Syndepositional Structural Systems, Northern Gulf of Mexico

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Overview

In the last decade, as explorers have moved into new plays such as deep water turbidites, subsalt and fold belts, there has been a renewed industry interest in trying to understand GOM geology on a regional scale as a means to mitigate exploration risk. New regional work has been bolstered by regional 3D and deep record length seismic, and new insights have emerged about fundamental controls on the geology and distribution of hydrocarbons in the GOM. One such insight is in the concept of Syndepositional Structural Systems and their distribution in Tectonic Provinces.

The Structural System Concept

Syndepositional structures form in response to sedimentary loading. Given that deltaic and turbidite fan complexes which comprise the sedimentary load are on a size scale of tens of miles, then logically the syndepositional structures must be of similar size. We have come to recognize that hydrocarbon trapping structures are actually quite small components of these larger-scale syndepositional structural systems.

We define syndepositional structural systems as structural complexes comprised of a number of different but genetically related types of structures that occur in generally repetitive and predictable patterns linked causally with reservoir distribution and the nature of the unstable substrate being loaded. Because the individual components that make up a structural system, including the reservoir, are genetically related, they tend to occur within the system in an orderly and generally repetitive pattern. With a good understanding of the general patterns of a syndepositional system, one has a predictive tool to apply to the specifics of an area or prospect being evaluated.

Within the northern GOM there are three principal types of structural systems: shale-based detachment faults, salt-withdrawal minibasins, and salt-based detachment faults. These systems are not distributed at random but are by-and-large segregated into areas dominated by a single system. These areas, defined here as Tectonic Provinces also have an organized

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pattern that reflects some of the fundamental controls on the development of the GOM basin.

Shale-Based Detachment Systems are gravity slide phenomena driven by progradation of the shelf margin onto an unstable shale resulting in a regional decollement. The updip zone of extension is characterized by listric splay and keystone faults and by the development of rollover structures and/or rotated fault blocks (Figure 1). Delta progradation stalls at the head of the system and sands tend to be stacked in the rollover, or are conveyor belted downdip along the fault ramp to form rotated wedges. In map view (Figure 1), the linear region of splay and keystone fault development is the zone which historically has been called the 'flexure'. The basinward edge of the flexure is a planar synthetic fault beyond which is a synclinal region, which tectonically is the true first order structure of the gravity slide, and which is typically filled with prodelta slope facies. Further basinward is the relatively undeformed slide block, typically seen as a horst, generally starved of coeval sedimentation and terminating in a compressional toe zone. The slide block and toe zone are often obscured or removed by the next younger system.

Salt-Withdrawal minibasin systems are circular to elliptical in map view. They are comprised of an asymmetric salt-withdrawal syncline with its coupled diapir(s), a north dipping so-called 'counter regional' fault and secondary basin rimming hinge faults (Figure 2). When the counter-regional is stepped, there will also be a secondary turtle and/or a series of hinge faults (Figure 2). The overall geometry of the minibasin and the nature of the sedimentary fill within the basin vary considerably depending on whether the minibasin was loaded in a shelf or slope environment.

Shelf-loaded minibasins formed by loading of thick salt, initially in deep water, then under prograding shelf loads. Development of the typical salt withdrawal system initiated in the Late Jurassic to Early Cretaceous with the formation of salt pillows with source rocks and turbidites ponded within the developing syncline. Subsequent loading of the minibasin by shelf sedimentation initiated rapid withdrawal of salt from the basin into diapirs, forming an asymmetric wedge of prodeltaic shale filling the developing syncline.

As the axis of synclinal development shifted basinward, the original syncline overturned leaving a turtle structure anticline in the wake of the migrating syncline. Progradation of the shelf margin stalled along the basin-rimming hinge faults due to the rapid subsidence, resulting in a thick section of stacked deltaic sands and shales. In map view, shelf-loaded salt withdrawal minibasins are typically aligned, forming a depo-trough (Figure 2).

Slope-loaded minibasins are similar to shelf minibasins, but are at an earlier evolutionary stage of development and involve much more salt than the shelf systems. The slope withdrawal basins are structurally simple, being flanked by salt walls with little fault rim development but unfortunately are typically obscured by salt wings, so that we see only glimpses of the primary structure through windows (Figure 2). As with the shelf loaded minibasins, formation of the slope loaded minibasins began during the late Jurassic to early Cretaceous with ponding of turbidites triggering the diapiric stage. Because of the great thickness of autochthonous salt involved, turbidite ponding is more or less continuous so long as there is salt withdrawing form the basin. Should the depocenter shift during the diapiric phase, during the hiatus, a wing forms which overflows the basin, which regionally results in the formation of a salt canopy (Figure 2). Once the allochthounous salt has been evacuated, subsequent turbidite deposition bypassed the basin.

Salt-based Detachment systems (Roho[1]) are combination gravity slides and salt withdrawal structures formed in response to the progradation of shelf sediments onto a salt wing. The updip zone of extension is marked by a series of nested highly listric faults (Figure 3), which in map view, display a characteristic horseshoe geometry. Deltaic sands and shales tend to be stacked in the rotated wedges associated with these faults. The central portion of the structural system is typically manifest as a complicated zone of remnant salt, perched diapirs, salt-floored faults, and strike slip faults. Basinward of this region is the compressional toe, which consists of a melange of salt and deformed sediment. All faults sole into the evacuated remnant of the original salt tablet, which typically overlies a salt-withdrawal minibasin. In map view (Figure 3), the overall geometry of the salt-based detachment system is constrained by the geometry of the salt tablet upon which it is forming.

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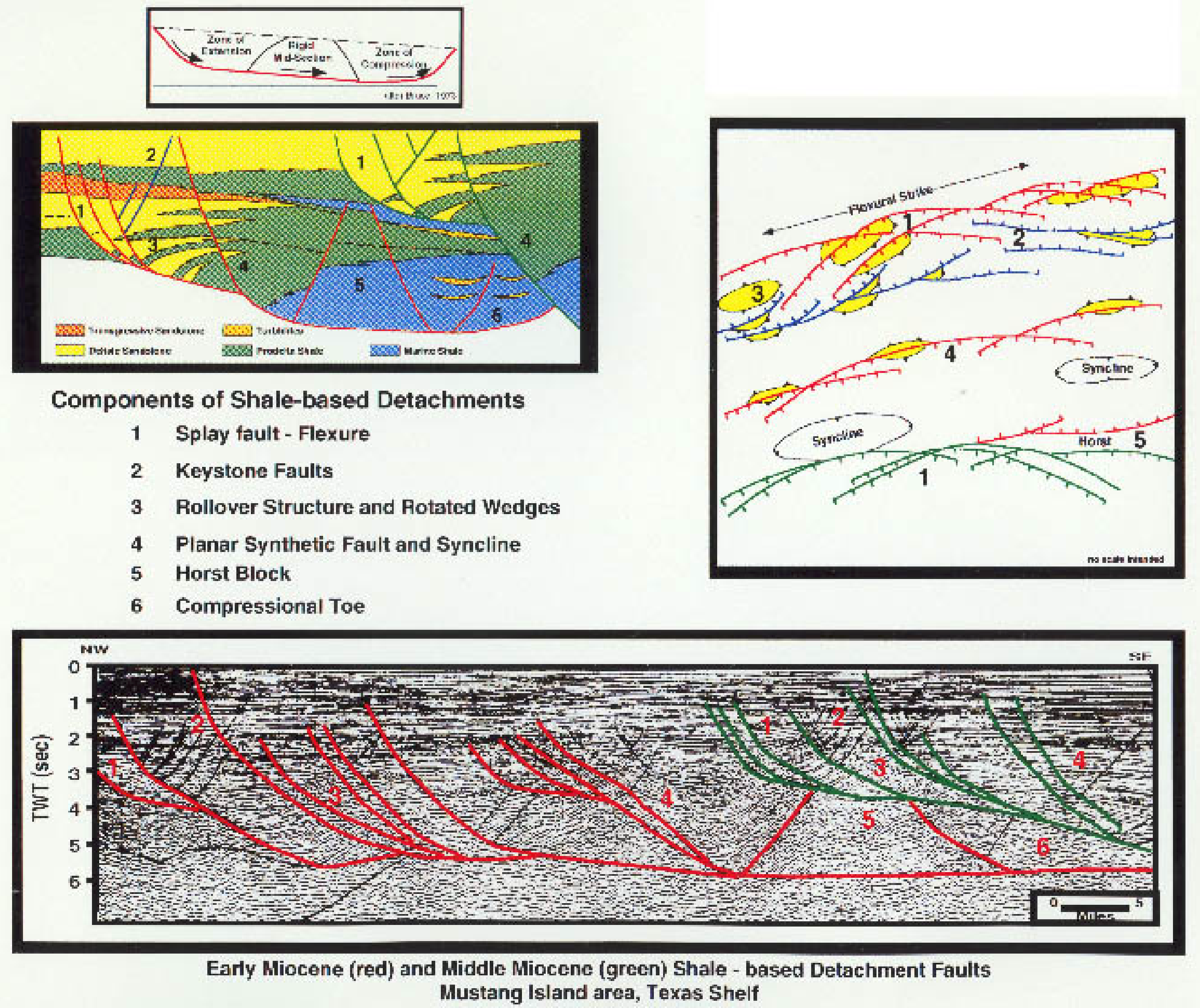
[1] Roho is a contraction of Roripaugh’s Moho, named after Shell Geophysicist Chuck Roripaugh who, in the late 1960’s, first identified the detachment as evacuated salt. Admonished to map ”from water bottom to Moho”, the evacuated salt surface was effectively Roripaugh’s Moho, and he labeled his maps accordingly. The term, which was popularized within Shell, has since escaped into the literature.

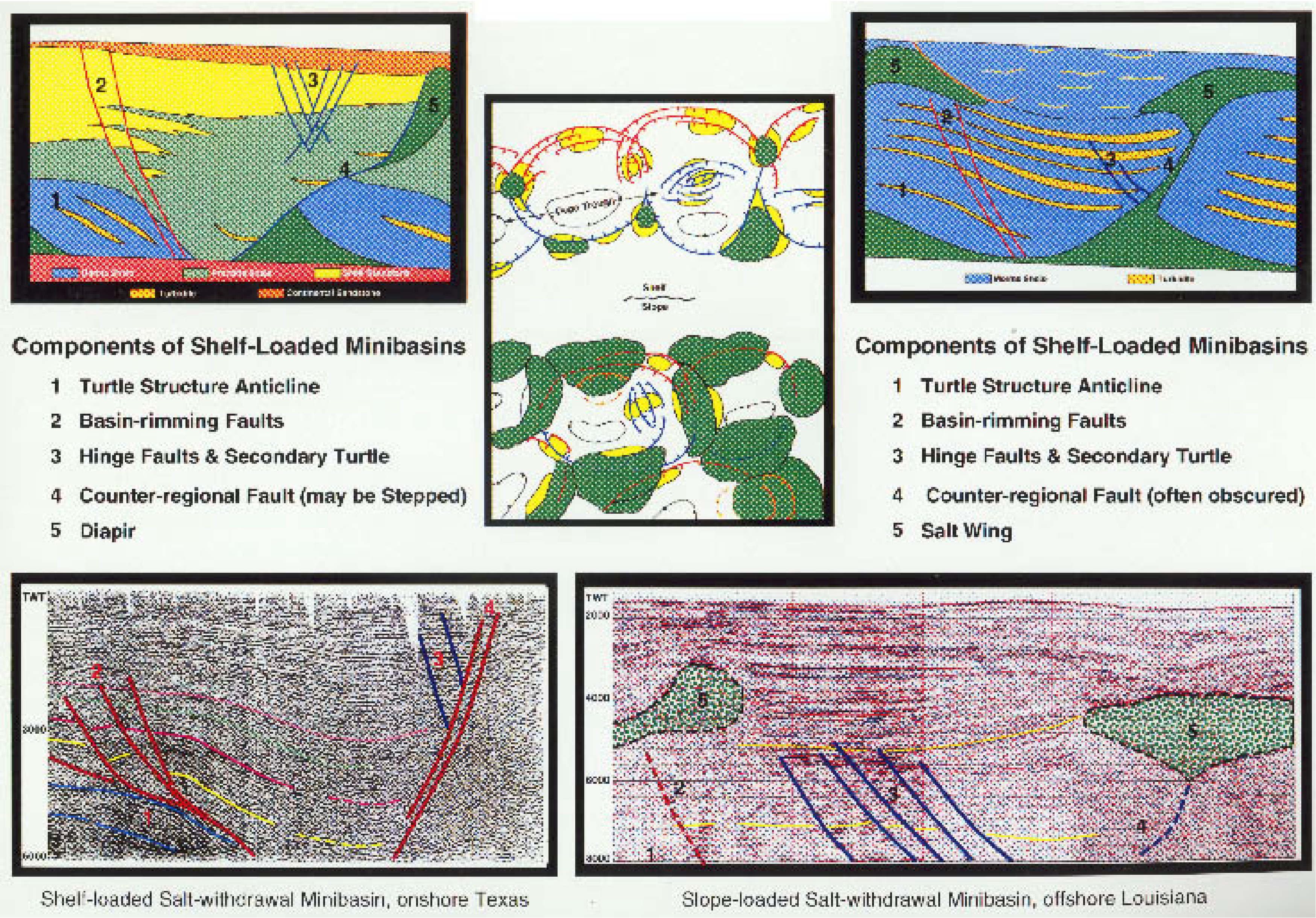


Components of Shale-based Detachments

1 Splay fault - Flexure
2 Keystone Faults
3 Rollover Structure and Rotated Wedges
4 Planar Synthetic Fault and Syncline
5 Horst Block
6 Compressional Toe

Early Miocene (red) and Middle Miocene (green) Shale - based Detachment Faults
Mustang Island area, Texas Shelf

Figure 1 Shale-based Detachment Fault System



Components of Shelf-Loaded Minibasins

1 Turtle Structure Anticline
2 Basin-rimming Faults
3 Hinge Faults & Secondary Turtle
4 Counter-regional Fault (may be Stepped)
5 Diapir

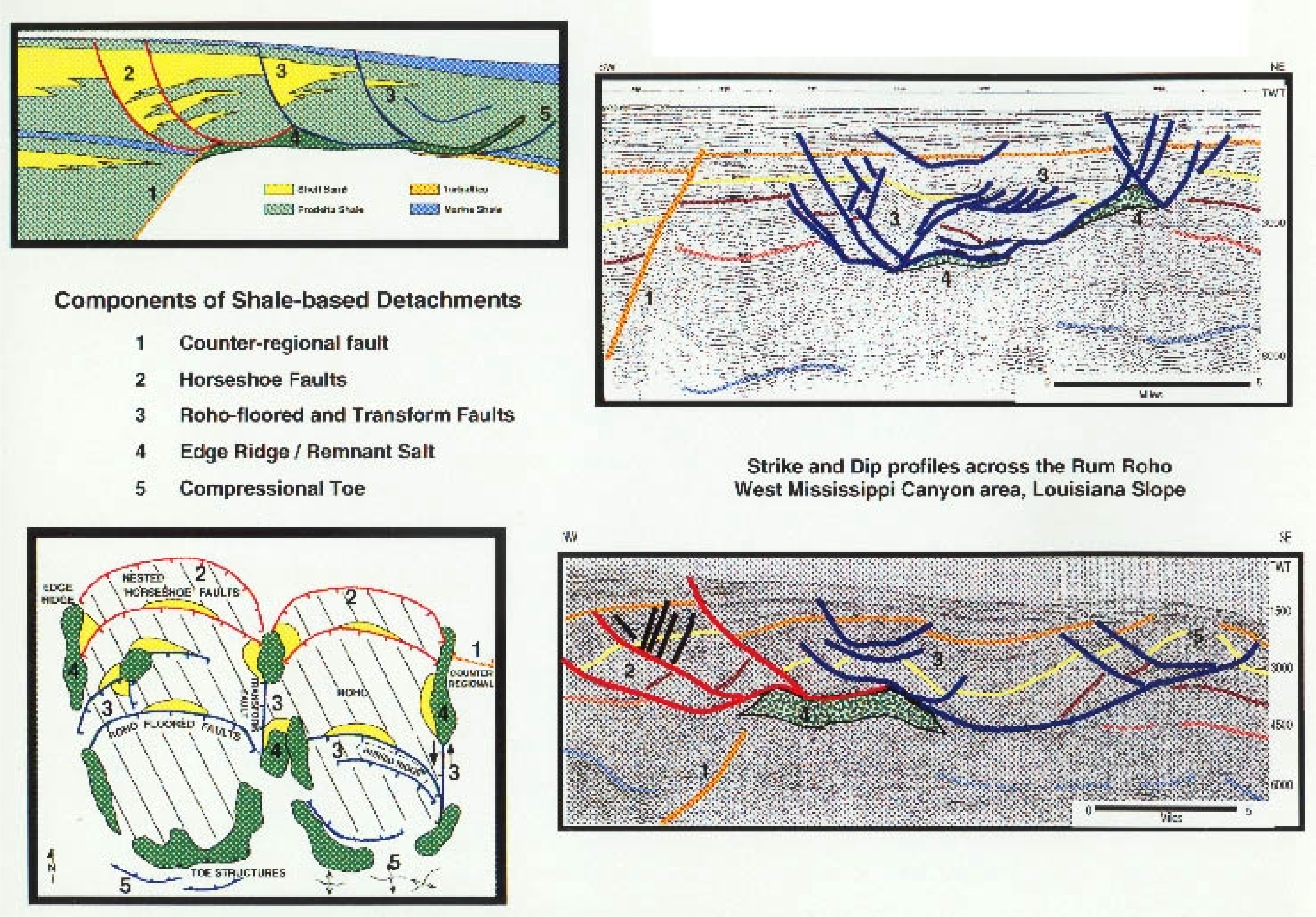
Components of Shelf-Loaded Minibasins

1 Turtle Structure Anticline
2 Basin-rimming Faults
3 Hinge Faults & Secondary Turtle
4 Counter-regional Fault (often obscured)
5 Salt Wing

Shelf-loaded Salt-withdrawal Minibasin, onshore Texas

Slope-loaded Salt-withdrawal Minibasin, offshore Louisiana

Figure 2 Salt-Withdrawal Minibasins



Components of Shale-based Detachments

1 Counter-regional fault
2 Horseshoe Faults
3 Roho-floored and Transform Faults
4 Edge Ridge / Remnant Salt
5 Compressional Toe

Strike and Dip profiles across the Rum Roho
West Mississippi Canyon area, Louisiana Slope

Figure 3 Salt-Based Detachment Fault System (Roho)