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SHALLOW GAS POTENTIAL

E&P OPPORTUNITIES
FOR THE
INDEPENDENT OPERATOR

By

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Abstract

In the Louisiana coastal areas south of Lake Pontchartrain and in the offshore waters to the east, deep Miocene - Oligocene sands have been prolific producers of hydrocarbons. Also, the subsurface of southeastern Louisiana's "Florida Parishes" area north of Lake Pontchartrain and east of the Mississippi River is known for its Upper Cretaceous (Tuscaloosa) production. However, little attention has been given to the gas potential of the Miocene interval located beneath the thick (2000-3500 feet or 610-1067 meters) Plio-Pleistocene fresh water aquifer and above the Oligocene *Heterostegina* limestone and Frio interval.

Preliminary regional mapping of the Miocene interval shows that it thickens to 4000 feet (1220 meters) in a southerly direction. The interval, consisting mostly of fluvio-deltaic, stacked distributary channels, has a high sand/shale ratio (>60%). By applying standard log correlation techniques, the Miocene sequence is divided into 4 correlatable units each of which contains gas reservoir sands. The underlying Oligocene Frio interval consists mostly of shallow water marine deposits and its uppermost sand is a gas reservoir. Both Miocene and Upper Oligocene gas appear to be biogenic methane similar to that found up-dip in Mississippi and in coastal Alabama. The methane source is from interbedded lignites located within this interval. Reported production from the sands has ranged between 100 and 600 thousand cubic feet per day (3-18 thousand cubic meters per day). The overall geologic framework is presented with particular emphasis placed on illustrating the depositional environments and trapping mechanisms associated with these shallow gas reservoirs. These mechanisms are mainly stratigraphic in nature with a minor structural component in some areas.

Introduction

The deep subsurface in southeastern Louisiana is well known for its Upper Cretaceous (Tuscaloosa) and Paleocene-Eocene (Wilcox) production (Howe, 1962; Thomson, 1979; Franks, 1980; Self et. al., 1986; Johnson and Johnson, 1987; Miller and Groth, 1990; Corcoran et al., 1993; Fillon et. al., 1998; Goddard et. al., 2002a, 2002b). In the Louisiana coastal areas, south of Lake Pontchartrain and in the offshore waters east of the lake, the deeper Miocene sands have been prolific producers of oil and gas (Limes and Stipe, 1959; The New Orleans Geologic Society Study Group, 1962; Rainwater, 1964; Thorsen, 1964; Curtis, 1970; Smith and Tieh, 1984). However, the "Florida Parishes" located north of Lake Pontchartrain and east of the

Mississippi River (Fig. 1) have only recently received minor interest with regard to their Miocene/Oligocene gas potential. In this area, the Miocene/Oligocene shallow marine and fluvio-deltaic deposits of interest are located beneath a thick (2000- 3500 feet or 610-1067 meters) Plio-Pleistocene fresh water aquifer (Southern Hills Aquifer System) (Fig. 2).

Between 1990 and 1993, a few independent operators, seeking deeper Tuscaloosa and Wilcox production, encountered commercial Miocene/Oligocene gas sands in the West and East Feliciana Parishes. Commonly, the interval has a high sand/shale ratio (>60%). Recent commercial gas discoveries in the shallow Miocene of the western-most part of the Florida Parishes and in offshore Mississippi-Alabama to the east have similar stratigraphic intervals and depositional environments. This suggests that the intervening areas in the Florida Parishes may also be capable of containing significant, shallow natural gas reserves. Recently, some independents have been developing exploration programs aimed at locating these shallow gas reservoirs.

The objectives of this paper are twofold: 1) to provide a regional geologic framework of the Miocene/Oligocene deposits in the parishes of West Feliciana, East Feliciana, East Baton Rouge, Saint Helena, Livingston, Tangipahoa, Washington, and Saint Tammany, and 2) to provide basic information regarding the sedimentological characteristics and depositional environments of these deposits. An attempt is made to delineate areas that appear to have the best possibility of containing commercial quantities of relatively shallow Miocene/Oligocene gas. However, in the final analysis, geochemical and geophysical techniques probably will be required to define trends, determine the exact location of potential gas reservoirs and estimate reserves.

Study Area

The study area covers approximately 5800 square miles. Regional mapping was performed over the entire area. However, detailed log correlations and reservoir studies were made in the northernmost four parishes near the Mississippi State line because these were found to contain most of the Miocene/Oligocene gas bearing sands. Surface elevations of the Pleistocene terraces that cover the northern part of the area range between 250 and 380 feet (76-116 meters) (Howe, 1962).

Stratigraphy

The lowermost interval of interest is the Oligocene Frio consisting of an interbedded sandstone and shale sequence that rests conformably on the Vicksburg Shale (Fig. 3). The Frio interval is from 1000 to 1800 feet (305-550 meters) thick with its uppermost limit being overlain by a 200 to 600 foot thick (60-180 meters) sequence of limestone, calcareous sandstone and shale of the Anahuac Formation (Howe, 1962). This Upper Oligocene interval can be identified throughout the study area from the well logs because of its characteristic limestone beds (*Heterostegina* lime or " Het lime"). A Miocene clastic sequence (Napoleonville, Duck Lake, and Clovelly Formations) overlies the Oligocene Anahuac Formation. In the northwestern part of the study area, the Miocene interval, consisting of interbedded sandstone, shale and rare, thin (<20 feet or 6 meters) lignite or "coal" beds, ranges from 800 feet (244meters) to approximately 2000 feet (610 meters) in thickness.

A thick (100 to 400 feet or 30 to 122 meters) interdistributary bay shale interval is located below the Plio-Pleistocene aquifer (Stringfield, et al., 1957; Self, 1986). It behaves as a regional seal to the underlying Miocene gas reservoirs (Fig. 2). Wireline electric log evidence indicates the shale interval contains lignite beds that may also possibly source methane gas to occasional sandstone reservoirs observed within this interval.

Structural Characteristics

Preliminary regional mapping based on tops picked from wireline log correlations resulted in structural maps on top of the intervals of interest (Fig. 4 a, b). The structure on top of the Miocene, just below the Plio-Pleistocene Southern Hills Aquifer (thickness ranges between 2000 feet or 610 meters and 3400 feet or 1036 meters), shows a distinctive south plunging structural nose in East Feliciana Parish (Fig. 4a). It appears that this feature is partly responsible for trapping the gas in the Miocene reservoirs in this area. A detailed structural map on the top of the Miocene (Fig. 5) clearly depicts the south trending structural nose. Another interesting characteristic about this interval that was observed on some electric logs of the region is that it thickens in a southerly direction to about 4000 feet (1220 meters). Regarding the structure on top of the Oligocene (Het lime), it dips gradually in a southerly direction from -3000 feet (-915 meters) to -7000 feet (-2134 meters) near Lake Pontchartrain (Fig. 4b).

Depositional Environments

Published literature describing depositional environments of the Miocene/Oligocene interval of interest in the Florida Parishes is scarce. However, two papers are noteworthy (Rainwater, 1964; Krutak and Beron, 1992). Furthermore, because core data is also lacking, the combination of electric log interpretations and detailed net sand mapping of individual sand bodies provide the only adequate information for facies identification. Using these methodologies and the log evidence of lignite or coal layers within the Miocene, it follows that the sediments were deposited in a lower delta plain setting (Fig. 6). Therefore, the thicker sand bodies, the principal sedimentary feature in the Miocene, are interpreted to be stacked distributary channels (Fig. 7). These individual sand bodies can be as thick as 300 feet (91meters). Thinner sand bodies are probably associated with crevasse splay deposits and bay fill facies. The interbedded shale and siltstone layers are most probably associated with interdistributary bay and marsh facies deposits (Fig.6).

The Upper Oligocene Anahuac interval consists of limestone, calcareous sandstone and shale. Based on these lithologies and the position of the Oligocene with respect to shallower Miocene deltaics, leads one to believe that these sediments were deposited in a marine environment. The underlying thick sandstone and interbedded shale sequence of the Frio Formation are also interpreted by us to be shallow marine deposits and that the stacked sandstones are distributary mouthbars and/or barrier bars.

Characteristics of the Gas Reservoirs

The gas, which is primarily methane from a biogenic origin similar to that found in Mississippi and Alabama (Champlin et. al., 1994), probably has its source in the lignites of the thick interdistributary shale and/or lignites observed in the Miocene section. Quite possibly the gas was emplaced into the Miocene/ Oligocene sandstone reservoirs through a process termed "stratigraphic capture" (Echols and Goddard, 1992). This process is simply the vertical and/or lateral movement or flow of gases (and fluids) between porous and permeable facies. The communication route between beds occurs as a result of scouring and channel filling during the development of distributary channels, or infilling of bar sands or scoured tidal channels (Fig. 8). However, both the vertical and lateral migration of the gas may be partially or completely restrained by changes in the petrophysical and mineralogical parameters of the intervals/formations involved.

Using standard electric log correlation techniques, it was possible to divide the Miocene interval into four correlatable units (Fig. 9). Unlike the sand channels that are difficult to correlate over long distances, some of the shale layers could be and these helped to roughly delineate the units. Detailed correlations of the lithologies within the sand-shale sequence using gamma ray, spontaneous potential, and resistivity curves on the logs permit fairly reliable subdivisions. The exercise was mainly an attempt at correlating the gas producing reservoirs within the Miocene. It was observed that in both West and East Feliciana Parish, sandstones within each of the units have tested gas. Typically, the Miocene sandstone channels are 50 to 100 feet thick (15 - 30 meters), thinly laminated sandstone bodies with a 12 to 16 feet (3.5-4.8 meters) gas cap resting on water (Fig. 10). In order to help avoid rapid coning, well completions are usually realized through the perforation of the uppermost two feet of the gas reservoir. In this area, this completion technique has resulted in production rates of 100 to 600 thousand cubic feet of gas per day (mcfd). Examples of these rates can be observed in the listing of some of the Miocene/Oligocene gas producers in West and East Feliciana Parishes (Fig. 11). In a Florida Parish's example (Fig.12), amplitude variation with offset (AVO) processing of 2D seismic lines have been used to locate gas induced bright spots in the Miocene and to delineate approximate dimensions of the respective potential reservoirs.

Within the Oligocene, just below the Anahuac (Het lime) interval, the first sandstone body is considered the top of the Frio Formation. In several areas this first "Frio sand" has tested gas. Commonly, the gas is trapped in the reservoir in the uppermost 10 to 20 foot (3 - 6 meters) section of thinly laminated sandstone bodies whose thickness ranges from 100 to 175 feet (30 - 53 meters) (Fig. 13). These thin gas capped reservoirs, like those of the Miocene, also rest on thick water sands and must be perforated high to avoid rapid coning of the underlying water. The limestone and shale layers within the Anahuac act as seals to the gas reservoirs which are generally found in the uppermost Frio sandstone layer.

Trapping Mechanisms

It is a well-known fact that deltaic and shallow marine clastic reservoirs in southeastern Louisiana are associated primarily with subtle stratigraphic and structural traps, or a combination of these. Reservoirs in the shallow Miocene /Oligocene intervals in the study area are no exception. Evidence indicates that, as the gas moves within the Miocene/Oligocene sands, it accumulates primarily in four types of traps or their combination (Fig.14). The first type (structural), termed "compaction anticline" by Milton and Bertram (1992), is a depositional topographic high within a main distributary channel or secondary channel. These highs are formed through differential compaction of surrounding sediments, normally shale, outside the thick sand channels and result in structural/stratigraphic traps (Fig. 14a). Normally, this domal type of trap is sealed by a combination of overlying argillaceous lignite or shale that drapes over the sandstone high.

The other types of traps (stratigraphic), each of which results from facies changes, are those manifested as subtle permeability barriers between sand bodies (Fig. 14b), the "channel pinch-out" (Fig. 14c), and the "shale-out" (Fig. 14d). Subtle permeability barriers are usually difficult to detect using electric log correlations alone and sidewall samples are necessary for determining permeability. Because of the predominance of a network of stacked braided channels, compaction anticlines and channel pinch-outs are probably the most prevalent types of traps recognized in the study area.

Economic and Reserve Considerations

Based on supply-economic-regulatory conditions in the early 1990's, such as declining reserves, rising gas prices and the favorable Federal Energy Commission's restructuring rules (Order 636), there was an increase in the number of rigs drilling for gas prospects. As a result of this activity, a few important gas finds were made by independents in shallow Miocene sands in the Gulf Coast area. Probably the most significant of these was in offshore Alabama in and adjacent to Mobile Bay. Although small by comparison to that area's deeper ~20,000 feet (610 meters) Jurassic Norphlet sour gas reservoirs, these shallow (3000 feet/915meters) Miocene gas plays, at the time of their development, added considerably to Alabama's offshore gas production of some 700 million cubic feet per day (mmcfd). In 2003 a similar situation exists for the Florida Parishes, but with gas prices above $5/mcf instead of $2 /mcf of the early 1990's.

Small gas prospects with reserves in the order of 250-500 mmcf were also first exploited in 1990-1993 in shallow Miocene/Oligocene sands in Louisiana's West and East Feliciana Parishes (Figs. 10, 13). It has been observed that the shallow Miocene trend in Alabama is traceable across Mississippi, through southeastern Louisiana's Florida Parishes to as far west as the Mississippi River (Howe, 1962; Champlin, 1994). Although not yet as prolific as Alabama's Mobile Bay shallow gas fields, production from 10-15 feet gas columns in wells in East and West Feliciana Parishes have tested 100-600 mcfd (Fig. 11). Because of the regional extent of potential reservoirs in the Florida Parishes (approx. 5800 square miles), the probabilities of finding significant accumulations of shallow Miocene/Oligocene gas pockets are considered to be high. These shallow prospects make it economically feasible for small independent producers to become involved in gas exploration.

Another similar example, but of different age, is the biogenically sourced prolific shallow gas producing Eocene Wilcox deltaic reservoirs in northern Louisiana (Echols, 2000, 2001). Located in 2300 square miles of Winn Parish, the area has produced 330 billion cubic feet of gas up to 1993. Furthermore, over one trillion cubic feet of remaining reserves have been estimated for this area. Geochemical evidence indicates that this gas is also sourced from interbedded lignites/coals. With all of these similarities and the fact that the study area is twice the size, substantial gas reserves might be expected for the Florida Parishes of southeastern Louisiana.

Summary

Because of environmental concerns, gas has become the fuel of choice over the past few years. For this and other reasons, demand for gas is steadily increasing. Because the Miocene/Oligocene gas reservoirs of the Florida Parishes are quite shallow, the economics of these low rate producers (100-600 mcfd) are ideally suited for the small operator. However, most operators consider that these gas volumes do not justify shooting expensive 3D seismic surveys. Therefore, AVO reprocessing of existing 2D seismic lines is the technique being applied successfully for locating the shallow gas reservoirs. Such reserves as those estimated for areas of northern Louisiana, if found in the study area, would represent significant earnings for independent producers able to operate with reduced capital and operational expenses. Successful production of these reserves would also provide a tax revenue value (based on $0.12/mcf average state tax rate) of several million dollars to the state of Louisiana from gas taxes alone.

Acknowledgements

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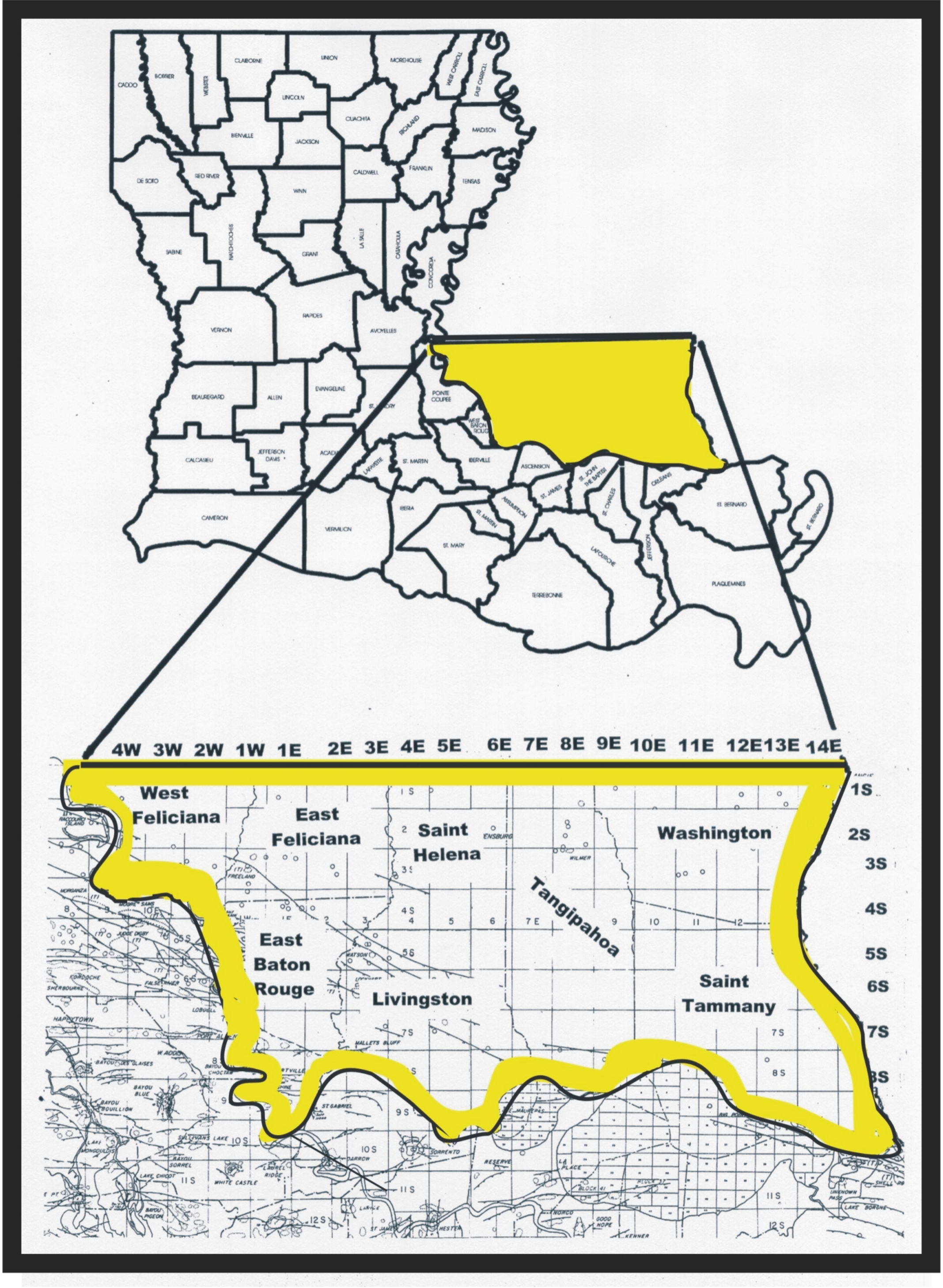

Figure 1. Location map of southeast Louisiana's Florida Parishes located between the Mississippi River to the west and the Mississippi State boundary to the east and north. Together, the Parishes cover approximately 5800 square miles.

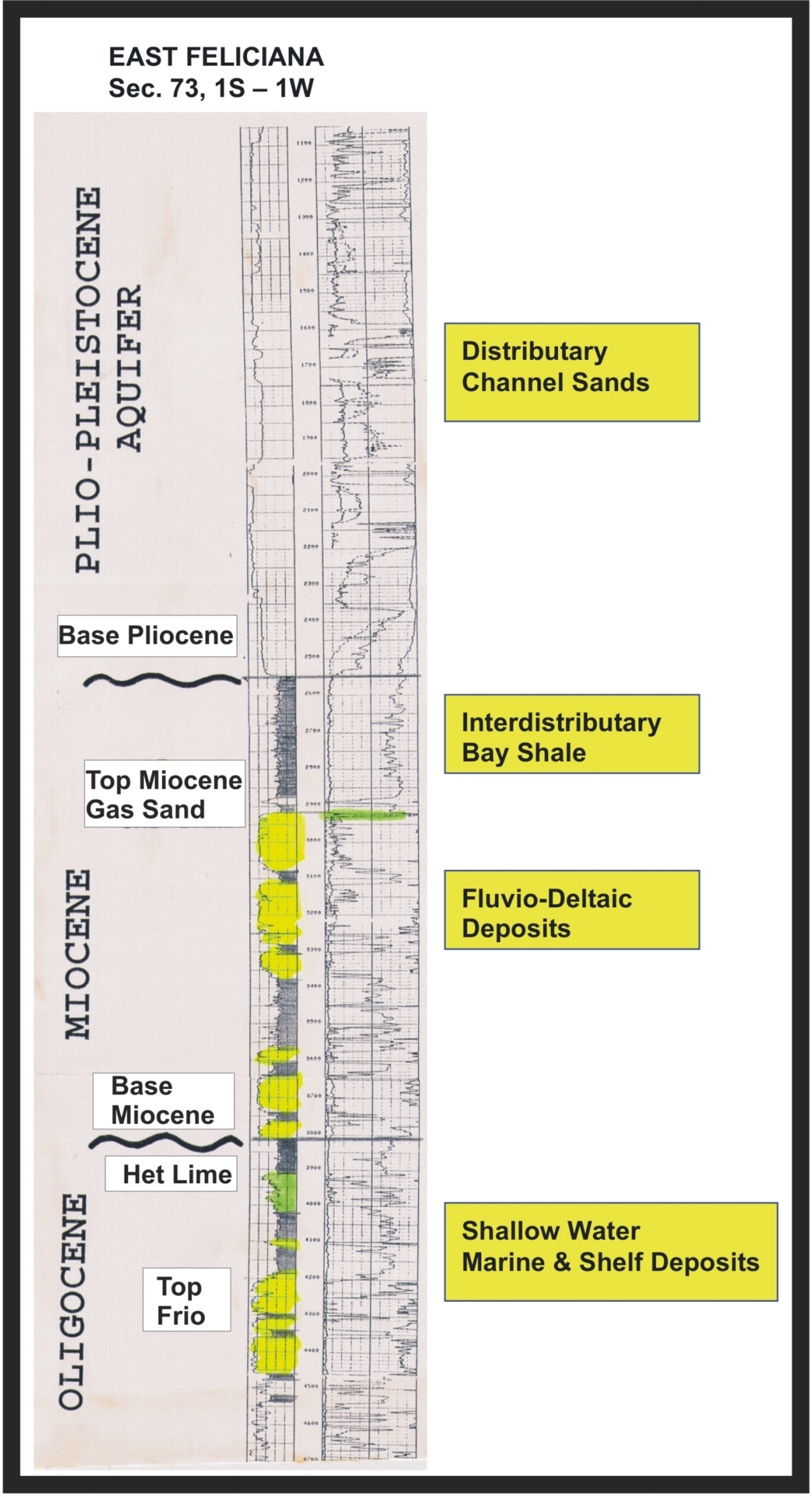

Figure 2. A selected annotated e-log showing depositional environments and sand-shale distribution within the Plio-Pleistocene, Miocene, and Oligocene formations of southeast Louisiana.

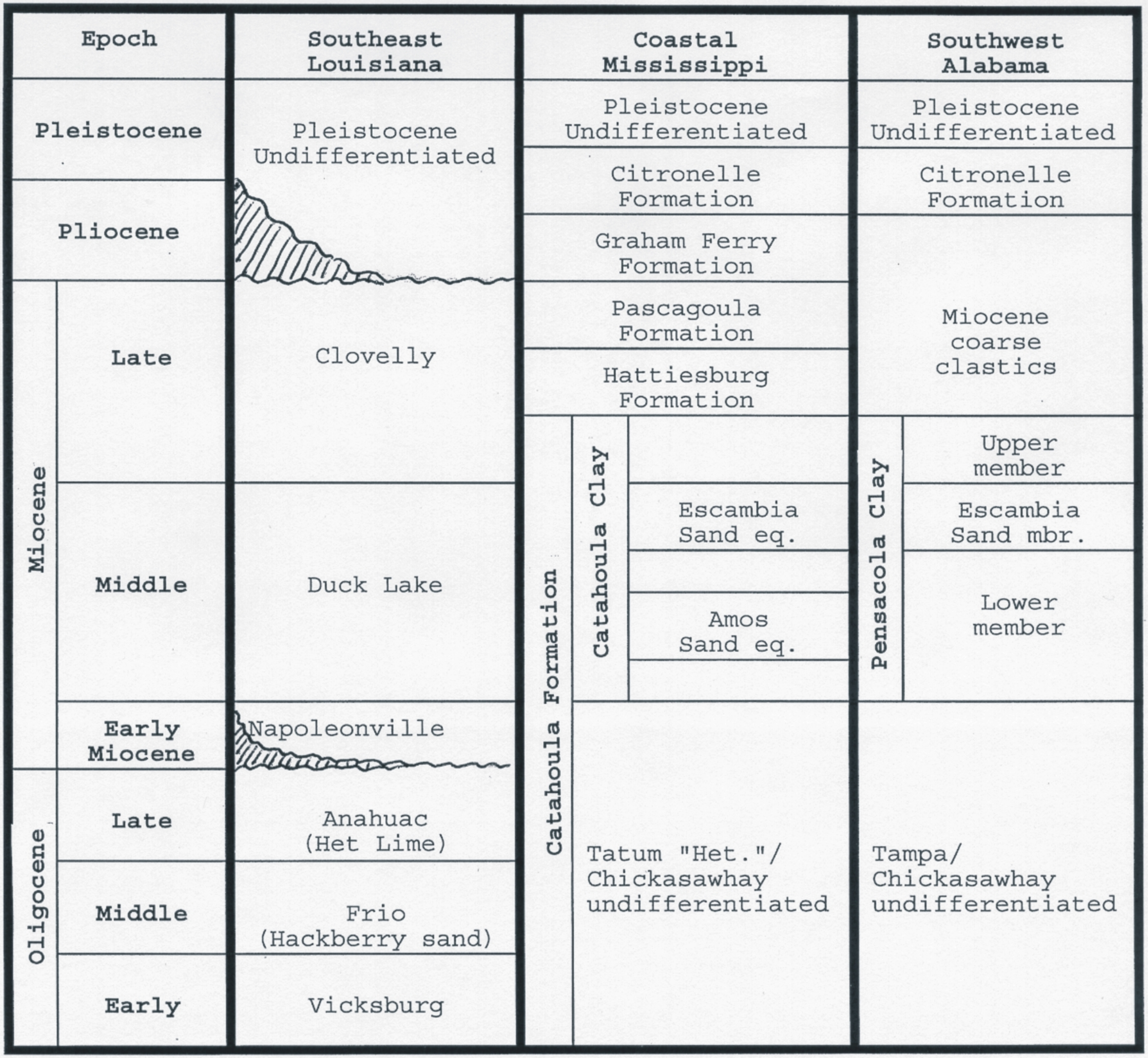

Figure 3. Stratigraphic column of the Plio-Pleistocene, Miocene and Oligocene of the southeast Louisiana Florida Parishes (modified after Champlin et al, 1994, their Figure 10).

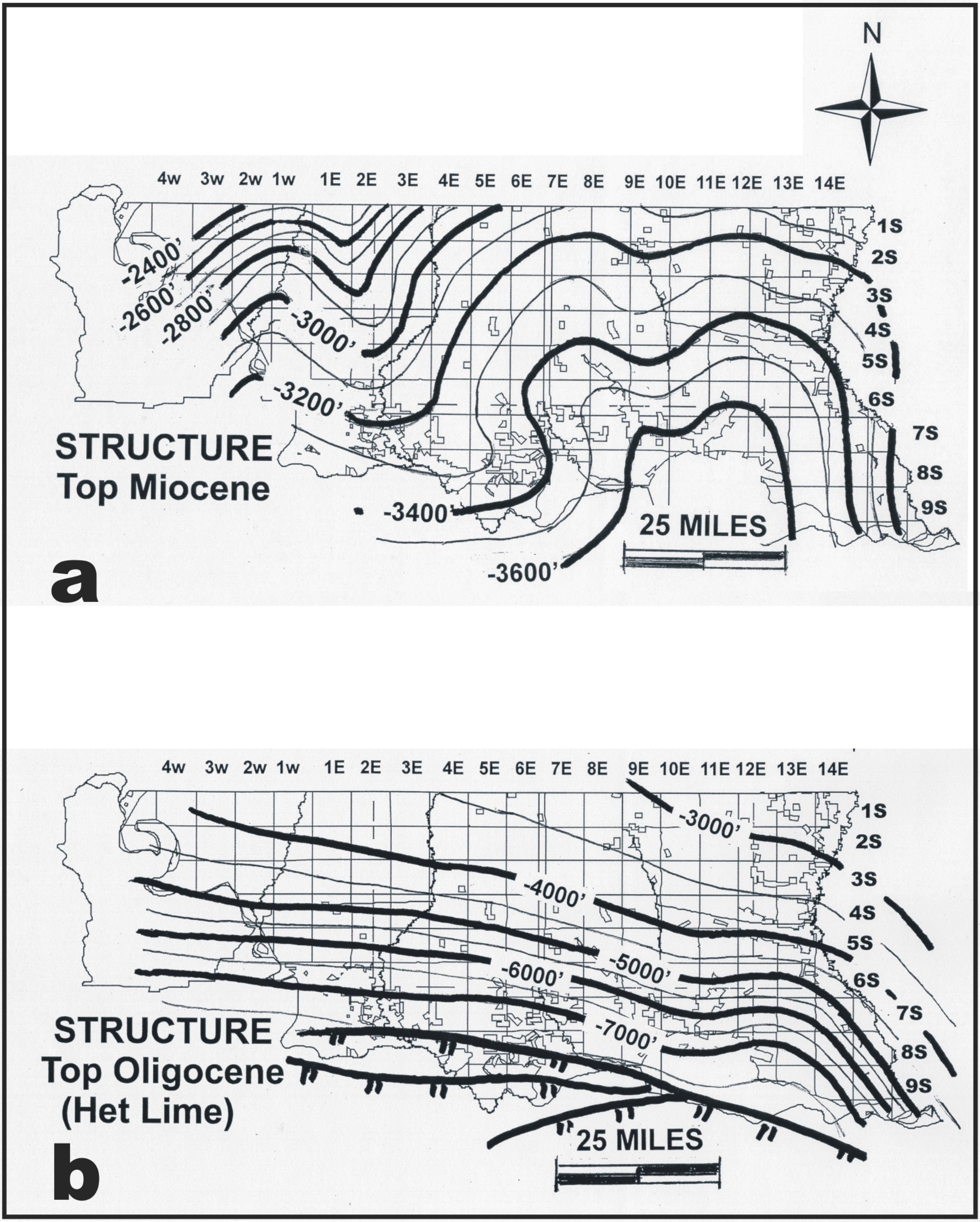

Figure 4. Structure maps of the intervals of interest: **(a)** structure on top of the Miocene interval; **(b)** structure on top of the Oligocene interval

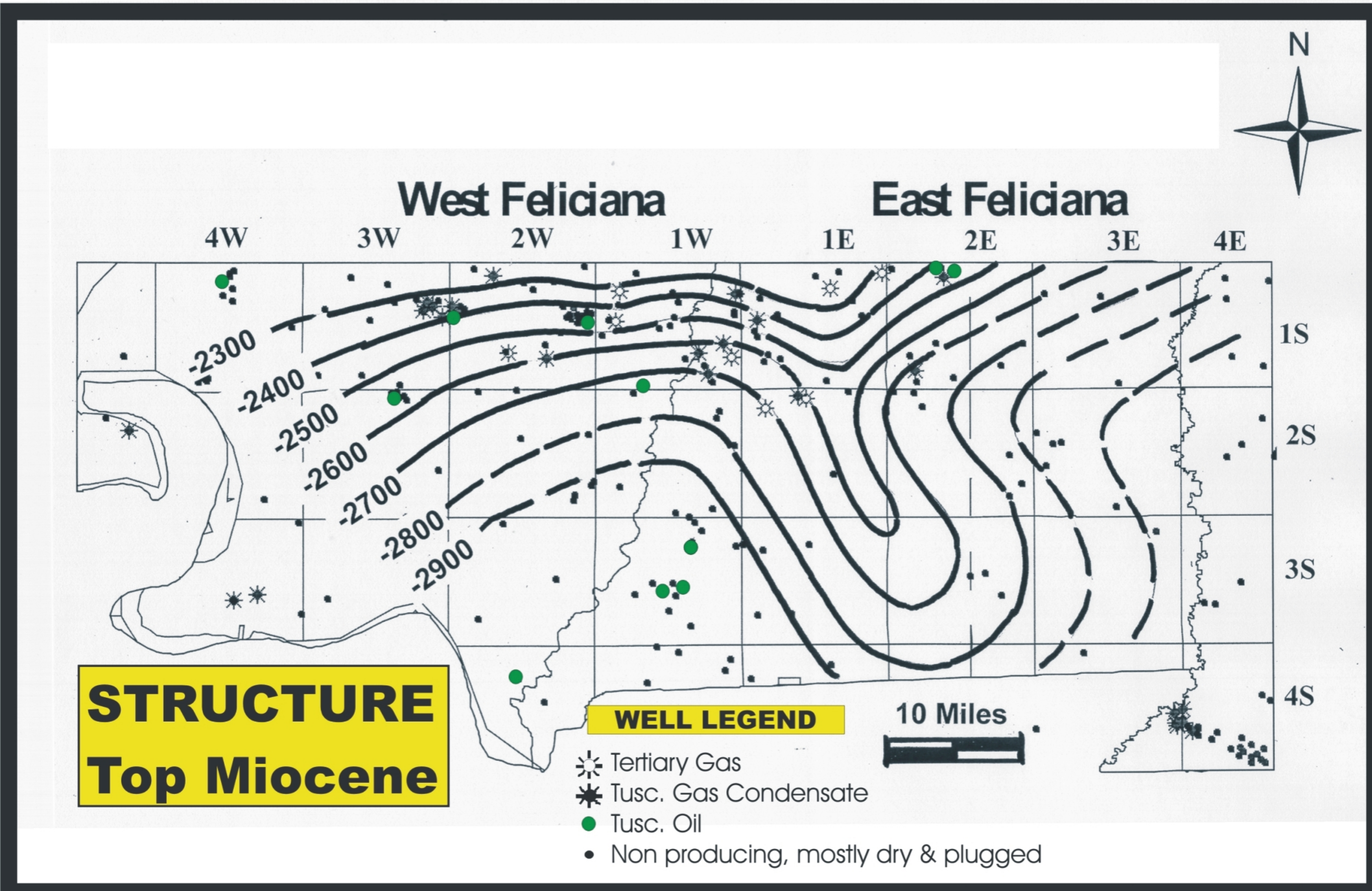

Figure 5. Detailed structural map (bar scale) on top of the Miocene showing the south trending structural nose in East Feliciana Parish.

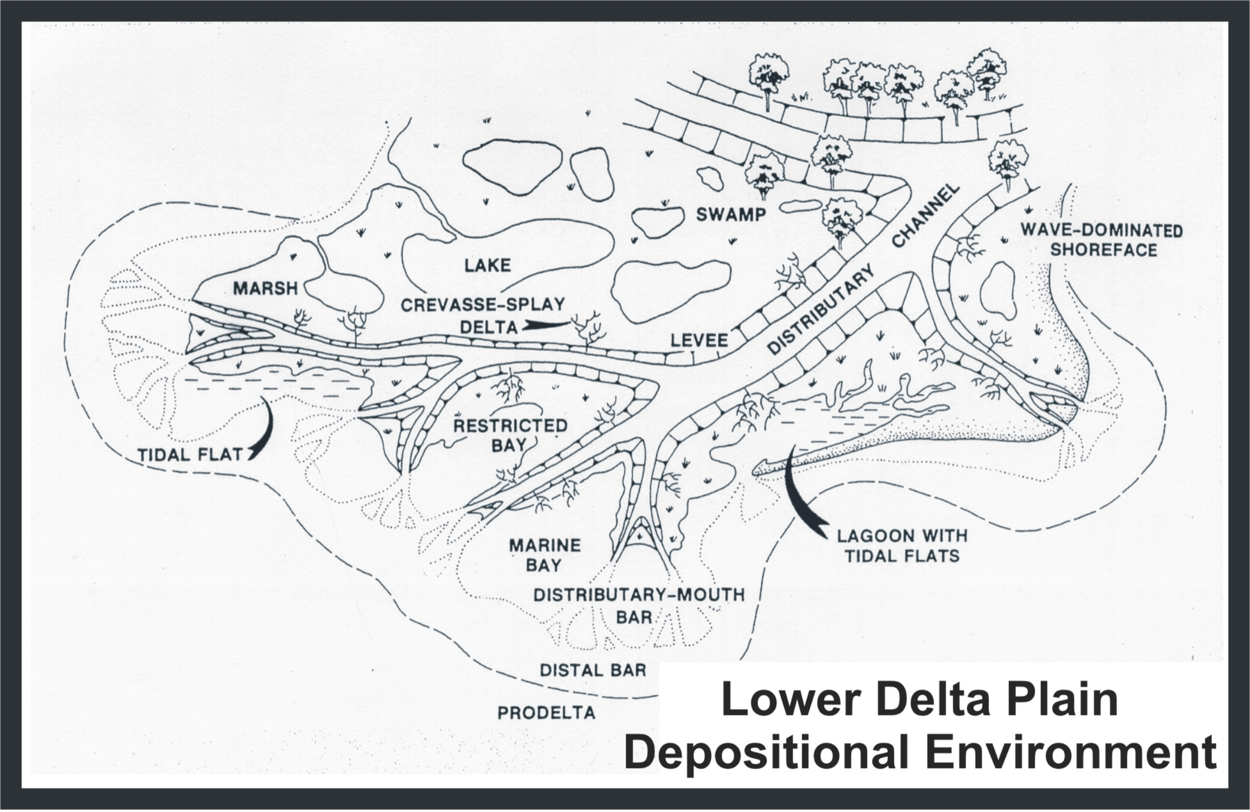

Figure 6. A lower delta plain depositional model for the Miocene and Oligocene deposits in southeast Louisiana's Florida Parishes (after May and Stonecipher, 1990).

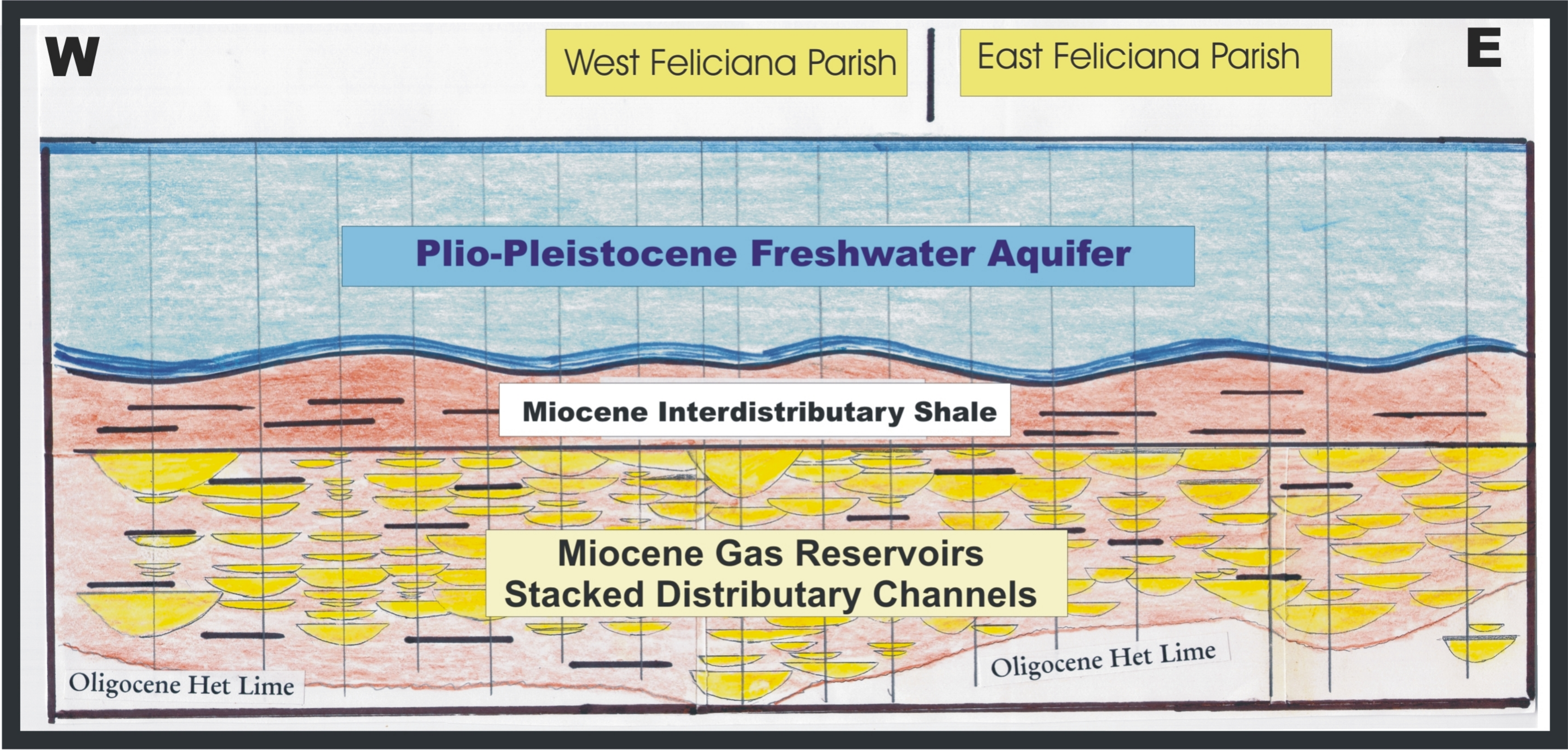

Figure 7. West to east diagrammatic cross section (not to scale) through West and East Feliciana Parishes showing actual distribution of stacked distributary channels within the Miocene interval. These were interpreted from electric logs and shown as stick sections through the two parishes. Location of well profiles shown as vertical lines.

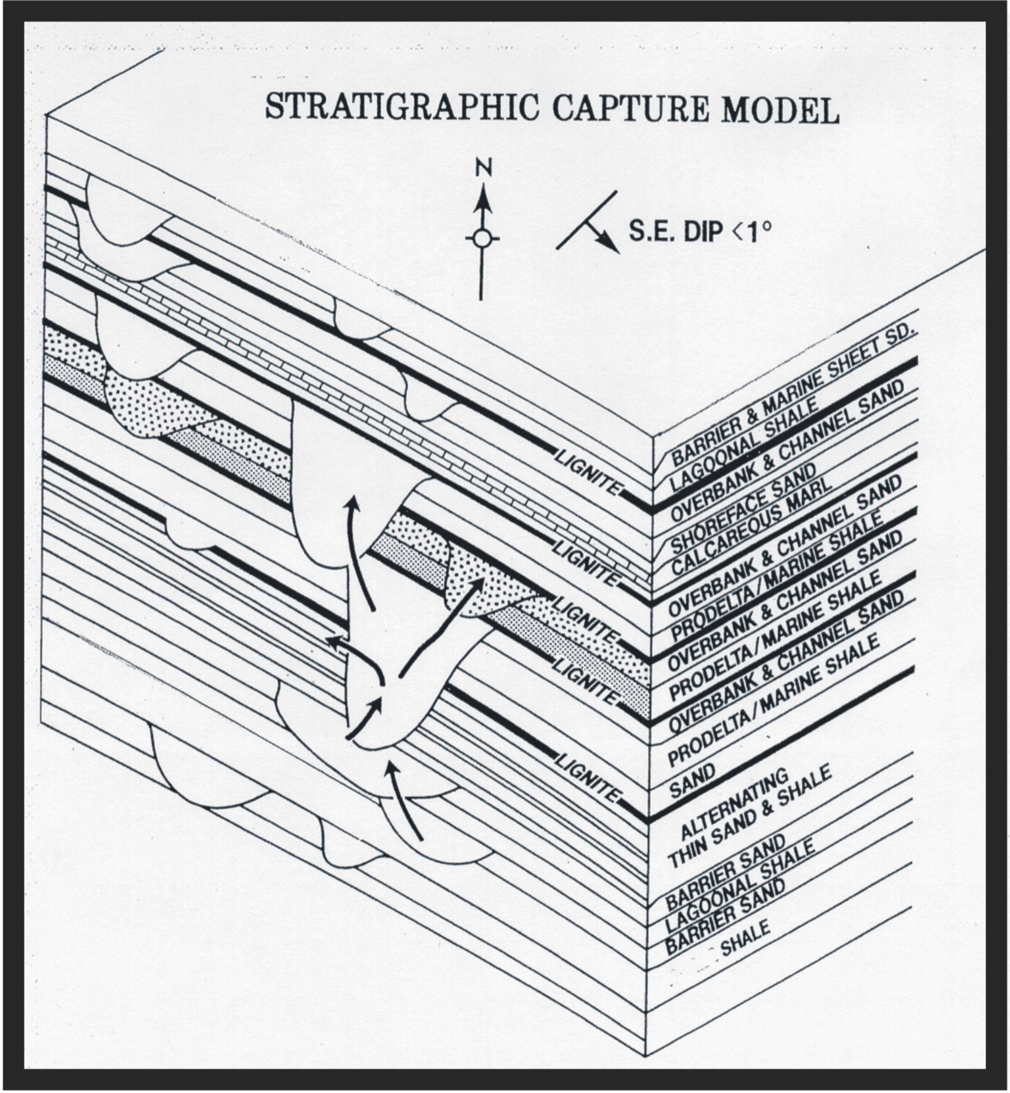

Figure 8. A drawing depicting the "stratigraphic capture" process or vertical and lateral movement of fluids between permeable beds (modified after Echols and Goddard, 1992).

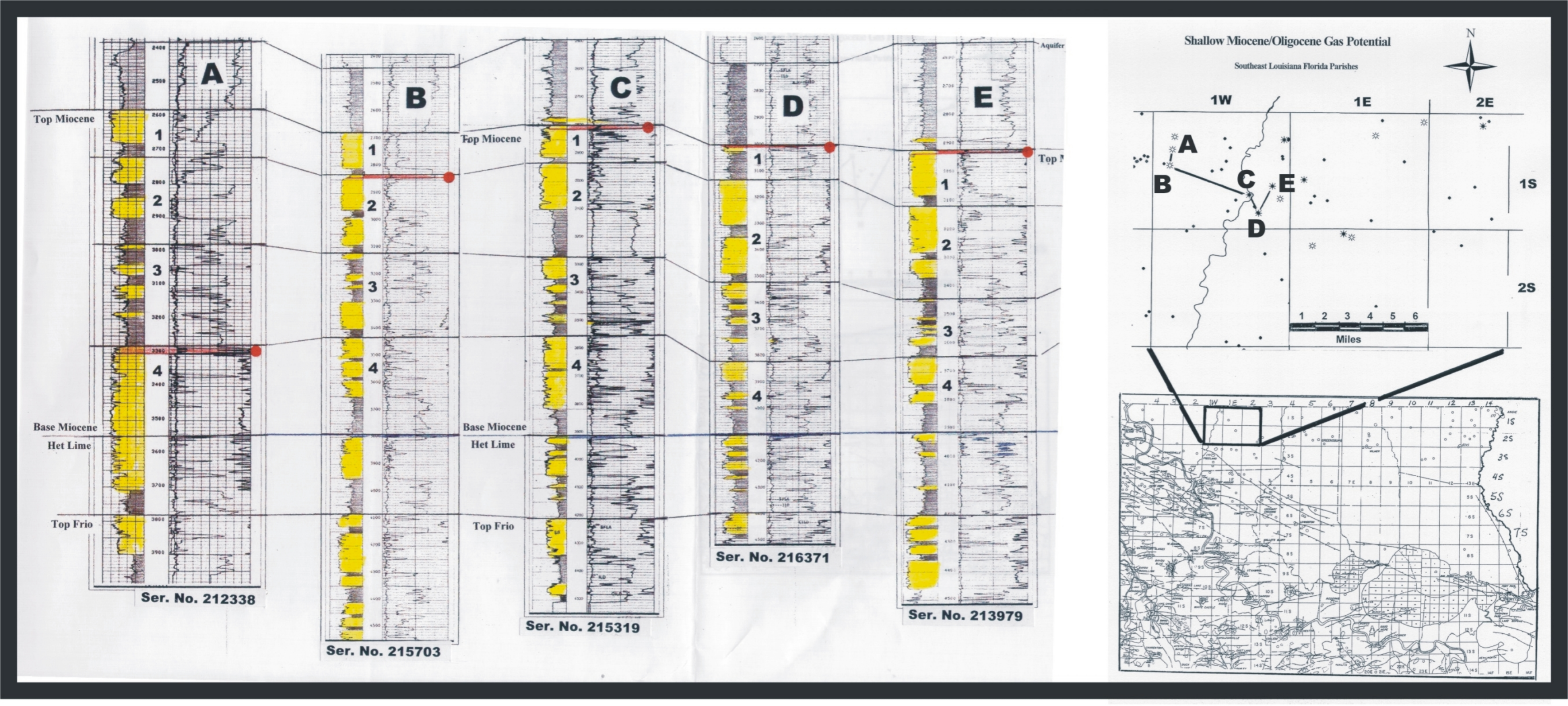

Figure 9. West to east well correlation across West and East Feliciana Parishes showing the division of the Miocene interval into four correlatable units.

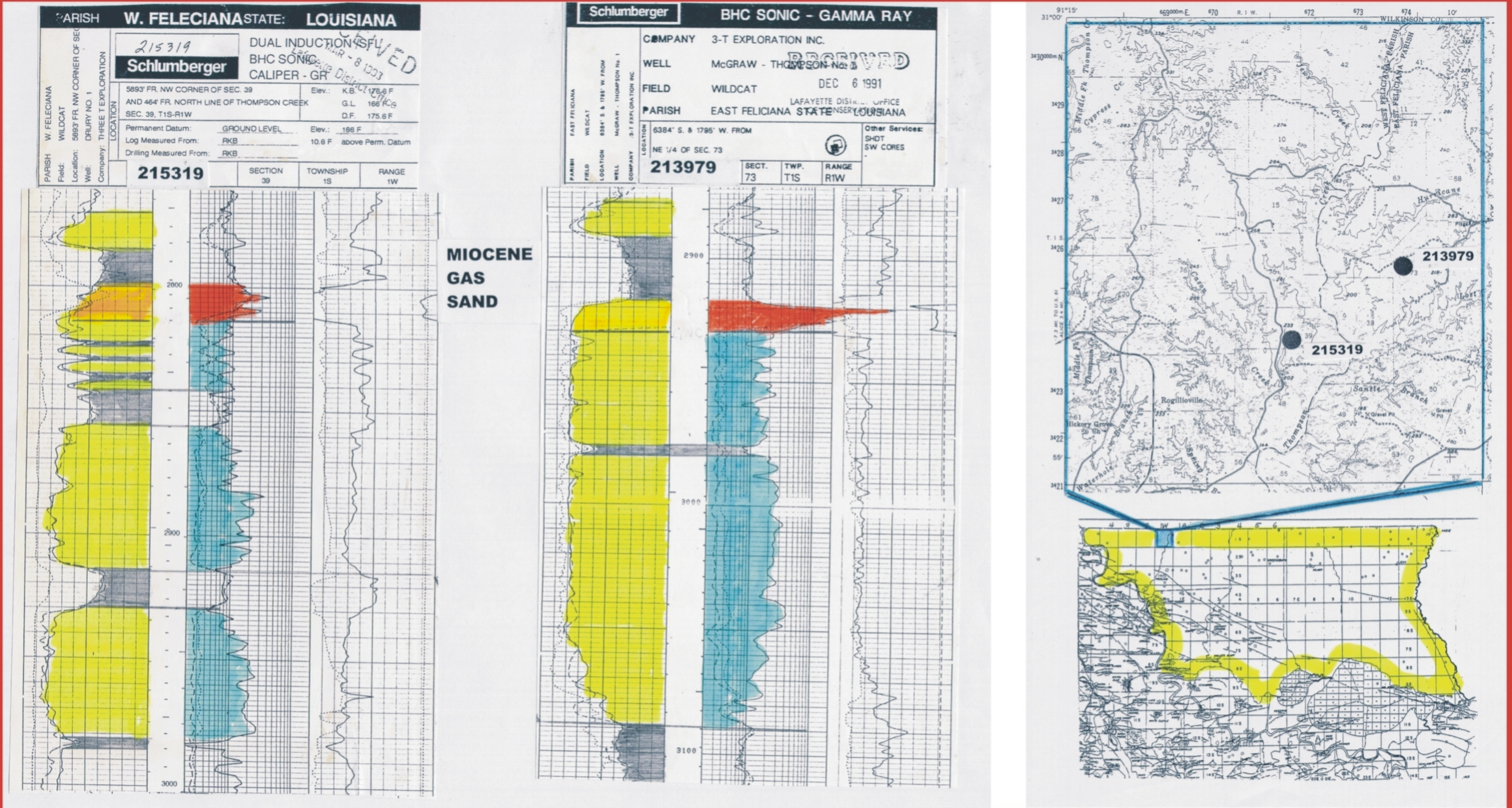

Figure 10. E-logs showing thick Miocene sandstone with an upper thin gas zone resting on underlying water. The overlying shale acts as a seal to the reservoir.

WELL	SER. #.	LOCATION	PERFS (Feet)	RATE (MCFD)	RESERVOIR
SUA; MEEKS 1990	212301	W. Feliciana 1W 1S	3103 - 3104	400	Miocene
SUA; WALKER 1990	212338	W. Feliciana 1W 1S	3281 - 3282	375	Miocene
SUA HARVY SR. 1991	214020	W. Feliciana 1S 2W	3273 - 3276	470	Frio
WILLIAM MCKENZIE 1992	214103	W. Feliciana 1S 2W	2840 - 2845	108	Miocene
DEGOLYER ET AL 1994	217269	W. Feliciana 1S 2W	2734 - 2735	293	Miocene
RICHARD MUNSON 1995	215703	W. Feliciana 2W 1S	2821 - 2834	128	Miocene
VUB; DRURY 1993	215319	W. Feliciana 1W 1S	2798 - 2799	335	Miocene
VUD; DUNN 1994	216371	E. Feliciana 1W 1S	2996 - 2997	320	Miocene
VUA; MCGRAW 1991	213979	E. Feliciana 1W 1S	2919 - 2921	375	Miocene
HARVEY HEIRS 1993	215600	E. Feliciana 1W 1S	3054 - 3056	105	Miocene
MARION ELDRIDGE 1994	217106	E. Felicina 1E 1S	3137 - 3139	205	Miocene
HENRY WATSON 1992	214601	E. Feliciana 1E 2S	4541 - 4544	605	Frio
SUA: J. HOWELL 1990	211541	E. Feliciana 1E 2S	3041 - 3053	250	Miocene
VUA: ROLLOINS 1996	213194	E. Feliciana 1E 1S	3948 - 3951	240	Frio
SUA; HAYNES 1991	213589	E. Feliciana 1E 1S	3789 - 3792	255	Frio
ALBERT GUTTZEIT 1993	216207	E. Feliciana 1E 2S	Log @ 4572'	No Test	Frio
BARTON 1991	213199	E. Feliciana 2E 2S	Log @ 3650'	No Test	Miocene
1-KENT 1996	218887	E. Feliciana 3E 1S	3902 - 3904	200	Frio
2 - KENT 1996	218991	E. Feliciana 3E 1S	3945 - 3947	200	Frio
ROUCHON - 3 1997	220808	E. Feliciana 3E 1S	4138 - 4140	400	Frio
ROUCHON - 1 1996	219020	E. Feliciana 2E 1S	4138 - 4140	225	Frio
1-SULLIVAN 1996	219104	E. Feliciana 2E 1S	4246 - 4247	177	Frio
SUA; WHITE 1996	218888	E. Feliciana 2E 1S	4174 - 4176	225	Frio
SUA; CAIN 1996	218886	E. Feliciana 2E 1S	4171 - 4174	250	Frio

Figure 11. Listing of some of the Miocene/Oligocene producing wells in West and East Feliciana Parishes. Name, spud date, serial number, location and initial gas producing rates are given.

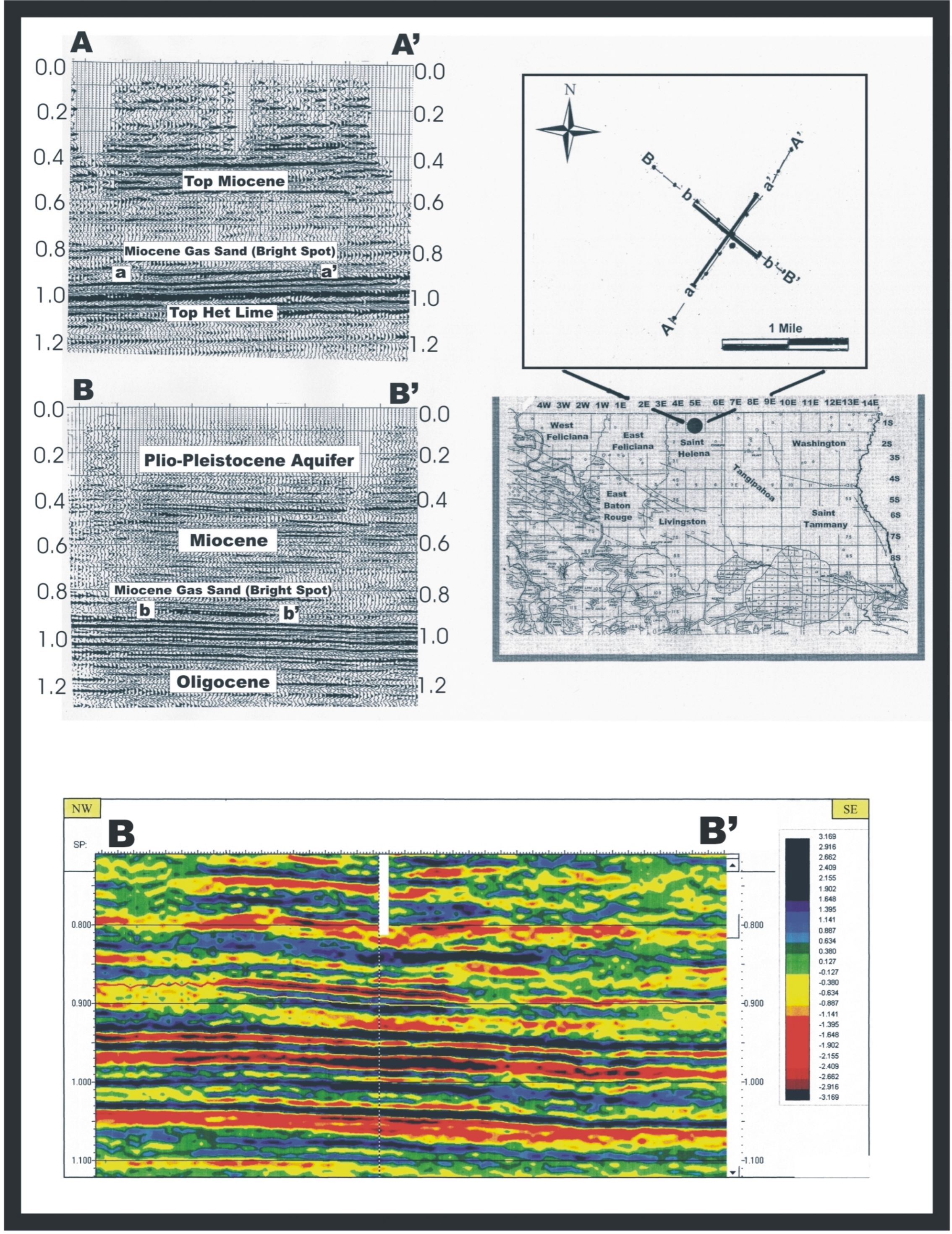

Figure 12. Two black and white 2D seismic lines (A-A', B-B') showing a gas indication (reflections at a-a' and b-b') at a 2-way seismic time of 0.9 seconds. Amplitude variation with offset (AVO) processing was performed on line B-B' and confirms the bright spot at 0.9 seconds on the bottom seismic section (in color). The amplitude color scale is shown on right side of the section.

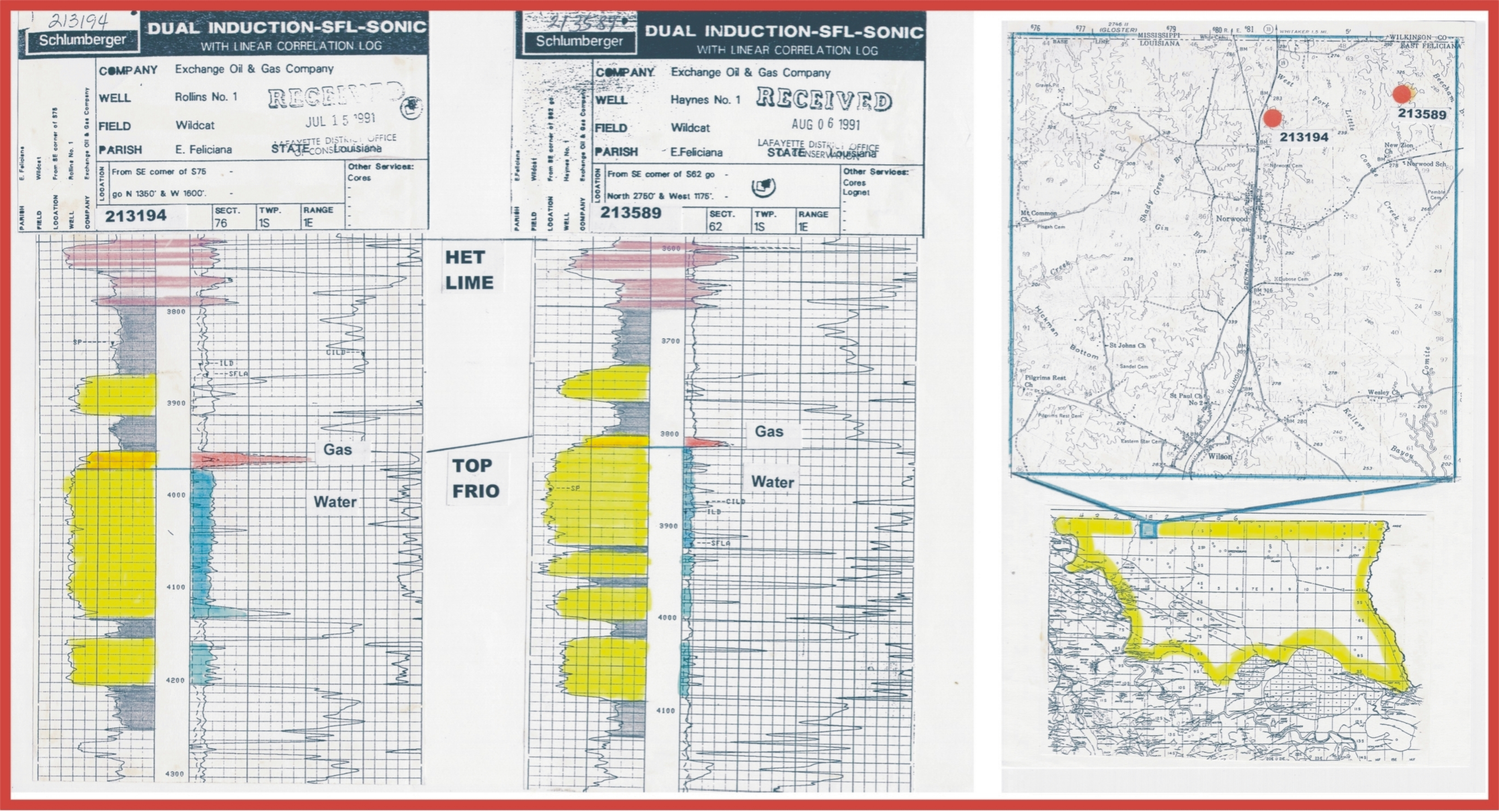

Figure 13. E-logs showing thick Oligocene Frio sandstone with upper thin (12' and 20') gas zones resting on underlying water sands.

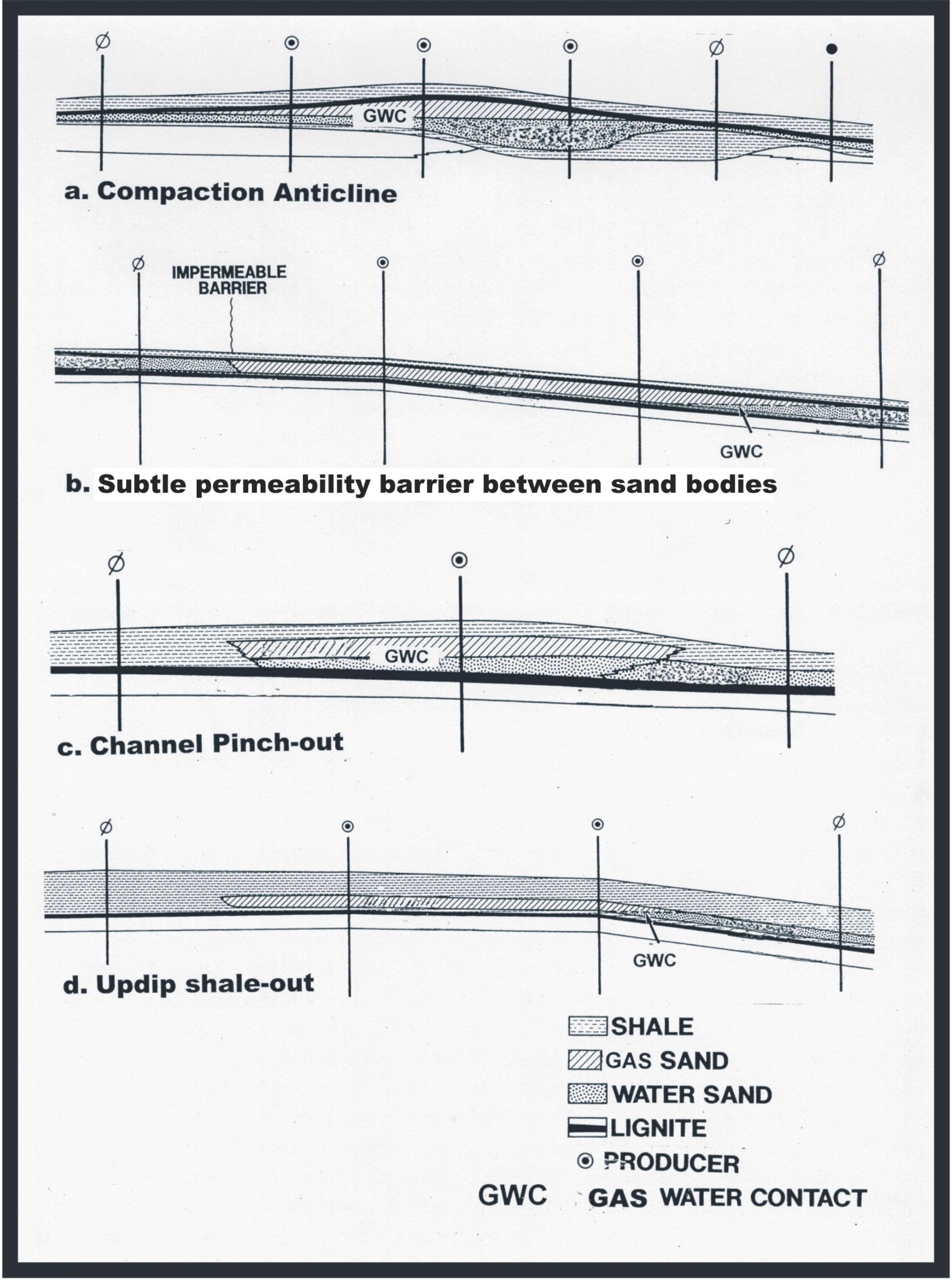

Figure 14. Possible structure and stratigraphic trapping mechanisms associated with the Miocene and Oligocene gas reservoirs. (a) Compaction anticline, (c) subtle permeability barrier between sand bodies, (c) channel pinch-out, and (d) updip shale-out (modified after Goddard and Echols, 1993).