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Application of Microseismic Technology to Hydraulic Fracture Diagnostics: GRI/DOE Field Fracturing Multi-Sites Project

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Application of Microseismic Technology to Hydraulic Fracture Diagnostics: GRI/DOE Field Fracturing Multi-Sites Project

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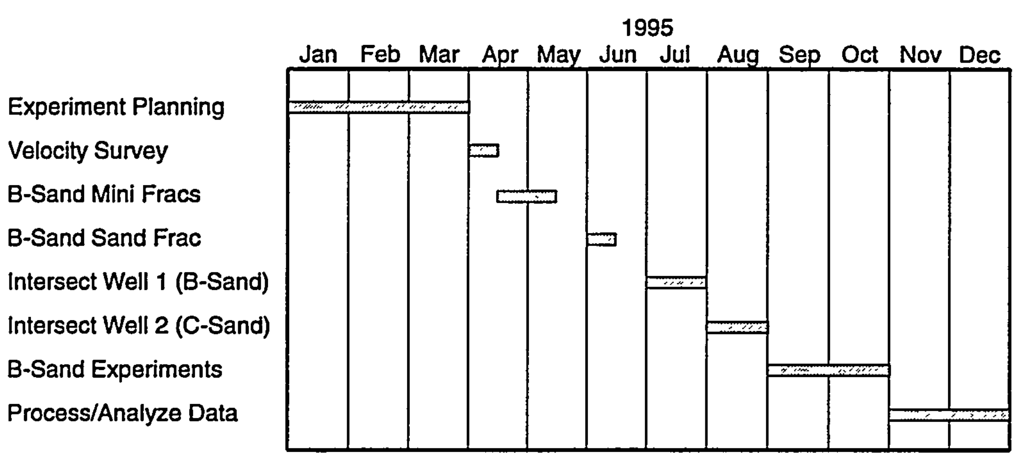

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OVERALL OBJECTIVE OF THE PROJECT

The objective of the Field Fracturing Multi-Sites Project (M-Site) is to conduct field experiments and analyze data that will result in definitive determinations of hydraulic fracture dimensions using remote well and treatment well diagnostic techniques. In addition, experiments will be conducted to provide data that will resolve significant unknowns with regard to hydraulic fracture modeling, fracture fluid rheology and fracture treatment design. These experiments will be supported by a well-characterized subsurface environment as well as surface facilities and equipment conducive to acquiring high-quality data. It is anticipated that the project's research advancements will provide a foundation for a fracture diagnostic service industry and hydraulic fracture optimization based on measured fracture response.

BACKGROUND INFORMATION

The M-Site Project is jointly sponsored by the Gas Research Institute (GRI) and the U.S. Department of Energy (DOE). The site developed for M-Site hydraulic fracture experimentation is the former DOE Multiwell Experiment (MWX) site located near Rifle, Colorado, as shown in Figure 1. The MWX project drilled three closely-spaced wells (MWX-1, MWX-2 and MWX-3) which were the basis for extensive reservoir analyses and tight gas sand characterizations in the blanket and lenticular sandstone bodies of the Mesaverde Group. The research results and background knowledge gained from the MWX project are directly applicable to research in the current M-Site Project. The contractor team organized by GRI and DOE to execute the M-Site Project includes CER, Sandia National Laboratories, Resources Engineering Systems, Branagan & Associates, and James E. Fix & Associates.

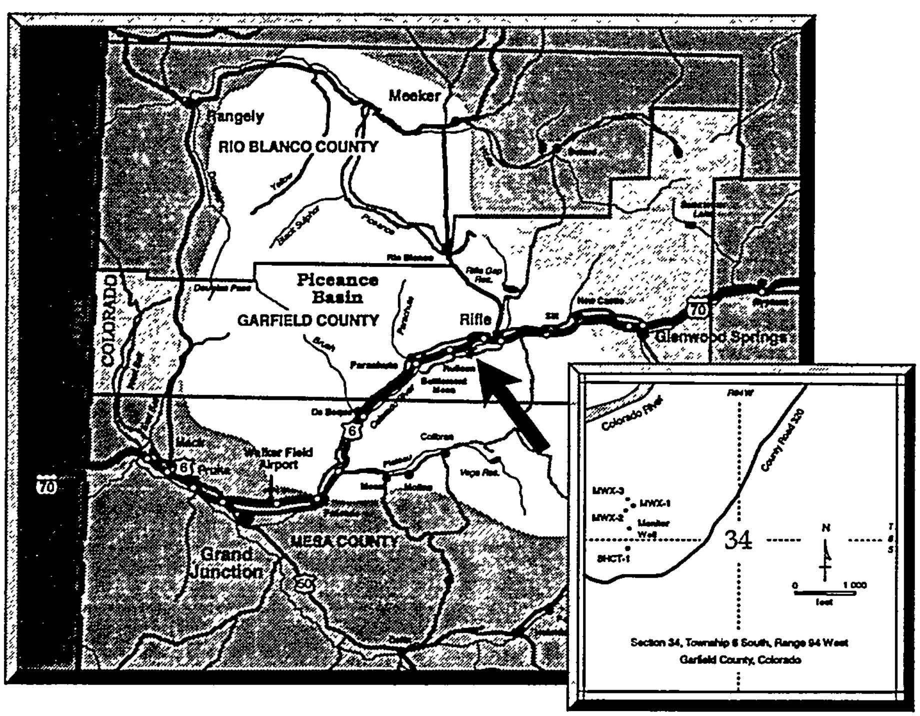


Figure 1 Location of the Field Fracturing Multi-Sites Project

All of the proposed M-Site experimentation is occurring in several sandstone units, shown in Figure 2 and informally referred to as the A, B and C Sands, which are present in the upper Mesaverde Group between 4,100 and 5,000 ft. The B and C Sand units at the M-Site have the following characteristics:

- paralic depositional environment which resulted in relatively thick and widely continuous sand bodies;
- normal pressure gradient;
- core-sample permeability averaging 0.02 md and porosity averaging 6.1 percent; and
- high water saturations averaging 80 to 90 percent.

The deeper A Sand interval is within the fluvial transition zone of the Mesaverde and, therefore is laterally discontinuous, slightly over-pressured, and capable of gas production.

TECHNICAL APPROACH TO M-SITE FIELD OPERATIONS AND RESEARCH ACTIVITIES

The M-Site field operations and research activities described in this document occurred during the period from October 1993 to October 1994 and include the following primary activities:

- fracture diagnostics experiments in the A Sand interval; and
- drilling and instrumentation of Monitor Well No. 1.

These activities are consistent with a "staged approach" wherein each project phase builds upon the previous to result in more comprehensive experiments and data acquisition. A more complete description of the technical approach to the above two activities is included in the following sections.

Fracture Diagnostics Experiments In The A Sand Interval

A series of A Sand data acquisition operations and experiments were planned interval to accomplish the following objectives:

Characterization of the A-Sand Velocity Structure. The stratigraphy of the upper Mesaverde section is characterized by layered sandstone, siltstone and mudstone lithologies. Processing of seismic data in subsequent experiments (i.e., accurate location of remotely-detected microseismic events which occur as a result of hydraulic fracturing) to be conducted at the M-Site requires that the velocity structure of the A-Sand interval be well characterized. Therefore, a crosswell velocity survey was planned using the MWX-2 well to emplace a five-level borehole accelerometer package and the MWX-3 well for emplacing an airgun seismic source.

Remote-Well Seismic Data Acquisition with Multi-Level Accelerometers. The objectives of the fracture diagnostic experiments in the A Sand were to use multiple seismic receivers (triaxial accelerometers) in a remote observation well to: a) develop fielding techniques for the more comprehensive accelerometer array to be installed in the Monitor Well No. 1; and b) to substantially reduce vertical wavefield errors thereby providing data for more accurate location of microseismic events. To accomplish this goal, four mini-fracs were to be pumped during which a multi-level accelerometer array, placed in the borehole on a fiber optics wireline, would detect microseisms and transmit these data to surface recording systems. Three of the mini-fracs were planned to be fluid only. The fourth mini-frac

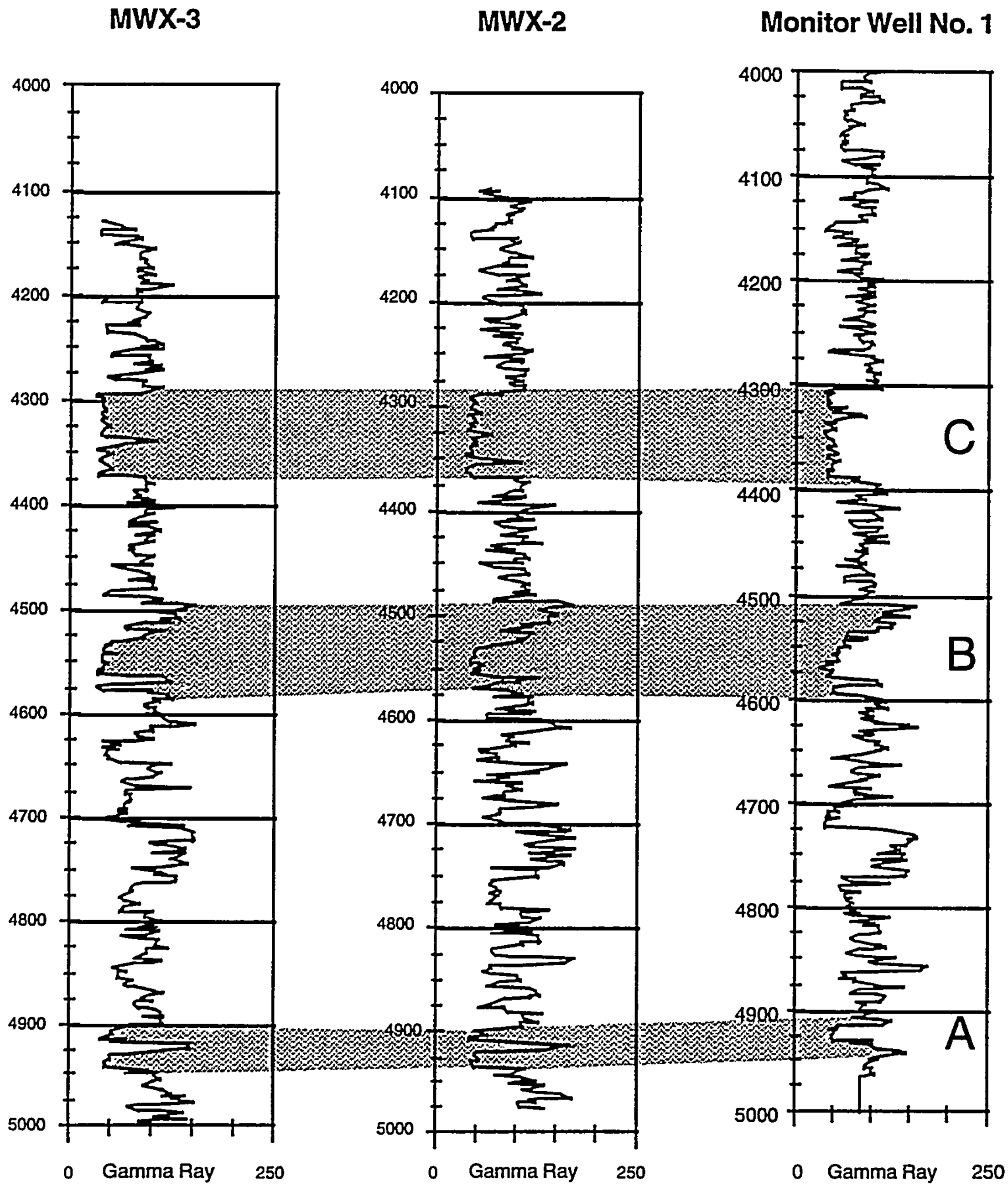


Figure 2 Upper Mesaverde Sandstone Units Targeted for Research in the Multi-Sites Project

would include proppant, thereby providing an opportunity to contrast the character of microseismic events from the two types of treatments.

Development of Event Detection and Data Processing Capabilities. The overall diagnostic strategy at the M-Site is to automate all of the seismic processing to avoid the time spent searching for and capturing microseismic events from taped data. Thus, microseisms which occur as a result of the A Sand fracture treatments will provide data that can be processed and used to develop the automatic techniques for rapidly defining the location of microseismic events.

Verification of Treatment Well Fracture Diagnostic Techniques. The objective of this set of experiments was to use the new borehole accelerometer technology to independently validate the H/Z technique for determining fracture height and azimuth. Verification would be achieved by comparing the fracture height results determined from the remote-well multi-level seismic array with the H/Z data.

Assessment of Convective Processes During Hydraulic Fracturing. An experiment was designed to improve the understanding of factors related to effective placement of proppant in a hydraulic fracture and fluid convective processes which may redistribute this proppant in the fracture and/or the wellbore. The basic strategy was to pump a propped frac (Propped Frac No. 4-A) in which the fluid and proppant have been tagged with three different radioactive tracers. Wireline logging runs with a spectral gamma ray tool would then be performed to monitor the location of these tracers in and around the wellbore.

Drilling and Instrumentation of Monitor Well No. 1

Comprehensive seismic experimentation which has the potential for clearly defining the dimensions of a hydraulic fracture requires an instrumentation array beyond that which can be fielded on a wireline retrievable system. Therefore, the objective of this phase of the M-Site Project was to execute the following operations:

Drill and Case a Specially Designed Wellbore. The design of Monitor Well No. 1 was driven by the need to cement instrumentation arrays in a downhole environment where they are likely to function for a long time. Thus, this design required a 12-1/4-in. borehole drilled to 5,000 ft with a minimum of borehole deviation; 9-5/8-in. casing would then be set and cemented.

Acquire and Analyze Select Data Sets. In the process of drilling Monitor Well No. 1, additional opportunities would be presented to acquire data in the A, B and C sand intervals. Thus, coring, core analysis and wireline logging programs were designed to selectively evaluate reservoir character and stress magnitude/direction.

Emplace Seismic and Earth-Tilt Instrumentation. Of primary importance to M-Site fracture diagnostics experiments would be the successful emplacement of 30 accelerometers, 6 inclinometers and their respective cabling in the 4,000- to 4,900-ft interval of Monitor Well No. 1. Thus, special procedures and precautions were designed to secure the instruments to a tubing string and cement this assembly in place.

RESULTS

The results of the two primary research activities described in this document are provided in the following sections.

Fracture Diagnostics Experiments in the A Sand Interval

A series of experiments and data acquisition operations were designed and executed between October 25 and November 5, 1993, in the A Sand interval of the Mesaverde section. The primary experiments were performed in conjunction with a series of small hydraulic fracturing treatments in MWX-3 while simultaneously collecting seismic data in both the treatment well (MWX-3) and a remote observation well (MWX-2). As shown in Figure 3, MWX-3 was perforated in the A Sand at 4,900-20 ft and 4,930-46 ft with 72 holes (0.4 inches) at 2 shots per foot (SPF) and 120° phasing. Figure 3 also shows the wellbore configuration of the MWX-2 well, as a seismic monitor well, during the mini-frac testing. Three separate fluid-only mini-frac treatments were performed and one propped treatment was performed in this effort. Tables 1 and 2 summarize the salient details of these treatments. Detailed results of these operations and research results are found in CER and others, 1995a. These results of these activities are summarized as follows:

Crosswell Tomography. The initial phase of field data acquisition which occurred prior to the mini-fracs involved a comprehensive crosswell tomographic survey to characterize the velocity structure of the gross interval between 4,500 and 5,200 ft. The A-Sand interval was completely covered in the crosswell tomography survey by varying the depth interval that the accelerometer array was locked into and by varying the depth of the airgun source. Receivers were moved at 10-ft increments between 4,500 and 5,000 ft, while airgun shots were positioned at 5-ft intervals between 4,500 and 5,200 ft. The crosswell survey used MWX-3 for emplacement of the seismic source and MWX-2 for emplacement of the borehole accelerometer array.

The data from the tomographic survey are high quality, with clear p-wave arrivals. Generally, there are good signal-to-noise ratios for these traces with excellent p-wave first-arrival standout and visible waves.

Analysis of the p-wave arrival first breaks were completed first, as p-wave data required considerably less processing than the s-wave results. Several test tomographic inversion runs were performed to determine proper processing parameters and to winnow poor quality first-arrival picks. In the final tomographic inversion, a starting velocity model was constructed with sonic log data from MWX-2 and MWX-3. Best results were obtained by allowing inversion to proceed with velocities constrained to fit the starting model at the top and bottom of the tomogram. In these areas, pixel velocities are poorly resolved because of the limited ray path coverage. Global velocity constraints were applied to keep topographic velocities within a few percent of the sonic log velocities. Figure 4 shows a black and white representation of the inversion results. The higher velocity A Sand at 4,940 ft and B sand at 4,530 ft can be clearly seen.

Fracture Dimensions Based on Remote-Well Microseismics. Remote well (MWX-2) seismic monitoring was performed during each of the four mini-frac treatments using a multi-level downhole seismic receiver array, fiber optic wireline and surface data acquisition system. The receiver array, configured to obtain the widest possible aperture, consisted of three receivers spaced at 10-ft intervals and a fourth receiver 50 ft below the third. The receivers were clamped and oriented in the cased wellbore between 4,885 and

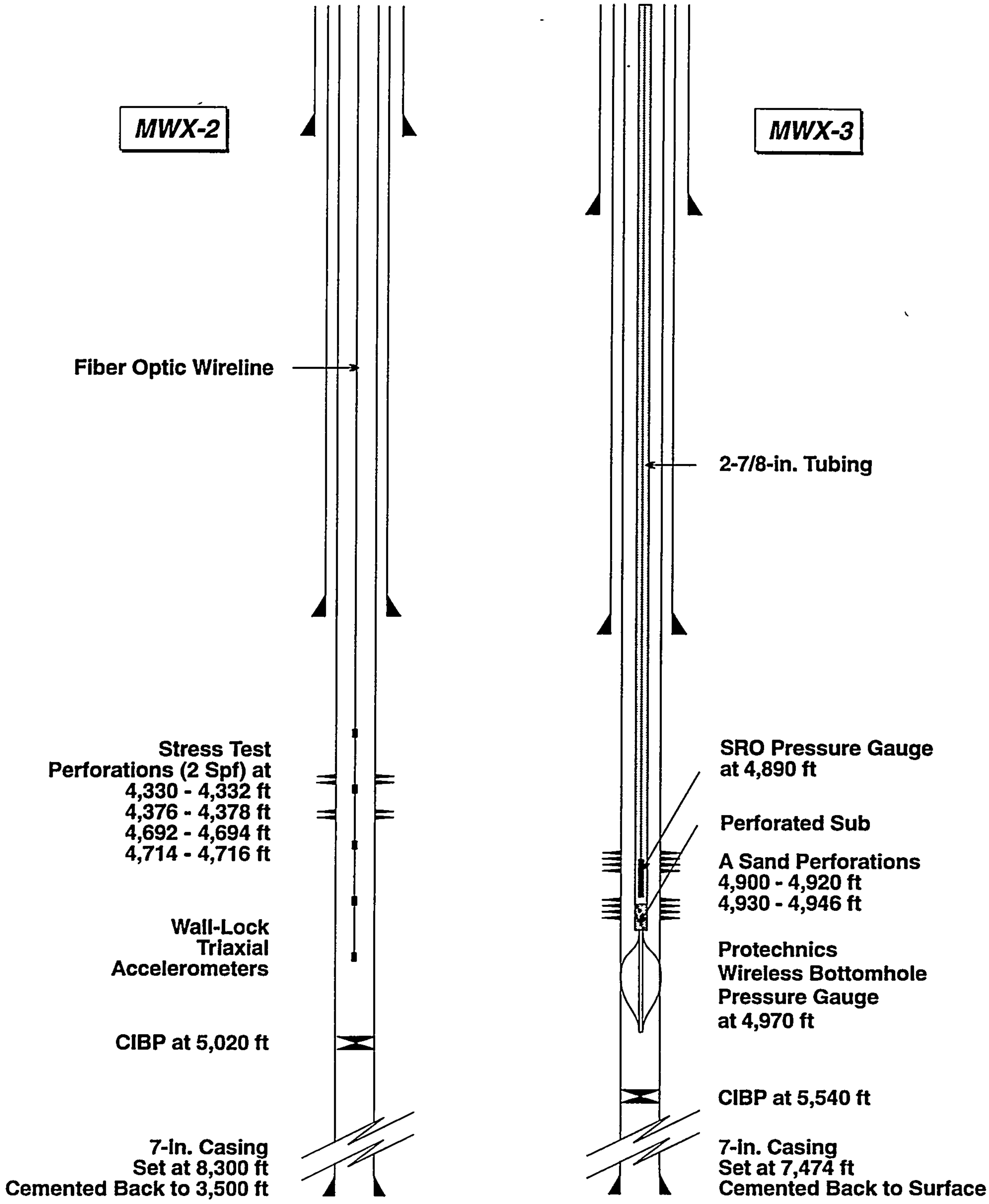


Figure 3 Configurations of the MWX-2 Observation Well and the MWX-3 Treatment Well for A Sand Mini-Fracs

Table 1. Treatment Volumes for Mini-Fracs No. 1-A to 3-A

	Treatment Volume	Injection Rate	Fluid Type
Mini-Frac No. 1-A	450 bbl	25.0 bpm	40 lb/Mgal linear gel
Mini-Frac No. 2-A	400 bbl	15.1 bpm	40 lb/Mgal linear gel
Mini-Frac No. 3-A	434 bbl	20.4 bpm	40 lb/Mgal linear gel

Table 2. Pump Schedule for Propped Frac No. 4-A

Stage	Slurry Volume, bbl	Slurry Rate, bpm	Stage Sand, lb	Comments
1	75	20	---	Pad (40 lb/Mgal linear)
2	52	20	4,400[1]	2 ppg proppant
3	51	20	---	Start flush
4	---	---	---	Shutdown for ISIP
5	80	20	---	Underdisplace
6	---	---	---	Run RA log
7	90	20	---	Overdisplace
9	72	20	---	Pad (40 lb/Mgal X-link)
10	84	20	12,500[2]	4 ppg proppant
11	36	15	---	Flush (40 lb/Mgal linear)
12	---	---	---	Shutdown for ISIP
13	104	17	---	Flushed to top perf
14	---	---	---	Run RA log

[1]Proppant tagged with ^{192}Ir Zero Wash
[2]Proppant tagged with ^{124}Sb Zero Wash

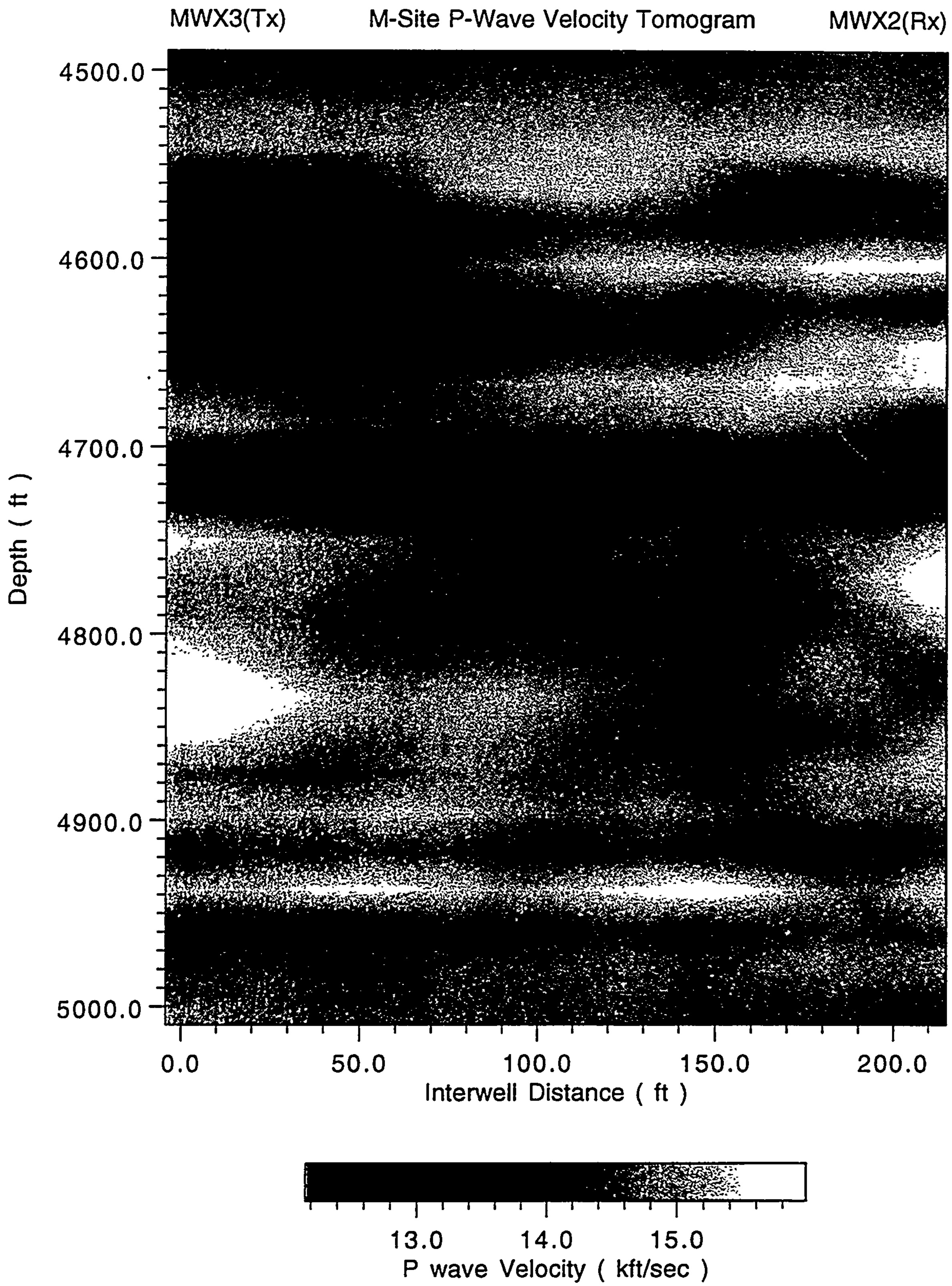


Figure 4 Black and White Representation of the Tomographic Inversion

4,955 ft. In addition to collecting raw data, microseismic event detection capabilities were developed based on amplitude triggering. The event detection compares a moving-amplitude window with a resettable threshold for each channel to determine if events have been recorded. The system incorporates flexibility in being able to turn off noisy channels, to change the threshold when conditions are noisy (e.g., during pumping), or to bias the search for signals by choosing particular channels.

Figure 5 shows a correlated plot of bottom-hole pressure with microseismic events triggered by the event detector for Mini-Frac No. 1-A. Initially, the event-detector threshold was set high to minimize pump-noise events, and, thus, few events were triggered when pumping started The threshold was subsequently lowered and approximately 5 minutes into the treatment, events were being detected at an average rate of about 5 per 2-minute interval. While the number of events jumped at shut-in, they rapidly declined after shut-in to fewer than one event per minute.

Seventy-eight of these seismic events were subsequently analyzed to determine their locations. Figure 5 also illustrates a plan and profile view of the final plot of event locations using the most accurate imaging analysis possible with the 4-level array. As shown in this figure, the final plot illustrates a fracture-wing asymmetry of 2:1. This plot, however, does not adequately portray the development of fracture geometry with time. This fracture growth with time is interpreted as follows:

- After only 12 minutes of pumping, the fracture reached its total length extent with very little height growth.
- Seven minutes later, some upward and downward height growth are noted which correlates to a decrease in the treating pressure.
- At the shut-in time at 30 minutes, there is some additional height growth and an increasing width of signals in the horizontal plane.
- Upward and downward growth continue for about 9 minutes after shut-in.

Microseismic events occurring as a result of Mini-Frac No. 2-A were also analyzed and indicate that the fracture is asymmetric (but to a lesser degree than that observed in the Mini-Frac No. 1-A) and the band of microseisms is wider possibly because of leakoff-induced microseisms. Mini-Frac No. 3-A also shows a tendency for greater width of the signal zone. The fourth mini-frac, which included a proppant stage, was notable for its excessive amount of non-microseismic signals.

Fracture Dimensions Based on Treatment Well Microseismics. Treatment well diagnostics for fracture top and bottom were conducted as a part of the Mini-Frac No. 3-A experiment design and used a single 3-component receiver in the MWX-3 treatment well. The H/Z fracture height determination technique was applied and is based on Continuous Microseismic Radiation, i.e., the continuum of small background earth motion events which occur following a hydraulic stimulation. The background motion data are formed into its two vector components: the horizontal component H and the vertical component Z. The top and bottom of the hydraulic fracture is interpreted to occur where the H/Z ratio inverts from a vertical dominance to a horizontal dominance.

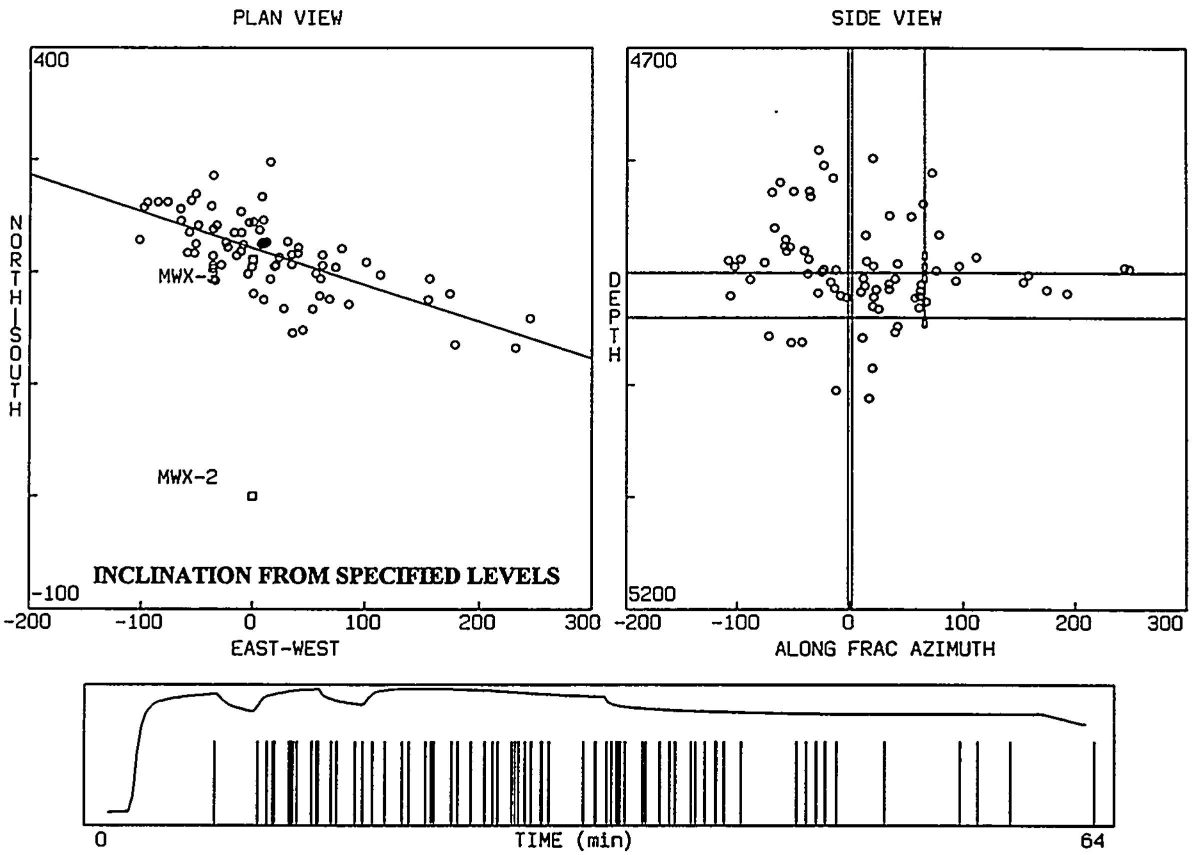


Figure 5 Correlated Plot of Bottomhole Pressure With Seismic Events and a Plan and Profile View of Microseismic Event Locations for Mini-Frac No. 1-A

Following Mini-Frac No. 3-A, 17 depth stations were occupied between 4,900 and 5,300 ft. The results of the fracture height processing, as shown in Figure 6, indicate that the top of the fracture is at 4,725 ft and the bottom of the fracture is at 4,975 ft for an overall height of 250 ft.

Fracture Dimensions Based on 3D Fracture Modeling. The 3-D hydraulic fracture model FRACPRO, developed for GRI by Resources Engineering Systems, was used to record and analyze the pressure and flow data in real time during all four injections. Data were collected via a serial connection to a data acquisition computer which was receiving data from the fracturing service company. For treatments where it was not directly measured, surface pressures were used by the wellbore model to estimate bottomhole pressure. The closure stress profile used for these analyses were the same as used for previous analyses of the four mini-fracs conducted in 1992 (CER and others, 1992). Similarly, the three-layer modulus model and leakoff properties are the same as for the 1992 tests. While model results were developed for all four injections, only those results for Mini-Frac No. 1-A are reported here.

Mini-Frac No. 1-A consisted of pumping 450 bbl of 40 ppg linear gel (circulated to the perforations before fracturing) in several stages and flushed with KCl water. The intermediate shut-ins were useful for matching fall-off behavior. Analysis of the first mini-frac benefited from the use of the bottomhole pressure data

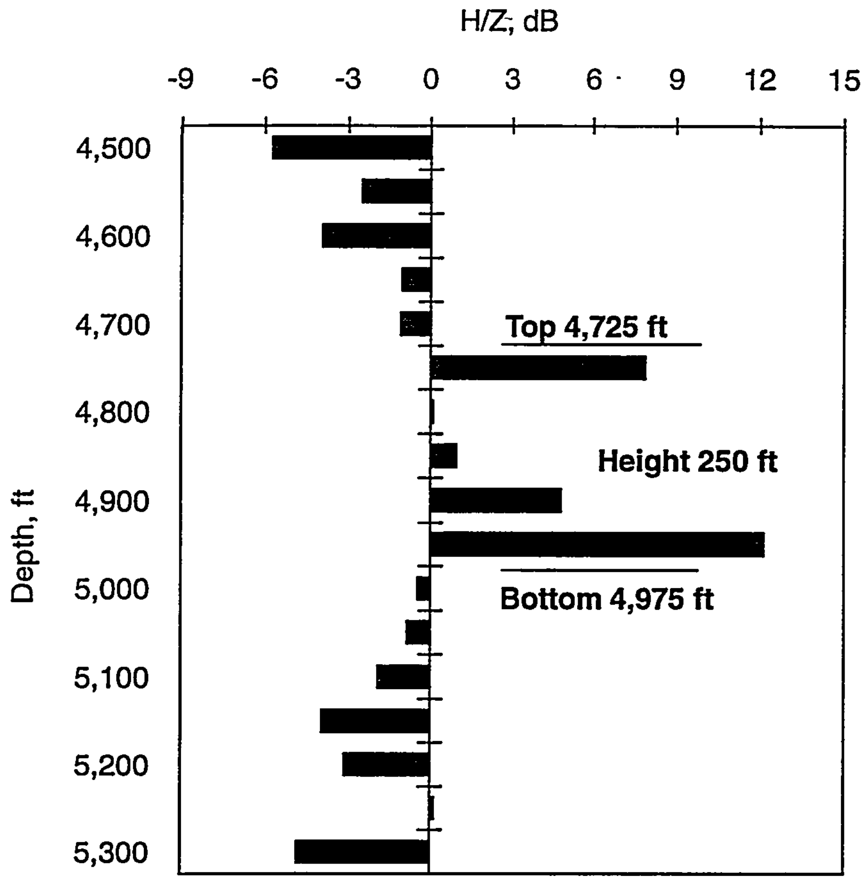
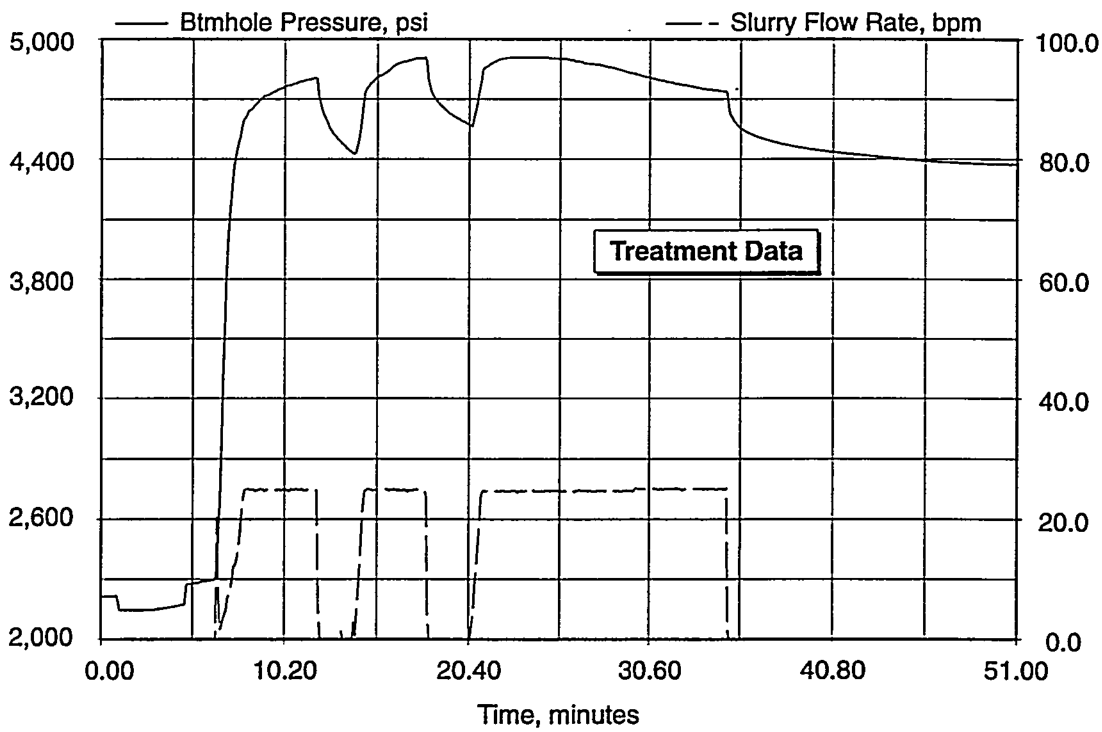


Figure 6 Fracture Height as Determined by H/Z Analysis

which was used to correlate the model pressures with the observed net. Two quick shutdowns also assisted in evaluating the degree of near-wellbore friction. The treatment data and net pressure match are shown in Figure 7. Perforation/tortuosity pressure losses were estimated to be approximately 150 psi at 26 BPM, which agrees with previous and subsequent injections. Figure 8, which shows a schematic of one wing of the fracture at shut-in, also shows the net pressure predicted by FRACPRO. Efficiency was estimated to be about 56 percent at shut-in. Fracture containment was minimal, and the resulting fracture geometry was estimated to be essentially radial.

Fracture Dimensions and Convective Processes Based on Tracer Investigations. A series of investigations employing radioactive (RA) tracers were undertaken as a part of Mini-Frac No. 4-A. The objectives of these tracer investigations were to 1) assess slurry convection processes which may redistribute the proppant; and 2) evaluate early and final proppant and frac fluid placement (frac height). The strategy used to achieve these investigative objectives involved three different short-lived RA tracers to tag each of the fracture treatment component (i.e., gelled frac fluid and the two stages of proppant) and monitor the location of these tracers in and around the wellbore using multiple logging surveys with gamma ray (GR) and spectral GR detector logging tools.

The observations of wellbore RA activity suggests that large-scale convection failed to



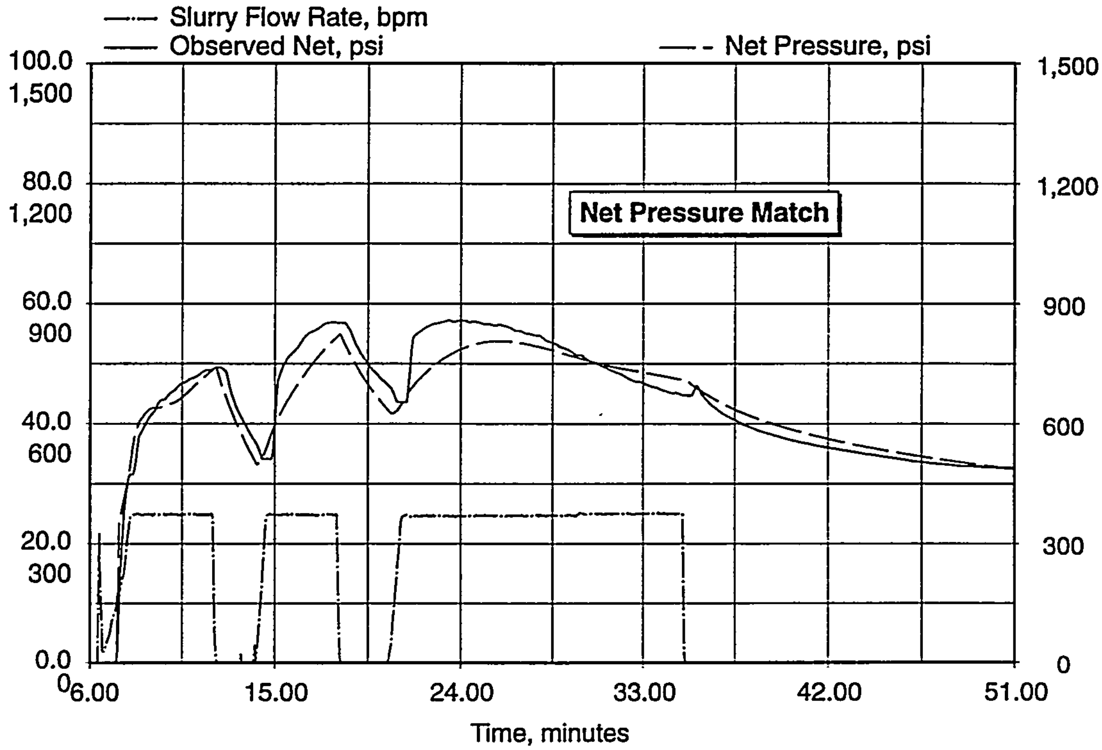


Figure 7 Treatment Data and Net Pressure Match from Mini-Frac No. 1-A

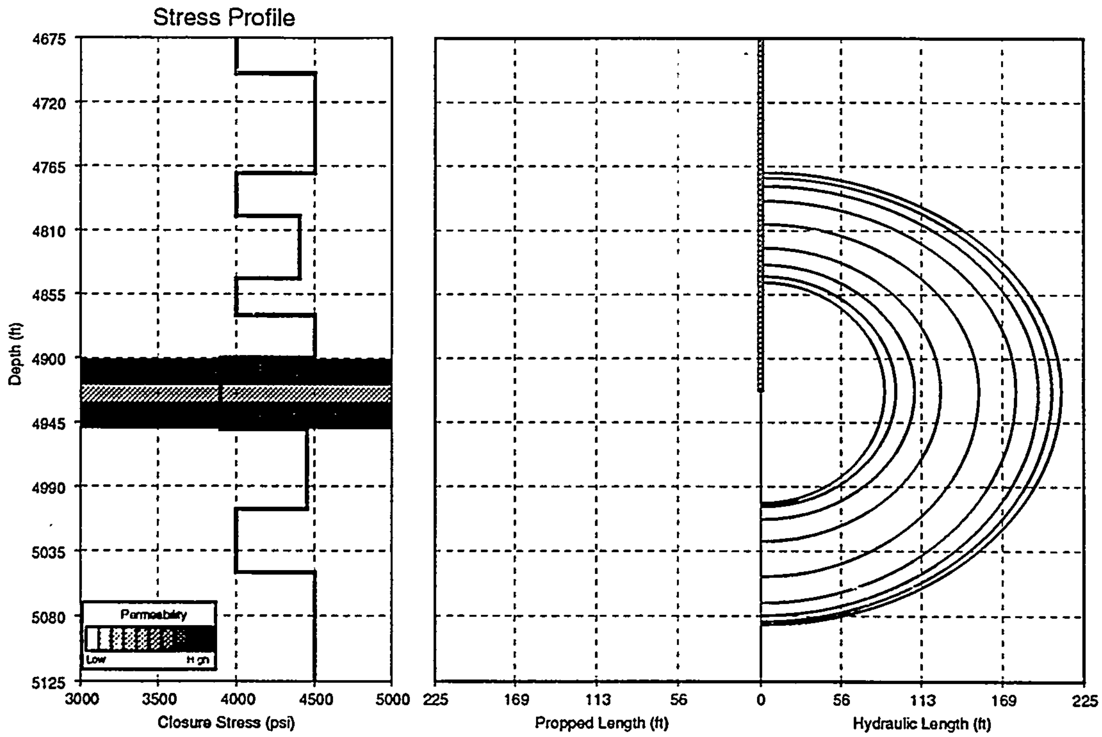


Figure 8 Mini-Frac No. 1 Geometry as Determined by 3-D Modeling

occur, at least not within the available open wellbore area or between the wellbore and frac. Although some of the RA material appears in the "rat hole" below the perfs, it may have been dragged there, viscously or otherwise, during the descent of the logging tool to bottom prior to initiating the actual GR surveys. Further, the quantities of RA found below the perfs are rather minor amounting to about 3 percent of the total wellbore activity. Had unimpeded density convection occurred in the wellbore, almost 200 ft of RA tagged slurry initially located above the base of the perfs could be expected to be found lying on the well bottom (±5,300 to 5,500 ft) after having displaced the less dense water. Although some loss of RA material from the wellbore is evident, these losses could easily be explained by fracture leakoff coupled with wellbore decompression; thus, these data and observations do not suggest any gross occurrence of convection and/or settling.

The first proppant stage (4,400 lb of 20/40 sand at 2 ppg) of Mini-Frac No. 4-A was tagged with the RA tracer ^{192}Ir. The second proppant stage (12,500 lb of 20/40 sand at 4 ppg) was tagged with ^{124}Sb. The 3,024 gal of x-linked gelled frac fluid that constituted the fluid stage of the 4 ppg slurry was tagged with ^{46}Sc. Spectral GR logging surveys then provided data regarding the spacial position of these three different tracers, thereby identifying the corresponding location of each stage of the fracturing treatment.

The final measured near-wellbore location of the second 4 ppg proppant stage and attendant frac gel fluid were defined during the post-frac spectral GR survey. It was noted earlier that the 4 ppg stage was tagged with ^{124}Sb while the x-link gel was tagged with ^{46}Sc and that these GR activity values represent those sources of activity located behind pipe. Activity values for the 4 ppg proppant stage are considerably diminished above

4,825 ft and below 5,050 ft, while activity from the x-link gel appears to fall off similarly below 5,050 ft but remains high up to the top of the survey at 4,750 ft. This suggests that the unpropped frac height may have grown above 4,750 ft.

To assist in defining propped frac height, the ^{124}Sb spectral activity was accumulated and then normalized. The results are as shown in Figure 9 where this normalized activity for the 4 ppg proppant stage is displayed as a function of depth. Propped frac height was then interpreted to correspond to a depth range of 4,800 to 5,010 ft.

Discussion of A Sand Experiment Results. The primary reasons for developing fracture diagnostic technology are 1) to optimize the fracture process by understanding fracture growth in a particular reservoir, and 2) to validate and improve fracture models. The first reason is not applicable at M-Site because there is no attempt to produce these reservoirs. The second objective is, however, of particular interest because of the wealth of high-quality data. With accurate bottomhole pressure measurement, the pressure history-match model runs have provided state-of-the-art calculations of fracture size.

Figure 10 shows a combined plot of the Mini-Frac No. 1-A (fluid only) fracture geometry as determined from 3D fracture modeling and the loci of microseismic events detected by the 4-level remote-well accelerometer array. For reference, the Mini-Frac No. 3-A (fluid only) fracture height as determined by H/Z seismic monitoring in the treatment well and the Propped Frac No. 4-A near-wellbore fracture height determined from GR logging of the RA-tagged proppant are also shown on the composite plot.

Mini-Frac 1-A, common to both the 3D fracture modeling and the microseismic event locations, has an obvious disagreement in the fracture wing symmetry. On one wing, the microseisms extend somewhat farther than the model predicts, and on the other wing, the measured fracture length is considerably less. Such asymmetry, however, is one facet of fracture growth that cannot be handled by any fracture model unless data on the stress or lithology factors that have limited the growth on one wing can be measured and factored into the models. If not for the asymmetry, it is likely that the calculated and measured wing lengths would have been reasonably close.

Upward fracture growth is one feature that found agreement between the 3D modeling and the microseismic event locations. Fracture growth downward found more of a difference between the diagnostics and the fracture model calculations. This discrepancy may have been due to any of four factors: 1) inaccurate stress data below the fracture; 2) inaccurate model prediction; 3) insufficient understanding of the correct interpretation of the microseismic data; or 4) inaccurate microseism locations due to layering.

Since only limited stress data were available around this sand, and those data were used to calibrate a sonic-based stress log, it is possible that high stress zones exist below the A Sand and were not detected or used for modeling purposes. Such high stress layers would have reduced fracture growth downward and brought the two techniques into agreement.

Drilling And Instrumentation Of Monitor Well No. 1

A significant accomplishment of the M-Site research program has been the emplacement of a comprehensive seismic and earth-tilt instrumentation array in a new well drilled on the M-Site location. The location of this well, in relation to the

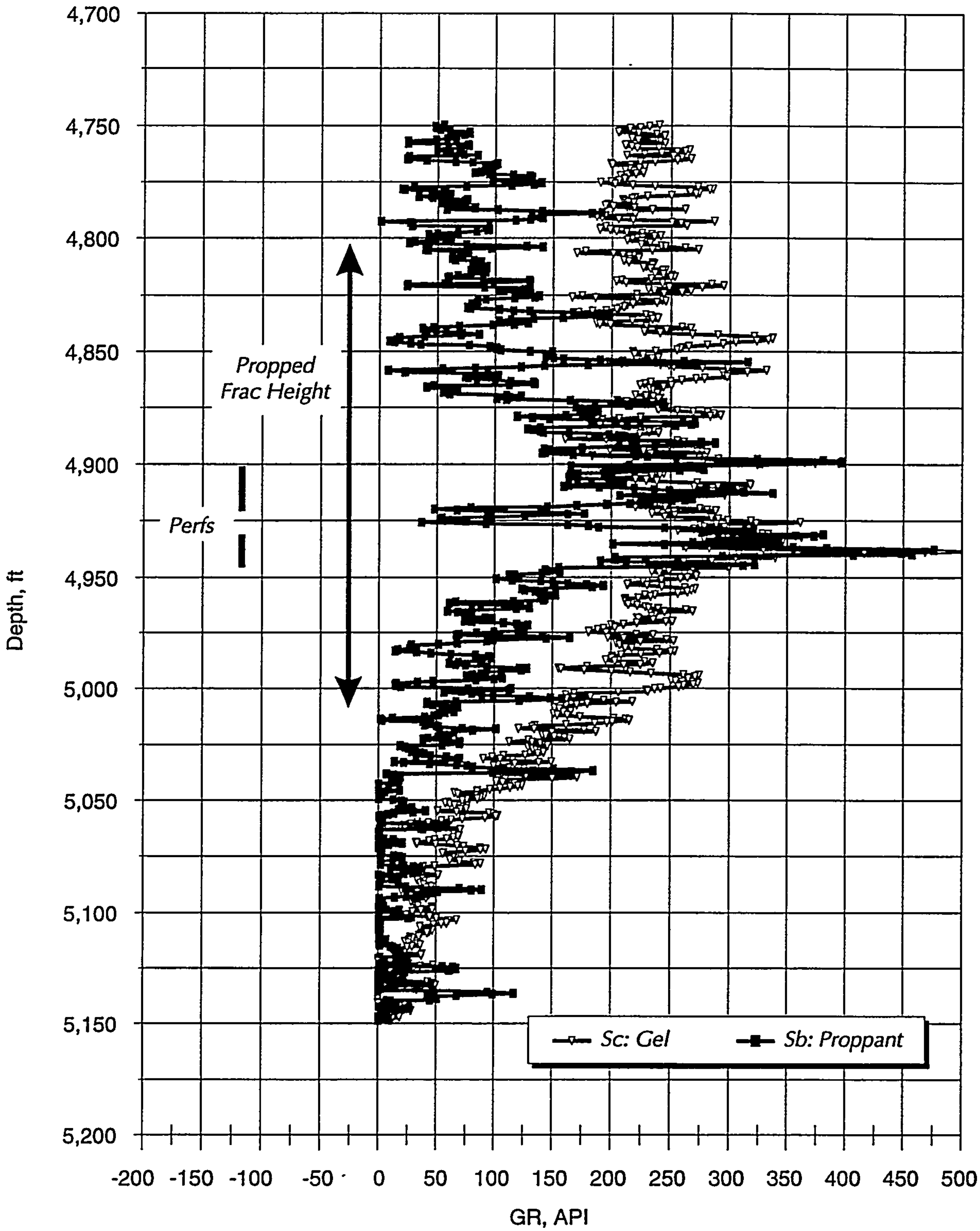


Figure 9 RA Activity for the 4ppg proppant Stage Showing Frac Height at the Wellbore

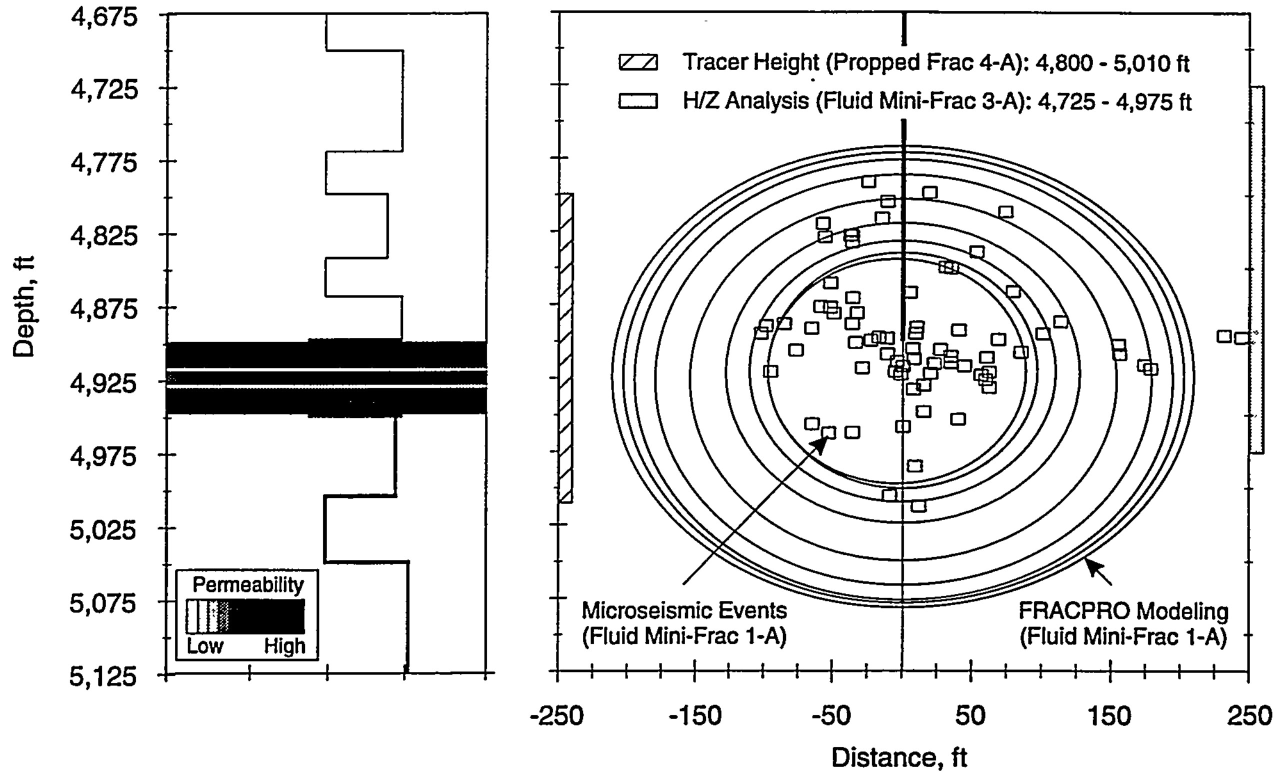


Figure 10 Composite Plot of the A Sand Fracture Geometry from all Available Techniques

MWX wells, is shown in Figure 11. The Monitor Well No. 1 was drilled in February and March 1994 to a total depth of 5,000 ft; 9-5/8-in. casing was subsequently run to TD and cemented to 2,120 ft (CER and others, 1995b). In the drilling phase of the Monitor Well, a focused dataset was acquired and used to further characterize the C and B Sand intervals. A total of 103 ft of core and log data were acquired for characterization of natural and induced fractures, assessment of reservoir fluids and porosities, and development of a mechanical properties/stress profile. These data were analyzed and used to confirm that the C and B sand intervals are thick and relatively homogenous, appear to be unfractured, have high water saturations, and have low permeability. Special core analyses (e.g., circumferential velocity analysis) were performed which indicate that the general stress orientation appears to be ESE-WNW which is in agreement with previous data from this site.

In October 1994, an instrumentation array composed of 30 accelerometers, 6 inclinometers and their respective cabling systems was secured to a tubing string and run in the wellbore to the approximate depth interval between 4,014 and 4,882 ft. The tubing and attached instrumentation cabling were cemented in place, thereby allowing comprehensive fracture diagnostics experiments to be implemented in the 1995 research program. Figure 12 illustrates the configuration of this instrumentation array.

FUTURE WORK

Field operations and experiments are planned for 1995 according to the project schedule shown in the Contract Information section. These experiments will be conducted using MWX-2 as the treatment well, MWX-3 as an observation well for wireline seismic instruments, and the Monitor Well No. 1 for acquisition of comprehensive

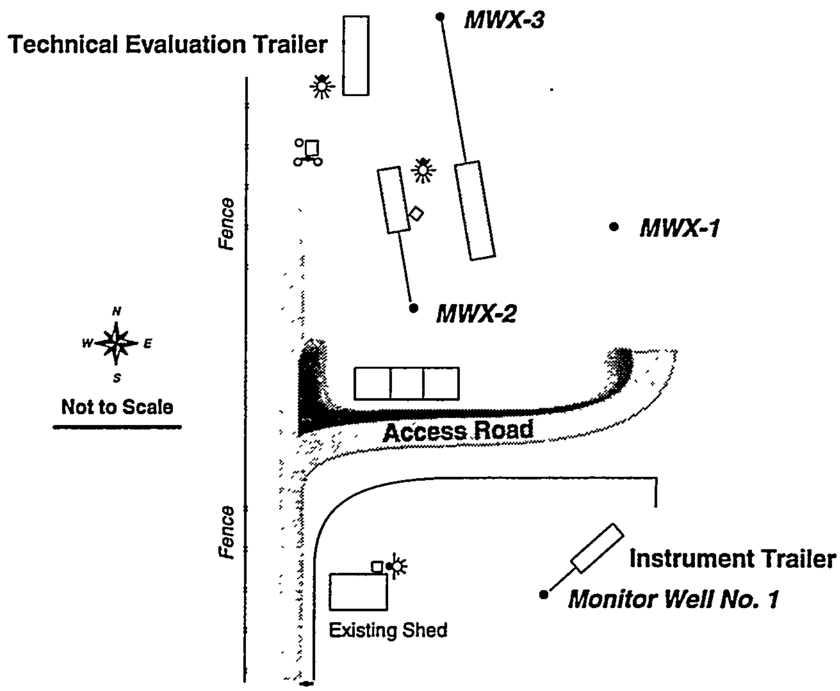


Figure 11 Location of Monitor Well No. 1 and the MWX Wells

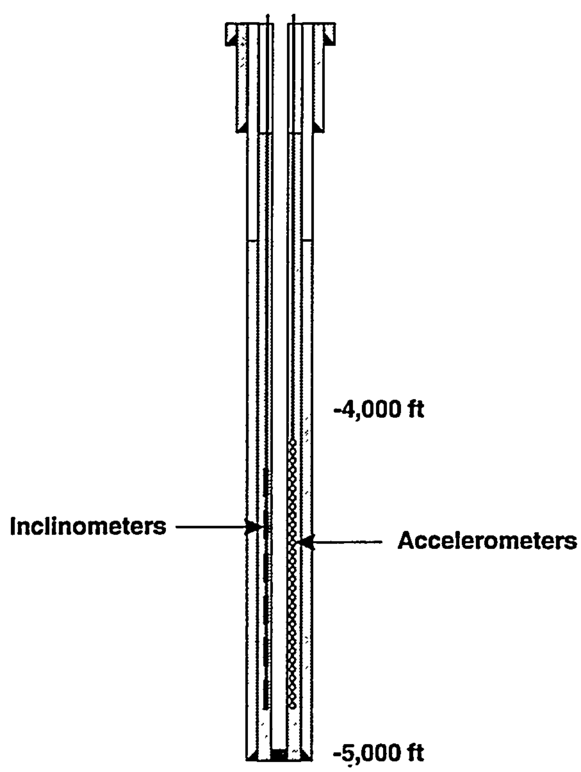


Figure 12 Configuration of the Monitor Well Instrumentation Array

seismic and earth-tilt data. The experiments planned to be conducted in 1995 are summarized as follows:

B Sand Experiments

The initial data acquisition activity to be performed in the B Sand interval will be a velocity survey to more completely characterize the seismic velocity structure in this interval. Subsequently, a series of fluid-only mini-fracs and a propped frac treatment will be executed to accomplish the following research objectives:

a) Acquire comprehensive seismic data during sequential hydraulic fracture treatments. These data will allow a comparison of seismic responses in un-fractured rock and re-fractured rock.

b) Compare fracture mapping results using redundant seismic instrumentation systems (30 level in Monitor Well, 5 level in MWX-3, 1 level in MWX-2) that will allow comparison of fracture mapping results.

c) Assess fracture opening and closure resulting from the mini-frac using the Monitor Well No. 1 inclinometers.

d) Pump multiple mini-frac treatments that are tagged with unique radioactive, chemical or color tags for assessment of multiple crack generation during the intersecting well phase of the project.

e) Acquire bottomhole pressure data for 3-D fracture modeling.

One of the potential seismic experiments to be conducted in the B Sand will be to map the extent of the shear-wave shadow. Shear-wave shadow experiments could be performed using MWX-3 for deployment of a downhole seismic source and the Monitor Well as the seismic-signal receiver well. Execution of this seismic experiment would provide additional interpretation of hydraulic fracture length and height. The last fracture treatment to be pumped in the B Sand would include proppant for additional fracture diagnostics experiments and for fracture technology research to be conducted in the next phase of the project.

B Sand Intersecting Well

The goal of this phase of the project is to a) drill a new wellbore which will intersect the propped hydraulic fracture created in the last B Sand injection; and b) perform hydraulic fracture conductivity tests between the treatment well and the intersection well. The goals of the intersecting well phase of the project are described as follows:

a) Verify hydraulic fracture orientation by coring through the hydraulic fracture at a known remote location and subsequent spectral gamma ray logging through the open-hole interval.

b) Determine if there are multiple fractures and re-create their generation through visual inspections of the core and RA tracer logging on recovered core.

c) Measure proppant distribution within a fracture by cutting and recovering core at several points across the plane of the fracture thereby allowing proppant concentrations to be assessed and compared to model-predicted values.

d) Measure conductivity within the fracture by injecting fluids in the treatment well and recovering them in the intersect well.

C Sand Intersecting Well

A second deviated wellbore is planned for the C Sand interval. This borehole, however, would cut across the C Sand and would be in place *prior* to initiation of hydraulic fracture treatments in the C Sand. The intent of this experiment would be to 1) measure the hydraulic pressure at the leading edge of the fracture; 2) provide a direct indication of the horizontal growth rate of the fracture wing and, thus, provide comparisons of fracture length determined from seismic and net pressure calculations; and 3) provide estimates of fracture width. It is anticipated that emplacement of the C Sand wellbore will be accomplished in 1995 and that the experiments would be conducted in 1996.

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