GL04714

OPERATIONS PLAN

Ferron Sandstone Coring, Logging and Sampling Program

Definition of Stratigraphic Heterogeneity
Using Borehole Imaging

DRAFT

May 17, 1991

CONTENTS

1. INTRODUCTION

Drilling of two coreholes in the Ferron Sandstone is the second phase of an investigation into Definition of Stratigraphic Heterogeneity Using Borehole Imaging. The first phase of the project (Nielson et al.,1991) simulated borehole imaging data by collecting dip orientations in outcrop. The Statistical Curvature Analysis Technique (SCAT; Bengtson, 1981) was then evaluated as a method for interpreting borehole imaging data in a stratigraphic context (see also Bengtson and Ziagos, 1987).

Outcrop investigations for Phase 1 of the study have been done on exposures of the Ferron sandstone in Emery County, Utah. Figure 1 is an index map showing outcrops of the Ferron and the areas where UURI has measured bedding orientation data. Sections were measured at Miller Canyon, Muddy Creek, and Dry Wash that represent a progression from more landward and fluvial-dominated at Miller Canyon to more seaward and marine dominated at Dry Wash. Measured stratigraphic sections for these areas are shown in Figure 2 (Ryer, 1981b). The UURI analysis has concentrated on marine sandstone #4 and above, and most data has been collected from the measured sections in Muddy Creek and Dry Wash.

In addition to the work being done at UURI, the Texas Bureau of Economic Geology has been studying the permeability of the same outcrops. Their work has concentrated on unit #5 in the Muddy Creek area. Figure 3 shows the areas being measured by BEG and the sections measured by UURI in the Muddy Creek area.

2. OBJECTIVES

The purpose of Phase 2 of this project is to

1. Continue to build the data bases that are required for an interpretive and predictive capability,
2. Test the ability of borehole imaging logs to collect the data necessary for these interpretations, and
3. Evaluate the ability to predict reservoir heterogeneity in the subsurface.

To these ends, two coreholes will be drilled through the Ferron Sandstone in the Muddy Creek area near the outcrops that were measured in Phase 1 of the work. The objectives of the coreholes are as follows.

1. Collect core through the Ferron Sandstone.
2. Provide holes for borehole imaging and other logs for correlation with the core and outcrop data.

Two coreholes were proposed to allow testing of capabilities to predict heterogeneities on the basis of the borehole imaging techniques.

Figure 1

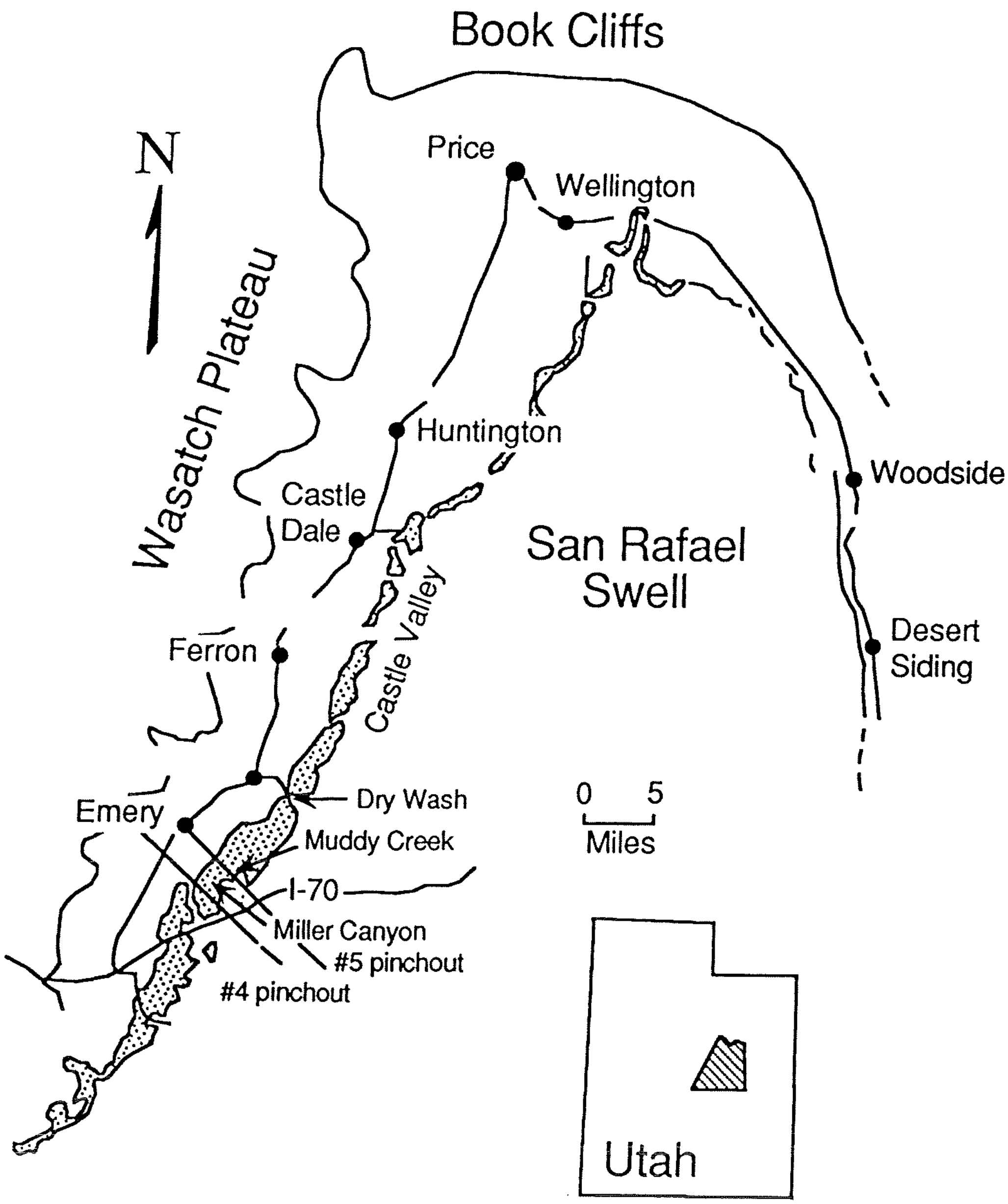

Figure 1. Outcrop of the Ferron Sandstone in east-central Utah

Figure 2

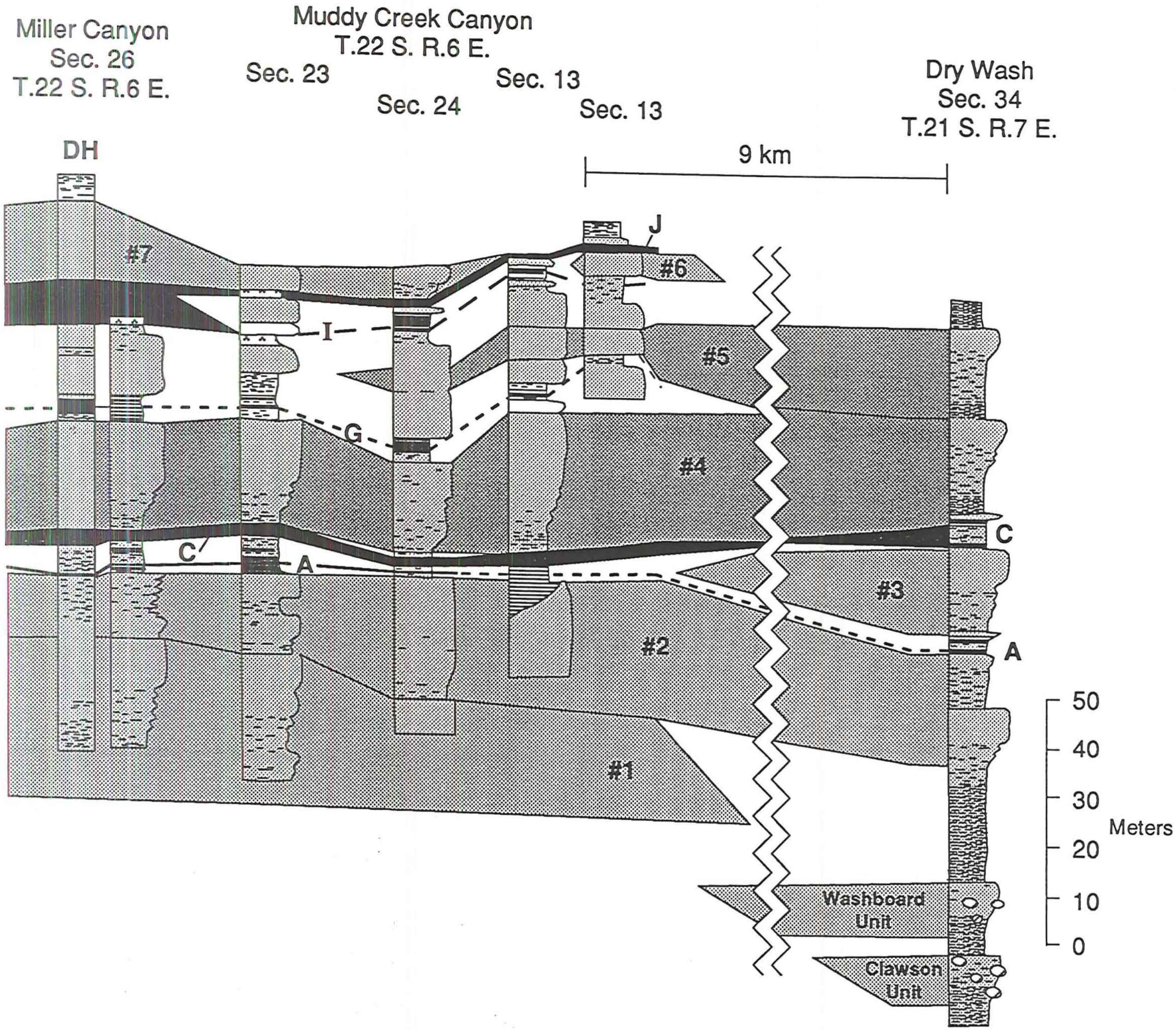

Figure 2. General stratigraphic sections of the Ferron Sandstone in Emery County. (Modiified from Ryer 1981b.)

3. SITE GEOLOGY

3.1 Units #6 and #7

The stratigraphy of the Muddy Creek area is shown on Figure 2. The portion of this diagram labeled section 13 illustrates the sequence of rocks expected to be encountered in the holes. Depending on the specific locations, the holes will be spudded in either the Blue Gate Shale Member of the Mancos Shale or in the upper portions (#6 or #7 marine sandstones) of the Ferron Member. The J coal, separating the #6 and #7 sandstones, averages about 6 feet in thickness and has been mined on the ridge west of measured section MC-4 (Fig. 3). Between the J coal and the channel sandstones overlying the #5 sandstone are carbonaceous and fine-grained delta-plain deposits up to 20 ft thick. A few isolated fluvial channels are also present in the delta-plain deposits. One such channel from section MC-4 has bedding orientations concentrated at N 60° E.

3.2 Unit #5

At Muddy Creek, the #5 sandstone is characterized by abundant channel cuts into the marine section. Most of the scours on the north and west sides of the canyon are filled with large distributary channel sandstones, but empty scallops at the top of the east side of the canyon indicate the presence of some previously mud-filled (abandoned) channels. On the east side of the canyon, the upper portion of the marine section of the #5 is a distributary mouth bar deposit characterized by beds of planar lamination or bioturbation (with Ophiomorpha-like burrows). On the west side, distributary channels are present directly above (have cut into) distal mouth bar deposits, characterized by hummocky cross-bedding. Near section MC-9, one distributary channel has cut all the way through the underlying marine section into the delta-plain deposits overlying the #4, and now rests on the G coal.

Bedding orientations in the distributary channel sandstones have a broad distribution (from - -50 to -10 degrees) with a concentration of azimuths at -45 degrees (Fig. 4). A second maximum occurs between 10 and 50 degrees. The bedding orientations in the #5 marine sandstone have maximum concentrations in both the south and the north directions (Fig. 5). This, along with consideration of the northwest trend of the #5 pinchout, suggests primary transport of the sands to the north with tidal influences producing the southerly dips.

In a drillhole located on the west side of Muddy Creek, thick (up to 40 ft thick) northwest-trending channel sandstones can be expected to be encountered on top of a thinner (20 to 30 ft thick) marine sandstone unit. The distributary channel unit will consist predominantly of trough crossbedded sandstone, in which bimodal current directions can be expected. The underlying marine unit will contain amalgamated hummocky crossbeds of sandstone in the upper part, thin bioturbated mudstone and rippled shale beds in the lower part, and will generally dip northward.

The #5 marine sandstone and the overlying system of distributary channels have been the main focus of the BEG's work on permeability.

3.3 Unit #4

Delta plain deposits between the marine shale and the top of the #4 sandstone are

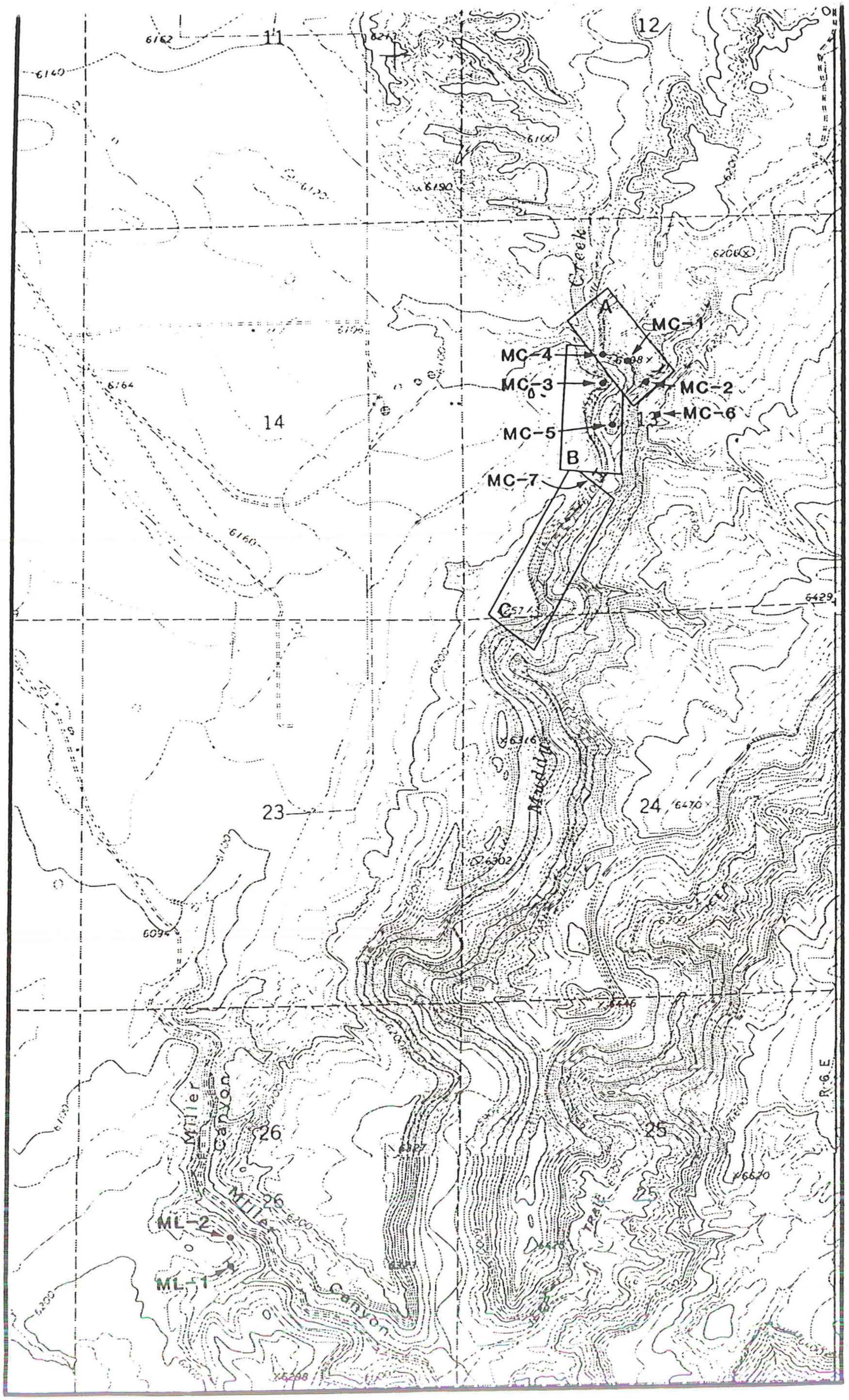

Figure 3. Locations of measured sections in Muddy Creek and Miller Canyon.

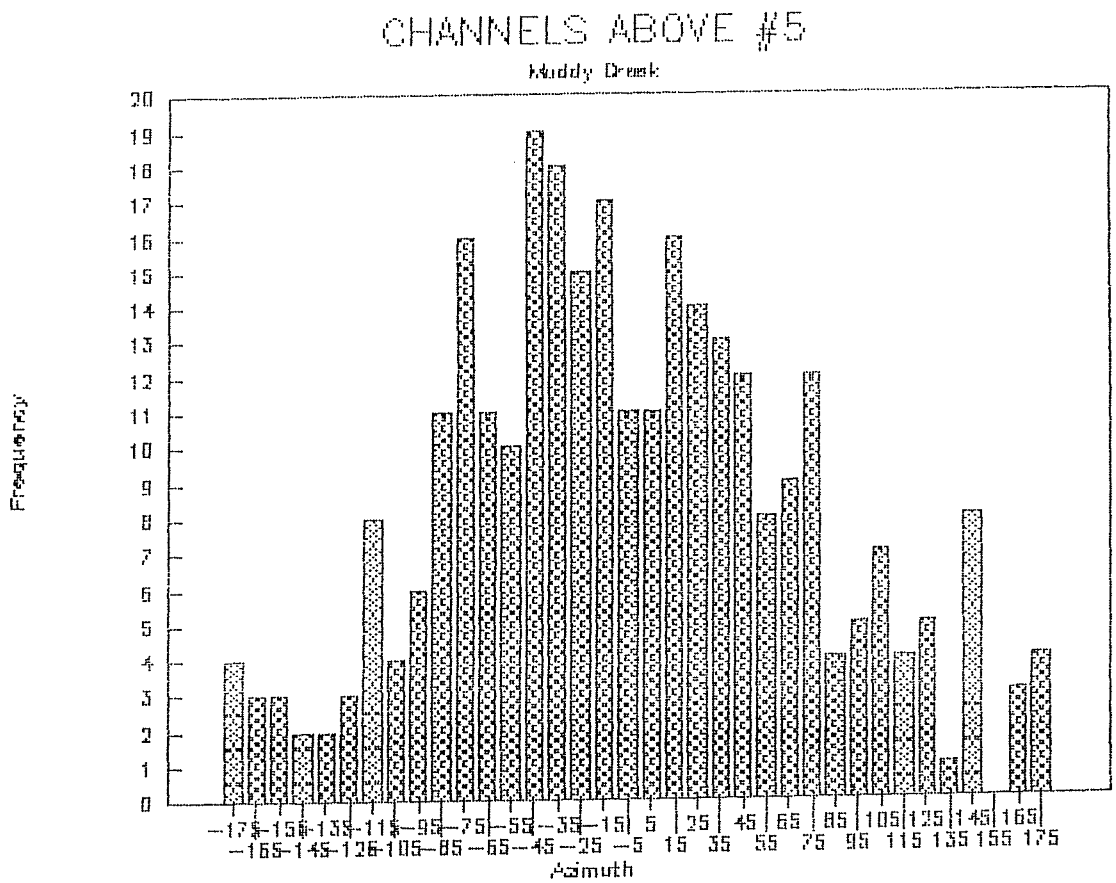

Figure 4. Histogram of dip azimuth measurements from distributary channel sandstones of the #5.

Figure 5

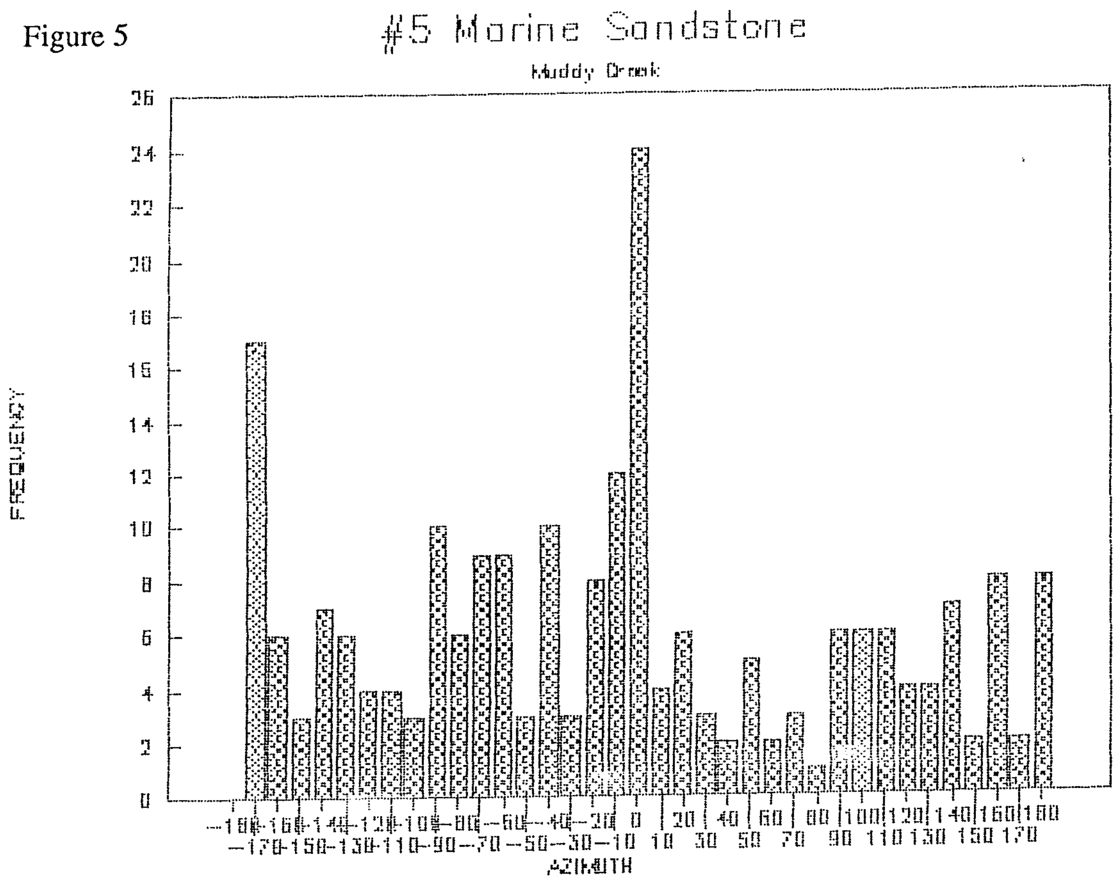

Figure 5. Histogram of dip azimuth measurements of the #5 marine sandstones.

predominantly fine-grained and ripple-laminated sandstone beds. Several fining-upward fluvial channel sandstones and coal beds are also present in this interval.

The #5 marine unit and the G coal are separated by a medium-grained, trough crossbedded sandstone unit that appears to be present throughout the canyon. The thickness of the unit and dip orientations of bedding features the are extremely variable. The thickness varies from about 30 ft in MC-5 and MC-9, to about 8 ft in MC-7. Orientation data for the entire unit (composed of several sets of trough crossbedded sandstones) exhibit concentrations in the range from N70W in MC-5 to N 20° E in MC-7 to N 90° E in MC-9.

The G swamp deposits are about 10 ft thick and are predominantly carbonaceous shale. In section MC-9, the G unit contains a coal bed, 2.3 ft thick.

Below the G swamp deposits and above the #4 is an interval containing many fluvial channel sandstone units separated by shales or rippled fine-grained sandstone. In MC-7, it is about 40 ft thick and predominantly sandstone. Trough crossbedded medium-grained sandstone beds grade upward into ripple laminated fine-grained sandstone and are interpreted to represent point-bar deposits. Orientation data from the individual channel sandstone units (5-10 ft thick) indicate depositional trends from North to N 40° W (Fig. 6). Some fine-grained sandstones are also present and are interpreted to be splay-filled channels. In MC-9, this interval is only about 25 ft thick and consists predominantly of mudstone. The lowest part of this interval of delta-plain deposits is shale above the distributary channels of the #4.

The marine portion of the #4 is up to 80 ft thick; sandstone beds make up the upper 30 ft of this. In contrast to the #5, channeling into the marine portion of the #4 appears to be localized. In sections MC-7 and MC-9, these channels are characterized by trough crossbedding and are less than 10 ft thick. In section MC-7, the distributary channels overlie fine-grained, carbonaceous, prominently ripple-laminated or bioturbated sandstone beds, which are interpreted to represent bay-fill deposits. Both sections MC-7 and MC-9 contain hummocky cross-stratified sandstone beds in the lower portion of the sandstone interval, which are interpreted to represent distal bar deposits. Prodelta shales are about 20 ft thick below the marine sandstones and above the C coal.

Orientation data from the distal bar hummocky sandstone beds of the #4 (Fig. 7) indicate depositional trends toward the northwest.

3.4 Unit #2

Delta-plain deposits above the #2 are about 40 thick and consist of coal and carbonaceous mudstones with few sandstone beds. The C and A coals occur together within an 8 ft interval, separated by several thin tonsteins and underlain by about 20 ft of A swamp shale above the #2 sandstone.

The entire #2 is about 60 ft thick; most of this is sandstone. The upper portion of the #2 is characterized by large distributary channels that cut into mouth bar deposits. The distributary channel sandstone unit is 12-20 ft thick, medium-grained and trough crossbedded. It forms a prominent white-cap in outcrop in the area. An oyster shell hash channel-fill is present at the top of distributary channel unit in both Miller Canyon and Muddy Creek Canyon.

The mouth-bar sandstones are characterized by trough crossbedded units up to 15 ft thick. Some bioturbated or planar laminated beds are also present. The orientation data indicate concentrations at N30°E (Fig. 8) for both the distributary channel and the mouth-bar sandstones.

Figure 6

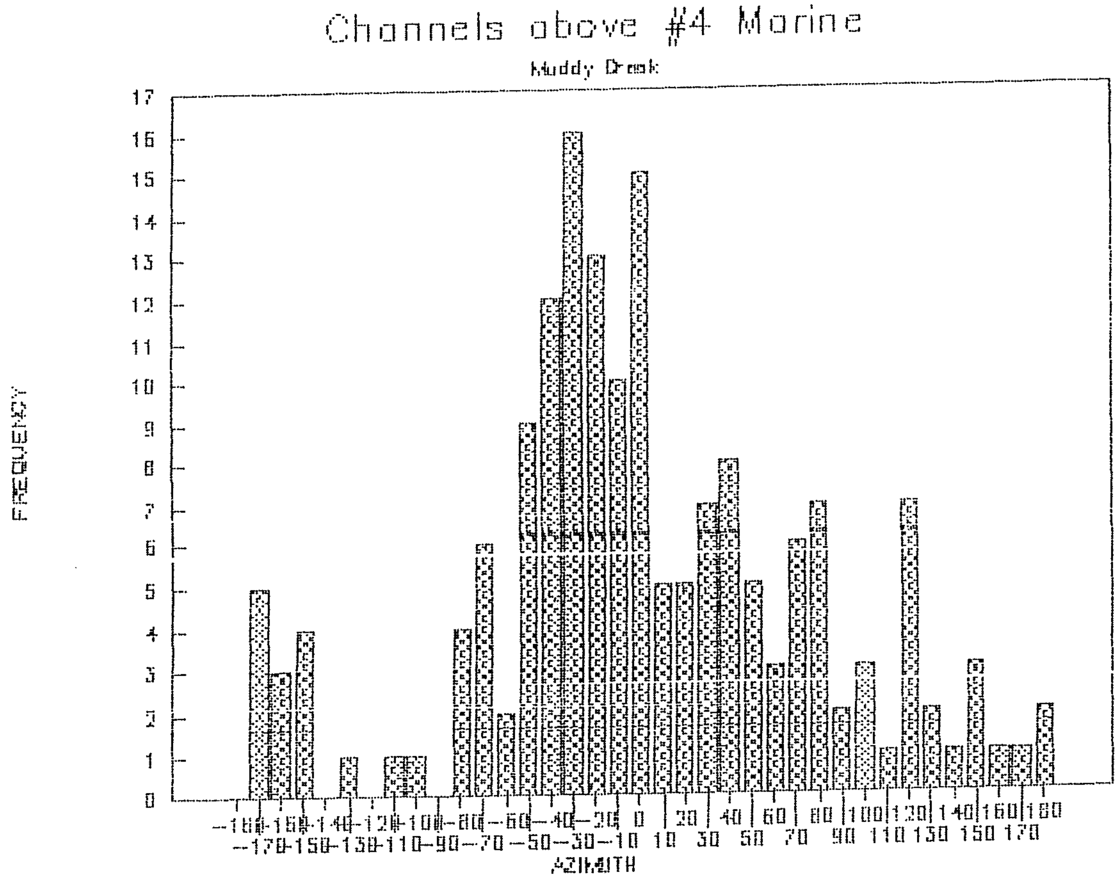

Figure 7

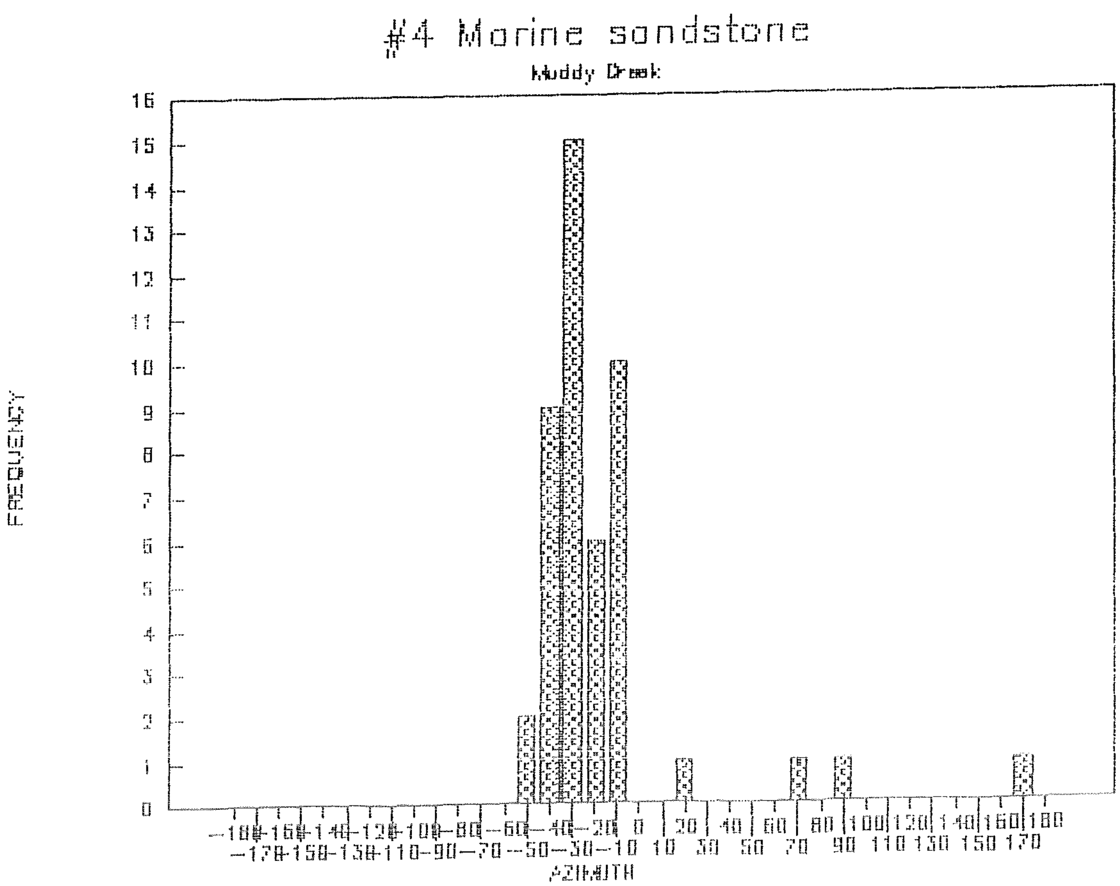

Figure 6. Histogram of dip azimuth measurements of fluvial channel sandstones above the #4.

Figure 7. Histogram of dip azimuth measurements of the #4 marine sandstone.

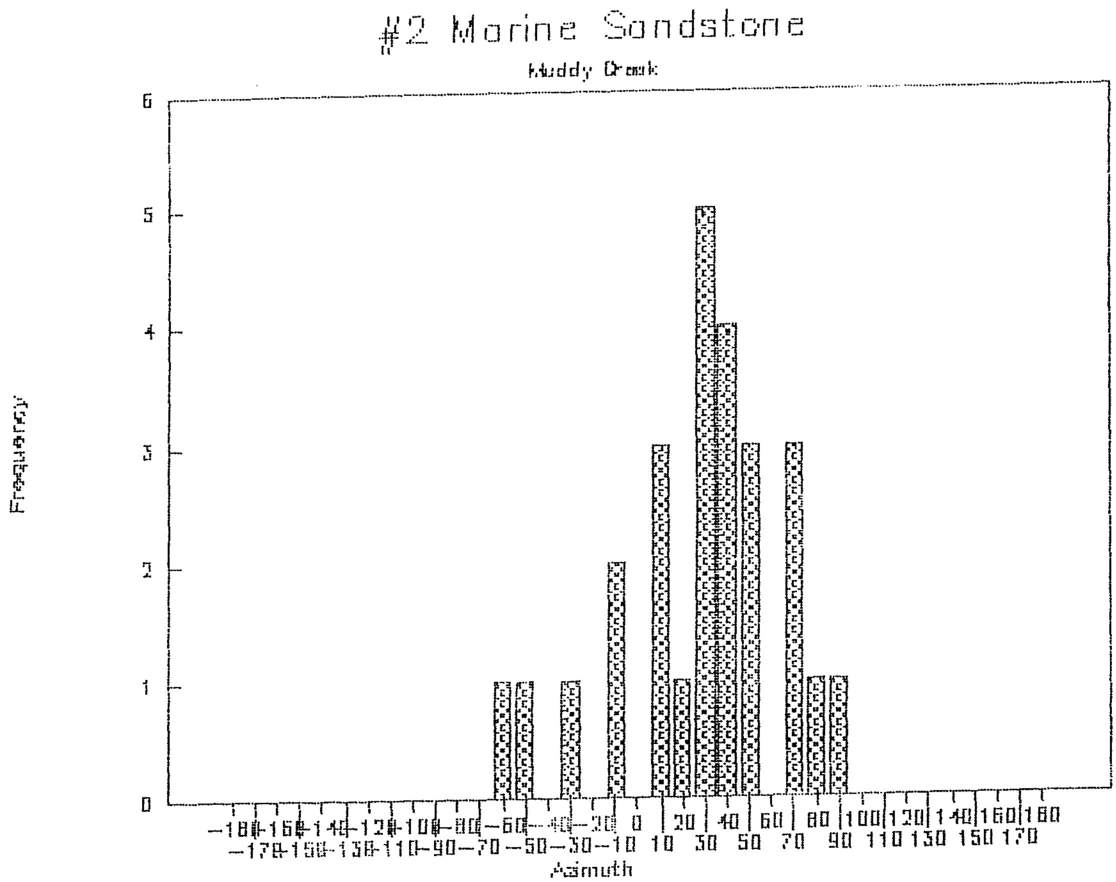

Figure 8. Histogram of dip azimuth mearsurements from the ditributary channel and mouthbar sandstones of the #2.

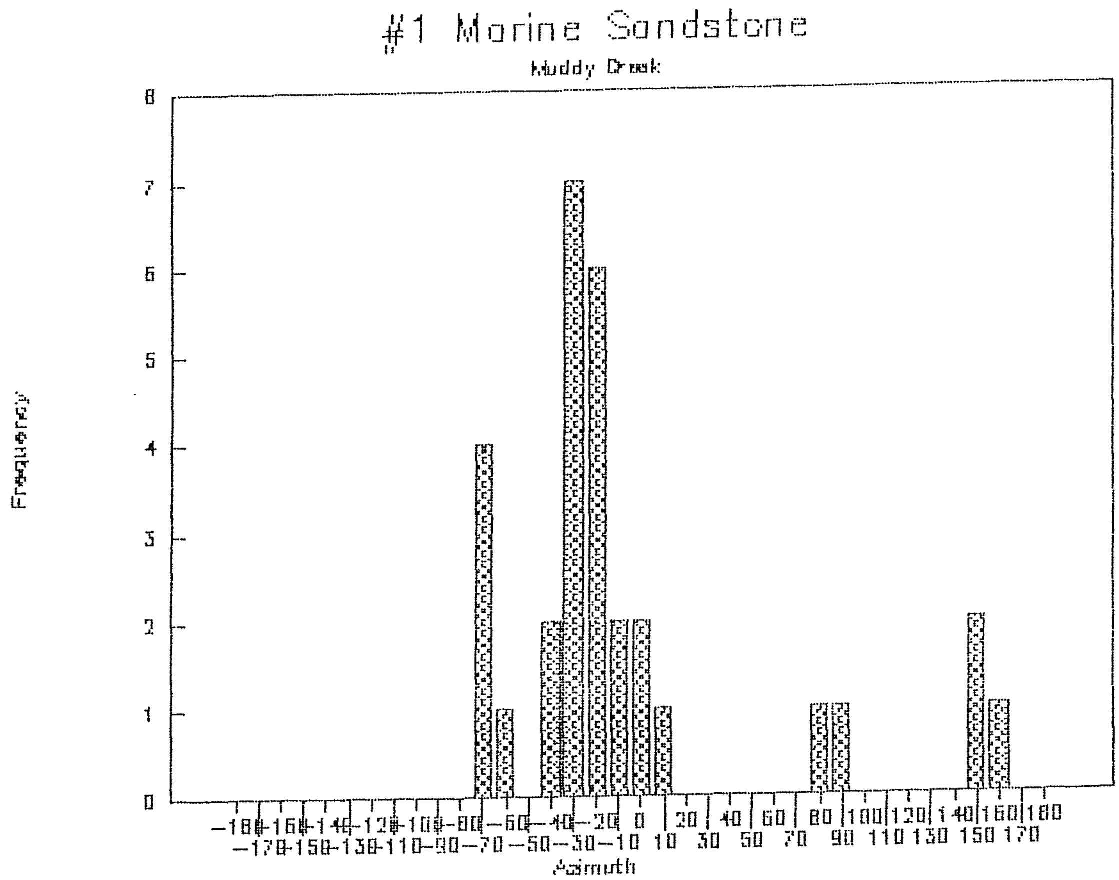

Figure 9. Histogram of dip azimuth measurements of the #1 marine sandstone.

The #2 does not contain much in the way of distal bar deposits and the prodelta shales are only 14 ft thick on top of the #1 sandstone.

3.5 Unit #1

The thickness of the #1 unit and the underlying prodelta shale over the Tunuck Shale is about 80 ft. The #1 marine sandstone itself is about 38 ft thick.

The #1 exhibits the classic vertical facies change from dominantly hummocky crossbedded in the lower part, to dominantly trough crossbedded in the middle part, to planar bedded or bioturbated in the upper part; representing lower to upper shoreface to foreshore deposition with progradation of the delta. Herringbone crossbedding at the top of the trough crossbedded unit indicate bimodal current directions.

Orientation data exhibit a concentration at N 30° W for the entire marine unit (Fig. 9). The herringbone crossbeds indicate orientations at N 40° W and S 50° E. The difference of 180 degrees is probably indicatives of tidal deposition.

4. CORING PROGRAM

4.1 Drilling Site

The drilling site for the corehole (s) will be sited close enough to the measured sections in Muddy Creek that the lithologies, sedimentary structures and facies can be extrapolated with some degree of confidence. However, the well should be positioned far enough behind the outcrop that lost circulation will not be a problem. Springs and surface water in the vicinity of the proposed drill site suggest that the section will be saturated, minimizing lost circulation problems and facilitating geophysical logging of the well.

The west side of Muddy Creek is owned by the BLM, the State of Utah and private entities. Access to the area will be along any of the existing unimproved roads indicated in Figure 3. Some of the roads are gavelled, and all directly connect with the town of Emery, Utah, approximately 3 miles to the northwest.

Figure 10 is the BLM land plat map of the area in which the drill site will be located. Petroglyph Point and Teardrop Hill are located in section 13 on federal (BLM) land. Sections 12 and 24 are also predominantly BLM-owned. Plats that are labelled with a prefix of "U" or "SL" are BLM land that is administrated by the Salt Lake City, Utah district office.

Plats surrounded by a dark line are patented; that is, the title has been transferred from federal ownership. Plats that are labelled with numbers are privately owned. If the number is followed by "OG" or "Coal", then the BLM retained the oil, gas or coal mineral rights.

State lands are indicated by plat numbers with the prefix "SS" (state selection), "IL" (indemnity list) or hyphenated numbers such as 43-81-0012.

In section 13, patented plat 656362 Coal (80 acres) is owned 50% by Pittsburgh Midway Coal Mining Co. and 50% by Consolidated Coal Co., however, the coal in that plat is owned by the BLM. Tax records from the county recorder's office indicate that Consolidated Coal, a division of Conoco, in Ponca City, Oklahoma pays the taxes on the land.

Status of Public Domain Land and Mineral Titles
Township 22 South, Range 6 East, of Salt Lake Meridian, Utah
Moab District 060
Emery County

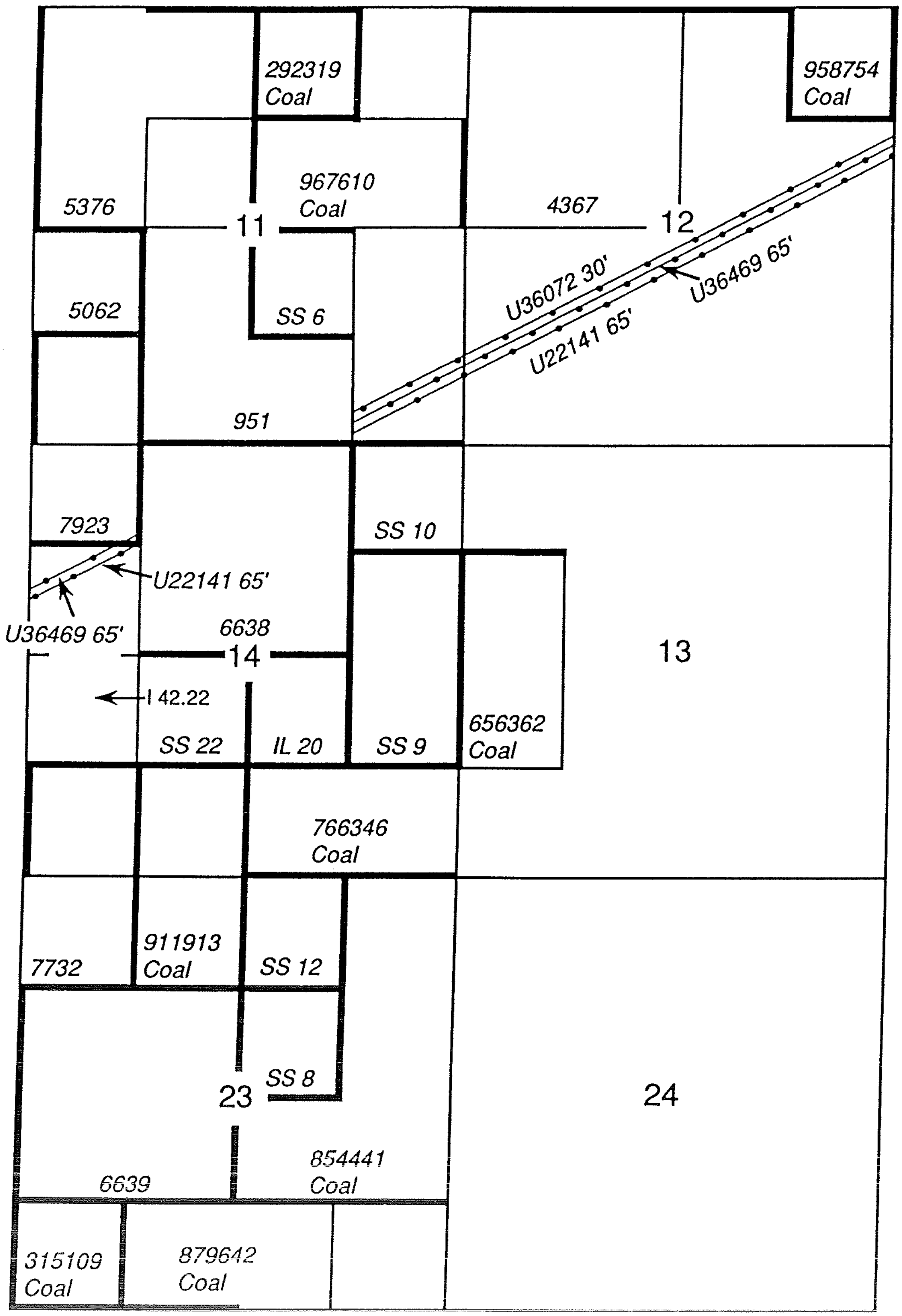

Figure 10. BLN plat map of the drilling site, west of Muddy Creek.

The Emery County Recorder has indicated that most of section 14 is also owned by the Pittsburgh Midway and Consolidated Coal companies, with the exception of several parcels to the northeast and southeast which are owned by Chevron.

UURI has the operator's packets for both the State of Utah and the Bureau of Land Management as well as the Application for Permit to Drill, Deepen, or Plug Back for both entities. Processing of the APD should only take 30 days. The guidelines for the drilling program, surface use, waste disposal, and site restoration set forth in either the BLM's Onshore Oil and Gas Order No. 1 or the State of Utah's Oil and Gas Conservation General Rules will be followed.

4.2 Well Design

Figure 11 is an engineering diagram of the proposed wells. It is anticipated that the upper portion of the holes will be rotary drilled and surface casing will be set at a depth of approximately 50 feet. This casing will be cemented in place and will be anchored in a competent rock.

The remainder of the holes will be cored to total depth. It our desire to drill a hole that is approximately 7 inches in diameter to allow the operation of standard oil field logging tools. It is also important that the core collected be close in size to the well diameter to facilitate the correlation of bedding features documented in the core with those detected by the borehole imaging logs. For this reason, it is anticipated that the holes will be cored using conventional rather than wireline equipment. In addition, oriented core will not be collected; its orientation will be determined using the borehole imaging logs.

Both the electrical dipmeter type of logs and the sonic borehole televiewer tools require fluid in the holes to achieve optimum results. Therefore, one of the principal concerns during drilling will be control of lost circulation. Mud and lost circulation materials will be the principal means of remediation. Cement plugs will be used as a last resort.

4.3 Operations Management

A representative of UURI will be on-site at all times during the drilling operations. This on-site manager will have sole authority over the conduct of the operations and discussions with the drilling subcontractor.

The site manager will be responsible for keeping accurate records of all aspects of the project. This includes a diary of the drilling operations with times of core runs, drilling problems, mud compositions, bits used, mechanical problems on the rig, etc. These records will be maintained on a personal computer and transmitted to UURI's office on a daily basis.

There are budget constraints on the conduct of the drilling operations. Should conditions arise that jeopardize the plan to drill two wells, the following will prevail. The first priority will be completion of the first well. This will be done at the expense of the second well if necessary. However, should lost circulation problems be so severe that it does not appear that the first well will not be capable of holding fluids for the logging operations, it may be appropriate to abandon the effort short of target depth to insure the successful completion of the second well in an area where lost circulation problems would be less extreme.

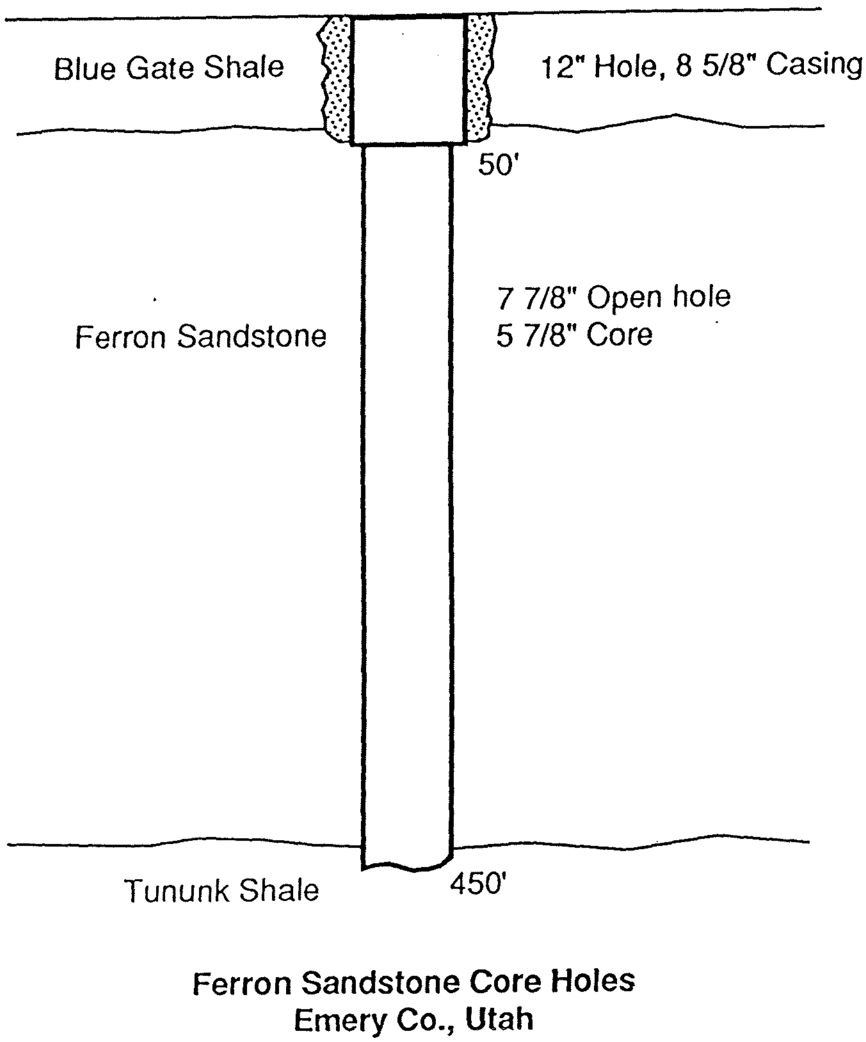

Figure 11. Engineering diagram of the proposed borehole(s).

Decisions concerning the changes in the drilling program will be the responsibility of the project manager.

4.4 Core Protocol

4.4.1 On-site Core Handling and Access

The core handling protocol for this project is modified from Goff (1986) who established the procedures as part of the Continental Scientific Drilling Program. UURI has used these procedures successfully on DOE/OBES scientific drilling in the Valles caldera New Mexico. The effort is to avoid mix up of the core due to accident or carelessness when it is being transported or handled by investigators.

The UURI on-site representative will be present when the core is removed from the well.

1. The core will be emptied onto a core trough. It is important the all pieces be placed in their proper sequence and orientation and fit snugly together.
2. Washing of any pieces requiring it will be done at this stage.
3. The core will be marked with a double line running the length of the core. The lines will be made by two magic markers taped together and will be oriented with black on the left and red on the right facing up hole.
4. Core pieces longer than the core width will be numbered from the top down with the run number followed by the number of the piece (for example 4-10 indicates the tenth piece down from the top of core run 4). The piece number will be in a consecutive fashion from the top to the bottom of the run.
5. The percent recovery will be calculated by measuring the length of the core and comparing this with the depth interval recorded by the driller.
6. The core will be boxed starting with the top of the run in the upper left of the core box. If it is necessary to break pieces of core for sampling, the new pieces will be numbered A, B etc. from the top of the piece down.
7. The core boxes will be labeled with the beginning footage and the ending footage.
8. The UURI representative will maintain a field log of the core that will be of sufficient detail to follow the drilling through the stratigraphic section. This logging will be on printed forms at a scale of 1" = 10'.
9. The core will be transported to UURI's sample library in Salt Lake City for additional sampling and logging. Core will be transported to Salt Lake on a regular basis, and the entire core may not be available on site at any given time.

Industry participants and scientific investigators are encouraged to visit the site, particularly when specific zones of interest to them are being cored. However, there will be no sampling of material from the drill site.

4.4.2 Photography and Lithologic Logging

Following transport of the core to Salt Lake, it will be photographed and a more detailed lithologic log will be constructed.

4.4.3 Goniometer Measurements

A computerized goniometer will be used to document the orientations of bedding features within the core. The purpose of this will be a direct comparison with the borehole imaging logs. It is important that this data be collected before the core is slabbed.

4.4.4 Petrography

UURI's contract calls for some X-ray diffraction and petrography of the core. This work will largely be completed to aid in questions of interpretation of the well logs.

4.4.5 Physical Property Measurements

4.4.6 Curation

The reference split of the core will be housed at UURI's core library in Salt Lake City.

5. WELL LOGGING

Well logging is being provided as part of the in-kind contributions of the logging company participants. The following logs will be collected.

5.1 Dipmeter

5.2 Formation Microscanner

5.3 Televiewer

5.4 Natural Gamma

5.5 Resistivity

5.6 Density

6. OTHER BOREHOLE EXPERIMENTS

The wells will be made available for experiments and equipment trials as long as those uses do not jeopardize the integrity of the wells. We request that information or reports generated during these experiments be filed with UURI who will maintain an updated data base. Exceptions are made for those industry participants who wish to test proprietary equipment or procedures. At this time, the following borehole experiments are anticipated.

6.1 Borehole Electrical

UURI is developing a borehole electrical system that can be used in a borehole to borehole, borehole to surface, or surface to borehole configuration. The system is being designed for applications in geothermal wells, but will be field tested in the Ferron wells.

7. WELL ACCESS

Well heads will be capped and locked. Access to the wells can be obtained by contacting Dennis Nielson at UURI. Non-participants must make a written request outlining the experiments to be run. These requests and participant's request for non-traditional logging in the wells may be reviewed by a committee consisting of UURI, GRI, and Utah Engineering Division.

UURI, GRI, and UED will not be responsible for tool damage resulting from the use of this test facility.

It is anticipated that the wells will remain open and available for logging for an indefinite amount of time.

8. SCHEDULE

To be completed. This will be a graphic representation of well logging and core measurements.

9. COMMUNICATIONS

There will be a mobile phone available at the drill site, and the number will be distributed to all participants when it is available.

Daily drilling reports will be sent to UURI by electronic mail. Participants will be given a phone number and access code so daily reports can be retrieved electronically. In order to do this, it will be necessary to have a modem and communications software.

10. DATA DISTRIBUTION

Data will be made available to the project participants as soon as it is available.

11. PROJECT PARTICIPANTS

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