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ABSTRACT

The Wilds delta comprises a subsurface interval deposited during the transgressive systems tract within Paleocene middle Wilcox time. Because of excellent well coverage through this interval in a four township area of east - central Louisiana, precise mapping based on detailed e-log correlations was possible. Net sand mapping has provided a means of recognizing genetic facies architectures within the Wilds delta. A conventional core collected through the distributary channel portion of the Wilds provided the means of measuring the physical parameters within this thick (50' - 130') channel system.

X-ray radiography of selected intervals, thin section petrography, and detailed petrophysical evaluation indicate that channel fills can differ considerably in architecture within one deltaic system. The data show the Wilds distributary channel to consist mainly of subangular to subrounded, very fine to medium sized quartz grains. Occasional siltstones and shales are interbedded within the sandstone layers; the latter contain flaser bedding, planar laminations and rip-up clasts. Porosity within this predominantly sandstone portion of the channel averages 30%, permeability ranges between 91 and 524 md and average 280 md. Only in those intervals of the channel where the grains are totally cemented by calcite cement are the porosities very low (7%) and permeability is totally lacking. Hydrocarbon accumulations within the Wilds interval in central Louisiana is believed to be the function of stratigraphy, manifested in subtle traps sourced through vertical migration pathways.

INTRODUCTION

Numerous sedimentological studies of the modern Mississippi delta (Fisk et al., 1954; Gagliano, 1965; Morgan, 1970; Coleman, 1973; Penland et al., 1988; Coleman and Roberts, 1990), and studies on smaller deltas such as the Atchafalaya (Roberts et al. 1980; Roberts and van Heerden, 1992), are excellent analogs for a comparison with the thin stacked deltas present in the subsurface in the Paleocene Wilcox of east-central Louisiana (Echols, 1991).

Factors such as river regime, coastal processes and climate, which control the depositional processes within the modern deltaic setting, give rise to a variety of sedimentary facies. Since the facies concept is fundamental to understanding the major and minor components of both modern and ancient deltas, the following generalized definition is applicable: "A facies is a restricted stratigraphic unit, or any genetically related sedimentary deposit, which exhibits lithologic, petrographic, structural, or paleontolgical characteristics significantly different from those of another part of the same unit" (Teichert, 1958).

The lower part of a fluvially dominated delta system such as the Mississippi can be divided into: 1) a lower delta plain marsh distributary channel facies consisting of distributary channel sands, overb gbThe 4.19(are l).7016,54(s)aths3.9(2

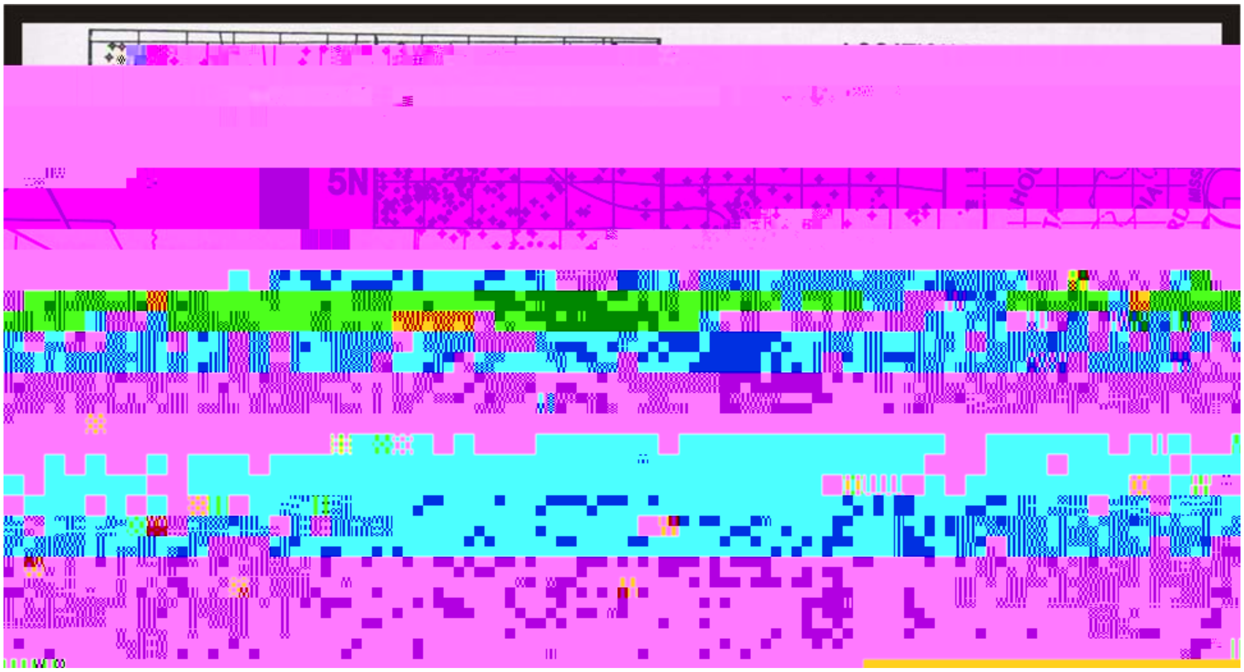

Figure 1: Location map of the four township study area, showing the well coverage and the location of the core taken in the Angelina BBF no. 1 well.

STRATIGRAPHY

In Louisiana, the Wilds deltaic interval overlies the Campbell sandstone, the equivalent of the McKittrick in Mississippi (Echols, 1991). The Wilds sandstone interval itself has no correlative sand equivalent in Mississippi. A Wilds distributary channel system is evidence of a more widespread delta system that formed in Paleocene Middle Wilcox time. A regional transgressive marine shale interval, the Baker Shale systems tract proceeded north and north westward from Mississippi into Louisiana. The developing depositional surface climbed through the Wilds section (Figure. 2). Where underlying concentrations of Wilds distributary channel and bay fill sands were present, the transgression reworked them to produce barrier island arcs, shoals and related offshore sand bodies (Echols, 1991). These deposits are known as the overlying Nichols sandstone (Figure 2). Where the middle Paleocene Baker transgression crossed areas of little or no underlying sand, thin Wilds deposits are overlain by a thick Baker shale interval. This shale acts as a seal to fluids contained in the Wilds sandstone reservoirs.

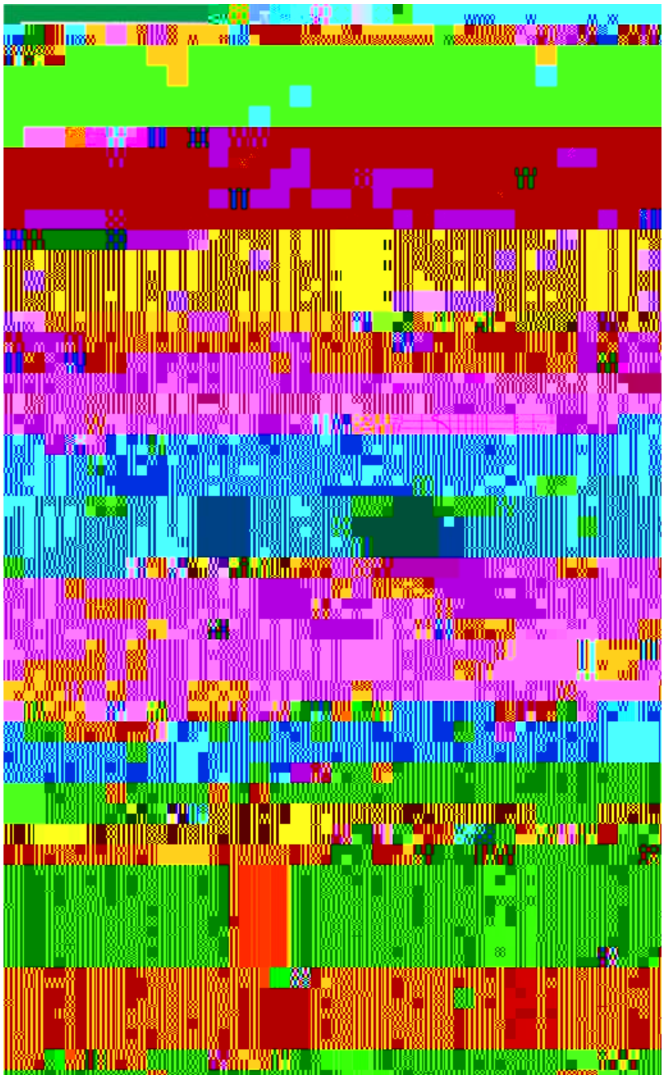

Figure 2: GR/SP, litho-density and neutron logs showing the stratigraphic position of the Wilds distributary channel below the Nichols barrier sand and above the Campbell interval. Calcareous hard streaks are located within the channel interval at the top and near the base.

STRUCTURAL AND NET SAND MAPPING

A regional structure map of the top of the Wilds interval shows a monocline with a gentle 1º to 2º dip to the southeast (Figure. 3A). The subsurface depth below mean sea level is 5250' at the NW corner of the study area and reaches 6750' at the SE corner. Locally, dips can be accentuated by structural noses or depositional topographic highs related to thick sandstone accumulations. These highs are the result of differential compaction of surrounding fine-grained sediments peripheral to thicker sand bodies belonging to various depositional environments. The dipmeter readings taken in the Wilds channel show an upward increase in dip angle within the basal sands, evidence of current bedding (Figure 4). These were created by the migration of sand waves within the channel. In the upper half of the channel fill, the dips are shown to be decreasing upward which depicts the filling of the channel by sand layers that conformed to the shape of the channel (Serra, 1985) .

Genetic facies determinations of stratigraphic units within the Wilds delta were possible from 1) the resulting net sand geometries observed on the net thickness sand map (Figure 3B), 2) certain patterns on the log curves of the old e-logs and the modern log suite, and 3) detailed sedimentological and petrophysical characteristics obtained from the core (Figure 5). Merging these data sets was especially useful in describing the varying facies of the delta. From the net sand map (Figure 3B), the architecture of the distributary channel complex, small crevasse splay deltas, and the widespread overbank bay fill facies are quite obvious. The north - south trending channels have widths that vary from 0.5 to 2.0 miles, and average 1.0 mile. The thickness of the sand filling the channel ranges from 50 to 130 feet and averages 70 feet. Two crevasse splays appear to have developed along the east and southwest sides of the distributary channel complex (Fig. 3B). These breaches through the levees allowed water and sediment to flow out into the interdistributary bay areas where it formed small overbanks or crevasse splay deltas. These cover approximately six square miles each and average 30 feet in thickness. In the numerous interdistributary bays, fine sands, silts and silty shales were deposited. They constitute the widespread overbank bay fill facies that average some 30 feet in thickness.

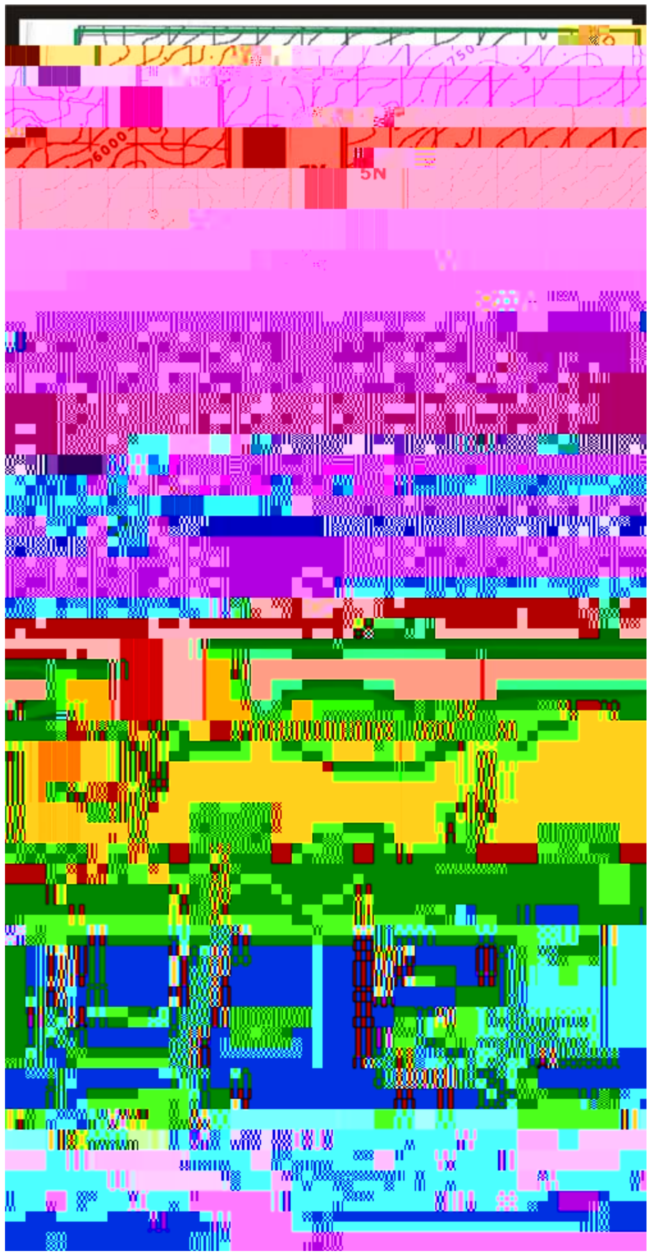

Figure 3: Maps of the Wilds sand: A) Structure on top of the Wilds interval showing a gentle 1° - 2° SE dipping monocline going from -5250' to -6750' below mean sea level (C.I. = 50'); and B) Wilds net sand geometry map depicting the facies architecture of that delta system.

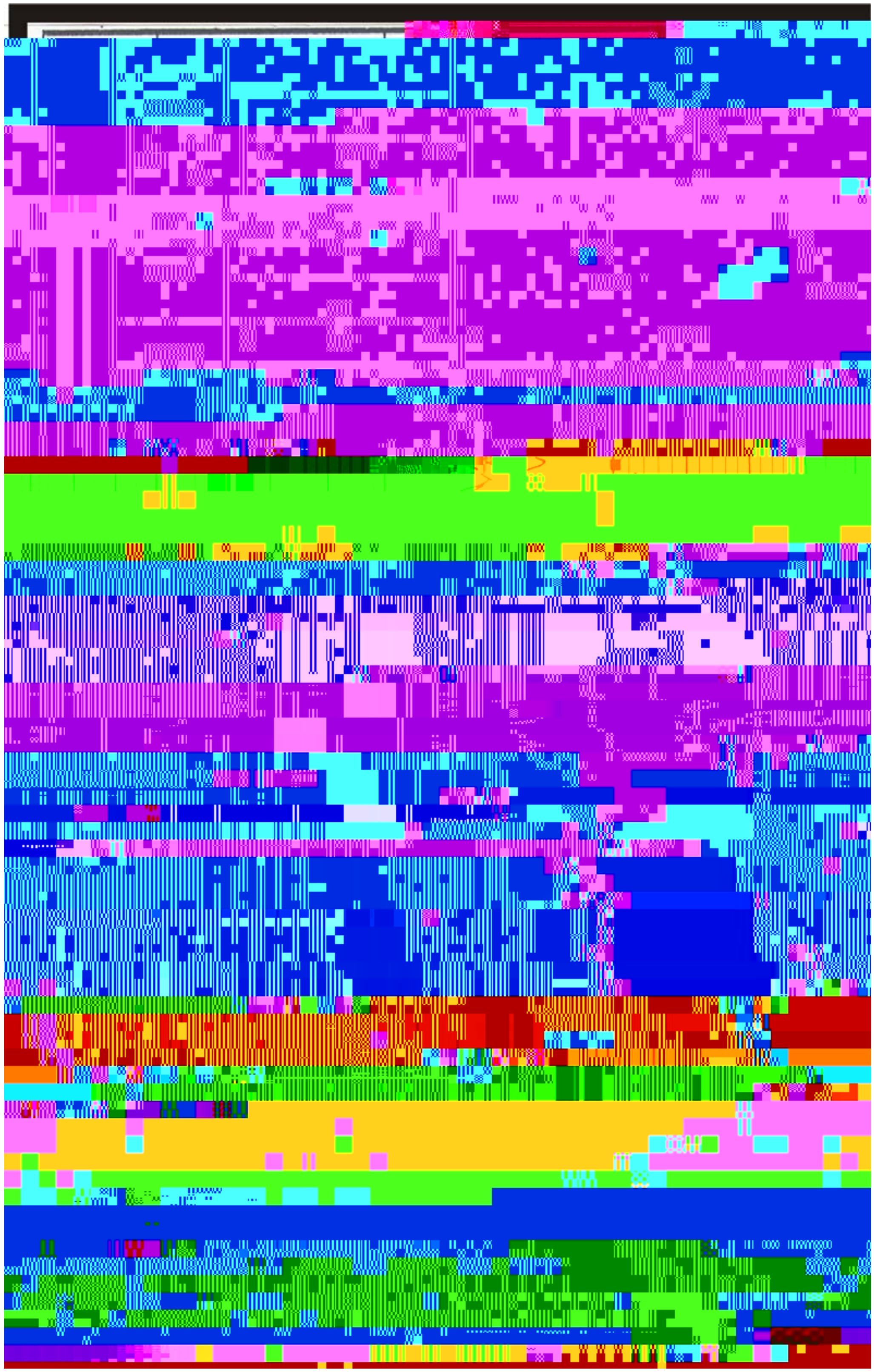

Figure 4: Dipmeter through the Wilds channel showing basal current bedding by an upward increase in dip angle. Toward the upper part of the interval there is an upward decrease in dips as sand fills the channel.

DISTRIBUTARY CHANNEL LITHOFACIES

The $\pm$ 63' interval (6391'3" - 6453' 11") of the core penetrated a distributary channel that forms an integral part of the Wilds deltaic complex. The channel cut into an interdistributary bay deposit consisting of laminated siltstones (Figure. 5). The base of the Wilds channel consists of a well sorted, fine to medium grained (0.22-0.27 mm), predominantly subangular to subrounded quartz sandstone. Accessory components consist of plagioclase, muscovite, zircon, and opaque minerals (hematite and magnetite) (Figure 6). Current ripple lamination in the form of low-angle dipping foreset bedding, and horizontal planar laminations are the principal sedimentary structures observed on x-ray radiographs of this section of the core (Figures 6).

Moving up through the channel fill, the sandstone exhibits variations in grain size from medium (0.24 - 0.29 mm) to interbedded intervals of subangular to subrounded coarse grained sandstones. Variations in mineralogy are minor. Flaser bedding and small current ripples are the predominant sedimentary structures throughout. Erosional contacts and thin shale lamina that separate the more massive sandstone layers reflect pulsating channel filling. Occasional siltstone layers (6410') and silty shale intervals (6399') were deposited within the channel when the flow regime diminished (Figure 5). Two intervals, consisting of very fine-grained calcareous ($CaCO_3$) cemented sandstone, were observed within the channel. These are: 1) an interval with planar laminations and parallel wavy bedding (6438'-6441) and 2) one without observable sedimentary structures at the top of the channel between 6392' and 6394'. The calcite cement is believed to have precipitated from interstitial fluids associated with marine conditions as the distributary channel approached the coast. Although located within the channel, these calcareous sandstone intervals were probably cemented in much the same manner as "beach rock" commonly found near the fresh-marine water interface along sandy marine shorelines.

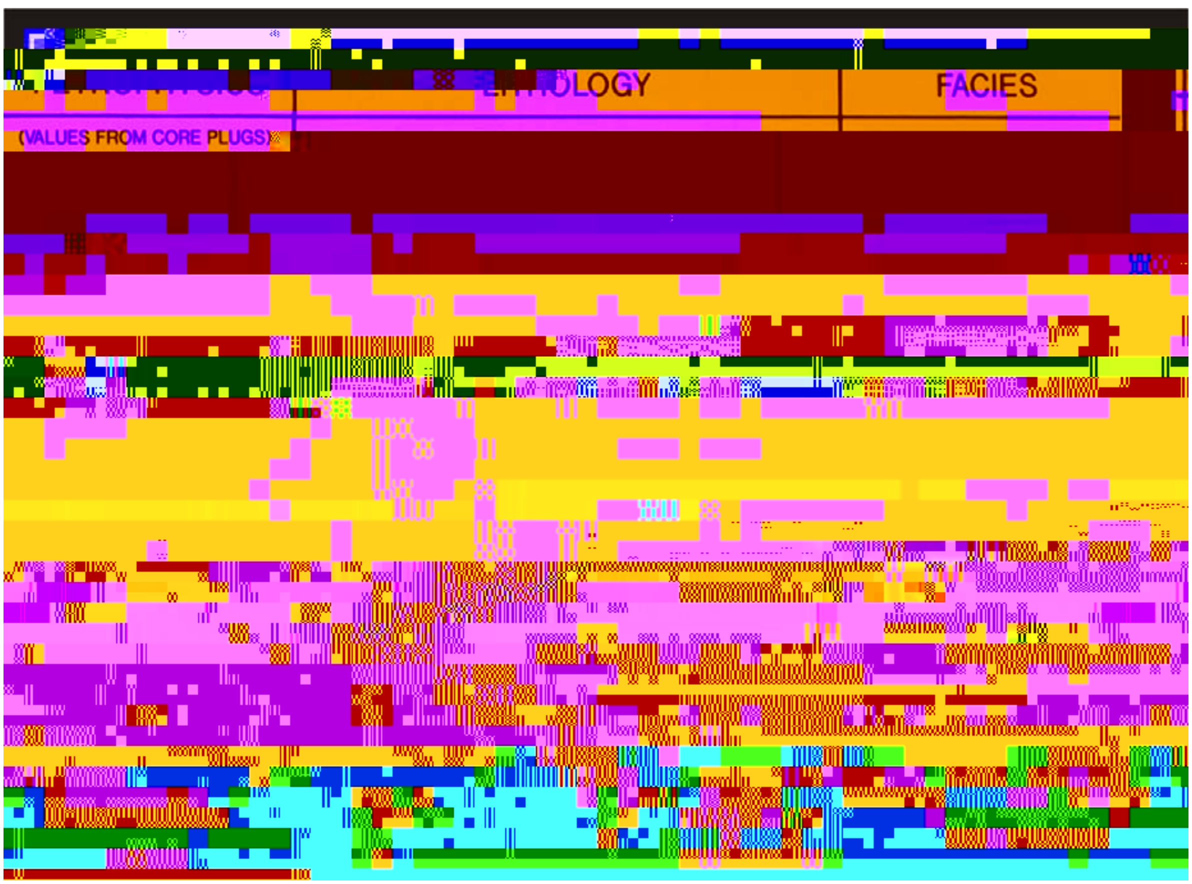

Figure 5: Core description of the Wilds channel presenting lithology, sedimentary structures, porosity and permeability values throughout the interval. Two calcareous ($CaCO_3$) cemented sandstone layers can be observed, one at the surface and the other near the basal portion of the channel.

Figure 6: (A) X-ray radiograph (6442' 11" - 6443' 7") showing current ripple and parallel lamination. The photomicrograph shows grain size, angularity and excellent pore/perm values consistent with a distributary channel facies. (B) X-ray radiograph (6450' 3" - 6450' 10") showing horizontal planar laminations as the main sedimentary structure. Photomicrograph shows grain size, angularity and excellent porosity typical of distributary channel sands.

PETROPHYSICS

Porosity and permeability data derived from the Elan computation of a modern suite of logs and from numerous 1" diameter plugs taken from the core, produce fairly constant values throughout the Wilds distributary channel. Figure 6 shows log porosity values tend to be lower than core plug values, whereas log permeability values are generally higher than those of the core plugs. The difference can be attributed to the fact that log-derived values are based on estimates of a number of petrophysical parameters for similar rocks. Core plug values represent direct measurements on the rock

CONCLUSIONS

The Wilds distributary channel complex forms part of a more widespread deltaic interval within the Paleocene Wilcox Group of thin stacked deltas. The distributary channel itself is a 63' thick interval consisting of fine to medium grained well-sorted sandstone that has cut into an interdistributary bay deposit. In the channel layers, flaser bedding, small current ripples and horizontal planer laminations are the predominant sedimentary struct

Penland, S., R. Boyd and J. R. Suter, 1988, Transgressive depositional systems of the Mississippi delta plain: a model for barrier shoreline and shelf sand development: Jour. Sed. Petrology, v. 58, p. 932-949.

Roberts, H. H., R. D. Adams and R. H. Cunningham, 1980, Evolution of the sand dominant subaerial phase, Atchafalaya delta, Louisiana: American Association of Petroleum Geologists Bulletin, v. 64, p. 64-279.

Roberts, H. H. and I. van Heerden, 1992, The Atchafalaya delta: an analog for thin deltas and subdeltas in the subsurface: Basin Research Institute Bulletin, v. 2, p. 31-42.

Serra, O., 1985, Sedimentary environments from wireline logs: Schlumberger, 211 p.

Teichert, C., 1958, Concepts of facies: American Association of Petroleum Geologists Bulletin v. 42, p. 2718-2744.

Zimmerman, R. K., 1994, Evidence of wrench faulting in north and central Louisiana: Basin Research Institute Bulletin, v. 4, no. 1, p. 53-61.

2. Reservoir Characterization

of the

Wilcox Miller Sandstone

East-Central Louisiana

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LSU Center for Energy Studies

June 2007

ABSTRACT

The Paleocene Middle Wilcox interval in east-central Louisiana typically consists of 15 major, easily correlatable sandstone bodies; six of which are oil producers. Of these, the Miller sandstone is one of the important reservoirs within this 800-ft interval. From 1959 to the present it has produced approximately 1.1 million barrels of 40^o to 49^o API gravity oil within the four township study area (4N/6E, 4N/7E, 5N/6E, 5N/7E). The depositional framework of the sandstone bodies was determined from detailed correlation and mapping, using 1007 E-logs in a 144 square mile area.

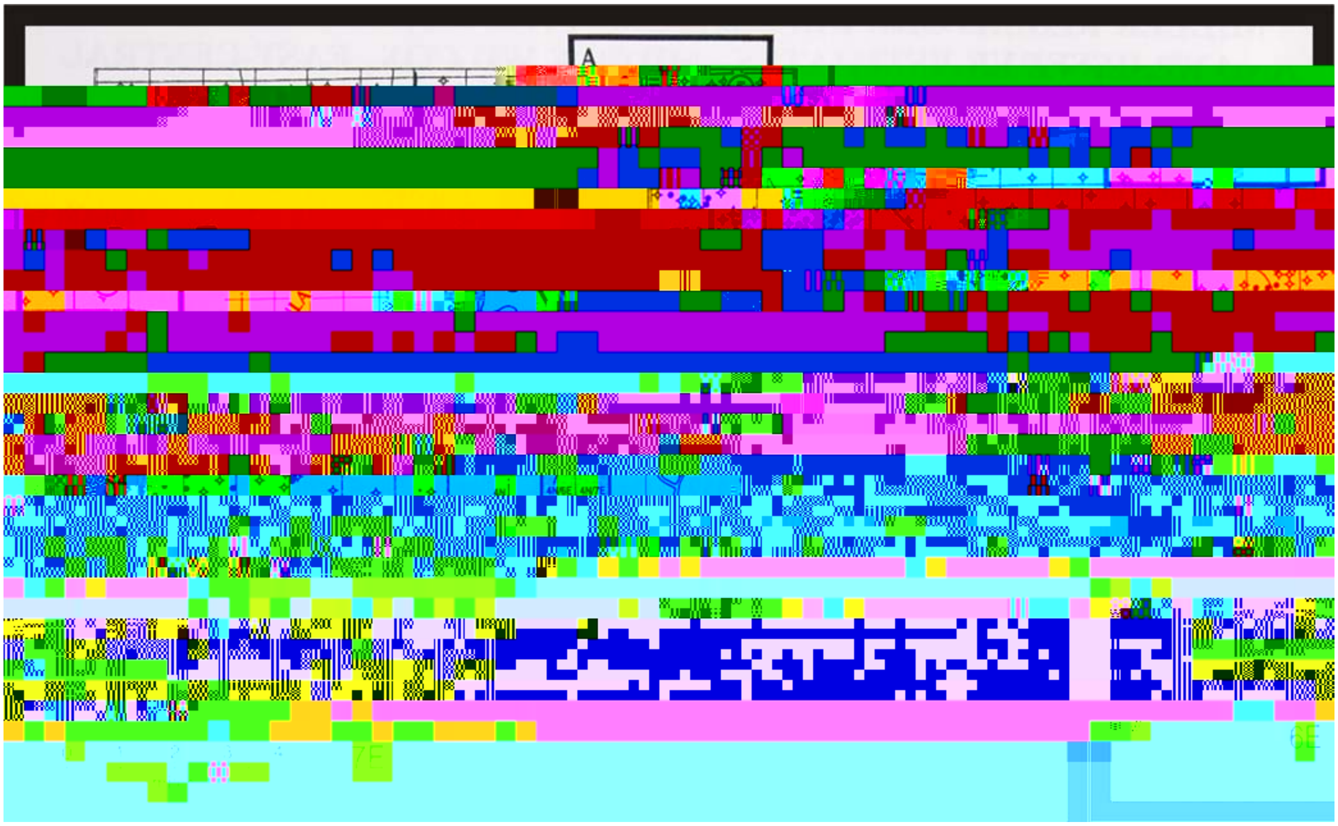

Figure 1: Location map of the four township study area showing the well coverage and the main Miller reservoir producing areas (1 to 12).

STRATIGRAPHY

The stratigraphy of the entire Wilcox Group in Louisiana has been described as consisting of alternating sandstone and shale and occasional lignite beds of Paleocene-Eocene age and deposited on top of the Paleocene Midway Group. The upper boundary of the Wilcox is formed by the Eocene Tallahata Formation (Galloway, 1968; Echols, 1991). The reservoir of interest in this study is the Miller sandstone located within the Middle Wilcox between the Big Shale

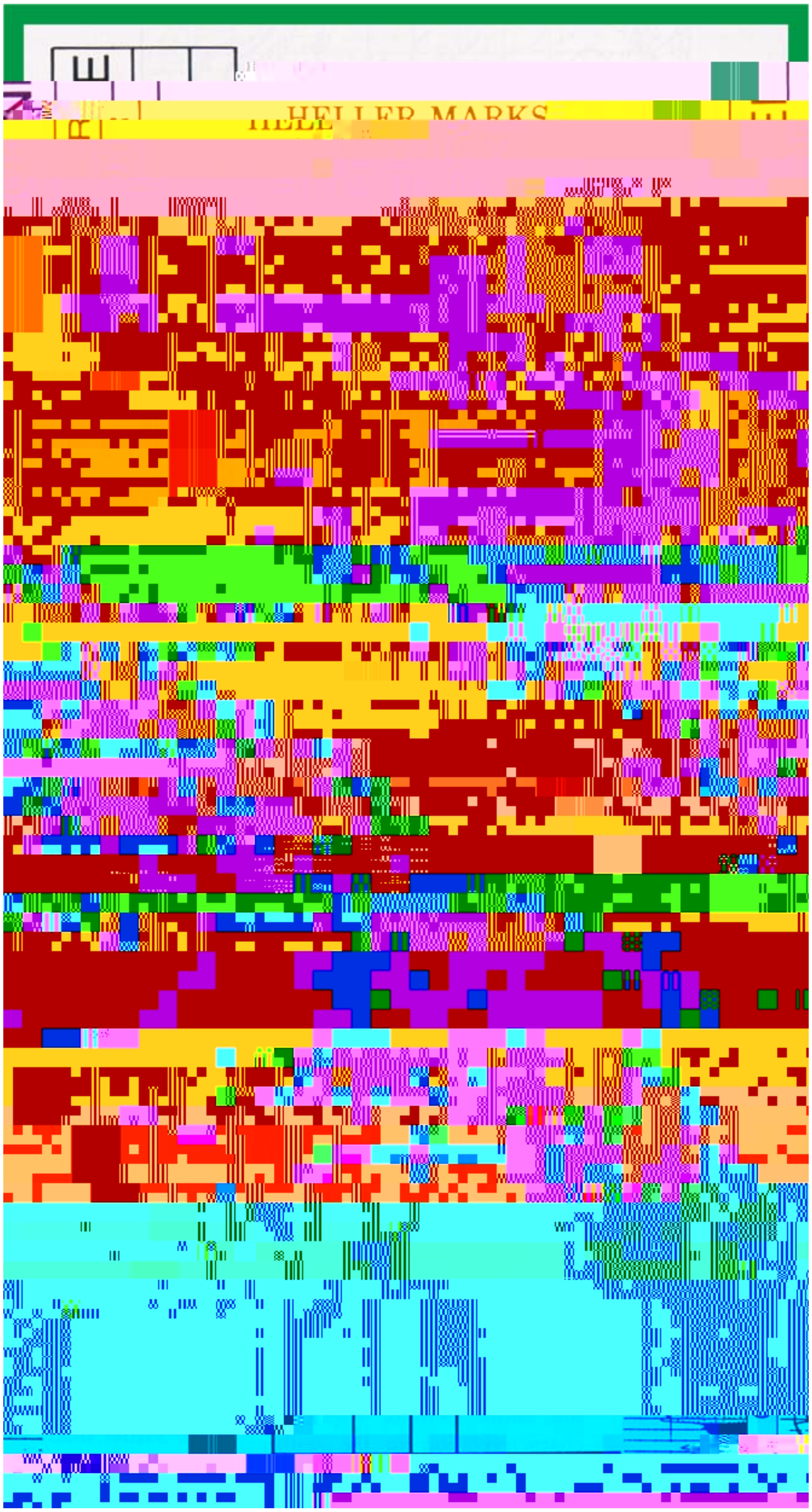

Figure 2: A representative e-log and stratigT1e1ћ

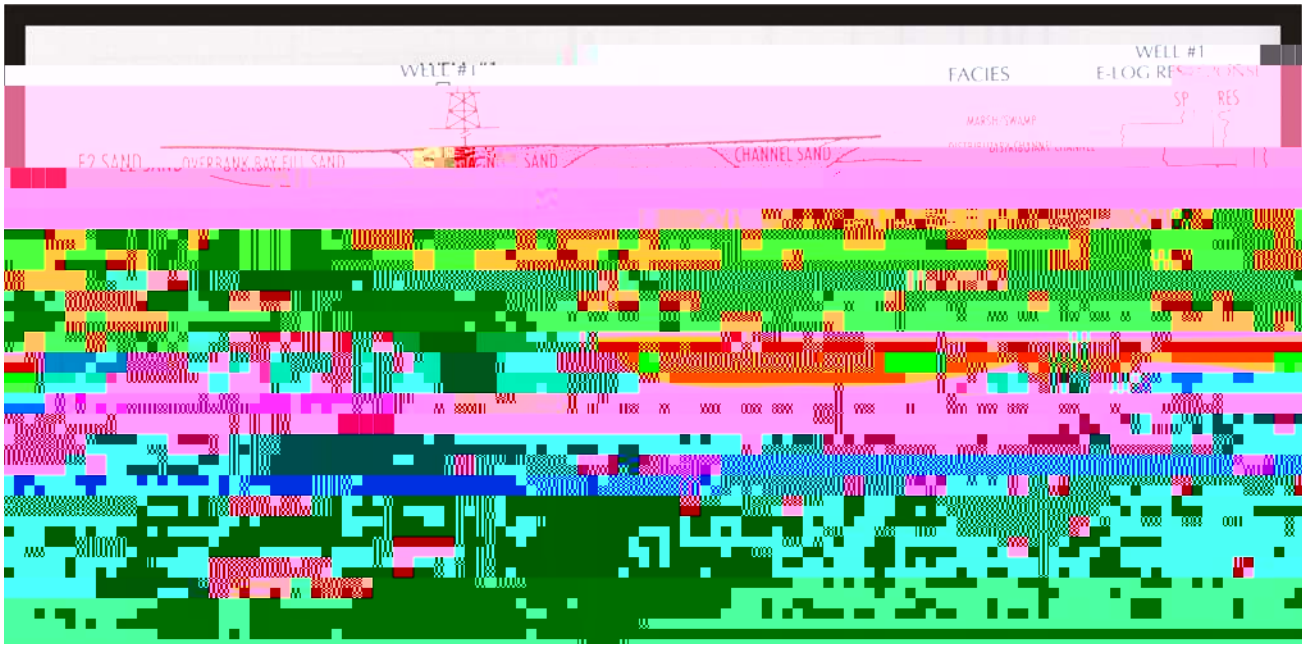

Figure 3: A model of the Middle Wilcox showing cyclic deposition within a deltaic environment.

MAPPING METHODS

Using basic concepts of electric log correlation (Tearpock and Bischke, 1991), the Miller sand was easily correlatable throughout the four township area. After completing the detailed correlation, the sand top and thickness data from 1007 E-logs was loaded into a mapping data file (TERRASCIENCE). Subsequently, a computer generated subsurface structure map on top of the Miller sandstone with a 50' contour interval and a scale of 1" = 2000' (1:24000) was obtained. It was found to be adequate for depicting the channel (Echols and Goddard, 1992). The width of the Miller distributary channel averages 1.5 miles and reaches a maximum sand thickness just over 100 feet. A number of crevasses formed along the length of the principal Miller channel. These breaches through the levees, shown in Figure 4B, allowed water and sediments to flow out into the overbank and interdistributary bay areas. Secondary channels and crevasse-splay deltas developed (see maps Appendix I). These features formed the principal conduits for sediment transport and constitute the overbank and bay fill facies. With widths of approximately 0.5 miles and thicknesses of 20 to 30 feet, dimensions of these sand bodies are considerably smaller than the distributary channel.

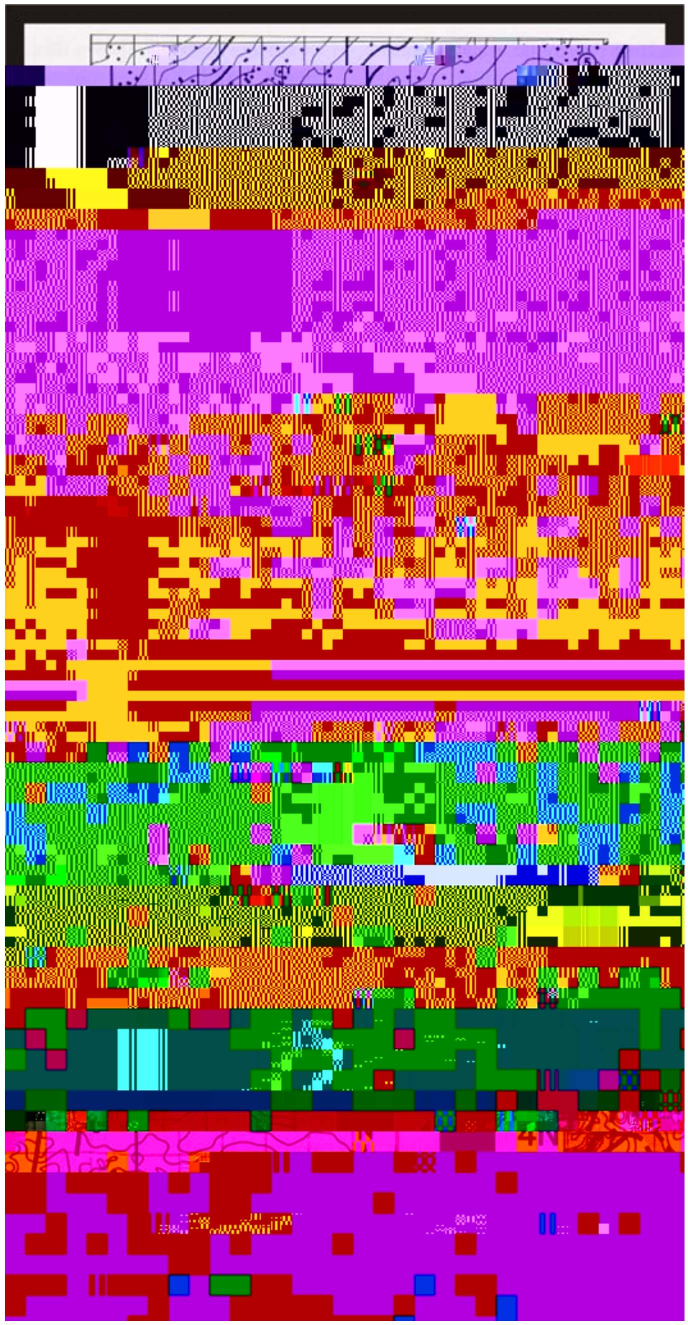

Figure 4: The regional structur

HYDROCARBON ACCUMULATION

Hydrocarbons have moved vertically up into the Miller reservoir through a process termed "stratigraphic

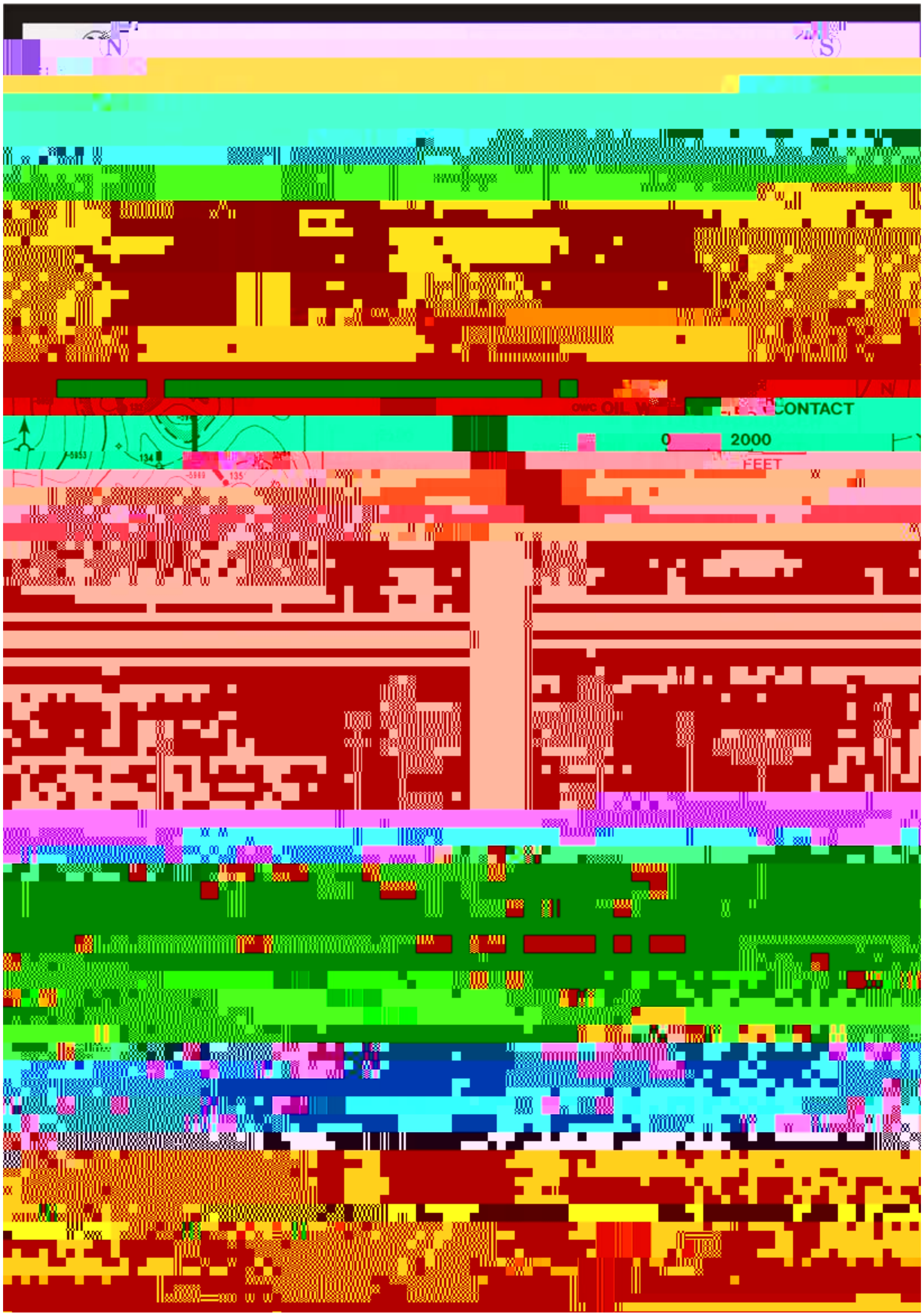

Figure 6: The stratigraphic trapping style in area 2 of Lake Curry field is a compaction anticline (A). The trapping style in area 4 of South Monterey field is a facies change that gives rise to an impermeable barrier (B).

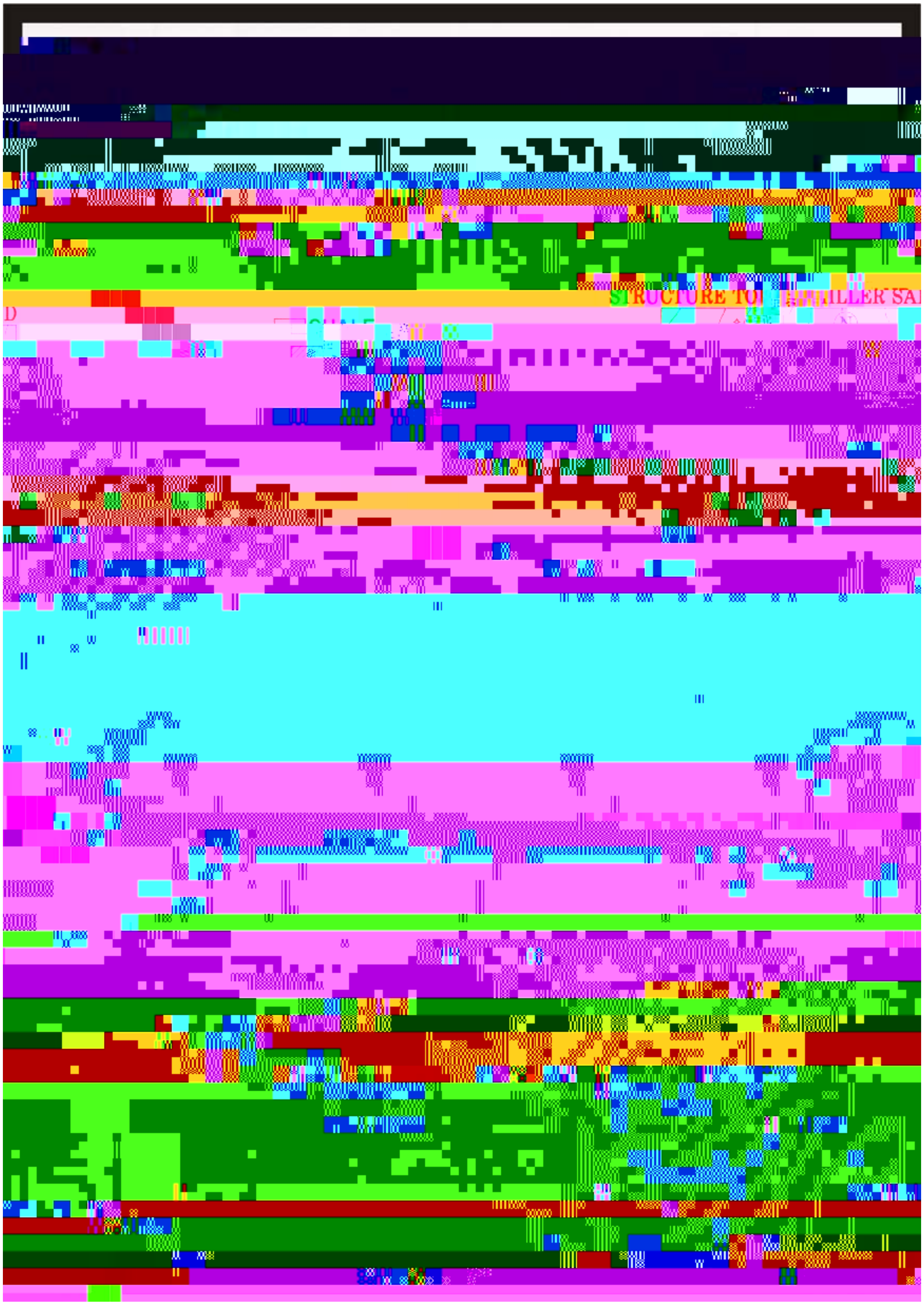

Figure 7: The straigraphic trapping style in area 6 of South Monterey field is a channel shale-out (A). The trapping style of area 3 of Bee Brake field is an updip shale-out (B).

RESERVOIR PARAMETERS

Water saturation for the Miller reservoir was estimated using the Archie equation:

$$Sw = \sqrt{\frac{F \times Rw}{Rt}}$$

Average porosity (Ø) of the Miller reservoir is 30% and because the typical formation factor (F) is given as $0.81/Ø^2$, the formation factor for the Miller is equal to 0.81/0.09 or 9. Water resistivity (Rw) for the Miller sandstone saturated with 80,000ppm is 0.02 (average Wilcox Rw) and the true formation resistivity obtained form the e-log is 1.5 Ω. Therefore, water saturation (Sw) is equal to: $\sqrt{\frac{9 \times 0.2}{1.5}}$ = 0.346 or approximately 35%.

In the study area, the depths below the surface to the reservoir range from approximately 5600' in the northwest to 6200' in the southeast sector. The Miller sandstone reservoir produces in the small and large distributary channels, varying in thickness from only 4 feet to 12 feet, and averaging 10 feet.. Reservoir pressure for different depths of the Miller reservoir can be estimated by multiplying an approximate pressure gradient of 0.466 psi/ft times the depth. In the study area, pressures range between 2500 psi and 2850 psi and average 2675 psi.

The reservoir temperature for different depths is 1.

REFERENCES

Echols, J.B., 1991, Sea level high stand shales and thin stacked deltas; Paleocene Middle Wilcox of Central Louisiana and Southwest Mississippi: GCAGS Trans., v. 41, p. 221-236.

Echols, J.B. and D.A. Goddard, 1992, STRATIGRAPHIC CAPTURE: a depositional process facilitating fluid and gas movement between porous and permeable beds: GCAGS Trans., v. 42, p. 333-340.

Ferrell, R.E. and G.M. Melancon, 1992, Microtextural analysis of Wilcox Formation potential reservoirs: Basin Research Institute Bulletin, v. 2, n. 1, p. 12-30.

Fisher, W.L. and J.H. McGowen, 1967, Depositional systems in the Wilcox Group of Texas and their relationship to occurrence of oil and gas: GCAGS Trans., v. 17, p. 105-125.

Galloway, W. E., 1968, Depositional systems of the Lower Wilcox Group, North-Central Gulf Coast Basin: GCAGS Trans., v. 18, p.275-289.

Goddard, D.A. and J.B. Echols, 1992, Significance of lignites in Paleocene Middle Wilcox stratigraphy in East Central Louisiana: GCAGS Trans., v. 42, p. 303-313.

Goddard, D.A. (Ed), 1995, Deltaic reservoir characterization: geological, petrophysical and Engineering applications: Basin Research Institute Technical Report No. 95-2, 123 pp.

Kaiser, W.R., 1978, Depositional systems in the Wilcox Group (Eocene) of East-Central Texas and the Occurrence of lignite: in Proceedings Gulf Coast Lignite Conference University of Texas, Austin: Bureau of Economic Geology, 23 pp.

May, J.A. and S.A. Stonecipher, 1990, Depositional environments of the Wilcox Group, Texas Gulf Coast: stratigraphic and early diagenetic signatures: GCAGS Trans., v. 40, p. 551-574.

Milton, N.J. and G.T. Bertram, 1992, Trap styles - a new classification based on sealing surfaces: AAPG Bulletin, v. 76, no. 7, p. 983-999.

Schenewerk, P., D. Goddard, and J. Echols, 1994, Reservoir characterization and preliminary modeling of deltaic facies, Lower Wilcox, Concordia Parish, Louisiana: GCAGS Trans., v. 44, p. 663-674.

Tearpock, D.J. and R.E. Bischke, 1991, Applied Subsurface Geological Mapping: Prentice Hall Inc., Englewood Cliffs, N.J., 647 p.

Tye, R.S., T.F. Moslow, W.C. Kimball and C.W. Wheeler, 1991, Lithostratigraphy and production characteristics of the Wilcox Group (Paleocene-Eocene) in Central Louisiana: AAPG Bulletin, v. 75, no. 11, p. 1675-1713.

Williams, L.B., B.R. Wilcoxon, R.E. Ferrell and R. Sassen, 1991, Diagenesis of ammonium during hydrocarbon maturation and migration: Basin Research Institute Bulletin, v. 1, n. 1, p.21.

Table 1. Milk production

Table 2. Miller Reservoir Reserve Estimates

AREA	FIELD	LOCATION	RECOVERABLE OIL (STB)	CUMULATIVE PRODUCTION (bbl)	% OF STB PRODUCED	NO. OF WELLS	YEARS	TRAP TYPE
2	7	1	1977-80	CHANNEL SHALE-OUT	1. DISC BOOK	SEC 8 4N-6E	186,200	13,79
3	22	4	1964-84	COMPACTION	2. LAKE	SEC 16	210,000	45,40

3. Organic Geochemistry of Wilcox Shale, Coal, and Oils Concordia Parish, Louisiana.

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LSU Center for Energy Studies

June 2007

ABSTRACT

Results of an organic geochemical study of Middle and Lower Wilcox rocks and oils from a conventional core taken in Concordia Parish, Louisiana, helped determine the potential organic facies thermal maturity and enabled oil-rock correlations. The geochemical techniques applied included: (1) total organic carbon (TOC) and Rock-Eval analyses; (2) visual kerogen analysis for vitrinite reflectance and kerogen typing; (3) whole extract gas chromatography (gc); 4) whole oil gc; (5) pyrolysis-gas chromatography (py-gc) of S_1 and S_2 , and (5) gas chromatography-mass spectrometry (gc/ms) of

Wilcox shales are thermally immature and incapable of sourcing crude oils. However, in the southern Gulf Coast, organic rich Wilcox shales are thermally mature and, in part, responsible for sourcing the Wilcox reservoirs in south Louisiana and Texas (Chinn, 1992).

As part of a detailed sedimentological, geochemical, petrophysical, and petroleum engineering study of the Bee Brake Field in east-central Louisiana, a continuous 510 foot conventional core was taken in the Angelina BBF No. 1 well (Schenewerk et al., 1994, Goddard, 1995) (Figure 1). The core was sampled in several middle and lower Wilcox shale and coal intervals for organic and geochemical analyses. Oil samples from the productive Minter interval were also analyzed geochemically. The objectives of this detailed organic geochemical study were the following: (1) determine organic matter and depositional variations within the cored interval; (2) determine the thermal maturity of the shales and coals; (3) identify the organic maturities and organic facies of the source rock for the Minter oil and (4) use the results of this study for oil-oil and oil-source rock correlation comparisons with data from previous regional studies.

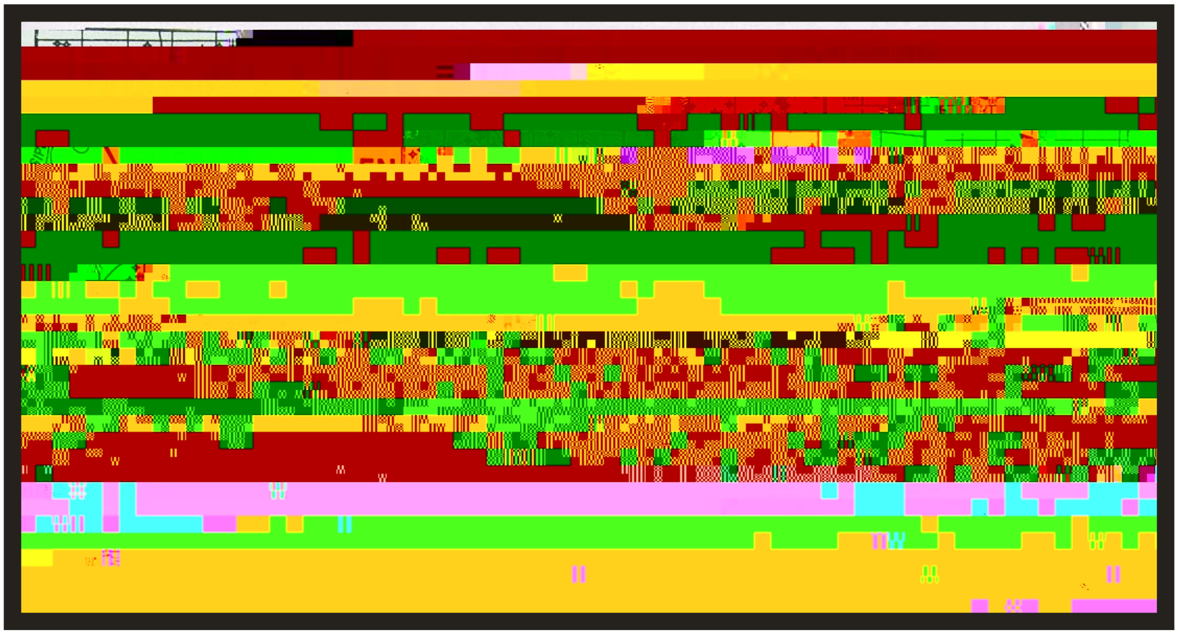

Figure 1: Location map showing where the core was taken in Bee Brake Field in Concordia Parish.

METHODOLOGY

Twenty-six rock samples from seven coal and nineteen shale beds were selected for analyses from Middle to Lower Wilcox core interval between 6361'3" and 6871'8" (e-log depths) (Figure 2). Also, one crude oil sample from the productive Minter reservoir in the lower Angelina sandstone at 6756'-6758' and an oil extract from the upper Bee Brake sandstone at 6744' were analyzed. The following organic geochemical techniques were used in the analysis of the rocks and oils: (1) Total organic carbon (TOC) and Rock-Eval analyses were completed on all twenty-six rock samples; (2) visual kerogen analysis techniques were employed for v.9 Tw[.1wp)3.7(e)4(i)3.70 0 4(t)4

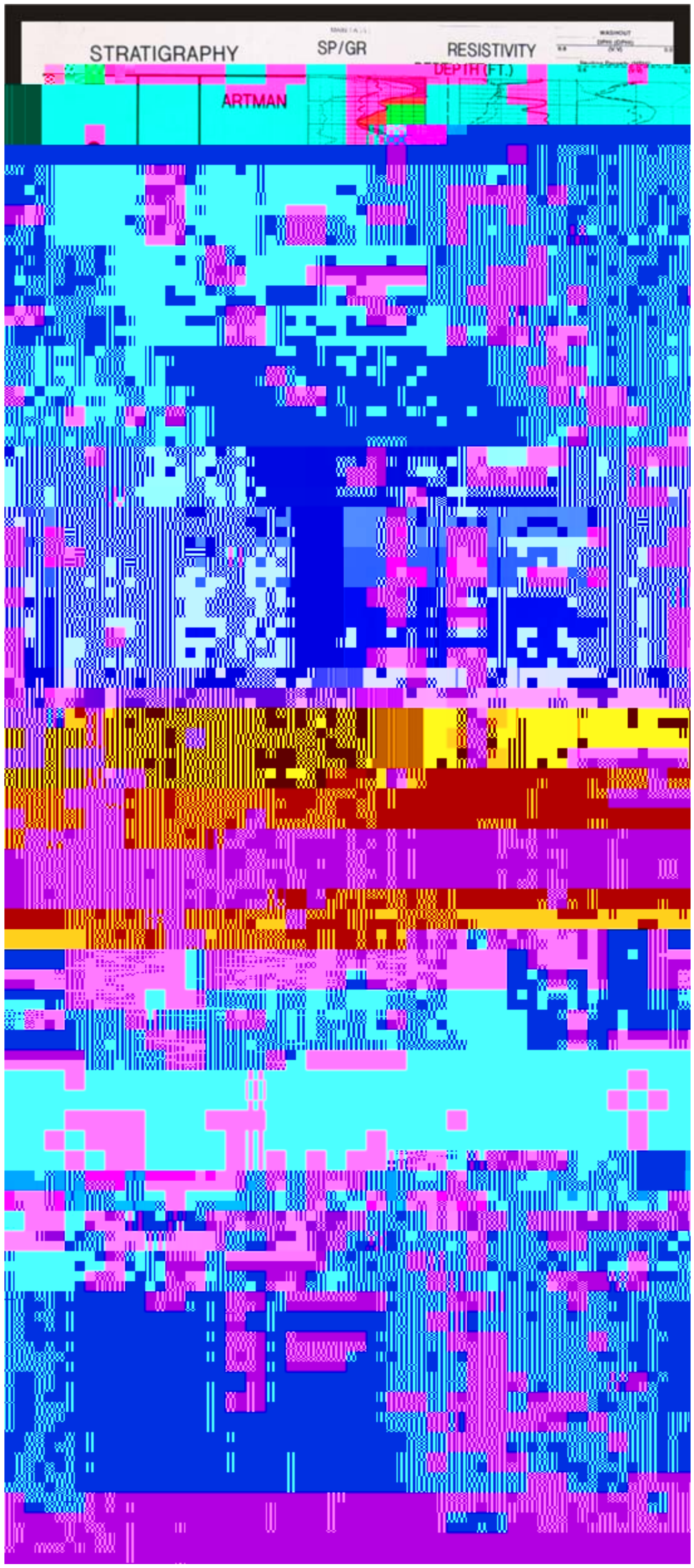

Figure 2: The cored interval in the Angelina BBF No.1 well between 6361' 3' and 6871' 8' showing the coal layers and the Minter reservoir from which the oil samples were selected.

TOC ROCK-EVAL PYROLYSIS

Based on the results of the TOC and Rock-Eval analyses (Table 2) the rock samples could be subdivided into

KEROGEN PETROGRAPHY

Results from the kerogen microscopy show a 0.44% R_o mean reflectance for both the coals and the shales. The reflectance data places the coals within the thermally immature lignite - subbituminous rank.

Group 1 coals and shales are petrographically different. The coals contain 5 to 15% structured lipids comprised mainly of resinite and sporinite with subordinate liptodetrinite and cutinite. Desmocollinite, a lipid-rich vitrinite (VL) is prominant in all these coals. Amorphous kerogen is absent in the coals. The shales, however, have 10 to 75% amorphous kerogen but less structured lipids and lipid-rich vitrinite when compared to the coals. The amorphous kerogen in the shales is hydrogen rich, thus having good potential for oil generation.

Group 2 shales contain 50 to 85% amorphous kerogen, 10% structured lipids and little or no lipid-rich vitrinite. The kerogens have low oil and gas generating potential.

Group 3

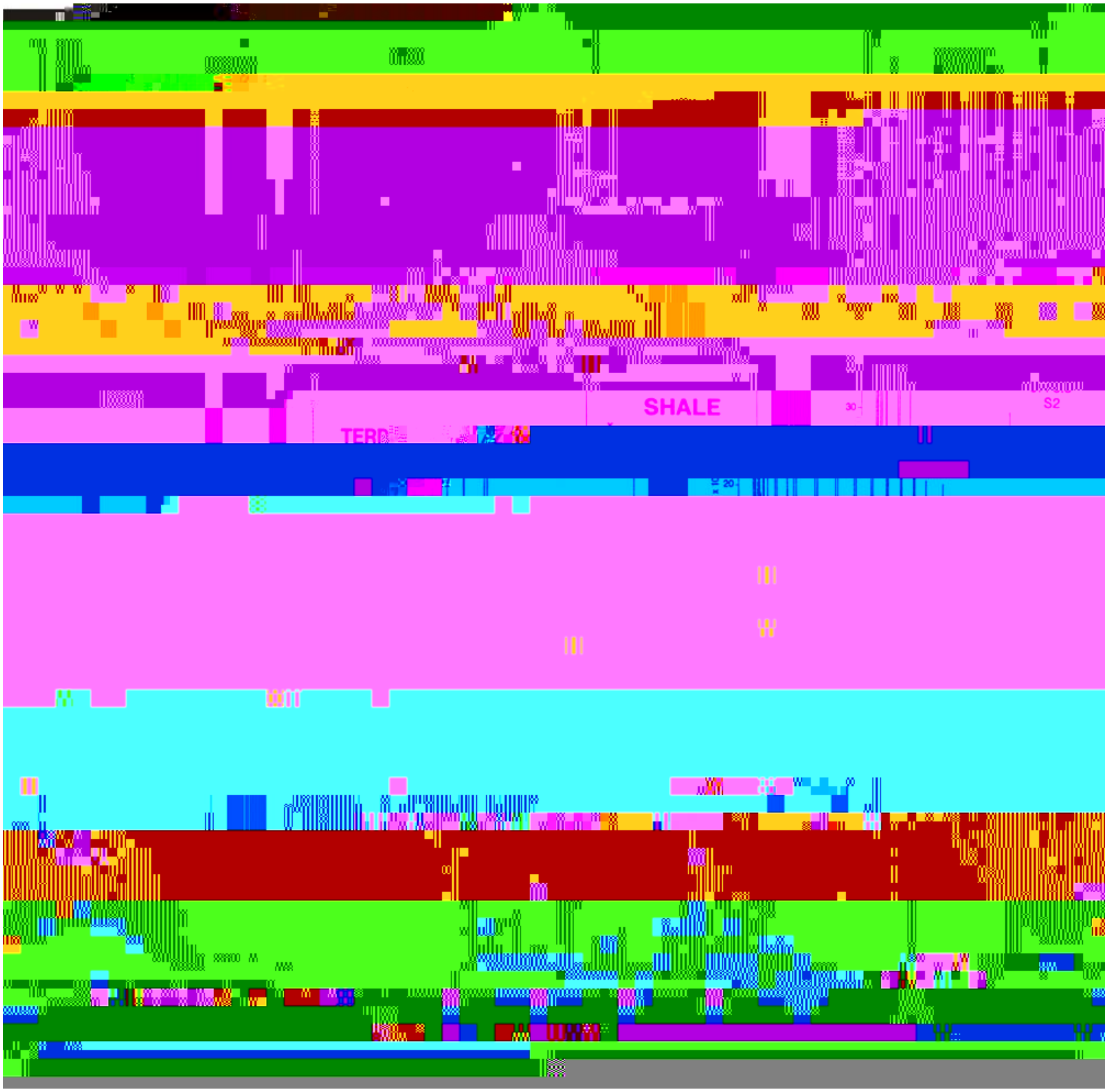

Figure 4: (A) The pyrolysis gas chromatogram (S2) of a coal (6619') and two shales (6770' & 6507') indicate that the shales do not exhibit the high C25+ waxy components of the coal. In (B) the gc-ms analysis of terpanes (m/z -191) in the coal, shale, and oil samples shows that the oil is quite different from the rocks.

WHOLE EXTRACT AND WHOLE OIL GC

Whole extract gas chromatograms of 7 coals and 9 shales indicate that they are immature and contain essentially terrestrial organic matter. Whole oil gas chromatograms of the Minter oils (Angelina and Bee Brake) are very similar with a minor but significant presence of C_{25+} n-alkanes. This suggests the source rock consisted of mixed organics with significant terrigenous components. The oils were expelled at a thermal maturity of about 0.80 - 0.90 R_o equivalent. The chromatograms in Figure 5 show the similarities between the shale and coal and their definite lack of correlation with the Minter oil.

CONCLUSIONS

The core interval (6361'3" - 6871'8") from the Angelina BBF No. 1 Well, Bee Brake Field, Louisiana contains several thin beds of immature (mean reflectance 0.44% R_o), coals and organic-rich to organic-lean shales with dominant terrigenous organic matter constituents. Based on TOC values and amorphous kerogen content these samples could be separated into four groups. The strata represent middle and early Wilcox deposition in a lower delta plain environment. Reflectance data places the coals within the lignite-subbituminous rank. The coals (6492', 6584'5", 6619', 6742'5", 6758', 6798' and 6814') and organic-rich shales (6525', 6648', 6770' and 6824') contain oil-prone Type II-III kerogen capable of generating oil at adequate maturity. Kerogen petrography data support their deposition on a lower delta plain. These

TABLE 1: Shale, coal and oil samples from Angelina BBF No. 1 well.

Depth (Feet)	Sample	TOC Rock Eval	Kerogen Petrography	Whole Extracxt & Oil GC	Pyrolysis GC	GC Mass Spec & Biomarkers
6770'	Shale	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6795'	Shale	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Coal	X	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Shale	X	[illegible]	[illegible]	[illegible]	[illegible]
6824'	Shale	X	[illegible]	[illegible]	[illegible]	[illegible]
6864'	Shale	X	[illegible]	[illegible]	[illegible]	[illegible]