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Final

INCREASED OIL PRODUCTION AND RESERVES UTILIZING SECONDARY/TERTIARY RECOVERY TECHNIQUES ON SMALL RESERVOIRS IN THE PARADOX BASIN, UTAH

(Contract No. DE-FC22-95BC14988)

TECHNICAL PROGRESS REPORT

Submitted by

Utah Geological Survey
Salt Lake City, Utah 84109
July 14, 1995

Contract Date: February 9, 1995
Anticipated Completion Date: February 8, 2000
Government Award (fiscal year): $786,880
Program Manager: Thomas C. Chidsey, Jr.
Principal Investigator: M. Lee Allison

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Reporting Period: April 1 - June 30, 1995

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Objectives

The primary objective of this project is to enhance domestic petroleum production by demonstration and technology transfer of an advanced oil recovery technology in the Paradox basin, southeastern Utah. If this project can demonstrate technical and economic feasibility, the technique can be applied to approximately 100 additional small fields in the Paradox basin alone, and result in increased recovery of 150 to 200 million barrels of oil. This project is designed to characterize five shallow-shelf carbonate reservoirs (Fig. 1) in the Pennsylvanian (Desmoinesian) Paradox Formation and choose the best candidate for a pilot demonstration project for either a waterflood or carbon dioxide-flood project. The field demonstration, monitoring of field performance, and associated validation activities will take place in the Paradox basin within the Navajo Nation. The results of this project will be transferred to industry and other researchers through a petroleum extension service, creation of digital databases for distribution, technical workshops and seminars, field trips, technical presentations at national and regional professional meetings, and publication in newsletters and various technical or trade journals.

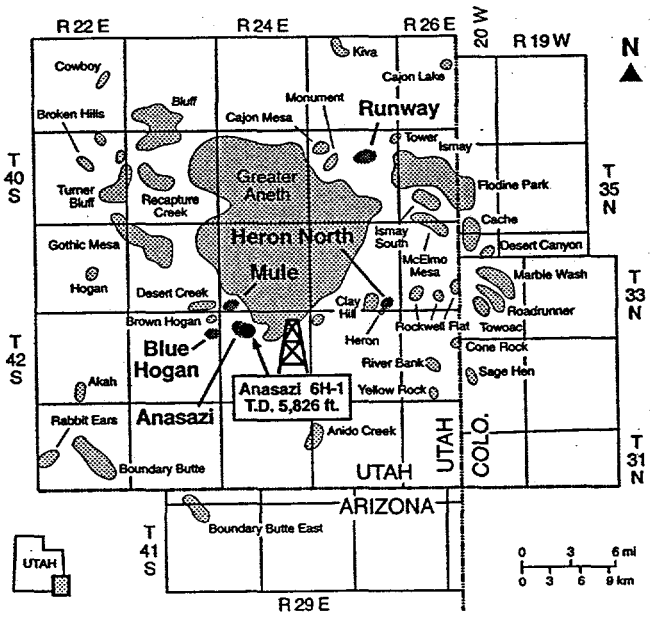

Figure 1. Five shallow-shelf carbonate fields (dark shading with names in bold type) on the Navajo Nation, San Juan County, Utah are targeted for geological and reservoir characterization. Also shown is the approximate location of the first project development well, the Anasazi 6H No. 1, drilled in the Anasazi field.

Summary of Technical Progress

Three activities began this quarter as part of the geological and reservoir characterization of carbonate mound buildups in the Paradox basin: (1) core study, (2) data collection, (3) and development well drilling, logging, and completion.

Geological Setting

The Paradox basin was a structural and depositional trough associated with the Pennsylvanian-age Ancestral Rocky Mountains. The climate in the region was subtropical to arid. The subsiding basin developed a shallow-water carbonate shelf which locally contained carbonate mound buildups on the south and southwest margins. These carbonate mounds and the material shed from their flanks formed petroleum traps where reservoir-quality porosity and permeability have developed. Eby *et al.*[1] have identified from core, five different types of carbonate mounds in the Desert Creek zone of the Paradox Formation: (1) crinoid/sponge mounds, (2) coralline algal "reefs" mounds, (3) bryozoan-dominated mounds, (4) phylloid algal mounds, and (5) bioclastic calcarenites "beach" mounds. The controls on the development of each mound type were water depth, prevailing wave energy, and paleostructural position.

Core Study

Examination of core from the five fields being evaluated for the project shows that three mound types are present (Table 1). Phylloid algal mounds are present in four of the five project fields. This mound type, which dominates the area southwest of Greater Aneth field, developed where shallow water depth and low wave energy allowed establishment of algal colonies on possible paleohighs. The principal reservoir rock in phylloid algal mounds is bafflestone (calcified leaves of the green algae *Ivanovia*) with occasional dolomitization. Good to excellent primary porosity, ranging from 10 to 25 %, consists of interparticle, shelter, and moldic porosity types. Permeability ranges from 10 to 100 millidarcies (md).

A bioclastic calcarenite mound is present in Heron North field. This mound type, common east and southeast of the Greater Aneth field, represents high energy conditions where beaches developed over foreshore rubble zones. The principal reservoir rock in bioclastic calcarenite mounds is grainstone with extensive dissolution and complete dolomitization. Good to excellent porosity, ranging from 10 to 25 %, consists moldic and intercrystalline porosity types. Permeability is variable often due to bitumen plugging and ranges from 1 to 200 md.

A bryozoan-dominated mound is present in Runway field. This mound type, abundant northeast of the Greater Aneth field, developed below wave base along Mississippian fault blocks. The principal reservoir rocks in bryozoan-dominated mounds are bindstone and framestone with rare dolomitization. The primary porosity type is intraskeletal and ranges from 8 to 15 %. Permeability is variable with isolated pores connected by bryozoan sheets.

TABLE 1

Project Fields In The Paradox Basin, San Juan County, Utah

Field	Active Wells	Cumulative Production*			Mound Type
		Oil (bbls)	Gas (MCF)	Water (bbls)	
Anasazi	3	1,535,090	1,138,079	23,408	Phylloid Algal
Blue Hogan	1	269,106	238,453	1,698	Phylloid Algal
Mule	2	315,106	177,662	13,738	Phylloid Algal
Heron North	1	191,152	260,936	18,633	Bioclastic Calcarenite
Runway	3	722,038	2,063,517	1,947	Bryozoan-dominated/ Phylloid Algal

*As of January 1, 1995 (Utah Division of Oil, Gas and Mining[2]).

Data Collection

Reservoir data, cores and cuttings, geophysical logs, various reservoir maps, and other information from the project fields and regional exploratory wells are being collected by the Utah Geological Survey (UGS). Well locations, production reports, completion tests, core analysis, formation tops, and other data are being compiled in a database developed by the UGS. This database, *INTEGRAL*gim*, is a geologic-information manager that links a diverse set of geologic data to records using *PARADOX™* for DOS software. The database is designed so that geological information, such as lithology, porosity, or depositional environment, can be exported to software programs to produce strip logs, lithofacies maps, various graphs, statistical models, and other types of presentations. As of June 30, 1995, the UGS had acquired information for 51 project wells. Production data, geophysical log types, and well cutting information for these project wells were entered into the UGS *INTEGRAL*gim* database. In addition, completion test data and formation tops were also entered for 33 of these wells into the database.

The database containing information from the project will be available as a UGS open-file (digital format) report at the conclusion of phase 1, the geological and reservoir characterization study.

Drilling of Development Well

The first project development well, the Anasazi 6H No. 1, was spudded on May 20, 1995 and drilled to a total depth of 5826 ft in the Anasazi field, SE1/4NE1/4 section 6, T. 42 S., R. 24 E., Navajo Nation, San Juan County, Utah (Fig. 1). The well location was designed to increase the well density in the field from 80 acres per well to 30 to 40 acres per well. Data from the well will enable assessment of: (1) the frequency of reservoir compartments (reservoir heterogeneity) in a given area, (2) the amount of communication between compartments, (3) how a waterflood or CO_2 flood will move from one compartment to another, and (4) the areal extent of an average compartment.

The principal reservoir to be evaluated, a phylloid algal mound in the Desert Creek zone of the Paradox Formation, was penetrated at 5624 ft. The mound was cored (120 ft of whole core recovered) and described. Geophysical logs run consisted of the dual laterolog, spectral density, dual-spaced neutron, gamma ray, and long-spaced sonic. The wireline formation tester obtained reservoir pressures throughout the Desert Creek zone ranging from 300 to 1200 psi. The main pay intervals held 15 to 25 % of the original reservoir pressure.

A completion plan was developed for the well; the plan includes two initial perforated intervals (5723 to 5730 ft and 5680 to 5694 ft), acidization (1050 gal [50 gal/ft] of 15 % hydrochloric acid), and a single well, flow/buildup test for each perforated interval. The pressure buildup tests will be used to determine average reservoir pressure, boundaries, and flow properties of the: (1) high permeability algal bafflestone interval in the lower part of the mound, and (2) low permeability dolomite intervals in the upper part of the mound. Fluid samples taken from these intervals will be used for extensive compositional studies. Pressure buildup data from the three other Anasazi field wells and the feasibility of conducting pulse tests was assessed. It was determined that pulse tests between the Anasazi 6H No. 1 and the other wells are not practical due to minimal predicted pressure response.

References

1. D. E. Eby, G. G. Groen, and J. F. Johnson, *Composition of Seismically Identified Satellite Mounds Surrounding Greater Aneth Field, Southeast Utah* (abs), Am. Assoc. of Pet. Geol. Bull., 77(8): 1446-1447 (August 1993).

2. Utah Division of Oil, Gas and Mining, *Oil and Gas Production Report*: (December 1994).

Next Quarter Activities

Activities planned for the next quarter (July 1 through September 30, 1995) include:

1. A team of geologists, reservoir engineers, and geophysicists from Harken will evaluate the second potential development location for the project fields.

2. Conduct completion operations and reservoir testing on the Anasazi 6H No. 1 well, Anasazi field.

3. Conduct relative permeability and phase behavior work. Develop preliminary EOS (based on original PVT studies) for the laboratory phase behavior program and preliminary 1D compositional simulation. Set up the 1D reservoir analogue compositional simulator to study preliminary depletion performance from compositional stand point and produce preliminary CO_2 design once the updated EOS is developed.

4. Describe cores and cuttings Anasazi field wells. Define layers or units with bounding surfaces for Desert Creek in Anasazi field.

5. Continue thin section petrography of Anasazi wells in order to: (a) establish a catalog of grain types and depositional facies, (b) develop a display and catalog of major porosity types as seen in thin section, (c) develop a display of typical porosity types and lithology as a function of log response, and (d) construct a diagenetic history for the reservoir zones.

6. Continue data collection. Well information such as production; completion and testing; oil, gas, and water analyses; core descriptions; reservoir tops; and other data will be entered into the UGS database for manipulation.

7. Suitable base maps will be obtained and updated. Begin work on various reservoir maps for project fields.

8. Prepare for and conduct outcrop work on phylloid algal mounds exposed along the San Juan River as reservoir analogues.

9. Conduct the following technology transfer activities: (a) prepare and present new project exhibit for the UGS display booth at the 1995 American Association of Petroleum Geologists (AAPG) Rocky Mountain Section meeting in Reno, Nevada, (b) write an abstract on the project fields and submit for presentation at the 1996 AAPG national convention in San Diego, California, (c) prepare and submit papers on the five project fields for the Utah Geological Association (UGA) Publication 22 entitled *Oil and Gas Fields of Utah*, second edition, (d) release the July issue of the UGS *Petroleum News*, (e) present an oral paper on the geology of the Paradox basin and the project to the Fort Worth Geological Society, and (f) begin initial planning of a Paradox basin symposium sponsored by the UGS, UGA, U.S. Geological Survey, Four Corners Geological Society, and Bureau of Indian Affairs. A UGS workshop presenting the results of phase 1 (budget period 1) will be part of this symposium.