Northern Gulf of Mexico: Basins, Massifs, and the Upper Crust

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Summary

Quantitative interpretation of extensive high-resolution potential field data sets, integrated with other data by means of modern 3D earth modeling techniques, provides new insight into relationships between deep basins, basement massifs, and the crust under the northern Gulf of Mexico.

Most world oil and gas production has been established in regions underlain by continental crust. Now recent exploration has moved into deep water regions considered by some as underlain by oceanic crust. Despite high industry and academic interest in mapping the limits of oceanic crust in the Gulf of Mexico basin, there is no real consensus as to how and where the oceanic/continental crust boundaries can best be defined (Ibrahim and Uchupi, 1982; Pindell, 1985; D. Hall, 1990; Sawyer et al, 1991; S. Hall and Najmuddin, 1994). This paper addresses the boundary question and also illustrates correlations between basement structure, crustal thickness, and mantle depth.

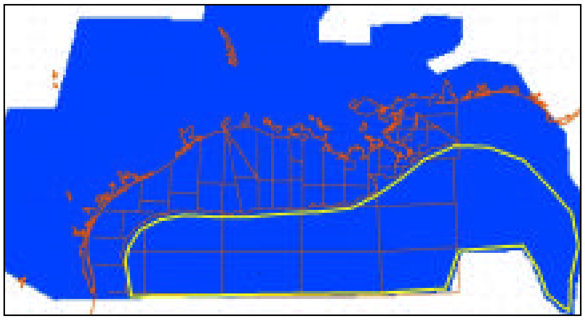
Basement Structure and Crustal Model

An important component of the total interpretation is configuration of the basement surface. Some published interpretations show the offshore basement surface to be a relatively flat and unstructured erosional contact at the base of salt of the mid-Jurassic Louann Formation (Hall et al, 1993; Peel et al, 1995). However, a detailed magnetic interpretation, based on analysis of over 268,000 line miles of aeromagnetic data and correlated with published seismic reflection and refraction data and well data, reveals a different picture. It shows a rugose igneous basement surface resulting from both compressional and extensional tectonic events. As a result of these events, basement has been deformed into a complex of sub-basins, horst-and-graben structures, thrusted blocks, and igneous plugs.

The 3D earth model integrated five key data sets: bathymetry; a sedimentary section with density derived from well velocity analysis; magnetic basement; marine gravity; seismic refraction depths, and regional USGS and satellite-derived gravity. The extensive and detailed marine gravity consisted of over 95,000 line miles of data in the deep water region of the northern Gulf of Mexico. Use of this areally-wide, high resolution gravity data set allowed better definition of crustal boundaries and discontinuities than previously obtained with satellite-derived gravity data.

The Index Map shows a shaded area of approximately 334,000 square miles covered by the basement structural interpretation. The detailed crustal interpretation of the deep water region, highlighted in yellow, covers approximately 120,000 square miles.

INDEX MAP



Oceanic/Continental Crustal Boundary

The northern Gulf oceanic/continental crustal boundary has been characterized as either abrupt or transitional. Analysis of the 3D earth model and its results provide a new way to define and map the boundary; that is, by locating the feather edge of the upper (continental) crust as it extends to or over the shallowing lower or oceanic crust. This boundary is also associated with the model's rapid change in the depth to the mantle, and in many areas, an alignment of basement high blocks.

Key Isopach and Structure Maps

A suite of model-derived isopach and structure maps illustrates several important geological features:

- Pre-Jurassic (?Paleozoic) sediments are thickest in the eastern Gulf and in structural troughs offshore southeast and south Texas. Onshore pre-mid Jurassic thicks correlate with major basins such Mississippi Salt Basin, North Louisiana Salt Basin, Houston Embayment, Brazos Basin, and East Texas Salt Basin. In the remaining areas these older sediments may be thin or absent; or, not unlikely, they may have been altered or even metamorphosed and may physically have become part of the underlying crust.

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- There are NE-SW alignments of thick pre-mid Jurassic (?Paleozoic) sediments (deep basins) where the upper (continental) crust is thin or possibly absent. This, together with a correlative shallowing of the Moho surface, is an indication of pseudo-oceanic, small-oceanic, or rift conditions.

- In general, the onshore upper and lower non-sedimentary crust is thinner (30 km or less) than that of a typical craton. The upper crust thins southward to a feather edge into the deep water regions offshore. This thinning is considered primary.

- The lower crust/oceanic crust is thickest (9 km) onshore and thins southward beneath the abyssal plain where it overlies a relatively shallow mantle.

Central Offshore Basement Massif

One of the more significant geological features covered by this interpretation study is the large, structurally complex basement uplift (Central Offshore Basement Massif) in the central portion of the offshore area. Detailed basement mapping show the massif to consist of several large individual basement highs and lows, with a basement fault pattern radiating from its center. It is bounded to the west, north, and east by deep (pre-mid Jurassic?) trench-like basins; its southern edge lies south of the interpretation area. Earth modeling indicates that thickness distribution of the upper crust is variable across the massif, but averages about 5 km.

It appears that the massif is a relatively or absolutely buoyant positive crustal feature on the southward-thinning continental crustal wedge. It may thus have its origin in Paleozoic tectonics of the original North American craton continental margin. With its critical location in an important hydrocarbon-producing area, any subsequent post-Paleozoic to Recent influence on structural activity has implications for oil and gas accumulation.

Bathymetry/Magnetic Basement/ Salt Sills/Moho

The integrated interpretation reveals a strong correlation in location between the Sigsbee Escarpment, a rapid change in Moho depth, and a chain of magnetic basement high blocks. It is most evident along a sigmoid trend from Alaminos Canyon Area eastward to Green Canyon Area. A secondary correlation, more subdued, exists along bathymetric features and basement troughs and ridges from Mississippi Canyon to Lund areas.

The seaward edge of the salt sheet complex, the allochthonous salt, in Alaminos Canyon, Garden Banks, Keathley Canyon, Green Canyon, and Walker Ridge areas also correlates with both the Sigsbee Escarpment and the chain of basement structural highs noted above.

It follows that if the edge of the salt sheet complex and various bathymetric anomalies correlate with basement structure, there has been some continued basement movement into recent time.

Basement Definition

The geologic term basement can be defined several ways. This interpretation considers basement to be magnetic or crystalline basement as defined in *Encyclopedic Dictionary of Exploration Geophysics*. Magnetic basement may therefore include not only Precambrian plutons, but also Paleozoic plutons or igneous intrusives, thick sequences of Triassic extrusives, and/or Cretaceous igneous plugs.

Refraction basement is usually identified with the first deep high-velocity seismic refractor having velocities ranging between 5.3 to 7.2 km/sec. Seismic velocity of the upper mantle refractor (Moho) ranges between 7.8 and 8.3 km/sec.

Data Sources

Basement and crustal mapping required the interpretation and/or integration of aeromagnetic, marine gravity, refraction seismic velocities and depths, checkshot velocities and satellite-derived gravity data. The data sources, type of data, and the volume of data, used in this interpretation are summarized in the following table.

Data Sources

Fugro-FAS, Ottawa, Canada	aeromagnetics	268,000 line miles
Fugro-LCT, Houston,Texas	marine gravity	95,000 line miles
AIRMAG, N. Philadelphia, Penn	aeromagnetics	9,370 line miles
Integrated Geophysics Corp., Houston, Texas	clastic sediment velocity database	3500 salt edited checkshots
NURE	aeromagnetics	35,000 line miles
Defense Mapping Agency(DMA)	Bouguer gravity	1982 & 1985 files
Sandwell et al	satellite-derived free air gravity	Version 7.2
LDGO, UTIG, USGS	seismic refraction	81 sites
Various sources	basement/igneous penetrations	64 wells

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Fugro Companies: LCT & Airborne Systems
AIRMAG Surveys
Scripps Institute of Oceanography
USGS
University of Texas Institute for Geophysics
LDGO