QUARTERLY TECHNICAL PROGRESS REPORT
FOR THE PERIOD ENDING MARCH 31 2006

TITLE: ANALYSIS OF CRITICAL PERMEABLITY, CAPILLARY PRESSURE AND ELECTRICAL PROPERTIES FOR MESAVERDE TIGHT GAS SANDSTONES FROM WESTERN U.S. BASINS

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DISCLAIMER:

ABSTRACT:

Progress is reported for the period from January 1, 2006 to March 31, 2006. Currently work has been performed on Tasks 3, 4, and 8. Industry has shown great interest in the project and willingness to participate through contribution of core. A comprehensive sample database of Mesaverde lithofacies across the study region has been collected. To date a total of 824 core plugs have been obtained from 38 wells. . The wells sampled are widely geographically distributed across the five principal basins of the study area. The numbers of samples within each basin are appropriately distributed: Wind River75, Green River-184, Washakie-100, Uinta-192, Piceance-175, Washakie/Sand Wash-14, and Powder River-40. Intervals sampled in wells represent the range of lithofacies and porosity exhibited by the Mesaverde in these wells. Core plugs from recently drilled wells are continuing to be contributed by industry partners. Of the 824 core plugs obtained 739 have been lithologically characterized and 494 digital images of core have been obtained. All core intervals and samples collected for petrophysical analysis were classified using the five number digital classification (e.g. 12345) which encodes grain size/sorting, consolidation, sedimentary structure, and mineralogy of pore filling materials. On-going basic properties measurements indicate that permeability of the Mesaverde sandstones analyzed to date comprise the better range of permeabilities, at any given porosity, for the Mesaverde/Frontier trend previously reported. Core collection, and basic analysis will proceed through the next quarter and electrical measurement s will continue.

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INTRODUCTION

Objectives - Industry assessment of the regional gas resource, projection of future gas supply, and exploration programs require an understanding of the reservoir properties and accurate tools for formation evaluation of drilled wells. The goal of this project is to provide petrophysical formation evaluation tools related to relative permeability, capillary pressure, electrical properties and algorithm tools for wireline log analysis. Major aspects of the proposed study involve a series of tasks to measure drainage critical gas saturation, capillary pressure, electrical properties and how these change with basic properties such as porosity, permeability, and lithofacies for tight gas sandstones of the Mesaverde Group from five major Tight Gas Sandstone basins (Washakie, Uinta, Piceance, Upper Greater Green River, and Wind River). Critical gas saturation (Sgc) and ambient and *in situ* capillary pressure (Pc) will be performed on 150 rocks selected to represent the range of lithofacies, porosity and permeability in the Mesaverde.

Project Task Overview -

Task 1. Research Management Plan
Task 2. Technology Status Assessment
Task 3. Acquire Data and Materials
- Subtask 3.1. Compile published advanced properties data
- Subtask 3.2. Compile representative lithofacies core and logs from major basins
- Subtask 3.3. Acquire logs from sample wells and digitize

Task 4. Measure Rock Properties
- Subtask 4.1. Measure basic properties (k, ϕ, grain density) and select advanced population
- Subtask 4.2. Measure critical gas saturation
- Subtask 4.3. Measure in situ and routine capillary pressure
- Subtask 4.4. Measure electrical properties
- Subtask 4.5. Measure geologic and petrologic properties
- Subtask 4.6. Perform standard logs analysis

Task 5. Build Database and Web-based Rock Catalog
- Subtask 5.1. Compile published and measured data into Oracle database
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Task 6. Analyze Wireline-log Signature and Analysis Algorithms
- Subtask 6.1. Compare log and core properties
- Subtask 6.2. Evaluate results and determine log-analysis algorithm inputs

Task 7. Simulate Scale-dependence of Relative Permeability
- Subtask 7.1. Construct basic bedform architecture simulation models
- Subtask 7.2. Perform numerical simulation of flow for basic bedform architectures

Task 8. Technology Transfer, Reporting, and Project Management
- Subtask 8.1 Technology Transfer
- Subtask 8.2. Reporting Requirements
- Subtask 8.3. Project Management

EXECUTIVE SUMMARY:

Industry has shown great interest in the project and willingness to participate through contribution of core. A comprehensive sample database of Mesaverde lithofacies across the study region has been collected. To date a total of 824 core plugs have been obtained from 34 wells. . The wells sampled to date are widely geographically distributed across the five principal basins of the study area. The numbers of samples within each basin are appropriately distributed: Wind River75, Green River-184, Washakie-100, Uinta-192, Piceance-175, Washakie/Sand Wash-14, and Powder River-40 (Figure 1). Intervals sampled in wells represent the range of lithofacies and porosity exhibited by the Mesaverde in these wells. Core plugs from recently drilled wells are continuing to be contributed by industry partners. Of the 824 core plugs obtained 739 have been lithologically characterized and 494 digital images of core have been obtained. All core intervals and samples collected for petrophysical analysis were classified using the five number digital classification (e.g. 12345) reported by Cluff, Byrnes, and Webb (1994) which encodes grain size/sorting, consolidation, sedimentary structure, and mineralogy of pore filling materials. On-going basic properties measurements indicate that permeability of the Mesaverde sandstones analyzed to date comprise the better range of permeabilities, at any given porosity, for the Mesaverde/Frontier trend previously reported (Byrnes, 1997).

RESULTS AND DISCUSSION:

TASK 3. ACQUIRE DATA AND MATERIALS

Subtask 3.1. Compile published advanced properties data

Approximately 350 references relevant to low-permeability sandstones and Mesaverde have been obtained. Government publications are still being located and obtained. Relevant data in these publications is being entered into a database either from tables in the publication or is being interpreted from figures.

Subtask 3.2. Compile representative lithofacies core and logs from major basins

Table 1 lists U.S. Geological Survey (U.S.G.S.) Core Research Center and Industry Participant wells from which core plugs have been obtained. A total of 824 core plugs have been obtained from 38 wells. The wells sampled to date are widely geographically distributed across the five principal basins of the study area. The numbers of samples within each basin are appropriately distributed: Wind River75, Green River-184, Washakie-100, Uinta-192, Piceance-175, Washakie/Sand Wash-14, and Powder River-40 (Figure 1). Intervals sampled in wells represent the range of lithofacies and porosity exhibited by the Mesaverde in these wells. Core plugs from recently drilled wells are continuing to be contributed by industry partners. Because of drilling schedules, fresh core will continue to be submitted through the next quarter and some core may be submitted in the third quarter. Analysis is proceeding on received cores and cores arriving later will placed in the analysis workflow.

Core samples range in depth from 124-16,723 ft (m; Figure 3). The distribution for the sample depths is shown in Figure 2 and reflects the approximate complete range in depth of the Mesaverde for the basins studied. Within the Piceance and Uinta basins further sampling is planned to obtain deeper samples that were not obtained. The present core sample set (n=824) is significantly greater than proposed in the work plan (n=300). This increase was considered warranted given the lithofacies and depth range exhibited during well sampling. The additional sampling is being accommodated within the allocated budget by additional in-kind effort.

Table 1. Summary of wells sampled and number of samples. Basins abbreviations: GR- Green River, P-Piceance, PR-Powder River, U-Uinta, WR-Wind River, W-SW-Washakie-Sand Wash, W – Washakie.

BASIN	API #	OPERATOR	FIELD	WELL NAME	TWN		RNG		SEC	COUNTY	ST	SMPL
WR	049-013-20724	BROWN TOM INC		31-22 TRIBAL PHILLIPS	4	N	3	E	31	FREMONT	WY	6
WR	049-013-20786	MICH WISC PIPELINE	LYSITE	1-9 LYSITE	38	N	91	W	9	FREMONT	WY	34
WR	049-013-20966	MONSANTO OIL	MADDEN	1-27 LOOKOUT	38	N	91	W	1	FREMONT	WY	20
WR	049-013-20836	MONSANTO OIL	MADDEN	2-1 CHEVRON	39	N	91	W	27	FREMONT	WY	15
PR	049-009-05481	BELCO PETROLEUM	FLAT TOP	3 SHAWNEE	33	N	69	W	23	CONVERSE	WY	7
PR	049-009-21513	DAVIS OIL COMPANY	MIKES DRAW	2 FRED STATE	35	N	70	W	36	CONVERSE	WY	10
PR	049-005-25627	LOUISIANA LAND & EXP	BRIDGE DRAW	1 BARLOW 21-20	48	N	75	W	20	CAMPBELL	WY	22
GR	049-037-05349	HUMBLE OIL & REF		B-2A SPIDER CREEK	18	N	110	W	27	SWEETWATER	WY	10
GR	049-035-20622	AMERICAN HUNTER EXPL	WILDCAT	1 OLD ROAD	27	N	108	W	27	SUBLETTE	WY	19
GR	049-035-05742	BELCO PETROLEUM	TIP TOP SHALLOW	C-47 TIP TOP SHALLOW	28	N	113	W	22	SUBLETTE	WY	14
GR	049-035-06020	BELCO PETROLEUM	BIG PINEY	B-54 BIG PINEY	29	N	113	W	26	SUBLETTE	WY	19
GR	049-013-08024	EL PASO NATURAL GAS	PINEDALE	5 PINEDALE	30	N	108	W	5	SUBLETTE	WY	15
GR	049-035-06200	BELCO PETROLEUM	MASON	K-2 MASON	31	N	113	W	13	SUBLETTE	WY	8
GR	049-035-20088	INEXCO OIL COMPANY	MERNA	A-1 WASP	36	N	112	W	28	SUBLETTE	WY	109
W	049-007-21170	FUEL RESOURCES DEV	SAVERY	C-11 /FEE	12	N	90	W	11	CARBON	WY	1
W	049-037-21075	AMOCO PRODUCTION	WILD ROSE	1 CHAMPLIN 237 AMOCO C	17	N	94	W	5	SWEETWATER	WY	18
W	049-037-05405	MOUNTAIN FUEL SUPPLY	CHIMNEY ROCK	1 CHIMNEY ROCK	18	N	102	W	12	SWEETWATER	WY	1
W	049-037-	FOREST OIL CORP	PATRICK DRAW	102-7-10 ARCH UNIT	19	N	98	W	7	SWEETWATER	WY	9
W	049-037-05683	FOREST OIL CORP	PATRICK DRAW	65-1-7 ARCH UNIT	19	N	99	W	1	SWEETWATER	WY	14
W	049-037-21053	AMOCO PRODUCTION	FIVE MILE GULCH	3 UNIT	21	N	93	W	35	SWEETWATER	WY	49
W	049-037-23956	AMOCO PRODUCTION	SIBERIA RIDGE	5-2 SIBERIA RIDGE UNIT	21	N	94	W	5	SWEETWATER	WY	8
W-SW	005-081-06718	COCKRELL OIL CORP	WEST CRAIG	1-691-0513	6	N	91	W	5	MOFFAT	CO	8
W-SW	005-081-06724	COCKRELL OIL CORP	CRAIG DOME	1-791-2613	7	N	91	W	26	MOFFAT	CO	6
P	005-103-09406	FUEL RESOURCES DEV	WHITE RIVER DOME	M-30-2-96W /D-037934	2	N	96	W	30	RIO BLANCO	CO	15
P	005-103-	WESTERN FUELS ASSOC	LOWER WHITE RIVER	21011-5 MOON LAKE	2	N	101	W	1	RIO BLANCO	CO	10
P	005-045-060011	CER CORPORATION	RULISON	MWX-2 SUPERIOR	6	S	94	W	34	GARFIELD	CO	74
P	--	WILLIAMS		PA 424 -34	6	S	95	W	34	GARFIELD	CO	36
P	005-045-06578	BARRETT ENERGY	GRAND VALLEY	MV 24-20 CHEVRON	6	S	96	W	20	GARFIELD	CO	11
P	--	BILL BARRETT CORP.	MAMM CREEK	LAST DANCE 43C-3-792	7	S	92	W	3	GARFIELD	CO	53
P	005-045-	USGS-CG		1 BOOK CLIFFS-DRILL HOLE	7	S	104	W	17	GARFIELD	CO	11
U	043-047-30584	MAPCO INCOPORATED	NATURAL BUTTES	11-17F RIVER BEND UNIT	10	S	20	E	17	UINTAH	UT	14
U	--	KERR-MCGEE	NATURAL BUTTES	NBU 1022-1A	10	S	22	E	1	UINTAH	UT	52
U	043-047-30545	ENSERCH EXPLORATION	BONANZA	2-7 FLAT MESA FEDERAL	10	S	23	E	7	UINTAH	UT	90
U	043-047-30584	ENSERCH EXPLORATION	AGENCY DRAW	4-5 US LAMCO	13	S	20	E	5	UINTAH	UT	12
U	043-047-30860	CHAMPLIN PETROLEUM		3-24 US LAMCO	13	S	20	E	24	UINTAH	UT	7
U	043-019-	USGS-CG		3 BOOK CLIFFS	17	S	24	E	3	GRAND	UT	11
U	043-019-	USGS-CG		4 BOOK CLIFFS	17	S	24	E	31	GRAND	UT	6

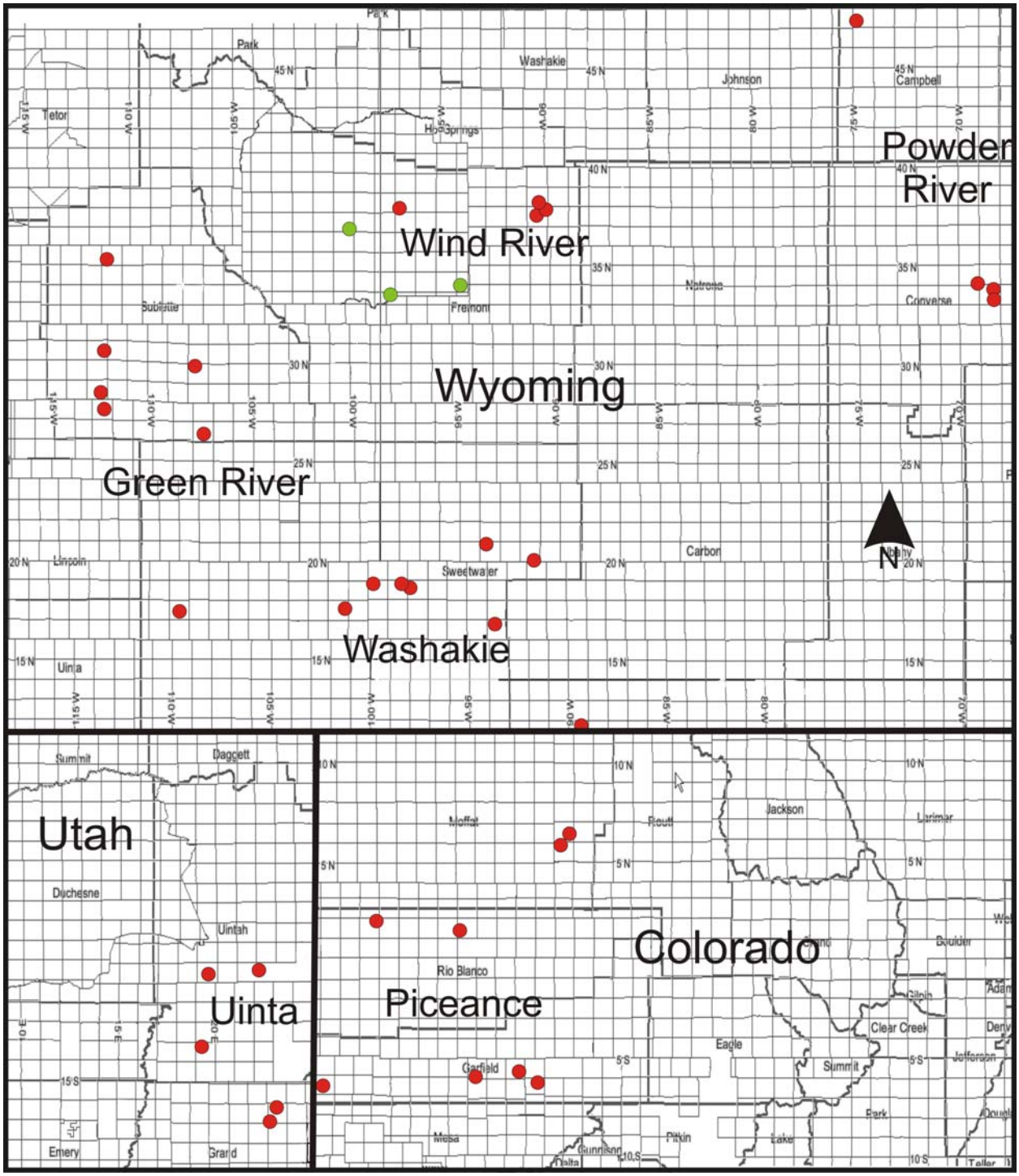

Figure 1. Well locations for sampled wells listed in Table 1.

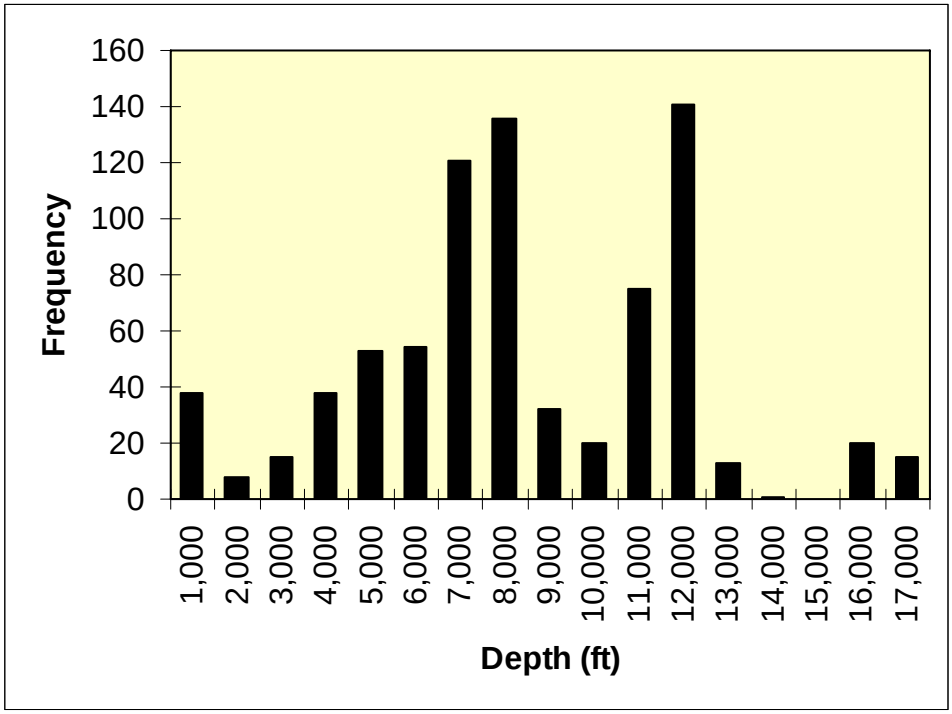

Figure 3. Frequency distribution histogram of sample depths for all core samples (n=824) representing the approximate range of Mesaverde depths in the basins studied.

Subtask 3.3. Acquire logs from sample wells and digitize

Logs have been obtained for many of the wells for which core plugs were obtained. The remaining logs are being obtained.

TASK 4. MEASURE ROCK PROPERTIES

Subtask 4.1. Measure basic properties (k, ϕ, grain density) and select advanced population

As noted, the present core sample set (n=824) is significantly greater than the proposed sample set (n=300). This has required greater time than planned for sample collection and sample preparation. Measurement of basic properties has continued on core plugs obtained in the first quarter and early in the second quarter. The remainder of the core plugs have been prepared for analysis (cut, dried, caliper dimensions, weight). Comparison of measured *in situ* Klinkenberg permeability versus routine porosity (Figure 4) shows that the present sample population exhibits higher permeability than the previously published Mesaverde/Frontier dataset (Byrnes 1997). This is due partially to the absence of argillaceous Frontier samples and due to the high fraction of less argillaceous sandstones in the analyzed sample set to date.

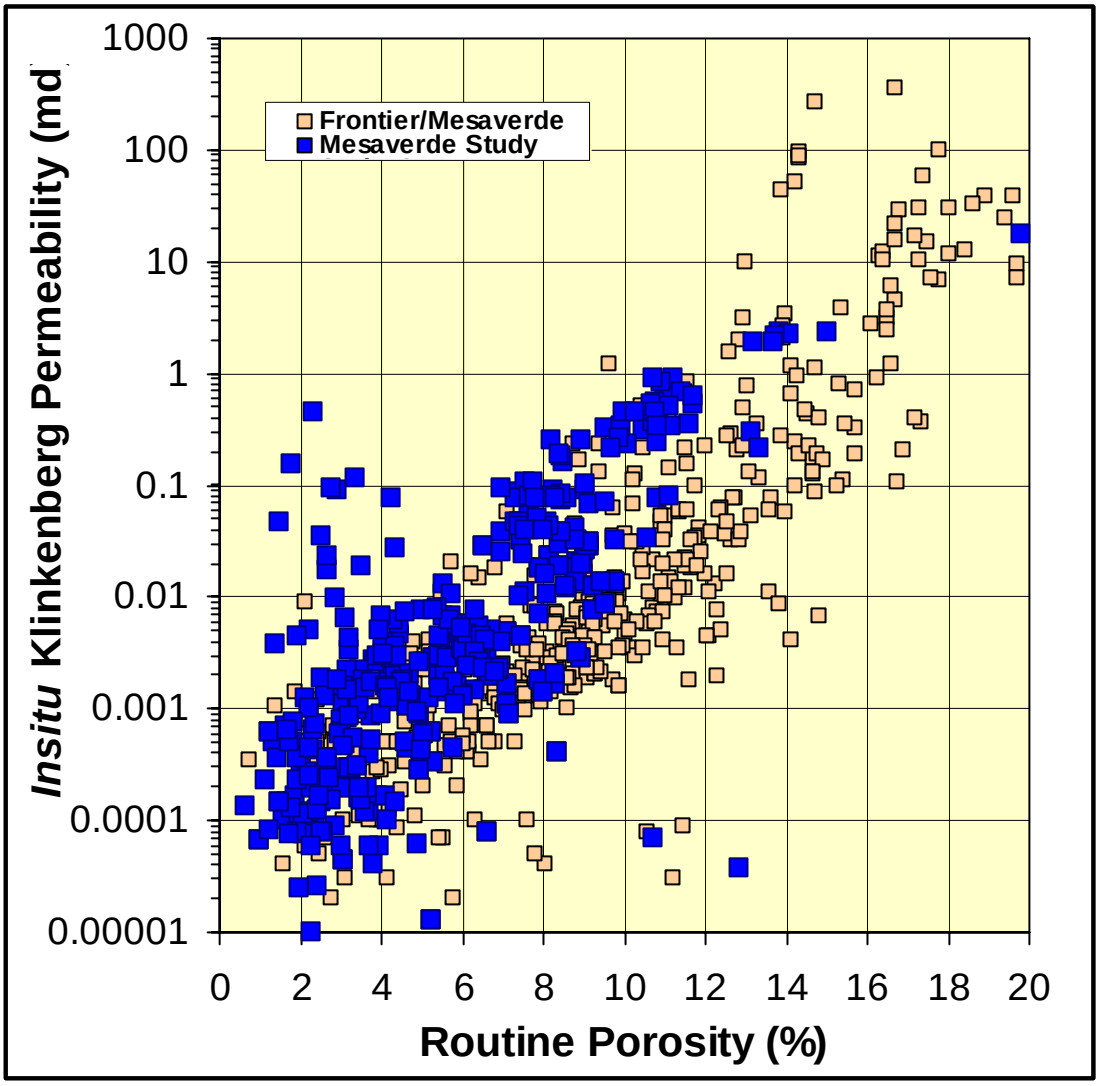

Figure 4. Crossplot of i*n situ* Klinkenberg permeability versus routine helium porosity for samples in present Mesaverde study and for previously published Mesaverde/Frontier samples (Byrnes, 1997). Present study samples exhibit similar trend though permeabilities are generally better at any given porosity. This is interpreted result from the absence of argillaceous Frontier samples in the present sample set.

Subtask 4.5. Measure geologic and petrologic properties

Of the 824 core plugs obtained 739 have been lithologically characterized. All core intervals and samples collected for petrophysical analysis were classified using a five number digital code (e.g. 12345) reported by Cluff, Byrnes, and Webb (1994) which encodes grain size/sorting, consolidation, sedimentary structure, and mineralogy of pore filling materials (Table 2). This system allows accurate lithologic characterization and digital integration of lithologic variables with petrophysical variables. The fine grained intervals of the Mesaverde Group are dominated by mudstones and silty shales (rock types 10x19 and 11x29), lenticular and wavy bedded very shaly sandstones (12x3x and 12x4x), and wavy bedded to ripple cross-laminated shaly sandstones (13x4x and 13x6x). The sandstone intervals of the Mesaverde Group are dominated by ripple cross-laminated and cross-bedded, very fine to fine grained sandstones (rock types

14x6x, 14x7x), low angle cross-laminated to planar laminated sandstones (14x8x), and massive sandstones (14x9x). Medium grained sandstones are mostly restricted to the Upper Almond (15x7x and 15x9x. The rock classification system used is objective and independent of any interpretations of depositional environments or stratigraphic position.

Table 2. Basic macroscopic rock description digital classification system showing digits of relevance to present study.

MAJOR GROUPS

0xxxx Organic rocks (coals, etc.)
1xxxx Siliciclastic rocks

SECOND DIGIT: Grain size, sorting, texture

10xxx Shales
11xxx Silty shales (60-90% clay)
12xxx Siltstones or very shaly sandstones (40-65% clay and silt)
13xxx Moderately shaly sandstones (10-40% clay and silt)
14xxx Sandstones, fine to very fine
15xxx Sandstones, medium
16xxx Sandstones, coarse

THIRD DIGIT: Degree of consolidation or cementation

1x0xx Totally cemented, dense, hard, unfractured
1x1xx Dense, fractured
1x2xx Well indurated, mod-low porosity (3-10%), unfractured
1x3xx Well indurated, mod-low porosity (3-10%), fractured
1x4xx Well indurated, mod-low porosity (3-10%), highly fractured
1x5xx Indurated, mod-high porosity (>10%), unfractured
1x6xx Indurated, mod-high porosity (>10%), fractured
1x7xx Indurated, mod-high porosity (>10%), highly fractured
1x8xx Poorly indurated, high-v. high porosity, soft
1x9xx Unconsolidated sediment

FOURTH DIGIT: Primary sedimentary structures

1xx0x Vertical perm barriers, shale dikes, cemented vert. fractures
1xx1x Churned/bioturbated to burrow mottled (small scale)
1xx2x Convolute, slumped, large burrow mottled bedding (large scale)
1xx3x Lenticular bedded, discontinuous sand/silt lenses
1xx4x Wavy bedded, continuous sand/silt and mud layers
1xx5x Flaser bedded, discontinuous mud layers
1xx6x Small scale (< 4 cm) x-laminated, ripple x-lam, small scale hummocky x-bd
1xx7x Large scale (> 4 cm) trough or planar x-bedded
1xx8x Planar laminated or very low angle x-beds, large scale hummocky x-bd
1xx9x Massive, structureless

FIFTH DIGIT: Dominant cementation or pore filling mineral

1xxx0 Sulfide pore filling (RhoG=3.85-5.0)
1xxx1 Siderite (RhoG=3.89)
1xxx2 Phosphate (RhoG=3.13-3.21)
1xxx3 Anhydrite or Gypsum (RhoG=2.98 or 2.35)
1xxx4 Dolomite (RhoG=2.89)
1xxx5 Calcite (RhoG=2.71)
1xxx6 Quartz (RhoG=2.65)
1xxx7 Authigenic clay (RhoG=2.12-2.76)
1xxx8 Carbonaceous debris (RhoG= 2.0)
1xxx9 No pore filling material or detrital clay filled intergranular voids

Using the five-digit classification system Figure 5 shows the distribution of the grain size/sorting (digit 2) for the 824 core samples.

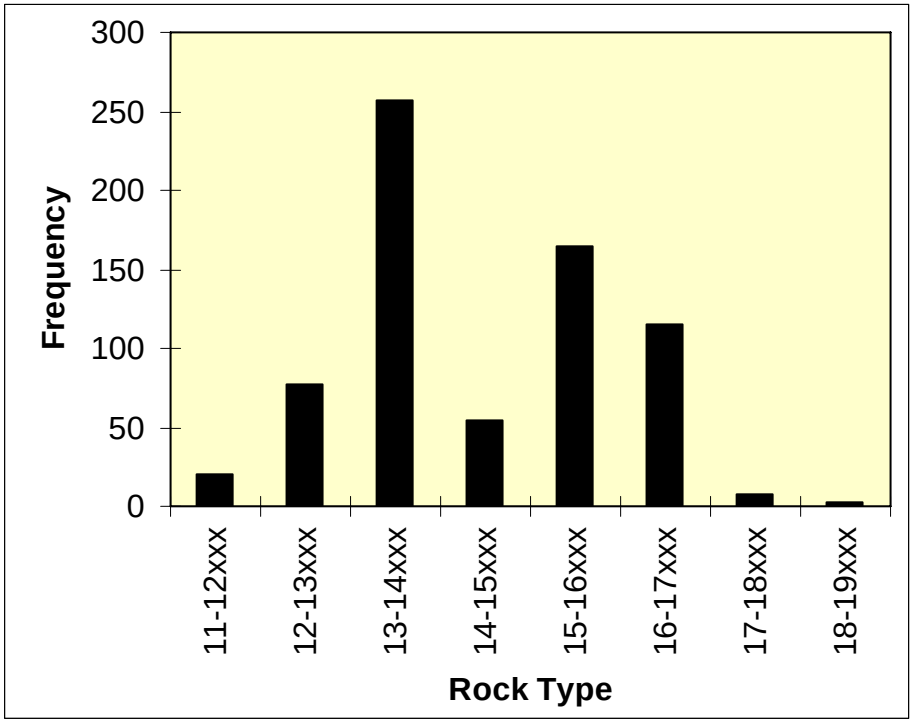

Figure 5. Frequency distribution histogram of grain size/sorting characteristic (digit 2) for all 824 core samples collected to date.

Figure 6 illustrates some of the lithofacies present in the Mesaverde sampled. To date 494 full-diameter core images have been obtained. There are less images than samples because for some full-diameter cores multiple core plug samples were taken representing either multiple samples of similar lithofacies form a given core or multiple samples of different lithofacies from a given core interval shown on one image. In addition, a few full-diameter cores were not slabbed and images are not available for these wells. The core images are being loaded into a database for on-line access.

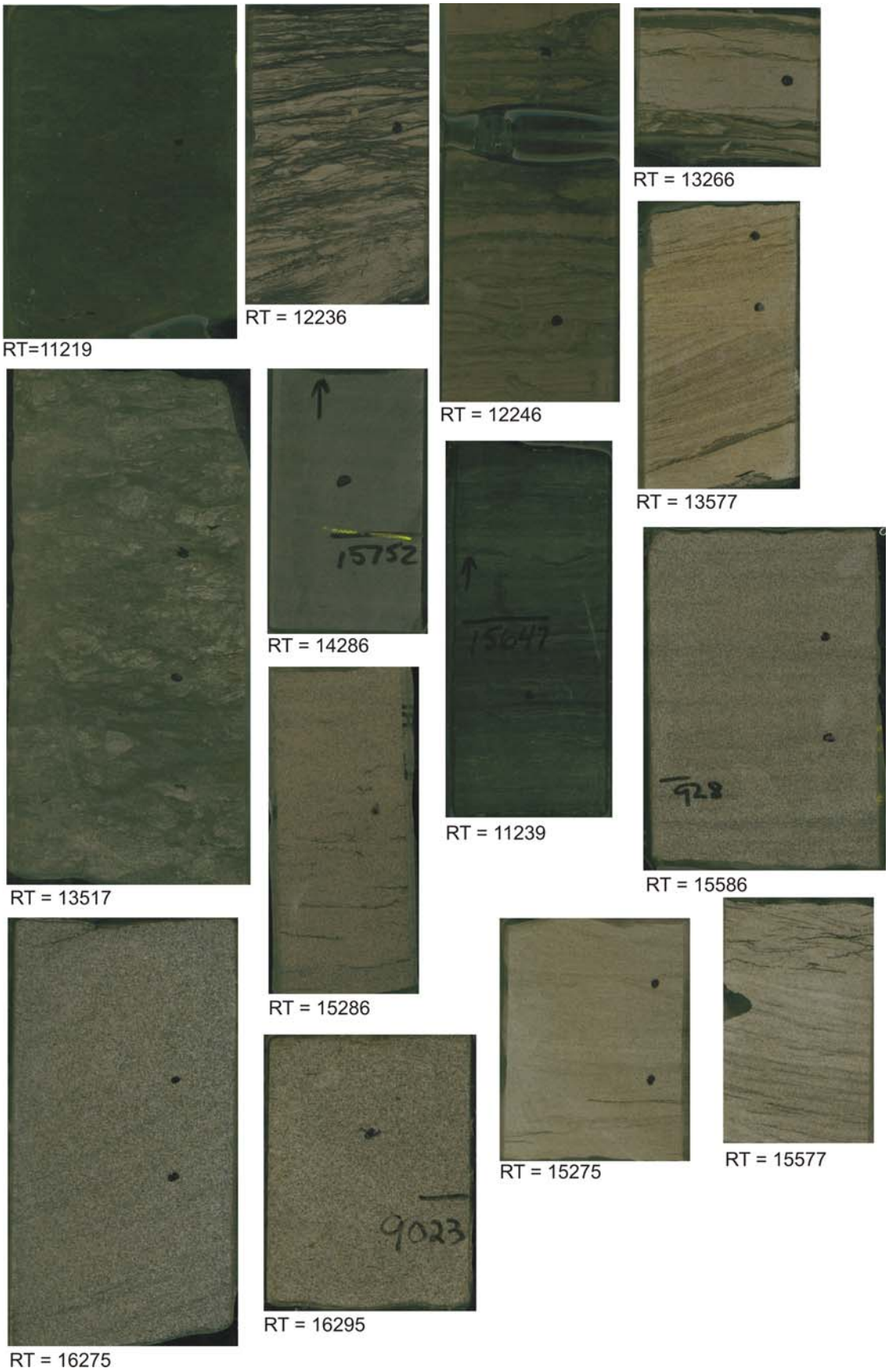

Figure 6. Example Mesaverde lithofacies with rock type digital classification.

TASK 8. TECHNOLOGY TRANSFER, REPORTING, PROJECT MANAGEMENT

Subtask 8.1 Technology Transfer

A Powerpoint presentation was created to present to companies to inform them of the project and request participation through contribution of newly-obtained fresh core. Presentations were made to major and independent gas industry companies to solicit participation directly through contribution of core and indirectly through review of activities and methods and results. Presentations were made in both Denver, CO and Houston, TX. Companies that have contributed core to date include Kerr-McGee, Bill Barrett Corp., and Williams Gas. Companies that are interested in contributing core and with which arrangements are being made to obtain core include; Exxon-Mobil, BP Exploration and Production, Inc., Shell Exploration and Production, Encana, Endurance Resources, and Questar Corp.

CONCLUSIONS

Industry has shown great interest in the project and willingness to participate through contribution of core. Because several industry participants wish to contribute core that will be taken in Spring 2006, the sampling plan has extended the period over which core material will be obtained. A comprehensive sample library of Mesaverde core plugs representing a wide range of lithofacies distributed across the study region has been compiled. Examination of the lithofacies present in the sample database indicates that the Mesaverde exhibits similar fluvial, coastal, and marine lithofacies across the study region. Permeability-porosity relationships are likely to be regionally robust. On-going basic properties measurements, electrical properties and capillary pressure will provide data to examine the role of lithofacies on petrophysical properties.

REFERENCES

Byrnes, A.P., 1997, Reservoir characteristics of low permeability sandstones in the Rocky Mountains, The Mountain Geologist, v. 34, no. 1, p. 39-51.

Cluff, R.M., Byrnes, A.P., and Webb, J.C., 1994, Rock-petrophysics-log correlation in the Mesaverde group, Washakie basin; Proceedings American Association of Petroleum Geologists Annual Convention, June 12-15, Denver, CO, p. 122.