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DEVELOPMENT OF AN ASSESSMENT METHODOLOGY FOR GEOPRESSURED ZONES OF THE UPPER GULF COAST BASED ON A STUDY OF ABNORMALLY PRESSURED GAS FIELDS IN SOUTH TEXAS

Progress Report

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R. K. Swanson, P. Oetking, J. S. Osoba, R. C. Hagens

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

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John R. Barton

John R. Barton, Vice President
Instrumentation Research Division

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ABSTRACT

During the fourth quarterly reporting period of ERDA Contract E(11-1)-2687, project change-in-scope was approved extending the study area to include Brooks, the remainder of Kenedy and Live Oak Counties. This document is an interim progress report covering that reporting period.

Effort during the quarter was directed toward (1) locating drillstem and production test results from geopressed formations, (2) determining formation parameters in an additional large number of producing wells, and (3) searching production records for assessment of geopressed production in Brooks and Kenedy Counties.

Several unsuccessful completion tests of geopressed water sands (attempted as gas completions) have been located and these give insight into the problems of completing high-volume water wells in that zone. A successful fracture treatment in a geopressed gas well indicates a producibility increase equivalent to a two-fold improvement in permeability.

Permeability calculations for a large number of geopressed and normally pressured gas wells throughout the study area have been completed. In no case has a producing Rio Grande Valley gas well deeper than 10,000 ft. been identified with effective permeability as great as 10 md.

Preliminary investigation of Brooks County production has located geopressed production in seven gas fields and in North Kenedy County, an additional three.

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I. INTRODUCTION

This report is the Fourth Quarterly Progress Report of ERDA Contract E(11-1)-2687. The project has received a change-in-scope in which a new research task has been added and the performance time extended to 31 August 1976. The next scheduled report will be the Final Report due on that date.

A. Project Objective

The purpose of this program is to establish a resource assessment-methodology for the deep geopressured zone in South Texas, based on an examination of gas fields which have produced substantial quantities of fluids from these zones. The study has covered a four-county area in South Texas where deep geopressured conditions are known to be general. Originally, it was intended to include only the eastern two-thirds of Hidalgo County, but a preliminary study indicated that the Vicksburg sediments near the Frio-Vicksburg flexure in the western part of the County represented a geothermal potential, perhaps as promising as that in the Frio formation to the east. Consequently, the study has included all of Hidalgo, Cameron and Willacy Counties and the southern half of Kenedy County.

Early in the project the effort of locating wells was greatly enhanced by securing the services of the Geomap Co. of Houston. This company provides continually updated regional maps, and wherever this service is available, it is highly recommended in future assessment tasks. Although the geologic coverage of the deeper horizons by Geomap is not complete, it is useful. Field studies of the deep geopressured zone, however, have been obtained from private industry sources, or mapped by project personnel. There are no general regional geologic maps available for the deep horizons of the area.

B. Methodology

The methodology, as it has developed, consists of the following steps:

1. All the producing fields in the region were tabulated from Railroad Commission records, supplemented by private information.
2. Each of the fields was examined for geopressured conditions. The basis of this investigation included production records, well logs, Railroad Commission records and private information sources. For all fields recording production deeper than 7,000 ft., at least one well log was obtained from the deepest available well in the field, and the depth of the geopressured zone identified.

3. In those fields identified as productive from the geopressured zone, detailed production histories, geologic information, well logs, core data, water sample data and all other information available was obtained.

4. Each of the fields was classified according to production zone, depth, size of field and type of production.

5. Based on depth, temperature and field size, local field geology of representative fields was mapped.

6. Reservoir parameters in each of the fields were assessed and critical parameters identified. (These include formation thickness, porosity, permeability and reservoir extent.)

II. SUMMARY OF WORK TO DATE

A. Producing Fields

A total of 115 producing fields were identified in Hidalgo County, 12 in Cameron County, 24 in Willacy County and 19 in the southern half of Kenedy County, within the area chosen for study. Of this total of 170 fields, 24 involved production from geopressured formations. Twenty of these fields are in Hidalgo County, 3 in the south half of Kenedy County and one in Cameron County. There was no geopressured production identified in Willacy County. The locations of these geopressured fields are shown on the map in Figure 1. These fields are generally located in accordance with four primary growth faults that dominate the geology in the region, shown on the map in Figure 2.

1. Vicksburg Trend

In western Hidalgo County, six deep geopressured gas fields on the Vicksburg trend are associated with the Frio-Vicksburg flexure in eastern Starr County. (This trend, continuing into Brooks County, is now the subject of an additional assessment task in this program.) The six Hidalgo County fields in this area (identified by map number) are: (1) Kelsey, (2) McMoran, (3) McAllen Ranch, (4) Arrowhead, (5) McCook, and (6) Jeffress.

These fields produce from a series of Vicksburg sands in which the top of the geopressured zone can be identified at depths as shallow as 6,000 feet in Jeffress Field to 11,000 feet in Arrowhead field, with average depth near 8,000 feet. Current gas production is from isolated sand elements from 6,000 ft. to 13,500 ft. in depth, generally located in small fault blocks, the pattern of which becomes more complex with depth. The McAllen Ranch field and the Jeffress Field are the two largest fields in this area, and are both typical.

The Jeffress Field is characterized by a relatively long transition zone to high abnormal pressures. An intermediate casing string is normally set near 7,000 feet, and a second intermediate string at depths from 9,500 to 10,500 feet. The Vicksburg "S" sand (shown in the type-log section in Figure 3) is a blanket sand, relatively undisturbed by faults, and at relatively high pressure. This sand is mapped in Figure 4. Other sands in the series below the "S" are discontinuous and less easily correlated. Deeper producing horizons, which extend through the Vicksburg "W", become increasingly faulted, with individual producing units of small areal extent the rule.

FIGURE 1. GEOPRESSURED GAS FIELDS IDENTIFIED IN ORIGINAL STUDY REGION.

FIGURE 2. MODIFIED STUDY REGION SHOWING MAJOR FAULTING.
 (1) Live Oak, (2) Brooks, (3) Kenedy, (4) Willacy,
 (5) Cameron, (6) Hidalgo Counties.

FIGURE 3. TYPICAL WELL LOG, JEFFRESS FIELD, HIDALGO CO., TEXAS (Coastal States, #6 E. M. Jeffress Estate)

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FIGURE 4. STRUCTURAL MAP ON VICKSBURG "S" SAND, JEFFRESS FIELD, HIDALGO COUNTY, TEXAS. (Field "6", Figure 1)

The temperature gradient in the Jeffress Field is abnormal, with a value as high as $2.2^{\circ}\text{F}/100\text{ ft.}$ This gradient is typical of geopressed fields in Hidalgo County. The "corrected" depth of the 300°F geothermal surface averages about 11,200 feet, with occasional occurrence at depths as shallow as 10,000 feet.

The total thickness of the Jeffress geopressed Vicksburg sands is in excess of 500 ft., often totalling 1,000 ft. or even more. The deepest penetration in the field to date is 14,318 ft. and the sedimentation at that depth is consistent with shallower zones.

The sands are characteristic of Vicksburg sediments, extremely fine grained, shaley, with both laminar and co-mingled shale. A considerable amount of lime is present, and probably constitutes the principal cementation material. Porosity ranges from a maximum of about 14% downward, and permeability is low.

The remainder of the fields in this trend are markedly similar to Jeffress in most regards. The largest field in the area is McAllen Ranch, discussed in previous reports.

2. Tabasco Fault Region

The Tabasco Fault runs through the approximate center of Hidalgo County and is the setting for several oil and gas fields, most of which are of relatively minor importance. Three of the fields have produced from geopressed sediments in the Vicksburg. Referring to Figure 1, these are (7) Monte Cristo, (8) Foy and (9) Oblate. These fields produce from 9,500 ft. to 11,356 ft. in Vicksburg sands that are generally less well developed than those in Jeffress and McAllen Ranch. Sands are apparently isolated, lenticular and badly faulted. All three fields have produced most of their oil and gas from normally pressured sediments at shallower depths. Control in the deeper horizons is incomplete. Effective permeability in the deeper horizons of the three fields ranges from 0.1 to 1.0 md. The depth of the 300° geotherm averages 11,000 ft.

3. McAllen Fault

The McAllen Fault is a large, transverse growth fault extending from within Mexico, through the eastern half of Hidalgo County, through Kenedy County and beyond. Several important geopressed fields are located within the effective area of this fault, throughout Hidalgo and Kenedy Counties. Two of the most important of these fields, McAllen-Pharr and South Edinburg, are fully discussed in a recent paper by the

project participants.* The fields produce from deep Frio-Vicksburg sands, mainly below 10,000 ft. One of the deepest producing fields within the South Texas study area is in the Pharr Field, with production recorded at 13,788.

Along the fault to the north are three fields in Hidalgo County and two in southern Kenedy County. These are Cerda, Hargill and Lajara in Hidalgo County and Stillman and Tordilla in Kenedy County. They produce from generally massive Frio sands, and exhibit the best permeability of any of the geopressured sands in south Texas fields. These sands are, however, at relatively shallow depths (9,500 to 10,500 ft.) and the temperatures are low. Areal extent of the fields is limited.

Farther to the north, still under the control of the McAllen Fault, is the Candelaria Field. Geopressured production in this prolific field, however, has been limited to 3 wells, although several deep wildcats (one to 20,000 ft.) have been drilled in the area. Deep production is too limited to permit a good assessment of the reservoir parameters, but the three geopressured wells for which data are available indicate permeabilities less than 1.0 md.

4. Donna Fault

The McAllen-Pharr trend is isolated within a large fault block between the McAllen Fault and the Donna Fault to the east. East of the Donna Fault are several fields which have produced from geopressured formations. These include (in Figure 1) (17) North Weslaco, (18) South Weslaco, (19) Southwest Mercedes, (20) Mercedes. All these fields produce from massive Frio sands in which the top of geopressure averages 9,500 ft. to 10,500 ft. Production is from sands generally referred to as "fresh water" sands. Reliable salinity measurements from production samples as low as 4000 ppm chlorine have been recorded. No water samples from other areas have reported lower salinity than fields on this trend.

5. Cameron County

Only one geopressured field has been identified in Cameron County and it represents a rather special geologic condition. The field is the San Martin Field near Port Isabel, producing from

*Osoba, J. S., Swanson, R. K., Oetking, P., and Hagens, R. C., "Production of Water from Geopressured-Geothermal Reservoirs in South Texas", Second Geopressured-Geothermal Energy Conference, Austin, Texas, February 1976.

Miocene sands at approximately 10,000 ft. The pressure gradient is about 0.6. Producing fields in Cameron County are limited in number and generally shallow. Deep tests have been drilled throughout the County, but the (petroleum) results have been disappointing. There are known to be, however, deep geopressured Miocene sands, and the Frio sands extend to depths of at least 18,000 ft. The 300° geothermal surface through these deep sediments averages about 14,000 ft., and the top of geopressure is from 10,000 to 12,000 feet.

B. Reservoir Parameters

As discussed in the previous Quarterly Progress Report, reservoir parameters in all of the geopressured fields in the original study area have been examined. The critical parameter in every case is permeability. Permeability values for all the fields have been calculated from production records, potential tests and, where possible, from build-up draw-down tests. Permeability in the study area has been discussed in previous reports, and in the previously referenced paper, and will be discussed further in the next section of this report.

III. ACTIVITY DURING THE PRESENT QUARTER

Since the last progress report, effort has been concentrated in three areas: (1) Additional reservoir information, particularly drillstem test information, has been sought and obtained for the geopressured fields previously identified; (2) Calculations of permeability for an additional large number of South Texas producing wells have been performed; and (3) investigation of geopressured production in Brooks and Kenedy Counties has begun. The latter is in response to an additional task proposed and approved, extending the study area to include Brooks County, the remainder of Kenedy County and Live Oak County. Work since 1 May has concentrated on examination of this extended area. These subjects will be discussed separately.

A. Reports of Well Tests

The results of several drill stem and production tests of unsuccessful gas well completions in the geopressured zone have been located. These give considerable insight into the problems of developing high-volume water wells in these reservoirs.

1. Donna Area

The most recent of these tests was in the Mercedes-Donna area, near the Donna fault (Lone Star Prod. Co. #1 Denzer). The well is typical of the area east of the Donna Fault near the Cameron County line, exhibiting low salinity, high-resistivity Frio sands. We believe this well was completed in a water sand, and represents an unwitting test of a geopressured water zone. The log is reproduced in Figure 5.

Several unsuccessful deep completion attempts were made, after which the well was perforated (selectively) from 9371 - 9268, acidized and given a nitrogen pressure treatment. The well flowed gas, nitrogen and formation water. On a 20/64 inch production choke, the well tested an absolute open-flow potential of 280 mcf gas per day, plus 450 barrels of water (5400 ppm/Cl). This quickly declined to 120 mcf plus 140 barrels of water, and the completion was aborted with a plug. Other perforations at depths from 8994 to 8818 produced similar results and the well was abandoned.

This completion attempt opened a total of 42 ft. of perforations in the geopressured zone from which the potential test was made. The 450 barrels of water/day with substantial gas is probably typical of the test results one can expect from water sands in this area. Likewise, the rapid decline can be expected, and is undoubtedly the result of gas released

FIGURE 5. SOUTH HIDALGO COUNTY TEST WELL. Highly resistive, fresh water sands are typical of deep Frio in this area. (Lone Star #1 Denzer, Donna Area. See text.)

from the water due to the pressure drop in the formation. The relative permeability of the formation to gas is higher than that for water and the released gas quickly dominates the flow, blocking further water flow as a result. This reduces the rate at which gas can be released, and the rate of flow of both steadily declines. We believe this sort of performance can be expected in any flow test in the consolidated formations of this region, unless measures are taken to drastically restrict flow rate.

2. Santa Maria Area

A somewhat deeper test in the same general vicinity is reported by Shell in the No. 1 W. H. Drawe in the Santa Maria area, south of the Weslaco Field. In this completion test, perforations selectively opened a total of 10 ft. between 11,594 and 11,660. The report only indicates that the well "flowed small amount gas and water through 3/8 inch choke", but the flowing tubing pressure dropped from 5,000 lbs. to 20 lbs. during the test, indicating the same general condition as in the first test reported above.

3. Mercedes Area

In a third well, (J. M. Huber Corporation No. 1 A.M. Miller,) similar test results were obtained about 1 mile southwest of the Mercedes Field. The log of this well is shown in Figure 6. A total of 27 ft. of perforations was opened between 12,873 and 13,083 and the well tested 450 mcf/day plus 350 barrels of water/day. Tubing pressure while flowing dropped slowly from 4317 psi to 39 psi. This well also was abandoned.

4. Edinburg Area

A fourth dry hole is of interest because it lies off the flank of the South Edinburg Field in one of the favorable geopressured areas of Hidalgo County, from the standpoint of geopressured sand development. This well (Standard of Texas, No. 1 L.E. German Unit) is located 4 miles southeast of Edinburg on the south flank of South Edinburg Field. The tests reported open hole drillstem test of the Reichert sand, a deep Vicksburg blanket sand in the area, and production tests in the Marks & Bond Sands. The deeper test, a 4-1/2 minute open-hole drillstem test, was run below 5 inch casing from 13,206 to 13,665 feet, through an 8/64 inch choke with full stage water cushion. The test recorded shut-in pressure of 11,275 to 11,445 psi, and flowing pressure of 6,926 to 7,553 psi. The test recovered 5,400 ft. of gas-cut mud. A plug was set at 12,000 ft. and a number of production tests attempted through perforations in the Bond and Marks series from 11,598 to 10,977. Each of these tests produced a small amount of water and some gas. Water salinity of recovered water varied from 14,000 ppm to 4,500 ppm in the various sands of these zones.

FIGURE 6. J.M. HUBER #1A MILLER, WESLACO AREA
HIDALGO COUNTY, TEXAS

We believe this latter well represents a part of the South Edinburg field stratigraphically isolated from the main field, with about the same reservoir parameters (less than 1 md permeability). The normally productive sands are wet in this well. The differential permeability, gas and water, is such that when the sands are water saturated, little flow is obtained. The gas is probably the result of reduction in pressure near the borehole, released from water solution. This behavior seems to be representative of the Edinburg field when the sands are wet. Typically wells below the gas-water contact will not flow, or will flow only a small amount of water.

5. Southern Brooks Co., Encinitas Area

Test results of Vicksburg geopressured sands in southwestern Brooks County have been reported by Coastal States Prod. Co., in the No. 1 DeLuna in the East Encinitas Field, 8 miles south of the town of Rachal.

A section of the well log of this well is reproduced in Figure 7. It is a typical Vicksburg zone of a type represented by fields such as Kelsey Deep, McAllen Ranch and Jeffress in Hidalgo County. The well was bottomed in the Vicksburg at 11,377 feet and casing set to bottom. Top of geopressure (not shown in the Figure) is between 8,700 and 8,800 feet.

Production testing in this well began in the deeper zone, through perforations from 10,895 to 11,134. This zone failed to produce fluid, even after bailing dry. The sand is undoubtedly wet, but with water permeability essentially zero, in spite of the fact that it is an example of excellent deep Vicksburg sand development. These perforations were squeezed.

The well was then perforated in the next higher zone from 10,447 to 10,749. This 300 ft. interval flowed a small amount of water in initial tests. After bailing the perforations, the well flowed a small amount of gas and condensate with a flowing tubing pressure of 850 lbs. The zone was reperforated from 10,555 to 10,749 and given a fracture treatment. The well immediately sanded-up (frac sand). The well was cleaned and swabbed in after which it flowed gas, some water and continued to flow frac sand. The completion was unsuccessful and the well was squeezed.

Final perforations were made in the upper zone from 9,766 to 79. The well flowed gas, condensate and water on test, with a tubing pressure of 1,275 lbs. (flowing). The well was squeezed and reperforated from 9,766 to 73, and successfully completed, with AOF potential of 11 million CFGPD at a bottom hole shut-in pressure of 6,365 psi.

This zone has a calculated kh, from buildup-drawdown tests, of 22.5 md feet (3.2 md).

The tests of the lower zones in this well are very discouraging; sand development is good, pressure gradient is high, and the equilibrium temperature close to 300°F, at a relatively shallow depth. The producibility is simply not there, certainly not for thousands of barrels of water per day.

Other wells in the Encinitas Field have produced at depths below 10,000 ft., but only gas, and none with permeability as high as the 9,700 ft. zone in the DeLuna well. The deepest production recorded in the field, the Texaco #36 McGill Bros. was completed in a zone from 10,707 to 10,942. The effective kh of the entire 235 foot zone was less than 1 md-ft.

6. Effect of Fracture Treatment

Another well in the same field gives insight into the effect of hydraulically fracturing low permeability, Vicksburg sands. A section of the log of this well, the Coastal States #1 Pettus, is shown in Figure 8. Abnormal pressures were encountered at approximately 8,500 ft. Recorded bottom hole temperature at 10,908 was 236°F. The well was completed in the zone from 10,213 to 10,422. On production test, the well tested 3.4×10^6 CFDPD. Calculated permeability after fracturing was .09 md, an improvement of a factor of approximately 2. This is typical of successful fracture treatments in Gulf Coast formations of this kind, with a producibility increase generally corresponding to a two- to four-fold improvement in effective permeability.

B. Permeability Calculations

In previous reports the effective permeability of South Texas geopressured gas reservoirs has been shown to be the critical parameter in determining their performance. The geopressured gas fields examined in this project, with one exception, have been confined to the Frio and Vicksburg formations. Sands of Miocene age have possible potential in eastern Cameron and Willacy Counties, but with the exception of the San Martin Field in southern Cameron County, on-shore gas production from abnormally pressured Miocene reservoirs does not exist in South Texas.

Reservoir studies in both Vicksburg and Frio producing formations emphasize the importance of defining geopressured zones with much higher permeability than exist in the known gas reservoirs. In

FIGURE 8. SOUTH BROOKS COUNTY VICKSBURG WELL IN WHICH FRAC TREATMENT IS SHOWN TO INCREASE EFFECTIVE PERMEABILITY ABOUT TWO-FOLD. (Coastal States #1 Pettus, see text)

Figure 9 is shown a plot of effective permeability vs. depth of approximately 100 geopressed gas wells from all fields in the study area, and the significance is obvious. In no case has a producing reservoir deeper than 10,000 ft. been identified with effective permeability as high as 10 md. At depths corresponding to the 300°F geothermal surface (from 11,000 to 13,000 ft.) permeabilities are shown to be, without exception, in the range of 1 md or lower. There is no question about the importance of this evidence. If the production of 300°F geothermal fluid is to become a practical reality, one of three things must occur: (1) stimulation methods of much greater effectiveness than present methods must be developed, (2) permeability values at least two orders of magnitude greater than those so far identified must be located, or (3) economic means of producing and utilizing these fluids at greatly reduced flow rates, or at greatly reduced temperatures, must be developed.

Hydraulic fracturing of geopressed formations is only as effective as the propping agents, and two- to five-fold improvement in effective permeability is presently a realistic maximum.

We have been unable to discover reservoirs in South Texas Frio or Vicksburg formations, at adequate depths, capable of sustained production of large volumes of water. Nevertheless, off-structure water sands have not been tested, nor have reliable core results (measured under confinement) in such wells been reported.

Finally, much lower production rates (less than 10,000 bbls/day) must be considered. While it is difficult to envision wells of low producibility being economically viable, this probability must be faced.

C. New Study Area

The producing gas fields in Brooks and Kenedy Counties have been identified and are presently being examined for geopressed conditions. A preliminary tabulation of these abnormally pressured fields, subject to revision, includes the following:

Brooks County -

Kelsey Deep	Ann Mag
Encinitas	Viboras
La Encantada	Skipper
Scott & Hopper	

Northern Half of Kenedy County -

Rita	El Paistle	Sarita
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FIGURE 9. EFFECTIVE PERMEABILITY vs. DEPTH FOR A LARGE NUMBER OF GAS WELLS IN HIDALGO, BROOKS, CAMERON AND KENEDY COUNTIES IN SOUTH TEXAS.

x normally pressured wells

• geopressured wells

Detailed examination of Live Oak County will be performed early in the next reporting period.

The Brooks County geopressured fields extend from Kelsey Field (partially in Hidalgo County) along the Frio-Vicksburg flexure, in a generally diagonal direction across the County to the northeast. All the geopressured fields are located to the east of this major fault system, and except for two of the fields, Viboras and Ann Mag, represent Vicksburg production. Viboras and Ann Mag are Frio fields, and more closely resemble those in Kenedy County.

D. General Project Status

The project has done a great deal to place the South Texas geopressure-geothermal resource in perspective. The extent of production experience in the South Texas geopressured zone has been documented, and significant reservoir parameters identified. Several geographic areas with good likelihood of continuous aquifers of considerable extent are known. Sand deposition thickness, in total, is adequate in many locations, in both the Vicksburg and Frio formations. The critical parameter in every case has been shown to be permeability.

IV. WORK TO BE ACCOMPLISHED

During the last remaining reporting period effort will be concentrated on completing the field study in Brooks, Kenedy and Live Oak Counties, and in preparation of the Final Report. Two detailed studies in Kenedy County are presently underway in Candelaria and El Paistle Fields, and will be complete early in the next reporting period. El Paistle has the deepest production reported in the study area.

Selection of representative fields for detailed study in Brooks and Live Oak Counties is now underway.

The project can be completed on schedule within the remaining funds.