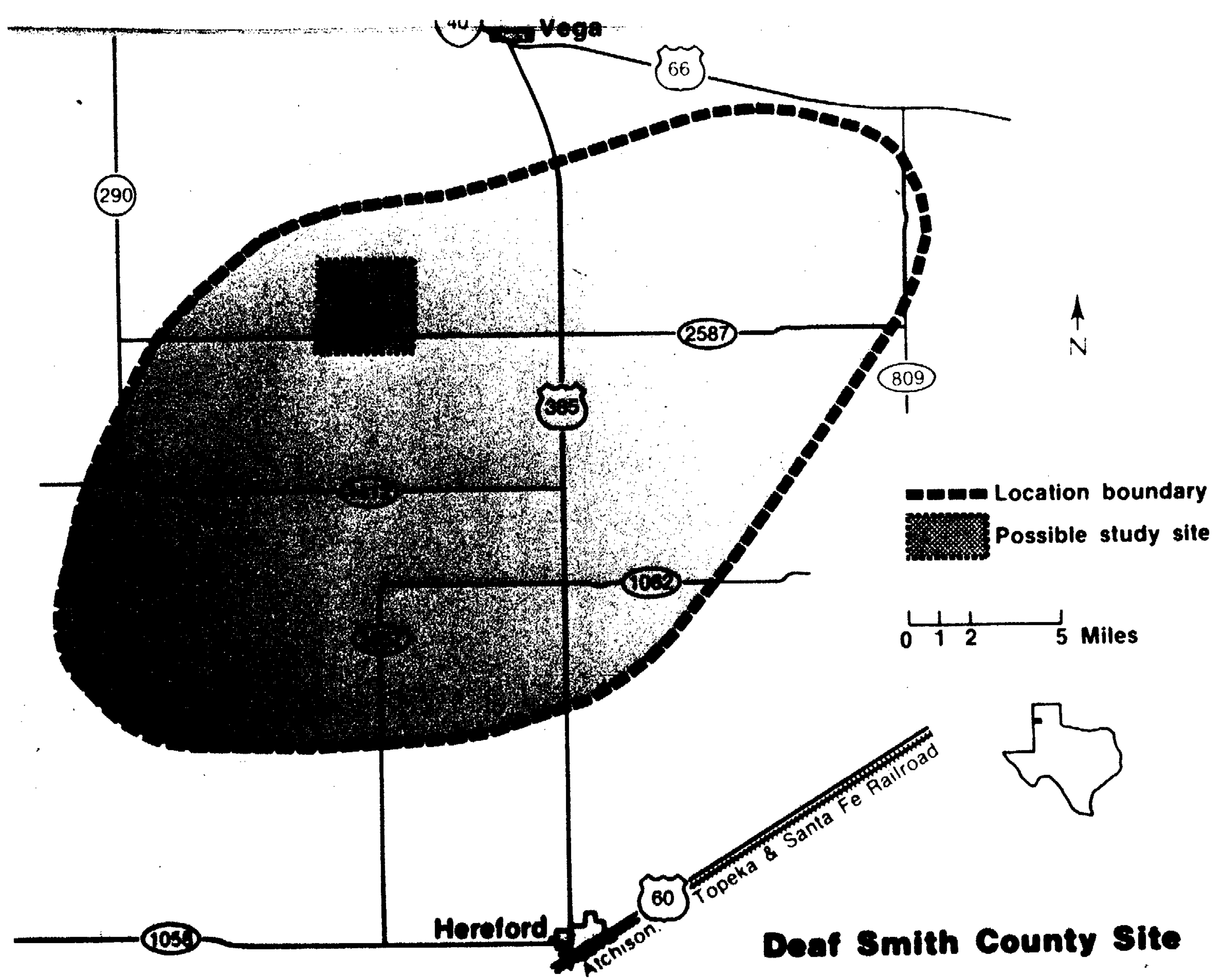

SP millivolts
(15)
− +
Resistivity
0
75 ohms m²/m
Depth below kelly bushing (feet X 100)
88
89
90
91
Mississippian dolomite
Ellenburger dolomite
Olivine diabase
Metamorphosed dolomite
Biotite diabase
Sandy metasiltstone
Sun Oil Co
Haberer #1
0 30mi
0 30km
from Roth, 1960
QA1898
Bureau of Economic Geology


-50
-25
0

DISTRIBUTION OF NEOGENE SEDIMENTS



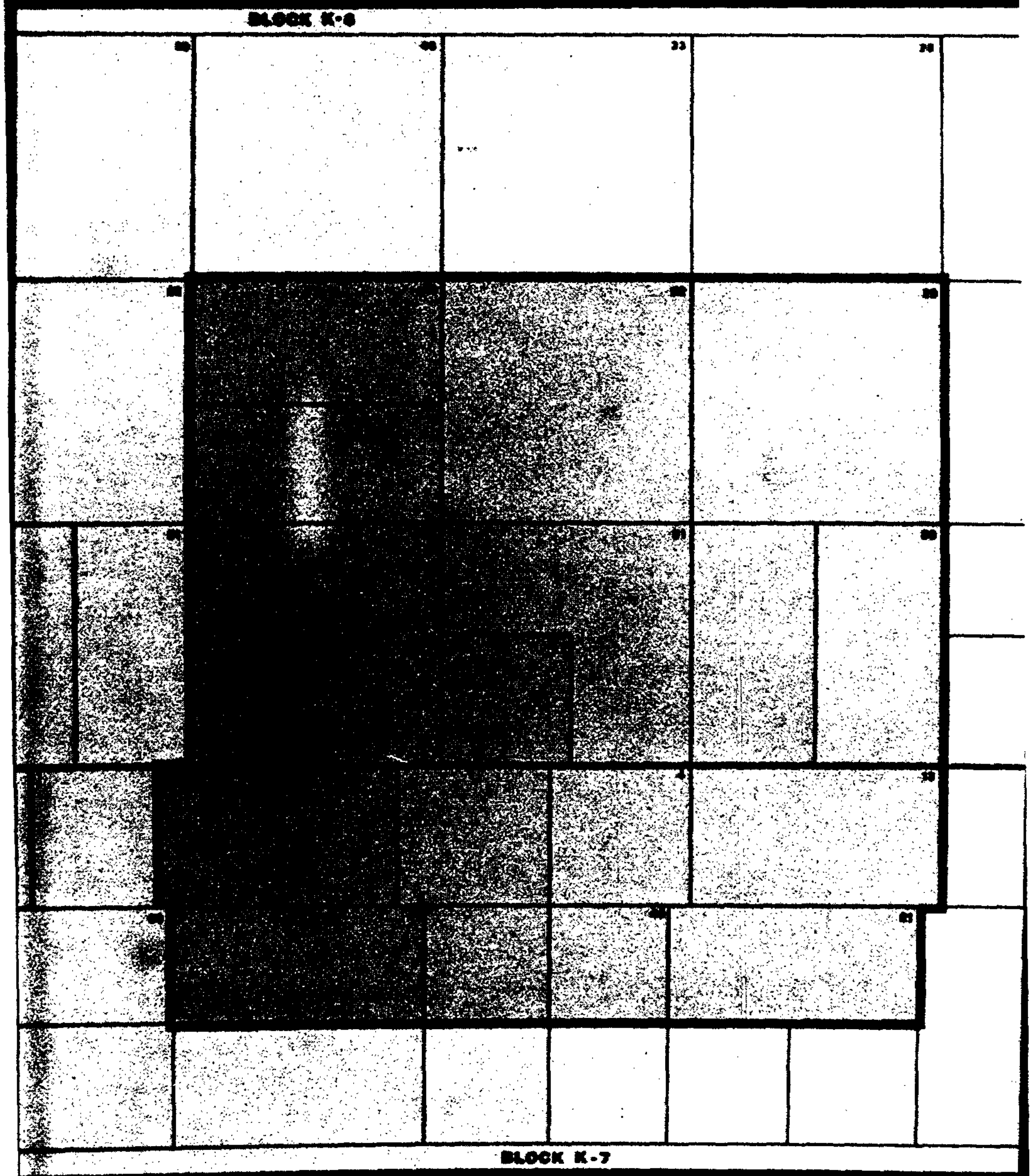




Deaf Smith County Site

Possible 9-Square-Mile Study Site
Deaf Smith County, Texas

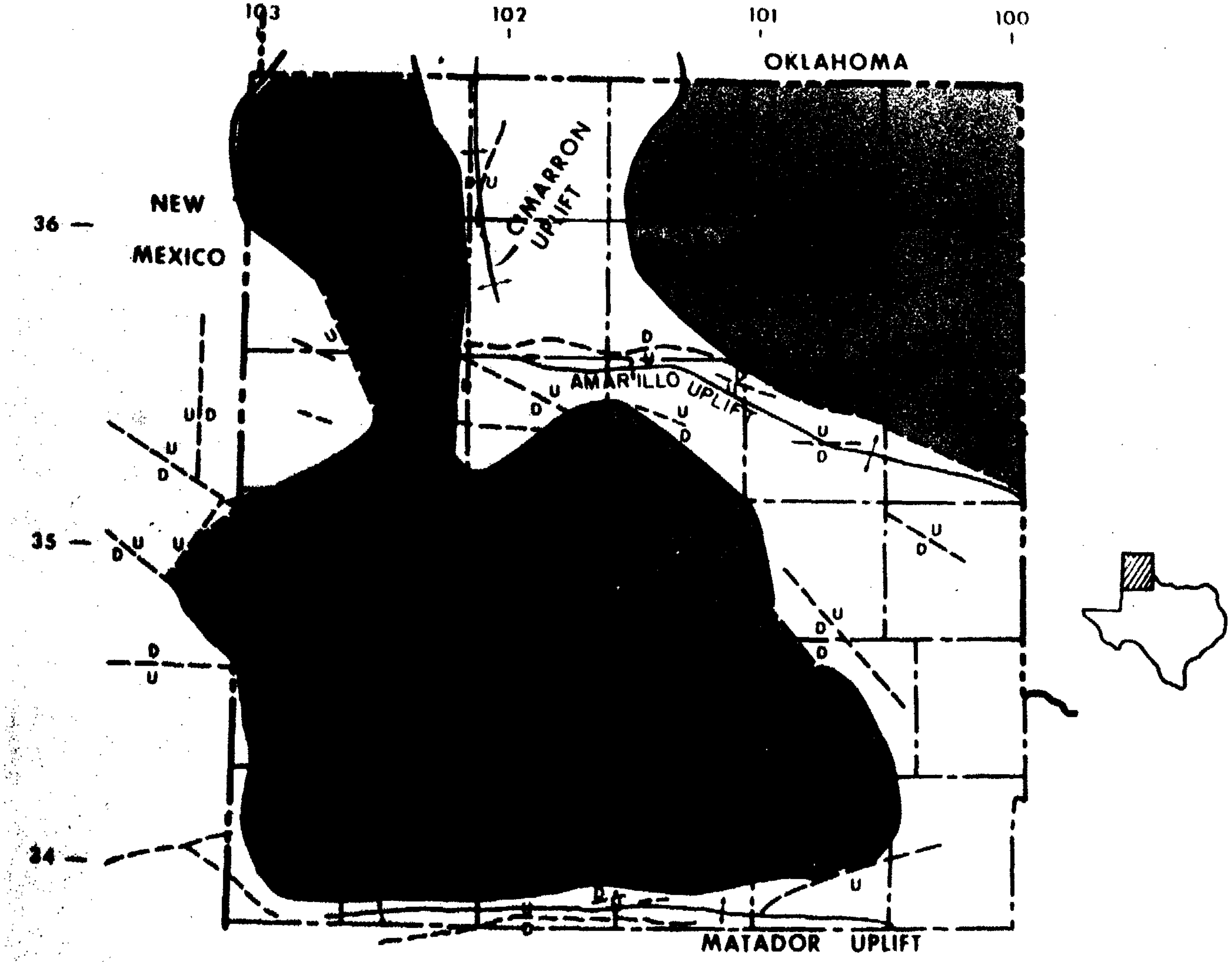
G.B.&C.N.G. RR



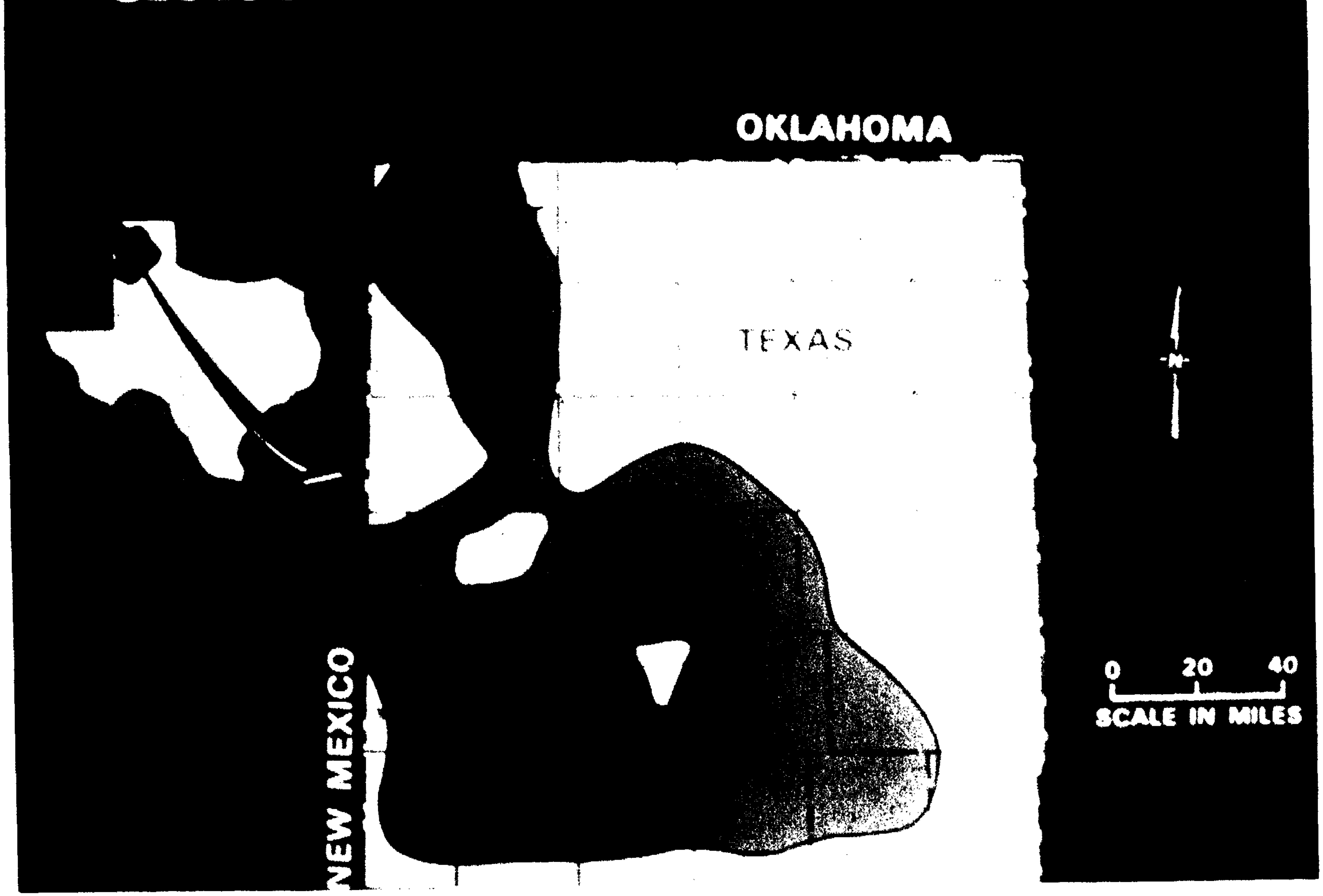
Possible study site boundary

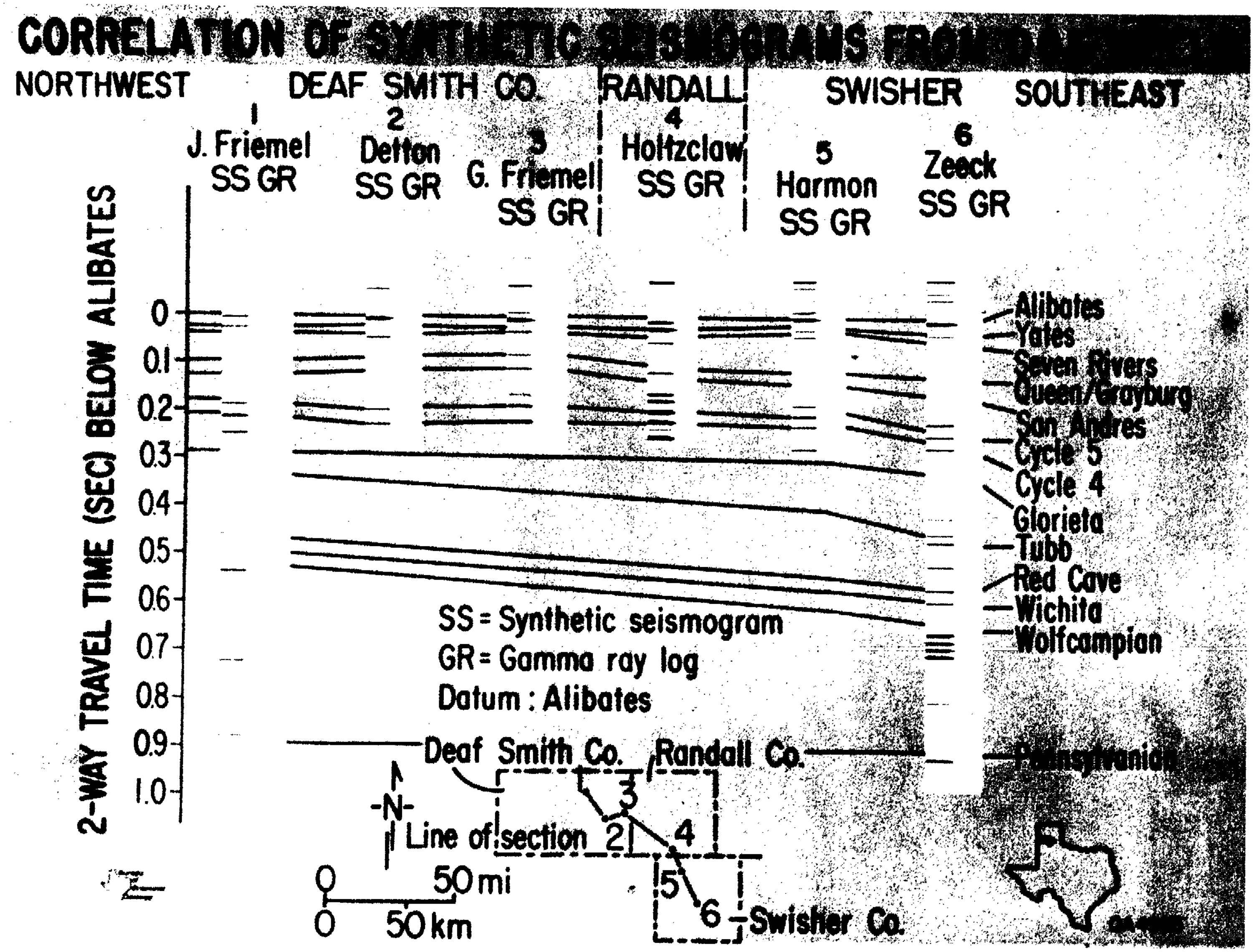
Block boundary

TECTONIC MAP



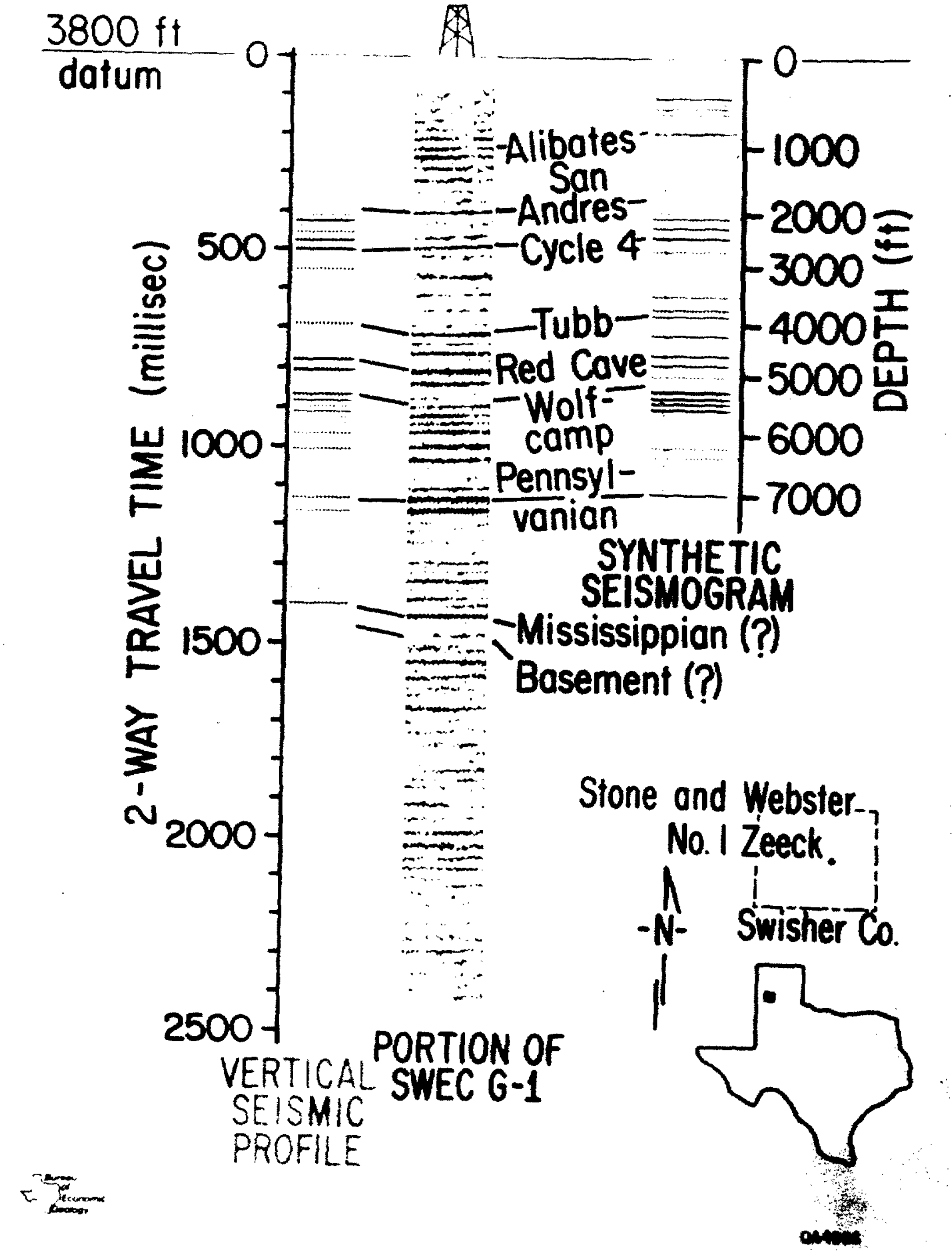
GEOLOGIC EXPLORATION — PERMIAN BASIN

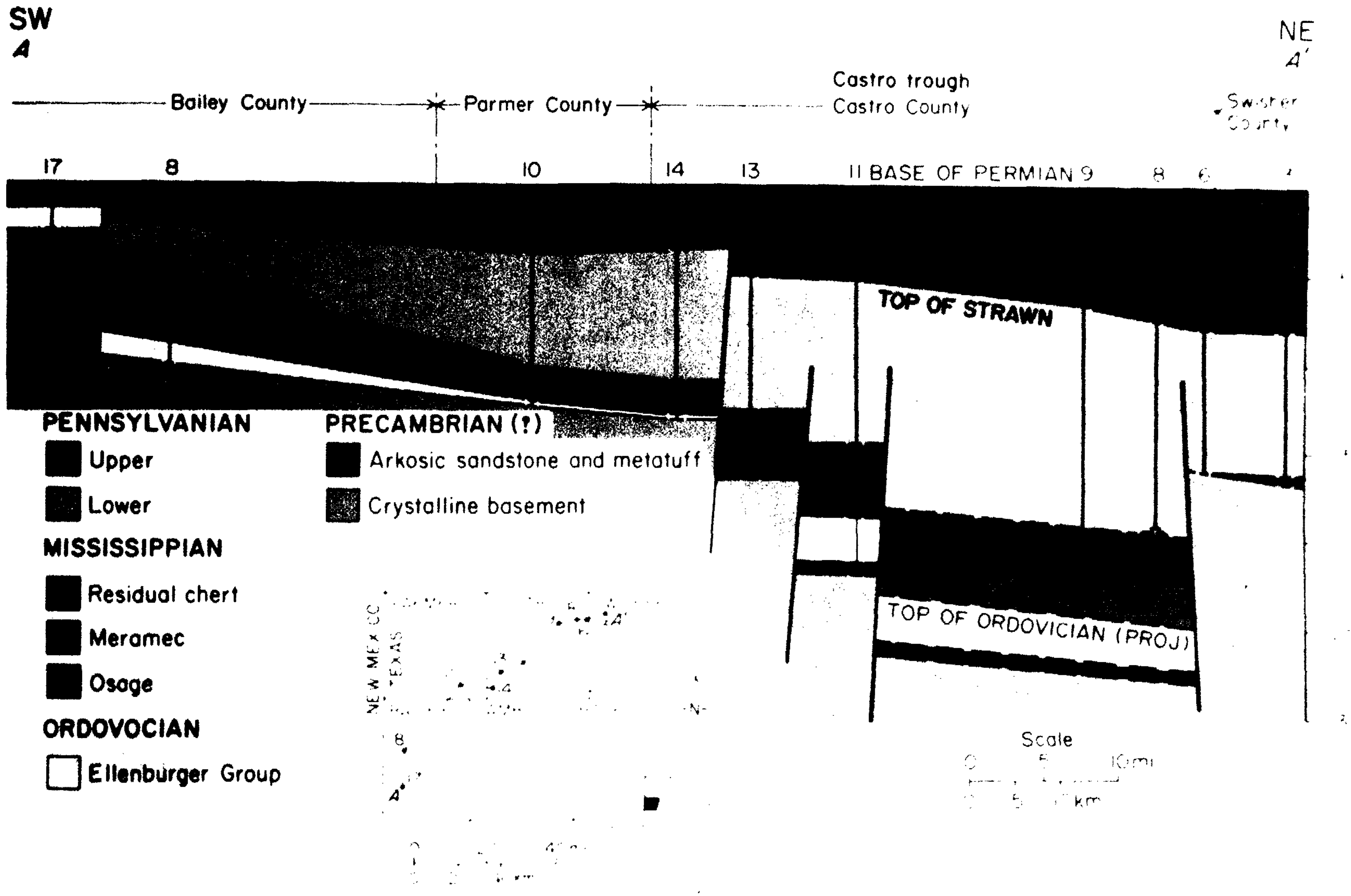



CORRELATION OF SYNTHETIC SEISMOGRAMS
NORTHWEST
DEAF SMITH CO.
RANDALL
SWISHER
SOUTHEAST
1 J. Friemel SS GR
2 Detton SS GR
3 G. Friemel SS GR
4 Holtzclaw SS GR
5 Harmon SS GR
6 Zeeck SS GR
2-WAY TRAVEL TIME (SEC) BELOW ALIBATES
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Alibates
Yates
Seven Rivers
Queen/Grayburg
San Andres
Cycle 5
Cycle 4
Glorieta
Tubb
Red Cave
Wichita
Wolfcampian
Pennsylvanian
SS = Synthetic seismogram
GR = Gamma ray log
Datum : Alibates
Deaf Smith Co.
Randall Co.
Swisher Co.
-N-
Line of section
0 50 mi
0 50 km

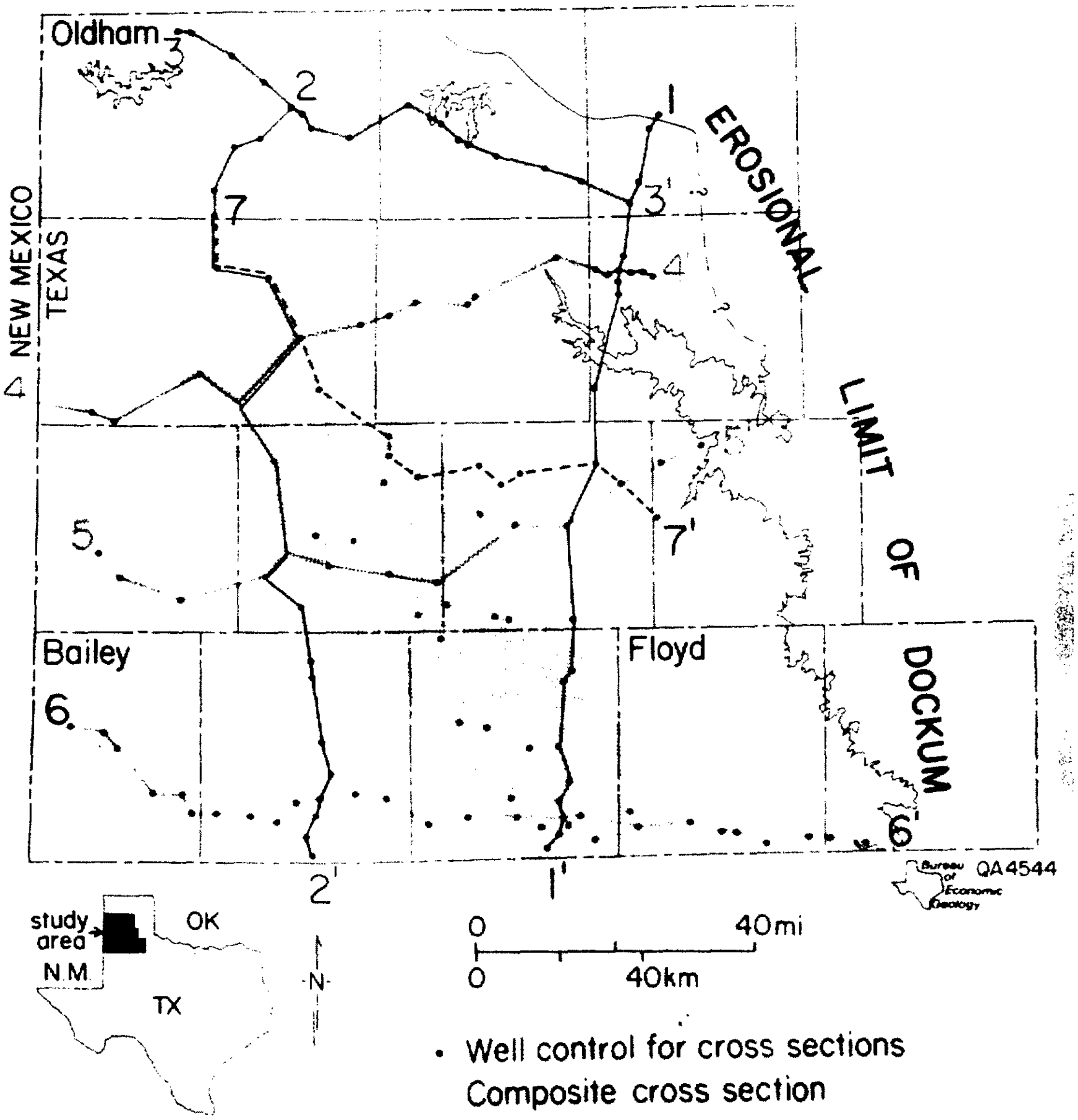
CORRELATION OF VSP, SYNTHETIC SEISMOGRAMS, & SEISMIC DATA

Stone and Webster
No. 1 Zeeck



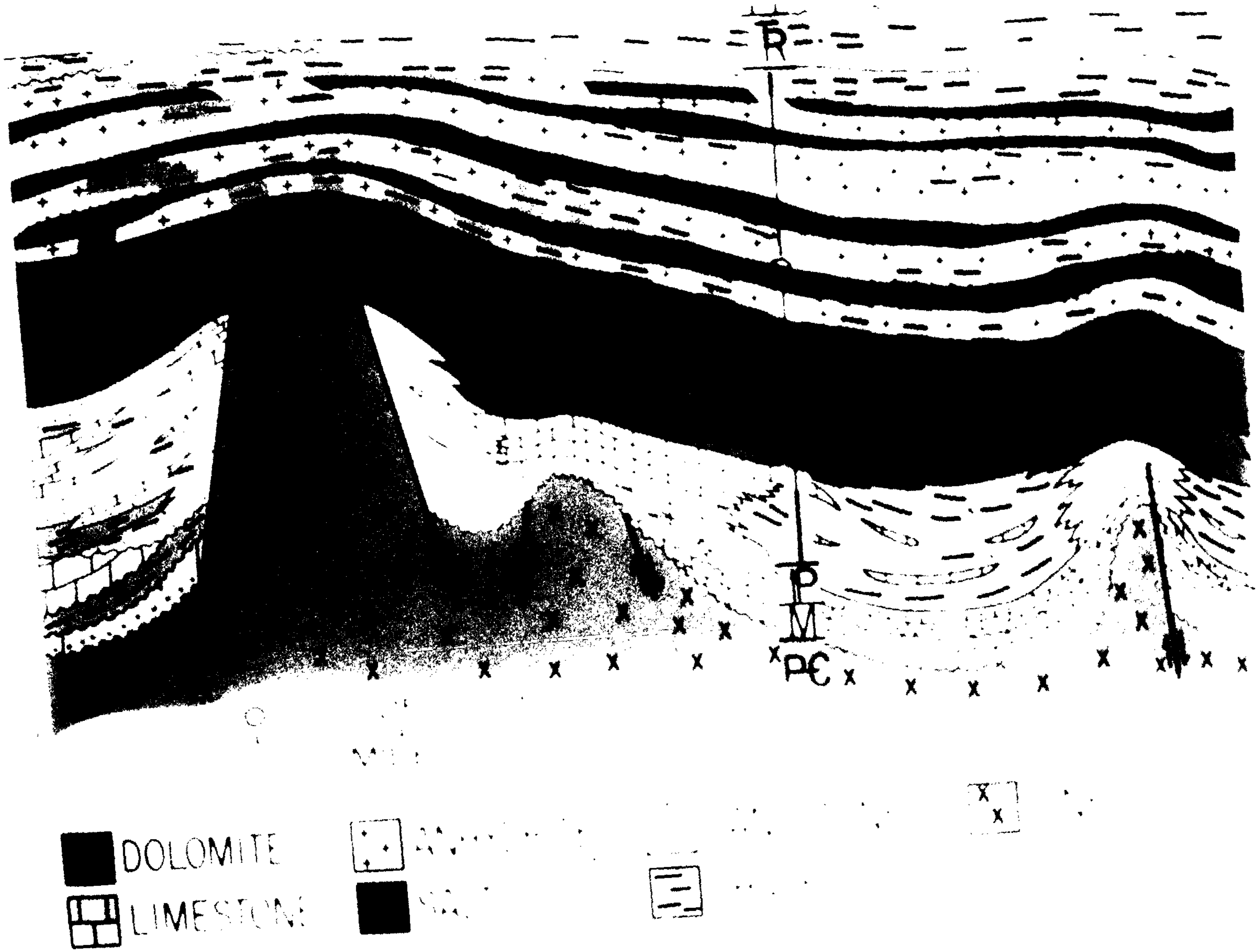

SW
A
NE
A'
Castro trough
Bailey County
Parmer County
Castro County
17
8
10
14
13
11 BASE OF PERMIAN 9
8
TOP OF STRAWN
TOP OF ORDOVICIAN (PROJ)
PENNSYLVANIAN
Upper
Lower
MISSISSIPPIAN
Residual chert
Meramec
Osage
ORDOVOCIAN
Ellenburger Group
PRECAMBRIAN (?)
Arkosic sandstone and metatuff
Crystalline basement
Scale

INDEX MAP

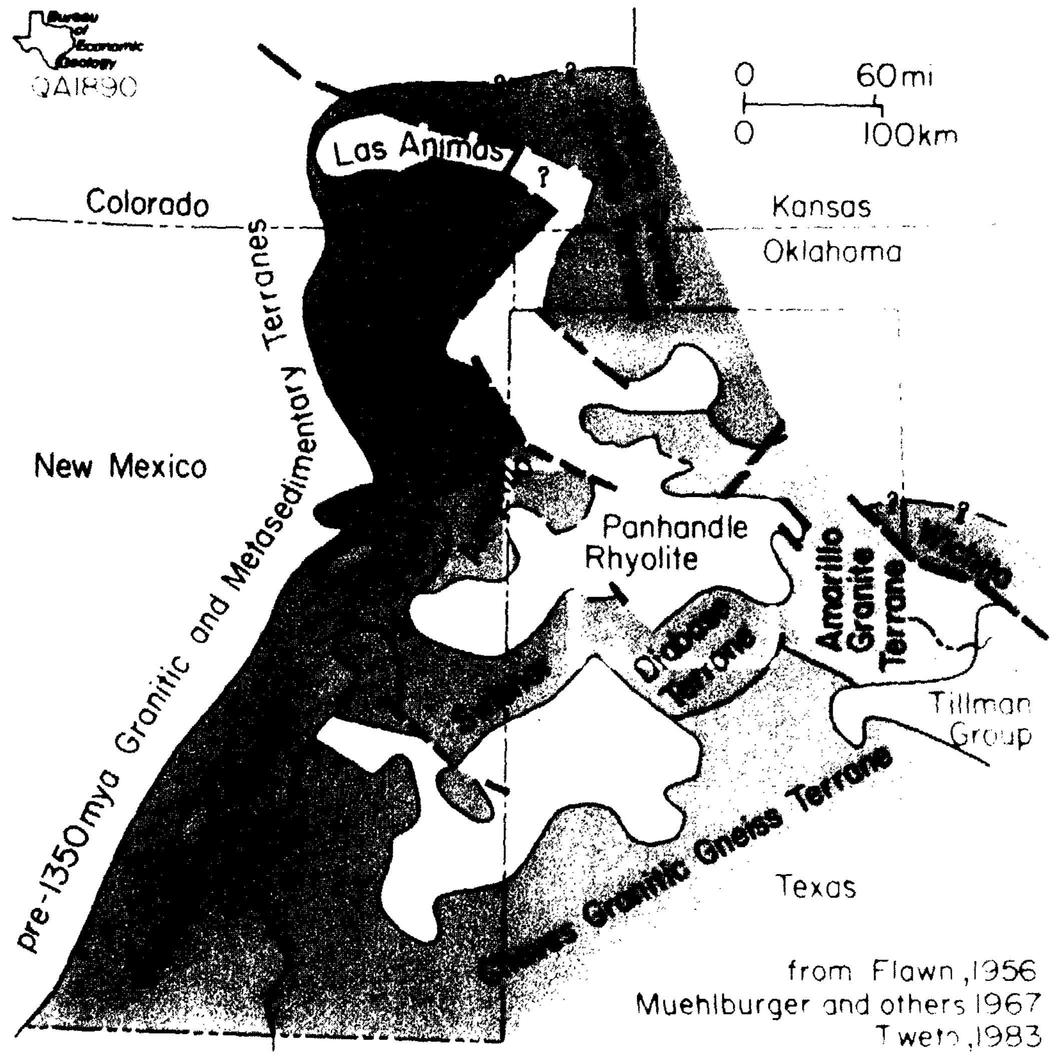


- Well control for cross sections

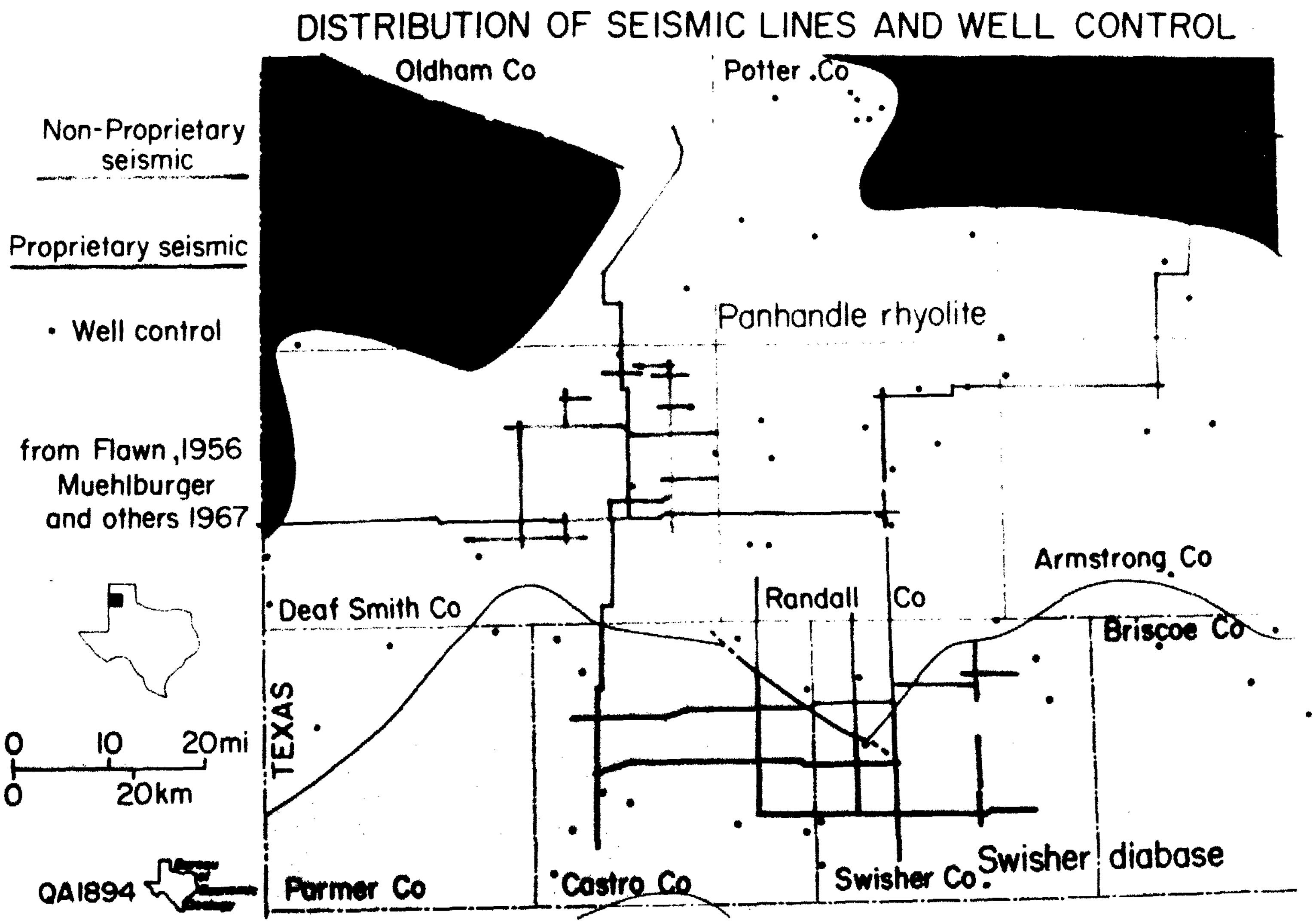
Composite cross section

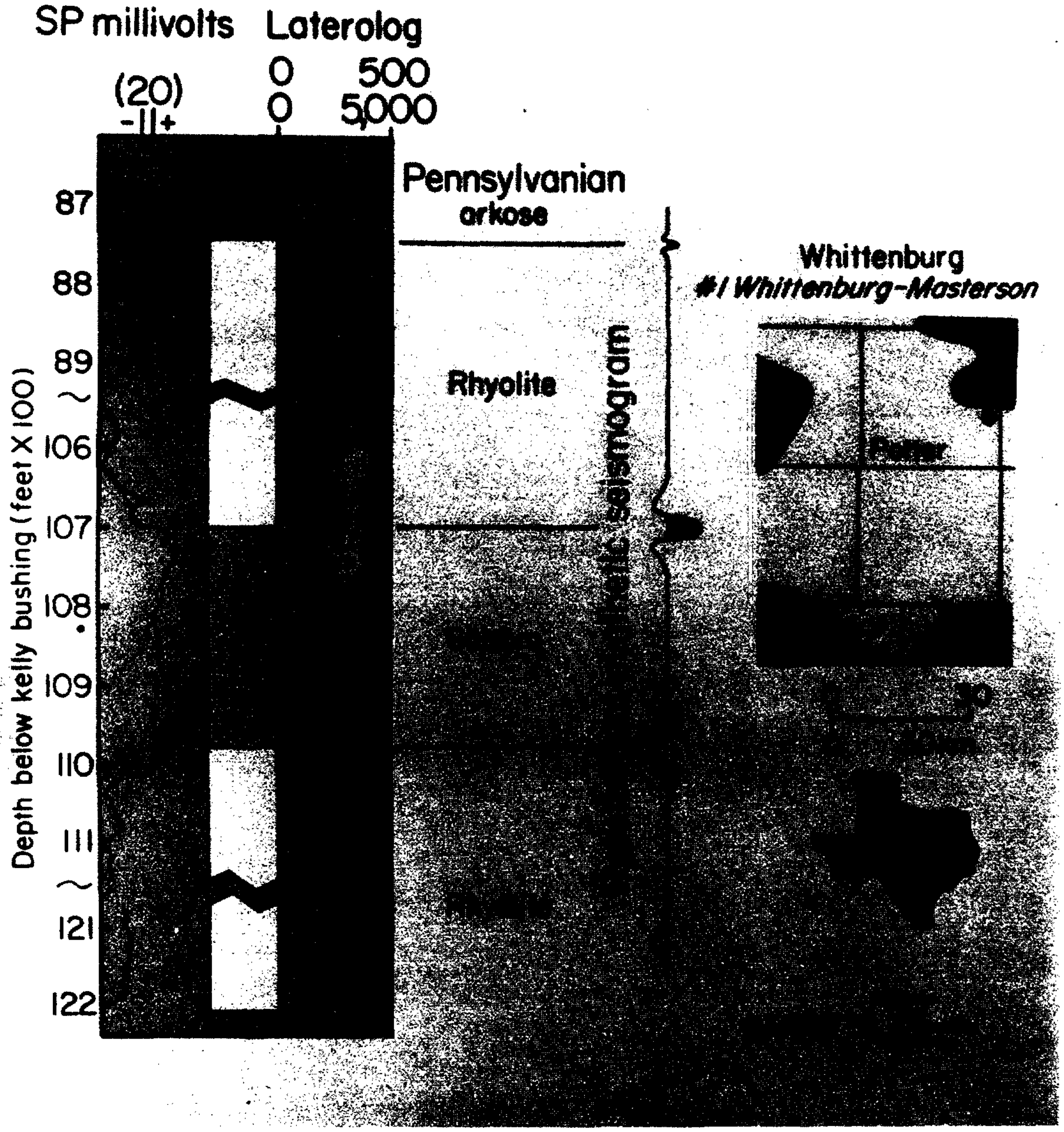


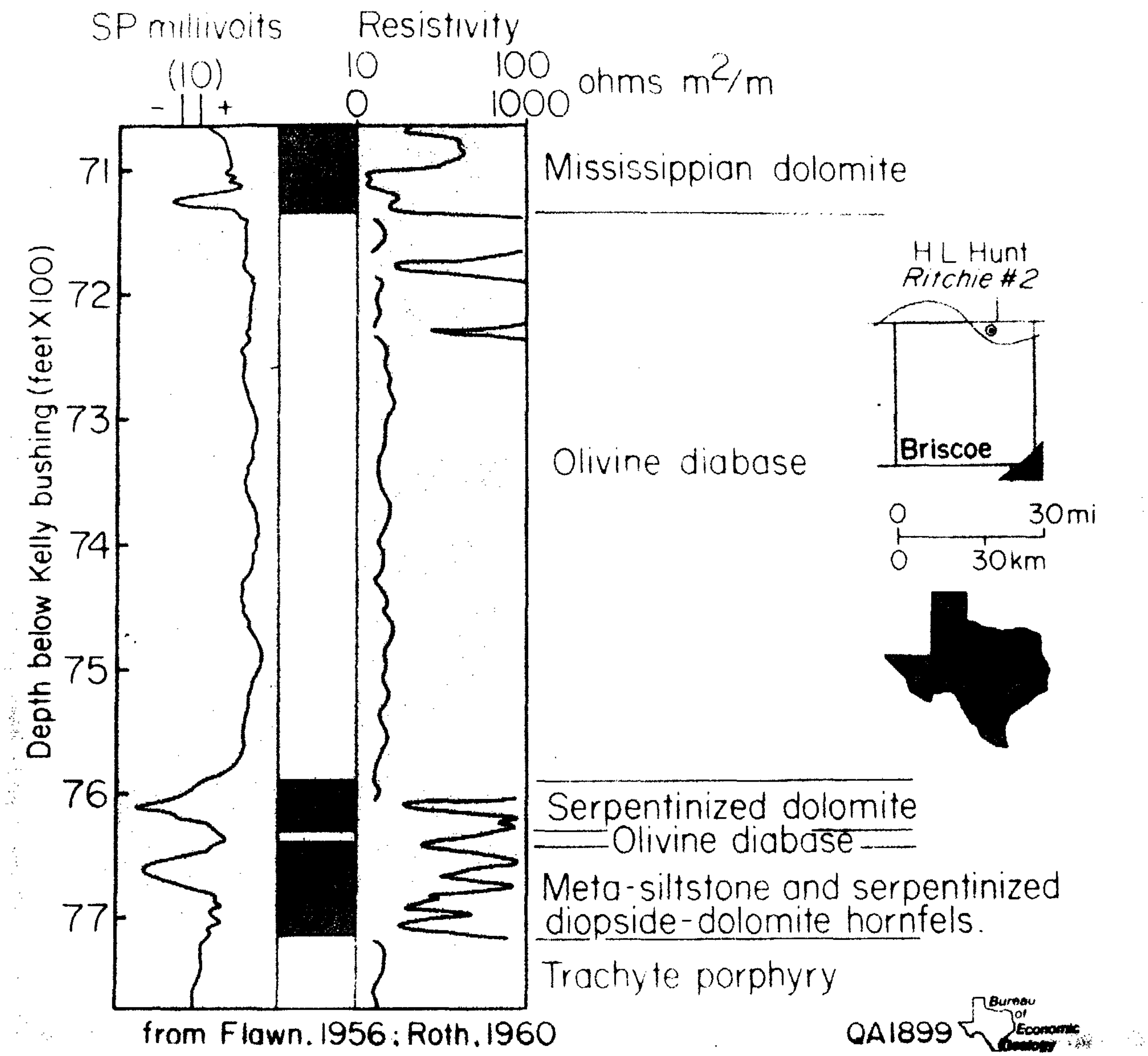
P
M
PЄ
DOLOMITE
LIMESTONE

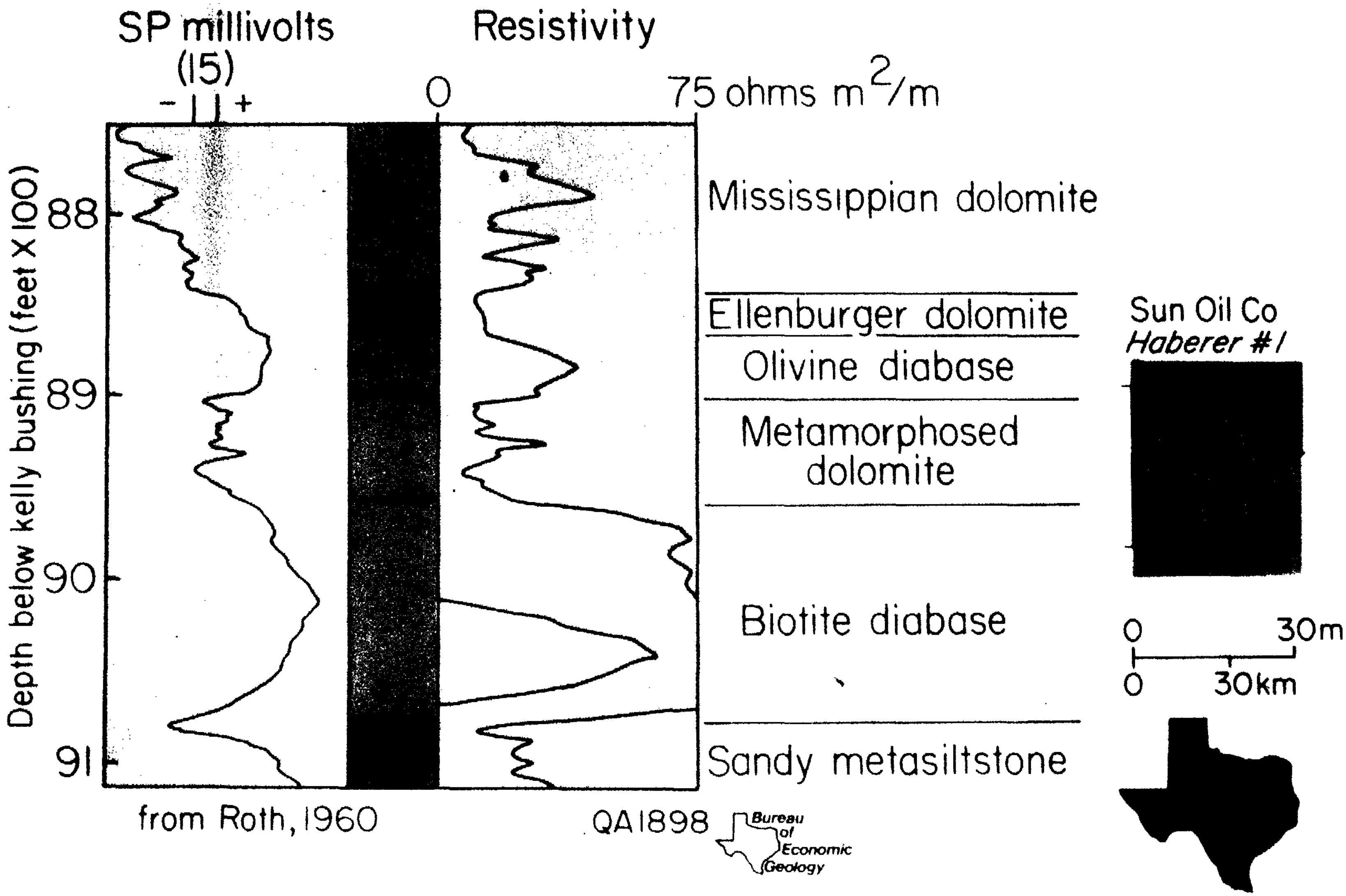


DISTRIBUTION OF BASEMENT TERRANES

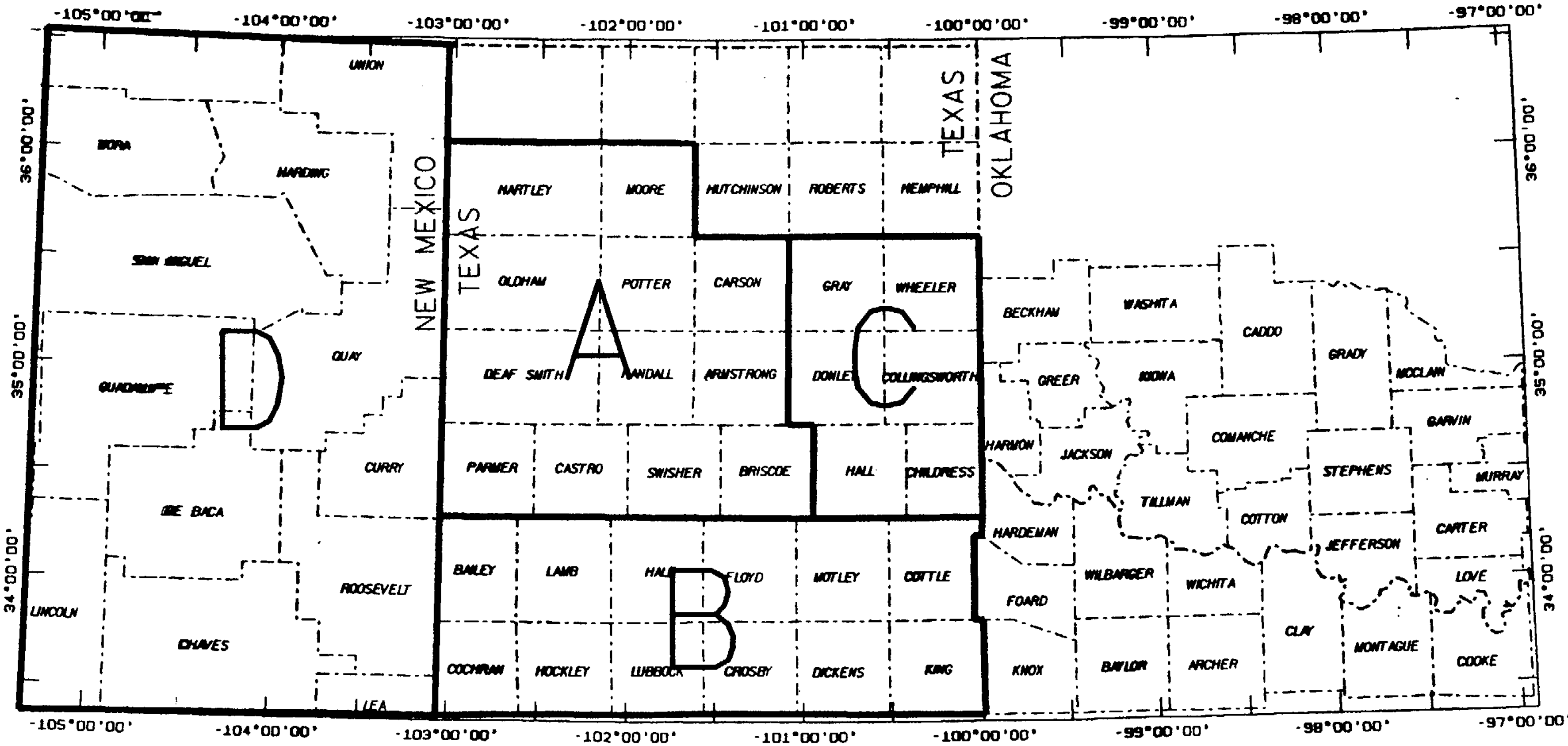

DISTRIBUTION OF SEISMIC LINES AND WELL CONTROL
Oldham Co
Potter Co
Non-Proprietary seismic
Proprietary seismic
Well control
Panhandle rhyolite
from Flawn, 1956
Muehlburger and others 1967
Armstrong Co
Deaf Smith Co
Randall Co
Briscoe Co
TEXAS
0 10 20mi
0 20km
Swisher diabase
QA1894
Parmer Co
Castro Co
Swisher Co


SP millivolts
Laterolog
(20)
-||+
0 500
0 5,000
87
88
89
106
107
108
109
110
111
121
122
Depth below kelly bushing (feet X 100)
Pennsylvanian
arkose
Rhyolite
seismogram
Whittenburg
#1 Whittenburg-Masterson


SP millivolts
(10)
- +
Resistivity
10
0
100
1000
ohms m2/m
71
72
73
74
75
76
77
Depth below Kelly bushing (feet X 100)
Mississippian dolomite
Olivine diabase
Serpentinized dolomite
Olivine diabase
Meta-siltstone and serpentinized
diopside-dolomite hornfels.
Trachyte porphyry
H L Hunt
Ritchie #2
Briscoe
0
30mi
0
30km
from Flawn, 1956; Roth, 1960
QA1899
Bureau of Economic Geology

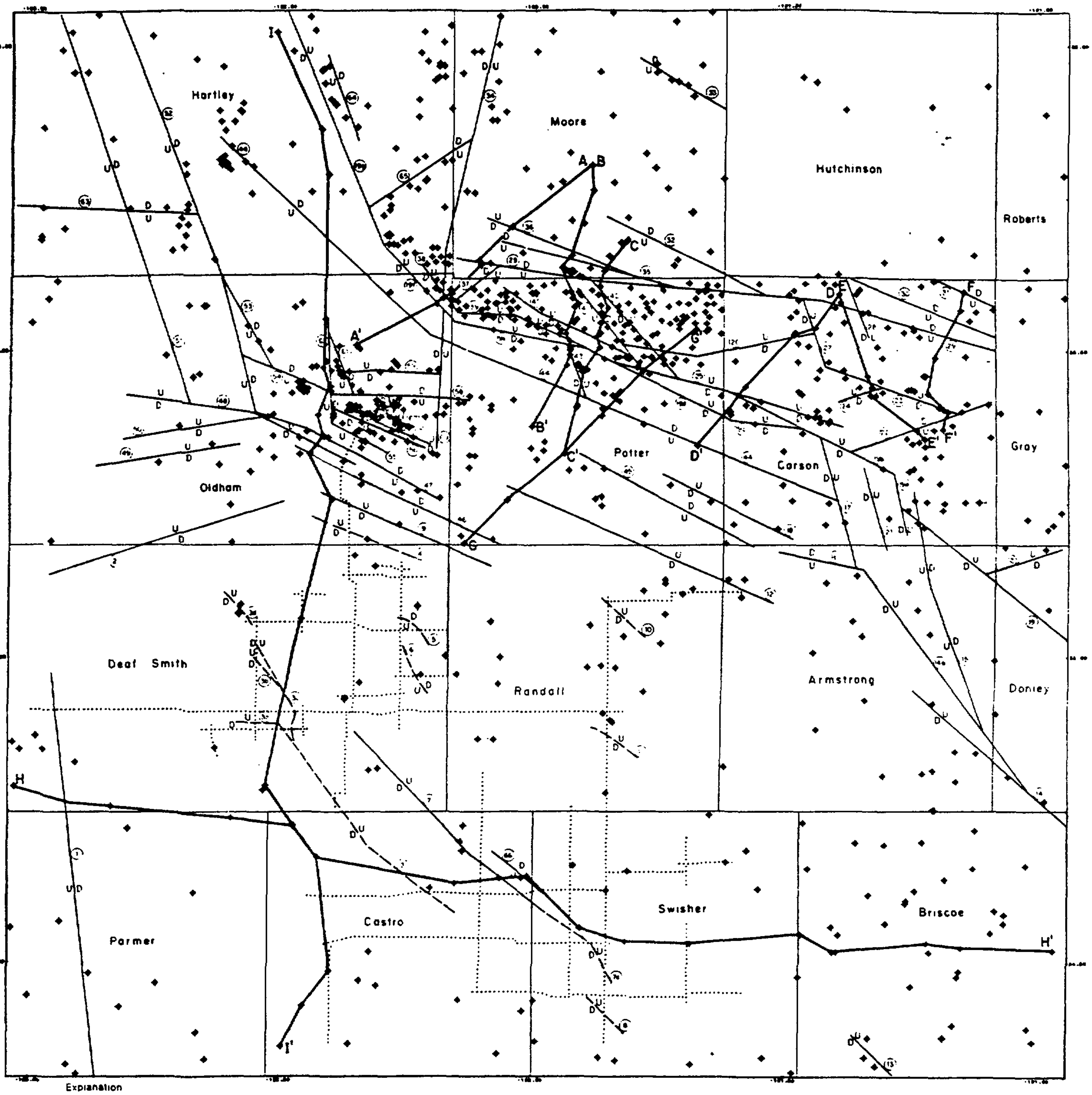

SP millivolts
(15)
- +
Resistivity
0
75 ohms m2/m
Depth below kelly bushing (feet X 100)
88
89
90
91
Mississippian dolomite
Ellenburger dolomite
Olivine diabase
Metamorphosed dolomite
Biotite diabase
Sandy metasiltstone
Sun Oil Co
Haberer #1
0
30mi
0
30km
from Roth, 1960
QA1898
Bureau of Economic Geology

GRAVITY RESIDUAL ANOMALIES



A : Northern Palo Duro Basin
B : Matador Uplift
C : Eastern Panhandle
D : Eastern New Mexico

Figure 1



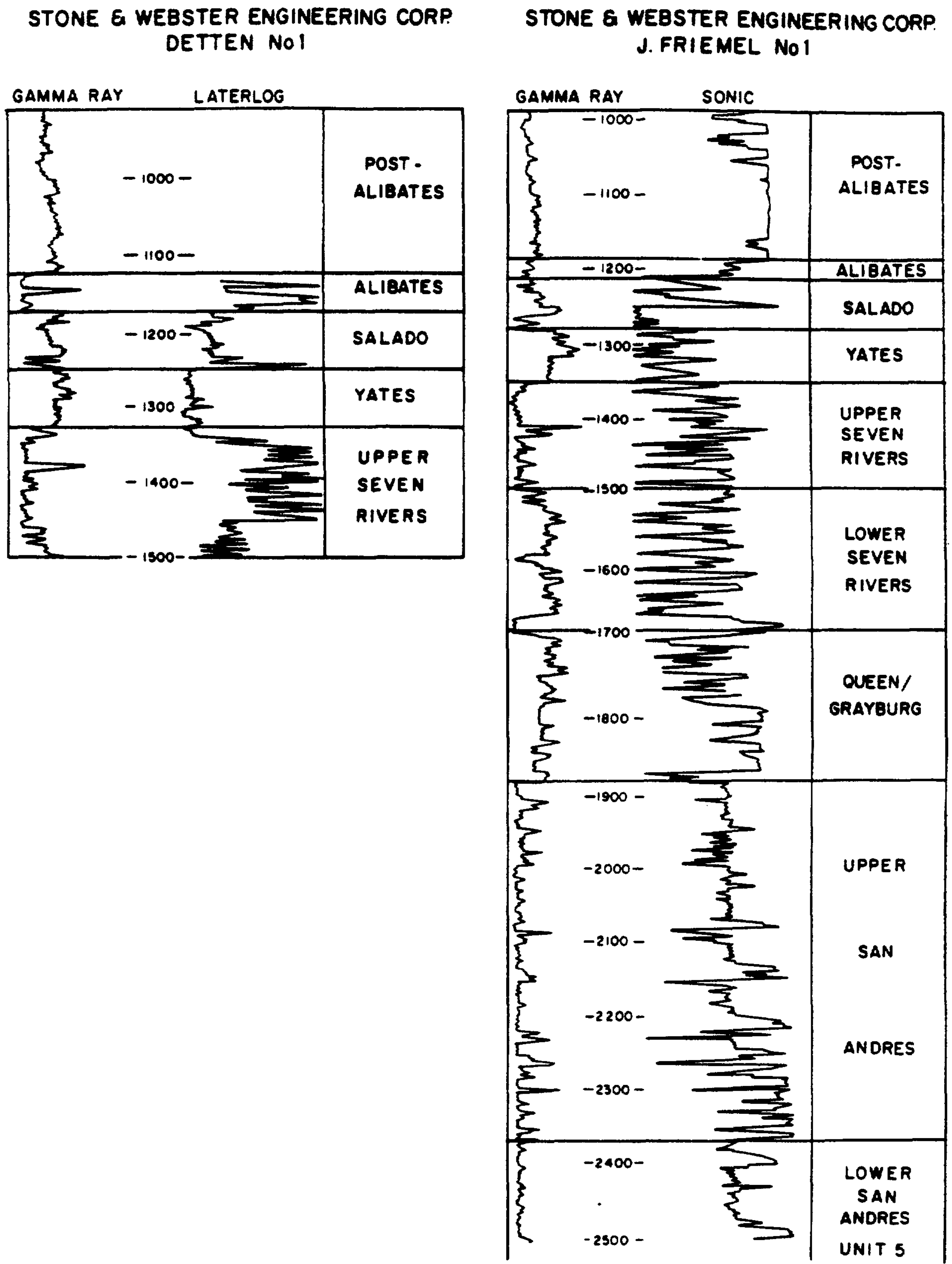
Explanation
Numbers identifying Faults Refer to Tables 1 and 2
H—H' Cross Section Line
Seismic Line
Well Control
Fault Interpreted from Geophysical Well Log Data (U-Upthrown, D-Downthrown)
Fault Interpreted by Long, 1983 (U-Upthrown, D-Downthrown)
Fault Identification Number

0 5 10 15 20
Scale-Miles

0 5 10 15 20
Scale-Kilometers

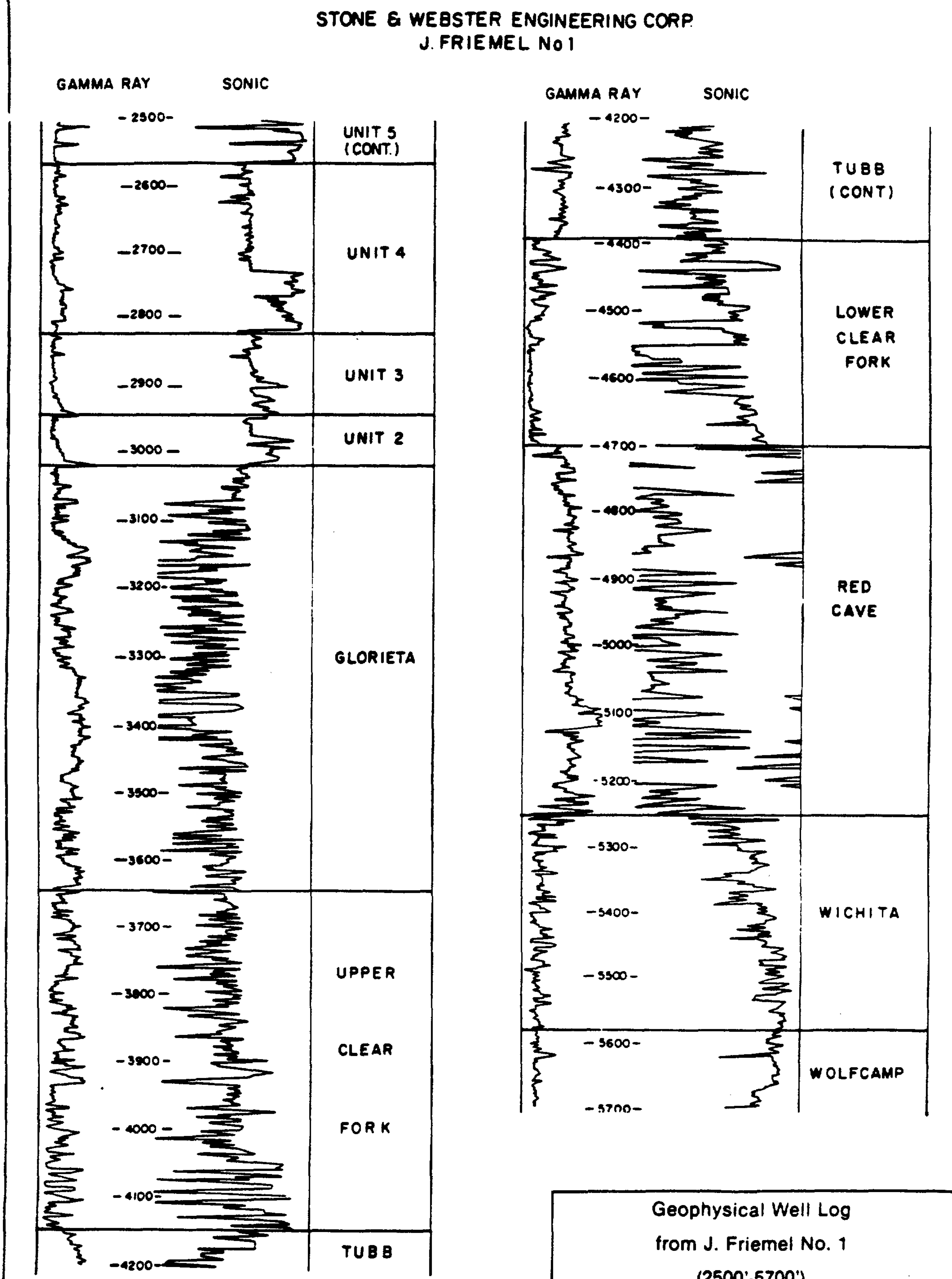
Index Map of Study Ar

FIGURE 2



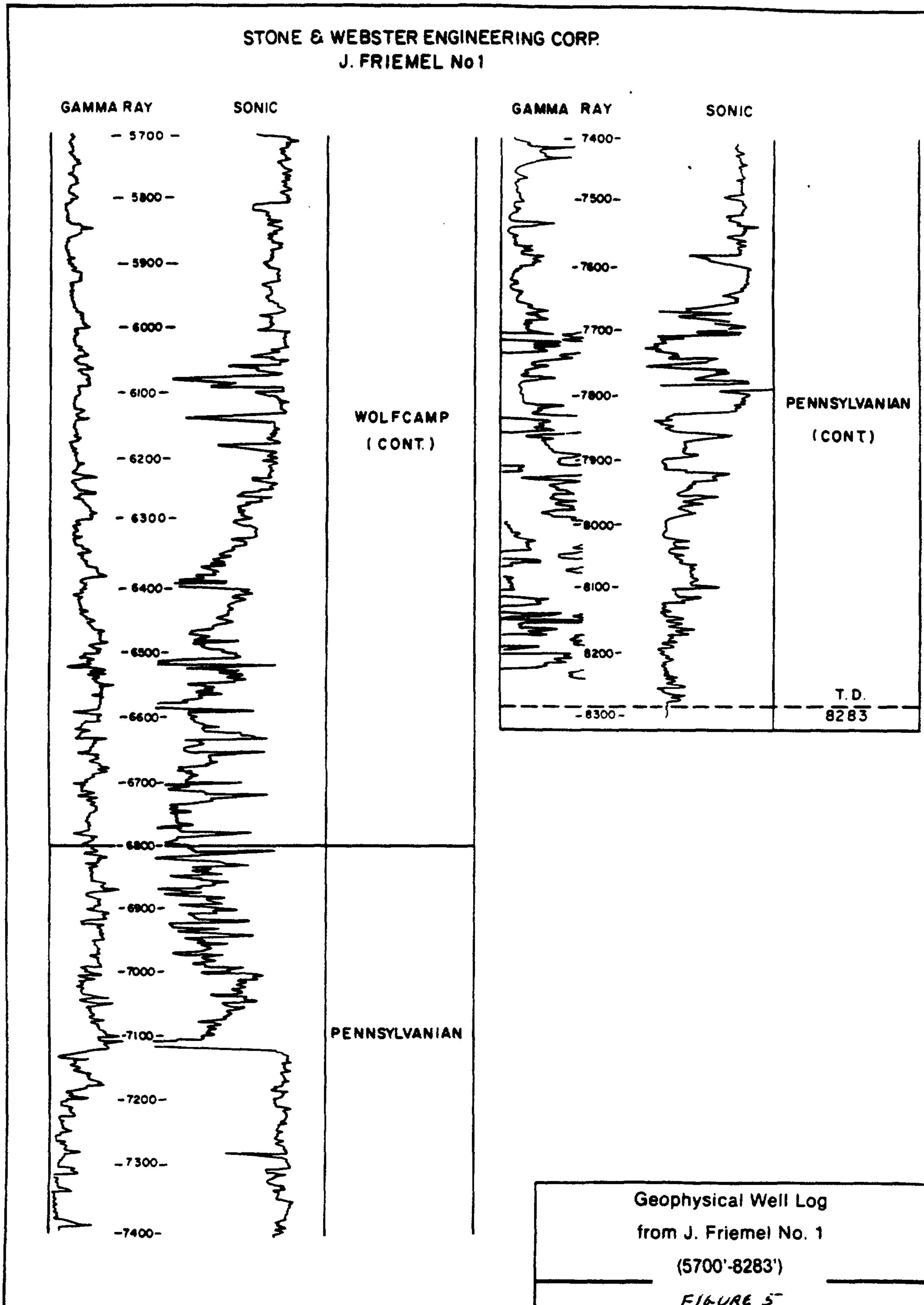
Geophysical Well Logs
from Detten No. 1 (900'-1500')
and J. Friemel No. 1 (1000'-2500')

FIGURE 3



Geophysical Well Log
from J. Friemel No. 1
(2500'-5700')

FIGURE 4



Geophysical Well Log
from J. Friemel No. 1
(5700'-8283')

FIGURE 5

STRATIGRAPHIC SECTION CONT.
PRECAMBRIAN TO PENNSYLVANIAN

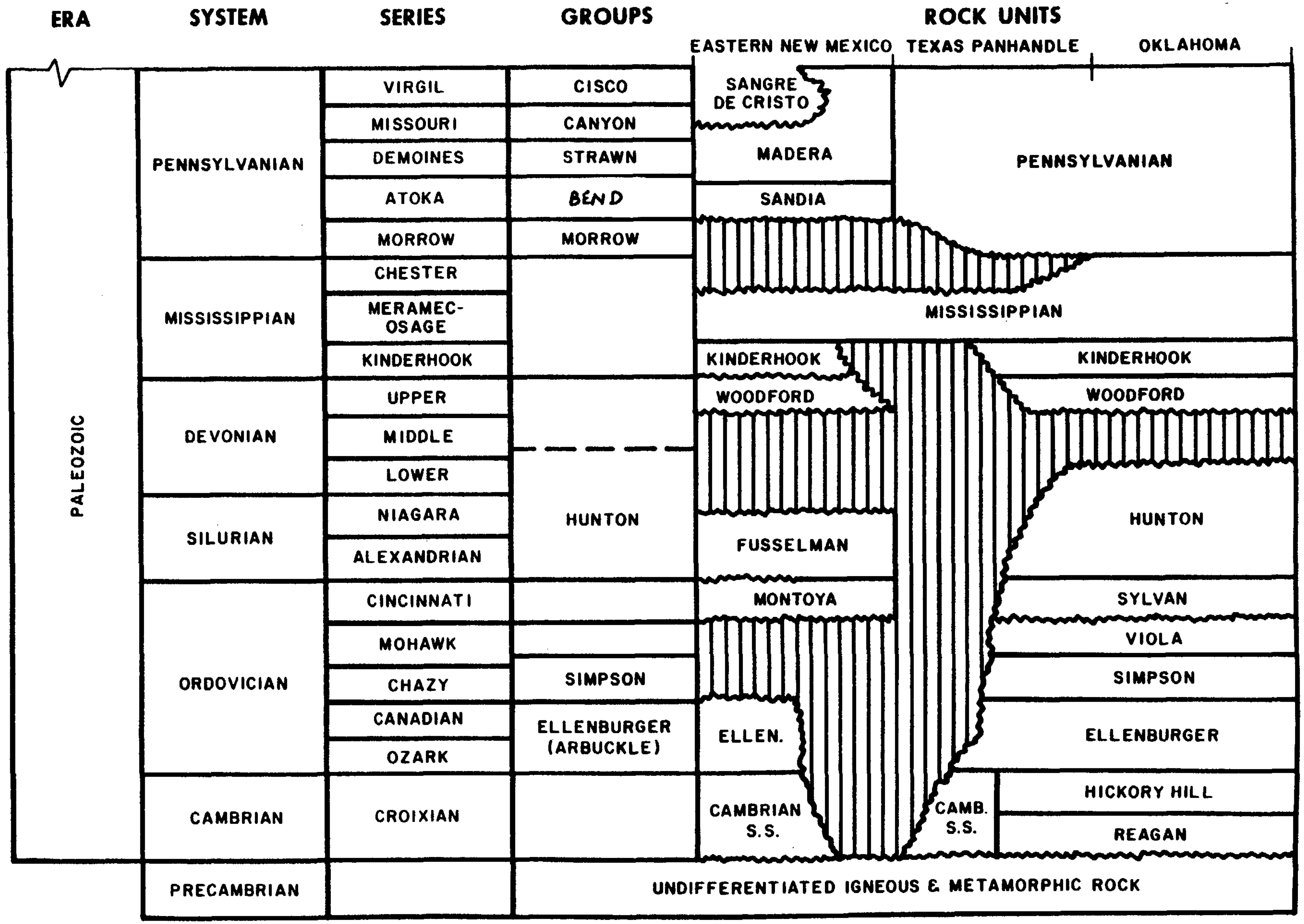


FIGURE 6

85-44,008

STRATIGRAPHIC SECTION CONT.
PERMIAN SYSTEM

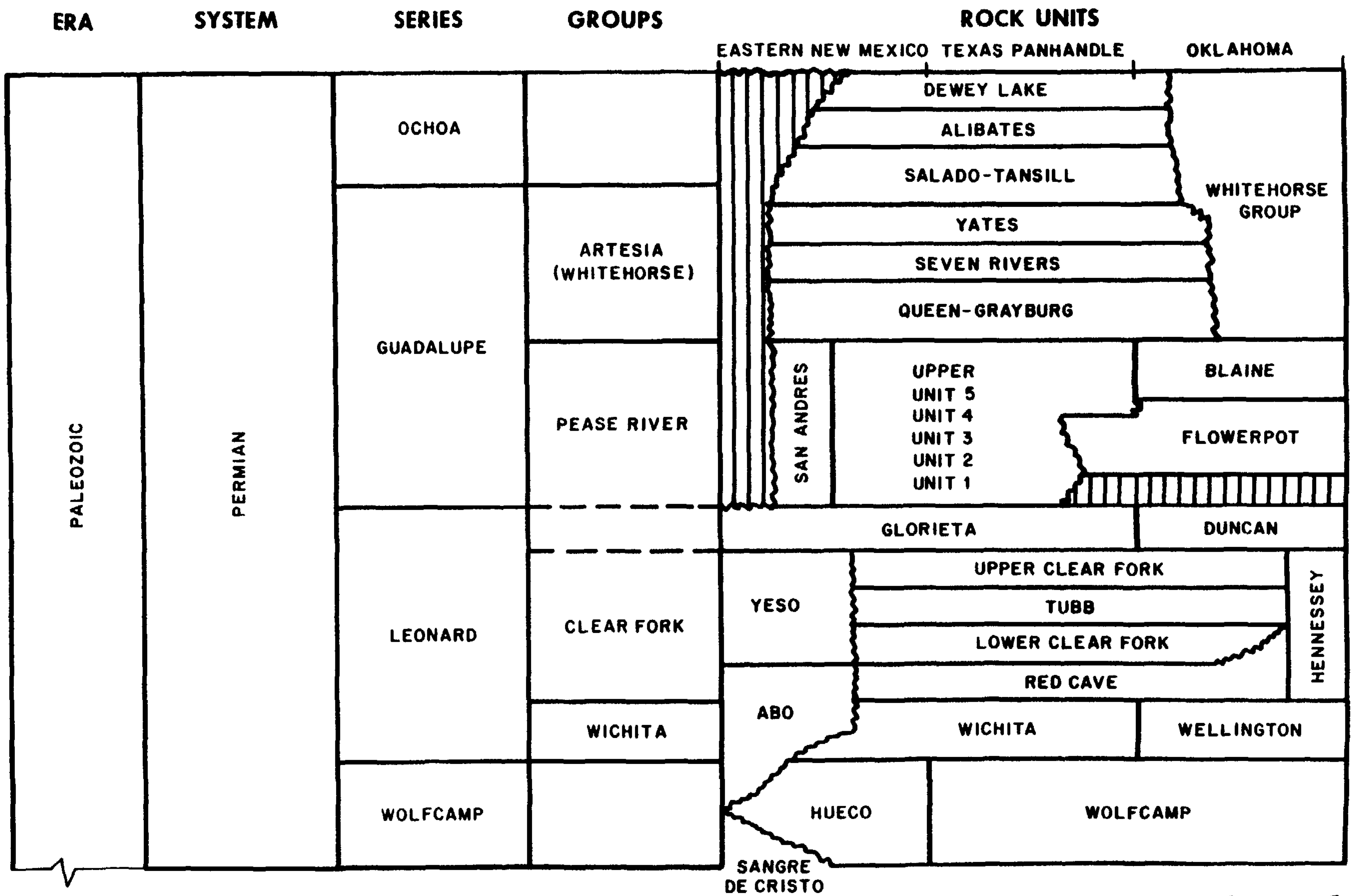
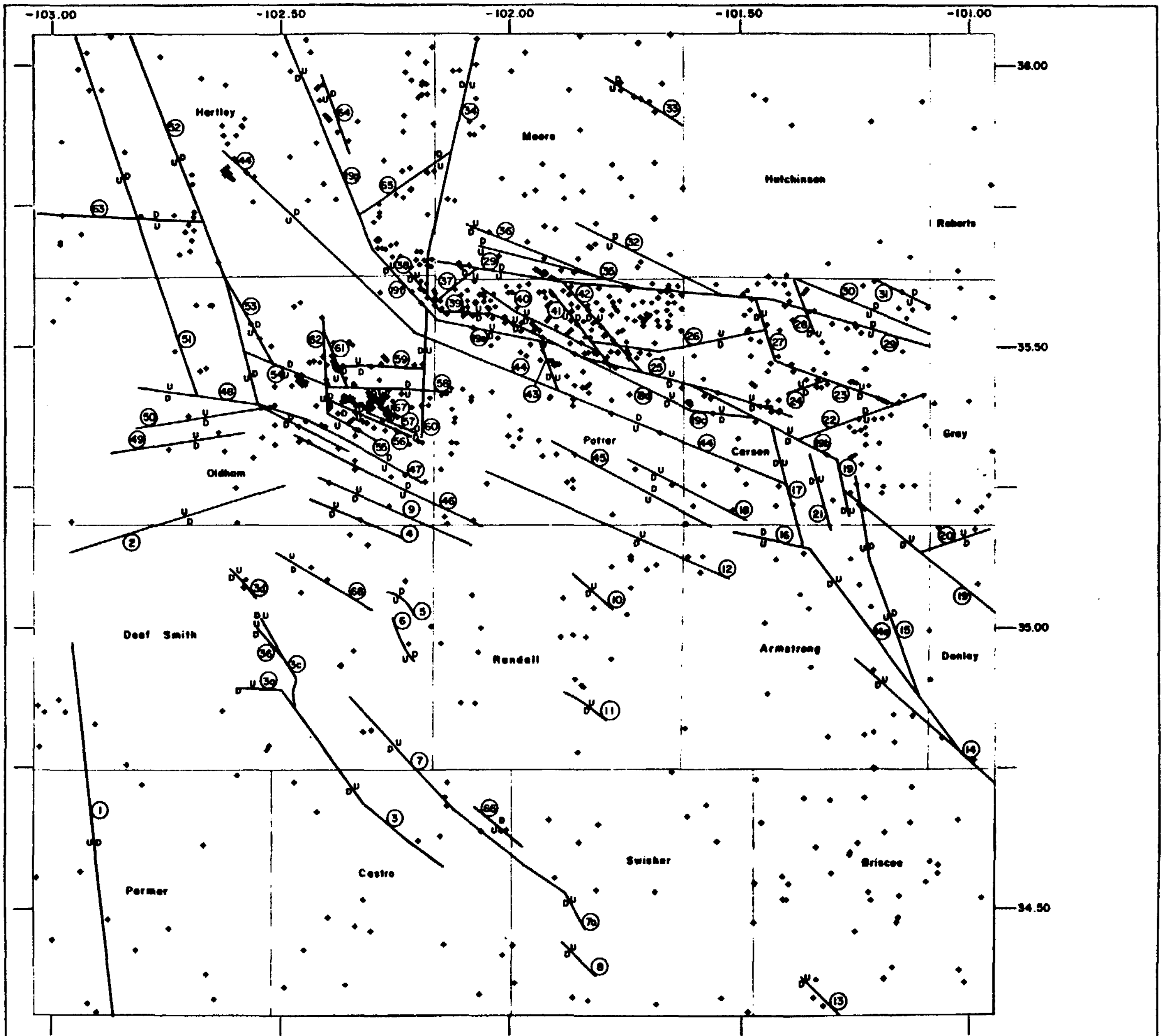


FIGURE 7

STRATIGRAPHIC SECTION
TRIASSIC TO RECENT

ERA	SYSTEM	SERIES	GROUPS	ROCK UNITS: EASTERN NEW MEXICO	ROCK UNITS: TEXAS PANHANDLE	ROCK UNITS: OKLAHOMA
CENOZOIC	QUATERNARY	RECENT		UNCONSOLIDATED SANDS & GRAVELS		
		PLEISTOCENE				
	TERTIARY	PLIOCENE-EOCENE		OGALLALA		
MESOZOIC	CRETACEOUS			NIOBRARA		
				CARLILE		
				GREENHORN		
				GRANEROS		
				DAKOTA		DAKOTA
			FREDRICKSBURG TRINITY	PURGATOIRE	FREDRICKSBURG TRINITY	
	JURASSIC			MORRISON		
				BELL RANCH-WANAKAH		
				TODILTO		
				EXETER (ENTRADA)		
	TRIASSIC		DOCKUM	CHINLE	DOCKUM	
				SANTA ROSA		

FIGURE 8



Legend:
- Well Control
- Fault Interpreted from Geophysical Well Log Data
- Fault Identification Number

Note:
Numbers Identifying Faults Refer to Table 1

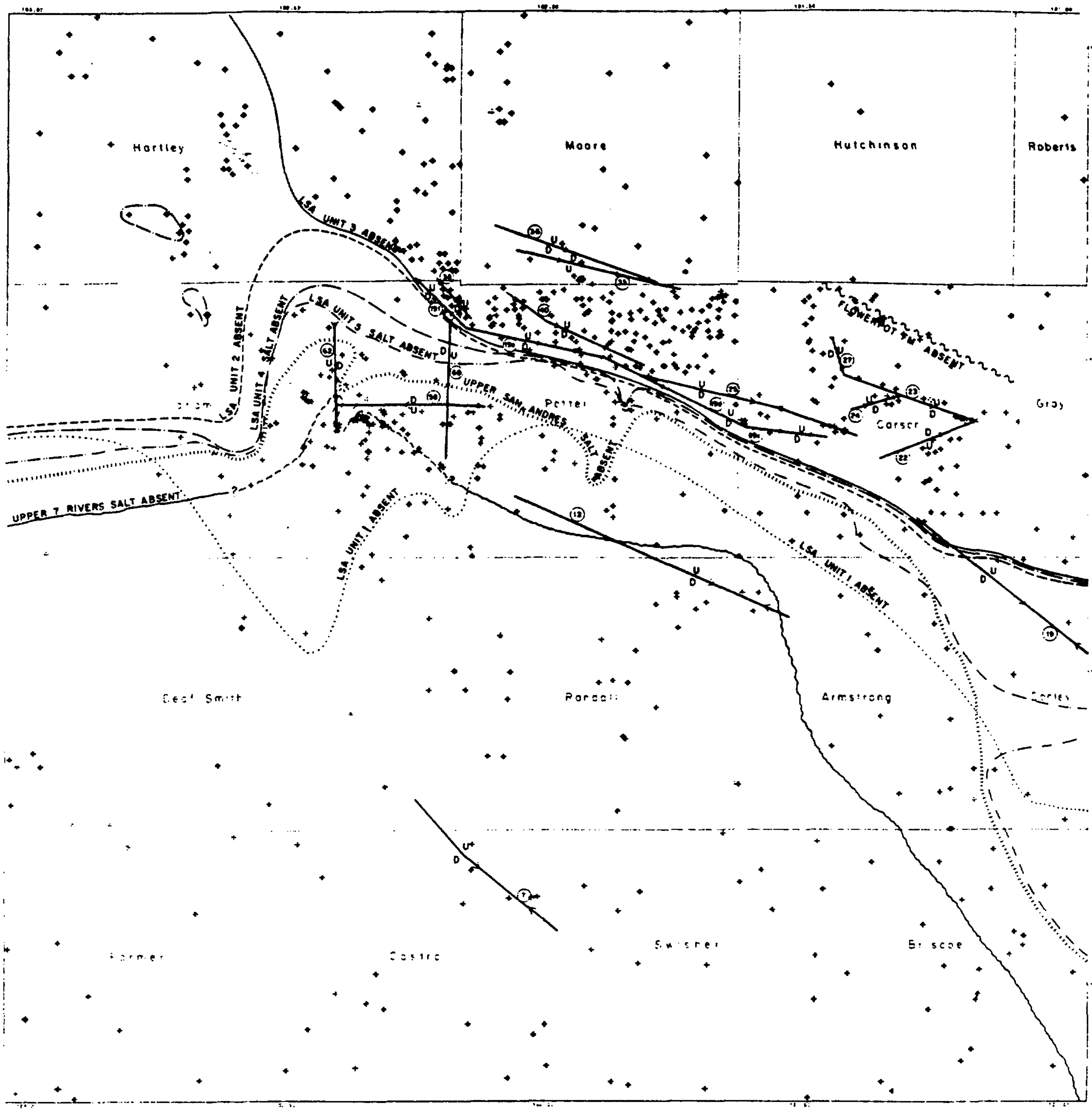
0 5 10 15 20
SCALE-MILES

0 5 10 15 20
SCALE-KILOMETERS

Index Map of Faults
in the Deaf Smith Area

Figure 3

FIGURE 9



Explanation:

Numbers Identifying Faults Refer to Tables 1 and 2.

Fault Interpreted From Geophysical Well Log Data (U-Upthrown, D-Downthrown). Arrows Indicate Areas With Maximum Observed Displacement.

Well Control

Fault Identification Number

0 5 10 15 20
Scale - Miles

0 5 10 15 20
Scale - Kilometers

Sources: SWEC Sketch 13897.54-N-1, Salt Information From Boyd and Murphy 198-

Areal Extent of Selected Upper Permian Units

FIGURE 18

Ruppel 8/5

PALO DURO BASIN STRATIGRAPHIC STUDIES

BUREAU OF ECONOMIC GEOLOGY

UNIT	MAJOR CONTRIBUTORS
Precambrian	Flawn, Budnik
Cambrian, Ordovician	Ruppel
Mississippian	Ruppel
Pennsylvanian	Dutton, S.
Permian	
Wolfcamp	*Handford, Dutton, S., *Herron, Conti, Hovorka, Posey
Wichita	Hovorka
Red Cave	*Handford
Lower Clear Fork	*Handford
Tubb	*Presley
Upper Clear Fork	*Presley, *McGinnis
Glorietta	*Presley, *McGinnis
San Andres	*Presley, *Ramonoetta, *Bein, Hovorka, Fracasso
Queen-Grayburg	*Kolker, Hovorka, Nance
Seven Rivers	*Kolker, Hovorka, Nance
Yates	*Kolker, Hovorka, Nance
Tansill-Salado	*McGillis, *Presley, *Kolker, Nance
Alibates	*McGillis, *Presley, Nance
Dewey Lake	*Kolker, Fracasso, Johns
Triassic	
Dockum	*McGowen, *Granata, Seni, Johns
Teritary	
Ogallala	Seni, Gustavson
Quaternary	
Blackwater Draw, Etc.	Caran, Baumgardner, Gustavson

* No longer with the Bureau of Economic Geology

SYSTEM	SERIES	GROUP	Palo Duro Basin FORMATION	Dalhart Basin FORMATION	General Lithology and depositional setting
QUATERNARY	HOLOCENE		alluvium, dune sand Playa	alluvium, dune sand Playa	
	PLEISTOCENE		Tahoka "cover sands" Tule / "Playa" Blanco	"cover sands" "Playa"	Lacustrine clastics and windblown deposits
TERTIARY	NEOGENE		Ogallala	Ogallala	Fluvial and lacustrine clastics
CRETACEOUS	-		undifferentiated	undifferentiated	Marine shales and limestone
TRIASSIC		DOCKUM			Fluvial-deltaic and lacustrine clastics
PERMIAN	OCHOA		Dewey Lake	Dewey Lake	Sabkha salt, anhydrite, red beds, and peritidal dolomite
			Alibates	Alibates	
	GUADALUPE	ARTESIA	Salado/Tansill	Artesia Group undifferentiated	
			Yates		
			Seven Rivers		
			Queen/Grayburg		
			San Andres	Blaine	
	LEONARD	CLEAR FORK	Glorieta	Glorieta	
			Upper Clear Fork	Clear Fork	
			Tubb	undifferentiated Tubb-Wichita Red Beds	
			Lower Clear Fork		
			Red Cave		
		WICHITA			
	WOLFCAMP				Shelf and shelf-margin carbonate, basinal shale, and deltaic sandstone
?			?	?	
PENNSYLVANIAN	VIRGIL	CISCO			
	MISSOURI	CANYON			
	DES MOINES	STRAWN			
	ATOKA	BEND			
	MORROW				
MISSISSIPPIAN	CHESTER				Shelf carbonate and chert
	MERAMEC				
	OSAGE				
ORDOVICIAN		ELLENBURGER			Shelf dolomite
CAMBRIAN ?					Shallow marine(?) sandstone
PRECAMBRIAN					Igneous and metamorphic

Figure 26. Stratigraphic column and general lithology of the Palo Duro and Dalhart Basins. After Handford and Dutton (1980).

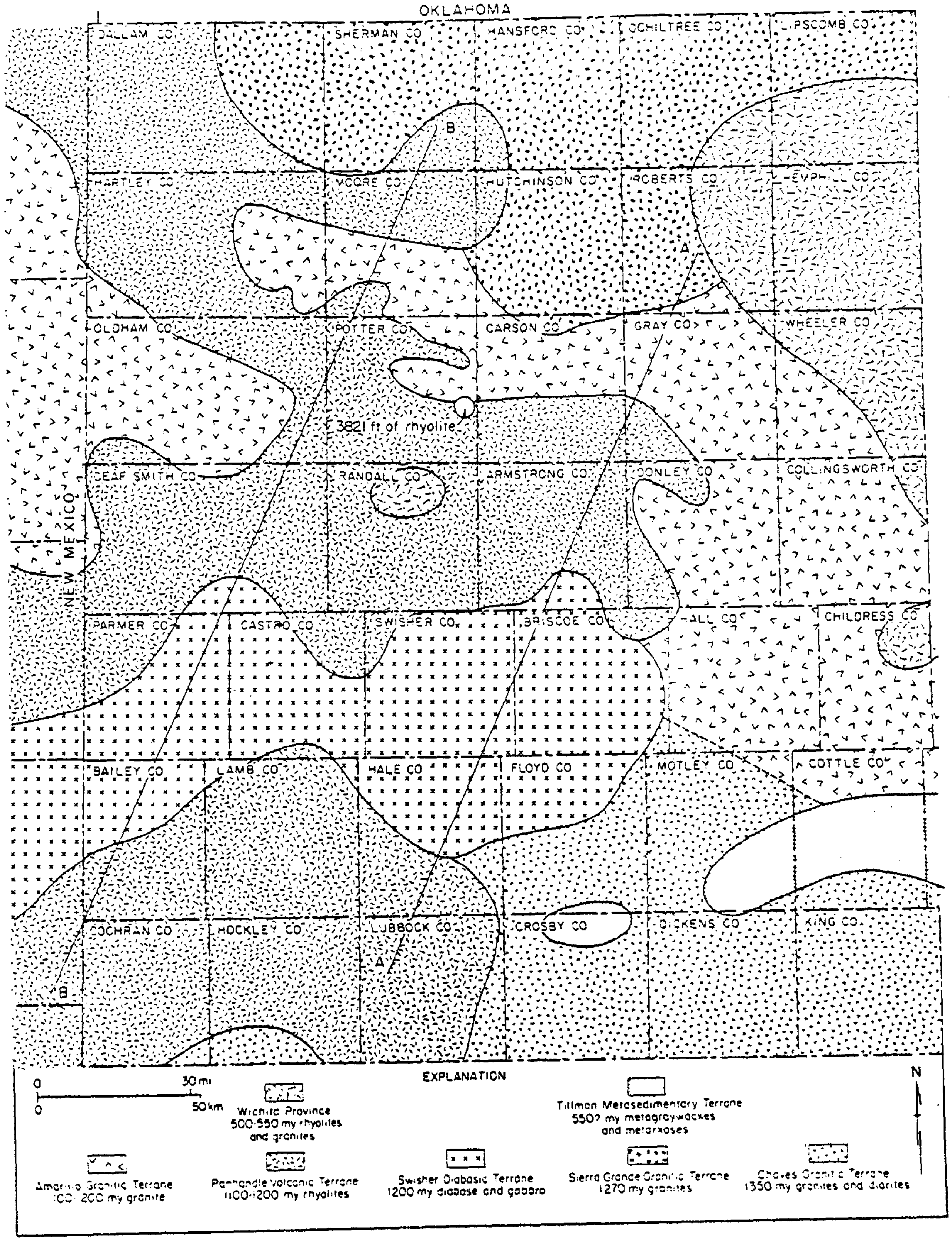
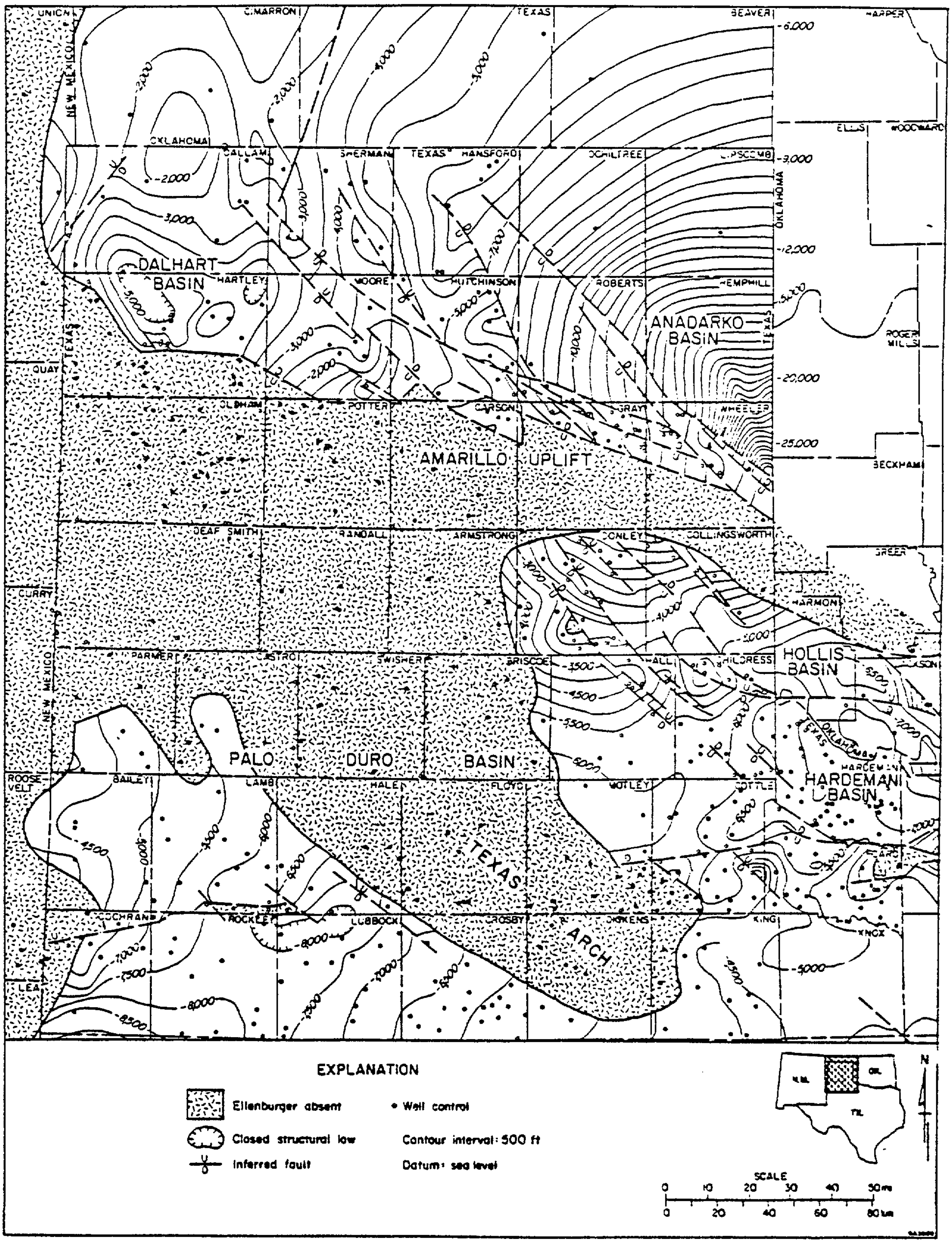
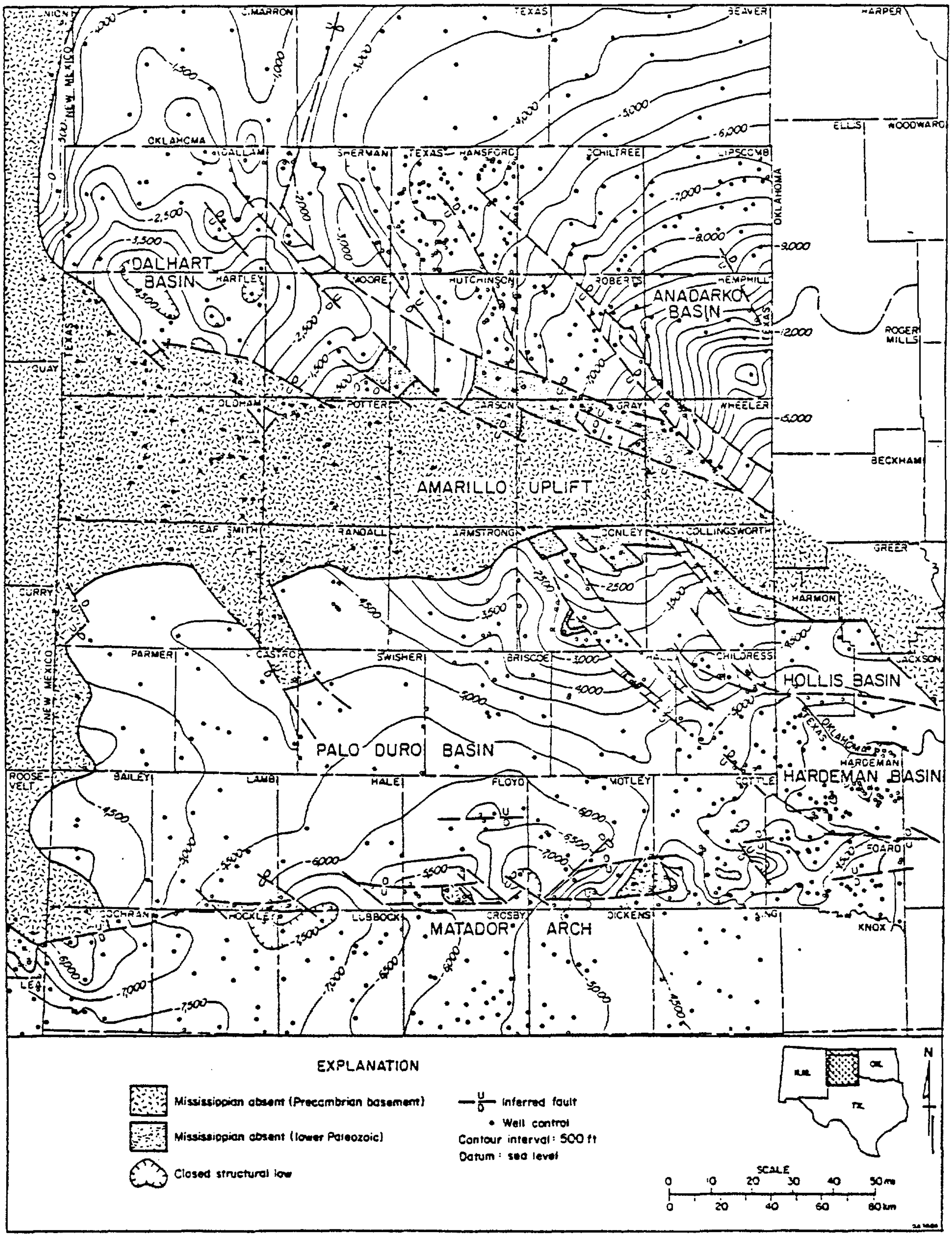


Figure 42. Basement lithologic provinces in the Texas Panhandle (from Muehiberger and others. 1967). A-A' and B-B' are locations of gravity models discussed in this report (see figs. 43 and 44).

ORDOVICIAN ELLENBURGER GROUP: STRUCTURE MAP



MISSISSIPPIAN SYSTEM: STRUCTURE MAP



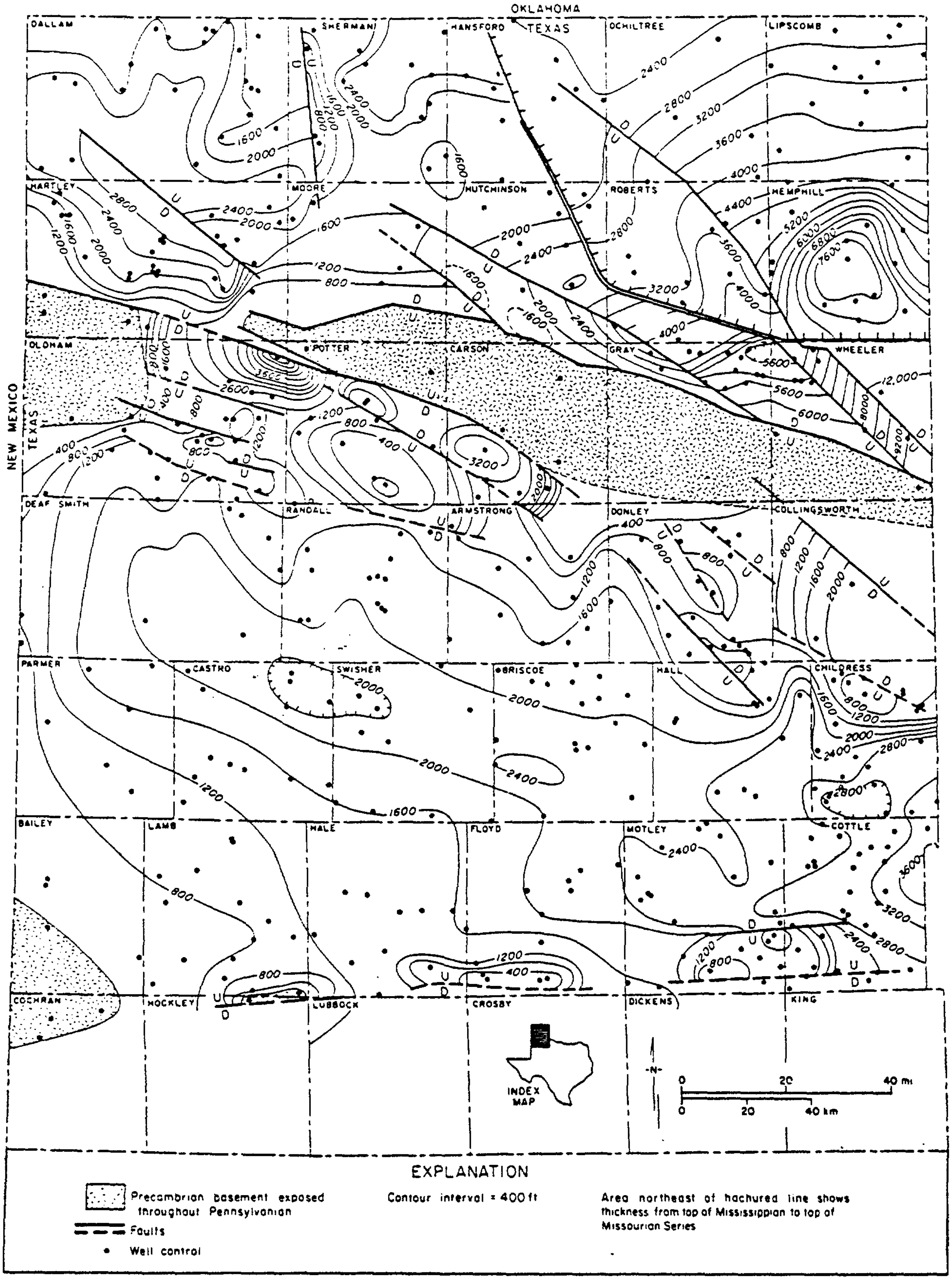


Figure 14. Isopach map of Pennsylvanian System, Texas Panhandle. Sediments thin onto uplifts that were exposed during Pennsylvanian Period.

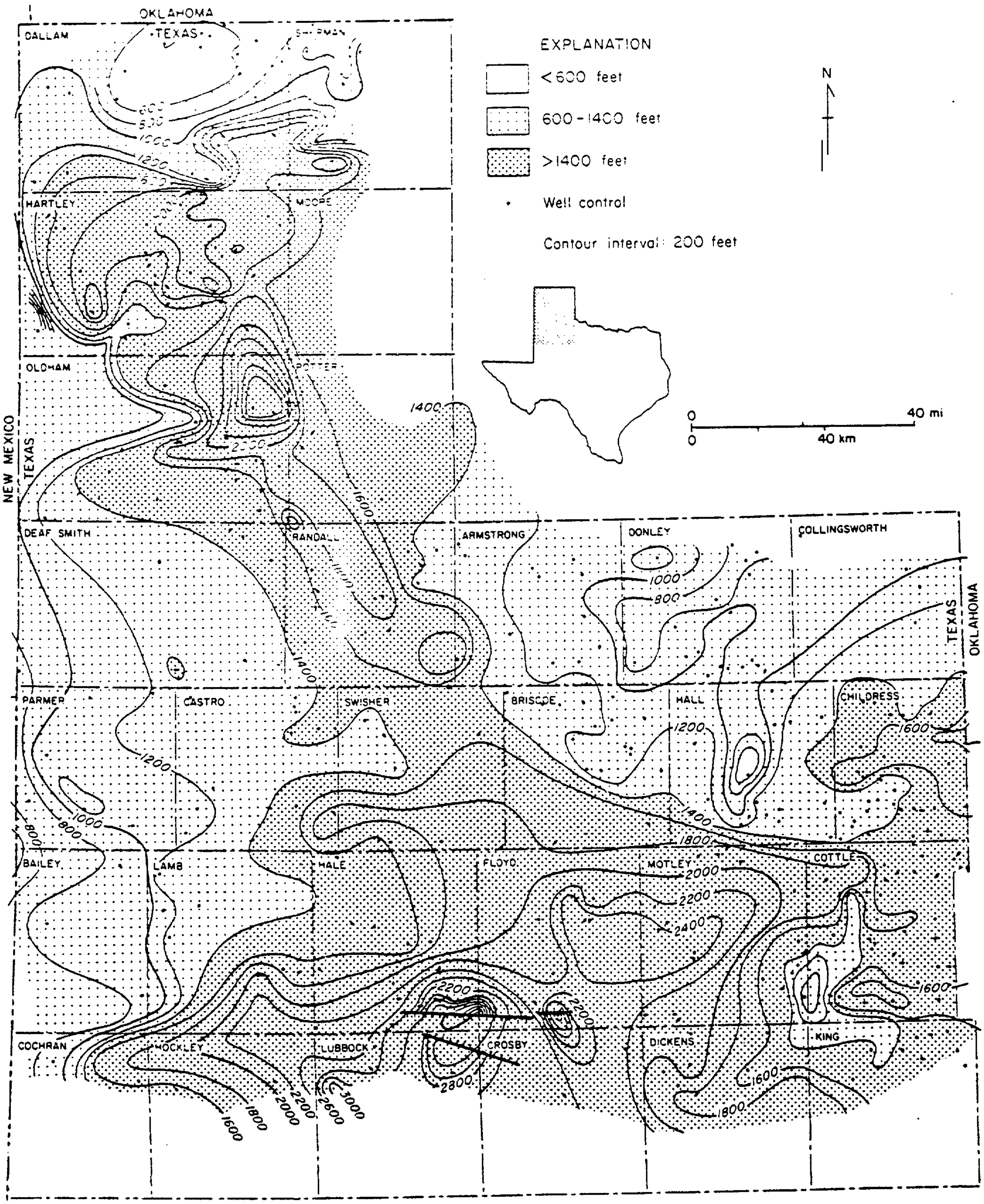


Figure 16. Isopach map of Wolfcampian Series, Palo Duro Basin (Handford, unpublished data).

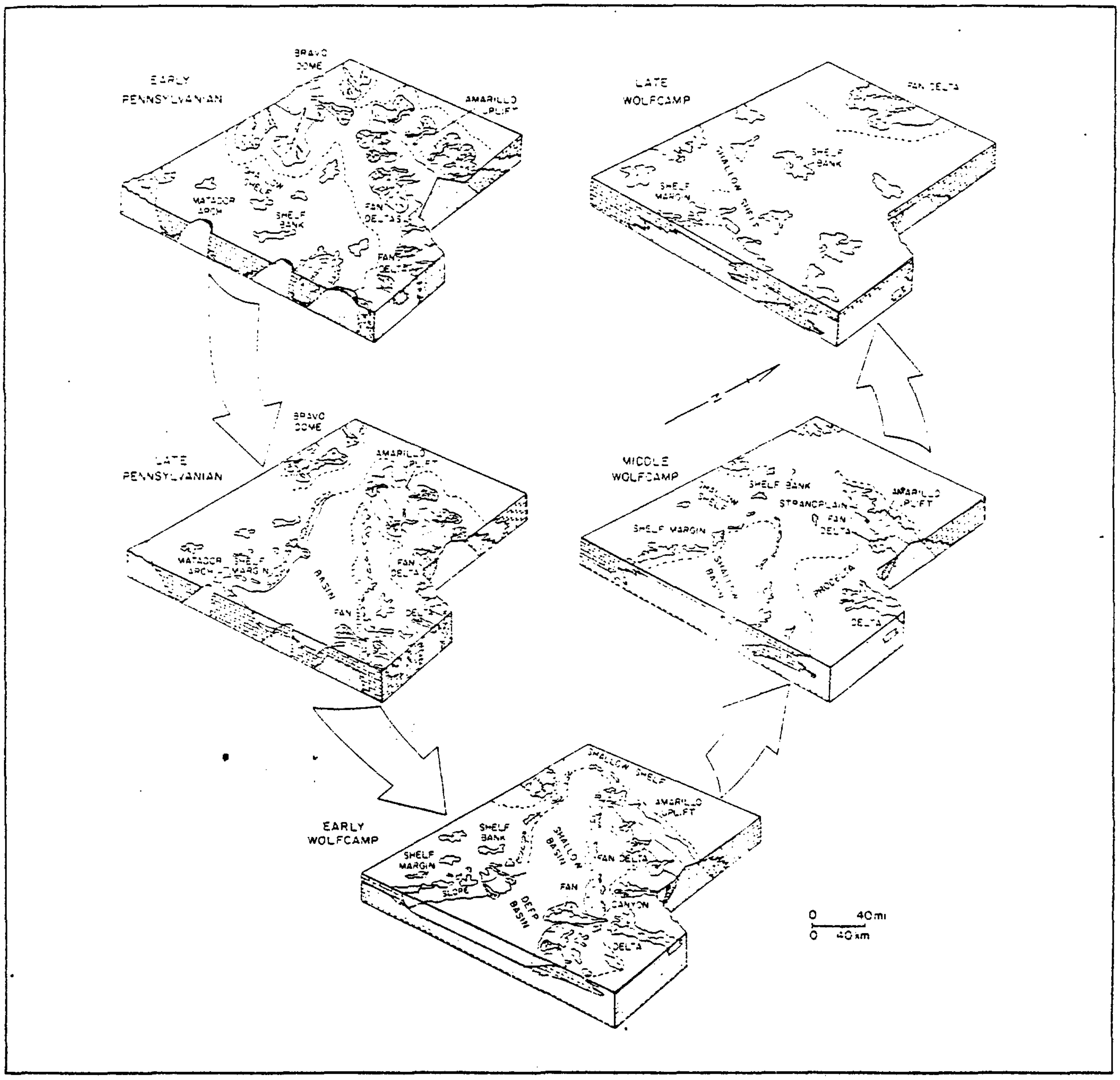


Figure 23. Block diagrams of paleogeographic evolution of Palo Duro Basin during Pennsylvanian and Wolfcampian time (from Handford and Dutton, 1980).

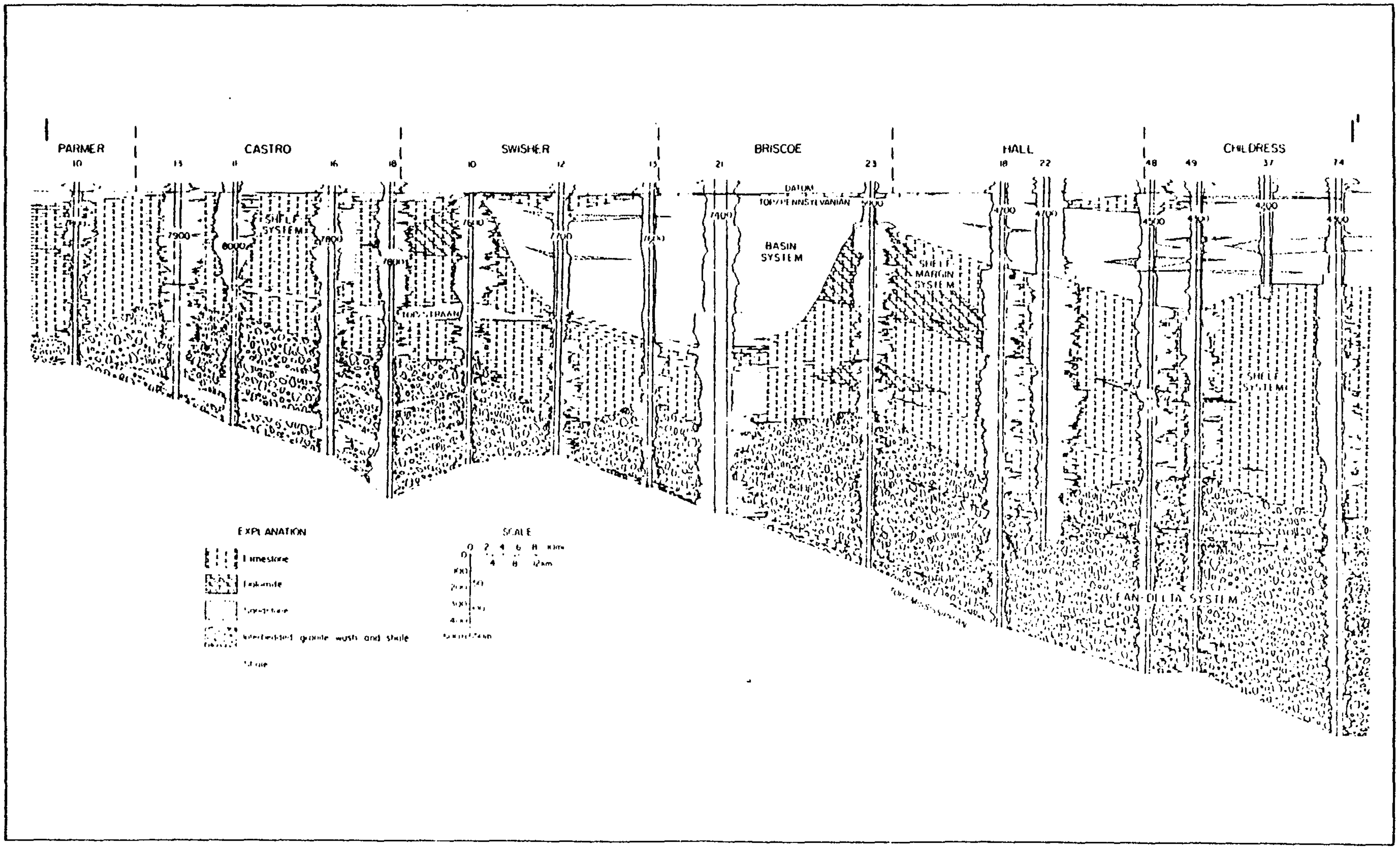


Figure 25. East-west cross section I-I' of Pennsylvanian strata, Parmer to Childress Counties (see fig. 3 for location).

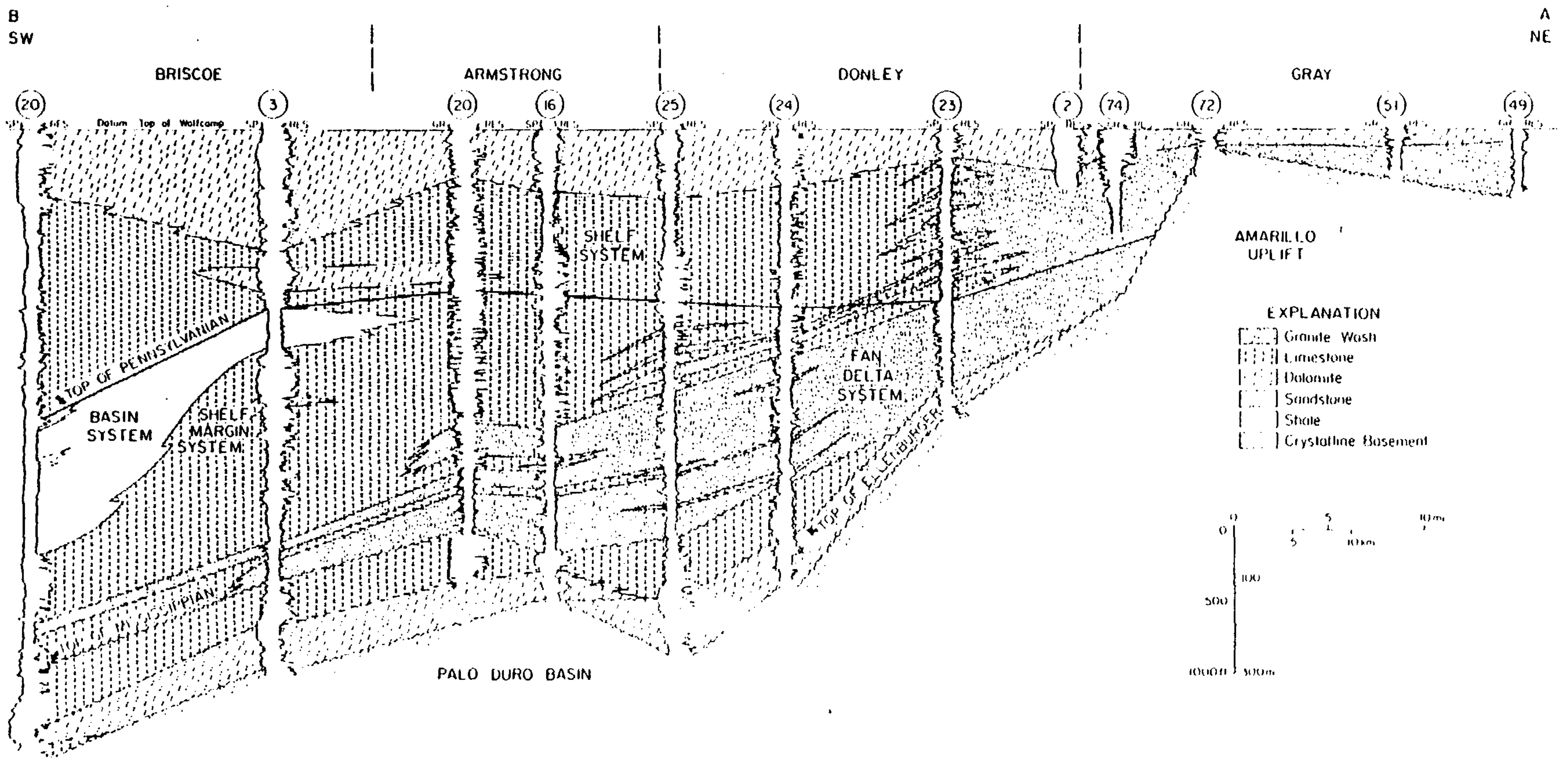


Figure 59. North-south regional cross section A-B from the central Palo Duro Basin to the Amarillo Uplift. Line of section shown in figure 57.

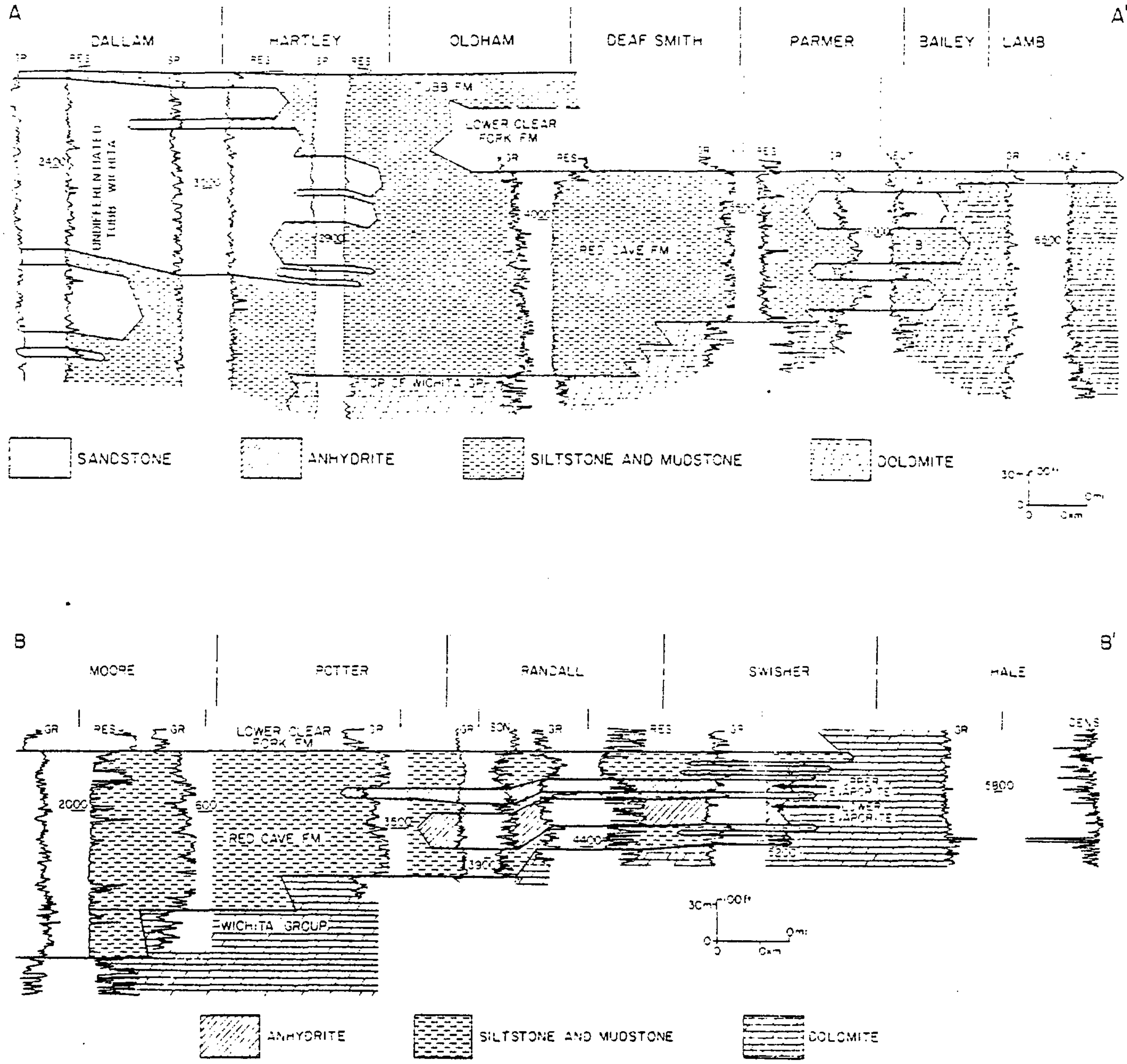


Figure 3. North-south cross sections A-A' and B-B' through the Red Cave Formation.

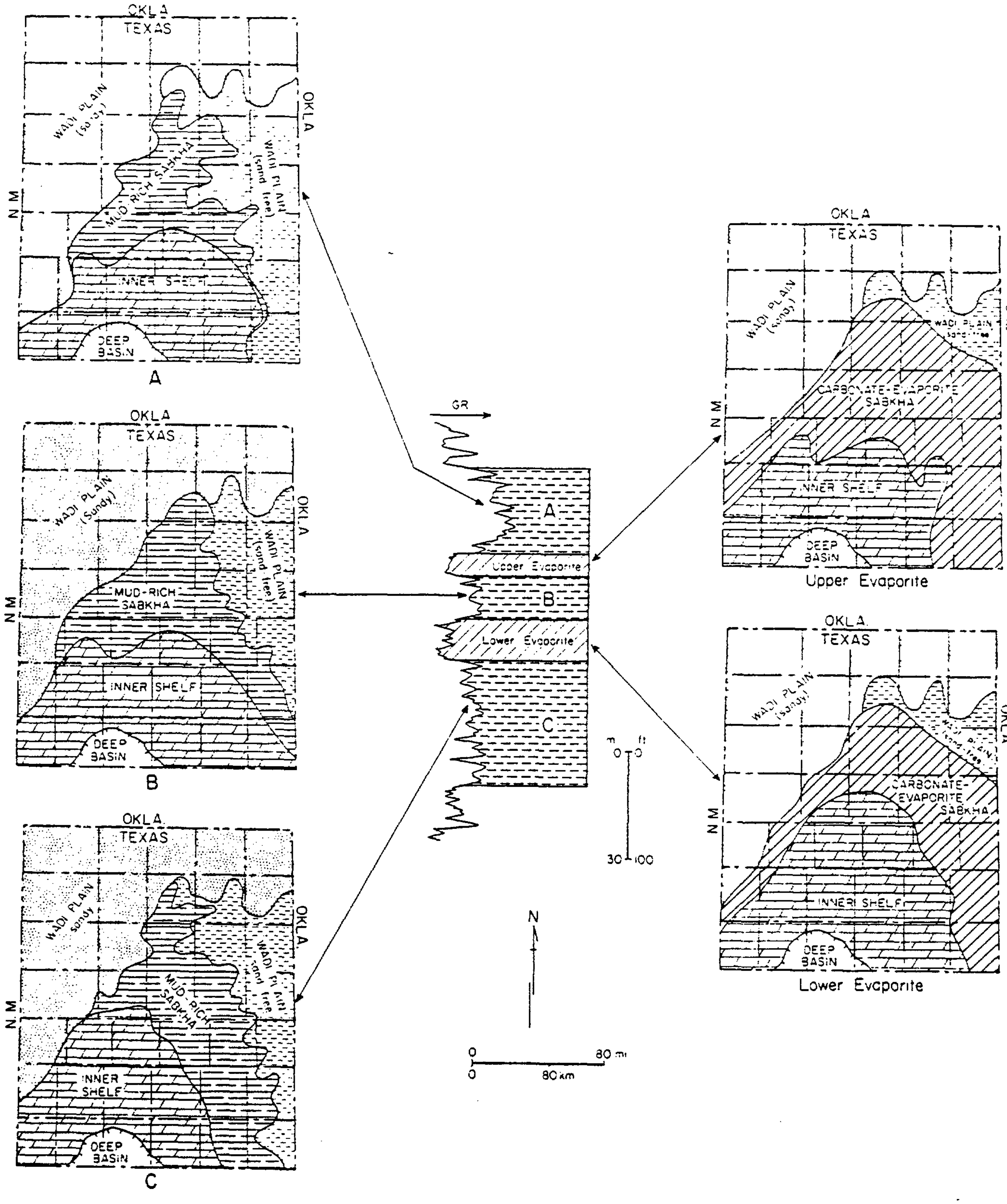


Figure 19. Paleogeography of the Red Cave Formation. Cyclic clastic and carbonate-evaporite facies reflect alternating styles of sabkha deposition that were brought on by the periodic availability and supply of clastics to sabkha environments.

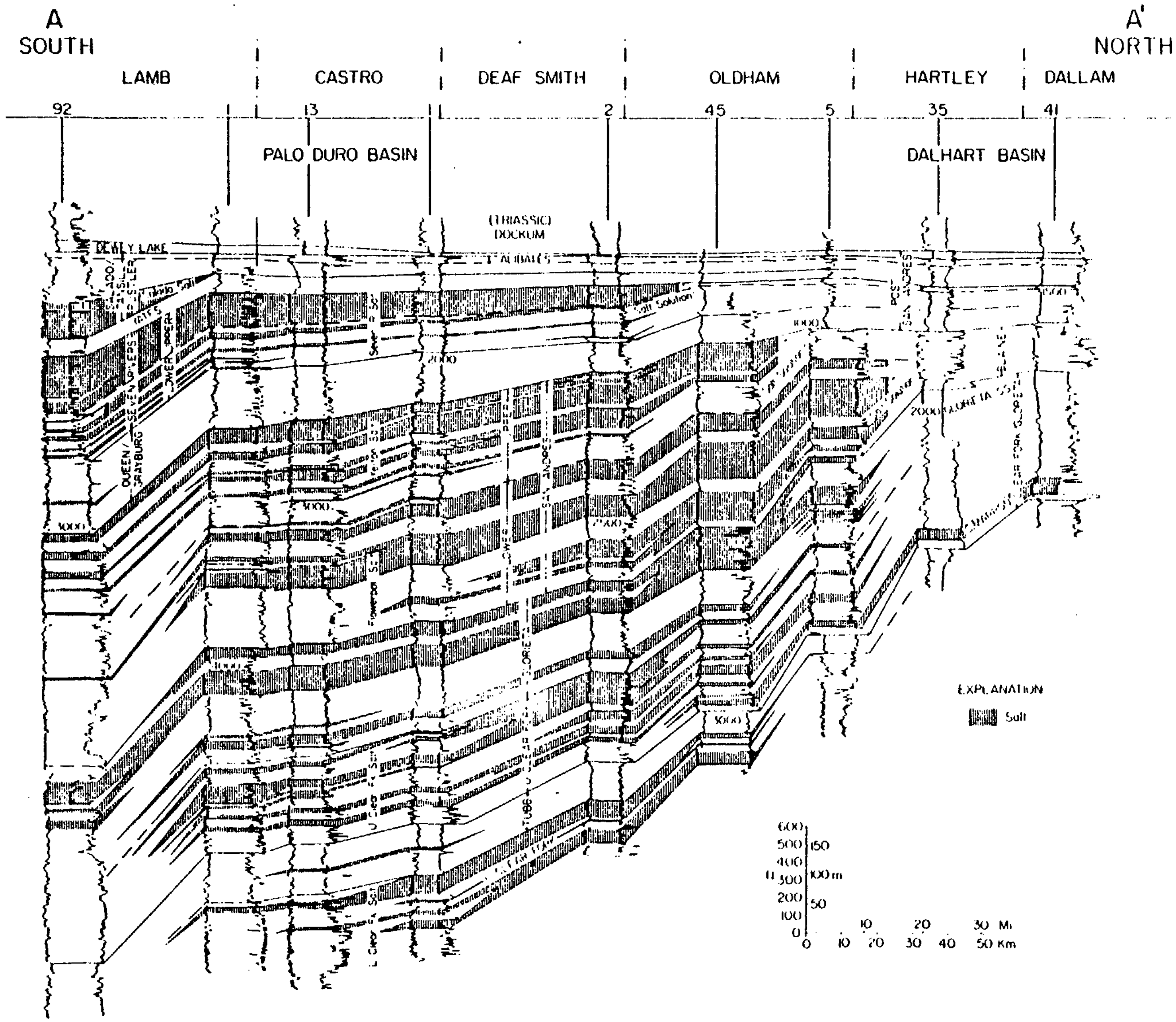


Figure 5. North-south cross section, Upper Permian salt-bearing strata, Texas Panhandle. Generalized salt units are correlated. Location of section in figure 4.

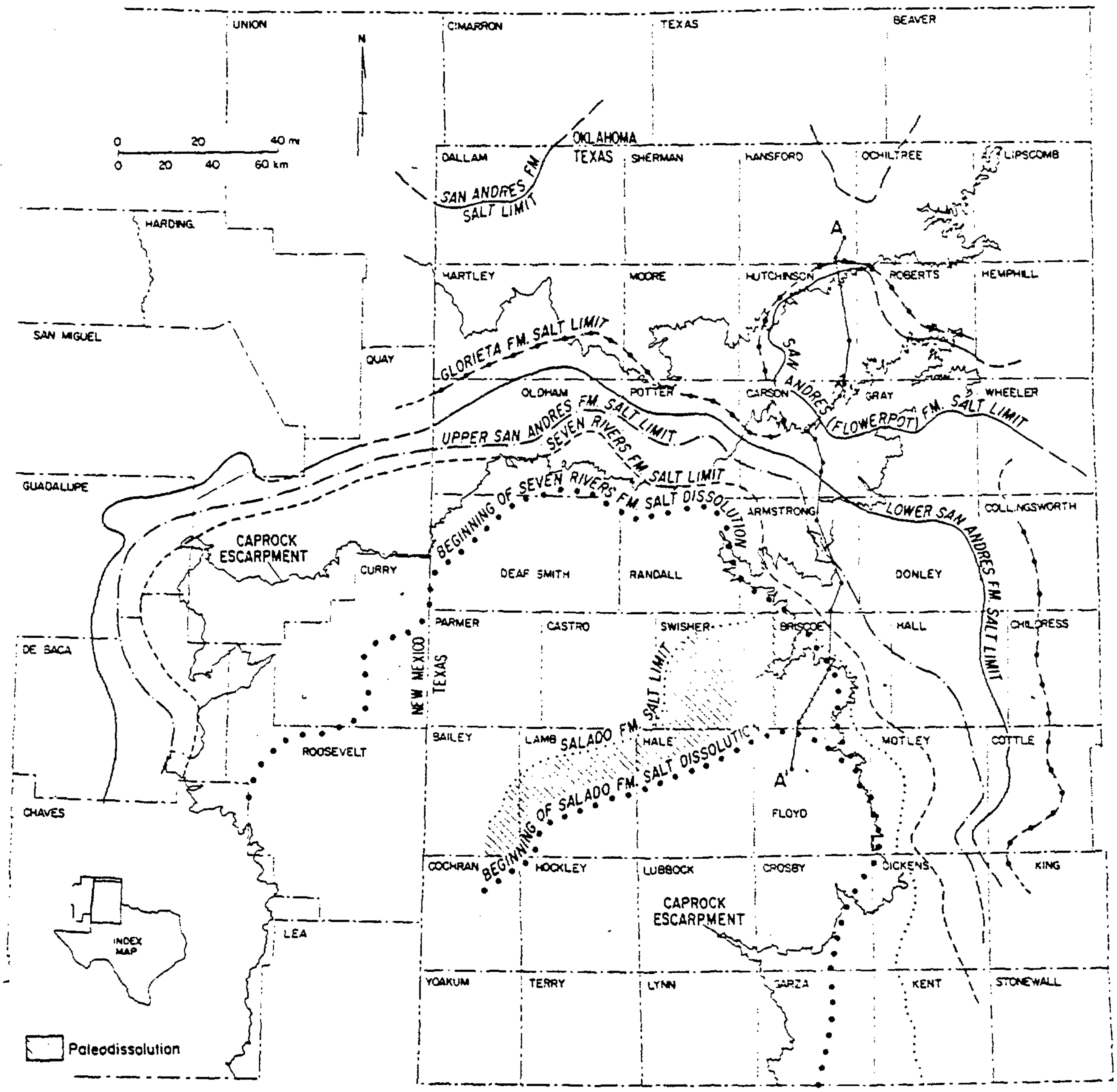


Figure 72. Salt dissolution zones, Texas Panhandle and eastern New Mexico. Except for the Seven Rivers and Salado Formations, where both the beginning of salt dissolution and the limit of salt are shown, the limit of salt for the younger formation marks the approximate beginning of salt dissolution for the next older formation (from Dutton and others, 1979).

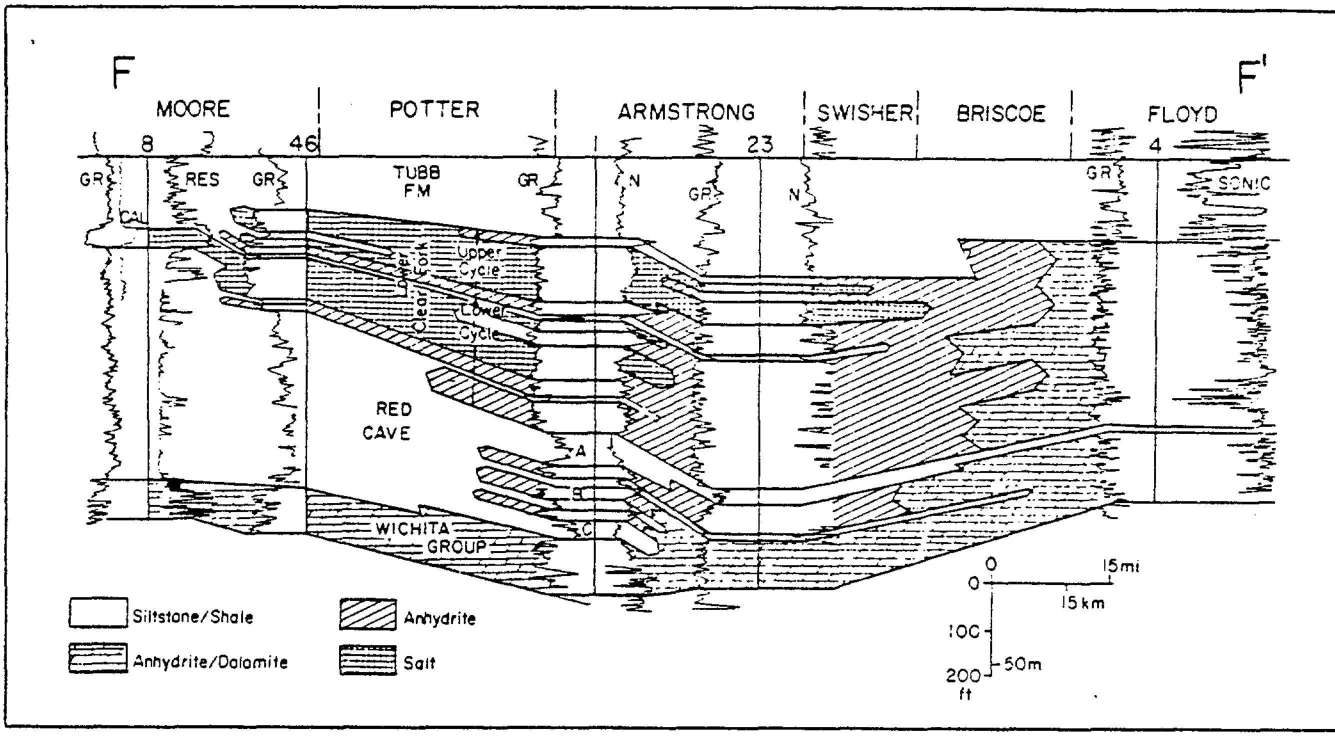


Figure 34. North-south cross section F-F' of lower Clear Fork Formation. See figure 3 for location (from Handford, 1981).

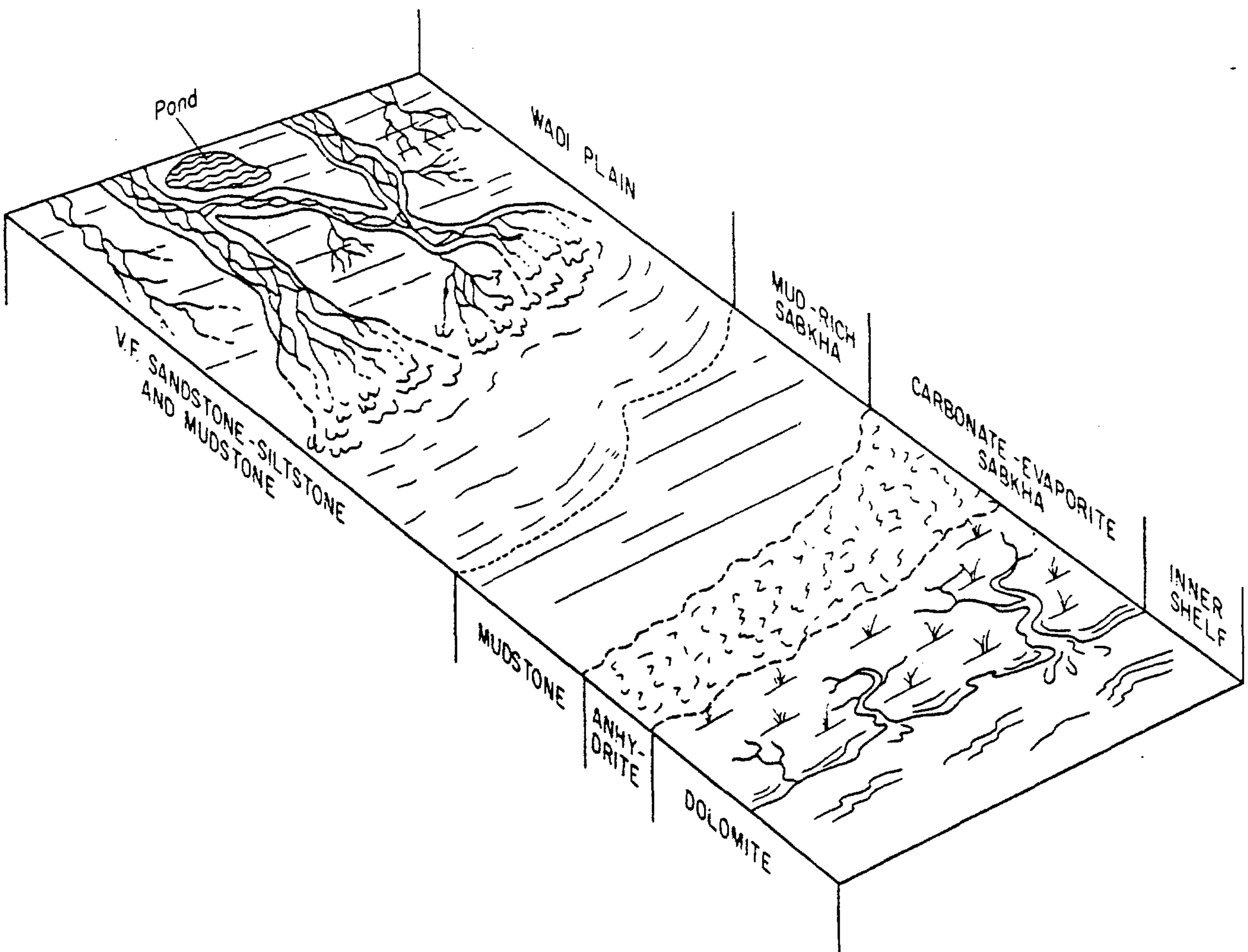


Figure 17. Composite depositional model for Red Cave carbonate, evaporite, and clastic facies.

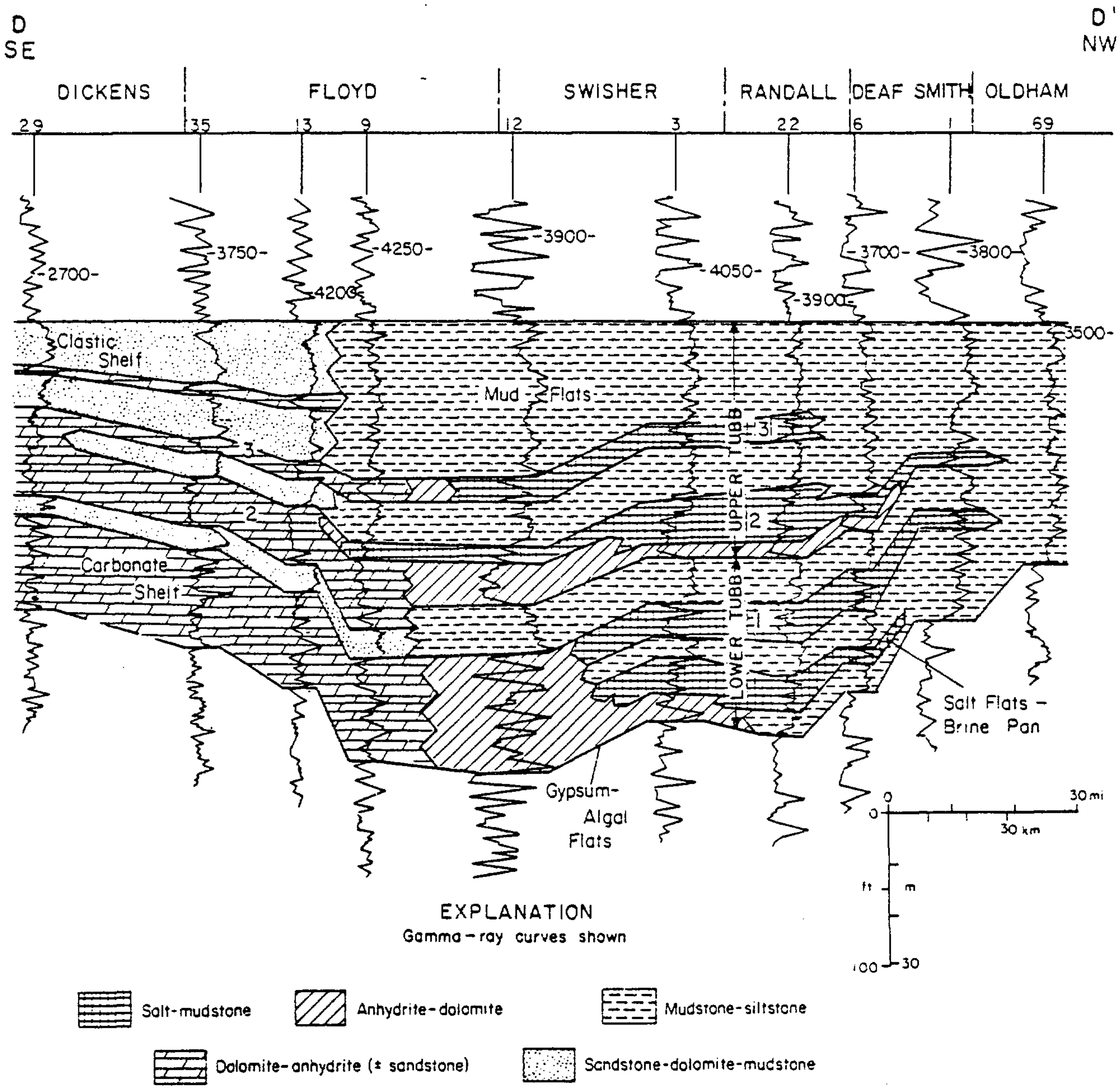


Figure 41. Northwest-southeast cross section, Tubb Formation, Palo Duro Basin. Line of cross section is indicated in figure 87. From Presley (1980b).

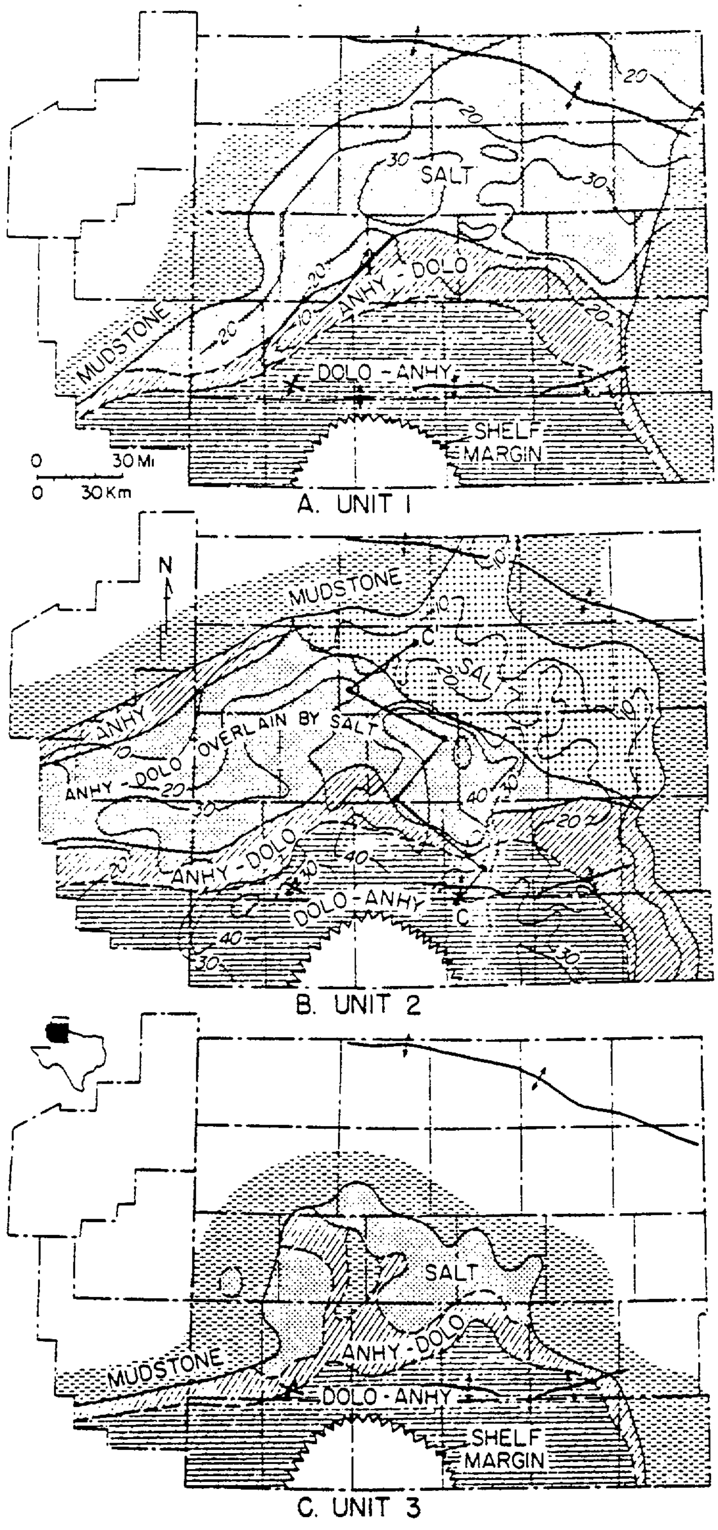


Figure 42. Facies maps of evaporite-carbonate units 1, 2, and 3 (oldest to youngest) of the Tubb Formation. Salt is dominant in updip regions to the north; carbonate is dominant to the south. These units show progressive southerly migration of evaporite-carbonate facies. From Presley (1980b).

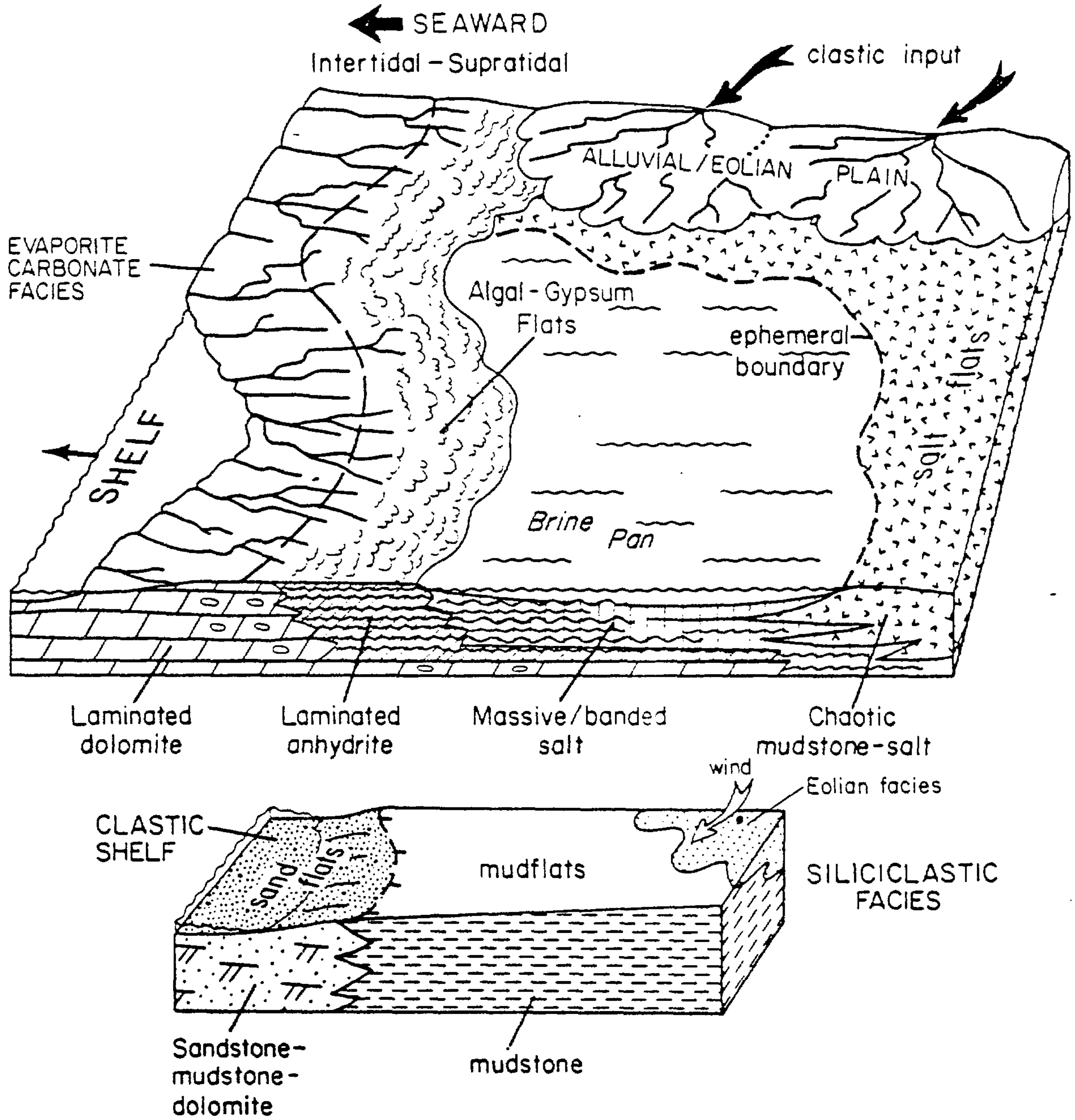


Figure 40. Facies and environments recorded in Tubb strata of the Palo Duro and Dalhart Basins. Evaporite-carbonate facies record a gradual basinward shift in environments. Siliciclastic (red-bed) facies dominate the Tubb sequence, and were deposited in tidal mud flats, which graded basinward into tidal sand flats. From Presley (1980b).

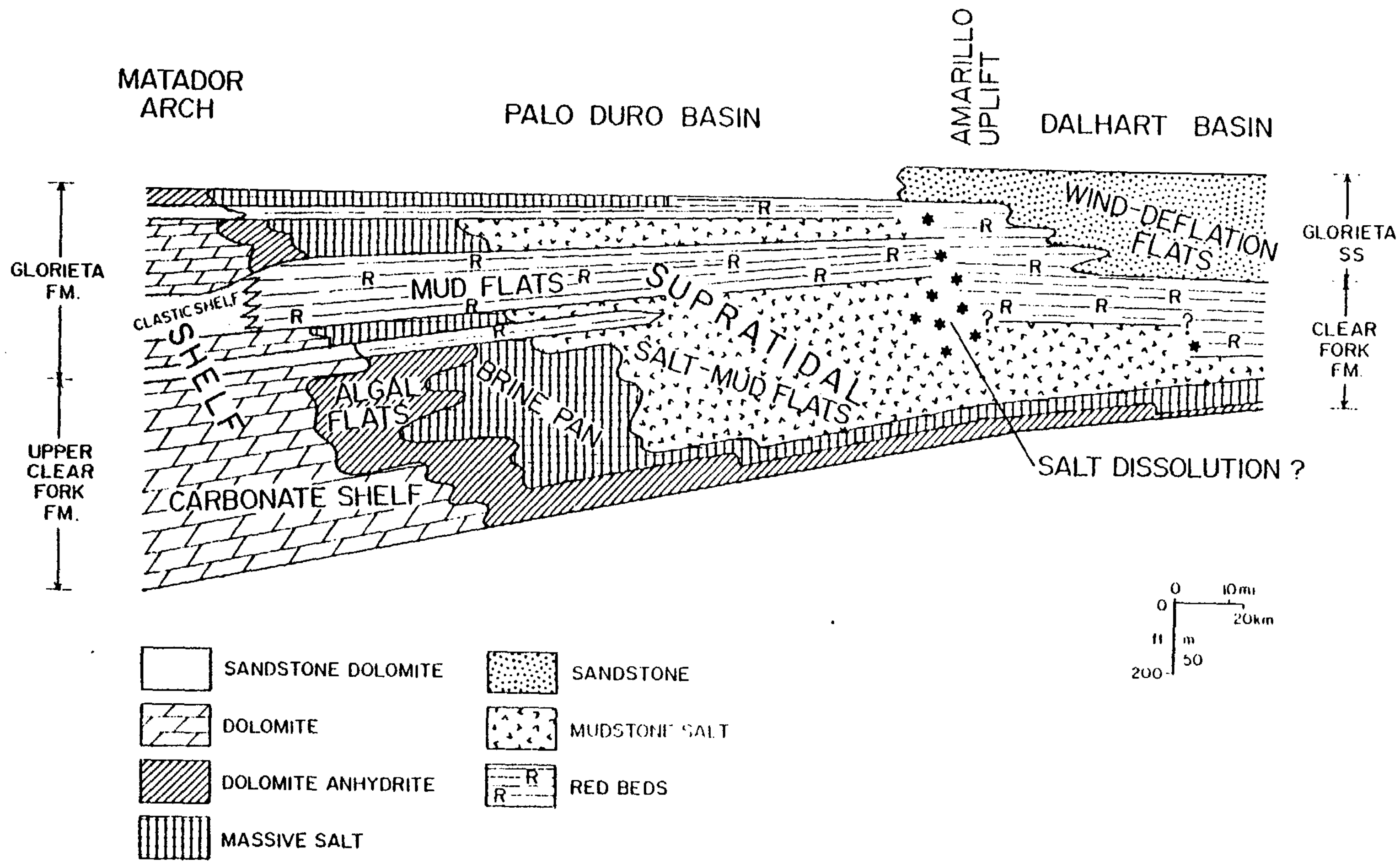


Figure 43. North-south facies cross section through Palo Duro and Dalhart Basins showing relation of environments for the upper Clear Fork and Glorieta Formations. From Presley (unpublished data).

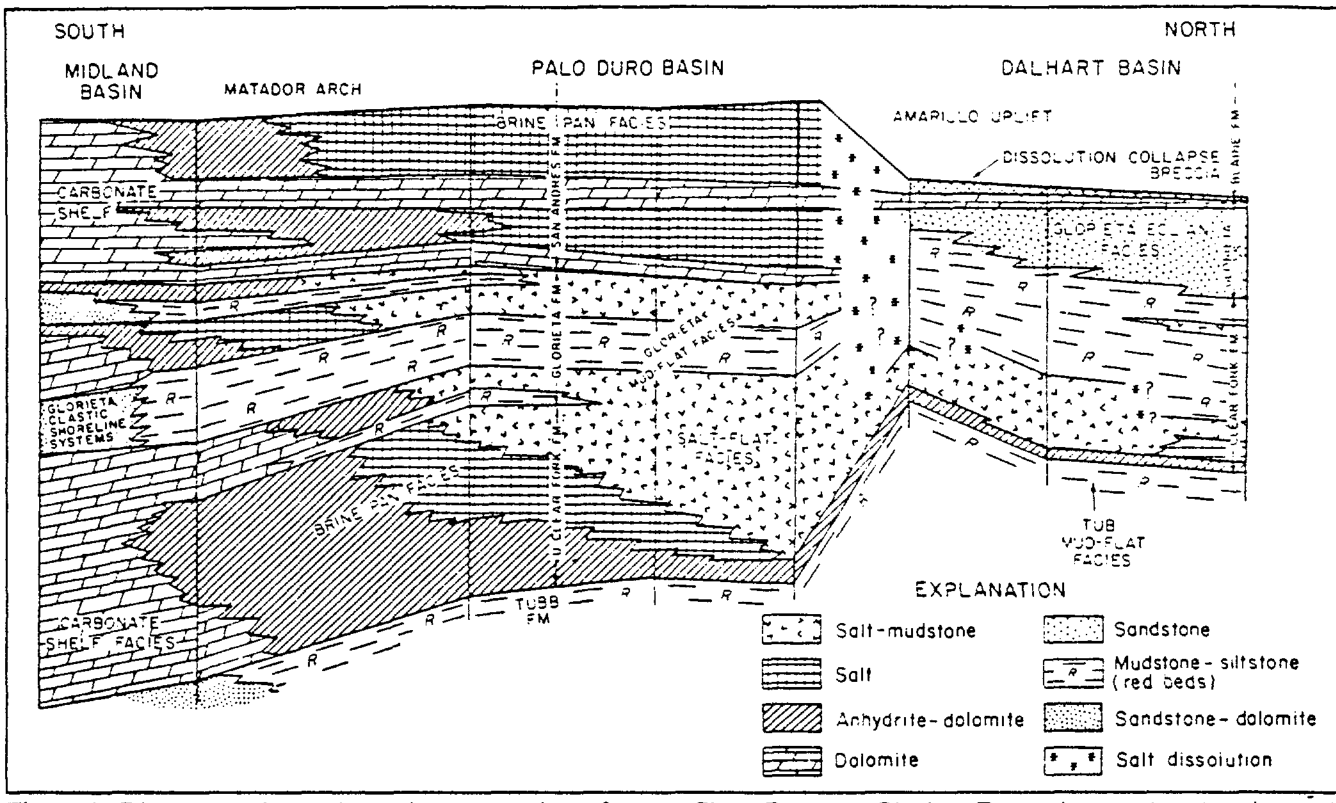


Figure 2. Diagrammatic north-south cross section of upper Clear Fork and Glorieta Formations and underlying and overlying units in Texas Panhandle. Generalized facies interpretations are shown. Location generally follows line of section A-A′ in figure 1.

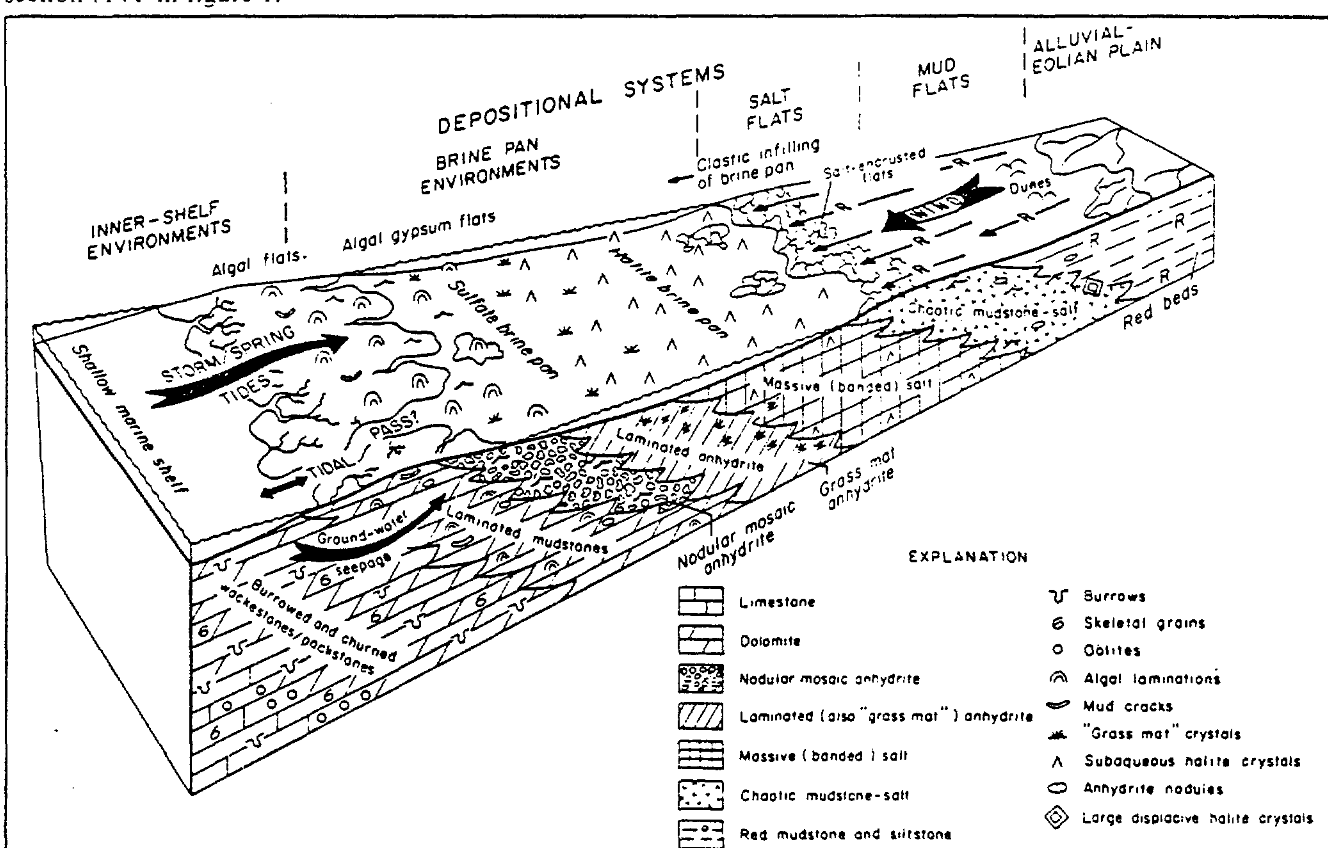


Figure 3. Evaporite and carbonate depositional facies and environments inferred for upper Clear Fork and Glorieta rocks.

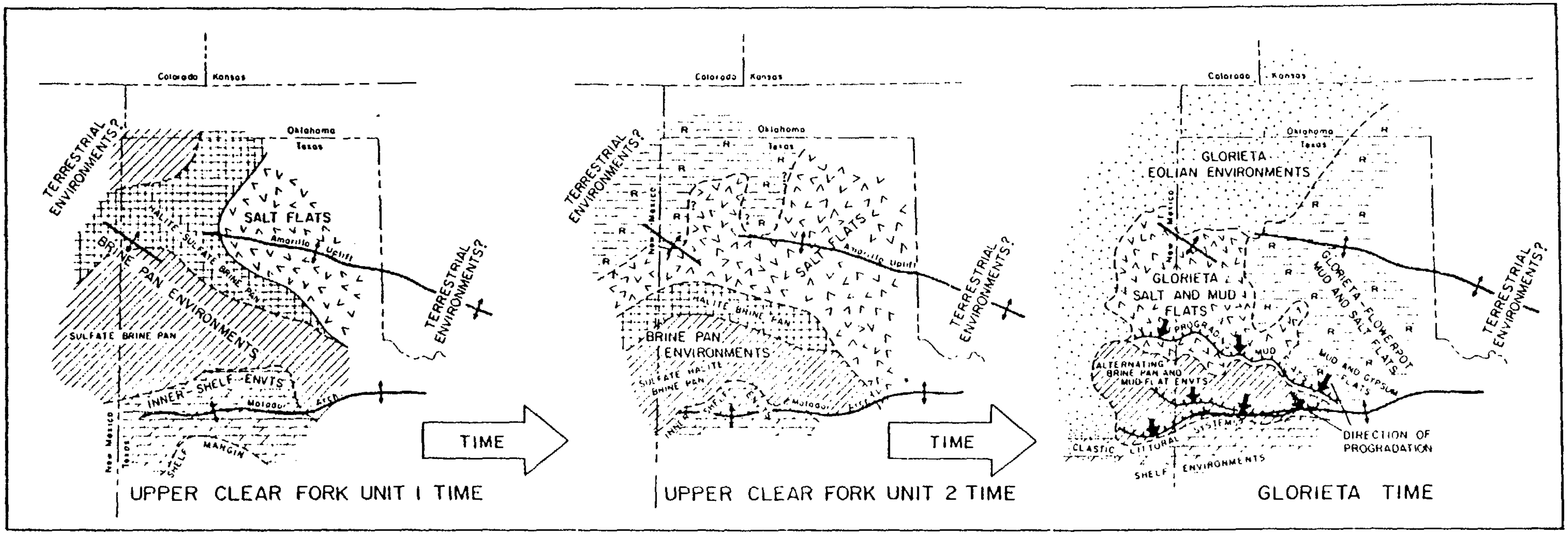


Figure 5. Paleogeography at the time of deposition of the upper Clear Fork and Glorieta Formations.

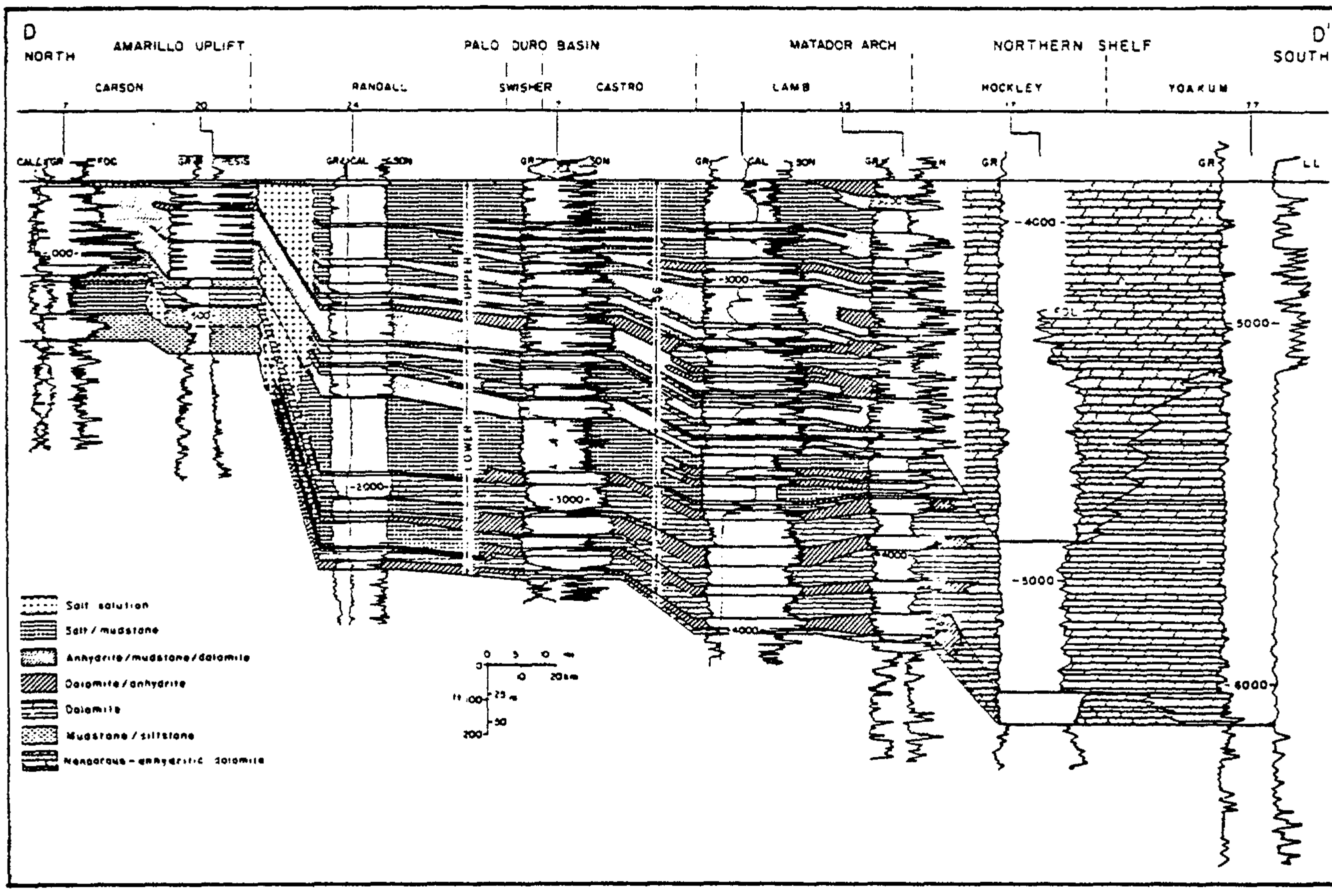
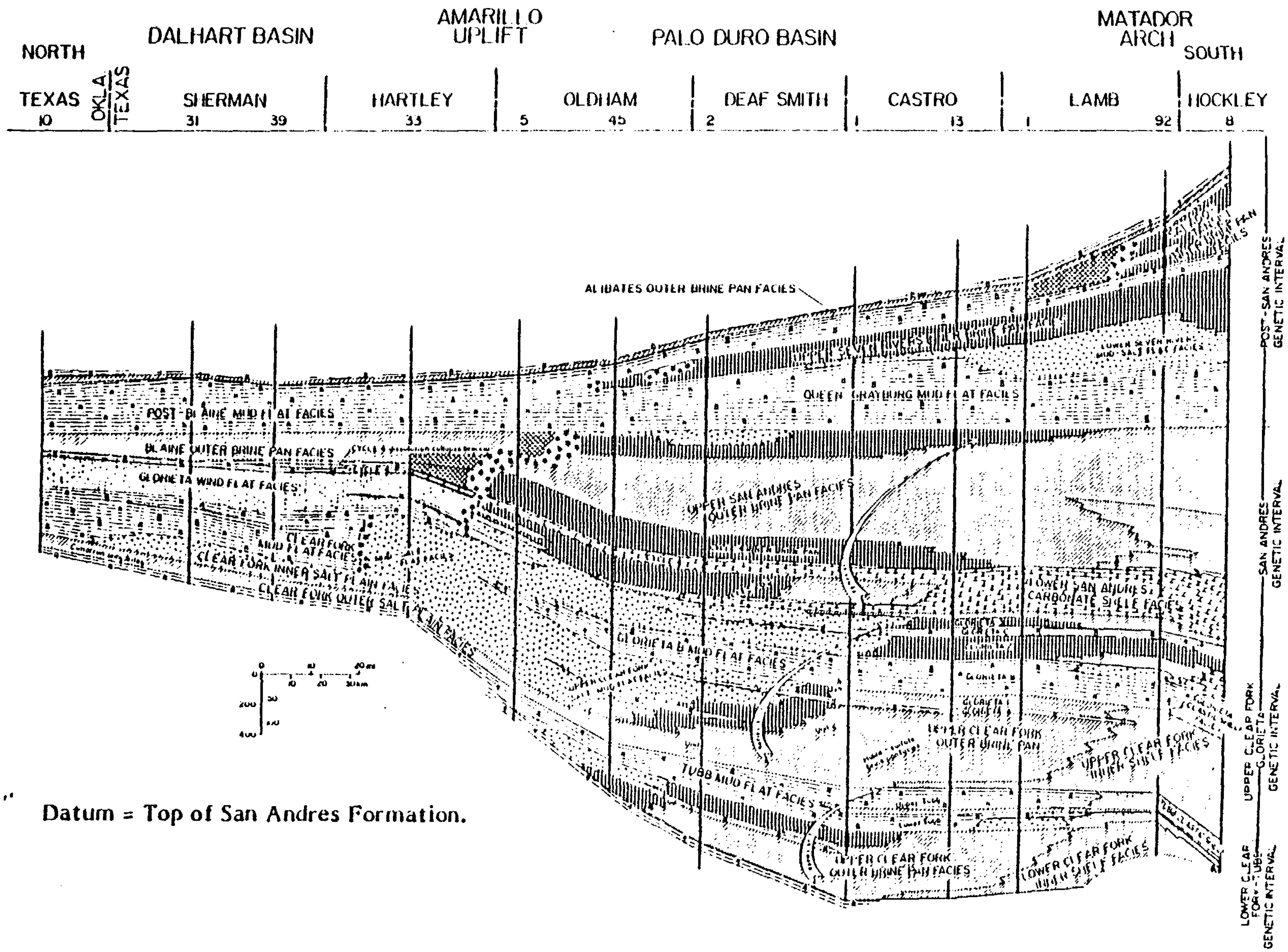


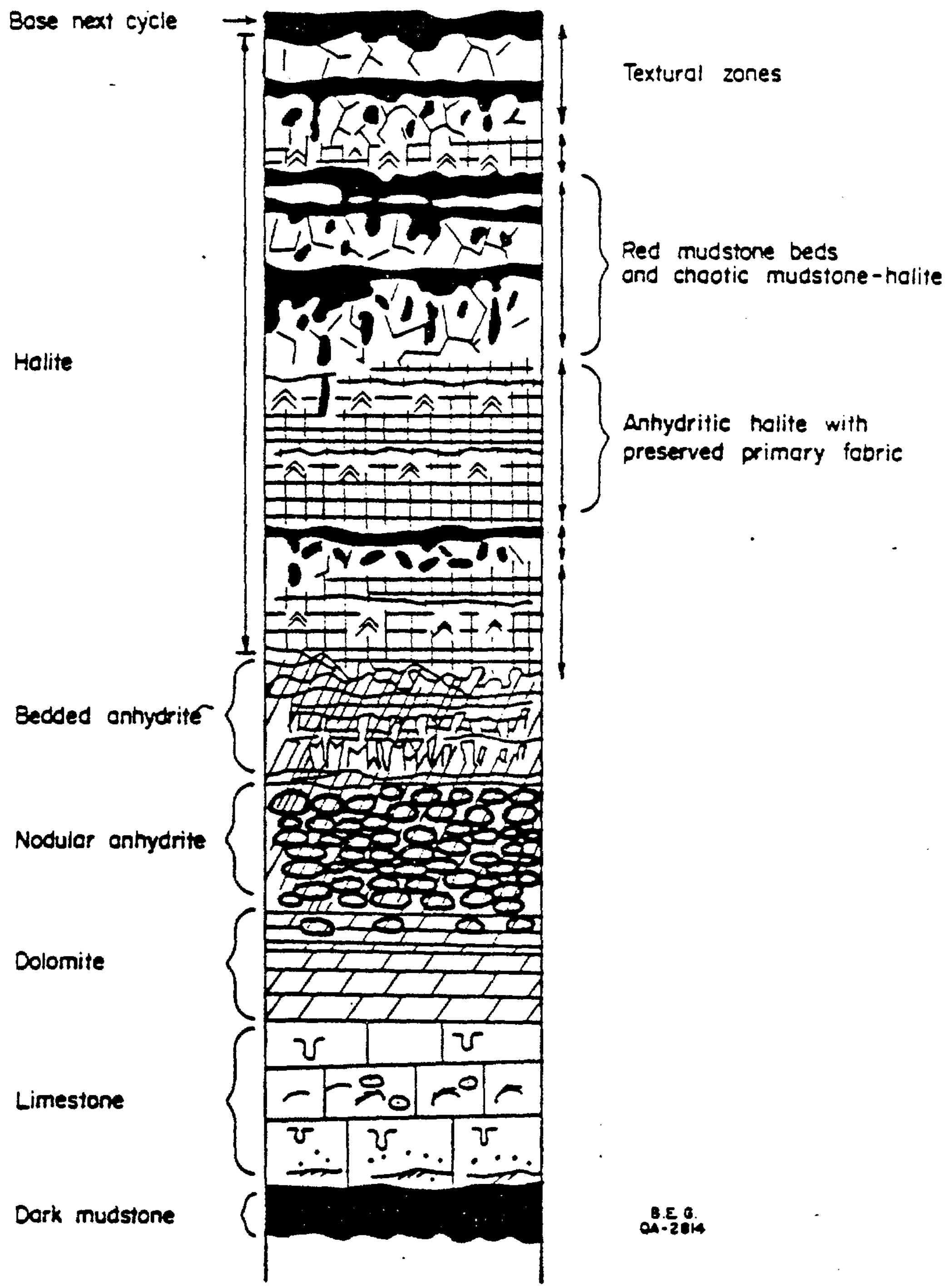
Figure 2. North-south cross section through the study area (after Presley, 1979, and P. Ramondetta, personal communication, 1981). Pinch-out of salt and anhydrite preclude detailed log correlation to the south. Datum: Top San Andres. See figure 1 for line of section.

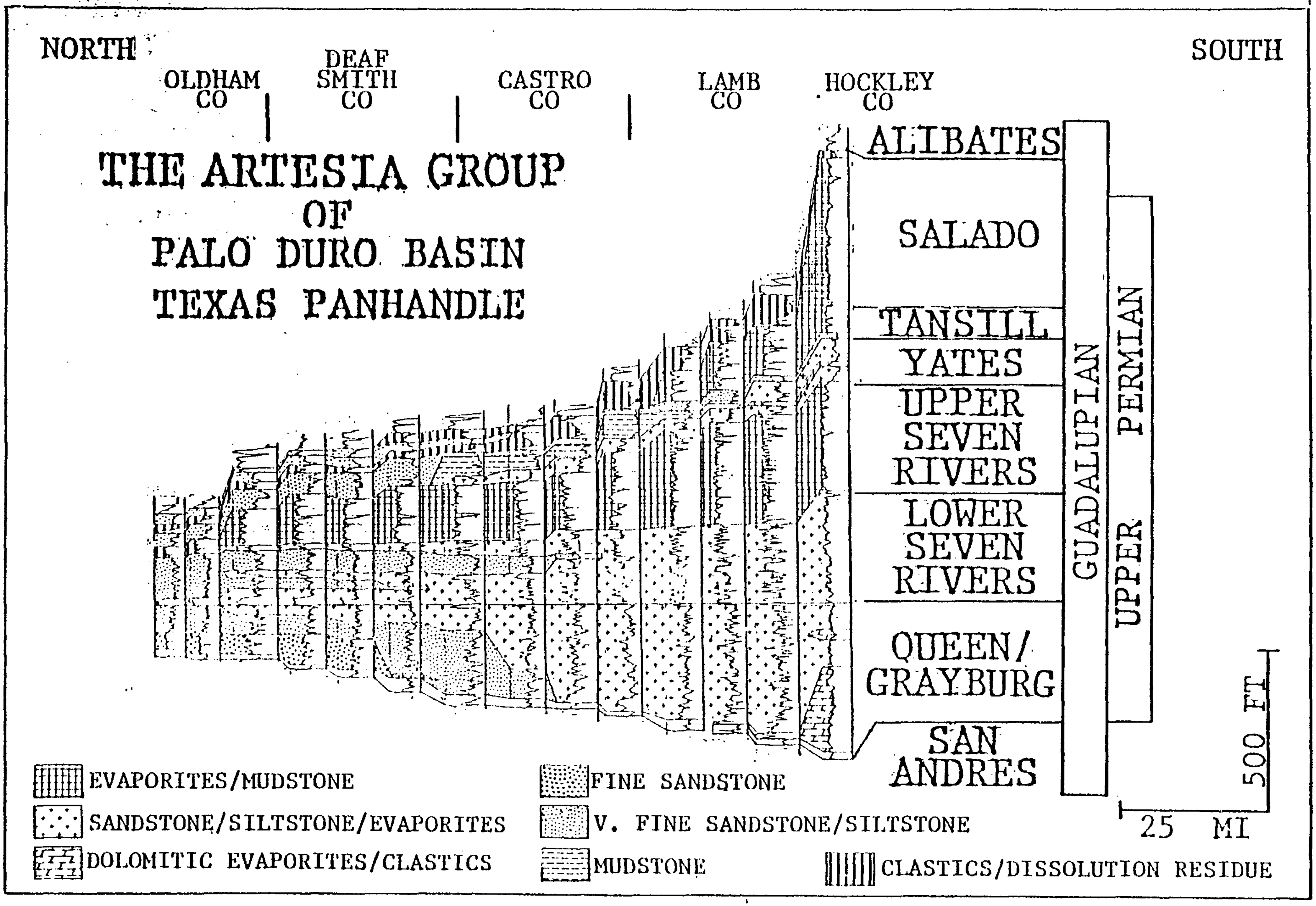
Figure 2



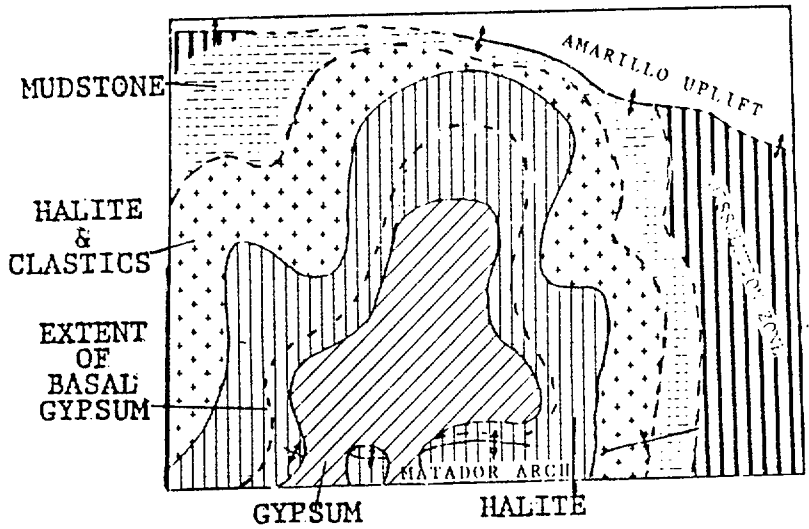
Datum = Top of San Andres Formation.

TYPICAL SAN ANDRES CYCLE

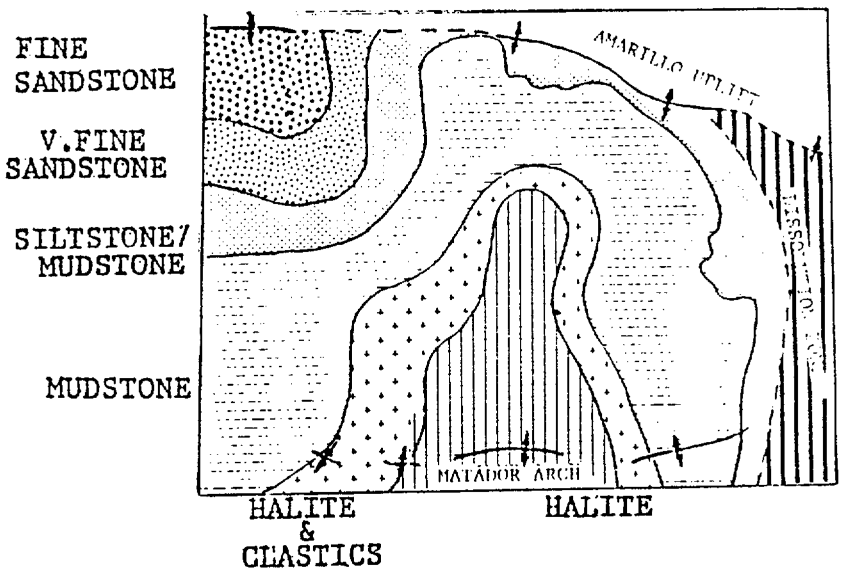



NORTH
SOUTH
OLDHAM CO
DEAF SMITH CO
CASTRO CO
LAMB CO
HOCKLEY CO
THE ARTESIA GROUP OF PALO DURO BASIN TEXAS PANHANDLE
ALIBATES
SALADO
TANSILL
YATES
UPPER SEVEN RIVERS
LOWER SEVEN RIVERS
QUEEN/ GRAYBURG
SAN ANDRES
GUADALUPIAN
UPPER PERMIAN
500 FT
25 MI
EVAPORITES/MUDSTONE
SANDSTONE/SILTSTONE/EVAPORITES
DOLOMITIC EVAPORITES/CLASTICS
FINE SANDSTONE
V. FINE SANDSTONE/SILTSTONE
MUDSTONE
CLASTICS/DISSOLUTION RESIDUE

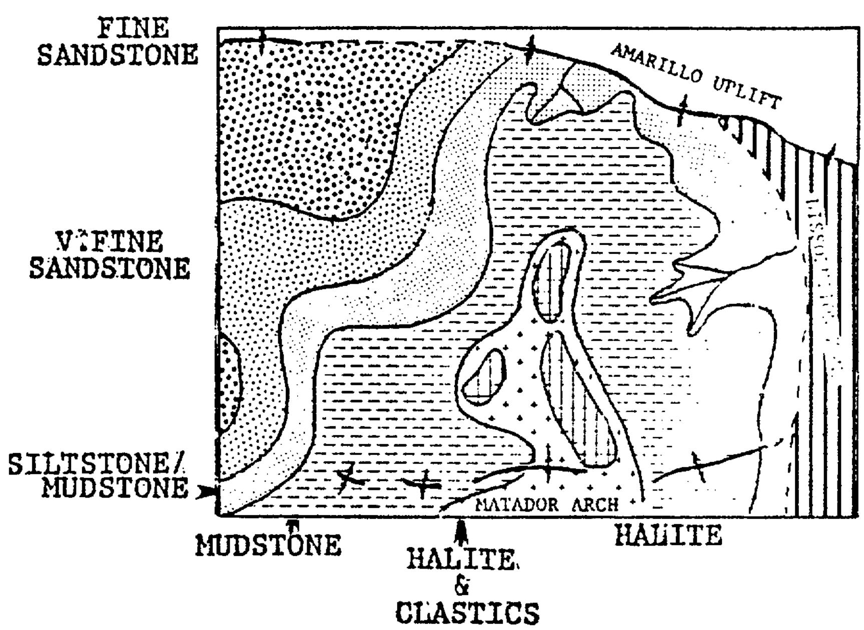
STAGE I



STAGE II



STAGE III



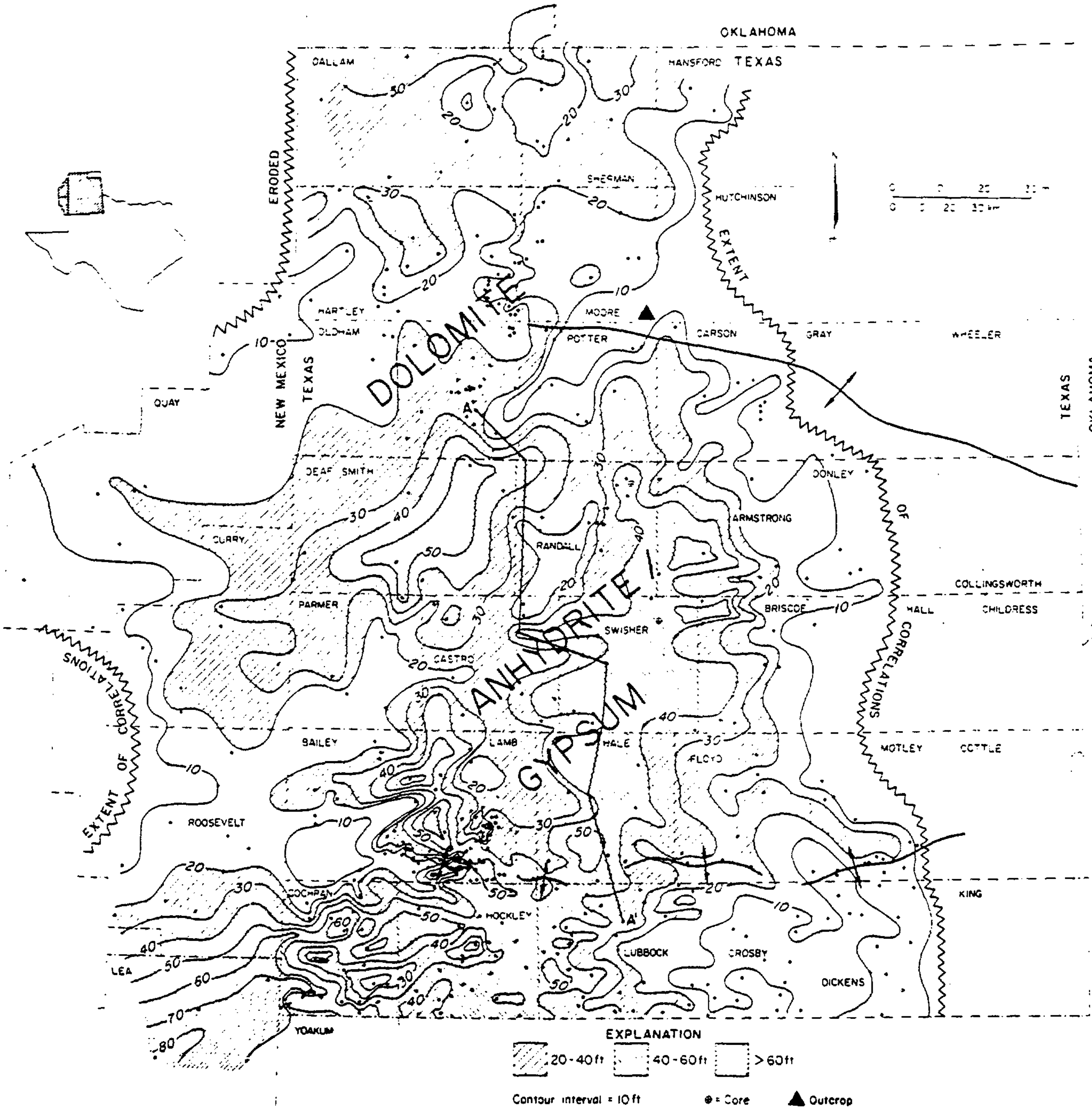


Figure 10. Isopach map, Alibates Formation. Serrate lines mark limit of correlation and erosional boundaries. Outcrop shown in Moore County. Maximum thickness in central and southern Palo Duro Basin.

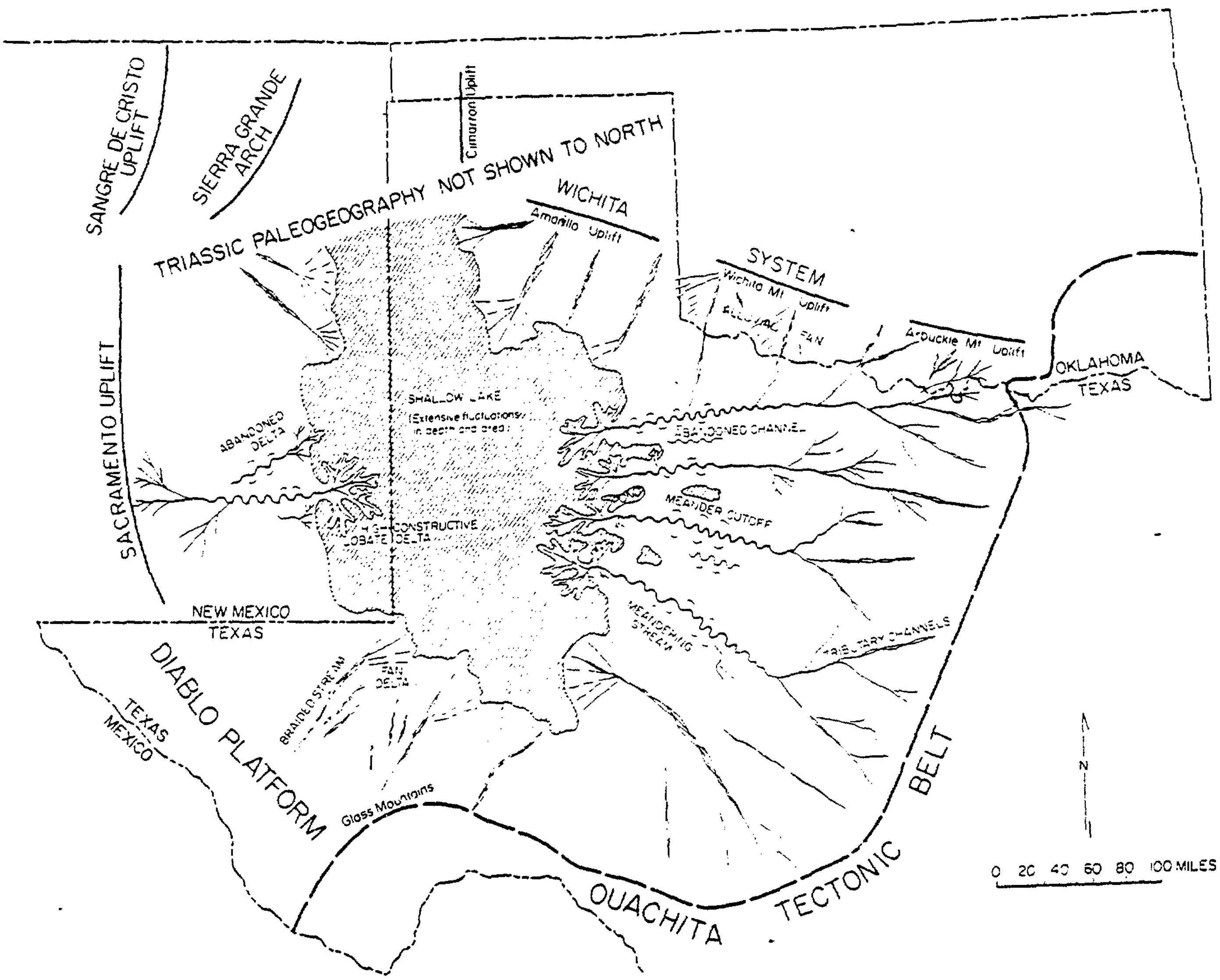


Figure 5. Inferred paleogeography during the initial stage of Dockum sedimentation in the area south of Amarillo Uplift - Bravo Dome. Depositional elements are braided streams, alluvial fans, fan deltas, meandering streams, distributary deltas, and shallow lakes.