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Western Gas Sands Project Status Report

October 31, 1978

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

MASTER

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1. SUMMARY

This edition of the WGSP Status Report summarizes September, 1978 progress of the government-sponsored projects directed towards 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*.

The Williston Basin Symposium, was held in Billings, Montana, the 24th through the 27th of September, 1978.

The USGS continued work on characterization and assessment of the resource in the four primary study areas and completed the 1978 field work in the Sand Wash and Green River Basins.

CER Corporation is evaluating a Twin Arrow drill site, located on the Douglas Creek Arch for the possibility of obtaining core, and preparations are being made for the Logging Program meeting to be held at the CER offices the latter part of October, 1978.

The design phase for the pressure coring system has been completed and work is progressing on the fabrication and testing of the improved system. The National Laboratories and Energy Technology Centers continued work on mathematical model development, new tools and instrumentation systems, data analysis techniques and rock mechanics.

Work continued on the field tests and demonstrations aspect of the WGSP. Bids sent to several service companies by Mitchell Energy Corporation, for a massive fracture treatment, are due back in October and the treatment is expected to be performed in mid-November. Mobil Research and Development fractured Zone 8 of their PCU 31-13 well, then shut it in due to anticipated winter weather and work was started on Zone 9. Sandia's mineback program involved evaluation of the Hole No. 6 Formation Interface Fracture Experiment.

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2. PROJECT MANAGEMENT

2.1 TECHNICAL MONITORING AND EVALUATION

P.T. Branagan, CER Corporation, traveled to Vernal, Utah to make a route and site inspection of Gas Producing Enterprises Well, NBU No. 21, for which the DOE Well Test Facility may be used.

H.E. Newman, CER Corporation, traveled to Billings, Montana to attend the Williston Basin Symposium held the 24th through the 27th of September, 1978. Papers were presented by industry, government and service companies from Canada and the United States. Copies of the *WGSP Core Program* were made available to interested people during the symposium.

2.2 TECHNOLOGY TRANSFER

2.2.1 Documentation and Reports

The third *Quarterly Basin Activities Report, July 31, 1978* has been completed and released. Data compilation continued for the fourth *Quarterly Basin Activities Report*, which includes information for the months of July, August and September. The *Status Report August 31, 1978* has been completed and will be released shortly, and the Fiscal Year 1979 Project Plan has been completed and distributed. Work is continuing on the operations manual to assist in the set up and operation of the DOE Well Test Facility. The compiling of material for the WGSP Bibliography continued.

2.2.2 Project Data Bank

Stratigraphy and Correlation charts and structure maps are being drawn for areas within the Greater Green River Basin. Work has begun on a series of special reports on the sub-basins of the Greater Green River Basin for inclusion in the *Quarterly Basin Activities Report*.

The proceedings of the Williston Basin Symposium have been placed in the WGSP Project Files. Pertinent stratigraphic and structural cross-sections are included as well as a number of interesting and relevant papers.

CER Corporation is now receiving *Energy Research Abstracts*, published by Technical Information Center, U.S. Department of Energy on a monthly basis. This service covers all scientific and technical reports, journal articles, conference papers and proceedings, books, patents, theses, and monographs originated by the U.S. Department of Energy, its laboratories, energy technology centers, and contractors.

2.2.3 Articles and Publications

The Williston Basin Symposium was held the 24th through 27th of September, 1978 in Billings, Montana. Papers were presented by industry, government and service companies from Canada and the United States. These papers included discussions of the geology and the problems associated with producing oil and gas from the Williston Basin. Most of the papers were centered around the paleozoic carbonates, which make up the greatest percentage of Williston Basin production. However, Mr. D.D. Rice, USGS-Denver, presented his paper on the natural gas resources of the Northern Great Plains Province and Mr. George W. Shurr, St. Cloud State University, St. Cloud, Minnesota, presented his paper on the potential gas occurrence of the Upper Cretaceous in western South Dakota.

2.2.4 Calendar of Events

The following future meetings and symposiums are of interest to the WGSP:

February 26-28

Sixth Energy Technology Conference

Contact: Martin Heavner
Energy Technology Conference
4733 Bethesda Avenue
N.W. Washington, D.C. 20014

May 20-22

SPE-AIME Symposium on Low-Permeability Gas Reservoirs

Contact: SPE-AIME

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3. RESOURCE ASSESSMENT

Geological, geophysical and reservoir evaluation studies are necessary to define and characterize the resource base. The USGS is performing the majority of these studies with support provided by field test data and core acquisition and analysis.

3.1 U.S. GEOLOGICAL SURVEY ACTIVITIES

3.1.1 Greater Green River Basin

The Washakie Basin cross section B-B' is being reviewed prior to open filing, cross section C-C' is ready for review, and cross section D-D' is in preparation (See Figure 3-1).

T.F. Tyler and John Webb are completing a report on petrographic and x-ray analysis of cores in the Washakie Basin.

C.W. Spencer continued work on lineament analysis in the Washakie and Red Desert Basins.

The 1978 field season in Sand Wash Basin was completed with emphasis on Tertiary reservoirs.

The 1978 field season in the Green River Basin was completed.

Geochemical samples (down to 19,500 ft) were collected from a Rainbow Resources deep test (26,000 ft) that is presently drilling ahead in northeast Green River Basin.

Cores from western Green River Basin, on loan from Tenneco, were described and sampled.

Tentative agreements were made with Belco Petroleum to acquire all of their cores from the Rocky Mountain Region.

Preparation of a paper for the SPE-AIME meeting was begun.

B.E. Law will present an abstract entitled "Wrench Faulting and Hydrocarbon Occurrence in the Northwestern Powder River Basin, Montana, and Wyoming," at the National AAPG Meeting in Houston, Texas.

Figure 3-1 Washakie Basin Cross Sections

Figure 3-1 Continued

3.1.2 Piceance Basin - Uinta Basin

The plotting of information from three measured sections of the Mesaverde Group in the Piceance Basin was begun. Sections were described at Rifle Gap, Yellow Creek, and the west side of the Grand Mesa. A graphical plot and a summary of the information for each section are being prepared and will be released upon completion.

A study of carbonate cements in low-permeability Eocene sandstones in the southeast Uinta Basin was completed. Two separate cycles of carbonate mineral cementation were present and an understanding of the distribution of each carbonate type seemed to be a major factor in determining the porosity and permeability. A report will be released as part of an S.P.E. volume in the spring of 1979.

3.1.3 Northern Great Plains Province

D.D. Rice prepared a talk for the October 1978 Potential Gas Committee meeting to be held in Florida.

An abstract on the development of the Bowdoin Field was prepared for the SPE meeting.

Donald Gautier prepared an abstract on the occurrence of authigenic tourmaline in Eagle sandstone in the Tiger Ridge Field for the 1979 AAPG-SEPM meeting.

Core was sampled for foraminiferal analysis by Dr. W.G.E. Caldwell of Saskatchewan.

Core samples were received from a producing Milk River well in southeastern Alberta.

The study area has been expanded to include all of the states of North and South Dakota, effective October 1, 1978. G.W. Shurr is currently doing stratigraphic analysis, particularly on chalk facies in the eastern parts of these states.

3.1.4 Schedule Status

Figure 3-2 is a milestone chart showing status of FY1978 projects.

3.2 CORE PROGRAM

CER personnel contacted many operators active within the USGS recommended core areas in each study basin or province. At month's end there were many good possibilities but no agreements were made.

Figure 3-2 Milestone Chart - USGS

Figure 3-2 Continued

WGSP-USGS	FY-78											
B. NORTHERN GREAT PLAINS PROVINCE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
ADD ON TASKS (continued)												
Prepare Admin. Report No. 3		▼	→	→	→							
Lineament analysis--Montana		▼	→									
Prepare report on Tertiary and Cretaceous oil and gas fields in Montana and North and South Dakota			▼	→								
Prepare paper for American Gas Association, monthly Gas Review Publication										▼	→	→
Prepare talk on Northern Great Plains Province for Oct. 1978 meeting of Potential Gas Committee										▼	→	→
Make contracts with South Dakota State Geological Survey concerning the study of Niobrara (chalk) core and the possibility of shallow coring near recent Eagle (Shannon) discoveries			▼	→	→							

WGSP-USGS	FY-78											
C. PICEANCE BASIN	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SCHEDULED TASKS												
Prepare cross section along southern Piceance Basin illustrating rock facies containing low-permeability reservoirs for open-file report					▼	→	→	→	→	→	→	→
Prepare cross section from south to central part of Piceance Basin illustrating rock facies containing low-permeability reservoirs for open-file report								▼	→	→	→	→
ADD ON TASKS												
Oral presentation and abstract on uppermost Cretaceous and lower Tertiary, Piceance Basin					▼	→	→	→	→	→	→	→
Prepare Isopachs of southern Piceance Basin						▼	→	→	→	→	→	→
Prepare oil and gas chart cross section Piceance Basin	▼	→	→	→	→	→	→	→	→	→	→	→
Core analysis of clay separate from the Rio Blanco area			▼	→	→	→	→	→	→	→	→	→
Report on mineralogy of core from CER Rio Blanco Unit E-01									▼	→	→	→

Figure 3-2 Continued

WGSP-USGS	FY-78											
C. PICEANCE BASIN	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
ADD ON TASKS												
Prepare paper-Maestrichtian conglomerates in southwestern Piceance Basin					▼	→						
Field work on Maestrichtian, Campanian and Paleocene units in southeast Piceance Basin						▼	→	→	→	→	→	

WGSP-USGS	FY-78											
D. UINTA BASIN	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SCHEDULED TASKS												
Prepare cross section from north-central to southeast Uinta Basin illustrating rock facies and engineering data of low-permeability reservoirs for open-file report					▼	→	→	→	→	→	→	→
Prepare abstract and oral presentation on petrographic characteristics of low-permeability rocks in Price River Canyon, western Uinta Basin						▼	→					
Prepare abstract and oral presentation on characteristics of low-permeability reservoirs in the Pariette Bench Field, southeast Uinta Basin						▼	→					
ADD ON TASKS												
Prepare Price River Canyon chart on Upper Cretaceous and Lower Tertiary rocks, southwest Uinta Basin			▼	→								
Prepare oil and gas chart cross section Uinta Basin	▼	→	→									
Trace low-permeability reservoir bearing units—Eastern Uinta Basin to central Wasatch Plateau		▼	→	→								

Figure 3-2 Continued

Figure 3-2 Continued

CER is presently evaluating a Twin Arrow drill site, C&K 4-14, Section 14, T3S, R101W, located on the Douglas Arch for the feasibility of coring the Mesaverde. The USGS has recommended the coring of this well.

3.3 LOGGING PROGRAM

An abstract and paper entitled "Formation Evaluation and Gas Detection in Shallow, Low-Permeability Shaly Sands of the Northern Great Plains Province," is being prepared by G.C. Kukal, CER Corporation, and will be sent to SPE of AIME by October 2, for consideration in the SPE-AIME 1979 Symposium on Low-Permeability Gas Reservoirs. The paper will include log interpretation of the Northern Great Plains Province, Hydrology (R_w distribution) and log analysis of the Joseph J.C. Paine & Associates, Midlands Gas Federal No. 1-0296 well.

Preparations are being made for the logging program meeting to be held at the CER office during the last part of October.

3.4 SURVEY OF BASIN ACTIVITIES

Drilling and testing activities in the four primary study areas continued to be monitored as a part of resource assessment. Figures 3-3 through 3-7 indicate the four areas and recent wells of special interest to the WGSP. The following paragraphs give a brief account of drilling activity.

3.4.1 Greater Green River Basin

During September, 57 new wells were staked in horizons and locations of interest to the WGSP. Eighteen wildcat wells and 39 development gas wells were located throughout the Greater Green River Basin (Figure 3-3). The greatest number of wells were in southeastern Sweetwater County and west Carbon County. The major objectives were the Almond and Ericson Formations within the Mesaverde Group. The Lewis was the objective in Hay Reservoir Field, Sweetwater County and in the Great Divide Field, Moffat County, Colorado. Also in the southern part of the Basin a well was staked in Hiawatha Field, Sweetwater County, to test the Ft. Union.

Completions during September accounted for 29,453 MCFD of gas production. There were seven development wells completed, none of which were D&A, and six wildcats, three of which were new field discoveries. Producing horizons included the Tertiary (960 MCFD), Lewis (760 MCFD), Jack's Draw (1,726 MCFD), Frontier (1,195 MCFD), 2nd Frontier (3,019 MCFD) and commingled Frontier/Bear River (9,700 MCFD).

Table 3-1 summarizes recent wells of interest to the WGSP. These wells are located on Figure 3-3.

Figure 3-3

Greater Green River Basin Showing Wells of Interest and USGS Designated Core Areas (Refer to Table 3-1)

Table 3-1 Summary of Wells - Greater Green River Basin

OPERATOR	WELL NAME	MAP INDEX NO. ¹	LOCATION Sec/T/R	HORIZON ²	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Texas Oil & Gas	1 Federal 477	1	21/25N/96W Unnamed Field Sweetwater Cty, Wyoming	Rock Springs (14,300)			Located	
Pacific Trans- mission Supply Co.	24-19 Federal	2	19/33N/114W Wildcat Field Sublette Cty, Wyoming	Frontier (11,650)			Located	
Amoco Pro- duction	1 Champlin 536 Amoco A	3	1/21N/92W Unnamed Field Sweetwater Cty, Wyoming	Mesaverde Ericson Member (12,530- 12,544)	12,640 PB 12,596	Acidized- 1,638 gal. 65,000 gal. oil 100,000 lb sand	Completed	536

¹ Refer to Figure 3-3

² Horizon - projected depth or producing interval

Table 3-2 shows the status of those wells pointed out in the August 31 and September 31 Status Reports. Details of basin activity for the months of July, August and September will be compiled in the *October 31 Quarterly Basin Activities Report*, presently in preparation.

During July, 26 wells were staked. At the end of September, four had reached total depth, five were drilling ahead, three were being tested, two were completed D&A and one well was abandoned. In August, the number of new locations increased to 39 with drilling now underway at seven.

Table 3-2 Summary of Wells - July and August, 1978

DATE	OPERATOR	WELL NAME	LOCATION	HORIZON AND PROJECTED DEPTH	STATUS 9-30-78
First Reported 7-11-78	Sun Oil Co.	1-34 Echo Springs Federal	34/19N/93W Unnamed Field Carbon Cty, Wyoming	Mesaverde (9,620 ft)	On location
First Reported 7-26-78 Spud 9-10-78 Comp 9-23-78	Robert Klabzuba	1-2 Federal	2/30N/113W Wildcat Field Sublette Cty, Wyoming	Mesaverde (5,200 ft)	Completed D&A
First Reported 6-26-78 Spud 8-9-78	Davis Oil	1 Picket Lake Unit	24/26N/97W Wildcat Field Sweetwater Cty, Wyoming	Mesaverde (14,000 ft)	at 13,123 ft prepare to run drill-ste stem test
First Reported 7-31-78	Davis Oil	1 Eva Federal	2/21N/92W Wildcat Field Sweetwater Cty, Wyoming	Ericson (12,500)	On location
First Reported 8-3-78 Spud 8-25-78	Woods Petroleum	1 Lost Valley Unit	17/25N/98W Wildcat Field Sweetwater Cty, Wyoming	Baxter (14,180 ft)	Drilling at 11,804 ft

3.4.2 Northern Great Plains Province

During this reporting period, 40 new wells of interest to the WGSP were staked. Twenty-six of the wells were located in proven gas fields and 14 were wildcats. The objectives were the Eagle & Greenhorn Formations, Phillips Member and the Bow Island Formation. The majority of tests were in the northern Montana Counties of Toole, Liberty, Pondera, Hill, Chouteau, Blaine, Phillips and Valley. By September 30, wells at three of these locations had been spudded. One well was completed D&A, another had reached total depth and one location was abandoned.

Figure 3-4

Northern Great Plains Province Showing Wells of Interest and USGS Designated Core Areas A,B,C and D

Figure 3-5

Detail of USGS Designated Core Areas, Northern Great Plains Province

Table 3-3 Summary of Wells - Northern Great Plains Province

OPERATOR	WELL NAME	MAP INDEX NO. ¹	LOCATION Sec/T/R	HORIZON ²	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Elenberg Exploration	28-28-13 Cankee	1	28/28N/13E Wildcat Field Chouteau Cty, Montana	Eagle (1,200)			Located	
Polumbus Petroleum	28-7 Rossmiller	2	28/26N/3E Wildcat Field Chouteau Cty, Montana	Bow Island (1,335)			Located	
Webb Resources	9-7 Federal (M-9,522)	3	9/8S/22E Wildcat Field Carbon Cty, Montana	8,200 ft test			Located	
A.K. Guthrie	1 Federal M-37119	4	35/7S/53E Wildcat Field Powder River Cty, Montana	Muddy Sand (5,000)			Located	
Tricentrol United States	1-1 Hegle	5	1/30N/15E Tiger Ridge Field, Hill Cty, Montana	Eagle (1,389- 1,395)	1,600 PB 1,509	38,000 lb sand	Comp.	1,200

¹ Refer to Figure 3-4 and 3-5

² Horizon - projected depth or producing interval

The southern part of the Northern Great Plains Province generally has much less activity than the northern areas. However, two wells of interest to the WGSP were staked this month. Webb Resources located an 8,200 ft test on the southwestern boundary of the Province and AK Guthrie staked a well to test the Muddy in the vicinity of core area A (Table 3-3, Figure 3-4 and 3-5).

Completions during the month added 5,773 MCFD of new gas production. Twenty development wells were completed with 40 percent success and nine wildcats were carried to completion with 44 percent success.

Table 3-4 summarizes the status of wells pointed out in the two previous status reports. During July, 32 new wells were staked and at the end of September, six were D&A, eight reached total depth, three were producing gas, and one well was drilling. In August the number of new locations increased to 74, which was partially due to the initiation of a 20 well series in Leroy Field by Fuel Resources Development and a 17-20 well development program in the Bowdoin Field in Phillips County by Midlands Gas Co. At the end of September, 14 wells were completed D&A, 17 had reached total depth, four were drilling, and the remaining 39 wells were staked.

Table 3-4 Summary of Wells - July and August, 1978

DATE	OPERATOR	WELL NAME	LOCATION	HORIZON AND PROJECTED DEPTH	STATUS 9-30-78
First Reported 6-28-78	Trio Petro	1 Nylander	1/31N/27E Wildcat Field Phillips Cty, Montana	Phillips (2,300 ft)	Located, tight hole
First Reported 7-5-78	Joseph J.C. Paine	1-0396 Porteen	3/29N/36E Wildcat Field Valley Cty, Montana	Phillips (1,900 ft)	Located
First Reported 7-5-78 Spud 7-19-78 Comp 8-9-78	Energy Reserves Group	1L Anderson	12/29N/36E Wildcat Field Carbon Cty, Montana	Morrison (4,650 ft)	Comp. D&A
First Reported 7-6-78	Jerry McCutchin, Jr.	4 Heikkila	7/16N/2E West Short Pine Hills Harding Cty, Montana	Shannon (2,000 ft)	Located
First Reported 8-1-78	Fuel Resources Dev.	J-13-24-17-N M-20200	13/24N/17E Wildcat Field Blaine Cty, Montana	Eagle (1,430 ft)	Located
First Reported 8-25-78	Marmik Oil	1-26 State	26/19N/1E Wildcat Field Harding Cty, S. Dakota	Shannon (1,500 ft)	Located

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

Table 3-5 Summary of Wells - Piceance Basin

OPERATOR	WELL NAME	MAP INDEX NO. ¹	LOCATION Sec/T/R	HORIZON ²	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
Adolph Coors	1-19-USAC 7867	1	19/3S/103W Wildcat Field Rio Blanco Cty, Colorado	Mancos (4,000)			Located	
Teton Energy	1 Calahan	2	29/8S/97W Debeque Field, Mesa Cty, Colorado	Mesaverde (1,600)			Located	
Chandler & Associates	13-31 Grumhaus- Federal	3	31/9S/96W Shire Gulch Field, Mesa Cty, Colorado	Corcoran (3,500)			Located	
Norris Oil	21-3 Nichols		21/10S/96W Plateau Field Mesa Cty, Colorado	Rollins (2,731- 2,817) Cozzette (3,045-56) Corcoran (3,178- 3,246)	3,419 PB 3,357	166,362 gal. water, 374,000 lb sand	Comp.	833

¹ Refer to Figure 3-6

² Horizon - projected depth or producing interval

3.4.3 Piceance Basin

Six new wells (one wildcat and five development wells) with relevance to the WGSP were staked in the Piceance Basin. See Table 3-5 and Figure 3-6.

Completions during the reporting period added 1,759 MCFD of gas. The producing formations were the Mancos (1,139 MCFD) and the Mancos B (638 MCFD). A total of seven wells were completed with no wildcat well completions. The production was from the established gas fields of Dragon Trail, Thunder, and Cathedral in Rio Blanco County and Plateau in Mesa County.

All wells completed during September utilized massive sand-water or sand-gel fracture treatments.

Table 3-6 is a summary of the status of wells pointed out in the previous status reports. In July, 18 wells were staked and at the end of September, three had reached total depth and one was on stream. During August, operators staked twenty-two wells, of which one reached total depth at month's end, and the remaining wells were not spudded.

Table 3-6 Summary of Wells - July and August, 1978

DATE	OPERATOR	WELL NAME	LOCATION	HORIZON AND PROJECTED DEPTH	STATUS 9-30-78
First Reported 7-6-78	Norris Oil Co.	13-3 Friends	13/10S/96W Plateau Field Mesa Cty, Colorado	Corcoran (4,150 ft)	Located
First Reported 3-14-78 Spud 6-18-78	General Crude Oil	15-29 Colorow Gulf Federal	29/3N/97W Wildcat Field Rio Blanco Cty, Colorado	Weber (12,400 ft)	@11,840, RDRT
First Reported 8-4-78	Adolph Coors	2-19 Feters et al	19/10S/96W Plateau Field Mesa Cty, Colorado	Mesaverde	Located
First Reported 8-22-78	William Moss Properties	7-8-97 Federal	8/2S/97W Piceance Creek Field, Rio Blanco Cty, Colorado	Wasatch (6,200 ft)	Located

3.4.4 Uinta Basin

Twenty new wells, having application to the WGSP, were staked during September, which is a 44 percent decrease from August activity. Three wildcats and 17 development wells were reported. Four of the new wells were spudded and are drilling ahead at month's end. The majority of tests were located in the very productive Natural Buttes Field and were scheduled to test the Wasatch Formation. The major operator in this area was CIG Exploration, which staked 10 Wasatch tests.

Figure 3-7

Uinta Basin Showing Wells of Interest and USGS Designated Core Areas

Table 3-7 Summary of Wells - Uinta Basin

OPERATOR	WELL NAME	MAP INDEX NO. ¹	LOCATION Sec/T/R	HORIZON ²	FINAL TD	FRACTURE TREATMENT	STATUS	IPF in MCFD
CIG Exploration	22-15-9-20 CIGE	1	15/9S/20E Natural Buttes Field, Uintah Cty, Utah	Wasatch (7,200)			Located	
Odessa Natural	18-1 Sowers Canyon Unit	2	18/6S/5W Wildcat Field Duchesne Cty, Utah	Mesaverde (15,400)			Located	
Enserch Exploration	1-8 Sage Brush-Federal		8/10S/23E Natural Buttes Field, Uintah Cty, Utah	Mesaverde (6,390-7,496)	7,525	262,164 gal. gel, 409,000 lb sand	Comp.	1,519

¹ Refer to Figure 3-7

² Horizon - projected depth or producing interval

An ideal location for acquiring core has been staked by Odessa Natural. The operator, contacted by CER Corporation personnel, has indicated, however, that a coring operation is not possible due to anticipated drilling problems.

Completions during September produced 12,948 MCFD of gas from the following established gas fields: Peters Point, Carbon County, Indian Canyon, Duchesne County and Natural Buttes, Uintah County. The producing horizons were the Wasatch (10,542 MCFD), the Mesaverde (1,519 MCFD) and the Green River (887 MCFD).

Table 3-8 is a summary of the significant wells pointed out in the two previous reports. During July, 13 new wells were staked and one well had reached total depth at the end of September. Thirty-six new wells were staked in August and at month's end three were drilling ahead, one reached total depth, and three were abandoned locations.

Table 3-8 Summary of Wells - July and August, 1978

DATE	OPERATOR	WELL NAME	LOCATION	HORIZON AND PROJECTED DEPTH	STATUS 9-30-78
First Reported 8-2-78	Belco Petroleum	542 B Natural Buttes Unit	2/9S/21E Natural Buttes, Uintah Cty, Utah	Wasatch (8,700ft)	Located
First Reported 8-21-78 Spud 9-4-78	W.A. MonCrief	10-1 Reimann	10/4S/6W Wildcat Field Duchesne Cty, Utah	Unnamed test	Drilling at 6,133 ft

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

4.1 BARTLESVILLE ENERGY TECHNOLOGY CENTER

4.1.1 Improved Pressure Coring System

The design phase for the pressure coring system has been completed. Work is now proceeding on the fabrication and testing of the improved system.

4.1.1.1 Core Retriever Design

The design drawings have been completed for the core retriever. These drawings are available for review by anyone interested in cost-sharing the fabrication of the system. The latest design provides for an increased pressure capability and a new procedure for closing the ball valve using mud pressure. In addition, the entire retriever has been strengthened for improved reliability.

4.1.1.2 Coring Fluid Selection

Two additional coring fluids have been tested. An oil-base fluid was found unacceptable, while a water-base fluid had excellent results. No invasion was measurable in a five-hour test at 400 psi overbalance pressure. Invasion tests during coring with this fluid were conducted in September. A one-foot sandstone core was cut with an NQ Stratapax core bit that operated at a differential pressure estimated at 200 psi. No fluid invasion of the core was observed.

At this time, the water-base "Sanheal" is recommended for use with the new pressure coring system. However, a current study to determine dynamic invasion rates at bottomhole conditions may provide results influencing final selection.

4.1.1.3 Bit Design

The drawings of the full bit body (8-1/2 in.) have been completed and are available for review. Seventeen stud-mounted cutters have been computer positioned on a 45° crown file. Eight conventional mud ports are oriented a maximum of 15° from vertical. Their location is calculated to minimize fluid invasion of the core while adequately cleaning the full bit. Construction of this bit will begin in October. A five axis numerical control milling machine will be used.

4.1.1.4 Schedule Status

Figure 4-7 is a milestone chart for the status of the Improved Pressure Coring System.

4.1.2 Interface Conductivity Effects on Electric Logging

Resistivity measurements on core plugs from the Mesaverde Group continued, however the measurements were plagued by repeated oil leaks into the cores. Modifications to the equipment are presently being made to eliminate this problem. Measurements with 2.0, 3.5 and 5.0 percent KCl solutions on one core (Number 8,066) before an oil leak occurred resulted in a calculated formation factor of 178.

Surface area measurements of several core samples are being made.

4.1.4 Logging Techniques and Interpretations

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

Cores from Joseph J.C. Paine's Number 1-0296 Federal, located in Section 2, T29N, R36E, Valley County, Montana were received during the last week of September. In the shipment were about eleven feet of core ranging in depth from 555 to 1,696 feet. Study of these cores and logs of the cored intervals is in progress.

Instrumentation for Formation Evaluation and Advanced Logging Techniques--Sandia Laboratories.

Sandia has compiled an up-to-date selection of literature available from professional journals and from logging service companies. In addition, individual researchers from logging companies and petroleum research groups have been interviewed. Findings to date are summarized as follows.

- For shallow to medium invasion depths, currently available formation testers which sample up to 24 gal. in two stages provide satisfactory samples of formation water. The deep invasion in tight reservoirs requires a new formation tester which extracts larger volumes and numerous, segregated samples or a continuous sampler with in situ R_w measurement capability.

- Calculations and Sandia experience with rock penetrators indicate that a sidewall penetrator/ R_w experiment package combination cannot be designed to accommodate the invasion depths required in low permeability formations. Similarly, proposed sidewall coring schemes which employ the natural formation fluid as the drilling fluid to avoid invasion are dismissed for R_w measurements; if formation water can be used as a drilling fluid, why not produce it to measure R_w ?

● Geophysical logging is hindered by the presence of clay in the matrix of tight formations which complicates the calculations of R_w and subsequent saturations. Rather than refining the analysis of current logging practice, Sandia is investigating those tools (commercial and research) which either directly measure clay volume for more accurate adjustment of available logs or directly measure S_w without requiring an R_w value. The more promising probes are the dielectric constant log (variable frequency), the closely related induced polarization log, and the nuclear magnetic resonance log. Each has hardware limitations which prevent immediate application to low-permeability formations, and significant amounts of background laboratory work are needed to develop useable relationships between log response and petrophysical significance.

4.1.5 Rock-Fluid Interactions

Particle size analysis was performed on three samples of frac fluid produced from GPE well CIGE No. 2. The range of particle size of two samples is between 2 to 40 microns (shown in Figure 4-1). This particle distribution, which is present at a very high concentration ($\cong 200,000/\text{ml}$) in the produced frac fluid could probably plug the propped fracture. Such plugging would result in a buildup of pressure until the particles were forced out, then replugging would stop fluid production again, etc.¹.

4.1.6 Reservoir Stimulation Studies

Parametric Analysis of MHF Test Data; *An Engineering Study of Western Gas Sands*---Intercomp, Inc.

The data on four wells in the Piceance Basin and Uinta Basin of Colorado and Utah have been received, reviewed, and are scheduled for analysis.

Mobil's well F-31-13G was chosen as a starting point. The well has seven perforated and tested zones and four MHF treatments. Zone 1, from 10,549 - 10,680 ft, has several sands perforated. Build-up data is available for the pre-frac and post-frac periods. Classical transient testing techniques were applied to the pre-and post-frac build-up data. The pre-frac kh (permeability-thickness) value obtained was reported at 0.3 md. ft. The post-frac value was 1.1 md. ft.

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¹ Donaldson, D., Baker, B. and Carroll, H.B., "Particle Transport in Sandstones," SPE 6905, 52nd Annual Fall Technical Conference, Denver, Colorado. October 9-12, 1977.

Figure 4-1 Particle Size Distribution in Fluid Produced from CIGE #2

A three-dimensional, cylindrical coordinate, dry gas simulator is being used to simulate well behavior under the conditions of the tests. The simulator has been modified to account for the presence of a fracture. The third dimension, the z direction, is used to simulate the effect of various sands that may be open to the wellbore.

Several runs were attempted with the kh values specified by build-up analysis. The wellbore boundary condition was fixed at 100 psi specified at the surface outlet of the tubing string. The gas flow rate from the well was computed by the simulator. Using the kh values computed by the build-up analysis, the well would not produce the observed rate for the pre-frac draw-down period. A value for kh of 1.45 was used and the computed rate and bottom-hole pressure corresponded to the observed values. This method is valid if the well was not fractured and the skin value was zero.

A type curve for the pre-frac build-up of Zone 1, given in Figure 4-2, shows a constant Slope of 0.2 after an initial wellbore storage period. This behavior is not typical of type curves found when the reservoir properties are affecting the build-up. Also shown on Figure 4-2 is the simulated results for the pre-frac case, given $kh = 1.45$, $h = 60$ ft, $\phi = 0.04$ and a wellbore storage volume of 1,988 CF. The storage volume is computed for the wellbore using a 7 in. casing and a 3/8 in. tubing without packer.

It can be seen, on Figure 4-3, that the observed storage is smaller than expected during the initial shut in. This could be due to two storage periods: the first for the 2 3/8 in. tubing followed by storage in the annulus. This could account for the observed behavior.

Figure 4-4 is a Horner plot of the observed and simulated results for the pre-frac case. The kh value analyzed from the simulated data is 0.9 with a skin value of -2.6. This analysis is incorrect since storage is still affecting the solution.

The post-frac period was simulated using reservoir properties determined from pre-frac draw-down simulations. Several fracture half-lengths (X_f) were used. The simulation run which gave the best results is shown on Figure 4-5 and Figure 4-6 along with the observed data. The fracture half-length used in this simulation is 35 feet, which is much smaller than the design. A fracture half-length of 100 feet shows a definite slope of 0.5 on a type curve plot seen on Figure 4-6. Since no slope of 0.5 can be seen on the type curve for the observed data, Figure 4-4 the fracture must be smaller than the X_f of 100 feet.

The kh values determined from the slope of the Horner plot, Figure 4-5 are close to the kh calculated from the observed data of 1.1 md. ft. The effect of after flow for these tight gas sands must not be neglected as the kh value determined from build-up analysis is smaller than actual when analyzed using classical transient testing techniques.

Figure 4-2 Type Curve for Pre-Frac Buildup of Zone 1, Mobil Well F-31-13G

Figure 4-3 Observed Storage during Initial Shut in, Mobil F31-13G

Figure 4-4 Horner Plot of Observed and Simulated Results for Pre-Frac Case, Mobil Well F-31-13G

Figure 4-5 Post-Frac Period Simulation using Reservoir Properties Determined from Pre-Frac Draw-down Simulations

Figure 4-6 Post-Frac Period Simulation using Reservoir Properties Determined from Pre-Frac Draw-down Simulation

4.1.7 Petrophysics

Log analysis of the CER-MHF3 well is currently underway. Initial crossplotting of log data has been completed. Core analysis data on this and two other wells is to be provided by CER Corporation.

4.1.8 Schedule Status

Figure 4-7 is a milestone chart depicting the status of BETC projects.

Figure 4-7 Milestone Chart - BETC

4.2 LAWRENCE LIVERMORE LABORATORY

4.2.1 Model Development And Application

In addition to the applications, LLL has been developing the mathematical forms to include interfacial friction for inclusion in the hydraulic fracturing models. The preliminary forms have been completed and written in Fortran and are currently being included in the models for debugging.

Figure 4-7 Continued

WGSP-BETC	FY-78											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
C. LOGGING												
Data Correlations												
Conductivity—Rink & Schopper Equation												
Permeabilities												
3. LOGGING TECHNIQUES												
Neutron Log												
Contract Negotiation												
Data Evaluation												
Acoustic Log												
Contract Negotiation												
Data Evaluation												
Density Log												
Contract Negotiation												
Data Evaluation												
In Situ Rw Instrument Design												
Contract Negotiation												
Data Evaluation												

WGSP-BETC	FY-78											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
D. RESERVOIR MODELING AND STIMULATION												
PARAMETRIC ANALYSIS OF MHF TEST DATA: AN ENGINEERING STUDY												
Conduct Study												
Contract Negotiations												
Report												

Figure 4-7 Continued

The analysis of the strain variables along the interface, for calculations where the interface between two materials is well bonded, is being conducted. These analyses, when compared to similar calculations with frictional contact along the interface, will provide insight on the effects of friction in the transport of strain energy across the interface.

Some analyses of the effect of the lenses themselves on the local stresses around the lenses have been completed. These calculations do not include the plastic relaxation. Although relaxation should normally reduce the stress variations around the lenses, these elastic calculations provide an indication of stress variation due to the presence of lenses of one type of material embedded in another material. To determine the stress perturbations caused by the presence of a lens, the following problem was analyzed with a numerical model. A lens is embedded in a homogeneous material, shown in Figure 4-8. Poisson's ratio for both materials is 0.35 and Young's modulus for the lens (0.1 Mbar) is half that of the surrounding material. A constant normal stress (ϕ_0) is applied in the negative y direction along $y = 0$. Since the distances and displacements in the problem will scale, the distances are given in terms of the lens thickness ℓ . Two-dimensional plane strain is considered so that the lens and the material is assumed to extend infinitely in the z direction. Furthermore, displacement in the x direction at $x = \pm 40\ell$ was not allowed.

The normal stress in the y direction (σ_y) along the lines labeled BB and B'B' in Figure 4-8 is shown in Figure 4-9. The stresses along the two lines are identical due to problem symmetry. Increasing σ_y/σ_0 corresponds to increasing compression. From Figure 4-9 compression is greatest along the lens and least about 2ℓ above and about 2ℓ below the lens. It is expected that a horizontal fracture entering from outside the area of the lens would tend to cross line BB or BB' at one of these two points.

The normal stress in the x direction (σ_x) along the line labeled AA in Figure 4-8 is shown in Figure 4-10. Again, increasing stress corresponds to increasing compression. The stress along line A'A' does not differ appreciably from the stress along AA. Inelastic deformation was not allowed in this analysis. Consequently, some of the severe character in the curve near the lens would be smoothed somewhat if plastic deformation occurred. In Figure 4-10, the least compression occurs above and below the center of the lens. A vertical hydrofracture would be expected to intersect the lens near its center.

4.2.2 Experimental Program

The large sandstone cylinder which was fractured in late August (see NVO/0655-130) was broken open as the block remained intact after the initial fracture had partially surfaced. The fracture grew in a plane containing the injection tube. Below the bottom of the injection hole, the crack turned and grew toward the side of the cylinder. The bedding planes in the sandstone cylinder were perpendicular to the axis of the cylinder, i.e., the injection tube. It appears that the injection hole influenced the direction of crack growth in the region of the injection hole, but the direction of bedding had more influence below the injection hole. During September, several more fracture growth experiments were performed on 7-inch cubes of sandstone and limestone.

Figure 4-8 The Lens Geometry (Stresses along the dashed line are given later)

Figure 4-9 Normal Stress in the y Direction along the lines BB and $B'B'$ in Figure 4-8. Increasing stress corresponds to increasing compression

Figure 4-10 Normal Stress in the x Direction along the line AA in Figure 4-8

Analyses of these experiments are not yet complete. However, preliminary observations imply that the initial burst of crack growth, indicated by a sudden drop in fluid pressure, is greater in area in the sandstone than in the limestone. Prior to fracturing, the limestone absorbs a relatively large amount of oil, becoming saturated and building up pore pressure in the region around the bottom of the borehole. The sandstone absorbs relatively no oil due to its low-permeability and porosity. The larger crack growth seen in the sandstone is consistent with the theoretical model prediction that as the pore pressure builds around the top of the crack, the mode I stress intensity factor decreases, thereby making further crack growth more difficult.

During September, experiments were begun to study the effect of water saturation on crack growth across interfaces in Indiana limestone. The standard three-block experiments were performed in which fracturing fluid was injected into the central block of a three-block sandwich. The blocks were placed in a hydraulic press which produced a normal stress load across the two interior interfaces. The central block and one of the outer blocks were dry; the other outer block was water saturated. Earlier experiments showed that the threshold normal stress for cracks to cross an interface between dry limestone blocks was about 625 psi. The current experiments indicate that the threshold normal stress for cracks to grow from a dry to a saturated block is about 500 psi. Further experiments of this type are planned. Also planned is measurement of the tensile strength of the saturated rock for comparison with that of the dry rock.

4.2.3 A Collection of Technical Data for Tight Gas Sands in Support of the Massive Hydraulic Fracturing System

4.2.3.1 Introduction

An initial study has been completed that includes the following topics:

- Case histories of logging problems/requirements in tight gas sand areas.
- Production histories/completion information on selected Uinta Basin tight gas sand wells,
- Geologic guidance and additional technical input for computer simulation of tight gas sand well behavior, and
- Information about production histories, completion techniques and reservoir rock characteristics from selected tight gas sand key wells in the Piceance and Green River Basins.

The data collected and analyzed have been obtained from the files of the State of Utah's Department of Natural Resources in Salt Lake City and from personal communications with logging company and gas producing company representatives in the western states of interest. Details of these studies will be presented in subsequent status reports.

4.2.3.2 Logging Problems Case History Study

Twelve operating companies and four logging contractors have been contacted to determine the nature of problems encountered in the derivation of critical reservoir properties from electrical logs.

All companies contacted agreed that logging problems are severe in the tight gas sands in which they operate. The "conventional" suite of logs, i.e., dual induction laterolog, density, sonic, and neutron logs, is only good for a first look. Precise logging techniques are required. Cases were cited in which sands appeared to have 80 to 100 percent water saturations and yet produced gas, while the more common occurrence was that sands which appeared to have 40-50 percent water saturations, produced mostly water or very little gas. Compounding the interpretive problem is the lack of good spontaneous potential curves resulting from the use of salt-based drilling muds.

4.2.3.3 Uinta Basin Wells' Production Histories and Completion Information

Gas production statistics have been assembled for 66 Uinta Basin tight gas sand wells (Wasatch and/or Mesaverde Group).

The number of months the wells were produced per year are not necessarily, and in most cases not, consecutive months. Typically, these wells were off production from 1 to 20 days during each of several months of the year.

The production data are plotted in log-log form for wells with sufficient data points to warrant plotting. Curves which exhibit pronounced changes in slope were broken into segments and the slope was determined for each segment.

The distribution of slopes for these wells is presented as follows (late time segments were used for wells with pronounced breaks in slope and wells with dual completions were considered to be two separate "wells"):

SLOPE	NUMBER OF WELLS
0.50	15
0.50-0.59	12
0.60-0.69	14
0.70-0.79	7
0.80-0.89	2
0.90-1.00	2

This distribution indicates that very few of these wells exhibit radial flow, assuming that a slope of 0.5 corresponds to linear flow and a slope of 1.0 corresponds to radial flow.

4.2.3.4 Geologic Guidance and Additional Technical Input for Computer Simulation of Tight Gas Sand Well Behavior

Sand Body Dimensions

Estimates of the "average" length and width of sand bodies completed in selected wells was determined. These dimensions are best estimates based upon outcrop studies conducted south of the productive area. The distribution of the "best estimate" sand body lengths and widths is presented as follows:

WIDTH, ft.	LENGTH, ft.	NO. OF WELLS
0-100	0-1,000	0
101-200	1,001-2,000	0
201-300	2,001-3,000	2
301-400	3,001-4,000	5
401-500	4,001-5,000	13
501-600	5,001-6,000	10
601-700	6,001-7,000	1

Indicated by these distributions, the "best estimate" sand lengths are predominantly between 3,000 and 6,000 ft and widths between 300 and 600 ft.

Clay Plugging

An important geologic consideration which may be applicable is the potential for kaolinite to be present in the pores of the tight gas sands and not be detected in the electric log data. Robert Schneeflock of Tenneco Oil Company has reported in the May 1978 issue of the Bulletin of the American Association of Petroleum Geologists (p. 848-853) that there is evidence that kaolinite plugged the pores in portions of the Gatchell sand in the Coalinga area of Fresno County, California, after the sand was deposited. (Chemical reactions between the formation water and feldspar and mica are cited as the cause of the kaolinite formation.) Schneeflock points out, however, that the hydrocarbon-bearing portion of the Gatchell are virtually free of kaolinite. He concludes that generally, hydrocarbons displaced formation water before kaolinization began in the hydrocarbon-bearing zones and that the low-permeability hydrocarbon-bearing sands are those in which some kaolinization occurred prior to the hydrocarbons displacing the formation water.

It is conceivable that this process may have been operative in the western tight gas sands and could be the cause of some of the extremely low degrees of continuity observed.

Uinta Basin Regional Geology

Tom Fouch and Bill Cashion of the U.S. Geological Survey have completed a series of cross sections through the Uinta Basin. The effort concentrated on outcrop studies and it is felt that the Tertiary sand sections are fairly well identified from well to well. There appears to be significant differences in the sand sequences, e.g., primary porosity in the shallow sands versus secondary porosity at depth in the Cretaceous. Also, it is felt that the Green River tongues in the Wasatch are some of the more productive sequences.

There is pessimism about finding any significantly continuous sands except for those marine sands in the lower Mesaverde. These marine sands seem to be gas productive only where there is a structure. The sands observed in outcrop contain numerous channels which generally have clay boundaries. These boundaries, expected to be barriers to gas flow, would significantly reduce the continuity of the reservoir sands.

The work is far enough along to begin correlating the reservoir engineering data and computer simulation results with the type sand sections they have developed particularly in the Tertiary rock of the Uinta Basin.

4.2.3.5 Recommendations

The following recommendations are offered as a result of the findings in this study:

- Logging Research

Logging research is needed to provide a reliable means of assessing the occurrence of mobile hydrocarbons, porosity, and water saturations for tight gas sands. Initially it is suggested that a study of the data for Green River wells be made. After this study is completed, contacts with the major logging companies would be appropriate.

After this experience has been gained, it would then be appropriate to contact a number of the major oil companies regarding specific research efforts which could be jointly carried out by LLL and industry.

- Frac Damage Analysis

An excellent opportunity exists to pursue the problem of "scum" (frac damage) by initiating a study of wells in the Green River Basin which have been severely damaged as a result of their being killed with calcium chloride water. It is recommended that a study be considered to investigate means for mitigating the effects of "scum," using these wells as the data base.

- **Reservoir Productivity Prediction Capability Investigation**

The adequacy of existing reservoir models and computer programs to predict gas production from tight gas sand wells should be investigated using the 16-17 year production data available for Uinta Basin wells.

4.2.4 Environmental Studies

Several projects are underway. The most active one currently concerns Mitchell Energy Corporation's project in Limestone Co., Texas. A preliminary assessment which was sent to Nevada Operations Office, DOE, Las Vegas, has been completed and the Environmental Report will be finished in the next few weeks.

4.2.5 Other Related Activity

During the month LLL personnel visited Prof. B. Haimson to discuss the progress and findings of his hydraulic fracturing experiments in a polyaxial stress cell.

4.2.6 Schedule Status

Figure 4-11 is a milestone chart depicting the status of LLL projects through September, 1978.

4.3 SANDIA LABORATORIES

4.3.1 Advanced Borehole Logging Program

The Sandia Laboratories has continued its research effort investigating the capabilities of current, as well as proposed, borehole logging measurements in light of the numerous problems presented by the low-permeability shales and shaly sands of the Enhanced Gas Recovery project. Earlier findings by this group have recommended concentration in primarily two areas: first, nuclear magnetic resonance (NMR), and second, advanced electro-magnetic theory. Progress made in these areas follows.

- **NMR**

Following a visit to Chevron Oil Field Research Labs, Sandia contacted Terra Tek to request representative core samples from the Uinta Basin, Natural Buttes, Well No. 21. Intervals were chosen on the basis of encouraging shows on the Schlumberger Saraband log of this same well. Representative samples were requested from the following intervals:

Figure 4-11 Milestone Chart - LLL

Interval	Depth
1	4,402-4,414 ft
2	4,477-4,484 ft
3	6,483-6,488 ft
4	7,563-7,570 ft
5	8,457-8,485 ft
6	8,510-8,514 ft

The cores will be subjected to both core analysis and NMR analysis at Chevron Labs, in cooperation with Dr. Aytekin Timur of Chevron. The study is to determine the reliability of empirical NMR-petrophysical parameter relationships derived from the core sample study. In this way, an evaluation of whether or not NMR techniques (given substantial future hardware improvements) can provide accurate measures of in situ permeability and fluid saturations in low-permeability reservoirs.

● Advanced Electromagnetic Theory

Several recent publications have shown great promise for electrical measurements at very high frequencies (up into GHz frequencies). The findings of these laboratory studies have shown a correspondence between such dielectric constant measurements and petrophysical parameters such as porosity, formation water salinity, shaliness and saturation. At least two tools are being developed to provide measurements at high frequencies. Both of which are mono-frequency tools. Many time-dependent electromagnetic phenomena (e.g., induced polarization, complex dielectric, nuclear magnetism) are indicators of pertinent reservoir characteristics. Sandia has initiated development of a computer code to model the tool response of an induction device within a borehole having horizontal layering and concentric layering (invasion) at the same time, allowing the electrical characteristics of the media to be frequency dependent. This code development is underway and not yet complete.

4.3.2 Schedule Status

Figure 4-12 is a milestone chart of Sandia's FY78 activities.

Figure 4-12 Milestone Chart - Sandia

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5. FIELD TESTS AND DEMONSTRATIONS

5.1 BACKGROUND

Field tests and demonstrations are an essential part of the WGSP. Only through practical application can the findings of laboratory tests and modeling studies be verified. The active WGSP demonstrations follow:

- 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 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	WELL	INTERVAL FRACTURED	FRAC. DATE	FRAC. TREATMENT	FLUID INJECTED
	T / R / Sec		Feet		Lbs of Sand	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 O
CONSORTIUM MANAGED BY CER CORPORATION Piceance, Mesaverde	3S, 98W, S11 Rio Blanco Co. Colorado	RB-MHF-3	8,048- 8,078	10-23-74	400,000	117 Gel
			7,760- 7,864	5- 2-75	880,000	285 Gel
			5,925- 6,016	5- 4-76	815,000	400 Gel
			5,851- 5,869	11- 3-76	448,000	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	9-21-76	424,000	280 Gel
			7,224- 8,676	9-28-76	784,000	364 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
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	7- 2-75	518,000	183 Emul 8 Gel
			10,120-10,790	10-20-75	1,422,000	459 Gel
MOBIL Piceance, Mesaverde	2S, 97W, S13 Rio Blanco Co. Colorado	F-31-13G	10,549-10,680	6-22-77	580,000	316 Gel
			9,432- 9,538	8-24-77	600,000	260 Gel
			8,163- 8,650	7- 6-78	660,000	288 Gel
			7,704- 7,794	9- 7-78	218,000	120 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	10-22-76	766,000	276 Gel
			5,376- 5,960	11-30-77	243,000+ 22,500 Beads	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

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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.

5.2 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 until September 30, 1978.

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 have been distributed to the project participants for their concurrence.

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.

**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	<u>\$7,759,000</u>

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.

5.4 GAS PRODUCING ENTERPRISES

5.4.1 Summary of Past Activities

On August 8, 1978, an MHF treatment was performed on GPE's Natural Buttes unit well No. 2 (CIGE 2-29). By the end of August, CIGE 2-29 had been worked over and was flowing a mixture of gas and water to the pit. It is not yet possible to determine the results of the MHF treatment. Natural Buttes Unit No. 9, 14, 20 and 22 were produced for 31 days, Natural Buttes No. 18 for 10 days and No. 19 was shut in. Natural Buttes No. 21 was flowed to the pit after being perforated for test and No. 23 was shut in waiting completion.

5.4.2 Current Status

Natural Buttes Unit well No. 18 produced for 24 days, No. 14 and No. 20 produced for 7 days, No. 22 produced for 30 days and No. 9 produced for 17 days. Unit No. 23 and No. 19 are shut in for completion and proration, respectively. Specific production data on these wells appears in Figures 5-1 and 5-6.

Natural Buttes No. 21 is flowing to the pit after being perforated for test at 7,741, 7,742, 7,743, and 7,744 on September 21, 1978. The perforations were broken down with 5,450 gallons of 3 percent KCl water. The perforations at 8,201-8,205 ft made an average of 14 BWPD while producing.

Figure 5-1
Flow Rate Performance
of Natural Buttes No. 9
Well

Figure 5-2
Flow Rate Performance of
Natural Buttes No. 14
Well

Figure 5-3
Flow Rate Performance of
Natural Buttes No. 18
Well

Figure 5-4
Flow Rate Performance of
Natural Buttes No. 19
Well

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

Figure 5-6
*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	<u>1,074,550</u>
	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.

5.5 MITCHELL ENERGY CORPORATION

5.5.1 Summary of Past Activities

The Mitchell Energy Corporation, Muse-Duke No. 1 reached total depth at 11,633 ft and was logged on August 31, 1978. Four hundred forty-seven ft of core was cut including 95 ft of overlying Bossier Shale, 210 ft of Cotton Valley lime and 142 ft of underlying Buckner.

One in situ formation breakdown was attempted at 11,556 ft by Terra Tek with straddle packers. The bottom packer failed at 3,000 psi, 1,000 psi under its rating and before the breakdown of the formation was achieved. The remaining tests were abandoned and 5-1/2 in. production casing was cemented to 11,633 ft.

5.5.2 Current Status

The MEC Muse-Duke No. 1 is now flowing on test at a rate of 2,034 MCFGPD through a 7/64" choke at a flowing tubing pressure of 4,289 psi. Preliminary production and pressure transient tests have been initiated to evaluate the natural flow capabilities of the lime before fracture treating.

On September 27, the Cotton Valley Lime was perforated with 15 selected shots as indicated on the attached log (Figure 5-7). Each of the perforations was "balled out" to insure that they were open, and at the same time, the formation was acidized through the perforations with 5,000 gallons of 15 percent HCl acid at rate of 6BPM at 5,900 psi. The well came in flowing.

Shown by the attached log analysis data sheet (Figure 5-8), the Cotton Valley Lime has a range of porosities from 1-1/2 to 11 percent with 36 feet greater than 4 percent. The average water saturation calculates to be about 30 percent. Preliminary core analyses indicate some natural fractures in a very dense matrix with permeability less than 0.01 md in most of the lime section. The higher than expected initial producing rate is probably due to the natural fractures.

The fracture treatment is expected to be performed in the middle part of November.

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.

5.6 MOBIL RESEARCH AND DEVELOPMENT CORPORATION

5.6.1 Summary of Past Activities

Remedial cementing of Zone 8 was accomplished. The casing was perforated at 7,818-7,820 with 8 shots. Circulation to the surface failed. After perforation at 7,650-7,652 ft with 8 shots, circulation across the zone was established. The zone was cemented with 150 sacks; circulation was lost during cementing.

Zone 8 was perforated in the intervals, 7,704-7,736 and 7,776-7,796 ft with 27 jet charges carried in a 4 in. centralized gun. The zone was then broken down with 138 Bbl of 2 percent KCl water; ball-off was achieved. After breakdown, the well flowed a little water for two hours and died. Noise/temperature logs show most of the fluid was coming from the lower zone.

5.6.2 Current Status

Zone 8 was fractured on September 7. The most severe treating pressure increase to date was encountered while pumping the treatment. Initial ISIP was 800 psi, after pumping 3,000 gal. of pad. Initial (static) treating pressure, measured on the tubing, while pumping was 900 psi. Pressure increased rapidly to about 3,400 psi when sand-out occurred after pumping 218,000 pounds of 20-40 mesh sand in 120,000 gallons of gel at 15 bpm. A sketch of the treating pressure record is attached (Figure 5-8).

Following the frac and a brief flow-back period, sand fill was found at about 7,780 ft, just below the top of the lower set of perfs. Attempts to get the well to flow by swabbing and unloading with nitrogen resulted in only intermittent flow. A packer was set above the perfs on September 12. Flow rates observed were:

Date	Gas, MMCF/day	Water, bbl/day
9/13	148	68
9/14	148	28
9/15	149	-
9/16	161	-
9/17	181	23

It is believed that sand covering the lower set of perfs was severely restricting flow from that interval. Because of approaching winter, the well was shut in and work on Zone 9 begun.

Some difficulties were encountered in moving the bridge plug from below Zone 8 to below Zone 9. Remedial cementing of Zone 9 was accomplished on September 25 without difficulty. Cement was circulated between perfs below and above the zone. After cementing, the upper set of perfs failed to hold pressure and attempts to squeeze these with cement began.

Figure 5-8 Sketch of Treating Pressure Record, Zone 8, F31-13G Well

Zone 9 will be perforated with 1 shot/2 ft in the interval 7,322-7,474 (77 holes). The interval will be broken down with KCl water, flow tested and pressure buildup data obtained. If suitable for MHF, the zone will be fractured with 700,000 pounds of 20-40 mesh sand carried by 365,000 gallons of gel at 60 bpm. We have decided to use a high-rate, low-viscosity treatment on the zone because of the severe treating pressure increase observed on Zone 8 in a low-rate, high-viscosity treatment.

Note: Perfs above Zone 9 were successfully squeezed on October 10, and the cement retainer was being drilled on October 13. Perforating is scheduled for October 16 and fracturing is tentatively scheduled for November 1. Table 5-2 is a summary of zones fractured and completion information through September, 1978.

Table 5-2 PCU No. 31-13 Completion Information

Zone	No.	Perfs Interval	PBSD, ft.	Tubing	Packer	Gas Gravity	Temp.* °F	Porosity	Pressure Transient Tests	
									Before Frac	After Frac
1	46	10,549-10,680	10,730	2-3/8 @ 10,450	None	N.A.	235		PBU	PBU
2	10	10,186-10,196	10,530	-----	----	N.A.	230		None	Not Fractured
	2	10,202-10,204								
	4	10,255-10,261								
	10	10,415-10,427								
	3	10,472-10,476								
3	18	9,392-9,432	9,600	2-7/8 @ 9,120	9,120	0.678	215		PBU	PBU
	16	9,517-9,538								
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	8,765-8,773	9,040	2-3/8 @ 8,625	None	0.669	205		PBU	PDD
	11	8,790-8,810								
	5	8,826-8,834								
	9	8,914-8,930								
	10	8,954-8,972								
6	10	8,443-8,463	8,725	2-3/8 @ 8,300	None	Zones 6 and 7 combined	199		PBU	Pressure drawdown (PDD) test was run
	6	8,472-8,482								
	12	8,506-8,528								
	19	8,614-8,650								
7	10	8,163-8,181	8,425	2-3/8 @ 8,050	None	after frac 0.668	194		PBU	Zones 6 and 7 combined after frac
	9	8,210-8,226								
	9	8,250-8,266								
	4	8,279-8,285								
	4	8,349-8,355								
	4	8,366-8,372								
8	27 27	7,704-7,736 7,776-7,794	7,812	2-3/8 @ 7,675	7,675	N.A.	191		PBU	

Average porosity for all of these zones is about 9% with an average water saturation of about 60%.

*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.

RIO BLANCO MASSIVE HYDRAULIC FRACTURING EXPERIMENT

EY-76-C-08-0623

CER Corporation
Las Vegas, Nevada

Status: Awaiting Advisory
Committee Decision

Interagency Agreement Date:
Anticipated Completion Date:

June 19, 1974
December 31, 1978

Project Cost (estimated):

DOE	\$1,975,000
Industry	1,630,000
Total	\$3,605,000

Principal Investigator:
Technical Advisor for DOE:

G. R. Luetkehans
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.

5.7 RIO BLANCO NATURAL GAS COMPANY

5.7.1 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.

5.7.2 Current Status

Gas flow continued to be restricted due to persistent 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 mineback for direct observation and evaluation.

5.8 SANDIA LABORATORIES - MINEBACK

5.8.1 Summary of Past Activities

The examination and analysis of the Hole No. 6 Formation Fracture Experiment continued. The entire length of the fracture at the interface was mined back. After the mineback was terminated, an exploratory coring program was initiated to define the extent of the fractures. The fractures were mostly filled with green grout; indicating that the lower fracture had propagated well up into the welded tuff. The welded tuff also exhibited a severe amount of branching.

Examination of existing analyses and experiments revealed a deficiency in the treatment of the interface as a discontinuous change of material properties. The emphasis was changed to the more realistic "smeared interface problem," where properties change in a smooth manner.

5.8.2 Current Status

The primary activity in September was the continued evaluation of the Hole No. 6 Formation Interface Fracture Experiment. This test examined the problem of hydraulic fracture containment by mineback analysis of two grout-filled fractures propagated above and below a geologic interface of hard welded volcanic tuff overlaying a soft bedded ashfall tuff. The lower zone (ashfall tuff) was treated with 5,000 gallons of green grout, followed by 4,000 gallons of black grout, and the upper fracture (welded tuff) was propagated with 5,000 gallons of blue grout.

The entire length of the fracture at the interface was previously mined back and it was found that the lower fracture broke through the interface even though the modulus of the welded tuff is an order of magnitude greater than the modulus of the ashfall tuff. To further characterize the fracture behavior, an exploratory coring program was initiated to determine the extremities of the fracture. The results of coreholes EV6-4 and EV6-5 in Figures 5-9 and 5-10 were previously described and coreholes EV6 No. 6 and EV6N No. 10 were completed in September. The purpose of these holes was to define the boundaries of the lower fracture below the interface and to determine if the interface did indeed contain the fracture, if only near the fracture tips. Grout was located only in corehole EV6 No. 6 at the indicated position in Figures 5-9 and 5-10, about 25 ft below the interface and 15 ft beyond the mined back region. Grout was not found in the coreholes that were drilled closer to the interface nor in holes that were directed farther away from the mineback region. Thus, the fracture did not extend farther out just below the interface. The main thrust of fracture propagation was apparently vertical rather than horizontal and the upper and lower extremities of the fractures will be investigated by further coring.

Figure 5-9 Plan View of Hole #6 Mineback and Exploratory Coreholes

Figure 5-10 Longitudinal View of Hole #6 Mineback and Exploratory Coreholes

5.8.3 Other Program Activities

A working session will be held October 11 and 12, 1978, at Sandia Laboratories in Albuquerque, to allow detailed examination and discussion of the experimental data from the Mineback Project. Industrial and DOE personnel have been invited.

5.8.4 Schedule Status

Figure 5-11 is a milestone chart, indicating the progress of the mineback program through FY1978.

Figure 5-11 Milestone Chart - Sandia (Mineback)