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Horizontal Components of Gulf of Mexico Salt Tectonics

The existence and importance of vertical salt movement and structuring in the Gulf of Mexico is well known and documented by extensive drilling results and detailed comprehensive publications. However, on the southern additions of the Louisiana and Texas shelf and onto the slope, the existence of both horizontal components of salt movement and probable subsalt traps are gaining increasing acceptance. For many years, hundreds of wells were drilled into salt on the outer shelf and slope of the Gulf of Mexico. Unless drilled on the flanks of a clearly interpreted vertical salt diapir, which themselves were probably secondary re-mobilizations of ancestral horizontal salt, these wells all drilled into the regional horizontal salt sills that are visible on present day seismic data. They stopped far short of testing the great deep petroleum potential of the Subsalt Exploration Trend of the Offshore Gulf of Mexico.

The best documentation of this occurrence is in the form of 7-15 wells drilled through and/or into varying thicknesses of salt on the southern Louisiana/Texas shelf and slope, which on seismic data do not appear to be associated with vertical salt piercement. Based on recently acquired high resolution seismic data, these horizontal sills are scattered across a broad area of the southern shelf from Galveston through Main Pass, and out onto the slope as far south as the present day Sigsbee Scarp.

Five of these wells have drilled through large, thick horizontal sills, miles away from the sill edges, and their operators have been required to release much of their wellbore data over the past eight years. Specifically, West Cameron 505 #2 (1984), Garden Banks 171 #1 (1984), South Marsh Island 200 #1 (1986), Vermilion 356 #1 (1988), and Mississippi Canyon 211 #1 (1990) are subsalt exploratory tests that demonstrate the drillable potential of the regional horizontal salt sills. They also define the more critical thick, clastic subsalt stratigraphic sections that will soon yield a significant subsalt, commercial discovery in the Offshore Gulf of Mexico. Several other wells have been drilled through similar large regional sills and their wellbore data is still held confidential. However, the seismic data displayed over Garden Banks 165 #1 (1992), Ship Shoal 349 #1 (1993), Garden Banks 260 #2 (1993), South Marsh Island 169 #1 (1993) and Garden Banks 119 #1 (1993) will present good evidence for interpreting the probable subsalt penetration of these wellbores. Eight additional wells will be displayed that have penetrated the edges of Gulf of Mexico regional salt sills, or have encountered small, remnant salt sills either adjacent or isolated from the larger sills. Wellbore data and seismic transects will be displayed (poster space permitting) over Ship Shoal 366 #2 (1983), Green Canyon 98 #1 (1984), Green Canyon 39 #1 ST (1984), East Breaks 170 #1 (1985), East High Island A-374 #1 (1985), Mississippi Canyon 400 #1 & #2 (1984/85), and Green Canyon 152 #1ST (1985), Vermilion 412 #1 (1987). Rather than being continuous and uniform in appearance, these sills show considerable variation on seismic and can be grouped into eight broadly defined structural styles (Figure 1). These eight styles also show variation in distribution across the Louisiana/Texas shelf and slope and thus can generally be divided into four areas of salt movement (Figure 2).

Area I extends from the shoreline to approximately the boundary of the North and South Additions of Galveston through Grand Island and then eastward across the upper Mississippi Canyon area. North of this line, salt structures primarily exhibit vertical components with some overhangs and associated shale sheaths.

Area II extends southward across the lower Texas and Louisiana shelf from Galveston Island through Main Pass to a southern limit 10 to 15 miles south of the shelf edge. In this area there is extensive seismic evidence of both horizontal and vertical salt movement, shale flowage, and several wells penetrating horizontal salt features. Of the eight structural styles, 2 through 6 are found in this area.

Area III extends southward across the middle slope from East Breaks through Green Canyon, is the largest of the four areas and shows evidence of shallow seismic salt tops and both vertical and horizontal movement (Style 7). However, seismic visibility of the base of salt is much more limited than in Areas II and IV due probably to the additional seismic complications of flowed shale, thick salt, under-compacted sediments, and complex salt surfaces. Wells have been drilled in this area into seismic "dead zones" interpreted as salt piercements only to find undercompacted or shaley sediments. Specific styles in this area are therefore hard to define, but are roughly described as an interconnected series of salt ridges or walls with interspersed vertical piercements.

Area IV covers the area just north of and parallel to the Sigsbee Scarp where shallow horizontal salt bodies similar to Style 8 are common. These on occasion show some evidence of reverse faults and compressed folds associated with southward creep of horizontal salt tongues or sheets. Base of salt reflection becomes more visible as salt thickness decreases and surfaces are less structured. The recent Mississippi Canyon 211 subsalt discovery lies in this area. Additional recent drilling across the southern Louisiana onshore indicate other older areas of horizontal movement could also exist north of Area I.

The boundaries between Areas I, II, III, and IV, as defined by seismic, vary considerably. The most distinct and abrupt change is between Areas I and II with the II-III boundary being somewhat more nebulous. The division between III and IV is currently the most difficult to define and, in fact, may be a gradational change as the salt thins to the south and injection becomes more recent.

Within Area II a further division of salt styles based on seismic is possible. The most visible and common top and base of salt reflectors associated with shallower horizontal components appear along the boundary of High Island and West Cameron, in Vermilion, southeast Galveston, and along the Vermilion-South Marsh Island line. The later Vermilion-South Marsh Island salt body is penetrated by two of the known documented wells through salt (Style 3). The best documented subsalt sands are associated with this sill, in South Marsh Island Block 200 where a 1000′ thick, massive wet sand was encountered roughly 2000′ below the base of the 1000′ thick salt sill.

In West Cameron, Ship Shoal, and South Timbalier, the interpreted seismic indications of horizontal salt are primarily deeper (below 3.0 seconds), in thinner layers and sometimes associated with large glide plane growth faults (Style 5&6) although limited examples of Styles 3 and 4 occur.

In Southern High Island, East Cameron and Eugene Island, seismic definition of top and base of salt is much more obscured due to overall depth of burial, and possible increased occurrence of shale deposition and flowage.

The concepts and timing of salt deposition/injection, subsequent loading, and the specific subsalt exploration potential is actively being pursued and debated. Currently, delineation and mapping of subsalt structural traps remains challenging and requires processing enhancements for mappable subsalt seismic events, extensive knowledge of overlying velocity variation, and utilization of computer technology for generation of depth maps. The presence of massive subsalt sands however, such as those documented in South Marsh Island Block 200, and subsalt hydrocarbon discoveries such as those documented in Mississippi Canyon Block 211, encourage further exploration efforts. As seismic resolution improves and subsalt well control increases, our understanding will broaden and should ultimately lead to discoveries in unique traps below the salt. The 1990s will be the Decade of Discovery for this giant hidden petroleum potential waiting beneath the prolific and mature giants of the supra-salt Offshore Gulf of Mexico.

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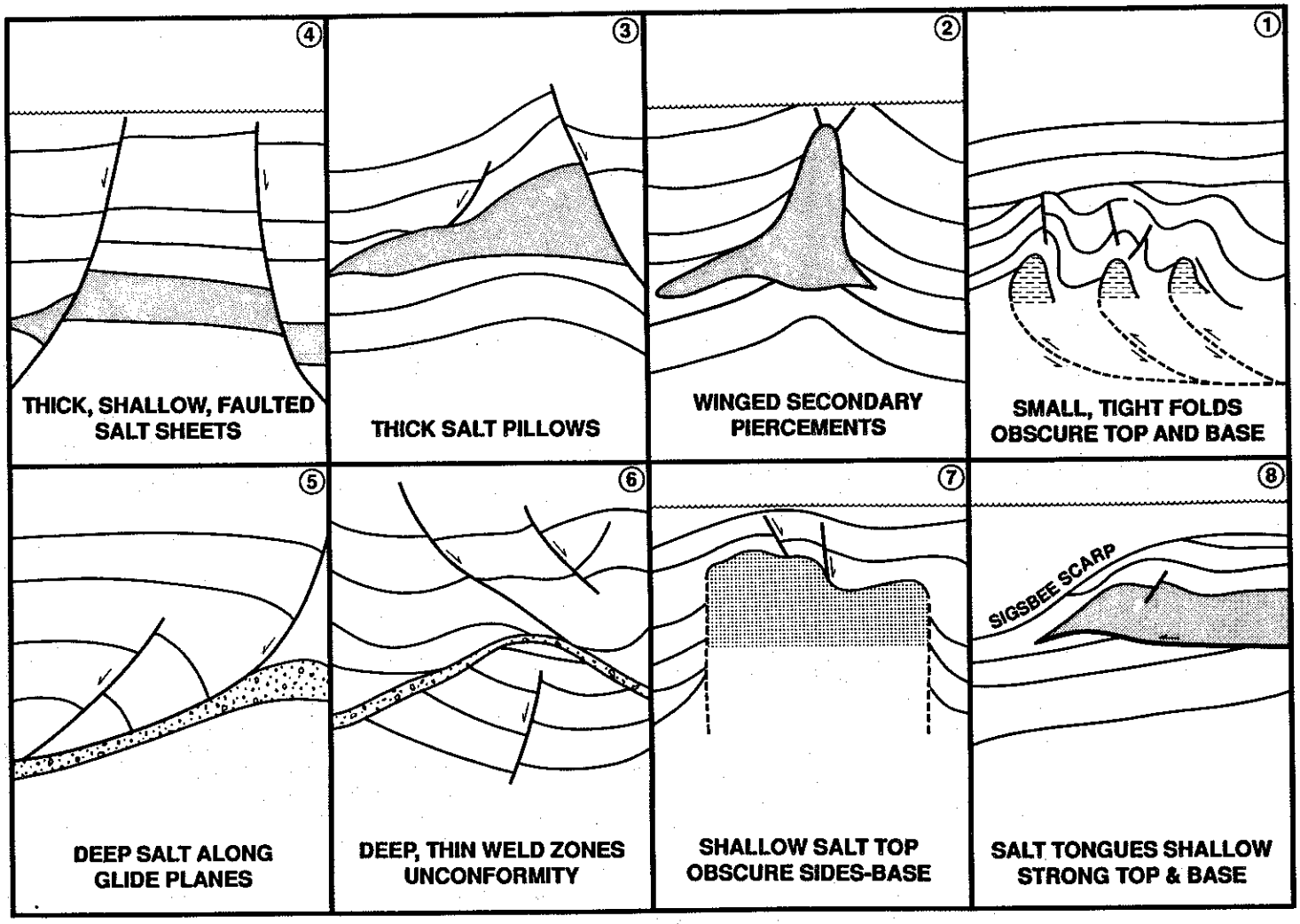

Fig. 1 Structural styles of salt / shale flowage, horizontal componets.

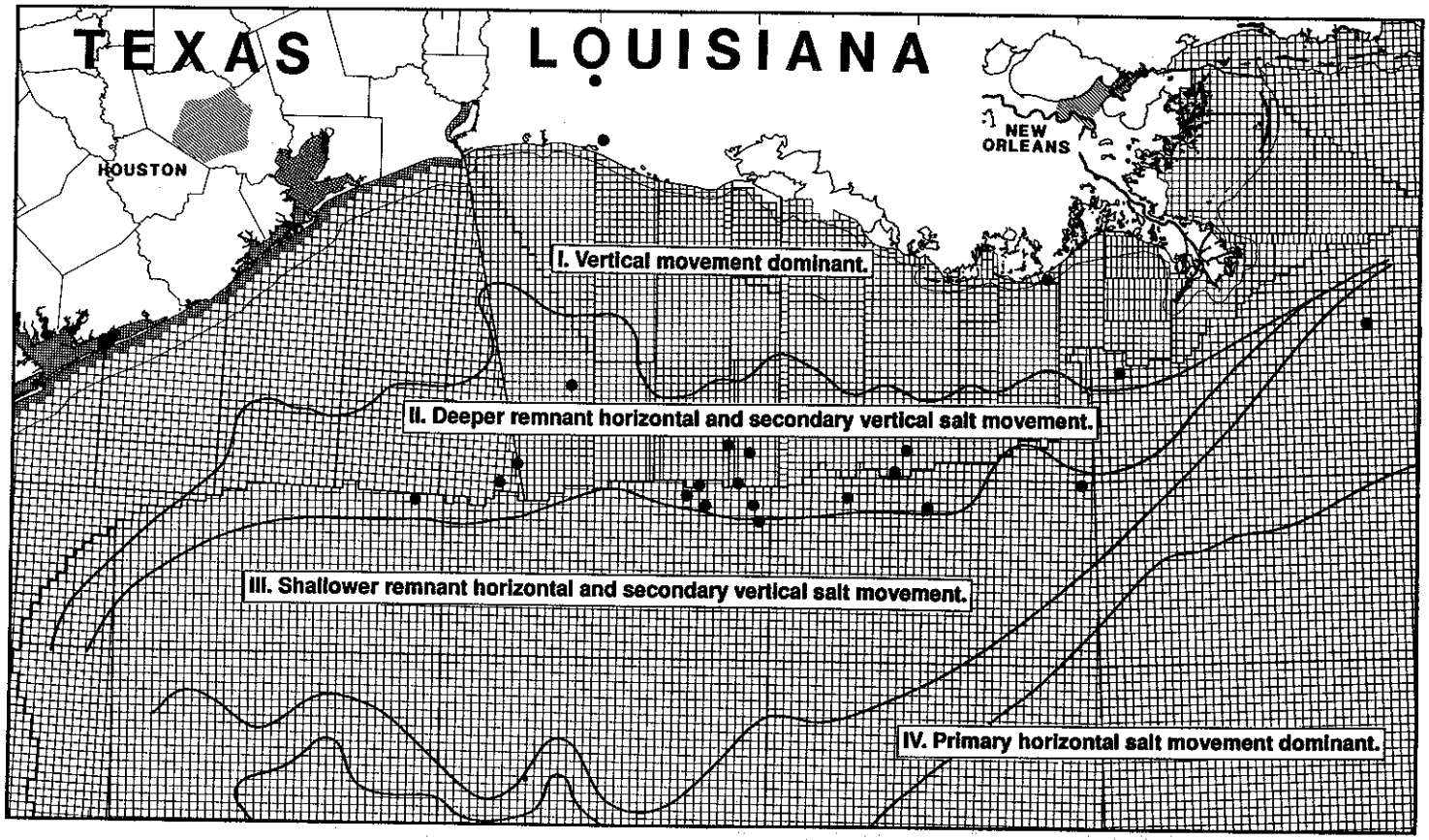

Fig. 2 Salt tectonics, distributions and styles, Gulf of Mexico.