Geothermal Gradients and Subsurface Temperatures in the Northern Gulf of Mexico*

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Abstract

Geothermal gradients have been calculated in 1131 fields and wells, and a map has been prepared showing the below-mudline depth to the 300°F subsurface isotherm over the northern Gulf of Mexico. Since the 300°F isotherm values are a direct reflection of thermal gradient, thermal conductivity, and heat flow, the map may be considered as a portrayal of subsurface temperature distribution. Based on interpreted vertical and horizontal temperature patterns, the northern Gulf can be subdivided into six thermal domains. The Texas shelf domain shows the highest subsurface temperatures with a pattern of elongate, northeast-trending isotherm contours related to the regional pattern of faulting. A prominent temperature high perpendicular to the regional trend may reflect the southeast-plunging San Marcos arch. The High Island domain coincides with a late Miocene depocenter and has anomalously low temperatures caused by either a deep overpressure zone or shallow thermal conductive zone. Moderately high temperatures and a pattern of isotherm contours related to salt features characterize the Louisiana shelf domain. The Mississippi Canyon domain coincides with the Mississippi fan and displays very low temperatures due to thermal suppression from thick, rapid Quaternary sedimentation. The Walker Ridge domain coincides with the Texas-Louisiana slope and has the coolest temperatures found to date in the northern Gulf. The Alaminos Canyon domain falls within the Northwest slope and the Perdido diapir provinces and displays temperatures intermediate in value between the Texas shelf and Walker Ridge domains.

Introduction

Approximately 44,000 oil and gas exploratory and development wells have been drilled in the US Federal waters of the northern Gulf of Mexico since 1947 (Figure 1). These wells have encountered a variety of temperature conditions that range from abnormally low to abnormally high, indicating that the pattern of subsurface heat in the basin is complex. Limited data has been published documenting temperatures in specific wells, fields, or local areas, but the only regional temperature analyses of the area are modeling studies that predict timing of hydrocarbon maturation by tracing temperature evolution (Mello and Karner, 1996; Jones and Nagihara, 2003; Jones et al., 2003). No studies exist that show the detailed regional distribution of present-day temperatures. This study summarizes our work in putting together a map illustrating subsurface thermal conditions in the northern Gulf and presents preliminary interpretation of the spatial temperature patterns. Ideally such an analysis would be carried out using equilibrium bottom-hole temperatures (BHTs) measured from each well during geophysical logging runs. BHTs are sporadically recorded on the well log headers, but they have not been digitized or summarized in a systematic manner that is publicly available. In addition, very few, if any, wells have recorded the data necessary to calculate equilibrium BHT values. Publicly released wells are available through the Minerals Management Service (MMS), but the number of logs exceeds 250,000 for the 44,000 wells drilled. The time and expense necessary to purchase and process these logs would be excessive. We therefore have relied on publicly available data on average sand temperatures in fields calculated by the Minerals Management Service supplemented by data from 90 wells.

The result of our analysis is a map that illustrates below-mudline (BML) depths to the 300-degree (BMLD300) subsurface isotherm throughout the northern Gulf. This map can be considered as a portrayal of subsurface temperature distribution, as the BMLD300 values are a direct reflection of thermal gradient, thermal conductivity, and heat flow. The map illustrates the complexity of subsurface temperatures in the northern Gulf. In some cases this complexity can be related to known geological conditions, but in other cases the relationship is ambiguous. The most serious shortcomings of the map are (1) its dependence on average values for calculating thermal gradients, (2) a mixed source of original temperature values (derived from both non-equilibrium BHT data measured during logging runs and temperatures measured during bottom-hole pressure surveys) and (3) the relative paucity of data in deep-water areas (>1,000 ft of water depth). Despite these weaknesses we feel the map documents valid regional variations in temperature distribution and provides a good tool for estimating temperatures for drilling and for basin-analysis work. The map will be improved over time as new and more accurate data becomes available.

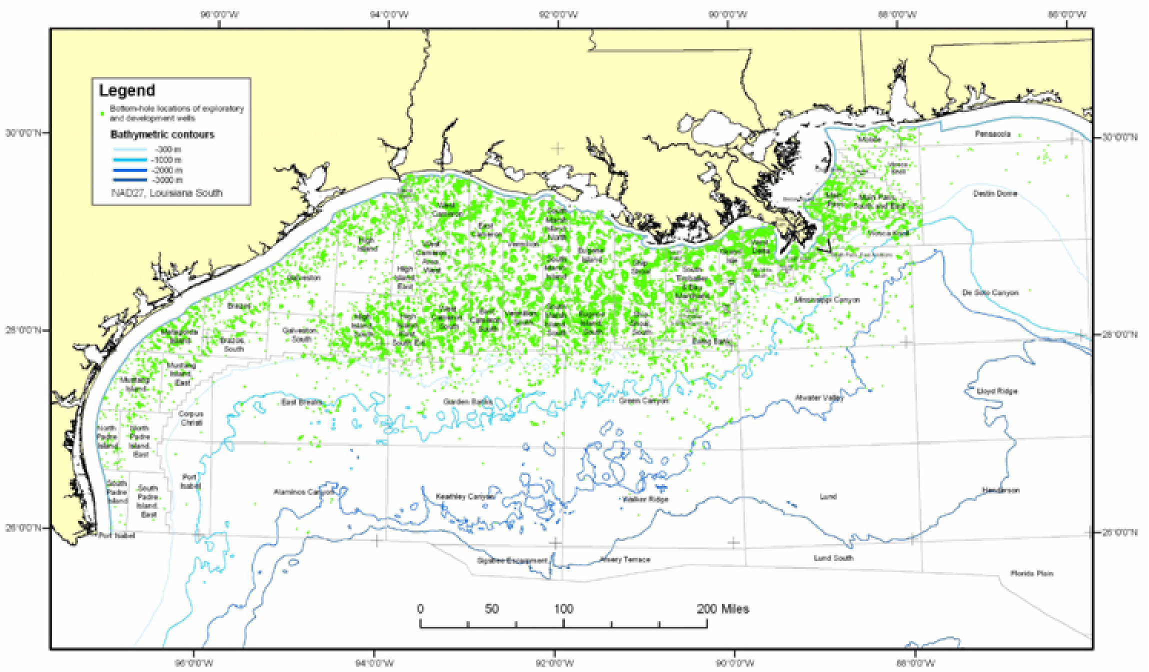


Figure 1. Bottom-hole locations of exploratory and development wells drilled in the northern Gulf of Mexico through April 2004. Well locations from the MMS borehole file.

Geothermal Gradients in the Northern Gulf of Mexico

It is well established that temperatures increase with depth in the Earth, indicating that heat is generated at depth and transferred through rock and sediment layers to the surface. This so-called terrestrial heat flow is described by the following equation:

$$Q_z = \lambda \frac{\Delta T}{\Delta D} \qquad (1)$$

where:

Q_z = Heat flow per unit area in the vertical direction
λ = Thermal conductivity
$\frac{\Delta T}{\Delta D}$ = Geothermal gradient

Blackwell and Richards (2004) present the most recent interpretation of heat flow in the Gulf of Mexico as part of their Geothermal Map of North America, but little data on thermal conductivity is available for the region. The thermal maturation modeling studies that have proliferated in recent years require thermal conductivities over an entire stratigraphic section as an input to calculate heat flow. For the most part these values are estimated from wells logs or extrapolated from analogous geological settings. Thermal conductivity values used in the studies are rarely published as part of a basic documenting data set.

Since heat flow and thermal conductivity data are rarely available for petroleum applications, bottom-hole temperatures measured in boreholes are the principal basis for calculating geothermal gradients. The basic equation for the calculation, and the method utilized in this study, is as follows:

$$\text{Geothermal Gradient} = \frac{\text{Formation Temperature} - \text{Mean Annual Surface Temperature}}{\text{Formation Depth}} \quad \ldots\ldots. (2)$$

Problem of Mean Annual Surface Temperature

In calculating geothermal gradient using equation 2 a value of mean annual surface temperature is subtracted from the measured BHT before being divided by the formation depth. The mean annual surface temperature serves as an approximation of temperature at the top of the rock-sediment column. For the Texas Gulf Coast area an annual mean surface temperature of 68-70°F is typically applied. Because of the intervening water column, the air temperature in offshore areas does not truly reflect temperature at the top of the rock-sediment column (i.e., the mudline) and, therefore, may produce spurious results in geothermal gradient calculations. This is especially true in deep-water areas, where the mean air temperature at the water surface may be considerably higher than the temperature at the seafloor, or mudline. For the present study, we have used the mean annual temperature at the mudline as the “surface temperature,” thus eliminating the misleading influence of a water column that is not in thermal equilibrium with the underlying rock-sediment section. This standard has also been adopted recently by both

API Subcommittee 10 for estimating subsurface temperatures for cementing and API Subcommittee 13 for estimating subsurface temperatures for calculating the true density and viscosity properties of drilling fluids at actual well-bore temperatures.

Good data is available for water temperatures versus depth through the World Ocean Database (http://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html). This data consists of mean annual water temperature-depth profiles gathered over many years from the world's oceans by the US National Ocean and Atmospheric Administration (NOAA). For the northern Gulf of Mexico 3495 profiles containing over 70,000 data points were obtained and used in this study. A plot of the data points is shown in Figure 2. We have averaged the data values for successive depth increments of 100 feet, and these average values are plotted in Figure 3. Below 3800-3900 feet the average annual water temperature falls asymptotically to a constant value of around 40° F (4.4º C) that prevails to abyssal depths.

The gradient calculated for each field or well is based therefore on a mud-line temperature that reflects the water depth at which the field or well occurs. The resulting BML geothermal gradient is a better reflection of heat flow and thermal conductivity in the field or well, without the misleading influence of the water column with its reversed (temperature decreasing with depth) and unrelated thermal gradient.

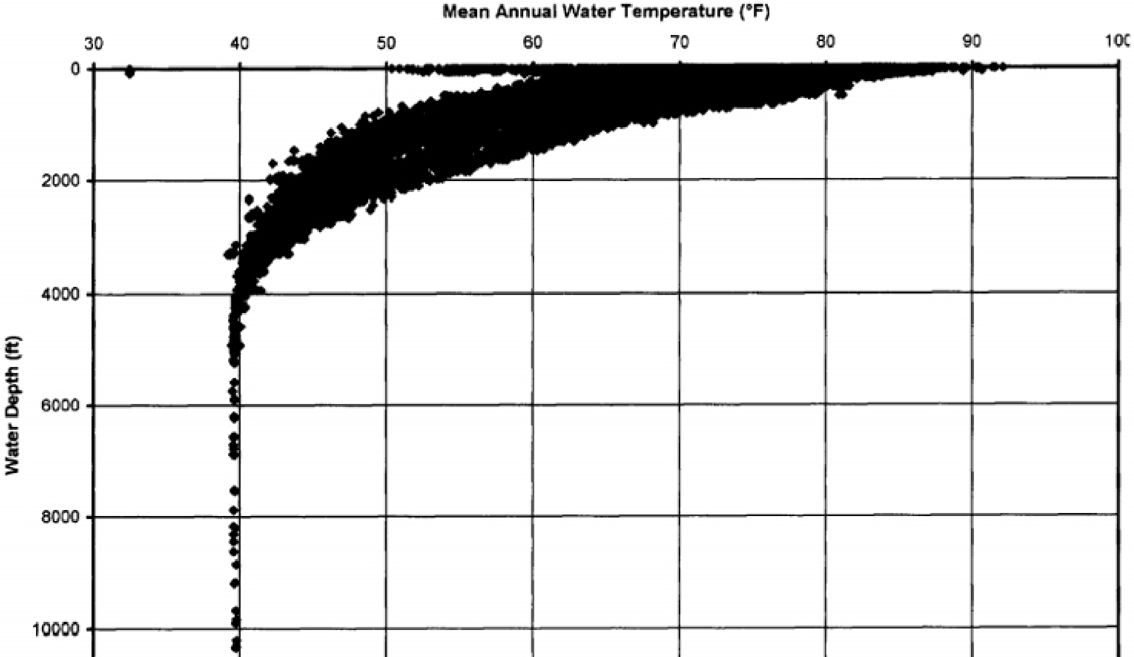


Figure 2. Mean annual temperature of water vs. depth for 3495 profiles (70,000 measurements) in the northern Gulf of Mexico. Data from the NOAA World Ocean Database.

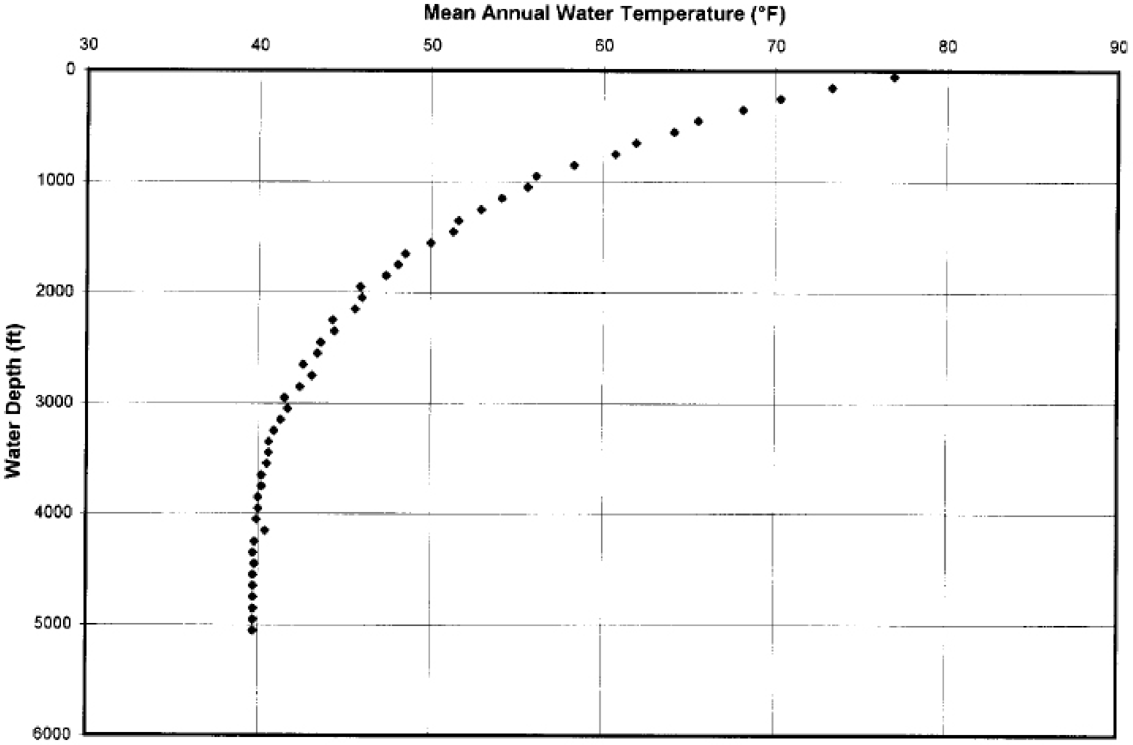


Figure 3. Mean annual water temperature vs. depth averaged for 100-foot intervals of depth in the northern Gulf of Mexico. Data from the NOAA World Ocean Database.

Calculating Geothermal Gradients and BMLD300 Values

Two sources of data were used to derive geothermal gradients from which the BMLD300 was calculated:

- average temperature data from sands in fields
- bottom-hole temperatures from supplemental wells.

The main data source was the Minerals Management Service's 2001 publication "Atlas of Northern Gulf of Mexico Gas and Oil Sands." In that work the MMS calculated a series of weighted reservoir parameters for sands in fields recognized as of January 1999. The MMS defined a "sand" as all productive formations in a field that are geologically correlative. Reservoir characteristics for all sands were calculated, weighted according to the relative importance of the reservoir in the field, and averaged. A particular sand's temperature may be derived from many wells in a field or from only one well, if only one produces from the formation. Depth values assigned to the temperatures are weighted average sub-sea TVD values of the wells producing from the sand.

Average weighted values obviously do not reflect all possible variation in temperatures in a field. However, as discussed in an earlier section, obtaining a regional grid of good static bottom-hole temperatures from wells is essentially impossible in the Gulf. We recognize the weakness in the data, but feel strongly that it still allows a valid regional overview of temperature distribution. An obvious advantage of the MMS data set is its large size (13,000 average sand temperatures from 1041 fields) and its good regional distribution. Locations of the fields that were used are shown in Figure 4.

Since the data available from the MMS Atlas publication covers only fields recognized up to January 1999, it was necessary to add data from individual wells to give better coverage to deep-water areas, which have a limited number of fields. We reviewed 4500 logs from 250 deep-water wells in which the BML total depth was at least 15,000 feet or greater. Only 90 wells were found to have usable temperature data. The distribution of the wells used is shown in Figure 4.

To calculate gradients, an Excel spreadsheet was developed that contained all data points for each field and well. The BML depth of each data point was calculated by subtracting the water depth from the average depth of the sand or the depth of the value in a well. The MMS data had already been converted to a sub-sea true vertical depth. We corrected the well data to TVD-SS using directional survey data from the log headers. An Excel macro was developed to plot data points from each field on a temperature- depth graph (Figures 5, 6 and 7, for examples). Each plot was examined and a gradient line or series of gradient lines was visually established and drawn through the points. The average annual mud-line temperature developed from the World Ocean Database was used as the shallowest point ('annual mean surface temperature').

After establishing the gradient lines, values were extracted from each plot to calculate a gradient and a BMLD300 value (Figures 5, 6, and 7). If a field demonstrated dogleg gradients (see next section for discussion), the temperature of the deepest point above the deepest dogleg was recorded, and the gradient of this last step was used to calculate the depth to reach 300°F in the field or well.

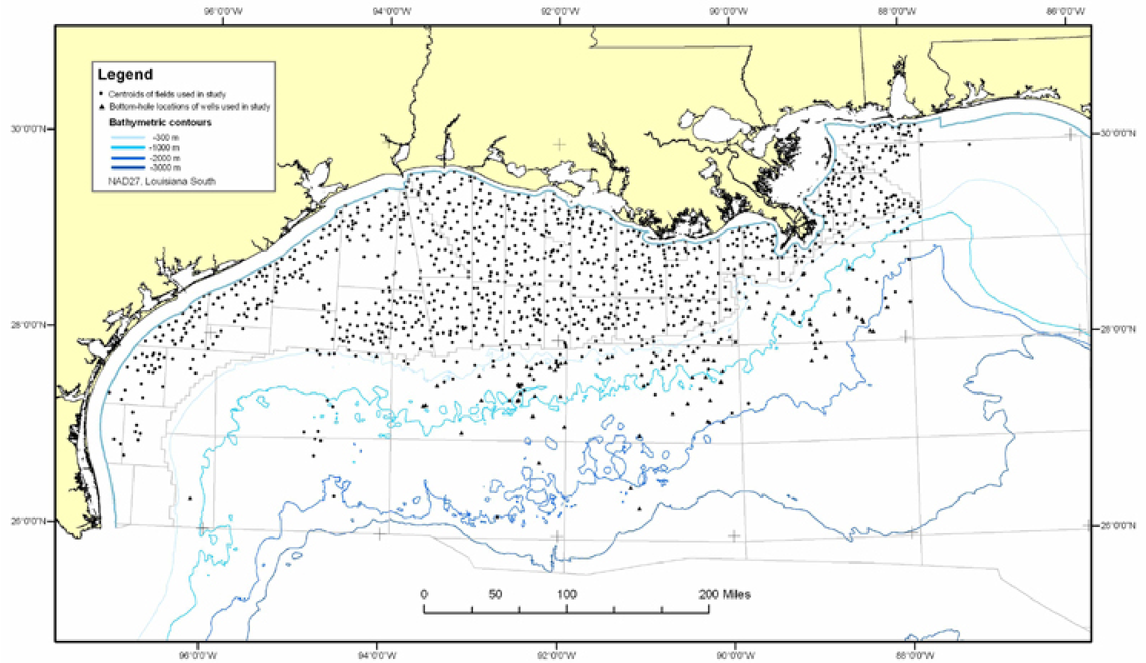


Figure 4. Location of fields and wells used in calculating geothermal gradients and BMLD300 values. Field locations from MMS Atlas of Northern Gulf of Mexico Gas and Oil Sands (2001); well locations from MMS Borehole File.

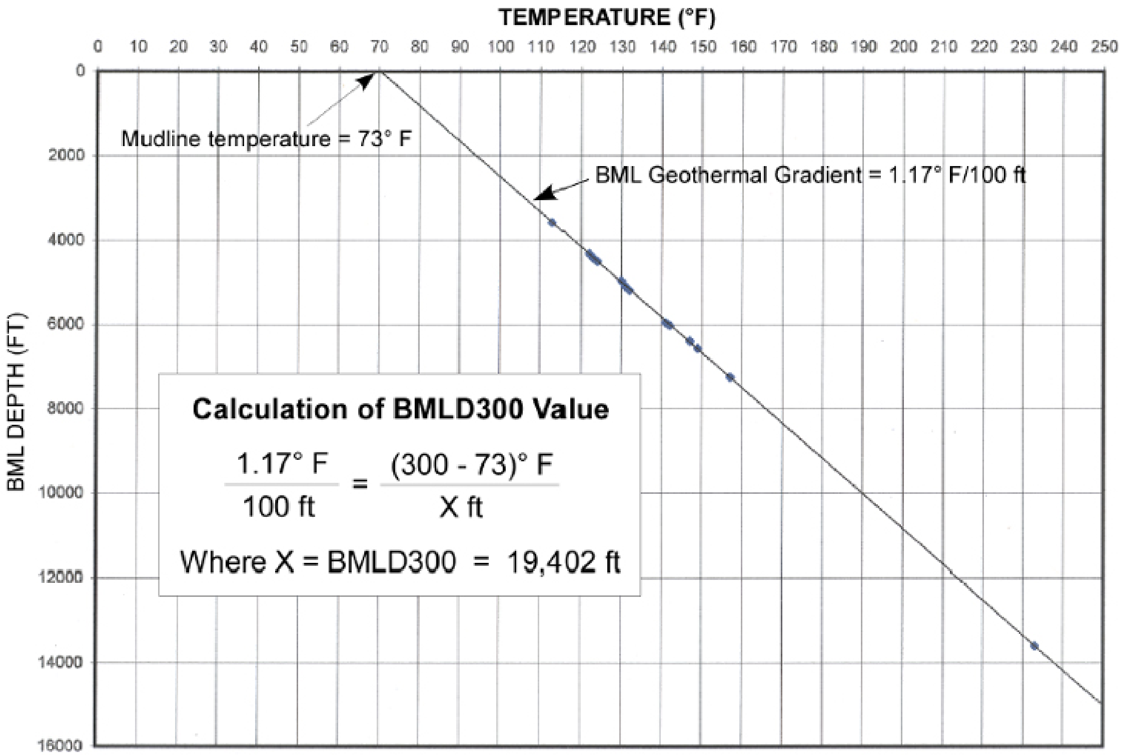


Figure 5. Average temperature-depth plot of sands in the West Delta 86 (WD086) Field. Data from MMS Atlas of Northern Gulf of Mexico Gas and Oil Sands (2001).

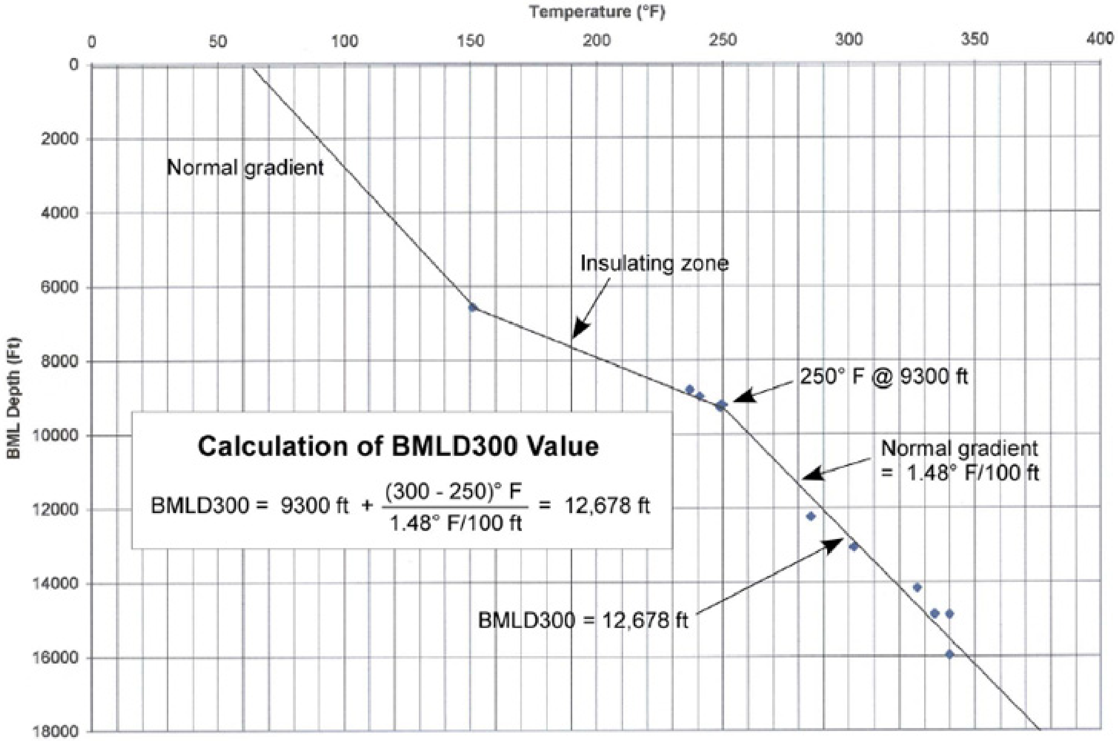


Figure 6. Average temperature-depth plot of sands in the Brazos 133A (BA133A) Field. Data from MMS Atlas of Northern Gulf of Mexico Gas and Oil Sands (2001).

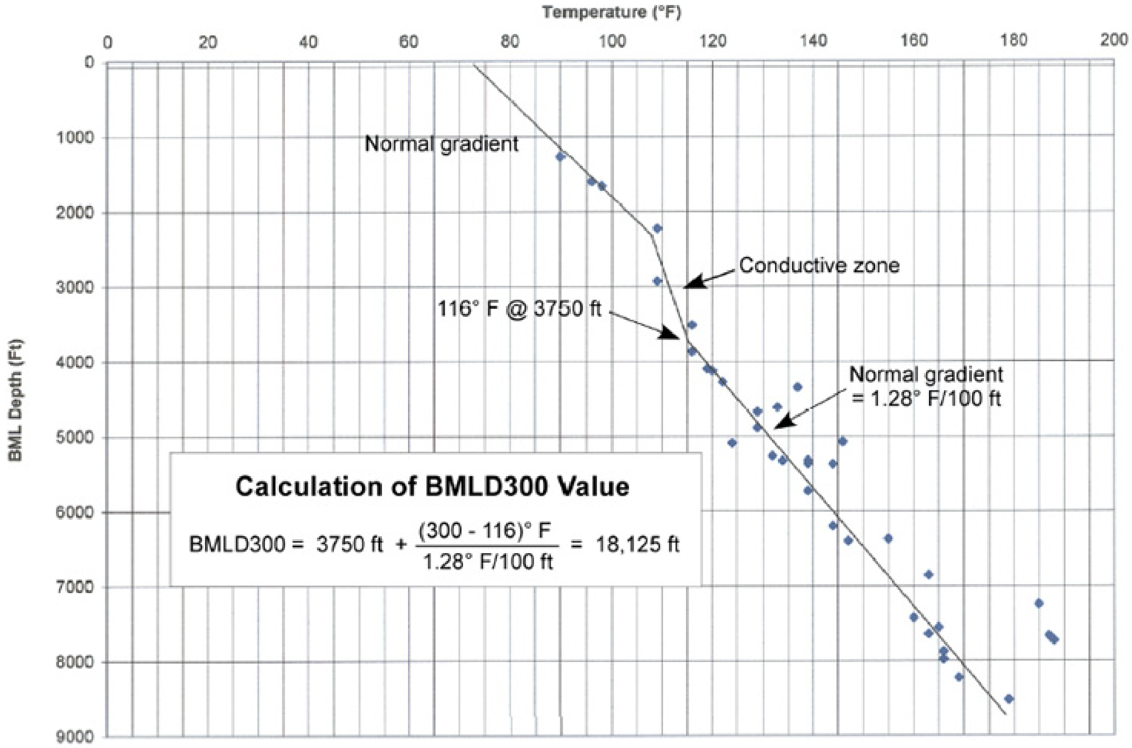


Figure 7. Average temperature-depth plot of sands in the Eugene Island 292 (EI292) field. Data from MMS Atlas of Northern Gulf of Mexico Gas and Oil Sands (2001).

Dogleg Thermal Gradients

A commonly observed phenomenon in the Gulf Coast and Gulf of Mexico is that geothermal gradients have two or more distinct linear segments, indicating that the gradient varies in a step-like fashion with depth. These gradient variations are often coincident, or near-coincident, with the top of overpressure in the stratigraphic section (Jones, 1969, Leftwich, 1993) or with a change in average thermal conductivity of the section (Blackwell and Steele, 1989). Hunt (1996) has referred to these zones of variable gradient as “dogleg geothermal gradients.”

In this study multi-linear, or dogleg, geothermal gradients have been observed throughout the northern Gulf, but not in all fields and wells. In many fields the gradient trend shows no obvious change in rate (Figure 5). This may reflect the true gradient situation in the field, or the data may not extend deep enough to intersect an insulating or conducting zone (Lewis and Rose, 1970), such as an overpressure zone or zone of thermal conductivity change. The apparent non-occurrence of insulating zones in many plots may reflect as well the fact that geothermal gradients calculated in fields by the MMS are almost exclusively derived from sand reservoirs. The plots contain little or no temperature data from shales, which form the great bulk of the Gulf of Mexico’s stratigraphic section and are commonly the insulating zones.

Multiple doglegs are interpreted to occur in many fields in the study (Figures 6 and 7). Though it was out of the scope of the present work, we feel that mapping the distribution of dogleg thermal gradient zones could be useful in determining regional patterns of overpressure and thermal conductivity change.

Subsurface Temperature Distribution in the Northern Gulf

Mapping BMLD300 Values

To map the BMLD300 values we used the field outlines published by the MMS in the 2001 Atlas study. A latitude-longitude centroid was calculated for each field and this was the point used to map the BMLD300 value in the field. Values for wells were plotted at the bottom-hole locations. Contouring was carried out initially with the automated contouring package Surfer 8.0 (trademark of Golden Software, Inc., 809 14th Street, Golden, CO 80401), using the Kriging method with a very dense gridding interval. Most of the fields in the Gulf of Mexico produce from multiple sands, and in many cases not all the sands in a field are stacked vertically; some sands may be located in a position displaced from the main body of the field. Every sand in a field was, therefore, assigned a centroid and the same BMLD300 value, so that displaced sands would be mapped within the contour value of the field. The results were good, but since each field area is represented in the gridding process by a single point, the boundary areas of some fields and sands are partially contained in adjacent contours.

The completed Surfer map was converted to an ESRI (Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373) shapefile and loaded into ArcGIS 9.0 (trademark of ESRI). The contours were converted to closed polygons, and extraneous lines were cleaned up for final map presentation.

Distribution of Subsurface Temperatures in the Gulf

Figure 8 is the completed interpretation of BMLD300 values for the northern Gulf. The most remarkable aspect of temperature distribution is the distinct differentiation between shelf and deep-water areas. The shallowest BMLD300 values, and thus the highest thermal gradients and heat flow, occur on the Texas-Louisiana shelf, which is the area above 300 m (984 feet or approximately 1000 feet) water depth. At these water depths BMLD300 values range from 9700 feet to 45,000 feet, but these extremes are uncommon and restricted in occurrence; by far the most common depth range is 15,000– 19,000 feet.

In the deep-water areas, below 300 m of water, the BMLD300 values range from 11,000 to 45,000+ feet, with most common range being from 21,000 to 37,000 feet. Further differentiations can be made within the deep-water areas between water depth-ranges of 300m-1000m and 1000m-2000m, but these distinctions are very subjective. In the shallower of these two ranges the BMLD300 values range from 11,000 to 45,000 feet, with the most common depths being 21,000 to 31,000 feet. Between 1000m and 2000m the BMLD300 values are 13,000 to 45,000+, with the most common values being from 21,000 to 37,000 feet.

The average geothermal gradient, and therefore subsurface temperature, tends to be lower in the deep-water areas than on the shelf. This point is illustrated in Figure 9, which shows the range of BMLD300 values and the midpoint depth of the most prevalent range of BMLD300 for each protraction area in the northern Gulf (see Table 1 for summary).

Though we feel that the general trend of cooler temperatures in deep-water areas is real, it should be noted that temperature patterns throughout the northern Gulf show a great range of variability. There are areas on the shelf that are nearly as cool as those in the deep- water, and areas in deep-water as warm as those on the shelf.

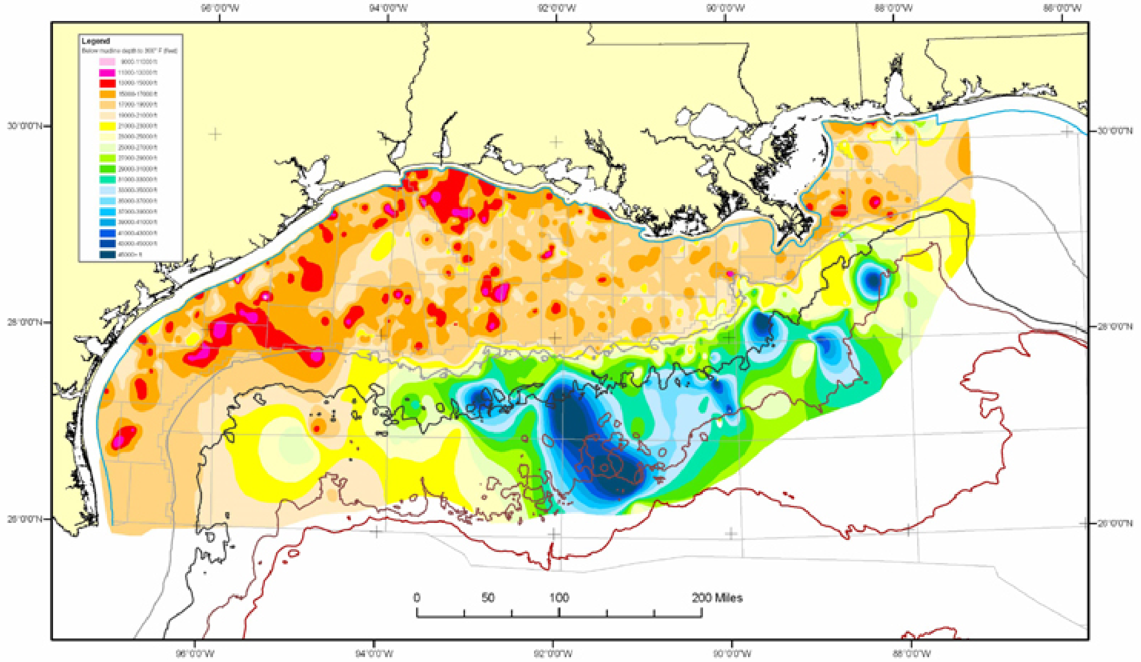


Figure 8. Map of interpreted below-mudline depths to 300°F (BMLD300). areas in the Gulf of Mexico. See Table 1 for summary of data and key to protraction area abbreviations.

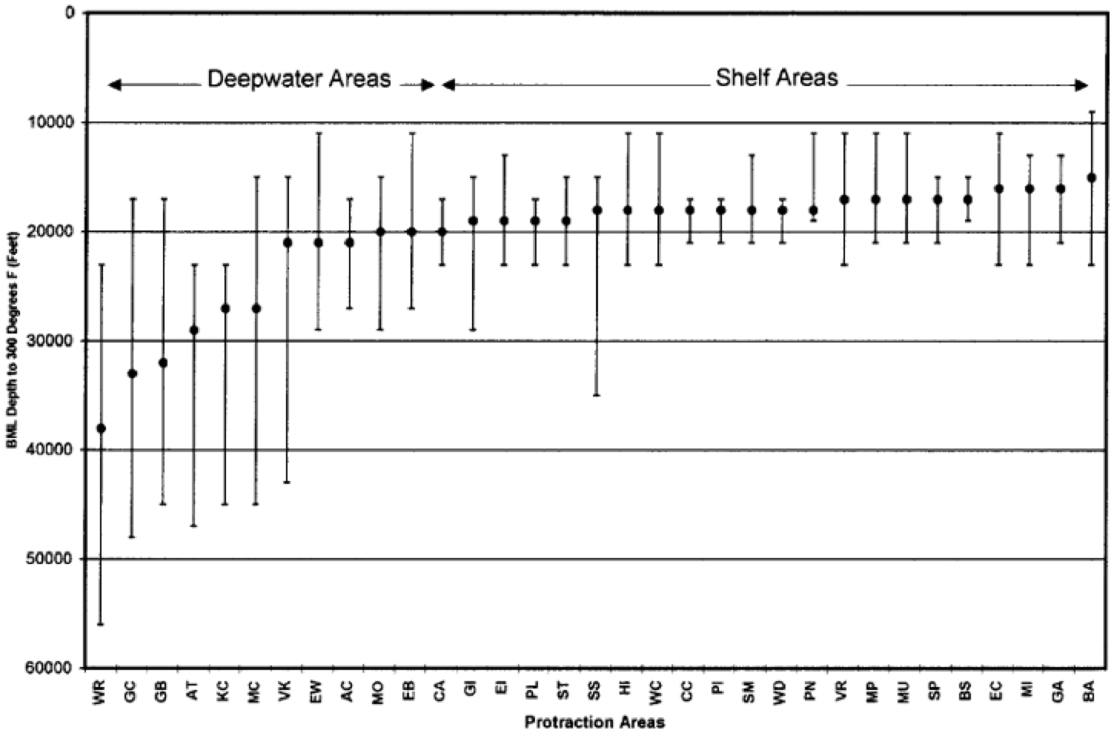
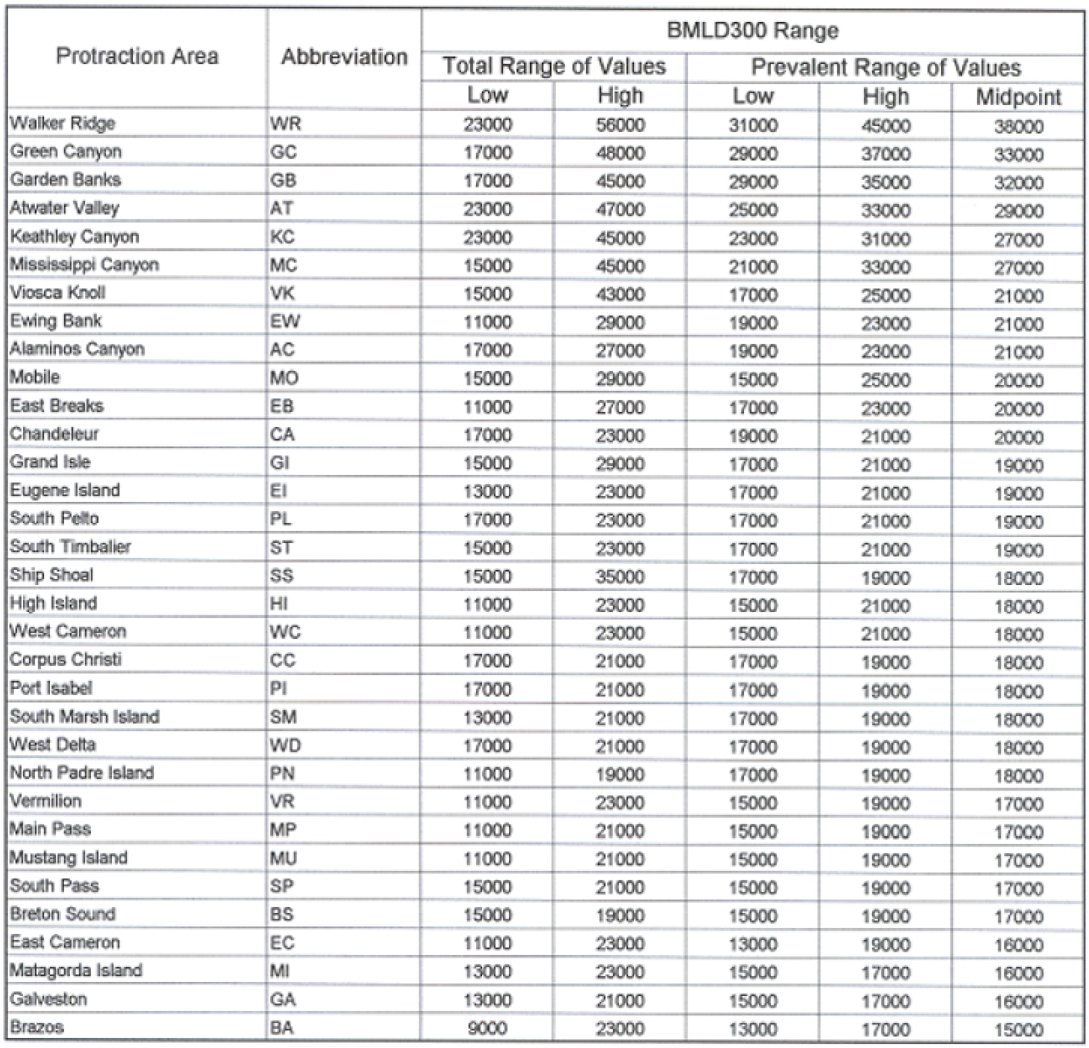


Figure 9. Range of BMLD300 values and midpoints of the most prevalent range for protraction areas in the Gulf of Mexico. See Table 1 for summary of data and key to protraction area abbreviations.



Protraction Area	Abbreviation	BMLD300 Range				
		Total Range of Values		Prevalent Range of Values		
		Low	High	Low	High	Midpoint
Walker Ridge	WR	23000	56000	31000	45000	38000
Green Canyon	GC	17000	48000	29000	37000	33000
Garden Banks	GB	17000	45000	29000	35000	32000
Atwater Valley	AT	23000	47000	25000	33000	29000
Keathley Canyon	KC	23000	45000	23000	31000	27000
Mississippi Canyon	MC	15000	45000	21000	33000	27000
Viosca Knoll	VK	15000	43000	17000	25000	21000
Ewing Bank	EW	11000	29000	19000	23000	21000
Alaminos Canyon	AC	17000	27000	19000	23000	21000
Mobile	MO	15000	29000	15000	25000	20000
East Breaks	EB	11000	27000	17000	23000	20000
Chandeleur	CA	17000	23000	19000	21000	20000
Grand Isle	GI	15000	29000	17000	21000	19000
Eugene Island	EI	13000	23000	17000	21000	19000
South Pelto	PL	17000	23000	17000	21000	19000
South Timbalier	ST	15000	23000	17000	21000	19000
Ship Shoal	SS	15000	35000	17000	19000	18000
High Island	HI	11000	23000	15000	21000	18000
West Cameron	WC	11000	23000	15000	21000	18000
Corpus Christi	CC	17000	21000	17000	19000	18000
Port Isabel	PI	17000	21000	17000	19000	18000
South Marsh Island	SM	13000	21000	17000	19000	18000
West Delta	WD	17000	21000	17000	19000	18000
North Padre Island	PN	11000	19000	17000	19000	18000
Vermilion	VR	11000	23000	15000	19000	17000
Main Pass	MP	11000	21000	15000	19000	17000
Mustang Island	MU	11000	21000	15000	19000	17000
South Pass	SP	15000	21000	15000	19000	17000
Breton Sound	BS	15000	19000	15000	19000	17000
East Cameron	EC	11000	23000	13000	19000	16000
Matagorda Island	MI	13000	23000	15000	17000	16000
Galveston	GA	13000	21000	15000	17000	16000
Brazos	BA	9000	23000	13000	17000	15000

Table 1. Summary of BMLD300 ranges by protraction areas.

Temperature Domains

Even a casual glance at Figure 8 suggests that the area of the study can be divided readily into distinct areas of temperature distribution. We have interpreted six "temperature domains," which we define as regional geographic areas that share noticeable similarities in their temperature distribution patterns, which can be related to geological factors in the area (Figure 10).

The Texas Shelf Domain

This area, which includes the Texas shelf and a portion of the western shelf of Louisiana, has the highest temperature gradients and broadest pattern of shallow BMLD300 values in the northern Gulf of Mexico. The shallowest BMLD300 value occurs in the Brazos 437 (BA437) field at 9700 feet. The range of BMLD300 values in the domain is 9700 to 25,000 feet, but the dominant depths range from 13,000 to 17,000 feet. Several temperature patterns that can be directly related to geological features occur in the domain. The northeast-trending BMLD300 contour pattern in the domain is consistent with the known geology of the Texas offshore, which is dominated by northeast-trending fault systems that extend for long distances. The coincidence of the high temperature zone that falls along the Corsair fault trend suggests a causative relationship (Figure 11). Bodner and Sharp (1988) found similar temperature highs concentrated along the trends of the Wilcox and Vicksburg fault systems, which parallel the Corsair and are located to the west of it onshore south Texas. Perpendicular to the Corsair thermal high is a northwest-trending high-temperature zone (shown by the 13,000-15,000-foot BMLD300 contour) that extends from the Brazos area across Brazos South, Galveston South and into East Breaks. This feature parallels the trend of the San Marcos arch, a basement nose that plunges southeast from the Llano uplift.

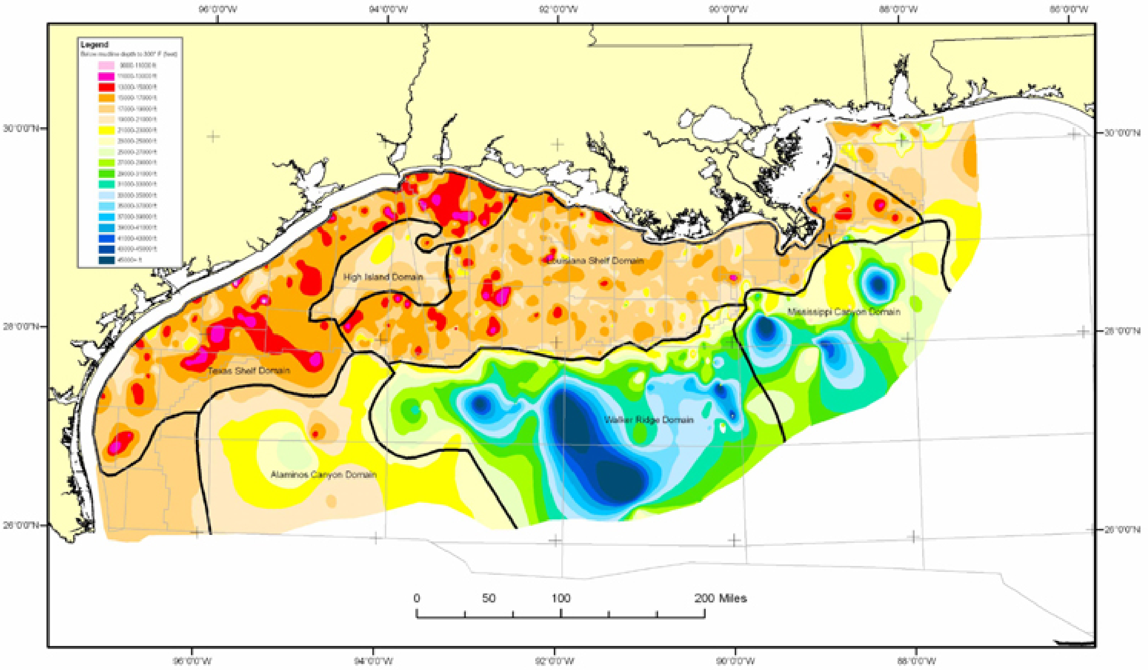


Figure 10. Interpreted temperature domains in the northern Gulf of Mexico.

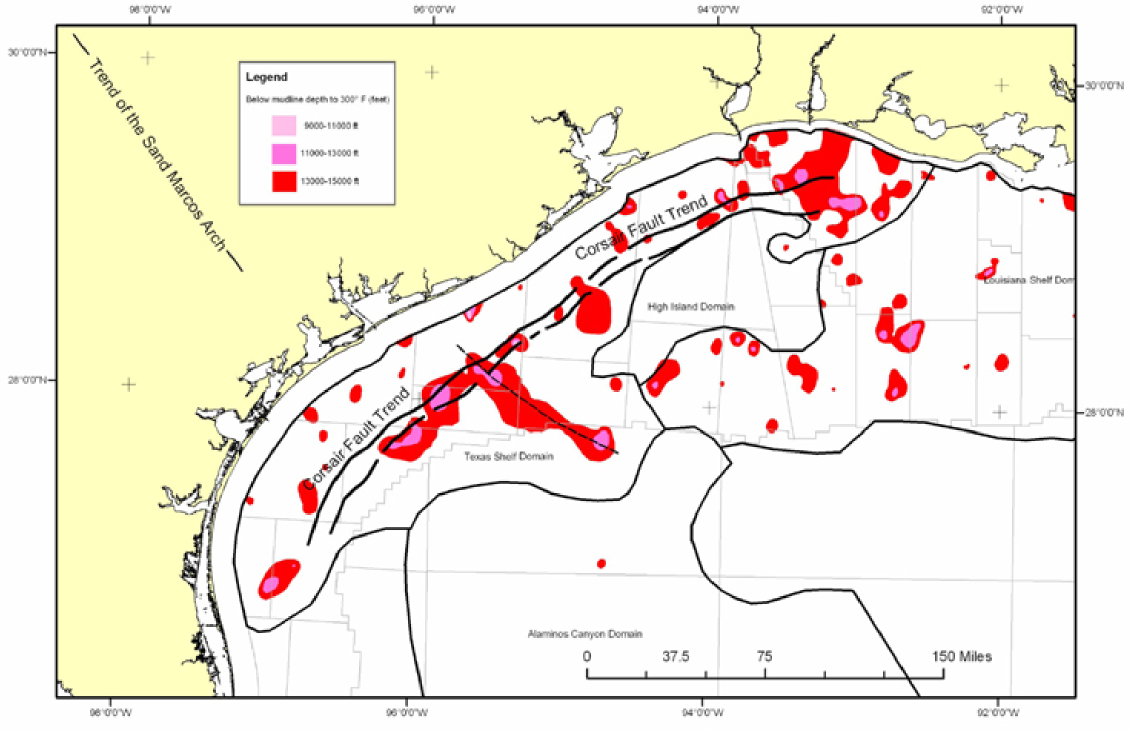


Figure 11. Texas shelf domain showing coincidence of the NE-trending high temperature zone with the Corsair trend and alignment of the NW-trending high temperature zone with the San Marcos Arch. Corsair trend and San Marcos arch from Ewing and Flores (1991).

High Island Domain

Within the Texas shelf domain is another anomalous area centered approximately in the High Island region. This area is bounded to the northwest by the Corsair fault trend and is the site of a late Miocene depocenter, as outlined by Winker (1982). BMLD300 values in the domain range from 17,000 to 23,000 feet, classifying it as anomalously cool in relationship to the surrounding Texas shelf domain. We speculate that a deep overpressure zone or a shallow conductive zone may underlie the High Island domain. Reference to Figure 1 shows that the High Island domain is also an area of remarkably low-drilling density.

Louisiana Shelf Domain

This area is characterized by BMLD300 values that range from 13,000 to 33,000 feet, with a most common range of 15,000 to 19,000 feet. In addition to being generally cooler than the Texas shelf domain the pattern of temperature distribution is dominated by numerous small "bulls-eye" contour anomalies, which contrast with the elongate pattern of contours on the Texas shelf. This pattern is most likely a reflection of salt dome tectonics that have produced the short, arcuate fault system pattern that characterizes the Louisiana shelf. High temperature anomalies are often associated with salt domes (Gretener, 1981). We have compared the pattern of BMLD300 anomalies to the pattern of known salt domes on the Louisiana shelf and find good general agreement, though not absolute coincidence. In an investigation of geothermal patterns around salt domes in south Louisiana, Kumar (1989) found that there is a general rise in temperatures in the vicinity of domes but that isotherms do not always conform to them.

Mississippi Canyon Domain

This deep-water area coincides with the Mississippi fan, a large complex that extends south from the edge of the Louisiana shelf to abyssal depths and consists of a thick section of Quaternary submarine deposits. BMLD300 values in the domain range from 23,000 to 43,000 feet, with the most common depths ranging from 27,000 to 37,000 feet. Mello and Karner (1996), Jones and Nagihara (2003), and Jones et al. (2003) have suggested that the rapid deposition of a thick section of young sediments in the fan has suppressed regional isotherms, resulting in anomalously low surface heat flow.

Walker Ridge domain

This deep-water domain coincides with the Texas-Louisiana slope and is characterized by salt diapirism, lateral emplacement of salt tongues and sheets, and from mass downslope transport of surface sediments. Worrall and Snelson (1989) have interpreted the Texas-Louisiana slope as a large overthrust complex in which salt forms the basal thrust surface and in which salt is tectonically thickened relative to the shelf areas. BMLD300 values range from 25,000 to 56,000 feet, with the most common values in the range of 29,000 to 43,000 feet. It is tempting to relate the deep BMLD300 values in some way to the dominance of salt-related phenomena in the domain, but Jones et al. (2003) have concluded that lateral salt tongues, such as those that characterize the Texas-Louisiana Slope, do not affect heat flow. There is no evidence in the domain of the rapid thick sedimentation that has formed the Mississippi fan to the east. The low geothermal gradients in the area are indeed anomalous, and we cannot relate them at the present time to any known geological features. It should be noted however that data control in the area is sparse and that interpretation of thermal conditions in the area will no doubt become clearer with additional data points.

The Alaminos Canyon Domain

This deep-water area displays BMLD300 values that are intermediate between those of the Texas Shelf and Walker Ridge domains. The values range from 13,000 to 27,000 feet, with predominant values from 21,000 to 25,000 feet. The area of the Alaminos Canyon domain falls within two geological provinces described by Ewing (1991), the Northwest slope diapir province and the Perdido diapir province. The Northwest slope province has less salt-tectonic activity and a thinner stratigraphic section compared to the adjacent Texas Louisiana Slope. Though the Perdido province displays considerable salt tectonic activity, the salt is fairly continuous compared to the Texas-Lousiana slope to the east and the stratigraphic section is thinner, not displaying the massive, rapid sedimentation seen to the east. Like the Walker Ridge domain, the Alaminos Canyon area suffers from sparse data, and its interpretation will most likely change with additional control.

Conclusions

Equilibrium bottom-hole temperature data in the northern Gulf of Mexico is difficult to obtain, but the use of the large set of field-based sand data from the MMS supplemented by wells gives a valid regional picture of thermal trends in the basin. The interpreted pattern of BMLD300 (below-mudline depth to 300^{o}F) values derived from geothermal gradients allows us to divide the northern Gulf into six temperature domains. Three domains on the shallow-water shelf areas have generally higher geothermal gradients and shallower BMLD300 values than those in the three deep-water domains. The shallowest BMLD300 values (and thus highest heat flow values) occur in the Texas shelf domain and appear to be related to the northeast-trending Corsair fault and possibly the extension of the San Marcos arch. The deepest BMLD300 values (and therefore the lowest heat flow values) occur in the Walker Ridge and Mississippi fan domains. The Mississippi fan pattern can be explained by rapid, thick sedimentation that has suppressed regional isotherms resulting in low surface heat flow. The pattern in the Walker Ridge area is more anomalous and cannot be related at the present time to known geological features. Data control in the deep-water areas is sparse, and the interpreted temperature trends there are subject to significant future revision as additional control becomes available.

Despite its data weaknesses the BMLD300 map gives a good preliminary overview of thermal conditions in the northern Gulf and can be used readily by drilling engineers and basin modelers as an indication of present-day subsurface temperature distribution.

Acknowledgements

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