INTEGRATED GEOPHYSICS CORPORATION

FOOTNOTES
ON INTERPRETATION

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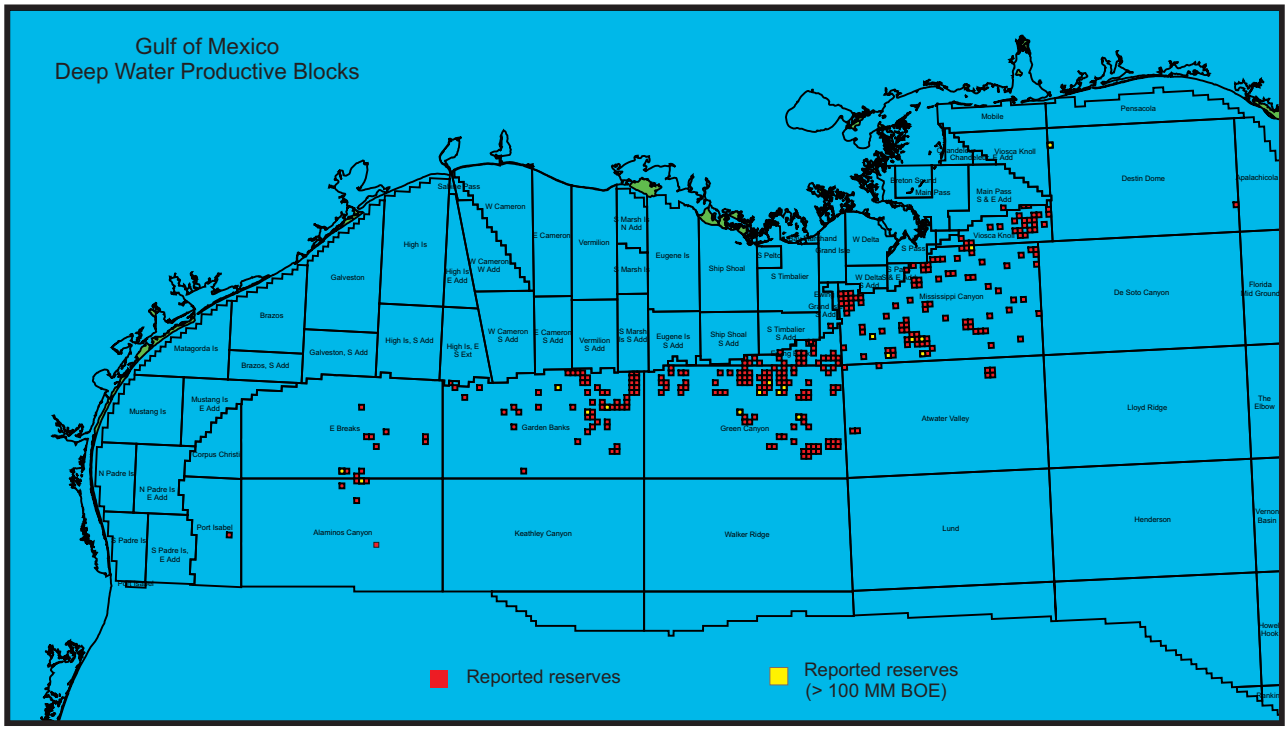
Gulf of Mexico study links deep basement structures to oil fields

Demonstrating deep structural control



Today's almost singular focus on deep water drilling has placed the Gulf of Mexico firmly in the spotlight, accounting for almost 90 percent of the Gulf's discovery prospects - and with good reason. A forecast at a recent industry conference indicated that drilling further offshore and in deeper waters (over 1,500 ft) has doubled the number of discoveries worldwide from 1998 to 1999. Further, the number of discoveries in the 3000-5000 ft water depth range tripled during the same period. Fueling this excitement, new developments in sub-sea processing have resulted in the emergence of fifth generation rigs capable of drilling in water depths up to 8000 feet.

Almost ironic, is the fact that the correlation between the Gulf of Mexico's basement structure and the location of oil and gas fields has never been studied. This is even more perplexing, given the tremendous potential in the Gulf and the historic application of basement structure analysis in evaluating oil and gas targets in all other areas of the world, including deepwater.

As primary interpreters within the Gulf over the past decade, we realized that we had amassed enough basement data to complete a comprehensive analysis of the correlation between the basement structure and oil and gas discovery fields within the Northern Gulf. As long term advocates of establishing basement tectonics as the first step in the evaluation of an international frontier, we were excited at the opportunity to test out our hypotheses or to prove our theory was applicable in the deepwater Gulf.

Our research objective was to correlate the relationship between oil and gas fields and discovery wells with regional structural basement characteristics and to demonstrate the rationale for utilizing regional basement structure as an evaluation tool.

Simply stated, the position of oil and gas fields can be a vital parameter in predicting the viability of future exploration sites when the correlation between producing and projected sites can be identified. In the deepwater regime of the northern Gulf of Mexico, the availability of a reliable regional basement structure map and a documented number of oil and gas discoveries provided an opportunity to assess the strategy.

Anticline Theory

Despite the technological explosion of recent years, arguably, the most cost effective concept defining the location of oil and gas fields is still the "anticline theory": - a closed structural high at reservoir level. Such a structural anomaly must be located in the pathway of oil and gas, which migrates both laterally and vertically in order to maximize its trapping potential. On the regional scale, a structural high must be in close proximity to a structural low (syncline, depocenter, or sub-basin).

From a basin-wide perspective, high structural anomalies become the focal points of migrating oil and gas. Regional (low) structural anomalies are the generating depocenters. In most cases, basement anomalies underlie and caused regional basin wide structural anomalies. This is the primary rationale underlying the practical application of basement maps as an exploration tool.

A less accepted, or merely less known fact, is that in any producing basin oil and gas are concentrated in specific areas of the basin. In fact, 75% or more of oil and gas in a producing basin are contained in just 25% or less of the total basin area. Further, structural positive (high) anomalies near structural negative (low) anomalies are the preferred targets.

Methodology

Our study utilized IGC's interpretation of the regional magnetic basement structure and published data describing the locations of oil and gas fields and discovery wells in the deepwater of the northern Gulf. The basement map is the result of several years of depth estimates derived from the Geoterrex aeromagnetic database and correlated to geologic and seismic refraction data.

Published data identified the location of over 250 OCS blocks associated with oil and gas discoveries. Estimated reserves in the northern Gulf in water depths greater than 1,500 ft are available for approximately 50% of those fields as "proven reserves in million boe".

First, we plotted the acreage blocks carrying the MMS-reported fields as well as the reported discoveries. The location and the geological-structural framework of these productive blocks were correlated to the IGC magnetic basement structural interpretation and classified into three primary categories:

!On top of basement structural high

!In steep and faulted flanks of basement structural highs

!In basement structural lows.

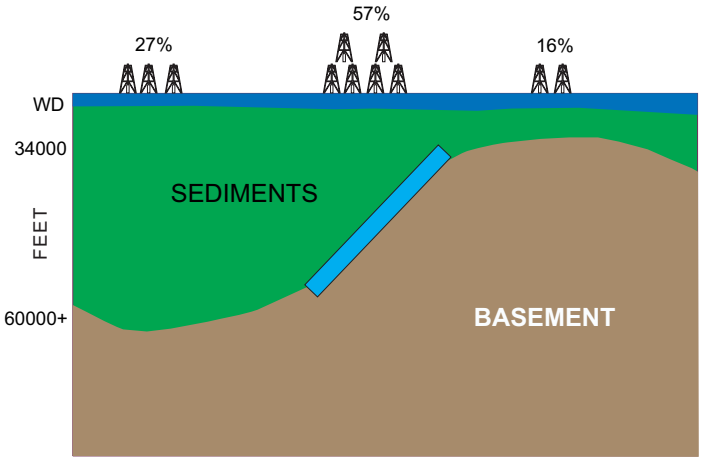
Study results

Our study observed 23 fields lying within the area, each with proven reserves of over 100 million boe. Total reserves in the selected 23 deepwater fields are reported as 5,141 million boe. The number and percentage of fields correlated to type of regional basement structure are:

Reserves located on steep/faulted flanks of basement highs: 13 fields (56% of total) containing 2,929 million boe, or 57% of total reserves

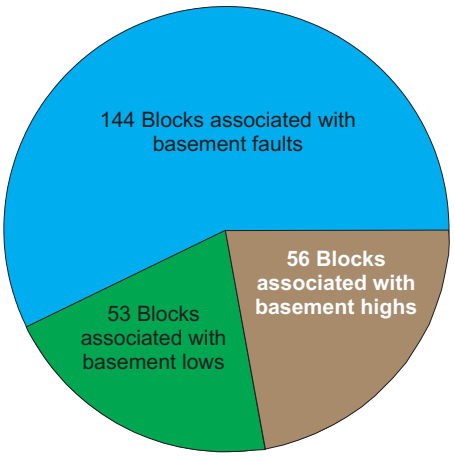
Reserves located on top of basement highs: 5 fields (22% of total) containing 820 million boe, or 16% of total reserves

Reserves located in basement lows. 5 fields (21 % of total) containing 1,392 million boe or 27% of total reserves.



Simply stated, approximately 73% of reported oil/gas reserves are located on structural basement highs or associated faults, and 27% of oil/gas reserves in structural basement lows. These findings are compatible with other industry studies for other productive basins on a worldwide scale.

Further, in terms of Productive Acreage Blocks analyzed, of the 253 acreage blocks in the Gulf deep-water offshore region publicly reported as carrying discovery wells or as being a part of an oil/gas field development operation, our findings determined the following relationships to basement structure:



OCS Blocks associated with steep/faulted flanks of basement highs: 144 blocks or 57%

OCS Blocks associated with top of basement highs: 56 blocks or 22%

OCS Blocks associated with basement lows: 53 blocks or 21% of blocks

Similar to the large oil fields discussed above, our study found that approximately 80% of all blocks analyzed are located on top or on the flanks of basement highs, and 20% of all blocks are located in basement lows.

One observation of this study is that regional structural highs near a deep basement structural low are attractive sites for oil and gas accumulations in the offshore northern Gulf . Structural lows will contain thicker sediment columns than adjacent structural topographic lows, including thicker sections of potential oil and gas source beds. Oil and gas generated in such regional lows will migrate updip, wherever possible, onto adjacent structural highs. Structural highs located between two adjacent basement lows offer special attractions for oil and gas migrating from both sides. Prospects in this structural position have been tested in the northern Gulf and have proven productive.

Logical connection

For many skeptics, the absence of a logical connection, or rather the lack of data concerning a connection between basement structure and the required structural relationship at the level of deeper Jurassic, Cretaceous, and Eocene source beds, is critical.

Such a connection is required to assign a higher exploration value to the basement structure map. Unfortunately, there are no maps from these deeper levels today. Therefore, we must restrict our analysis of prospective acreage blocks to the observed relationships between the magnetic basement structure map and the location and distribution of productive acreage blocks, and of discovered oil/gas reserves.

Basement structures in the offshore northern Gulf are the result of multiple deep-seated tensional and shear faulting at the basement level. Subsequent basement motions as well as the impact of topographical differences at the level of sedimentation during Mesozoic and Lower Tertiary times originally led to the development of regional lows and regional highs. The quality of basement structure mapping has been continuously improved over the years with better data and more refined interpretation techniques.

Today, structure maps available from high-resolution aeromagnetic surveys in the Gulf permit the analysis of basement structural anomalies at a scale that allows prospect analysis. However, no well has yet been drilled to basement, and no direct geophysical data from basement rocks are known from the region. This is no small surprise, since the top magnetic basement is mapped to lie at least 30,000 feet deep in the offshore Gulf.

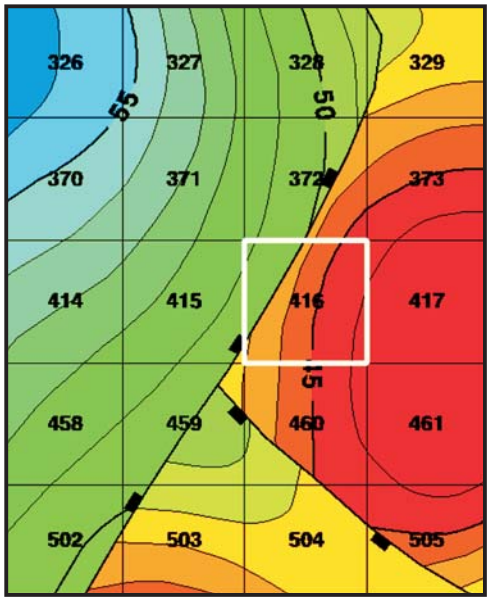
Field position, basement structure

Historically, regional low areas became the sites for increased sediment deposition with a preferred content of oil/gas source beds (depocenters). Regional highs became the sites for reservoir development, especially on the flanks of regional highs where sand units pinch out against existing topographic and structural highs. Finally, oil and gas that was thermally generated in regional structural lows migrated updip to regional structural or topographic highs (migration pathways).

These structural basement highs are associated with the location oil/gas fields with relatively shallow, Late Tertiary sand reservoirs. The fields are concentrated together. They are formed by oil and gas leaking from deeper accumulations and/or migrating updip directly from generating source beds via a fault induced by basement faulting.

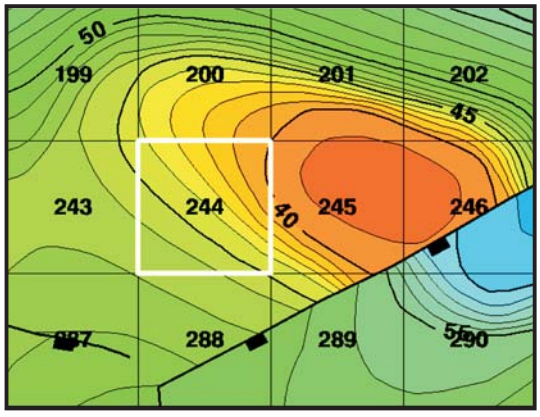
The two example basement maps accompanying are subsets from an interpretation that spans over 450,000 square miles. The interpretation was derived from depth analysis techniques applied to high-resolution aeromagnetic data from surveys collected from 1986 through 1999.

A discovery in OCS block 416 in Green Canyon (McKinley Field) is an example of a *field position to basement fault* correlation. The block is situated on the western flank of a magnetic basement structural high. It lies across a west-dipping normal basement fault and near a southwest-dipping normal basement fault. This example shows depth to basement ranges from 44,000 ft to 56,000 ft.



OCS block 416 in Green Canyon

Discovery OCS block 244 in Green Canyon, Troika Field is an example of a *field position to basement structure high.* The OCS block is near the crest or the western flank of a magnetic basement high. No fault has been mapped in the block. Significant basement faulting is indicated along the southeastern flank of this structure high. In the block, the average depth to basement is 44,000 ft.



OCS block 244 in Green Canyon

Conclusion

Deepwater drilling in the northern Gulf of Mexico is at the frontier of a new era in exploration. For decades, production from the Gulf was derived from the shelf. The traps are shallow, and structurally influenced by salt. Today, almost 90% of production over the next five years will come from the deepwater regions of the Gulf, accompanied by a host of new complexities compounding those associated with the shelf.

This study's findings are analogous with producing basins around the world and support the view that hydrocarbon migration pathways are basement controlled. For many explorationists, IGC's findings are a rude awakening. Today's new era of deepwater drilling associated spiraling costs make a strong case for the inclusion of basement structure in the analysis and economic assessment of prospective Gulf targets.

Acknowledgments

Many have contributed to the IGC basement structural interpretation and findings discussed in this article, notably, Michael Alexander, Geophysicist with IGC (formerly Exxon) and J.C. Pratsch, Consulting Geologist (formerly Mobil & Sohio). Geoterrex of Canada provided support and the aeromagnetic database utilized in this undertaking.

Recommended Reading

Worldwide areas and basins that have been discussed in publications which described the concentration of oil/gas fields on basement structural highs include: the Los Angeles Basin of California, the Overthrust Belt of Wyoming, the East Texas basin, the Sirte basin of Libya, offshore Tunisia, north-central Algeria, western Morocco, Senegal, the Gulf of Suez, onshore West Egypt, and onshore Sudan, Saudi Arabia. Also many basins located in Argentina, Peru, Ecuador, the Austrian Vienna basin, Yugoslavia, the Hungarian plains, several in the former USSR, on/offshore China, and Northwestern Sumatra, western and eastern offshores of India have oil/gas production associated to basement structure. The following publications are recommended for additional reference: 1) J.C. Pratsch, 1998, Geologic Applications of Gravity and Magnetics: Case Histories, SEG Geophysical References Series, no.8, AAPG Studies in Geology no.43, p.28-31, 2) J.C. Pratsch, 1986, The distribution of oil and gas reserves in major basin structures: an example from the Powder River basin, Wyoming, USA, Journal of Petroleum Geology, vol.9, no.4, p. 393-412

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