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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 misties 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.

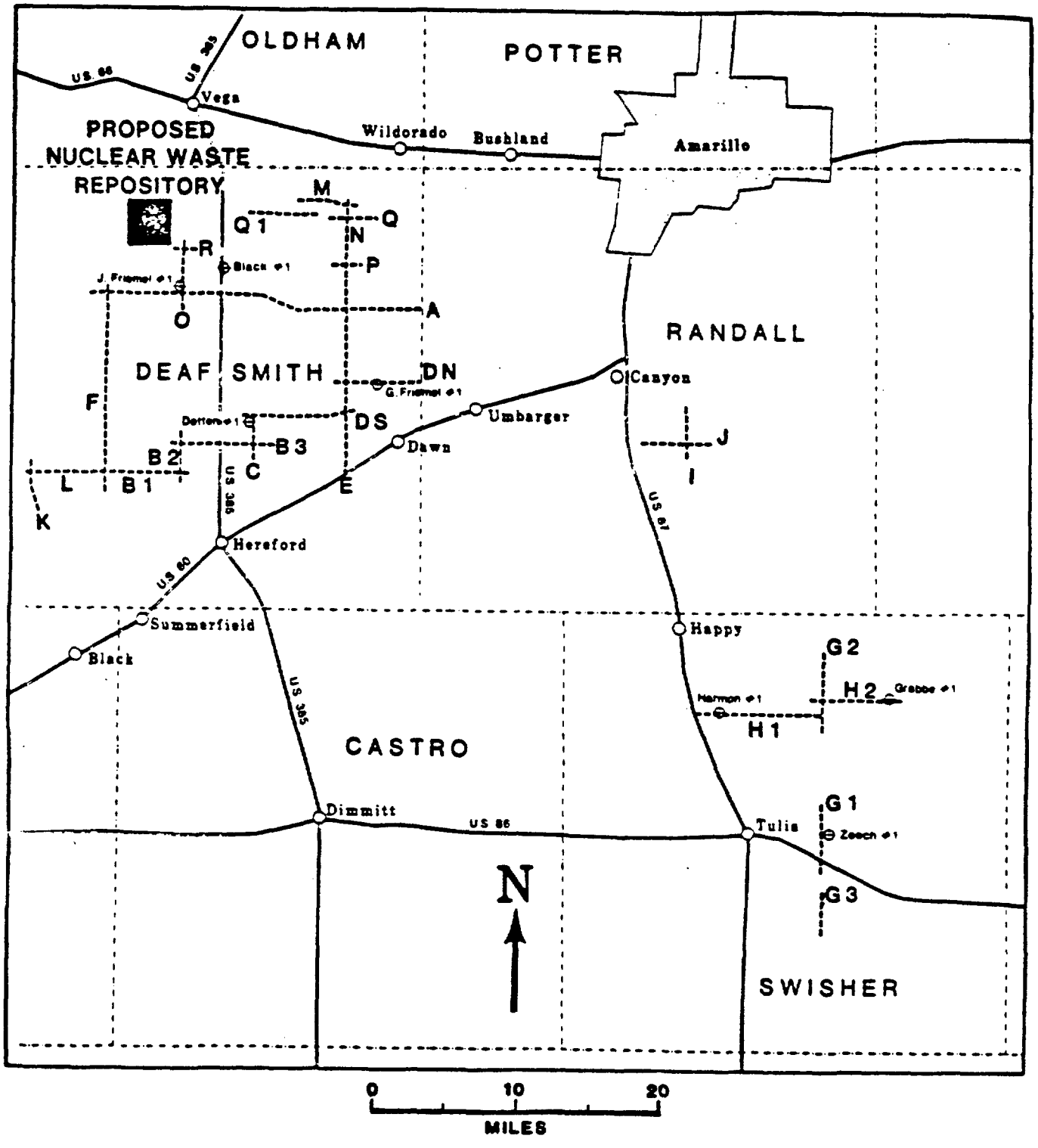

OLDHAM
POTTER
US 66
US 385
Vega
PROPOSED
NUCLEAR WASTE
REPOSITORY
Wildorado
Bushland
Amarillo
M
Q1
Q
N
R
P
Black #1
J. Friemel #1
O
A
RANDALL
DEAF SMITH
DN
G. Friemel #1
Canyon
F
Dorton #1
DS
Umbarger
B3
B2
Dawn
J
C
L
B1
E
I
K
US 385
US 87
Hereford
US 60
Summerfield
Happy
Black
G2
H2
Grabbe #1
Harmon #1
H1
US 385
CASTRO
Dimmitt
US 66
Tulia
G1
Zeech #1
N
G3
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
FD-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

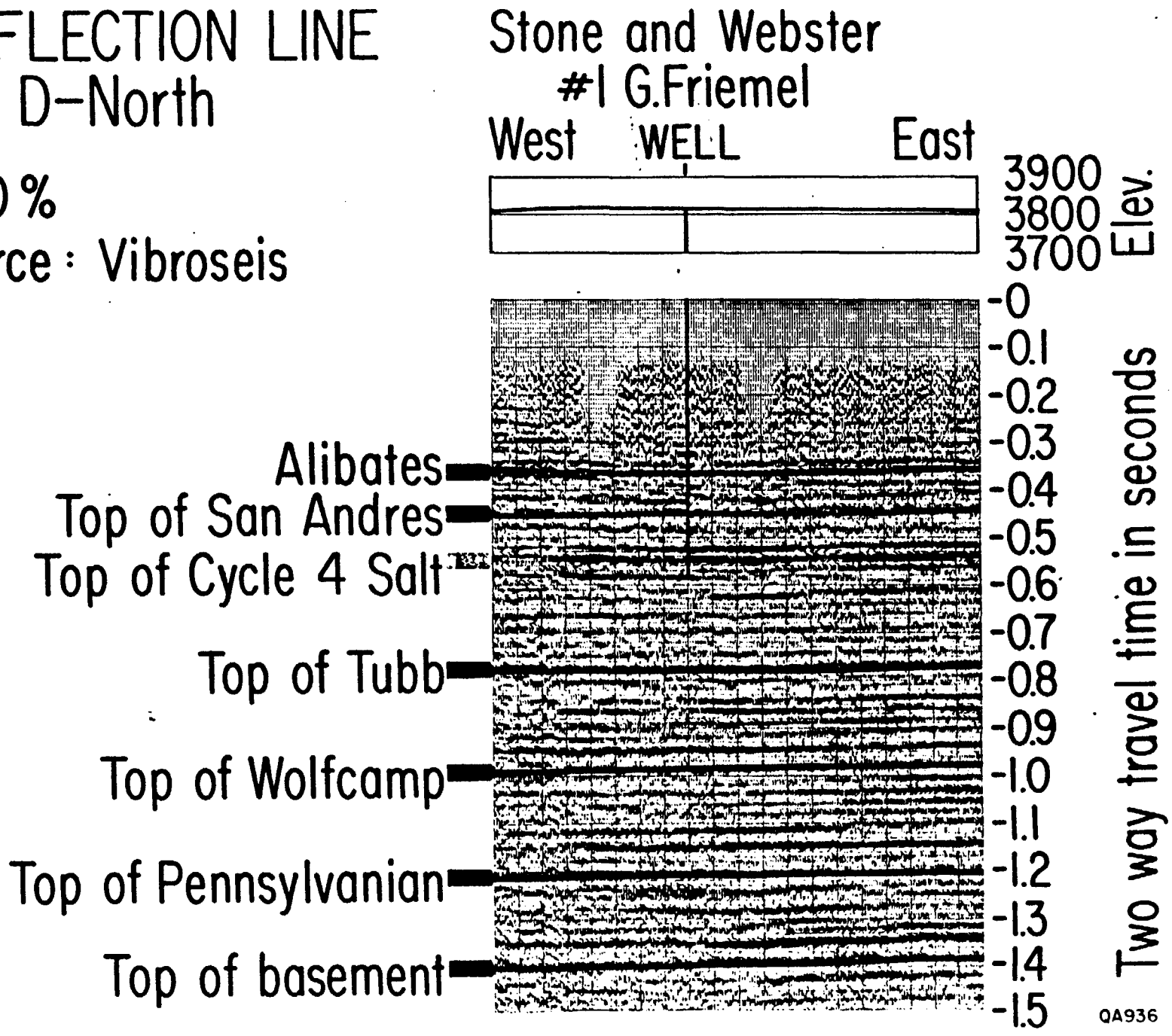
/elocity Data

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

SEISMIC REFLECTION LINE
SWEC D-North

Fold : 2400 %

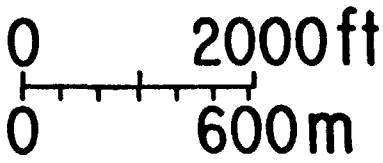
Energy source : Vibroseis

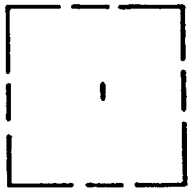


SEISMIC REFLECTION LINE
SWEC G-1

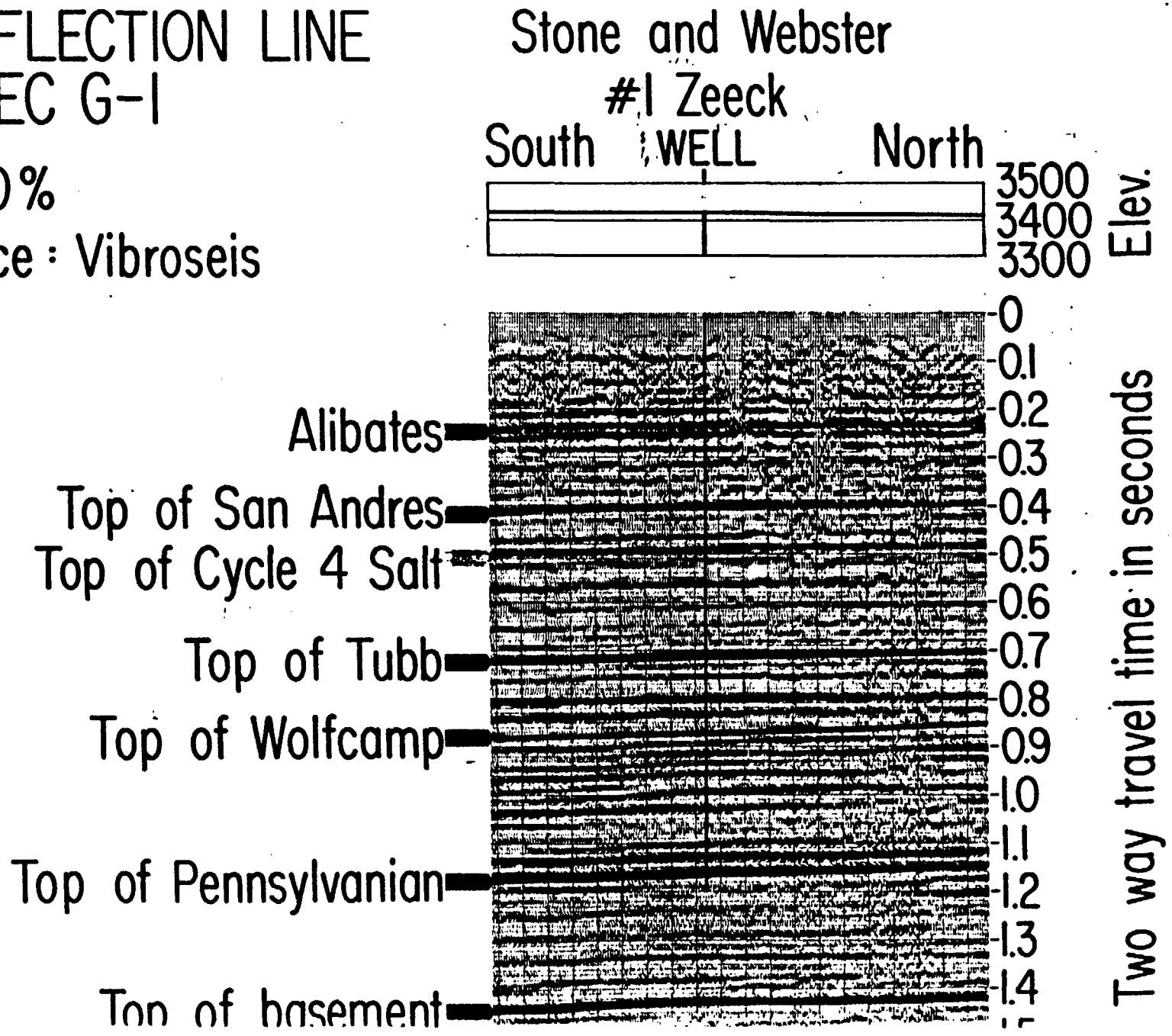
Fold : 2400%

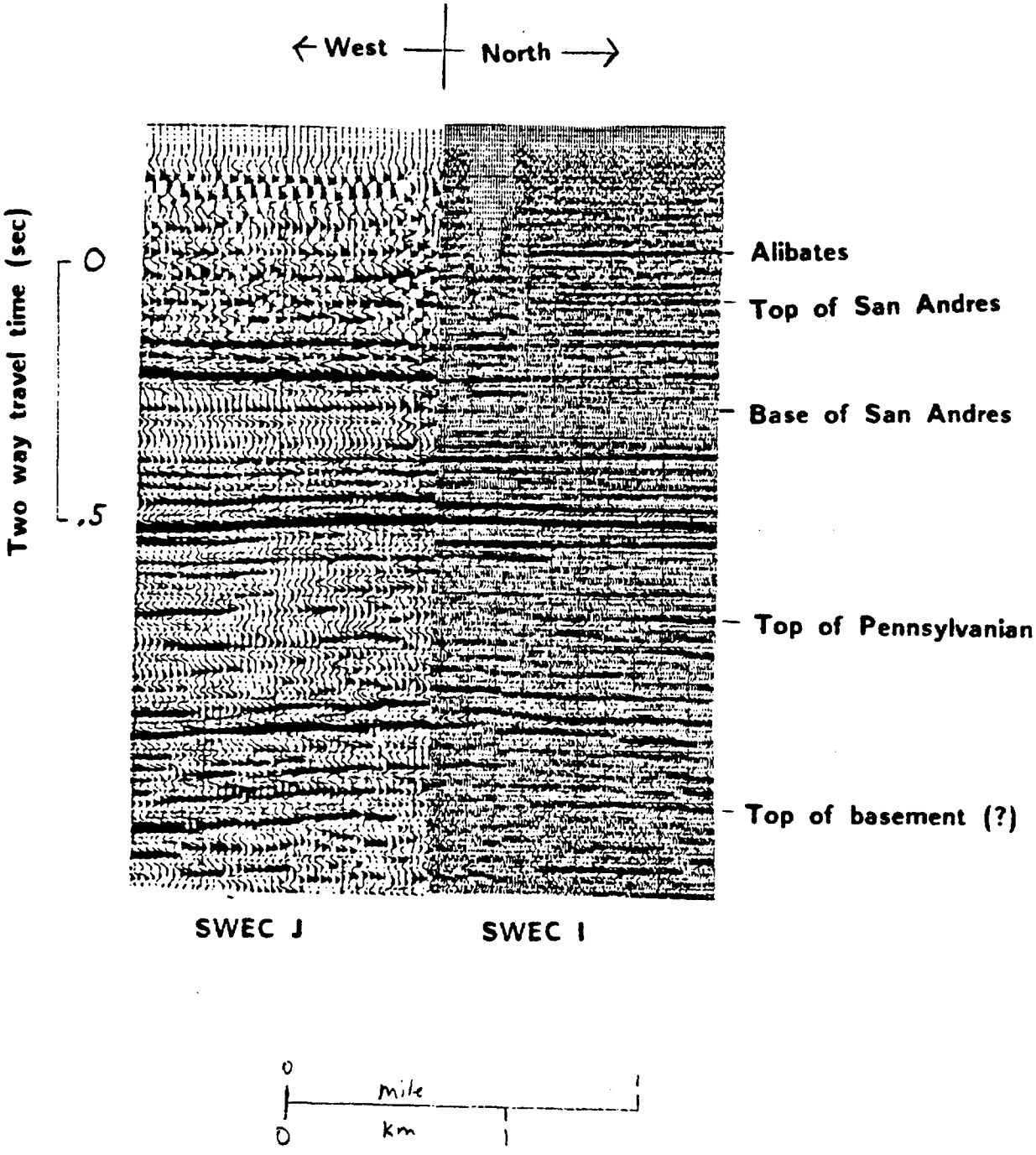
Energy source : Vibroseis

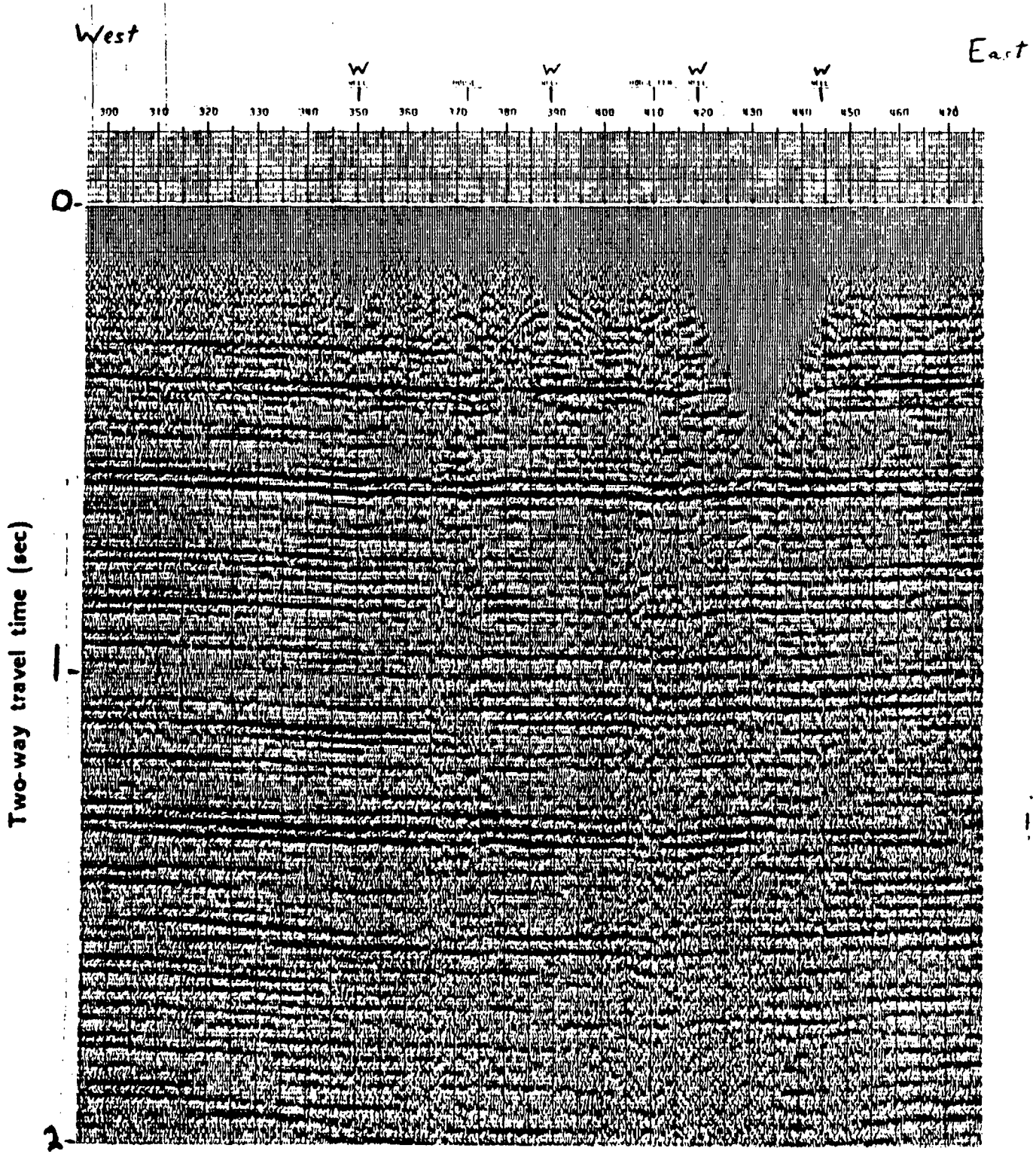




Swisher Co.




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



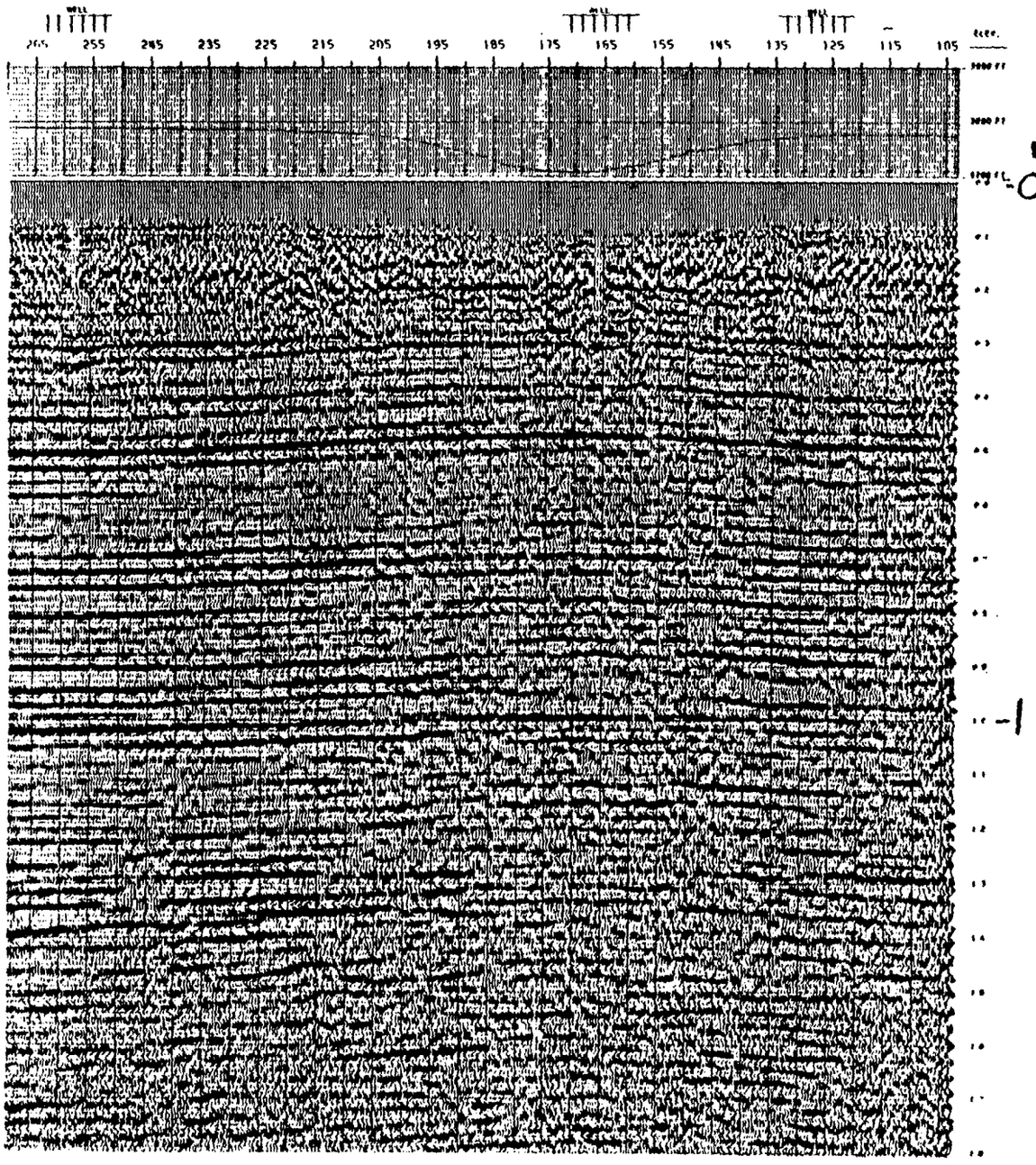
SWEC B-3

Distortion of data in vicinity of irrigation wells

mile

km

SWEC-Q



topography

0 1 mile

0 1 Km

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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)

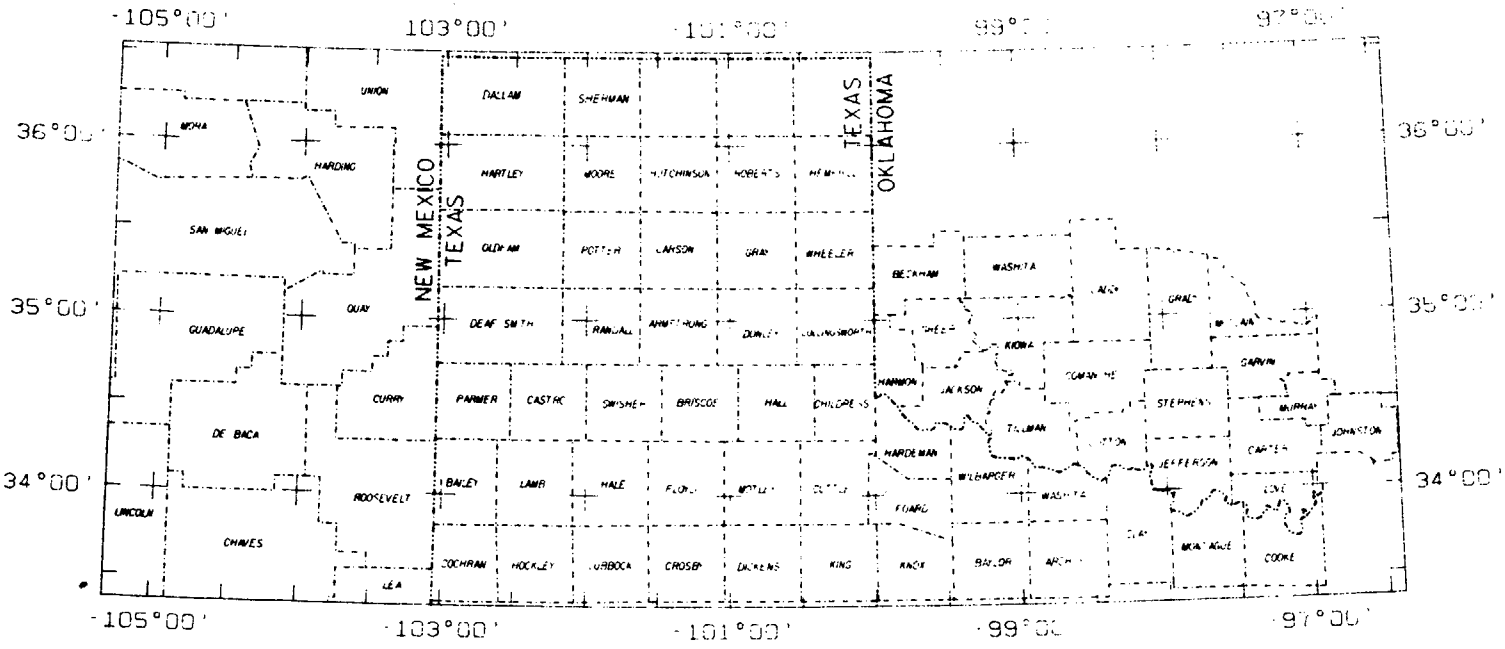
NRC WORKSHOP
November 19 - 21, 1985
Mapping from Geologic Data Base

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



0 50 100 150 200

Scale: Miles

0 50 100 150 200

Scale: Kilometers

Explanation:

County boundary

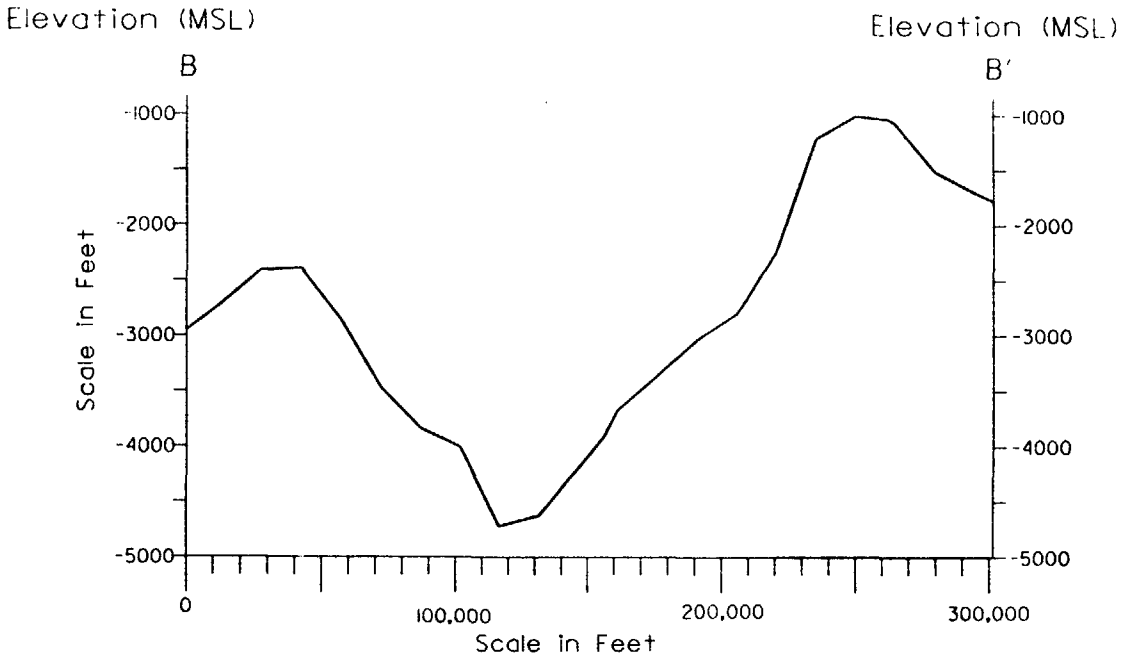
State boundary

Projection: Lambert Conformal

PRELIMINARY

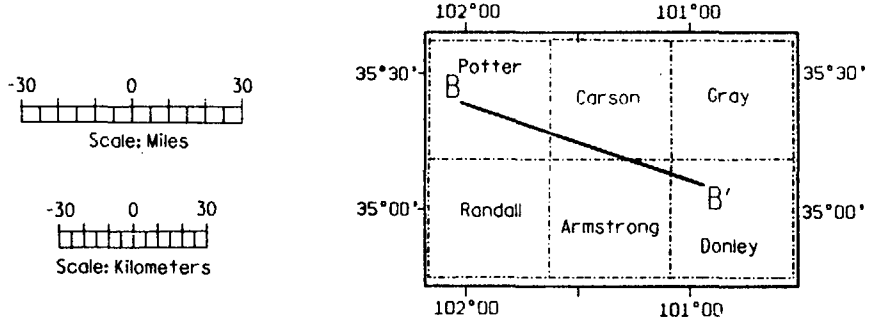
FOR COMMENTS ONLY

Extent of the Project Study Area



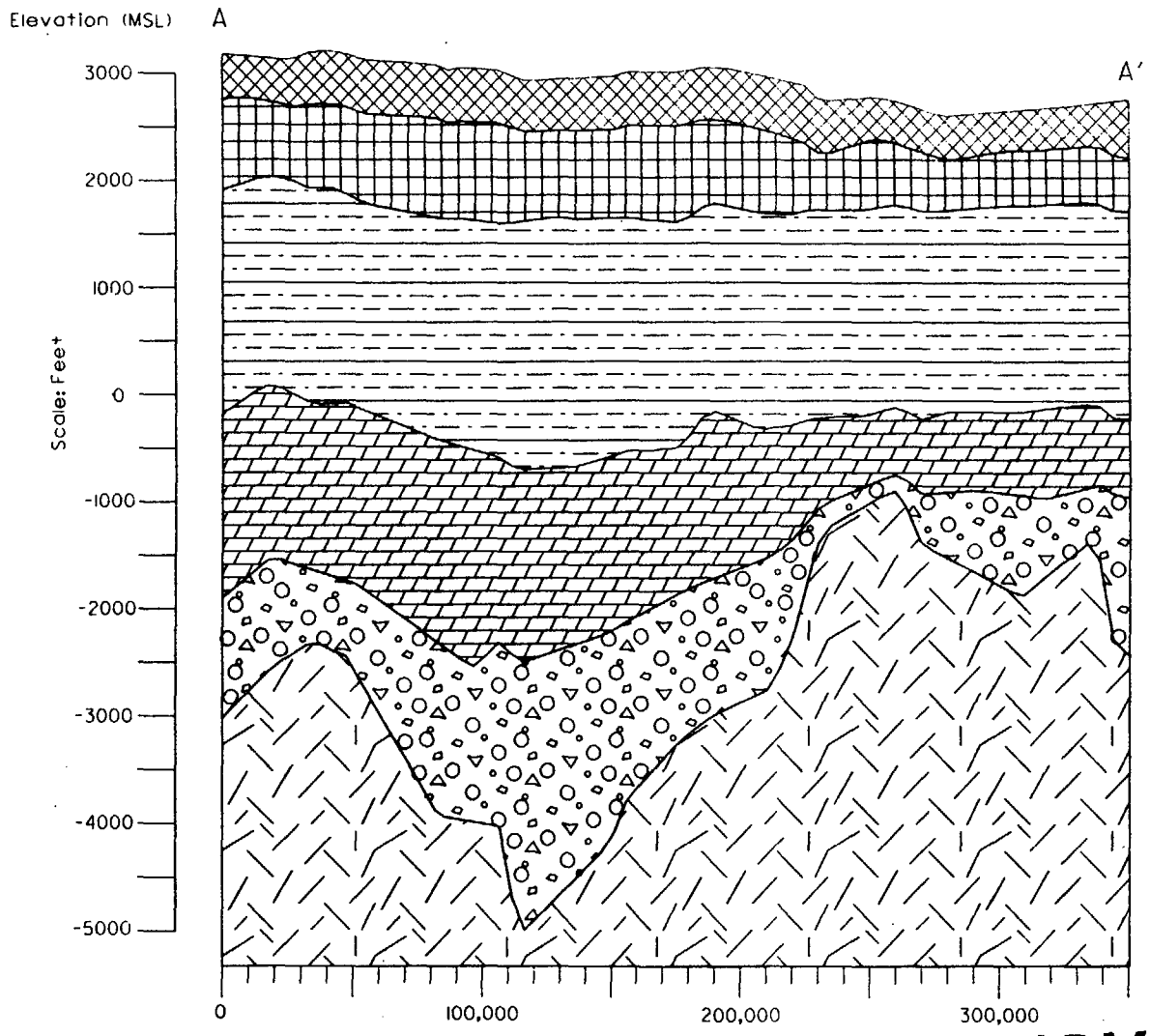
Note:

Vertical Exaggeration: 500x



PRELIMINARY
FOR COMMENTS ONLY

Cross Section of
a Single Horizon



EXPLANATION

County Line

Cross Section Line

Alibates - Queen/Grayburg

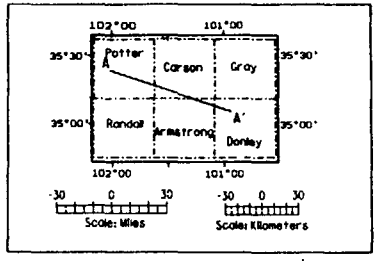
San Andres

Glorieta - Wichita

Wolfcamp

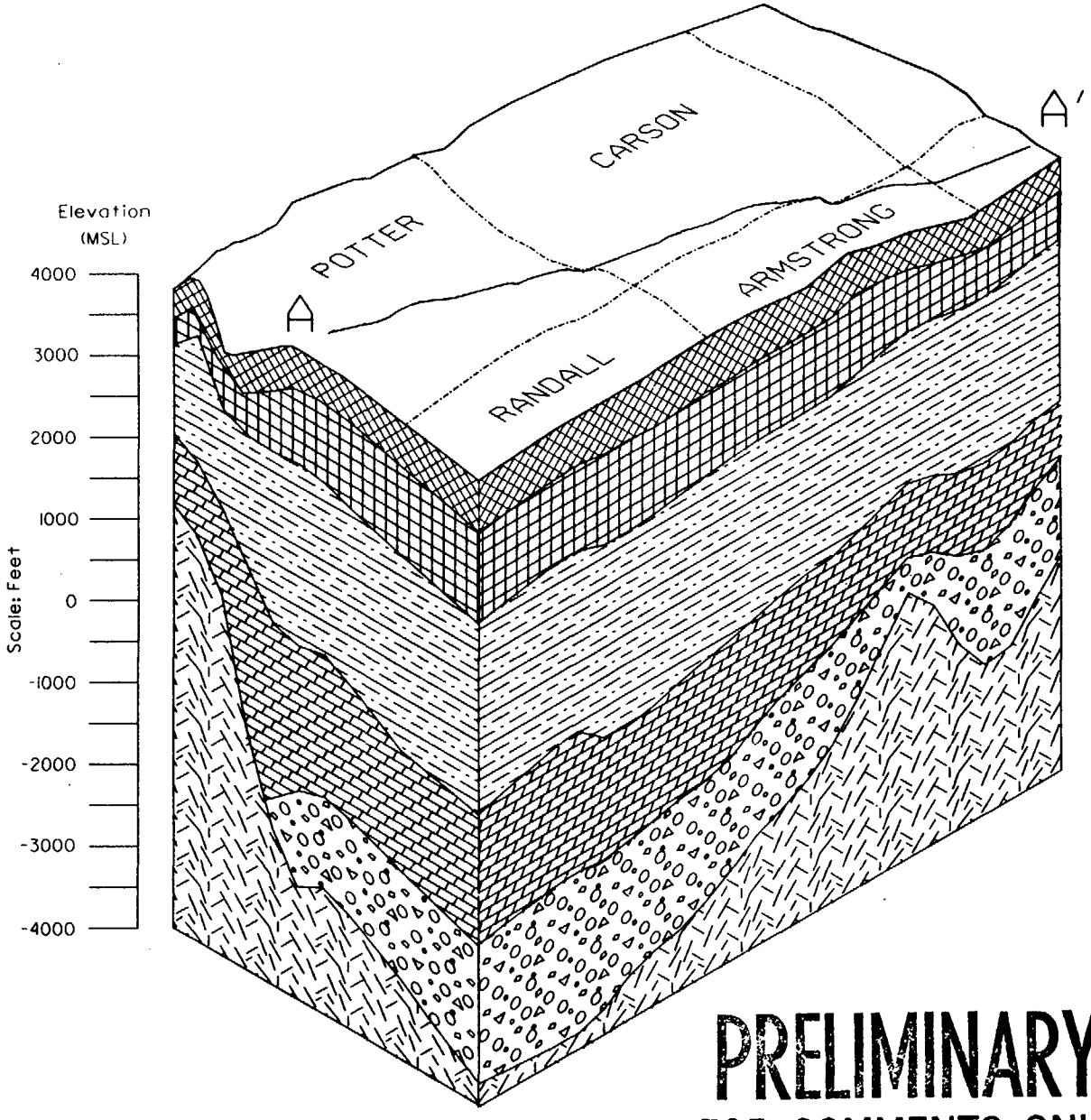
Pennsylvanian

Precambrian



PRELIMINARY
FOR COMMENTS ONLY

Patterned Cross Section



EXPLANATION

County Line

Cross Section Line

Alibates - Queen/Grayburg

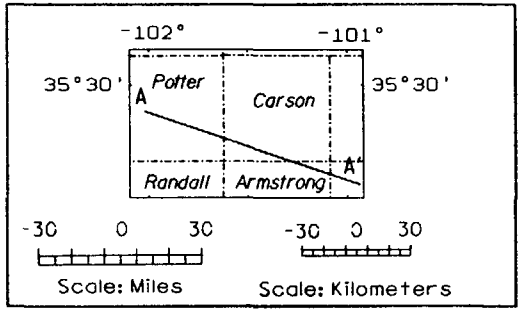
San Andres

Glorieta - Wichita

Wolfcamp

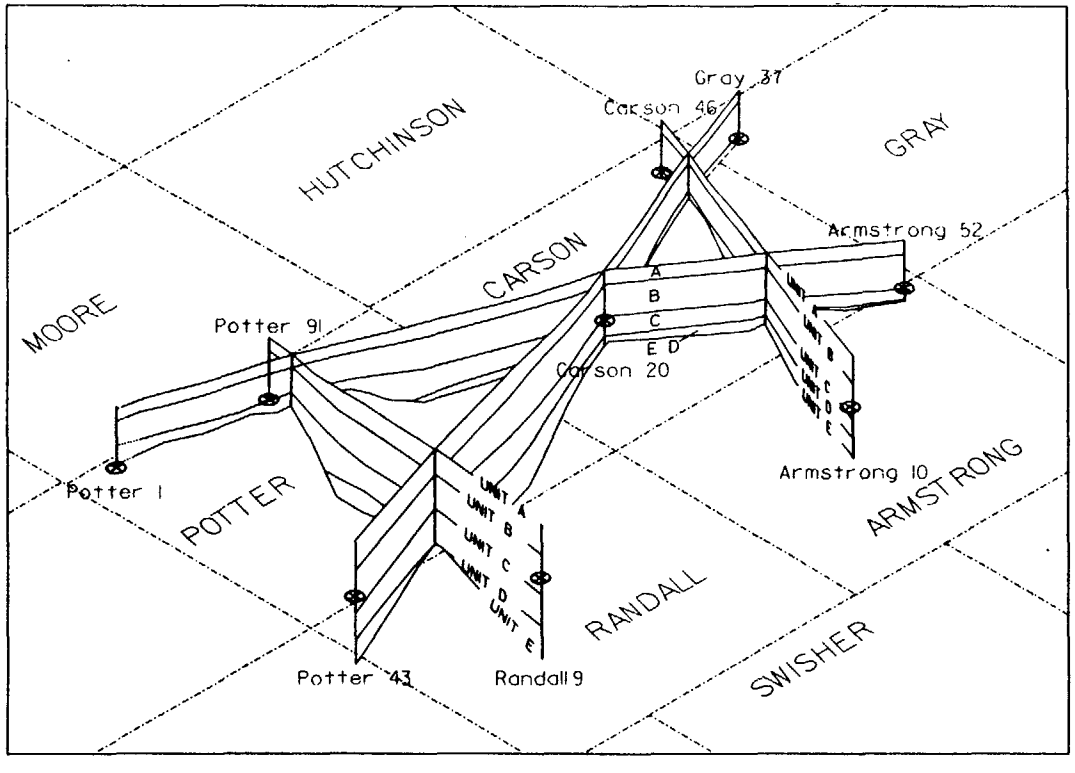
Pennsylvanian

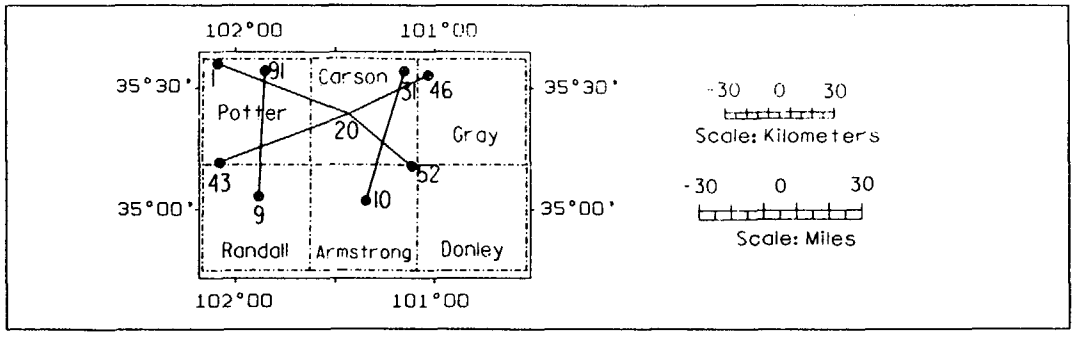
Precambrian



PRELIMINARY
FOR COMMENTS ONLY

Block Diagram





EXPLANATION

UNIT A: Albates - San Andres

UNIT B: Glorieta - Wichita

UNIT C: Wolfcamp

UNIT D: Pennsylvanian

UNIT E: Precambrian

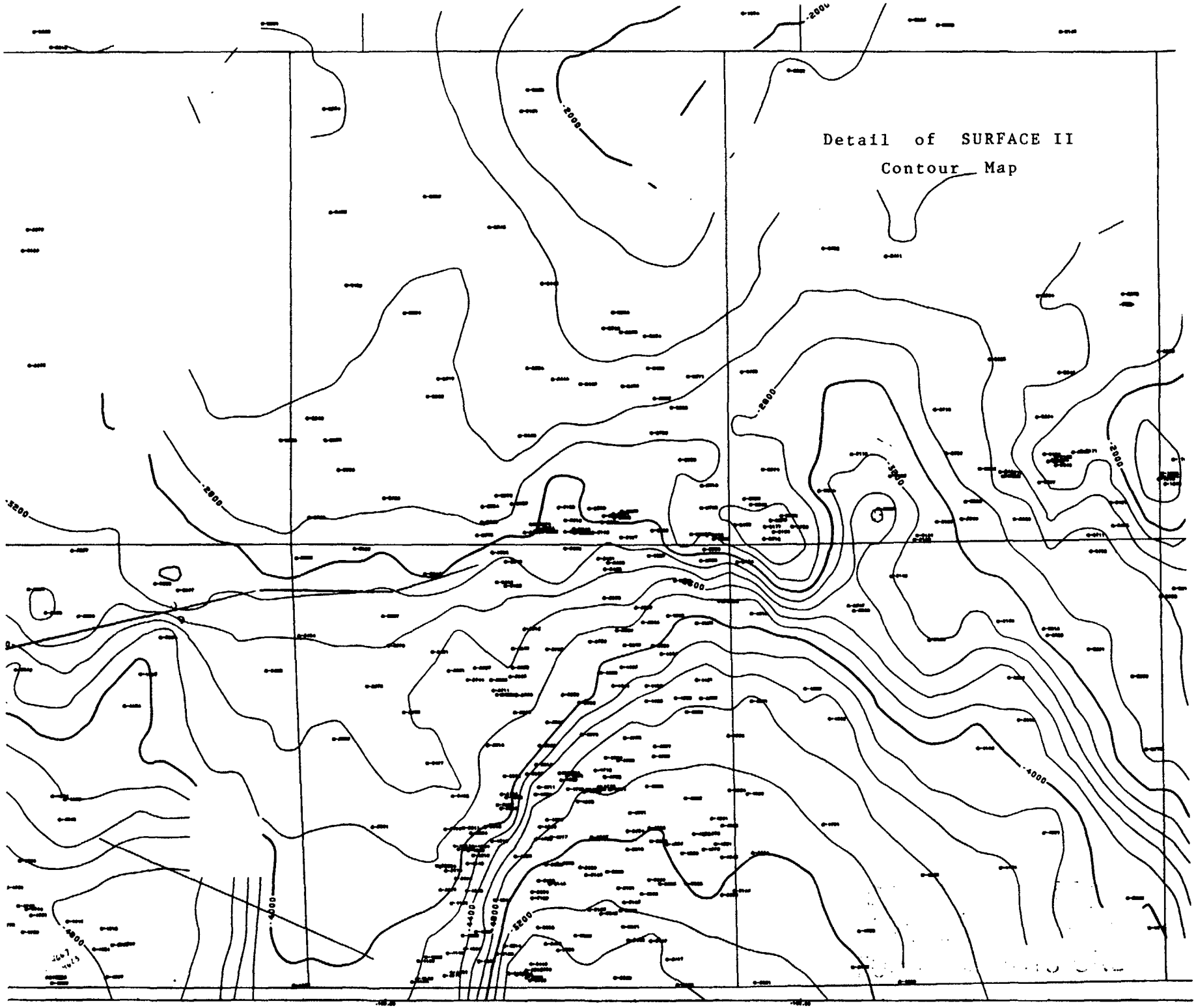
⊕ Well Symbol

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

PRELIMINARY

FOR COMMENTS ONLY

Fence Diagram


Detail of SURFACE II
Contour Map
-2000
-2200
-2400
-2600
-2800
-3000
-3200
-3400
-3600
-3800
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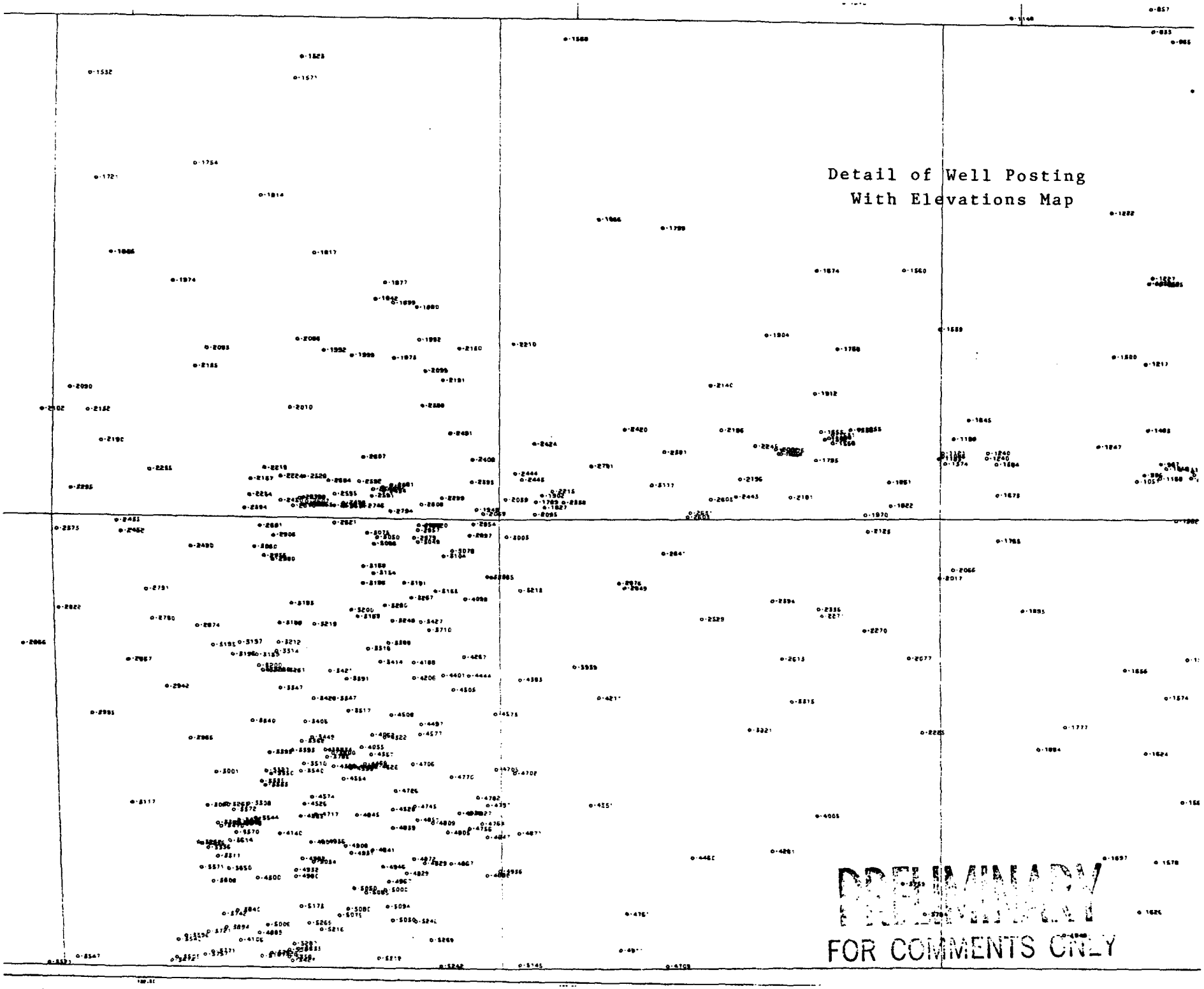
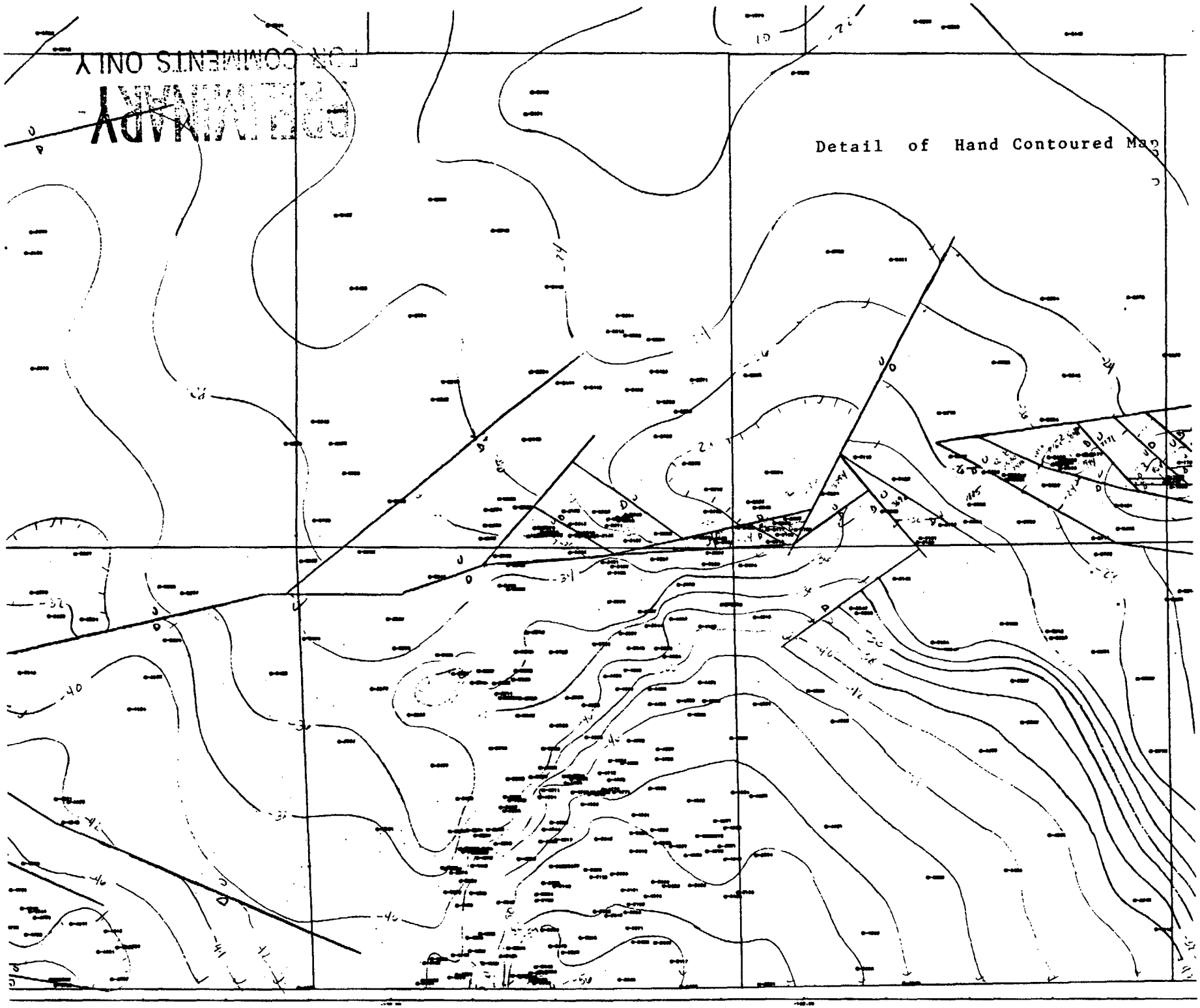
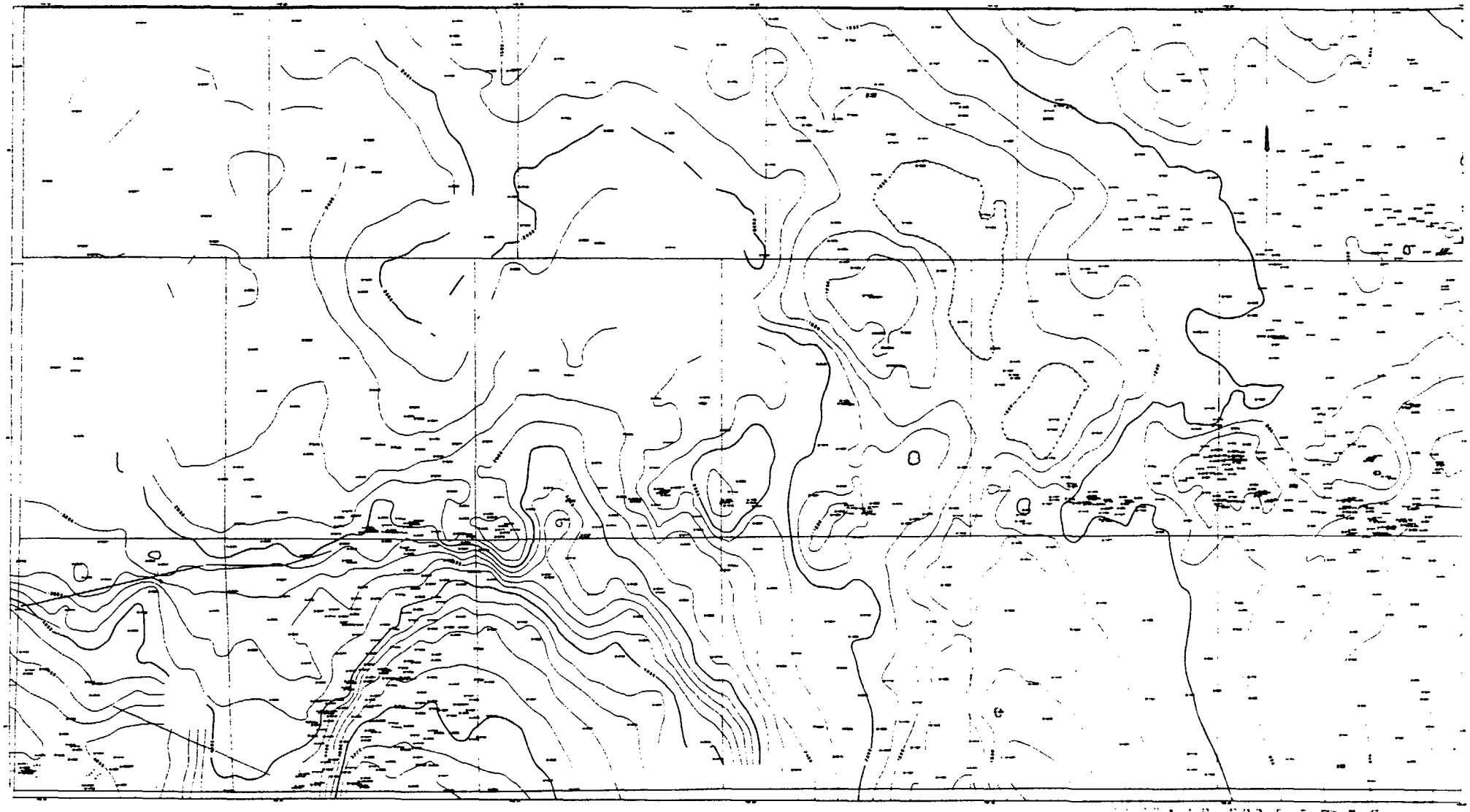
-4200
-4400
-4600
-4800


Detail of Well Posting
With Elevations Map
PRELIMINARY
FOR COMMENTS ONLY

PRELIMINARY
FOR COMMENTS ONLY

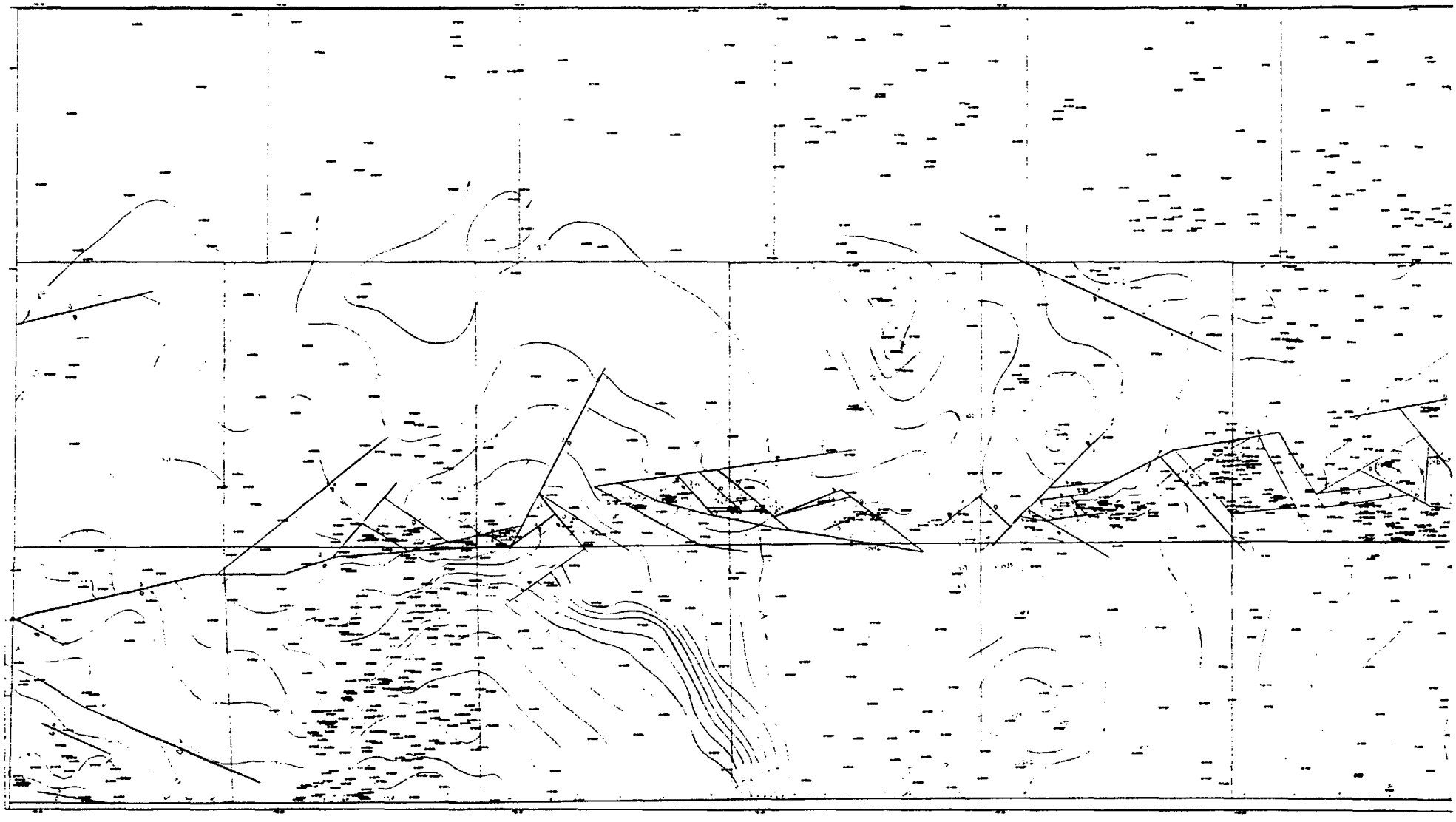
Detail of Hand Contoured Map





SURFACE II Contour Map

PRELIMINARY
FOR COMMENTS ONLY

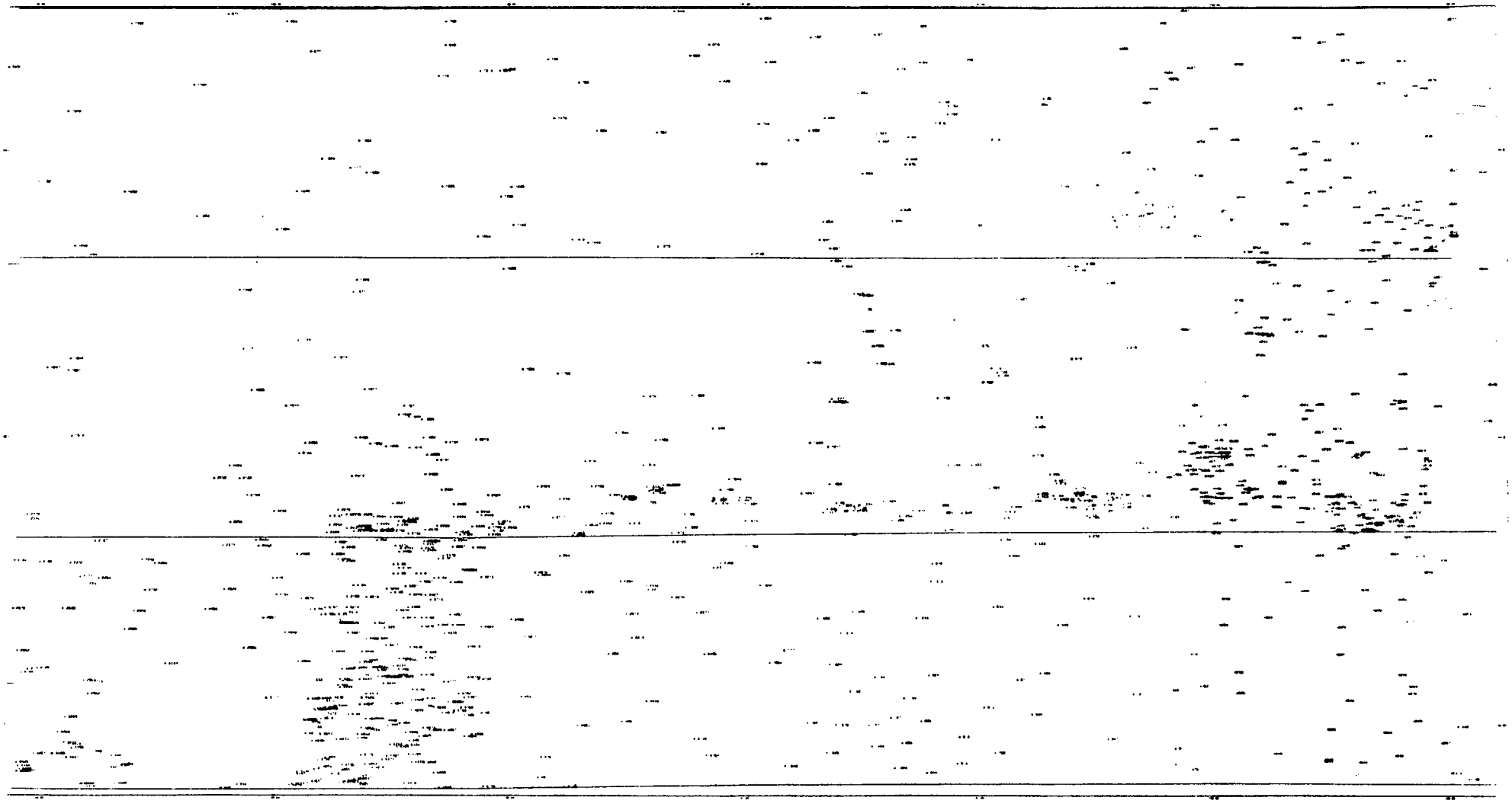


Hand Drawn Contour Map

Based on SURFACE II Map

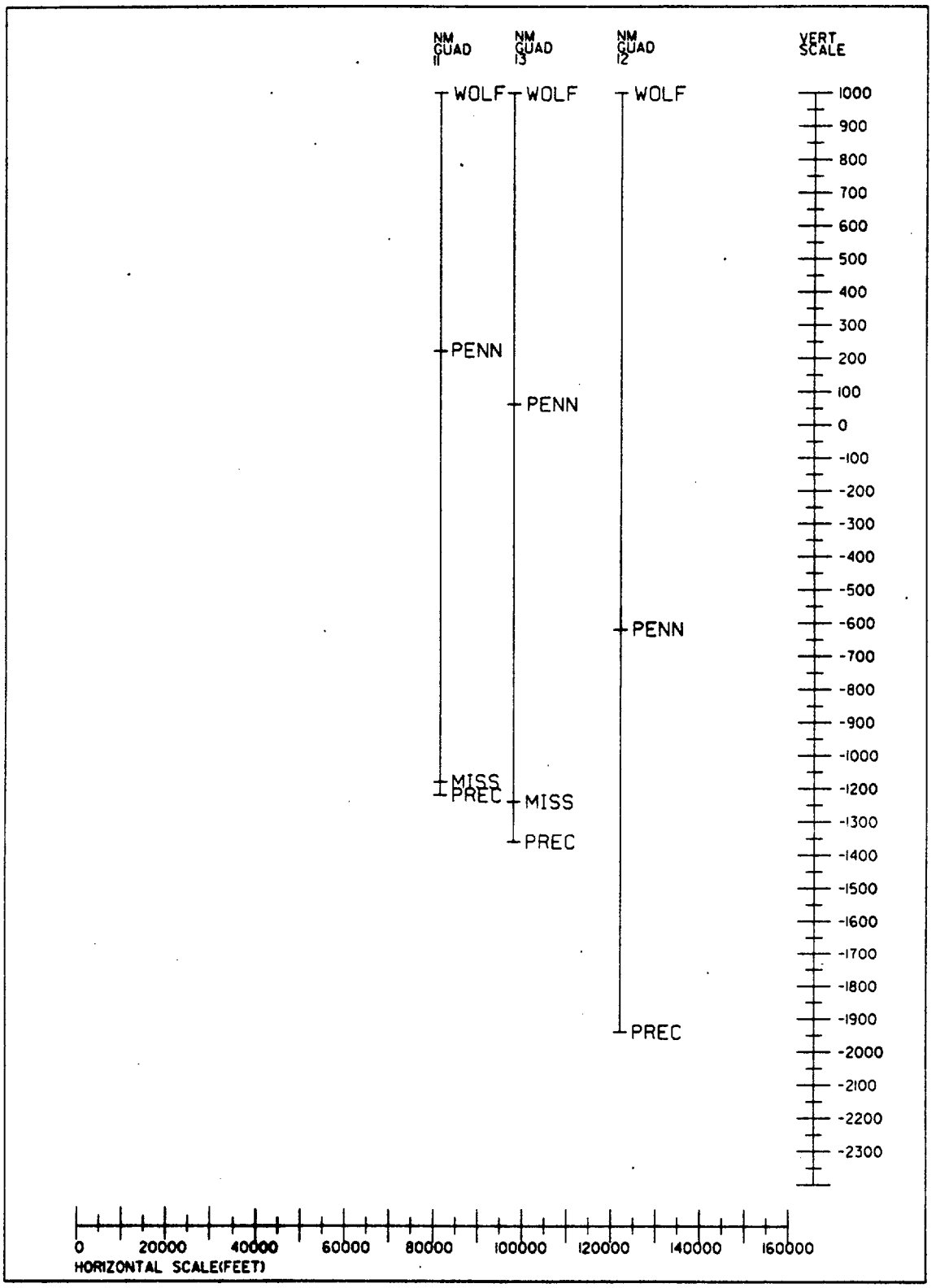
PRELIMINARY

FOR COMMENTS ONLY



Well Posting Map with Z Values

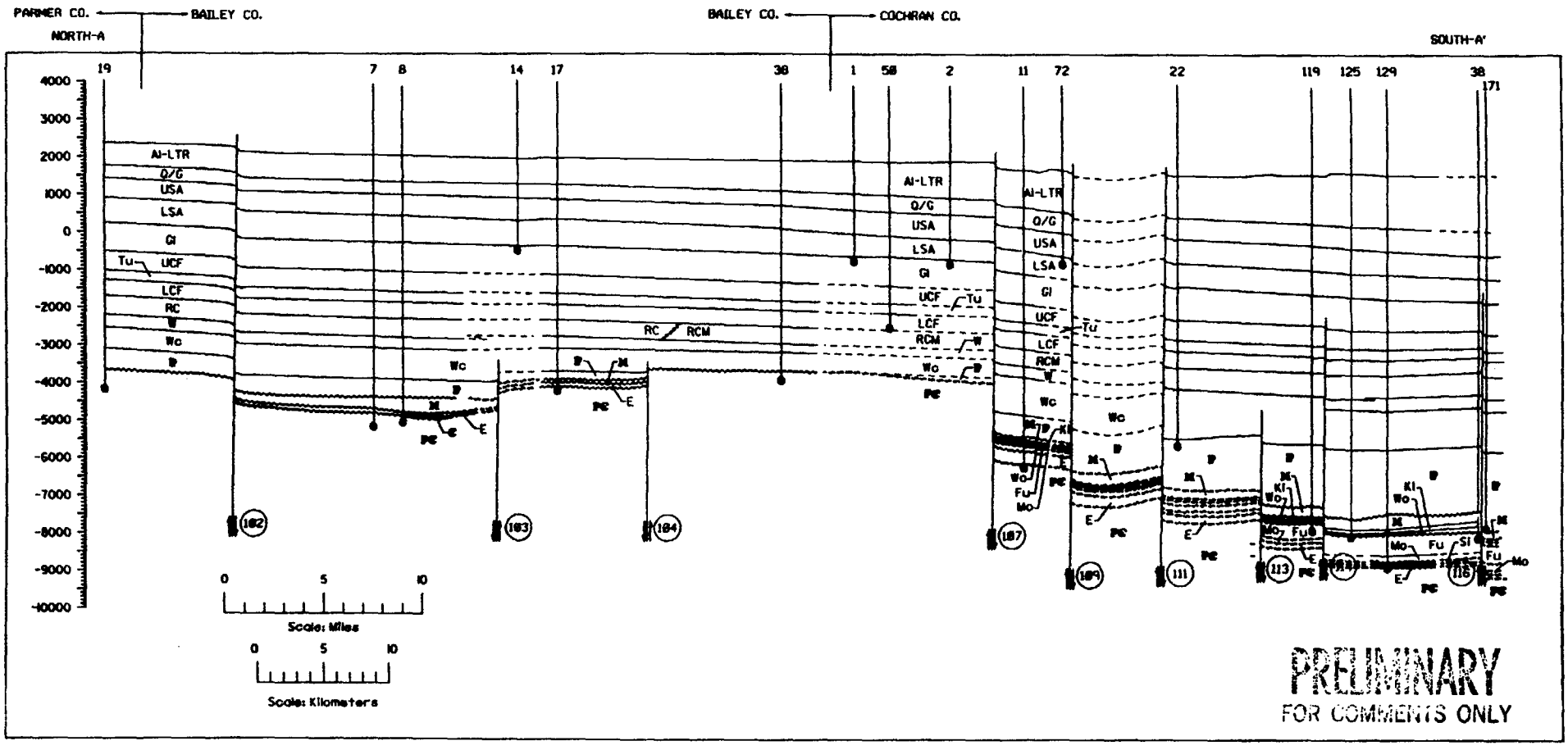
ONLY



PRELIMINARY

FOR COMMENTS ONLY

Example of WELLMAP Cross Section


PARMER CO.
BAILEY CO.
NORTH-A
BAILEY CO.
COCHRAN CO.
SOUTH-A'
4000
3000
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-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
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38
1
58
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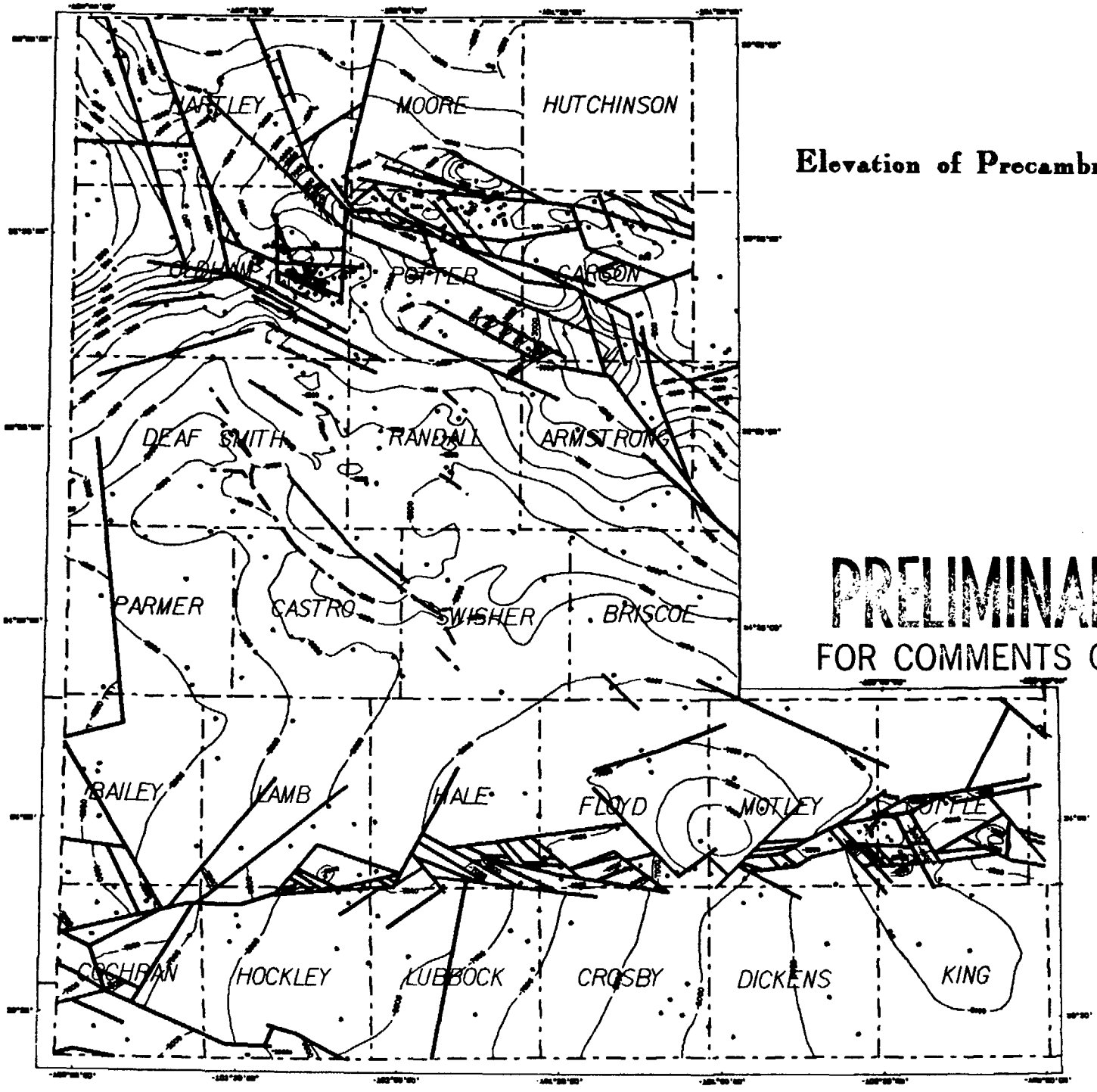
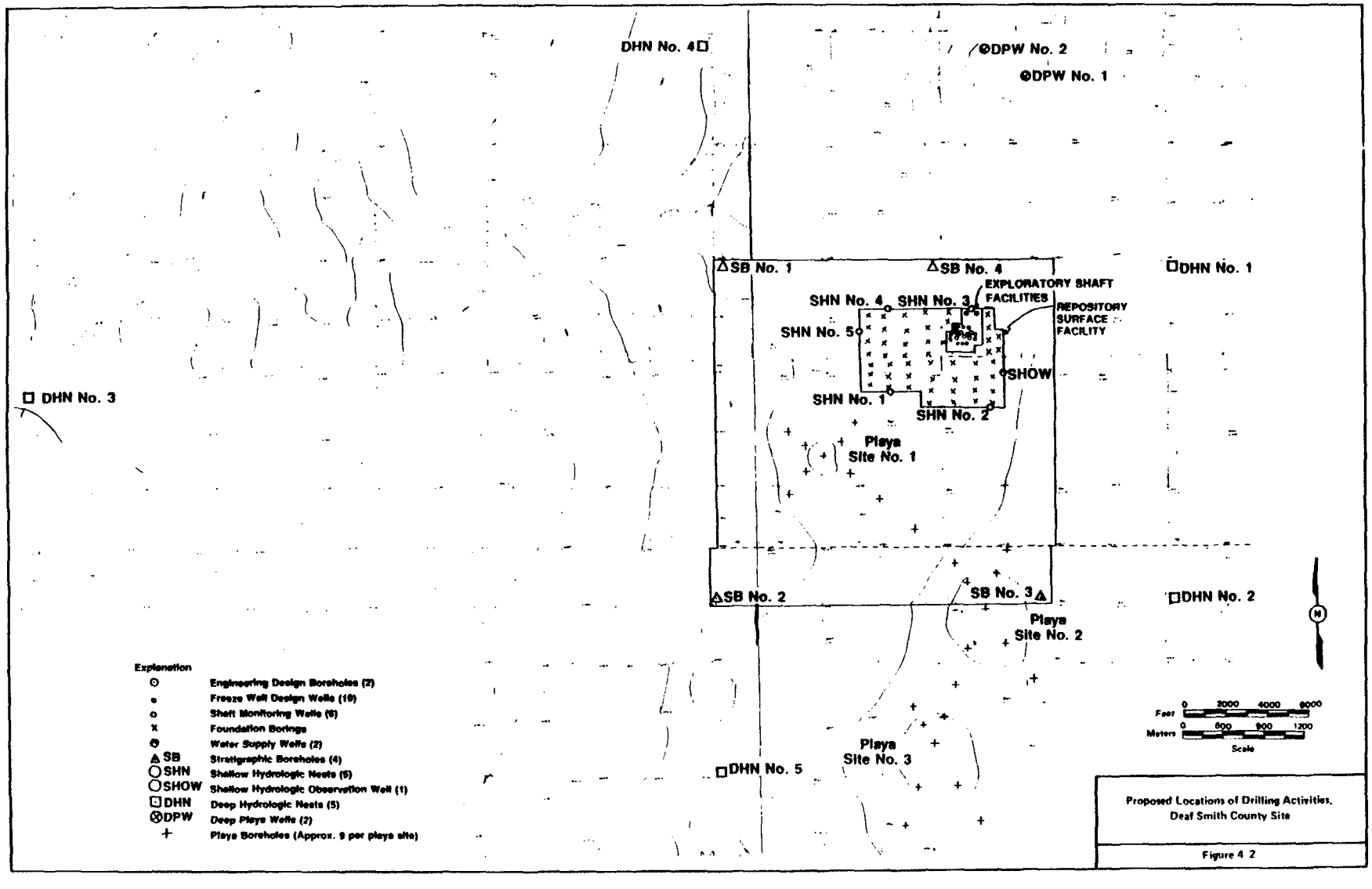


Elevation of Precambrian

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

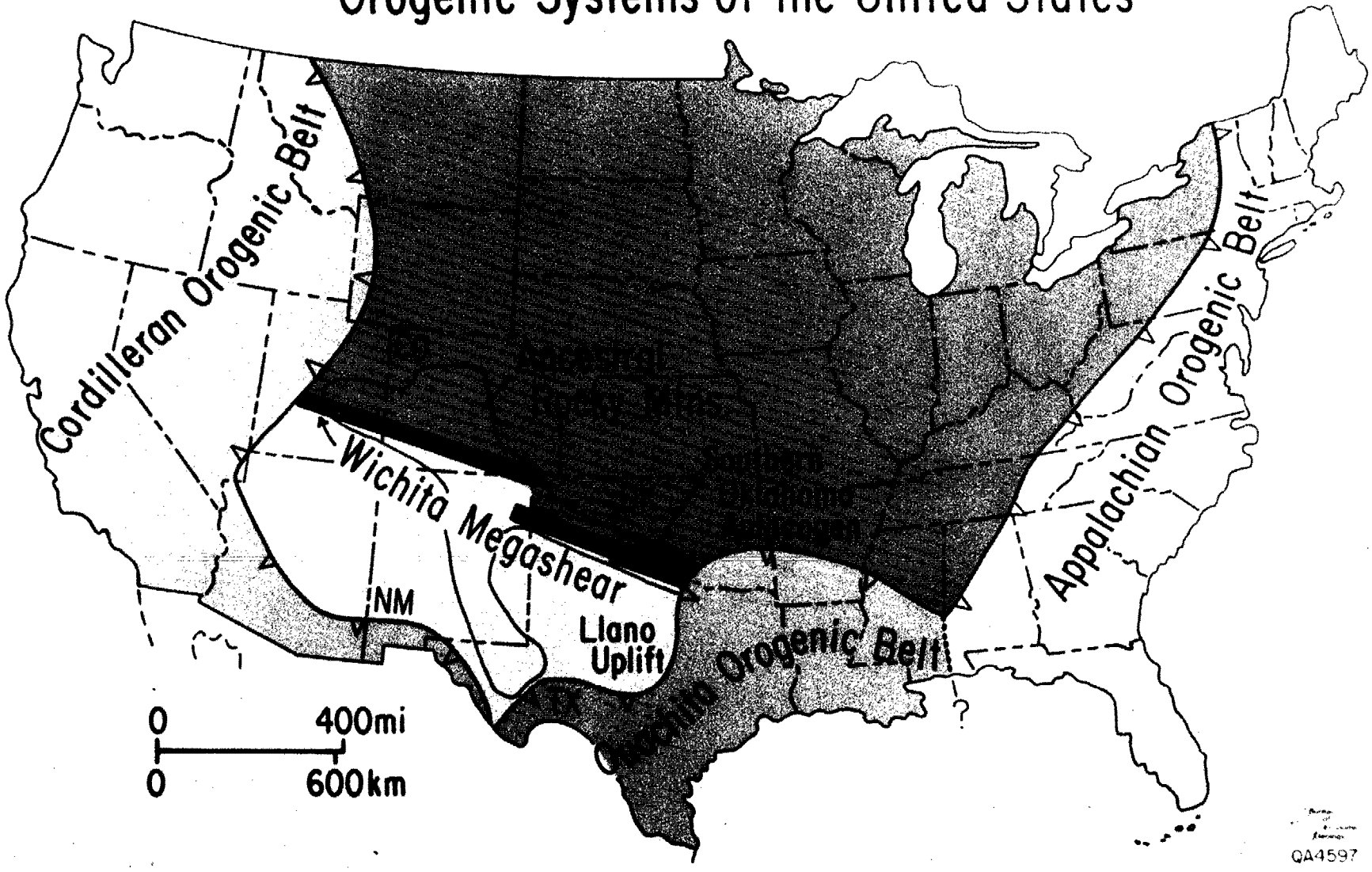
Seismic Reflection Survey Data
Reviewed by NRC

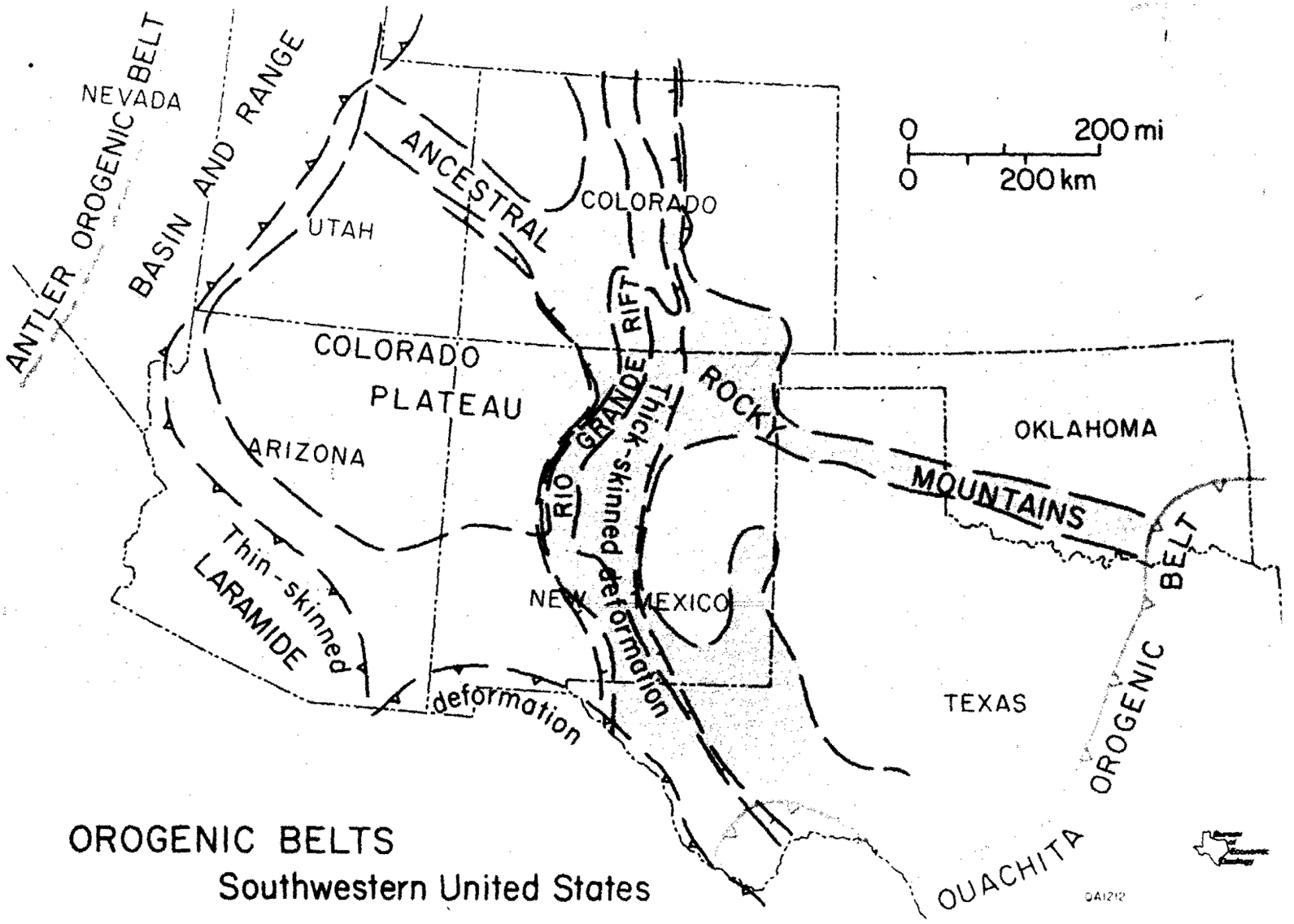
Seismic survey data of a proprietary nature were reviewed by the NRC staff and contractors. These consisted of the following lines designated on SWEC drawing "Sketch No. 13697-44-A-1":

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

0240C

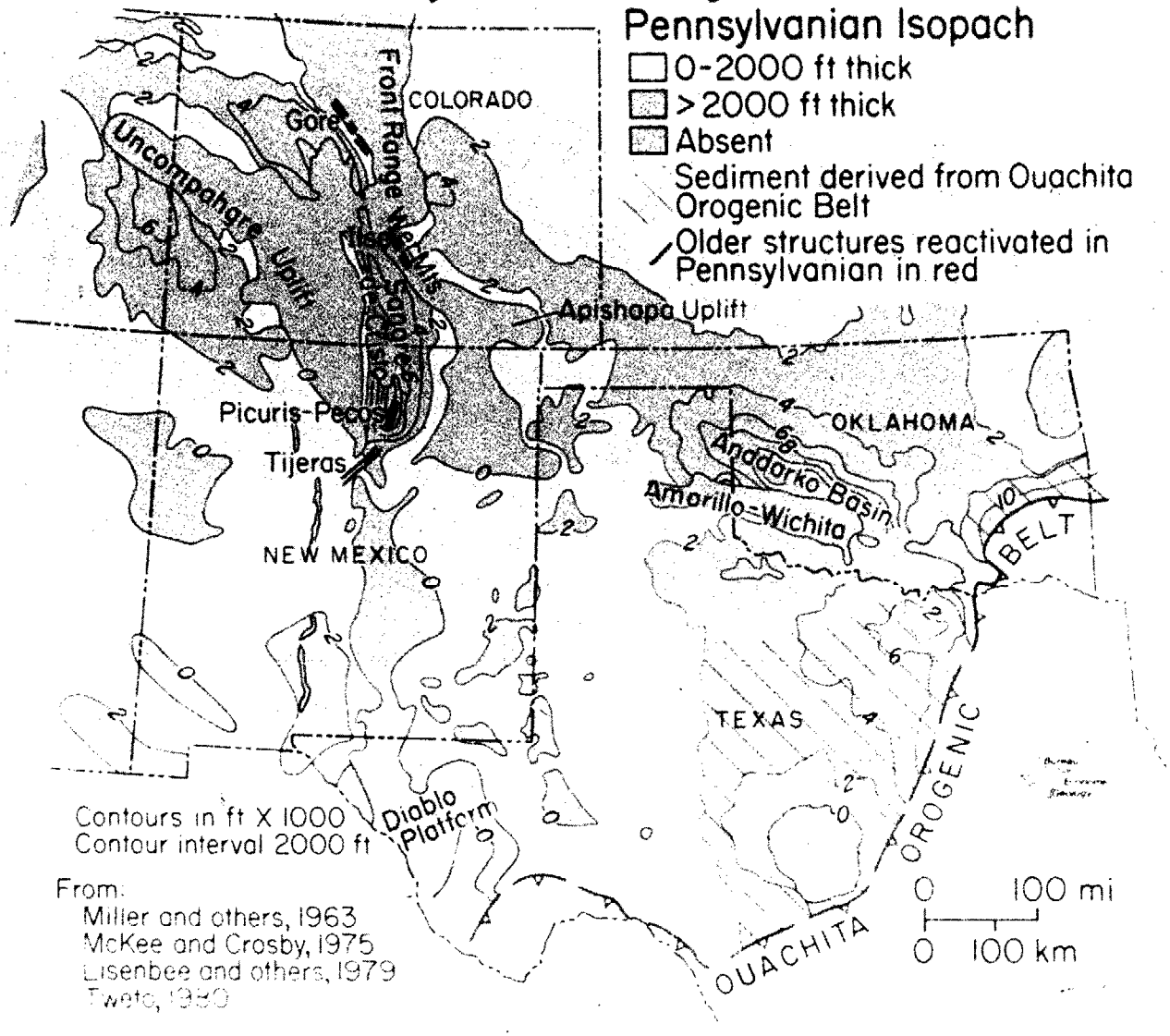
Orogenic Systems of the United States



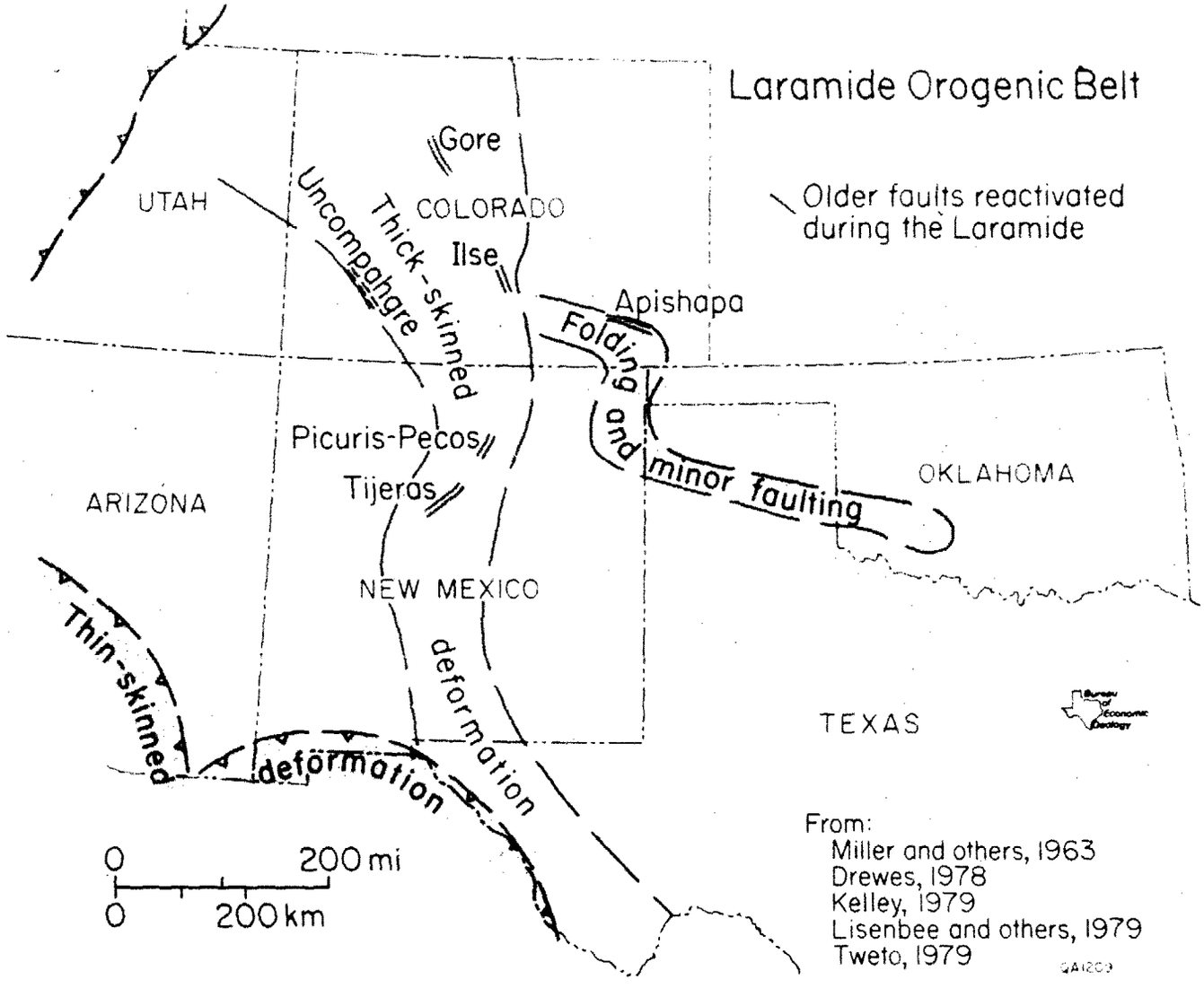


OROGENIC BELTS
Southwestern United States

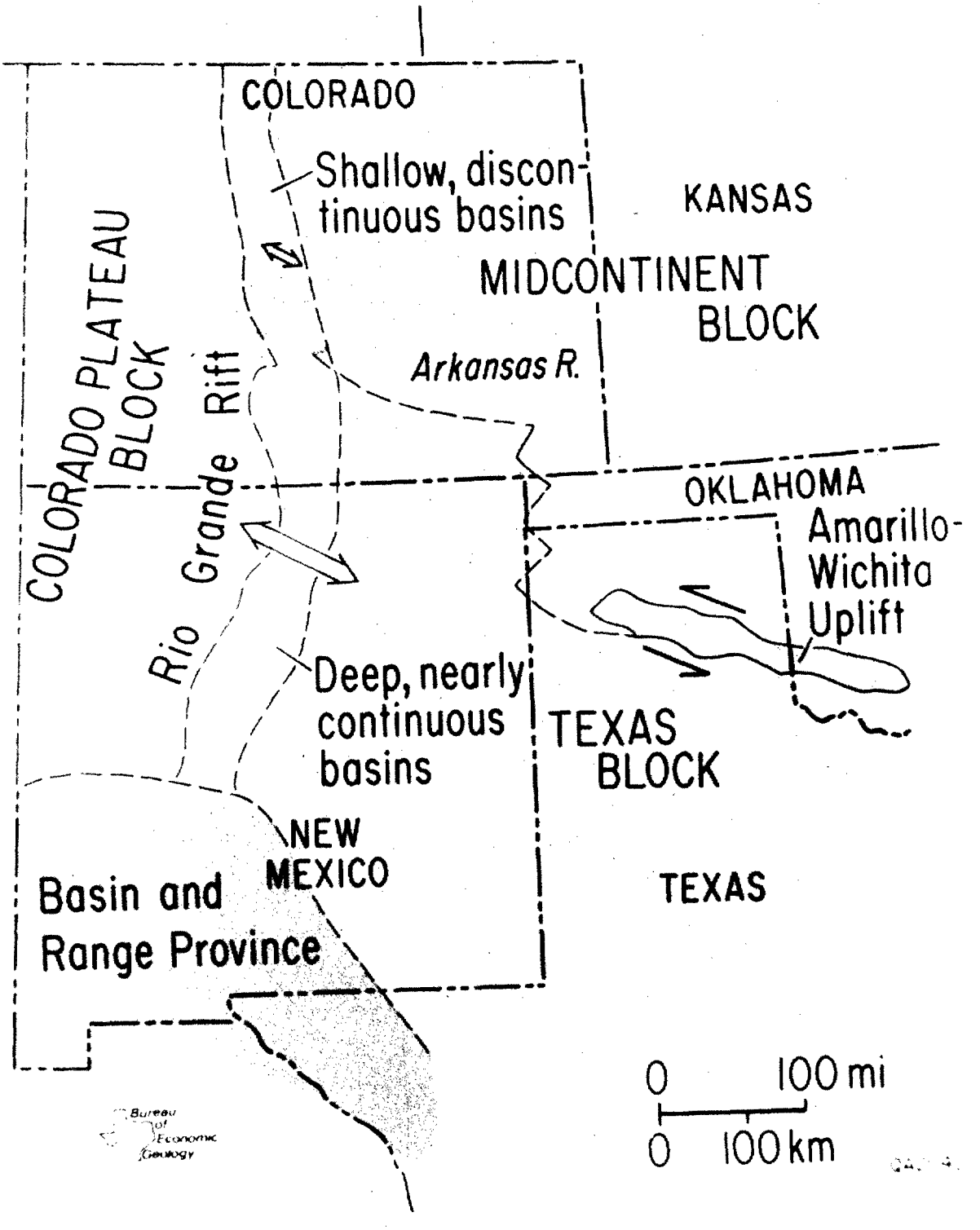
Ancestral Rocky Mountain Orogenic Belt / Pennsylvanian Isopach

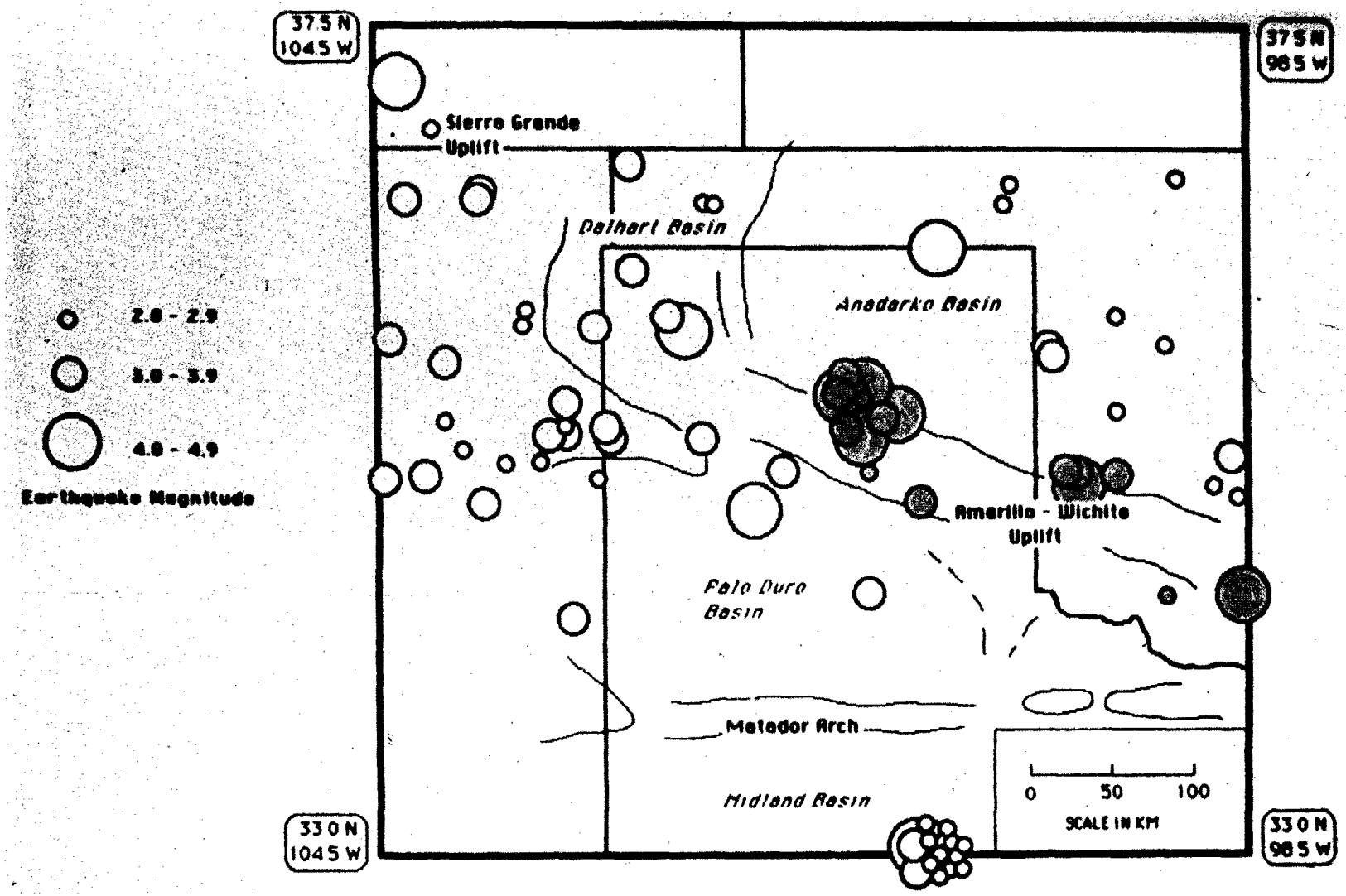


From:
Miller and others, 1963
McKee and Crosby, 1975
Lisenbee and others, 1979
Tweto, 1980

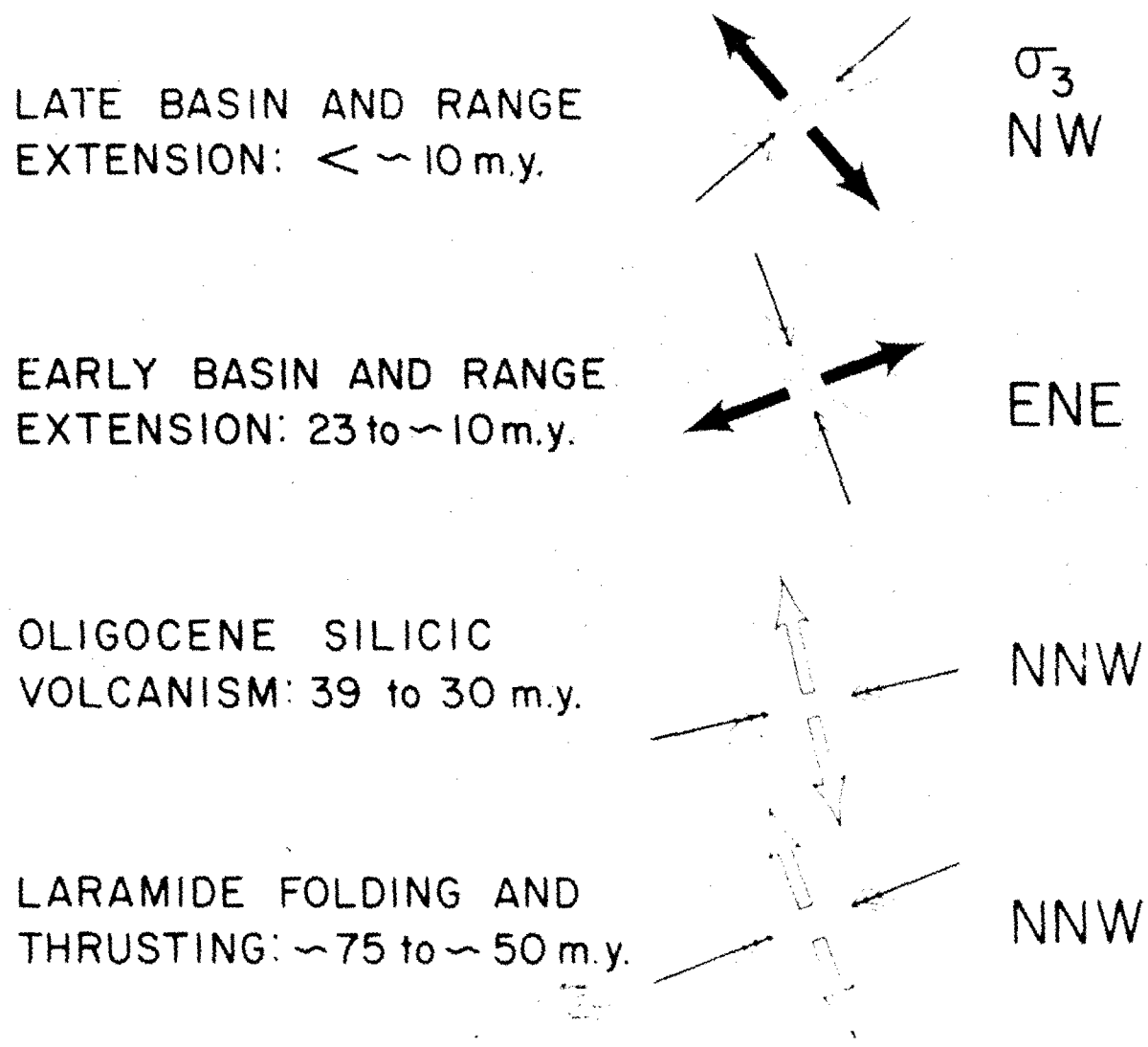

Laramide Orogenic Belt
Older faults reactivated during the Laramide
UTAH
COLORADO
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
Gore
Ilse
Apishapa
Picuris-Pecos
Tijeras
Uncompahgre
Thick-skinned
Folding and minor faulting
Thin-skinned deformation
deformation
0 200 mi
0 200 km
From:
Miller and others, 1963
Drewes,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

NEOGENE TECTONIC SETTING

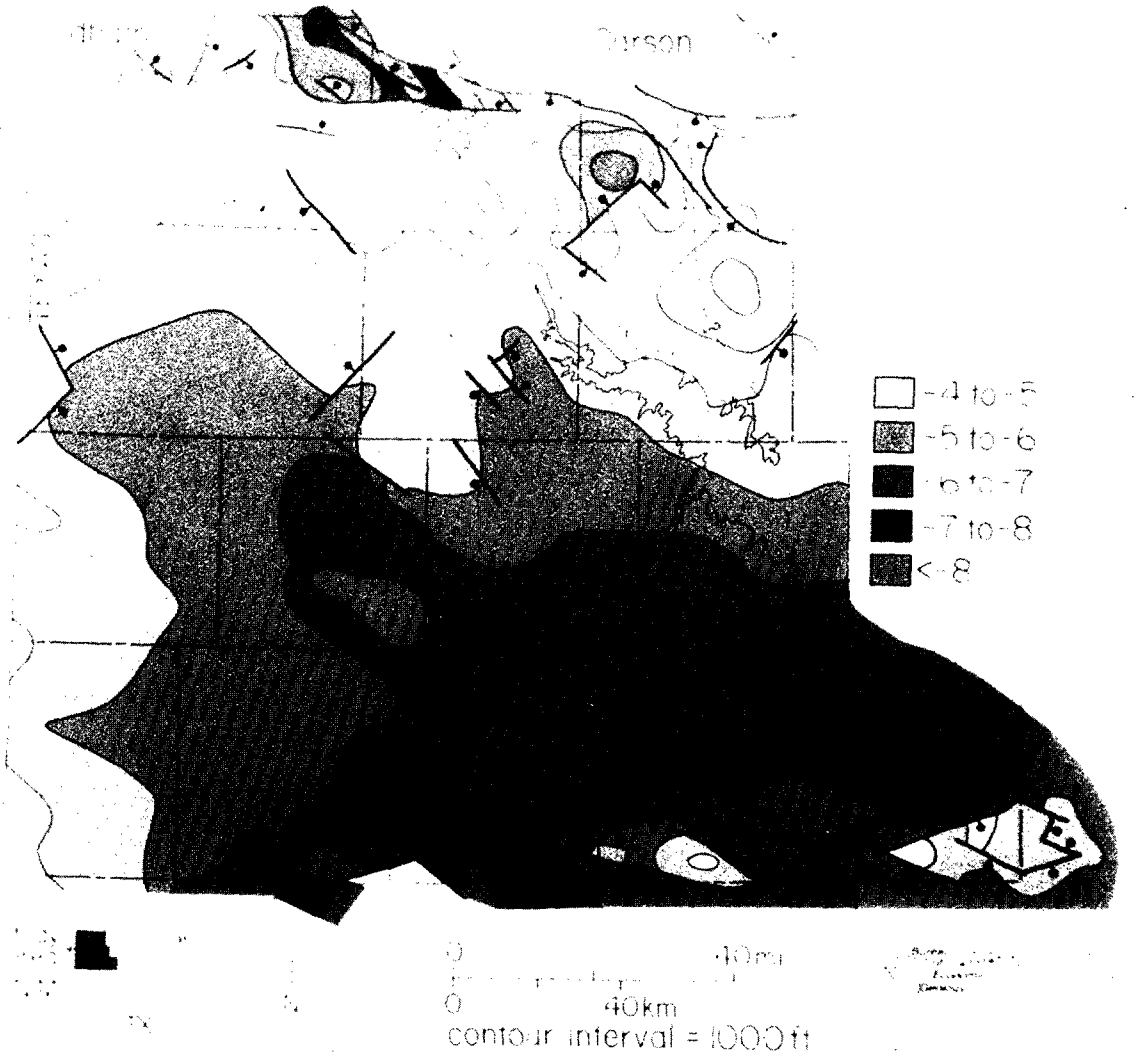



37.5 N
104.5 W
37.5 N
98.5 W
Sierra Grande
Uplift
Dalhart Basin
Anadarko Basin
Amarillo - Wichita
Uplift
Palo Duro
Basin
Matador Arch
Midland Basin
0
50
100
SCALE IN KM
33.0 N
104.5 W
33.0 N
98.5 W
2.0 - 2.9
3.0 - 3.9
4.0 - 4.9
Earthquake Magnitude

SANGRE DE
CRISTO UPLIFT
SACRAMENTO UPLIFT
SIERRA GRANDE
ARCH
CO


LATE BASIN AND RANGE
EXTENSION: < ~ 10 m.y.
σ3
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

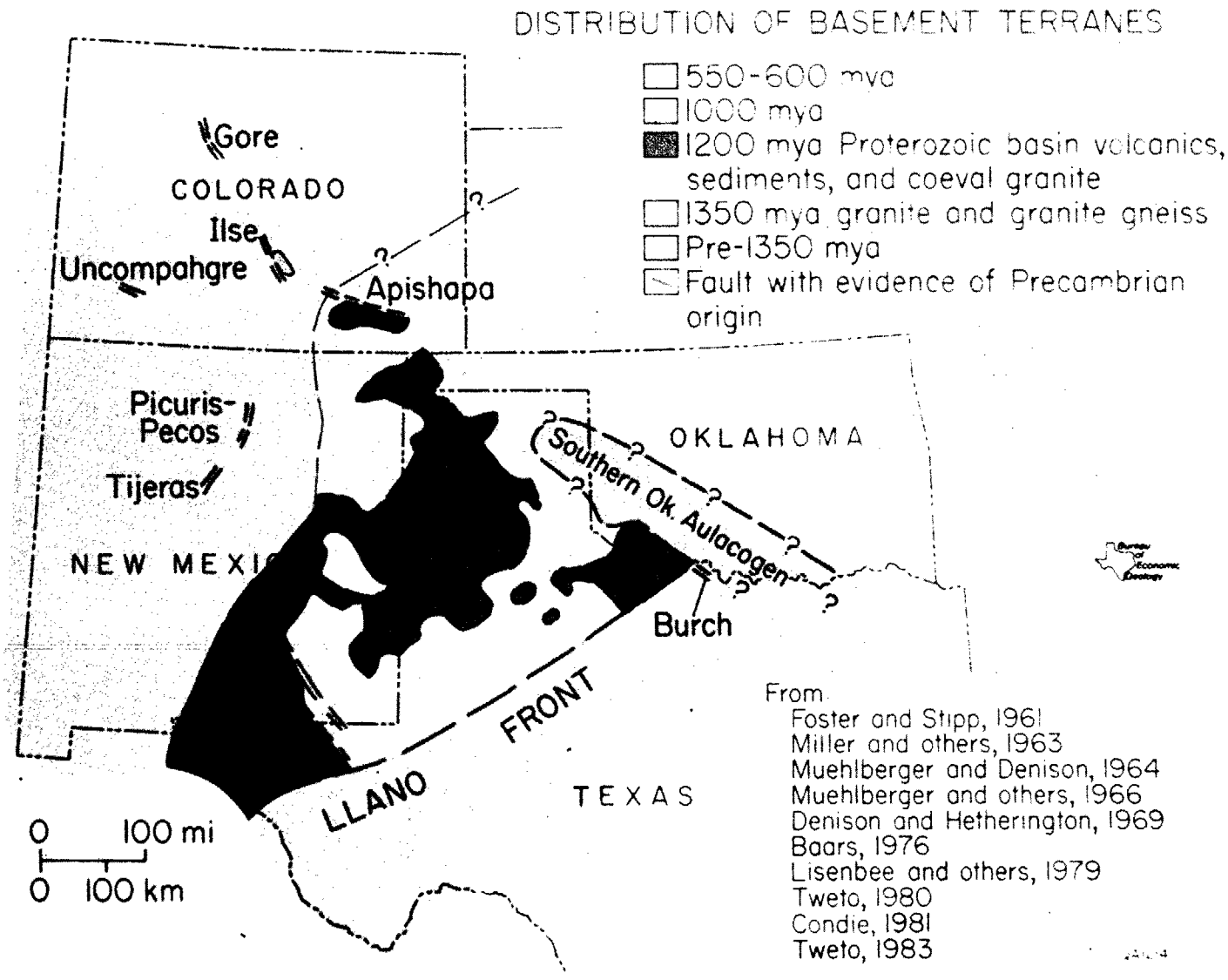
SIMPLIFIED BASEMENT STRUCTURE



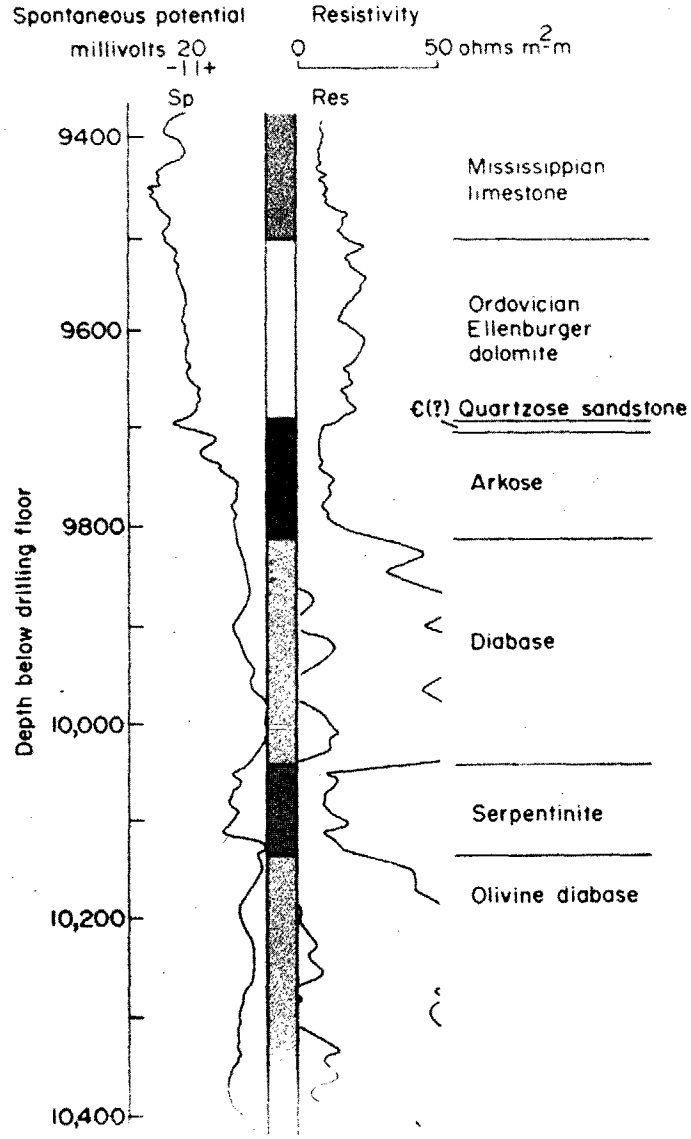
EXPLANATION (ft X 1000)

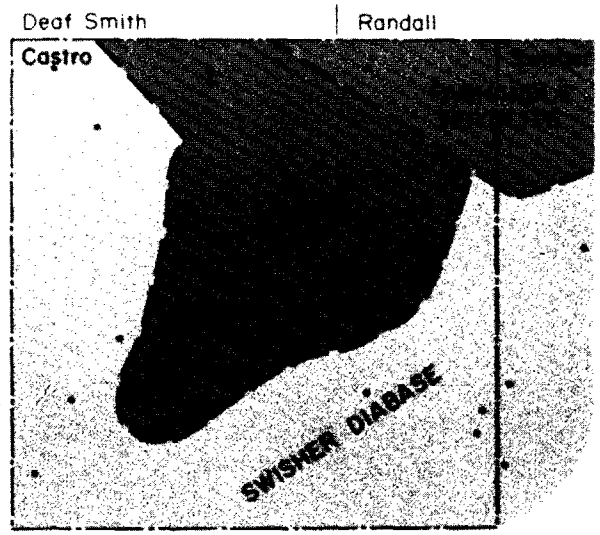
(from Budnik, 1984)

- >1
- 1 to 0
- 0 to -1
- -1 to -2
- -2 to -3
- -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 MEXICO
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





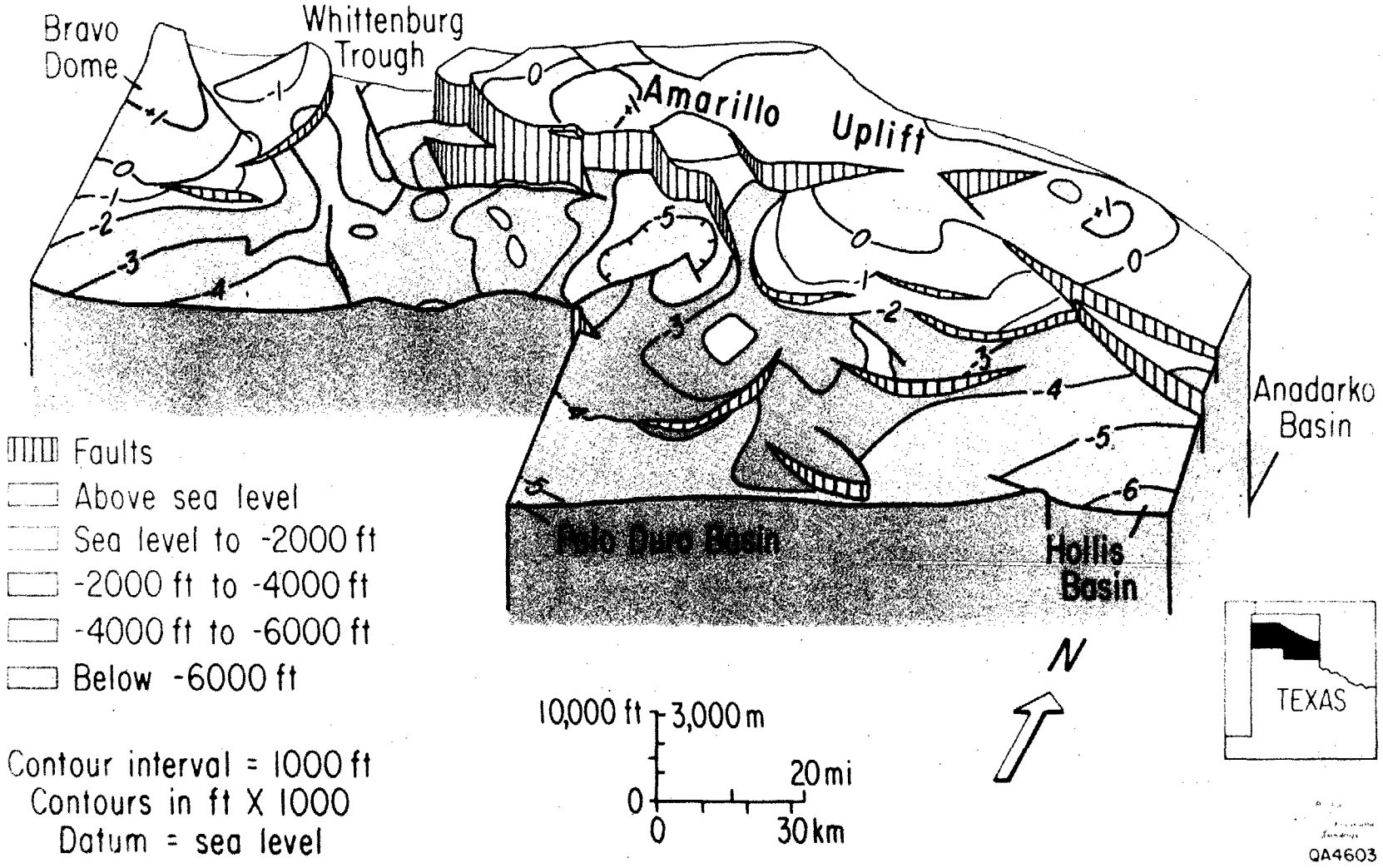
Distribution of pre-Ellenburger Group arkose in Castro Trough

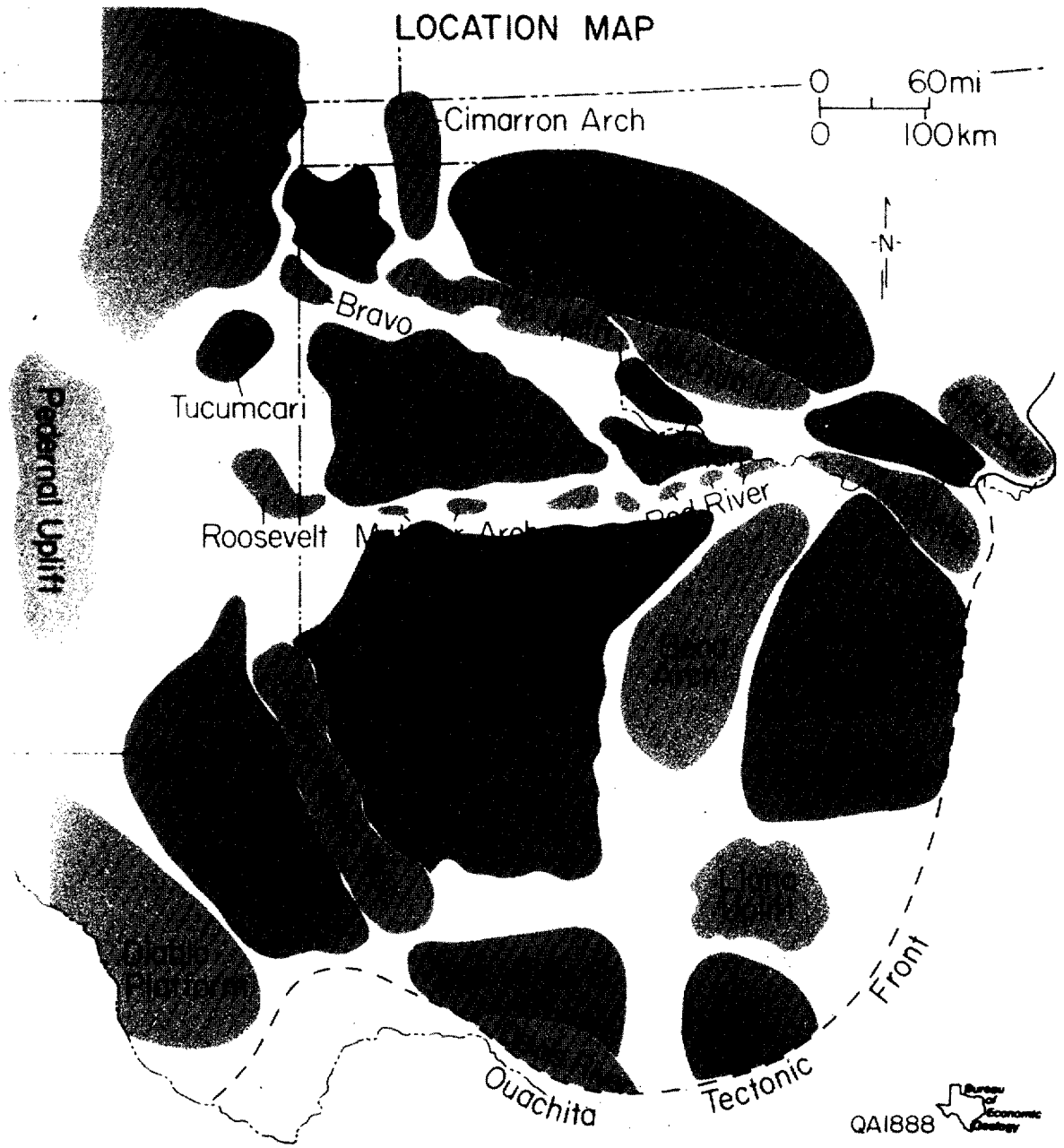
• Well control

⊙ Wells penetrating pre-Ellenburger arkose

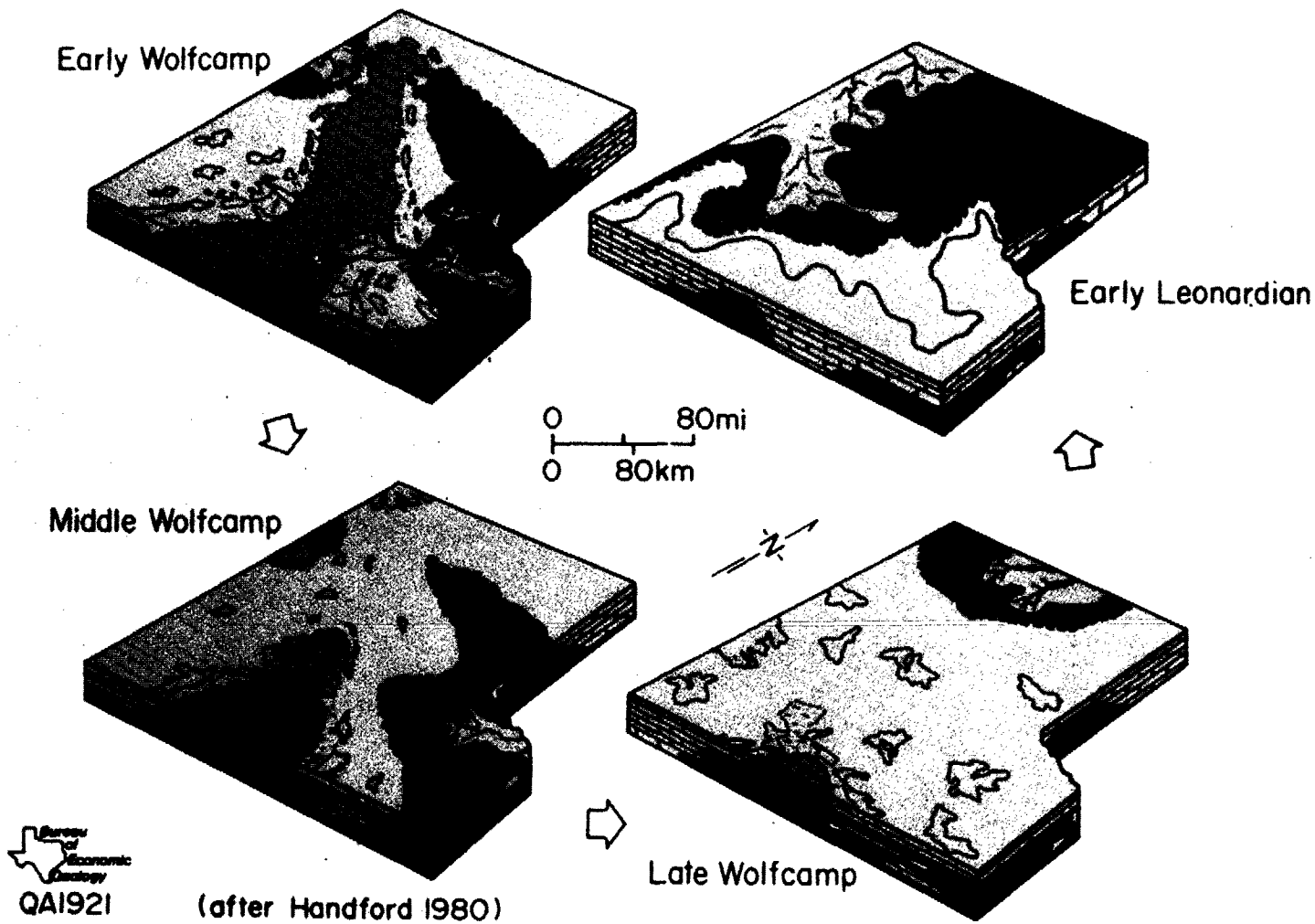
0 10 mi
0 10 km

Block diagram of basement surface of Amarillo Uplift



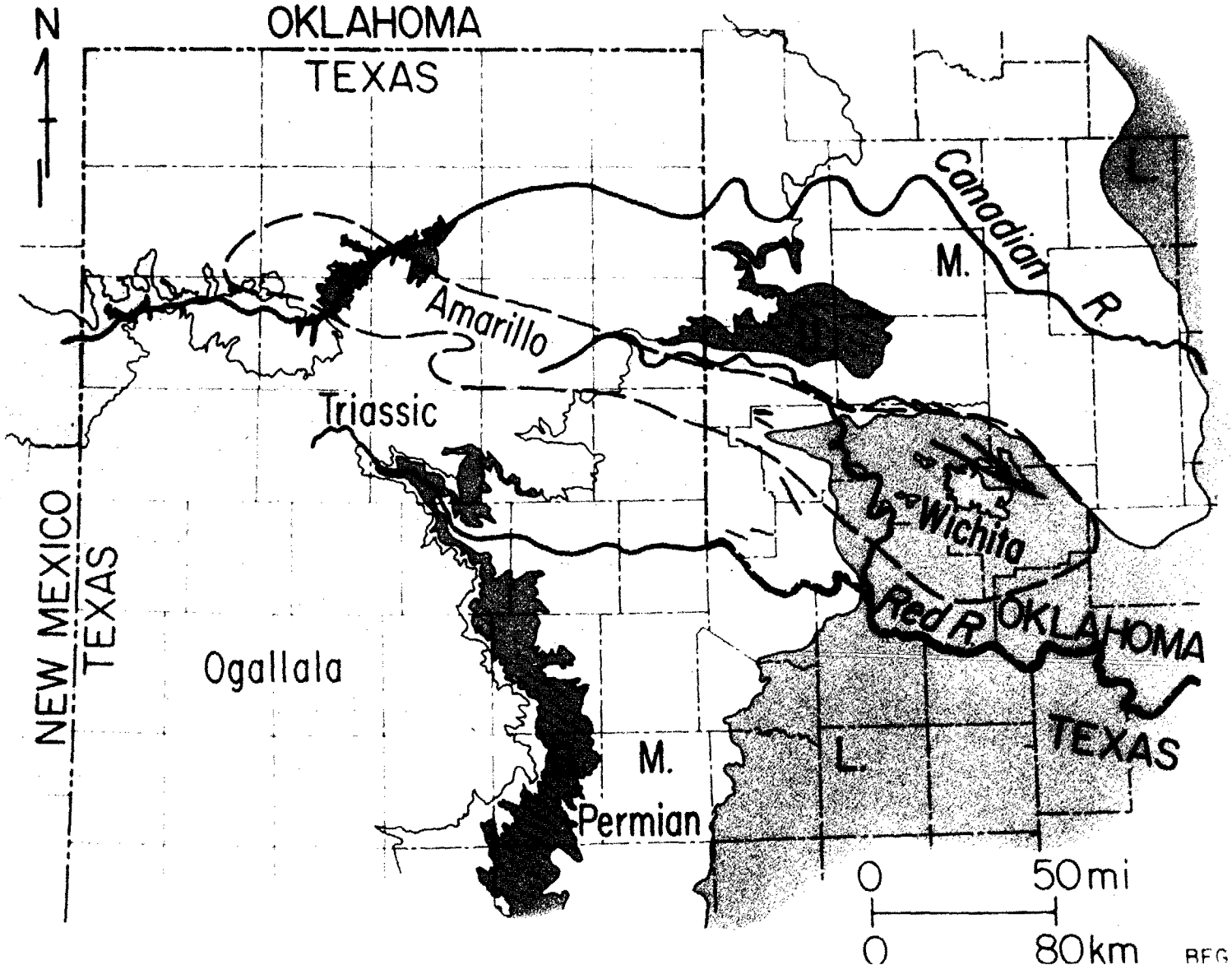

LOCATION MAP
0 60mi
0 100km
N
Cimarron Arch
Bravo
Tucumcari
Pedernal Uplift
Roosevelt
Red River
Ouachita
Tectonic
Front
QA1888

PALEOGEOGRAPHIC EVOLUTION OF PALO DURO BASIN

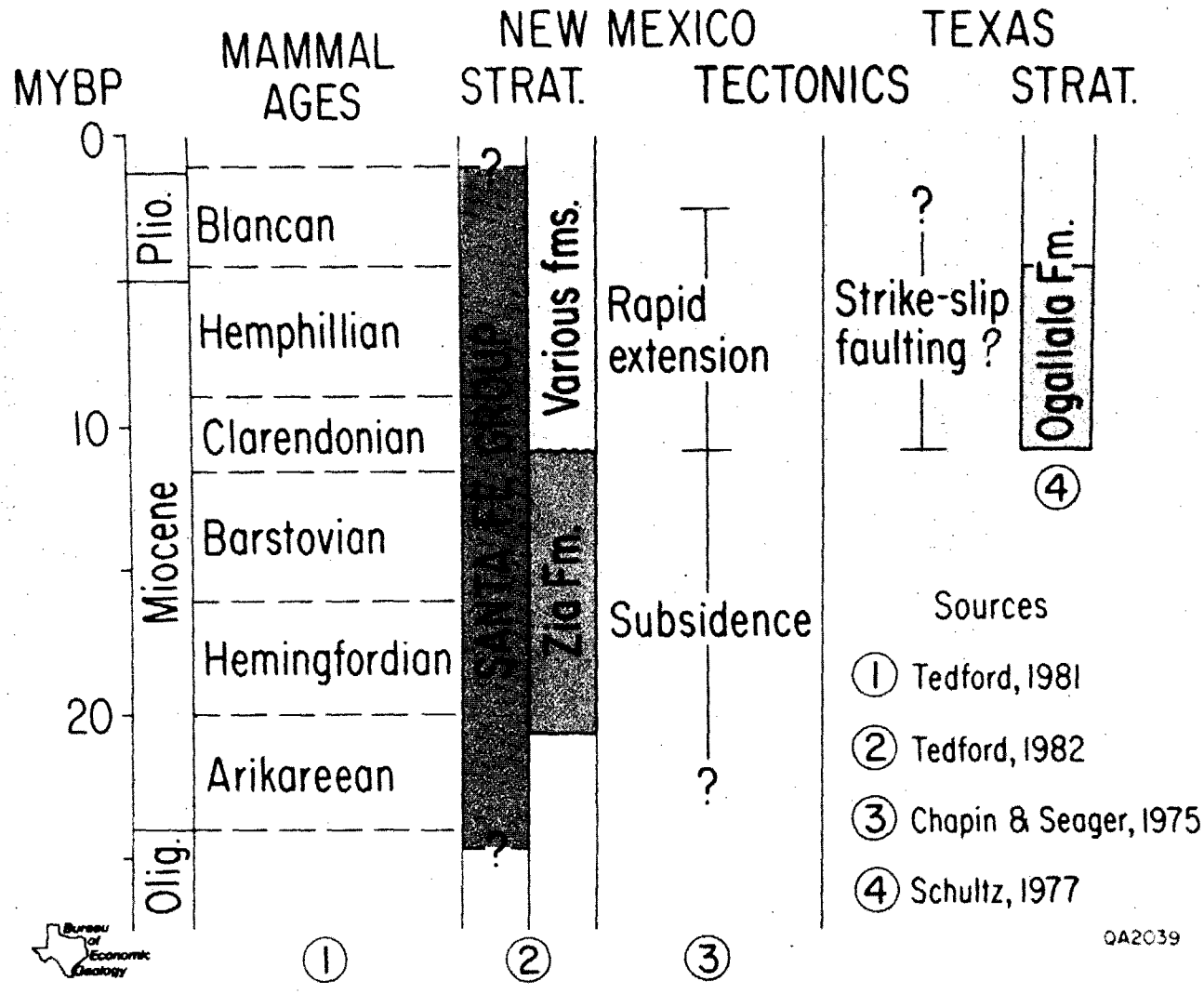


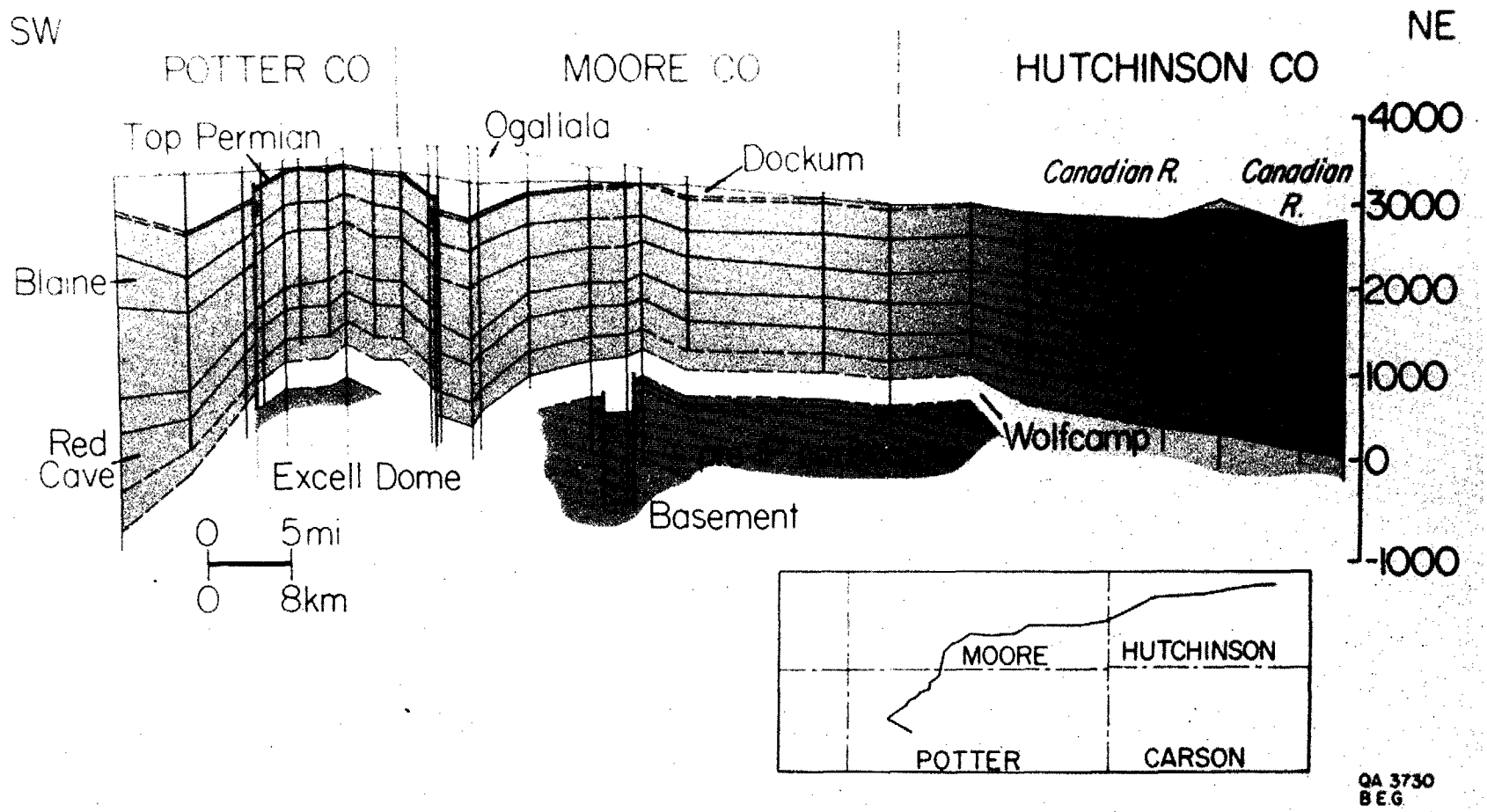
QA1921

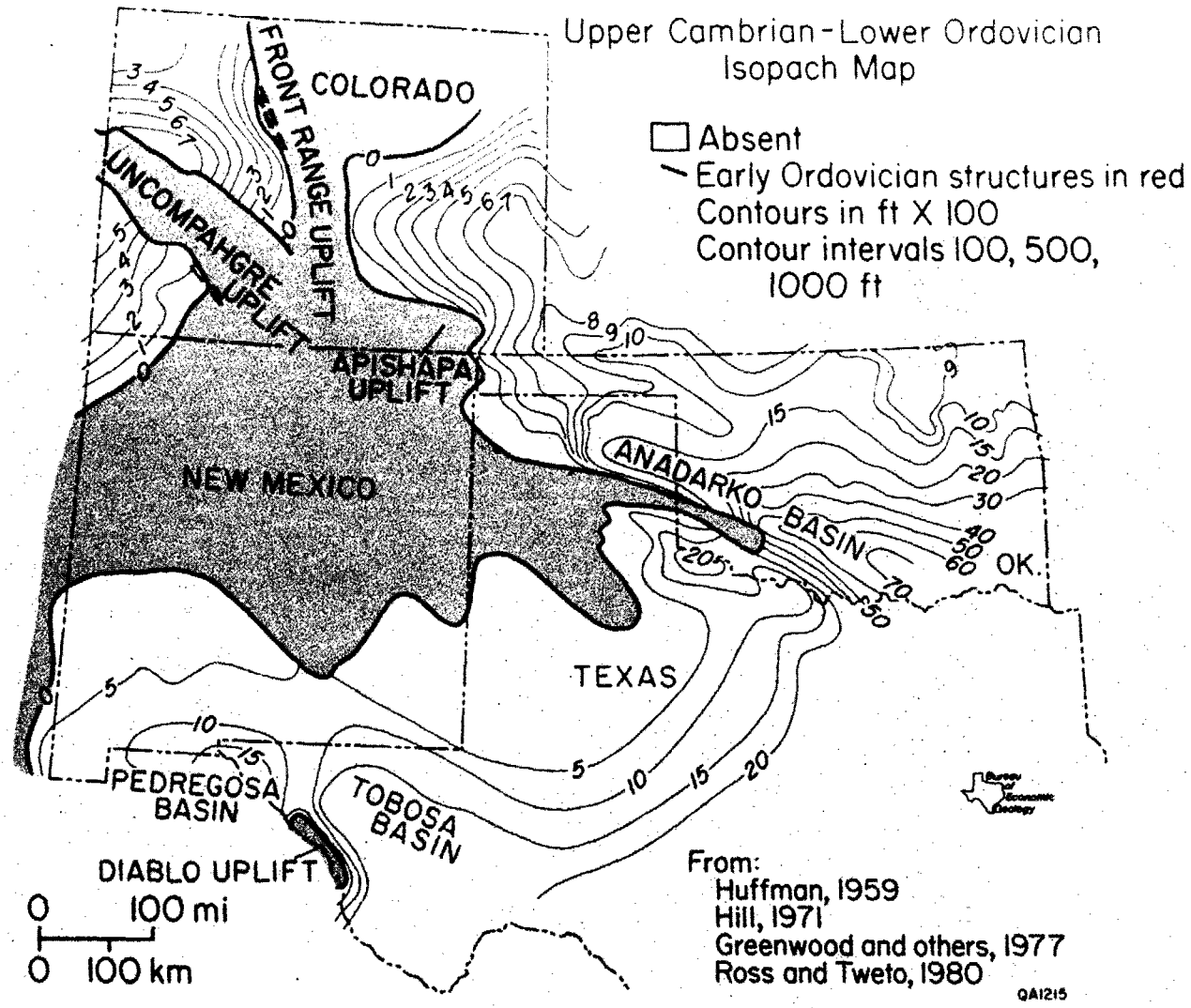
(after Handford 1980)


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

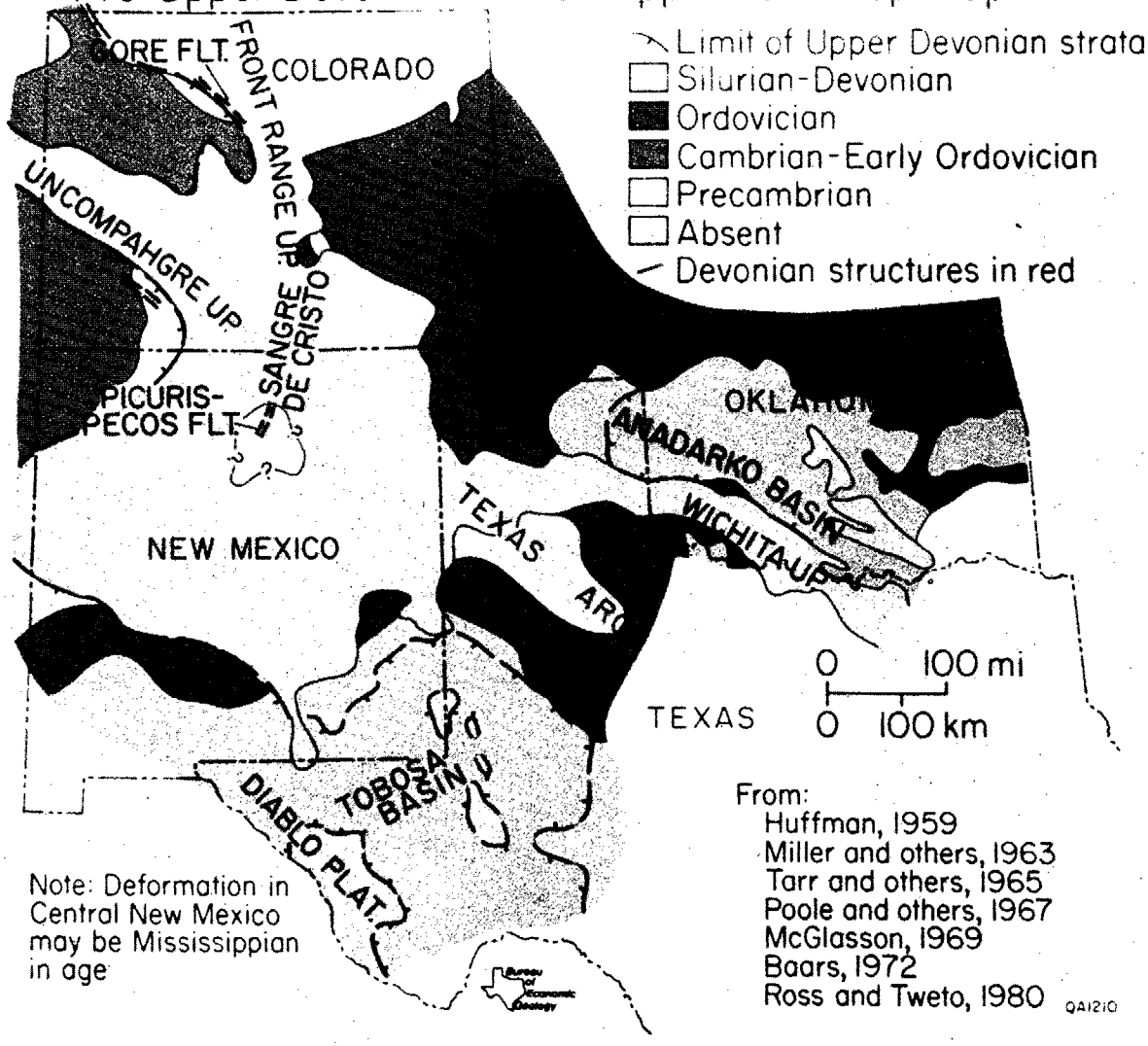
CORRELATION CHART



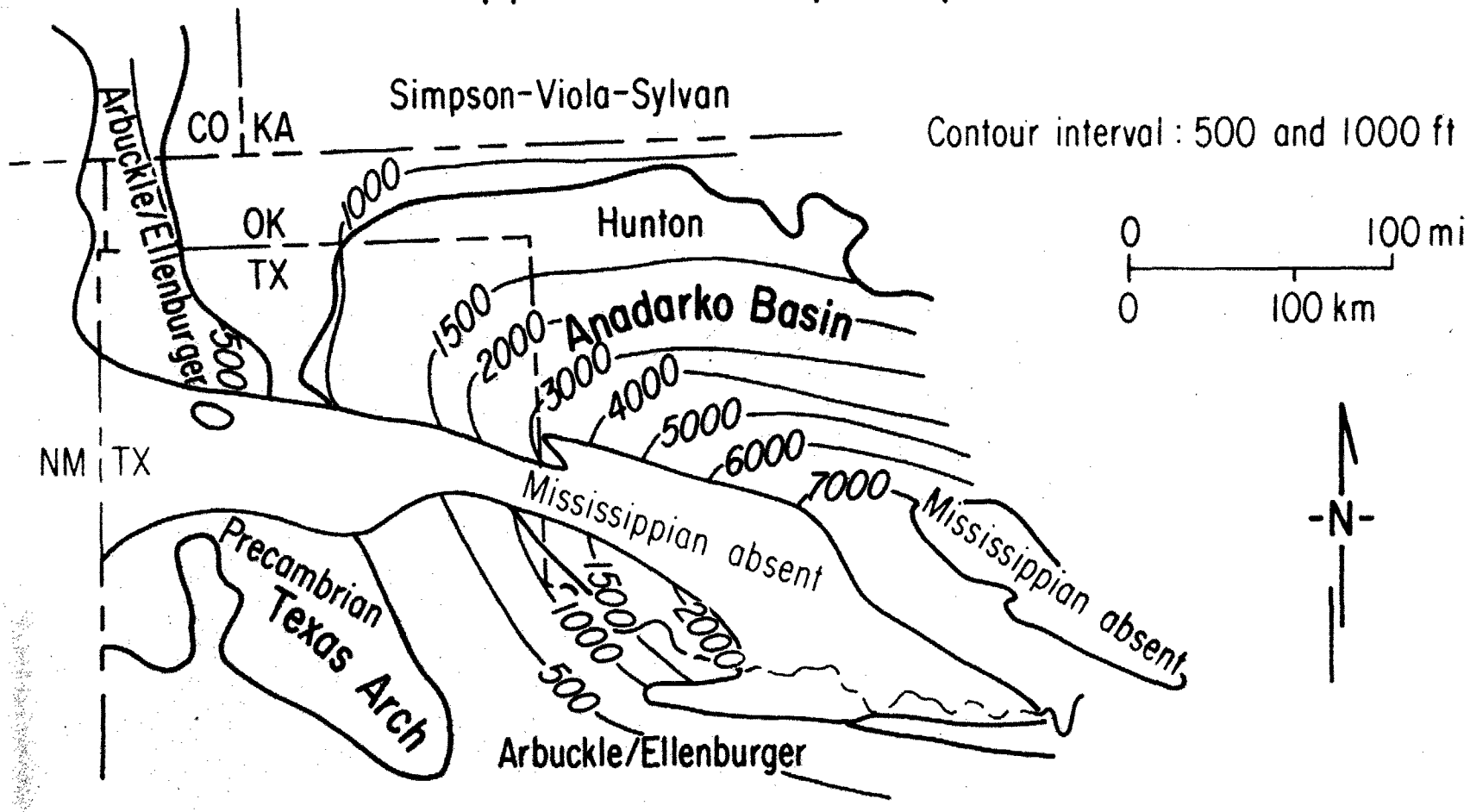

SW
NE
POTTER CO
MOORE CO
HUTCHINSON CO
Top Permian
Ogallala
Dockum
Canadian R.
Canadian R.
Blaine
Red Cave
Excell Dome
Wolfcamp
Basement
0 5mi
0 8km
4000
3000
2000
1000
0
-1000
MOORE
HUTCHINSON
POTTER
CARSON
QA 3730
BEG


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 UPLIFT
UNCOMPAHGRE UPLIFT
APISHAPA UPLIFT
NEW MEXICO
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



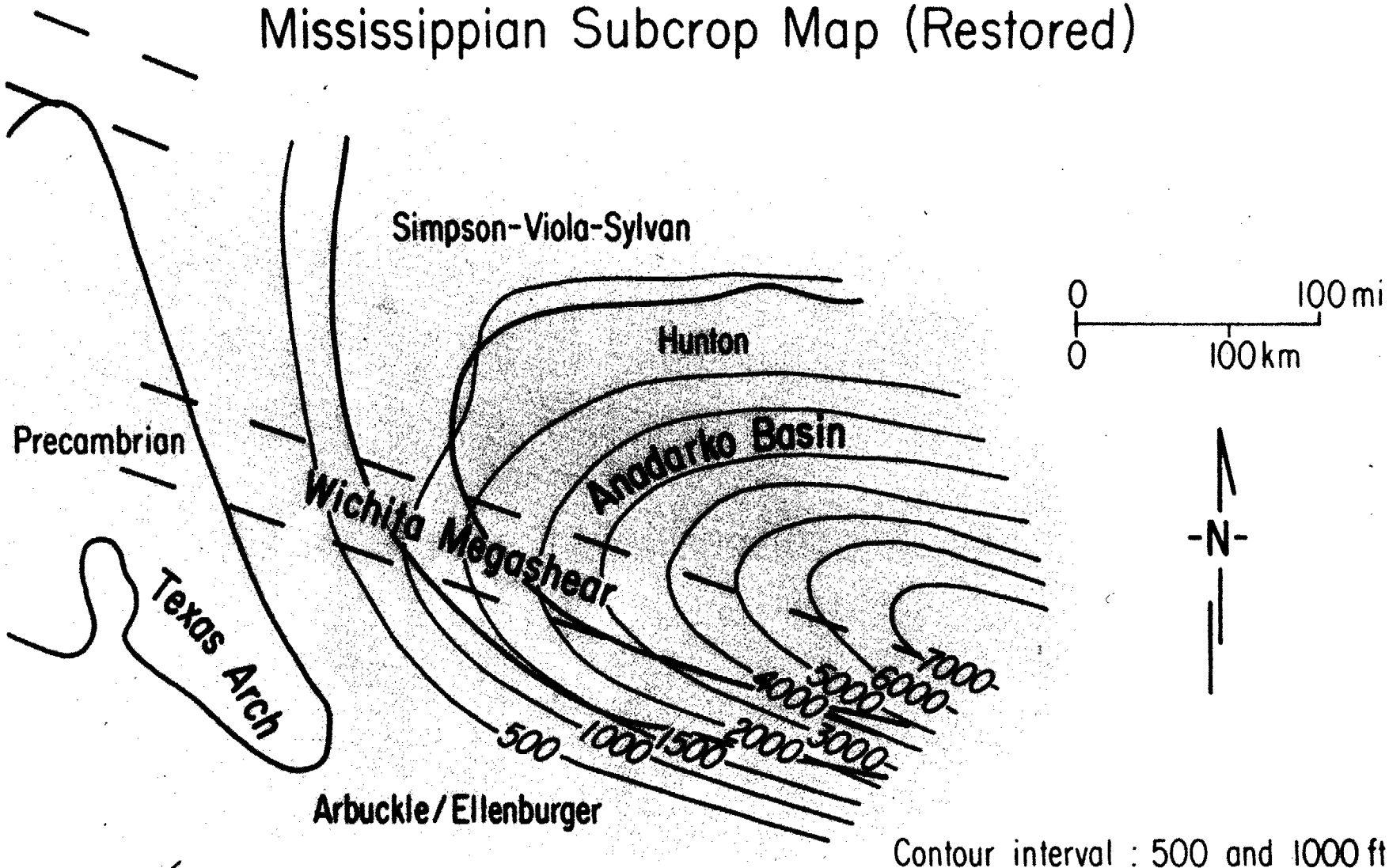
Mississippian Subcrop Map (Present)



500 Isopach lines, Arbuckle/Ellenburger Group

QA4599

Mississippian Subcrop Map (Restored)

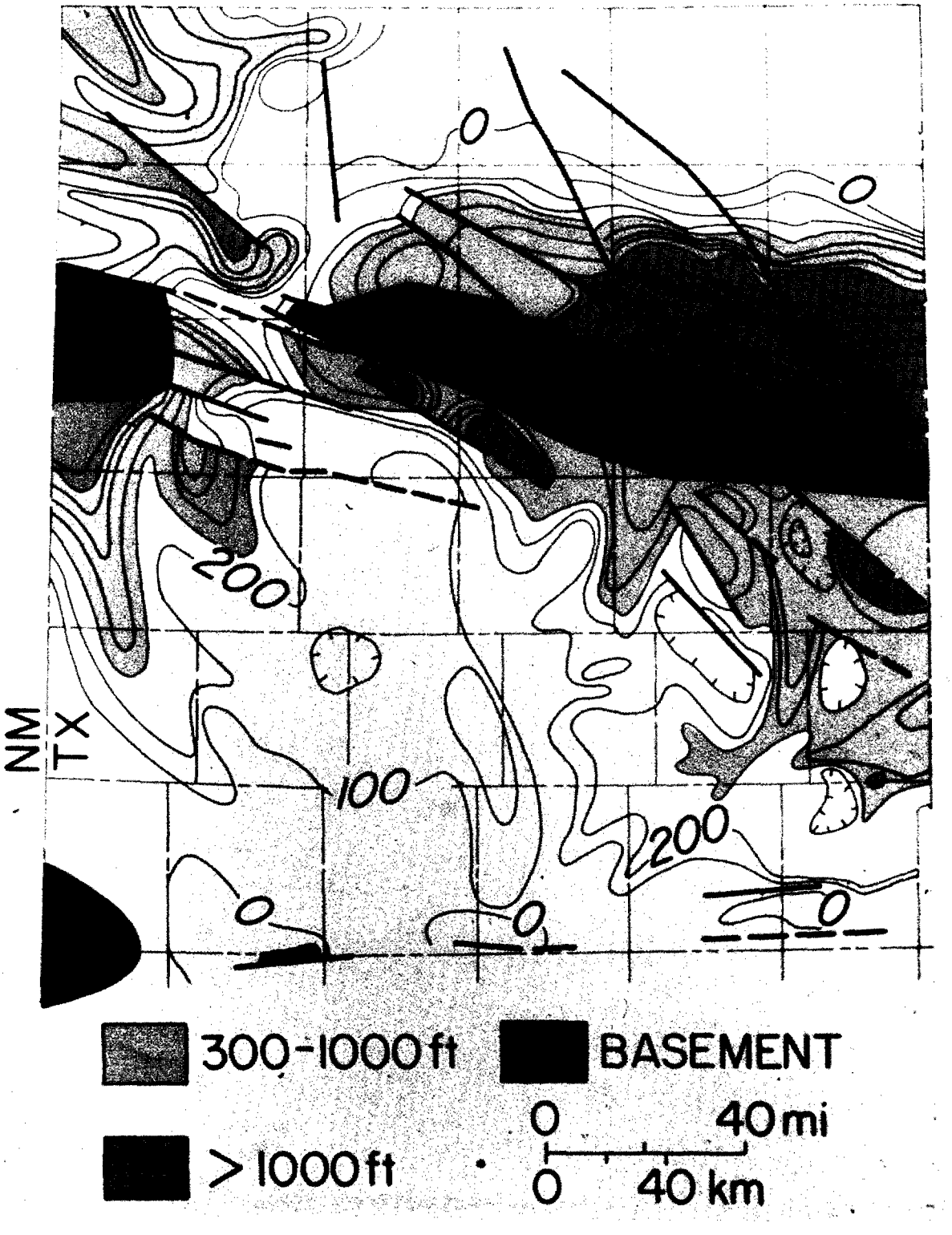


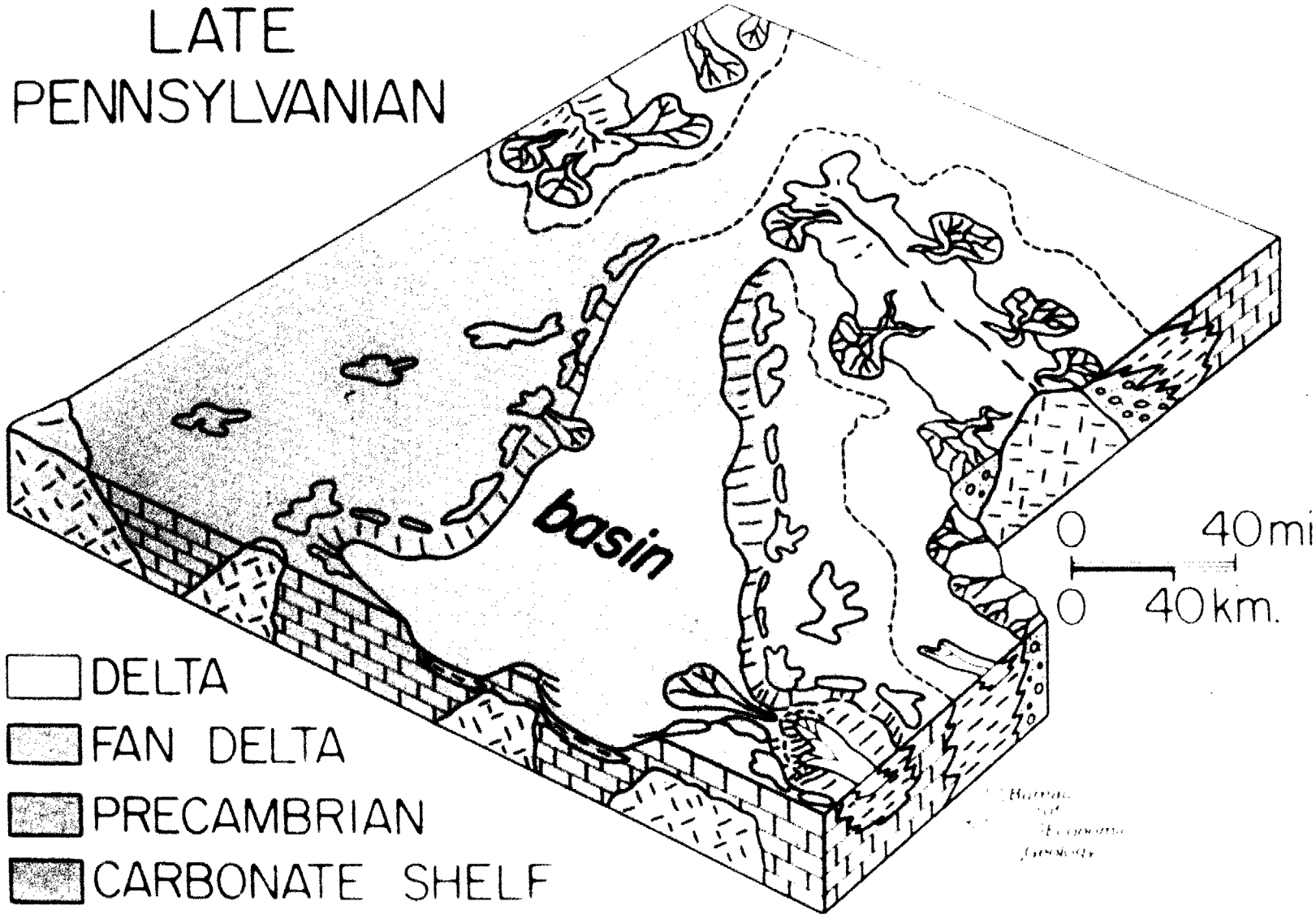
Contour interval : 500 and 1000 ft

500 Isopach lines, Arbuckle/Ellenburger Group

QA4598

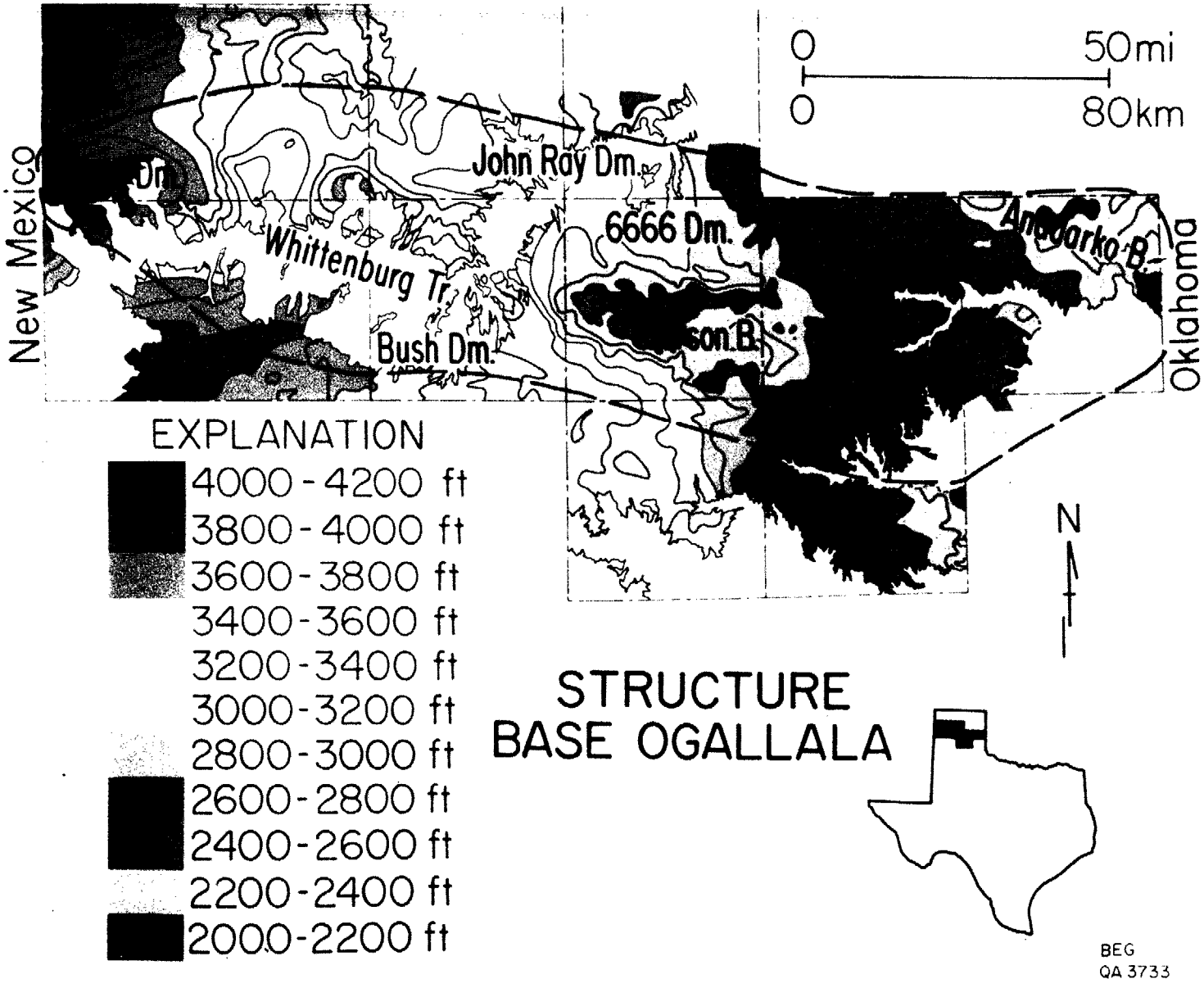
NET GRANITE WASH



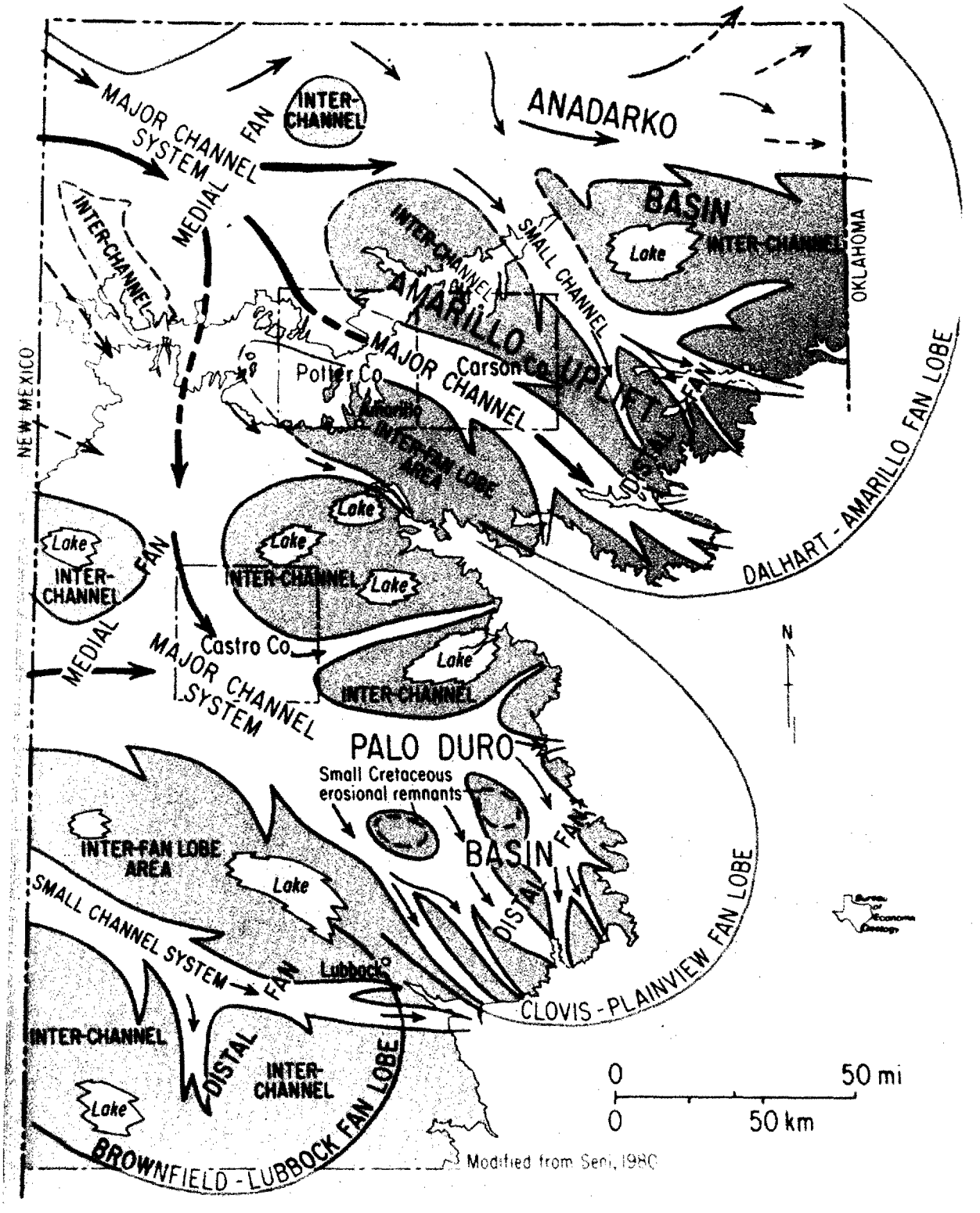

LATE
PENNSYLVANIAN
basin
0 40mi
0 40km.
DELTA
FAN DELTA
PRECAMBRIAN
CARBONATE SHELF

ISOPACH
PERMIAN post Wolfcamp

BEG
QA-3223

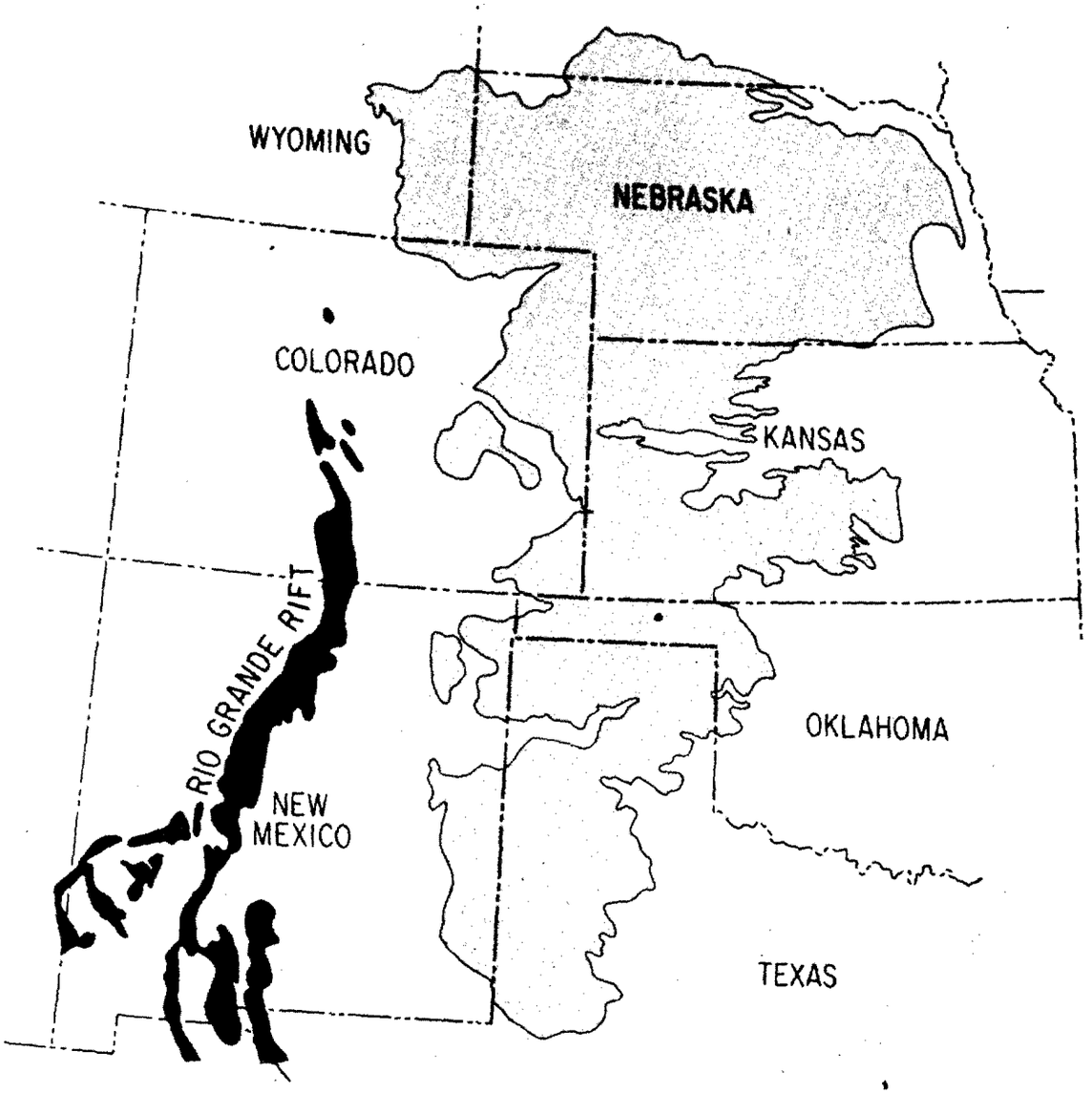

New Mexico
Oklahoma
John Ray Dm.
6666 Dm.
Whittenburg Tr.
Bush Dm.
son B.
Anadarko B.
0
50mi
0
80km
N
EXPLANATION
4000 - 4200 ft
3800 - 4000 ft
3600 - 3800 ft
3400 - 3600 ft
3200 - 3400 ft
3000 - 3200 ft
2800 - 3000 ft
2600 - 2800 ft
2400 - 2600 ft
2200 - 2400 ft
2000 - 2200 ft
STRUCTURE
BASE OGALLALA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

DEPOSITIONAL PATTERNS OF OGALLALA FM.



Modified from Seni, 1980

DISTRIBUTION OF NEOGENE SEDIMENTS



Ogallala Fm.

Santa Fe and related fms.

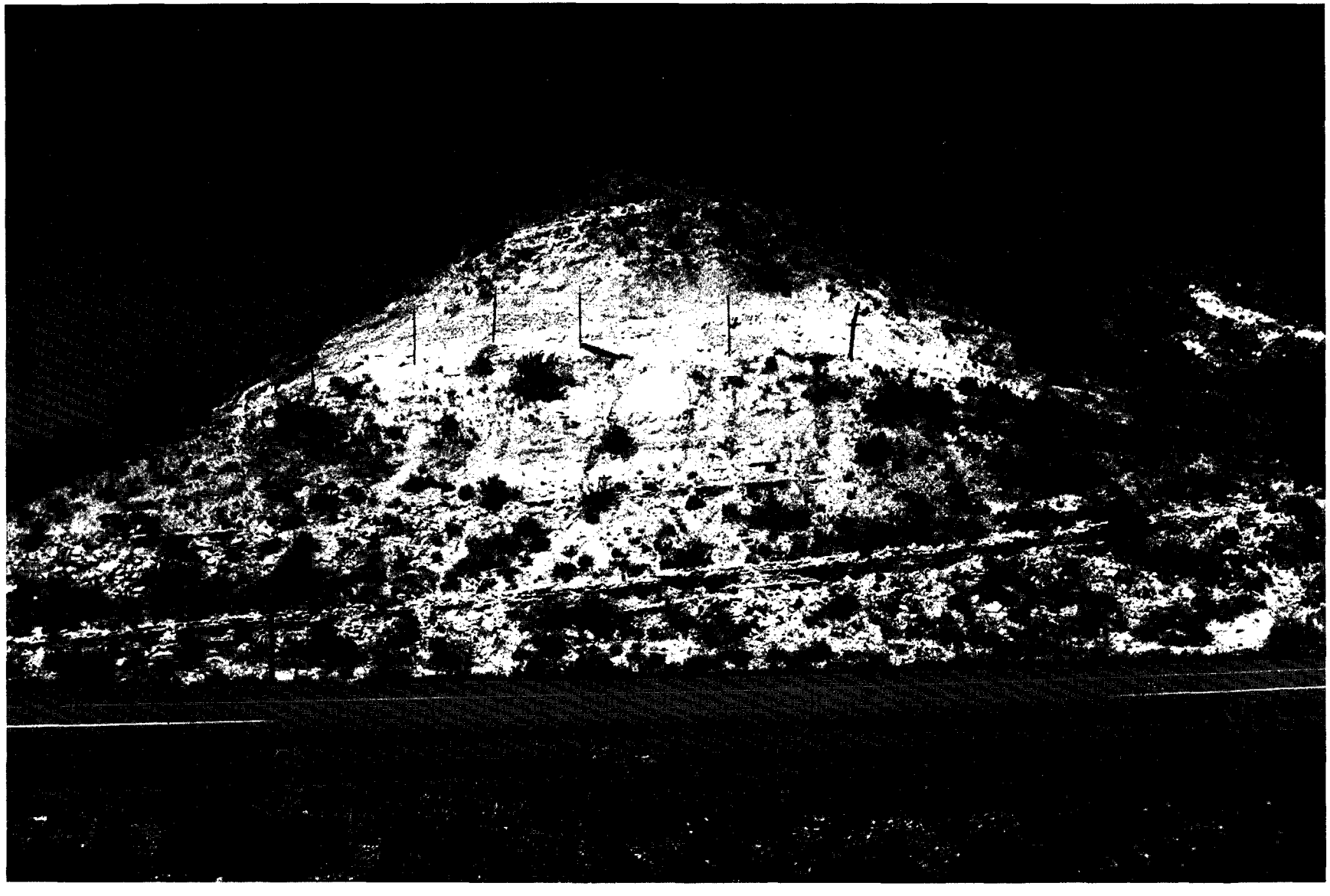
0 200 mi

0 200 km

Sources

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

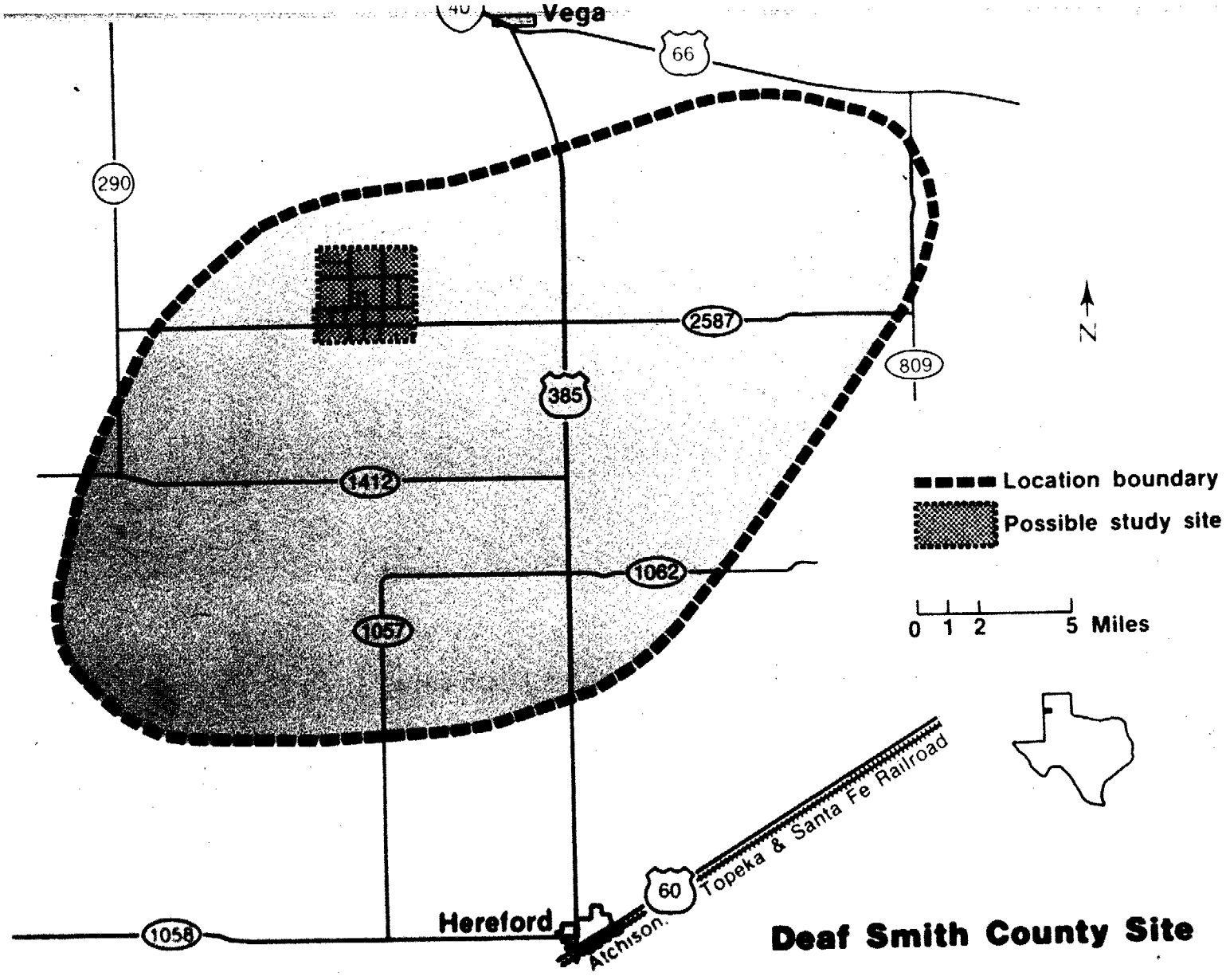
QA2038



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		

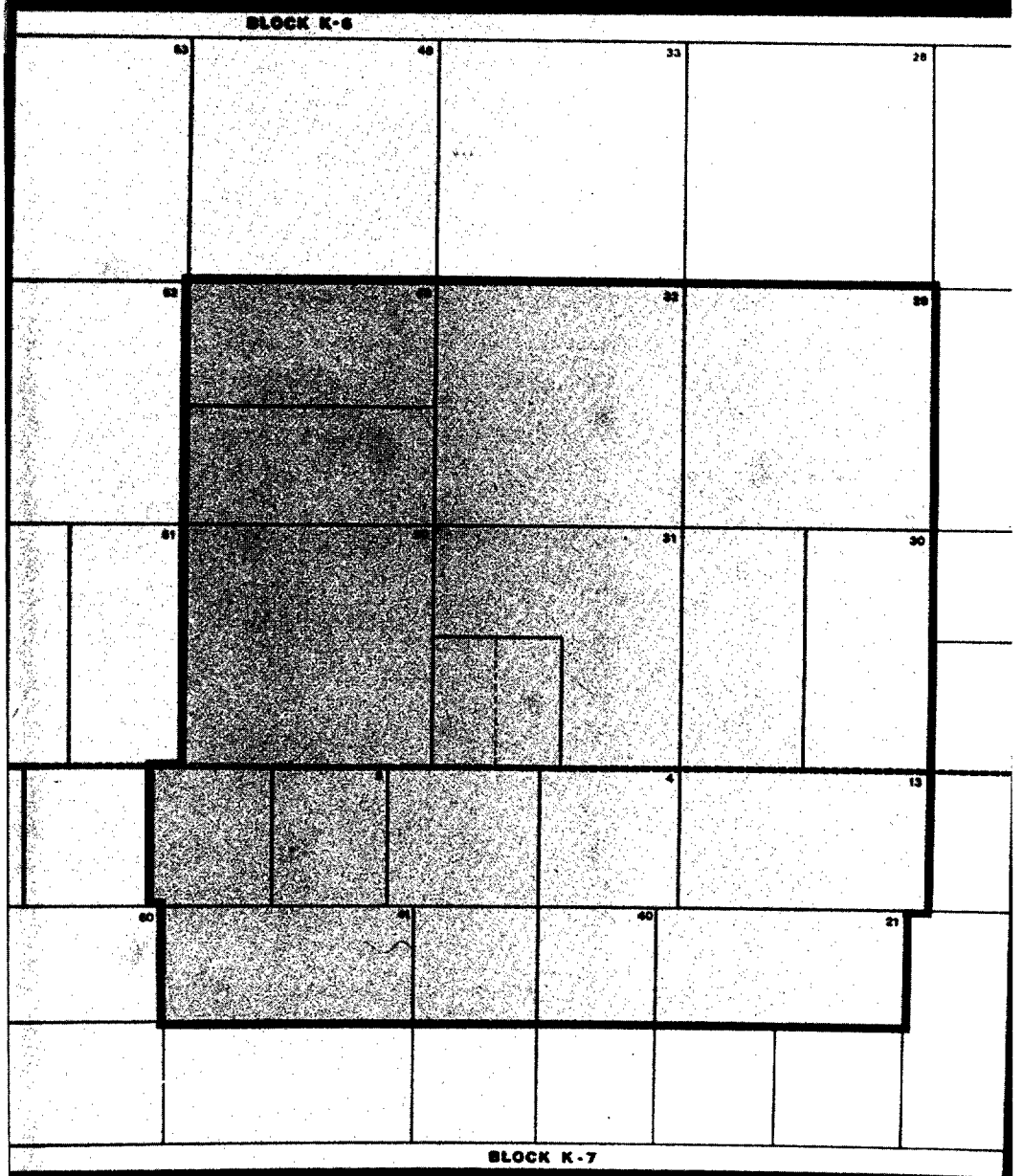
[redacted]



Deaf Smith County Site

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

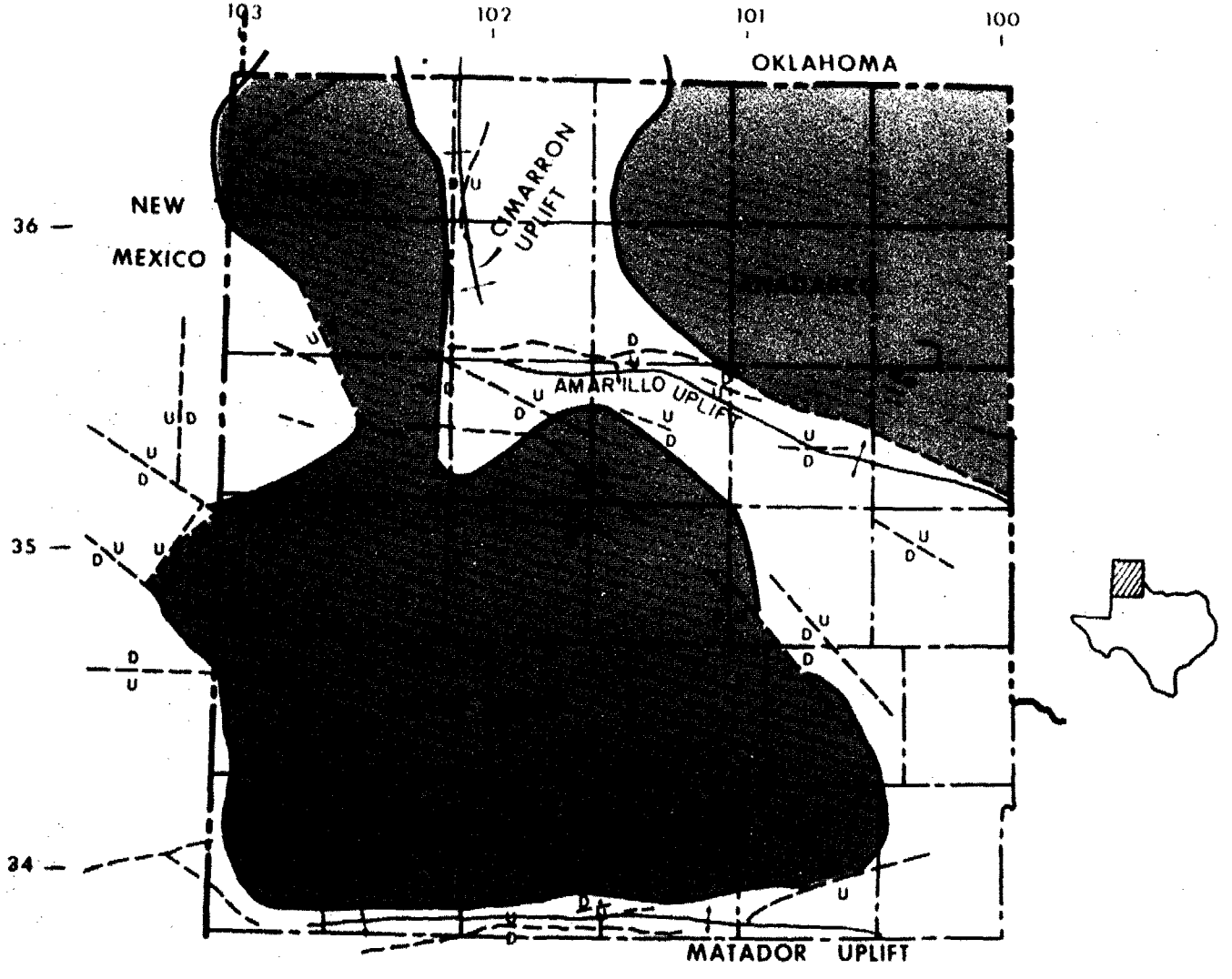
G.B.&C.N.G. RR



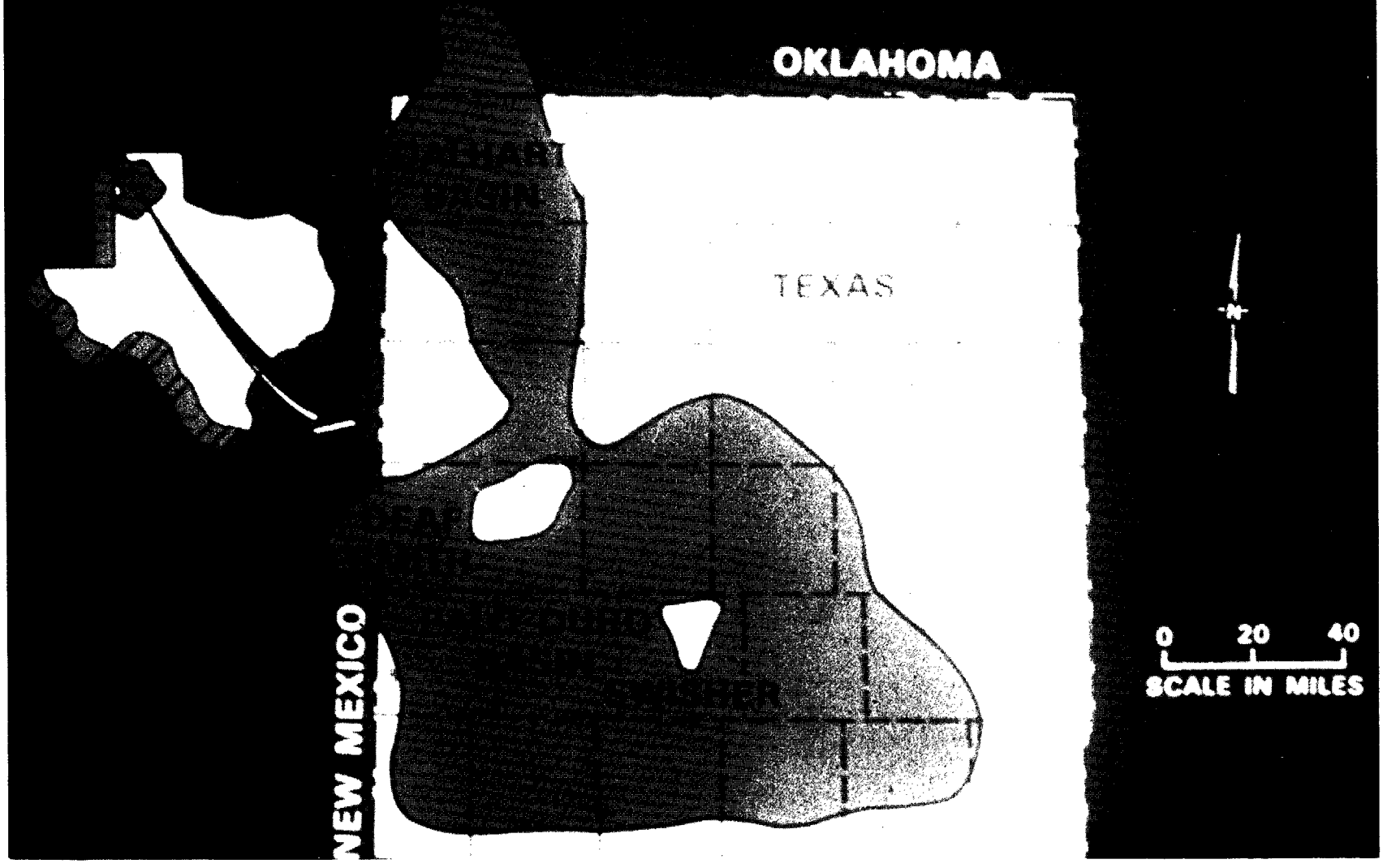
Possible study site boundary

Block boundary

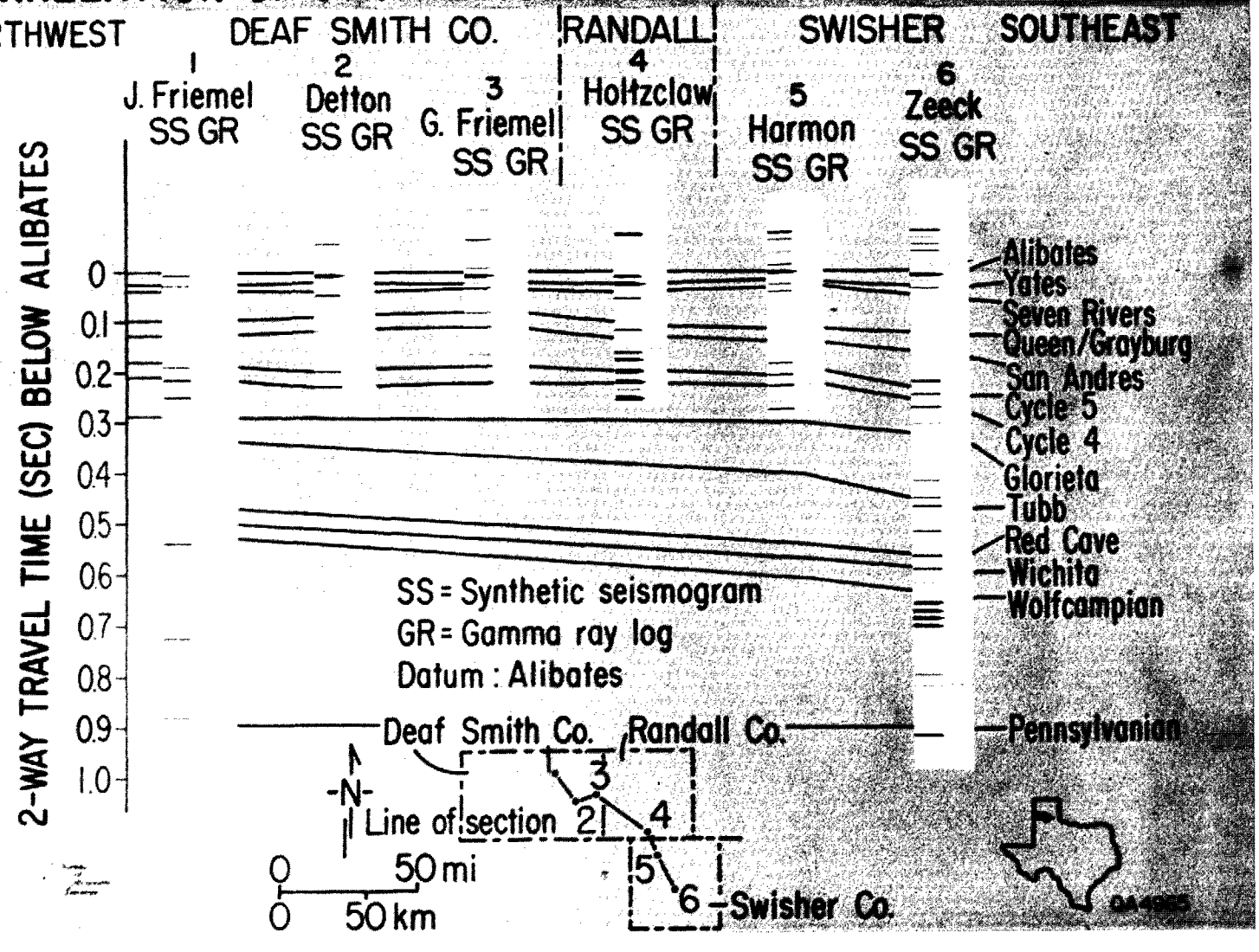
TECTONIC MAP



GEOLOGIC EXPLORATION — PERMIAN BASIN

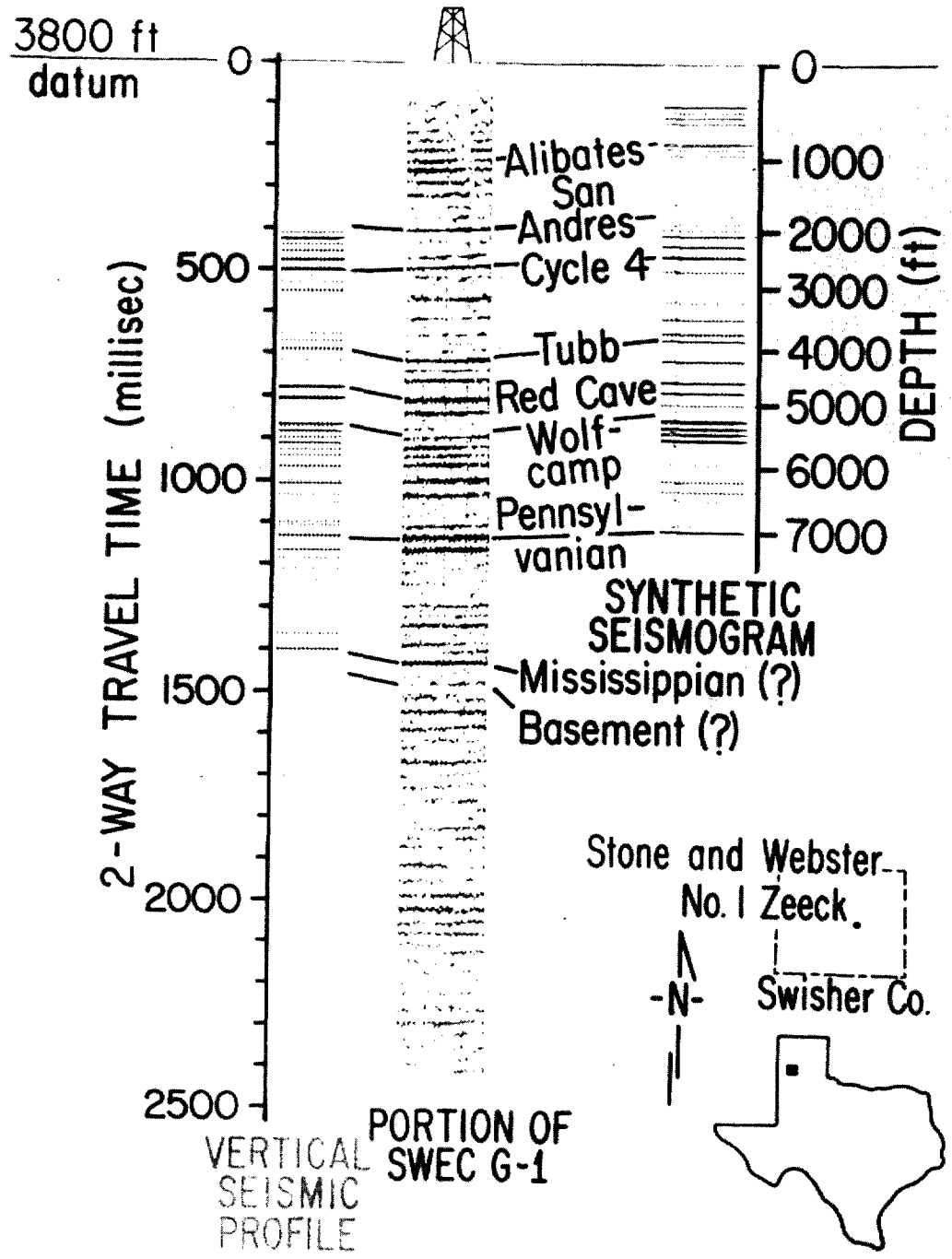


CORRELATION OF SYNTHETIC SEISMOGRAMS FROM DOE WELLS

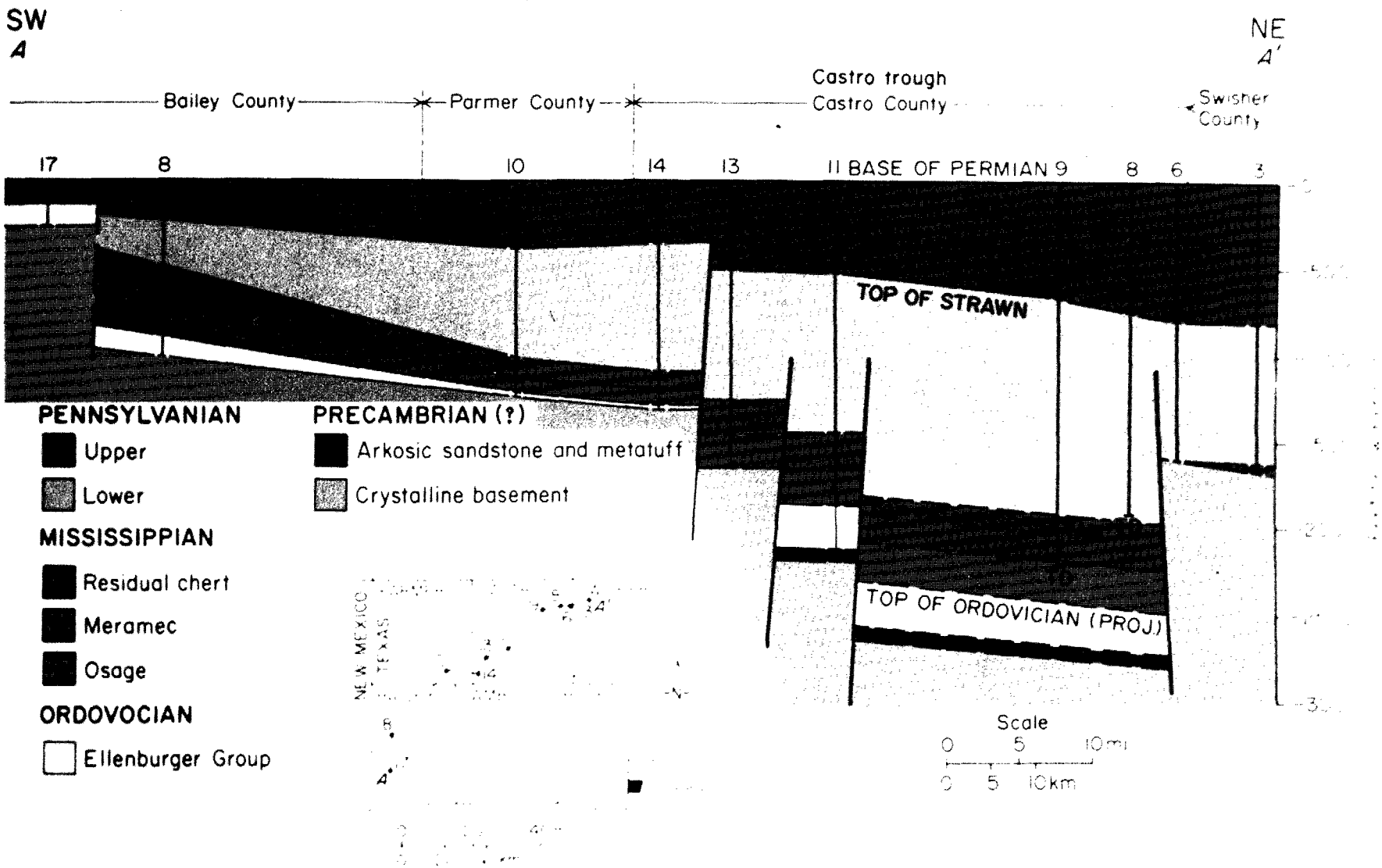


CORRELATION OF VSP, SYNTHETIC SEISMOGRAMS, & SEISMIC DATA

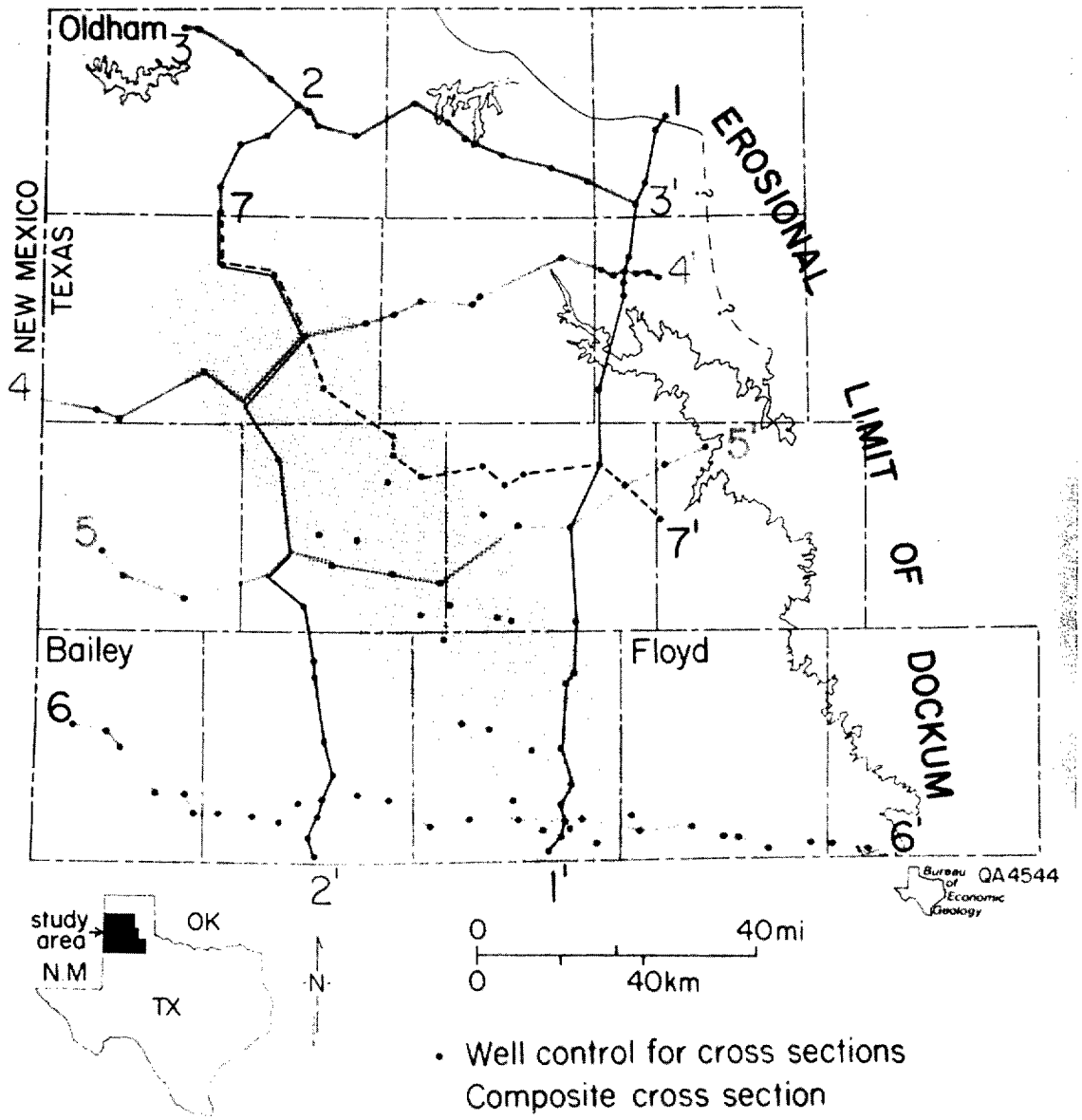
Stone and Webster
No. I Zeeck



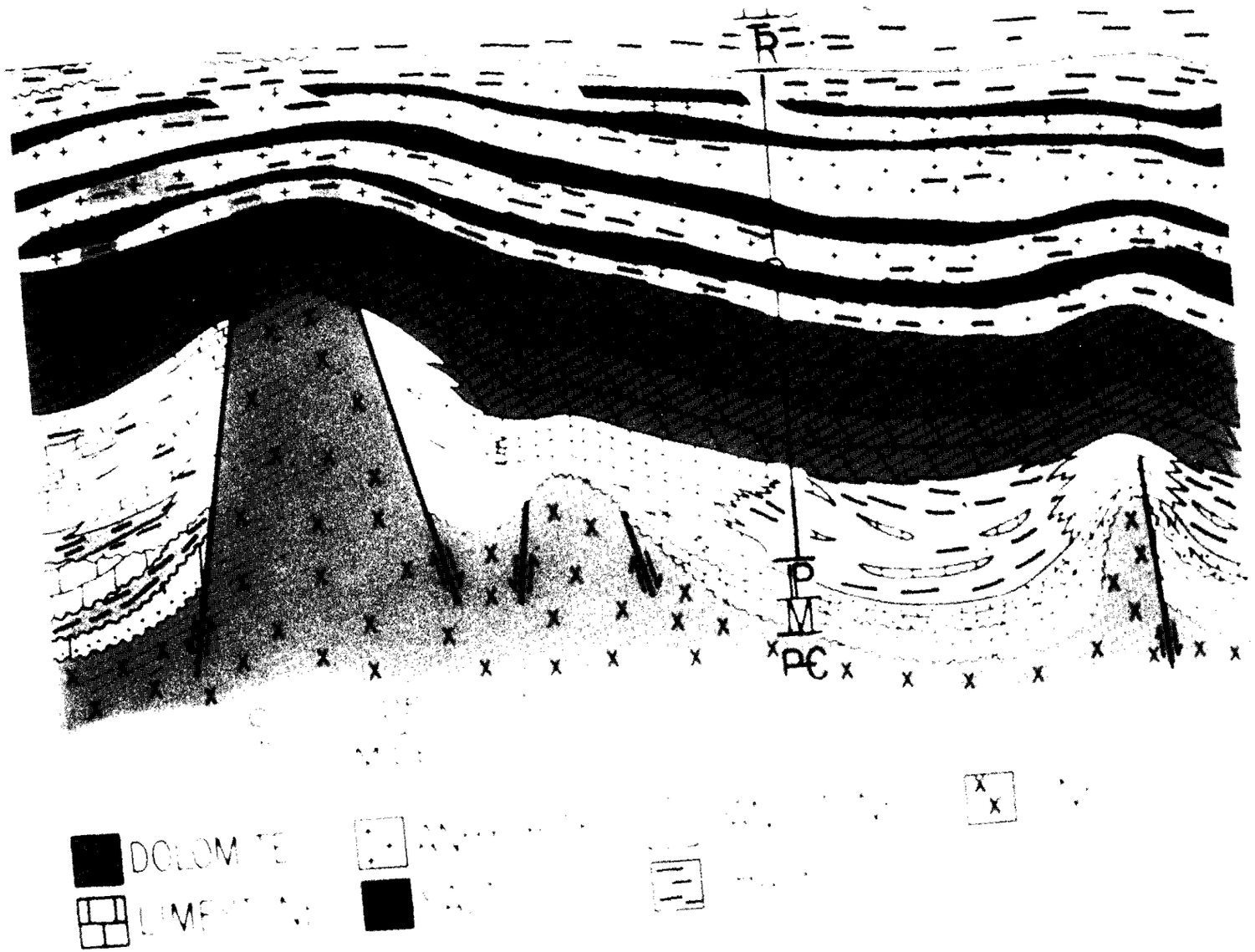
QA4966

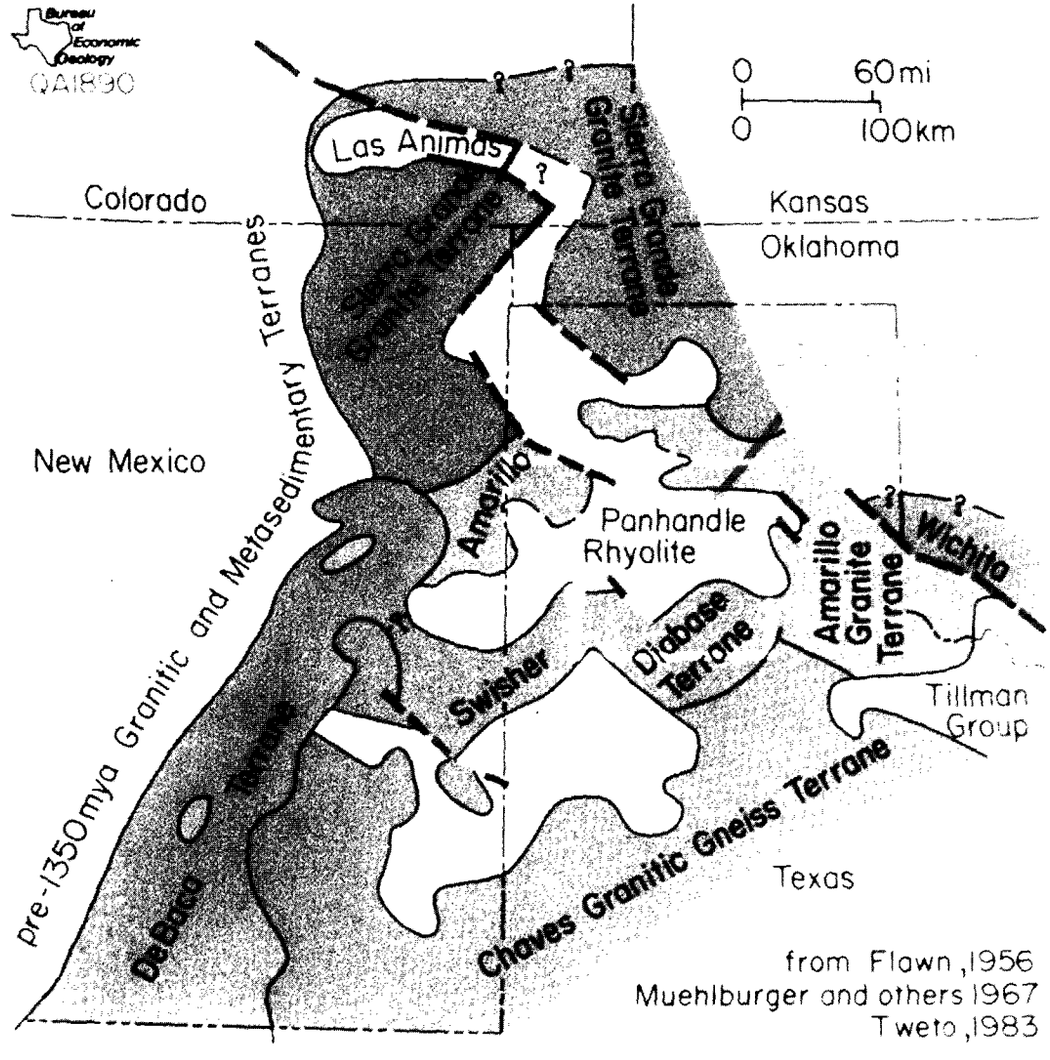

SW
A
NE
A'
Bailey County
Parmer County
Castro trough
Castro County
Swisher County
17
8
10
14
13
11 BASE OF PERMIAN 9
8
6
3
TOP OF STRAWN
TOP OF ORDOVICIAN (PROJ.)
PENNSYLVANIAN
Upper
Lower
MISSISSIPPIAN
Residual chert
Meramec
Osage
ORDOVICIAN
Ellenburger Group
PRECAMBRIAN (?)
Arkosic sandstone and metatuff
Crystalline basement
NEW MEXICO
TEXAS
Scale
0 5 10 mi
0 5 10 km

INDEX MAP



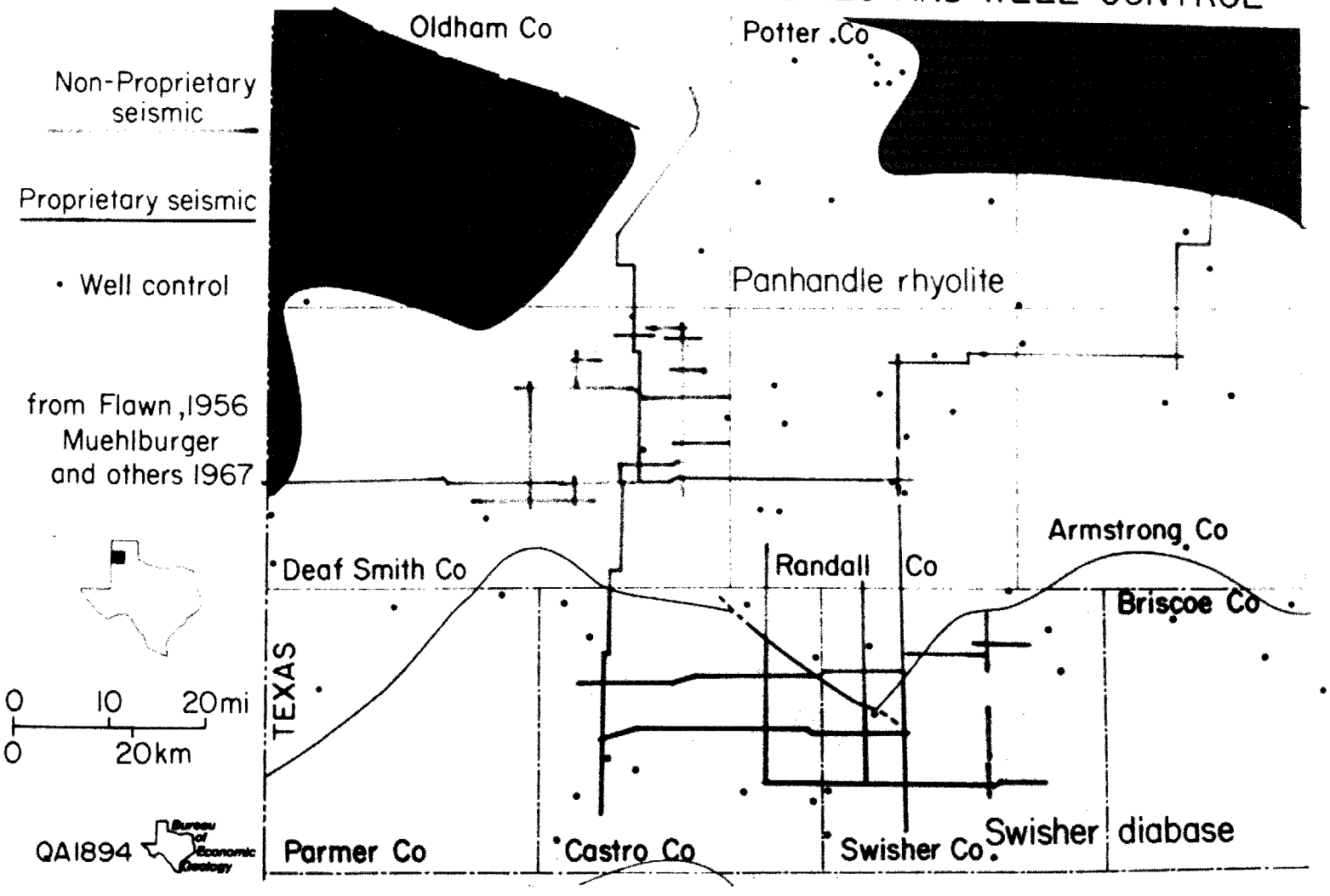
• Well control for cross sections
Composite cross section

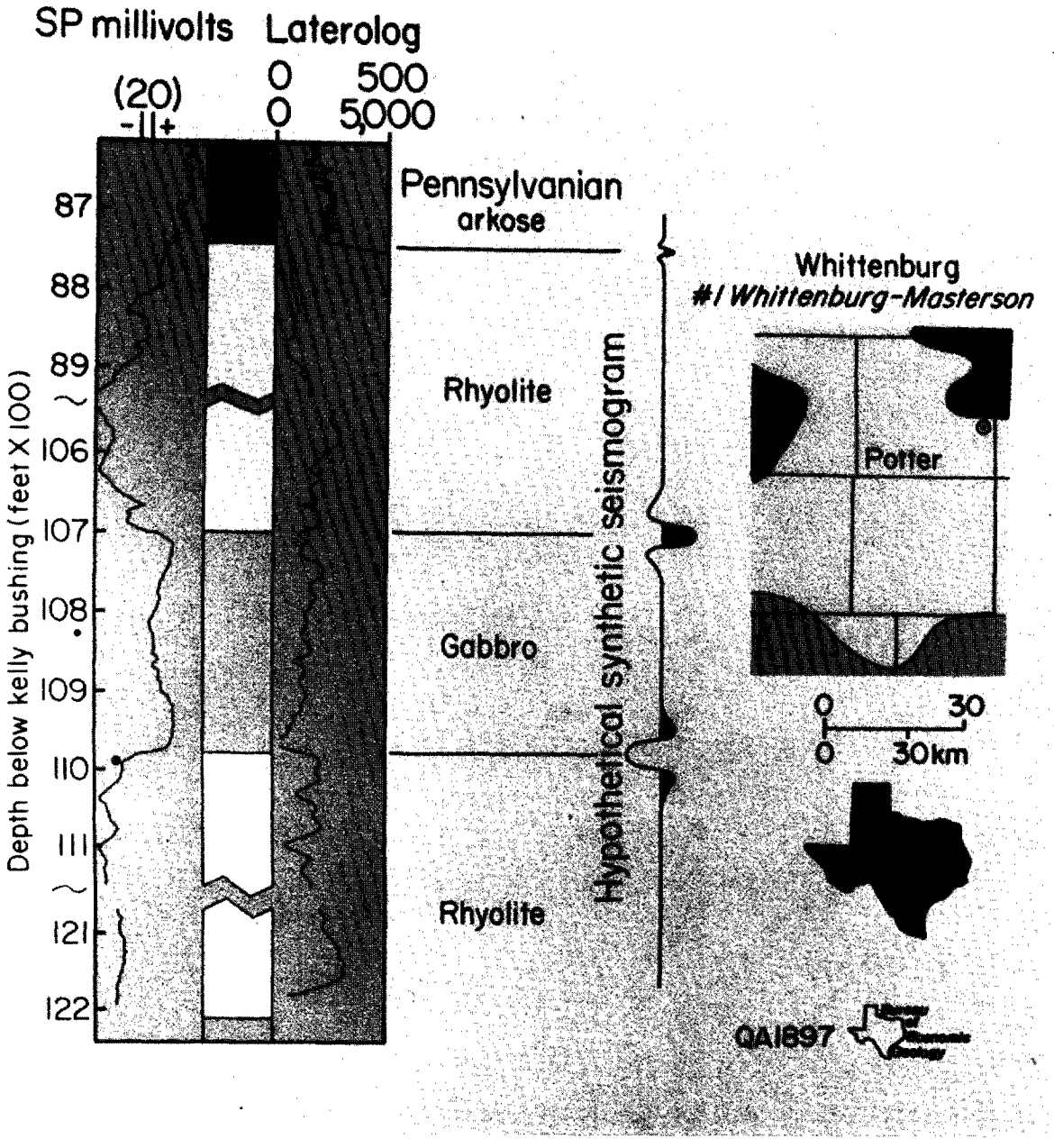

R
P
M
PЄ
DOLOMITE

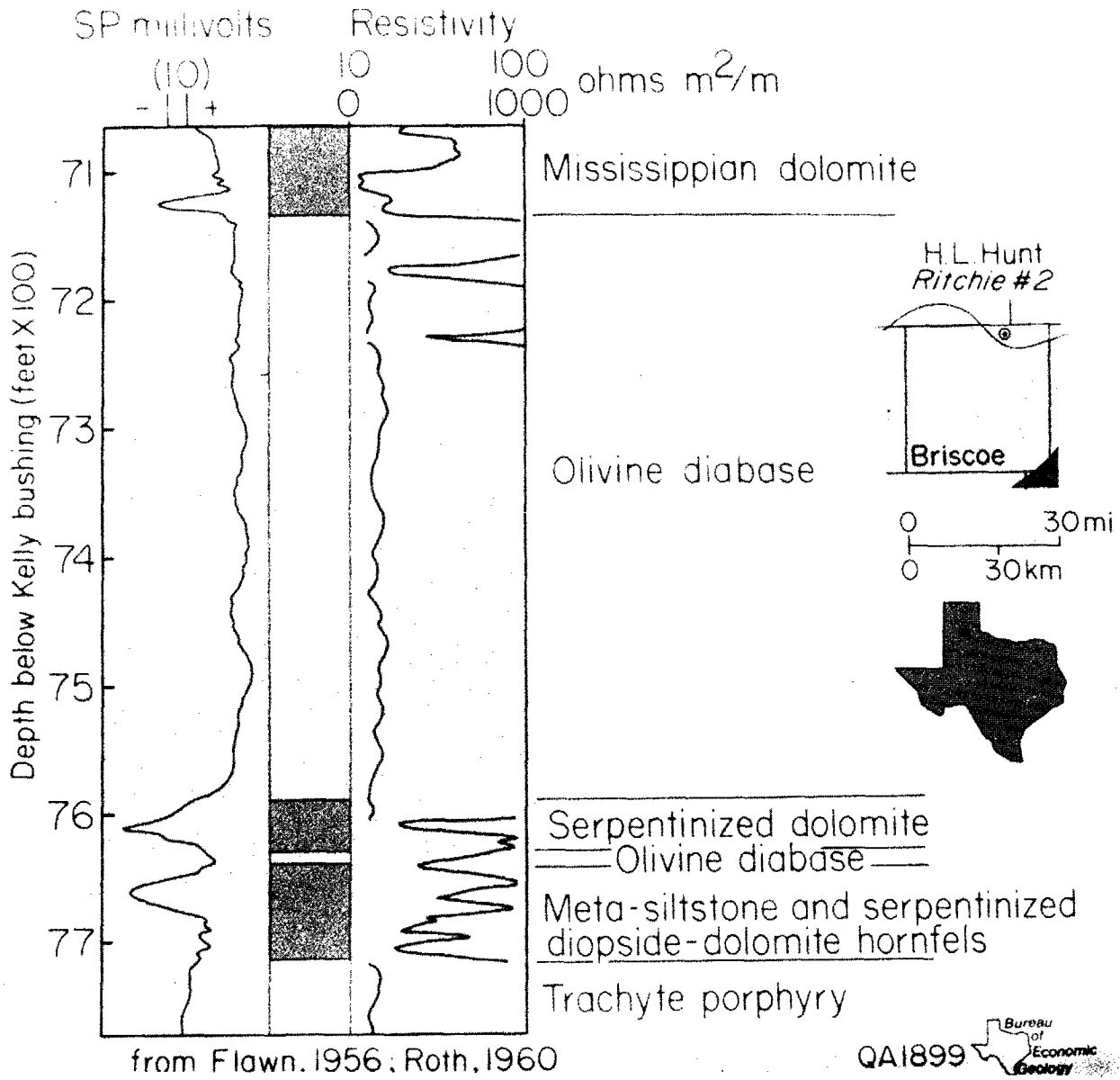


DISTRIBUTION OF BASEMENT TERRANES

DISTRIBUTION OF SEISMIC LINES AND WELL CONTROL



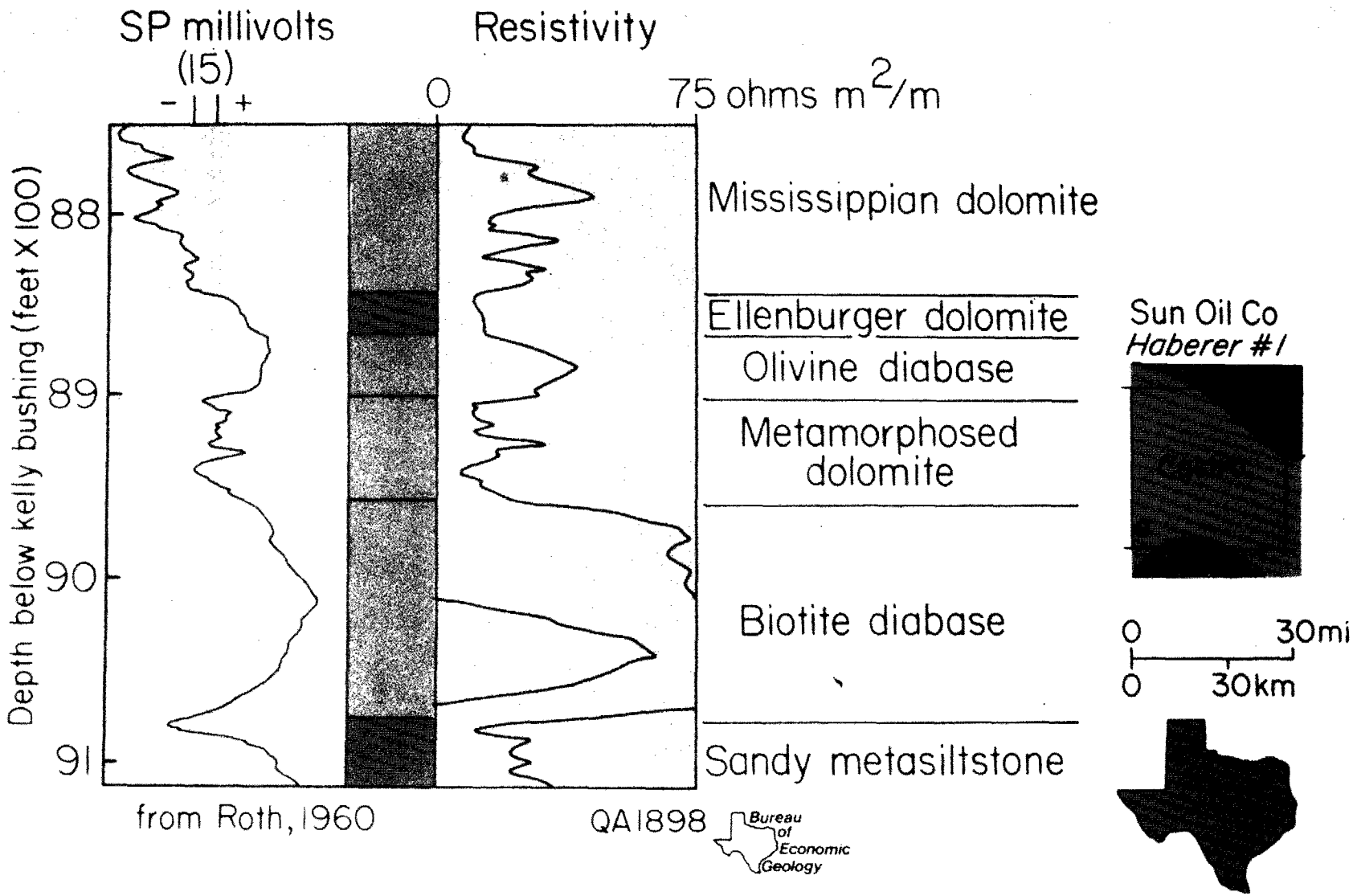

SP millivolts
(20)
-||+
Laterolog
0 500
0 5,000
Depth below kelly bushing (feet X 100)
87
88
89
106
107
108
109
110
111
121
122
Pennsylvanian
arkose
Rhyolite
Gabbro
Rhyolite
Hypothetical synthetic seismogram
Whittenburg
#1 Whittenburg-Masterson
Potter
0 30
0 30km
QA1897

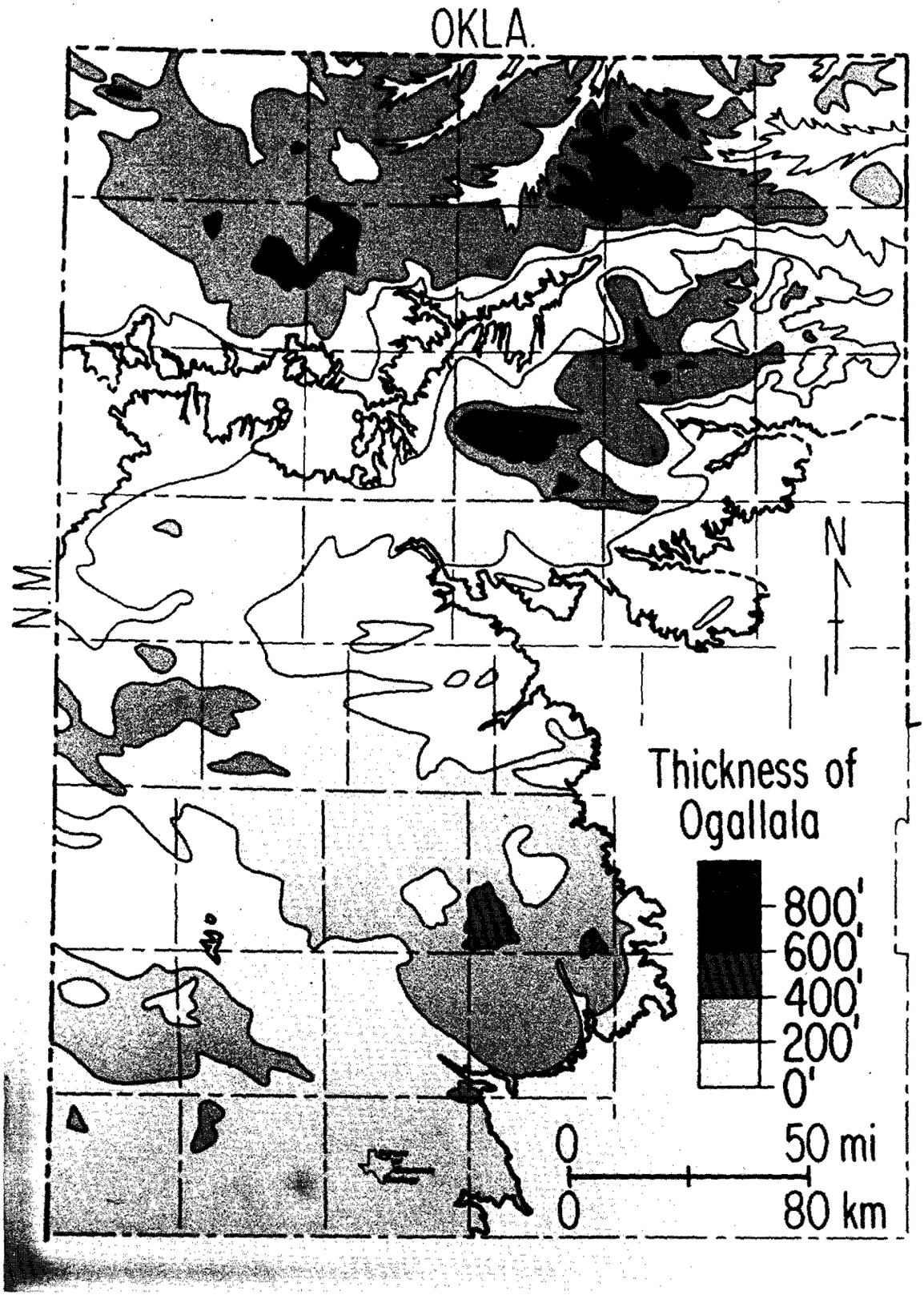


from Flawn, 1956; Roth, 1960

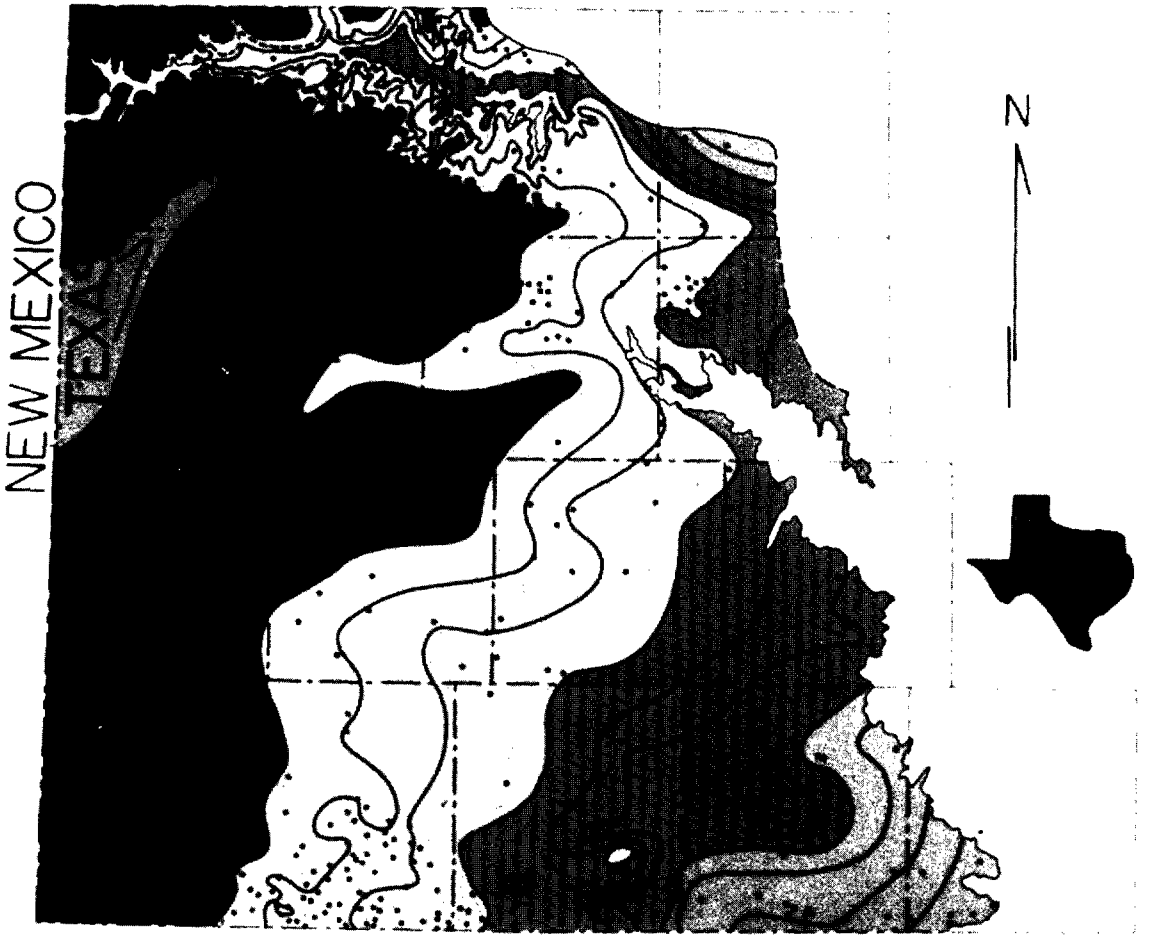
QA1899

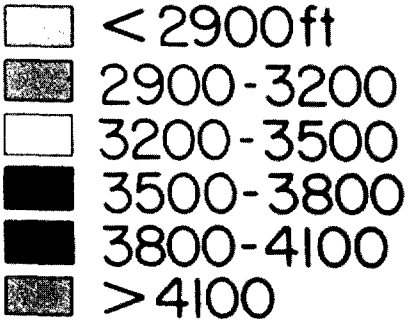
Bureau of Economic Geology

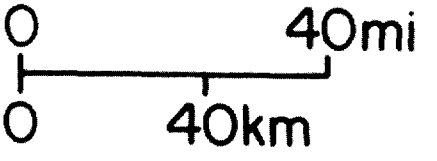

SP millivolts
(15)
- +
Resistivity
0
75 ohms m²/m
Depth below kelly bushing (feet X 100)
88
89
90
91
Mississippian dolomite
Ellenburger dolomite
Olivine diabase
Metamorphosed dolomite
Biotite diabase
Sandy metasiltstone
Sun Oil Co
Haberer #1
0
30mi
0
30km
from Roth, 1960
QA1898
Bureau of Economic Geology


OKLA.
N.M.
N
Thickness of Ogallala
800'
600'
400'
200'
0'
0
50 mi
0
80 km

STRUCTURE CONTOUR
TOP OF DOCKUM GROUP



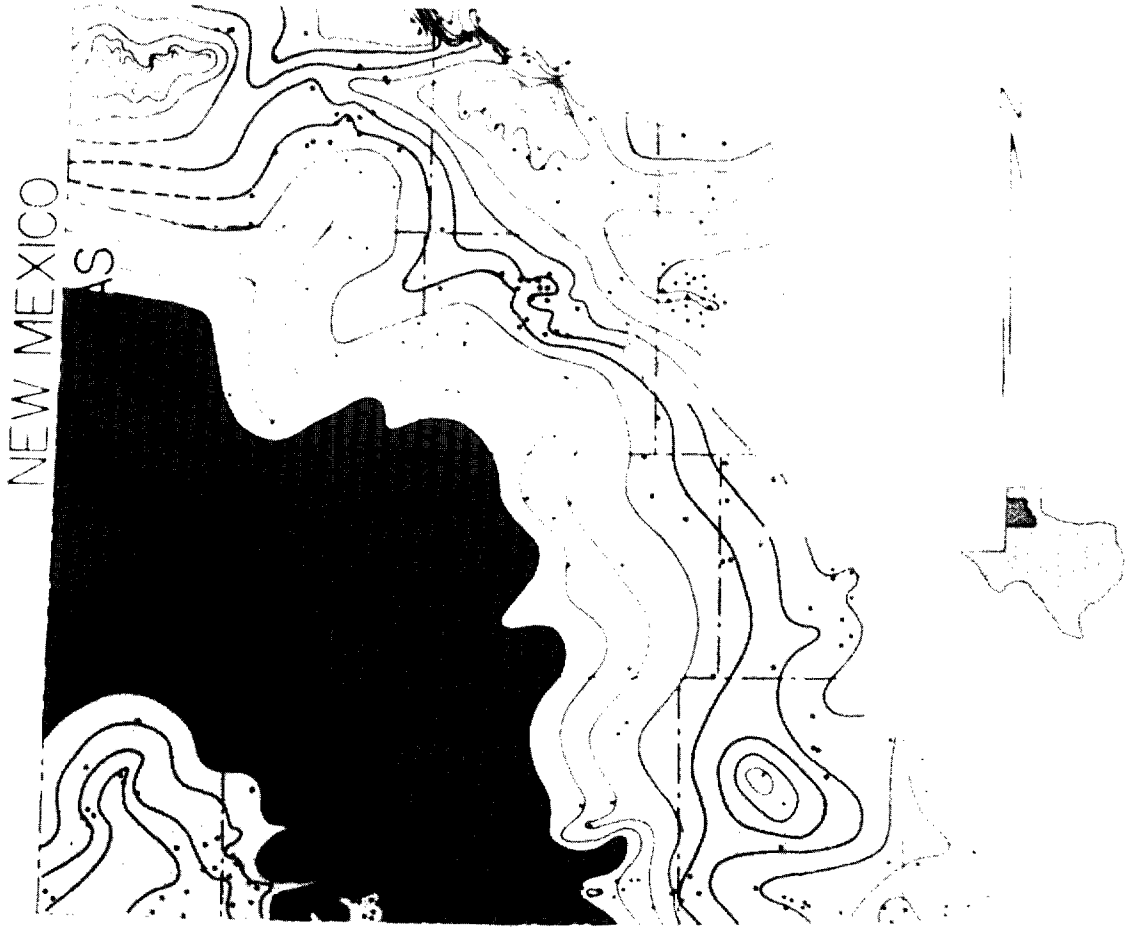




Contour interval = 100ft

QA-1907

ISOPACH - DOCKUM GROUP

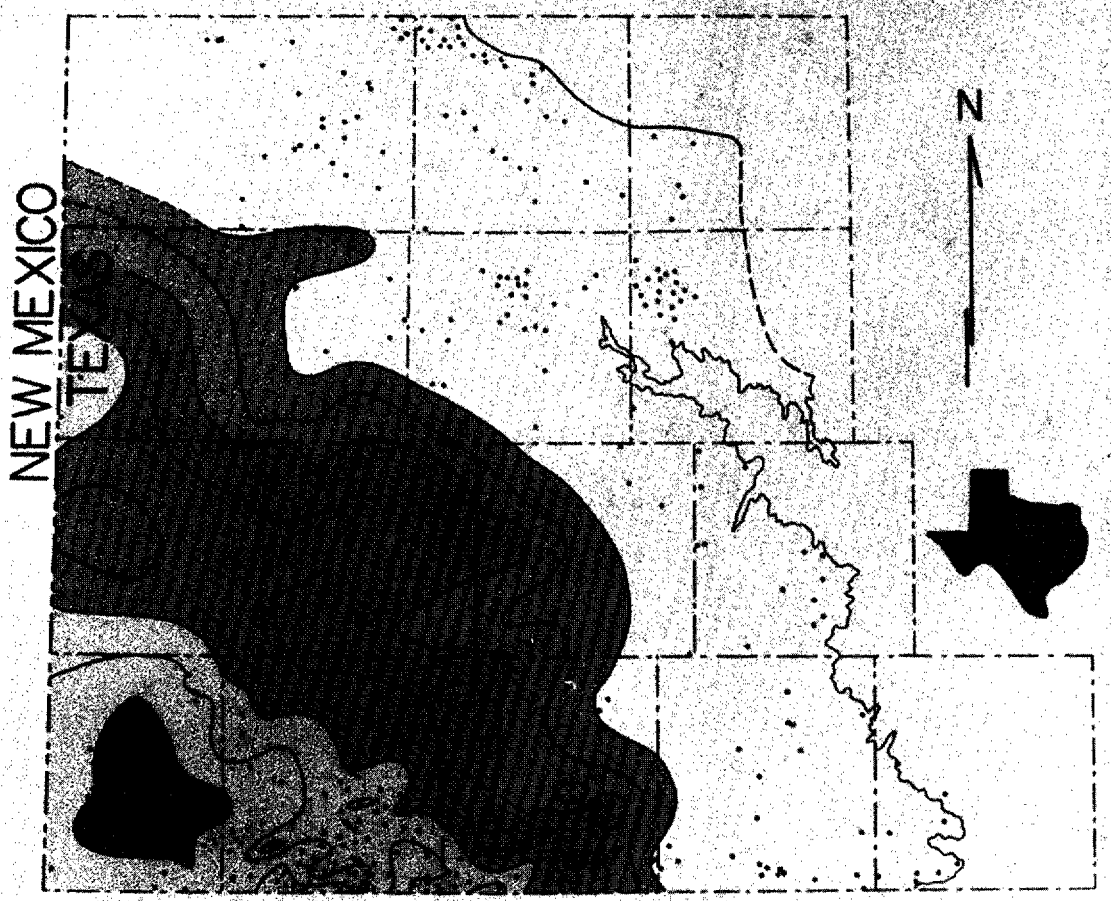


0-300 ft
300-600
600-900
900-1200
1200-1500
>1500

0 40mi
0 40km

Contour interval = 100ft

ISOPACH - UPPER DOCKUM



0-200 ft
200-400
400-600
> 600

0 40mi
0 40km

Contour interval = 100 ft

QA-1903

ISOPACH - LOWER DOCKUM

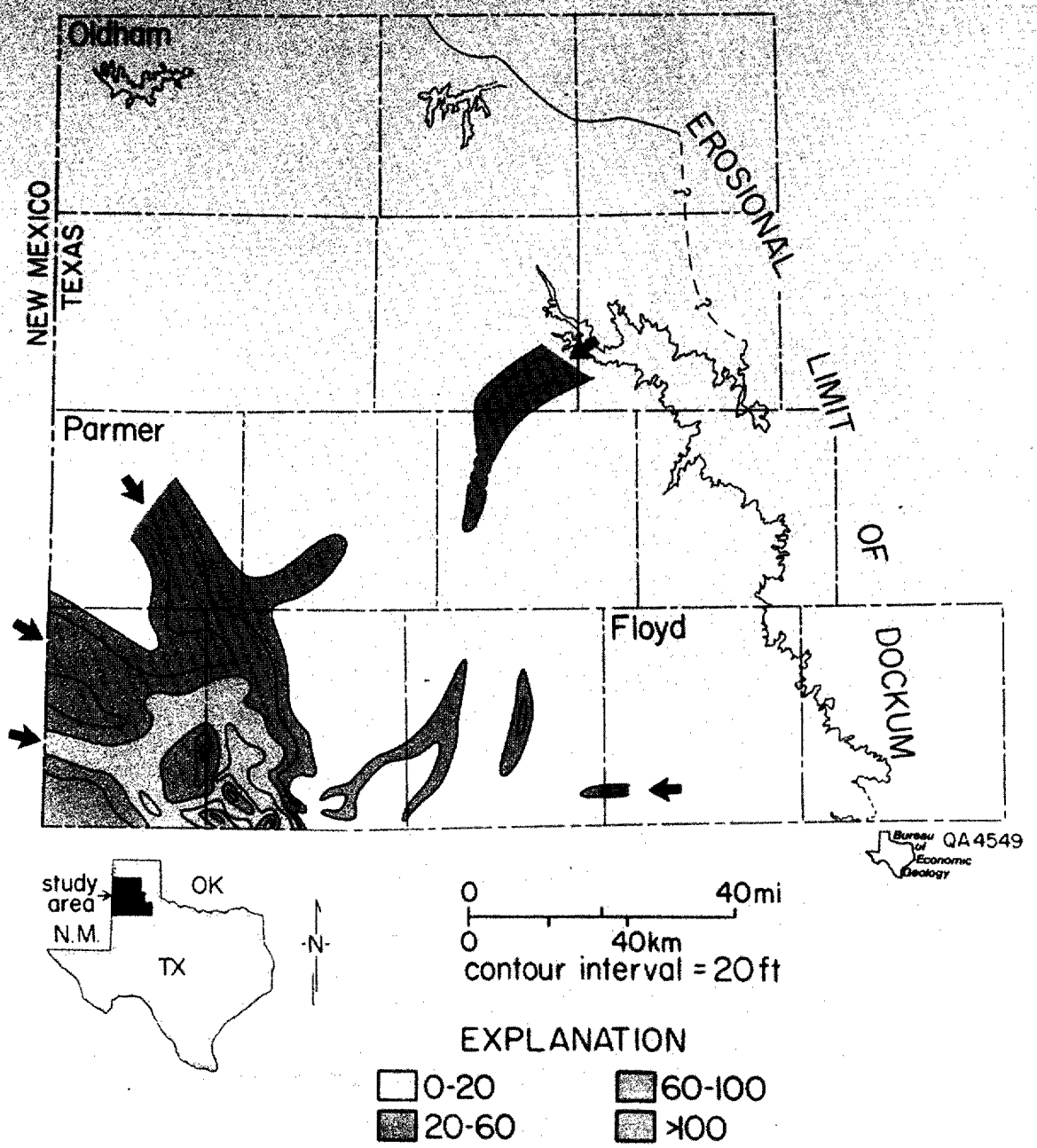
0-200 ft
200-400
400-600
600-800
800-1000
1000-12000
> 1200

0 40mi
0 40km

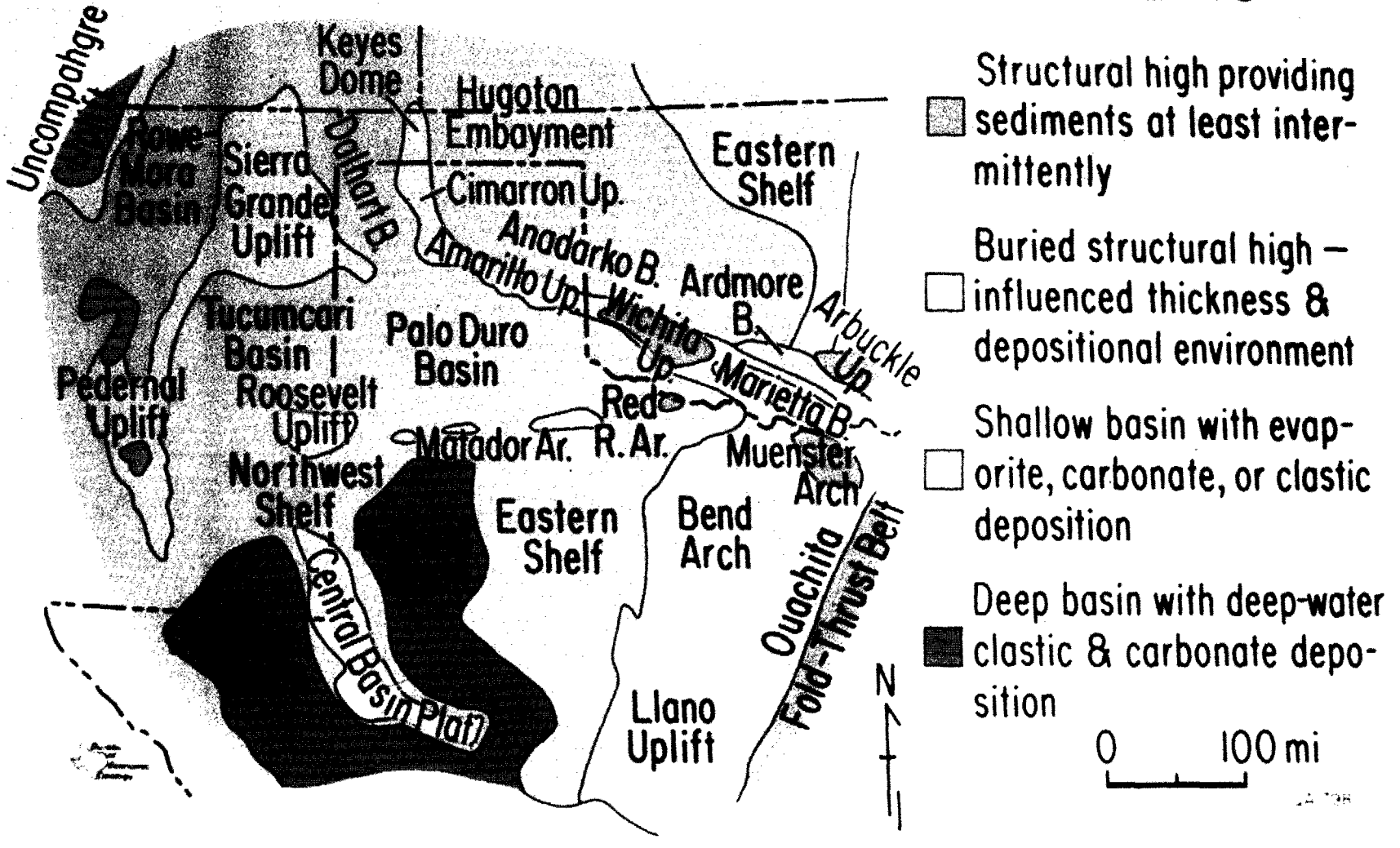
Contour interval = 100'

QA-1905

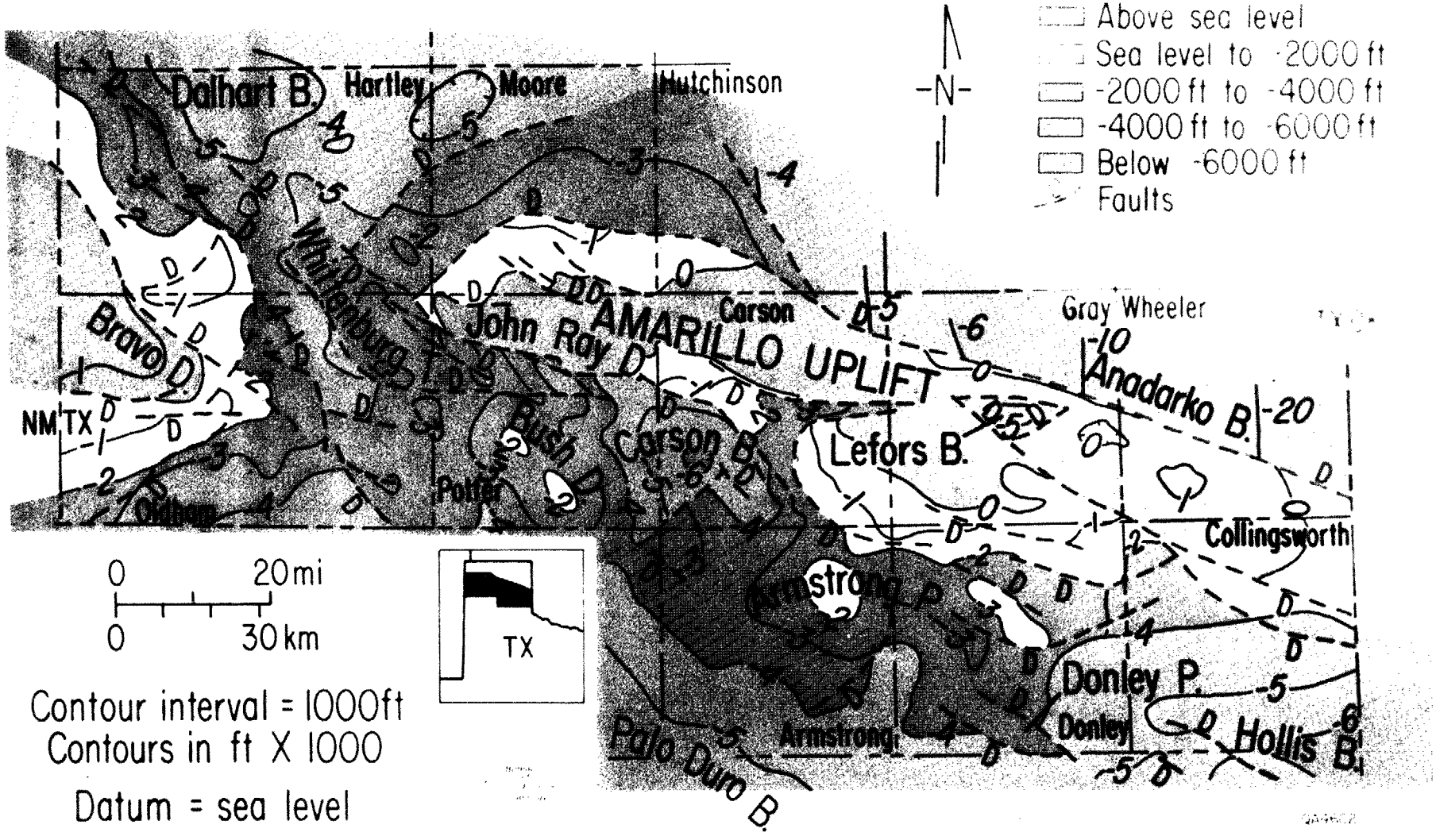
NET SANDSTONE PACKAGE NO.5



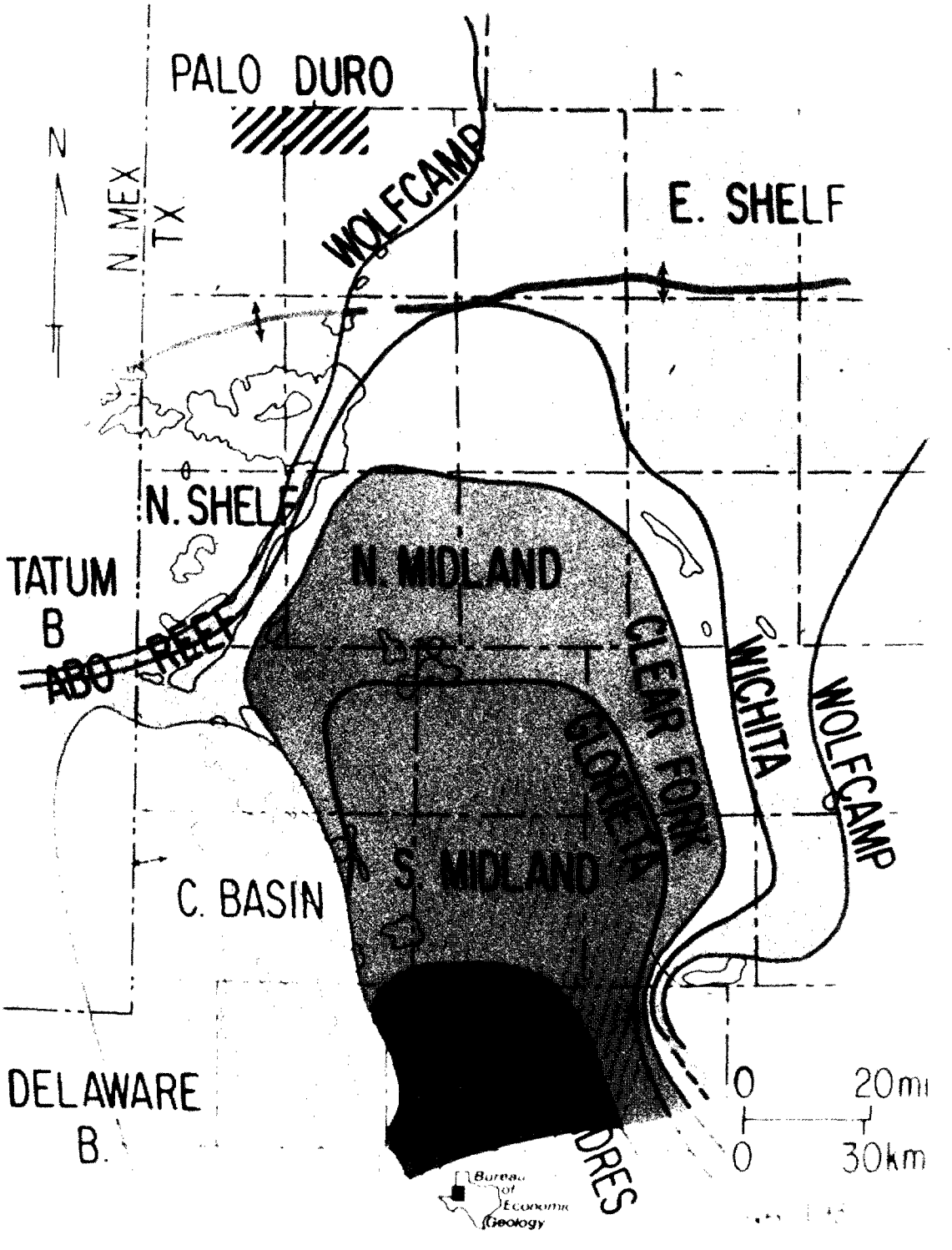
MIDDLE & LATE PERMIAN TECTONIC ELEMENTS



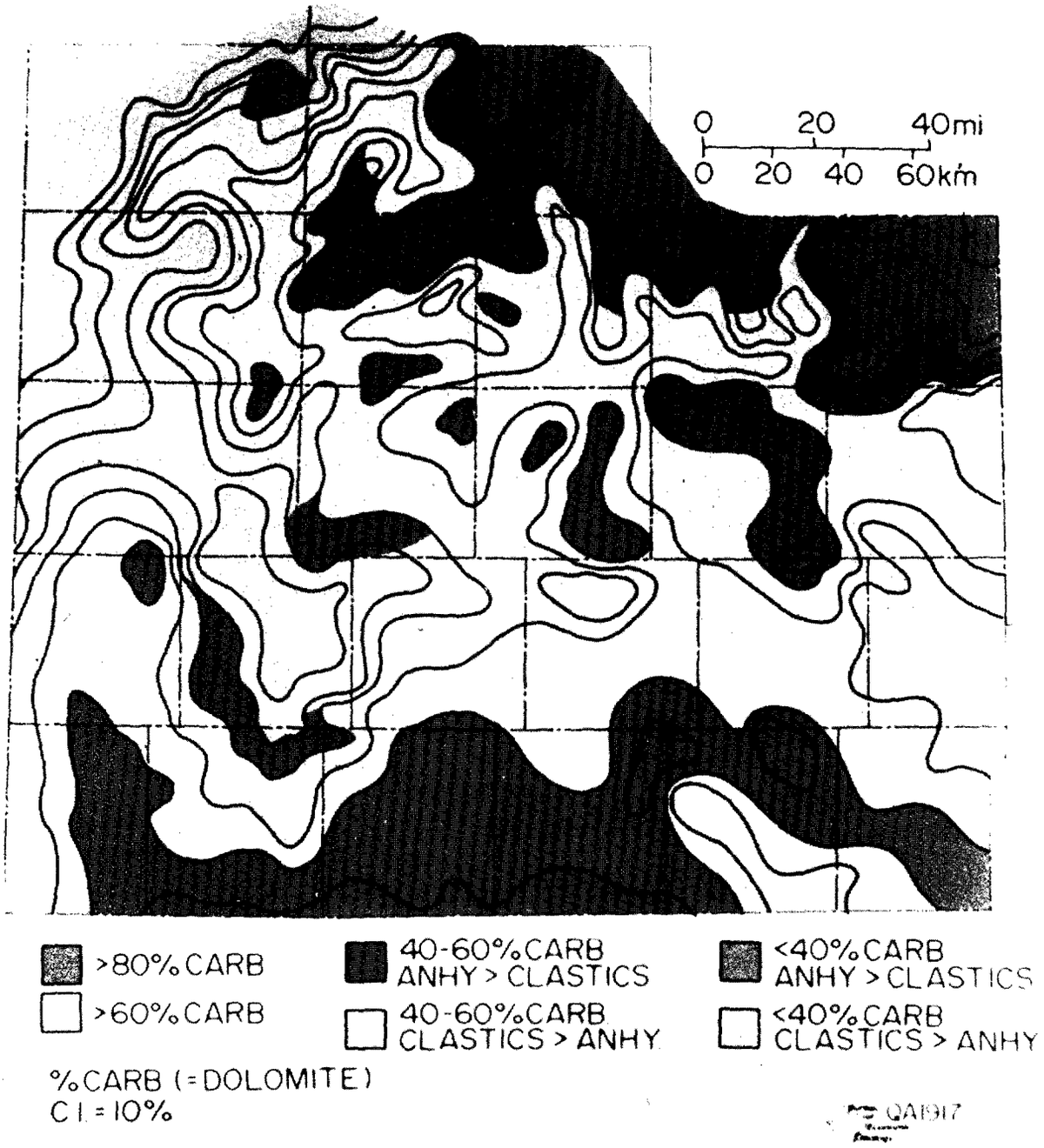
Basement structure map of Amarillo Uplift

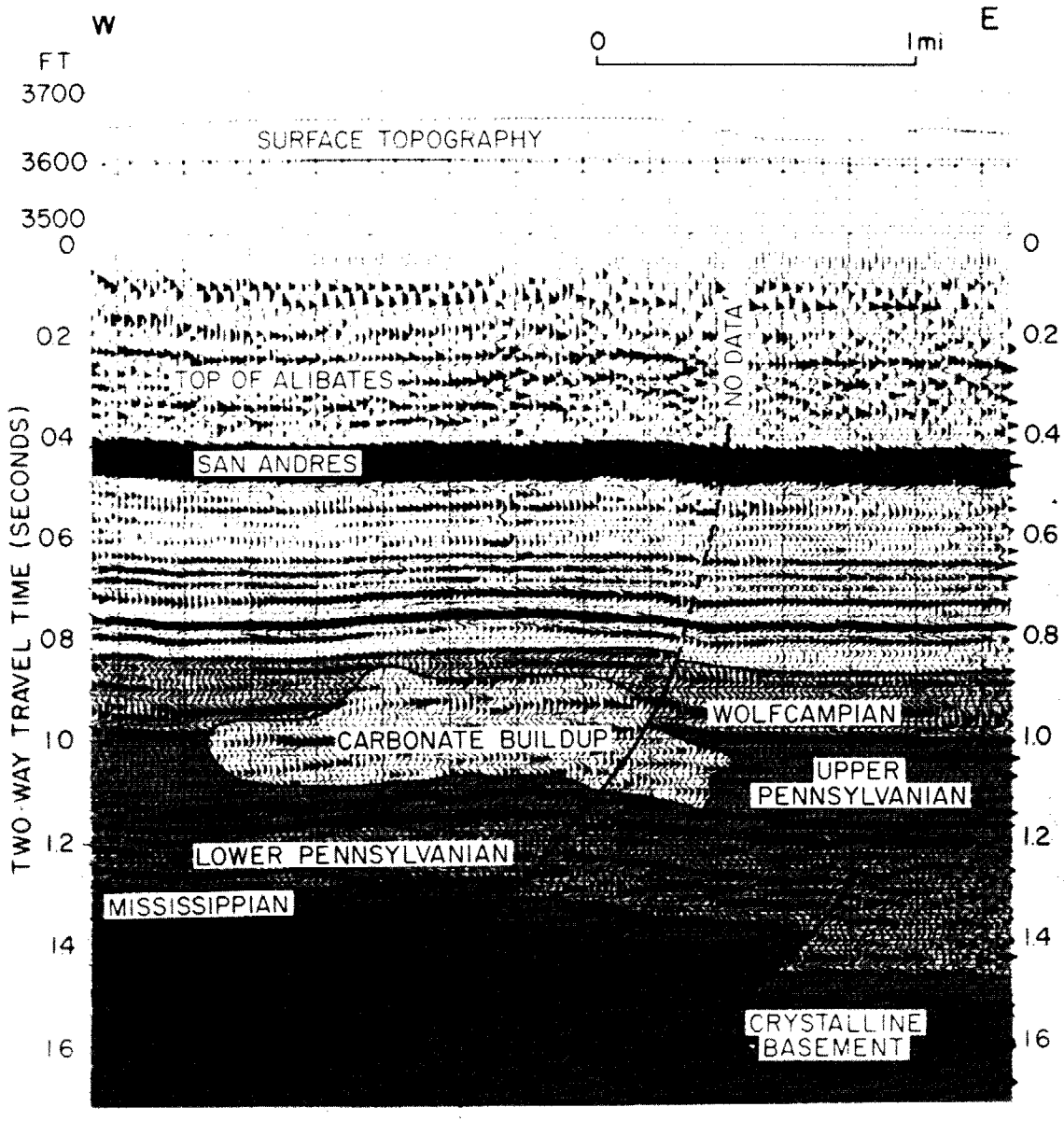


PROGRADATION OF PERMIAN SHELF MARGIN SOUTHERN TEXAS PANHANDLE

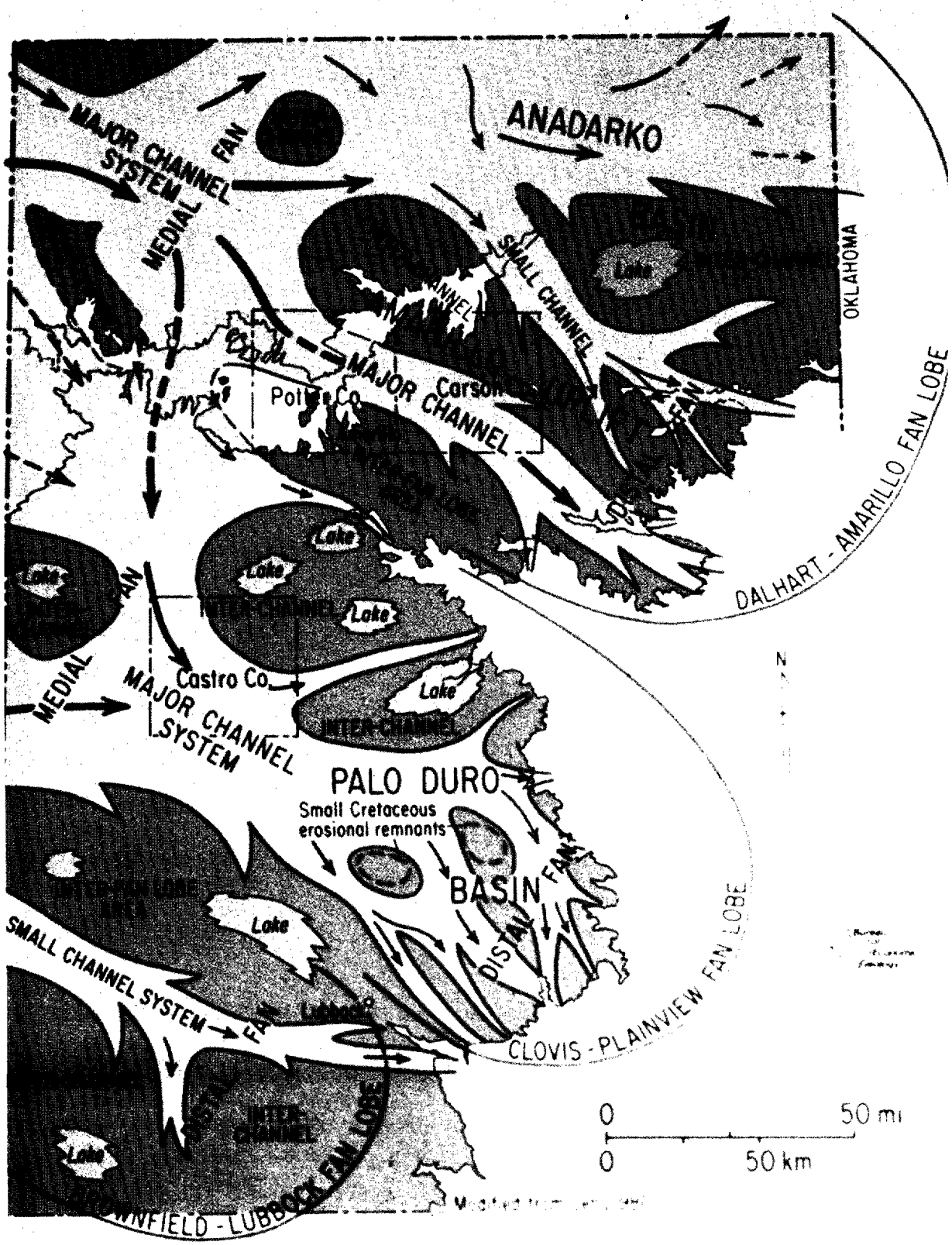


GENERALIZED LITHOFACIES - WICHITA GROUP

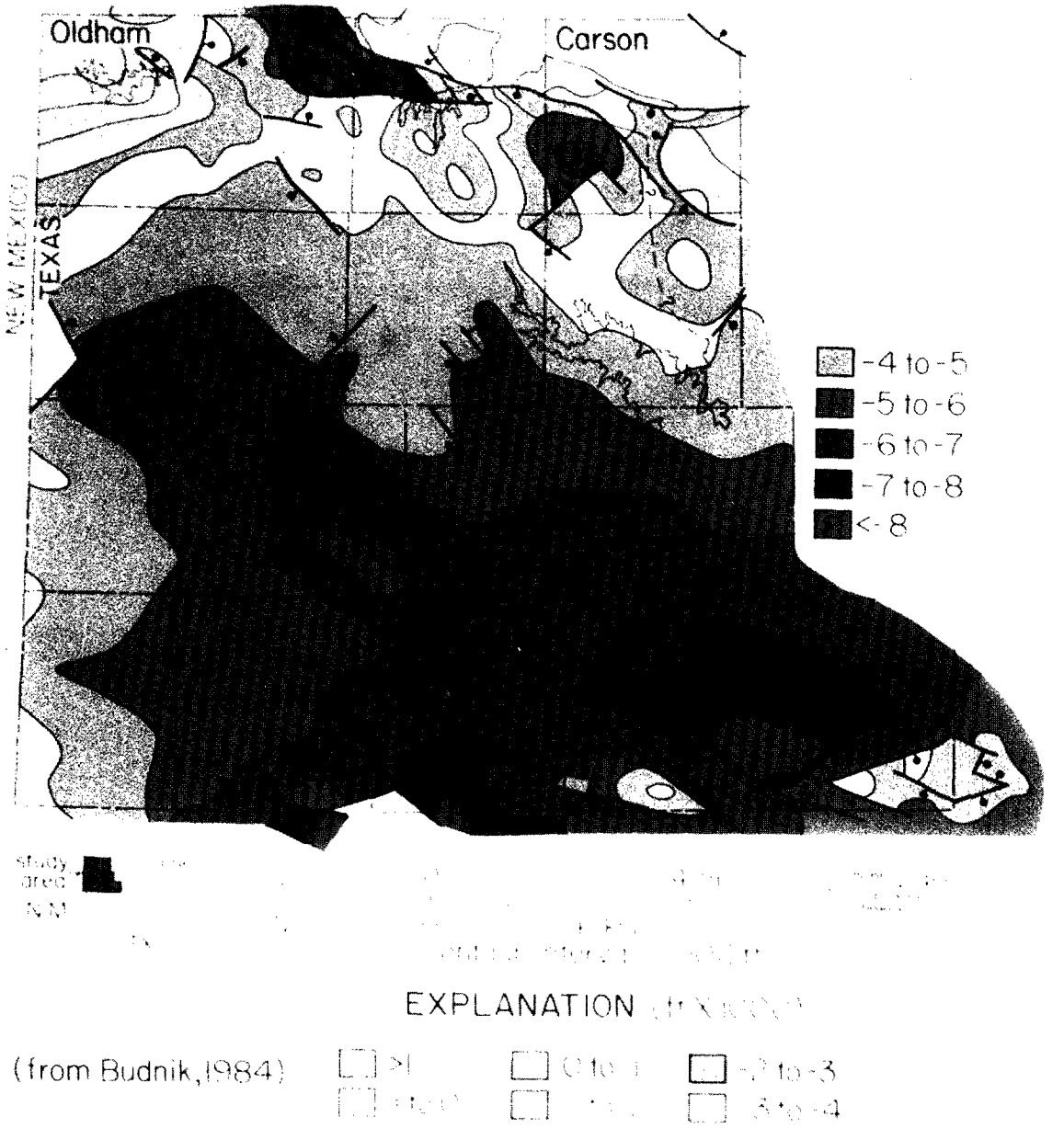



W
E
0
1 mi
FT
3700
3600
3500
SURFACE TOPOGRAPHY
TWO-WAY TRAVEL TIME (SECONDS)
0
02
04
06
08
10
1.2
14
16
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
TOP OF ALIBATES
NO DATA
SAN ANDRES
WOLFCAMPIAN
CARBONATE BUILDUP
UPPER PENNSYLVANIAN
LOWER PENNSYLVANIAN
MISSISSIPPIAN
CRYSTALLINE BASEMENT

DEPOSITIONAL PATTERNS OF OGALLALA FM

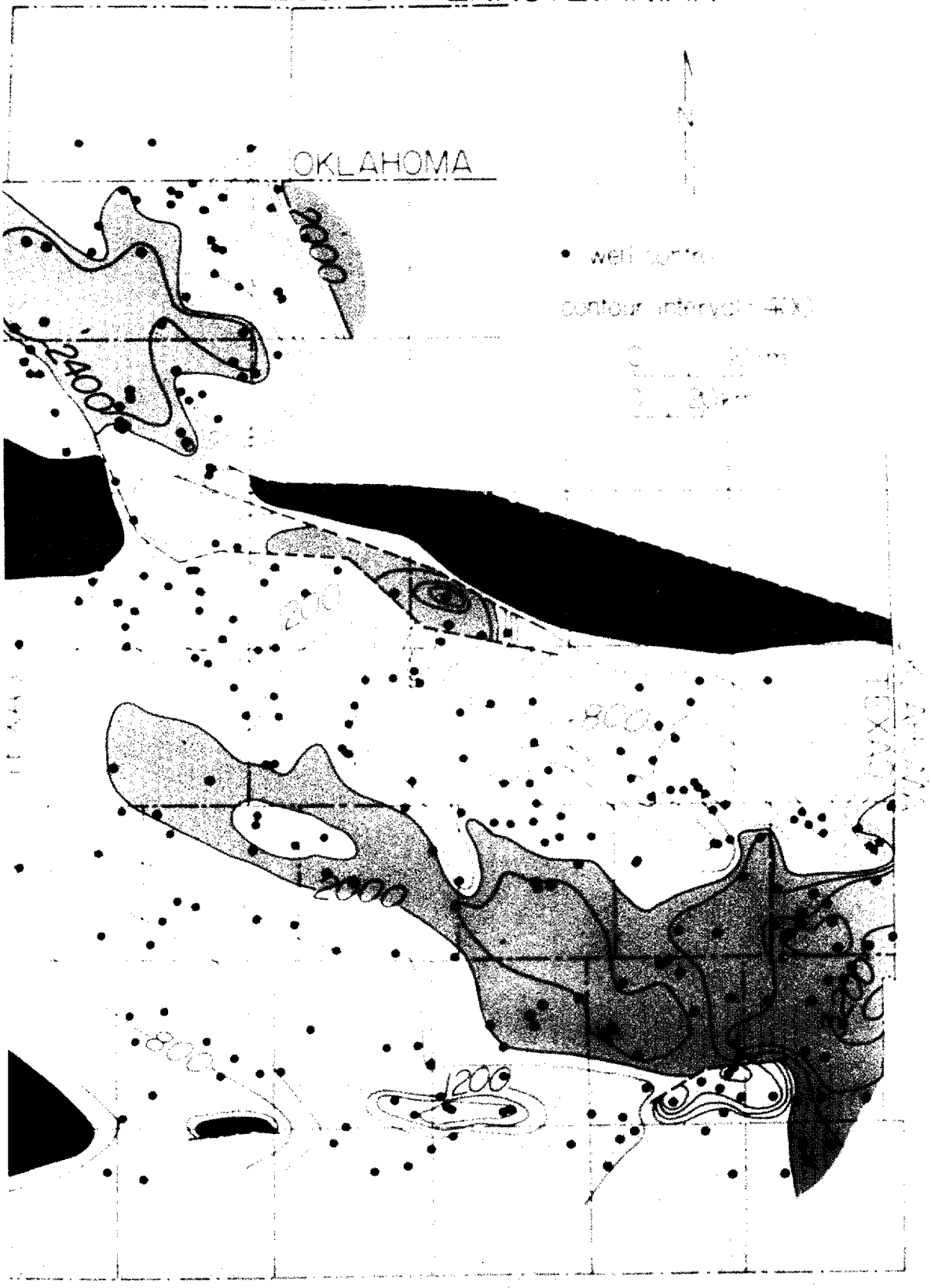


SIMPLIFIED BASEMENT STRUCTURE

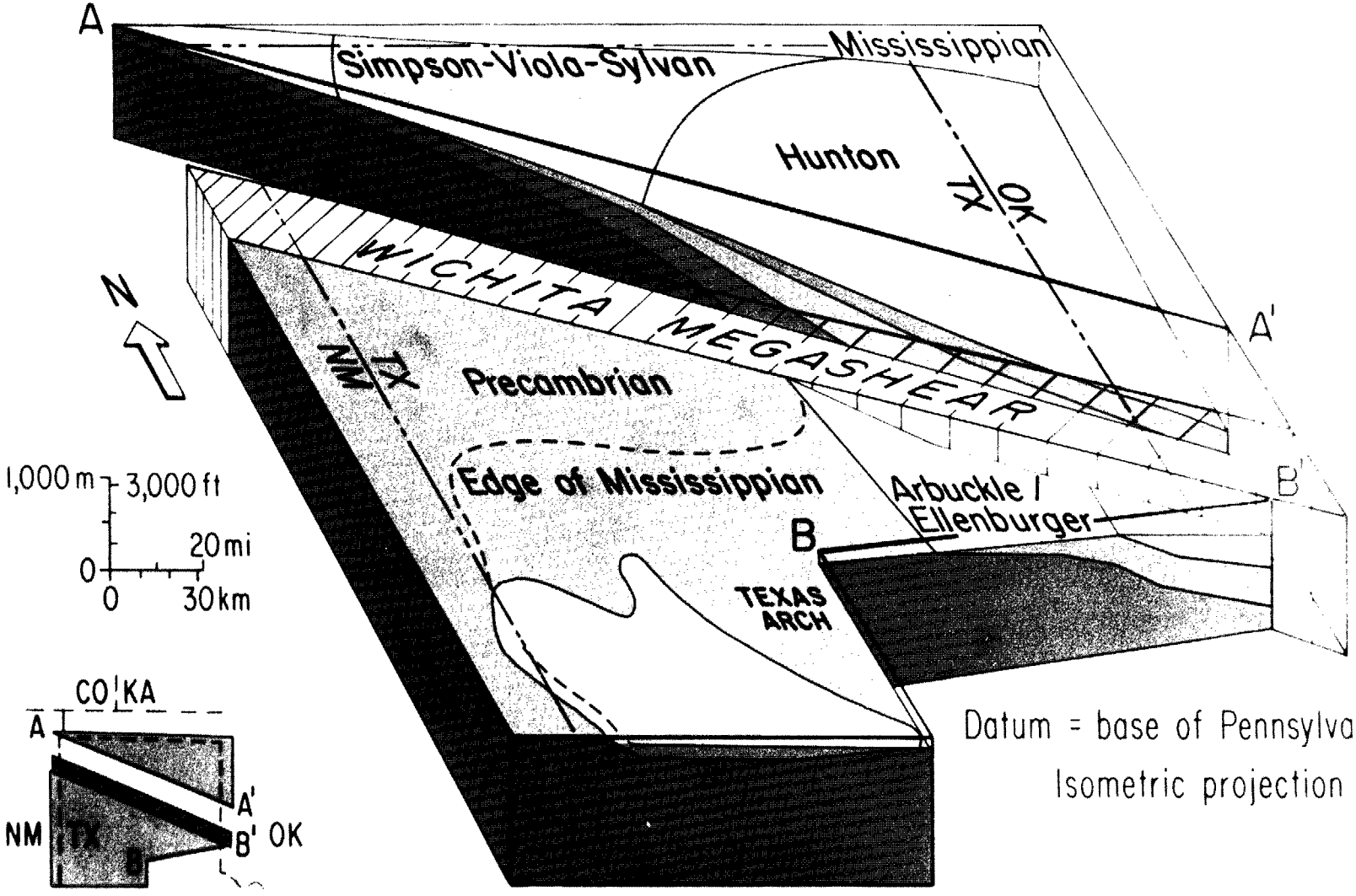


(from Budnik, 1984)

THICKNESS OF PENNSYLVANIAN



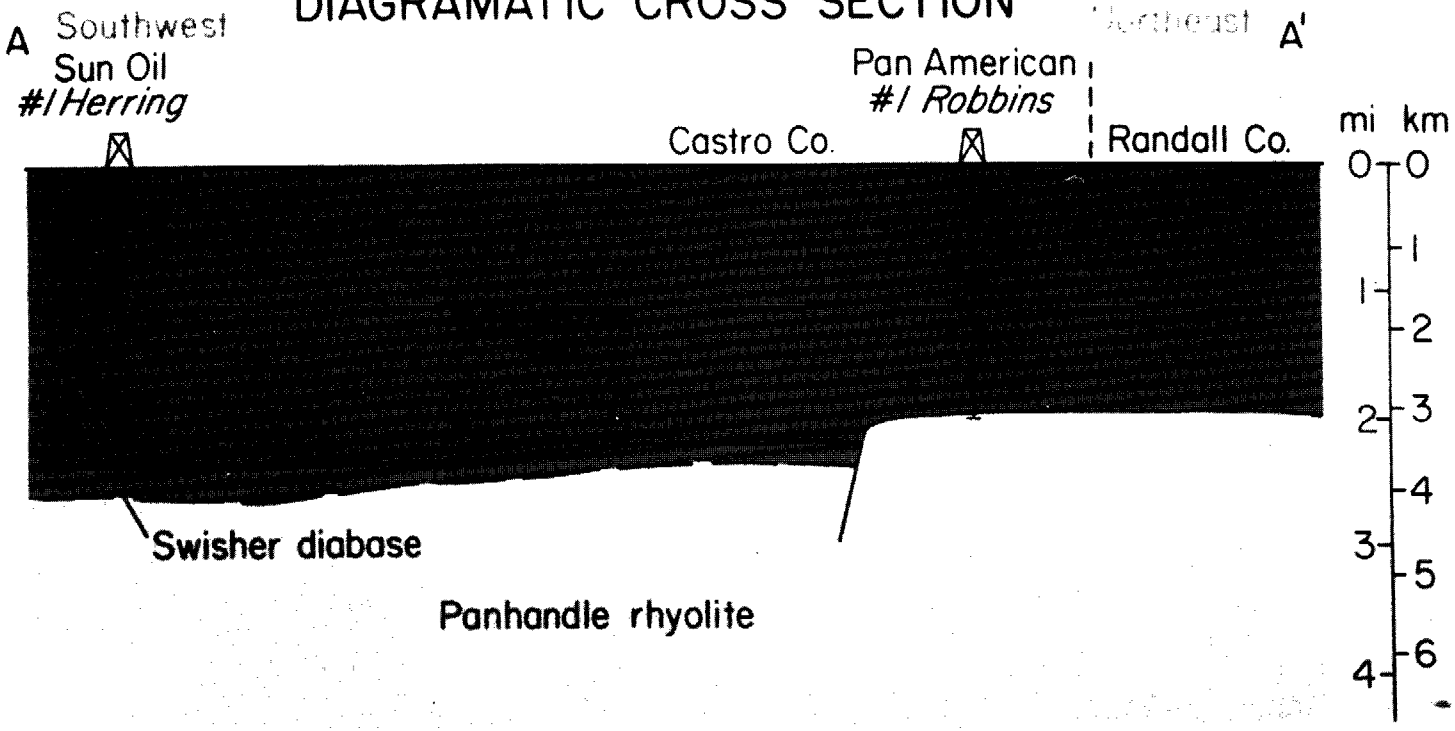
Schematic block diagram of the Texas Panhandle

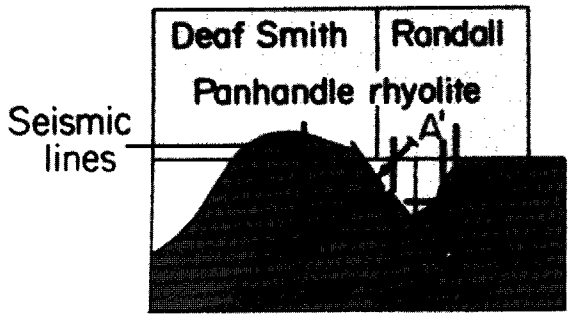


Datum = base of Pennsylvanian

Isometric projection

DIAGRAMATIC CROSS SECTION





0 10 mi
0 10 km

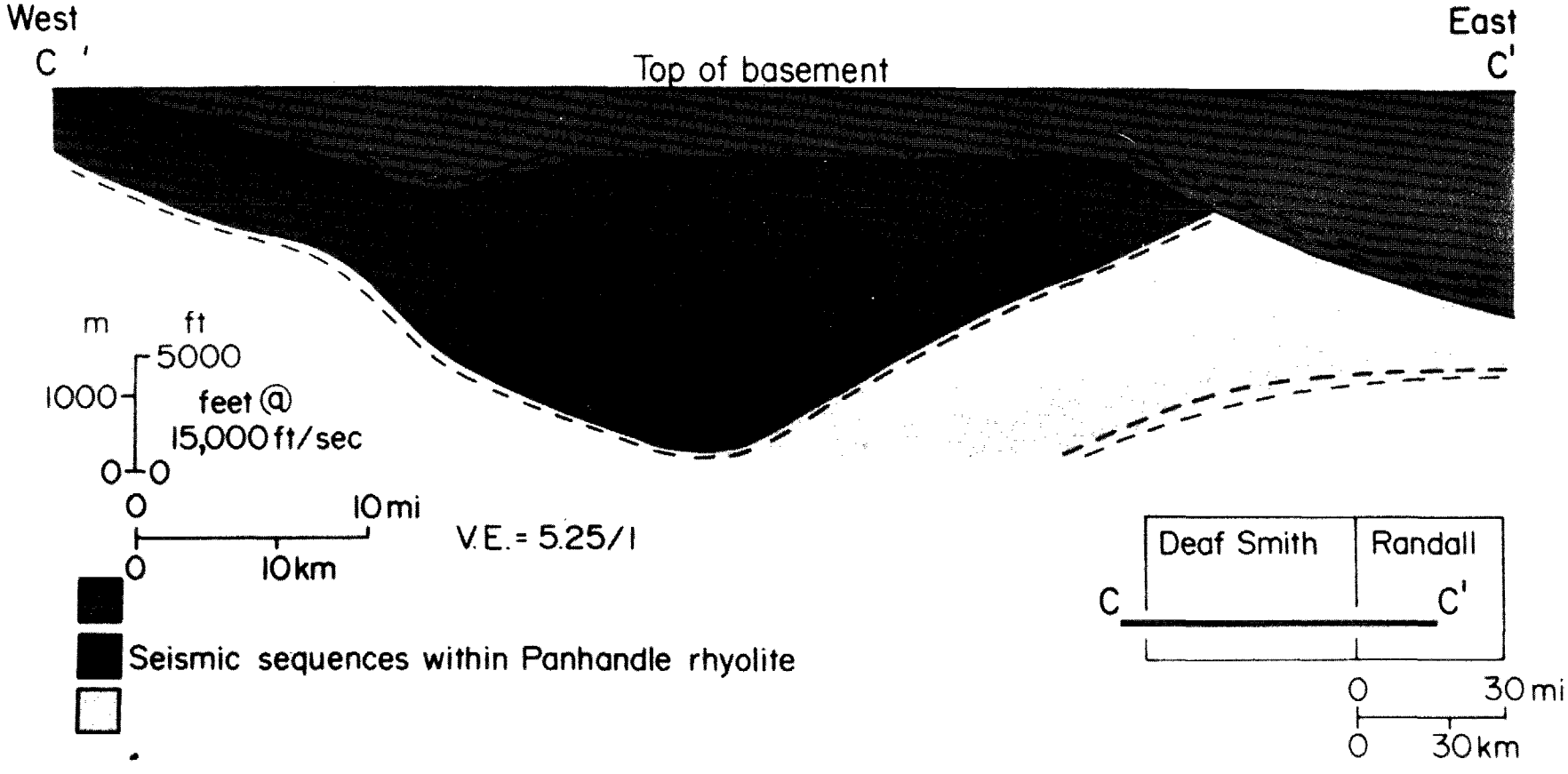
V.E. = 3.4 to 1
@ 15,000 ft/sec.

0 30 mi
0 50 km

Bureau of Economic Geology

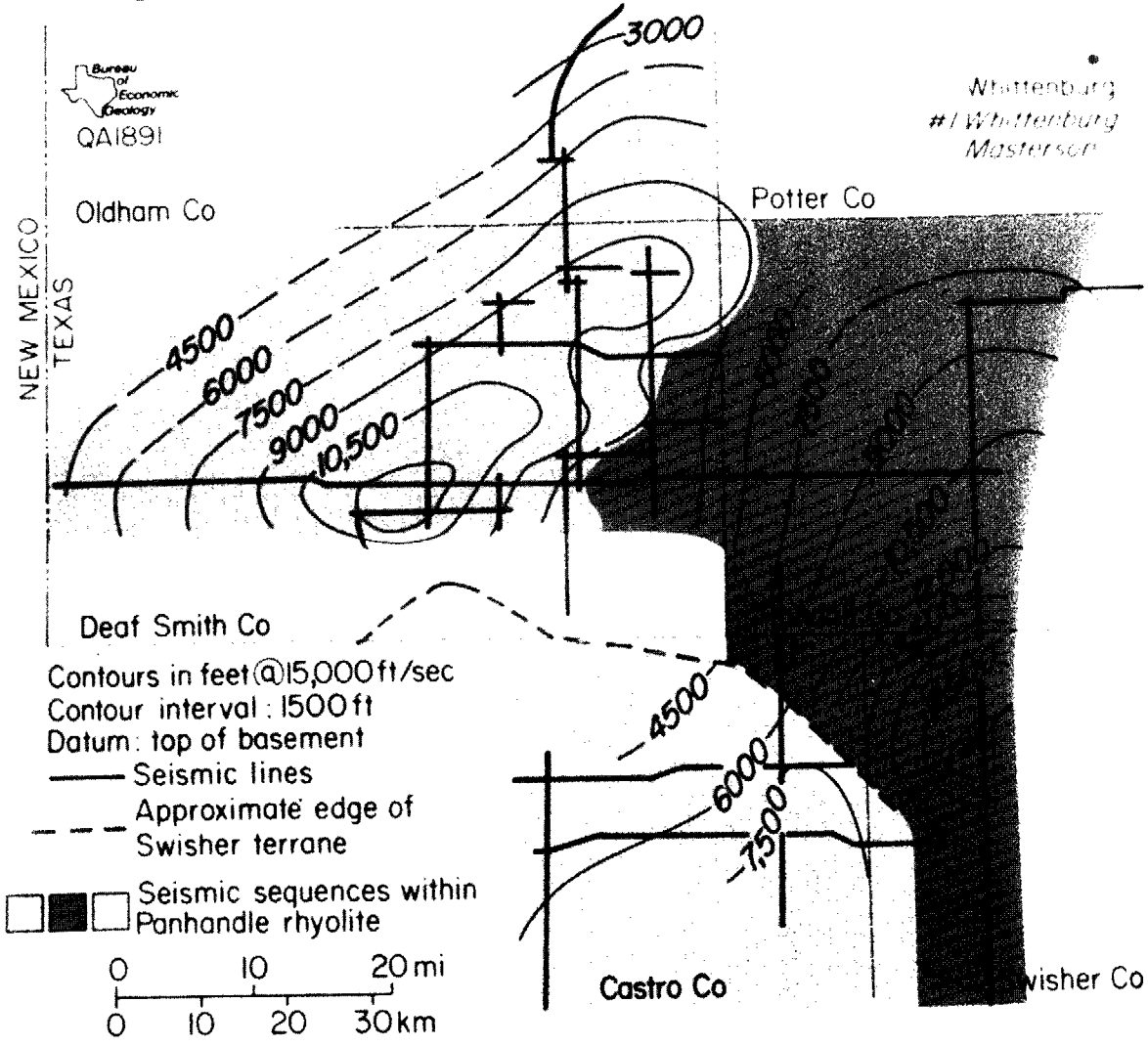
QA1893

SEISMIC-DERIVED CROSS-SECTION

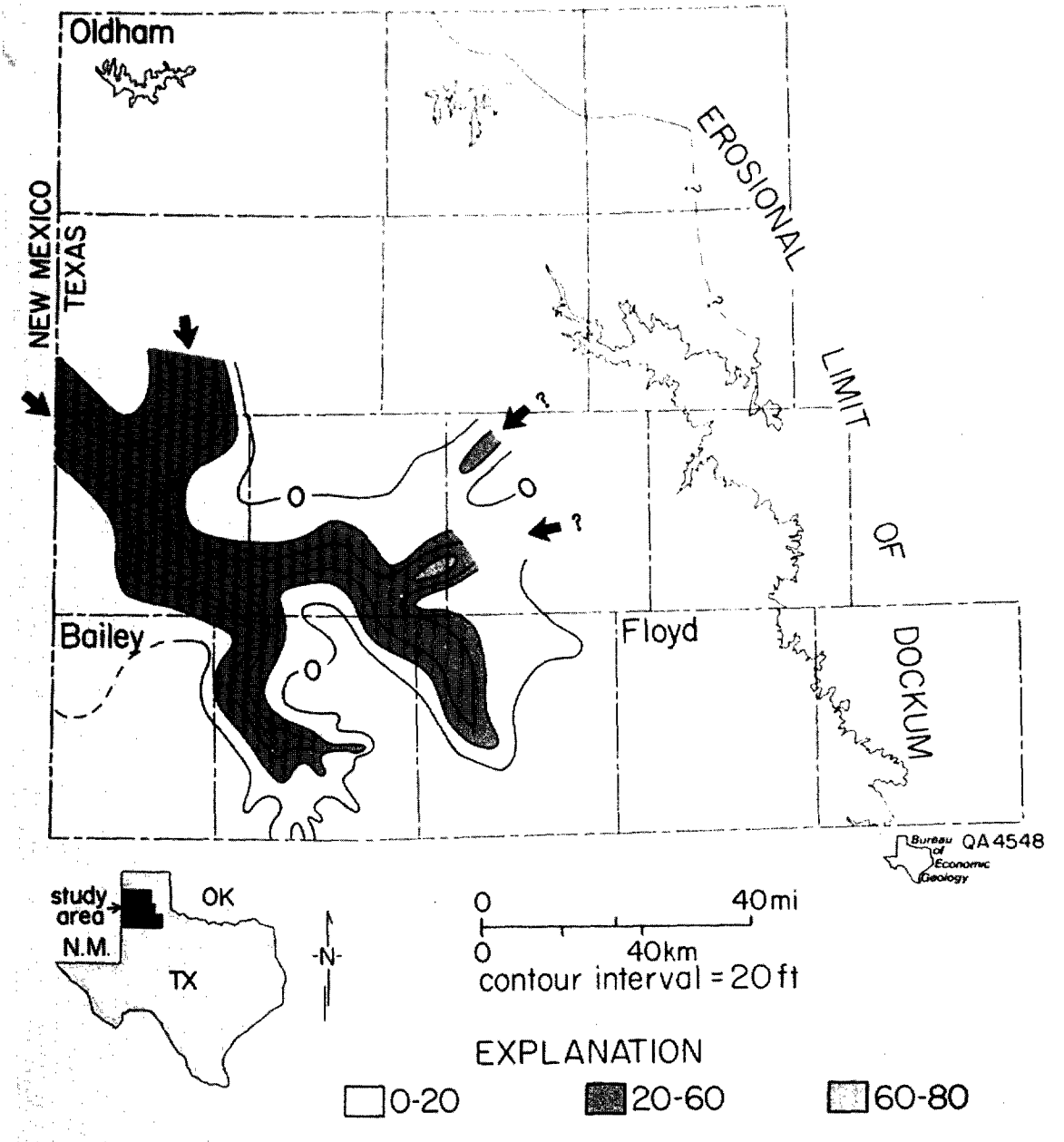


Bureau of Economic Geology QA1895

STRUCTURE ON BASE OF SEISMIC SEQUENCES



NET SANDSTONE PACKAGE NO. 4



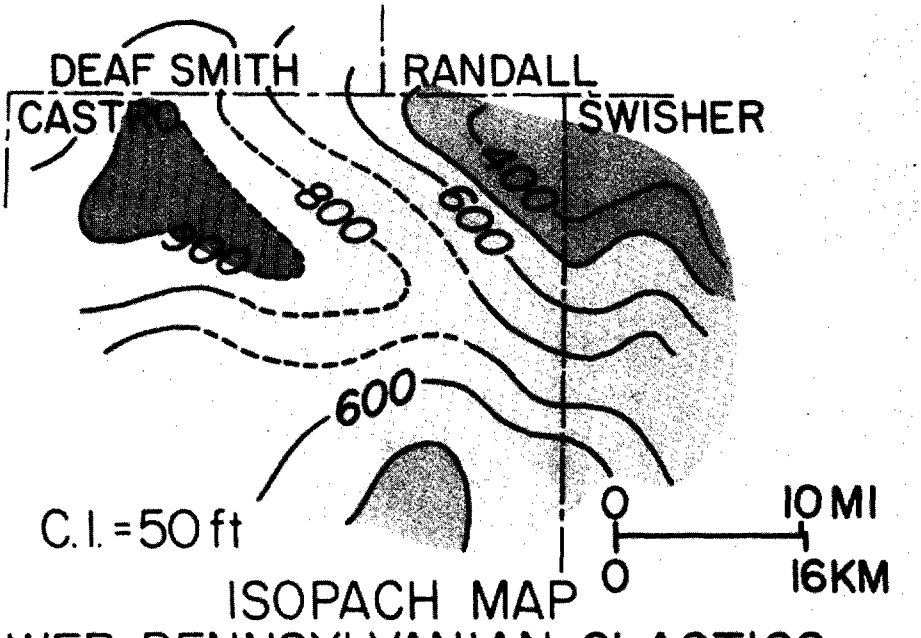
STRUCTURE CONTOUR
BASE OF DOCKUM GROUP

< 2000
2000-2300
2300-2600
2600-2900
2900-3200
> 3200

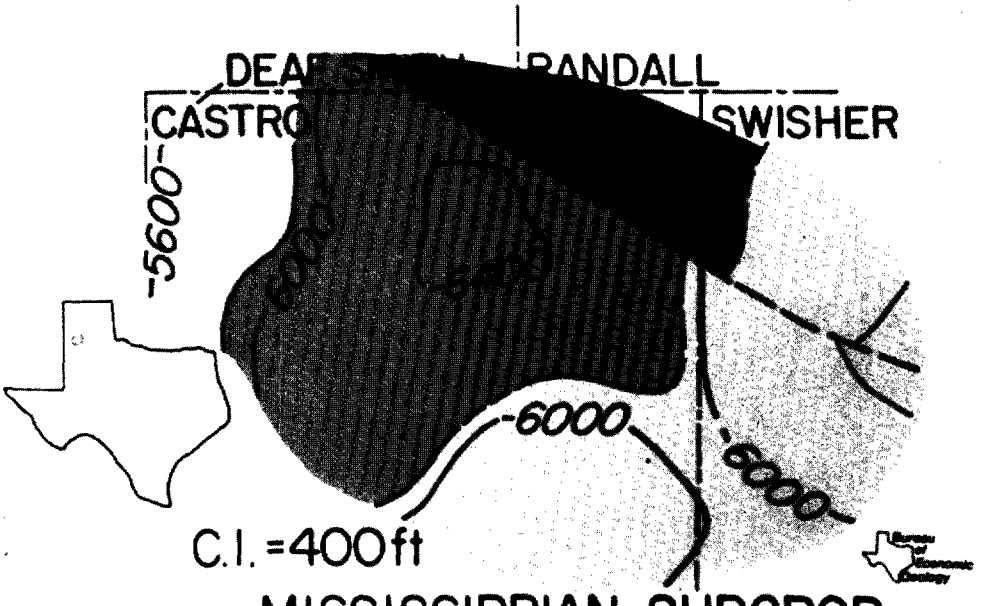
0 40 mi
0 40 km

Contour interval = 100 ft

CASTRO TROUGH



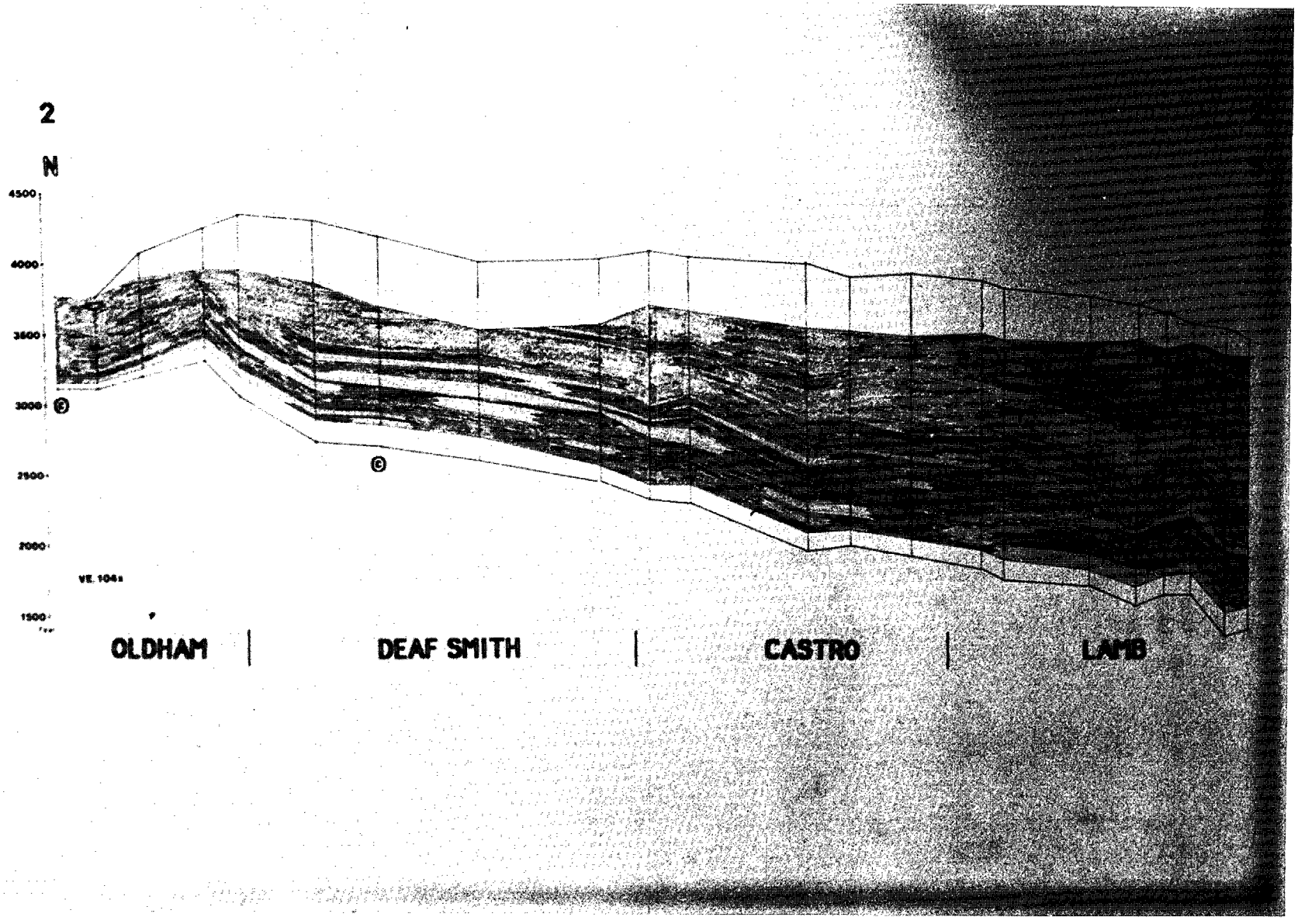
ISOPACH MAP
LOWER PENNSYLVANIAN CLASTICS



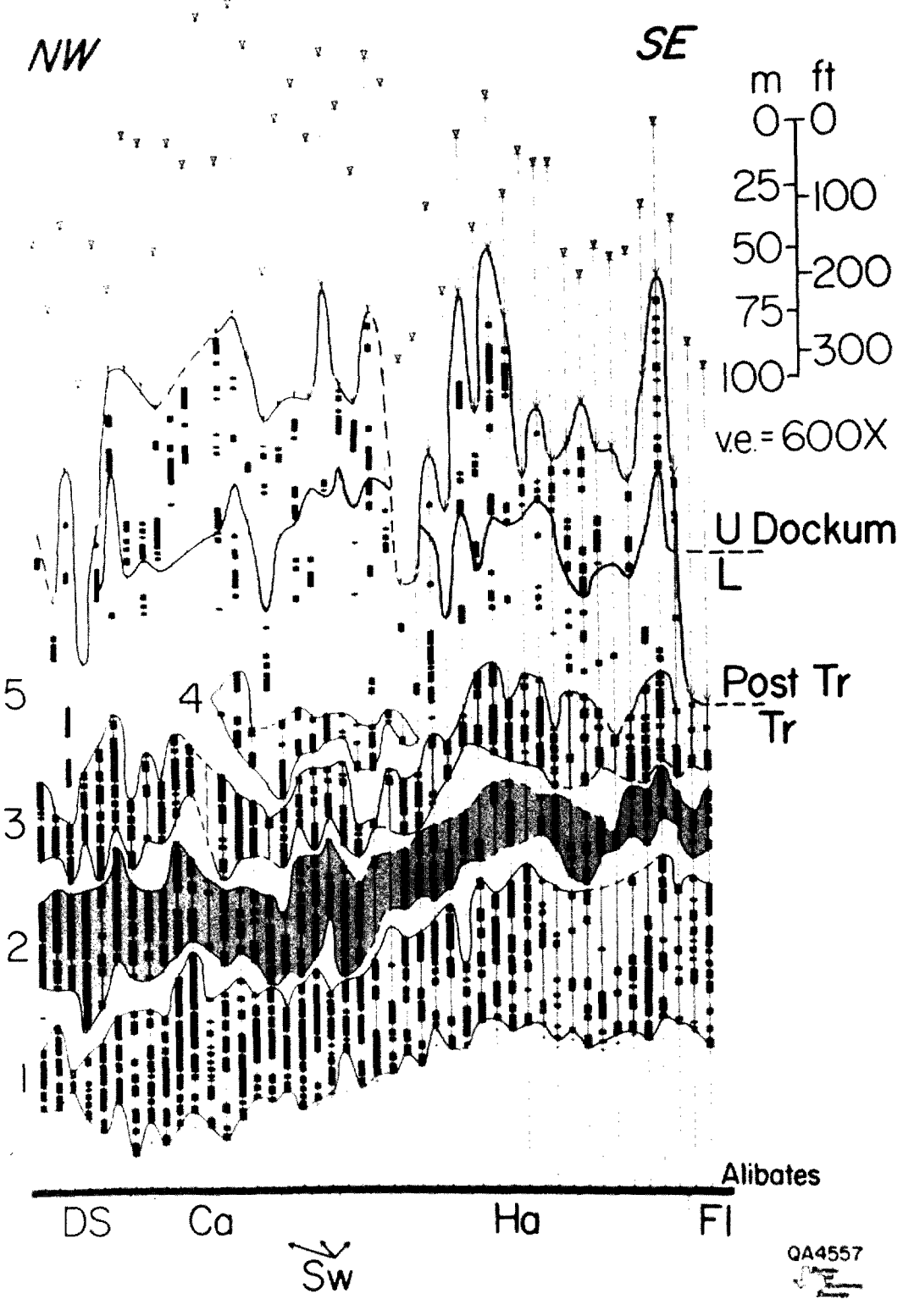
MISSISSIPPIAN SUBCROP
AND BASEMENT STRUCTURE

M on Ellenberger
M on basement
IP on basement

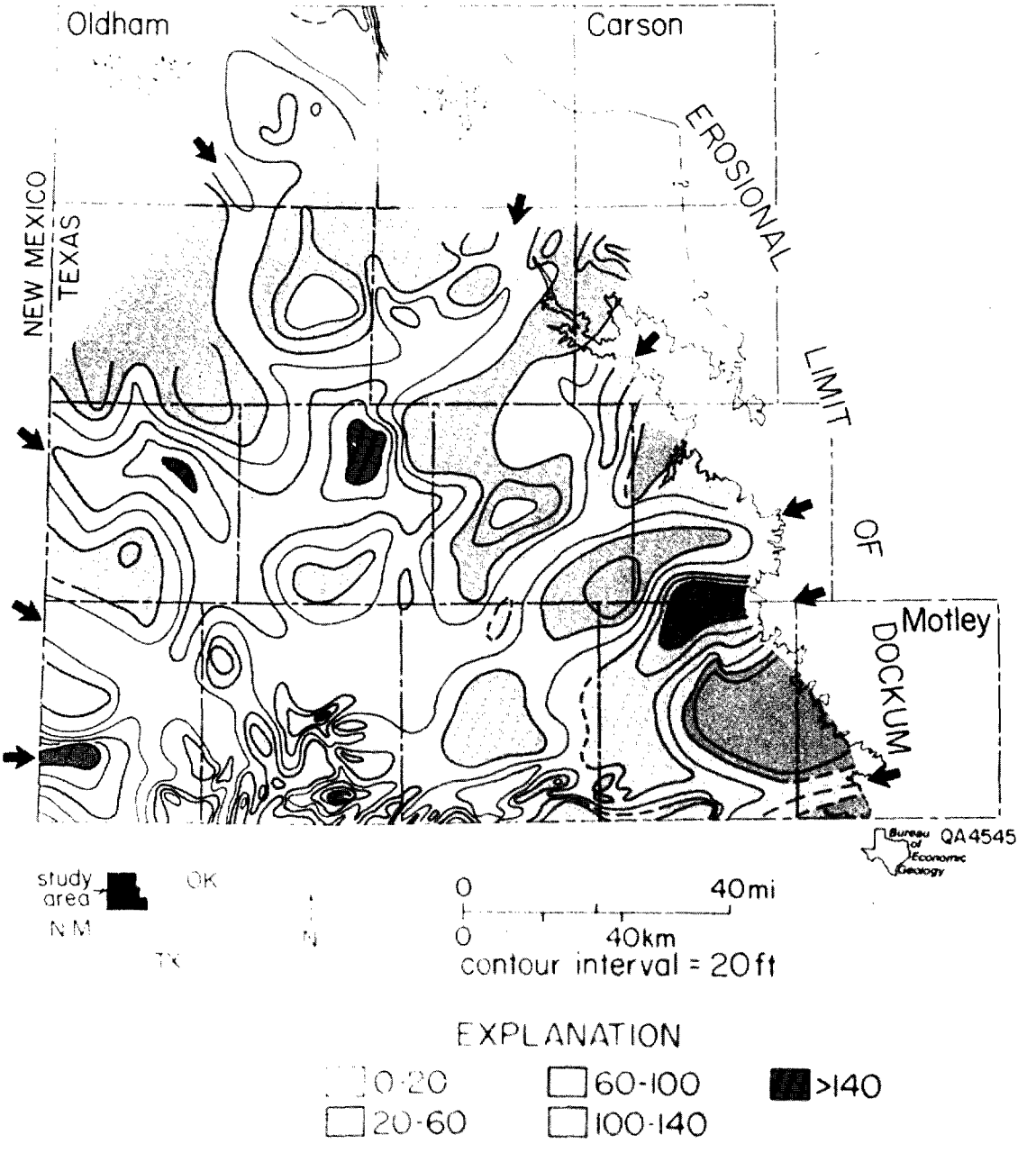
QA578


2
N
4500
4000
3500
3000
2500
2000
1500
VE. 104x
OLDHAM
DEAF SMITH
CASTRO
LAMB

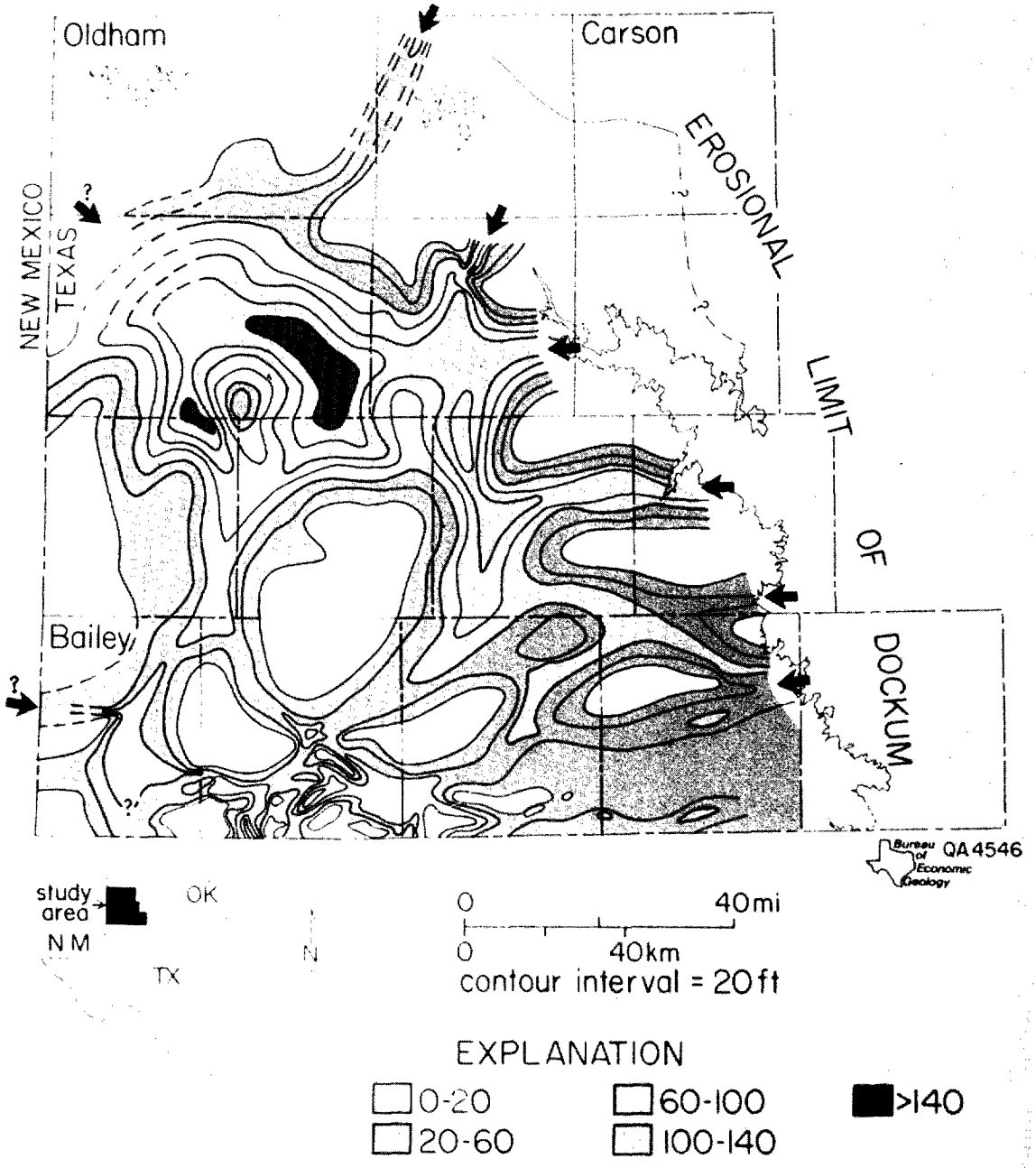
Composite Cross Section



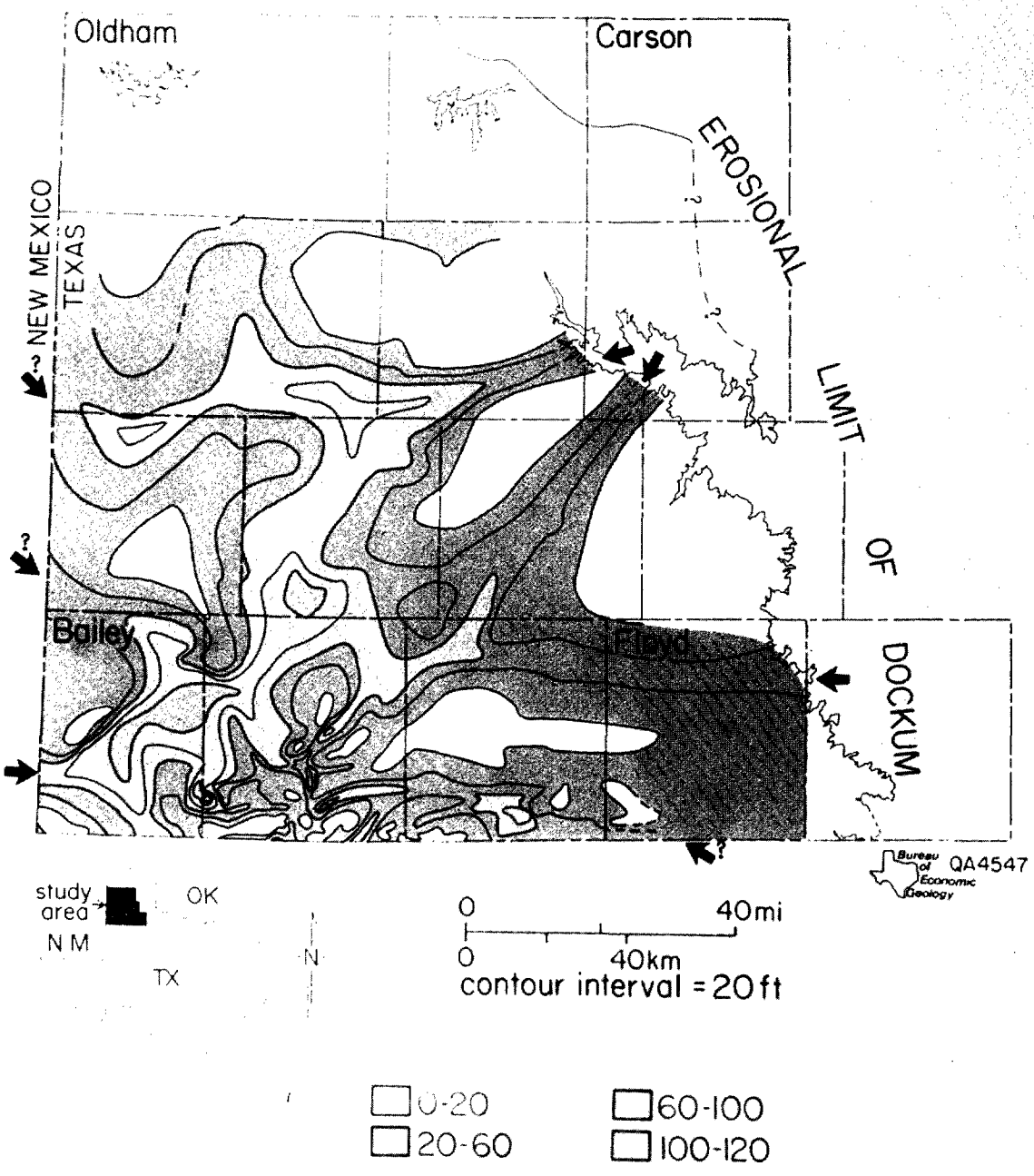
NET SANDSTONE PACKAGE NO.1



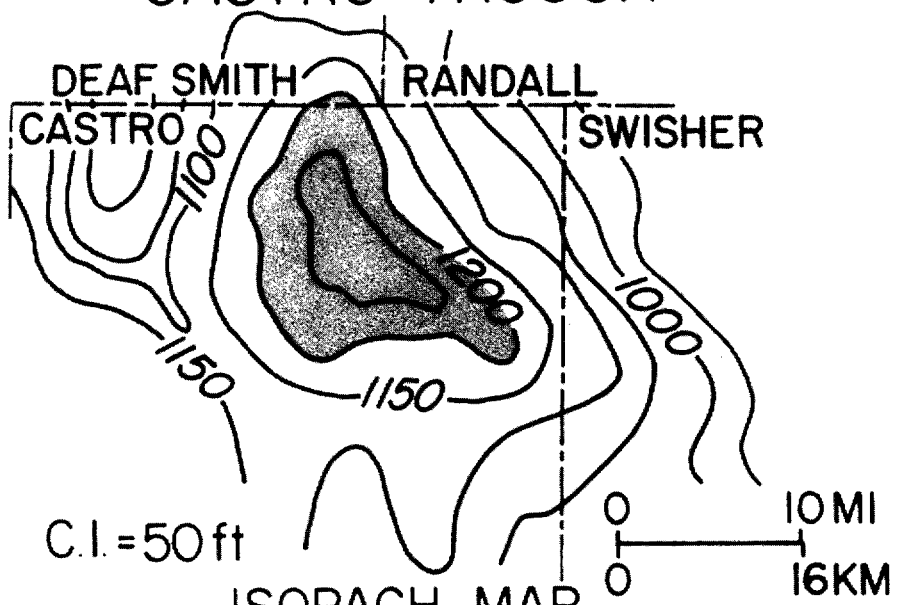
NET SANDSTONE PACKAGE NO.2



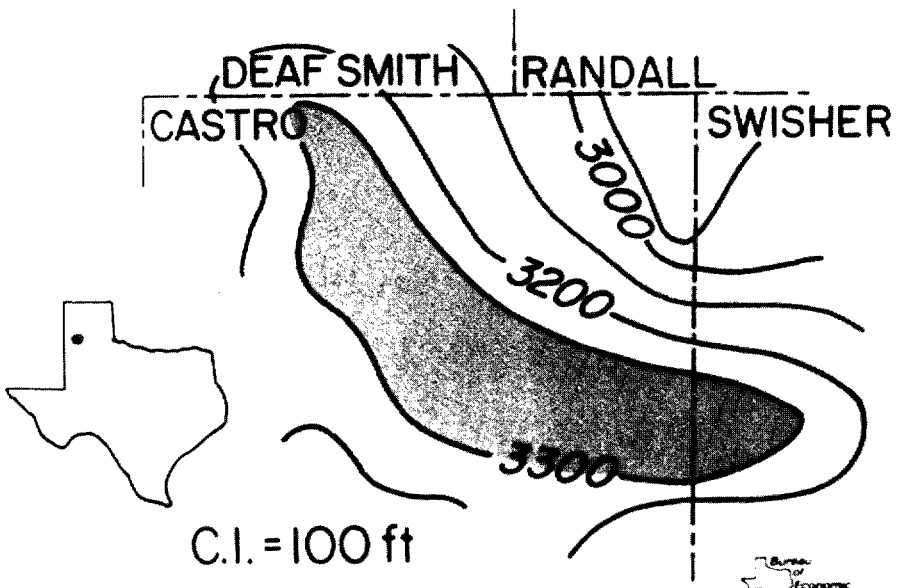
NET SANDSTONE PACKAGE NO.3



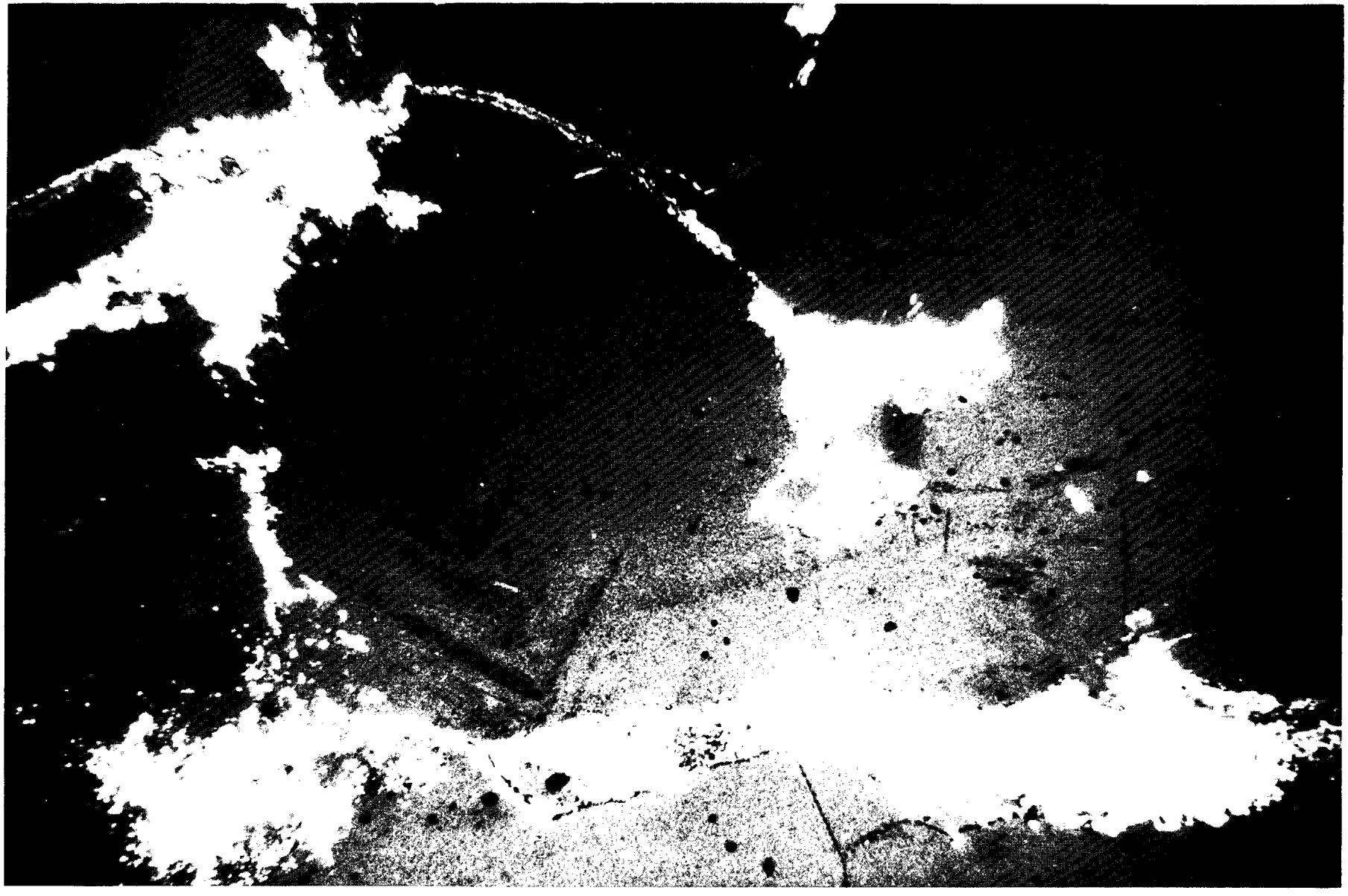
CASTRO TROUGH

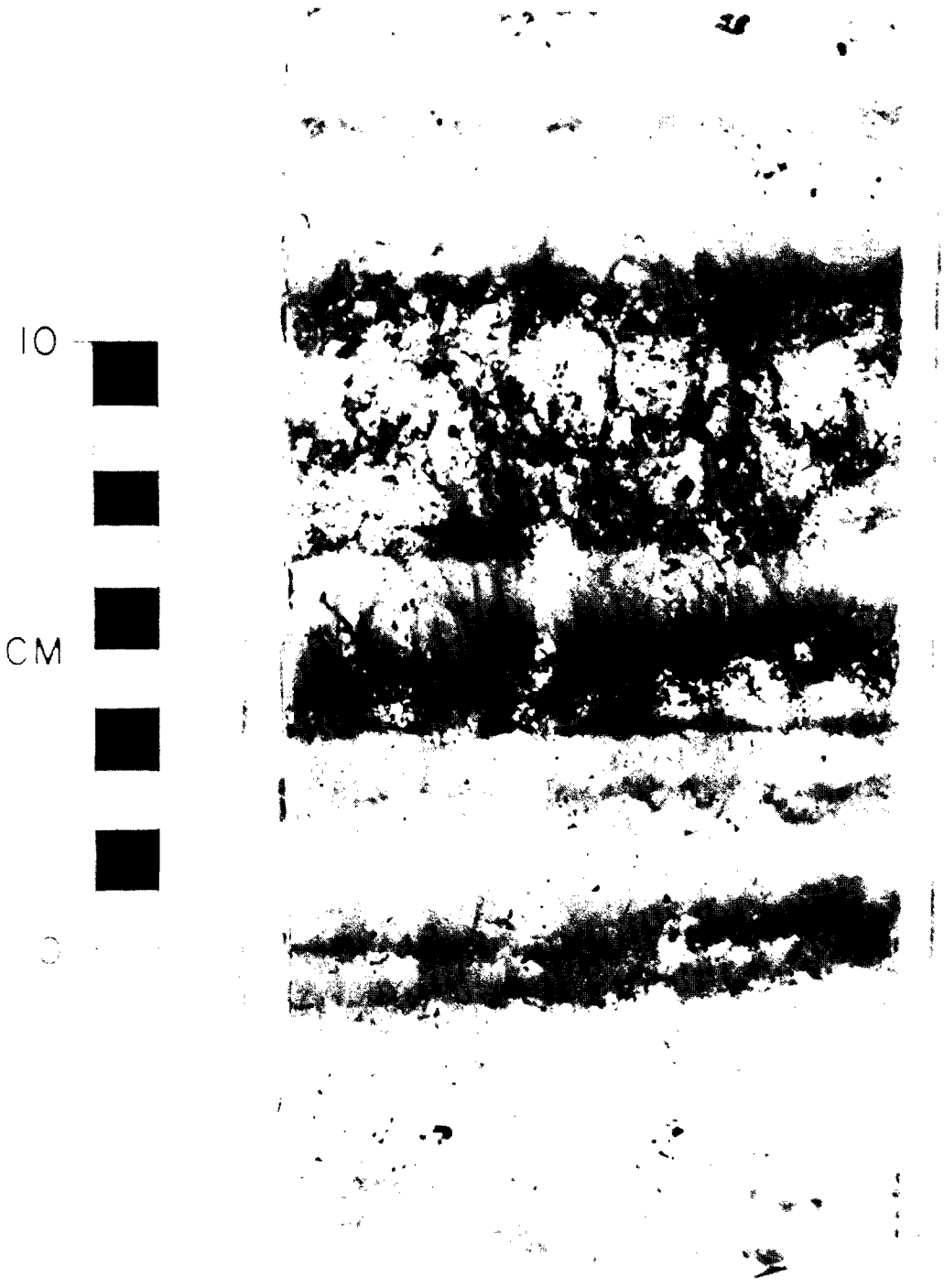


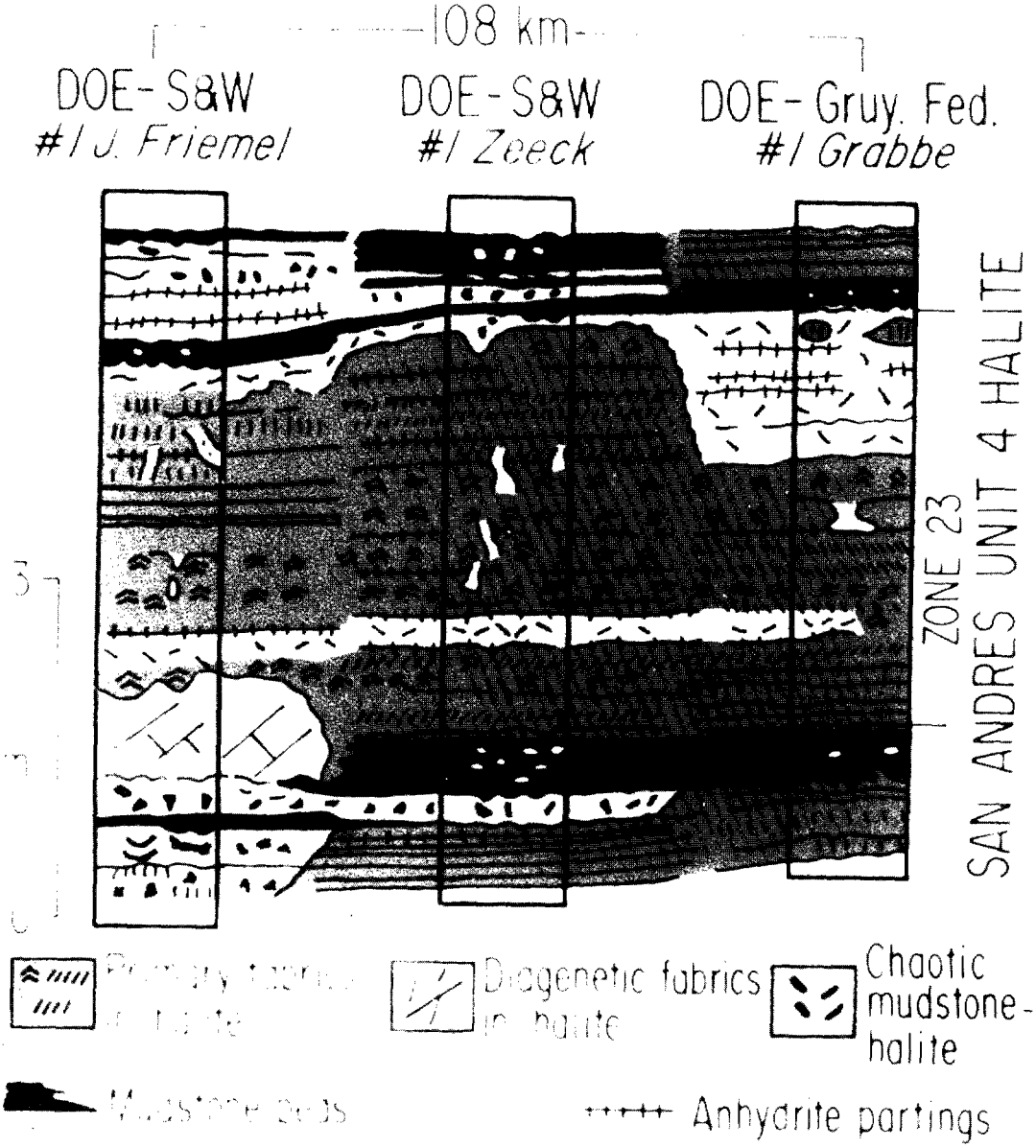
ISOPACH MAP
UPPERMOST PERMIAN-UPPER TRIASSIC
Top of Alibates to base of Ogallala

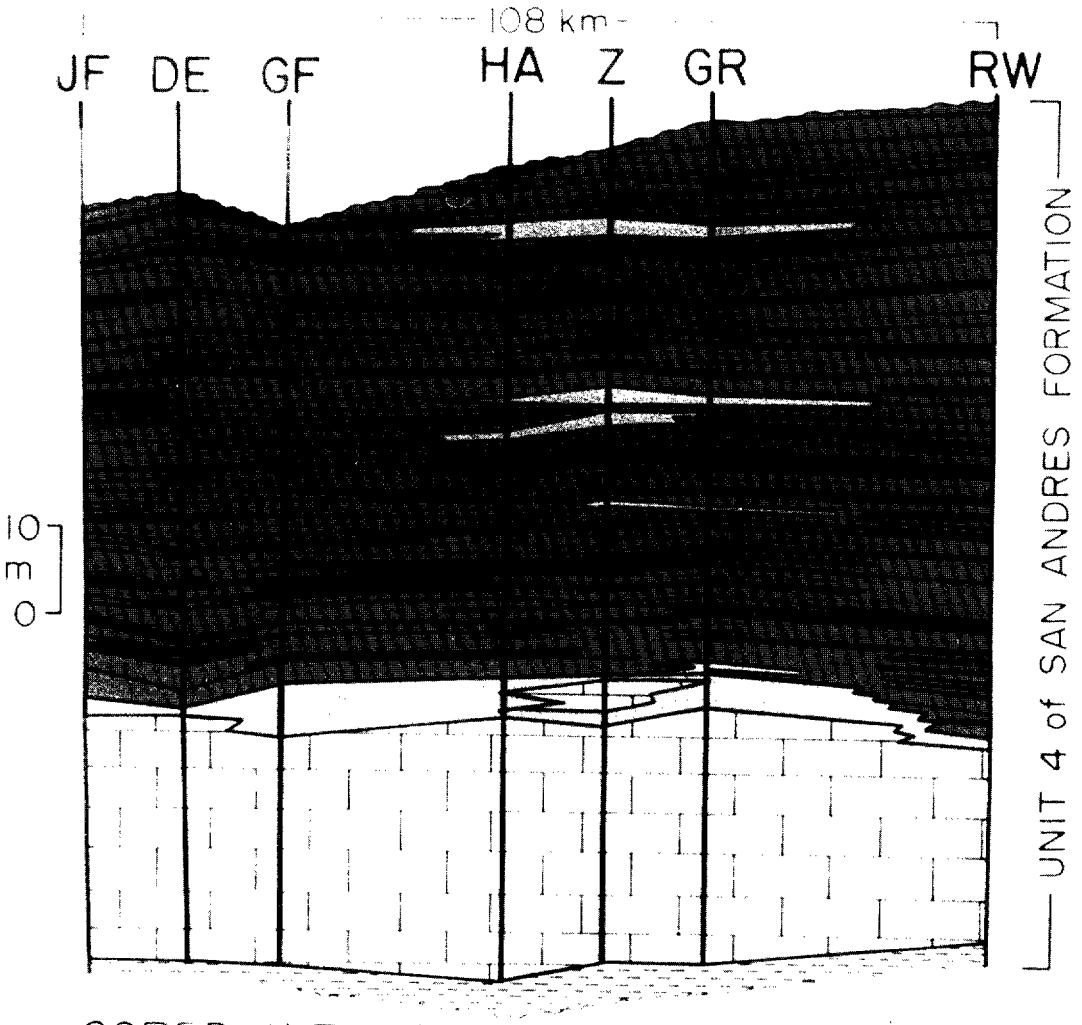


ISOPACH MAP
MIDDLE AND UPPER PERMIAN
Top of Tubb to top of Alibates




10
CM
0


108 km
DOE-S&W
#1 J. Friemel
DOE-S&W
#1 Zeeck
DOE-Gruy. Fed.
#1 Grabbe
SAN ANDRES UNIT 4 HALITE
ZONE 23
Diagenetic fabrics in halite
Chaotic mudstone-halite
Anhydrite partings



CORED WELLS:

RW = Rex White, **GR** = Grabbe, **Z** = Zeeck, **HA** = Harman, **GF** = G. Friemel, **DE** = Detten, **J.F** = J. Friemel

Anhydritic halite

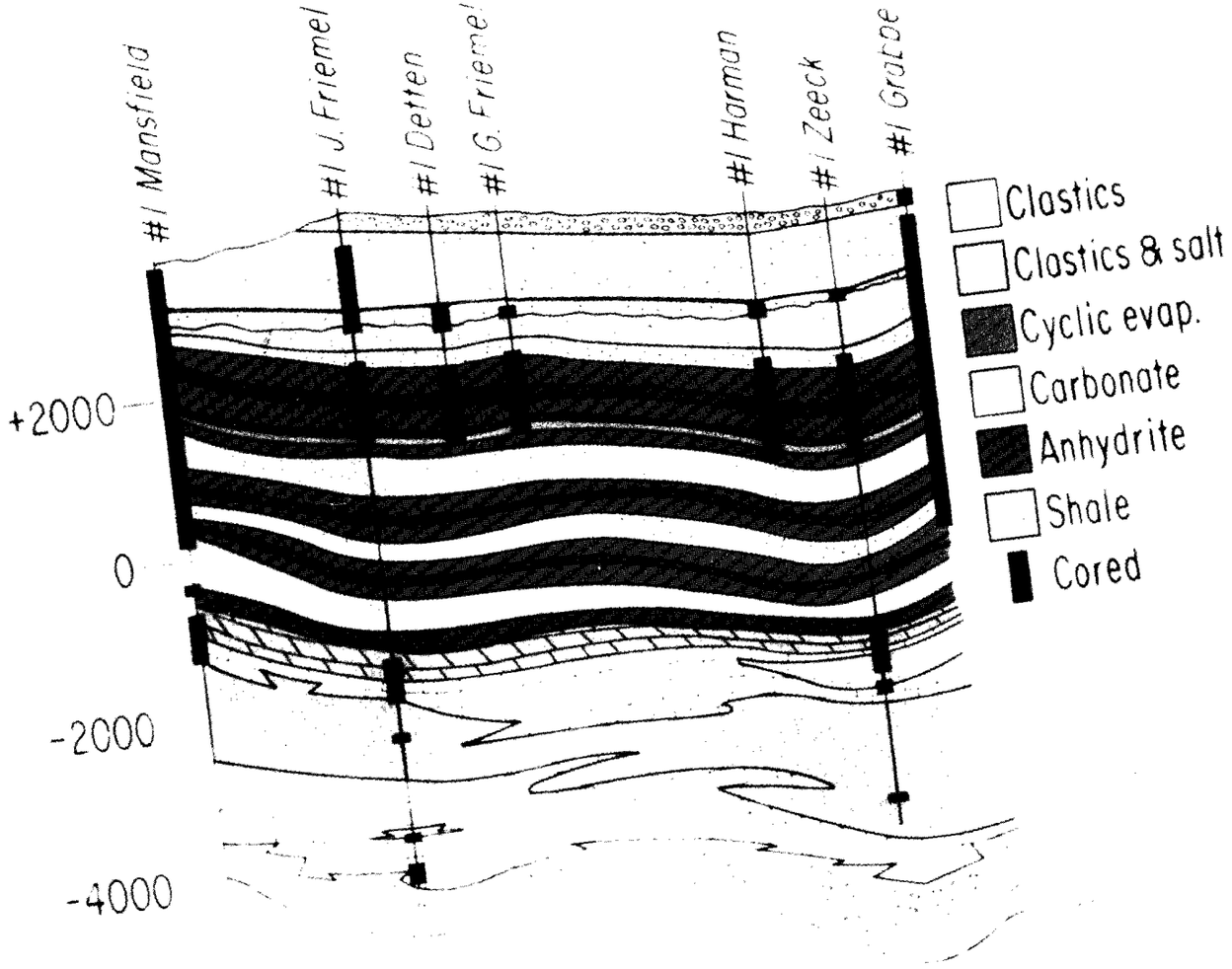
Muddy halite

Mudstone

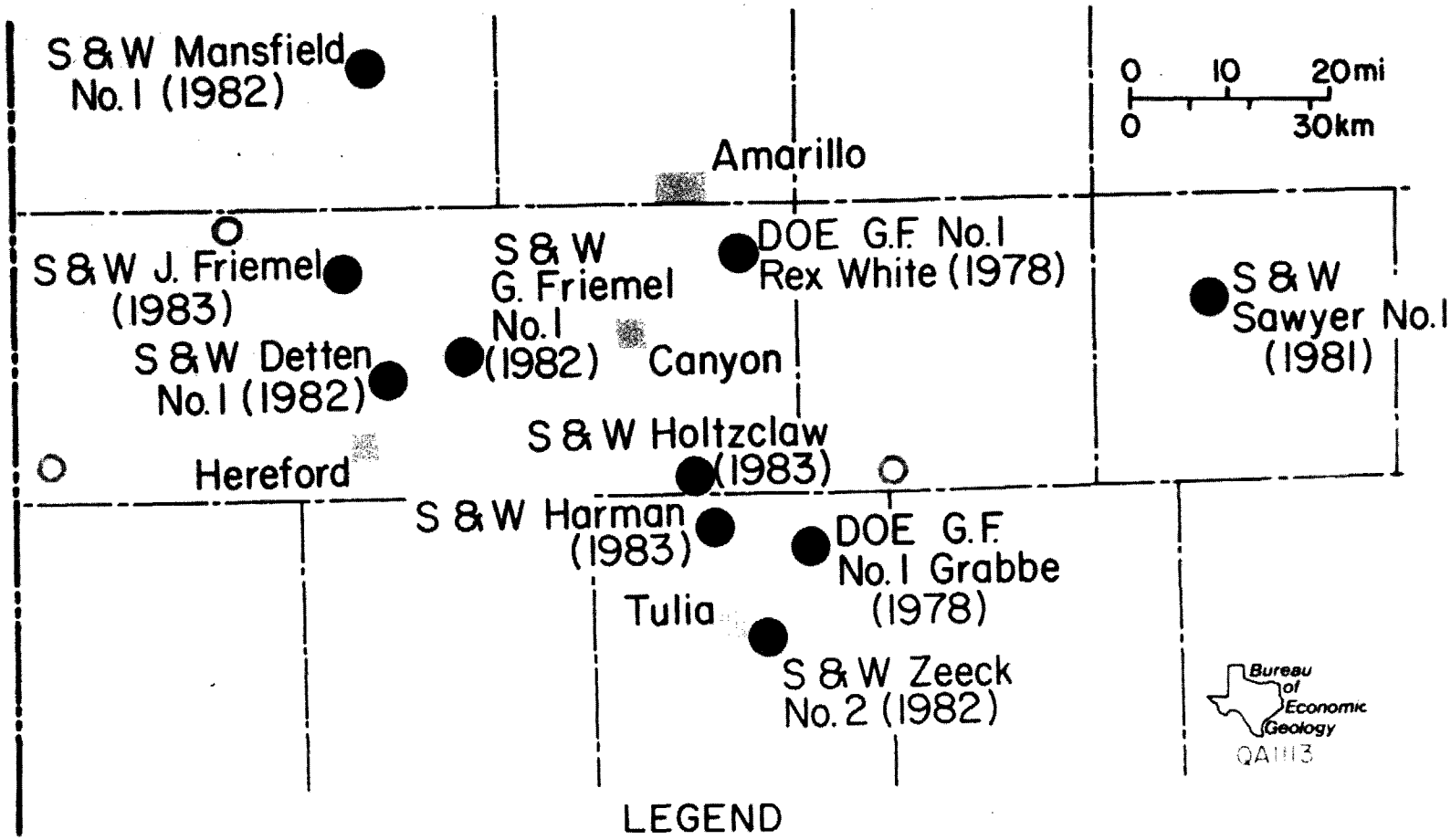
Anhydrite

Carbonate

GLORIETA-
FLOWERPOT
BLAINE
WHITEHORSE
N
131 miles
GLORIETA
SAN ANDRES
QUEEN-
GRAYBURG
S


#1 Mansfield
#1 J. Friemel
#1 Detten
#1 G. Friemel
#1 Harman
#1 Zeeck
#1 Grabbe
+2000
0
-2000
-4000
Clastics
Clastics & salt
Cyclic evap.
Carbonate
Anhydrite
Shale
Cored

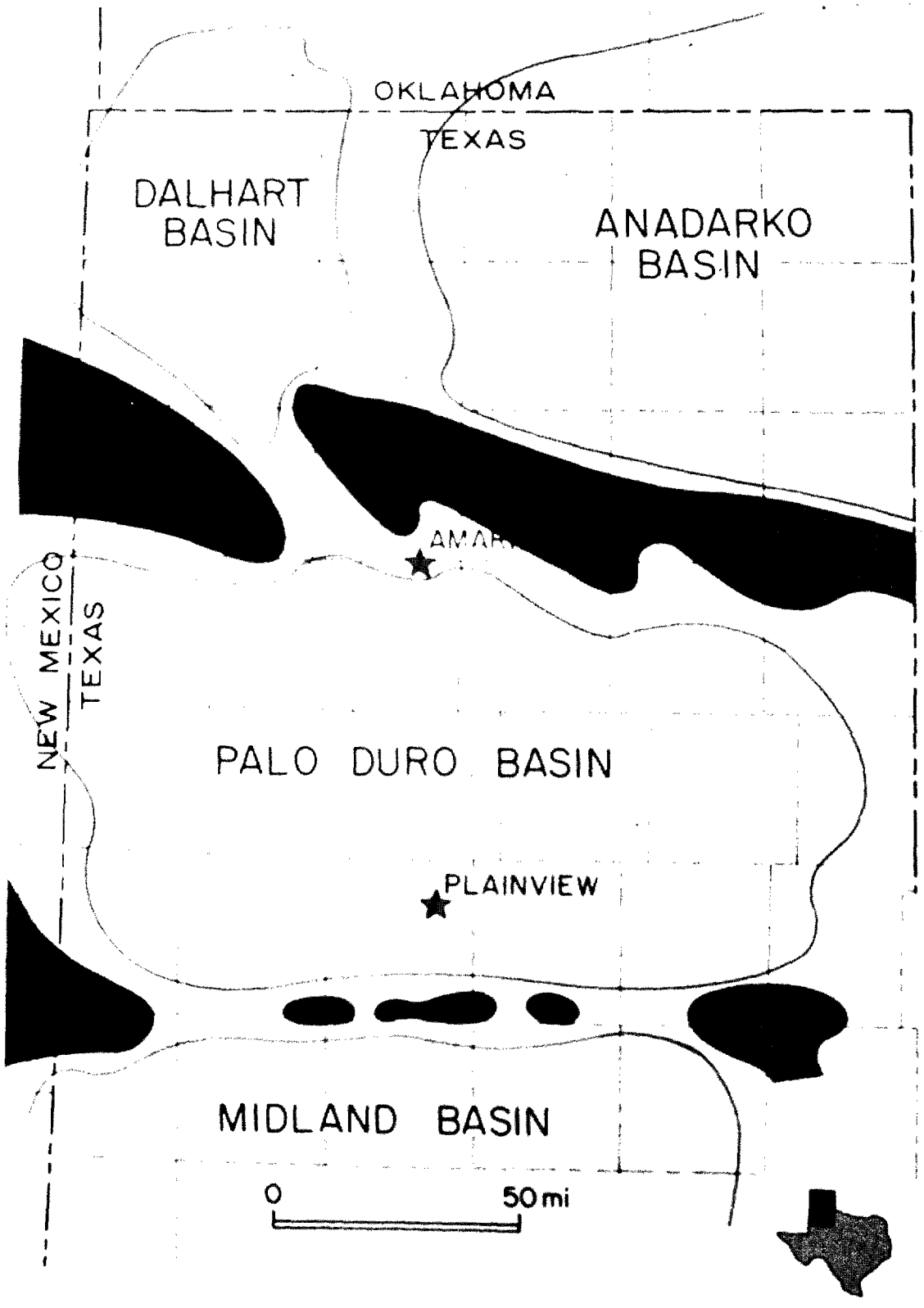
NWTS TEST WELLS



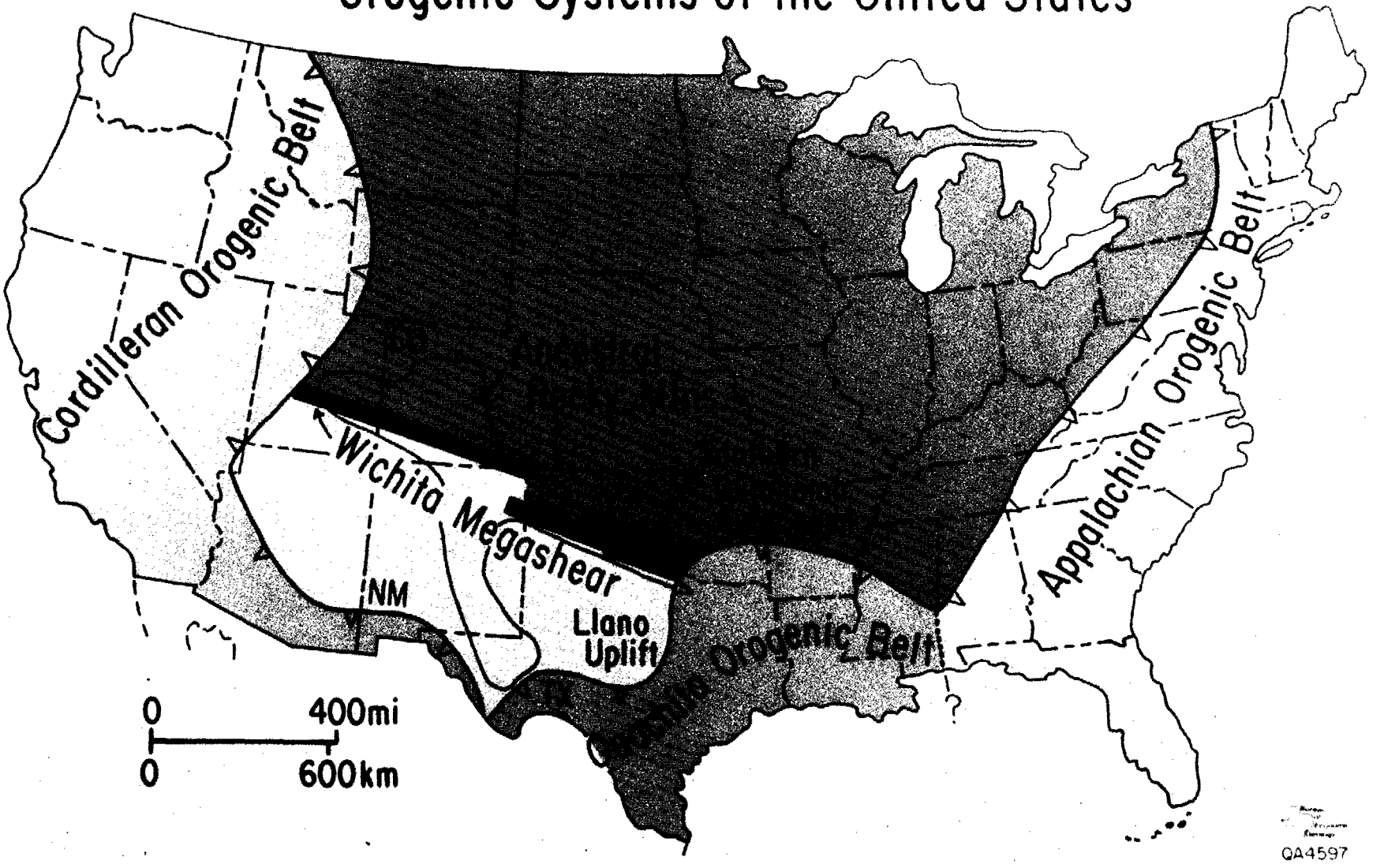
LEGEND

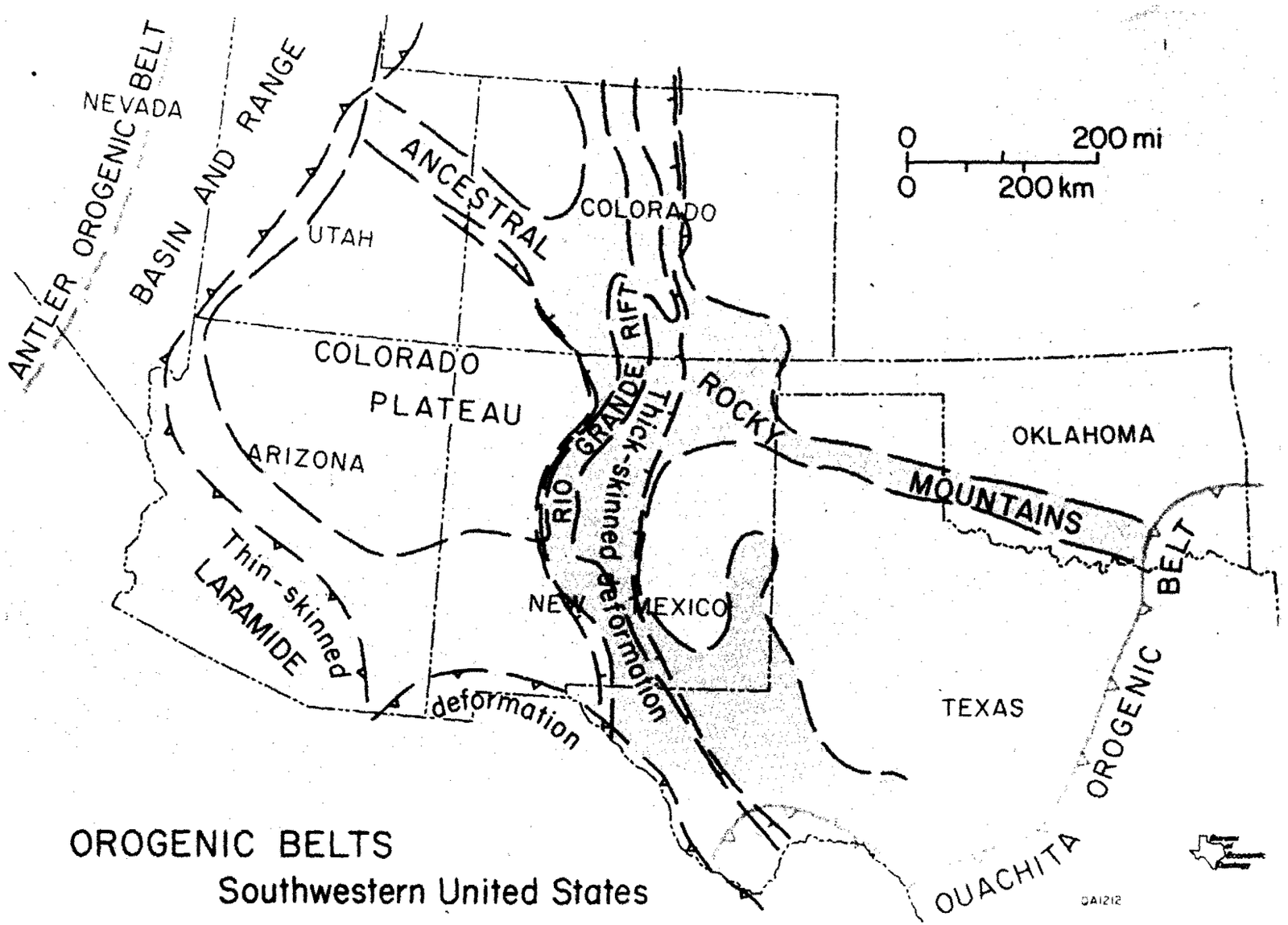
● NWTS Program test wells

FY84 Proposed well locations


OKLAHOMA
TEXAS
DALHART BASIN
ANADARKO BASIN
AMARILLO
NEW MEXICO
TEXAS
PALO DURO BASIN
PLAINVIEW
MIDLAND BASIN
0
50 mi

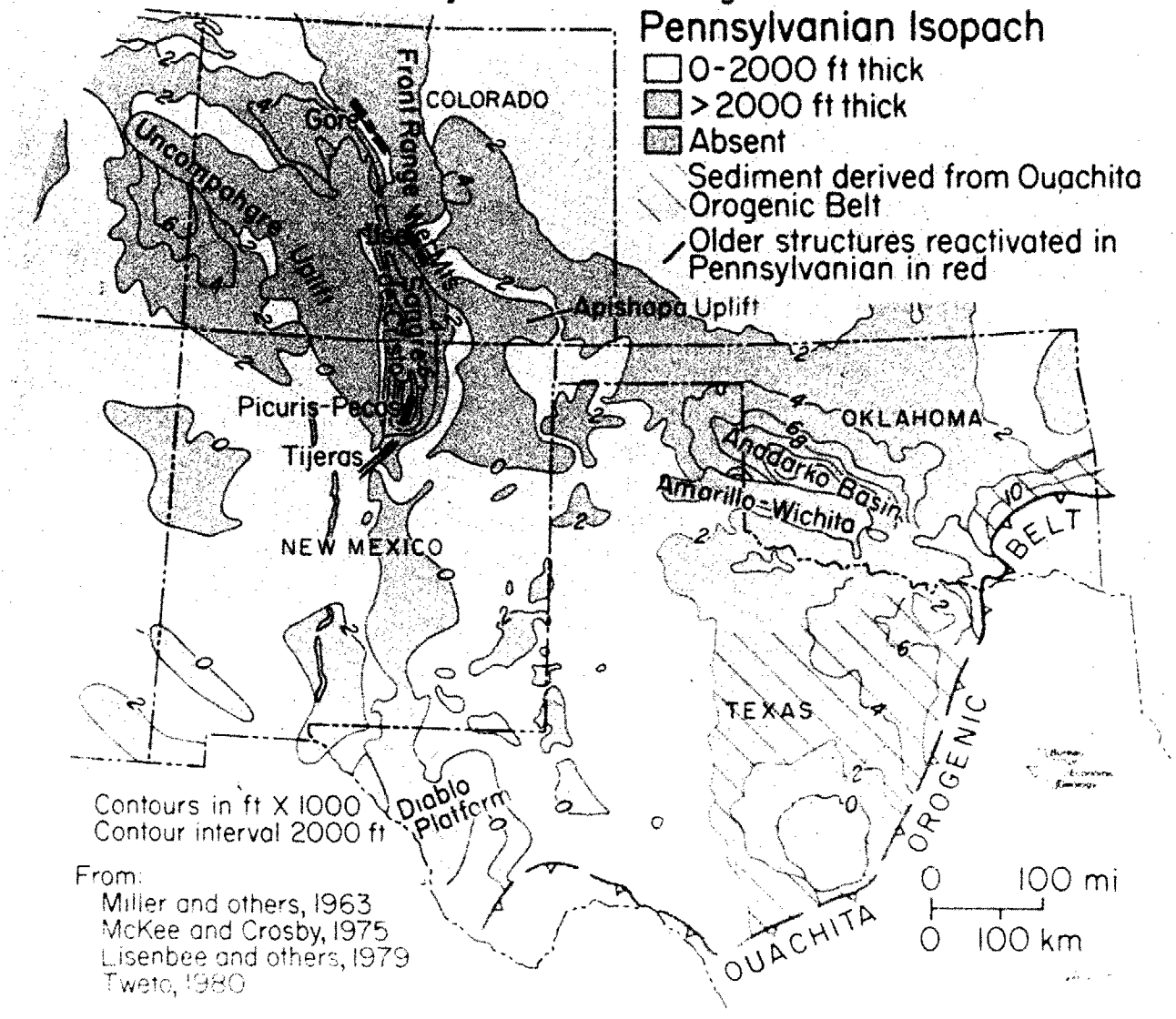
Orogenic Systems of the United States

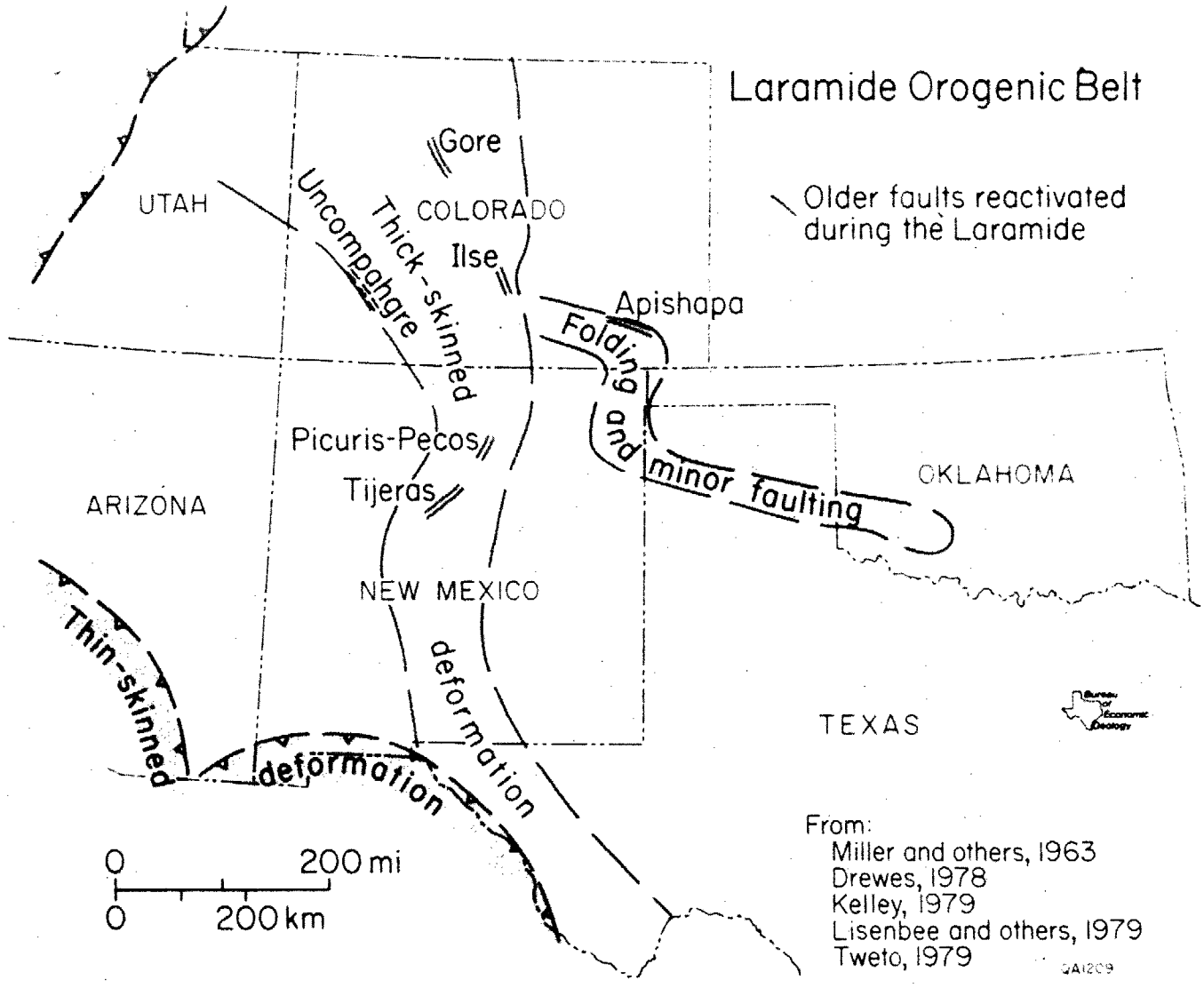




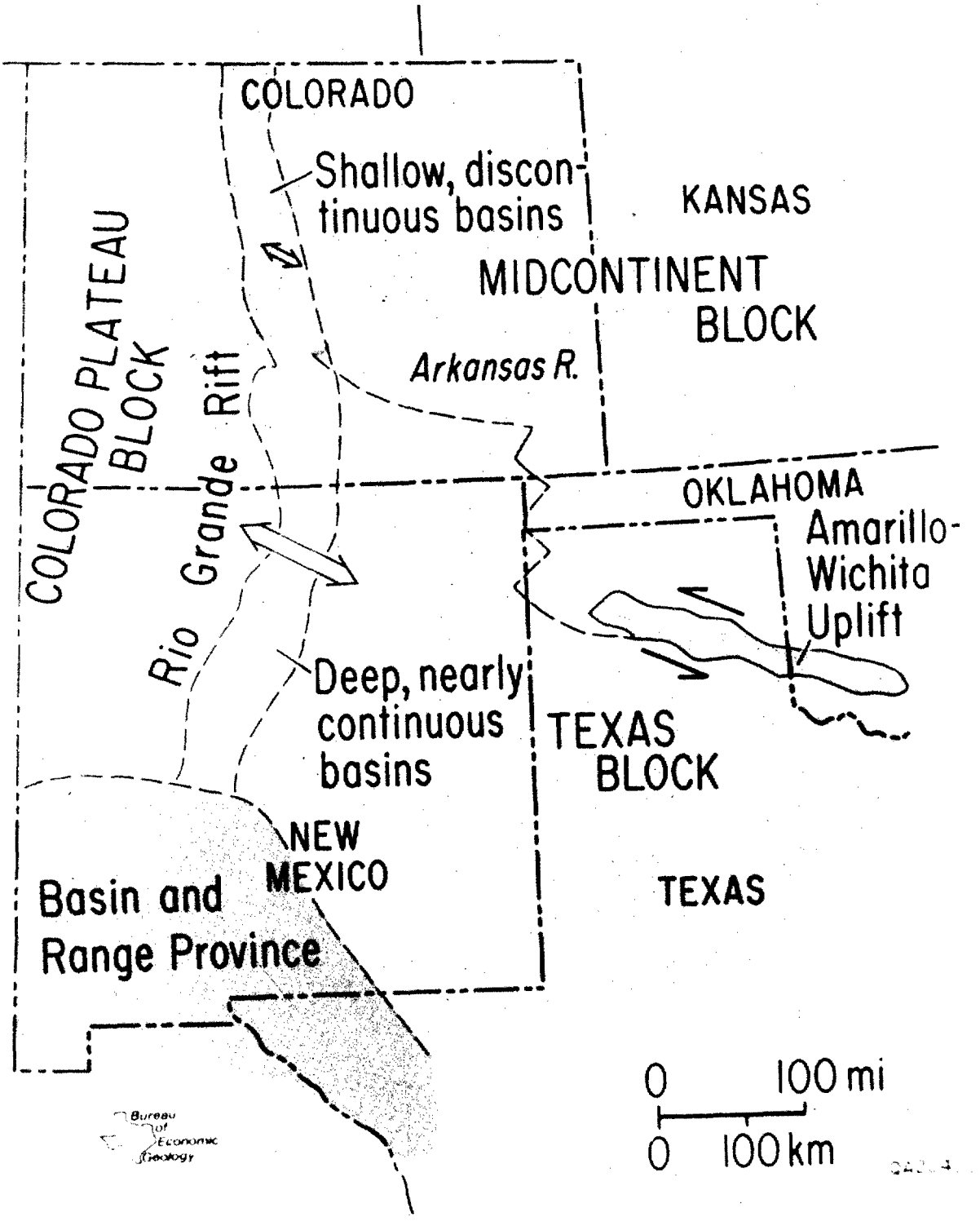
OROGENIC BELTS
Southwestern United States

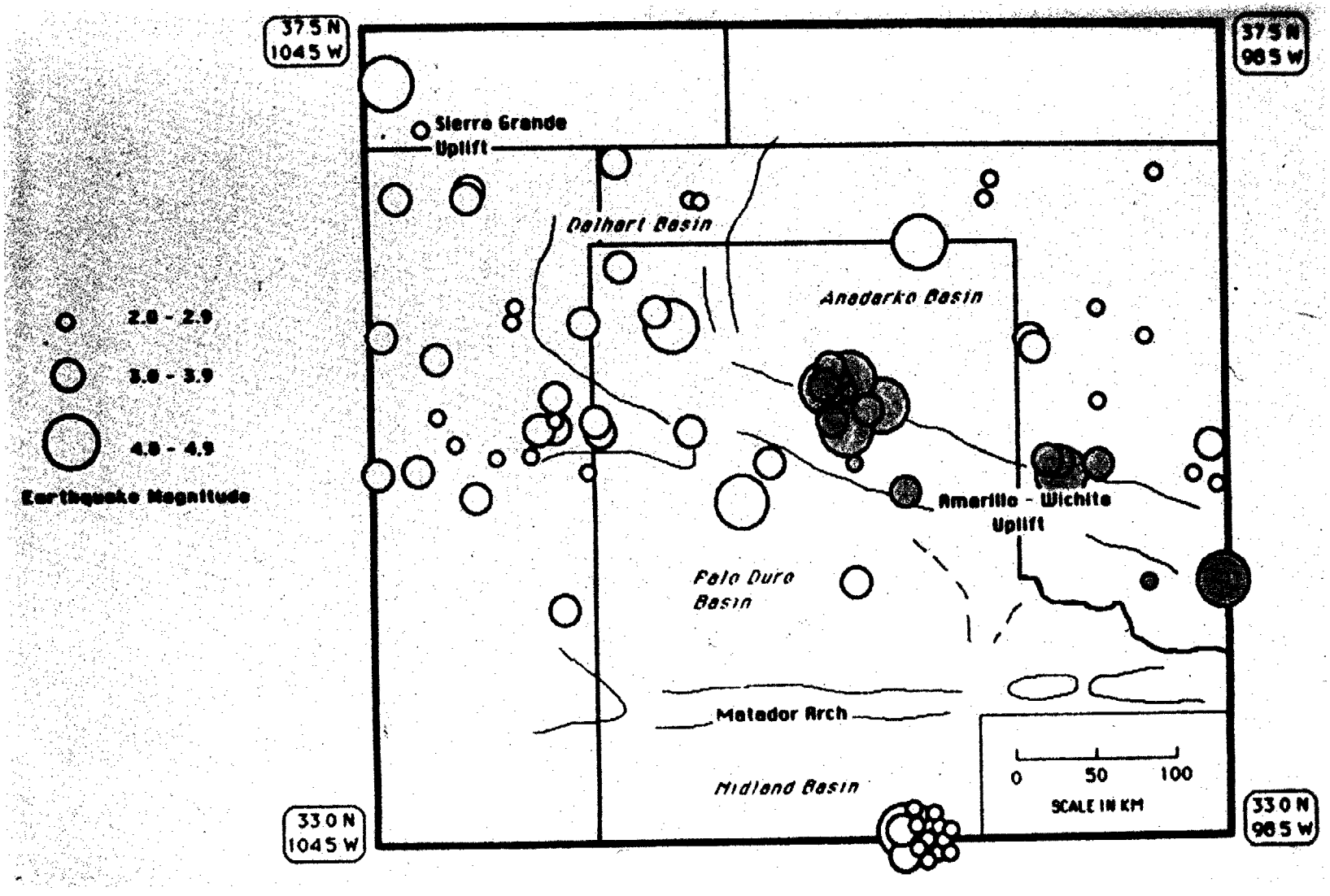
Ancestral Rocky Mountain Orogenic Belt / Pennsylvanian Isopach



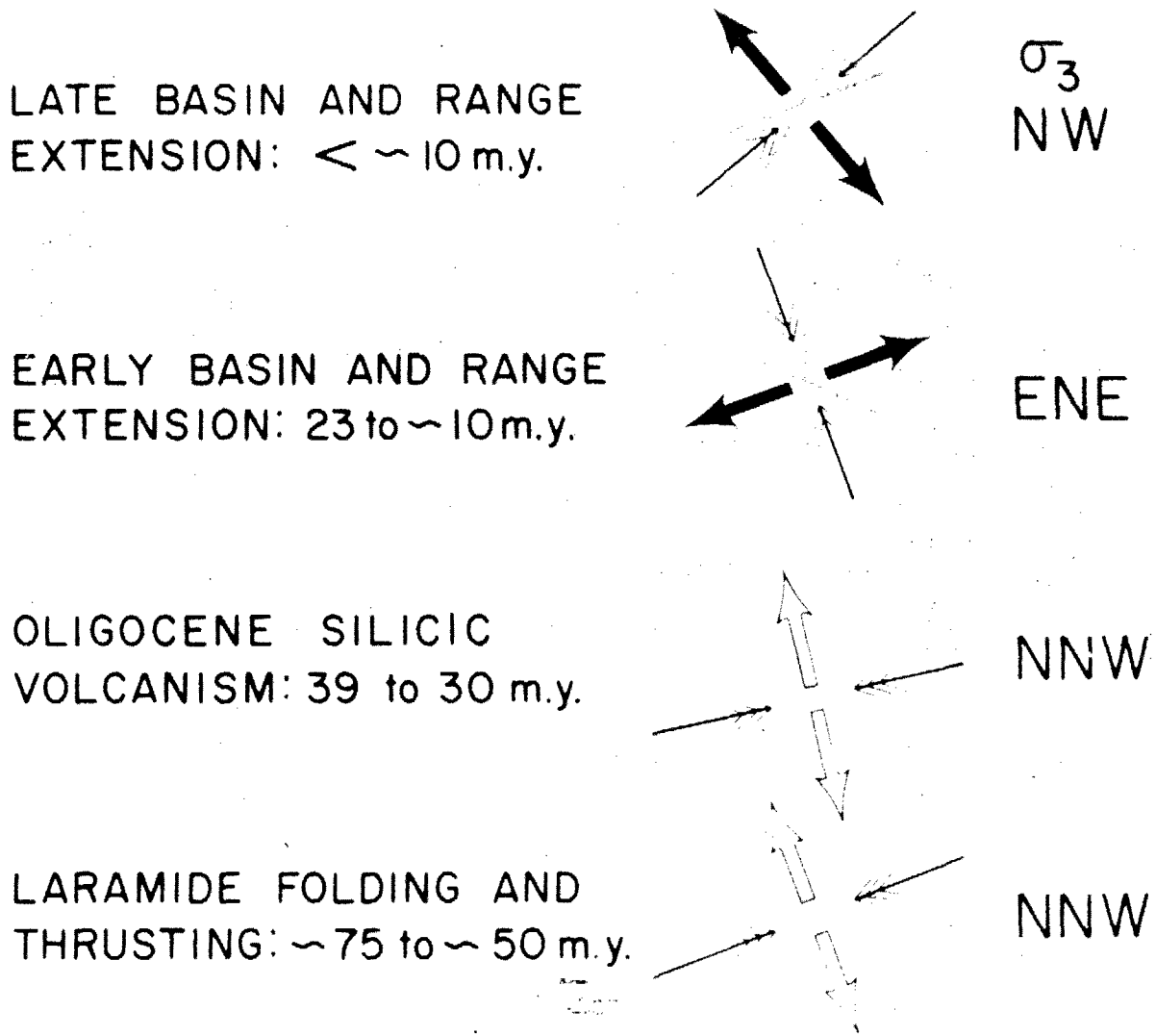

Laramide Orogenic Belt
Older faults reactivated during the Laramide
UTAH
COLORADO
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
Gore
Ilse
Apishapa
Picuris-Pecos
Tijeras
Uncompahgre
Thick-skinned deformation
Folding and minor faulting
Thin-skinned deformation
0 200 mi
0 200 km
From:
Miller and others, 1963
Drewes,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

NEOGENE TECTONIC SETTING

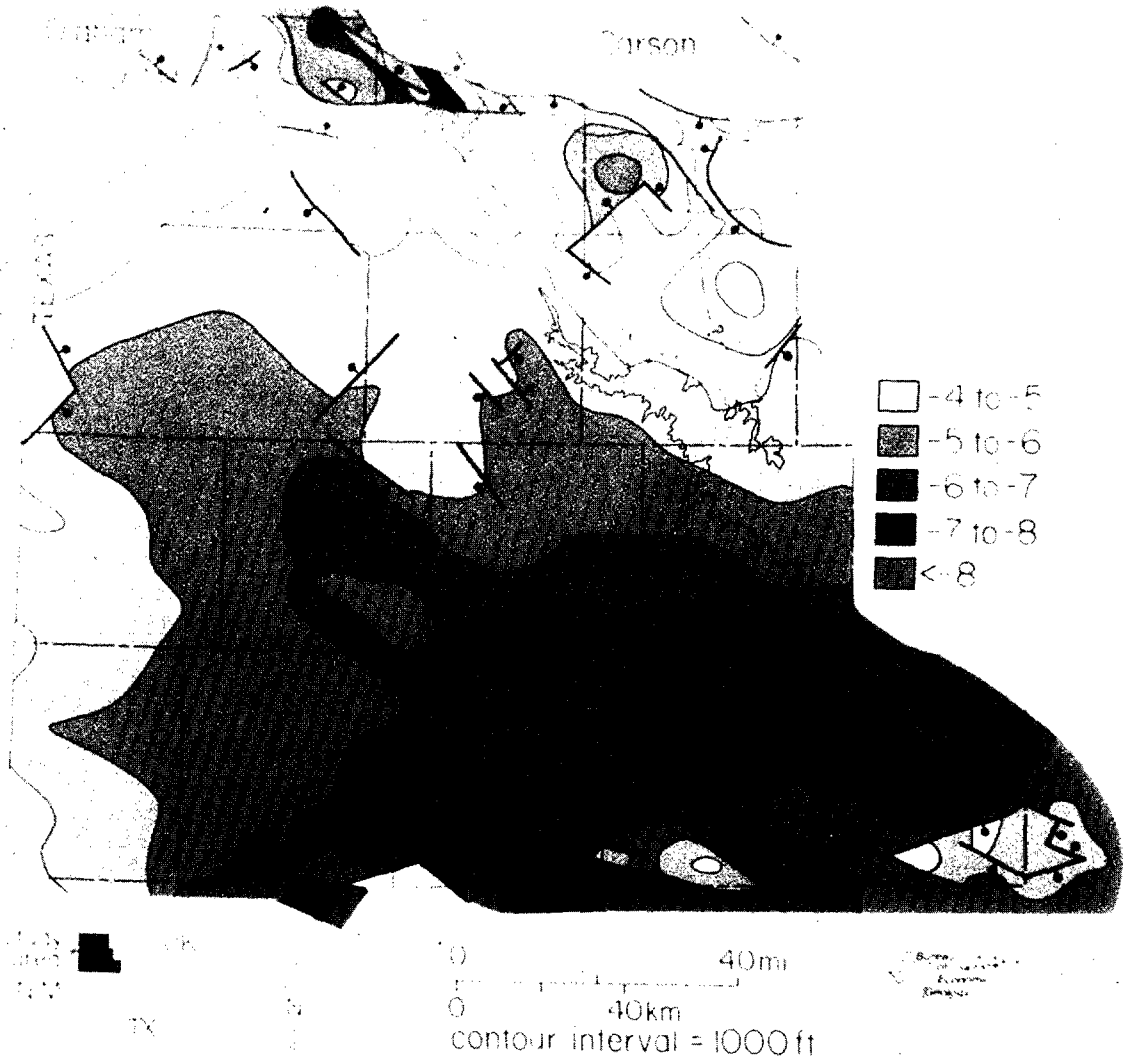



37.5 N
104.5 W
37.5 N
98.5 W
Sierra Grande Uplift
Dalhart Basin
Anadarko Basin
Amarillo - Wichita Uplift
Palo Duro Basin
Matador Arch
Midland Basin
0 50 100
SCALE IN KM
33.0 N
104.5 W
33.0 N
98.5 W
2.8 - 2.9
3.8 - 3.9
4.8 - 4.9
Earthquake Magnitude

SANGRE DE CRISTO UPLIFT
SIERRA GRANDE ARCH
OKLAHOMA
WICHITA
SYSTEM
SACRAMENTO UPLIFT
PLATFORM
OUACHITA
TECTONIC
BELT


LATE BASIN AND RANGE EXTENSION: < ~ 10 m.y.
σ_3 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

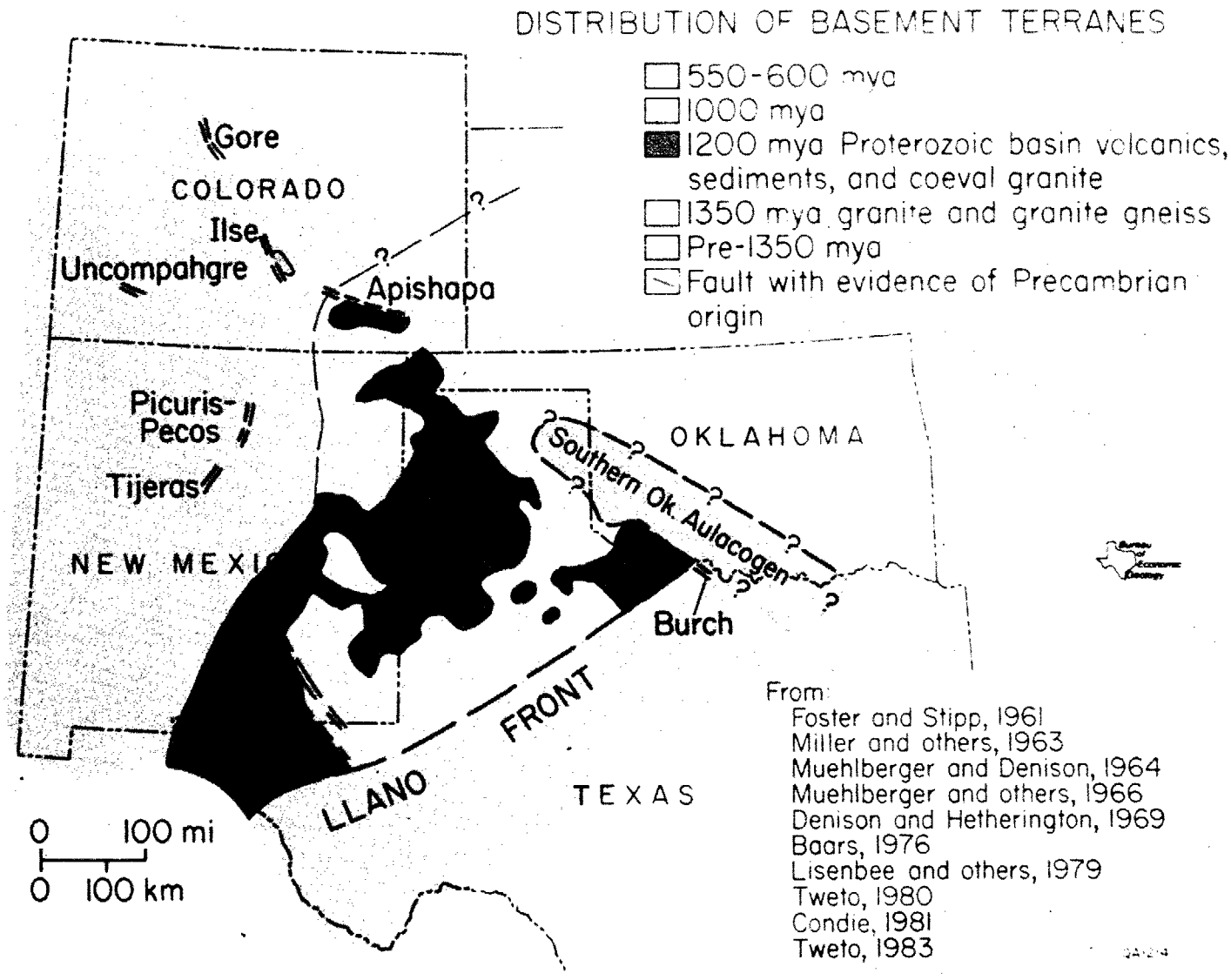
SIMPLIFIED BASEMENT STRUCTURE



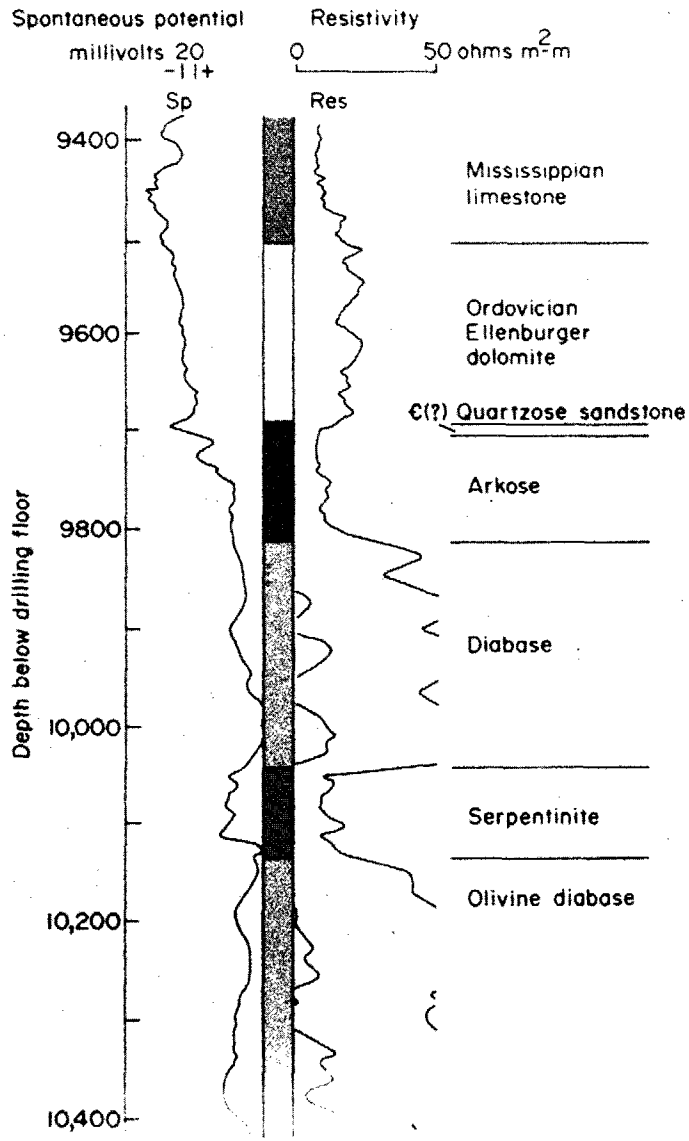
EXPLANATION (ft X 1000)

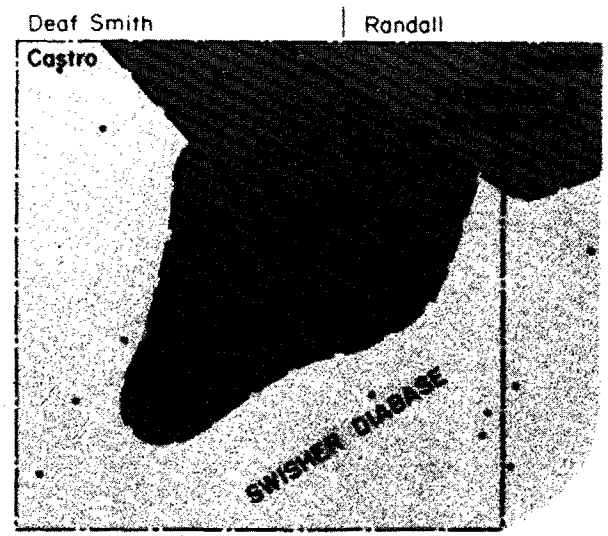
(from Budnik, 1984)

- >1
- 1 to 0
- 0 to -1
- -1 to -2
- -2 to -3
- -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 MEXICO
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



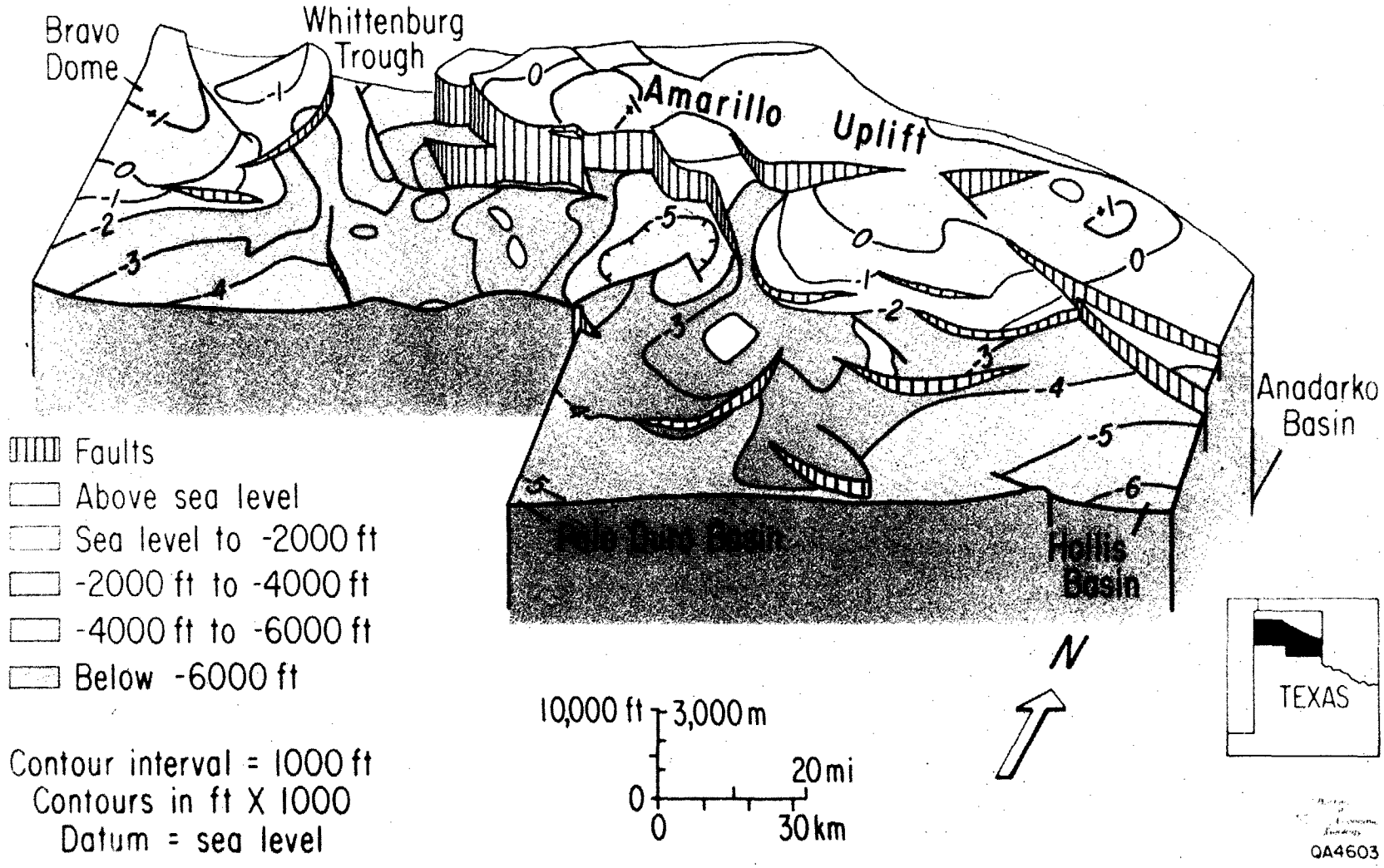


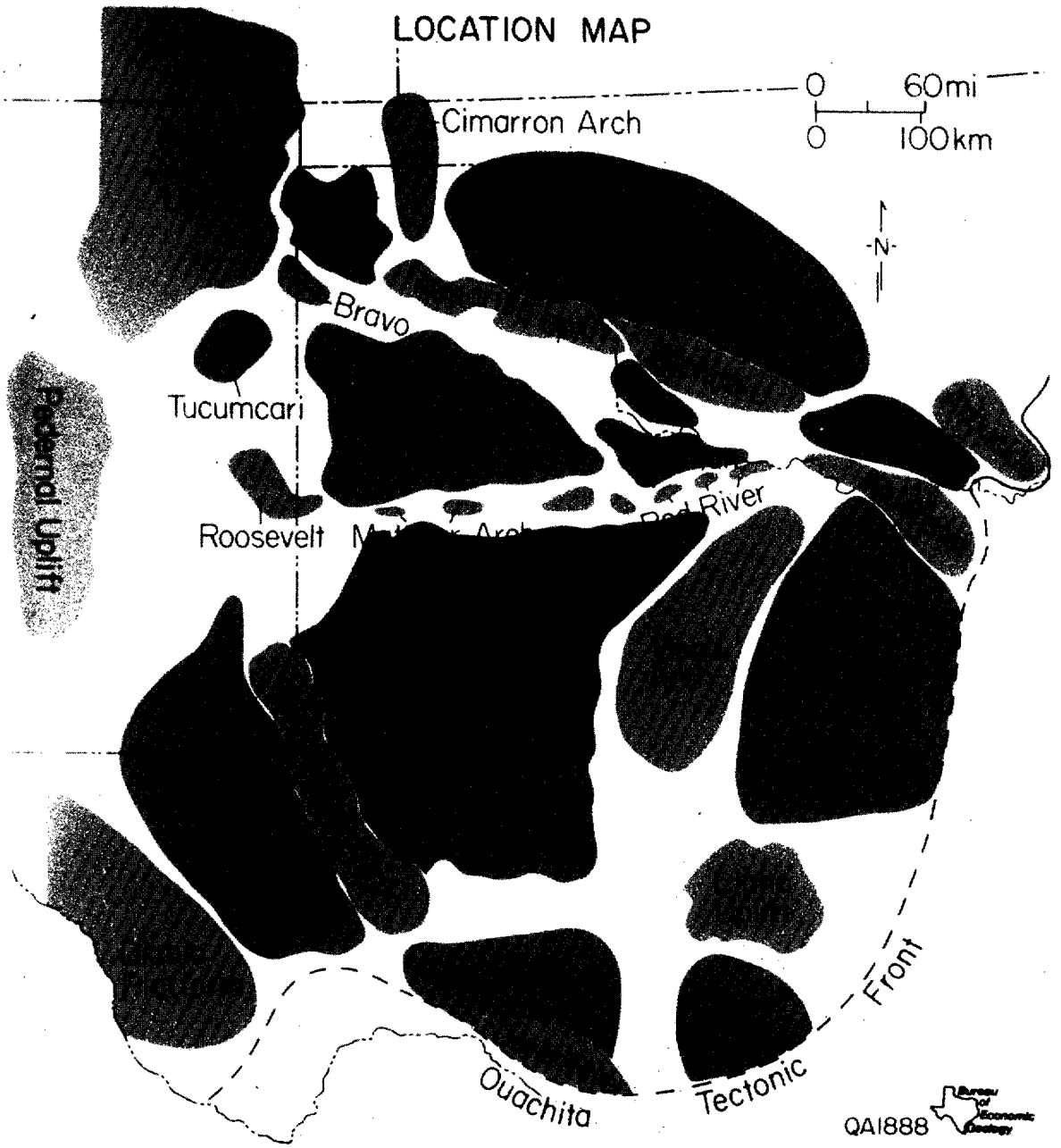
Distribution of pre-Ellenburger Group arkose in Castro Trough

- Well control
- ⊙ Wells penetrating pre-Ellenburger arkose

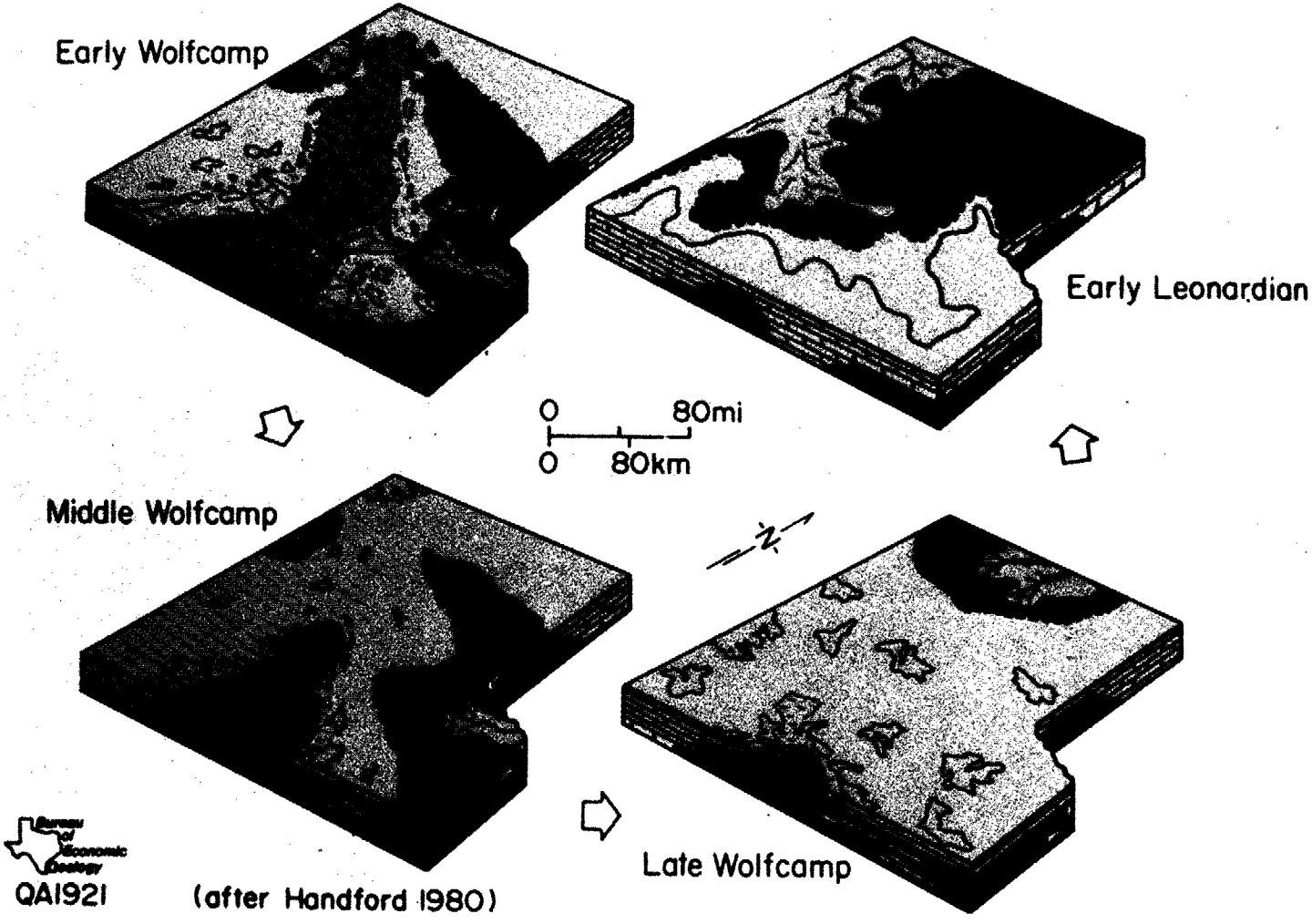
0 10 mi
0 10 km

Block diagram of basement surface of Amarillo Uplift



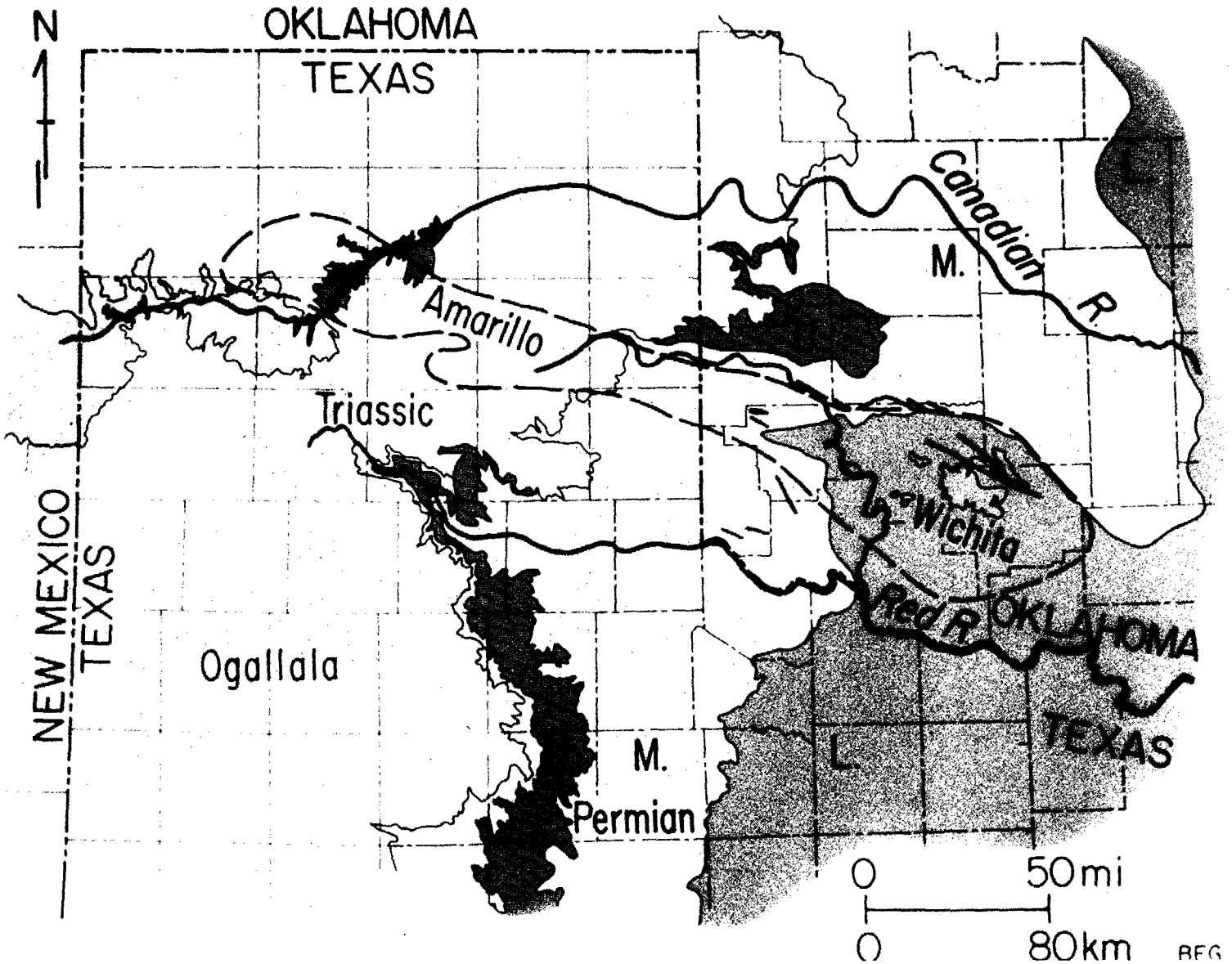

LOCATION MAP
0
60mi
0
100km
Cimarron Arch
N
Bravo
Tucumcari
Pedernal Uplift
Roosevelt
River
Ouachita
Tectonic
Front
QA1888

PALEOGEOGRAPHIC EVOLUTION OF PALO DURO BASIN

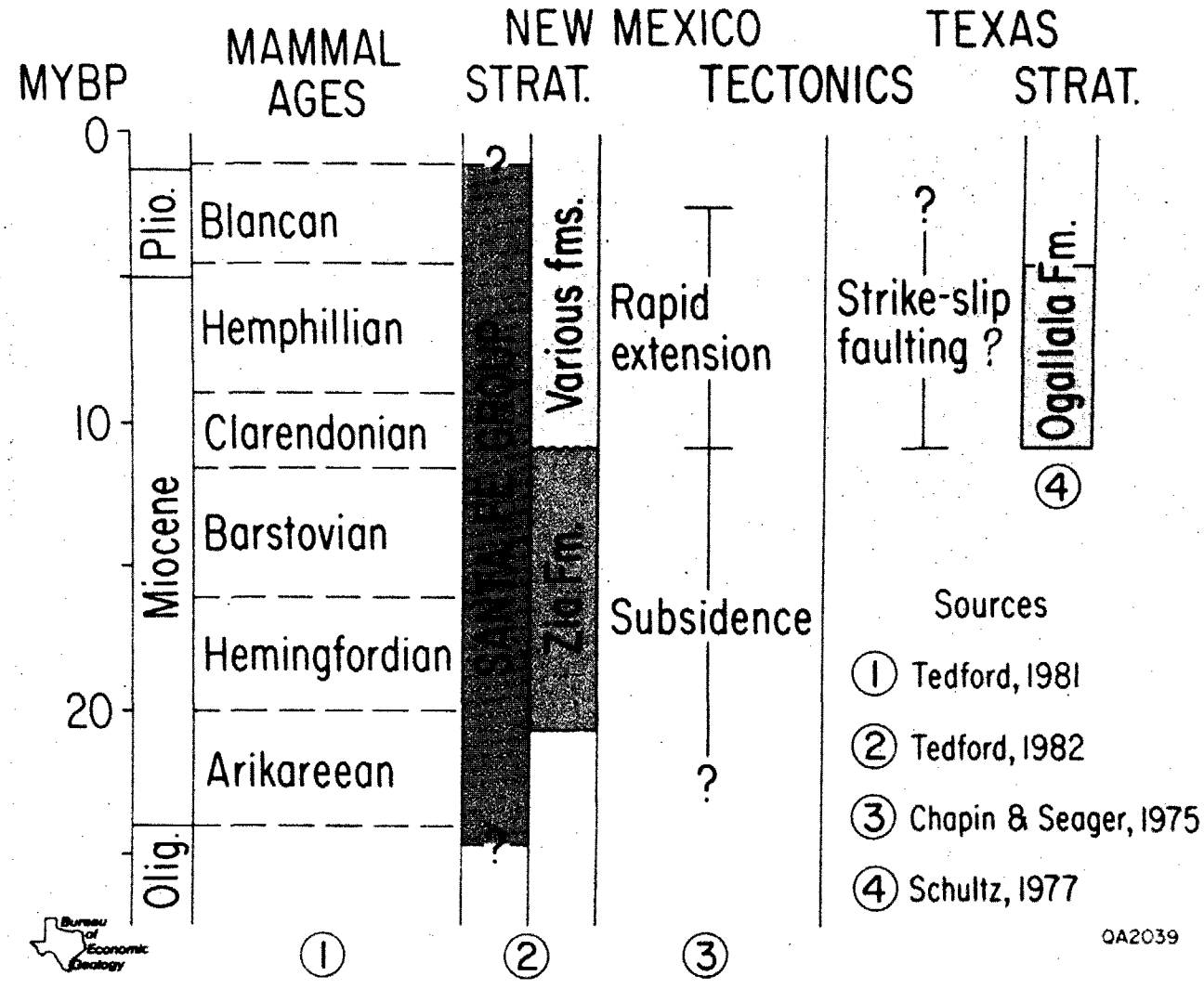


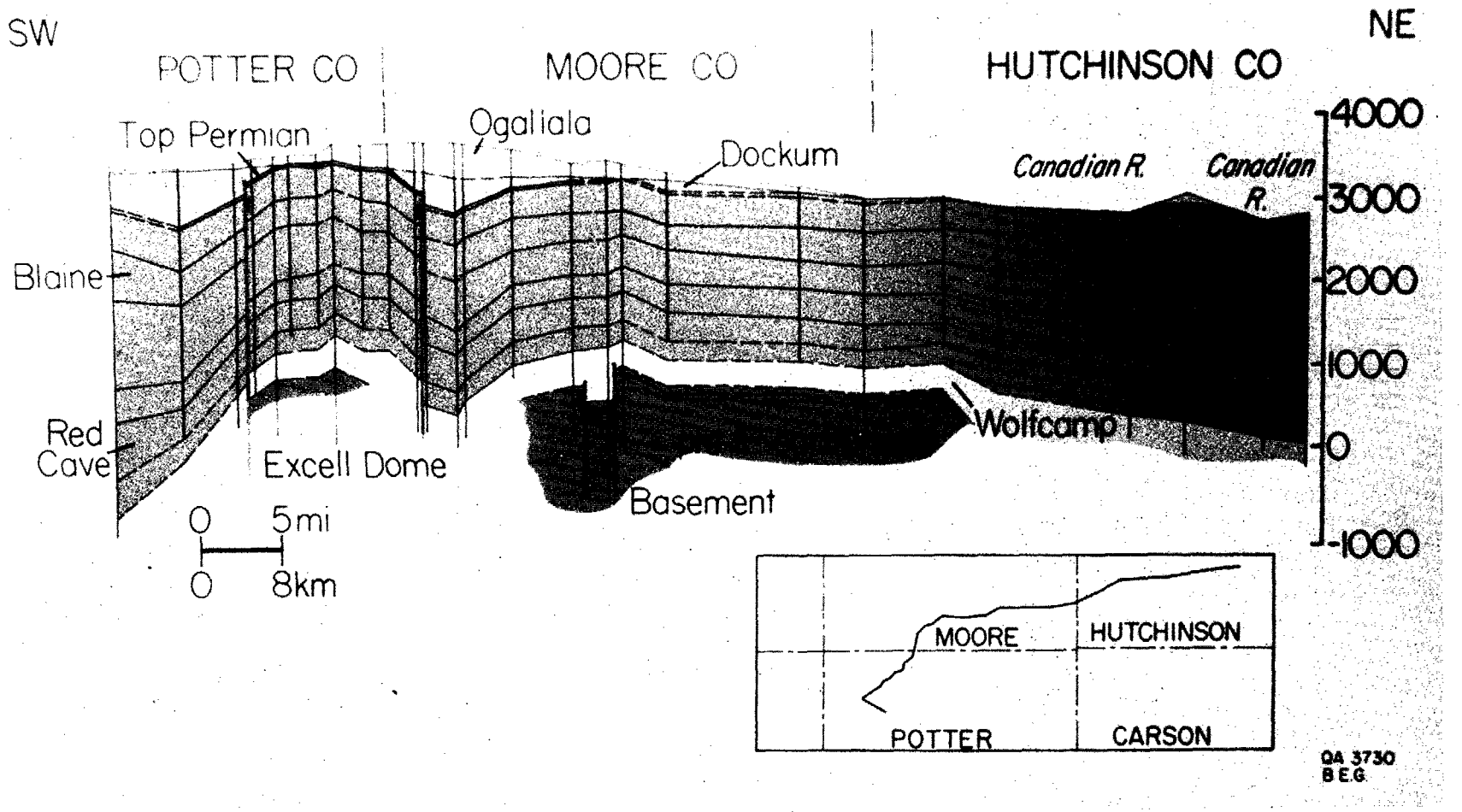
QA1921

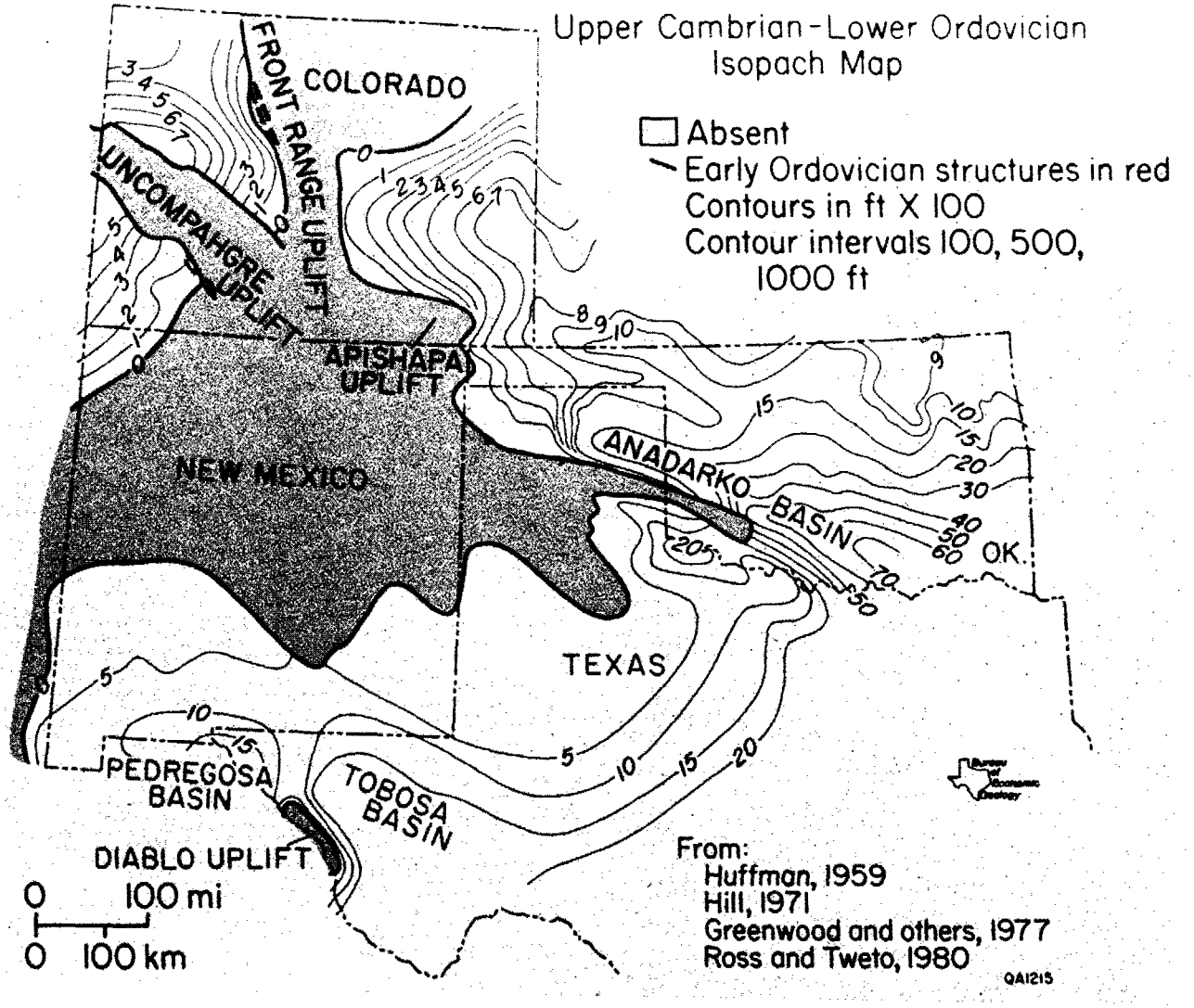
(after Handford 1980)


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

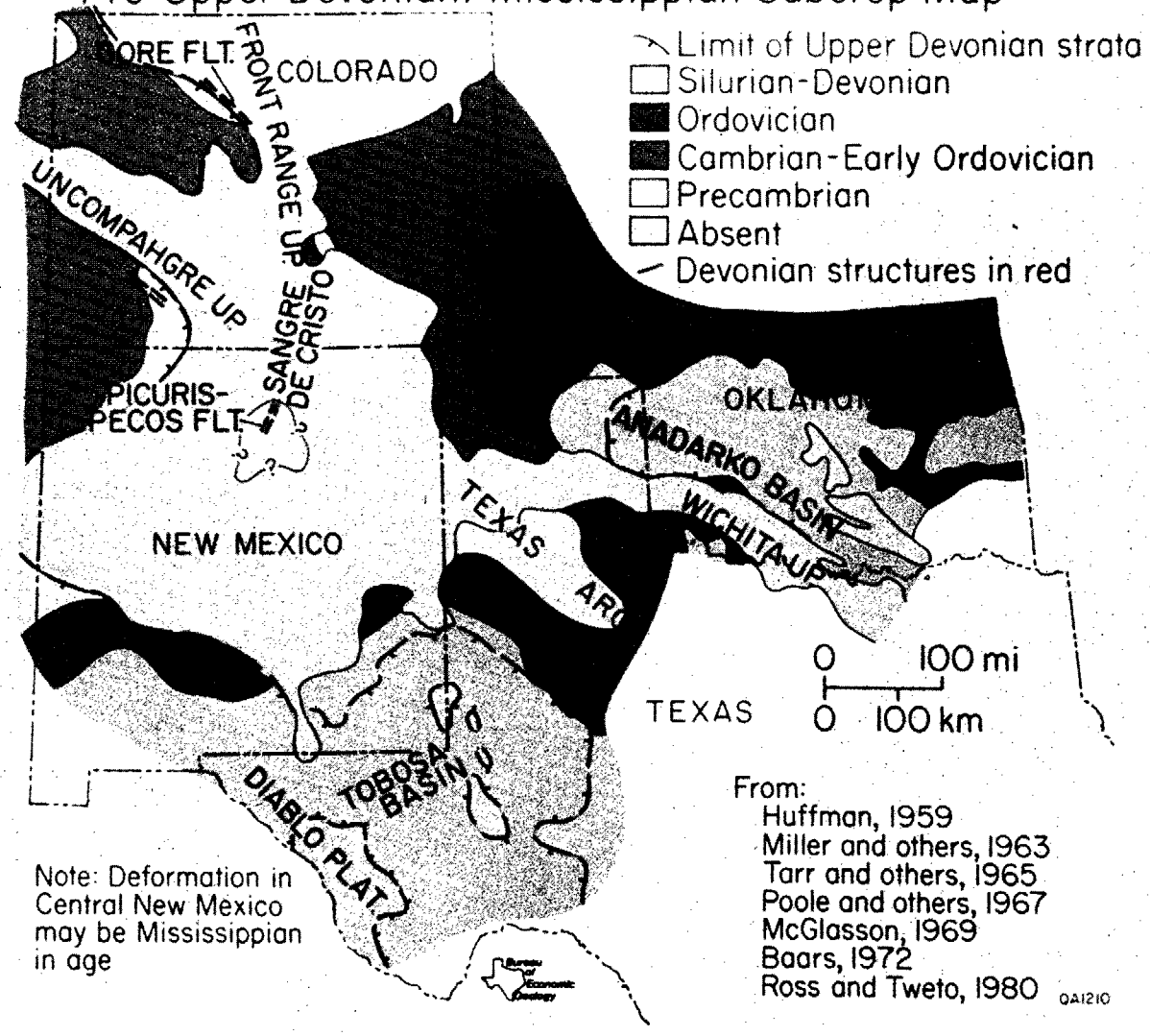
CORRELATION CHART



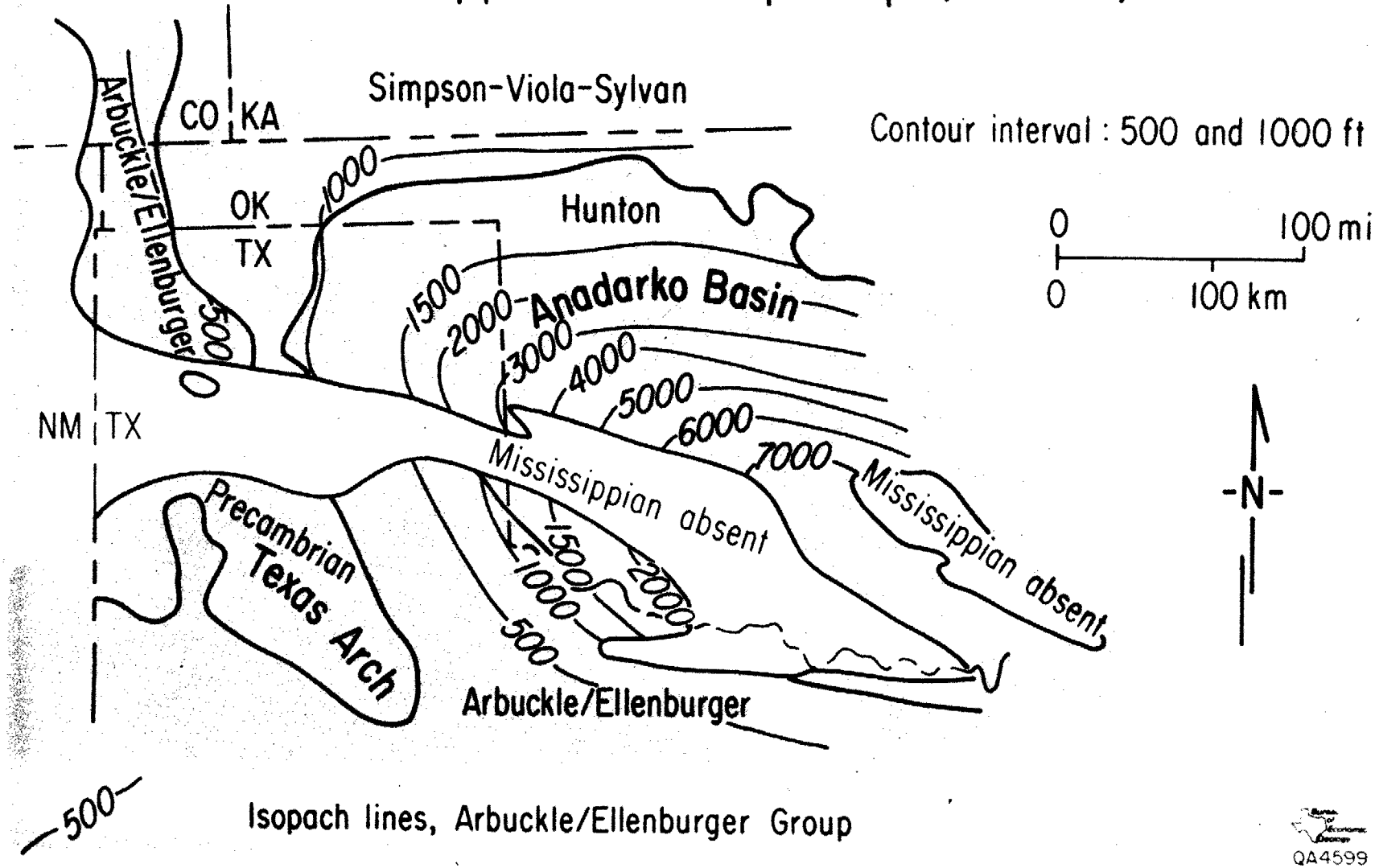

SW
NE
POTTER CO
MOORE CO
HUTCHINSON CO
Top Permian
Ogaliala
Dockum
Canadian R.
Canadian R.
Blaine
Red Cave
Excell Dome
Basement
Wolfcamp
4000
3000
2000
1000
0
-1000
0 5mi
0 8km
MOORE
HUTCHINSON
POTTER
CARSON
QA 3730
B.E.G.


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 UPLIFT
UNCOMPAHGRE UPLIFT
APISHAPA UPLIFT
NEW MEXICO
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

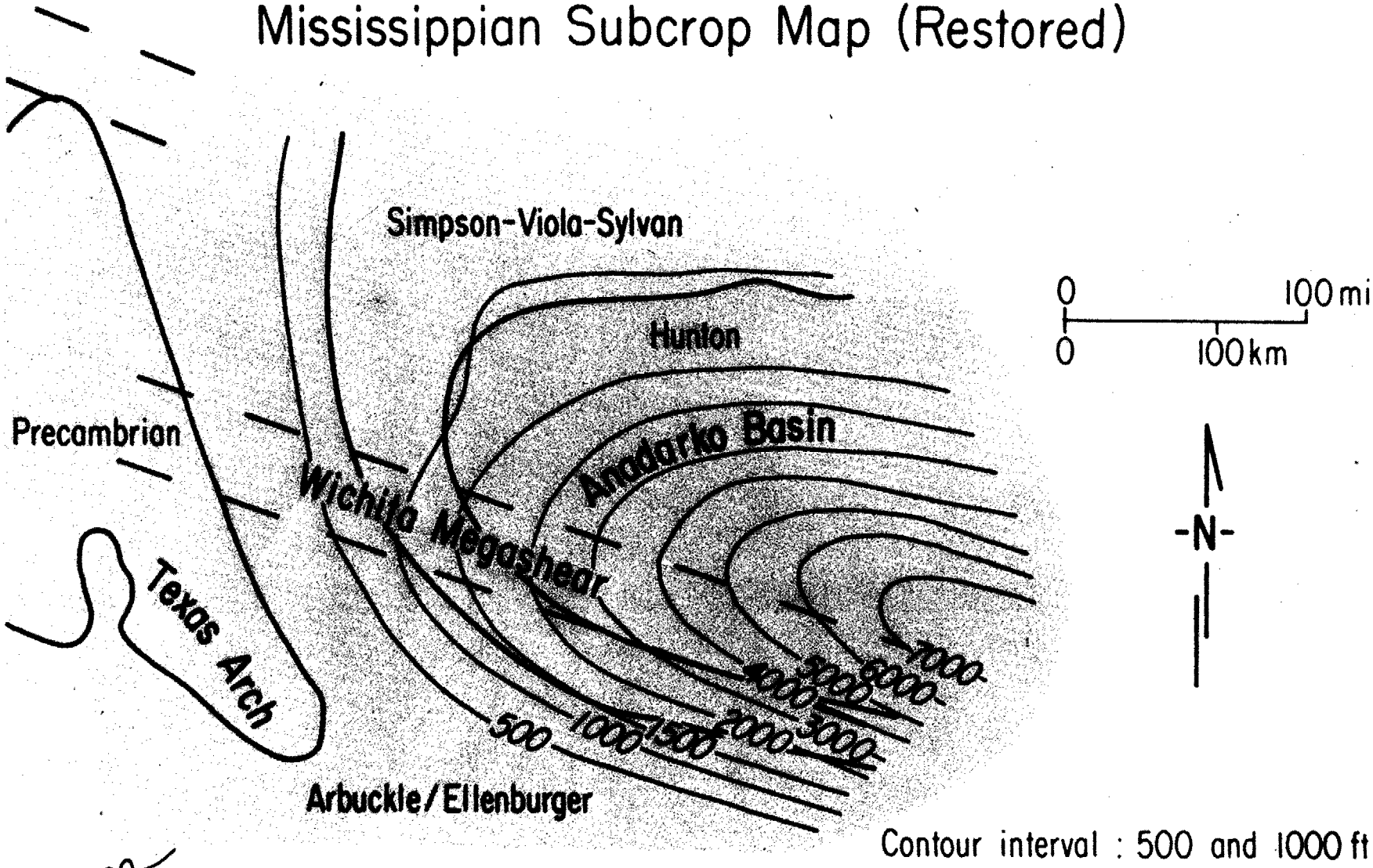


Mississippian Subcrop Map (Present)

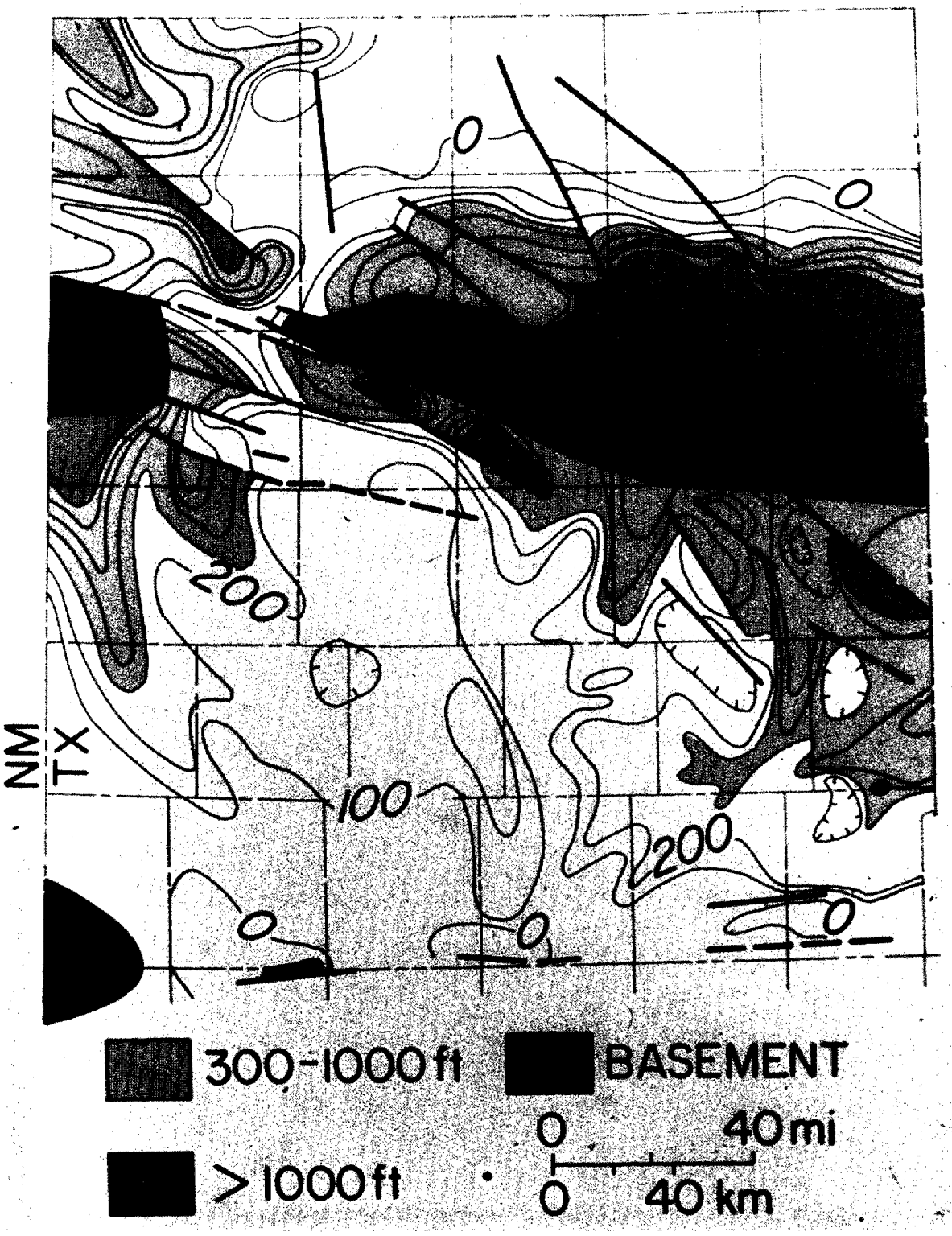


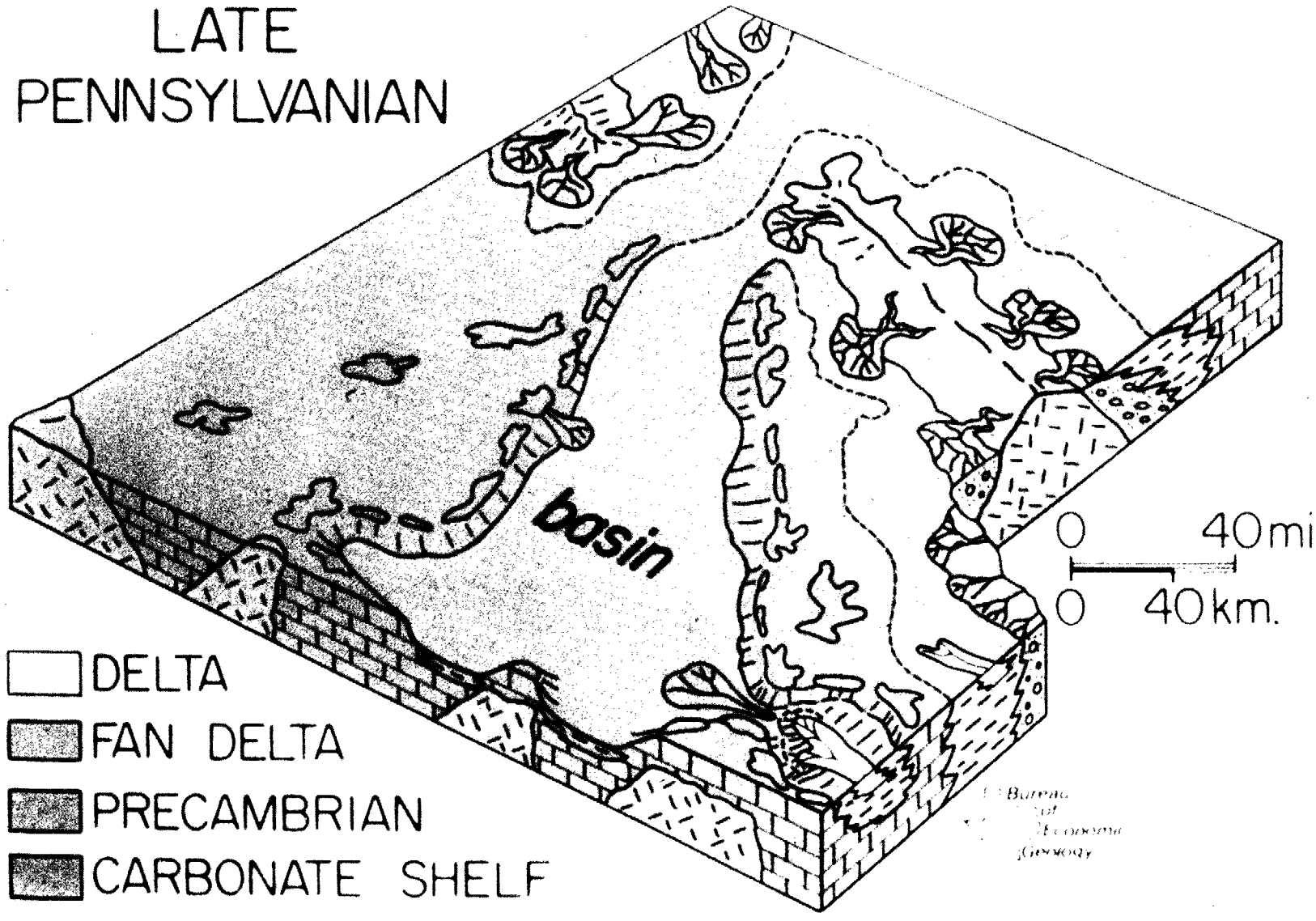
QA4599

Mississippian Subcrop Map (Restored)



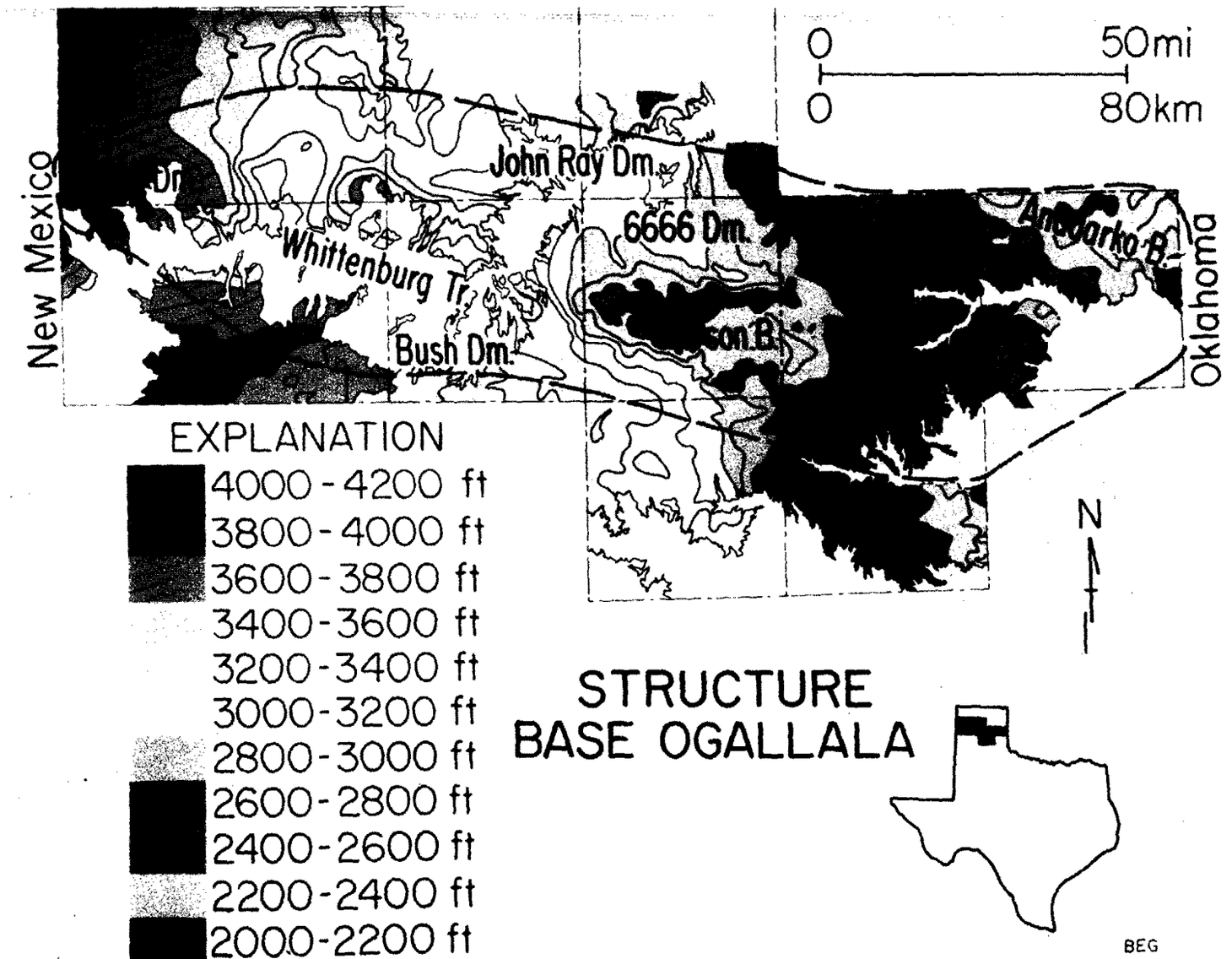
NET GRANITE WASH



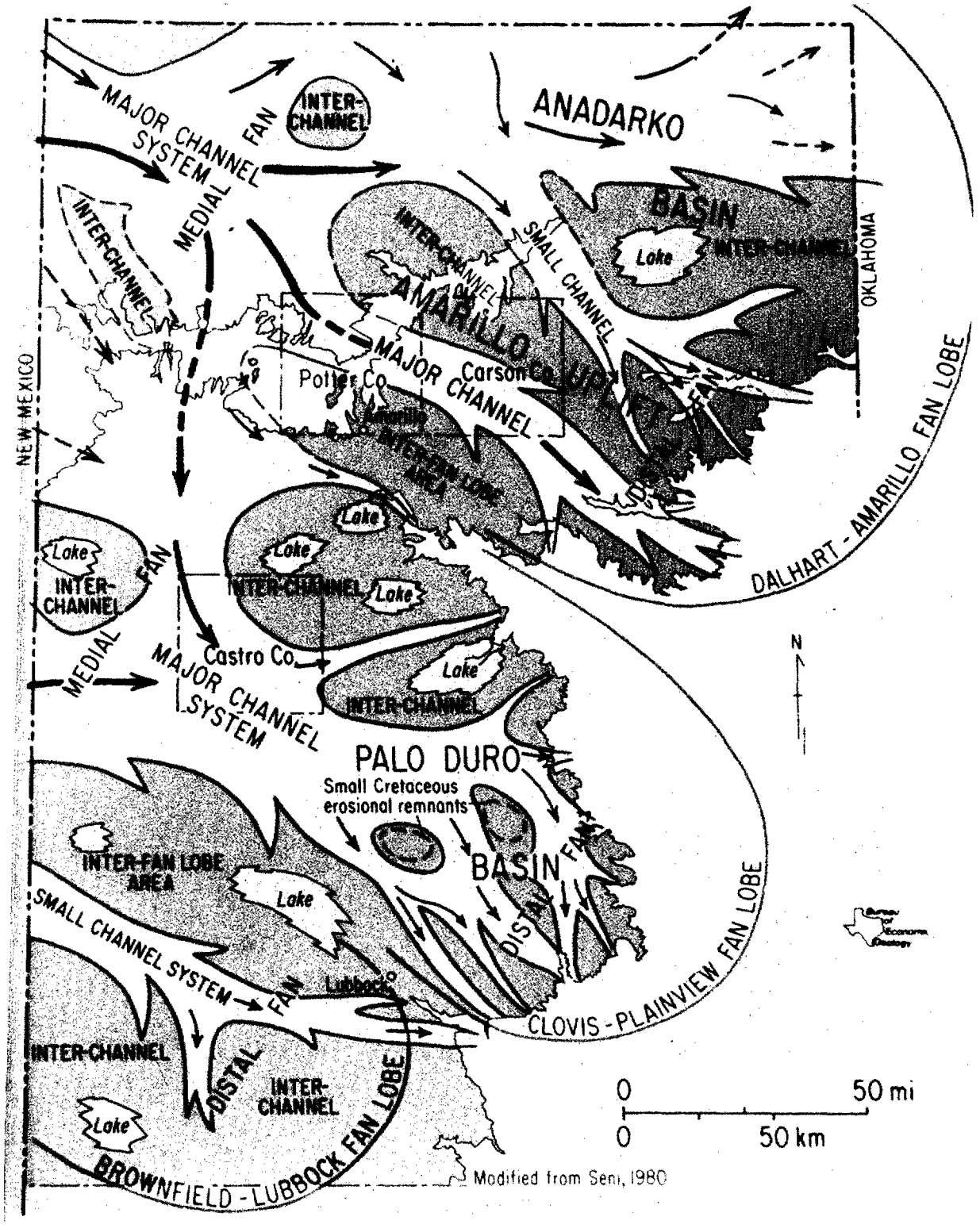

LATE
PENNSYLVANIAN
basin
0 40mi
0 40km.
DELTA
FAN DELTA
PRECAMBRIAN
CARBONATE SHELF

ISOPACH
PERMIAN post Wolfcamp

BEG
QA-3223

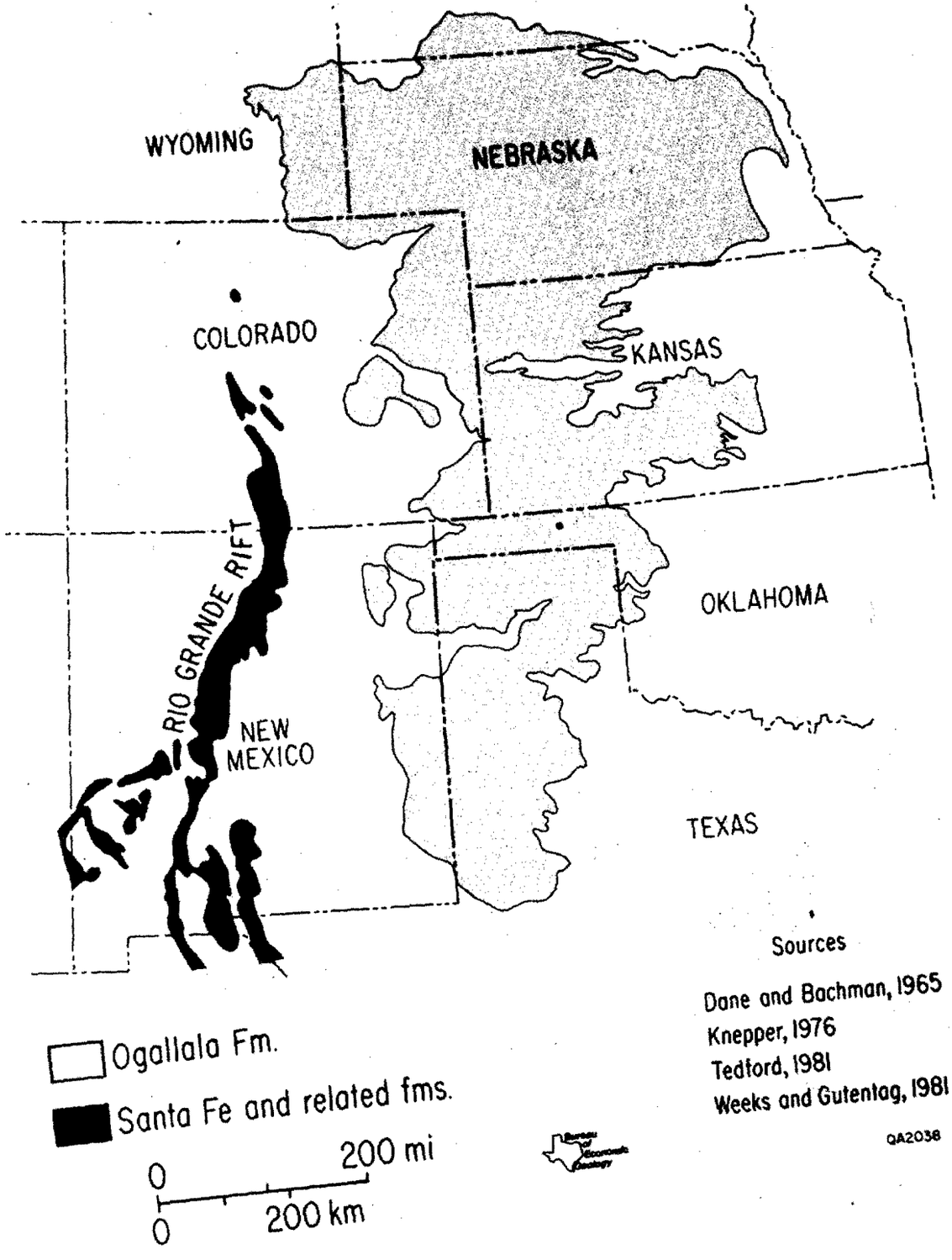

0
50mi
0
80km
New Mexico
Oklahoma
John Ray Dm.
6666 Dm.
Whittenburg Tr.
Bush Dm.
Anadarko B.
N
EXPLANATION
4000 - 4200 ft
3800 - 4000 ft
3600 - 3800 ft
3400 - 3600 ft
3200 - 3400 ft
3000 - 3200 ft
2800 - 3000 ft
2600 - 2800 ft
2400 - 2600 ft
2200 - 2400 ft
2000 - 2200 ft
STRUCTURE
BASE OGALLALA
BEG
QA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

DEPOSITIONAL PATTERNS OF OGALLALA FM.



Modified from Seni, 1980

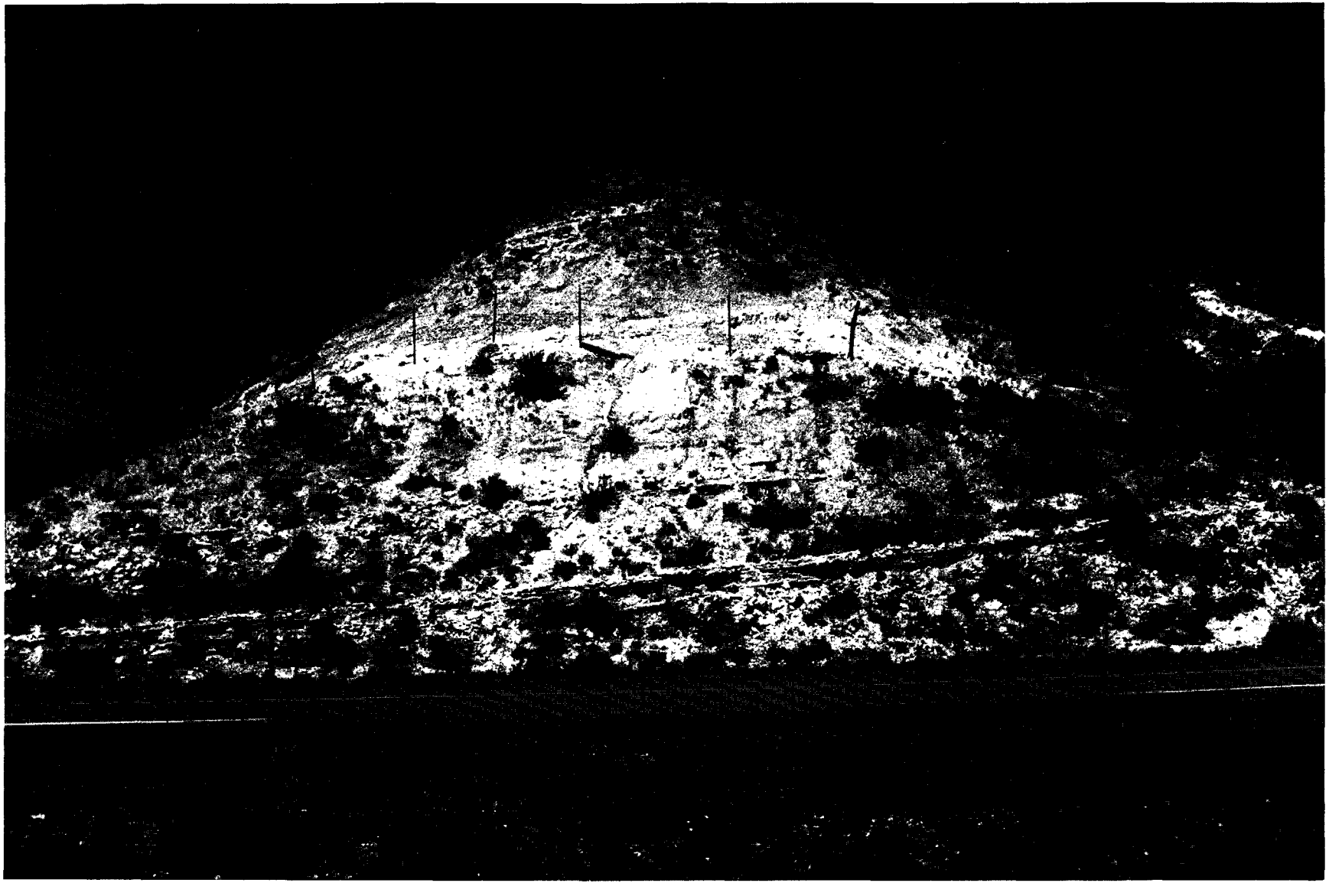
DISTRIBUTION OF NEOGENE SEDIMENTS



Sources

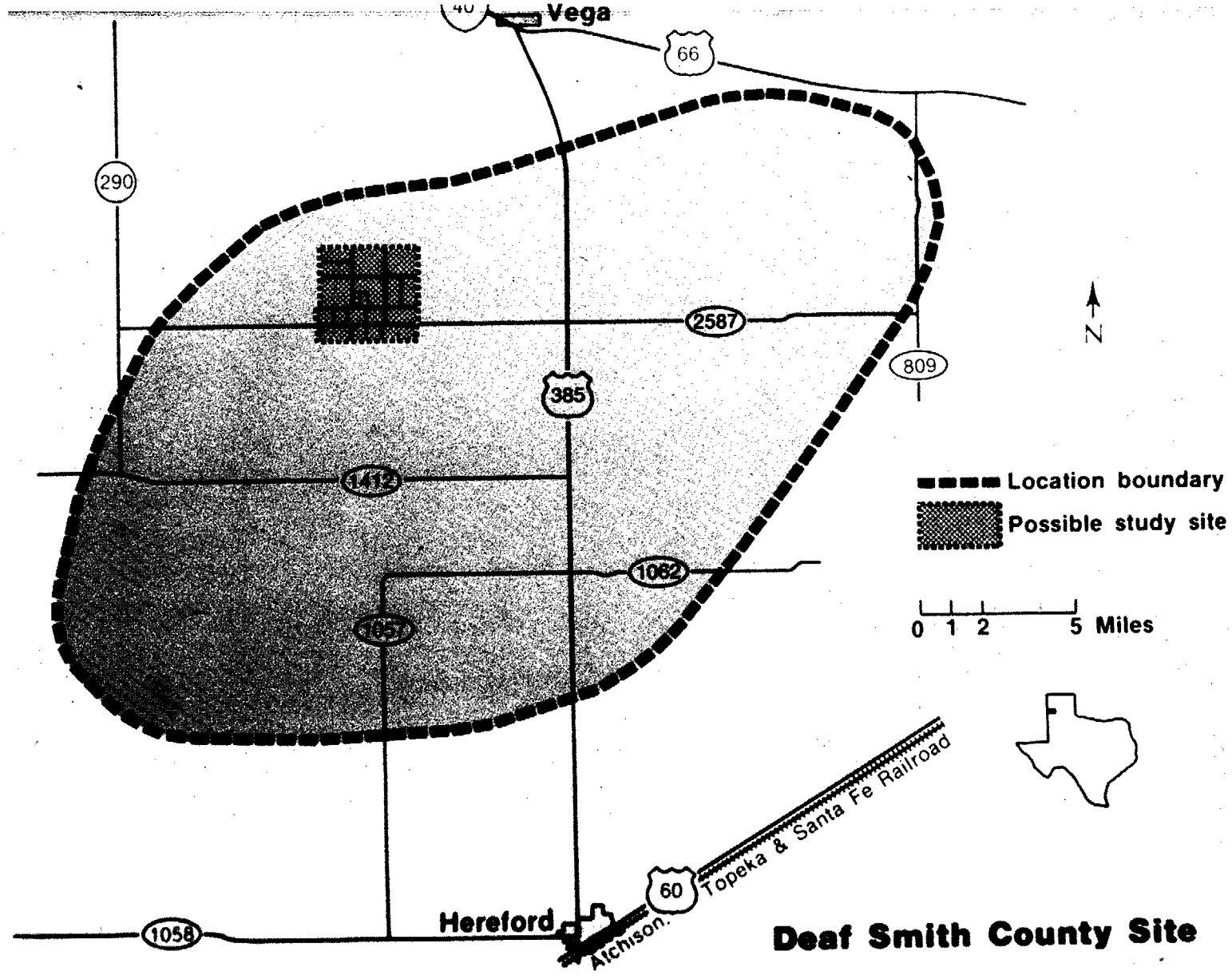
Dane and Bachman, 1965
Knepper, 1976
Tedford, 1981
Weeks and Gutentag, 1981

QA2038



STRATIGRAPHIC COLUMN

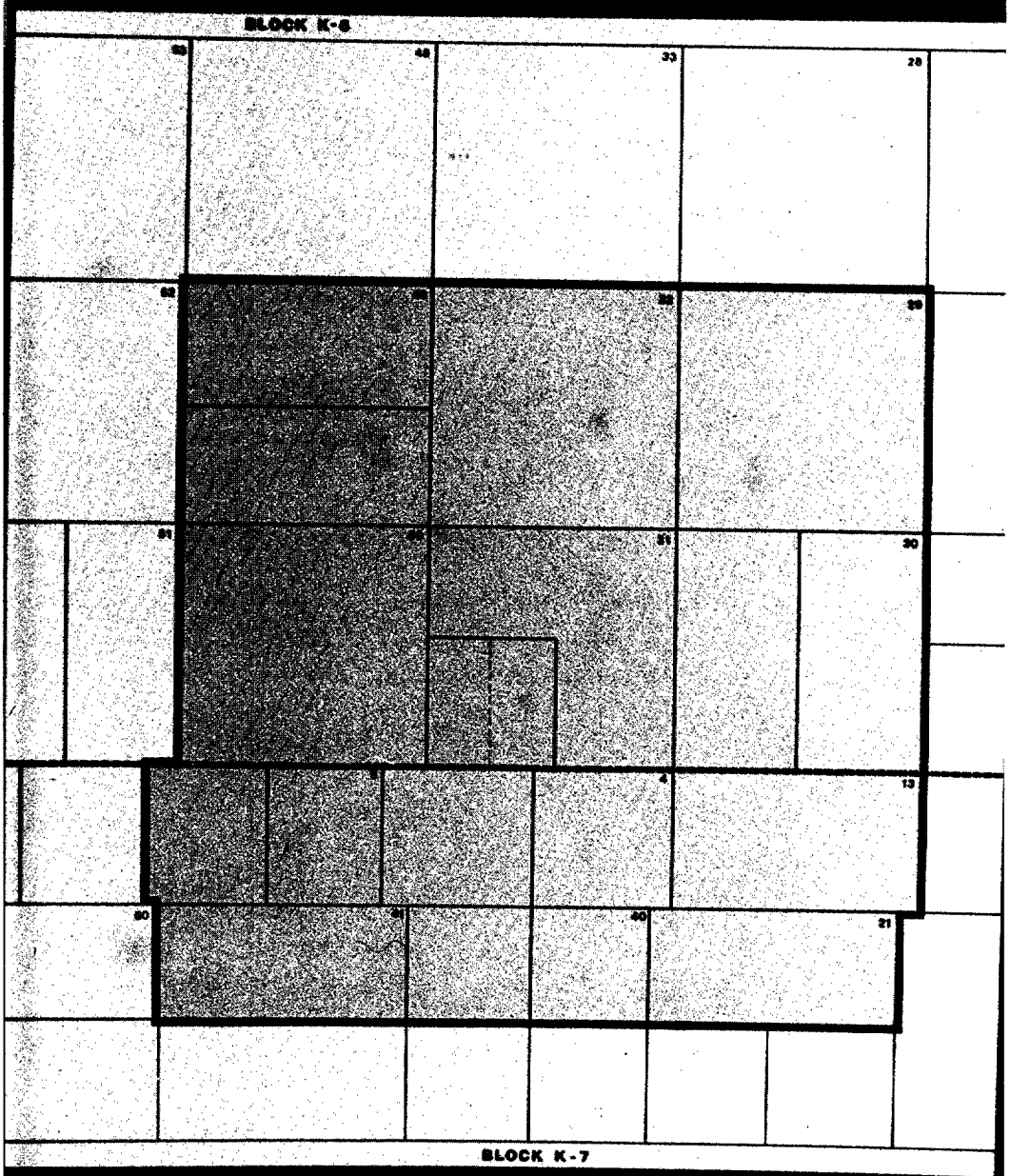
SYSTEM	GROUP	FORMATION
QUATERNARY		RECENT FLUVIAL & LUCUSTRINE DEPOSITS
TERTIARY		OGALLALA
CRETACEOUS	DAKOTA	
		FREDRICKSBURG
		TRINITY
JURASSIC		MORRISON
		EXETER
TRIASSIC	DOCKUM	
PERMIAN		DEWEY LAKE
		ALIBATES
	ARTESIA/WHITEHORSE	
		YATES
		QUEEN/GRAYBURG
	CLEAR FORK	
		TUBB
		RED CAVE
	WICHITA	
	WOLFCAMP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



Deaf Smith County Site

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

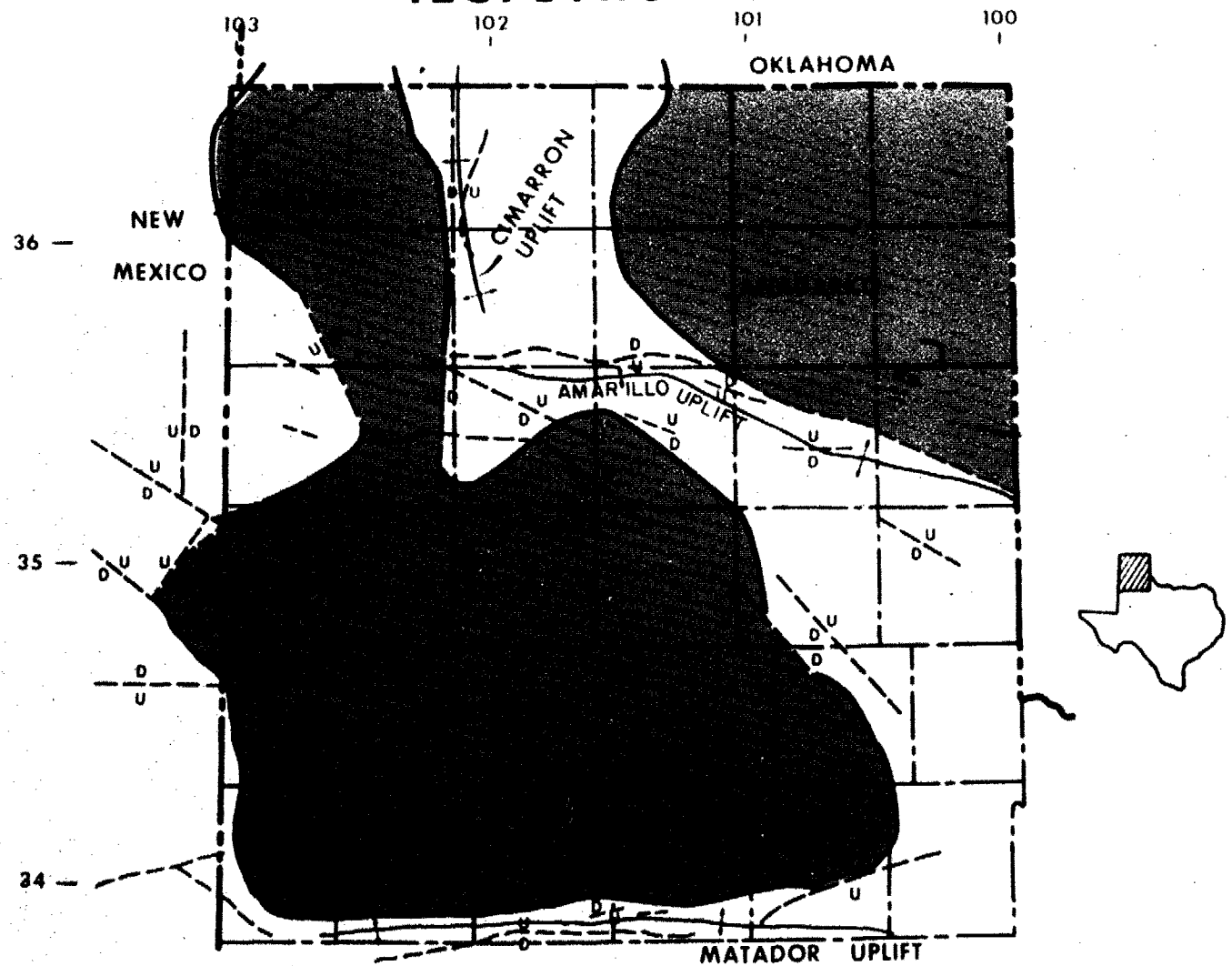
G.B.&C.N.G. RR



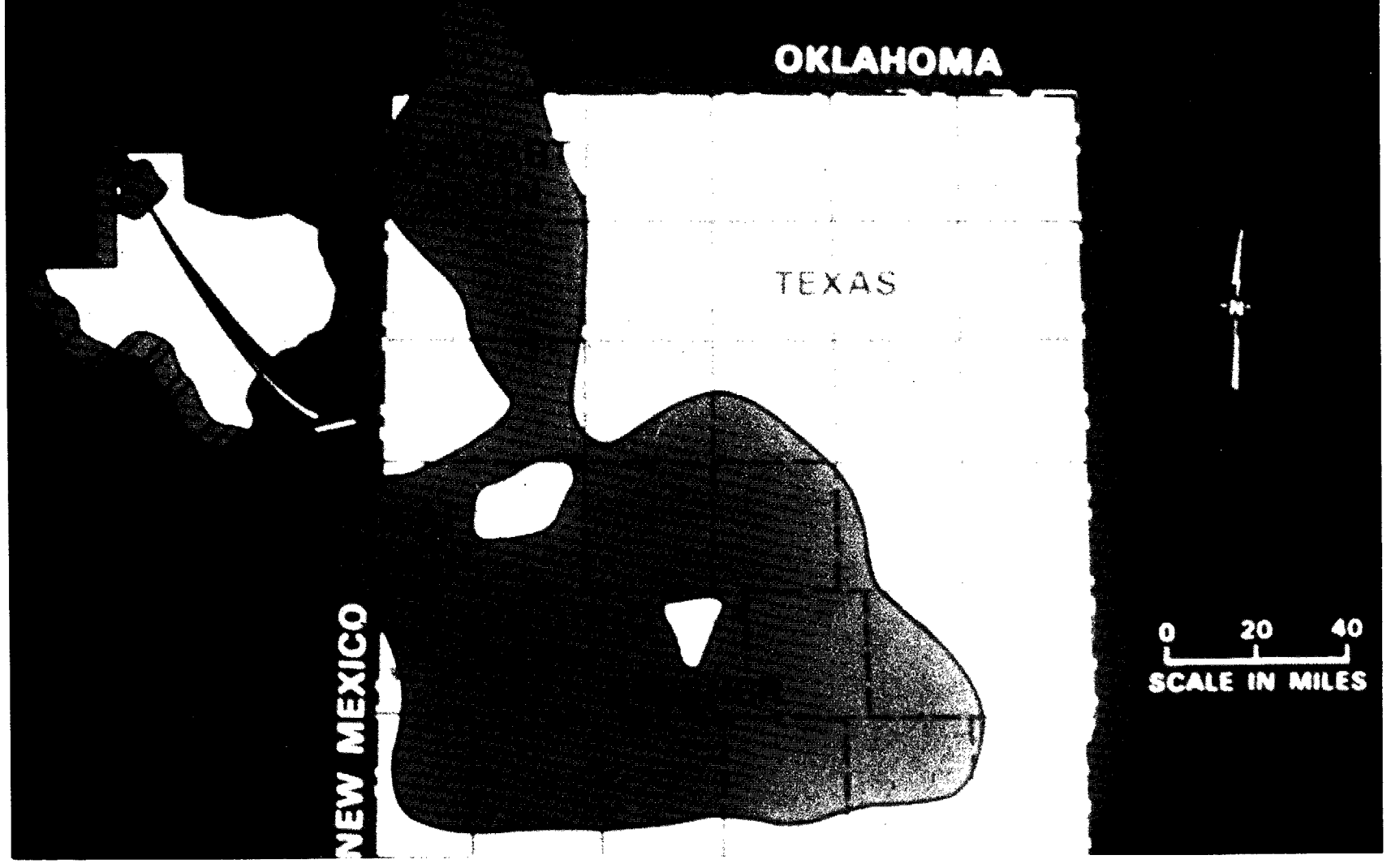
Possible study site boundary

Block boundary

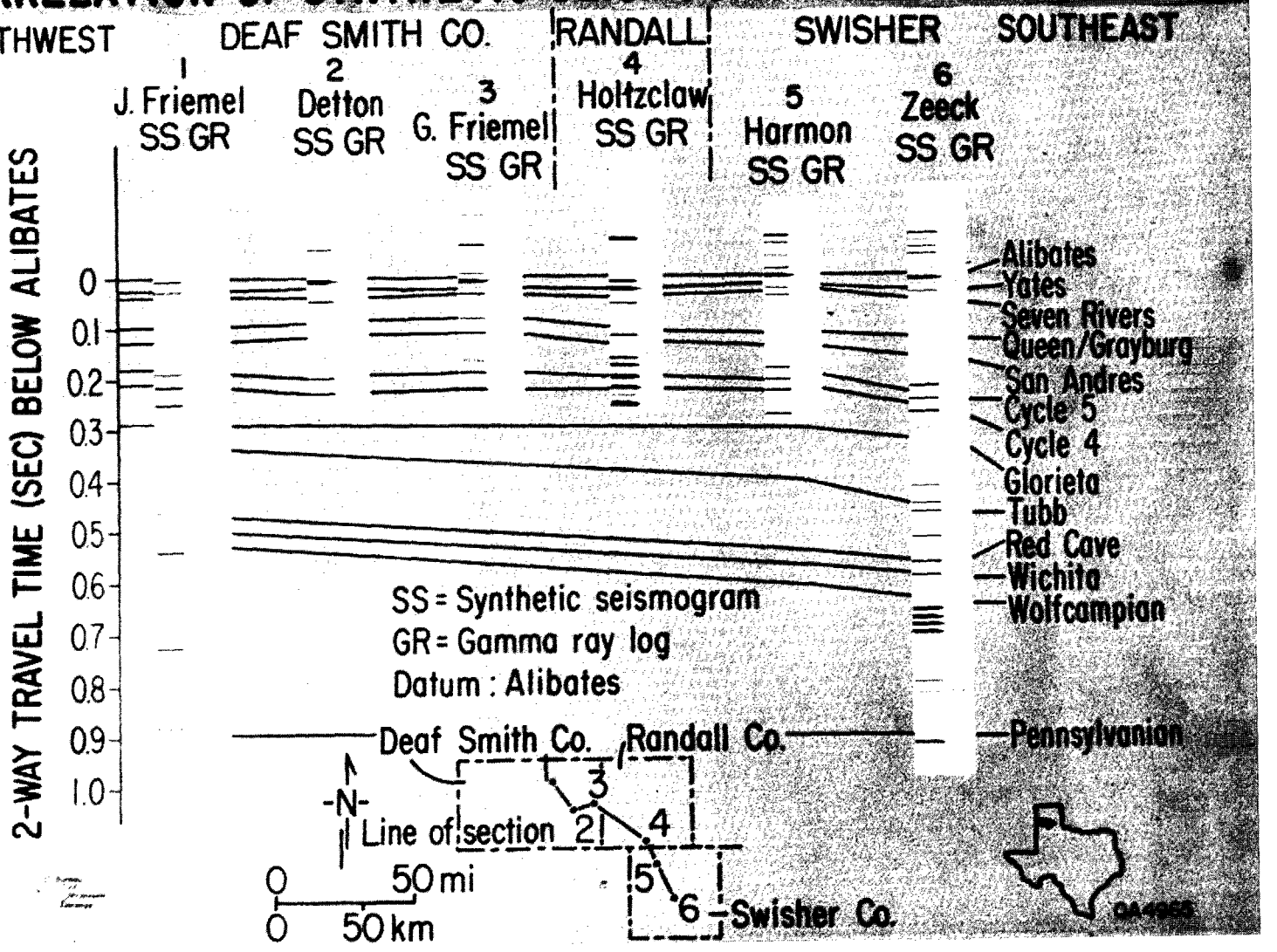
TECTONIC MAP



GEOLOGIC EXPLORATION — PERMIAN BASIN

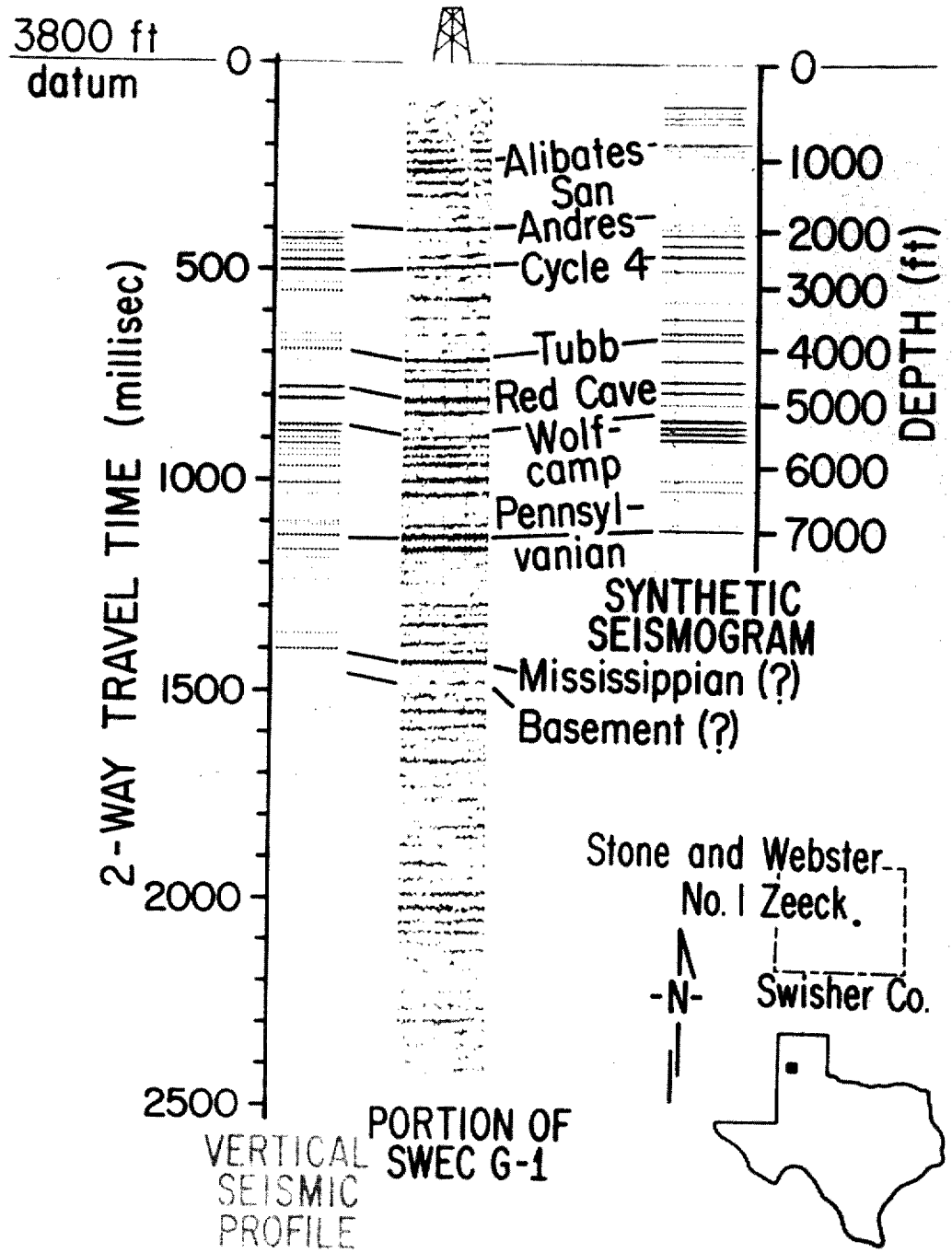


CORRELATION OF SYNTHETIC SEISMOGRAMS FROM DOE WELLS

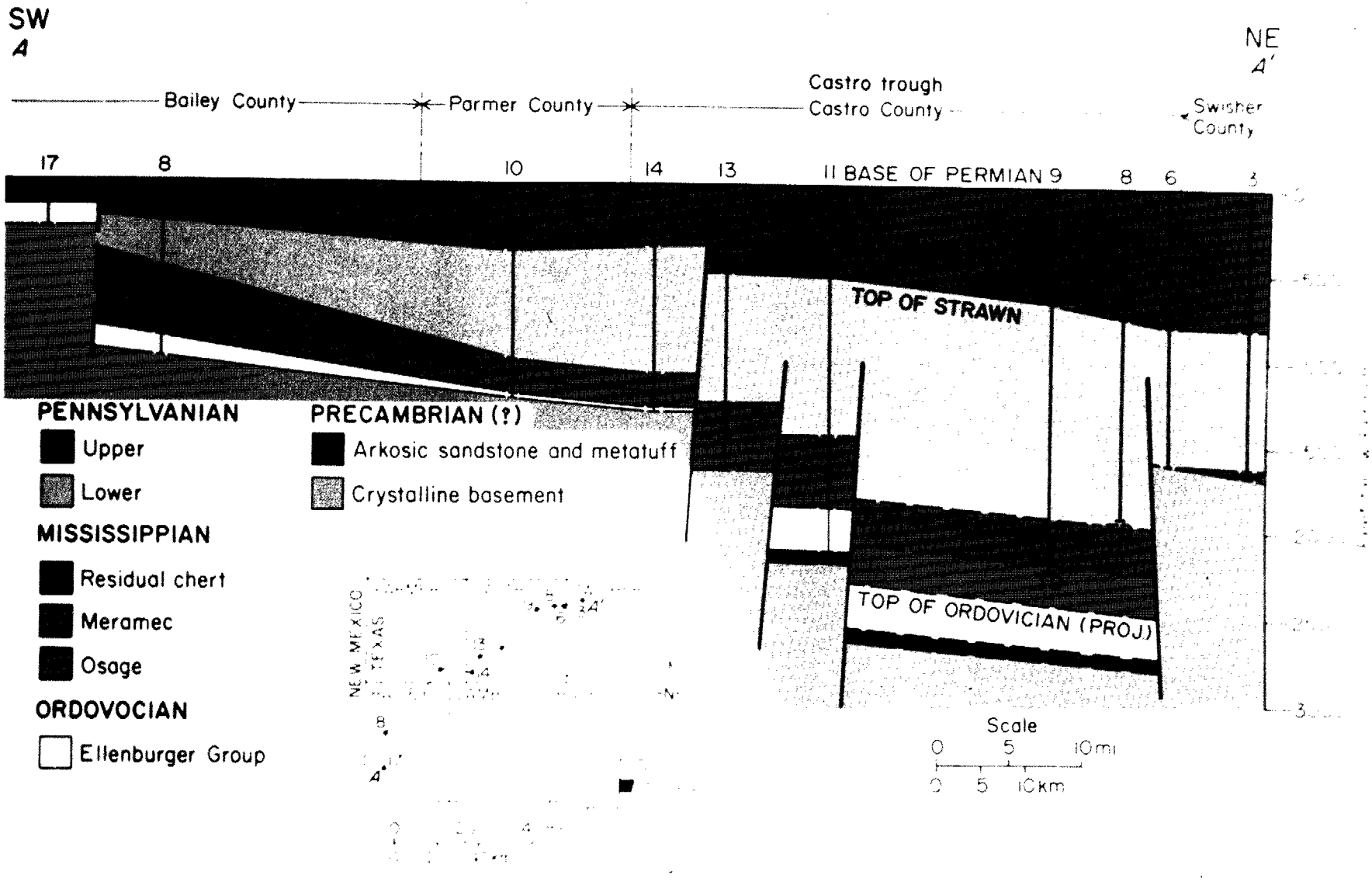


CORRELATION OF VSP, SYNTHETIC SEISMOGRAMS, & SEISMIC DATA

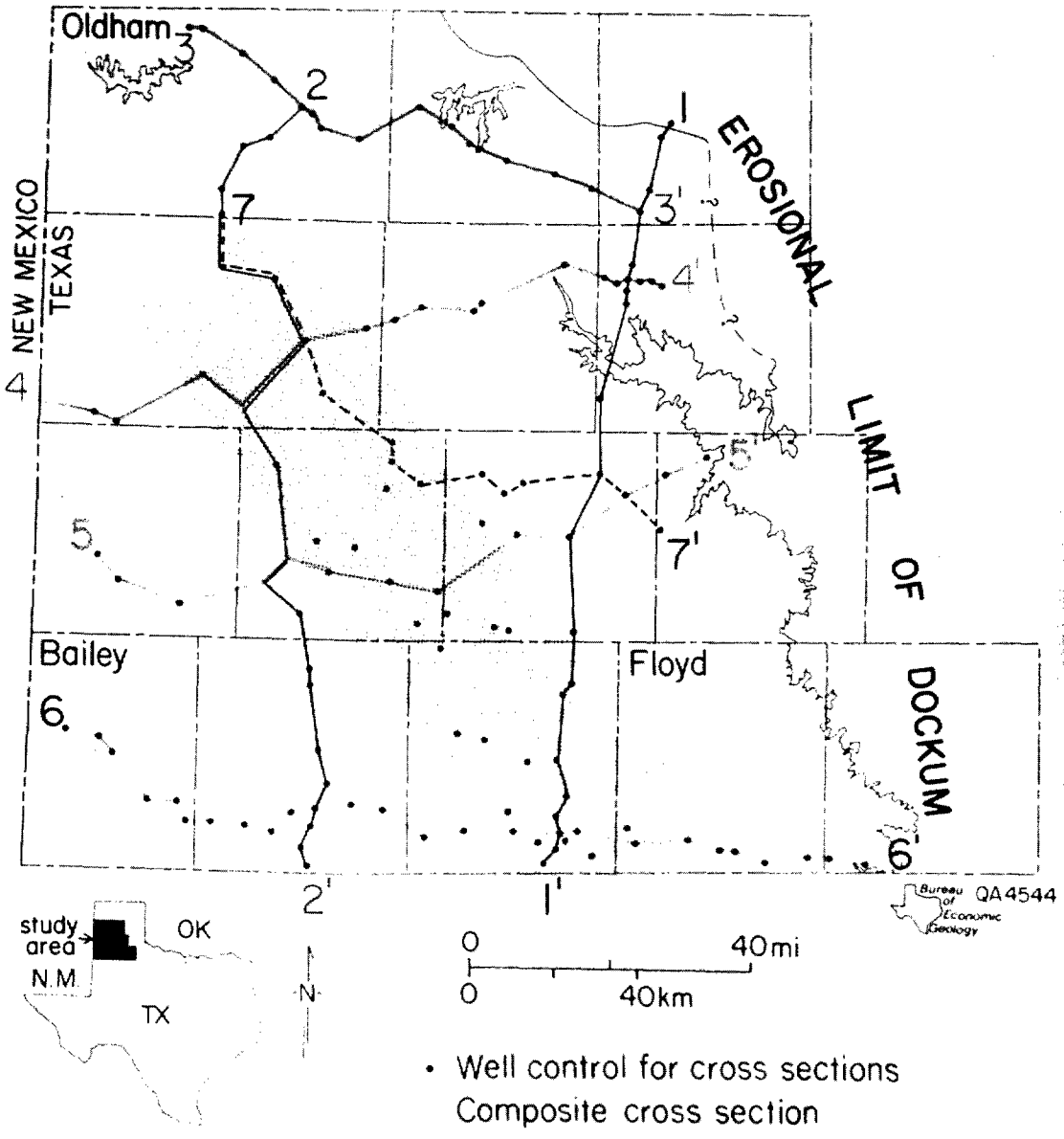
Stone and Webster
No. I Zeeck



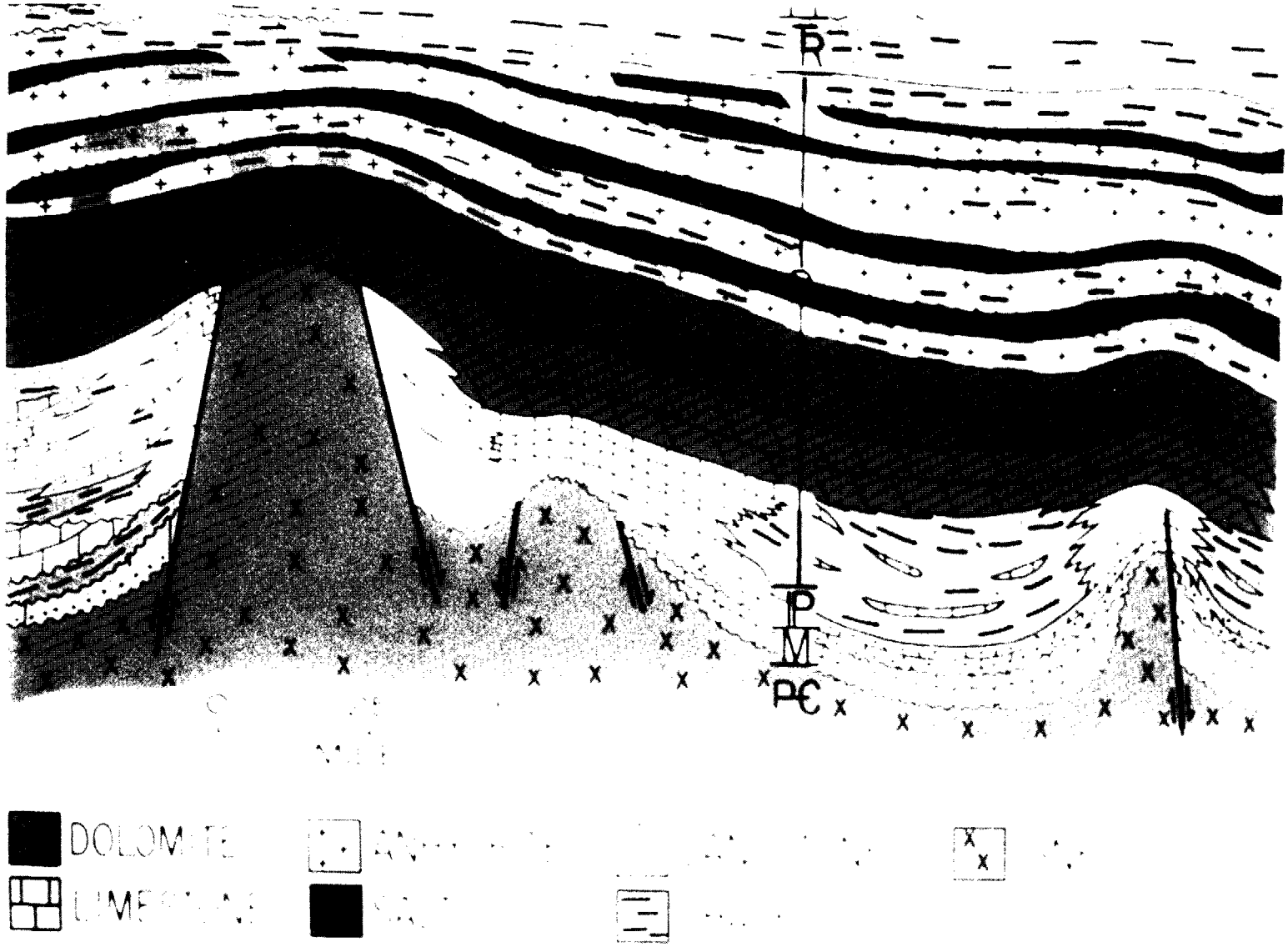
QA4966

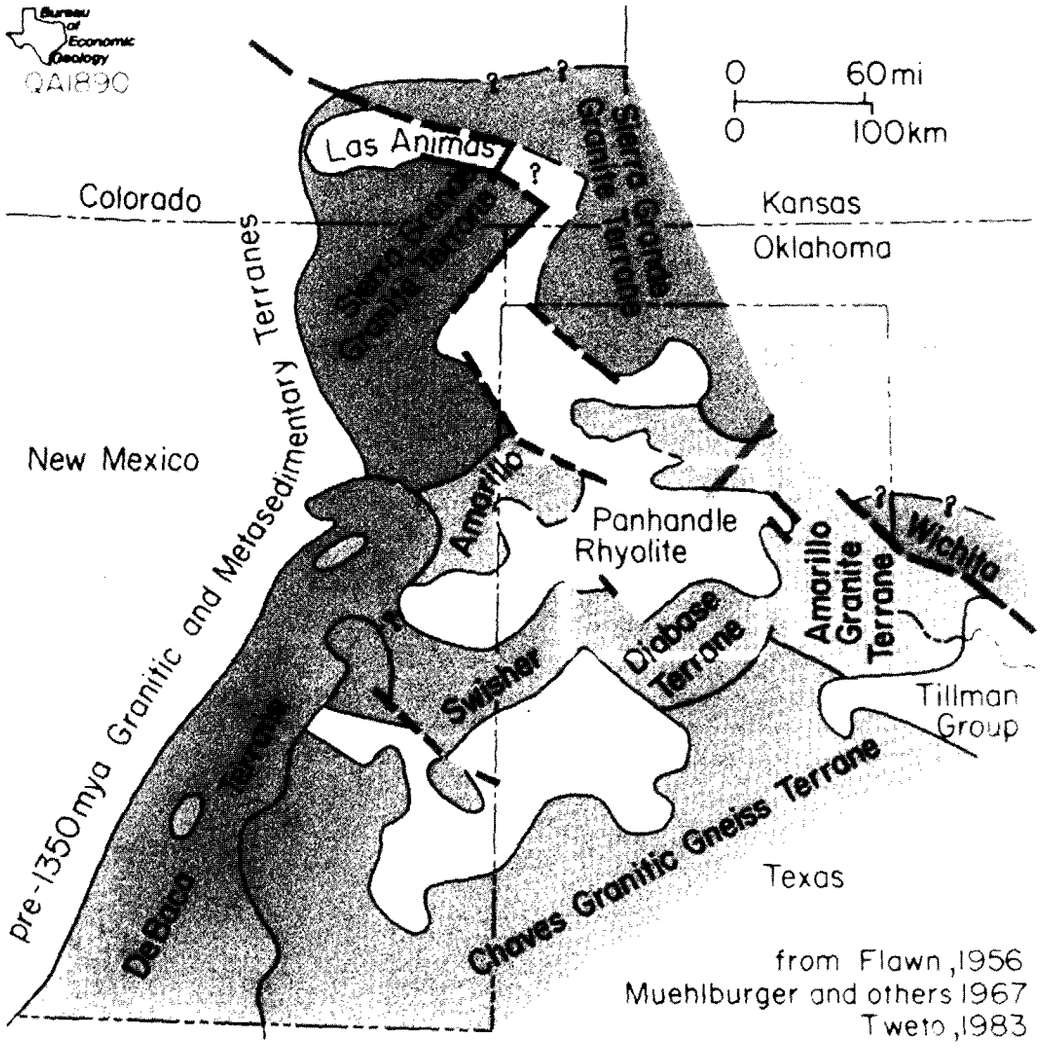

SW
A
NE
A'
Bailey County
Parmer County
Castro trough
Castro County
Swisher County
17
8
10
14
13
11 BASE OF PERMIAN 9
8
6
3
TOP OF STRAWN
TOP OF ORDOVICIAN (PROJ)
PENNSYLVANIAN
Upper
Lower
MISSISSIPPIAN
Residual chert
Meramec
Osage
ORDOVOCIAN
Ellenburger Group
PRECAMBRIAN (?)
Arkosic sandstone and metatuff
Crystalline basement
NEW MEXICO
TEXAS
Scale
0 5 10mi
0 5 10km

INDEX MAP



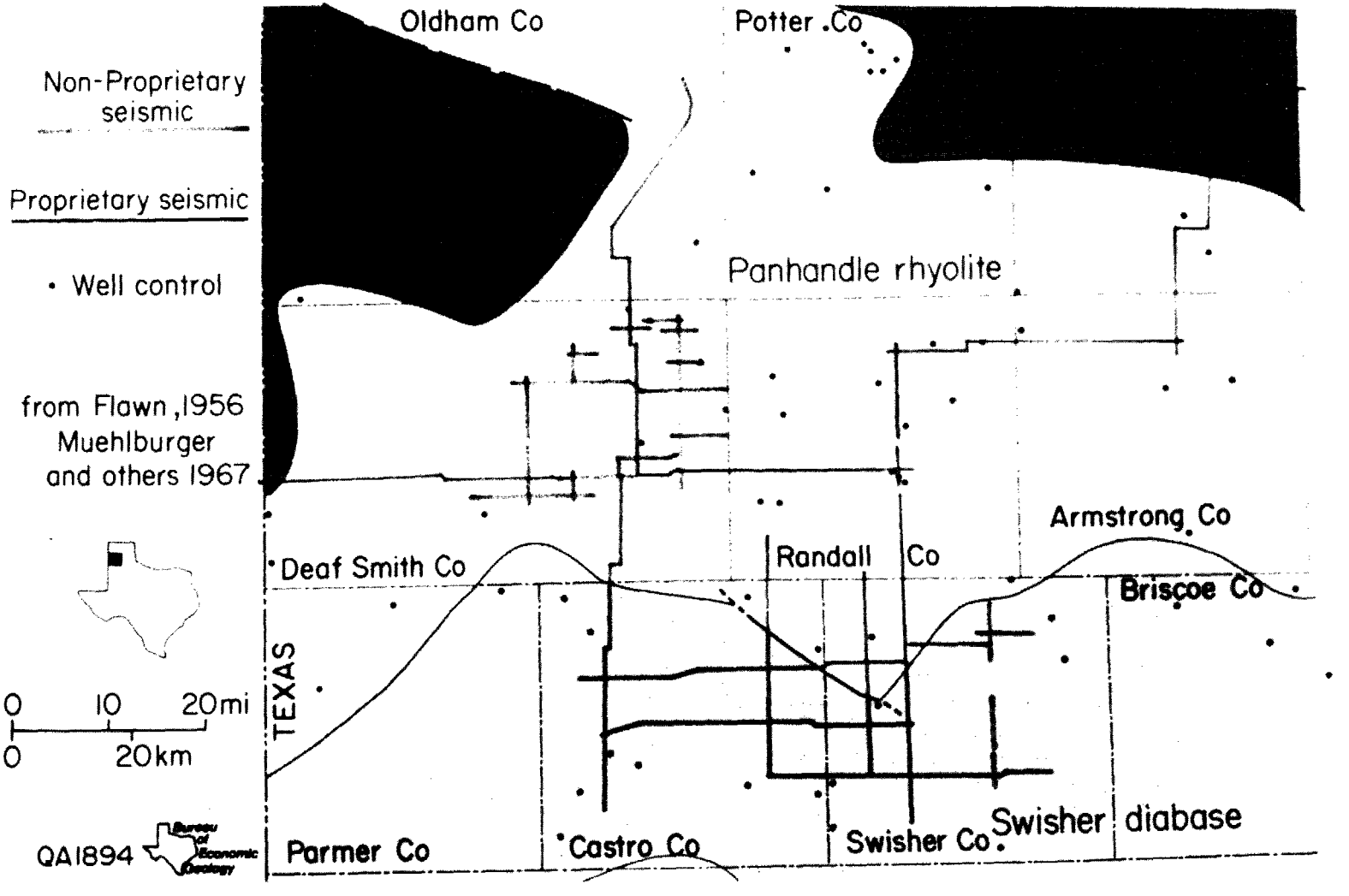
• Well control for cross sections
Composite cross section

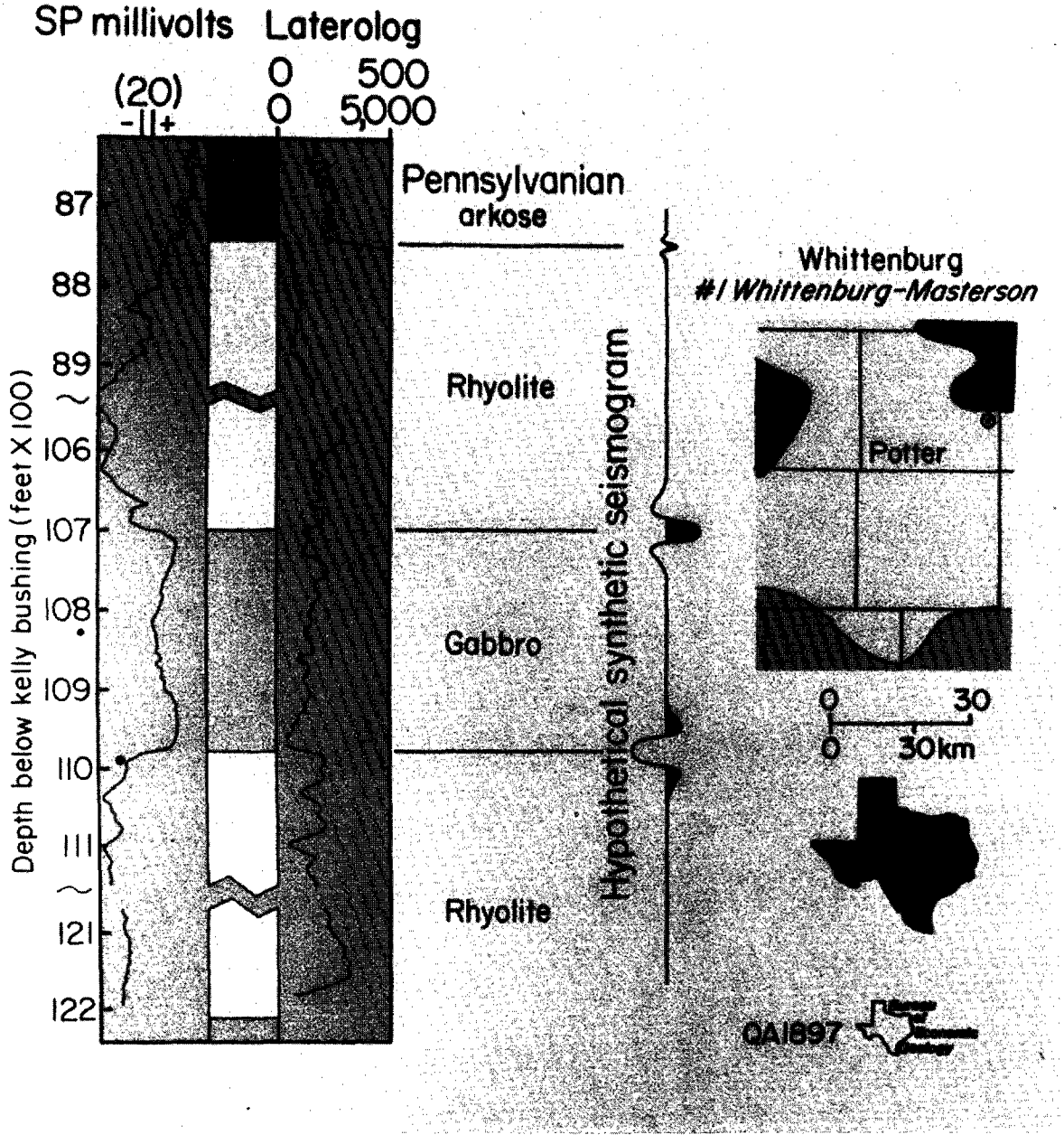

R
P
M
PЄ
DOLOMITE

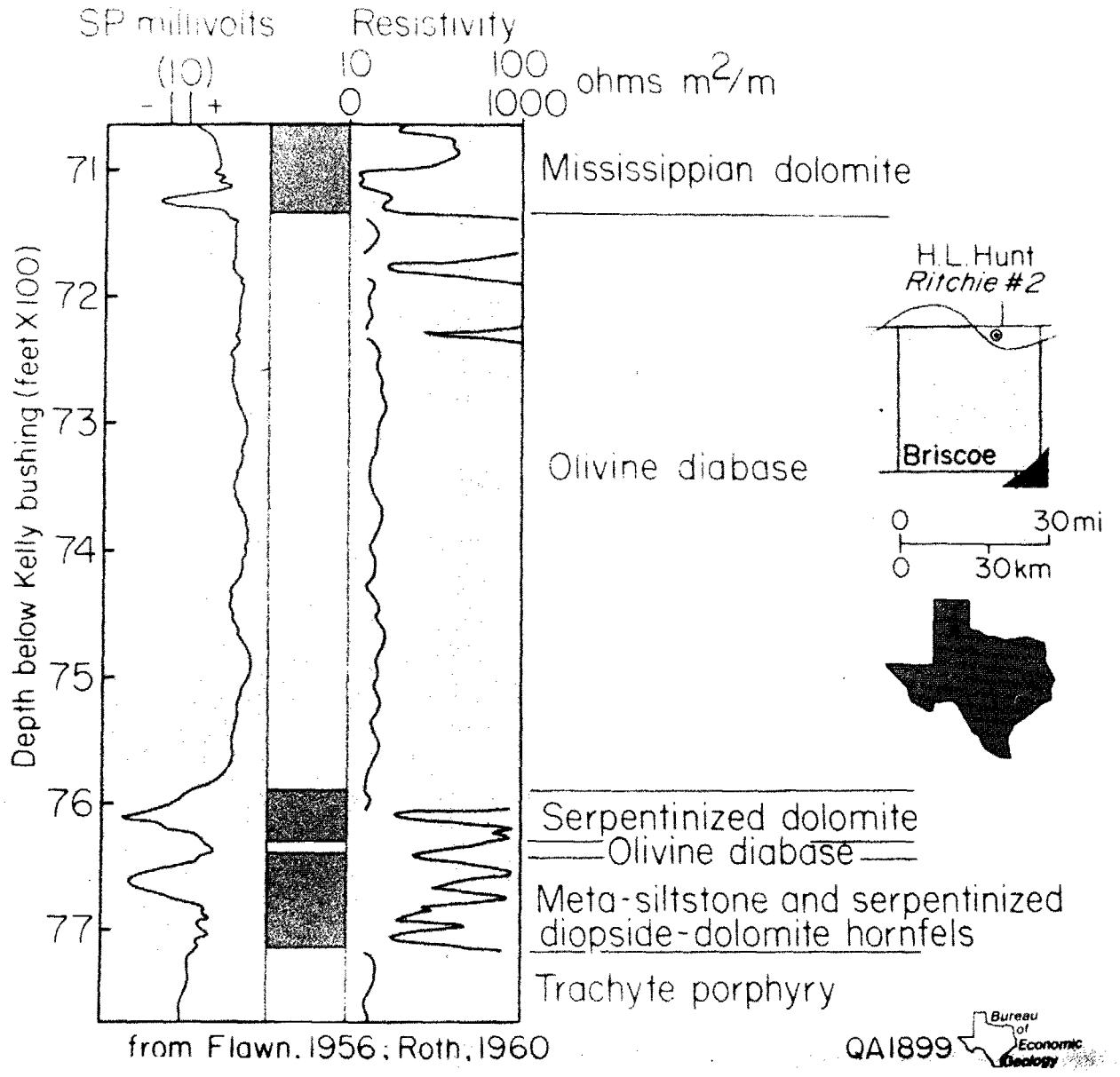


DISTRIBUTION OF BASEMENT TERRANES

DISTRIBUTION OF SEISMIC LINES AND WELL CONTROL



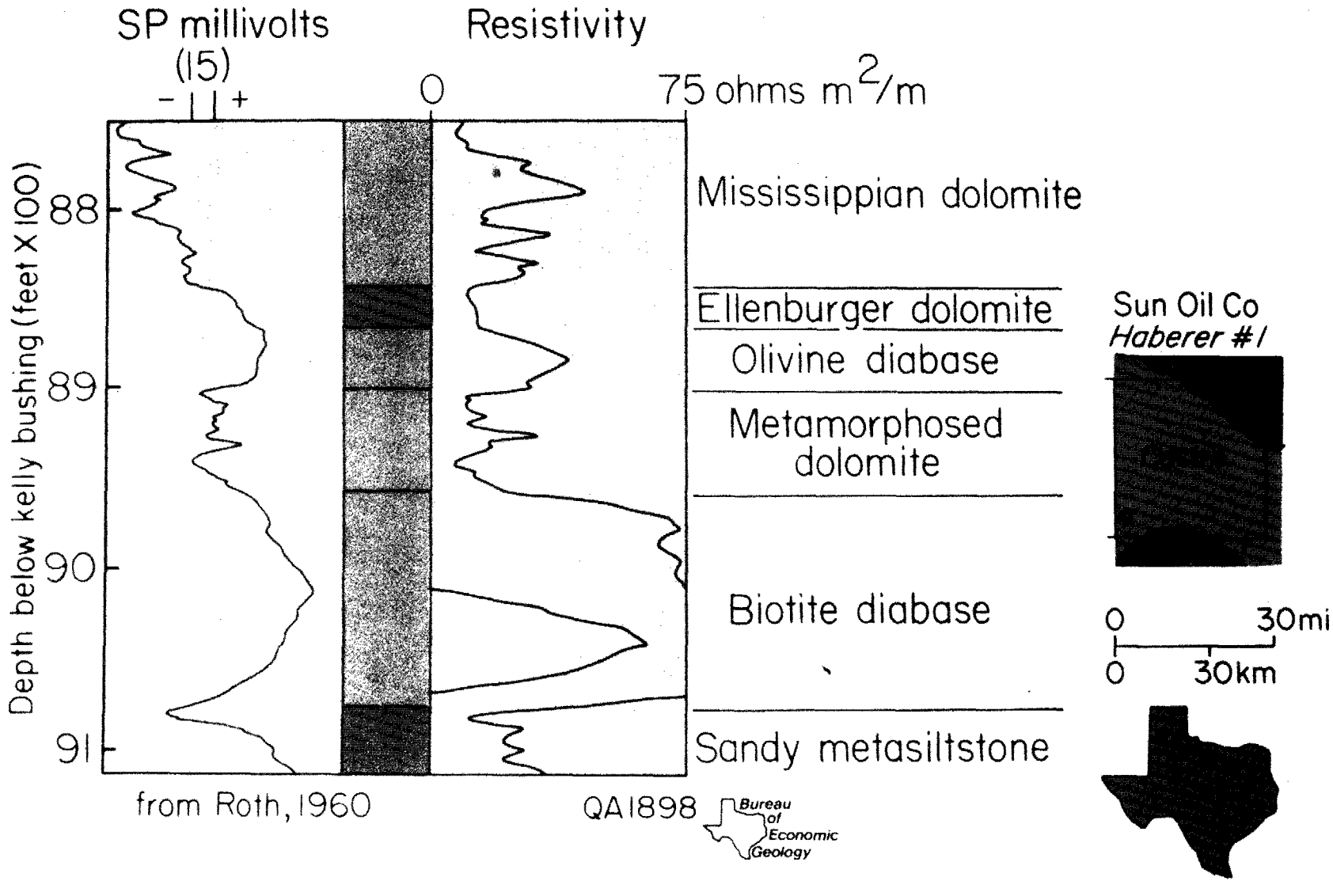

SP millivolts
Laterolog
(20)
-||+
0
500
0
5,000
Pennsylvanian
arkose
Rhyolite
Gabbro
Rhyolite
Hypothetical synthetic seismogram
Depth below kelly bushing (feet X 100)
87
88
89
106
107
108
109
110
111
121
122
Whittenburg
#1 Whittenburg-Masterson
Potter
0
30
0
30km
OA1897

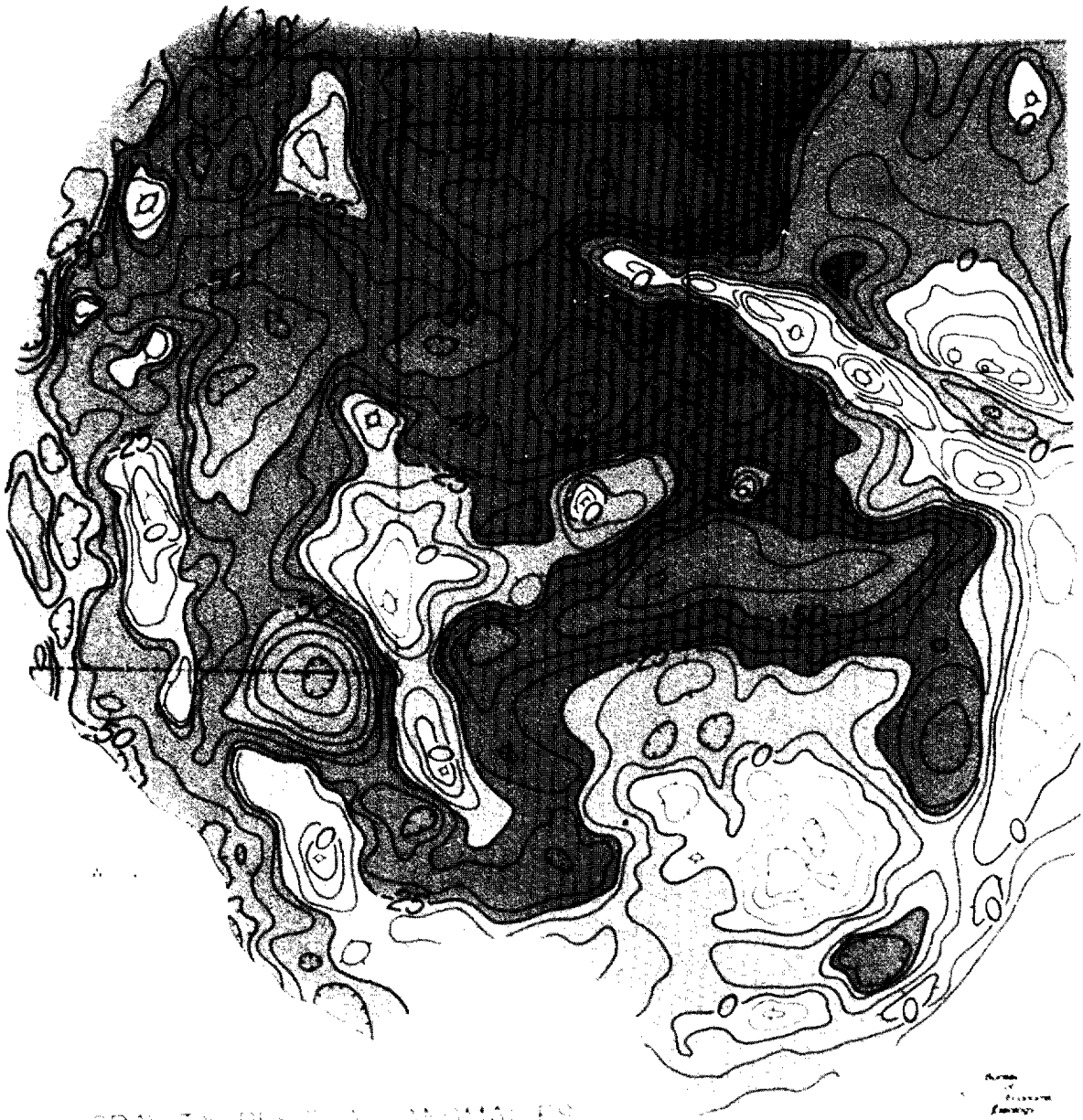


from Flawn, 1956; Roth, 1960

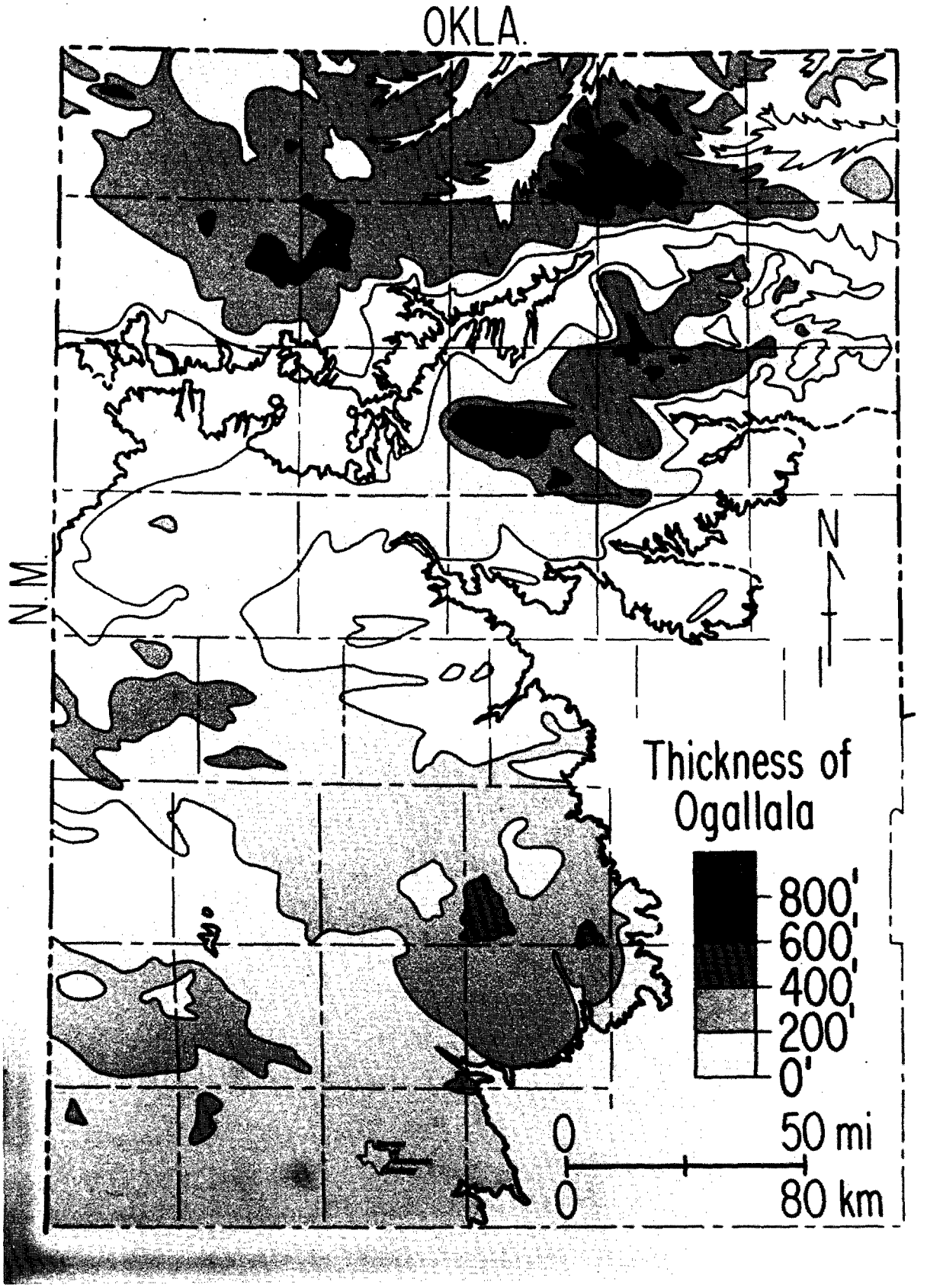
QA1899

Bureau of Economic Geology

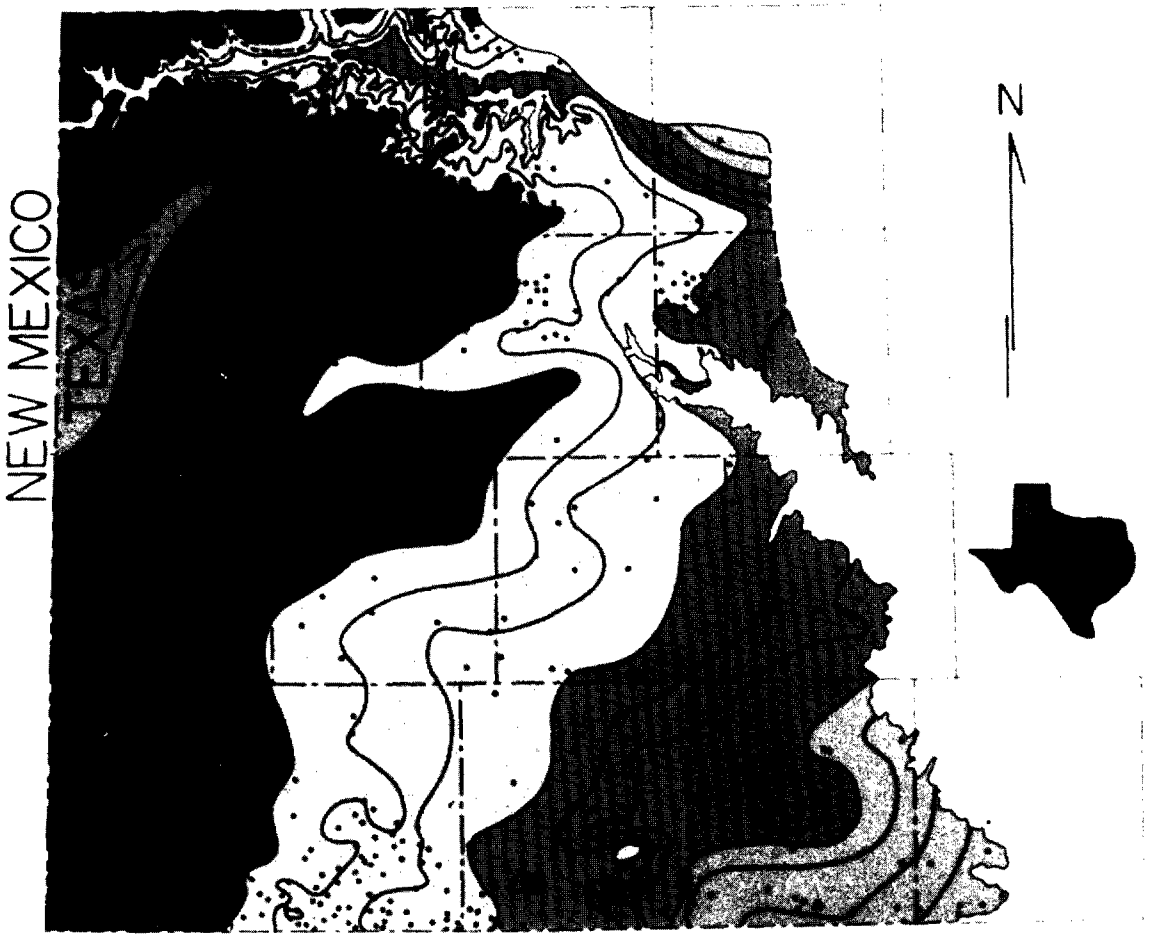

SP millivolts
(15)
- +
Resistivity
0
75 ohms m²/m
Depth below kelly bushing (feet X 100)
88
89
90
91
Mississippian dolomite
Ellenburger dolomite
Olivine diabase
Metamorphosed dolomite
Biotite diabase
Sandy metasiltstone
Sun Oil Co
Haberer #1
0
30mi
0
30km
from Roth, 1960
QA1898
Bureau of Economic Geology



GRAVITY RESIDUAL ANOMALIES


OKLA.
N.M.
N
Thickness of Ogallala
800'
600'
400'
200'
0'
0
50 mi
0
80 km

STRUCTURE CONTOUR
TOP OF DOCKUM GROUP



- < 2900ft
- 2900-3200
- 3200-3500
- 3500-3800
- 3800-4100
- > 4100

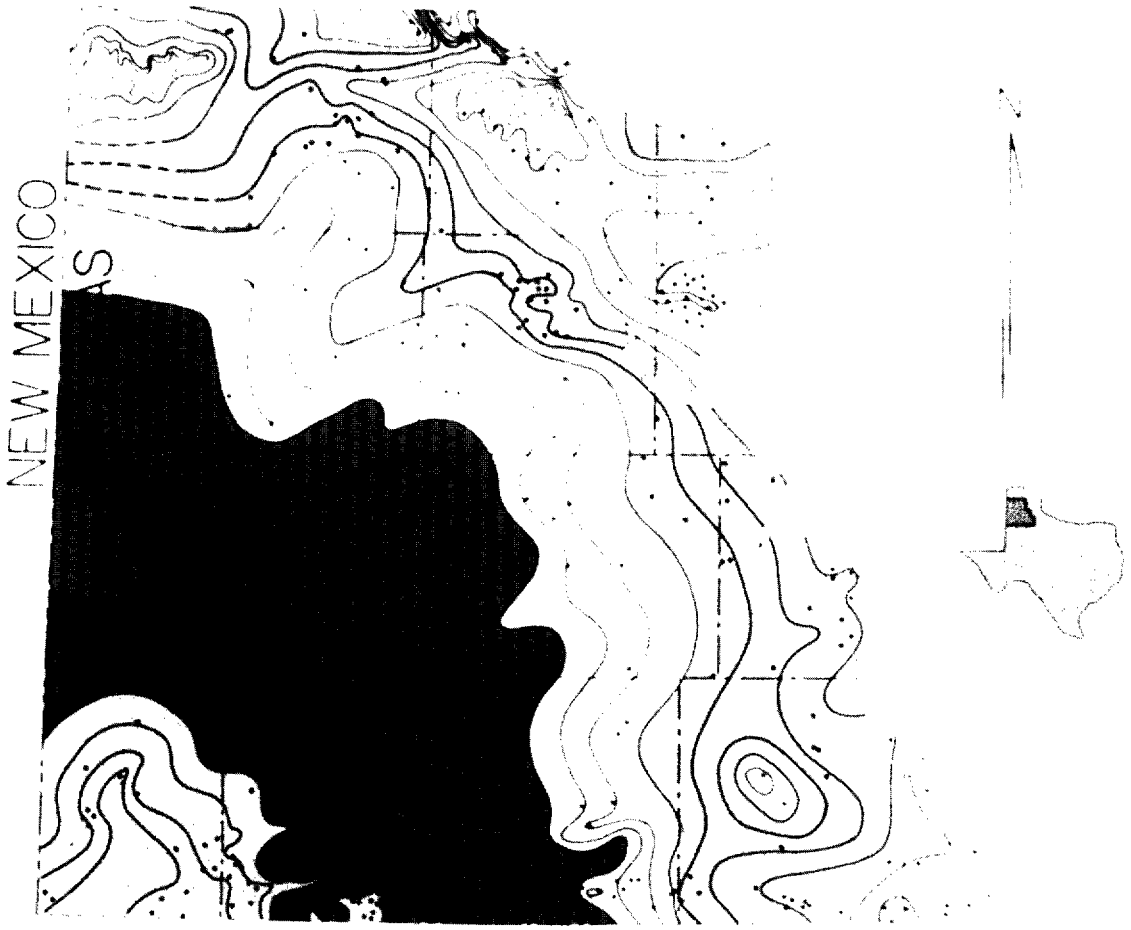
0 40mi

0 40km

Contour interval = 100ft

QA-1907

ISOPACH - DOCKUM GROUP

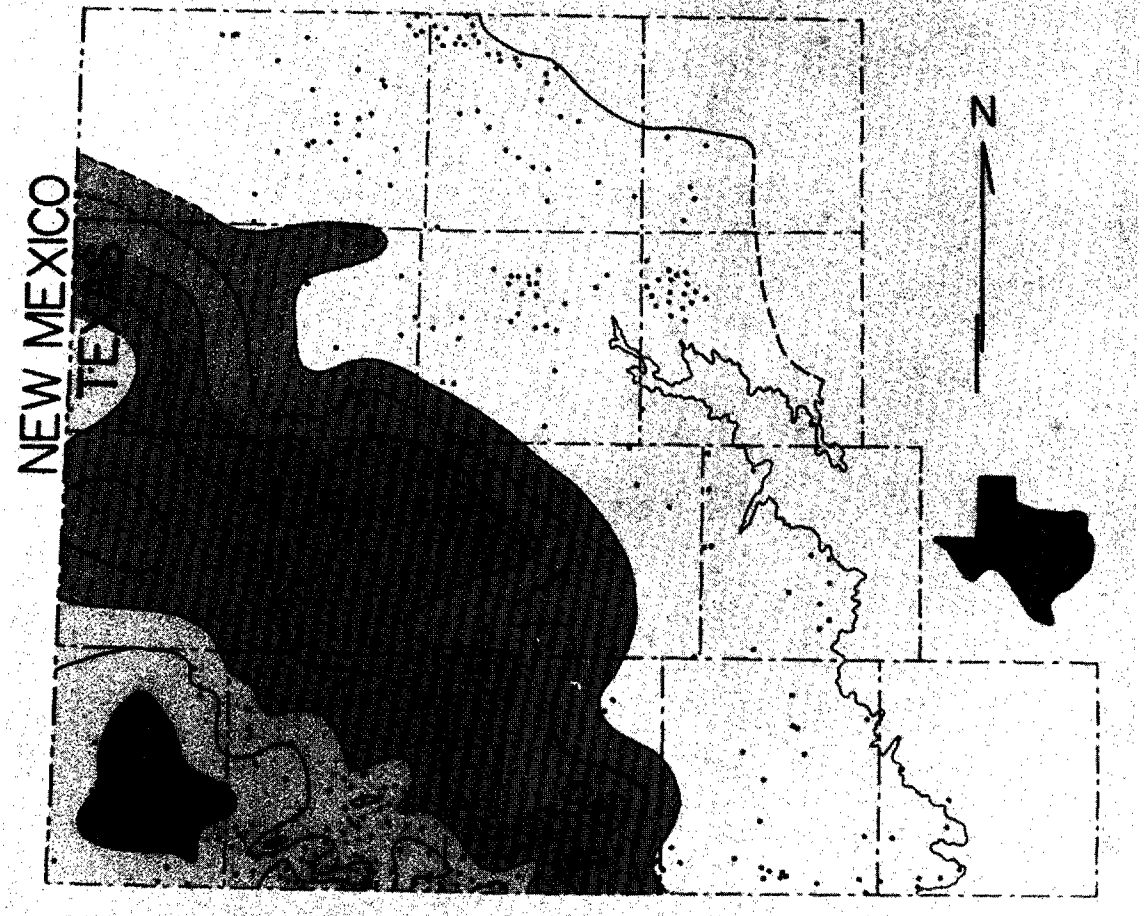


0-300 ft
300-600
600-900
900-1200
1200-1500
>1500

0 40mi
0 40km

Contour interval = 100ft

ISOPACH - UPPER DOCKUM



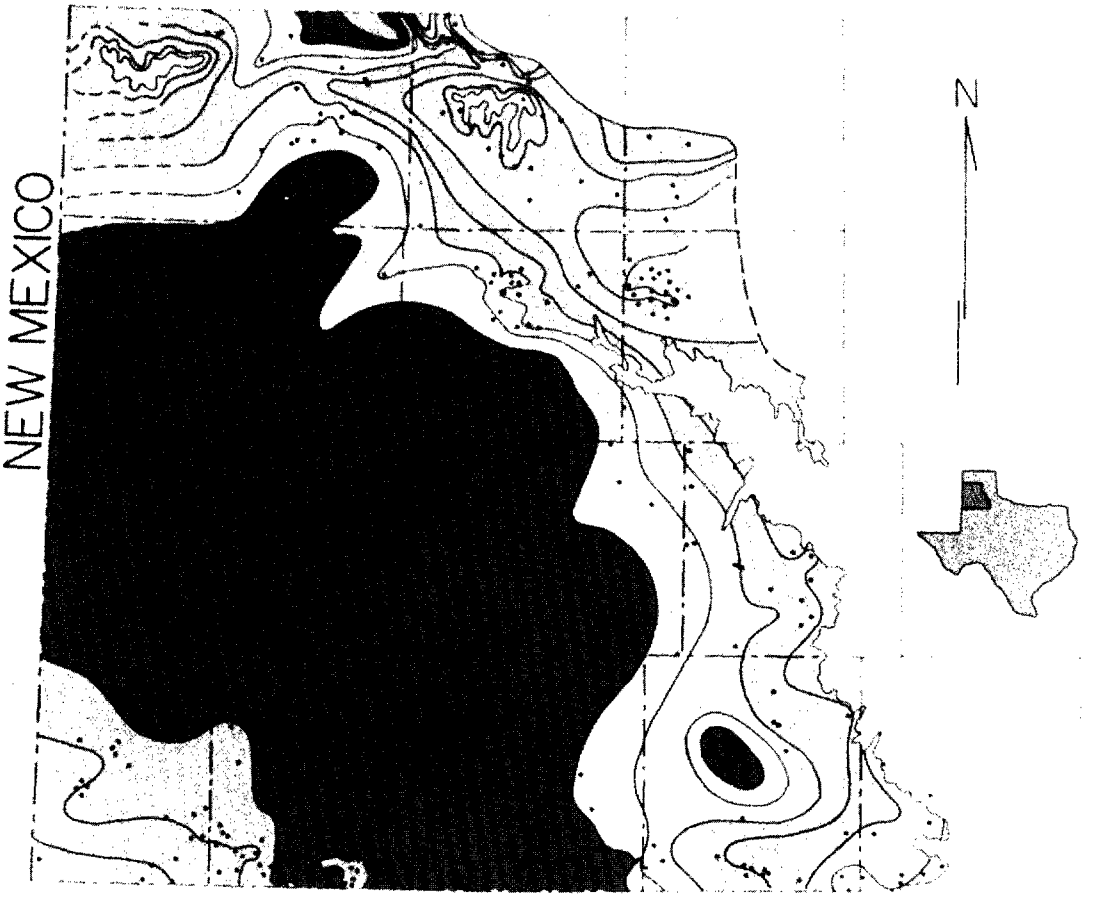
0-200 ft
200-400
400-600
> 600

0 40mi
0 40km

Contour interval = 100 ft

QA-1903

ISOPACH - LOWER DOCKUM



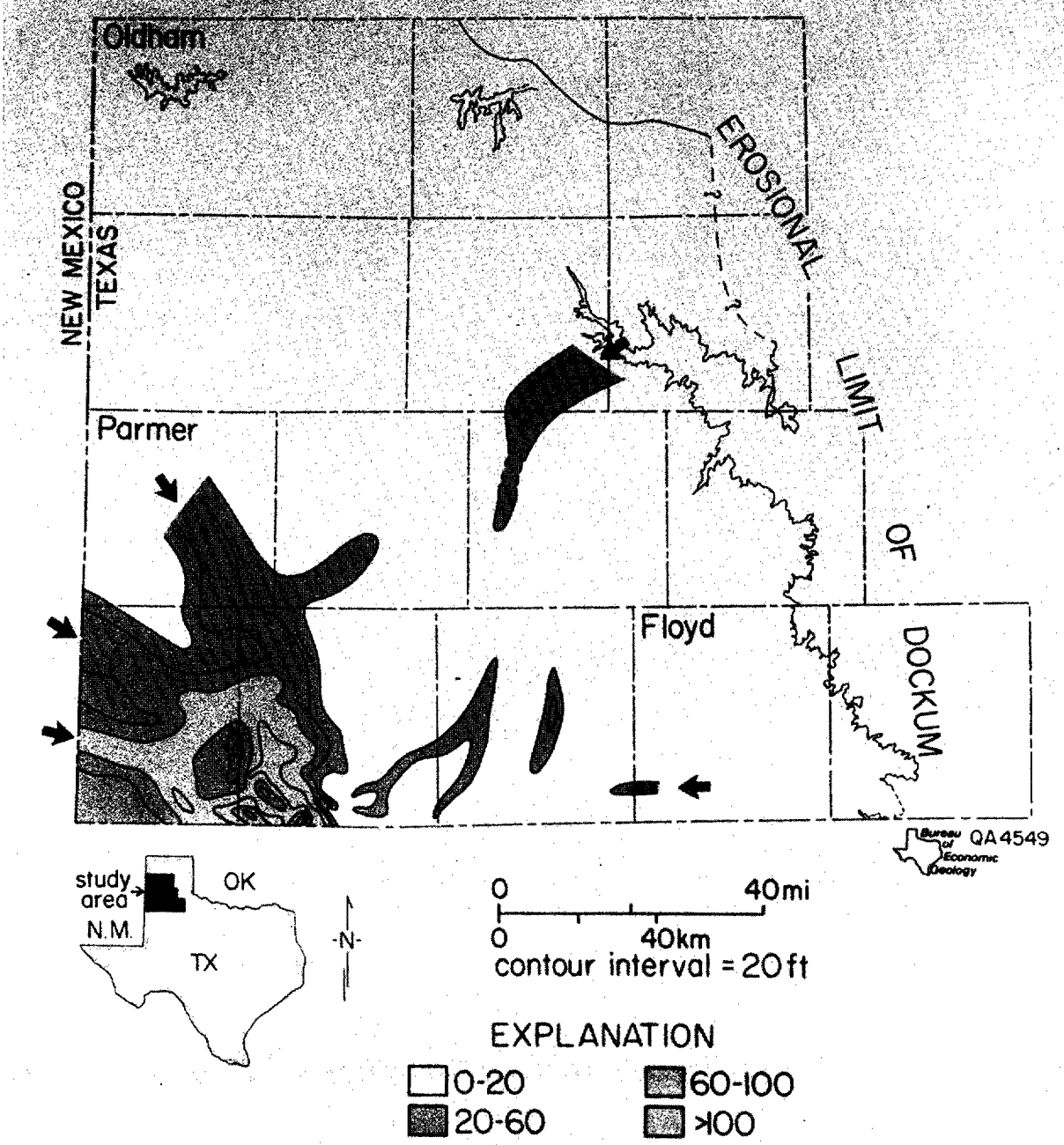
0-200 ft
200-400
400-600
600-800
800-1000
1000-12000
> 1200

0 40mi
0 40km

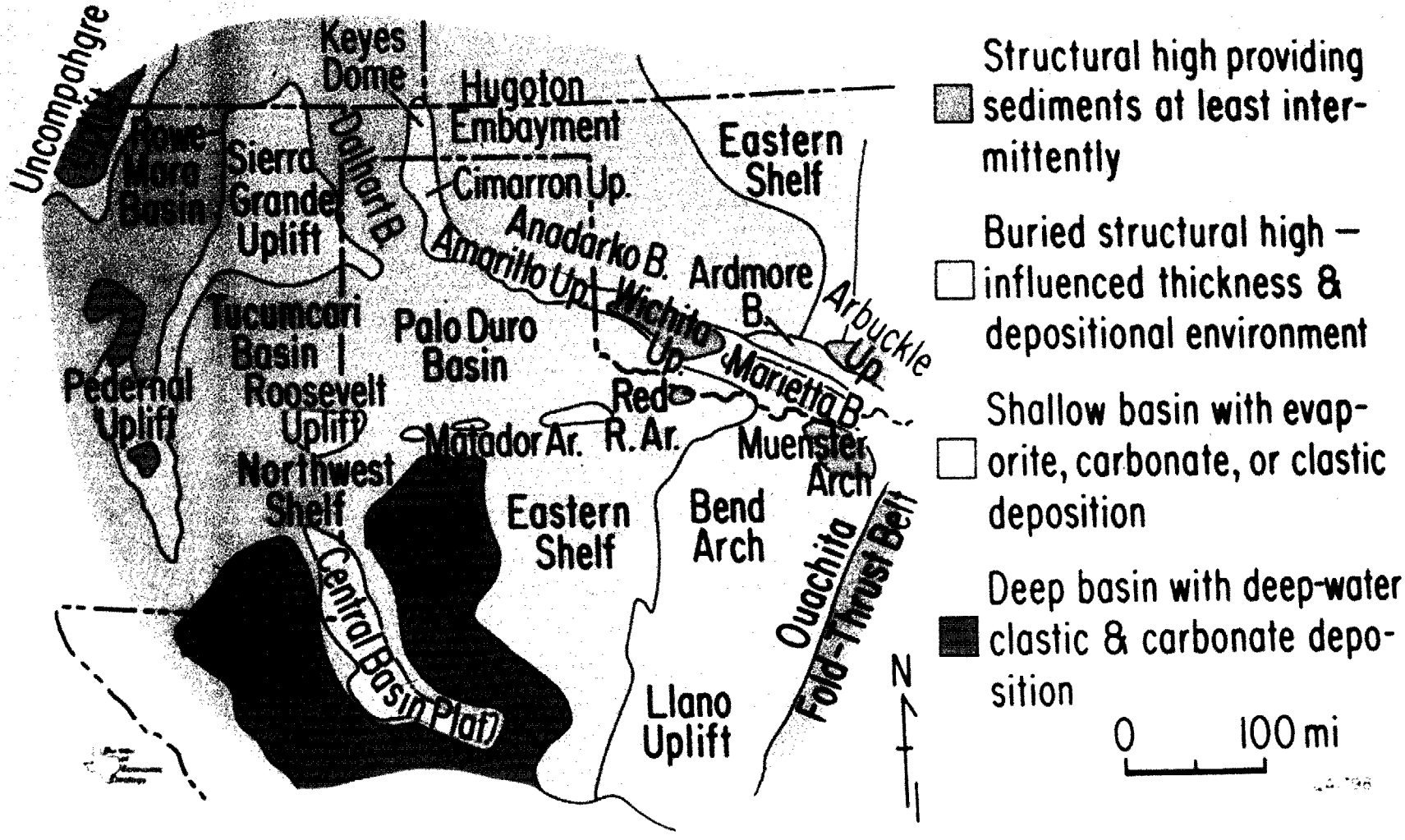
Contour interval = 100'

QA-1905

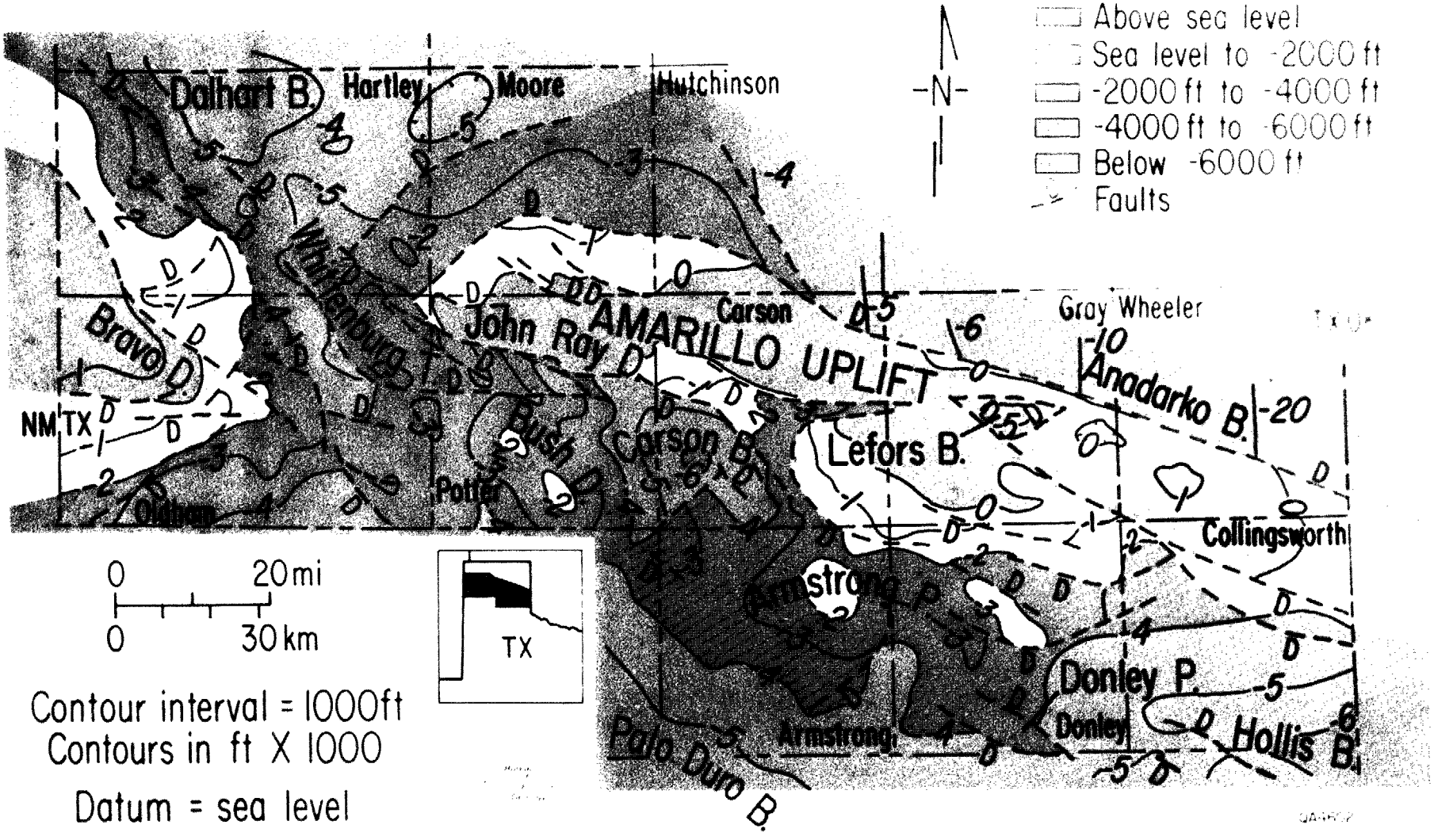
NET SANDSTONE PACKAGE NO.5



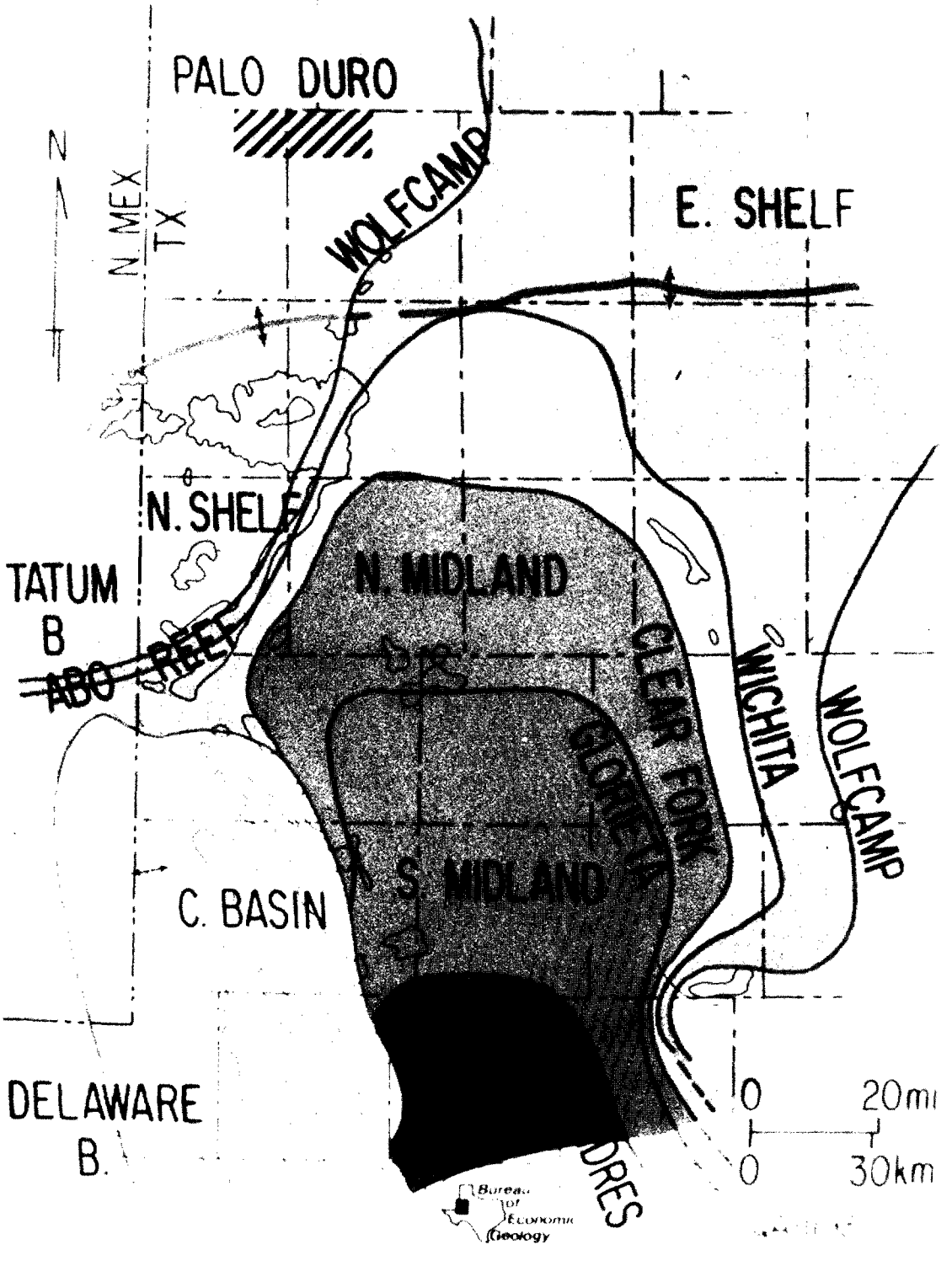
MIDDLE & LATE PERMIAN TECTONIC ELEMENTS



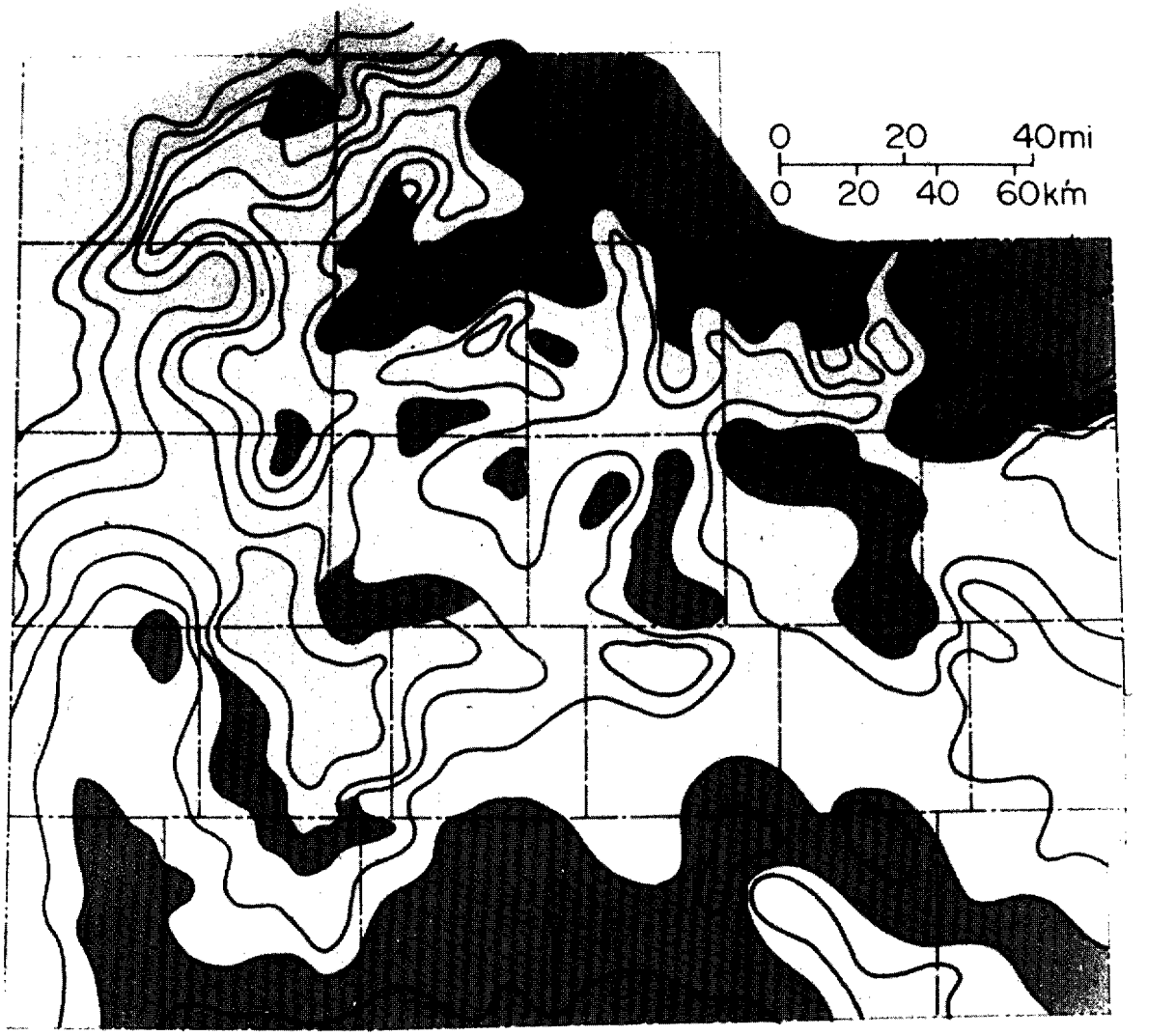
Basement structure map of Amarillo Uplift



PROGRADATION OF PERMIAN SHELF MARGIN SOUTHERN TEXAS PANHANDLE



GENERALIZED LITHOFACIES - WICHITA GROUP



>80% CARB

>60% CARB

40-60% CARB ANHY > CLASTICS

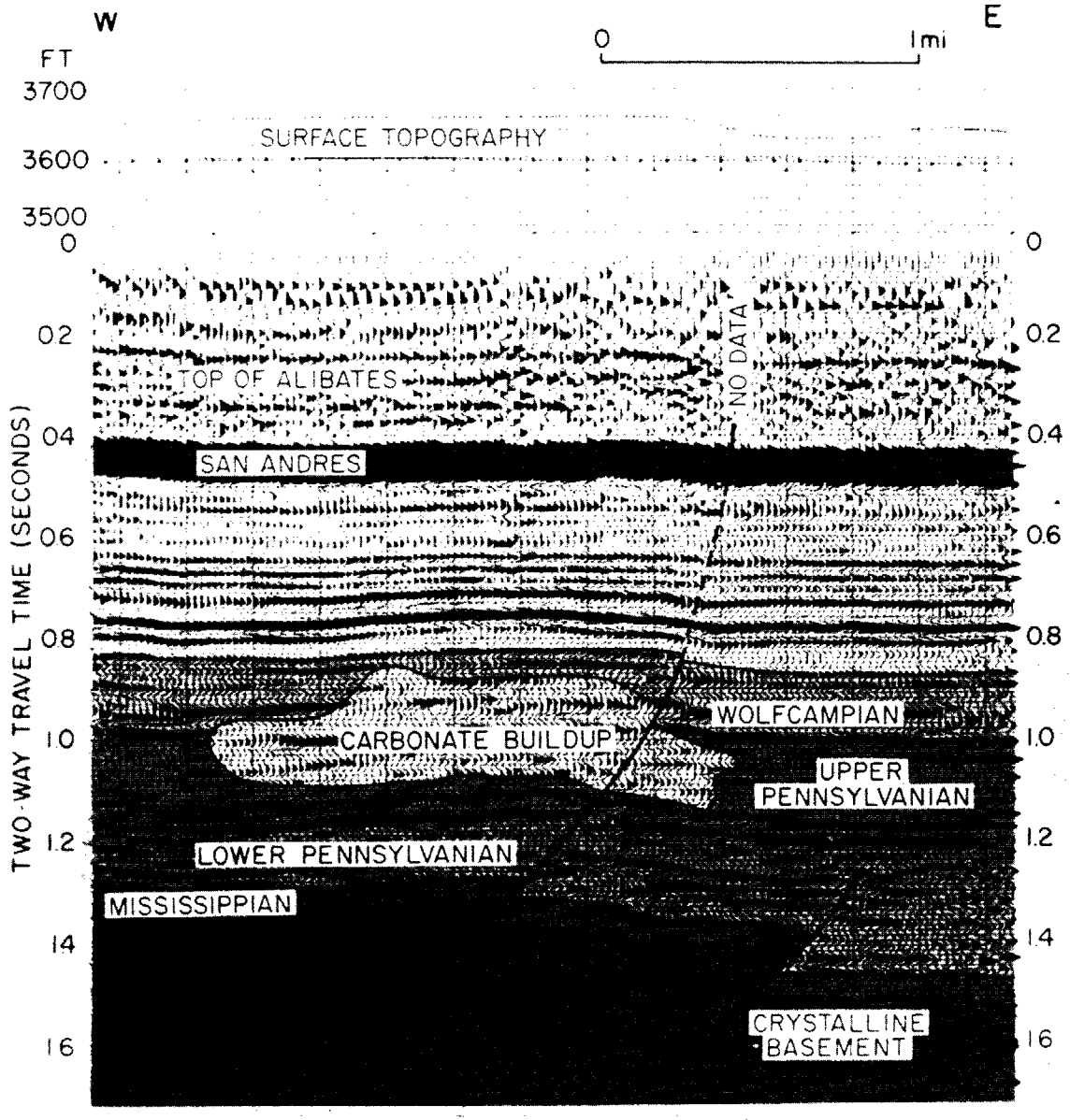
40-60% CARB CLASTICS > ANHY

<40% CARB ANHY > CLASTICS

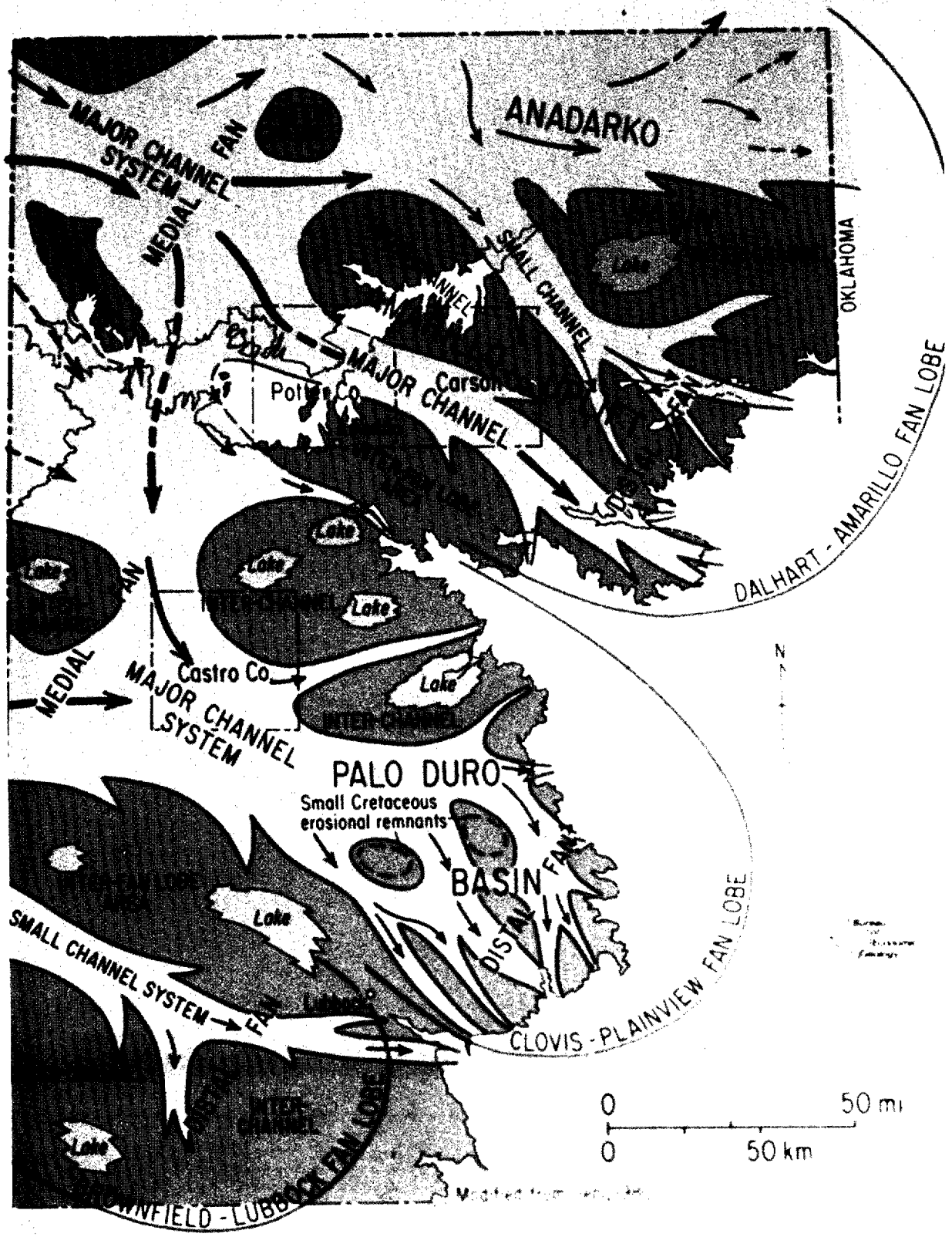
<40% CARB CLASTICS > ANHY

% CARB (= DOLOMITE)
C.I. = 10%

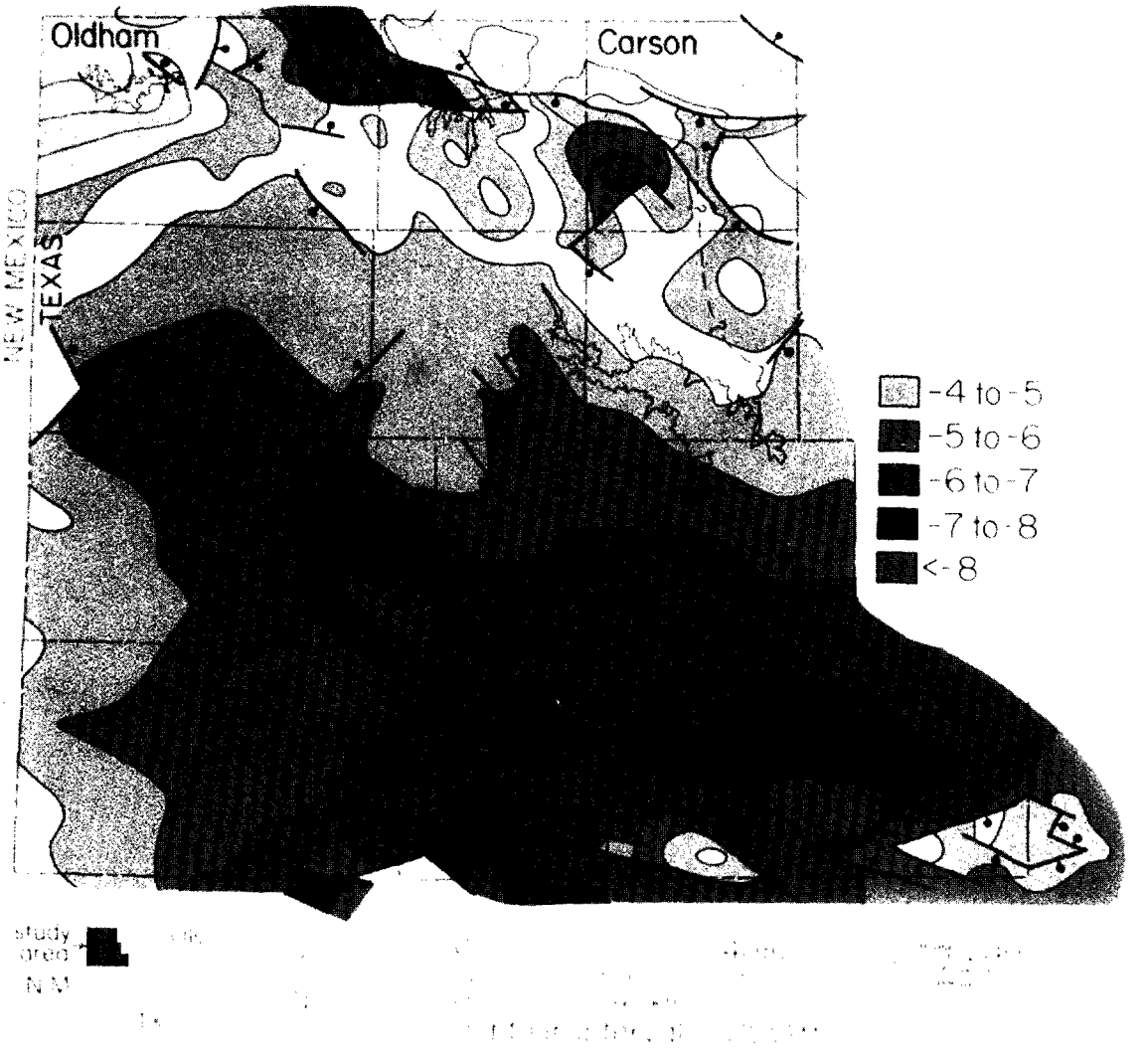
QA1917


W
E
0
1mi
FT
3700
3600
3500
SURFACE TOPOGRAPHY
TWO-WAY TRAVEL TIME (SECONDS)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
TOP OF ALIBATES
NO DATA
SAN ANDRES
WOLFCAMPIAN
CARBONATE BUILDUP
UPPER PENNSYLVANIAN
LOWER PENNSYLVANIAN
MISSISSIPPIAN
CRYSTALLINE BASEMENT

DEPOSITIONAL PATTERNS OF OGALLALA FM



SIMPLIFIED BASEMENT STRUCTURE



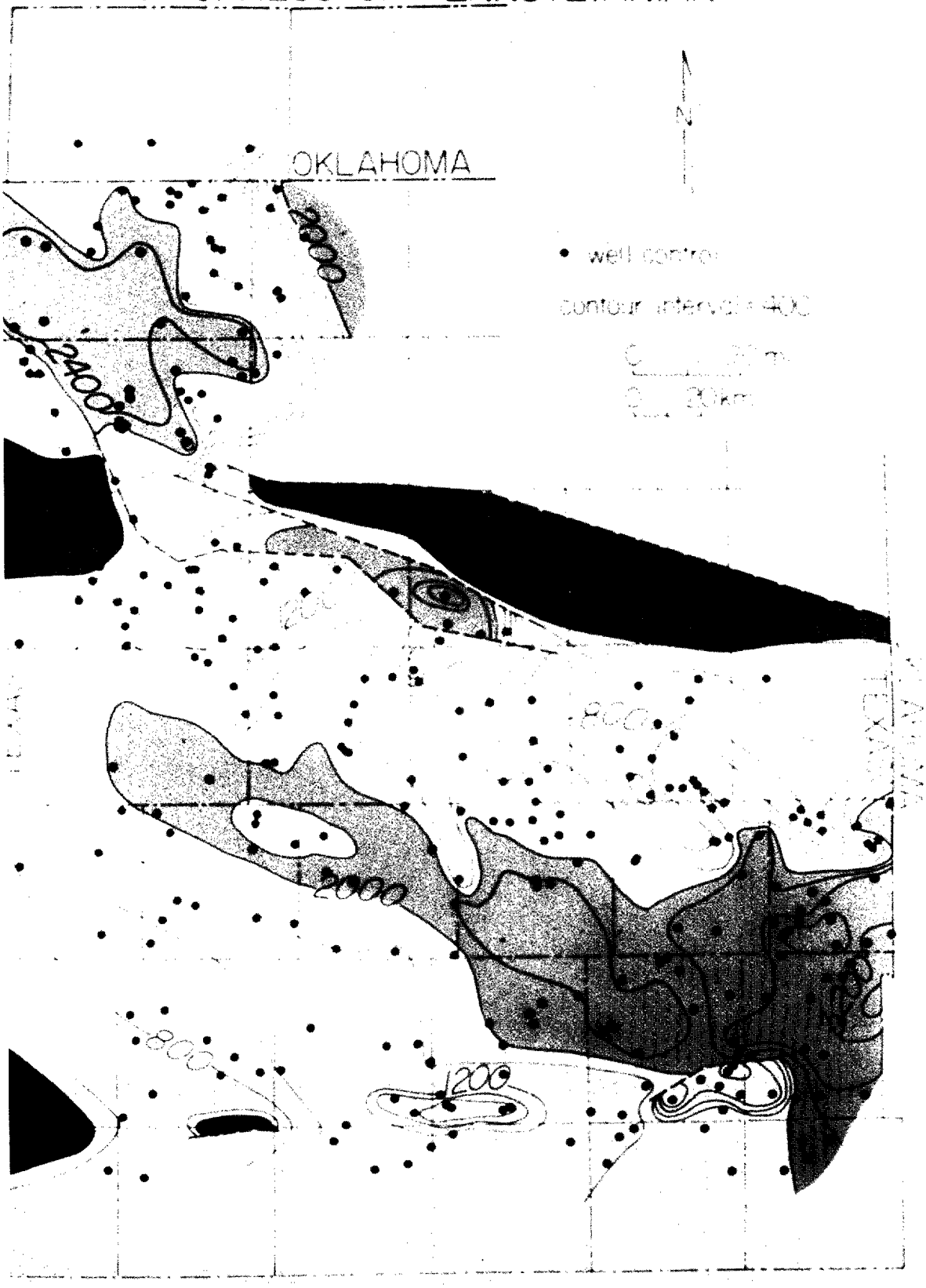
EXPLANATION

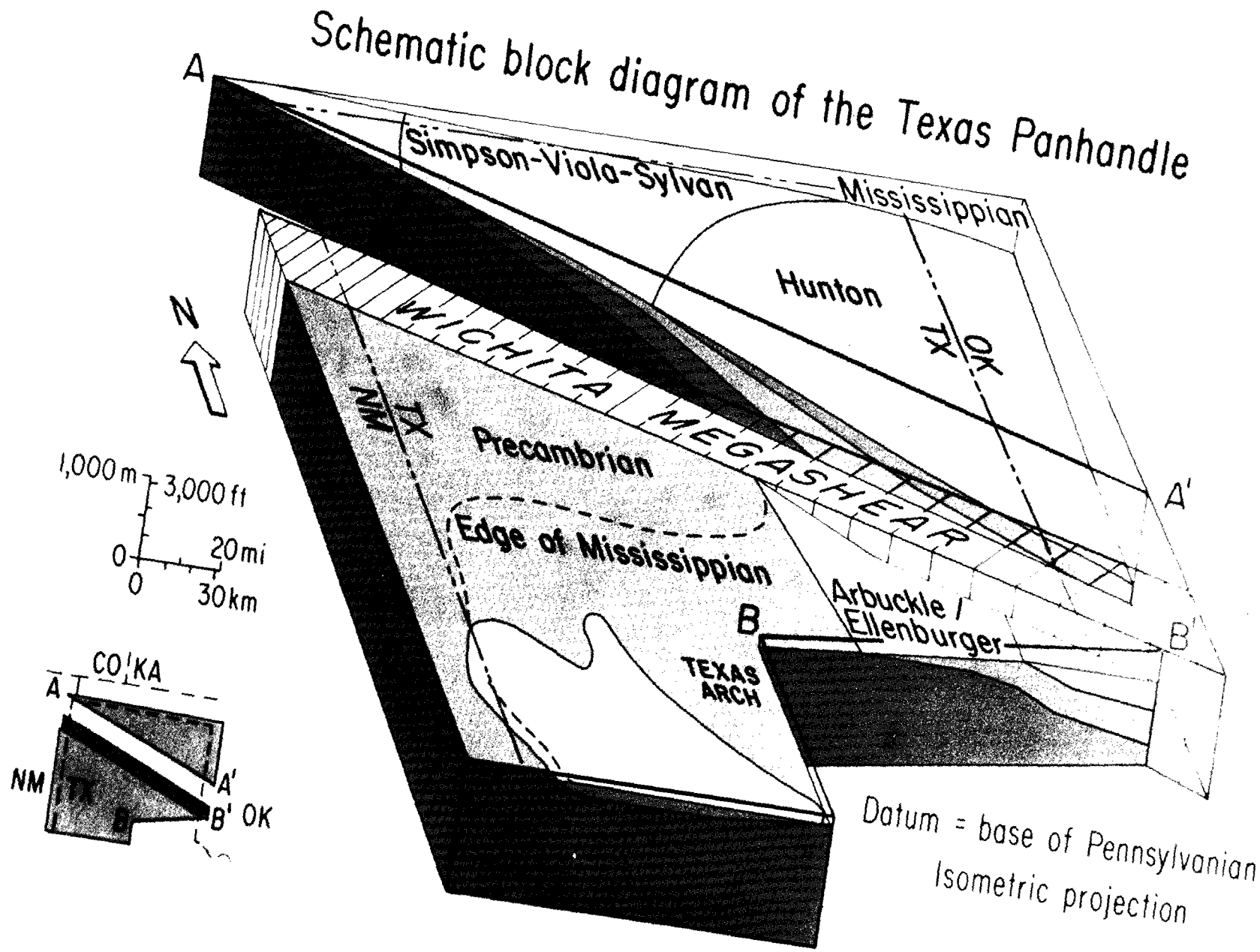
(from Budnik, 1984)

-2 to -3

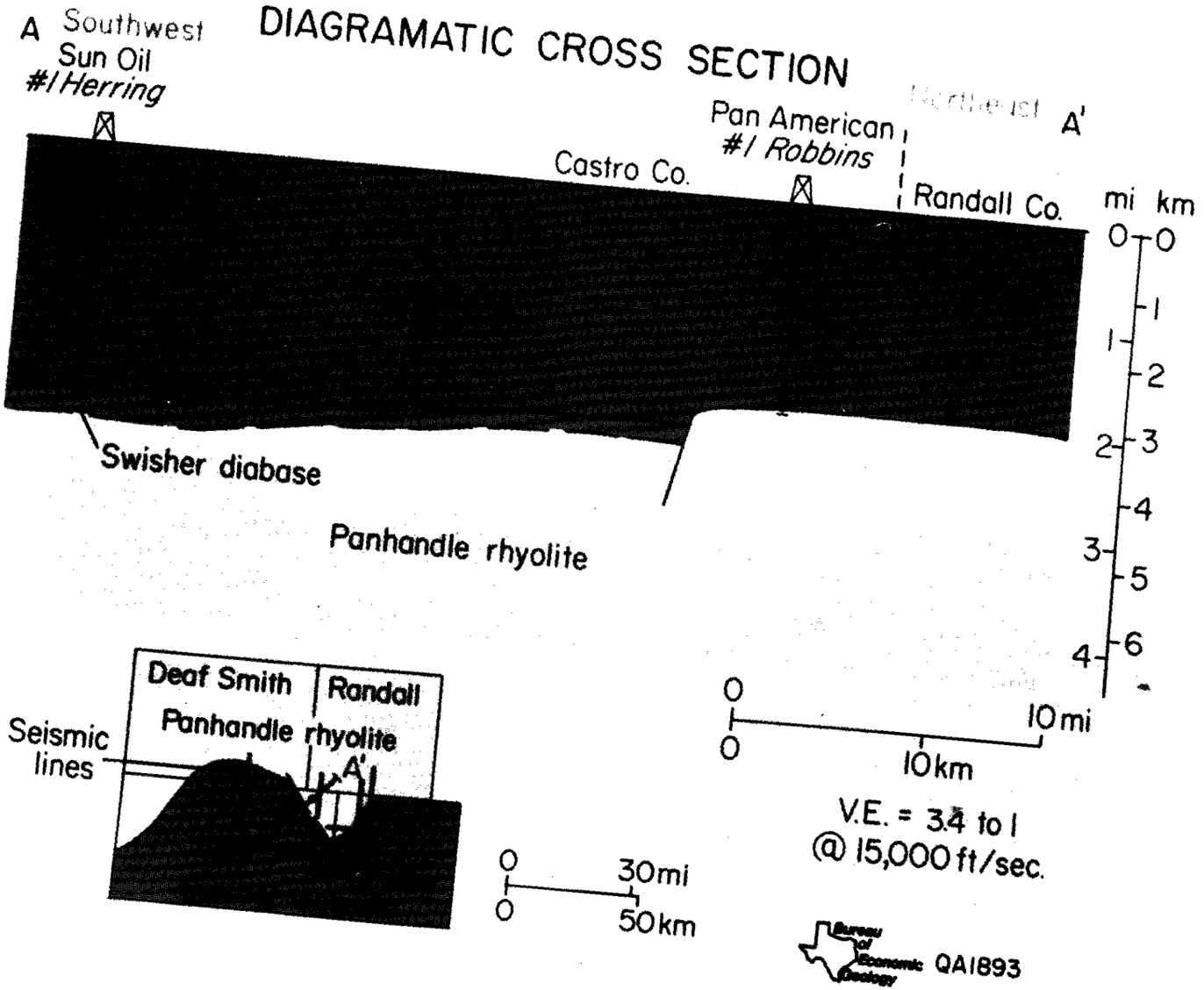
-3 to -4

THICKNESS OF PENNSYLVANIAN

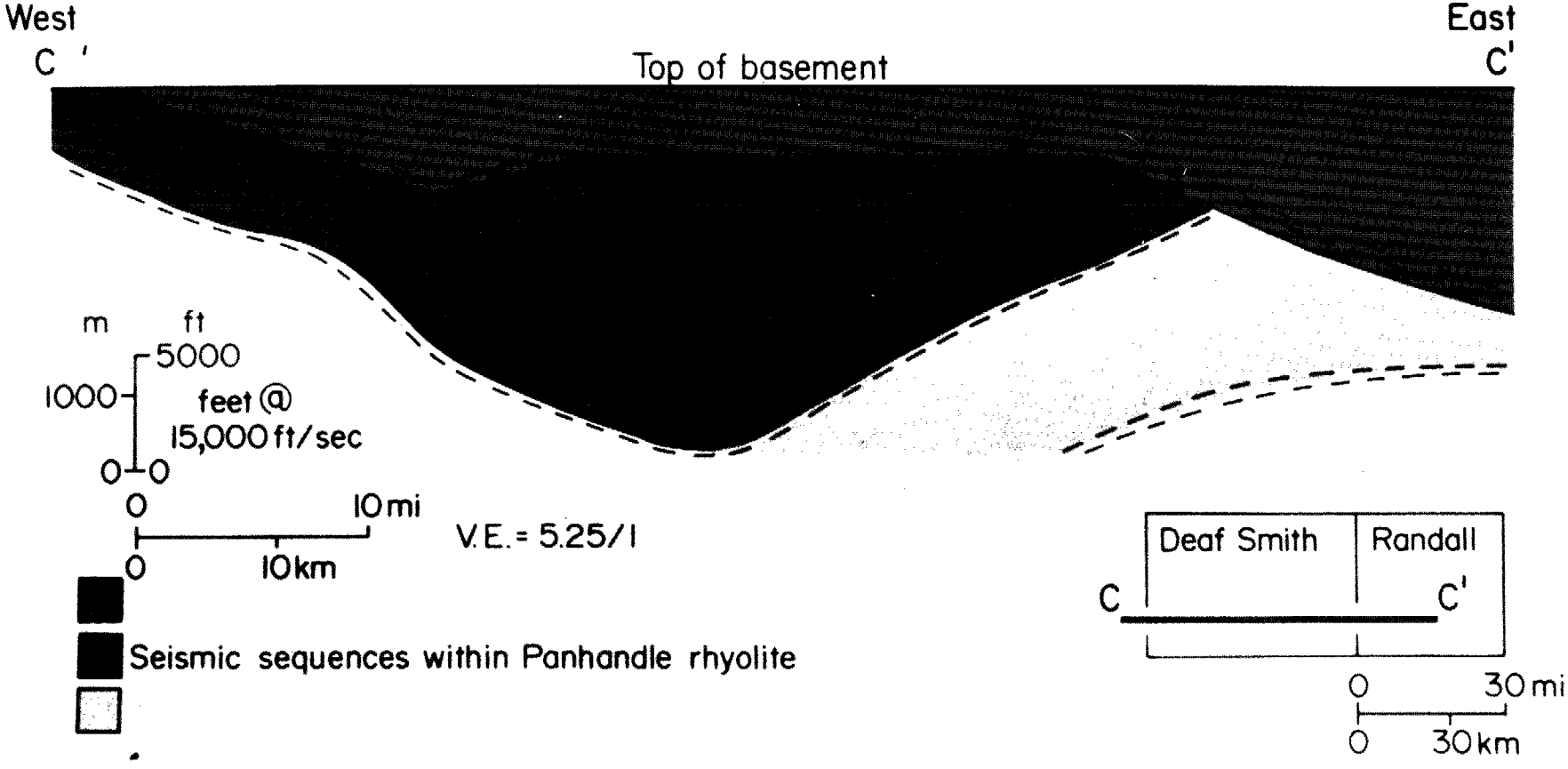



Schematic block diagram of the Texas Panhandle
A
Simpson-Viola-Sylvan
Mississippian
Hunton
OK
WICHITA MEGASHEAR
NM
Precambrian
Edge of Mississippian
A'
B
Arbuckle / Ellenburger
B'
TEXAS ARCH
N
1,000 m
3,000 ft
0
20 mi
0
30 km
CO
KA
A
A'
NM
TX
B
B'
OK
Datum = base of Pennsylvanian
Isometric projection

DIAGRAMATIC CROSS SECTION

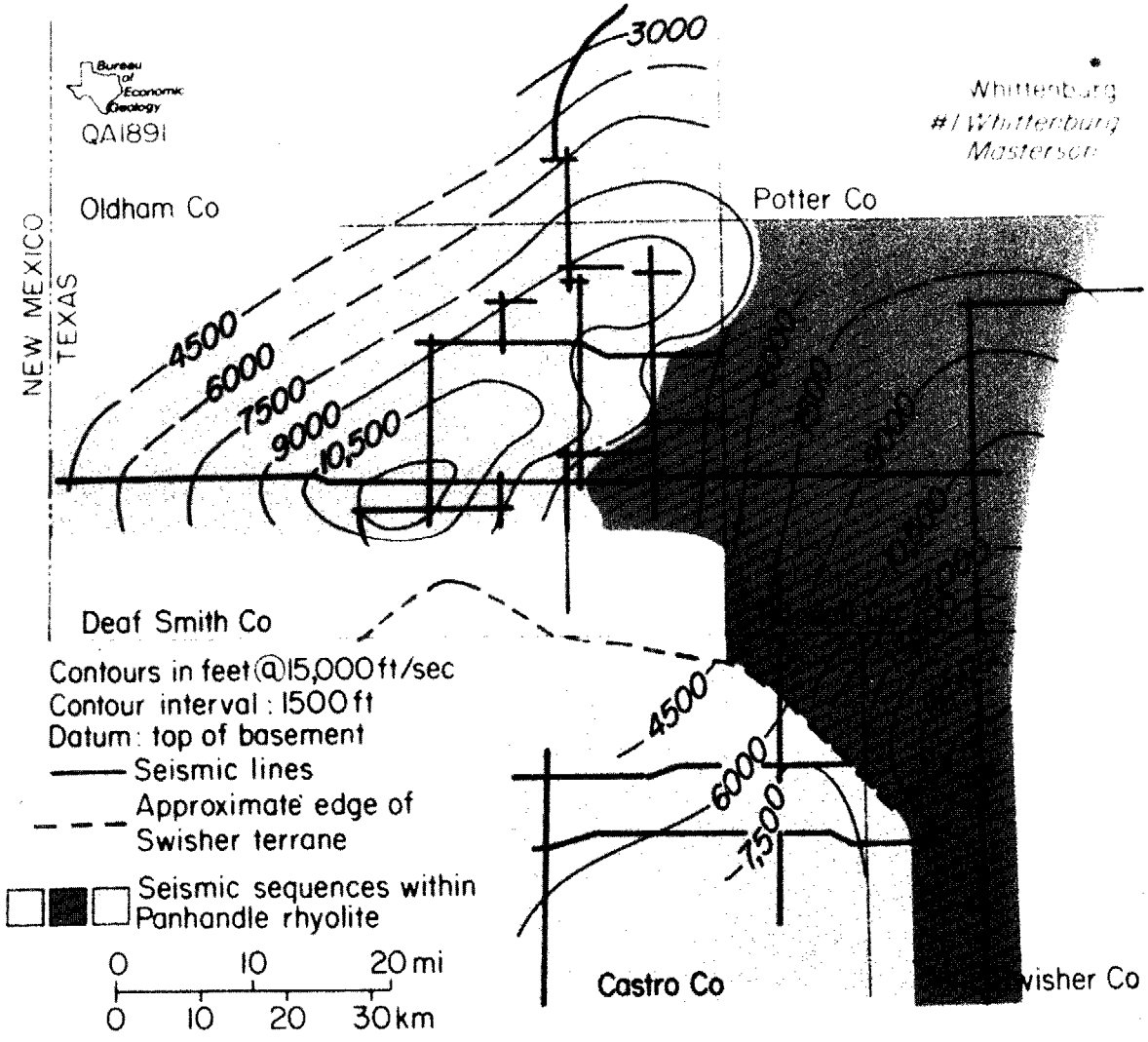


SEISMIC-DERIVED CROSS-SECTION

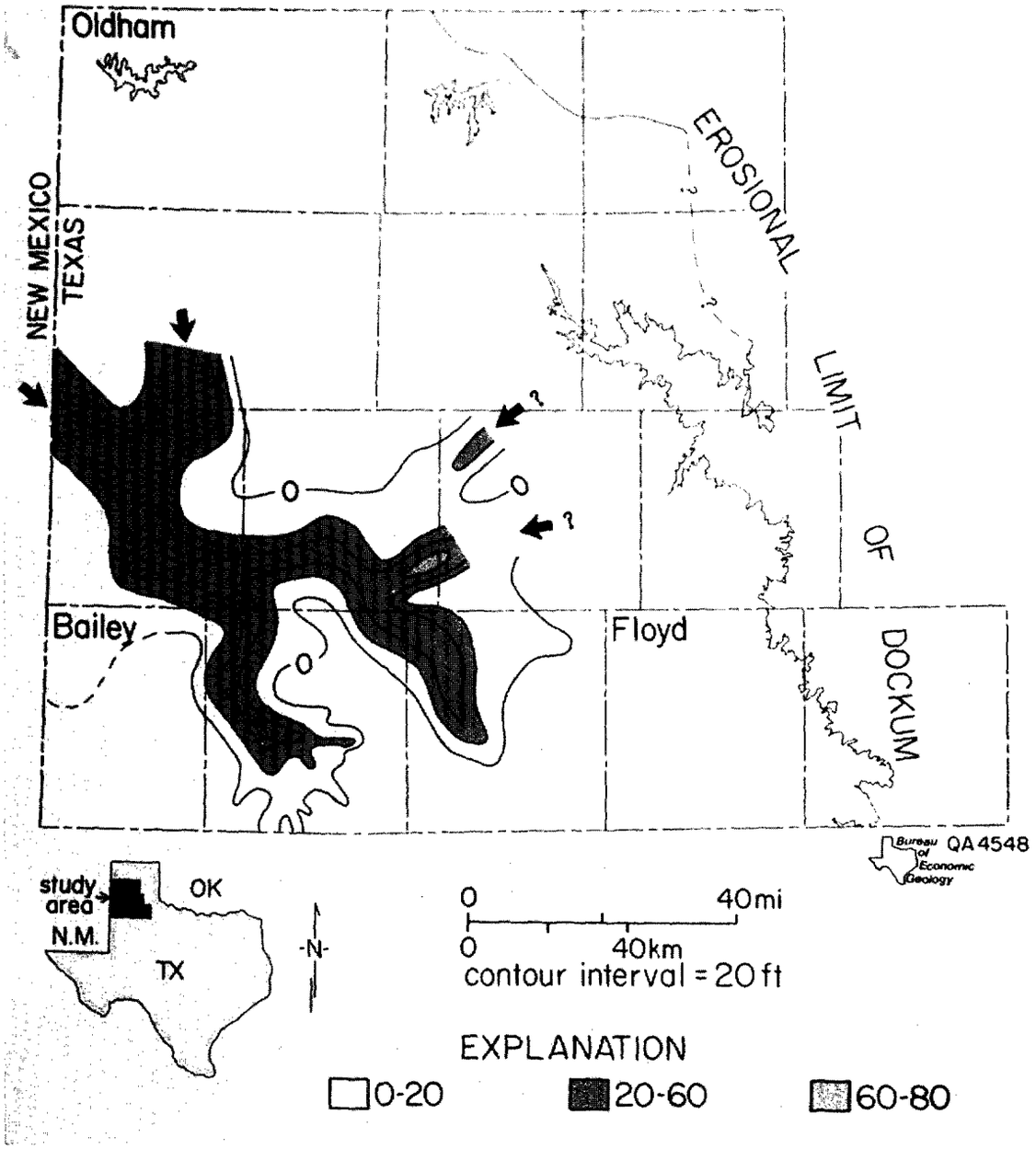


Bureau of Economic Geology QA1895

STRUCTURE ON BASE OF SEISMIC SEQUENCES



NET SANDSTONE PACKAGE NO. 4

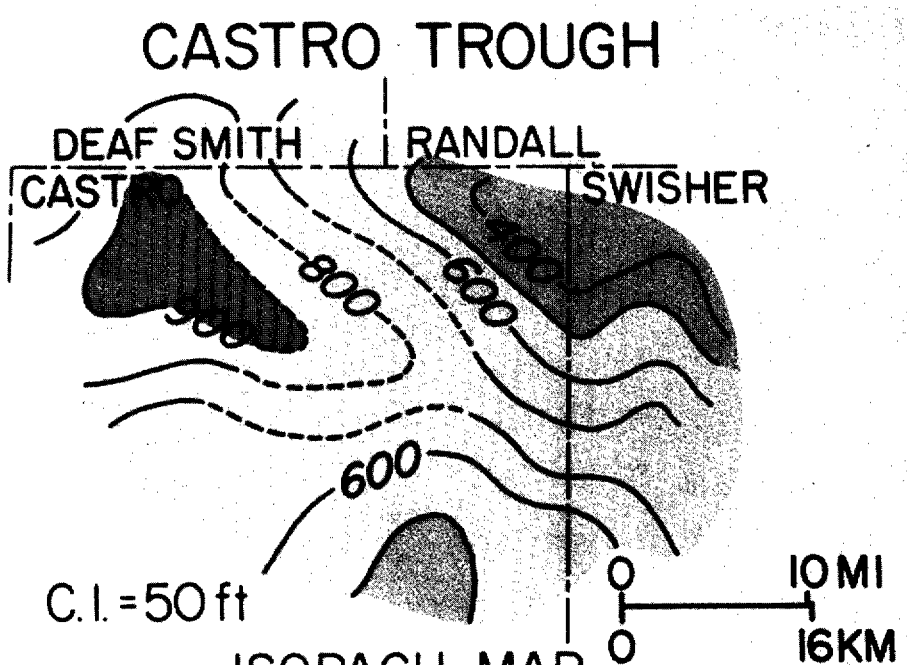


STRUCTURE CONTOUR
BASE OF DOCKUM GROUP

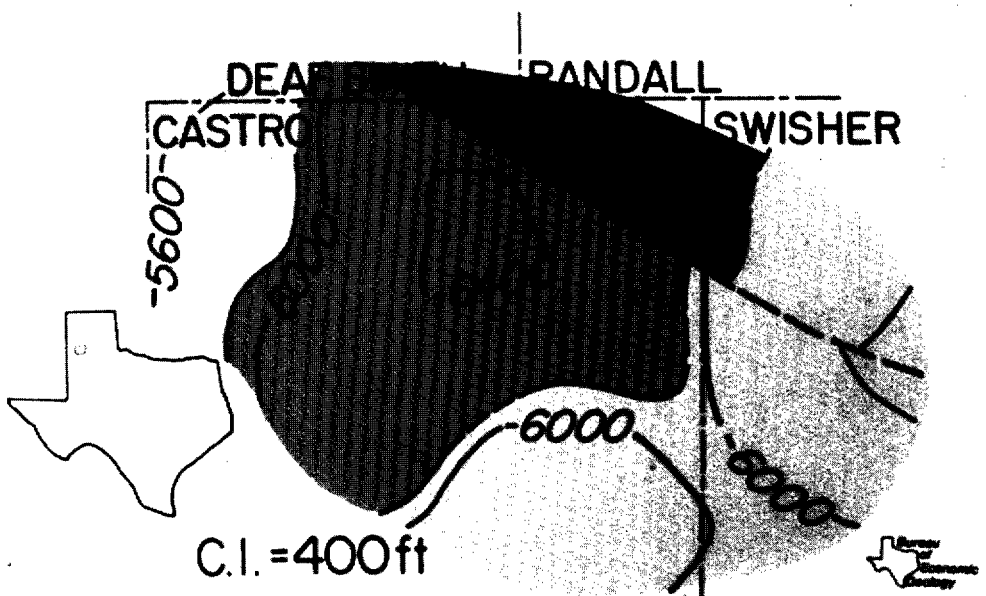
< 2000
2000-2300
2300-2600
2600-2900
2900-3200
> 3200

0 40 mi
0 40 km

Contour interval = 100 ft



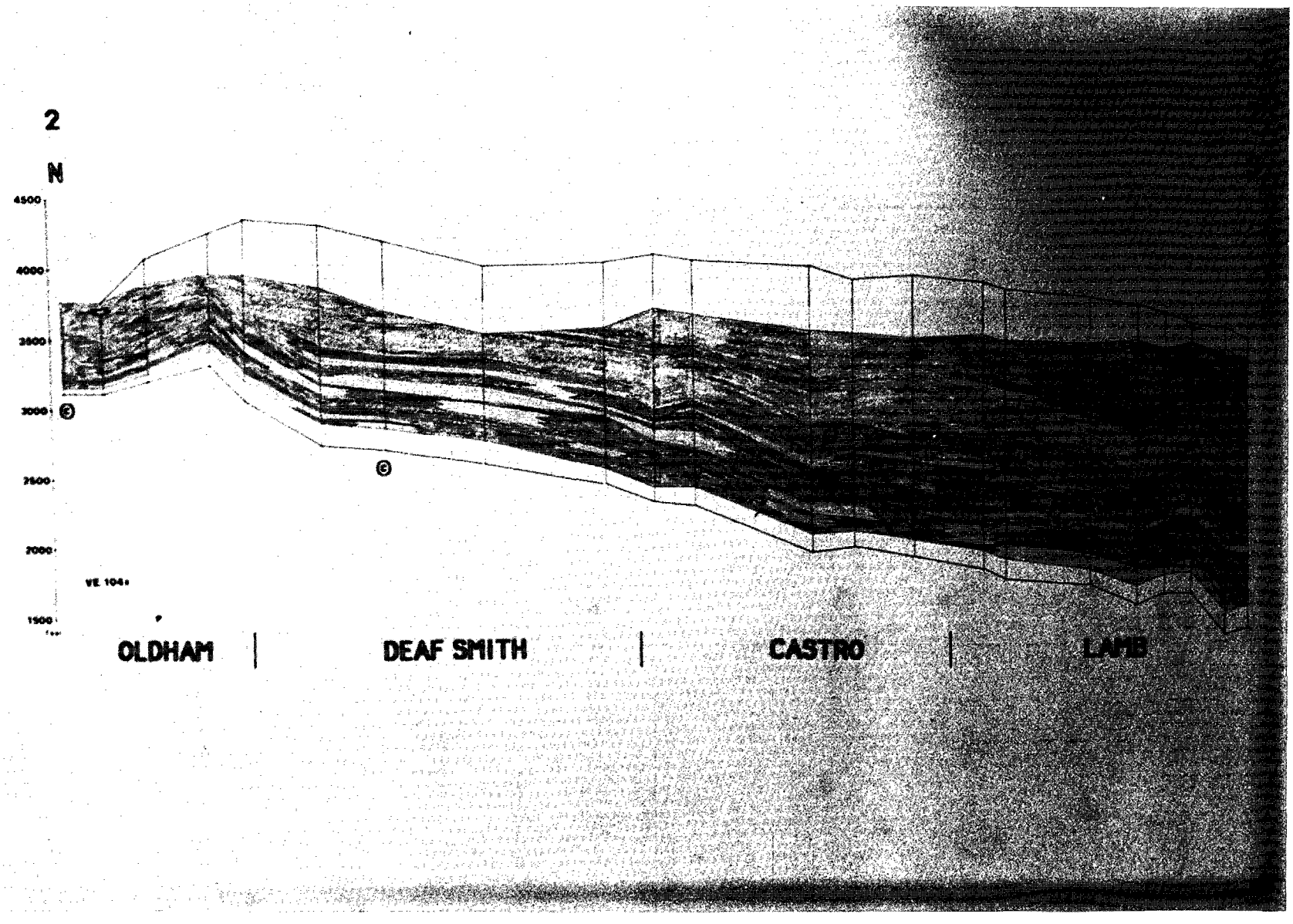
ISOPACH MAP
LOWER PENNSYLVANIAN CLASTICS



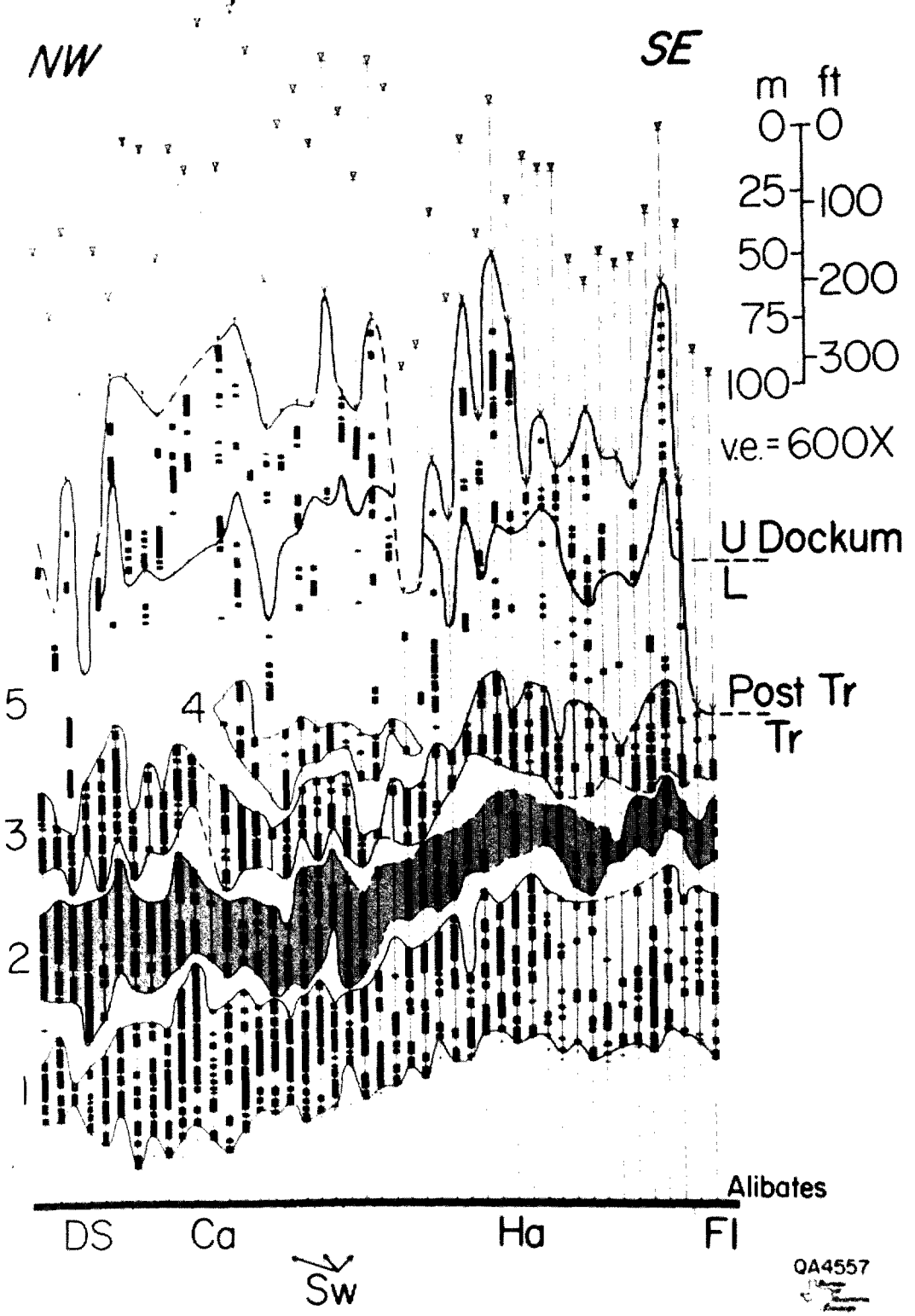
MISSISSIPPIAN SUBCROP
AND BASEMENT STRUCTURE

M on Ellenberger
M on basement
IP on basement

QA578


2
N
4500
4000
3500
3000
2500
2000
1500
VE 104x
OLDHAM
DEAF SMITH
CASTRO
LAMB

Composite Cross Section



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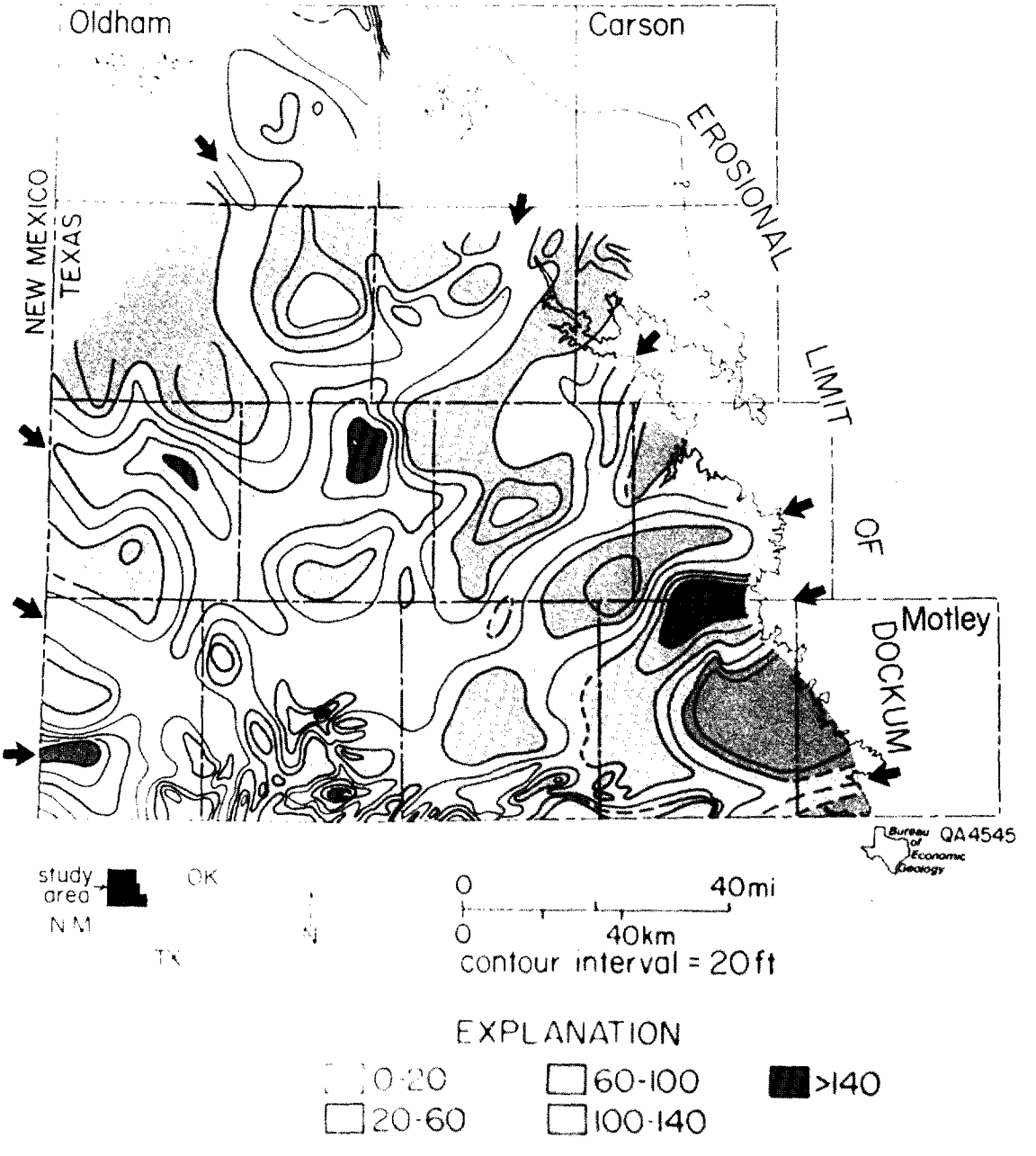

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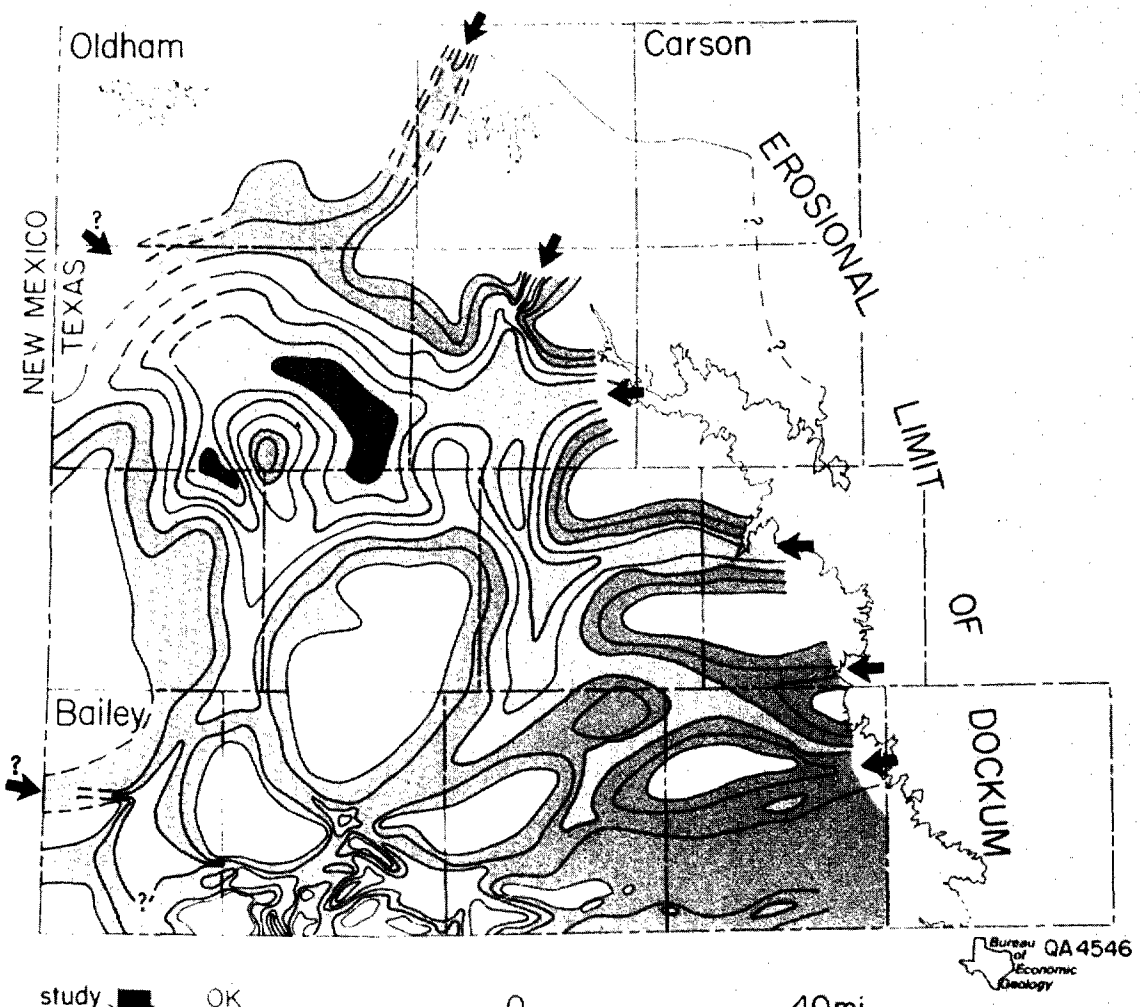
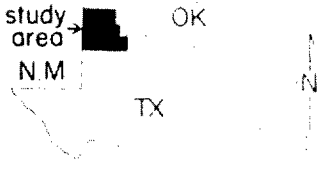




0 40mi

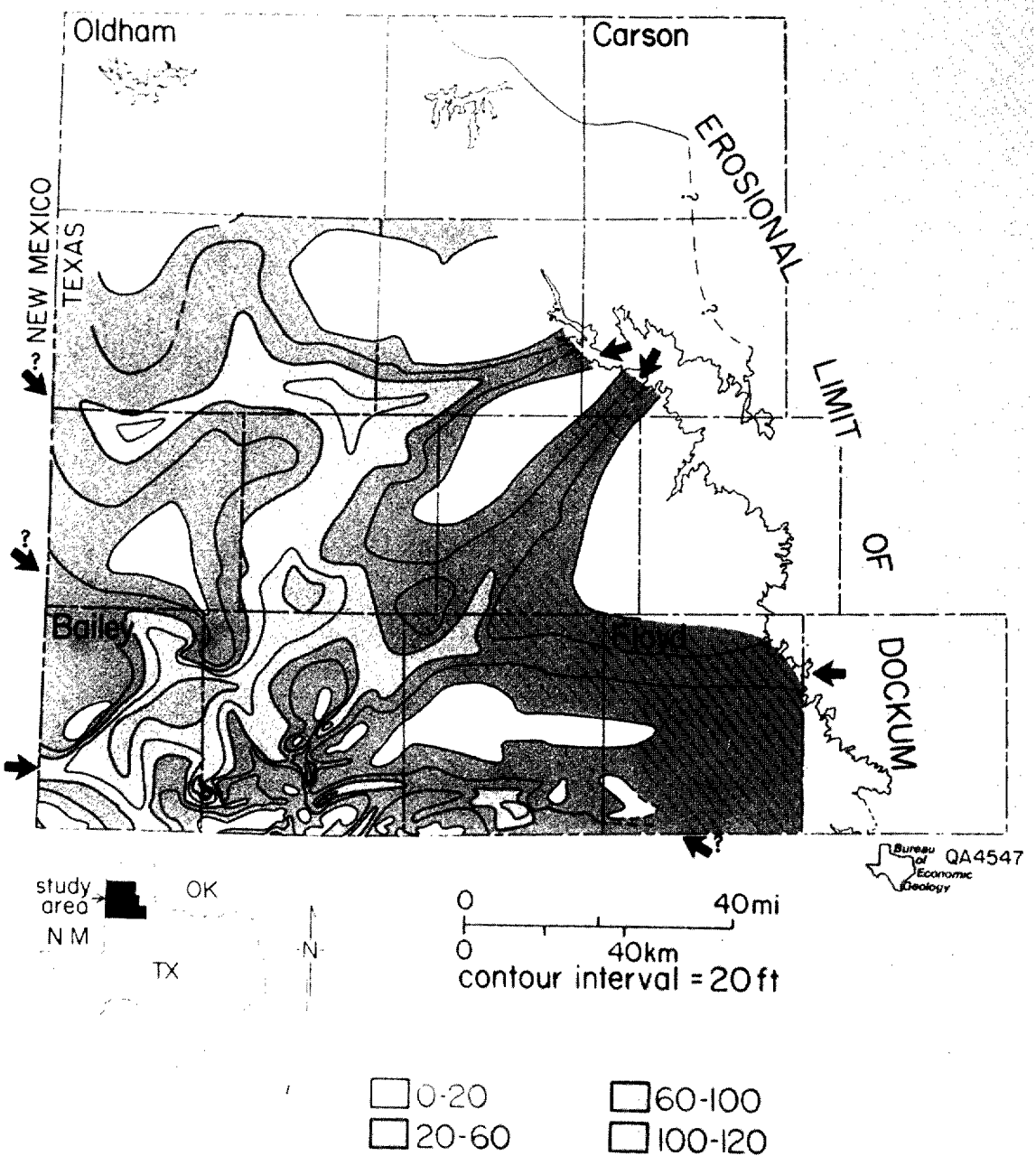
0 40km

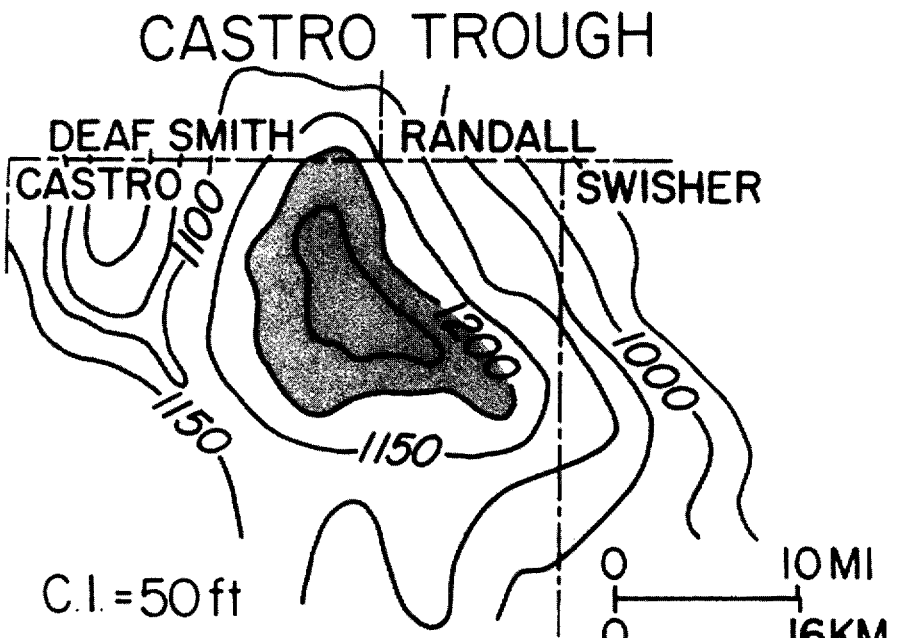
contour interval = 20ft

EXPLANATION

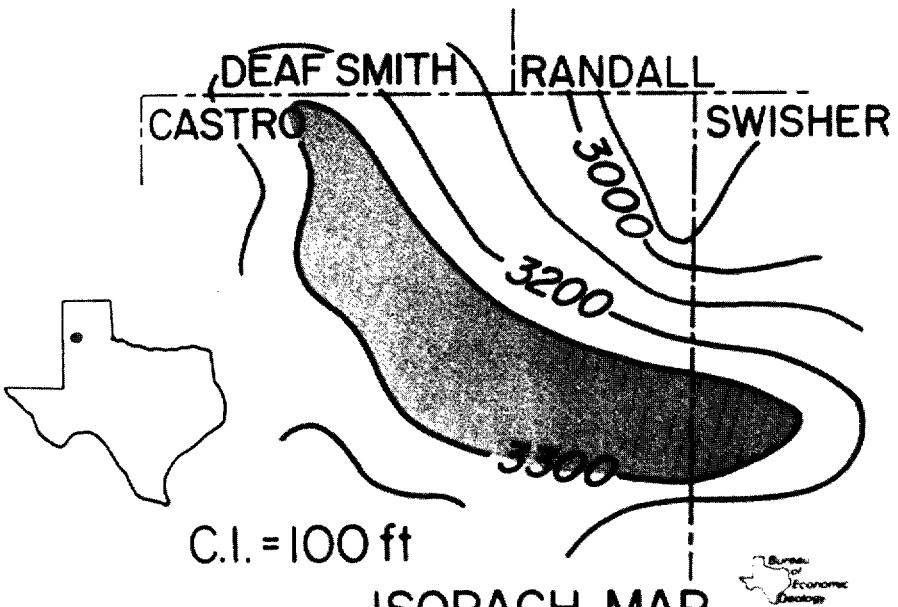
0-20
20-60
60-100
100-140
>140

NET SANDSTONE PACKAGE NO.3

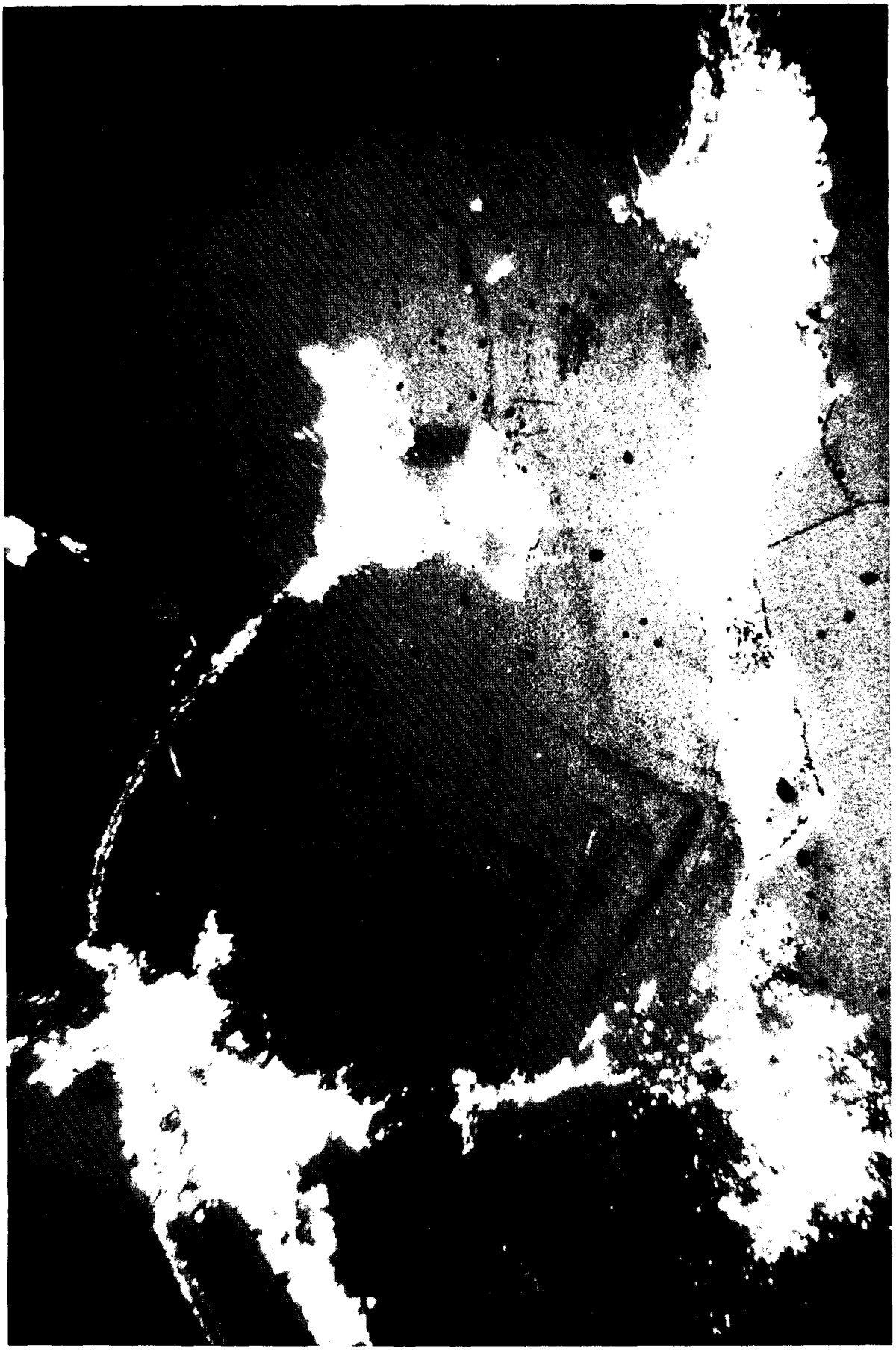


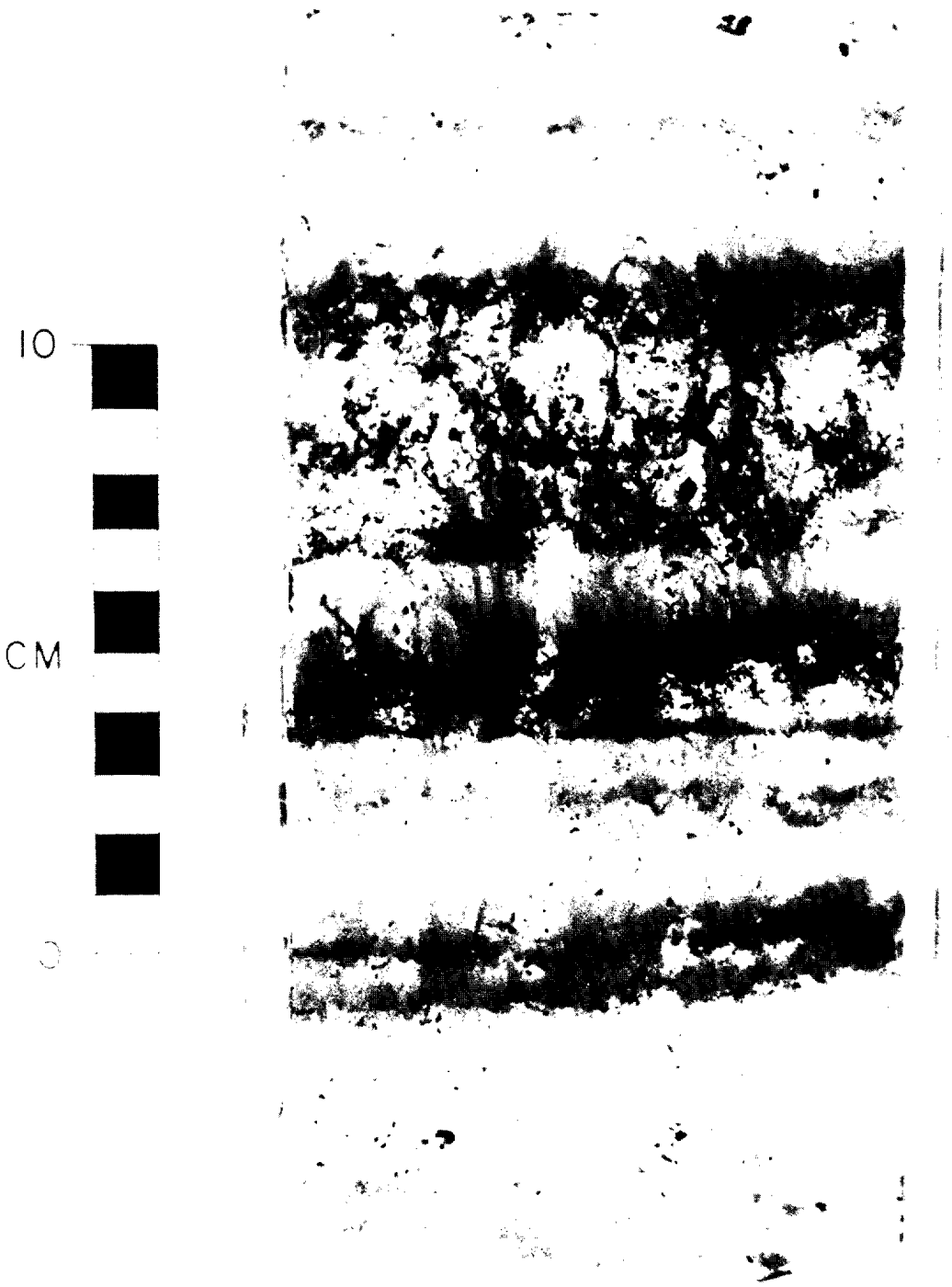


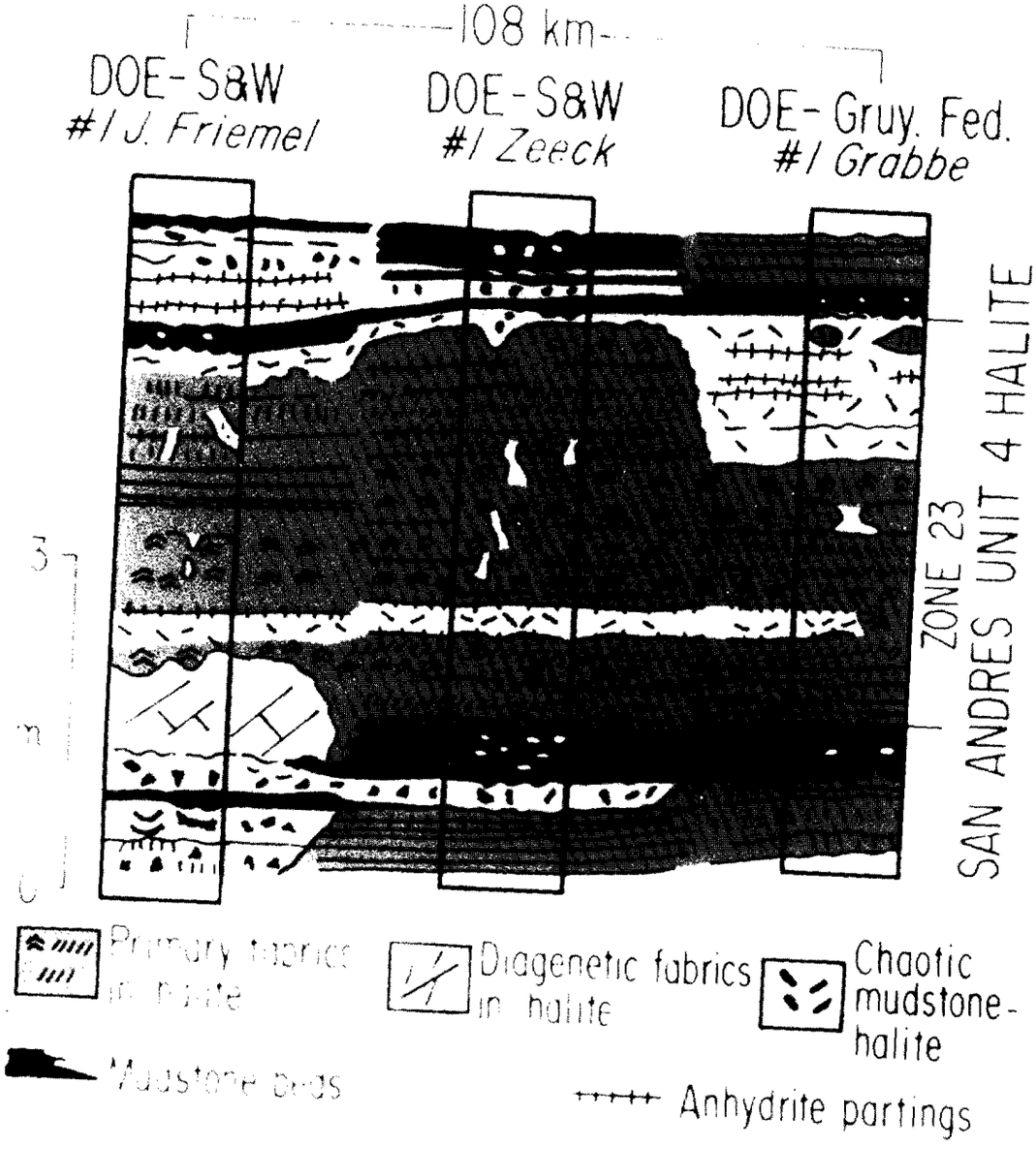
ISOPACH MAP
UPPERMOST PERMIAN-UPPER TRIASSIC
Top of Alibates to base of Ogallala

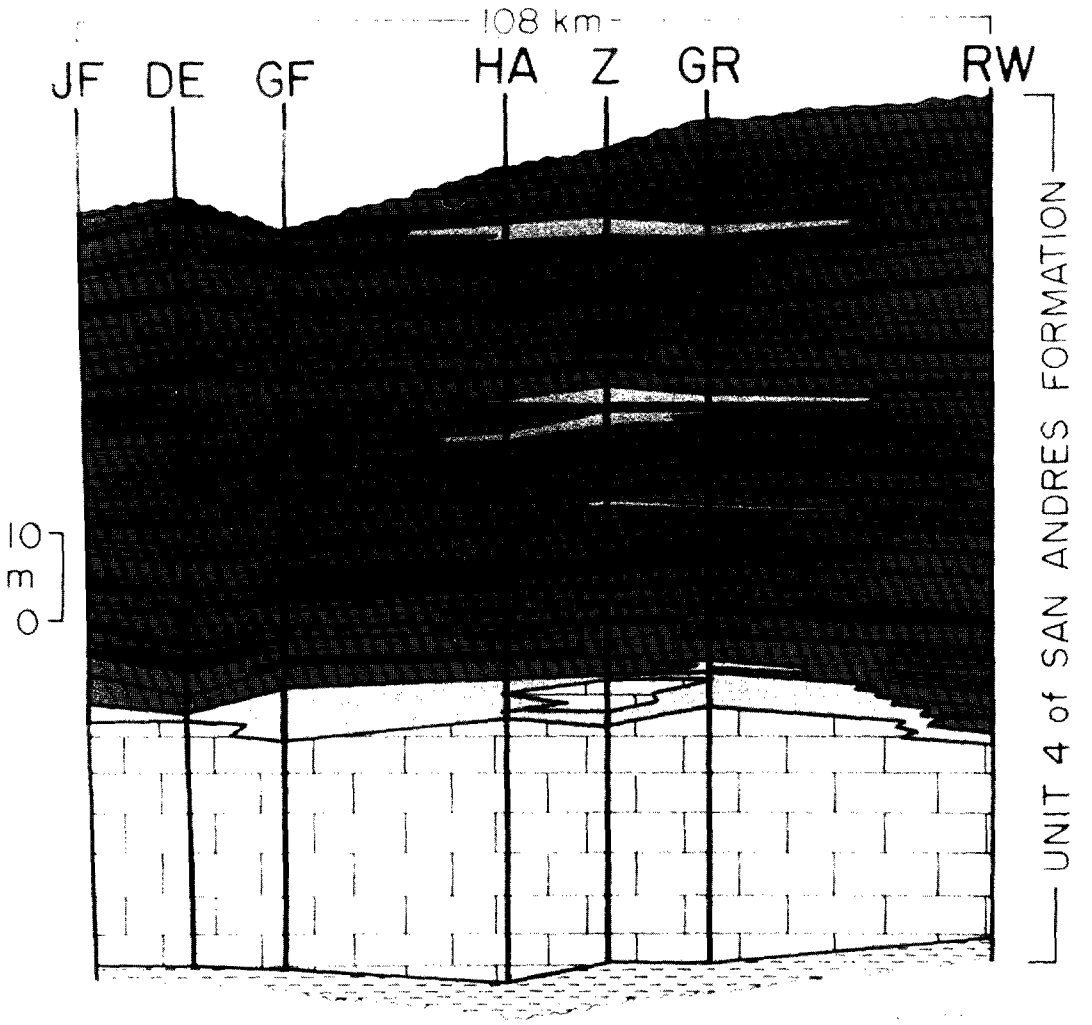


ISOPACH MAP
MIDDLE AND UPPER PERMIAN
Top of Tubb to top of Alibates




10
CM
0


108 km
DOE-S&W
#1 J. Friemel
DOE-S&W
#1 Zeeck
DOE-Gruy. Fed.
#1 Grabbe
SAN ANDRES UNIT 4 HALITE
ZONE 23
Primary fabrics in halite
Diagenetic fabrics in halite
Chaotic mudstone-halite
Mudstone beds
Anhydrite partings



CORED WELLS:

RW = Rex White, **GR** = Grabbe, **Z** = Zeeck, **HA** = Harman, **GF** = G. Friemel, **DE** = Detten, **J.F** = J. Friemel

Anhydritic halite

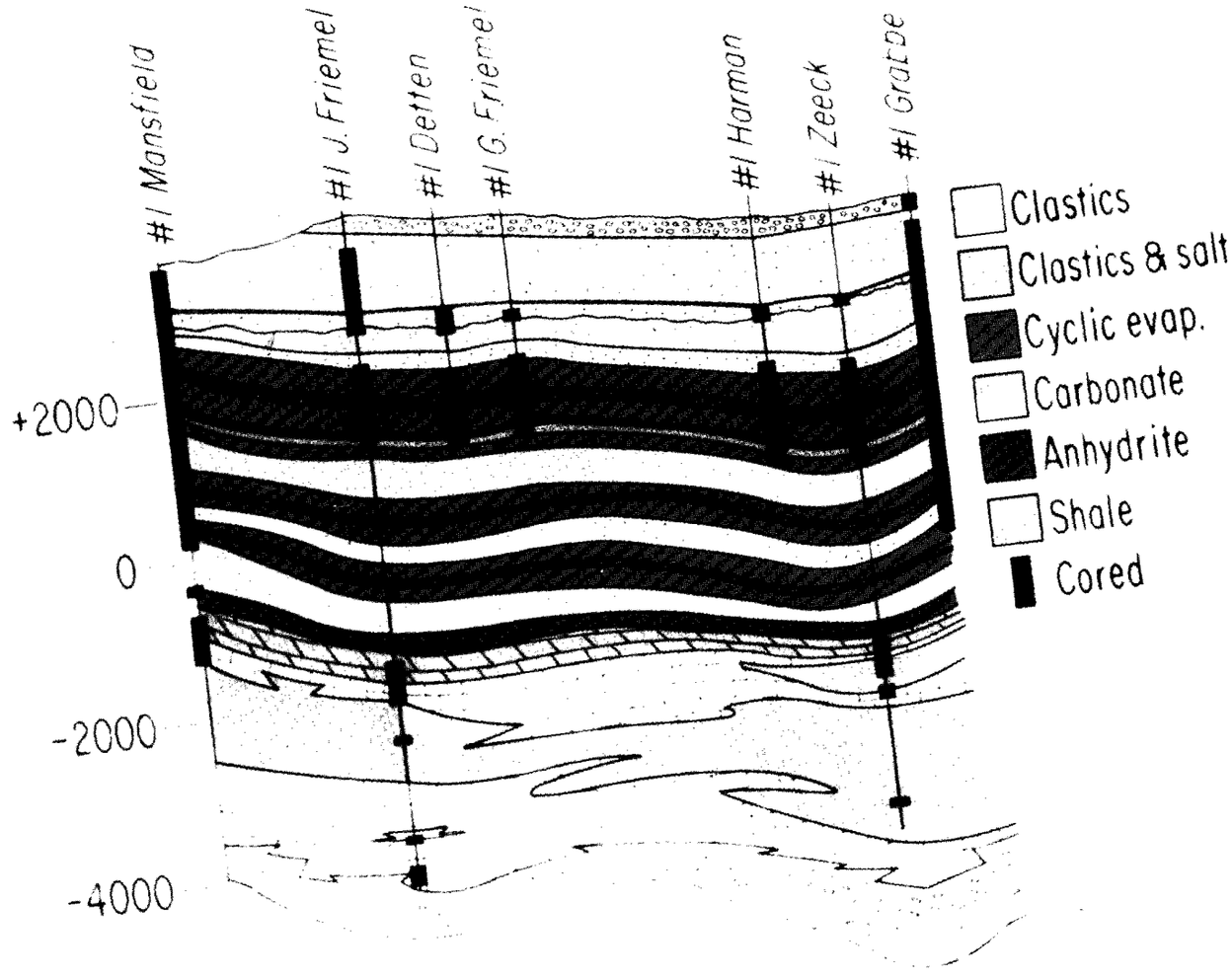
Muddy halite

Mudstone

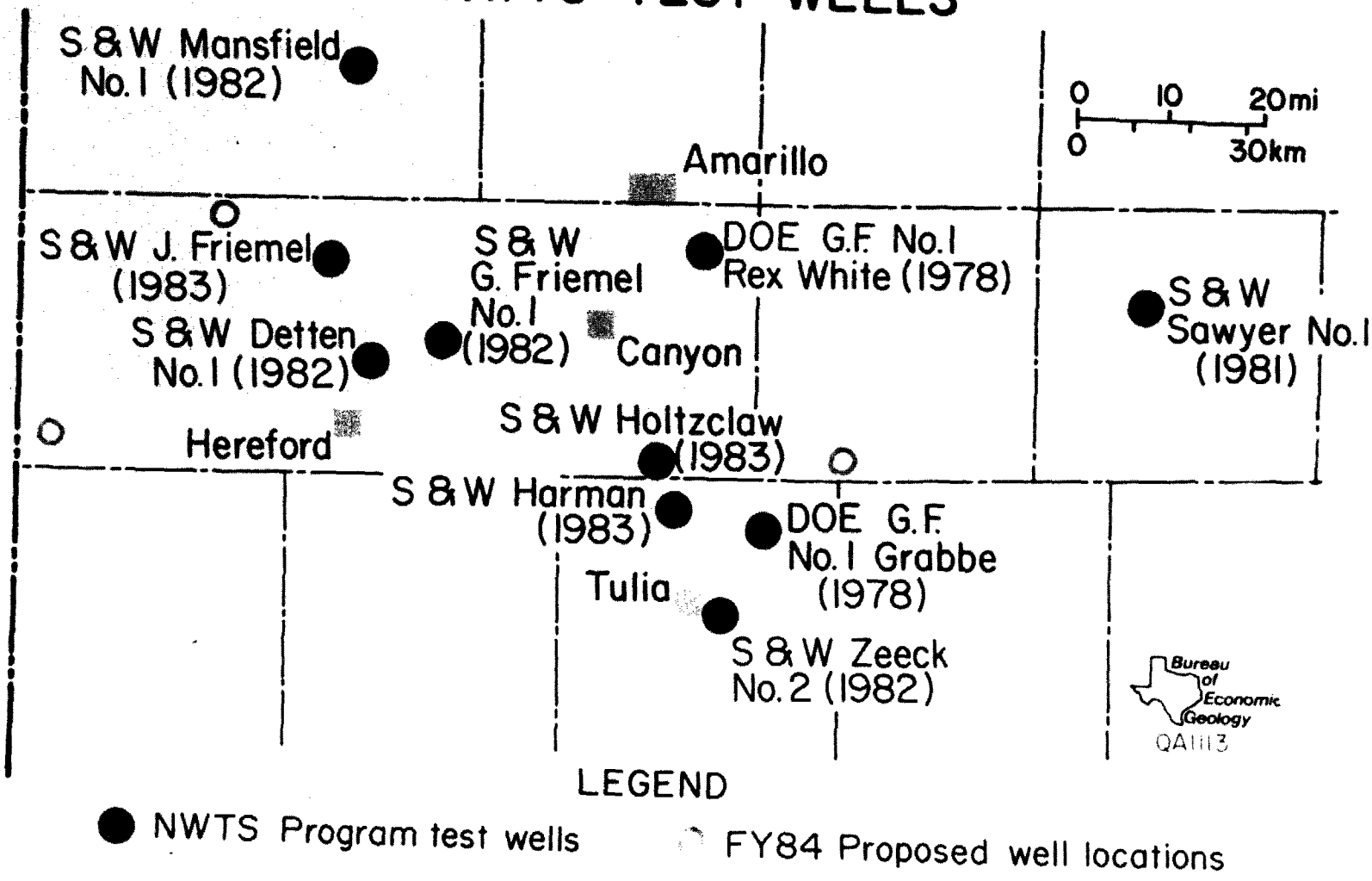
Anhydrite

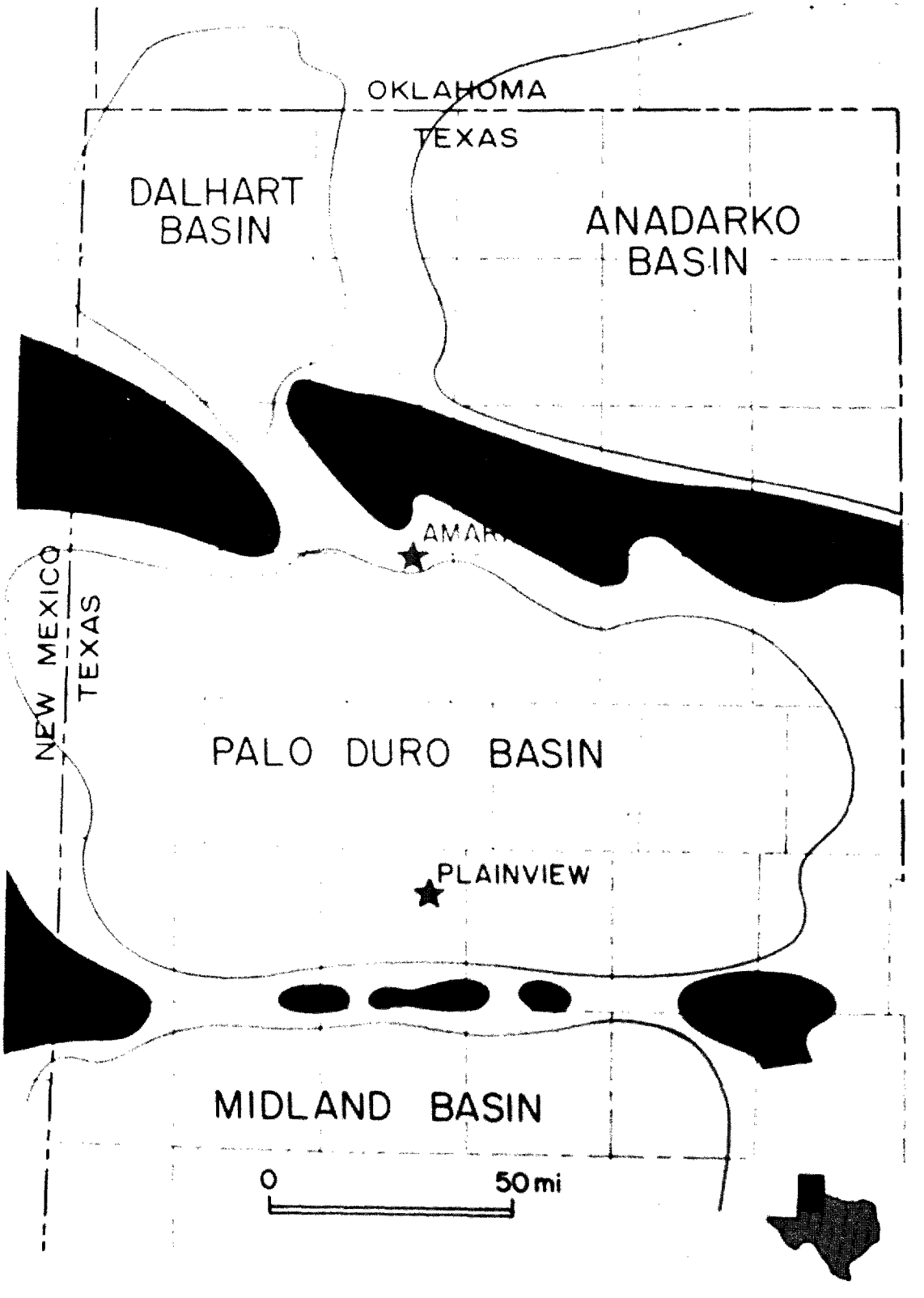
Carbonate

GLORIETA-
FLOWERPOT
BLAINE
WHITEHORSE
N
131 miles
GLORIETA
SAN ANDRES
QUEEN-
GRAYBURG
S


#1 Mansfield
#1 J. Friemel
#1 Detten
#1 G. Friemel
#1 Harman
#1 Zeeck
#1 Gratbe
+2000
0
-2000
-4000
Clastics
Clastics & salt
Cyclic evap.
Carbonate
Anhydrite
Shale
Cored

NWTS TEST WELLS




OKLAHOMA
TEXAS
DALHART BASIN
ANADARKO BASIN
AMARI
NEW MEXICO
TEXAS
PALO DURO BASIN
PLAINVIEW
MIDLAND BASIN
0
50 mi

Enclosure 1

Attendance List 11/19/85

NRC/SRP Workshop - Structure & Tectonics of the Palo Duro Basin

Name	Affiliation	Telephone
Jim Hileman	ONWI	(614) 424-7534
AL Funk	ONWI	(614) 424-4118
Don Turner	ONWI	(614) 424-6186
Ken Johnson	ONWI	(405) 325-3031
Glyn Jones	NRC Western Geophysical	(619) 366-9191
Vin Murphy	NRC/Western Geophy.	612 366-8191
A. Ibrahim	NRC	301-427-4211
JB Hoody	Battelle/ONWI/Rep. Dept.	(614) 424-5536
Owen Swanson	ONWI/Field Ops	FTS 976 5241
Charles Kuntz	ONWI/Geotech. Dept	614-424-5282
James George	Battelle/ONWI	614-424-5975
Richard Gillespie	Stone & Webster	617-589-2207
Everett Washer	Stone & Webster	617-589-2130
Douglas Pierce	Stone & Webster	617-589-2058
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Albert M. La Sala, Jr.	U.S. Geological Survey	614-424-5916
Stanley G. Rossier	Stone & Webster	617-589-2053
Hemendra Acharya	Stone & Webster	617-589-5819
G. J. Long	G.J. Long & Associates Inc	713-461-9931
Frederick W. Ross	US. NRC	FTS-427-4539
Roy E. Williams	USNRC Consultant	208 883 0453
Terry Regan	SWEC	617 589-2862

Attendance List 11/19/85

NRC/SRP Workshop - Structure & Tectonics of the Palo Duro Basin

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HARRY MCKAGUE	LAWRENCE LIVERMORE NAT LAB (LLNL)	415 422-6494
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David W. Carpenter	LLNL	415 - 422-3776
Rus PURCELL	LLNL	714-556-2707
RICHARD H. BERRY	LLNL	(703) 323-5211
Ernie Majer	Lawrence Berkeley Labs	(415) - 486-6709
Charles Clark	CER Corp.	424-1596
Thomas C. Gustavson	Texas Bureau of Econ. Geol.	(512) 471-1534
Eddie Collins	Texas Bureau of Econ. Geol.	512 - 471-1534
Jay RANEY	" " " "	" - " - "
Roy Budnik	" " " "	" " "
DAVID TILLSON	EEI/UNWMG	801-363-4091
MARGARET NART	Tx. WATER COMMISSION	512 · 463 · 7797
Janice Perttu	Utah	(801) 538-5554
JEFFREY C. BROWN	WILLIAM + ASSOC. (NRC)	(208) 883-0153
Barry J. Solomon	BPMD	(614) 424.7212
Susan L. Buchanan	DOE - SRPO	(614) 424-5916; FTS 976-59
JO-ANN SHERWIN	DOE-SRPO	" " "
TOM BAILLIEUL	U.S. DOE - SRPO	(614) 424-5916
Gordon Appel	DOE-CH/SRPO	" " "
Don Ballmann	ONWI/Regulatory Dept.	(614) 424-4764
JIM BENNETT	Bendix Field Engineering	(303) 242-8621
Scot Adams	ONWI	614-424-7286
MIKE FERRIGAMI	DOE/SRPO	614-424-5916; FTS 976-5916
Philip J. Murphy	SWEC	617-589-2173
TIM BRUNO	SWEC	617-589-2206
Teek VERMA	NRC (Columbus)	(614) 424-5916
JOHN S. TAPP	NRC/WMGT	301 427-4545
Robert L. Johnson	NRC/WMRP	(301) 427-4764
Ernst G. Zurflueh	NRC/RES	(301) 427-4343
RICHARD Lee	NRC/WMGT	(301) 427-4526
JEROME R PEARRING	NRC/WMEG	(301) 427-4648

Enclosure 1

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NRC/SRP Workshop - Structure & Tectonics of the Palo Duro Basin

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MIKE FERRIGAN	DOE/SRPO	614-424-5916; FTS 976-5916
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JOHN H. Peck	SWEC	806-373-3048
[illegible]	[illegible]	[illegible]
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VINCENT MURPHY	NRC/WESTON GEOPHY.	617 366-9191
Glyn Jones	NRC/Weston Geophys.	617 366-9191
JAY RANEY	TEXAS BUR. ECONOMIC GEOLOGY	
Ray Bendik	" " " "	
Eddie Collins	" " " "	(512) 471-7721
Susan Horvath	" " " "	" "
Thomas C. Gustavson	" " " "	" "
Susan L. Buchanan	DOE - SRPO	(614) 459-0787; FTS 976-5916
Tom Baillieul	U.S. DOE - SRPO	614-424-5916
Owen Swenson	ONWI - Field Ops.	614-424-0 & FTS 976-5241
Donald Ballman	ONWI - Regulatory	(614) 424-4764
JOANN SHERWIN	DOE - SRPO	FTS 976·5916
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Hemandra Acharya	Stone & Webster	617-589-5819
DONALD TURNER	ONWI	617 424 6186
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JIM HILEMAN	ONWI	(617) 424-7534

Attendance List 11/20/85

NRC/SRP Workshop — Structure & Tectonics of the Palo Duro Basin

Name	Affiliation	Telephone
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RICHARD LEE	NRC/WMGT	(301) 427-4526
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Ernst Zurfluch	NRC	(301) 427-4343
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Douglas S. Pierce	Stone & Webster	617/589-2058
Everett M. Washer	Stone & Webster	617/589-2130
Albert M. La Sala, Jr.	U.S. Geol. Survey	614-424-5916
Allan Razem	ONWI	614-424-5766
Frederick Ross	U.S. NRC	FTS-427-4539
JEFFREY C. BROWN	Williams & Assoc. (NRC)	(208) 883-0153
RICHARD GILLESPIE	STONE & WEBSTER	617 589-2207
TIMOTHY BRUNO	STONE & WEBSTER	617-589-2206
JAMES GEORGE	Battelle-ONWI	(614) 424-5975
Ed Russell	ONWI	(614) 424-6196
Charles Kurtz	ONWI	614-424-5282
Scot Adams	ONWI	614 424-5286
ROY E. WILLIAMS	NRC CONSULTANT	208 883 0153
JIM BENNETT	Bendix Field Engineering	(303) 242-8621
Don Ballmann	ONWI/Regulatory Dept.	(614) 424-4764
JOHN TREADWELL	ONWI/FIELD OPS	(614) 424-4173

Enclosure 1

Attendance List 11/21/85

NRC/SRP Workshop – Structure & Tectonics of the Palo Duro Basin

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David W. Carpenter	LLNL	415-422-3976
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RICHARD H. BERRY	LLNL/CONSULTANT	703-323-5211
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[illegible]	Utah	(801) [illegible]
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Ed Russell	ONWI	(614) 424-6196
Jay A Raney	Tx. Bur. Econ Geol.	
Ray T. Budnik	" " " "	512 471-1534
Eddie Collins	" " " "	" " "
Thomas C. Gustavson	" " " "	" " "
Barry Solomon	ONWI	614-424-7212
[illegible] SITERWIN	DOE-SRPO	(614) 424-5916
DAVID TILLSON	EEI/UNWMG (CONSULTANT)	(801) 363-4091
Roy E. Williams	Williams & Associates (NRC Consultants)	208 [illegible]
Tom Baillieul	U.S. DOE-SRPO	614-424-5916
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Don Ballmann	ONWI/Regulatory Dept.	(614) 424-4764
JIM BENNETT	Bendix Field Engineering	(303) 242-8621
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Charles Chisholm	CER	(614) 424-5916
Charles KUNTZ	ONWI	614 424-5282
Robert L. Johnson	NRC/WMRP	(301) [illegible]
John S. TAAPP	NRC / WMGT	301-427-4545
TIMOTHY BRUNO	SWEC	617-589-2206
Philip J Murphy	SWEC	617-589-2173
DON TURNER	ONWI	614-424-[illegible]
AL FUNK	ONWI	614-424-4118

Attendance List 11/21/85

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RICHARD LEE	NRC/WMGT	(301) 427-4526
Ernst Zurflueh	NRC/RES	(301) 427-4373
[illegible]	NRC	(301) 427-4211
Glyn Jones	NRC/Houston Geophysical	(617) 366-9191
Vincent Murphy	NRC/Houston Geophysical	617 366 9191
Ken Johnson	ONWI	405/325-3031
G.J. Long	GSRA/SWCC	713/461-9921
Douglas Pierce	Stone & Webster	617-589-2058
Everett Wooster	Stone & Webster	617-589-2130
Allan Razem	ONWI	614-424-5766
Frederick Ross	U.S. NRC	FTS-427-4539
James George	BPMD/ONWI	(614) 424-5975
Richard Gillespie	SWEC	617 589-2207
Terry Regan	SWEC	(617) 589-2862
Stanley C. Rossier	SWEC	(617) 589-2053
Hemendra Acharya	SWEC	(617) 589-5819
Albert M. La Sala, Jr.	U.S.G.S.	614-424-5916
Scot Adams	ONWI	614-424-7286
CHARLES CHISHOLM	OER	614-424-5916