Tectonic Provinces of the Northern Gulf of Mexico

George Jamieson, Schlumberger Geco-Prakla
John F. Karlo, Shell Exploration and Production Technology Co.
Robert C. Shoup, Shell Deepwater Development Inc.

The northern GOM basin can be divided into a number of tectonic provinces arranged arcuately around the basin center (fig. 1). The provinces show a succession of structural styles that a gradually thickening wedge in the eastern half of the basin and a thin salt veneer that abruptly thickened in the western half.

The sequence of provinces begins with a peripheral belt of Mesozoic and early Tertiary salt structures. The province consists (fig. 2a) of an updip zone of salt pillows and rollers, minor salt withdrawal synclines and rafted blocks and a downdip zone of relatively low relief salt withdrawal mini-basins and small diapirs, typically static at top chalk. These structures became stationary owing to insufficient salt volume to continue feeding structural growth and are buried beneath later Tertiary sediments.

Because salt displacement could not maintain structural growth, the early structures are superimposed by gravity slide detachments driven by the late Tertiary sedimentation. In the Texas onshore and shelf (fig. 2b), these make up a wide belt with a multi-storied set of detachments that step up section basinward. An associated belt of compressive folds and reverse faults is present along the outer shelf and upper slope. In onshore

Louisiana (fig. 2c), the detachment province differs in being narrow, discontinuous and generally single storied. The detachments are seen updip to be controlled by major lithologic breaks in the sedimentary section. However, towards the basinward margin of the province (and also from west to east) the structuration of autochthonous salt, while still secondary, were controlled by a basinward thickening Luann salt wedge with a fundamental division between increasingly affected the detachment systems. Reactivation of small and scattered sub-detachment mini-basins by thick Tertiary sediment load induced sags in the detachments and the localized incorporation of small salt masses into the detachments. Less commonly but more easily

Paper presented at the AAPG Hedberg Research Conference, "Integration of Geologic Models for Understanding Risk in the Gulf of Mexico," September 20–24, 1998 (Galveston, Texas).

observed, reactivation induced piercing of the detachments by deep rooted diapirs.

Where there was sufficient salt supply to feed continuous structural growth, stratigraphically controlled detachments did not form. The main tectonic elements of the Houston Salt Embayment, parts of onshore Louisiana and most of the Louisiana shelf are asymmetric, fault rimmed, salt withdrawal mini-basins. The basins are aligned in sub parallel linear trends with salt domes intermittently along the bounding faults. Deep seismic resolution is irregular and discontinuous; however, where there is good resolution these mini-basins are seen bottoming into complex collapse structures at approximately 9-9.5 sec (≈40-45,000'). The seismic reflectors at that depth are only weakly constrained by regional seismic ties but are correlated with the Cretaceous and Paleogene section. The Jurassic Luann is not seismically resolved under the minibasins with certainty; however, the seismic data demonstrate that the minibasins have structural and subsidence histories that are continuous, beginning at least in the Cretaceous, and we interpret the minbasins as all sourced directly from autochthonous salt. The structural style of the mini-basins reflects basinward increasing salt thickness. They progress through three styles (fig. 3a) from simple withdrawal basins updip to more complicated stepped counter-regional basins and thence further downdip into salt-withdrawal mini-basins that fed amalgamated allochthonous salt tablets.

These tablets, along the present outer shelf of offshore Louisiana, were subsequently evacuated under loading by shelf edge progradation, leaving a thin allochthonous remnant salt horizon (fig. 3a) (referred to as Roho, a term that escaped into the literature and which originated partly as a tribute to geophysicist Chuck Roripaugh who recognized and mapped the Roho in the 1970's). The remnant salt separates a hydropressured and mostly Plio-Pleistocene deltaic suprastructure from underlying geopressured mini-basin substructure of Miocene and older deep water sediments. Seismic resolution sub-Roho is generally poor, but mini-basins and salt-feeder systems rooting into the 9.5 second reflector package can occasionally be observed. The areas of Roho may may be continuous with orderly sets of down-to-basin faults detaching onto it (organized Roho) or may be patchy with variable overlying structural styles (disorganized Roho). The difference is linked to the degree of amalgamation of the original tablets.

Opposite to the pattern of the detachment province, the region of salt tectonics for Louisiana is very wide with a full progression of structural styles, while offshore Texas is characterized by the detachment province, devoid of major salt structures, abruptly juxtaposed against an area of mainly tabular salt.

An extensive salt canopy extends across the region of the slope. The canopy is composed of amalgamated tablets similar to those that preceded Roho formation, and in the basin center the canopy is contiguous with

the Roho province. In the upper slope deep seated, salt flanked primary mini-basins are seen (fig. 3b) containing major thicknesses of Plio-Pleistocene sediments but rooting into the Mesozoic section. These basins are both at an earlier stage of development and involve much more salt than the structurally more complex shelf mini-basins. Distinct from these, secondary minibasins are also present, particularily downdip, where ponded sediments are subsiding into the allochthonous salt. In the lower slope in the center of the basin, amalgamation of allocthonous tablets completely obscures the feeding systems and maximum salt thickness approaches 20,000'.

The salt canopy has been taken as a uniformitarianistic element in a number of interpretations of the tectonic history of the Gulf of Mexico. It has been interpreted as the latest in a series of multiple canopies that began with the Oligo-Miocene detachment of South Louisiana and that step basinward through time. Along with this idea, the minibasins of onshore South Louisiana and shelf and associated salt structures have been interpreted as rooted in the Roho's of the earlier canopies. The deep recrord length seismic currently available to industry now makes such a model untenable.

Flanking and extending from beneath the salt canopy are salt and thrust cored folds, of the Perdido and Mississippi Fan fold belts, generally Oligocene and Miocene in ages, respectively. These compressive structures are an "edge effect" in the autochthonous salt, localized at the downdip limit of original salt deposition.

The areal distribution of the provinces is related to boundaries of crustal types from rifting and crustal fragmentation along transform faults and how the basement structure controlled original salt thickness (fig. 4). The salt in a passive margin typically formed in the structural sag created by crustal thinning along the line of continental rifting with the downdip limit of the salt basin at approximately the boundary with oceanic crust. Additional salt may also be deposited over normal (thick) continental crust in subsidiary grabens that flank or branch off the main rift basin. Between the grabens only a thin veneer of evaporites is commonly deposited. Salt in the northern Gulf of Mexico was deposited in both basin settings. The onshore salt basins and the Desoto Salt Basin were deposited in subsidiary grabens in normal crust and the very thick salts under the present day slope formed in the main sag basin over attenuated crust.

Passive margins also commonly develop an asymmetric half graben profile during rifting with a high basement platform on one rift flank juxtaposed against a listric fault defined plunging ramp on the other rift flank. Along the length of a margin, the 'polarity' of the margin may change across major transform boundaries. The fundamental difference between the Texas and Louisiana halves of the basin is interpreted as derived from having a platform profile to the west with a narrow and sharply defined zone of

crustal stretching, and a ramp profile with a wide zone of stretching to the east separated by a significant transform boundary located coincidentally near the offshore extension of the Texas – Louisiana state line.

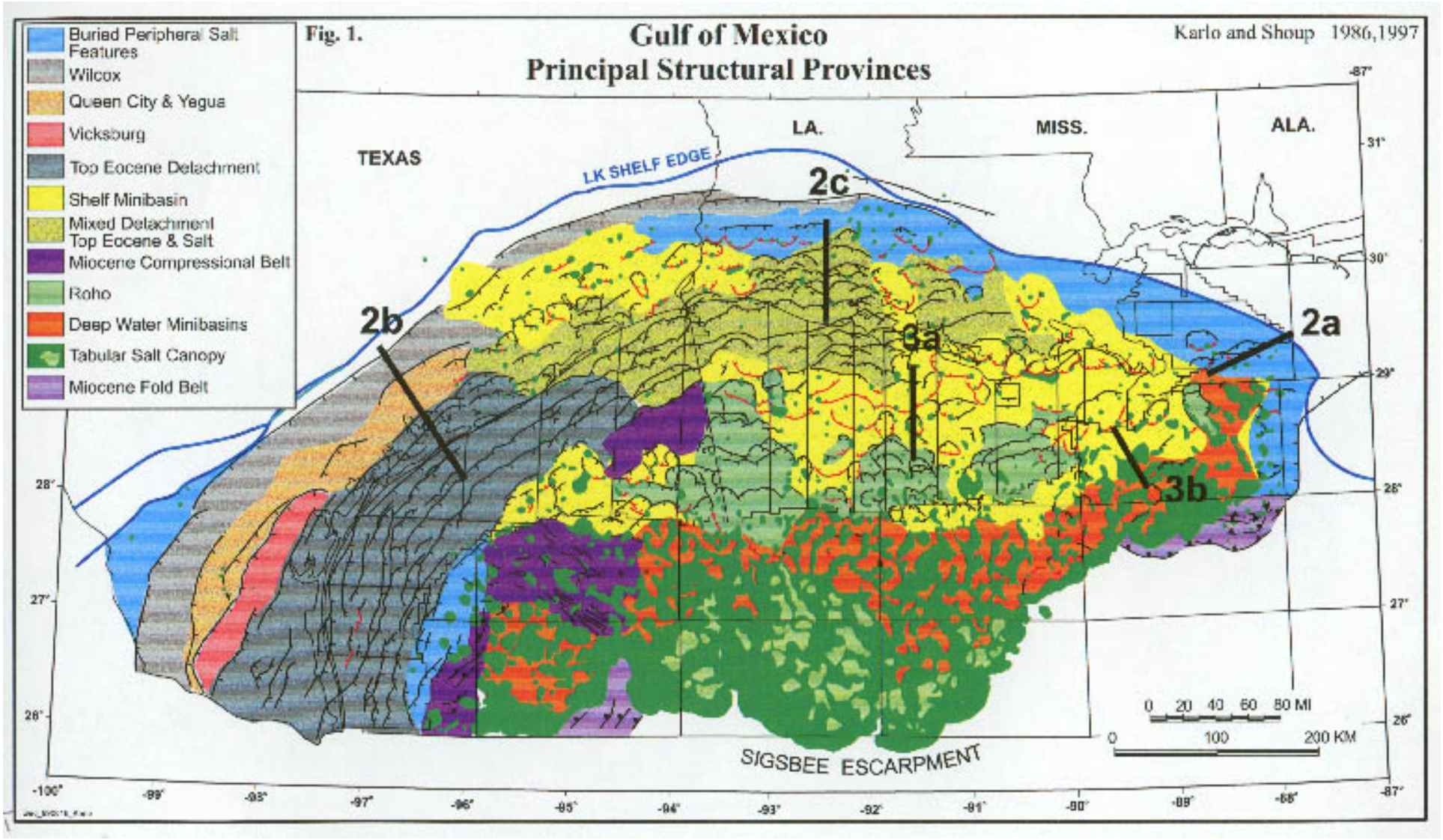

Figure 1 Gulf of Mexico Principal Structural Provinces

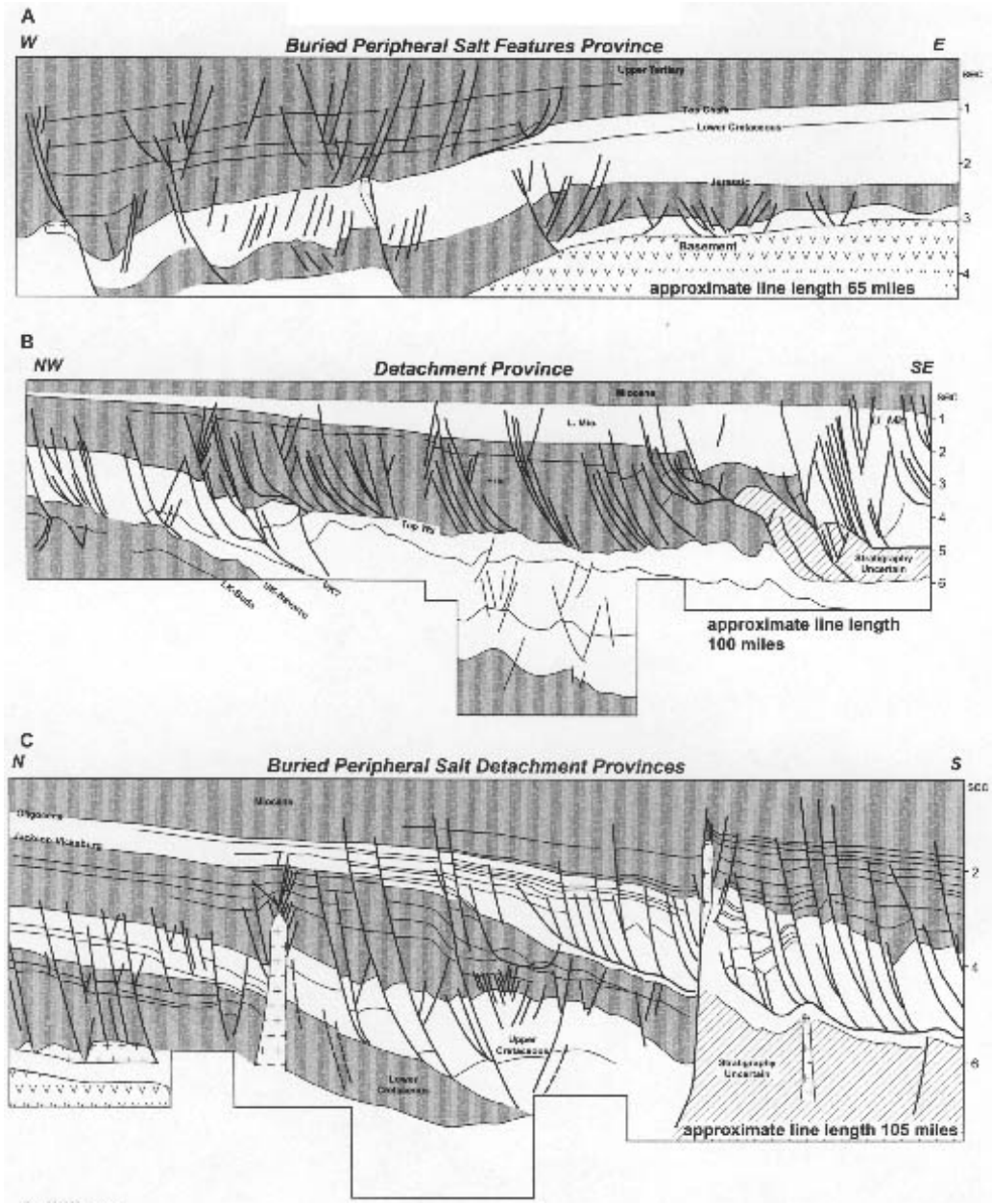

Figure 2a Major Structural Provinces, Top Salt Distribution and Seismic Database Coverage

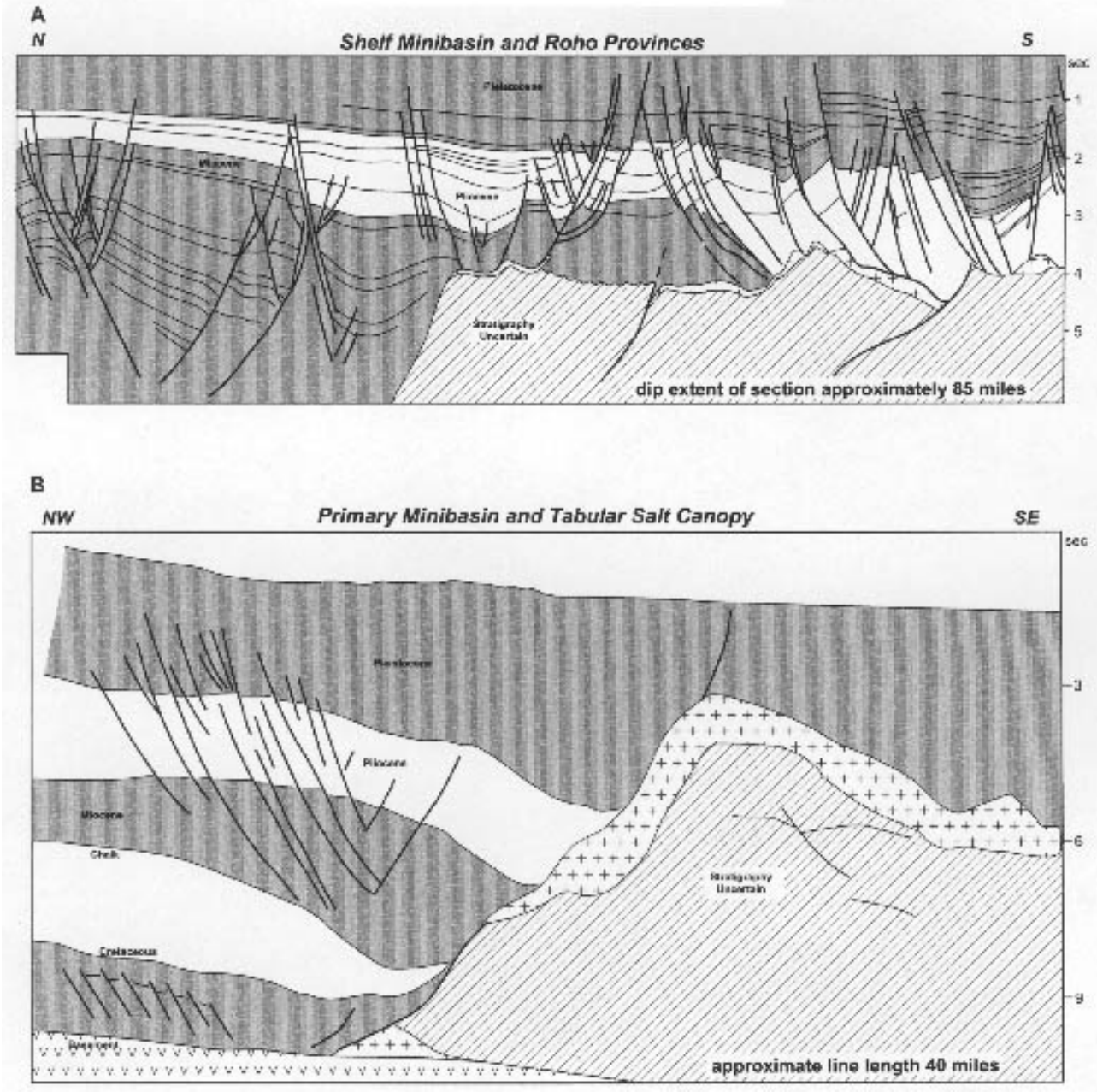

Figure 3 Simplified Regional Cross-sections Taken from Composite Seismic Profiles

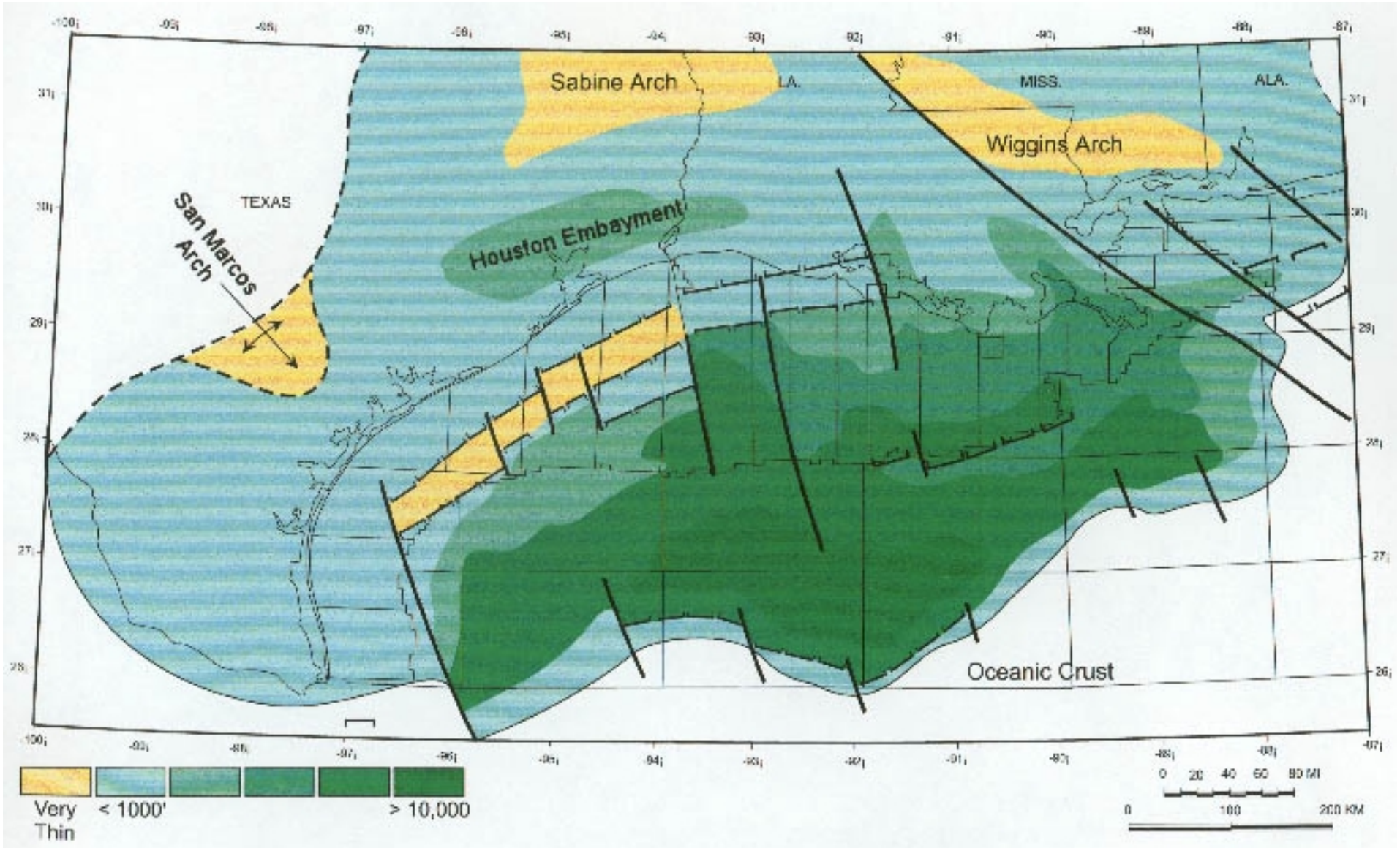

Figure 4 Gulf of Mexico Diagramatic Original Salt Distribution