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THE GEOPRESSURED-GEOTHERMAL RESOURCE, RESEARCH AND USE

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ABSTRACT

The Geopressured-Geothermal Resource has an estimated accessible resource base of 5,700 quads of gas and 11,000 quads of thermal energy in the onshore Texas and Louisiana Gulf Coast area alone (Wallace et al., 1978). After 15 years the program is now beginning a transition to commercialization. The program presently has three geopressured-geothermal wells in Texas and Louisiana. The Pleasant Bayou Well has a 1 MWe hybrid power system converting some gas and the thermal energy to electricity. The Gladys McCall Well produced over 27 MM bbls brine with 23 scf per bbl over 4 1/2 years. It is now shut-in building up pressure. The deep Hulin Well has been cleaned out and short-term flow tested. It is on standby awaiting funds for long-term flow testing.

Supporting research in the Geopressured Program includes research at the University of Texas at Austin on rock mechanics, logging, geologic studies, reservoir modeling, and co-location of brine and heavy oil in Texas and California; at the Louisiana State University on environmental monitoring and geologic studies; and at the University of Southwestern Louisiana on hydrocarbons associated with the geopressured brines and development of a pH monitor for harsh environments. Recently, Lawrence Berkeley Laboratory has been added to the research support in prediction of reservoir behavior. EG&G Idaho, Inc. is developing feasibility studies in FY-1990 on four use areas: 1) Thermal Enhanced Oil Recovery, 2) Direct Use, 3) Hydraulic and Thermal Conversion, and 4) Use of Supercritical Processes and Pyrolysis in Detoxification. This on-going research and well operations are preparing the way to commercialization of the Geopressured-Geothermal Resource.

In January 1990 an Industrial Consortium for the Utilization of the Geopressured-Geothermal Resource was convened at Rice University, Houston, TX. Sixty-five participants heard industry cost-shared proposals for using the hot geopressured brine. Proposals ranged from thermal enhanced oil recovery to aquaculture, energy conversion, and environmental clean up processes. By the September meeting at UTA-Balcones Research Center, industry approved charters will have been received, an Advisory Board will be appointed, and election of officers from industry will be held. The 2-volume proceedings of the January meeting have been completed and are available to interested parties.

INTRODUCTION

Geological formations located in the northern Gulf of Mexico contain large reservoirs of hot, saline brine under abnormally high pressure and temperatures. Estimates of the energy potential of this undeveloped resource range as high as 160,000 quadrillion BTUs (quads) (DOE, 1989). The U. S. Geological Survey has estimated that there are 5,700 quads of accessible gas and 11,000 quads of thermal energy in the onshore Gulf Coast reservoirs without regard to economics (Wallace, 1978). Because the energy consumption of the United States is presently 80 quads per year (DOE/EIA, Energy Monthly, August, 1989), this resource could conservatively provide a portion of the domestic energy supply for many centuries. Geopressured-geothermal resources have been developed slowly because of the relative price advantage of other energy resources and the technical limitations on exploitation of this resource.

A goal of the DOE is to provide energy research, development, and utilization of stable, long-term, domestic energy. One area of research is the development of the geopressured-geothermal energy resource. In recent years, the DOE has been sponsoring the Geopressured-Geothermal Research Program and three DOE well operations with the assistance of the Idaho National Engineering Laboratory (INEL) to assess and evaluate the technical and production characteristics of this undeveloped resource. Current direction of the Geopressured-Geothermal Program is to develop new technologies to profitably produce electricity for $0.07 to $0.11/kWh (in 1990 dollars) by 1995 (DOE, 1989), plus investigating various process heat applications of the resource. A consortium for the utilization of geopressured resource was initiated January 10, 1990, at Rice University with sixty-five participants. This activity heralds the transition to commercialization for this undeveloped resource.

THE RESOURCE

A geopressured reservoir has a pressure gradient exceeding the normal hydrostatic gradient of 0.465 psi/ft in the Gulf Coast area. Pressures may approach lithostatic pressure and gradients have actually been measured up to 1.05 psi/ft in the Gulf Coast area (Figure 1.). Geopressured reservoirs are a normal phase of basin evolution. Present geopressured basins occur in many locations throughout the world and in many states in the U. S. (Figures 2. and 3.). Data shown are from Strongin (1981), and Meyer, (private communication, U.S.G.S., 1989), and Fertl et al.(1976).

Geopressured-geothermal resources have three energy forms: thermal, hydraulic, and methane gas. These three energy forms can also be converted to higher value forms of energy using available technologies. Thermal energy can be converted to electricity using a geothermal

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turbine. Hydraulic energy can be converted to electricity using a hydraulic turbine. Dissolved methane gas can be separated and sold, burned, compressed, liquefied, converted to methanol, or converted to electricity by fueling a turbine (Plum et al., 1989).

DOE GEOPRESSURED PROGRAM STATUS

The present program includes three geopressured wells: Gladys McCall Well in Cameron Parish, Louisiana; Pleasant Bayou Well in Brazoria County, Texas; and the Hulin Well in Vermilion Parish, Louisiana. The Gladys McCall is shut-in, being monitored for pressure buildup which is approaching the original pressure after extensive flowtesting. At the Pleasant Bayou Well a 1 MWe hybrid power system was constructed and is in operation. Power sales to Houston Power and Light passed the one-million kWh mark on January 8, 1990. The Hulin Well was reworked and short term flow-tested. It is presently shut-in, until additional funding for testing is available (Eaton et al., 1988).

Data concerning the wells, brine, and reservoir characteristics are provided in Table 1. Data sources include Eaton Operating Company Reports, DOE Program Reports, Geothermal Reviews, University of Texas at Austin, Louisiana State University, and Idaho National Engineering Laboratory.

The DOE also supports continuing research at the University of Texas at Austin (UTA), Louisiana State University (LSU), and the University of Southwestern Louisiana (USL). Research emphasis at this present time is on rock mechanics, well logging, geology, reservoir engineering, environmental monitoring, hydrocarbons content, and co-location of geopressured brine with medium to heavy oil in Texas, Louisiana, and Kern County, California.

A discussion of the Geopressured wells follows:

Gladys McCall

Data from the Gladys McCall reservoir testing and analyses represent the most comprehensive information available on long-term production and depletion of a geopressured-geothermal reservoir. This design well was drilled in 1981 to 16,510 ft, plugged back to 15,831 ft, and completed with 5-in. production tubing. After initial testing of a deeper sand zone, the well was perforated from 15,160 to 15,470 ft in Sand Zone No. 8. Testing of this zone was initiated in October 1983, and the well was shut-in October 1987. Initial static reservoir conditions were 12,784 psia and 298°F. Brine temperatures at the surface remained relatively constant at 268°F during most of the testing. Gas content in the brine ranged from 22.9 to 29.7 scf/bbl, depending on the separator pressure. Average salinity of the brine was 57,000 mg/L and total dissolved solids (TDS) content was 95,000 mg/L (IGT, private communication, 1988). During the testing period, production rates ranged from about 10,000 to 30,000 bpd, with an average production rate of about 17,000 bpd. A total of over 27 MM bbls brine and 23 scf/bbl natural gas were produced during this period; water was reinjected in a shallow saline aquifer without difficulty.

Based on the performance during testing, the UTA estimated the reservoir volume to be 4 billion barrels; UTA performed geological and rock mechanics studies to estimate the reservoir parameters of permeability, compressibility, etc. Reservoir calculations using these parameters indicated that the well could produce 40,000 bpd for 5 y with a final wellhead pressure of 1300 psi.

This projection may be optimistic, however, in view of the actual performance of the well during the testing period. During 1986, for example, the production rate declined from 31,000 to 25,000 bpd while maintaining the first-stage separator at 1000 psia. Projections of reservoir performance made by S-Cubed indicate that the well could sustain a production rate of 25,000 bpd for about 7 y with a wellhead pressure of 1000 psia at the end of that time. Anticipating that the well could sustain this production rate for 10 y is considered optimistic; anticipating 20 y is considered unrealistic. Similar projections for a production rate of 30,000 bpd indicate that the well could sustain this flow for 4 to 5 y before the wellhead pressure dropped below 500 psia.

However, it is important to note that analyses of pressure buildup data obtained since the well was shut-in indicate that the recovery is better than would have been anticipated from simulations based on drawdown data alone. This type of performance could affect long-term development alternatives.

Pleasant Bayou

The first design well drilled at the Pleasant Bayou prospect encountered completion problems that precluded its use as a production test well. Pleasant Bayou #2 was drilled to a depth of 16,465 ft, perforated in the Frio sand at 14,644 to 14,704 ft, and completed with 5-1/2 in. O.D. production tubing. Structural failures in the production tubing occurred on two separate occasions after the well was drilled in 1979, necessitating expensive rework operations. Initial static reservoir conditions were 11,168 psi and 302°F. The brine temperature at the surface under production is about 292°F. The brine's salinity averages 127,000 ppm and the gas produced at a separator pressure of 800 psi is 24 scf/bbl (Eaton Operating Company, 1989). Analyses of the gas indicate that about 85% of the gas is methane, another 6% is ethane and higher components, and the remainder is CO_2.

Early estimates of reservoir volume based on initial testing of the well were on the order of 2 billion barrels. Initial projections of brine production rate suggest the well could produce 20,000 bpd for 6 to 7 y and 30,000 bpd for 3 to 4 y. More recent projections (Riney, private communication, 1989) indicate the flowing wellhead pressure would decline to about 1200 psia after 5 y of production at 20,000 bpd. Since June 1988, the flow rate has been 18,000 to 20,000 bpd. Reservoir size based on UTA geological studies and reservoir modeling has been revised upward to 8 billion barrels (Riney, private communication, 1989) and may provide better estimates of reservoir performance.

It should be noted that production from the well is limited to 20,000 bpd because of sand production that occurred at brine production rates above 22,000 bpd. Sand production could be a short- or long-term problem and is currently one of the primary considerations in controlling well operations.

Hulin

The Hulin Well was drilled and completed to a depth of 21,546 ft by Superior Oil Company in 1978. After 19 months of gas production, the wellhead pressure had declined to 1000 psi. Subsequent efforts to restore production resulted in a packer or tubing failure and the well was abandoned. It was subsequently transferred to DOE to test geopressured-geothermal zones above the gas production zone.

Well log interpretations indicate that the well penetrated a massive geopressured zone from 20,010 to 21,120 ft. The first test zone was perforated after well rework in late 1988. The DOE Program initiated short-term flow testing in December 1989. These tests resulted in preliminary estimates of 34 scf/bbl and 7,200 psia shut-in wellhead pressure. These data are from the first three perforation zones, two at the base and one at the top of the 500 ft thick sand that is the major production target.

Estimates of resource parameters based on well logs and data obtained during rework indicated a reservoir temperature of 350 to 375°F, a brine salinity of 195,000 mg/L and a gas content of about 50 scf/bbl (Meahl, private communication, 1989). Occurrence of free gas has been suggested from well log interpretations (Dunlap, private communication, 1989). However, thus far the limited testing has not shown evidence of free gas.

Reservoir volume estimates as high as 14 billion bbls have been calculated based on probable fault block size and expected porosity (geological studies at UTA and Riney, private communication, 1989). These calculations are preliminary and may require more definition based on well performance.

The Hulin Well provides an example of using a reworked oil or gas well, rather than drilling a geopressured well. The production will be limited from 15,000 to 18,000 bpd by the well depth and tubing size restrictions. This wellbore limitation would be typical for depleted wells that are recompleted for geopressured-geothermal production. Thus, it is not reasonable to assume 40,000 bpd production from an existing reworked well even with excellent reservoir conditions.

South Texas

Higher temperature geopressured-geothermal resources, based on available data from the Wilcox Formation in the Mirando trend in south Texas, have reported temperatures of from 350 to 500°F (C. Kimmell, private communication, 1989). Typical geopressured conditions are found below 12,000 ft in the onshore Gulf Coast area but are encountered at 6,000 ft or less in the Mirando trend. The zones of interest in the Wilcox Formation are located at 16,000 to 18,000 ft with reported porosities of 26 to 30%. Gas content in the brine is reported to be high; 62 scf/bbl and 100 scf/bbl are estimated based on temperature, pressure, and total dissolved solids of 3,600 mg/L (INEL analysis, 1989; Negus-de Wys 1989; Kimmell, private communication, 1989).

There is no available information on the productivity of these zones. It is expected that, like Hulin, the production may be wellbore limited; thus, production rates of 20,000 bpd are reasonable. Little excess pressure at the surface is expected because of the depth of the resource and wellbore losses; therefore, utilization of hydraulic energy may not be realistic for these cases.

However, the Wilcox may contain some of the more promising geopressured-geothermal reservoirs due to the higher temperatures and pressures, low total dissolved solids, and potentially high gas contents. The south Texas Wilcox Formation should be tested with dedicated geopressured-geothermal wells.

RESEARCH

Supporting research for the Geopressured-Geothermal Program is performed at Louisiana State University (LSU). The University of Texas at Austin (UTA), and the University of Southwestern Louisiana (USL). Research at LSU in Environmental Monitoring, Geological Studies, and Co-location of brine and heavy oil will be reviewed by Dr. Charles Groat. Lawrence Berkeley Laboratory has been added to the research team this year and will be working on modeling prediction of reservoir behavior. Additionally, the INEL is developing four feasibility reports on utilization of the geopressured resource. These reports include thermal enhanced oil recovery, direct use, energy conversion to electricity, and supercritical fluid processes.

The UTA research includes work in rock mechanics, logging, geological studies, co-location of brine and heavy oil, and reservoir modeling carried on by S-Cubed under a subcontract to UTA. These areas of research are coordinated by Dr. Myron Dorfman.

Dr. Henry Dunlap's Logging Research this past year has focused on the effect of boron concentrations on the porosity log, and interpretations of the Hulin Well logs. Numberous publications have resulted from this research, and the UTA Logging Consortium has received support through this work.

Dr. Ken Gray has reported the following accomplishments in rock mechanics research:

1. Published a paper at the Energy Sources Technology Conference on a finite element wellbore stability model.

2. Obtained cyclic uniaxial compaction, triaxial compaction, and pore-pressure drawdown compaction data for use in reservoir-mechanics modeling.

3. Developed apparatus and procedures for determining tensile strength of geopressured-geothermal sandstones at elevated pressures.

4. Designed, built, and implemented a pore pressure loading system for use in apparatus to determine strength and deformation moduli of geopressured-geothermal cores under in-situ conditions of three-dimensional stresses.

Dr. Jay Raney, P.I. for Geological Studies at UTA Bureau of Economic Geology, has reported data on the following:

1. Bottomhole pressure versus cumulative brine production at the Pleasant Bayou Test Well.

2. Bottomhole pressure versus cumulative gas production at Pleasant Bayou Test Well.

3. The relationship of reservoir pressure (p) to gas compressibility (z), for depletion type, aquifer support, and linear extrapolation curves. This represents a decline curve used commonly to estimate recovery factor and the reservoir drive mechanism.

4. Upper Wilcox Geothermal Fairways and Heavy Oil Reservoirs.

Descriptions of this work were prepared by Mr. Scott Hamlin (UTA):

"The decline in flowing bottomhole and static reservoir pressures at the test well was plotted as a function of cumulative brine and gas production. The pressures have declined by about 300 psi from their original levels during a cumulative brine production of 7 million barrels and a cumulative gas production of 162.2 million cubic feet. Straight line extrapolation of the flowing pressure decline trend to 7,000 psi (below which economic gas production rate may not be sustainable) indicates that 38 million stb (stock tank barrels) of brine and 1.1 billion scf (standard cubic feet) of gas will be recovered by that time.

Approximatly 6 billion barrels of brine in-place has been estimated at Pleasant Bayou in the C-Zone (Hamlin and Tyler, 1988). With a gas-brine ratio of about 24 scf/stb (standard cubic feet/stock tank barrel) this translates into a gas volume of 144 billion cubic feet. Therefore, when the pressure has declined to 7,000 psi the cumulative brine and gas recovery would be less than 1% of the original estimated volume in-place. However, additional factors will influence ultimate recovery. These factors include: the effects of aquifer recharge, changes in formation and fluid compressibility with pressure depletion, free-gas movement and shale dewatering. Interplay of these factors has not been fully determined in the early depletion history of the Pleasant Bayou reservoir."

"The plot of p/z (reservoir pressure/gas compressibility factor) versus cumulative gas production represents a decline curve used commonly to estimate recovery factor and reservoir drive mechanism. Most geopressured reservoirs do not exhibit ideal linear depletion characteristics. Aquifer recharge, shale dewatering and compressibility changes introduce non-linearity in the decline curve. Evaluation of production history from other geopressured gas reservoirs in the vicinity of Pleasant Bayou reflect some common factors: (1) deliverability is high in early life due to gas and brine expansion, then drops off sharply as reservoir pressures decline, (2) after depletion to hydrostatic pressure, the decline is often flat with increased co-production of water, due to water drive from a communicating aquifer. The decline at Pleasant Bayou is still at an early stage and its final character will be determined by a combination of factors outlined above."

"In South Texas heavy oil reservoirs in the Jackson and Yegua Formations (Eocene) overlie Wilcox Group (Paleocene to lower Eocene) geopressured-geothermal sandstones. The reservoir characteristics of various parts of the deep upper Wilcox geopressured-geothermal zone have been summarized using data from previous University of Texas at Austin Bureau of Economic Geology Studies (Gregory and others, 1980; Bebout and others, 1982). Areas with the highest temperatures and pressures occur downdip (southeast) and in the northeast. These downdip areas have low salinities, but porosities are also low. Higher porosities and thicker sandstones generally coincide with lower temperatures and pressures. However, in general, the entire region outlined has fair to good geopressured-geothermal potential."

The earlier described characteristics of the geopressured resource in the Mirando Trend (hotter, more gas, lower TDS) are from unpublished data made available to the author.

The S-Cubed reservoir modeling work was reported by Dr. David Riney (Riney, private communication, 1990).

During FY 1989 S-Cubed developed a three-dimensional heterogeneous reservoir simulation model for the Pleasant Bayou geopressured resource. The model employs a reservoir configuration, based on geologic studies by the UTA Bureau of Economic Geology, consisting of a main high-porosity sandstone layer sandwiched between low-porosity layers which represent thinner, more isolated sandstones that are considered to comprise the "remote volume" of the reservoir. BEG estimates the total C-Zone reservoir volume to be about 8.0 billion barrels and concludes that most of the sandstone in the remote volume is interconnected by circuitous flow paths around shale interbeds and internal faults with the main reservoir sandstone in which the well has been perforated. The effective pore volume of the C-zone is estimated to be between 6.2 and 6.6 billion barrels.

S-Cubed synthesized information from various researchers to develop the input parameters required to construct a reservoir simulation model within the BEG configuration. The model employs rock properties measured on core samples by the UTA rock mechanics group, fluid properties measured at various laboratories, data from the current production testing of Pleasant Bayou Well No. 1 by IGT/EOC, and S-Cubed's interpretation of pressure transient tests at the well during 1980 and 1988-89. The hydrologic boundaries detected by the pressure data were correlated with the geologic faults mapped by BEG.

Recently, the S-Cubed Pleasant Bayou reservoir simulation was extended in time using the test well production history from May 26, 1988 (test day 0) through January 31, 1990 (test day 584). The model continues to match the reservoir response over the full 584-day production history. The data points include the bottomhole measurements during May 26-June 1, 1988 multi-rate drawdown/buildup test and values estimated from wellhead recordings during 1988-1990 production testing using a calibrated wellbore flow model.

The reservoir model will be used as a tool for synthesizing and integrating new data from measurements being made under the continuing test program being conducted by DOE at the Pleasant Bayou site.

During 1989-1990 the total available data sets from the Gladys McCall test well have been re-evaluated. Analysis of the pressure transient data from the four separate downhole tests has shown that both the drawdown and buildup portions of the Reservoir Limits Test infer a near-well transmissivity of kh = 44,090 md-ft, whereas all three subsequent tests infer a transmissivity of kh = 28,340 md-ft for Sand Zone 8. Analysis of the change in the wellhead pressure, just prior to and just after shut-in following periods of stable flow, infer values of the skin factor that are related to the effective stress on the formation adjacent to the wellbore. It is reconfirmed that when scale inhibitor pills were injected the skin factor also abruptly increased and that the most plausible explanation for the change in near-well kh value is plugging of Sand Zone 8 below the shale stringer present near the center of the zone (since November 1984). Recalibration of the wellbore flow model using all available profile data has allowed better estimates of bottomhole pressure values from wellhead recordings.

The depositional model for Gladys McCall provides a geological basis for much larger reservoir lateral dimensions than were assumed in earlier simulation calculations. The lack of information for the actual reservoir properties away from the test well require that the simulated production history be repeated in a series of calculations in which the assumed values were varied and the final choices represent "effective reservoir parameters" that provide the best history match. The enlarged reservoir with heterogeneous properties has permitted a good match to the complete data available.

The connected pore volume for the enlarged reservoir model is 7.8 billion barrels. This value may be compared with the estimate of 2.5 billion barrels made in August 1985 and used in earlier simulations. In contrast to the Pleasant Bayou case, the geological information at Gladys McCall was too limited to allow the construction of a reservoir model configuration with a pre-test estimate for the connected pore volume.

Drs. Dean Keeley, John Meriwether, and Mr. William Koon of the University of Southwestern Louisiana are conducting geochemical research on the fluids produced from geopressured wells. Specifically, they are studying the dynamics of the production of dissolved aromatic hydrocarbons from the various wells and the physical and chemical characteristics of the nearly 100 compounds that make up the dissolved aromatics.

In addition to this basic work, the research team has recently developed two devices which have the potential to be applied in other research and industrial endeavors.

The first of these devices is the gas scrubbing system installed at the Pleasant Bayou Well. The inlet gas is dispersed through fritted metal into a high molecular weight oil. The compounds of interest from the gas are partitioned in the oil and vapor until they reach equilibrium. After collection, the samples are sealed and returned to the laboratory where head space/gas chromatographic analyses are used to determine the collected compounds. The vapor pressure of the collected compounds can be increased by raising the temperature of the oil during analysis to detect compounds which had very low concentrations in the original gas. This system can be used to collect and detect compounds in the air or other gaseous media. The system should find application in environmental analyses.

One of the chemical parameters that is required for the study and operation of geopressured wells is the pH of the flowing brine (it changes rapidly when a sample is removed to atmospheric pressure). The research team including Chen Jie, a graduate student from China, is testing a new pH probe based on ISFET technology (Ion Sensitive Field Effect Transistors). These probes are rapidly coming into general laboratory use, but have not been tested under the harsh environment found in geopressured brines. A high pressure test cell with a heater will be used to simulate well conditions. The research group has already tested probes at various temperatures (at low pressures) in the experimental setup. The probes have so far performed very well.

The ISFET probes should also find application in many industrial environments where the pH must be measured in harsh process streams.

INDUSTRIAL CONSORTIUM FOR THE UTILIZATION OF THE GEOPRESSURED-GEOTHERMAL RESOURCE

An industrial consortium planning meeting was held in September, 1989, at Eaton Operating Company, Houston, TX. This planning meeting was attended by 35 participants, fifteen of whom were from industry. On January 10, 1990, the first consortium meeting was held to present industry cost-shared proposals for utilization of the resource. Sixty-five participants convened at Rice University, Houston, TX, two-thirds of whom represented industry. Cost-shared proposals included: (1) thermal enhanced oil recovery, (2) integrated systems (agriculture/aquaculture), (3) conversion of thermal and hydraulic energy, and (4) use of supercritical water for detoxification of pollutants. Areas for resource utilization and cost-shared proposals are shown in Figure 4. The proceedings from this consortium have been compiled into two volumes that are available to interested parties. Direct use projects are covered in the paper by Mr. Ben Lunis; Use of Supercritical Fluids by Ms. C. Rofer; Thermal Enhanced Oil Recovery by C. Kimmell, and Modular Conversion by Mr. K. V. Nichols.

A proposed consortium charter was reviewed and made available for comments and discussion. Comments are due to Dr. J. Negus-de Wys at INEL by April 30, 1990, after which a final draft will be sent out for approval and signatures. Consortium funds will be escrowed with the Geothermal Resource Council in an interest bearing account with a moderate fee to GRC.

Interest and response to the January consortium meeting have been excellent, with an average of two new calls per week. The mailing list is approaching 200. Dr. David Goldstein of the Naval Surface Warfare Center (NSWC) has submitted a topic to the Naval SBIR to develop a Nitinol (shape memory alloy) heat engine to be tested on a geopressured-geothermal well. The Western Resources Technology Company has obtained a geopressured well in Calcasieu Parish near Hayes, LA. They have obtained the funds to work over the well and plan to develop the gas, install a heat transfer system, and try secondary hydrocarbon recovery. This is a direct spinoff from the Industrial Consortium activities. DOE will make technology available through the Oregon Institute of Technology, Eaton Operating Company, the Ben Holt Company, and the Institute of Gas Technology.

FUTURE PLANS

The next meeting of the consortium is Tuesday, September 11, 1990, at the University of Texas. The organization sequence for the Consortium is shown in Figure 5. Interested industries or individuals may contact Dr. J. Negus-de Wys at the Idaho National Engineering Laboratory (208/526-1744) or Dr. Myron Dorfman at University of Texas at Austin (512/471-7265).

Maps showing the location of known geopressured-geothermal reservoirs in Texas and Louisiana Gulf Coast are shown in Figures 6 and 7. Theoretical locations of geopressured basins in California are shown in Figure 8 (Berry, 1977). Geopressured-Geothermal wells in the present program will be made available to industry for utilization projects in the next two years.

An estimate of the percentage of wells producing from geopressured reservoirs along the Texas Gulf Coast was made in 1987 by Timothy Jackson and Malcolm Light then at the UTA Bureau of Economic Geology. They concluded from 1983 data that 2% of the producing wells were producing from geopressured reservoirs; however, some of those reservoirs would not be considered viable. The data base included 50,938 actively producing wells, of which 989 gas wells and 35 oil wells were producing from geopressured reservoirs. By Texas State law, inactive wells must be plugged and abandoned. Thus, to obtain wells for utilization in the geopressured program it would be necessary to negotiate during the latter term of production or prior to plugging and abandoning. These numbers would suggest that at the 1983 drilling level an estimated 2,000 wells might be among candidates for utilization in the Texas and Louisiana Gulf Coast on-shore area with 1989 total drilling effort about 10% of that in the 1983 study, this estimate is reduced to 200 wells for 1989 alone.

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REFERENCES

1. Bebout, D. G., Weise, B. R., Gregory, A. R., and Edwards, M. B., 1982, Wilcox Sandstone Reservoirs in the Deep Subsurface Along the Texas Gulf Coast--Their Potential for Production of Geopressured-Geothermal Energy: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 117, 125 p.

2. Berry, F. A. F., 1973, High Fluid Potential in California Coast Ranges and their tectonic significance, Bull. Am. Assoc. Pet. Geol., 57: 1219-1249.

3. DOE/EIA, Energy Monthly Review, August 1989. DOE/EIA-0035 (May 1989).

4. DOE, 1989, Geothermal Energy Program Summary, Volume 1: Overview Fiscal Year 1988, Geothermal Technology Division, U.S. Department of Energy, Washington, DC, p.11.

5. Eaton, B.C., C. R. Featherston and T. E. Meahl, 1988. U.S. Gulf Coast DOE Geopressured-Geothermal Energy Program Field Research Site Operations FY-1986 to Present Accomplishments and Goals, Proceedings, ASME Geothermal Energy Symposium, New Orleans, LA.

6. Eaton Operating Company, Monthly Status Report, February 28, 1989.

7. Fertl, W.H., G.V. Chilingarian, and H. H. Rieke III, 1976. Abnormal Formation Pressures, Elsevier Scientific Publishing Co., New York, 382 pp.

8. Gregory, A. R., Dodge, M. M., Posey, J. S., and Morton, R. A., 1980, Volume and Accessibility of Entrained (Solution) Methane in Deep Geopressured Reservoirs--Tertiary Formations of the Texas Gulf Coast: The University of Texas at Austin, Bureau of Economic Geology, p. 17-20.

9. Hamlin, H. S., and Tyler, Noel, 1988, Consolidation of Geologic Studies of Geopressured-Geothermal Resources in Texas: The University of Texas at Austin, Bureau of Economic Geology, Annual Report prepared for the U. S. Department of Energy, Advanced Technologies Division, under Contract No. DE-FC07-85NV10412, 45 p.

10. Negus-de Wys, J., 1989, Geopressured-Geothermal Well and Brine Characteristics and Opportunities for Industrial Utilization, Geothermal Review VII, San Francisco, California, proceedings.

11. Plum, M. M., J. Negus-de Wys, D. D. Faulder, and B. C. Lunis, 1989, Economic Review of the Geopressured-Geothermal Resource with Recommendations, Idaho National Engineering Laboratory, Idaho Falls, ID, EGG-2581, work performed under DOE Contract No. DE-AC07-76ID01570.

12. Strongin, O., 1981, Identification of Geopressured Occurrences Outside of the Gulf Coast, Phase II, Final Report, Science Applications, Inc., McLean, VA. 22102 Prepared for DOE, Nevada Operations Office, Las Vegas, Nevada 89114, Under Contract No. DE-AC08-80NV10133.

13. Wallace, R.H. Jr., T.F. Kraemer, R.E. Taylor, and J.B. Wesselman, 1978, Assessment of Geopressured Resources in the Northern Gulf of Mexico Basin, in Assessment of Geopressured Resources of the United States, L.J.P. Muffler, ed. U.S. Geological Survey Circular 790.

Table 1. Wells, Brine, and Reservoir Characteristics for the Three Department of Energy Wells[1]

	Gladys McCall	Pleasant Bayou	Hulin[2]
Depth of Reservoir (ft)	15,831	16,465	21,546
Maximum Flow Rate (bbd)	40,000	25,000	15,000
Bottomhole Pressure (psia)	12,784	9,800	18,500
Flowing Wellhead Pressure (psia)	2,000	3,000	3,500[3]
Bottomhole Temperature (°F)	298	302	360
Flowing Wellhead Temperature (°F)	268	292	330
Gas/Water Ratio (scf/bbl)	27	24	34
Methane (% of gas)	85	85	93
CO_2(% of gas)	9.7	10	4
Estimated Reservoir Size (billion bbls)	4	8	14
Total Dissolved Solids (mg/L)	95,000	127,000	195,000
Chlorides (mg/L)	57,000	70,000	115,000

[1] Resource Estimates

[2] Short Term Testing Only

[3] 7,500 psia Shut-in WHP

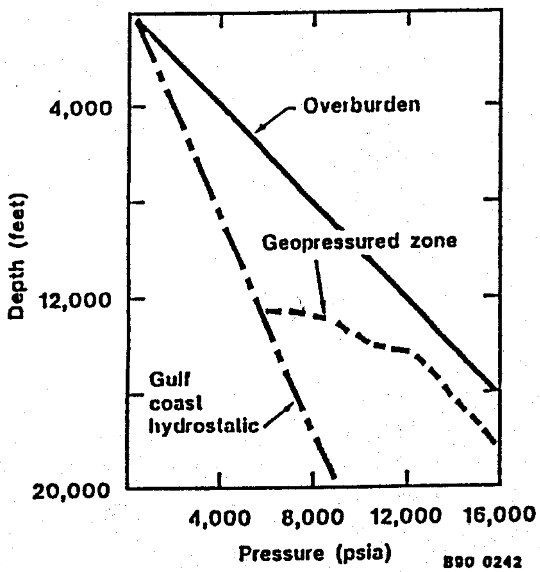

Figure 1. Geopressured-Geothermal Zone Characteristics

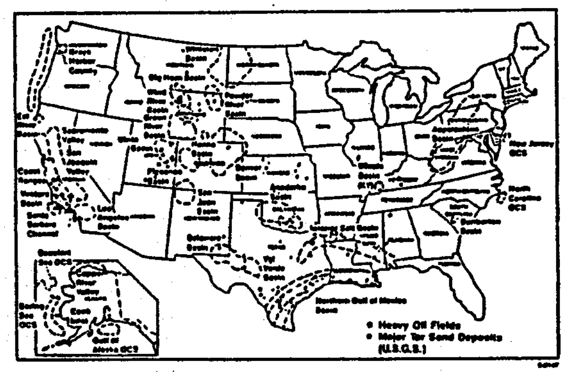

Figure 2. Location of Geopressured Basins, Heavy Oil Fields, and Major Tar Sands in the U.S.

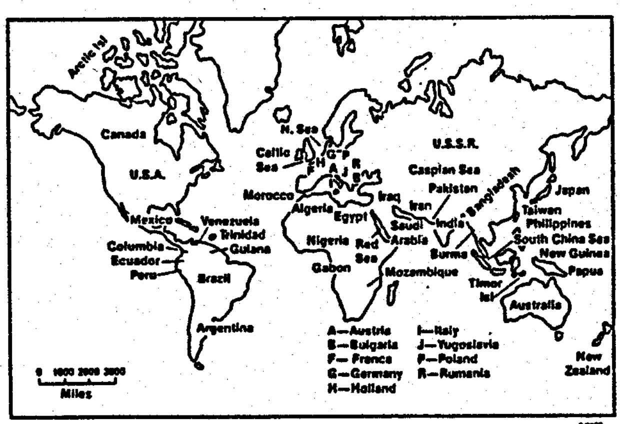

Figure 3. Worldwide Occurrence of Abnormal Formation Pressures (after Fertl, 1976).

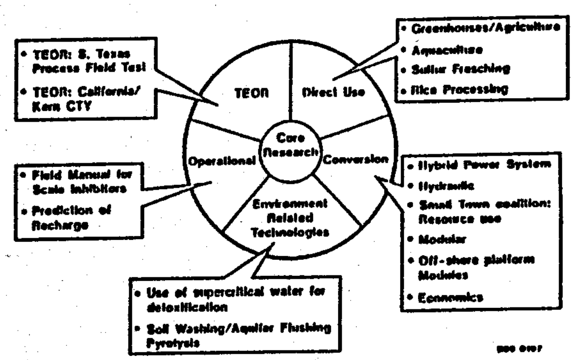

Figure 4. Utilization of the Geopressured-Geothermal Resource

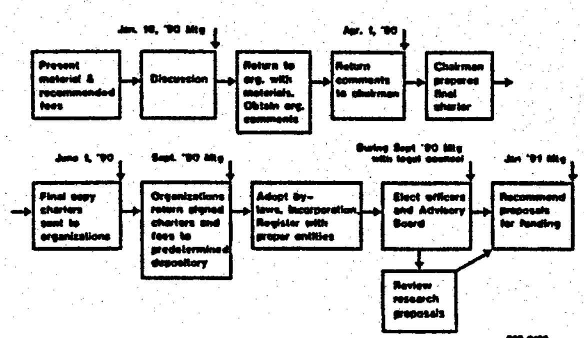

Figure 5. Sequence of Organization for the Industrial Consortium

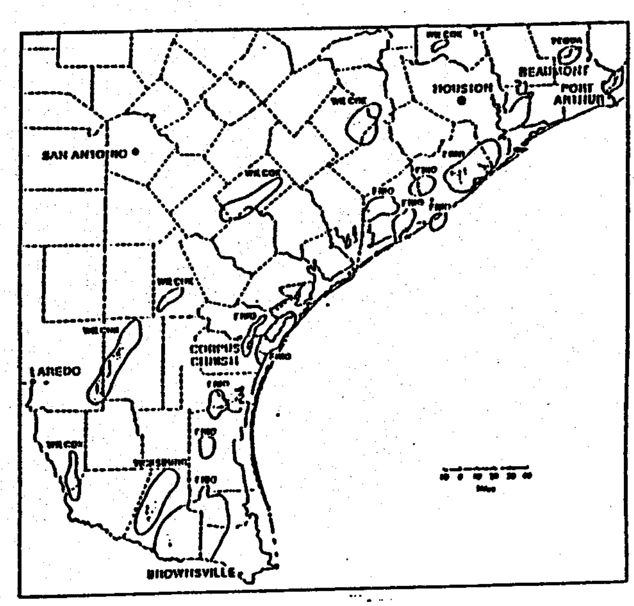

Figure 6. Geopressure Aquifers in Texas (UTA-BEG, 1990, personnel communication).

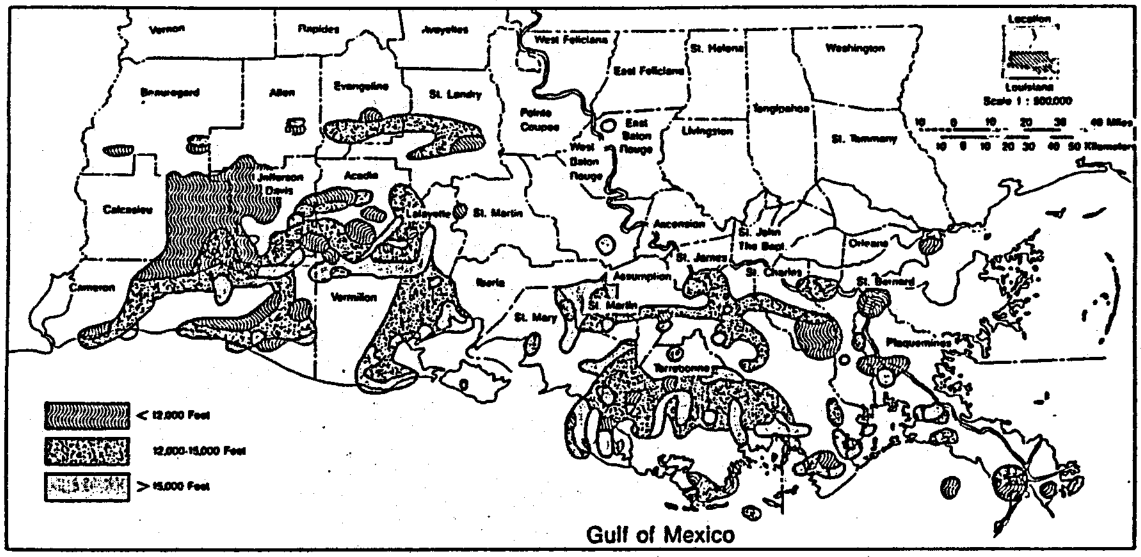

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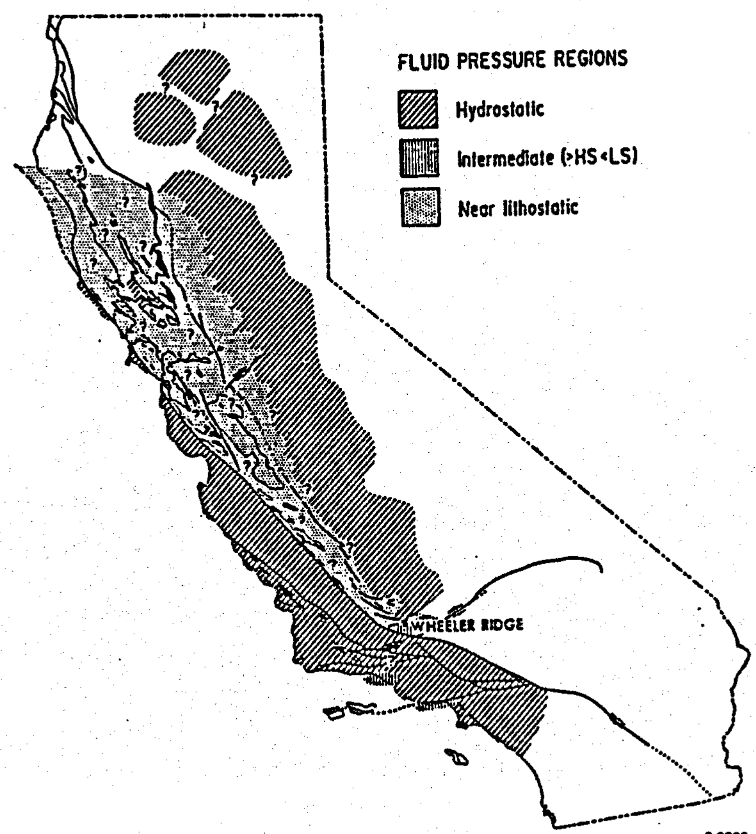
Figure 7. Geopressured Reservoirs in Louisiana Shown in Three Depth Ranges (LSG, 1990, private communication).



6-0208

Figure 8. Fluid Pressure Regions (Berry, 1973)