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RESERVOIR STUDY OF SOUTHEAST PECAN ISLAND GEOPRESSURED WATER SANDS

by Zaki A. Bassiouni and William J. Bernard,
Members SPE-AIME, Louisiana State University, and
James H. Welsh, Louisiana Office of Conservation

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ABSTRACT

The detailed technical evaluation of the Southeast Pecan Island geopressure aquifer prospect is described. The quantitative evaluation was based on detailed geology consisting of structural, isophachous, and cross-sectional maps of the geopressured zone. Pressure, water salinity, porosity, and permeability data were obtained from well logs.

The gathered information was used to choose a location for a proposed exploratory well.

The evaluation of this prospect can serve as a guide for future analysis of other geopressured prospects.

INTRODUCTION

Sixty-three potential areas of interest for the geopressure energy resource were found in a preliminary geologic study of southern Louisiana.[1] The geographic area of the study included all southern Louisiana (south of Baton Rouge) including the State-owned offshore area.

At present, the sixty-three potential areas of interest are being ranked, and the most promising prospects are being mapped and studied in much greater detail. A preliminary ranking indicates that the better prospects tend to lie in the western half of the study area. The prospects in the eastern half of the study area were down-graded primarily because of poorer sand development, but it is entirely possible that several of these prospects will be attractive upon closer inspection.

Detailed geologic studies have been started on five prospects. A suitable site for a geopressured test well will be selected within each of these prospects. It is hoped that a test well will be started at one of these sites before the end of the year.

At present, the Southeast Pecan Island area appears to be a promising prospect. This area is identified on Figure 1 together with the other four prospects.

The Southeast Pecan Island Prospect is located in the extreme southern portion of Vermilion Parish, Louisiana, being approximately 25 miles south-southwest of Abbeville, and approximately 6 miles southeast of Pecan Island, Figure 2. The prospect is surrounded by the Pecan Island Field to the northwest, Vermilion Block 16 Field to the southwest, and Fresh Water Bayou Field to the north. It is separated from these fields by large regional faults.

The primary source of data used in the detailed evaluation of the prospect was electric well logs obtained from the files of the Louisiana Office of Conservation. Logs from forty-six wells drilled in the area were available. Core data, water analyses and production test results were available from a limited number of these wells.

The evaluation techniques used are basically those used by the oil and gas industry. However, because of the nature of the problem and the limited data available, the evaluation methodology is noteworthy. Also, this methodology can serve as a guide for future analysis of other geopressured prospects. The following aquifer properties are important and have been evaluated: (1) Areal extent, (2) depth, (3) thickness, (4) temperature, (5) pressure, (6) porosity, (7) salinity, (8) permeability, and (9) dissolved natural gas content.

GENERAL GEOLOGY

Geopressured zones in Louisiana are known to occur in Tertiary sediments in the southern part of the State. This Middle and Lower Miocene trend ranges in width from 50 to 70 miles northward of the Louisiana coastline. The coastal area is underlain by a sedimentary section which ranges

References and illustrations at end of paper.

from 40,000 to 60,000 feet in thickness and contains approximately 150,000 cubic miles of sediments. These trends are in and are part of the Gulf Coast geosycline.

The porous and permeable geopressured sands of the Lower Miocene (Frio) are the sands present in the prospect. For the S.E. Pecan Island prospect the Frio has been divided into three stratigraphic intervals: the uppermost Interval "A"; the middle Interval "B"; and the lowermost Interval "C." Structure maps and total sand isopach maps have been prepared on each interval. The limiting geologic features of the prospect are Fault "A" to the north and Fault "B" to the south, Figure 3. These faults are typical east-west striking, down to the south, normal growth faults. Several minor faults were mapped within the prospect, however, it is hoped that these minor faults are nonsealing.

Well control data indicate the lenticular geopressured sands of the uppermost interval "A" range from 0' to 275' thick. The thickest development occurs in the area just south of Fault A. There is no sand development in the eastern portion of the prospect. Calculations indicate that Interval "A" contains 164 billion cubic feet of geopressured sand. The middle interval "B" ranges from 125' to 825' thick. Thickest development occurs over a large area in the center of the prospect. Interval "B" contains 828 billion cubic feet of geopressured sand. The lower interval ranges in thickness from 70' to 670', with the thickest sand development in the western portion of the prospect. Interval "C" contains 330 billion cubic feet of geopressured sand.

A composite net sand isopach map for the three stratigraphic intervals A, B, and C is shown on Figure 4. The prospect covers an area of 67 square miles. The top of the geopressured interval lies between 13,400 and 14,500 feet below sea level. The prospect has a maximum net sand thickness of 1495 feet, average sand thickness of 700 feet, and total sand volume of 1322 billion cubic feet.

AQUIFER TEMPERATURE

The temperature is essential to the estimation of some of the aquifer parameters. It is also a measure of the geothermal energy potential of the aquifer. Bottom hole temperatures are usually recorded during well logging, and several logging runs and temperatures are usually available in one well. It is a common practice to assume linear temperature gradient with depth, however, it is important to recognize that this assumption may not be accurate in many cases, especially in deep wells drilled through the geopressured interval. It has been observed that the bottom hole temperatures measured during these runs at different depths seem to best fit an exponential function such that a straight line results from a plot of the logarithm of temperature versus depth.

Figure 5 illustrates the plot made for Humble Fee #31 (Well #10 on the base map) where seven temperature measurements are available. Figure 6 represents the temperature data collected from all the wells. For the S.E. Pecan Island area the temperature distribution is of the form:

$$T = 79\ e^{7.7 \times 10^{-5}\ D}$$

where T is the temperature in degree fahrenheit and D is the depth in feet. Figure 6 indicates a temperature of 368°F at 20,000 feet. This is equivalent to a gradient of 1.46°F/100 ft.

AQUIFER PRESSURE

The wells lying within the prospect limits were drilled using heavy mud weights of 17.2 to 18.1 ppg (equivalent to gradients of 0.89 to 0.94 psi/foot). Very few pressure measurements are available in the geopressured interval. The only pressure data available indicate a pressure gradient of 0.88 psi/ft in the 17400-17900 ft interval of Humble Fee #26 (Well #11 on the base map).

Abnormal formation pressures can be detected and evaluated using electric logs.[2] The resistivity recorded in shale formations is plotted versus depth and a trend line is then established for normal compaction as shown on Figure 7 and 8 prepared for Humble Fee #26 and Humble Fee #31.

The equation of the normal trend observed in this geologic region is of the form

$$R_{sh} = a\ e^{bD}$$

where R_{sh} is the shale resistivity (ohm-m) and D is the depth (feet). The normal trend in the two wells displayed the same slope (b = 0.00007), but different values of "a" were observed. The "a" values are 0.401 and 0.476 in Humble Fee #26 and Humble Fee #31 respectively.

Interpretation of geopressure from such a plot depends on the departure from the normal trend. The divergence of observed shale resistivity value, $(R_{sh})_o$, from the extrapolated normal trend line value, $(R_{sh})_n$ determines the shale resistivity ratio $(R_{sh})_o/(R_{sh})_n$. From Figure 9 the fluid pressure gradient (FPG) corresponding to the shale resistivity ratio is found. Figure 9 was plotted using data collected by Hottman and Johnson[2] in overpressured Miocene and Oligocene formations of these data is forced through FPG = 0.465 at $(R_{sh})_o/(R_{sh})_n = 1.0$. This type of forced fit was first proposed by Lane and Macpherson.[3] It should be noted that when sufficient pressure data is available in an area of interest, a specific shale resistivity ratio-formation pressure gradient correlation should be established.

The observed shale resistivity in the interval 17400-17900 feet of Humble Fee #26 ranges between 0.5 and 0.6 ohm-m. The corresponding shale resistivity ratio is between 0.41 and 0.36. Using Figure 9 we obtain a formation pressure gradient ranging between 0.81 and 0.84 psi/ft. These values are in close agreement with measured pressure gradients of 0.88 psi/ft. A pressure gradient of

0.84 to 0.88 was obtained over the same interval in well Humble Fee #31.

The same procedure was used in all wells where data is available. The maximum fluid gradient observed varied between 0.74 and 0.87 psi/ft with an average value of 0.81 psi/ft.

AQUIFER SALINITY

Water salinities were calculated using conventional well logging interpretation techniques. The water resistivity was first calculated from the SP log. The salinity was then obtained using the following correlation:[4]

$$ppm(NaCl) = 10^x$$

with

$$x = \frac{3.562 - \log(Rw_{75} - 0.0123)}{0.955}$$

where Rw_{75} is the water resistivity at 75°F.

The salinities calculated for the prospect covered a wide range (35,352-109,765 ppm) with an average value of 70,000 ppm. Actual water sample analyses exhibited a similar range. These analyses were obtained from the US Geological Survey computer data bank.

AQUIFER POROSITY

The side wall samples obtained in the geopressured intervals of Humble Fee #23, Humble Fee #26 and Simmons C-1 (wells 9, 11 and 14 on the base map), displayed porosities in the range 13.2-30.5%.

The porosities derived from available logs using conventional well logging interpretation techniques vary between 17.8 and 27.4%. Combined sidewall cores and log derived data indicated an average porosity close to 23%.

AQUIFER PERMEABILITY

A recent master's thesis at Louisiana State University investigated the possibility of deriving aquifer permeabilities from electric logs.[5] A correlation has been found to exist between the formation resistivity factor (F) and permeability (K). Figure 10 illustrates the F-K correlation for the S.E. Pecan Island prospect. The correlation is expressed as:

$$F = 41\ K^{-0.25}$$

Figure 10 was prepared using core analyses reported in the geopressured intervals of Humble Fee #23, Humble Fee #26 and Simmons C-1.

The permeability of the geopressured sands derived from this method are in the range of 7 to 278 millidarcies with an average of 98 md.

DISSOLVED NATURAL GAS CONTENT

Based on the total bulk volume of geopressured sands estimated at 1322 billion cubic feet and an average porosity of 23%, the total volume of water in place is 54 billion barrels.

Assuming that the water is saturated with methane an average gas solubility of 42 SCF/Bbl was estimated, based on the correlation of Culberson and McKetta[6] and the salinity correction of Eichelberger.[7] The estimated gas content was obtained considering the temperature distribution of Figure 6, an average pressure gradient of 0.81 psi/ft, an average salinity of 70,000 ppm and an average depth of 16,000 feet.

If the water is saturated with gas as assumed, 2268 billion SCF of gas is in solution in the water saturating the geopressured sands of the Southeast Pecan Island Prospect.

TEST WELL SITE

The sand deposition is such that there are no "blanket" sands, but rather the sands seem to come and go. It is difficult to correlate a given sand member over a large distance as shown on Figures 11 and 12. The isopach map of Figure 4 is an isopach of total sand found in each well, but is not intended to portray the idea that all the sands are continuous throughout the prospect. Because of the nature of the sand deposition, the test well site was selected in an area exhibiting a maximum total sand, close to a control point, and far enough from any detected faults.

The tentative test well site lies in the vicinity of the northwestern quarter of section 16 (Township 17S, Range 1E) near Well #12 (Exxon-Vermilion Parish School Board #1). The well would likely be drilled through all three stratigraphic intervals to a total depth of 17,700 ft. The top of the geopressured interval should be reached at 13,700 feet. The total net pay expected is about 1400 feet with 600 feet being in the deepest stratigraphic interval "C."

Calculations show that if a well can effectively drain a five-square-mile area from 600 feet of pay, a flow rate of 40,000 barrels per day can be maintained for at least 10 years. This is based on semi-steady state flow equations and realistic values for compressibility, porosity, pressure, etc.[8,9] The problem, in the authors' view, is whether or not a well can drain such a large area.

The primary concerns are splinter faults are difficult to detect with limited geological and geophysical control. If present, they could restrict the effective aquifer volumes drained by the well.

One of the questions that will be hopefully answered by a test well will be how much "leakage" will occur across these splinter faults and how much communication exists between the seemingly uncorrelated sand members. The other main objectives of the test well are to determine aquifer parameters (permeability, porosity, temperature, pressure, etc.), water properties (salinity, viscosity, gas in solution, etc.) and production history (flow rates, production decline, pressure decline, etc.).

CONCLUSIONS

The Southeast Pecan Island appears favorable as geopressured prospect from all technical viewpoints--sand volume, pressure, porosity and permeability. A total sand volume of 1322 billion cubic feet, an average pressure gradient of 0.81 psi/ft, an average porosity of 23% and an average permeability of 98 millidarcies were estimated. The northwestern quarter of Section 16 (Township 17S, Range 1E) seems to be a reasonable test site. The test well should encounter the top of the geopressured interval at 13700 feet and reach a total depth of 17,700 feet. A total geopressured sand thickness of 1400 feet is expected.

ACKNOWLEDGEMENTS

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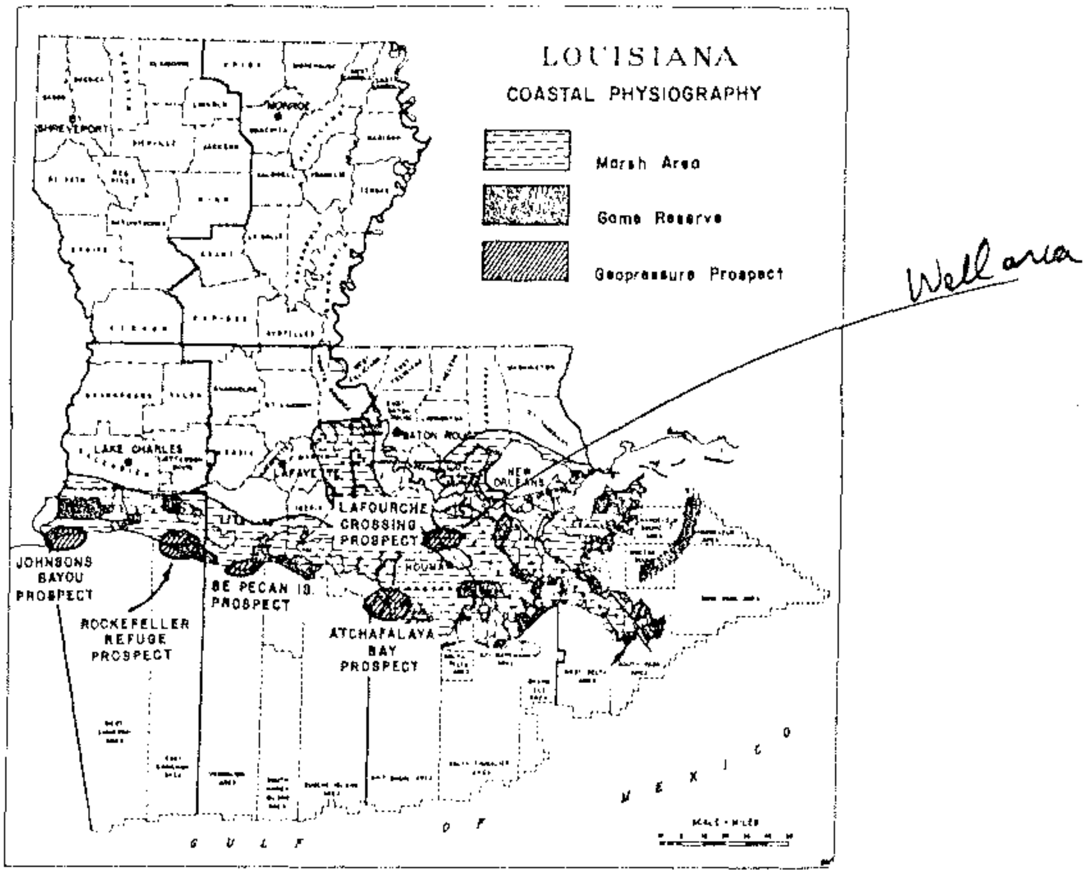

Fig. 1 - Louisiana showing the location of the five geopressure prospects presently under investigation.

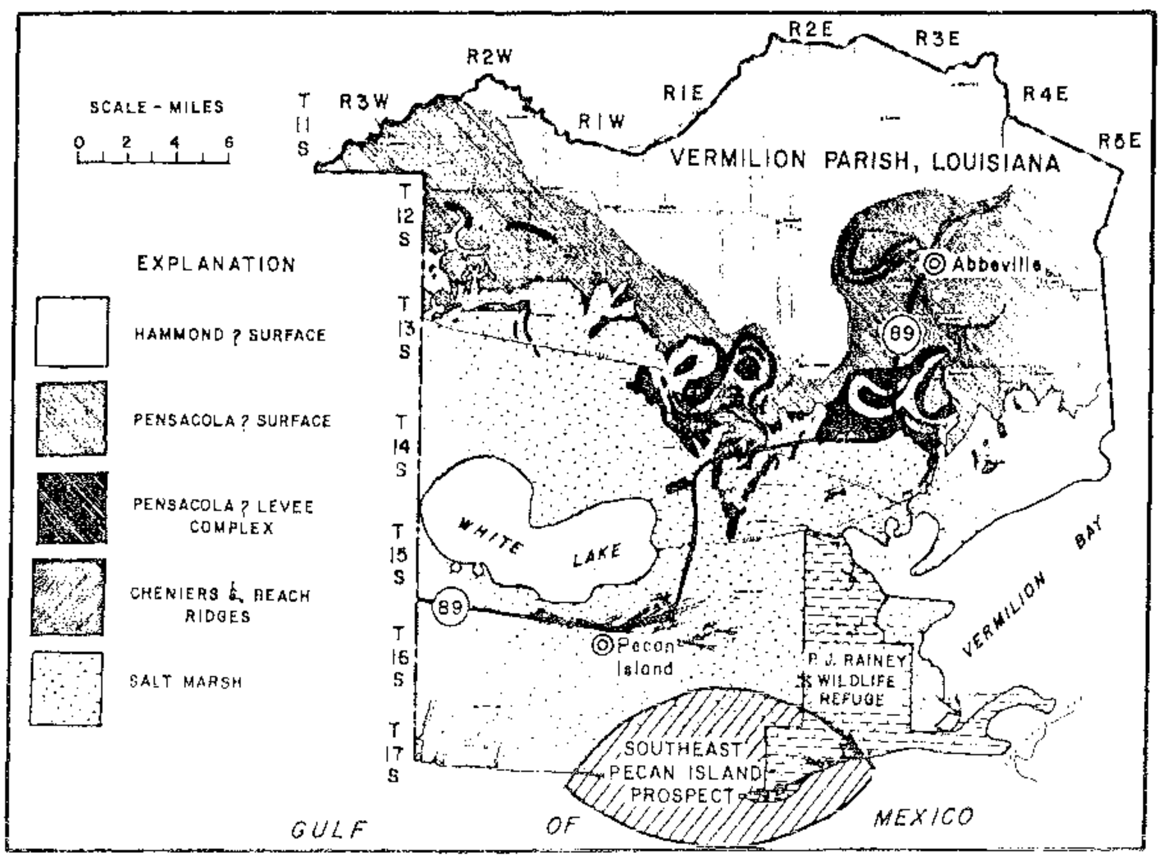

Fig. 2 - Vermilion Parish, Louisiana showing the SE Pecan Island Prospect location.

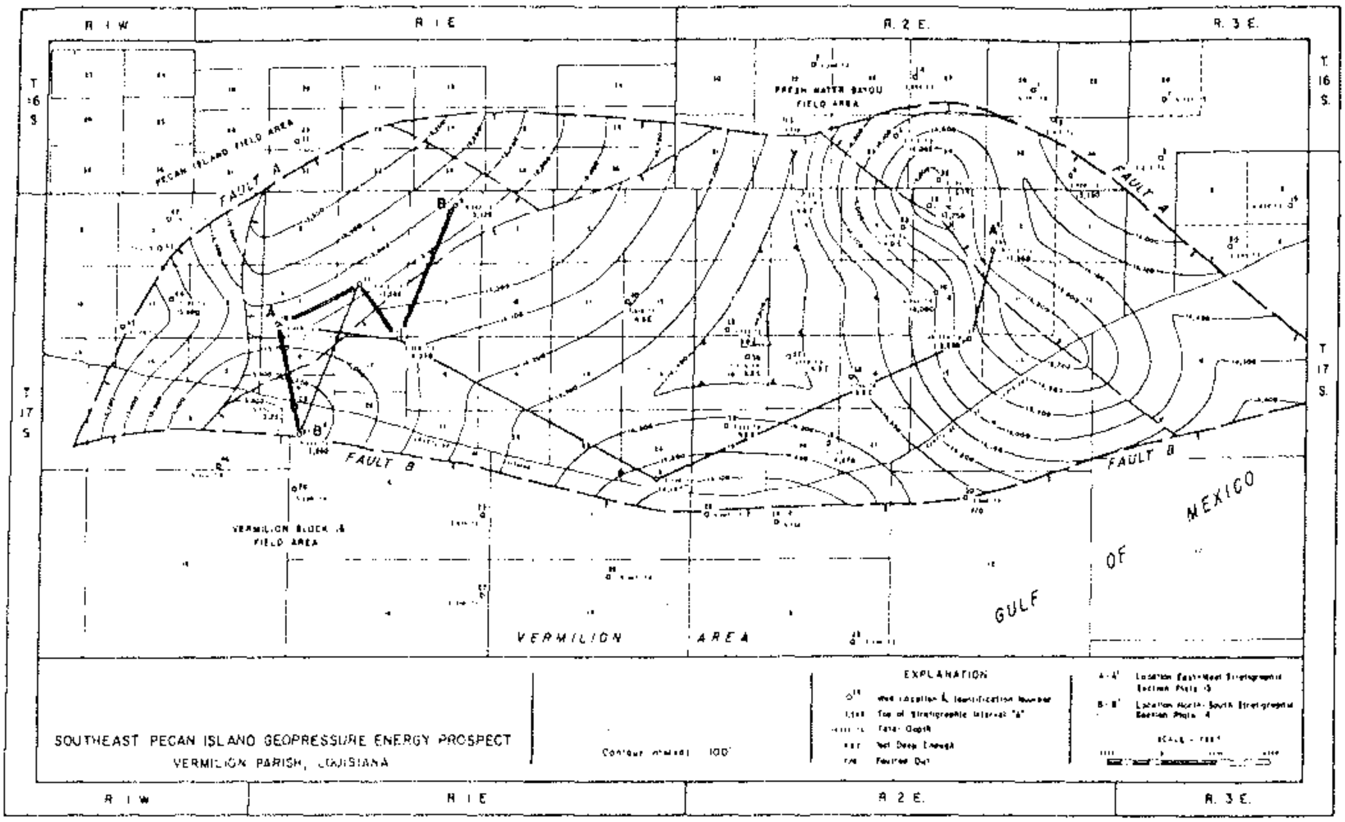

Fig. 3 - Structural map, top of stratigraphic interval "A".

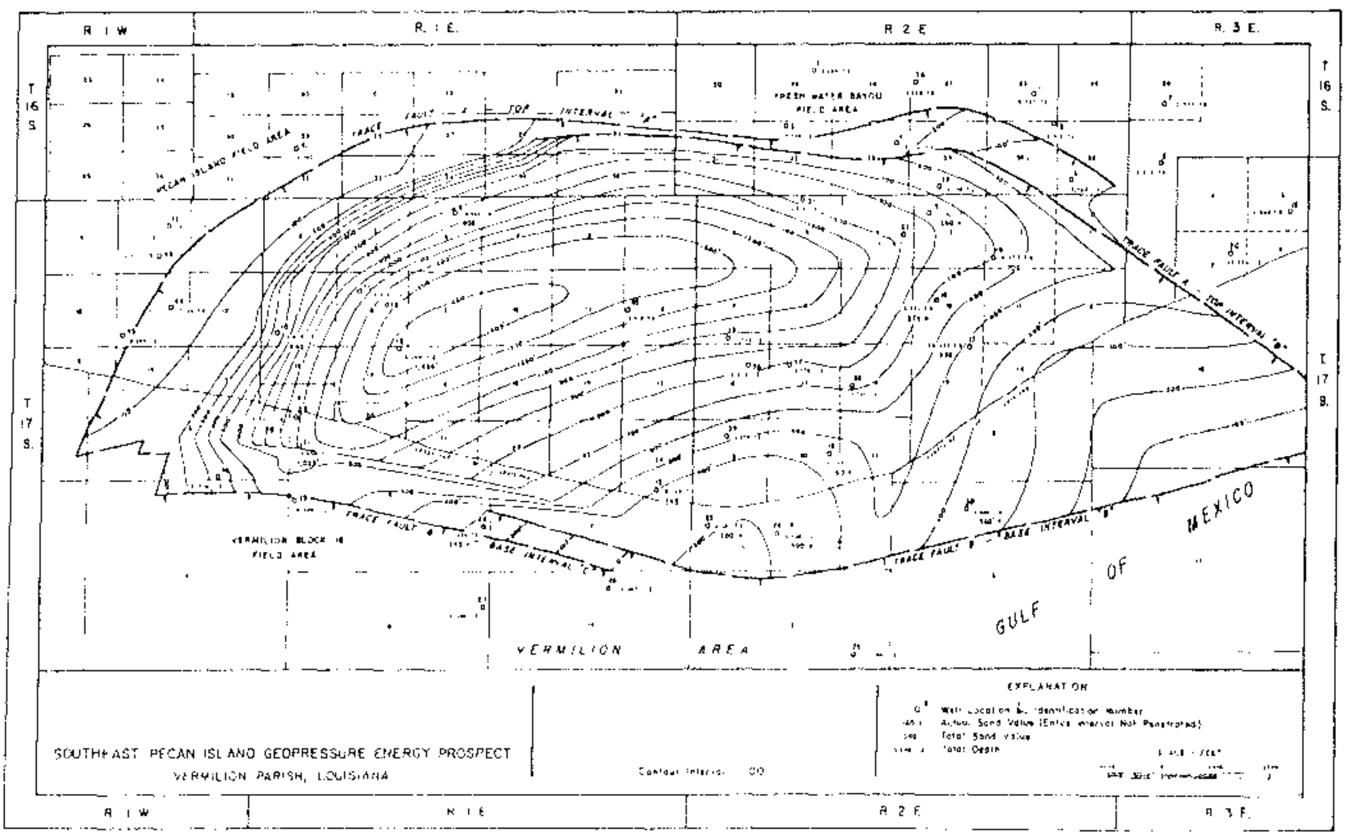

Fig. 4 - Net sand isopach map, total stratigraphic intervals "A," "B" & "C" of the geopressured interval.

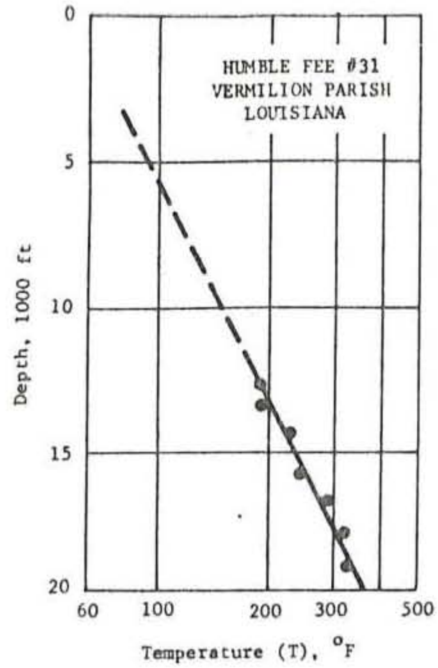

Fig. 5 - Temperature distribution in Humble Fee #31 Vermilion Parish, Louisiana.

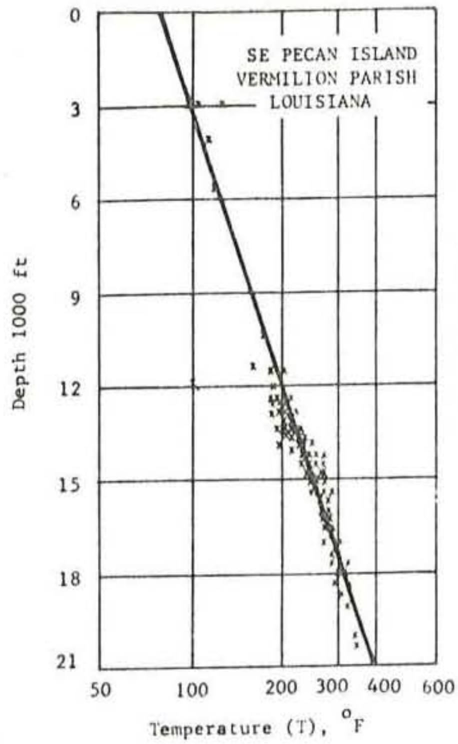

Fig. 6 - Temperature distribution for the SE Pecan Island Prospect.

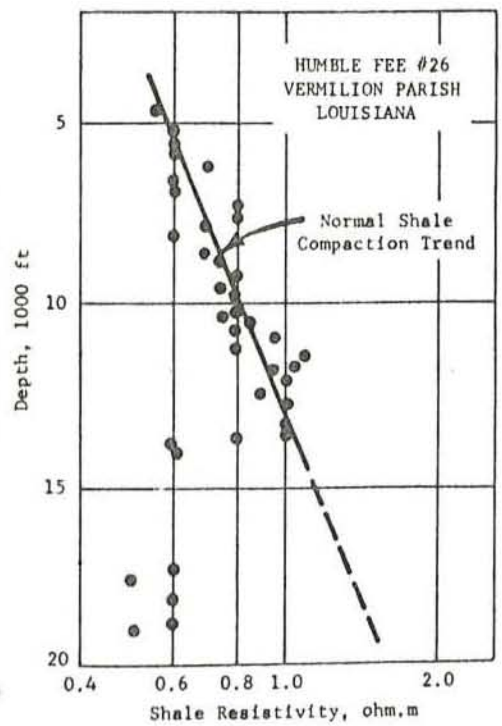

Fig. 7 - Shale resistivity plot for Humble Fee #26.

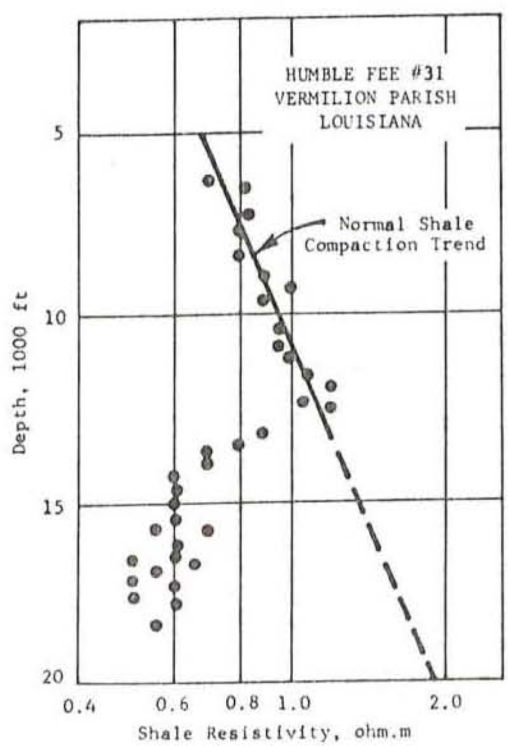

Fig. 8 - Shale resistivity plot for Humble Fee #31.

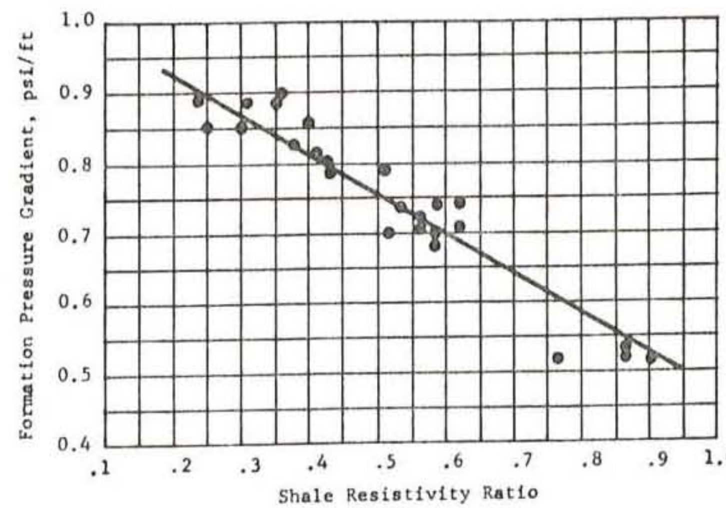

Fig. 9 - Formation pressure gradient-shale resistivity ratios correlation miocene/oligocene formations US Gulf Coast area (after Hottman and Johnson[2]).

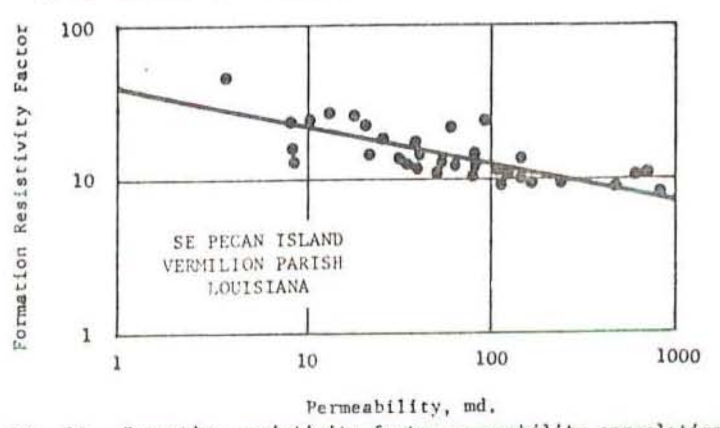

Fig. 10 - Formation resistivity factor-permeability correlation for the SE Pecan Island Prospect.

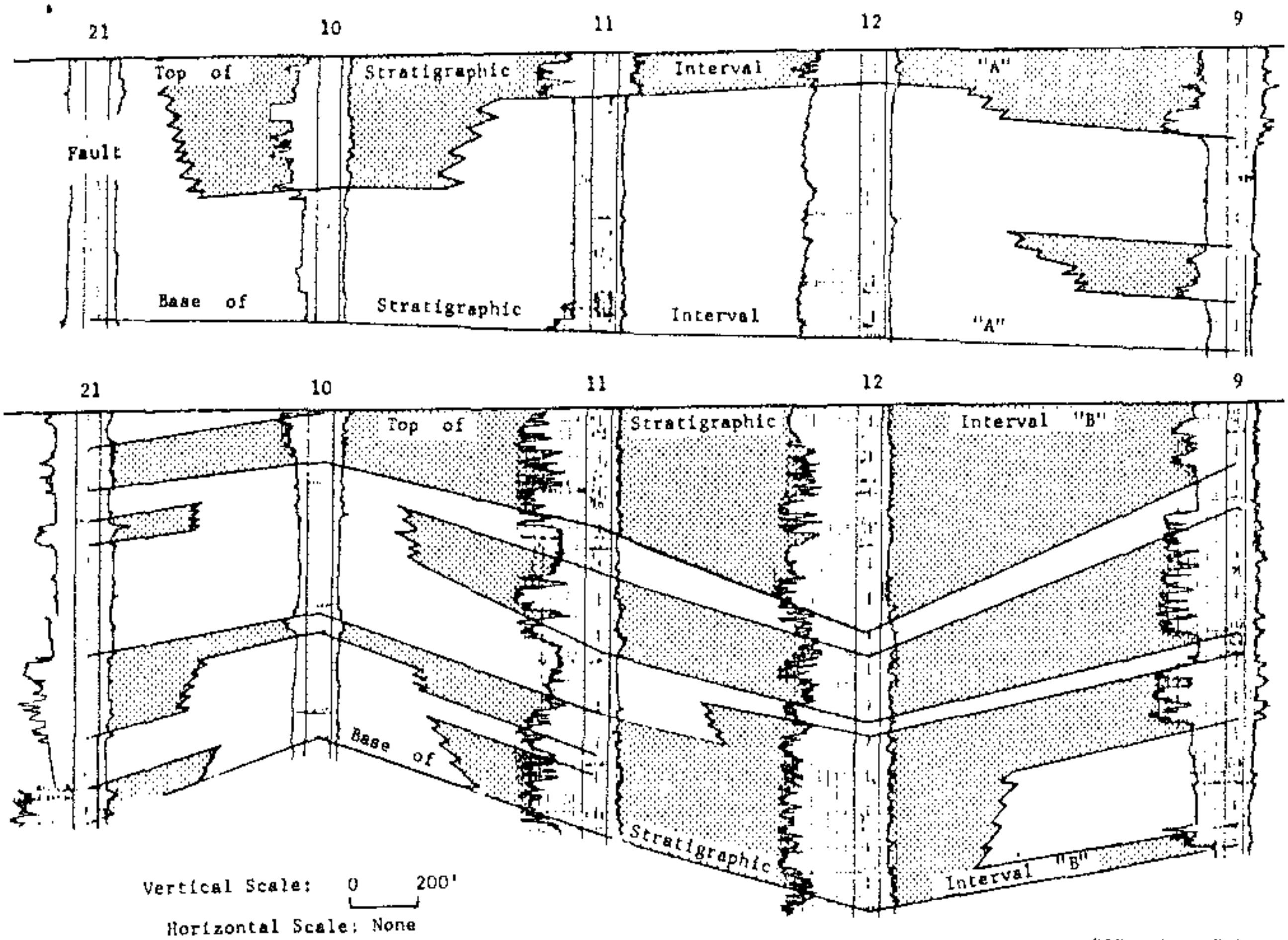

Fig. 11 - SE Pecan Island Prospect Vermilion Parish, Louisiana stratigraphic sections - intervals "A" & "B". "C".

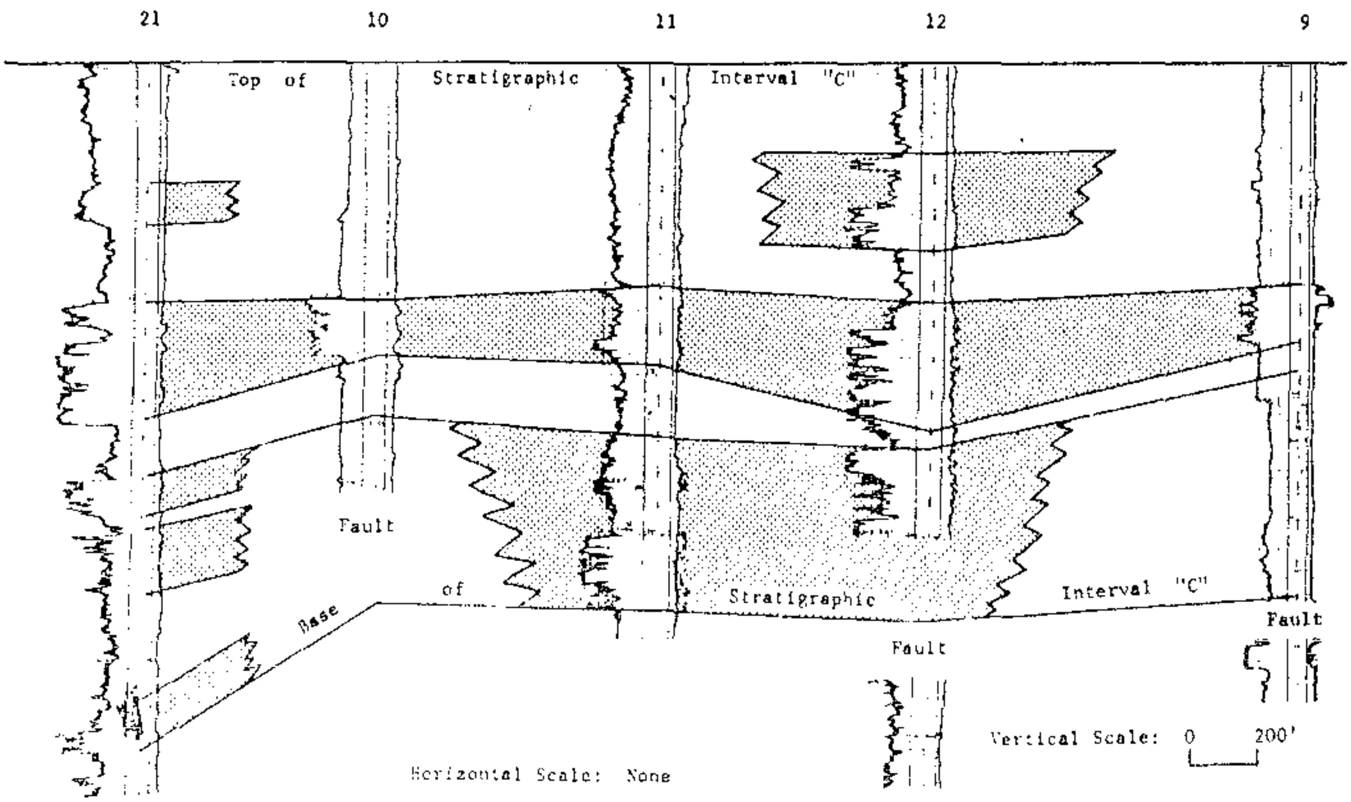

Fig. 12 - SE Pecan Island Prospect Vermilion Parish, Louisiana stratigraphic section - interval