

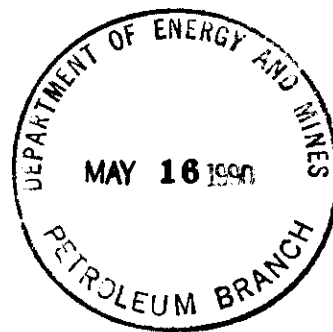


## Chevron Canada Resources

500 - Fifth Avenue S.W., Calgary, Alberta T2P 0L7  
Phone (403) 234-5000 Fax (403) 234-5947

D.M. Clementz  
Manager, Engineering

1990-05-11



### Special Core Analysis Lodgepole Formation

Department of Energy and Mines  
Petroleum Branch  
555 - 330 Graham Avenue  
Winnipeg, Manitoba  
R3C 4E3

Attention: Mr. L. R. Dubreuil  
Director

Gentlemen:

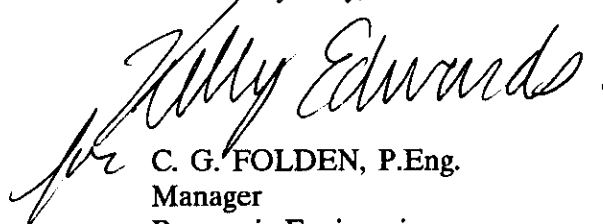
Enclosed are two copies of a special core analysis study carried out on preserved Lodgepole core from the following wells:

Chevron Virden Prov. 13C-24-11-26 W1M  
Chevron Virden 1D-26-11-26 W1M

Tests included wettability, capillary pressure, relative permeability, and compressibility measurements.

Please contact Mr. Kelly Edwards at (403) 234-5388 if you have any questions regarding the study.

Yours very truly,

  
C. G. FOLDEN, P.Eng.  
Manager  
Reservoir Engineering

KAE/kt  
Enclosure

NEW FILE  
VIRDEN LODGEPOLE  
A POOL  
SPECIAL CORE  
ANALYSIS



**Western Atlas  
International**

A Litton/Dresser Company

**CORE  
LABORATORIES**

SPECIAL CORE ANALYSIS STUDY  
FOR  
**CHEVRON CANADA RESOURCES**

Chevron Virden Prov 13C-24-11-26 W1M  
Chevron Virden 1D-26-11-26 W1M  
Lodgepole Formation  
Manitoba

FILE NUMBER: 52132-89-83

DATE: 1990 03 20



## CORE LABORATORIES

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1990 03 20

Chevron Canada Resources  
500 - 5th Avenue S.W.  
Calgary, Alberta  
T2P 0L7

Attention: Mr. Scott Robinson

Subject: Special Core Analysis Study  
Chevron Virden Prov 13C-24-11-26 WLM  
Chevron Virden 1D-26-11-26 WLM  
File Number: 52132-89-83

Gentlemen:

The Special Core Analysis Department of Core Laboratories is pleased to present results of a study performed on core samples representing the Lodgepole Formation of the subject wells. Tests include:

1. Permeabilities to Brine
2. Combined Amott/USBM Wettability
3. Air-Water Centrifuge Capillary Pressure
4. Oil-Water Centrifuge Capillary Pressure
5. Unsteady-State Water-Oil Relative Permeability
6. Steady-State Water-Oil Relative Permeability
7. Rock (Pore Volume) Compressibility
8. Interfacial Tension Measurement

A discussion of analytical procedures and the test results follow this letter. The Interfacial Tension Measurement of crude oil was performed in our Dallas lab and results are appended to this report.

We appreciate the opportunity to be of service to Chevron Canada Resources. Should you have any questions or if we may be of further assistance, please do not hesitate to contact us.

Yours truly,

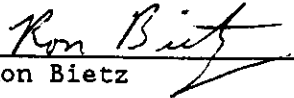
CORE LABORATORIES

Norman Gruber, P.Eng.  
Supervisor, Advanced Core Analysis

CG/nb  
Enclosures

PROGRAM PARTICIPANTS

Laboratory Measurements and Data Review

  
Ron Bietz

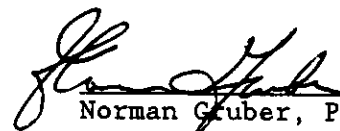
  
Art Lui

  
Dexter Woo

Report Preparation and Review

  
Cheryl Garand

Final Review

  
Norman Gruber, P.Eng.

### INTRODUCTION

In August of 1989, the Special Core Analysis Department was instructed to perform analyses on core material from the subject wells. The tests were authorized by Mr. Scott Robinson of Chevron and include Permeability to Brine, Amott/USBM Wettability, Centrifuge Capillary Pressure, Relative Permeability and Rock (Pore Volume) Compressibility. An Interfacial Tension Measurement of crude oil from the North Scallion Unit #1 well was also performed in our Dallas, Texas facility.

The requested study has now been completed and the results are presented in final form. This report contains data previously submitted in preliminary reports. Any revisions to the preliminary data have been made to correct errors and/or to provide more accurate interpretation of the test results.

## SPECIAL CORE ANALYSIS PROCEDURES

### Sample and Fluid Preparation

With the exception of sample drilling, the plugs used in this study were prepared in accordance with Chevron's ACCUPERM Procedure. The ACCUPERM Procedure specifies that plugs be drilled from preserved core using refined oil as the bit lubricant and coolant. Unfortunately, the instructions were received after the 25 mm and 31 mm diameter plugs had already been drilled from the brine preserved core using our standard lab brine. As indicated by the ACCUPERM Procedure, the plugs were cleaned by miscible flushing of toluene then methanol over two cycles. Each solvent in each cycle was flowed until the effluent was colorless. This was performed in a hydrostatic core holder at a requested net overburden pressure of 7 450 kPa. While maintaining the net confining stress, the methanol was displaced with simulated formation brine and stable permeabilities were measured. Results are reported herein and samples preceded by an asterisk indicate those not used for subsequent analysis. It should be pointed out that several samples had measured permeabilities to oil at irreducible water saturation equal to or higher than the permeabilities to 100 percent brine. This suggests that possibly sample dissolution was occurring or perhaps the ACCUPERM procedure did not fully clean the samples.

On August 15, 1989, Mr. Scott Robinson selected six of the plugs for additional tests. Permeability to air and porosity values were determined upon completion of their respective testing, cleaning and drying processes. The petrophysical properties along with lithological descriptions have been provided for the six test plugs.

The test fluids used in this study were simulated formation brine and refined mineral oil. As instructed, the 1.7 mPa.s mineral oil was filtered through silica gel and alumina prior to use in the tests. The simulated brine was prepared from a submitted water analysis of the Calstan Scallion Prov. 3-11-11-26 W1M well. The simulated brine contained approximately 140 740 ppm total dissolved solids. Both the analysis and simulated brine composition are presented in this report. Although not used in testing, a water analysis of the Chevron Virden 10-26-11-26 W1M well is also included.

#### Amott/USBM Wettability Test

An Amott/USBM Wettability Test was performed on sample SCA-4/1-26 at 27°C. The brine saturated plug was initially flushed to immobile water saturation with the 1.7 mPa.s filtered, mineral oil and an effective permeability was measured. The sample was then placed in a calibrated imbibition container filled with simulated brine and allowed to imbibe brine spontaneously. After spontaneous imbibition ceased, the brine filled receptacle containing the sample was placed in the high-speed centrifuge apparatus and the water-displacing-oil cycle was performed. The sample was spun non-stop at rates of rotation that were incrementally increased until a corresponding pressure of approximately 107 kPa was achieved. Sufficient time was allowed at each rate of rotation for an equilibrium condition to be attained within the plug. The amount of oil displaced at each rate was recorded.

For the next cycle, the sample was placed in a calibrated receptacle filled with oil and allowed to imbibe oil spontaneously. The sample was then centrifuged under oil to complete the oil-displacing-water cycle. As before, sufficient time was allowed at each speed for sample equilibrium and the amount of fluid displaced was monitored.

The Amott Wettability Index is the ratio of the volume of spontaneous oil or water imbibition to the total mobile volume of oil or water imbibed. A wettability index of 1.0 indicates strongly wet by the imbibed fluid whereas 0.0 indicates non-wetting by the imbibed fluid. At the time of testing in the laboratory, the sample performed in a strong water-wet manner.

The USBM method for determining wettability utilizes the drainage and imbibition centrifuge data. Average water saturations for both cycles were calculated from the volume of fluid displaced at each rotational speed. The average water saturation versus pressure was plotted for both cycles. The area under each curve was planimetered and the logarithm of the area ratio was calculated. The resulting USBM wettability index of 0.824 indicates a strong water-wet condition.

#### Air-Water Centrifuge Capillary Pressure

After the Amott/USBM Wettability test, sample SCA-4/1-26 was resaturated with simulated formation brine in preparation for an Air-Water Centrifuge Capillary Pressure test at 27°C. The sample was loaded into the high-speed centrifuge apparatus and spun non-stop at rates of rotation which were increased incrementally to generate equivalent capillary pressures ranging from 6 kPa to 2 000 kPa in an air-displacing-brine system. Fluid saturations were calculated after an equilibrium condition was attained at each rate.



#### Oil-Water Centrifuge Capillary Pressure

Oil-Water Centrifuge Capillary Pressure Tests were performed on samples SCA-5/13-24 and SCA-1/1-26. The tests were performed at 27°C using simulated formation brine and filtered mineral oil. The plugs were centrifuged under oil at seven increasing rates of rotation which gave equivalent capillary pressures ranging from 6 kPa to 700 kPa in an oil-water system.

It is interesting to note that all three Centrifuge Capillary Pressure tests yielded extremely low irreducible water saturations, in the range of 3 to 6 percent. This is quite unusual in light of the fact that the Wettability test indicated a strongly water-wet condition. Low irreducible water saturations were also obtained on the two Steady-State Relative Permeability tests.

#### Unsteady-State Water-Oil Relative Permeability

After the special cleaning and permeability to brine measurement, sample SCA-8/13-24 was subjected to an Unsteady-State Water-Oil Relative Permeability Test at room temperature. The saturated plug was flushed to immobile brine saturation with filtered mineral oil and an effective permeability to oil was determined. The oil was then displaced with simulated brine and volumes of each effluent fluid were determined at measured time intervals. Since all the oil was produced at the beginning of the flood, incremental test data is not available. A summary or end-point test data has been provided.

#### Steady-State Water-Oil Relative Permeability

Water-Oil Relative Permeability Tests were performed on samples SCA-7A/13-24 and SCA-2/1-26 in the steady-state apparatus at room temperature. The plugs were flushed to immobile brine saturation with mineral oil and effective permeabilities to oil were measured. The steady-state tests were performed using several water-oil ratios in the imbibition, water saturation increasing, direction. The oil and water flow rates were monitored during testing and subsequently used to calculate the relative permeability data.

#### Rock (Pore Volume) Compressibility

After the steady-state relative permeability test, sample SCA-2/1-26 was prepared for a Rock (Pore Volume) Compressibility Test. The core plug and end-stems were encased in shrinkable plastic tubing, placed in a hydrostatic core holder and saturated with brine. External and internal pressures, resulting in effective overburden pressures ranging from 2 000 kPa to 68 000 kPa, were applied in measured increments to the sample. At each equilibrium pressure, the quantity of brine forced out of the pore space was measured. Matrix failure started to occur in the plug at 49 000 kPa net overburden pressure.

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

IDENTIFICATION OF SAMPLES

<u>SAMPLE NUMBER</u>	<u>DEPTH, METRES</u>	<u>PERMEABILITY TO AIR, MILLIDARCYS</u>	<u>POROSITY, FRACTION</u>	<u>GRAIN DENSITY kg/m<sup>3</sup></u>	<u>LITHOLOGICAL DESCRIPTION</u>
<u>Chevron Virden Prov 13C-24-11-26 W1M</u>					
SCA-5/13-24	608.60	26.8	0.104	2700	LS: lt brn, wkst/grst, intgran & p.p. por
SCA-7A/13-24	609.14	13.4	0.126	2710	LS: lt brn-bu, grst, com foss frags, com p.p. & sml vugs
SCA-8/13-24	609.92	6.44	0.097	2690	LS: lt brn-bu, grst, abd p.p. & loc sml vugs, foss frags
<u>Chevron Virden 1D-26-11-26 W1M</u>					
SCA-1/1-26	595.68	21.7	0.102	2690	LS: lt brn-bu, grst, com p.p. & sml vugs, loc foss frags
SCA-2/1-26	595.98	28.3	0.118	2670	LS: lt brn-bu, grst w/ com foss frags(crin), p.p. & sml vugs
SCA-4/1-26	598.09	42.2	0.159	2690	LS: lt brn-bu, grst, com p.p. & loc sml vugs, foss frags

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SIMULATED BRINE COMPOSITION

<u>CONSTITUENTS</u>	<u>CONCENTRATION, mg/L</u>
Sodium Chloride (NaCl)	109 232
Potassium Chloride (KCl)	898
Calcium Chloride (CaCl <sub>2</sub> )	17 429
Magnesium Chloride (MgCl <sub>2</sub> .6H <sub>2</sub> O)	6 681
Sodium Bicarbonate (NaHCO <sub>3</sub> )	737
Sodium Sulphate (Na <sub>2</sub> SO <sub>4</sub> )	5 761

The brine composition was prepared from the following analysis:

COMPANY California Standard Company  
WELL Calstan Scallion Prov. 3-11-11-26  
LOCATION LSD 3-11-11-26 W1M

FORMATION  
FIELD Roselen  
PROVINCE Manitoba

<u>CONSTITUENTS</u>	<u>CONCENTRATION mg/L</u>
Sodium and	
Potassium	45 507
Calcium	4 752
Magnesium	799

<u>CONSTITUENTS</u>	<u>CONCENTRATION mg/L</u>
Chloride	77.75
Bicarbonate	535
Sulphate	3 896

## WATER ANALYSIS

Plastic CONTAINER IDENTITY		Chevron Canada Resources OPERATOR		LABORATORY NUMBER	
LSD 10-26-11-26 WLM LOCATION		Chevron Virden 10-26-11-26 WELL OR SAMPLE LOCATION NAME		PAGE	
Virden, Manitoba FIELD OR AREA				KB ELEV. (m) GR ELEV. (m)	
		POOL OR ZONE		SAMPLER	
TEST TYPE & NO.		TEST RECOVERY			
		POINT OF SAMPLE		@ °C	
		PUMPING FLOWING		MUD RESISTIVITY	
		WATER m <sup>3</sup> /d OIL m <sup>3</sup> /d GAS m <sup>3</sup> /d		SWAB	
TEST INTERVALS (metres)					
SEPARATOR		RESERVOIR		CONTAINER WHEN SAMPLED @ °C	
				CONTAINER WHEN RECEIVED @ °C	
PRESSURES, kPa (gauge)				TEMPERATURES, °C	
DATE SAMPLED (Y/M/D)		DATE RECEIVED (Y/M/D)		DATE ANALYZED (Y/M/D)	
89 09 27		89 09 29		LS	
				ANALYST	
				REMARKS	

CATIONS				ANIONS			
ION	mg/L	mg Fraction	MEQ/L	ION	mg/L	mg Fraction	MEQ/L
Na	56500	.3624	2457.6	Cl	91236	.5852	2573.4
K	592	.0038	15.1	Br			
Ca	2584	.0166	128.9	I			
Mg	837	.0054	68.8	HCO <sub>3</sub>	353	.0023	5.8
Ba				SO <sub>4</sub>	3805	.0244	79.3
Sr				CO <sub>3</sub>	0	.0000	0.0
Fe	Present			OH	0	.0000	0.0
				H <sub>2</sub> S	Not Detected		

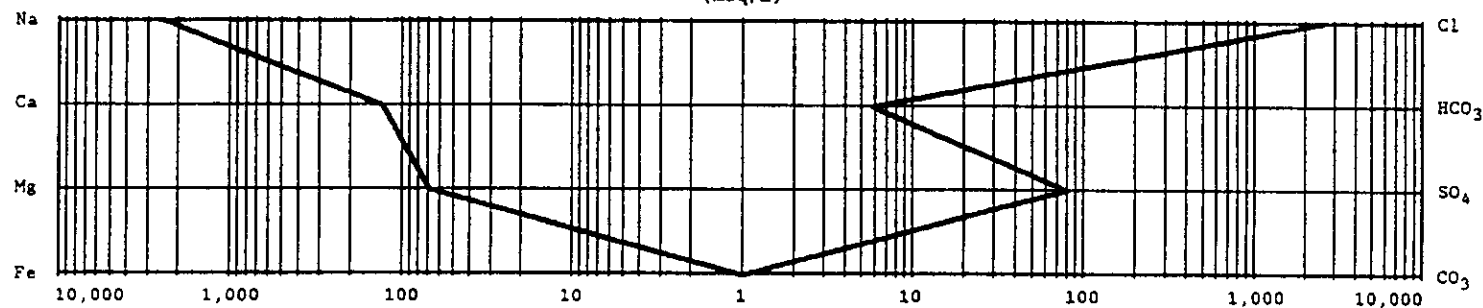
TOTAL SOLIDS  
(mg/L)

BY EVAPORATION @ 110°C BY EVAPORATION @ 180°C

155907

AT IGNITION

CALCULATED

1.1078 @15.6°C  
SPECIFIC GRAVITY1.3561 @22 °C  
REFRACTIVE INDEX6.9  
pH0.053 @25°C  
RESISTIVITY(OHM-METRES)LOGARITHMIC PATTERN OF DISSOLVED IONS  
(meq/L)

REMARKS: NaCl equiv. 154454

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

PERMEABILITY TO BRINE

<u>SAMPLE NUMBER</u>	<u>DEPTH, METRES</u>	<u>PERMEABILITY TO SIMULATED BRINE, MILLIDARCYs</u>
<u>Chevron Virden Prov 13C-24-11-26 W1M</u>		
*SCA-3A/13-24	606.83	0.17
*SCA-3B/13-24	606.83	0.60
SCA-5/13-24	608.60	13.2
*SCA-6/13-24	608.66	2.03
SCA-7A/13-24	609.14	10.3
SCA-8/13-24	609.92	4.28
*SCA-9/13-24	609.97	1.04
*SCA-10/13-24	610.26	14.4
<u>Chevron Virden 1D-26-11-26 W1M</u>		
SCA-1/1-26	595.68	4.58
SCA-2/1-26	595.98	18.8
*SCA-3/1-26	598.04	33.4
SCA-4/1-26	598.09	20.8
*SCA-5/1-26	602.27	2.14

\*Sample not used for subsequent analysis.

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SUMMARY OF AMOTT METHOD WETTABILITY TEST RESULTS

SAMPLE CONDITION: Restored

INITIAL FLUID IMBIBED: Water

SAMPLE NUMBER:	SCA-4/1-26
DEPTH, METRES:	598.09
PERMEABILITY TO AIR, mD:	42.2
POROSITY, FRACTION:	0.159
IMMOBILE WATER SATURATION, *	
FRACTION PORE SPACE:	0.165
PERMEABILITY TO OIL AT	
IMMOBILE WATER SATURATION, mD:	26.4
SPONTANEOUS WATER IMBIBITION,	
FRACTION PORE SPACE:	0.412
FORCED WATER IMBIBITION,	
FRACTION PORE SPACE:	0.114
TOTAL WATER IMBIBITION,	
FRACTION PORE SPACE:	0.526
IMMOBILE OIL SATURATION, **	
FRACTION PORE SPACE:	0.309
PERMEABILITY TO WATER AT	
IMMOBILE OIL SATURATION, mD:	-
SPONTANEOUS OIL IMBIBITION,	
FRACTION PORE SPACE:	0.026
FORCED OIL IMBIBITION,	
FRACTION PORE SPACE:	0.289
TOTAL OIL IMBIBITION,	
FRACTION PORE SPACE:	0.315
WETTABILITY INDEX TO WATER:	0.783
WETTABILITY INDEX TO OIL:	0.083

\*WATER PRESENT JUST PRIOR TO WATER IMBIBITION

\*\*OIL PRESENT JUST PRIOR TO OIL IMBIBITION

WETTABILITY INDEX =  $\frac{\text{SPONTANEOUS IMBIBITION}}{\text{TOTAL IMBIBITION}}$

**CORE  
LABORATORIES**

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

USBM WETTABILITY DATA

<u>SAMPLE NUMBER</u>	<u>PERMEABILITY TO AIR, MILLIDARCYS</u>	<u>POROSITY, FRACTION</u>	<u>INITIAL WATER SATURATION, PORE VOLUME FRACTION</u>	<u>PRESSURE, kPa</u>	<u>AVERAGE WATER SATURATION, PORE VOLUME FRACTION</u>
--------------------------	---	-------------------------------	---	--------------------------	---

Water Displacing Oil

SCA-4/1-26	42.2	0.159	0.165	4	0.634
				10	0.655
				25	0.670
				45	0.680
				70	0.686
				88	0.691
				107	0.691

Oil Displacing Water

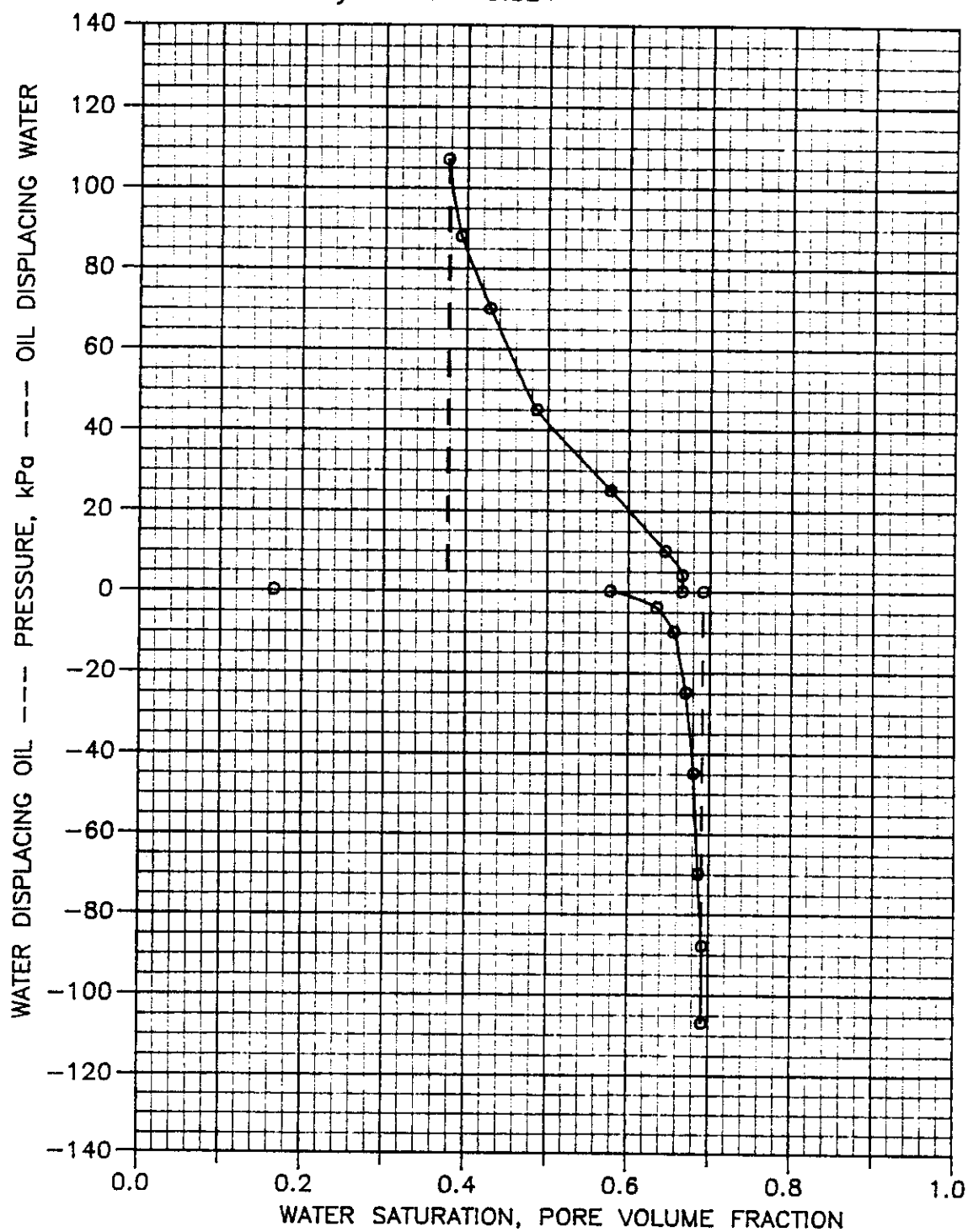
4	0.665
10	0.644
25	0.577
45	0.485
70	0.428
88	0.392
107	0.376

# AVERAGE WATER SATURATION VERSUS PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-4/1-26  
Depth, Metres: 598.09  
Permeability, mD: 42.2  
Porosity, Fraction: 0.159  
USBM Wettability Index: 0.824





FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

AIR-WATER CENTRIFUGE CAPILLARY PRESSURE DATA

PRESSURE, kPa: 6 15 35 70 175 350 700 1400 2000

INITIAL

PERMEABILITY  
TO AIR,  
MILLIDARCY

POROSITY,  
FRACTION

WATER SATURATION,  
PORE VOLUME FRACTION

HASSLER CORRECTED WATER SATURATION, PORE VOLUME FRACTION

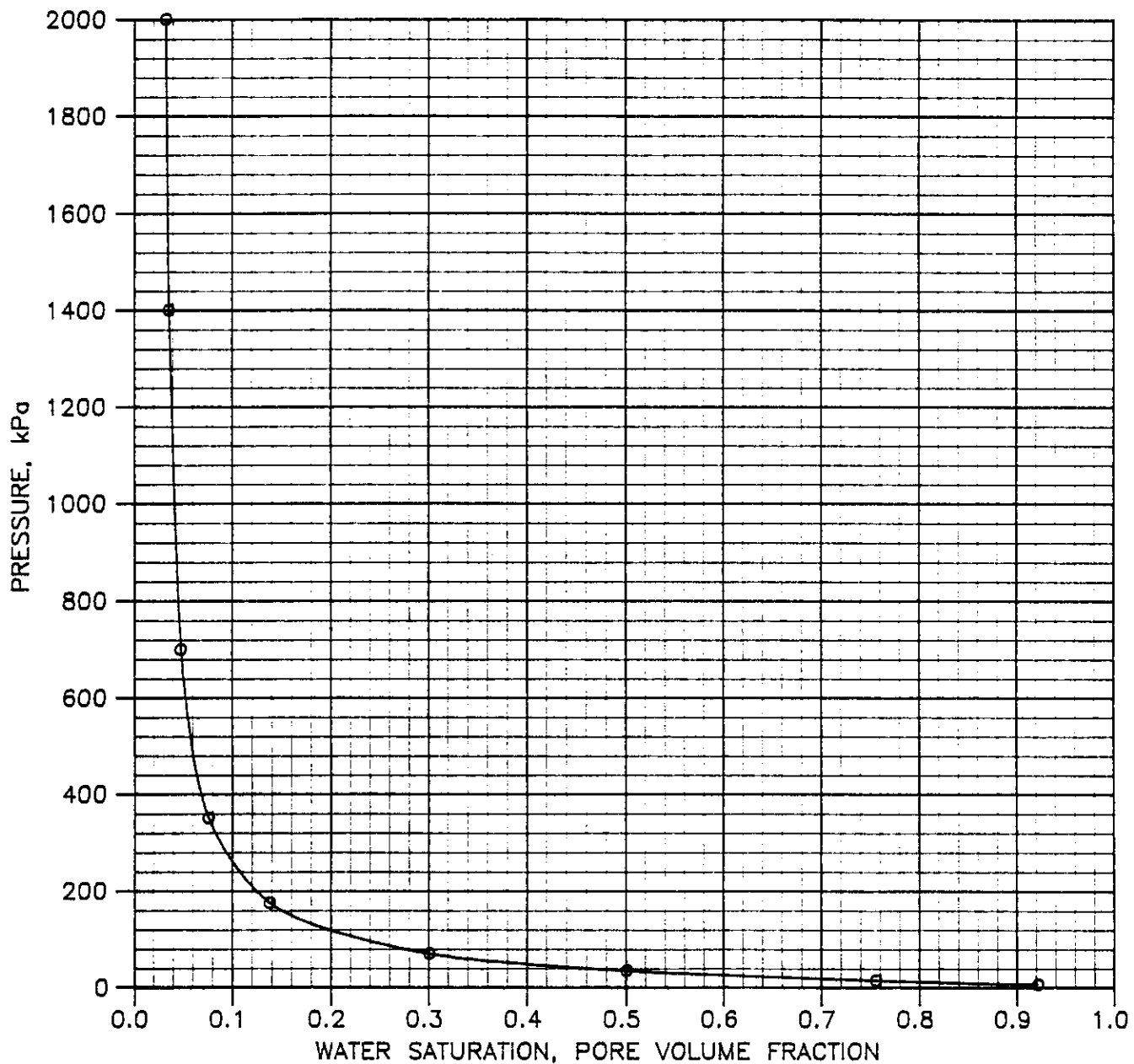
SCA-4/1-26 42.2 0.159 1.000 0.921 0.755 0.500 0.300 0.137 0.075 0.047 0.035 0.032

# AIR-WATER CENTRIFUGE CAPILLARY PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-4/1-26  
Depth, Metres: 598.09  
Permeability, mD: 42.2  
Porosity, Fraction: 0.159



FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virde  
PROVINCE Manitoba

OIL-WATER CAPILLARY PRESSURE DATA

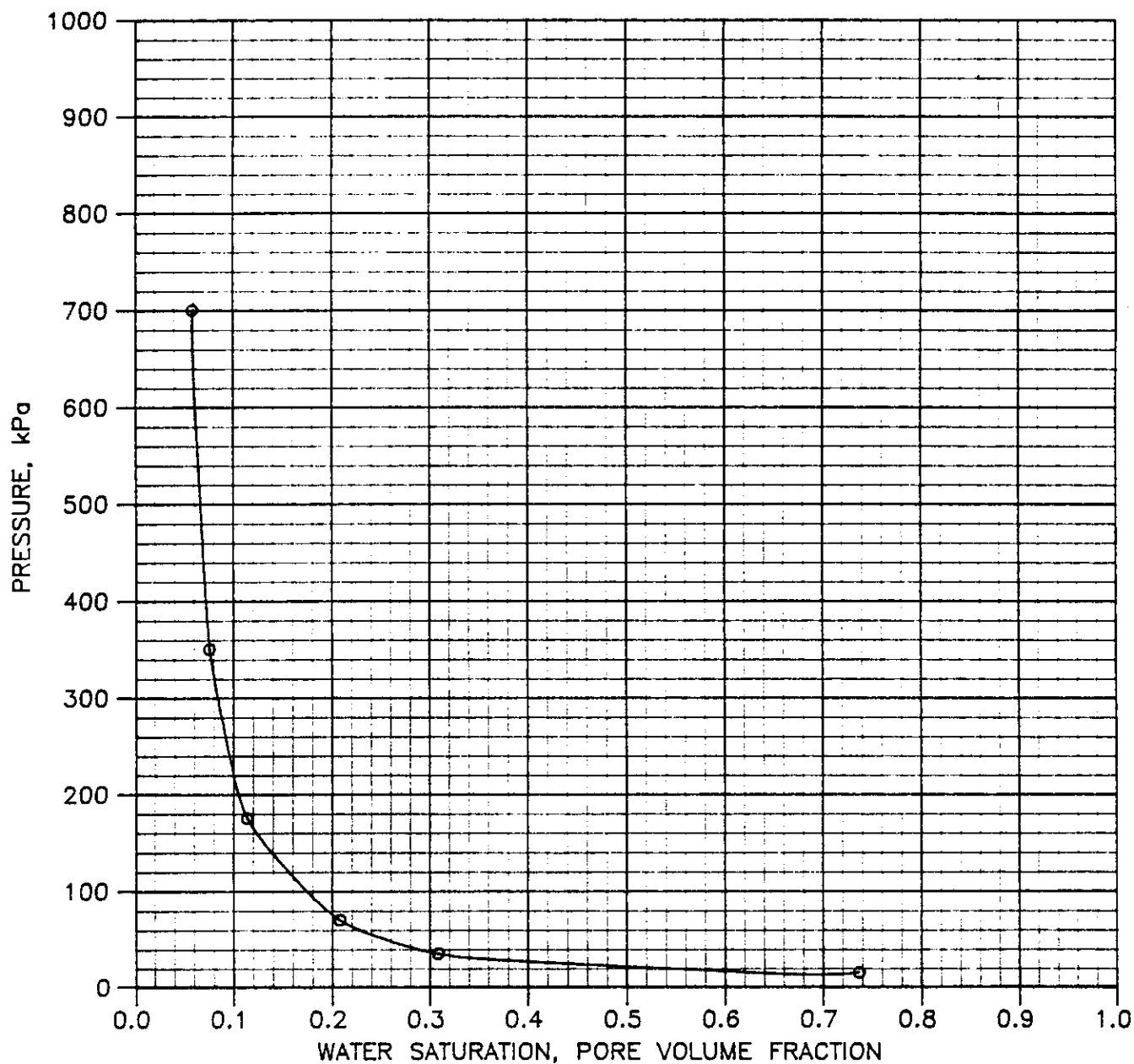
SAMPLE NUMBER	PERMEABILITY TO AIR, MILLIDARCS	POROSITY, FRACTION	PRESSURE, kPa:					HASSLER CORRECTED WATER SATURATION, PORE VOLUME FRACTION				
			INITIAL WATER SATURATION, PORE VOLUME FRACTION	6	15	35	70	175	350	700		
<u>Chevron Virden Prov 13C-24-11-26 WIM</u>												
SCA-5/13-24	26.8	0.104	1.000	1.000	0.736	0.308	0.207	0.113	0.075	0.058		
<u>Chevron Virden 1D-26-11-26 WIM</u>												
SCA-1/1-26	21.7	0.102	1.000	0.853	0.521	0.265	0.187	0.111	0.085	0.062		

# OIL-WATER CENTRIFUGE CAPILLARY PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-5/13-24  
Depth, Metres: 608.60  
Permeability, mD: 26.8  
Porosity, Fraction: 0.104

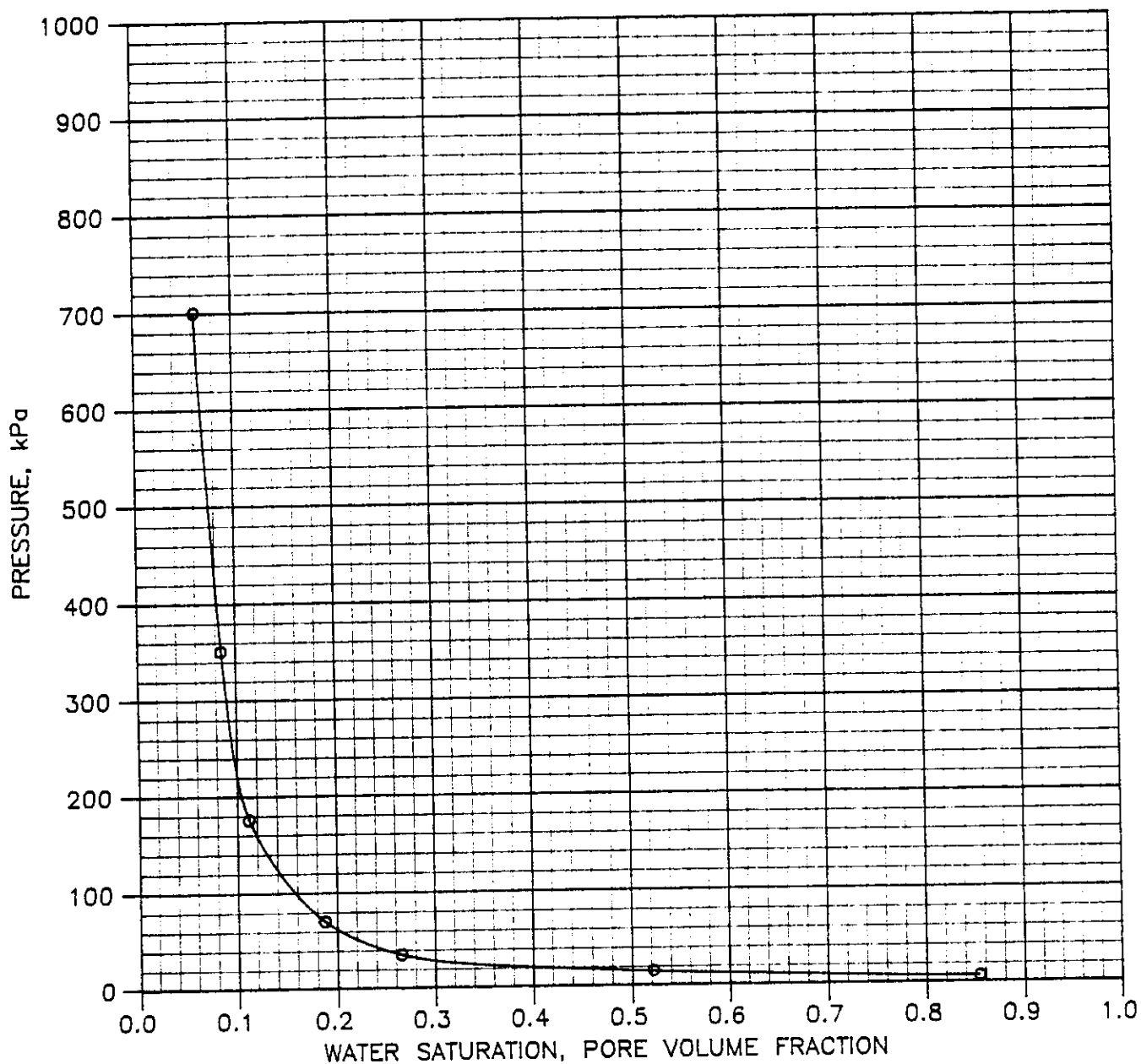


# OIL-WATER CENTRIFUGE CAPILLARY PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-1/1-26  
Depth, Metres: 595.68  
Permeability, mD: 21.7  
Porosity, Fraction: 0.102



FILE 52133-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26  
LOCATION LSD 13-24-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SUMMARY OF ROOM CONDITION UNSTEADY-STATE WATER-OIL RELATIVE PERMEABILITY TEST RESULTS

SAMPLE NUMBER	DEPTH, METRES	PERMEABILITY TO AIR, MILLIDARCYS	POROSITY, FRACTION	INITIAL CONDITIONS		TERMINAL CONDITIONS		OIL RECOVERED	
				WATER SATURATION, FRACTION TO OIL, PORE SPACE MILLIDARCYS		OIL SATURATION, FRACTION TO WATER, PORE SPACE MILLIDARCYS		FRACTION PORE SPACE	FRACTION OIL IN PLACE
SCA-8/13-24	609.92	6.44	0.097	0.229	4.61	0.340	0.71	0.431	0.559

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SUMMARY OF ROOM CONDITION STEADY-STATE WATER-OIL RELATIVE PERMEABILITY TEST RESULTS

SAMPLE NUMBER	DEPTH, METRES	PERMEABILITY TO AIR, MILLIDARCYS	INITIAL CONDITIONS		TERMINAL CONDITIONS		OIL RECOVERED		
			POROSITY, FRACTION	WATER	SATURATION, FRACTION TO OIL, MILLIDARCYS	SATURATION, FRACTION TO WATER, PORE SPACE MILLIDARCYS	FRACTION PORE SPACE	FRACTION OIL IN PLACE	
<u>Chevron Virden Prov 13C-24-11-26 W1M</u>									
SCA-7A/13-24	609.14	13.4	0.126	0.037	10.3	0.447	0.530	0.516	0.536
<u>Chevron Virden 1D-26-11-26 W1M</u>									
SCA-2/1-26	595.98	28.3	0.118	0.041	21.0	0.413	6.51	0.546	0.569

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26  
LOCATION LSD 13-24-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

STEADY-STATE WATER-OIL RELATIVE PERMEABILITY DATA

SAMPLE NUMBER: SCA-7A/13-24 INITIAL WATER SATURATION,  
FRACTION PORE SPACE: 0.037  
PERMEABILITY TO AIR, mD: 13.4  
POROSITY, FRACTION: 0.126

PERMEABILITY TO OIL AT  
INITIAL WATER SATURATION, mD: 10.3

<u>WATER SATURATION, FRACTION PORE SPACE</u>	<u>WATER-OIL RELATIVE PERMEABILITY RATIO</u>	<u>RELATIVE PERMEABILITY TO WATER* FRACTION</u>	<u>RELATIVE PERMEABILITY TO OIL* FRACTION</u>
0.037	0.000	0.000	1.000
0.356	0.088	0.012	0.137
0.394	0.238	0.020	0.084
0.456	1.19	0.031	0.026
0.491	3.23	0.042	0.013
0.521	6.96	0.048	0.0069
0.553		0.052	

\*Relative to Permeability to Oil at Initial Water Saturation.



FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

STEADY-STATE WATER-OIL RELATIVE PERMEABILITY DATA

SAMPLE NUMBER: SCA-2/1-26 INITIAL WATER SATURATION,  
PERMEABILITY TO AIR, mD: 28.3 FRACTION PORE SPACE: 0.041  
POROSITY, FRACTION: 0.118  
PERMEABILITY TO OIL AT  
INITIAL WATER SATURATION, mD: 21.0

<u>WATER SATURATION, FRACTION PORE SPACE</u>	<u>WATER-OIL RELATIVE PERMEABILITY RATIO</u>	<u>RELATIVE PERMEABILITY TO WATER* FRACTION</u>	<u>RELATIVE PERMEABILITY TO OIL* FRACTION</u>
0.041	0.000	0.000	1.000
0.209	0.107	0.017	0.159
0.226	0.198	0.023	0.114
0.271	0.870	0.043	0.050
0.321	4.03	0.073	0.018
0.351	10.4	0.090	0.0086
0.587		0.309	

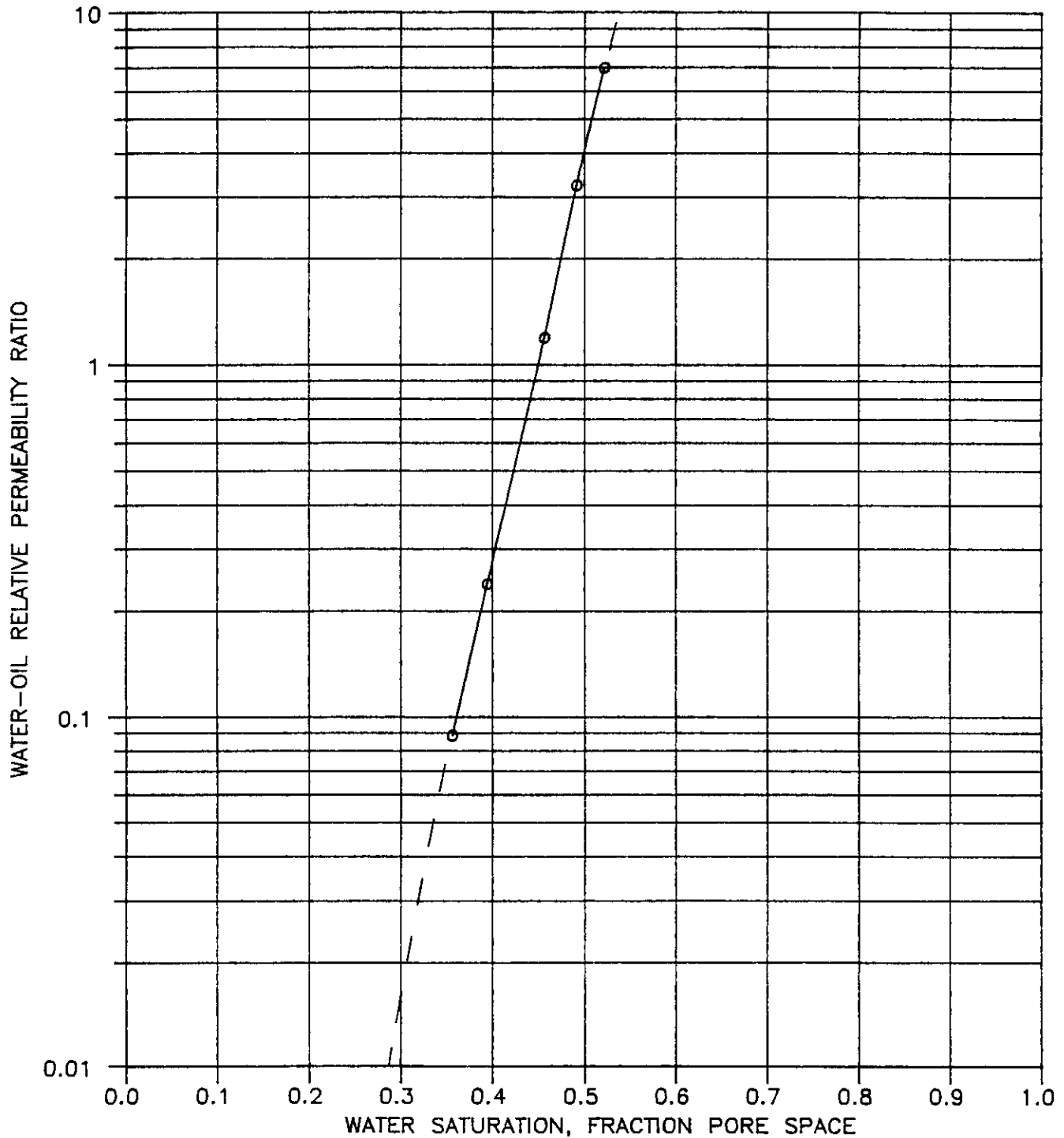
\*Relative to Permeability to Oil at Initial Water Saturation.

# WATER-OIL RELATIVE PERMEABILITY RATIO (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-7A/13-24  
Depth, Metres: 609.14  
Permeability, mD: 13.4  
Porosity, Fraction: 0.126

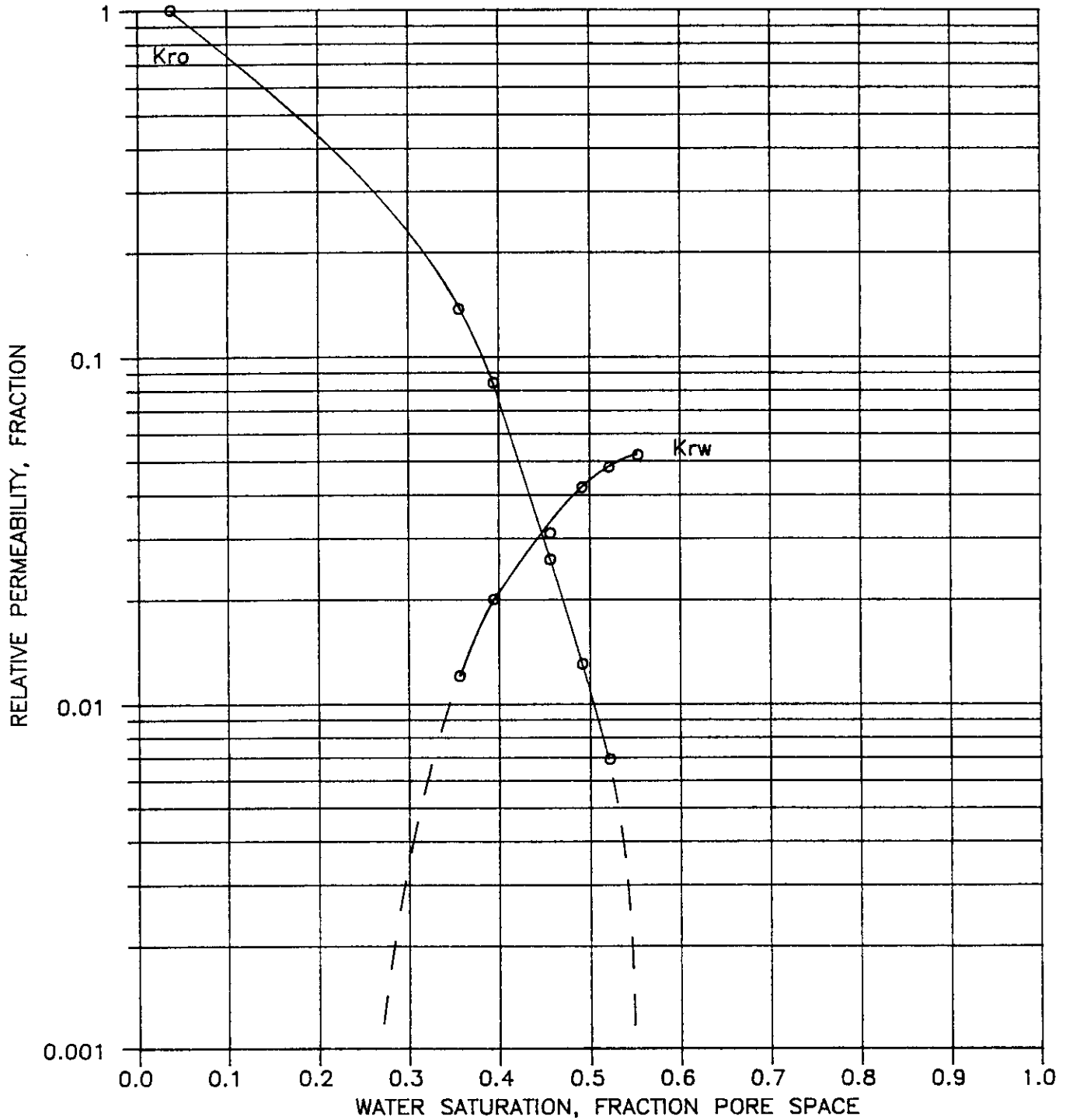


# WATER-OIL RELATIVE PERMEABILITY (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-7A/13-24  
Depth, Metres: 609.14  
Permeability, mD: 13.4  
Porosity, Fraction: 0.126

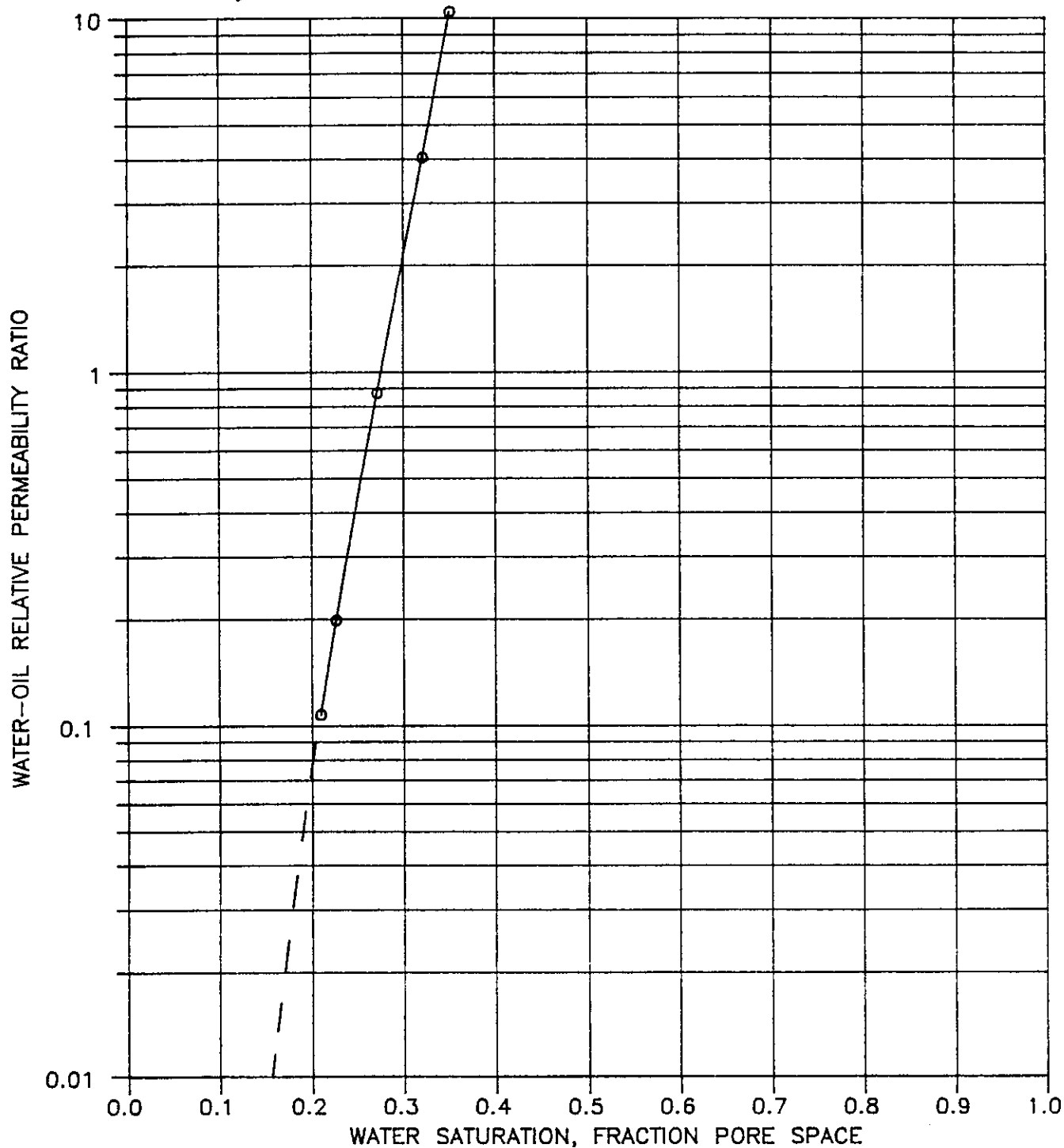


# WATER-OIL RELATIVE PERMEABILITY RATIO (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-2/1-26  
Depth, Metres: 595.98  
Permeability, mD: 28.3  
Porosity, Fraction: 0.118

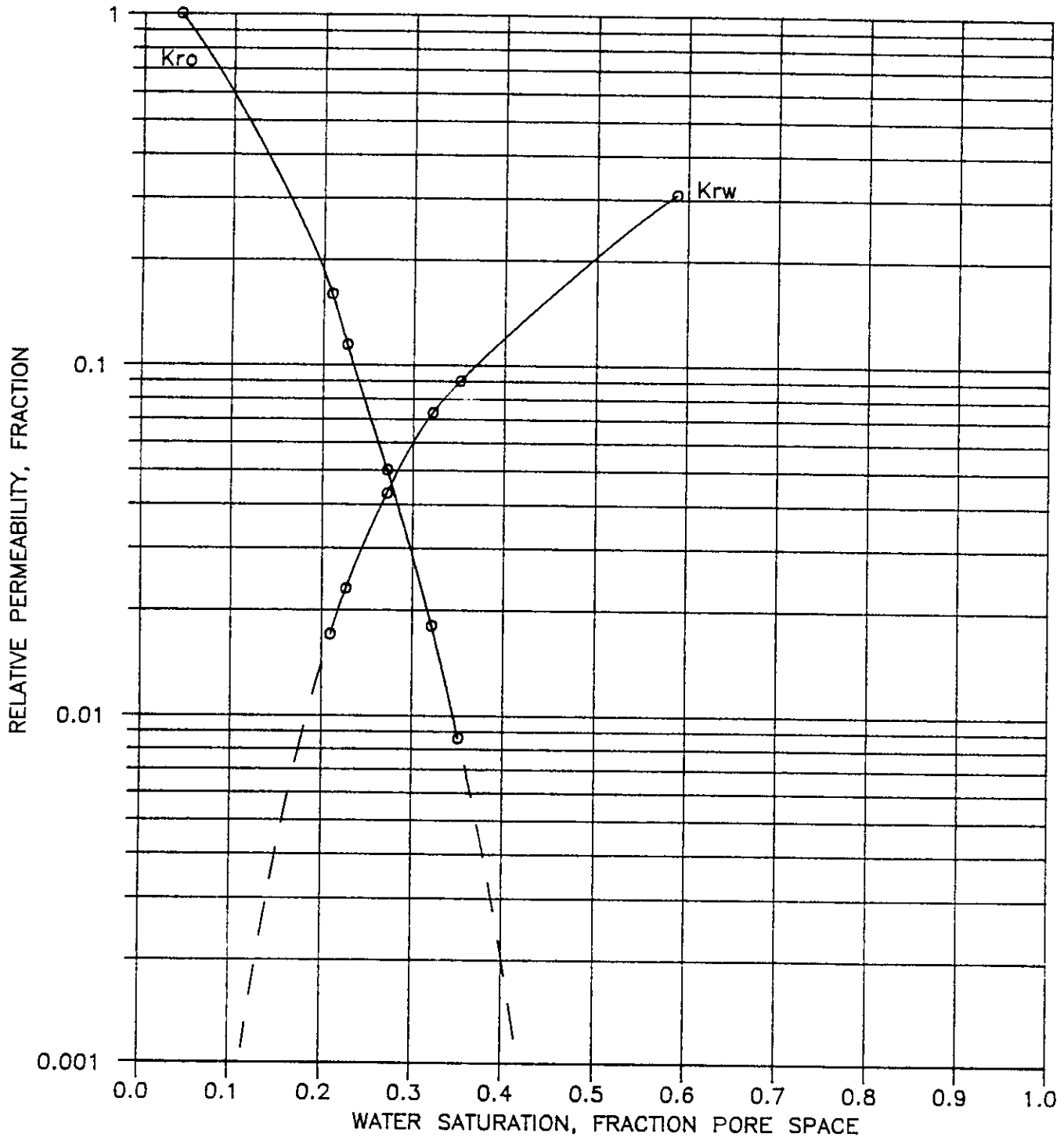


# WATER-OIL RELATIVE PERMEABILITY (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-2/1-26  
Depth, Metres: 595.98  
Permeability, mD: 28.3  
Porosity, Fraction: 0.118



COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

ROCK (PORE VOLUME) COMPRESSIBILITY

SAMPLE NUMBER	DEPTH, METRES	PERMEABILITY TO AIR, MILLIDARCYs	EFFECTIVE OVERBURDEN PRESSURE, kPa	PORE VOLUME cm <sup>3</sup>	BULK VOLUME cm <sup>3</sup>	POROSITY, FRACTION	COMPRESSIBILITY, $pv/pv/kPa \times 10^{-7}$	
							(1)	(2)
SCA-2/1-26	595.98	28.3	2 000	3.383	34.232	0.099	-	-
			7 000	3.353	34.212	0.098	14.9	9.22
			14 000	3.324	34.173	0.097	9.58	5.93
			21 000	3.308	34.157	0.097	7.80	4.83
			28 000	3.293	34.142	0.096	7.31	4.52
			35 000	3.276	34.125	0.096	6.89	4.26
			42 000	3.257	34.106	0.096	6.58	4.07
			49 000	3.235	34.084	0.095	10.4	6.44
			56 000	3.216	34.065	0.094	13.1	8.11
			63 000	3.185	34.034	0.094	15.0	9.29
			68 000	3.153	34.002	0.093	16.1	9.97

(1) Measured in laboratory under hydrostatic loading conditions.

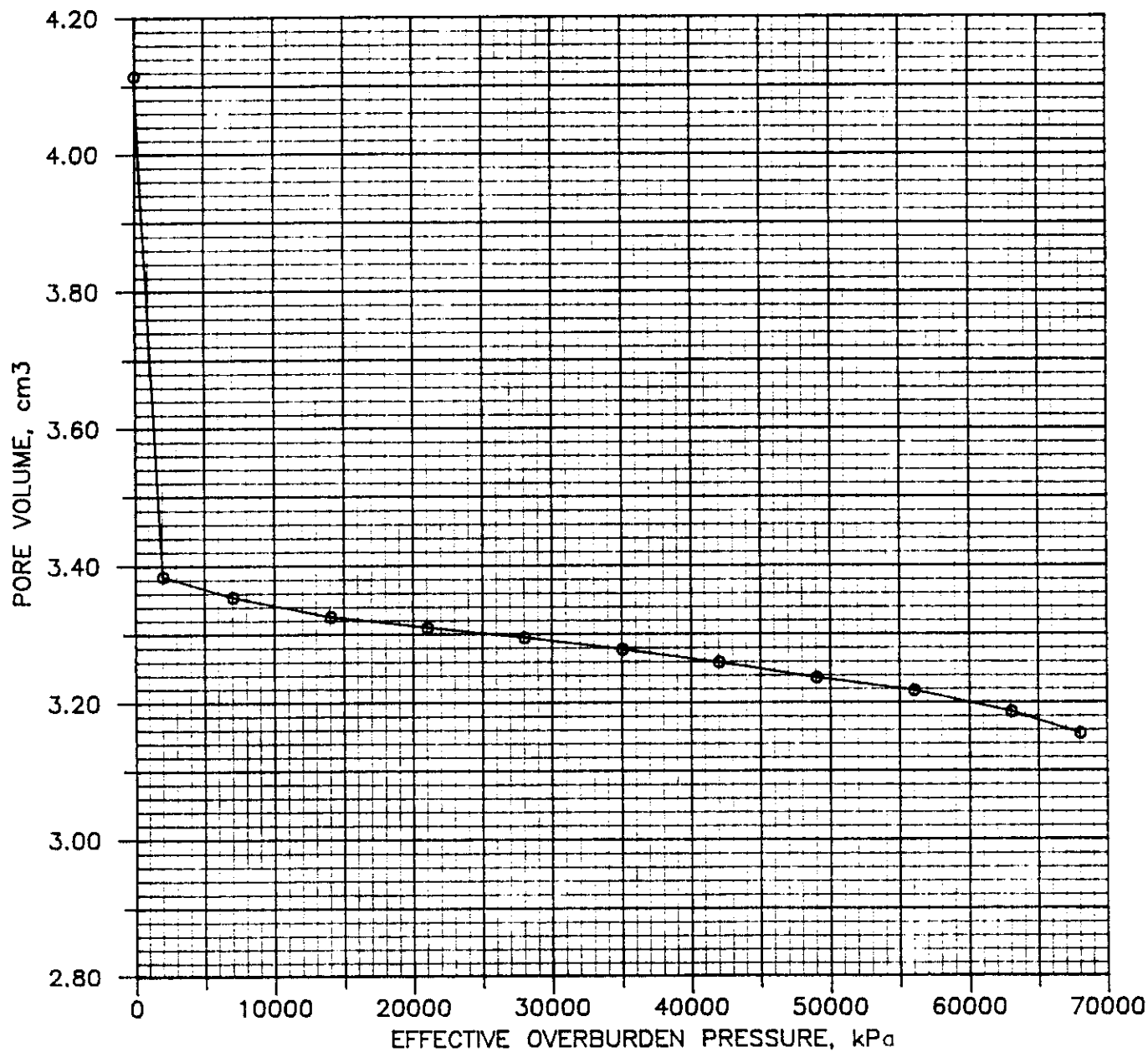
(2) Uniaxial loading conditions, transformed from hydrostatic data using an average translation factor of 0.619 as per Teeuw, Dirk: "Prediction of Formation Compaction from Laboratory Compressibility Data," Trans., AIME (1971) 251, 263-271.

## ROCK (PORE VOLUME) COMPRESSIBILITY

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-2/1-26  
Depth, Metres: 595.98  
Permeability, mD: 28.3  
Porosity, Fraction: 0.118



## **APPENDIX**





## CORE LABORATORIES

January 3, 1990

Core Laboratories  
Calgary, Alberta, Canada

Attention: Mr. Norm Gruber

Subject: Interfacial Tension Measurement  
Chevron Canada Resources, Ltd.  
North Virden Scallion Unit #1 Well  
Lodgepole Formation  
Manitoba, Canada  
File Number: SCAL-89198

Dear Mr. Gruber:

A laboratory study to measure the interfacial tension of crude oil from the subject well has been performed for Core Laboratories, Calgary. This study was authorized on behalf of Chevron Canada Resources, Ltd. in your transmittal of October 12, 1989. Final results of Pendant Drop Interfacial Tension measurements are included herein.

### Test Preparation

Test parameters and a formation brine analysis were specified in the letter of authorization. Synthetic formation water, see composition, Page 1, was prepared to match the analysis provided. A 2-litre sample of degassed crude oil was received by Core Lab-Calgary and forwarded to the Dallas Production Services Laboratory on September 18, 1989. Oil/water interfacial tension measurements were performed at 26.7°C and atmospheric pressure as described below.

### Interfacial Tension (IFT)

In preparation for the oil/water IFT tests, a portion of the dead crude oil was circulated with synthetic formation water to establish chemical equilibrium between the two phases. The equilibrated brine was transferred into a stainless steel sight-gauge cell located within a controlled temperature air-bath oven and a test temperature of 80°F (26.7°C) established. (A slight positive pressure was maintained in order to prevent outgassing of the test fluids.) Interfacial tension measurements then were performed by injecting the degassed crude oil through a needle extending into the brine-filled cell until a pendant drop was formed on the tip of the needle.

Photographs of the drops were taken as quickly as possible, then additional photographs taken after 5, 15, 30, 60, 120, 240, 480, and 1200 minutes. IFT values were calculated from the drop dimensions using the equation:

$$\delta = \Delta \rho g d_e^2 / H$$

where:

$\delta$  = interfacial tension, dynes/cm

$\Delta \rho$  = difference in density between the droplet and the phase surrounding it, gm/cm<sup>3</sup>

$g$  = gravitational constant, cm/sec<sup>2</sup>

$d_e$  = maximum (equatorial) diameter of the unmagnified drop, cm

$H$  = shape correction factor, dimensionless


Densities of the water and the degassed crude oil at 26.7°C were determined using a hydrometer.

#### Discussion of Test Results

A terminal IFT value of 29.0 dynes/cm was obtained after 1200 minutes of equilibration. This value is in the expected range for uncontaminated crude oil.

Please contact us should you have any questions. Thank you for this opportunity to be of service.

Very truly yours,



Michael W. Dann, Supervisor  
Production Services Laboratory  
Dallas Core Services

MWD:PGM:ed

SYNTHETIC BRINE COMPOSITION

<u>Constituents</u>	<u>Concentration, g/l</u>
Sodium Chloride (NaCl)	110.498
Calcium Chloride (CaCl <sub>2</sub> )	13.159
Magnesium Chloride (MgCl <sub>2</sub> ·6H <sub>2</sub> O)	6.682
Sodium Bicarbonate (NaHCO <sub>3</sub> )	0.737
Sodium Sulfate (Na <sub>2</sub> SO <sub>4</sub> )	5.761

The brine composition was prepared from the following analysis:

Company: Chevron Canada Resources, Ltd.  
Well: North Virden Scallion Unit #1

<u>Constituent</u>	<u>Concentration, mg/l</u>	<u>Constituent</u>	<u>Concentration, mg/l</u>
Sodium	45,507	Chloride	77,750
Calcium	4,752	Bicarbonate	535
Magnesium	799	Sulfate	3,896

PENDANT DROP INTERFACIAL TENSION TEST RESULTS

Fluids: Synthetic Formation Water      Temperature: 80°F (26.7°C)  
Scallion Unit #1 Degassed Crude Oil      Pressure: Ambient

<u>Cumulative Elapsed Time, minutes</u>	<u>Interfacial Tension, dynes/cm</u>
1	34.2
5	32.3
15	30.9
30	30.2
60	30.1
120	29.6
240	29.3
480	29.1
1200	29.0



**Western Atlas  
International**

A Litton/Dresser Company

**CORE  
LABORATORIES**

SPECIAL CORE ANALYSIS STUDY  
FOR  
**CHEVRON CANADA RESOURCES**

Chevron Virden Prov 13C-24-11-26 W1M  
Chevron Virden 1D-26-11-26 W1M  
Lodgepole Formation  
Manitoba

FILE NUMBER: 52132-89-83

DATE: 1990 03 20



## CORE LABORATORIES

1990 03 20

Chevron Canada Resources  
500 - 5th Avenue S.W.  
Calgary, Alberta  
T2P 0L7

Attention: Mr. Scott Robinson

Subject: Special Core Analysis Study  
Chevron Virden Prov 13C-24-11-26 W1M  
Chevron Virden 1D-26-11-26 W1M  
File Number: 52132-89-83

Gentlemen:

The Special Core Analysis Department of Core Laboratories is pleased to present results of a study performed on core samples representing the Lodgepole Formation of the subject wells. Tests include:

1. Permeabilities to Brine
2. Combined Amott/USBM Wettability
3. Air-Water Centrifuge Capillary Pressure
4. Oil-Water Centrifuge Capillary Pressure
5. Unsteady-State Water-Oil Relative Permeability
6. Steady-State Water-Oil Relative Permeability
7. Rock (Pore Volume) Compressibility
8. Interfacial Tension Measurement

A discussion of analytical procedures and the test results follow this letter. The Interfacial Tension Measurement of crude oil was performed in our Dallas lab and results are appended to this report.

We appreciate the opportunity to be of service to Chevron Canada Resources. Should you have any questions or if we may be of further assistance, please do not hesitate to contact us.

Yours truly,

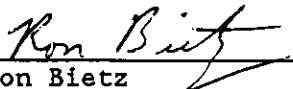
CORE LABORATORIES

Norman Gruber, P.Eng.  
Supervisor, Advanced Core Analysis

CG/nb  
Enclosures

PROGRAM PARTICIPANTS

Laboratory Measurements and Data Review

  
Ron Bietz


  
Art Lui

  
Dexter Woo

Report Preparation and Review

  
Cheryl Garand

Final Review

  
Norman Gruber, P.Eng.



### INTRODUCTION

In August of 1989, the Special Core Analysis Department was instructed to perform analyses on core material from the subject wells. The tests were authorized by Mr. Scott Robinson of Chevron and include Permeability to Brine, Amott/USBM Wettability, Centrifuge Capillary Pressure, Relative Permeability and Rock (Pore Volume) Compressibility. An Interfacial Tension Measurement of crude oil from the North Scallion Unit #1 well was also performed in our Dallas, Texas facility.

The requested study has now been completed and the results are presented in final form. This report contains data previously submitted in preliminary reports. Any revisions to the preliminary data have been made to correct errors and/or to provide more accurate interpretation of the test results.

## SPECIAL CORE ANALYSIS PROCEDURES

### Sample and Fluid Preparation

With the exception of sample drilling, the plugs used in this study were prepared in accordance with Chevron's ACCUPERM Procedure. The ACCUPERM Procedure specifies that plugs be drilled from preserved core using refined oil as the bit lubricant and coolant. Unfortunately, the instructions were received after the 25 mm and 31 mm diameter plugs had already been drilled from the brine preserved core using our standard lab brine. As indicated by the ACCUPERM Procedure, the plugs were cleaned by miscible flushing of toluene then methanol over two cycles. Each solvent in each cycle was flowed until the effluent was colorless. This was performed in a hydrostatic core holder at a requested net overburden pressure of 7 450 kPa. While maintaining the net confining stress, the methanol was displaced with simulated formation brine and stable permeabilities were measured. Results are reported herein and samples preceded by an asterisk indicate those not used for subsequent analysis. It should be pointed out that several samples had measured permeabilities to oil at irreducible water saturation equal to or higher than the permeabilities to 100 percent brine. This suggests that possibly sample dissolution was occurring or perhaps the ACCUPERM procedure did not fully clean the samples.

On August 15, 1989, Mr. Scott Robinson selected six of the plugs for additional tests. Permeability to air and porosity values were determined upon completion of their respective testing, cleaning and drying processes. The petrophysical properties along with lithological descriptions have been provided for the six test plugs.

The test fluids used in this study were simulated formation brine and refined mineral oil. As instructed, the 1.7 mPa.s mineral oil was filtered through silica gel and alumina prior to use in the tests. The simulated brine was prepared from a submitted water analysis of the Calstan Scallion Prov. 3-11-11-26 W1M well. The simulated brine contained approximately 140 740 ppm total dissolved solids. Both the analysis and simulated brine composition are presented in this report. Although not used in testing, a water analysis of the Chevron Virden 10-26-11-26 W1M well is also included.

#### Amott/USBM Wettability Test

An Amott/USBM Wettability Test was performed on sample SCA-4/1-26 at 27°C. The brine saturated plug was initially flushed to immobile water saturation with the 1.7 mPa.s filtered, mineral oil and an effective permeability was measured. The sample was then placed in a calibrated imbibition container filled with simulated brine and allowed to imbibe brine spontaneously. After spontaneous imbibition ceased, the brine filled receptacle containing the sample was placed in the high-speed centrifuge apparatus and the water-displacing-oil cycle was performed. The sample was spun non-stop at rates of rotation that were incrementally increased until a corresponding pressure of approximately 107 kPa was achieved. Sufficient time was allowed at each rate of rotation for an equilibrium condition to be attained within the plug. The amount of oil displaced at each rate was recorded.

For the next cycle, the sample was placed in a calibrated receptacle filled with oil and allowed to imbibe oil spontaneously. The sample was then centrifuged under oil to complete the oil-displacing-water cycle. As before, sufficient time was allowed at each speed for sample equilibrium and the amount of fluid displaced was monitored.

The Amott Wettability Index is the ratio of the volume of spontaneous oil or water imbibition to the total mobile volume of oil or water imbibed. A wettability index of 1.0 indicates strongly wet by the imbibed fluid whereas 0.0 indicates non-wetting by the imbibed fluid. At the time of testing in the laboratory, the sample performed in a strong water-wet manner.

The USBM method for determining wettability utilizes the drainage and imbibition centrifuge data. Average water saturations for both cycles were calculated from the volume of fluid displaced at each rotational speed. The average water saturation versus pressure was plotted for both cycles. The area under each curve was planimetered and the logarithm of the area ratio was calculated. The resulting USBM wettability index of 0.824 indicates a strong water-wet condition.

#### Air-Water Centrifuge Capillary Pressure

After the Amott/USBM Wettability test, sample SCA-4/1-26 was resaturated with simulated formation brine in preparation for an Air-Water Centrifuge Capillary Pressure test at 27°C. The sample was loaded into the high-speed centrifuge apparatus and spun non-stop at rates of rotation which were increased incrementally to generate equivalent capillary pressures ranging from 6 kPa to 2 000 kPa in an air-displacing-brine system. Fluid saturations were calculated after an equilibrium condition was attained at each rate.

### Oil-Water Centrifuge Capillary Pressure

Oil-Water Centrifuge Capillary Pressure Tests were performed on samples SCA-5/13-24 and SCA-1/1-26. The tests were performed at 27°C using simulated formation brine and filtered mineral oil. The plugs were centrifuged under oil at seven increasing rates of rotation which gave equivalent capillary pressures ranging from 6 kPa to 700 kPa in an oil-water system.

It is interesting to note that all three Centrifuge Capillary Pressure tests yielded extremely low irreducible water saturations, in the range of 3 to 6 percent. This is quite unusual in light of the fact that the Wettability test indicated a strongly water-wet condition. Low irreducible water saturations were also obtained on the two Steady-State Relative Permeability tests.

### Unsteady-State Water-Oil Relative Permeability

After the special cleaning and permeability to brine measurement, sample SCA-8/13-24 was subjected to an Unsteady-State Water-Oil Relative Permeability Test at room temperature. The saturated plug was flushed to immobile brine saturation with filtered mineral oil and an effective permeability to oil was determined. The oil was then displaced with simulated brine and volumes of each effluent fluid were determined at measured time intervals. Since all the oil was produced at the beginning of the flood, incremental test data is not available. A summary or end-point test data has been provided.

### Steady-State Water-Oil Relative Permeability

Water-Oil Relative Permeability Tests were performed on samples SCA-7A/13-24 and SCA-2/1-26 in the steady-state apparatus at room temperature. The plugs were flushed to immobile brine saturation with mineral oil and effective permeabilities to oil were measured. The steady-state tests were performed using several water-oil ratios in the imbibition, water saturation increasing, direction. The oil and water flow rates were monitored during testing and subsequently used to calculate the relative permeability data.

### Rock (Pore Volume) Compressibility

After the steady-state relative permeability test, sample SCA-2/1-26 was prepared for a Rock (Pore Volume) Compressibility Test. The core plug and end-stems were encased in shrinkable plastic tubing, placed in a hydrostatic core holder and saturated with brine. External and internal pressures, resulting in effective overburden pressures ranging from 2 000 kPa to 68 000 kPa, were applied in measured increments to the sample. At each equilibrium pressure, the quantity of brine forced out of the pore space was measured. Matrix failure started to occur in the plug at 49 000 kPa net overburden pressure.

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

IDENTIFICATION OF SAMPLES

<u>SAMPLE NUMBER</u>	<u>DEPTH, METRES</u>	<u>PERMEABILITY TO AIR, MILLIDARCYS</u>	<u>POROSITY, FRACTION</u>	<u>GRAIN DENSITY kg/m<sup>3</sup></u>	<u>LITHOLOGICAL DESCRIPTION</u>
<u>Chevron Virden Prov 13C-24-11-26 W1M</u>					
SCA-5/13-24	608.60	26.8	0.104	2700	LS: lt brn, wkst/grst, intgran & p.p. por
SCA-7A/13-24	609.14	13.4	0.126	2710	LS: lt brn-bu, grst, com foss frags, com p.p. & sml vugs
SCA-8/13-24	609.92	6.44	0.097	2690	LS: lt brn-bu, grst, abd p.p. & loc sml vugs, foss frags
<u>Chevron Virden 1D-26-11-26 W1M</u>					
SCA-1/1-26	595.68	21.7	0.102	2690	LS: lt brn-bu, grst, com p.p. & sml vugs, loc foss frags
SCA-2/1-26	595.98	28.3	0.118	2670	LS: lt brn-bu, grst w/ com foss frags(crin), p.p. & sml vugs
SCA-4/1-26	598.09	42.2	0.159	2690	LS: lt brn-bu, grst, com p.p. & loc sml vugs, foss frags

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SIMULATED BRINE COMPOSITION

<u>CONSTITUENTS</u>	<u>CONCENTRATION, mg/L</u>
Sodium Chloride (NaCl)	109 232
Potassium Chloride (KCl)	898
Calcium Chloride (CaCl <sub>2</sub> )	17 429
Magnesium Chloride (MgCl <sub>2</sub> .6H <sub>2</sub> O)	6 681
Sodium Bicarbonate (NaHCO <sub>3</sub> )	737
Sodium Sulphate (Na <sub>2</sub> SO <sub>4</sub> )	5 761

The brine composition was prepared from the following analysis:

COMPANY California Standard Company  
WELL Calstan Scallion Prov. 3-11-11-26  
LOCATION LSD 3-11-11-26 W1M

FORMATION  
FIELD Roselen  
PROVINCE Manitoba

<u>CONSTITUENTS</u>	<u>CONCENTRATION</u> <u>mg/L</u>	<u>CONSTITUENTS</u>	<u>CONCENTRATION</u> <u>mg/L</u>
Sodium and		Chloride	77.75
Potassium	45 507	Bicarbonate	535
Calcium	4 752	Sulphate	3 896
Magnesium	799		

WATER ANALYSIS

Plastic CONTAINER IDENTITY		Chevron Canada Resources OPERATOR		LABORATORY NUMBER	
LSD 10-26-11-26 WIM LOCATION		Chevron Virden 10-26-11-26 WELL OR SAMPLE LOCATION NAME		PAGE	
Virden, Manitoba FIELD OR AREA				KB ELEV. (m) GR ELEV. (m)	
		POOL OR ZONE		SAMPLER	
TEST TYPE & NO.		TEST RECOVERY			
		POINT OF SAMPLE		@ °C	
		PUMPING FLOWING		MUD RESISTIVITY	
				SWAB	
		WATER m <sup>3</sup> /d OIL m <sup>3</sup> /d GAS m <sup>3</sup> /d			
TEST INTERVALS (metres)					
SEPARATOR RESERVOIR		CONTAINER WHEN SAMPLED @ °C		CONTAINER WHEN RECEIVED @ °C	
-----		PRESSURES, kPa (gauge) -----		TEMPERATURES, °C -----	
DATE SAMPLED (Y/M/D)		DATE RECEIVED (Y/M/D)		DATE ANALYZED (Y/M/D)	
89 09 27		89 09 29		LS	
				ANALYST	
				REMARKS	

CATIONS

ANIONS

ION	mg/L	mg Fraction	MEQ/L
Na	56500	.3624	2457.6
K	592	.0038	15.1
Ca	2584	.0166	128.9
Mg	837	.0054	68.8
Ba			
Sr			
Fe	Present		

ION	mg/L	mg Fraction	MEQ/L
Cl	91236	.5852	2573.4
Br			
I			
HCO <sub>3</sub>	353	.0023	5.8
SO <sub>4</sub>	3805	.0244	79.3
CO <sub>3</sub>	0	.0000	0.0
OH	0	.0000	0.0
H <sub>2</sub> S	Not Detected		

TOTAL SOLIDS  
(mg/L)

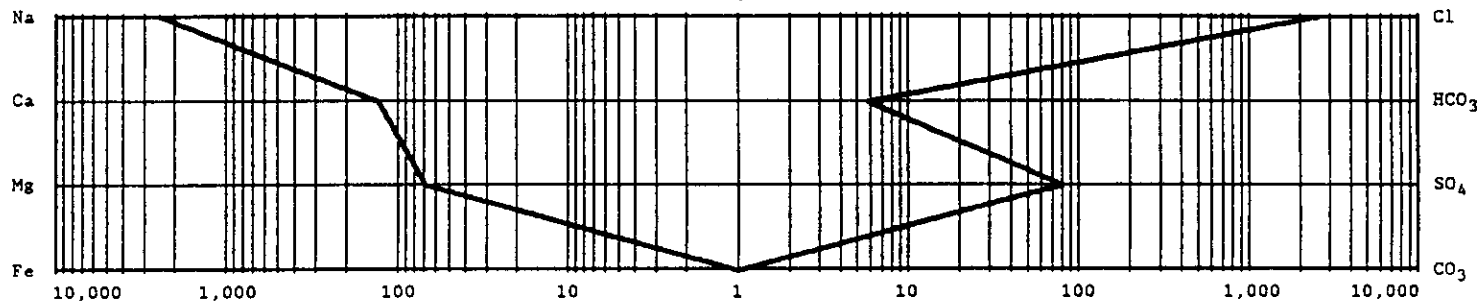
BY EVAPORATION @ 110°C BY EVAPORATION @ 180°C

AT IGNITION 155907  
CALCULATED

1.1078 @15.6°C 1.3561 @22 °C  
SPECIFIC GRAVITY REFRACTIVE INDEX

6.9 0.053 @25°C  
pH RESISTIVITY(OHM-METRES)

LOGARITHMIC PATTERN OF DISSOLVED IONS  
(meq/L)



REMARKS: NaCl equiv. 154454

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

PERMEABILITY TO BRINE

<u>SAMPLE NUMBER</u>	<u>DEPTH, METRES</u>	<u>PERMEABILITY TO SIMULATED BRINE, MILLIDARCS</u>
<u>Chevron Virden Prov 13C-24-11-26 W1M</u>		
*SCA-3A/13-24	606.83	0.17
*SCA-3B/13-24	606.83	0.60
SCA-5/13-24	608.60	13.2
*SCA-6/13-24	608.66	2.03
SCA-7A/13-24	609.14	10.3
SCA-8/13-24	609.92	4.28
*SCA-9/13-24	609.97	1.04
*SCA-10/13-24	610.26	14.4
<u>Chevron Virden 1D-26-11-26 W1M</u>		
SCA-1/1-26	595.68	4.58
SCA-2/1-26	595.98	18.8
*SCA-3/1-26	598.04	33.4
SCA-4/1-26	598.09	20.8
*SCA-5/1-26	602.27	2.14

\*Sample not used for subsequent analysis.



FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SUMMARY OF AMOTT METHOD WETTABILITY TEST RESULTS

SAMPLE CONDITION:	Restored	INITIAL FLUID IMBIBED:	Water
SAMPLE NUMBER:		SCA-4/1-26	
DEPTH, METRES:		598.09	
PERMEABILITY TO AIR, mD:		42.2	
POROSITY, FRACTION:		0.159	
IMMOBILE WATER SATURATION, *			
FRACTION PORE SPACE:		0.165	
PERMEABILITY TO OIL AT			
IMMOBILE WATER SATURATION, mD:		26.4	
SPONTANEOUS WATER IMBIBITION,			
FRACTION PORE SPACE:		0.412	
FORCED WATER IMBIBITION,			
FRACTION PORE SPACE:		0.114	
TOTAL WATER IMBIBITION,			
FRACTION PORE SPACE:		0.526	
IMMOBILE OIL SATURATION, **			
FRACTION PORE SPACE:		0.309	
PERMEABILITY TO WATER AT			
IMMOBILE OIL SATURATION, mD:		-	
SPONTANEOUS OIL IMBIBITION,			
FRACTION PORE SPACE:		0.026	
FORCED OIL IMBIBITION,			
FRACTION PORE SPACE:		0.289	
TOTAL OIL IMBIBITION,			
FRACTION PORE SPACE:		0.315	
WETTABILITY INDEX TO WATER:		0.783	
WETTABILITY INDEX TO OIL:		0.083	

\*WATER PRESENT JUST PRIOR TO WATER IMBIBITION

\*\*OIL PRESENT JUST PRIOR TO OIL IMBIBITION

WETTABILITY INDEX - SPONTANEOUS IMBIBITION  
TOTAL IMBIBITION

**CORE  
LABORATORIES**

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

USBM WETTABILITY DATA

<u>SAMPLE NUMBER</u>	<u>PERMEABILITY TO AIR, MILLIDARCYS</u>	<u>POROSITY, FRACTION</u>	<u>INITIAL WATER SATURATION, PORE VOLUME FRACTION</u>	<u>PRESSURE, kPa</u>	<u>AVERAGE WATER SATURATION, PORE VOLUME FRACTION</u>
--------------------------	---	-------------------------------	---	--------------------------	---

Water Displacing Oil

SCA-4/1-26	42.2	0.159	0.165	4	0.634
				10	0.655
				25	0.670
				45	0.680
				70	0.686
				88	0.691
				107	0.691

Oil Displacing Water

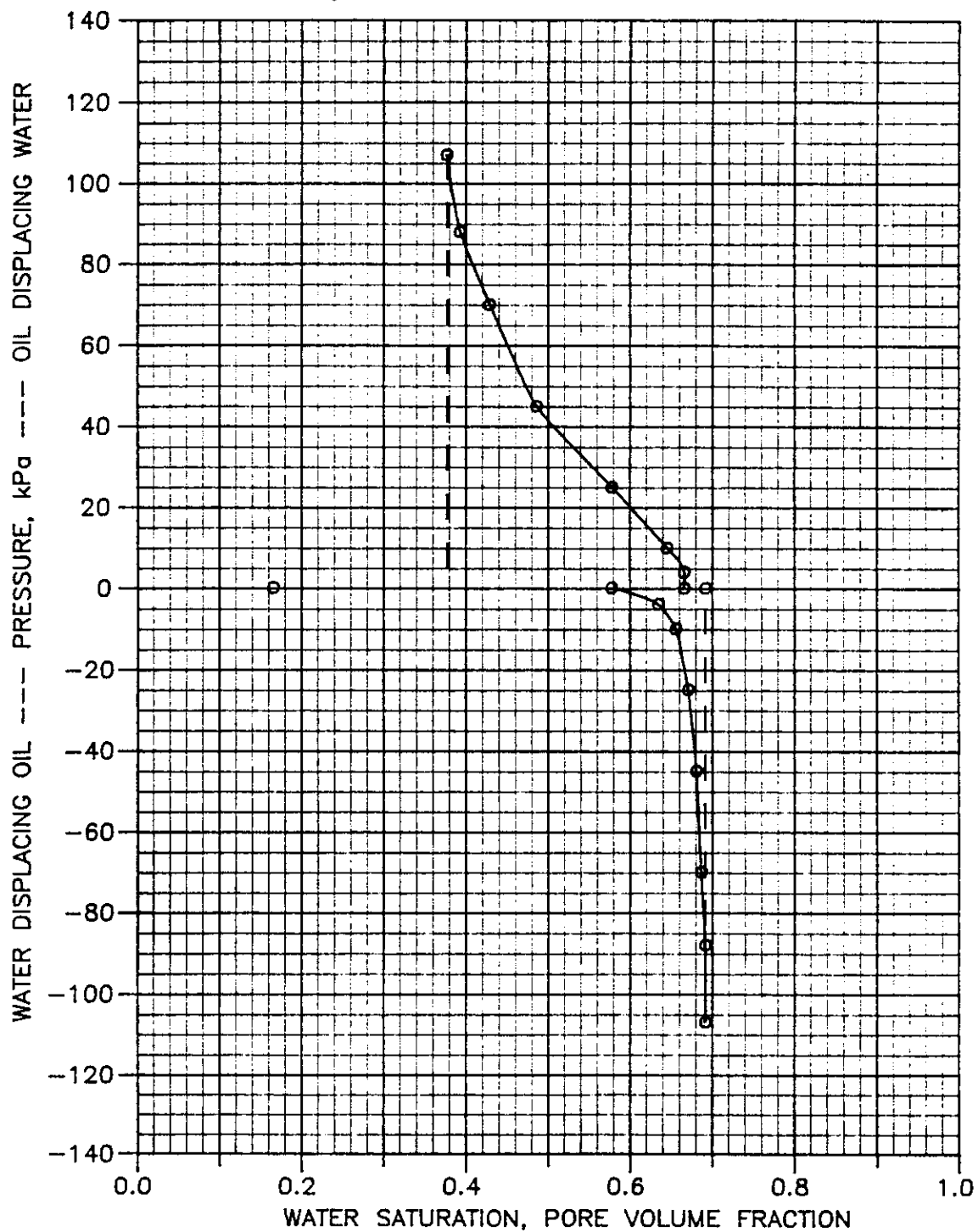
	4	0.665
	10	0.644
	25	0.577
	45	0.485
	70	0.428
	88	0.392
	107	0.376

# AVERAGE WATER SATURATION VERSUS PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-4/1-26  
Depth, Metres: 598.09  
Permeability, mD: 42.2  
Porosity, Fraction: 0.159  
USBM Wettability Index: 0.824



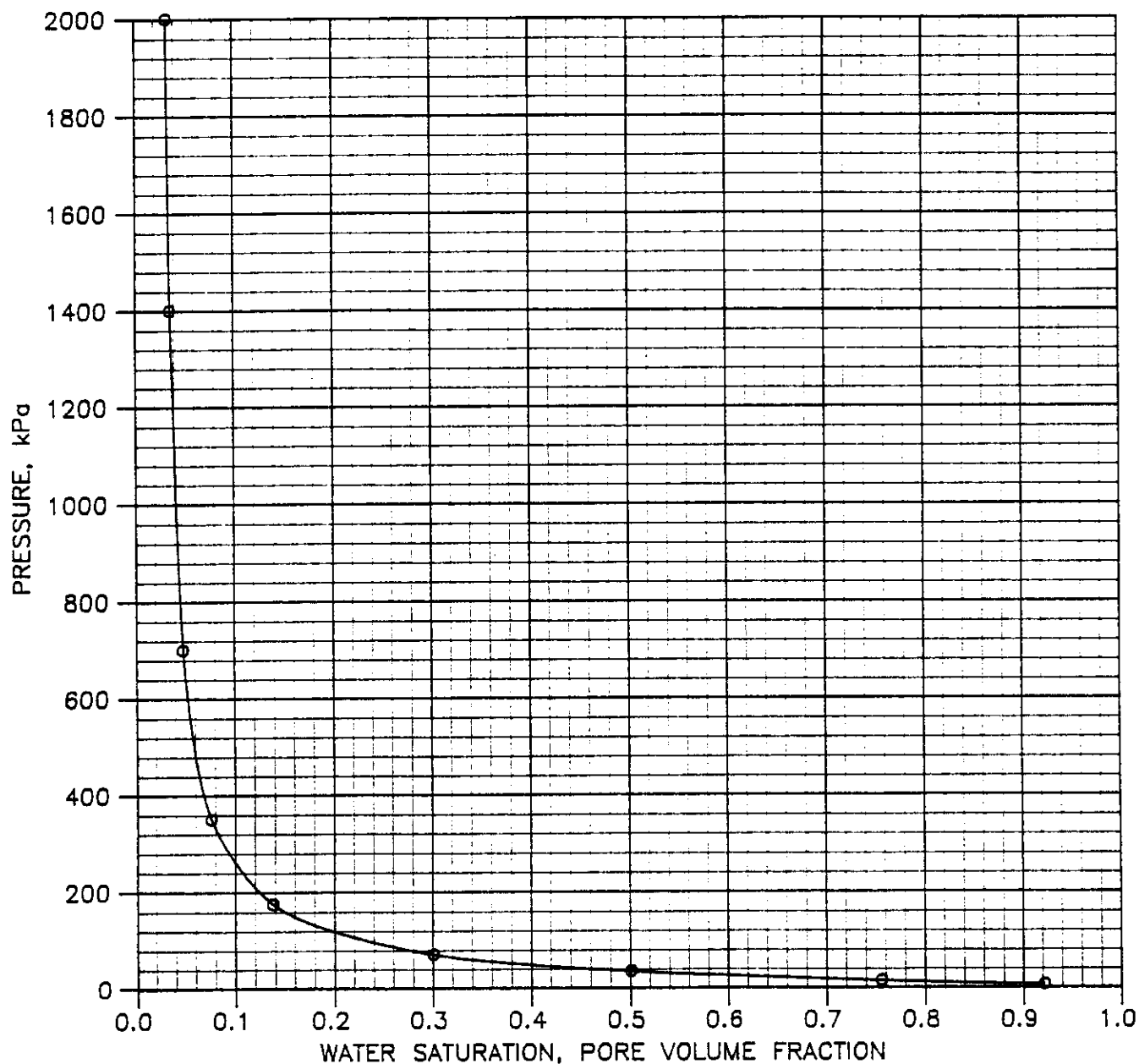


# AIR-WATER CENTRIFUGE CAPILLARY PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-4/1-26  
Depth, Metres: 598.09  
Permeability, mD: 42.2  
Porosity, Fraction: 0.159



COMPANY	Chevron Canada Resources
WELL	
LOCATION	

FORMATION	Lodgepole
FIELD	Virden
PROVINCE	Manitoba

### OIL-WATER CENTRIFUG CAPILLARY PRESSURE DATA

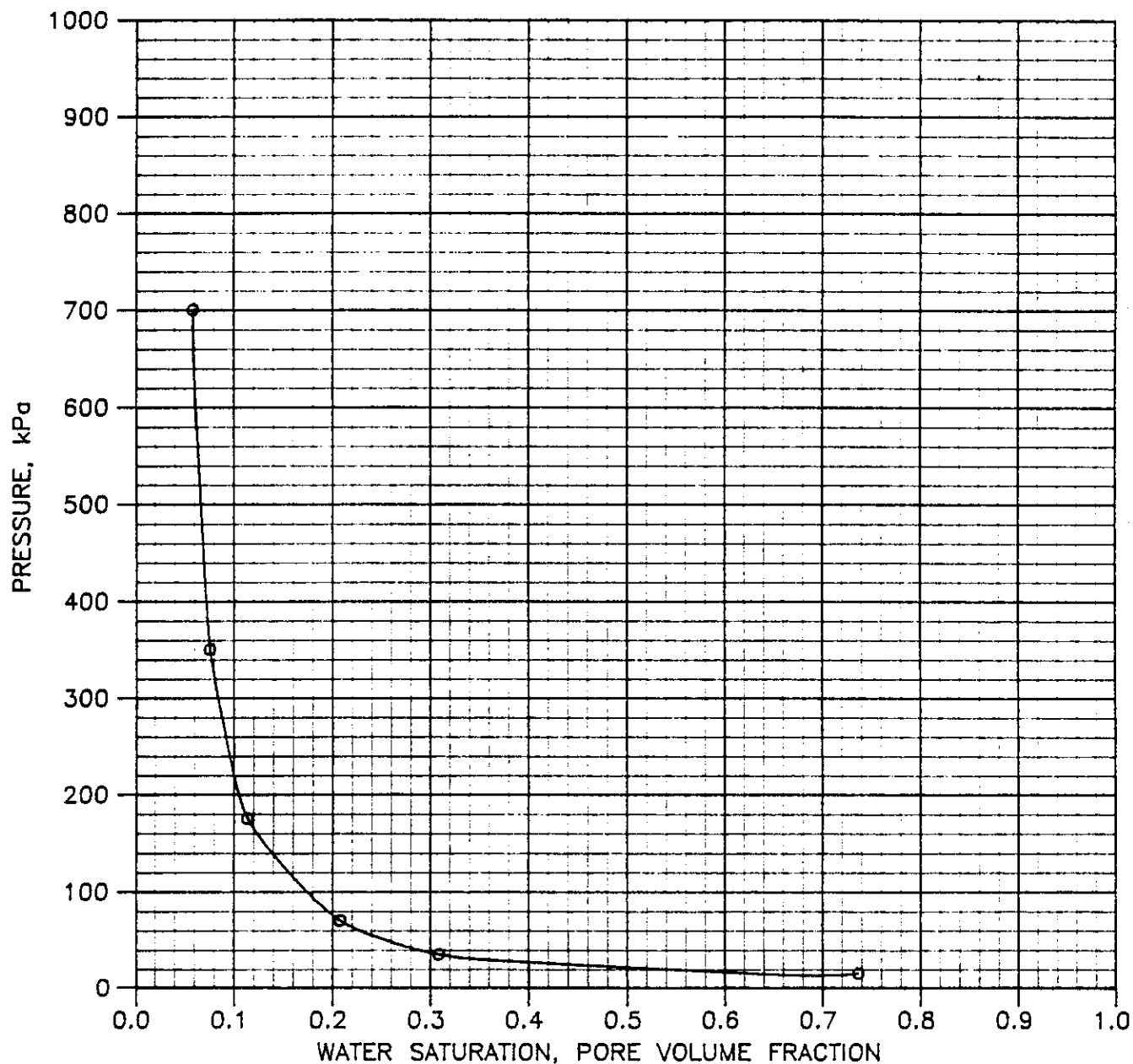
SAMPLE NUMBER	PERMEABILITY TO AIR, MILLIDARCS	POROSITY, FRACTION	PRESSURE, kPa:							HASSLER CORRECTED WATER SATURATION, PORE VOLUME FRACTION
			INITIAL	WATER SATURATION, PORE VOLUME FRACTION	6	15	35	70	175	
<u>Chevron Virden Prov. 13C-24-11-26 W1M</u>										
SCA-5/13-24	26.8	0.104		1.000	0.736	0.308	0.207	0.113	0.075	0.058
<u>Chevron Virden 1D-26-11-26 W1M</u>										
SCA-1/1-26	21.7	0.102		1.000	0.521	0.265	0.187	0.111	0.085	0.062

# OIL-WATER CENTRIFUGE CAPILLARY PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-5/13-24  
Depth, Metres: 608.60  
Permeability, mD: 26.8  
Porosity, Fraction: 0.104

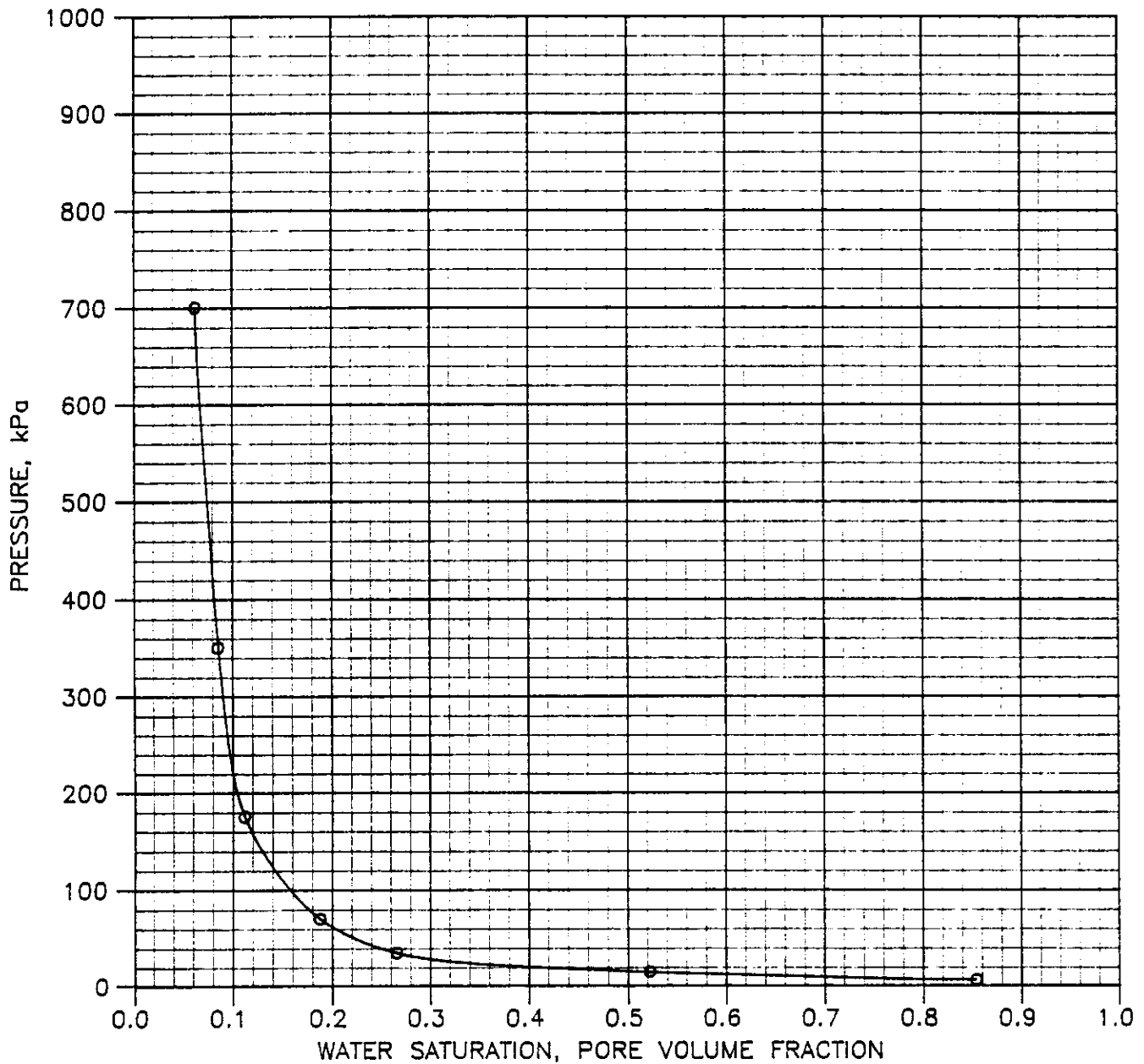


# OIL-WATER CENTRIFUGE CAPILLARY PRESSURE

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-1/1-26  
Depth, Metres: 595.68  
Permeability, mD: 21.7  
Porosity, Fraction: 0.102





FILE 52133-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26  
LOCATION LSD 13-24-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SUMMARY OF ROOM CONDITION UNSTEADY-STATE WATER-OIL RELATIVE PERMEABILITY TEST RESULTS

SAMPLE NUMBER	DEPTH, METRES	PERMEABILITY TO AIR, MILLIDARCYS	INITIAL CONDITIONS			TERMINAL CONDITIONS			OIL RECOVERED	
			WATER			OIL			FRACTION	
			SATURATION,	PERMEABILITY		SATURATION,	PERMEABILITY		PORE	FRACTION
			FRACTION	TO OIL,		FRACTION	TO WATER,		SPACE	OIL IN
			PORE SPACE	MILLIDARCYS		PORE SPACE	MILLIDARCYS		SPACE	PLACE
SCA-8/13-24	609.92	6.44	0.229	4.61		0.340	0.71		0.431	0.559

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL  
LOCATION

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

SUMMARY OF ROOM CONDITION STEADY-STATE WATER-OIL RELATIVE PERMEABILITY TEST RESULTS

SAMPLE NUMBER	DEPTH, METRES	PERMEABILITY TO AIR, MILLIDARCYS	INITIAL CONDITIONS			TERMINAL CONDITIONS			OIL RECOVERED	
			WATER			OIL			FRACTION	
			SATURATION, FRACTION TO OIL, PORE SPACE	PERMEABILITY TO OIL, MILLIDARCYS		SATURATION, FRACTION TO WATER, PORE SPACE	PERMEABILITY TO WATER, MILLIDARCYS		PORE SPACE	FRACTION OIL IN PLACE
Chevron Virden Prov 13C-24-11-26 W1M										
SCA-7A/13-24	609.14	13.4	0.037	10.3	0.126	0.447	0.530		0.516	0.536
Chevron Virden 1D-26-11-26 W1M										
SCA-2/1-26	595.98	28.3	0.041	21.0	0.118	0.413	6.51		0.546	0.569

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26  
LOCATION LSD 13-24-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

STEADY-STATE WATER-OIL RELATIVE PERMEABILITY DATA

SAMPLE NUMBER: SCA-7A/13-24 INITIAL WATER SATURATION,  
FRACTION PORE SPACE: 0.037  
PERMEABILITY TO AIR, mD: 13.4 POROSITY, FRACTION: 0.126

PERMEABILITY TO OIL AT  
INITIAL WATER SATURATION, mD: 10.3

<u>WATER SATURATION, FRACTION PORE SPACE</u>	<u>WATER-OIL RELATIVE PERMEABILITY RATIO</u>	<u>RELATIVE PERMEABILITY TO WATER* FRACTION</u>	<u>RELATIVE PERMEABILITY TO OIL* FRACTION</u>
0.037	0.000	0.000	1.000
0.356	0.088	0.012	0.137
0.394	0.238	0.020	0.084
0.456	1.19	0.031	0.026
0.491	3.23	0.042	0.013
0.521	6.96	0.048	0.0069
0.553		0.052	

\*Relative to Permeability to Oil at Initial Water Saturation.

FILE 52132-89-83

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26  
LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
FIELD Virden  
PROVINCE Manitoba

STEADY-STATE WATER-OIL RELATIVE PERMEABILITY DATA

SAMPLE NUMBER: SCA-2/1-26 INITIAL WATER SATURATION,  
FRACTION PORE SPACE: 0.041  
PERMEABILITY TO AIR, mD: 28.3 POROSITY, FRACTION: 0.118  
PERMEABILITY TO OIL AT  
INITIAL WATER SATURATION, mD: 21.0

<u>WATER SATURATION, FRACTION PORE SPACE</u>	<u>WATER-OIL RELATIVE PERMEABILITY RATIO</u>	<u>RELATIVE PERMEABILITY TO WATER* FRACTION</u>	<u>RELATIVE PERMEABILITY TO OIL* FRACTION</u>
0.041	0.000	0.000	1.000
0.209	0.107	0.017	0.159
0.226	0.198	0.023	0.114
0.271	0.870	0.043	0.050
0.321	4.03	0.073	0.018
0.351	10.4	0.090	0.0086
0.587		0.309	

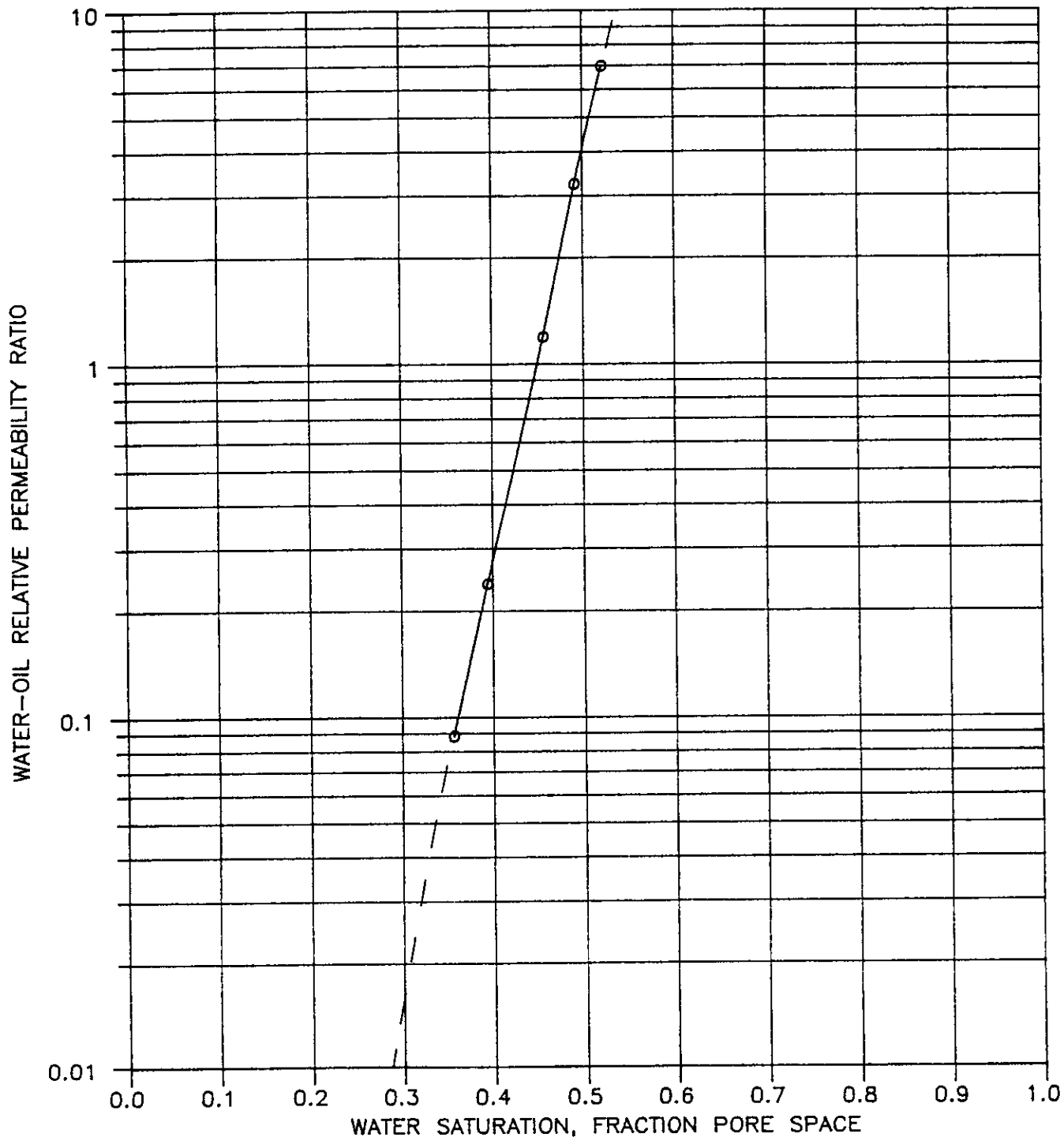
\*Relative to Permeability to Oil at Initial Water Saturation.

# WATER-OIL RELATIVE PERMEABILITY RATIO (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-7A/13-24  
Depth, Metres: 609.14  
Permeability, mD: 13.4  
Porosity, Fraction: 0.126

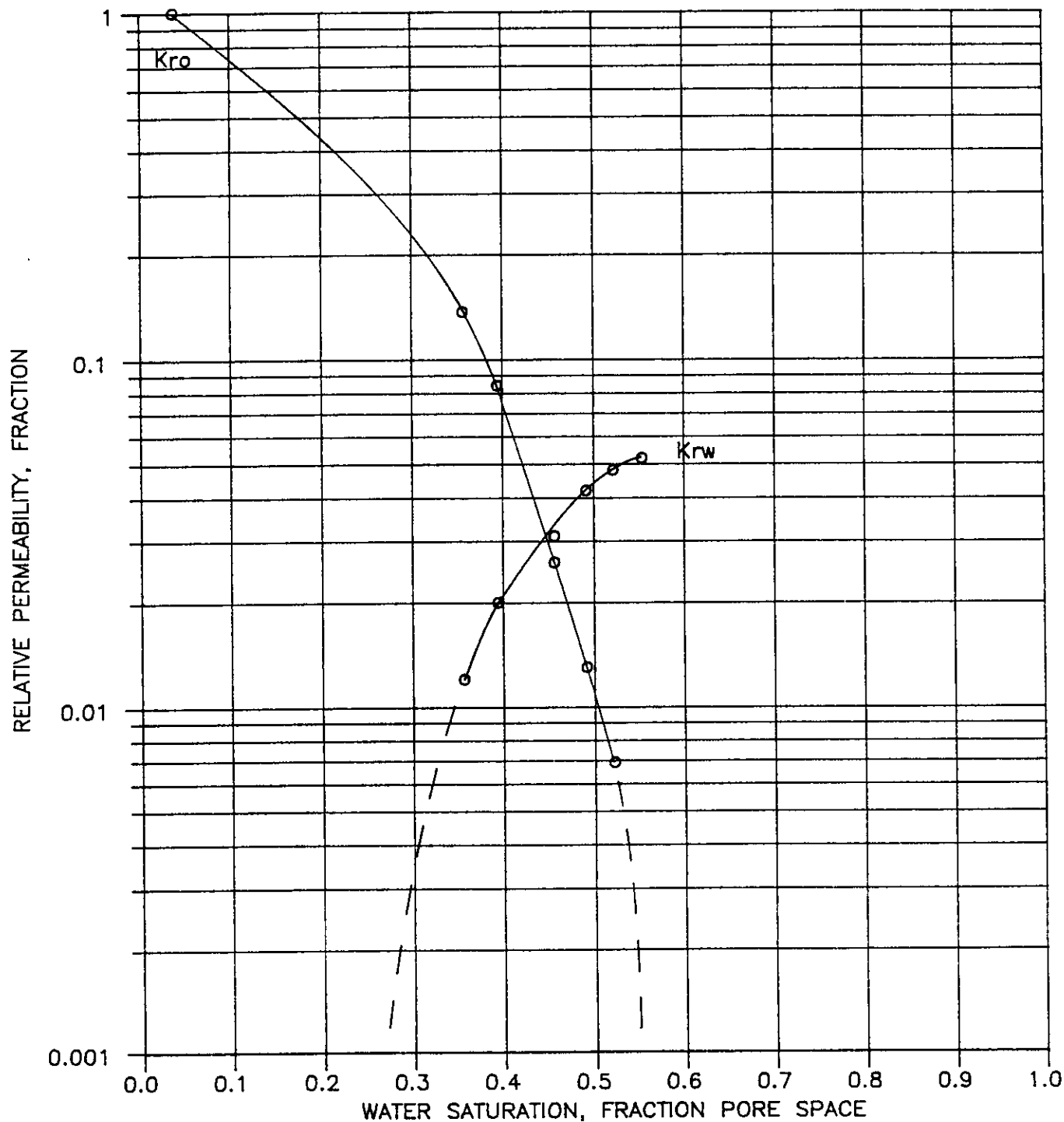


# WATER-OIL RELATIVE PERMEABILITY (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden Prov 13C-24-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-7A/13-24  
Depth, Metres: 609.14  
Permeability, mD: 13.4  
Porosity, Fraction: 0.126

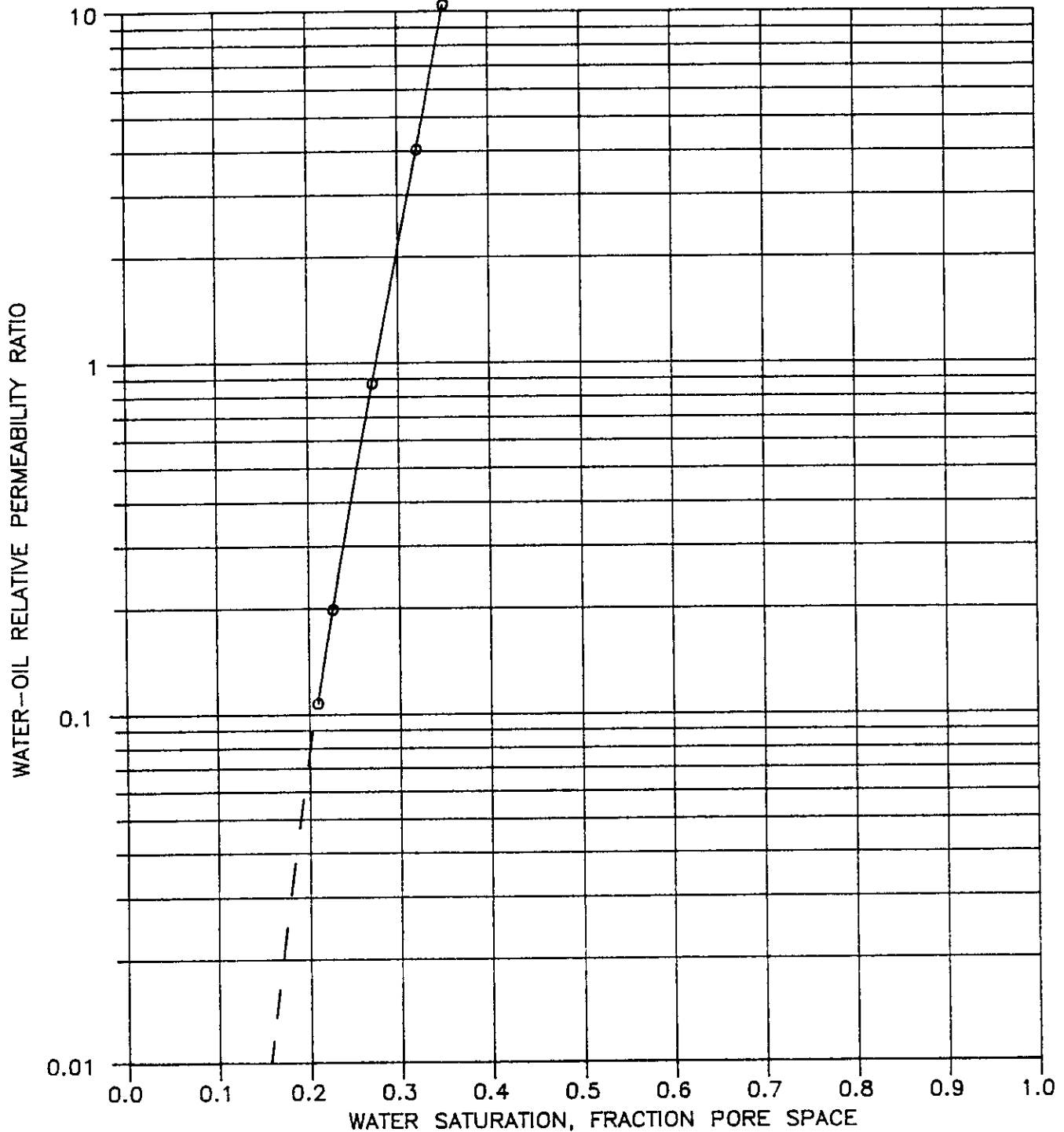


# WATER-OIL RELATIVE PERMEABILITY RATIO (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-2/1-26  
Depth, Metres: 595.98  
Permeability, mD: 28.3  
Porosity, Fraction: 0.118

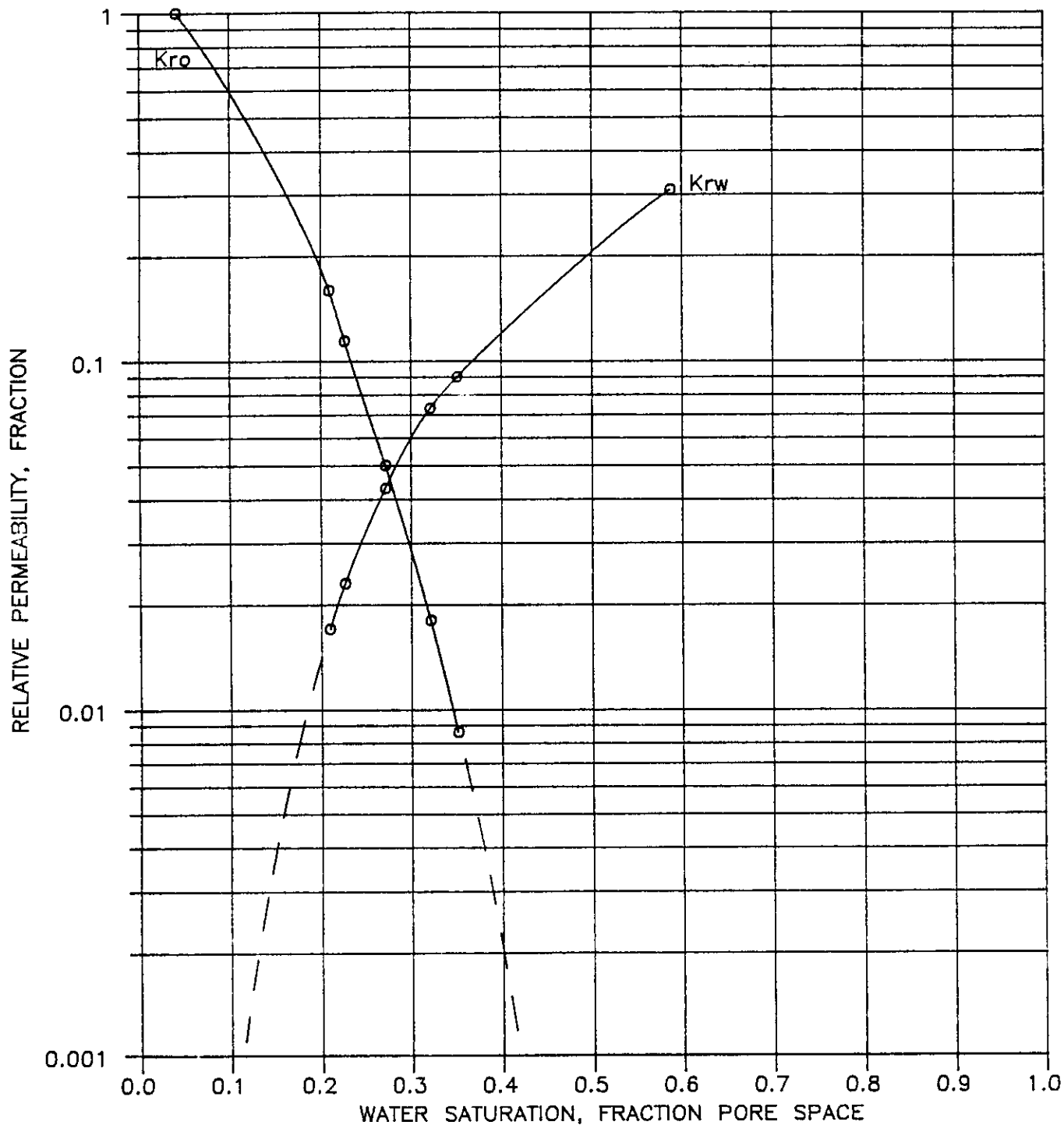


# WATER-OIL RELATIVE PERMEABILITY (Steady-State)

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-2/1-26  
Depth, Metres: 595.98  
Permeability, mD: 28.3  
Porosity, Fraction: 0.118





COMPANY Chevron Canada Resources  
 WELL Chevron Virden 1D-26-11-26  
 LOCATION LSD 1-26-11-26 W1M

FORMATION Lodgepole  
 FIELD Virden  
 PROVINCE Manitoba

ROCK (PORE VOLUME) COMPRESSIBILITY

SAMPLE NUMBER	DEPTH, METRES	PERMEABILITY TO AIR, MILLIDARCYS	EFFECTIVE OVERBURDEN PRESSURE, kPa	PORE VOLUME cm <sup>3</sup>	BULK VOLUME cm <sup>3</sup>	POROSITY, FRACTION	COMPRESSIBILITY, $p_v/p_v/kPa \times 10^{-7}$	
							(1)	(2)
SCA-2/1-26	595.98	28.3	2 000	3.383	34.232	0.099	-	-
			7 000	3.353	34.212	0.098	14.9	9.22
			14 000	3.324	34.173	0.097	9.58	5.93
			21 000	3.308	34.157	0.097	7.80	4.83
			28 000	3.293	34.142	0.096	7.31	4.52
			35 000	3.276	34.125	0.096	6.89	4.26
			42 000	3.257	34.106	0.096	6.58	4.07
			49 000	3.235	34.084	0.095	10.4	6.44
			56 000	3.216	34.065	0.094	13.1	8.11
			63 000	3.185	34.034	0.094	15.0	9.29
			68 000	3.153	34.002	0.093	16.1	9.97

(1) Measured in laboratory under hydrostatic loading conditions.

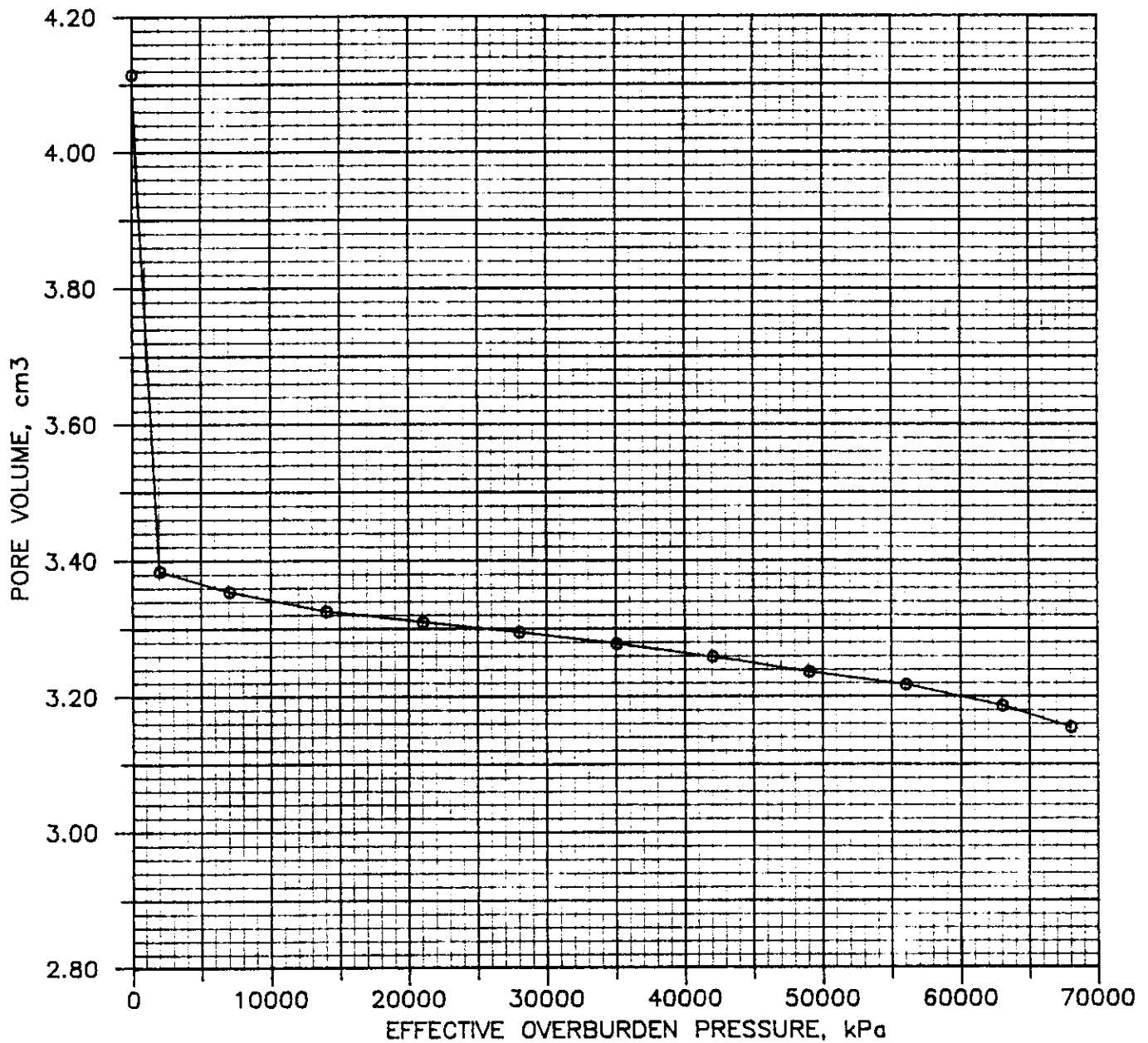
(2) Uniaxial loading conditions, transformed from hydrostatic data using an average translation factor of 0.619 as per Teeuw, Dirk: "Prediction of Formation Compaction from Laboratory Compressibility Data," Trans., AIME (1971) 251, 263-271.

## ROCK (PORE VOLUME) COMPRESSIBILITY

COMPANY Chevron Canada Resources  
WELL Chevron Virden 1D-26-11-26 W1M

FILE 89-83  
FORMATION Lodgepole

Sample: SCA-2/1-26  
Depth, Metres: 595.98  
Permeability, mD: 28.3  
Porosity, Fraction: 0.118



## **APPENDIX**



## CORE LABORATORIES

---

January 3, 1990

Core Laboratories  
Calgary, Alberta, Canada

Attention: Mr. Norm Gruber

Subject: Interfacial Tension Measurement  
Chevron Canada Resources, Ltd.  
North Virden Scallion Unit #1 Well  
Lodgepole Formation  
Manitoba, Canada  
File Number: SCAL-89198

Dear Mr. Gruber:

A laboratory study to measure the interfacial tension of crude oil from the subject well has been performed for Core Laboratories, Calgary. This study was authorized on behalf of Chevron Canada Resources, Ltd. in your transmittal of October 12, 1989. Final results of Pendant Drop Interfacial Tension measurements are included herein.

### Test Preparation

Test parameters and a formation brine analysis were specified in the letter of authorization. Synthetic formation water, see composition, Page 1, was prepared to match the analysis provided. A 2-litre sample of degassed crude oil was received by Core Lab-Calgary and forwarded to the Dallas Production Services Laboratory on September 18, 1989. Oil/water interfacial tension measurements were performed at 26.7°C and atmospheric pressure as described below.

### Interfacial Tension (IFT)

In preparation for the oil/water IFT tests, a portion of the dead crude oil was circulated with synthetic formation water to establish chemical equilibrium between the two phases. The equilibrated brine was transferred into a stainless steel sight-gauge cell located within a controlled temperature air-bath oven and a test temperature of 80°F (26.7°C) established. (A slight positive pressure was maintained in order to prevent outgassing of the test fluids.) Interfacial tension measurements then were performed by injecting the degassed crude oil through a needle extending into the brine-filled cell until a pendant drop was formed on the tip of the needle.

Photographs of the drops were taken as quickly as possible, then additional photographs taken after 5, 15, 30, 60, 120, 240, 480, and 1200 minutes. IFT values were calculated from the drop dimensions using the equation:

$$\delta = \Delta \rho g d_e^2 / H$$

where:

- $\delta$  = interfacial tension, dynes/cm
- $\Delta \rho$  = difference in density between the droplet and the phase surrounding it, gm/cm<sup>3</sup>
- $g$  = gravitational constant, cm/sec<sup>2</sup>
- $d_e$  = maximum (equatorial) diameter of the unmagnified drop, cm
- $H$  = shape correction factor, dimensionless

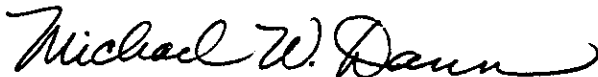
Densities of the water and the degassed crude oil at 26.7°C were determined using a hydrometer.

#### Discussion of Test Results

A terminal IFT value of 29.0 dynes/cm was obtained after 1200 minutes of equilibration. This value is in the expected range for uncontaminated crude oil.

Please contact us should you have any questions. Thank you for this opportunity to be of service.

Very truly yours,



Michael W. Dann, Supervisor  
Production Services Laboratory  
Dallas Core Services

MWD:PGM:ed

SYNTHETIC BRINE COMPOSITION

<u>Constituents</u>	<u>Concentration, g/l</u>
Sodium Chloride (NaCl)	110.498
Calcium Chloride (CaCl <sub>2</sub> )	13.159
Magnesium Chloride (MgCl <sub>2</sub> ·6H <sub>2</sub> O)	6.682
Sodium Bicarbonate (NaHCO <sub>3</sub> )	0.737
Sodium Sulfate (Na <sub>2</sub> SO <sub>4</sub> )	5.761

The brine composition was prepared from the following analysis:

Company: Chevron Canada Resources, Ltd.  
Well: North Virden Scallion Unit #1

<u>Constituent</u>	<u>Concentration,</u> <u>mg/l</u>	<u>Constituent</u>	<u>Concentration,</u> <u>mg/l</u>
Sodium	45,507	Chloride	77,750
Calcium	4,752	Bicarbonate	535
Magnesium	799	Sulfate	3,896

PENDANT DROP INTERFACIAL TENSION TEST RESULTS

Fluids: Synthetic Formation Water  
Scallion Unit #1 Degassed Crude Oil

Temperature: 80°F (26.7°C)  
Pressure: Ambient

<u>Cumulative Elapsed Time, minutes</u>	<u>Interfacial Tension, dynes/cm</u>
1	34.2
5	32.3
15	30.9
30	30.2
60	30.1
120	29.6
240	29.3
480	29.1
1200	29.0