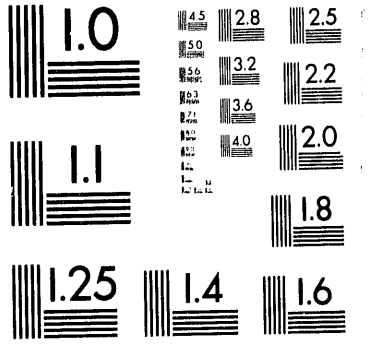
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2.8
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5.0
3.2
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1.8
1.25
1.4
1.6

1 of 1

2

PRRC 93-24

FIELD VERIFICATION OF CO_2-FOAM

DOE Grant No. DE-FG21-89MC26031

New Mexico Petroleum Recovery Research Center
New Mexico Institute of Mining and Technology
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Contract Date: September 29, 1989
Anticipated Completion Date: September 28, 1993

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Reporting Period: April 1 to June 30, 1993

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OBJECTIVE

This project is a cooperative industry-university-government effort to transfer laboratory research technology to a field demonstration test. The primary objective of the project is to evaluate the use of foam for mobility control and fluid diversion in a field-scale CO_2 flood. Seven tasks were identified for the completion of this four-year project: 1) evaluate and select a field site, 2) develop an initial site-specific plan, 3) conduct laboratory CO_2-foam mobility tests, 4) perform reservoir simulations, 5) design the foam slug, 6) implement a field test, and 7) evaluate results.

SUMMARY OF TECHNICAL PROGRESS

The East Vacuum Grayburg/San Andres Unit (EVGSAU), operated by Phillips Petroleum Company (PPCo), is the site selected for a comprehensive evaluation of the use of foam for improving the effectiveness of a CO_2 flood. The Petroleum Recovery Research Center (PRRC), a division of the New Mexico Institute of Mining and Technology (NMIMT), is providing laboratory and research support for the project. The four-year project is jointly funded by the EVGSAU Working Interest Owners (WIO), the U.S. Department of Energy (DOE), and the State of New Mexico. A Joint Project Advisory Team (JPAT) composed of WIO technical representatives from several major oil companies provides input, review, and guidance for the project. The project began in late 1989, and is now in the fourth and final year.

Fig. 1 shows the pattern (3332) selected for the foam injection test, the pattern injector (3332-001), and the observation well (3332-003) that was drilled to aid in evaluating the test. During this quarter, the results of the first foam test (July to October, 1992) were evaluated, and a second foam test

was initiated. A meeting of the JPAT was held in Socorro on June 30 to July 1, 1993, to review all of the data obtained from the project to date. This report summarizes the most important data and provides a status of the project.

RESPONSE FROM THE FIRST FOAM TEST

OCT 28 1993
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Producing Well Response

As reported in the last quarterly report, Well 3332-032 is showing a positive oil response and reduced gas production as a result of the first foam test. This well ceased flowing on about May 1, 1993, and a pumping unit was installed. Since then, the well has produced a steady 25 BOPD, and this production rate will serve as a baseline prior to the second foam test. As expected, this well is the first to respond to foam injection. Responses from other producers in the pattern area are being assessed.

Injection Well Response

The reduced mobilities observed during and following the first foam test were discussed in previous reports. The rate and pressure data for the foam injector are updated in Fig. 2.

As reported previously, injection profile tests suggest that much of the foam was probably generated in the higher permeability zones, but a slight improvement in injection profile was observed. Injection profiles obtained with CO_2 after the first foam test (see Fig. 3) suggest that the fluid distribution from the wellbore has returned to the distribution observed prior to the foam test. Thus, the effect near the wellbore was not a permanent profile modification. However, the pressure/rate data suggest that foam is still present away from the wellbore.

Analysis of the pressure transient data requires type-curve matching, thus the analysis is subjective and may be somewhat imprecise, especially because of the uncertainty of CO_2 saturation in the area analyzed and the marked influence of CO_2 compressibility. However, PPCo analyses of the pressure falloff tests and the injectivity data provide the mobilities shown in Table 1, and the mobilities calculated by the two methods are quite similar. These data suggest that the foam treatment reduced mobility of CO_2 by about one-third to one-half of the prefoam value.

Observation Well Logging

Results obtained during the logging program in the observation were presented this quarter at the SPWLA Annual Logging Symposium.[1] These results indicate that most of the fluid saturation changes as a result of the foam treatment occurred in the higher permeability subzones. During the CO_2 injection cycle at the end of 1992, an increase in CO_2 saturation in the high permeability C-2 zone presumably corresponds to a higher trapped CO_2 saturation. In January 1993, a change in profile was indicated, and the increase in CO_2 saturation and a decrease in oil saturation in Zone E suggest that mobile oil was being displaced as a result of the foam.

RESPONSE FROM THE SECOND FOAM TEST

Based on the favorable response observed as a result of the first foam injection test, a second foam test was initiated during this quarter. Following the four months of water injection on May 21, 1993, CO_2 was injected for 12 days to establish a base gas injection rate. As is typical when switching from water to CO_2, the injection pressure increased about 600 psi because of the difference in hydrostatic pressure between water and CO_2. On June 2, 1993, the second foam test was started with the same conditions as in the first test. Early indications are that foam was generated quickly and the wellhead

pressure response during the second foam test at a surfactant concentration of 2500 ppm are similar to the first test at the same concentration. A current hydrostatic gradient will be obtained to assess the response at bottomhole conditions.

SIMULATION STUDIES

University of Houston Studies

Improvements in the history match of WAG operations in the pilot area have continued to be made by varying the permeabilities between the foam injection well and the surrounding eight producing wells. A copy of the input data for the history match was made available for interested individuals. For the foam history match, the apparent foam viscosities were reduced by about an order of magnitude to achieve reasonable injection rates of CO_2 at the observed bottomhole pressures.

Data have been constructed for four predictive cases to compare WAG and foam scenarios: (1) WAG operations without foam consisting of cycles of four months CO_2 and eight months water, (2) same as the first case but WAG cycles consisting of one month CO_2 and two months water, (3) a baseline foam operation as conducted during the first foam injection test followed by three months CO_2, four months water, and continued WAG cycles consisting of four months water and eight months water, (4) repeat foam cycles separated by CO_2 and water cycles. After the predictive cases are completed early in the next quarter, work will begin on the final report that will include the detailed history match data as well as the predictive cases.

PRRC Studies

At the PRRC, the simulated annealing method (SAM) for reservoir description has been applied to the EVGSAU. SAM is a nongradient, global optimization technique that can incorporate hundreds of variables yet jump over local minima to converge on the optimum solution. This history matching method characterizes the individual grid blocks in terms of permeability, saturations, and pressure. Additionally, an estimate of the average oil-water relative permeability and capillary pressure functions is produced. SAM is a nonsubjective means of automatically matching reservoir pressure and production/injection history, and the resulting grid block description is a useful reservoir management tool.

In the EVGSAU project, SAM was used to match six years of water injection and the oil, water, and solution gas history of 15 wells surrounding the CO_2-foam injection well. In the first step, DOE's black oil simulator, *BOAST*, was used on an HP-9000 minicomputer to solve the 2-D, inverse problem. The solution requires about 3000 *BOAST* iterations on the 256 grid block problem. The resulting reservoir description was then used to match the six years of CO_2 injection performance using the *UTCOMP* compositional simulator, graciously provided by Gary Pope at the University of Texas.

Plans for further development include an adaptation of SAM and black oil model to full parallelization for use on fast, parallel-processor computers. A CO_2-foam mechanism is also being developed for *UTCOMP*, as well as DOE's miscible simulator (MASTER). A paper[2] containing the application of SAM to the EVGSAU was prepared this quarter and will be presented at the Annual SPE Meeting in October, 1993.

PROJECT PLANS

Following the second test at a surfactant concentration of 2500 ppm, a decision will be reached regarding the conditions for injecting the remaining surfactant on hand. A smaller working group of the JPAT will meet in late July to evaluate all of the results obtained in the project and to prepare a presentation of the results that can serve as material for subsequent technical papers as well as for a final report on the project.

REFERENCES

1. Butler, R., Gerard, M., and Stevens, J.: "The Use of Monitor Logging to Evaluate CO_2 Foam Flooding in the East Vacuum Grayburg San Andres Unit," presented at the SPWLA 34th Annual Logging Symposium, June 13-16, 1993.

2. Sultan, J., Ouenes, A., and Weiss, W.W.: "Reservoir Description by Inverse Modeling: Application to EVGSAU Field," paper SPE 26478 to be presented at the 1993 SPE Annual Technical Conference and Exhibition, Houston, Oct. 3-6.

TABLE 1
FLUID MOBILITIES

Fluid	Fluid Mobility, md/cp	
	Pressure Falloff Data	Hall Plot Slopes
Water before Foam	224	212
CO_2 before Foam	308	313
CO_2 after Foam	116*	114

*Based on analysis of early linear-flow portion of data.

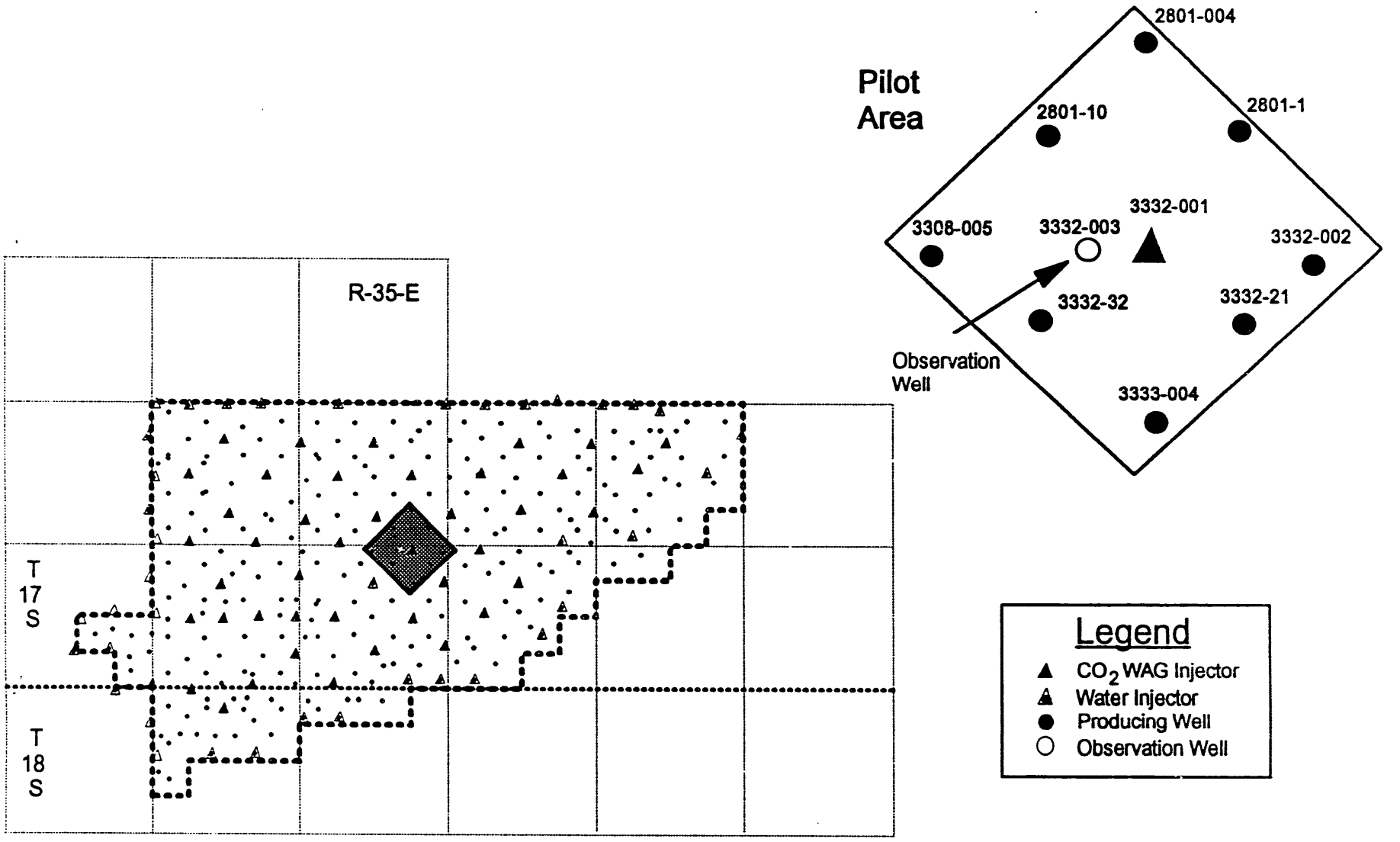

Fig. 1. Location of the EVGSAU Foam Pilot Area

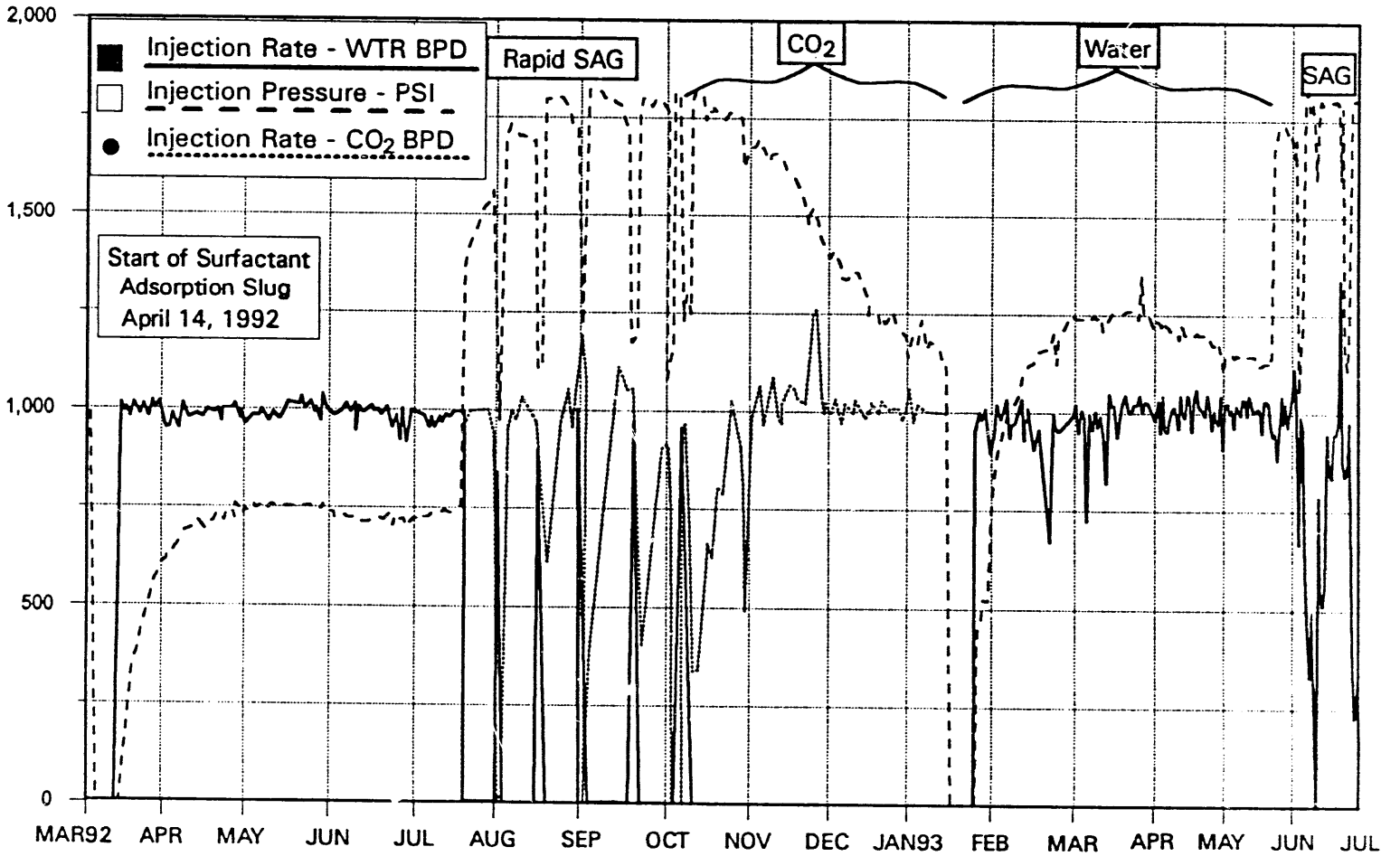

Fig. 2. 3332-001 Injection Pressure and Rate During Foam Generation

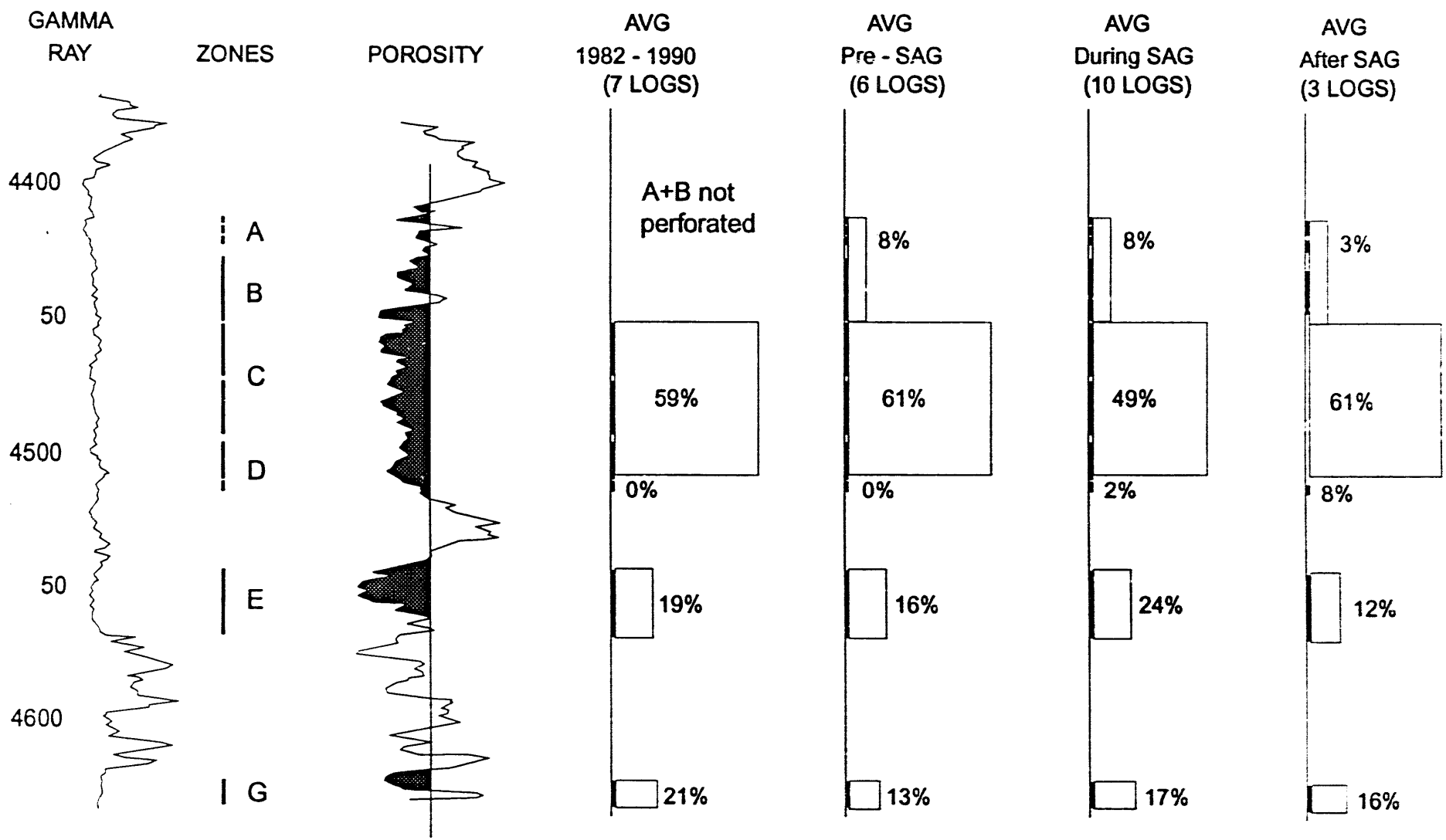

Fig. 3. Injection Profile for Well 3332-001

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