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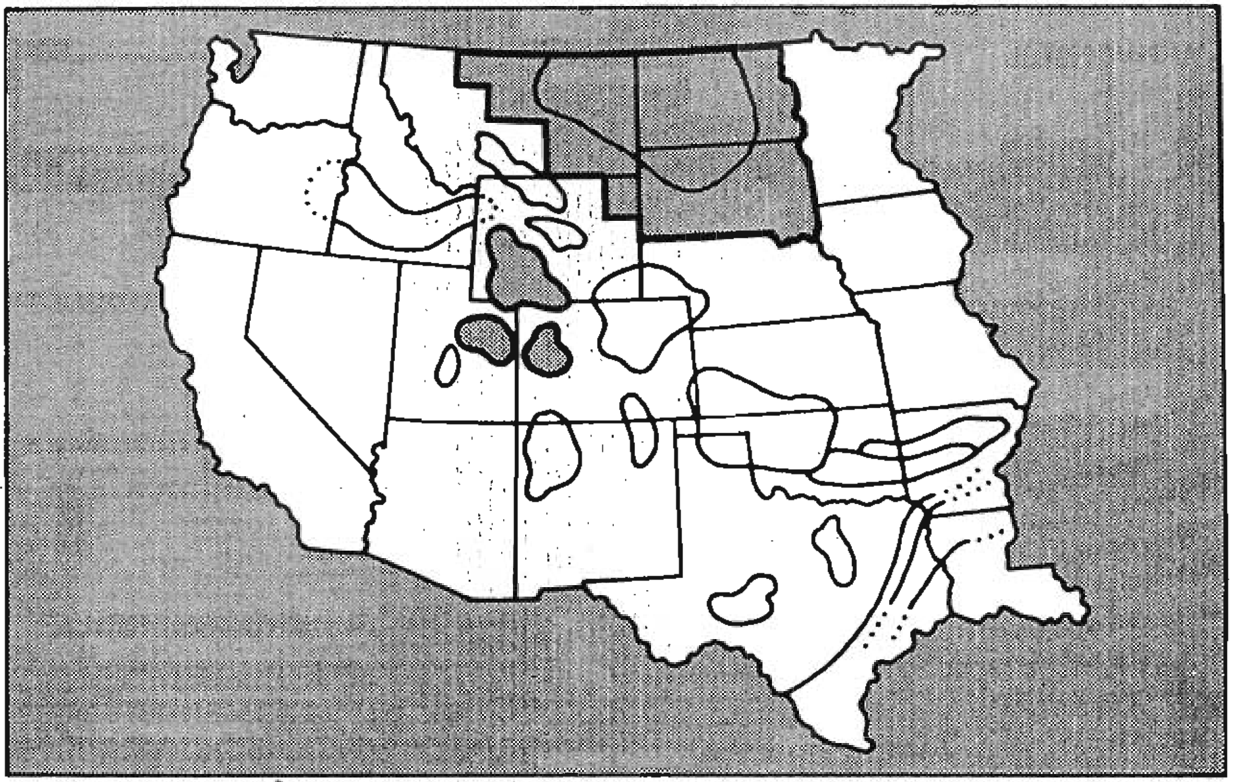
Western Gas Sands Project Status Report



1 April – 30 April, 1980

Prepared for
U.S. Department of Energy
Bartlesville Energy Technology Center
Las Vegas Field Office
Compiled by CER Corporation
Las Vegas, Nevada
Contract DE-AC08-79BC10003

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SUMMARY

The progress of the government-sponsored projects directed towards increasing gas production from the low permeability gas sands of the western United States, is summarized in this April, 1980, WGSP Status Report. Background information is provided in the September, 1977, Status Report, NVO-0655-100.

Planning activities continued for the multi-well experiment. Bartlesville Energy Technology Center continued formation evaluation studies for the WGSP. Theoretical analyses continued at Lawrence Livermore Laboratory for fracture growth across frictional interfaces and fluid flow in a fracture. Studies have begun at Los Alamos Scientific Laboratory on NMR signals coming from fluids in porous media. Analyses continued of information gathered from Sandia's fracture experiment in Grayson County, Texas.

Tests using the DOE Well Test Facility were completed for the Colorado Interstate Gas Company cyclic dry gas injection experiment. At the NTS, Sandia is conducting minifractures.

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SECTION 1

PROJECT MANAGEMENT

TECHNICAL MONITORING

C. H. Atkinson (DOE), H. E. Newman (CER Corporation) and W. O. Murphy (TRW) met with USGS in Denver on April 7 for the annual review of WGSP-related activities conducted by USGS.

CER personnel met with Intercomp April 7-9 in Houston, Texas. The purpose of the meeting was to familiarize CER with Interlog, their log analysis program.

P. M. Goodwin and M. Ostby (CER Corporation) attended the Hydraulic Fracturing Symposium in Tulsa, Oklahoma, April 7-10. The symposium was sponsored by Oil & Gas Consultants International, Inc.

A multi-well experiment (MWX) core committee meeting was held in Bartlesville, Oklahoma, April 30. Personnel from DOE, BETC, IGT, Sandia Laboratories and CER Corporation were in attendance to discuss core handling field procedures and subsequent laboratory analyses.

TECHNOLOGY TRANSFER

DOCUMENTATION REPORTS

TRW is conducting an evaluation of existing computer data bases to assess their suitability for the proposed Tight Gas Sands Data Base. The WGSP Logging Program document has been revised, updated and distributed. The WGSP Financial Supplement for April 1980, and the March WGSP Status Report have been distributed. Compilation of data is nearly complete for the Quarterly Basin Activities Report for First Quarter 1980, and the WGSP section of the DOE Semi-Annual Report for the Unconventional Gas Recovery Program (period ending March 31, 1980). Revision and updating continued on the DOE Well Test Facility Operations Manual. Research for the WGSP Greater Green River Basin Review and a similar report for the Uinta Basin continued. A draft copy of "Stratigraphy of the Piceance Basin" has been completed. A report is in preparation on the production history of the Piceance Basin.

PROJECT DATA BANK

Updating and cataloging continued on the WGSP bibliography and map file.

ARTICLES AND PUBLICATIONS

The following paper relates to the WGSP and is included in the WGSP bibliography. The introduction is included.

Developments in Hydrocarbon Fluids for High-Temperature Fracturing

by J. W. Burnham, L. E. Harris and B. W. Daniel
Halliburton Services

The original fracturing fluids were refined oils and crude oils because of an initial concern with the possible detrimental aspects of contacting a hydrocarbon reservoir with a nonacidizing aqueous fluid. Subsequent experience has shown that with the appropriate additives (clay control materials, surfactants, etc.), most reservoirs can be treated using an aqueous fluid. The applicability of aqueous fluids in the fracture stimulation of a given reservoir is determined best by laboratory tests on formation cores or consistent field results. Use of these evaluation procedures has resulted in some reservoirs being labeled as responding best when a hydrocarbon fluid is used. Presently, fracturing jobs using hydrocarbon fluids represent less than 10 percent of the total number of fracturing treatments performed.

The satisfactory performance of many wells stimulated with aqueous fracturing fluids coupled with the cost, hazard, and limited availability of hydrocarbon fracturing fuids are the major reasons for the preference of aqueous fluids over hydrocarbon fluids. An additional factor has limited the use of hydrocarbon fluids in some instances: heretofore, the viscosity stability of gelled hydrocarbon fluids relative to aqueous fluids has been inferior at elevated temperatures (>225°F or 107°C). This problem is magnified because of the low specific heat of hydrocarbon fluids, which results in more rapid fluid heat-up in the fracture relative to aqueous fluids. Although hydrocarbon-base fracturing treatments have been performed above this temperature in the past, in general they have met with only limited operational success. An improvement in the viscosity stability of hydrocarbon fracturing fluids has been realized through the use of a new process, which is comprised of an initial gel prepared on the surface and subsequent incorporation of a delayed thickener added during the fracturing operation to provide additional viscosity in the fracture. This allows the preparation of a hydrocarbon gel on the surface that possesses a manageable viscosity but exhibits increased viscosity in the fracture. A similar technique using a delayed thickener for aqueous-base fracturing fluids has been used successfully for several years.

SECTION 2

RESOURCE ACCESSMENT

U.S. GEOLOGICAL SURVEY ACTIVITIES

UINTA-PICEANCE BASINS

The mineralogy of Cretaceous rocks in the area of Wilkins Ridge, East Tavaputs Plateau was examined.

A paper is being prepared on the stratigraphy, sedimentology, and diagenesis of core from Pariette Bench field Tertiary rocks.

Mineralogic and paleontologic data is being compiled from analysis of Cretaceous and Tertiary rocks in the Price River Canyon area of the Uinta Basin. The resulting data will characterize stratigraphy and reservoir-rock character of tight gas-bearing units in the western part of the Book Cliffs.

Geophysical logs are being digitized through cored intervals in Uinta Basin fields. Log analysis will be calibrated to results of core studies.

The Piceance Basin Cretaceous structure map and the Cretaceous-to-Rollins sandstone isopach map are in review prior to publication.

Little new core is available from the Rio Blanco area, so analysis has been completed and the results to date have been published.

GREATER GREEN RIVER BASIN

Stratigraphic analysis of the Greater Green River Basin continued.

Gas desorption and analyses were completed from Rainbow Resources No. 1-3 Pacific Creek Federal well.

Work on porosity characteristics of the sandstone from the Superior-Pacific Creek well has been suspended because new core material was received from the Rainbow Resources No. 1-3 Federal well.

Data for the reports on clay mineralogy and petrography of Tierney wells are being compiled and will be published as an oil and gas chart.

Core was sampled and described from the Champlin No. 221 Amoco C well in Sec. 19, T18N, R95W, Sweetwater County, Wyoming.

An in-house-review of project work was conducted for DOE and coordinating groups.

A paper entitled "Evaluation of organic matter and subsurface temperature and pressure with regard to gas generation in low-permeability Upper Cretaceous and Lower Tertiary sandstones in the Pacific Creek area, Sublette and Sweetwater Counties, Wyoming," by Ben E. Law, Charles W. Spencer, and Neely H. Bostick was accepted for publication in *The Mountain Geologist.*

NORTHERN GREAT PLAINS PROVINCE

Work continued on the resource potential of the Northern Great Plains for the National Petroleum Council.

DOE and National Laboratories were briefed on studies in the Northern Great Plains.

SCHEDULE STATUS

Figure 2-1 is a milestone chart showing USGS WGSP progress.

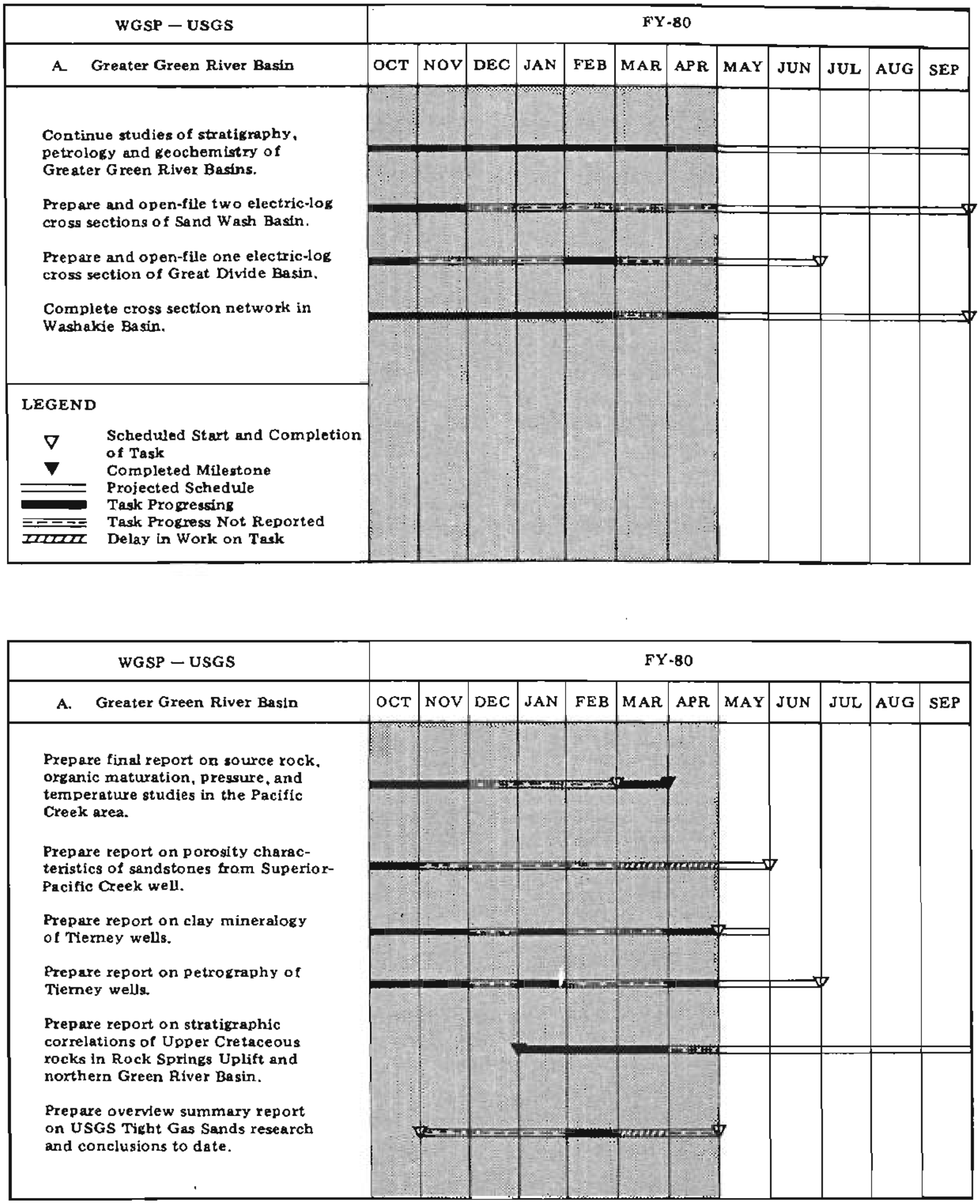
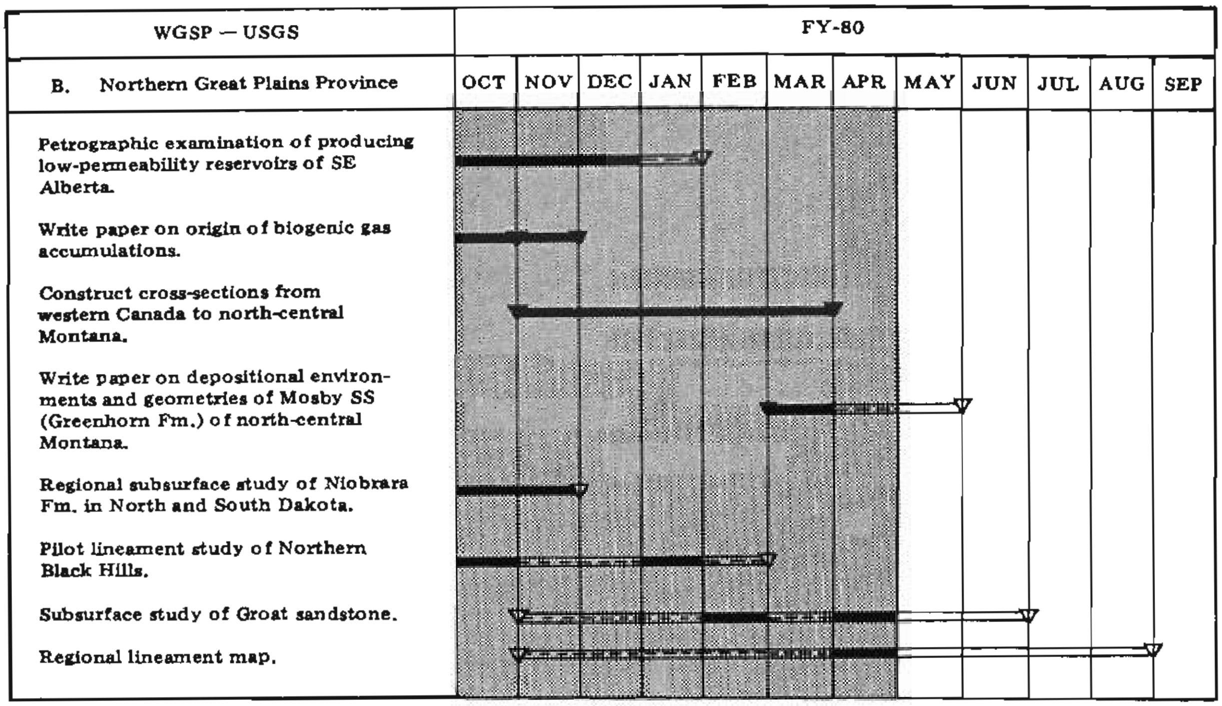


Figure 2-1 Milestone Chart — USGS



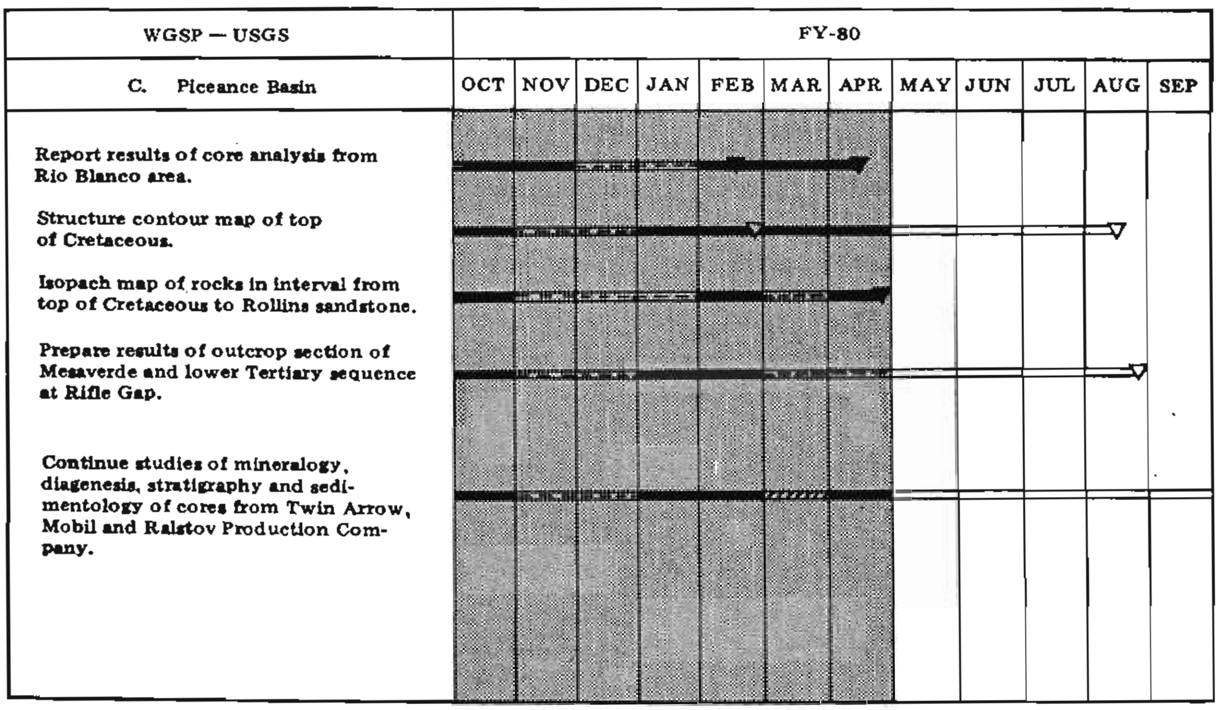


Figure 2-1 Continued

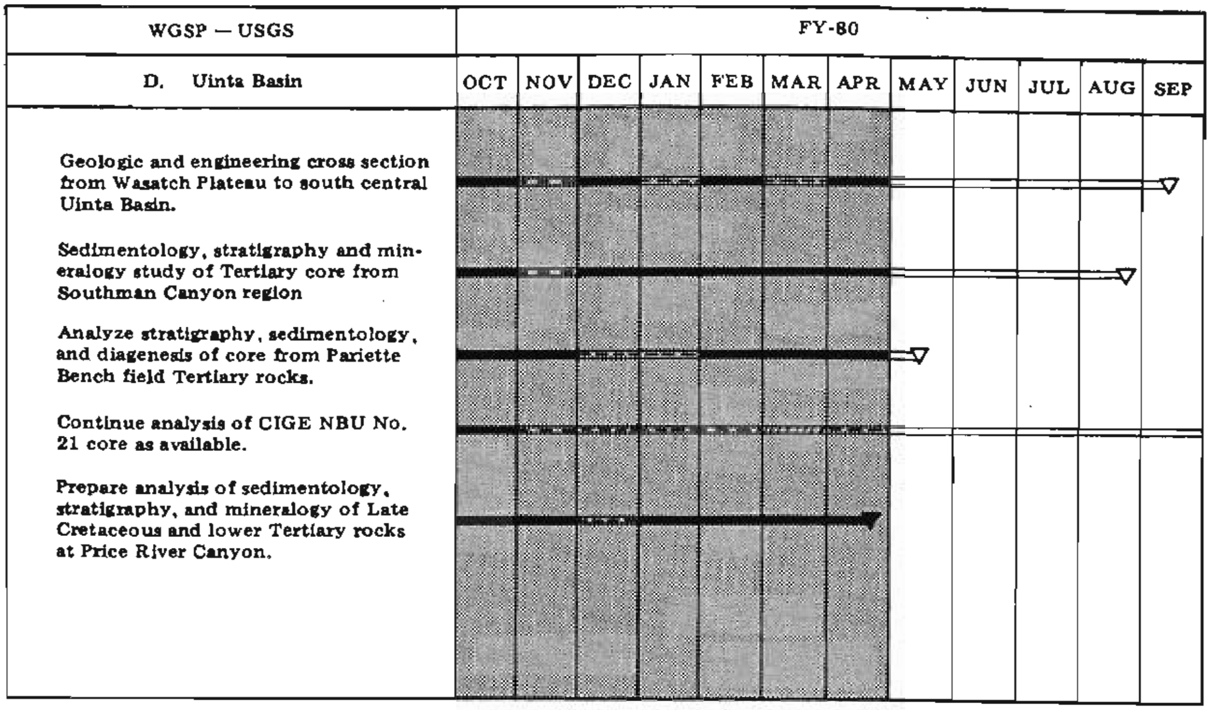


Figure 2-1 Continued

SURVEY OF BASIN ACTIVITIES

GREATER GREEN RIVER BASIN

Activity was limited this month in the basin. Three development wells were reported completed as gas producers and one wildcat well was a discovery. Initial potential flow totaled 1,453 MCFD from the contributing horizons of Almond, Frontier and Frontier/Bear River commingled.

Nineteen new locations were staked: 13 development and 6 wildcat.

Table 2-1 is a summary of wells from the basin, and Figure 2-2 shows the locations of these wells.

NORTHERN GREAT PLAINS PROVINCE

The Eagle and Bow Island Formations were the contributing horizons of the 6 producing wells reported this month. Total initial potential flow of new gas was 2,364 MCFD. Three development wells were reported as producers, three wildcats were discoveries and four development and one wildcat well were D&A. One development location was abandoned.

Eleven development and eight wildcat locations were staked during April.

Table 2-2 is a sampling of wells and locations in the NGPP, and Figure 2-3 shows their locations.

PICEANCE BASIN

Seven wells were reported complete this month: four development wells were producers and two were D&A; one wildcat well was D&A. Contributing horizons included the Mancos undifferentiated, Rollins/Cozzette/Corcoran commingled and Cozzette/

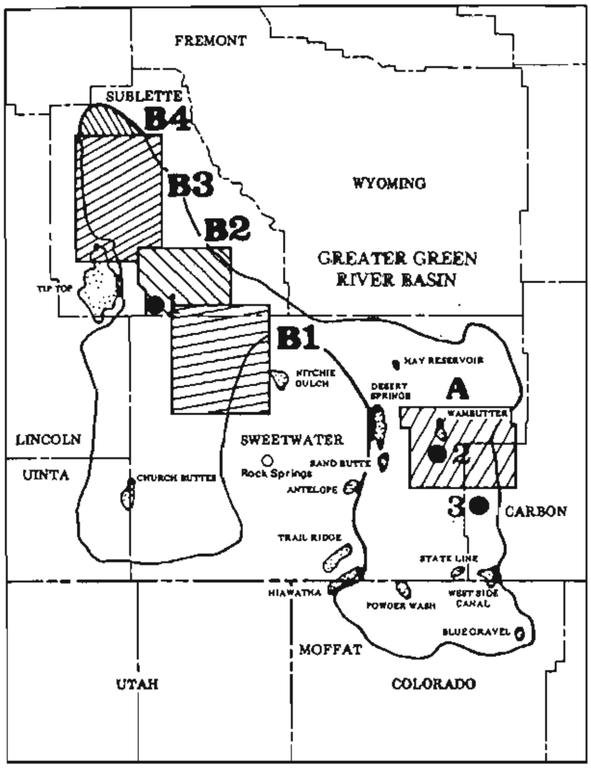


Figure 2-2 Greater Green River Basin Showing Wells of Interest and USGS Designated Core Areas (refer to Table 2-1)

Table 2-1 Summary of Wells — Greater Green River Basin

OPERATOR	WELL NAME	MAP INDEX NO.[1]	LOCATION Sec/T/R	HORIZON[2] ft	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Energetics Inc.	40-32 Federal	1	s½se 32/27N/ 111W Bird Canyon Field Sublette Cnty, WY	2nd Frontier 9,110-9,280 (gross) Bear River 9,666-9,679	9,910 PB: 9,679	115,000 gal water, 175,000 lb sand.	Develop. well, comp. 2-20-80. Commingled production.	500
Amoco Production	1 Champlin 220 Amoco-B	2	nesw 19/19N/94W Unnamed Field Sweetwater Cnty, WY	Almond 9,655-9,696 (gross)	10,050 PB: 9,696	Acidized twice w/ total 1,925 gal.	Wildcat field discovery, comp. 1-23-80. No cores.	171
Kemmerer Coal	29-1 Barrel Springs Unit	3	nese 29/16N/93W Barrel Springs Field Carbon Cnty, WY	Mesaverde 12,280			Develop. location, reported 4-14-80.	

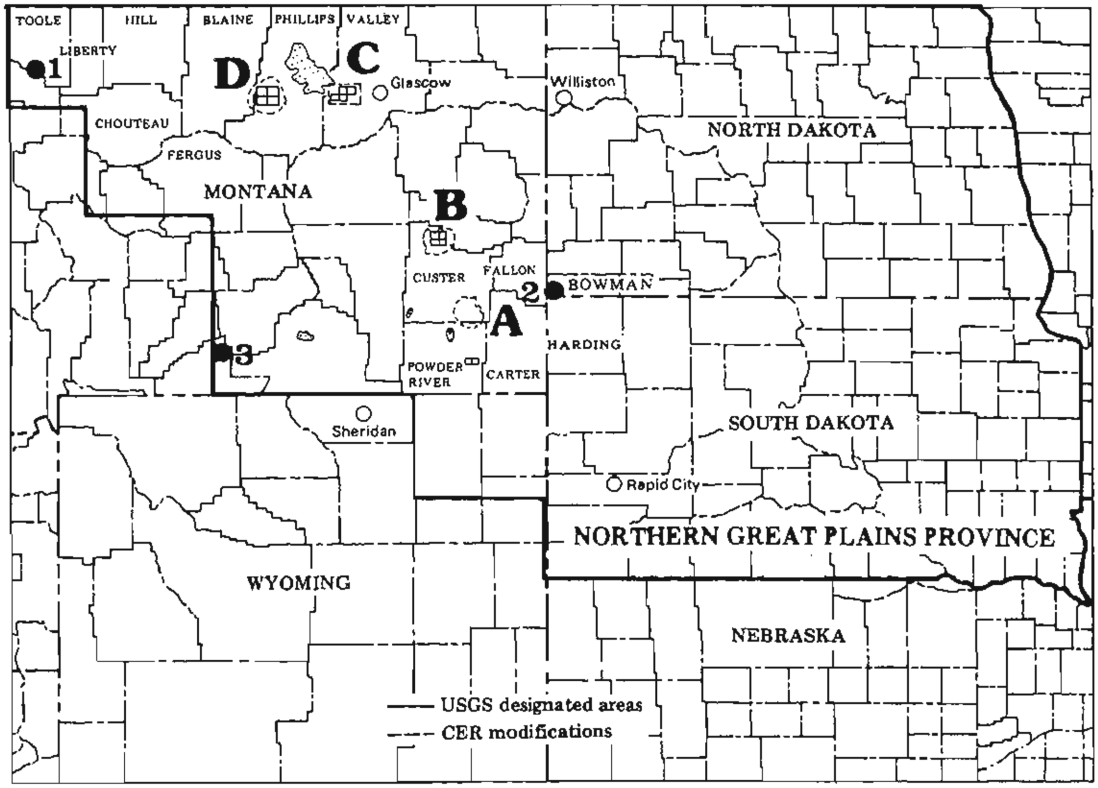


Figure 2-3 Northern Great Plains Province Showing Wells of Interest and USGS Designated Core Areas (refer to Table 2-2)

Table 2-2 Summary of Wells — Northern Great Plains Province

OPERATOR	WELL NAME	MAP INDEX NO.[1]	LOCATION Sec/T/R	HORIZON[2] ft	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Balcron Oil	1-17 Kell Ranch	1	nese 17/30N/1W Ledger Field Toole Cnty, MT	Bow Island 309-322 (open hole)	322		Wildcat outpost extension, comp. 8-16-79. No logs run; no cores or tests.	275
Joseph J. C. Paine & Associates	1-32 Chapman	2	swne 32/130N/106W Little Missouri Field Bowman Cnty, ND	Eagle 1,122-1,253 (gross)	1,341	23,985 gal water, 50,000 lb sand.	Develop. well comp. 10-17-79. No cores or tests.	595
Nelvel E. Murphy	1 Victor-Grabowski	3	nene 26/6S/23E Wildcat Field Carbon Cnty, MT	Frontier 400			Wildcat location, reported 4-16-80.	

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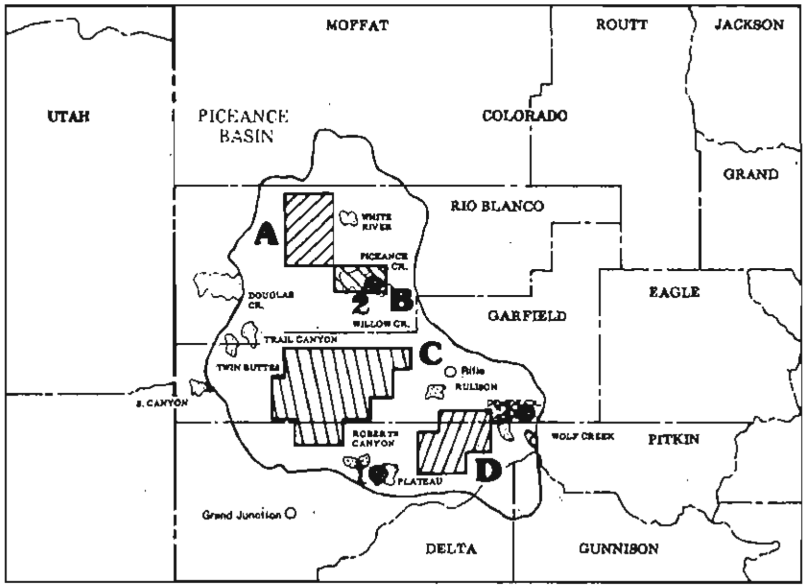


Figure 2-4 Piceance Basin Showing Wells of Interest and USGS Designated Core Areas (refer to Table 2-3)

Table 2-3 Summary of Wells — Piceance Basin

OPERATOR	WELL NAME	MAP INDEX NO.[1]	LOCATION Sec/T/R	HORIZON[2] ft	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Bow Valley Petroleum	14-2 Pallaoro	1	sesw 14/10S/96W Plateau Field Mesa Cnty, CO	Rollins 3,044-3,101 Cozzette 3,380-3,428 Corcoran 3,515-3,589	3,680 PB: 3,626	Fractured 3 times w/ total 96,000 gal water, 187,000 lb sand.	Develop. well comp. 12-3-79. No cores or tests. Commingled production.	677
Great Eastern Energy	15-2-95 Government	2	senw 15/2S/95W Piceance Creek Field Rio Blanco Cnty, CO	Wasatch 6,000	4,050		Wildcat outpost, comp. 2-26-80 D&A.	
Dome Petroleum	2-33 Barnby-Federal	3	swsw 33/7S/90W Wildcat Field Garfield Cnty, CO	9,550 ft Cretaceous test			Wildcat location, reported 4-18-80.	

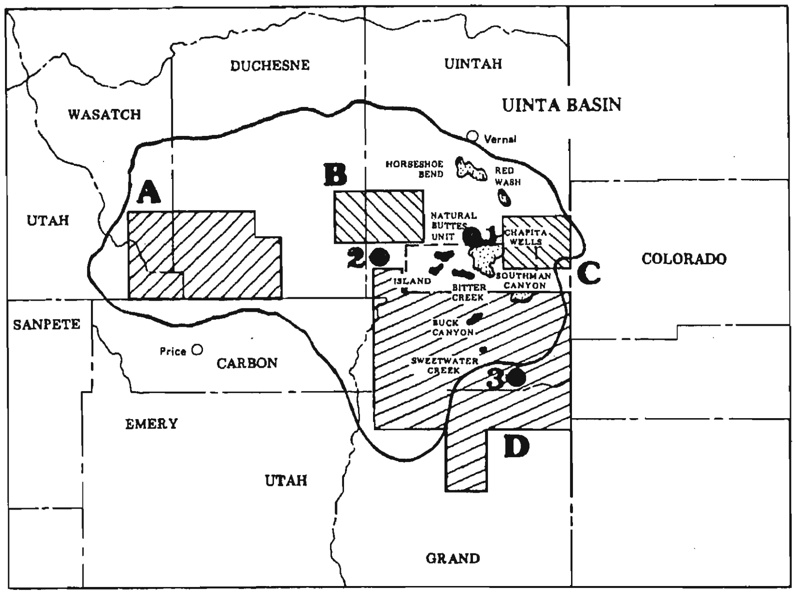


Figure 2-5 Uinta Basin Showing Wells of Interest and USGS Designated Core Areas (refer to Table 2-4)

Table 2-4 Summary of Wells — Uinta Basin

OPERATOR	WELL NAME	MAP INDEX NO.[1]	LOCATION Sec/T/R	HORIZON[2] ft	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Conoco Inc.	9-33 Duncan-Federal	1	swse 33/8S/21E Natural Buttes Field Uintah Cnty, UT	Wasatch 6,643-7,017 (gross)	7,408	Acidized w/ 1,700 gal; fractured w/ 98,000 gal emulsion, 168,000 lb sand.	Develop. well, comp. 12-16-79. No cores or tests.	922
Mapco Production	7-25A Federal	2	swne 25/9S/18E Wildcat Field Uintah Cnty, UT	Mesaverde 9,158-9,387	9,570	Acidized w/ 3,200 gal; fractured w/ 74,000 gal water, 142,000 lb sand.	Wildcat field discovery, comp. 2-19-80. No cores or tests.	331
Coseka Resources	4 Black Horse Canyon	3	swnw 8/15S/24E Wildcat Field Uintah Cnty, UT	Mancos 6,100			Wildcat location, abandoned.	

Corcoran commingled. Total initial potential flow was 1,284 MCFD of new gas.

Five new locations were staked: three development and two wildcat.

Table 2-3 is a summary of wells reported this month, and their locations are shown in Figure 2-4.

UINTA BASIN

Activity was also slow in this basin during April. Four completions were reported for the month: two development wells were producers, one wildcat was a discovery and one development well was D&A. One wildcat location was abandoned. Total initial potential flow was 2,036 MCFD of new gas from the Wasatch and Mesaverde undifferentiated. One new development location was staked during the month.

An abbreviated summary of wells is listed in Table 2-4, and Figure 2-5 shows their locations.

C K GEOENERGY

The final report is being prepared on the Green River/Wind River Studies, under contract No. DE-AC08-79BC10005, Techniques for Optimizing Selection and Completion of Western Tight Gas Sands.

MULTI-WELL EXPERIMENT

THEORETICAL ANALYSIS

An important aspect of the multi-well experiment (MWX) is the proper spacing of wells for optimum results. There is concern that small fractures radiating from the stress well will affect the large fractures from the primary well, leading to a desire to place the stress well as far as possible from the first well. However, the greater the separation of the wells, the greater the chance that the stress well will miss important sand lenses penetrated by the primary well.

To provide a stronger basis for optimum well spacing, probabilities have been calculated for the successful penetration of one or more sand lenses previously hit by the main well. These probabilities are shown in Figure 2-6, where the probability of success (a hit) by the stress well is plotted against the well spacing, normalized to the width of a sand lense. The present spacing suggestion is about 400 ft, which is about equal to a lense width. For a single lense, the success probability is only about 0.36. For success through a number of good lenses, the probabilities go even lower: 0.13 for complete success with two lenses, and 0.05 with three lenses. The odds improve if some misses are accepted. For instance, if at least two good lenses out of three are hit, the curve labeled "2 or 3 out of 3" gives a success probability of 0.30. This is still a low success level, and argues for some reduction in spacing.

PLANNING ACTIVITIES

The legal agreements concerning the oil and gas lease and the surface rights for the proposed MWX site are being prepared and approved. Formal approval is anticipated in May.

Cleveland Cliffs Iron Company in Rifle, Colorado, is presently providing core analysis support to the Eastern Gas Shales Program. They have agreed to prepare a proposal of maintaining a MWX core library based on storage of 6,000 ft of core, 500 ft of core display, a limited amount of laboratory space, and a person to be custodian of the library and to handle shipping, receiving, and inventory of the core.

Preliminary oil-based drilling mud invasion tests under simulated reservoir conditions (4,000 psi and 200^{o}F) on tight sands core from a well near Pinedale, Wyoming, indi-

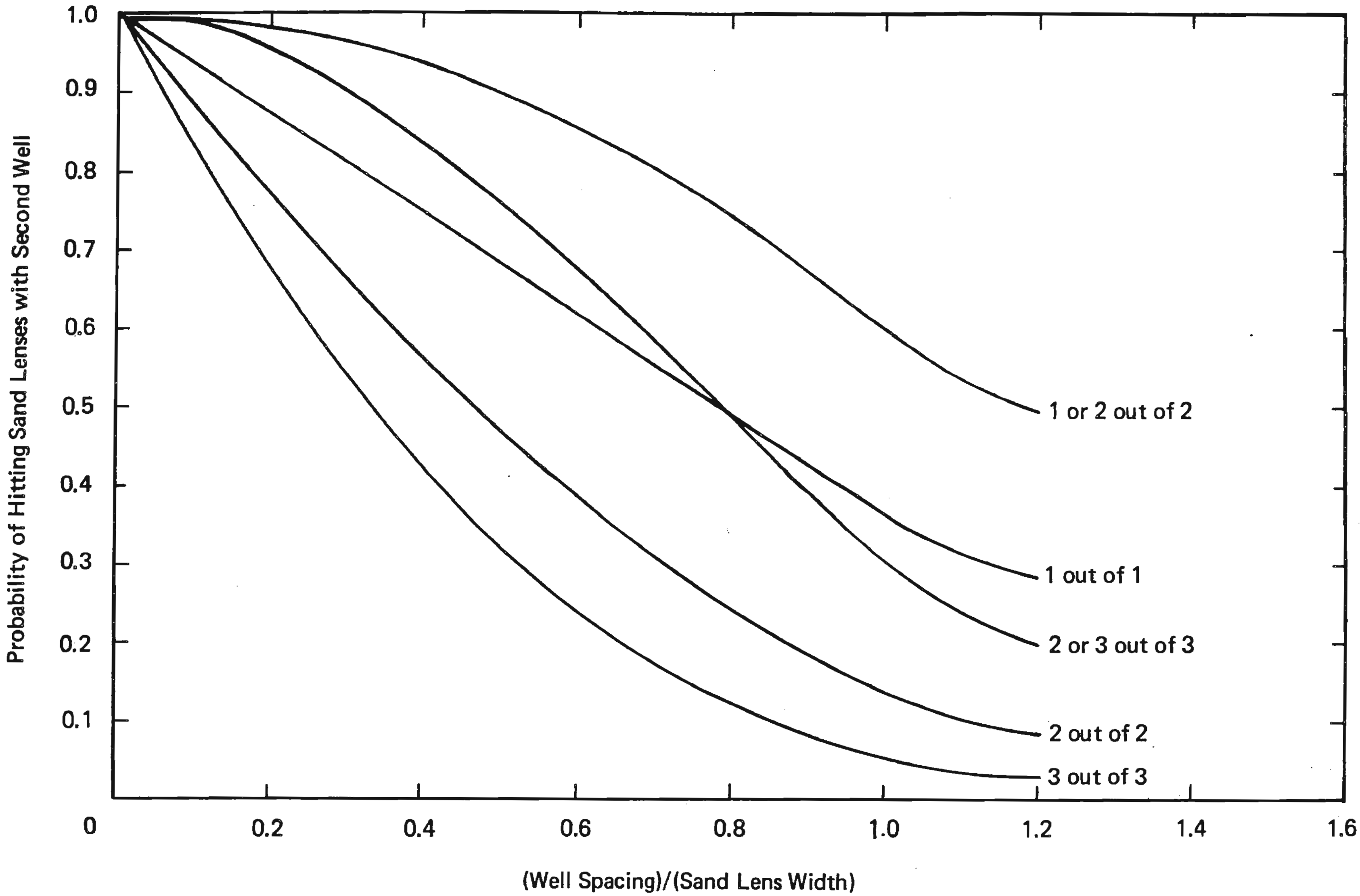


Figure 2-6 Probability of Hits Through Multiple Sand Lenses

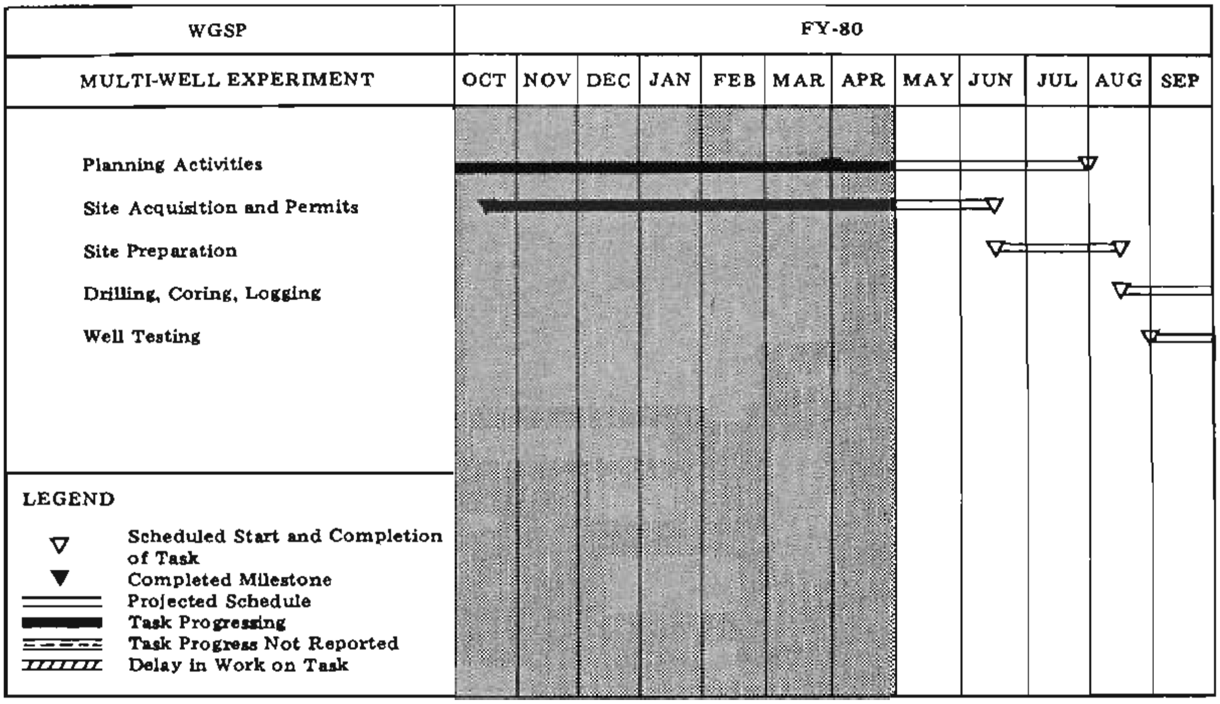


Figure 2-7 Milestone Chart — Multi-Well Experiment

cated no significant invasion (< 1 mm). Thus, invasion may not be a problem.

Other activities included:

- location layout for the experiment;
- designing utility routes;
- designing core handling facility for experiment;
- obtaining Garfield County Environmental Impact forms;
- filing forms with Petroleum Frequency Coordinating Committee of American Petroleum Institute for VHF radio assignment usage by well test personnel during the stay at multi-well site;
- preparing cost estimate for site preparation; and
- designing and fabricating equipment for in situ stress testing on MWX site.

A MWX core committee meeting was held in Bartlesville, Oklahoma, April 30, with personnel attending from DOE, BETC, IGT, Sandia and CER Corporation.

Agenda items included:

- core processing in the field including slabbing, plugging of core, and sealing;
- the necessity of and a place for a special consultant who would do supplementary lithologic description;
- any applications of paleomagnetism to MWX;

- the advisability of having a representative or engineer of a commercial laboratory on site because of the complex core analyses to be done;
- data management; and
- a core library and storage facilities.

Resulting action items included:

- all major users of core must acquaint Sandia and CER with their special requirements prior to fielding;
- optimization of sealing and preservation procedures for plugs taken from MWX core in the field;
- examination of potential hazards created during field processing of core; and
- scheduling a core committee meeting immediately after coring MWX I to examine the fast track core analysis results, logging results and the core prior to proceeding with the middle track core analysis plan.

SCHEDULE STATUS

Figure 2-7 is a milestone chart showing the progress of the multi-well experiment.

SECTION 3

RESEARCH & DEVELOPMENT BY ENERGY TECHNOLOGY CENTERS & NATIONAL LABORATORIES

BARTLESVILLE ENERGY TECHNOLOGY CENTER

IN SITU PERMEABILITY

Measurement of Formation Characteristics for Western Tight Sands — Institute of Gas Technology

Measurements on core samples from the Mapco RBU No. 11-17F well, Sec. 17, T10S, R20E, Uinta County, confirm earlier observations that the slope of the Klinkenberg plot decreases as net confining pressure increases. The gas permeability of cores from 8,243.3 ft, 8,298.4 ft. and 8,234.9 ft decreased considerably as a result of increasing net confining pressure. Klinkenberg plots for the three cores are shown in Figures 3-1 through 3-3. With increased net confining pressure, the slope of the lines and the extrapolated permeability values at infinite mean pore pressure decreased sharply. The slope and intercept values are shown in Table 3-1 as a function of net confining pressure.

Figures 3-4 and 3-5 show the reduction of gas permeabilities (measured at a mean pore pressure of 34.7 psia) and extrapolated permeabilities as a function of net confining stress. The reduction in permeability of these cores is more pronounced than other core samples studied from the same well. Permeability of the core samples from 8,298.4 ft and 8,234.9 ft dropped to extremely low values (approaching zero permeability) at confining pressures above 3,000 psi.

LOGGING STUDIES

Interface Conductivity Effects on Electric Logging

A semi-automated method for cation exchange capacity (CEC) determination is almost complete. Up to 17 samples (10 g per sample) can be accommodated by the ion exchanger. The technique involves Ba^{++} exchange at 9.2 pH. One of the more difficult aspects of this technique was establishing a simplistic and yet accurate condometric titrator.

Since many reservoirs contain significant amounts of clay, the CEC has been an important parameter in such areas as electric logging and polymer flooding. Most CECs are measured at room temperature and applied at reservoir temperatures. Because cation exchange is a surface phenomenon, it might be expected to exhibit a relatively strong temperature dependence. As a first attempt to determine the magnitude of this effect, the CEC of bentonite is currently being studied at elevated temperatures. Although the method of removing excess cations has been worked out at room temperature, such methods do not necessarily apply at elevated temperatures. Initial results should be available next month.

Mapping and Contouring Water Resistivities in Tight Western Gas Sands — Texas A&M University

Conoco, Exxon, Schlumberger, Tenneco, Shell and Texaco have agreed to assist in collecting water samples from Upper Cretaceous formations in the Uinta Basin. Schlumberg in Vernal, Utah, has volunteered access to their formation waters library. Belco's Vernal office has volunteered to collect water samples during May and supply all pertinent

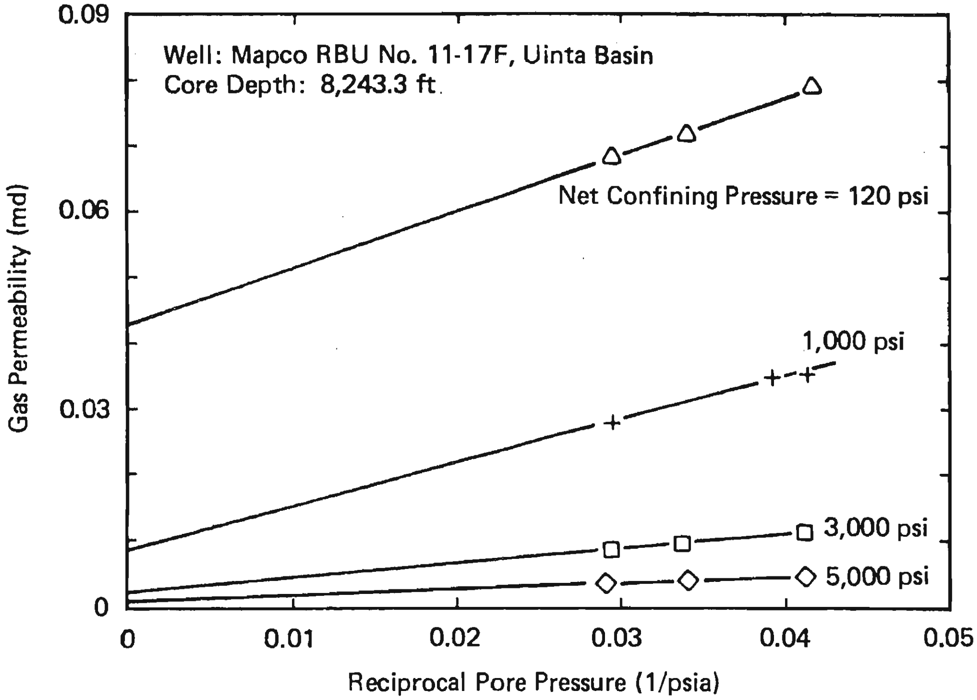


Figure 3-1 Effect of Net Confining Pressure on Gas Slippage at Core Depth 8,243.3 Ft

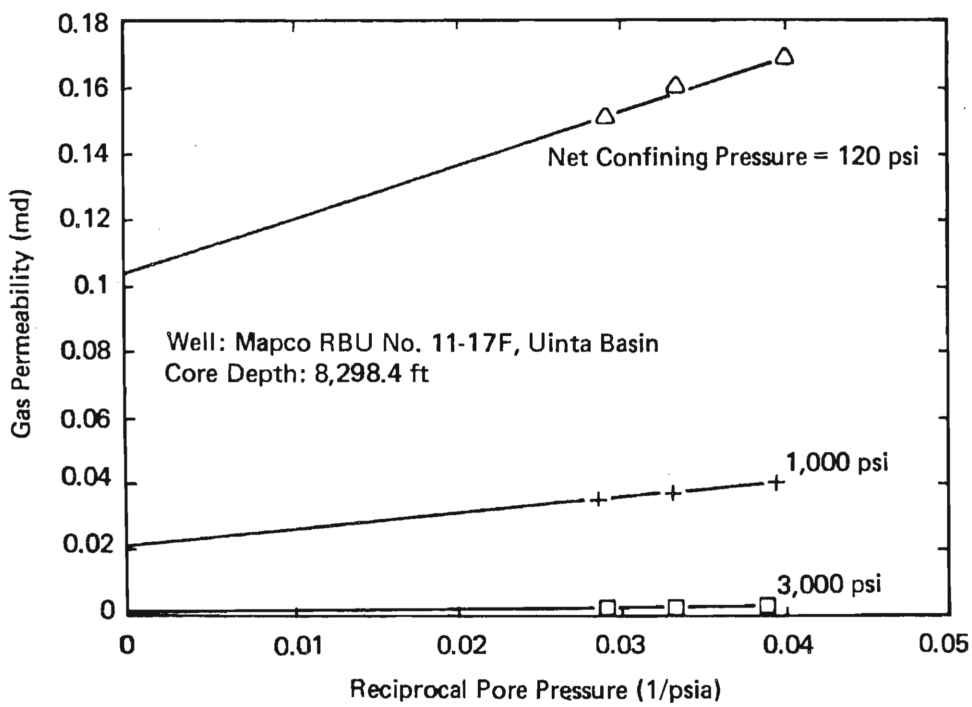


Figure 3-2 Effect of Net Confining Pressure on Gas Slippage at Core Depth 8,298.4 Ft

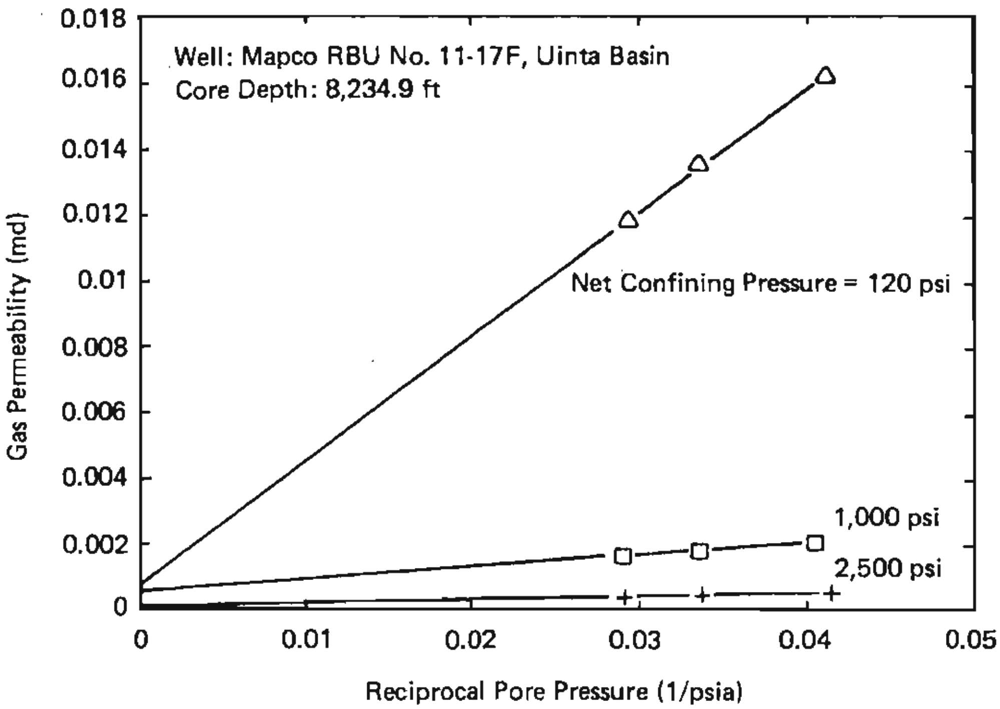


Figure 3-3 Effect of Net Confining Pressure on Gas Slippage at Core Depth 8,234.9 Ft

Table 3-1 Slope and Intercept Values as a Function of Net Confining Pressure

Net Confining Pressure, psi	Slope of Klinkenberg Plot, md psi	Intercept K_∞, md
Core Depth: 8,243.3 ft		
120	0.9040	0.04200
1,000	0.6850	0.00810
3,000	0.2230	0.00220
5,000	0.1190	0.00049
Core Depth: 8,298.4 ft		
120	1.6150	0.10500
1,000	0.4680	0.02200
3,000	0.0450	0.00046
Core Depth: 8,234.9 ft		
120	0.3710	0.00092
1,000	0.0340	0.00063
2,500	0.0091	0.00013

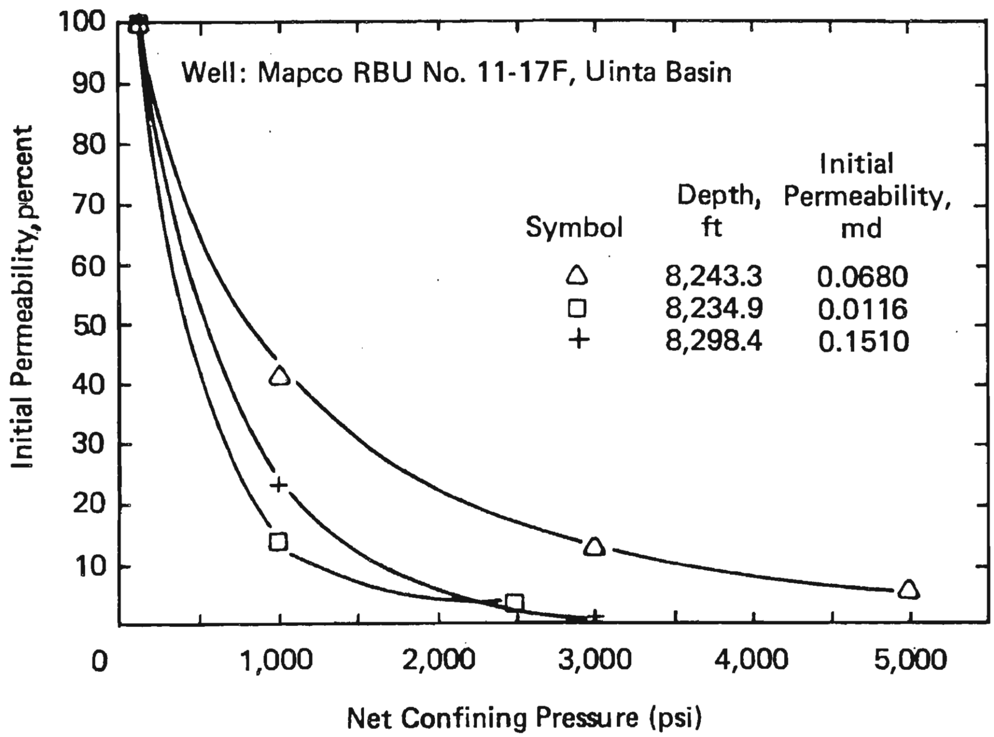


Figure 3-4 Reduction in Gas Permeability Due to Net Confining Pressure

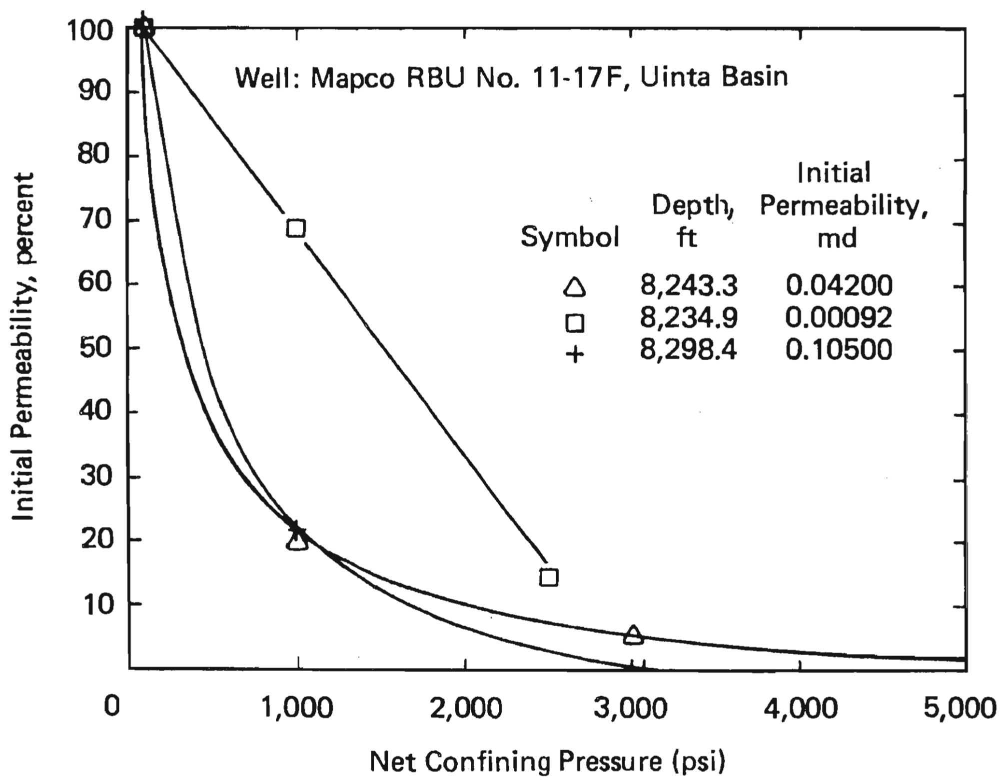


Figure 3-5 Reduction in Extrapolated Gas Permeability Due to Net Confining Pressure

information before wells are shut-in for the summer (when demand for natural gas is light). Texaco's Denver office advised that none of their Upper Cretaceous producers yield anything but gas and distilled water.

Study of Sonic, Neutron and Density Logging of Low Permeability Gas Sands — Texas A&M University

The carbonate content of cores from the CIGE NBU No. 21 well was measured and the effect of the carbonate on the matrix density is shown in Figure 3-6.

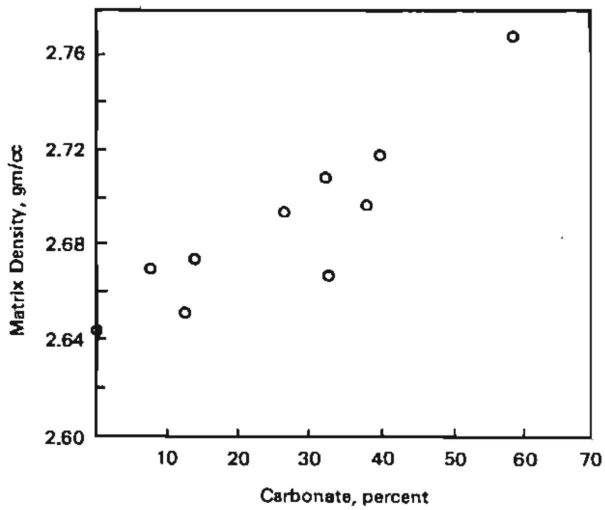


Figure 3-6 Matrix Density vs Percent Carbonate, CIGE No. 21

Samples from the Mitchell Energy Muse-Duke No. 1 well, Limestone County, Texas, and Pacific Transmission Supply Company No. 24-19 Federal well, Sublette County, Wyoming, have been cut to lengths that can be used for travel time analysis. The results for porosities measured with the matrix volume cap are listed in Table 3-2.

The previous monthly report outlined the results of the matrix travel time experiments with samples from CIGE NBU No. 21. Sample 28 gave consistent results. Samples 17 and 33 behaved as if they were not 100 percent saturated with liquid. After resaturation of sample 17, the matrix travel time was determined to be 55.8 μsec/ft. Table 3-3 lists the properties of samples 28 and 17. These initial results indicate that the carbonate cement does not decrease the matrix travel time as expected (the matrix travel time for a 100 percent limestone sample is 47.6 μsec/ft). Also, sample 17, with the higher porosity of the two, has a matrix travel time similar to that of sandstone. The limited amount of limestone data prevents definite conclusions. More samples are being prepared for matrix travel time analysis.

ADVANCED LOGGING TECHNIQUES AND INTERPRETATIONS

Dielectric Constant Measurement for Formation Evaluation

The interaction between capacitance and inductance in the dielectric constant measurement system was studied during the month.

The interaction is caused by the distributed parameter nature of the bridge circuit. Numerous modifications to minimize the effect have been tried and accurate results can now be obtained from 500 KHz to 20 MHz at a specific point in the circuit. A distributed transmission line correction will be required to relate the measurement at the specific point to sample parameters in the sample holder. This effort will continue during May.

Developments and Applications of a Wide Band Laboratory Dielectric Constant Measurement System — Colorado School of Mines

The sample holder is being tested to confirm its suitability for both housing the sample for measurements and for sample saturation.

Table 3-2 Porosity Results Measured with Matrix Volume Cap

PTS No. 24-19 Federal

Sample	Depth, ft	Porosity, Percent
P1	5,120	12.4
P2	5,173	11.9
P3	5,193	5.6
P4	5,206	13.5
P5	5,210	13.4
P6	5,222	14.0

Muse-Duke No. 1 Well

Sample	Depth, ft	Porosity, Percent
M1	11,223	2.40
M2	11,251	2.80
M3	11,363	2.40
M4	11,387	1.65
M5	11,437	2.00
M6	11,460	2.10
M7	11,491	1.80
M8	11,554	2.30
M9	11,278	2.30
M10	11,522	1.80

Table 3-3 Matrix Travel Times CIGE NBU No. 21 Well

	Sample 28	Sample 17
Matrix Travel Time, μ sec/ft	63.000	55.800
Matrix Density, gm/cc	2.772	2.645
Carbonate, percent	58.000	13.000
Rock Fragments, percent	16.000	20.000
Feldspar Plagioclase, percent	0.000	9.000
Porosity	3.200	8.500

Ten sandstone cores were prepared for the laser experiment and the dielectric experiment using bridges.

Use of Sonic Techniques to Measure In Situ Stresses — Lawrence Livermore Laboratory

A theoretical evaluation of the continuous wave response of two waves propagating in rock has been studied to determine if the velocities of each wave can be found from the total response. Analysis is continuing of stress and velocity distributions for same-face or borehole geometries.

The acoustic birefringence method has been tested for the transmission mode on rocks with 3 percent to 30 percent anisotropy using a low resolution data acquisition system. The tradeoff among transducer frequency, sample length and acoustic attenuation is being evaluated.

Preliminary continuous wave measurements made from a sample of Nugget sandstone for uniaxial loads from 0 to 500 psi showed positive results.

ROCK-FLUID INTERACTION

Proppant Embedment Studies

The method of measuring the degree of fracture closure with increasing overburden has been improved. Sintered bauxite is now being studied and the program will be extended to include new high strength proppants as they become available. In an experiment designed to compensate for compression of the formation under load, berea collapsed when placed under 13,700 psi/in.

Simulated Fracture Conductivity

A long-term flow-through stressed-proppant experiment is in operation. A 2 percent KCl solution will flow through the simulated proppant-filled fracture at a flowrate of approximately 3 mls per minute. Periodic samples of the fracture effluent will be collected for 5 days to measure the change in size and quantity of particles generated from the simulated fracture.

SCHEDULE STATUS

Figure 3-7 shows the progress of BETC WGSP projects.

GAS RESEARCH INSTITUTE SPONSORED PROJECTS

Work continued on the development of a matrix or information model to identify the state-of-the-art in tight gas sands technology. Numerous departures from the matrix model proposed by the Project Advisors have been recommended.

Northwest Exploration Company declined the opportunity to participate in a cooperative coring/logging field project near the proposed site of the MWX. However, negotiations are continuing in an effort to secure final approval by Northwest Exploration Company for use of a Northwest lease in the Piceance Basin for the MWX.

A comprehensive Annual Report is in preparation, covering all project activities during the period from project inception in early 1979 through March 1980.

EVALUATION OF SEISMIC DATA FOR DETAILED STRATIGRAPHIC STUDIES OF LENTICULAR SAND

Processing of the Bryson Canyon Site 3-D seismic data is almost complete. Reruns of some 3-D time slices at shallower depths and different filter parameters are expected in early May. Interpretation of the seismic data has been an ongoing activity throughout April by Sandia Laboratories. Results of the

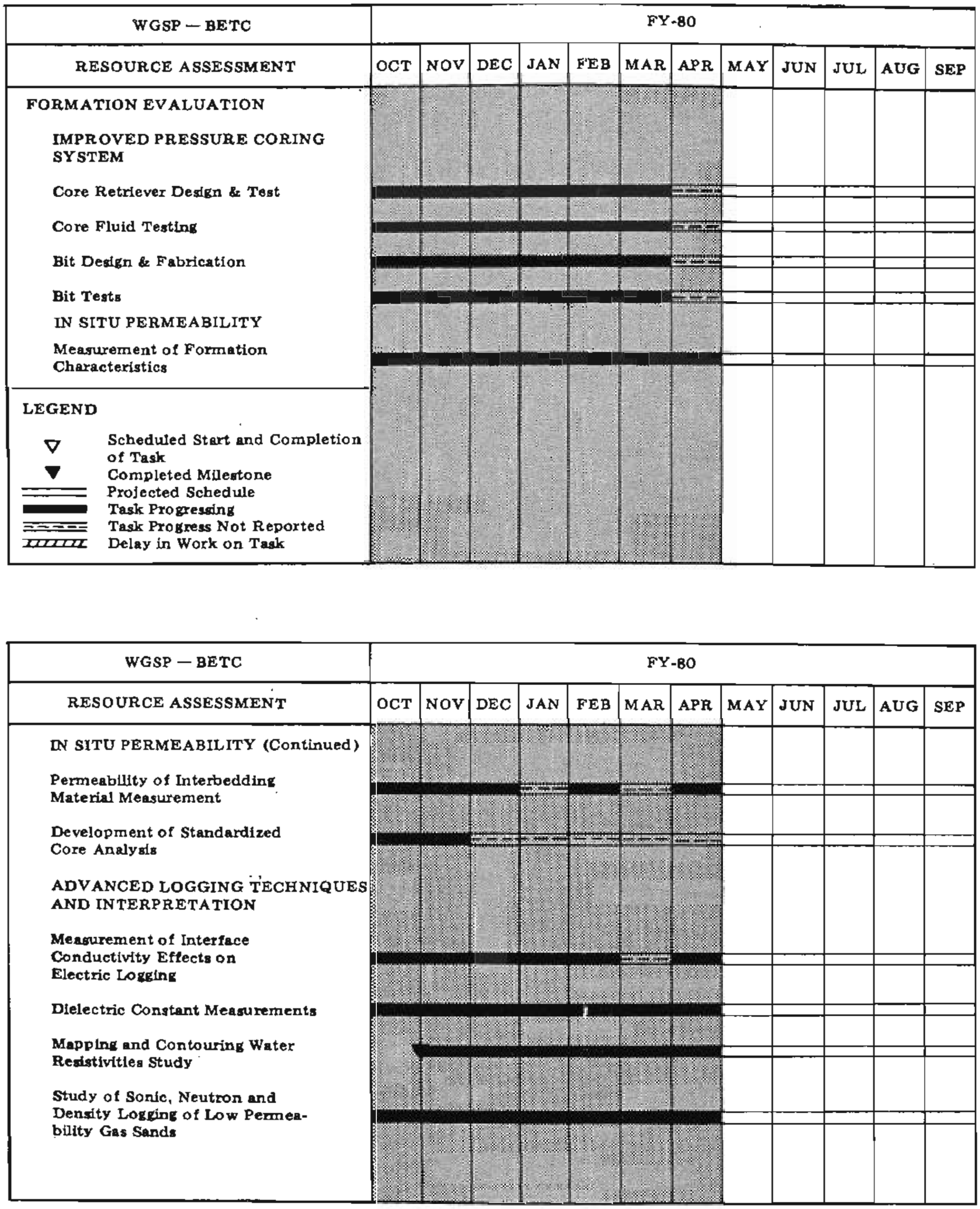
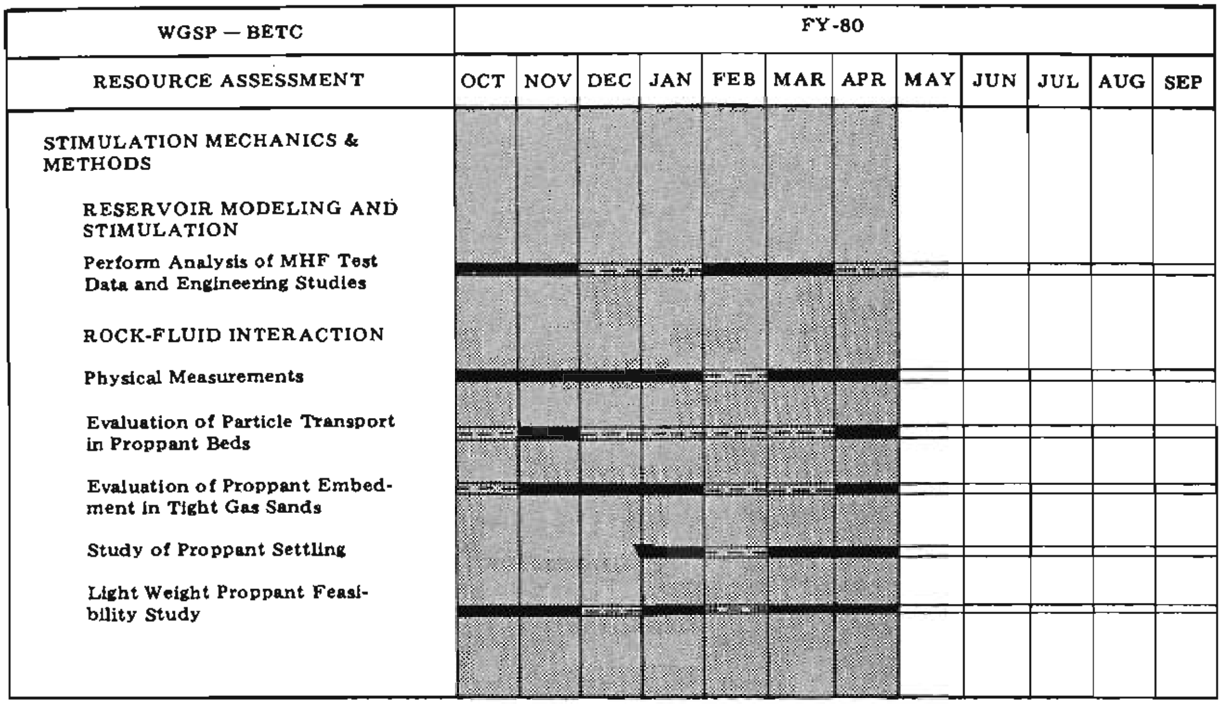


Figure 3-7 Milestone Chart — BETC



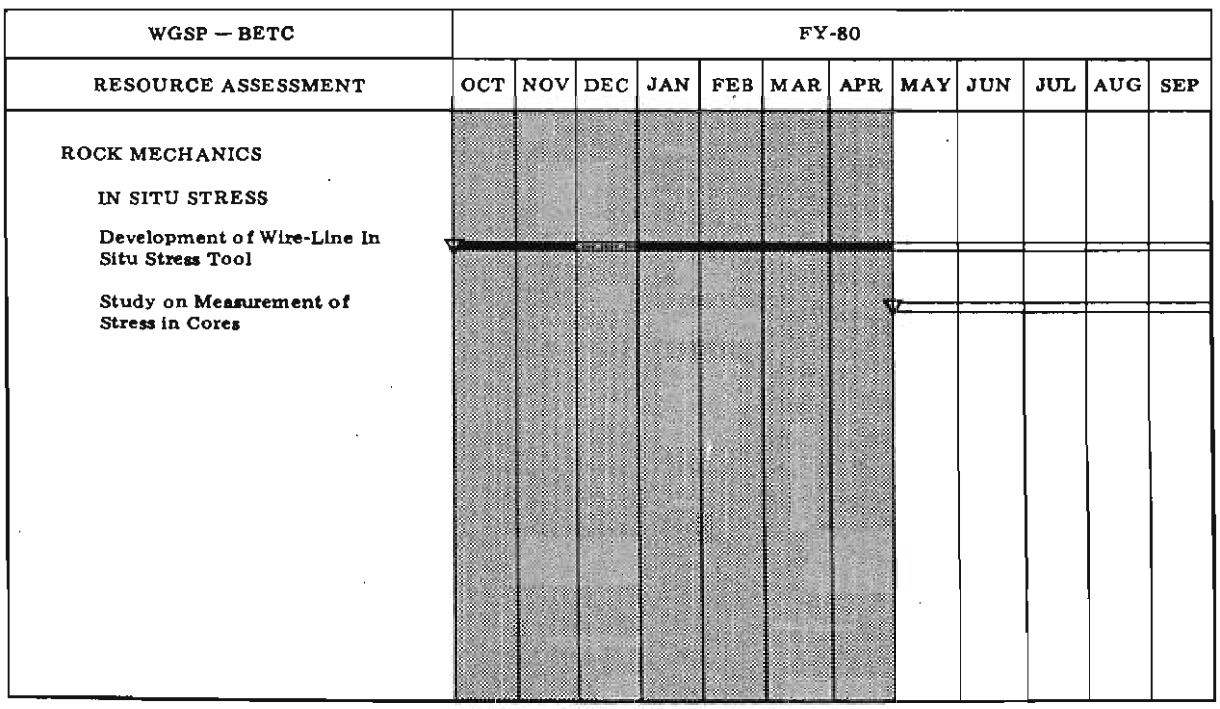


Figure 3-7 Continued

interpretive effort are now being compiled and made ready for presentation for review. At that time, suggested options for further work at this site and for continuation of the program will be discussed.

SECONDARY BASIN STUDIES

Literature review and a geologic background study continued on the combined Arkoma Basin/Ouachita Mountains Province of Oklahoma and Arkansas. A report is in preparation. Preliminary review continued on the Raton Basin of New Mexico and Colorado.

LAWRENCE LIVERMORE LABORATORY

THEORETICAL ANALYSIS

Crack Growth Across Frictional Interfaces

Theoretical calculations to analyze some aspects of hydraulic fracture penetration through a frictional interface have continued. It was previously reported that the stress intensity factor changes due to frictional slip as a pressurized fracture approaches an interface. Although the stress intensity factor can be used to predict how a fracture will be influenced by a frictional interface, it cannot be used to predict penetration of the material on the other side of the interface. This is because relative motion along the frictional interface precludes evaluation of the stress state across the interface with this technique. To evaluate hydraulic fracture penetration across a frictional interface a set of calculations have been utilized to calculate the strain energy density, e_t, at the fracture tip and directly across the interface as a pressurized fracture approaches the interface.

Figure 3-8 displays the normalized strain energy density on a semilog plot as a function of crack position for several values of β, where β is the ratio of the shear stress that the frictional interface can support in the absence of a pressurized crack to the pressure in the crack, p_c. The strain energy density is normalized by obtaining the ratio of e_t with p_c/E where E is Young's modulus for the material. The crack tip position, δ, has been normalized with the crack length and the interface is located at $\delta = 0.0$.

The frictional interface does not affect the pressurized fracture until the crack is less than one crack length from the interface. It is obvious that the crack has to be nearer to the interface before the strain energy density increases as β is increased. The strain energy density appears to approach an asymptote as the fracture tip approaches the interface. These results show that fracture propagation is enhanced by frictional slippage along an interface as the tip approaches the interface.

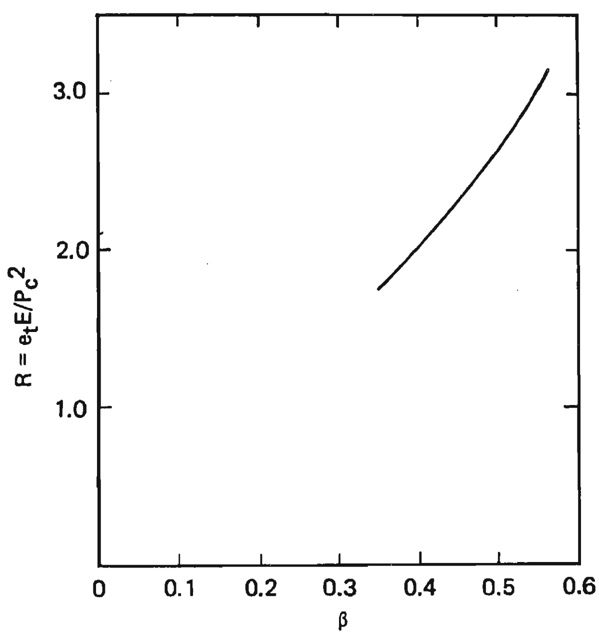


Figure 3-9 Normalized Strain Energy Density as a Function of β in the Material across the Interface from the Crack

Figure 3-9 shows the normalized strain energy density in the material opposite the fracture as a function of β. The strain energy density shown on this plot was the value in the material across the interface as the fracture

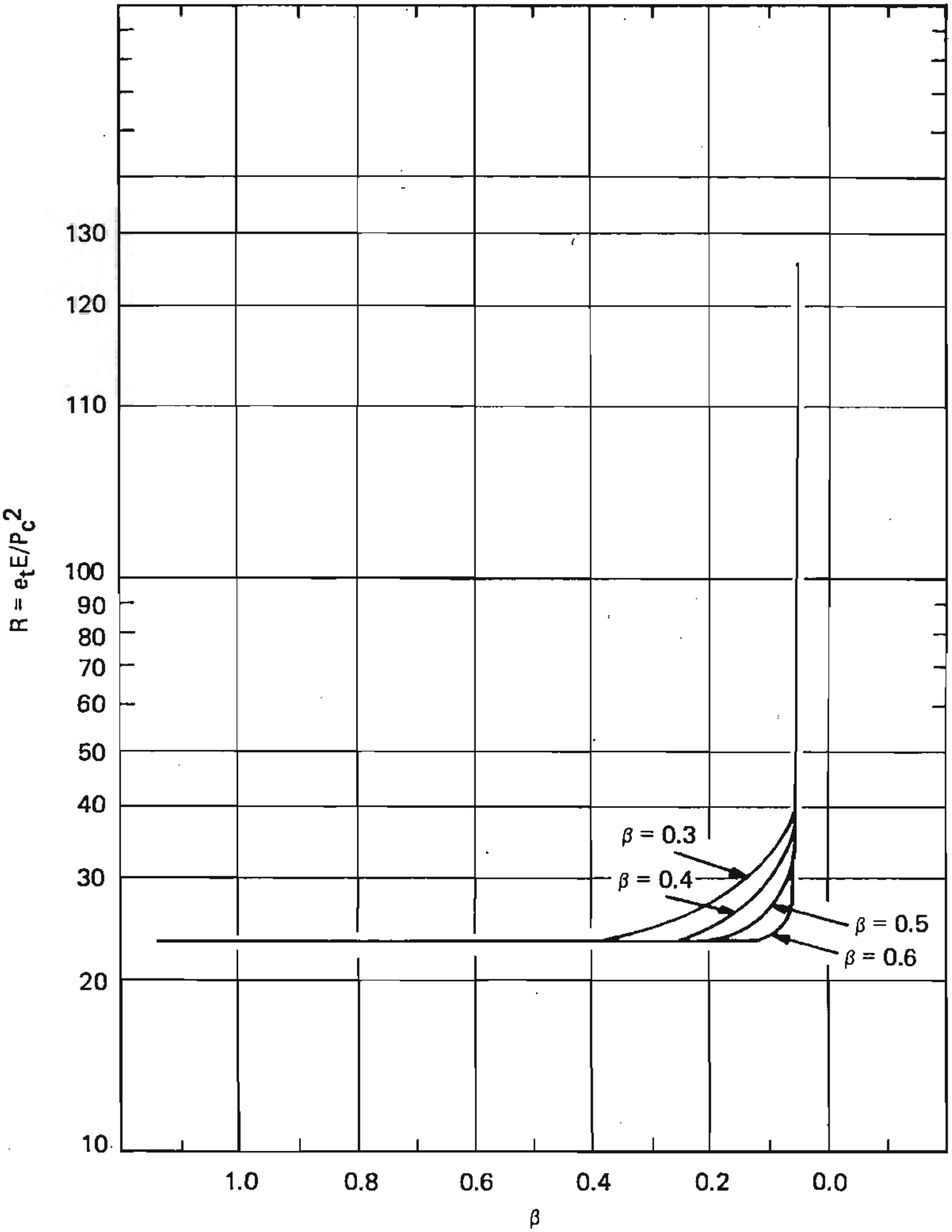


Figure 3-8 Normalized Strain Energy Density at the Crack Tip as a Function of Distance from the Interface for Several Values of β

reached the interface. These results show that for increasing β, higher frictional stress supported by the interface, the strain energy density increases rapidly across the interface. This increases the likelihood of fracture propagation across the interface. The results presented here are for values of frictional shear stress somewhat less than those which have been experimentally shown for interface penetration.

It should be noted that for these calculations the fluid pressure was assumed constant over the entire length of the crack. It is believed that the fluid does not penetrate the entire crack length and hence the load experienced by the crack would be somewhat less than predicted in these calculations.

Fluid Flow in a Crack

Work on the code to calculate fluid motion in a propagating expanding crack continued. At present, the code calculates flow in a closed rectangular region. The specific boundary conditions for the problem, inflow on one boundary and either free-slip or no-slip on the other three, have been built in.

Preliminary analysis indicates difficulty in accurately calculating the fluid pressure on the fluid rock interface. Since the crack aperture is determined by the fluid pressure distribution this part of the calculation is crucial.

EXPERIMENTAL PROGRAM

During April some experiments on crack growth across partially lubricated interfaces in Indiana limestone were performed to check the repeatability of experiments performed earlier. Some preliminary experiments were begun on growing penny-shaped cracks between loaded interfaces in plexiglas. These experiments are similar to those performed by Papadopoulos and Cleary at MIT.[1]

[1] Papadopoulos, J. M. and M. P. Cleary, "Laboratory Experiments on Hydraulic Fracture," Informal Report to LLNL, February 1980.

Work continued on debugging the apparatus for simultaneous ultrasonic velocity measurements in multiple directions. At a confining pressure of 0.8 GPa, the inner cylinder of the high pressure vessel failed. Construction of a new inner cylinder is expected to take about three months. Preparation of Mesaverde sandstone and shale samples from Colorado and of Mesaverde shale from Sublette County, Wyoming, has been completed.

GEOLOGY

Work continued on compilation and comparison of subsurface structure, hydraulic fractures, surface joints and near-surface stress determinations from the Rangely oil field.

SCHEDULE STATUS

Figure 3-10 is a milestone chart which depicts LLL's progress within the WGSP.

LOS ALAMOS SCIENTIFIC LABORATORY

During April, measurement of water in the pore space of solid, porous samples continued using magnetic resonance techniques. The inverse geometry instrument was used. Nuclear spin-lattice (T_1) and spin (T_2) relaxation time measurements for water were determined in several samples. Three sample types were used: packed sea sand of different sieve sizes, sintered alumina (Al_2O_3) solids and a western gas sands core.

All measured T_2's showed a nonexponential decay. Although this could result from several factors, the deviation is most likely caused by improper magnetic field homogeneity over the sample. Different results are expected when improved magnets are available. Spin-lattice relaxation times (T_1's) were described using a single exponential decay constant for the sea sand experiments. This uniformity could be the result of narrow pore size distribution used through this sample set. The sintered alumina ceramics demonstrated a

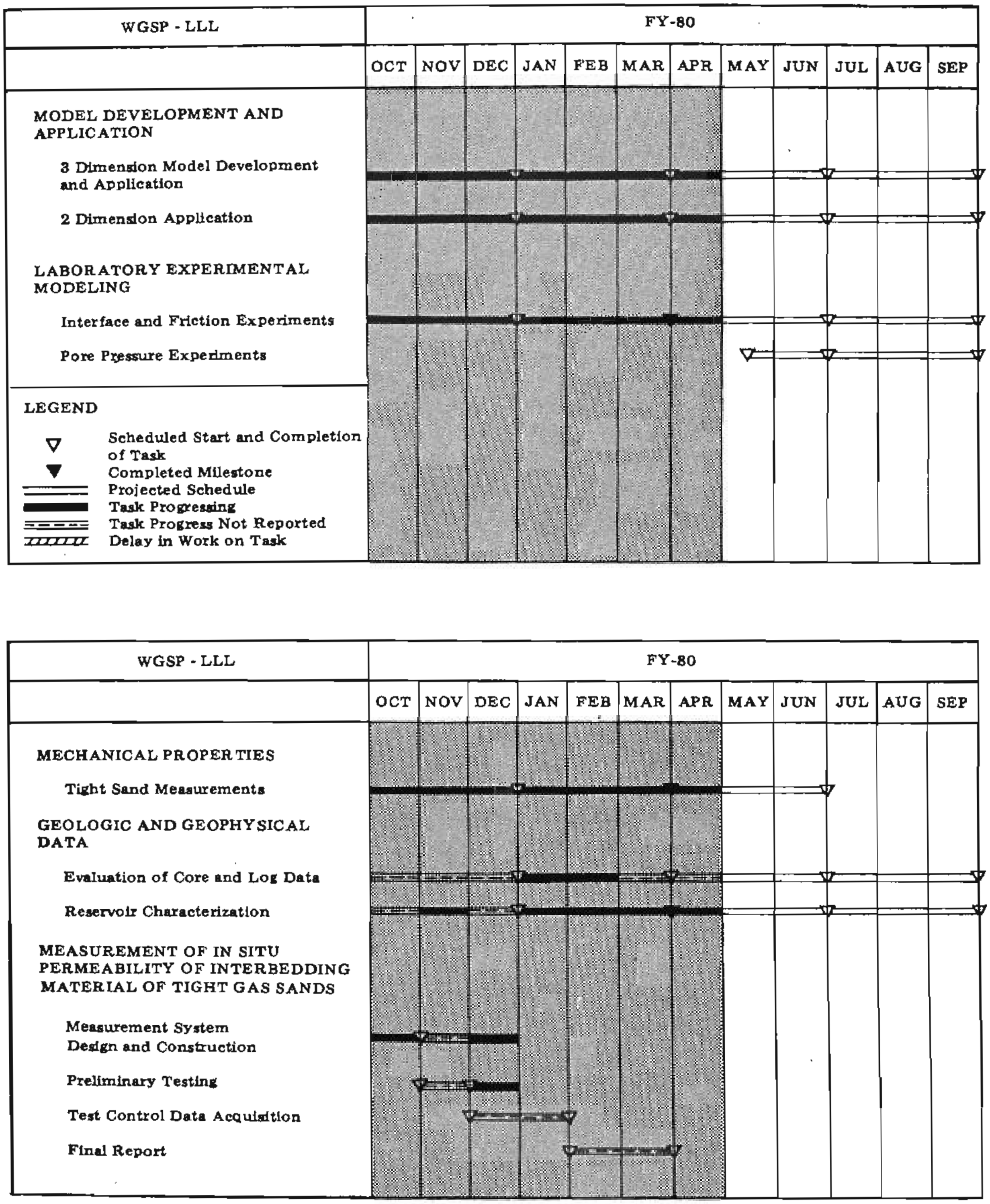


Figure 3-10 Milestone Chart — LLL

T_1 with an exponential decay, which also suggests narrow pore size distribution. The pore size distribution was determined with mercury invasion with a peak of approximately 1 micron with 10 percent and 90 percent points at 0.5 and 2.0 micron, respectively. Initial results with the gas sands core showed a marked nonexponential T_1, which could be explained in part by a larger pore size distribution.

Work began on the mounting and alignment system for the new permanent magnet pair. Improved instruments for RF pulse generation and RF transmitting have been located, and a 3 KW pulse transmitter will be acquired which should greatly improve the current measurement system. Studies have begun on the NMR signals coming from fluids (water) in porous media.

The WGSP progress of LASL is shown in Figure 3-11.

SANDIA LABORATORIES

HYDRAULIC FRACTURE CHARACTERIZATION

On February 26 and 27, 1980, a breakdown and fracture experiment was performed on Shell Oil Company's Big Mineral Creek "S" Sand Unit No. 343, Grayson County, Texas. The perforated zone was 5,823 to 5,835 ft.

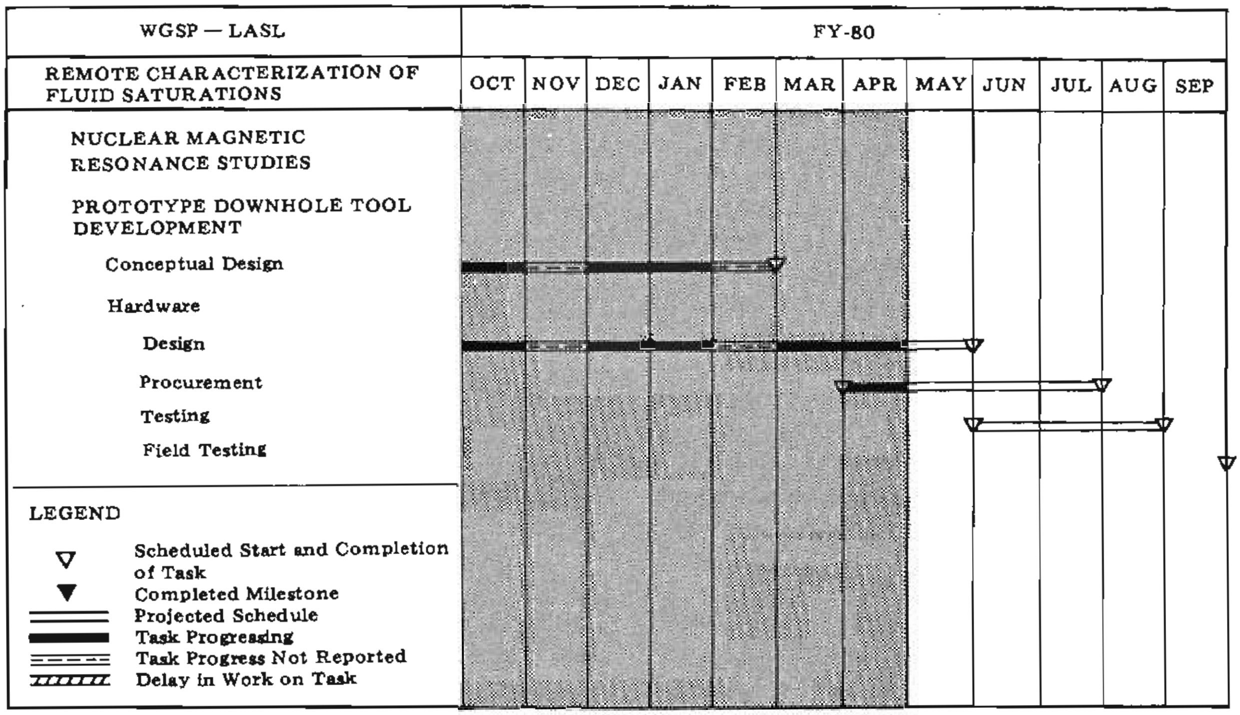
Prior to the breakdown portion of the experiment, three 5-lb explosive charges were detonated at 5,700 ft from Unit No. 343 at S 60° W, S 30° W and due south of Unit No. 343. The purpose of these detonations was to obtain the orientation of the seismic systems. For verification purposes, a gyro orientation unit was installed on the Unit 343 seismic system.

Following the explosive shots, a borehole seismic system was clamped at a depth of 5,862 ft in Unit 343. A second seismic system was clamped at a depth of 5,765 ft in Unit No. 309, an offset well approximately 580 ft east of Unit No. 343. During breakdown, Unit 343 was filled with 25 BBL of clear water and the formation was treated in three stages. The first stage consisted of 25 BBL at 5 BPM, followed by a 20-minute shut-in period to record any seismic signals generated from the fracture. The second stage was 50 BBL at 10 BPM followed by a 25-minute shut-in; and the third was 75 BBL at approximately 14 BPM with a 40-minute shut-in.

The main fracture experiment was performed on February 27. The seismic system in Unit 343 was removed and clamped at a depth of 5,330 ft in Unit No. 210, a second offset well approximately 560 ft south of Unit 343. The seismic system in Unit 309 was not moved. Again for orientation purposes, three 5-lb explosive charges were detonated within 10 ft of the first orientation shots. No gyro backup was used. The systems in Units 210 and 309 were recorded for approximately two hours while a 48,000 gal fracture treatment was performed on Unit 343.

For analysis, slow speed paper records were produced from the magnetic tape recordings to determine possible events. These events were then examined with a high-speed paper recorder to obtain accurate timing for digitizing and to eliminate nonseismic signals and seismic signals too low in amplitude to be useful. The remaining signals were then digitized and stored in the computer. The horizontal geophone signals were used to plot and examine hodograms for direction (azimuth) to the event. With the explosive orientation shots, this produced the direction of alignment of the horizontal geophones.

Examination of the orientation shots produced a direction for the reference geophone of N 67°E for the system in Unit 343 with a spread of zero degrees on the three shots. The reference geophone direction in Unit 309 was determined to be N 35°E with a spread of -14° to +9° for the six shots. The system in Unit 210 was oriented to be N 50_oE. The



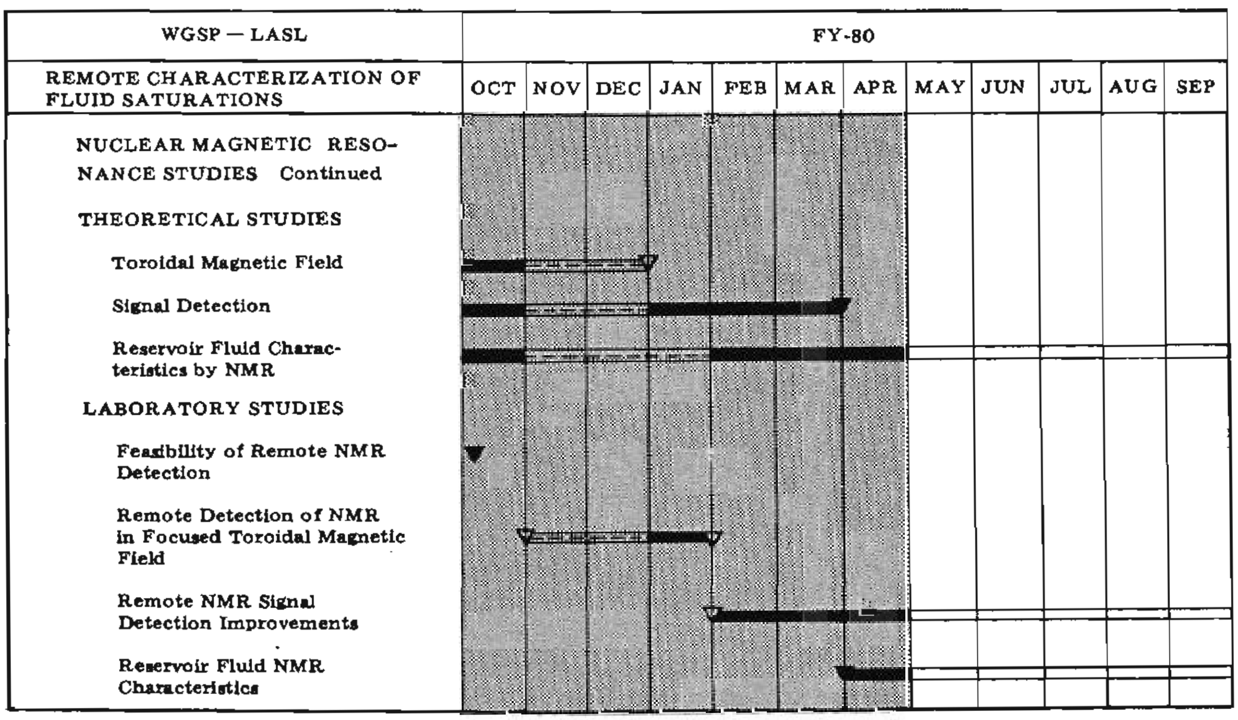


Figure 3-11 Milestone Chart — LASL

spread of the three shots for this well was also zero degrees. The gyro attached to the system in Unit 343 indicated a direction of N 60°E. The large spread of directions in Unit 309 was due to high background noise present in that well.

Of approximately 60 signals recorded during breakdown for the seismic system in Unit 343, 20 were useful in determining fracture direction. The other signals were eliminated from analysis because the direction could not be determined due to low amplitude, high amplitude, dual signal interference, or uncertainty as to the recognition of the compressional wave. These 20 signals are plotted for every 10 degrees in Figure 3-12.

During breakdown on the system in Unit 309, 31 (out of 50 total) usable seismic signals were recorded. These signals fell into two categories. The first indicated a location in the NE to SW quadrants and the second in the NW to SE quadrant. Twenty-four signals indicated a source direction to the northeast or southwest. These signals are plotted in Figure 3-13 for every 10 degrees. Five of these signals occurred prior to any pumping in Unit 343. If the assumption is made that the other seven signals are generated from the fracture in Unit 343 rather than originating somewhere to the southeast, their locations are then shown in Figure 3-14 along with the location of all three wells. Distances from Unit 309 were calculated using a compressional wave velocity of 13,700 ft per second and assuming a Poisson ratio of 0.25. A velocity of 13,700 ft per second was obtained from the sonic log of Unit 343.

During the main fracture experiment, only two signals were received on the seismic system in Unit 309. Nine out of 15 signals could be used to determine source location in the Unit 210 system. The positions of the signals received in Unit 210 are also shown in Figure 3-14. No signals were received in Unit 210 other than during the pumping in Unit 343.

None of the locations in Figure 3-14 have been corrected for elevation angle because there is not a computer program to do this. When an elevation correction is made, it will pull all of the locations shown in Figure 3-14 closer to Units 309 and 210. The two signals received in Unit 309 indicate locations consistent with that of Figure 3-13. It is speculated that the lack of signals in Unit 309 during the fracture is due to some part of the system deteriorating and the sensitivity being reduced. However, no verification could be made when the system was removed from the well.

The surface electrical potential system (SEPS) was also fielded for this experiment. Forty-eight test probes were utilized at two potential probe locations around the fracture well No. 343: Radius 1 (1,200 ft) and Radius 2 (1,600 ft). Current was injected into the formation at 5,700 ft via the current injection probe and two current sinks. The first sink was another well located approximately 8,900 ft to the south-southeast (Line 1) and the second was that of the fracture well casing (Line 2). Both methods produced signals of comparable strength. The fracture well casing, however, produced the best looking waveshapes. The potential measurement boxes (PMBs) which monitor the probe potentials were operated at a gain of 72 db. The risetime of the injected current pulse was increased. Shielded current wire was used throughout the PMB portion of the system array.

The first step of the data analysis has been completed. The data obtained from Radius 2 when current was injected between the current probe (5,700 ft deep - 100 ft above fracture zone) and the fracture well 343 casing (Line 2) produced the best results. The predominant direction indicated was between 50° and 60° (as shown in Figure 3-15).

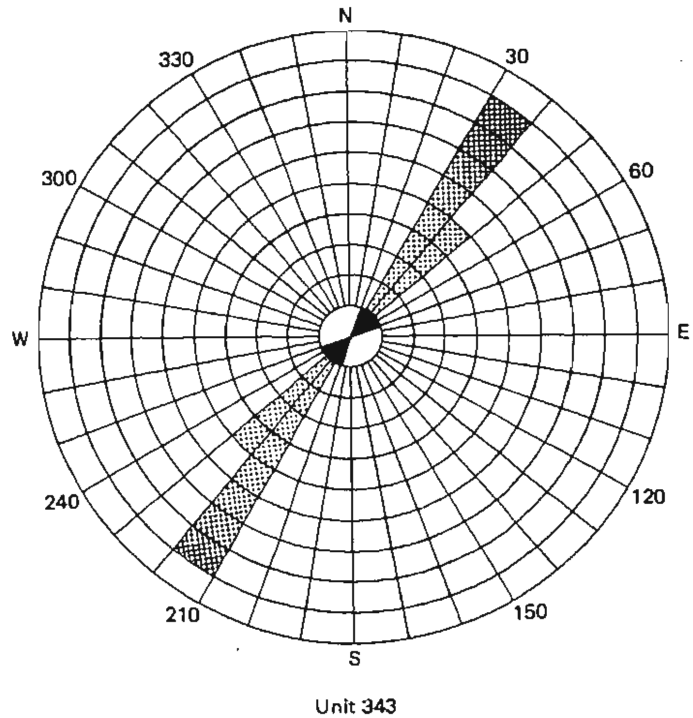


Figure 3-12 Shell Big Mineral Creek Breakdown Seismic Signals, February 26, 1980

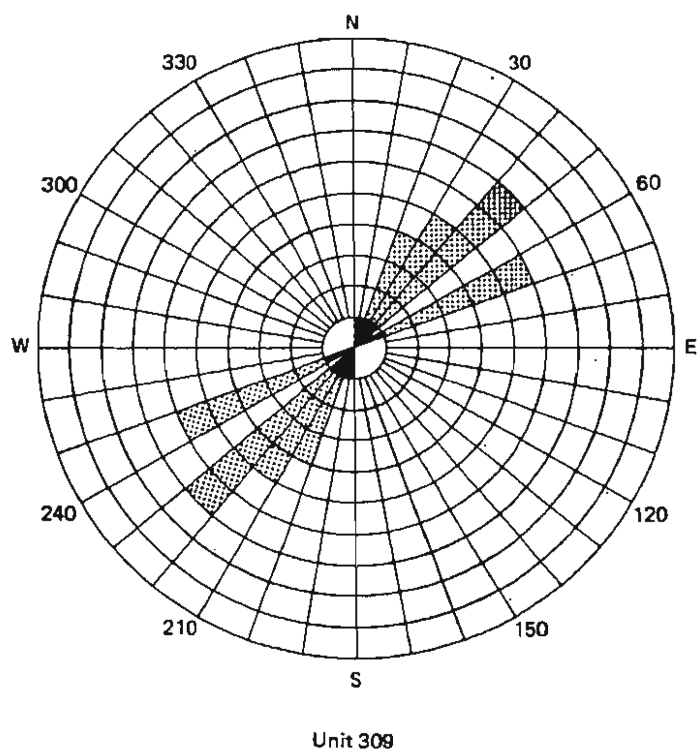


Figure 3-13 Shell Big Mineral Creek Breakdown Seismic Signals, February 16, 1980

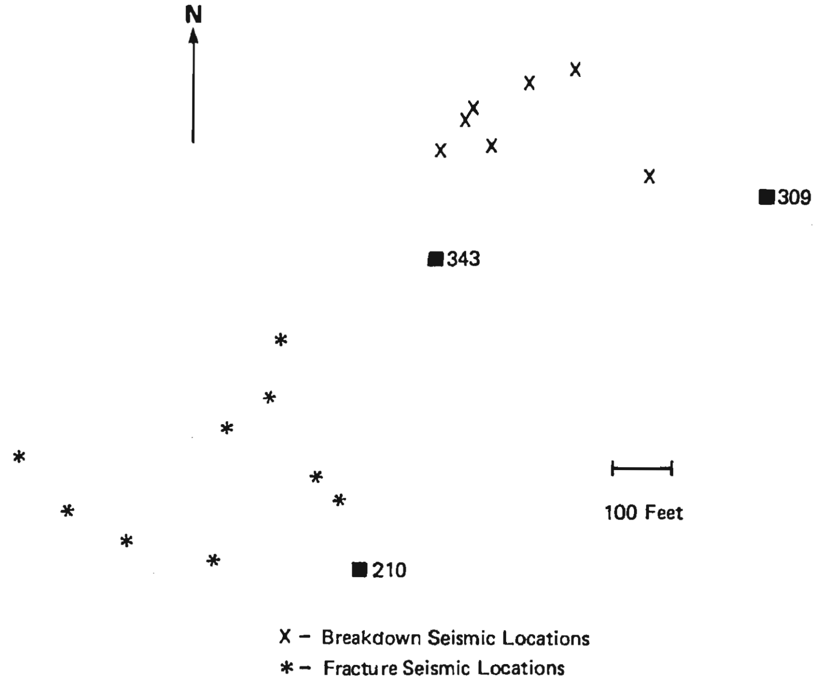


Figure 3-14 Location of Breakdown and Fracture Seismic Signals, Shell Big Mineral Creek Fracture Experiment

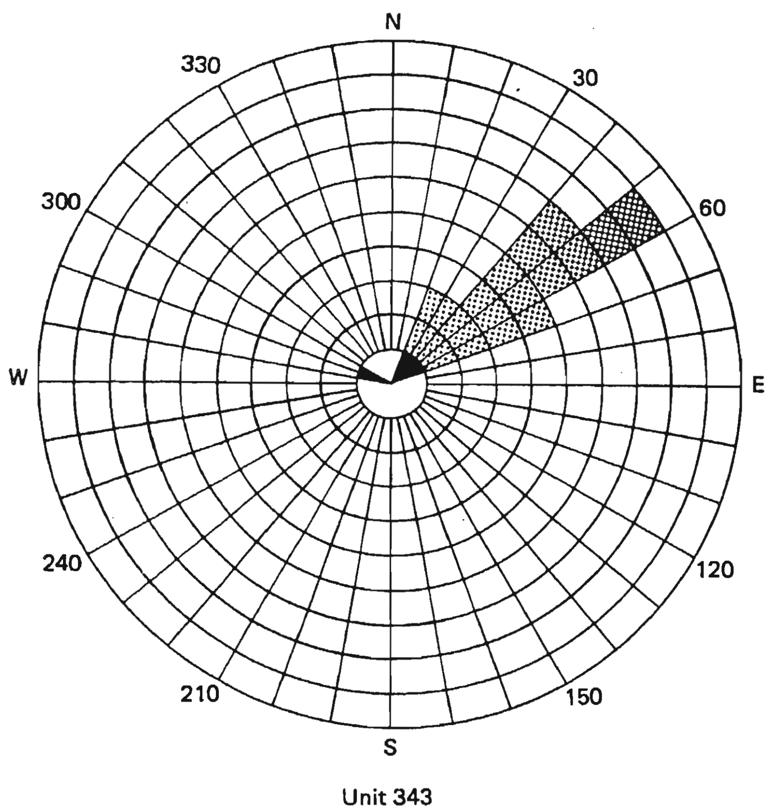


Figure 3-15 Shell Big Mineral Creek SEPS Electrical Direction, February 17, 1980

BOREHOLE RESISTIVITY SYSTEM

A parametric study was carried out using the recently developed one-dimensional solution. The study revealed:

- the sensitivity of probe measurements (potentials or equivalent apparent resistivities) to variations in the radial extent of the invaded zone, and
- the sensitivity of probe measurements to the structure of and transition region when this region is moved to several different radial positions.

The conductivity profiles and predicted apparent resistivities at the probe are shown in Figures 3-16 and 3-17. The apparent resistivities show sensitivity to large movements (meters) of the entire transition region, and also to transition region details when the transition region is close to the probe (< 4 meters). When the transition region is moved out to 8 meters, the sensitivity to its structure is degraded. To be noted is the width of the transition region remained constant throughout. The transition region might make a greater impact on probe measurements if it is of greater width.

HIGH RESOLUTION SEISMIC FORMATION MAPPING

Processing of the Bryson Canyon Site 3-D seismic data is being completed. Reruns of some 3-D time slices at shallower depths and different filter parameters are expected in early May. The preliminary interpretations are as follows:

- When comparing early 2-D seismic models generated by this program and other relevant published models to 2-D data sections generated at the site, several similarities are shown. Foremost are discontinuous reflection patterns, accurate-shaped reflections, zones of reflector thickening, and anomalous amplitude responses. Secondary effects, such as distortion of deeper, blanket reflectors, were not observed in the data as these deeper beds were obliterated by unavoidable shot-generated noise.
- Observed segments suggestive of channeling are traceable from section-to-section and may be mapped across the site. At least one such reflector may be correlated to a known sand body encountered in the DOE-GC-1 well.
- Comparison of mapped trends from 2-D section interpretation with trends observed on 3-D time slices show a good correlation, implying that the 3-D displays effects which suggest channel trend. Other structural features (general SSW-SW dip, zones of warping, slumping, etc.) are superimposed on the channeling effects which complicates the interpretation.
- Projection of trends to outcrop suggests several possible channels observed in outcrop may be tied to the well.

The results of the interpretive effort are now being compiled for presentation for review.

ELECTROMAGNETIC LOGGING

Sonde Modeling

Major effort during the month was concentrated on the analytical transformations and numerical computations with displays for refractive index charts. These study areas were directed toward the borehole effects under coaxial-loop couplings.

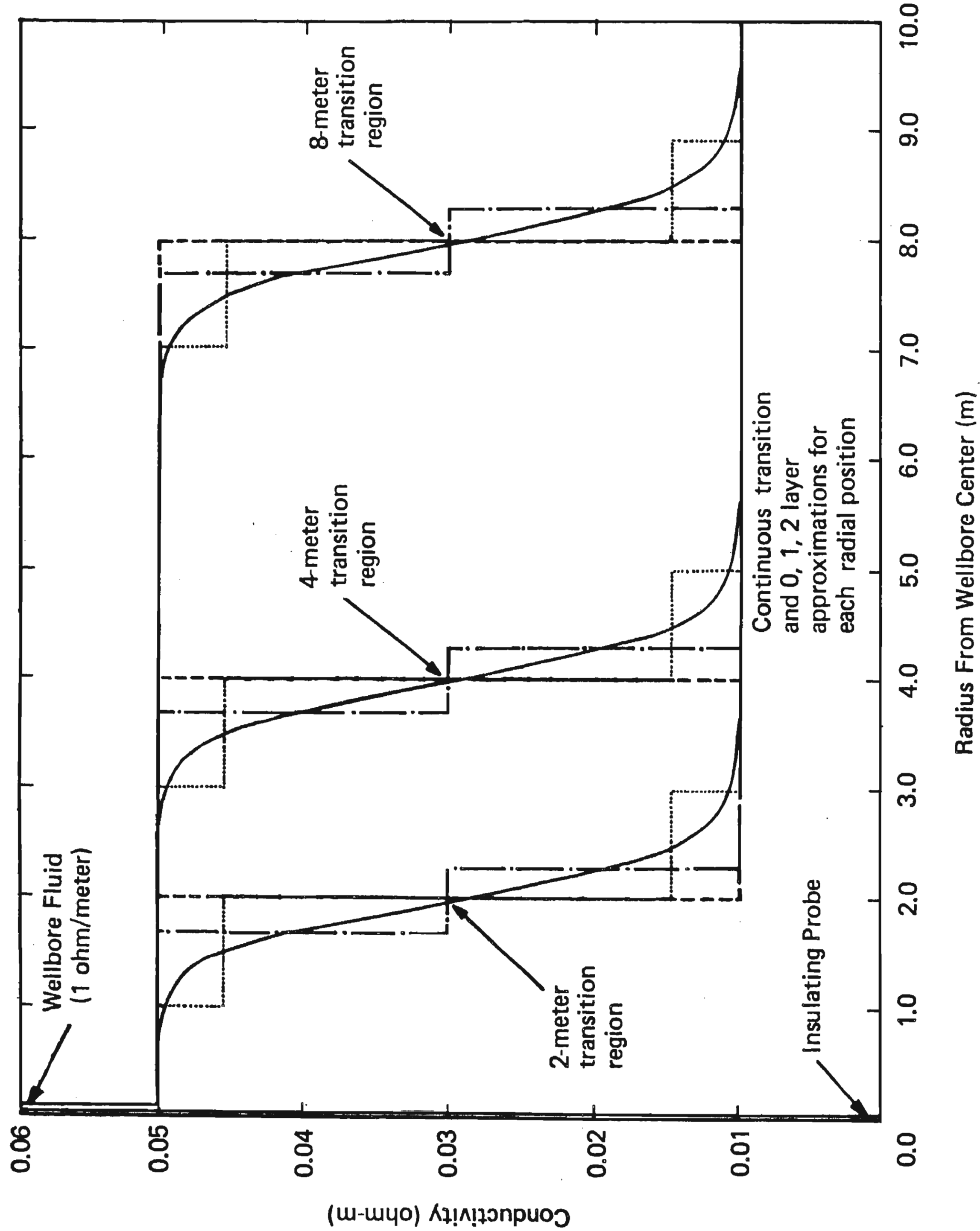


Figure 3-16 Conductivity Profile

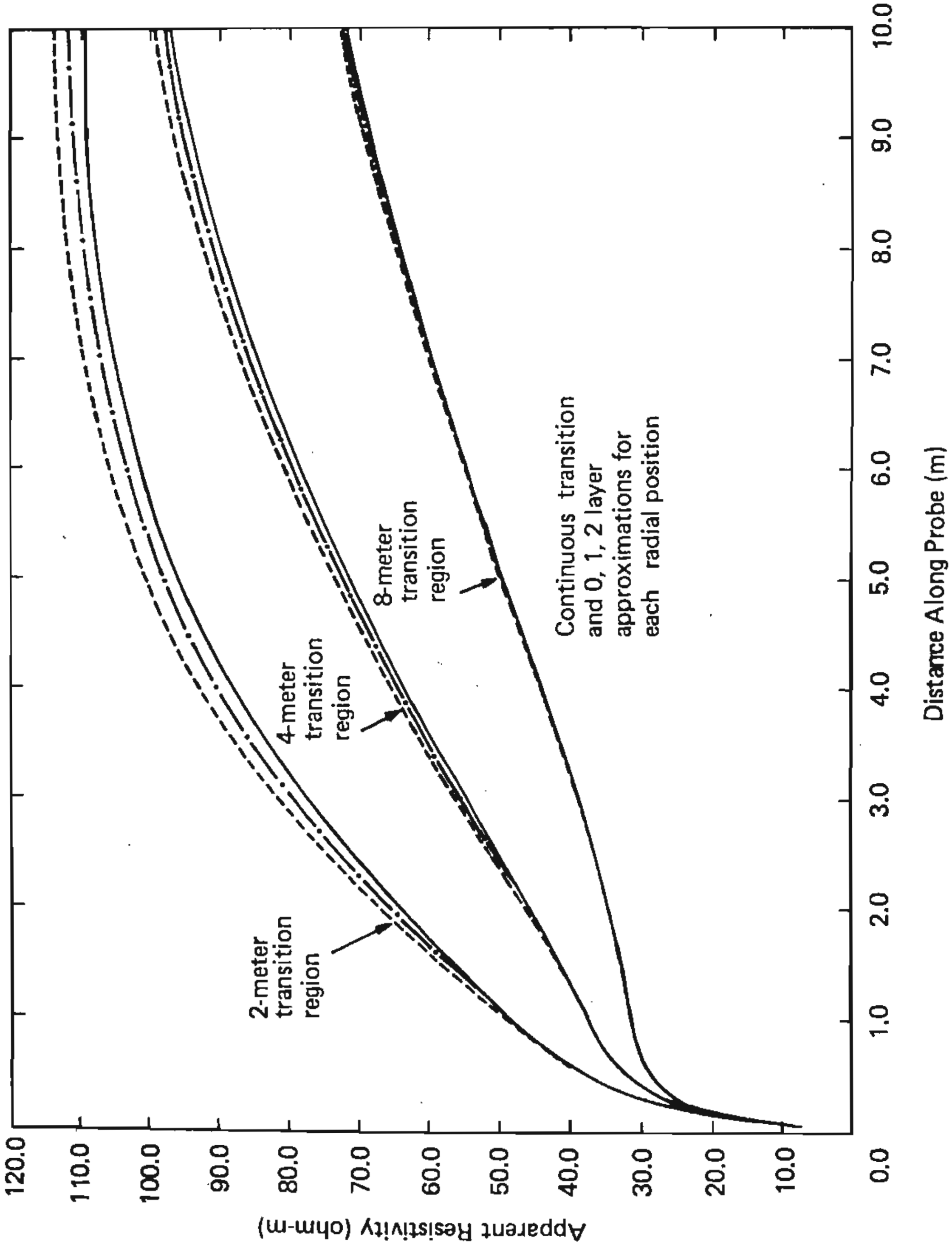


Figure 3-17 Predicted Apparent Resistivities at Probe

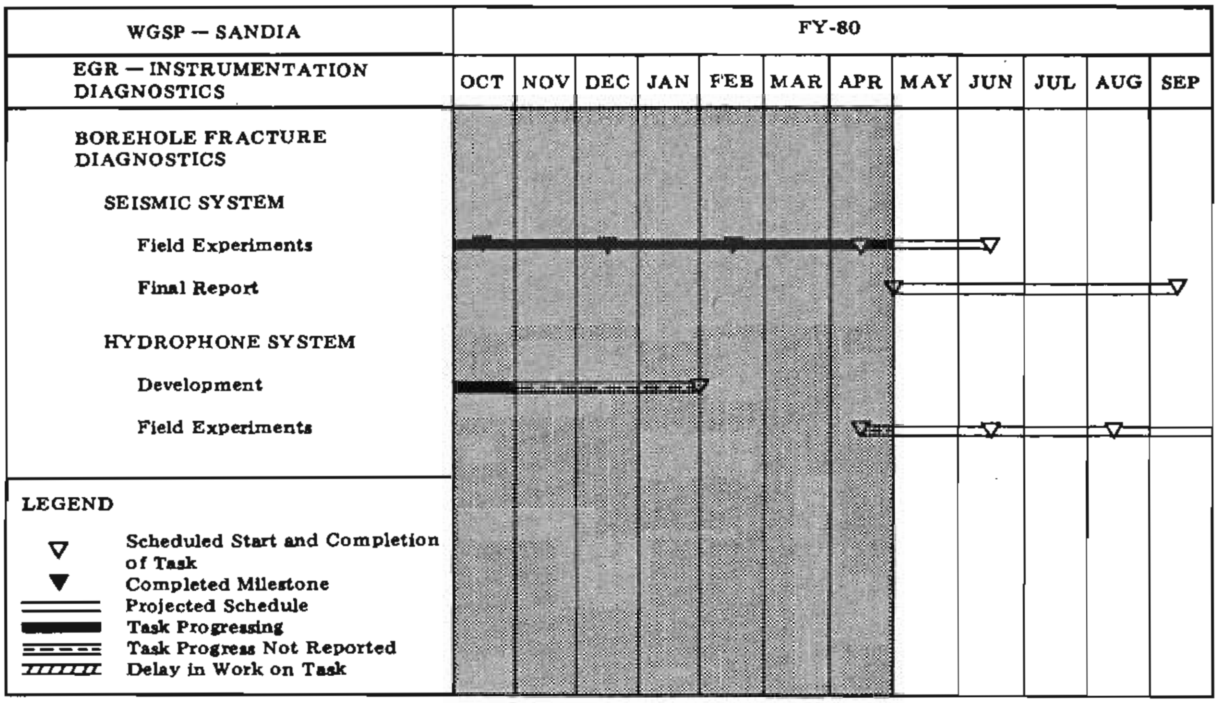
Borehole effects are referred to as perturbations resulting from coaxial-loop couplings in environments other than the baseline environment, which is ideally homogeneous and unbonded. The refractive index charts for the transfer impedances of coaxial coils were constructed earlier to serve as baseline responses. Several charts were produced for a borehole filled with sea water. Significant perturbations were most pronounced at highest frequency of 80 MHz, and became less as frequencies were lowered to 40 and 20 MHz. A more realistic simulation of air in the borehole was also completed. The results were encouraging because no significant perturbations from the baseline responses were observed. As coils are housed in the sonde filled with air, the baseline charts can be directly used to determine the spatially averaged refractive indices.

Laboratory Investigations

To obtain accurate experimental data of the dielectric properties of rock samples, past and present techniques must be understood. Hence, visits were made to Dr. G. R. Olhoeft of the USGS in Denver and Dr. G. V. Keller of the Colorado School of Mines. Dr. Olhoeft is presently studying dielectric and electrical properties of rocks over a wide frequency range. Dr. Keller has measured these rock properties in the past and is in the preliminary stages of an experiment to measure the loss tangent of rocks at microwave frequencies. The data by Poley, et al, goes only to about 10 KHz in the low frequency end. Based on the data gathered, the frequency range was extended below the originally planned value of 100 KHz to a lower limit of 10^{-4} to 10^{-6} Hz. To do this, the method employed by Olhoeft will be used. Simply stated, this method compares the applied waveform to that passed through the sample and determines the attenuation and phase shift of the signal in the sample. From this the dielectric properties can be obtained.

SCHEDULE STATUS

Figure 3-18 shows Sandia's WGSP progress.



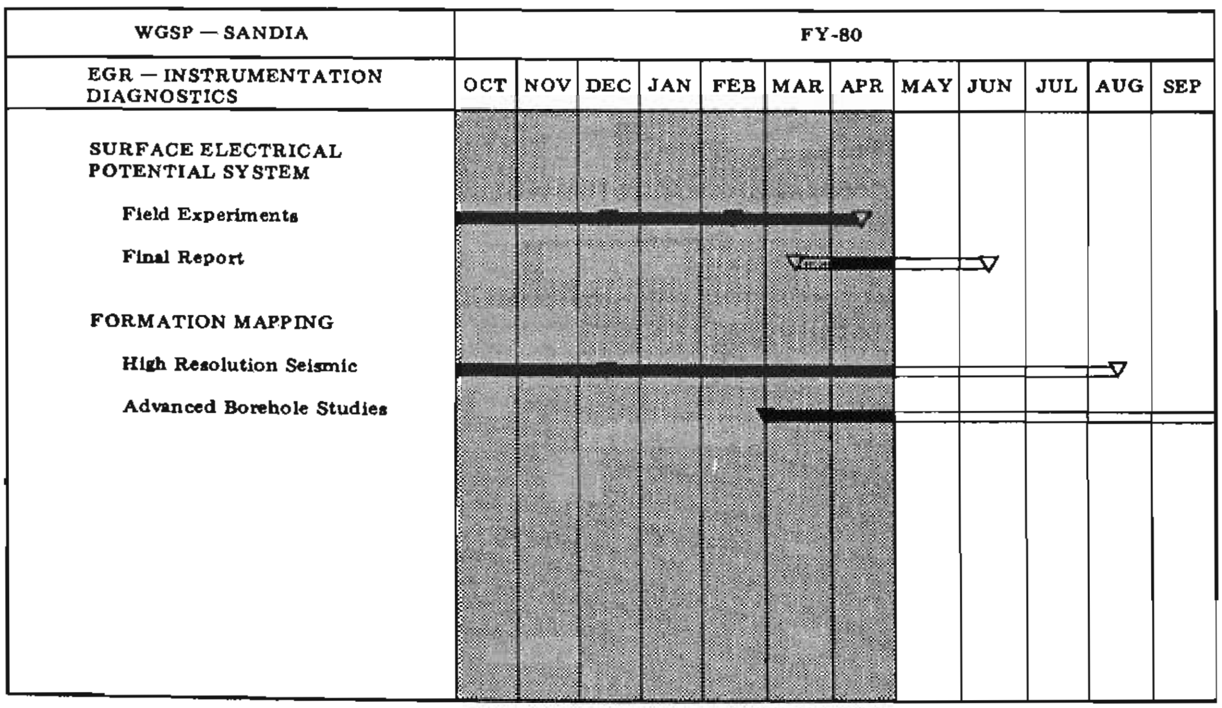


Figure 3-18 Milestone Chart — Sandia Laboratories

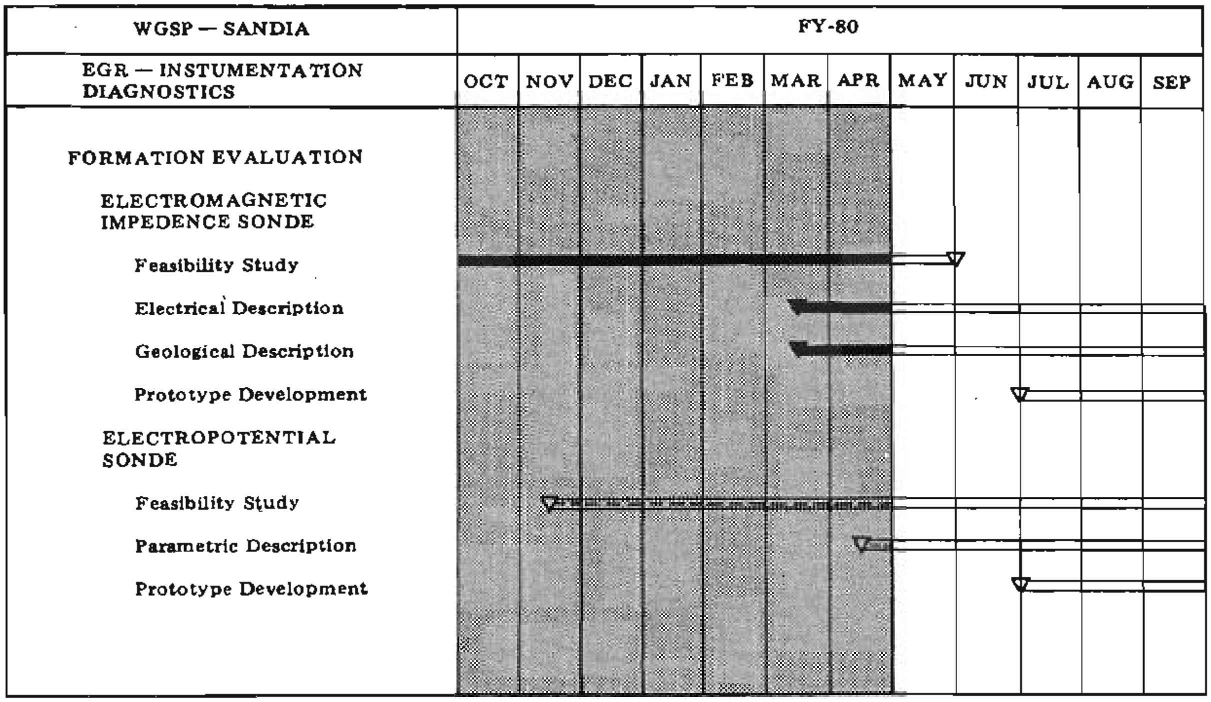


Figure 3-18 Continued

SECTION 4

FIELD TESTS & DEMONSTRATIONS

BACKGROUND

Field tests are essential to verify the findings of laboratory tests and modeling studies. The field test and demonstration program involves cooperation between industry and government and also interacts geologic studies with laboratory research and development. The following projects are active in the WGSP:

- a dry gas injection experiment in the Wattenberg Field, Colorado, by Colorado Interstate Gas Company,
- MHF demonstrations by Gas Producing Enterprises in the Uinta Basin, Utah,
- MHF treatment of the Cotton Valley Limestone Formation in Limestone County, Texas, by Mitchell Energy Corporation, and
- a mineback testing program by Sandia Laboratories.

Table 4-1 summarizes WGSP MHF treatments. Progress of these projects is presented in the following sections.

UGR File #261
April 1980
DOE/BC/10003-9
CER Corporation

Table 4-1 MHF Contract Location and Frac Data

Company Basin & Formation	Location T/R/Sec	Well	Interval Fractured ft	Fracture Date	Fracture Treatment Lb of Sand	Injected Fluid 10^3 Gal	Production Rates MCFD Before	After	Ratio
AUSTRAL	7S/94W/Sec 3	Federal	6,198-6,333	8-13-76	420,000	226 Gel	35	62	1.8
Piceance,	Garfield Cty,	3-94	5,170-5,630	8-25-76	720,000	316 Gel			
Mesaverde	Colorado								
CONSORTIUM	3S/98W/Sec 11	RB-MHF-3	8,048-8,078	10-23-74	400,000	117 Gel	60	60	—
MANAGED BY	Rio Blanco Cty,		7,760-7,864	05-02-75	880,000	285 Gel	—	40	—
CER CORPORATION	Colorado		5,925-6,016	04-04-76	815,000	400 Gel	42	160	3.8
Piceance, Mesaverde			5,851-5,869	11-03-76	448,000	228 Gel	57	70	1.2
DALLAS	Ben D. Smith	Ferguson	5,957-6,794	09-16-76	506,000	139 Foam	40	15	—
PRODUCTION	Survey A-779	A-1				198 Emul			
Fort Worth,	Wise Cty,								
Bend Cong.	Texas								
EL PASO	30N/108W/Sec 5	Pinedale	10,950-11,180	07-02-75	518,000	183 Emul	150	340	2.3
NATURAL GAS	Sublette Cty,	Unit				8 Gel			
Northern Green River,	Wyoming	No. 5							
Fort Union			10,120-10,790	10-20-75	1,422,000	459 Gel	—	150	—
GAS PRODUCING	10S/22E/Sec 10	Natural	6,490-8,952	09-22-76	1,480,000	745 Gel	—	1,400	—
ENTERPRISES, INC.	Uintah Cty,	Buttes							
Uinta, Wasatch	Utah	No. 18							
and Mesaverde									
	10S/21E/Sec 21	Natural	8,909-9,664	09-21-76	424,000	280 Gel	—	166	—
	Uintah Cty,	Buttes	7,224-8,676	09-28-76	784,000	364 Gel			
	Utah	No. 19							
	9S/21E/Sec 22	Natural	6,646-8,004	03-15-77	1,093,000	544 Gel	38	800	21.0
	Uintah Cty,	Buttes							
	Utah	No. 14							
	9S/21E/Sec 28	Natural	8,498-9,476	06-22-77	826,000	322 Gel	75	1,200	16.0
	Uintah Cty,	Buttes							
	Utah	No. 20							
	10S/22E/Sec 18	Natural	6,838-8,550	11-21-77	1,151,000	499 Gel	—	700	—
	Uintah Cty,	Buttes							
	Utah	No. 22							
	9S/22E/Sec 19	Natural	5,661-8,934	03-27-78	554,000	349 Gel	140	540	3.9
	Uintah Cty,	Buttes							
	Utah	No. 9							
	10S/21E/Sec 29	CIGE	9,237-9,653	06-22-78	170,500	203 Gel	—	Water	—
	Uintah Cty,	No. 2	7,251-8,774	08-08-78	1,965,000	722 Gel	—	Water	—
	Utah								
	10S/22E/Sec 7	Natural	5,080-6,294	10-04-78	470,000	240 Gel	—	800	—
	Uintah Cty,	Buttes							
	Utah	No. 23							
MITCHELL ENERGY	Limestone Cty,	Muse-Duke	11,235-11,418	11-15-78	2,800,000	891 Gel	2,000	6,600	3.3
Cotton Valley,	Texas	No. 1							
Limestone Trend									
MOBIL	2S/97W/Sec 13	F31-13G	10,549-10,680	06-22-77	580,000	316 Gel	300	800	2.7
Piceance,	Rio Blanco Cty,		9,392-9,538	08-24-77	600,000	260 Gel	700	2,600	3.7
Mesaverde	Colorado		8,765-8,972	05-10-78	388,000	150 Gel	479	430	—
			8,163-8,650	07-06-78	660,000	288 Gel	—	360	—
			7,704-7,794	09-07-78	218,000	120 Gel	—	180	—
			7,324-7,476	11-15-78	700,000	365 Gel	1,000	2,000	2.0
PACIFIC	8S/23E/Sec 25	Federal	NO FRACTURES PERFORMED						
TRANSMISSION	Uintah Cty,	23-25							
Uinta, Mesaverde	Utah								
RIO BLANCO	4S/98W/Sec 4	Federal	6,150-6,312	10-22-76	766,000	276 Gel	57	130	2.3
NATURAL GAS	Rio Blanco Cty,	498-4-1	5,376-5,960	11-30-77	243,000+	164 Gel	80	350	4.4
Piceance, Mesaverde	Colorado				22,500 Beads				
WESTCO	10S/19E/Sec 34	Home Fed.	10,014-10,202	12-21-76	500,000	248 Gel	33	155	4.7
Uinta, Mesaverde	Uintah Cty,	No. 1	7,826-9,437	10-01-76	600,000	412 Gel	40	Water	—
	Utah								

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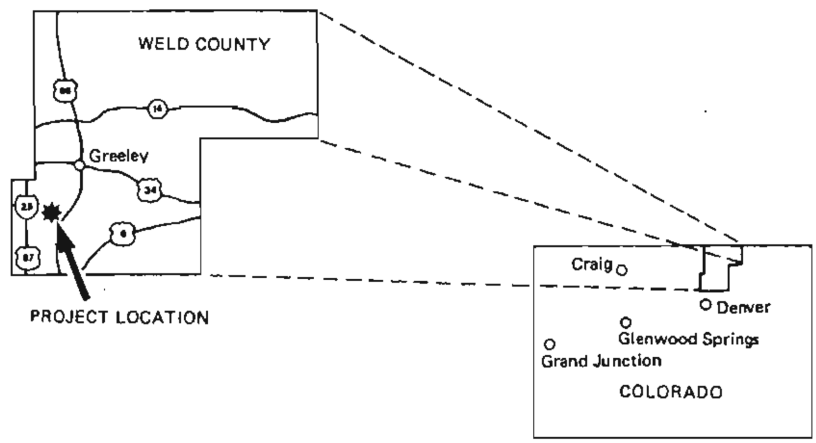
WATTENBERG FIELD

DE-AC08-77ET12046

Colorado Interstate Gas Company
Colorado Springs, Colorado
Status: Active



Contract Date:	September 1, 1977	
Anticipated Completion Date:	March 1, 1981	
Total Project Cost:	DOE	$ 75,000
	CIG	$345,314
	Total	$420,314
Principal Investigator:	David Wilson	
Technical Project Officer for DOE:	C. H. Atkinson	

OBJECTIVE

Cyclic injection of dry natural gas is the method to be used to increase production of tight gas sands.

COLORADO INTERSTATE GAS COMPANY

Measurement of bottom-hole pressure at both the Miller No. 1 and the Sprague No. 1 wells has been completed. The Rolo calcium chloride dehydrators did not perform satisfactorily, and therefore will be replaced with a glycol dehydrator installed on the suction side of the compressor to allow operation in either direction. CIG will try out a new pump on the glycol dehydrator for a six-month period. Since this new pump can operate down to 40 psi, it should operate at any pressure compatible with the compressor.

CER Corporation is analyzing the BHP data for the Miller No. 1 well. The pressure data from Cable Inc. on the Sprague No. 1 well indicates that there has been some improvement in formation permeability. The Sprague No. 1 well began exhibiting radial flow after 500 hrs; previously this well had not reached radial flow after 1,100 hrs.

DOE WELL TEST FACILITY

The DOE Well Test Facility was on site at Miller No. 1 in the Wattenberg field, Colorado, in support of the joint DOE/CIG dry gas injection experiment. The remaining portions of a modified isocronal test were completed during the first week of April.

The facility was transported to Las Vegas during the third week of the month. The instrumentation trailer will be undergoing repair and modification, with emphasis on the electrical system.

Analysis of the dry gas injection data gathered during the past several months will continue through May.

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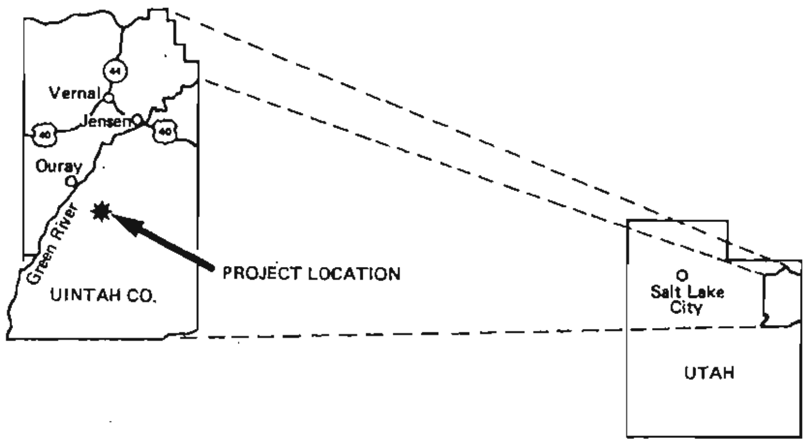
CER Corporation

NATURAL BUTTES
UINTAH COUNTY, UTAH

DE-AC08-76 ET 12060

Massive Hydraulic Fracturing Demonstration

Gas Producing Enterprises, Inc.
Subsidiary of Coastal States Gas Co.
Houston, Texas
Status: Active



Contract Date:	July 1, 1976	
Anticipated Completion:	March 31, 1980	
Total Project Cost (estimated):	DOE	$2,827,000
	Industry (prior costs)	1,881,000
	Industry (new costs)	3,051,000
	Total	$7,759,000
Principal Investigator:	W. E. Spencer	
Technical Project Officer for DOE:	C. H. Atkinson	

OBJECTIVE

To evaluate the effectiveness of massive hydraulic fracturing for stimulating natural gas production from thick, deep sandstone reservoirs having low-permeability.

GAS PRODUCING ENTERPRISES, INC.

GPE's Natural Buttes Unit Nos. 9, 14, 18, 19 and 20 flowed to sales during April with a total 44,821 MCF. NBU Nos. 21 and 22 were shut in. Figures 4-1 through 4-6 show the production histories of these wells.

A final report is in preparation.

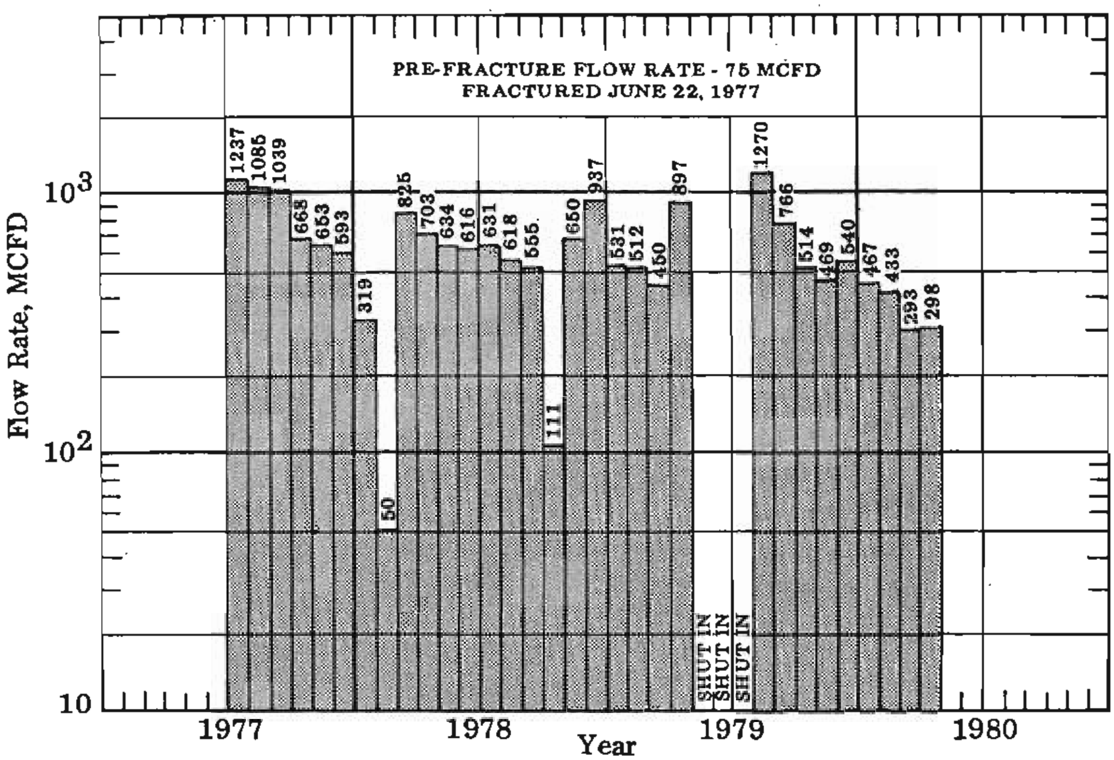


Figure 4-1 Flow Rate Performance of Natural Buttes No. 9 Well

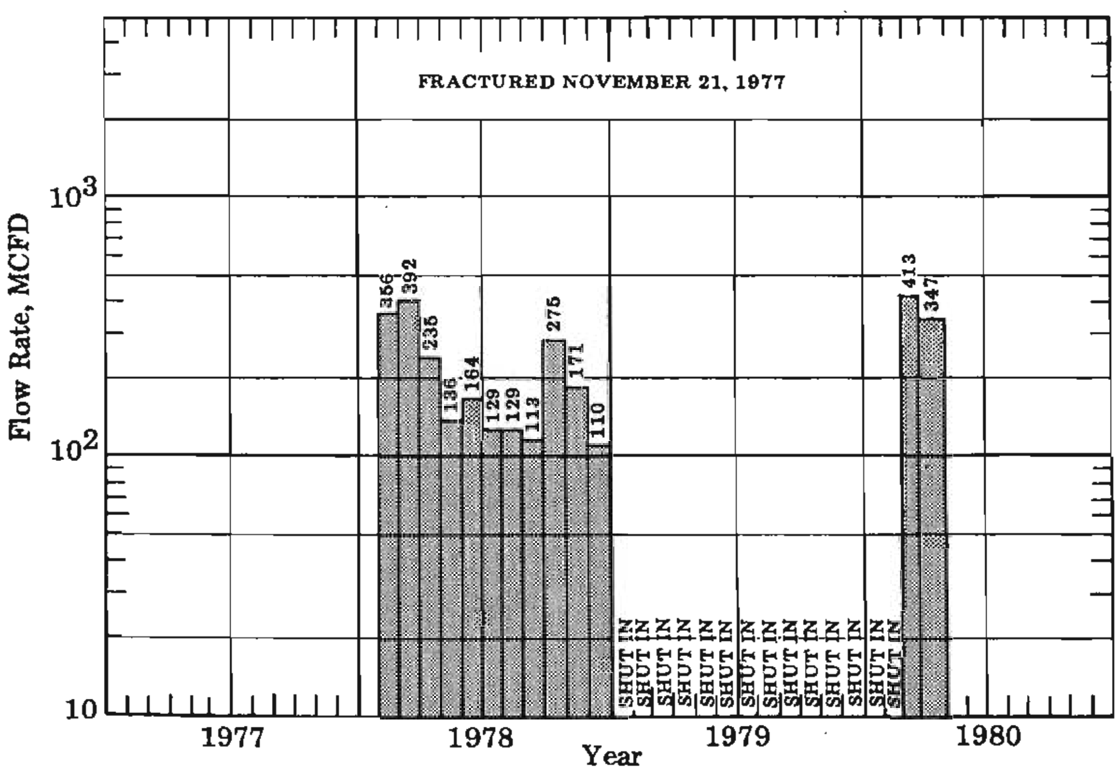


Figure 4-2 Flow Rate Performance of Natural Buttes No. 14 Well

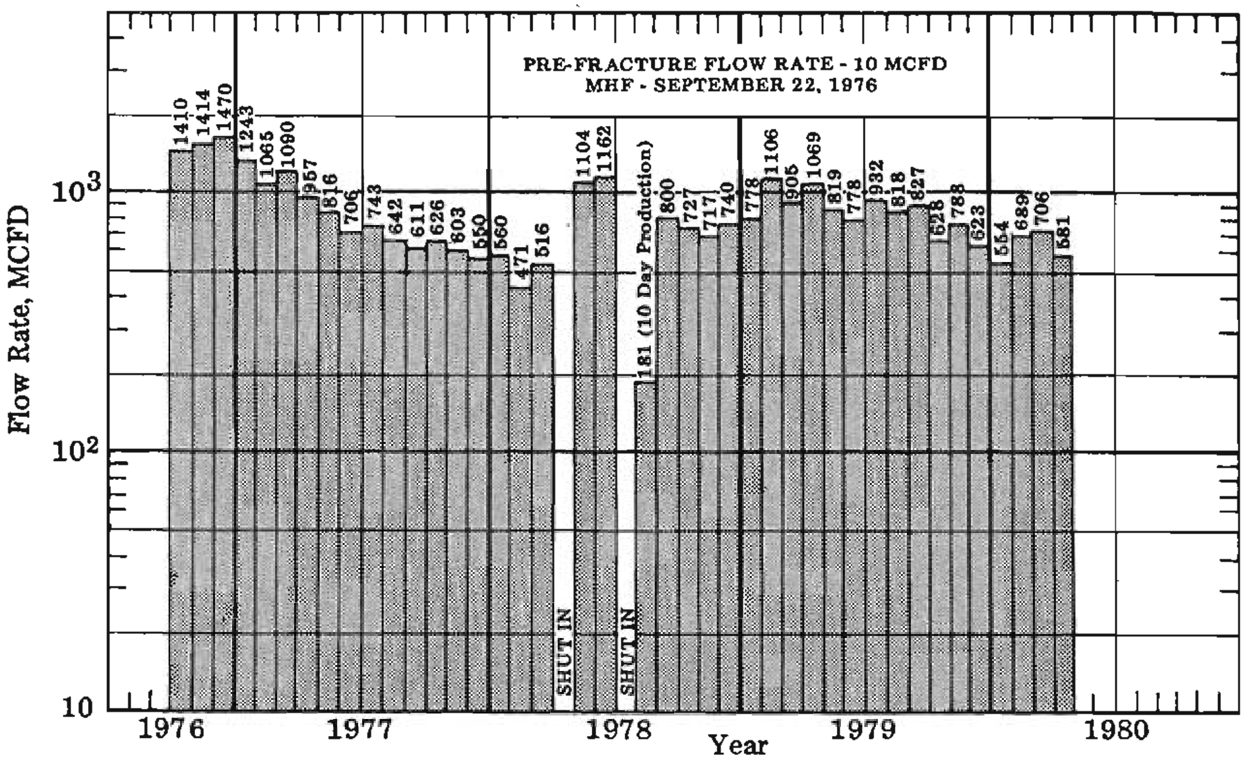


Figure 4-3 Flow Rate Performance of Natural Buttes No. 18 Well

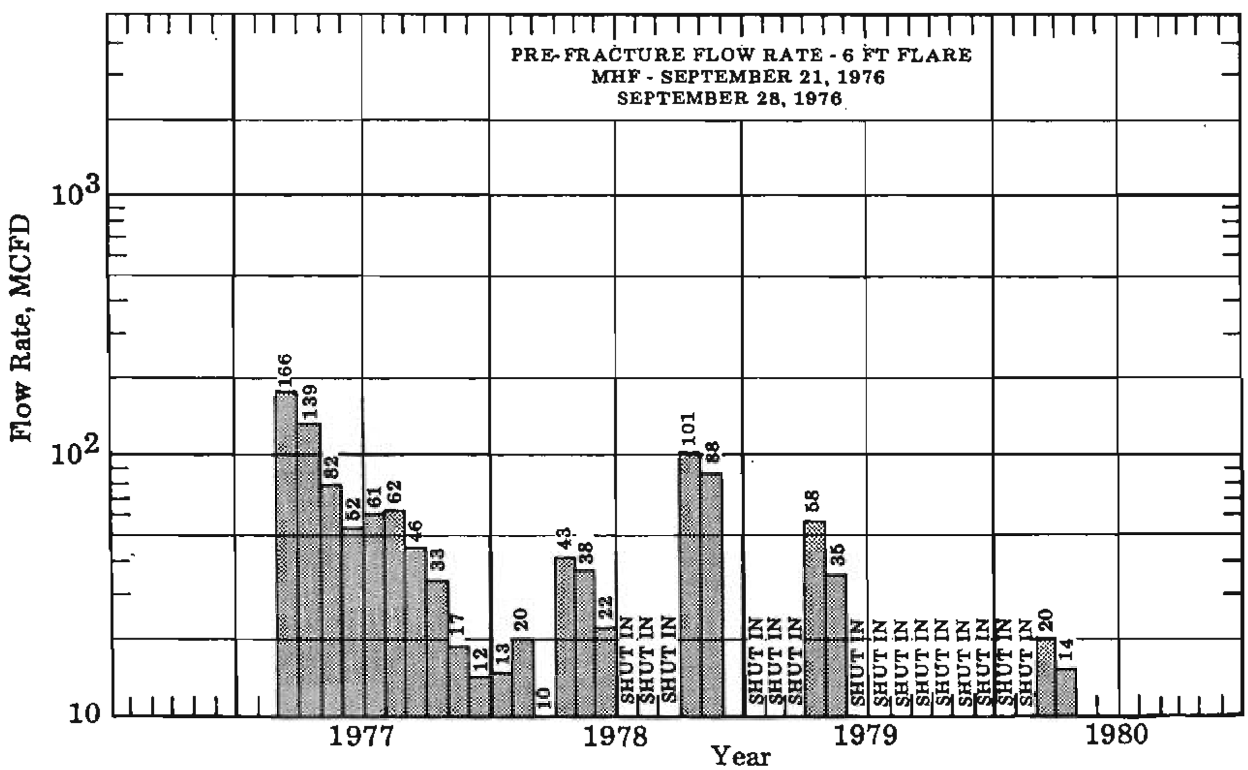


Figure 4-4 Flow Rate Performance of Natural Buttes No. 19 Well

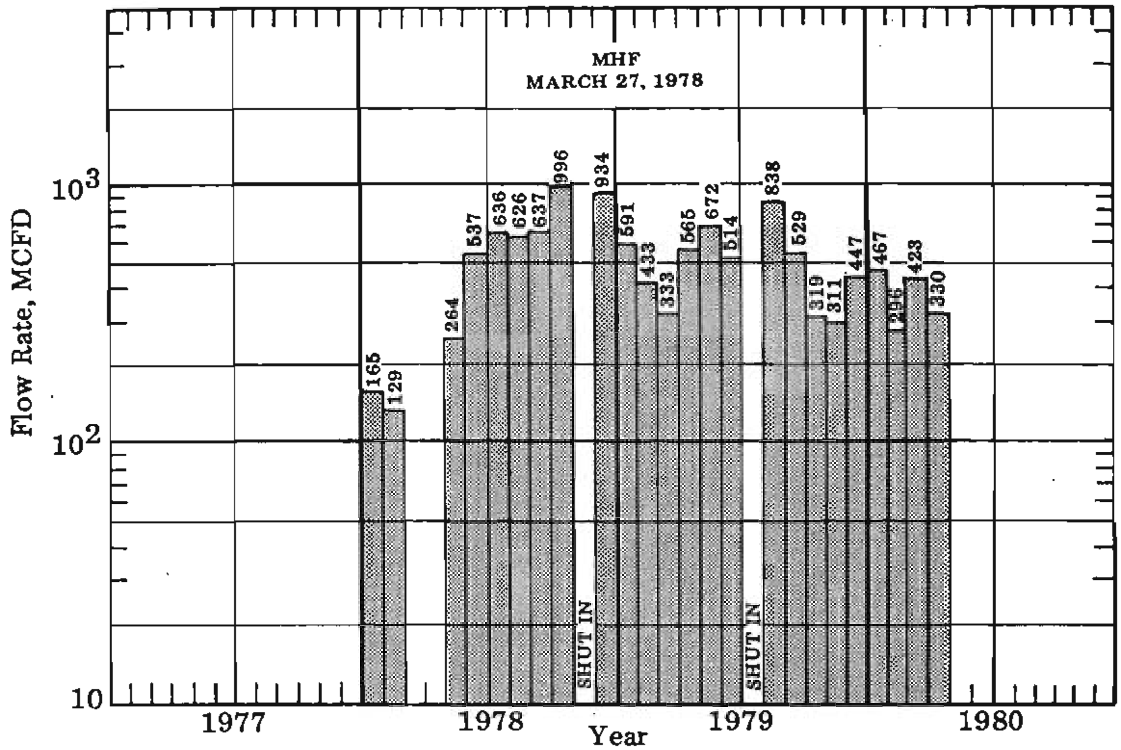


Figure 4-5 Flow Rate Performance of Natural Buttes No. 20 Well

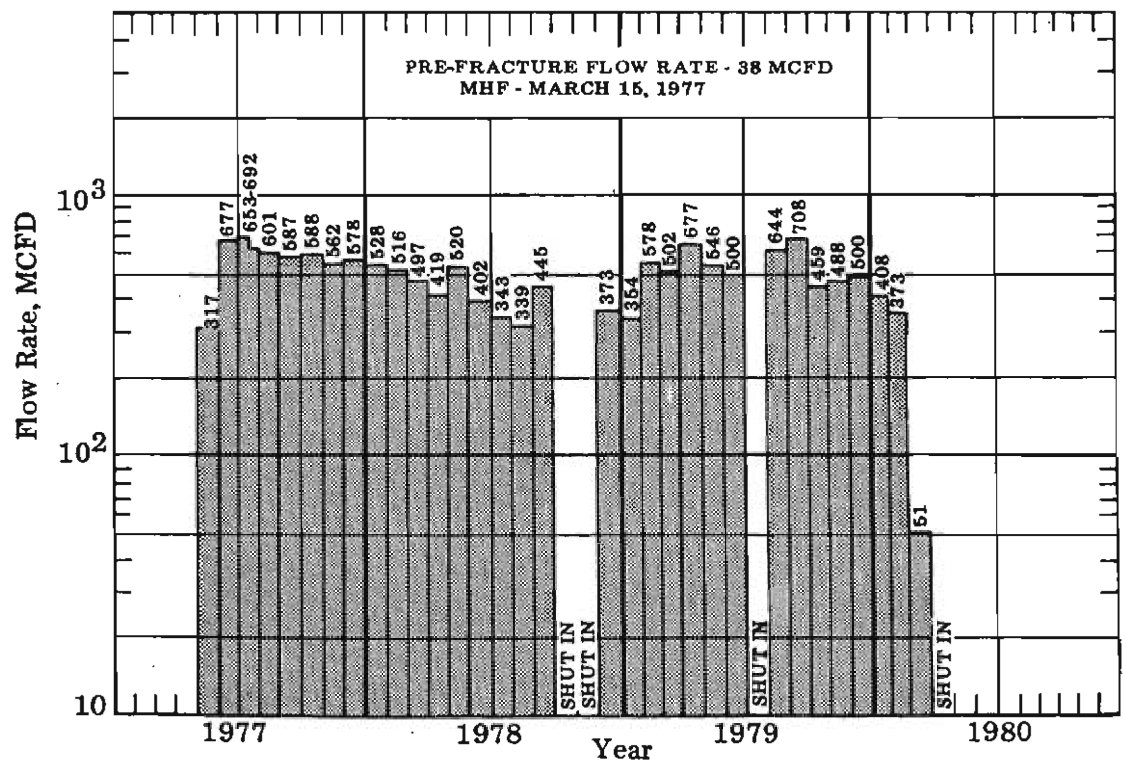


Figure 4-6 Flow Rate Performance of Natural Buttes No. 22 Well

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CER Corporation

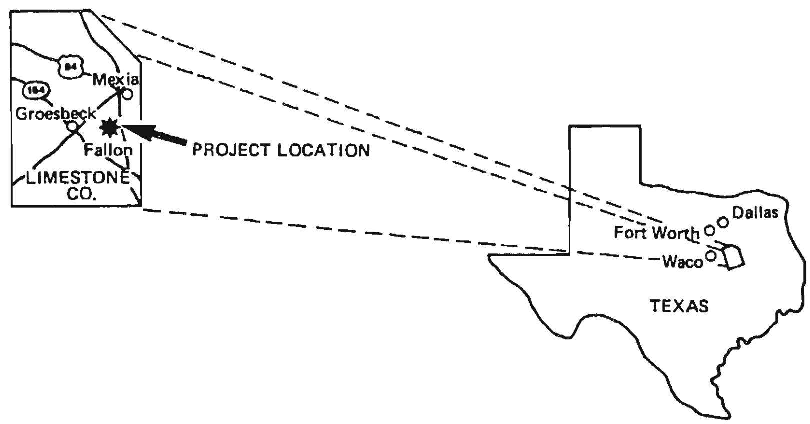
FALLON-NORTH PERSONVILLE FIELD, TEXAS

DE-AC08-78ET12150

Massive Hydraulic Fracturing Demonstration

Mitchell Energy Corporation
Houston, Texas

Status: Active



Contract Date:	March 15, 1978
Anticipated Completion:	Project completed, waiting on final report.
Total Project Cost (estimated):	DOE .... $ 553,771
	Industry 1,074,550
	Total $1,628,321
Principal Investigator:	F. D. Covey
Technical Project Officer for DOE:	C. H. Atkinson

OBJECTIVE

To test massive hydraulic fracturing in the Cotton Valley Limestone Formation.

MITCHELL ENERGY CORPORATION

The final report draft is expected in August.

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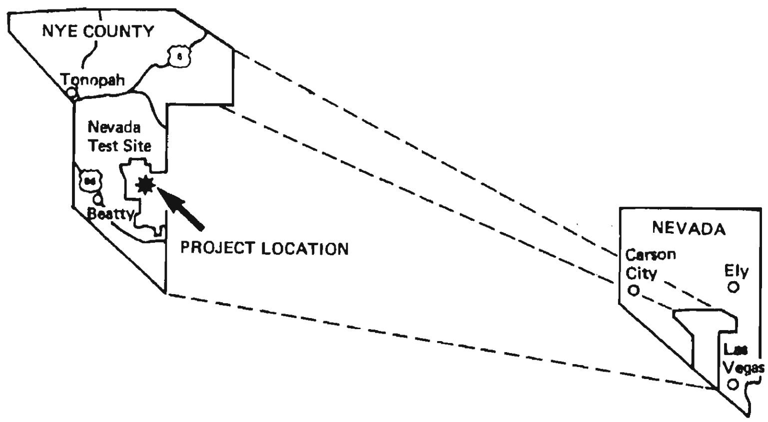
CER Corporation

NEVADA TEST SITE
NYE COUNTY, NEVADA

Mineback Testing

Sandia Laboratories
Albuquerque, New Mexico
Status: Active



Principal Investigator: D. A. Northrop

OBJECTIVE

To develop an understanding of the fracturing process for stimulation and thereby improve the production of natural gas from low-permeability reservoirs. This will be accomplished by conducting controlled fracture experiments which are accessible by mineback for direct observation and evaluation.

SANDIA/MINEBACK

HYDRAULIC FRACTURING

Hole No. 6 Formation Interface Fracture Experiment

The exploratory coring program to determine the overall shape of the fractures has now been completed. Thirty-one holes were cored and the fracture width data from these holes is now being assembled for width contouring. A number of minifracs will be conducted in two of the coreholes to determine in situ stresses in the fracture region.

Interface Test Series

Work on this activity has been completed.

Fluid Mechanics/Proppant Transport Experiments

The process of hydraulic fracturing is recognized to be a complex interaction between rock mechanics and fluid mechanics considerations. However, the fluid mechanics aspects of fracturing are generally less understood than the global rock mechanics considerations, such as crack dilation under a pressure load. The important fluid mechanics processes associated with fracturing can be broadly divided into two categories. The first is basic phenomena, such as the pressure distribution and the width in a propagating fracture. Experiments to measure the pressure and width at various locations in a fracture during propagation are presently being planned. The second area is proppant transport and the resultant conductivity.

An in-tunnel pump system capable of pumping high viscosity gels with sand concentrations up to 3 ppg should be completed by July 1. A site for these experiments is being prepared and an evaluation of the in situ stress magnitude and orientation will be conducted before the experiment locations are defined.

In Situ Stress Measurement by Hydraulic Fracturing Through Performations

Mineback experiments have shown that the most important factor governing containment of hydraulic fractures is differences in the minimum principal in situ stress. Material property differences and interface characteristics (friction) appear to be insignificant. In the Piceance Basin MWX, the distribution of minimum in situ stress will be measured through the Mesaverde horizon. Minifracs will be conducted through perforations to obtain pertinent measurements. To be certain that performing tests through perforations will yield accurate and reliable data, an experiment is being conducted in G-tunnel to compare the fracturing through perforations to open hole fracturing.

In the first test, PERF 1, a horizontal hole was drilled from the tunnel to a total depth of 65 ft and was cased and perforated in five zones (60, 48, 36, 24 and 12 ft). The 60-ft zone had four perforations, and the other zones had two perforations each, aligned at different orientations with respect to the principal in situ stresses directions. These zones were fractured with small volumes (< 10 gal) of dyed water at flow rates of 4 to 8 gpm. However, only the 60-ft zone behaved normally. The fracturing pressure was 1,300-1,400 psi with instantaneous shut-in pressure (ISIP) of $\sim$ 900 psi, which is typical of the minimum in situ stress in this area. In the 48-ft zone, the fracturing pressure rose to $\sim$ 2,200 psi, and it was obvious that the perforations were very small (most likely only a ruptured casing). However, the ISIP was 900 to 1,000 psi, which is normal. The other three zones were also not perforated well, exhibiting fracturing pressures of > 2,400 psi, no obvious ISIP, and leaks around the casing. Clearly, adequate perforation size is imperative for a valid test.

A second hole, PERF 2, will be drilled 3 ft above PERF 1, cased and pressure cemented, and perforated with stronger charges. Four or five minifracs will then be conducted in this hole. Finally an open hole will be drilled 6 to 8 ft away and open-hole fractured to determine the stresses under more controlled conditions. Stress measurements under both conditions (cased and open-hole) will then be compared to determine the effect of the perforated zone on ISIP measurements.

SCHEDULE STATUS

Figure 4-7 is a milestone chart depicting Sandia Mineback WGSP progress.

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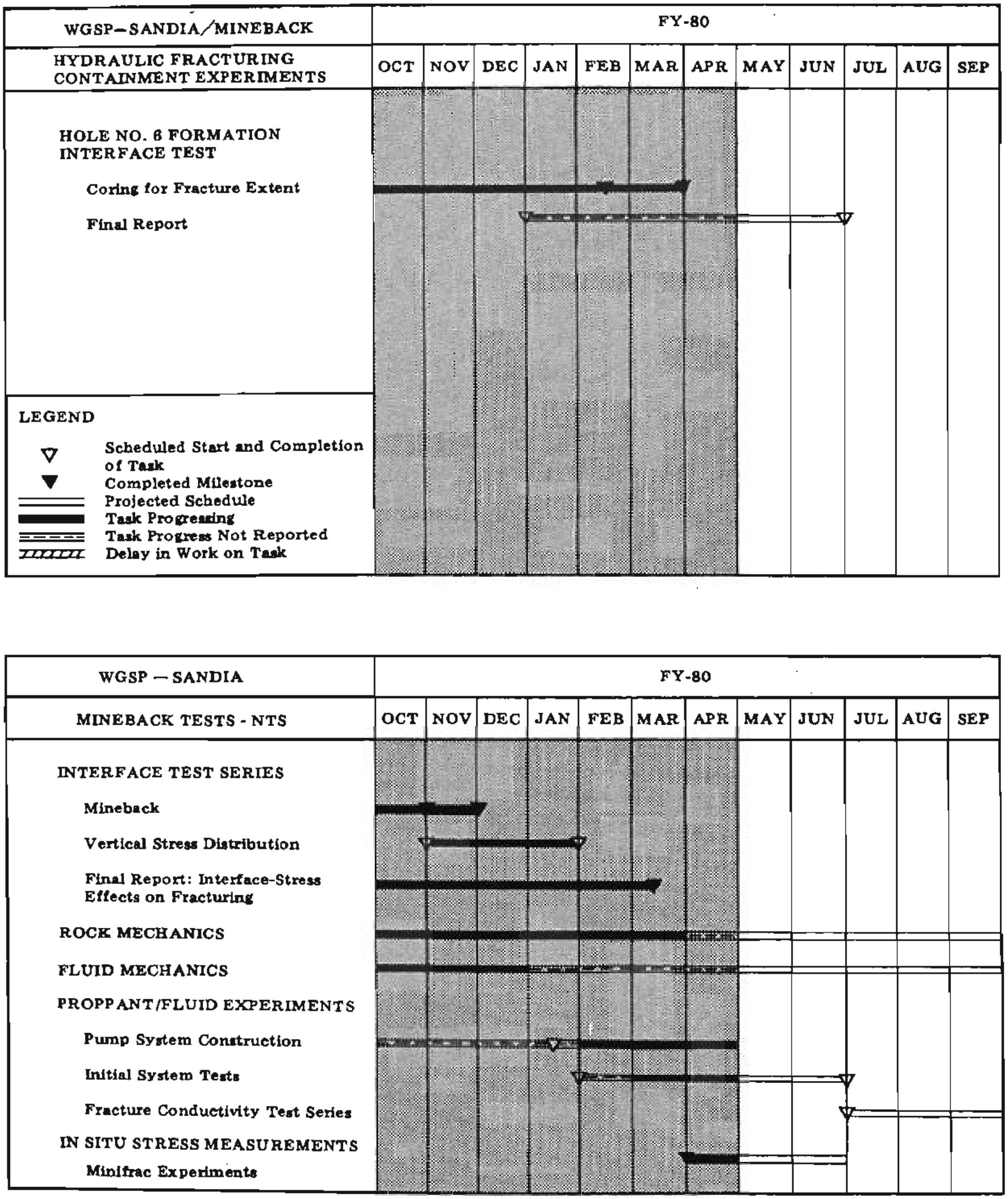

Figure 4-7 Milestone Chart — Sandia Mineback