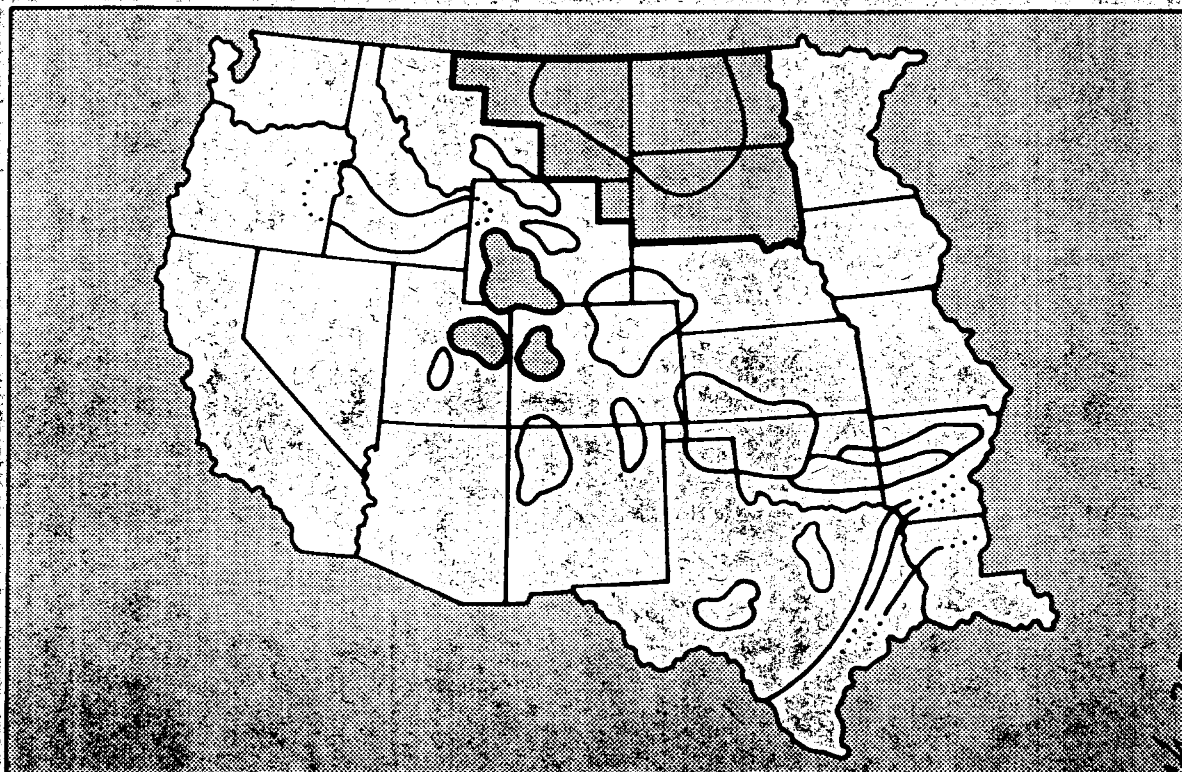
DOE/BG/01569-6

Western Gas Sands Project Status Report



1 March 1979 - 31 March 1979

Prepared for
U.S. Department of Energy

Bartlesville Energy Technology Center
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Compiled by CER Corporation
Las Vegas, Nevada

Contract DE-AC08-79 BG01569

NATIONAL TECHNICAL INFORMATION SERVICE
PAPER COPY PRICES EFFECTIVE JANUARY 1, 1979

Page Range	Domestic Price
001-025	$4.00
026-050	$4.50
051-075	$5.25
076-100	$6.00

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1. SUMMARY

March, 1979 progress of the government-sponsored projects directed toward increasing gas production from low-permeability gas sands of the western United States is summarized in this edition of the WGSP Status Report. The September, 1977 Status Report, NVO/0655-100, provides background information.

G. R. Luetkehans, President, CER Corporation, met with J. C. Ball and C. C. Linville in Bartlesville regarding a WGSP display for the next International Petroleum Exposition in Tulsa, Oklahoma. R. L. Mann, CER Project Manager, met with F. DiGrappa and J. Brunel, Teton Energy Company in Denver to discuss a cooperative coring project in the Piceance Basin. C. H. Atkinson and CER personnel met in Las Vegas with C. Draffin, Fossil Fuel Extraction DOE Headquarters, regarding the WGSP program.

During March, National Laboratories and Energy Technology Centers generally progressed on schedule. Bartlesville Energy Technology Center continued work on fracture conductivity, rock-fluid interaction, and log evaluation techniques. Theoretical and experimental work on hydraulic fracturing mechanics and analysis of well test data continued at Lawrence Livermore Laboratory. Sandia Laboratories completed preparations for the NTS evaluation test of the borehole seismic system. M. D. Wood, Inc. monitored the formation of a hydraulic fracture in the Wattenberg gas field, Weld County, Colorado.

The CER Corporation RB-MHF 3 final report will be distributed by the end of April. Measurement of bottom-hole pressure in the Miller No. 1 and Sprague No. 1 wells for the CIG cyclic gas injection project continued. The Mitchell Energy Corporation Muse-Duke No. 1 was flowing 4,000 MCFD in March. Efforts to clean out Mobil's PCU F31-13G well continued.

2. PROJECT MANAGEMENT

2.1 TECHNICAL MONITORING AND EVALUATION

R. L. Mann, CER Project Manager, met with Bob Chancellor in Denver, Colorado on March 6 to discuss a proposal to frac well No. 397 in the Piceance Creek area, Colorado, and discuss the possibility of Rio Blanco Natural Gas Company releasing some of their seismic data to Geosource to determine if more work on defining sand lens shape and orientation is feasible with existing seismic data.

C. H. Atkinson visited the Bartlesville Energy Technology Center March 6-7 to review progress of the WGSP and to discuss management, budget and procurement matters. He was accompanied by G. R. Luetkehans, President, CER Corporation, who met with John Ball and C. C. Linville regarding a WGSP display for the upcoming International Petroleum Exposition in Tulsa, Oklahoma.

R. L. Mann met with Frank DiGrappa (President) and John Brunel (Vice President), Teton Energy Company, concerning a cooperative coring project in the Piceance Basin. He also visited the DOE Well Test Facility in the Wattenberg Field, Weld County, Colorado on March 7. O. R. Coats and R. Wilmer, CER personnel were also on location waiting for CIG to clean out the Miller No. 1 well.

Cyril Draffin, Fossil Fuel Extraction, DOE Headquarters, visited C. H. Atkinson and CER personnel in Las Vegas on March 9, regarding WGSP program planning.

R. L. Mann attended a National Petroleum Council meeting in Denver, Colorado on March 20-22. He is accumulating gas well operating cost figures from the Rocky Mountain region (Piceance, Uinta, Green River, Wind River, and Greater Green River Basins), Northern Great Plains Province (Montana, North Dakota and South Dakota), Mid Continent area (Denver, San Juan and Arkoma Basins), and Texas (Sonora Basin and Cotton Valley Trend), which will be summarized and presented at a National Petroleum Council meeting to be held May 22, in Denver, Colorado.

J. E. Evered met with Hal Aronson and Ernie Bond of TRW Energy Systems Group to discuss wells of mutual interest to the WGSP and the possibility of TRW aiding in the conduct of gas desorption analyses of core samples.

2.2 TECHNOLOGY TRANSFER

2.2.1 Documentation and Reports

The fourth Quarterly Basin Activities Report, January 31, 1979 is in final review and the January Status Report will be mailed out in early April. The WGSP Status Report, 1 February 1979 - 28 February 1979, is awaiting DOE approval for printing and work has begun on the April status report.

The final report on the CER-managed government/industry MHF-3 demonstration well is expected to be distributed to project participants by April 30.

2.2.2 Project Data Bank

Work continued on the WGSP bibliography. One Rocky Mountain Discovery Map, 1978 and a Preliminary Geologic Map of Vernal 1° by 2° quadrangle, Colorado, Utah and Wyoming were added to the project files.

2.3 GAS RESEARCH INSTITUTE ACTIVITIES

CER Corporation is assisting the TRW Energy Systems Group in generating a data base which will be used by TRW to prepare economic comparisons of various stimulation methods applicable to tight sand formations. TRW work is being performed under contract for the Gas Research Institute (GRI). The data base will also be used by CER Corporation in detailed economic analyses of production from the western tight gas sands.

This data base will include the following types of information:

- Description of producing horizons and reservoirs, gas flow before stimulation, gas production history after stimulation, and a detailed description of stimulation treatments for a significant fraction of wells in each basin;

- Current drilling, completion and stimulation costs.

Specific long-term objectives are:

- Evaluate well costs, stimulation and production costs, flow rates, reserves, and use with current and projected gas prices to determine profit potential;

- Calculate rates of return on investment for different stimulation processes and reservoirs;

- Rank various stimulation techniques (and/or variations of the same basic technique tested in terms of cost-effectiveness and make recommendations as to where future research should be emphasized;

- Prepare cost reports and case histories which would be made available to industry to encourage commercial development of these reservoirs.

3. RESOURCE ASSESSMENT

3.1 U.S. GEOLOGICAL SURVEY ACTIVITIES

3.1.1 Greater Green River Basin

- Work continued on stratigraphic analysis of the Greater Green River Basin.
- Petrographic examination of core chips from the Superior No. 1 Pac. Crk. well, sec. 27, T. 27 N., R. 103 W., Sublette County, Wyoming continued.
- Samples from the Forest Oil well, Federal 31-1 (sec. 31, T. 22 N., R. 106 W.) and the Rainbow Resources well, Pacific Creek Federal 1-34 (sec. 34, T. 27 N., R. 106 W.) were submitted for organic analyses.
- A petrographic study of the Tierney wells (T. 19 N., R. 94 W.) in the Washakie Basin, Wyoming was initiated.
- Work continued on lineament studies in the Washakie and Great Divide Basins.
- Cross-sections through the Washakie and Green River Basins are being prepared.
- An exhibit for the AAPG-SEPM meeting in Houston, April 1-4, 1979 is being prepared.

3.1.2 Uinta Basin - Piceance Basin

- Lithology and depositonal environments were plotted for natural gas reservoirs at the Island and Stone Cabin fields in the southern Uinta Basin. This information is being incorporated on a detailed stratigraphic cross-section which extends from the Wasatch Plateau to the Island Gas field.
- Rock types and depositional environments of Upper Cretaceous natural gas bearing reservoirs in the area of Piceance Creek Dome were related to one another.
- Core samples of Tertiary age reservoir rock from Shell Oil Company gas wells in Southman Canyon gas field were obtained.

3.1.3 Northern Great Plains Province

- A paper entitled "Development of Shallow Gas Reserves in Low-Permeability Reservoirs of Late Cretaceous Age, Bowdoin Dome Area, north-central Montana" was completed by G. L. Nydegger, D. D. Rice and C. A. Brown for the SPE symposium.

- Work continued on a manuscript characterizing reservoir properties of the Eagle Sandstone in the Bearpaw Mountains area.

3.1.4 Schedule Status

Figure 3-1 is a milestone chart depicting the status of all USGS projects for the WGSP.

3.2 CORE PROGRAM

CER personnel, H. E. Newman and D. C. Bleakly were on site for coring the True Oil well, Bluewater Federal No. 3-18 in the Washakie Basin on March 5. On March 7, fishing operations began to recover the core bit and barrel stabilizers. Fishing operations were still in progress on March 14 and True Oil then decided against making any further attempt at coring the well.

Operators contacted during March about participating in the WGSP core program included Pacific Transmission Supply for locations in the Uinta Basin; Teton Energy, Northwest Exploration, Chandler and Associates, and Fuelco for locations in the Piceance Basin; Michigan-Wisconsin Pipeline, Dome Petroleum, Woods Petroleum, Kemmerer Coal Company, and Forest Oil for locations in the Greater Green River Basin; and Kansas-Nebraska, Universal Gas, Trio Petro, and Odessa Natural Gas Corp. for sites in the Northern Great Plains Province. Although no agreements were reached with these operators, CER will continue to be aware of new developments in areas of interest.

Tables 3-1 and 3-2 list the core analyses reports on the Twin Arrow C&K 4-14 well, Rio Blanco County, Colorado.

3.3 LOGGING PROGRAM

Figure 3-2 is the core-gamma surface log of the Twin Arrow C&K 4-14 well in Rio Blanco County, Colorado.

3.4 SURVEY OF BASIN ACTIVITIES

3.4.1 Greater Green River Basin

In the Greater Green River Basin, 11,142 MCFD of new gas was added from completed wells of interest. Producing horizons were the second Frontier, Mesaverde Group, Almond, Lewis, Fort Union, and Wasatch formations. Twenty-three wells were completed: 12 development wells and 11 wildcats. Development wells were 66 percent successful (8 of 12 wells), and wildcats were 27 percent successful (3 of 11).

Twelve wildcats and seven development wells were staked during March.

Wells of interest to the Western Gas Sands Project are listed in Table 3-3 and located on Figure 3-3.

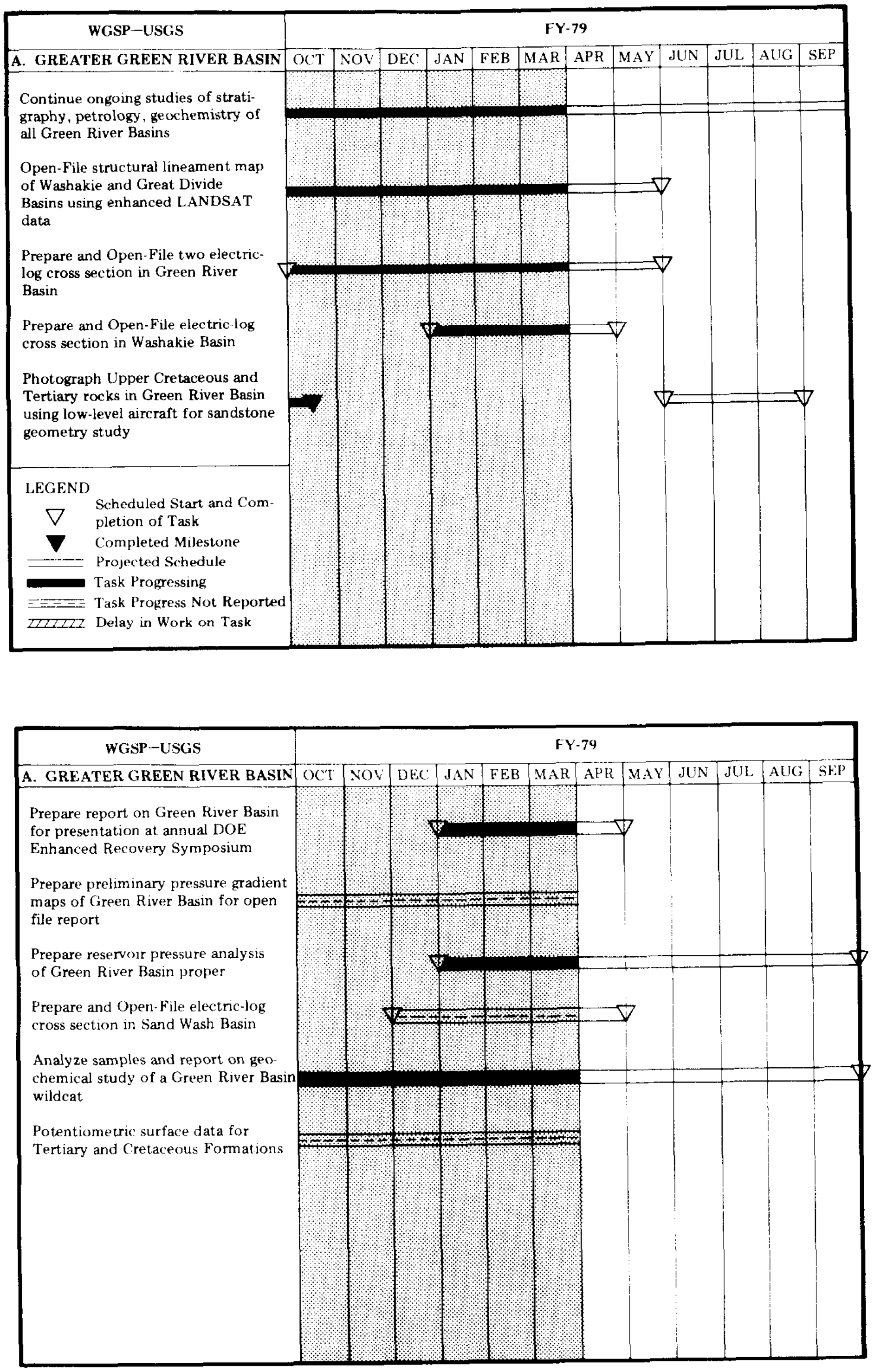
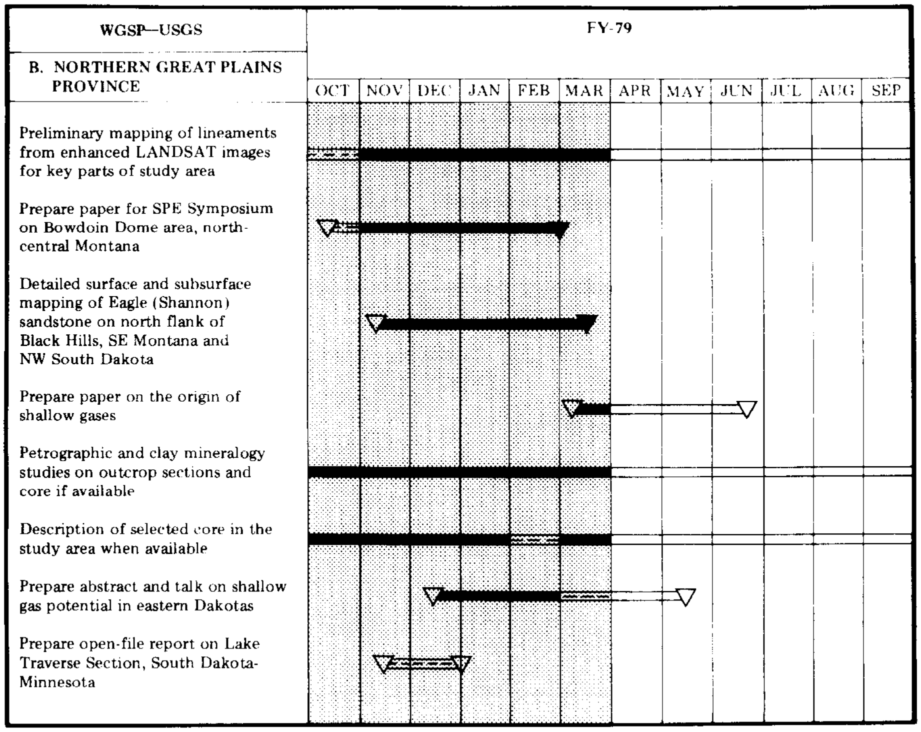


Figure 3-1 Milestone Chart — USGS



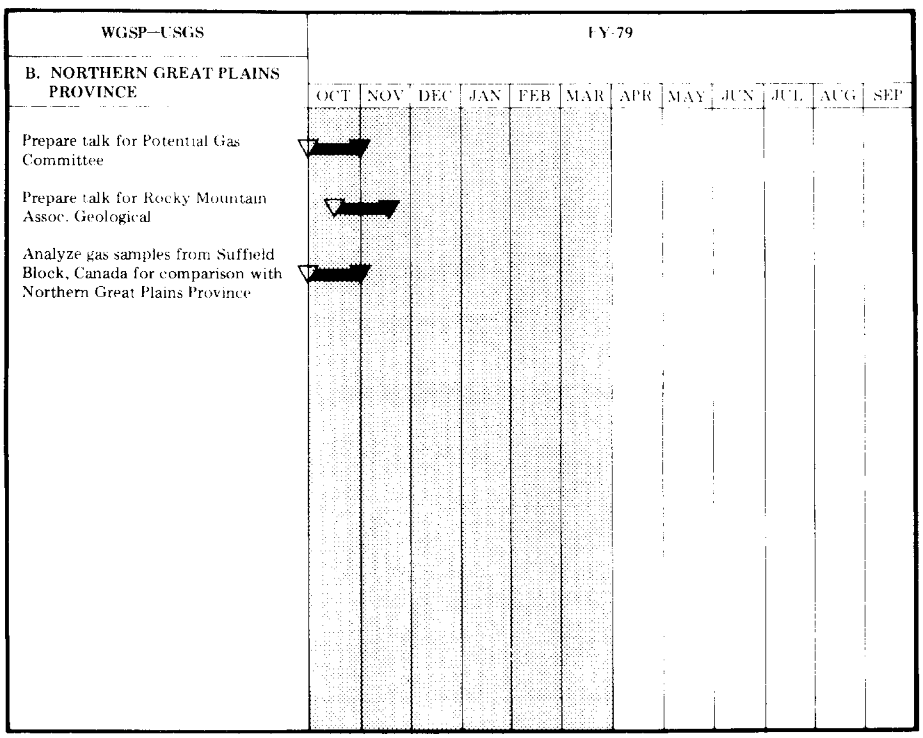
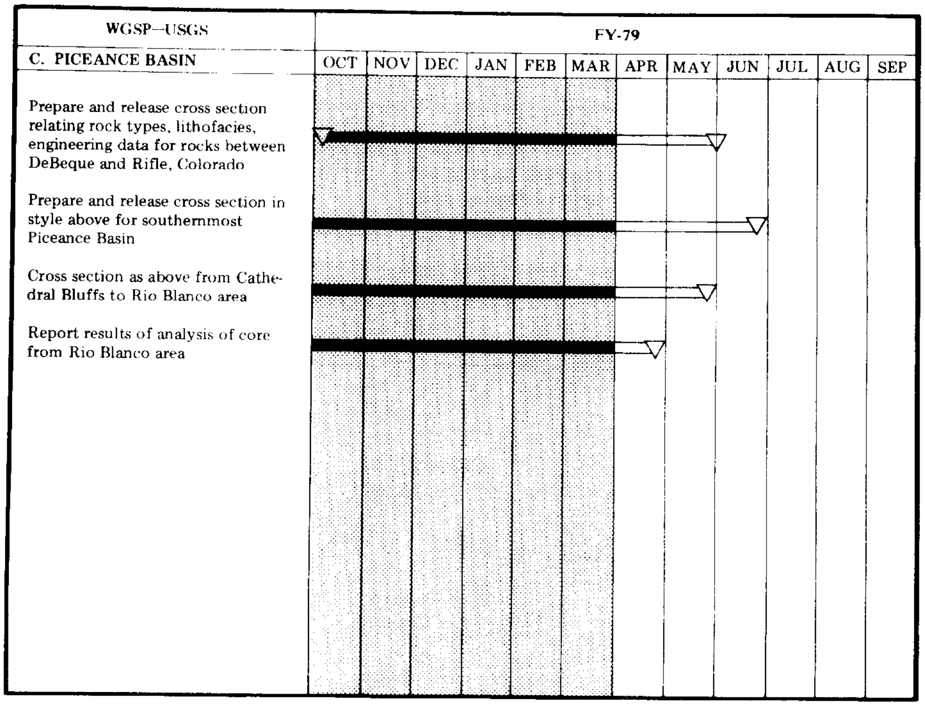


Figure 3-1 Continued



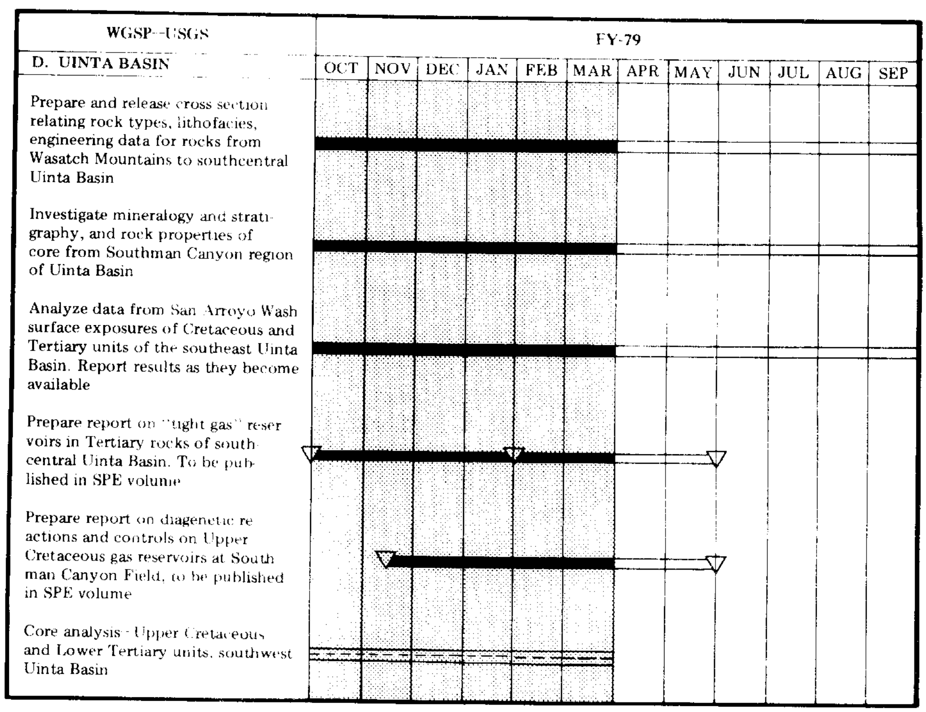


Figure 3-1 Continued

Table 3-1 Analytical Report — Twin Arrow C&K 4-14

TWIN ARROW, INC.	FORMATION : WILLIAMS FORK-MESAVERDE	DATE	: 1-9-79
C&K 4-14	DRLG. FLUID : WATER BASE MUD	FILE NO.	: RP-4-4963-N
CATHEDRAL FIELD	LOCATION : SEC 14 T3S-R101W	ANALYSIS	: BOWEN
RIO BLANCO CO.	STATE : COLORADO	ELEVATION	: 6938 KB

SAMPLE NUMBER	DEPTH	CATION EXCHANGE CAPACITY	GRAIN DENSITY
1	992-93	2.72	
2	997-98	7.87	2.56
3	998-99	7.70	2.55
4	999-1000	8.82	2.59
5	1000-01		2.56
6	1001-02		2.58
7	1002-03		2.57
8	1023-24	8.55	2.66
9	1024-25	7.08	2.58
10	1025-26		2.67
11	1034-35	7.80	
12	1036-37	9.52	
13	1041-42	0.25	
14	1044-45	0.50	
15	1053-54	5.05	
16	1053-54	0.17	
17	1055-56	5.50	
18	1058-59		2.62
19	1059-60	10.2	2.56
20	1060-61		2.61
21	1063-64	0.37	
22	1065-66	0.37	
23	1067-68	0.50	
24	1071-72		2.64
25	1072-73	8.05	2.65
26	1073-74		2.61
27	1077-78	1.05	
28	1079-80	0.62	
29	1127-28	0.37	
30	1128-29	0.62	
31	1129-30	0.25	
32	1130-31	0.50	
33	1131-32	0.25	
34	1132-33	0.17	
35	1133-34	0.17	
36	1134-35	0.17	
37	1135-36	0.37	
38	1136-37	0.50	
39	1137-38	0.25	
40	1138-39	0.37	
41	1139-40	0.25	
42	1140-41	0.25	
43	1141-42	0.07	
44	1143-44	0.17	
45	1145-46	0.17	

Table 3-2 Whole Core Analysis -- Boyle's Law Helium Porosity — Twin Arrow C&K 4-14

TWIN ARROW, INC.	FORMATION :WILLIAMS FORK-MESAVERDE	DATE	:1-9-79
C&K 4-14	DRLG. FLUID :WATER BASE MUD	FILE NO.	:RP-4-4963-N
CATHEDRAL FIELD	LOCATION :SEC 14 T3S-R101W	ANALYSIS	:BOWEN
RIO BLANCO CO.	STATE :COLORADO	ELEVATION	:6938 KB

SAMPLE NUMBER	DEPTH	PERM. TO AIR (MD) MAX.	90 DEG.	POR. B.L.	DESCRIPTION
1	991-92	29	25	20.9	2.65 SD, GY FG
2	992-93	118	*	21.1	2.64 SD, GY MG
3	993-94	1.4	*	18.5	2.65 SD, GY FG
4	994-95	6.5	6.3	18.7	2.68 SD, GY FG
	995-1005				NON SAMPLED INTERVAL
5	1005-6	1.3	1.1	15.6	2.72 SD, GY FG ACC/MIN
	1006-1019				NON SAMPLED INTERVAL
6	1019-20	0.40	0.13	9.7	2.67 SD, GY FG SHY
	1020-1025				NON SAMPLED INTERVAL
7	1025-26	0.16	0.14	8.1	2.65 SD, GY FG SHY
	1026-1031				NON SAMPLED INTERVAL
8	1031-32	0.23	0.15	9.5	2.69 SD, GY FG SHY
	1032-1039				NON SAMPLED INTERVAL
9	1039-40	249	234	23.5	2.68 SD, GY MG
10	1040-41	227	*	22.1	2.64 SD, GY MG
11	1041-42	241	228	22.9	2.68 SD, GY MG
12	1042-43	175	175	24.6	2.69 SD, GY MG
13	1043-44	61	45	22.3	2.71 SD, GY MG ACC/MIN
14	1044-45	38	*	21.2	2.66 SD, GY FG
15	1045-46	25	23	21.1	2.75 SD, GY FG ACC/MIN
16	1046-47	2.6	2.0	17.5	2.71 SD, GY FG ACC/MIN
	1047-1052				NON SAMPLED INTERVAL
17	1052-53	16	15	19.0	2.72 SD, GY MG ACC/MIN
18	1053-54	24	*	20.1	2.66 SD, GY FG
19	1054-55	38	*	20.6	2.67 SD, GY FG
20	1055-56	4.7	*	19.4	2.67 SD, GY FG
21	1056-57	1.7	1.2	16.9	2.69 SD, GY FG ACC/MIN
	1057-1061				NON SAMPLED INTERVAL
22	1061-62	5.5	3.7	9.2	2.64 SD, GY FG SHY
	1062-63				NON SAMPLED INTERVAL
23	1063-64	19	*	19.8	2.65 SD, GY FG
24	1064-65	12	12	21.7	2.72 SD, FY FG ACC/MIN
25	1065-66	0.26	*	11.0	2.73 SD, FY FG ACC/MIN
26	1066-67	0.61	*	12.6	2.74 SD, GY FG ACC/MIN
27	1067-68	0.37	*	10.9	2.74 SD, GY FG ACC/MIN
28	1068-69	1.4	0.74	13.2	2.67 SD, GY FG SHY
	1069-1075				NON SAMPLED INTERVAL
29	1075-76	8.4	7.8	15.8	2.63 SD, GY FG SHY
30	1076-77	40	39	22.7	2.70 SD, GY FG ACC/MIN
31	1077-78	2.0	*	17.0	2.64 SD, GY FG SHY
32	1078-79	55	*	14.5	2.74 SD, GY FG ACC/MIN
33	1079-80	8.7	5.8	12.3	2.74 SD, GY FG ACC/MIN
34	1080-81	1.7	*	16.8	2.71 SD, GY FG ACC/MIN
35	1081-82	0.18	0.16	4.3	2.54 SH, BLK SLTY
	1082-1086				NON SAMPLED INTERVAL
36	1086-87	1.0	0.60	9.6	2.73 SD, GY FG SHY ACC/MIN
	1087-1091				NON SAMPLED INTERVAL
37	1091-92	0.90	0.60	8.9	2.72 SD, GY FG SHY ACC/MIN
	1092-1098				NON SAMPLED INTERVAL
38	1098-99	1.5	1.0	8.3	2.65 SD, GY FG V/SHY
	1099-1105				NON SAMPLED INTERVAL
39	1105-6	5.1	1.5	10.0	2.69 SD, GY FG V/SHY ACC/MIN
	1106-1119				NON SAMPLED INTERVAL

Table 3-2 Continued

SAMPLE NUMBER	DEPTH	PERM. TO AIR (MD) MAX.	90 DEG.	POR. B.L.	DESCRIPTION
40	1119-20	0.36	0.14	10.9	2.72 SD, GY FG ACC/MIN
	1120-1124				NON SAMPLED INTERVAL
41	1124-25	3.4	3.4	16.6	2.72 SD, GY FG ACC/MIN
	1125-1127				NON SAMPLED INTERVAL
42	1127-28	2.2	2.2	13.5	2.70 SD, GY FG SH/LAM ACC/MIN
43	1128-29	44	43	21.7	2.72 SD, GY FG ACC/MIN
44	1129-30	23	*	19.7	2.68 SD, GY FG
45	1130-31	72	67	22.5	2.69 SD, GY MG ACC/MIN
46	1131-32	12	12	17.3	2.70 SD, GY FG ACC/MIN
47	1132-33	46	45	21.1	2.68 SD, GY FG
48	1133-34	9.3	8.4	16.7	2.68 SD, GY FG
49	1134-35	37	36	20.7	2.70 SD, GY FG ACC/MIN
50	1135-36	33	32	19.9	2.68 SD, GY MG
51	1136-37	19	16	18.0	2.68 SD, GY MG
52	1137-38	12	12	18.8	2.70 SD, GY MG ACC/MIN
53	1138-39	27	27	20.3	2.69 SD, GY MG ACC/MIN
54	1139-40	38	38	20.3	2.70 SD, GY MG ACC/MIN
55	1140-41	75	*	22.2	2.68 SD, GY MG
56	1142-43	22	21	17.8	2.74 SD, GY MG ACC/MIN
57	1142-43	17	17	15.7	2.75 SD, GY MG ACC/MIN
58	1143-44	25	25	19.5	2.73 SD, GY MG ACC/MIN
59	1144-45	17	17	19.2	2.72 SD, GY MG ACC/MIN
60	1145-46	12	11	18.1	2.72 SD, GY MG ACC/MIN
61	1146-47	33	33	19.0	2.73 SD, GY MG ACC/MIN
	1147-1167				NON SAMPLED INTERVAL
62	1167-68	1.7	1.5	14.0	2.64 SD, GY FG SHY
	1168-1185				NON SAMPLED INTERVAL
63	1185-86	0.14	0.10	10.6	2.73 SD, GY FG SHY ACC/MIN
	1186-1193				NON SAMPLED INTERVAL
64	1193-94	1.8	1.7	15.9	2.66 SD, GY FG
	1194-1199				NON SAMPLED INTERVAL
65	1199-0	0.04	0.03	3.4	2.68 SD, GY FG V/SHY
	1200-1203				NON SAMPLED INTERVAL
66	1203-4	0.02	0.02	5.8	2.67 SD, GY FG V/SHY
	1204-1207				NON SAMPLED INTERVAL
67	1207-8	0.14	0.11	4.3	2.67 SD, GY FG SHY
	1208-1210				NON SAMPLED INTERVAL
68	1210-11	0.02	0.02	3.4	2.68 SD, GY FG SHY

* SAMPLE NOT SUITABLE FOR WHOLE CORE ANALYSIS

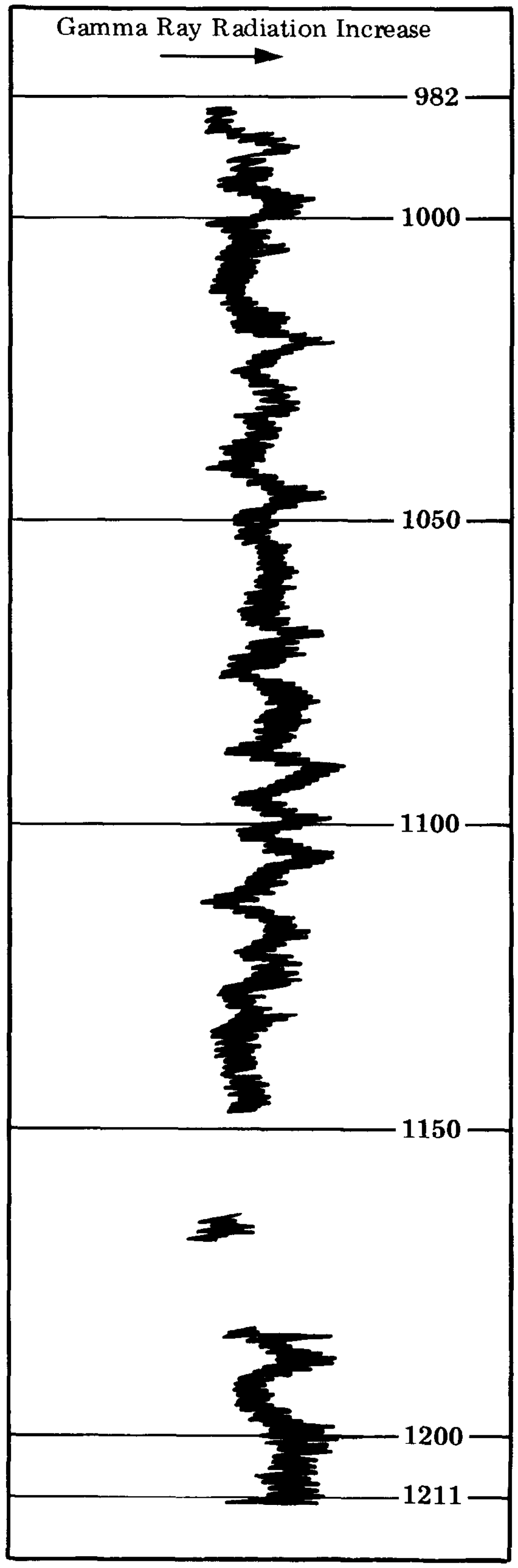


Figure 3-2

Core Gamma Surface Log — Twin Arrow C&K 4-14

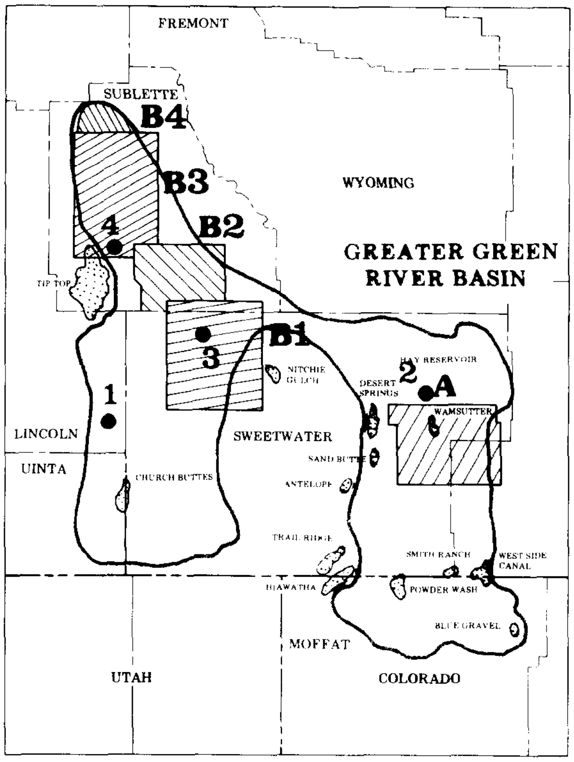


Figure 3-3

Greater Green River Basin Showing Wells of Interest and USGS Designated Core Areas (refer to Table 3-3)

Table 3-3 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
Amoco Production	19 Unit	1	nesw 15/21N/112W Whiskey Buttes Field Lincoln Cty, WY	Second Frontier (11,036-11,082 gross)	11,190		Completed DG, cored 11,012-11,071. Comp. 2-21-79	4,000
Pacific Transmission Supply	3-2 Federal	2	w½sw 2/22N/94W Wildcat Field Sweetwater Cty, WY	Mesaverde (12,100)			Wildcat located in core area A. Old info: OWDD, Comp 3-12-79, D&A,OTD 3,400	
Davis Oil	1 Simpson Gulch Unit	3	swne 31/25N/107W Unnamed Field Sweetwater Cty, WY	Mesaverde (10,537-10,541)	17,180 PB: 17,130		Wildcat comp. 7-14-77, Mesaverde Discovery-New Field	97
Wood Petroleum	23-1 GUIO	4	swne 23/30N/112W Wildcat Field Sweetwater Cty, WY	Frontier (14,000)			WF located in core area B_3	

[1] Refer to Figure 3-3
[2] Horizon - projected depth or producing interval

3.4.2 Northern Great Plains Province

Thirteen wells were completed in horizons and locations of interest to the WGSP (8 development wells and 5 wildcats). Completed wells added 3,081 MCFD of new gas during March. Producing horizons were the Blackleaf, Bow Island, Greenhorn, Second White Specks, and the Eagle.

Six of the 8 development wells were successful (2 wells were D&A), and 2 of the 5 wildcats were successful (3 wells D&A).

Ten new wells were staked in the Northern Great Plains Province (8 wildcats and 2 development wells), with 3 spudding in by month end.

Wells of special interest to the WGSP are listed in Table 3-4 and located on Figures 3-4 and 3-5.

Table 3-4 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
Pete Lien & Sons	1 Tonn Bros	1	sesw 11/2N/49E Wildcat Field Custer Cty, MT	Judith River (2,200)			WF	
Xeno Inc.	3-11 Chouteau	2	nenw 11/35N/19E Unnamed Field Blaine Cty, MT	Eagle (1,588-1,668)	1,724 PB: 1,722		Completed 7-16-78, no cores or tests	1,565
Montana Power	9-36 ML-50 State	3 36	nese 36/36N/14E Unnamed Field Hill Cty, MT	White Speck (2,500-2,535) gross)	3,010 PB: 2,811	30,000 lb sand	White Specks Discovery-New Field, no cores	7
Shenandoah Oil	1 Harrison La Roche Trust	4	senw 13/36N/31E Unnamed Field Phillips Cty, MT	Bowdoin (1,281-1,452) Greenhorn (1,457-1,496)	1,700 PB: 1,654	95,000 lb sand	Completed 6-6-78, no cores or tests, commingled production	532

[1] Refer to Figures 3-4 and 3-5
[2] Horizon - projected depth or producing interval

3.4.3 Piceance Basin

Horizons of interest in the Piceance Basin produced 6,687 MCFD of new gas during March, 1979. Fifteen of nineteen development wells and two of two wildcats produced from the Mancos zone. Two development wells were completed D&A.

Five new wells were staked in the Piceance Basin (4 development wells and 1 wildcat).

Special wells are shown on Figure 3-6 and listed in Table 3-5.

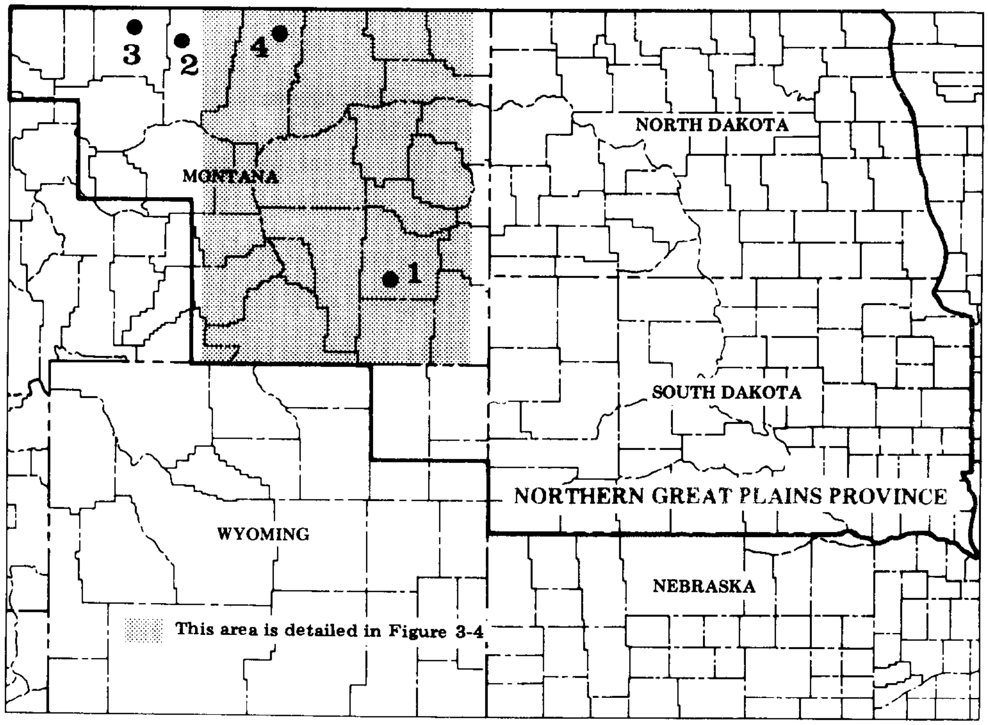


Figure 3-4
Northern Great Plains Province Showing Wells of Interest (refer to Table 3-4)

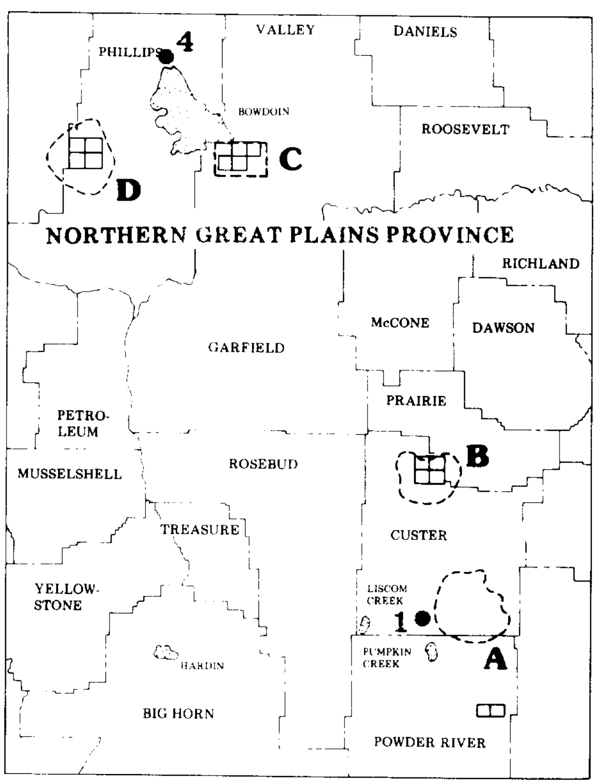


Figure 3-5
Detail of USGS Designated Core Areas (refer to Table 3-4)

Figure 3-6

Piceance Basin Showing Wells of Interest and USGS (Designated Core Areas (refer to Table 3-5)

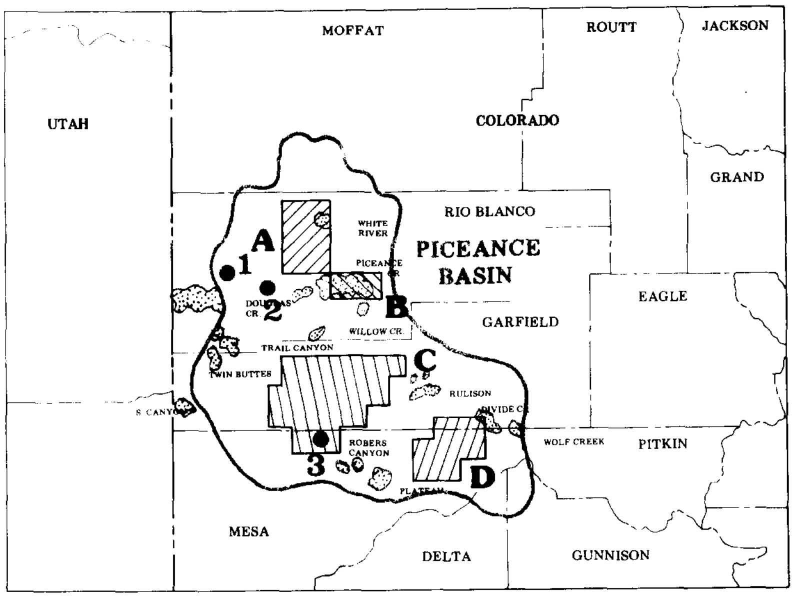


Table 3-5 Summary of Wells — Piceance Basin

OPERATOR	WELL NAME	MAP INDEX NO.[1]	LOCATION Sec/T/R	HORIZON[2] ft	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Chandler & Associates	10-22-1-1 Fork Unit	1	nwse 22/1S/102W North Douglas Creek Rio Blanco Cty, CO	Mancos (2,356-2,411)	2,689	93,030 gal water 230,000 lb sand	Completed 12-19-78, no cores or tests	1,150
David B. Munson	5-2-99 Federal	2	swnw 5/2S/99W Unnamed Field Rio Blanco Cty, CO	Mancos (6,812-8,342)	8,952 PB: 8,426	105,000 gal emulsion 246,000 lb sand	Completed 2-1-79, no cores or tests	663
Teton Energy	29-2 Federal	3	swnw 29/8S/97W Debeque Field Mesa Cty, CO	Corcoran (4,400)			WD located in core area C.	

[1]Refer to Figure 3-6
[2]Horizon - projected depth or producing interval

3.4.4 Uinta Basin

The Green River and Wasatch formations produced 18,678 MCFD of new gas. Fifteen development wells (15 successful wells) and 3 wildcats (1 successful well) were completed in March, 1979.

Eight new wells were staked (6 development wells and 2 wildcats), one had been spudded and was drilling ahead by month end.

Wells of interest are shown on Figure 3-7 and are listed in Table 3-6.

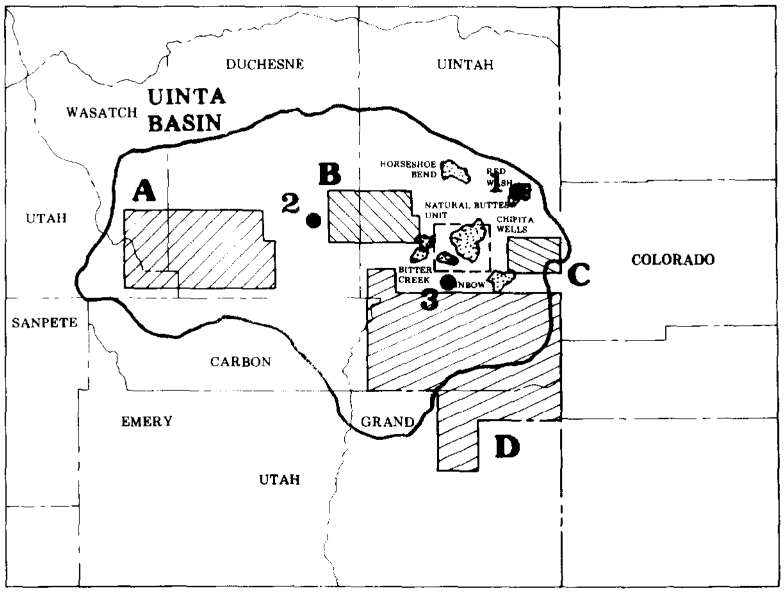


Figure 3-7

Uinta Basin Showing Wells of Interest and USGS Designated Core Areas (refer to Table 3-6)

Table 3-6 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
Chevron	USA 244 (23-19c) Red Wash Unit	1	nesw 19/7S/24E Red Wash Field Uintah Cty, UT	Green River (5,829-7,317)	5,525 PB: 5,350	1,800 gal acid	Completed 12-20-78, no cores or tests	600
Pacific Transmission Supply	44-36 State	2	sese 36/8S/15E Unnamed Field Duchesne Cty, UT	Parachute Creek - Green River (2,942-2,968)	7,165 PB: 5,000	14,000 gal acid	WFD, no cores Parachute Creek Discovery-New Field	60
CIG Exploration Inc.	CIGE 47-14-10-21 Natural Buttes Unit	3	nwse 14/10S/21E Natural Buttes Field Uintah Cty, UT	Wasatch (5,195-6,414)	6,550 PB: 6,519	1,500 gal acid 110,000 gal emulsion 255,000 lb sand	Completed 2-6-79, no cores or tests	2,100

[1] Refer to Figure 3-7
[2] Horizon - projected depth or producing interval

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

Proposals received in response to RFP 13-5031 have been evaluated and an industry partner for joint development and testing of an improved coring system has been identified. A contract is being negotiated based on the winning proposal. Modifying the existing core barrels to use the Sandia two-piece bits and the low invasion coring fluid will be provided for in this contract. The use of an existing barrel circumvents most of the design flaws identified in the sub-contracted engineering design.

4.1.1.2 Core Fluid Tests

The Hassler cell core holder and associated equipment ordered from Core Laboratories was received. This equipment has been assembled and tested, and experimental procedures are being developed. Cores have been drilled from the Brown sandstone and Indiana limestone; permeability tests have been run on both rock types. The Brown sandstone has a permeability to water of about 230 md under simulated reservoir conditions of 2,500 psi triaxial stress. This high permeability is representative of a number of good California, mid-continent, and Gulf Coast oil sands. The Indiana limestone had a permeability to water of only 0.24 md, which makes it unsuitable for invasion testing.

Core Laboratory analysis on the Berea sandstone, Brown sandstone, and Indiana limestone has been completed and will be available soon. Each rock type was tested for porosity, horizontal and vertical permeability, and pore size distribution. This data should aid in selection of the optimum particle size distribuiton of low invasion fluid. The extra parts for the Fann rotary viscometer have arrived. The viscometer will measure the power-law viscosities of the required very viscous low invasion fluids, and maximum pressure buildup in the core barrel caused by extruding the low invasion fluid around the core and past the pilot bit face can be calculated.

4.1.1.3 Bit Design and Fabrication

A 6-1/2 in. main bit and a 2-1/2 in. pilot bit are being designed and fabricated for use with existing core barrels for an early field test. This will provide the earliest possible introduction of the improved coring system to the oil patch.

Fabrication of the 8-1/2 in. main bit body is complete and diffusion bonding of the diamond compax cutter to studs for this bit and to the first pilot bit body will be completed the first week of April. Evaluation testing of the diffusion bonds will include ultrasonic inspection and shear testing.

4.1.2 Interface Conductivity Effects on Electric Logging

Conductivity measurements on core plugs from the CIGE No. 21 well are continuing. The cation exhange capacity (CEC) for several core plugs is shown in Table 4-1. Water extracts from these samples gave a white precipitate with ammonium oxalate indicating that Ca and/or Mg could be present. The moist core sample had a pH of 9.0 which could be due to invasion by basic drilling mud or the presence of an akaline form of Ca, such as $CaCO_3$. Because Ca^{++} can compete with NH_4^+ for adsorption onto clay, Ca was removed in some samples. The CEC was also determined at a pH of 7.0 and 8.0 as summarized in Table 4-1.

Table 4-1 Cation Exchange Capacity (meg/g) measurements under different conditions (CIGE No. 21 core samples).

Technique \ Depth in ft	6498.9	6498.4	6475.0	64.99
		.0256	.0101	
pH = 7.0	.0174	.0246	.0121	.0115
pH = 7.0				.0115
pretreated			.0096	.0125
pH = 8.0				.0125
pretreated				.0122

Pretreated samples were allowed to stand over night in acetic acid adjusted to pH 2.0 with NH_3. The samples were then washed with 1.0 N NH_4Ac at pH 7.0 until the filtrate from these three consecutive washings was at pH 7.0. The same procedure was used for a pH of 8.0.

Although samples 6498.9 and 6498.4 are separated by only 6 in., the latter had 44 percent higher CEC, which was attributed to shale stringers passing through that portion of the core. Even so, the CEC was small. High calcium removal and pH change (over this limited range) does not appear to influence the CEC.

4.1.3 Reservoir Simulation Studies

Parametric analysis of MHF Test Data -- Intercomp Inc.

Analysis of pressure buildup data from various zones in the Mobil PCU F31-13G well has continued. Total buildup time was longer than flow time for all of these tests. This, together with long periods of wellbore storage, caused errors in results from type curve match analysis of the buildup data. Available type curves give drawdown solutions and may be used for analysis of buildup data if the flow time preceding buildup is much larger than the buildup time. A set of buildup type curves that take flow time into account have been developed to help in analysis of data from the PCU F31-13G well.

Figures 4-1 and 4-2 are log/log plots of dimensionless pressure rise, p_{DS}, vs dimensionless shut-in time, Δt_{Dxf}. Dimensionless flow time, t_{Dxf}, is a parameter in these plots. Figure 4-1 gives curves for a well with an infinite conductivity vertical fracture and Figure 4-2 gives curves for a well with a uniform flux fracture. The reservoir is considered to be infinite in both cases. Dimensionless time is defined as:

$$t_{Dxf} = 0.0002637 \frac{kt}{\Phi \mu c_t x_f^2}$$

where

t	=	time, hrs
k	=	permeability, md
Φ	=	porosity
μ	=	viscosity, cp
c_t	=	total compressibility, psi^{-1}
x_f	=	fracture half-length

Dimensionless pressure rise for a gas well is:

$$p_{Ds} = \frac{T_{sc} \ K \ h \ [m(p_{ws}) = m(p_{wf} @ \Delta t = 0)]}{50{,}300 \ p_{sc} \ q \ T}$$

where

$m(p_{ws})$	=	real gas potential of the buildup pressure, psi^2/cp
$m(p_{wf} @ \Delta t = 0)$	=	real gas potential of the flowing pressure just prior to buildup, psi^2/cp
T_{sc}	=	standard condition temperature, ^oR
T	=	reservoir temperature, ^oR
P_{sc}	=	standard condition pressure, psia
h	=	thickness of the producing interval, ft

The top curve in each figure is the drawdown solution. In this case, the dimensionless pressure is defined in terms of $m(p_i)$, the real gas potential of initial reservoir pressure, and $m(p_{wf})$, the real gas potential of the flowing pressure.

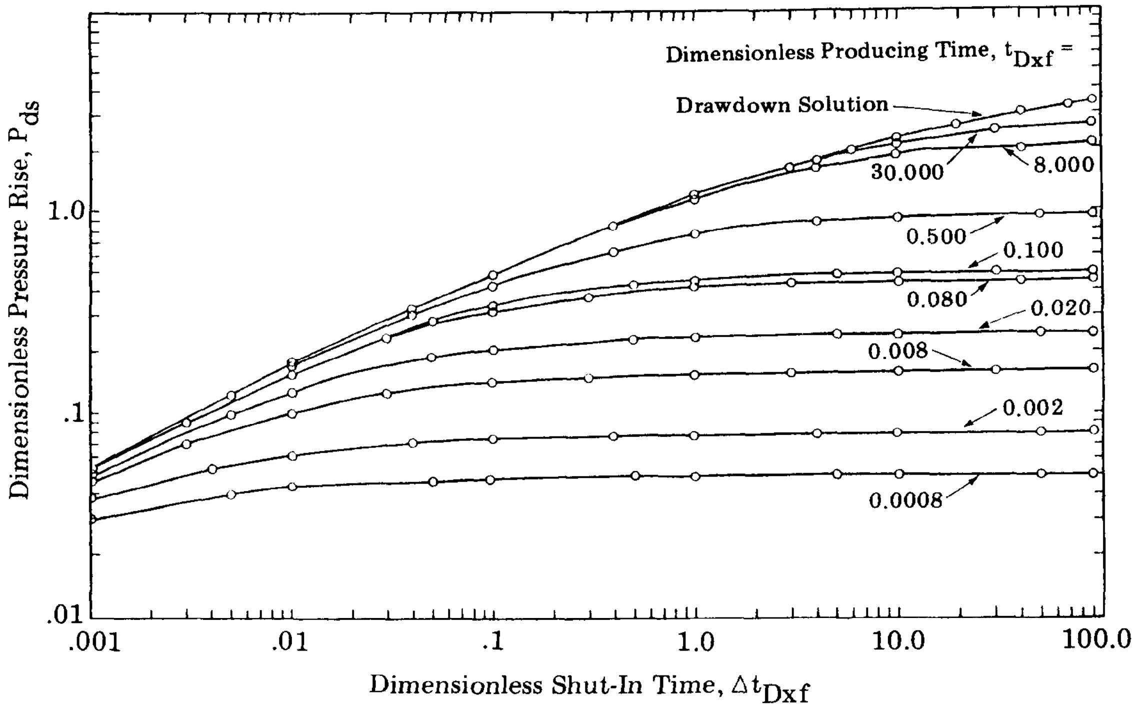


Figure 4-1 Infinite Conductivity Fracture in an Infinite Reservoir

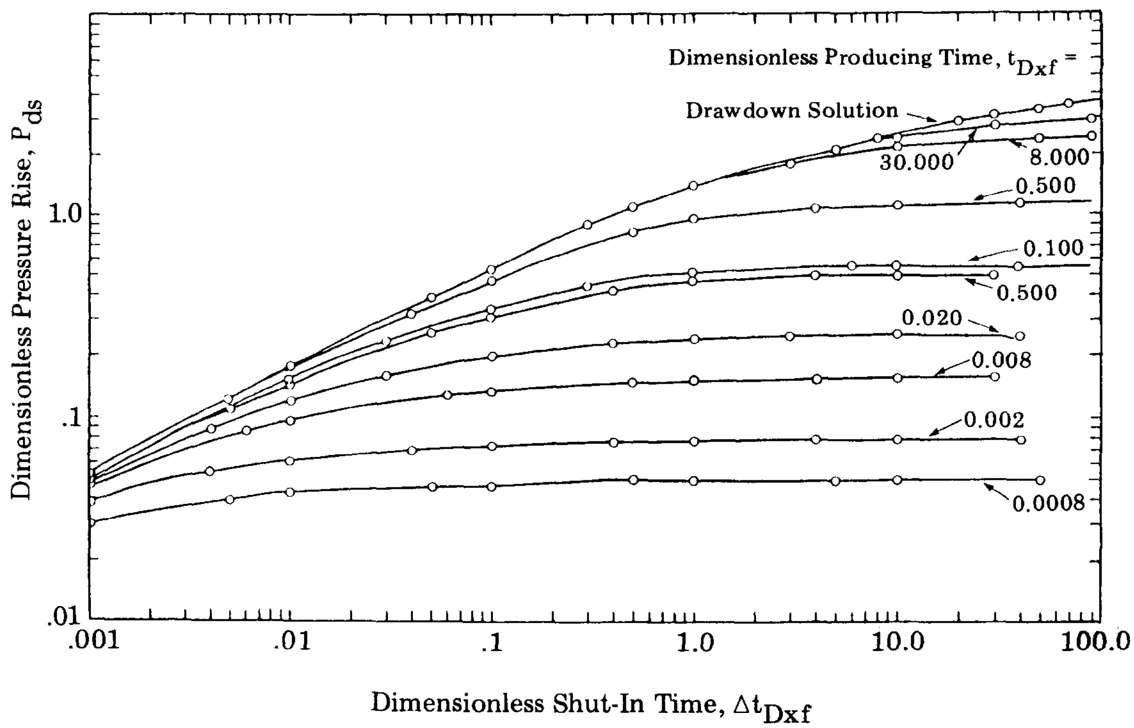


Figure 4-2 Uniform Flux Fracture in an Infinite Reservoir

The figures show that at early times the buildup and drawdown solutions are the same. At longer buildup times, the two solutions separate with the buildup solution considerably lower than the drawdown solution at small producing times. This limits the time during which the drawdown solution can be used for analyzing buildup data. If early buildup pressures are controlled by wellbore storage, the drawdown solution cannot be used to analyze buildup data taken following short flow periods. The curves given in Figures 4-1 and 4-2 are used in this situation.

A type curve plot which exhibits a straight line with a slope of 0.5 usually indicates a fractured well. The curves of Figures 4-1 and 4-2 show that the 0.5 slope line may not be present in buildups following short flow times.

Core and log data on several wells are in the final stages of analysis. Two additional cores will be incorporated into the study to provide additional control. Natural Buttes No. 21 core was received during February. Data on Natural Buttes No. 21 is not very extensive, but will provide a few more control points for the study. Core on RB-MHF 3 (not received until March), is extensive and should aid considerably in the petrophysical study. Rio Blanco 498-4-1 is being studied and analysis of it should be finished shortly.

4.1.4 Rock Fluid Interaction

4.1.4.1 Fracture Simulation

Several samples of sintered bauxite proppants were obtained with the same particle size range as the sand proppants and will be used in place of sand for part of the simulated fracture studies. Relatively fast settling rates have been observed with the material in a 40 lb. guar gelled 2 percent KCl fluid.

4.1.4.2 In-Situ Permeability

Permeabilities of several cores from the Mobil PCU F31-13G and CIGE No. 21 wells have been completed. In situ permeabilities have the typical curve shown in Figure 4-3 for the Mobil core 6499.5. After careful examination of the core mounting procedure, problems with variation in the data were eliminated.

4.1.5 Measurement of Formation Characteristics for Western Tight Sands - Institute of Gas Technology

4.1.5.1 Pressure Dependence of Single-Phase Permeability

Steady state and pulse determined permeabilities for cores No. 8498 and No. 7011 (Figures 4-4 and 4-5) display a decrease in permeability with increasing pore pressure. High pore pressure permeabilities are less than the Klinkenberg extrapolated permeabilities for the same effective stress at low pore pressure for No. 8498, but greater for No. 7011. Further testing is required to distinguish between possible Klinkenberg effects or deviations from the effective stress assumption. Figure 4-6 illustrates the difference in effect of similar overburden pressures on initial gas permeability for No. 7011 at low pore pressure and high pore pressure. Neither curve is corrected for the Klinkenberg gas slip. Each curve was at a constant mean pore pressure up to 5,000 psi overburden pressure. Differences between the curves indicate some difference in gas slippage and may also indicate some constant addition

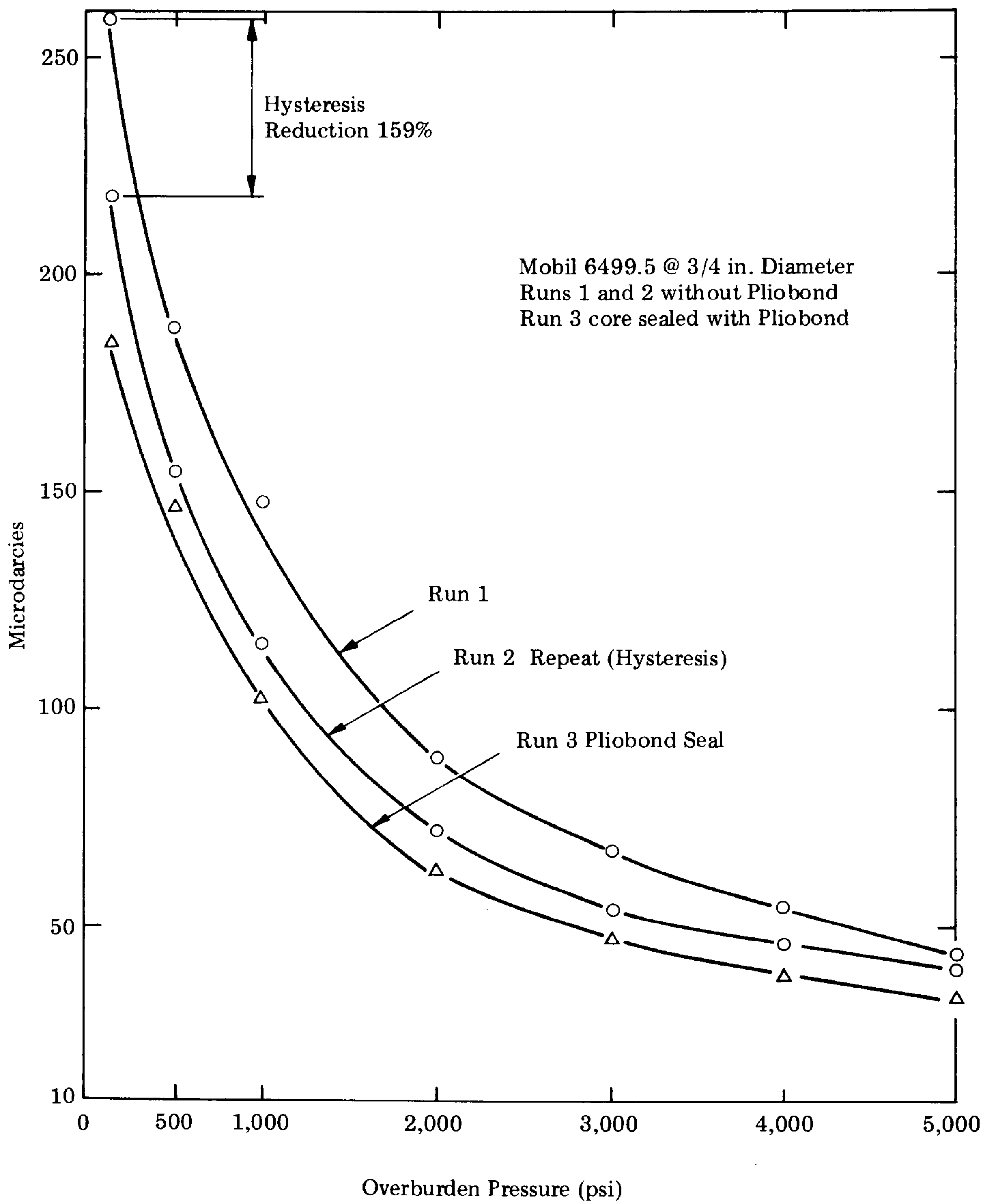


Figure 4-3 In-Situ Permeabilities for Mobil Core 6499.5

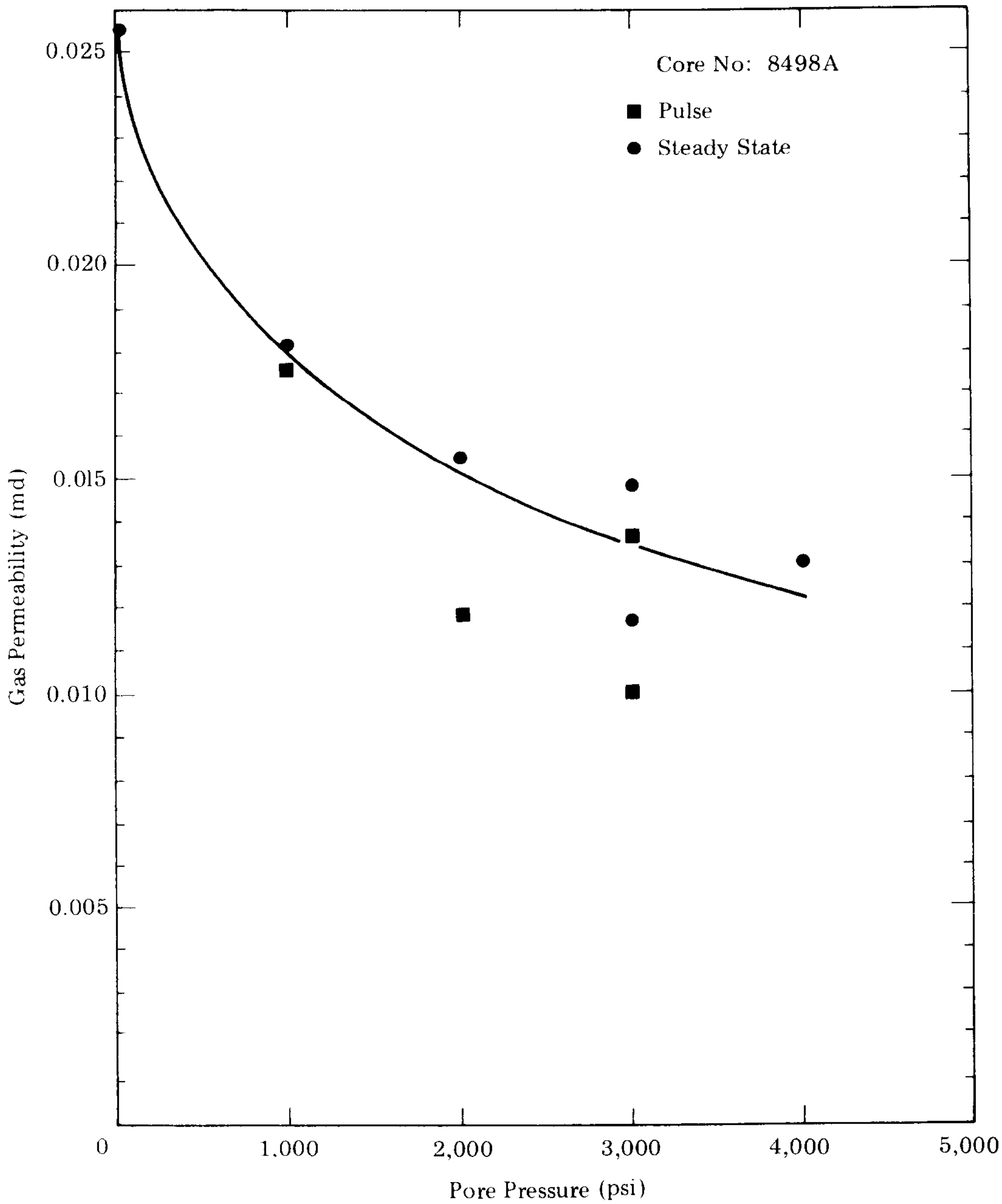


Figure 4-4 Effect of Pore Pressure on Rock Permeability

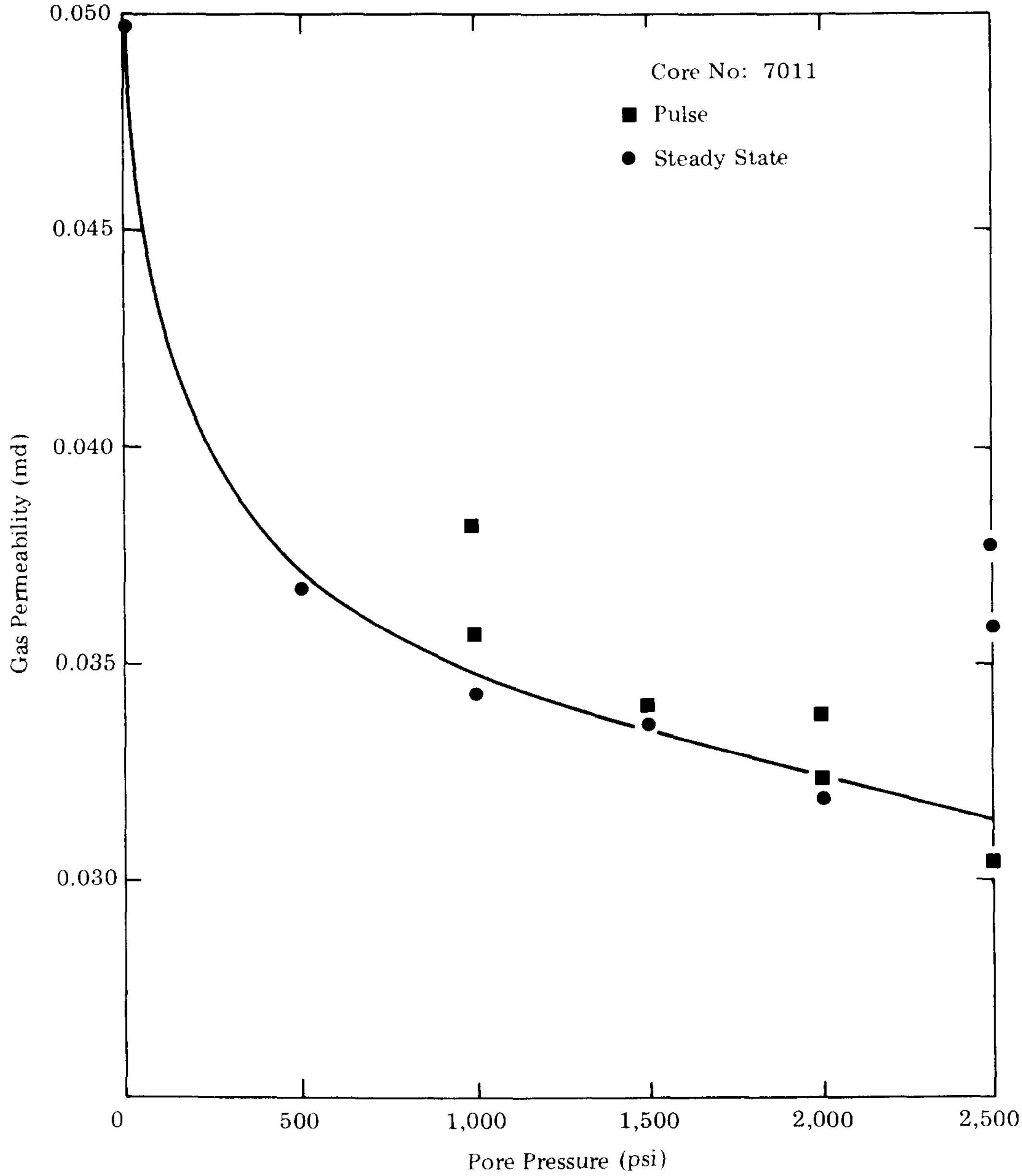


Figure 4-5 Effect of Pore Pressure on Rock Permeability

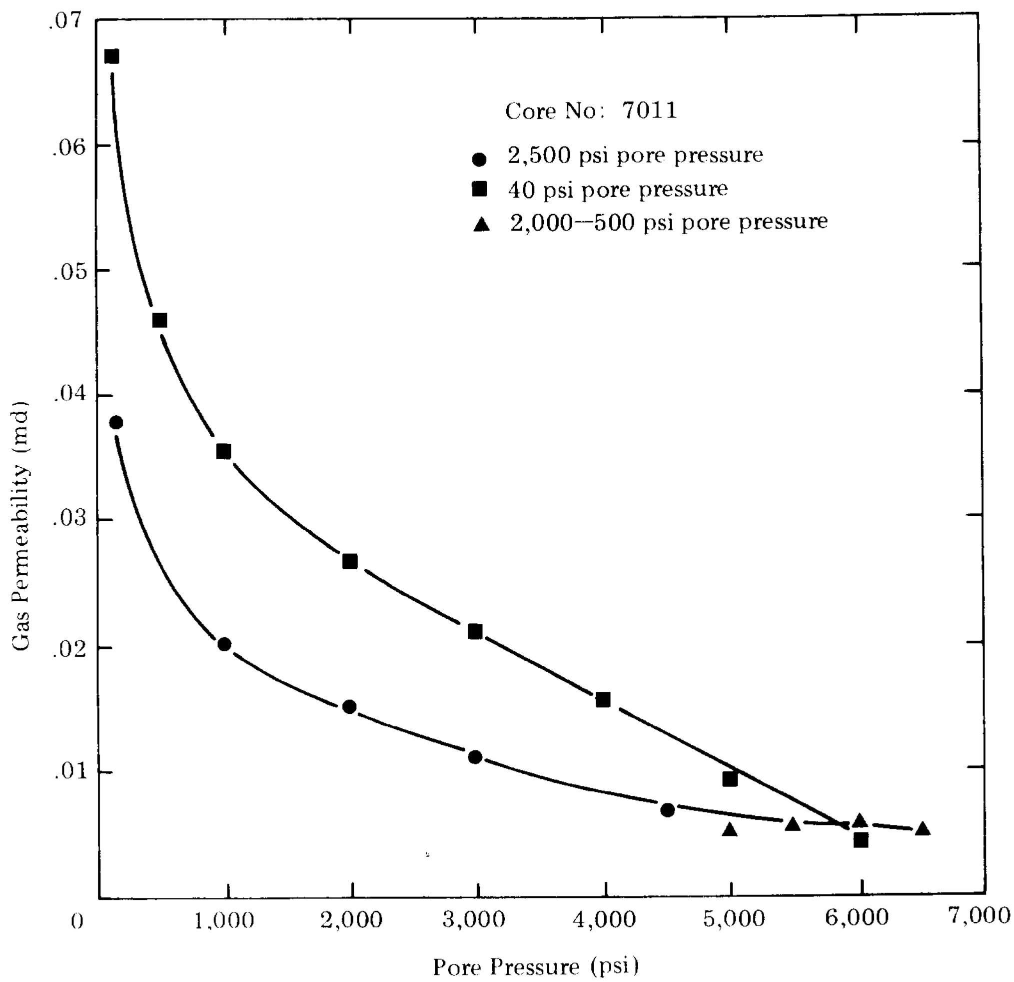


Figure 4-6 Effect of Overburden Pressure on Gas Permeability at High and Low Pressures

due to rock properties. The similar shape of the two curves up to 5,000 psi overburden pressure indicates any rock property difference due to different pore pressures is roughly constant for the entire overburden range. Four points are plotted for pore pressure decreasing from 2,500 psi to 500 psi at a constant confining pressure for core No. 7011. This simulates the behavior of an actual reservoir. No significant permeability change was noted. However, the contribution of gas slip with decreasing pore pressure would increase measured values. If the pore pressure had been kept constant from an overburden pressure of 5,000 to 7,000 the slope may have roughly paralleled the low pore pressure curve.

In the four runs simulating a reservoir, the flows measured are under the same flow conditions as in the reservoir assuming no unknown instrumental effects. No Klinkenberg correction was required since gas slip was taking place at these pore pressures in the apparatus, as it would in the reservoir.

Pulse decay data is shown in Figure 4-7 for the PCU F31-13G No. 9957. This displays the same trend as No. 7011 and No. 8498A. Steady state data were not as consistent and are being reviewed and retested.

4.1.5.2 Effect of Core Saturation History on Relative Permeability to Gas and Water

Measurement of liquid permeabilities was attempted using 10 g/l NaCl solution to test for accuracy of Klinkenberg extrapolated permeabilities in February. During testing, flow in one direction would quickly decrease and when the flow was reversed, it would increase to a maximum value and then begin decreasing sharply, indicating fines were dislodged and then resealing pores. Two oscillations showed that the permeability reached the same maximum value before decreasing, irrespective of the flow direction.

Scanning electron microscopy revealed extensive fine clays blocking pores in Canyon Largo No. 256 - No. 7011 and PCU F31-13G No. 9957. There are extensive fine clay grains intergrown across and throughout pores in both rocks. A complete diagenetic description will follow after rock thin section work is completed. Testing is in progress on No. 9957A to find a fluid that will not significantly dislodge and move the clay particles and prevent pore blockage.

4.1.6 Schedule Status

Figure 4-8 is a milestone chart which depicts March progress of BETC projects.

4.2 LAWRENCE LIVERMORE LABORATORY

4.2.1 Theoretical Analysis

Some calculations of displacement histories near a dynamically propagating hydrofracture, which approach an interface, have been completed. Effects due to the crack stopping or penetrating the interface were not included as part of these analyses since calculations were terminated just before the propagating crack reached the interface. The emphasis was directed toward determining how various adjacent materials affected the propagating fracture. Seven calculations ranging from a rigid boundary (Young's modulus is infinite) to

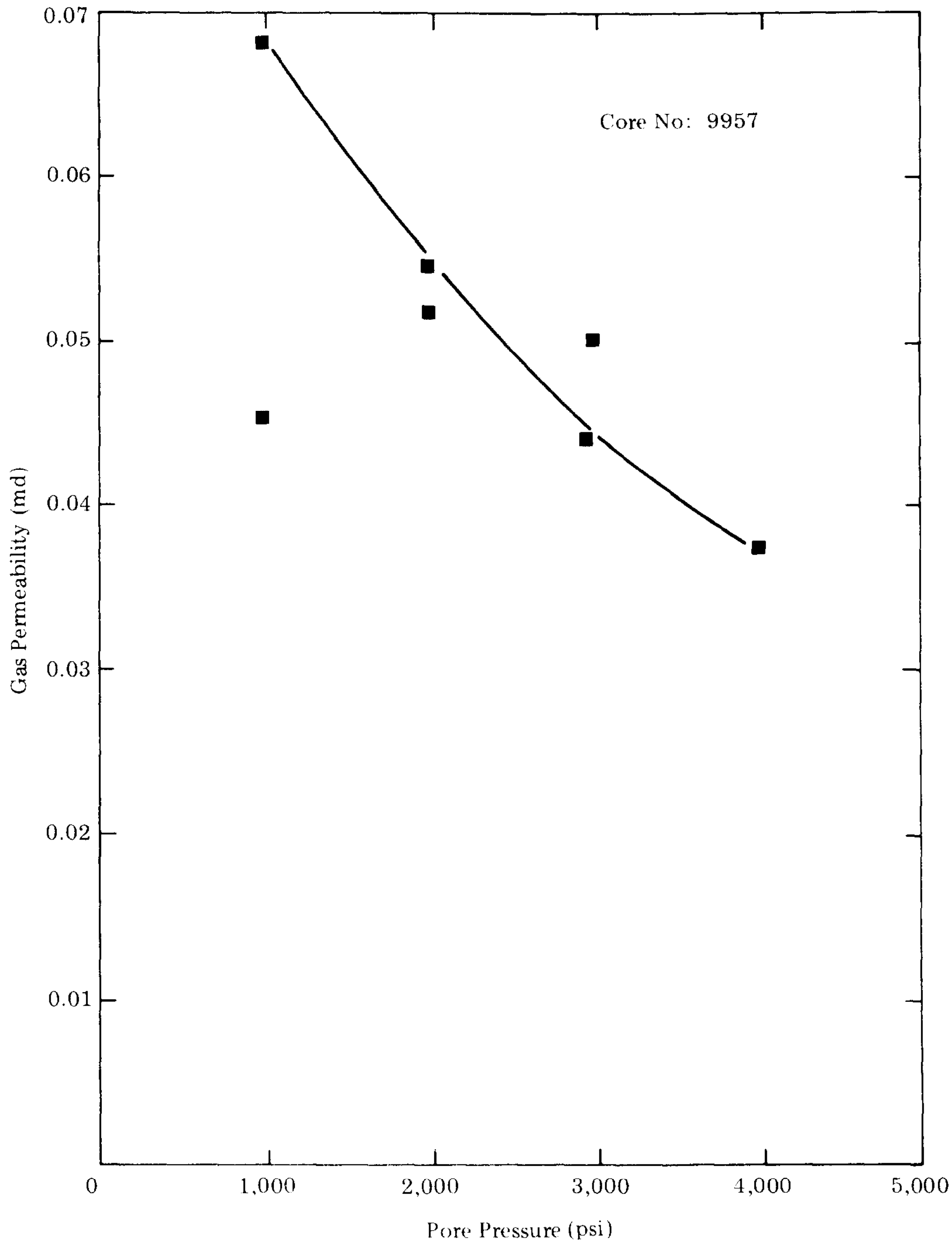
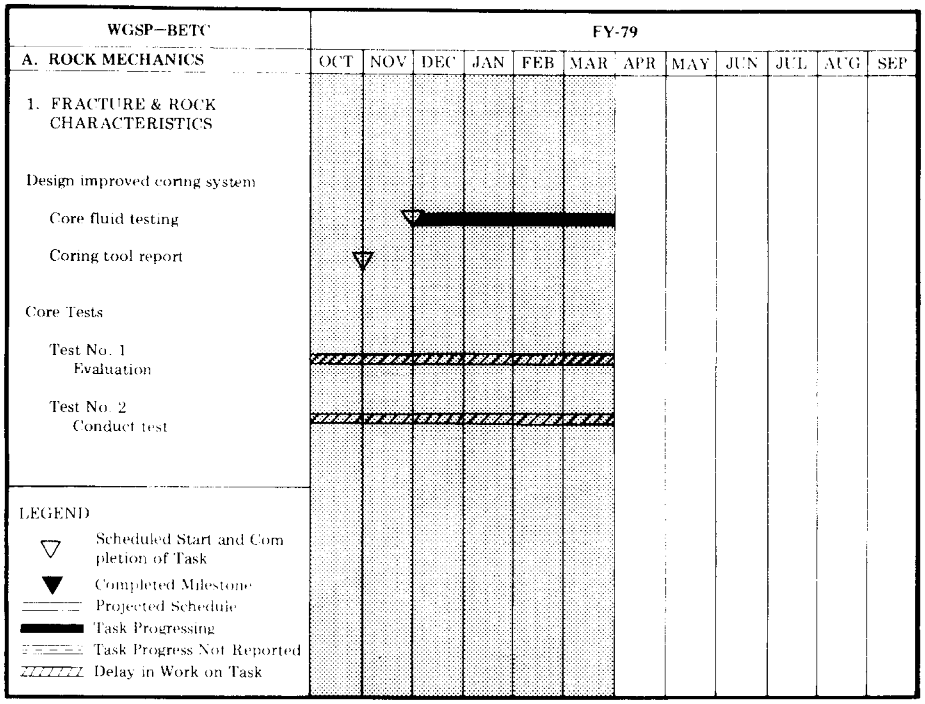


Figure 4-7 Effect of Pore Pressure on Gas Permeability Pressure Pulse Decay Measurements



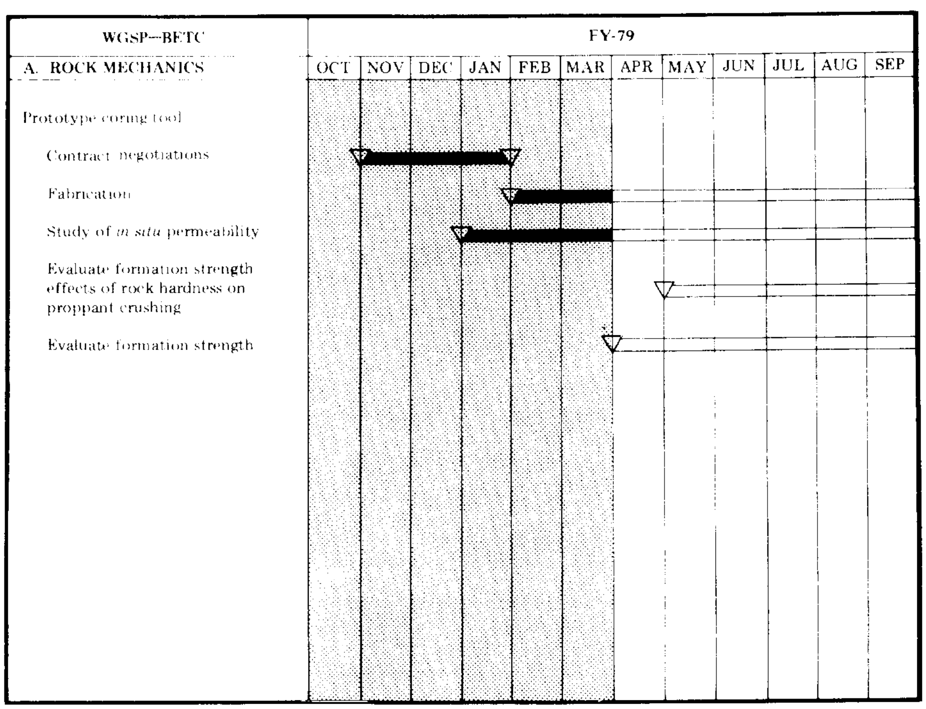
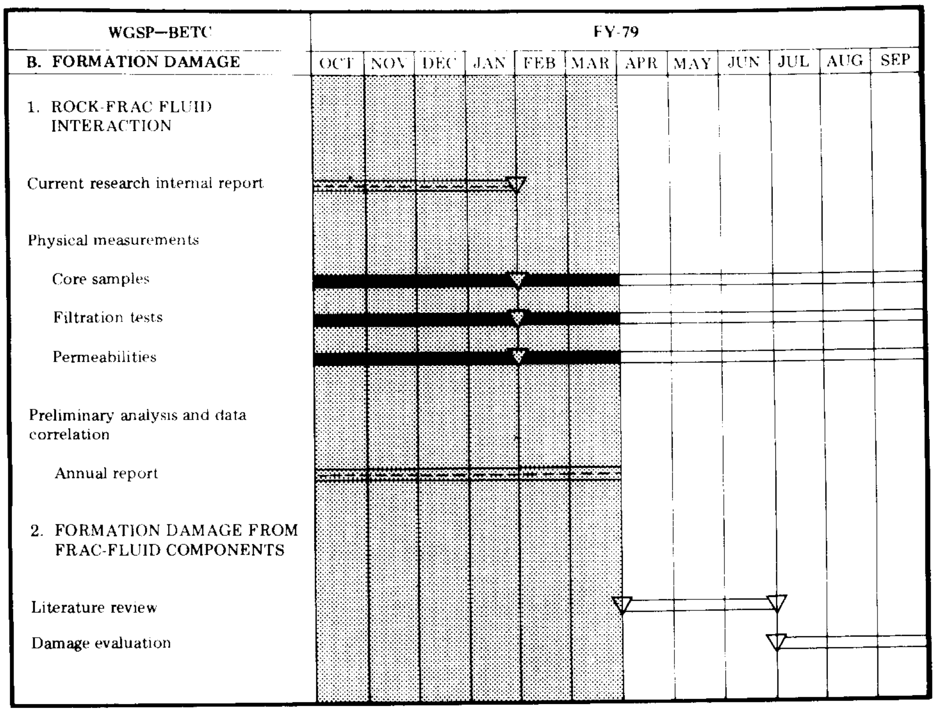


Figure 4-8 Milestone Chart — BETC



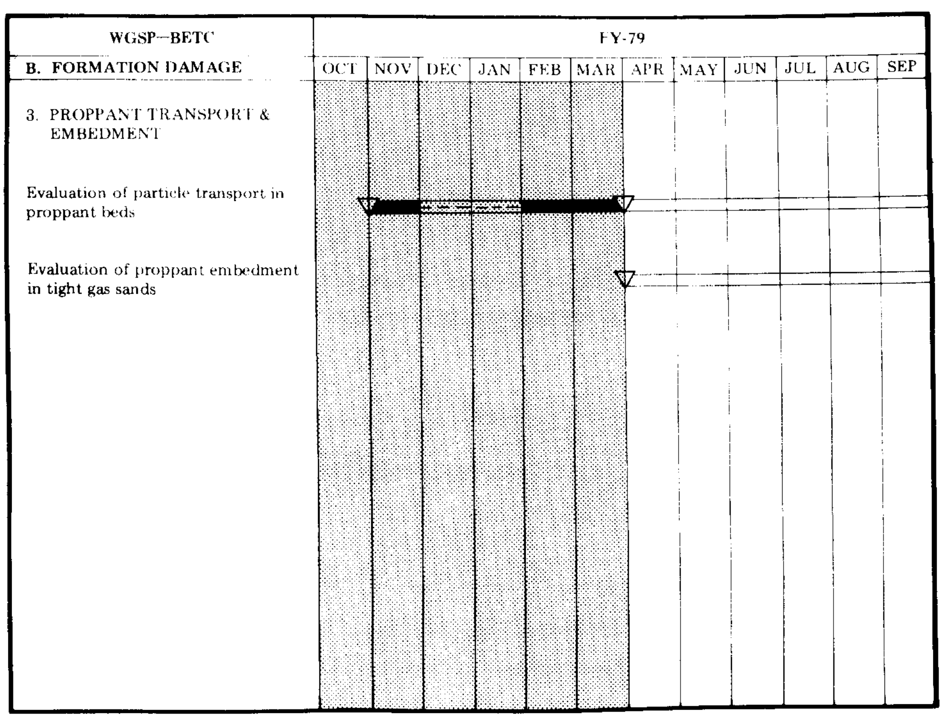
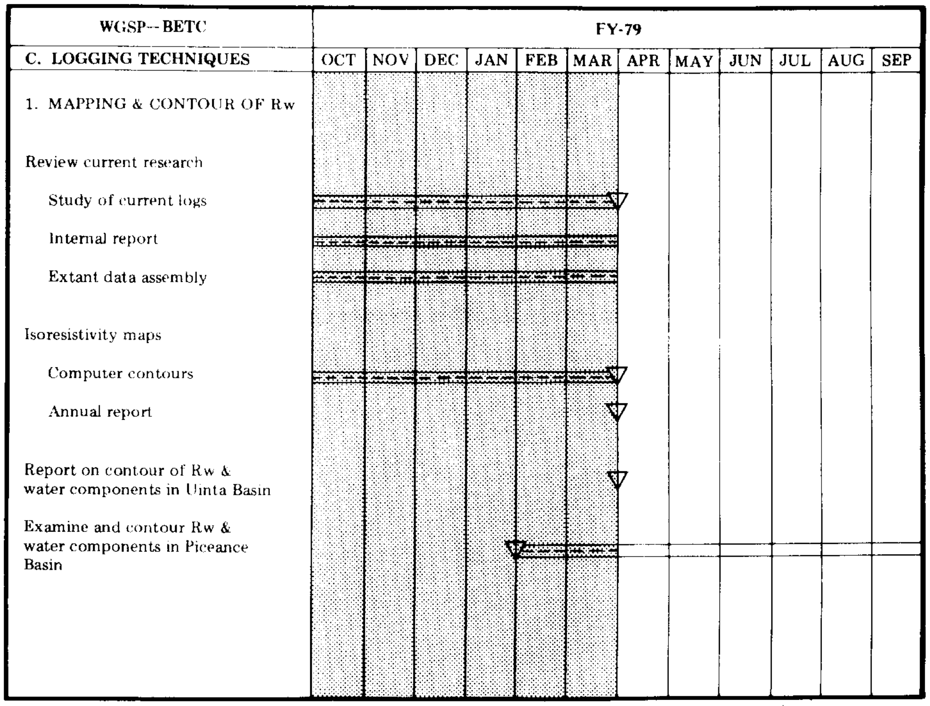


Figure 4-8 Continued



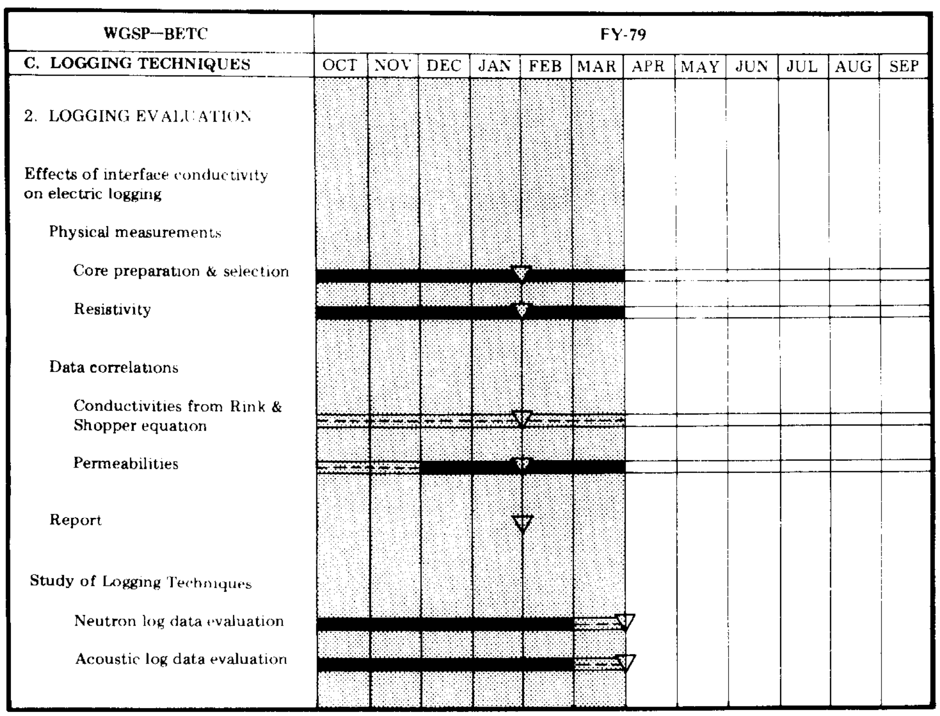
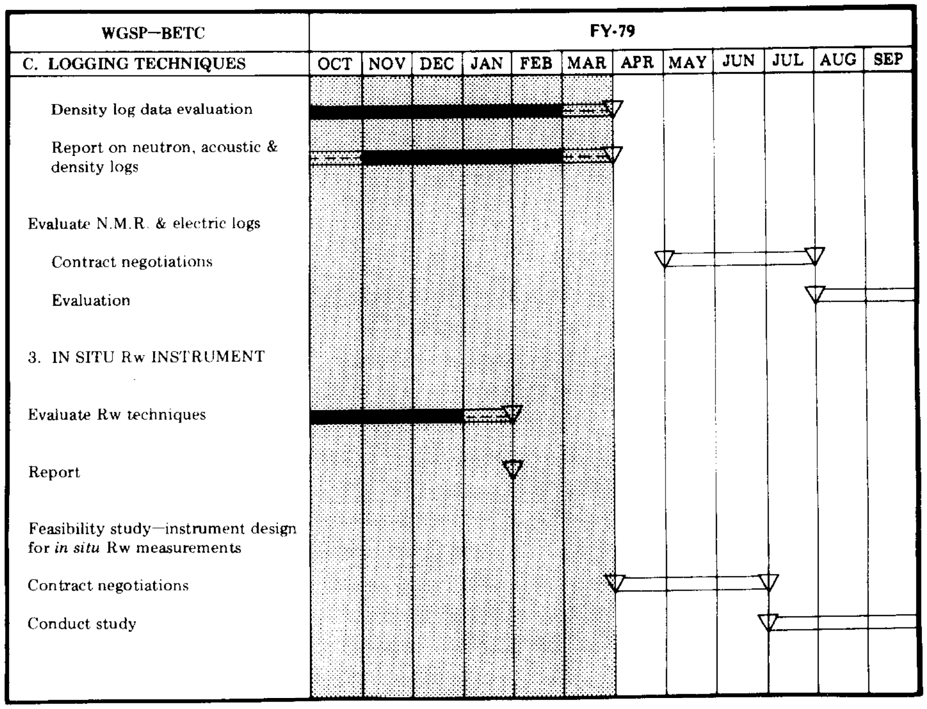


Figure 4-8 Continued



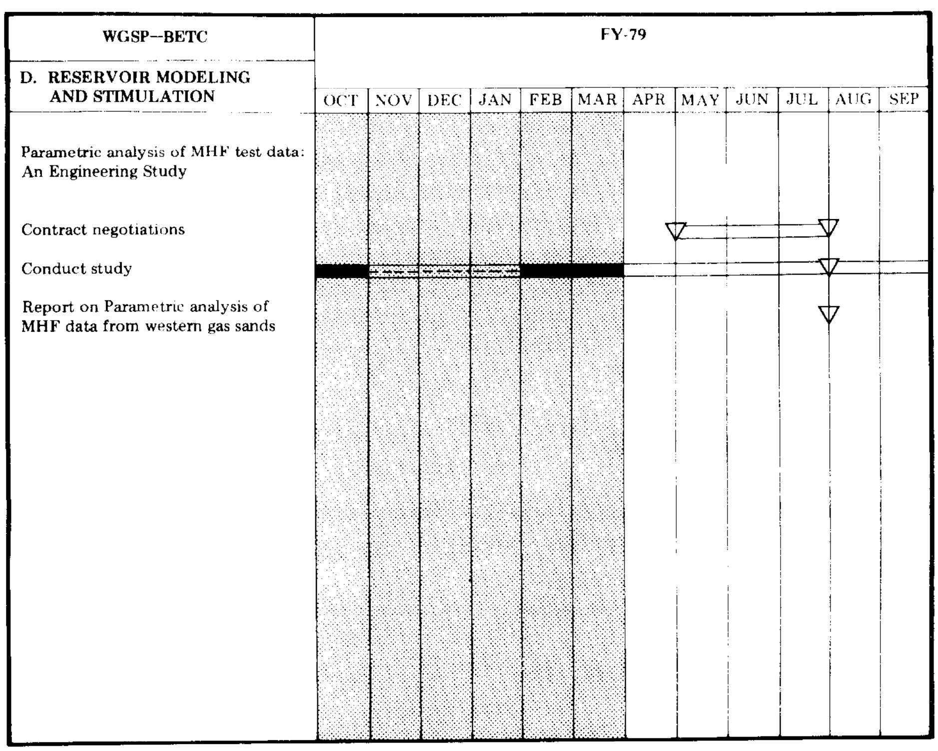


Figure 4-8 Continued

a free boundary were made. Crack propagation was enhanced as the adjacent material became less rigid. The amount of enhancement, however, was less than expected for the static case if the crack was stationary. Calculations will be performed where the crack has stopped at the interface and the character of displacements in this region will be analyzed.

4.2.2 Experimental Program

Laboratory experiments designed to study frictional forces between rock surfaces are continuing. A typical record from an experiment to measure sliding friction between smooth limestone surfaces was shown in the 1 January 1979 - 31 January 1979 WGSP Status Report. In this type of experiment a large relative displacement (∿ 2 in.) occurs. As a result of the sliding, the nature of the rock surfaces changes. A considerable amount of limestone is pulverized and a layer of powdered rock builds up in the sliding interface and acts as a lubricant. Frictional measurements after the first few increments of displacement are not representative of the frictional characteristics of the rock interface as it exists in one of the hydraulic fracture experiments. To obtain a more representative measure of the frictional character of the surface, experiments have been performed in which the applied frictional driving force at each level of the applied normal load is increased only until sliding is initiated and then released slightly. The normal load is then increased and the process is repeated. In this type of experiment, the total relative displacement during an entire run is less than 1/4 in. and the resulting damage to the interface is much less than in the previous type of experiment. A record from this type of run is shown in Figure 4-9. The horizontal scale is time which increases from right to left. The stairstep record is the amplitude of the normal load across the interface while the spikes are the amplitudes of the frictional driving force necessary to initiate slip at that value of the normal load. From a series of experiments on dry Indiana limestone with smooth surfaces a mean value of μ = 0.51 was obtained for the coefficient of static friction. In the hydraulic fracture experiments using smooth unbonded interfaces in dry Indiana limestone, it was found that the threshold normal stress across the interface for hydraulic crack growth was about 650 psi. At that normal stress level the friction experiments indicate that a shear stress of about 350 psi can be transmitted across that interface before significant microscopic slippage will occur. This number compares to about 7 percent of the shear strength and 43 percent of the tensile strength of Indiana limestone.

4.2.3 Rock Mechanics Measurements

During March, measurements and data reduction for material from the Mesaverde Group, Rio Blanco County, Colorado continued. Work on this material included the following:

- Uniaxial stress loading in compression to determine failure envelopes,
- Data reduction for Brazil tests and,
- Preparation for jacketing the samples for pressure/volume determination were started.

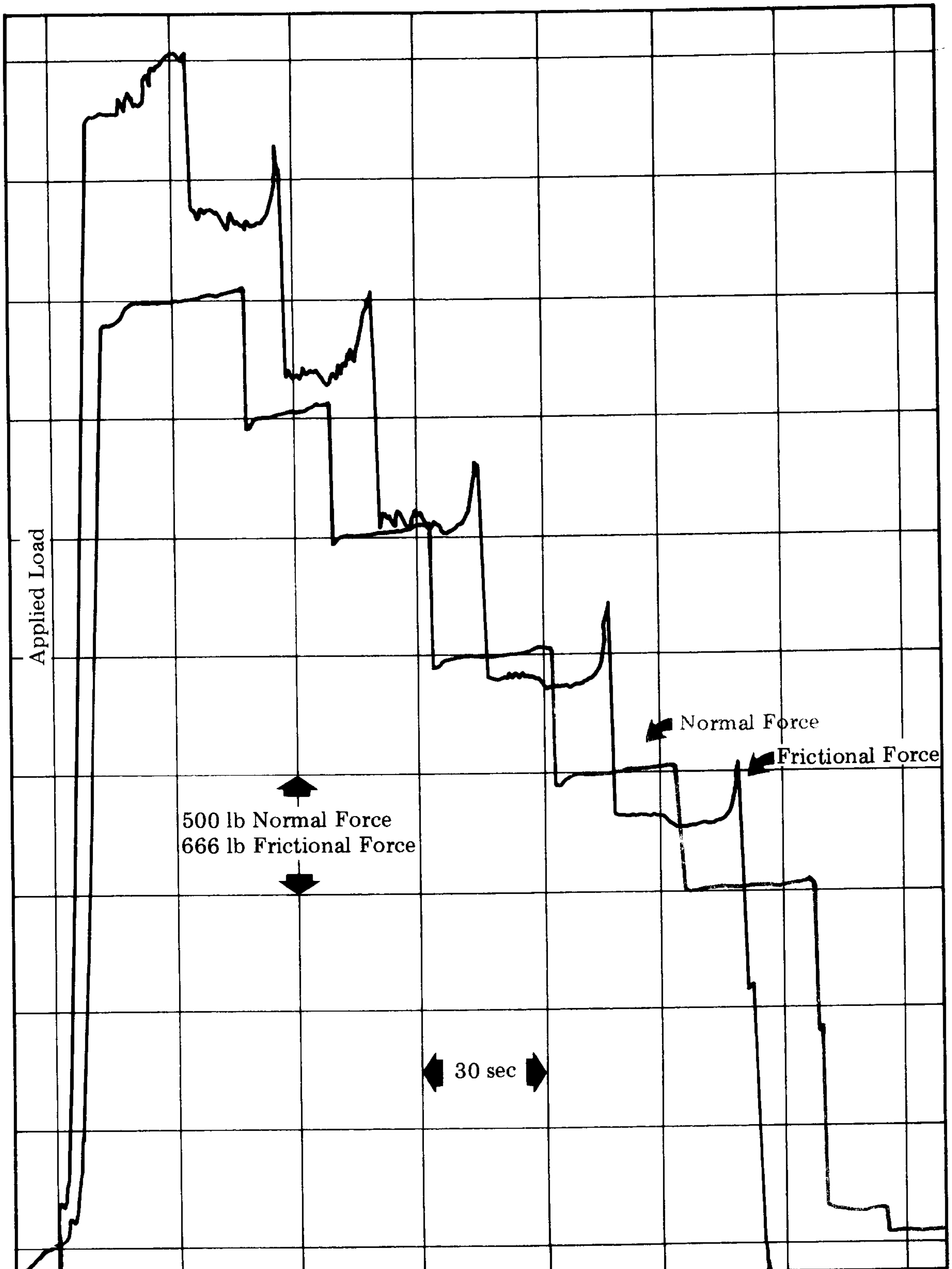


Figure 4-9 Record from Static Friction Measurement of Indiana Limestone

4.2.4 Logging

The first deployment of the LLL dryhole acoustic logging tool was completed in the Columbia Gas Well No. 20569, Mingo County, West Virginia. The tool was plagued with some problems including the averager on the tool, an intermittent circuit, and some degradation in the signal level during the operation. Another problem occurred when interfacing with the logging truck resulted in damage to a transformer in the tool. This was caused by inadvertent connection to a high voltage supply in the truck. This latter problem resulted in the loss of a syncronization pulse when the transmitted crystals were activated. The loss of this syncronization pulse precluded the use of an analog type data recorder. Hence, the data were recorded from the scope with a polaroid camera.

Recording measurements started at 8:00 p.m., Tuesday, March 11. Over 200 pictures were recorded over the following intervals: Devonian shale 4,200 - 4,032 ft; Berea sandstone, 3,400 - 3,328 ft; Weir sandstone, 2,940 - 2,874 ft; and the Big Lime, 2,740 - 2,674 ft. Problems were encountered with receivers which failed at 3,346 ft, about halfway through the experiment; however, two other receivers continued to function throughout the experiment.

Most of the tool problems have been corrected. Work with the data indicates that it would be advisable to digitally record the data on magnetic tape in a computer compatible format to facilitate reduction and interpretation.

4.2.5 Schedule Status

Figure 4-10 is a milestone chart of LLL activities through March, 1979.

4.3 SANDIA LABORATORIES

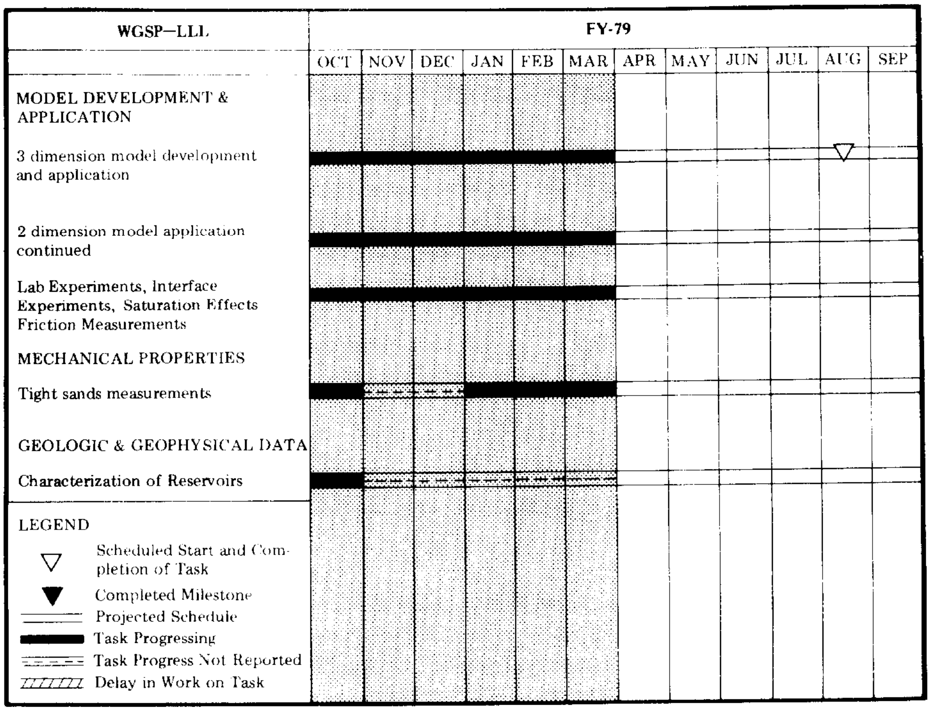
4.3.1 EGR Instrumentation and Diagnostic Program

4.3.1.1 Hydraulic Fracture Characterization

There has been no significant activity on the Surface Electrical Potential System (SEPS) this month. The SEPS hardware and software are in readiness and are awaiting a field test which is presently being scheduled.

The SEPS computer (PDP11-34) is being used to develop software for use with the borehole seismic system. The first effort was that of a three channel A/D (analog to digital) program which acquired the seismic data from magtape and stored the digital data form on an RK05 file. Each seismic event could produce up to 16,128 words of data or 5,376 words on each channel. Each channel can be sampled at a minimum of 100 microseconds. This is a sampling frequency of 10 kHz, allowing a seismic data source containing 2 kHz to be sampled. The software is complete.

A second effort to meet a minimum threshold requirement has begun on a software program for an on-site seismic acquisition and display of seismic events. Polar plots of these events are presented in near-real time and the data is written on an RK05 data file. This software capability is being developed.



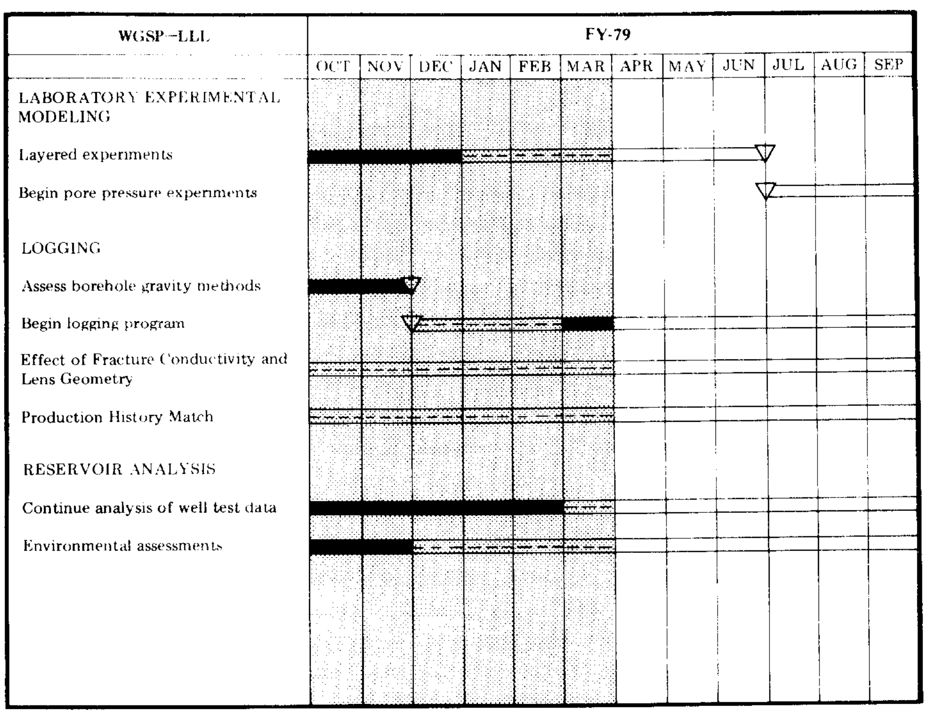


Figure 4-10 Milestone Chart — LLL

Preparations for the NTS evaluation test of the borehole seismic system have been completed. Holes in the floor of the Madison drift in the G-tunnel are now being drilled. It is anticipated that the holes will be complete by mid-April and that the tests can be completed by the first week in May.

The new feed-through connector for use in electrical testing of the Edo Western hydrophones at high pressures has been fabricated, checked, and found to be operating properly to 10,000 psi. Arrangements are being made to commence the electrical testing of the hydrophone at the higher pressures.

Electrical circuits and all hardware for a complete hydrophone system are now available for assembly. The first hydrophone unit will be assembled after high pressure electrical testing is completed.

Investigation into the design and fabrication of a directional system that would have the capability of determining azimuthal direction of fracture oriented acoustic signals has been initiated.

A second hydraulic fracture was initiated from Hole 6 in October, 1977. The packer interval was set between 37 and 43-1/2 ft above the wellbore bottom in a region of welded tuff. The welded tuff extends downward approximately eight ft below the bottom of the packer interval where a transition region begins. This transition region is approximately eight ft thick and is sandwiched between the welded tuff above and an extended region of ashfall tuff below. Four triaxial geophone packages were grouted into the ashfall tuff approximately 200 ft northeast of the wellbore. Seismic signals induced during the hydrofracture operation were recorded by the geophone array.

Due to the small signal levels and presence of large periodic noise components, filtering was necessary before the location of the seismic event foci could be determined. An adaptive filter using the "Widrow-Hoff least mean square algorithm" was applied to the data. This filter resulted in more than 30 db attenuation of the periodic noise components. After filtering the time signature and hodogram (particle velocity direction), plots were produced. The time of arrival of the P and S phases as well as the P wave particle velocity direction were chosen from these plots. Eight events were of sufficient strength to be located. Two methods were used to locate the event foci. The "vector" method made use of the P wave particle velocity direction and the time difference between P and S phase arrival at each geophone. The "S-P" solution utilized the time difference between P and S phase arrivals at three sets of geophones. Solutions for all eight events are shown in Figures 4-11 and 4-12.

The majority of events are located northwest of the wellbore, while the remainder were observed in the northeast. Hydrofracture number one propagated northeast from the wellbore perpendicular to the direction of least principle stress in the ashfall tuff. Although stress measurements have not been performed in the welded tuff, the direction of least principle stress is thought to be nearly the same as in the ashfall tuff. Natural fractures in the welded tuff, however, are known to be oriented northwest. Thus, slip activity induced into the natural fracture system may be responsible for the seismic activity in the northwest which was observed during the second hydraulic fracture.

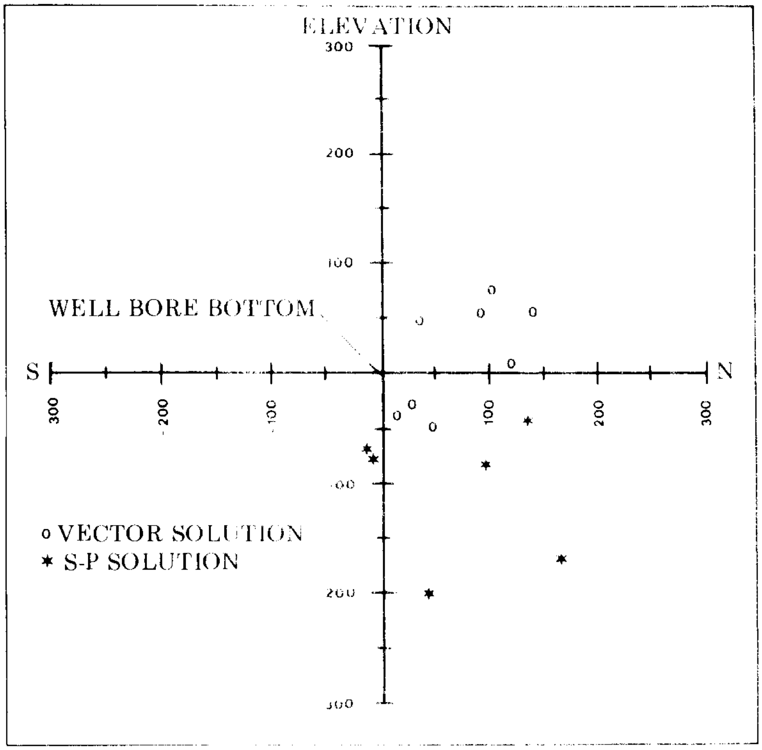


Figure 4-11

Seismic Signal Locations During Second Hole No. 6 Hydraulic Fracture; Elevation.

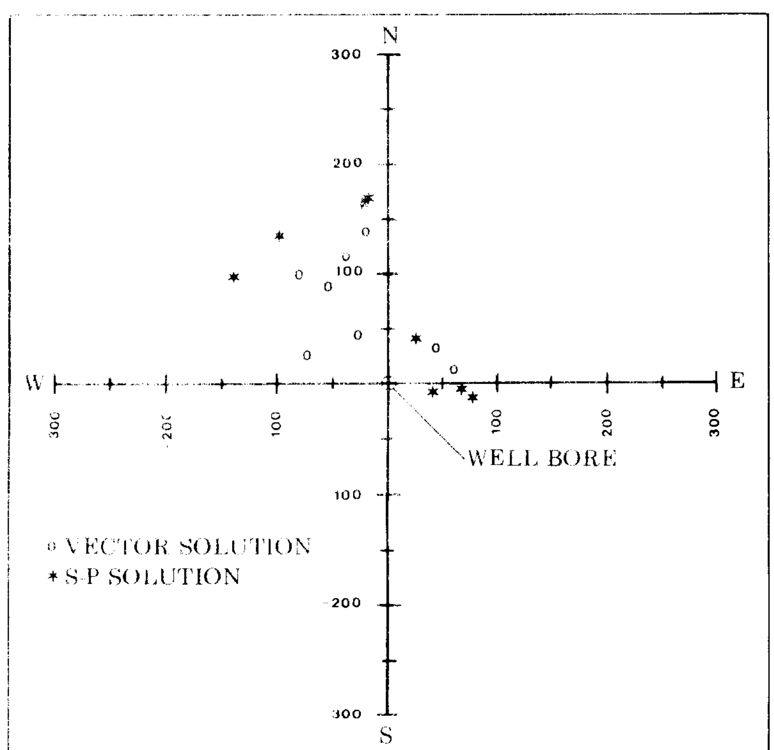


Figure 4-12

Seismic Signal Locations During Second Hole No. 6 Hydraulic Fracture, Plan View.

4.3.1.2 Advanced Borehole Logging

Sandia technical staff members visited Chevron Oil Field Research Company laboratories to provide an update of Sandia activities on logging research and to further discuss the joint Sandia-COFRC program of nuclear magnetic resonance (NMR) applications to low permeability gas sandstone reserviors. The proposed objective of this program is to subject eleven cores from the CIGE No. 21 well from the Uinta Basin to analysis to determine petrophysical parameters, such as porosity, permeability, clay mineralogy, acoustic properties and pore size distribution, and combine these with measurements of the nuclear magnetic resonance response of these samples. Prior studies on higher permeability reservoirs have shown a relationship between NMR and characteristics such as permeability and residual oil saturation. Similar analyses should be applied to the low permeability, clayey sandstones typical of the WGSP to determine if similar relationships can be expected. Formalization of program operations and responsibilities is currently underway with hopes that it will be in progress starting April, 1979.

Development of the computer code, INDINV, to model the response of an induction tool in a borehole with variable conditions of horizontal layering and depths of filtrate invasion is progressing very slowly. Formulation of the proper treatment at the source edge has not been accomplished. It is expected that r^{-2} and r^{-3} terms in the electromagnetic fields near the magnetic dipole source require a fine mesh near the source to resolve the behavior. An alternative approach that can be used for code testing is to make the source region larger. These methods remain to be tested. The difficulty is now thought to be problem resolution near the source rather than trouble with boundary conditions.

4.3.1.3 Formation Mapping

Visits to the preferred survey site in east-central Utah are presently hampered by snow pack in the area. Recent discussions with Dr. Carroll Knutson of C. K. GeoEnergy indicate that a site visit should be possible in mid-April. This visit will coordinate seismic, outcrop and core-hole drilling studies, layout possible seismic lines, determine presently available subsurface well control in the area, and anticipate problems regarding land access and permitting associated with the proposed survey.

4.3.2 Schedule Status

The status of Sandia's WGSP activities is shown in Figure 4-13.

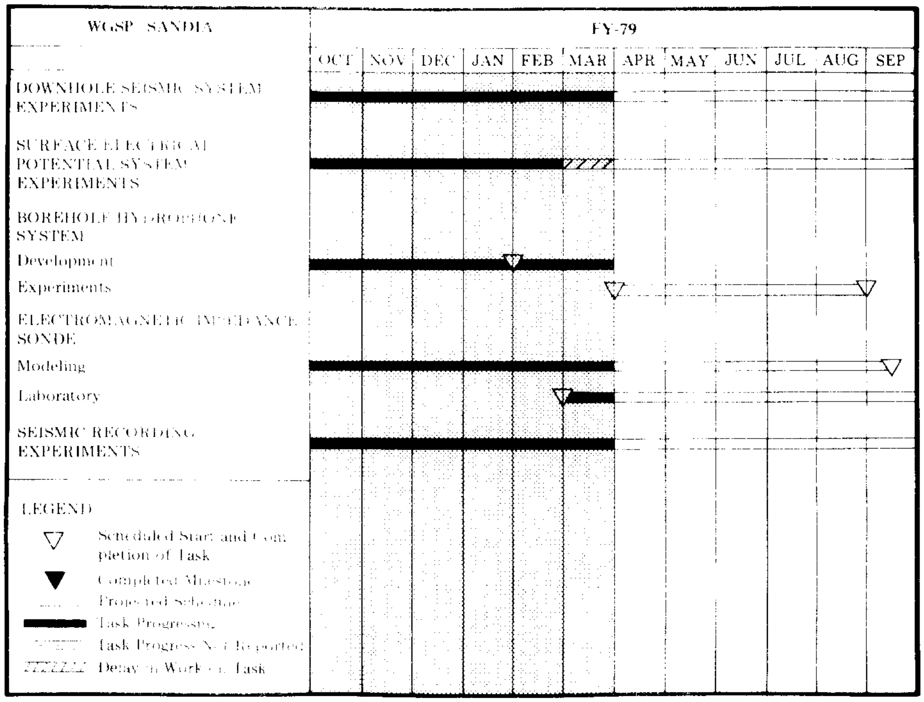


Figure 4-13 Milestone Chart Sandia

5. FIELD TESTS AND DEMONSTRATIONS

5.1 BACKGROUND

The following projects are in 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, and
- A mineback testing program by Sandia Laboratories.

The CER Corporation RB-MHF 3 is on an inactive status pending satisfactory contractual arrangement to perform additional tests, and for final disposition of the well. The final report on the RB-MHF 3 will be distributed by the end of April.

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 ft	FRAC DATE	FRAC TREATMENT Lb of Sand	INJECTED FLUID 10^3 Gal
AUSTRAL Piceance, Mesaverde	7S/94W, Sec 3 Garfield Cty Colorado	Federal 3-94	5,170- 6,333	8-25-76	1,140,000	542 Gel Gel H O
CONSORTIUM MANAGED BY CER CORPORATION Piceance, Mesaverde	3S/98W, Sec 11 Rio Blanco Cty 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/Sec 10 Uintah Cty Utah	Natural Buttes No. 18	6,490- 8,952	9-22-76	1,480,000	745 Gel
	10S/21E/Sec 21 Uintah Cty Utah	Natural Buttes No. 19	8,909- 9,664 7,224- 8,676	9-21-76 9-28-76	424,000 784,000	280 Gel 364 Gel
	9S/21E/Sec 22 Uintah Cty Utah	Natural Buttes No. 14	6,646- 8,004	3-15-77	1,093,000	544 Gel
	9S/21E/Sec 28 Uintah Cty Utah	Natural Buttes No. 20	8,498- 9,476	6-22-77	826,000	322 Gel
	10S/22E/Sec 18 Uintah Cty Utah	Natural Buttes No. 22	6,858- 8,550	11-21-77	1,091,000	479 Gel
	9S/21E/Sec 19 Uintah Cty Utah	Natural Buttes No. 9	5,661- 8,934	3-27-78	554,000	349 Gel
	10S/21E/Sec 29 Uintah Cty Utah	Natural Buttes No. 2	7,251- 8,774	8- 8-78	1,965,000	722 Gel
	10S/22E/Sec 7 Uintah Cty Utah	Natural Buttes No. 23	5,080- 6,294	10- 4-78	440,000	240 Gel
DALLAS PRODUCTION Fort Worth, Bend Cong.	Ben D. Smith Survey A-779 Wise Cty Texas	Ferguson A-1	5,957- 6,794	9-10-76	506,000	139 Foam 198 Emul
EL PASO NATL. GAS Norther Green River, Fort Union	30N/108W/Sec 5 Sublette Cty 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
MITCHELL ENERGY Cotton Valley, Limestone Trend	Limestone Cty Texas	Muse-Duke No. 1	11,220-11,430	11-15-78	2,800,000	891 Gel
MOBIL Piceance, Mesaverde	2S/97W/Sec 13 Rio Blanco Cty Colorado	F-31-13G	10,549-10,680 9,392- 9,538 8,765- 8,972 8,163- 8,650 7,704- 7,794 7,324- 7,476	6-22-77 8-24-77 5-10-78 7- 6-78 9- 7-78 11-15-78	580,000 600,000 388,000 660,000 218,000 700,000	316 Gel 260 Gel 150 Gel 288 Gel 120 Gel 365 Gel
PACIFIC TRANSMISSION Uinta, Mesaverde	8S/23E/Sec 25 Uintah Cty Utah	Federal 23-25	NO FRACS PERFORMED			
RIO BLANCO NATL. GAS Piceance, Mesaverde	4S/98W/Sec 4 Rio Blanco Cty 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/Sec 34 Uintah Cty Utah	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

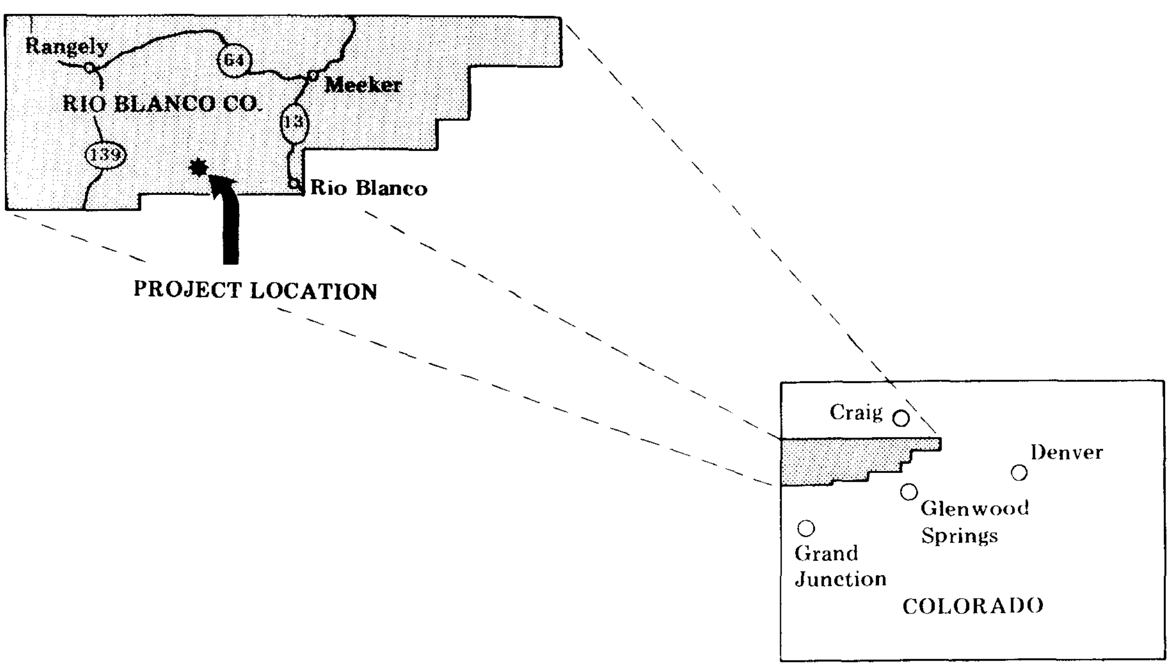
CER Corporation
Las Vegas, Nevada

Status: Awaiting Advisory Committee Decision

Interagency Agreement Date:	June 19, 1974	
Anticipated Completion Date:	July 1, 1979	
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

Field activities on the Rio Blanco MHF-3 well have been suspended. Negotiations have taken place with an outside party to complete the commingling of fractured 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.

The final report on the RB-MHF 3 will be distributed by the end of April.

WATTENBERG FIELD

EY-77-C-08-1514

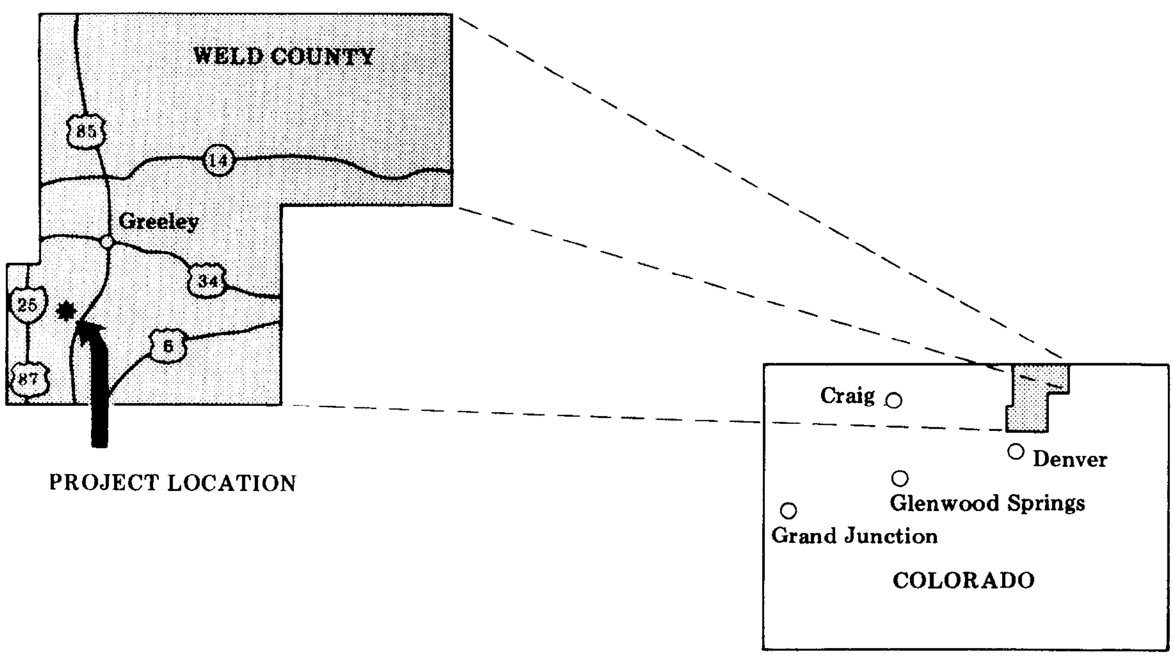
Colorado Interstate Gas Company
Colorado Springs, Colorado

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

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

The Ajax "DPC-160/H2" compressor and packing case has been installed at the Sprague No. 1 well site.

Three Rolo dry bed dehydrators have been delivered and installed.

Measurement of bottom-hole pressure in the Miller No. 1 and Sprague No. 1 wells is continuing. Bottom-hole pressure at the Miller No. 1 well is increasing slowly and inconsistantly at 4 to 6 lb per day and an average of 3 lb per day at the Sprague No. 1 well. Since it is not advantageous to continue to measure BHP at this rate of buildup, the cycling process will be started as soon as all of the equipment is installed and working properly.

DOE WELL TEST FACILITY — EY-76-C-08-0623

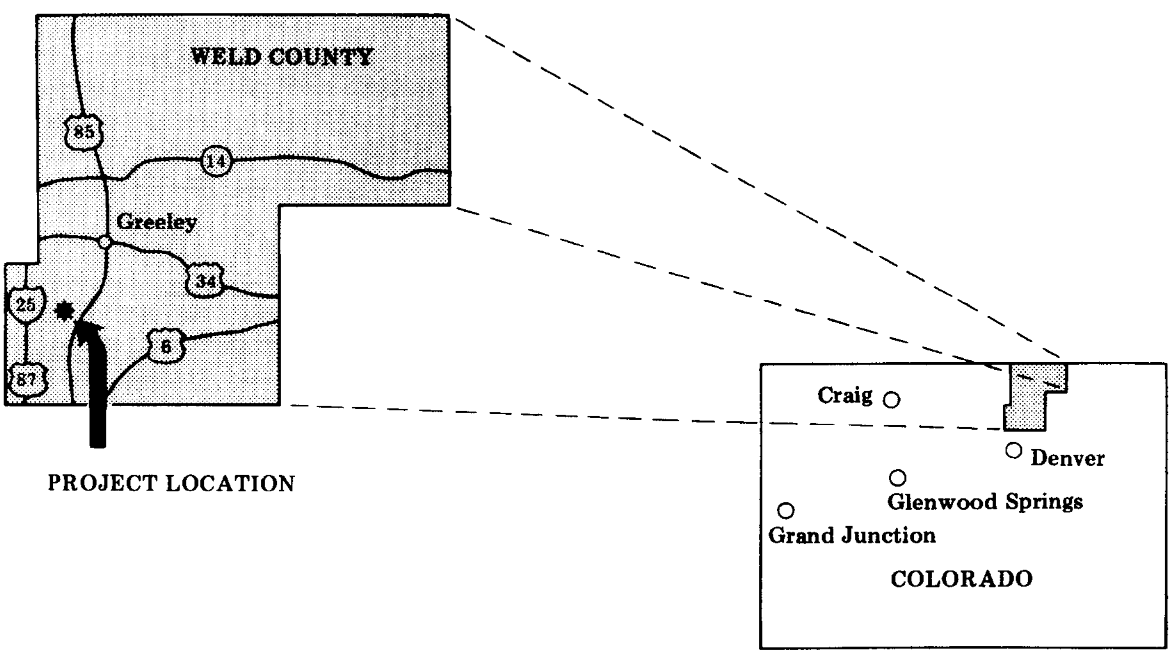
CER Corporation
Las Vegas, Nevada

Status: Equipment checkout and test proceeding

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

OBJECTIVE

The DOE 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

CER's support contract includes the operation of a well test facility at various locations selected by DOE. A 10 ft x 50 ft trailer, a two-ton truck equipped with a hydraulically controlled telescoping 50 ft mast, and two trailer-mounted 30 kw and 90 kw electric generators comprise the facility.

The DOE Well Test Facility has been on location at the Miller No. 1 well site in the Wattenberg field since the third week in February. The facility is being utilized to acquire bottom hole pressure buildup data from the Miller No. 1 well in support of the joint DOE/CIG Cyclic Dry Gas Injection Project.

5.4.2 Current Status

Before running bottom hole pressure and temperature gauges into the Miller No. 1 well, sinker bars were lowered in order to assess the condition of the tubing. A soft obstruction was encountered in the tubing at 7,820 ft, about 70 ft above the perforated intervals. CIG flushed the tubing with nitrogen. Nitrogen circulation continued until an impenetrable obstruction was encountered at 7,830 ft, at which time the operation was discontinued.

The well was blown down until water production became imperceptible. The H.P. pressure gauge and G.O. temperature tool were lowered to 7,810 ft and the well then produced at 100 MCFD for about 74 hrs. The well was shut in on March 13, and the measured initial pressure (P_{ow}) was 506.6 psia. Table 5-2 is an abridged list of bottom-hole and surface build-up data for the Miller No. 1 well acquired up to and including March 31. Since data was taken every 10 min., there were over 2,000 data points. A complete list of the data will be made available after the buildup test is completed. Both G.O. multiplexing temperature tools became inoperable and no further real time downhole temperature data was available after 3:00 p.m. March 23. A temperature of 248^{o}F was manually set into the G.O. pressure data processor. This value is in agreement with bottom-hole temperature data taken from the Sprague No. 1 well.

The obstruction at 7,830 ft made the condition of the tubing and casing uncertain, therefore surface tubing and surface casing pressure measurements were taken at varying time intervals. Figure 5-1 is a plot of the surface tubing pressure and surface casing pressure versus buildup time. Communication existed between the tubing and casing, (as indicated in Figure 5-1) and thus the packer at 7,880 ft was either no longer functional or was bypassed.

A log-log or type curve plot of the difference between the squared pressure and squared initial pressure versus buildup time is shown on Figure 5-2. Several slopes are included as references, namely 1, 1/2 and 1/4. These slopes according to Cinco[1] are representative of wellbore storage, linear fracture flow, and bilinear flow, respectively. Radial flow would occur last and would be defined by a set of points whose slope would be less than 1/4. The data are following along a slope that is greater than 1/4, and therefore indicate that the radial flow period has not been reached and is still in some form of linear flow.

---

[1]Cinco, H., Samoniego, F., "Transient Pressure Analysis for Fractured Wells," SPE 7490, October 1978.

Bottom-hole buildup pressure data on the Sprague No. 1 well is being gathered using a retrievable pressure bomb. The Sprague No. 1 well was shut-in on March 6. The initial bottom hole pressure was 544 psig and the temperature was 252°F (see Table 5-3).

Figure 5-3 is the type curve plot of the bottom-hole pressure derived from the data in Table 5-3. As was the case with the Miller No. 1 well, the condition of the tubing and casing were unknown. The apparent erratic behavior in the pressure was not understood and may be attributed to either or both sporatic or continuous leakage from the tubing to casing or casing to formation. Surface casing pressure was not recorded during the early buildup period. However, periodic readings are being taken and there is now an indication that the casing pressure is tracking the tubing pressure.

5.4.3 Future Plans

Tentative scheduling calls for the DOE Well Test Facility to be in the Uinta Basin, Rockhouse Section, in June and assist C. K. GeoEnergy with the acquisition of bottom-hole pressure and temperature data on Diamond Shamrock and Belco wells.

Table 5-2 DOE/CIG Cyclic Dry Gas Project Bottom Hole and Surface Build-up Data for the Miller No. 1 well.

Date	Time (hrs)	Δt (hrs)	P_{ws} (psig)	T_{ws} (F)	P_{sst} (psig)	P_{ssc} (psig)	Remarks
3/13	1005	0.0	506.59	292.3			
3/13	1015	0.167	506.57	292.3			
3/13	1025	0.333	517.59	292.3			
3/13	1035	0.500	528.76	292.3			
3/13	1045	0.667	535.06	292.3			
3/13	1120	1.250	539.89	292.3			
3/13	1200	1.917	547.11	292.3			
3/13	1255	2.833	556.46	292.3	437.	460.	
3/13	1516	5.183	586.46				
3/13	2000	9.917	621.01				
3/14	0010	14.083	640.90				
3/14	1005	24.00	675.45	291.6	504	540	
3/14	1630	30.417	691.67	289.8	550	560	
							Inoperable, temperature tool pulled at 2000 hrs and replaced
3/15	1510	53.083	728.5	248.3			
3/16	1035	75.5	755.52	247.7	600	620	
3/16	1435	79.5	760.34	247.6	612.5		
3/17	830	94.42	779.56	246.5	612.5		
3/17	1700	102.92	787.62	247.4	625.		
3/18	830	118.42	800.92	247.4	625.		
3/18	1700	126.92	807.5	247.4	630.		
3/19	800	141.92	817.9	247.2	655		
3/19	1600	149.92	823.8	247.0	637.5		
3/20	1000	167.92	835.11	246.8	650	675	
3/21	1000	191.92	848.85	246.8	662.5	700	
3/22	800	215.92	860.05	247.1		700	
3/23	800	239.92	871.41	248.2			
3/24							Inoperable, temperature tool pulled at 1400 hrs. Processor set at 248°F
3/24	1500	270.92	884.03	248*	700		
3/25	800	287.92	890.93	248*	700	735	
3/26	1000	313.92	899.77	248*	712	735	
3/27	800	335.92	908.46	248*	730	750	
3/28	800	359.92	916.37	248*	745	755	
3/29	1300	389.92	926.35	248*	745	755	
3/30	800	407.92	931.36	248*			
3/30	1700	416.92	933.99	248*	755	765	
3/31	800	431.92	938.38	248*	755	765	

* Temperature set in G.O. Processor. No bottom hole temperature available.

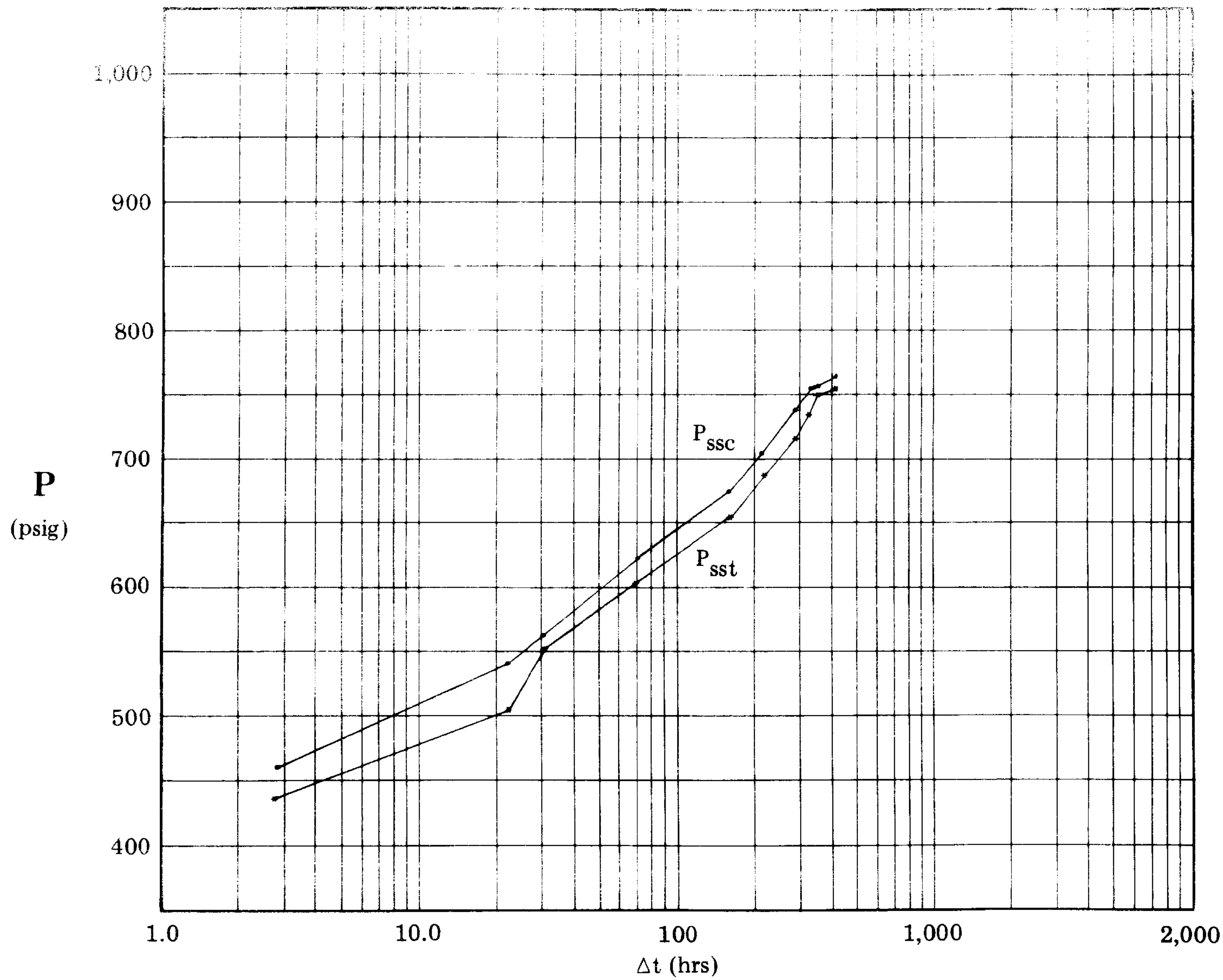


Figure 5-1 Surface Casing Pressure (P_{ssc}) and Surface Tubing Pressure (P_{sst}) versus Buildup Time Δt for the Miller No. 1 well.

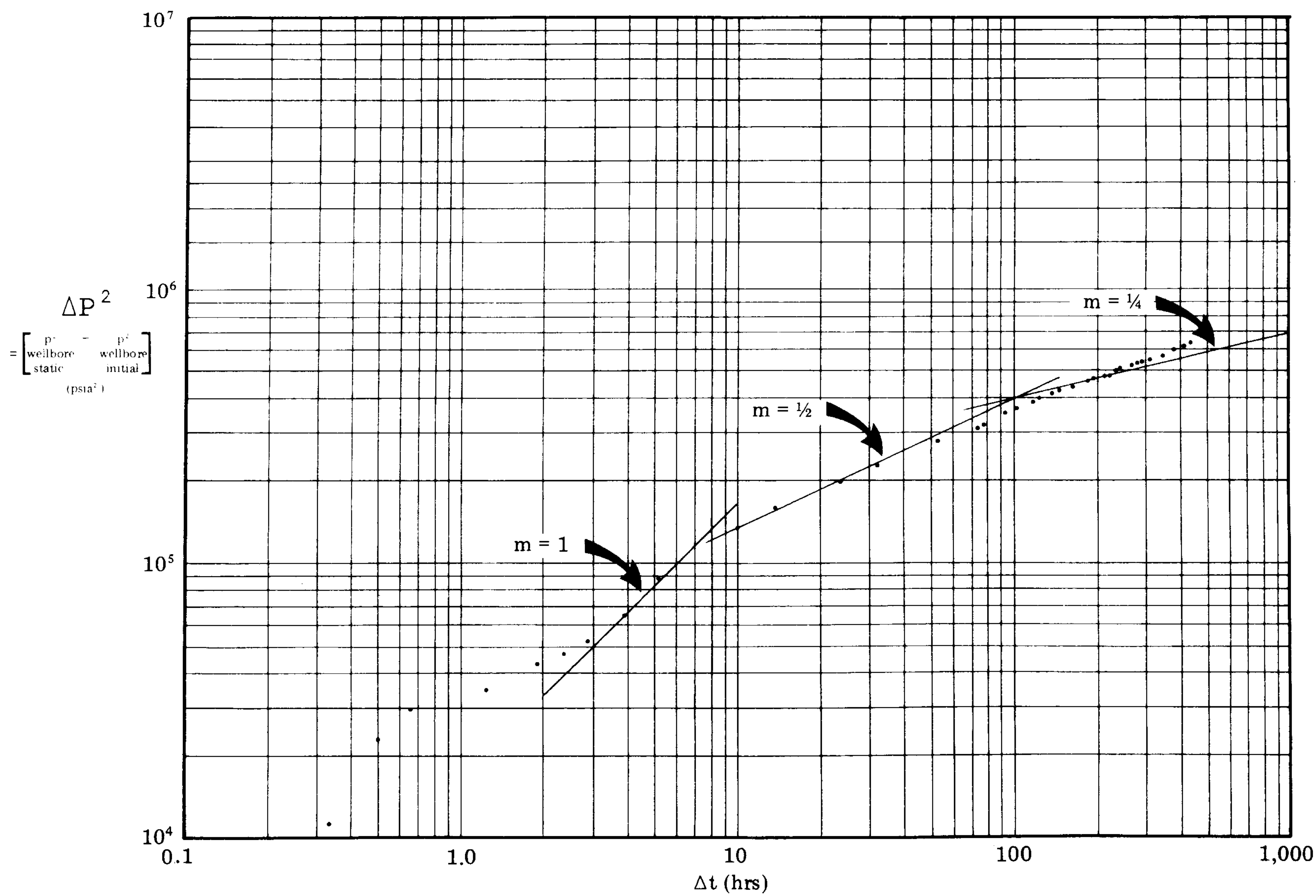


Figure 5-2 Type Curve Plot of Bottom-Hole Buildup Pressure Data for the Miller No. 1 well.

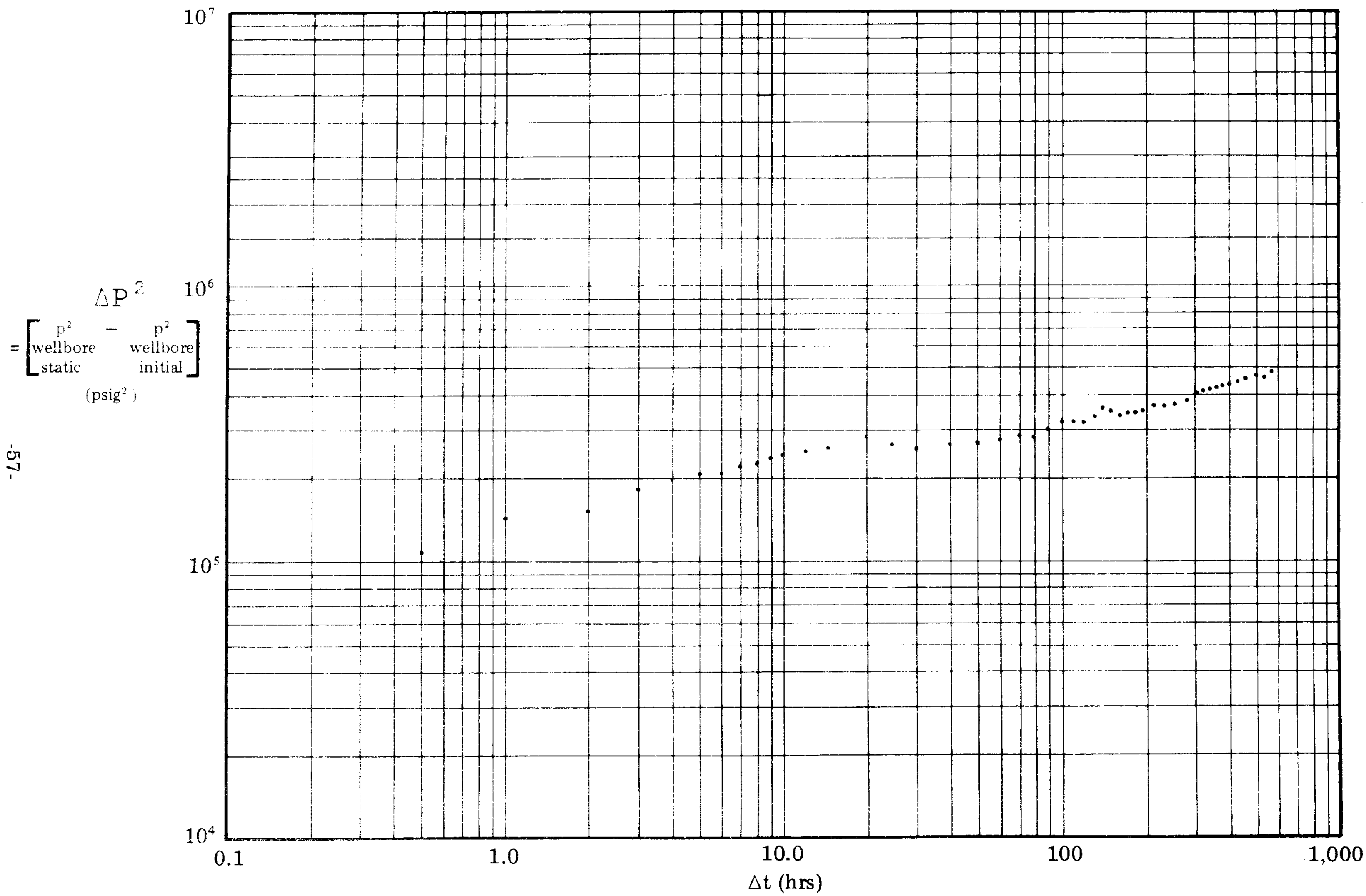


Figure 5-3 Type Curve Plot of Bottom-Hole Buildup Pressure for the Sprague No. 1 well.

Table 5-3 DOE/CIG Cyclic Dry Gas Project Bottom-Hole and Surface Build-up Data for the Sprague No. 1 well.

Date	Δt (hrs)	P_{ws} (psig)	Date	Δt (hrs)	P_{ws} (psig)
3/7	0	544	3/14	150	803
3/7	0.5	637	3/14	160	801
3/7	1.0	661	3/14	170	801
3/7	2	665	3/15	180	803
3/7	3	695	3/15	190	806
3/8	4	703	3/16	200	808
3/8	5	707	3/16	210	811
3/8	6	710	3/17	220	813
3/8	7	715	3/17	230	815
3/8	8	720	3/17	240	816
3/8	9	725	3/18	250	818
3/8	10	730	3/18	260	820
3/8	12	735	3/19	280	821
3/8	15	744	3/20	300	837
3/8	20	759	3/21	320	840
3/8	25	749	3/22	340	845
3/9	30	747	3/22	360	850
3/9	40	749	3/23	380	854
3/10	50	754	3/24	400	857
3/10	60	759	3/25	420	860
3/10	70	761	3/26	440	864
3/11	80	759	3/27	460	867
3/11	90	774	3/27	480	872
3/12	100	781	3/28	500	874
3/12	110	784	3/29	520	876
3/12	120	789	3/30	540	879
3/13	130	793	3/31	560	881
3/13	140	810			

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

EY-76-C-08-0681

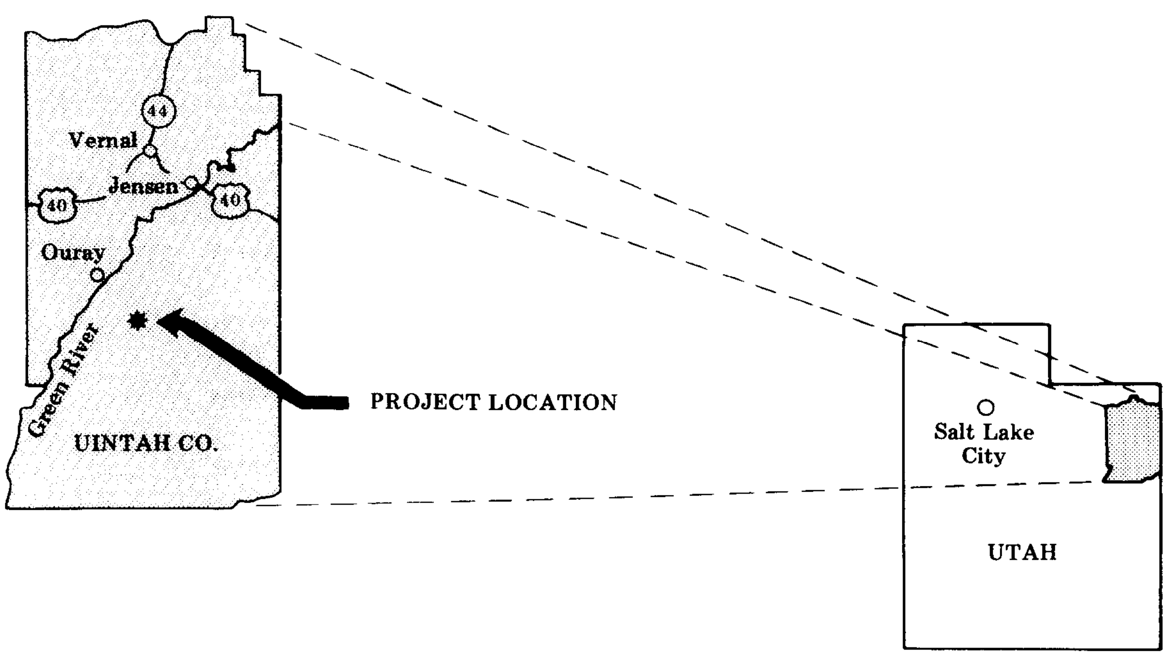
Gas Producing Enterprises, Inc.
Subsidiary of Coastal States Gas Co.
Houston, Texas

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.

The GPE wells, Natural Buttes Units 9, 14, 18, and 20 flowed to sales during March. Figures 5-4 through 5-9 show production figures for the month. Natural Buttes No. 19 and 22 were shut in and NBU No. 21 was temporarily abandoned. Table 5-4 is a summary of MHF treatments performed to date.

Table 5-4 Summary of MHF Treatments

Well	No. of Zones Perf.	Net Ft. of Pay	Net Ft. Per Zone	Average ϕ	Average SW	% Sd	Type of Fluid	Frac Job Size Gal of Gel	Lb of Proppant	Calc. Frac Length ft	Est. 1st Year Avg. Prod. Rate MCFD
Natural Buttes No. 18 DOE	18	224	12.5	10.0	48	88.0	Versa Frac	695,000	1,480,000	882	1,200
Natural Buttes No. 19 DOE	19	194	10.2	9.5	47	87.0	40# Guar Gum	655,000	1,237,000	950	60
Natural Buttes No. 14 DOE	15	271	18.0	9.9	49	65.0	YF4-PSD	544,000	1,082,000	879	600
Natural Buttes No. 20 DOE	8	65	8.1	9.9	44	88.5	YF4-PSD	309,000	826,000	1,150	800
Natural Buttes No. 22 DOE	24	196	8.1	12.0	45	85.0	YF4-PSD	478,758	1,091,000		
Natural Buttes No. 9 DOE	(35)	779*	22.0*	Unkn	Unkn	Unkn	40# Guar Gum	314,000	553,000		
CIGE 2-29-10-21 DOE Stage 1	10	91	9.1	10.0	40	80.0	MY-T-GEL III	195,000	170,500		
CIGE 2-29-10-21 DOE Stage 2	12	181	15.1	11.3	42	85.0	MY-T-GEL III	805,230	1,956,000		
CIGE 23-7-10-22 DOE	10	156	15.6	9.0	60	78.0	YF4-PSD	240,000	470,000		

*Using GR as only indication of net sand which more closely equals gross sand.

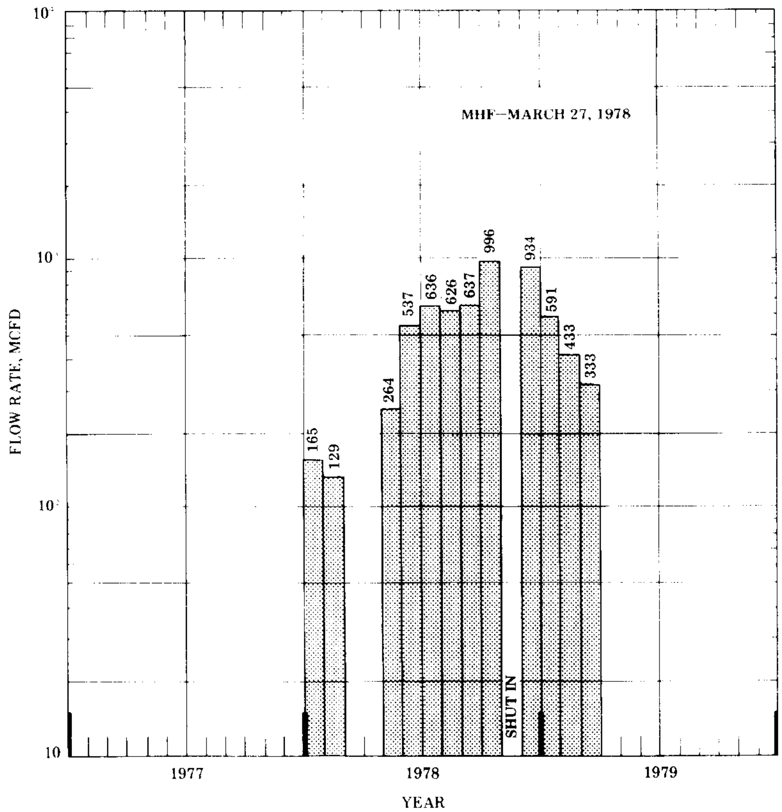


Figure 5-4
Flow Rate Performance of Natural Buttes No. 9 well

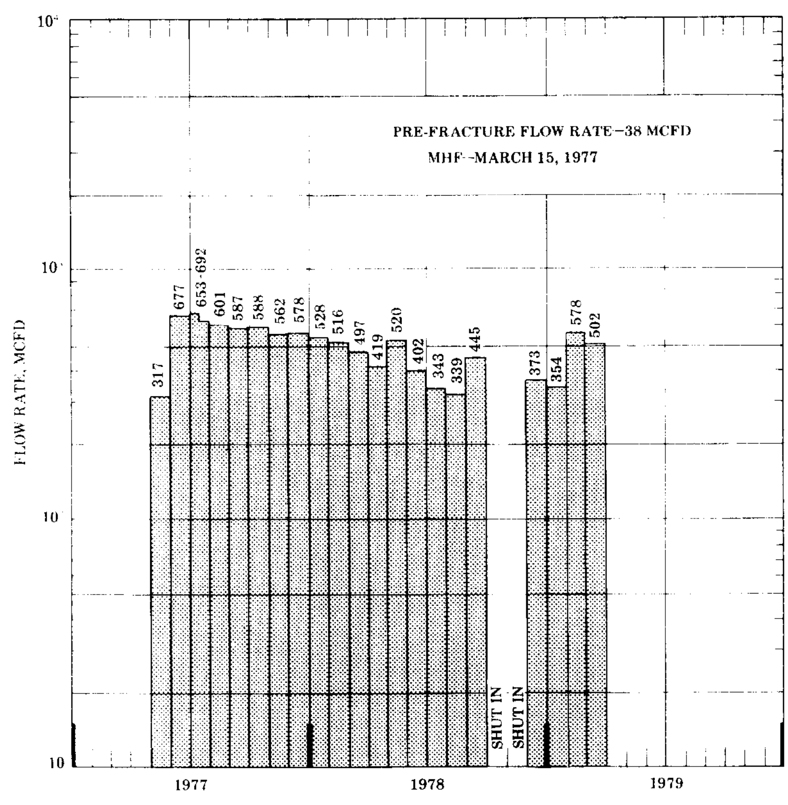
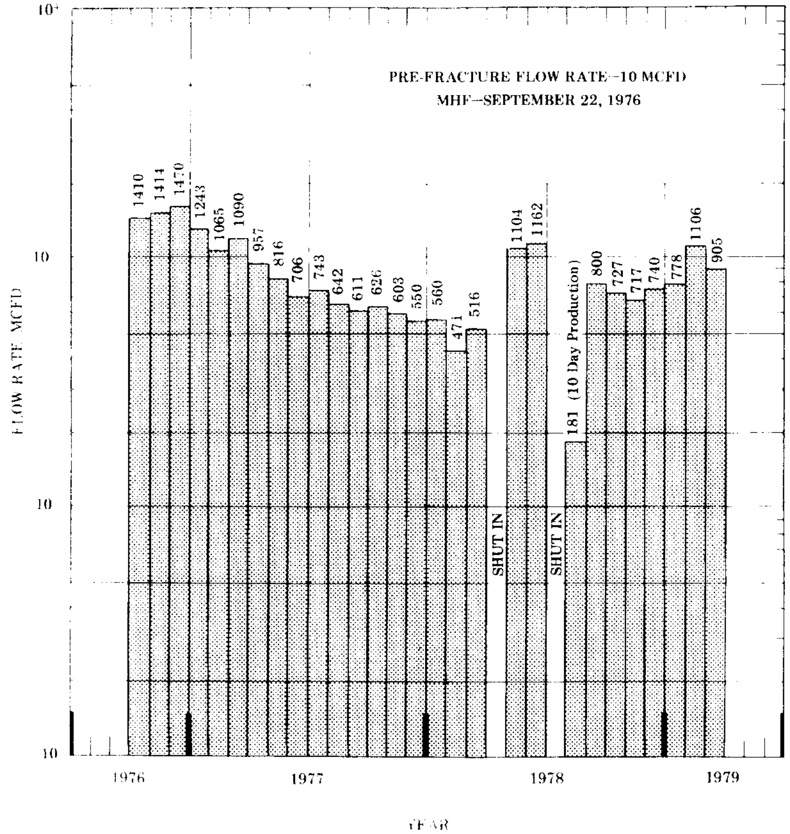


Figure 5-5
Flow Rate Performance of Natural Buttes No. 14 well

Figure 5-6

Flow Rate Performance of Natural Buttes No. 18 well



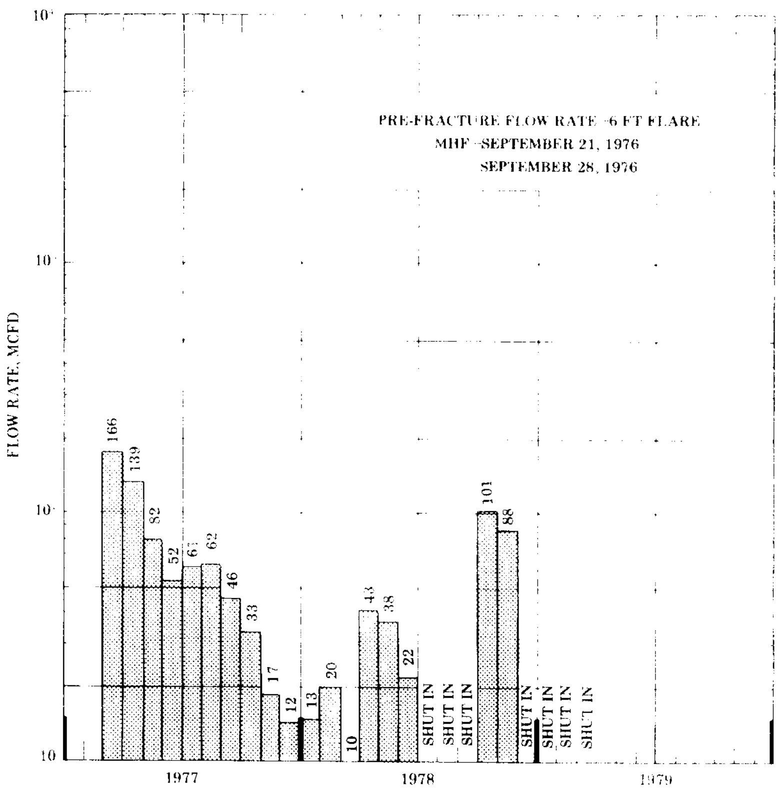


Figure 5-7

Flow Rate Performance of Natural Buttes No. 19 well

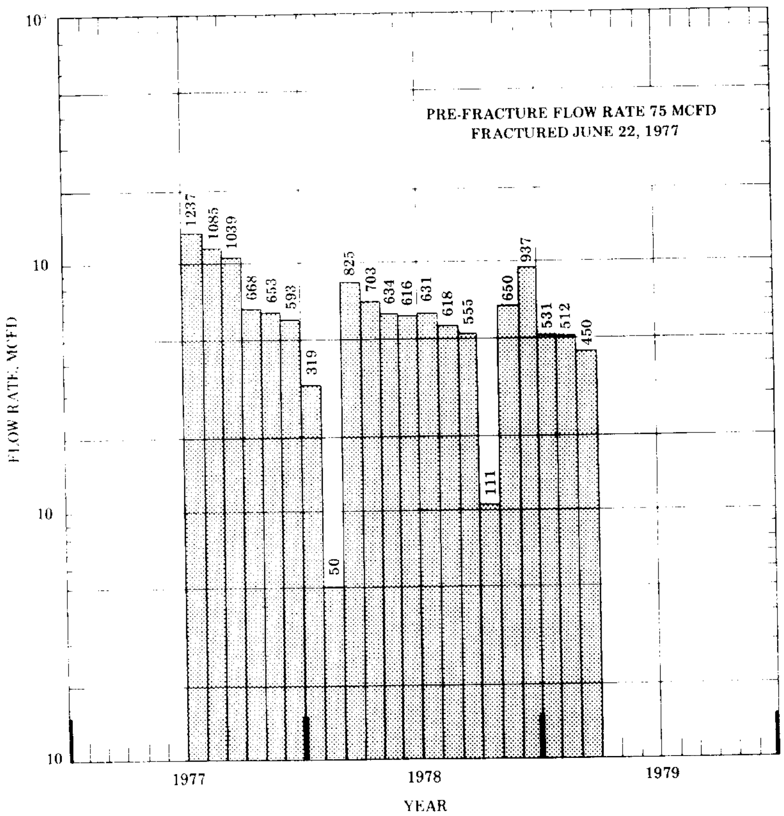


Figure 5-8

Flow Rate Performance of Natural Buttes No. 20 well

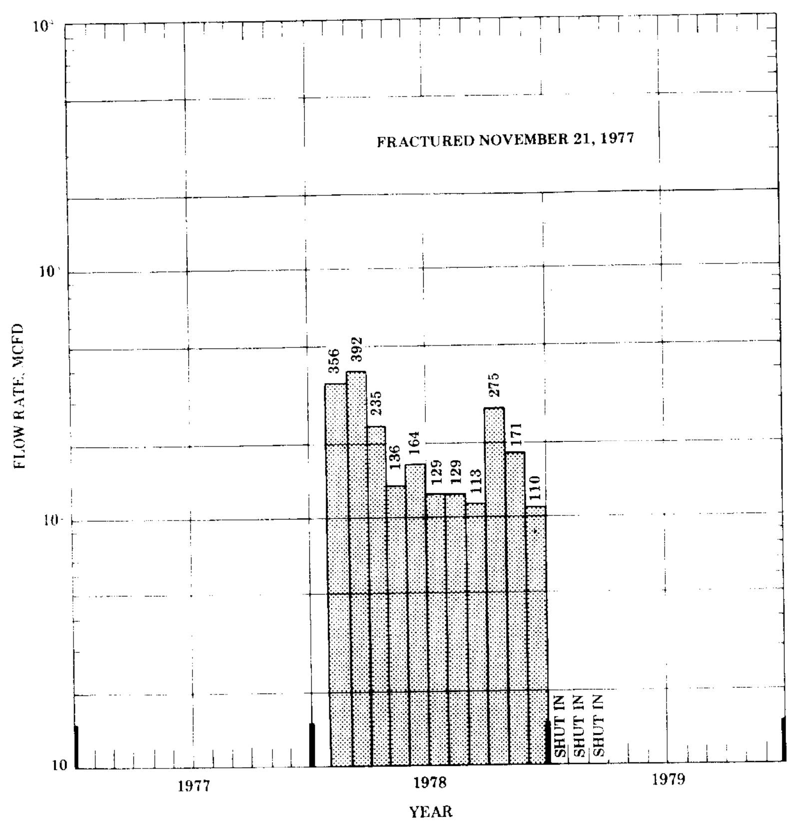


Figure 5-9

Flow Rate Performance of Natural Buttes No. 22 well

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

EF-78-C-08-1547

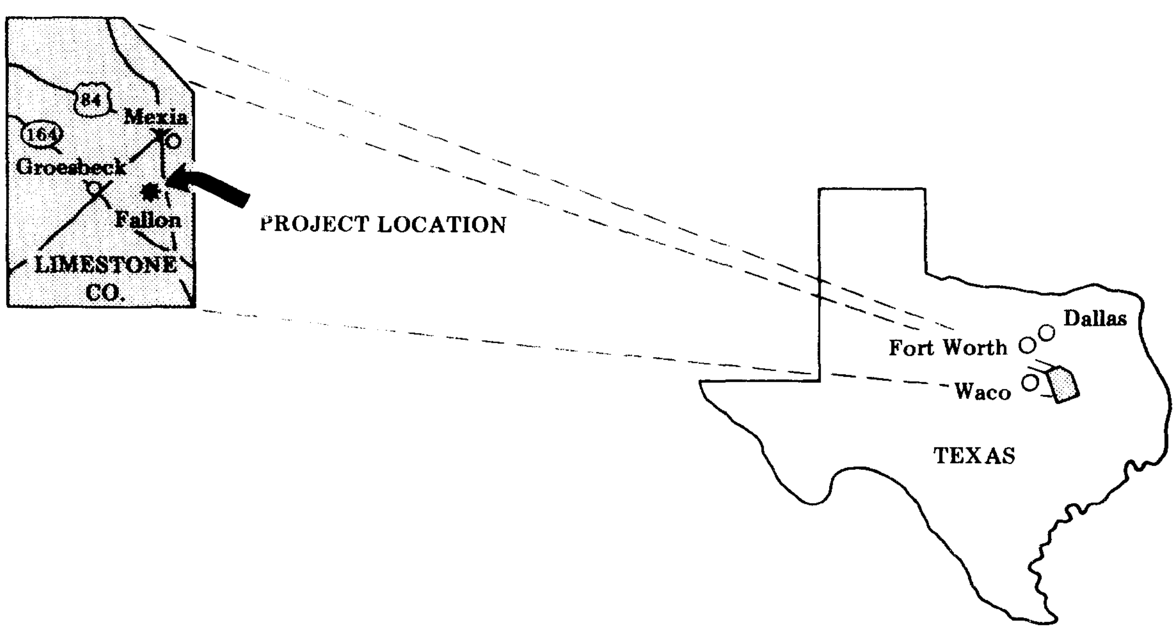
Mitchell Energy Corporation
Houston, Texas

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

The Mitchell Energy Corporation Muse-Duke No. 1 was flowing 4,000 MCFG and 25 BBL of frac water per day through a 24/64 in. choke with a flowing tubing pressure of 1,100 psi during March. Flow rates and pressures are continuing to drop at a slow rate.

The scheduled post pressure transient tests and clean-out work have not been completed.

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:	June 1st 1979

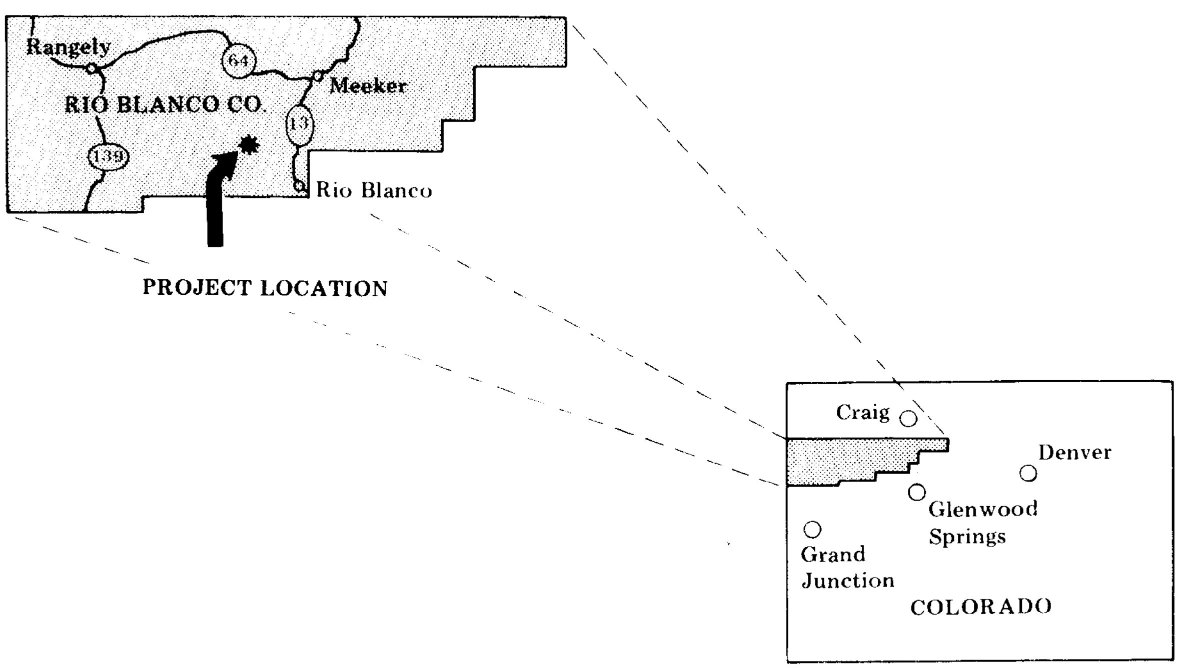
Total Project Cost (estimated):

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

5.7.1 Current Status

Efforts to clean out the PCU F31-13G well continued through March. Junk from the top plug, partially drilled up, was resting on a sand fill at about 8,829 ft. While attempting to mill-up this junk the milling equipment, including a set of jars, became stuck. This sticking was presumably due to influx of frac sand from the fractured intervals above. After backing off, the hole was circulated to remove sand and an overshot was run to retrieve the fish. During this attempt the fishing tools also became stuck.

Operations will be suspended until a thorough study can be made of the problem and a new plan of action formulated. Tubing was landed just above the fish and the well swabbed 5 days with no flow. It was then shut in.

5.7.2 Future Plans

A meeting is scheduled on April 16 to formulate plans for additional clean-out efforts. In addition to Mobil personnel, a drilling and completion consultant, and representatives of a fishing tool company will participate in these deliberations.

RIO BLANCO COUNTY, COLORADO MASSIVE HYDRAULIC FRACTURING DEMONSTRATION

EY-76-C-08-0677

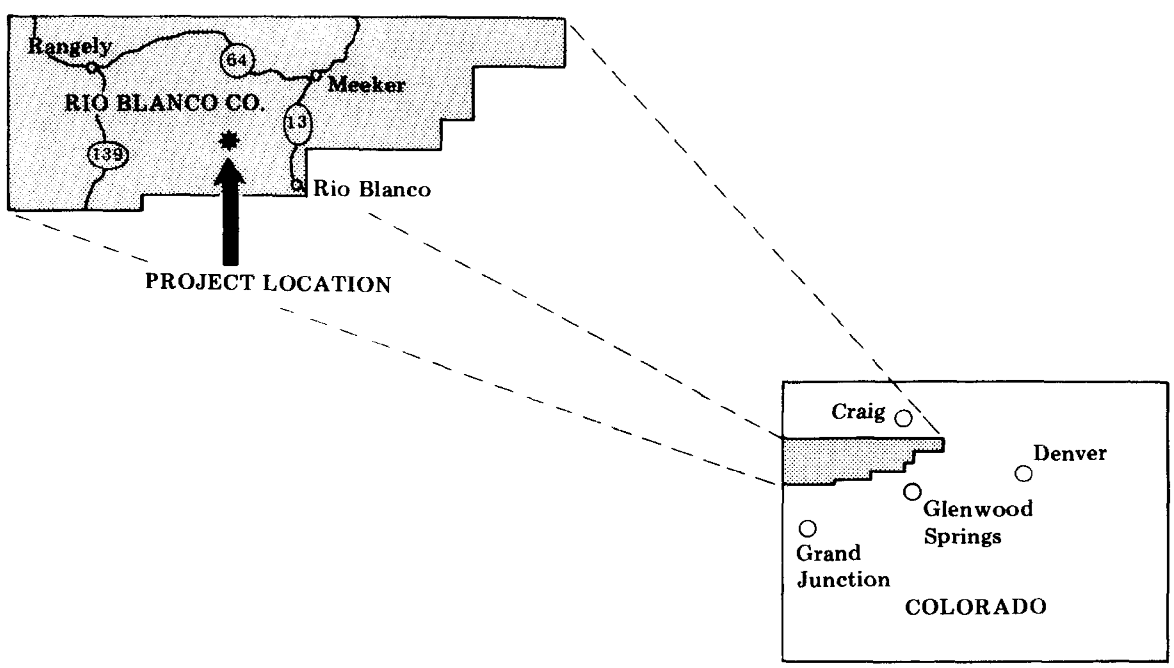
Rio Blanco Natural Gas Company
Denver, Colorado

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

Due to cyclic water production in March, gas flow continued to be restricted to a rate of 200 MCFD. The well is currently being flowed for clean-up.

NEVADA TEST SITE
NYE COUNTY, NEVADA
MINEBACK TESTING

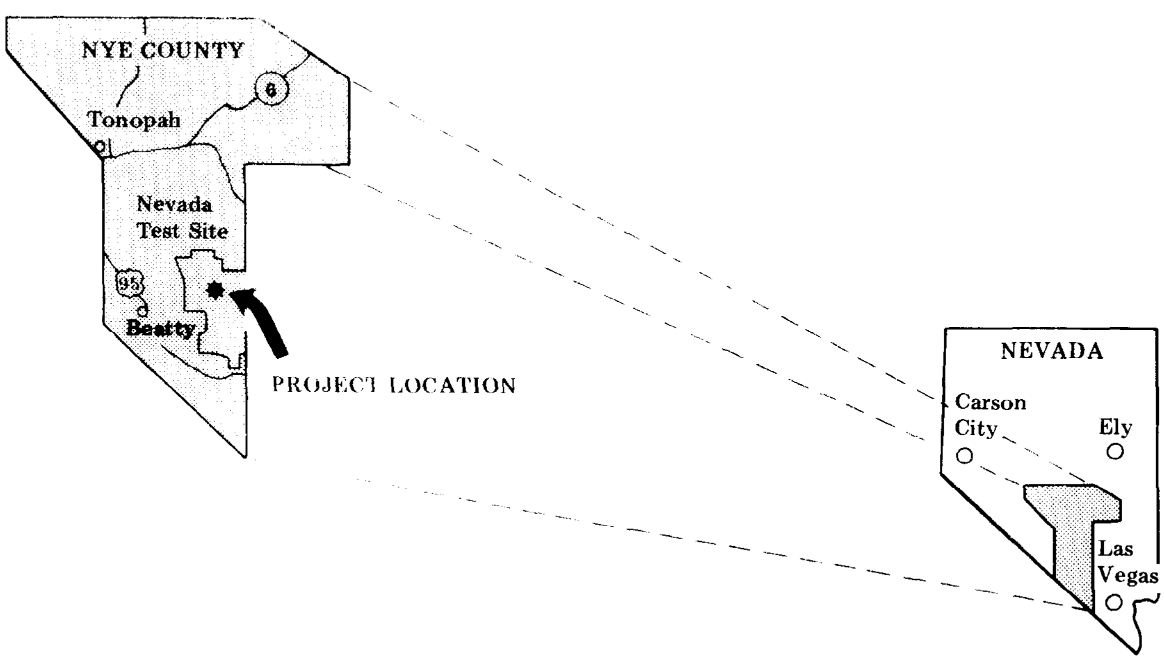
Sandia Laboratories
Albuquerque, New Mexico

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 Summary of Past Activities

During February, analysis and modeling of rock and fluid mechanics continued. A rock mechanics/fracture mechanics model was extended to include a description of the orientation of the microcracks within a zone and the effects of an anisotropic in situ stress state. Preliminary studies of fluid mechanics of the fracturing model showed that the system of equations did not readily converge. Photomicrographs of some microfractures from hydrofrac No. 6 were examined.

5.9.2 Current Status

5.9.2.1 Hydraulic Fracturing Containment Experiments

There was no further work on the Hole No. 6 experiment during March. The work crew performing the exploratory coring to determine the shape of the fractures has been temporarily assigned to another project. An additional drilling alcove near Hole No. 6 has been mined and reinitiation of coring is anticipated in April.

The Interface Test Series is a series of small hydrofractures that were conducted to test the effect of the pump rate on containment of a hydraulic fracture at a material property interface. Numerous zones in three different holes will be fraced at various flow rates. The first of these holes, designated CFE No. 1, was a preliminary test that was conducted in March at the location shown in Figure 5-10, near the Hole No. 6 fractures. CFE No. 1 was drilled above horizontal (+ 16 percent) in the ashfall tuff just below the welded tuff zone that was utilized in the Hole No. 6 experiment. The purpose of this preliminary test was threefold: the pumping system utilized in in-tunnel experiments was limited to 8 gal/min. All zones of CFE No. 1 were fraced at the maximum rate to determine if that rate was sufficient to propagate fractures across the interface. Secondly, this test provided additional data to verify the results of the Hole No. 6 test (difference in elastic moduli). Thirdly, the in situ stresses in this region could be easily determined by first conducting a small volume breakdown in each zone.

Six different zones of CFE No. 1 were fraced with 150 gal of dyed water in 3 stages. In each zone a small breakdown pump (3 to 5 gal) was first conducted to obtain the breakdown pump shut in pressures. Secondly, another small volume (5 to 7 gal) of fluid was pumped and the shut in pressure was recorded again. Finally, the remaining fluid (140 gal) was pumped into the zone at the prescribed flow rate. Only 90 gal of the fluid was pumped into the zone closest to the collar since this zone was primarily a test of a new dye water system. Three of the other five zones exhibited breakdown peaks and all five showed a slow pressure increase during fracturing. Mineback of these zones will occur in April and will determine if the fractures propagated across the interface. If so, the CFE No. 2 and No. 3 will be drilled and different pumping rates used for hydraulic fracturing of various zones.

M. D. Wood, Inc. fielded three tiltmeters in the G-tunnel to monitor the CFE No. 1 hydraulic fractures. The intent was to allow a calibration of the tiltmeter technique since the actual fracture geometry will be determined via mineback, and to evaluate if such a technique could yield useful information on fracture width and growth during fracturing.

The tiltmeters were fielded in a vertical, 12 in. diameter, 23 ft deep, sand-filled hole located in the tunnel just to the side of CFE No. 1. Three meters were located vertically near the bottom, middle and top of this hole. Excellent data records were obtained and are presently being analyzed by M. D. Wood, Inc. and Sandia.

5.9.2.2 Modeling and Analysis

Material properties were measured on tuff cores taken near the Hole No. 6 experiment. Several cores were obtained along each of the five stratigraphic layers for obtaining values of tensile strength, elastic moduli, and fracture toughness. The five stratigraphic layers will hopefully be adequate to characterize the region of varying properties lying between the ashfall and welded tuffs. Tensile strength and Young's modulus were obtained from direct-pull tension tests, while fracture toughness required separate tests. Table 5-5 summarizes the results of these tests.

Table 5-5 Material Property Data Near Hole No. 6 Experiment

Zone	Specimen Diameter (in)	Fracture Toughness (psi in)	Fracture Strength (psi)	Initial Young's Modulus (x 10^6 psi)
Welded*	—	—	—	—
Vitric Ash-Flow	4.0	518	119	0.492
		648	102	0.862
Ash-Flow With Abundant Lithics	6.0	649	89	1.868
Bas Ash-Flow	4.1	198	422	1.512
		530	> 140**	0.963
Ash Fall	3.9	254	> 28**	0.236
		151	18	0.271

* Data from two sets suspect due to fractured samples. Additional specimens being prepared.

** Failed at endcap, but failure was imminent.

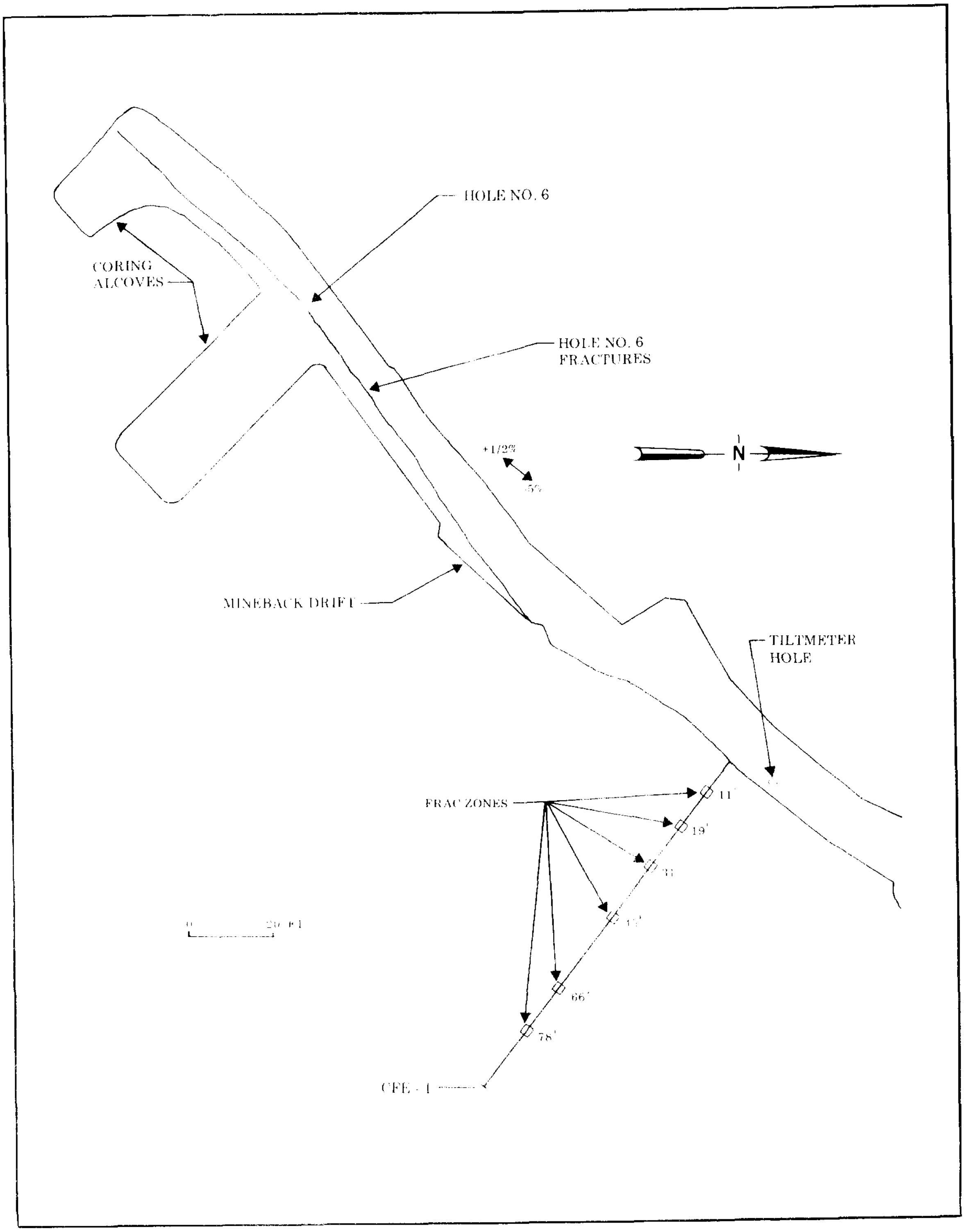


Figure 5-10 CFE No. 1 Experiment Location in G-Tunnel, NTS

Various stratigraphic layers are listed in order of their occurrence with the ashfall being the deepest. The Young's modulus values indicate that the most significant interface occurs between the ashfall tuff and the basal ash-flow tuff. The ashfall tensile strength and Young's modulus values compare well with previously obtained values measured by Holmes and Narver. However, data in the three transition layers obtained here do not compare well with the two tests performed by Holmes and Narver on core from this region. More data will be required to resolve this apparent discrepancy. Fracture toughness values are the first of their kind obtained on this material. Results of these tests, primarily fracture toughness and Young's modulus, will be used in finite element calculations in an attempt to model containment, in general, of hydraulic fractures in layered media.

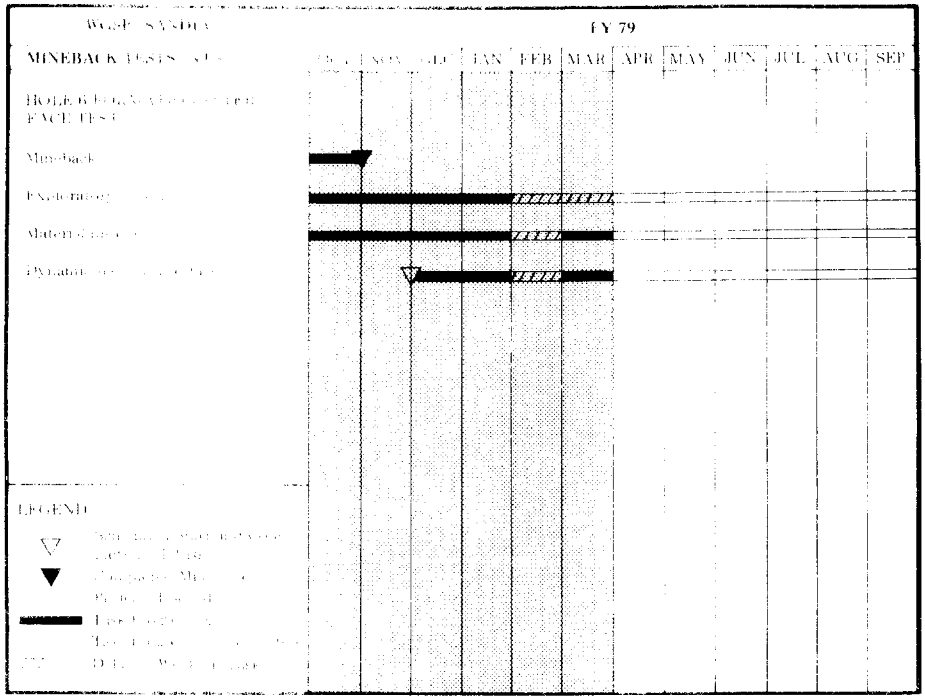
Fracture toughness tests were performed using a relatively new specimen design known as the short-rod configuration. Three "control" tests were performed on samples of Westerly granite for which fracture toughness values are well established. Test results provided values of fracture toughness that were highly consistent among themselves (1850, 1850, 1890 psi in), but almost 30 percent lower than established values using ASTM standard specimen configurations. Additional control tests on samples of Indiana limestone are being prepared.

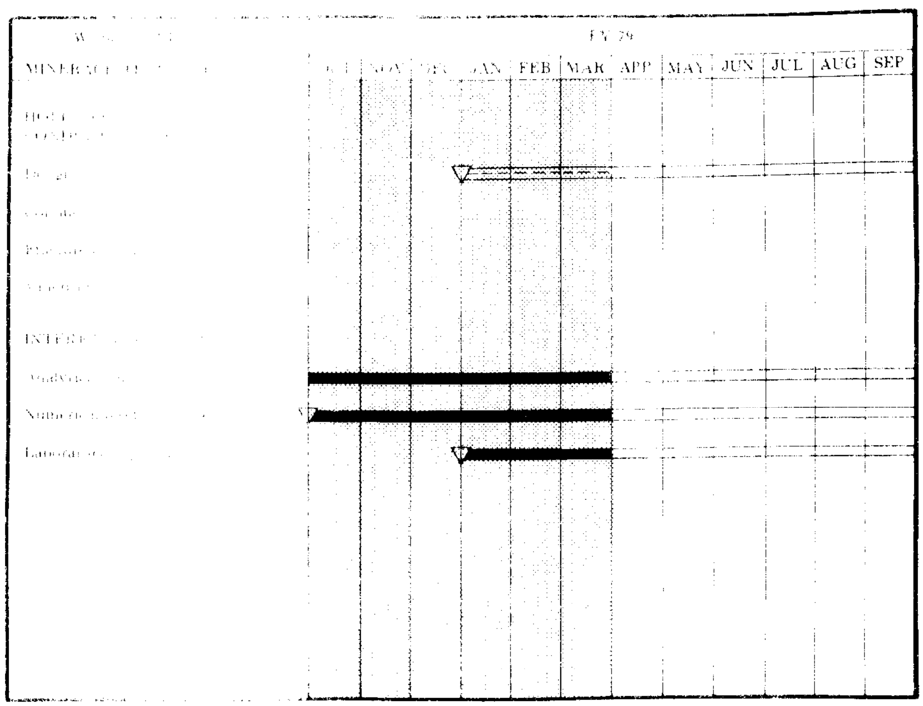
The present system of equations does not readily converge, therefore, convergence techniques continue to be investigated.

A memorandum on the results of preliminary petrographic analysis of microcracking in the vicinity of the Hole No. 6 fracture has been completed. Hydraulically-induced microfractures were not identified in the thin sections examined.

5.9.3 Schedule Status

Figure 5-11 is a milestone chart of the Sandia's mineback progress.





5.11 Milestone Chart — *Sandia Mineback*