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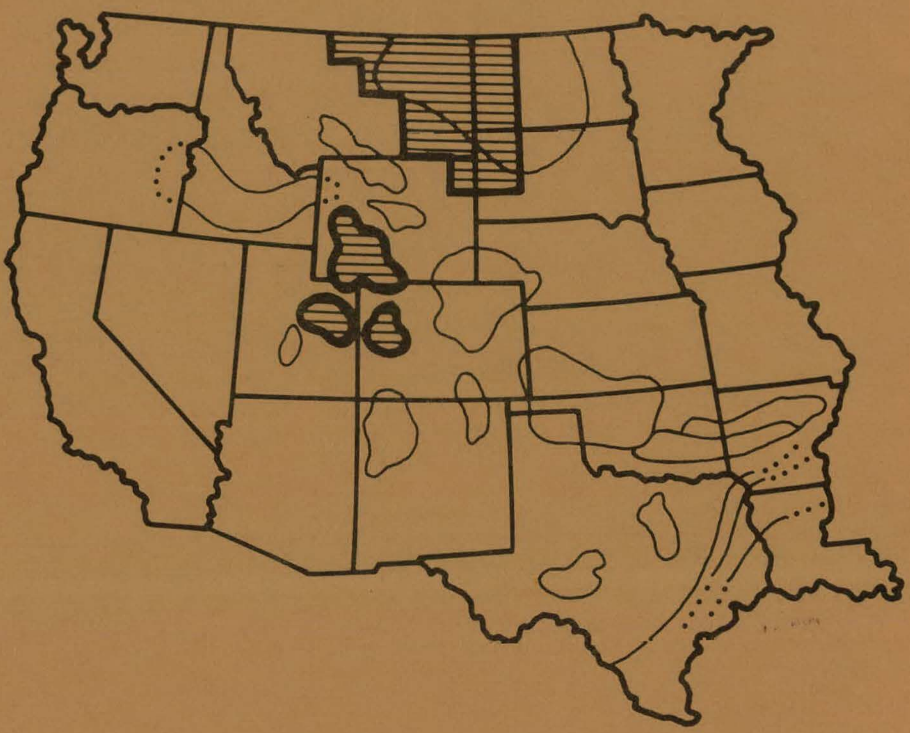
August 31, 1978 NVO/0655-111

Western Gas Sands Project Status Report



Prepared for
U.S. Department of Energy

Bartlesville Energy Technology Center
Charles H. Atkinson
Project Manager

Compiled by CER Corporation
Las Vegas, Nevada

Contract EY-76-C-08-0655

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1. SUMMARY

This edition of the WGSP Status Report summarizes the progress during July, 1978, of the government-sponsored projects directed toward increasing gas production from the low-permeability gas sands of the western United States. Background information is provided in the September 1977 Status Report, NVO/0655-100.

On-site personnel were provided by CER Corporation to assist in coring and logging the Joseph J.C. Paine well located in Valley County, Montana. The information gathered was the first for the WGSP Coring and Logging Programs.

The DOE test trailer was moved to Grand Junction, Colorado and then to the MHF 3 well site for trial runs and checkout of the test equipment.

The USGS continued work on characterization and assessment of the resource in the four primary study areas.

The National Laboratories and Technology Centers are continuing activities toward the development of mathematical modeling, new tools and instrumentation systems, data analysis and rock mechanics.

Field tests and demonstrations in the WGSP continued. Mitchell Energy Corporation had reached 9,160 ft in their Muse-Duke well No. 1, and Mobil Research and Development Corporation fractured zones 6 and 7 (8,443-8,650 ft and 8,173-8,372 ft) in the PCU 31-13 well.

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2. PROJECT MANAGEMENT

2.1 TECHNICAL MONITORING AND EVALUATION

CER Corporation provided on site personnel for coring and logging of the Joseph J.C. Paine well in Valley County, Montana. Approximately 290 feet of core was recovered from the Eagle, Bowdoin and Greenhorn Formations. The core was shipped to Core Labs, Inc. in Casper, Wyoming for routine analysis and then will be distributed to the USGS and various laboratories for specific studies.

2.2 ACTIVITY COORDINATION

The DOE Test Trailer was moved to Grand Junction, Colorado and then to the MHF-3 well site for trial runs and debugging of the test equipment. The PDP-11/10 computer was shipped to Grand Junction and installed in the trailer. The water analysis equipment and gas chromatograph have been ordered.

Drs. Wildschutte and Donahue, Gulf Science and Technology Co., Pittsburgh, PA, visited C.H. Atkinson and CER Personnel to obtain information on low-permeability gas reservoirs.

Personnel from Intercomp visited the Project Office at CER Corporation to obtain data for their study.

Atkinson and G.R. Luetkehans of CER monitored the MHF treatment of zones 6 and 7 in Mobil's Piceance Creek, Colorado test well.

2.3 TECHNOLOGY TRANSFER

2.3.1 Documentation and Reports

Draft copies of the Western Gas Sands Project, Project Plan Document FY79 and the Logging Program are being prepared. Work has started on the WGSP Quarterly Basin Activities Report and the Operations and Technical Manuals for the DOE Well Test Facility are being prepared.

2.3.2 Project Data Bank

The bibliography of the Western Gas Sands Project information files is being prepared.

"The U.S. Geological Survey Oil and Gas Resource Investigations Program," announced as in preparation at the 2nd U.S. Geological Survey Petroleum Resources and Research Seminar held in Golden, Colorado on April 14 and 15, 1978, has been received and placed in the WGSP file.

3. RESOURCE ASSESSMENT

The USGS is performing the majority of the geologic studies for resource assessment, but additional activity, primarily in the area of field tests and core analysis, provides data to support its work.

3.1 U. S. GEOLOGICAL SURVEY ACTIVITIES

3.1.1 Greater Green River Basin

C.W. Spencer prepared an oral presentation on the USGS Tight Gas Sands Program to be given to the Wyoming Geological Association, August 18, 1978, and also reviewed the USGS Western Tight Gas Sands Program with Merle Hansen of Lawrence Livermore Laboratory.

B.E. Law and J.R. Peterson are conducting investigations in the Green River Basin proper.

L.W. Kiteley and N. Noreen are doing field work on the Tertiary rocks of Sand Wash Basin.

New Drill Stem Test (DST) pressures for gradient maps were received and the maps are being drafted.

The new 1:250,000 base maps have been completed.

C.W. Spencer reviewed maps and text for a National Geographic article on unconventional gas, to be published in November, 1978.

3.1.2 Northern Great Plains Province

Outcrop samples were collected for petrographic study and comparison with nearby cores where available.

A petrographic study of the Eagle sandstone was completed in the vicinity of the Bearpaw Mountains.

Outcrop reconnaissance of tight reservoirs in the vicinity of the Bearpaw Mountains and also in the Black Hills vicinity was performed with the South Dakota Geological Survey.

3.1.3 Piceance Basin

Upper Cretaceous and Lower Tertiary units from the Grand Hogback and southern parts of the Piceance Basin were collected, measured and described.

3.1.4 Uinta Basin

Upper Cretaceous and Lower Tertiary units present in the Westwater Canyon area of the east-central Book Cliffs were measured and described. Examples of most low-permeability reservoirs of southeast Uinta Basin were present in these exposures. The study included collection of specimens for geochemical, paleontological, and mineralogical analysis. The dominant genetic sandstone types were described for each depositional environment and the vertical and lateral dimensions of the sandstone bodies were characterized.

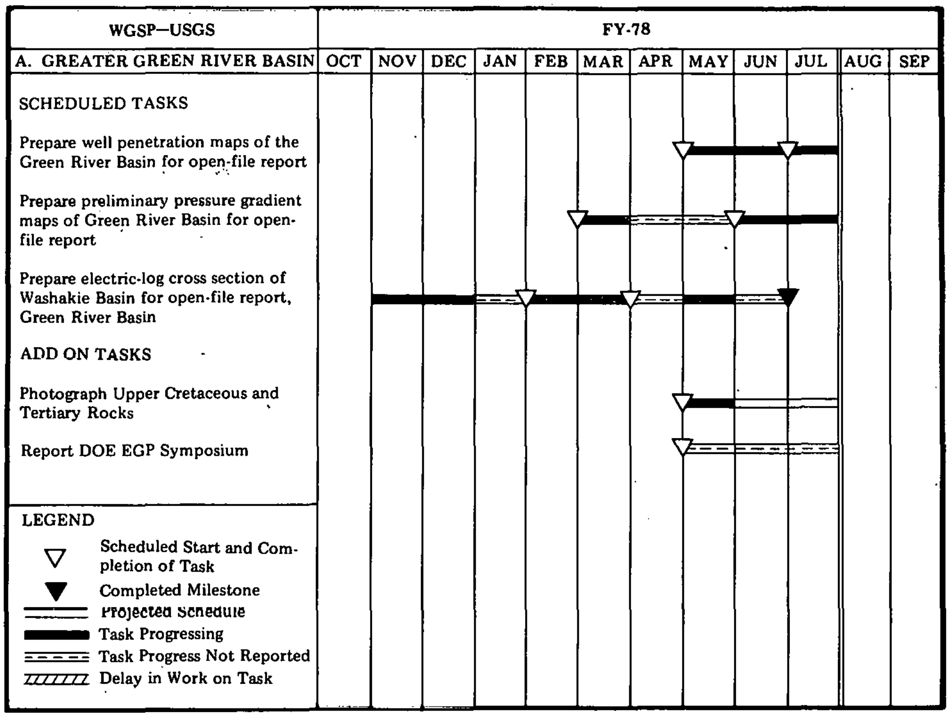
Petrographic and mineralogic analysis of core from the Southman Canyon gas field in the southeast Unita Basin was continued. The initial results are being summarized and will be released upon completion of the report.

3.1.5 Schedule Status

Figure 3-1 is a milestone chart depicting the progress of the USGS projects through July 31, 1978.

3.2 CORE PROGRAM

During the early part of July, the first core was acquired for the WGSP Core Program from a Joseph J.C. Paine & Associates well located in Valley County, Montana. Three hundred seventy-five feet of section was targeted and 293 feet was recovered in the Eagle, Carlile, Carlile-Bowdoin Member, Greenhorn, Greenhorn-Phillips Member. Thirteen runs were made using a 30 foot core barrel. Two runs were made in the Upper Eagle, three runs in the Lower Eagle, five runs in the Bowdoin Member of the Carlile and three cores in the Greenhorn-Phillips Member. The cores were shipped to Core Lab, Casper, Wyoming for routine core analysis of selected intervals. These tests were grain density, porosity, permeability, water saturation and a core gamma log on the entire core.



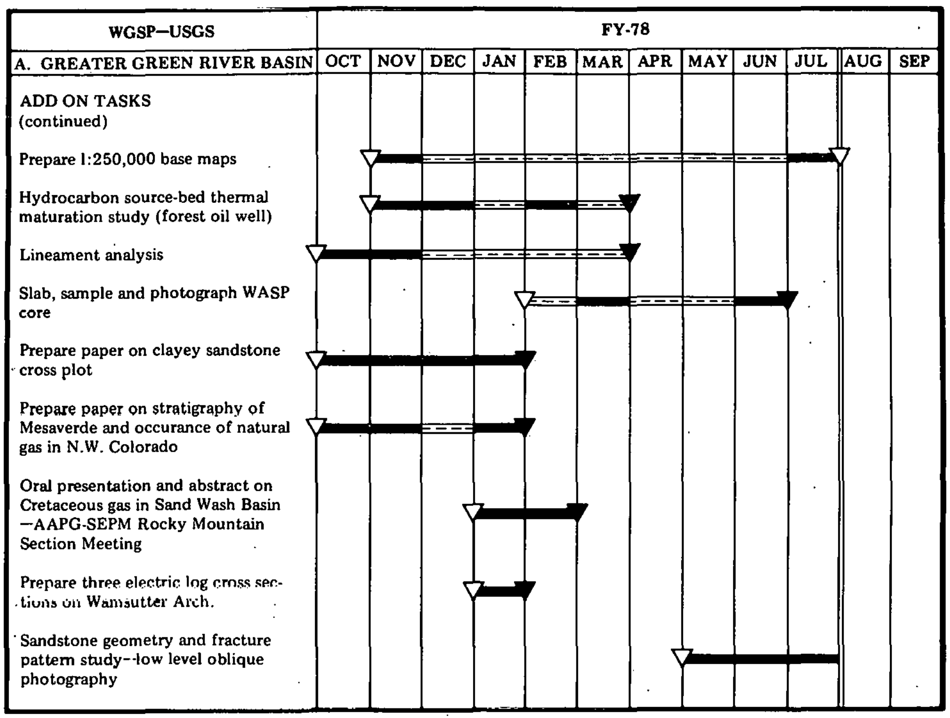
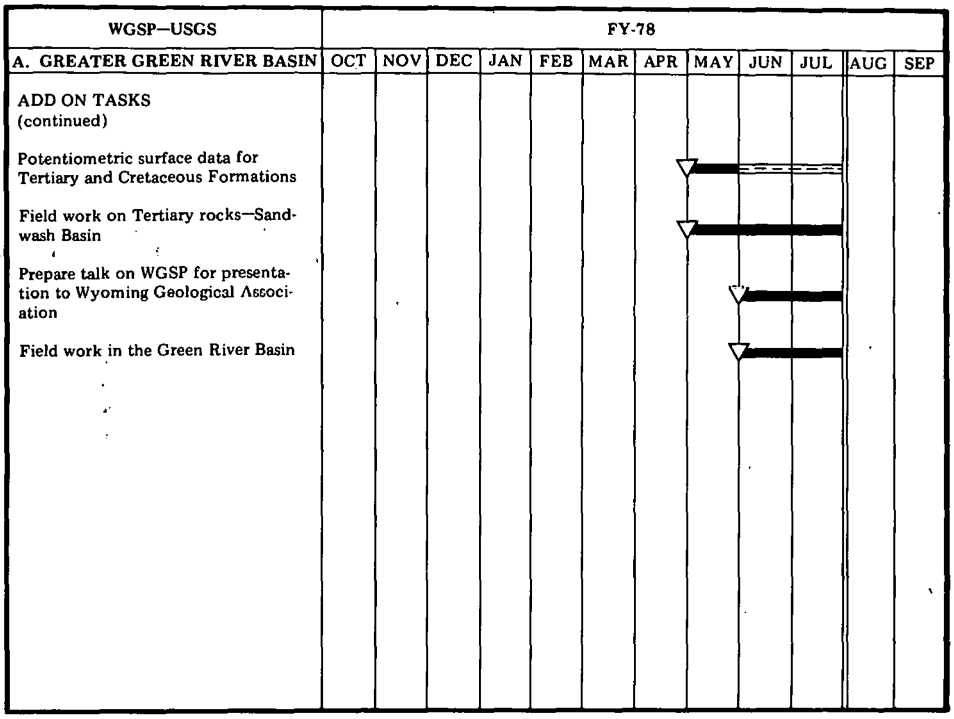
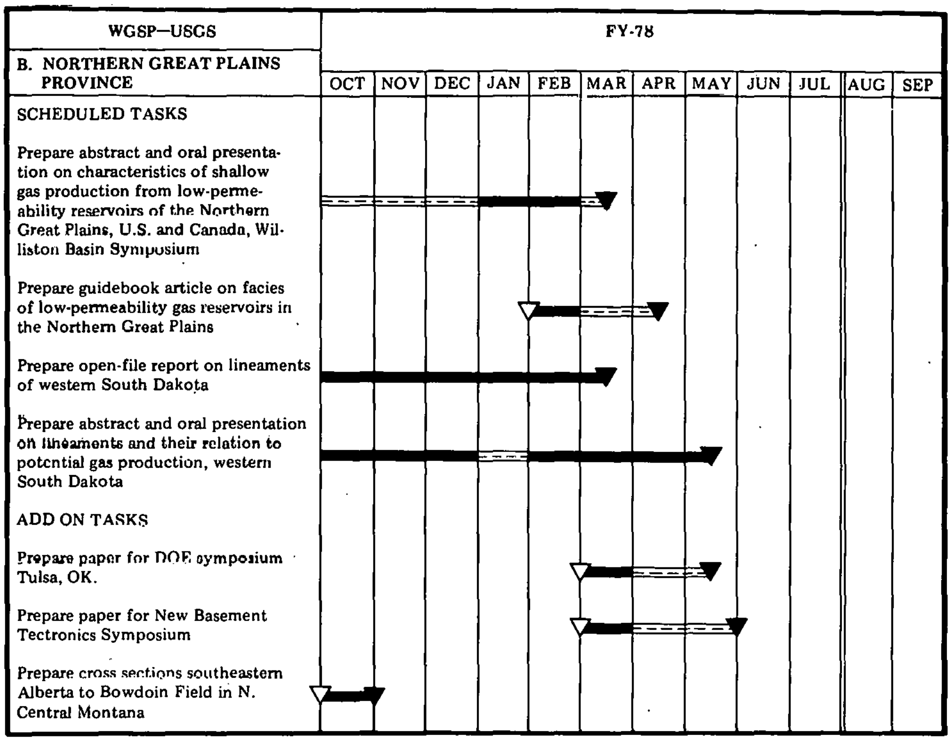


Figure 3-1 Milestone Chart—USGS





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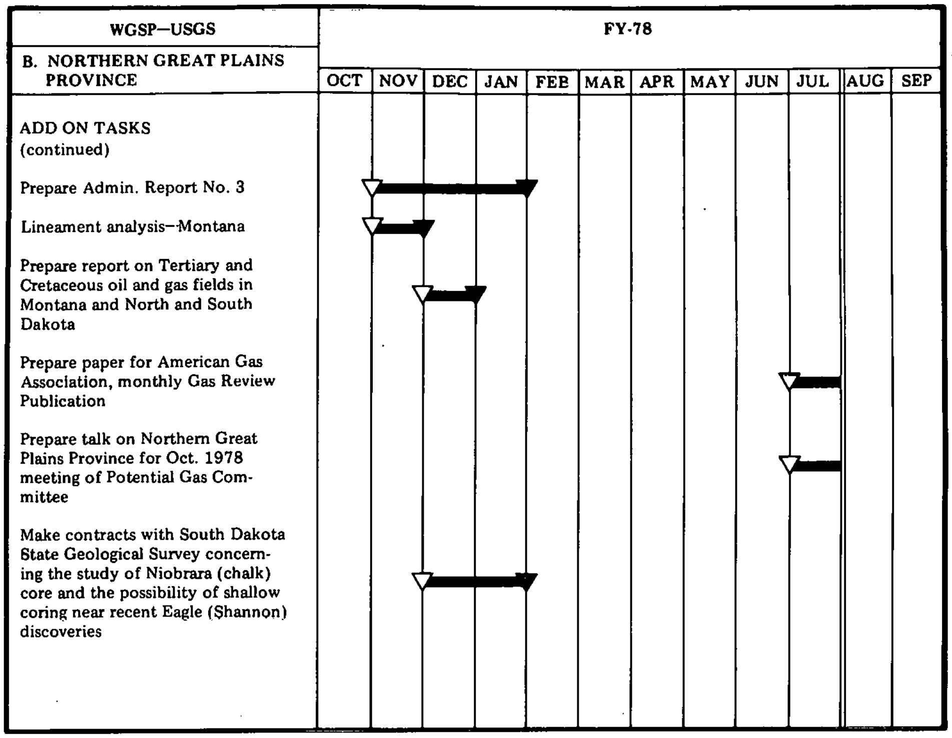

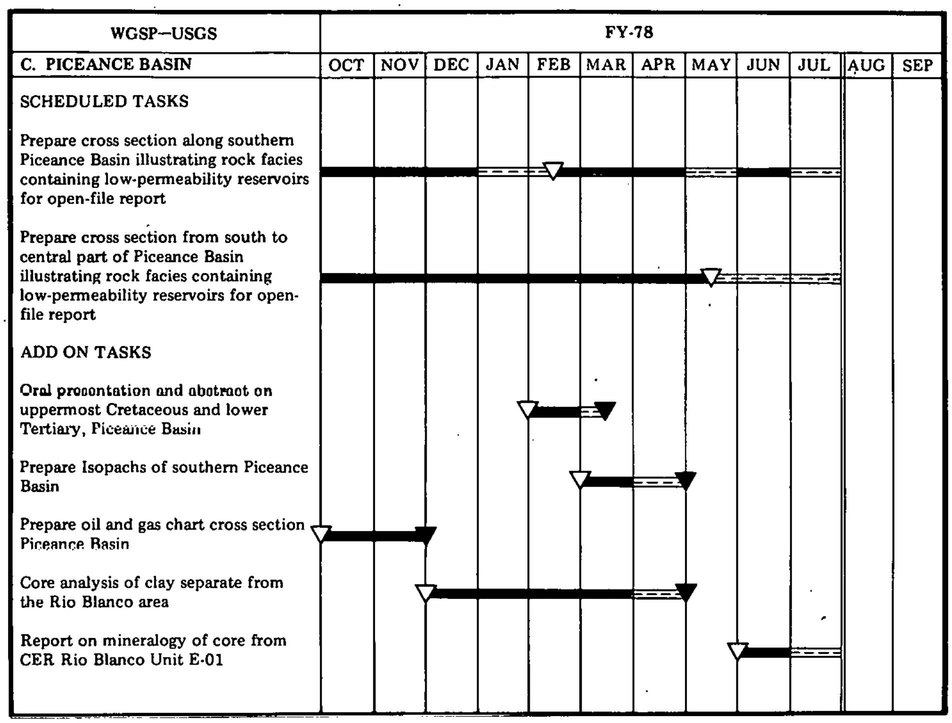

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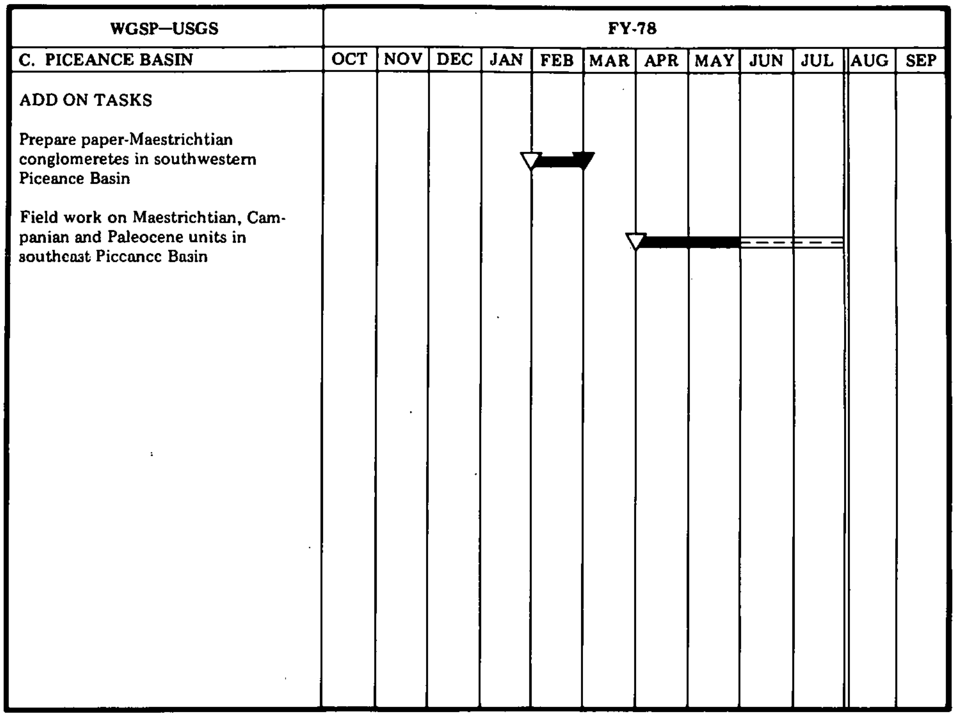

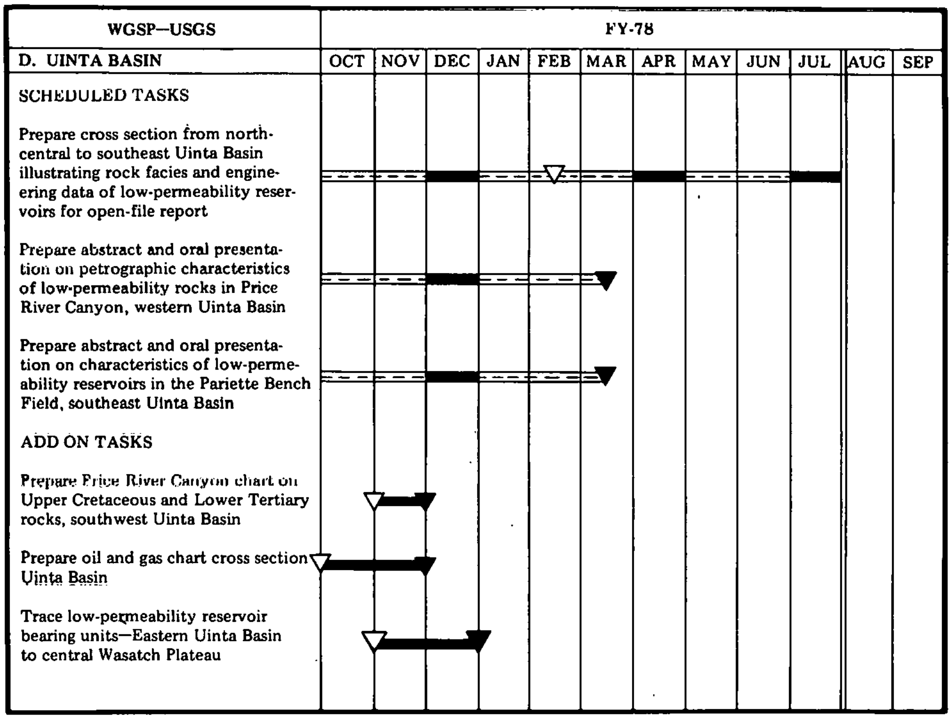

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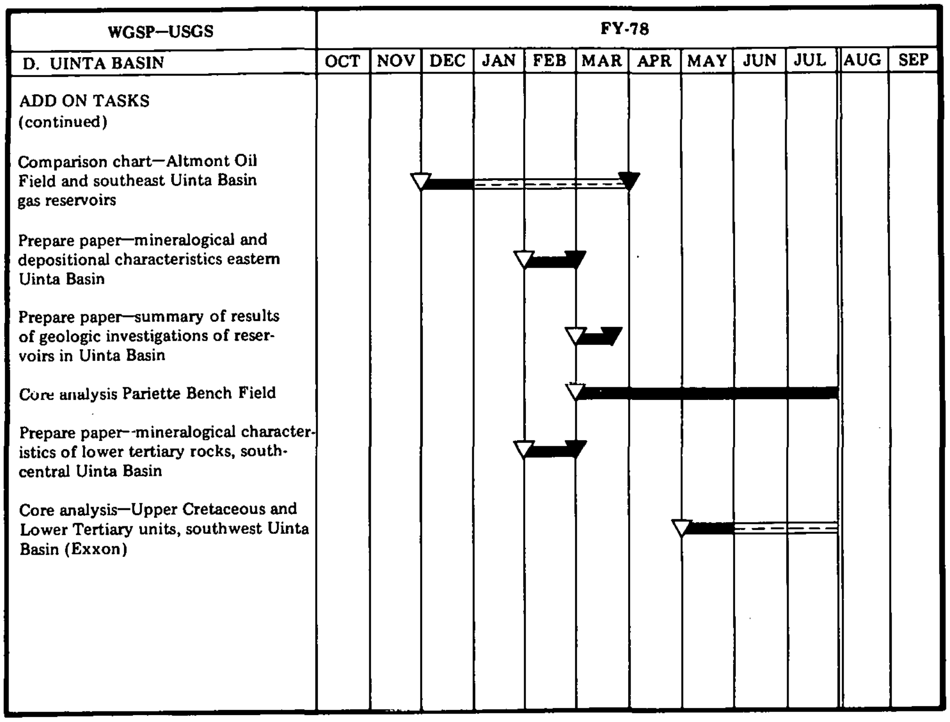


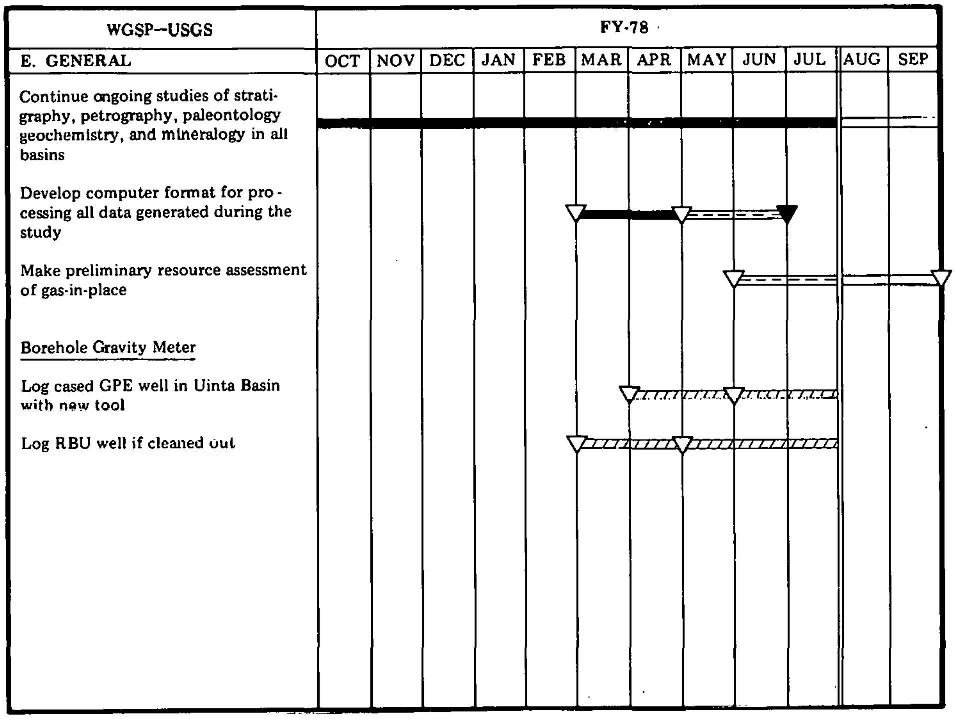


Figure 3-1 Continued

The results are being evaluated and participating research laboratories are sending CER requests for specific core intervals. (Refer to the WGSP Core Program Document, January 12, 1978, for the specific requirements of each laboratory). The core will finally be shipped to the USGS Core Library in Golden, Colorado.

3.3 LOG PROGRAM

Open hole logs were run on Joseph J.C. Paine Midlands Gas Federal 1-0296, Valley County, Montana. The log suite included Dual Induction Laterolog with SP and Gamma Ray, Compensated Neutron, Formation Density with Gamma Ray and Caliper, Borehole compensated Sonic log with Gamma Ray and caliper, Proximity Log, Microlog with caliper and collapsed sonde mud log. The logs were taped, and computed logs included Code 10 Sandstone analysis and Saraband Sandstone Analysis. Final prints have been distributed to participating national laboratories and technology centers.

The logging of this well was the first of the WGSP Log Program. The logs appeared to be of highest quality and adhered to the log quality control checklist, included in a Log Program document, which is in the final stages of preparation.

Plans are to perforate this well the first week in September. If the well cleans up and if production is substantial, production logs will be run, which consist of a spinner survey, temperature log, and noise log.

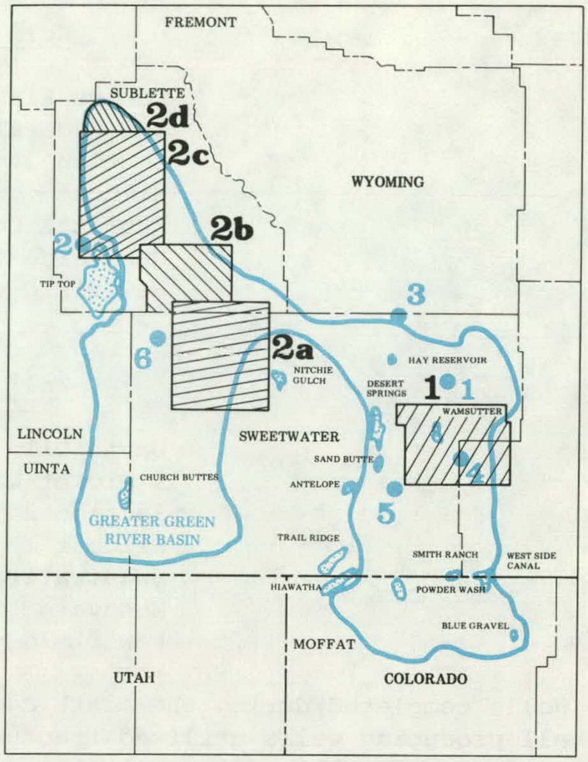
3.4 STUDY OF BASIN ACTIVITIES

Drilling and testing activities in the four primary study areas are being monitored (Figure 3-2 through 3-6 show recent wells of significance to the WGSP and the new USGS core areas). Background information on these core areas is given in the WGSP Quarterly Basin Activities Report, April 1, 1978, NVO/0655-05.

3.4.1 Greater Green River Basin

There were 26 new wells staked in horizons of interest to the WGSP in the Greater Green River Basin during July. Half of these wells were located in close proximity to Core Area #1 (Figure 3-2). Active operators were Amoco Production, Davis Oil, Sun Oil, Cotton Petroleum and Sinclair Oil (Well No. 1). The major objective was the Mesaverde at 9,270-10,960 feet.

Figure 3-2 Greater Green River Basin Showing Wells of Interest and USGS Designated Core Areas



Well No. 1

Sun Oil Company
1-34 Echo Springs-Federal
Section 34, T19N, R93W
Unnamed field
Carbon County, WY
Mesaverde test (9,620 ft)
Wildcat outpost

Operators active in the western portion of the basin usually test deeper formations such as the Frontier and Dakota. Davis staked a 11,500 ft Dakota test of interest to the WGSP Core Program due to its closeness to core area #2a, and Belco Petroleum located an 8,075 ft Frontier test in the Pinegrove Field, Sublette County. Also in this area, Robert Klabzuba Co. staked a 5,200 ft Mesaverde wildcat well in Sublette County near the Tip Top Field (Well No. 1) and Davis planned a 14,000 ft Mesaverde test in the northeastern quarter of Sweetwater County (Well No. 2).

Well No. 2

Robert Klabzuba
1-2 Federal
Section 2, T30N, R113W
Wildcat
Sublette County, WY
Mesaverde test (5,200 ft)
New field wildcat

Well No. 3

Davis Oil
1 Picket Lake Unit
Section 24, T26N, R97W
Wildcat
Sweetwater County, WY
Mesaverde test (14,000 ft)
New field wildcat

Wells completed during the month added 17,467 MCFD of new production; all producing wells utilized fracture treatments. The producing horizons were the Almy (83 MCFD), Lance (53 MCFD), Ft. Union (449 MCFD), Mesaverde (9,314 MCFD) and Frontier (7,568 MCFD). Twenty-one wells were completed, nine of which were wildcat wells which were 44 percent successful. New fields were discovered by Getty and Marathon Oil (Well No. 4) in the southwest corner of Carbon County and by Davis Oil in central and northeastern Sweetwater County, (Well Nos. 5 & 6, Figure 3-2).

Well No. 4

Marathon Oil
1-2 Standard Draw-Federal
Section 2, T18N, R93W
Standard Draw Field
Carbon County, WY
Mesaverde Production-Almond Member
(8,671-9,108 ft)
New field discovery
Frac: 188,000 gal. emul, 256,000 lb sand
IPF: 5,800 MCFD
Completion date: 7/26/78

Well No. 5

Davis Oil Company
1 North Fork-Federal
Section 14, T17N, R97W
Unnamed field
Sweetwater County, WY
Lance Production (9,204-16 ft)
New field discovery
Frac: 49,700 gal. gel,
15,800 gal. acid,
127,000 lb sand
IPF: 53 MCFD
Completion date: 7/26/78

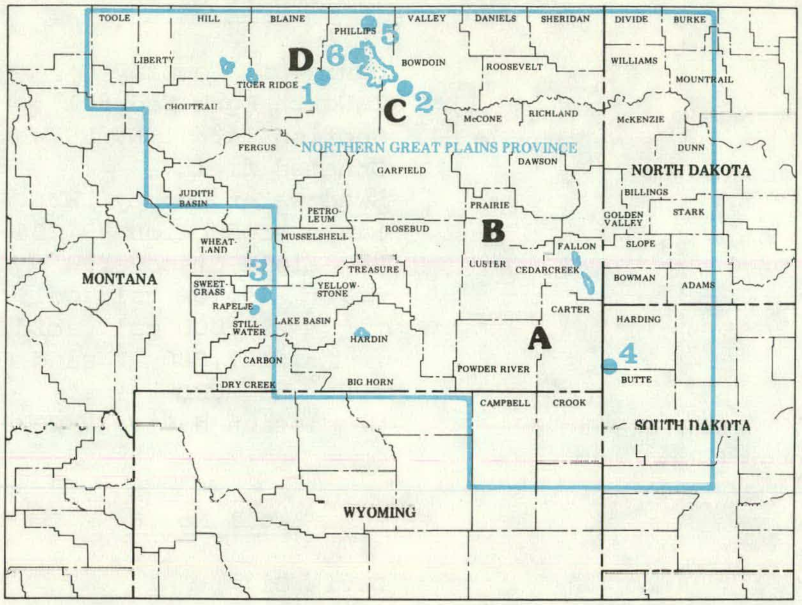
Well No. 6

Davis Oil
1 Stanley Federal
Section 30, T25N, R109W
Unnamed field
Sweetwater County, WY
2nd Frontier Production (10,750-10,764 ft)
New field discovery
Frac: acidized-500 gal.,
311,300 gal. emul.,
626,000 lb sand
IPF: 93 MCFD
Completion date: 7/26/78

3.4.2 Northern Great Plains Province

Thirty-two new wells were staked during July in horizons of interest to the WGSP and half were wildcat wells. The active operators were Gordon H. Prescott, Trio Petro, Joseph J.C. Paine, Tricentrol United States, Xeno, Inc., Energy Reserves Group, Midlands Gas Co., Jerry McCutchin,Jr., Polumbus Petroleum, Montana Power, Petroquest and Elenburg Exploration. Most of these operators are active in the northern Montana Counties of Liberty, Hill, Chouteau, Blaine, Phillips and Valley. Trio Petro and Joseph J.C. Paine have locations close to core sites "C" and "D" (Well No. 1 & 2, Figures 3-3 and 3-4).

Figure 3-3 Northern Great Plains Province Showing Wells of Interest and USGS Designated Core Areas



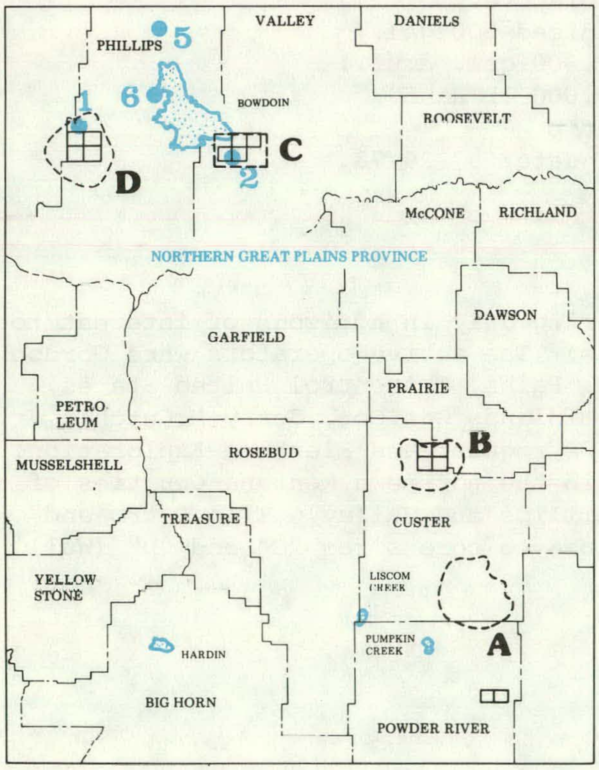


Figure 3-4 Detail of USGS Designated Core Areas, Northern Great Plains Province

Well No. 1

Trio Petro
1 Nylander
Section 1, T31N, R27E
Wildcat field
Phillips County, MT
Phillips test (2,300 ft)
New field wildcat

Well No. 2

Joseph J.C. Paine
1-0296 Federal
Section 2, T29N, R36E
Wildcat field
Valley County, MT
Phillips test (1,900 ft)
New field wildcat

In the southern part of the Province, Energy Reserve Group located a wildcat Morrison test in Carbon County (Well No. 3) and Jerry McCutchin, Jr. staked two additional wells in the West Short Pine Hills Field, Harding County, South Dakota.

Well No. 3

Energy Reserves Group
1L Anderson
Section 12, T4S, R21E
Wildcat field
Carbon County, MT
Morrison test (4,650 ft)
New Field Wildcat

Well No. 4

Jerry McCutchin, Jr.
Heikkila
Section 7, T16N, R2E
West Short Pine Hills Field
Harding County, SD
Shannon test (2,000 ft)
Development

During July, 7,725 MCFD was produced from Upper Cretaceous horizons. Two wells were fractured and produced from the Bowdoin, Greenhorn and Phillips (Well No. 5 & 6); the remainder was natural production from the Eagle.

Well No. 5

Joseph J.C. Paine & Associates
1-0471 Federal R. Anderson
Section 4, T37N, R31E
Unnamed field
Phillips County, MT
Commingled Production: Bowdoin (1,445-89 ft)
Greenhorn (1,623-33 ft)
Phillips (1,641-56 ft)
Frac: acidized-250 gal.
sand fractured (no size given)
IPF: 447 MCFD

Well No. 6

Midlands Gas Company
1 Federal 1441
Section 14, T34N, R31E
Unnamed field
Phillips County, MT
Phillips Production (1,273-99 ft)
Frac: 7,980 gal. water,
40,000 lb sand
IPF: 252 MCFD

Twenty-one wells were completed this month with 11 D&A. Of the 11 D&A wells, six were wildcats.

3.4.3 Piceance Basin

Eighteen new wells were staked to test horizons of interest to the WGSP in the Piceance Basin during July. The primary objective was the Mancos at 2,150-4,750 ft. Active operators were Norris Oil, Northwest Exploration, Fuel Resources Development, Wexpro, Twin Arrow, Chancellor and Ridgeway, Taiga Energy, Teton Energy and William Moss Properties. Well sites were concentrated into the proven gas fields of Cathedral, Lower Horse Draw, Philadelphia Creek and White River in Rio Blanco County and the Plateau Field in Mesa County (Well No. 1 Figure 3-5). No wildcat wells were staked within the Piceance Basin boundaries; however, of interest to the Core Program, was General Crude Oil Co.'s wildcat well to test the Weber (Well No. 2).

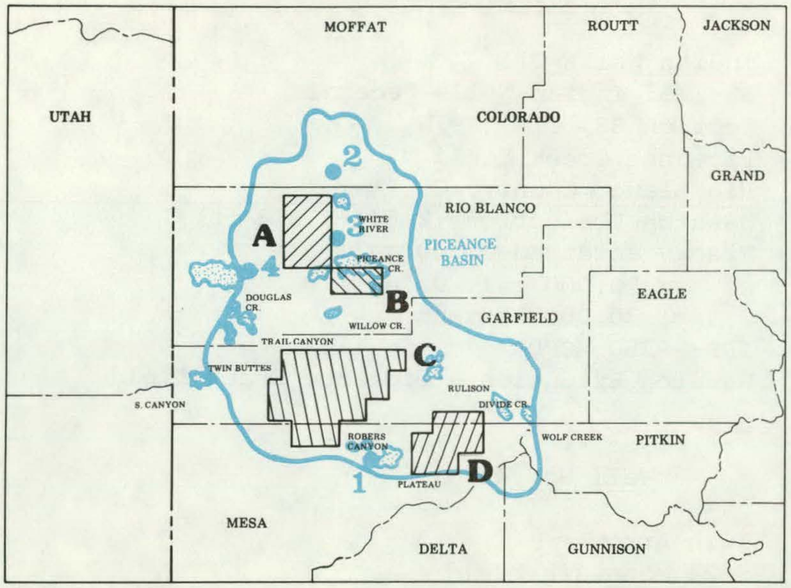


Figure 3-5 Piceance Basin Showing Wells of Interest and USGS Designated Core Areas

Well No. 1

Norris Oil Company
13-3 Friends
Section 13, T10S, R96W
Plateau Field
Mesa County, CO
Corcoran test (4,150 ft)
Development well

Well No. 2

General Crude Oil
15-29 Colorow Gulf Federal
Section 29, T3N, R97W
Wildcat field
Rio Blanco County, CO
Weber test (12,400 ft)
Status: drilling at 6,207 ft

Completed wells produced 2,232 MCFD of gas during July. Two hundred fifty MCFD was Wasatch production from the Piceance Creek Field (Well No. 3) and the remainder was Mancos and Mancos "B" production from the Cathedral and Douglas Creek Fields (Well No. 4).

Well No. 3

Indian Wells Oil
33-1-97 Indian Wells-Federal
Section 33, T1S, R97W
Piceance Creek Field
Rio Blanco County, CO
Wasatch Production (2,544-5,823 ft)
Frac: acidized-3,500 gal.
20,000 gal. water
30,000 lb sand
IPF: 250 MCFD
Wasatch Extension - Piceance Creek Field

Well No. 4

Twin Arrow
5-24 Mountain Fuel
Section 34, T2S, R101W
Cathedral Field
Rio Blanco County, CO
Mancos Production (1,959-2,220 ft)
Frac: acidized-1,000 gal.
212,000 lb sand
100 tons CO_2
IPD: 261 MCFD
Development gas well

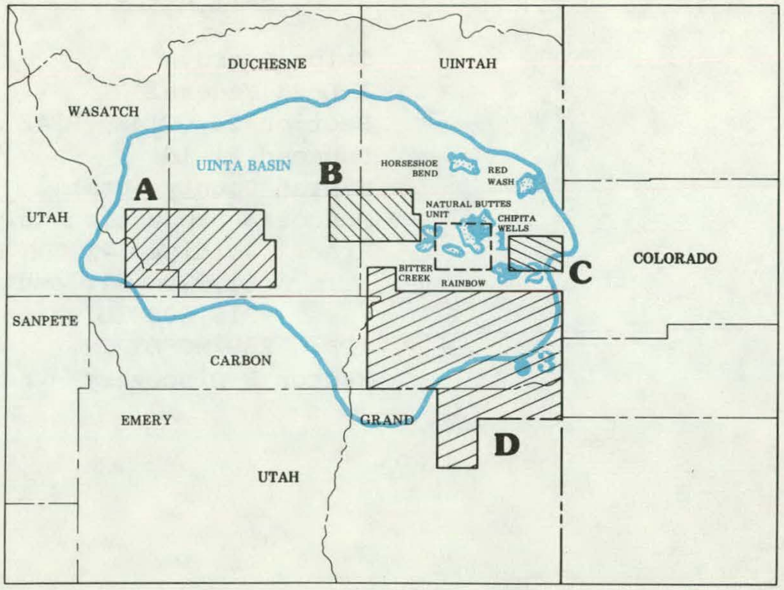
3.4.4 Uinta Basin

Thirteen new wells of interest to the WGSP were staked in the Uinta Basin. The objectives were the Wasatch, Mesaverde and Mancos zones, and most new tests were located in the Natural Buttes Field, Uintah County, Utah.

Belco Petroleum is the most active operator in the area. Less active companies are Energy Reserves Group, CIG Exploration, Pacific Transmission Supply, Enserch Exploration, Taiga Energy, Amoco Production and Gulf Oil.

Completions during the month added 10,367 MCFD of gas. Completed wells produced from the treated Wasatch (Well No. 1), Mesaverde (Well No. 2) and Mancos (Well No. 3 Figure 3-6).

Figure 3-6 Uinta Basin Showing Wells of Interest and USGS Designated Core Areas



Well No. 1

Belco Petroleum
44-10 Chapita Wells Unit
Section 10, T9S, R22E
Natural Buttes Field
Uintah County, UT
Wasatch Production (5,696-6,370 ft)
Frac: 134,750 gal. emul.
280,000 lb sand
IPF: 2030 MCFD
Development gas well

Well No. 2

Enserch Exploration
1-7 Flat Mesa
Section 7, T10S, R23E
Natural Buttes Field
Uintah County, UT
Commingled Production:
Wasatch (5,580-94 ft)
Mesaverde (6,587-6,954 ft)
Frac: acidized-1,638 gal.
131,000 gal. water,
230,000 lb sand
IPF: 3,000 MCFD
Development gas well

Well No. 3

Taiga Energy
1-L-23 Federal
Section 23, T14S, R24E
Unnamed field
Uintah County, Utah
Mancos B production (5,416-5,804 ft)
Frac: acidized -2,000 gal.
61,970 gal. emul.
216,000 lb sand
IPF: 288 MCFD
Mancos B Discovery - new field

4. RESEARCH AND DEVELOPMENT BY ENERGY TECHNOLOGY CENTERS AND NATIONAL LABORATORIES

4.1 BARTLESVILLE ENERGY TECHNOLOGY CENTER

4.1.1 Improved Pressure Coring System

4.1.1.1 Core Retriever Design

Maurer Engineering indicates that work is progressing as scheduled on the drawings for the core retriever.

4.1.1.2 Coring Fluid Selection

Two low-invasion coring fluid candidates have been tested this month. An oil-based fluid with the trade name, "Native State Coring Fluid," was found to be unacceptable. At pressure differentials of 200 psi, the oil was filtered from the fluid and penetrations of over one inch were experienced in the sandstone core test specimen. Any significant invasion of oil into the core would make accurate core analysis difficult or impossible.

A water based fluid, specifically recommended as a solution for severe fluid loss zone problems, was tested with excellent results. No invasion was measurable in a five-hour test at 400 psi overbalance pressure. The powdered product "Sanheal" was mixed with tap water at a ratio of 100 lb per barrel. A defoamer was added to facilitate mixing. The apparent viscosity of this fluid at room temperature was 95 centipoise but higher viscosities are easily obtained; however, this mix ratio appeared to give the thickness necessary for good chip removal while maintaining relatively low discharging and pumping forces.

In the near future this fluid will be evaluated as a coring fluid in sandstone using the pilot bit, and its properties at dry ice temperatures will be determined.

4.1.1.3 Bit Design

The HQ Stratapax core bits that will be used to further evaluate the pilot bit concept are out of the shop and are ready for bonding of the cutters. The cutters have been trimmed to the desired shape using laser cutting of the diamond, and conventional saw cutting of the tungsten carbide substrate. The ratio of the rock removed to the fluid dispersed for this bit is inferior to that of the final pilot bit design. However, valuable information may still be gained from a test with regard to chip cleaning and drilling characteristics when tested in conjunction with the low-invasion coring fluid.

The drawings of the full bit body (8-1/2") have been completed. Seventeen stud-mounted cutters are used on a 45° crown profile. The eight conventional mud ports, oriented a maximum of 15° from vertical, are located to minimize fluid invasion of the core while adequately cleaning the full bit. A three axis numerical control milling machine will be used in the construction of this bit, scheduled to begin in September.

The final design for the pilot bit that mates to the bit body, has also been completed. The wall thickness is one-half inch and the extended length is two inches. Three internal gauge trimmers are used to assure correct core size.

4.1.2 Interface Conductivity Effects on Electric Logging

Conductivity measurements on tight gas sand cores have continued. Runs are being made at five different KCl concentrations (2.0%, 3.5%, 5.0%, 7.0%, 8.5%) and two temperatures (70°C and 80°C).

4.1.3 Mapping and Contouring Formation Water Resistivity (R_W)

No progress reported.

4.1.4 Logging Techniques and Interpretations

4.1.4.1 Study of Sonic Neutron and Density Logging of Low-Permeability Gas Sands

During the month of July, research was directed toward determining the porosities of various zones in several wells in Wyoming and Colorado. The porosities were determined using essentially standard techniques from log readings of the neutron, density and sonic logs, when they were available. Detailed analysis was not made because the core analysis of the wells was not yet available.

In general, the porosities obtained by the various logs were in fair agreement and ranged between six and eleven percent. In Wyoming, the Pinedale and the Merna Field showed average porosities to be between six and eight percent. Individual sands were fairly thin and averaged about eight feet at depths below 10,000 feet. Pinnacle Number 8, a wildcat drilled by Mountain Fuel Supply Company, showed sands that were thicker than the eight feet and the porosities of the zones were higher than those of the Pinedale Number 8 well. In these wells, the porosity was about eight percent for sands at about 8,000 feet. In general, the porosity of all zones will be less as the depth increases.

Colorado's Rulison Field contained zones which had sand porosities in the range from eight to eleven percent at around 8,000 feet.

Based on the logs that have been analyzed, which is only a small sampling of those available, the porosities of the zones did not vary greatly. In general, at shallower depths, the porosities tended to increase, whereas the deeper zones had porosities down to about six percent. In the zones where several porosity logs were available, the porosities still did not vary greatly. However, the porosity from the density log tended to be a little more consistent than the porosities obtained with the sonic or the neutron logs. Both the average porosity of the various sand members and the variation of individual porosities within each member seemed to be about the same.

4.1.4.2 Instrumentation for Formation Evaluation and Advanced Logging Techniques

Activities included: 1) a continuing literature search and interview schedule to evaluate current, commercial formation fluid samplers, 2) a similar evaluation of currently applied, as well as more exotic, borehole logging operations, and 3) an evaluation of the use of sidewall ballistic penetrators.

4.1.4.2.1 Formation Fluid Sampling

Most logging service contractors offer a formation testing tool, which under proper conditions will obtain a sample, or samples of produced fluids. This allows measurement of pressure buildup while sampling and, thus an indication of formation permeability. Various trade names such as Schlumberger Formation Interval Tester (FIT*), Repeat Formation Tester (RFT*) and Dresser Atlas Formation Tester, incorporate similar tool designs. Combinations of valves, sample chambers, perforating guns or jets, and hydraulic systems allow a seal pad to be put in contact with the formation (or casing). The perforator is actuated to provide flow paths, and fluid/gas samples are obtained while shut-in and flowing pressures are monitored. A significant advance in tool design (as in the RFT) is the use of two sample chambers (up to approx. 24 gal. capacity) instead of the typical single chamber (generally one gallon). The two chambers are filled sequentially allowing comparison of fluids produced early versus those at later flows. In theory, this is to

* Trademark, Schlumberger Well Services

evaluate or eliminate misinterpretation due to filtrate invasion; the later sample should represent true formation fluids. However, it is known that invasion in low-permeability (usually with low-porosity) sands is deeper than in higher permeability sands. Even with low porosities, the deep invasion implies significant volumes of filtrate and correspondingly long testing time intervals before true formation waters are sampled. Therefore, it is felt that: 1) Single chamber formation testers will have too much filtrate contamination to be useful for tight gas sand evaluation. 2) Although dual chamber units have been proven satisfactory for normal reservoirs (A. Timur, Chevron Oil Field Research Co., personal communication), the invasion depths in low-permeability (<1 md) reservoirs may also contribute significant filtrate contamination. These problems may be minimized if detailed chemical analyses of filtrate and produced water allow for calculation of the unknown chemical analysis of the formation water. However, the volume ratios of the two fluids in the recovered sample is unknown, therefore, this approach is believed impossible. It is thought that a tool design of a continuous sampler may be an appropriate solution to the problems posed by commercially available tools. Such a tester would sample a discrete volume of water, measure its resistivity, eject the sample, and repeat. A plot of resistivity versus volume produced should show a trend which assymptotically approaches R_w and not S_w or water-oil ratio determinations. The obvious disadvantage would be a long time for the test as low-permeability formations yield low flow rates. Currently BETC is investigating the feasibility of such a tool design.

4.1.4.2.2 Borehole Logging

A future report will contain a complete summary of borehole logging applications to R_w determination. The following sections present those logs currently being investigated which show promise as possible indicators of R_w. Standard electrical logs are not discussed in this report.

4.1.4.2.3 High Frequency Dielectric Logging

Laboratory studies (Poley, et al., 1978) show that behavior of the complex dielectric constant of saturated, porous rock is such that the real component (ε") is dependent on salinity of the pore fluid and hence may be a useful tool for R_w determination. Necessary studies relating the volume of sample (penetration depth) of such tools to the salinities and filtrate invasions involved are required for a complete evaluation.

4.1.4.2.4 Nuclear Magnetism Logging (NML)

This log is unique in that it "sees" only free fluid in rock pores and not in matrix, shales, etc. The log behavior depends on many factors including pore size, paramagnetic substances in the matrix, and in solution.

A comprehensive study of bulk water relaxation (basically log response) versus salinity is necessary to evaluate the NML response as a salinity indicator. Current hardware limitations, however, make it very difficult to obtain measurements downhole in very low-permeability formations. Therefore, applicability of NML to tight gas sands (for R_w or permeability) is questioned as far as a downhole device is concerned.

4.1.4.2.5 Induced Polarization (IP) Logging

The induced polarization concept has long been a tool of the mining geophysicist in surveying for disseminated sulfide ore deposits. Recently similar applications to coal evaluation (sulfur content) have been employed. Whereas IP response is enhanced by the presence of metallic ores, it is also known that increased salinity also contributes to the IP signal. It has been suggested that the IP tool could be used to discriminate fresh/salt water zones but that the standard resistivity tools might be less expensive and more accurate under typical conditions. Again, substantial experimentation relating salinity to IP in a borehole formation environment is required. An additional complicating circumstance is that shales (clays) produce significant IP response, and, as the low-permeability of western gas sands is in part due to their shaliness, this may be an overriding characteristic of the IP log in a tight gas sand.

4.1.4.2.6 Instrumented Penetrator

Sandia Laboratories has investigated the penetration of bullets into rock formations as part of a drilling system which fires projectiles ahead of the drill bit to increase drilling rates. Studies have shown that a projectile velocity of 2,000 ft/sec would be required to penetrate a few inches into a sandstone formation. Such velocities are exceedingly difficult to obtain over the lateral dimensions of a borehole; it would be easier penetrating into the bottom over some specific muzzle length (vertical). The maximum velocity thus far obtained for a trailing wire penetrator (lead wires to experimental package within penetrator) has been about 1,000 ft/sec. With the suspected depths of invasion of 1 foot or more, present experience indicates that this procedure is not feasible. Further investigations concerning sidewall drilling and logging while coring (special non-invading coring apparatus) are recommended instead.

4.1.5 Rock-Fluid Interaction

4.1.6 Reservoir Stimulation

On July 13 and 14, 1978, an information meeting was held at CER offices in Las Vegas with CER, Intercomp, and DOE personnel to discuss the objectives and initiate the project entitled "Parametric Analysis of MHF

Test Data; an Engineering Study of Western Gas Sands." Intercomp received existing MHF data from CER and DOE.

4.1.7 Schedule Status

Figure 4-1 is a milestone chart indicating the status of BETC Projects through July 31, 1978.

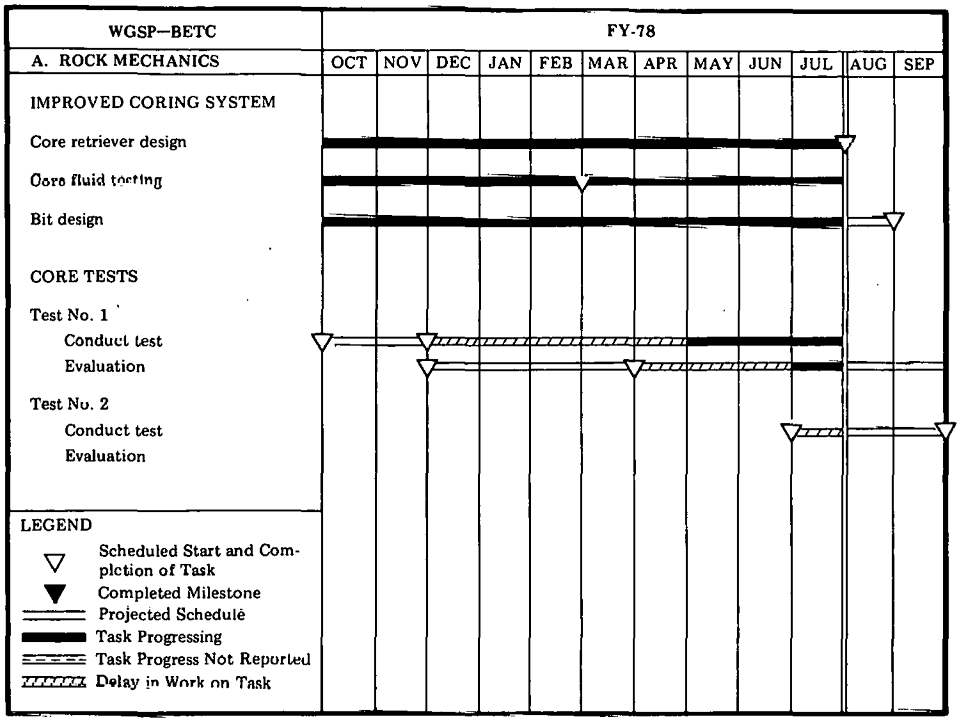


Figure 4-1 Milestone Chart—BETC

4.2 LAWRENCE LIVERMORE LABORATORY

4.2.1 Theoretical Analysis and Model Development

LLL has begun an analysis of elastic stress variations due to finite lens configuration in geologic structures. In these preliminary calculations, the assumption was made that the elastic moduli in the layers is different than in the surrounding medium and any plastic relaxation was not included.

To perform this analysis, a static finite element code was expanded to include multilayer capabilities. It was used to study some basic triple-layer geometries where the layers are typified by a Young's modulus which is half that of the surrounding medium. The layer geometries are

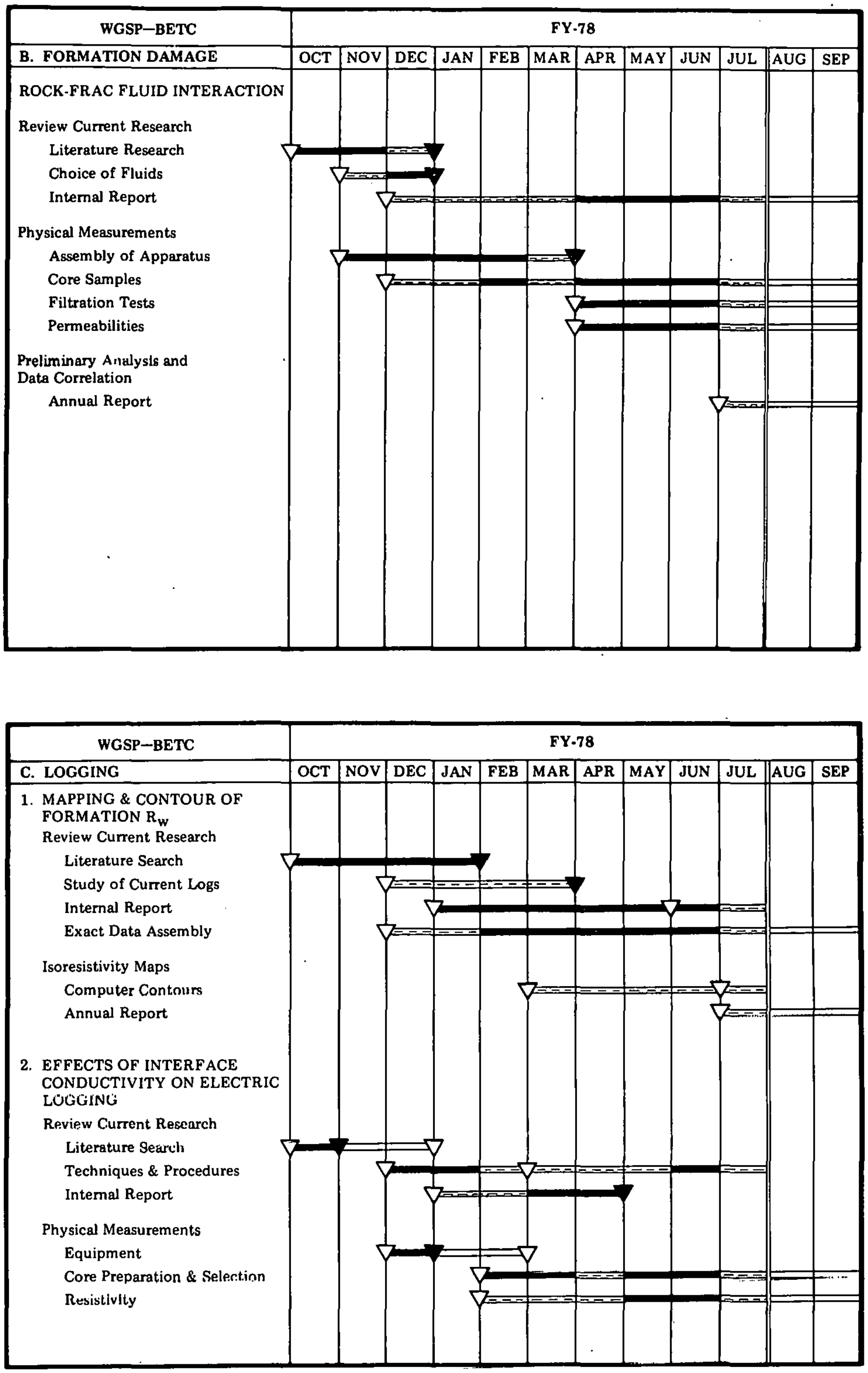
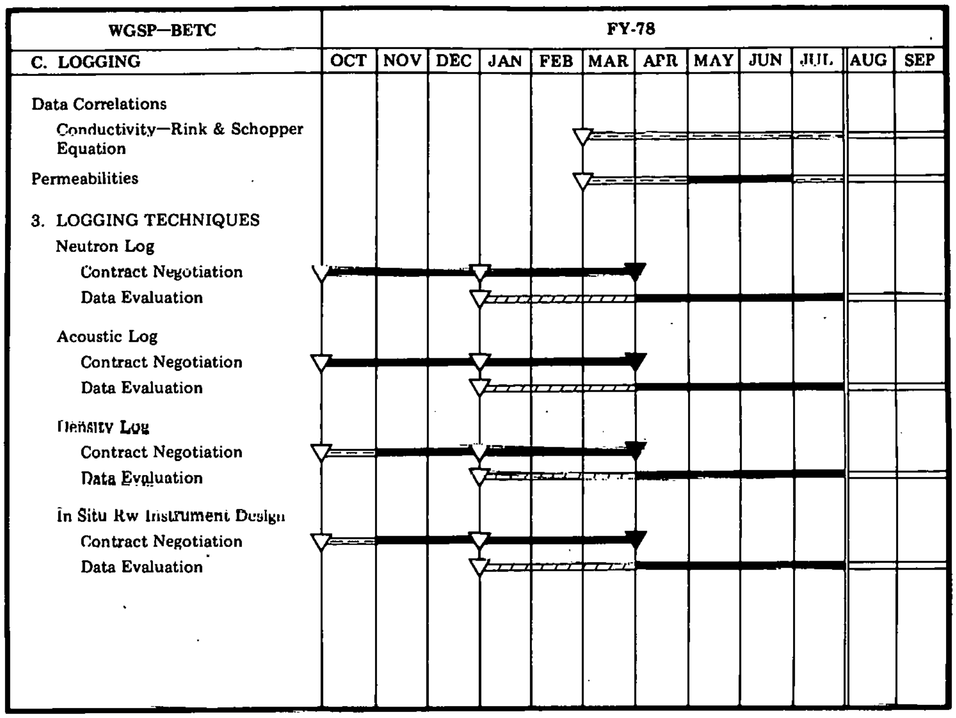


Figure 4-1 Continued



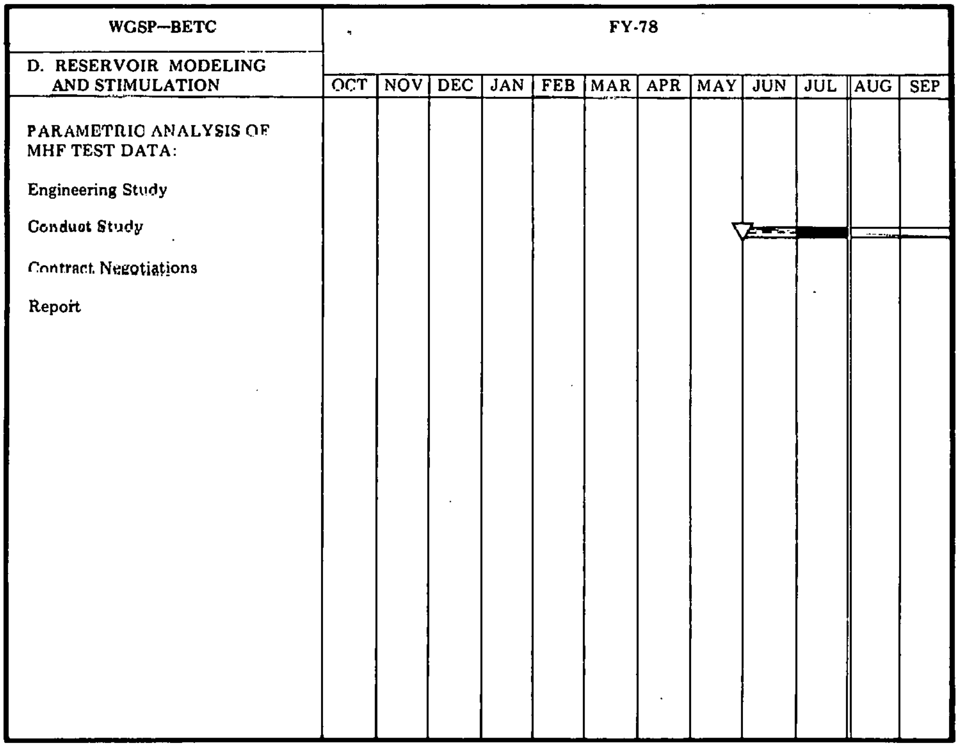


Figure 4-1 Continued

evident in the grid plots (Figure 4-2). The medium is subjected to a compressive stress in the vertical direction. In addition, the horizontal extremities of the grid have been constrained to allow no motion in the horizontal direction. These extremities are not shown in the figures because the grid was reduced to amplify the region of interest. The top of each figure represents the ground surface.

Figure 4-3 shows dilatation (sum of the principal strain) contours for the four triple-layer configurations. The plots in Figure 4-3 are in the same order as Figure 4-2, i.e., Figure 4-3a has dilatation contours for the geometry shown in 4-2a etc. Negative dilatation, or compression, which is located at the layers, is not shown. Primary interest is in the effect the layers have on the stress and strain field. To determine this, principal strain direction and magnitudes near the layers need to be plotted.

4.2.2 Experimental Program

Small scale laboratory experiments to study crack initiation and growth across an interface have continued. When no load is applied across a bonded interface between Nugget sandstone and Indiana limestone, the crack consistently grows preferentially in the sandstone. These results are consistent with the calculational prediction of a higher stress intensity factor in the less permeable medium having a lower Poisson's ratio. Some attempts were made to perform experiments on crack initiation and growth across a PMMA-limestone interface. So far the laboratory has not been able to obtain a bond across the interface of sufficient strength to withstand the pressurization along the interface, i.e., the interface breaks apart before fracture initiation occurs.

4.2.3 Logging Program

The borehole seismic reflection system built by Southwest Research Institute (SWRI), has been field tested at the Nevada Test Site. It performed well, with only minor difficulties which will require repair at SWRI.

There appears to be no problem operating the system in a manner that is safe for the borehole. Setup time before needing the logging truck, is about an hour, and setup time with the truck is about 1/2 hour. First indications are that about one hour is required to place the sonde in a borehole and one half hour to remove it. Less time will be required if a drill rig is on the hole. Data-taking rate is about 8 stations per hour.

Data obtained in both sedimentary rock and alluvium appears to be good. It is possible, however, that a severe tool signal is present and laboratory tests are needed.

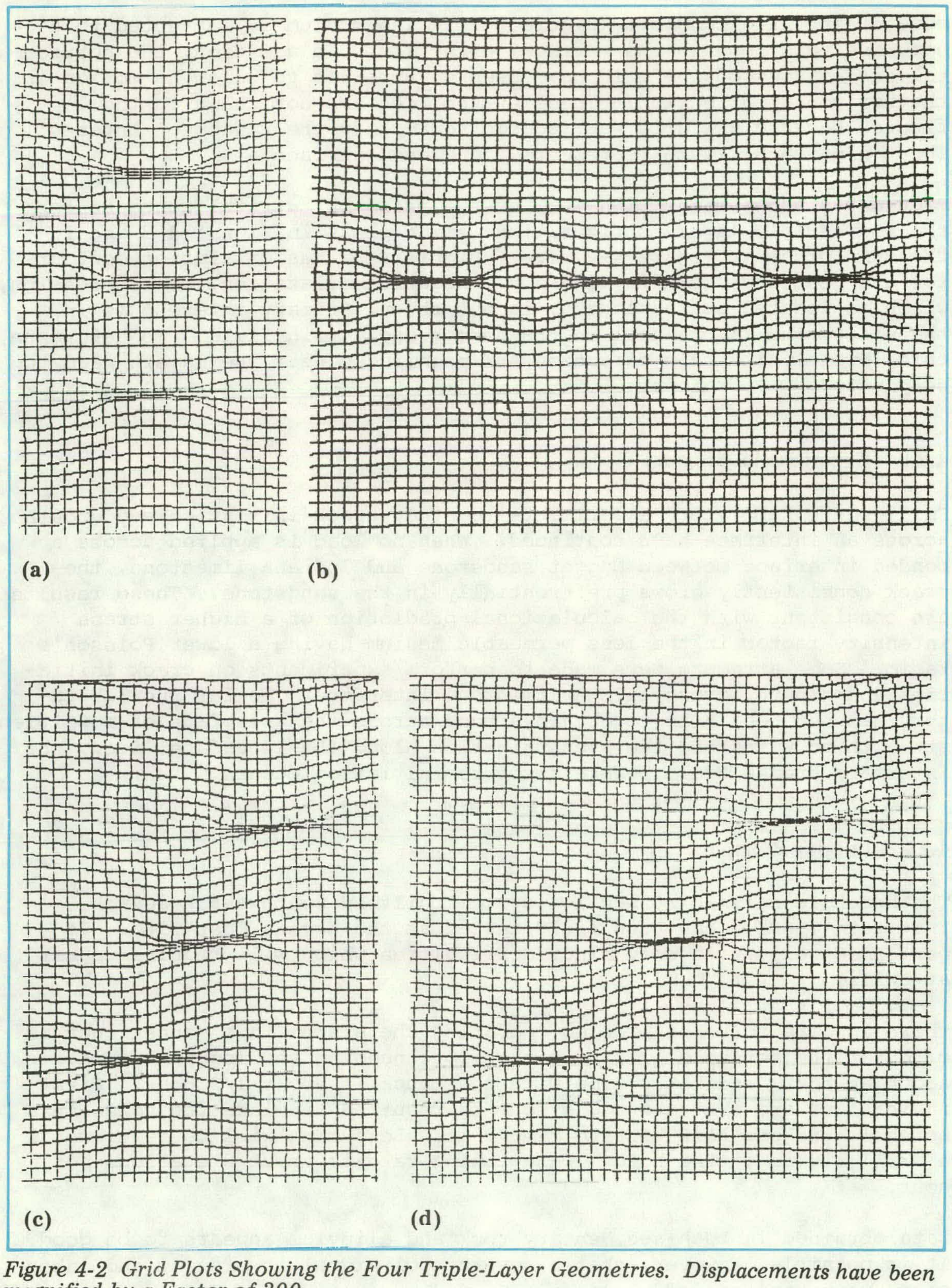


Figure 4-2 Grid Plots Showing the Four Triple-Layer Geometries. Displacements have been magnified by a Factor of 300

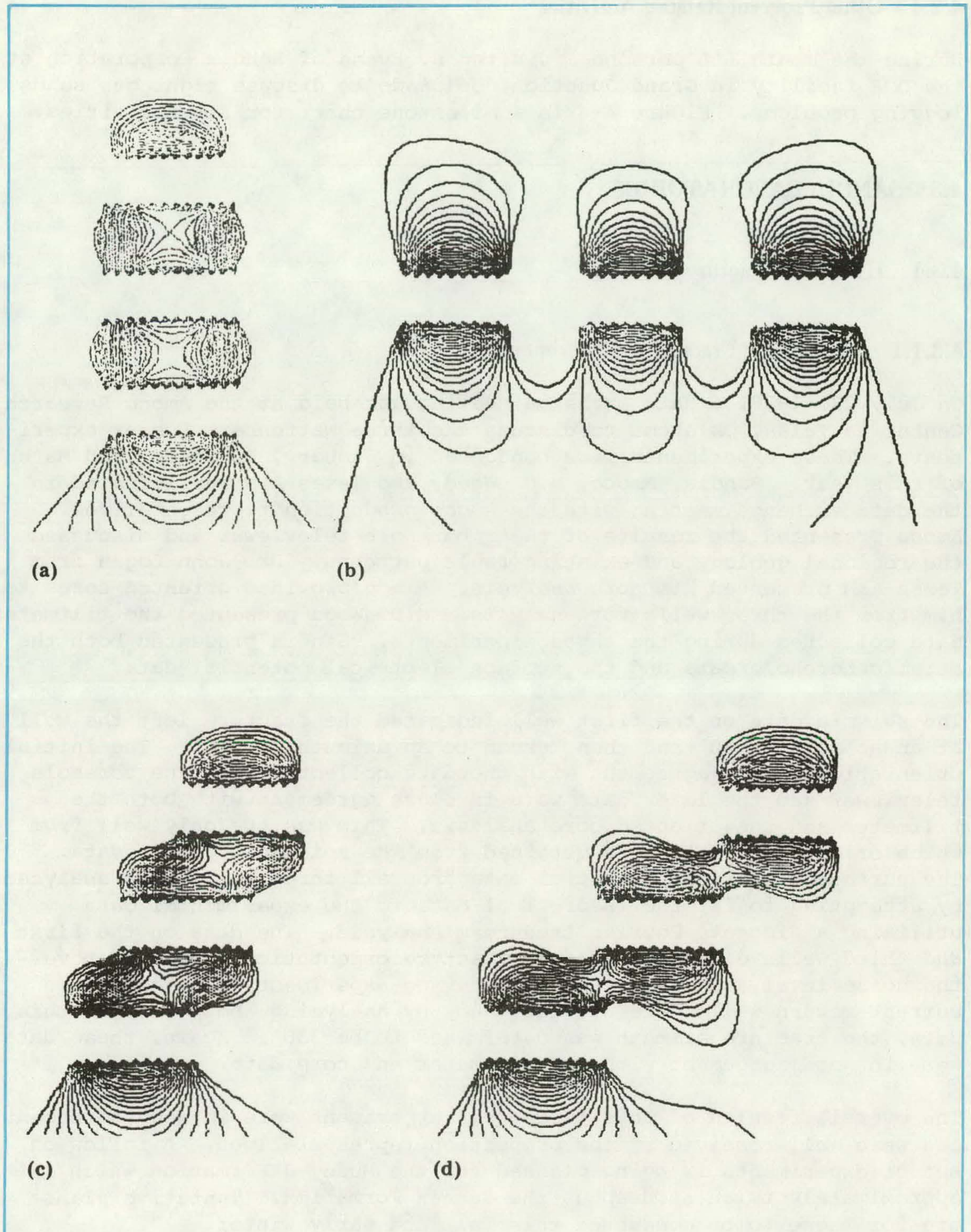


Figure 4-3 Dilatation Contours for the Four Triple-Layer Configurations. Contour Interval is 1.2×10^{-5}

4.2.4 Other Program Related Activities

During the month LLL personnel visited B. Evans of Bendix Corporation at the DOE facility in Grand Junction, Colorado to discuss tight gas sands logging problems. Figure 4-4 is a milestone chart for LLL activities.

4.3 SANDIA LABORATORIES

4.3.1 Hydraulic Fracture Mapping

4.3.1.1 Wattenburg Fracturing Experiment

On July 27, 1978, a data exchange meeting was held at the Amoco Research Center in Tulsa, Oklahoma to discuss the three Wattenberg Sussex experiments. These experiments were conducted in January, February, and March of this year. Sandia, Amoco, M.D. Wood, and Texas A&M participated in the data exchange meeting with the Amoco production representatives. Amoco presented the results of their borehole televiewer and discussed the regional geology and existing fault patterns. Dr. John Logan from Texas A&M presented his core analysis. Amoco provided oriented cores to him from the three wells for analysis. M.D. Wood presented the tiltmeter data collected during the three experiments. Sandia presented both the seismic borehole data and the surface electrical potential data.

The seismic data on the first well indicated the fracture left the well at an azimuth of 60° and then turned to an azimuth of 350°. The initial orientation was in agreement with the data collected from the borehole televiewer and the later data were in close agreement with both the tiltmeter and the oriented core analysis. This was the only well from which orientation data were obtained from the seismic borehole data. The surface electrical potential data from all three wells were analyzed by attempting to fit the theoretical data to the experimental data utilizing a discrete Fourier transform analysis. The data on the first and third wells did not produce a fracture orientation that was above the noise level. On the second fracturing experiment, two separate current return wells were utilized and, by analyzing both sets of this data, the fracture azimuth was determined to be 330°. Again, these data were in good agreement with the tiltmeter and core data.

The overall results of this three-well experiment were in good agreement and were well received by the production representatives. A follow-on set of experiments is being planned for the Muddy J Formation which is approximately twice as deep as the Sussex Formation. Tentative plans are for these to be conducted this fall and early winter.

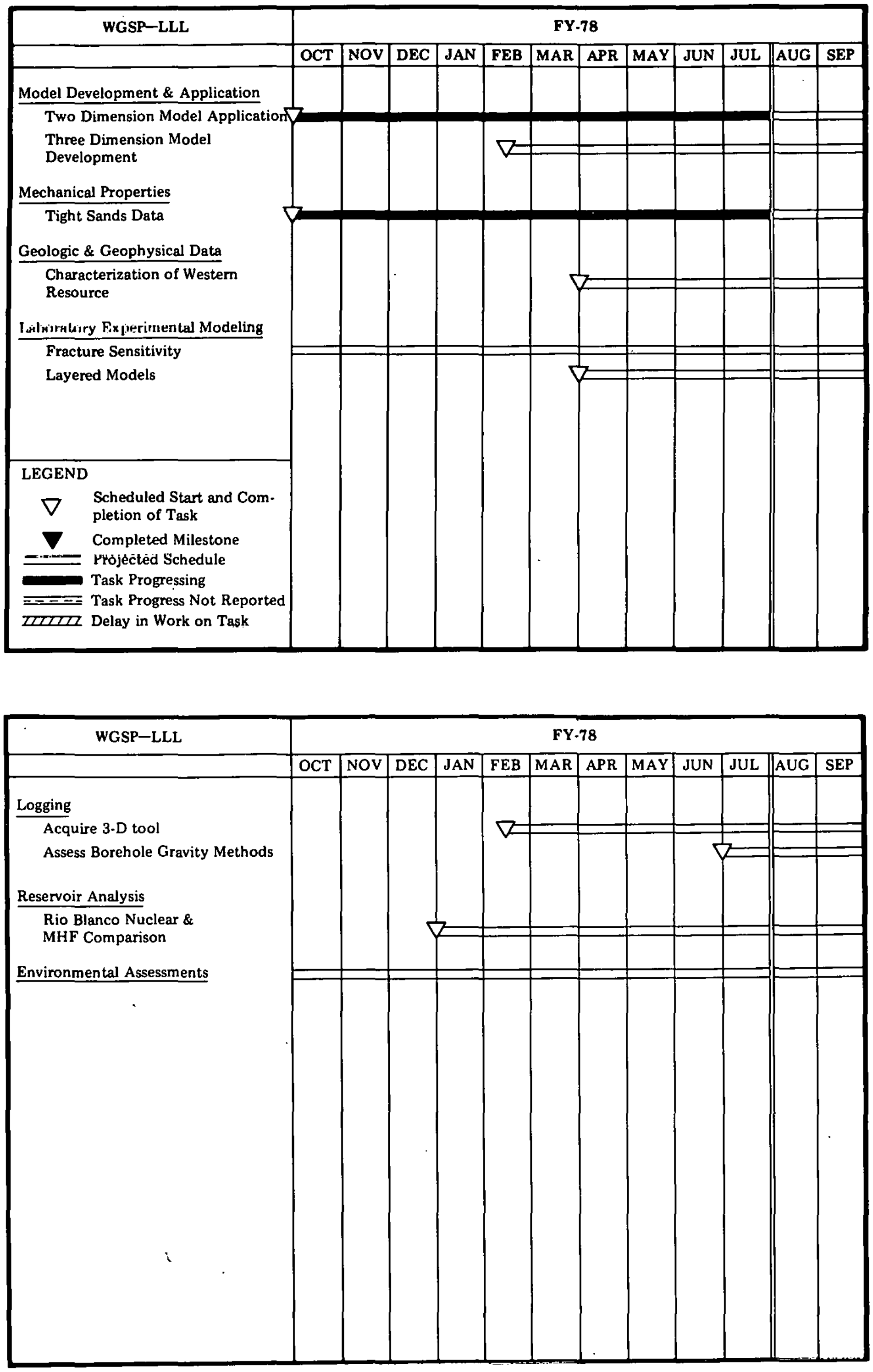


Figure 4-4 Milestone Chart—LLL

4.3.2 Schedule Status

Figure 4-5 is a milestone chart and shows the progress of the Sandia projects.

4.4 U. S. GEOLOGICAL SURVEY BOREHOLE GRAVITY METER

Work continued on instrumentation and testing.

4.5 M. D. WOOD, INC. TILTMETER

Report on progress during July, 1978 was not received.

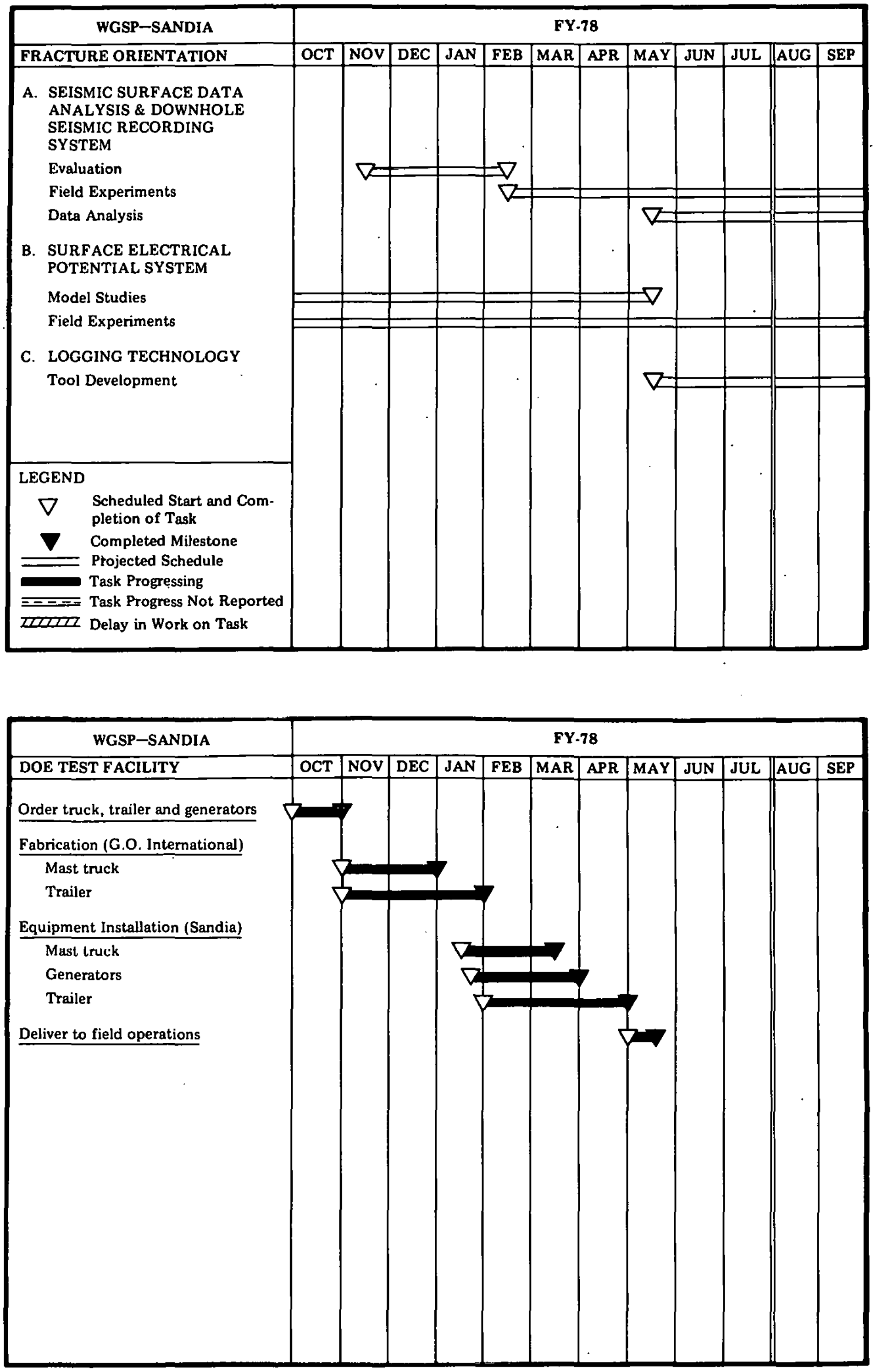


Figure 4-5 Milestone Chart —Sandia

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5. FIELD TESTS AND DEMONSTRATIONS

5.1 BACKGROUND

Specific 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 in an active status 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,
- MHF demonstrations in the Piceance Basin, Colorado, by Mobil Research and Development Corporation and Rio Blanco Natural Gas Company,
- A mineback testing program by Sandia Laboratories, and
- The utilization of a DOE well testing facility by CER Corporation to evaluate the productive potential of all types of wells.

The CER Corporation RB-MHF 3 is on an inactive status pending satisfactory contractual arrangements to perform additional tests, and for final disposition of the well.

Table 5-1 summarizes both completed and active WGSP MHF treatments. Progress of these ongoing projects is presented in the following sections.

Table 5-1 MHF Contract Locations and Frac Data

COMPANY, BASIN	LOCATION T / R / Sec	WELL	INTERVAL FRACTURED Feet	FRAC. DATE	FRAC. TREATMENT Lbs of Sand	FLUID INJECTED 10^3 Gal
AUSTRAL Piceance, Mesaverde	7S, 94W, S3 Garfield Co. Colorado	Federal 3-94	5,170- 6,333	8-25-76	1,140,000	542 Gel Gel H 0
CONSORTIUM MANAGED BY CER CORPORATION Piceance, Mesaverde	3S, 98W, S11 Rio Blanco Co. Colorado	RB-MHF-3	8,048- 8,078 7,760- 7,864 5,925- 6,016 5,851- 5,869	10-23-74 5- 2-75 5- 4-76 11- 3-76	400,000 880,000 815,000 448,000	117 Gel 285 Gel 400 Gel 228 Gel
GAS PRODUCING ENTERPRISES, INC. Uinta, Wasatch and Mesaverde	10S, 22E, S10 Uintah County Utah	Natural Buttes No. 18	6,490- 8,952	9-22-76	1,480,000	745 Gel
	10S, 21E, S21 Uintah County Utah	Natural Buttes No. 19	8,909- 9,664 7,994- [illegible]	9-21-76 [illegible]	424,000 704,000	280 Gel [illegible] Gel
	9S, 21E, S22 Uintah County Utah	Natural Buttes No. 14	6,646- 8,004	3-15-77	1,093,000	544 Gel
	9S, 21E, S28 Uintah County Utah	Natural Buttes No. 20	8,498- 9,476	6-22-77	826,000	322 Gel
	10S, 22E, S18 Uintah County Utah	Natural Buttes No. 22	6,858- 8,550	11-21-77	1,091,000	479 Gel
	9S, 21E, S19 Uintah County Utah	Natural Buttes No. 9	5,661- 8,934	3-27-78	554,000	349 Gel
	10S, 21E, S29 Uintah County Utah	Natural Buttes No. 2	7,251- 8,774	8- 8-78	1,965,000	722 Gel
DALLAS PRODUCTION Fort Worth, Bend Cong.	Ben D. Smith Survey A-779 Wise County Texas	Ferguson A-1	5,957- 6,794	9-10-76	506,000	139 Foam 198 Emul
EL PASO NATL. GAS Northern Green River, Fort Union	30N, 108W, S5 Sublette Co. Wyoming	Pinedale Unit No. 5	10,950-11,180 10,120-10,790	7- 2-75 10-20-75	518,000 1,422,000	183 Emul 8 Gel 459 Gel
MOBIL Piceance, Mesaverde	2S, 97W, S13 Rio Blanco Co. Colorado	F-31-13G	10,540-10,680 9,432- 9,538 8,163- 8,650	[illegible] 8-24-77 7- 6-78	580,000 600,000 660,000	310 Gel 260 Gel 388 Gel
PACIFIC TRANSMISSION Uinta, Mesaverde	8S, 23E, S25 Uintah County	Federal 23-25	NO FRACS PERFORMED			
RIO BLANCO NATL. GAS Piceance, Mesaverde	4S, 98W, S4 Rio Blanco Co. Colorado	Federal 498-4-1	6,150- 6,312 5,376- 5,960	10-22-76 11-30-77	766,000 243,000+ 22,500 Beads	276 Gel 164 Gel
WESTCO Uinta, Mesaverde	10S, 19E, S34 Uintah County	Home Fed. No. 1	7,826- 9,437 10,014-10,202	12-21-76 10- 1-76	500,000 600,000	412 Gel 248 Gel

RIO BLANCO MASSIVE HYDRAULIC FRACTURING EXPERIMENT

EY-76-C-08-0623

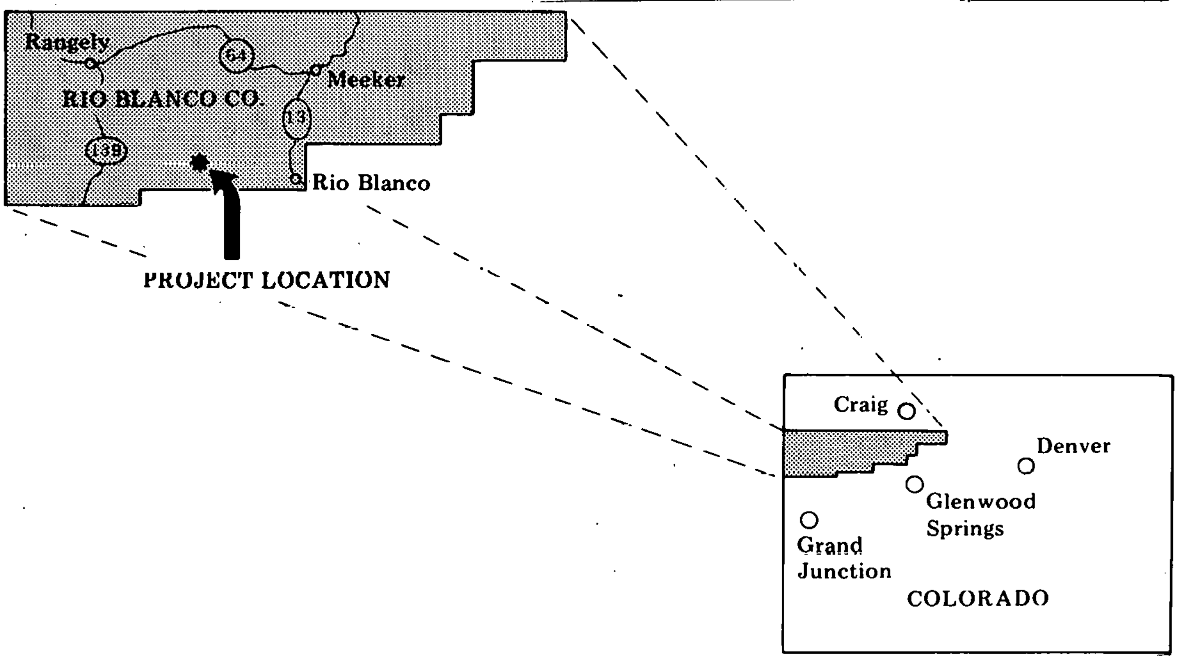
CER Corporation
Las Vegas, Nevada

Status: Awaiting Advisory Committee Decision

Interagency Agreement Date:	June 19, 1974
Anticipated Completion Date:	December 31, 1978
Project Cost (estimated):	DOE $1,975,000
	Industry 1,630,000
	Total $3,605,000
Principal Investigator:	G. R. Luetkehans
Technical Advisor for DOE:	C. H. Atkinson

OBJECTIVE

This stimulation experiment is being conducted in low-permeability, massive gas-bearing sandstone reservoirs in the Piceance Basin in western Colorado, to test advanced hydraulic fracturing technology where it has not been possible to obtain commercial production rates. This test is located about 1 mile from the 1973 Rio Blanco nuclear stimulation site to permit comparison of nuclear and hydraulic fracturing techniques in this area.



5.2 CER CORPORATION

5.2.1 Summary of Past Activities

DOE contract EY-76-C-08-0623 was awarded to CER Corporation in March 1974. The original contract provided for the drilling of a new well and two MHF treatments. Contract modifications added two additional MHF treatments and extended the term of the contract to an undisclosed date.

5.2.2 Current Status

Field activities on RB-MHF 3 well have been suspended. Negotiations have taken place with an outside party to complete the commingling of the fractured gas zones and to perform additional tests in return for the well and subsequent gas production. Legal documents are being prepared for distribution to the project participants for their concurrance.

WATTENBERG FIELD

EY-77-C-08-1514

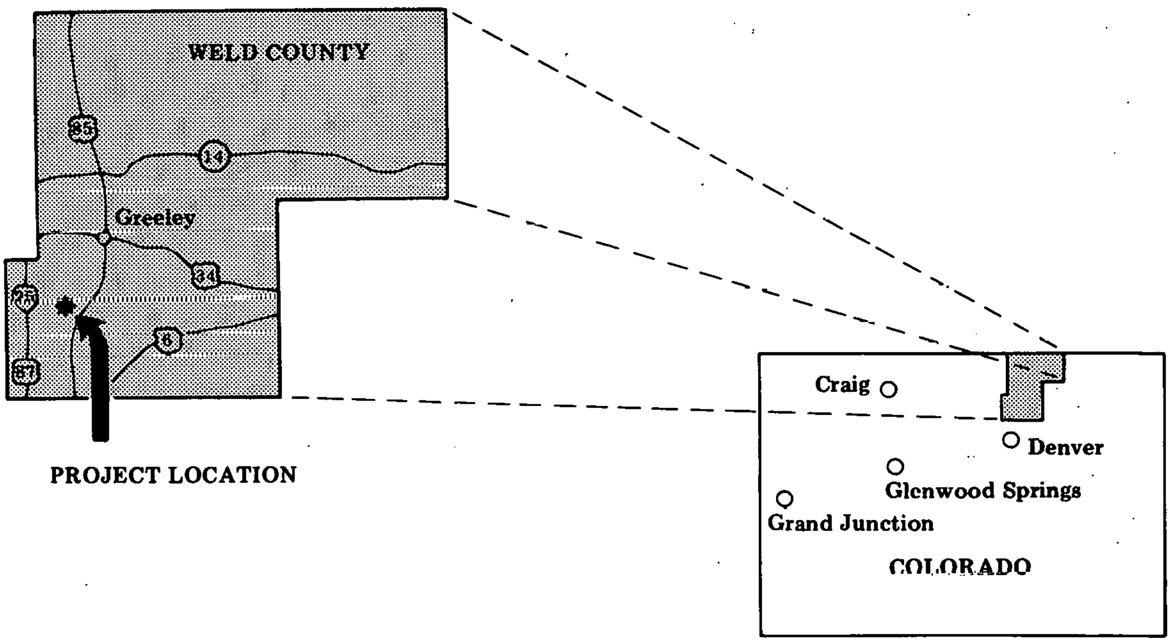
Colorado Interstate Gas Company
Colorado Springs, Colorado

Status: Active

Contract Date:	September 1, 1977	
Anticipated Completion Date:	March 1, 1981	
Total Project Cost (estimated):	DOE	$ 75,000
	CIG	99,000
	Total	$174,000
Principal Investigator:	Howard Fredrickson	
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.



5.3 COLORADO INTERSTATE GAS COMPANY

5.3.1 Scope of Work

DOE and Colorado Interstate Gas Company (CIG) entered into Contract No. EY-77-C-08-1514 on September 1, 1977. The experiment will determine if productivity of wells completed in low permeability natural gas reservoirs can be improved by reducing the interstitial water saturation by cyclic injection of dry natural gas. In addition, cyclic injection of dry natural gas may improve productivity by dehydrating matrix clays and by removal of formation damage adjacent to the surfaces of induced fractures.

5.3.2 Current Status

A special compressor has been ordered with delivery expected in December, 1978. One additional month is required for completion of site preparation and BHP buildup, and the first cyclic injection-withdrawal is expected to begin around February 1, 1979.

DOE WELL TEST FACILITY

EY-76-C-08-0623

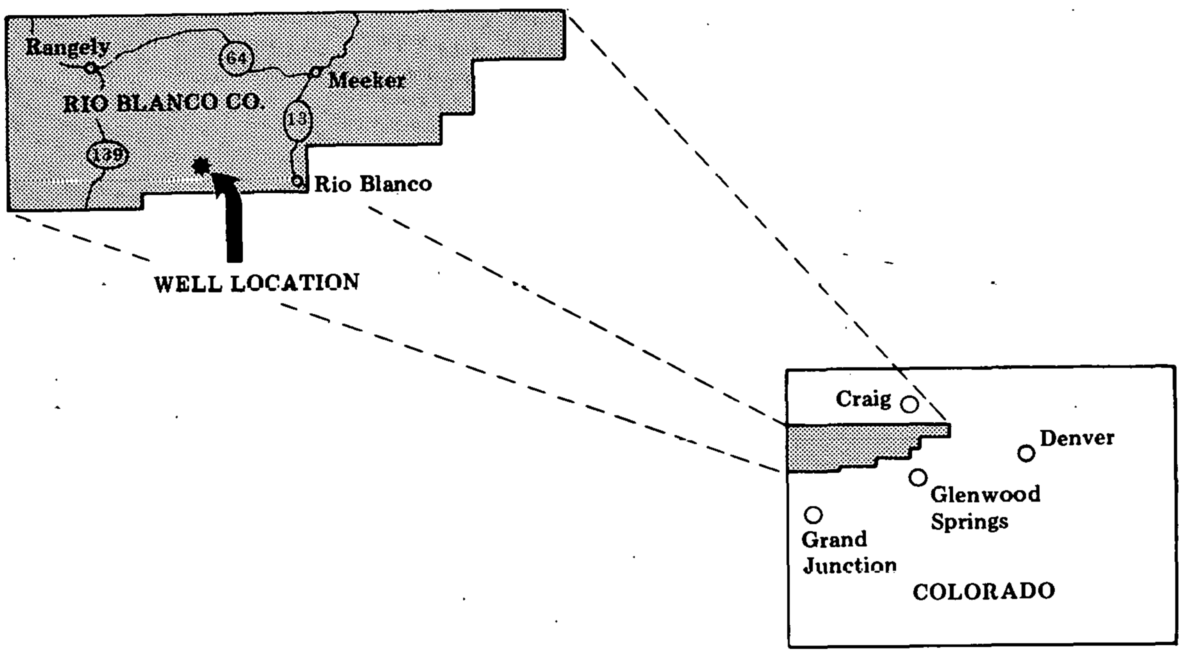
CER Corporation
Las Vegas, Nevada

Status: Equipment checkout and test proceeding

Principal Investigator: R. L. Mann
Technical Advisor for DOE: C. H. Atkinson

OBJECTIVE

The DOE Mobile Well Test Facility, consisting of two vehicles, will provide a deep well instrumentation and investigation system to monitor and evaluate the productive potential of all types of wells.



5.4 DOE WELL TEST FACILITY

5.4.1 Background

A modification to CER's DOE Contract EY-76-C-08-0655, provides for the operation of the DOE Well Test Facility at various locations selected by DOE. The facility is comprised of a 10 ft x 50 ft trailer, a two-ton truck mounting a 50 ft telescoping hydraulically controlled mast, and two individually trailer-mounted 30 and 90 KW electric generators.

5.4.2 Summary of Past Activities

The DOE Well Test Facility was transported to RB-MHF 3, (Rio Blanco Colorado) to complete a systems check on a familiar well location.

A program for the PDP-11/10 computer was finalized which will allow the operator to designate when and how often the computer will interrogate the various transducers, and store the data on the RK-05 discpack. This data acquisition program is performed in the "foreground," is continuously operational, and allows the operator the option of performing other programming in the "background." This allows optimum use of computer time and permits continuous surveillance of the well.

5.4.3 Current Status

CER is continuing preparation of software to perform well test analysis from build-up pressure data and Dr. Steve Holditch (Sovereign Engineering, College Station, Texas) is preparing an automatic type curve history matching program. The writing of maintenance and operation manuals for the test facility by CER personnel is proceeding and complete checkout of the system will continue until late August (see Figure 5-1).

The scheduled testing program has been delayed due to the late delivery of surface equipment.

The testing sequence will be accomplished while modifications and additions are being made on the system. This is dependent upon the availability of the NBU 21 well, Vernal, Utah, and on the delivery of additional instrumentation.

The PDP 11/10 computer and printer, transported from Las Vegas to RB-MHF-3 on July 6th was installed into the instrument trailer, connected to a regulated power supply and checked out. The data acquisition program was completed, excepting minor format changes that will be made when a calibration and outputting routines are added.

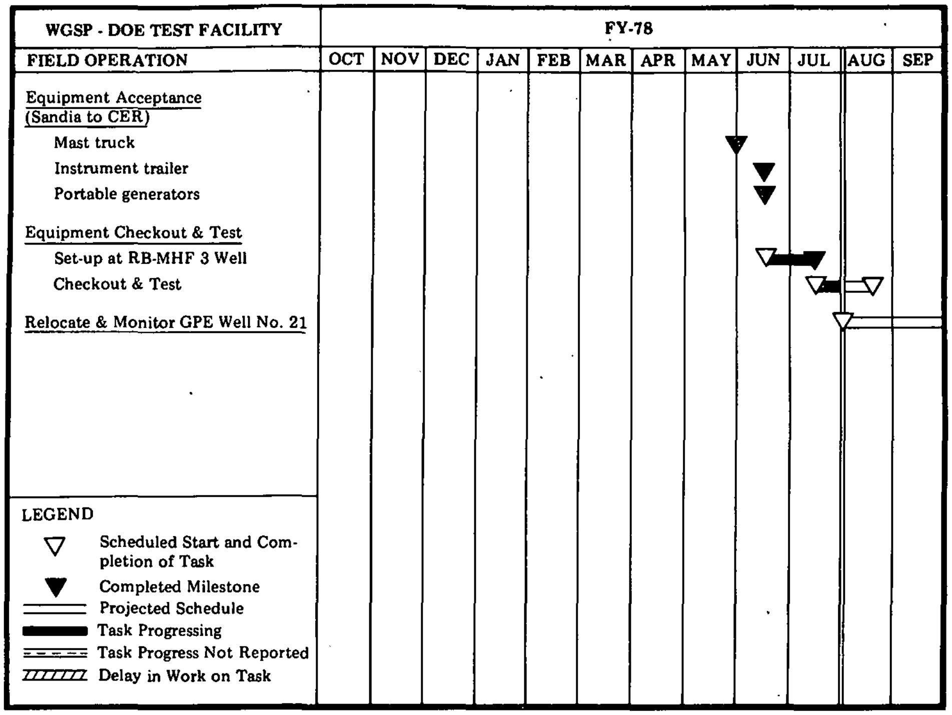


Figure 5-1 Milestone Chart—DOE Well Test Facility

Fabrication of a surface cable system for use during flow testing of a well was started. The power cable reel, along with junction boxes, will permit easy electrical connections from the instrumentation trailer to the transducers at the wellhead. The densitometer was mounted on a workbench and tested and calibrated over full range. Additional modifications to the mast truck and instrument trailer were completed.

A meeting of DOE, CER, and Intercomp personnel was held at CER in Las Vegas to consider the availability of remote terminal access to the Intercomp software for log analysis and reservoir engineering.

NATURAL BUTTES UNIT, UINTAH COUNTY, UTAH MASSIVE HYDRAULIC FRACTURING DEMONSTRATION

EY-76-C-08-0681

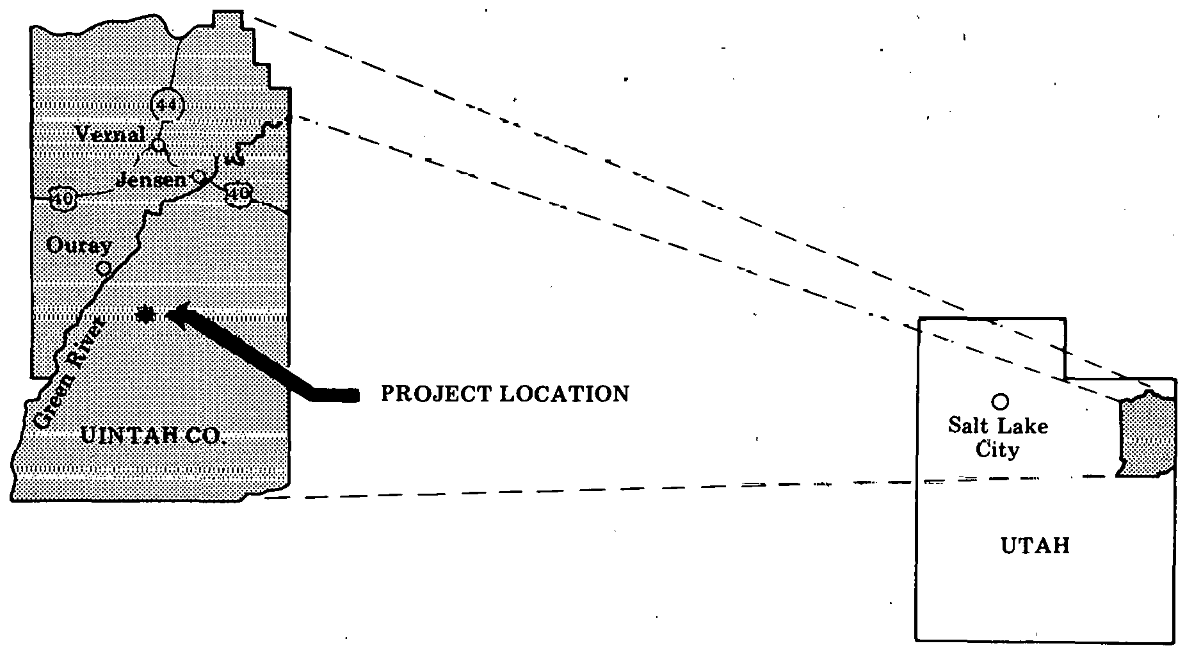
Gas Producing Enterprises, Inc.
Subsidiary of Coastal States Gas Co.
Houston, Texas

Status: Active

Contract Date:	July 1, 1976	
Anticipated Completion:	September 30, 1979	
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.



5.5 GAS PRODUCING ENTERPRISES, INC.

5.5.1 Summary of Past Activities

Gas Producing Enterprises was awarded DOE Contract EY-76-C-08-0681 in July, 1976. Originally, two old wells, Natural Buttes Unit Wells 14 and 18, and four new wells, 19, 20, 21, and 22 were to receive MHF treatments. Three contract modifications have been entered into, adding one old well, Natural Buttes Unit No. 9, two new wells, 23 and CIGE 2-29-10-21, and increasing the scope of work for Natural Buttes Unit Well No. 21.

5.5.2 Current Status

Natural Buttes Unit Wells No. 9, 14, 18, 19, 20, and 22 were flowing to sales during June. Specific production data on these wells appears in Figures 5-2 through 5-7.

Natural Buttes Unit Well No. 21 is flowing to the pit. This well was perforated at 8,509, 8,510, 8,511, 8,512, and 8,513 ft. The perforations were broken down with 3 percent KCl water and ball sealers. The well balled out to 6,030 psig. The well has produced 100 BBL of water per day since the breakdown with no measurable amount of gas*. Natural Buttes Unit Wells No. 9, 14, 20, and 22 flowed a total of 1.7 million cubic feet of natural gas to sales during July. Specific flow data on Natural Buttes Unit Wells are shown by Figures 5-2 through 5-7. Natural Buttes Unit Wells No. 18 and 19 are both shut in due to field proration and No. 21 is still flowing to the pit.

CIGE No. 2 was flow tested and cleaned up and No. 23 is presently shut in waiting completion. Bids will be solicited for the MHF to be performed.

* Table 5-2 indicates recommended zones for testing and Table 5-3 shows intervals of NBU 21 core.

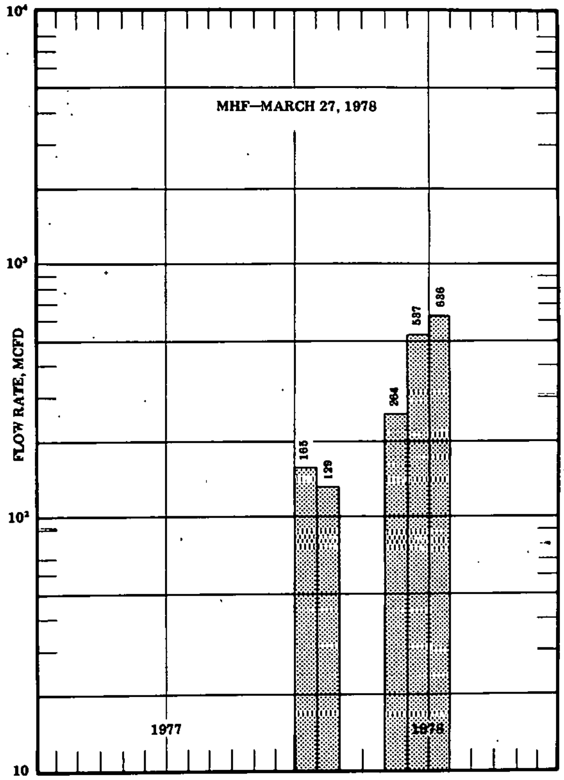


Figure 5-2 Flow Rate Performance of Natural Buttes No. 9 Well

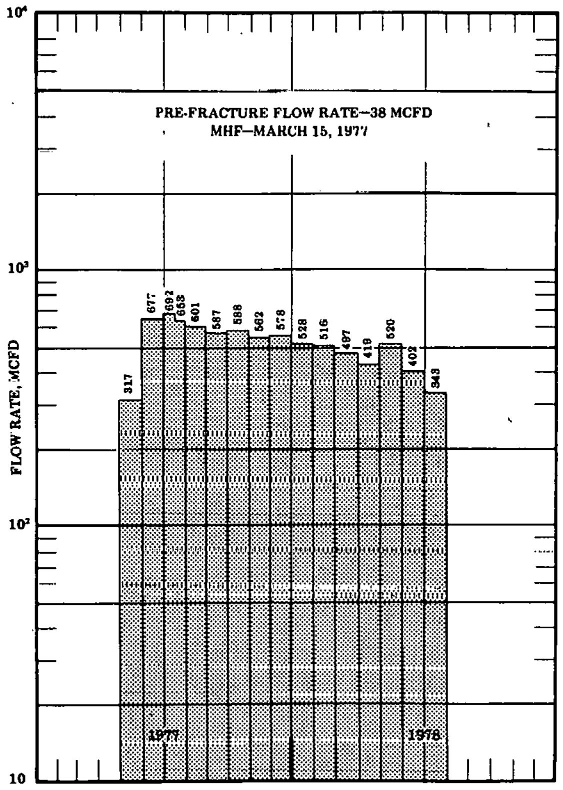
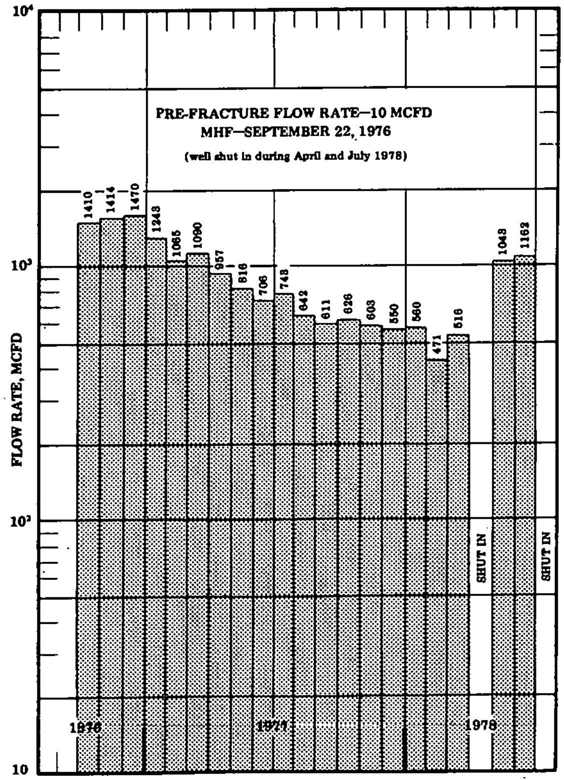


Figure 5-3 Flow Rate Performance of Natural Buttes No. 14 Well

Figure 5-4 Flow Rate Performance of Natural Buttes No. 18 Well



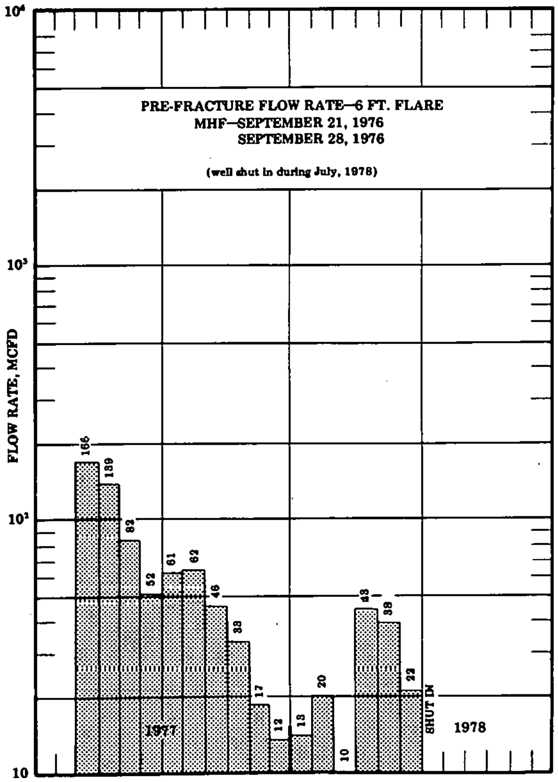


Figure 5-5 Flow Rate Performance of Natural Buttes No. 19 Well

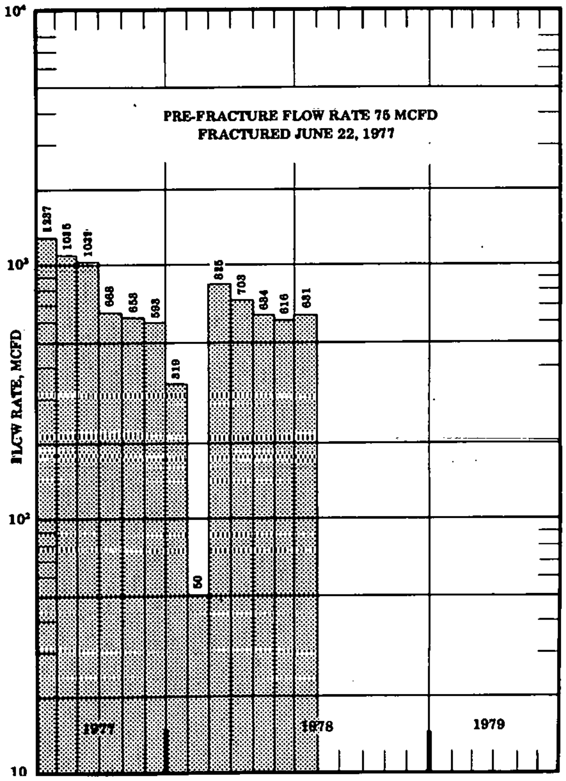


Figure 5-6 Flow Rate Performance of Natural Buttes No. 20 Well

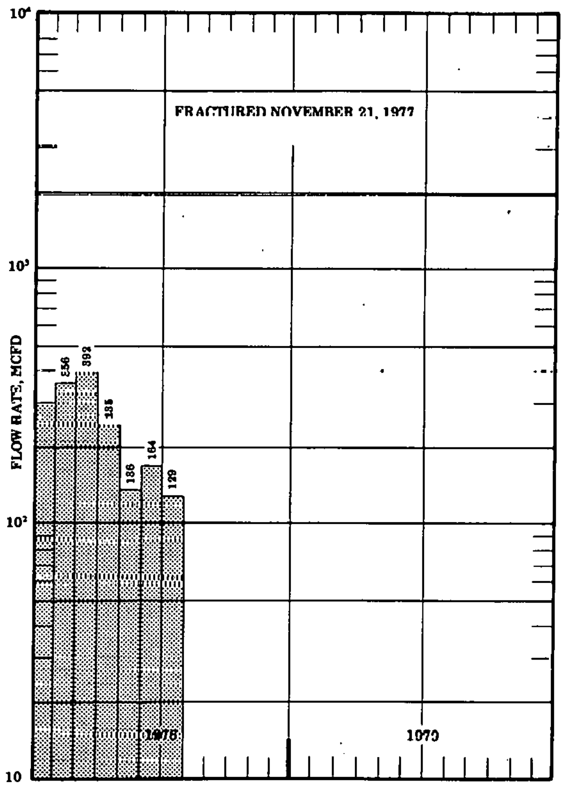


Figure 5-7 Flow Rate Performance of Natural Buttes No. 22 Well

Table 5-2 CIGE 21 Proposed Test Intervals

Interval, ft	Porosity, %	Sw, %	Vsh, %	Remarks
8,509-8,513	.11-.12	.44	.02	Castlegate. Core 14. Good permeability massive marine sandstone.
8,474-8,482	.08-.10	.50-.40	.02-.04	Castlegate. Core 13. Good isolation, marine sandstone
8,201-8,205	.105	.32	.10	Sego. Interval not cored. Regressive marine to lagoonal environment. Fair isolation. One of best looking sands in well.
7,739-7,743	.12	.35	.05	Mesaverde. Interval not cored. Continental channel sandstone. Good isolation.
7,563-7,570	.09	.41	.10	Mesaverde. Interval not cored. Near Core 10. Good isolation. Testing is contingent upon results of interval 4.
6,483-6,488	.10	.55	.08	Mesaverde. Core 7. Best sand in Upper Mesaverde cored interval. Good isolation. Channeled sandstone.
4,403-4,415	.06-.10	.88	.06	Wasatch. Core 1. Cleanest sand in Wasatch cored interval. Lagoonal or near shore sandstone.

Table 5-3 Intervals for CIGE 21 Core Analysis

Sand Zones Coring Depths, ft	Saraband Depth, ft	Porosity, %	Sw, %	Vsh, %	Remarks
4,403-4,416	4,403-4,416	6.5-10.0	90-100	11	Wet zone Most priminent sand of Wasatch cored interval. Zone had good isolation
6,488-6,506[1]	6,484-6,502	9.5-10.0	50-55	8-10	Best developed sand of upper K_{mv} cored interval. This zone has also been recommended for testing. Note discrepancey between CER log-core correlation and GPE log-core correlation. Zone has good isolation.
8,485-8,496[2]	8,473-8,484	8.0-10.5	37-50	0-4	Best looking sand in Castlegate cored interval. This zone has been recommended for testing. There is evidently a discrepancy between the CER and the GPE log-core correlation and the "shale" of core interval 8,490-91 should actually be a sand.

[1]GPE called this interval 6,490-6,508 ft
[2]GPE called this interval 8,491-8,496 ft

FALLON-NORTH PERSONVILLE FIELD, TEXAS, MASSIVE HYDRAULIC FRACTURING DEMONSTRATION

EF-78-C-08-1547

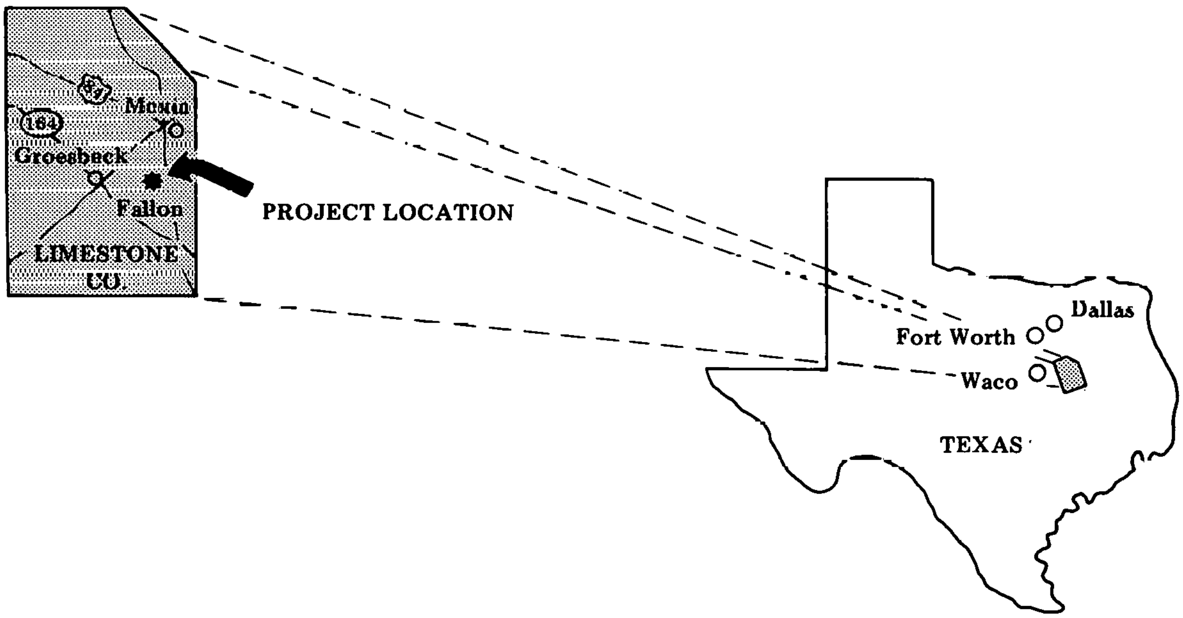
Mitchell Energy Corporation
Houston, Texas

Status: Active

Contract Date:	March 15, 1978	
Anticipated Completion:	April 30, 1979	
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.



5.6 MITCHELL ENERGY CORPORATION

5.6.1 Scope of Work

DOE Contract EF-78-C-08-1547 was signed with Mitchell Energy Corporation in March, 1978. The scope of work includes drilling, coring, logging and testing a new well, Muse-Duke No. 1, treating with MHF and evaluating results.

5.6.2 Current Status

The well for the Cotton Valley Lime massive hydraulic fracture test was spudded July 7, 1978. The name and location of the well, changed from that originally proposed, is now Mitchell Energy Corporation Muse-Duke No. 1, and is located 6,688 ft FNWL and 14,760 ft FNEL of the Juan N. Acosta Survey A-1, Limestone County, Texas.

Total depth is estimated to be 11,650 ft and as of July 31, the well was drilling at 9,160 ft. Surface casing (95/8 in.) was set at 4,520 ft and cemented to the surface.

PICEANCE CREEK FIELD, COLORADO, MASSIVE HYDRAULIC FRACTURING DEMONSTRATION

EY-76-C-08-0678

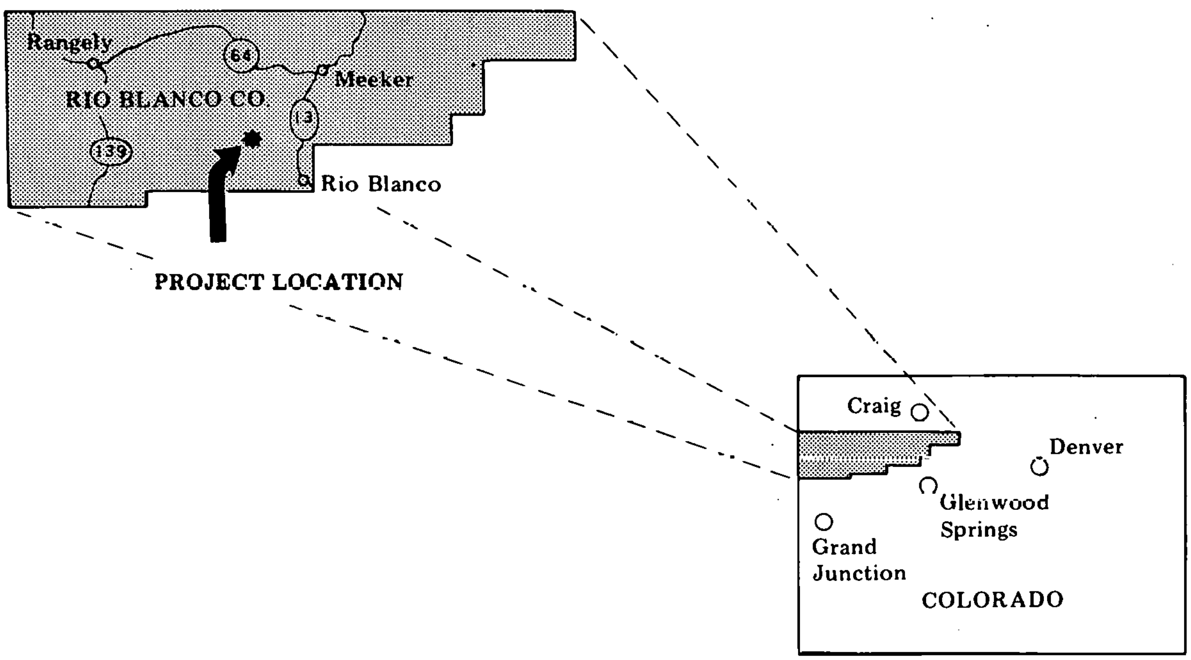
Mobil Research and Development Corporation
Dallas, Texas

Status: Active

Contract Date:	July 1, 1976
Anticipated Completion:	December 31, 1978
Total Project Cost (estimated):	DOE $2,510,000
	Contractor (prior costs) 2,376,485
	Contractor (new costs) 1,590,515
	Total $6,477,000
Principal Investigator:	John L. Fitch
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 extremely low-permeability.



5.7 MOBIL RESEARCH AND DEVELOPMENT CORPORATION

5.7.1 Summary of Past Activities

Mobil was awarded DOE Contract EY-76-C-08-0678 in July, 1976, to perform up to six MHF treatments in a new well (PCU 31-13) in Rio Blanco County, Colorado. The well was drilled by Signal Drilling Company under separate DOE Contract EY-77-C-08-1504. Two treatments were performed in 1977, one in June on Zone 1 and the second in August on Zone 3. Zones 2 and 4 did not meet frac requirements and were abandoned. The two treated zones were commingled and produced to sales during the winter. The third MHF treatment was performed in May, 1978 on Zone 5. Table 5-4 is a summary of all zones completed to date and Figure 5-8 depicts graphically the sands fractured.

5.7.2 Current Status

5.7.2.1 Technical Progress

Zones 6 and 7 (8443-8650 and 8173-8372 ft. overall) were fractured on July 6. The planned treatment was for 900,000 pounds of 20-40 mesh sand carried by 346,000 gallons of gel plus 5 percent condensate at 15 barrels per minute. The treating plan was followed until treating pressure increase led to a sand-out. The treatment summary is as follows:

Rate - 15 bpm
Fluid Volume 288,000 gal., incl. 15,120 gal. condensate
Sand - 660,000 pounds
Initial ISIP - 600 psi
Treating Pressure - 1,000 psi increasing to 2,900 psi before screen-out
Final ISIP - Could not be determined.

Treating pressure increased from the beginning of the job but "broke back" sharply at three points in the treatment.

After the screen-out an attempt was made to run a temperature log. Sand fill was encountered just above the perforations. A decrease in temperature was observed at the lowest depth logged indicating that the upper zone took some frac fluid.

Excess sand was circulated from the well on July 7-8. In the absence of sustained natural flow, the well was swabbed and flowed intermittently until July 12, when sustained flow was achieved. During the flow period

July 12-25 the hourly flow rate was highly variable due to insufficient gas to lift the water at a steady rate. Best estimates of the average flow rates are as follows:

July	Gas, MCF/day	Water,bbl/day (Est.)
13	500	650
14-16	450	550
17-20	400	300
21	380	200
22	360	200
23	330	200
24	325	200
25	320	200

Noise/temperature logs run during the flow period show that most of the production is from Zone 6.

Work toward remedial cementing of Zone 8 began on July 28. Sand could not be circulated off the bridge plug at 8725. Apparently, ball sealers and fragments of packer rubber were mixed with the sand. The debris was removed with the aid of a "drag shoe" and the plug recovered on August 3.

Fracture propagating pressure increases continue to hamper efforts to obtain long narrow fractures. Analysis of treating records from the Piceance Creek well, and from other wells in the Piceance Basin, show that the basic pressure increase is not due to ineffective proppant transport. This is illustrated by Figure 5-9, which shows the treating pressure record from Zone 5. This record clearly indicates that the basic upward slope of the treating pressure vs time is established before any sand arrives at the perforations. Although some breaks in the treating pressure do occur, the basic upward trend persists until the combination of increasing crack width and fluid leak-off (with increasing pressure) culminates in a screen-out. A quantitative explanation for this kind of treating pressure increase is not available.

Table 5-4 PCU No. 31-13 Completion Information

Zone	No.	Perfs Interval	PBTD, ft.	Tubing	Packer	Gas Gravity	Temp.* °F	Porosity	Pressure Transient Tests Before Frac	Pressure Transient Tests After Frac
1	46	10,549-10,680	10,730	2-3/6 @ 10,450	None	N.A.	235		PBU	PBU
2	10 2 4 10 3	10,186-10,196 10,202-10,204 10,255-10,261 10,415-10,427 10,472-10,476	10,530	-------	----	N.A.	230		None	Not Fractured
3	18 16	9,392-9,432 9,517-9,538	9,600	2-7/8 @ 9,120	9,120	0.678	215	Average porosity for all of these zones is about 9% with an average water saturation of about 60%.	PBU	PBU
4A	33	9,254-9,320	9,370	2-3/8 @ 9,150	None	N.A.	212		PBU	Not Fractured
4B	32	9,086-9,124	9,210	2-3/8 @ 8,980	None	N.A.	209		PBU	Not Fractured
5	5 11 5 9 10	8,765-8,773 8,790-8,810 8,826-8,834 8,914-8,930 8,954-8,972	9,040	2-3/8 @ 8,625	None	0.669	205		PBU	PDD
6	10 6 12 19	8,443-8,463 8,472-8,482 8,506-8,528 8,614-8,650	8,725	2-3/8 @ 8,300	None	Zones 6 and 7 combined	199		PBU	Pressure drawdown (PDD) test was run
7	10 9 9 4 4 4	8,163-8,181 8,210-8,226 8,250-8,256 8,279-8,285 8,349-8,355 8,366-8,372	8,425	2-3/8 @ 8,050	None	after frac 0.668	194		PBU	Zones 6 and 7 combined after frac

*From temperature logs run over various intervals at different times, the geothermal temperature gradient through the Mesaverde averaged about 1.75°F/100 ft.

Note: Casing is 7 in., 26 lb set at 10,800 ft.

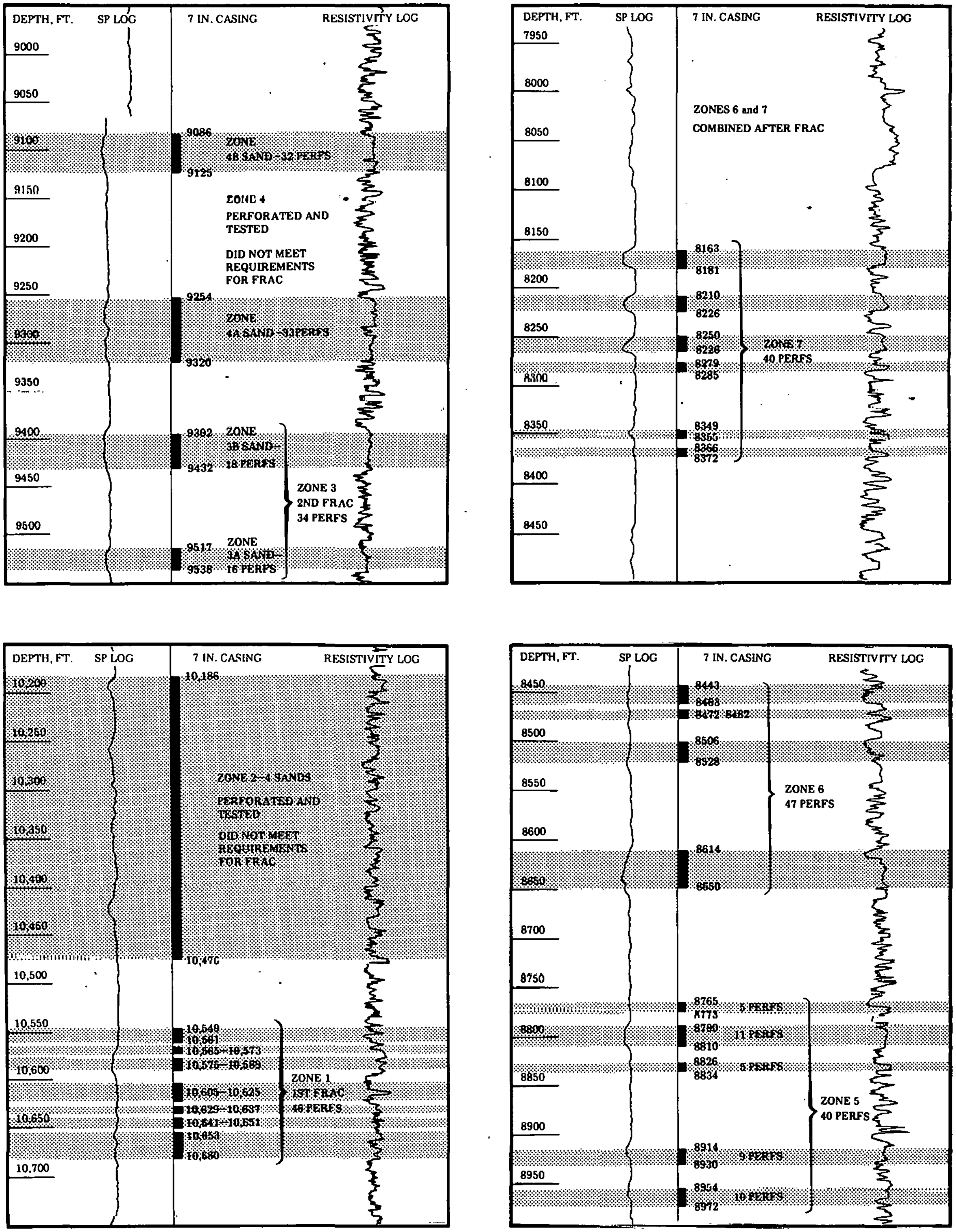


Figure 5-8 Mobil F-31-13G Well Showing Sands Fractured

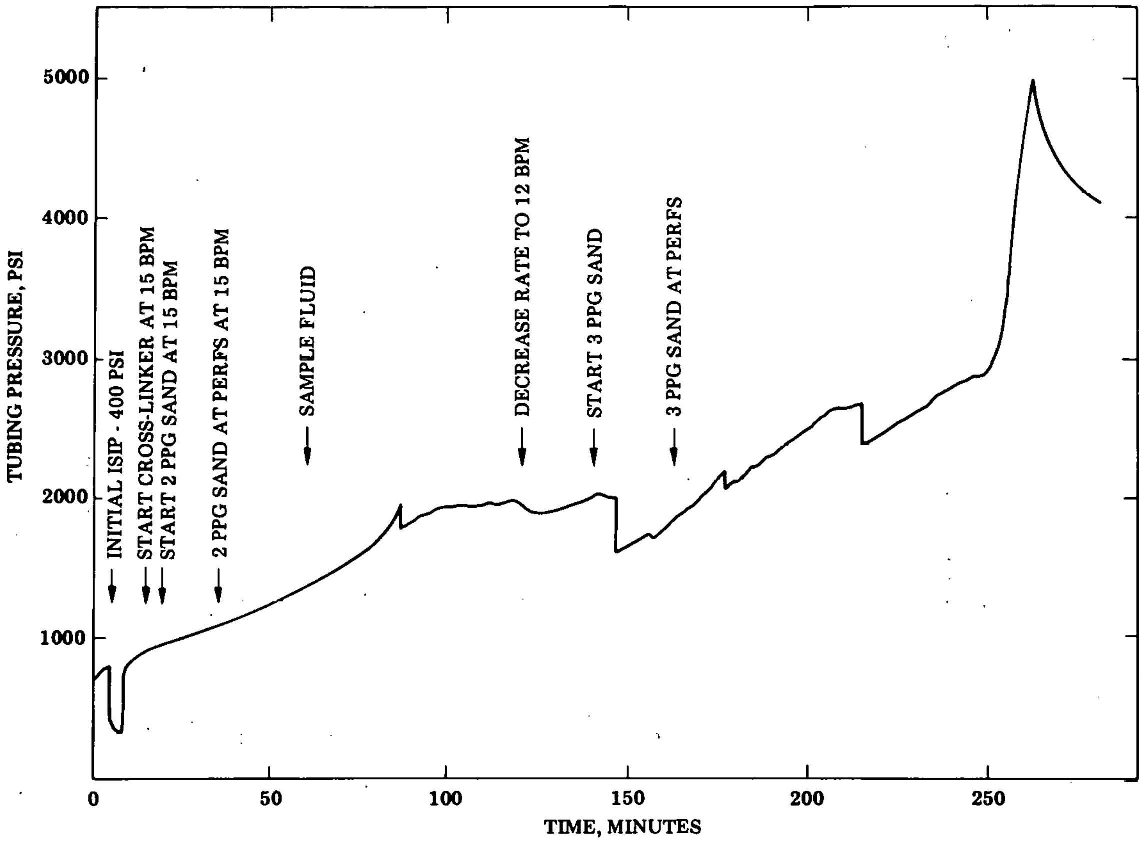


Figure 5-9 PCU No. 31-13, Zone 5, Massive Frac Treatment

Future Plans

An attempt will be made to circulate behind pipe to surface from below Zone 8. If this fails, as expected, an attempt will be made to circulate and cement across the zones of interest. If this fails, conventional block squeezes will be used to isolate Zones 8 and 9. After Zone 8 is isolated it will be perforated, broken down and tested for suitability for MHF. If suitable, the zone can probably be fractured the last week in August.

RIO BLANCO COUNTY, COLORADO MASSIVE HYDRAULIC FRACTURING DEMONSTRATION

EY-76-C-08-0677

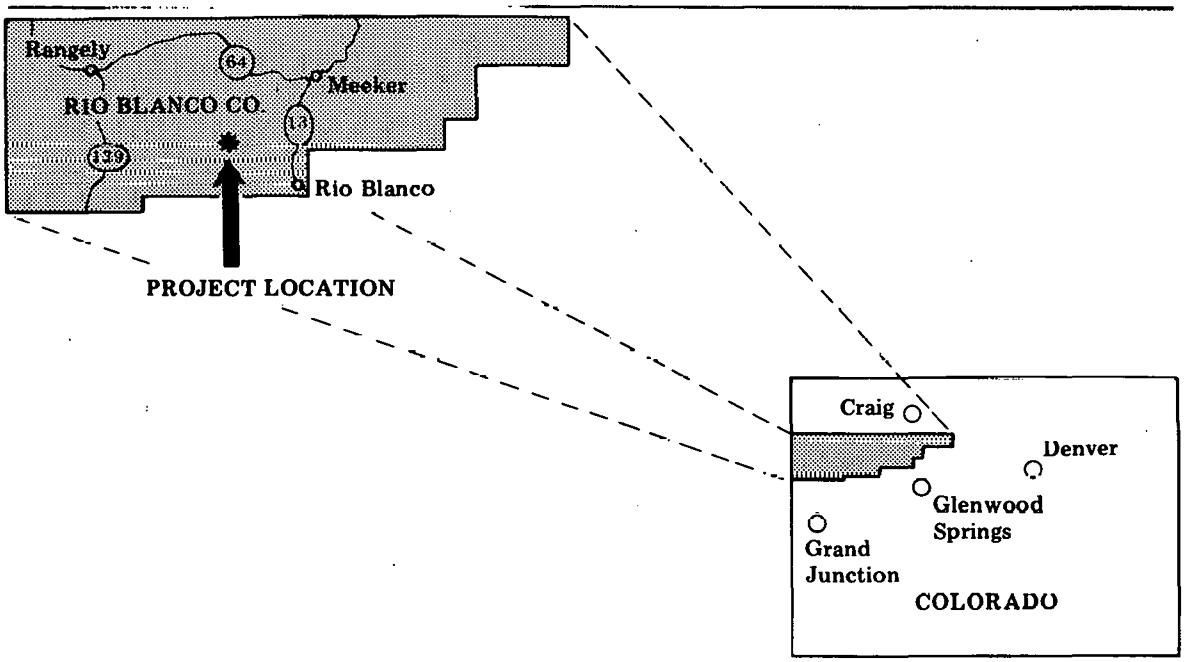
Rio Blanco Natural Gas Company
Denver, Colorado

Status: Active

Contract Date:	August 1, 1976
Anticipated Completion:	December 15, 1978
Total Project Cost (estimated):	DOE .... $ 410,000
	Contractor.......................... 593,000
	Total...................... $1,003,000
Principal Investigator:	Robert E. Chancellor
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 extremely low permeability.



5.8 RIO BLANCO NATURAL GAS COMPANY

5.8.1 Summary of Past Activities

DOE Contract EY-76-C-08-0677 was signed with Rio Blanco Natural Gas Company in June 1976. The first MHF treatment was performed on October 22, 1976. A supplemental agreement, effective October 1, 1977, provided for a second MHF treatment, which was performed on November 30, 1977.

5.8.2 Current Status

Gas flow continued to be restricted due to persistant cyclical water production. The present production rate is 200 MCFD plus water with the well being flowed for further clean up.

NEVADA TEST SITE
NYE COUNTY, NEVADA
MINEBACK TESTING

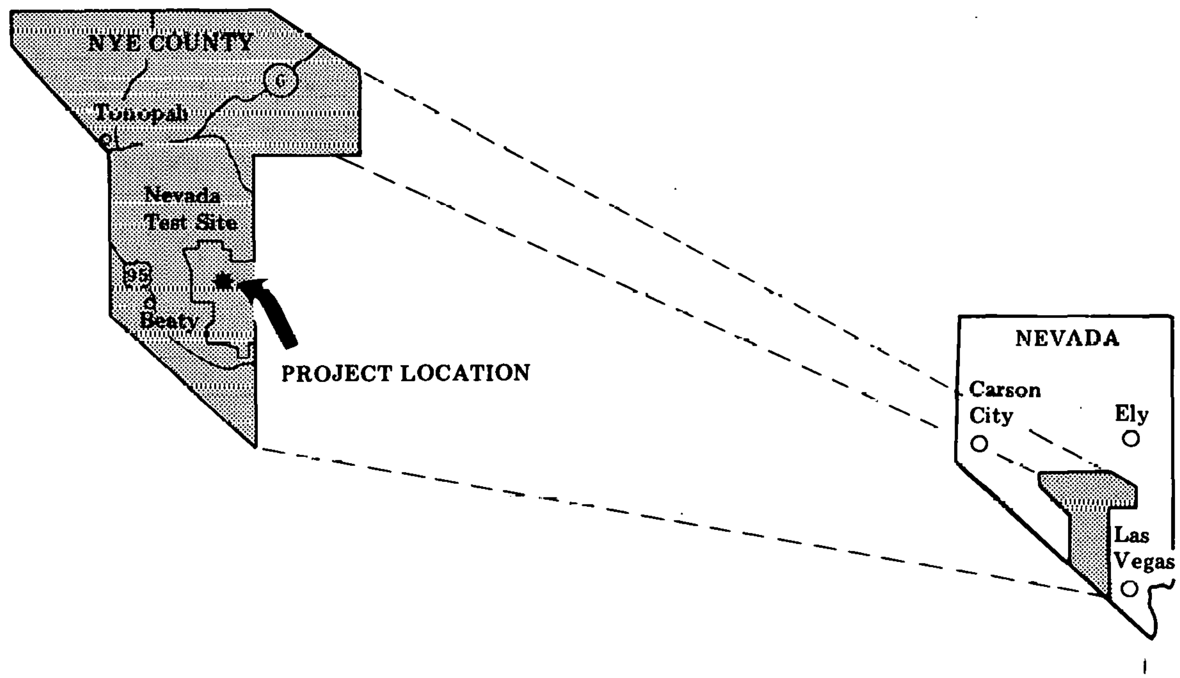
Sandia Laboratories
Albuquerque, New Mexico

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 mine-back for direct observation and evaluation.



5.9 SANDIA LABORATORIES - MINEBACK

5.9.1 Objective

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

5.9.2 Summary of Past Activities

Both fractures of the Hole #6 interface experiment were located. The lower fracture, initiated in the ash fall tuff with green and black grout, was intercepted in May while the upper fracture, initiated in the densely welded tuff with blue grout, was detected in June.

The lower fracture, well behaved in the ash fall tuff formation, broke through the transition zone into the densely welded tuff, and appeared to have propagated out some distance and then fractured through the borehole above the packed-off interval. The green, black and gray grout was observed at the wellbore in the interval where the upper fracture was initiated. The gray grout had been observed in places along the lower fracture.

In the 10-12 ft high tunnel, driven along the transition zone, a 6 x 6 x 20 ft raise was blasted out above the tunnel to examine the upper fracture interval where abundant natural fractures affected the hydrofracs by off-setting them and in some cases terminating individual strands.

5.9.3 Current Status

As of July, the mineback of the Hole #6 Interface Experiment fractures was essentially completed. Fractures were initiated above and below a geologic formation interface of densely welded volcanic tuff overlaying a bedded ashfall tuff and the entire length of these fractures along the interface was mined back. A brief description of the fractures was given in the June monthly report.

Figure 5-10 shows a plan view of the mineback region and the location of the fractures. An alcove was excavated at the far end of the mineback to allow exploratory coreholes to be drilled to locate the extent of the fractures. These coreholes will also be used for in situ stress measurements via small volume hydraulic fracturing. Figure 5-11 shows a longitudinal view of the mineback in the area where the fractures were observed as well as the geology of the interface relative to the mineback. The transition region, which is about 8-12 ft thick, is subdivided into the three separate units, shown in the figure. A sketch of the last face that was excavated (∿ 60 ft from the borehole) is shown in Figure 5-12. At this location, the fracture had nearly pinched out and only a small amount of green and gray grout was observed. In some locations, the grout had filled natural fractures that were intersected by the hydraulic fracture.

It is most significant that the lower fracture propagated into the higher modulus welded tuff wherever there was contact and the formation interface proved to be an ineffective boundary. Also, the total length of the fracture at the interface is ∿ 150 ft, which is only 25 percent of the expected length. Further delineation of the fracture geometry will be carried out by coring. The sites for material property samples have also been selected and these will be obtained in August.

5.9.4 Other Program Activities

R.A. Schmidt presented a seminar at the Los Alamos Scientific Laboratory Los Alamos, New Mexico, on July 27, 1978. The title was "Laboratory Investigations of Rock Fracture with Applications to Energy Research." Several informal discussions on a variety of topics were part of his visit.

Figure 5-13 is a milestone chart depicting the status of Sandia's mine-back program.

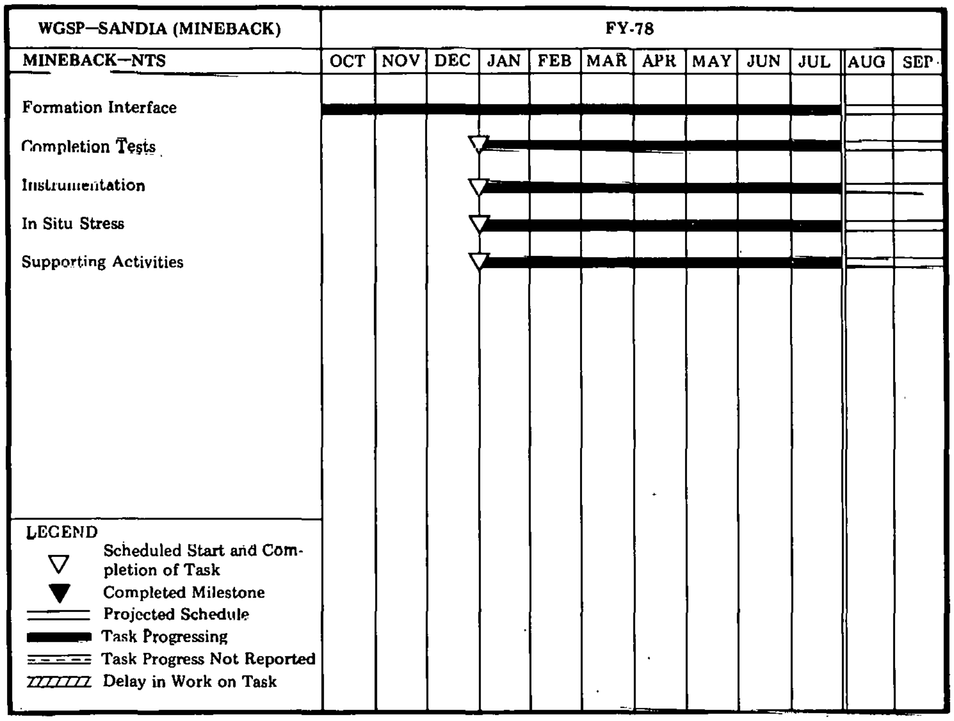


Figure 5-13 Milestone Chart—Sandia (Mineback)

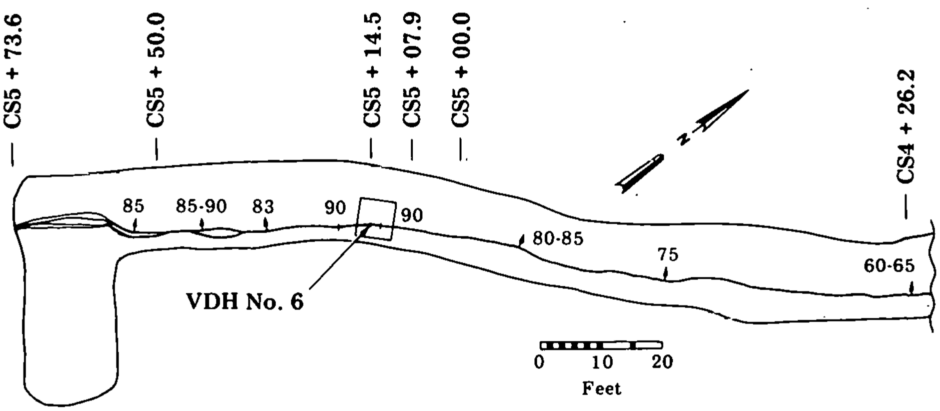


Figure 5-10 EV-6 Drift Plan View at +6 ft

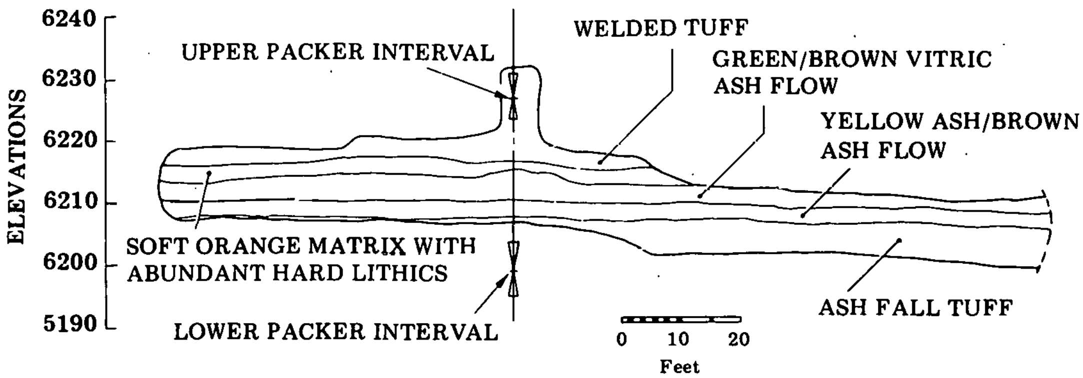


Figure 5-11 EV-6 Drift Longitudinal View

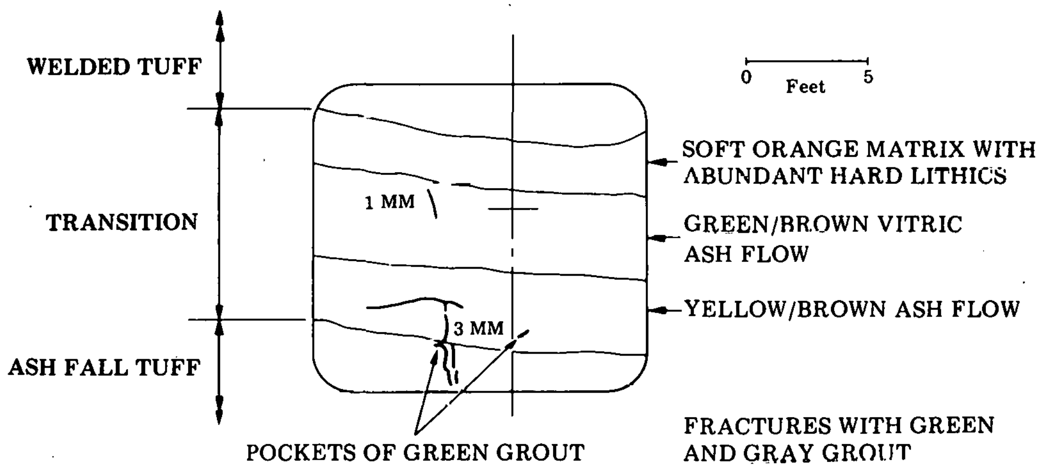


Figure 5-12 Section F-F of EV-6 (CS5 + 73.6)