Volume I
EXECUTIVE SUMMARY

Coalbed/Devonian Shale Degasification Project

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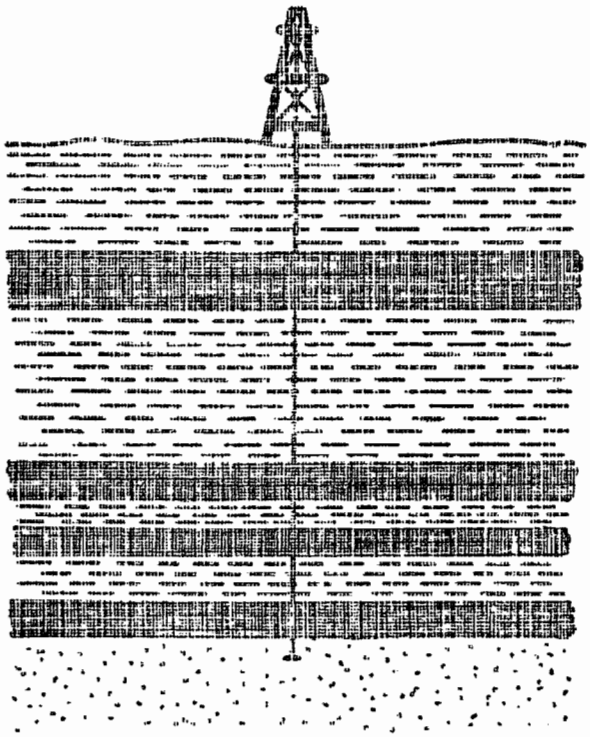
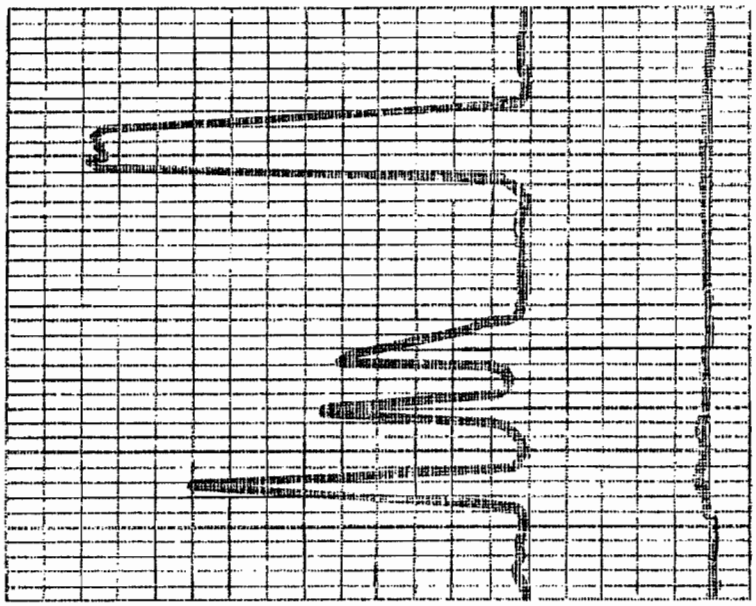
AMERICAN PUBLIC GAS ASSOCIATION





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VOLUME I

EXECUTIVE SUMMARY

OF

COALBED/DEVONIAN SHALE

DEGASIFICATION PROJECT

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November 30, 1986

PREPARED BY

GUSTAVSON ASSOCIATES, INC.

BOULDER, COLORADO

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

AMERICAN PUBLIC GAS ASSOCIATION (APGA)

HISTORY AND MEMBERS

The American Public Gas Association (APGA) is an organization which represents a large group of local publicly owned gas systems, consisting of:

- **Municipal gas systems.**
- **Public utility districts.**
- **County districts.**
- **Other public agencies having gas facilities.**

The organization was chartered in 1961 and has members in over twenty-eight states throughout the United States.

Objectives

The objectives of the APGA as determined in 1961, and which continue to guide the Association are as follows:

- **Promote the cooperation between public entities which own and operate gas distribution systems or gas-using facilities.**
- **Promote the mutual improvement of its members.**
- **Render service to its members, particularly in the fields of:**
  - **Management and operation.**
  - **Engineering, design, construction, operation and research.**
  - **Accounting and commercial practice.**
  - **Legal policy.**
  - **Other matters as may be common to public gas systems such as the**

production of unconventional gas.

Future Goals

The members of APGA believe that public gas has two major goals:

- To provide gas at the lowest possible cost, and with the best possible service, in order to lighten the burden of everyday living and to stimulate the growth of the nation's economy.
- To provide a means for the democratic control of one of the most important industries in America.

INTRODUCTION

OVERVIEW OF COALBED/DEVONIAN SHALE DEGASIFICATION

Project History and Purpose

In 1979, the U. S. Department of Energy provided the American Public Gas Association (APGA) with a grant to demonstrate the feasibility of bringing unconventional gas such as methane produced from coalbed or Devonian Shale directly into rural utility system distribution lines. In conjunction with this grant, a seven-year program was initiated where a total of sixteen wells were drilled for the purpose of providing this untapped resource to rural communities. While coalbed degasification ahead of coal mining was already a reality in several parts of the country, the APGA demonstration programs was aimed at actual consumer use of the gas. Emphasis was therefore placed on degasification of deep-lying coals with high methane gas content and on utilization of conventional oil field techniques.

Use of Resource for Municipalities

The reserve potential of coalbed/Devonian Shale methane gas has been estimated at 400 TCF of original gas-in-place located in 16 major coal basins throughout the United States. Many of these basins are located in isolated rural areas where small utility companies are dependent on the economic market and suppliers.

Development of unconventional methane gas:

- Gives the user long-term independence from gas suppliers as well as stabilizes the economic conditions involved in erratic market demands.
- Provides a low-cost fuel source capable of growing with a community's needs.
- Maximizes energy value of coal resources.

Results of Activities

- A total of eight project sites involving sixteen wells were selected throughout the United States for the purpose of demonstrating the feasibility of developing this unique resource.
- Project sites were selected from the following states: Alabama, Colorado, Indiana, New Mexico, New York and Tennessee.
- Eleven of the sixteen wells were drilled to underlying coal seams with the intent of exploiting the trapped methane gas.
- Five of these coal degasification wells are currently producing with the most successful wells drilled within the City limits of Pleasant Grove, Alabama.
- The remaining five of the sixteen wells were targeted at Devonian Shale horizons.
- Three of these five Devonian wells are presently producing gas in the small village of Bath, New York.

A project map (see Figure 1) illustrating the approximate locations of each of

WELL LOCATION MAP

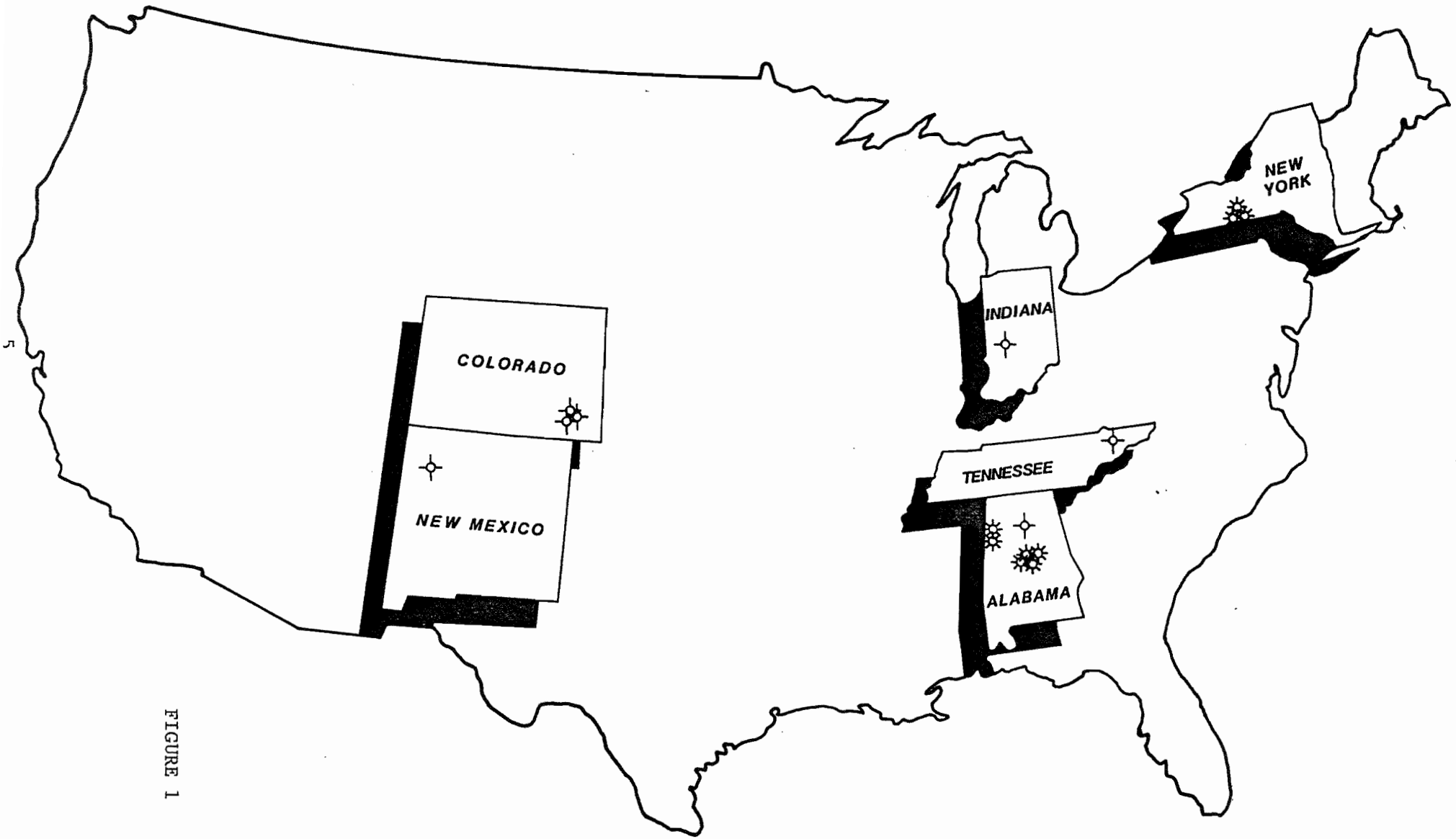


FIGURE 1

these projects has been provided on Page 5 of this Report.

A summary for each project, outlining the individual results has been compiled in the following text. Details of each project have been compiled in Volume 2. Volumes 3 and 4 provide data for public use in determining if a coalbed/Devonian project might be feasible as well as guidance toward its implementation.

Results of this program have proved to be encouraging, as some of the wells have yielded economic quantities of methane gas on basis of relatively low capital expenditures. Not all of the eight project tests were successful. However, with each well drilled, a more complete understanding of the reservoir characteristics and effective methods for extracting the trapped hydrocarbons were experienced. The knowledge gained from these wells has been compiled and summarized in this report as well as disseminated to interested parties during the conduct of the program.

CRITERIA FOR SELECTING A DEGASIFICATION PROGRAM

Prior to authorizing a major expenditure toward the utilization of gas generated from coal or shale beds, a technical study of the geologic environment, availability of manpower and equipment costs of drilling and operations, as well as potential reserves and return on investment will need to be conducted. A study addressing these topics is necessary to determine whether or not methane gas trapped by degasification processes is a feasible source of energy for a particular application. The following "checklist" outlines the general criteria that must be considered prior to initiating a full-scale program.

Criteria For Test Well Location

There are five major criteria for identifying and locating potential degasification wells which are listed in the following checklist:

- **Existence of coal or shale beds.**
- **Minimal thickness of coals in the two to three-foot range.**
- **Depth of burial of 1,000 to 3,000 feet.**
- **Prior evidence of gas content in coals or shale.**
- **Availability of at least a 300-acre lease under favorable terms.**

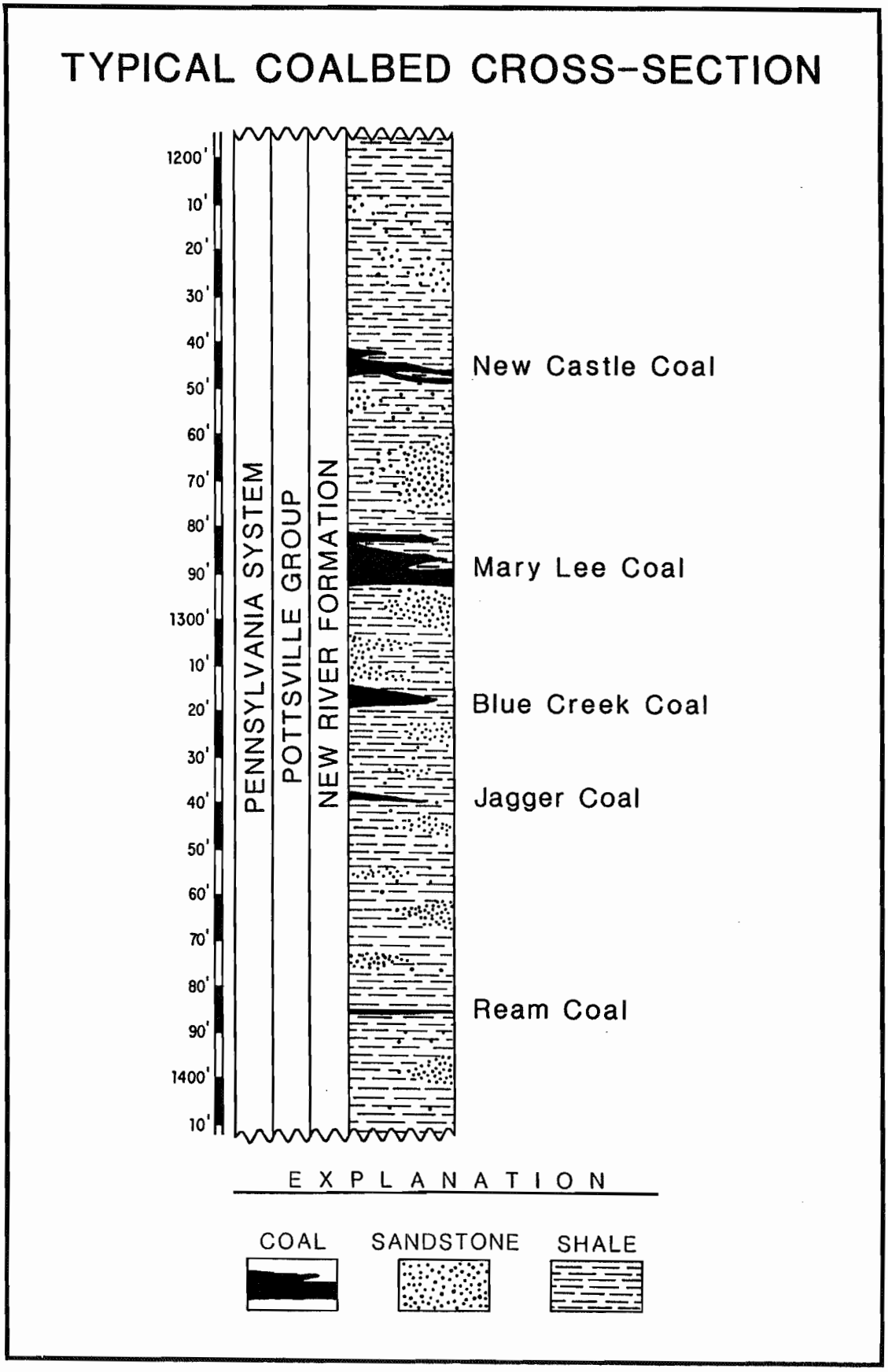
The first criterion for determining the feasibility of a degasification project is to determine the existence of coal or shale beds in the immediate area. Simple geologic cross sections can be derived from outcropping beds,

depositional environment, previous well data, and current geologic mapping. Based on this information, the thickness and depth of burial can be estimated. A minimal thickness of two to three feet of coal bed must be present to allow for adequate gas generation and trapping, as well as proper formation stimulation. Figure 2 on the following page illustrates a typical cross-sectional view of a gas-bearing coal seam with adequate thickness. In the case of shale several hundreds of feet of fractured shale is usually required.

The depth of burial should range between 1,000 and 3,000 feet. At depths greater than 3,000 feet the drilling tend to become less cost effective and at depths shallower than 1,000 feet, the generation and trapping of the methane gas tend to be less efficient. In many instances, evidence of gas contained within coal or shale beds can be found in older well records (oil or water wells), or from mining operations. This information is important, as it suggests that proper maturation has taken place and methane gas has been allowed to accumulate.

Other important criteria include the community's needs and potential distribution of such an energy source. Depending on the size and energy usage of a community, a reasonable amount of lease acreage must be obtained to met these needs. A lease block of approximately 300 acres should be more than adequate to test a supply for a small community and yet allow for future development and expansion. Figure 3 on Page 10 illustrates the major coal fields in the continental United States. A location above any of these would meet the criteria outlined earlier.

FIGURE 2


TYPICAL COALBED CROSS-SECTION
1200'
10'
20'
30'
40'
50'
60'
70'
80'
90'
1300'
10'
20'
30'
40'
50'
60'
70'
80'
90'
1400'
10'
PENNSYLVANIA SYSTEM
POTTSVILLE GROUP
NEW RIVER FORMATION
New Castle Coal
Mary Lee Coal
Blue Creek Coal
Jagger Coal
Ream Coal
EXPLANATION
COAL
SANDSTONE
SHALE

Coal Fields of the Continental United States

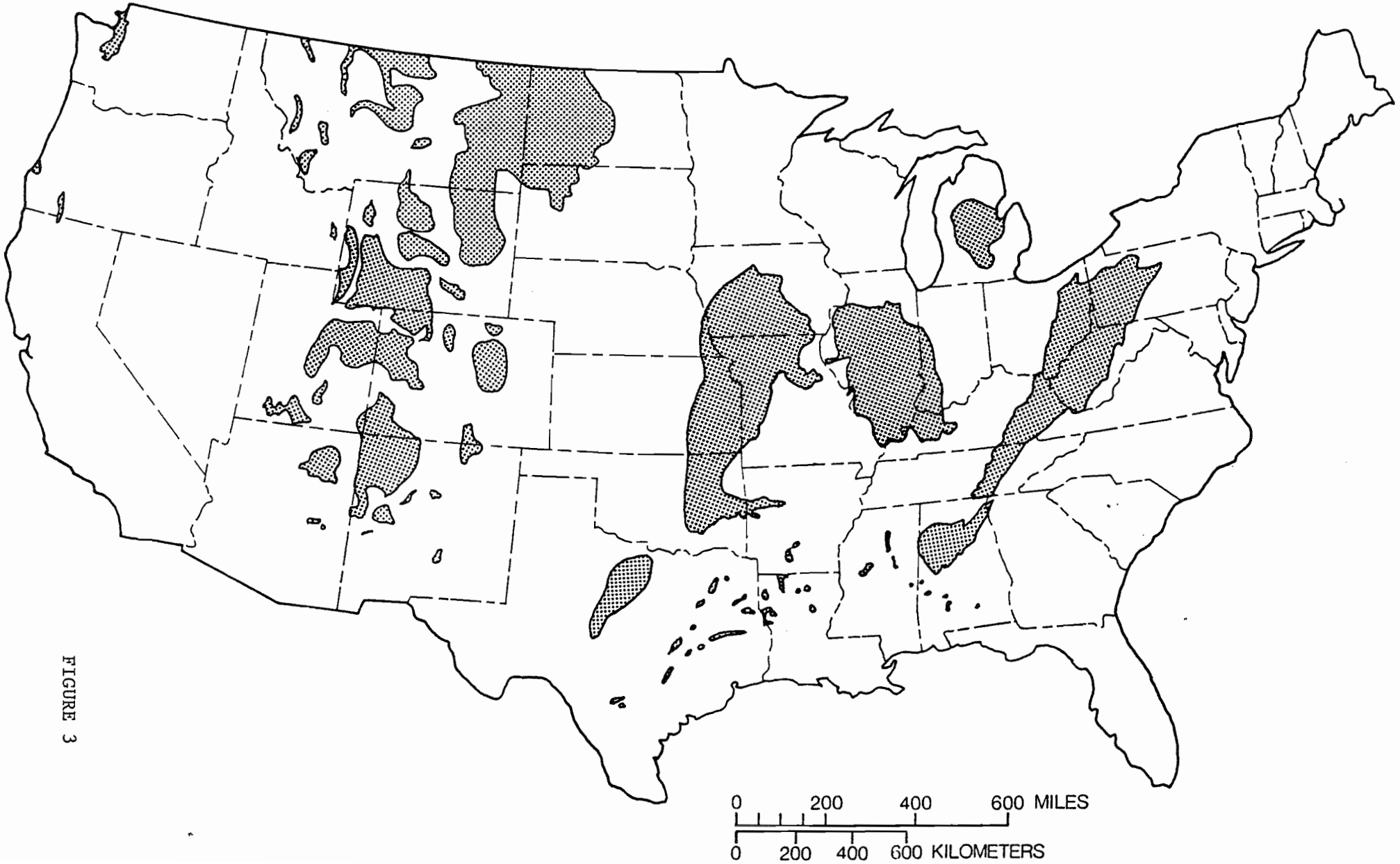


FIGURE 3

ECONOMICS OF COALBED GAS UTILIZATION

Any utility company or other user of coalbed methane must, by necessity, include the economics considerations of bringing this resource into a distribution system. There are two major cost factors which need to be considered, namely the:

- **initial drilling and development of the coalbed degasification wells,**
- **the subsequently long-term operating cost of the wells,**

including the preparation of the methane gas to meet distribution system specifications.

Of these two cost items, the first one is generally considered a capital investment of relatively high magnitude and short duration. In contrast, the operating cost, as well as the cost of preparing the gas for use, are relatively low level and very long-term cost items. These latter operating costs can generally be covered out of the income derived from the gas and need not be considered from a capital investment standpoint. From an overall economic standpoint, both the above cost factors must be considered.

Oil Industry Economics

It is customary in the oil industry to evaluate the commercial feasibility of a project by considering the initial capital cost of drilling and development as an investment and then consider the operating life of the wells as the period for recovery of the invested capital, plus a potential profit. During this period of capital recovery, the gross income from the gas is reduced by

applicable royalties to landowners, taxes and by the above mentioned operating expenses. Any remaining revenue is distributed and accounted for against the initial investment and as profit.

At the end of the life of the wells, it is then possible to calculate an internal rate of return for the overall project, the magnitude of which, first of all should be positive, and secondly, should preferably be higher than the prevailing cost of money, roughly expressed as the prime interest rate plus 2%.

Utility Industry Economics

In the utility industry, a relatively low rate of return may be acceptable in view of the consumer-directed public service, which is provided. For purposes of the following economic discussions, a desired rate of return of 8% is assumed. Adjustments may be made by individual utility companies or other gas users to coincide with their particular economic parameters.

Economic Feasibility

After having compared the desired rate of return with the internal rate of return as estimated for the specific project at prevailing gas prices, a decision can be made whether or not to proceed. The above approach is used by the conventional oil and gas industry. In the case of a utility company or another individual user of coalbed methane, it is often desirable to reverse the process and instead of utilizing gas prices as presently experienced when

purchasing from major pipelines, fix an acceptable internal rate of return. Thereafter, a number of technical and economic parameters may be developed which ultimately will lead to a substitution gas price which would be experienced through a specific project.

For example, given a set of technical parameters such as;

- **the depth to the coalbeds,**
- **the content of methane gas in the coalbeds**
- **prevailing drilling prices,**
- **other cost parameters,**

it is possible to derive a final substitution price for the produced gas as an average over the life of the project. A utility company or other user can then determine whether methane gas at that particular price is acceptable. The resulting number may be an acceptable alternative to normal pipeline supplies or fractions thereof, representing a locally controlled uninterruptible source of gas.

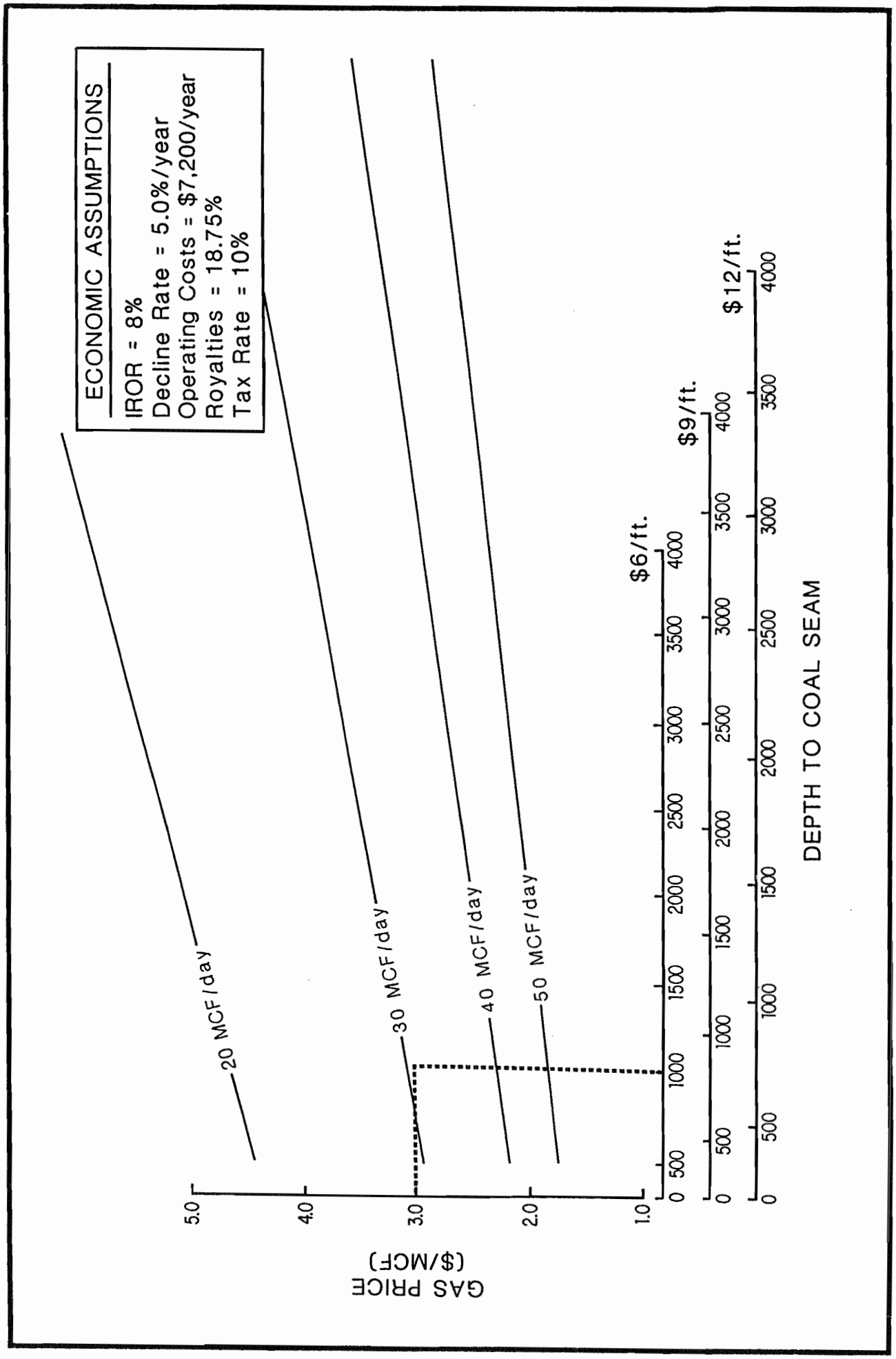
Figure 4 has been prepared to provide planning information. Additional curves for other economic parameters are presented in Volume 3 in this series of reports. The required parameters for this initial planning are held as simple as possible in order to facilitate the process.

Economic Example

For a utility or user with:

- **8% as an acceptable internal rate of return**
- **a well depth of 1,000 feet and a drilling cost of $6/ft.**

FIGURE 4 - ECONOMIC ANALYSIS (IROR 8%)



- **an initial gas flow rate of 31 MCF per day**
- **the substitution price of gas would be $3.00 per MCF.**

Parties interested in more details or variations of the parameters to fit more specifically into a local situation, are invited to contact the U. S. Department of Energy, the American Public Gas Association or this Consultant. Small personal computer programs can be made available at a nominal cost to adapt to a specific situation.

RECOMMENDATION FOR DRILLING AND COMPLETION

The following text outlines the drilling and completion methods recommended for a coalbed degasification well. These recommendations are a result of the knowledge and experience gained after drilling twelve coalbed degasification wells for the American Public Gas Association over a seven-year period.

Drilling

- **Drill a sufficient size hole (7 7/8 inch), capable of handling a 5-1/2" diameter string of casing.**
- **This hole should be drilled with air in order to prevent damage to the productive coal seams.**
- **The casing program and setting depths should be designed to meet the state's requirements for protecting fresh water zones encountered during the drilling operations.**

Completion

- **The production string should be cemented with a light-weight foam cement (6 to 8 lb/gal) when cementing operations must be performed across a targeted coal seam.**

The reason for using a light-weight foam cement is to prevent the cement from entering the coal seam and causing severe formation damage. Another alternative is to simply open-hole complete the well. This involves drilling

through the targeted zone and not setting any type of casing across the zone.

This technique is commonly used; however, recent experience has shown that these open-hole completions when performed in soft, friable coal seams may lead to complications during stimulation operations as well as sloughing problems throughout the life of the well.

- **Therefore, it is recommended that casing should be set across the desired formation and a light-weight foam cement be used to minimize formation damage during these operations.**

Stimulation

The hole can then be plugged back to the desired depth and stimulation operations instigated. Many different stimulation techniques have been tested by this project and by various organizations over the past years and each technique has specific reasoning and designs for a particular area.

- **The generally accepted technique involves a nitrogen foam frac with the appropriate quantities of sand, depending on the designed fracture length.**
- **Small frac treatments range from 15-30,000 lbs. of sand and larger frac treatments range from 40-80,000 lbs. Unfortunately, the nitrogen foam frac is also one of the most expensive techniques presently available.**
- **A gel fracture treatment is another method, where a gelled substance is used to carry the sand into the formation. Again, this is also a fairly expensive method.**

- **A common and yet inexpensive technique involves large volumes of water pumped at high rates, combined with the sand mixtures. This technique is cost effective; however, the chances of fracing the well out of zone are increased due to the high pressures experienced as a result of the rate at which the water is pumped into the formation.**

The technology to stimulate a well using the three above methods has been in practice for many years and is common in all parts of the United States. The most popular methods currently used are the

- **Nitrogen foam treatment and the**
- **Water stimulation method,**

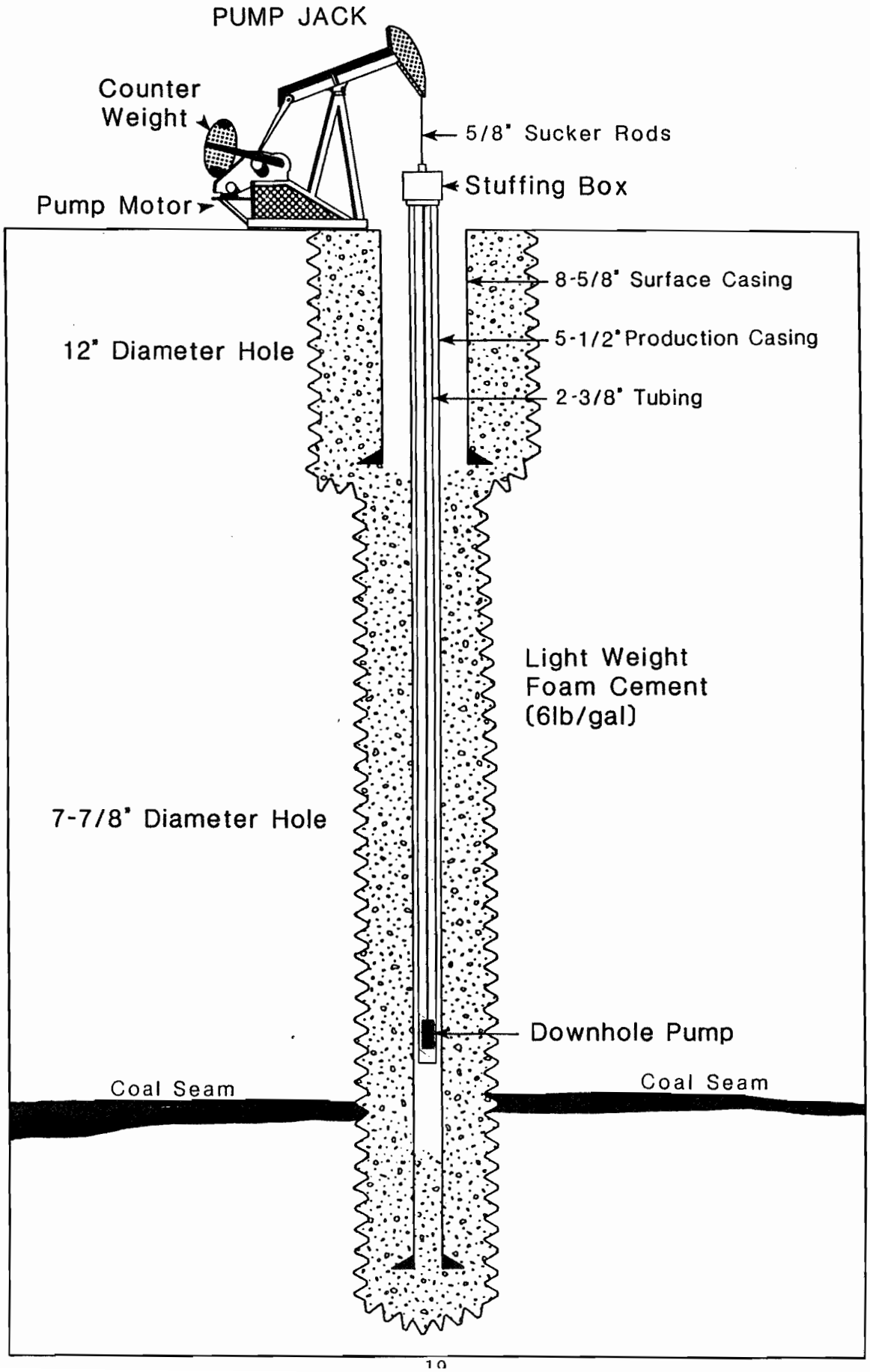
depending on the regional area. This study concludes that the initial well(s) in a new area should be fractured with nitrogen foam until knowledge of the formation has been gained. Then, less expensive materials may be tested for subsequent wells.

Surface Equipment

Once the well is drilled and stimulated, a pumping unit similar to the illustration on page 20 is most commonly used to pump the hydrostatic head of water from the wellbore and allow the coalbed to release methane gas. This pumping unit, referred to as a "sucker-rod pump" has been used in the oil business for many years and is particularly applicable at shallow depths and low quantities of fluid volumes. Downhole rotary pumps may be used where large water volumes need to be removed.

FIGURE 5

TYPICAL PUMP & HOLE CONFIGURATION



Operations

Following the successful stimulation of a well and the installation of the appropriate surface equipment such as dryers and odorizers, the task of daily operating and maintaining the well is required.

- **The main objective at this point is to keep the well producing gas by unloading water, maintain the equipment, and keep operating expenses at a minimum.**
- **The gas is generally a high methane content pipeline quality gas which may need only drying and odorizing before distribution to local consumers.**

SUMMARY OF ACTIVITIES

OVERVIEW

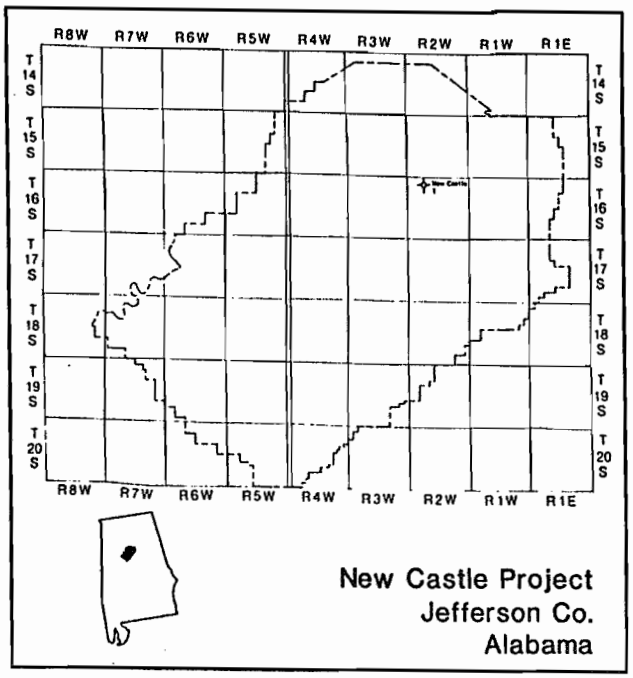
The following text is an overview of each project drilled by the American Public Gas Association under the Department of Energy grant. The projects are listed in alphabetical order according to the state in which the wells were drilled.

- **A total of sixteen wells were drilled over the seven-year period of the program.**
- **Eight separate project sites were selected from the following states: Alabama, Colorado, Indiana, New Mexico, New York and Tennessee.**
- **Eleven of the sixteen wells were drilled to underlying coal seams with the intent of exploiting the trapped methane gas.**
- **Five of these coal degasification wells are currently producing with the most successful wells drilled within the city limits of Pleasant Grove, Alabama.**
- **The remaining five of the sixteen wells were targeted at Devonian shale horizons.**
- **Three of these five Devonian wells are presently producing gas in the small village of Bath, New York.**

A project map illustrating the approximate locations of each of these projects has been provided on Page 2 of this Report.

Alabama, New Castle

FIGURE 6



Number of Wells: 1

State: Alabama

County: Jefferson

Community: New Castle

Date Drilled: May 31, 1980

Target Zone: "Jane B" Coal Seam

Approximate Depth: 1,764 Feet

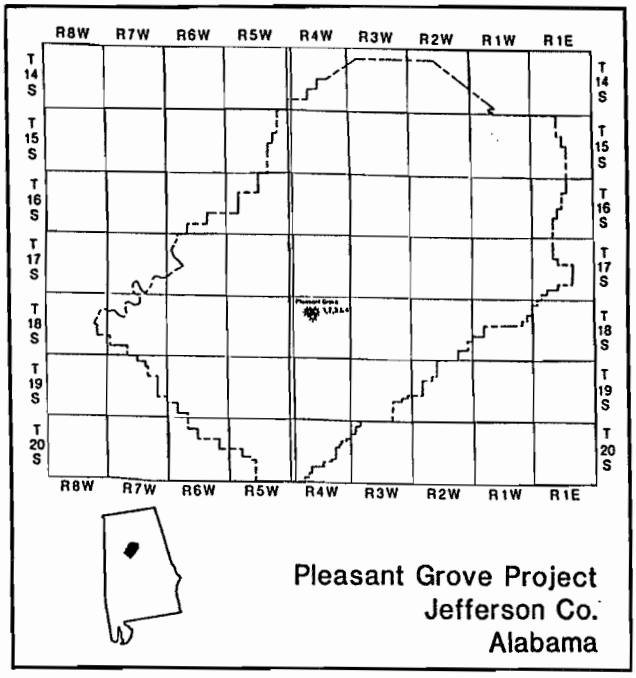
Current Status: Plugged and Abandoned

Comments:

- Geological reports obtained from core samples cut over the target horizon indicated that the coal seam had shaled out in this particular location and that no substantial quantities of hydrocarbon gas existed in the shale matrix.
- Consideration was made whether to attempt to complete the well in a shallower zone uphole at 805 feet (Black Creek).
- Again, laboratory desorption tests indicated that only small quantities of gas were present.
- Based on these test results and estimated costs associated with completion operations, the decision was made to plug and abandon the well.

Alabama, Pleasant Grove

FIGURE 7



Number of Wells: 4

State: Alabama

County: Jefferson

Community: Pleasant Grove

Date Drilled: December 9, 1979

July 1, 1980

June 12, 1986

June 18, 1986

Target Zone: Mary Lee, Blue Creek

Black Creek

Approximate Depth: 1,550 Feet

Current Status: Producing

Comments:

- **These four wells represent the most successful wells drilled by the American Public Gas Association over the project's seven-year history.**
- **All four wells are currently supplying the City of Pleasant Grove with coalbed methane gas at an average of 25 MCF per day per well.**
- **The first three wells drilled were open-hole completed during which many mechanical problems were experienced with the down-hole equipment.**
- **Due to these mechanical problems, individual zones were not adequately isolated and limited fracture lengths were experienced.**

- The fourth well was completed with casing in an attempt to prevent the shortcomings experienced in the previous wells. A light-weight foam cement was used to secure the casing across the coal formation.
- The gas production from these wells has averaged 20-30 MCF/day/well over the past five years and has given the City of Pleasant Grove long-term independence from economic markets and suppliers.

FIGURE 8

Alabama, University of Alabama

Number of Wells: 2

State: Alabama

County: Tuscaloosa

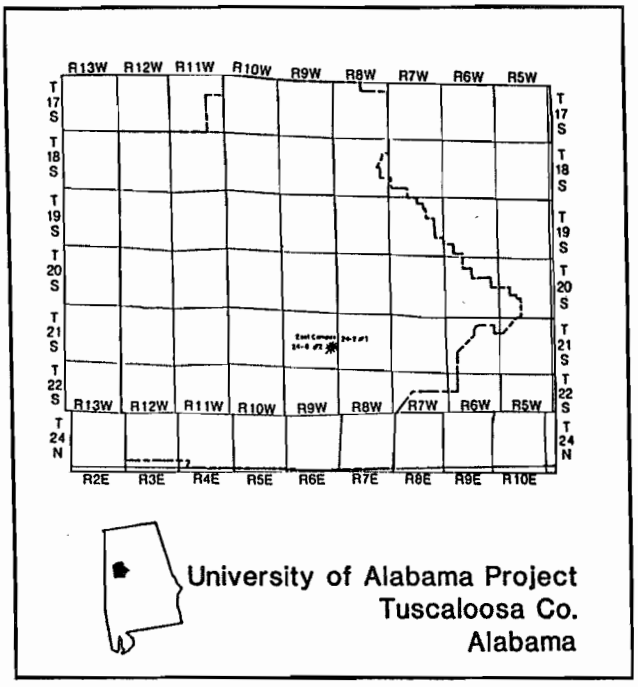
Community: Tuscaloosa

Date Drilled: March, 1981; April, 1983

Target Zone: Mary Lee, Blue Creek

Approximate Depth: 2,290 Feet

Current Status: Shut-In

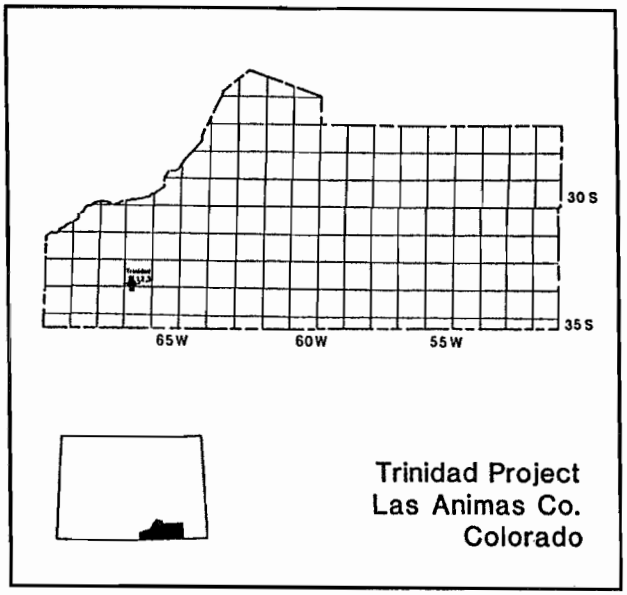


Comments:

- The first well drilled was successfully completed in the Mary Lee and Blue Creek coal seams with initial recoveries of 20 MCF/day.
- Geological information gathered from this well indicated that the coal seams were 100 feet structurally lower than near-by core hole data as a result of significant subsurface faulting.
- Large quantities of water were produced from this well which reduced the ability to produce gas. The water production was directly related to the faulting witnessed in the area.
- The second well was also successfully completed in the Mary Lee and Black Creek coal seams with initial recoveries of 30-40 MCF/day.
- Similar water problems encountered in the first well were also experienced in the second well. Downhole rotary pumps were tested.
- Methane gas produced from these wells helped supply the fuel needs of other ongoing research projects at the University of Alabama.

Colorado, Trinidad

FIGURE 9



Number of Wells: 3

State: Colorado

County: Las Animas

Community: Trinidad

Date Drilled: Mid-1982

Target Zone: Vermejo

Approximate Depth: 1,600 Feet

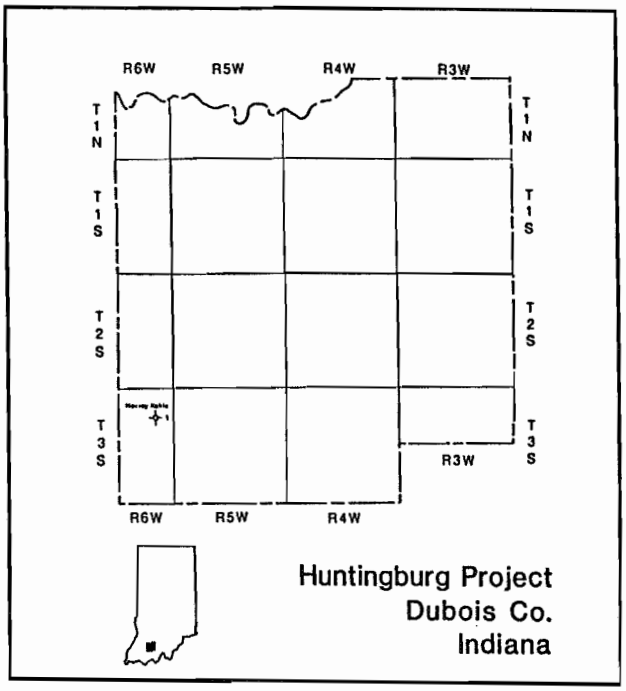
Current Status: Plugged and Abandoned

Comments:

- **All three wells showed sufficiently high methane contents from coalbed core samples taken to justify a completion.**
- **Large quantities of water were encountered requiring extensive dewatering.**
- **Structural deformation of the local coalbeds, combined with substantial interfingering of porous sand bodies appear to have caused the large continuous influx of water.**
- **Only small quantities of gas (1-3 MCF/day/well) were recovered so the wells were plugged and abandoned.**

Indiana, Huntingburg

FIGURE 10



Number of Wells: 1

State: Indiana

County: Dubois

Community: Huntingburg

Date Drilled: January, 1983

Target Zone: Mississippian/Devonian New Albany Shales

Approximate Depth: 2,480 Feet

Current Status: Plugged and Abandoned

Comments:

- **The shale was located at the predicted depth and thickness.**
- **An attempt to complete the gas-bearing shale proved unsuccessful.**
- **An underlying limestone producing excessive amounts of brine water which coupled with only small quantities of methane gas resulted in the abandonment of the well.**

FIGURE 11

New Mexico, Farmington

Number of Wells: 1

State: New Mexico

County: Navajo Indian Lands

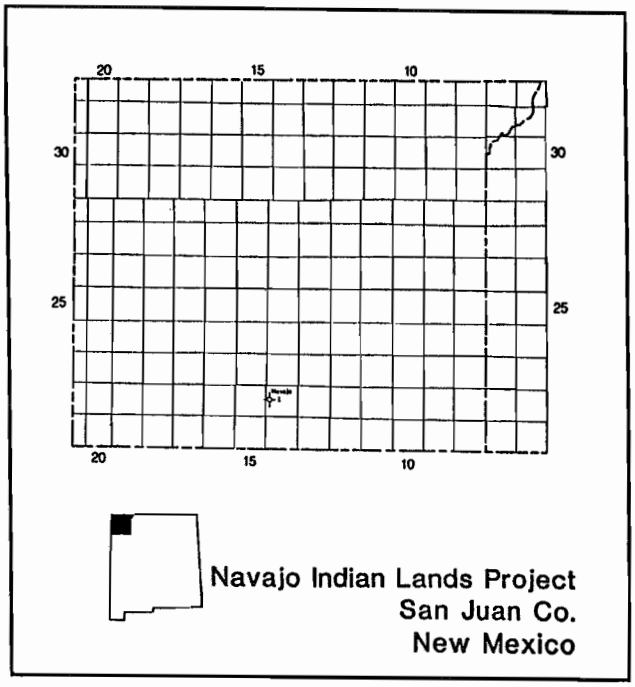
Community: Indian Reservation

Date Drilled: December, 1980

Target Zone: Fruitland

Approximate Depth: 915 Feet

Current Status: Plugged and Abandoned

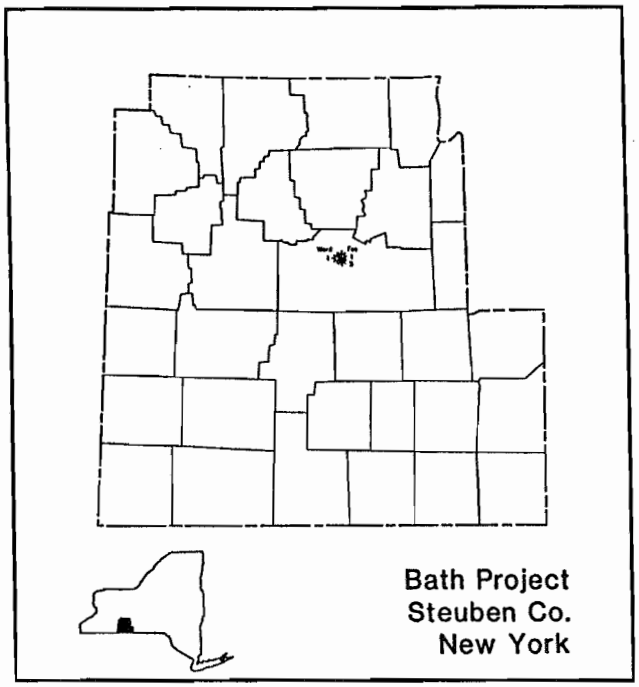


Comments:

- **An impressive seven feet of coal were penetrated in three separate coal seams.**
- **Desorption tests revealed a low methane content per ton of coal.**
- **The well was recommended for abandonment and was not stimulated.**

New York, Bath

FIGURE 12



Number of Wells: 3

State: New York

County: Steuben

Community: Bath

Date Drilled: February 27, 1981

September 30, 1981

October 8, 1981

Target Zone: Devonian Marcellus Shale

Approximate Depth: 2,900 Feet

Current Status: Producing

Comments:

- Test cores from the initial well confirmed the presence of kerogen-rich, black shales with natural fracturing.
- Desorption analysis revealed a free gas range of .84 to 1.80 cu. ft. of gas per ton of shale.
- The wells were successfully completed and initial production ranged from 10 to 20 MCF/day/well.
- Production performance from these wells was impaired due to negotiations with pipeline companies which delayed the production of these wells for over a one-year period.
- Gas produced from these wells has been used by the small village of Bath to help offset the fuel needs of the community.

Tennessee, Hawkins County

FIGURE 13

Number of Wells: 1

State: Tennessee

County: Hawkins

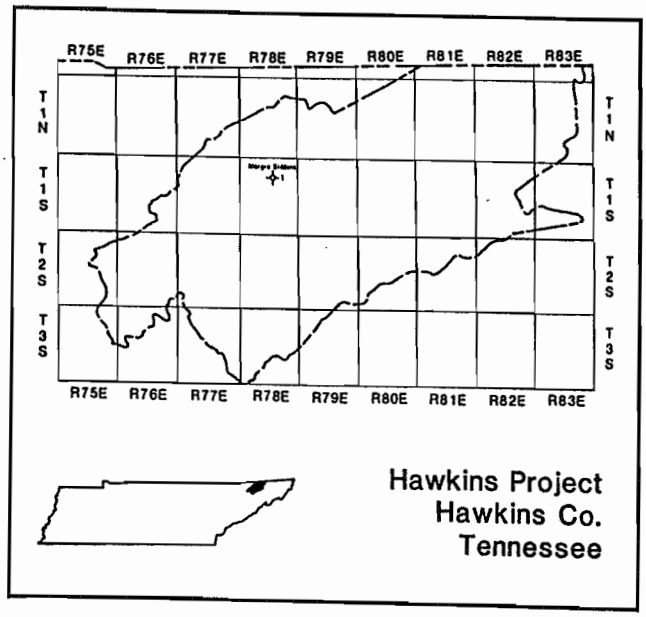
Community: Rogersville

Date Drilled: November, 1983

Target Zone: Chattanooga Shale

Approximate Depth: 3,880 Feet

Current Status: Plugged and Abandoned



Comments:

- **Laboratory tests on core samples taken from the well indicated a low gas content, but logs showed evidence of natural fractures.**
- **Completion attempts were made on several zones but proved unsuccessful as only small amounts of methane gas were recovered.**
- **The well was plugged and abandoned.**