Microbasin Analysis of South Louisiana: An Exploration Model, Or: Hutton and Lyell Were Wrong!

Richard L. Adams
Mitchell Energy Corp., P.O. Box 4000, The Woodlands, TX. 77387-4000

ABSTRACT

In 1785, James Hutton proclaimed " The present is the key to the past!" Now our understanding of microbasin tectonics indicate that we should be saying, " the past is the key to the present!" Basement tectonics have a significant effect on later sedimentation patterns, even when the intervening sediment thickness is on the order of 16,000 meters (50,000 ft). In south Louisiana, the relationship can be seen from the Tuscaloosa (mid-Cretaceous) to the Upper Miocene. Northwest-southeast basement transforms offset paleobathymetry trends, sediment isopachs, structural trends, and production. Gravity and magnetic mapping allow the preparation of a basement pseudo-structure map which is used to put the South Louisiana Basin into a microbasin context for predictive exploration.

Basement horsts, grabens, and counter-rotated half-grabens influence the location of major growth fault regimes and production trends. Growth faults are preferentially found over the leading edge of high basement blocks, and major fields are often associated with these growth faults. Of the major fields in the study area, 78 per cent are found over basement grabens or the immediate edge of the grabens.

Salt domes, stocks, pillows, sills, and tongues all have their origin in the Jurassic Louann salt at depth. The location of these salt features, as well as the original salt thickness, are directly linked to the pre-salt structure.

These basement grabens also form the "kitchens" for hydrocarbon maturation. Migration takes place by pulsed expulsion up major growth faults to charge reservoirs near or above the top of abnormal pressure. By combining these data into a three-dimensional framework, a comprehensive exploration plan can be implemented, even for a mature province such as south Louisiana.

INTRODUCTION

Earlier descriptive models have demonstrated probable relationships between inherited basement tectonic elements and subsequent depositional patterns (Adams, 1993) for south Texas, north Louisiana-south Arkansas and southeast Texas. In the south Louisiana study area, northwest-southeast aligned basement transforms (Fig. 1) are defined using gravity and magnetics data. These same transforms show clear definition on production maps, maps of paleobathymetry, interval isopachs, linear patterns of salt features and other structural trends, maps of geopressure depths, and surface geomorphic features. These relationships have also been described for several other basins both in the U.S. and on other continents (Gay, 1995).

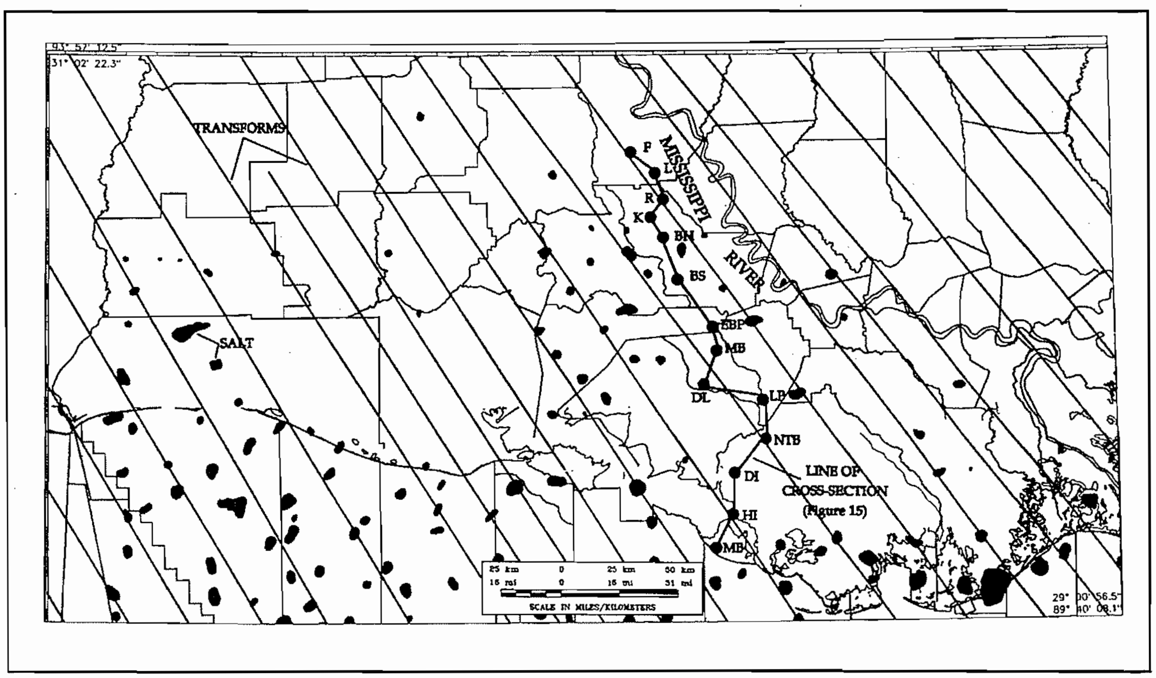

Figure 1. South Louisiana study area, showing basement transforms, salt features and alignment of the Mississippi River with basement transforms. Figure 15 (regional cross-section) location is highlighted.

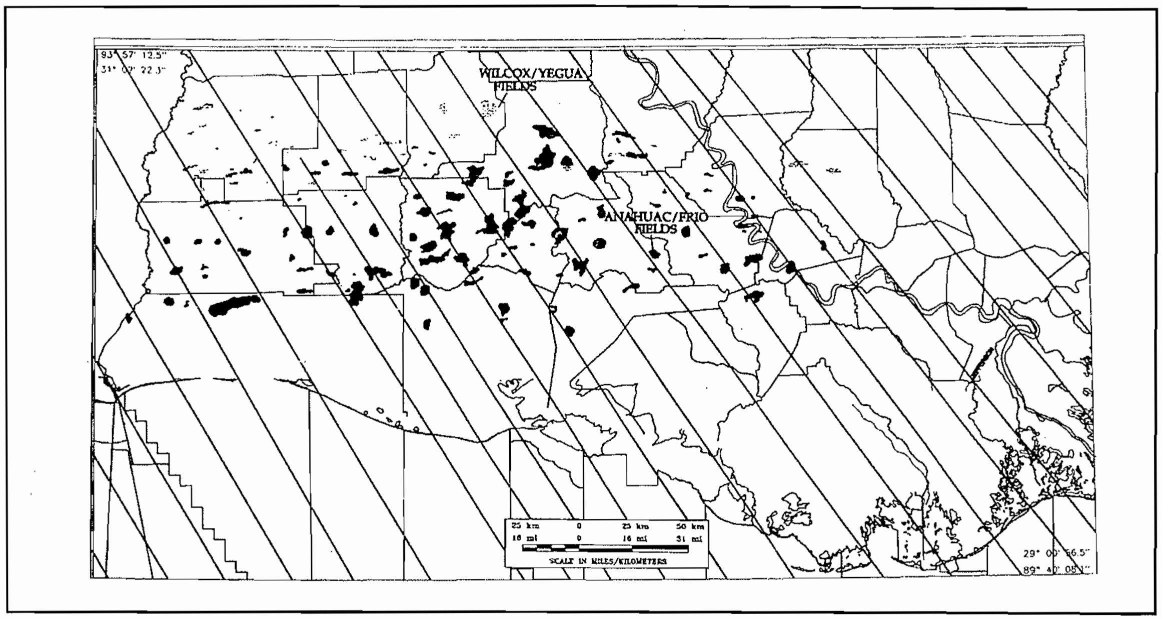

Figure 2. Study area with transforms, showing offsets of production trends for the Eocene Wilcox / Yegua and the Oligocene Anahuac / Frio zones.

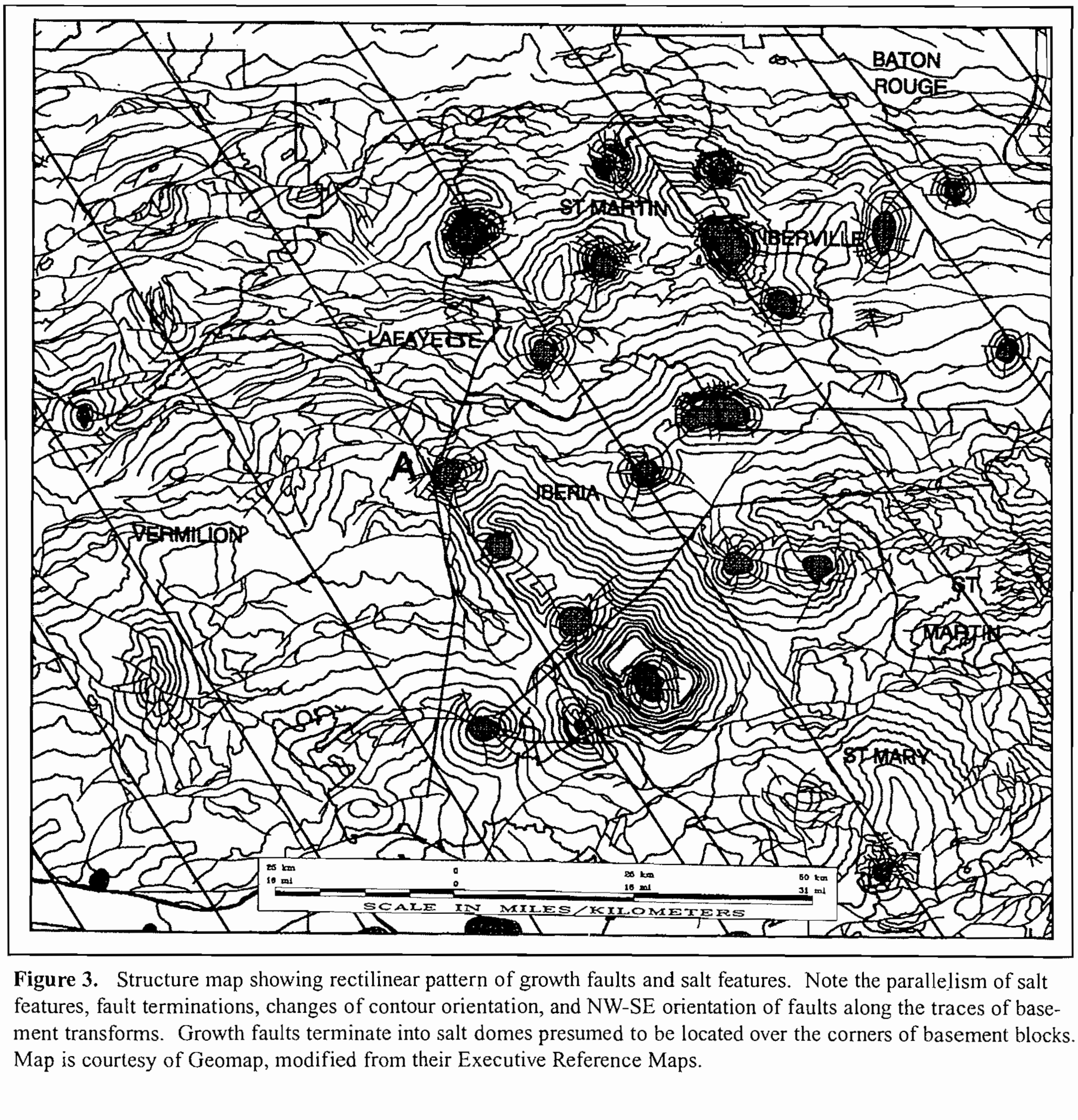

Figure 3. Structure map showing rectilinear pattern of growth faults and salt features. Note the parallelism of salt features, fault terminations, changes of contour orientation, and NW-SE orientation of faults along the traces of basement transforms. Growth faults terminate into salt domes presumed to be located over the corners of basement blocks. Map is courtesy of Geomap, modified from their Executive Reference Maps.

In south Louisiana, these transforms offset linear patterns of major fields (Fig. 2), even though the basement surface is at a depth of as much as 12,500 to 17,000 meters (40,000 to 55,000 ft) across the study area. Between the transforms, data suggests the presence of alternating horsts, grabens, and counter-rotated half-grabens (CRHG's) below the base of salt. These show a NE-SW strike, perpendicular to the strike of the transforms. This uneven surface controls the isopach of the overlying salt. Growth faults preferentially developed over the leading edges of basement highs, and salt features formed above the corners of high basement blocks. Microbasins (Adams, 1993) formed over the basement grabens and controlled later depositional patterns. Hydrocarbons generated in the Mesozoic and lower Cenozoic "kitchens" move upward along major growth faults by pulsed migration into expanded marine shelf to shelf-margin sand packages. The expanded sand-rich sections are also a response to the growth faults location. In south Louisiana, 78 per cent of the major fields in the study area (> 100 billion cubic ft of gas (BCFG) or > 10 million barrels of oil (MMBO) for a single producing interval) are located above basement grabens. The linkage of basement structure, salt tectonics, fault positioning and fault control of sedimentation patterns and migration paths make it critical to understand the microbasin setting of exploratory wells in both mature and frontier basins. James Hutton proposed his Principle of Uniformitarianism, "the present is the key to the past" (Gilluly, et al, 1968) in 1785, and it was popularized by Charles Lyell in the mid-1800s. It states that the rock record is the product of depositional processes that can be seen today. But today, we must look at exploration in a new light. Microbasin principles tell us that we must look at the past to understand the present. Thus, our motto should be " the past is the key to the present."

MICROBASIN PRINCIPLES

The microbasin concept (Adams, 1993) presumes that paleostructure on the Triassic rifted surface of the U. S. Gulf Coast has influenced depositional patterns from the Louann Salt to the present. As defined in Adams (1993), a microbasin is "a limited area of deposition, the boundaries of which reflect, or can be presumed to reflect, buried, basement-related faulting". NW-SE transforms have been described and inferred from widely different areas across the Gulf Coast (Adams, 1993) as well as the rest of the United States (Gay, 1995), and their relationship to later structural and sedimentation patterns is always the same. Salt thicks form in lows over basement grabens and become vertical salt elements over the corners of basement highs adjacent to the grabens. Because of this preference to form over the corners of the basement blocks, they are reliable markers for the basement transforms. Low relief salt elements also form in response to sediment loading. In south Louisiana, these salt features and their associated growth faults often form rectilinear patterns, and the growth faults often terminate into or pass through major salt domes (Fig. 3, see point A near Jefferson Island Field). Horizontal salt tongues and sheets are often the product of salt migration up the back side of counter-regional faults (Fig. 4). It is interpreted that these faults often form on the down-dip side of microbasins and are frequently generated over the north side of basement horst blocks.

Sediment influx preferentially follows basement transforms. River systems follow the transforms as the path of least resistance, especially following the low side where adjacent basement blocks have a discernable elevation difference. Note the alignment of several segments of the Mississippi River with underlying basement

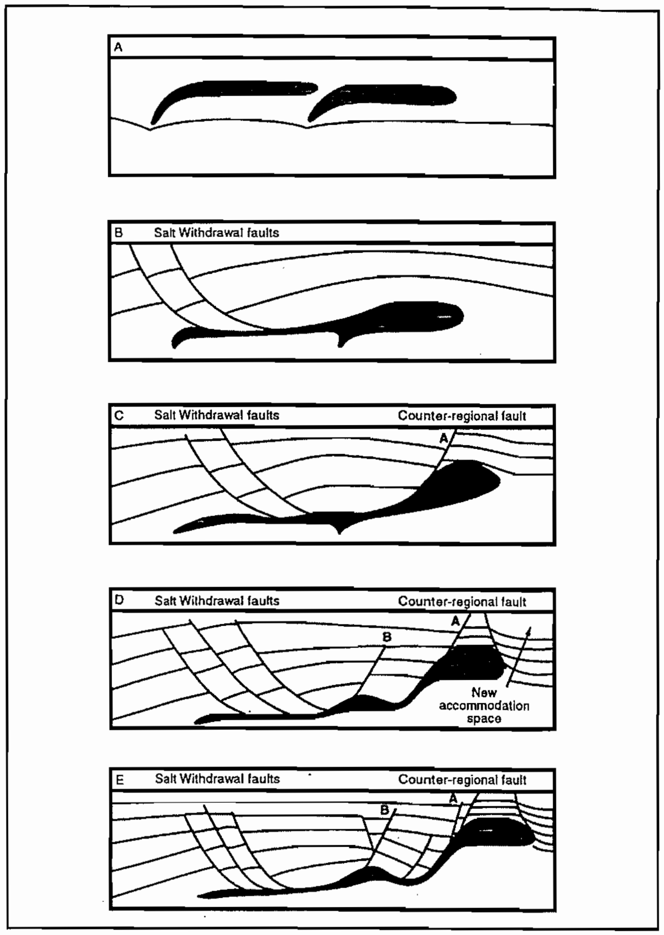

Figure 4. Evolution of secondary salt tongue in response to salt-withdrawal and counter-regional faults. Adapted from Zhang and Watkins, 1994.

transforms (Fig. 1). Where the river mouth overlies a microbasin, subtle changes in gradient slow the current and sediment deposition begins. Sediment loading initiates the formation of low relief salt elements and the formation of growth faults.

The large growth faults are also vital as hydrocarbon migration pathways (Leach, 1994). The basement grabens form the "kitchens" where kerogens are turned into hydrocarbons. The growth faults are the conduits that leak off formation pressure and carry the hydrocarbon molecules out of the "kitchen" and up to the reservoirs (Salah and Alsharhan, 1996). Pressures in the "kitchen" increase due to burial, clay dewatering, and hydrocarbon generation. When these pressures approach the frac gradient of the enclosing rock, pressure expulsion moves fluids upward to reservoirs where the pressures are lower. This process may be repeated multiple times between the initial hydrocarbon generation site and the filling of current reservoirs. In south Louisiana, most commercial geopressured fields are limited to the top 1600 meters (5000)' of the geopressured section (Leach,1994). Mapping the top of geopressure (12.5 pound per gallon equivalent mud weight), (Fig. 5) gives a fair estimation of the deepest commercial reservoirs for a given area. Leach (1994) discusses this in detail and explains how to determine remaining exploratory potential. Growth faults, being the loci for the thickest sediments, link the basement grabens, hydrocarbon "kitchens", migration pathways and thick sand packages to form major fields in south Louisiana.

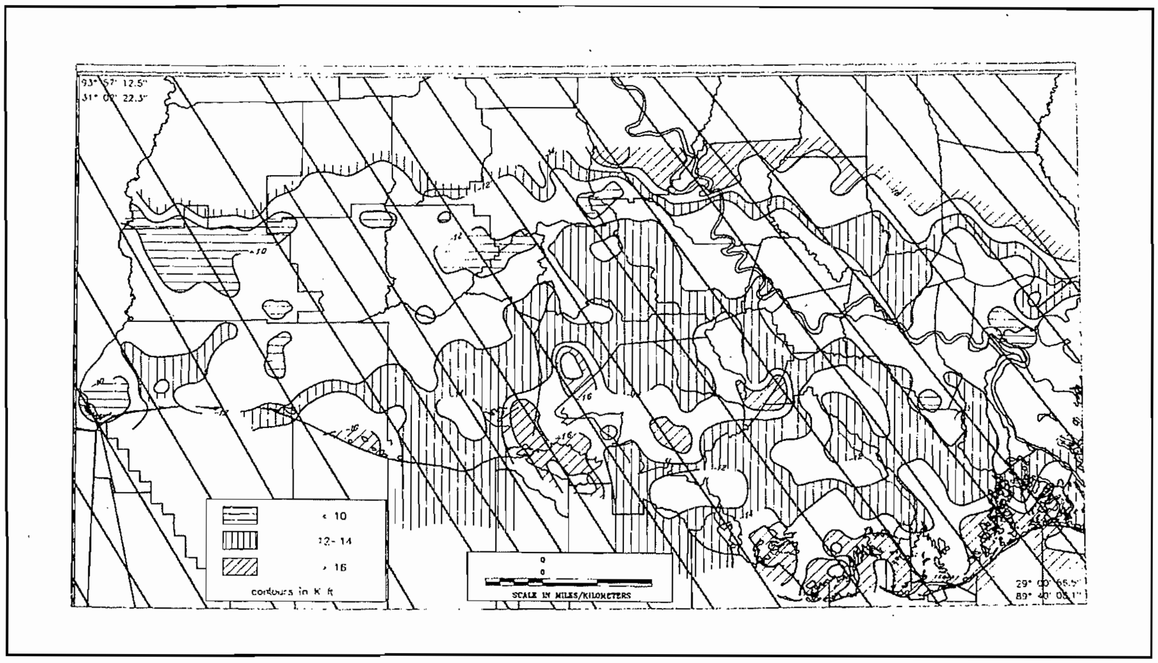

Figure 5. Map of the top of geopressure showing offsets of the pattern over the basement transforms. Data is from P.I.'s Petro-Rom data set.

BASEMENT PSEUDO-STRUCTURE

Gravity and magnetics data provide a useful picture of the pseudo or relative structure on the basement surface of south Louisiana. The purpose of this map is not an absolute structure map of exact elevations on the top of basement, but rather a relative estimate of high versus low and an approximation of the orientation and magnitude of basement faults. For the purpose of this discussion, basement refers to the base of the Pre-Salt Jurassic surface. The relative elevations and an estimate of the magnitude of offset on basement faults is needed to prepare a microbasin model for south Louisiana. The gravity and magnetics maps used in this evaluation were generated by Bill Cathey of Earthfield Technology from Mitchell proprietary data merged with public domain datasets. Gravity maps generated included: Bouguer gravity, and 30-40 km, 50-70 km, and 70-100 km high band-pass filter of the Bouguer gravity (Fig. 6). Merging and leveling of the disparate data sets was critical to generating reliable maps. Magnetic susceptibility maps generated included: reduced to pole (RTP) magnetics, and 50-70km and 70-100 km high band-pass filter of the RTP magnetics (Fig. 7). The 70-100 km high band-pass maps of the gravity and magnetic fields give the best data for interpreting the basement structure because they focus deepest in the section. The shorter bandpass filters give a better definition of gravity and magnetic variations within the sedimentary section. In the southernmost part of the basin the shorter bandpass gravity maps help define shallow salt piercement features as well as possible tongues and wedges. In areas such as east Texas and southwest Alabama basement reflectors are resolvable on seismic data.

In south Louisiana, basement structure can only be inferred by indirect means. Therefore, good quality gravity and magnetic data are essential to predict basement faulting, as well as having a good workable model to guide the interpretation. Locations of transforms have been inferred on the gravity and magnetics maps by changes in contour spacing, contour orientation, and contour offsets. Where three or more features fall along a line approximately N45W to N60W, a transform was drawn and compared to other data sets. The transform locations shown here are the result of iterative comparisons. Rock types may change drastically across basement faults, especially across transforms. Thus, care must be taken when making an assumption of fault throw direction. Gay (1995) describes the use of aeromagnetic data to map basement fault patterns in order to predict later sedimentation patterns and structural trends. He discusses the pitfalls of direct one-to-one correlation of magnetic intensity to structural depth. He also confirms several common characteristics of basement transforms which he refers to as shear zones (Gay, 1995):

1. shear zones are parallel to sub-parallel to each other
2. distance between shear zones (periodicity) averages 4-8 km (2.5-5 mi)
3. basement rock types often change across shear zones
4. shear zones width can be 1-2.5 km (.6-1.5 mi)
5. post-shear geology and structural style often change across shear zones

Adams (1993), and Sigsby(1976), show that basement faults are present across the Gulf Coast from south Texas to Florida. These include transforms with an azimuth orientation from N45W toN60W. Between the transforms is an arrangement of horsts, grabens, and CRHGs with strikes predominantly perpendicular to the bounding transforms (Fig. 8). This orientation was used as a template for evaluating the basement structure where the data is poor. The fault patterns mapped, especially the long transform faults, are intended as a representation of fault zones or fault sets covering a much wider band than the line width shown. Most of these are probably en echelon fault sets covering 1.6 km (one mile) or more in width. The density of gravity and magnetic data points, plus the depth to basement preclude a more detailed interpretation. Fortunately, in south Louisiana, we have many other types of data with which to compare and refine our basement model.

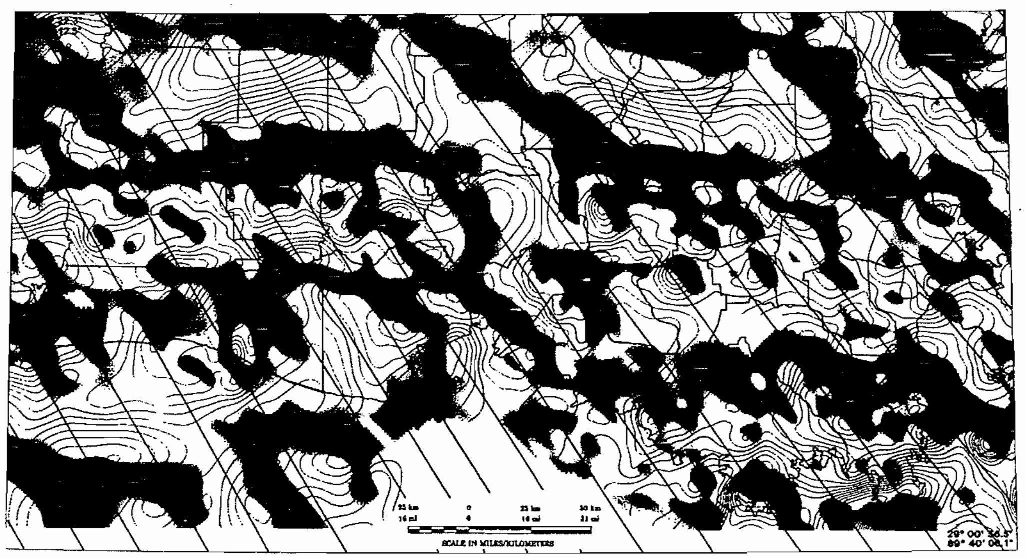

Figure 6. 70-100 km high bandpass gravity map showing offsets across the transforms. Map generated by Earthfield Technology.

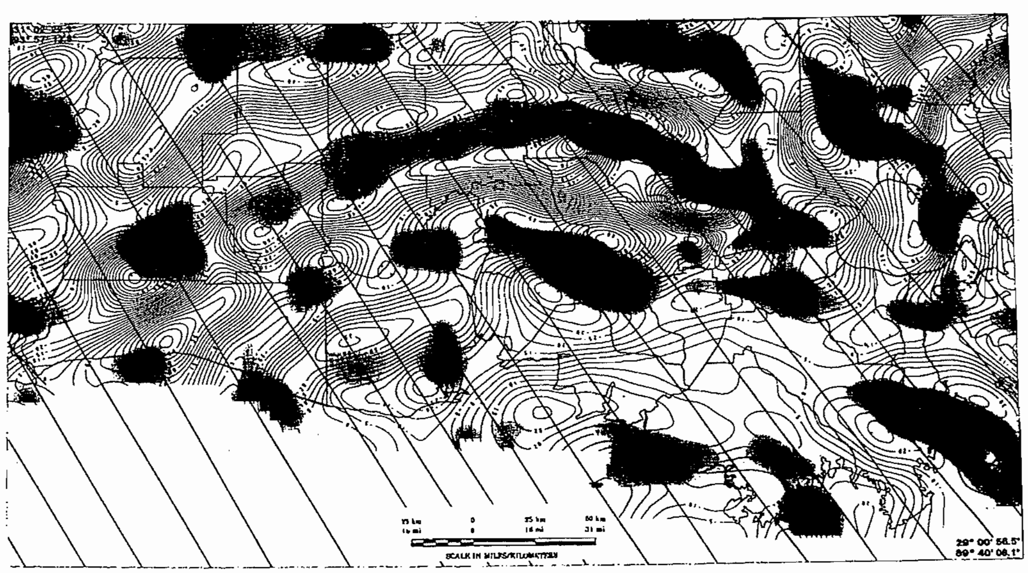

Figure 7. 70-100 km high bandpass magnetic map for the same portion of the study area as Figure 6. Magnetic susceptibility at longer wavelengths is usually a response to changes in the basement.
Map generated by Earthfield Technology.

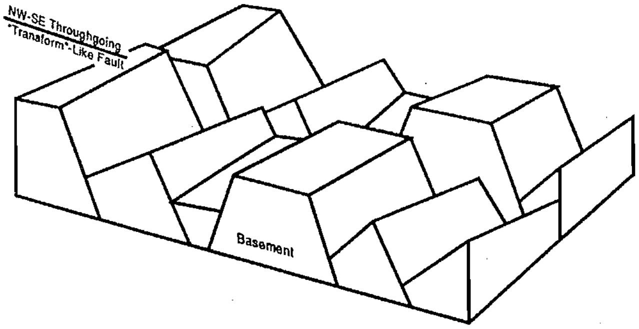

Figure 8. Basement block diagram, Stage I, from Adams (1993), demonstrating idealized basement configuration of NW-SE oriented transforms, with horsts and grabens between the transforms. Map generated by Earthfield Technology.

PALEOBATHYMETRY

Many authors have studied the paleontology of the Cenozoic section in south Louisiana (Rainwater, 1964; Vidrine, 1971; and McFarlan and LeRoy, 1988 among others), and many companies have serviced the exploration industry by providing age dating and paleobathymetry data for the south Louisiana Basin. Using the paleo-top data, water-depth data, and interval isopachs available from Paleo-Data for south Louisiana (Fig. 9), shelf margins have been interpreted for the major oil and gas producing intervals from the Paleocene to the Upper Miocene. Combining these shelf margins with the interval isopachs highlights the location of the time-equivalent depocenters. Four significant elements become obvious when these maps are overlain on the basement interpretation.

1. the shelf margin can be viewed as a series of sub-linear line segments oriented NE-SW with right angle offsets at certain major transforms (Fig.10)
2. most major depocenters are located over major basement grabens (Fig. 10).
3. the channel systems feeding these depocenters are preferentially located over basement transforms (Fig.10).
4. the direction and amount of channel avulsion is controlled by the spacing and location of the microbasins.

This preference is demonstrated in the NW-SE oriented sections of the Mississippi River from northwest of Baton Rouge to the mouth of the river (Fig. 1), as well as the locations of paleodrainages(Figs. 10 & 11). The locations of the depocenters are triggered by the location of major growth fault complexes which are in turn triggered by the location of the leading edge of basement horsts and CRHGs. The inter-transform cross-faulting on Figures 10 and 11 is an interpretation based on gravity and magnetics data, regional structure mapping, analysis of production and paleobathymetry data, and interval isopach data. Shelf margins and depocenters migrate southeastward through time and date the growth of the Mississippi River delta complex and the major channel avulsions (Fig. 11). The channel location and orientation is influenced by the basement transforms because the mechanics of the strike-slip motion cause one side to generally be low, sometimes substantially low to the other side.

Linkage between basement structure and paleobathymetry implies a linkage to sedimentation patterns. Irregular initial salt thicknesses are deposited in response to inherited irregularities in the pre-salt topography (Fig. 12). Growth fault locations are controlled by basement structures and salt movement forming inherent zones of weakness (Fig. 13). These growth faults are usually found near the shelf break and are most active near the mouths of rivers where the thickest sands are deposited in the delta front (Fig. 14). Reverse drag forms hanging wall anticlines in the sandier section (Hamblin,1965). Since most salt domes are located over the corners of basement blocks, the major growth faults are also often associated with salt domes. The growth faults sole out at depth into decollement zones interpreted to be deep water shales (i.e. maximum flooding surfaces or condensed sections) or remobilized salt. This is evi-

SERIES	STAGE	ROCK UNIT/FAUNAL ZONATION
HOLOCENE	RECENT	
PLEISTOCENE	UPPER	Sangamon Trim A
	LOWER	Trim B Ang B Cris S Lentic 1
PLIOCENE	UPPER	Glob alt
	MIDDLE	Bul 1
	LOWER	Text X
MIOCENE	UPPER	Rob E* Big A Cris K Amph E Cyclam 3 Disc 12 Text G Text L
	MIDDLE	Big 2* Uvig 3 Rob 5 Text W Big hum Cris I* Cib op Amph B Rob L* Rob M Gyro 9
	LOWER	Cris A-Rob C* Marg A Siph dav Plan palm Lentic h Cris R*
OLIGOCENE	ANAHUAC	Rob A Disc grav Het Cib jeff Bol perc Marg idio Marg vag Marg howei
	FRIO	Text 14 Cam A* Miogyp Cib haz Marg tex Bol mex Nod blan
	VICKSBURG	Text W - Text miss
EOCENE	JACKSON	YAZOO
		MOODY'S BRANCH
	CLAIBORNE	COCKFIELD (=YEGUA)
		COOK MTN. (=CROCKETT)
		SPARTA
		CANE RIVER
	WILCOX	WILCOX
PALEOCENE	MIDWAY	MIDWAY

Figure 9. Stratigraphic chart of rock units and faunal zonation for the South Louisiana study area (adapted from Paleo-Data). Brackets enclose depocenter intervals mapped in Figure 11.

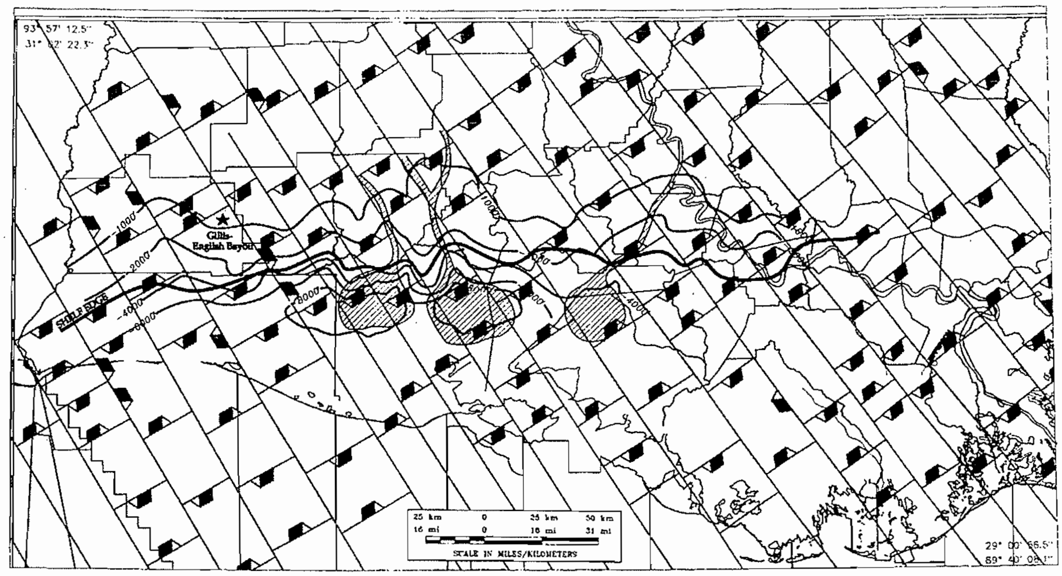

Figure 10. Cross- contoured interval isopach map (adapted from Paleo-Data) with interval depocenters and shelf edge for Cris R (Anahuac) to Camerina A (Upper Frio). The location of Gillis-English Bayou , and it's salt sheet ,is highlighted with a star. It overlies the NW edge of a basement horst as predicted by the models of Adams (1993) and Zhang and Watkins (1994).

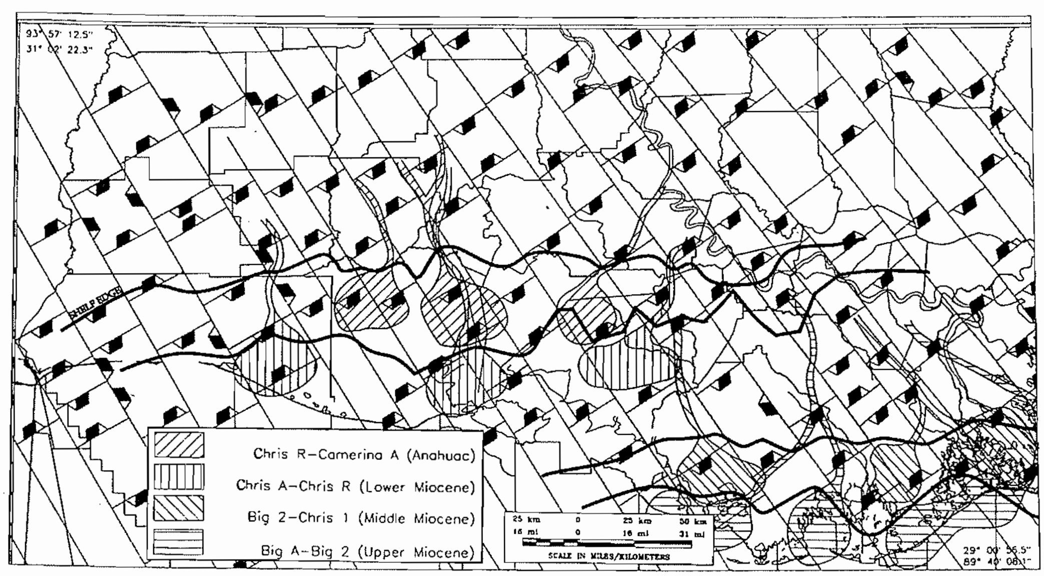

Figure 11. Map of sequential depocenters and shelf edges (adapted from Paleo-Data) for the Cris R to Camerina A (Late Oligocene), the Cris A to Cris R (Lower Miocene), the Big 2 to Cris I (Middle Miocene) and the Big A to Big 2 (Upper Miocene), for south Louisiana.

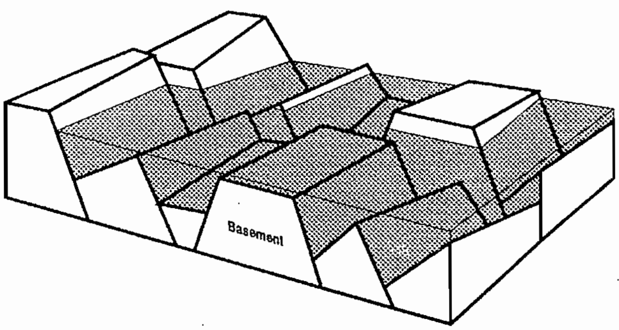

Figure 12 Basement block Diagram, stage II, from Adams (1993), demonstrating initial salt thickness as a function of pre-salt topography.

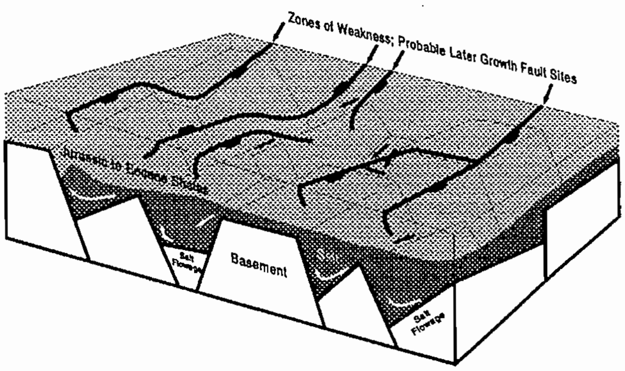

Figure 13. Basement Block Diagram, stage III, from Adams (1993), demonstrating location of inherent zones of weakness which will become growth faults, over the leading edge of basement horsts and CRHG's.

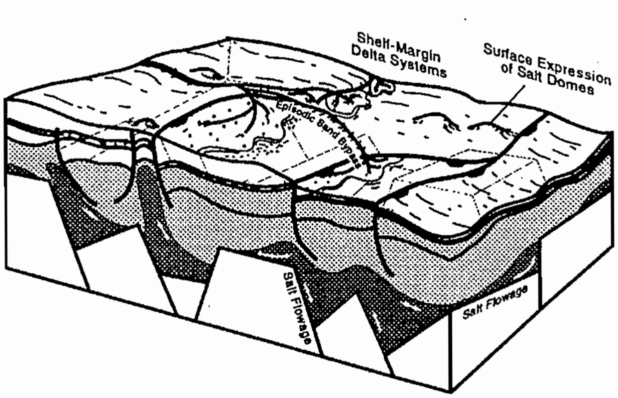

Figure 14. Basement Block Diagram, stage IV, from Adams (1993), demonstrating sand deposition proximal to growth faults located over the leading edge of basement horsts and CRHG's. Sediment influx is channeled along the basement transforms into the microbasins.

dent on regional cross-section (Fig. 15). The deeper part of the cross-section is an idealized representation of the types of basement-salt-sediment interactions predicted by the microbasin model. Basement structure controls salt movement. Deep-water shales (maximum flooding surfaces?, condensed sections?) control growth fault decollement surfaces. Basement structure and salt movement control the location of growth faults. Growth faults control sediment distribution and sand facies as well as structuring and migration pathways.

SALT STRUCTURES

The relationship of salt structures to basement structure is a fundamental relationship in microbasin tectonics. Original salt thickness is an exact cast of the pre-salt surface. Original basement grabens are overlain by salt thicks. As a comparison of Figures 8 and 12 shows, basement ridges and horsts are covered by salt thins or may have no salt at all. Salt thicks within the basement grabens move into vertical salt structures. Much important early work on salt movement was done in Germany (Trusheim, 1960) on ridges, stocks, and spines in northwest Germany near Ruhr. This work showed the relationship of sediment loading to salt movement. Workers in the U.S. have shown the critical relationship of salt structure to external strain rate and the resultant salt features , especially to their relative location (e. g., Jackson and Talbot, 1986). Other workers (Parker and McDowell, 1955; Selig and Wermund, 1966; and Jenyon, 1985) have shown that salt will flow from areas where it is thick to form pillows, walls, and piercement features over the adjacent basement highs. In an environment of horsts and grabens such as south Louisiana, the final salt highs will often be over the corners of basement blocks and will preferentially align along the transforms that define the ends of the basement horsts. Note the alignment of piercement salt features along NW-SE lines on Figure 1.

Where secondary salt movement has taken place, these structures will often be displaced laterally (Zhang and Watkins, 1994). This is especially true where the original salt movement was to the SE. In this configuration, the salt will often be extruded up and over a horst that forms the southeastern boundary of the basement graben and result in a salt sill that spreads laterally rather than vertically (Fig. 4). This scenario is very common in the offshore but has seldom been demonstrated in the south Louisiana onshore to date. One exception is described by Spencer and Sharpe (1993), where a salt sill is demonstrated seismically in the Gillis-English Bayou area of Calcasieu Parish. Note the location of the Gillis-English Bayou area on Figure 10 relative to the northwest flank of the basement horst. Rapid sediment loading along the northwest flank of the microbasin pushes the salt to the southeast and the salt flows up and over the southern boundary of the microbasin. The combination of sediment loading and salt evacuation generates (reenforces?) an up-to-the-basin antithetic fault and often a salt sill or tongue forms as well (Fig. 4).

PRODUCTION TRENDS

The south Louisiana basin has been explored for decades and sufficient production data is present to define trends as well as to define "sweet spots" within each trend. An example is shown for the Anahuac and Frio intervals (Fig. 16). Compare this map with the underlying basement map to see the offsets in the trend at major transforms. The same map also shows that the major fields (high-

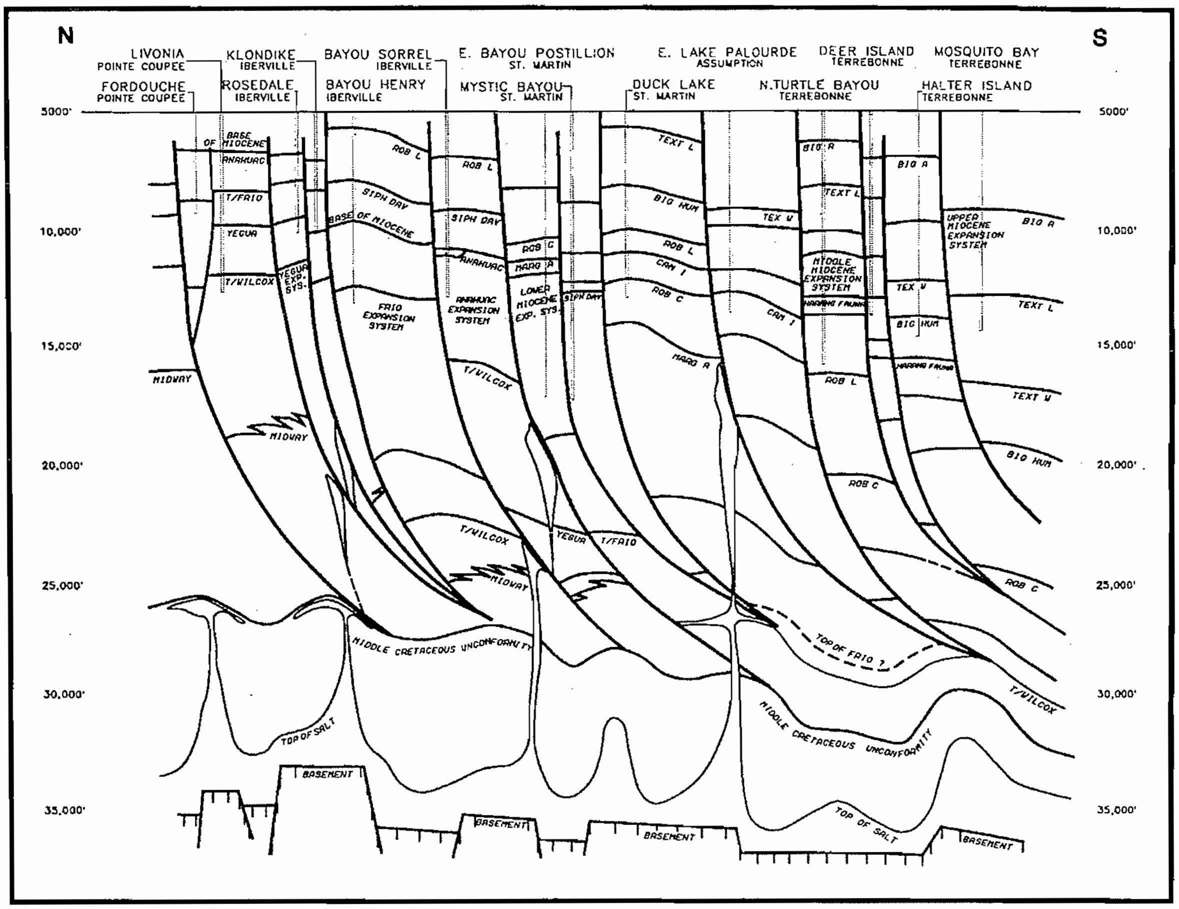

Figure 15. North-South Regional Cross-section showing successively younger growth fault expansion systems moving from north to south, plus inferred basement-salt-decollement surface relationships. Location of the cross-section is shown on Figure 1.

lighted) are preferentially found over or adjacent to the grabens. The Anahuac / Frio (which approximates the Cris R to Camerina A paleo interval) is representative of most trends (Fig. 16). It shows that most of the production to date has come from the shelf facies (zones 2 and 3 of Paleo-Data, the inner and outer shelf). Relatively little drilling has penetrated the shelf margin and slope facies, especially into the hard geopressured section. Microbasin modelling allows us to project sands into those portions of the slope facies overlying basement grabens with increased confidence. Not all transforms will offset all production trends. Nor will all transforms offset all shorelines or all of any other mapped criteria, because not all transforms have vertical relief across the fault at all points along their strike. Perhaps major offsets in production trends, shoreline trends, top of geopressure, and primary depocenters are coincident with intervals of greater vertical offset across the transform in question. Transforms may carry through diverse data sets and exhibit offset at several intervals along strike and yet pass through areas where no stratigraphic offset or structural change is evident. It is not a prerequisite of transform formation that structural elevation and rock type change at all points along the fault's length. Data suggests that these transforms have their origin in Pre-Cambrian zones of weakness (Adams, 1993; Gay, 1995), and reflect Jurassic reactivation during the opening of the Gulf of Mexico. We should not expect them to be apparent on gravity and magnetic data, where the transforms are cut by post-rift age igneous intrusives. In south Louisiana, pattern matching suggests that structural and stratigraphic responses demonstrate a right-lateral sense of offset where offset exists.

HYDROCARBON GENERATION AND MIGRATION

A most critical element of the microbasin model is the concept of kerogen "kitchens" where oil is generated and moved by pulsed migration upward along regional growth faults to reservoirs capable of accepting migrating fluids (Leach, 1994). Mesozoic carbonates and deep marine shales followed immediately after the Louann salt sequence in filling the microbasins. Burial of these source beds into high temperature and pressure regimes allow the generation of movable hydrocarbons. The origin of south Louisiana hydrocarbons has been traced to both Lower Tertiary and Mesozoic-age source rocks (Sassen, 1990) and to Miocene anoxic salt-controlled intraslope basins (Dow, 1984). Either would fall into today's hard geopressured section and allow vertical migration along growth faults. Fertl and Leach, 1990; Burst, 1969; Hunt, 1990; and Hunt et al, 1994, among others, discuss the mechanics of the generation, migration, expulsion theory and timing of this process. Our only concern is that the major growth faults form the primary migration conduits (Anderson et al, 1994).

In offshore south Louisiana, Anderson et al, 1994 discuss the results of drilling into a growth fault in Eugene Island South

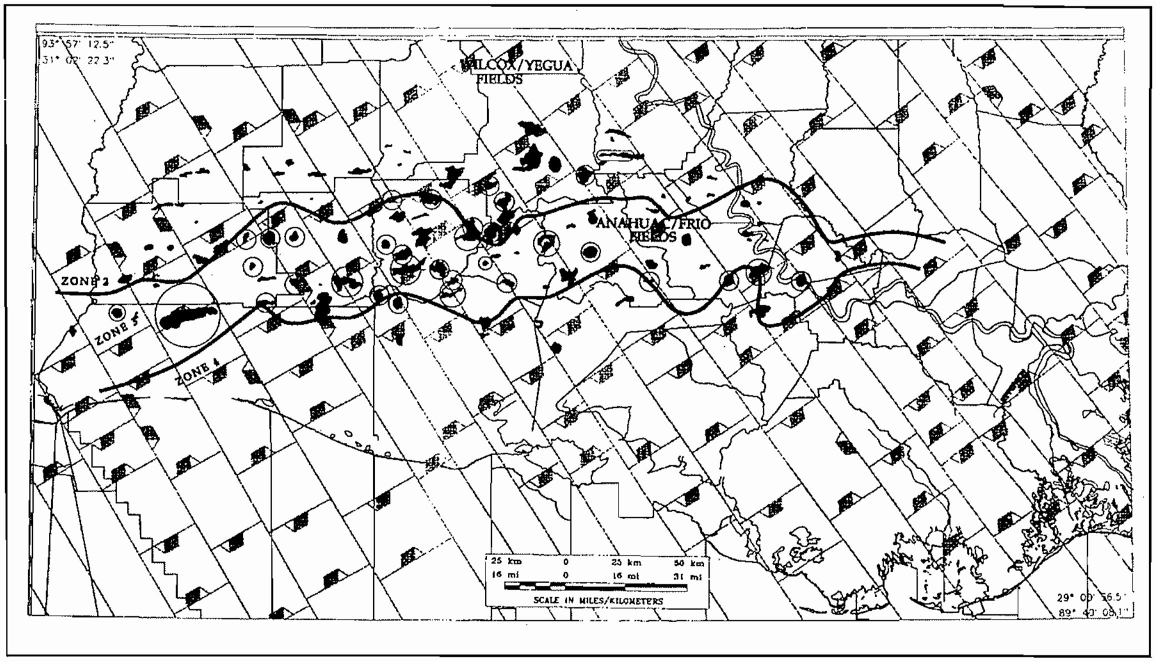

Figure 16. Production trend map for the Frio and Anahuac interval (approximates the Cris R to Camerina A faunal interval). Major fields are highlighted with circles to show their relationship to paleobathymetry for zones 2 (inner shelf), 3 (outer shelf), and 4 (slope). Twenty-five of the thirty-two major fields are within or adjacent to basement grabens. To successfully explore we must apply this concept to find other areas where the production has not yet been established.

Addition Block 330 to test the idea that hydrocarbons are currently migrating up the fault plane. To quote from them: " ...... oil is expelled up the fault zones, but the very act of releasing the fluid drops the pressure and the fault becomes tight again." The pulsed migration moves hydrocarbons up the inclined fault planes into lower pressured reservoirs, and ultimately much of the movable hydrocarbons end up in reservoirs at or near the top of geopressure (Leach, 1994). Movement is initiated as burial, compaction, and fluid expulsion from clays and fine-grained rocks generate geopressures greater than the fracture gradients of the enclosing rocks. This eventually moves much of the movable hydrocarbons into the upper 1600 meters (5000 ft) of the geopressured section and the lower part of the hydropressured section. A map of the top of geopressure was made from analysis of the depth where operators set their first string of protective casing across the study area (Fig. 5). This map was generated from P. I.'s Petro-Rom data set for south Louisiana and is based on selected representative wells from each township across the study area. The depth where protective intermediate casing was set should approximate the top of the geopressured section. This map shows contour offsets and terminations of the contours at certain major transforms plus a decided lineation in a NW-SE sense.

SUMMARY

Where does analysis of these diverse data types and data sets take us? The basement structure of the Gulf Coast Basin is a network of NW-SE transforms cutting through a terrain of horsts, grabens, and CRHGs aligned perpendicular to the transforms. This surface has been eroded and the grabens partially filled by fanglomerates and other facies of the Eagle Mills or its equivalents. Salt was precipitated over this uneven surface, filling the grabens with salt and then burying the lower horsts. The higher horsts and the high corners of some CRHGs were no doubt emergent. Burial of the salt by mesozoic carbonates and deep water shales proceeded as the basement sank through the process of crustal cooling. Piercement salt structures developed as salt flowed away from basement grabens and over the corners of certain adjacent horsts and CRHGs. Non-piercement salt features (pillows and rollers) formed by differential loading under growth faults and are mostly parallel to the growth faults and perpendicular to the transforms.

Organic matter in the sediments was converted to kerogens and oil and eventually these were expelled upward along growth faults into reservoirs at or near the top of the geopressured section. Kerogen and oil expulsion, by being localized along growth faults preferentially channeled oil and gas into reservoirs over or immediately adjacent to basement grabens. Growth faults were also important in localizing thick sands along paleo shelf margins in depocenters (microbasins) overlying the basement grabens. In south Louisiana, 78 per cent of the major fields in the study area were associated with basement grabens. Figure 17 is a diagrammatic representation of the microbasin model for south Louisiana.

The microbasin concept makes a simple, workable model for exploration in both unexplored and mature basins. In south Louisiana, the microbasin model points to underexplored areas and new trends in a mature basin. Additionally, it serves as a model for exploration in unexplored basins both domestically and overseas with similar growth histories. Lyell and Hutton were correct for their time. But to understand this basin, or any other basin from a microbasin perspective please remember " the past is the key to the present".

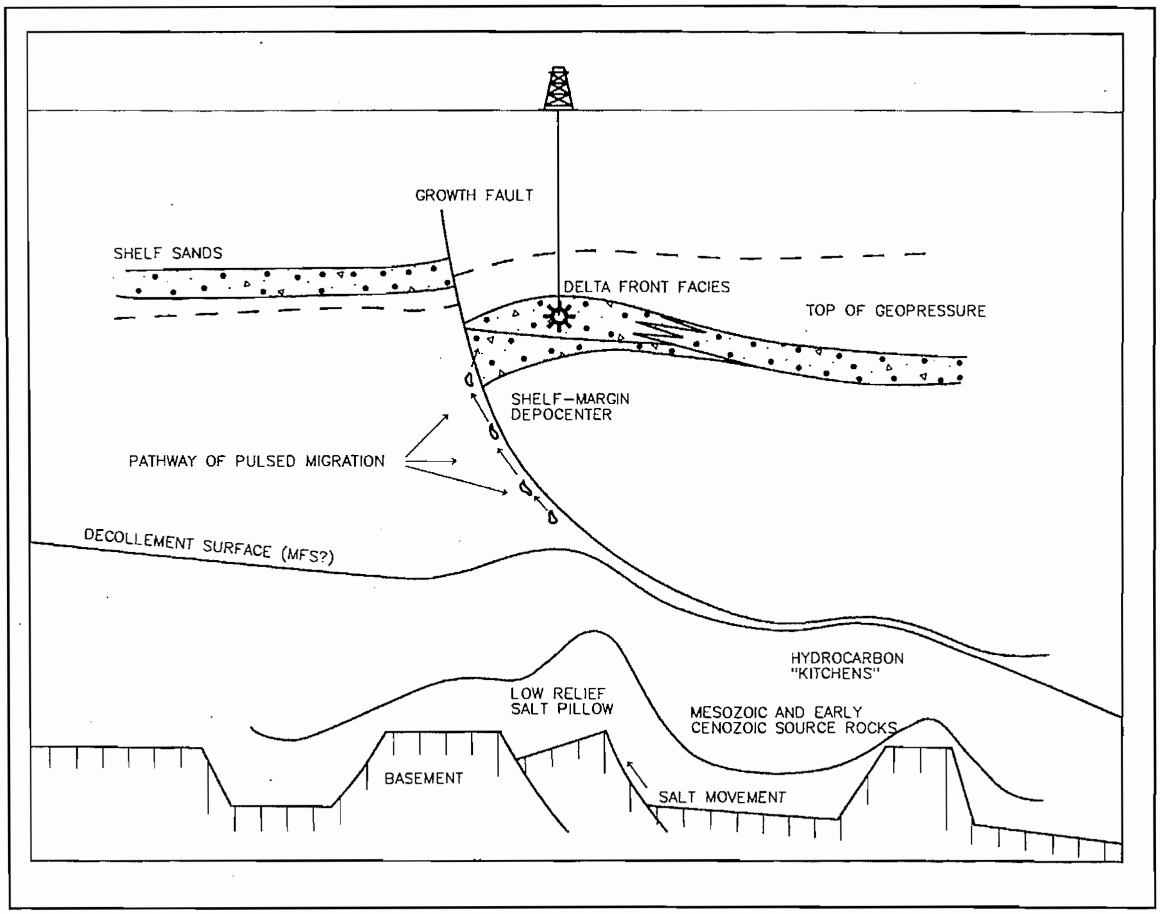

Figure 17. Diagrammatic cross-section representing the microbasin model for South Louisiana. Growth faults tie basement tectonics, "kitchens", migration pathways, geopressure, thick reservoir sands and major field locations into a simple model for exploration.

ACKNOWLEDGEMENTS

Mitchell Energy Corporation allowed me to publish the results of this fourteen month study of south Louisiana. In particular Steve Adcock, Ray Smith, Bruce Martin, Arville Slaughter, Donis Snellenberger, Chris Veeder, Susan McDougall and Tom Fiorito contributed valuable criticism, ideas, and encouragement. Mitchell also allowed the use of their drafting staff to prepare the maps and diagrams, including Pat Barnes, Sonya Guenther, Virginia Villarreal, Brian Leveston, Jesse Juarez, and Kirsten Stephen. Bill Cathey of Earthfield Technology generated the gravity and magnetics maps, and Bill Cathey, David Lane and David Meaux of their staff provided insight into interpretation of their data. Paleo-Data generated paleobathymetry and interval isopach maps as part of their commerciallly available mapping services. Norm Vallette was most helpful in answering questions and researching data. Geo-Map allowed use of data from their Executive Reference Maps, and P. I. Corp. allowed use of their production and WHCS Petro-Rom data. The author gratefully acknowledges the use of these data as well as the efforts on his behalf from all of these companies. Finally, many other unnamed geologists and geophysicists at Mitchell gave freely of their time and ideas. I gratefully acknowledge their help. The concepts and ideas are theirs as well as mine, the mistakes and errors are mine alone.

REFERENCES CITED

Adams, R. L., 1993, Effects of inherited pre-Jurassic tectonics on the U. S. Gulf Coast: Gulf Coast Association of Geological Societies Transactions, v. 43, p. 1-9.

Anderson, R. N., P. Flemings, S. Losh, J. Austin, and R. Woodhams, 1994, Gulf of Mexico growth fault drilled, seen as oil, gas migration pathway: Oil and Gas Journal, June 6, 1994, p. 97-104.

Burst, J. F., 1969, Diagenesis of Gulf Coast clayey sediments and its possible relationship to petroleum migration: American Association of Petroleum Geologists Bulletin, v. 53, no. 1, p. 73-93.

Dow, W. G., 1984, Oil source beds and oil prospect definition in the upper Tertiary of the Gulf Coast: Gulf Coast Association of Geological Societies Transactions, v. 34, p. 329-339.

Fertl, W. H. and W. G. Leach, 1990, Formation temperature and formation pressure affect the oil and gas distribution in Tertiary coast sediments: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 205-216.

Gay, S. Parker Jr., 1995, The basement fault block pattern: its importance in petroleum exploration, and its delineation with residual aeromagnetic techniques, in R. W. Ojakangas, ed., Proceedings Volume of the 10th Basement Tectonics Conference, 1995, p. 1-41.

Gilluly, J. , A. C. Waters and A. O. Woodford, 1968, Principles of Geology, Third Edition: San Francisco, CA., W. H. Freeman and Co., 687 p.

Hamblin, W. K., 1965, Origin of "reverse drag" on the downthrown side of normal faults: Geological Society of America Bulletin, v. 76., p. 1145-1164.

Hunt, J. M., 1990, Generation and migration of petroleum from abnormally pressured fluid compartments: American Association of Petroleum Geologists Bulletin, v. 74, no. 1, p. 1-12.

Hunt, J. M., J. K. Whelan, L. B. Eglinton, and L. M. Cathles III, 1994, Gas generation- a major cause of deep Gulf Coast overpressures: Oil and Gas Journal, July 18, 1994, p. 59-63.

Jackson, M.P.A. and C.J. Talbot, 1986, External shapes, strain rates, and dynamics of salt structures: Geological Society of America Bulletin, v, 97, p. 305-323.

Jenyon, M. K., 1985, Fault-associated salt flow and mass movement: Journal of the Geological Society of London, vol. 142, p. 547-553.

Leach, W. G., 1994, Distribution of hydrocarbons in abnormal pressure in South Louisiana, U. S. A.: Chapt. 14 in Studies in Abnormal Pressure, Developments in Petroleum Science, 38,in W.H. Fertl, R. E. Chapman and R. F. Hotz eds., Amsterdam, Oxford and New York, Elsevier Publishing, p. 391-428.

McFarlan, E. Jr. and D.O. LeRoy, 1988, Subsurface geology of the late Tertiary and Quaternary deposits, coastal Louisiana and the adjacent continental shelf: Gulf Coast Association of Geological Societies Transactions, v. 38, p. 421-433.

Parker, T. J. and A. N. McDowell, 1955, Model studies of salt-dome tectonics: American Association of Petroleum Geologists Bulletin, v. 39, no. 12, p. 2384-2470.

Rainwater, E.H., 1964, Regional stratigraphy of the Gulf Coast Miocene: Gulf Coast Association of Geological Societies Transactions v. 14, p. 81-124.

Salah, M. G. and A. S. Alsharhan, 1996, Structural influence on hydrocarbon entrapment in the northwestern Red Sea, Egypt: American Association of Petroleum Geologists Bulletin, v. 80, no. 1, p. 101-118.

Sassen, R., 1990, Lower Tertiary and Upper Cretaceous source rocks in Louisiana and Mississippi: Implications to Gulf of Mexico crude oil: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 857-878.

Selig, F. and E. G. Wermund, 1966, Families of salt domes in the Gulf Coastal Province: Geophysics, v. XXXI, no. 4, p. 726-740.

Sigsby, R. J., 1976, Paleoenvironmental analysis of the Big Escambia Creek-Jay-Blackjack Creek Field area: Gulf Coast Association of Geological Societies Transactions, v. 26, p. 258-278.

Spencer, J. A. and C. L. Sharpe, 1993, Deep-seated salt sheet in eastern Calcasieu Parish, Louisiana:Gulf Coast Association of Geological Societies Transactions, v. 43, p. 363-371.

Trusheim, F., 1960, Mechanism of salt migration in Northern Germany: American Association of Petroleum Geologists Bulletin, v. 44, no. 9, p. 1519-1540.

Vidrine, L.O., 1971, Production potential of deep Miocene rocks in southeastern Louisiana: American Association of Petroleum Geologiists Bulletin, v. 55, no. 2, p. 227-240.

Zhang, J. and Watkins, J. S., 1994, Plio-Pleistocene structural characteristics of central offshore Louisiana with emphasis on growth-fault interplay with salt tectonics, Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 745-754.