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THREE DIMENSIONAL SEISMIC INVESTIGATION OF THE GEOPRESSURED-GEOTHERMAL RESERVOIR
AT PARCERDUE LOUISIANA: DIRECT DETECTION OF PRODUCTION VOLUME

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ABSTRACT

Two three dimensional (3-D) seismic surveys are to be performed to investigate the geopressed-geothermal reservoir of the Dow/DOE Sweezy No. 1 well, Parcerdue Louisiana. 3-D surveys are superior to 2-D surveys for reasons of positioning of reflections on displays, availability of data surfaces and decreased interference of data. Two surveys are to be performed and specially processed to detect the actual volume of the reservoir which yields fluids upon production. Part of the special processing is subtraction of the first survey, pre-production, from the second survey, post production. If successful, these techniques promise to aid the industry in efficient production of geopressed-geothermal reservoirs.

INTRODUCTION

The Dow/DOE Sweezy No. 1 well in Parcerdue Louisiana is a designed geopressed-geothermal test well. It is to test a sand at 13370 ft known as the Cib Jeff (Cibicides Jeffersonensis) sand. One of the main purposes of this test well is to gain production data on a geopressed sand of known volume. The small reservoir at Parcerdue was chosen so that data could be obtained from beginning to depletion of the pressure drive in a reasonable period of time. It is expected that the pressure in this well will be depleted from about 12000 psi to about 8000 psi in nine months to a year.

In order for the data to be extrapolated to larger reservoirs, which may take on the order of twenty-five years to similarly deplete, the volume of the Parcerdue reservoir is needed. This reservoir was chosen because its extent is uncommonly well documented by both existing well control and existing CDP (common depth point) seismic lines. (Figure 1) However, even maps based on as much control as that in figure 1 involve considerable interpolation between control points many hundreds to thousands of feet apart and extrapolation into regions of no control. In addition the possibility of permeability barriers within the supposed reservoir, yet undetectable by well control or the available seismic data, still exists and may have major effects on the true producing volume of the reservoir. This paper is a brief description of a project which is in progress to better determine the true producing volume of the Parcerdue reservoir. To accomplish this goal we are performing two three-dimensional, 3-D, surveys of the area...one before fluid production and one after production.

Advantages of Three-dimensional Seismic Surveys

Three dimensional seismic surveys allow the reflection points to be put back where they belong in three dimensions not just two. Two dimensional surveys are typically acquired with source points and receiver points arranged in one line. If the subsurface consists of flat-horizontal layers, then the true reflection point for each source-receiver pair will be on the vertical plane containing the source-receiver line and under the point one-half way between the source and the receiver. If the subsurface layering deviates from this geometric restriction, then the true reflection point will not fall under the half-way point. Various techniques, known generally as two-dimensional migration utilize information from many source-receiver pairs in the line to move, or migrate, the reflected energy so that on a two-dimensional display the energy does not appear simply under the half-way point but appears in a position consistent with the component of dip of the reflecting horizons which is along the survey line. The effect of cross-dip, component of the dip of horizons perpendicular to the survey line, cannot be corrected for, because source-receiver pairs with mid-points along lines perpendicular to the survey line do not exist. Consequently, energy which

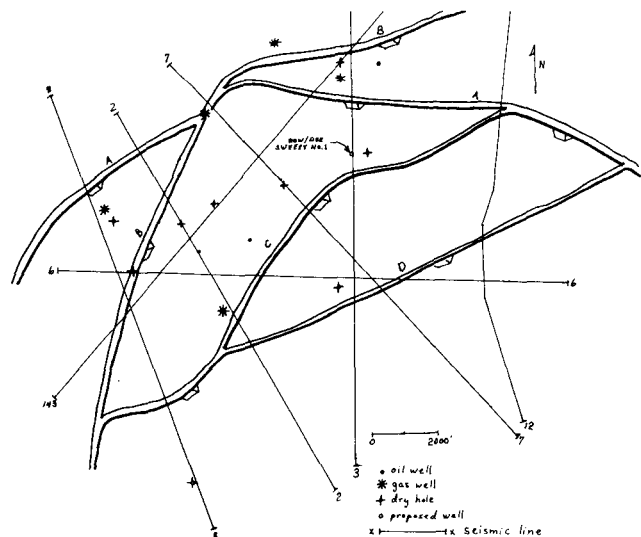


Fig. 1 Fault Map at Cib Jeff level showing well and seismic control. Reservoir apparently bounded by faults A, B and C. Adapted from Department of Energy (1980).

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was actually reflected from points not in the plane of the source-receiver line must, by default, be illustrated in the final display on a single sheet as if it had been reflected from points on that plane. This energy becomes superimposed on correctly placed energy, gets involved in the two-dimensional migration process, gets involved in other calculations performed on the data, and in general makes for confusion and loss of resolution in the final presentation.

The advantage of three dimensional data in migration is that reflection points exist throughout a volume allowing computations to be performed to correctly place true reflection points where they belong in the volume, consistent with the true dip of all horizons. These data are kept in a "volume" within the computer and can be accessed onto any two-dimensional sections through the volume which are desired. On these accessed two dimensional sections all energy is where it should be as the volume has been three-dimensionally migrated.

This ability to take any two dimensional section has other distinct advantages. It allows one to have a planar display under any line desired, not just under lines of sources and receivers. This flexibility has obvious advantages if one is at all aware of the geographical restriction on the placement of surface source-receiver lines or is aware of the desirability of having another section in another place as interpretation progresses. Since any two-dimensional section can be taken, one is no longer restricted to vertical sections. Now the uniquely desirable horizontal section is also available. On this section faults and strata appear much as they do on geologic maps. Since maps are usually the end result of interpretation of seismic data, the horizontal section makes a large step to the goal available directly from the seismic data volume. These advantages make maps from 3-D data more accurate because the resolution of the data is better and interpolations and extrapolations are nearly or completely eliminated.

Direct Detection of the Portion of the Reservoir from Which Fluids are Produced

The seismic properties of the Cib Jeff sand will change when the fluids are produced from it during the depletion. By performing 3-D surveys of the reservoir before and again after the depletion of the fluids, these changes may be detected. The area of the reservoir over which the changes are detected should coincide with the area from which the fluids were produced. As mentioned earlier this is an important factor in the reservoir evaluation.

The changes in the reservoir due to production and the detectable effects of the changes on seismic data are not well understood; however, the following five factors are expected to be important:

- 1) If free gas exsolves within the reservoir upon depletion of pressure, the two phase fluid would have a significantly reduced seismic velocity. Figure 2 illustrates that an increase in free dispersed gas from near or actually zero to a few percent yields a considerable reduction

in velocity. Calculations based on the planned pressure depletion indicate that about 1% by volume free gas may exsolve yielding, from figure 2, a decrease in velocity on the order of 1000 ft/sec. However, figure 2 is most relevant to a shallower sand with a lithification history different from the Cib Jeff sand. The seismic velocity of the Cib Jeff may be more dependent on the matrix and less on the pore fluids than that for figure 2.

- 2) Geopressed sediments generally have slower seismic velocities than non-pressured sediments because the pressure reduces the effective stress (non isotropic vertical component of stress) felt by the matrix. This reduction in effective stress reduces the ability of the matrix to pass the vertically traveling compressional waves and results in a lowered velocity. In our reservoir the change in pore pressure from 12000 psi to 8000 psi will result in an increase in effective stress of 4000 psi and possibly a velocity increase of about 2000 ft/sec.

- 3) Absorption of seismic energy in rocks is frequency dependent. Changes in the reservoir due to production may alter this frequency dependency. Free gas in the fluid would probably increase the absorption of high frequency signal resulting in a lowering of frequency of signals returned from the reservoir and below. Increase in effective stress would likely decrease absorption at high frequencies due to better transmission characteristics.

- 4) The density of the reservoir is likely to decrease as the compressed fluids are removed (compaction is not likely to be great enough to compensate or over-balance the effect of fluid removal). Density and velocity changes from 1) and/or 2) above will result in reflection strength changes according to the equation:

$$\text{Reflection Coefficient} = \frac{V_2 \rho_2 - V_1 \rho_1}{V_2 \rho_2 + V_1 \rho_1}$$

which gives the reflection coefficient of a media boundary where V_1 and ρ_1 are the velocity and density in the first medium and V_2 and ρ_2 are for the second medium.

- 5) Compaction of the reservoir is likely to occur. If the 75 gross feet of reservoir

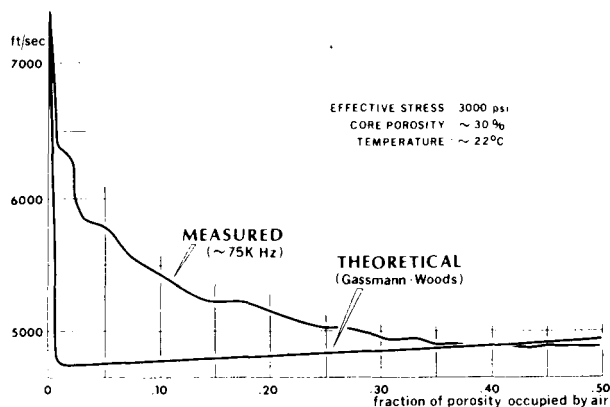


Fig. 2 Theoretical and Measured P-wave velocities versus free gas saturation in water in sand. Taken from Flowers (1976).

interval compacted only 7%, the top boundary of the reservoir would fall about 5 feet. If this compaction is taken up before it reaches the surface by elastic or anelastic mechanisms the distance to the reservoir will increase by 5 feet or the two way distance for reflection by 10 feet. These 10 feet, at a velocity of 10000 feet per second (roughly what is known from check shot surveys and sonic logs), would result in a reflection timing increase of .001 sec. The mechanisms for compensation for the compaction are also likely to create a zone of reduced velocity over the reservoir which will further increase two way travel time.

Each of these possible variations is small. In fact the real question is not whether there will be effects as described above but will the seismic method detect them? Two seismic sections, one from before and one from after production, processed and presented as normally done for petroleum exploration, e.g. variable area wiggly trace, are not expected to be enough different for an interpreter to detect differences. Recent progress in seismic processing and presentation allowing the seismic attributes of reflection strength, instantaneous frequency, instantaneous phase and instantaneous velocity to be separated and individually plotted (Taner and Sheriff 1977) and an innovation of this project, subtractive processing, will allow us to present and analyze the data in ways which will take full advantage of the ability of the seismic method to detect the small expected changes.

Subtractive processing is a technique being developed for this project. Basically the two data sets from the before and after surveys are to be subtracted from one another in the computer and the difference plotted. This subtraction is to be performed not only on the normal data but on the attribute data as well. Since the data volumes extend above, below and to all sides of the reservoir, the remainder should be zero (or reduced to noise) outside of the reservoir and show consistent changes only in those portions of the reservoir from which production occurred. It is expected that this subtractive technique will allow changes on the order of those predicted in 1) - 5) to be detected if they exist.

Modeling

To evaluate the data achieved and the differences found in the data in terms of subsurface conditions and changes, computer and physical models are also being studied. The University of Houston Seismic Acoustics Laboratory (SAL) has the equipment, software and experience to physically scale model subsurface situations and actually shoot scaled down seismic surveys over them. As well SAL has equipment, software and experience to perform computer modeling of seismic surveys. SAL is a subcontractor, with principal investigators John McDonald and Gerry Gardner, to this project to help plan the surveys and analyze the data based on the experience of their personnel and on model studies of the Parcperdue reservoir.

Shooting Plan

Geophysical Systems Corporation (GSC) is subcontracting to this project to perform the sur-

veys. The surveys will utilize vibrator energy sources and 1024 recording channels. The availability of a system with such a large number of channels and the vibrator energy sources was a major factor in choosing GSC as the subcontractor. The vibrators allow the survey to be performed with dense source spacing along existing roads and the many recording channels allow a dense subsurface data grid over a large area with a number of vibrator lines consistent with the roads available and little moving of the receiver lines. Figure 3 illustrates the general plan for each of the surveys. The three east-west lines are vibrator lines on roads. The north-south lines are receiver lines. The survey will progress with two receiver lines live as the source moves toward them. When the source reaches line one, the line will be turned off (removed) and the third line activated. This "leapfrogging" of active lines will progress across the area for each vibrator line. CDP lines will also be collected along each vibrator line in

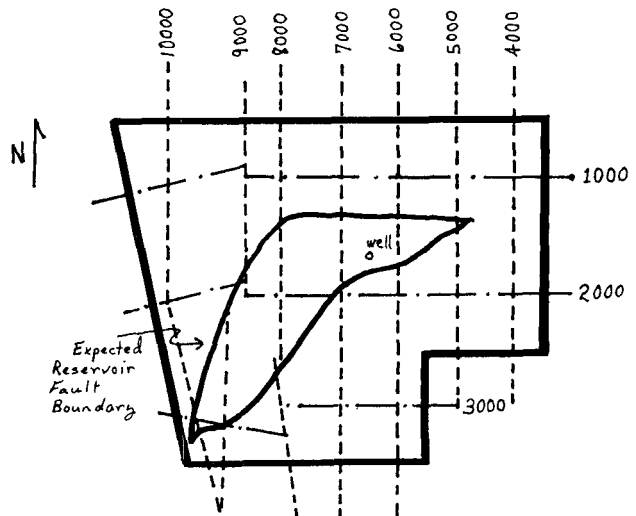


Fig. 3 Survey plan. Heavy line is boundary of expected subsurface 3-d coverage. E-W, dash-dot, lines are vibrator lines. N-S, dashed, lines are phone lines.

the conventional manner with phones in line with the vibrators. Each survey will yield about 800,000 seismic traces over seven square miles of 3-D data and 10.5 miles of CDP with subsurface depth point spacing of 27.5 ft. x 27.5 ft. for the 3-D and 27.5 ft. in line for the CDP.

Processing

GSC will provide initial processing of the 3-D and CDP data and the attribute processing. SAL will perform further processing on the 3-D data volume and the subtractive processing.

CONCLUSION

Though no data are available at the time this paper is going to press, this project prom-

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ises to yield data and insights of great importance not only to the Parcerdue Project but to the geopressured-geothermal program as a whole. If it can be shown that the producing volume can be directly detected, then over the lifetime of a commercial reservoir the drainage limits may be monitored by periodic seismic surveys and development of the resource accurately guided.

REFERENCES

Flowers, B. S., 1976, Overview of Exploration Geophysics - Recent Breakthroughs and Challenging New Problems: Bull. AAPG, V. 60 no.1, pp. 3-11.

Taner, M.T., and R.E. Sheriff, 1977, Application of Amplitude, Frequency, and Other Attributes to Stratigraphic and Hydrocarbon Determination, in Charles E. Payton, ed., Seismic Stratigraphy - Applications to Hydrocarbon Exploration Memoir 26: Tulsa, AAPG Press, pp. 301-327.

Department of Energy, 1980, Geopressured-Geothermal Drilling and Testing Plan Volume 1: Drilling and Completion Dow Chemical Co. - Dept. of Energy Dow-DOE Sweezy No. 1 Well Vermilion Parish Louisiana, p. 1-8.

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