Southwest Texas Heavy Oil Province – A Review*

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Summary

The Southwest Texas Heavy Oil Province is the largest heavy oil resource in the Gulf Coast region, perhaps the largest in the United States. It extends for 4300 km^2, at depths of 0-3200 ft (0-1000 m). The province includes asphalt hosted in early to middle Campanian carbonate grainstone shoals (Anacacho Formation), and asphalt and heavy oil hosted in late Campanian - Maastrichtian sandstone (San Miguel, Olmos, and Escondido formations).

Anacacho asphalt has been used for paving material since 1888, with two active quarries. The published figure of 550 million barrels in-place (from 23,400 acres, 94.7 km^2 in the Anacacho Limestone) underestimates the likely resource (due to oxidation of natural outcrops). Stratigraphy indicates that the entire 147-sq.mi. (380-km^2) outcrop area contains asphalt.

The San Miguel 'D' Sandstone (2100 ft, 640 m in depth; 256 mi^2, 663 km^2) was targeted for heavy oil research in the early 1980s, when Exxon and Conoco produced 417,673 barrels from pilot plants. This oil is extraordinarily heavy (10° to -2°) and viscous. Published work indicates 3.2 billion barrels in-place -- the second-largest identified reservoir in the United States; but newer studies suggest 7-10 billion barrels in-place. Many other Upper Cretaceous sandstones within the province also contain heavy oil, with local dry gas accumulations.

The province lies on the northeastern margin of the Maverick Basin, which was rapidly subsiding during the Late Cretaceous, and the southwest flank of the coeval San Marcos Arch. Unconformities in the Maastrichtian and the Paleocene provided regional traps to long-distance migration.

The province-wide resource is poorly known, it but may exceed ten billion barrels in-place. This is a tempting target for advanced technology, despite daunting obstacles; it deserves another look.

Setting and Stratigraphy

The Southwest Texas Heavy Oil Province is located on the northern flank of the Rio Grande Embayment (Maverick Basin) in South Texas (Figure 1). Heavy oil and asphalt have been found in Campanian carbonates (Anacacho) and Campanian and Maastrichtian sandstones (San Miguel, Olmos and Escondido; Figure 2). Both types of occurrences are located on and southwest of the Frio River Hingeline, a Late Cretaceous hingeline between the rapidly subsiding Maverick Basin / Mexican foredeep to the southwest and the slowly subsiding and unconformity-riddled San Marcos Arch to the northeast (Ewing, 1987, 2003).

Anacacho Formation

Shoal-water carbonate banks formed along the north edge of the subsiding Maverick Basin during early and middle Campanian, overlying the regionally uniform Austin Formation. The Anacacho carbonates are dominated by algal plates, and also contain a varied shelly fauna. The Anacacho shoals are intimately associated with the Uvalde volcanism and regional uplift. Shoals ring individual volcanic centers and coalesce into regional sheets. A major shoal was built on the west and southwest side of the ‘Uvalde Salient’, a 120-mi (20-km) diameter uplifted area associated with phonolitic magmas (Ewing, 2004). This shoal extends westward 30 mi (50 km) into Kinney County, forming the south-dipping cuesta known as the Anacacho Mountains. In the subsurface, this shoal extends about 12-15 miles (20 km) south, where it passes into a thinner basinal calcareous shale with over 500 ft (150 m) of depositional relief on the shoal (see Figures 7- 9). This relief decreases to 200 ft (62 m) or so eastward into Zavala County, where the Anacacho shoals break-up to rim the numerous volcanic centers.

Porous, asphalt-filled carbonate has been quarried for cold-mix paving material for over a century at the east end of the Ancacho Mountains, in and around a number of submarine to subaerial volcanoes (Figure 3; see Ewing, 2004).

San Miguel Formation

A series of four to six wave-dominated deltas mark the first influx of sand into the Maverick Basin (Weise, 1980; Figure 4). Most sandstones are inferred to have had a northwesterly source, although some in Frio County were sourced from the north. A complex sequence stratigraphy, with strong transgressions after each sand pulse, has largely eliminated the coeval nonmarine facies, at least in Texas.

The lowest sandstone in the heavy oil province, locally called the Basal San Miguel or San Miguel ‘D’, is the host for the most extensive and significant heavy-oil accumulation. Porosity over 25% in this unit suggests early migration and entrapment of hydrocarbons. A ‘Basal San Miguel’ unit with similar stratigraphic position (labeled ‘D’) is exposed near Eagle Pass and on the Chittim Anticline.

Olmos Formation

Overlying the San Miguel is the coal-bearing, nonmarine to marginal marine Olmos Formation (Tyler and Ambrose, 1986; Figure 5). The contact between the two is not clean, and may be gradational; a traditional top is picked on the highest marine flooding surface in the San Miguel. Coal is extensive and abundant in western Maverick County and in adjacent Coahuila, where numerous large strip mines are located. The Olmos sandstones contain heavy oil in various wells, but regional-scale reserves have not yet been demonstrated.

A regional unconformity forms the top of the Olmos Formation in the northern Maverick Basin, as noted by Tyler and Ambrose (1986). I call this the 'Bigfoot Unconformity', as it truncates an Olmos sandstone to form the large Bigfoot oil field in Frio County. The Olmos and upper San Miguel sandy section is truncated by this unconformity, and it does not crop out on the north flank of the Maverick Basin. The unconformity decreases in magnitude to the south and is merely diastemic in the Eagle Pass area and in southern Zavala County.

Escondido Formation

The first deposits overlying the Bigfoot Unconformity are marly shales of the '*Lituola'* zone, probably correlative with the Corsicana of the East Texas Basin. Overlying this is the relatively thick Escondido Formation. This formation contains a thick set of resistive sandstones in the heavy oil province, perhaps forming a shoreline or wave-dominated delta sequence (see Pisasale, 1980). Asphaltic sandstones of the Escondido Formation crop out along the Nueces River in southern Uvalde and northernmost Zavala Counties (Figure 6).

Unconformities

Three unconformities mark the heavy-oil-bearing section in the province (Figure 7). The lowest is the sub-Pecan Gap unconformity, which marks the erosion of the upper Austin and lower Taylor (Anacacho) strata across the San Marcos Arch. The middle unconformity is the significant Bigfoot Unconformity, described above, which separates the middle Maastrichtian Escondido from the lower Maastrichtian Olmos strata. This unconformity cuts down-section to the north and may be an ultimate trap for the Anacacho heavy oil. The upper unconformity lies at the base of the Indio Formation of the Wilcox Group (Paleocene) in the Uvalde area; it appears to bound the top of the heavy-oil system.

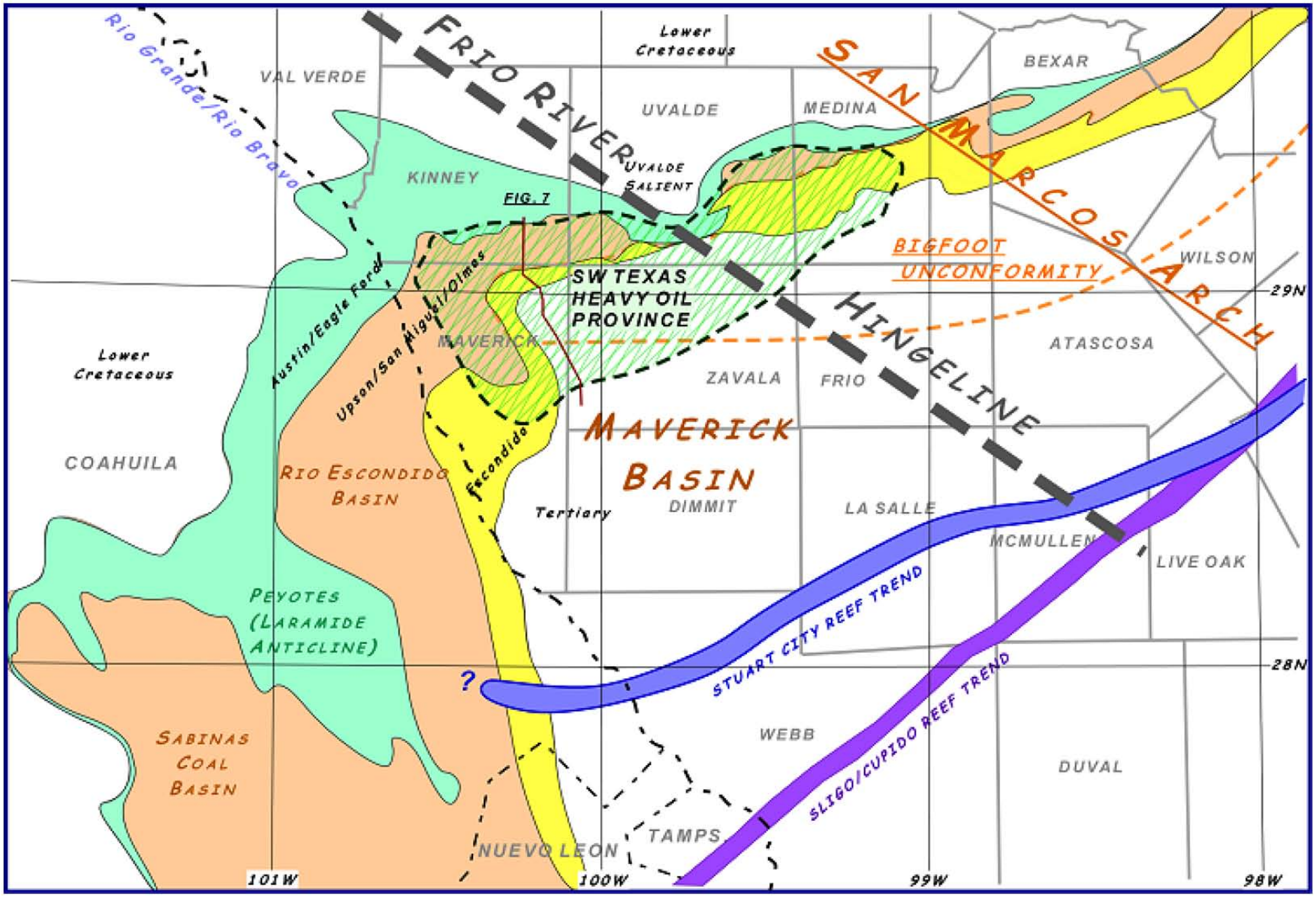

Figure 1. Setting of the Southwest Texas Heavy Oil Province. The map shows the outcrop patern of Upper Cretaceous units, the downdip Lower Cretaceous shelf margins, the Frio River Hingeline between the shelf and basin, and the extent of the Bigfoot Unconformity.

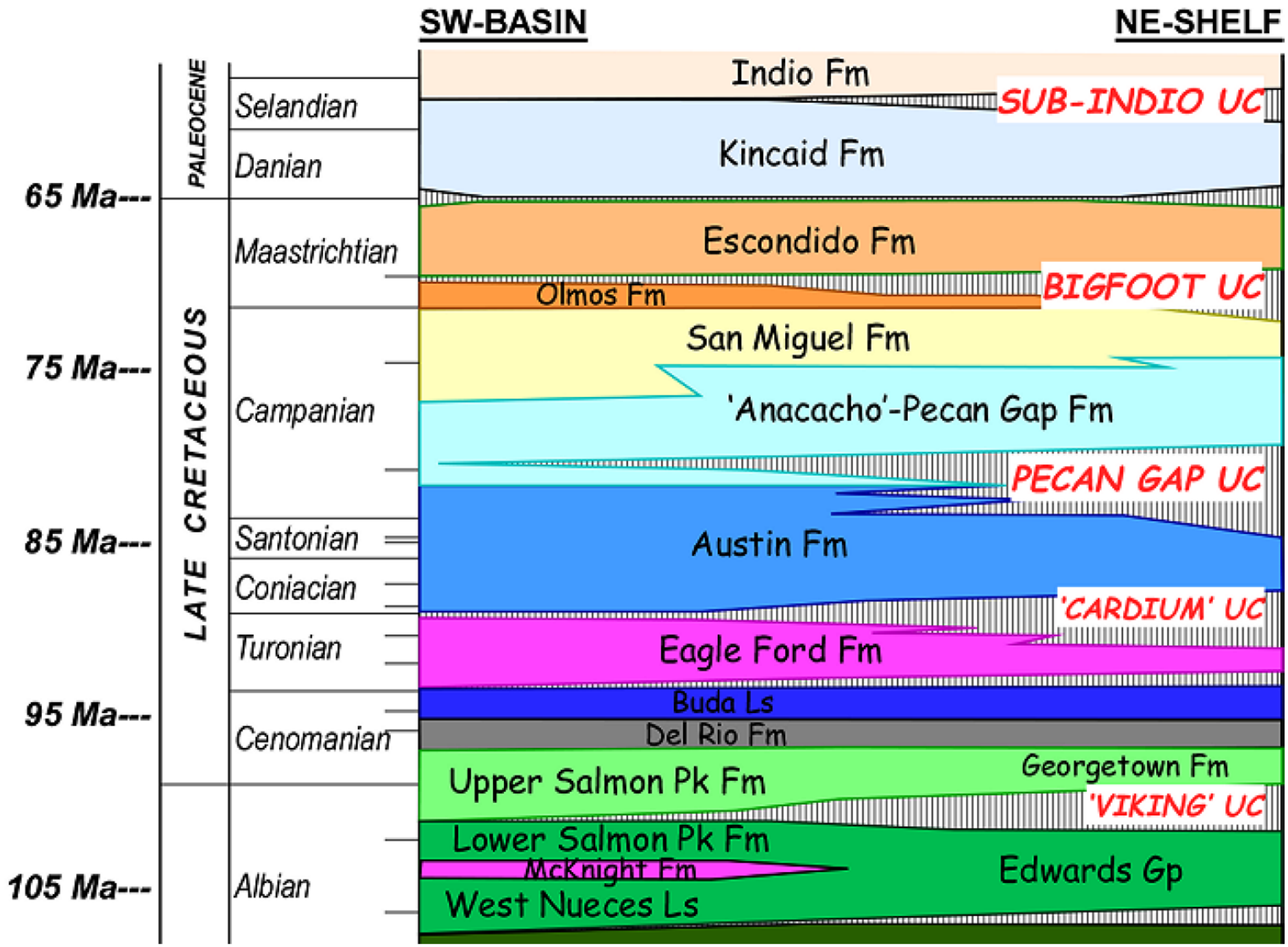

Figure 2. Time stratigraphic chart of the Upper Creraceous stratigraphic units of the Maverick Basin and the San Marcos Arch. Heavy oil is found in the Anacacho, San Miguel, Olmos, and Escondido formations.

Figure 3. Highwall of the Smyth Pit; north wall as of 2004, asphalt in porous Anacacho Limestone. Notice the oxidized ‘cap’ near the land surface, and variation in saturation within the asphaltic limestone.

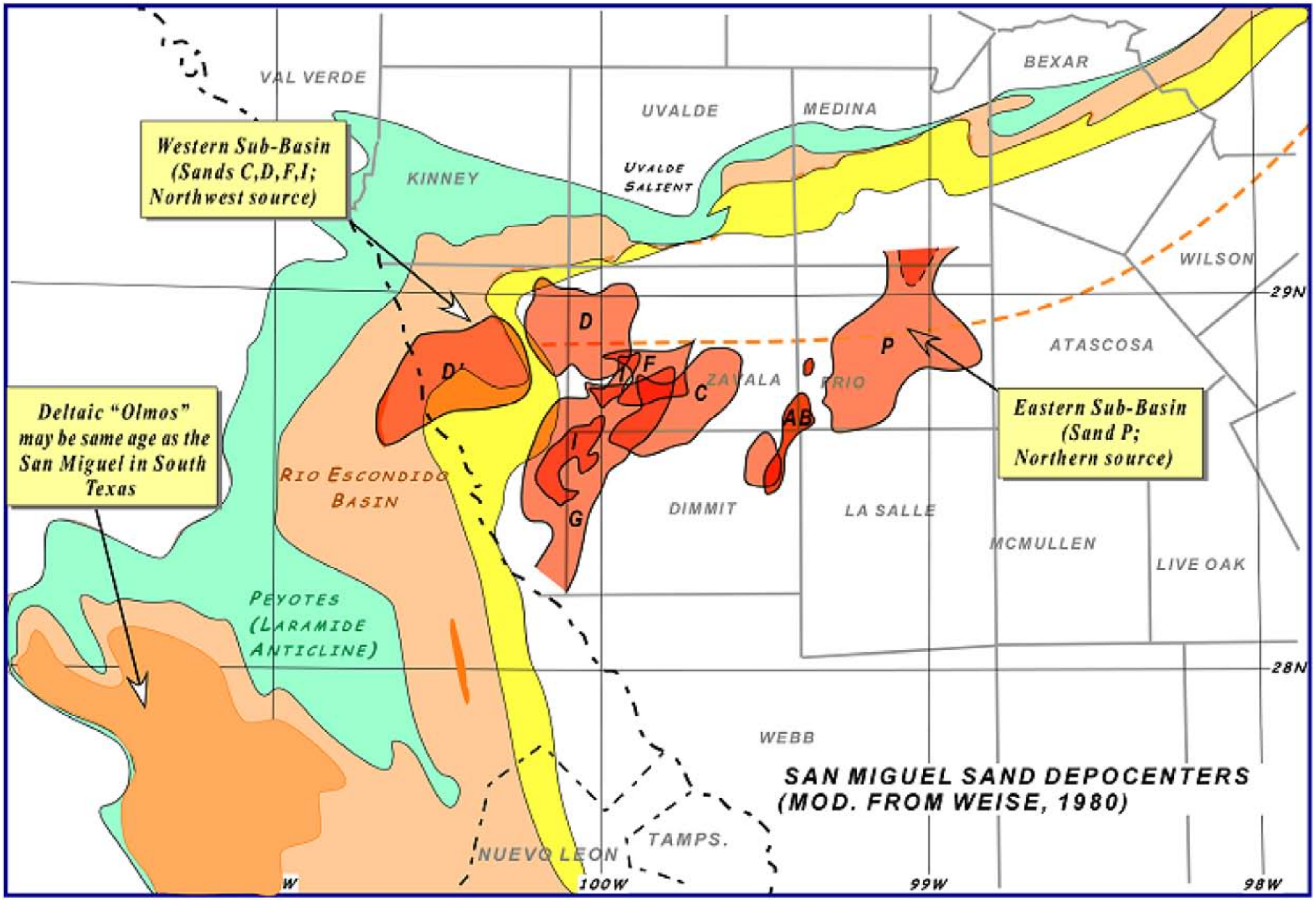

Figure 4. Stratigraphic setting of the San Miguel Formation as a series of marinedominated shorelines and wave-dominated deltas. Texas data from Weise (1980).

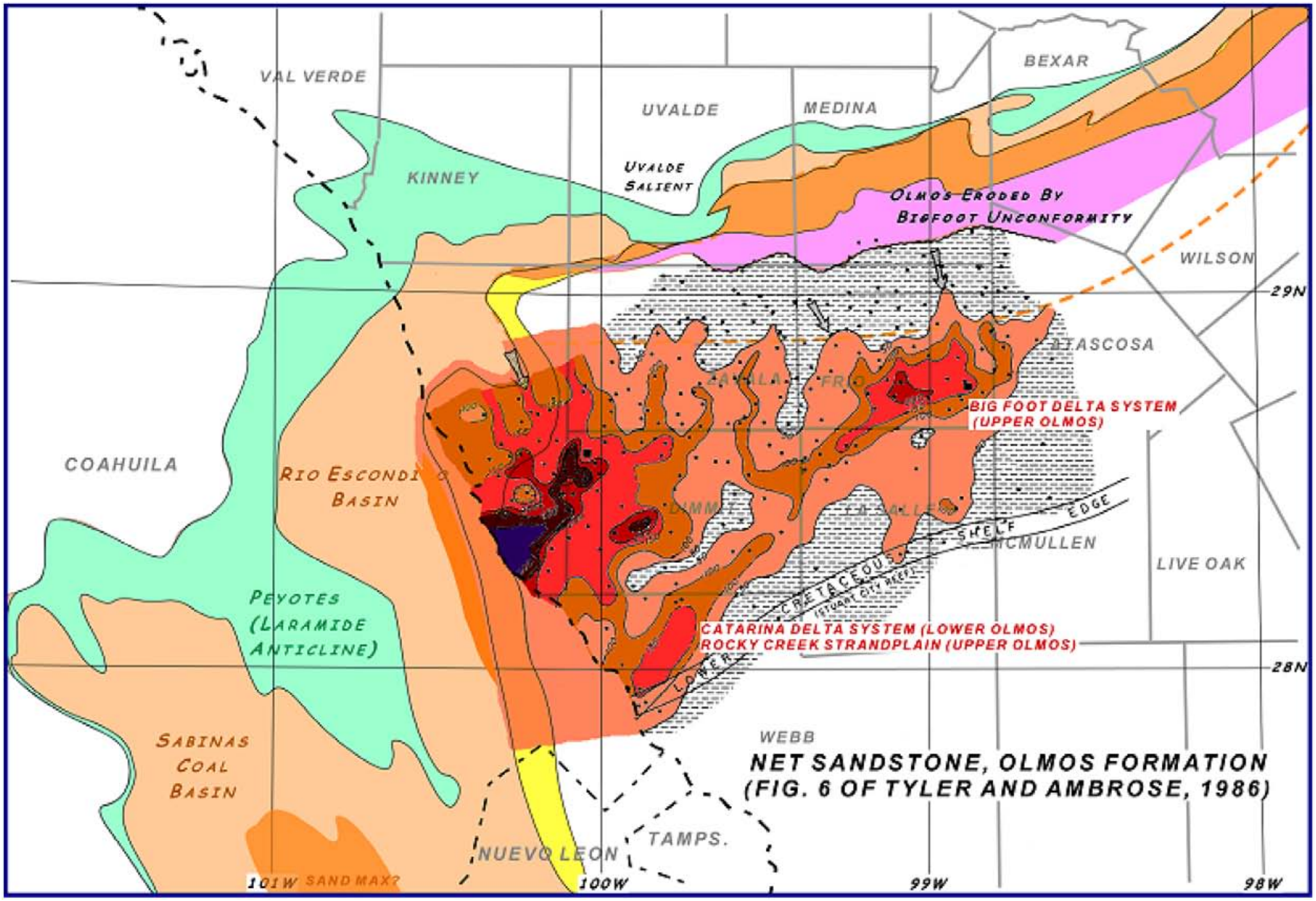

Figure 5. Stratigraphic setting of the Olmos Formation as a fluvial deltaic system and associated shorelines. Texas data from Tyler and Ambrose (1986).

Figure 6. Natural outcrops of Escondido asphaltic sandstone at Smyth Crossing of the Nueces River. The sandstone beds dip southwest from the Uvalde Uplift. The resource potential of Escondido asphaltic sandstones has not been estimated.

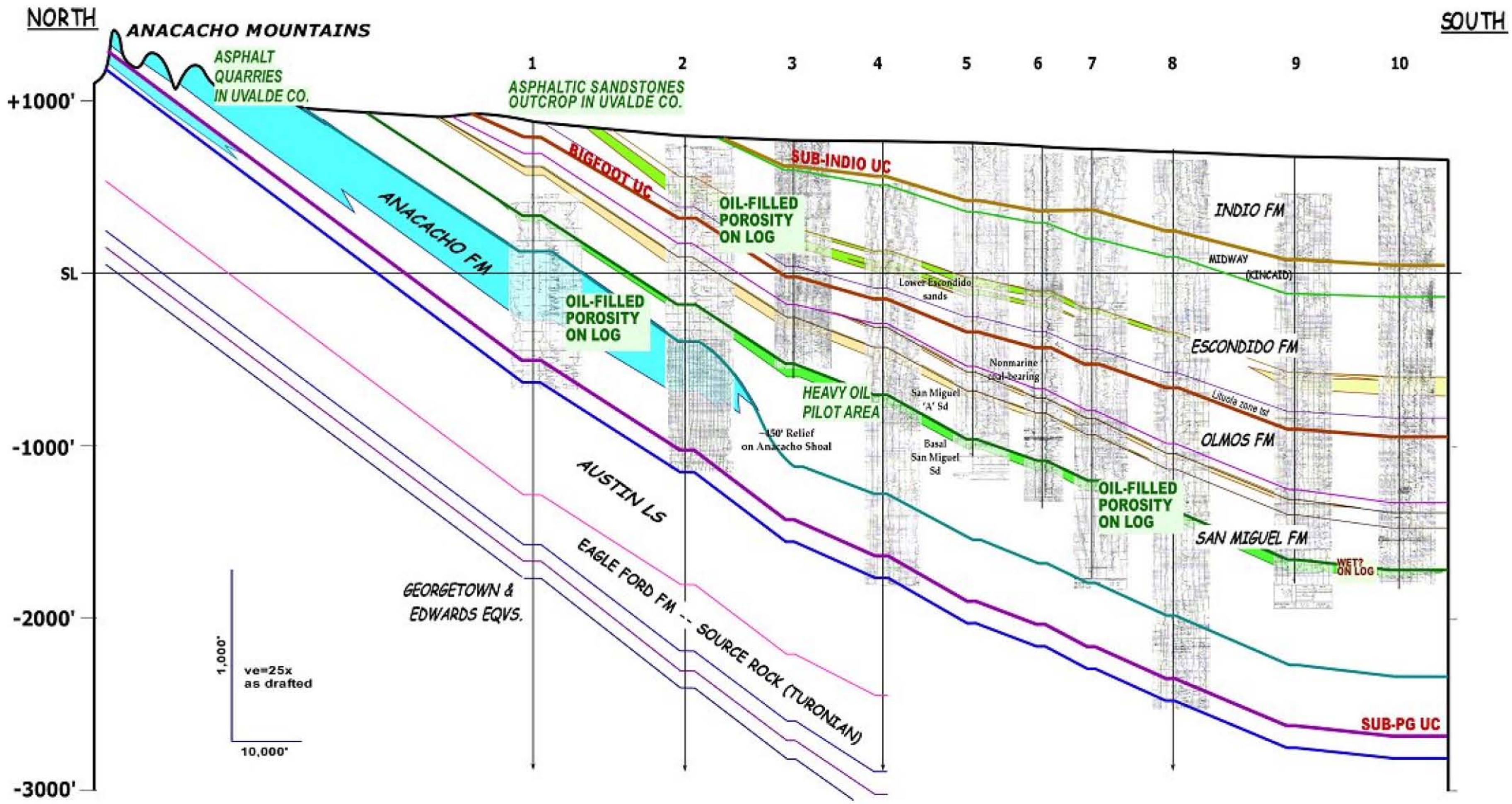

Figure 7. North-south cross section through eastern Maverick County, showing the relationship of Anacacho through Escondido units and the bounding unconformities. The Anacacho shows up to 500 ft (150 m) of depositional relief into the basinal equivalents.

Definition of the Heavy Oil Province

The Southwest Texas Heavy Oil Province is defined here to include all of the Upper Cretaceous (post-Austin) strata in Southwest Texas that contain heavy or superheavy oil or asphalt. This definition includes both the surface and near-surface Anacacho asphalt deposits and the San Miguel 'D' superheavy oil (or bitumen) reservoir, for which Kuuskraa et al. (1987) estimated reserves. The province also includes other asphaltic sandstones in the San Miguel, Olmos, and Escondido Formations, local dry gas reservoirs found on structural highs in these formations, and additional asphalt possibilities in the Anacacho Mountains (Figure 8).

The updip limits are at the outcrop in Maverick, Kinney, Uvalde, and Medina Counties. The downdip limits have been estimated using the reported API gravities of produced oil in the San Miguel and Olmos formations (too few Escondido reservoirs are reported to generate contours); and the gravity of produced gas and presence of condensate. Lines can be drawn, to the northwest of which produced oil is below 20°API, and gas is dry, with gravity less than 0.60.

These limits define a broad triangular area from the Chittim Anticline in central Maverick County northeast to central Medina County. The province does not extend very far southwest of the Chittim Anticline, as high-gravity oil is produced at very shallow depths near the Rio Grande. The northeastern limit of the area is in central Medina County near Hondo, where the heavy-oil line intersects the outrop. Oil east of this point is generally high-gravity, except where contacted by fresh water in Austin reservoirs.

Testing of the Heavy Oil Province

The heavy oil province has been tested in various localities over the years:

1. The surface exposures of asphalt in Anacacho Limestone in the Asphalt Belt in southwestern Uvalde County have been quarried since 1888 (Vaughan, 1897; Eldridge, 1901; Phillips, 1902; Baker, 1928; Gorman and Roebeck, 1945; Ball, 1952; Maxwell, 1962; Ewing, 2004). The asphalt deposits were originally discovered in streambed exposures; the hillside exposures are typically oxidized and asphalt-free. Major quarries are still in operation today by Vulcan Materials and by Martin-Marietta.
2. C.C. Winn drilled and tested a set of wells in the subsurface Anacacho in northeastern Maverick County in the 1960s (results not reported).
3. The San Miguel 'D' reservoir was tested by pilot programs during the 1970s and early 1980s in the Saner Ranch and Street Ranch areas in northeastern Maverick County. Conoco developed fracture-assisted steamflood (FAST) technology and reported their results extensively. The Street Ranch pilot began in late 1977, and through June 1980 it had produced 169,040 barrels of tar, at an average recovery efficiency of over 50% (Britton et al., 1983). The Saner Ranch pilot then recovered 133,260 barrels in 23 months (Britton, 1987). Exxon and Mobil both had pilot projects in the immediate area. Texas Tar Sands (Hart, 1984) and Nucorp also conducted pilot projects near the Maverick-Zavala county line. All of these efforts combined to produce 417,673 BO), as reported by the Railroad Commission.

4. The San Miguel 'D' reservoir was also evaluated in the Bandera Tank field area of western Zavala County, where Shell drilled a test well in 1980 (#10T Pickens & Coffield; Freedman and Studlick, 1981) but elected not to pursue development.
5. Heavy oil has also been produced from San Miguel sandstones at Little Tom field in central Zavala County. The field was discovered in 1950. Hanover Petroleum operated 14 wells and a fireflood in the 1970s, and others have proposed or applied various experimental treatments since then. Hanover reported the field to cover 5500 acres and contain 76 million barrels of 15-20° oil in-place (ERDA, 1975).
6. More recently, TXCO Resources has drilled three test patterns for the San Miguel 'D' sand, in cooperation with Pearl Exploration and Production on a 61,000-acre AMI (from presentations and press releases on the TXCO website, accessed in October, 2009). A shallow pattern was drilled in November, 2006, on the crest of the Chittim Anticline (Chittim 'B' lease, section 158, A-169, 200 ft depth). This was followed by a deep pattern to the northeast on the same lease (A-92, 2150 ft depth) and by a 5-spot vertical and 3-spot horizontal pattern on the Saner Ranch (A-470, 1450 ft depth) in March-May, 2008. Both of these latter patterns include horizontal wells. The Chittim deep locality was reportedly going to test SAGD (steam assisted gravity drainage) technology; the project entered high-temperature injection in Fall, 2008. The Saner Ranch pilot was designed to test an upgraded FAST technology similar to Conoco's test; in Fall, 2008, it was in a preheat phase. Some oil was produced in late 2008. As of March, 2009, the pilots are reported to be shut-in due to lowered oil prices and other financial difficulties.

Reservoir Properties

A comprehensive log suite from the San Miguel 'D' reservoir, penetrated in the Shell #10T Pickens & Coffield well (Zavala County) and published by Freedman and Studlick (1981), is compiled in Figure 9. The sandstone there is 80 ft (24 m) in gross thickness and about 45 ft (13.7m) in net pay. The porosity in the pay intervals is high (24-28%), with good permeability (100s of md) from whole-core analysis. Oil saturations were calculated and measured in the 45-60% range. The sand does have a series of tight, lime-cemented baffles which separate parts of the porous and permeable sandstone; these were also noticed at the Street Ranch pilot (Britton et al., 1983). These zones cause overall sweep by steamfloods to be reduced; however, the lateral extent and continuity of these tight zones is not known and may not be great. Similar reservoir parameters were observed in other San Miguel 'D' tests (Table 1), where oil in-place of 988-1410 BO/ac-ft was calculated.

In the Anacacho, more limited data are available (Evans, 1975 and earlier sources). It appears that porosity ranges from 8-20%. The unit is probably stratified such that vertical permeability is considerably less than horizontal. The section is over 1150 ft (350 m) thick, with 450 ft (137 m) of that being reservoir-quality carbonate. Oil in-place has been calculated at the quarries as 603 BO/ac-ft.

Resource Calculations

The published resource figures for heavy oil in the SWTHO (from Kuuskraa et al., 1987), are:

- Anacacho limestone, 550 million barrels in-place over 23,400 acres (94.7 km^2). However, the continuous stratigraphy indicates that the entire 147-mi^2 (380-km^2) outcrop area should contain asphalt. Including the outcrop area would increase the heavy oil resources into the billions of barrels.
- San Miguel ‘D’ sandstone, 3.2 billion barrels in-place over 256 mi^2 (663 km^2).

No estimate has been made for heavy-oil reserves in any other sandstone reservoirs. Some sandstone units in the Olmos and upper San Miguel contain substantial amounts of heavy oil; and the Escondido is definitely saturated in the outcrop and in the subsurface.

An unpublished study of the San Miguel ‘D’ by DeGolyer and McNaughton for TXCO Resources is reported to show in-place reserves of 7-10 billion barrels of 0^o gravity oil (as reported via news release, September 29, 2008). The study is also reported to indicate “the potential for another 100 million barrels of 10^o -14^o API gravity oil in separate traps.”

The total resource in the province may exceed 10 billion barrels, making this province one of the largest in the United States (Whiting, 1979).

Problems in Ultraheavy Oil Operations

All tar sand and ultraheavy oil operations face substantial difficulties in producing and upgrading the hydrocarbon resource. In general, substantial heat needs to be applied to liquefy the resource and move it into and up wellbores for in situ operations. Then the low gravity requires blending and other refining before it can be shipped in the usual fashion.

Problems in Production

The San Miguel ‘D’ oil has a viscosity of 20,000,000 centipoises and is a solid at reservoir conditions. Because of this, conventional steamfloods that require a continuous fluid path from injector to producer do not work. Three alternatives are available:

1. Cyclic steam injection and production (huff’n puff) can ‘melt’ the oil and produce it; but volumes are limited, and the process is not very efficient.
2. Inject steam at pressures high enough to fracture the rock and asphalt to establish a connecting path from injector to producer (FAST technology).
3. Inject steam in a horizontal well to ‘melt out’ a cavity, then oil can stream downward into a parallel producer (steam-assisted gravity drainage, or SAGD).

The major cost for all of these processes is creation of steam, which requires large energy inputs. Traditionally this was done with natural gas, but alternate sources can be envisioned. Water for making steam is scarce in the area, and substantial reserves would need to be secured to enable a commercial operation.

In the San Miguel 'D', the presence of limy or lime-cemented layers within the reservoir limit the flood conformance. However, the lateral extent and continuity of the limy layers are not well understood.

Problems in Utilization

The larger problem is what to do with the highly viscous, low-gravity crude asphalt once it is produced. In the older pilots, high-gravity diluent (WTI) was imported to make the product stream up to pipeline grade. However, this external cost is substantial and one would like alternate solutions. Fortunately, there are now refineries in the Gulf Coast area that prefer heavy crudes; they can provide a better market. In recent economic modeling by TXCO, they estimate a $15/bbl discount to WTI for their produced product.

Alternate products can also be investigated. It may be possible to generate electricity directly by a system of 'minemouth generation', as currently done for lignite resources. Also, emulsion systems can be produced similar to the Venezuelan 'Orimulsion' for use in boilers.

There are chemical components in the heavy crude that need to be mitigated, notable a high sulfur content (10%). Fortunately, metals content is reported to be low (V at 85 ppm, Ni at 24 ppm; Britton, 1987).

Further Work Needed

Our understanding of the Southwest Texas Heavy Oil Province is incomplete in several respects. Stratigraphically, we need to understand the complex Lower Escondido system, which shows significant thickness of oil sand. We need to look at Olmos and upper San Miguel sand units, which are regionally wet but contain heavy oil at various places. Both units need to have high-resolution stratigraphy applied to understand their architecture.

It would be good to know the source of this major oil accumulation. Ewing (2003) proposed that the oil migrated from Mexico northeastward towards the San Marcos Arch and Uvalde Uplift. However, are the source rocks Upper Cretaceous, or is there vertical migration from deeper generating zones and/or reservoirs?

Our understanding of the carbonate-hosted deposits should be improved. Although they have lower oil saturation and porosity, their thickness leads to a substantial target. Are the Anacacho and San Miguel 'D' systems related?

The internal reservoir characteristics of the San Miguel 'D' need more definition. If these are wave-dominated deltas, we might expect a pastiche of shingling sand bodies and limited lateral extent of the lime-cemented baffle zones. However, this sort of detailed reservoir characterization has not yet been done. There may be some limited outcrops of the San Miguel 'D' back on the ranches which could also be examined.

The key research, though, is not geological but engineering in nature; how do we develop an integrated system for producing and using these low-grade resources with minimal inputs of natural gas and fresh water?

References

Baker, C.L., 1928, Possible distillation of oil from organic sediments by heat and other processes of igneous intrusions – asphalt in the Anacacho Formation of Texas: AAPG Bulletin, v.12, 10, p. 995-1003.

Ball, M.W., 1952, Report on oil-impregnated strippable deposits in Texas as of May, 1950; *in* The synthetic liquid fuel potential of Texas (Ford, Bacon, and Davis, Inc.): US Bureau of Mines, p. D1-D14.

Britton, M.W., W.L. Martin, R.J. Leibrecht, and R.A. Harmon, 1983, The Street Ranch pilot test of fracture-assisted steamflood technology: Journal of Petroleum Technology, v.35, no.3, p. 511-522.

Britton, M.W., 1987, Problems frequently encountered in evaluating tar sand resources -- the South Texas San Miguel deposit, *in* Exploration for heavy crude oil and natural bitumen, R.F. Meyer, ed.: AAPG Studies in Geology 25, p. 489-506.

Eldridge, G.H., 1901, The asphalt and bituminous rock deposits of the United States: U.S. Geological Survey, 22nd Annual Report, Part I, p. 210-464; Uvalde County, p. 322-327.

ERDA, 1975, Oil recovery by thermal methods, contract H0252002; *in* Contracts and grants for cooperative research on enhancement of recovery of oil and gas; Progress Review #2, April 1975, p. 21-42. (Also reports in following months).

Evans, T.J., 1975, Native bituminous materials in Texas: Bureau of Economic Geology Mineral Resource Circular 57, 18p.

Ewing, T.E., 1987, The Frio River Line in South Texas – transition from Cordilleran to Northern Gulf tectonic regimes: GCAGS Transactions, v.37, p. 87-94.

Ewing, T.E., 2003, Upper Cretaceous (Post-Edwards) stratigraphic framework of the Maverick/Rio Escondido Basin, Southwest Texas and Coahuila – a progress report, *in* Structure and Stratigraphy of South Texas and Northeast Mexico: Applications to Exploration: GCSSEPM Foundation and South Texas Geological Society, p.122-141.

Ewing, T.E., 2004, Volcanoes, asphalt, tectonics and groundwater in the Uvalde area, southwest Texas: South Texas Geological Society Guidebook 2004-1, 82p.

Freedman, R., and J.R.J. Studlick, 1981, How a Texas heavy oil prospect was evaluated: Oil and Gas Journal, Nov. 30, 1981, p. 63-76.

Gorman, J.M., and R.C. Roebeck, 1945, Asphalt deposits near Uvalde, Uvalde County, Texas: U.S. Geological Survey Open-File Report, 10p.

Hart, P., 1984, Pilot project taps tar sand reservoir in Texas: Oil and Gas Journal, July 9, 1984, p. 60-61.

Kuuskraa, V.A., E.C. Hammershaimb, and M. Pague, 1987, Major tar sand and heavy-oil deposits of the United States, *in* Exploration for heavy crude oil and natural bitumen, R.F. Meyer, ed.: AAPG Studies in Geology 25, p. 123-136.

Maxwell, R.A., 1962, Asphalt rock; in Mineral resources of South Texas, region served through the port of Corpus Christi: University of Texas at Austin. Bureau of Economic Geology Report of Investigations 43, p. 17-21.

Phillips, W.B., 1902, Coal, lignite and asphalt rock: University of Texas at Austin Mineral Survey Bulletin 3, 137p.

Pisasale, E.T., 1980, Surface and subsurface depositional systems in the Escondido Formation, Rio Grande Embayment, South Texas: University of Texas at Austin, M.A. thesis, 72p.

Stang, H.R., and Y. Soni, 1984, The Saner Ranch pilot test of fracture-assisted steamflood technology: SPE Paper 13036, 59th Annual Technical Conference.

Tyler, Noel, and W.A. Ambrose, 1986, Depositional systems and oil and gas plays in the Cretaceous Olmos Formation, South Texas: University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 152, 42p.

Vaughan, T.W., 1897, The asphalt deposits of western Texas: U.S. Geological Survey, 18th Annual Report, Pt. V. p. 930-935.

Weise, B.R., 1980, Wave-dominated delta systems of the Upper Cretaceous San Miguel Formation, Maverick Basin, Texas: University of Texas at Austin, Bureau of Economic Geology Report of Investigations 107, 39p.

Whiting, R.L., 1979, Heavy crude oil and tar sand resources and reserves of the United States – emphasis on Texas, *in* The future of heavy crude oils and tar sands; UNITAR, First International Conference, Edmonton, Alberta, p. 90-96.

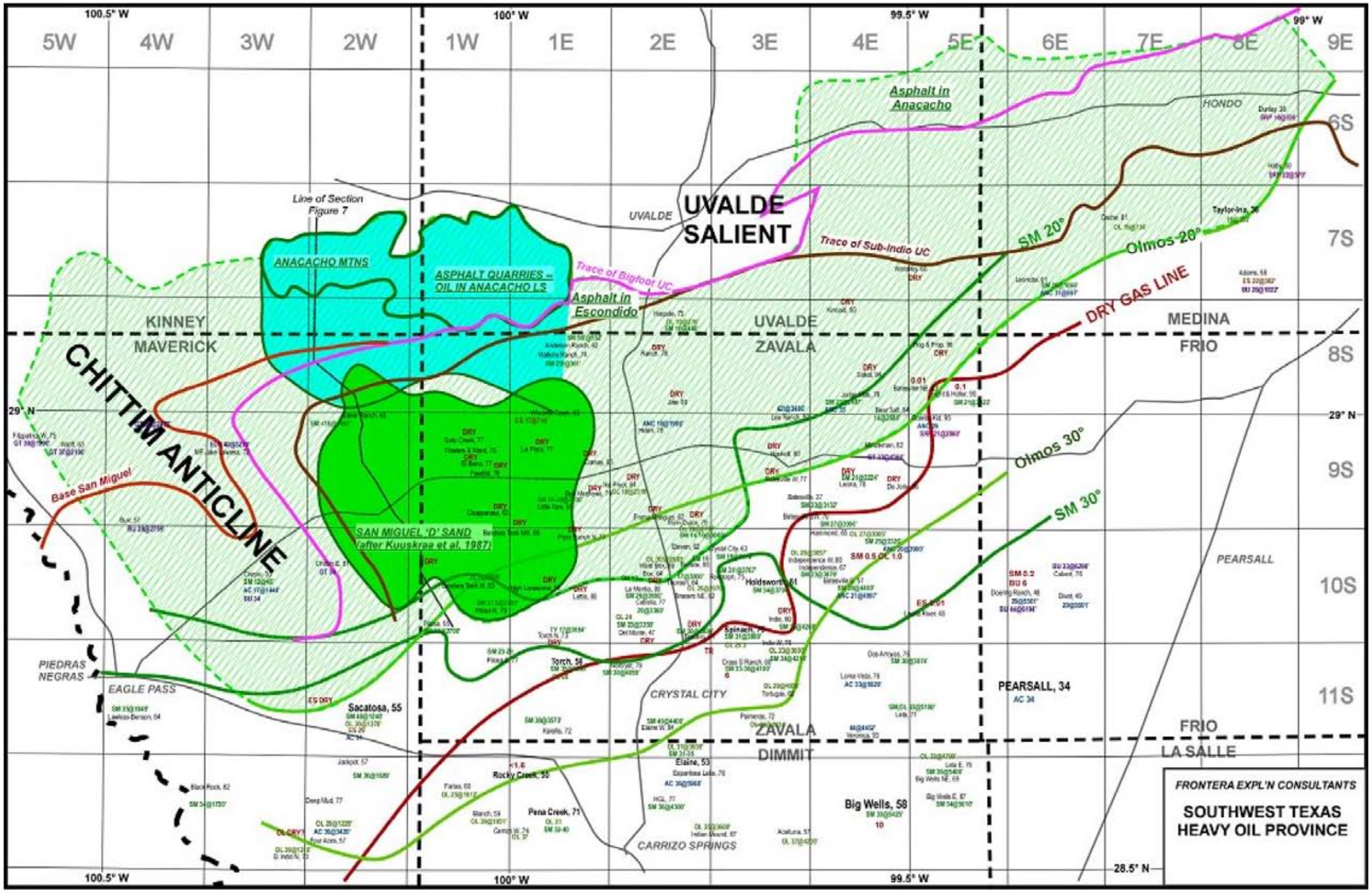

Figure 8. Map of the Southwest Texas Heavy Oil Province (shaded green). The smaller, darker green area is the outline of San Miguel 'D' heavy oil reserves, from Kuuskraa et al. (1987). The blue area to the north is the outcrop belt and subsurface continuation of the main Anacacho Limestone shoal. The green northeasttrending lines are isogravity lines in the San Miguel and Olmos sandstones, defining the southeastern limit of heavy oil; the red line is the southeastern limit of dry gas reservoirs.

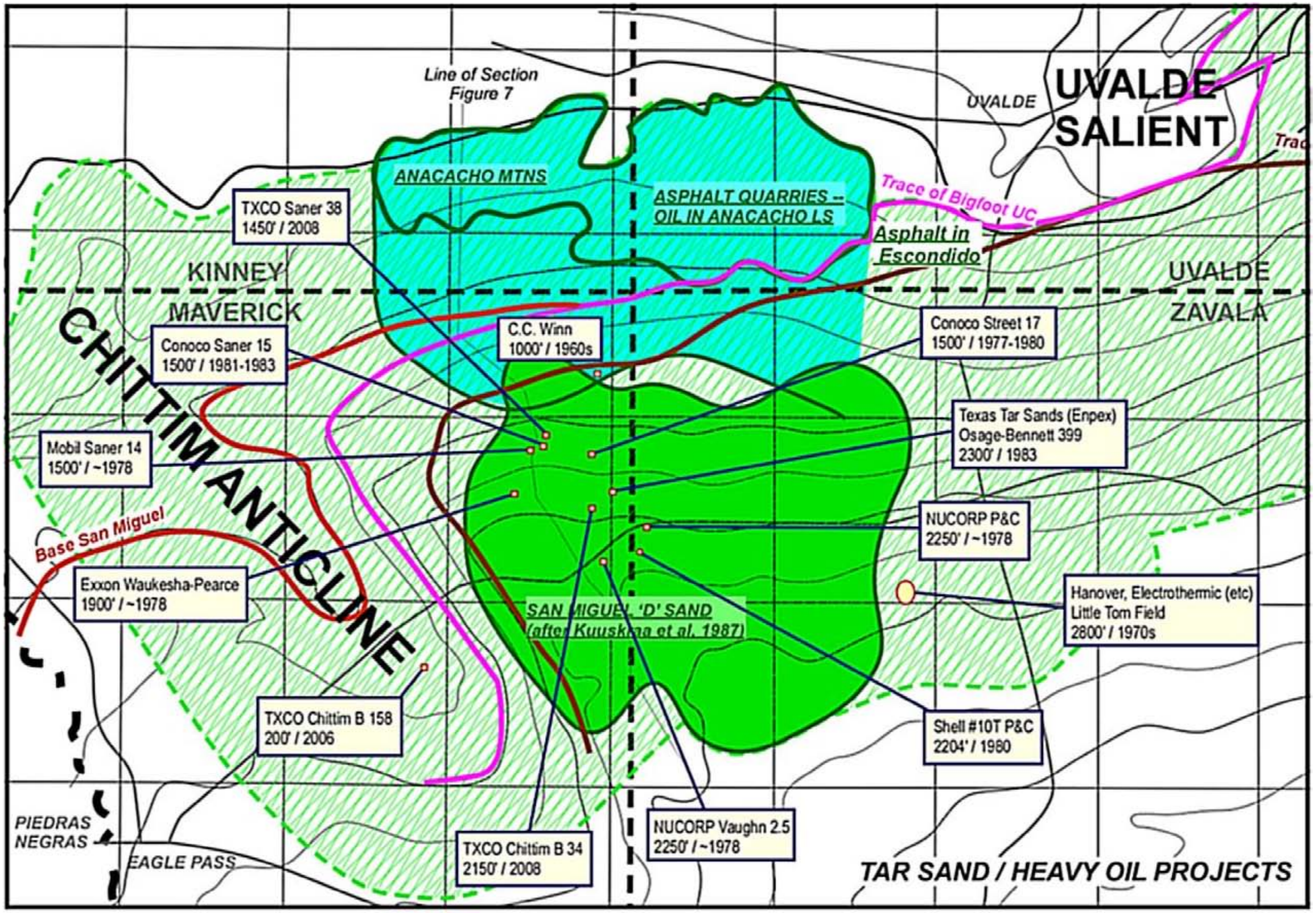

Figure 9. Tar sand and heavy oil projects in the core area of the Southwest Texas Heavy Oil Province.

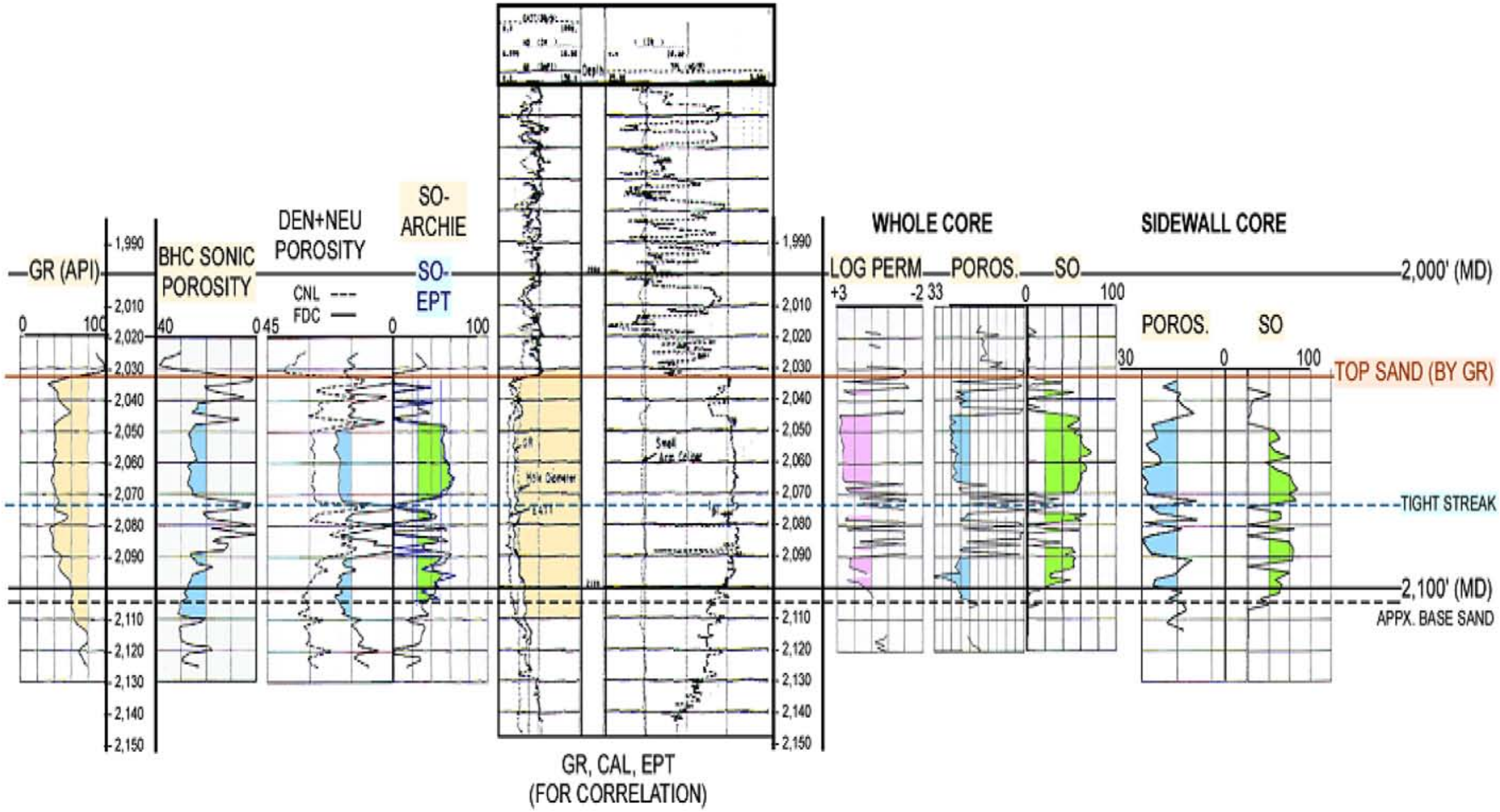

Figure 10. Log suite of the Shell #10T Pickens & Coffield, Bandera Tank area, Zavala County, Texas; assembled from figures in Freedman and Studlick (1981).

LOCALITY / PROPERTY	BANDERA TANK *Shell evaluation Test, in Freedman and Studlick (1981)*	LITTLE TOM *Hanover Pet. data, from ERDA (1975)*	STREET RANCH *Conoco; Data from Britton and others (1983)*	SANER RANCH *Conoco; Data from Stang and Soni (1984) as reported in Britton (1987)*	TEXAS TAR SANDS *Data from Hart (July 9, 1984)*	ANACACHO QUARRIES *Data from Evans (1975) and earlier sources*
GRAVITY (°API)	0-8	18	-2	-2	-2	???
VISCOSITY@RT (CP)	>2,000,000	90	20,000,000			
POUR POINT (°F)			180			110?
TEMPERATURE (°F)	100	125	95		100	70
DEPTH (FT)	2000	2800	1500	1400	1750	SURFACE
POROSITY	24%	22%	27%	28%		8-20%
PERM. (Air, Flushed)	200-500	64	>250	>250		
OIL SAT'N (SO, %)	45-60%	57%	48%	44%		
NET PAY (ft)	45	14	40.5	66		1150
GROSS INTERVAL (ft)	65	35	52			450
OIP (BO/Ac-ft)	723	988	1007	1418		603
RECOVERY (BO/Ac-ft)	75-138	315-415	543			603
TECHNIQUE:	STEAMFLOOD	FIREFLOOD	FAST	FAST	FRAC+STEAM	QUARRY
EXTRACTION TEMP. (° F)	550 PROP.		325		650	NA
DATE	1980	1972-75	1977-80	1980-82	1983-84	1888-PRESENT

Table 1. Heavy oil fluid and reservoir properties from the literature.