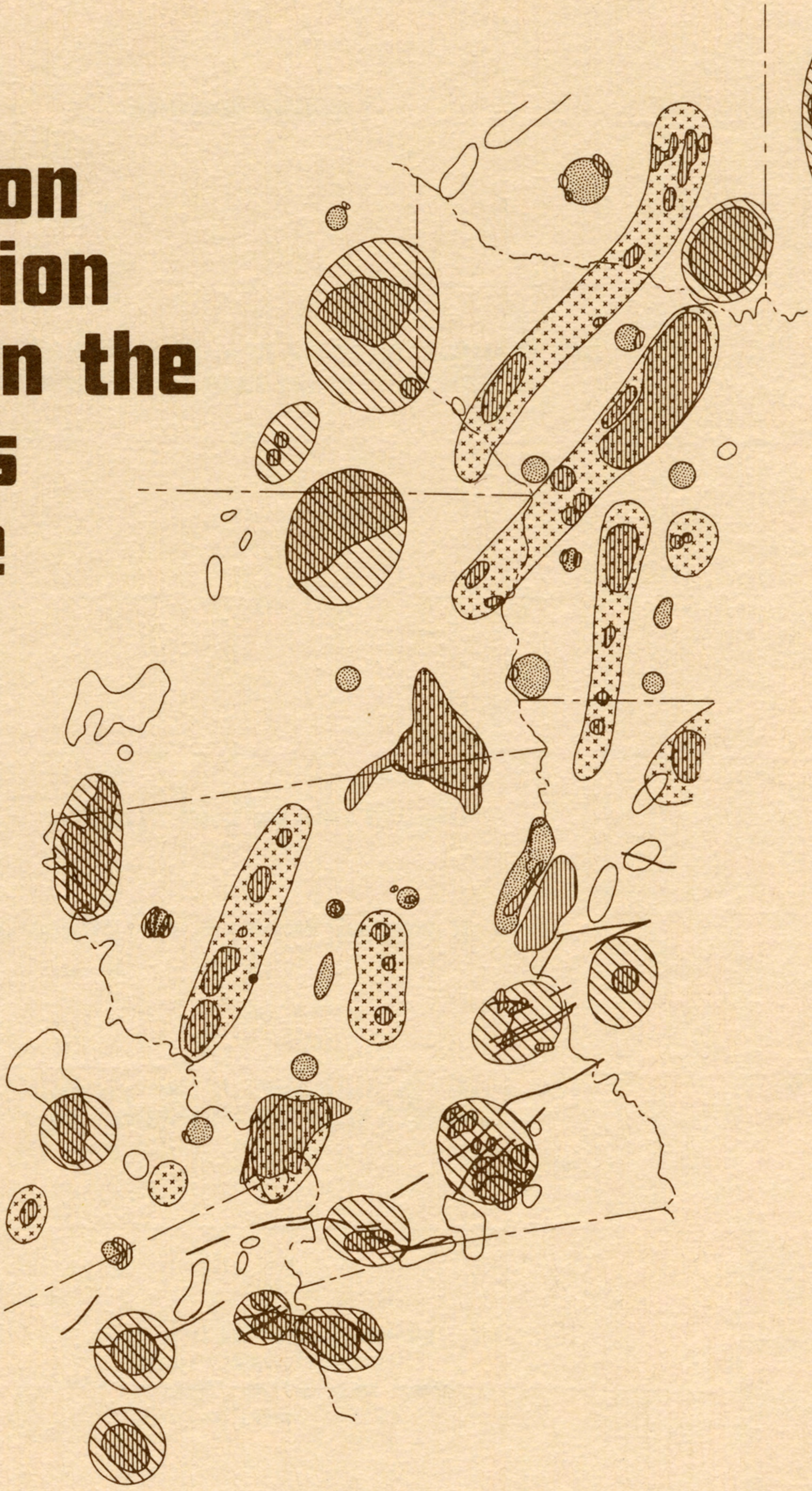
Geological Circular 82-6

Hydrocarbon Accumulation Patterns in the East Texas Salt Dome Province



Debra H. Wood
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1982

Bureau of Economic Geology W. L. Fisher, Director
The University of Texas at Austin Austin, Texas 78712

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HYDROCARBON ACCUMULATION PATTERNS IN THE EAST TEXAS SALT DOME PROVINCE

by

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ABSTRACT

Mobilization of the Louann Salt created the present structural configuration in the central part of the East Texas Basin and was the major control on hydrocarbon accumulation in the area. Salt-cored anticlines, turtle-structure anticlines, and salt diapirs were produced by flow of salt. Of these, the most prolific oil- and gas-producing structures have been anticlines with deep salt cores. These deep-seated salt domes uplifted thick stratigraphic sections; thus, their crestal anticlines are multiple-zoned productive structures. Turtle-structure anticlines are less important as hydrocarbon traps. Low productivity of turtle-structure anticlines compared with salt-cored anticlines may result from later development of turtle structures and from uplift of a relatively thinner stratigraphic section. Production associated with shallow salt domes has been relatively minor. If a large amount of oil or gas accumulated over the early pillow forms of these diapirs, then much of it may have leaked along faults associated with dome growth or been caused by erosional breaching of reservoirs over the dome crest after uplift. Deeper exploration of each type of structure (salt-cored anticlines, turtle-structure anticlines, and shallow salt domes) may be productive to the oil and gas companies.

Shallow salt domes in East Texas have been evaluated as repositories for isolation of nuclear waste. A suitable site must not harbor natural resources that might attract interest and lead to future breaching of the repository. Substantial hydrocarbon accumulations have not been discovered at most of the shallow domes in East Texas. However, these domes have attracted much drilling activity primarily because of highly successful exploration of shallow salt domes in the Gulf Coast Basin.

INTRODUCTION

The East Texas Basin (fig. 1) is bounded on the north and west by the Mexia-Talco Fault System, a series of normal faults forming subparallel, strike-trending, en echelon grabens. The Sabine Uplift defines the east margin of the basin. The Elkhart Graben - Mount Enterprise Fault System, which generally coincides with a trend of salt-cored anticlines, marks the southern limit of the study area. Most other salt structures in the basin, both piercement and nonpiercement salt domes, are concentrated along the axis of the basin.

Commercial interest in and active oil and gas exploration of the East Texas Basin have spanned many decades, in part because of the diversity of hydrocarbon traps in the area. Most of the petroleum in the basin accumulated in three kinds of traps: (1) traps with structural closures adjacent to faults of the Mexia-Talco Fault System; (2) traps related to the Sabine Uplift, such as the giant East Texas field; and (3) traps related to salt movement in the central part of the basin. As part of a study of the suitability of salt domes in East Texas for isolation of nuclear wastes, our research examined hydrocarbon traps of the third category. This report discusses salt mobilization, delineates the major salt-related structures, and describes the distribution of hydrocarbons within the central part of the basin.

SALT TECTONICS

Maximum deformation of Jurassic, Cretaceous, and Tertiary strata in the East Texas Basin resulted from the development of salt structures in the central part of the basin (figs. 2, 3, and 4). Salt structures formed by flowage of the Middle Jurassic Louann Salt. Seismic profiles of the area generally show an undeformed basal salt contact, a suggestion that units underlying the salt are not similarly deformed (fig. 5). These seismic lines also indicate that in the central part of the basin, Upper Jurassic - Lower Cretaceous clastics of the Bossier-Pettet interval normally are the oldest strata above the Louann Salt that exhibit major variations in thickness indicative of contemporaneous salt flow (figs. 5 and 6). Therefore, initial salt mobilization in this area probably coincided with the influx of fluvial-deltaic sediments that constitute much of the Bossier-Pettet interval. An exception is near Oakwood salt dome, where the variable thickness of the Smackover Limestone suggests that salt flowed before deposition of the Bossier Formation (Kreitler and others, 1981).

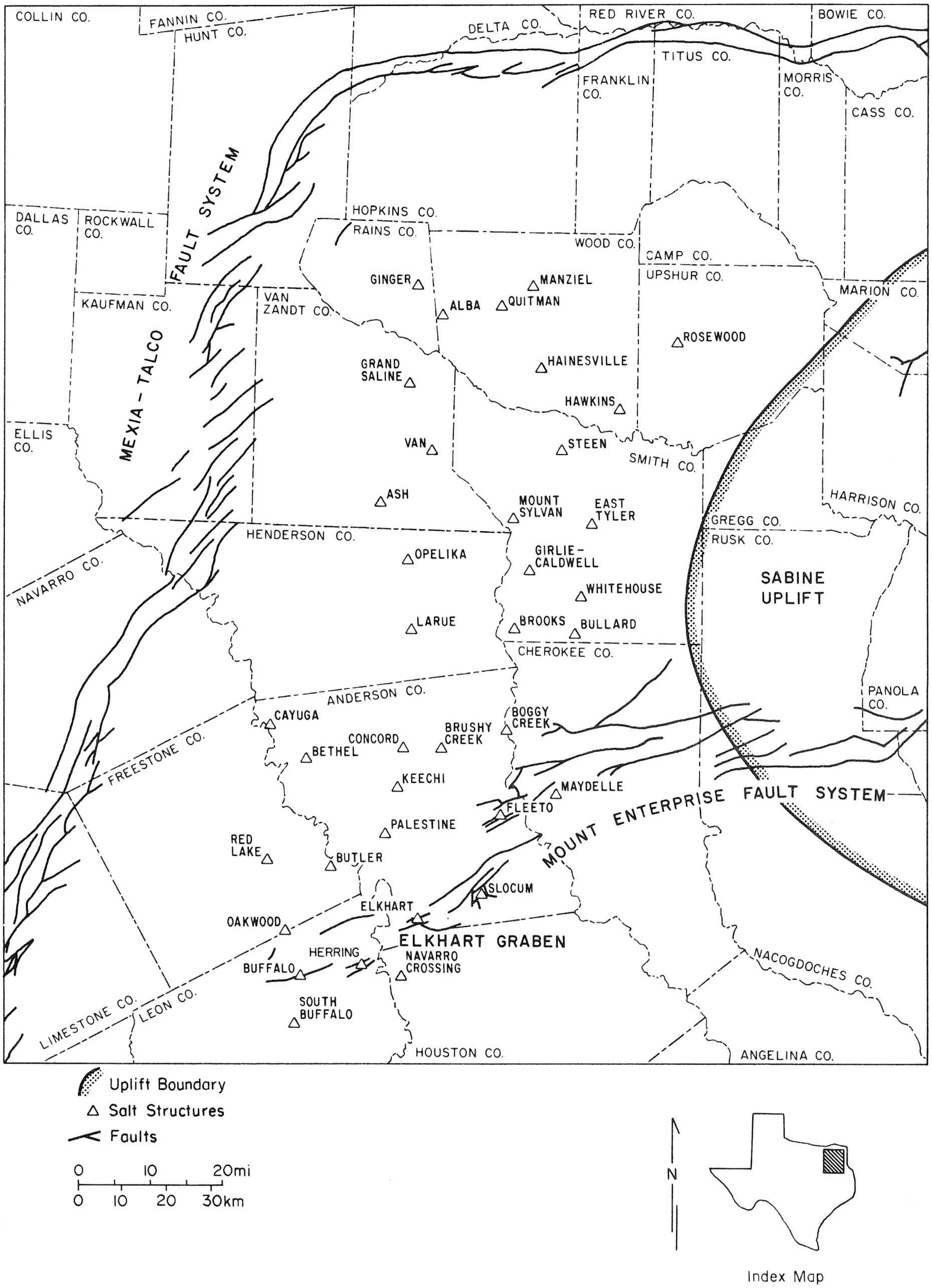

Figure 1. Major structural elements of the East Texas Basin.

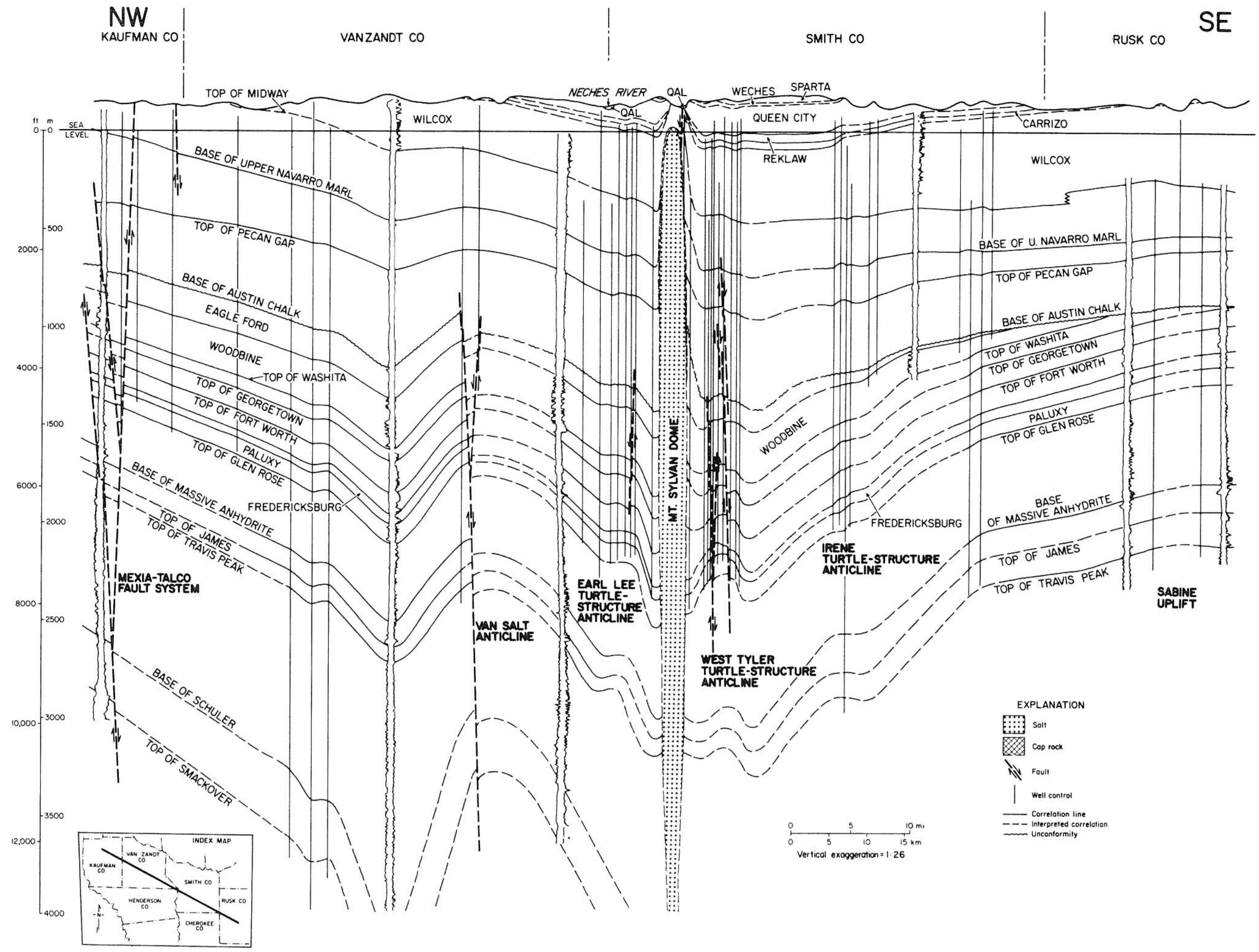

Figure 2. Northwest-southeast dip section across the East Texas Basin. Movement of salt deformed Jurassic, Cretaceous, and Tertiary strata and created diapirs, salt-cored anticlines, and turtle-structure anticlines. Salt diapirs such as Mount Sylvan Dome developed along the central axis of the basin.

One of the most prominent models describing salt-dome formation was developed by Trusheim (1960) from his study of the Zechstein Salt of northern Europe. Trusheim's model can be used to explain similar features in East Texas (fig. 7). Initially, salt flows laterally to form a nonpiercing pillow structure (fig. 7A, 7B). A rim syncline develops far from the dome crest in the area of salt withdrawal, and it fills by subsequent sedimentation. Strata thin over the growing structure. As the mother salt is depleted from the rim syncline, the syncline and the corresponding depocenter migrate domeward (fig. 7C and D). With the onset of diapirism, the salt pillow begins to deflate, and anticlines may form from the thickened sediments at the site of the original rim synclines (fig. 7D). Such anticlines are termed "turtle-structure anticlines" because they are typically broad and rounded. In the mature dome (fig. 7E), the rim syncline and pinch-out of the mother salt have migrated to the

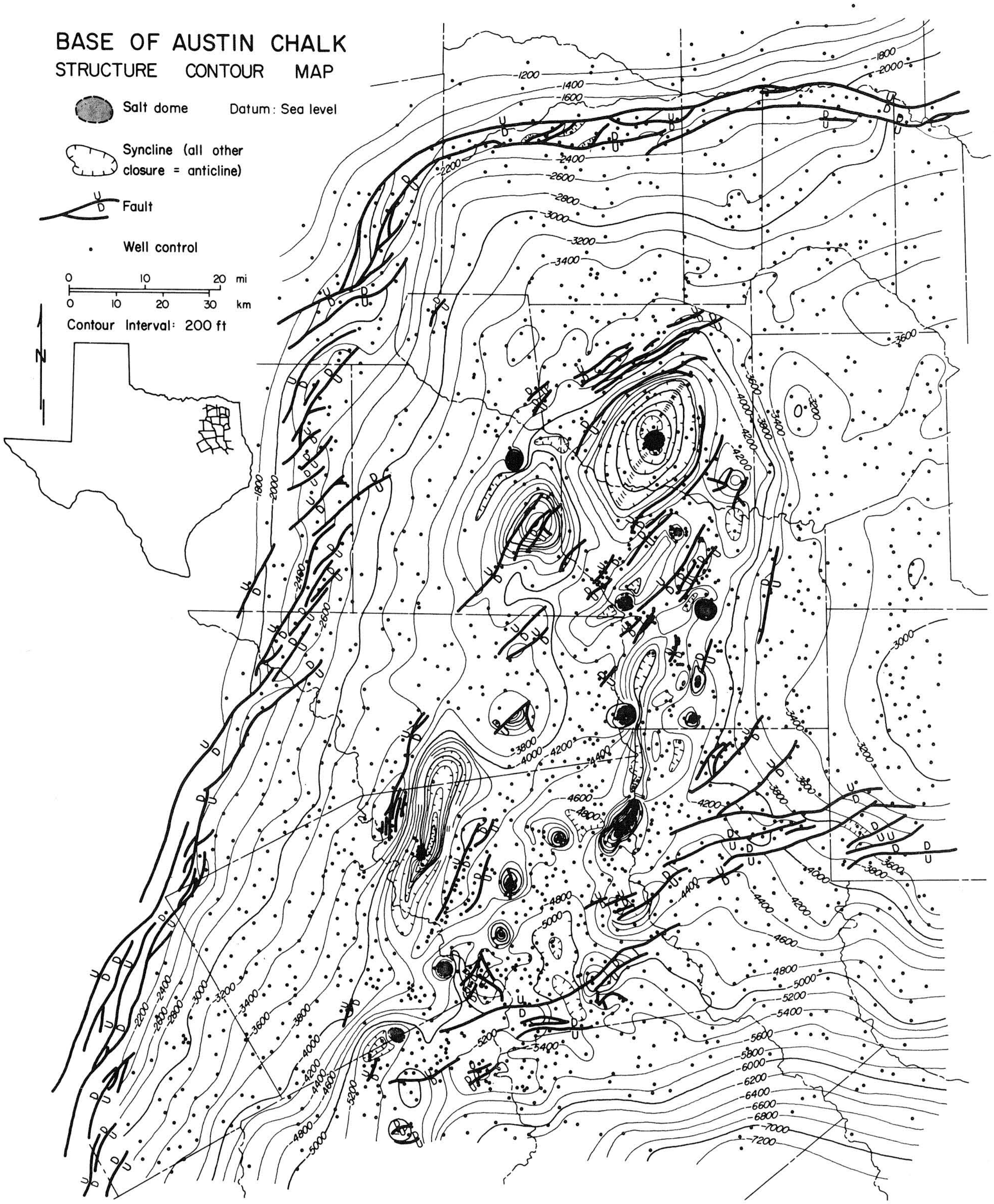

Figure 3. Structure map of the base of the Austin Chalk in the East Texas Basin showing deformation of strata caused by salt movement. Datum is sea level. Faults modified from Geomap Company (1980).

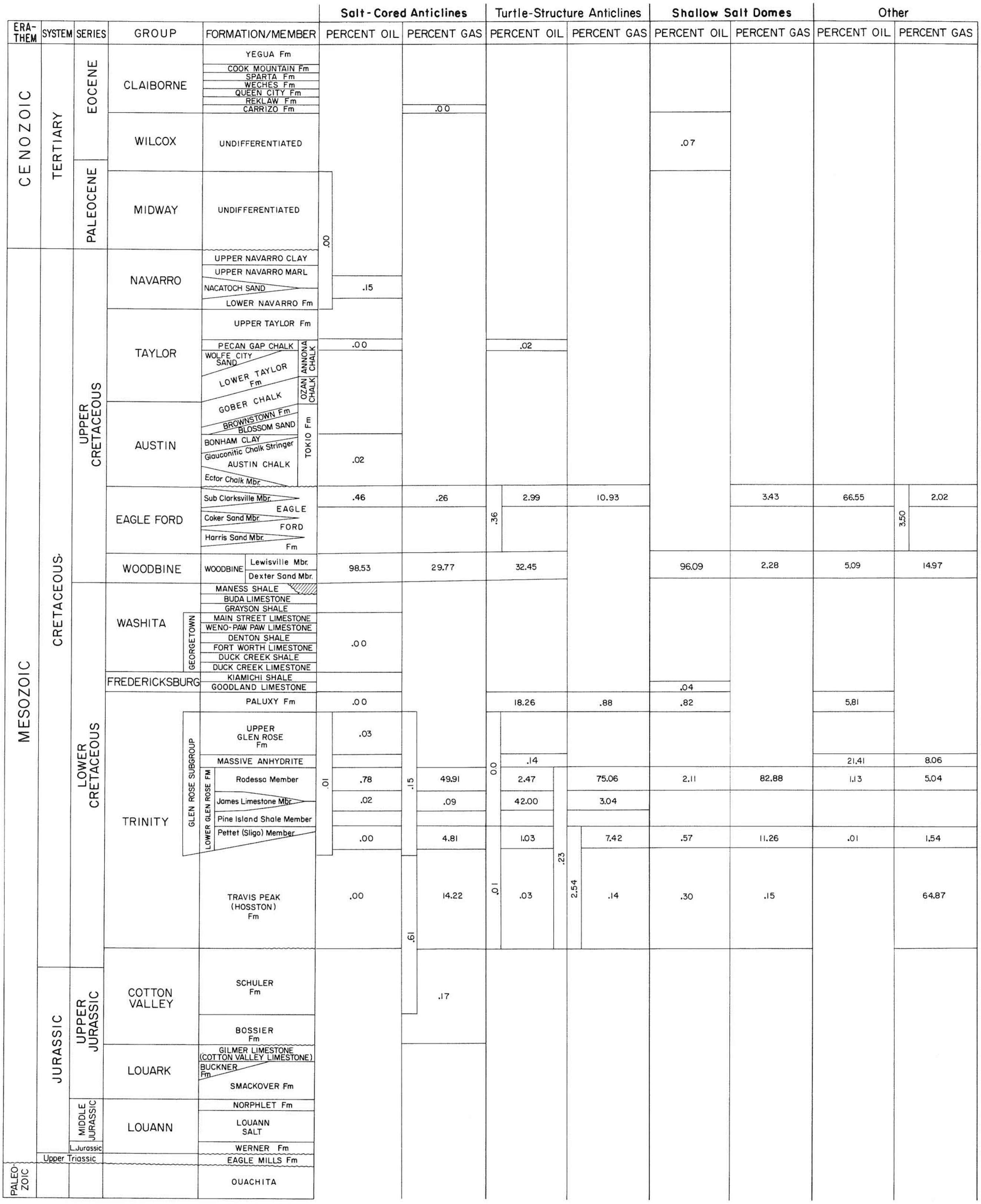

Figure 4. Stratigraphic succession and nomenclature in the East Texas Basin, with oil and gas production (percents) for salt-cored anticlines, turtle-structure anticlines, shallow salt domes, and other production in the central basin area. Production statistics from tables 1 through 4.

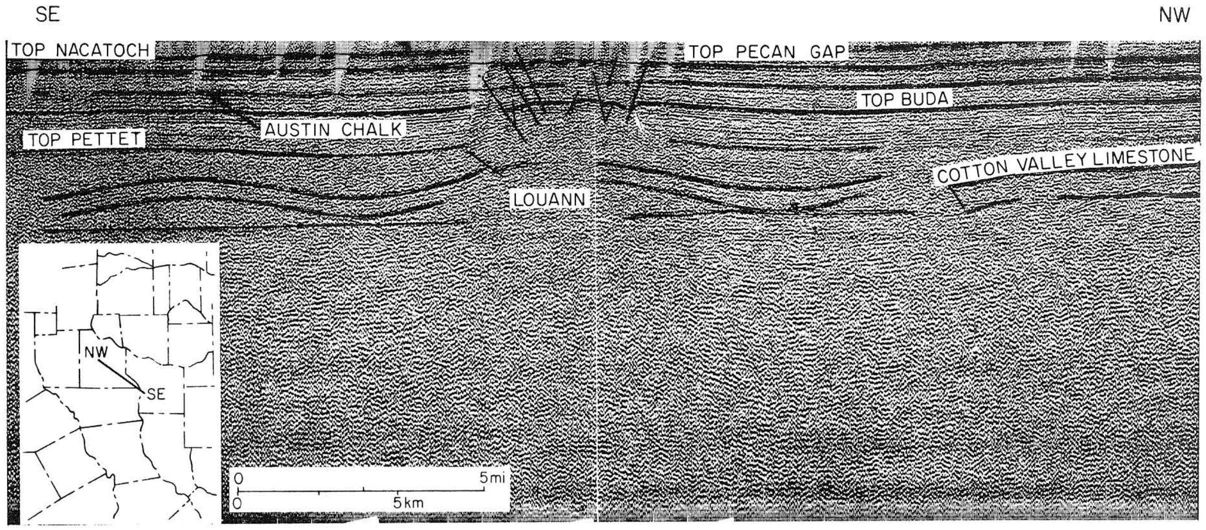

Figure 5. Southeast-northwest seismic section across the Van Dome area. Unmigrated seismic section courtesy of Teledyne Exploration Company. The crestal anticline and associated faults trap hydrocarbons over the deep salt pillow. Dome location shown in figure 1.

base of the dome so that further sediment loading should not cause additional dome growth.

The evolution of the salt and turtle-structure anticlines can be interpreted using well and seismic data. For example, sites of initial salt withdrawal north and south of Mount Sylvan Dome (fig. 6) are marked by thickened strata in the Pettet-Cotton Valley Limestone interval. These are now turtle-structure anticlines. The domeward thinning of Upper Jurassic-Lower Cretaceous strata north and south of Mount Sylvan Dome reflects an early pillow stage of the dome similar to that shown in figure 7C, whereas domeward-thickening sediments document the migration of the rim syncline to near the dome edge by the end of Buda deposition (similar to fig. 7D).

Because salt diapirs develop from salt pillows, domes display a wide range of evolutionary maturity. In the East Texas Basin, salt structures in which the top of salt is below 6,000 ft (1,829 m) lift the surrounding and overlying strata up into broad anticlines. Shallower structures normally are much smaller and more mature; their rim synclines typically have moved adjacent to the dome, and the dome may "pierce" the surrounding sediments. In this report, salt structures more than 6,000 ft (1,829 m) deep are classified as salt pillows, and the arched strata above them are called salt-cored anticlines. The shallow salt structures are called shallow salt domes, or diapirs.

Using well and residual gravity survey data, we delineated and mapped shallow salt domes, salt-cored anticlines, and turtle-structure anticlines within the central part of the East Texas Basin (fig. 8). First, shallow salt domes and anticlinal structures were identified with well data and a few seismic profiles. Salt-cored anticlines were then differentiated from turtle-structure anticlines by their negative

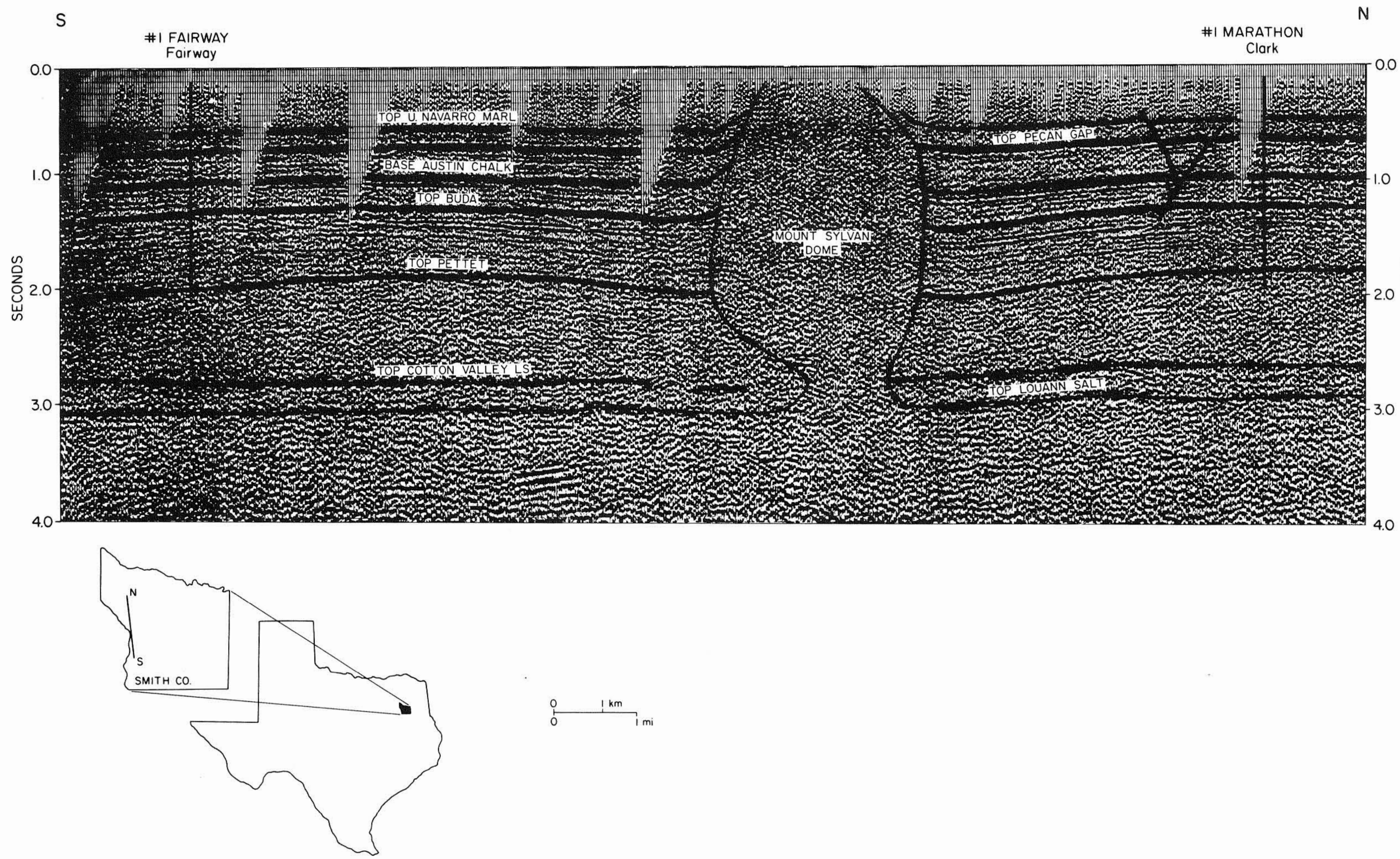

Figure 6. South-north seismic section across Mount Sylvan Dome. Pre-Pettet sediment thicks have formed turtle-structure anticlines on each side of the dome. Hydrocarbons are trapped in the faulted crest of the northern turtle-structure anticline in the Bud Lee and Lindale fields. Dome location shown in figure 1. Unmigrated seismic section courtesy of Teledyne Exploration Company.

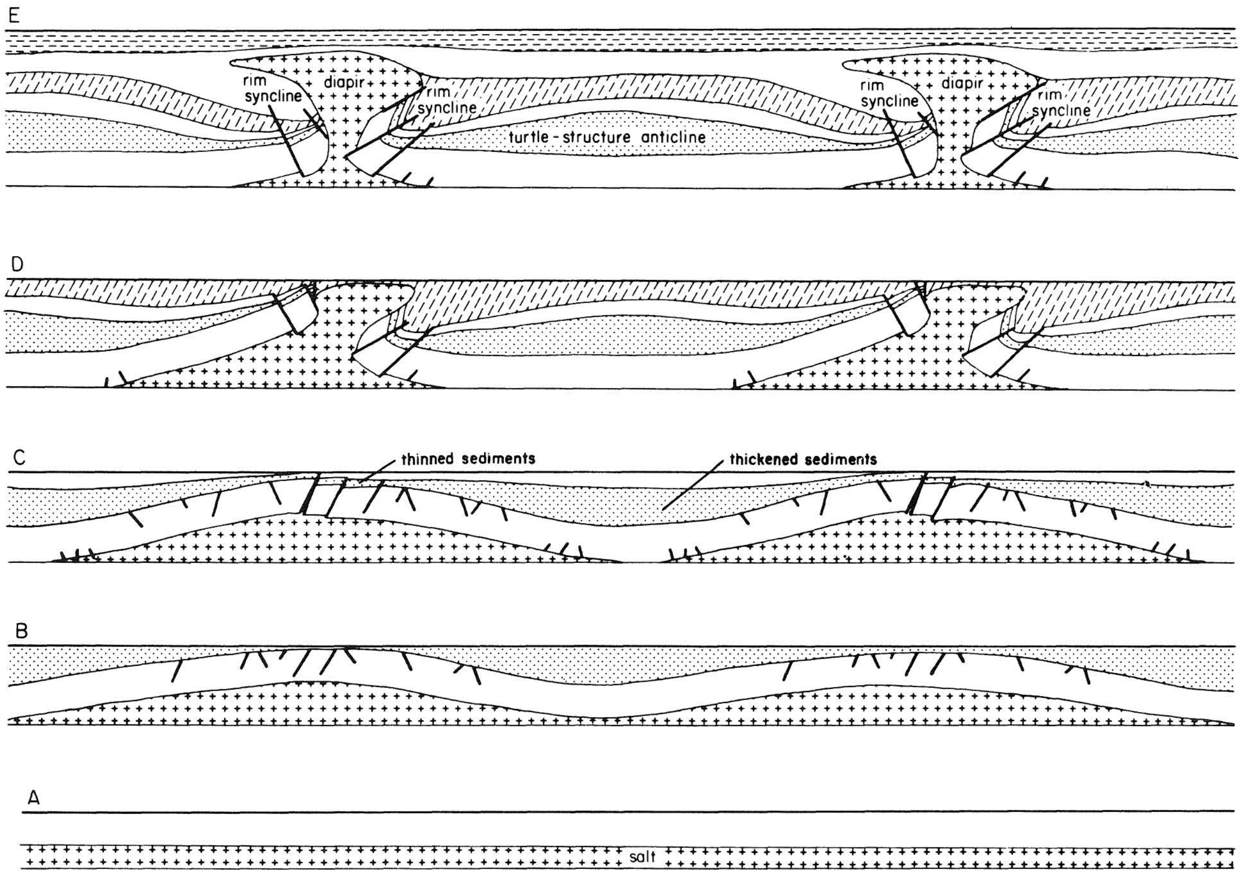

Figure 7. Model of evolution of salt domes and turtle-structure anticlines A through E (modified from Trusheim, 1960). A. Initial configuration. B, C. Salt pillow stage with distant rim syncline. D, E. Salt diapir stage. Rim syncline is adjacent to dome. Turtle-structure anticline is fully developed.

gravity anomalies; turtle-structure anticlines display relatively positive gravity values because they lack any underlying salt core. Well data verified that the Bossier-Pettet strata are relatively thick in most turtle-structure anticlines and that subjacent strata above the basement are uniformly thick. These relations disappear on the flanks of the basin where strata thin and where other types of structures exist.

Well-developed turtle structures are surrounded by shallow salt domes and salt-cored anticlines. Several of the turtle structures are elongated, narrow structures (fig. 8) that consist of small, aligned, discontinuous areas of closure. They are associated with systems of normal faults that trend along the length of the structure. The elongate pattern of these turtle structures suggests that some of the shallow salt domes and salt-cored anticlines developed from elongate salt ridges that were subsequently dissected by changes in direction of salt movement. Salt-cored anticlines are broad, subcircular structures that typically are also overlain by normal faults bounding crestal grabens.

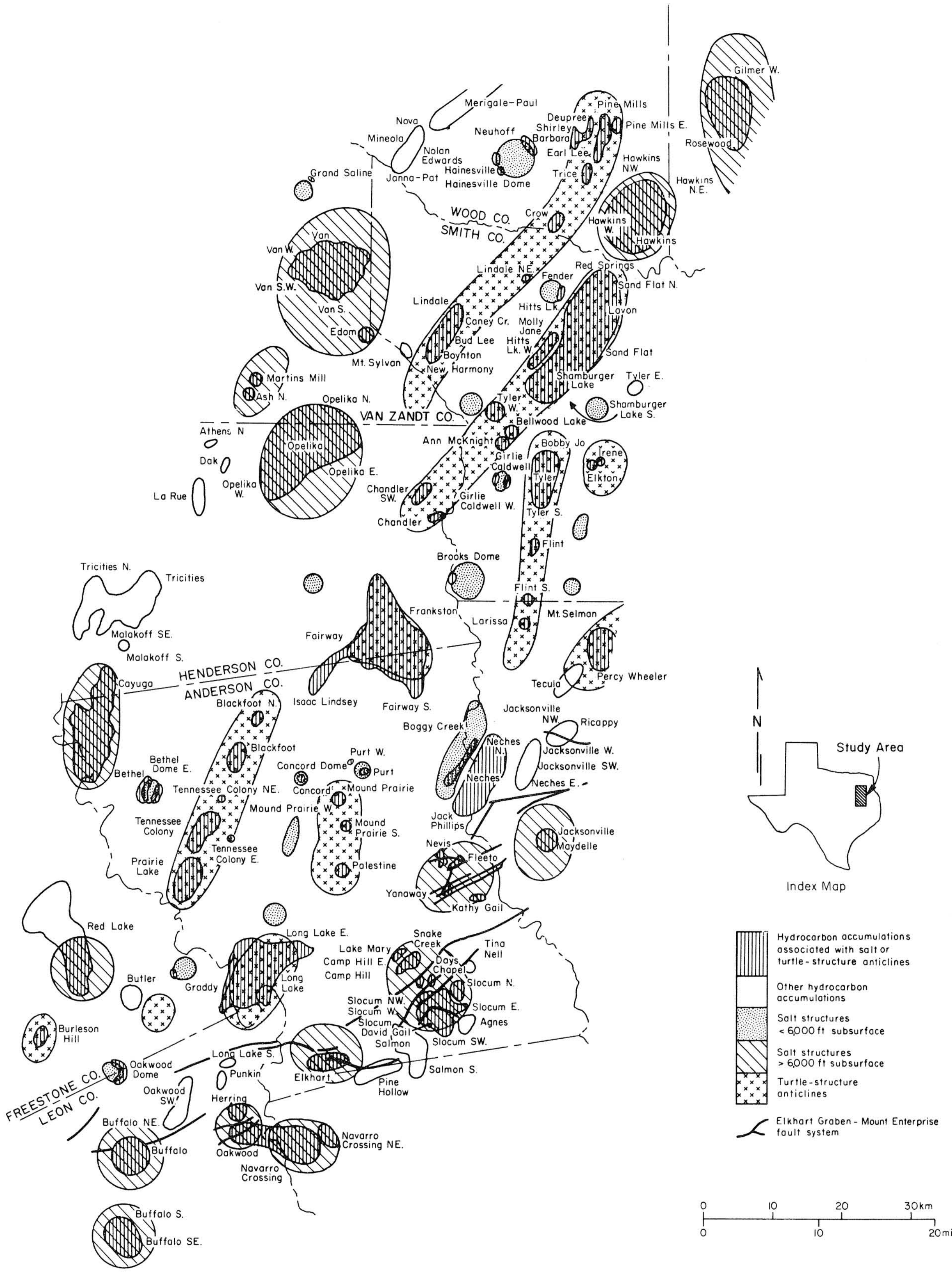

Figure 8. Shallow salt domes (salt structures <6,000 ft deep), salt-cored anticlines (salt structures >6,000 ft deep), turtle-structure anticlines, and hydrocarbon fields of the central East Texas Basin.

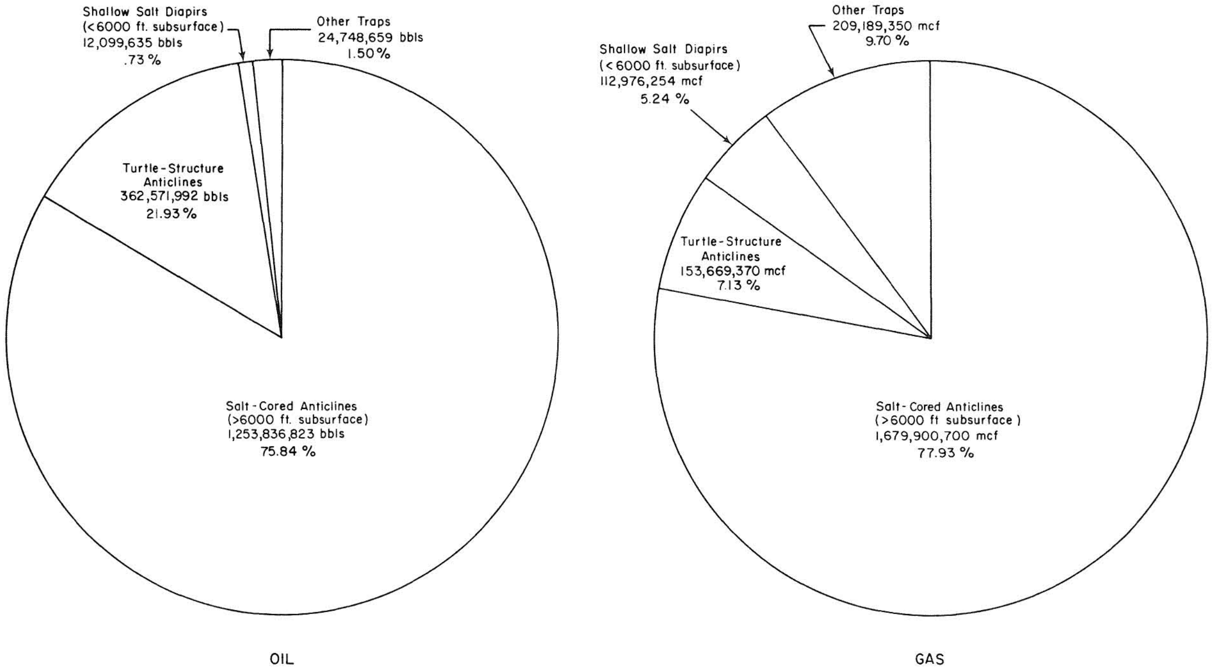

Figure 9. Relative hydrocarbon production associated with salt structures and turtle-structure anticlines in the central East Texas Basin. Production data are from the Railroad Commission of Texas (1978) and the International Oil Scouts Association (cumulative through 1978).

Flowage of salt created the present structural configuration and controlled hydrocarbon accumulation in the center of the basin. Woodbury and others (1980) showed that salt domes are traps for hydrocarbons wherever domes occur on the perimeter of the Gulf of Mexico and around the world. They found that in East Texas, North Louisiana, and Mississippi, 38 percent of the currently known hydrocarbons are associated with salt domes or turtle-structure anticlines. Our study focuses on the central part of the East Texas Basin, where salt movement was the dominant tectonic style and where salt-related structures can be easily identified. In the central basin, 98.5 percent of the oil and 90.3 percent of the gas produced before 1979 are related to salt-cored anticlines, shallow salt domes, or turtle-structure anticlines (fig. 9).

STRATIGRAPHIC OCCURRENCE OF HYDROCARBON RESERVOIRS

Sediments that fill the East Texas Basin comprise several alternating sequences of marine and nonmarine strata ranging in age from Late Triassic (?) through Eocene (fig. 4); Jurassic, Cretaceous, and Tertiary strata yield hydrocarbons. Production data through 1978 show some trends. Hydrocarbon production from Jurassic rocks in the central East Texas Basin was restricted to gas-bearing sandstones of the Cotton Valley Group.

Of the Lower Cretaceous sediments, limestones and dolomites of the Rodessa, James, and Pettet Members of the Lower Glen Rose Formation were the major oil-producing units through 1978; lesser amounts of oil were produced from the limestones of the Georgetown and Fredericksburg Groups and from sandstones of the Paluxy and Travis Peak Formations. Rodessa carbonates, along with some sand lenses, are the major gas reservoirs in the central part of the basin, accounting for about 49 percent of the total gas production through 1978. Significant amounts of gas have also been produced from Travis Peak (Hosston) sandstones.

Sandstones of the Eagle Ford and Woodbine Groups are the major Upper Cretaceous oil and gas reservoirs. Before 1979, the Woodbine sandstones alone produced over 82 percent of the oil derived from the central part of the basin, which does not include the prolific East Texas field. Lesser amounts of oil came from the Austin and Pecan Gap Chalks and from the Nacatoch Sand and the marl of the Navarro Group.

Minor amounts of oil were produced from Tertiary sandstones of the Wilcox Group over Boggy Creek Dome. Small amounts of gas were produced from sandstones of the Carrizo Formation over Slocum Dome.

STRUCTURAL ASSOCIATION OF HYDROCARBON RESERVOIRS

Salt-Cored Anticlines

Of the three structural features described (shallow salt domes, salt-cored anticlines, and turtle-structure anticlines), by far the most prolific oil and gas traps are the salt-cored anticlines. Fields associated with these structures have produced almost 76 percent of the oil and 78 percent of the gas in the central East Texas Basin (fig. 9).

Entrapment of hydrocarbons on salt-cored anticlines is controlled mainly by structural closure. Associated faults and crestal grabens provide secondary traps. These structural elements are visible on a seismic profile of Van Dome (fig. 5). Stratigraphic traps are also important in many fields associated with salt-cored anticlines.

Trapping mechanisms vary among fields. Simple closure traps hydrocarbons of the Woodbine Formation in the anticline at the Buffalo field (Smith, 1951). Cayuga, Hawkins, Herring, Northwest Slocum, Van, and Elkhart fields are trapped by closure against normal faults over or on the flanks of anticlines (Jones, 1951; Wendlandt, 1951a; Koonce and Battan, 1959; Ewing and Woodhams, 1963; Betts, 1951; Schoeneck, 1951). Other fields such as Camp Hill, North Slocum, and David Gail are structural/stratigraphic traps that combine the dip of strata on the flanks of salt-cored anticlines with stratigraphic or lithologic variations such as decreased porosity or the unconformity at the base of the Austin Chalk (Trueheart, 1951; Love and others, 1957). Hydrocarbon accumulations at Opelika and West Slocum fields (Love and others, 1957; Procter, 1951b) are controlled by anticlinal traps and faults combined with updip or lateral variations in permeability and porosity.

As a group, salt-cored anticlines produce hydrocarbons from strata of Late Jurassic to Eocene age (fig. 4). Because they uplift very thick stratigraphic sections, their crestal anticlines typically are multiple-zoned producers (table 1). For example, Van Dome produces hydrocarbons from many reservoirs ranging in age from Nacatoch to Cotton Valley. However, the minor production from Cotton Valley strata (0.17 percent of gas from salt-cored anticlines) and the absence of production from deeper units are unexpected, given their favorable structure. Many of the salt-cored anticlines have not been thoroughly explored at depth. If diagenesis has not limited porosity and permeability, future exploration will almost certainly uncover substantial, deep accumulations over salt-cored anticlines.

Turtle-Structure Anticlines

The second most prolific hydrocarbon production areas in the central East Texas Basin are the fields associated with turtle-structure anticlines. They have produced almost 22 percent of the oil and over 7 percent of the gas in the central basin (table 2; fig. 9). Two explanations account for the lower productivity of turtle structures relative to salt-cored anticlines. (1) Turtle-structure anticlines were formed after the salt-cored anticlines (fig. 7); so petroleum that migrated before development of the turtle structure moved toward the adjacent, growing, deep-salt structure. (2) A relatively thinner stratigraphic section exhibits the anticlinal closure over the turtle-structure anticlines. Turtle structures do not grow upward and are therefore buried by younger sediments. Furthermore, unlike a salt-cored anticline, a turtle-structure anticline does not involve all the strata down to the salt. Strata deposited after the salt, but before the salt mobilized and the rim syncline developed, are probably flat-lying (fig. 7E). If turtle structures developed primarily from Schuler-Travis Peak depositional centers, it is unlikely that deeper strata would be productive from structural traps related to salt migration. Production associated with turtle structures has in fact been restricted to Cretaceous strata ranging from the Travis Peak Formation to the Pecan Gap Chalk (fig. 4; table 2).

Table 1. Hydrocarbon production associated with salt-cored anticlines (>6,000 ft deep), central East Texas Basin.*

Field	Associated Salt Structures	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
Southeast Buffalo	South Buffalo	Woodbine	-	540,692
South Buffalo	South Buffalo	Woodbine	34,494	38,001,302
		Rodessa	-	7,509,685
		Pettet	-	522,781
Buffalo	Buffalo	Woodbine	2,652,926	125,401,462
Northeast Buffalo	Buffalo	Woodbine	75,549	967,399
Oakwood	Herring	Woodbine	486,216	48,446,859
Herring	Herring	Nacatoch	424	-
		Pecan Gap	2,935	-
		Sub-Clarksville	-	194,373
		Woodbine	-	3,848,168
Navarro Crossing	Navarro Crossing	Sub-Clarksville	72,555	-
		Woodbine	5,383,617	-
		Glen Rose	98,199	2,580,537
		Pettet	-	1,242,060
Northeast Navarro Crossing	Navarro Crossing	Sub-Clarksville	100,372	-
Elkhart	Elkhart	Woodbine	11,617	-
		Pettet	-	36,307,868
Snake Creek	Slocum	Woodbine	204,478	-
Lake Mary	Slocum	Woodbine	991,745	8,762,613
Days Chapel	Slocum	Woodbine	4,684	443,303
East Camp Hill	Slocum	Woodbine	-	11,320
Camp Hill	Slocum	Carrizo	-	38,766
		Sub-Clarksville	1,856,544	-
		Woodbine	-	9,388
North Slocum	Slocum	Sub-Clarksville	1,613,928	-
East Slocum	Slocum	Sub-Clarksville	2,865	-
		Woodbine	5,594	-
West Slocum	Slocum	Woodbine	4,070,170	187,271
Southwest Slocum	Slocum	Woodbine	117,207	-
Slocum	Slocum	Woodbine	8,217,170	-
David Gail	Slocum	Sub-Clarksville	1,766,712	-
Northwest Slocum	Slocum	Woodbine	6,330,079	14,262,871
Kathy Gail	Fleeto	Woodbine	606	-
Fleeto	Fleeto	Sub-Clarksville	153,448	29,145
Nevis	Fleeto	Woodbine	29,131	-
		Rodessa	-	4,866,847
Yanaway	Fleeto	Navarro	336	-
Maydelle	Maydelle	Woodbine	-	115,198
Jacksonville	Maydelle	Rodessa	-	-
Red Lake (1/2 field total)	Red Lake	Sub-Clarksville	17,754	4,192,456

*Production statistics are cumulative through 1978 and are from the Railroad Commission of Texas (1978) and the International Oil Scouts Association (1978).

Table 1. (continued)

Field	Associated Salt Structures	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
		Woodbine	-	1,342,693
		Rodessa	-	4,602,821
Cayuga	Cayuga	Woodbine	60,499,574	243,143,627
		Georgetown	1,065	-
		Rodessa	587,833	229,559,674
		Pettet	-	11,920,911
		Cotton Valley (Schuler-Bossier)	-	119,612
Opelika	Opelika	Rodessa	8,735,603	460,826,658
		James	-	66,234
		Pettet	-	29,421,162
		Travis Peak	-	238,157,726
		Cotton Valley (Schuler)	-	2,141,304
East Opelika	Opelika	Rodessa	5,773	-
North Opelika	Opelika	Pettet	-	775,542
West Opelika	Opelika	Rodessa	42,147	-
Martins Mill	Ash	Rodessa	-	-
North Ash	Ash	Rodessa	-	37,419
Van	Van	Nacatoch	1,842,432	-
		Austin Chalk	243,768	-
		Sub-Clarksville	132,639	-
		Woodbine	469,106,007	13,158
		Rodessa	68,123	99,252
South Van	Van	Sub-Clarksville	12,699	-
Southwest Van	Van	Woodbine	1,022,648	-
West Van	Van	Woodbine	4,351	-
		Paluxy	4,628	-
		Upper Glen Rose	323,481	-
		Rodessa	201,261	1,076,855
		James	270,379	1,514,421
		Pettet	36,075	593,086
		Travis Peak	18,625	727,939
Edom	Van	Cotton Valley	-	16,415
Northeast Hawkins	Hawkins	Sub-Clarksville	1,545	-
Northwest Hawkins	Hawkins	Rodessa	66,751	-
West Hawkins	Hawkins	Rodessa	126,207	-
Hawkins	Hawkins	Woodbine	676,152,919	14,564,111
		Paluxy	28,935	-
		Rodessa	-	129,931,792
Rosewood	Rosewood	Travis Peak-Schuler	-	10,198,742
West Gilmer	Rosewood	Cotton Valley (Schuler)	-	567,182
		TOTALS	1,253,836,823	1,679,900,700

Table 2. Hydrocarbon production associated with turtle-structure anticlines, central East Texas Basin.*

Field	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
Burleson Hill	Rodessa	-	2,442,372
	Pettet	-	211,725
	Travis Peak	-	217,162
Long Lake	Pecan Gap	57,813	-
	Sub-Clarksville	225,637	231,131
	Woodbine	33,747,946	-
	Rodessa	-	4,295,146
	Pettet	-	7,705,739
East Long Lake	Woodbine	3,801,804	-
Prairie Lake	Rodessa	129,581	33,000,325
Tennessee Colony	Rodessa	3,939,911	7,550,076
	Pettet	2,276,296	255,186
East Tennessee Colony	Rodessa	-	1,472,778
Northeast Tennessee Colony	Travis Peak	38,868	-
Blackfoot	Rodessa, Pettet, Travis Peak	839,600	-
North Blackfoot	Rodessa	-	-
Palestine	Rodessa	-	177,366
	Pettet	-	3,222,034
	Travis Peak	10,808	-
Mound Prairie	Rodessa	19,434	-
	Pettet, Travis Peak	25,971	3,901,838
West Mound Prairie	Travis Peak	51,265	-
South Mound Prairie	Rodessa	-	20,533
Isaac Lindsey	James	-	607,956
	Pettet	92,571	-
Fairway	Massive Anhydrite	502,365	-
	Rodessa	1,292,902	-
	James	151,804,354	238,259
	Pettet	247,269	-
South Fairway	Pettet	929,739	-
Frankston	James	471,788	3,823,575
Jack Phillips	Sub-Clarksville	1,466	-
Neches	Sub-Clarksville	3,961,032	-
	Woodbine	72,440,934	-

*Production statistics are cumulative through 1978 and are from the Railroad Commission of Texas (1978) and the International Oil Scouts Association (1978).

Table 2. (continued)

Field	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
North Neches	Sub-Clarksville	159,392	-
Percy Wheeler	Travis Peak	-	-
Mount Selman	Sub-Clarksville	-	16,559,803
Larissa	Pettet	152,968	-
South Flint	Travis Peak	10,974	-
Flint	Paluxy	-	1,348,645
South Tyler	Paluxy	1,233,360	-
	Rodessa	60,002	9,395,757
Tyler	Paluxy	2,165,018	-
	Rodessa	-	19,464,777
Bobby Jo	Paluxy	30,674	-
Elkton	Paluxy	-	-
Irene	Paluxy	11,963	-
Chandler	Rodessa	128,181	2,675,407
Southwest Chandler	Rodessa	11,327	-
	Pettet	37,806	-
Ann McKnight	Paluxy	35,843	-
Bellwood Lake	Paluxy	223,147	-
West Tyler	Paluxy	20,989	-
South Shamburger Lake	Paluxy	104,930	-
Shamburger Lake	Paluxy	23,895,299	-
Sand Flat	Paluxy	23,971,008	-
Lavon	Glen Rose	9,170	-
	Rodessa	10,385	78,335
North Sand Flat	Rodessa	212,923	4,502,364
Red Springs	Rodessa	807,992	22,526,705
Hitts Lake	Paluxy	9,254,459	-
	Rodessa	88,300	-
West Hitts Lake	Paluxy	123,379	-
Molly Jane	Paluxy	2,491,647	-
New Harmony	Paluxy	144,310	-
Boynton	Paluxy	299,368	-
Bud Lee	Paluxy	691,793	-
Caney Creek	Travis Peak	-	-
Lindale	Rodessa	-	7,744,384
Northeast Lindale	Paluxy	11,682	-
Crow	Rodessa	260,529	-
Trice	Woodbine	733,416	-
Earl Lee	Woodbine	2,066,057	-
Shirley Barbara	Sub-Clarksville	1,281,255	-
	Eagle Ford	484,632	-
Deupree	Woodbine	95,741	-
	Sub-Clarksville	259,486	-

Table 2. (continued)

Field	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
Pine Mills	Sub-Clarksville	4,721,942	-
	Eagle Ford	829,327	-
	Woodbine	6,372,625	-
	Paluxy	1,497,760	-
East Pine Mills	Sub-Clarksville	243,718	-
	Woodbine	417,861	-
	TOTALS	362,571,992	153,669,378

The mechanism for trapping hydrocarbons in turtle-structure anticlines is similar to that of salt-cored anticlines. The arching of strata is the primary trap; associated normal faults also contribute to entrapment in most fields. Stratigraphic and lithologic factors such as variations in porosity and permeability may also be important complementary trapping mechanisms. Fields associated with turtle-structure anticlines are typically traps within either discontinuous areas of closure or structural noses.

Fields with structural traps include Bud Lee and Lindale fields north of Mount Sylvan Dome (fig. 6), where the faulted crest of the anticline traps hydrocarbons (Loetterle, 1951; Krause, 1951). Shamburger Lake, Sand Flat, North Sand Flat, Molly Jane, Northeast Lindale, and Pine Mills fields also are structural traps on turtle-structure anticlines (Mabra and Gardner, 1958; Wendlandt, 1951b; Ewing and Woodhams, 1963; Moore, 1951b).

Many other fields combine structure with lithologic variations. The large Neches field southeast of Boggy Creek Dome (fig. 10) produces hydrocarbons from Woodbine sandstones that exhibit lateral variations in porosity because of bentonite content and lenticularity of sand bodies (Cawthon and Slater, 1964). Sub-Clarksville production at Neches field is also controlled by porosity variations (Hunt and O'Connor, 1954). The turtle-structure anticline located southeast of Bethel Dome (fig. 11) provides a trap for Rodessa and Pettet carbonate reservoirs at the Tennessee Colony field, where normal faults and variations in porosity and permeability have exerted a secondary control on petroleum accumulation (Ely, 1951). A similar trapping mechanism occurs in the turtle structure east of Steen Dome (fig. 12) at the Red Springs field, which also produces from the Rodessa Member of the Lower Glen Rose Formation (Phillips, 1951).

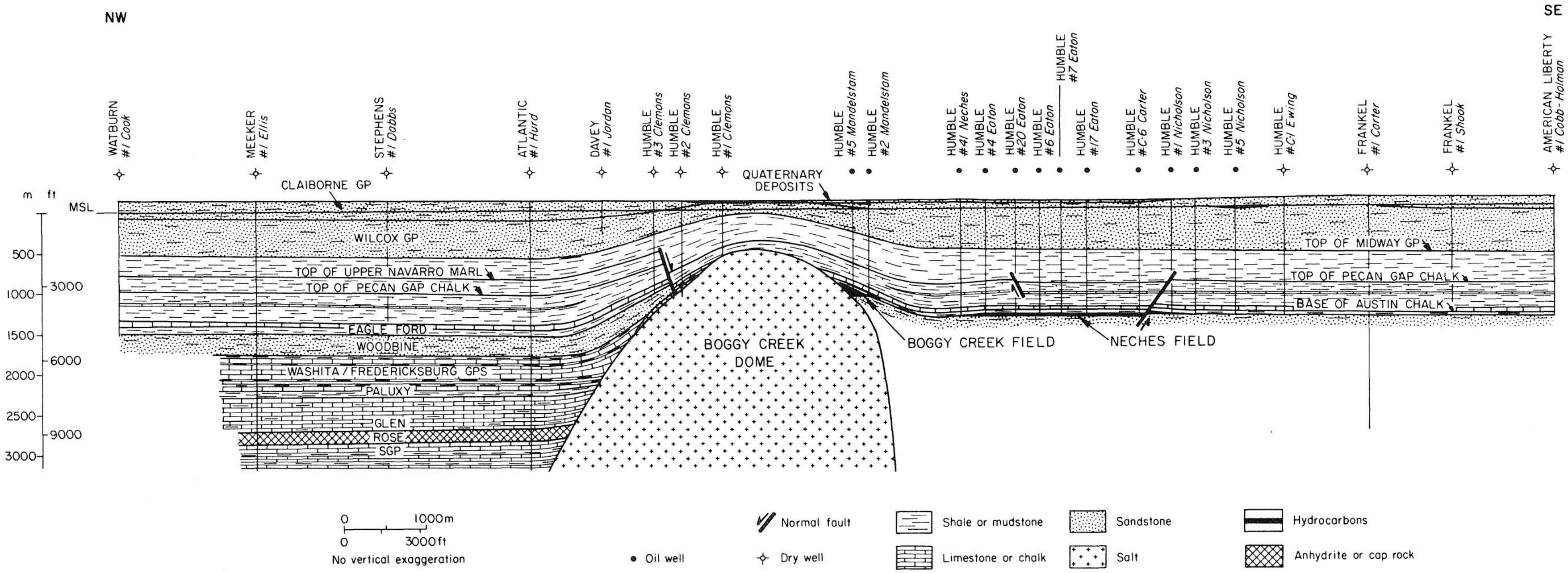

Figure 10. Northwest-southeast structure section across Boggy Creek Dome, Anderson and Cherokee Counties, Texas. The Boggy Creek field produces from strata on the flank of the dome; the Neches field produces from the turtle-structure anticline southeast of the dome. Locations shown in figure 1.

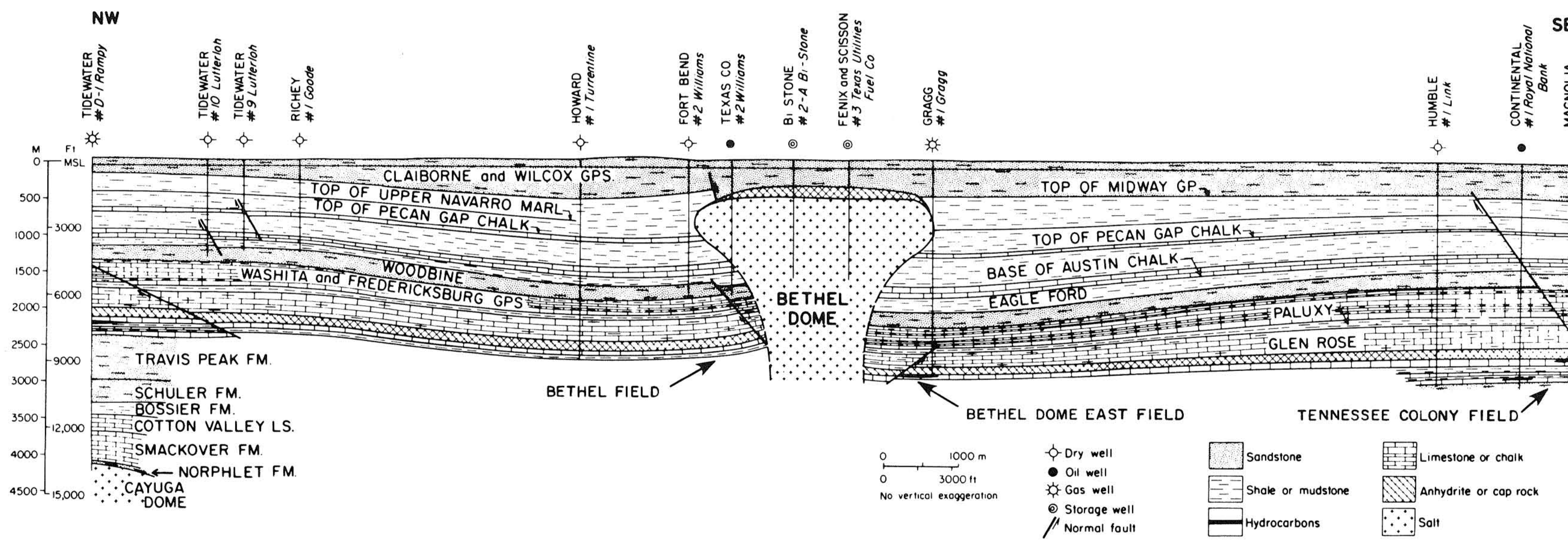

Figure 11. Northwest-southeast structure section across Bethel Dome, Anderson County, Texas, with a turtle-structure anticline southeast of the dome. Dome location shown in figure 1.

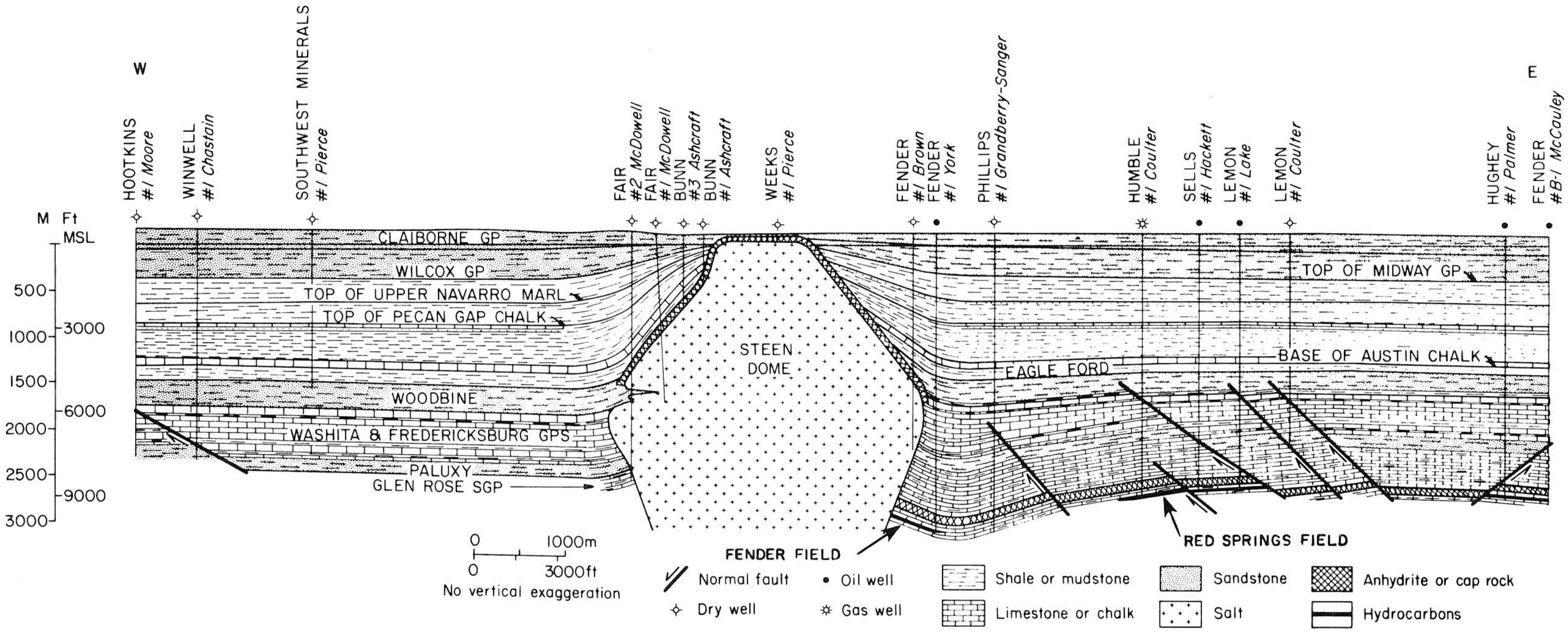

Figure 12. West-east structure section across Steen Dome, Smith County, Texas; a turtle-structure anticline is east of the dome. Dome location shown in figure 1. Data for the Ashcroft wells were supplied by J. R. Bunn.

Variations of porosity within carbonate sediments also supplement structural traps at Blackfoot, Fairway, and Larissa fields (Branson, 1951; Burford, 1951; Perkins, 1964).

Facies relationships have combined with structure to create conditions that favor large accumulations of hydrocarbons associated with turtle-structure anticlines. In one well-documented example, topographic relief over a developing turtle-structure anticline contributed to deposition of the oil-producing facies. Forty-two percent of the oil associated with turtle structures (fig. 9; table 2) has been produced at Fairway field from reef and reef-associated facies of the James Limestone, Lower Glen Rose Formation. Terriere (1976) used facies analysis and isopach maps to show that the structure was active when the reef was deposited. The flanks of the turtle-structure anticline collapsed when salt withdrew into nearby salt diapirs. The resultant topographic relief favored growth of the reef. Many turtle-structure anticlines that have been explored only at shallow depths, such as in the Neches field area, appear also to be promising at greater depths. Closure should increase for strata down to the sedimentary core of the anticlines.

Shallow Salt Domes

In spite of early discoveries of oil fields trapped at salt domes farther south in the Gulf Coast Basin, hydrocarbon production associated with the relatively shallow salt domes in East Texas has been minimal. Most fields that have been discovered near these diapirs are relatively small (table 3). Shallow salt domes account for less than 1 percent of the oil and about 5 percent of the gas production in the central basin area (fig. 9). The small size of fields might be expected because the domeward migration of the rim syncline with increased domal maturity diminished the area of structural closure on the dome, so structural closure became small and localized. Isopach data indicate that rim synclines of most of the shallow East Texas diapirs migrated to the dome edge before or during Early Cretaceous time. If large amounts of oil and gas had accumulated over the early salt pillow phase of these diapirs, then the hydrocarbons must have leaked along faults associated with dome growth or during uplift and erosion of the reservoirs over the dome crest.

Woodbury and others (1980) attributed the low productivity of diapirs in the East Texas Basin compared with Lower Gulf Coastal Plain domes to different histories caused by possibly thinner mother salt and thinner strata above the salt in the East Texas Basin. Many East Texas Basin diapirs extruded salt during much of their history, and are adjacent to their rim synclines. Consequently, their drainage area for hydrocarbon migration was limited. Most Gulf Coastal Plain domes that have extruded

Table 3. Hydrocarbon production associated with shallow salt domes (<6,000 ft deep), central East Texas Basin.*

Field	Associated Salt Dome	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
Graddy	Butler	Woodbine	763	-
Fender	Steen	Rodessa	175,232	-
Oakwood Dome	Oakwood	Woodbine	2,115,715	3,568
Brooks Dome	Brooks	Paluxy	1,199	-
Boggy Creek	Boggy Creek	Wilcox	8,666	-
		Woodbine	6,738,911	292,718
Bethel	Bethel	Woodbine	1,107,513	2,274,819
		Rodessa	-	58,210,379
		Pettet	-	8,157,345
East Bethel Dome	Bethel	Rodessa	45,740	35,424,064
		Pettet	69,106	4,564,377
Purt	Brushy Creek	Woodbine	134,110	-
West Purt	Brushy Creek	Rodessa	33,905	-
Grand Saline (1 well)	Grand Saline	Paluxy	80,609	-
Hainesville	Hainesville	Sub-Clarksville	-	3,882,866
Hainesville Dome	Hainesville	Travis Peak	36,405	-
Neuhoff	Hainesville	Woodbine	53,336	-
Concord	Concord	Woodbine	16,527	-
Concord Dome	Concord	Woodbine	1,459,126	-
Girlie Caldwell	Girlie Caldwell	Goodland	5,467	-
West Girlie Caldwell	Girlie Caldwell	Paluxy	17,305	-
		Travis Peak	-	166,118
		TOTALS	12,099,635	112,976,254

*Production statistics are cumulative through 1978 and are from the Railroad Commission of Texas (1978) and the International Oil Scouts Association (1978).

salt have not exhausted their salt supply, so the surrounding strata remain uplifted and thinned. Coupled with the thick stratigraphic section in the Gulf Coastal Plain, this configuration favored migration of hydrocarbons to the domes there.

Four types of hydrocarbon traps are associated with shallow salt domes in East Texas: (1) traps in upturned strata abutting the salt plug, (2) traps beneath overhangs, (3) unconformities, and (4) traps against faults downthrown either away from or toward the dome.

Several East Texas diapirs have traps in which reservoirs terminate against the flank of the dome (type 1). For example, the Boggy Creek field, the oldest and most productive field associated with a shallow salt dome in East Texas, produces hydrocarbons from Woodbine sandstone reservoirs that abut the southeast flank of the dome (fig. 10). Similar traps exist at Brushy Creek Dome, where the Purt field produces hydrocarbons from Woodbine sandstones that terminate against the dome along with some crestal faults over the dome (fig. 13). A small oil field, Graddy, was discovered in Woodbine sandstones abutting Butler Dome (fig. 14); however, production was abandoned after only 763 barrels of oil were pumped.

Hydrocarbons are trapped beneath the overhangs of several of the shallow East Texas domes (type 2). At the Oakwood Dome field, oil has been produced from Woodbine sandstones beneath the eastern overhang of the dome (fig. 15). Oil produced from the Rodessa Member of the Lower Glen Rose Formation at the Fender field on the east flank of Steen Dome is also trapped by an overhang (fig. 12). At Hainesville Dome, oil and gas are trapped in sandstones of the Woodbine, Paluxy, and Travis Peak Formations at Hainesville and Neuhoff fields from beneath an overhang; there also is some entrapment beneath a local unconformity (type 3) (fig. 16). Production from beneath an overhang at Bethel Dome is from porous Rodessa and Pettet carbonates and from Woodbine sandstones (fig. 11). These reservoir strata were deposited during the pillow stage of dome development (Kreitler and others, 1980), which may explain the relatively high porosities of Rodessa and Pettet carbonates near the dome. Paluxy sandstones beneath the overhang at Brooks Dome produced insignificant amounts of oil, 1,199 barrels, before drilling ceased (fig. 17).

Faults (type 4) appear to control entrapment of oil in sandstones of the Paluxy Formation on the northeast flank of Grand Saline Dome (fig. 18). Some shallow, dry domes, such as Keechi, Bullard, and Whitehouse, have been drilled only to shallow depths. Other diapirs produce hydrocarbons from strata as deep as Travis Peak (table 3); so perhaps other shallow domes warrant deeper exploration.

Other Fields

The remaining 1.5 percent of oil and 9.7 percent of gas in the central basin (fig. 9) are produced from fields that are not closely associated with well-defined turtle structures, salt-cored anticlines, or shallow salt domes (fig. 8; table 4). Some of these fields are associated with structures that may be related to salt migration but that cannot be classified because of inconsistent or limited data. Tri-Cities, La Rue, and Nolan Edward are examples of fields on such anticlinal structures (Howard, 1951;

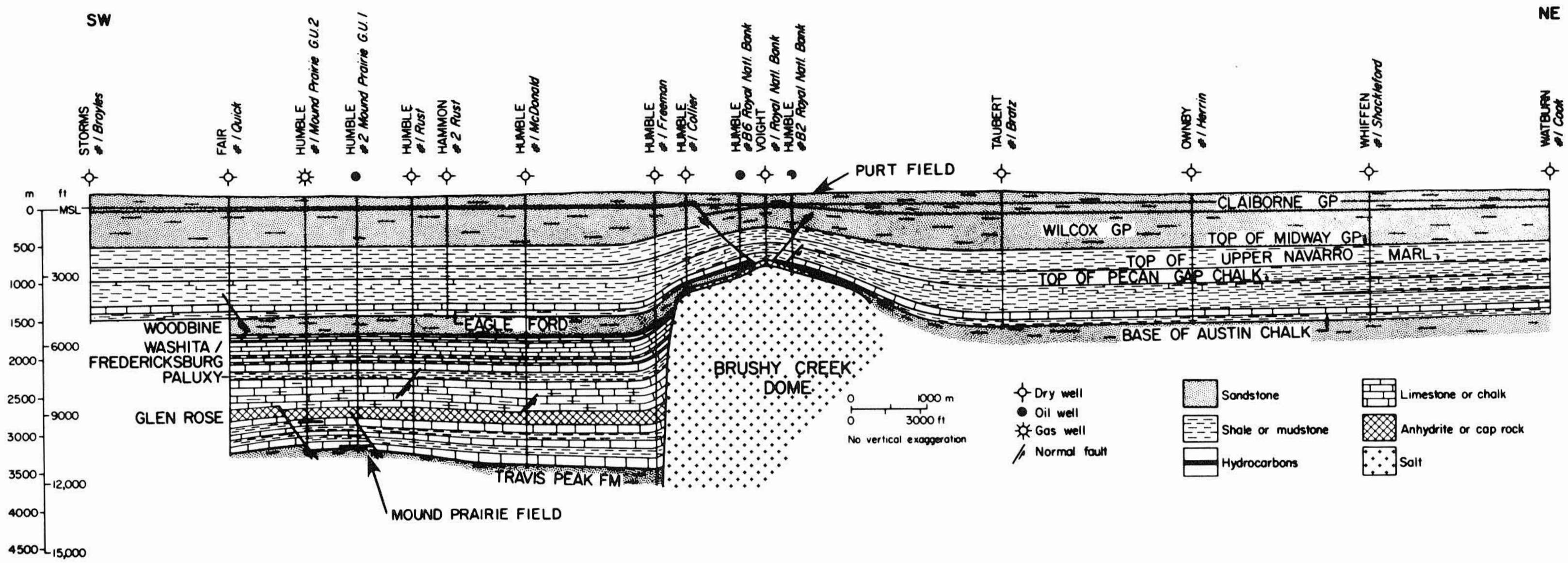

Figure 13. Southwest-northeast structure section across Brushy Creek Dome, Anderson County, Texas. Dome location shown in figure 1.

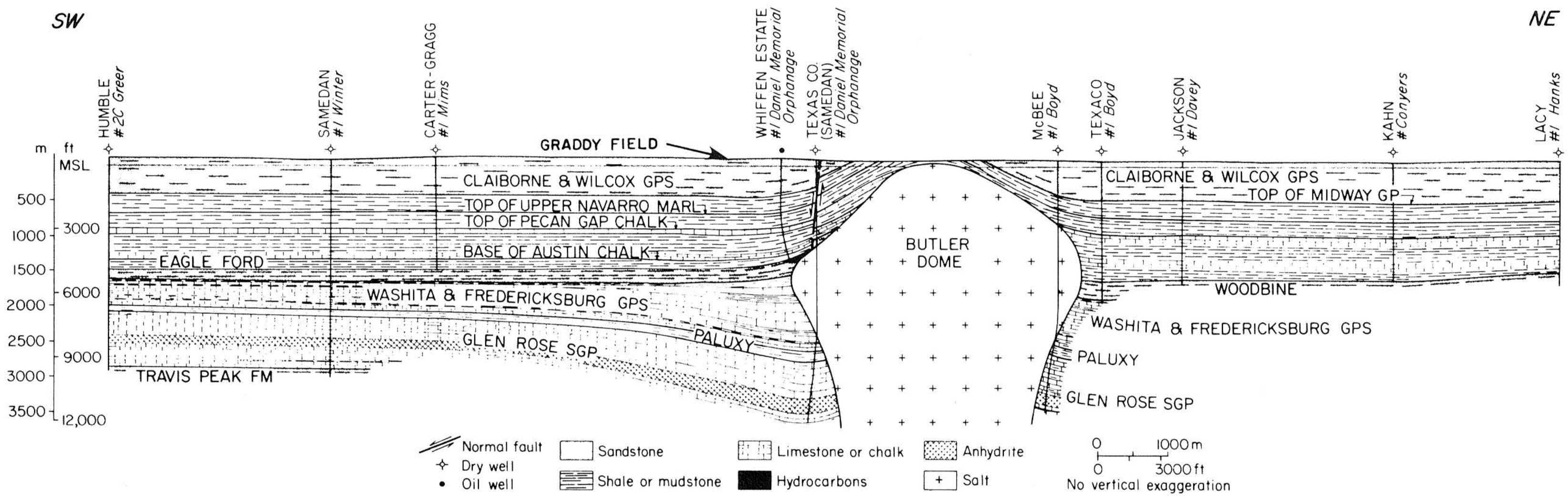

Figure 14. Southwest-northeast structure section across Butler Dome, Freestone County, Texas. Dome location shown in figure 1.

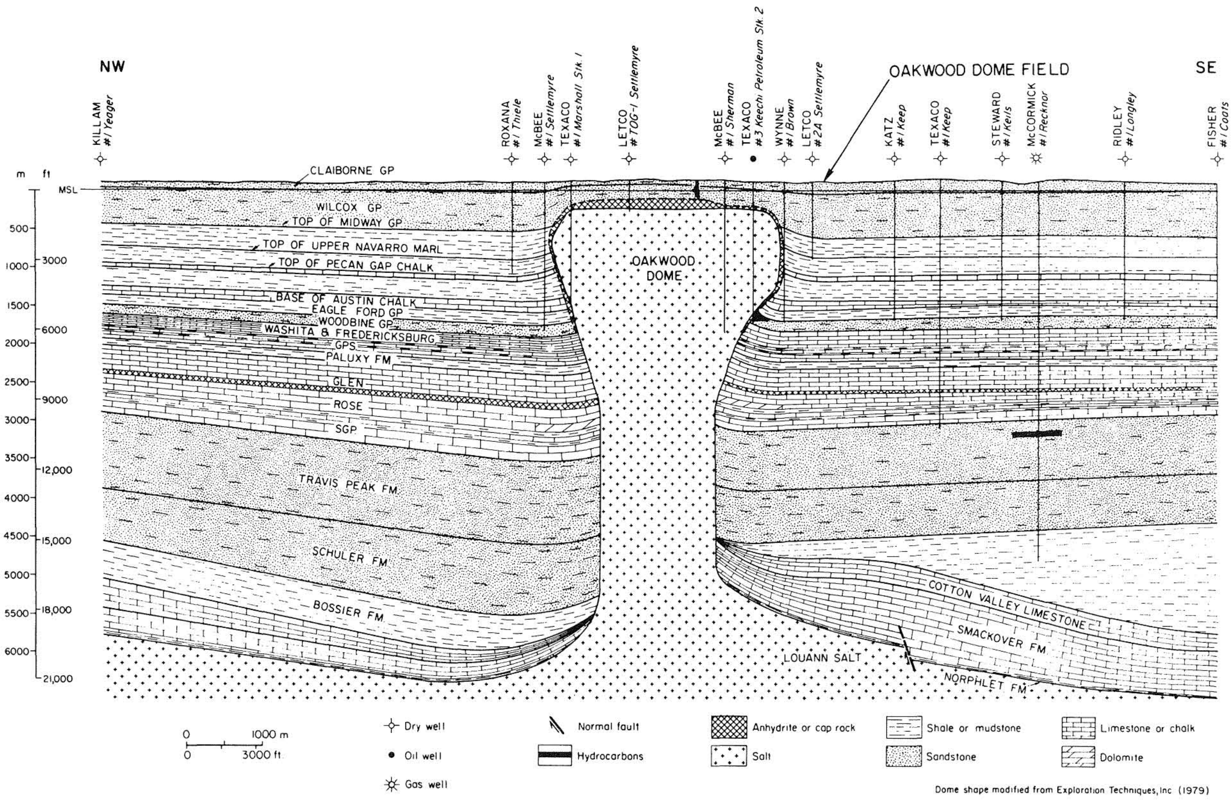

Figure 15. Northwest-southeast structure section across Oakwood Dome, Freestone and Leon Counties, Texas. Geology based partially on seismic profile. Dome location shown in figure 1.

Procter, 1951a; Moore, 1951a). Other fields in this category, such as South Salmon and East Neches fields (Ewing and Woodhams, 1963; Fox and others, 1965), produce from stratigraphic traps.

Some facies-controlled stratigraphic traps remote from the salt structures and turtle structures may be related to salt migration. Sands may have been deposited preferentially in the rim syncline of a dome. In work related to the present study (Seni and Fogg, in preparation), Seni showed that Wilcox sands are relatively thick in the rim syncline around Oakwood Salt Dome. Seni also showed that sands were similarly concentrated in rim synclines around East Texas salt domes during Early Cretaceous (Paluxy) time (Kreitler and others, 1981). Because the rim syncline traces migration of salt through time from the site of original mobilization to a location adjacent to a salt diapir, it may have accumulated sands anywhere between the adjacent turtle-structure anticline (location of initial salt mobilization) to the youngest rim syncline. The location of these thick sands and possible hydrocarbon accumulations might be predicted by studying migration of the rim syncline through time.

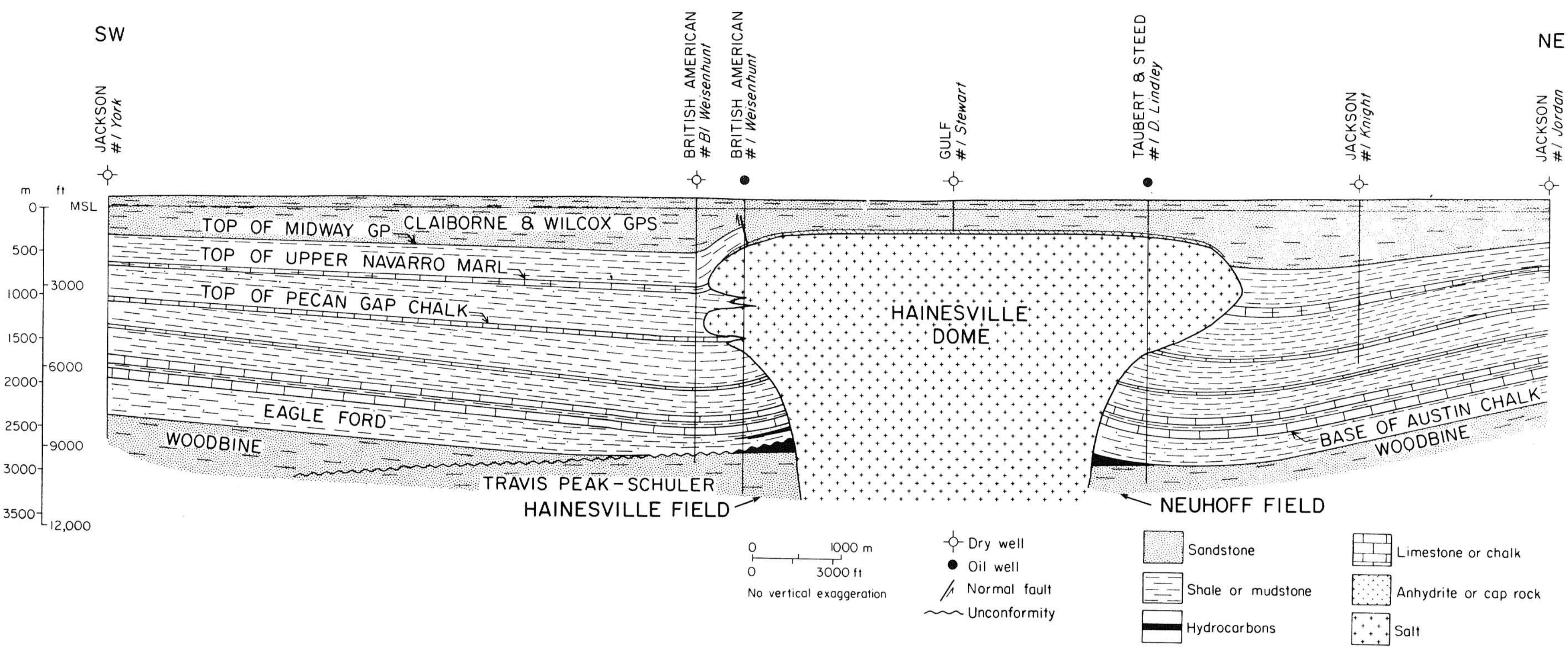

Figure 16. Southwest-northeast structure section across Hainesville Dome, Wood County, Texas. Dome location shown in figure 1.

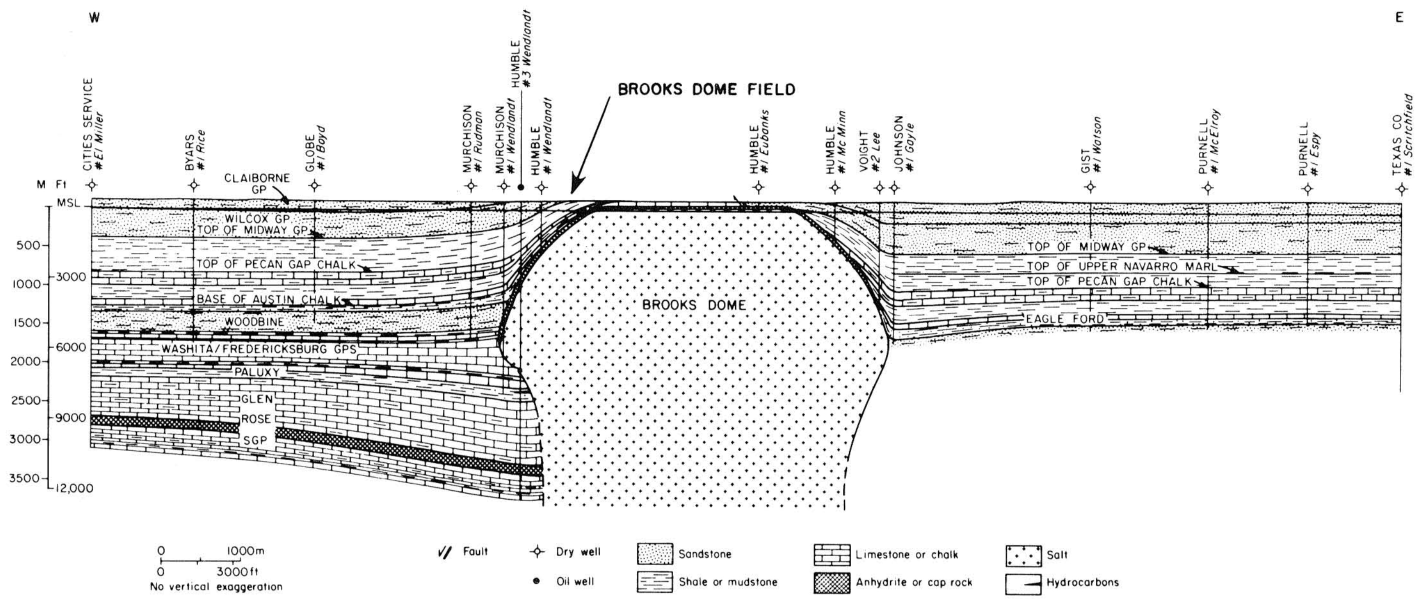

Figure 17. West-east structure section across Brooks Dome, Smith County, Texas. Dome location shown in figure 1.

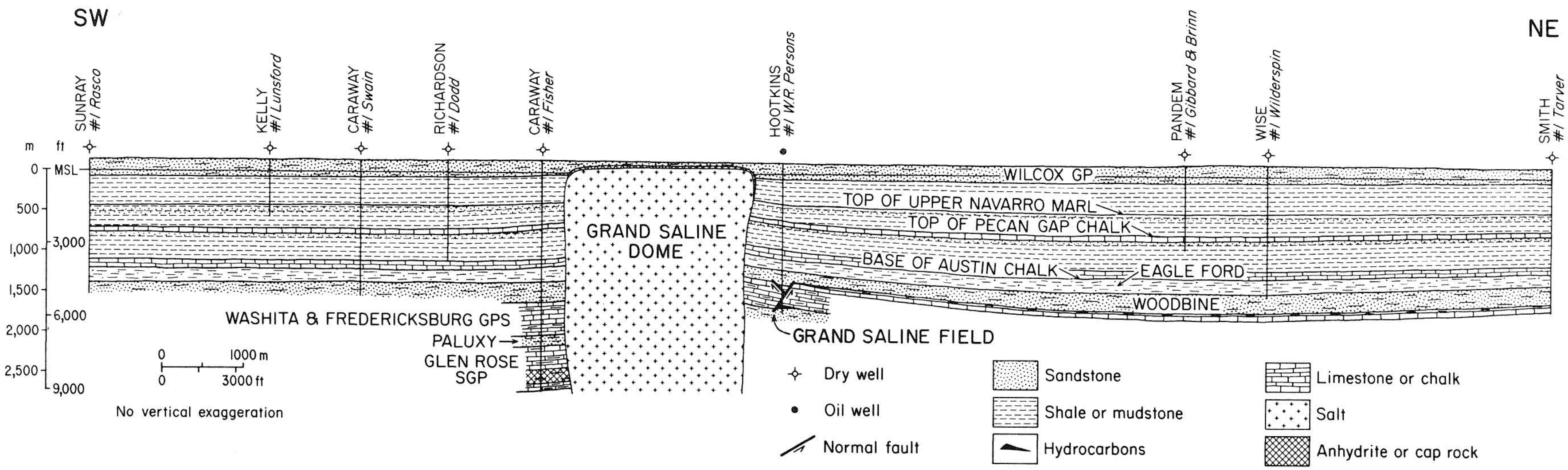

Figure 18. Southwest-northeast structure section across Grand Saline Dome, Van Zandt County, Texas. Dome location shown in figure 1.

Table 4. Hydrocarbon production not associated with salt structures or turtle-structure anticlines, central East Texas Basin.*

Field	Reservoir	Crude Oil Production, bbl	Gross Gas Production, mcf
Southwest Oakwood	Woodbine	-	26,171,830
Punkin	Woodbine	-	-
South Long Lake	Sub-Clarksville	-	28,627
	Woodbine	-	297,582
Pine Hollow	Woodbine	36,752	-
South Salmon	Sub-Clarksville	42,637	-
Salmon	Sub-Clarksville	3,101,794	-
Agnes	Woodbine	-	156,113
Tina Nell	Woodbine	54,482	-
Butler	Woodbine	-	1,777,867
East Neches	Woodbine	580,283	-
Southwest Jacksonville	Woodbine	-	1,349
West Jacksonville	Woodbine	587,165	594,078
Northwest Jacksonville	Woodbine	-	981,902
Ricappy	Rodessa	-	61,099
	Pettet	-	362,024
Tecula	Sub-Clarksville	-	-
	Eagle Ford	-	7,324,701
	Rodessa	-	3,858,039
	Pettet	-	1,575,241
East Tyler	Paluxy	141,364	-
Tri-Cities	Massive Anhydrite	2,134,535	16,858,948
	Rodessa	-	1,024,711
	Pettet	-	1,276,562
	Travis Peak	-	130,624,704
North Tri-Cities	Rodessa	-	1,004,384
South Malakoff	Massive Anhydrite	1,845,903	-
	Pettet	1,802	-
	Travis Peak	-	4,014,339
Southeast Malakoff	Massive Anhydrite	45,393	-
La Rue	Massive Anhydrite	1,274,613	-
	Travis Peak	-	1,057,280
Dak	Rodessa	270,075	-
North Athens	Rodessa	10,108	-
Mount Sylvan	Paluxy	1,295,660	-
Janna-Pat		-	-
Nolan Edwards	Sub-Clarksville	2,294,182	-
Mineola	Sub-Clarksville	2,834	-
Nova	Sub-Clarksville	77,087	-
Merigale-Paul	Sub-Clarksville	10,934,236	-
Red Lake (1/2 field total)	Sub-Clarksville	17,754	4,192,456
	Woodbine	-	1,342,693
	Rodessa	-	4,602,821
	TOTALS	24,748,659	209,189,350

*Production statistics are cumulative through 1978 and are from the Railroad Commission of Texas (1978) and the International Oil Scouts Association (1978).

IMPLICATIONS FOR NUCLEAR WASTE ISOLATION IN SALT DOMES

Salt domes in the East Texas Basin have been evaluated as potential repositories for isolation of nuclear waste. One criterion for a suitable site is that there be no natural resources associated with the dome that might attract economic interest and lead to future breaching of the repository (Kreitler, 1978). Relatively substantial hydrocarbon accumulations have not been discovered at the shallow salt domes in the East Texas Basin. However, salt domes there may attract future interest. Historically, drilling activity over East Texas salt domes was motivated by successful exploration of domes in the Gulf Coast Basin. Salt domes could attract future drilling activity that might lead to breaching of a repository.

SUMMARY

Almost 98 percent of the oil produced in the central part of the East Texas Basin has come from anticlines formed by deep-seated salt masses and from turtle-structure anticlines (fig. 9). The high production from the salt-cored anticlines may be accounted for by (1) their large area of closure, (2) their formation before development of the turtle-structure anticlines, and (3) uplift and closure of a greater thickness of strata relative to turtle-structure anticlines.

Anticlines formed by deep salt pillows also are the most prolific gas producers in the central part of the basin (fig. 9). The shallow salt domes produce relatively small amounts of oil and gas because of their small drainage areas. If significant amounts of hydrocarbons did accumulate over these domes during the early pillow stages, most of this accumulation either has been lost along faults and during erosion or has yet to be discovered.

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