DOE/NV/10174--T1

DE84 016279

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

DOE/NV/10174--T1

RESULTS FROM GEOPRESSURED-GEOTHERMAL SUBSIDENCE STUDIES

TRAHAN, Drukell B.*

Benchmark networks have been installed around each of the U.S. Department of Energy geopressured-geothermal test sites in southwestern Louisiana. These networks are periodically surveyed to detect subsidence which may be attributable to depressurization of the geopressured-geothermal reservoirs. The acquired leveling data have been adjusted to account for regional base-line movement determined in another study.

The effects of geopressured-geothermal development can only be assessed after carefully examining other potential causes of subsidence. The histories of oil and gas production and ground-water withdrawal around the geopressured-geothermal test site at Parcperdue indicate that oil, gas, and ground-water production may contribute much more to anomalous subsidence than recent geopressured-geothermal brine production.

A trend-surface analysis of leveling data for the Parcperdue test site allowed for the separation of a regional component of movement attributable to uplift in the Iberian structural axis to the east and subsidence above a Pleistocene depocenter to the west of the test site. Residual deviations from the regional trend may be associated with the temporary loading and compaction of surface soils caused by the weight of drilling equipment and with ground-water withdrawal.

*Louisiana Geological Survey, Box G, University Station, Baton Rouge, Louisiana.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RECEIVED
MAY 1984

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

840

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Introduction

Comparison of repeated leveling surveys at geopressured-geothermal test sites in southwestern Louisiana should provide information on natural and man-induced vertical movements of the land surface. Natural movement in these areas may be associated with structural uplift of salt domes or with subsidence due to compaction of young soils in alluvial valleys. Man may cause subsidence through marsh reclamation by drainage or by oil, gas, and ground-water withdrawal.

Because measured subsidence rates may reflect the effects of historical fluid production in these areas, the use of models which incorporate production data from individual oil, gas, and ground-water wells and fields would be necessary. Correlations could be made with fluid volumes, reservoir geometries, and pressure changes during production. Some of these data have been obtained for the geopressured-geothermal program, but only for the geopressured-geothermal wells. Preliminary data are presented here for the other wells and fields around the Parcperdue geopressured-geothermal test site south of Lafayette, Louisiana. Similar data for other test sites are also being gathered.

Comparisons of leveling data were made using the base-line subsidence rates calculated by Trahan (1984, this volume) for reference. A trend-surface analysis was used to separate regional and local components of subsidence and to attempt correlations with structural elements, geomorphic elements, and producing well fields.

Discussion

The effect of geopressured-geothermal production on subsidence rates may only be assessed after careful examination of historical production of oil, gas, and ground water in the area surrounding each test site. Because of a potential time lag between production and subsidence, consideration must be given to some minimum backlog of data. For this purpose, an arbitrary period of six years has been chosen. In addition, cumulative production from each field has been considered. Subsidence monitoring is most complete in the area around the Parcperdue geopressured-geothermal test site, and that data is examined here.

The fields producing oil, gas, or both near the Parcperdue test site are Parcperdue and North Parcperdue (Fig. 1). The North Parcperdue field, dating back to 1972, has the greatest total historical production. Cumulative production to October 1983 is given below:

Crude:	209,166 bbl (barrels)
Condensate:	2,109,384 bbl
Natural gas:	74,677,992 MCF (thousand cubic feet)
Casing-head gas:	703,349 MCF

Monthly production data from January 1978 to October 1983 are given in Table 1. Yearly production of liquid petroleum for this period

averages about 250,000 bbl (figures are for condensate alone up to July 1982, then for condensate and crude to the end of record). Total monthly production per year increased through the period (Table 1). A similar trend is apparent for gas production (Table 2).

Of the 15 wells drilled in the North Parcperdue field, 3 were dry holes that are now plugged; 3 have been plugged and abandoned (of these, 2 produced for some time); and 9 are producing (Table 3). The perforated intervals in the producing wells range from 3658 to 4877 m (12,000-16,000 ft) deep and average 4552 m (14,933 ft). The thicknesses of these intervals range from 2 to 19 m (7-62 ft) and average 9 m (29 ft). Ten of these wells have produced gas and only one has produced crude oil.

The Parcperdue field, the oldest in the area (1959), is located about 1067 m (3500 ft) west of the North Parcperdue field. Although Parcperdue was discovered much earlier than North Parcperdue, its production history has been somewhat limited. The Parcperdue field now produces only crude oil and casing-head gas in much lower quantities than North Parcperdue. Since its discovery, the Parcperdue field has produced the following cumulative totals:

Crude:	1,352,403 bbl
Condensate:	50,292 bbl

Natural gas:	2,345,889 MCF
Casing-head gas:	3,608,197 MCF

Crude production, which decreased steadily from January 1978 to September 1982, varied from 370 to 110 bbl per month per year (Table 4). Production of casing-head gas was more variable, beginning at 765 MCF per month in 1978 and then decreasing roughly one order of magnitude in 1979, 1980, and for half of 1981. Production increased more than ten-fold in August 1981 and has remained steady for most of the remaining record (Table 5).

The Parcperdue field has been relatively nonproductive. Seven wells drilled in the field were dry, two wells produced but were then plugged and abandoned, one is producing, and one is temporarily shut in (Table 6). The average depth to the producing intervals is 4088 m (13,411 ft), and the intervals are 1.5 to 4 m (5-14 ft) thick. Two wells have produced crude oil and one has produced gas. The geopressured-geothermal well has produced from an interval 17 m (57 ft) thick at a depth of 4086 m (13,406 ft). This well produced 1,940,000 bbl of brine and 31,500 MCF of gas during its short production history. Two saltwater disposal wells inject oil-field brines into shallow aquifers above the Parcperdue field. The DOE saltwater disposal well injected into an interval 1420 m (4650 ft) deep and 43 m (140 ft) thick. Another well, exact location unknown, injects fluids into a shallower horizon 655 m (2150 ft) deep and 6 m (20 ft) thick.

The limits of the producing fields (Fig. 1) are generalized. Production is actually concentrated along a band approximately 152 to 305 m (500-1000 ft) wide, which is bounded to the north by the northernmost

fault defining the Parcperdue fault block. All wells producing in this trend are considered to be in the North Parcperdue field. Another trend, which is 305 to 610 m (1000-2000 ft) wide, extends from the major trend to the southwest through sec. 34, T. 11 S., R. 4 E. Most wells in this trend are considered to be in the Parcperdue field.

The chief use of ground water in the Parcperdue area has historically been rice irrigation. Although total rice acreage has decreased during the last few years, rice irrigation still outweighed other uses during the period 1978-83. Ground-water production was estimated by calculating rice acreage during each of the years shown (Table 7). A review of aerial photographs, discussions with various area agricultural officials, and crop yield reports revealed the locations and acreages supplied by each well. The amount of water required for rice irrigation has been estimated at 30 acre-inches per year. By multiplying the acreage supplied by each well by this factor, ground-water production was calculated (Table 7).

Water from six wells is used to irrigate rice primarily during April and May. Total ground-water production in the area from April 1978 to May 1983 was approximately 62,110,000 bbl, most of which was concentrated at two wells (Table 7). Average production by well was 10,350,000 bbl for the same period. The two major producing wells each discharged about 4,000,000 bbl per year. These wells are 70 to 91 m (230-300 ft) deep and are located 3.2 km (2 mi) southeast and 2.4 km (1.5 mi) south-southwest of the test site, respectively (Fig. 2).

The subsidence monitoring data for the Parcperdue test site has been referenced to the movement of a benchmark in Lafayette along the survey line which traverses south Louisiana from Orange, Texas, to Baldwin, Louisiana. Base-line movement along this line was determined in a separate study which referenced all movements from north to south Louisiana to the movement of the Monroe uplift in northeastern Louisiana (Trahan, 1984, this volume).

The Symap procedure (Dougenik and Sheehan, 1977) was used to contour the velocities of movement and to establish weighted trend surfaces for the periods 1980-81 and 1981-83. In both instances, the second-order trend surface was most significant and indicated a general southeast-northwest trend toward greater subsidence in the area (Figs. 3 and 4). This trend is possibly due to uplift of the Five Island salt dome ridge to the east and southeast and to subsidence of a depocenter formed by Pleistocene Red River alluviation to the west and northwest of the test site.

Residuals off the general trend are considered to represent subsidence anomalies not associated with regional subsidence. The residuals mapped on the 1980-81 velocity surface (Fig. 5) are consistent with the unweighted contour pattern (Fig. 6), indicating significant variability from the general trend. One subsidence anomaly, centered in the Parcperdue test site, may be due to the temporary loading and compaction of the surface caused by the weight of the drilling equipment. That same anomaly is not evident for the second period of monitoring probably due to release of the static load after removal of the drilling equipment

(Fig. 7). However, one anomaly, located about 1.6 km (1 mi) south of the test site, is persistent during both periods. This anomaly would coincide well with the Parcperdue producing trend if the stresses above the compacting reservoir were offset to the east.

Summary

The analysis of subsidence will continue as more data become available for Parcperdue and for the other design well prospects. The important considerations in oil-field subsidence analyses are 1) the reduction in reservoir pressure, 2) the rate and degree of pore pressure reduction, and 3) the uniaxial compaction coefficient (Geertsma, 1973).

The reduction in reservoir pressure is a function of the mobility, solubility, density, and compressibility of fluids as well as reservoir boundary conditions. Pore pressure reductions depend on the permeability distribution, well locations, and production rate. The compaction coefficient depends on rock type (the number, size, and shape of grain contacts in sandstones), the degree of cementation, porosity, and depth of burial.

The effect of geopressured-geothermal development on subsidence rates will not be instantaneous. A lag in the transfer of stresses to the surface is expected for geopressured-geothermal development and for other fluid production activities. The effect of historical fluid production may be apparent in our data. Modeling studies which take into consideration the production histories of the producing fields; changes in pressures, depths, and production volumes; and other factors will be attempted in the future.

Some of the data necessary for such an analysis are presented here, although much more will be necessary. Ground-water production may also cause subsidence of the land surface; however, the mechanism for compaction is different than that for deeper oil and/or gas reservoirs. In most cases, changes in pressure in shallow aquifers are small due to a relatively steady recharge into these aquifers. Subsidence can occur if the piezometric head is lowered significantly due to a low water budget (that is, discharge exceeds recharge). Therefore, future work will also include an analysis of these conditions.

References

- Dougenick, J. A., and D. E. Sheehan, 1977, Symap user's manual: Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard.
- Geertsma, J., 1973, Land subsidence above compacting oil and gas reservoirs: *Jour. Petr. Technology*, June, p. 734-44.
- Trahan, D. B., 1984 (this volume), Regional and local subsidence in Louisiana: Conference on Compressibility Phenomena in Subsidence, Engineering Foundation, New York.

FIGURE 1. Net sand isopach of *Cibicides jeffersonensis* sandstone, Parcperdue oil and gas fields, Louisiana.

FIGURE 2. Fluid production near the Parcperdue geopressured-geothermal prospect.

FIGURE 3. Weighted second-order trend surface, change in elevation (mm/yr), Parcperdue geopressured-geothermal test site, 1980-81.

FIGURE 4. Weighted second-order trend surface, change in elevation (mm/yr), Parcperdue geopressured-geothermal test site, 1981-83.

FIGURE 5. Second-order residual surface, change in elevation (mm/yr), Parcperdue geopressured-geothermal test site, 1980-81.

FIGURE 6. Contoured velocity surface, change in elevation (mm/yr), Parcperdue geopressedured-geothermal test site, 1980-81.

FIGURE 7. Second-order residual surface, change in elevation (mm/yr), Parcperdue geopressured-geothermal test site, 1981-83.

TABLE 1. Production of liquid petroleum (in barrels)
from North Parcedue field (Figures for January 1978
through June 1982 are for condensate only; figures for
crude and condensate are combined as of July 1982.)

<u>YEAR</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>
1978	4,613	3,495	3,813	3,652	3,250	2,464	1,967
1979	19,007	14,440	15,332	12,532	12,781	12,144	18,409
1980	21,199	20,834	19,415	18,022	20,792	21,103	22,404
1981	20,151	16,906	17,477	17,146	18,288	17,736	18,998
1982	28,346	25,051	28,176	28,227	45,336	37,962	31,417
1983	37,265	33,953	36,666	35,486	36,107	35,932	32,760

<u>YEAR</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Total</u>	<u>Average</u>
1978	857	280	343	448	6,057	32,237	2,603
1979	19,111	18,526	21,402	20,335	20,698	204,717	17,060
1980	21,931	23,028	24,784	20,595	21,290	255,397	21,283
1981	18,996	17,994	20,890	23,987	27,180	235,749	19,646
1982	27,647	29,069	29,296	29,827	30,557	370,911	30,909
1983	32,458	31,807	24,736	—	—	337,170	28,097

Table 2. Production of natural gas (in thousands of cubic feet)
from the North Parcedue field. (Figures for natural and
casing-head gas are combined as of July 1982.)

<u>YEAR</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>
1978	179,700	144,904	166,947	155,757	149,302	115,844	100,575
1979	518,161	581,654	474,361	255,157	262,540	253,299	504,263
1980	694,773	646,404	513,193	471,032	617,052	664,018	688,802
1981	597,537	476,600	469,838	491,540	524,832	506,600	546,848
1982	1,437,415	1,288,569	1,381,845	1,368,730	1,598,032	1,319,992	1,107,584
1983	1,311,464	1,164,429	1,296,182	1,273,905	1,219,300	1,301,371	1,095,594
<u>YEAR</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Total</u>	<u>Average</u>
1978	54,314	37,031	37,723	50,906	179,462	1,372,015	114,335
1979	516,799	542,078	691,722	673,374	707,090	5,980,498	498,374
1980	665,297	711,068	776,055	625,463	633,724	7,706,881	642,240
1981	567,351	555,226	675,080	1,239,699	1,395,373	8,046,524	670,544
1982	917,281	1,012,311	1,030,654	1,080,751	1,147,449	14,690,613	1,224,218
1983	1,143,973	1,136,626	858,266	11,801,110	—	22,432,220	2,039,293

TABLE 3. Data for wells in the North Parcedue oil and gas field.

	Section Township, and Range	North Latitude	West Longitude	Perforated Interval Bottom Depth and Thickness (ft)	Total Depth (ft)	Type Fluid Produced*	Completion Date (mo/d/yr)
DRY AND PLUGGED	22,11 S.,04 E.	30°04'23"	92°02'43"	0	17,500	0	09/27/76
	26,11 S.,04 E.	30°03'19"	92°02'06"	0	17,736	0	03/26/74
	27,11 S.,04 E.	---	---	0	16,014	0	0
PLUGGED & ABANDONED	23,11 S.,04 E.	30°04'12"	92°01'52"	15,814 & 56	17,190	2	06/12/74
	27,11 S.,04 E.	30°03'53"	92°02'38"	15,590 & 17	18,000	2	08/06/73
	55,11 S.,04 E.	---	---	0	17,850	0	0
ACTIVE — PRODUCING	26,11 S.,04 E.	30°03'47"	92°02'15"	15,720 & 32	16,560	2	09/17/72
	26,11 S.,04 E.	30°03'42"	92°02'15"	13,196 & 42	13,317	2	09/04/78
	27,11 S.,04 E.	30°03'36"	92°03'09"	14,424 & 12	15,750	2	03/23/73
	52,11 S.,04 E.	30°03'03"	92°03'37"	15,553 & 62	15,650	2	07/13/78
	54,11 S.,04 E.	---	---	15,820 & 43	16,526	2	04/15/81
	54,11 S.,04 E.	---	---	13,110 & 26	13,250	1	04/06/82
	55,11 S.,04 E.	---	---	15,820 & 7	16,923	2	10/05/81
	55,11 S.,04 E.	---	---	15,798 & 16	16,040	2	11/03/82
	40,12 S.,04 E.	---	---	13,736 & 9	17,975	2	06/10/82

*0 = no fluid or brine only

1 = oil

2 = gas

TABLE 4. Crude oil production (in barrels)
from the Parcperdue field.

<u>YEAR</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>
1978	425	393	382	402	394	384	351
1979	307	282	298	306	208	295	303
1980	295	284	287	275	279	254	243
1981	218	213	227	109	196	187	206
1982	136	165	188	170	185	160	167
1983	171	154	169	153	164	6	42

<u>YEAR</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Total</u>	<u>Average</u>
1978	314	365	367	362	303	4442	372
1979	298	285	290	281	302	3455	288
1980	240	232	244	230	247	3110	259
1981	176	197	180	187	185	2281	190
1982	173	161	169	164	171	2009	167
1983	74	58	—	—	—	991	110

TABLE 5. Production of casing-head gas (in thousands of cubic feet)
from the Parcperdue field.

<u>YEAR</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>
1978	765	765	765	765	765	765
1979	73	73	73	73	73	73
1980	70	70	70	70	70	70
1981	70	70	70	70	70	70
1982	793	1023	1078	900	943	1031
1983	1097	1087	1108	982	1057	36

<u>YEAR</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>
1978	765	765	765	765	765	765
1979	73	73	73	73	73	73
1980	20	70	70	70	70	70
1981	70	891	934	844	1168	1289
1982	1198	926	893	1039	1055	1098
1983	292	705	687	---	---	---

TABLE 6. Data for wells drilled in the
Parcperdue oil and gas field.

	Section Township, and Range	North Latitude	West Longitude	Perforated Interval Bottom Depth and Thickness (ft)	Total Depth (ft)	Type Fluid Produced*	Completion Date (mo/d/yr)
DRY & PLUGGED	27,11 S.,04 E.	30°03'03"	92°03'00"	0	12,450	0	09/10/66
	33,11 S.,04 E.	30°02'45"	92°03'28"	0	15,274	0	11/19/65
	34,11 S.,04 E.	30°02'59"	92°03'11"	0	12,400	0	10/21/77
	35,11 S.,04 E.	30°02'40"	92°02'17"	0	17,330	0	04/16/75
	35,11 S.,04 E.	—	—	0	18,150	0	03/23/82
	41,12 S.,04 E.	30°01'41"	92°03'09"	0	18,224	0	03/17/71
	41,12 S.,04 E.	30°01'55"	92°03'11"	0	12,795	0	01/21/79
PLUGGED & ABANDONED	34,11 S.,04 E.	30°02'54"	92°02'47"	13,283 & 5	13,620	1	03/12/59
	34,11 S.,04 E.	30°02'33"	92°02'56"	14,818 & 8	15,368	2	12/28/59
ACTIVE—PRODUCING	34,11 S.,04 E.	30°02'50"	92°03'04"	12,297 & 9	13,500	1	10/21/67
SHUT-IN, PRODUCTIVE	34,11 S.,04 E.	30°02'50"	92°03'04"	13,280 & 14	13,500	1	10/12/59
GEOPRESSURED	26,11 S.,04 E.	—	—	13,406 & 57	13,612	0	08/16/81
SALTWATER DISPOSAL	26,11 S.,04 E.	—	—	4,660 & 140	5,011	—	02/28/82
	26,11 S.,04 E.	—	—	2,076 & 20	2,150	—	10/31/74

*0 = no fluid or brine only

1 = oil

2 = gas

TABLE 7. Ground-water production (in millions of barrels) from rice irrigation wells near the Parcperdue geopressured-geothermal prospect.

<u>YEAR</u>	<u>Well Number</u>								
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1978	4.76	----	5.98	0.27	----	----	0.78	1.76	----
1979	4.84	----	3.72	----	----	----	----	1.10	----
1980	4.84	0.23	3.03	0.28	----	----	----	0.45	----
1981	4.67	----	3.95	0.61	----	----	----	2.23	----
1982	4.17	1.37	3.56	0.52	----	----	----	1.87	----
1983	2.33	1.82	2.12	----	----	----	----	0.85	----
TOTAL	25.61	3.42	22.36	1.68	----	----	0.78	8.26	----