GREATER GREEN RIVER BASIN PRODUCTION IMPROVEMENT PROJECT

Final Report
October 2001

By:
B. Blakeney DeJarnett
Frank H. Lim
Lee F. Krystinik
Mark L. Bacon

Date Published: November 30, 2001

Performed Under Contract No. DE-AC21-95MC31063

Union Pacific Resources
Fort Worth, Texas

Anadarko Petroleum Corporation
Houston, Texas

Table of Contents

UPR/DOE Greater Green River Basin Production Improvement Project: Final Report

List of Figures

List of Tables

List of Appendices

UPR/DOE Greater Green River Basin Production Improvement Project:
Final Report

Phase I Site Characterization Report, Stratos Location

Phase II Topical Report Drilling, Testing, and Completion of the UPRC Stratos Federal #1

Phase III Drilling, Testing and Completion of a Horizontal Well in the Frontier Formation, the UPR Rock Island #4-H

Phase IIIa Additional Reservoir Characterization through Logging and Coring of Two Offset Wells

Project Summary

It has been estimated that the Greater Green River Basin of southwestern Wyoming may contain as much as 5,000 TCF of gas trapped within unconventional, overpressured, very tight, basin-centered gas reservoirs Among the many potentially productive horizons in the Greater Green River Basin (GGRB) is the mid-Cretaceous Frontier Formation, estimated to contain at least 300 TCF of natural gas The Frontier Formation has been recognized as a very large gas resource for over three decades, and all of the wells penetrating the deep, basin-centered Frontier Formation in the GGRB have encountered gas However, none of these deep wells that drilled through the overpressured Frontier prior to this project had proven to be economic This has been due to the very low average permeability within the reservoir (as low as 0 0001 md in situ permeability)

The Greater Green River Basin Production Improvement Project (GGRBPIP) has been a multi-year partnership between the oil and gas industry and the U S Department of Energy Federal Energy Technology Center (FETC), now the National Energy Technology Laboratory (NETL) The primary objective of the project was to identify and evaluate new technologies to make drilling for and producing this strategic gas resource economically viable During the last six years FETC/NETL has worked with

Union Pacific Resources (now Anadarko Petroleum Corporation) and their partners Andex Resources, Belco Energy, Yates, Texaco and Flying J, along with the Gas Research Institute, Sandia National Labs, Advanced Resources International, Schlumberger and Baker Hughes to 1) identify optimum drilling locations, 2) reduce drilling time and expense, 3) test new horizontal drilling techniques, 4) evaluate and characterize the reservoir, and 5) establish economically viable production All of these goals were successfully accomplished

The GGRBPIP culminated in the drilling and completion of the UPR Rock Island #4-H well (RI 4-H) Results from this well included 1) Cost for drilling deeper than 15,000' (4572 m) TVD was reduced by 50% of the previous industry average, 2) Over 400 open natural fractures were intersected in a 1750' (533 m) horizontal leg, 3) The deepest horizontal tight-gas sandstone cores in the world were taken, 4) One of the highest gas flow capacities ever encountered in the tight-gas province of the Frontier Formation was established (> 14 MMCF/D), and 5) An ongoing drilling effort was established by industry to further evaluate and exploit this resource

The RI 4-H well was spudded on October 14, 1998, and a 14-3/4" vertical borehole was drilled to a depth of 9,517 ft (2900 m) and set with 11-3/4" casing A 10-5/8" vertical borehole was then drilled to a depth of 14,440 ft (4401 m) with a kick-off point for directional drilling From kick-off point a 10/5/8" medium radius borehole was drilled at an initial build-up rate (BUR) of 14 degrees per 100 ft (14 degrees per 30 5 m), decreasing to a BUR of 4 degrees/100 ft (30 5 m) in the lower curve At a depth of 15,025 ft (4580 m) the borehole deviation was 88 degrees and a 7-5/8" liner was cemented into the curve Using UPR geosteering technology, the 6-1/2" horizontal lateral was directionally drilled to stay inside a 20-ft (6 1 m) vertical window within the marine sandstone of the Second Frontier Formation Since no vertical pilot hole was drilled, offset well logs from the Table Rock #44 well, over 2 miles (3 2 km) from the RI 4-H, were used for correlation Once the lateral penetrated the Second Frontier fluvial sandstone zone and drilled into the underlying marine sandstone zone, the well remained in the marine target zone until it faulted back to the fluvial sandstone near the end of the lateral Total length of the lateral was 1,750 ft (533 4 m) to a final well TD of 16,784 ft (5115 8 m) MD (14,953 ft or 4557 7 m TVD) Three horizontal cores totaling 77 feet (23 5 m) were taken between 15,424 ft – 15,951 ft (4701 2 – 4861 9 m) MD (14,889 ft - 14,928 ft or 4538 2 – 4550 1 m TVD), and are considered to be the deepest horizontal tight gas sandstone cores ever taken

Core, log and production test information from a nearby vertical well, combined with regional 3-D seismic data, were critical to site selection of the UPR Rock Island #4-H The target reservoir consists of massive to hummocky cross-stratified, very fine-grained, nearshore-marine sandstone with 10-12% porosity, 25 microdarcy permeability (dry, unstressed) and intense fracturing Many of the fractures in the vertical offset well and in the horizontal RI 4-H well indicate shear displacement with a dominant strike orientation ranging from 80 to 110 degrees The fractures are open to partially filled by calcite, quartz, kaolinite and bitumen Fracture spacing in the horizontal well is variable, with the most intense fracturing occurring near several small faults penetrated by the well Analysis of core and resistivity images shows that although east-west striking, open fractures occur along the entire length of the well, unfractured zones up to 20' (6 1 m) long are also present These unfractured zones greatly increase the risk of a vertical well missing the fracture system Microfractures are also common in the core samples Dissolution of feldspar and lithic grains along microfractures significantly enhances permeability along these surfaces and may be critical to successfully draining gas from the reservoir

The UPR Rock Island #4-H was completed open-hole using a 4" slotted liner and was equipped with 2-7/8" tubing and packer The well was flow tested to a 12 MMCFD rate, and it flowed to a gas sales pipeline at an average rate of 14 MMCFD for the first full month of production These rates represent some of the highest gas flow capacities ever encountered in the tight-gas province of the Cretaceous Frontier Formation

Since the initial success of the RI 4-H well, several other horizontal wells have been drilled in order to delineate and further characterize the reservoir Two of these wells, the

Sidewinder 1-H and the Sidewinder 2-H (SW-1H and SW-2H), were drilled down-dip along the same fault system as the RI 4-H

Phase IIIa of the GGRBPIP was initiated at this time in order to provide industry with as much reliable data as possible on this tight-gas resource This was in keeping with the overall objective of the GGRBPIP of reducing technical risks and economic uncertainty associated with these tight gas reservoirs Phase IIIa consisted of additional reservoir characterization of the Frontier Formation through the logging and coring of the Sidewinder 1-H and the logging of the Sidewinder 2-H The Sidewinder 1-H well was drilled on the upthrown side of the same fault system as the RI 4-H, and encountered over 1240 open fractures in the marine sandstones of the Second Frontier The well had very high flow rates of water and sub-economic rates of gas The SW 2-H was drilled on the downthrown side of the fault and encountered lower reservoir pressures than in the SW 1-H The Sidewinder 2-H produced no water and only small quantities of gas Electric logs indicate that a Second Frontier fluvial channel has scoured into, and removed much of the Second Frontier marine sandstone reservoir

The integration of the horizontal core and the wellbore imaging logs has resulted in a much more accurate interpretation of the fracture system in these Frontier reservoirs Analysis of the fractures in the cores has shown why some fracture systems in the horizontal wells appear to be more productive than other systems These findings alone will be invaluable to future assessment of this unconventional resource

The cores contain two sets of natural fractures The fracture sets are vertical and near-orthogonal, and each set exhibits different mineralization The numerically subordinate set consists of north-south striking fractures that are variably occluded by a combination of quartz and calcite Although these fractures are probably not significant in the overall system, the north-south fractures may play a local role in connecting fractures of the dominant east-west set

The numerically dominant fracture set strikes east-west (between 80 and 110 degrees) and is mineralized with an early phase of bitumen that is pierced from underneath by a later growth of fine, druzy quartz crystals These are in turn overlain by patchy to layered deposits of calcite crystals, and finally by kaolinite Some of these fractures consist solely of hairline traces of bitumen or tightly mineralized fractures in otherwise intact rock, but at least half of the fractures have macroscopically visible remnant void space despite multiple phases of mineralization

Approximately one third to one-half of the cored fractures display slickenlines along the kaolinite that lines the fracture faces The trend of these slickenlines in the Rock Island core is sub-horizontal and indicates right-lateral motion Slickenlines on fracture faces in the Sidewinder core are variable from sub-horizontal to nearly vertical The fact that the majority of the fractures do not display evidence of shear suggests that shearing was due to a local reactivation of the fractures rather than to their primary origin mechanism The shear reactivation of the fractures is probably in response to motion on a nearby Laramide-age, right-lateral wrench fault It appears that local reactivation in shear may be the key to creating significant fracture permeability in these reservoirs This is supported by the uneconomic gas flow rates observed from the Frontier in the Amoco Frewen #4 well several miles to the east The core from the Frontier in this well exhibits large numbers of large, partially open, but unsheared fractures

In summary, results from the drilling effort and reservoir characterization of the Frontier sandstones have yielded a complex picture of this basin-centered, tight gas system Some basic observations included 1) The matrix sandstone appears to be regionally gas-saturated, 2) Large numbers of natural fractures can occur along large linear strike-slip or shear faults, 3) These fractures can be productive of gas or water, 4) Productivity from fractures appears to be related to shear reactivation, 5) The Frontier Formation reservoir appears to be divided into a number of isolated pressure cells ranging from near-normal pressure to nearly 0 9 psi/ft 6) Water production is related to structural position within each pressure cell, and 7) Water production, when encountered, does not appear to suggest an infinite aquifer

1. Phases I to IIIa – Greater Green River Basin Production Improvement Project

1.1 Introduction

The Greater Green River Basin (GGRB) of Wyoming (Fig 1) has produced abundant oil and gas out of multiple reservoirs for over 60 years, and large quantities of gas remain untapped in tight gas sandstone reservoirs Recent gas resource estimates for low permeability Cretaceous and Tertiary reservoirs in the GGRB range from 1,968 TCF in place (the Scotia Group) to 5,064 TCF in place (U S Geological Survey) (DOE Topical Report by the Scotia Group, 1993) Current activity, including the Greater Green River Basin Production Improvement Project, is focusing on ways to convert this vast resource into economically recoverable gas

Even though GGRB production has been established in formations from the Paleozoic to the Tertiary, recent activity has focused on several Cretaceous reservoirs Two of these formations, the Almond and the Frontier Formations, have been classified as tight sands (permeabilities <0 1 millidarcy) and are prolific gas producers in the GGRB The formations are typically naturally fractured and have been exploited using conventional vertical well technology In most cases, hydraulic fracture treatments must be performed when completing these wells to increase gas production rates to economic levels However, hydraulic fracture treatments may not be the most effective method for improving gas production from these tight fractured reservoirs With the maturation of horizontal drilling technology, it has become apparent that horizontal drilling may be particularly well suited to reservoirs where hydraulic fracturing is inefficient either because hydraulic fractures are parallel to natural fracture strike and/or because encasing shales are poor stress barriers to limit excessive hydraulic fracture height growth

Several horizontal completions have been made in the Almond Formation in the Wamsutter Arch area (i e Amoco Champlin 254-B2-H in T20N-R93W), and several more horizontal completions are planned as alternatives to vertical, hydraulically-fractured wells The purpose of this project was to apply alternative completion technology (i e horizontal drilling) to the Second Frontier Formation in the Greater Green River Basin of southwestern Wyoming (Fig 1), and to compare horizontal vs vertical production improvements by drilling, testing and completing a horizontally drilled wellbore at a location favorable for fracture occurrence where nearby vertical completion control would allow for realistic comparison

1.2 Objectives of the project and technical approach

The objective of the Greater Green River Basin (GGRB) production improvement project has been to assess the technical and economic feasibility of horizontal completion technology in the marine sandstones of the deep Second Frontier Formation located in the GGRB, Sweetwater County, Wyoming Phases I and II of the project involved the site characterization and subsequent drilling, coring, testing, and evaluation of a vertical well located in the deep basin between the Moxa Arch and Rock Springs Uplift (the UPRC Stratos Federal #1 located in the SE ¼ of Sec 24-T22N-R107W) The site characterization report (Phase I) for the UPRC Stratos Federal #1 is included in this topical report as Appendix 1 The topical report (Phase II) for the Stratos well describes the drilling of the well, as well as the coring, testing and evaluation of the Frontier Formation This report is included in its entirety within this final report as Appendix 2

It was decided not to attempt a horizontal lateral in the Stratos area after evaluation of the reservoir properties and production test data from the Frontier Fm in the Stratos location Phase III of the GGRB project was then implemented and involved the site selection and subsequent drilling of a horizontal well to test the Frontier in a prospective area east of the Rock Springs Uplift

The technical approach involved the drilling, coring, testing and completing of a horizontal well in the Second Frontier Formation east of the Rock Springs Uplift on the Wamsutter Arch in southwest Wyoming This phase of the project was subdivided into several steps Step c was optional, pending analysis of data from the drilling and testing phase of the project Each phase is described as follows

Step a The objective of Step a was to complete the permitting process, geologic characterization and NEPA reporting for a wellsite location in Section 4, T19N-R97W, Sweetwater County, Wyoming

Step b The objective of Step b was to drill, complete and test a horizontal wellbore in the Second Frontier Formation

Step c. The objective of Step c was to design, test and evaluate the effectiveness of alternative completion scenarios in the horizontal lateral that was to be drilled in the marine sandstone bench of the Second Frontier Step c included a comparison of the completion effectiveness of the horizontal lateral and the nearby vertical, naturally fractured well, the Texaco Government Union #4 located in section 8 of T19N-R97W Project results were presented at appropriate technology transfer workshops and are documented in this report

2. Phase III – Drilling, Testing and Completion of a Horizontal Well in the Frontier Formation, the UPR Rock Island #4-H

2.1 Location of the selected site for the project

The selected site was designated the Rock Island Unit #4-H and is located in Section 4, T19N-R97W, Sweetwater County, Wyoming The location of the well is shown in Figure 1, and is located in the eastern part of the GGRB, approximately 36 miles (58 km) east of the east flank of the Rock Springs Uplift Union Pacific Resources owns the subsurface mineral rights, and the surface owner is the U S Bureau of Land Management The Second Frontier was the target formation at approximately 15,000 ft (4572 m), and the primary objectives were marine shoreface sandstones within the Second Frontier (Second Bench of the Second Frontier) (Fig 2) A site selection report for the Rock Island #4-H was generated as part of this project, and is included in this report as Appendix 3 The details of the regional and site-specific geological and geophysical analyses that led to the choice of the Rock Island #4-H location as an optimal drillsite are presented in the site selection report

The Second Frontier at the selected wellsite contained both marine shoreface sandstones and fluvial channel-fill sandstones The presence of the fluvial and marine sandstones in wells adjacent to the proposed location provided the basis for significant production potential Based on offsetting log and core information, a combined net pay of over 40 ft (12 2 m) was anticipated, with an average porosity of 9 percent and an average water saturation of 40 to 45 percent Seismic information, well log and core analysis, and field examination all supported the likelihood of natural fractures occurring in the proposed well The location is northeast of the Texaco Government Union #4, a Frontier completion located in section 8 of T19N-R97W, which produced gas at initial rates of 8,000 MCFD Present production is at a rate of 6,000 MCFD In its first year of production, the Texaco Government Union #4 well produced about 2 BCF of gas, and reasonable engineering projections suggested that the well would eventually produce a total of 15 BCF of gas The probability of encountering gas in the Rock Island #4-H was very high, however there were risks associated with recoverable reserve levels and the payout potential for the combined drilling, completion, and testing costs associated with the proposed project

2.2 Drilling History

A summary of the drilling and completion of the Rock Island 4-H is shown in Table 1, and Union Pacific Resources' daily drilling reports are included in this report as Appendix 4 Baker Hughes/Inteq has also provided an End of Well Report (Appendix 5) that includes copies of their own daily drilling reports, description of bottom hole assemblies, drilling parameters, and surveys run The Rock Island 4-H was spud on October 14, 1998 A vertical hole of 14-3/4" was drilled to 9515' (2900 m), and 11-3/4" casing was run (See wellbore diagram in Figure 3) A 10-5/8" vertical hole was drilled to 14,440' (4401 3 m), the kick-off point for the horizontal well From kick-off point a 10-5/8" medium radius borehole was drilled at an initial build-up rate (BUR) of 14 degrees per 100 ft (30 5 m), decreasing to a BUR of 4 degrees per 100 ft (30 5 m) in the lower curve At a depth of 15,025 ft (4579 6 m), the borehole deviation was 88 degrees and a 7-5/8" liner was cemented into the curve Using geosteering technology patented by Union Pacific Resources, the 6-1/2" horizontal was directionally drilled to stay inside a 20' (6 1 m) vertical window within the marine sandstones of the Second Frontier Formation Since no vertical pilot hole was drilled, offset well logs from the Table Rock #44 well, over 2 miles (3 2 km) from the RI-4H, were used for correlation Once the lateral penetrated the fluvial zone and into the marine zone, the well remained in the marine target zone until it faulted back to the fluvial section near the end of the lateral (Fig 4) Total length of the lateral was 1,750 ft (533 4 m) for a final well TD of 16,784 ft (5115 8 m) or 14,953 ft (4557 7 m) TVD Three horizontal cores were taken with the marine target zone (cores 1 and 2 from 15,424-15,483 85' (4701 2-4719 5 m), and core #3 from 15,931-15,951' (4855 8-4861 9 m)) A summary of the coring process was written by Diamond Products International (DPI) and is included as Appendix 6 The reservoir was then logged with a variety of tools A mud log was also constructed for the entire well by Pason and is available as Appendix 7 Figure 4 is a UPR-generated graph that shows the time and estimated costs associated with the drilling of the Rock Island #4-H

2.3 Geological Characterization of the Frontier Formation in the Rock Island 4-H

The Second Frontier Formation in this part of the Green River Basin is characterized by an upper fluvial section and an underlying marine section (Fig 2) The fluvial sediments typically consist of channel sandstones and floodplain mudstones and siltstones The marine section of the Second Frontier consists of offshore mudstones that grade up into a relatively sharp-based shoreface sandstone Variable amounts of the shoreface sandstone can be removed by erosion associated with the overlying fluvial channels The shoreface sandstones are typically very fine-grained, massive to hummocky cross-stratified with varying amounts of bioturbation

2.31 Frontier core sedimentology and interpretations

Since a vertical pilot hole was not drilled at the RI 4-H location, the only logs through the Frontier section are from the horizontal lateral section of the wellbore These logs indicate that the Second Frontier consisted of an upper 10-ft fluvial sandstone that was separated from the lower marine sandstones by mudstone (Fig 5) Two sandstone benches were encountered in the marine section of the Second Frontier Cores 1 and 2 were taken from the upper bench and core 3 was taken from the lower bench (Fig 6) Core photographs by Reservoirs Inc and a core description done by Terra Tek indicate that the Second Frontier Formation in cores 1 and 2 was deposited in a marine environment, specifically in a middle to upper shoreface setting (Fig 7 and Appendices 8 and 9) *Ophiomorpha* burrows are particularly abundant in core 1 (See red arrows on Fig 9) According to Terra Tek, low- angle, wedge-shaped cross beds and wave-dominated ripples are the dominant sedimentary structures Clasts comprised of carbonaceous mudstone are common in several intervals throughout the sandstone The reservoir sandstone is very fine-grained, and there is very little interlaminated siltstone or mudstone A slightly deeper water environment (middle to lower shoreface) is proposed for the Frontier Formation from Core 3 (See the core description in figure 8) The sandstone is very fine-grained, and hummocky cross-stratification is the most common sedimentary structure *Ophiomorpha* burrows are absent, and there are more very small carbonaceous fragments and detrital clays mixed in with the sandstone

The lithofacies encountered in the Rock Island 4-H cores are very similar to the lithofacies encountered in the Texaco Table Rock #104 core (S19-19N-97W) and in the Texaco Government Union #4 core (S8-19N-97W) Figures 11 and 12 are core descriptions for those wells respectively The Texaco Table Rock #104 core (Fig 11) did encounter a thin fluvial interval, but the bulk of the sandstone was very fine to fine-grained, hummocky cross-stratified, occasionally wave-rippled, and burrowed to bioturbated, the unit was interpreted as a marine lower shoreface sandstone The Government Union #4 well (Fig 12) cored predominantly hummocky cross-stratified, very fine-grained sandstone with some interbedded mudstone near the base It was interpreted to represent deposition in the lower shoreface environment Please refer to the site characterization report for more details on these offset wells and for stratigraphic cross-sections through these wells (Appendix 3)

2.32 Petrographic Analysis of the Frontier Formation

Six samples from the Second Frontier sandstone were selected for petrographic analysis, and Reservoirs, Inc performed the analysis This included thin section petrography (including point count modal analysis), scanning electron microscopy (SEM), and X-ray diffraction (XRD) All of the samples chosen for petrographic analysis were very well sorted, very fine-grained sandstones, with very little to no detrital clay Thin section petrography indicates that all of the sandstones can be classified as sublitharenites to subarkoses (Fig 13) Quartz is the principal framework grain component (64 0-70 8% by point count), with less common rock fragments of feldspars and biotite The lithic grains assemblage consists primarily of chert (2 0-5 2%), with fewer undifferentiated argillaceous and metamorphic rock fragments A summary of the thin section petrographic data (point count analysis) is shown in Table 2, and the complete report of the petrographic analysis by Reservoirs, Inc is included as part of Appendix 10

The sandstone samples were all moderately to well cemented Total cement ranges from 14 8-22 8%, and averages 18 1% Authigenic clays (5 6-14 8%) and quartz overgrowths (4 0-11 2%) are the principal cementing agents (See Appendix 10 for thin section photomicrographs) Pyrite/opaques (0 4-2 4%) and feldspar overgrowths (0-0 8%) occur as additional cements Based on XRD analysis, clay fraction (2-5% by weight) is composed primarily of mixed layer chlorite/smectite (0-97%) with locally common chlorite (0-71%) and illite (3-24%) (Table 3) The difference in point count total clay content and XRD clay totals is due to the fact the point count data is by volume (includes associated microporosity) and XRD is by weight Thin section and SEM analyses show that authigenic clays at least partially fill every intergranular pore space in these sandstones Quartz overgrowths also partially fill most of the intergranular pore spaces Total visible porosity ranges from 0 8 to 4 4% by point count (Table 2) Measured porosity values from the same sandstones range from 9 5-12 1% This discrepancy can probably be attributed to the abundance of microporosity associated with the authigenic clays Open intergranular pores are uncommon and very small where present Authigenic clays have replaced most of the intergranular macropores with ineffective micropores Secondary porosity created by the dissolution of grains is uncommon except along a few of the microfractures observed in thin sections

2.33 Core Analyses

<u>Routine core analyses</u>

Routine core analysis from one-inch diameter plugs (performed by Terra Tek) indicates that porosities in the Second Frontier sandstone range from 9-12 percent (Table 4) Permeability values are all less than 0 1 md Table 5 is a summary of the routine core analysis data for cores 1,2, and 3 and gives the arithmetic average values for porosity, permeability, water saturation and grain density from 75 core plugs Graphs of vertical permeability versus porosity are shown for cores 1, 2 and 3 in Figure 10, and histograms and frequency distributions of all of the properties are given in Appendix 8

Reservoirs, Inc also performed routine core analysis on the six plugs from the same depths as the samples taken for petrographic analysis This data is shown in Table 6b Full diameter analysis on three different whole core samples was also performed by Reservoirs, Inc , and the data is shown in Table 6a

Figures 14a, b, and c show the relationship between the different properties measured by routine core analysis These plots include data from cores 1,2 and 3 Data from cores 1 and 2 are shown as green circles and data for core 3 are shown as red triangles

NMR (Nuclear Magnetic Resonance) Analysis

Six core plugs were selected for nuclear magnetic resonance (NMR) analysis The end trims of these plugs provided the material for the petrographic analyses discussed above The routine core analysis data from these six plugs is shown in both Tables 6b and 6c Helium porosities range from 9 5-12 1%, and permeabilities range from 0 006 to 0 026 md Irreducible water saturations were determined by centrifuging the samples to capillary pressures of both 200 psi and 300 psi The irreducible water saturations at 300 psi range from 33% to 73% and generally have an inverse relationship with permeability A summary of the NMR data is presented in Table 6c

Magnetic susceptibilities range from 0 251 to 3 357 The two deepest samples (15,937 1' and 15,948 2' or 4857 6 m and 4861 m) range from 3 267 to 3 357, and the four shallower samples (15,430 5' to 15,470 5' or 4703 2 m to 4715 4 m) vary from 0 251 to 0 586 Based on petrographic analyses, Reservoirs, Inc stated that this might be because of the higher amounts of iron-rich chlorite and biotite in the two deepest samples, possibly leading to the higher measured magnetic susceptibilities

NMR T_2 distributions were generated at 100% water saturation and at partial water saturations for each core plug The T_2 distributions were displayed by plotting the amplitude versus their associated relaxation times on a logarithmic scale The T_2 distributions were then used to calculate NMR porosity, free fluid index (FFI), bulk volume irreducible (BVI) and logarithmic mean relaxation times (T_{2ml}) Total NMR porosity is proportional to the area under the T_2 distribution curve (See figures under NMR heading in Appendix 10) NMR porosity of the Frontier sandstones ranged from 9 5 to 12 1%, and it is in excellent agreement with the helium porosities measured by standard core analysis "Effective" porosity was calculated from the T_2 distributions using a T_2 minimum of 3 ms This yielded porosities that ranged from 79 to 92% of total NMR porosity These lower values were expected, however, due to the abundance of the pore-filling authigenic clays

T_2 measurements at an irreducible brine saturation were also acquired for the Frontier sandstones in order to determine a T_2 cutoff for separating bulk volume irreducible from free fluid index and to compare NMR-derived irreducible water saturation (Swi) with measured core Swi (Table 6c) The T_2 cutoffs for the sandstones centrifuged down to Swi at an equivalent capillary pressure of 300 psi ranged from 5 3-16 0 ms, with an average of 9 9 ms The T_2 cutoffs for the sandstones centrifuged at 200 psi air-brine capillary pressure ranged from 6 0-26 0 ms, with an average of 14 5 ms The T_2 cutoffs applicable for processing the downhole tool data were 14 5 ms (Swi at a capillary pressure of 200 psi) or 9 9 ms (Swi at 300 psi capillary pressure) These values were lower than the standard sandstone value of 33 ms because of the effects of the authigenic clay and the elevated capillary pressures At 300 psi capillary pressure, BVI's ranged from 4 1 to 7 3% and measured FFI's were 2 2 to 7 8 At 200 psi capillary pressure, BVI's ranged from 4 9 to 9 4%, and measured FFI's ranged from 0 7 to 7 0%

Mercury Injection Analyses

Capillary pressure data and pore throat size distribution were acquired by high-pressure (0 to 60,000 psi) mercury injection (Tables 6 through 11 and Figures 7 through 24 in Appendix 10 under heading of "Mercury Injection") The data showed that the majority of the pore throats had radii of 0 1 micron or smaller, and all of the pore throat radii were smaller than 0 3 microns Displacement pressures ranged from 520 to 819 psi Again, the abundance of very small pores and pore throats can be attributed to the abundance of authigenic clays and grain compaction

2.34 Fracture Characterization

Geoscientists at several different companies and institutions studied and characterized the fractures in the Frontier cores These include John Lorenz of Sandia National Laboratories, Reservoirs, Inc , Steve Laubach and K Milliken at the Texas Bureau of Economic Geology, and Lee F Krystinik and Joe Fultner at UPR, as well as many other UPR personnel The fracture analysis performed by Reservoirs, Inc is included in Appendix 10 (under heading of "Fracture Analysis"), and John Lorenz's report is included as Appendix 11 In summary, approximately 76 natural fractures are present in the 78 2 ft (23 8 m) of near-horizontal core Almost as many natural fractures (36) occur in the 20 2 ft (6 2 m) of core in core #3 as are present (40) in the 58 contiguous feet (17 7 m) of core in cores 1 and 2 Therefore, fracture spacing varies significantly along the length of the cores The maximum length of unfractured core is 3 8 ft (1 16 m) in core #3, compared to a maximum of 16 9 ft (5 15 m) of unfractured core in cores 1 and 2 Minimum fracture spacing in all cores is less than one inch (2 54 cm)

There are two sets of fractures present in the cores The numerically dominant set strikes generally east west, with strikes ranging from 50-120° but strongly concentrated between 80 and 110° (Fig 15) This set is also the oldest set of fractures preserved in the core A younger set of extension fractures strikes approximately north-south, between 0 and 10 degrees (Fig 15) Reservoirs, Inc took digital core photographs for the entire length of core that included both "rolled" and unrolled" images of the core These photos clearly document the natural fractures and their orientations (Fig 16) Figure 16 is included as an example of the entire set of photos that can be found in Appendix 10

The older, east-west fracture set is typically mineralized with a quartz druze, a black, solid bitumen lining, and a later, patchy to thick, white to tan kaolinite layer (Lorenz, 1999) The younger, north-south fractures are mineralized with quartz druze exhibiting a larger and clearer crystal habit than that found on the east-west fractures, and local patches of calcite Approximately one-third of the fractures have been reactivated by right-lateral to oblique shear The shear typically indicates that rock on the southern side of the fracture has moved westward and possibly down, relative to the rock north of the fracture

The east-west fractures formed first, in response to overpressured conditions, and were then reactivated later during local faulting The north-south extension fractures may be contemporaneous with reactivation of the first set, and may be related to extension over the crest of a local flexure (Lorenz, 1999) Some of the fractures are tightly mineralized or consist solely of hairline traces of bitumen, but at least half of the fractures have macroscopically visible remnant open aperture despite mineralization John Lorenz's interpretation of the sequence of fracture formation and mineralization in the Rock Island #4-H is summarized in Table 7

An important component of the fracture fill is the presence of solid bitumen within the east-west fractures Geochemical analysis of the solid bitumen residue documented that the residue was 13 33 weight % carbon and 28 6 weight % sulfur (See Appendix 12 for the complete geochemical report done by DGSI out of Houston, TX) This results in a sulfur/carbon ratio of 2 15 DGSI, the lab that performed the geochemical analysis concluded that the solid bitumen residue contained a very high proportion of sulfur relative to carbon Therefore, the crude oil that precipitated the solid bitumen must have been quite sulfur-rich The Baxter and Mowry Shales that respectively overlie and underlie the Frontier Formation are currently considered the source rocks for the Frontier gas They are both classified as producing Type II-D kerogen with very little sulfur, and are therefore unlikely to have produced the sulfur-rich bitumen in the Frontier fractures It is postulated that a possible source for the bitumen is the Permian Phosphoria Formation (very sulfur-rich source rock), and that the oil migrated up into the Frontier Formation along fractures The bitumen is confined to the areas immediate to the natural fractures in the Rock Island 4-H, and is not pervasive in the matrix

Data from one-inch plugs taken along and across fractures suggest that permeability has been enhanced by a factor of approximately 2 parallel to the east-west fractures (Figs 17 and 18) The same plug data show that permeability is not significantly affected by the north-south fractures The permeability values from plugs taken across a fracture suggest that permeability has not been degraded in the directions across either fracture set (Figs 17 and 18)

J C Lorenz (1999) characterized the fractures in three other deep Frontier cored wells in order to compare them to the fractures in the Rock Island 4-H The Table Rock #104 contained 13 natural fractures in 28 ft (8 5 m) of vertical Frontier core The orientations for these fractures are shown in the rose diagram in Figure 19 The Texaco Government

Union #4 contained 33 natural fractures in the Frontier vertical core, and the orientations of those fractures are shown in Figures 20a and b Note that 13 petal fractures (induced fractures) were described from this core, allowing for the documentation of the inferred orientation of present-day maximum horizontal stress Figures 20a and b show that the orientation of maximum horizontal stress is perpendicular to the orientation of the dominant fracture set in the Government Union #4 This data is summarized in Figure 21, data for the Amoco Frewen #4 well has also been included for comparison Table 7a from Lorenz, 1999 is a comparison of the fracture history of three deep Frontier wells Significant differences between the non-economic Frewen #4 well and the two productive Frontier wells include thrust faulting and associated reactivation of east-west fractures in strike-slip or oblique–slip shear in the two productive wells, and the absence of kaolinite mineralization in the Frewen #4 well The presence of pyrobitumen in the pores and fractures of the Frewen #4 well also acted to reduce reservoir permeability (See Lorenz, J C , et al , 1998 for more details regarding the drilling, completion, and reservoir characterization of the Frewen #4 well)

2.35 Log Analysis

Wireline logs run through the horizontal part of the wellbore included natural gamma-ray spectroscopy (15,030-16,421' or 4581 1-5005 1 m), accelerator porosity/litho-density/gamma ray (15,030'-16,454' or 4581 1-5015 2 m), azimuthal resistivity imager/gamma ray (15,050-16,310' or 4587 2-4971 3 m), elemental capture log gamma ray (15,030-16,360' or 4581 1-4986 5 m), and combinable magnetic resonance imager/gamma ray (15,030-16,374' or 4581 1-4990 8 m) Formation MicroImager (FMI) Borview interpretations at both 5" and 25" scales were performed The Formation MicroImager log was also run at a 5" scale over the interval of 15,030-16,487' (4581 1-5025 2 m) ELAN processing was done at a 5" scale from 15,035-16,300' (4582 7-4958 2 m) The FMI and core images were also juxtaposed on a 240" scale display from 15,430-15,487' (4703 1-4720 4 m) and from 15,935-15,955' (4857 0-4863 1 m) All of the log data and the interpreted FMI and ELAN displays through the horizontal section are included in Figures 5a, 5b, and 5c

2.4 Completion and testing of the Rock Island #4-H

After coring and logging were completed, a 7-5/8" tie-back liner was run from 8217' (2540 5 m) to surface, and a 4" perforated liner was run in the lateral from 14,510' to 16,784' (4422 6 to 5115 8 m) (Table 1) The well was completed with 2-7/8" tubing that was run to 14,490' (4416 6 m) with a packer set at 14,446' (4403 1 m) On 2/25/99 (135 days after spud) the well was flowed to the pit for initial wellbore cleanup The result was a 100' (30 5 m) flare at 11/64 choke and 5600 psi FTP From 3/2/99 to 3/9/99 the operator flowed the well through separator test measuring equipment and the rates measured up to 12 million cubic feet of gas per day Four-point conventional flow tests were run at rates of 6, 8, 10, and 12 million cubic feet of gas per day, and the well produced 26 MMCFG from 3/6/99 to 3/14/99 The well was shut-in from 3/14 to 3/25/99 for bottom hole pressure build-up The resulting bottom hole pressure was measured at 9,650 psi From 3/26/99 to 5/12/99 the well was again shut-in, waiting on a pipeline connection The well opened to first gas sales on 5/13/99 at an initial rate of 12 million cubic feet of gas per day A summary of the daily production since the well was connected to a pipeline is shown in Figure 22 Daily production has averaged approximately 6-7 million cubic feet of gas per day in the past nine months Figure 23 shows the monthly production values, and illustrates how the gas production has remained relatively steady (300 million cubic feet of gas per month declining to 180 million cubic feet of gas per month) despite a significant increase in water production (15,000 barrels of water per month to almost 40,000 barrels of water per month)

3. Phase IIIa - Additional Reservoir Characterization through Logging and Coring of two Offset Wells

3.1 Introduction

The overall objective of the GGRBPIP contract was to reduce the technical risks and the economic uncertainty associated with increased efficient industry development of the low-permeability (tight) gas resources of the Greater Green River Basin of Wyoming The overall goal of the contract was to encourage development and utilization of the GGRB tight gas sand resources by industry Without further verification and extension of the reservoir discovered in the successful RI-4H horizontal well, attempts by industry to develop the deep Frontier gas resource would remain quite risky In order to further delineate and characterize the deep Frontier reservoir, UPR drilled 2 offset wells to the RI-4H The two wells (Sidewinder #1H and #2H) were not part of the original DOE contract work However, the DOE chose to extend the contract to include additional reservoir characterization work from the two offset wells, and participated in the coring and logging of the two wells DOE's participation in this additional reservoir characterization work has provided industry with a significant amount of new and much-needed data on the complexities in the deep Frontier gas reservoir The work has also provided valuable insights into the complexities of theoretically "continuous" basin-centered gas accumulations in general

3.2 Site Selection History for the Sidewinder #1-H and #2H

The preferred locations for the Sidewinder #1H and #2H wells were chosen after detailed analysis of geophysical (3-D seismic), geological (structural, depositional, diagenetic), reservoir (matrix, fractures), and production (drilling, well test) data from the area The locations are shown on the depth structure map on top of the Frontier Formation shown as Figure 24 The two wells are located on either side on the northeastern extension of the major NE-trending oblique reverse-strike-slip fault that is just north of the Rock

Island #4-H well (Fig 24) The Rock Island #4-H well was located at a major change in orientation of the Table Rock Fault system As seen in Figure 24, two major faults, a thrust fault that trends N30E and an oblique reverse strike-slip fault that trends approximately N60E are joined at a junction in close proximity to the Rock Island #4-H As discussed previously in this report this area has a complex structural history because of its setting The core and log data from the Rock Island #4-H were invaluable in deciphering the tectonic history for the well The Sidewinder #1-H and 2-H wells are located where the tectonic history was expected to be somewhat different from the Rock Island location For example, the Sidewinder #1-H was drilled further to the northeast along the upthrown side of the same oblique reverse strike-slip fault as the Rock Island #4-H, but away from any probable effects of the thrust fault The Sidewinder #2-H was drilled to test the previously untested downthrown side of the same oblique reverse strike-slip fault

4. Sidewinder #1-H Well

4.1. Drilling History

The Sidewinder #1-H (950' (290 m) FNL, 250' (76 m) FWL, Sec 35, T20N-R97W) was spud on August 4, 1999 and the vertical pilot hole was drilled to a total depth of 15,744' (4798 8 m) The pilot hole was logged on September 26, 1999 Kick-off point in the vertical well was 14,900' (4541 5 m) The first lateral was drilled to a total depth of 16,080' (4901 2 m) MD and was sidetracked for geological reasons The target Frontier reservoir was the marine sandstone underlying the fluvial sandstone in the Second Frontier Original interpretation of the geosteering data was that the wellbore had penetrated through the fluvial and was in the marine sandstone However, as drilling continued, it became apparent that the wellbore had actually drilled out of the fluvial sandstone and up into an overlying shalier lithology The well was sidetracked in order to drill down through the fluvial section and on into the target marine sandstone Figure 25 shows the interpreted wellbore paths of the multiple sidetracks and the structural interpretation for the Sidewinder #1-H The second lateral had a kick-off point of

15,600’ (4754 9 m) MD and reached a total depth of 16,280’ (4962 1 m) MD The Frontier was cored from 15,959-16,019’ (4864 3-4882 6 m) MD in this second lateral wellbore Unfortunately, the second lateral had to be sidetracked for mechanical reasons, and a third lateral was drilled The third lateral had a kick-off point of 15,560’ (4742 7 m) MD or 15,432’ (4703 7 m) TVD and reached a measured depth of 16,879’ (5144 7 m) or 15,553 89’ (4740 8 m) TVD (Figure 25) The (Formation MicroImager) FMI and combined magnetic resonance) CMR logs were run in this third lateral, and will be discussed later in this report The logs for both the Sidewinder #1-H and #2-H are included in this report as Appendix 20 The Frontier section was drilled with 14 0 to 14 5 ppg mud A complete set of the daily drilling reports is included in this report as Appendix 13, and the Baker Hughes-Inteq end-of-well recap report is included as Appendix 14

4.2 Core Analysis and Petrography

A sixty-foot horizontal core was taken in the second lateral in order to characterize the Second Frontier Formation (15,959’-16,019’ or 4864 3-4882 6 m) Routine porosity and permeability data were taken from 57 horizontal plugs The routine analyses were conducted at multiple overburden pressures of 1000, 2000, 4000, 7000 and 9500 psi Dean-Stark saturation data were also provided for each of the fifty-seven horizontal plugs A summary of these analyses performed by Core Laboratories is included as Table 8 Six whole core samples were also analyzed by Core Laboratories, and a summary of the routine core analysis (including Kmax, K90°, and Kvertical) for the whole core pieces is provided in Table 9 These routine analyses were also done for multiple overburden pressures (1000, 2000, 4000, 7000, and 9500 psi)

Fourteen thin sections were prepared from samples deemed to be representative of the bulk of the cored lithology, and the thin sections were analyzed at UPR for mineralogical content, diagenetic history, and clay content and distribution The complete report is included as Appendix 16 X-ray diffraction analysis was also performed on the same samples, and the results of this analysis are shown in Table 10 The X-ray diffraction indicates that all of the sandstones sampled can be classified as sublitharenites with 87 1-91 8% quartz and 1 4-3 7% plagioclase feldspar by weight Porosity in the sandstones ranges from 9 3 to 11 7%, with one very fine-grained sample having only 7 4% porosity These porosity values were measured at 7,000 psi overburden pressure The porosity is a combination of 1) intragranular porosity formed from the dissolution of feldspars and other labile grains, 2) microporosity developed within the clay matrices and in the partial dissolution of chert grains, and 3) minor preserved, intergranular primary porosity The porosity has been reduced by a combination of compaction, cementation by silica overgrowths, and the abundant authigenic clays Permeabilities from the thin section samples are very low, with values ranging from 0 017 md to 0 046 md at 1,000 psi overburden and 0 005 md to 0 001 md at 7,000 psi overburden

The low permeabilities associated with these Frontier sandstones are due to the abundance of authigenic clay in the samples Total clay content in the sandstones is significant and ranges from 6 8 to 9 6% by weight The most common clay type in all of the samples is mixed layer illite/smectite Chlorite, mixed layer chlorite/smectite, and illite comprise the rest of the total clay percent Four photos from each thin section are included in an SEM (scanning electron microscopy) report that was generated by Tad Taylor at UPR (Appendix 17) The distribution and structure of the mixed-layer clays are nicely illustrated in this report Microporosity, quartz overgrowths, and traces of kaolinite are also illustrated in the SEM photos

4.3 Fracture Analysis

Core Laboratories also analyzed the fractures in the Sidewinder #1-H well The fractures in the core occur between 15,973' (4868 6 m) and 16,014' (4881 1 m) (approximately 40 ft (12 2 m) of the 60 ft (18 3 m) core) Core Laboratories recorded a total of forty-two fractures in the cored interval, Table 11 summarizes the depths and attributes for these recorded fractures The majority of the natural fractures in the cored interval strike between 100 and 120°, with a mean strike orientation of 113 93° Figure 26 is a rose diagram that shows the orientation of the strike of the natural fractures Most of the fractures dip to the south-southeast with a true dip angle of 70-80°

The cored interval of the Frontier Formation consists primarily of light gray, very fine- to fine-grained sandstone, with rare argillaceous laminations Hummocky cross-stratification is the most common type of sedimentary structure observed in the core The complete core description by Core Laboratories is shown in Figure 27 A summary of all of the core analyses and fracture studies performed by Core Laboratories is included as Appendix 15 This report also includes whole core photographs taken in specialized formats that allow for easy visual analysis of the natural fractures in the core The first format is termed a whole core 360° format in which each photo shows three feet of core that has been "unrolled" to show the entire surface of the core in 360° The other format included in the Core Labs report consists of "four-side" photography This format shows 24 ft of core per photograph, and covers the entire cored interval The same 24 ft of core are photographed in four views, with the first view being 0° and the subsequent three views being where the core is rotated 90, 180, and 270° respectively

John Lorenz of Sandia National Laboratories and Joe Fultner of UPR also described and characterized the natural fractures in the Sidewinder #1-H well Their comments and descriptions are shown in Table 11 They described forty natural fractures, the majority of which had E-W strikes (90 to 110°) The fractures were partially to completely filled with varying amounts of pyrobitumen, quartz, kaolinite, and calcite Four of the fractures show evidence of left-lateral oblique movement while six show evidence of only vertical offset Fifteen of the fractures show no apparent movement along the fracture plane It was not possible to discern offset on the remainder of the described fractures.

4.4 Log Analysis

The logging program on the Sidewinder 1H vertical wellbore consisted of resistivity, three porosity tools, and gamma ray The resistivity tool was a phasor induction, DIT-E This tool provides deep and medium induction measurements and a shallow, focused resistivity measurement from an SFL The gamma ray measures the naturally-occurring radiation present in the formation It is used to differentiate between clean reservoir rock and the clay minerals present as shale intervals

Porosity data was obtained from three tools First, the Lithodensity tool (LDT) provides a density porosity based on a process known as Comptons scattering Gamma rays at an energy level of 662 keV are emitted from a chemical source into the formation As these gamma rays travel through the formation, they collide with electrons, lose energy, and are scattered The number of lower-energy gamma rays detected by the tool is representative of the density of the formation This density is then converted to porosity information based on lithology and fluid parameters By comparing the number of gamma rays in this Compton scattering region to the number of gamma rays of even lower energy levels, the photoelectric absorption index, Pef, can be determined This measurement is used to determine the mineralogy of the rock, such as dolomite, calcite, silica, etc

The Compensated Neutron Log (CNL) provides a porosity measurement based on the number of hydrogen atoms present in the formation High energy, fast neutrons emitted from a radioactive source travel through the formation, colliding with the nuclei of the materials present Each collision results in a loss of energy The least loss occurs when the neutrons collide with hydrogen atoms, since the mass of these neutrons is very close to the mass of a hydrogen atom The neutrons continue to slow and lose energy until they reach thermal levels, about 025 eV, at which time they are detected by the 2 detectors of the CNL tool The count rates from these detectors are then converted to porosity information, based on lithology and borehole parameters

The Borehole Compensated Sonic Log (BHC) is an acoustical tool that provides porosity data based on the travel time of sound through the formation

Observation of the composite log shows that there are two distinct sand bodies separated by a shaley interval (Fig 28) The SP, resistivity, and porosity tools clearly define the lower sand interval to be 15,427’ to 15,450’ (4702 1 to 4709 2 m) The gamma-ray tool shows the top of this sand to be at 15,417' (4699 1 m) This discrepancy is due to a tool pull lower in the borehole, while the gamma-ray measure point was adjacent to the top section of this sand The porosity and gamma-ray tools show the upper sand interval to be 15,394' to 15,411' (4692 1 to 4697 3 m) The resistivity measurements in this interval are suspect due to second tool pull

Petrophysical analysis was done using ELAN ELAN processing solves a set of simultaneous equations to determine the mineral and fluid makeup of the reservoir as defined by the log analyst Inputs to the program are generally log or core data The outputs are defined by a model input by the analyst and are determined from cuttings, cores, or local knowledge of the area

The ELAN model was comprised of quartz, illite, gas, and water The input tools were bulk density, neutron porosity, sonic travel time, deep resistivity, and gamma ray Due to the tool pulls and resulting erroneous data, the weight factor for the gamma ray was reduced, resulting in the gamma-ray data not being used to solve the model Shale volumes were determined using the porosity data

The ELAN solution shows two clean sand bodies, separated by a shaley, very silty interval (Fig 29) The sands exhibit porosities in the 4-6% range with water saturations of 50-60% After determining the model results, ELAN reconstructs the input tools based on the final solution A gamma-ray curve was reconstructed based on this reservoir model solution, and this reconstructed curve was used in the Geosteering program used to control drilling of the horizontal portion of this prospect

A Formation MicroImager log (FMI), a combined magnetic resonance (CMR) and gamma-ray log were run in the horizontal sidetrack #3 of the Sidewinder #1 well. The logs were run from 15,550' to 16,850' (4739 6 to 5135 9 m) An FMI Borview interpretation using all of the logs is presented in Appendix 20 at both 1" = 20' (2 54 cm = 6 1 m) and 3" = 5' (7 62 cm = 1 5 m) A total of 628 conductive fractures, 538 low quality open fractures, and 78 resistive (healed) fractures were identified from the FMI The majority of the fractures exhibited strikes between 80 and 110 degrees

4.5 Results from the Sidewinder #1-H Well

The Sidewinder #1-H well was drilled on the upthrown side of the ENE-trending oblique reverse strike-slip fault in an area predicted to be heavily fractured Log and core analysis allowed identification of 1206 open fractures in the Frontier Formation Surprisingly, the well produced water at high rates and produced sub-economic rates of gas (430 BWPD and 30 MCFGPD) Bottom hole pressure was 7890 psi at 13,870' (4227 6 m) The high rate of water production had not previously been encountered in other Frontier wells in the Green River Basin The water analysis from the Sidewinder #1-H indicated that the produced water was similar to the water being produced in the Rock Island #4-H Although the Frontier sandstone matrix appears to be regionally gas-saturated, the Sidewinder #1-H showed that the large, open fractures encountered in the deep basin Frontier could be productive of gas or water UPR analyses indicated that the water production, where encountered, did not appear to suggest an infinite aquifer Water production also appears to be related to structural position within isolated pressure cells within the Frontier

5. Sidewinder #2-H

5.1. Drilling History

The Sidewinder #2-H was spud on August 20, 1999 at a surface location of 1170' (357 m) FWL and 1450' (442 m) FNL, Section 30, T20N-R96W, Sweetwater County, Wyoming, approximately four miles (6 4 km) east of the Rock Island #4-H well (Fig 24) Daily drilling reports for the Sidewinder #2-H are included as Appendix 18 The vertical pilot hole was drilled to a total depth of 16,550' (5044 4 m) TD The Frontier reservoir was 960' (292 6 m) low to the Frontier in the Sidewinder #1-H and 1550' (472 4 m) low to the Frontier in the Rock Island #4-H The Frontier section in the vertical pilot hole was drilled with 14 2 ppg mud The lateral portion of the wellbore was drilled to a total depth of 17,043' (5194 7 m) MD with 593' (180 7 m) open hole (Fig 30) Abundant free quartz crystals were observed in the cuttings, indicating the presence of natural fractures There were poor formation gas shows, with low rates of penetration The lateral portion of the hole was drilled with 14 0-14 5 ppg mud FMI and sonic logs were run in the lateral portion of the wellbore, and an open hole DST was conducted The DST indicated virtually no inflow, and no water was recovered Bottom hole pressures were estimated at 8500 to 9000 psi There was no core taken in the Frontier Formation, but FMI analysis and cuttings from the lateral indicated that the Second Frontier fluvial sandstone had scoured into, and removed much of the Second Frontier marine sandstone Therefore, the sandstone encountered in the wellbore was almost entirely fluvial (Fig 31) Fluvial current bedding analyzed on the FMI logs indicated that transport was to the southeast

5.2 Log Analysis (including fracture analysis)

The logging program on the Sidewinder 2H vertical wellbore consisted of two logging runs in the borehole The first run included the Induction/Sonic logs The induction tool was a phasor induction (DIT-E) This tool provides deep and medium induction measurements and a shallow, focused resistivity measurement from an SFL The Borehole Compensated Sonic Log (BHC) is an acoustical tool that provides porosity data based on the travel time of sound through the formation

The second logging run was Lithodensity/Neutron with Gamma Ray The Lithodensity tool (LDT) provides a density porosity based on a process known as Comptons scattering Gamma rays at an energy level of 662 keV are emitted from a chemical source into the formation As these gamma rays travel through the formation, they collide with electrons, lose energy, and are scattered The number of lower energy gamma rays detected by the tool is representative of the density of the formation This density is then converted to porosity information based on lithology and fluid parameters By comparing the number of gamma rays in this Compton scattering region to the number of gamma rays of even lower energy levels, the photoelectric absorption index, Pef, can be determined This measurement is used to determine lithology

The Compensated Neutron Log (CNL) provides a porosity measurement based on the number of hydrogen atoms present in the formation High energy, fast neutrons emitted from a radioactive source, travel through the formation, colliding with the nuclei of the materials present Each collision results in a loss of energy The least loss occurs when the neutrons collide with hydrogen atoms, since the mass of these neutrons is very close to the mass of a hydrogen atom The neutrons continue to slow and lose energy until they reach thermal levels, about 025 eV, at which time they are detected by the 2 detectors of the CNL tool The count rates from these detectors are then converted to porosity information, based on lithology and borehole parameters

The gamma-ray tool measures the naturally-occurring radiation present in the formation It is used to differentiate between clean reservoir rock and the clay minerals present as shale intervals

Observation of the composite log shows that there are two distinct sand bodies separated by a shaley, silty interval (Fig 32) The upper sand interval is from 16,299' to 16,335' (4967 9 to 4978 9 m), while the lower interval is from 16,344' to 16,393' (4981 7 to 4996 6 m) The tension curve from the induction/sonic run indicates a tool pull from 16,324' to 16,299' (4975 6 to 4967 9 m) This results in erroneous resistivity data from 16,318 to 16,292' (4973 7 to 4965 8 m) Sonic data is good through the zone of interest since the sonic measure point is up-hole from the resistivity The tension curve from the density/neutron logging run shows numerous tool pulls through the zone of interest By taking the measure point distances into consideration, it was determined that the density data is invalid from 16,372' to 16,299' (4990 2 to 4967 9 m) The density is valid below 15,372' (4685 4 m) to the base of the sand The neutron is valid in the lower sand interval from 16,352' to 16,387' (4984 1 to 4994 8 m)

Petrophysical analysis was done using ELAN ELAN processing solves a set of simultaneous equations to determine the mineral and fluid makeup of the reservoir as defined by the log analyst Inputs to the program are generally log or core data The outputs are defined by a model input by the analyst and are determined from cuttings, cores, or local knowledge of the area

The ELAN model was comprised of quartz, illite, gas, and water The input tools were bulk density, neutron porosity, sonic travel time, deep resistivity, and gamma ray The interval from 16,372' to 16,387' (4990 2 to 4994 8 m) was used to determine and verify the endpoints used in the ELAN processing This is the interval in which all of the logging data are valid The endpoints were chosen such that the reconstructed curves from the ELAN solution match the input log curves in this interval The entire sand interval was then processed using sonic data to compute porosity and gamma ray information for clay volume

The final ELAN solution results show that the upper sand interval is shaley, with almost no effective porosity (Fig 33) The lower sand is fairly clean at the base, shaling upward to the top Porosities range from 6% at the base to 4% or less at the top

The FMI tool was run from 16,550 to 17,040 ft (5044 4 to5193 8 m) in sidetrack #2 This data is included in Appendix 20 A total of 351 fractures were imaged, for an average of one fracture every 1 6 ft (or one fracture every 0 5 meters) The data showed 210 high quality conductive fractures, with a mean strike of 134° There were 109 lower quality conductive fractures with a mean strike of 127°, and 32 resistive (healed) fractures with a mean strike of 84° Nine faults were interpreted from the FMI data, with a mean strike of 85° The interpretation by Union Pacific Resources technical personnel and John Lorenz was that the majority of the fractures encountered in the Sidewinder #2-H well were not reactivated by shear like the fractures were from the Rock Island #4-H and Sidewinder #1-H wells

5.3 Results of the Sidewinder #2-H

After running a DST, it was interpreted that the Frontier Formation was drilled overbalanced The higher pressure gradient present in the Baxter Shale was not representative of the reservoir pressure in the Frontier Only small flares of gas of ten ft or less (less than 3 meters) were recorded during the DST in the Frontier Formation No water was recovered on the DST from the Frontier, and this in itself is strong evidence for compartmentalization within the Frontier The Sidewinder #2-H fluvial sandstone is apparently not in communication with the Frontier sandstone in the Sidewinder #1-H well that produced significant amounts of water updip from this well

The Sidewinder #2-H intersected 319 open fractures in just 490 ft (149 4 m) of rock In comparison, the highly productive Rock Island #4-H encountered approximately only 400 open fractures in 1750 ft (533 4 m) of rock Therefore, the low productivity of the Sidewinder #2-H cannot be explained by the sheer number of open fractures present in the reservoir It is possible that the heavy weight of mud (14 5 to 15 2 ppg) used to drill the Sidewinder #2-H damaged the formation, and resulted in an inadequate production test of the Frontier reservoir

6. Conclusions and Recommendations for the GGRB Production Improvement Project – Phases III and IIIa.

(Conclusions and recommendations associated with Phase II of the GGRB Project are in the topical report included as Appendix 2 of this report.)

The primary objective of the GGRB production improvement project was to identify and evaluate new technologies to make drilling for and producing the strategic gas resources of the deep Greater Green River Basin economically viable Participants in this multi-year partnership between the oil and gas industry and the Department of Energy worked to 1) identify optimum drilling locations, 2) reduce drilling time and expense, 3) test new horizontal drilling techniques, 4) effectively evaluate and characterize the reservoir, 5) establish economically viable production, and 6) encourage and stimulate industry activity in the area All of these goals were successfully accomplished during the course of the GGRBPIP

The GGRBPIP culminated in the drilling and completion of the UPR Rock Island #4-H well Results from this well included 1) Cost for drilling deeper than 15,000' (4572 0 m) TVD was reduced by 50% of the previous industry average, 2) Over 400 open natural fractures were intersected in a 1750' horizontal leg, 3) The deepest horizontal tight-gas sandstone cores in the world were taken, 4) One of the highest gas flow capacities ever encountered in the tight-gas province of the Frontier Formation was established (> 14 MMCF/D), and 5) An ongoing drilling effort was established by industry to further evaluate and exploit this resource

Industry's knowledge about the deep-basin Frontier reservoirs also increased tremendously as reservoir characterization data from two offset wells to the Rock Island #4-H (the Sidewinder #1-H and #2-H) became available through the GGRBPIP The Sidewinder #1-H intersected over 1200 open fractures in the marine bench of the Second Frontier, however, the well produced copious amounts of water and very low rates of gas The Sidewinder #2-H produced no water and very little gas, and encountered lower reservoir pressures than in the #1-H Integration of wellbore imaging logs and horizontal cores from the Sidewinder wells helped to determine why some fracture systems seemed to be more productive than others in the Frontier

Industry also received an invaluable database regarding fracture spacing in the Frontier Formation Fracture spacing is highly variable in the Rock Island #4-H, ranging from a maximum of 3 8 ft (1 2 m) of unfractured core in core #3 to a maximum of 16 9 ft (5 2 m) of unfractured core in cores 1 and 2 With this much variability in fracture spacing, it is likely that a conventional vertical wellbore might not encounter a highly fractured interval even though fractures may occur in close proximity to the vertical wellbore As another example, the vertical pilot hole drilled for the Sidewinder #1-H encountered tight sandstone (4-6% porosity from logs) with poor gas shows, and drilling data indicated a general lack of fracturing This lack of fracturing was inferred from the lack of chattering of the bit while drilling through the reservoir as well as the lack of any free quartz crystals in the cuttings However, gas shows and free quartz crystals were observed in all three laterals that were drilled off of the vertical pilot hole, indicating the presence of fractures in the horizontal wellbores In addition, core from the horizontal leg of the well also indicated in situ porosities ranging from 9 2-12 0% (significantly higher than the log porosity values) and forty fractures in the cored interval The CMR (combined magnetic resonance) porosity data confirmed the porosity values derived from the core This information gained from the evaluation of the three horizontal Frontier wells should be considered when evaluating other potential drillsites or previously drilled deep Frontier wells For example, the Stratos vertical well that was drilled as part of Phase I of the GGRBPIP was not heavily fractured, however it still may be in close proximity to fractured zones Indications for this are the two nearby Blue Rim wells that tested between 800 MCFD and 1 3 MMCFD from vertical wellbores in the Frontier (See Appendices 1 and 2 for further discussion of the Stratos well and offsetting key wells)

As stated in the project summary section of this report, results from the drilling effort and reservoir characterization of the Frontier sandstones have yielded a complex picture from this basin-centered, tight gas system Important observations from the drilling of the Stratos #1, the Rock Island #4-H and the two Sidewinder wells include 1) The Frontier

Formation reservoir appears to be divided into a number of isolated pressure cells with pressure gradients ranging from 0 5 to 0 85 psi/ft , 2) The matrix sandstone appears to be regionally gas-saturated, 3) Intense fracturing occurs adjacent to large linear strike-slip or shear faults, 4) Productive fractures appear to be opened by shear reactivation, 5) Fractures can be productive of gas or water, 6) Water production is related to structural position within each pressure cell, and 7) Water production, when encountered, does not appear to suggest infinite aquifer support

Stratigraphic reservoir compartments in the Frontier Formation have undergone different pressure histories due to intermittent movement along shear faults These shear faults reactivate and open fractures, but they can also rupture pressure seals and allow water into the fracture system Finding a balance between adequate open fractures and low water production will be critical to economic success in this unconventional play

7. Technology Transfer and list of abbreviations found in report

Results of the various phases of the GGRBPIP have been presented at several venues over the course of the project These venues have included DOE-sponsored technical symposiums, Rocky Mountain Association of Petroleum Geologists Technical Symposiums, two national American Association of Petroleum Geologists Annual meetings, and others The events, dates and locations for all of these technical presentations are summarized below The events are listed in order by date, from earliest to most recent presentation Several trade journal articles also published results of the project, these are also listed below in order by date of publication Copies of articles, abstracts and any available slides from the technical presentations are included as Appendix 19 of this report

Blakeney-DeJarnett, B and F H Lim, 1997, Greater Green River Basin Production Improvement Project. U S DOE Natural Gas Conference, March 24-27, 1997, Houston, TX

Krystinik, L F and Lim, F H , 1999, GGRB Production Improvement Project, Rock Island 4-H Horizontal Well, Table Rock Field, Frontier Formation. Consortium for Emerging Gas Resources in the Greater Green River Basin, Denver, Colorado, April 26, 1999 (sponsored by GRI, U S DOE, PTTC, and IPAMS)

1999, Lorenz, J C and Mroz, T H , Natural fracturing in horizontal core near a fault zone The Rock Island Unit #4-H Well, Green River Basin, WY Consortium for Emerging Gas Resources in the Greater Green River Basin, Denver, Colorado, April 26, 1999 (sponsored by GRI, U S DOE, PTTC, and IPAMS)

1999, Oil and Gas Journal Press Release on Rock Island #4-H, May 17, 1999, p 67

1999, Industry/DOE well in Wyoming, World Oil, June 1999, p 23

1999, Lim, F H , 1999, Greater Green River Basin Production Improvement Project, Rock Island #4-H, Table Rock Field, Frontier Formation 1999 Oil and Gas Conference Technology Options for Producer Survival, June 28-30, 1999, Dallas, TX (sponsored by FETC and NPTO)

1999, Lyle, Don, Deep Opportunity Hart's Oil and Gas World, August, 1999, p 32-33

1999, Lorenz, J C and Mroz, T H , Natural fracturing in horizontal core near a fault zone The Rock Island Unit #4-H Well, Green River Basin, WY PTTC Meeting, Farmington, NM, Sept 29, 1999

Krystinik, L F, and Lim, F H , 1999, Hunting fractures three miles down – Integrated reservoir geology and horizontal drilling technology for the UPR/DOE Rock Island #4-H Well, Frontier Formation, southwestern Wyoming AAPG/SPWLA Hedberg Research Conference on Horizontal Wells – Focus on the Reservoir, October 10-13, 1999, The Woodlands, TX

Krystinik, L F and Lim, F H , 1999, Hunting fractures three miles down Integrating reservoir geology and horizontal drilling results for the UPR/DOE Rock Island 4-H Well, Frontier Formation, southwestern Wyoming *in* the Geology of Wyoming, Wyoming Geological Survey, University of Wyoming Department of Geology and Geophysics, and the Wyoming Geological Association 1999 Joint Conference, October 14-15, 1999, Laramie, Wyoming

Freeman, Diane, 1999, Deep Horizontal Experiment Taps Tight Gas It's a 'Frontier Play' in Green River American Association of Petroleum Geologists Explorer, December, 1999, p 16-17

Krystinik, L F, Lim, F H , and Lorenz, J C , 2000, Hunting fractures three miles down integrating reservoir geology, drilling and production for the UPR/DOE Rock Island #4-H Well, Frontier Formation, southwest Wyoming American Association of Petroleum Geologists Annual Meeting, April, 2000, New Orleans, LA

Lorenz, J C , Krystinik, L F , Griffith, T W , and Mroz, T H , 2000, Production from natural fractures reactivated by faulting The Rock Island Unit 4-H Horizontal Well, Green River Basin, WY American Association of Petroleum Geologists Annual Meeting, April, 2000, New Orleans, LA

Krystinik, L F and J C Lorenz, 2000, New perspectives on basin-centered gas from horizontal drilling, Frontier Formation, SW Wyoming RMAG Basin Center Gas Symposium, sponsored by Rocky Mountain Association of Petroleum Geologists, Rocky Mountain PTTC, GRI and DOE, October 6, 2000, Denver, CO

Krystinik, L F , 2001, Big bucks or money disposal project? New perspectives on basin-centered gas from horizontal drilling, Deep Frontier Formation, Green River Basin, SW Wyoming American Association of Petroleum Geologists Annual Meeting, June 3-6, 2001, Denver, CO

List of Abbreviations

BCF	billion cubic feet
BUR	build-up rate
BVI	bulk volume irreducible
FFI	free fluid index
FTP	flowing tubing pressure
Kmax	maximum permeability
Kvertical	vertical permeability
K90	permeability 90 degrees from maximum permeability
MCFD	thousand cubic feet per day
md	millidarcy(ies)
MD	measured depth
MMCFD	million cubic feet per day
NMR	nuclear magnetic resonance
ppg	pound per gallon
psi	pound per square inch
SEM	scanning electron microscope
SFL	spherically focused log
sp	spontaneous potential
TCF	trillion cubic feet
TD	total depth
TVD	true vertical depth
XRD	x-ray diffraction

Bibliography

Cobban, W A and Reeside, J B , Jr , 1952, Frontier Formation, Wyoming and adjacent areas American Association of Petroleum Geologists Bulletin, v 36, no 10, p 1913-1962

DeChadenedes, J F , 1975, Frontier deltas of the western Green River Basin, Wyoming, *in* Deep drilling frontiers of the central Rocky Mountains Rocky Mountain Association of Geologists Symposium, 1975, Denver, Colorado, p 149-157

Dutton, S P , 1993, Influence of provenance and burial history on diagenesis of Lower Cretaceous Frontier Formation sandstones, Green River Basin, Wyoming Journal of Sedimentary Petrology, v 63, no 4, p 665-677

Hale, L A , 1962, Frontier Formation - Coalville, Utah and nearby areas of Wyoming and Colorado, *in* Symposium on Early Cretaceous rocks of Wyoming Wyoming Geological Association 17th Annual Field Conference Guidebook, p 211-220

Hamlin, H S , 1992, Frontier Formation stratigraphy and depositional systems architecture, Green River Basin, Wyoming a record of sequence development in a proximal foreland basin (abstract) American Association of Petroleum Geologists 1992 Annual Convention Official Program, p 50-51

Harstad, H , L W Teufel, and J C Lorenz, 1995, Characterization of natural fractures in the Frontier Formation, Green River Basin, Wyoming application to reservoir stimulation of horizontal wells (abs) American Association of Petroleum Geologists Bulletin, v 79, n0 8, p 1221

_____, 1995, Characterization of natural fractures in the Frontier Formation, Green River Basin, Wyoming influence of bed thickness on fracture intensity and interconnectivity (abs) American Association of Petroleum Geologists Bulletin, v 79, no 6, p 919

Jump, C J , in press, Stratigraphic framework of the Frontier Formation in the Rock Springs Uplift and Manila, Utah area Unpublished Masters thesis, Colorado State University, Fort Collins, CO

Laubach, S E , 1992, Fracture networks in selected Cretaceous sandstones of the Green River and San Juan basins, Wyoming, New Mexico, and Colorado, *in* Schmoker, J W , E B Coalson, and C A Brown, eds , Geological studies relevant to horizontal drilling examples from western North America, Rocky Mountain Association of Geologists, Denver, CO, p. 115-127

Laubach, S E , 1991, Fracture patterns in low-permeability-sandstone gas reservoir rocks in the Rocky Mountain region SPE Rocky Mountain Regional Meeting and Low Permeability Reservoirs Symposium, Denver, CO, April 15-17, 1991, p 501-510

Law, B E , 1984, Relationships of source-rock, thermal maturity, and overpressuring to gas generation and occurrence in low-permeability Upper Cretaceous and Lower Tertiary rocks, Greater Green River Basin, Wyoming, Colorado, and Utah, *in* J Woodward, F F Meissner, and J L Clayton, eds , Hydrocarbon source rocks of the greater Rocky Mountain region Rocky Mountain Association of Geologists, p 469-490

Law, B E and W W Dickinson, 1985, Conceptual model for origin of abnormally pressured gas accumulations in low-permeability reservoirs American Association of Petroleum Geologists Bulletin, v 69, no 8, p 1295-1304

Law, B E , 1979, C W Spencer, and N H Bostick, 1979, Preliminary results of organic maturation, temperature, and pressure studies in the Pacific Creek area, Sublette County, Wyoming, *in* Proceedings of the 5th DOE Symposium on Enhanced Oil and Gas Recovery and Improved Drilling Methods Tulsa, Petroleum Publishing Co , v 3, K2/1-2/13

Law, B E , C W Spencer, and N H Bostick, 1980, Evaluation of organic matter, subsurface temperature, and pressure with regard to gas generation in low-permeability Upper Cretaceous and Lower Tertiary sandstones in Pacific Creek area, Sublette and Sweetwater Counties, Wyoming The Mountain Geologist, v 17, no 2, p 23-35

Law, B E and C. R Smith, 1983, Subsurface temperature map showing depth to 180 F Fahrenheit in the Greater Green River Basin, Wyoming, Colorado, and Utah USGS Miscellaneous Field Studies Map MF-1504

Law, B E , R M Pollastro, and C W Keighin, 1986, Geologic characterization of low-permeability gas reservoirs in selected wells, Greater Green River Basin, Wyoming, Colorado, and Utah, *in* C W Spencer and R F Mast, eds , Geology of tight gas reservoirs American Association of Petroleum Geologists Studies in Geology 24, p 253-269

Law, B E , C W Spencer, R R Charpentier, R A Crovelli, R F Mast, G L Dolton, and C J Wandrey, 1989, Estimates of gas resources in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah Wyoming Geological Association 40th Annual Field Conference, p 39-61

Lorenz, J C , Billingsley, R L , and L W Evans, 1998, Permeability reduction by pyrobitumen, mineralization, and stress along large natural fractures in sandstones at 18,300-ft depth Destruction of a reservoir SPE Reservoir Evaluation and Engineering, February 1998, p 52-56

Lorenz, J C , 1993, Reservoir fracture and permeability trends inferred from reconstructions of tectonic stress orientations examples from the Green River Basin, Wyoming (abs), 1993 American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists Annual Meeting Abstracts, p 141

Lorenz, J C and R E Hill, 1992, Measurement and analysis of fractures in core, *in* Schmoker, J W , E B Coalson, and C A Brown, eds , Geological studies relevant to horizontal drilling examples from western North America, Rocky Mountain Association of Geologists, Denver, CO, p 47-59

Lorenz, J C , L W Teufel, N R Warpinski, 1991, Regional fractures a mechanism for the formation of regional fractures at depth in flat-lying reservoirs American Association of Petroleum Geologists Bulletin, v 75, n 11, p 1714-1737

McGookey, D P , 1972, Cretaceous system, in W W Mallory, ed , Geologic atlas of the Rocky Mountain region Rocky Mountain Association of Geologists, p 190-228

McPeek, L A , 1981, Eastern Green River Basin - a developing giant gas supply from deep, overpressured Upper Cretaceous sandstones American Association of Petroleum Geologists Bulletin, v 65, p 1078-1098.

Merewether, E A , 1983, The Frontier Formation and mid-Cretaceous orogeny in the foreland of southwestern Wyoming The Mountain Geologist, v 20, no 4, p 121-138

Merewether, E A and W A Cobban, 1972, Unconformities within the Frontier Formation, northwestern Carbon County, Wyoming U S Geological Survey Professional Paper 800-D, p D57-D66

Merewether, E A and W A Cobban, 1986, Biostratigraphic units and tectonism in the mid-Cretaceous foreland of Wyoming, Colorado, and adjacent areas, *in* J A Peterson, ed , Paleotectonics and sedimentation in the Rocky Mountain region, United States American Association of Petroleum Geologists Memoir 41, p 443-468

Merewether, E A , P D Blackmon, and J C Webb, 1984, The mid-Cretaceous Frontier Formation near the Moxa arch, southwestern Wyoming U S Geological Survey Professional Paper 1290, 29 pp

Merewether, E A , K B Krystinik, and M J Pawlewicz, 1987, Thermal maturity of hydrocarbon-bearing formations in southwestern Wyoming and northwestern Colorado USGS Miscellaneous Investigations Map I-1831

Mieras, B D , 1993, Sequence stratigraphy and depositional controls, mid-Cretaceous Frontier Formations, south-central Wyoming Unpublished PhD dissertation, University of Colorado, Boulder, CO, 397 pp

Moslow, T F , and Tillman, R W , 1986, Sedimentary facies and reservoir characteristics of Frontier Formation sandstones, southwestern Wyoming, *in* C W Spencer and R F Mast, eds , Geology of tight gas reservoirs American Association of Petroleum Geologists Studies in Geology 24, p 271-311

Moslow, T F , and Tillman, R W , 1989, Characterization and distribution of Frontier Formation reservoir facies in Wyoming fields Oil and Gas Journal, v 87, p 95-104

Myers, R C , 1977, Stratigraphy of the Frontier Formation (Upper Cretaceous), Kemmerer area, Lincoln Co , Wyoming, *in* Rocky Mountain thrust belt geology and resources Wyoming Geological Association 29th Annual Field Conference Guidebook, p 271-311

Rathbun, F C , 1986, Abnormal pressures and conductivity anomaly, northern Green River Basin, Wyoming 43rd Annual Fall Meeting, Society of Petroleum Engineers, SPE Paper 2205, p 1-8

Rathbun, F C and P Dickey, 1969, Abnormal pressures and conductivity anomaly, northern Green River Basin, Wyoming The Log Analyst, v. 10, no 4, p 3-8

Reeside, J B , Jr , 1955, Revised interpretation of the Cretaceous section on Vermilion Creek, Moffat Co , Colorado, *in* Green River Basin Wyoming Geological Association 10th Annual Field Conference Guidebook, p 85-88

Ryer, T A , 1977, Coalville and Rockport areas, Utah, in E G Kauffman, ed , Cretaceous facies, faunas, and paleoenvironments across the western Interior Basin The Mountain Geologist, v 14, p 105-128

Spencer, C W , 1987, Hydrocarbon generation as a mechanism for overpressuring in Rocky Mountain region American Association of Petroleum Geologists Bulletin, v 71, n 4, p 368-388

Standard Geological, 1996, Fracture Analysis of a Core from the Texaco Govt Union #4 Well, Sweetwater County, Wyoming Standard Geological Services Inc , Englewood, CO

Stands, R E , 1999, Depositional sequence analysis of the Upper Cretaceous Frontier Formation, Darby Thrust – Moxa Arch area, Southwestern Wyoming Colorado School of Mines unpublished PhD dissertation, Golden, CO, 619 pp

Stonecipher, S A , R D Winn, Jr , and M G Bishop, 1984, Diagenesis of the Frontier Formation, Moxa Arch a function of sandstone geometry, texture and composition, and fluid flux American Association of Petroleum Geologists Memoir 37, p 289-316

The Scotia Group, 1993, Reserves in Western Basins - Part I Greater Green River Basin Topical Report for DOE Contract No DE-AC21-91MC28130 The Scotia Group, Inc , Dallas Texas

Wach, P H , 1977, The Moxa Arch, an overthrust model? *in* Rocky Mountain thrust belt geology and resources Wyoming Geological Association, 29th Annual Field Conference Guidebook, p 651-664

Winn, R D , Jr , S A Stonecipher, and M G Bishop, 1984, Sorting and wave abrasion controls on composition and diagenesis in Lower Frontier sandstones, southwestern Wyoming American Association of Petroleum Geologists Bulletin, v 68, no 3, p 268-284

ROCK ISLAND #4-H Wellsite

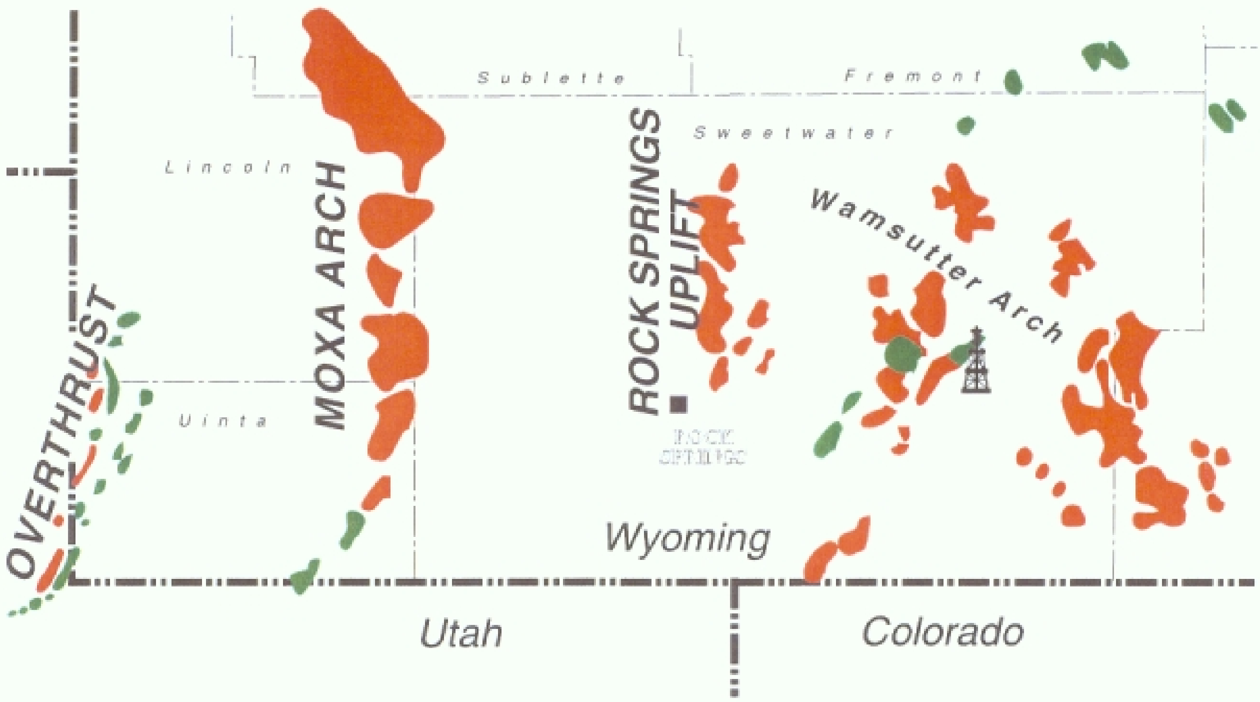


Figure 1. Index map of major oil and gas fields in the Greater Green River Basin, Wyoming with respect to the Rock Island #4-H wellsite in Sweetwater County. Derrick indicates location of the well.

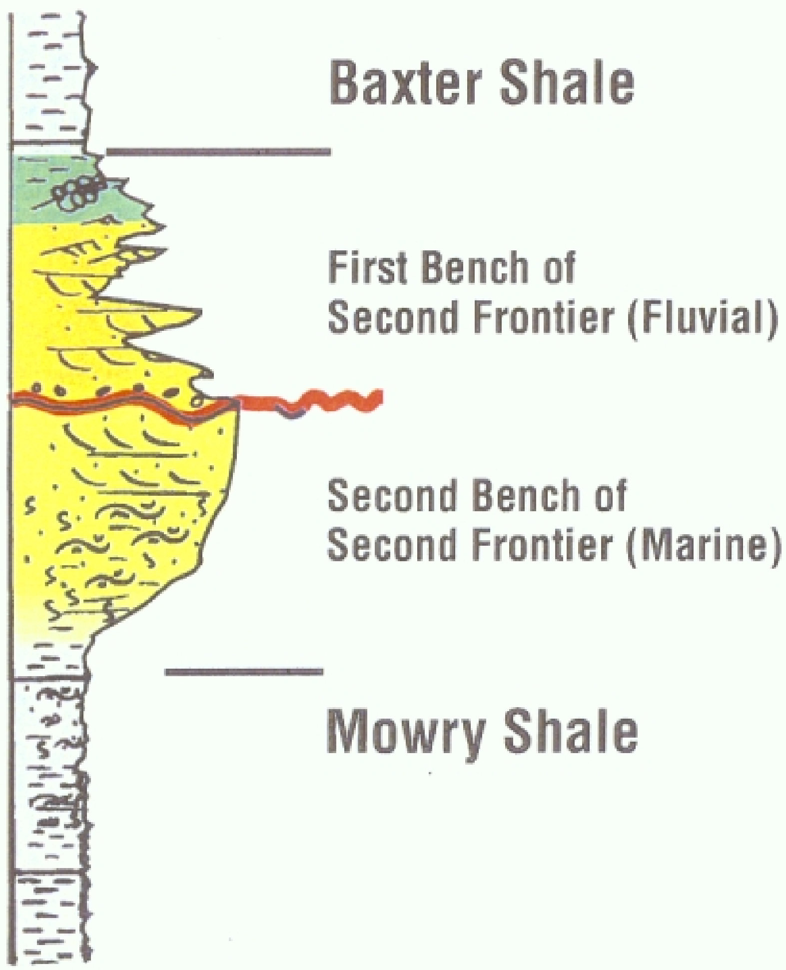


Figure 2. Schematic vertical profile of the Second Frontier Formation near the proposed Rock Island #4-H location, Sweetwater Co., Wyoming.

R.I. 4-H Wellbore Diagram

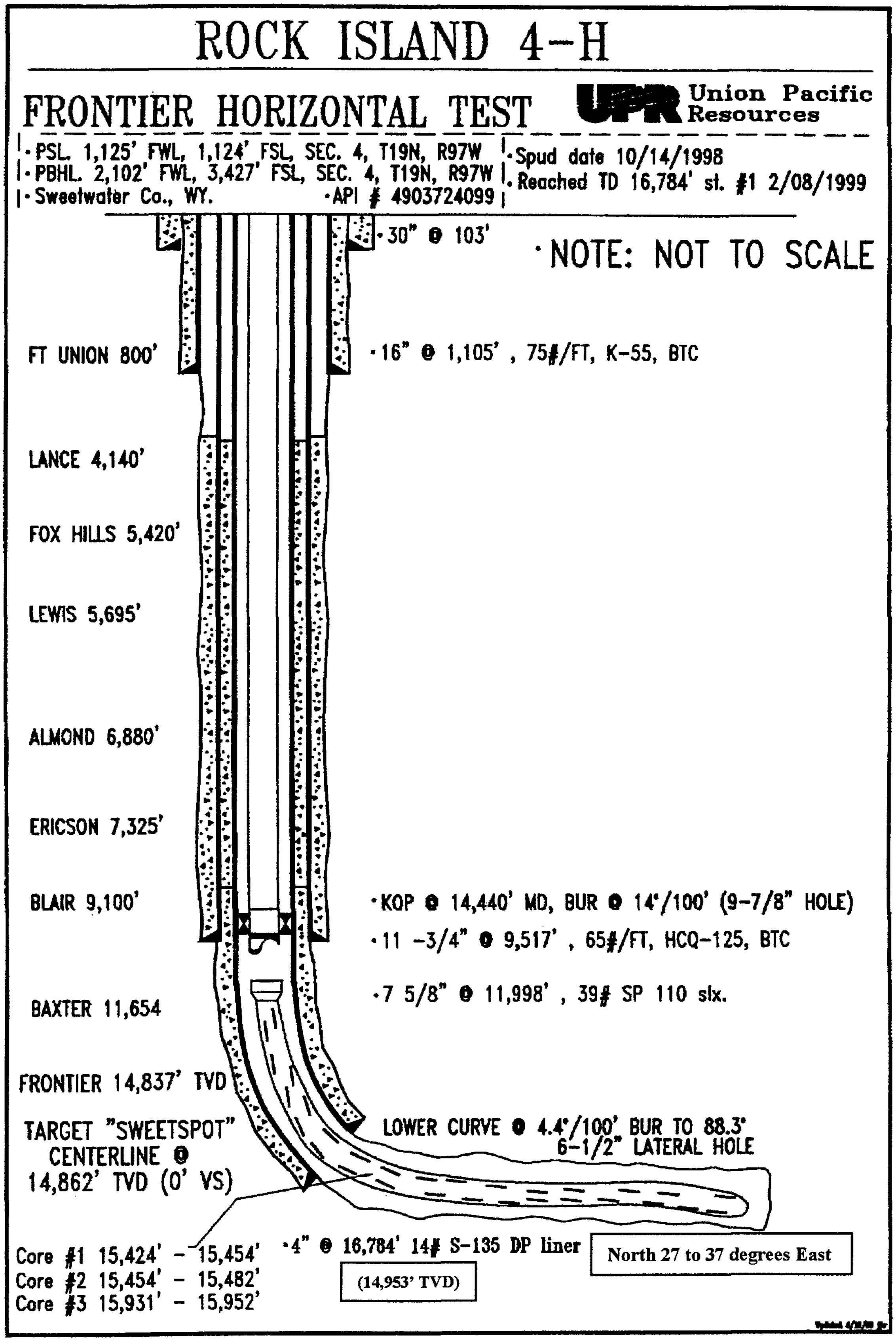


Figure 3 Wellbore diagram for the Rock Island #4-H well

DRILLING RESULTS vs. TIME

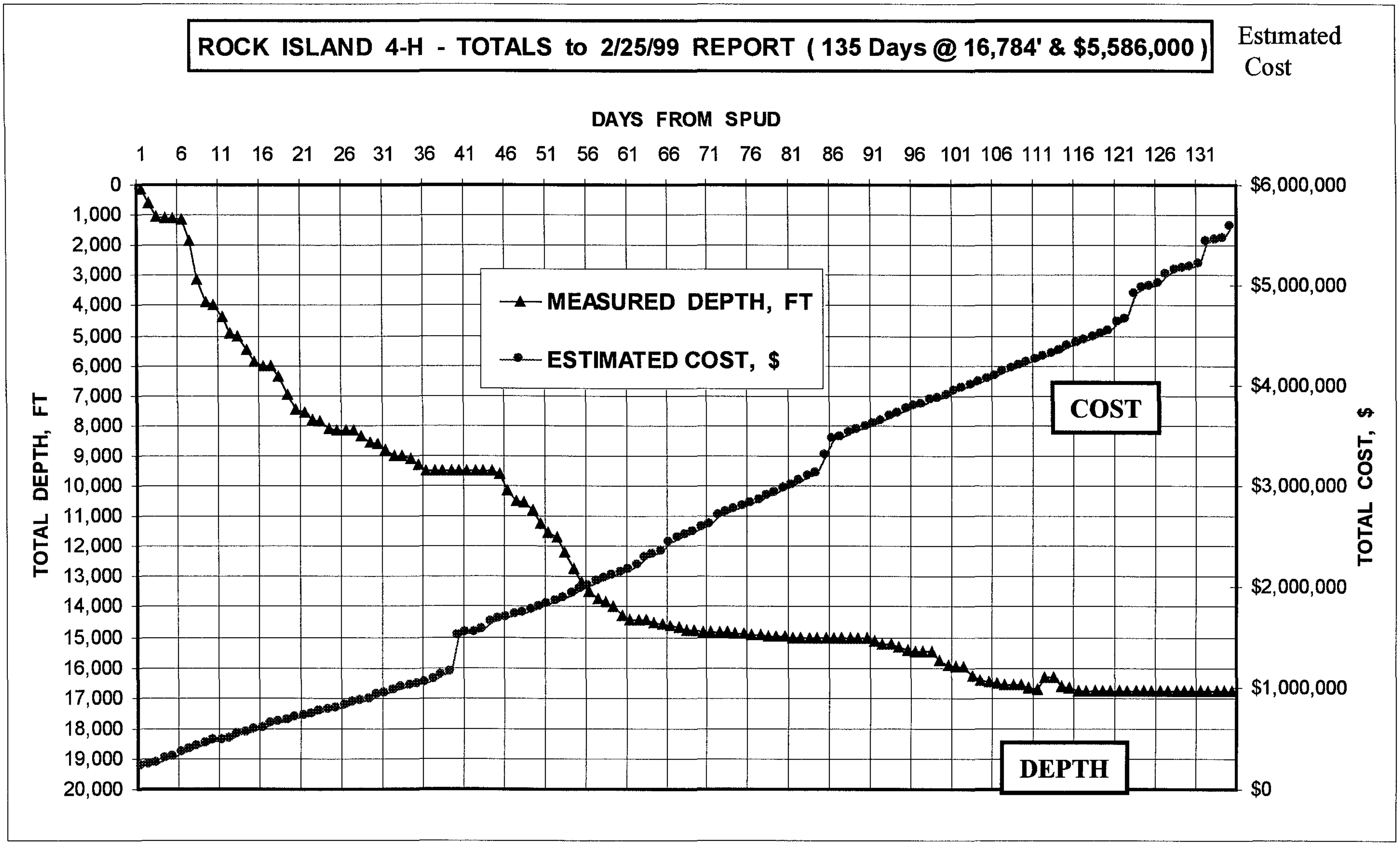


Figure 4. Drilling results with respect to time and cost, Rock Island #4-H.

FIGURE 5a. FMI BorView Interpretation, 5" Scale, Rock Island #4-H.

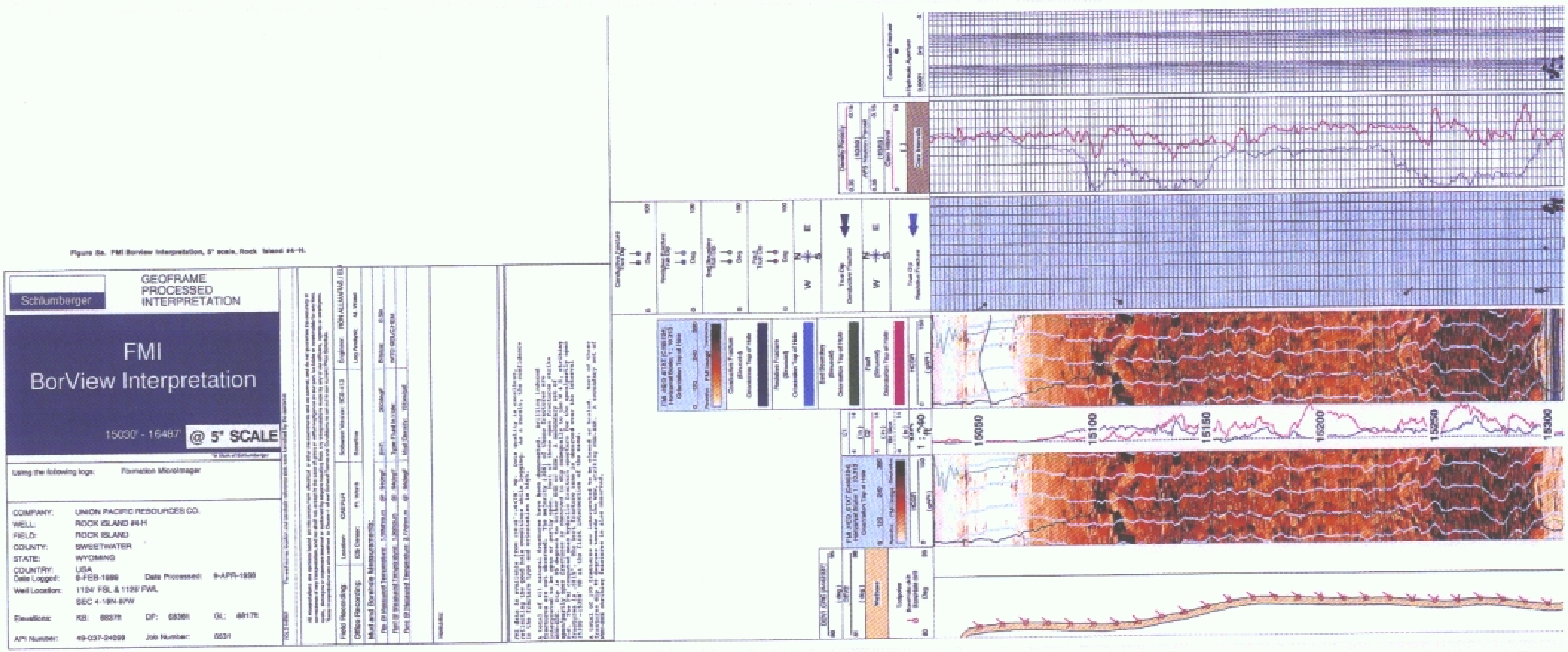


Figure 5b. ELAN processing log, 5" scale, Rock Island #4-H.

Schlumberger

GEOFRAME
PROCESSED
INTERPRETATION

ELAN Processing

15035' - 16300' @ 5" scale

*A Mark of Schlumberger

Using the following logs: HNGS-IPLT
ARI-CMR-ECS-GPIT-GR

COMPANY:	UNION PACIFIC RESOURCES CO.
WELL:	ROCK ISLAND #4-H
FIELD:	ROCK ISLAND
COUNTY:	SWEETWATER
STATE:	WYOMING
COUNTRY:	USA
Date Logged:	9-FEB-1999
Date Processed:	8-APR-1999
Well Location:	1124' FSL & 1125' FWL SEC 4-19N-97W
Elevations:	KB: 6837ft DF: 6836ft GL: 6817ft
API Number:	49-037-24099
Job Number:	6531

FOLD HERE The well name, location and borehole reference data were furnished by the customer.

Field Recording: Location: CASPER | Software Version: 9C0-413 | Engineer: RON ALLMARAS / EL

Office Recording: ICS Center: Ft. Worth | Baseline: | Log Analyst: M. Wood

Mud and Borehole Measurements:

Rm @ Measured Temperature: 1.99ohm.m @ 64degF	BHT: 260degF	Bitsize: 6.5in
Rmf @ Measured Temperature: 1.3ohm.m @ 64degF	Type Fluid in Hole: WTD GEL/CHEM	
Rmc @ Measured Temperature: 2.77ohm.m @ 64degF	Mud Density: 15lbm/gal	

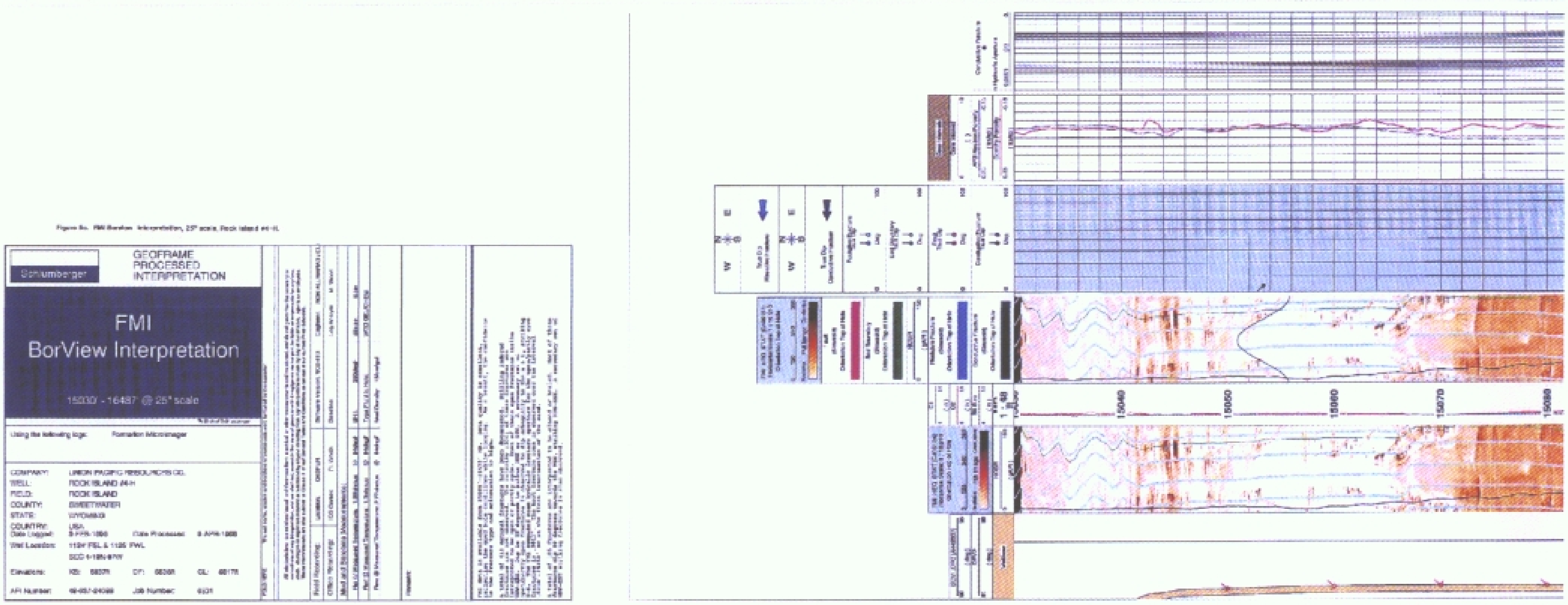
Remarks:

A mineral model was determined based on the mineralogical analysis done on six core plugs. This analysis showed the reservoir to be composed of quartz with small amounts of clay minerals, and no carbonates. The clay minerals are chlorite & illite or mixed layered chlorite-smectite. The ELAN model is:

Illite, Chlorite, Quartz, Gas, and Water, including Irreducible water.

The ECS WWY are used to determine clay and matrix volumes with the HNGS is used to differentiate the clay minerals. The density and neutron determine porosity and near wellbore gas. Deep resistivity determines unmoved hydrocarbon volumes. The CMR is used to measure the irreducible water volume. The CMR was processed using total porosity algorithm and a 33 msec taper cut-off.

FIGURE 5c. FMI BorView Interpretation, 25" Scale, Rock Island #4-H.



RI 4-H Geosteering Results of Horizontal Lateral

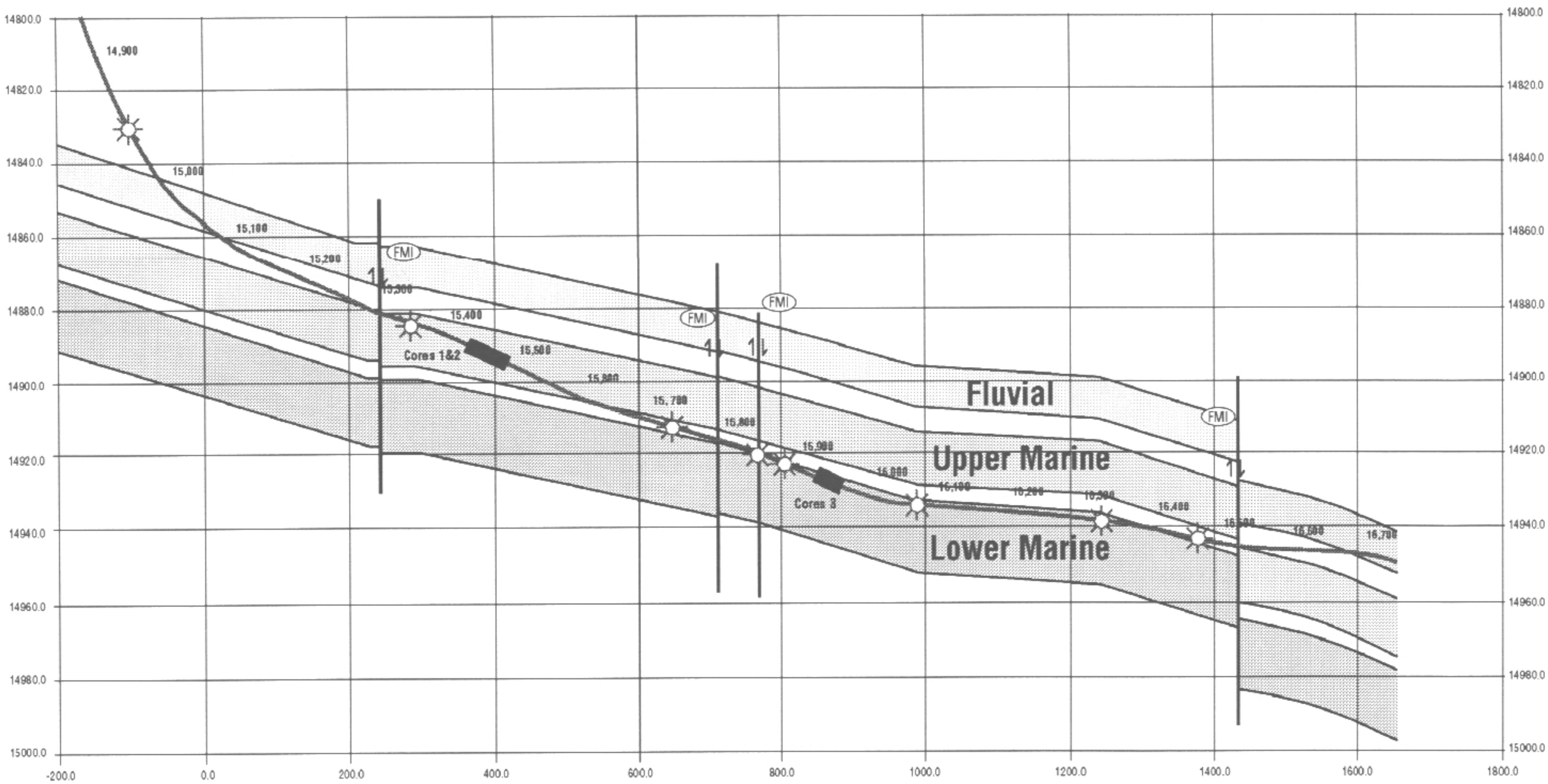


Figure 6. Diagram showing the geosteering results of the horizontal lateral Rock Island #4-H. Location of Cores 1,2, and 3 are shown on the diagram.

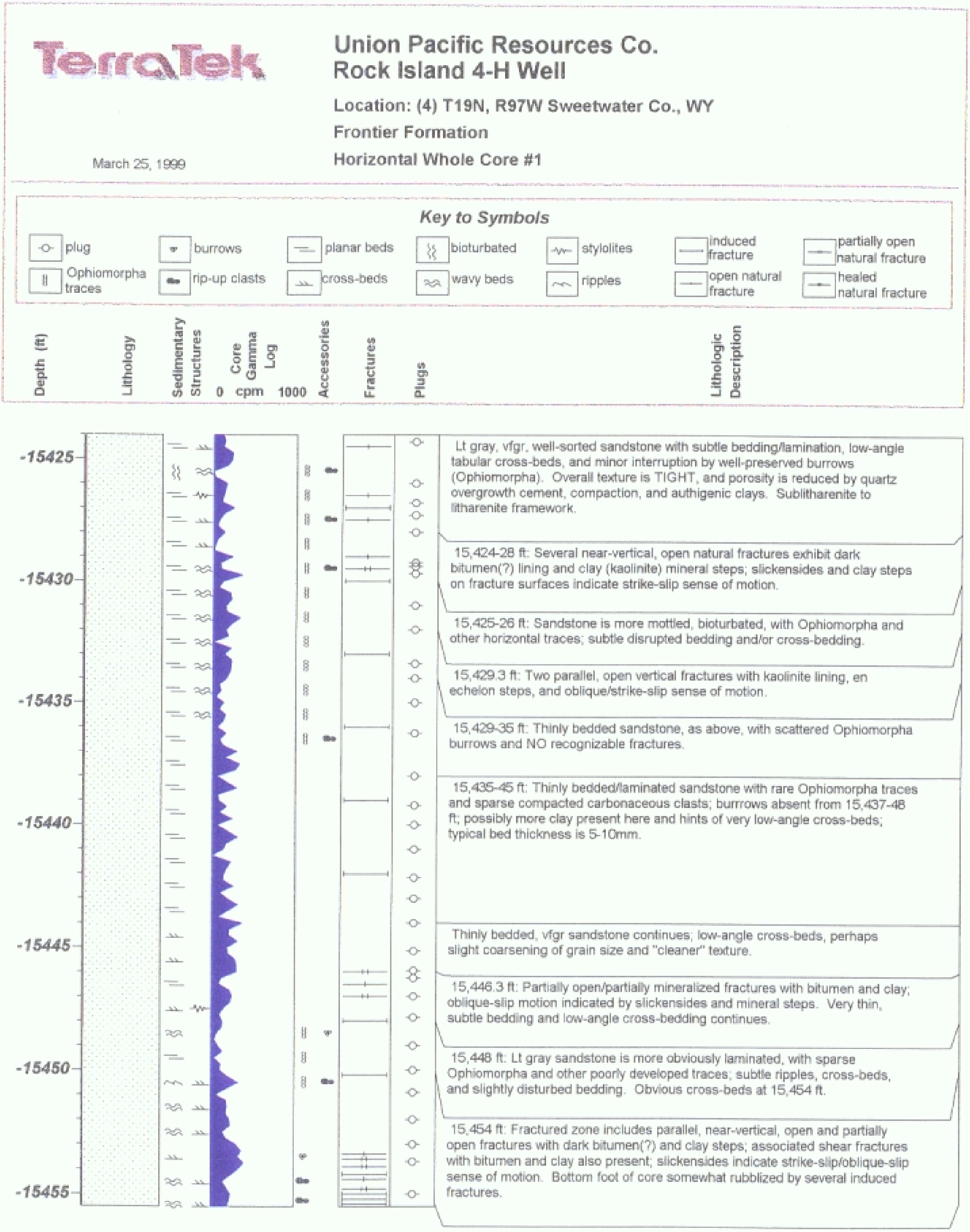


Figure 7. Core description for Cores 1 and 2, Rock Island #4-H.

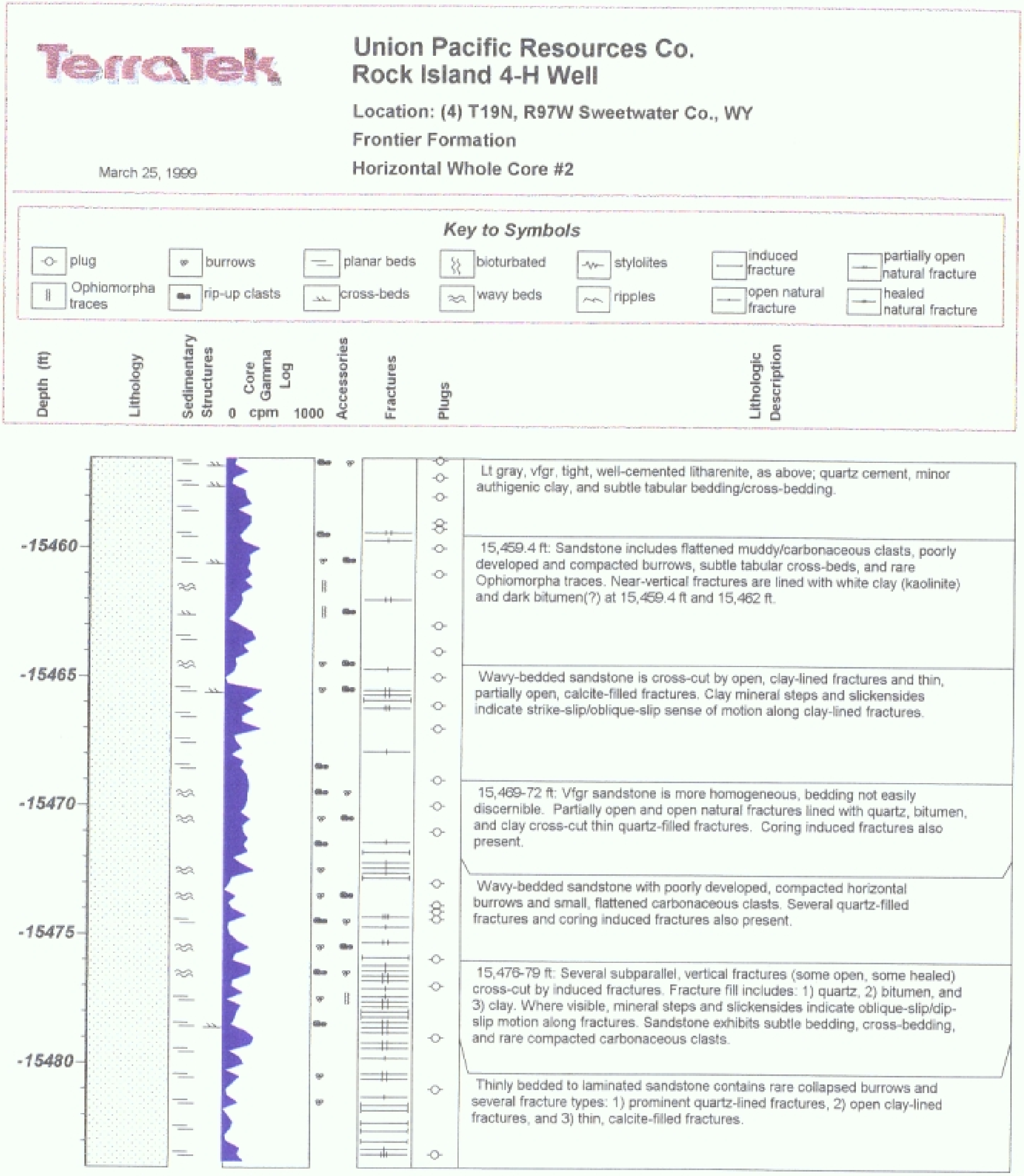

TerraTek
Union Pacific Resources Co.
Rock Island 4-H Well
Location: (4) T19N, R97W Sweetwater Co., WY
Frontier Formation
Horizontal Whole Core #2
March 25, 1999
Key to Symbols
plug
Ophiomorpha traces
burrows
rip-up clasts
planar beds
cross-beds
bioturbated
wavy beds
stylolites
ripples
induced fracture
open natural fracture
partially open natural fracture
healed natural fracture
Depth (ft)
Lithology
Sedimentary Structures
Core Gamma Log
0 cpm 1000
Accessories
Fractures
Plugs
Lithologic Description
-15460
-15465
-15470
-15475
-15480
Lt gray, vfgr, tight, well-cemented litharenite, as above; quartz cement, minor authigenic clay, and subtle tabular bedding/cross-bedding.
15,459.4 ft: Sandstone includes flattened muddy/carbonaceous clasts, poorly developed and compacted burrows, subtle tabular cross-beds, and rare Ophiomorpha traces. Near-vertical fractures are lined with white clay (kaolinite) and dark bitumen(?) at 15,459.4 ft and 15,462 ft.
Wavy-bedded sandstone is cross-cut by open, clay-lined fractures and thin, partially open, calcite-filled fractures. Clay mineral steps and slickensides indicate strike-slip/oblique-slip sense of motion along clay-lined fractures.
15,469-72 ft: Vfgr sandstone is more homogeneous, bedding not easily discernible. Partially open and open natural fractures lined with quartz, bitumen, and clay cross-cut thin quartz-filled fractures. Coring induced fractures also present.
Wavy-bedded sandstone with poorly developed, compacted horizontal burrows and small, flattened carbonaceous clasts. Several quartz-filled fractures and coring induced fractures also present.
15,476-79 ft: Several subparallel, vertical fractures (some open, some healed) cross-cut by induced fractures. Fracture fill includes: 1) quartz, 2) bitumen, and 3) clay. Where visible, mineral steps and slickensides indicate oblique-slip/dip-slip motion along fractures. Sandstone exhibits subtle bedding, cross-bedding, and rare compacted carbonaceous clasts.
Thinly bedded to laminated sandstone contains rare collapsed burrows and several fracture types: 1) prominent quartz-lined fractures, 2) open clay-lined fractures, and 3) thin, calcite-filled fractures.

Figure 7.

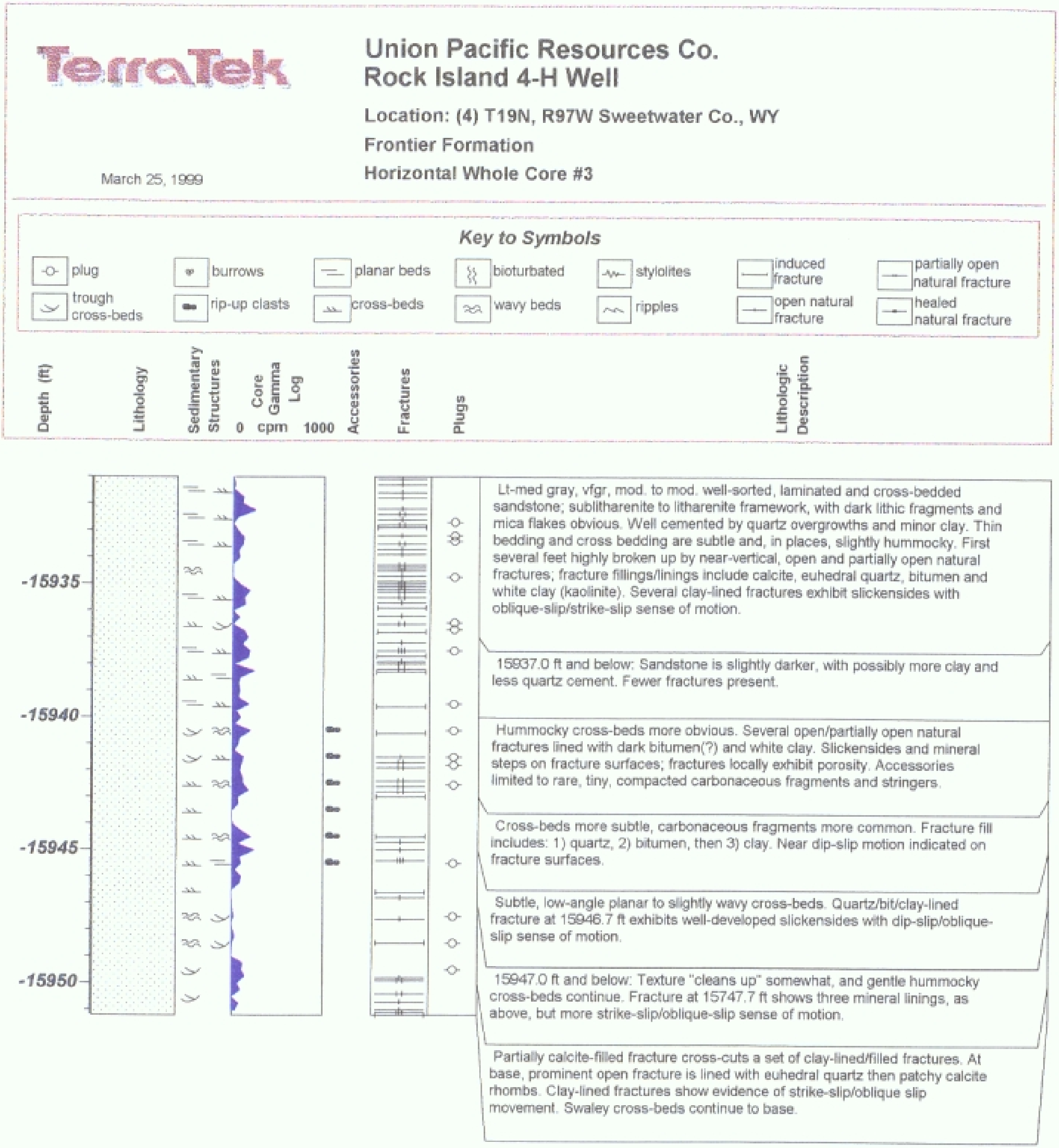
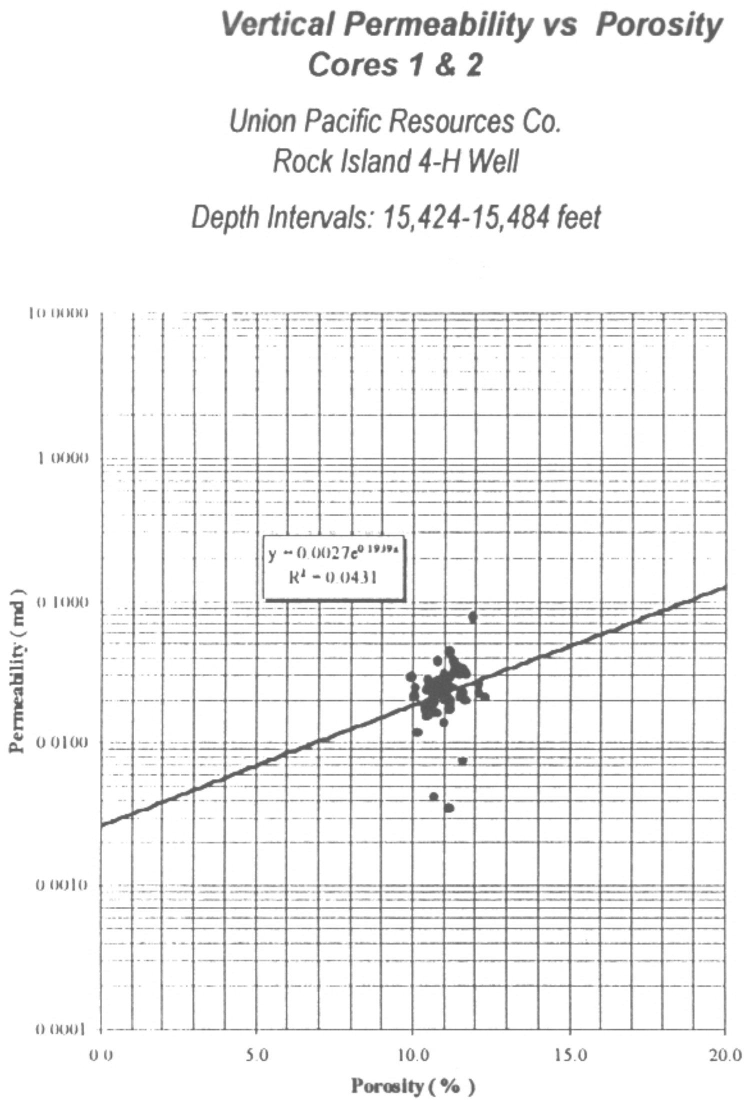


Figure 8. Core description for Core 3, Rock Island #4-H.

Figure 9. Core photograph showing *Ophiomorpha* trace fossil in lower shoreface sandstone, Second Frontier marine bench, Rock Island #4-H.



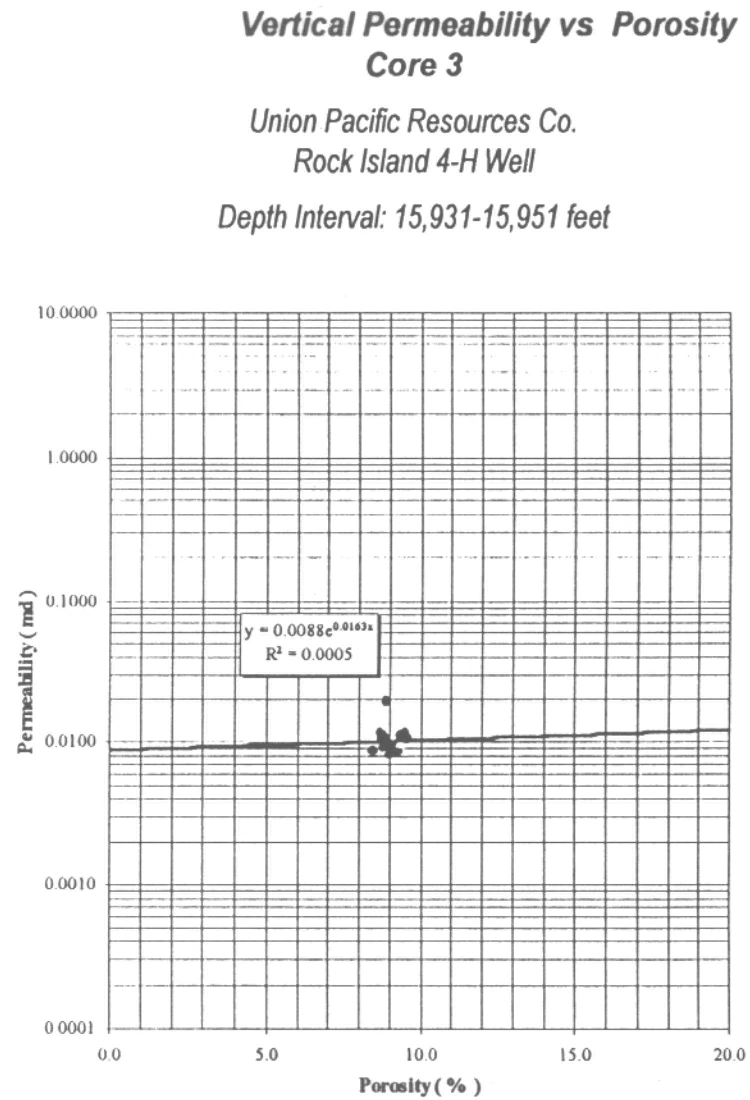


Figure 10. Vertical porosity versus permeability, Rock Island #4-H (TerraTek).

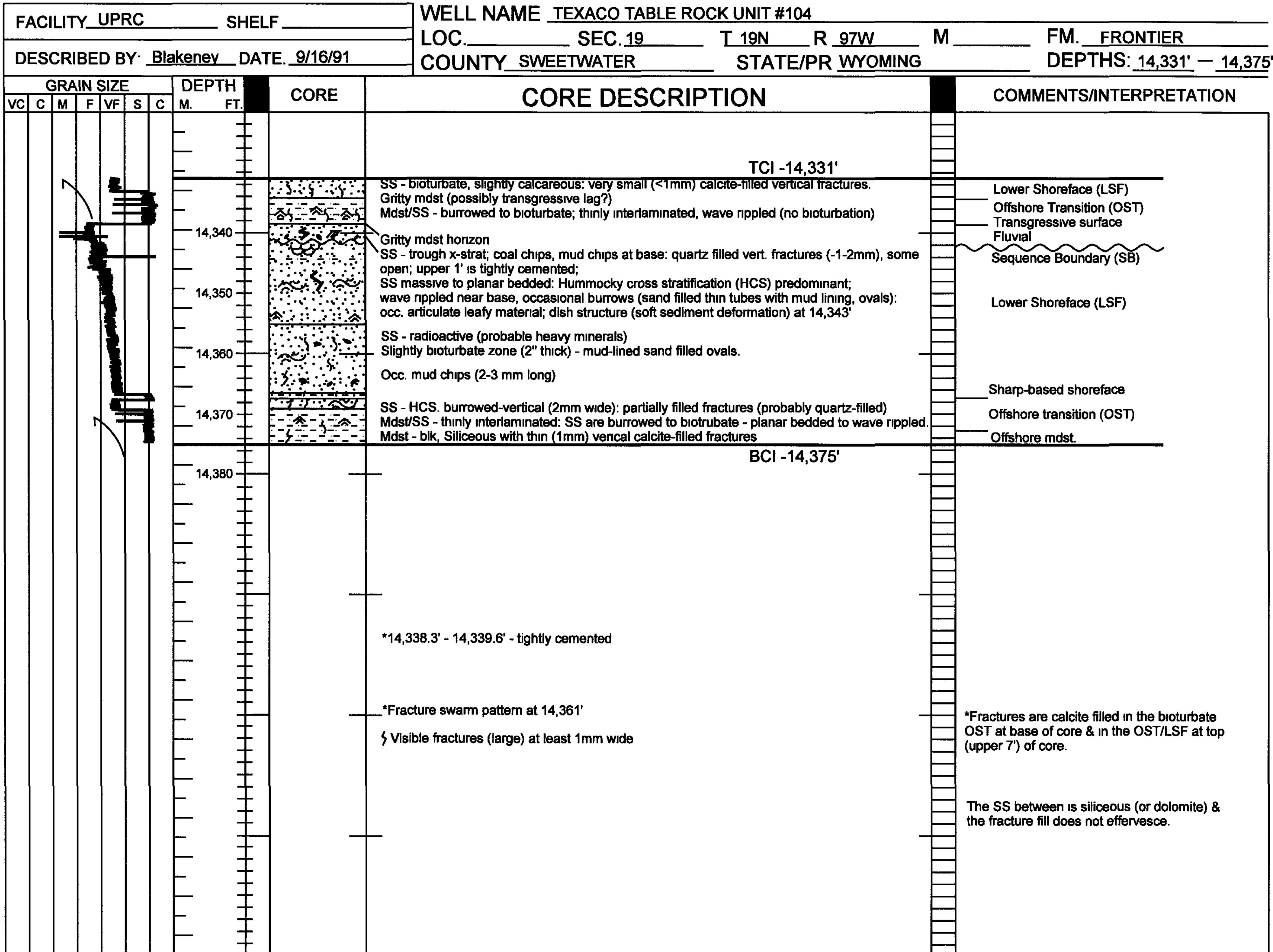


Figure 11 Texaco Table Rock #104 core description.

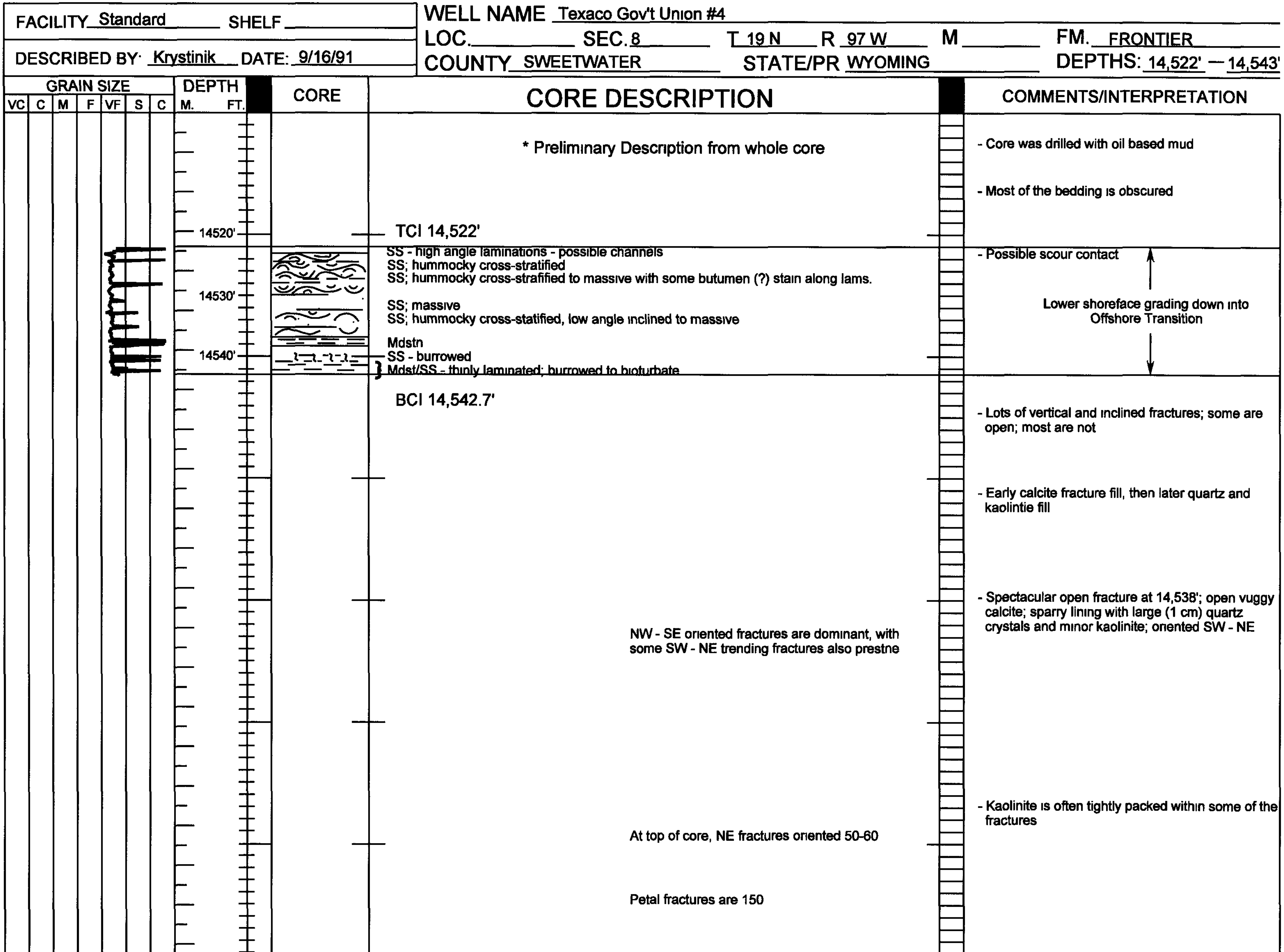
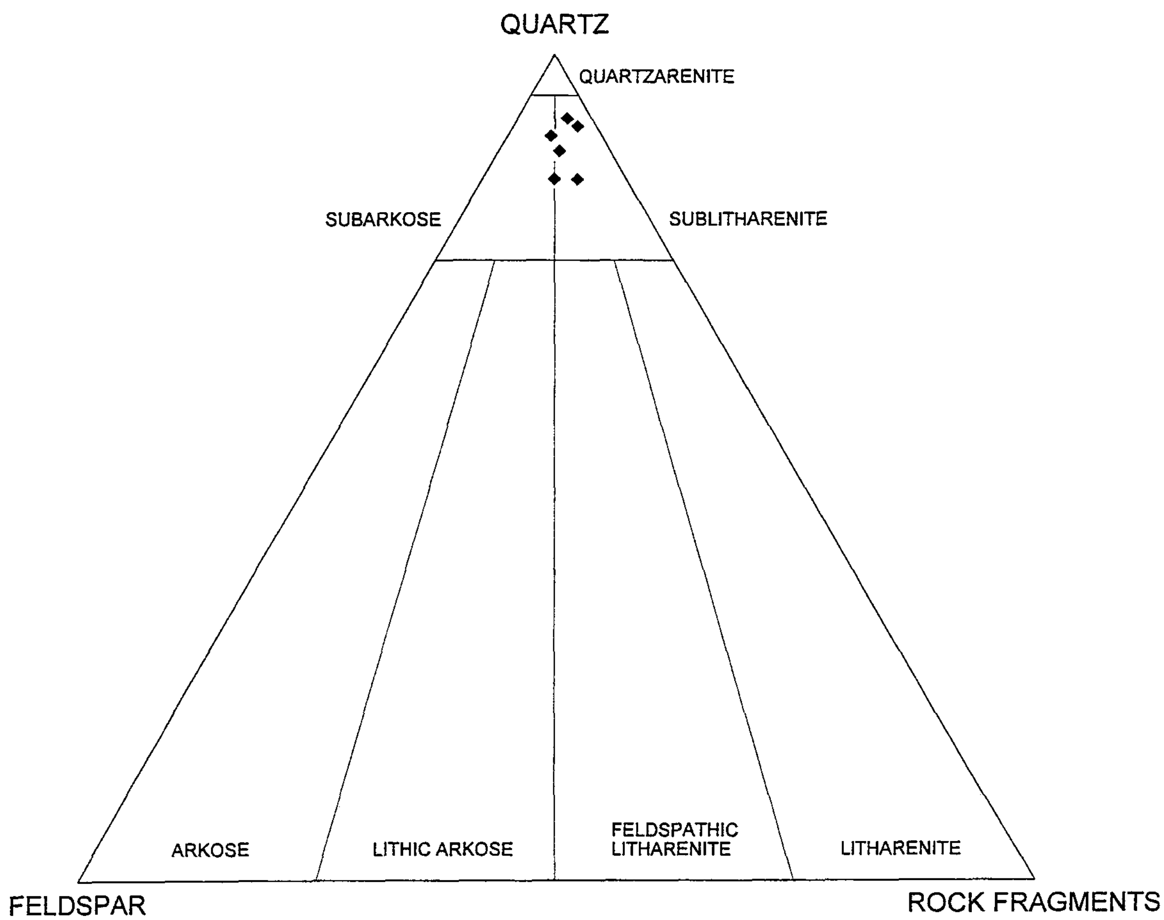


Figure 12. Texaco Government Union #4 core description.

TERNARY PLOT
Union Pacific Resources
Rock Island 4-H Well
Sweetwater County, Wyoming



Folk Sandstone Classification

Figure 13 Ternary diagram for sandstone composition and classification, Frontier Formation, Rock Island #4-H (Reservoirs Inc)

ROCK ISLAND 4H, HORIZONTAL WELL CORE DATA - DEEP FRONTIER FORMATION

CORE #1 and #2 15,424'-82' MD (14,889'-94' TVD) CORE #3 15,931'-52' MD (14,926'-28' TVD)

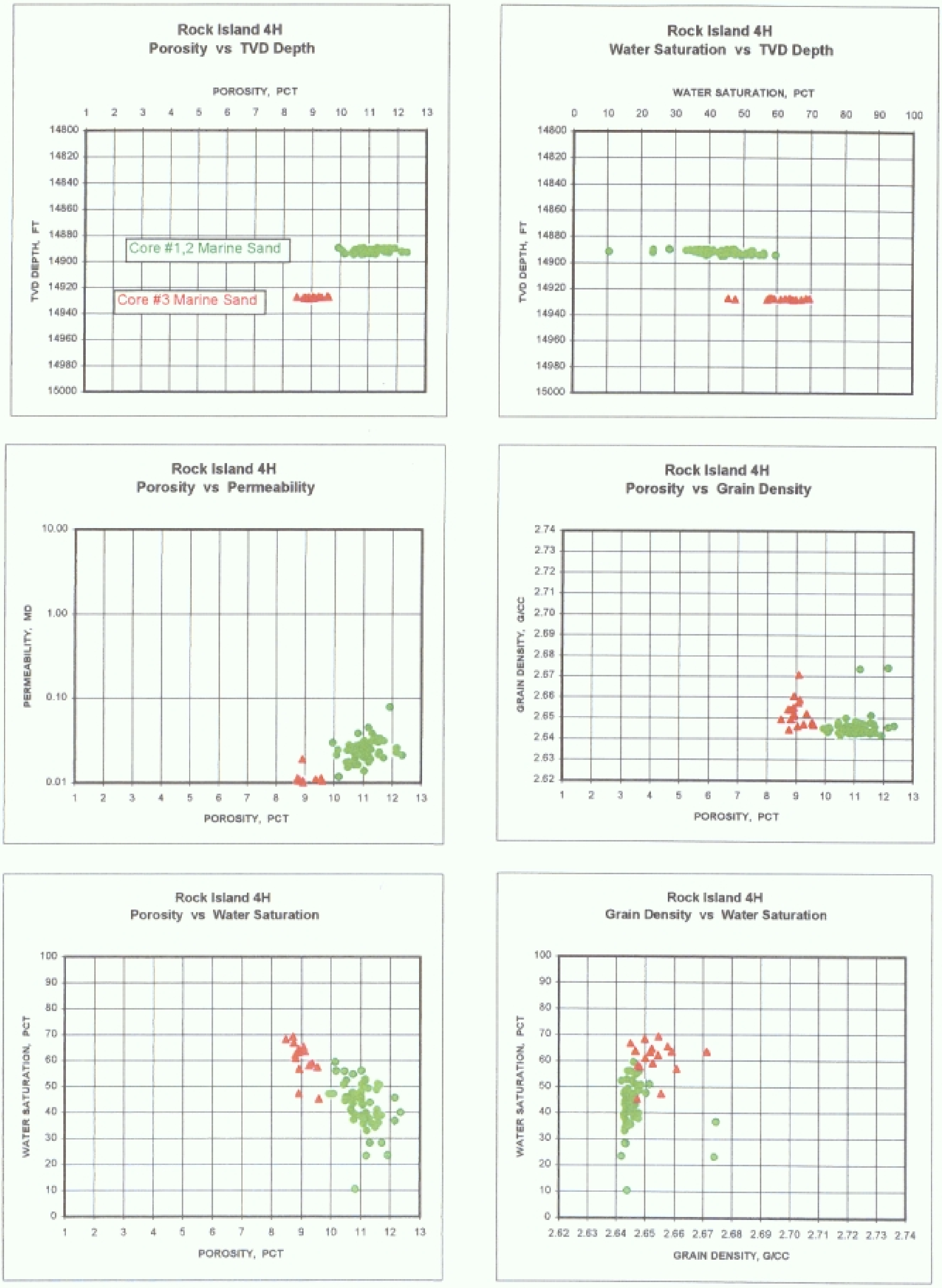


Figure 14a. X-Y plots for core properties (porosity, permeability, true vertical depth, water saturation, grain density) from cores 1, 2, and 3, Rock Island #4-H (data prepared by F. H. Lim, UPRC).

ROCK ISLAND 4H, HORIZONTAL WELL CORE DATA - DEEP FRONTIER FORMATION
MARINE SAND, CORE #1 and #2 15,424'-82' MD (14,889'-94' TVD)

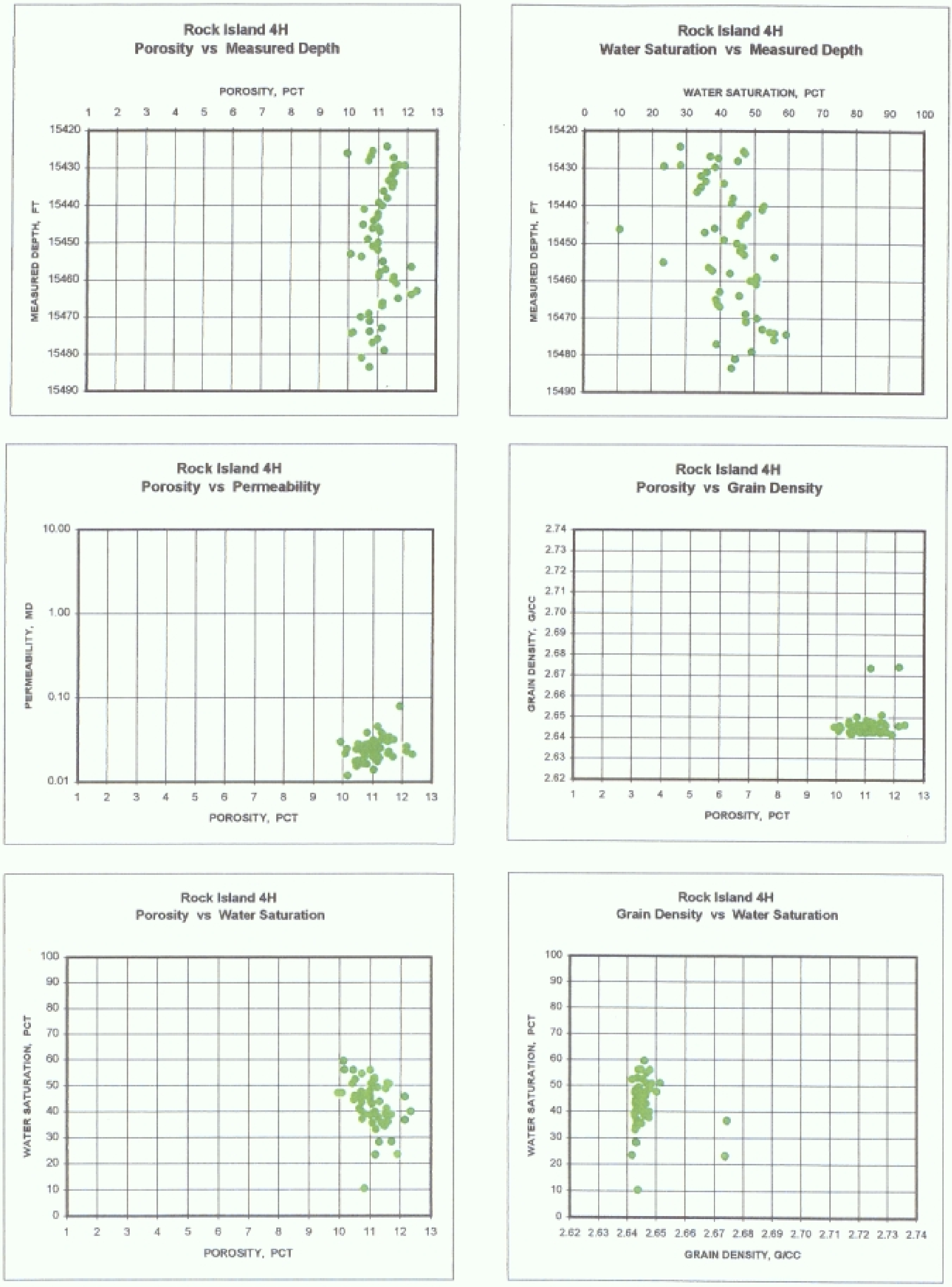


Figure 14b. X-Y plots for core properties (porosity, permeability, measured depth, water saturation, grain density) from cores 1 and 2, Rock Island #4-H (data prepared by F. H. Lim, UPRC).

ROCK ISLAND 4H, HORIZONTAL WELL, CORE DATA - DEEP FRONTIER FORMATION
MARINE SAND, CORE #3 15,931'-52' MD (14,926'-28' TVD)

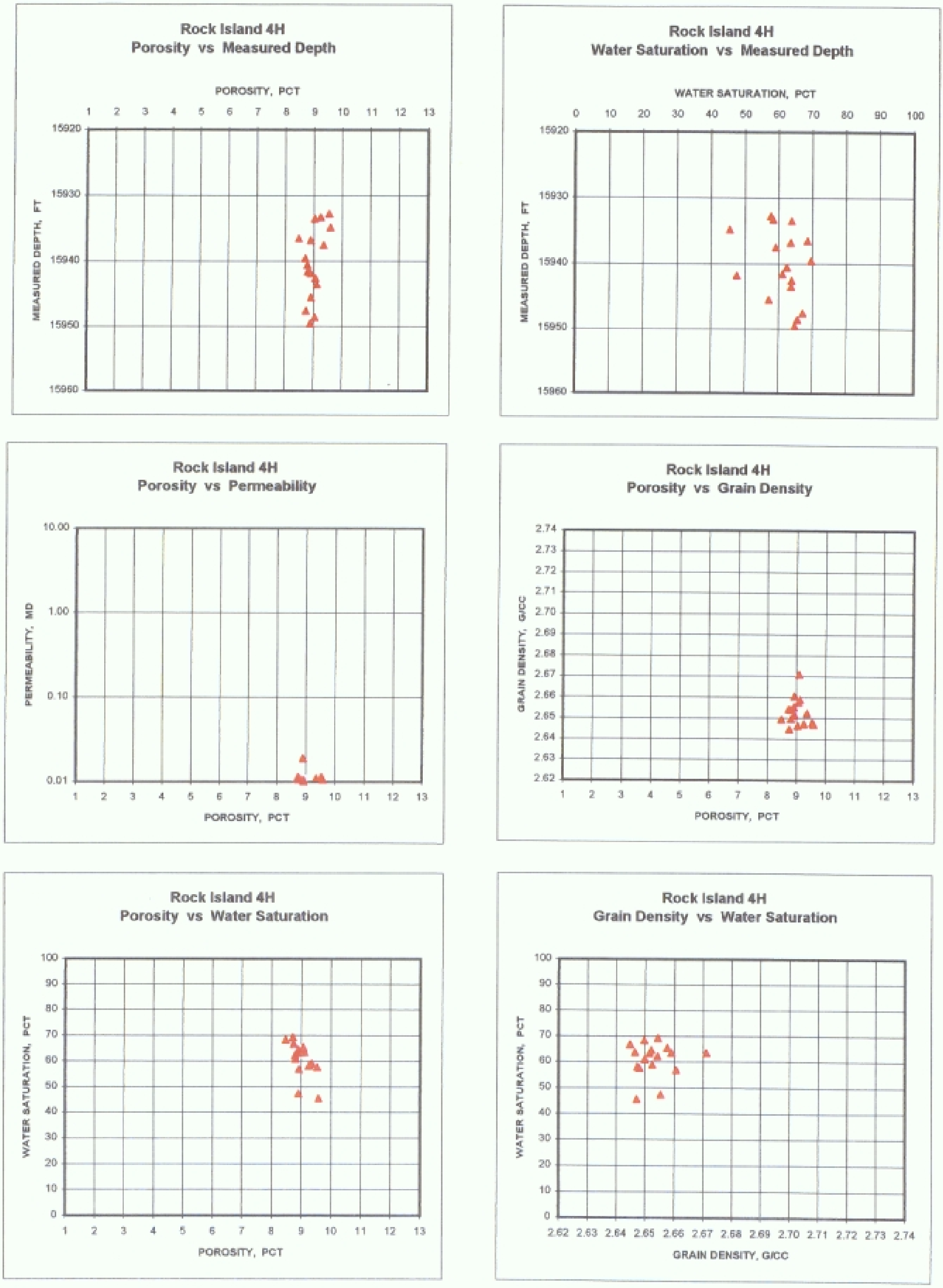
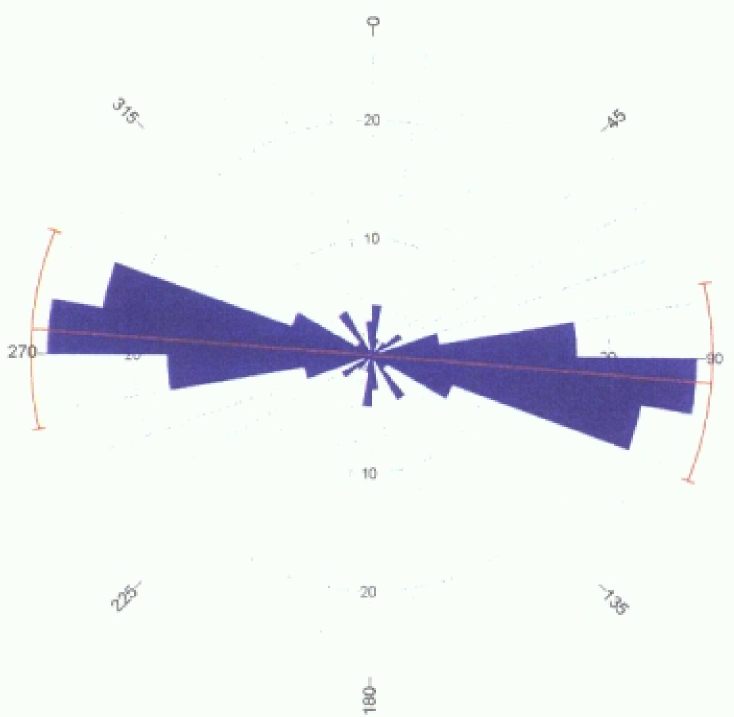


Figure 14c. X-Y plots for core properties (porosity, permeability, measured depth, water saturation, grain density) from core 3, Rock Island #4-H (data prepared by F. H. Lim, UPRC).

FIGURE 6

ROSE DIAGRAM
UNION PACIFIC RESOURCES
ROCK ISLAND 4H WELL
SWEETWATER COUNTY, WYOMING



Calculation Method .... Frequency
Class Interval .... 10 Degrees
Length Filtering ...... Deactivated
Azimuth Filtering ..... Deactivated
Data Type .... Bidirectional
Population 70
Maximum Percentage .... 27.1 Percent
Mean Percentage .... 7.7 Percent
Standard Deviation .... 8.62 Percent
Vector Mean .... 274.29 Degrees
Confidence Interval ... 17.24 Degrees
R-mag 0.88

Figure 15. Rose diagram for all fracture orientations in the Rock Island #4-H core (Reservoir Inc.).

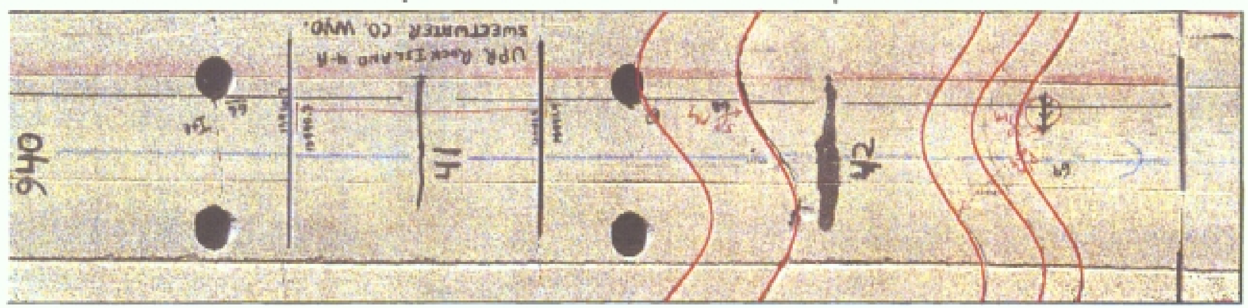
HORIZONTAL CORE IMAGES and FRACTURE IDENTIFICATION
PLAN VIEW*

Union Pacific Resources Company
Rock Island 4H Well
Sweetwater County, Wyoming

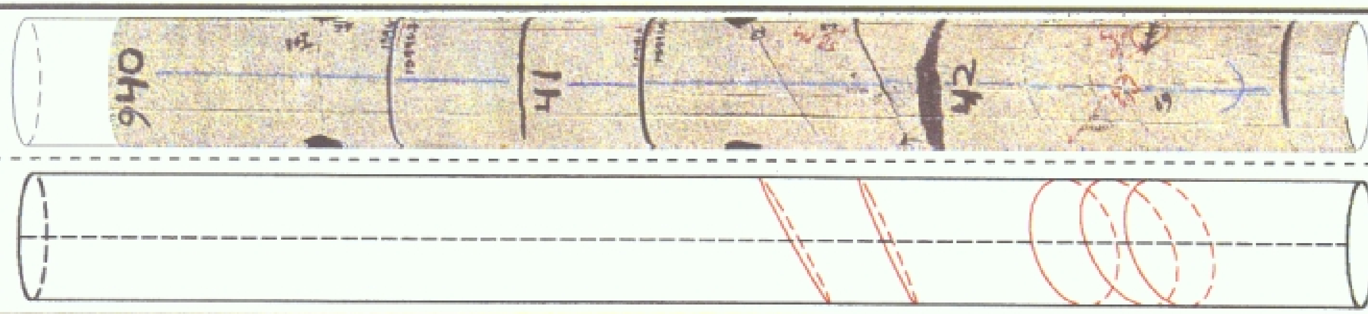
Core Depth: 15,940 - 15,943'

SCALE (feet): 15,940 | 15,941 | 15,942 | 15,943

UNROLLED CORE IMAGE

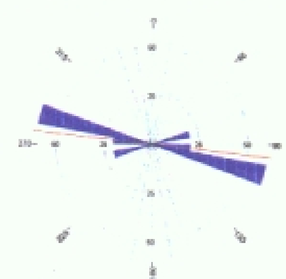


3-D VOLUMES



FRACTURE DATA SUMMARY

DEPTH (ft)	STRIKE	DIP
15,941.6	95	85N
15,941.8	100	85N
15,942.3	74	54N
15,942.4	104	57N
15,942.5	108	57N



* Blue stripe down the center of the core image = top of core

Figure 16. Example of rolled and unrolled digital core photos with rose diagram showing strike of natural fractures (Reservoir Inc.). Complete sets of core photos are included as Appendices 10 and 11.

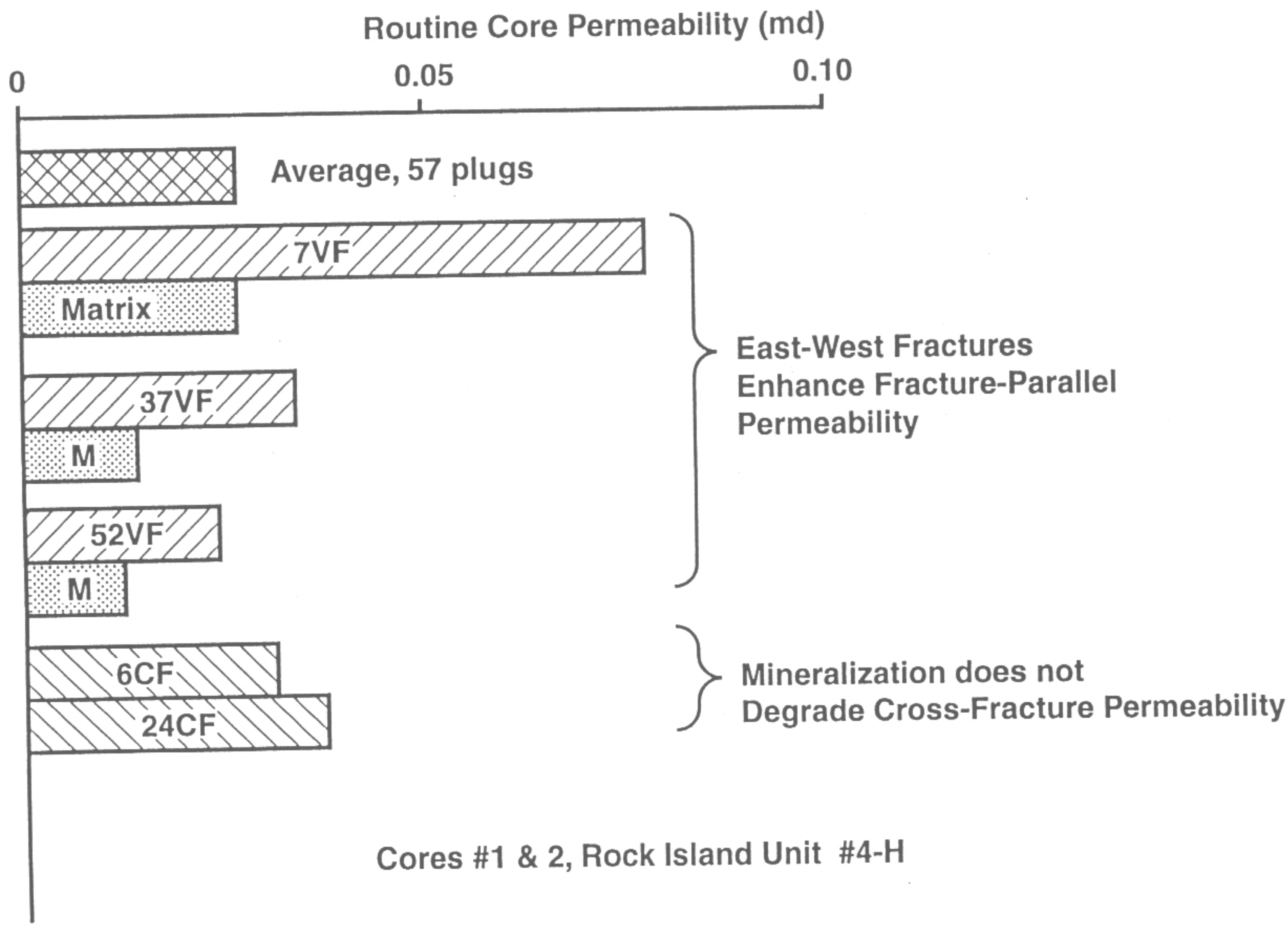


Figure 17. Comparison of permeability with respect to fracture trends and fracture mineralization – Cores 1 and 2, Rock Island #4-H (Lorenz).

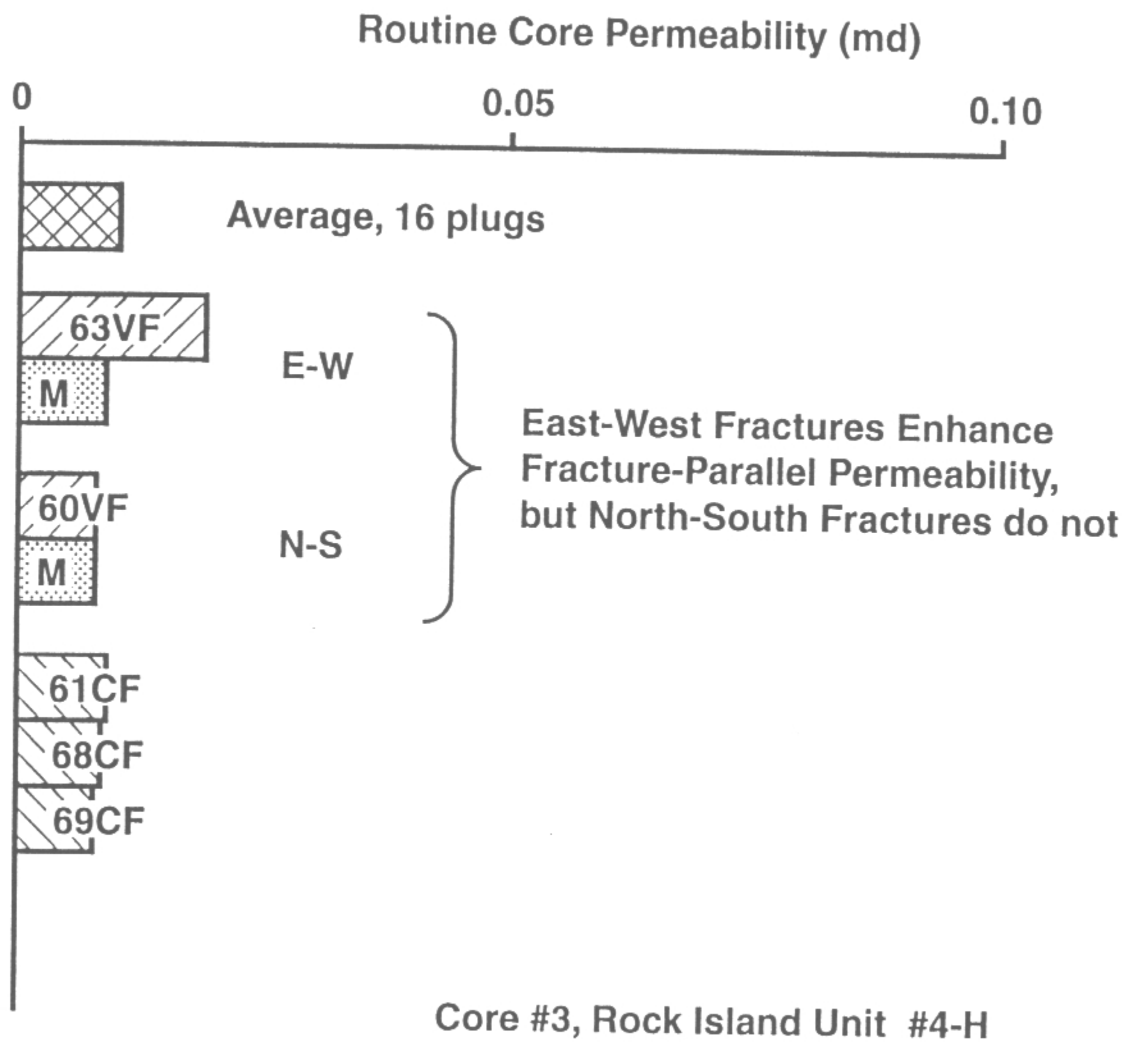


Figure 18. Comparison of permeability with respect to fracture trends and fracture mineralization – Core 3, Rock Island #4-H (Lorenz).

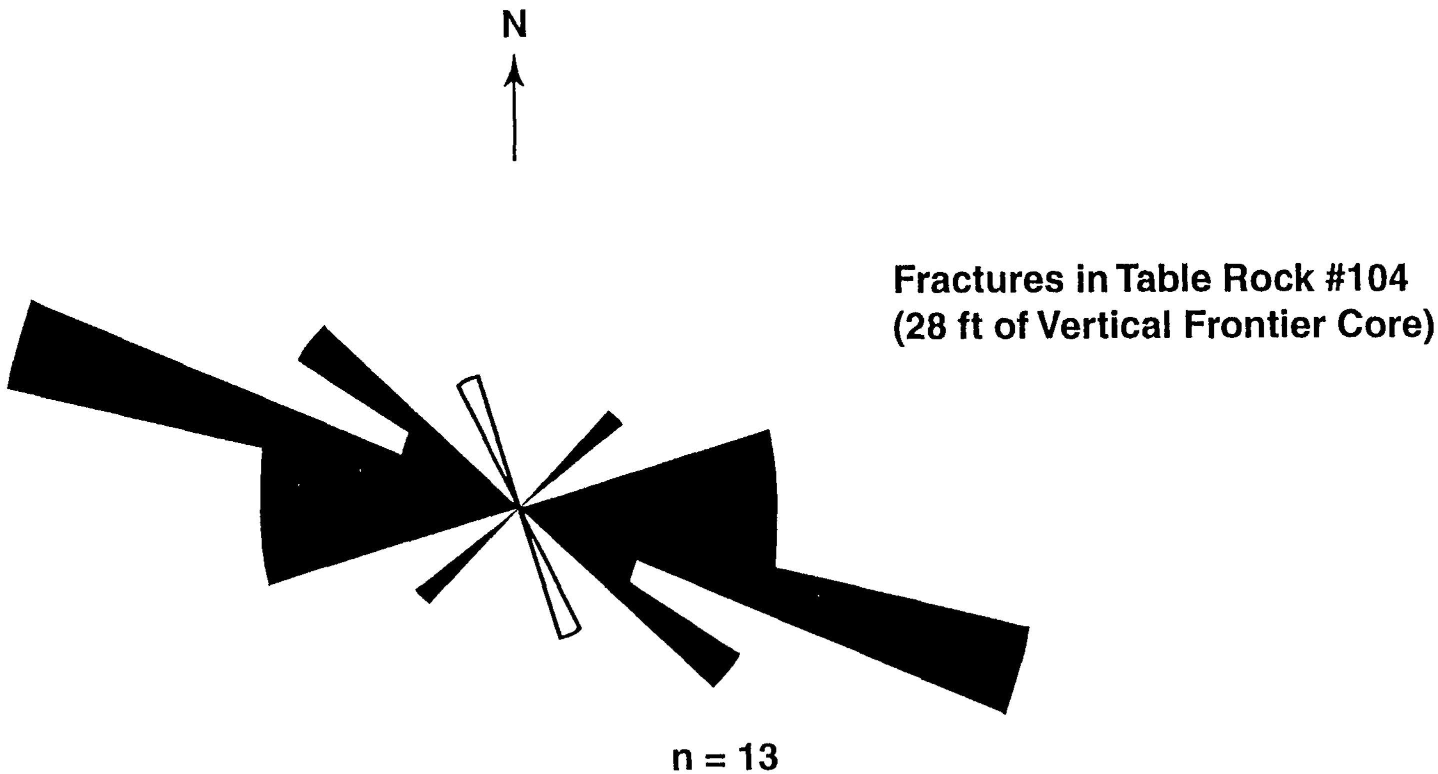


Figure 19 Rose diagram showing strike of natural fractures – Texaco Table Rock #104 well (Lorenz).

Fractures in Vertical Core, Gov't Union #4

Maximum Horizontal Stress is Normal to the Dominant Fracture Set

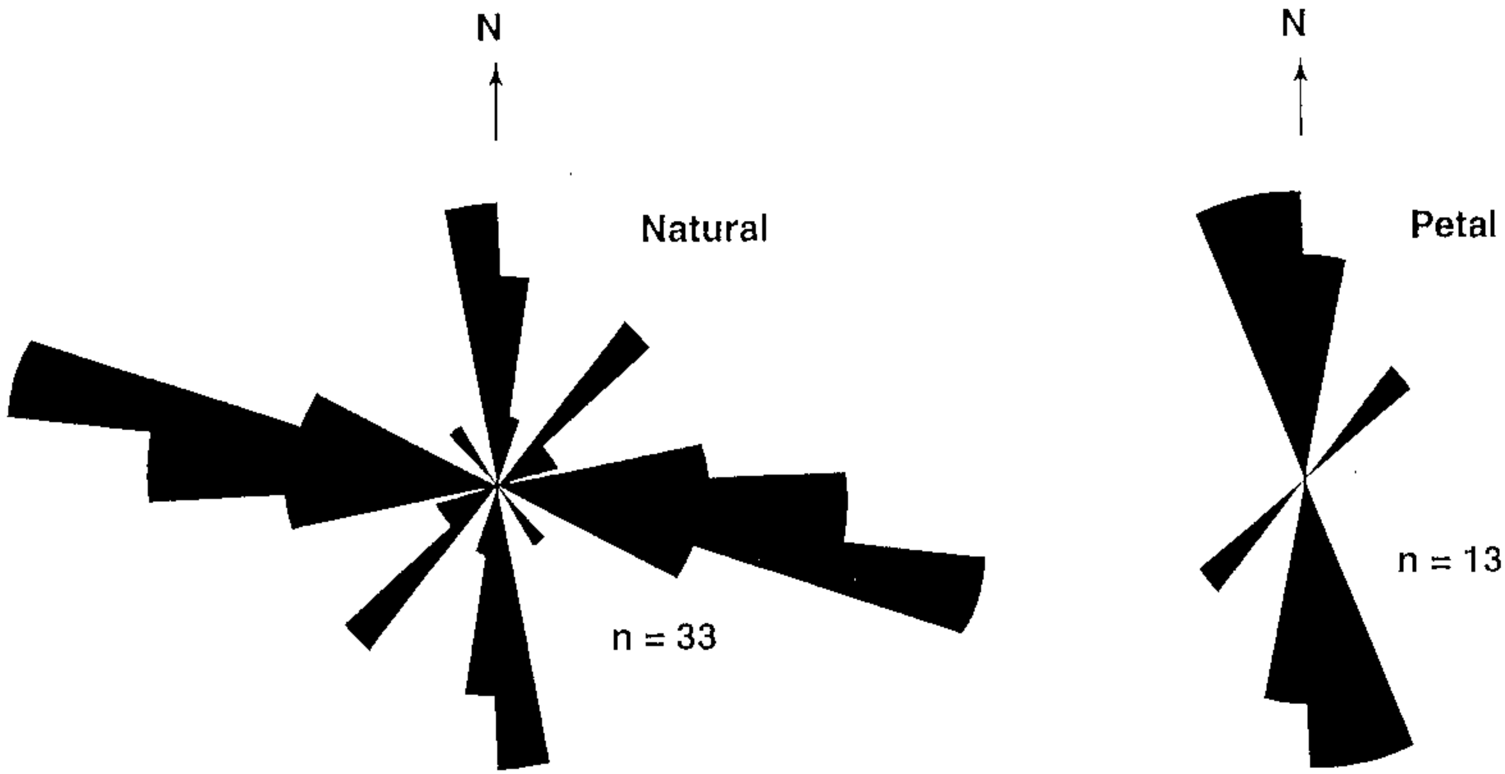


Figure 20a. Rose diagram showing strike of natural fractures – Texaco Government Union #4 well (Lorenz).

Fracture Orientations
(Natural vs. Induced)

Texaco Govt. Union #4
Sweetwater County, Wyoming

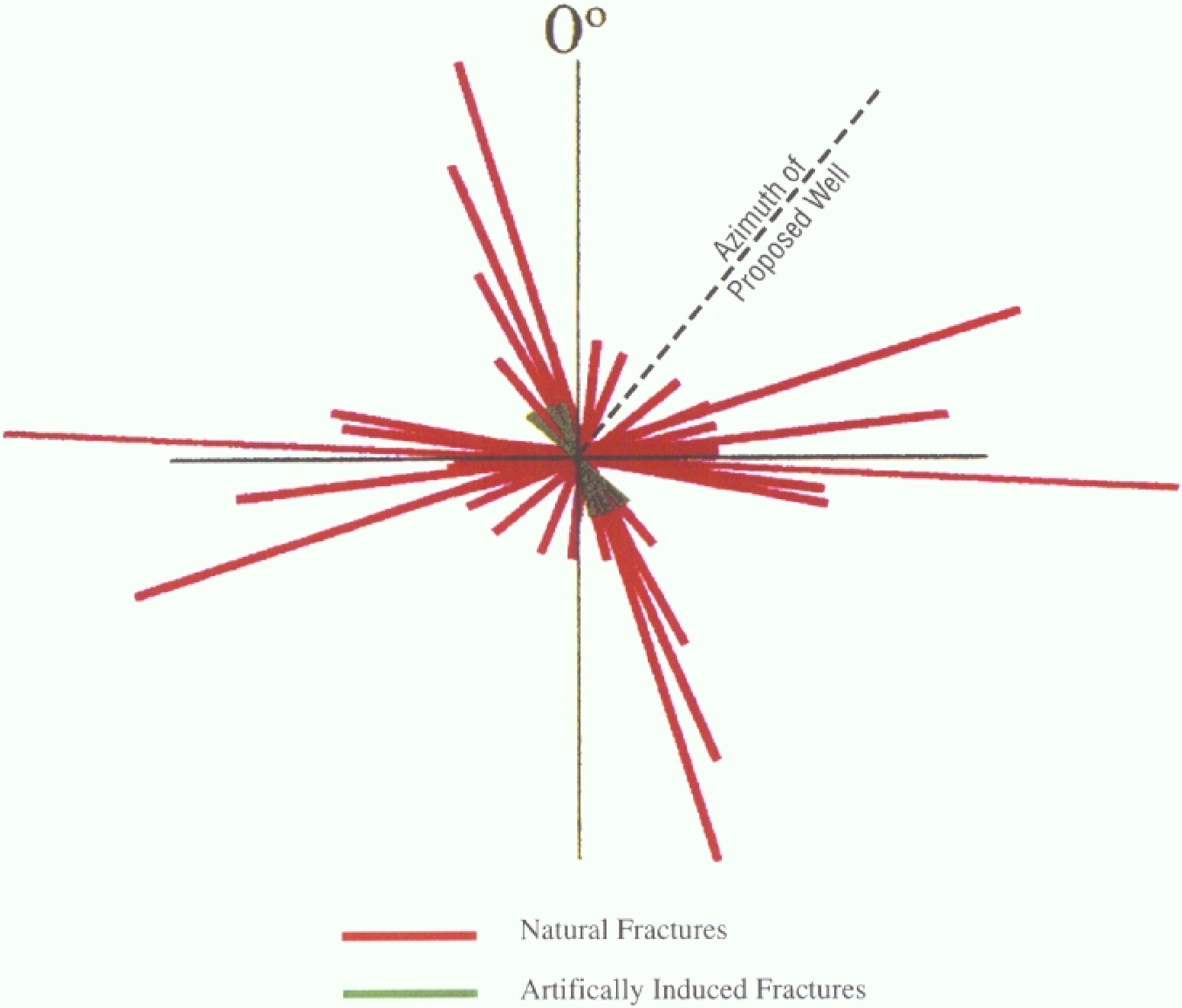


Figure 20b. Rose diagram showing strike of natural fractures – Texaco Government Union #4 well (Standard Geological, 1996).

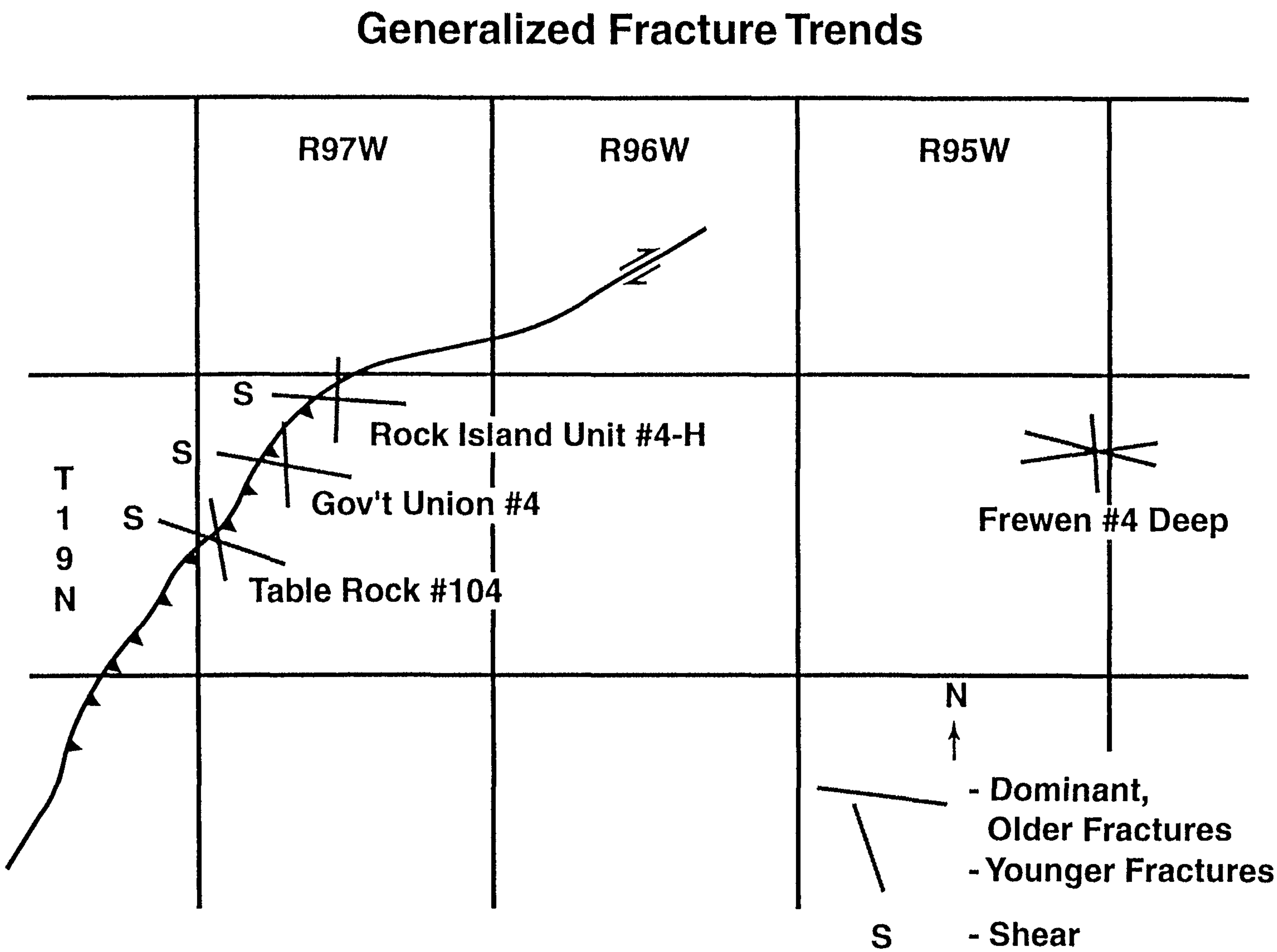


Figure 21. Generalized fracture trends for the Rock Island #4-H and three nearby wells (Lorenz).

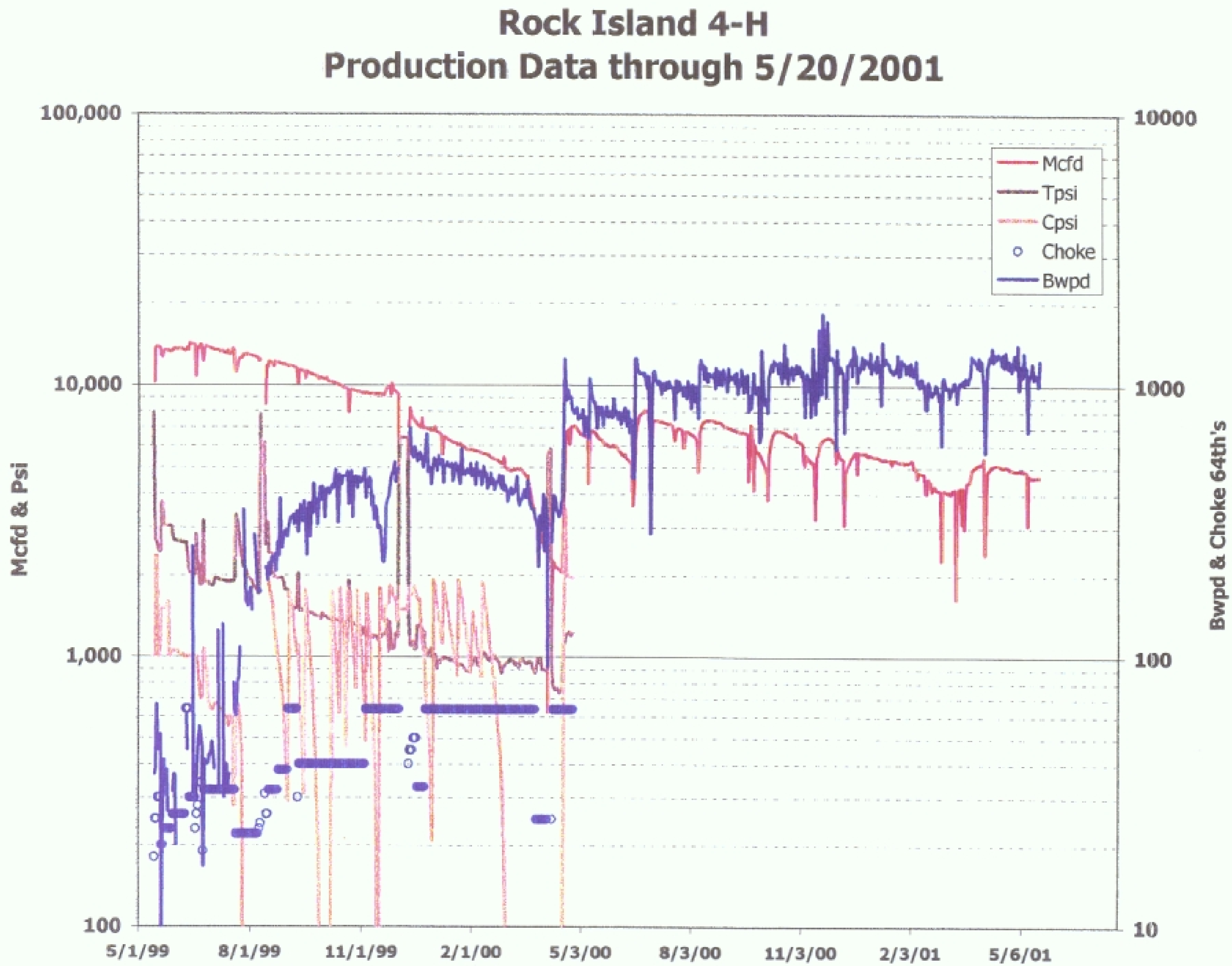


Figure 22. Summary of daily production through 5/20/2001, Rock Island #4-H well.

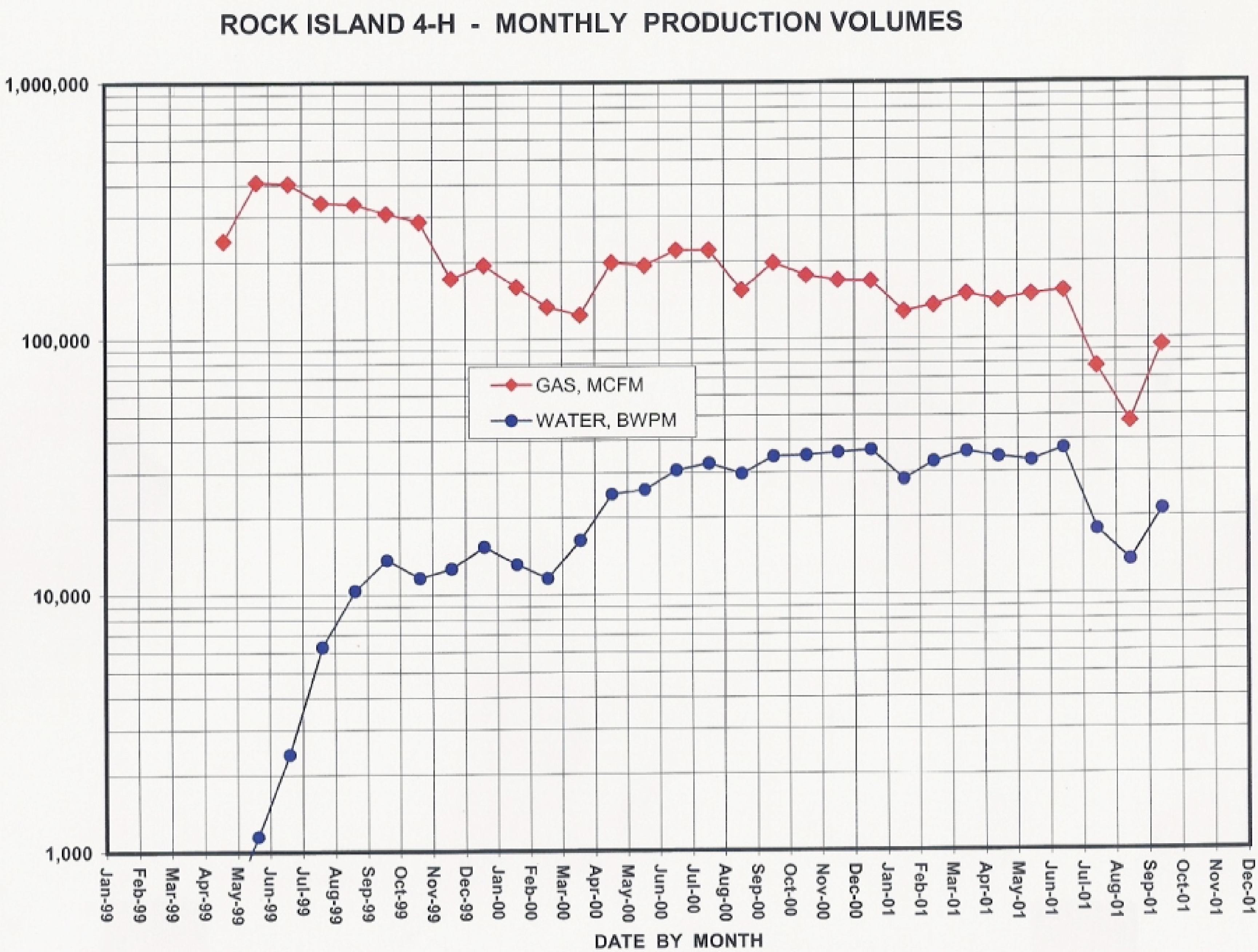


Figure 23. Summary of monthly production volumes, Rock Island #4-H well.

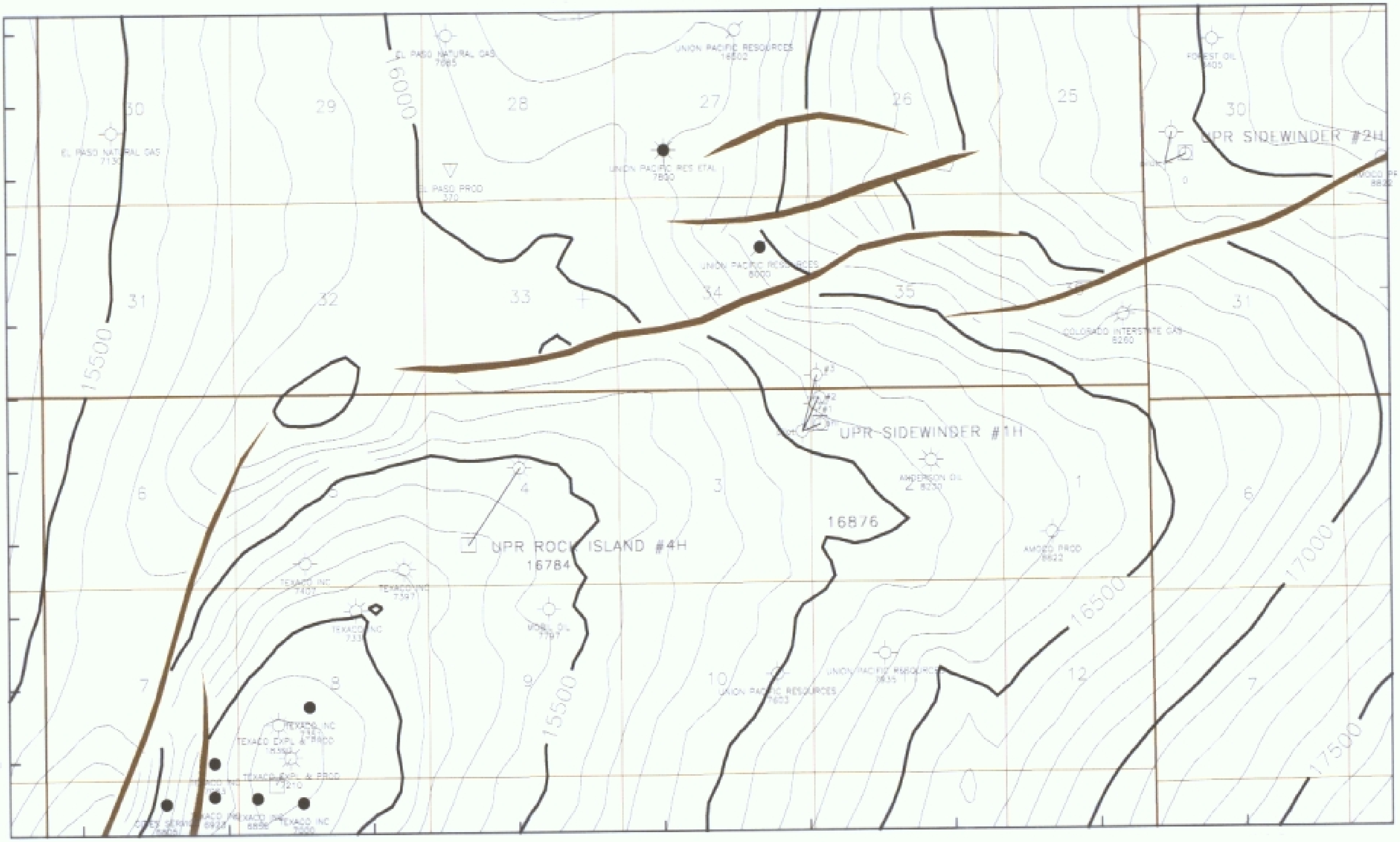
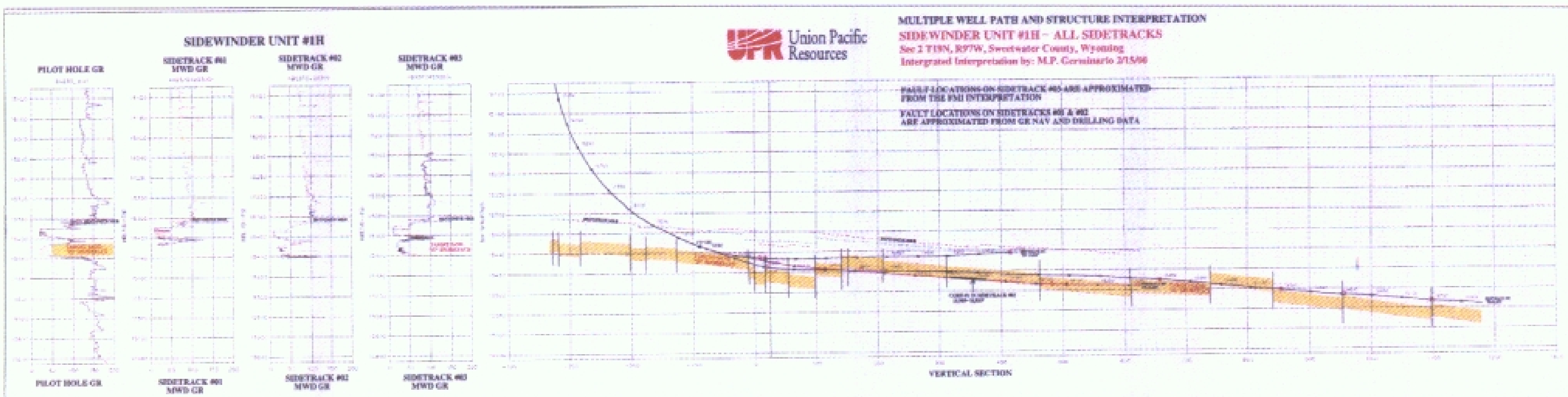
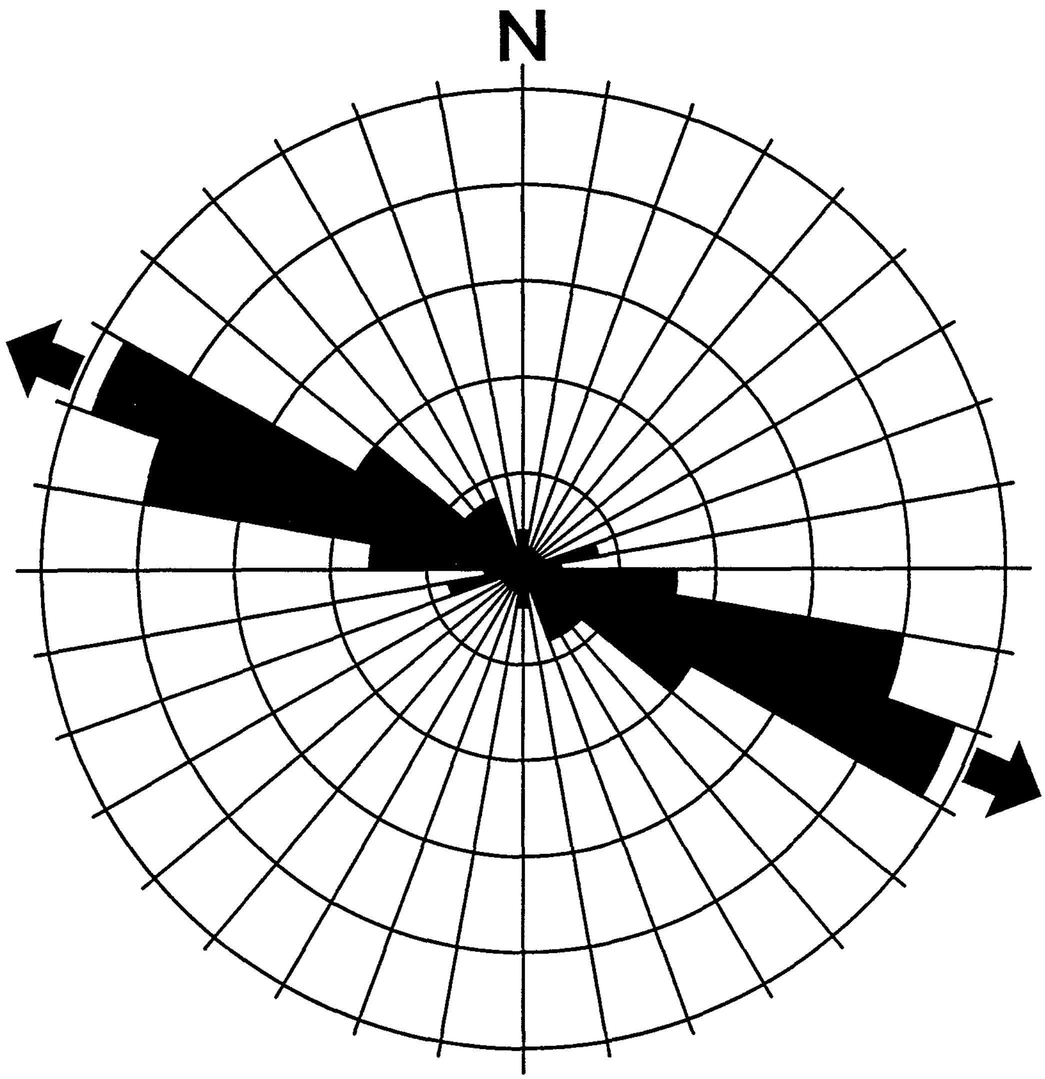


Figure 24. Top Depth Structure Map on the Frontier Formation – shows Sidewinder well locations with respect to the Rock Island #4-H well.

FIGURE 25. Interpreted wellbore path and structural interpretation, Sidewinder #1-H well, UPRC.





Fracture Strike Orientation			
N=42	Mean=113 93	R=0 869	

Figure 26 Rose diagram showing strike of natural fractures, Sidewinder #1-H well

FIGURE 27. Sidewinder #1-H core description, Core Lab.

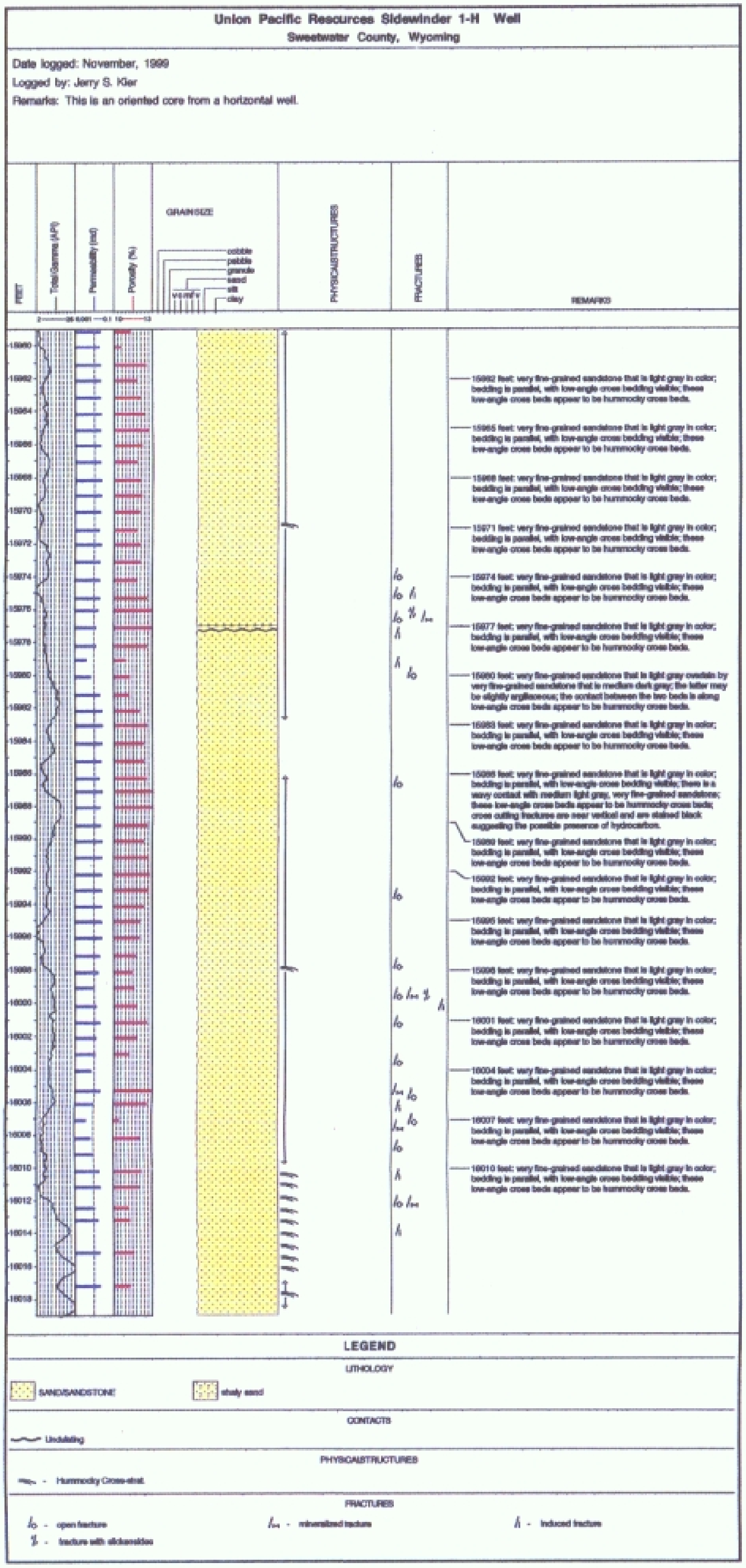


Figure 27. Sidewinder #1-H core description, Core Lab.

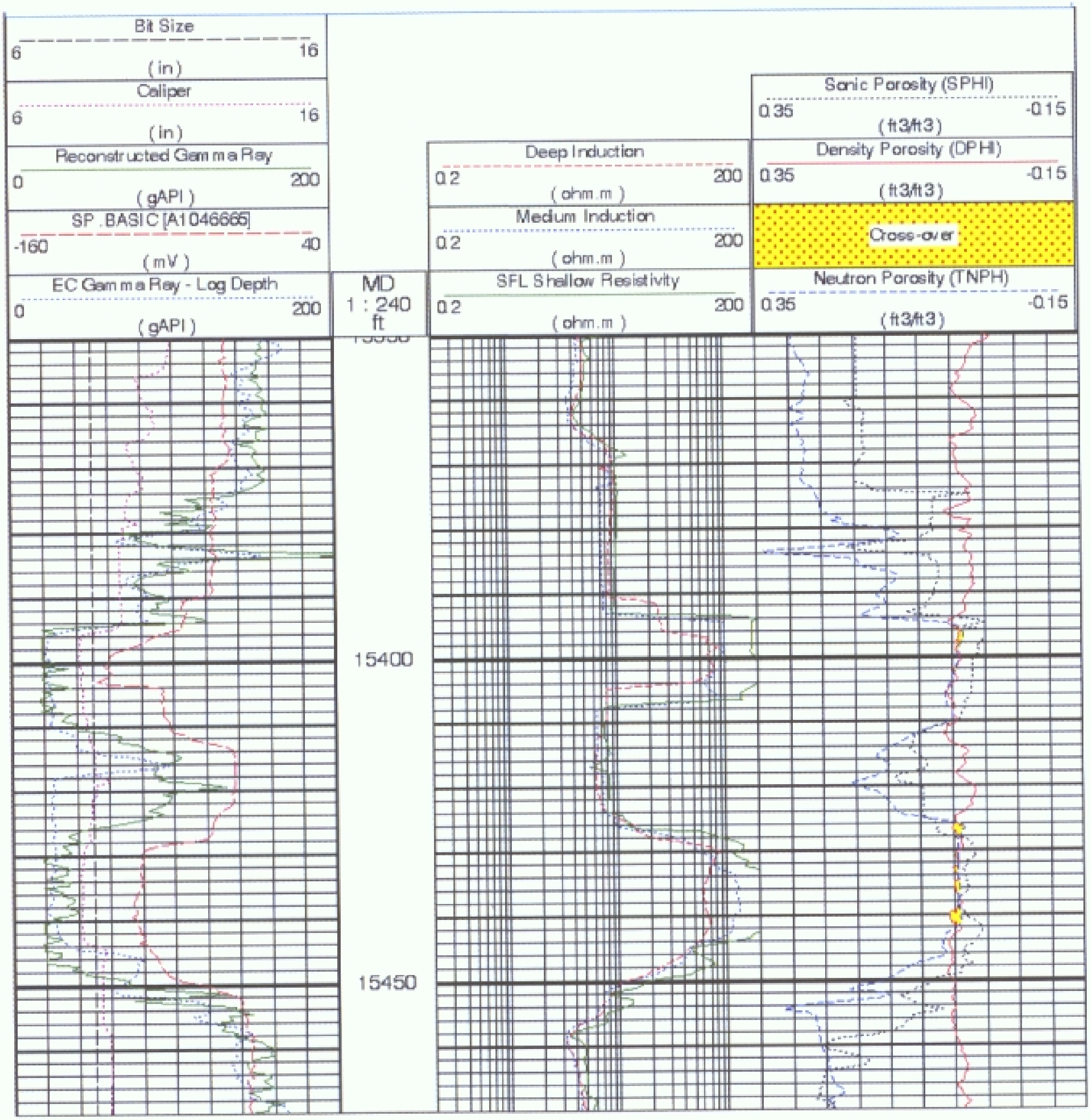


Figure 28. Sidewinder #1-H Composite Log (Schlumberger).

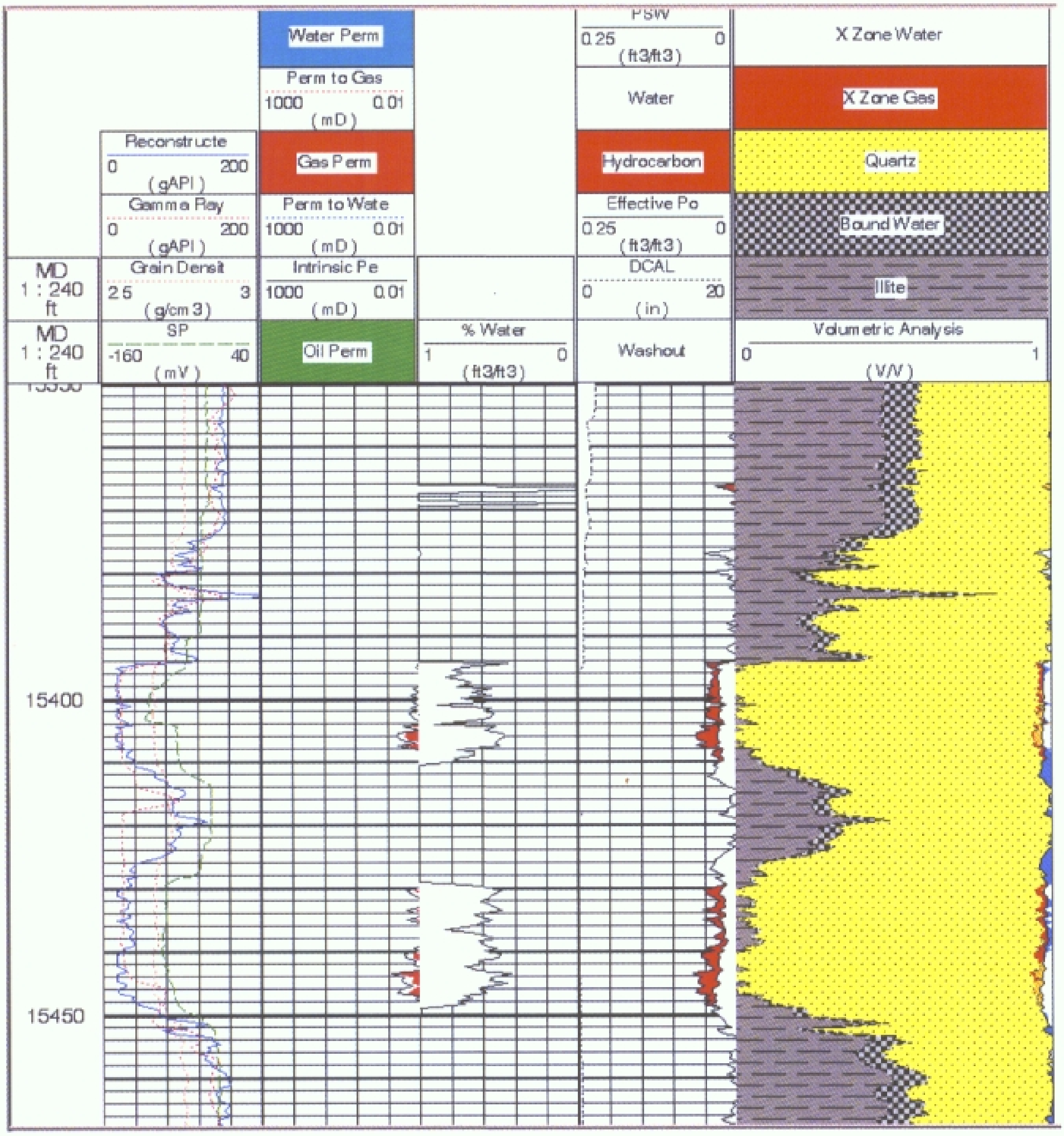


Figure 29. Sidewinder #1-H ELAN with reconstructed Gamma Ray (Schlumberger).

FIGURE 30. Interpreted wellbore path, Sidewinder #2-H, UPRC.

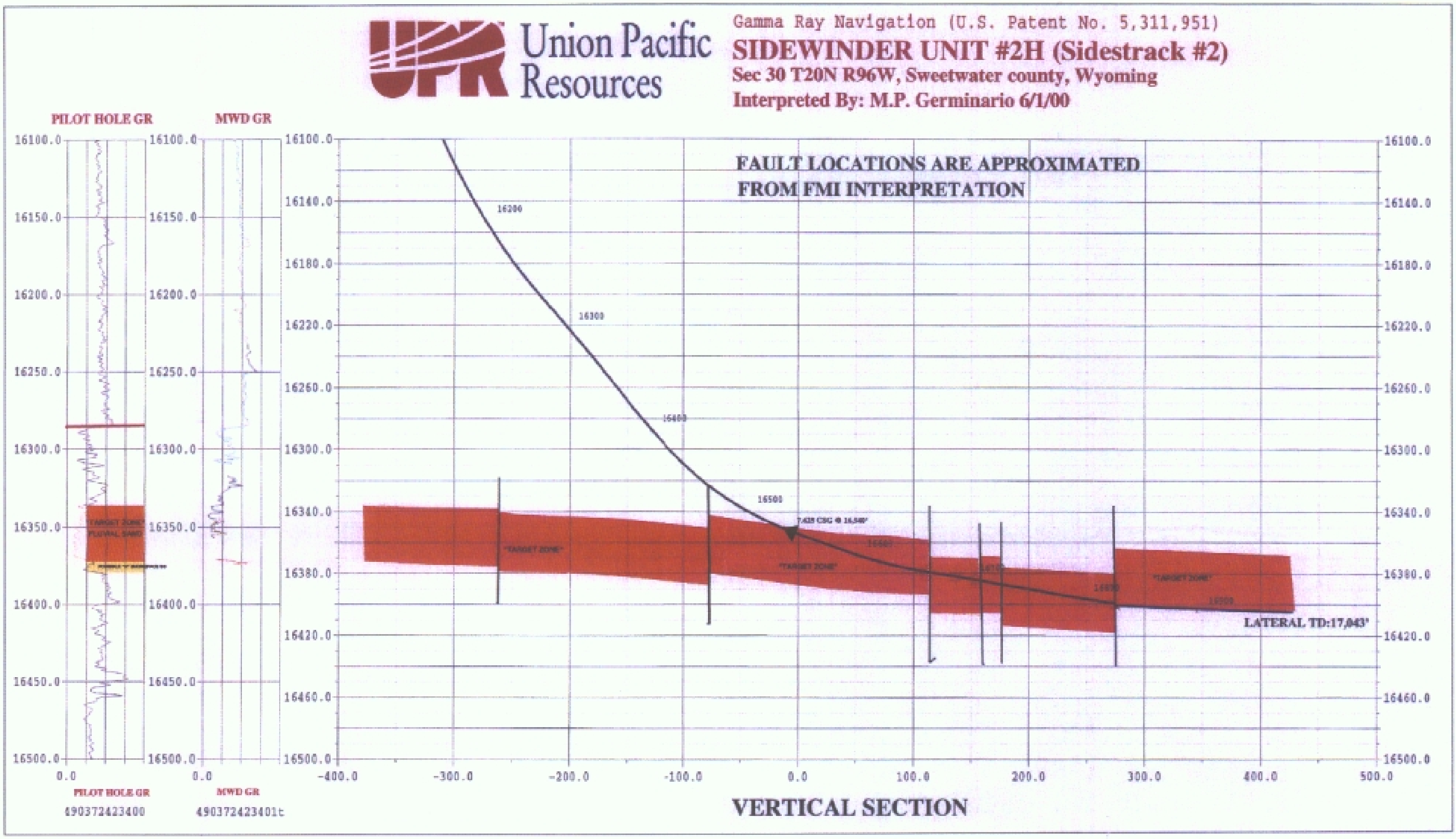


Figure 30. Interpreted wellbore path, Sidewinder #2-H, UPRC.

FIGURE 31. Stratigraphic cross-section through the Frontier Fm. Showing the relationship between the Sidewinder wells, the Texaco Government Union #4 well and the Frewen Deep Unit #4 well (UPRC).

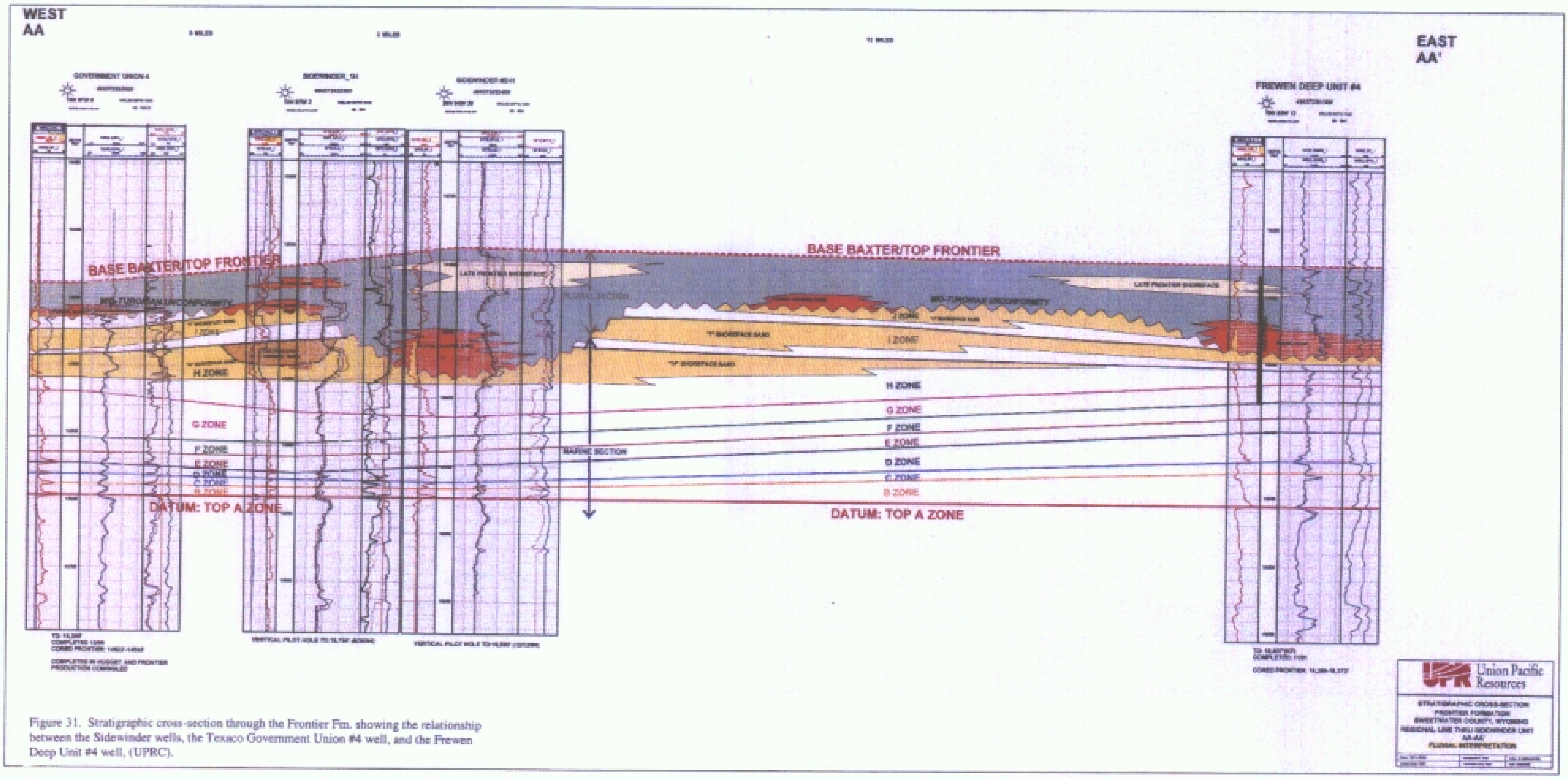


Figure 31. Stratigraphic cross-section through the Frontier Fm. showing the relationship between the Sidewinder wells, the Texaco Government Union #4 well, and the Frewen Deep Unit #4 well, (UPRC).

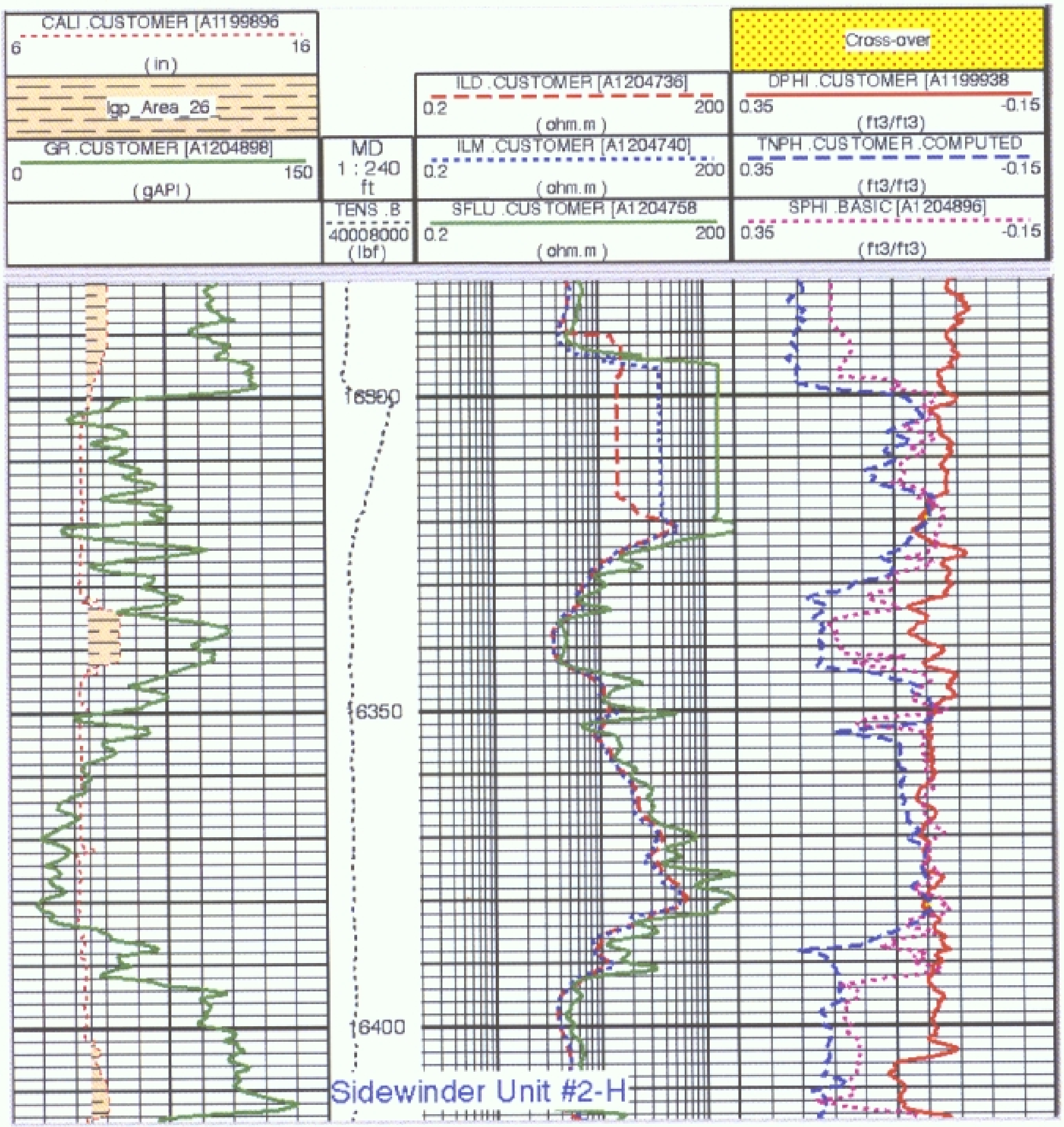


Figure 32. Sidewinder #2-H Composite Log (Schlumberger).

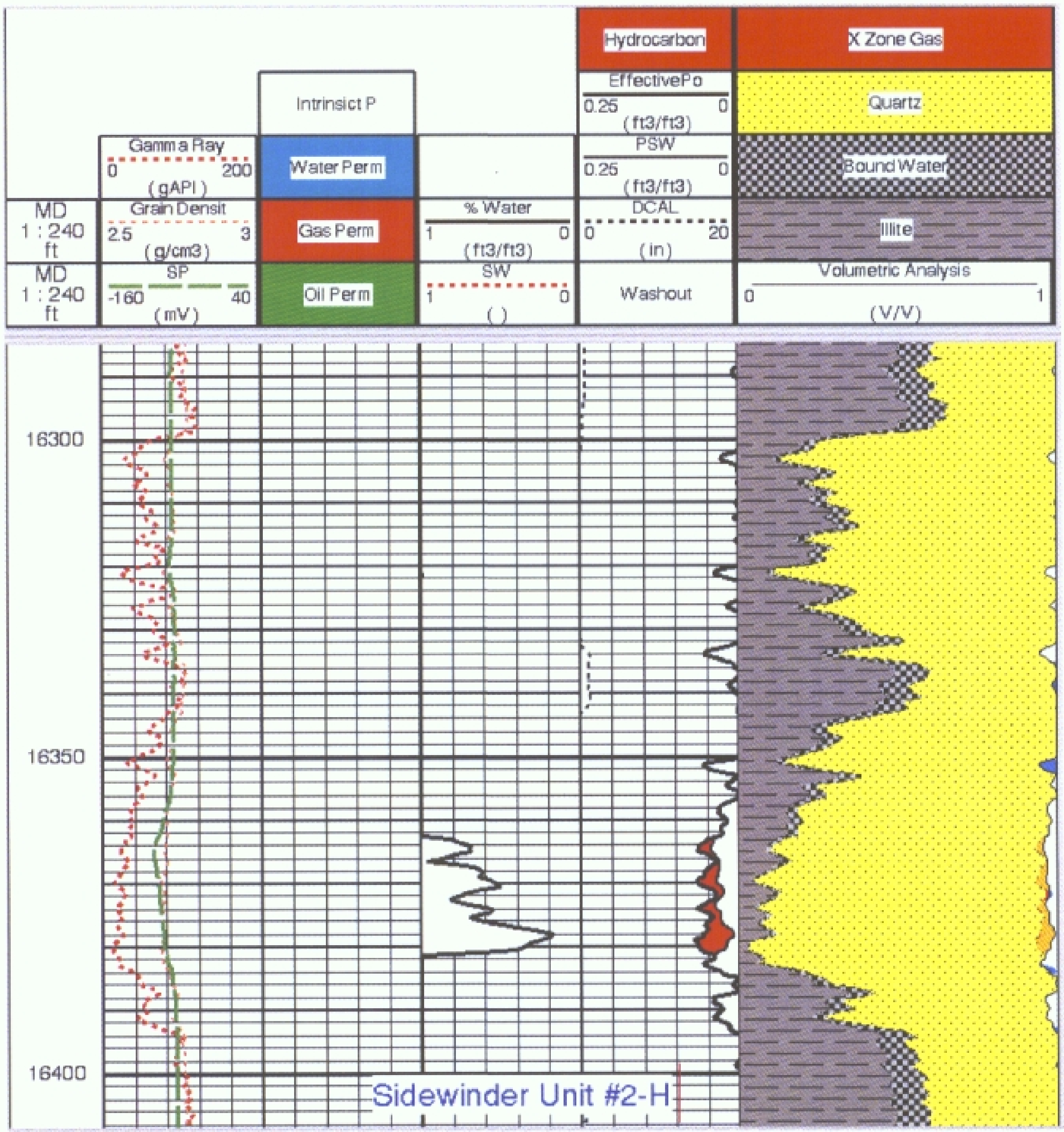


Figure 33. Sidewinder #2-H ELAN (Schlumberger).

10/14/98 to 11/22/98	**Spud, Drill 14-3/4" Vertical to 9,517', Run 11-3/4" Casing**
11/23/98 to 12/15/98	**Drill 10-5/8" Vertical to 14,440' KOP (Kick Off Point)**
12/16/98 to 01/08/99	**Build 10-5/8" Curve to 15,025', Run 7-5/8" Liner**
01/09/99 to 02/11/99	**Drill 6-1/2" Horizontal Lateral to 16,784' (Core and Log)**
02/12/99 to 02/24/99	**Run 7-5/8" Tie-back Liner from 8,217' to Surface**
	Run 4" Perforated Liner in Lateral from 14,510' to 16,784'
	Run 2-7/8" Tubing to 14,490' with packer set at 14,446'
02/25/99	**Flow Well to Pit 6 hours for Initial Wellbore Cleanup,**
	(100' Flare at 11/64 choke and 5600psi FTP)
03/02/99 to 03/09/99	**Flow Well through Separator Test Metering Equipment,**
	(Rates Measured up to 12 MMCFD)
03/13/99 to 03/14/99	**Run 4-Point Conventional Flow Test at 6, 8, 10, & 12 MMCFD**
	(26 MMCF Cumulative Gas Produced 3/6/99 to 3/14/99)
03/14/99 to 03/25/99	**Run Shut-in, Bottomhole Pressure Build-up (9,650psi BHP)**
03/26/99 to 05/12/99	**Well Shut-in Waiting on Pipeline Connection**
05/13/99	**Well Open to Gas Sales at 12 MMCFD Initial Rate**

Table 1 Summary of the drilling and completion history for the UPR Rock Island #4-H well

THIN SECTION PETROGRAPHIC DATA
Union Pacific Resources Company
Rock Island 4H Well
Sweetwater County, Wyoming

Sample Depth (ft)	15430.5	15449.5	15461.5	15470.0	15937.1	15948.2
Porosity (%)	12.0	11.0	12.1	10.8	9.9	9.5
Permeability (md)	0.026	0.021	0.021	0.011	0.006	0.006
TEXTURE						
Average Grain Size (mm)	UVF (0.100)	UVF (0.108)	UVF (0.100)	UVF (0.102)	UVF (0.094)	LVF (0.092)
Sorting	Very Well	Very Well	Very Well	Very Well	Very Well	Very Well
FRAMEWORK CONSTITUENTS (vol %)						
Quartz - Monocrystalline	65.2	68.8	69.2	68.4	64.8	62.4
Quartz - Polycrystalline	0.8	0.4	1.6	0.4	1.6	1.6
Plagioclase Feldspar	2.0	1.6	3.6	1.6	4.8	2.0
Potassium Feldspar	2.0	--	0.8	--	0.8	0.8
Plutonic Rock Fragments	--	--	--	0.4	0.4	1.2
Rock Fragment, Undifferentiated	1.2	0.4	--	0.4	0.8	0.4
Metamorphic Rock Fragments	--	0.4	--	0.8	--	0.4
Argillaceous Rock Fragments	1.6	0.4	1.6	0.8	2.8	1.6
Chert	3.2	4.0	3.6	2.0	2.4	5.2
Heavy Minerals/Opaques	--	--	--	--	0.8	0.4
Carbonaceous Debris	--	--	--	0.4	--	--
Fossil Fragments	--	--	--	--	--	--
Undetermined Grains	--	--	--	--	--	--
Carbonate Grains	--	--	--	--	--	--
Biotite	--	1.2	1.2	0.4	3.2	3.2
Total Framework Constituents	**76.0**	**77.2**	**81.6**	**75.6**	**82.4**	**79.2**
INTRAGRANULAR REPLACEMENTS (vol %)						
Dolomite	--	--	--	--	--	--
Kaolinite	--	--	--	--	--	--
Clay	0.8	2.8	1.6	0.8	1.2	0.8
Other	--	--	--	--	--	--
Total Intragranular Replacements	**0.8**	**2.8**	**1.6**	**0.8**	**1.2**	**0.8**
MATRIX (vol %)						
Clay	--	--	--	--	--	--
Organics	--	--	--	--	--	--
Total Matrix	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PORE-FILLING CONSTITUENTS (vol %)						
Quartz Overgrowths	8.0	4.8	4.0	5.6	7.2	11.2
Feldspar	0.8	--	--	--	--	0.8
Calcite	--	--	--	--	--	--
Undifferentiated Clay	6.8	12.8	11.2	14.8	5.6	6.4
Kaolinite	0.4	--	--	--	0.4	--
Pyrite/Opaques	2.0	1.2	0.4	2.4	1.6	0.4
Other	--	--	--	--	--	--
Total Pore-Filling Constituents	**18.0**	**18.8**	**15.6**	**22.8**	**14.8**	**18.8**
PORE SPACE (vol %)						
Intergranular	4.4	1.2	1.2	0.8	1.6	0.8
Leached-Grain	0.8	--	--	--	--	0.4
Other	--	--	--	--	--	--
Total Pore Space	**5.2**	**1.2**	**1.2**	**0.8**	**1.6**	**1.2**

Table 2. Summary of Point Count Data for the Rock Island #4-H.

MINERALOGICAL DATA BY X-RAY DIFFRACTION
Union Pacific Resources Company
Rock Island 4H Well
Sweetwater County, Wyoming

	MINERALOGY OF WHOLE ROCK SAMPLE (WEIGHT %)			MINERALOGY OF CLAY FRACTION (RELATIVE %)				
Depth (ft)	Qtz	Plag	Clay	Ill	C/S	Kaol	Chl	C/S
15430.5	95	1	4	3	97	0	0	50/50
15449.5	94	2	4	8	92	0	0	50/50
15461.5	95	1	4	9	90	0	1	50/50
15470.5	94	1	5	7	91	0	2	50/50
15937.1	90	7	3	24	0	5	71	--
15948.2	90	8	2	9	55	1	35	50/50
Min:	90	1	2	3	0	0	0	50/50
Max:	95	8	5	24	97	5	71	50/50
Avg:	93	3	4	10	71	1	18	50/50

KEY:
Qtz = quartz
Plag = plagioclase
Clay = total clay
Ill = illite
C/S = mixed-layer chlorite/smectite
Chl = chlorite
Kaol = kaolinite
C/S comp = percent chlorite layers in I/S

Table 3. XRD Analysis, Rock Island #4-H.

Sample Number	*Sample Depth (ft)*	*Porosity (%)*	*Grain Density (g/cm^3)*	*Gas Permeability (md)*	*Saturation Water (%)*	*Lithologic Description*
1	15424.30	11.30	2.643	0.038	28.2	ss, ltgy, vfgr, sil, lam
1-A	15425 40	10.80	2.643	0.024	46.8	ss, ltgy, vfgr, sil, carb
2C&E[*]	15426.00	9.93	2.645	0.030	47.2	ss, ltgy, vfgr, sil, xbdd, carb, styl
2-1[**]	15426.00	9.26	2.633	N/A	59.6	ss, ltgy, vfgr, sil, xbdd, carb, styl
2-2[**]	15426.00	9 18	2.637	N/A	54.0	ss, ltgy, vfgr, sil, xbdd, carb, styl
3	15426.80	10.74	2.643	0.027	37.0	ss, ltgy, vfgr, sil, xbdd, bur, carb
4	15427.30	11.52	2.642	0.030	39 4	ss, ltgy, vfgr, sil, bdd
5	15428.00	10.67	2.644	0.026	45.1	ss, ltgy, vfgr, sil, bdd
6CF[†]	15429.25	11.71	2.643	0.031	28.3	ss, ltgy, vfgr, sil, lam, bur, of
7VF[†]	15429 40	11.91	2.642	0.078	23 4	ss, ltgy, vfgr, sil, lam, pofs/clyffs
8VC[‡]	15429 70	11.55	2.643	0.023	38.4	ss, ltgy, vfgr, sil, lam
9	15431.00	11.59	2.643	0.033	36.0	ss, ltgy, vfgr, sil, xlam, bur
10	15432.00	11.48	2.643	0.031	34.4	ss, ltgy, vfgr, sil, xlam, bur, carb
11	15433 40	11.37	2.645	0.035	35.7	ss, ltgy, vfgr, sil, bur, lam
12	15434.00	11.55	2.643	0.032	41.1	ss, ltgy, vfgr, sil, xlam, carb
13	15435.00	11.48	2.643	0.030	34.3	ss, ltgy, vfgr, sil, xlam, carb
14	15436.25	11.19	2.643	0.029	33.1	ss, ltgy, vfgr, sil, lam
15	15438.00	11.31	2.643	0.031	43.7	ss, ltgy, vfgr, sil, xlam
16	15439.20	11.03	2.643	0.031	43.3	ss, ltgy, vfgr, sil, xlam
17C&E[*]	15440.00	11.15	2.643	0.029	52.8	ss, ltgy, vfgr, sil, xlam, carb
17-1[**]	15440.00	10.78	2.638	N/A	43.9	ss, ltgy, vfgr, sil, xlam, carb
17-2[**]	15440.00	11.21	2.655	N/A	69 4	ss, ltgy, vfgr, sil, xlam, carb
18C&E[*]	15441.00	10.51	2.642	0.028	52.3	ss, ltgy, vfgr, sil, bdd
18-1[**]	15441.00	10.62	2.637	N/A	69.0	ss, ltgy, vfgr, sil, bdd
18-2[**]	15441.00	10.45	2.641	N/A	66.4	ss, ltgy, vfgr, sil, bdd
19	15442.15	11.01	2.643	0.028	48.0	ss, ltgy, vfgr, sil, bdd

Table 4 Routine Plug Analysis, Rock Island #4-H.

Sample Number	*Sample Depth (ft)*	*Porosity (%)*	*Grain Density* (g/cm^3)	*Gas Permeability (md)*	*Saturation Water (%)*	*Lithologic Description*
20	15443.00	10.99	2.643	0.028	47.3	ss, ltgy, vfgr, sil, xbdd
21	15444.00	10.85	2.646	0.028	46.0	ss, ltgy, vfgr, sil, xbdd, carb
22	15445 15	10.49	2.646	0.018	45.9	ss, ltgy, vfgr, sil, xbdd, carb
23	15445 95	11.02	2.646	0.023	38.4	ss, ltgy, vfgr, sil, xlam, carb
24CF†	15446.20	10.81	2.644	0.038	10.4	ss, ltgy, vfgr, sil, xlam, carb, of
25	15447.00	11.07	2.645	0.025	35.5	ss, ltgy, vfgr, sil, xlam, carb
26	15447.85	10.70	2.645	0.023	40.3	ss, ltgy, vfgr, sil, lam
27	15449.00	10.66	2.644	0.023	41.1	ss, ltgy, vfgr, sil, lam, bur
28C&E*	15450.00	11.01	2.645	0.024	44.9	ss, ltgy, vfgr, sil, xbdd, carb
28-1**	15450.00	10.74	2.638	N/A	62.2	ss, ltgy, vfgr, sil, xbdd, carb
28-2**	15450.00	10.36	2.632	N/A	62.2	ss, ltgy, vfgr, sil, xbdd, carb
29	15450.90	10.83	2.645	0.023	46.6	ss, ltgy, vfgr, sil, xbdd
30	15452.00	11.00	2.644	0.022	45.7	ss, ltgy, vfgr, sil, xbdd, bur
31	15453.00	10.07	2.643	0.021	47 1	ss, ltgy, vfgr, sil, bdd
32	15453.70	10.45	2.648	0.024	55.9	ss, ltgy, vfgr, sil
33	15455.00	11.18	2.674	0.020	23.3	ss, ltgy, vfgr, sil, xbdd, carb
34	15456.50	12.15	2.674	0.023	36.7	ss, ltgy, vfgr, sil, xbdd, carb
35	15457.25	11.27	2.647	0.025	37 7	ss, ltgy, vfgr, sil, xbdd
36	15458.00	11.07	2.646	0.023	42.9	ss, ltgy, vfgr, sil, xbdd
37VC#	15459.00	11.04	2.648	0.014	50.7	ss, ltgy, vfgr, sil, xbdd, carb
38VF†	15459.25	11.56	2.651	0.034	50.9	ss, ltgy, vfgr, sil, xbdd, pofs
39C&E*	15460.00	11.52	2.648	0.021	48.7	ss, ltgy, vfgr, sil, bdd, carb
39-1**	15460.00	11.02	2.638	N/A	56.6	ss, ltgy, vfgr, sil, bdd, carb
39-2**	15460.00	10.58	2.632	N/A	54.3	ss, ltgy, vfgr, sil, bdd, carb
40	15461.00	11.64	2.647	0.007	50.5	ss, ltgy, vfgr, sil, bdd
41	15463.00	12.34	2.646	0.021	39.9	ss, ltgy, vfgr, sil, xbdd

Table 4 continued

Sample Number	*Sample Depth (ft)*	*Porosity (%)*	*Grain Density (g/cm^3)*	*Gas Permeability (md)*	*Saturation Water (%)*	*Lithologic Description*
42	15464.00	12.15	2.646	0.026	45 7	ss, ltgy, vfgr, sil
43	15465.00	11.69	2.646	0.020	38.7	ss, ltgy, vfgr, sil
44	15466.10	11.18	2.647	0.017	39.2	ss, ltgy, vfgr, sil, bdd
45	15467.00	11 17	2.648	0.045	39.8	ss, ltgy, vfgr, sil, bdd
46	15469.00	10.70	2.650	0.016	47.5	ss, ltgy, vfgr, sil, carb
47C&E*	15470.00	10.42	2.647	0.017	50.8	ss, ltgy, vfgr, sil, carb
47-1**	15470.00	9.90	2.632	N/A	62.5	ss, ltgy, vfgr, sil, carb
47-2**	15470.00	9.67	2.632	N/A	75.6	ss, ltgy, vfgr, sil, carb
48	15471.00	10.73	2.646	0.004	47.5	ss, ltgy, vfgr, sil, carb
49	15473.00	11.15	2.645	0.004	52.4	ss, ltgy, vfgr, sil, carb, pyr
50	15473.85	10.73	2.647	0.021	54.6	ss, ltgy, vfgr, sil, xbdd, carb
51VC#	15474.10	10.16	2.645	0.012	56.0	ss, ltgy, vfgr, sil, xbdd, carb
52VF!	15474.40	10.13	2.646	0.024	59 4	ss, ltgy, vfgr, sil, bdd, pof/clyff, carb
53	15475.95	11.01	2.644	0.020	56.0	ss, ltgy, vfgr, sil, xbdd
54	15477.00	10.82	2.643	0.016	39.0	ss, ltgy, vfgr, sil, qff
55C&E*	15479.00	11.24	2.644	0.019	49.3	ss, ltgy, vfgr, sil, xbdd
55-1**	15479.00	11.74	2.638	N/A	62.3	ss, ltgy, vfgr, sil, xbdd
55-2**	15479.00	11.07	2.637	N/A	67.5	ss, ltgy, vfgr, sil, xbdd
56	15481.00	10.46	2.643	0.015	44.4	ss, ltgy, vfgr, sil, xbdd
57	15483.50	10.73	2.645	0.019	43.4	ss, ltgy, vfgr, sil
58	15932.70	9.54	2.648	0.012	57 7	ss, ltgy, vfgr, sil, mica
59VC#	15933.20	9.24	2.647	0.008	58.2	ss, ltgy, vfgr, sil, xbdd, mica
60VF!	15933.40	9.04	2.646	0.008	63.8	ss, ltgy, vfgr, sil, xbdd, cff/pof, mica
61CF!	15934.75	9.58	2.647	0.011	45.5	ss, ltgy, vfgr, sil, of/qff, mica
62VC#	15936.45	8.47	2.650	0.009	68.4	ss, ltgy, vfgr, sil, bdd, mica
63VF!	15936.70	8.89	2.651	0.019	63.5	ss, ltgy, vfgr, sil, xbdd, clyff/pof, mica

Table 4 continued

Sample Number	*Sample Depth (ft)*	*Porosity (%)*	*Grain Density* (g/cm^3)	*Gas Permeability (md)*	*Saturation Water (%)*	*Lithologic Description*
64	15937.50	9.35	2.652	0.011	59.1	ss, ltgy, vfgr, sil, bdd, mica
65C&E*	15939.50	8.71	2.654	0.012	69.4	ss, ltgy, vfgr, sil, mica
65-1**	15939.50	8.99	2.648	N/A	65.9	ss, ltgy, vfgr, sil, mica
65-2**	15939.50	8.83	2.652	N/A	71.5	ss, ltgy, vfgr, sil, mica
66HC&E*	15940.50	8.79	2.654	0.011	62.4	ss, ltgy, vfgr, sil, bdd, mica
66-1**	15940.50	8.64	2.649	N/A	66.8	ss, ltgy, vfgr, sil, bdd, mica
66-2**	15940.50	8.63	2.647	N/A	66.5	ss, ltgy, vfgr, sil, bdd, mica
67	15941.50	8.80	2.650	0.009	61.1	ss, ltgy, vfgr, sil, bdd, mica
68CF†	15941.80	8.90	2.655	0.010	47.6	ss, ltgy, vfgr, sil, bdd, of/clyff, mica
69HF@	15942.55	9.08	2.671	0.008	63.7	ss, ltgy, vfgr, sil, bdd, pof/cly-bitff, mica
70	15943.50	9.11	2.659	0.009	63.7	ss, ltgy, vfgr, sil, carb, mica
71	15945.50	8.92	2.661	0.010	57.0	ss, ltgy, vfgr, sil, bdd, mica
72	15947.50	8.74	2.645	0.011	67.0	ss, ltgy, vfgr, sil, bdd, mica
73C&E*	15948.50	9.06	2.658	0.010	65.5	ss, ltgy, vfgr, sil, mica
73-1**	15948.50	9.32	2.650	N/A	73.5	ss, ltgy, vfgr, sil, mica
73-2**	15948.50	8.90	2.649	N/A	78.3	ss, ltgy, vfgr, sil, mica
74	15949.50	8.90	2.652	0.011	64.6	ss, ltgy, vfgr, sil, xbdd, mica

Sample Designation Notes – All plugs horizontal except:

- *center plug
- **end plug
- † cross-face plug (across fracture face)
- ‡ vertical plug, fractured
- # vertical plug, unfractured comparison
- @ horizontal plug, fractured

Table 4 continued

PRELIMINARY PLUG CORE ANALYSIS (by TERRA TEK)

ROCK ISLAND 4H, HORIZONTAL WELL CORE DATA
DEEP FRONTIER FORMATION

CORE #1 and #2 from 15,424'-82' MD (14,889'-94' TVD)

Second Frontier Marine Sandstone
Average Routine Core Anaysis from 58 Plug Samples

11.1%	**POROSITY**
0.025 md	**PERMEABILITY**
42.7 %	**WATER SATURATION**
2.646 g/cc	**GRAIN DENSITY**

CORE #3 from 15,931'-52' MD (14,926'-28' TVD)

Second Frontier Marine Sandstone
Average Routine Core Anaysis from 17 Plug Samples

9.0%	**POROSITY**
0.010 md	**PERMEABILITY**
61.1 %	**WATER SATURATION**
2.653 g/cc	**GRAIN DENSITY**

Table 5 Summary of Routine Core Analysis, Rock Island #4-H, Cores 1, 2, and 3

BASIC ROCK PROPERTIES

Union Pacific Resources Company
Rock Island 4H Horizontal Well
Frontier Formation
Sweetwater County, Wyoming

A: Full Diameter Analysis

Depth (ft)		Khor Perp. (md)	Khor Long Axis (md)	Kvert (md)	Porosity %	Grain Density (g/cc)
Low Temperature Analysis						
15432 7	15433 0	0 049	0 024	0 051	11 8	2 64
15471 6	15471 9	0 021	0 012	0 014	6 7	2 65
15940 7	15941 0	0 011	0 010	0 010	9 2	2 66
High Temperature Analysis						
15432 7	15433 0	0 064	0 061	0 046	12 2	2 64
15471 6	15471 9	0 021	0 015	0 015	6 8	2 65
15940 7	15941 0	0 012	0 009	0 011	9 6	2 66

Table 6a Full diameter – three whole core samples – Core Analysis, Rock Island #4-H

B: Core Plug Analysis

Depth (ft)	Permeability to gas (md)	Porosity (%BV)	Grain Density (g/cc)
15430 5	0 026	12 0	2 66
15449 5	0 021	11 0	2 66
15461 5	0 021	12 1	2 66
15470 5	0 011	10 8	2 66
15937 1	0 006	9 9	2 66
15948 2	0 006	9 5	2 66

Table 6b Routine Core Analysis, six plugs, Rock Island #4-H

Table 6c. NMR Core Data Summary, Rock Island #4-H.

NMR DATA SUMMARY
Union Pacific Resources Company
Rock Island 4H Horizontal Well
Frontier Formation
Sweetwater County, Wyoming

Core Depth (ft)	Core Analysis Data				NMR DATA													
					100% Brine Saturation						Partial Brine Saturation Pc = 200 psi A/B				Partial Brine Saturation Pc = 300 psi A/B			
	Porosity (%)	Permeability (md)	Grain Density (g/cc)	Swi (%)	Porosity (%)	Effective Porosity (%)	T_{2ML} (ms)	BVI % (33 ms)	FFI % (33 ms)	Swi % (33 ms)	BVI (%)	FFI (%)	Swi (%)	T_2 Cutoff (ms)	BVI (%)	FFI (%)	Swi (%)	T_2 Cutoff (ms)
15430.5	12.0	0.026	2.66	33.0	11.9	11.0	9.3	11.9	0.0	100.0	4.9	7.0	41.2	8.2	4.1	7.8	34.5	7.2
15449.5	11.0	0.021	2.66	39.7	11.2	9.2	6.0	11.1	0.1	99.1	5.6	5.6	50.0	6.0	4.8	6.4	42.9	5.3
15461.5	12.1	0.021	2.66	46.1	12.1	10.9	7.6	12.1	0.0	100.0	7.8	4.3	64.5	9.6	5.9	6.2	48.8	7.6
15470.5	10.8	0.011	2.66	64.9	10.7	8.9	6.1	10.6	0.1	99.1	9.4	1.3	87.9	11.0	7.6	3.1	71.0	8.4
15937.1	9.9	0.006	2.67	67.9	9.9	8.0	8.4	9.2	0.7	92.9	8.6	1.3	86.9	26.0	7.1	2.8	71.7	16.0
15948.2	9.5	0.006	2.66	73.0	9.5	7.5	7.6	9.2	0.3	96.8	8.8	0.7	92.6	26.0	7.3	2.2	76.8	15.0

Sequence of Fracture Formation in the Frontier Sandstone, Rock Island Unit #4-H

1. **Deep burial, overpressuring, and east-west fracturing**

2. **Overmaturation of hydrocarbon to bitumen**

3. **Mineralization of fractures with quartz druze**

4. **Mineralization of fractures with kaolinite**

5. **Thrust faulting and associated reactivation of east-west fractures in strike-slip or oblique-slip shear**

6. **Formation of north-south fractures**

7. **Mineralization of north-south fractures with quartz druze and later calcite**

Table 7 Sequence of fracture formation and mineralization, Rock Island #4-H – Lorenz

COMPARISON OF FRACTURE HISTORY IN THREE WELLS

	Rock Island #4-H	Government Union #4	Frewen #4 Deep
1. Deep burial, overpressuring, and east-west fracturing	X	X	X[1]
2. Overmaturation of hydrocarbon to bitumen	X	X	X
3. Mineralization of fractures with quartz druze	X	X	X
4. Mineralization of fractures with kaolinite	X	X	-
5. Thrust faulting and associated reactivation of east-west fractures in strike-slip or oblique-slip shear	X	X	-
6. Formation of north-south fractures	X	X	X
7. Mineralization of north-south fractures with quartz druze and later calcite	X	X	X

[1]Frontier sandstones in the Frewen area underwent second east-west fracture event, separated from first by vertical pressure solution

Table 7a. Comparison of Fracture History of Three Deep Frontier Wells - J. Lorenz

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	1	15959.20	1000.00	0.020	0.036	11.1	2.099	33.3	11.3	0.0	11.3	44.6	0.000	44.654	16.846	2.651
1	1	15959.20	2000.00	0.006	0.019	10.7	2.020	34.7	11.7	0.0	11.7	46.4	0.000	44.654	16.846	2.651
1	1	15959.20	4000.00	0.004	0.013	10.3	1.932	36.2	12.2	0.0	12.2	48.5	0.000	44.654	16.846	2.651
1	1	15959.20	7000.00	0.004	0.010	10.0	1.875	37.3	12.6	0.0	12.6	49.9	0.000	44.654	16.846	2.651
1	1	15959.20	9500.00	0.004	0.009	9.9	1.851	37.8	12.8	0.0	12.8	50.6	0.000	44.654	16.846	2.651
1	2	15960.10	1000.00	0.017	0.031	10.4	1.969	38.1	10.7	0.0	10.7	48.8	0.000	44.838	16.968	2.643
1	2	15960.10	2000.00	0.005	0.017	10.0	1.891	39.7	11.1	0.0	11.1	50.8	0.000	44.838	16.968	2.643
1	2	15960.10	4000.00	0.005	0.013	9.6	1.805	41.5	11.7	0.0	11.7	53.2	0.000	44.838	16.968	2.643
1	2	15960.10	7000.00	0.003	0.008	9.4	1.755	42.7	12.0	0.0	12.0	54.7	0.000	44.838	16.968	2.643
1	2	15960.10	9500.00	0.003	0.007	9.3	1.737	43.2	12.1	0.0	12.1	55.3	0.000	44.838	16.968	2.643
1	3	15961.20	1000.00	0.021	0.041	12.2	2.318	34.5	11.1	0.0	11.1	45.6	0.000	43.913	16.638	2.639
1	3	15961.20	2000.00	0.008	0.023	11.9	2.239	35.7	11.5	0.0	11.5	47.2	0.000	43.913	16.638	2.639
1	3	15961.20	4000.00	0.005	0.016	11.5	2.163	37.0	11.9	0.0	11.9	48.9	0.000	43.913	16.638	2.639
1	3	15961.20	7000.00	0.005	0.015	11.3	2.119	37.8	12.1	0.0	12.1	49.9	0.000	43.913	16.638	2.639
1	3	15961.20	9500.00	0.005	0.013	11.2	2.097	38.1	12.3	0.0	12.3	50.4	0.000	43.913	16.638	2.639
1	4	15962.20	1000.00	0.021	0.039	11.6	2.211	36.2	13.3	0.0	13.3	49.5	0.000	44.416	16.841	2.637
1	4	15962.20	2000.00	0.007	0.022	11.2	2.121	37.7	13.8	0.0	13.8	51.5	0.000	44.416	16.841	2.637
1	4	15962.20	4000.00	0.005	0.015	10.9	2.052	39.0	14.3	0.0	14.3	53.3	0.000	44.416	16.841	2.637
1	4	15962.20	7000.00	0.004	0.014	10.4	1.952	41.0	15.0	0.0	15.0	56.0	0.000	44.416	16.841	2.637
1	4	15962.20	9500.00	0.004	0.011	10.4	1.945	41.1	15.1	0.0	15.1	56.2	0.000	44.416	16.841	2.637
1	5	15963.20	1000.00	0.019	0.037	11.8	2.228	44.9	3.9	0.0	3.9	48.8	0.000	44.091	16.682	2.643
1	5	15963.20	2000.00	0.007	0.022	11.3	2.133	46.9	4.1	0.0	4.1	51.0	0.000	44.091	16.682	2.643
1	5	15963.20	4000.00	0.005	0.015	10.9	2.044	48.9	4.3	0.0	4.3	53.2	0.000	44.091	16.682	2.643
1	5	15963.20	7000.00	0.004	0.013	10.7	1.996	50.1	4.4	0.0	4.4	54.5	0.000	44.091	16.682	2.643
1	5	15963.20	9500.00	0.004	0.011	10.6	1.976	50.6	4.4	0.0	4.4	55.0	0.000	44.091	16.682	2.643
1	6	15964.20	1000.00	0.023	0.042	12.1	2.275	41.3	8.0	0.0	8.0	49.3	0.000	43.618	16.533	2.638
1	6	15964.20	2000.00	0.008	0.024	11.7	2.190	42.9	8.3	0.0	8.3	51.2	0.000	43.618	16.533	2.638
1	6	15964.20	4000.00	0.006	0.017	11.3	2.110	44.6	8.6	0.0	8.6	53.2	0.000	43.618	16.533	2.638
1	6	15964.20	7000.00	0.004	0.014	11.1	2.070	45.4	8.8	0.0	8.8	54.2	0.000	43.618	16.533	2.638
1	6	15964.20	9500.00	0.004	0.013	11.1	2.057	45.7	8.8	0.0	8.8	54.5	0.000	43.618	16.533	2.638
1	7	15965.20	1000.00	0.021	0.036	12.4	2.341	42.7	5.4	0.0	5.4	48.1	0.000	43.828	16.535	2.651
1	7	15965.20	2000.00	0.010	0.029	12.0	2.252	44.4	5.6	0.0	5.6	50.0	0.000	43.828	16.535	2.651
1	7	15965.20	4000.00	0.005	0.016	11.6	2.165	46.2	5.9	0.0	5.9	52.0	0.000	43.828	16.535	2.651
1	7	15965.20	7000.00	0.004	0.014	11.3	2.116	47.3	6.0	0.0	6.0	53.3	0.000	43.828	16.535	2.651
1	7	15965.20	9500.00	0.004	0.013	11.2	2.093	47.8	6.1	0.0	6.1	53.8	0.000	43.828	16.535	2.651
1	8	15966.10	1000.00	0.021	0.039	11.9	2.231	40.3	8.2	0.0	8.2	48.5	0.000	43.761	16.546	2.645
1	8	15966.10	2000.00	0.007	0.021	11.5	2.142	42.0	8.5	0.0	8.5	50.5	0.000	43.761	16.546	2.645
1	8	15966.10	4000.00	0.005	0.016	11.1	2.060	43.7	8.9	0.0	8.9	52.5	0.000	43.761	16.546	2.645
1	8	15966.10	7000.00	0.004	0.014	10.9	2.015	44.7	9.0	0.0	9.0	53.7	0.000	43.761	16.546	2.645
1	8	15966.10	9500.00	0.004	0.012	10.8	1.996	45.1	9.1	0.0	9.1	54.2	0.000	43.761	16.546	2.645

Table 8. Routine Core Analysis – plugs, Sidewinder #1-H, Core Labs.

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	9	15967 10	1000.00	0.021	0.037	11.5	2.131	46.9	4.7	0.0	4.7	51.6	0.000	43.515	16.448	2.646
1	9	15967.10	2000.00	0.006	0.020	11.0	2.041	49.0	4.9	0.0	4.9	53.9	0.000	43.515	16.448	2.646
1	9	15967.10	4000.00	0.004	0.014	10.6	1.957	51.1	5.1	0.0	5.1	56.2	0.000	43.515	16.448	2.646
1	9	15967.10	7000.00	0.004	0.013	10.4	1.910	52.4	5.2	0.0	5.2	57.6	0.000	43.515	16.448	2.646
1	9	15967 10	9500.00	0.004	0.011	10.3	1.889	52.9	5.3	0.0	5.3	58.2	0.000	43.515	16.448	2.646
1	10	15968.20	1000.00	0.022	0.038	11.8	2.228	35.9	12.0	0.0	12.0	47.9	0.000	44.116	16.673	2.646
1	10	15968.20	2000.00	0.006	0.021	11.4	2.137	37 4	12.5	0.0	12.5	50.0	0.000	44.116	16.673	2.646
1	10	15968.20	4000.00	0.004	0.015	10.9	2.030	39.4	13.2	0.0	13.2	52.6	0.000	44.116	16.673	2.646
1	10	15968.20	7000.00	0.004	0.014	10.5	1.962	40.8	13.6	0.0	13.6	54.4	0.000	44.116	16.673	2.646
1	10	15968.20	9500.00	0.004	0.012	10.4	1.941	41.2	13.8	0.0	13.8	55.0	0.000	44.116	16.673	2.646
1	11	15969.10	1000.00	0.022	0.040	11.9	2.233	42.5	5.9	0.0	5.9	48.5	0.000	43.628	16.491	2.646
1	11	15969.10	2000.00	0.007	0.022	11.5	2.144	44.3	6.2	0.0	6.2	50.5	0.000	43.628	16.491	2.646
1	11	15969.10	4000.00	0.005	0.016	11.1	2.057	46.2	6.5	0.0	6.5	52.6	0.000	43.628	16.491	2.646
1	11	15969.10	7000.00	0.005	0.015	10.9	2.007	47.3	6.6	0.0	6.6	53.9	0.000	43.628	16.491	2.646
1	11	15969.10	9500.00	0.004	0.012	10.7	1.985	47.9	6.7	0.0	6.7	54.5	0.000	43.628	16.491	2.646
1	12	15970.10	1000.00	0.020	0.038	11.7	2.203	40.8	7.6	0.0	7.6	48.4	0.000	43.956	16.630	2.643
1	12	15970.10	2000.00	0.007	0.021	11.2	2.103	42.8	7.9	0.0	7.9	50.7	0.000	43.956	16.630	2.643
1	12	15970.10	4000.00	0.005	0.015	10.8	2.023	44.5	8.2	0.0	8.2	52.7	0.000	43.956	16.630	2.643
1	12	15970.10	7000.00	0.004	0.014	10.4	1.939	46.4	8.6	0.0	8.6	55.0	0.000	43.956	16.630	2.643
1	12	15970.10	9500.00	0.004	0.011	10.4	1.936	46.5	8.6	0.0	8.6	55.1	0.000	43.956	16.630	2.643
1	13	15971.20	1000.00	0.018	0.037	11.6	2.164	39.3	11.4	0.0	11.4	50.6	0.000	43.581	16.490	2.643
1	13	15971.20	2000.00	0.007	0.022	11.2	2.071	41.1	11.9	0.0	11.9	52.9	0.000	43.581	16.490	2.643
1	13	15971.20	4000.00	0.005	0.015	10.8	1.992	42.7	12.3	0.0	12.3	55.0	0.000	43.581	16.490	2.643
1	13	15971.20	7000.00	0.005	0.013	10.6	1.953	43.5	12.6	0.0	12.6	56.1	0.000	43.581	16.490	2.643
1	13	15971.20	9500.00	0.004	0.011	10.5	1.934	44.0	12.7	0.0	12.7	56.7	0.000	43.581	16.490	2.643
1	14	15972.10	1000.00	0.022	0.040	11.8	2.200	45.5	3.9	0.0	3.9	49.4	0.000	43.573	16.502	2.641
1	14	15972.10	2000.00	0.007	0.022	11.3	2.107	47.5	4.1	0.0	4.1	51.6	0.000	43.573	16.502	2.641
1	14	15972.10	4000.00	0.005	0.015	10.9	2.020	49.5	4.3	0.0	4.3	53.8	0.000	43.573	16.502	2.641
1	14	15972.10	7000.00	0.004	0.014	10.7	1.973	50.7	4.4	0.0	4.4	55.1	0.000	43.573	16.502	2.641
1	14	15972.10	9500.00	0.004	0.011	10.6	1.952	51.2	4.4	0.0	4.4	55.7	0.000	43.573	16.502	2.641
1	15	15973.10	1000.00	0.020	0.038	11.8	2.202	34.1	14.8	0.0	14.8	48.8	0.000	43.635	16.527	2.640
1	15	15973.10	2000.00	0.007	0.022	11.3	2.108	35.6	15.4	0.0	15.4	51.0	0.000	43.635	16.527	2.640
1	15	15973.10	4000.00	0.005	0.015	10.9	2.013	37.3	16.1	0.0	16.1	53.4	0.000	43.635	16.527	2.640
1	15	15973.10	7000.00	0.004	0.013	10.6	1.958	38.3	16.6	0.0	16.6	54.9	0.000	43.635	16.527	2.640
1	15	15973.10	9500.00	0.004	0.011	10.5	1.934	38.8	16.8	0.0	16.8	55.6	0.000	43.635	16.527	2.640
1	16	15974.20	1000.00	0.021	0.039	11.6	2.178	45.9	4.5	0.0	4.5	50.4	0.000	43.694	16.519	2.645
1	16	15974.20	2000.00	0.007	0.021	11.2	2.078	48.1	4.7	0.0	4.7	52.9	0.000	43.694	16.519	2.645
1	16	15974.20	4000.00	0.004	0.014	10.7	1.984	50.4	5.0	0.0	5.0	55.4	0.000	43.694	16.519	2.645
1	16	15974.20	7000.00	0.004	0.012	10.5	1.933	51.7	5.1	0.0	5.1	56.8	0.000	43.694	16.519	2.645
1	16	15974.20	9500.00	0.003	0.010	10.4	1.911	52.3	5.2	0.0	5.2	57.5	0.000	43.694	16.519	2.645

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	17	15975.30	1000.00	0.021	0.042	12.3	2.309	42.0	16.8	0.0	16.8	58.9	0.000	43.575	16.480	2.644
1	17	15975.30	2000.00	0.009	0.025	11.9	2.226	43.6	17.5	0.0	17.5	61.0	0.000	43.575	16.480	2.644
1	17	15975.30	4000.00	0.006	0.017	11.5	2.144	45.3	18.1	0.0	18.1	63.4	0.000	43.575	16.480	2.644
1	17	15975.30	7000.00	0.005	0.015	11.3	2.099	46.2	18.5	0.0	18.5	64.7	0.000	43.575	16.480	2.644
1	17	15975.30	9500.00	0.004	0.012	11.2	2.082	46.6	18.7	0.0	18.7	65.3	0.000	43.575	16.480	2.644
1	18	15976.10	1000.00	0.015	0.030	12.7	2.369	39.7	3.8	0.0	3.8	43.5	0.000	42.914	16.225	2.645
1	18	15976.10	2000.00	0.006	0.019	12.3	2.281	41.2	4.0	0.0	4.0	45.2	0.000	42.914	16.225	2.645
1	18	15976.10	4000.00	0.005	0.015	11.9	2.197	42.8	4.1	0.0	4.1	46.9	0.000	42.914	16.225	2.645
1	18	15976.10	7000.00	0.005	0.015	11.7	2.155	43.6	4.2	0.0	4.2	47.8	0.000	42.914	16.225	2.645
1	18	15976.10	9500.00	0.004	0.014	11.7	2.143	43.9	4.3	0.0	4.3	48.1	0.000	42.914	16.225	2.645
1	19	15977.10	1000.00	0.012	0.026	12.6	2.374	42.1	20.9	0.0	20.9	63.0	0.000	43.387	16.397	2.646
1	19	15977.10	2000.00	0.005	0.016	12.3	2.290	43.7	21.7	0.0	21.7	65.3	0.000	43.387	16.397	2.646
1	19	15977.10	4000.00	0.005	0.014	11.9	2.218	45.1	22.4	0.0	22.4	67.5	0.000	43.387	16.397	2.646
1	19	15977.10	7000.00	0.004	0.012	11.7	2.178	45.9	22.8	0.0	22.8	68.7	0.000	43.387	16.397	2.646
1	19	15977.10	9500.00	0.004	0.010	11.6	2.157	46.4	23.0	0.0	23.0	69.3	0.000	43.387	16.397	2.646
1	20	15978.20	1000.00	0.012	0.027	12.3	2.315	41.0	11.1	0.0	11.1	52.2	0.000	43.461	16.443	2.643
1	20	15978.20	2000.00	0.005	0.016	11.9	2.225	42.7	11.6	0.0	11.6	54.3	0.000	43.461	16.443	2.643
1	20	15978.20	4000.00	0.004	0.014	11.5	2.144	44.3	12.0	0.0	12.0	56.3	0.000	43.461	16.443	2.643
1	20	15978.20	7000.00	0.004	0.012	11.3	2.101	45.2	12.3	0.0	12.3	57.5	0.000	43.461	16.443	2.643
1	20	15978.20	9500.00	0.003	0.010	11.2	2.082	45.6	12.4	0.0	12.4	58.0	0.000	43.461	16.443	2.643
1	21	15979.10	1000.00	0.004	0.012	10.8	2.008	42.3	13.1	0.0	13.1	55.4	0.000	43.751	16.540	2.645
1	21	15979.10	2000.00	0.004	0.010	10.7	1.982	42.9	13.3	0.0	13.3	56.1	0.000	43.751	16.540	2.645
1	21	15979.10	4000.00	0.003	0.008	10.5	1.941	43.8	13.5	0.0	13.5	57.3	0.000	43.751	16.540	2.645
1	21	15979.10	7000.00	0.003	0.007	10.3	1.896	44.8	13.9	0.0	13.9	58.7	0.000	43.751	16.540	2.645
1	21	15979.10	9500.00	0.003	0.006	10.1	1.868	45.5	14.1	0.0	14.1	59.6	0.000	43.751	16.540	2.645
1	22	15980.10	1000.00	0.007	0.017	11.1	2.062	50.9	7.7	0.0	7.7	58.6	0.000	43.710	16.529	2.644
1	22	15980.10	2000.00	0.005	0.011	10.7	1.977	53.1	8.0	0.0	8.0	61.1	0.000	43.710	16.529	2.644
1	22	15980.10	4000.00	0.003	0.007	10.3	1.893	55.5	8.4	0.0	8.4	63.8	0.000	43.710	16.529	2.644
1	22	15980.10	7000.00	0.002	0.006	10.0	1.845	56.9	8.6	0.0	8.6	65.5	0.000	43.710	16.529	2.644
1	22	15980.10	9500.00	0.002	0.005	9.9	1.824	57.6	8.7	0.0	8.7	66.2	0.000	43.710	16.529	2.644
1	23	15981.20	1000.00	0.020	0.036	11.0	2.054	48.7	6.4	0.0	6.4	55.1	0.000	43.949	16.623	2.644
1	23	15981.20	2000.00	0.005	0.018	10.6	1.961	51.0	6.7	0.0	6.7	57.7	0.000	43.949	16.623	2.644
1	23	15981.20	4000.00	0.004	0.014	10.1	1.877	53.3	7.0	0.0	7.0	60.3	0.000	43.949	16.623	2.644
1	23	15981.20	7000.00	0.004	0.009	9.9	1.833	54.6	7.2	0.0	7.2	61.8	0.000	43.949	16.623	2.644
1	23	15981.20	9500.00	0.003	0.007	9.8	1.813	55.2	7.3	0.0	7.3	62.4	0.000	43.949	16.623	2.644
1	24	15982.20	1000.00	0.024	0.042	11.7	2.165	41.6	18.8	0.0	18.8	60.4	0.000	43.004	16.259	2.645
1	24	15982.20	2000.00	0.008	0.023	11.3	2.074	43.4	19.6	0.0	19.6	63.0	0.000	43.004	16.259	2.645
1	24	15982.20	4000.00	0.005	0.016	10.9	1.992	45.2	20.4	0.0	20.4	65.6	0.000	43.004	16.259	2.645
1	24	15982.20	7000.00	0.004	0.014	10.6	1.919	46.9	21.2	0.0	21.2	68.1	0.000	43.004	16.259	2.645
1	24	15982.20	9500.00	0.004	0.010	10.5	1.909	47.2	21.3	0.0	21.3	68.4	0.000	43.004	16.259	2.645

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	25	15983.10	1000.00	0.024	0.043	12.3	2.277	35.1	13.3	0.0	13.3	48.4	0.000	43.112	16.232	2.656
1	25	15983.10	2000.00	0.008	0.024	11.9	2.185	36.6	13.8	0.0	13.8	50.4	0.000	43.112	16.232	2.656
1	25	15983.10	4000.00	0.006	0.018	11.5	2.104	38.0	14.4	0.0	14.4	52.4	0.000	43.112	16.232	2.656
1	25	15983.10	7000.00	0.004	0.014	11.1	2.027	39.5	14.9	0.0	14.9	54.4	0.000	43.112	16.232	2.656
1	25	15983.10	9500.00	0.004	0.014	11.2	2.046	39.1	14.8	0.0	14.8	53.9	0.000	43.112	16.232	2.656
1	26	15984.20	1000.00	0.024	0.042	12.0	2.240	40.2	9.8	0.0	9.8	50.0	0.000	43.337	16.349	2.651
1	26	15984.20	2000.00	0.008	0.022	11.6	2.146	41.9	10.2	0.0	10.2	52.2	0.000	43.337	16.349	2.651
1	26	15984.20	4000.00	0.005	0.016	11.2	2.067	43.5	10.6	0.0	10.6	54.2	0.000	43.337	16.349	2.651
1	26	15984.20	7000.00	0.005	0.015	11.0	2.015	44.7	10.9	0.0	10.9	55.6	0.000	43.337	16.349	2.651
1	26	15984.20	9500.00	0.005	0.012	11.0	2.011	44.7	10.9	0.0	10.9	55.7	0.000	43.337	16.349	2.651
1	27	15985.30	1000.00	0.023	0.040	12.0	2.224	31.5	8.1	0.0	8.1	39.6	0.000	43.166	16.287	2.650
1	27	15985.30	2000.00	0.007	0.021	11.6	2.141	32.7	8.4	0.0	8.4	41.1	0.000	43.166	16.287	2.650
1	27	15985.30	4000.00	0.005	0.016	11.3	2.065	33.9	8.7	0.0	8.7	42.6	0.000	43.166	16.287	2.650
1	27	15985.30	7000.00	0.005	0.015	11.1	2.025	34.6	8.9	0.0	8.9	43.5	0.000	43.166	16.287	2.650
1	27	15985.30	9500.00	0.003	0.013	11.0	2.009	34.9	9.0	0.0	9.0	43.8	0.000	43.166	16.287	2.650
1	28	15986.30	1000.00	0.018	0.033	12.2	2.275	35.2	8.4	0.0	8.4	43.6	0.000	43.224	16.304	2.651
1	28	15986.30	2000.00	0.009	0.027	11.9	2.197	36.4	8.7	0.0	8.7	45.1	0.000	43.224	16.304	2.651
1	28	15986.30	4000.00	0.006	0.016	11.5	2.122	37.7	9.0	0.0	9.0	46.7	0.000	43.224	16.304	2.651
1	28	15986.30	7000.00	0.005	0.014	11.3	2.077	38.5	9.2	0.0	9.2	47.7	0.000	43.224	16.304	2.651
1	28	15986.30	9500.00	0.005	0.013	11.2	2.056	38.9	9.3	0.0	9.3	48.2	0.000	43.224	16.304	2.651
1	29	15987 10	1000.00	0.024	0.042	12.6	2.361	33.9	9.9	0.0	9.9	43.8	0.000	43.296	16.333	2.651
1	29	15987 10	2000.00	0.009	0.025	12.2	2.279	35.1	10.3	0.0	10.3	45.4	0.000	43.296	16.333	2.651
1	29	15987.10	4000.00	0.007	0.019	11.9	2.213	36.2	10.6	0.0	10.6	46.7	0.000	43.296	16.333	2.651
1	29	15987.10	7000.00	0.005	0.016	11.6	2.147	37.3	10.9	0.0	10.9	48.2	0.000	43.296	16.333	2.651
1	29	15987.10	9500.00	0.005	0.015	11.6	2.145	37.3	10.9	0.0	10.9	48.2	0.000	43.296	16.333	2.651
1	30	15988.10	1000.00	0.021	0.040	12.7	2.367	42.2	7.6	0.0	7.6	49.9	0.000	43.311	16.337	2.651
1	30	15988.10	2000.00	0.011	0.029	12.3	2.281	43.8	7.9	0.0	7.9	51.7	0.000	43.311	16.337	2.651
1	30	15988.10	4000.00	0.007	0.019	11.9	2.202	45.4	8.2	0.0	8.2	53.6	0.000	43.311	16.337	2.651
1	30	15988.10	7000.00	0.006	0.016	11.7	2.159	46.3	8.4	0.0	8.4	54.7	0.000	43.311	16.337	2.651
1	30	15988.10	9500.00	0.006	0.016	11.6	2.140	46.7	8.4	0.0	8.4	55.2	0.000	43.311	16.337	2.651
1	31	15989.20	1000.00	0.023	0.042	12.3	2.281	46.0	6.0	0.0	6.0	52.0	0.000	43.289	16.333	2.650
1	31	15989.20	2000.00	0.009	0.025	11.8	2.189	48.0	6.2	0.0	6.2	54.2	0.000	43.289	16.333	2.650
1	31	15989.20	4000.00	0.006	0.018	11.5	2.118	49.6	6.4	0.0	6.4	56.0	0.000	43.289	16.333	2.650
1	31	15989.20	7000.00	0.005	0.015	11.2	2.068	50.8	6.6	0.0	6.6	57 4	0.000	43.289	16.333	2.650
1	31	15989.20	9500.00	0.005	0.014	11.2	2.068	50.8	6.6	0.0	6.6	57 4	0.000	43.289	16.333	2.650
1	32	15990.20	1000.00	0.024	0.043	12.1	2.246	49.0	6.7	0.0	6.7	55.6	0.000	43.288	16.327	2.651
1	32	15990.20	2000.00	0.009	0.025	11.7	2.161	50.9	6.9	0.0	6.9	57.8	0.000	43.288	16.327	2.651
1	32	15990.20	4000.00	0.006	0.018	11.3	2.077	53.0	7.2	0.0	7.2	60.2	0.000	43.288	16.327	2.651
1	32	15990.20	7000.00	0.004	0.014	11.1	2.036	54.0	7.3	0.0	7.3	61.4	0.000	43.288	16.327	2.651
1	32	15990.20	9500.00	0.004	0.013	11.0	2.027	54.3	7 4	0.0	7 4	61.6	0.000	43.288	16.327	2.651

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	33	15991.20	1000.00	0.025	0.046	12.4	2.305	43.4	9.6	0.0	9.6	53.0	0.000	43.031	16.227	2.652
1	33	15991.20	2000.00	0.010	0.027	12.0	2.220	45.0	10.0	0.0	10.0	55.0	0.000	43.031	16.227	2.652
1	33	15991.20	4000.00	0.007	0.020	11.6	2.135	46.8	10.4	0.0	10.4	57.2	0.000	43.031	16.227	2.652
1	33	15991.20	7000.00	0.005	0.015	11.4	2.092	47.8	10.6	0.0	10.6	58.4	0.000	43.031	16.227	2.652
1	33	15991.20	9500.00	0.005	0.015	11.4	2.081	48.1	10.7	0.0	10.7	58.7	0.000	43.031	16.227	2.652
1	34	15992.20	1000.00	0.024	0.046	12.5	2.327	43.0	12.3	0.0	12.3	55.3	0.000	43.122	16.280	2.649
1	34	15992.20	2000.00	0.010	0.027	12.1	2.243	44.6	12.7	0.0	12.7	57.3	0.000	43.122	16.280	2.649
1	34	15992.20	4000.00	0.007	0.020	11.7	2.156	46.4	13.2	0.0	13.2	59.6	0.000	43.122	16.280	2.649
1	34	15992.20	7000.00	0.005	0.015	11.5	2.112	47.3	13.5	0.0	13.5	60.9	0.000	43.122	16.280	2.649
1	34	15992.20	9500.00	0.005	0.015	11.4	2.102	47.6	13.6	0.0	13.6	61.2	0.000	43.122	16.280	2.649
1	35	15993.20	1000.00	0.025	0.046	12.4	2.297	47.9	7.0	0.0	7.0	54.9	0.000	43.187	16.241	2.659
1	35	15993.20	2000.00	0.009	0.026	12.0	2.216	49.6	7.2	0.0	7.2	56.9	0.000	43.187	16.241	2.659
1	35	15993.20	4000.00	0.006	0.018	11.6	2.134	51.6	7.5	0.0	7.5	59.1	0.000	43.187	16.241	2.659
1	35	15993.20	7000.00	0.005	0.014	11.4	2.093	52.6	7.7	0.0	7.7	60.2	0.000	43.187	16.241	2.659
1	35	15993.20	9500.00	0.004	0.014	11.4	2.084	52.8	7.7	0.0	7.7	60.5	0.000	43.187	16.241	2.659
1	36	15994.20	1000.00	0.024	0.044	12.1	2.258	46.5	8.0	0.0	8.0	54.5	0.000	43.570	16.381	2.660
1	36	15994.20	2000.00	0.009	0.026	11.7	2.180	48.2	8.3	0.0	8.3	56.5	0.000	43.570	16.381	2.660
1	36	15994.20	4000.00	0.006	0.018	11.4	2.104	49.9	8.6	0.0	8.6	58.5	0.000	43.570	16.381	2.660
1	36	15994.20	7000.00	0.004	0.014	11.2	2.065	50.8	8.8	0.0	8.8	59.6	0.000	43.570	16.381	2.660
1	36	15994.20	9500.00	0.004	0.013	11.1	2.052	51.2	8.8	0.0	8.8	60.0	0.000	43.570	16.381	2.660
1	37	15995.10	1000.00	0.024	0.043	11.8	2.184	38.9	12.7	0.0	12.7	51.6	0.000	43.327	16.295	2.659
1	37	15995.10	2000.00	0.005	0.018	11.3	2.084	40.8	13.3	0.0	13.3	54.1	0.000	43.327	16.295	2.659
1	37	15995.10	4000.00	0.003	0.007	10.8	1.968	43.2	14.1	0.0	14.1	57.3	0.000	43.327	16.295	2.659
1	37	15995.10	7000.00	0.002	0.004	10.3	1.878	45.3	14.8	0.0	14.8	60.0	0.000	43.327	16.295	2.659
1	37	15995.10	9500.00	0.001	0.002	10.0	1.818	46.8	15.2	0.0	15.2	62.0	0.000	43.327	16.295	2.659
1	38	15996.10	1000.00	0.024	0.042	11.7	2.182	41.2	8.3	0.0	8.3	49.6	0.000	43.706	16.440	2.658
1	38	15996.10	2000.00	0.005	0.017	11.1	2.055	43.8	8.8	0.0	8.8	52.6	0.000	43.706	16.440	2.658
1	38	15996.10	4000.00	0.002	0.005	10.7	1.961	45.9	9.3	0.0	9.3	55.2	0.000	43.706	16.440	2.658
1	38	15996.10	7000.00	0.001	0.003	10.5	1.933	46.6	9.4	0.0	9.4	56.0	0.000	43.706	16.440	2.658
1	38	15996.10	9500.00	0.001	0.002	10.5	1.930	46.6	9.4	0.0	9.4	56.1	0.000	43.706	16.440	2.658
1	39	15997.20	1000.00	0.021	0.039	11.5	2.125	47.1	5.0	0.0	5.0	52.0	0.000	43.261	16.282	2.657
1	39	15997.20	2000.00	0.005	0.015	10.8	1.980	50.5	5.3	0.0	5.3	55.8	0.000	43.261	16.282	2.657
1	39	15997.20	4000.00	0.002	0.004	10.3	1.874	53.4	5.6	0.0	5.6	59.0	0.000	43.261	16.282	2.657
1	39	15997.20	7000.00	0.001	0.003	10.2	1.842	54.3	5.7	0.0	5.7	60.0	0.000	43.261	16.282	2.657
1	39	15997.20	9500.00	0.001	0.002	10.1	1.838	54.4	5.7	0.0	5.7	60.1	0.000	43.261	16.282	2.657
1	40	15998.20	1000.00	0.016	0.032	11.3	2.073	44.9	4.4	0.0	4.4	49.3	0.000	43.091	16.206	2.659
1	40	15998.20	2000.00	0.004	0.011	10.5	1.894	49.1	4.8	0.0	4.8	53.9	0.000	43.091	16.206	2.659
1	40	15998.20	4000.00	0.002	0.004	9.8	1.766	52.7	5.2	0.0	5.2	57.8	0.000	43.091	16.206	2.659
1	40	15998.20	7000.00	0.001	0.002	9.6	1.728	53.8	5.3	0.0	5.3	59.1	0.000	43.091	16.206	2.659
1	40	15998.20	9500.00	0.001	0.002	9.6	1.724	54.0	5.3	0.0	5.3	59.3	0.000	43.091	16.206	2.659

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	41	15999.10	1000.00	0.010	0.024	11.4	2.118	38.7	16.5	0.0	16.5	55.2	0.000	43.577	16.401	2.657
1	41	15999.10	2000.00	0.003	0.009	10.8	1.993	41.1	17.5	0.0	17.5	58.6	0.000	43.577	16.401	2.657
1	41	15999.10	4000.00	0.002	0.004	10.4	1.901	43.1	18.3	0.0	18.3	61.5	0.000	43.577	16.401	2.657
1	41	15999.10	7000.00	0.001	0.002	10.2	1.873	43.8	18.6	0.0	18.6	62.4	0.000	43.577	16.401	2.657
1	41	15999.10	9500.00	0.001	0.001	10.2	1.870	43.9	18.6	0.0	18.6	62.5	0.000	43.577	16.401	2.657
1	42	16000.20	1000.00	0.013	0.027	11.6	2.161	46.3	8.8	0.0	8.8	55.1	0.000	43.910	16.536	2.655
1	42	16000.20	2000.00	0.003	0.009	11.0	2.044	48.9	9.4	0.0	9.4	58.3	0.000	43.910	16.536	2.655
1	42	16000.20	4000.00	0.001	0.003	10.4	1.920	52.1	10.0	0.0	10.0	62.0	0.000	43.910	16.536	2.655
1	42	16000.20	7000.00	0.001	0.002	10.0	1.837	54.5	10.4	0.0	10.4	64.9	0.000	43.910	16.536	2.655
1	42	16000.20	9500.00	0.001	0.001	9.9	1.807	55.3	10.6	0.0	10.6	65.9	0.000	43.910	16.536	2.655
1	43	16001.20	1000.00	0.021	0.041	12.3	2.289	39.3	15.5	0.0	15.5	54.8	0.000	43.290	16.305	2.655
1	43	16001.20	2000.00	0.006	0.017	11.8	2.184	41.2	16.2	0.0	16.2	57 4	0.000	43.290	16.305	2.655
1	43	16001.20	4000.00	0.002	0.005	11.2	2.066	43.6	17.1	0.0	17.1	60.7	0.000	43.290	16.305	2.655
1	43	16001.20	7000.00	0.001	0.003	10.8	1.981	45.4	17.9	0.0	17.9	63.3	0.000	43.290	16.305	2.655
1	43	16001.20	9500.00	0.001	0.002	10.6	1.941	46.4	18.2	0.0	18.2	64.6	0.000	43.290	16.305	2.655
1	44	16002.10	1000.00	0.013	0.027	11.6	2.138	35.1	22.8	0.0	22.8	57.9	0.000	43.151	16.249	2.656
1	44	16002.10	2000.00	0.006	0.018	11.4	2.093	35.8	23.3	0.0	23.3	59.1	0.000	43.151	16.249	2.656
1	44	16002.10	4000.00	0.004	0.014	11.2	2.047	36.6	23.8	0.0	23.8	60.5	0.000	43.151	16.249	2.656
1	44	16002.10	7000.00	0.004	0.013	11.1	2.020	37.1	24.1	0.0	24.1	61.3	0.000	43.151	16.249	2.656
1	44	16002.10	9500.00	0.004	0.010	11.0	2.010	37.3	24.3	0.0	24.3	61.6	0.000	43.151	16.249	2.656
1	45	16003.10	1000.00	0.011	0.023	11.0	2.042	19.6	37.5	0.0	37.5	57.1	0.000	43.998	16.584	2.653
1	45	16003.10	2000.00	0.002	0.007	10.0	1.847	21.7	41.5	0.0	41.5	63.1	0.000	43.998	16.584	2.653
1	45	16003.10	4000.00	0.001	0.003	9.3	1.708	23.4	44.8	0.0	44.8	68.2	0.000	43.998	16.584	2.653
1	45	16003.10	7000.00	0.001	0.002	9.1	1.667	24.0	45.9	0.0	45.9	69.9	0.000	43.998	16.584	2.653
1	45	16003.10	9500.00	0.001	0.001	9.1	1.662	24.1	46.1	0.0	46.1	70.1	0.000	43.998	16.584	2.653
1	46	16004.10	1000.00	0.007	0.017	9.9	1.827	27 4	45.9	0.0	45.9	73.3	0.000	44.365	16.690	2.658
1	46	16004.10	2000.00	0.006	0.012	9.7	1.797	27.8	46.7	0.0	46.7	74.5	0.000	44.365	16.690	2.658
1	46	16004.10	4000.00	0.004	0.009	9.5	1.756	28.5	47.8	0.0	47.8	76.2	0.000	44.365	16.690	2.658
1	46	16004.10	7000.00	0.002	0.006	9.3	1.720	29.1	48.8	0.0	48.8	77.8	0.000	44.365	16.690	2.658
1	46	16004.10	9500.00	0.002	0.005	9.2	1.700	29.4	49.3	0.0	49.3	78.8	0.000	44.365	16.690	2.658
1	47	16005.30	1000.00	0.021	0.038	12.7	2.396	33.4	2.4	0.0	2.4	35.8	0.000	43.555	16.414	2.654
1	47	16005.30	2000.00	0.007	0.018	12.4	2.318	34.5	2.5	0.0	2.5	37.0	0.000	43.555	16.414	2.654
1	47	16005.30	4000.00	0.004	0.011	11.9	2.226	35.9	2.6	0.0	2.6	38.5	0.000	43.555	16.414	2.654
1	47	16005.30	7000.00	0.001	0.003	11.5	2.134	37.5	2.7	0.0	2.7	40.2	0.000	43.555	16.414	2.654
1	47	16005.30	9500.00	0.001	0.002	11.3	2.089	38.3	2.8	0.0	2.8	41.1	0.000	43.555	16.414	2.654
1	48	16006.10	1000.00	0.009	0.022	12.3	2.283	39.4	9.1	0.0	9.1	48.5	0.000	43.222	16.292	2.653
1	48	16006.10	2000.00	0.002	0.007	11.7	2.161	41.6	9.6	0.0	9.6	51.3	0.000	43.222	16.292	2.653
1	48	16006.10	4000.00	0.001	0.003	11.1	2.037	44.2	10.2	0.0	10.2	54.4	0.000	43.222	16.292	2.653
1	48	16006.10	7000.00	0.001	0.002	10.7	1.954	46.1	10.7	0.0	10.7	56.7	0.000	43.222	16.292	2.653
1	48	16006.10	9500.00	0.0005	0.001	10.6	1.926	46.7	10.8	0.0	10.8	57.5	0.000	43.222	16.292	2.653

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS
Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys		Porosity, percent PV	Pore Volume, cc	Water Saturation, percent PV	Uncorrected Oil Saturation, percent PV	Filtrate Saturation, percent PV	Corrected Oil Saturation, percent PV	Corrected Total Saturation, percent PV	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
				Klinkenberg @O.B.	to Air @O.B.	@O.B.	@O.B.	@O.B.	@O.B.	@O.B.	@O.B.	@O.B.				
1	49	16007.10	1000.00	0.004	0.010	10.3	1.887	42.4	11.4	0.0	11.4	53.8	0.000	43.710	16.468	2.654
1	49	16007.10	2000.00	0.004	0.008	9.9	1.808	44.2	11.9	0.0	11.9	56.2	0.000	43.710	16.468	2.654
1	49	16007.10	4000.00	0.001	0.002	9.5	1.738	46.0	12.4	0.0	12.4	58.4	0.000	43.710	16.468	2.654
1	49	16007.10	7000.00	0.001	0.002	9.2	1.675	47.8	12.9	0.0	12.9	60.6	0.000	43.710	16.468	2.654
1	49	16007.10	9500.00	0.0004	0.001	9.1	1.646	48.6	13.1	0.0	13.1	61.7	0.000	43.710	16.468	2.654
1	50	16008.20	1000.00	0.007	0.019	11.8	2.187	29.7	15.7	0.0	15.7	45.4	0.000	43.399	16.346	2.655
1	50	16008.20	2000.00	0.002	0.006	11.2	2.054	31.6	16.7	0.0	16.7	48.3	0.000	43.399	16.346	2.655
1	50	16008.20	4000.00	0.001	0.002	10.5	1.927	33.7	17.8	0.0	17.8	51.6	0.000	43.399	16.346	2.655
1	50	16008.20	7000.00	0.001	0.001	10.1	1.842	35.3	18.6	0.0	18.6	53.9	0.000	43.399	16.346	2.655
1	50	16008.20	9500.00	0.0004	0.001	10.0	1.811	35.9	19.0	0.0	19.0	54.8	0.000	43.399	16.346	2.655
1	51	16009.20	1000.00	0.010	0.023	10.0	1.835	54.5	12.5	0.0	12.5	67.0	0.000	43.747	16.480	2.655
1	51	16009.20	2000.00	0.002	0.007	8.7	1.562	64.0	14.6	0.0	14.6	78.7	0.000	43.747	16.480	2.655
1	51	16009.20	4000.00	0.001	0.003	7.7	1.379	72.5	16.6	0.0	16.6	89.1	0.000	43.747	16.480	2.655
1	51	16009.20	7000.00	0.001	0.002	7.4	1.326	75.4	17.2	0.0	17.2	92.6	0.000	43.747	16.480	2.655
1	51	16009.20	9500.00	0.001	0.001	7.4	1.320	75.8	17.3	0.0	17.3	93.1	0.000	43.747	16.480	2.655
1	52	16010.20	1000.00	0.017	0.033	11.9	2.204	52.2	6.2	0.0	6.2	58.4	0.000	43.322	16.321	2.654
1	52	16010.20	2000.00	0.007	0.021	11.7	2.153	53.4	6.4	0.0	6.4	59.8	0.000	43.322	16.321	2.654
1	52	16010.20	4000.00	0.005	0.015	11.3	2.083	55.2	6.6	0.0	6.6	61.8	0.000	43.322	16.321	2.654
1	52	16010.20	7000.00	0.005	0.012	11.0	2.023	56.8	6.8	0.0	6.8	63.7	0.000	43.322	16.321	2.654
1	52	16010.20	9500.00	0.003	0.010	10.9	1.997	57.6	6.9	0.0	6.9	64.5	0.000	43.322	16.321	2.654
1	53	16011.20	1000.00	0.022	0.041	11.7	2.159	41.7	13.3	0.0	13.3	55.0	0.000	43.457	16.374	2.654
1	53	16011.20	2000.00	0.008	0.023	11.2	2.072	43.4	13.9	0.0	13.9	57.3	0.000	43.457	16.374	2.654
1	53	16011.20	4000.00	0.005	0.015	10.8	1.987	45.3	14.5	0.0	14.5	59.8	0.000	43.457	16.374	2.654
1	53	16011.20	7000.00	0.005	0.012	10.6	1.938	46.4	14.8	0.0	14.8	61.3	0.000	43.457	16.374	2.654
1	53	16011.20	9500.00	0.004	0.009	10.5	1.917	47.0	15.0	0.0	15.0	61.9	0.000	43.457	16.374	2.654
1	54	16012.50	1000.00	0.011	0.022	11.0	2.039	41.7	11.3	0.0	11.3	53.0	0.000	44.096	16.566	2.662
1	54	16012.50	2000.00	0.005	0.017	10.6	1.956	43.5	11.8	0.0	11.8	55.2	0.000	44.096	16.566	2.662
1	54	16012.50	4000.00	0.003	0.008	10.2	1.873	45.4	12.3	0.0	12.3	57.6	0.000	44.096	16.566	2.662
1	54	16012.50	7000.00	0.003	0.006	9.9	1.825	46.6	12.6	0.0	12.6	59.2	0.000	44.096	16.566	2.662
1	54	16012.50	9500.00	0.003	0.006	9.8	1.804	47.1	12.7	0.0	12.7	59.9	0.000	44.096	16.566	2.662
1	55	16013.20	1000.00	0.016	0.030	11.1	2.079	46.6	12.0	0.0	12.0	58.6	0.000	44.099	16.571	2.661
1	55	16013.20	2000.00	0.007	0.023	10.7	1.987	48.8	12.5	0.0	12.5	61.4	0.000	44.099	16.571	2.661
1	55	16013.20	4000.00	0.004	0.009	10.3	1.901	51.0	13.1	0.0	13.1	64.1	0.000	44.099	16.571	2.661
1	55	16013.20	7000.00	0.003	0.008	10.1	1.856	52.3	13.4	0.0	13.4	65.7	0.000	44.099	16.571	2.661
1	55	16013.20	9500.00	0.003	0.008	10.0	1.839	52.7	13.5	0.0	13.5	66.3	0.000	44.099	16.571	2.661
1	56	16015.20	1000.00	0.020	0.037	11.4	2.114	49.7	15.8	0.0	15.8	65.5	0.000	43.710	16.399	2.665
1	56	16015.20	2000.00	0.006	0.019	11.0	2.027	51.8	16.5	0.0	16.5	68.3	0.000	43.710	16.399	2.665
1	56	16015.20	4000.00	0.005	0.015	10.6	1.944	54.0	17.2	0.0	17.2	71.2	0.000	43.710	16.399	2.665
1	56	16015.20	7000.00	0.004	0.009	10.4	1.902	55.2	17.6	0.0	17.6	72.8	0.000	43.710	16.399	2.665
1	56	16015.20	9500.00	0.003	0.008	10.3	1.888	55.6	17.7	0.0	17.7	73.3	0.000	43.710	16.399	2.665

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Horizontal Dean Stark Samples

Union Pacific Resources
Sidewinder # 1 H Well

File: DAL 99207

Core Number	Sample Number	Sample Depth, feet	Overburden Pressure, (O.B.) psi	Horizontal Permeability, millidarcys Klinkenberg @O.B.	Horizontal Permeability, millidarcys to Air @O.B.	Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Water Saturation, percent PV @O.B.	Uncorrected Oil Saturation, percent PV @O.B.	Filtrate Saturation, percent PV @O.B.	Corrected Oil Saturation, percent PV @O.B.	Corrected Total Saturation, percent PV @O.B.	Tracer Concentration, ppm	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
1	57	16017.20	1000.00	0.020	0.035	11.1	2.063	41.2	4.5	0.0	4.5	45.7	0.000	43.913	16.488	2.663
1	57	16017.20	2000.00	0.005	0.017	10.7	1.975	43.0	4.7	0.0	4.7	47.8	0.000	43.913	16.488	2.663
1	57	16017.20	4000.00	0.005	0.013	10.3	1.892	44.9	4.9	0.0	4.9	49.9	0.000	43.913	16.488	2.663
1	57	16017.20	7000.00	0.003	0.008	10.1	1.847	46.0	5.1	0.0	5.1	51.1	0.000	43.913	16.488	2.663
1	57	16017.20	9500.00	0.003	0.007	10.0	1.828	46.5	5.1	0.0	5.1	51.6	0.000	43.913	16.488	2.663

Table 8 continued

SUMMARY OF ROUTINE CORE ANALYSES RESULTS
Whole Core Dean Stark Samples
Humidity Dried

File: DAL-99207

Union Pacific Resources
Sidewinder # 1-H Well
Wyoming

Sample Number	Sample Depth, meters		Overburden Pressure, (O.B.) psi	Permeability to Air, millidarcys			Porosity, percent PV @O.B.	Pore Volume, cc @O.B.	Dry Weight, grams	Grain Volume, cc	Grain Density, gm/cc
	Top	Bottom		Vertical @O.B.	Kmax @O.B.	K90° @O.B.					
1W	15964.50	15965.00	1000.00	0.047	0.024	0.026	11.4	55.578	1157.100	431.367	2.682
			2000.00	0.043	0.021	0.022	10.3	49.708			
			4000.00	0.043	0.017	0.018	10.2	48.780			
			7000.00	0.042	0.015	0.015	10.0	47.869			
			9500.00	0.041	0.014	0.014	9.5	45.338			
2W	15970.50	15971.00	1000.00	0.054	0.021	0.022	10.1	50.868	1195.000	453.855	2.633
			2000.00	0.052	0.017	0.019	8.9	44.443			
			4000.00	0.047	0.014	0.015	8.5	42.375			
			7000.00	0.039	0.012	0.012	8.0	39.644			
			9500.00	0.034	0.010	0.014	7.7	37.976			
3W	15982.50	15983.00	1000.00	0.058	0.031	0.026	10.9	53.419	1164.000	436.012	2.670
			2000.00	0.053	0.025	0.022	9.8	47.619			
			4000.00	0.049	0.020	0.018	9.6	46.107			
			7000.00	0.048	0.017	0.015	9.3	44.459			
			9500.00	0.045	0.015	0.014	9.0	43.295			
4W	15991.50	15992.00	1000.00	0.049	0.026	0.027	10.9	56.853	1220.400	465.880	2.620
			2000.00	0.047	0.022	0.022	9.2	47.471			
			4000.00	0.045	0.018	0.018	9.1	46.915			
			7000.00	0.042	0.015	0.015	8.7	44.224			
			9500.00	0.041	0.014	0.014	8.5	43.332			
5W	16000.50	16001.00	1000.00	0.047	0.024	0.024	10.6	52.872	1182.200	447.560	2.641
			2000.00	0.047	0.021	0.019	9.1	44.899			
			4000.00	0.045	0.018	0.016	8.3	40.657			
			7000.00	0.045	0.015	0.013	8.1	39.283			
			9500.00	0.044	0.014	0.012	7.1	34.307			
6W	16009.50	16010.00	1000.00	0.053	0.023	0.019	10.5	53.834	1205.200	459.750	2.621
			2000.00	0.048	0.019	0.016	9.4	47.631			
			4000.00	0.045	0.015	0.013	8.2	41.002			
			7000.00	0.043	0.012	0.011	8.8	44.552			
			9500.00	0.043	0.011	0.010	8.6	43.186			

Core Laboratories

Table 9. Routine Core Analysis – whole core, Sidewinder #1-H, Core Labs.

X-RAY DIFFRACTION ANALYSIS

UNION PACIFIC RESOURCES SIDEWINDER #1 H

Mineralogical Content (Percent by Weight) Determined by X-Ray Diffraction Analysis

PLUG NO.	DEPTH	QUARTZ	PLAGIOCLASE	CHLORITE	ILLITE	ILLITE/ SMECTITE	CHLORITE/ SMECTITE	TOTAL SMECTITE	TOTAL CLAYS
2	15,960.1'	87.8	2.9	1.8	0.6	2.7 (20)	4.2 (32)	1.9	9.3
7	15,965.2'	87.9	3.2	1.5	0.5	2.9 (18)	4 (28)	1.6	8.9
11	15,969.1'	87.6	3.4	1.6	0.6	3.1 (20)	3.7 (30)	1.7	9
15	15,973.1'	88.7	2.8	1.6	0.5	3 (20)	3.4 (28)	1.6	8.5
18	15,976.1'	88.1	2.3	1.9	0.6	3.6 (18)	3.5 (26)	1.6	9.6
22	15,980.1'	87.7	2.8	1.8	0.6	3.4 (22)	3.7 (26)	1.7	9.5
26	15,984.2'	88.5	2.4	1.9	0.6	3.2 (18)	3.4 (28)	1.5	9.1
35	15,993.2'	89.5	2.7	2	0.7	2.3 (20)	2.8 (26)	1.2	7.8
40	15,998.1'	87.1	3.7	2.4	0.8	3.8 (22)	2.2 (26)	1.4	9.2
44	16002.1'	89.3	2.8	2.1	0.8	3.4 (18)	1.6 (26)	1.0	7.9
46	16004.1'	90.6	1.5	2.7	0.8	3.6 (18)	0.8 (26)	0.9	7.9
47	16005.4'	89.4	2.5	2.9	0.8	3.8 (18)	0.6 (26)	0.8	8.1
51	16009.2'	91.8	1.4	2	0.9	3.1 (18)	0.8 (26)	0.8	6.8
56	16015.2'	88.1	3	3.7	0.9	3.5 (18)	0.8 (26)	0.8	8.9

Numbers in parentheses indicate percent smectite in the mixed-layer clay
Total smectite is smectite from the mixed-layer clays.

Standard Geological Services, Inc.

Table 10. XRD Analysis, Sidewinder #1-H, Standard Geological.

X-RAY DIFFRACTION ANALYSIS

UNION PACIFIC RESOURCES SIDEWINDER #1 H

Mineralogical Content (Percent by Weight) Determined by X-Ray Diffraction Analysis

PLUG NO.	DEPTH	QUARTZ	PLAGIOCLASE	CHLORITE	ILLITE	ILLITE/ SMECTITE	CHLORITE/ SMECTITE	TOTAL SMECTITE	TOTAL CLAYS
2	15,960.1'	87.8	2.9	1.8	0.6	2.7 (20)	4.2 (32)	1.9	9.3
7	15,965.2'	87.9	3.2	1.5	0.5	2.9 (18)	4 (28)	1.6	8.9
11	15,969.1'	87.6	3.4	1.6	0.6	3.1 (20)	3.7 (30)	1.7	9
15	15,973.1'	88.7	2.8	1.6	0.5	3 (20)	3.4 (28)	1.6	8.5
18	15,976.1'	88.1	2.3	1.9	0.6	3.6 (18)	3.5 (26)	1.6	9.6
22	15,980.1'	87.7	2.8	1.8	0.6	3.4 (22)	3.7 (26)	1.7	9.5
26	15,984.2'	88.5	2.4	1.9	0.6	3.2 (18)	3.4 (28)	1.5	9.1
35	15,993.2'	89.5	2.7	2	0.7	2.3 (20)	2.8 (26)	1.2	7.8
40	15,998.1'	87.1	3.7	2.4	0.8	3.8 (22)	2.2 (26)	1.4	9.2
44	16002.1'	89.3	2.8	2.1	0.8	3.4 (18)	1.6 (26)	1.0	7.9
46	16004.1'	90.6	1.5	2.7	0.8	3.6 (18)	0.8 (26)	0.9	7.9
47	16005.4'	89.4	2.5	2.9	0.8	3.8 (18)	0.6 (26)	0.8	8.1
51	16009.2'	91.8	1.4	2	0.9	3.1 (18)	0.8 (26)	0.8	6.8
56	16015.2'	88.1	3	3.7	0.9	3.5 (18)	0.8 (26)	0.8	8.9

Numbers in parentheses indicate percent smectite in the mixed-layer clay
Total smectite is smectite from the mixed-layer clays.

Standard Geological Services, Inc.

Table 10 continued

Sidewinder Unit 1H Horizontal Core Fracture Orientations Joe Fultner & John Lorenz 12-6-99

*fracture depth measured from its intersection with the top of core, all fracture and slickenside measurements are in degrees

B = pyrobitumen; Q = quartz, K = kaolinite, C = calcite, V=vertical

where present quartz druze appears to underlie the other mineralization

Number	Depth	Strike	Dip	Mineralization	Movement	Comments
1	15973.87	102	80S	K B Q	left-lateral oblique	faint slickensides indicate movement
2	15975.12	69	~V	K B Q	left-lateral oblique	rake on pronounced slicks on main fracture is 45 pointing down to the WSW, a second partially healed fracture bifurcates dipping ~70S, this fracture is partially open with ~1mm aperture and is lined with Q druze
3	15976.2	109	85S	K B Q patchy C	left-lateral oblique	slicks rake down 25 to W, one patch of calcite ~ .25 inches in diameter
4	15976.5	89	~V	C possible other	?	healed fracture, intact rock, minor splays suggest left-lateral movement
5	15977.4	96	~V	K Q	?	hint of en echelon movement
6	15978.12	106	~V	K	none	no apparent movement, no Q B or C why?
7	15979.22	95	~V	K	none	"
8	15979.5	102	~V	K	none	"
9	15980.33	100	~V	K B	none	
10	15985.2				?	~ 1 inch of core missing, probably was a natural fracture here, but evidence is gone
11	15985.9	119	~V	B		partially healed fracture
12	15986			B Q	?	Zone of wispy mares tails, black-highlighted, irregular planes within the rock. Local small 1mm openings with Q crystals. Black planes are curved in several places and they join and split.
13	15986.55	97	85N	K B Q	?	rough fracture face, bifurcations off main fracture, drilling or handling induced fracture crosses this area, chips of core missing
14	15986.65	110	~V	K B Q	?	rough fracture face, chips of core missing
15	15993.5	99	72S	K B Q	vertical	faint suggestion of vertical movement
16	15994	99	~V	Q	none	irregular fracture face
17	15997.5	104	70S	K B Q	left-lateral oblique	slicks rake down 78 to E, Q druze in hollows, left-lateral movement suggested, not definite
18	15999.43			B K Q	near vertical	zone of partially open healed fractures oriented roughly E-W, lined with Q druze openings as great as 2mm aperture. One shows slicks, near vertical, rake of 85 pointing down to E, south side is down. Area is hard to describe, a picture is worth a thousand words.
19	16001.12	103	80N	K B Q	vertical	One fracture has Q druze under B and patchy K, with vertical slicks, zone of multiple mares tails, black-highlighted planes
20	16003.33	~100		Q	suggestion of V	fault breccia zone >= 1.5 cm thick, hint of vertical striations on one face, mm scale breccia that is glued together by a cement of acicular Q crystals. Q mineralization post dates shearing?

Table 11. Fracture Characterization of Sidewinder #1-H core, J Fultner and J Lorenz.

Sidewinder Unit 1H Horizontal Core Fracture Orientations Joe Fultner & John Lorenz 12-6-99						
*fracture depth measured from its intersection with the top of core, all fracture and slickenside measurements are in degrees						
B = pyrobitumen; Q = quartz, K = kaolinite, C = calcite, V=vertical						
where present quartz druze appears to underlie the other mineralization						
Number	Depth	Strike	Dip	Mineralization	Movement	Comments
1	15973.87	102	80S	K B Q	left-lateral oblique	faint slickensides indicate movement
2	15975.12	69	~V	K B Q	left-lateral oblique	rake on pronounced slicks on main fracture is 45 pointing down to the WSW, a second partially healed fracture bifurcates dipping ~70S, this fracture is partially open with ~1mm aperture and is lined with Q druze
3	15976.2	109	85S	K B Q patchy C	left-lateral oblique	slicks rake down 25 to W, one patch of calcite ~ .25 inches in diameter
4	15976.5	89	~V	C possible other	?	healed fracture, intact rock, minor splays suggest left-lateral movement
5	15977 4	96	~V	K Q	?	hint of en echelon movement
6	15978.12	106	~V	K	none	no apparent movement, no Q B or C why?
7	15979.22	95	~V	K	none	"
8	15979.5	102	~V	K	none	"
9	15980.33	100	~V	K B	none	
10	15985.2				?	~ 1 inch of core missing, probably was a natural fracture here, but evidence is gone
11	15985.9	119	~V	B		partially healed fracture
12	15986			B Q	?	Zone of wispy mares tails, black-highlighted, irregular planes within the rock. Local small 1mm openings with Q crystals. Black planes are curved in several places and they join and split.
13	15986.55	97	85N	K B Q	?	rough fracture face, bifurcations off main fracture, drilling or handling induced fracture crosses this area, chips of core missing
14	15986.65	110	~V	K B Q	?	rough fracture face, chips of core missing
15	15993.5	99	72S	K B Q	vertical	faint suggestion of vertical movement
16	15994	99	~V	Q	none	irregular fracture face
17	15997.5	104	70S	K B Q	left-lateral oblique	slicks rake down 78 to E, Q druze in hollows, left-lateral movement suggested, not definite
18	15999.43			B K Q	near vertical	zone of partially open healed fractures oriented roughly E-W, lined with Q druze openings as great as 2mm aperture. One shows slicks, near vertical, rake of 85 pointing down to E, south side is down. Area is hard to describe, a picture is worth a thousand words.
19	16001.12	103	80N	K B Q	vertical	One fracture has Q druze under B and patchy K, with vertical slicks, zone of multiple mares tails, black-highlighted planes
20	16003.33	~100		Q	suggestion of V	fault breccia zone >= 1.5 cm thick, hint of vertical striations on one face, mm scale breccia that is glued together by a cement of acicular Q crystals. Q mineralization post dates shearing?

Table 11 continued

21	16003.75	~100		K Q	?		1.5 cm wide zone that strikes parallel to the shear zone above, partially healed with open apertures to 3mm suggests offset
22	16005.19	107	75N	K? B Q C	none		intersection of E-W & N-S fracture, E-W fracture shows no movement, well developed Q druze with possible K on top,< dime size patch of C on top of Q & located at intersection with N-S fracture
23	16005.19	350	50E	Q	none		healed fracture no suggestion of movement, this is the only N-S striking fracture in the core
24	16005.55	102	87N	K	none		partially healed fracture openings to 2mm
25	16005.6	109	87N	K	none		very thick K >= 2mm
26	16005.75	101	81N	K	none		
27	16006.25	105	84N	K Q	none		some Q overlain by K
28	16006.75	109	89N	K Q	none		"
29	16007	103	~V	?	?		intact rock 2-3 interconnected healed fractures
30	16007 42	95	~V	?	?		healed
31	16008.65	94	85S	B K Q	none		
32	16010.45	103	~V	K Q	none		rough surface no apparent offset
33	16012	~E-W	~V	B K Q	possible V		zone ~5 inches wide with a swarm of 5-6 interconnected crossing and bifurcating partially healed fractures, most in intact rock, some open apertures, one opening >3mm, strikes hard to ascertain, but strikes appear to range from < 90 to > 120
34	16012.12	89	85N	K Q & unidentified	possible V		unhealed fracture in the middle of above swarm, suggestion of possible vertical slicks, blue-gray unidentified clay like material coating fracture face
35	16013	104	~V	K Q	none		2 closely spaced parallel fractures
36	16013.9	92	~V	Q	?		intersected by induced fractures
37	16014	?	?	B Q	?		~1 ft. wide rubble zone, core was shattered by torque when breaking free of formation, examination of the rubble reveals multiple partially healed fractures, impossible to decipher strike or dip, some fractures have open aperture < .5 mm, some fractures have brown euhedral Q and others have clear euhedral Q, Clear Q
38	16016	?	?	Q	?		4 inch wide rubble shatter zone with at least one fracture
39	16016.83	89	~V	?	?		healed fracture
40	16017	?	?	K	?		~ 1ft. Wide rubble shatter zone at least one fracture with K

Table 11 continued

21	16003.75	~100		K Q	?		1.5 cm wide zone that strikes parallel to the shear zone above, partially healed with open apertures to 3mm suggests offset
22	16005.19	107	75N	K? B Q C	none		intersection of E-W & N-S fracture, E-W fracture shows no movement, well developed Q druze with possible K on top,< dime size patch of C on top of Q & located at intersection with N-S fracture
23	16005.19	350	50E	Q	none		healed fracture no suggestion of movement, this is the only N-S striking fracture in the core
24	16005.55	102	87N	K	none		partially healed fracture openings to 2mm
25	16005.6	109	87N	K	none		very thick K >= 2mm
26	16005.75	101	81N	K	none		
27	16006.25	105	84N	K Q	none		some Q overlain by K
28	16006.75	109	89N	K Q	none		"
29	16007	103	~V	?	?		intact rock 2-3 interconnected healed fractures
30	16007.42	95	~V	?	?		healed
31	16008.65	94	85S	B K Q	none		
32	16010.45	103	~V	K Q	none		rough surface no apparent offset
33	16012	~E-W	~V	B K Q	possible V		zone ~5 inches wide with a swarm of 5-6 interconnected crossing and bifurcating partially healed fractures, most in intact rock, some open apertures, one opening >3mm, strikes hard to ascertain, but strikes appear to range from < 90 to > 120
34	16012.12	89	85N	K Q & unidentified	possible V		unhealed fracture in the middle of above swarm, suggestion of possible vertical slicks, blue-gray unidentified clay like material coating fracture face
35	16013	104	~V	K Q	none		2 closely spaced parallel fractures
36	16013.9	92	~V	Q	?		intersected by induced fractures
37	16014	?	?	B Q	?		~1 ft. wide rubble zone, core was shattered by torque when breaking free of formation, examination of the rubble reveals multiple partially healed fractures, impossible to decipher strike or dip, some fractures have open aperture < .5 mm, some fractures have brown euhedral Q and others have clear euhedral Q, Clear Q
38	16016	?	?	Q	?		4 inch wide rubble shatter zone with at least one fracture
39	16016.83	89	~V	?	?		healed fracture
40	16017	?	?	K	?		~ 1ft. Wide rubble shatter zone at least one fracture with K

Table 11 continued