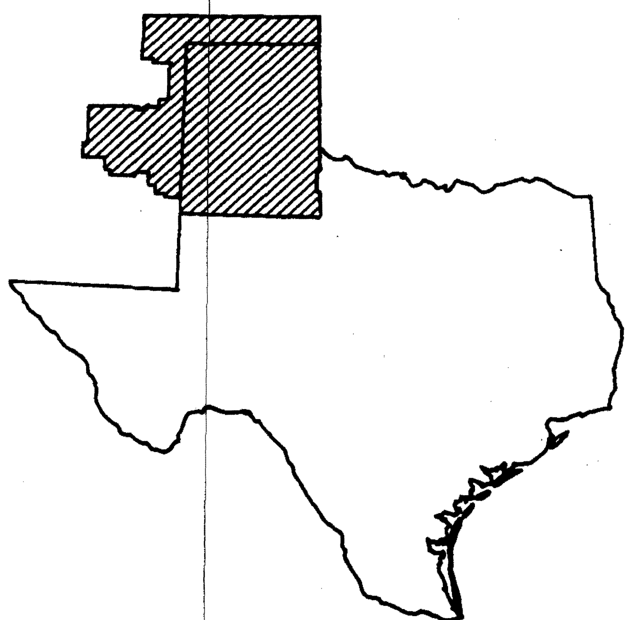
REGIONAL STRUCTURAL CROSS SECTIONS, MID-PERMIAN TO QUATERNARY STRATA, TEXAS PANHANDLE AND EASTERN NEW MEXICO

DISTRIBUTION OF EVAPORITES AND AREAS OF EVAPORITE DISSOLUTION AND COLLAPSE



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and Ann D. Hoadley

BUREAU OF ECONOMIC GEOLOGY

W. L. Fisher, Director — 1985
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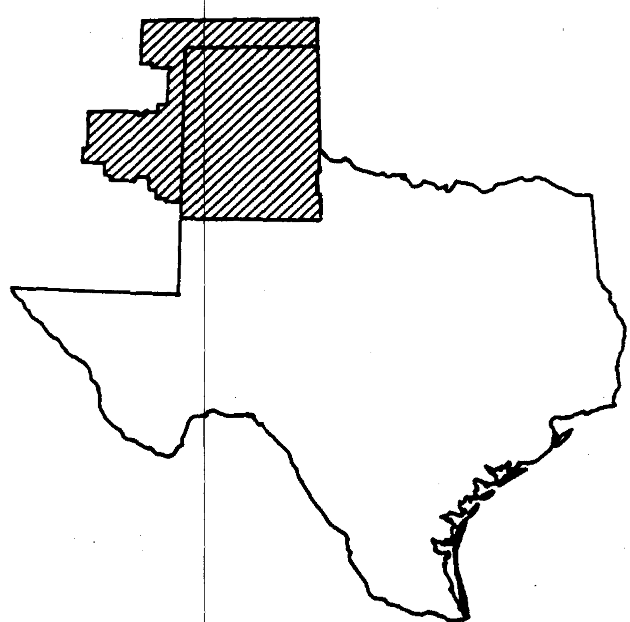

BUREAU OF ECONOMIC GEOLOGY

W. L. Fisher, Director **1985**

The University of Texas at Austin **Austin, Texas 78713**

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Regional Structural Cross Sections, Mid-Permian to Quaternary Strata, Texas Panhandle and Eastern New Mexico: Distribution of Evaporites and Areas of Evaporite Dissolution and Collapse

Introduction

The Palo Duro and Dalhart Basins of the Texas Panhandle and eastern New Mexico contain bedded Permian salts of sufficient thickness and depth to be considered potential sites for long-term storage and isolation of high-level nuclear waste. Salt (primarily halite) is a desirable host rock because of its low permeability, high thermal conductivity, low moisture content, and high gamma-ray shielding properties (Johnson, 1976b).

A major concern that must be addressed if nuclear waste is to be stored in the Texas Panhandle is the long-term integrity of the bedded-salt host rock. Areas where salt has been removed by dissolution have been identified beneath the Southern High Plains, along the eastern and western escarpments of the Southern High Plains, and along the Canadian River valley (Gustavson and others, 1980b; Presley, 1980a, 1980b).

Regional cross sections of mid-Permian to Quaternary strata in the Texas Panhandle and eastern New Mexico illustrate lithologic and structural relations that are interpreted to have resulted from the regional dissolution of salt and the collapse of overlying strata. The cross sections were constructed using gamma-ray logs, sample logs, and surface geologic maps (Handford, 1980a; McGillis, 1980). Gamma-ray logs are shown on the cross sections because they best demonstrate variations in evaporite strata. Figure 1 is an index map depicting the locations of the cross sections. Stratigraphic nomenclature used on the cross sections is given in table 1.

Geologic Setting of the Texas Panhandle

During the early Paleozoic, episodes of shallow-marine shelf deposition in the Texas Panhandle alternated with periods of subaerial erosion. Cambrian(?) rocks consist of arkosic and glauconitic sandstones (Birsa, 1977). Shallow-shelf carbonates of the Ellenburger Group were deposited in the Early Ordovician (Dutton, 1979). Upper Ordovician, Silurian, and Devonian strata are missing in the Texas Panhandle. During Mississippian time, marine shelf carbonate deposition probably extended over the entire area.

In the late Paleozoic, blocks of crust were uplifted to form the Wichita - Amarillo Uplift and the Matador Arch (Goldstein, 1982). These are the major positive structural features bounding the Palo Duro Basin on the north and south, respectively, and they separate the Palo Duro Basin from the Anadarko, Dalhart, and Midland Basins (fig. 2). Terrigenous clastic sediments, informally called "granite wash," dominated early Pennsylvanian sedimentation and were derived from and concentrated near the principal uplifts (Handford and Dutton, 1980). Sedimentation during the late Pennsylvanian was characterized by shelf carbonate deposition; deeper parts of the basin were filled by fine-grained clastics.

Lower Wolfcampian (earliest Permian) shallow-marine carbonates, coarse arkosic deposits, and deep-basin shales are overlain by upper Wolfcampian dolomitic rocks that were deposited in high-energy oolite and skeletal grainstone environments (Handford, 1980b; Hovorka and Budnik, 1983). By Wichita time, increasing restriction behind supratidal or subtidal shoals created environments in which carbonates, terrigenous clastic mudstone, and bedded gypsum (later converted to anhydrite) were deposited (Handford, 1979, 1980b; Hovorka and Budnik, 1983). Limited faunal diversity, sparse burrows, and the presence of anhydrite beds indicate hypersaline conditions. During Red Cave time, terrigenous clastic deposition alternated with carbonate-grainstone and bedded-anhydrite deposition in hypersaline evaporite pans or lagoonward of supratidal environments (Hovorka and Budnik, 1983).

Clear Fork, San Andres, and post-San Andres (middle and upper Permian) rocks are dominantly dolomite, mudstone, salt, and anhydrite deposited in arid shallow-marine to subaerial environments. Middle and upper Permian evaporite and clastic sediments were deposited in tabular beds landward of oolitic bars or shoals on a vast (62 by 124 mi [100 by 200 km]) subtidal to subaerial flat. Red beds, which are commonly intercalated with evaporites, consist of terrestrially derived, fine-grained clastics that were distributed across the region by eolian and submarine processes (Bein and Land, 1982). Presley's (1981) model of evaporite deposition (fig. 3) was inferred from study of well logs, cores,

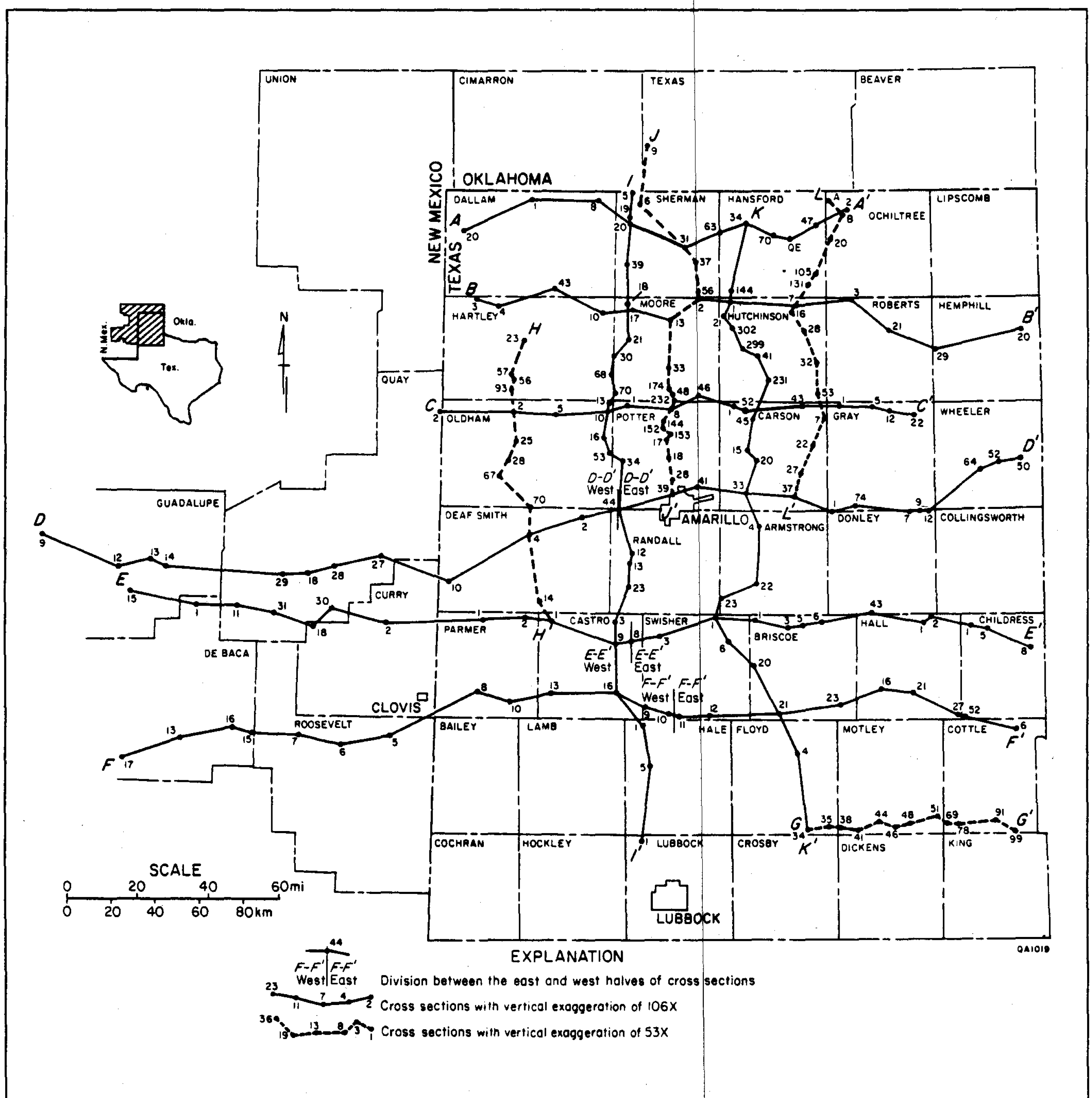

Figure 1. Index map of the study area showing locations of cross sections.

and outcrops. The model shows massive (banded) salt and laminated and nodular anhydrite sedimentation by evaporation (1) in periodically flooded brine pans, (2) on salt flats that were isolated from open-marine water, and (3) on mud flats where salt crystals grew by displacing the mud matrix. Bein and Land's (1982) petrographic and geochemical study of the San Andres Formation in cores, on the other hand, indicates that evaporite rocks were deposited in a shelf basin or lagoon in which brine composition changed as $CaCO_3$, $CaSO_4$, and NaCl were successively precipitated. Carbonate strata in the upper San Andres and Alibates Formations consist predominantly of dolomite.

Salt beds in the Palo Duro Basin range from a few feet to 200 ft (61 m) thick. Before dissolution of upper salt units in the northern Texas Panhandle and around the northern, eastern, and western margins of the Palo Duro Basin, the most wide-

Table 1. Stratigraphic chart, Permian to Quaternary strata, Palo Duro Basin and surrounding area.

System	Series	Eastern New Mexico	Palo Duro Basin		Dalhart Basin	Anadarko Basin
Quaternary		Blackwater Draw Fm.	Blackwater Draw Fm.		Blackwater Draw Fm.	Blackwater Draw Fm.
Tertiary		Ogallala Fm.	Ogallala Fm.		Ogallala Fm.	Ogallala Fm.
Cretaceous		several formations, undifferentiated				
Jurassic		Exeter Ss.			Exeter Ss.	
Triassic		Dockum Gp.	Dockum Gp.		Dockum Gp.	
Permian	Ochoa	Dewey Lake Fm.	Dewey Lake Fm.		Dewey Lake Fm.	Quartermaster Fm.
	Ochoa	Alibates Fm.[1]	Alibates Fm.[1]		Alibates Fm.[1]	Alibates Fm.[1]
	Ochoa	Salado Fm.	Salado Fm.		Salado Fm.	Cloud Chief Fm.
	Guadalupe	Artesia Gp.	Artesia Gp.	Tansill Fm.[1]	Artesia Gp.	Cloud Chief Fm.
				Yates Fm.[1]		
				Seven Rivers Fm.[1]		Whitehorse Gp.
				Queen and Grayburg Fms.[1]		
		San Andres Fm.	San Andres Fm.		Blaine Fm.	Blaine Fm. / Dog Creek Fm.[1] / Flowerpot Fm.[1]
	Leonard	Glorieta Sandstone	Glorieta Fm.[1]		Glorieta Sandstone	Glorieta Fm.[1]
		Yeso Fm. / Sangre de Cristo Fm.	Clear Fork Gp.	upper Clear Fork Gp. undifferentiated	Clear Fork Gp.	Clear Fork Gp.
				Tubb Fm.[2]		
				lower Clear Fork Gp. undifferentiated		
		Abo Fm. / Sangre de Cristo Fm.	Wichita Gp.		Wichita Gp.	Wellington Fm.

[1]Formation's lithology is not the same as the formally designated stratotype.
[2]The Tubb Sandstone member is informally designated Tubb Formation.

spread salt beds may have extended over the entire Palo Duro, Dalhart, and Anadarko Basins. Lower San Andres evaporite beds are generally thicker, purer, and more laterally persistent than upper San Andres or Clear Fork evaporites. Salt beds are interbedded with anhydrite, dolomite, or red beds within the Palo Duro Basin. In the southern Palo Duro Basin, evaporite beds thin and pinch out as carbonates become predominant. Northward into the Dalhart Basin and Cimarron Arch area, evaporite beds thin and terrigenous clastics are more predominant.

Following a depositional hiatus, humid conditions apparently prevailed in the Late Triassic during deposition of the Dockum Group. The Dockum Group consists of fluvial, deltaic, and lacustrine clastic facies that accumulated in a large fluvial-lacustrine basin (fig. 4; McGowen and others, 1979). Dockum strata are overlain unconformably by the Upper Jurassic Exeter Sandstone in eastern New Mexico and western Dallam County, Texas. Carbonates of the Lower Cretaceous Kiamichi Formation (Fredericksburg Group), sandstones and conglomerates of the Dakota Group, and shales of the Kiowa Formation are present in the southern Palo Duro Basin, the northwestern Texas Panhandle, and parts of eastern New Mexico.

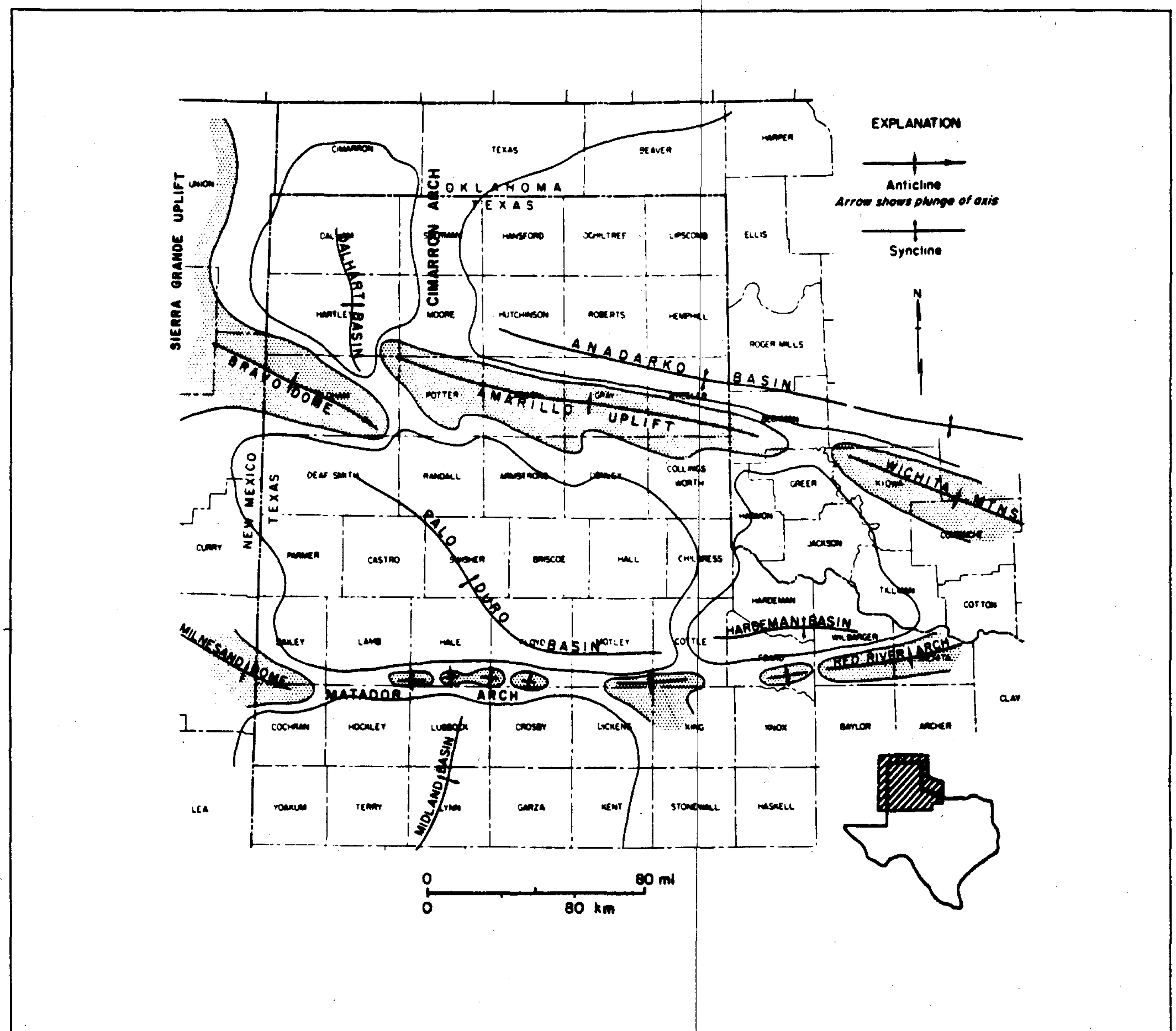

Figure 2. Structural elements of the Texas Panhandle and adjacent areas (after Nicholson, 1960).

Cenozoic orogeny caused regional uplift and created an east-dipping land surface, resulting in a period of rapid erosion over the Texas Panhandle. Figure 5 shows the intervals of time from the middle Permian through the Quaternary that are represented by sedimentation and nondeposition or erosion in the Palo Duro Basin. Paleocene through middle Miocene sediments have not been recognized in the Texas Panhandle.

The Ogallala Formation of late Tertiary age unconformably overlies Permian, Triassic, Jurassic, and Cretaceous strata in the Texas Panhandle. Ogallala sediments derived from mountains to the west compose an alluvial apron deposited by coalescent alluvial fans. In the Texas Panhandle (fig. 6), Ogallala sediments were deposited in medial- and distal-fan environments. Pre-Ogallala valleys and collapse basins are filled with up to 800 ft (250 m) of Ogallala deposits (Seni, 1980).

The upper Ogallala surface is extensively calichified to form the Caprock caliche. Late Pleistocene eolian sediments of the Blackwater Draw Formation mantle the Ogallala Formation, although locally these sediments have been stripped to expose the

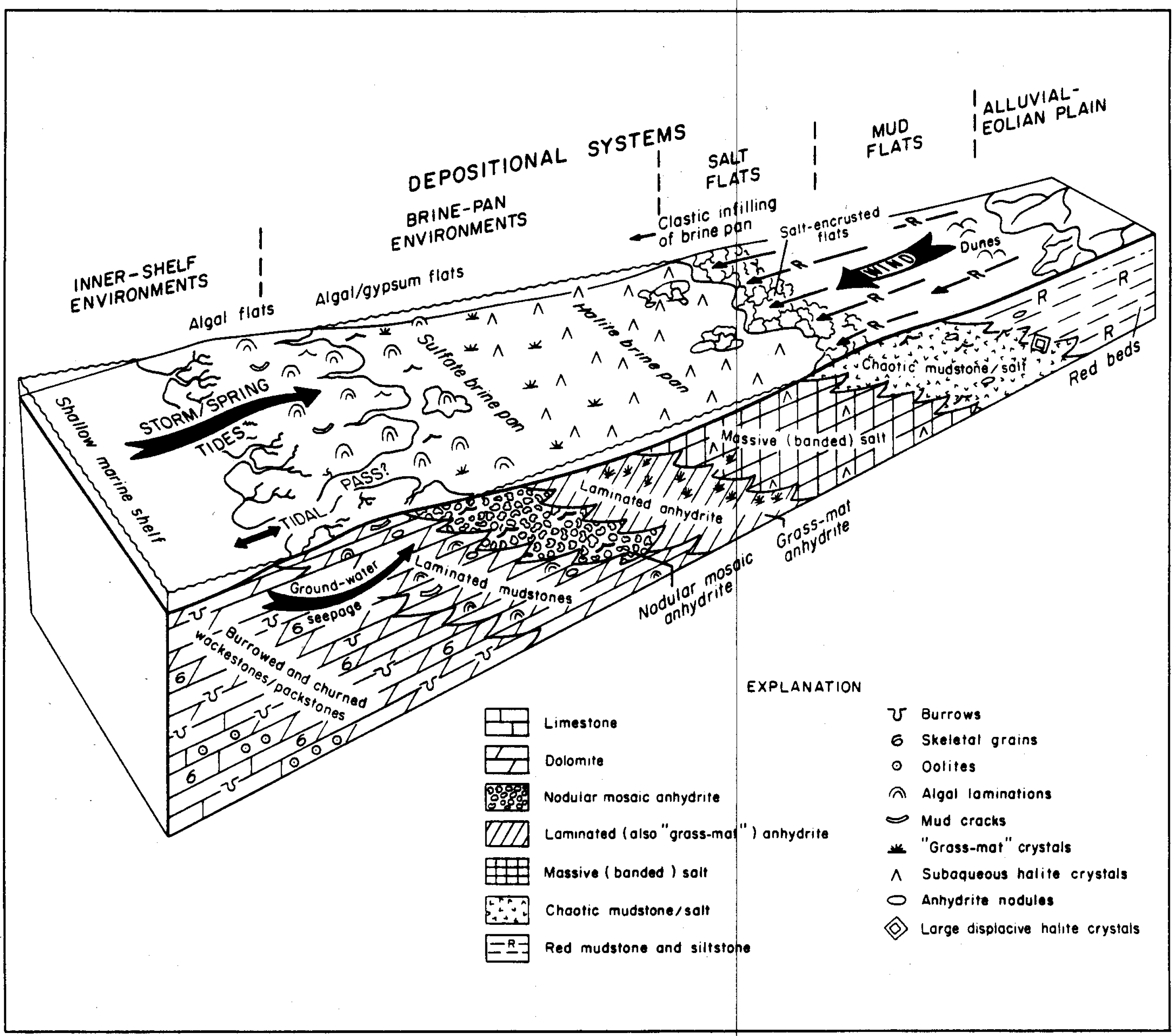

Figure 3. Evaporite, carbonate, and terrigenous clastic facies and inferred environments of middle and upper Permian rocks, Texas Panhandle (Presley, 1981).

underlying Ogallala Formation (Barnes, 1969). Late Tertiary to early Pleistocene fluvial and lacustrine deposits occur locally between the Ogallala Formation and the Pleistocene eolian sediments.

Blackwater Draw (Quaternary) and Ogallala (Tertiary) lithologies are undifferentiated on the cross sections in this report and are represented by a single pattern. Triassic, Jurassic, and Cretaceous sediments are also undifferentiated on most sections. Permian rock types are indicated by individual patterns as shown in the explanation of each cross section.

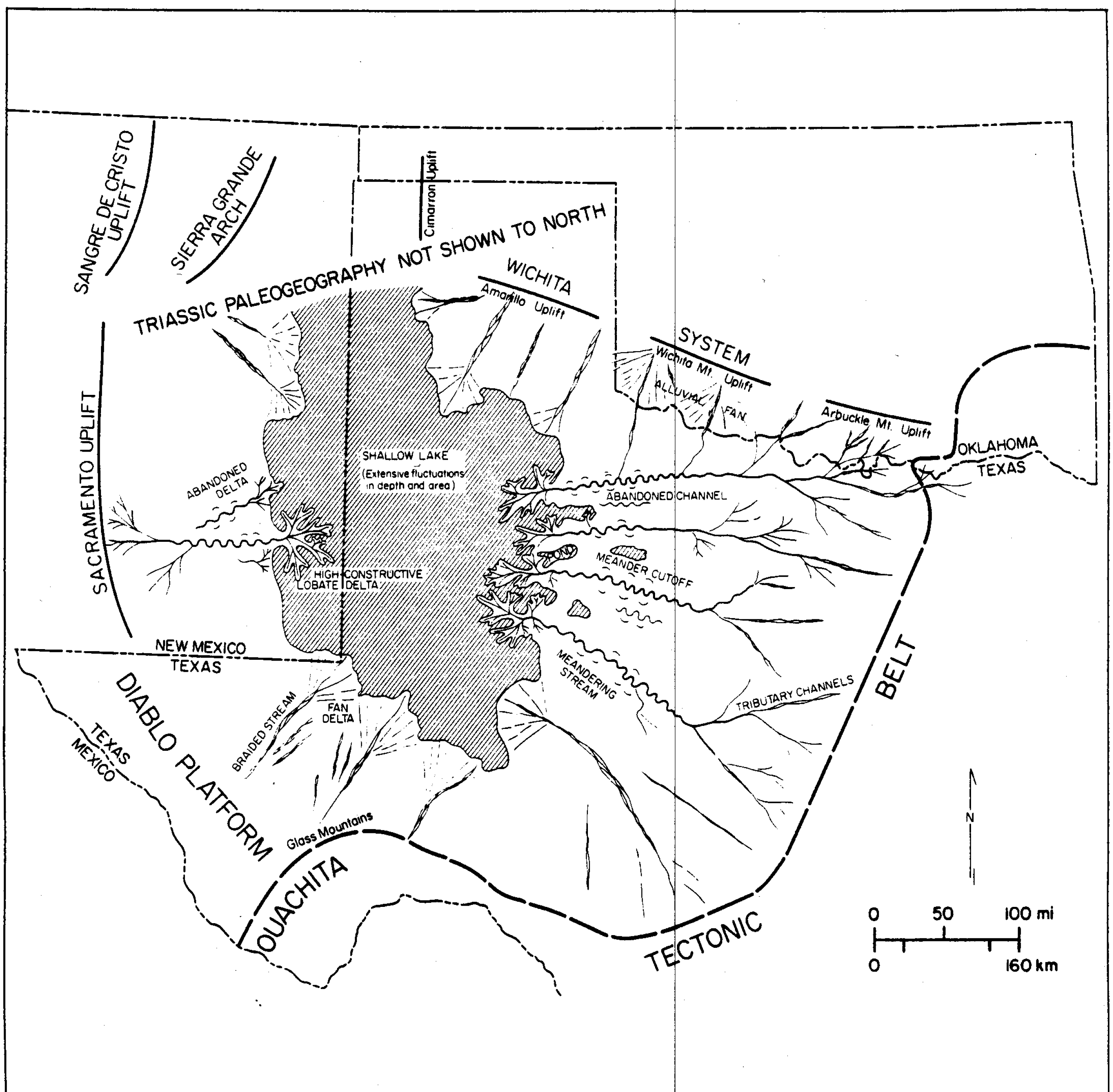

Figure 4. Inferred paleogeography during the initial stage of Dockum sedimentation south of the Amarillo Uplift and Sierra Grande Arch. Deposition was in braided streams, alluvial fans, fan deltas, meandering streams, and shallow lakes (McGowen and others, 1979).

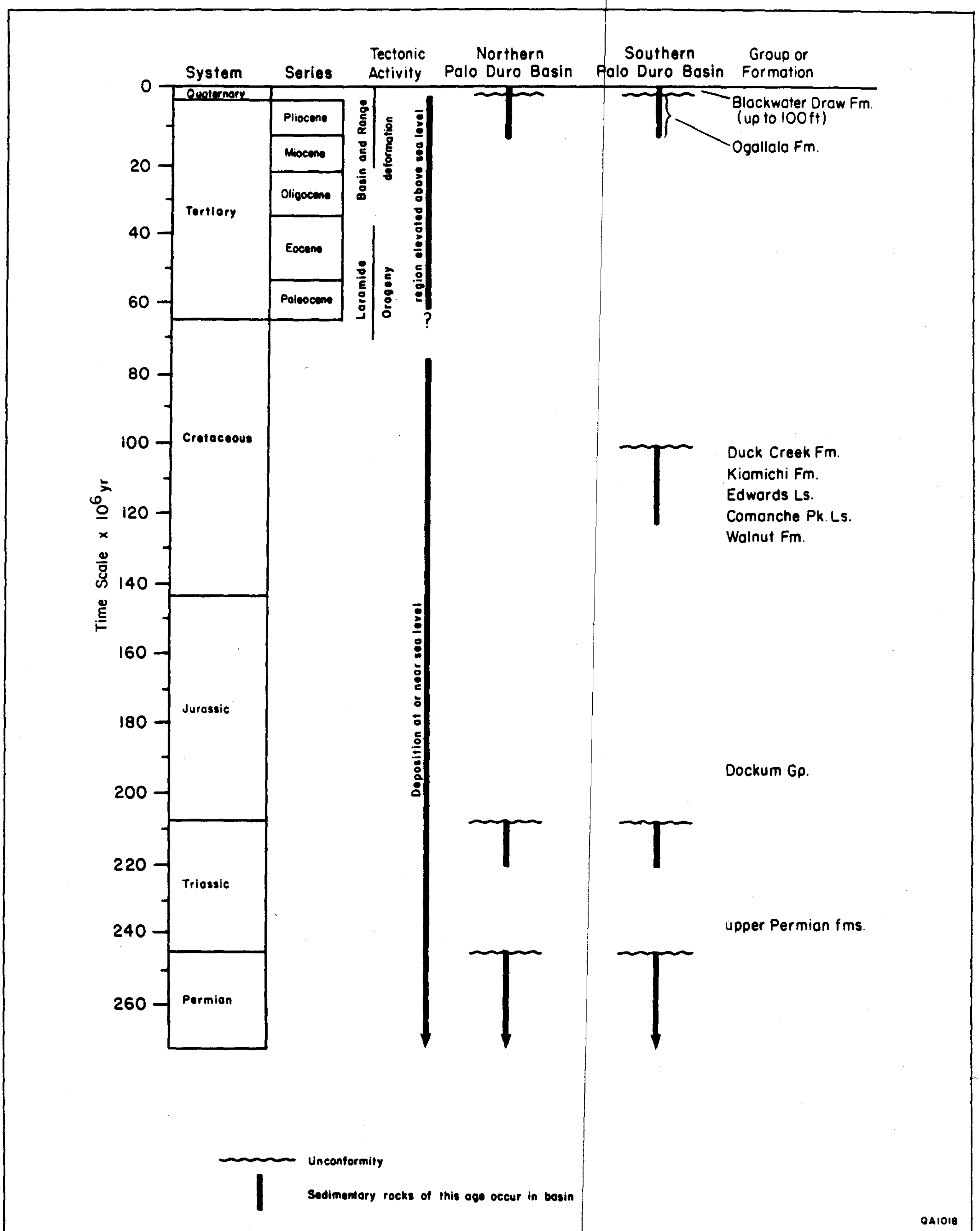

Figure 5. Geologic time scale showing intervals of time represented by Permian to Quaternary strata in the Palo Duro Basin. Time units adapted from Palmer (1983).

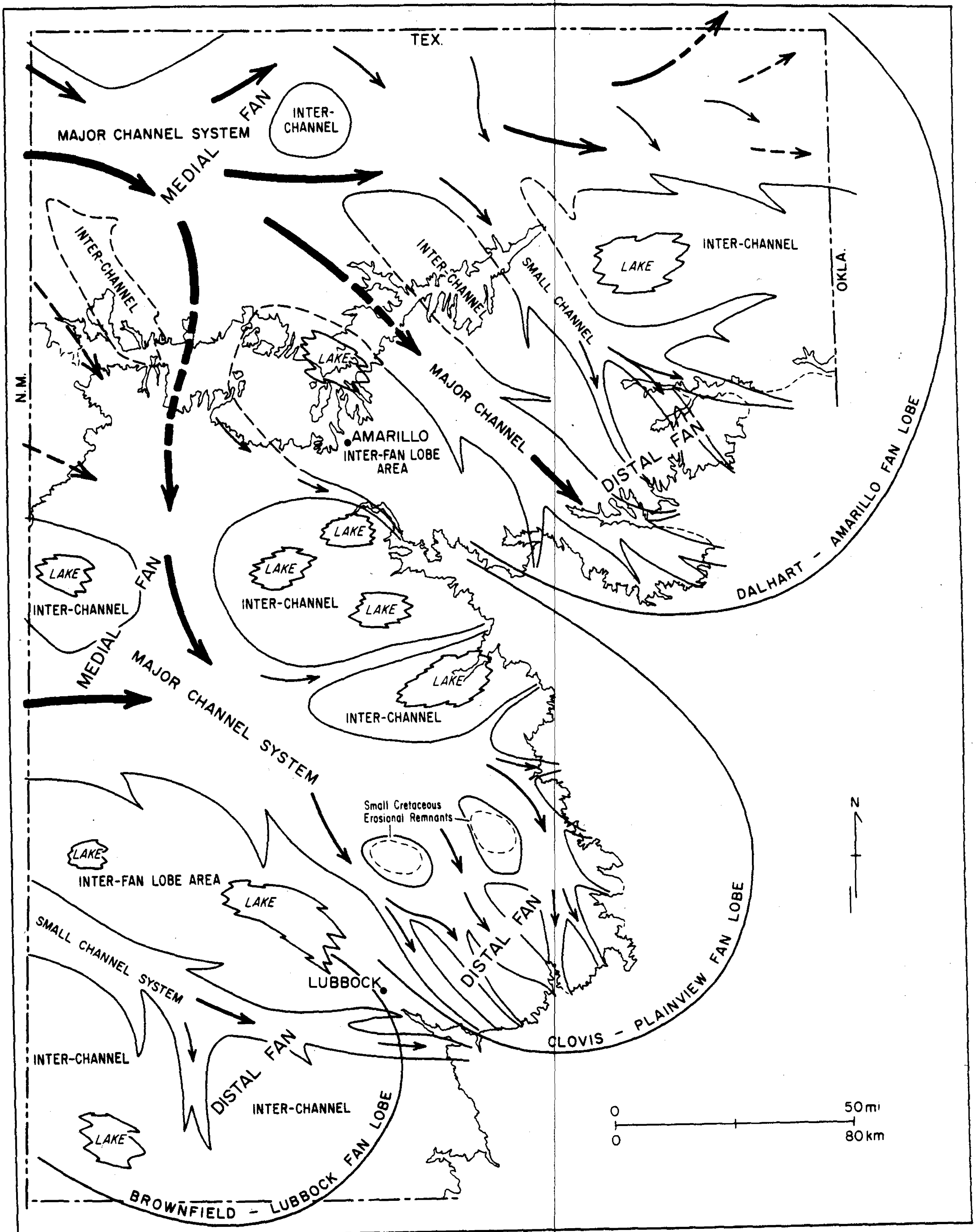

Figure 6. Schematic illustration of Ogallala depositional facies and inferred sediment dispersal systems, Texas Panhandle. Width and length of arrows indicate relative intensity of fluvial processes. Facies are not time-equivalent (Seni, 1980).

Salt Dissolution and Collapse of Overlying Strata

Salt dissolution and the subsequent collapse of overlying strata have affected a substantial part of the Texas and Oklahoma Panhandles and eastern New Mexico (Gustavson and others, 1980b, 1982). Most of the dissolution of Permian bedded salt has occurred within approximately 1,300 ft (400 m) of the surface. Collapse caused by salt dissolution is active along the western, northern, and eastern escarpments of the Southern High Plains (Gustavson and others, 1981a). For example, numerous sinkholes, small-displacement faults, and undrained depressions have formed since 1950 in northern Hall County in the Texas Panhandle (Gustavson and others, 1982). Salt dissolution may also have occurred during the late Tertiary or Quaternary beneath the Southern High Plains (Gustavson and Budnik, 1984). Other instances of recent salt collapse have been reported in Meade County, Kansas (Johnson, 1901), and in Curry County, New Mexico (Judson, 1950).

Seven salt-bearing stratigraphic units occur within the Permian Basin of the Texas Panhandle and eastern New Mexico (fig. 7), and, with the probable exception of the lower Clear Fork Formation, all the salt-bearing units have been affected by salt dissolution on a regional scale. Evidence that salt dissolution occurs in eastern New Mexico and the Texas Panhandle includes the following:

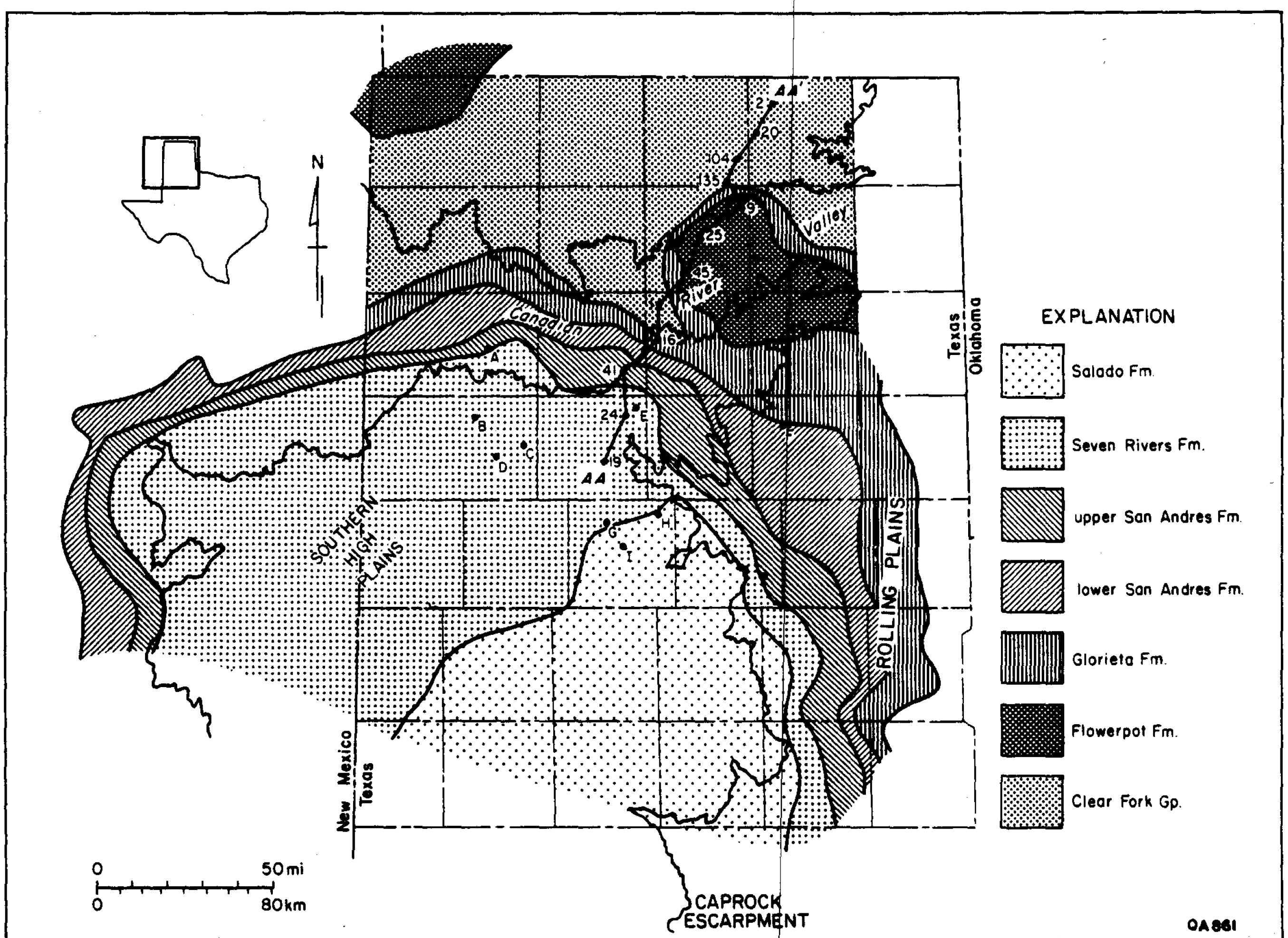

Figure 7. Geographic extent of existing salt beds within the Texas Panhandle and eastern New Mexico. The stratigraphically uppermost (youngest) salts have been subjected to dissolution throughout the area. Wells drilled by the U.S. Department of Energy - Gruy Federal or Stone and Webster Engineering Corporation are indicated by letter: (A) Mansfield No. 1, (B) J. Friemel No. 1, (C) G. Friemel No. 1, (D) Detten No. 1, (E) Rex White No. 1, (F) Sawyer No. 1, (G) Harmon No. 1, (H) Grabbe No. 1, and (I) Zeeck No. 1. Line of cross section AA-AA' (fig. 8) shown.

(1) All the streams that drain the region surrounding the Southern High Plains carry high solute loads. For example, the Prairie Dog Town Fork of the Red River carries a mean annual solute load of 1.0035×10^6 tons of dissolved solids per year, including 0.4253×10^6 tons of chloride per year (U.S. Geological Survey, 1969-1977). Brine springs and salt pans occur in this and other stream valleys.

(2) The abrupt loss of salt beds between relatively closely spaced wells and the abrupt thinning of stratigraphic sequences away from salt-bearing strata suggest dissolution rather than facies change (cross sections A-A' through L-L').

(3) Examination of cored intervals through the uppermost salts from Department of Energy (DOE) - Gruy Federal and DOE - Stone and Webster Engineering Corporation wells (fig. 7) indicates that dissolution of the top parts of the uppermost salt beds has occurred (S. D. Hovorka, personal communication, 1984). Reddish-brown mudstone several feet thick overlies the uppermost salt beds penetrated in these wells. This mudstone is probably a salt-dissolution residue. Laterally extensive areas of extension fractures also occur above uppermost salts in the subsurface.

(4) Folds, breccia-filled chimneys, and brecciated beds along Permian outcrops in the Canadian River valley and east of the High Plains Escarpment are commonly the result of structural adjustments produced by salt dissolution and collapse of overlying strata (Gustavson and others, 1980b, 1982).

Evidence of salt dissolution at the northern margin of the Palo Duro Basin is illustrated on cross sections H through L and on figure 8. The cross sections show correlation of Glorieta, San Andres, and Flowerpot strata from areas where salt is preserved into areas where equivalent-age stratigraphic units do not contain salt. Analogy of older widespread salt beds of the Clear Fork Group to salt beds of the younger Glorieta, Flowerpot, and San Andres Formations suggests that salt of the Glorieta, Flowerpot, and San Andres Formations extended beyond their present limits. For example, upper and lower Clear Fork evaporites display a laterally extensive tabular geometry that extends beyond the northern margin of the Palo Duro Basin and also beyond the area of dissolution that affects salt in the Glorieta, Flowerpot, and San Andres Formations (fig. 8; cross sections I-I' and K-K'). Salt was deposited in topographically flat Permian coastal environments; this means that the dip of late Permian strata exhibited on the cross sections was largely caused by postdepositional subsidence, regional uplift, and resulting fault movements. Clear Fork salt and anhydrite beds display only minor variations in thickness and well-log character across the structurally high, fault-bounded Amarillo Uplift; this suggests that the Amarillo Uplift was only a minor influence on evaporite deposition in Clear Fork time. The tabular geometry and lateral extent of anhydrite beds overlying and underlying the salt-dissolution zones in Glorieta and San Andres evaporites suggest a lack of structural control on sedimentation at the margins of the Palo Duro Basin. Consequently, in areas where Glorieta and San Andres salt beds are truncated at the northern margin of the basin, it is inferred that the salt beds may have extended, at least in part, across the northern margin of the basin (similar to stratigraphically lower Clear Fork salt beds that are unaffected by salt dissolution), and they are interpreted to have been removed by salt dissolution.

Other geologic relationships observed on the cross sections suggest salt dissolution. In general, Permian and post-Permian rocks are structurally lower above areas of inferred salt dissolution. Structural lows at the base of the Ogallala Formation and thickened Ogallala strata in the lows suggest that dissolution in many areas occurred either before or concurrently with Ogallala deposition. The present course of the Canadian River may also have been influenced by dissolution of salt during post-Ogallala time (Gustavson, 1982). The evidence of salt dissolution as documented by the cross sections, in combination with surface and core data, suggests that the Glorieta and San Andres salt beds that extended beyond the northern margin of the Palo Duro Basin have been removed by dissolution. Similar evidence indicates that salt has also been dissolved from the eastern and western margins of the basin.

Nonsalt strata generally retain their gamma-ray log character and thickness across the dissolution zone, and the former extent of the salt beds is indicated only by insoluble residue of salt dissolution (for example, see McGillis and Presley, 1981). Where the salt-dissolution symbol on the cross sections marks the truncation of an entire salt bed, the former presence of the salt unit beyond the dissolution symbol is evidenced by the salt-dissolution residue. The residue is composed predominantly of clay- and silt-sized clastic sediments contained within the salt bed before it was dissolved. This mudstone residue is recognized on the gamma-ray logs as high-radioactivity deflections where it is intercalated with low-radioactivity deflections of anhydrite strata. Where the dissolving salt pinches out into mudstone, the response of mudstone residue on gamma-ray logs is commonly not distinguishable from that of mud-

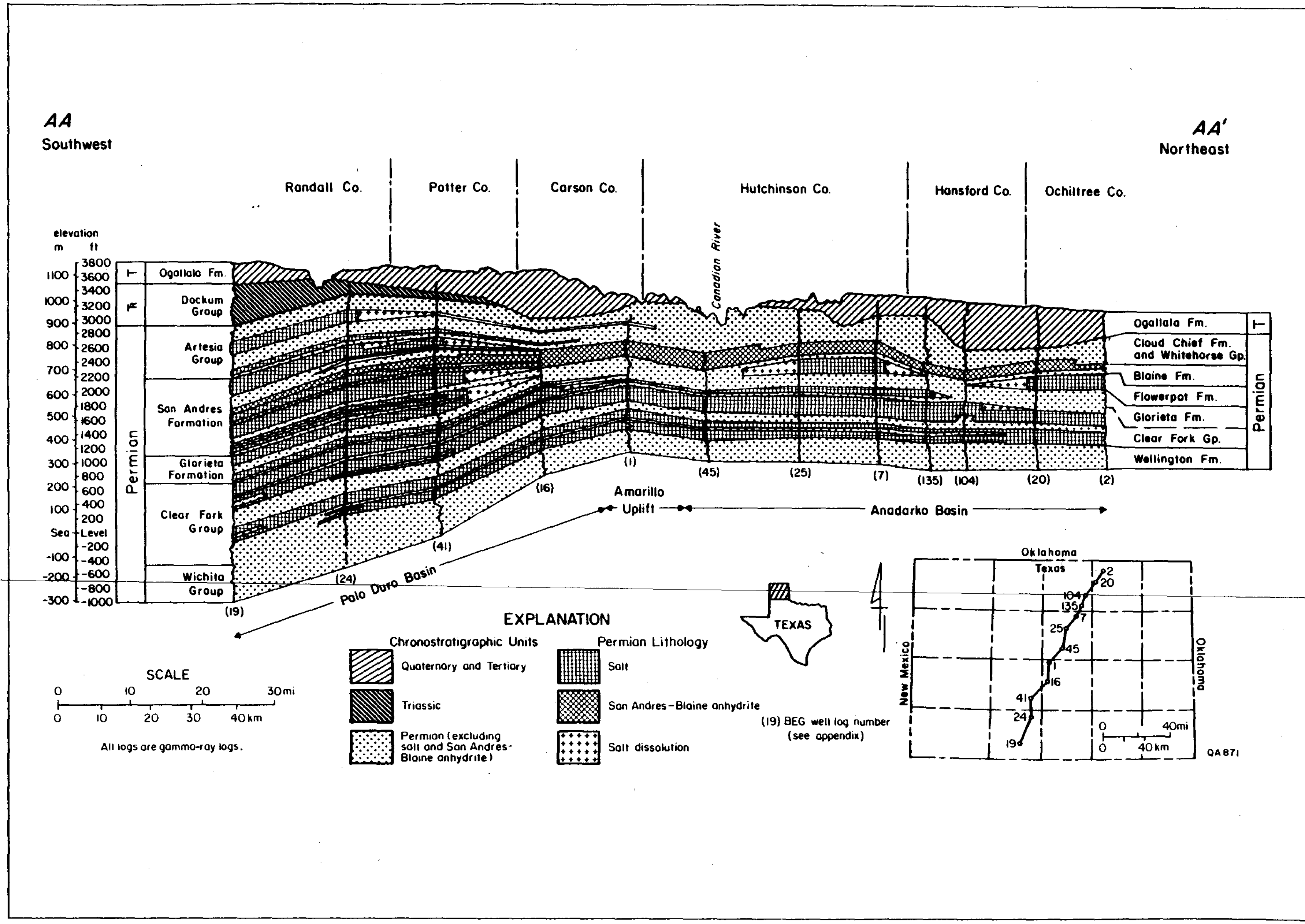

Figure 8. Cross section AA-AA' showing evidence for interpretation of salt dissolution, Texas Panhandle. Salt-bearing strata of the San Andres Formation in the Palo Duro Basin correlate with salt-bearing strata of the Flowerpot Formation in the Anadarko Basin across equivalent-age stratigraphic units that do not contain salt.

stone. For this reason, and because mudstones are generally less than 10 ft (3 m) thick, the mudstone residue is not usually correlated as a separate unit on the cross sections.

The shallowest salts, which are the structurally highest salt strata, are the first to be dissolved. After the salt has been removed, it is difficult to determine the volume of original salt because facies changes may also have produced changes in salt thickness, especially over structurally high areas. Therefore, the distribution of depositional environments must be mapped to distinguish between areas where salt was not deposited and areas where it has been dissolved (McGookey, 1981).

Correlation of beds across the dissolution zone is possible by correlating the bases of salt beds that are undergoing dissolution and assuming that the missing interval is caused by dissolution from the top of the uppermost salt beds. This procedure was followed in the construction of the cross sections. The amount of salt dissolved can be estimated on a cross section by subtracting the thickness of a section where dissolution has occurred from the thickness of a nearby equivalent stratigraphic section where a complete salt section is preserved. Original salt thicknesses have not been interpreted in areas where salt has been totally removed.

The salt-dissolution symbol between gamma-ray logs on the cross sections indicates where salt has been removed or thinned by dissolution. The salt-dissolution symbol followed by a question mark indicates where salt may have been dissolved or not deposited. This symbol is used in areas of lithofacies changes from salt to nonsalt facies. For example, on cross section H-H', upper Glorieta eolian sand facies grade into salt-bearing marginal marine facies between Hartley No. 93 and Oldham No. 2 (see appendix for well names) where salt is abruptly lost from Blaine and lower Glorieta Formations.

General Explanation of Cross Sections

Quaternary-Tertiary, Cretaceous, Jurassic, and Triassic time-stratigraphic units are undifferentiated on most cross sections. Permian strata are subdivided into rock-stratigraphic units; lithology is based on interpretation of gamma-ray logs. Salt-dissolution symbols are used to note changes in thickness of salt between adjacent gamma-ray logs. Where salt dissolution is strongly inferred by abrupt loss of salt and collapse of overlying rocks, as well as by other supporting evidence, the salt-dissolution symbol is used without a question mark. In areas where absence of salt may be caused by nondeposition of salt or salt dissolution, a question mark is added to the salt-dissolution symbol. Cross sections A-A' through F-F', I-I', and K-K' have a vertical exaggeration of 106 times; cross sections G-G', H-H', J-J', and L-L' have a vertical exaggeration of 53 times.

Faults on the cross sections are shown diagrammatically. Lithologies interpreted from well logs are extrapolated to the fault. Although faults are shown by a single vertical line they may actually be zones of complex faulting. Faulting and differential subsidence locally influenced Permian sedimentation, generally resulting in thickening of some Permian units toward the axis of the Palo Duro Basin. Post-Permian fault movements have made precise correlation of some Permian strata across faults difficult, in part because of thickness changes. For example, the interpreted thickness of salts generally thins northward between the Shell Oil No. 1 Bivins Ranch (10) well and the Colorado Interstate Gas No. A-111 Bivins (13) well on cross section I-I'. In addition, dissolution of salt has further complicated correlations across fault zones. For example, on cross section I-I', the thickness of sandstone within the Glorieta thins 70 ft (21 m), from 120 ft (37 m) on the upthrown side to 50 ft (15 m) on the downthrown side. Part of this thickness change may be accounted for by facies change or by depositional thinning or the thickened part of the sandstone may actually include some insoluble residues from Glorieta salts that were dissolved north of the fault but are still present south of the fault.

Summary

The cross sections in this report illustrate where dissolution is interpreted to have truncated salt beds and disturbed stratigraphic relationships that existed prior to dissolution. The cross sections demonstrate the generally tabular geometry of Permian evaporite beds, areas where salt has been lost from the strata by dissolution, and the influence of dissolution on Permian and post-Permian rocks. Salt dissolution is inferred from physical evidence of the former presence of salt in cores and by interpretation of the former presence of salt from gamma-ray log response and from field studies. Salt beds may be abruptly truncated by dissolution, or they may be lost more gradually over several miles through dissolution, facies change, or both; careful interpretation is necessary to distinguish the effects of dissolution from those resulting from facies changes. Using the cross sections, it is possible to trace the extent of salt beds and to identify areas where salt has probably been removed by dissolution.

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Appendix: List of gamma-ray logs used on cross sections

BEG No.	Operator	Well Name
	ARMSTRONG COUNTY*	
4	Sunray Mid-Continent Oil Co.	#1 Cope
22	W. V. Harlow	#1 Mattie Hedgecoke
23	Burdell Oil Co.	#1 McGehee strat. test
	BRISCOE COUNTY	
1	Texaco-Seaboard, Inc.	#1 Thelma Bivins
3	Hassie Hunt Trust Estate	#1 Owens
5	H. L. Hunt	#9 Ritchie
6	H. L. Hunt	#2 Ritchie
20	Gulf Oil Corp.	#D-1 S. A. Rodgers
21	Cockrell Corp.	#1 C. O. Allard
23	Amerada Petroleum Corp.	#1 J. C. Hamilton
	CARSON COUNTY	
1	Headington Co.	#D-1 Sanford
7	Skelly Oil Co.	#262 Schafer Ranch
15	Bridger Petroleum Corp.	#1 Leven
16	E. H. Rice	#1 Chapman
20	Texas Gulf Producing	#1 Bobbitt
22	Consolidated Gas & Mining Corp. and Harvest Queen Mill & Elevator Co.	#1 Biggs "A"
27	L. B. Newman	#4 Meaker
33	Roy H. King et al.	#1 F. M. & C. M. Peacock
37	J. M. Huber Co.	#1 Newton
43	Sand Springs Home	#27 Long
45	Cities Service Oil Co.	#4 Burnett "F"
52	Gulf Oil Corp.	#64 S. B. Burnett
	CASTRO COUNTY	
1	Amarillo Oil Co.	#1 C. R. Veigel
3	Pan American Petroleum	#1 Mary Lee Robbins
8	I. A. Stephens	#1 I. C. Little
9	Ashmun & Hilliard	#1 Willis
13	Amarillo Oil Co.	#1 L. C. Boothe
16	Ashmun & Hilliard	#1 John L. Merritt
	CHILDRESS COUNTY	
1	Seitz et al.	#1 Ray Albaugh
5	Russell Maguire	#1 Smith L. & C.
8	Shell Oil Co.	#1 Mitchell
52	L. B. Taylor	#1 E. B. Johnson
	COTTLE COUNTY	
6	Pan American Petroleum	#1 Coda Bevers
69	Miami Oil	#1 Swenson
78	General Crude	#29-1-C Swenson
91	Robinson	#2 Tippen
99	Hovgard & Fitzgerald	#1 Jamie Cate
	CURRY COUNTY, NEW MEXICO	
2	Exxon Co., USA	#1 Evelyn Brown
18	Southern Petroleum Exploration, Inc.	#1 Harrell
	DALLAM COUNTY	
1	Shell Oil Co.	#1 Simms
8	Cabot Carbon	#1 Murdock
20	Skelly Oil Co.	#1 Robinson
43	Skelly Oil Co.	#1 Noble
	DEAF SMITH COUNTY	
2	Frankfort Oil Co.	#1 Allison-Hayes
4	Texas Crude Oil Co.	#1-78 Rose
10	Gardner Bros. Drilling Co.	#1 Collett
14	LaMance Drilling Co.	#1 Western Realty
	DE BACA COUNTY, NEW MEXICO	
1	Peters Oil Co.	#1 Peters State
13	Nearburg & Ingram	#1 Milton
15	Shell Oil Co.	#26-69 strat. test
16	Cities Service Oil Co.	#1 Hobson
17	Eugene Talbert	#1 Federal

*Texas counties unless otherwise indicated.

BEG No.	Operator	Well Name
	DONLEY COUNTY	
1	H. E. Bryan	#1 Hermesmeyer
7	James W. Witherspoon	#1 McMurtry
9	El Paso Natural Gas Co.	#3 Lewis
12	El Paso Natural Gas Co.	#A-1 Baptist Foundation
43	Miami Petroleum Co.	#1-162 Lazy R. G. Ranch
	FLOYD COUNTY	
4	Lovelady	#1 E. E. Wells
34	Pan American Petroleum	#A-1 H. Hammond
35	Lovelady	#1 Couch
	GRAY COUNTY	
1	E. B. Clark Drilling Co.	#1 D. J. Barnett
5	Sidewell Oil and Gas	#1 Fatheree
12	Underwood	#1 Jackson
22	Phillips Petroleum Co.	#1-B Troy
74	Quintin Little	#1 Kirby
	GUADALUPE COUNTY, NEW MEXICO	
9	A. G. Hill-Gardner Petroleum Co.	#1-A Federal
12	Bert Thompson	#1 Tucumcari National Bank
13	General Crude Oil Co.	#1-1 State
14	Husky and General Crude Oil Co.	#1 Hanchett State
15	Baker & Taylor Drilling Co.	#1 Dale Smith
	HALE COUNTY	
1	El Rey Petroleum, Inc.	#1 T. L. Whitten
5	Mason & Walsh	#1 Harrell
	HALL COUNTY	
1	Amarillo Oil Co.	#1 Grace Cochran
2	Sun Oil Co.	#1 T. E. Spear
16	Sinclair Oil Co.	#1 Shannon
21	Sinclair Oil Co.	#2 Annie C. Hughes
27	Atlantic Refining Co.	#1 W. E. Garrison
	HANSFORD COUNTY	
34	Falcon-Seaboard	#1 Dahl
47	R. L. Foree	#1 O.D.C.
63	Paradox Petroleum Co.	#1-59 Bivins
70	Gulf Oil Corp.	#1 Rhoda Hart
104	Texas Co.	#1 H. L. Wilbanks
105	Hamilton Bros.	#1-115 Willbanks
131	Southern California Petroleum Co.	#1 Yanda
135	John Eisner	#1 Carson
144	Humble Oil Co.	#1-18 Hart "A"
QE	Gulf Oil Corp. (TDWR)	#1 Ogle Gas Unit
	HARTLEY COUNTY	
3	Burnett	#1 Bennett
4	Pan American Petroleum	#1 Wharton Ranch
10	Phillips Petroleum Co.	#1-L Morris
23	Sinclair Oil Co.	#1 Reynolds Cattle
30	Phillips Petroleum Co.	#1 Ostia
56	Amarillo Oil Co.	#1 Houghton
57	Sinclair Oil Co.	#1 Houghton
68	Phillips Petroleum Co.	#2 Feltz
70	Sinclair Oil Co.	#15 Bivins Estate
93	Amarillo Oil Co.	#2 Houghton
	HEMPHILL COUNTY	
20	Phillips Petroleum Co.	#1 McQuiddy "A"
29	Humble Oil & Refining Co.	#1 R. A. Flowers
	HUTCHINSON COUNTY	
1	McCulloch Oil	#1-B Cunningham
7	Edwin L. Cox	#1 Holt
16	Anadarko Production	#B-1 Kirk
21	J. M. Huber Corp.	#5 Harrison
25	Gulf Oil Corp.	#1 B. Wisdom
28	Claro, Inc.	#1 M.A.T. Petroleum
32	Gulf Oil Corp.	#1 Duncan

Appendix (cont.)

BEG No.	Operator	Well Name
	HUTCHINSON COUNTY (cont.)	
41	A. E. Herrmann Corp.	#15 Hardin
45	A. E. Herrmann Corp.	#5 Scott
53	Roy H. King	#1 T. J. Price
231	Phillips Petroleum Co.	#1 Veta
299	Power Petroleum Co.	#9 Fred
302	Graham-Michaelis Drilling Co.	#4 Pritchard
	LUBBOCK COUNTY	
1	Delfern Oil	#1 Hines
	MOORE COUNTY	
2	Petro Exploration, Inc.	#1 M. Cator
13	Diamond Shamrock	#1 Robertson Storage
17	Texas Co.	#1 Lacy Meek
18	Texas Co.	#1-B Lacy Meek
21	Pioneer Products	#1 Thompson
33	Socony Mobil Oil	#6-M R. S. Coon
46	Colorado Interstate Gas Co.	#36-A Masterson
48	Anadarko Production	#1-E Sneed
174	Colorado Interstate Gas Co.	#10 Sneed "A"
232	Colorado Interstate Gas Co.	#31R Masterson
	MOTLEY COUNTY	
38	Humble Oil Co.	#4-B Matador
41	Humble Oil Co.	#6-B Matador
44	E. E. Moss & Sons	#1 Ollie Scott
46	Cascade Petroleum	#1 E. C. Stearns
48	Locke	#1 Heath Robinson
51	La Coastal	#1-44 Swenson
	OCHILTREE COUNTY	
2	Texas Pacific Oil Co.	#1 Sell
20	Horizon Oil & Gas	#1-57 Weicker
A	Skelly Oil Co.	#1 Kuntson
B	Texas Pacific Oil Co.	#1 Newman
	OLDHAM COUNTY	
2	Shell Oil Co.	#1-68 strat. test
5	Shell Oil Co. and Atlantic Refining Co.	#98-1 Fulton
10	Shell Oil Co.	#1 Bivins Ranch
13	Colorado Interstate Gas Co.	#A-111 Bivins
16	Shell Oil Co.	#B-1 L. S. Ranch
25	Shell Oil Co.	#2-68 strat. test
28	Superior Oil Co.	#3 Matador
53	Shell Oil Co.	#4-58 strat. test
67	Barnell Oil Co.	#1 Currie
70	Lonnie Glasscock, Jr.	#1 Howard
	PARMER COUNTY	
1	U.S. Smelting	#1-A S. H. Osborn
2	Gulf Oil Corp.	#A-1 Kellehor
8	Texaco, Inc.	#1 Owen Patton
10	Sunray Oil	#1 Kimbrough
	POTTER COUNTY	
1	Sinclair Oil Co.	#13 Bivins
8	Colorado Interstate Gas Co.	#34-R Masterson
17	Bivins	#1 Strip
18	Amarillo Oil Co.	#1 Frank Givens
28	James Brown Assoc.	#1 T. V. Hill
34	Standard of Texas	#1 R. C. Bush

BEG No.	Operator	Well Name
	POTTER COUNTY (cont.)	
39	Texaco, Inc.	#1 L. T. Bivins
41	ARCO	#129 WDW
44	Humble Oil & Refining Co.	#1 O. H. Gouldy
144	Colorado Interstate Gas Co.	#69-B Masterson
152	Colorado Interstate Gas Co.	#29-A Masterson
153	Colorado Interstate Gas Co.	#56-B Masterson
	QUAY COUNTY, NEW MEXICO	
2	Humble Oil & Refining Co.	#1 C. P. State
11	Shell Oil Co.	#4-69 strat. test
18	Henderson & Erickson	#1 Redondo Mesa
27	Shell Oil Co.	#20-69 strat. test
28	Shell Oil Co.	#19-69 Pueblo strat. test
29	Shell Oil Co.	#7-69 strat. test
30	Shell Oil Co.	#15-69 Pueblo strat. test
31	Shell Oil Co.	#8-69 strat. test
	RANDALL COUNTY	
12	Amarillo Oil Co.	#1 Irene Hicks
13	Arkla Exploration Co.	#1-55 Skypala
19	Frankfort Oil Co.	#1 Grogan
23	Frankfort Oil Co.	#1 Stinnett
24	Meridian Oil Corp.	#1 Winters
	ROBERTS COUNTY	
3	Phillips Petroleum Co.	#1 McGarraugh "B"
21	C. C. Lee	#1 D. D. Payne
	ROOSEVELT COUNTY, NEW MEXICO	
5	Humble Oil & Refining Co.	#1 "CT" State New Mexico
6	Humble Oil & Refining Co.	#1 Blonnie C. Rea
7	Southern Petroleum Exploration	#1 Hensley
	SHERMAN COUNTY	
5	Texas Co.	1st State Bank of Stratford
6	Cherry Bros.	#1 Arthur Ross
19	K&H Operating Co.	#1 Wiggins
20	K&H Operating Co.	#1 Wohlford
31	Petroleum Exploration, Inc.	#1 Bullington
37	Shamrock Oil & Gas Corp.	#1 Lucile Ferguson
39	Petro Associates	#1-332 Pronger
56	Gulf Oil Corp.	#1 Blake Unit
	SWISHER COUNTY	
1	Frankfort Oil Co.	#1 Wesley
3	Frankfort Oil Co.	#1 Culton
6	Standard Oil Co.	#1 Johnson
9	Humble Oil & Refining Co.	#1 A. B. Nanny
10	Consolidated Gas & Equipment Co.	#1 Patton
11	Consolidated Gas & Equipment Co.	#1 H. O. Thompson
12	Frankfort Oil Co.	#1 Sweatt
	TEXAS COUNTY, OKLAHOMA	
9	Phillips Petroleum Co.	#1 De Lier
	WHEELER COUNTY	
50	Chevron Oil Co.	#1 W. F. James
52	Mobil Oil Co.	#1 M. W. Walker
64	Johnny Grimm	#2 Porter