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GEOLOGY AND POTENTIAL USES OF THE GEOPRESSURE RESOURCES OF THE GULF COAST

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PREFACE

The manuscript which follows presents the abstract of a talk entitled "Geology and Potential Uses of the Geopressure Resources of the Gulf Coast" and the text of the talk itself. The presentation was made at the 1976 annual convention of the American Association of Petroleum Geologists in New Orleans, Louisiana.

ABSTRACT

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The United States Energy Research and Development Administration has supported efforts to evaluate the potential contribution to the national energy supply of geopressured geothermal resources in the Gulf Coast. Efforts include a program of resource assessment and programs to examine utilization of the resource for the production of electricity and as a source of industrial-process heat.

Work on resource assessment has suggested the presence of perhaps as much as 6,000 MW-centuries of recoverable electric energy and of 200 Tcf of methane. This program has emphasized finding significantly large sand bodies within the geopressured stratigraphic section in addition to defining the distribution of abnormal fluid pressures and formation temperatures. Regional sand facies analyses conducted thus far indicate five locations in the Frio formation of Central and South Texas where adequately large geopressured geothermal resources may be present.

Engineering studies of energy-conversion systems based on total-flow, flashed-steam, and binary-cycle concepts show that development of electric power from the Gulf Coast geopressure resource is technically feasible. However, such recovery is only marginally economic in view of the relatively low temperatures involved (less than 300°F or 149°C), and especially if dissolved methane is not present at saturation levels. Under favorable circumstances, investment in exploitation of the complete geothermal resource can produce rates of return of 15 to 30 percent. Rates of return as large as 10 percent appear unlikely under present and near-term future circumstances if only electric energy is recovered from the resource.

Study of use of the resource as process heat in pulp and paper mills and new sugar refineries has shown that these uses also are technically sound. The thermal content of a barrel of geothermal brine can cost as little as 9 mills when credited for recoverable hydraulic energy and methane. The value of heat approaches 50 mills per bbl for certain applications. Again, under favorable circumstances, the use of geopressure resources for these nonelectric applications is economically attractive.

All programs have pointed out clearly the need for better specific understanding of the resource, especially its dissolved methane content and its ability to produce for tens of years.

TEXT OF THE TALK

INTRODUCTION

The topic of this paper is "Geology and Potential Uses of the Geopressure Resources of the Gulf Coast. Co-authors and their affiliations are listed in the first figure.

This presentation will review the Energy Research and Development Administration's involvement so far with the geopressure resource. The geopressure resource is defined here as connate water at pressures greater than 0.7 psi per foot of depth of its occurrence. The energy content of the resource consists of these components:

- 1) pressure in excess of normal hydrostatic pressures;
- 2) heat at temperatures roughly above 120°F and;
- 3) whatever methane is dissolved in the brine.

This talk will cover those topics listed in Figure 2. Contributions to the assessment of the resource have been made by Lawrence Livermore Laboratory, the U.S. Geological Survey, the University of Texas at Austin, Texas A&M University, McNeese State University, and Louisiana State University. A discussion of schemes for utilization of the resource is also included. These have been done for electric generation by Lawrence Livermore Laboratory and by other groups and for non-electrical uses by DSS Engineers. The presentation will consider economics analyses of the appreciable problems that remain and that must be solved if there is to be development of the geopressure resource. I will not explain ERDA's participation in all this work. I would, however, like to call your attention to the proceedings of the first and second Geopressed Geothermal Energy Conferences which were held at the University of Texas at Austin. A great deal of technical and administrative information can be found in those proceedings.

ESTIMATES OF THE GROSS SIZE OF THE RESOURCE

Lawrence Livermore Laboratory has carried out resource estimates using the approach shown in the third figure. The steps include estimating the total volume on shore wherein the resource occurs. This volume has been set equal to the product of its areal extent and the depth over which it might be found and drilled. The second step calls for discounting this volume in order to estimate more clearly the volume of potentially exploitable resource. The total volume is discounted by a guess as to the fraction which holds reservoirs of acceptable size, the fraction that is potentially producing sand and by an estimate of the average porosity of such sands. Finally this discounted volume is converted to energy on the basis of an assigned "recoverable" energy per unit volume basis. The word "recoverable" appears in quotes because there is not a very clear understanding of

the amount of fluid in situ that might in fact be removable to the earth's surface for conversion to electrical energy, for instance. Figure 4 shows the location and depth of occurrence of the top of the geopressure zone in the Northern Gulf of Mexico basin. Distribution is shown in a very general way in the depth ranges of 1500, 3000, and 4500 meters (5000, 10,000, and 15,000 feet). Conclusions about the size of the resource by LLL are shown in Figure 5. They are listed according to so called reservoir class, which in turn is based on the depth of first occurrence of geopressure, namely 5,000, 10,000, and 15,000 feet in this study. In terms of energy units of megawatt - centuries, there are thought to be approximately 6,000 megawatt centuries of presumably recoverable electrical energy. In addition, these are slightly more than 22×10^{13} standard cubic feet of natural gas associated with the geopressure brine capable of leading to 6,000 megawatt centuries of electrical energy. It is important to realize that these numbers should be discounted by a factor between zero and 100% that would factor in consideration of the amount of fluid that could actually be moved to the surface of the earth and be processed for resource recovery.

The choice of numerical values used in arriving at the numbers shown in Figure 5 is subject to long explanation and debate. Perspective on the reasonableness of all those choices can be gained by comparing them to U.S. Geological Survey estimates for recoverable geopressure resource. According to Circular 726, these are between 9,000 and 38,000 megawatt centuries of electric energy and between 11 and 72×10^{13} scf of gas. It would appear, therefore, that a number of people believe that an appreciable amount of energy is contained in situ in the resource but that the upper and lower bounds of actually recoverable resource are educated guesses at this time.

WORK ON INDIVIDUAL RESERVOIRS WITHIN THE OVERALL RESOURCE

In an effort to more accurately estimate the size of the technically and economically exploitable geopressure resource, attention has been increasingly directed at definition of bona fide individual reservoirs. These must be found if the resource is to be exploited. A target reservoir should in the least have the parameters listed on Figure 6. These include a large storage volume, decent permeability, temperatures of 250°F or more and gas at saturation levels. The University of Texas at Austin has been involved in the definition of exploitable reservoirs, in particular in defining sand sections within the geopressure section with adequate thickness and volumes. Their work (Figure 7) has called attention to several fairways which appear to include reservoirs having adequate volumes of producible sand. These fairways are in the South Texas Gulf Coast in Hidalgo, Willacy and Cameron Counties and in middle Texas Gulf Coast in Matagordo County. Another fairway is present in Nueces County. Location of these fairways is shown in Figure 8. Details of this work can be found in reports issued by the Bureau of Economic Geology of Texas. Figure 9 is a simplified version of a net sand map prepared by this group. There appear to be more than 400 feet of sand, for instance, in the T5-T6 stratigraphic interval of the Frio formation in coastal middle Texas according to work by Bebout and others.

Reservoir permeabilities for South Texas geopressured gas field's are a cause of concern inasmuch as data reviewed to date indicate permeabilities roughly an order of magnitude less than the minimum desired for a target reservoir. Most of the values reported by Professor Joseph Osaba and his colleagues at Texas A&M and Southwest Research Institute are in the range of 1 to 2 millidarcies, whereas the desired minimum permeability is in the range of tens of millidarcies. It should be recognized that the analyses done thus far are for only a part of the entire geopressure resource, namely South Texas. However, this work strongly emphasizes the need to gather data on flow capabilities of wells completed in the geopressure section.

In order to evaluate more adequately the prospects of producibility of the geopressure resource, ERDA has supported an effort which is supervised at McNeese State University to test a brine well completed in the geopressure section. The configuration of this well is shown in Figure 11. It would be most encouraging to see this well produce 40,000 barrels or more per day for an extended period of time. When that well is operating, LLL expects to hook up the turbine shown in Figure 12 in order to get some "hands-on" insight into producing electricity from this resource.

WORK ON ENERGY RECOVERY SYSTEMS

In addition to having supported assessments of the size of the geopressure resource, ERDA has supported work on several schemes for generation of electricity. Lawrence Livermore Laboratory has analyzed the production of electricity based on the total flow process, the flashed steam system, and the binary system. Dow Chemical Company and Brown and Root, Inc., have analyzed the flashed steam system and the binary system, respectively (Figure 13). Figure 14 is a diagram of a power plant that involves a total flow expander. The total flow concept, in brief, calls for the use of the entire wellhead product in the development of electricity. In this plan, the wellhead fluid is degassed slightly prior to entry of the fluid into a hydraulic turbine for the conversion of pressure energy into electricity. Following exit from the hydraulic turbine, additional methane is recovered. Brine is then directed to a total flow expander. Back pressure on the total flow expander is maintained by a separator kept at low pressure by a combination pump and condenser system. The bulk of the wellhead product is eventually reinjected into the subsurface.

Details of other schemes for recovery of electricity can be found in the proceedings of the First and Second Geopressure Conferences which were held at the University of Texas, and they will not be included in this presentation.

ECONOMICS OF ELECTRIC GENERATION FROM THE GEOPRESSURE RESOURCE

A question of major interest to all investors in the resource business is the attractiveness of investment in the geopressure resource. Figure 15 shows the internal rate of return for geopressure power plant as a function of electric and gas values. This particular figure applies to a so called class II resource having an assumed temperature of 250°F, a depth of occurrence of about 13,000 feet and a methane content of 30 scf per barrel. It is assumed that the well production system will sustain the power plant for a 20-year period.

Under favorable circumstances, acceptable rates of return are possible. For instance, at a sales price of \$2.00 per MCF of gas, 50 mills per kilowatt-hour of electricity, and with injection, and for the costs incumbent on the energy conversion scheme shown in Figure 14, a 15 percent rate of return is forecast.

In the event that no methane is present in the resource, internal rates of return are only marginally acceptable. Figure 16 shows that for a class II resource, a 15% rate of return is possible only if electrical energy can be sold for 110 mills per kilowatt-hour. For a hotter resource, the economics are more favorable; 15 percent can be realized at a sales price of 60 mills per kilowatt-hour.

Economic analyses by others as reported in the Second Geopressured Geothermal Energy Conference lead to similar conclusions.

USE OF THE GEOPRESSURE RESOURCE FOR NON-ELECTRICAL APPLICATIONS

In addition, to the potential use of the geopressure resource to produce electricity, the resource may also be used directly in a number of industrial processes which are indigenous to the Gulf Coast. Possible application in the pulp and paper, sugar milling and sugar refining industries has been studied by DSS Engineers. No process diagrams of these applications are included in this report but they can be found in LLL report UCRL-13633 and in the proceedings of the first geopressure conference. There appear to be no problems of technical feasibility provided that the brine is no more chemically obnoxious than reported to date. Economics analyses of non-electrical use of the resource has focused on the cost of a barrel of geopressure brine and then on the value of that brine owing to its replacing alternative fuels used in

the industrial process. Figure 17 shows that the costs and the value of a barrel of geopressure fluid is low. Costs range from 8 to 33 mills depending on well costs and on the credit one may assign to a barrel of fluid owing to the value of extractable gas and in-plant electric generation it can support. The value of the heat in the fluid depends on the temperature of the fluid, on its temperature when it exits the process, on the processes in which it can be used in an industry, and on the costs of the alternative fuels such heat can displace. The value of this heat for the industries considered ranges from 21 to 58 mills per barrel. These are not large numbers when compared with oil at \$10 per barrel. However, flow rates should be high, and rates of return to the well system owner, i.e., the process heat supplier, if paid on a rate keyed to the cost of displaced fossil fuel are forecast to be 8 to 25% depending on the industry (Figure 18). A pulp and paper mill especially designed to use geopressure fluid could realize a 25% rate of return to the fuel supplier. Returns to sugar mills are low because of low annual load factors for such mills.

KEY QUESTIONS AND SUMMARY

Key questions for geopressure resource development are shown in Figure 19. Is dissolved methane present at saturation levels in the geopressure fluid? Its presence has a major impact on the economics of development of the geopressure resource. Do wells completed in the geopressured section have the capacity for long, large flows? Geopressure wells are very expensive and must be long lived to pay off. Although little has been said here about the impact of development of the geopressure resource on the environment, acceptable environmental impact will, of course, have to be realized. Finally, who is going to demonstrate technical and economic performance of this resource? Forecasts for performance are one thing but there is no substitute for performance itself.

ERDA has supported work on the assessment of the gross size of the geopressure resource on efforts to detail specific reservoirs and on its potential use for the generation of electricity and for process heat in certain industries. The resource appears to be quite large but the size of the technically and economically recoverable fraction of the resource is hardly known. Exploitation to produce electricity and for use in certain non-electrical applications appears technically feasible and economically acceptable insofar as various assumptions about life of the wells and methane dissolved in the fluid are themselves valid. Hard data are needed to substantiate these claims for feasibility. ERDA welcomes the opportunity to work with industry to obtain that data.

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FIGURE 1.

**GEOLOGY AND POTENTIAL USES OF THE GEO-
PRESSURE RESOURCES OF THE GULF COAST**

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FIGURE 2.

**THIS TALK WILL PRESENT AN UPDATE OF ERDA
INVOLVEMENT IN GEOPRESSURE RESOURCE
DEVELOPMENT AND WILL COVER:**

Resource assessments work by –

- LLL
- USGS (Circular 726)
- UT/Austin
- Texas A&M University
- McNeese State/LSU

Utilization schemes for

- Electrical generation by
 - LLL
 - Others
- Non-electrical by
 - DSS Engineers

Economics analyses

Outstanding remaining problems

FIGURE 3.

**LAWRENCE LIVERMORE LABORATORY HAS
CARRIED OUT RESOURCE ESTIMATES USING THE
FOLLOWING PROCEDURE**

1. Estimate total volume of resource
 - Areal extent
 - Depth ranges
2. Discount to yield exploitable volume
 - Acceptable size reservoir
 - Per cent sand
 - Per cent porosity
3. Convert exploitable volume to energy on an assigned "recoverable" energy/unit volume basis

FIGURE 4.

**LOCATION & DEPTH OF OCCURRENCE OF THE GEOPRESSURED ZONE
IN THE NORTHERN GULF OF MEXICO BASIN**

FIGURE 5.

**TOTAL GULF COAST GEOPRESSURE RESOURCE
ESTIMATES BY LLL ARE AS LISTED HERE**

Reservoir class (depth-ft.)	"Recoverable" electrical energy (MW-cent)	"Recoverable" natural gas (10¹³ scf)
5-10,000	1020	6.02
10-15,000	3740	12.7
15-20,000	<u>1230</u>	<u>3.45</u>
Total	5990	22.2

From House, Johnson, and Towse (1975)

FIGURE 6.

**BONA FIDE INDIVIDUAL RESERVOIRS MUST BE
FOUND IF THE RESOURCE IS TO BE EXPLOITED.
A TARGET RESERVOIR SHOULD HAVE THE FOLLOW-
ING PARAMETERS**

Thickness — 300 feet of sand
Stored volume — 3 cubic miles
Permeability — 20 millidarcies
Individual well production capability — 40,000 BBLS/day
Temperature — 250° F
Gas content — at saturation levels

FIGURE 7.

**RESOURCE ASSESSMENTS WORK HAS BEEN
CARRIED OUT AT THE UNIVERSITY OF TEXAS
AT AUSTIN**

Approach emphasizes finding thick sand sections
within the geopressure section

Findings — South Texas Frio study:
Fairways — Hidalgo, Willacy, Cameron County;
Nueces County

Findings — Middle Texas Frio study:
Fairways — Matagordo County

**GEOPRESSURE RESOURCE FAIRWAYS DEFINED BY UT/AUSTIN-
TEXAS BUREAU OF ECONOMIC GEOLOGY ARE SHOWN HERE**

Figure 8.

NET SAND MAP – T5-T6 UNITS MIDDLE TEXAS GULF COAST

Figure 9.

REPRESENTATIVE RESERVOIR PERMEABILITIES FOR SOUTH TEXAS GEOPRESSURED GAS FIELDS ARE A CAUSE OF CONCERN

FIGURE 10.

GEOHERMAL TEST WELLBORE DIAGRAM EDNA DELCAMBRE NO 1, TIGRE LAGOON, VERMILLION PARISH, LOUISIANA

FIGURE 11.

FIGURE 12.

FIGURE 13.

**SCHEMES FOR GENERATION OF ELECTRICITY
FROM GEOPRESSURE RESOURCE HAVE BEEN
DEVELOPED BY SEVERAL ORGANIZATIONS**

LLL analyses include:

- Total flow
- Flashed steam
- Binary

Others have done:

- Flashed steam: Dow Chemical, U.S.A.
- Binary: Brown and Root, Inc.

DIAGRAM OF A TOTAL FLOW POWER PLANT FOR GEOPRESSURE RESOURCE

FIGURE 14.

From House, Johnson, and Towse (1975)

INTERNAL RATE OF RETURN FOR GEOPRESSURE WELLS AS A FUNCTION OF ELECTRIC AND GAS VALUES ARE SHOWN BELOW. UNDER FAVORABLE CIRCUMSTANCES ACCEPTABLE RATES OF RETURN ARE POSSIBLE

FIGURE 15.

From House, Johnson, and Towse (1975)

**INTERNAL RATES OF RETURN FOR GEOPRESSURE WELLS
"PRODUCING" ELECTRICITY ONLY ARE marginally ACCEPTABLE.**

FIGURE 16.

No credit given for gas
From House, Johnson, and Towse (1975)

FIGURE 17.

**COSTS AND VALUE OF GEOPRESSURE FLUID FOR
DIRECT USE ARE LOW**

Costs

8.1 to 32.8 mills per barrel
Dependent on well depth, gas and electric
generation credit

Value

21.3 to 57.6 mills per barrel
Based on savings of alternative fuels.

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FIGURE 18.

RATES OF RETURN FOR VARIOUS NON-ELECTRICAL APPLICATIONS ARE IN THE RANGE OF 8 TO 25%

<u>Industry</u>	<u>Rate of return due to fuel cost savings</u>
Pulp and paper	14.7 – 25.8%
Sugar mill	7.6 – 8.1%
Sugar refinery	13.2 – 15.9%

FIGURE 19.

KEY QUESTIONS FOR GEOPRESSURE RESOURCE DEVELOPMENT

1. Presence of dissolved gas at saturation levels – 30 scf/bbl
2. Capacity for large, long flow per well – 40,000 bbl/day for 20 years
3. Tolerable environmental impact-subsidence
4. Demonstrated technical and economic performance

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