THE BDM CORPORATION
EDA McLAIN NO. 18-22 WELL
UPSHUR CO., WEST VIRGINIA

VOLUME I
CORE ANALYSES AND VISIBLE LIGHT PHOTOGRAPHS

Performed by:

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VOLUME I
PART I

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SECTION 1

INTRODUCTION

Laboratory analyses were performed on four silty shale samples taken from the Eda McLain No. 18-22 well, Upshur County, West Virginia. Analyses included slabbing, visible light photography, petrography, geochemistry, physical properties, and gas permeability. Gas permeability was measured at elevated stresses representative of in-situ reservoir conditions. Physical properties included grain density, porosity, and water saturation.

Analytic results are presented here in two separate volumes. Volume I (Part I) contains physical properties data, gas permeability data, and photographs of the slabbed core. These data were obtained in testing performed at Core Research, Mountain View, California. Volume II (Parts II and III) contain results of the geochemical and petrographic analyses. These analyses included thin section petrography, scanning electron microscopy, kerogen identification and vitrinite reflectance. These results were obtained from work performed by Core Laboratories, Inc., Dallas.

SECTION 2

SUMMARY OF RESULTS

Well Name:	Eda McLain No. 18-22		
Location:	Upshur County, West Virginia		
Sample Type:	Semipreserved plugs		
Lithology:	Silty shale		
Sample Depths:	I.D. No.	Depth (ft)	
	EM 18-22-1	7137.10	
	EM 18-22-2	7141.72	
	EM 18-22-3	7147.70	
	EM 18-22-4	7153.40	
Analyses Requested and Performed:	Helium porosity, grain density, gas permeability, and water saturation (gravimetric)		
Results:	*Porosity Range:	9 to 13 percent	
	Grain Density Range:	2.59 to 2.69 g/cc	
	Equilibrium Water Saturation Range:	6 to 12 percent	
	Permeability Range:	Net Stress 1:	0.197 to 4.97 μd
		Net Stress 2:	0.145 μd
		Net Stress 3:	No measurment made. See text for explanation.

See Section 4 for all tabulated results.

* Measured using toluene saturation method on irregularly shaped samples. See text for explanation.

SECTION 3
TEST PROCEDURES

Core Sample Preparation

Six semi-preserved whole cores were received and slabbed lengthwise to expose flat vertical faces. One slab of each core was photographed for lithologic description. Samples for vitrinite reflectance data were taken from the 3/4-inch slabs. Plugs, 1-1/2 inches in diameter, were taken from the slabbed core. These plugs were taken perpendicular to the long axis of core and therefore were horizontally oriented. Core preparation was performed using liquid nitrogen as a cooling fluid. Because of the shaley lithology, some fracturing of the samples occurred during plugging. The fractures were usually associated with the fissile bedding planes within the shale and prevented accurate measurement of length and diameter. All samples were carefully handled to minimize dessication during the analytical program.

Archimedes Porosity Measurement

Plug samples were vacuum oven dried at 40°C until weights were constant to within 0.01g/24 hr. Weight change of the preserved core, together with water density data, was used to calculate as received water saturation. Samples were cooled to 25°C in a desiccator and then porosity was determined by measuring pore volume and bulk volume. These measurements were made using toluene as the saturating fluid and measuring saturated and buoyant weights. The equations used are:

$$V_b = W_s\text{-}W_b/\rho_t$$
$$V_p = W_s\text{-}W_d/\rho_t$$

where V_b = bulk volume (cc)

V_p = pore volume (cc)

W_s = saturated weight (g)

W_b = buoyant weight (g)

W_d = dry weight (g)

ρ_t = density of toluene (g/cc)

Gas Permeability Measurement

After measurement of basic physical properties, plug samples were placed in a humidity oven at 60°C and 45 percent relative humidity until sample weights were constant to within 0.01g/24 hr. Weight gain in the samples was used to calculate equilibrium water saturation. The plugs were then installed in the gas permeameter and gas permeability was measured at specified stress conditions using a transient pulse decay technique. The three net stress conditions used in these measurements were chosen as 0.5, 1.0, and 1.6 times the reservoir overburden stress assuming overburden stress equal to 1 psi per foot of depth. Because of the fractured nature of the samples, it was necessary to epoxy individual chips together in order to perform this measurement. The resulting samples were pseudorectangular in shape. A length and width for each were used in calculating the 'diameter' (length * width = area = $(\pi/4)D^2$). These less than ideal samples imposed a significant constraint on our ability to measure permeability. On one sample (from 7137.1 feet) it was not possible to perform this measurement. This is discussed in greater detail in Section 5.

SECTION 4

TEST RESULTS

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TABLE 4-1. SUMMARY OF PHYSICAL PROPERTIES

Eda McLain No. 18-22 Well
Upshur County, West Virginia

Sample I.D.	Depth (ft)	Grain Density (g/cc)	Bulk Density, As Received (g/cc)	Porosity, Bench Conditions (%)	As Received Water Saturation (%)	As Tested[1] Water Saturation (%)
EM 18-22-1	7137.10	2.64	2.20	11.7	54	*
EM 18-22-2	7141.72	2.61	2.18	9.4	70	7
EM 18-22-3	7147.70	2.60	2.27	8.6	51	12
EM 18-22-4	7153.40	2.59	2.23	13.1	53	6

[1]Water saturation at time of gas permeability measurements. Please refer to text.

*Unable to measure due to poor sample quality.

TABLE 4-2. EFFECTIVE GAS PERMEABILITY AS A FUNCTION OF STRESS
(As tested water saturation data are given in Table 4-1)

Well Name: Eda McLain No. 18-22
Location: Upshur County, West Virginia

Sample I.D.	Sample Depth (ft)	Gas Permeability (μd) Net Stress (psi)		
		3553	7105	11,600
EM 18-22-1	7137.10	*	*	*
EM 18-22-2	7141.72	**	**	**
EM 18-22-3	7147.70	0.197	0.145	5.13^{+}
EM 18-22-4	7153.40	4.97^{++}	**	**

*Unable to measure due to poor sample quality.

**Permeability was below the lower limit of the permeameter.

$^{+}$See Section 5 for explanation.

$^{++}$Probably represents sample fracturing.

SECTION 5

DISCUSSION

Physical Properties

Porosity of the four core samples ranged from 8 to 13 percent. Porosity measurements were somewhat problematic because of the irregular shape, fissile lithology and fractured nature of the samples. Several different methods were used to determine porosity, including helium gas expansion, mercury immersion and toluene saturation (archimedes method). The archimedes method was used for the final data reduction. Because of the problems associated with these samples the results should be used with caution. Grain density ranged from 2.59 to 2.64 g/cc. Obviously these variations in grain density reflect minor mineralogic heterogeneity. For example, the sample with the highest grain density had the largest amount of pyrite and metamorphic rock fragments. Please refer to Part II of this report for details of sample composition.

As received water saturation of these semi-preserved samples ranged from 51 to 70 percent. Because of the core retrieval and preservation techniques used, these saturation values are not necessarily representative of actual reservoir saturations. Equilibrium water saturation, obtained by humidity oven treatment of the vacuum dried samples, ranged from 6 to 12 percent. Gas permeability was measured while the samples were at this equilibrium saturation. All water saturation data are expressed as percent of sample pore volume.

Gas Permeability

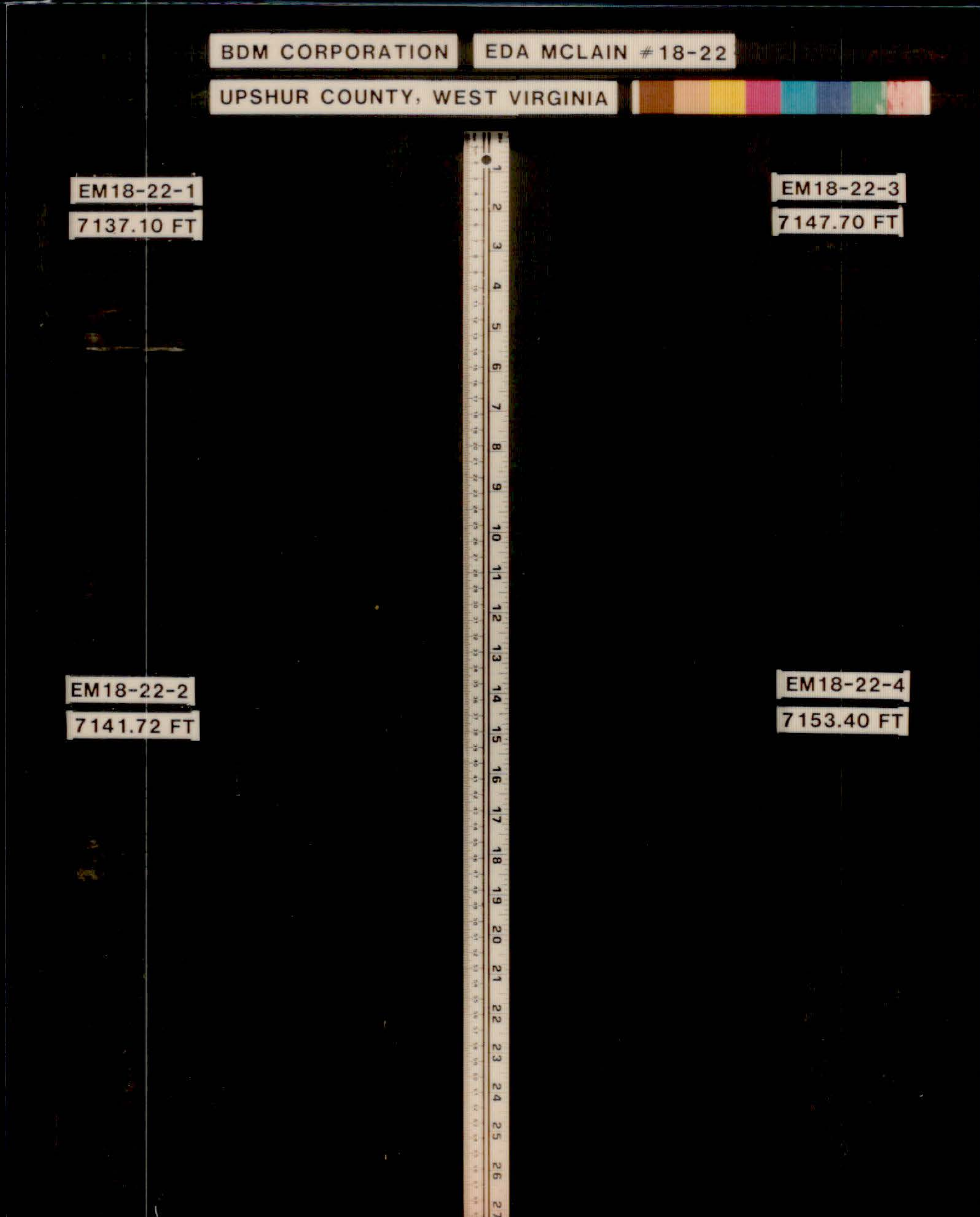
Of the three samples tested, only the sample from 7147.7 feet had a permeability of gas above the lower limit of resolution of the permeameter (about 20 nanodarcies). This sample measured 0.197 μd at a net pressure of 3553 psi and decreased to 0.145 μd at a net pressure of 7105 psi (see Table 4-2). At the highest net stress (11,600 psi), a measurement of 5.13 μd was recorded. This value is probably due to fractures that developed in the epoxy coating or between the epoxy and the rock with increasing stress. It should not be considered representative of the matrix permeability.

The sample from 7153.4 feet measured 4.91 μd at the lowest net stress. As stress was increased, permeability declined to below the resolution of the permeameter. The measured value of 4.91 μd probably represents fracture permeability. With increasing stress these fractures closed and permeability decreased to below the 20 nanodarcy cutoff. The sample from 7141.72 feet had permeability below the resolution of the permeameter at the lowest net stress.

The fragmented nature of the subject samples required special jacketting techniques. As with the porosity measurements, the irregular sample shape, small size, and fractured lithology all contribute to difficulty in making meaningful measurements. The reported values, therefore, should be interpreted with caution.

SECTION 6

CORE PHOTOGRAPH


BDM CORPORATION
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