GEOLOGICAL SURVEY OF CANADA
COMMISSION GEOLOGIQUE DU CANADA

Open File 2352

HYDROCARBON WETNESS, NGL, AND SULPHUR BYPRODUCTS OF NATURAL GASES IN WESTERN CANADA.

James P. Hea
Petroleum Resource Appraisal Secretariat
Institute of Sedimentary and Petroleum Geology
Calgary

April, 1991

TABLE OF CONTENTS

FIGURES

TABLES

ABSTRACT

Natural gas liquids in the reservoir are estimated using the hydrocarbon wetness ratio (Wh), calculated from natural gas compositions of non-associated and associated gas pools by grid area (15 by 30-minute latitude and longitude) across western Canada. Wh and hydrogen sulphide of Devonian to Cretaceous groupings of pools are mapped; genesis and distribution of NGL and sour gases are discussed; and, the shrinkage component of the recovery factor, used in calculating marketable gas is estimated by geological grouping for use in resource estimates of the endowment of natural gas and its by-products. Hydrocarbons and sour gases are controlled by depth of burial (paleotemperature) and by thermochemical reduction of sulphates, both increasing across the Alberta shelf towards the Rocky Mountains. Mapped Wh and sour gas gradients are predictive of new NGL and sulphur resources, respectively in the Lower Cretaceous and Devonian of the Alberta basin and British Columbia.

ACKNOWLEDGMENTS

Analysis of natural gas composition is part of the Western Canada Natural Gas Resources Assessment in progress at the Petroleum Resource Appraisal Secretariat. Drs. Richard Procter and Gordon Taylor of the Secretariat are thanked for help on resource assessment methodology. Grant Fullmer at the ISPG and Ken Hakes, a student at the University of Alberta are especially thanked for developing the Western Canada Sedimentary Basin - Gas Composition Data Base.

INTRODUCTION

Objectives

Natural gas compositions of non-associated and associated gas pools in the Western Canada Sedimentary Basin (WCSB) are analyzed as to their stratigraphic and regional distribution of natural gas liquids (NGL) and sulphur. Specific objectives are to evaluate the hydrocarbon wetness of gases by a carbon number estimator of NGL content, to map the estimator over the WCSB, to define type gas compositions by geological groupings, to describe in more detail the sour gas occurrences in the Devonian deep basin of central Alberta and NGL of the Cretaceous Mannville Formation, and to summarize liquid and sulphur yields from raw gas for use in resource assessments of natural gas by-products [10].

Data Retrieval

Natural gas composition and raw gas in-place by pool were retrieved from the Institute's mainframe HP3000, downloaded to 3.5-inch disks and formatted, sorted and printed using Microsoft EXCEL. Electronic and hardcopy files are available for reference at the ISPG. The data are sorted into twelve geological zones (Alberta Energy Resources Conservation Board and other provincial pool codes) from Devonian to Cretaceous and by 15′ latitude by 30′ longitude grid areas for Alberta and on a pool and well basis in British Columbia and Saskatchewan. Natural gas compositions for nearly 22,000 pools were retrieved for inclusion in the file which is named Western Canada Sedimentary Basin - Gas Composition Data Base (WCSB-GCDB).

Analysis of such a large file requires both scientific hypothesis and appropriate statistical methods of data reduction and testing. Minimum, maximum, mean, and standard deviation, by geological grouping and grid area, were run in EXCEL for gas in-place, H_2S, CO_2, H_2S+CO_2, C1, C2+ and C5+. The variability of gas composition within areas and groupings can be low or high. Regional gradients, especially after smoothing, proved to be remarkably consistent once the Wh estimator (see below) was weighted to the largest pools in the grouping. Inspection of summary statistics is key to selection of grouping and area representative gas composition. Analyses of variance and F-tests were run between groupings and areas. Statistical significance is evaluated as the measure of two-dimensional (mapping) consistency by the estimator; there is considerable scope for more rigorous data treatment beyond the assumptions and limited objectives here specified.

Gas compositions in the WCSB are related to geological zone, depth, and lithology (observable) and organic sources, thermal history, and migration of gases and fluids (inferred), but unique typing of gas composition by zone is usually not possible. Gas composition seems to be dependent on depth and on local, mainly unknown conditions. A cluster technique was deemed appropriate to classify pools by their methane, liquid and sulphur fractions. Once classified, type compositions were selected for clusters and subclusters; actual pools were matched to cluster means and variances to avoid "statistical hybrids" representing type gas compositions.

Thermochemical Gas

The process of maturation of organic matter from deposition through thermochemical conversion of crude oil into natural gas is recorded in the fractions and types of inert, acid and hydrocarbon components in the gas. Some indicators of the process based on ratios of carbon numbers are listed in Table 1 [3,4]. Correlations of Hydrocarbon Wetness (Wh) to NGL by geological zone in Table 2 show that Wh is an efficient estimator of total liquids for natural gases in the WCSB. High correlations are evident for ethane, propane, and butane but pentanes-plus are not well correlated to the ratio.

TABLE 1

Hydrocarbon Indicators

Indicator	Significance
C1	High in immature gases, fraction drops in liquid window, rises in over-mature gases;
C1/(C1+..C7)	<0.4 in mature gases; >0.7 in overmature gases;
C2/C3	Decreases with maturity;
iC4/nC4	>1 in immature gases; 0.7-0.8 in liquid window; follows iC5/nC5;
(C1+C2)/(C3+..C5)	Distinguishes HCs from coal-bed methane;
(C2/C3)/(iC4/nC5)	Regional studies;
C2+/(C1+C2+), 100xC2+/(C1+C2+)	Hydrocarbon wetness ratio,percentage (Wh).

TABLE 2

Correlations of Wh and NGL by Geological Zone (data from Table 5)

Wh to:	1	2	3	4
Ethane	0.97	0.97	0.96	0.96
Propane	0.95	0.97	0.97	0.95
Butane	0.94	0.92	0.95	0.97
Pentanes+	0.71	0.75	0.75	0.52
Total NGL	0.99	0.99	0.99	0.99

1. Cretaceous I, II, III;
2. Permo-Penn to Jurassic;
3. Mississippian;
4. Devonian.

Hydrogen sulphide is formed in sediments by microbial action, thermal cleavage of crude oils, and thermochemical reduction of sulphates by hydrocarbons [8]. Maturation lowers molecular weights, oils become more paraffinic as cycloalkanes transform into alkanes and aromatics, asphaltenes precipitate, and heteroatoms form N_2, H_2S, CO_2 and water. Crude oils can thus be transformed wholly to methane under extreme thermal cleavage with traces only remaining of the higher carbon numbers.

Dissolved sulphates react with hydrocarbons at high temperatures. Table 3 summarizes the conversion temperatures. The simplest, non-balanced reaction is

$$CH_2 + SO_4^{-2} + H_2O = H_2S + CO_2 + OH^-$$

Elemental sulphur forms by the reaction

$$H_2S + SO_4^{-2} = So + OH^- + H_2O$$

and is precipitated as native sulphur, remains under high H_2S concentrations as free sulphur in the gas, or under the usual conditions is exhausted by excess hydrocarbons in the reaction

$$So + CH_2 + H_2O = H_2S + CO_2 + H_2O$$

Super-acid gas and elemental sulphur occurrences in Devonian to Triassic pools attest to the importance of autocatalytic reactions of hydrocarbons and sulphates in the deep basin and disturbed belt of the WCSB. Because of low concentrations of sulphur in crudes (average $C_{100} H_{170} S$ oil gives a maximum of 2% H_2S), a feed of aqueous sulphate is required to sustain hydrocarbon conversions to acid gases. Massive anhydrites of the middle Devonian Keg River Formation, found subjacent to acid gas reservoirs, and interbedded formational anhydrites were presumably sources of sulphates. Faults and fractures, vertical and lateral permeability conduits, and ground water movement connected the source of sulphates to the pooled hydrocarbons. While abnormally pressured compartments exist in the deeper parts of the Alberta basin, overall pressure data show a hydrodynamically open system. This is confirmed by connate water analyses and salt ion concentrations from outcrop areas to depocentres of the basin [5].

The native sulphur - hydrocarbon reaction ("Tokind reaction") and other thermochemical reactions produce an excess of CO_2 over the fractions of H_2S and CO_2 actually present in the acid gas pools of the WCSB. The excess CO_2 is presumed lost by migration as dissolved gas in ground waters or precipitated as carbonates in the host rock. A diagenetic sequence of calcite and dolomite cements has been observed in Devonian and other reservoirs of the Alberta basin [7]. Calcium ions for carbonate reactions are additionally sourced by the reduction of sulphates. Porosity destruction and enhancement in the reservoir are a consequence of these reactions.

Expansion of the original reservoir volume accompanies thermal cleavage of crude oils into natural gases. Volume increase is estimated to be about 30 percent [2]. Given that most deep Devonian gas pools are normally pressured, fracture gradients of traps can be assumed to have been exceeded, with the result that acid gases permeated shallower zones, spilled laterally, or otherwise augmented initial oil saturated pore volume.

TABLE 3

Thermal Maturation of Hydrocarbons and Mineral Changes

Maturation	CH_2 or Mineral
Immature	C1 biogenic <50°C; gypsum to anhydrite >34°C;
Mature	Wet gas (oil) generated from kerogen; liquid window 40-80°C; hi-Mg calcite to dolomite >40°C;replacive anhydrite and dolomite >80°C; CH_2 reduction of sulphates 80-120°C;
Overmature	NGL unstable 120-160°C: 30% cracked >120°C 50% cracked >130°C 100% cracked >150°C excess carbon residue; H_2S gases >120°C associated with C1 and NGL; Methane and sour gases.

HYDROCARBON WETNESS MAPS

Hydrocarbon wetness percentage (Wh) of natural gases is mapped by seven geological groupings from Devonian to Upper Cretaceous (Figures 1-7; Table 4). Wh is calculated for each of the groupings by grid area, the data aggregated, a representative value estimated, mapped and smoothed using a nine-grid moving average routine. Table 5 gives a listing of "type pools" with their gas composition, NGL and sulphur by-products, and calculated Wh. The pools are referenced to the latitude and longitude of the NE corner of the grid area in the WCSB-GCDB.

Regional trends of hydrocarbon wetness are strongly predictive of NGL distribution where used in combination with type pools and the "high sulphur areas" map shown on Figure 8. Thus where Wh<10, no gas processing is required except for sour gases, while Wh>20 indicates areas of NGL-rich, usually associated gas pools (pools with lower Wh values, however, frequently occur within high Wh contours). A suggested use for Wh maps is to situate a given zone and area within its regional trend and retrieve gas composition and summary statistics from the

TABLE 4

Geological Groupings

Grouping	AERCB Zones	Reservoirs in Alta, B.C. and Sask.
CRETACEOUS I	0990-1649	Medicine Hat, Milk River, Belly River, Colorado
CRETACEOUS II	1700-2439	Cardium, Second White Specks, Dunvegan, Bow Island, Viking, Cadotte, Doe Creek, Basal Colorado
CRETACEOUS III	2440-3500	Mannville, Blairmore, Fahler, Bluesky, Colony, Gething, Glauconitic, Sunburst, McMurray, Grand Rapids , Ostracod, Cadomin, Ellerslie, Basal Quartz
JURASSIC	4000-4999	"Jurassic", Nordegg, Rock Creek, Swift, Nikanassin, Sawtooth, Kootenay
TRIASSIC	5000-5399	"Triassic", Baldonnel, Charlie Lake, Halfway, Doig, Inga, Montney
PERMO- PENNSYLVANIAN	5560-5600	"Permo-Penn", Belloy
MISSISSIPPIAN	6000-6469	Rundle, Banff, Turner Valley, Debolt, Pekisko, Shunda, Elkton, Kiskatinaw, Stoddart, Bakken, Mission Canyon
DEVONIAN I	6481-6699	Wabamun, Graminia, Kotcho
DEVONIAN II	6700-7039	Nisku, Winterburn, Blueridge, Camrose, Jean Marie, Kakiska
DEVONIAN III	7040-7320	Leduc, Woodbend, Grosmont, Ireton
DEVONIAN IV	7321-7698	Beaverhill Lake, Swan Hills, Slave Point, Pine Point, Watt Mountain
DEVONIAN V	7699-7890	Elk Point, Gilwood, Sulphur Point, Zama, Keg River, Muskeg, Granite Wash

TABLE 5
GAS COMPOSITIONS

TYPICAL PIPELINE GAS COMPOSITION

N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm³	Wh
		GAS COMPOSITION mole percent								LIQUIDS m³/Mm³					
0.30	0.00	2.00	91.70	5.70	1.60	0.30	0.30	0.10	149.04	58.59	27.22	22	239.67	0.00	8.02

CRETACEOUS I
Alberta

Lat	Long	Field	Pool No.	GIP Mm³	N_2	H_2S	C02	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm³	Wh
							GAS COMPOSITION mole percent								LIQUIDS m³/Mm³					
50-45	111-30	MedHat	158160	46016	3.09	0.00	0.19	96.31	0.24	0.02	0.01	0.00	0.00	6.28	0.73	0.45	0.00	7.46	0.00	0.28
53-00	112-30	Kelsey	126002	445	1.38	0.00	0.05	96.84	1.31	0.25	0.02	0.02	0.04	34.25	9.15	1.81	1.93	47.15	0.00	1.67
52-00	113-30	Davey	272001	520	0.29	0.00	0.51	91.79	2.17	1.21	0.36	0.43	0.56	56.74	44.31	35.84	26.98	163.87	0.00	4.90
55-00	119-30	Wapiti	126098	116	3.06	0.00	0.03	85.54	6.82	2.96	0.38	0.73	0.22	178.32	108.39	50.36	10.60	347.67	0.00	11.50
53-00	114-30	Pembina	126327	800	0.23	0.00	0.32	84.10	7.37	3.02	0.57	1.08	1.09	192.70	110.59	74.86	52.52	430.67	0.00	13.49
54-45	119-00	Cutbank	154098	258	0.26	0.00	0.02	81.50	8.90	4.30	0.61	1.03	0.82	232.70	157.46	74.41	39.35	504.08	0.00	16.12
52-30	115-00	Ferrier	126098	52	1.49	0.00	0.15	80.78	7.89	6.59	0.85	1.48	0.32	206.30	241.32	105.71	15.42	568.75	0.00	17.50
53-45	117-00	12011 Un	126098	338	0.26	0.00	0.03	79.86	10.63	5.05	0.81	1.53	1.43	277.94	184.93	106.17	68.90	637.93	0.00	19.59

CRETACEOUS II
Alberta

Lat	Long	Field	Pool No.	GIP Mm³	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm³	Wh
							GAS COMPOSITION mole percent								LIQUIDS m³/Mm³					
50-30	110-30	MedHat	601060	197	5.07	0.00	0.04	93.71	0.72	0.19	0.04	0.02	0.02	18.83	6.96	2.72	0.96	29.47	0.00	1.05
54-00	111-00	Duvernay	218009	102	3.28	0.00	0.00	94.53	1.76	0.32	0.03	0.03	0.00	46.02	11.72	2.72	0.00	60.46	0.00	2.21
54-15	113-30	Fairydell	218760	3071	2.54	0.00	0.26	92.85	2.61	1.00	0.17	0.24	0.28	68.24	36.62	18.60	13.49	136.95	0.00	4.43
50-00	111-00	Bow Is	213000	2667	2.99	0.00	0.01	90.80	3.02	2.51	0.20	0.22	0.02	78.96	91.91	19.06	0.96	190.90	0.00	6.17
55-15	119-00	Elmworth	232003	698	0.22	0.00	1.45	91.33	5.07	1.15	0.21	0.22	0.35	132.56	42.11	19.51	16.86	211.05	0.00	7.12
50-00	113-00	Granum	213001	560	3.58	0.00	0.18	84.84	6.48	3.21	0.35	0.83	0.42	169.43	117.55	53.54	20.24	360.75	0.00	11.74
54-30	116-30	Fox Creek	218001	3750	1.28	0.00	0.42	86.58	5.84	3.10	0.50	0.98	1.26	152.70	113.52	67.15	60.71	394.07	0.00	11.87
51-30	114-00	Crossfield	176001	1478	0.00	0.00	0.35	84.72	7.34	5.14	1.20	0.00	0.40	191.92	188.22	78.94	19.27	478.35	0.00	14.72
53-45	117-00	MedLodge	218001	786	0.70	0.00	1.15	83.34	7.54	2.60	0.45	0.76	3.45	197.14	95.21	54.90	166.23	513.48	0.00	15.08
53-00	114-30	Minhik	176010	709	1.12	0.00	0.00	81.93	9.80	4.70	0.54	1.14	0.36	256.24	172.11	76.22	17.35	521.91	0.00	16.80
52-15	113-30	Penhold	218001	193	0.37	0.00	0.71	72.65	10.51	9.60	1.16	2.99	1.99	274.80	351.54	188.29	95.88	910.51	0.00	26.54

CRETACEOUS II
British Columbia

Lat	Long	Field	Fm.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
56-00	120-30	Sunrise	Cadot.	698	0.83	0.00	0.52	95.91	2.63	0.05	0.02	0.01	0.00	68.77	1.83	1.36	0.00	71.96	0.00	2.75
56-00	120-00	Doe	Cadot.	979	0.80	0.00	0.00	93.44	4.66	0.89	0.10	0.10	0.00	121.84	32.59	9.07	0.00	163.51	0.00	5.80
55-45	120-30	Sundown	Cadot.	426	4.50	0.00	0.29	82.52	8.44	2.44	0.47	0.56	0.76	220.68	89.35	46.73	36.62	393.38	0.00	13.31

CRETACEOUS III
Alberta

Lat	Long	Field	Pool No.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
55-15	114-00	Decrene	280002	864	0.75	0.00	0.16	98.19	0.32	0.06	0.07	0.10	0.23	8.37	2.20	7.71	11.08	29.36	0.00	0.79
56-15	118-00	Whitelaw	326002	562	0.11	0.00	0.90	97.47	1.27	0.14	0.04	0.02	0.03	33.21	5.13	2.72	1.45	42.50	0.00	1.52
59-00	117-30	Pomme	304098	17	1.55	0.00	0.93	95.82	0.95	0.42	0.10	0.11	0.09	24.84	15.38	9.53	4.34	54.08	0.00	1.71
51-30	110-30	Oyen	350098	32	7.14	0.00	0.08	90.34	1.50	0.39	0.30	0.14	0.09	39.22	14.28	19.96	4.34	77.80	0.00	2.61
49-30	110-30	Manyber.	332018	338	4.59	0.00	0.10	92.18	0.94	0.78	0.27	0.42	0.58	24.58	28.56	31.31	27.95	112.39	0.00	3.14
53-30	112-00	Warwick	250020	747	1.76	0.00	0.96	94.31	2.44	0.25	0.07	0.05	0.12	63.80	9.15	5.44	5.78	84.18	0.00	3.01
50-00	111-00	Lindbergh	310098	44	0.51	0.00	0.00	92.44	2.49	2.11	0.59	0.80	1.00	65.10	77.27	63.06	48.18	253.62	0.00	7.03
52-15	111-30	Provost	248027	1109	2.21	0.00	0.00	90.44	3.60	2.16	0.58	0.56	0.43	94.13	79.10	51.72	20.72	245.66	0.00	7.50
54-45	116-30	Kaybob	251260	8347	1.15	0.00	0.34	91.02	4.41	1.54	0.03	0.38	0.82	115.31	56.39	30.85	39.51	242.06	0.00	7.57
54-30	114-00	Jarvie	336002	496	1.15	0.00	1.17	89.97	5.46	1.49	0.28	0.25	0.15	142.76	54.56	24.05	7.23	228.60	0.00	7.82
55-15	119-00	Elmworth	272061	3709	0.40	0.00	0.59	90.69	5.82	1.64	0.20	0.32	0.33	152.17	60.06	23.59	15.90	251.72	0.00	8.39
52-30	115-00	Strachan	300004	600	0.11	0.00	1.64	88.85	6.81	1.53	0.25	0.26	0.54	178.06	56.03	23.14	26.02	283.24	0.00	9.56
54-45	118-30	Wapiti	272501	2762	0.15	0.00	1.52	88.93	7.11	1.30	0.27	0.22	0.50	185.90	47.60	22.23	24.09	279.83	0.00	9.56
50-15	113-00	ParklndNE	310004	235	1.65	0.00	0.13	87.63	6.75	1.98	0.36	0.53	0.83	176.49	72.51	40.38	39.99	329.36	0.00	10.65
54-15	117-00	Fir	326001	1074	1.20	0.00	1.92	85.13	6.61	2.05	0.28	0.41	2.39	172.83	75.07	31.31	115.15	394.36	0.00	12.12
53-30	114-00	Pembina	312005	439	2.13	0.00	0.29	84.51	6.85	3.60	0.55	1.04	0.93	179.10	131.83	72.14	44.81	427.88	0.00	13.30
53-15	117-00	Boyer	244098	839	5.86	0.00	1.94	79.24	7.01	3.24	0.46	1.17	1.07	183.29	118.65	73.95	51.55	427.44	0.00	14.08
52-45	114-00	Westro S	301260	25555	1.37	0.00	2.25	81.52	8.90	3.75	0.48	0.84	0.87	232.70	137.32	59.89	41.92	471.83	0.00	15.40
53-30	115-30	Westpem	310098	694	0.32	0.00	3.61	81.06	8.81	3.86	0.59	1.03	0.68	230.35	141.35	73.50	32.76	477.96	0.00	15.59
53-45	116-30	Edson	326001	6751	0.21	0.00	1.88	82.45	9.35	2.90	0.44	0.59	2.18	244.47	106.20	46.73	105.04	502.43	0.00	15.79
51-15	113-00	Rockyford	250361	397	3.54	0.00	0.04	80.14	9.14	4.31	0.74	1.06	0.88	238.98	157.83	81.67	42.40	520.87	0.00	16.75
52-00	114-00	Garrington	248002	4000	0.59	0.00	1.17	74.64	12.91	6.41	1.04	1.35	1.88	337.55	234.73	108.43	90.58	771.30	0.00	24.02
51-30	114-00	Crossfield	334011	222	1.57	0.00	3.50	70.89	12.38	5.87	1.12	2.10	2.55	323.69	214.95	146.09	122.86	807.60	0.00	25.31
53-30	116-00	Westpem	310098	225	0.17	0.00	0.00	72.17	14.53	6.59	1.27	1.82	3.45	379.91	241.32	140.19	166.23	927.65	0.00	27.71
53-00	115-30	BrazeauR.	310098	228	0.00	0.01	1.21	71.24	15.10	8.11	1.27	2.14	0.88	394.81	296.98	154.71	42.40	888.91	0.00	27.85

CRETACEOUS III

British Columbia

Lat	Long	Field	Fm.	GIP Mm³	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm³	Wh
					GAS COMPOSITION mole percent									LIQUIDS m³/Mm³						
55-15	120-30	Wolverine	Dunlevy	50	0.26	0.00	2.53	96.91	0.30	0.00	0.00	0.00	0.00	7.84	0.00	0.00	0.00	7.84	0.00	0.31
54-45	120-30	Ojay	Dunlevy	1919	0.21	0.00	3.48	95.53	0.65	0.13	0.00	0.00	0.00	17.00	4.76	0.00	0.00	21.76	0.00	0.81
56-15	120-30	Airport	Dunlevy	163	0.34	0.13	1.61	96.81	0.84	0.11	0.03	0.03	0.10	21.96	4.03	2.72	4.82	33.53	1.64	1.13
56-00	120-00	Doe	Bluesky	1120	0.44	0.00	3.09	94.66	1.22	0.23	0.12	0.05	0.18	31.90	8.42	7.71	8.67	56.71	0.00	1.87
59-00	121-00	Kotcho E	Bluesky	347	0.60	0.00	4.38	90.20	4.41	0.11	0.28	0.00	0.00	115.31	4.03	12.70	0.00	132.04	0.00	5.05
57-15	120-00	Ladyfern	Gething	130	0.54	0.00	2.13	91.00	4.55	1.06	0.23	0.21	0.27	118.97	38.82	19.96	13.01	190.75	0.00	6.49
57-30	120-00	Velma	Gething	1229	0.25	0.60	2.04	89.63	4.43	1.67	0.25	0.53	0.60	115.83	61.15	35.39	28.91	241.28	7.56	7.70
57-00	120-00	Current W	Gething	65	0.57	0.00	1.38	89.49	5.78	1.73	0.18	0.43	0.42	151.13	63.35	27.68	20.24	262.39	0.00	8.71
57-00	121-30	Blueberry	Dunlevy	873	2.32	0.00	2.50	86.70	5.41	1.67	0.31	0.60	0.49	141.45	61.15	41.29	23.61	267.50	0.00	8.91
56-45	122-00	Blueb W	Dunlevy	252	0.23	0.36	2.50	87.50	5.76	2.10	0.34	0.65	0.56	150.60	76.90	44.92	26.98	299.40	4.54	9.71
56-45	121-00	Buick Cr	Dunlevy	2139	0.46	0.13	1.08	88.02	6.46	2.35	0.36	0.62	0.52	168.91	86.06	44.46	25.05	324.48	1.64	10.49
56-45	120-00	Rigel East	Gething	548	0.54	0.08	1.09	87.63	6.56	2.77	0.33	0.64	0.36	171.52	101.44	44.01	17.35	334.31	1.01	10.85
57-45	120-30	Dahl	Bluesky	4288	0.34	0.00	1.09	87.22	7.08	2.73	0.34	0.69	0.48	185.12	99.97	46.73	23.13	354.95	0.00	11.49
57-00	121-00	BuickCr N	Dunlevy	1193	0.47	0.33	1.39	86.06	7.06	2.55	0.43	0.74	0.97	184.59	93.38	53.08	46.74	377.79	4.16	12.01
57-30	121-30	Laprise Cr	Gething	47	3.03	0.00	2.07	82.68	7.70	2.49	0.39	0.77	0.86	201.33	91.18	52.63	41.44	386.58	0.00	12.87
57-15	121-30	Nig Cr N	Bluesky	267	1.08	0.00	0.76	85.10	7.17	3.63	0.48	0.96	0.82	187.47	132.93	65.33	39.51	425.24	0.00	13.31
56-45	121-30	Inga	Dunlevy	918	0.13	0.06	1.92	84.22	9.13	2.43	0.38	0.79	0.94	238.72	88.98	53.08	45.29	426.08	0.76	13.97
57-45	121-00	Silver	Bluesky	3177	0.38	0.00	0.88	83.87	9.38	3.53	0.42	0.88	0.66	245.25	129.27	58.98	31.80	465.30	0.00	15.06
57-30	121-00	Martin	Bluesky	100	0.38	0.00	0.00	83.71	9.73	4.33	0.61	0.91	0.33	254.41	158.56	68.96	15.90	497.83	0.00	15.97
57-15	121-00	Umbach	Gething	329	0.77	0.00	1.52	81.55	9.35	4.19	0.45	1.11	1.04	244.47	153.43	70.78	50.11	518.79	0.00	16.52

JURASSIC

Lat	Long	Field	Pool No.	GIP Mm³	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm³	Wh
					GAS COMPOSITION mole percent									LIQUIDS m³/Mm³						
49-15	110-00	1391 Und.	428098	64	0.61	0.00	2.78	96.00	0.00	0.18	0.09	0.05	0.15	2.61	6.59	6.35	7.23	22.79	0.00	0.59
49-45	110-30	Orion	428001	171	3.50	0.00	0.64	94.02	0.96	0.36	0.19	0.11	0.15	25.10	13.18	13.61	7.23	59.12	0.00	1.85
54-15	118-30	11671 Un	408098	272	0.30	0.00	0.85	96.82	1.65	0.19	0.11	0.22	0.05	43.14	6.96	5.90	2.41	58.41	0.00	2.04
54-45	119-30	Wapiti	408098	793	1.16	0.00	2.91	92.54	2.87	0.32	0.07	0.03	3.53	75.04	11.72	4.54	4.82	96.11	0.00	3.53
50-00	111-30	GRD FKS	428039	129	28.92	0.00	0.02	67.89	1.65	0.68	0.11	0.02	0.17	43.14	24.90	5.90	8.19	82.13	0.00	3.73
55-15	119-30	Elmworth	408098	344	7.77	0.00	5.77	76.94	8.04	0.97	0.11	0.13	0.26	210.22	35.52	10.89	12.53	269.15	0.00	11.00
54-15	114-30	Heldar	444002	790	0.14	0.00	1.96	85.59	6.82	2.71	0.35	0.65	0.50	178.32	99.24	45.37	24.09	347.02	0.00	11.42
51-30	114-00	Crossfield	432098	118	1.69	0.00	0.77	85.00	7.59	2.69	0.45	0.78	0.86	198.45	98.51	55.80	41.44	394.20	0.00	12.70
50-15	113-30	Parkland	420098	283	0.74	0.00	2.69	84.21	6.70	1.66	0.25	0.48	3.22	175.18	60.79	33.12	155.14	424.23	0.00	12.75
53-15	116-00	Peco	446002	1134	0.13	0.00	2.02	84.76	8.48	2.63	0.52	0.61	0.84	221.72	96.31	51.27	40.47	409.77	0.00	13.37
54-00	115-30	Leaman	432002	444	0.54	0.00	1.39	82.08	8.87	3.95	0.68	1.16	1.20	231.92	144.65	83.48	57.82	517.86	0.00	16.19
52-45	116-00	Bighorn	414098	184	0.57	0.00	13.38	70.91	7.98	4.09	0.57	1.13	1.36	208.65	149.77	77.13	65.53	501.08	0.00	17.59
52-15	114-30	Garrington	432098	356	0.80	0.00	0.00	81.53	9.81	3.86	0.74	1.31	1.93	256.50	141.35	93.01	92.99	583.85	0.00	17.80
54-45	118-30	Wapiti	408098	307	0.35	0.00	1.31	79.48	11.47	4.30	0.38	1.02	1.68	299.90	157.46	63.52	80.94	601.83	0.00	19.17
53-00	114-30	Minik	446003	120	0.84	0.00	0.00	74.89	13.69	5.52	0.88	1.70	2.37	357.95	202.14	117.05	114.19	791.33	0.00	24.39

PERMO - PENNSYLVANIAN AND TRIASSIC - Alberta

Lat	Long	Field	Pool No.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
54-45	119-30	10291 Un	556098	749	1.26	16.63	4.05	76.46	0.21	0.26	0.00	0.00	0.00	5.49	9.52	0.00	0.00	15.01	209.62	0.61
56-30	117-30	12931 Un	556098	77	0.64	0.00	1.65	94.19	2.18	0.69	0.23	0.20	0.17	57.00	25.27	19.51	8.19	109.97	0.00	3.55
54-40	116-00	Wolf	556098	53	0.17	1.72	4.45	88.50	3.24	0.88	0.20	0.28	0.55	84.71	32.22	21.78	26.50	165.22	21.68	5.50
55-30	118-30	Webster	556001	258	0.47	11.75	2.16	79.55	3.24	1.27	0.26	0.52	0.75	84.71	46.51	35.39	36.14	202.75	148.11	7.06
55-00	117-30	Stur Lk	560098	226	0.47	0.00	1.84	89.10	4.31	2.00	0.34	0.81	1.11	112.69	73.24	52.18	53.48	291.59	0.00	8.77
55-45	117-00	Grouvlle	556098	143	2.39	0.00	0.00	88.38	5.36	2.17	0.35	0.71	0.64	140.15	79.46	48.09	30.84	298.54	0.00	9.46
54-45	115-30	Virghill	556001	1278	0.70	1.84	3.41	84.59	4.77	1.99	0.34	0.80	1.51	124.72	72.87	51.72	72.75	322.07	23.19	10.01
55-00	117-00	LSmoky	560098	279	1.94	0.00	1.78	83.29	5.50	3.07	0.74	1.63	1.99	143.81	112.42	107.53	95.88	459.63	0.00	13.44
54-45	119-00	Wapiti	556098	245	9.92	0.00	1.41	74.12	9.89	3.44	0.32	0.53	0.30	258.59	125.97	38.56	14.45	437.58	0.00	16.34
54-15	116-30	Fir	500098	190	3.61	5.34	1.18	89.51	0.04	0.01	0.00	0.00	0.00	1.05	0.37	0.00	0.00	1.41	67.31	0.06
54-00	118-30	Findley	500001	308	0.49	5.41	2.16	91.59	0.30	0.02	0.00	0.00	0.00	7.84	0.73	0.00	0.00	8.58	68.19	0.35
54-45	118-30	Bilbo	516098	78	0.32	10.69	2.67	85.17	0.70	0.26	0.02	0.03	0.12	18.30	9.52	2.27	5.78	35.87	134.75	1.31
53-15	117-00	Shaw	512260	2345	0.14	1.21	4.52	92.55	1.26	0.29	0.01	0.01	0.00	32.94	10.62	0.91	0.00	44.47	15.25	1.67
53-00	116-30	7761 Und	500098	52	0.26	3.02	3.07	88.01	3.95	0.87	0.19	0.17	0.44	103.28	31.86	16.33	21.20	172.67	38.07	6.00
54-00	117-00	Oldman	500098	2084	1.07	0.00	4.59	88.02	3.43	1.21	0.38	0.49	0.81	89.68	44.31	39.47	39.03	212.49	0.00	6.70
56-00	118-30	Boucher	508098	84	0.75	0.00	0.73	87.89	6.85	2.35	0.28	0.64	0.50	179.10	86.06	41.74	24.09	330.99	0.00	10.78
56-45	118-00	Dixonvle	500098	219	1.56	0.00	1.03	86.24	6.01	2.67	0.38	0.85	1.22	157.14	97.77	55.80	58.78	369.50	0.00	11.43
56-15	119-30	Bonanza	510001	556	0.27	0.00	0.69	84.52	8.01	3.48	0.45	1.18	1.37	209.43	127.43	73.95	66.01	476.83	0.00	14.64
54-30	117-00	Kaybob	500002	2206	1.06	0.11	1.58	82.03	8.38	3.79	0.50	1.27	1.26	219.11	138.79	80.30	60.71	498.91	1.39	15.63
55-00	118-30	Elmworth	516002	507	0.49	0.00	0.36	80.64	10.12	4.32	0.59	1.43	1.98	264.60	158.20	91.65	95.40	609.84	0.00	18.61
55-30	119-00	Wembley	516202	5955	0.31	0.50	1.06	75.49	9.70	5.25	0.75	1.98	4.95	253.62	192.25	123.86	238.50	808.23	6.30	23.06

PERMO-PENNSYLVANIAN - TRIASSIC - British Columbia

Lat	Long	Field	Fm.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
55-30	121-30	Sukunka	Baldon.	2320	0.33	10.08	11.05	78.36	0.17	0.01	0.00	0.00	0.00	4.44	0.37	0.00	0.00	4.81	127.06	0.23
55-15	121-30	Bullmoose	Baldon.	3852	0.36	25.80	14.10	59.45	0.27	0.02	0.00	0.00	0.00	7.06	0.73	0.00	0.00	7.79	325.20	0.49
55-45	121-30	Commot	Baldon.	600	0.33	19.71	14.05	65.14	0.74	0.00	0.00	0.00	0.00	19.35	0.00	0.00	0.00	19.35	248.44	1.12
57-00	122-30	Cypress	Baldon.	2297	0.48	0.83	0.37	95.76	1.96	0.33	0.07	0.08	0.12	51.25	12.08	6.81	5.78	75.92	10.46	2.60
56-15	120-30	Ft.St.John	Belloy	2536	0.44	0.52	0.96	93.98	2.18	0.66	0.12	0.20	0.94	57.00	24.17	14.52	45.29	140.98	6.55	4.18
56-00	120-00	Doe	Bandon.	72	1.96	0.00	1.66	90.09	4.23	1.02	0.13	0.28	0.61	110.60	37.35	18.60	29.39	195.94	0.00	6.51
56-45	120-30	Oak	Halfway	1635	0.23	2.46	2.19	88.54	4.23	1.32	0.19	0.37	0.44	110.60	48.34	25.41	21.20	205.54	31.01	6.89
57-00	120-30	Peejay	Halfway	116	0.50	1.42	1.43	89.20	4.62	1.66	0.25	0.46	0.46	120.80	60.79	32.21	22.16	235.96	17.90	7.71
57-15	122-00	Beg	Baldon.	2620	0.53	2.30	1.25	86.83	6.22	1.67	0.36	0.37	0.47	162.63	61.15	33.12	22.65	279.55	28.99	9.48
57-15	122-30	Julien Cr	Baldon.	257	0.54	2.03	1.54	86.67	5.73	1.97	0.42	0.58	0.52	149.82	72.14	45.37	25.05	292.38	25.59	9.62
57-00	120-00	Currant W	Halfway	169	0.43	0.41	0.75	88.67	6.25	2.31	0.31	0.58	0.29	163.42	84.59	40.38	13.97	302.36	5.17	9.90
57-15	121-30	Nig Creek	Bandon.	3692	0.21	1.31	3.57	84.54	6.23	2.10	0.40	0.75	0.89	162.89	76.90	52.18	42.88	334.85	16.51	10.93
56-30	120-30	Stoddart	Belloy	9039	0.54	0.03	0.58	87.56	5.78	2.53	0.40	0.85	1.73	151.13	92.65	56.71	83.35	383.84	0.38	11.42
56-15	120-30	FtStJn.SE	Halfway	1000	0.19	2.49	1.92	83.94	5.77	2.45	0.45	0.83	1.96	150.87	89.72	58.07	94.44	393.09	31.39	12.01
57-45	122-00	TommyLk	Halfway	19247	1.14	4.46	3.45	79.77	6.61	3.10	0.39	0.55	0.50	172.83	113.52	42.65	24.09	353.09	56.22	12.26
56-45	121-30	Inga	Baldon.	494	0.20	1.80	2.75	83.28	7.65	2.29	0.29	0.76	0.97	200.02	83.86	47.64	46.74	378.25	22.69	12.56
56-45	121-00	Cache Cr	Halfway	1809	0.30	17.17	6.52	66.30	5.85	1.81	0.32	0.96	0.78	152.96	66.28	57.62	37.58	314.44	216.42	12.78
57-30	121-30	LapriseCr	Baldon.	3820	0.33	0.00	1.30	84.53	8.41	3.05	0.42	0.88	1.07	219.89	111.69	58.98	51.55	442.12	0.00	14.06
56-30	121-00	Red Creek	Halfway	503	0.33	18.22	2.09	67.04	6.23	3.14	0.41	0.90	1.64	162.89	114.98	59.43	79.02	416.33	229.66	15.52
57-45	120-30	Redeye	Halfway	535	0.68	0.00	0.74	82.43	9.53	4.17	0.44	1.15	0.85	249.18	152.70	72.14	40.95	514.97	0.00	16.37

MISSISSIPPIAN
Alberta

Lat	Long	Field	Pool No.	GIP Mm³	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent	Tot	SULPHUR t/Mm³	Wh
					GAS COMPOSITION mole percent									LIQUIDS m³/Mm³						
58-15	118-30	Haro	644003	198	0.31	0.00	3.15	95.21	0.75	0.28	0.11	0.07	0.09	19.61	10.25	8.17	4.34	42.37	0.00	1.35
50-00	112-30	Retlaw	628098	122	3.47	0.00	1.47	89.13	0.50	0.59	0.07	0.08	0.05	13.07	21.61	6.81	2.41	43.89	0.00	1.43
51-15	110-00	Bindloss	644098	500	2.43	0.00	0.01	96.01	1.26	0.07	0.06	0.00	0.10	32.94	2.56	2.72	4.82	43.05	0.00	1.53
54-15	116-30	Pine NW	638001	173	3.06	0.00	2.51	90.51	2.93	0.57	0.08	0.18	0.15	76.61	20.87	11.80	7.23	116.51	0.00	4.14
55-30	118-00	Teepee	606098	415	1.16	1.63	1.02	90.79	2.67	1.10	0.19	0.56	0.84	69.81	40.28	34.03	40.47	184.59	20.55	5.58
52-15	115-00	Strachan	610098	348	0.92	0.00	2.59	90.47	3.99	1.31	0.29	0.17	0.26	104.32	47.97	20.87	12.53	185.69	0.00	6.24
53-30	115-30	Pembina	640098	176	0.24	1.63	3.76	88.11	4.21	1.08	0.28	0.31	0.36	110.08	39.55	26.77	17.35	193.74	20.55	6.61
56-15	119-00	Blueberry	606001	1139	1.49	0.00	0.76	90.62	3.54	1.26	0.27	0.54	1.51	92.56	46.14	36.75	72.75	248.20	0.00	7.29
51-15	114-30	JumpPDW	610003	22059	0.95	8.27	5.59	78.60	3.63	0.88	0.31	0.31	1.45	94.91	32.22	28.13	69.86	225.13	104.24	7.73
53-15	117-00	Boyer	642098	702	0.00	1.22	1.89	88.52	5.73	1.34	0.20	0.38	0.68	149.82	49.07	26.31	32.76	257.97	15.38	8.60
54-15	115-00	Blueridge	642001	1139	0.27	0.00	2.80	88.26	5.49	1.67	0.27	0.56	0.68	143.54	61.15	37.66	32.76	275.12	0.00	8.95
55-15	116-00	12161 Un	612098	146	1.39	0.00	1.27	87.25	6.15	2.22	0.34	0.60	0.53	160.80	81.29	42.65	25.54	310.28	0.00	10.14
54-45	115-00	11741 Un	642098	263	0.33	0.00	1.68	85.22	5.66	2.36	0.42	0.77	0.56	147.99	86.42	53.99	26.98	315.38	0.00	10.29
56-00	118-00	Belloy	612003	362	4.37	0.00	0.00	84.32	5.65	3.03	0.49	0.89	0.96	147.73	110.96	62.61	46.25	367.55	0.00	11.56
50-45	113-30	Medallin	610098	466	2.71	0.11	5.35	80.64	6.04	3.00	0.47	0.92	0.75	157.93	109.86	63.06	36.14	366.98	0.00	12.18
51-45	113-00	Twining	610098	8000	1.30	0.00	0.57	85.00	8.25	2.88	0.50	0.78	0.70	215.71	105.46	58.07	33.73	412.97	1.39	13.36
53-45	115-00	Wildwood	642098	74	1.31	0.23	3.82	80.06	9.14	3.42	0.39	0.90	0.73	238.98	125.24	58.53	35.17	457.92	0.00	15.41
53-00	114-00	Minhik	644098	397	0.97	1.22	3.06	80.84	8.72	3.58	0.50	1.10	1.18	228.00	131.10	72.59	56.85	488.54	2.90	15.72
52-00	114-00	Harmtn E	610000	36252	0.60	0.00	4.04	75.97	8.87	4.18	0.77	1.43	4.13	231.92	153.07	99.81	198.99	683.79	15.38	20.33
51-45	112-00	Watts	644004	443	1.21	0.00	0.38	72.62	11.25	7.89	1.82	2.29	2.51	294.15	288.93	186.47	120.94	890.48	0.00	26.18

MISSISSIPPIAN
British Columbia

Lat	Long	Field	Fm.	GIP Mm³	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent	Tot	SULPHUR t/Mm³	Wh
					GAS COMPOSITION mole percent									LIQUIDS m³/Mm³						
57-15	122-30	Julien.Cr	Debolt	61	0.48	0.04	0.20	98.89	0.37	0.02	0.00	0.00	0.00	9.67	0.73	0.00	0.00	10.41	0.50	0.39
57-30	122-30	Pocketknf	Debolt	1834	0.81	0.00	0.00	98.78	0.36	0.05	0.00	0.00	0.00	9.41	1.83	0.00	0.00	11.24	0.00	0.41
56-00	120-00	Doe	Kiskat.	101	0.42	0.00	1.27	97.81	0.38	0.05	0.01	0.01	0.00	9.94	1.83	0.91	0.00	12.67	0.00	0.46
58-45	121-00	Kyklo	Debolt	395	3.80	0.00	3.28	92.16	0.37	0.37	0.00	0.00	0.00	9.67	13.55	0.00	0.00	23.22	0.00	0.80
56-30	120-00	BoundaryL	Kiskat.	1284	0.63	0.00	0.78	96.37	1.11	0.31	0.07	0.11	0.56	29.02	11.35	8.17	26.98	75.52	0.00	2.19
56-15	121-00	Monias	Kiskat.	310	0.35	0.00	0.42	93.39	2.30	1.20	0.27	0.49	1.73	60.14	43.94	34.48	83.35	221.91	0.00	6.03
57-00	122-00	Highway	Debolt	810	0.23	0.00	0.42	92.81	4.18	1.22	0.27	0.34	0.53	109.29	44.68	27.68	25.54	207.18	0.00	6.58
58-30	120-00	Bivouac	Debolt	313	0.30	0.00	2.36	90.39	5.47	1.07	0.28	0.01	0.09	143.02	39.18	13.16	4.34	199.70	0.00	7.11
56-15	120-00	Mica	Kiskat.	304	7.57	0.00	0.68	83.58	4.11	1.91	0.37	0.62	1.16	107.46	69.94	44.92	55.89	278.21	0.00	8.91
56-45	122-00	Kobes	Debolt	1381	0.34	1.10	1.21	88.15	5.68	1.67	0.42	0.45	0.98	148.51	61.15	39.47	47.22	296.36	13.87	9.45
57-00	121-30	Blueberry	Debolt	221	1.33	0.31	1.14	80.57	8.00	4.66	0.75	1.71	1.53	209.17	170.65	111.61	73.72	565.15	3.91	17.13

DEVONIAN
ALBERTA 56 - 60 N

Lat	Long	Field	Pool No.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
59-30	118-30	Zama	788120	20	0.90	0.00	2.57	91.01	3.09	1.34	0.22	0.44	0.41	80.79	49.07	29.94	19.75	179.56	0.00	5.90
59-00	118-30	Virgo	758098	79	2.55	0.00	2.86	87.91	2.15	1.17	0.16	0.42	2.67	56.33	43.84	26.31	128.64	264.02	0.00	6.95
57-30	119-00	Chinch	778098	154	2.20	0.00	0.48	88.09	4.54	1.57	0.28	0.49	2.35	118.71	57.49	34.93	113.23	324.36	0.00	9.48
58-45	119-00	Rainbow	758001	425	2.42	0.00	3.63	80.25	6.00	3.63	0.60	1.43	1.98	156.88	132.93	92.10	95.40	477.61	0.00	14.53
58-30	118-30	Rainbow	788035	586	2.59	0.73	1.29	73.11	11.56	5.83	0.82	1.75	2.05	302.25	213.49	116.60	98.77	731.12	9.21	23.14
57-30	118-30	Cranberry	758001	14256	3.28	0.00	1.12	72.69	10.75	5.22	0.92	1.85	4.12	281.08	191.15	125.67	198.51	796.41	0.00	23.93
58-15	119-00	Haro	788098	102	11.79	1.73	4.81	48.68	7.12	5.13	0.96	2.12	2.09	186.16	187.86	139.74	100.70	614.46	21.81	26.35
59-15	119-00	Shekilie	788098	944	0.80	0.41	1.56	67.63	12.14	6.59	1.31	2.83	3.02	317.42	241.32	187.83	145.51	892.08	5.17	27.71

DEVONIAN
ALBERTA 53 - 56 N

Lat	Long	Field	Pool No.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
55-00	112-30	Pleasant	658501	52	0.39	0.00	1.30	98.27	0.04	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	1.05	0.00	0.04
54-30	117-00	Bigstone	720001	13810	2.41	17.65	2.91	76.50	0.30	0.08	0.02	0.02	0.04	7.84	2.93	1.81	1.93	14.52	222.47	0.60
54-15	117-00	Berlriv	720001	3852	0.42	14.22	3.68	80.89	0.69	0.07	0.01	0.00	0.00	18.04	2.56	0.45	0.00	21.06	179.24	0.94
53-15	116-30	Minehead	744098	7143	1.95	13.36	9.24	75.37	0.02	0.01	1.03	0.00	0.00	0.52	0.37	46.73	0.00	47.62	168.27	1.39
53-15	116-00	Hanlan	744001	40000	0.60	9.15	10.69	78.21	1.19	0.07	0.01	0.01	0.04	31.11	2.56	0.91	1.93	36.51	115.33	1.66
55-15	113-00	Canal	658002	511	2.04	0.00	2.63	91.38	3.42	0.36	0.09	0.03	0.03	89.42	13.18	5.44	1.45	109.49	0.00	4.12
54-30	116-30	Kaybobs	744098	219	0.82	12.22	5.51	72.35	3.97	1.64	0.58	0.99	1.80	103.80	60.06	71.23	86.73	321.81	154.03	11.04
54-45	115-30	SwanH	744060	15232	4.50	0.02	1.09	59.29	4.77	1.99	0.34	0.80	1.51	124.72	72.87	51.72	72.75	322.07	0.25	13.70
54-15	117-00	Colt	658098	137	0.00	0.50	1.20	79.64	8.03	3.31	0.71	1.04	1.04	209.96	121.21	79.40	50.11	460.67	6.30	15.07
55-15	114-00	Mitsue	778001	12535	12.98	0.00	0.05	72.29	8.22	4.08	0.54	0.99	0.51	214.92	149.41	69.42	24.57	458.32	0.00	16.55
55-00	117-00	Stur Lks	720000	8967	8.61	7.16	1.73	66.63	8.18	4.58	0.45	1.29	0.80	213.88	167.72	78.94	38.55	499.08	90.25	18.67
55-00	116-30	GooseR.	744001	2083	1.99	0.00	0.34	78.01	13.56	4.57	0.39	0.78	0.25	354.55	167.35	53.08	12.05	587.03	0.00	20.04
54-30	115-30	Car Ck. N	744060	16473	2.02	0.02	1.59	75.00	12.71	5.30	0.65	1.54	1.12	332.32	194.08	99.36	53.96	679.73	0.25	22.14
53-15	113-30	Bonnglm	720001	17625	2.87	0.34	0.93	74.55	11.10	4.83	0.79	1.58	3.01	290.23	176.87	107.53	145.03	719.65	4.29	22.23
53-30	113-30	Leduc-WB	720001	11540	5.38	0.00	0.68	71.17	12.30	7.04	0.72	1.73	0.98	321.60	257.80	111.16	47.22	737.78	0.00	24.24
54-30	117-30	Simonete	720000	9706	2.41	16.30	1.59	60.09	9.58	5.02	0.87	1.92	2.09	250.48	183.83	126.58	100.70	661.59	205.46	24.48
54-45	116-30	Kaybob	744001	8756	1.53	0.00	0.48	70.18	14.57	8.30	0.91	2.21	1.75	380.96	303.94	141.55	84.32	910.77	0.00	28.33
53-30	113-30	Leduc-WB	696001	3761	3.06	0.96	0.49	66.39	17.45	8.45	0.82	1.63	0.67	456.26	309.43	111.16	32.28	909.13	12.01	30.42
53-15	116-00	Braz. R	696011	812	0.56	6.69	0.17	64.00	7.02	4.08	1.03	2.06	14.39	183.55	149.41	140.19	693.33	1166.48	84.33	30.87
54-45	115-30	Virghill	744000	6709	5.79	0.00	1.41	56.05	19.48	1.27	1.02	2.50	0.94	509.33	46.51	159.70	45.29	760.82	0.00	31.02
56-00	115-00	Nipisi	778001	7534	12.67	0.00	0.09	57.29	15.39	10.16	1.11	2.22	0.91	402.40	372.05	151.08	43.85	969.37	0.00	34.21
54-30	115-30	Judy Ck	744000	293	2.63	0.00	1.44	62.97	18.22	9.56	1.07	2.54	1.57	476.39	350.08	163.79	75.64	1065.90	0.00	34.36
54-45	115-00	Judy Ck	744001	16038	3.11	0.00	2.02	61.56	16.65	11.02	1.06	2.84	1.69	435.34	403.54	176.94	81.43	1097.25	0.00	35.08
54-45	117-00	Ante Ck	744000	2028	1.97	0.00	1.43	60.72	19.41	10.88	1.19	2.89	1.28	507.50	398.42	185.11	61.67	1152.70	0.00	36.99
55-00	115-00	SwanH	744060	29000	4.82	0.00	1.68	57.38	15.46	11.63	2.61	3.32	3.53	404.23	425.88	269.04	170.08	1269.23	0.00	38.91
53-15	113-30	WizardLk	720001	7303	1.10	0.56	1.13	56.04	21.56	12.18	1.70	3.59	2.14	563.72	446.02	240.01	103.11	1352.86	7.06	42.35

DEVONIAN - ALBERTA 49-53 N

Lat	Long	Field	Pool No.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
49-30	114-00	Waterton	658002	924	2.18	11.52	2.09	84.17	0.03	0.01	0.00	0.00	0.00	0.78	0.37	0.00	0.00	1.15	145.21	0.05
51-15	115-00	Ricinus W	720000	49494	0.32	32.69	6.87	59.37	0.55	0.06	0.00	0.01	0.13	14.38	2.20	0.45	6.26	23.30	412.05	1.25
52-00	115-00	Limestne	696260	1229	1.22	18.13	12.82	66.92	0.71	0.08	0.02	0.02	0.06	18.56	2.93	1.81	2.89	26.20	228.52	1.31
51-15	113-30	Crossfld	658001	37500	2.19	31.75	10.44	54.85	0.38	0.10	0.03	0.04	0.20	9.94	3.66	3.18	9.64	26.41	400.20	1.35
51-00	113-30	Okotoks	668098	18262	1.26	35.63	10.43	51.18	0.38	0.08	0.03	0.08	0.90	9.94	2.93	4.99	43.36	61.22	449.11	2.79
51-30	114-00	Crosse	658001	33333	2.20	33.94	10.53	49.15	0.66	0.20	0.04	0.06	3.20	17.26	7.32	4.54	154.18	183.30	427.81	7.80
52-12	115-00	Strachan	720000	40741	0.35	9.44	2.13	78.76	3.98	1.53	0.49	0.67	2.65	104.06	56.03	52.63	127.68	340.40	118.99	10.58
52-30	113-00	Nevis	696098	129	10.15	1.14	0.99	76.68	5.96	2.67	0.31	0.92	0.87	155.83	97.77	55.80	41.92	351.33	14.37	12.28
52-30	114-00	Homerimb	720000	30588	3.59	3.26	2.08	77.59	5.66	2.78	0.51	1.28	3.25	147.99	101.80	81.21	156.59	487.59	41.09	14.80
52-00	114-00	Innisfal	720000	5910	4.26	15.55	4.41	61.49	7.25	3.85	0.59	1.39	1.19	189.56	140.98	89.83	57.34	477.71	196.00	18.84
53-00	114-00	Westro S	720001	52006	2.59	1.35	1.51	74.23	9.79	4.30	0.81	1.62	3.79	255.97	157.46	110.25	182.61	706.29	17.02	21.48
53-00	113-30	Westrose	720000	5146	3.28	0.44	0.98	74.13	10.99	4.52	0.89	1.57	3.20	287.35	165.52	111.61	154.18	718.66	5.55	22.21
52-30	113-00	Clive	720000	2077	0.82	15.00	3.00	62.07	9.37	6.45	0.70	1.69	0.83	244.99	236.19	108.43	39.99	629.61	189.07	23.47
52-30	112-30	Stetler	720000	441	7.28	3.49	10.63	50.10	12.08	11.48	1.15	2.67	1.11	315.85	420.39	173.31	53.48	963.03	43.99	36.25

NE DEVONIAN - BRITISH COLUMBIA

Lat	Long	Field	Fm.	GIP Mm^3	N_2	H_2S	CO_2	C1	C2	C3	iC4	nC4	C5+	Eth	Prop	But	Pent+	Tot	SULPHUR t/Mm^3	Wh
					GAS COMPOSITION mole percent									LIQUIDS m^3/Mm^3						
59-00	121-30	Yoyo	Slave	1742	0.73	0.00	5.70	93.57	0.01	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.26	0.00	0.11
58-45	122-00	Klua	Pine	686	0.16	7.26	23.50	69.05	0.03	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.78	91.51	0.04
59-30	120-30	Helmet	Slave	6817	1.47	2.14	9.38	86.95	0.06	0.00	0.00	0.00	0.00	1.57	0.00	0.00	0.00	1.57	26.97	0.07
59-30	121-30	Tsea	Slave	1365	1.00	0.00	10.21	88.70	0.08	0.01	0.00	0.00	0.00	2.09	0.37	0.00	0.00	2.46	0.00	0.10
59-00	121-30	Yoyo	Pine	49823	0.58	2.26	13.07	84.04	0.10	0.01	0.00	0.00	0.00	2.61	0.37	0.00	0.00	2.98	28.49	0.13
58-45	122-00	Klua	Slave	2301	3.22	0.26	9.55	86.85	0.12	0.00	0.00	0.00	0.00	3.14	0.00	0.00	0.00	3.14	3.28	0.14
59-00	121-00	Kotcho E	Slave	4929	0.73	2.02	11.27	85.85	0.13	0.00	0.00	0.00	0.00	3.40	0.00	0.00	0.00	3.40	25.46	0.15
59-30	121-30	Cabin	Slave	1206	1.58	1.40	12.18	84.68	0.14	0.00	0.00	0.00	0.00	3.66	0.00	0.00	0.00	3.66	17.65	0.17
59-00	122-30	Roger	Pine	3425	1.21	0.18	10.81	87.65	0.15	0.00	0.00	0.00	0.00	3.92	0.00	0.00	0.00	3.92	2.27	0.17
58-45	122-30	Clarke Lk	Slave	59544	2.42	0.08	9.14	88.12	0.16	0.00	0.00	0.00	0.00	4.18	0.00	0.00	0.00	4.18	1.01	0.18
58-15	122-30	Adsett	Slave	445	0.28	1.26	21.73	76.64	0.05	0.00	0.00	0.00	0.09	1.31	0.00	0.00	4.34	5.64	15.88	0.18
59-00	121-00	Sierra	Pine	18736	0.45	0.63	13.62	85.10	0.14	0.01	0.00	0.00	0.01	3.66	0.37	0.00	0.48	4.51	7.94	0.19
60-00	120-30	July Lake	Pine	280	1.31	0.00	8.82	89.67	0.18	0.00	0.00	0.00	0.00	4.71	0.00	0.00	0.00	4.71	0.00	0.20
59-15	121-00	Kotcho Lk	Slave	2950	0.82	0.44	12.09	86.47	0.16	0.02	0.00	0.00	0.00	4.18	0.73	0.00	0.00	4.92	5.55	0.21
60-00	121-30	Petitot R	Slave	1421	2.42	0.44	10.97	85.97	0.12	0.08	0.00	0.00	0.00	3.14	2.93	0.00	0.00	6.07	5.55	0.23
59-45	121-30	Dilly	Slave	347	2.42	0.44	10.97	85.97	0.12	0.08	0.00	0.00	0.00	3.14	2.93	0.00	0.00	6.07	5.55	0.23
59-15	121-30	Louise	Slave	1630	1.17	0.86	9.63	88.12	0.14	0.01	0.01	0.01	0.05	3.66	0.37	0.91	2.41	7.34	10.84	0.25
56-15	120-00	Parkland	Wabam.	6300	2.44	0.00	5.85	91.45	0.14	0.09	0.02	0.01	0.00	3.66	3.30	1.36	0.00	8.32	0.00	0.28
59-45	120-30	Helmet N	Slave	361	0.58	0.08	6.35	92.50	0.46	0.02	0.00	0.00	0.00	12.03	0.73	0.00	0.00	12.76	1.01	0.52
59-45	120-30	Helmet N	Pine	546	1.16	1.06	9.59	87.63	0.48	0.00	0.00	0.00	0.00	12.55	0.00	0.00	0.00	12.55	13.36	0.55
58-45	121-30	Elleh	Slave	735	3.71	0.34	6.84	88.43	0.59	0.00	0.00	0.00	0.00	15.43	0.00	0.00	0.00	15.43	4.29	0.66
59-00	120-00	Shekilie	Slave	395	3.37	0.00	7.82	88.03	0.67	0.05	0.01	0.01	0.00	17.52	1.83	0.91	0.00	20.26	0.00	0.83
58-45	120-30	Ekwan	Slave	317	0.43	2.48	11.02	85.33	0.74	0.00	0.00	0.00	0.00	19.35	0.00	0.00	0.00	19.35	31.26	0.86
60-00	120-30	July Lake	Jean M.	277	1.18	0.00	1.43	95.57	1.15	0.29	0.07	0.05	0.26	30.07	10.62	5.44	12.53	58.66	0.00	1.87
59-30	120-30	Helmet	Jean M.	146	1.18	0.00	1.43	95.57	1.15	0.29	0.07	0.05	0.26	30.07	10.62	5.44	12.53	58.66	0.00	1.87
58-45	121-00	Junior	Slave	288	3.89	0.00	7.42	86.71	1.95	0.02	0.01	0.00	0.00	50.99	0.73	0.45	0.00	52.17	0.00	2.23

WCSB-GCDB. The search may have to encompass several areas and groupings, gas composition being non-singular, to achieve a confident assessment of liquids and sulphur.

DESCRIPTION OF WH MAPS

A brief description of producing zones, type compositions, and an interpretation for each Wh map follows:

CRETACEOUS I (Figure 1)

Zones and Fields

The distribution of Cretaceous I pools covers the southern one-half of Alberta and a small area of Saskatchewan. The geological grouping includes AERCB zone numbers 0990-1649. The main reservoirs are Medicine Hat, Milk River and Belly River sandstones (Table 4). Large fields, containing many pools of non-associated gas, are Medicine Hat (100 E9 m^3), Suffield (150 E9 m^3) and Alderson (25 E9 m^3). There are about 700 gas pools in the grouping and the gas resource is highly dispersed in many stratigraphic traps. Medicine Hat and Milk River pools are low pressured (shallow depth) and in addition are water sensitive because of swelling clays. CO_2 - water and foam facing of pay zones significantly increases well deliverability.

Type Gas Compositions

Table 5 shows a range of gas compositions for the Cretaceous I pools.The SE area of Alberta has Medicine Hat - Milk River pays with Wh<3 and typically Wh<1. To the west, Wh increases for Belly River pools and to Wh=15-20 in Belly River and Chinook pays in the Cutbank and Ferrier fields. On the eastern Alberta shelf, natural gases are immature, low in CO_2, have no H_2S, and are often rich in nitrogen.

Interpretation

Upper Cretaceous pools show clearly what is the dominant factor in the distribution of natural gas compositions in the WCSB, that is the control on gas wetness by depth and proximty to the disturbed belt of the Rocky Mountains. Deeply buried zones (Devonian to Jurassic) each have a "hot line" to the west of which are found only overmature, non-associated gas pools. The Cretaceous I Wh map shows that depths (3000m) in the "liquid window" are just being reached on the western boundary of known pools.

CRETACEOUS II (Figure 2)

Zones and Fields

The distribution of Cretaceous II pools covers the southern two-thirds of Alberta and nearby areas of British Columbia and Saskatchewan. The grouping includes AERCB zone numbers 1700-2439. Main reservoirs are Cardium, Second White Specks, Doe Creek, Dunvegan, Colorado, Bow Island, Cadotte and Viking sandstones (Table 4). Large fields include Pembina (110 E9 m^3), Viking-Kinsela (30 E9 m^3), Ricinus (10 E9 m^3), Bindloss Viking, Provost Viking and Westlock Viking. There are about 3850 pools in the grouping. Reservoirs belong to many fluvial, shoreline and shelf environments and have corresponding diverse geometries.

Type Gas Compositions

Table 5 shows a range of gas compositions in Alberta and British Columbia for Cretaceous II pools. Nearly all of the Viking and Cardium pools, which make up 90 percent of the reserves are non-associated gas, but these become intermixed in the Pembina, Willesden Green and Ricinus fields with associated gas pools. The result is an increase of Wh in this area. Nitrogen can be high and there is no sulphur.

Interpretation

There is the beginning of a Wh reversal in NW Alberta and British Columbia where gas compositions start to lose liquids toward the Foothills. The SW quadrant however is open westward to liquid-rich gases. As with Belly River pools, many gas zones are "behind pipe" in this grouping, bypassed where deeper zones were the exploration targets.

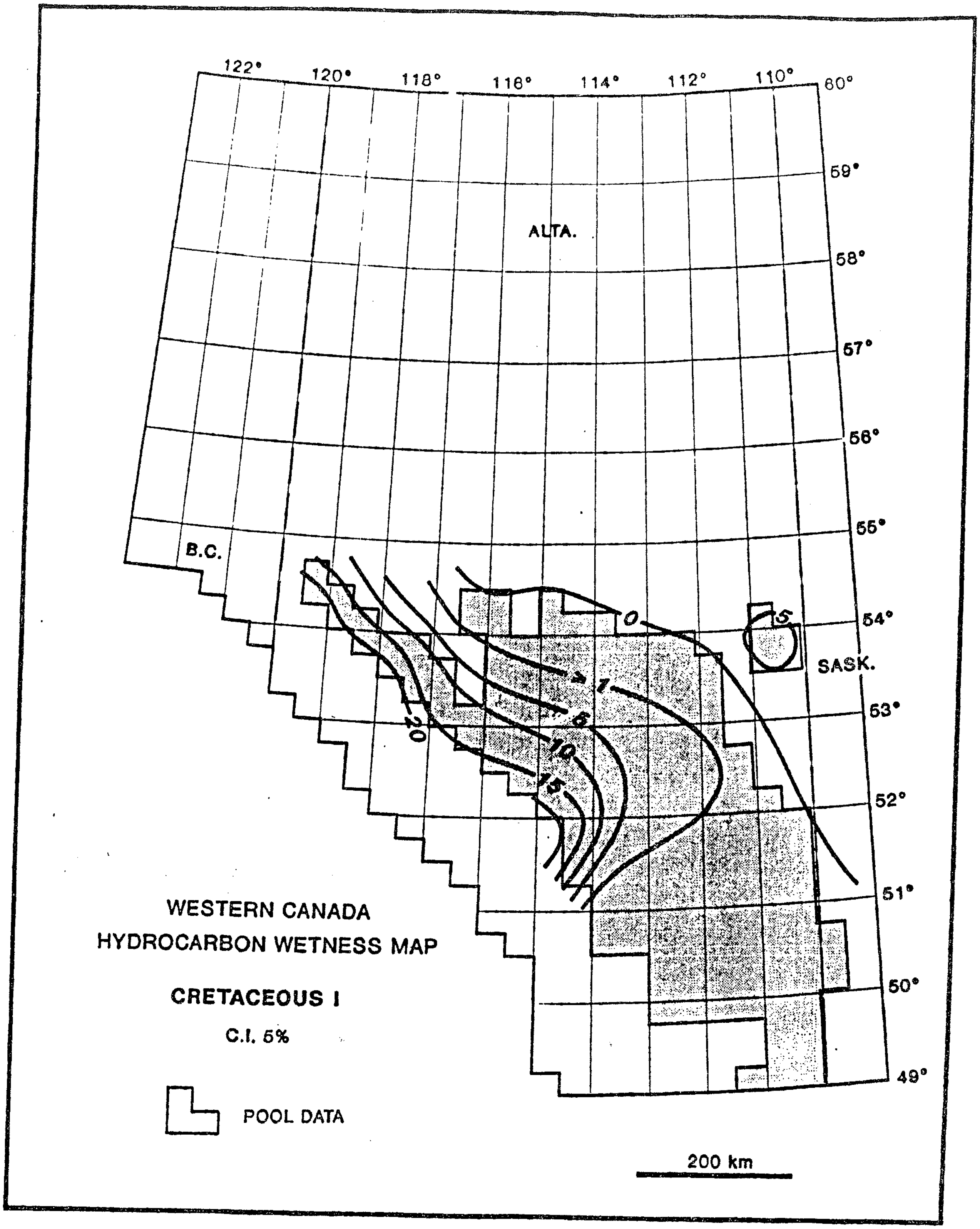

Figure 1. Hydrocarbon wetness map: Cretaceous I

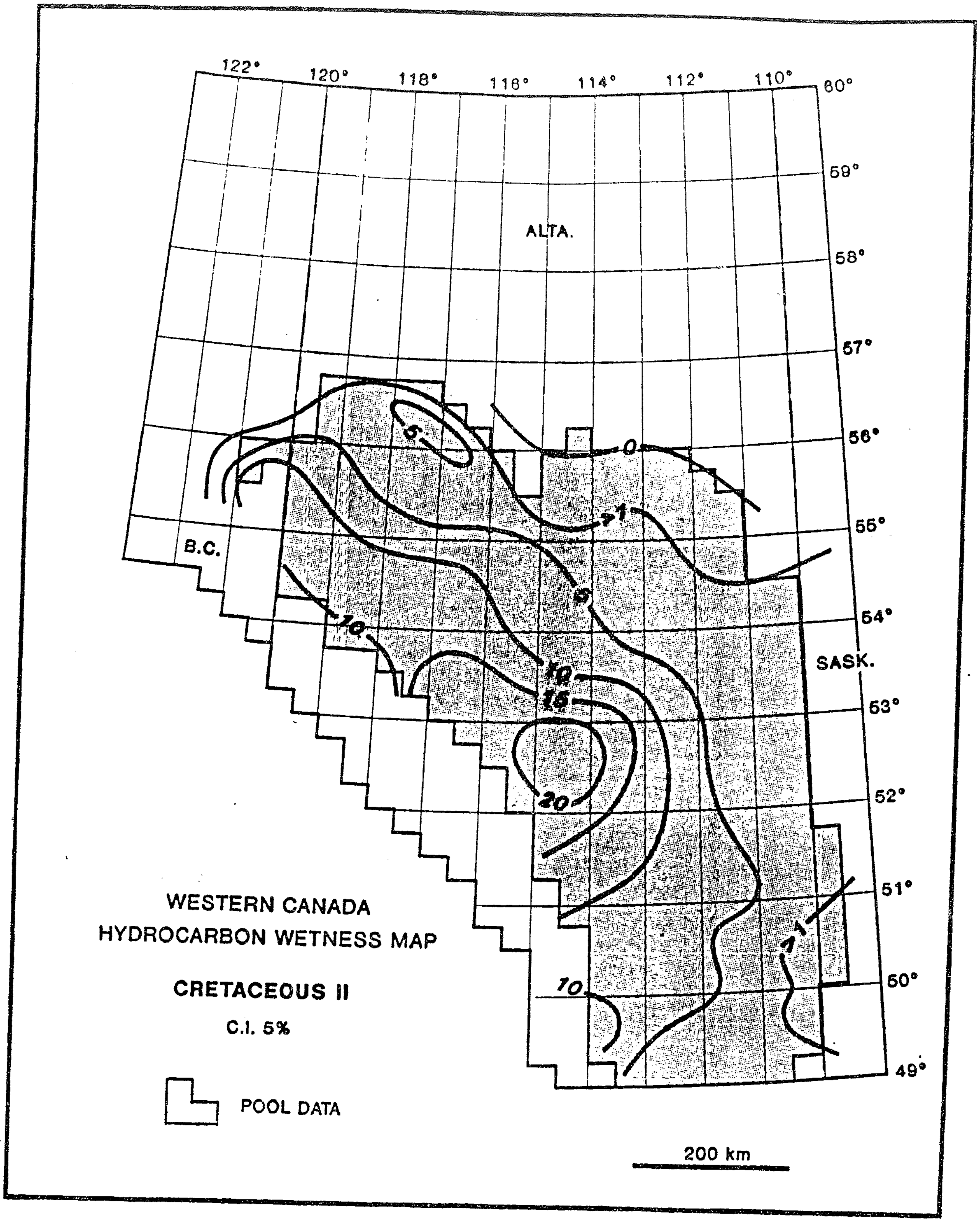

Figure 2. Hydrocarbon wetness map: Cretaceous II

CRETACEOUS III (Figure 3)

Zones and Fields

The distribution of Cretaceous III pools covers nearly all of Alberta and extensive areas of neighbouring provinces. Geological grouping includes AERBB zone numbers 2440-3500. Main gas reservoirs are Mannville, Fahler, Bluesky-Gething, Ostracod, Glauconitic and Ellerslie and their equivalents in Northern Alberta and British Columbia. The grouping encompasses over 15,000 gas pools which are widely dispersed in fields containing up to hundreds of pools. Large fields with Lower (and Upper) Cretaceous pools are Provost (31 $E9m^3$), Viking-Kinsela (30 $E9m^3$) and Cessford (20 $E9m^3$). A majority of the thousands of shut-in small pools discovered in the past decade or two are Cretaceous non-associated gas pools.

Type Gas Compositions

Table 5 shows a range of gas compositions for Cretaceous III pools. There has been an aerial expansion and increase in liquids over the Upper Cretaceous Wh maps. Gases are sweet, immature to mature, and sometimes very nitrogen-rich.

Interpretation

Lower Cretaceous pools undergo a westward increase in liquids and towards developing a "NGL belt" at the limits of known pool occurrence. The belt displays a tendency for Wh reversal, strong to the NW but more open in the Central Plains. It demarks an incipient "hot line" in the Alberta basin and is possibly infolded by thrusting in the Foothills. Turner Valley Blairmore pools give evidence of Wh reversal and at least local decreases in gas unit volume reservoir yields. The belt straddles the boundary of western (Blairmore) and eastern (Mannville) sediment provenance.

JURASSIC (Figure 4)

Zones and Fields

The distribution of Jurassic pools covers portions of the SW quadrant of Alberta and correlative sediments are found in southern Saskatchewan and NE British Columbia. Geological grouping includes AERCB zone numbers 4000-4999. The Jurassic is eroded elsewhere by the sub-Cretaceous unconformity. Pools are generally designated as "Jurassic" or by Nordegg, Kootenay, Nikanassin and Sawtooth formations (Table 4). The Jurassic is very shaly and pays are often thin sandstones (Nikanassin excepted) and carbonates.

The Jurassic is not a major gas producer but its potential may be understated because of low drilling density in the deeper parts of the Alberta basin and Foothills. There are few large fields such as Paddle River (8 $E9m^3$) and Green Court (4 $E9m^3$) but overall gas in-place for producing pools is equally split between 300-1500 Mm^3 and smaller pools. There are 425 gas pools in the WCSB-GCDB.

Type Gas Compositions

Table 5 shows a range of gas compositions for Jurassic pools. Gases are typically sweet, moderately liquids-rich in the Alberta basin and Foothills, and contain no sulphur in siliciclastic sediments. Some reservoirs on the SE Alberta shelf have abundant nitrogen.

Interpretation

Erosion has isolated Jurassic pools into three areas in Alberta, but even so, the remnants display a Wh pattern akin to suprajacent and subjacent groupings in the deep basin and Foothills. One culmination, in the central area, shows a distinct Wh reversal and encloses a "hot spot" of NGL-rich gases. Gases are generally mature on the Alberta shelf and spottily overmature in structurally deformed regions.

PERMO-PENNSYLVANIAN AND TRIASSIC (Figure 5)

Zones and Fields

The distribution of Permo-Pennsylvanian and Triassic pools covers about equal areas of NW Alberta and British Columbia, in and close to the Foothills; elsewhere, the units are missing by erosion or barren of gas. AERCB pool zone numbers are 5560-5600 for the Permo-Pennsylvanian and 5000-5399 for the Triassic. In Alberta, Permo-Pennsylvanian pays are mainly designated as "Permo-Penn" and Belloy; the bigger pools, such as Virginia Hills Belloy

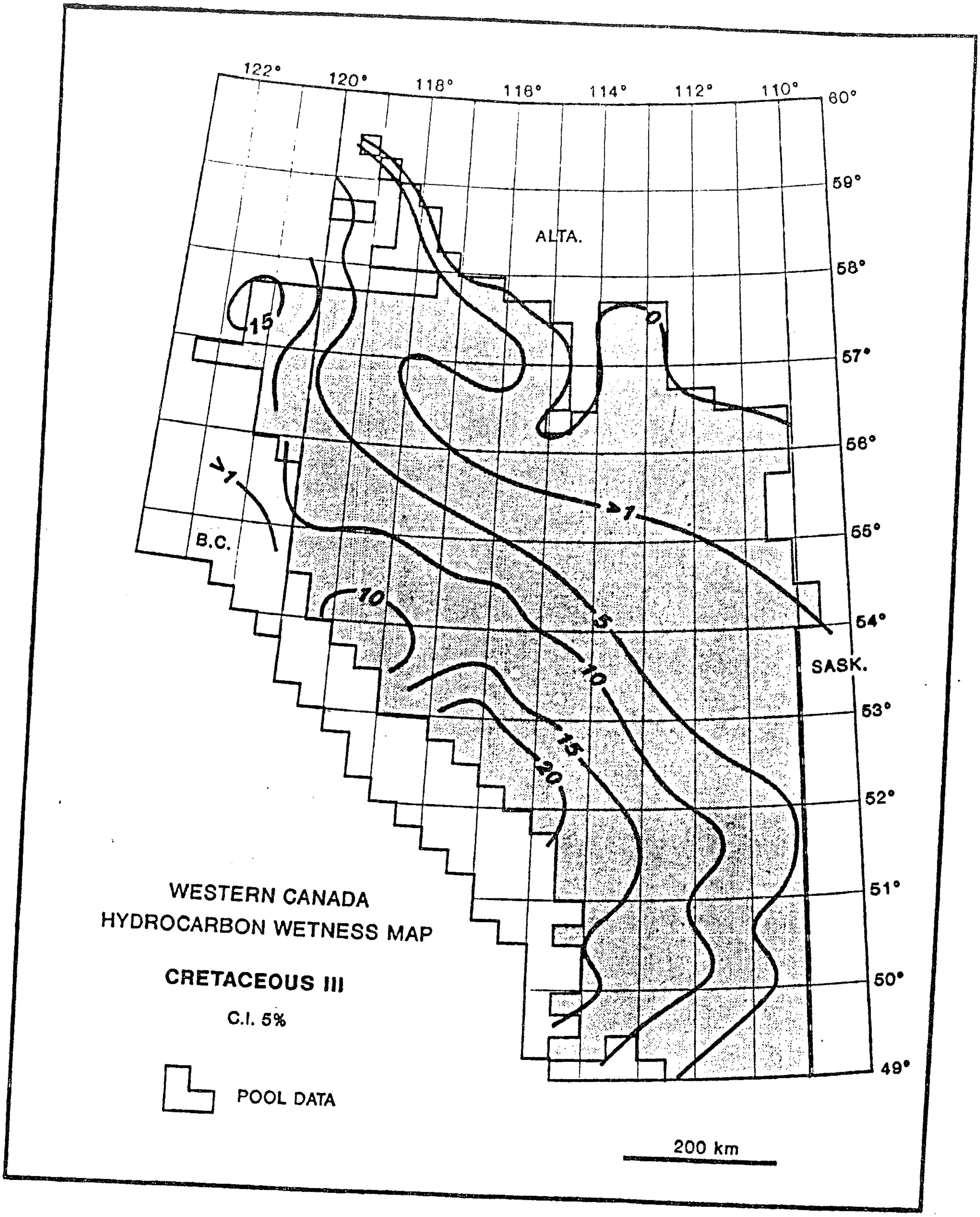

Figure 3. Hydrocarbon wetness map: Cretaceous III

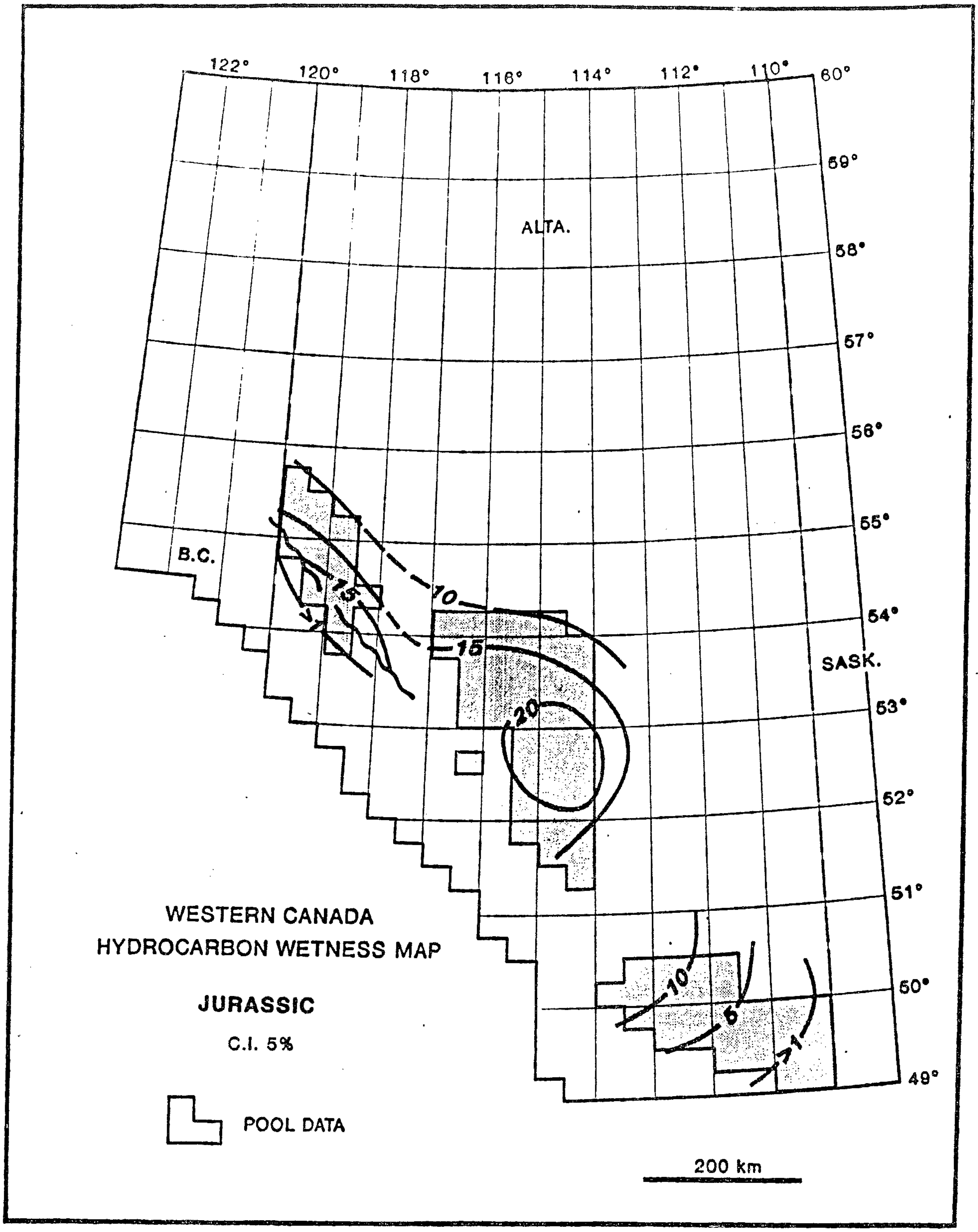

Figure 4. Hydrocarbon wetness map: Jurassic

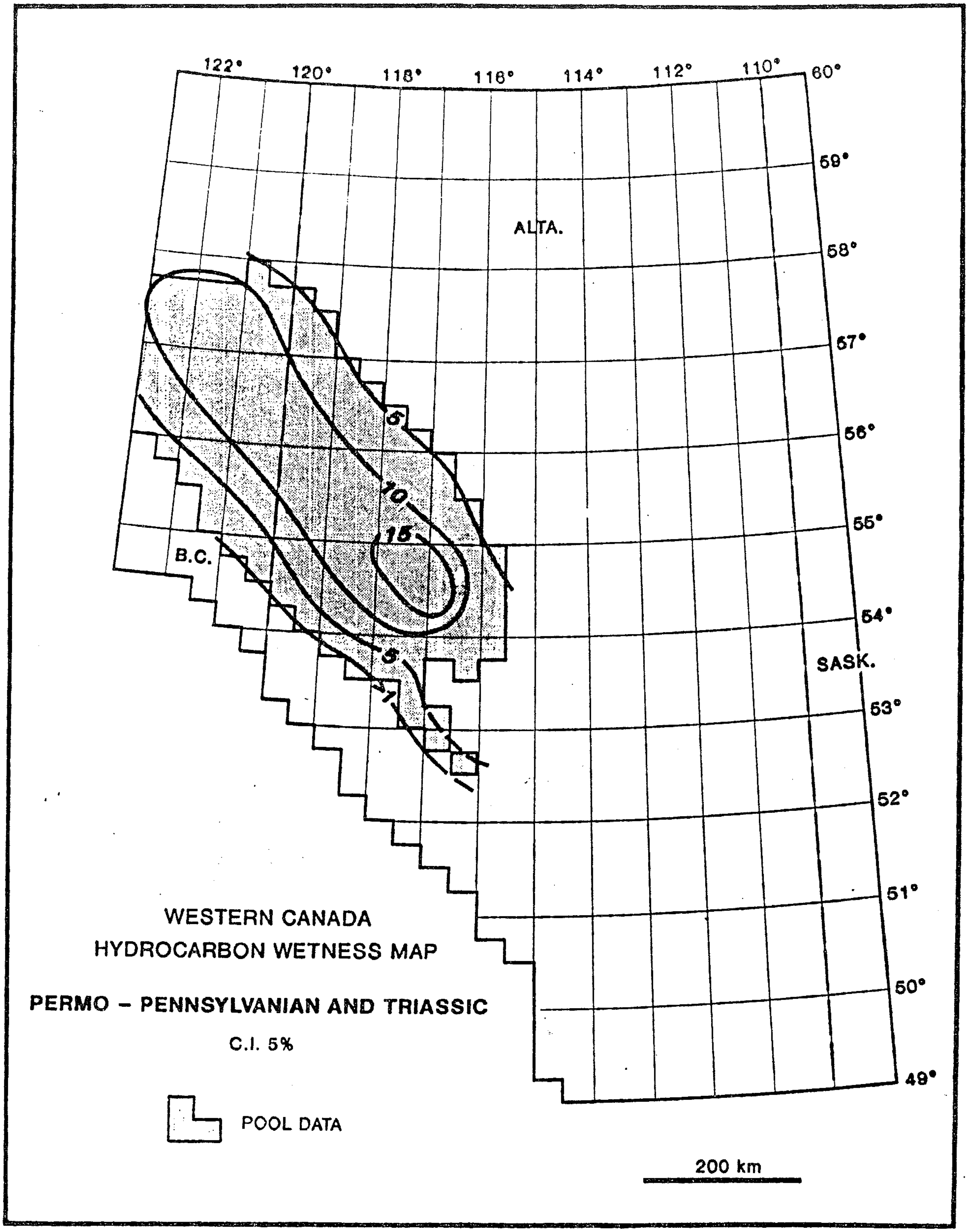

Figure 5. Hydrocarbon wetness map: Permo-Pennsylvanian and Triassic

(<2 E9m^3), are associated gas while other pools are mostly smaller (0.25-0.5 E9m^3); there are 50 pools in the WCSB-GCDB. In British Columbia, Permo-Pennsylvanian pays are mainly Belloy, the biggest field being Stoddart (7 E9m^3), and in some 25 mostly smaller pools (0.25-3 E9m^3).

Triassic gas pools make up much greater total volumes of raw gas. Pool designations are typically "Triassic" in Alberta; biggest fields are Fir (7 E9m^3) and Kaybob South (2 E9m^3) but other pools are much smaller (<1 E9m^3); there are 350 Triassic pools in the WCSB-GCDB. In British Columbia, pays include the Baldonnel, Halfway, Doig, Inga and Montney; Tommy Lakes (20 E9m^3) is a giant field and large fields are Laprise Creek (4 E9m^3), Nig Creek and Jedney while some 50 other pools are smaller (mean <1 E9m^3).

Type Gas Compositions

Table 5 shows a range of compositions for the grouping. NGL-rich pools are confined to NW Alberta in fields such as Kaybob, Elmworth and Wembley. The Foothills contain sour gases but most pools in Alberta are high in methane and sweet. In British Columbia, two trends of sour gases are in the Foothills and around Ft. St.John. Highest liquids are found at Laprise Creek and Redeye.

Interpretation

Triassic pools form a NW-trending "NGL belt" having Wh=10-20 covering one-half of the map. The Wh reversal is marked but contours end abruptly at Wh=5 on the NE flank while in the Foothills, gases become dry, sour, and overmature. There is potential for additional sour gas pools in the Foothills and in producing areas underlain by evaporites, but these are expected to be relatively poor in NGL yield, though perhaps important in liquids and sulphur endowment where discoveries are large.

MISSISSIPPIAN (Figure 6)

Zones and Fields

The distribution of Mississippian gas pools in the WCSB is confined to the Alberta basin and SE Alberta shelf and more scattered occurrences in NE British Columbia. In central and northern Alberta, the Mississippian is missing by erosion or is in remnants subcropping the sub-Cretaceous unconformity. The geological groupings include AERCB zone numbers 6000-6469. The main pays are Rundle-Banff and their statigraphic equivalents such as Turner Valley, Pekisko, Shunda, Debolt carbonates and Bakken Sand (Table 4). Reservoir quality is best in SW Alberta where large gas fields include Crossfield (50 E9m^3), Harmattan East (25 E9m^3), Harmattan-Elkton, Brazeau River, Carstairs and others in the Alberta basin and Jumping Pound West (27 E9m^3), Turner Valley (21 E9m^3), Waterton, Wildcat Hills, and others in the Foothills. Gas compositions are available for about 950 pools.

Type Gas Compositions

Table 5 shows a range of gas compositions for Mississippian pools. NGL-rich pools are restricted to the SW Alberta Plains while Foothills pools contain large reserves of sulphur at Waterton (27 Mt), Jumping Pound West (2 Mt), Quirk Creek and other fields. Gases are thus NGL-rich and sour, mature to overmature, except to the NE where pools may be sourced from the Cretaceous, at or close to the subcrop.

Interpretation

Mississippian pools have high Wh only at the southern culmination of the "NGL belt". The Wh reversal is abrupt on the NE flank and subdued toward the Foothills where a wide area, west of two northern culminations, is devoid of Mississippian discoveries(?).The superposition of the Mississippian "NGL belt," with lower liquids and sulphur on the Devonian "NGL belt," with higher liquids and sulphur demonstrates the control by depth of burial and proximity to sulphates for reduction by hydrocarbons, and no doubt considerably richer source rocks.

DEVONIAN (Figure 7)

Zones and Fields

The distribution of Devonian gas pools covers much of the WCSB except for the NE quadrant of Alberta and southern NE British Columbia.

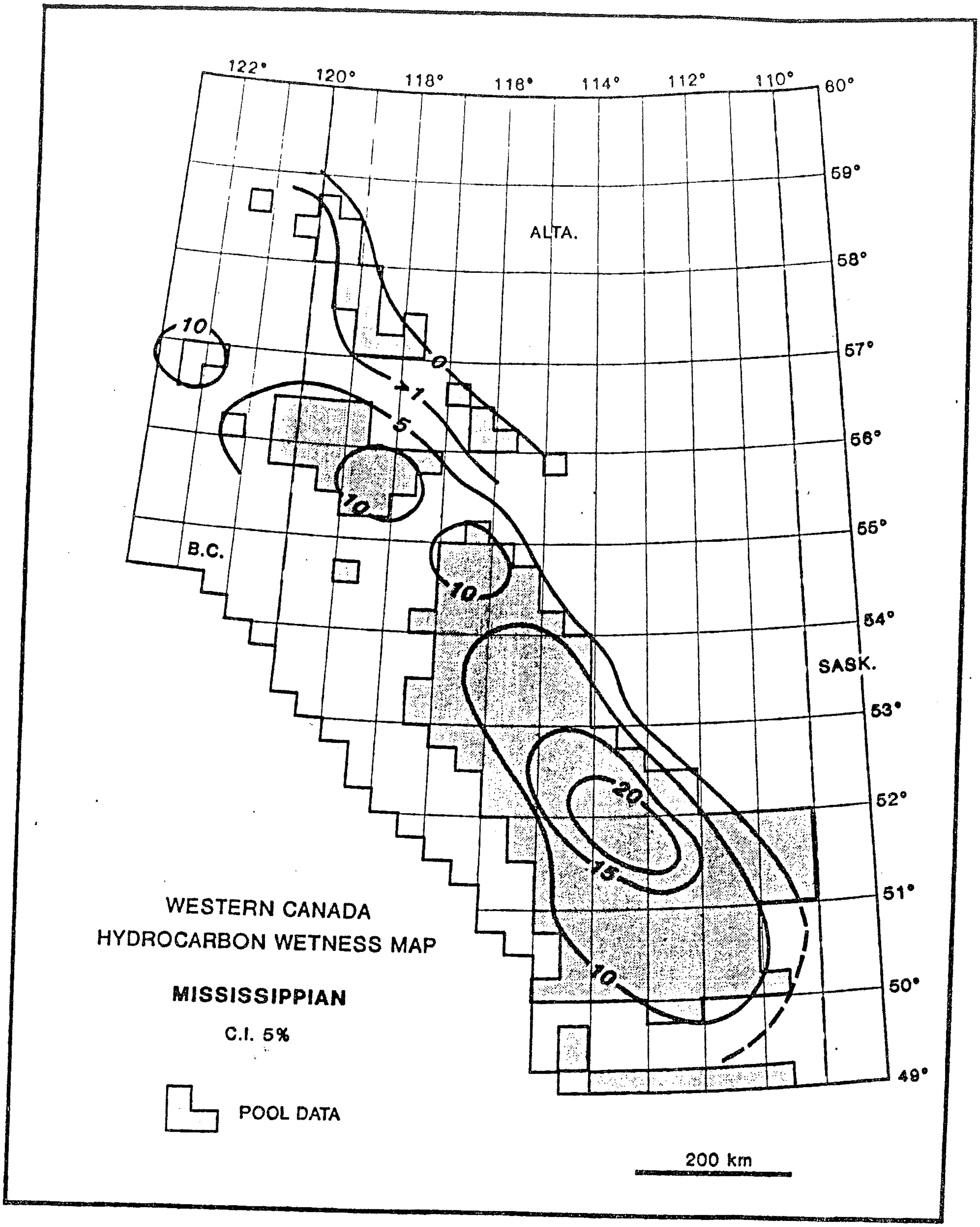

Figure 6. Hydrocarbon wetness map: Mississippian

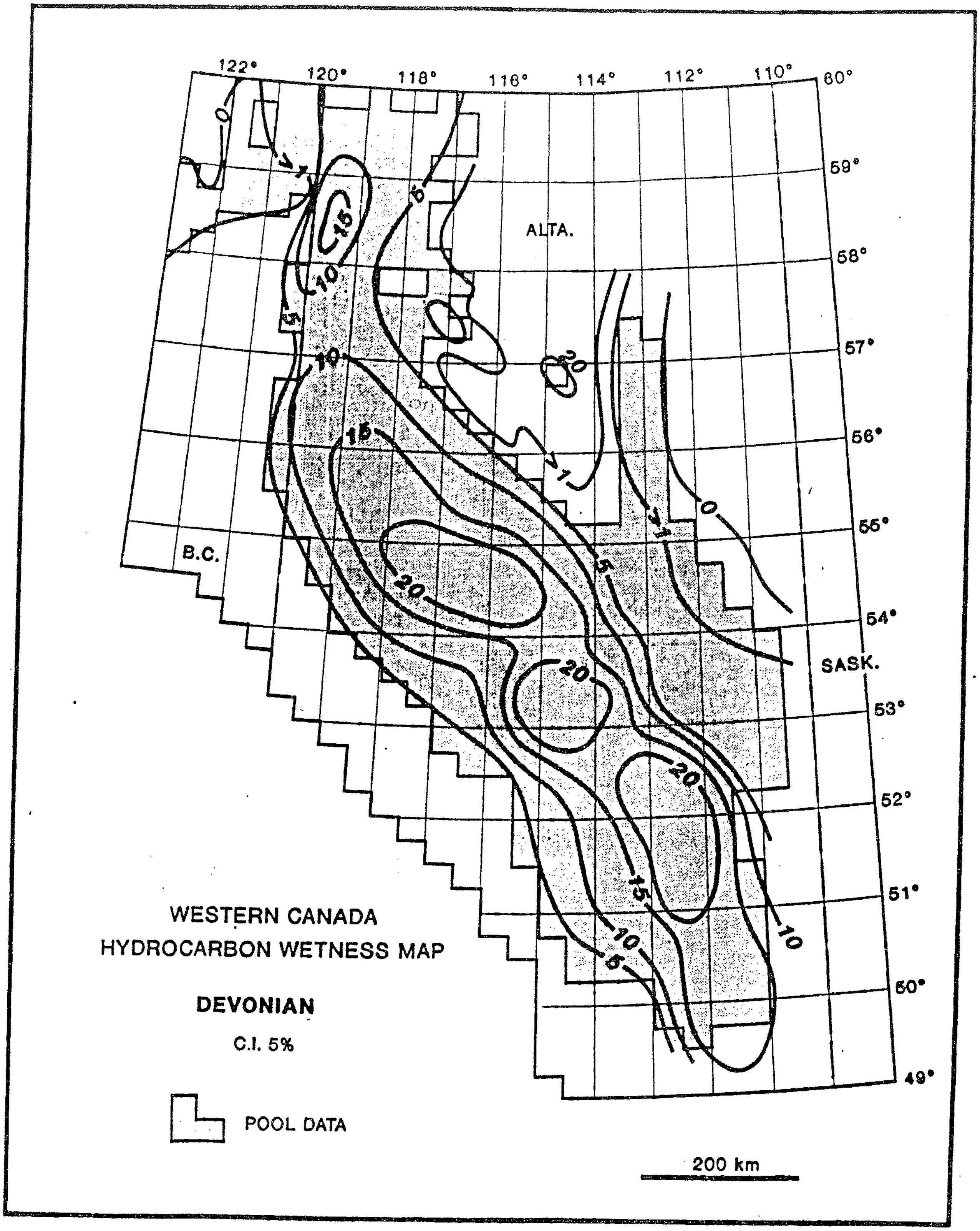

Figure 7. Hydrocarbon wetness map: Devonian

Retrieval of gas compositions were made in five geological subgroupings (AERCB zone numbers 6481-6699, 6700-7039, 7040-7320, 7321-7698, and 7699-7890). These correspond grossly to the Wabamun, Nisku, Leduc and Beaverhill Lake (Upper Devonian) and Gilwood, Slave Point and Keg River (Middle Devonian). Giant Devonian fields containing about 30 $E9m^3$ (1 TCF) of raw gas in-place include Waterton and Crossfield (Wabamun), Strachan, Westerose South, Nevis, Homeglen-Rimbey (Leduc), and Kaybob South, Caroline and Hanlan (Beaverhill Lake). The mean volume for the largest 250 non-associated and associated gas pools in the Devonian groupings is 5 $E9m^3$ gas in-place. Gas compositions exist for 2025 pools in the WCSB-GCDB.

Type Gas Compositions

Table 5 shows Devonian type gas compositions in three latitude "strips," N56-N60°, N53-N56°, and N49-N53° for Alberta and in one area for British Columbia. The map was constructed from the Wh grand mean of the five Devonian subgrouping means by grid area. Northern Alberta and British Columbia pools are mainly Middle Devonian whereas the southern three-quarters of Alberta contain Upper Devonian pools (codes on Tables 4 and 5).

Interpretation

The salient feature shown is the Devonian "NGL belt". Four Wh culminations within the belt, group Upper and Middle Devonian oilfields and their associated gases. Pool compositions with Wh<10 have different origins depending on which flank they occur. Gases over the broad area of the NE flank are in Wabamun eroded- edge traps and immature. Compositions of these pools in Devonian reservoirs are identical to Mannville pools and both are assumed to have been sourced by encasing Cretaceous shales.

The SW flank of the Devonian NGL belt is the WCSB's outstanding example of Wh trend reversal. The flank encompasses a bundle of "hot lines" marking for each unit, the transition from the NGL-rich, associated (and non-associated), mature gases of the belt to the wholly non-associated, overmature and acid gases of the deep basin and Foothills. There is a westward progression towards evermore sour acid gases (96 mole percent H_2S at Bearberry).

Middle Devonian gases of NE British Columbia and nearby Zama field are overmature, somewhat sour and contain high CO_2 gases (30 mole percent at Adsett Slave Point). The Upper Devonian Jean Marie is sweet gas and slightly richer in NGL.

HIGH SULPHUR AREAS (Figure 8)

The pool (> 100 Mm^3) with the highest H_2S fraction of all geological groupings in a grid area was selected to represent the maximum sulphur content for that grid. The fraction was plotted on the map as a mole percent on a logarithmic scale. Block outlines show where the maximum values exceed, or are close to 4 mole percent H_2S. Sour gas pools are mainly Triassic (British Columbia), Mississippian (25%) and Devonian (75% reserves) in Alberta. Sulphur resources are concentrated in the Foothills and Alberta Basin, but important sour gas areas are found in central NE British Columbia (Triassic) and in NE Alberta (Devonian of Zama-Rainbow) [9].

The block outlines of H_2S (>4%) concentration are shown to help interpretation of Wh maps; WCSB-GCDB should be interrogated to obtain sour gas composition by pool and grouping for specific areas.

DEVONIAN DEEP BASIN

An area of central Alberta south of the Peace River arch delimited by N52°30′ to N55° and W114°30′ to W119° (T43 to T70 and R9W5 to R7W6) was selected to analyze the natural gas composition of Devonian pools. These belong to four groupings in the WCSB-GCDB: Wabamun, Nisku, Leduc and Beaverhill Lake (Table 4).

Non-associated and associated gas pools of the Devonian deep basin are at depths of 2250-5000m and at temperatures within and above the "liquid window" stage of hydrocarbon maturation; contain wet, dry (overmature) and sour gases; are rich in NGL and sulphur by-products; and, the area has potential for giant sour gas discoveries.

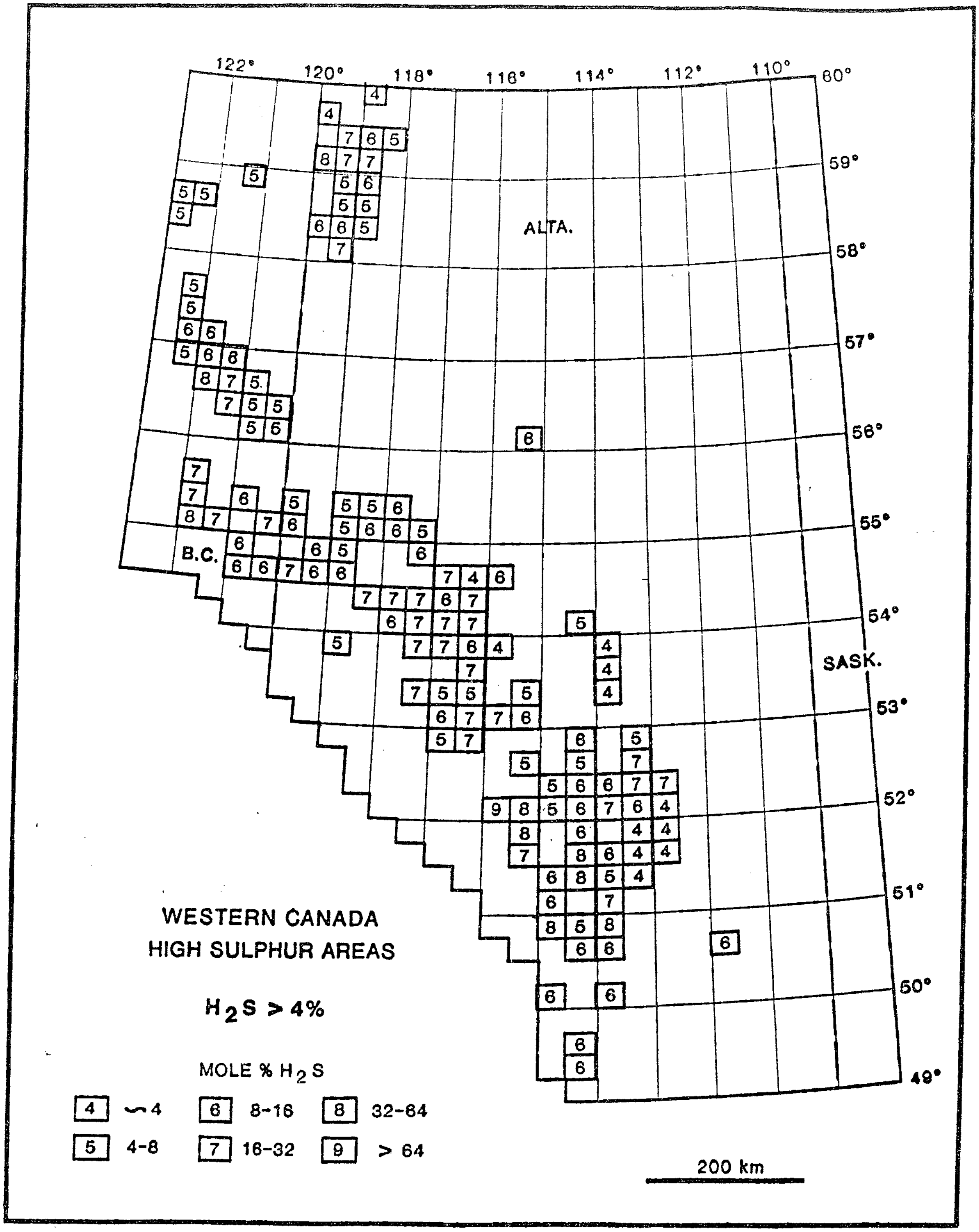

Figure 8. High sulphur areas

TABLE 6

Fractions of Pools and Gas In-Place by Gas Composition Type and by Geological Grouping (Zone) in Devonian Deep Basin

Zone		Gas Composition Type						
		Ia	Ib	Ic	Id	IIa	IIb	Total
Wabamun	(Pools)	0.000	0.059	0.032	0.027	0.081	0.043	0.242
	(GIP)	0.000	0.009	0.004	0.005	0.036	0.013	0.067
Nisku		0.022	0.032	0.086	0.016	0.200	0.086	0.444
		0.004	0.006	0.019	0.005	0.068	0.032	0.134
Leduc		0.011	0.032	0.038	0.000	0.097	0.032	0.210
		0.002	0.014	0.010	0.000	0.145	0.014	0.185
Beaverhill		0.000	0.005	0.016	0.000	0.064	0.022	0.107
Lake		0.000	0.001	0.027	0.000	0.375	0.375	0.613
Total		0.033	0.128	0.172	0.043	0.442	0.185	
		0.006	0.030	0.060	0.010	0.624	0.269	

Total Pools 115
Total GIP 340 E9m^3

TABLE 7

Gas Compositions of Nisku Pools in Brazeau River Field (mole percent)

Map Ref		Pool	C1	C2	C3	iC4	nC4	C5+	H_2S	Depth m
	Area 1									
1		Nisku A	84.4	10.1	2.6	0.0	0.6	0.2	0.0	3376
2		Nisku B	74.0	10.8	4.4	0.4	1.1	0.6	0.0	3376
3		Nisku D	63.8	11.5	6.2	0.8	1.6	1.0	0.0	3376
4		Nisku E	74.0	10.8	4.4	0.4	1.1	0.6	0.0	3376
	Area 2									
5		Bluer A	79.2	7.9	2.8	0.7	1.5	2.2	0.0	3399
6		Bluer 15	82.1	8.8	4.3	0.5	1.0	0.7	0.2	3376
7		Nisku F	73.2	12.5	6.8	1.4	2.2	2.1	0.1	3355
8		Nisku J	50.8	19.1	15.0	3.7	5.9	4.0	0.6	3361
9		Nisku M	65.1	9.3	4.8	1.3	2.3	14.6	0.7	3272
10		Nisku Q	63.4	9.4	5.1	1.3	2.3	13.8	2.8	3372
11		Nisku S	72.6	7.7	4.0	1.5	3.6	5.8	0.0	3762
	Area 3									
12		Nisku K	58.0	10.6	7.3	2.1	3.6	4.3	11.1	3844
13		Nisku N	75.6	2.2	0.6	0.1	0.1	0.3	16.7	3705
14		Nisku R	53.3	4.4	1.9	0.8	1.1	3.8	33.0	3658
15		Nisku W	56.5	7.1	2.8	0.8	1.6	9.4	19.1	3728
	Area 4									
16		Bluer 10	68.9	2.8	0.7	0.3	0.5	0.2	22.0	3137
17		Nisku P	55.8	5.7	2.9	0.8	1.6	11.1	19.8	3137
18		Nisku T	65.7	3.6	1.4	0.4	0.7	0.8	24.7	3048
19		Nisku V	71.2	6.1	2.4	0.5	0.7	0.6	16.6	3198

Gas compositions of pools in the basin cut across geological grouping, lithology, depth and type of trap. The model proposed to explain this variability and to predict compositions invokes two queries: **How hot was the kitchen** and **Could the fumes get away?** Tentative answers begin by looking at the types and distribution of gas in the four groupings.

Gas Composition

Gas pool analyses in the WCSB-GCDB for the Devonian deep basin were converted to unit volume yields of NGL (m^3/Mm^3) and sulphur tonnage (t/Mm^3) of gas in-place using standard volume - mole weight conversions for the carbon numbers and sulphur. A statistical technique was applied to define six gas composition clusters and to combine them into two types: Type I High Methane - Liquids and Type II High Sulphur.

Figure 9 shows box plots of gas composition types and subtypes versus depth for 115 non-associated gas pools of the Devonian deep basin. Table 6 shows the fractions of pools and gas in-place by type and geological grouping. Inspection of the table shows that while the highest fractions of gas in-place belong to the Beaverhill Lake and Leduc, the number of pools and types in the groupings exhibit no unique associations. Groupings cannot be uniquely defined by gas composition or depth.

Taken together, however, the box plots show that 50 percent of all pools (90% methane excepted) are concentrated at depths of 2900-3800m. Two comments also follow, one that Type I liquids (>600 m^3/Mm^3 or 100 B/MMCF) are narrowly constrained by depth, second that Type II liquids in association with sulphur cease at 4000m. This relationship is recast in figure 10 which shows total liquids versus depth for all pools and the same absence of liquids below the "overmature" threshold. As would be expected, pentanes followed by butane and propane disappear in order with depth, while ethane survives as traces. Figure 11 is a pressure versus depth plot for the same pools. Most are normally pressured but about 10 percent of pools approach geostatic gradients.

How hot was the kitchen? Thermal cracking of oil to gas has occurred over the entire depth range (paleotemperatures were higher before unroofing of at least 1000m of Tertiary cover). Liquids are converted totally for Type II sulphur-rich gases but straggle deeper for Type I sulphur-poor gases. Type I high methane box plot shows the bunching of pools at completed oil to gas conversion. By 5000m all that remain are super-acid gases.

Could the fumes get away? Explanations on gas composition intertwine, first that each zone crossed the threshold during burial and differences are due to depth (local factor), second that acid gases ("fumes") boiled from below, permeated overlying rocks, and mixed with less mature, pooled gases (regional factor).

Nisku Pools of Brazeau River Field

Sedimentary facies and depth relationships to hydrocarbon occurrences for Nisku pools in central Alberta have been well studied [7]. Conclusions as concern the Brazeau River field are that pools are pinnacle reefs on the Nisku basin slope and are flanked to the SE by bank-edge reefs; slope and bank are cut to the west by a "hot line" downdip of which are found only non-associated gas pools; oil was generated in Ireton source rocks at temperatures greater than 100 °C (2000-3000m) and migrated into Nisku reefs; replacive anhydrites and dolomites were formed and reacted with hydrocarbons to form H_2S and $CaCO_3$; there was a progressive enrichment then destruction of liquids with burial, formation of dead oil, elemental sulphur and more H_2S (135-160 °C); there was no hydrologic communication between pinnacles and bank (based on isotopic data); and, NW-trending steep faults are numerous and could be conduits for migration of fluids and gases.

Figure 12 is a map of the Brazeau River field showing pool parameters (depth, pressure and temperature). Table 7 lists gas compositions. The field can be divided into four areas: 1) associated gas pools in pinnacle reefs (limestones) having high ethane and no sulphur; 2) SW extension of first area having dolomitized pinnacles and non-associated gas pools with high liquids and no sulphur; 3) SW extension of second area having pervasively dolomitized pinnacles at greater

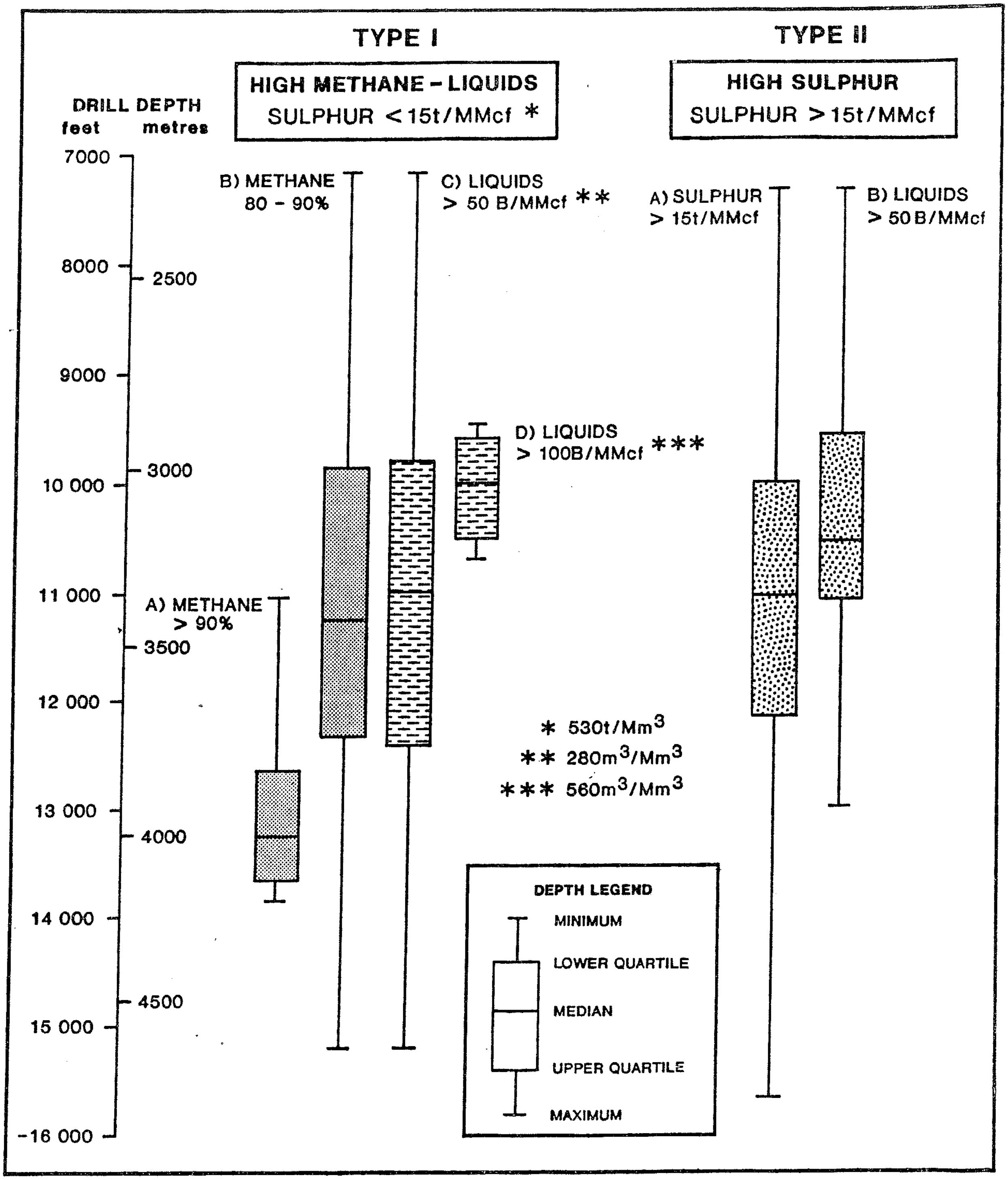

Figure 9. Box plots of composition and depth for Devonian deep basin pools

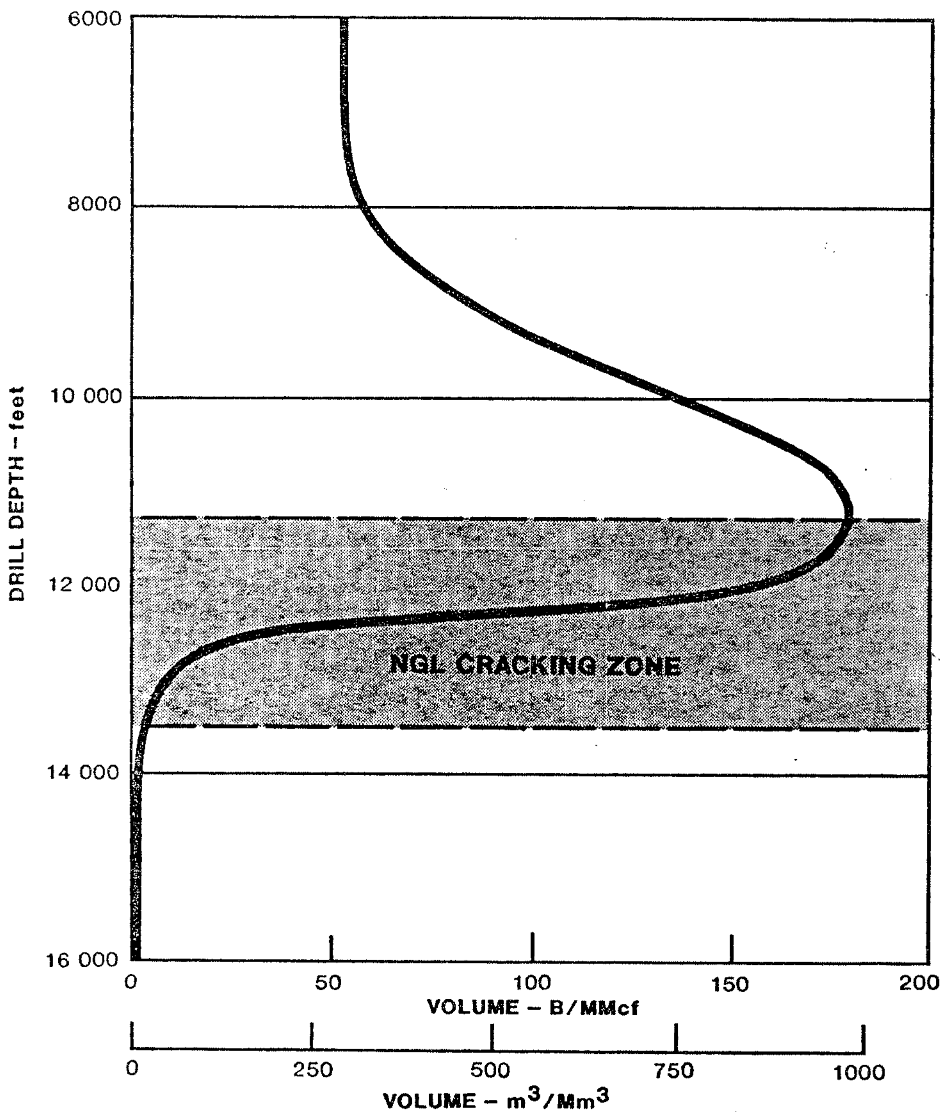

Figure 10. NGL vs. depth for Devonian deep basin pools

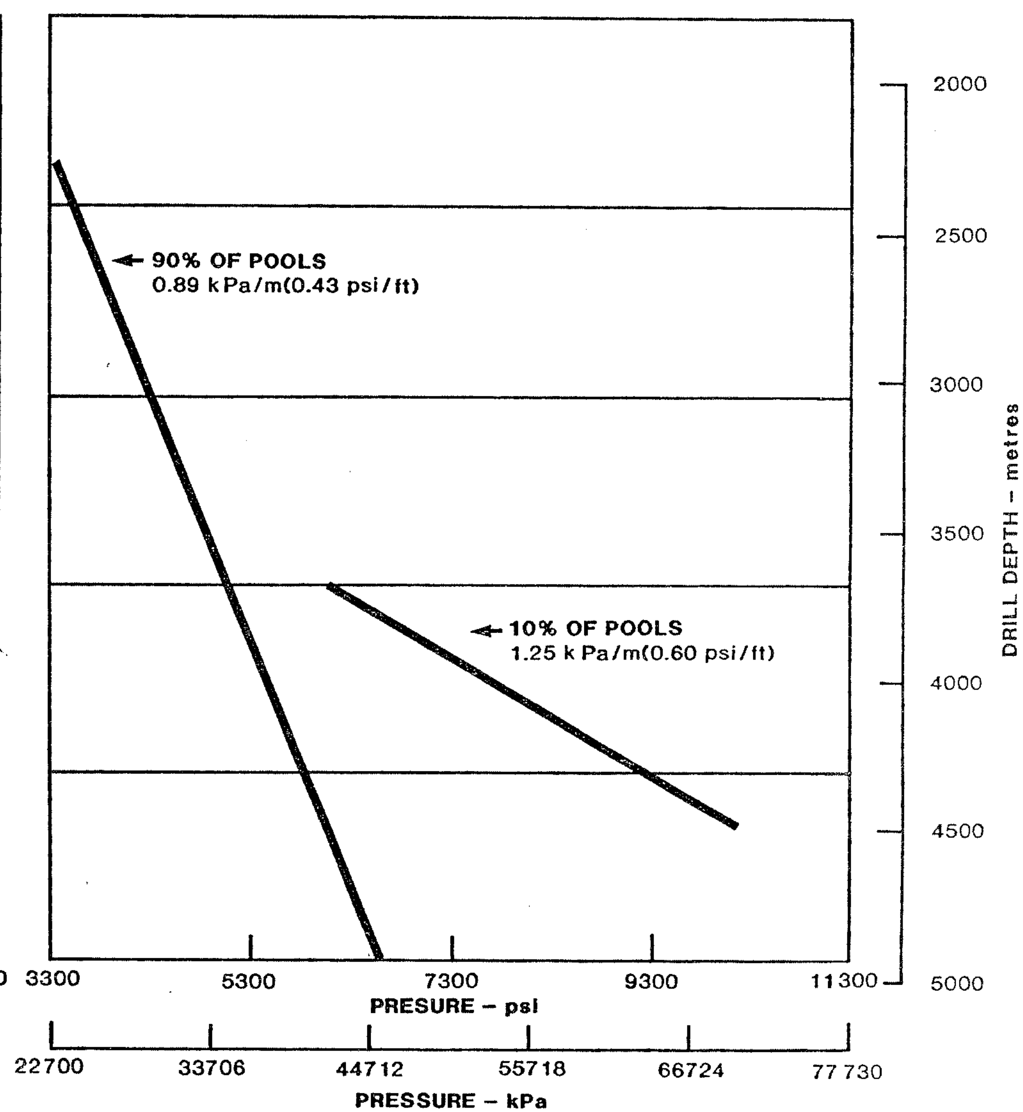

Figure 11. Pressure vs. depth for Devonian deep basin pools

pressure and non-associated gas pools with high sulphur; and, 4) cross trend of low pressure, high sulphur non-associated gas pools in dolomitized, bank-edge reefs.

Pressure data confirm that Nisku pinnacle pools are in pressure isolation from bank pools. However, Area 3 pools are closer in gas composition to Area 4 pools than to other pinnacles. Sulphur and liquid content is seemingly more independent of depth than theory would predict. This leads to the conclusion that the "hot line" separating oil and associated gas from non-associated gas pools does not define all gas compositions and these are at least partially independent of reservoir lithology in the Brazeau River field.

Windfall - Simonette Reef Complex

Leduc reef complexes are found in the Devonian deep basin at Windfall and Simonette. Similar, but detached complexes crop out in front range thrusts (Ancient Wall, Miette, Southesk-Cairn) and it is probable that all complexes were once connected, albeit separated during deposition by surge channels. Leduc reefs grew on a Swan Hills carbonate platform at whose northeast, updip edge are found the giant Beaverhill Lake pools. The stratigraphically higher complexes form an analogous, but westward and stepped-back reef front, along which are located the Leduc pools.

Figure 13 a map showing the gas composition relationships of Leduc pools. Two areas are outlined, Leduc-Ireton no-sulphur inlier and the main, surrounding Leduc high-sulphur reef complex-edge. Table 8 shows the gas compositions of pools in these areas. Leduc-Ireton pools (Harley, Plante, Wild River) average over 85 percent methane and are overmature gases (Type Ia or Ib). In part covering the inlier and inner reef complex-edge is a "NGL low" containing a mix of sulphur-free and acid gases (Types Ib, IIa). Lastly, Leduc reef complex-edge pools (Windfall, Simonette, Fir, Bigstone, Berland River) can be sulphur-rich without significant liquids (IIa) or liquid-rich (IIb).

TABLE 8

Composition of Non-associated Gas Pools
Windfall-Simonette Leduc Reef Complex

	C1 mole%	NGL m^3/Mm^3	H_2S mole%
Leduc-Ireton no-sulphur inlier			
Harley field	83.0	317	0.0
Plante field	83.0	448	0.0
Wild River field	98.8	3	0.0
Leduc high-sulphur reef complex-edge			
Windfall field	66.2	491	14.5
Simonette field	55.5	815	18.8
Fir field	82.8	31	12.8
Bigstone field	77.2	15	17.3
Berland River field	81.0	21	14.2

Conclusions drawn are that gas composition departs from strict dependence on depth (paleotemperature) once thermochemical reactions and diffusion start. Leduc pools can escape infusion of acid gases when encased by Ireton shales. Other evidence is the super-acid composition of the associated gases at Windfall. Several small Leduc and Nisku pools and a giant, Leduc associated gas pool (20 $E9m^3$ or 750 BCF) at Windfall contain 15-20 mole percent of H_2S while being otherwise "normal" in their methane and liquids. Associated gases usually contain only traces of H_2S. An explanation for this anomaly is leakage of acid gases ("fumes") from the Swan Hills platform and Beaverhill Lake pools. It is speculated, as an application of the principles discussed, that Wabamun pools in the south of Pine Creek field are sourced from undiscovered Leduc or deeper pools. In theory, the deep pools could contain many times the gas in-place of the shallow discoveries. This derives from the relationships between gas composition, pressures and temperatures of other Wabamun and Leduc pools within the field and projection of regional faults [6].

Kaybob South Sour Gas Pools

The largest gas accumulation in the Devonian deep basin is a Beaverhill Lake non-associated

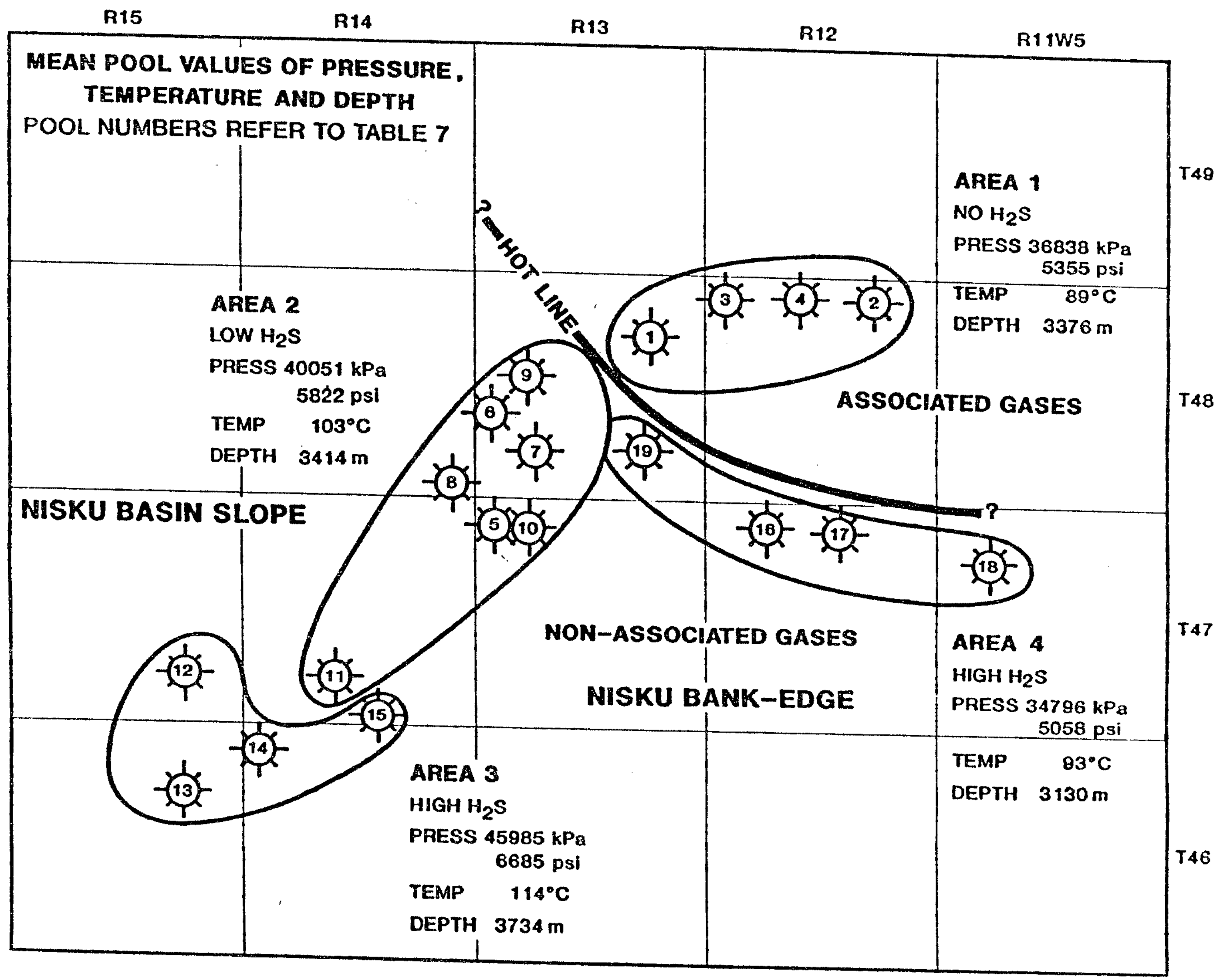

Figure 12. Map of Brazeau River field

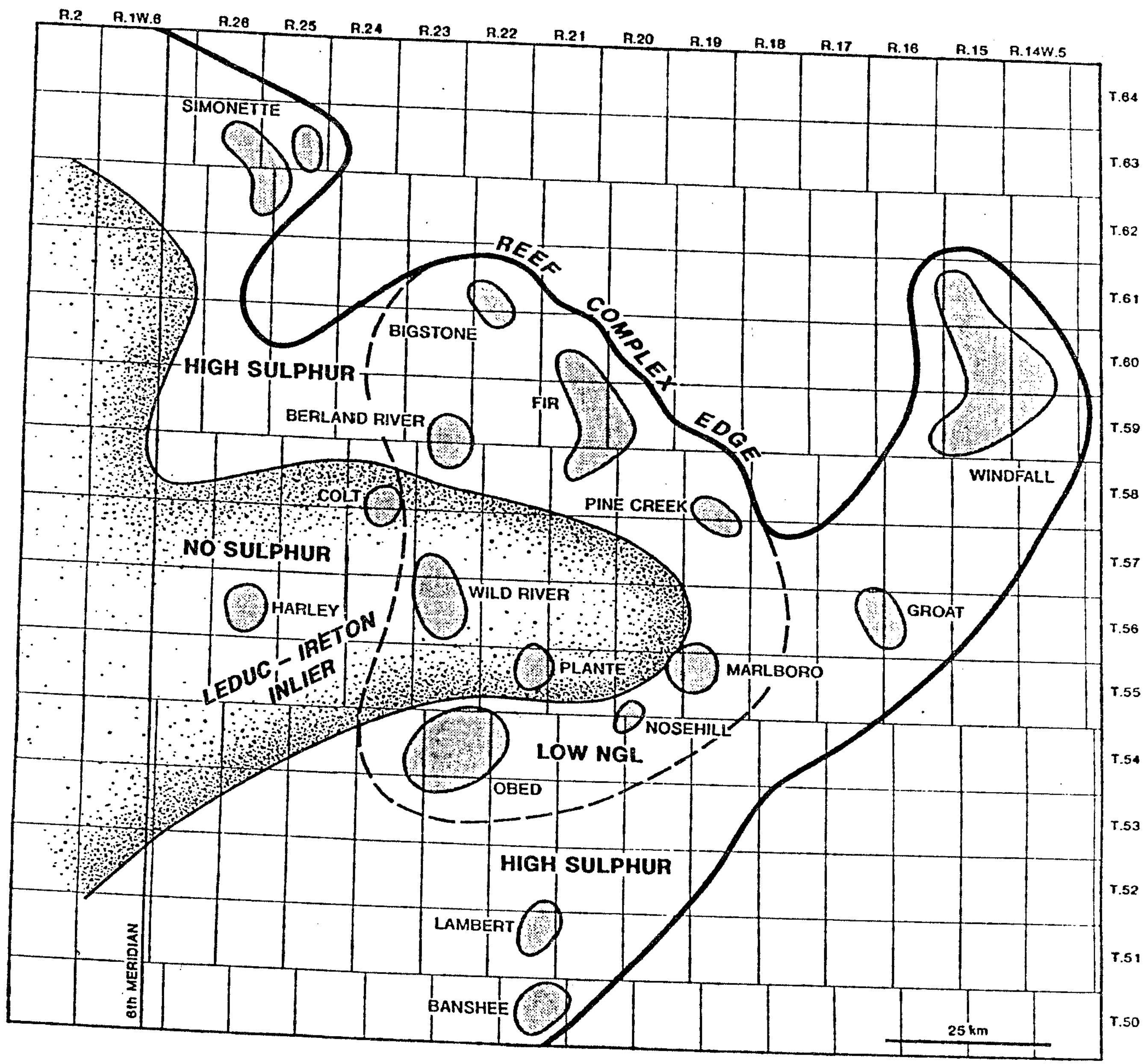

Figure 13. Map of Windfall-Simonette reef complex

34gas pool at Kaybob South (100 $E9m^3$ or 3.7 TCF). The pool is large (200 sq km), elongate, NW-trending, and the trap appears to be an updip termination of porous organic limestones (reef complex) against limy shales (surge channel infill), though faulting may also be involved [6,11].

Kaybob South may be a model for the upward flow of acid gases from deep sources (Beaverhill Lake) into shallow traps (Nisku). Thick Fort Vermillion and Elk Point anhydrites floor the basin below the Beaverhill Lake. Kaybob South is west of the "hot line" and all originally pooled crude oils have been converted to non-associated gases, containing up to 15-25 mole percent H_2S.

Figure 14 is a field plat of Nisku pools updip from Kaybob South Beaverhill Lake pools and Table 9 gives gas in-place, H_2S, iC4/nC4, and reservoir depths. Super-acid gases found within the "liquid window" depths of Nisku pools are only 500m above the Beaverhill Lake.

TABLE 9

Nisku and Beaverhill Lake Pools of Kaybob South Field

Pool	GIP $E9m^3$	H_2S mole%	iC4/nC4	Depth m
Nisku A	0.5	19.37	0.55	2908
Nisku B	0.3	23.75	0.55	2917
Nisku 5	0.1	19.37	0.55	2839
BHL A	105.0	17.02	0.55	3372
BHL B	0.1	14.62	0.53	3314
BHL 10	0.2	12.22	0.55	3306

The solubility gradients of H_2S in hot brines (0.6 g/l/°C) and at high pressures (0.005 g/l/kPa) allow that H_2S concentrations in rising connate waters from Beaverhill Lake pools would drop from 105 to 95 g/l and thus source sour gas (note higher H_2S) to the Nisku pools [2]. The model suggests that undiscovered Beaverhill Lake and Leduc pools may occur below known Nisku and Wabamun pools. This is conceptually similar to the "reservoir stacking" which occurs at Hanlan (Beaverhill Lake and Winterburn), Limestone (Leduc and Nisku, Wabamun), Pine Creek (Leduc and Wabamun), and Strachan (Leduc and Wabamun) fields and many examples on the Rimbey-Meadowbrook trend.

Other Beaverhill Lake Pools.

The distribution of gas composition in Beaverhill Lake pools of the Devonian deep basin can serve as a template to refine Wh maps and use of the WCSB-GCDB. Table 10 gives basic parameters for 15 non-associated gas pools in the grouping. A method, similar to previous clustering of pools by composition and depth, was used to classify Beaverhill Lake pools by methane, NGL, and H_2S. Table 11 gives the gas mole percentages for five type compositions (actual pools) of the Beaverhill Lake in the Devonian deep basin.

Figure 15 shows the distribution of C2+, H_2S and CO_2 mole percents of Beaverhill Lake pools over a portion of the Devonian deep basin. Associated gas pools in the northeast are included to better establish regional gradients. Liquids (and methane) increase towards the Devonian "NGL belt" on the east while acid gases increase to the south and west. Types I and II which constitute the dominant non-associated gases occur in separate thermochemical regimes. The Carson Creek composition proxies the low-sulphur, platform margins and reef complex outliers of the Beaverhill Lake in its limestone facies, while Kaybob South composition represents very sour gas, reef complex inliers of a more dolomitized facies to the west. The Minehead Beaverhill Lake pool can be taken to represent high-CO_2 gas composition.

MANNVILLE GAS YIELDS

The "Mannville" is taken to consist of Lower and Upper Mannville, Blairmore and equivalent Lower Cretaceous sandstones deposited on the Alberta shelf, in the Alberta basin, and Northern Plains. The Mannville is the most widespread and densely drilled of all gas zones in western Canada. Furthermore, the gas resource is highly dispersed in tens of thousands of multiple and coextensive, "stratigraphic" pools across the WCSB. Such a setting is ideal for testing the relationships between gas composition, reservoir depth and gas reserves.

The method used to quantify pool "yield" for the Mannville consisted of retrieving gas reserves, area and net pay for non-associated and associated gas pools and calculating gas yield per unit area (m^3/ha, MMSCF/ac) and per unit

TABLE 10

Pool Parameters for Beaverhill Lake Pools in the Devonian Deep Basin

Field	GIP $E9m^3$	C1 mole%	C2 mole%	NGL* m^3/Mm^3	SULF t/Mm^3	PRESS kPa	TEMP °C	DEPTH m	TYPE
KaybobS	105.0	57.9	7.7	570	214	31649	114	3372	IIb
Hanlan	40.2	78.2	1.2	5	115	43708	144	4625	IIa
Blckstne	18.4	79.3	0.0	0	135	45097	139	4738	IIa
Carsn Ck	11.0	72.3	14.7	365	0	25513	93	2621	Id
Minehead	7.2	75.4	0.1	1	168	42821	146	4388	IIa
Rosevear	7.1	80.5	3.0	92	96	32736	116	3219	IIa
Rosevear	6.1	80.4	3.0	93	97	32736	116	3236	IIa
Kaybob	2.3	69.2	11.5	647	14	30466	108	2963	IIb
Hanlan	1.3	79.0	1.1	10	105	43735	138	4774	IIa
Chickdee	0.4	78.2	2.7	248	63	27804	117	2978	IIb
KaybobS	0.2	72.5	4.0	218	154	29820	99	3306	IIb
Groat	0.2	68.0	6.9	410	128	32626	92	3080	IIb
Sakwatma	0.1	83.0	3.6	259	0	17396	83	2752	Id
Wild Riv	0.1	87.2	1.0	10	111	48977	122	4146	IIa
KaybobS	0.1	65.2	5.8	395	184	29820	98	3314	IIb

* includes propane, butane and pentanes-plus

TABLE 11

Type Non-Associated Gas Compositions Beaverhill Lake Deep Devonian Basin

Composition mole percent	High H_2S Kaybob S	High NGL Carson Ck	High C1 Sakwatam.	Low NGL Rosevear	High CO_2 Minehead
N2	1.15	2.42	1.54	1.11	1.95
H_2S	17.02	0.00	0.00	7.66	13.35
CO_2	3.40	1.45	1.87	5.72	9.24
C1	57.93	72.67	82.99	80.38	75.43
C2	7.70	14.71	7.28	2.97	0.02
C3	3.26	4.50	3.59	0.85	0.01
iC4	0.88	0.48	0.50	0.22	0.00
nC4	1.65	1.15	1.07	0.28	0.00
iC5	0.69	0.27	0.25	0.12	0.00
nC5	0.73	0.34	0.26	0.11	0.00
C6	1.23	0.44	0.22	0.13	0.00
C7	4.36	1.57	0.43	0.45	0.00

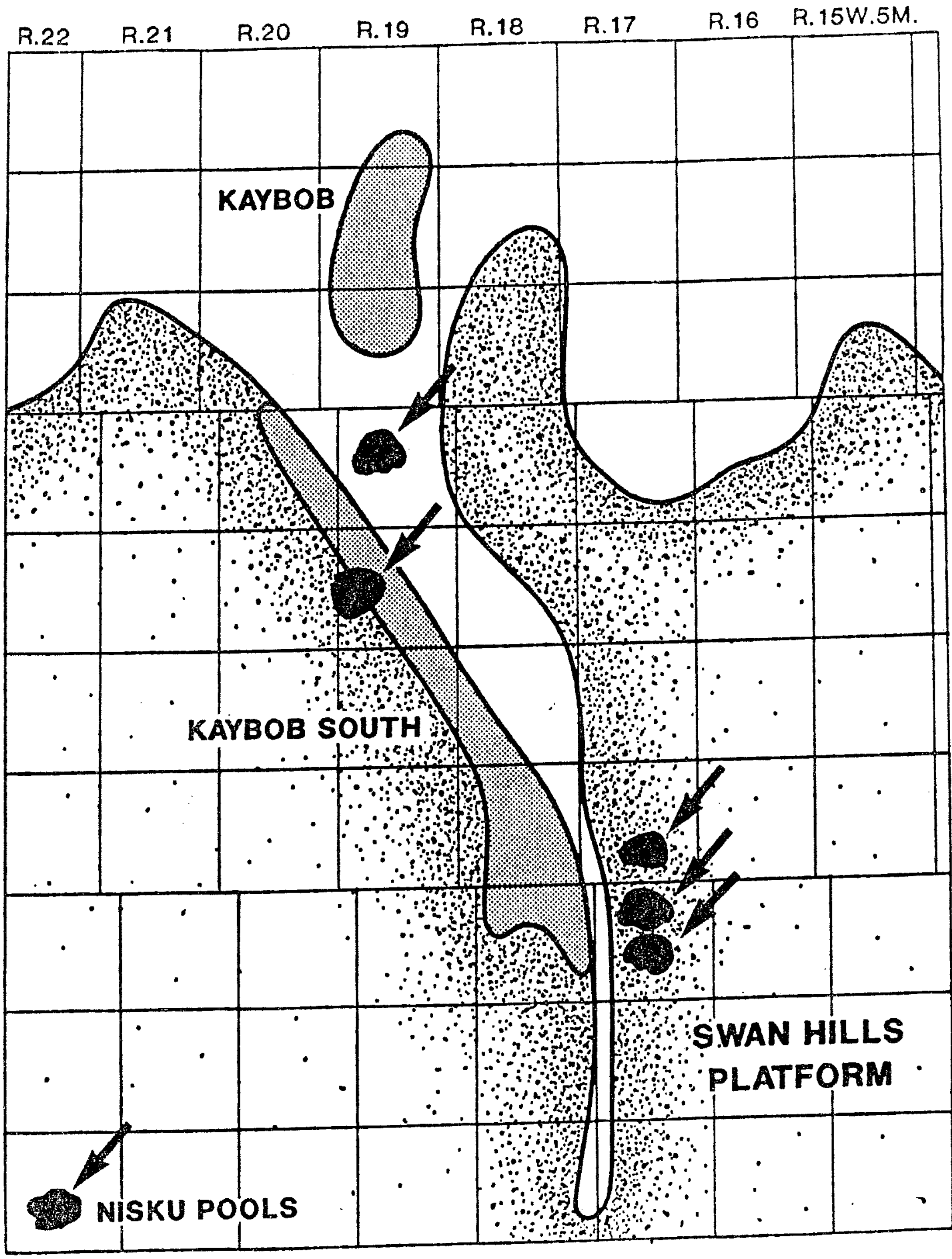

Figure 14. Map of Kaybob South field

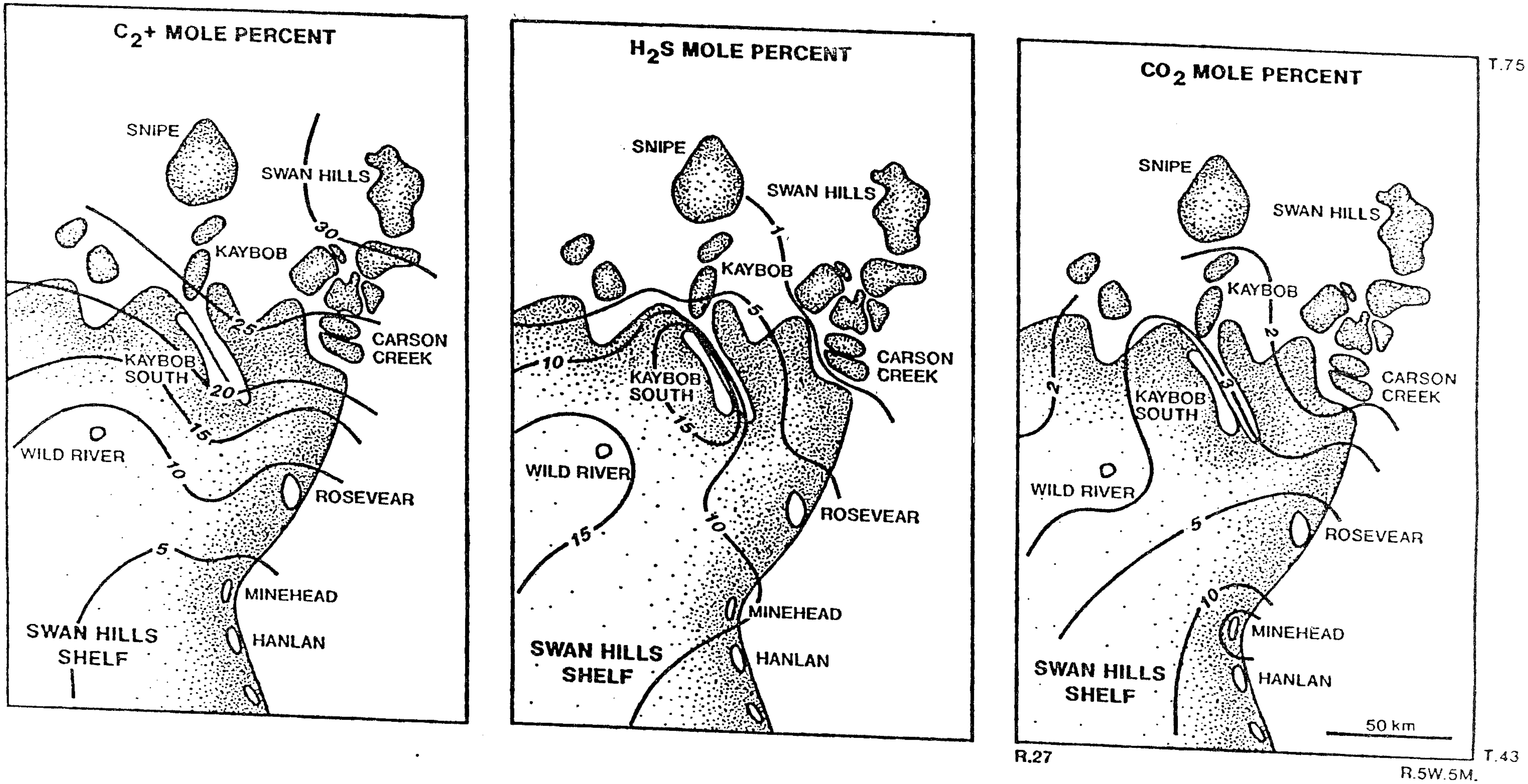

Figure 15. C2+, H_2S, CO_2 in Beaverhill Lake Formation of Devonian deep basin

volume (m^3/ha-m, MMSCF/ac-ft). After some trials, it was decided to reject unit volumes (area-net pay covariance) and to weight unit area yield by pool marketable gas to reduce the unknown bias of small pool area designations.

The weighted area yields were "double-smoothed" for mapping by form-lining a computer generated grid. This "computer-human hand" method was preferred to trend surface analysis in order to map Wh, gas yield and depth as consistently as possible. Figure 16 shows maps of mean reservoir depths and area yields for the Mannville. Figure 3 is the Wh map. The expected increase in area gas yields with depth (Boyle's law) is confirmed and matches the increase in Wh (hydrocarbon maturation). Broad highs of area gas yields on the SE Alberta shelf are caused by better reservoir quality and thicker pays. Conclusions drawn are that the Mannville (Blairmore) in the Alberta basin has the potential for NGL-rich pools and that small pool area and thin pays may be offset by higher gas yield.

GAS IN-PLACE AND RESERVES

Estimation of the total marketable gas which can be produced from a pool having a given volume of raw gas in-place depends on the pool recovery and surface loss, which are technical terms used by conservation boards (Appendix A). Surface loss (shrinkage) derives simply from gas composition and the extraction of inert and acid gases and NGL at a gas plant to meet a pipeline or fuel specification. The steps required in gas processing and definitions of gas composition in industry practice provide a necessary insight to the interpretation of molar composition in resource assessments (Appendix B).

Pool recovery is more uncertain because it is an engineering estimate of the efficiency of a recovery mechanism and field development under a set of economic conditions. Well flows, infill drilling, ground facilities, process design are but some of the data needed to quantify pool recovery.

WCSB Recovery Factors

Pool recoveries and surface losses for over one thousand producing pools (totalling 2.3 E12 m^3 initial gas in-place) in Alberta and British Columbia are summarized by geological grouping in Table 12. The product of pool recovery times (1 - surface loss), called the recovery factor is given in the right column. The (1 - surface loss) is strongly correlated to NGL (and Wh maps) increasing from about 0.84 for Middle Devonian to 0.94 for the Viking. Lower values reflect high NGL and acid gases of pre-Cretaceous pools. Non-associated gas pool recoveries are more variable than associated ones.

Devonian Deep Basin Recovery Factors

Super-acid and other pools of the Devonian deep basin are not developed on unit production spacing because of high completion and lifting costs, gas contracts, and reservoir variability. Thus, Kaybob South (spacing of 1 well per 200 ha), Kaybob (500 ha), Carson Creek, Hanlan and Rosevear (1000 ha), and Blackstone (3500 ha) having Beaverhill Lake reservoirs are developed on different well spacings.

Figure 17 is a cumulative distribution of recovery factors and surface losses (pool recovery about equal to surface loss) for 115 Devonian deep basin pools. Figure 18 is a box plot of pool recovery for these pools. Outliers of less than 0.5 comprise both large (Bigstone Leduc, Pine Creek Wabamun) and small pools; the extreme outlier is 0.1 (Windfall Leduc). Distributions show means and variances for pool recovery and surface loss. In summary, the recovery factor indicates a relatively low marketable gas fraction (mean = 0.57) of the gas in-place.

CONCLUSIONS

1. The hydrocarbon wetness ratio (Wh) is an efficient estimator of natural gas liquids on a regional scale in western Canada. Interpretations are strengthened where the Wh is referenced to type gas compositions and a map overlay of sour gas distribution.

2. Maps for Devonian to Cretaceous groupings of non-associated and associated gas pools display similar trends with an increase of Wh from east

TABLE 12

Recovery Factors for WCSB Gas Pools *

ASSOCIATED GAS

Zone	Pool Recovery	1-Shrinkage	Recovery Factor
Viking	0.88(0.05)	0.84(0.16)	0.75(0.15)
Mannville	0.85(0.07)	0.91(0.03)	0.78(0.06)
Jura-Triassic	0.84(0.04)	0.88(0.04)	0.73(0.05)
Mississippian	0.82(0.12)	0.87(0.13)	0.71(0.15)
U Devonian	0.82(0.11)	0.81(0.09)	0.66(0.10)
M Devonian	0.80(0.07)	0.87(0.03)	0.70(0.08)

NON-ASSOCIATED GAS

Viking	0.75(0.11)	0.93(0.06)	0.70(0.11)
Mannville	0.78(0.16)	0.93(0.04)	0.72(0.16)
Jura-Triassic	0.80(0.12)	0.89(0.09)	0.71(0.13)
Mississippian	0.79(0.15)	0.89(0.07)	0.70(0.14)
U Devonian	0.75(0.11)	0.86(0.14)	0.64(0.13)
M Devonian	0.83(0.07)	0.83(0.08)	0.70(0.09)

* Fractions are given by mean (standard deviation)

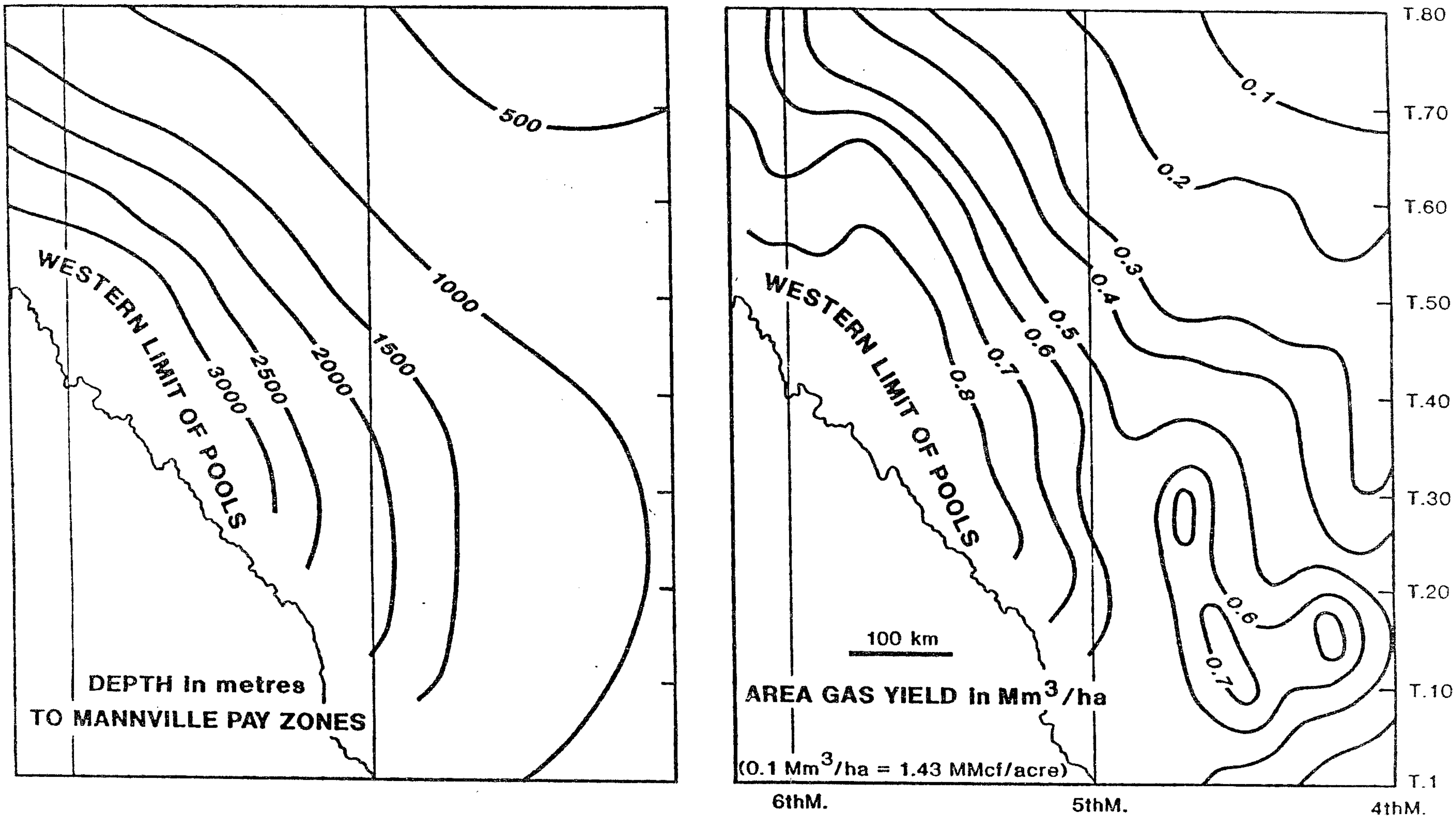

Figure 16. Area gas yields and depth maps for "Mannville" grouping

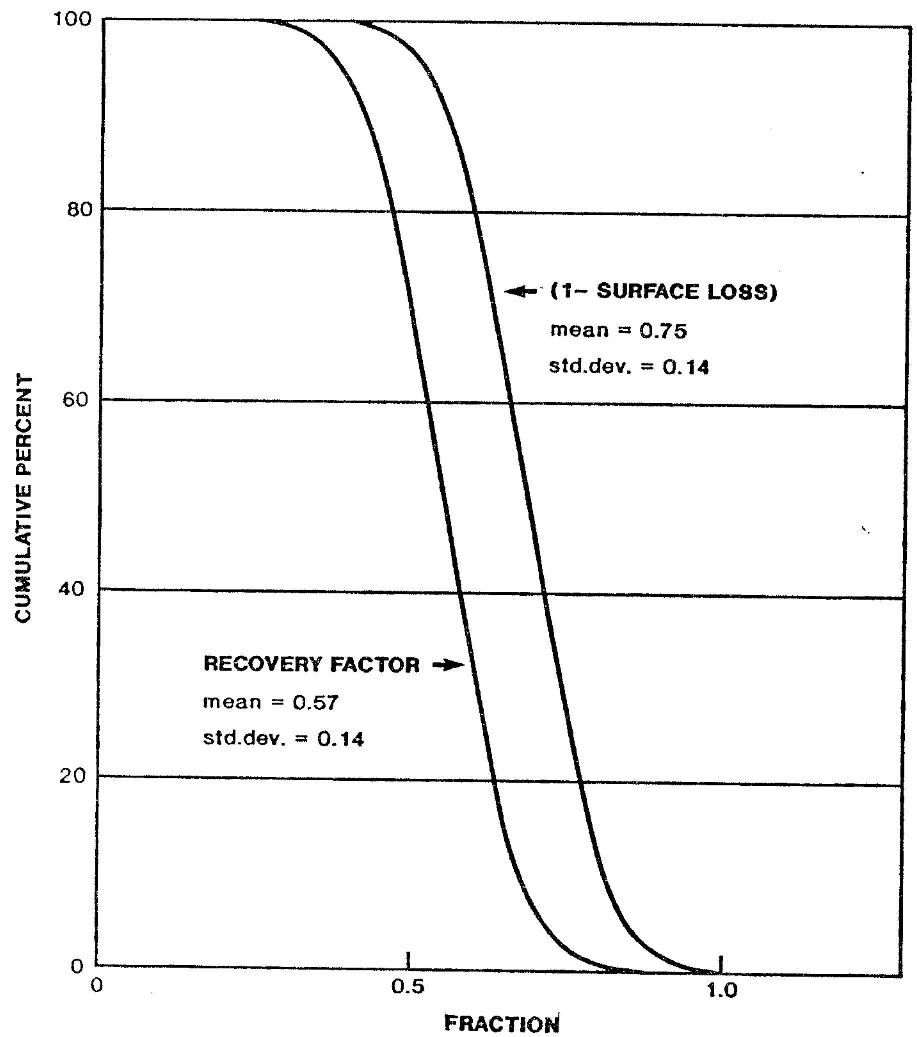

Figure 17. Cumulative distribution of recovery factor and surface loss in Devonian deep basin pools

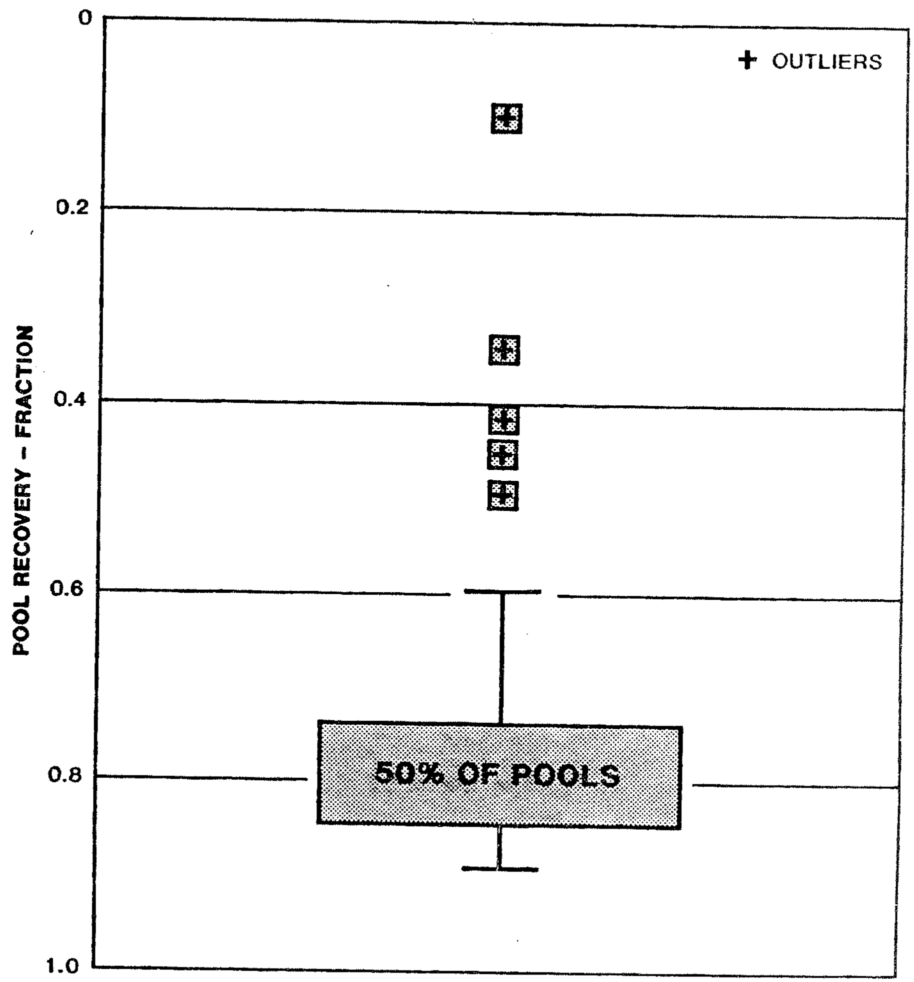

Figure 18. Box plot of pool recovery for Devonian deep basin pools

(Alberta shelf) to west (Foothills). Wh reversals do occur, however, in Devonian to Triassic groupings in the Foothills and disturbed belt at the "hot lines," to the west of which only non-associated gas pools are found. For these groupings, the Wh maps show a NW-trending, "High-NGL Belt" of both associated and non-associated gas pools, which is flanked by lower Wh, mainly non-associated gas pools; gases are typically less mature on the NE than on the SW flank.

3. A significant potential exists for high-NGL, sweet gases in the three Cretaceous groupings in the deeper, western parts of the WCSB because the Wh reversal found in older groupings is incipient only and can be expected to close in the Foothills or under the leading thrusts of the disturbed belt.

4. Devonian and Triassic sour gas pools are found in the deep basin and Foothills aligned along nearly continuous trends in Alberta and British Columbia. The trend contains H_2S mole percentages of 4 to nearly 100 percent and covers the area where gas processing to recover sulphur is commercial. Mississippian and Jurassic groupings contain less or no sour gas and pools are more scattered along the trend.

5. Wh maps identify areas where NGL gas processing can be expected. Pipeline specification gas equates to about Wh=8 or 275 m^3/Mm^3 (50 B/MMSCF) of total liquids. A Wh>15 contour outlines areas where gas processing will recover significant quantities of NGL by-products.

REFERENCES

1. Alberta Energy Resources Conservation Board
   1984: Alberta Gas Reserve Trends, p. 3-4.
2. Barker, C.
   1990: Calculated volume and pressure changes during the thermal cracking of oil to gas in reservoirs; American Association of Petroleum Geologists, Bull., v. 74, p. 1254-1261.
3. Barker, J.F. and Pollock, S.J.
   1984: Geochemistry and origin of natural gases in southern Ontario, Bull. of Canadian Petroleum Geology, v. 32, p. 313-326.
4. Haworth, J.H., Sellens, M., and Whittaker, A.
   1985: Interpretation of hydrocarbon shows using light (C1-C5) hydrocarbon gases from mud-log data, American Association of Petroleum Geologists, Bull., v. 69, p. 1305-1310.
5. Hitchon, B.
   1963: Geochemical studies of natural gas, part I. Hydrocarbons in western Canada natural gases, Journal of Canadian Petroleum Technology, v. 2, p. 60-76.
6. Jones, R.M.P.
   1980: Basinal isostatic adjustment faults and their petroleum significance, Bulletin of Canadian Petroleum Geology, v. 28, p. 211-251.
7. Machel, H.G.
   1985: Facies and diagenesis of the Upper Devonian Nisku Formation in the subsurface of central Alberta;Ph.D.thesis, McGill University, 392 p.
8. Orr, W.L.
   1974: Changes in sulphur content and isotopic ratios during petroleum maturation -- study of Big Horn Basin Palaeozoic oils, American Association of Petroleum Geologists, Bull., v. 58, p. 2295-2318.
9. Parsons, W.H.
   1973: Alberta; in The Future Petroleum Provinces of Canada -- Their Geology and Potential, R.G. McCrossan (ed.); Canadian Society of Petroleum Geologists, 720 p.
10. Podruski, J.A. et al.
   1987: Conventional oil resources of western Canada (light and medium), Geological Survey of Canada, Paper 87-26, 149 p.
11. Viau, C.
   1987: The Swan Hills Formation and the Beaverhill Lake Group at Swan Hills Field and adjacent areas, central Alberta, Canada; in Devonian lithofacies and reservoir styles in Alberta, F.F. Krause and O.G. Burrowes (ed.); Canadian Society of Petroleum Geologists, Core conference,p. 201-239.
12. Warren, A.
   1990: Albert's small gas pool reserves; Journal of Canadian Petroleum Technology, v. 29, p. 34-40.

APPENDIX A

RESERVES TERMINOLOGY

Natural gas pools are defined as to the raw gas contained in-place and as to the gas reserves which can be recovered by production under current economic conditions. The Alberta Energy Resources Conservation Board (AERCB) uses the following definitions:

Initial volume in-place is the gross volume of natural gas estimated to exist in the reservoir. The gas in-place may be proven (producing pools, older pools) or probable (non-producing pools, new pools). It is the practice to revise raw gas volumes because of appreciation. As a result of revisions and other AERCB and industry updates, few producing pools have a probable component in their reserves. Small pools or single wells which have not produced are given an initial volumetric raw gas on a nominal area (200-hectare) which is subject to revision by AERCB according to geology, location and pool size [12].

Information on the area of a pool is usually inadequate at the time of discovery and appreciation of raw gas volumes will occur as the result of extensions, development drilling and production history.

Pool recovery is the fraction of the in-place gas which is expected to be recovered under the subsisting recovery mechanism. The fraction may be increased when the wellhead value of gas increases faster than operating costs, thereby changing profitability and economic limit, and by technological advances (well stimulation, fracing, horizontal drilling, enhanced recovery). Some reservoirs have a lowered recovery because of well spacing, higher lifting and compression costs, and reservoir variability.

Surface loss is the fraction of recoverable gas removed as inert and acid gas, as liquid hydrocarbons (shrinkage), and used as fuel or flared.

Marketable gas is a mixture of mainly methane originating from raw gas with the removal or partial removal of some constituents to meet a fuel or pipeline requirement (see Table 5 for the composition of a typical pipeline gas in Alberta). Marketable gas is thus the product of the gas volume in-place, recovery fraction and surface loss fraction. Recoverable natural gas liquids, based on raw gas volume are typically 85 percent for propane, 95 percent for butane, and 100 percent of heavier ends.

Initial and remaining marketable gas refer respectively to the marketable gas deemed recoverable before production (subject to appreciation) and subsequently remaining after production (usually reported yearly).

Appreciation represents positive (sometimes negative) reserves revisions to a pool after discovery. AERCB [1] estimates that the larger pools (greater than 300 Mm^3 or 10 BCF) appreciate on average about six times over a period of twenty years by the formula

$$A = 1.0 + 4.42\ (1 - e\text{-}t/4.89)$$

where A = appreciation factor
t = number of years after discovery

which can be solved as follows

Year	A	Year	A	Year	A	Year	A
1	1.82	6	4.12	11	4.98	16	5.25
2	2.48	7	4.36	12	5.04	17	5.28
3	3.02	8	4.56	13	5.11	18	5.31
4	3.47	9	4.72	14	5.17	19	5.33
5	3.83	10	4.85	15	5.21	20	5.35

It is to be noted that t is from year of discovery rather from than date of production which introduces a conservative bias to appreciation. Small pools and single well pools can be expected to have a lower appreciation.

APPENDIX B

GAS PROCESSING

Raw gas normally consists of methane and variable amounts of heavier hydrocarbons (ethane through pentanes-plus), inert (He, N_2) and acid (CO_2, H_2S) gases, and connate water. Traces of hydrogen and sulphur compounds (carbon disulphide, carbonyl sulphide, mercaptans) may also be present. Processing is required to remove all (or nearly all) constituents from the gas other than methane and some quantities of heavier hydrocarbons to meet sales gas, pipeline specifications.

Those engaged in the "upstream" segment of the gas industry are concerned with natural gas in the reservoir, gas production and delivery to a field processing plant (some wellsite processing may be required to control hydrates, liquid slugs in lines, and dangerous sulphurous compounds). For the purposes of resource assessment, however, knowledge of the terms used in processing helps to interpret molar gas compositions as types of gas and in estimating marketable from raw gas.

Sour gas contains more than 1/4 grain (16 ppm) H_2S or more than 1 grain of total sulphurous compounds per 100 SCF while sweet gas contains less than this quantity. Terms used are

Sweet gas	:	0 mole percent H_2S
Sour gas	:	up to 10 mole percent H_2S
Very sour gas	:	above 10 mole percent H_2S
Super-acid gas	:	above 15 mole percent H_2S + CO_2

Wet gas contains more than 2.5 barrels of condensate (pentanes-plus) per MMSCF while dry gas contains correspondingly less.
Rich gas contains more than 20 B/MMSCF of propane and heavier hydrocarbons while Lean gas contains correspondingly less. Gas which contains more than 50 B/MMSCF of propane and heavier hydrocarbons can be called a very rich gas.

NGL or natural gas liquids refer to ethane plus heavier hydrocarbons while LPG or liquified petroleum gases refer to propane plus heavier hydrocarbons.

Steps required to process gas to pipeline specifications depend on the type of gas and involve some or all of the following:

1. Compression to pipeline requirements.
2. Recovery of condensate.
3. Removal of H_2S (if >4 ppm), excess CO_2 (if >2%), and water.
4. Flaring and venting small amounts of gas.
5. Removal of sulphur from NGLs if not done earlier.
6. Recovery of NGL and LPG (if C3>2%, if C4>0.5%).
7. Fractionation of NGL and LPG into ethane, propane, butane, and pentanes-plus.