# Basement Tectonics and Origin of the Sabine Uplift

**Richard L. Adams**

Carr Resources, Inc., 305 S. Broadway Ave., Tyler, Texas 75702

## ABSTRACT

**The same processes that formed the Gulf of Mexico Basin formed the Sabine Uplift. The Sabine Uplift is supported by a large rhombic area of basement fault blocks that originated as a mid-rift high during the Triassic rifting phase of the opening of the Gulf of Mexico. Sometimes referred to as a basement block, it covers an area that is 90 miles long (northwest-southeast) and 60 miles wide (southwest-northeast). Across the uplift the depth to magnetic basement is up to 10,000 ft shallower than in the middle of the East Texas Salt Basin. The northeast and southwest boundaries of this basement high are major transform fault systems that parallel the opening of the Gulf of Mexico. The northwest boundary is the East Texas Salt rift basin and the southeast side steps down into the South Louisiana Salt Basin. Within this mid-rift high, multiple smaller transform faults with horst and graben structures are evident by mapping the base of the Louann Salt from seismic data. Within the overall uplift area, these internal structures have influenced sedimentation on a smaller scale. Further uplift of this mid-rift high occurred during the middle to late Cretaceous and also during the Paleocene-Eocene.**

**While the mid-rift high has a thin Louann Salt cover, an estimated 5,000 to 7,000 feet of salt was deposited off this high in the East Texas Salt Basin. Salt isochrons infer both the external and internal shape of the mid-rift high. The Halbouty Ridge, located along the Smith-Rusk county line, and the San Augustine High are salt isochron thins that are evident on the mid-rift high.**

**The shape of the mid-rift high has also influenced later sedimentary depositional patterns. In the areas adjacent to it, i.e., southwest of the Trinity River and east of the Louisiana State Line, the Haynesville–Bossier–Cotton Valley System is aggradational due to very large available accommodation spaces. Conversely, in the area supradjacent to the mid-rift high, the Haynesville–Bossier–Cotton Valley System prograded across a flat marine shelf environment over an area nearly three times as large due to a loss of available accommodation space.**

**The Cotton Valley sands across this shallow marine mid-rift high are shoreface sands that were deposited along a shoreline that extended from southwest to northeast across the shelf. The sands of Overton Field, as well as the sands at Oak Hill, Willow Springs, and Carthage fields, are all examples of this deposition. Thin widespread limestone beds are present within the Cotton Valley across the Sabine Uplift. These limestones are interpreted as transgressive shell lags and back-bay oyster beds. The position of successive active shoreface systems prograded through time, with the oldest system to the northwest and the youngest migrated to the southeast.**

**Middle to late Cretaceous Laramide foreland tectonics applied lateral compression from the southwest and formed a foreland fold pair (the Sabine Uplift and the North Louisiana Salt Basin). Later, Paleocene-Eocene compression reactivated the uplift again. Pre-Jurassic transform fault lineations along northwest-southeast lines strongly**

Adams, R. L., 2009, Basement tectonics and origin of the Sabine Uplift: Gulf Coast Association of Geological Societies Transactions, v. 59, p. 3-19.

**influenced the shape and style of the resultant uplift. The current outline of the Sabine Uplift is defined by the edge of the Wilcox outcrop, resulting in a rectangular shape along a northwest-southeast axis.**

**Any exploration program for the Sabine Uplift area should include a serious consideration of Laramide compressional tectonics, subsalt structures, and both gravity and magnetic mapping early in the evaluation process.**

## INTRODUCTION

This paper will provide a framework for the structural and stratigraphic history of the Sabine Uplift that is better understood when looked at in a regional context. The origin of the Sabine Uplift has been the subject of many authors (Granata, 1963; Halbouty and Halbouty; 1982; Jackson and Laubach, 1988a, 1988b, 1991). It is herein suggested that a large left-lateral wrench fault system, originating near Saltillo, Mexico, was the source of external compression for the foreland folding that formed the Sabine Uplift (Fig. 1). The Sabine Uplift formed at a restraining stepover/side-step (Dooley and McClay, 1997) in that wrench fault system. This wrench system continues across the North American continent, and is referred to as the Saltillo–St. Lawrence Shear System.

## BASEMENT TECTONICS

Pre-salt structures reflect the Triassic rift tectonics that formed as the Africa–South America block separated from the North American block. Transfer faults, commonly known as “transform faults,” that formed by strike-slip motion during this rifting are oriented with strikes around ~N60°W (Fig. 2). Faults that parallel this orientation are present across the North American Craton (Tanner, 1967). These faults form the basic building blocks for understanding basement structural tectonics. Another fault orientation of ~N45°W strike is found almost exclusively within the post-salt sedimentary section. This orientation is the compressional synthetic shear that fol-

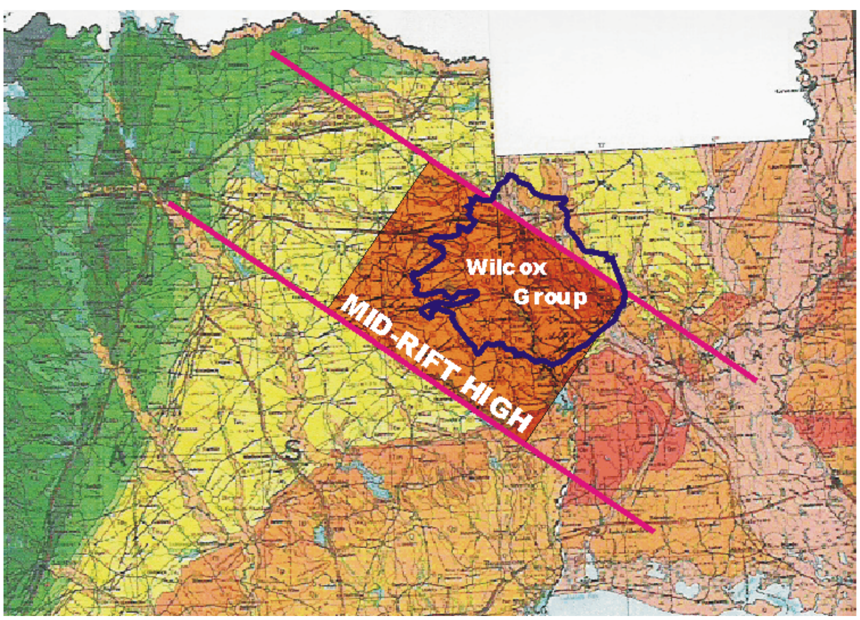


**Figure 1. Map of the Sabine Uplift as defined by the mid-rift high and the Wilcox (Paleocene-Eocene) outcrop of East Texas and Louisiana. Base map from geologic highway maps of Texas and Louisiana (modified after Renfro, 1979, and Bennison, 1975, reproduced with permission of the American Association of Petroleum Geologists).**

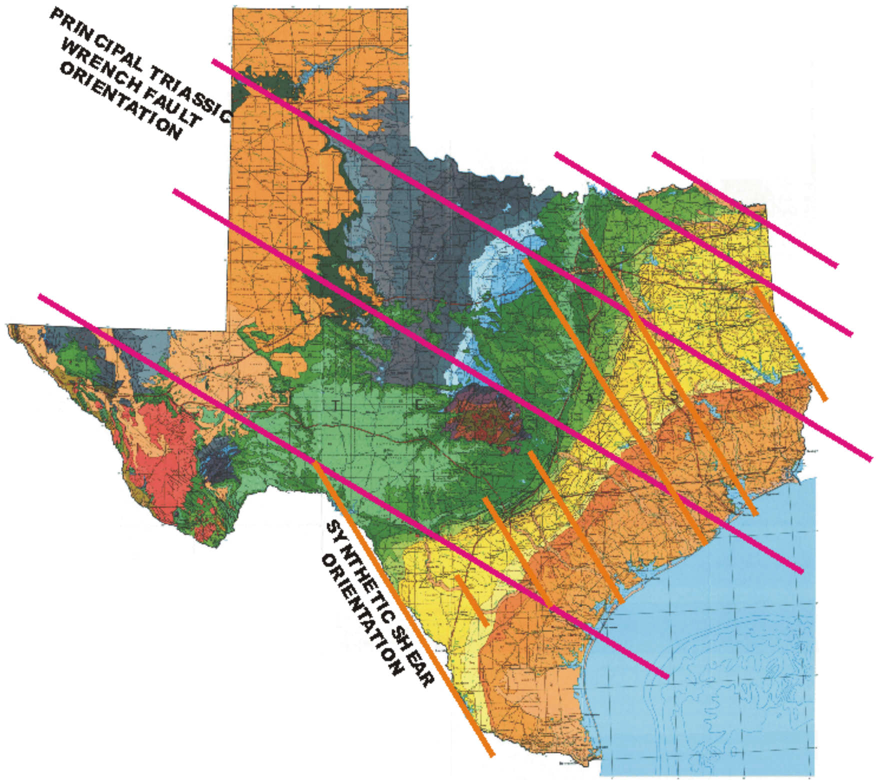


**Figure 2. Surface geologic map of the State of Texas (modified after Renfro, 1979, reproduced with permission of the American Association of Petroleum Geologists). Surface patterns reflect principal basement transform orientations and rivers define the synthetic shear orientations.**

lowed the Pennsylvanian/Permian Ouachita orogenic thrust faulting (Fig. 2). These faults were reactivated during the Triassic rifting and have formed linear shear zones that are affecting structural and sedimentary systems to present day. These synthetic shears control the course of all of the major river systems in Texas today and in the geologic past (Fig. 2). The Paleo-Trinity River controlled Bossier sedimentation on the west flank of the East Texas Basin in much the same way that the location of the Sabine River controls the location of the beaches and shelf sand deposits between Sabine Pass and Galveston, Texas, today.

Major transform systems are visible on maps of magnetic susceptibility, gravity, surface geologic maps, 2D seismic data, and surface lineament analyses. These features can also be inferred from surface geography and Landsat analysis. These major faults can be traced into the offshore domain where they merge into the major mapped transform faults of the Atlantic and Gulf coast margins (Stephens, 2001).

The expected suite of rift horst and graben can be found at right angles to the major transform orientation (Adams, 1989, 1993, 1997). These horsts and graben terminate into smaller strike-slip faults that also parallel the major transform orientation (Fig. 3). The net effect of this fault pattern is a mosaic of rectangular-rhombic fault blocks. The rectangles are elongate in a northeast-southwest direction, and the ends of the rectangles define smaller offset transform faults that are continuous for many miles, if not continuous across much of the basin. Across portions of the Sabine Uplift where the Louann Salt cover is thin (less than ~1000 ft), these fault blocks can be mapped utilizing seismic data. The base of the Louann Salt surface is critical to understanding later depositional and structural trends. Repetitive at large, intermediate, and small scales, features such as the East Texas Salt Basin and the Sabine Mid-Rift Horst, the Halbouty Ridge, and offset horsts such as those that influenced the seaward edge of Haynesville oolite shoal deposition at Gladewater, Gilmer, and Overton fields (Fig. 4) are all influenced by these basement fault blocks (Halbouty and Halbouty, 1982; Hughes, 1968).

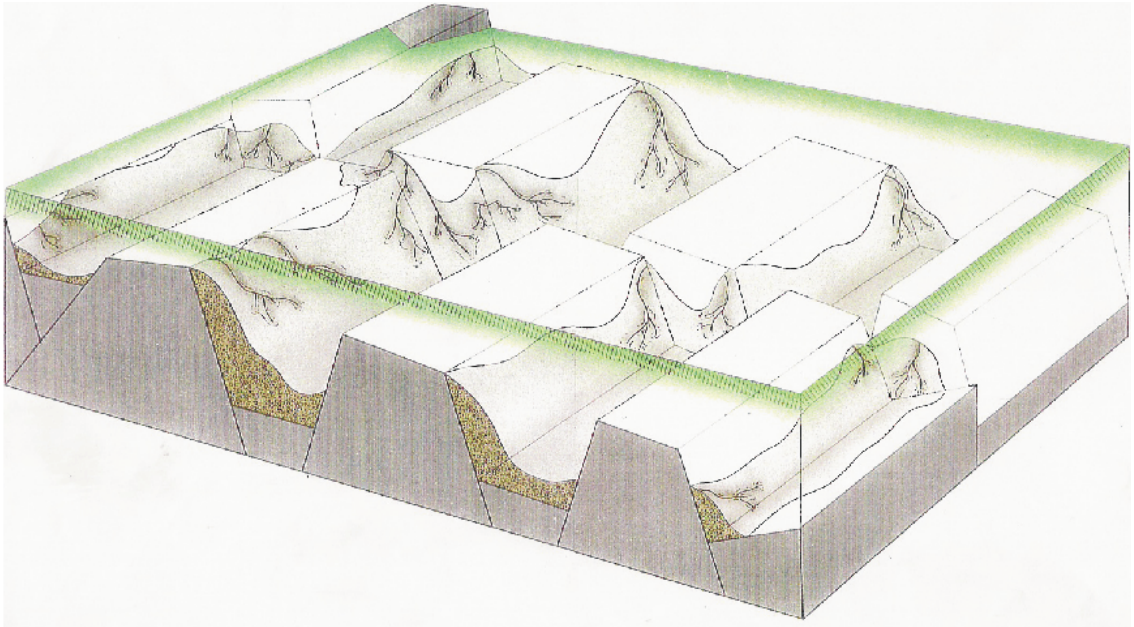

**Figure 3. Salt structuring is a direct response to overburden loading and original salt thickness. The original salt isopach is a cast of the rifted pre-salt surface (from Adams, 1993, reproduced with permission of the Gulf Coast Association of Geological Societies). After initial rifting, erosion on the horst blocks in an arid climate developed extensive alluvial fans, wadis, and eolian deposits. Precipitation of the Louann Salt covered the irregular topography. Some basement graben had thick salt sections precipitated, while some horsts had no salt deposition. Resultant salt thickness was inversely proportional to original elevation.**

The synthetic shear zones cut across this basement architecture and have a unique internal structure. These synthetic shear zones have opened by transverse shear along planes within the shear zone that are parallel to the major transform systems. This generates a linear series of rhomb-shaped basins with intervening horsts that are at an angle within the synthetic shear zones. Both modern and ancient rivers follow the synthetic shear zones by flowing diagonally across the individual rhomb-shaped basins (Fig. 5). These rhombs are also preferential sites for salt deposition because of their early formation. Features such as salt domes, pillows, and salt welds are all to be expected within these isolated rhombs.

The Sabine Uplift of today is a reactivated mid-rift high. This large rhomb-shaped area owes its origin to the same tensional forces that formed the East Texas Salt Basin, a large rift basin, and the basement transform faults. The northeast and southwest boundaries are major transform systems. They extend into the offshore Gulf of Mexico where they are among the transfer faults shown by Stephens (2001). Also in that paper, Stephens' (2001) work reflects both the N60°W and N45°W basement fault orientations. It is important to recognize that the origin of the Sabine Uplift cannot be interpreted without placing it into its proper regional context.

## SALT TECTONICS

The key to understanding salt tectonics across the Sabine Uplift is to initially understand the geometry of the Louann Salt at the end of salt deposition. The depositional surface of the Louann Salt was originally a flat surface (Holwerda and Hutchinson, 1968; Adams, 1989, 1993); therefore, the original salt isopach was a cast of the pre-salt surface (Fig. 3).

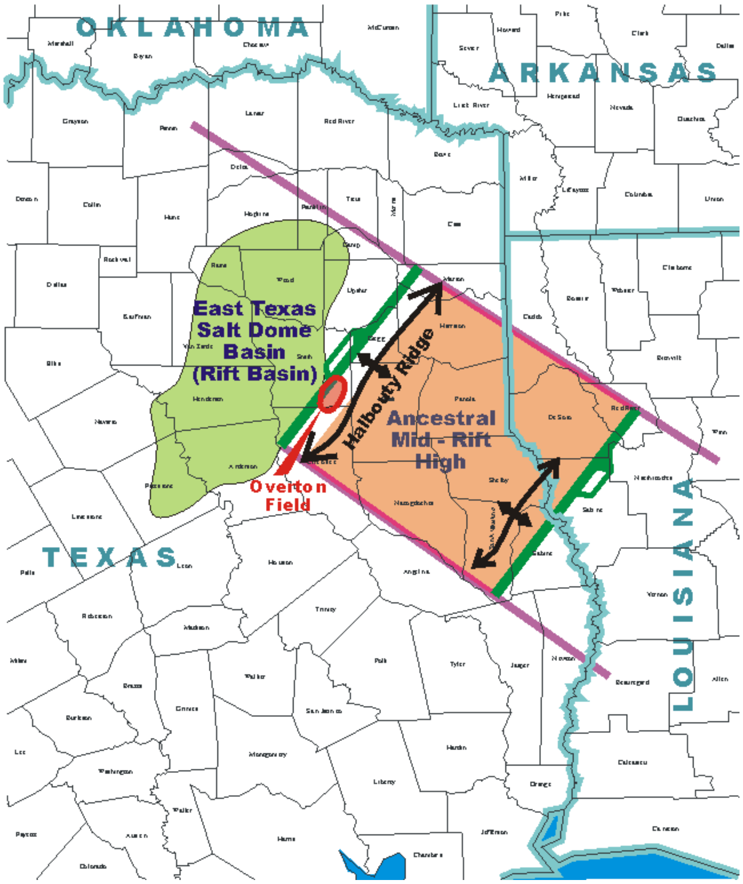


**Figure 4. Examples of large scale basement features in the East Texas Basin.**

It follows from this that subsequent sediment loading will cause salt deformation to proceed along predictable and repeatable paths (Trusheim, 1960; Parker and McDowell, 1955; Selig and Wermund, 1966). These paths will lead to salt deformation that yields structures that can now be used to predict the original salt isopach. Original salt thicknesses of less than about 1000 ft will deform very little, unless the salt thins abruptly against the edge of an adjacent horst. Thicker salt will deform into pillows, stocks, ridges and domes (Kupfer et al., 1976; Jenyon, 1985; Lobao and Pilger, 1985). Along the edge of the salt basin, the salt movement will cause the formation of large relief faults. Similarly, faults will form within the basin where the salt thins abruptly, or where the slope on the pre-salt surface is great enough to allow salt flowage downslope. Thus, salt structures can be used as indicators of subsalt faults (Hughes, 1968; Mathisen, 1995).

The shape, size, and type of salt deformation must be mapped and understood in order to map and understand the pre-salt tectonics; the pre-salt tectonics must be understood to predict its effects on later depositional and structural patterns. For example, salt domes, pillows, and ridges may form along the edges or more often in the corners of the basement graben (Jackson and Talbot, 1986). Proper analysis of the lines of domes and ridges will define the basement transform systems (Adams, 1993). The horsts and graben can often be determined after the transform systems are defined (Adams, 1993, 1997).

One of the most important conclusions to understand is the necessity for external forces to initiate salt movement. These external forces can be the gravitational force of uneven sediment loading, gravitational movement along a sloping basal surface, or external tectonic compression or tension which either change the confining pressures on the salt body or physically change the shape of the confining boundaries of the salt body.

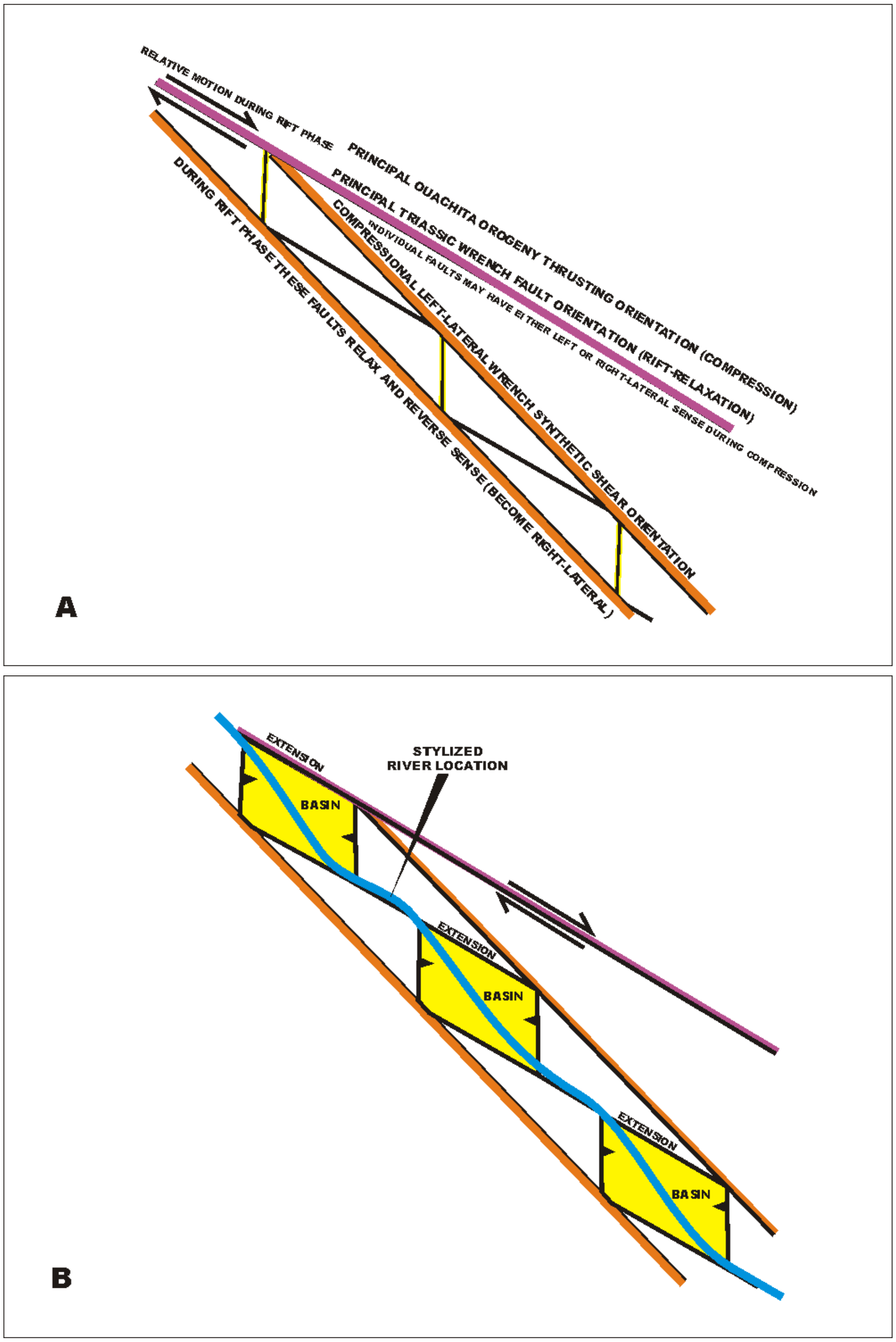


**Figure 5. (A) Both modern and ancient rivers follow the synthetic shears zones along the Texas Gulf Coast. The synthetic shears opened during Gulf rifting along internal faults that formed parallel to the principal wrench fault orientation. (B) River within the synthetic shear systems flow parallel to the principal wrench systems over the internal wrench faults and then flow diagonally across the intervening graben basins. Multiple releasing sidestep/stepover pull-apart basins formed over continental crust during early stages of rifting, resulting in multiple rhomb-shaped basins that define modern river systems and local basins.**

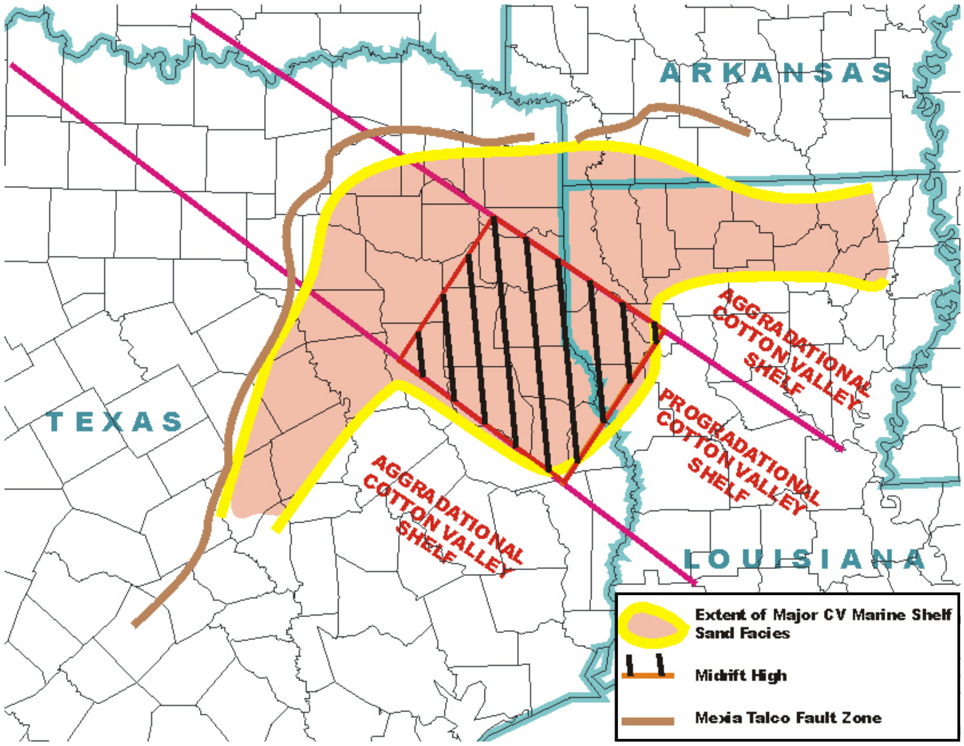


**Figure 6. This map shows a simplified comparison of the aggradational and progradational Cotton Valley shelf systems. The aggradational systems are narrower with stacked sand systems. The mid-rift high beneath the current Sabine Uplift has forced the Cotton Valley to prograde across the shelf, resulting in a shelf system that is nearly three times as wide as in an aggradational setting.**

## HAYNESVILLE–BOSSIER–COTTON VALLEY DEPOSITION

The Sabine Uplift had a profound effect on deposition of the Haynesville, Bossier, and Cotton Valley sediments (McGillis, 1984; Ewing, 1991; Collins, 1980). A subsiding shelf characterized the area southwest of the Trinity River and east of the Texas-Louisiana State Line (Fig. 6). In contrast, the area between the Trinity River and the Texas-Louisiana State Line was supported by the large mid-rift high in the pre-salt rocks. This area did not subside during the Jurassic deposition like the areas on either side. Therefore, the sedimentary section across the mid-rift high was forced to prograde to the southeast instead of aggrading in place.

The East Texas Salt Basin also had a profound influence on this Jurassic sedimentation. Because the top of the Louann Salt was deposited as a flat surface, the salt basin was a large flat area with little or no stream gradient potential, nor any relief to aid in the nucleation of Haynesville grainstone shoals. However, Haynesville grainstone shoals developed in front of the flat basin area and nucleated over the Halbouty Ridge (Ahr, 1981) on the northwest flank of the mid-rift high (Fig. 7). Detailed examination shows that the Halbouty Ridge is a ridge composed of many smaller horsts. Grainstone shoal development initiated supradjacent to these individual horsts and coalesced into a regional shelf-edge grainstone complex. At the end of Haynesville deposition, the carbonate system was drowned by the transgressive Bossier Shale influx. The shape and amount of the pre-Bossier relief on the Haynesville shelf-edge can be determined by isopaching the Bossier Shale as illustrated in the dip cross section (Fig. 8). The Haynesville porosity is time-transgressive to the east as it climbs stratigraphically. The Halbouty Ridge and the Haynesville grainstone shoal became part of a buttress that diverted major Bossier river systems.

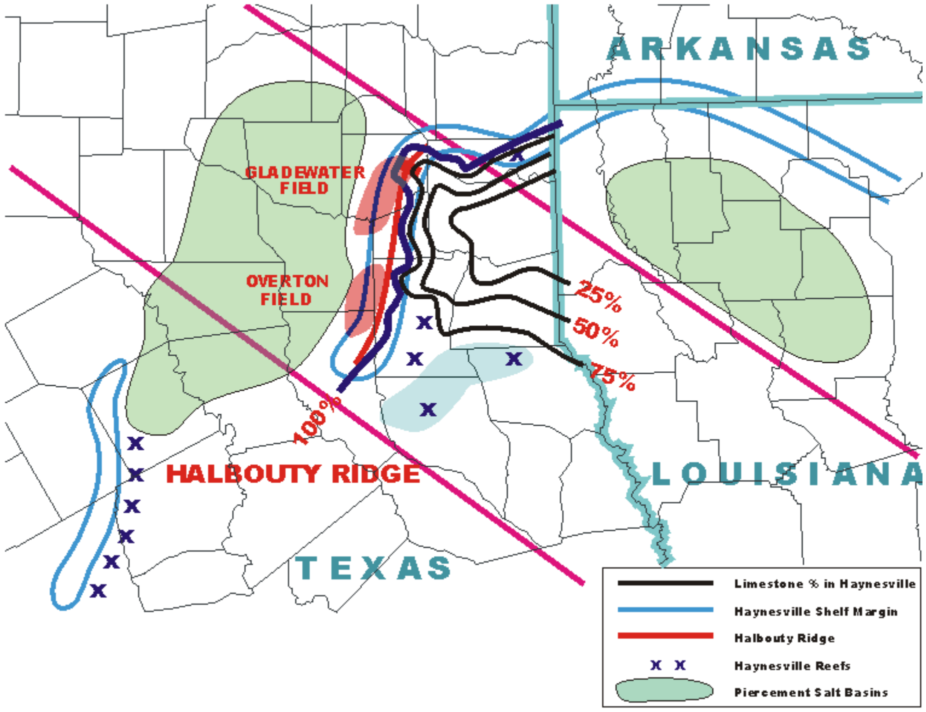


**Figure 7. Location of the Haynesville shelf margin and the limestone percentage of the Haynesville interval over the mid-rift high. The shale which replaces limestone across the shelf is interpreted to have been carried onto the shelf by longshore currents from North Louisiana.**

The Bossier rivers and streams were diverted around the flat area of the East Texas Salt Basin into the synthetic shear zones adjacent to the mid-rift high, i.e., the Trinity River. The East Texas Salt Basin had no sufficient stream gradient except only within the synthetic shear zones on either side of the East Texas Salt Basin and the Halbouty Ridge. Therefore, gravity forced these rivers into the synthetic shear zones. The Bossier is the basinward deepwater time equivalent of the Cotton Valley massive sands. During progradation of the Bossier–Cotton Valley Delta System the location of the Cotton Valley shorelines migrated across the East Texas Salt Basin onto the mid-rift high.

The Sabine Uplift mid-rift high became the ideal shallow water shelf for Cotton Valley sand deposition. Multiple bay-beach-shoreface systems (Balsley and Parker, 1991) developed with a northeast-southwest strike orientation and prograded across the shelf. Figure 9 shows a stylized distribution of the major Cotton Valley shoreface systems across the Sabine Uplift as depicted in the north-south cross-section in Figure 10. The lowermost Cotton Valley sequence for the Taylor sands contain minor transgressive events that cap each sand sequence with shell limestone lags that are correlative and mappable across the Sabine Uplift. On a regional scale these limestones correlate into time-equivalent shales that developed on the shelf basinward of the shoreface system. Each system prograded to a position seaward of its immediately preceding shoreface system. The limestones are important vertical seals within the predominantly sand-shale sequence and are almost always associated with the gas production from the Cotton Valley sands below.

A regional north-south cross-section shows the progradational nature and correlation for each general sand package and its capping limestone beds (Fig. 10). This cross-section also shows the effects of the Halbouty Ridge on Haynesville grainstone development, as well as the effect of basement graben on Haynesville sedimentation. In Harrison County, a large area of Haynesville Limestone in front of the Halbouty Ridge is replaced by a predominantly shale interval. Figure 7 includes a limestone percent map of the Haynesville interval where the shale in this trough is inferred to have its origin in the North Louisiana Salt Basin and is considered roughly correlative to the shales that encase the Gray sand.

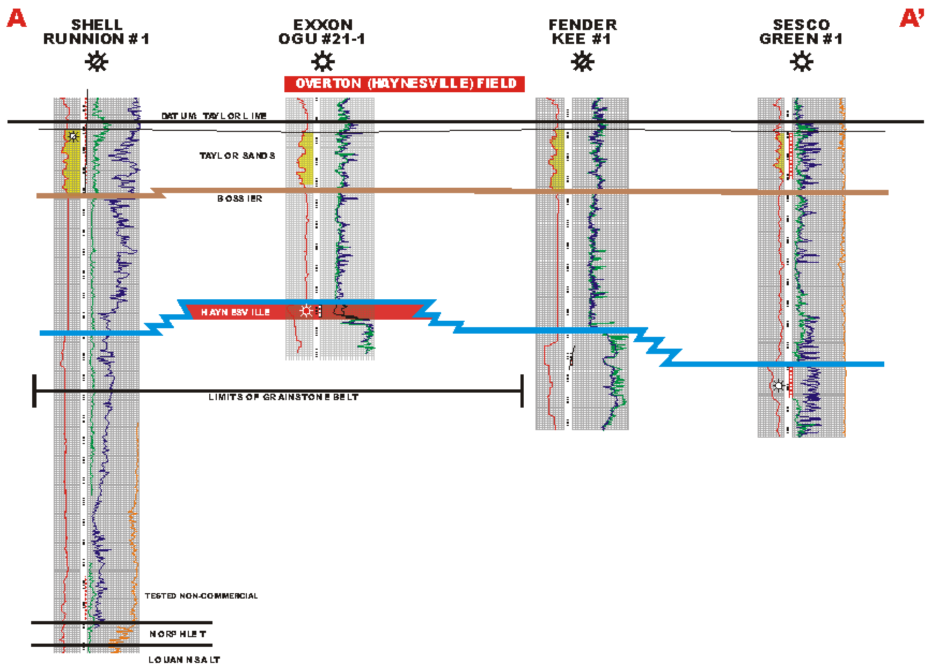


**Figure 8. Dip cross-section A-A' through the Haynesville grainstone shoal in Overton Field (Smith County, Texas) demonstrates the thickening of the Haynesville across the Halbouty Ridge and the abrupt thickening of the overlying Bossier Shale seaward (east) of the Haynesville shelf margin over the current Sabine Uplift. See Figure 7 for the location of Overton (Haynesville) Field and cross-section A-A'.**

## LARAMIDE COMPRESSION

The lasting effects of the mid-rift high do not stop with Cotton Valley deposition. The large basement high acted as a buttress during Laramide wrench faulting (Bolden, 1989) and became a fault-fold with significant thinning over the crest of the fold. Jackson and Laubach (1988a, 1988b, 1991) recognized the fold nature of the Sabine Uplift. They recognized the coincidence of timing of the folding with the Laramide Orogeny to the west, but they did not discuss the mechanism by which the Sabine Uplift was connected to the Laramide Orogeny. Further work and model studies have provided more insight into the nature of the fault origin and orientation of the Sabine Uplift. Aydin and Nur (1985) used the term stepover to describe the process of *en echelon* fault movement, while Dooley and McClay (1997) refined that terminology and included both stepover and side-step, as well as defining the nature of the geometry as either releasing or restraining. They also incorporate the term "double bend" as a fault style. This work is important in explaining how large amounts of energy can be transmitted long distances to form arches and uplifts. Scaled sand box models are used to demonstrate several of these styles (Dooley and McClay, 1997).

The Sabine Uplift is a rectangular uplift that owes its antecedent shape to the Triassic mid-rift high that underlies the current arch. The surface geologic map of the Sabine Uplift area shows the outline of the Wilcox outcrop to be a rectangle, with its long dimension oriented northwest-southeast (Fig. 1). Coincidentally, this Wilcox outcrop outline is very similar to the outline of the mid-rift high with displacement to the northeast. This strongly supports the idea that compression was from the southwest. It can be concluded that the forces that caused the Cretaceous and Eocene uplift of the Sabine Arch (Granata, 1963; Jackson and Laubach, 1988b, 1991; Halbouty and Halbouty, 1982) acted on the mid-rift basement block in its entirety. This data supports the opinion of Jackson and Laubach (1988b) that the arching is not due to volcanism or igneous intrusions, but rather to exterior compressive forces as being the most reasonable cause of the arching.

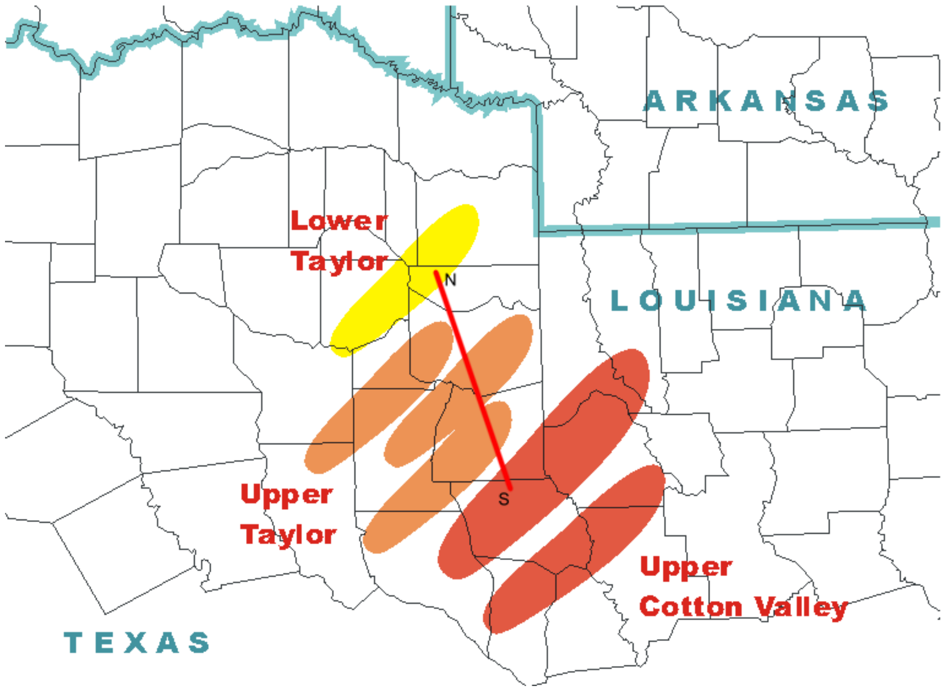


**Figure 9. A simplified map view of the prograding Cotton Valley barrier island systems across the Sabine mid-rift high. Lower Taylor sands are to the northwest and Upper Cotton Valley sands are to the southeast.**

It is suggested here that the external force responsible for the arching of the Sabine Uplift was transmitted to the southwest flank of the mid-rift high by a Laramide wrench fault that originated near Saltillo, Mexico, and which is oriented northeast-southwest from that point to near Jacksonville in Cherokee County, Texas. At that point the wrench fault is offset via the Mt. Enterprise Fault Zone to a point near Black Lake Field in eastern Natchitoches Parish, Louisiana, where the fault turns back to the northeast. The fault system continues to the northeast through the New Madrid Fault Zone, the Lima-Indiana (Trenton) Field, and exits the craton through the St. Lawrence River gap (Fig. 11). This wrench fault system is termed the Saltillo–St. Lawrence Shear System. Both surface and buried faults define most of this pathway, as do sites of historical seismicity. Occurrences of some of the larger earthquakes in Texas are near Jacksonville and Rusk in Cherokee County, where the wrench fault line (here defined by the Elkhart graben system) turns east along the Mt. Enterprise Fault Zone (Davis et al., 1985; Jackson, 1982).

The line of this wrench fault system defines a restraining double bend or restraining side-step where the system is offset by the Mt. Enterprise Fault. In this scenario, the Sabine Uplift becomes a fault-fold or a pop-up block at the point of impingement. Not unexpectedly, the periods of major uplift on the Sabine are coincident with the major periods of Laramide activity, namely the middle Cretaceous and the Paleocene-Eocene (Jackson and Laubach, 1988b).

## SABINE UPLIFT

What does the structure of the Sabine Uplift look like when viewed in the context of lateral compression across a restraining side-step along a continental-scale wrench fault? Figure 12 is a cartoon map view of this scenario. Note the position of the side-step relative to the basement mid-rift high. The mid-rift high is nearly bisected by the side-step in the Saltillo–St. Lawrence Shear System (the Mt. Enterprise Fault), and the offset of

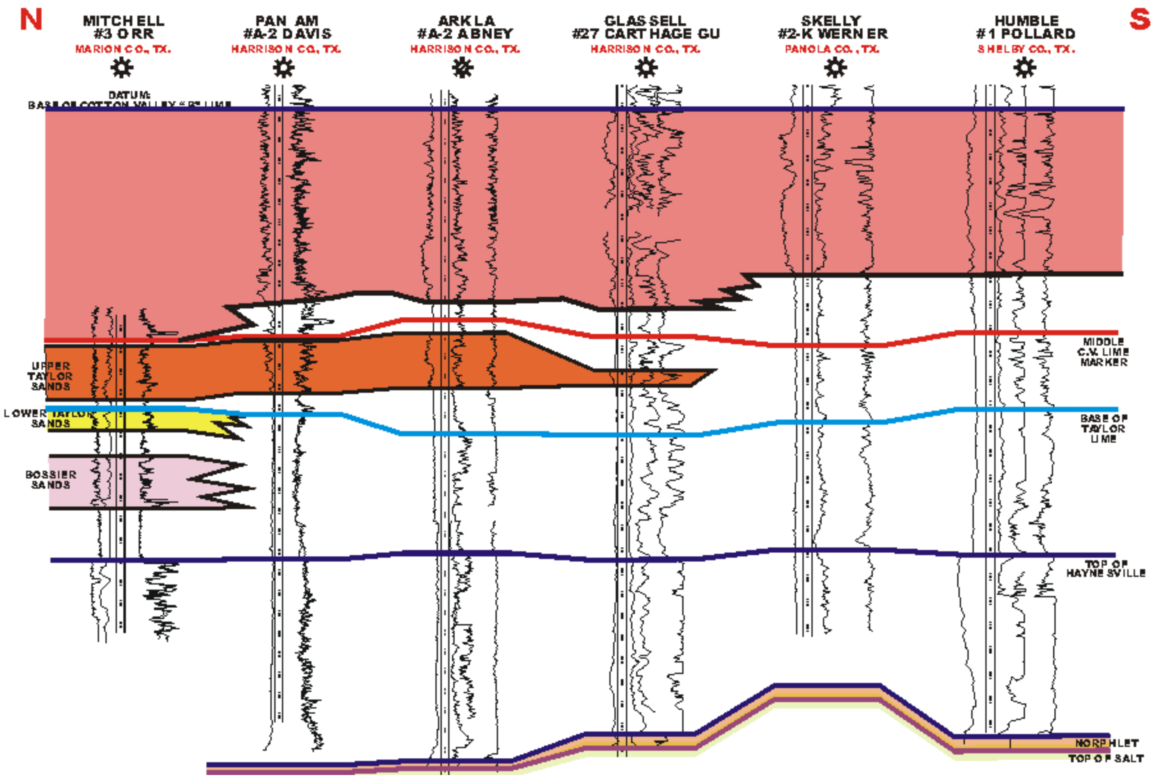


**Figure 10. A north-south stratigraphic cross-section from Marion County to Shelby County, Texas, showing the southward progradation of successive Cotton Valley sands and the correlation of the internal transgressive limestones that cap each sequence. The largest transgressive limestone is the Cotton Valley "B" or Knowles Limestone. Cross-section location is shown on Figure 9.**

the side-step is nearly coincident with the width of the mid-rift high. Also, the Wilcox outcrop outline is offset to the northeast.

Figure 13 is a northeast-southwest cross-section of this compressive system as viewed parallel to the wrench fault prior to the compression. Note the thick Jurassic salt away from the mid-rift high versus the thin salt over the mid-rift high. Also note the subtle thinning of the upper Jurassic and lower Cretaceous interval over the mid-rift high. This is a continuation of the Haynesville–Bossier–Cotton Valley response described earlier in this paper. Salt movement, crustal isostacy and differential compaction are all in part responsible for the thickening of this interval off of the mid-rift high. The mid-rift high is shown here with flanking blocks that gradually step deeper. This may not be the case in all orientations, but is valid for this model.

The resultant post-compression cross-sectional view is shown in Figure 14. The major uplift is accomplished by vertical reactivation of the northwest-southeast transform faults that flank the mid-rift high. Compression has squeezed the mid-rift high upward and reactivated transfer faults on the flanks. This change in motion was probably accompanied by the formation of additional fault splays at multiple scales. These faults are not seen on seismic but are inferred to fit the observed uplift based on the depths to magnetic basement. The two periods of uplift are demonstrated diagrammatically with the middle Cretaceous uplift centered over the mid-rift high and the Paleocene-Eocene uplift offset slightly to the northeast. This offset can be viewed as an early precursor to the formation of an overturned fold. Overturned folds are present along the Saltillo–St. Lawrence Shear System near Monterrey, Mexico, in the Huastecan Fold Belt. Differences in degree of fold asymmetry, or overturning, relate to strain variations along the shear system.

If the Sabine Uplift is a response to cratonwide stresses and intra-plate movement, it then stands to reason that other similar features may have a similar or related origin. For example, the Llano Uplift, the Monroe Uplift,

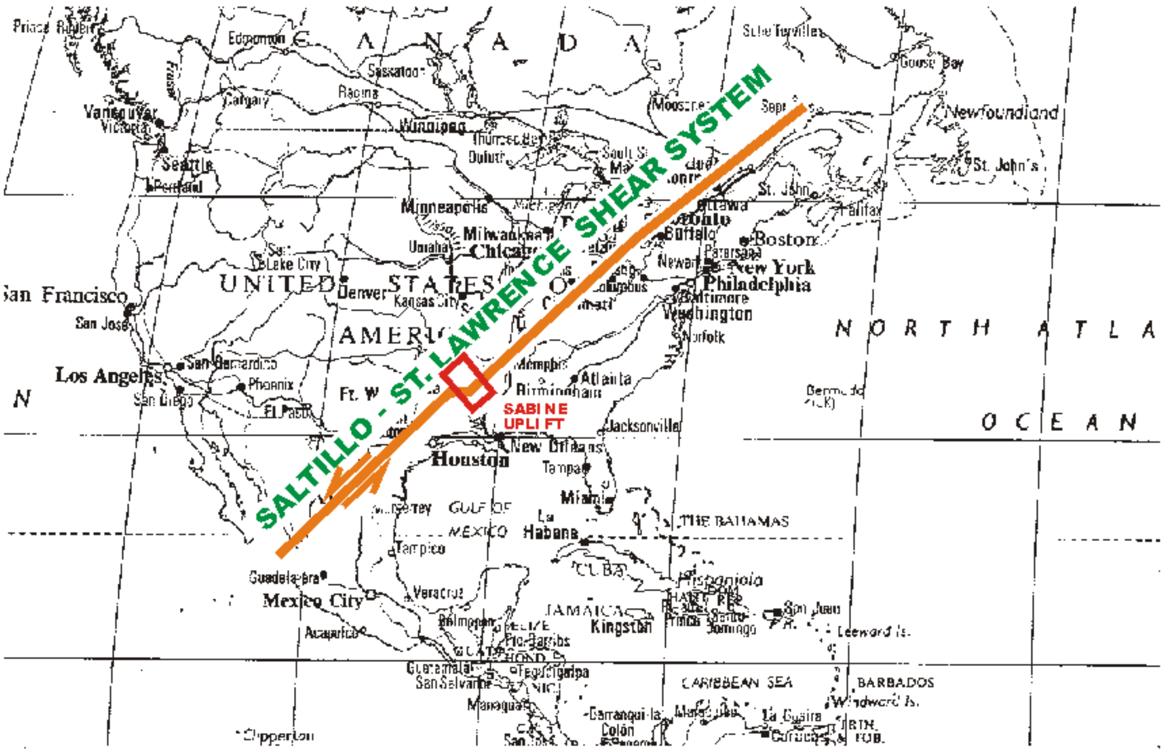


**Figure 11. Postulated location of the Saltillo–St. Lawrence Shear System. The Sabine Uplift is a fault fold related to a restraining double bend or a restraining side-step in the shear system. The fault movement was initiated by Laramide compression from the southwest.**

and possibly the Chittim Anticline all appear to have formed at similar times to the Sabine Uplift. Likewise, active salt dome growth in the East Texas and North Louisiana salt basins began in the middle early Cretaceous. If salt movement was more sensitive to external force rather than upwarping, salt deformation would have started prior to the major uplifts that are adjacent to the salt dome basins. The Sabine Uplift and the North Louisiana Salt Basin have the general appearance of a fold pair. That is, they appear to be related genetically in both time and space. The presence of a heretofore unmapped wrench fault system across the Gulf Coast of Texas has major implications for paleogeographic and structural reconstructions of the Gulf Coast, especially for the lower Cretaceous and older intervals. Many faults that have been mapped solely as down-to-the-coast faults along the middle Texas Coast may, in fact, have an important strike-slip component. This hypothesis would also impact fault and fracture orientation interpretations (Brown et al., 1980).

Occam's Razor states that when more than one solution is proposed for a problem, the more likely solution is the simpler solution. In the case of the origin of the Sabine Uplift, the simplest solution is the presence of a wrench fault system that links multiple known fault and earthquake zones and areas of known hydrothermal activity with a simple fault-fold geometry that is linked in time and space to known orogenic activity in Mexico.

## SUMMARY

Basement structures play an integral part in understanding the history of the Gulf Coast. The orientation of pre-existing transform faults and the presence of rift-related horst and graben structures control the location, size and shape of subsequent salt structures, fault systems, rivers, shelf margins, reefs, basins, and indeed all of the elements necessary for mapping and understanding a depositional system. For the Sabine Uplift, the presence of

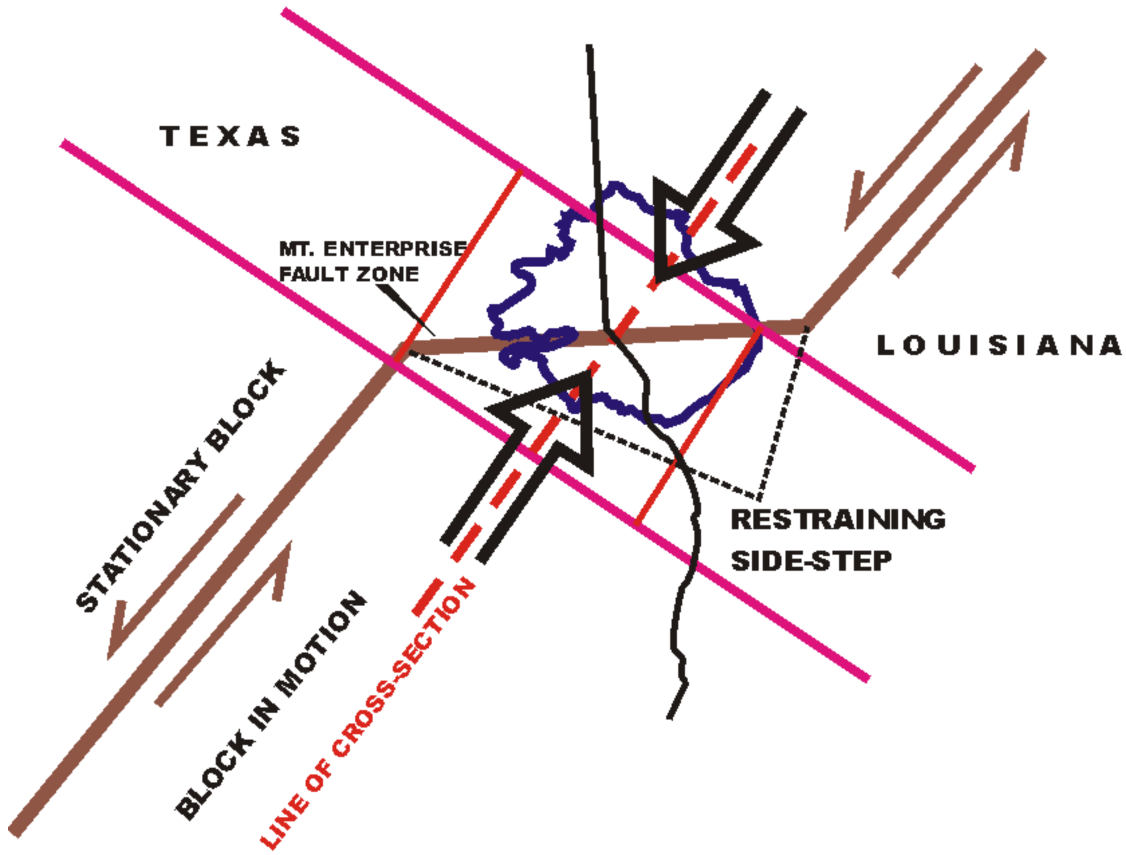


**Figure 12. Map view of compressive events that formed the Sabine Uplift from the earlier mid-rift high.**

a Triassic mid-rift high influenced the location of the Haynesville Shelf Margin, the location of the Bossier rivers and depocenters, the depositional slope and extent of the Cotton Valley shelf sand system, the orientation of the Cotton Valley shoreface systems, the extent of erosion during uplift, and the shape of the present-day surface outcrop pattern.

The transforms and rift structures control the extent and thickness of the original salt deposits. The extent and thickness of the original salt deposits control the shape, size, and orientation of the resultant salt structures.

The mid-rift high caused the Haynesville–Bossier–Cotton Valley sequence to prograde across a low-relief marine shelf while the same sequence on either side of the mid-rift high was aggradational.

The shape of the mid-rift high also determined the manner in which the Sabine uplift responded to the lateral compression associated with the Saltillo–St. Lawrence Shear System. The rectangular shape of the mid-rift high is reflected in the rectangular shape of the Sabine Uplift. The timing and extent of erosion during the uplift of the Sabine Uplift has controlled the trapping of some of the largest oil and gas fields in the United States.

## ACKNOWLEDGMENTS

John P. Carr and Carr Resources, Inc. have provided support for the work presented here as well as giving permission for publication. Many geologists with whom the author worked with for many years at Mitchell Energy Corporation provided valuable discussion of the concepts and applications of basement tectonics. The valu-

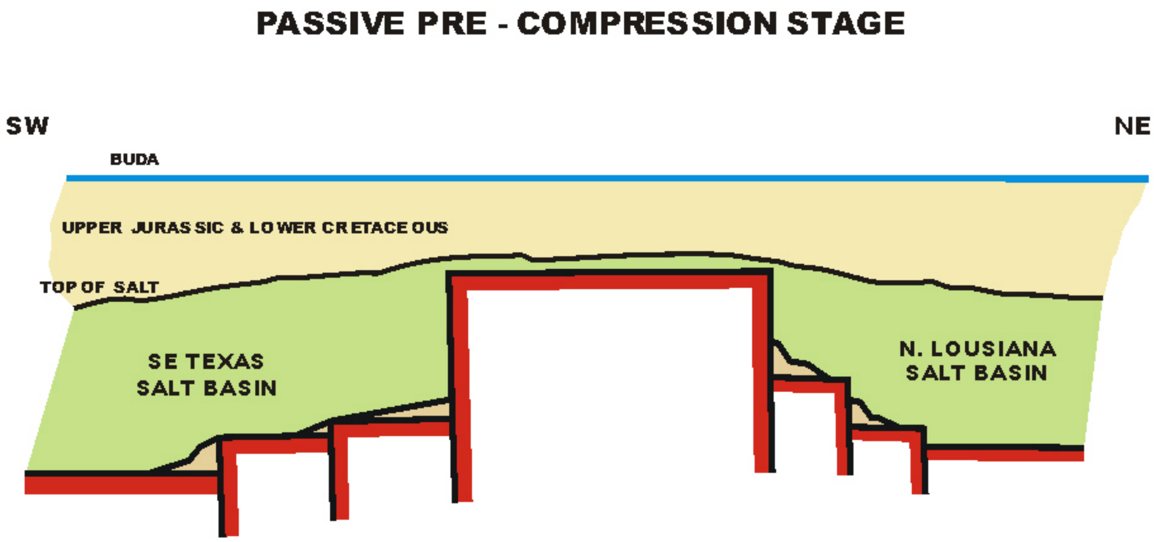


**Figure 13. Southwest-northeast pre-compression cross-section over the mid-rift high and fault restraining side-step.**

able discussions and ideas provided by John P. Carr and Dale Short have greatly improved the manuscript. Randy Permenter of AFAD Graphics did the drafting. The American Association of Petroleum Geologists (AAPG) has graciously provided permission to use the Geologic Highway Map of Texas (Renfro, 1979) and the Geologic Highway Map of the Southeast Region (Bennison, 1975). Mary Kay Grosvald and Ron Hart of AAPG were particularly helpful in making this data available. As with any endeavor, many people have contributed ideas and assistance. I gratefully acknowledge their assistance; however, any errors are mine alone. This paper was originally published by the East Texas Geological Society (Adams, 2006), and their permission for republishing is greatly appreciated. Mark O'Koren assisted greatly with final editing.

## REFERENCES CITED

Adams, R. L., 1989, Effects of inherited pre-Jurassic tectonics on the U.S. Gulf Coast: American Association of Petroleum Geologists Bulletin, v. 73, no. 3, p. 325-326.

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.

Adams, R. L., 1997, Microbasin analysis of South Louisiana: An exploration model, or: Hutton and Lyell were wrong!: Gulf Coast Association of Geological Societies Transactions, v. 47, p. 1-12.

Adams, R. L., 2006, Basement tectonics and origin of the Sabine Uplift, *in* R. Turner, ed., The Gulf Coast Mesozoic gas province: East Texas Geological Society, Tyler, p. 1-1 to 1-31.

Ahr, W. M., 1981, The Gilmer Limestone: Oolite tidal bars on the Sabine Uplift: Gulf Coast Association of Geological Societies Transactions, v. 31, p. 1-6.

Aydin, A., and A. Nur, 1985, The types and role of step-overs in strike-slip tectonics, *in* K. T. Biddle and N. Christie-Blick, eds., Strike-slip deformation, basin formation, and sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication 37, Tulsa, Oklahoma, p. 35-44.

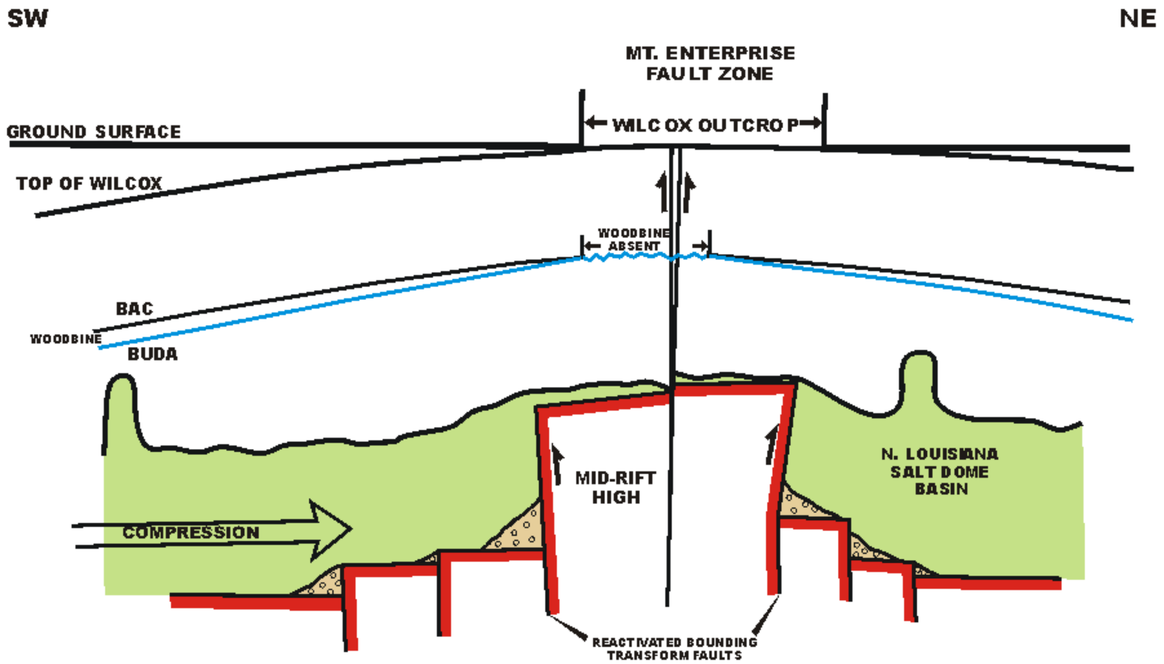


**Figure 14. Southwest-northeast post-compression cross-section over the mid-rift high and the resultant Sabine Uplift.**


Balsley, J. K., and L. R. Parker, 1991, Wave-dominated deltas, shelf sands and turbidites: Clastic depositional models for hydrocarbon exploration: American Association of Petroleum Geologists Field Trip Guidebook, Tulsa, Oklahoma, 219 p.

Bennison, A. P., 1975, Geological highway map of the southeastern region, Alabama, Louisiana, Florida, Mississippi, and Georgia: American Association of Petroleum Geologists, Tulsa, Oklahoma.

Bolden, G. P., 1989, Seismic and Landsat in a wrench faulting system, *in* E. Flis, R. C. Price, and J. F. Sarg, eds., Search for the subtle trap, hydrocarbon exploration in mature basins: West Texas Geological Society, Midland, p. 181-189.

Brown, R. O., Forgotson, J. M., and Forgotson, J. M., Jr., 1980, Predicting the orientation of hydraulically created fractures in the Cotton Valley Formation of East Texas: Society of Petroleum Engineers Paper 9269, Richardson, Texas, 12 p.

Collins, S. E., 1980, Jurassic Cotton Valley and Smackover reservoir trends, East Texas, North Louisiana, and South Arkansas: American Association of Petroleum Geologists Bulletin, v. 64, no. 7, p. 1004-1013.

Davis, S. D., W. D. Pennington, and S. M. Carlson, 1985, Historical seismicity of the State of Texas—A summary: Gulf Coast Association of Geological Societies Transactions, v. 35, p. 39-44.

Dooley, T., and K. McClay, 1997, Analog modeling of pull-apart basins: American Association of Petroleum Geologists Bulletin, v. 81, no. 11, p. 1804-1826.

Ewing, T. E., 1991, Structural Framework, *in* A. Salvador, ed., The Gulf of Mexico Basin: The geology of North America, v. J: Geological Society of America, Boulder, Colorado, p. 31-52.

Granata, W. H., Jr., 1963, Cretaceous stratigraphy and structural development of the Sabine Uplift area, Texas and Louisiana, *in* Report on selected North Louisiana and South Arkansas oil and gas fields and regional geology: Shreveport Geological Society Reference Report, v. 5, Louisiana, p. 50-95.

Halbouty, M. T., and J. J. Halbouty, 1982, Relationships between East Texas Field region and Sabine Uplift in Texas: American Association of Petroleum Geologists Bulletin, v. 66, no. 8, p. 1042-1054.

Holwerda, J. G., and R. W. Hutchinson, 1968, Potash-bearing evaporites in the Danakil area, Ethiopia: Economic Geology, v. 63, p. 124-150.

Hughes, D. J., 1968, Salt tectonics as related to several Smackover fields along the northwest rim of the Gulf of Mexico Basin: Gulf Coast Association of Geological Societies Transactions, v. 18, p. 320-330.

Jackson, M. L. W., and S. E. Laubach, 1988a, Cretaceous and Tertiary tectonics as cause of Sabine Arch, eastern Texas and northwestern Louisiana: American Association of Petroleum Geologists Bulletin, v. 79, no. 9, p. 1114.

Jackson, M. L. W., and S. E. Laubach, 1988b, Cretaceous and Tertiary tectonics as cause of Sabine Arch, eastern Texas and northwestern Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 38, p. 245-256.

Jackson, M. L. W., and S. E. Laubach, 1991, Structural history and origin of the Sabine Arch, East Texas and Northwest Louisiana: Texas Bureau of Economic Geology Geologic Circular 91-3, Austin, 47 p.

Jackson, M. P. A., 1982, Fault tectonics of the East Texas Basin: Texas Bureau of Economic Geology Geologic Circular 82-4, Austin, 31 p.

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, v. 142, p. 547-553.

Kupfer, D. H., C. T. Crow, and J. M. Hessenbruch, 1976, North Louisiana Basin and salt movements (halokinetics): Gulf Coast Association of Geological Societies Transactions, v. 26, p. 94-110.

Lobao, J. J., and R. H. Pilger, Jr., 1985, Early evolution of salt structures in the North Louisiana Salt Basin: Gulf Coast Association of Geological Societies Transactions, v. 35, p. 189-198.

Mathisen, M. E., 1995, Salt structures as indicators of subsalt rift basin faults and fault controlled reservoirs: Proceedings of the 16th Annual Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists Foundation Research Conference, Houston, Texas, p. 153-170.

McGillis, K. A., 1984, Upper Jurassic stratigraphy and carbonate facies, northeastern East Texas Basin, *in* M. W. Presley, ed., The Jurassic of East Texas: East Texas Geological Society, Tyler, p. 63-66.

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.

Renfro, H. B., 1979, Geological highway map of Texas: American Association of Petroleum Geologists, Tulsa, Oklahoma.

Selig, F., and E. G. Wermund, 1966, Families of salt domes in the Gulf Coastal Province: Geophysics, v. 31, no. 4, p. 726-740.

Stephens, B. P., 2001, Basement controls on hydrocarbon systems, depositional pathways, and exploration plays beyond the Sigsbee Escarpment in the central Gulf of Mexico: Proceedings of the 21st Annual Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists Foundation Research Conference, Houston, Texas, p. 129-154.

Tanner, J. H., III, 1967, Wrench fault movement along Washita Valley Fault, Arbuckle Mountain area, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 51, no. 1, p. 126-134.

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