AAPG Annual Meeting
March 10-13, 2002
Houston, Texas

Northern Gulf of Mexico: A Passive or Passive Active Margin?

Ghulam Sarwar, Adjunct Professor, Energy Research Institute, Department of Geology, The University of Louisiana at Lafayette. Subsurface Consultants and Associates, Lafayette, Louisiana.

The Gulf of Mexico (GOM) is a rift basin that was formed during the Triassic-Jurassic separation of North America from South America (Pilger, 1981, Buffler and Sawyer, 1985, Salvador, 1987).Evaporite deposition took place mainly during the Middle Jurassic accompanying rifting and was followed by a brief episode of sea floor spreading during the Late Jurassic which inserted a strip of oceanic crust between the formerly continuous northern Louann salt and southern Campeche salt provinces (Salvador, 1987, Buffler, 1991). The basin cooled and subsided during the Cretaceous, building carbonate banks that gave way to clastic deposition in the Paleogene.

The extended basin was divided into blocks with varying basement properties. Tectonic boundaries of these blocks were marked by transfer faults that had developed more or less perpendicular to the direction of spreading (Lister et.al.,1986). It is now generally agreed that the northern Gulf rift basin is right laterally segmented by a series of NW-SE trending transfer faults (Fig.1, Huh et.al., 1996, and the references therein. Please see Zimmerman, 1995, for a different view).

Since the GOM is an old rift basin, the transfer faults are generally regarded as little more than tectonically inactive remnants on a passive margin. The post rifting tectonics of the GOM are largely described in terms of growth faulting related to deltaic progradation, salt tectonics, and lately, folding and thrusting related to the mobile Sigsbee nappe and in other areas of the lower slope and rise. The fact that the GOM area is attached to the very active tectonic domains of the Caribbean, Mexico, and western North America (Fig.1), somehow gets ignored.

Based on several observations made over the years, this writer is of the opinion that the GOM forms an active tectonic link between the Caribbean to the south and Mexico and western North America to the west northwest. Please note that the term “active” is being used here to describe neo-tectonic activity on and along the Gulf Coast passive margin:

The modern bathymetric mapping of the Texas-Louisiana shelf and slope has revealed a wealth of information about the Upper Cenozoic evolution of this margin. Some of the numerous striking features of such maps are the sea floor lineaments that seem to be the seaward extensions of known transfer faults such as the Matagorda, Brazos, Galveston, Sabine and others (Fig.1). Several workers have written about the past tectonic influence of such faults on sedimentation, salt deposition, and growth fault patterns (Simmons, 1992, Huh et. al., 1996, Adams, 1997).

A few examples can be used to demonstrate that: One of the best present day example is the northwest southeast course of the Red River system in Louisiana, that lines up exactly with the Mississippi Canyon offshore, and is perhaps controlled by a major transfer fault. The hot springs of Hotwells, located west southwest of Alexandria, Louisiana, seem to be related to the same fault. If the Monroe uplift is showing currently active thrust faults (Washington, 2001), the Red River transfer fault is probably also active.

A few other onshore examples are the northwest-southeast trend of the Ouachita, Arkansas, Sabine and Brazos rivers that seem to have been controlled by transfer faults, some of which showing Tertiary and Holocene movements (see Cox et. al, 2000). A cursory search of the literature reveals that Quaternary and Holocene movements have been noted by several workers in the continental interior (Fisk, 1944). For example, the Kentucky river fault system (Vanarsdale, 1986), the New Madrid seismic zone in the Reelfoot rift, Arkansas, and the Meers fault, Oklahoma (Ramelli and Slemmons, 1990). Wrench faults and flower structures described from a vast area (Bolden, 2001) between Dallas and the Big Bend Park in Texas, may also be in part of Holocene origin.

The thickness of salt on the two sides of the Brazos transfer fault is very different (Huh et.al., 1996), indicating its past influence. However, the same fault (or the Galveston transfer fault ?), when extended offshore seems to line up with the Keathly-Alaminos Canyons. The scalloped pattern of the frontal lobe of the Sigsbee nappe seems to have developed due to notches that may mark its intersection points with the underlying transfer faults. The fact that the transfer faults seem to be “etched” through the overlying sedimentary cover and form prominent bathymetric linear patterns as pock marks, channels, strange depressions, or mini-basins, suggests their ongoing influence. Such features are visible in a vast area stretching from east of the Mississippi Canyon to the Alaminos Canyon. For example, note the linear shapes of the Mississippi Canyon, the Keathly Canyon, and the pockmarks along the southeast extension of the Matagorda transfer fault on bathymetric maps.

In the southern part of South Marsh Island area, on propreitary 3D seismic data, this writer has interpreted flower structures branching from great depths (35000-40000 feet) up to the mudline. The wrench system responsible for that would be related to the Sabine transfer fault.

In the West Cameron area, the Holocene clastics (MMS, 1986) seem to have been piled up on the east side of the Sabine transfer fault indicating more accomodation space on this side versus the other. Also, in the same area, bathymetric rollover folds, coming from the Texas side and oriented parallel to the shoreline, go enechelon and shift southward as they cross the Sabine transfer fault. It is probable that, in this instance, the culprit is a shallow growth fault and not the Sabine fault. However, it is intriguing that both the Holocene clastic pileup and the southward enechelon shift of the fold axes occur in the vicinity of the Sabine transfer fault.

In the Keathley Canyon area, the fold axes above the salt are oriented parallel to the adjacent transfer fault (Galveston ?). This has been interpreted as due to the buttressing effect of the fault on mobile folds developed above thick salt east of the fault (Shinol, 2000). However, if the shape and orientation of the 70 miles long Keathley Canyon is influenced by the underlying transfer fault, some distortion of the folds near the fault may possibly be due to wrench movement.

The observations made above tell us that the basement underlying the mobile sedimentary cover of the northern Gulf is probably also mobile with the various transfer faults accommodating differential movements among large crustal blocks. The Gulf coast seems to be a “not so passive margin” at present. Looking back, it seems to have been active for a long time. To give a single argument from among numerous ones, the widespread distribution of volcanics and clastics in and around the Gulf, dating back to the Cretaceous, testifies to that activity. Looking at the mega-tectonic framework of the western United States-Mexico, it appears that the right lateral trans-tensional domain (Fig.1) is well in control, and, through the right lateral segmentation of the GOM mentioned above, is linked with the Caribbean domain to the south.

It is a little too pre-mature to speculate whether the right lateral shear will tear the Gulf basin apart one day, like the western USA, but one thing is certain: Things are changing slowly on the on shore, in the Gulf basin, and, at a relatively faster pace, in Mexico. The dire predictions of the Aztec Calendar about the End scenario are easy to relate to when one realizes that the east-west trending six hundred miles long Trans-Mexican Volcanic Belt, that goes right through Mexico City, may be a budding transform exploding up (Fig.1). Such transforms can possibly link the north Caribbean transforms to those of the southern Salton Sea. This may have something to do with the active subduction dynamics of the East Pacific Rise and the future southward extension of the Salton Sea regime.

Finally, to emphasize the key point again, below the clastics and salt, the foundation of the GOM is reacting to the plate tectonic pace of the neighborhood, and the ancient transforms are not merely passive remnants of an active past. They are going with the plate tectonic flow of the day. We can feel and see this process from the Gulf to the Reelfoot, Rio Grande and beyond (Fig.1).

Reed (2001) argued for continuous rifting in the GOM since the Mesozoic. Regardless of what label we put on the process, the GOM has clearly been active for a long time. It is time to change our attitude toward the tectonics of the Gulf. We need to see if it is time to even change the paradigm. I hope that this short paper will encourage others to examine their deep seismic, gravity and magnetic data, as well as seismicity, and help us develop a better understanding of what is going on. Needless to say that, due to their tectonic influence on sedimentation, trap formation, fluid migration, and entrapment, the transfer faults should be of prime exploratory importance to the Energy companies.

Figure 1: Schematic plate tectonic map of the Gulf of Mexico, Mexico and North American region showing structural trends. Extracted and modified from the Pacific Basin Sheet of the Plate Tectonic Map of the Circum Pacific Region, published by the Circum Pacific Council for Energy and Mineral Resources, 1985.

Legend: A: Atlanta, BT: Brazos transfer fault, BDF and BTF: Probable budding transform faults,
CR: Caribbean Regime, D: Dallas, FL: Florida Lineament, GT: Galveston transform fault, H: Houston, M: Monterey, MC: Mexico City, MT: Matagorda transfer fault, N: New Orleans, P: Phoenix, RGR: Rio Grande rift, RRMT: Red River-Mississippi Canyon lineament, SF: San Andreas fault, ST: Sabine transfer fault, T: Tampico. Large arrows symbolize the regional right lateral shear regime that probably dominates the current tectonics of the area discussed.

Acknowledgement

I am indebted to Dr.Brian Lock for suggesting some linguistic improvements to the text.

REFERENCES

Adams, R.L., 1997, Microbasin analysis of South Louisiana: An exploration model, or: Hutton and Lyell were wrong: GCAGS Trans., v. XLVII. p.1-11.

Bolden, G.P., 2001, Flower structures and wrench fault tectonics: AAPG southwest section mtg. Abstr., v.85, p.384.

Braile, L.W., Hinze, W.J., Keller, G.R., Lidiak, E.J., and Sexton, J.L., 1986, Tectonic development of the New Madrid rift complex, Mississippi Embayment, North America: Tectonophysics, v. 131, p. 1-21.

Buffler, R.T., 1991, Seismic stratigraphy of the deep Gulf of Mexico basin and adjacent margins: in Salvador, A. ed., The Gulf of Mexico Basin, GSA, The Geology of North America, v.J, p.353-388.

Buffler, R.T., and Sawyer, D.S., 1985, Distribution of crust and early history, Gulf of Mexico basin: GCAGS Trans. v.35, p.333-344.

Cox, R.T., Van Arsdale, R.B., Forman, S.l., Beard. W., and Galluzi, J., 2000, Quaternary faulting in the Southern Mississippi Embayment and implication for tectonics and seismicity in an intraplate setting: GSA Bull.,v. 112, p. 1724-1735.

Fisk, H,N, 1944, Geological investigations of the alluvial valley of the lower Mississippi River: Vicksburg, Mississippi, Mississippi River Commission, and U.S. Army Corps of Engineers, 2 vols., 78p. and maps.

Huh, S., Watkins, J.s., Kasande, R., Fiduk, J.C., Bryant, S., Silver, K.E., Bradshaw, B.E., Xue, F., and Xi, J., 1996, Regional structure and tectonics of the Texas shelf: GCAGS Trans. v. XLVI, p. 39-51.

Lister, G.S., Etheridge, M.A, and Symonds, P.A., 1986, Detachment faulting and the evolution of passive continental margins: Geology, v. 14., p. 246-250.

MMS (Minerals Management Service) Visual No. 5, Geologic and geomorphic features, Sept.1986.

Pilger, R.H. Jr., 1981, The opening of the Gulf of Mexico: implications for the tectonic evolution of the northern Gulf: GCAGS Trans. v. 31, p. 377-381.

Ramelli, A. R., and Slemmons, D.B., 1990, Implications of the Meers fault on seismic potential in the central United States: in Krintzsiky, E.L., and Slemmons, D.B., eds., Neotectonics in earthquake evolution, GSA review in Eng. Geol., v.8, p. 59-75.

Reed, J.M., 2001, Cretaceous to Recent rifting in the Gulf of Mexico basin: GCAGS Trans. v. LI, p.273-283.

Salvador, A. 1987, Late Triassic-Jurassic paleogeography and origin of Gulf of Mexico basin: AAPG Bull. v. 71, p. 419-451.

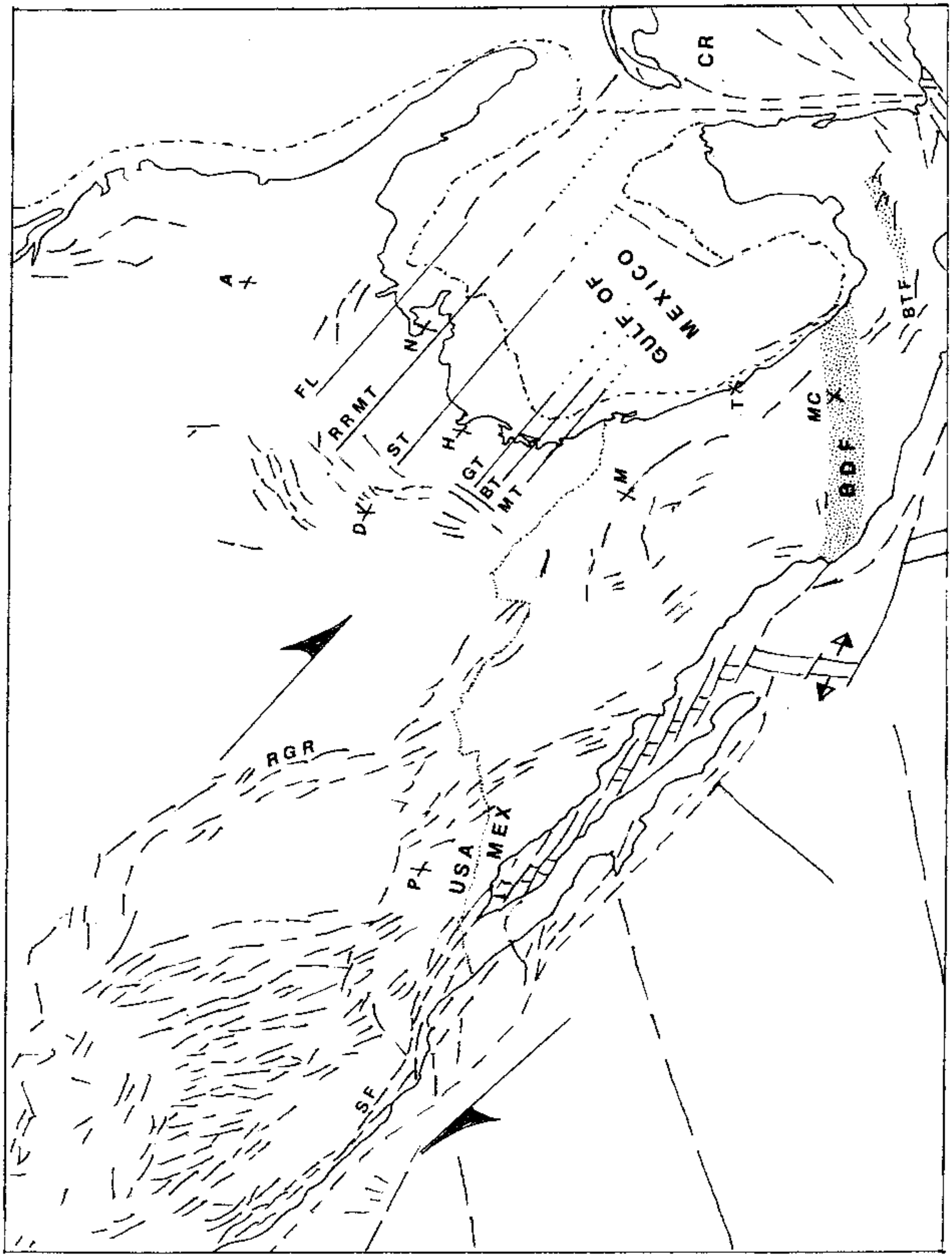
Shinol, J, 2000, AAPG Explorer, October 2000 issue article by Kathy Shirley, p.12.

Simmons, G.R., 1992, The regional distribution of salt in the northwestern Gulf of Mexico: Styles of emplacement and implications for early tectonic history: Texas A &M Univ. unpub. Ph.D. Dissert., 180p.

Vanarsdale, R.B., 1986, Quaternary displacements on faults within the Kentucky river fault system of east central Kentucky: GSA Bull., v.97, p. 1382-1392.

Washington, P.A., 2001, Evidence for significant neotectonic thrust faulting in and around the Monroe uplift: GCAGS Trans. v. LI, p. 359-366.

Zimmerman, R.K., 1995, Evidence and effects of wrench faulting, north central Gulf Coast region: GCAGS Trans. v. XLV, p. 629-635.


CR
GULF OF MEXICO
A
FL
RRMT
N
ST
H
GT
BT
MT
D
T
M
MC
BDF
BTF
RGR
P
USA
MEX
LT
SF