

GEOCHEMICAL STUDIES - 1
TRACE ELEMENTS IN ALBERTA CRUDE OILS

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"GEOCHEMICAL STUDIES"

This series of reports, under the general title "Geochemical Studies", makes available geochemical data on the formation fluids and rocks of Alberta which would otherwise remain unpublished. Two types of data fall in this category. First, "Geochemical Studies" will act effectively as a document despository in cases where a formal publication is available, but without the raw data having been published; additional interpretations may be included if pertinent. Second, "Geochemical Studies" will include both the raw data and a minimal descriptive report in the case where no formal publication is planned.

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ABSTRACT

Twenty-two trace elements, determined by neutron activation techniques, are reported for 86 conventional crude oils and two crude oils from the Athabasca oil sand deposit, Alberta. When these crude oils are grouped into three families, based on previously studied hydrocarbon characteristics, analysis of variance indicates that S, Se, V, Ni, Br, Co and Zn can be used to differentiate, at a 90 percent confidence level, at least one of the families. These elements may therefore be an additional basis for distinguishing the crude oil families. Further study using multivariate methods are justified.

It is suggested, tentatively, that crude oils with alkaline associated formation waters may be relatively depleted in Na, when compared to those with acidic associated formation waters. The contents of both Zn and V in crude oils may be related to the content of these elements in the source rocks. A geochemical model is presented for the occurrence of Br and I in formation waters and I in crude oils. These three geochemical observations, as well as the possible use of trace elements for the classification of crude oils into families, may be of value to explorationists and more study is justified.

INTRODUCTION

Trace elements have been known to be present in crude oils for many decades. Although the amounts found are generally small their impact on successful industrial processing is immense, especially with respect to petroleum refining and environmental concerns. In addition, they play a role in elucidating the origin of petroleum. Early studies on trace elements in Alberta crude oils comprise mainly the publications of Hodgson and his co-workers (Scott *et al.*, 1954; Hodgson 1954; Hodgson and Baker, 1957; Baker and Hodgson, 1959). These dealt mainly with the trace elements V, Ni and Mg.

The more recent work of Hitchon *et al.* (1975) represents the first published account of a multi-element study of trace elements in Alberta crude oils. Their study reported the general statistics for 22 elements in 86 conventional crude oils and two crude oils from the Athabasca oil sand deposit. Eleven elements (S, V, Cl, Na, Ni, Zn, Co, Mn, Se, Br and As) were studied by both Q-mode and R-mode statistical factor analysis. A separate R-mode analysis using the biquartimin solution was provided for V, Fe, Ni, Co, Mn and Cr in 20 selected crude oils. Recognizing the limitations imposed by the determination of trace elements in the total crude oil, when their content is sometimes essentially confined to a variable fraction such as the asphaltenes, Hitchon *et al.* (1975) concluded that S, V, Cl, Na, Ni, Zn, Co, Mn, Se, Br and As are controlled by maturation processes rather than migration processes, though this control may simply reflect maturation of the asphaltene fraction of the crude oils. More than one quarter of the cumulative variance is accounted for by S, V, Se and Ni, representing metalorganic complexes. The factor analyses further demonstrated not only the efficacy of their separation system between crude oil and entrained formation water, but also that it is most unlikely that the Fe present in the crude oils originates from corrosion products incorporated during production. Four elements, Fe, Mn, As and Co represent essentially unique factors.

Additional analytical data on the same suite of crude oils studied by Hitchon *et al.* (1975) can be found in Elofson *et al.* (1977), including the ESR properties of the crude oils, the percent asphaltenes, and both the ESR properties and elemental composition of the asphaltenes. The molecular weight (in benzene) of the asphaltenes was reported for selected samples.

This Open File Report will act effectively as a document depository for the raw data used by Hitchon *et al.* (1975). Additional analytical information on the same suite of crude oils is also provided. Hitchon *et al.* (1975) considered the 86 conventional crude oils and two crude oils from the Athabasca oil sand deposit as a single population, based on the results of the Q-mode analysis, and found maturation to be the controlling process for eleven elements. Additional information may be derived from the same data if the conventional crude oils are divided into the three major crude oil families distinguished by Deroo *et al.* (1977), and



the trace elements compared between families. For reasons to be explained elsewhere, the two crude oils from the Athabasca oil sand deposit are treated separately.

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TRACE ELEMENTS IN ALBERTA CRUDE OILS - DATA SHEETS

The raw data for the 22 elements in 86 conventional crude oils and two crude oils from the Athabasca oil sand deposit studied by Hitchon *et al.* (1975) is found in the Appendix. Also included is information on the field, pool, stratigraphic unit, well name and location, source of the sample and method of production, and the date sampled. The "Remarks" section of the data sheet shows any unusual features of the sample. For each stratigraphic unit a map is provided showing the distribution of crude oils sampled from that unit. All sample numbers correspond with those published in Elofson *et al.* (1977).

ADDITIONAL ANALYTICAL INFORMATION

The Kinematic viscosity at 70°F (21.1°C) and 100°F (37.8°C), and the Ramsbottom carbon residue were determined on most of the crude oils reported in the Appendix, and this data is presented in Table 1 without further comment. In addition to the determination of V in the crude oils by neutron activation (see Appendix), tetravalent V (V^{4+}) was determined on many of the same samples by ESR techniques; this data is also shown in Table 1 and will be considered briefly elsewhere in this report.

Table 1. Viscosity, carbon residue and V^{4+}
for 88 Alberta crude oils

SAMPLE NUMBER	KINEMATIC VISCOSITY (Centistokes)		RAMSBOTTOM CARBON RESIDUE (wt %)	V^{4+} (BY ESR) ($\mu\text{g/g}$)
	70°F	100°F		
1	6.44	3.64	1.72	*
2	15.2	6.85	2.54	*
3	10.3	4.07	2.11	*
4	5.32	3.53	0.70	*
5	17.4	8.43	1.89	4.6
6	3.44	2.41	0.29	*
8	2.15	1.68	0.32	*
9	14.6	-	1.76	0.25
10	6.65	4.23	0.66	*
11	0.53	-	0.08	*
12	23.7	11.2	-	6.2
14	36.2	14.8	-	3.1
15	9.4	5.58	1.38	*
16	13.6	7.47	1.17	*
17	6.6	4.69	0.74	*
18	9.85	5.97	-	*
19	4.73	3.35	-	*
20	10.6	-	1.10	*
21	6.27	4.26	0.59	*
22	9.90	5.86	-	0.12
24	241	-	7.22	108
26	165	57.5	6.65	82
27	8.94	5.78	1.65	2.7
28	-	-	3.05	8.1
29	12.3	-	2.34	4.4
30	37.2	-	4.32	26
31	6.00	4.10	0.98	*
32	8.58	5.26	2.21	2.5
33	2.89	2.72	0.30	*
34	29.3	15.8	4.68	28.9
35	59.3	-	4.75	29.3
36	-	-	4.31	15.9
37	0.91	0.71	0.05	*
38	4.50	3.23	1.30	*
39	86.6	23.1	4.43	23.6

(Table continued)

Table 1. (continued)

SAMPLE NUMBER	KINEMATIC VISCOSITY (Centistokes)		RAMSBOTTOM CARBON RESIDUE (wt %)	V ⁴⁺ (BY ESR) (μg/g)
	70°F	100°F		
40	5.49	3.79	2.30	5.3
41	23.4	13.3	4.64	37.6
42	3.82	2.72	0.42	*
43	-	-	-	279
94	-	-	12.6	-
44	-	-	5.21	39.6
45	33.3	-	5.22	33.5
46	77.8	36.6	7.67	88.4
47	38.8	8.48	3.25	35.1
48	6.88	4.48	1.85	15.9
49	7.76	5.84	2.35	18.7
50	6.16	4.19	0.74	0.17
52	-	-	1.01	1.4
53	4.57	3.34	1.51	1.15
54	10.3	5.96	1.24	*
55	4.03	2.86	0.58	*
56	4.91	3.44	0.98	*
57	38.0	18.2	4.14	14.4
58	13.2	-	4.02	12.2
59	4980	1070	-	211
60	35.8	12.8	2.61	5.1
61	2.46	2.09	0.44	*
62	4.75	3.30	1.37	1.1
63	4.98	3.41	1.05	*
64	1040	270	7.62	61.2
65	3.20	2.38	0.58	*
66	23.9	11.2	3.83	9.1
67	8.98	5.73	3.76	26
68	6.99	4.61	2.01	1.1
69	4.36	3.07	1.48	1.3
70	6.88	4.48	0.98	0.2
71	-	-	-	*
72	1.60	1.28	0.30	*
73	-	-	3.13	8.3
74	11.0	6.77	3.94	6.3

(Table continued)

Table 1. (continued)

SAMPLE NUMBER	KINEMATIC VISCOSITY (Centistokes)		RAMSBOTTOM CARBON RESIDUE (wt %)	V ⁴⁺ (BY ESR) (μg/g)
	70°F	100°F		
75	22.2	8.88	1.56	*
76	8.71	4.91	1.97	*
77	4.12	2.99	0.86	*
78	3.56	2.57	0.79	*
79	6.49	4.25	1.54	0.75
80	3.04	2.24	0.46	*
81	20.8	11.3	5.01	5.4
82	-	-	-	-
83	6.22	4.19	2.65	1.1
84	4.29	2.93	1.19	*
85	5.56	3.76	1.17	*
86	4.12	2.70	0.66	*
87	42.4	15.1	3.63	5.2
88	-	-	-	7.4
89	11.7	5.61	4.38	0.9
90	4.86	3.37	1.92	*
91	9.31	5.05	2.33	*
93	5.34	3.71	2.51	0.98

Note: Samples in same order as in the Appendix

* = Below detection

- = Not determined

GEOCHEMISTRY OF TRACE ELEMENTS IN ALBERTA CRUDE OILS

INTRODUCTION

Based on a very comprehensive study, Deroo *et al.* (1977) distinguished three crude oil families in Alberta. The most important criteria are summarized next.

- Group 1 (Upper Cretaceous Colorado and post-Colorado reservoirs)
These crude oils have the lowest contents of sulphur and aromatic hydrocarbons, are richest in saturated hydrocarbons, acyclic alkanes and acyclic isoprenoids but have n-alkane distributions similar to those of Group 2. They can be distinguished from the Group 3 crude oils only by the lower proportion of cyclo-alkanes with one and two rings, and also on the basis of their benzothiophene content, which is small and limited to the lower carbon number range.
- Group 2 (Lower Cretaceous Mannville Group, Jurassic, Carboniferous and Upper Devonian Wabamun Group reservoirs)
These crude oils are distinguished clearly from those of the other two groups on the basis of gross composition and sulphur content. They are richest in sulphur and aromatics but are the poorest in saturated hydrocarbons, acyclic alkanes, and acyclic isoprenoids relative to n-alkanes. Their very high sulphur contents are attributed to large amounts of benzothiophenes and dibenzothiophenes, with the latter having a wide carbon number range (C_{21} to C_{30}).
- Group 3 (Upper Devonian Winterburn and Woodbend Groups and Beaverhill Lake Formation reservoirs)
These crude oils contain a higher proportion of thiophenic compounds than Group 1 and they have a smooth distribution over a wide range of carbon numbers. The crude oils from Beaverhill Lake Formation reservoirs form Group 3b and generally contain a smaller proportion of thiophenic compounds than those in Group 3a from the overlying Woodbend and Winterburn Groups.

Deroo *et al.* (1977) noted some exceptions to this classification but because their exceptions are not among the crude oils studied in this report no further comment will be made on any exceptions to their broad classification given above.

Preliminary appraisal of the trace element data for the 86 conventional crude oils analyzed indicated that when they were grouped into the three families distinguished by Deroo *et al.* (1977) some of the trace element distribution trends might be of value for classification purposes. It was also observed that the two crude oils from the Athabasca oil sand deposit (Nos. 43 and 94) exhibited trace element content characteristics

markedly different from the Group 2 crude oils, even though they appear to be correctly and unequivocally part of that group. The strict conditions under which all the conventional crude oils were collected in the field, and their preliminary laboratory treatment are outlined by Hitchon et al. (1975); following the preliminary laboratory treatment they were further cleaned-up, as described by Filby and Shah (1975). The two crude oils from the Athabasca oil sand deposit had first to be extracted from the oil sand in a Soxhlet extractor with benzene, centrifuged and evaporated down, and even with extreme care, the possibility of contamination from entrained fine-grained mineral matter cannot be ruled out. For this reason, the two crude oils from oil sands are treated separately from the conventional crude oils in this report.

On the basis of the report of Deroo et al. (1977) the conventional crude oils analyzed in this study may be classified as follows:

GROUP 1:

- U. Cretaceous, post-Colorado Supergroup, Belly River Fm. (Nos. 1, 2, 3 and 4)
- U. Cretaceous, U. Colorado Gp., Cardium Fm. (Nos. 5, 6, 8 and 9)
- U. Cretaceous, U. Colorado Gp., other (Nos. 10, 11 and 12)
- U. Cretaceous, L. Colorado Gp., Viking Fm. (Nos. 14, 15, 16, 17, 18, 19, 20, 21 and 22)

GROUP 2:

- U. Cretaceous, L. Colorado Gp., Basal Colorado Ss. (No. 24)
- L. Cretaceous, Mannville Gp., (Nos. 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40 and 41)
- Jurassic (Nos. 44, 45 and 46)
- Carboniferous (Nos. 54, 56, 57, 58 and 59)

GROUP 3:

- U. Devonian, Wabamun Gp. (Nos. 60 and 61)
- U. Devonian, Winterburn Gp. (Nos. 62, 63, 64, 65, 66 and 67)
- U. Devonian, Woodbend Gp. (Nos. 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81 and 82)
- U. Devonian, Beaverhill Lake and Slave Point Fms. (Nos. 83, 84, 85 and 86)
- M. Devonian, Elk Point Gp. (Nos. 87, 88, 89, 90 and 91)
- Granite Wash (No. 93)

The total number of samples in Groups 1, 2 and 3 are 20, 25 and 33, respectively. For some of the samples, the group classification in this report differs from that of Deroo et al. (1977). They did not analyze crude oils from the Basal Colorado sandstone, but preliminary and subsequent study shows, quite clearly, that sample No. 24 is correctly classified with Group 2 and not Group 1. All samples from Carboniferous and Upper Devonian Wabamun Group reservoirs studied by Deroo et al. (1977) were from situations close to, or immediately underlying, the pre-Cretaceous unconformity, and hence were classified under Group 2. In

this study, two samples from Carboniferous strata (Nos. 52 and 53), and two from the U. Devonian Wabamun Group (Nos. 60 and 61) were situated far below the pre-Cretaceous unconformity. In the absence of definitive data on the hydrocarbon content of samples 52 and 53 they were omitted from this study, and samples 60 and 61 were included, as it turned out correctly, in Group 3. The Turner Valley field lies in the Disturbed Belt and was sampled from both the Lower Cretaceous Blairmore Group and Carboniferous reservoirs (samples 42 and 55, respectively). Because of the structural separation and the fact that both crude oils showed trace element characteristics unlike those of the other Group 2 crude oils they were not used in this study. No Triassic crude oils were analyzed by Deroo *et al.* (1977), and because samples 47, 48, 49 and 50 showed ambiguous trace element characteristics they also were not used in this study. Where pertinent, an attempt is made to classify those crude oils excluded from this study.

Hitchon *et al.* (1975) concluded that for their total population of 88 crude oils, eleven trace elements were controlled by maturation processes. It is therefore important to know, for at least these eleven trace elements, whether the grouping of crude oils according to the distinguishing criteria of Deroo *et al.* (1977) will also reflect a maturation trend. In the absence of data on the maximum temperature to which each reservoir has been subjected the present reservoir temperature can serve as a guide to the degree of thermal maturation. Based on published data from the Alberta Energy Resources Conservation Board the following general statistics can be calculated:

Present reservoir temperature (°C)

	Minimum	Median	Average	Maximum	Range
Group 1 crude oil reservoirs	36	59	56	89	53
Group 2 crude oil reservoirs	24	64	57	92	68
Group 3 crude oil reservoirs	34	66	70	110	76

These statistics suggest that although, on average, the Group 3 crude oil reservoirs are 15°C hotter than crude oil reservoirs in the two other groups, and there is an increase in both the range (23°C) and maximum temperature (21°C) between Group 1 and Group 3 reservoirs, any significant differences in trace element characteristics between the three groups of crude oils can be considered in terms of differences in source or of different processes operative after the crude oils were accumulated, bearing in mind that both source differences and processes can be affected by temperature differences. In simpler terms, the range in temperature of the reservoirs within each group is so large that the trace element characteristics within each group should exhibit the maturation trends demonstrated by Hitchon *et al.* (1975), but differences

in the trace element characteristics among the groups should reflect processes (other than maturation) or source differences.

As noted in the Introduction, Hitchon et al. (1975), thought that the control exerted by maturation processes on the eleven trace elements they studied may simply reflect maturation of the asphaltene fraction of the crude oils. As indicated in the previous paragraph, the temperature range of the reservoirs within each group of crude oils is so large that each group should exhibit a similar suite of maturation criteria, including similar statistics for the content of asphaltenes within each group. Based on the percent asphaltenes for these crude oils published by Eloffson et al. (1977) the following general statistics can be calculated:

Asphaltene content (% w/w)					
	Number of samples	Number of samples with no detectable asphaltenes (%)	Median (all samples)	Average (all samples)	Maximum
Group 1 crude oils	20	11 (55)	0.0	0.34	2.8
Group 2 crude oils	25	2 (8)	2.6	3.23	15.5
Group 3 crude oils	32	3 (9)	0.46	1.83	14.6

These statistics show that Group 1 crude oils are generally deficient in asphaltenes, in contrast to Groups 2 and 3, which have similar high average contents of asphaltenes and a much wider range, by almost an order of magnitude compared to those in Group 1. This suggests that differences in trace element characteristics between the groups, especially between Groups 2 and 3, should reflect source differences or differences in processes operative after the crude oils accumulated.

ANALYSIS OF VARIANCE

Introduction

Analysis of variance (ANOVA) is a univariate statistical technique that compares the variance of a variable (trace element content in this study) within each population (Groups 1, 2 and 3, as designated previously) with the variance between the populations to determine if the distribution of that variable is significantly different in one or more of the populations. The level of significance is obtained from a statistical term called the F statistic. Because ANOVA is a univariate method, it considers only one variable at a time, but is of value in such a study as this because it enables the selection, through examination of the F statistic, of only those variables which are statistically significant at a chosen level, and which can then be examined by a multivariate method if so desired.

Dummy Values

A persistent problem in statistical analysis is the lack of complete sets of variables for all samples studied. Among the reasons for incomplete sets of variables are non-determination of some variables in some samples for a variety of reasons, and variables below detection limits; the latter is especially pertinent for geochemical data. As far as the authors are aware, there are no rigid criteria which can be followed respecting the substitution of dummy values to fill "data holes", and much depends on the experience of the operator. In the past, the senior author has either limited statistical analysis to complete data sets where a large number of samples were available (Hitchon and Horn, 1974), or arbitrarily substituted a value of one tenth the detection limit where the number of samples was more limited and less than ten percent of the samples for any variable required the substitution of a dummy value (Hitchon et al., 1971).

In the present study, the problem of dummy values was approached in two ways. First, for crude oils from the same stratigraphic unit where the regional distribution of samples was relatively close, an isoconcentration map for the pertinent trace element was drawn and the best value based on concentration gradients was used as a dummy value. Second, where the sample was relatively isolated with respect to other samples from the same stratigraphic unit, an arbitrary value of one tenth the detection limit was substituted for the missing data. A further general restriction placed on the selection of samples for statistical analysis was that no more than one dummy value could be used in each sample; this criterion was relaxed for 12 of the samples studied in which an additional dummy value was allowed provided the other dummy value was from a pool in the same field or from an immediately contiguous field in the same stratigraphic unit. The only exception to this last restriction was the sample from the Rundle Group at Turner Valley, where four dummy values were used because of the desire to include this sample in the ungrouped population. As a result of all the above restrictions, 75 crude oils were subject to statistical analysis, with eleven variables each.

Logarithmic Transforms

One of the restrictions to the use of ANOVA is that the variable in each population be normally distributed. Because many geochemical data approximate a lognormal distribution, the eleven variables were tested for normality, within groups, using both the raw data and their logarithmic transforms. Ten exhibited a lognormal distribution and Mn a normal distribution, and it is these data which were used in the ANOVA, the results of which are shown in Figure 1.

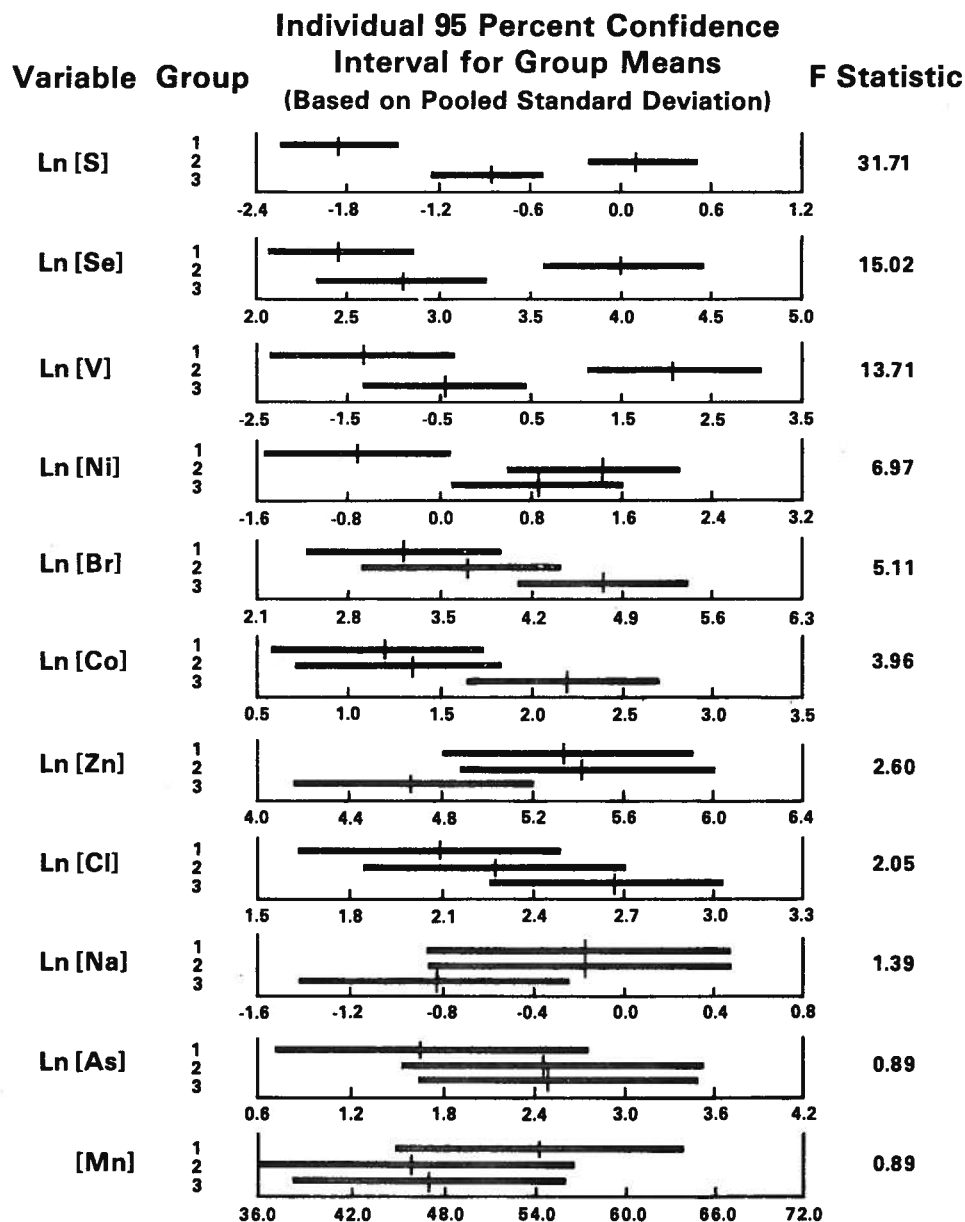


Figure 1. Bar charts showing 95 percent confidence interval, based on ANOVA for Alberta crude oils grouped according to the crude oil families distinguished by Deroo et al. (1977).

Results

For the data analyzed, values of the F statistic greater than about 2.5 are significant at the 90 percent level. Thus, for the logarithmic transforms of S, Se, V, Ni, Br, Co and Zn we can be more than 90 percent certain that there is a difference in the content of these elements in at least one of the groups. The bar charts in Figure 1 illustrate this point. It must be emphasized, however, that because three populations were studied, not all of these seven elements are, a priori, discriminators between the three crude oil families; only a multivariate statistical technique such as discriminant function analysis is capable of solving the intergroup correlation problem.

ALKALI METALS - SODIUM, RUBIDIUM AND CESIUM

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Na (ppm)	20	0.046	0.73	1.54	13.0
Rb (ppb)	3	1.870	5.43	24.9	67.5
Cs (ppb)	12	0.310	0.88	1.05	2.27
Group 2 crude oils (n=25)					
Na (ppm)	22	0.018	0.83	2.94	19.3
Rb (ppb)	2	28.1	43.0	43.0	57.8
Cs (ppb)	13	0.32	1.395	1.80	9.03
Group 3 crude oils (n=33)					
Na (ppm)	33	0.0174	0.632	4.61	64.7
Rb (ppb)	2	15.58	37.8	37.8	60.0
Cs (ppb)	13	0.641	1.71	3.78	19.45

Geochemistry

Effectively all samples contained Na, although the concentration range was wide (0.0174 to 64.7 ppm). Rubidium was detected in 9 percent of the samples and Cs in nearly 50 percent of the samples. In every sample in which all three alkali metals were detected, the order was always Na >> Rb > Cs, with the general proportions being 1000:10:1, respectively (in ppb). In 24 of the fields and pools, the co-produced formation water had been analyzed previously by Hitchon et al. (1971), including the determination of Na and Rb. Even if all the Rb in the associated crude oils had originated from entrained formation water, calculations show that it would be below detection in 17 of the crude oils and close to detection in the remainder. Therefore, the Rb contents reported in

the crude oils are not due to contamination by entrained formation water. Hitchon *et al.* (1975) have also shown that Na is unrelated to Cl, and therefore concluded that their sample preparation technique was effective in removing entrained formation water. With respect to relations of the alkali metals among the three groups of crude oils, although there are systematic changes in the average and maximum contents of both Na and Cs from Group 1 to Group 3 the ranges of concentration between the groups are so similar that neither of these alkali metals can be used to distinguish the crude oil groups. There are insufficient determinations of Rb to make a meaningful comment. The low value of the F-statistic for Na in the ANOVA confirms this observation.

Based on experiments with a Tertiary crude oil from California, Filby (1975) showed that 92 percent of the Na in that oil is present as an oil-soluble compound that is also water soluble or is hydrolyzed, perhaps as the Na salt of a petroleum acid. For the same 24 fields and pools cited in the previous paragraph, the pH of the co-produced formation water was determined in the field, and therefore as close to reservoir temperature as possible and with minimal loss of dissolved gases. The data on pH of the co-produced formation water and Na in the associated crude oil may be grouped as follows:

Number of samples	Formation water	Na in crude oil (ppm)		
		Minimum	Average	Maximum
10	pH > 7.0	0.13	4.1	19.3
14	pH < 7.0	0.02	5.8	57.8

If the Na in crude oils occurs as the Na salt of a petroleum acid then, in general, alkaline formation waters (pH > 7.0) should be relatively enriched in these Na organic salts, which would preferentially pass into the aqueous phase, and the crude oil relatively depleted. The grouped data above seem to support the suggestion of Filby (1975). Work carried out some years ago at the Alberta Research Council on the surface tension of formation waters showed a wide range in this property; formation waters with very low surface tensions and correspondingly high pH values also contained the largest amounts of salts of petroleum acids. Figure 2 shows the results of a portion of this work on surface tension in formation waters, with the data grouped on the basis of the study of Deroo *et al.* (1977). There is a wide range in surface tension within each group although it is not possible to distinguish the three groups on the basis of surface tension. The genetic relations among surface tension, pH and surfactants (such as Na salts of petroleum acids) in formation waters, and the content and form of bonding of Na in their associated crude oils justifies considerably more study. The results of such a

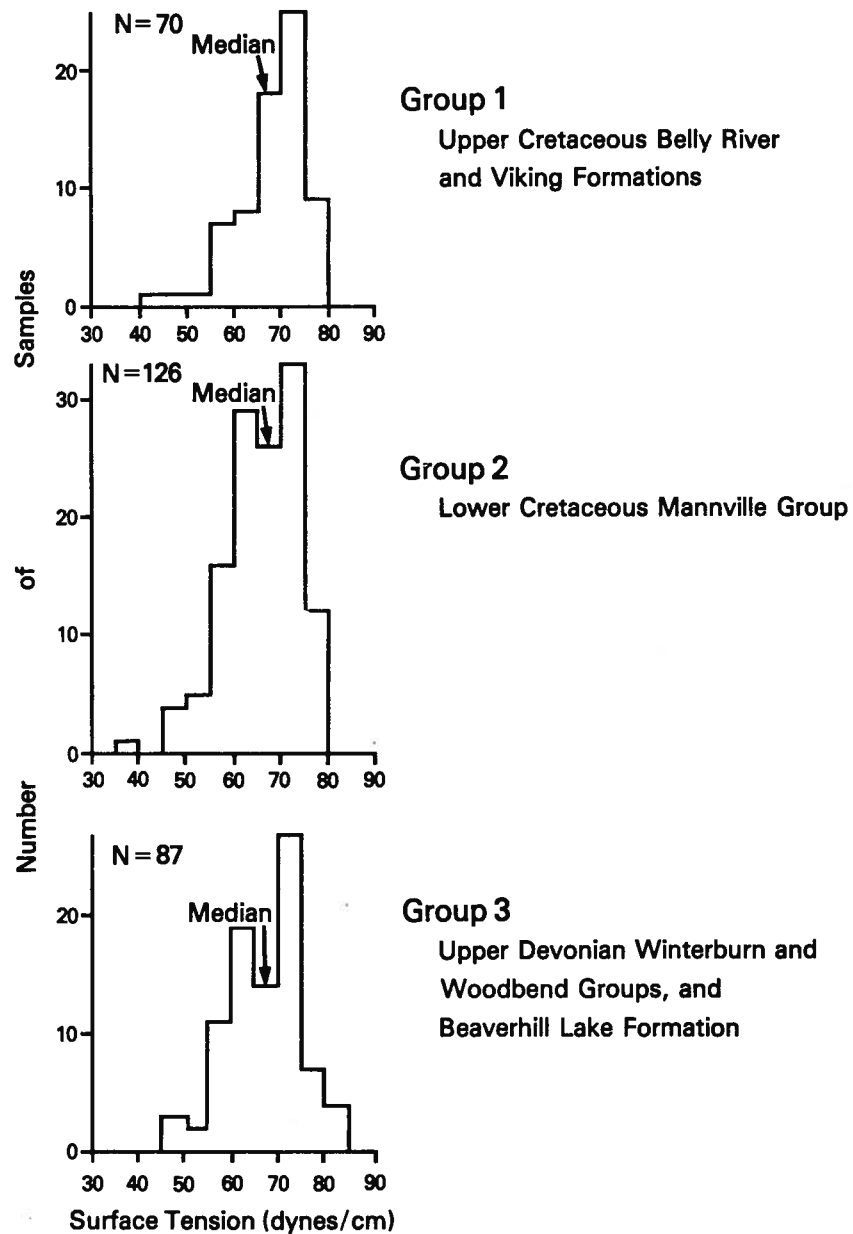


Figure 2. Histograms of frequency distribution of surface tension in formation waters from Alberta grouped according to the crude oil families distinguished by Deroo *et al.* (1977).

study have the potential of being of value to explorationists through the use of the salts of petroleum acids in formation waters as indicators for crude oil occurrence.

GOLD

Gold was detected in only three conventional crude oils (samples 12, 73 and 74) at levels of 0.078, 0.149 and 0.204 ppb, respectively. These crude oils appear to have no common characteristic and so this data on gold in Alberta crude oils is presented without further comment.

ZINC AND MERCURY

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Zn (ppb)	20	11.51	270	272	669.7
Hg (ppb)	11	1.60	8.05	32.6	202.2
Group 2 crude oils (n=25)					
Zn (ppb)	24	17.5	401	456	1277.0
Hg (ppb)	9	1.93	6.69	27.6	138.3
Group 3 crude oils (n=33)					
Zn (ppb)	28	13.40	140	573	5921.0
Hg (ppb)	15	1.34	6.57	85.6	398.6

Geochemistry

Zinc was detected in more than 90 percent of the crude oils and Hg in about 45 percent of the samples. Thirty-seven crude oils contained detectable amounts of both Zn and Hg, and in only three (Nos. 19, 31 and 77) was Hg > Zn; these three appear to have no other common feature, though it can be noted that sample 31 from the Lower Cretaceous Basal Quartz B pool at Niton was singled out by Deroo *et al.* (1977) as being unique in having a large content of heavy n-alkanes, which is characteristic of crude oils derived from nonmarine organic matter. The Zn/Hg ratio ranged from 0.127 to 406, with the average proportion of Zn:Hg being about 8:1. With respect to the relations of Zn and Hg among the three groups of crude oils, although there are systematic changes in the average and maximum contents of Zn from Group 1 to Group 3, and the statistics for Hg show that Groups 1 and 2 are similar, with Group 3 crude oils containing on average more than twice as much Hg as the first two groups, the ranges of concentration for both elements do not appear to show sufficiently significant differences to allow the use of Zn and Hg to distinguish the three crude oil groups. A value of 2.6 for the F

statistic for Zn in the ANOVA indicates that Zn may be marginally useful in crude oil correlation, however; only a multivariate analysis can confirm this indication. Within each group the Zn/Hg ratios exhibit similar ranges, but as can be expected from the above general statistics for the individual elements, the average Zn/Hg ratio for Groups 1 and 3 are similar (about 50), with Group 2 crude oils having a much higher average Zn/Hg ratio (130). Any suggestion that this higher Zn/Hg ratio in the extensively biodegraded crude oils of Group 2 is related to the biodegradation, can only be regarded as speculative at this time.

Hitchon (1977) has discussed the geochemical links between oil fields and ore deposits in sedimentary rocks with special reference to Alberta, and drew an analogy between the features of high salinity and high metal content of geothermal brines and the deeper, hotter, more saline formation waters from Alberta, which have leached evaporites to produce some of the solutes, possibly assisted by membrane filtration, and shales to produce the enhanced content of metals. A further analogy was developed between the generation and leaching of hydrocarbons from shale source rocks, and their subsequent migration and accumulation as oil fields, and the leaching of shales by hot, saline formation waters, with their subsequent migration and accumulation as ore deposits. This analogy is very well illustrated by the statistics presented in Table 2, in which data on Zn and Cl in formation waters from Alberta (Hitchon et al. (1971), Zn and Hg in crude oils (this report) and Zn in some Alberta shales (Hitchon, in press) is grouped according to the crude oil families distinguished by Deroo et al. (1977). In broad terms, the statistics in Table 2 may be summarized as follows:

	Group 1	Group 2	Group 3
Zn in shales	High	Intermediate	Low
Cl in formation waters	Low	Intermediate	High
Zn in formation waters	Low	Low	High
Zn in crude oils	Low	Intermediate	High
Hg in crude oils	Low	Low	High

This summary supports the thesis that the Zn in crude oils, and probably also Hg, as well as Zn in formation waters, have originated from shales which yielded the crude oil hydrocarbons through the specific action of hot, chloride-rich formation waters, with the consequent depletion of those shales in Zn (and probably also Hg).

Table 2. Statistics for Zn and Cl in formation waters, Zn and Hg in crude oils, and Zn in shales, Alberta, grouped according to the crude oil families distinguished by Deroo et al. (1977)

	GROUP 1	GROUP 2	GROUP 3
	U. CRETACEOUS	L. CRETACEOUS, JURASSIC AND CARBONIFEROUS	U. AND M. DEVONIAN
FORMATION WATERS			
No. of samples	15	25	34
Zn (mg/l) min.	0.00	0.03	0.05
avg.	0.36	0.32	1.43
max.	3.05	3.05	27.5
Cl (mg/l) min.	798	320	15 800
avg.	12 200	25 700	69 700
max.	38 200	95 800	172 000
CRUDE OILS			
No. of samples	20	24	28
Zn (ppb) min.	11.51	17.5	13.40
avg.	272	456	573
max.	669.7	1277.0	5921.0
No. of samples	11	9	15
Hg (ppb) min.	1.60	1.73	1.34
avg.	32.6	27.6	85.6
max.	202.2	138.3	398.6
SHALES			
No. of samples	7	12	7
Zn (ppm) min.	99	65	19
avg.	270	132	61
max.	943	261	100

SCANDIUM, EUROPIUM AND GALLIUM

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Sc (ppb)	8	0.013	0.13	0.126	0.241
Eu (ppb)	13	0.073	0.305	0.270	0.641
Ga (ppb)	1	-	1.13	-	-
Group 2 crude oils (n=25)					
Sc (ppb)	14	0.020	0.16	0.185	0.764
Eu (ppb)	16	0.050	0.40	0.373	0.661
Ga (ppb)	2	5.7	8.35	8.35	11.0
Group 3 crude oils (n=33)					
Sc (ppb)	23	0.014	0.094	0.090	0.178
Eu (ppb)	15	0.091	0.255	0.281	0.604
Ga (ppb)	13	0.07	15.82	63.4	445.0

Geochemistry

Scandium and Eu were each detected in nearly 60 percent of the crude oils, and Ga was detected in 20 percent of the samples. Of the 86 conventional crude oils analyzed, only 24 reported both Sc and Eu, in 22 of which Sc > Eu (Sc/Eu ratio ranged from 0.035 to 0.774). The similarities between the statistics for Sc and Eu among the three groups of crude oils means that these two elements cannot be used to distinguish between the groups. It is possible that the determination Al in crude oils could be used to indicate the degree of contamination by entrained clay minerals, and in the absence of data on the Al content, Ga contents might be substituted as indicators of clay mineral contamination. One would expect the most viscous crude oils, which are the most difficult to clean-up, to contain the highest contents of Ga (or Al, if that element was determined). If the viscosity data in Table 1 are grouped and treated statistically like the trace element data no relation is found between the statistical characteristics of viscosity and Ga. This finding is equivocal, but could be interpreted in terms of satisfactory procedures for the elimination of clay mineral contamination, and that Ga occurs only in the form of organic associations. This latter suggestion is supported by recent studies by the junior author.

ARSENIC AND ANTIMONY

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
As (ppb)	15	0.610	3.694	11.4	56.72
Sb (ppb)	6	0.10	0.25	0.343	0.810
Group 2 crude oils (n=25)					
As (ppb)	19	0.020	9.9	196	1988.0
Sb (ppb)	6	0.530	2.4	5.42	22.8
Group 3 crude oils (n=33)					
As (ppb)	28	0.63	12.8	104	1219.0
Sb (ppb)	9	0.190	2.55	6.15	34.8

Geochemistry

Arsenic was detected in 80 percent of the conventional crude oils, and Sb in 25 percent. Only 19 samples (22 percent) reported both As and Sb, which exhibited a random distribution when plotted together (correlation coefficient < 0.001). With respect to the relations of As and Sb among the three groups of crude oils, the Group 1 crude oils are distinct in having a much narrower range in the content of both elements than Groups 2 and 3, with an average content of As an order of magnitude less, and Sb about one fifteenth that of the other groups. Despite this, the ANOVA shows that As cannot be used in crude oil correlation. Study of As and Sb in individual samples may still be of interest, however; for example, sample No. 24 from the Basal Colorado sandstone, with As 79.8 ppb and Sb 1.07 ppb, is clearly a Group 2 crude oil, even though it occurs in a reservoir classified by Deroo *et al.* (1977) as belonging to Group 1. In this instance, migration of the crude oil from the underlying Mannville Group is strongly indicated. Group 2 crude oils cannot be distinguished, unequivocally, from Group 3 crude oils even though their average content of As is twice that of those in Group 3.

Filby (1975) has suggested that in crude oils, As and Sb appear to be present partly as low-molecular-weight compounds such as alkyl or aryl arsines and stibines, and that in the case of Sb, these compounds are strongly associated with the asphaltenes. As noted in the introduction to this section of the report, Group 1 crude oils are generally deficient in asphaltenes, in contrast to Groups 2 and 3, which have similar high average contents of asphaltenes and a much wider range, by almost an order of magnitude compared to those in Group 1. It seems likely, therefore, that the differences in the statistical distribution of As, and particularly Sb, between the crude oil groups is directly related to

their differences in asphaltene content, and also supports the suggestion of Filby (1975) on the occurrence and association of these elements in crude oils. Recent work by the junior author on As in oil sand bitumen supports the theory of As occurring in small molecules; Sb behaves quite differently from As, however. In the study of Hitchon *et al.* (1975) As represented an essentially unique factor, with a low (0.34) positive loading for Br; bearing in mind the work of Filby (1975), there is no obvious explanation for the weak association of As and Br in the Alberta crude oils, other than the speculation that Br also occurs in small organic molecules.

Evans *et al.* (1971) and Milner *et al.* (1977) have shown that the under-saturated oil systems of the Upper Devonian Beaverhill Lake Formation of west-central Alberta and the Middle Devonian Keg River Formation of north-western Alberta have both been subjected to gas deasphalting. The former comprise the Group 3b crude oils of Deroo *et al.* (1977). Samples from this study which have been subjected to gas deasphalting include Nos. 84, 85, 86 and 87. Although some of these have lower contents of asphaltenes and As (Sb was not detected) than both the average and median for all Group 3 crude oils, the small population precludes drawing a statistically valid conclusion respecting the effect of gas deasphalting on As and Sb in crude oils.

VANADIUM

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
V (ppm)	20	0.003	0.21	0.834	6.553
Group 2 crude oils (n=25)					
V (ppm)	23	0.068	20.88	28.1	138.8
Group 3 crude oils (n=33)					
V (ppm)	32	0.014	1.0	6.28	52.67

Geochemistry

Effectively all conventional crude oils contained detectable amounts of V, with a total range in content from 0.003 to 138.8 ppm. All groups of crude oils contained some samples with very low contents of V; the percentage of crude oils within each group with less than 1 ppm V were 85, 9 and 50, for Groups 1, 2 and 3, respectively. Among the three groups, the smallest median, average and maximum contents of V are found in Group 1, and the largest median, average and maximum values in Group 2; as a consequence, Group 3 exhibits statistical trends intermediate between Groups 1 and 2. The high value (13.71) of the F statistic in the ANOVA strongly suggests that V is of value in distinguishing crude

oil families. There is a high correlation between the contents of V and asphaltenes in Groups 1 and 2, with lower correlation for Group 3 (Table 3); lower correlation coefficients but similar relations exist between V and API gravity (Table 3).

Table 3. Correlation among V, asphaltenes, API gravity and V^{4+} for Alberta crude oils

Crude oil group	Correlation coefficient (r^2) between		
	V and % asphaltenes	V and API gravity	V and V^{4+}
1	0.87	0.59	0.60
2	0.86	0.68	0.98
3	0.56	0.16	0.75
All crude oils	0.66	0.52	0.96

The relation between V and asphaltenes is shown in Figure 3; both the general distribution charts and histograms are based on numerical data presented elsewhere in this report. Group 1 crude oils are characterized by low contents of both asphaltenes and V. As noted in the introduction to this section of the report, the frequency distribution of asphaltene content between Groups 2 and 3 is similar (as can be seen in figure 3), but their frequency distribution in V content is different. As suggested earlier, this would imply either different processes (other than maturation) operating after accumulation of the crude oils, or source differences. Bearing in mind the small number of samples involved, the removal of crude oils from reservoirs subjected to gas deasphalting does little to alter the profile of the frequency distribution diagram for V in the Group 3 crude oils (figure 3). The crude oils in Group 2 are known to be extensively biodegraded and this might account for the generally higher contents of V in these crude oils. Vanadium was determined in the Alberta shales studied by Hitchon (in press), and if the contents of V are grouped according to the crude oil families distinguished by Deroo *et al.* (1977) the statistics may be summarized as follows:

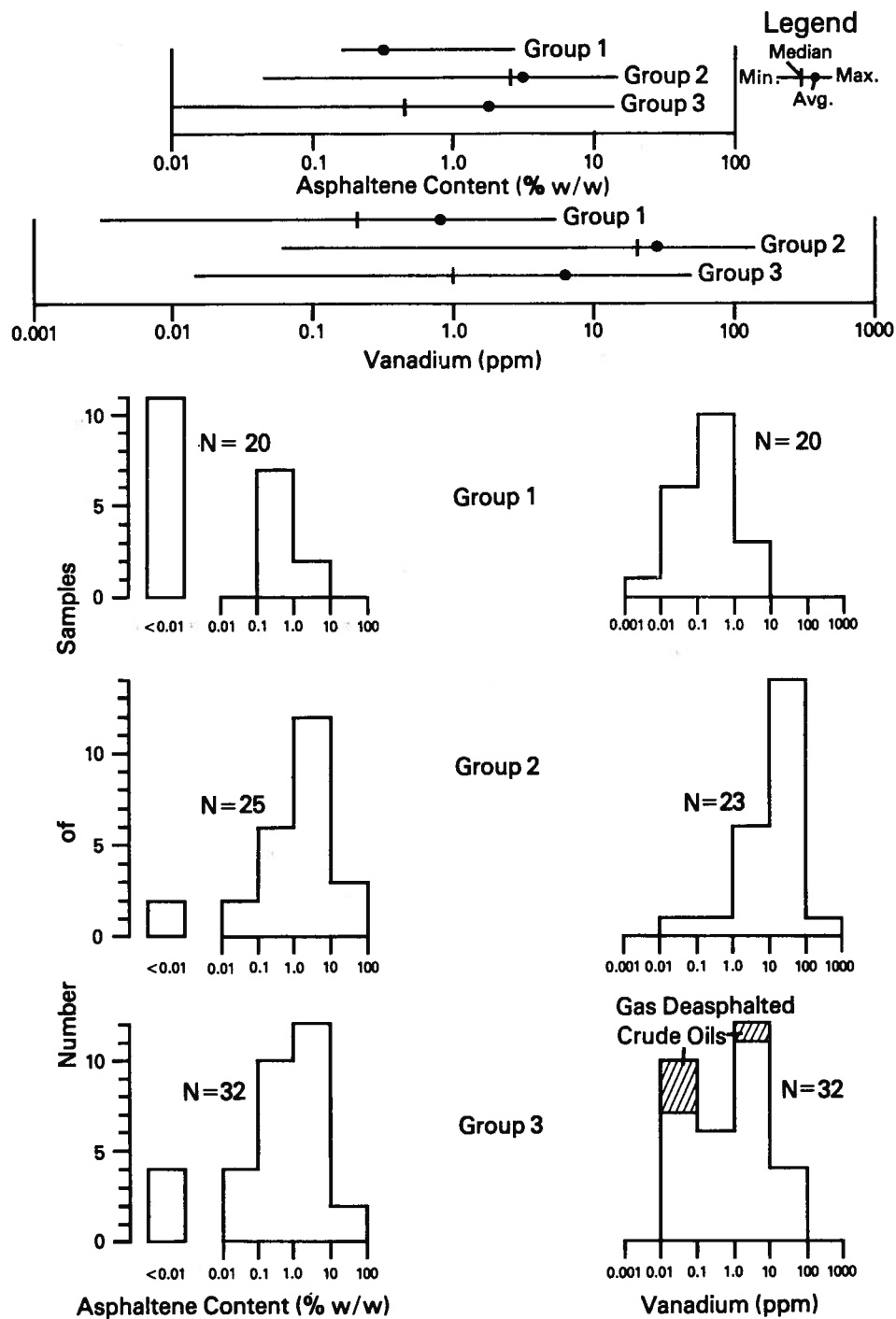


Figure 3. Statistical distribution and frequency histograms for asphaltenes and V in Alberta crude oils grouped according to the crude oil families distinguished by Deroo *et al.* (1977).

	Group 1 (U. Cretaceous)	Group 2 (L. Cretaceous, Jurassic and Carboniferous)	Group 3 (U. and M. Devonian)
No. of samples	7	12	7
V (ppm) min.	46	55	35
median	87	75	71
avg.	86	116	68
max.	127	421	101

This information does not preclude a source difference but extreme caution must be used in any extrapolation from such a small and varied population. If the collection of further data supports the suggestion that the higher content of V in Group 2 crude oils is a result of higher V contents of the source sediments, then the differences in V content of the Group 1 and 3 crude oils may be similarly related to source differences, probably coupled with different degrees of maturation of the source sediments. In all cases it will be necessary to determine the form (inorganic and organic) of V in the shales and to obtain a high correlation between V in the crude oils and V in extracted organic matter from the presumed source sediments. Such a study would be of considerable significance for the explorationist.

On the basis of its content of As and Sb, crude oil No. 24 from the Basal Colorado sandstone at Cessford was classified with Group 2; a V content of 59.82 ppm adds support to this classification. Two crude oils were sampled from the Turner Valley field, No. 42 from the Lower Cretaceous Blairmore Group (0.017 ppm V) and No. 55 from the Carboniferous Turner Valley Formation (0.028 ppm V). Both values fall outside the range for other Group 2 crude oils and this fact, plus the structural separation of the Turner Valley field from other Group 2 reservoirs in the Alberta plains, suggests that these two crude oils may have a common origin that is different from other Group 2 crude oils. The two crude oils from the Carboniferous reservoir at Eaglesham (samples 52 and 53) have V contents more closely related to those from Turner Valley than the rest of the Group 2 crude oils. It seems likely that a detailed study of Carboniferous crude oils might show two distinct groups, those immediately adjacent to the pre-Cretaceous unconformity and having affinities with Group 2 crude oils, and a second group with a source within Carboniferous rocks, stratigraphically, and sometimes structurally, separate and unrelated to the pre-Cretaceous unconformity. Deroo *et al.* (1977) did not analyze crude oils from Triassic reservoirs, but the stratigraphic position of samples 47, 48 and 49 is close to the pre-Cretaceous unconformity with only a thin intervening cover of Jurassic strata; all have V contents consistent with Group 2 crude oils. Crude

oil No. 50, with a V content of 0.185 ppm, also lies at the Triassic-Jurassic boundary but is overlain by more than 75 m of dark L. Jurassic Fernie shales and a local source cannot be ruled out.

Because essentially all V in crude oils occurs in the tetravalent form (V^{4+}) it is not surprising that there is a generally high correlation between the total V content as determined by neutron activation and the content of tetravalent V as determined by ESR techniques; such a correlation is without geochemical significance, however. The data in Table 3 show that this is true whether the crude oils are all considered together, or are divided into the three groups distinguished by Deroo et al. (1977).

SULPHUR AND SELENIUM

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
S (%)	20	0.040	0.135	0.214	1.244
Se (ppb)	18	3.74	8.96	12.9	48.1
Group 2 crude oils (n=25)					
S (%)	25	0.04	1.391	1.31	3.355
Se (ppb)	19	5.26	55.22	78.7	252.3
Group 3 crude oils (n=33)					
S (%)	33	0.101	0.443	0.717	2.991
Se (ppb)	16	4.0	14.4	22.3	73.6

Geochemistry

All crude oils analyzed contained S, and Se was detected in 20 percent of the samples. As noted by Deroo et al. (1977) the biodegraded crude oils of Group 2 are characteristically rich in S, although all groups contain some crude oils with both high and low contents of S. The detrimental effect of biodegradation is well illustrated when Groups 1 and 2 are compared; both are from clastic source facies. The higher median and average values for S in Group 3, compared to Group 1, are most likely a reflection of the higher S in crude oils from carbonate-evaporite source facies (Evans et al., 1971). Hitchon et al. (1975) showed a high correlation between S and Se and therefore, as might be expected, all the above features can be demonstrated also for Se. The high inter-correlation among S, Se and V (Hitchon et al., 1975) and the fact that V has been shown to be a useful tool in crude oil correlation, means that S and Se should also be of value for correlating crude oils. For S, a complete set of data is available and the importance of this

element for classification of crude oils into families can be demonstrated quite clearly by the high value of the F statistic in the ANOVA. Thus even on the basis of the very simple statistical approach used in this report its importance is apparent. Selenium also has a high value of the F statistic in the ANOVA, indicating it also is of value in crude oil correlation.

Figure 4 shows the range, median and average values for S in each of the three crude oil groups, together with the concentration range (thick bar) for 80 percent of the samples distributed about the mean values. For Groups 1 and 2 there is no overlap of S contents for 80 percent of the samples, and Groups 2 and 3 are reasonably distinct, with some overlap for Group 2 crude oils which have below average contents of S and Group 3 crude oils which have above average contents of S. In most cases consideration of the stratigraphic situation will allow correct classification. For example, with one exception (sample No. 67 from the Arcs Member, Winterburn Group at Youngstown), all Group 3 crude oils with above average contents of S are from carbonate reefs or carbonate structural-stratigraphic traps far below the pre-Cretaceous unconformity in positions which make it most unlikely that the crude oils came from the Mannville Group. At Youngstown the stratigraphic position (95 m below the pre-Cretaceous unconformity) and hydraulic regime might indicate a Mannville Group source for the crude oil, but evidence based on only one trace element is not conclusive. Clearly, a multivariate trace element approach is needed for this case. Another example is sample No. 24 which is again definitely classified with the Group 2, as are the three Triassic crude oils, Nos. 47, 48 and 49. Triassic sample No. 50 is indeterminate and, as for V, a local source cannot be ruled out.

CHROMIUM

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Cr (ppb)	7	3.71	7.80	8.39	15.51
Group 2 crude oils (n=25)					
Cr (ppb)	14	4.66	24.5	41.6	105.8
Group 3 crude oils (n=33)					
Cr (ppb)	16	3.63	14.8	32.6	205.8

Geochemistry

Just over 45 percent of the crude oils contained detectable amounts of Cr. Group 1 crude oils exhibited the lowest median and average values as well as the narrowest range in Cr content. Crude oils from Groups 2 and 3 have effectively similar median and average contents of Cr, and

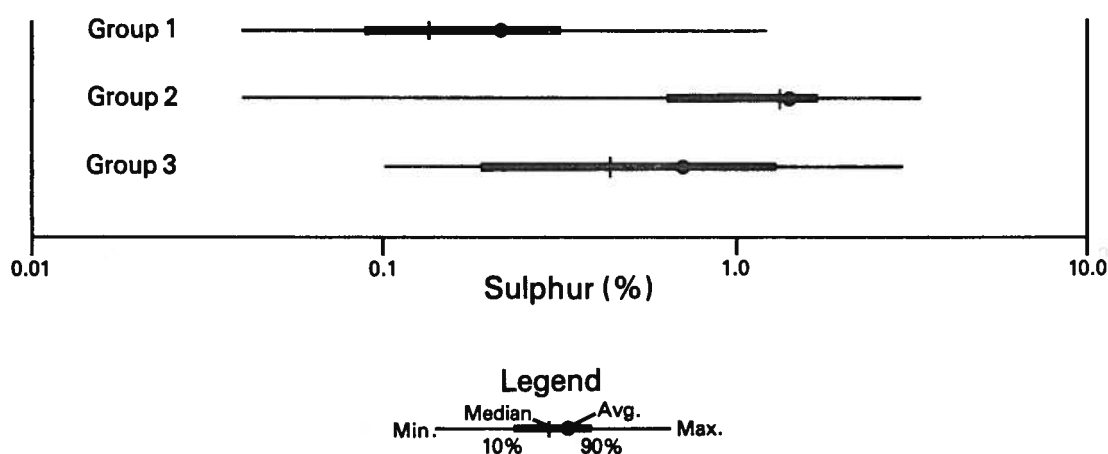


Figure 4. Statistical distribution of S in Alberta crude oils grouped according to the crude oil families distinguished by Deroo et al. (1977). The thick bar represents the range of 80 percent of the samples distributed about the mean.

maximum amounts an order of magnitude greater than those from Group 1. The fact that more than half the crude oils analyzed showed no detectable Cr means that this element is of minimal value in classifying crude oils. Hitchon et al. (1975) found a high correlation among Cr, V and Ni in their study of 20 selected crude oils and this suggests that if the detection limit can be lowered that Cr could be of use in classifying crude oils. This contention is supported by the fact that sample No. 24, with 95.2 ppb Cr has clear affinities with the Group 2 crude oils, as probably do samples 47, 48 and 49 from Triassic rocks.

HALOGENS - CHLORINE, BROMINE AND IODINE

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Cl (ppm)	20	2.16	6.91	9.48	38.74
Br (ppb)	20	5.641	19.2	32.3	127.4
I (ppb)	11	7.771	293.5	410	1364.0
Group 2 crude oils (n=25)					
Cl (ppm)	25	0.634	8.992	24.1	230.3
Br (ppb)	20	1.75	37.3	477	7529.0
I (ppb)	14	8.735	72.6	720	9005.0
Group 3 crude oils (n=33)					
Cl (ppm)	33	0.50	13.35	77.5	1014.0
Br (ppb)	32	4.27	87.5	923	12 470.0
I (ppb)	20	10.46	316	1077	7 396.0

Geochemistry

All crude oils contained detectable amounts of Cl, nearly 95 percent reported Br, and 60 percent showed I above detection limits. The values for the F statistic in the ANOVA indicate that Br, but not Cl, is of value in crude oil correlation. On initial appraisal the trends for Cl between the groups appear to be directly related to the trends for Cl in the co-produced formation waters, as shown in Table 2. This is fortuitous, however, because not only have Hitchon et al. (1975) shown that Na and Cl in crude oils are statistically unrelated, but plots of the ratios Na/Cl and Br/I between crude oils and their associated formation waters are effectively random, thus confirming that none of these elements (Na, Cl, Br or I) originate from entrained formation water. For 46 of the fields and pools represented by the 86 conventional crude oils analyzed, the contents of Cl and Br are available for the co-produced formation water, and calculations show that there is insufficient Cl reported in the crude oil to account for the Br content in more than half the samples, assuming all the Br originated from entrained formation water. Similar calculations for 32 pairs of crude oils and co-produced formations waters show enrichments of I in the crude oils of up to nearly 860 times that to be expected if all the I originated from

entrained formation water. This latter observation is particularly pertinent in view of the work of Hitchon and Horn (1974) on the use of I as a petroleum indicator in Paleozoic formation waters from Alberta. If the I-enrichment factors are classified into Mesozoic and Paleozoic groups, as were the formation waters studied by Hitchon and Horn (1974), the following statistics can be calculated:

Iodine-enrichment factor

	Minimum	Median	Average	Maximum
Mesozoic crude oils (n=16)	1.24	16.7	74.4	858
Paleozoic crude oils (n=16)	15.2	84.3	167	746

Although both groups of crude oils are enriched in I, those from Paleozoic rocks are particularly enriched in this element. A geochemical model for the occurrence of Br and I in formation waters and I in crude oils is shown in Figure 5. In non-producing situations the Br and I in formation waters essentially represents background Br and I from clays and I from organic matter in the adjacent (upflow) shales. In producing situations the background values of Br and I are still present but the higher content of organic matter in the source rock results in enhanced contents of I in the formation water, which is reflected in the I content of the crude oil. Thus although I was not a discriminator for the Mesozoic formation waters studied by Hitchon and Horn (1974) it nevertheless is relatively enriched in Mesozoic crude oils. Clearly, for certain biophile elements like I their distribution and geochemical occurrence in the fluids and rocks of sedimentary basins justifies more study and attention than they have received heretofor.

MANGANESE

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Mn (ppb)	20	1.0	50.6	54.9	119.2
Group 2 crude oils (n=25)					
Mn (ppb)	19	1.70	49.8	47.1	79.28
Group 3 crude oils (n=33)					
Mn (ppb)	31	17.93	49.2	52.6	176.6

Geochemistry

Manganese was detected in nearly 90 percent of the conventional crude oils analyzed. The grouped general statistics indicate that of all the

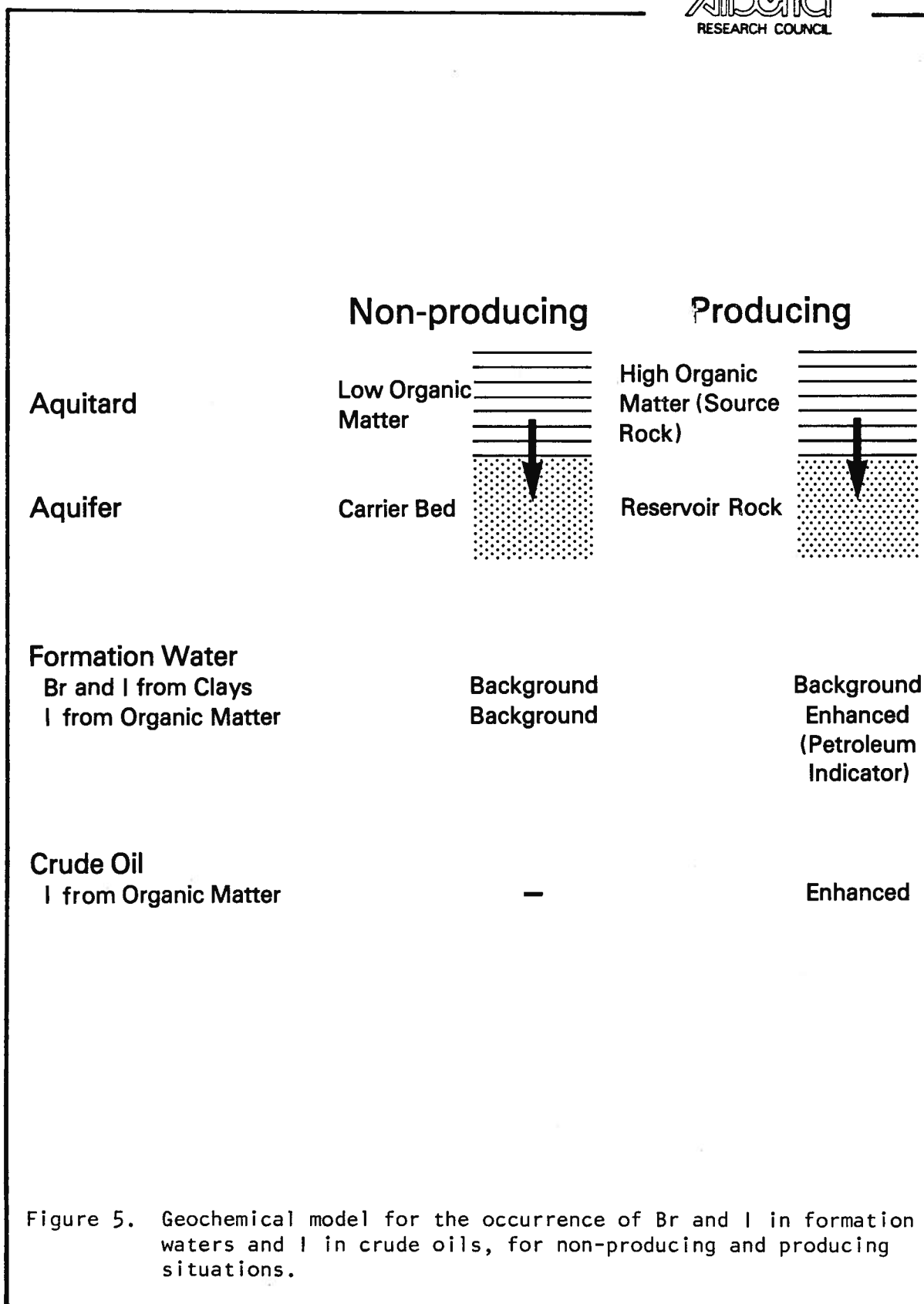


Figure 5. Geochemical model for the occurrence of Br and I in formation waters and I in crude oils, for non-producing and producing situations.

trace elements determined it is probably the most evenly distributed, not only among the three crude oil groups distinguished by Deroo *et al.* (1977) but also in those conventional crude oils not considered in the general statistics. Clearly, Mn cannot be used in the classification of crude oils, a fact confirmed by the ANOVA results. Hitchon *et al.* (1975) found that Mn was the only element forming a unique factor, without significant loadings of any other element. Even in their study of 20 selected crude oils Mn was effectively a unique factor, with only a minor loading for Cr. The factor study, together with the general statistics reported here, make it difficult to determine the manner of occurrence of Mn in crude oils, bearing in mind its factorially unique nature and its very even distribution across a suite of crude oils with widely differing properties from at least three distinct sources and in crude oils that have been subjected to maturation, biodegradation and gas deasphalting. The only distinct difference between the 86 conventional crude oils with their very uniform contents of Mn, and the sample from the Athabasca oil sand (No. 94) with an extremely high content of Mn (3853 ppb) is in sample preparation. This may imply some form of general contamination of the conventional crude oils by Mn during sample preparation, as yet unidentified.

IRON, COBALT AND NICKEL

General Statistics

	Number of samples reporting element	Minimum	Median	Average	Maximum
Group 1 crude oils (n=20)					
Fe (ppm)	10	0.071	0.466	0.545	1.671
Co (ppb)	18	0.261	2.71	8.05	29.07
Ni (ppm)	15	0.022	0.520	0.939	4.03
Group 2 crude oils (n=25)					
Fe (ppm)	12	0.286	0.587	0.94	2.19
Co (ppb)	25	0.397	4.484	10.2	60.22
Ni (ppm)	22	0.136	8.53	11.5	57.48
Group 3 crude oils (n=33)					
Fe (ppm)	16	0.216	0.566	2.04	19.77
Co (ppb)	32	0.516	8.66	22.7	202.6
Ni (ppm)	24	0.085	3.51	7.96	70.1

Geochemistry

For the 86 conventional crude oils studied, Fe was detected in 45 percent, Co in 95 percent and Ni in nearly 80 percent of the samples. With respect to Fe and Co, there is a gradual increase in the range and both the median and average values from Group 1 to Group 3 crude oils. Nickel shows a similar trend in the range of values from Group 1 to Group 3 but the median and average values for Group 2 crude oils are the

highest, with Group 1 crude oils having the lowest median and average contents of this element. With respect to Ni, therefore, the trends are very similar to those for V. Both Ni and V occur in crude oils as porphyrin compounds as well as in a non-porphyrin form, whereas Fe and Co appear to occur only as non-porphyrin material (Filby, 1975), and this may, in part, explain the differences in trends between Ni and V, and Fe and Co. Despite these apparent differences, both Ni and Co have values of the F statistic which suggest their use as crude oil correlation discriminators. The Ni content of sample No. 24 clearly places it in the Group 2 crude oils, as also do the Ni contents of samples 47, 48 and 49 from Triassic reservoirs. The data from the Carboniferous reservoir at the Eaglesham field is equivocal.

TRACE ELEMENTS IN CRUDE OILS FROM THE ATHABASCA OIL SAND DEPOSIT

The two crude oils from the Athabasca oil sand deposit (Nos. 43 and 94) are here treated separately from the 86 conventional crude oils because the nature of the material necessitated different sample preparation techniques and the possibility of contamination from entrained fine-grained mineral matter cannot be ruled out. They are, nevertheless, unequivocally classified as Group 2 crude oils. Table 4 lists the maximum value reported for all trace elements analyzed in Group 2 conventional crude oils and the values reported for samples 43 and 94 (in increasing order of magnitude). A subjective estimate of the probability of the values for the Athabasca oil sand deposit samples being due to contamination is shown in the last column. The dilute formation waters associated with the Athabasca oil sand deposit are essentially of the sodium bicarbonate type and this fact is the reason for the suggested very high and high probability of contamination for the alkali metals (Na, Rb and Cs) compared to the halogens (Cl and Br). In shales, the proportions of Ga:Sc:Eu are of the order 20:10:1; for samples 43 and 94 the proportions of these trace elements are 35:22:1 and 11.5:8:1, respectively. These proportions are strongly suggestive of contamination by entrained fine-grained clay minerals. The possibility of contamination by fine-grained entrained pyrite cannot be ruled out (although its presence was not sought in this study) and this may be the explanation for the very high contents of Fe, Co, Mn, and possibly Cr. Values for the other elements (S, V, Ni, As, Hg, Sb, Se, Cl and Br) probably reflect true amounts associated with the crude oil.

Table 4. Comparison of maximum content of trace elements in Group 2 conventional crude oils with trace elements of two crude oils from Athabasca oil sand deposit.

Element	Maximum in Group 2 conventional crude oils	Athabasca oil sand deposit	
		Reported contents	Probability of contamination
Na (ppm)	19.3	20.78 ; 40.33	High
Rb (ppb)	57.8	377.5 ; 720.2	Very high
Cs (ppb)	9.03	25.9 ; 68.53	Very high
Zn (ppb)	1277.0	-	
Hg (ppb)	138.3	81.7 ;	Low
Sc (ppb)	0.764	190.7 ; 199.0	Very high
Eu (ppb)	0.661	9.0 ; 23.2	Very high
Ga (ppb)	11.0	267.0 ; 315.0	Very high
As (ppb)	1988.0	320.9 ; 400.3	Low
Sb (ppb)	22.8	27.7 ; 30.61	Low
V (ppm)	138.8	176.5 ;	Low
S (%)	3.355	3.881 ;	Low
Se (ppb)	252.3	286.4 ; 517.1	Low
Cr (ppb)	105.8	1014.0 ; 1682.0	Intermediate/high
Cl (ppm)	230.3	7.961 ;	Low
Br (ppb)	7529.0	103.6 ; 155.3	Low
I (ppb)	9005.0	-	
Mn (ppb)	79.28	3853.0 ;	Very high
Fe (ppm)	2.19	141.7 ; 254.2	Very high
Co (ppb)	60.22	1349.0 ; 1998.0	Very high
Ni (ppm)	57.48	71.88 ; 74.11	Low
Asphaltenes (%w/w)	15.5	17.1 ;	

- = Not reported

SUMMARY

This preliminary study shows that when Alberta crude oils are grouped into families, based on their hydrocarbon characteristics, some trace elements may also be a basis for distinguishing the groups. Initial indications are that S, Se, V, Ni, Br, Co and Zn are likely to be the most important discriminators. The data have been treated in a univariate manner using only the most simplistic statistical approach and a more thorough, multivariate statistical analysis is clearly justified. In addition to the use of trace elements to classify crude oils into families the following geochemical observations were made:

1. It is suggested, tentatively, that crude oils with alkaline associated formation waters may be relatively depleted in Na, when compared to those with acidic associated formation waters. The genetic relations among surface tension, pH and surfactants (such as Na salts of petroleum acids) in formation waters, and the content and form of bonding of Na in their associated crude oils justifies considerably more study, and may be of value to explorationists through the use of salts of petroleum acids in formation waters as indicators for crude oil occurrence.
2. Comparison of Zn in shales, Cl and Zn in formation waters, and Zn and Hg in crude oils, all grouped on the basis of the work of Deroo et al. (1977), supports the thesis that the Zn in crude oils, and probably also Hg, as well as Zn in formation waters, have originated from shales which yielded the crude oil hydrocarbons through the specific action of hot, chloride-rich formation waters, with the consequent depletion of those shales in Zn (and probably also Hg).
3. Preliminary evidence is presented to suggest that the V content of crude oils may be related to the V content of the source rocks. A study to determine the form (inorganic and organic) of V in shales, and to seek the relationship between V in crude oils and V in extracted organic matter from the presumed source sediments, could be of considerable significance to the explorationist.
4. Some crude oils show enrichment of I of up to nearly 860 times that to be expected if all the I originated from entrained formation waters. Although almost all crude oils are enriched in I, those from Paleozoic rocks are particularly enriched, compared to those from Mesozoic rocks. A geochemical model is presented for the occurrence of Br and I in formation waters and I in crude oils; in non-producing situations the Br and I in formation waters essentially represents Br and I from clays and I from organic matter in the adjacent (upflow) shales, whereas in producing situations the background values of Br and I are still present but the higher content of organic matter in the source rock results in enhanced

contents of I in the formation water, which is reflected in the I content of the crude oil. Thus although I was not a discriminator for the Mesozoic formation waters studied by Hitchon and Horn (1974) it nevertheless is relatively enriched in Mesozoic crude oils. Clearly, for certain biophile elements like I their distribution and geochemical occurrence in the fluids and rocks of sedimentary basins justifies more study and attention than they have received heretofor.

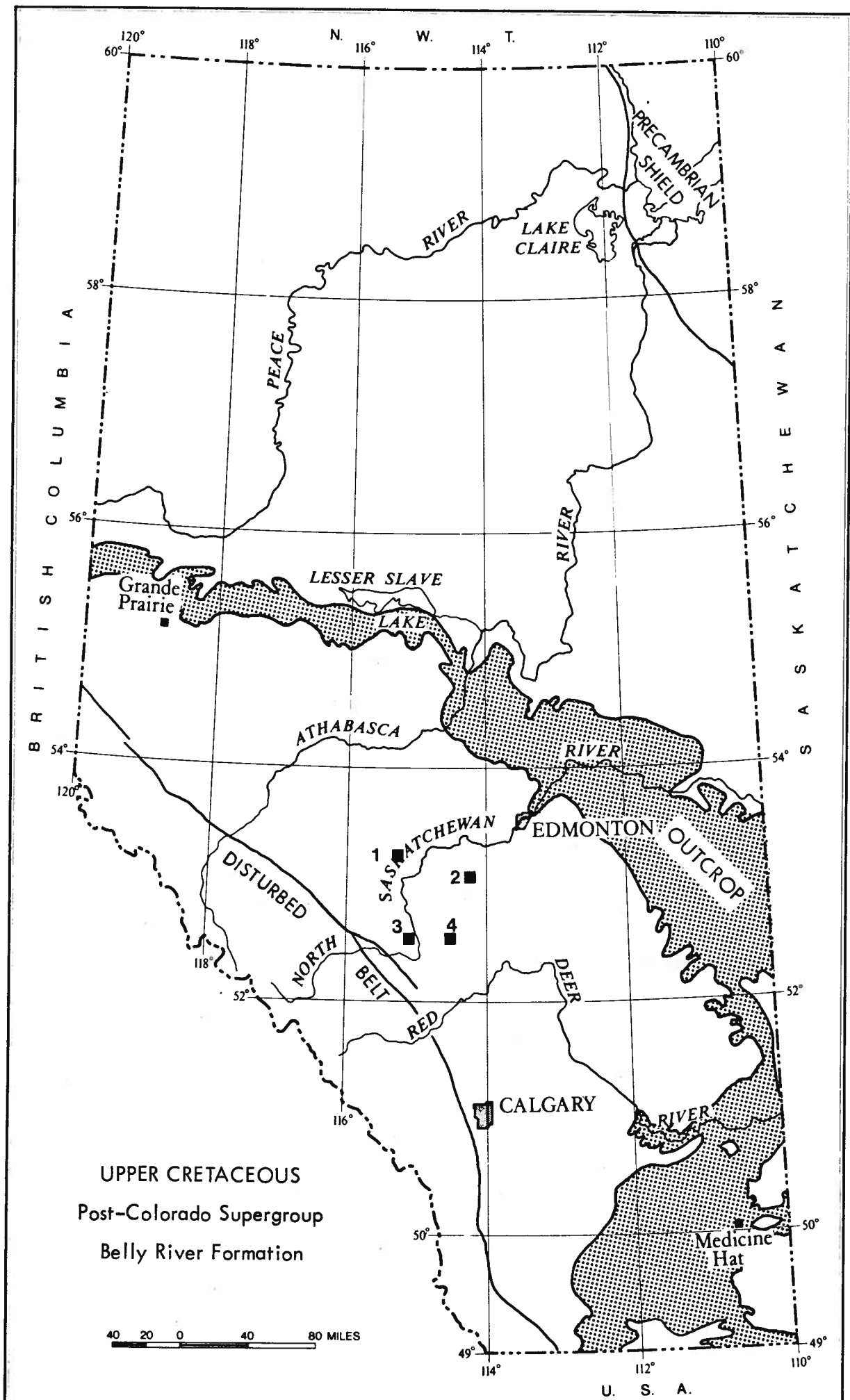
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APPENDIX

Trace Elements in Alberta Crude Oils - Data Sheets



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 1

Field (pool): Pembina (Belly River J)

Stratigraphic unit: U. Cretaceous, Belly River Fm.

Well name: Pan Am HB J-35 Pem 10-21-49-9

Location: Lsd 10 Sec 21 Twp 49 Rge 9 W 5 Mer

Source of sample: Wellhead - tubing Pressure: 150 psig Temperature: cold°F

Method of production: Pump Depth: 4050-4064 ft. (perforations)

Date sampled: 4th Feb. 1970

Remarks:

S	(%)				
V	(ppm)	0.461	(0.0143)		
Cl	(ppm)	8.860	(0.4840)		
Na	(ppm)	0.810	(0.0140)		
Fe	(ppm)				
Ni	(ppm)	0.574	(0.0356)		
Zn	(ppb)	172.0	(10.2)	Au	(ppb)
Co	(ppb)	7.564	(0.43)	Sb	(ppb) 0.129 (0.079)
I	(ppb)	116.20	(18.19)	Cr	(ppb)
Mn	(ppb)	73.40	(1.375)	Rb	(ppb)
Se	(ppb)	12.4	(1.90)	Sc	(ppb) 0.19 (0.0211)
Hg	(ppb)	8.05	(0.813)	Eu	(ppb)
Cs	(ppb)	1.3	(0.472)	Ga	(ppb)
Br	(ppb)	58.6	(1.12)		
As	(ppb)	34.0	(0.531)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 2
 Field (pool): Pembina (Keystone Belly River M)
 Stratigraphic unit: U. Cretaceous, Belly River Fm.
 Well name: Calstan Pembina 14-34BR-47-2
 Location: Lsd 14 Sec 34 Twp 47 Rge 2 W 5 Mer
 Source of sample: Wellhead-tubing Pressure: nil psig Temperature: cold°F
 Method of production: Pump Depth: 3154 ft. (perforations)
 Date sampled: 2nd Feb. 1970
 Remarks: Prior to sample preparation contained some silty material.

S	(%)	0.193	(0.0196)		
V	(ppm)	0.636	(0.0091)		
Cl	(ppm)	8.773	(0.2838)		
Na	(ppm)	0.307	(0.0050)		
Fe	(ppm)				
Ni	(ppm)	1.26	(0.245)		
Zn	(ppb)	130.0	(9.31)	Au	(ppb)
Co	(ppb)	12.43	(0.90)	Sb	(ppb)
I	(ppb)	1101.0	(16.08)	Cr	(ppb) 6.23 (1.80)
Mn	(ppb)	67.47	(1.640)	Rb	(ppb)
Se	(ppb)	12.0	(1.97)	Sc	(ppb)
Hg	(ppb)	13.45	(1.17)	Eu	(ppb) 0.212 (0.063)
Cs	(ppb)	2.15	(0.490)	Ga	(ppb)
Br	(ppb)	12.62	(0.50)		
As	(ppb)	4.35	(0.194)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 3
 Field (pool): Ferrier (Belly River A)
 Stratigraphic unit: U. Cretaceous, Belly River Fm.
 Well name: Amerada Cdn-Sup Ferrier 4-7-41-8
 Location: Lsd 4 Sec 7 Twp 41 Rge 8 W 5 Mer
 Source of sample: Test separator- Pressure: 120 psig Temperature: 62 °F
 Method of production: sight glass Pump Depth: 5545-5571 ft. (perforations)
 Date sampled: 17th Sept. 1970
 Remarks:

S	(%)	0.141	(0.0169)		
V	(ppm)	0.554	(0.0100)		
Cl	(ppm)	7.470	(0.3121)		
Na	(ppm)	0.561	(0.0098)		
Fe	(ppm)	0.357	(0.092)		
Ni	(ppm)	0.718	(0.0281)		
Zn	(ppb)	286.9	(10.2)	Au	(ppb)
Co	(ppb)	29.07	(0.548)	Sb	(ppb) 0.810 (0.312)
I	(ppb)	43.23	(6.147)	Cr	(ppb) 7.80 (1.18)
Mn	(ppb)	77.87	(2.088)	Rb	(ppb)
Se	(ppb)	14.23	(1.20)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.169 (0.0848)
Cs	(ppb)	1.0	(0.26)	Ga	(ppb)
Br	(ppb)	39.5	(1.79)		
As	(ppb)	3.694	(0.326)		

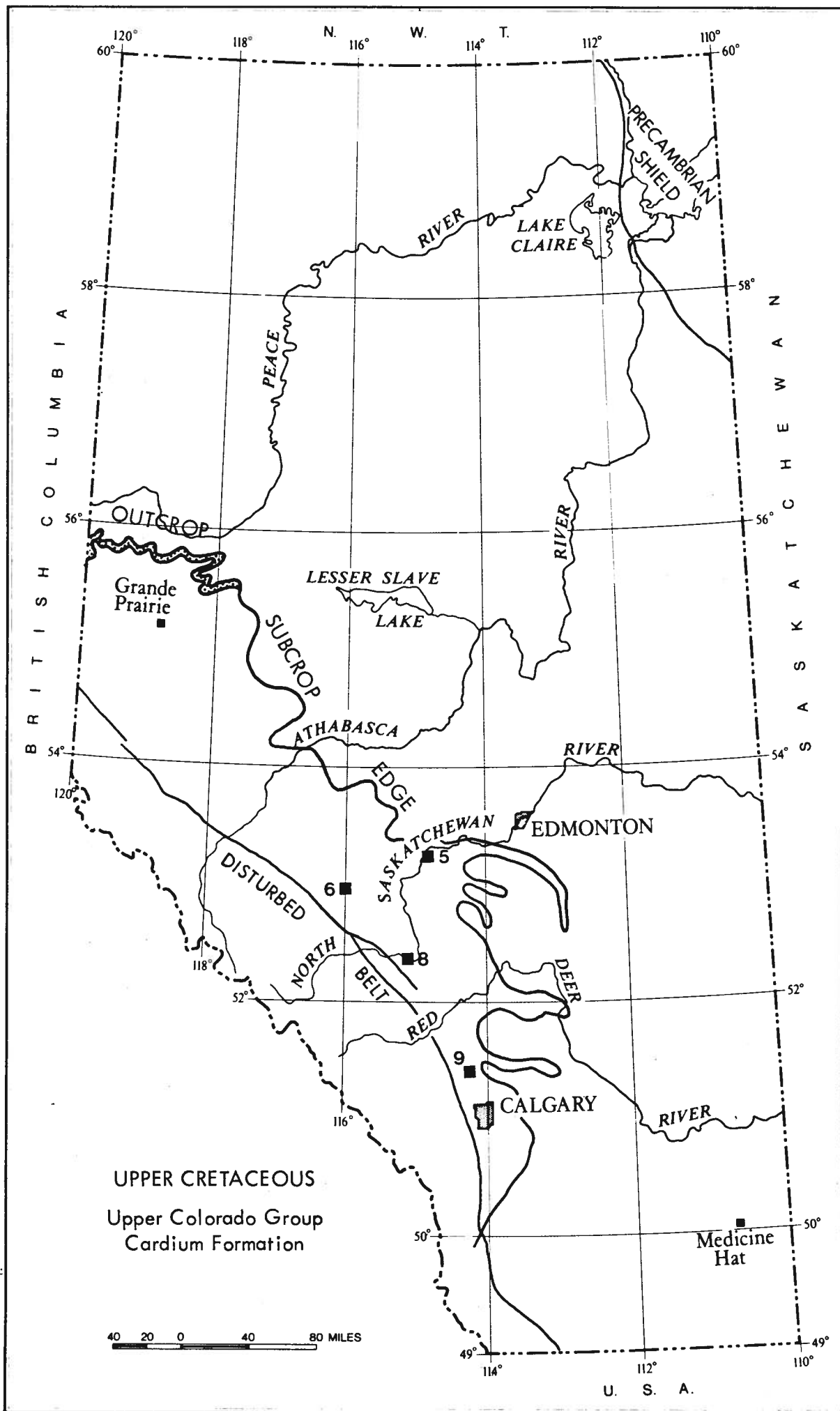
* - Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 4
 Field (pool): Gilby (Belly River A)
 Stratigraphic unit: U. Cretaceous, Belly River Fm.
 Well name: Hamilton Gilby 12-33-41-4
 Location: Lsd 12 Sec 33 Twp 41 Rge 4 W 5 Mer
 Source of sample: Wellhead-tubing Pressure: 38 psig Temperature: 37 °F
 Method of production: Flowing Depth: 4201-4205 ft. (perforations)
 Date sampled: 12th Feb. 1971 4209-4216
 Remarks:

S	(%)	0.109	(0.0167)		
V	(ppm)	0.176	(0.0060)		
Cl	(ppm)	8.645	(0.2988)		
Na	(ppm)	0.572	(0.043)		
Fe	(ppm)	0.107	(0.0293)		
Ni	(ppm)	0.277	(0.0093)		
Zn	(ppb)	186.6	(4.52)	Au	(ppb)
Co	(ppb)	2.81	(0.487)	Sb	(ppb)
I	(ppb)			Cr	(ppb) 3.71 (0.570)
Mn	(ppb)	73.06	(1.061)	Rb	(ppb)
Se	(ppb)	10.72	(0.68)	Sc	(ppb) 0.016 (0.004)
Hg	(ppb)	6.54	(0.579)	Eu	(ppb) 0.073 (0.031)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	23.4	(0.776)		
As	(ppb)	24.42	(0.530)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 5

Field (pool): Pembina (Cardium)

Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Cardium Fm.

Well name: Imp. Cdn-Sup Pembina 14-22C-49-6

Location: Lsd 14 Sec 22 Twp 49 Rge 6 W 5 Mer

Source of sample: Separator

Pressure: 225psig Temperature: 64 °F

Method of production: -

Depth: 4345.5 to ft. (perforations)

Date sampled: 14th July 1969

4382.5

Remarks:

S	(%)	0.233	(0.0595)		
V	(ppm)	1.107	(0.0188)		
Cl	(ppm)	17.44	(0.8181)		
Na	(ppm)	2.23	(0.014)		
Fe	(ppm)	0.457	(0.081)		
Ni	(ppm)	1.961	(0.044)		
Zn	(ppb)	177.7	(8.212)	Au	(ppb)
Co	(ppb)	25.0	(0.530)	Sb	(ppb)
I	(ppb)	367.4	(13.95)	Cr	(ppb)
Mn	(ppb)	62.36	(1.535)	Rb	(ppb)
Se	(ppb)	30.63	(1.97)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	0.562	(0.2173)	Ga	(ppb)
Br	(ppb)	48.2	(1.63)		
As	(ppb)	8.24	(0.661)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 6
 Field (pool): Brazeau River (Cardium A)
 Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Cardium Fm.
 Well name: HB Texaco BrazR 10-21-46-14
 Location: Lsd 10 Sec 21 Twp 46 Rge 14 W 5 Mer
 Source of sample: Storage tank Pressure: atmos. psig Temperature: 32°F
 Method of production: Flowing Depth: 7772-7777 ft (perforations)
 Date sampled: 19th Feb. 1970
 Remarks:

S	(%)	0.061	(0.0146)		
V	(ppm)	0.016	(0.0013)		
Cl	(ppm)	4.789	(0.2039)		
Na	(ppm)	0.647	(0.0053)		
Fe	(ppm)				
Ni	(ppm)	0.022	(0.005)		
Zn	(ppb)	34.3	(2.03)	Au	(ppb)
Co	(ppb)	0.442	(0.047)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	44.91	(0.9198)	Rb	(ppb)
Se	(ppb)	4.0	(0.46)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.102 (0.027)
Cs	(ppb)	0.532	(0.0711)	Ga	(ppb)
Br	(ppb)	13.70	(0.642)		
As	(ppb)	3.04	(0.276)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 8
 Field (pool): Ferrier (Cardium B)
 Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Cardium Fm.
 Well name: Sinclair Pacific Ferrier 8-28MU-39-8
 Location: Lsd 8 Sec 28 Twp 39 Rge 8 W 5 Mer
 Source of sample: Separator Pressure: 255 psig Temperature: 97 °F
 Method of production: Flowing Depth: 7382-7390 ft. (perforations)
 Date sampled: 16th Jan. 1971
 Remarks:

S	(%)				
V	(ppm)	0.013	(0.0015)		
Cl	(ppm)	3.702	(0.0292)		
Na	(ppm)	0.328	(0.0027)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	315.0	(5.40)	Au	(ppb)
Cd	(ppb)	0.264	(0.045)	Sb	(ppb) 0.290 (0.061)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	32.0	(0.77)	Rb	(ppb) 1.870 (0.913)
Se	(ppb)	3.74	(0.418)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.10 (0.0261)
Cs	(ppb)	0.430	(0.081)	Ga	(ppb)
Br	(ppb)	9.22	(0.367)		
As	(ppb)	0.755	(0.124)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 9

Field (pool): Crossfield (Cardium A)

Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Cardium Fm.

Well name: Baysel Shell Crossfield 8-21-28-2

Location: Lsd 8 Sec 21 Twp 28 Rge 2 W 5 Mer

Source of sample: Wellhead Pressure: 45 psig Temperature: 73 °F

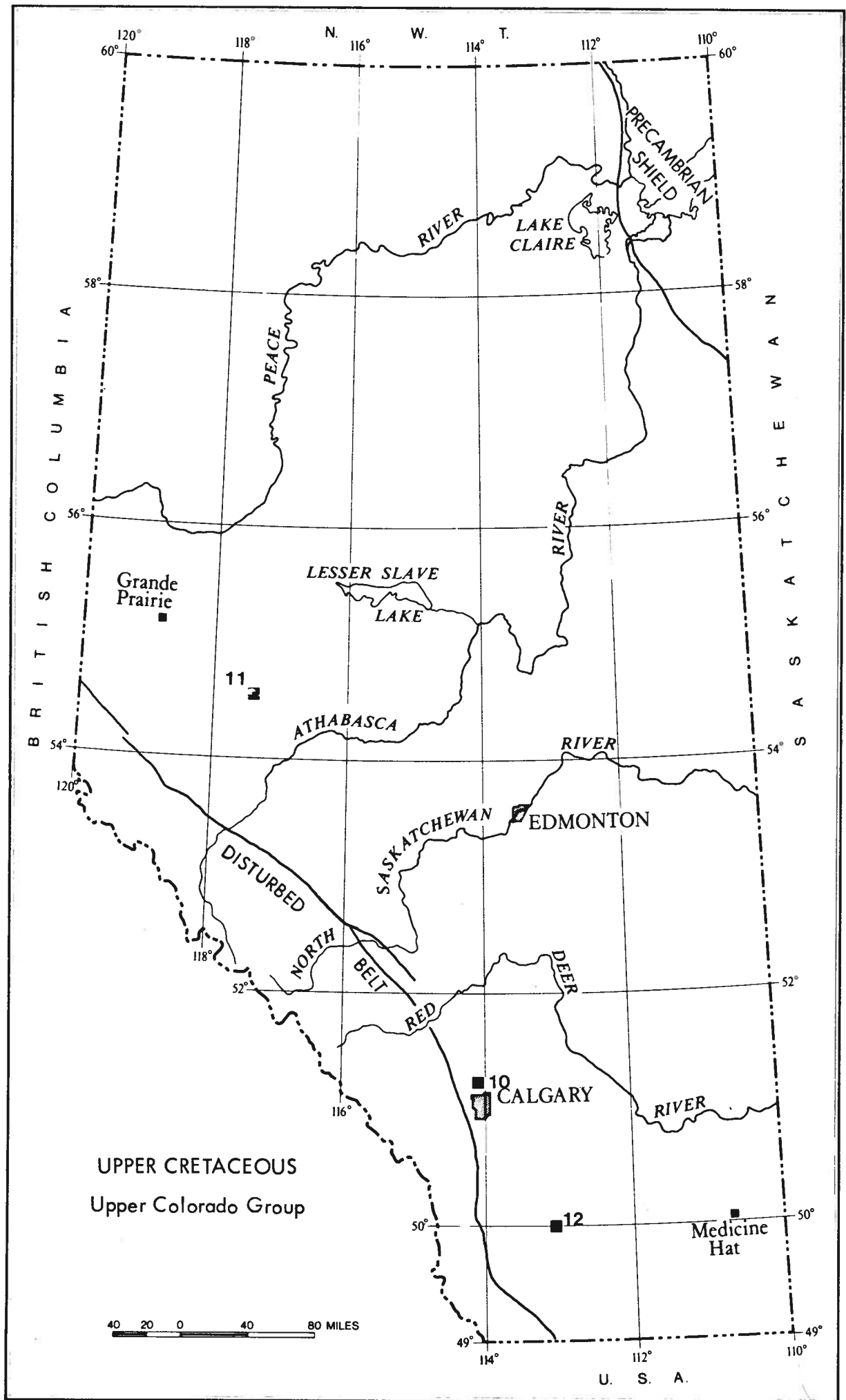
Method of production: Pump Depth: 6728.5-6739.5 ft. (perforations)

Date sampled: 23rd June 1970

Remarks:

S	(%)	0.198	(0.0258)		
V	(ppm)	0.381	(0.0079)		
Cl	(ppm)	8.860	(0.4840)		
Na	(ppm)	0.284	(0.0045)		
Fe	(ppm)	0.475	(0.150)		
Ni	(ppm)	0.520	(0.033)		
Zn	(ppb)	36.8	(3.79)	Au	(ppb)
Co	(ppb)	17.12	(0.814)	Sb	(ppb)
I	(ppb)			Cr	(ppb) 8.91 (1.50)
Mn	(ppb)	73.40	(1.375)	Rb	(ppb)
Se	(ppb)	8.51	(1.53)	Sc	(ppb)
Hg	(ppb)	17.7	(1.22)	Eu	(ppb) 0.641 (0.10)
Cs	(ppb)	0.75	(0.35)	Ga	(ppb)
Br	(ppb)	65.83	(2.45)		
As	(ppb)	6.69	(0.557)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 10
 Field (pool): Crossfield (Jumping Pound A)
 Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Jumping Pound Ss.
 Well name: Homestead et al Airdrie 10-31-26-1
 Location: Tsd 10 Sec 31 Twp 26 Rge 1 W 5 Mer
 Source of sample: Tank Pressure: nil psig Temperature: 80 °F
 Method of production: Pump Depth: 6828-6844 ft. (perforations)
 Date sampled: 23rd June 1970
 Remarks: Well shut in 19th June 1970

S	(%)				
V	(ppm)	0.090	(0.0051)		
Cl	(ppm)	6.723	(0.2624)		
Na	(ppm)	0.646	(0.0082)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	303.2	(8.60)	Au	(ppb)
Co	(ppb)	0.803	(0.210)	Sb	(ppb)
I	(ppb)	31.06	(6.707)	Cr	(ppb)
Mn	(ppb)	119.2	(1.879)	Rb	(ppb)
Se	(ppb)	8.09	(1.95)	Sc	(ppb) 0.060 (0.013)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	0.692	(0.180)	Ga	(ppb)
Br	(ppb)	24.4	(2.00)		
As	(ppb)	21.3	(0.99)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 11
 Field (pool): Waskahigan (Dunvegan A)
 Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Dunvegan Fm.
 Well name: Mobil Amoco Waskahigan 6-26-64-23
 Location: Lsd 6 Sec 26 Twp 64 Rge 23 W 5 Mer
 Source of sample: Gas plant Pressure: 10 psig Temperature: 48 °F
 Method of production: Flowing Depth: 5094-5113 ft. (perforations)
 Date sampled: 24th July 1970
 Remarks: Well fractured with Beaverhill Lake crude oil, therefore there may be traces of other oil in this condensate.

S	(%)		
V	(ppm)	0.003	(0.0007)
Cl	(ppm)	2.16	(0.125)
Na	(ppm)	0.051	(0.0008)
Fe	(ppm)	0.071	(0.029)
Ni	(ppm)		
Zn	(ppb)	11.51	(1.85)
Co	(ppb)	0.261	(0.059)
I	(ppb)		
Mn	(ppb)	1.0	(0.20)
Se	(ppb)		
Hg	(ppb)	3.310	(0.325)
Cs	(ppb)		
Br	(ppb)	7.002	(0.257)
As	(ppb)	0.610	(0.0731)
Au	(ppb)		
Sb	(ppb)	0.20	(0.077)
Cr	(ppb)		
Rb	(ppb)	5.43	(1.101)
Sc	(ppb)	0.013	(0.0034)
Eu	(ppb)		
Ga	(ppb)		

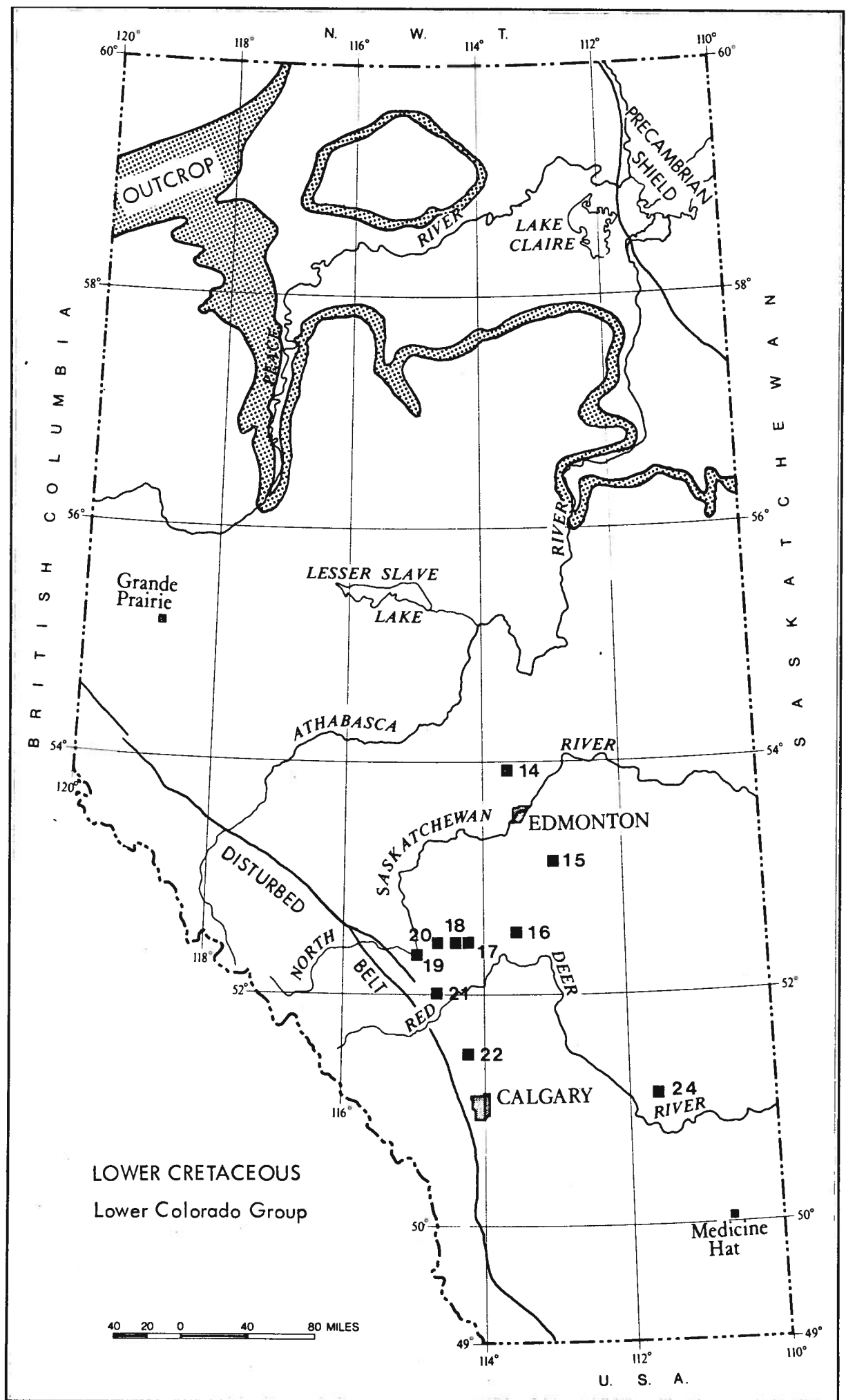
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 12
 Field (pool): Barons (Colorado)
 Stratigraphic unit: U. Cretaceous, Upper Colorado Gp., Fishscales Ss.
 Well name: Barons 1
 Location: Lsd 10 Sec 15 Twp 12 Rge 23 W 4 Mer
 Source of sample: Tank Pressure: nil psig Temperature: 88°F
 Method of production: Pump Depth: Open hole ft.
 Date sampled: 25th June 1970 completion. Barons sand 4105 ft.
 T. D. 4114 ft.
 Remarks:

S	(%)	0.314	(0.0347)		
V	(ppm)	4.992	(0.0686)		
Cl	(ppm)	3.654	(0.2101)		
Na	(ppm)	0.046	(0.0011)		
Fe	(ppm)	0.768	(0.1002)		
Ni	(ppm)	3.20	(0.068)		
Zn	(ppb)	324.8	(11.1)	Au	(ppb) 0.078 (0.0077)
Co	(ppb)	20.20	(0.460)	Sb	(ppb)
I	(ppb)	79.01	(7.273)	Cr	(ppb)
Mn	(ppb)	48.90	(1.305)	Rb	(ppb)
Se	(ppb)	27.7	(2.05)	Sc	(ppb)
Hg	(ppb)	3.08	(1.20)	Eu	(ppb) 0.305 (0.0727)
Cs	(ppb)			Ga	(ppb) 1.13 0.070
Br	(ppb)	38.74	(1.48)		
As	(ppb)	1.860	(0.148)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 14

Field (pool): Legal (Viking)

Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.

Well name: LWS 3 Legal 3-21-57-25

Location: Lsd 3 Sec 21 Twp 57 Rge 25 W 4 Mer

Source of sample: Wellhead Pressure: 200 psig Temperature: - °F

Method of production: Pump Depth: 2790-2792 ft. (perforations)

Date sampled: September, 1971

Remarks:

S	(%)	1.244	(0.0631)		
V	(ppm)	6.553	(0.0579)		
Cl	(ppm)	38.74	(0.9333)		
Na	(ppm)	13.0	(0.217)		
Fe	(ppm)	1.671	(0.123)		
Ni	(ppm)	4.03	(0.085)		
Zn	(ppb)	266.8	(11.07)	Au	(ppb)
Co	(ppb)	19.9	(0.513)	Sb	(ppb)
I	(ppb)	488.6	(13.28)	Cr	(ppb) 6.20 (2.0)
Mn	(ppb)	52.23	(1.167)	Rb	(ppb)
Se	(ppb)	48.1	(2.814)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	2.27	(0.30)	Ga	(ppb)
Br	(ppb)	127.4	(8.85)		
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 15
 Field (pool): Joarcam (Viking)
 Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.
 Well name: Imperial Gulf HB Armena 9-34-48-21
 Location: Lsd 9 Sec 34 Twp 48 Rge 21 W 4 Mer
 Source of sample: Satellite manifold Pressure: - psig Temperature: - °F
 Method of production: Pump Depth: 3254-3259 ft. (perforations)
 Date sampled: 14th July, 1969
 Remarks: Sample bottle contained sediment on bottom

S	(%)	0.145	(0.018)		
V	(ppm)	0.682	(0.0032)		
Cl	(ppm)	25.5	(0.528)		
Na	(ppm)	2.921	(0.0247)		
Fe	(ppm)	0.696	(0.0976)		
Ni	(ppm)	0.609	(0.0236)		
Zn	(ppb)	669.7	(14.34)	Au	(ppb)
Co	(ppb)	2.75	(0.087)	Sb	(ppb)
I	(ppb)	1364.0	(24.0)	Cr	(ppb)
Mn	(ppb)	48.0	(0.80)	Rb	(ppb)
Se	(ppb)	9.402	(1.19)	Sc	(ppb)
Hg	(ppb)	84.1	(2.79)	Eu	(ppb) 0.405 (0.096)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	72.01	(1.961)		
As	(ppb)	2.433	(0.522)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 16
 Field (pool): Chigwell (Viking B)
 Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.
 Well name: Pamoil et al Chigwell 10-3-41-25
 Location: Lsd 10 Sec 3 Twp 41 Rge 25 W 4 Mer
 Source of sample: Treater inlet Pressure: 20 psig Temperature: 50 °F
 Method of production: Pump Depth: 4592-4595 ft. (perforations)
 Date sampled: 24th June 1969
 Remarks: Sediment on bottom of sample bottle

S	(%)	0.126	(0.022)		
V	(ppm)	0.250	(0.0072)		
Cl	(ppm)	6.96	(0.512)		
Na	(ppm)	1.324	(0.010)		
Fe	(ppm)				
Ni	(ppm)	0.500	(0.0217)		
Zn	(ppb)	413.6	(10.8)	Au	(ppb)
Ce	(ppb)	2.67	(0.186)	Sb	(ppb)
I	(ppb)	615.5	(71.5)	Cr	(ppb)
Mn	(ppb)	41.9	(0.77)	Rb	(ppb) 67.5 (5.80)
Se	(ppb)	6.51	(1.30)	Sc	(ppb)
Hg	(ppb)	14.74	(0.723)	Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	14.90	(0.710)		
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 17

Field (pool): Gilby (Viking A)

Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.

Well name: Colstan Gilby 10-33V-40-2

Location: Tsd 10 Sec 33 Twp40 Rge 2 W 5 Mer

Source of sample: Separator-sight glass Pressure: 27 psig Temperature: 40 °F

Method of production: Pump Depth: 6002-6075 ft. (open hole)

Date sampled: 4th July 1969

Remarks:

S (%)

V (ppm) 0.061 (0.0029)

Cl (ppm) 3.585 (0.1267)

Na (ppm) 0.874 (0.0068)

Fe (ppm)

Ni (ppm) 0.053 (0.0138)

Zn (ppb) 664.3 (14.44) Au (ppb)

Co (ppb) 0.805 (0.145) Sb (ppb)

I (ppb) 7.771 (2.9660) Cr (ppb)

Mn (ppb) 45.39 (0.8260) Rb (ppb)

Se (ppb) 4.29 (1.238) Sc (ppb)

Hg (ppb) 3.473 (0.532) Eu (ppb) 0.351 (0.094)

Cs (ppb) Ga (ppb)

Br (ppb) 5.641 (0.693)

As (ppb)

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS — DATA SHEET

Sample number: 18
 Field (pool): Gilby (Viking C)
 Stratigraphic unit: Upper Cretaceous, Lower Colorado Gp., Viking Fm.
 Well name: HB Richfield Eckville 1
 Location: Lsd 10 Sec 2 Twp 40 Rge 3 W 5 Mer
 Source of sample: Separator Pressure: 45 psig Temperature: 70°F
 Method of production: Flowing Depth: 6270-6280 ft. (perforations)
 Date sampled: 18th June 1970
 Remarks:

S	(%)	0.128	(0.0163)		
V	(ppm)	0.148	(0.0043)		
Cl	(ppm)	6.524	(0.2861)		
Na	(ppm)	0.945	(0.0168)		
Fe	(ppm)	0.357	(0.161)		
Ni	(ppm)	0.064	(0.0303)		
Zn	(ppb)	480.0	(16.9)	Au	(ppb)
Co	(ppb)			Sb	(ppb) 0.10 (0.039)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	55.45	(0.8311)	Rb	(ppb)
Se	(ppb)	5.75	(2.1540)	Sc	(ppb) 0.241 (0.025)
Hg	(ppb)			Eu	(ppb) 0.324 0.18
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	13.7	(0.778)		
As	(ppb)	1.78	(0.293)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 19
 Field (pool): Ferrier (Viking A)
 Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.
 Well name: Seafort et al Ferrier 10-18-39-7
 Location: Lsd 10 Sec 18 Twp 39 Rge 7 W 5 Mer
 Source of sample: Tubing Pressure: 400 psig Temperature: 38 °F
 Method of production: Flowing Depth: 7927-7930 ft. (perforations)
 Date sampled: 29th Oct. 1970
 Remarks:

S	(%)	0.040	(0.011)		
V	(ppm)	0.018	(0.0024)		
Cl	(ppm)	4.54	(0.56)		
Na	(ppm)	0.709	(0.0138)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	63.0	(9.3)	Au	(ppb)
Co	(ppb)			Sb	(ppb)
I	(ppb)			Cr	(ppb) 10.38 (2.79)
Mn	(ppb)	44.71	(0.77)	Rb	(ppb)
Se	(ppb)	8.13	(1.952)	Sc	(ppb) 0.24 (0.026)
Hg	(ppb)	202.2	(11.0)	Eu	(ppb) 0.31 (0.164)
Cs	(ppb)	1.32	(0.50)	Ga	(ppb)
Br	(ppb)	6.67	(0.846)		
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 20

Field (pool): Willesden Green (Viking A)

Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.

Well name: Mobil Leafland 16-16 MU-40-5

Location: Lsd 16 Sec 16 Twp 40 Rge 5 W 5 Mer

Source of sample: Tubing Pressure: 350 psig Temperature: 39 °F

Method of production: Flowing Depth: 7019-7029 ft. (perforations)

Date sampled: 18th Nov. 1970

Remarks:

S (%)

V (ppm) 0.042 (0.0030)

Cl (ppm) 5.08 (0.1871)

Na (ppm) 0.751 (0.0126)

Fe (ppm)

Ni (ppm) 0.070 (0.0294)

Zn (ppb) 178.0 (10.1) Au (ppb)

Ce (ppb) 0.722 (0.274) Sb (ppb)

I (ppb) Cr (ppb) 15.51 (4.43)

Mn (ppb) 47.23 (0.8345) Rb (ppb)

Se (ppb) 9.52 (3.0) Sc (ppb) 0.22 (0.021)

Hg (ppb) Eu (ppb)

Cs (ppb) Ga (ppb)

Br (ppb) 6.34 (0.412)

As (ppb) 0.831 (0.160)

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 21
 Field (pool): Caroline (Viking A)
 Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.
 Well name: Altana Caroline 4-18-35-5
 Location: Lsd 4 Sec 18 Twp 35 Rge 5 W 5 Mer
 Source of sample: Separator Pressure: 40 psig Temperature: 52 °F
 Method of production: Pump Depth: 8383-8389; 8404-8408 ft. (perforations)
 Date sampled: 24th April 1970
 Remarks:

S	(%)	0.102	(0.0194)		
V	(ppm)	0.365	(0.0103)		
Cl	(ppm)	6.905	(0.1955)		
Na	(ppm)	1.680	(0.018)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	453.0	(10.9)	Au	(ppb)
Co	(ppb)	1.070	(0.170)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	85.04	(1.658)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.367 (0.072)
Cs	(ppb)	1.24	(0.281)	Ga	(ppb)
Br	(ppb)	12.1	(0.917)		
As	(ppb)	56.72	(0.947)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 22
 Field (pool): Crossfield (Viking A)
 Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Viking Fm.
 Well name: Cdn-Sup Canberra Cross 10-13-29-2
 Location: Lsd 10 Sec 13 Twp 29 Rge 2 W 5 Mer
 Source of sample: Tubing Pressure: 140 psig Temperature: 40°F
 Method of production: Pump Depth: 7123-7153 ft. (perforations)
 Date sampled: 22nd Oct. 1970
 Remarks:

S	(%)	0.091	(0.015)		
V	(ppm)	0.128	(0.0063)		
Cl	(ppm)	10.57	(0.3161)		
Na	(ppm)	2.735	(0.0233)		
Fe	(ppm)	0.495	(0.043)		
Ni	(ppm)	0.230	(0.011)		
Zn	(ppb)	273.1	(6.67)	Au	(ppb)
Co	(ppb)	1.06	(0.084)	Sb	(ppb) 0.530 (0.096)
I	(ppb)	293.5	(8.10)	Cr	(ppb)
Mn	(ppb)	3.55	(0.154)	Rb	(ppb)
Se	(ppb)	8.20	(0.832)	Sc	(ppb) 0.028 (0.005)
Hg	(ppb)	1.60	(0.436)	Eu	(ppb) 0.150 (0.034)
Cs	(ppb)	0.310	(0.10)	Ga	(ppb)
Br	(ppb)	46.0	(1.78)		
As	(ppb)				

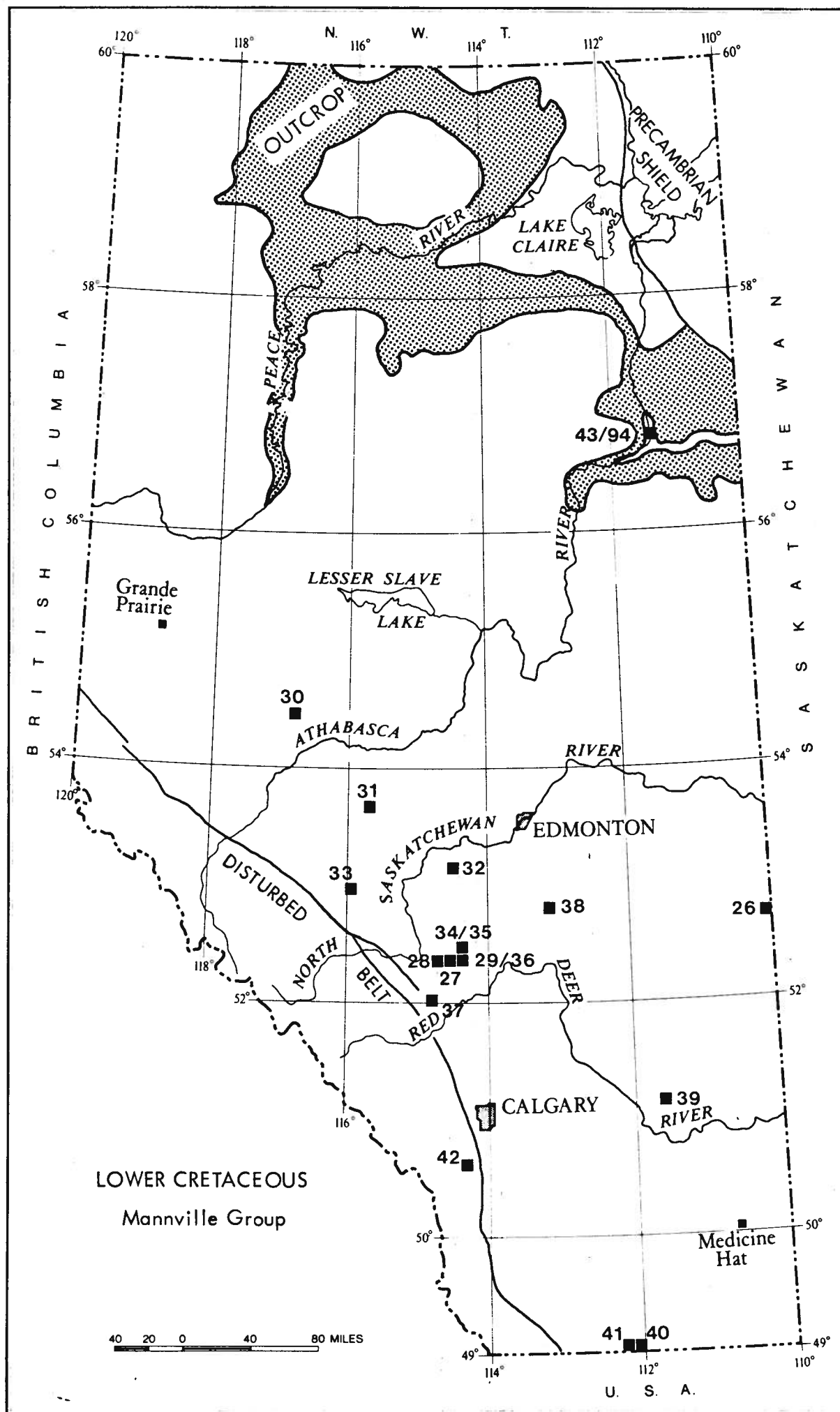
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 24
 Field (pool): Cessford (Basal Colorado A)
 Stratigraphic unit: U. Cretaceous, Lower Colorado Gp., Basal Colorado Ss.
 Well name: HB Unit 2 Cess 10-14-25-12
 Location: Lsd 10 Sec 14 Twp 25 Rge 12 W 4 Mer
 Source of sample: Wellhead-tubing Pressure: - psig Temperature: - °F
 Method of production: Pump Depth: 3046-3052 ft. (perforations)
 Date sampled: 12th Aug. 1969
 Remarks:

S	(%)	1.514	(0.1519)		
V	(ppm)	59.82	(0.5340)		
Cl	(ppm)	29.21	(0.5583)		
Na	(ppm)	19.3	(0.125)		
Fe	(ppm)	0.39	(0.063)		
Ni	(ppm)	25.2	(0.261)		
Zn	(ppb)	793.5	(10.87)	Au	(ppb)
Co	(ppb)	58.3	(0.444)	Sb	(ppb) 1.07 (0.103)
I	(ppb)	147.7	(9.806)	Cr	(ppb) 95.2 (2.28)
Mn	(ppb)	42.35	(1.0170)	Rb	(ppb)
Se	(ppb)	162.0	(4.53)	Sc	(ppb) 0.304 (0.010)
Hg	(ppb)			Eu	(ppb) 0.05 0.028
Cs	(ppb)	0.69	(0.178)	Ga	(ppb)
Br	(ppb)	177.0	(6.09)		
As	(ppb)	79.8	(3.43)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 26
 Field (pool): Chauvin (Mannville A)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Sparky Ss
 Well name: Trans-Era CPR Chauvin 16-21-C
 Location: Lsd 16 Sec 21 Twp 43 Rge 1 W 4 Mer
 Source of sample: Wellhead Pressure: - psig Temperature: - °F
 Method of production: Pump Depth: 2152-2171 ft. (perforations)
 Date sampled: 9th July 1969
 Remarks: Original sample contained formation water

S	(%)	2.591	(0.233)		
V	(ppm)	57.40	(0.430)		
Cl	(ppm)	85.50	(2.0)		
Na	(ppm)				
Fe	(ppm)	1.890	(0.1591)		
Ni	(ppm)	25.05	(0.4282)		
Zn	(ppb)	481.0	(12.7)	Au	(ppb)
Co	(ppb)	28.2	(0.262)	Sb	(ppb) 1.810 (0.336)
I	(ppb)	185.0	(34.0)	Cr	(ppb) 105.8 (5.87)
Mn	(ppb)	66.2	(1.93)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.764 (0.026)
Hg	(ppb)			Eu	(ppb) 0.385 0.0885
Cs	(ppb)			Ga	(ppb)
Br	(ppb)				
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 27
 Field (pool): Medicine River (Glaucinitic A)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Glaucinitic Ss.
 Well name: HB Medicine R 10-8-39-4
 Location: Lsd 10 Sec 8 Twp 39 Rge 4 W 5 Mer
 Source of sample: Separator Pressure: 45 psig Temperature: 62°F
 Method of production: Flowing Depth: 7361-7365; ft. (perforations)
 Date sampled: 18th June 1970 7368-7369;
 Remarks: 7371-7372;
 7379-7381

S	(%)	0.759	(0.0457)	
V	(ppm)	4.678	(0.0427)	
Cl	(ppm)	4.886	(0.2261)	
Na	(ppm)	0.728	(0.0134)	
Fe	(ppm)			
Ni	(ppm)	2.00	(0.090)	
Zn	(ppb)	1211.0	(29.0)	Au (ppb)
Co	(ppb)	3.02	(0.44)	Sb (ppb)
I	(ppb)			Cr (ppb)
Mn	(ppb)	23.46	(0.9574)	Rb (ppb)
Se	(ppb)	49.70	(4.20)	Sc (ppb)
Hg	(ppb)	4.70	(1.38)	Eu (ppb)
Cs	(ppb)	1.68	(0.562)	Ga (ppb)
Br	(ppb)			
As	(ppb)			

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 28
 Field (pool): Willesden Green (Glaucinitic A)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Glaucinitic Ss.
 Well name: CPOG Leaf 8-15-39-5
 Location: Lsd 8 Sec 15 Twp 39 Rge 5 W-5 Mer
 Source of sample: Separator Pressure: 40 psig Temperature: 52 °F
 Method of production: Pump Depth: 7550-7553; 7570-7573 ft. (perforations)
 Date sampled: 22nd Oct. 1970
 Remarks:

S	(%)	0.751	(0.0780)		
V	(ppm)	8.401	(0.0968)		
Cl	(ppm)	10.33	(0.2849)		
Na	(ppm)	1.84	(0.0312)		
Fe	(ppm)				
Ni	(ppm)	2.712	(0.069)		
Zn	(ppb)	392.0	(14.4)	Au	(ppb)
Cd	(ppb)	3.135	(0.336)	Sb	(ppb)
I	(ppb)	34.22	(6.1210)	Cr	(ppb)
Mn	(ppb)	79.28	(1.2080)	Rb	(ppb)
Se	(ppb)	50.72	(3.096)	Sc	(ppb) 0.183 (0.0211)
Hg	(ppb)	63.75	(5.89)	Eu	(ppb)
Cs	(ppb)	1.395	(0.473)	Ga	(ppb)
Br	(ppb)				
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 29
 Field (pool): Medicine River (Ostracod A)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Ostracod Mbr.
 Well name: Atlantic Medicine River 14-10-39-3
 Location: Lsd 14 Sec 10 Twp 39 Rge 3 W 5 Mer
 Source of sample: Wellhead Pressure: 155 psig Temperature: 50 °F
 Method of production: Pump Depth: 6842-6850 ft. (perforations)
 Date sampled: 18th June 1970
 Remarks: Some silt and formation water in original container

S	(%)	1.115	(0.0777)		
V	(ppm)	8.336	(0.0910)		
Cl	(ppm)	4.497	(0.1889)		
Na	(ppm)	0.226	(0.0036)		
Fe	(ppm)	0.286	(0.122)		
Ni	(ppm)	4.04	(0.273)		
Zn	(ppb)	104.0	(8.45)	Au	(ppb)
Co	(ppb)	3.392	(0.375)	Sb	(ppb)
I	(ppb)	18.61	(5.430)	Cr	(ppb) 13.60 (0.30)
Mn	(ppb)	46.21	(1.212)	Rb	(ppb)
Se	(ppb)	49.20	(3.90)	Sc	(ppb)
Hg	(ppb)	4.10	(1.30)	Eu	(ppb) 0.430 (0.109)
Cs	(ppb)	1.05	(0.44)	Ga	(ppb)
Br	(ppb)	3.10	(0.410)		
As	(ppb)	1.17	(0.148)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 30
 Field (pool): Kaybob (Cadomin B)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Cadomin Fm.
 Well name: Atlantic Kaybob 16-21-63-19
 Location: Lsd 16 Sec21 Twp 63 Rge 19 W 5 Mer
 Source of sample: Tubing Pressure: 50 psig Temperature: 55 °F
 Method of production: Pump Depth: 5920-5954; ft. (perforations)
 Date sampled: 21st July 1970 5961-5974
 Remarks: Some silt and formation water in original container

S	(%)	1.655	(0.1134)		
V	(ppm)	27.68	(0.2754)		
Cl	(ppm)	8.922	(0.2326)		
Na	(ppm)	2.043	(0.0420)		
Fe	(ppm)				
Ni	(ppm)	10.4	(0.124)		
Zn	(ppb)	645.3	(20.5)	Au	(ppb)
Co	(ppb)	6.93	(0.605)	Sb	(ppb)
I	(ppb)	103.8	(7.159)	Cr	(ppb)
Mn	(ppb)	67.73	(1.002)	Rb	(ppb)
Se	(ppb)	47.4	(5.20)	Sc	(ppb)
				0.06	(0.028)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	1.92	(0.57)	Ga	(ppb)
Er	(ppb)	29.2	(3.04)		
As	(ppb)	10.4	(1.10)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 31
 Field (pool): Niton (Basal Quartz B)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Ellerslie Fm.
 Well name: IOE; Niton 4-18-54-12
 Location: Lsd 4 Sec 18 Twp 54 Rge 12 W 5 Mer
 Source of sample: Tubing Pressure: - psig Temperature: - °F
 Method of production: Pump Depth: 6515-6524 ft. (perforations)
 Date sampled: 20th Feb. 1970
 Remarks: Sample may contain emulsion breaker; this was being injected downstream of sampling point; however, treated oil may have flowed back. Some silt and formation water in original container

S	(%)	0.508	(0.036)		
V	(ppm)	1.04	(0.019)		
Cl	(ppm)	43.9	(0.584)		
Na	(ppm)	1.31	(0.0137)		
Fe	(ppm)	1.89	(0.101)		
Ni	(ppm)	0.212	(0.011)		
Zn	(ppb)	41.1	(2.50)	Au	(ppb)
Co	(ppb)	0.992	(0.0611)	Sb	(ppb) 0.530 (0.063)
I	(ppb)	9005.0	(131.0)	Cr	(ppb)
Mn	(ppb)	1.70	(0.20)	Rb	(ppb)
Se	(ppb)	7.07	(0.83)	Sc	(ppb) 0.021 (0.005)
Hg	(ppb)	138.3	(6.79)	Eu	(ppb) 0.103 (0.029)
Cs	(ppb)	0.32	(0.114)	Ga	(ppb)
Br	(ppb)	1153.0	(15.6)		
As	(ppb)	40.9	(1.65)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 32

Field (pool): Pembina (Keystone Ellerslie A)

Stratigraphic unit: L. Cretaceous, Mannville Gp., Ellerslie Fm.

Well name: Cities Service Keystone 6-32

Location: Lsd 6 Sec 32 Twp 48 Rge 4 W 5 Mer

Source of sample: Separator Pressure: 60 psig Temperature: cold °F

Method of production: Flowing Depth: Ellerslie 5839 ft.

Date sampled: 4th Feb. 1970 Carboniferous 5910 ft.

Remarks: Sample from perforations, but depth not given

S (%) 0.928 (0.0784)

V (ppm) 3.015 (0.0359)

Cl (ppm) 7.108 (0.2320)

Na (ppm) 0.317 (0.0031)

Fe (ppm) 0.50 (0.043)

Ni (ppm) 0.80 (0.018)

Zn (ppb) 21.6 (2.10) Au (ppb)

Co (ppb) 1.25 (0.078) Sb (ppb)

I (ppb) 10.28 (5.686) Cr (ppb)

Mn (ppb) Rb (ppb)

Se (ppb) 32.7 (1.47) Sc (ppb)

Hg (ppb) Eu (ppb) 0.091 (0.030)

Cs (ppb) 0.355 (0.112) Ga (ppb)

Br (ppb) 37.62 (0.823)

As (ppb) 4.17 (0.23)

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 33

Field (pool): Brazeau River (Lower Mannville A)

Stratigraphic unit: L. Cretaceous, Lower Mannville Gp

Well name: HB BrazR 10-9-46-14

Location: Lsd 10 Sec 9 Twp 46 Rge 14 W 5 Mer

Source of sample: Separator Pressure: 44 psig Temperature: 30 °F

Method of production: Flowing Depth: 10237-10246; ft. (perforations)

Date sampled: 19th Feb. 1970 10247-10249

Remarks: Some silt at bottom of original container

S (%)

V (ppm)

Cl (ppm) 0.650 (0.074)

Na (ppm) 0.249 (0.0022)

Fe (ppm)

Ni (ppm)

Zn (ppb)

Au (ppb)

Co (ppb) 0.397 (0.1451)

Sb (ppb)

I (ppb)

Cr (ppb)

Mn (ppb)

Rb (ppb)

Se (ppb) 5.26 (1.303)

Sc (ppb)

Hg (ppb)

Eu (ppb) 0.250 (0.0873)

Cs (ppb)

Ga (ppb)

Br (ppb) 22.06 (0.633)

As (ppb) 33.4 (0.495)

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 34
 Field (pool): Gilby (Basal Mannville B)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp.
 Well name: Richfield Gabriel Lake 7-29
 Location: Lsd 7 Sec 29 Twp 40 Rge 3 W 5 Mer
 Source of sample: Separator Pressure: 52 psig Temperature: 56 °F
 Method of production: Pump Depth: 7015-7035 ft. (perforations)
 Date sampled: 4th July 1969
 Remarks:

S	(%)	1.534	(0.134)		
V	(ppm)	27.6	(0.278)		
Cl	(ppm)	21.8	(0.798)		
Na	(ppm)				
Fe	(ppm)				
Ni	(ppm)	9.0	(0.146)		
Zn	(ppb)	400.0	(16.0)	Au	(ppb)
Co	(ppb)	5.40	(0.31)	Sb	(ppb)
I	(ppb)	193.0	(12.12)	Cr	(ppb) 30.0 (3.77)
Mn	(ppb)			Rb	(ppb)
Se	(ppb)	49.2	(6.74)	Sc	(ppb) 0.20 (0.0161)
Hg	(ppb)	1.93	(0.406)	Eu	(ppb)
Cs	(ppb)			Ga	(ppb) 5.7 (0.26)
Br	(ppb)	120.0	(2.84)		
As	(ppb)	5.562	(0.356)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 36
 Field (pool): Medicine River (Basal Quartz B)
 Stratigraphic unit: L. Cretaceous, Mannville Gp., Ellerslie Fm.
 Well name: Hudson's Bay Medicine R 10-28-39-3
 Location: Tsd 10 Sec 28 Twp 39 Rge 3 W 5 Mer
 Source of sample: Tubing Pressure: 1235 psig Temperature: 40 °F
 Method of production: Flowing Depth: 6984-6990 ft.
 Date sampled: 22nd Oct. 1970

Remarks:

S	(%)	1.567	(0.1163)	
V	(ppm)	20.88	(0.1983)	
Cl	(ppm)	5.034	(0.7802)	
Na	(ppm)	1.766	(0.0122)	
Fe	(ppm)			
Ni	(ppm)	8.06	(0.202)	
Zn	(ppb)	85.31	(21.00)	Au (ppb)
Co	(ppb)	3.57	(1.00)	Sb (ppb)
I	(ppb)			Cr (ppb)
Mn	(ppb)	50.76	(1.094)	Rb (ppb)
Se	(ppb)	80.2	(9.72)	Sc (ppb)
Hg	(ppb)		(9.72)	Eu (ppb)
Cs	(ppb)			Ga (ppb)
Bi	(ppb)	47.4	(2.40)	
As	(ppb)	2.78	(0.510)	

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 37
 Field (pool): Caroline (Basal Mannville B)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp.
 Well name: Altana Caroline 4-2-35-6
 Location: Lsd 4 Sec 2 Twp 35 Rge 6 W 5 Mer
 Source of sample: Separator Pressure: 1050 psig Temperature: 16 °F
 Method of production: Flowing Depth: 9454-9459 ft.
 Date sampled: 12th Nov. 1970
 Remarks:

S	(%)		
V	(ppm)		
Cl	(ppm)	0.634	(0.135)
Na	(ppm)	0.033	(0.001)
Fe	(ppm)		
Ni	(ppm)		
Zn	(ppb)	17.5	(5.56)
Co	(ppb)	0.776	(0.154)
I	(ppb)		
Mn	(ppb)		
Se	(ppb)		
Hg	(ppb)		
Cs	(ppb)	0.486	(0.241)
Br	(ppb)	1.75	(0.133)
As	(ppb)		
Au	(ppb)		
Sb	(ppb)		
Cr	(ppb)	4.66	(1.36)
Rb	(ppb)		
Sc	(ppb)		
Eu	(ppb)	0.290	(0.106)
Ga	(ppb)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 38
 Field (pool): Malmo (Blairmore A)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp.
 Well name: Sun M and C Malmo 6-14B-44-22
 Location: Tsd 6 Sec 14 Twp 44 Rge 22 W 4 Mer
 Source of sample: Tubing Pressure: 35 psig Temperature: 20°F
 Method of production: Pump Depth: 4708-4721 ft. (open hole)
 Date sampled: 3rd Nov. 1970
 Remarks: Formation water and emulsion on bottom of original container

S	(%)	0.736	(0.0550)		
V	(ppm)	1.140	(0.0156)		
Cl	(ppm)	8.552	(0.2572)		
Na	(ppm)	0.927	(0.0070)		
Fe	(ppm)	0.507	(0.116)		
Ni	(ppm)	1.342	(0.0411)		
Zn	(ppb)	31.9	(6.56)	Au	(ppb)
Co	(ppb)	2.30	(0.244)	Sb	(ppb)
I	(ppb)	19.01	(5.084)	Cr	(ppb) 9.52 (3.09)
Mn	(ppb)	72.76	(1.276)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.518 (0.1109)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	26.6	(1.19)		
As	(ppb)	3.36	(0.433)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 39
 Field (pool): Cessford (Mannville C)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp.
 Well name: HB Delhi Cessford 1-27-25-12
 Location: Lsd 1 Sec 27 Twp 25 Rge 12 W 4 Mer
 Source of sample: Tubing Pressure: 212 psig Temperature: 44°F
 Method of production: Pump Depth: 3364-3370 ft. (perforations)
 Date sampled: 11th March 1970
 Remarks: Formation water and emulsion on bottom of original container

S	(%)	1.553	(0.1276)		
V	(ppm)	28.58	(0.2984)		
Cl	(ppm)	25.50	(1.114)		
Na	(ppm)	0.018	(0.0002)		
Fe	(ppm)	1.135	(0.185)		
Ni	(ppm)	14.96	(0.242)		
Zn	(ppb)	510.0	(20.3)	Au	(ppb)
Co	(ppb)	17.34	(0.69)	Sb	(ppb)
I	(ppb)			Cr	(ppb) 41.0 (6.18)
Mn	(ppb)	60.11	(1.553)	Rb	(ppb)
Se	(ppb)	127.2	(7.57)	Sc	(ppb) 0.023 (0.0066)
Hg	(ppb)			Eu	(ppb) 0.661 (0.141)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)				
As	(ppb)	0.020			

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 40
 Field (pool): Coutts (Moulton B)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp., Moulton Ss.
 Well name: Camac May Coutts 3-28-1-16
 Location: Lsd 3 Sec 28 Twp 1 Rge 16 W 4 Mer
 Source of sample: Tubing Pressure: 25 psig Temperature: cold °F
 Method of production: Pump Depth: 2505-2514 ft.
 Date sampled: 25th March 1970
 Remarks:

S	(%)	1.235	(0.0852)		
V	(ppm)	11.75	(0.1152)		
Cl	(ppm)	4.312	(0.1820)		
Na	(ppm)	0.398	(0.0046)		
Fe	(ppm)				
Ni	(ppm)	1.80	(0.043)		
Zn	(ppb)	821.0	(15.85)	Au	(ppb)
Co	(ppb)	1.984	(0.1763)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	47.18	(0.9589)	Rb	(ppb)
Se	(ppb)	25.06	(2.28)	Sc	(ppb)
Hg	(ppb)	2.02	(0.834)	Eu	(ppb) 0.214 (0.0850)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	2.19	(0.345)		
As	(ppb)	46.6	(0.662)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 41
 Field (pool): Red Coulee (Cut Bank B)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp., Cut Bank Ss.
 Well name: Salt Dome 2 Milk River 12-3-1-17
 Location: Lsd 12 Sec 3 Twp 1 Rge 17 W 4 Mer
 Source of sample: Tubing Pressure: 100 psig Temperature: cold°F
 Method of production: Pump Depth: 2733-2743 ft. (perforations)
 Date sampled: 11th Aug. 1970
 Remarks:

S	(%)	1.686	(0.1208)		
V	(ppm)	38.00	(0.4020)		
Cl	(ppm)	6.406	(0.2465)		
Na	(ppm)	0.685	(0.0116)		
Fe	(ppm)	0.534	(0.1194)		
Ni	(ppm)	13.44	(0.232)		
Zn	(ppb)	1277.0	(19.8)	Au	(ppb)
Co	(ppb)	8.754	(1.086)	Sb	(ppb) 3.030 (0.332)
I	(ppb)			Cr	(ppb) 36.12 3.70
Mn	(ppb)	64.96	(0.9730)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	0.940	(0.40)	Ga	(ppb)
Br	(ppb)	9.90	(1.27)		
As	(ppb)	1988.0	(12.4)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 42
 Field (pool): Turner Valley (-)
 Stratigraphic unit: L. Cretaceous, Blairmore Gp.
 Well name: Miracle 3
 Location: Lsd 11 Sec 4 Twp 19 Rge 2 W 5 Mer
 Source of sample: Tank-thief hatch Pressure: nil psig Temperature: 80 °F
 Method of production: Pump Depth: 4787 ft.
 Date sampled: 25th June 1970
 Remarks: This well only produces periodically. The sample came from the top of the tank and should be new oil. Last produced 22nd June, 1970.

S	(%)	0.085	(0.0204)		
V	(ppm)	0.017	(0.0023)		
Cl	(ppm)	3.854	(0.1591)		
Na	(ppm)	0.351	(0.0086)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	44.7	(5.17)	Au	(ppb)
Co	(ppb)	2.13	(0.322)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	58.67	(0.9010)	Rb	(ppb)
Se	(ppb)	20.9	(2.0)	Sc	(ppb)
				0.056	(0.016)
Hg	(ppb)			Eu	(ppb)
				0.377	(0.135)
Cs	(ppb)	1.45	(0.374)	Ga	(ppb)
				9.43	(0.783)
Br	(ppb)	15.12	(1.033)		
As	(ppb)	46.18	(1.24)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 43
 Field (pool): Athabasca oil sand deposit
 Stratigraphic unit: L. Cretaceous, Mannville Gp., McMurray Fm.
 Well name: -
 Location: Lsd - Sec - Twp - Rge - W - Mer
 Source of sample: - Pressure: - psig Temperature: - °F
 Method of production: - Depth: - ft.
 Date sampled: -
 Remarks:

S	(%)		
V	(ppm)		
Cl	(ppm)		
Na	(ppm) 40.33	(0.353)	
Fe	(ppm) 141.7	(4.48)	
Ni	(ppm) 74.11	(1.43)	
Zn	(ppb)		Au (ppb)
Co	(ppb) 1349.0	(52.6)	Sb (ppb) 30.61 (4.77)
I	(ppb)		Cr (ppb) 1014.0 (31.3)
Mn	(ppb)		Rb (ppb) 377.5 (91.3)
Se	(ppb) 286.4	(26.72)	Sc (ppb) 199.0 (2.13)
Hg	(ppb) 81.7	(19.4)	Eu (ppb) 9.0 (1.3)
Cs	(ppb) 25.9	(5.80)	Ga (ppb) 315.0 (11.3)
Br	(ppb) 155.3	(23.42)	
As	(ppb) 400.3	(13.4)	

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 35
 Field (pool): Gilby (Basal Mannville B)
 Stratigraphic unit: L. Cretaceous, Lower Mannville Gp.
 Well name: Richfield Gabriel Lake 7-29
 Location: Lsd 7 Sec 29 Twp 40 Rge 3 W 5 Mer
 Source of sample: Wellhead Pressure: 90 psig Temperature: 60 °F
 Method of production: Pump Depth: 7015-7035 ft. (perforations)
 Date sampled: 2nd July 1970
 Remarks:

S	(%)	1.391	(0.112)		
V	(ppm)	36.0	(0.32)		
Cl	(ppm)	34.5	(0.840)		
Na	(ppm)	3.545	(0.028)		
Fe	(ppm)	0.593	(0.161)		
Ni	(ppm)	13.32	(0.214)		
Zn	(ppb)	262.2	(13.0)	Au	(ppb)
Co	(ppb)	5.524	(0.395)	Sb	(ppb)
I	(ppb)	179.2	(30.9)	Cr	(ppb)
Mn	(ppb)	52.9	(0.882)	Rb	(ppb)
Se	(ppb)	143.6	(8.31)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	82.4	(2.8)		
As	(ppb)	9.9	(1.167)		

* Relative standard deviation (counting statistics) in parenthesis

ADDITIONAL DATA - Sample No. 43

Oil sand sample from Syncrude Canada Ltd. Extracted in Soxhlet extractor with benzene, centrifuged, and evaporated down at room temperature.

Asphaltenes: 17.1%

<u>Composition of asphaltenes:</u>	C	79.41%
	H	8.03%
	N	1.89%
	O (direct)	3.11%
	S	7.56%
	Ash	7.11%

EPR of total oil:

Number of spins/gm	6.1×10^{17}
g-value	2.00320
Response width	6.4 gauss
Total V^{4+}	$483 \mu\text{g/g}$

EPR of asphaltenes:

Number of spins/gm	2.6×10^{18}
g-value	2.00305
Response width	6.4 gauss
Total V^{4+}	$1740 \mu\text{g/g}$

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 44
 Field (pool): Gilby (Jurassic B)
 Stratigraphic unit: L. Jurassic, Nordegg Fm.
 Well name: Uno-Tex Gilby 4-30-40-3
 Location: Lsd 4 Sec 30 Twp 40 Rge 3 W 5 Mer
 Source of sample: Wellhead Pressure: 150 psig Temperature: 50 °F
 Method of production: Pump Depth: 7055-7062; ft. (perforations)
 Date sampled: 2nd July, 1970 7066-7076
 Remarks:

S	(%)	1.561	(0.1144)		
V	(ppm)	32.49	(0.3319)		
Cl	(ppm)	12.28	(0.7645)		
Na	(ppm)	2.292	(0.022)		
Fe	(ppm)	0.783	(0.138)		
Ni	(ppm)	11.15	(0.147)		
Zn	(ppb)	401.1	(7.56)	Au	(ppb)
Co	(ppb)	4.90	(0.367)	Sb	(ppb)
I	(ppb)			Cr	(ppb) 18.95 (3.43)
Mn	(ppb)	28.48	(0.7504)	Rb	(ppb)
Se	(ppb)	55.22	(4.20)	Sc	(ppb) 0.045 (0.015)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb) 11.0 (0.677)
Br	(ppb)	150.0	(3.75)		
As	(ppb)	23.60	(1.082)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 45
 Field (pool): Medicine River (Jurassic A)
 Stratigraphic unit: L. Jurassic, Nordegg Fm.
 Well name: HB RO Corp Medicine R 7-32-39-3
 Location: Lsd 7 Sec 32 Twp 39 Rge 3 W 5 Mer
 Source of sample: Wellhead Pressure: 31 psig Temperature: 50 °F
 Method of production: Pump Depth: 7036-7056 ft. (perforations)
 Date sampled: 18th June 1970
 Remarks:

S	(%)	1.438	(0.1252)		
V	(ppm)	33.45	(0.3392)		
Cl	(ppm)	8.967	(0.3249)		
Na	(ppm)	0.725	(0.0121)		
Fe	(ppm)	0.580	(0.19)		
Ni	(ppm)	14.36	(0.317)		
Zn	(ppb)	651.0	(19.2)	Au	(ppb)
Co	(ppb)	7.69	(0.665)	Sl	(ppb)
I	(ppb)	44.39	(7.266)	Cr	(ppb) 16.5 (4.13)
Mn	(ppb)	49.80	(0.9502)	Rb	(ppb)
Se	(ppb)	94.20	(5.29)	Sc	(ppb) 0.090 (0.0277)
Hg	(ppb)	.		Eu	(ppb)
Cs	(ppb)	1.59	(0.583)	Ga	(ppb)
Br	(ppb)	36.94	(1.69)		
As	(ppb)	8.64	(0.530)		

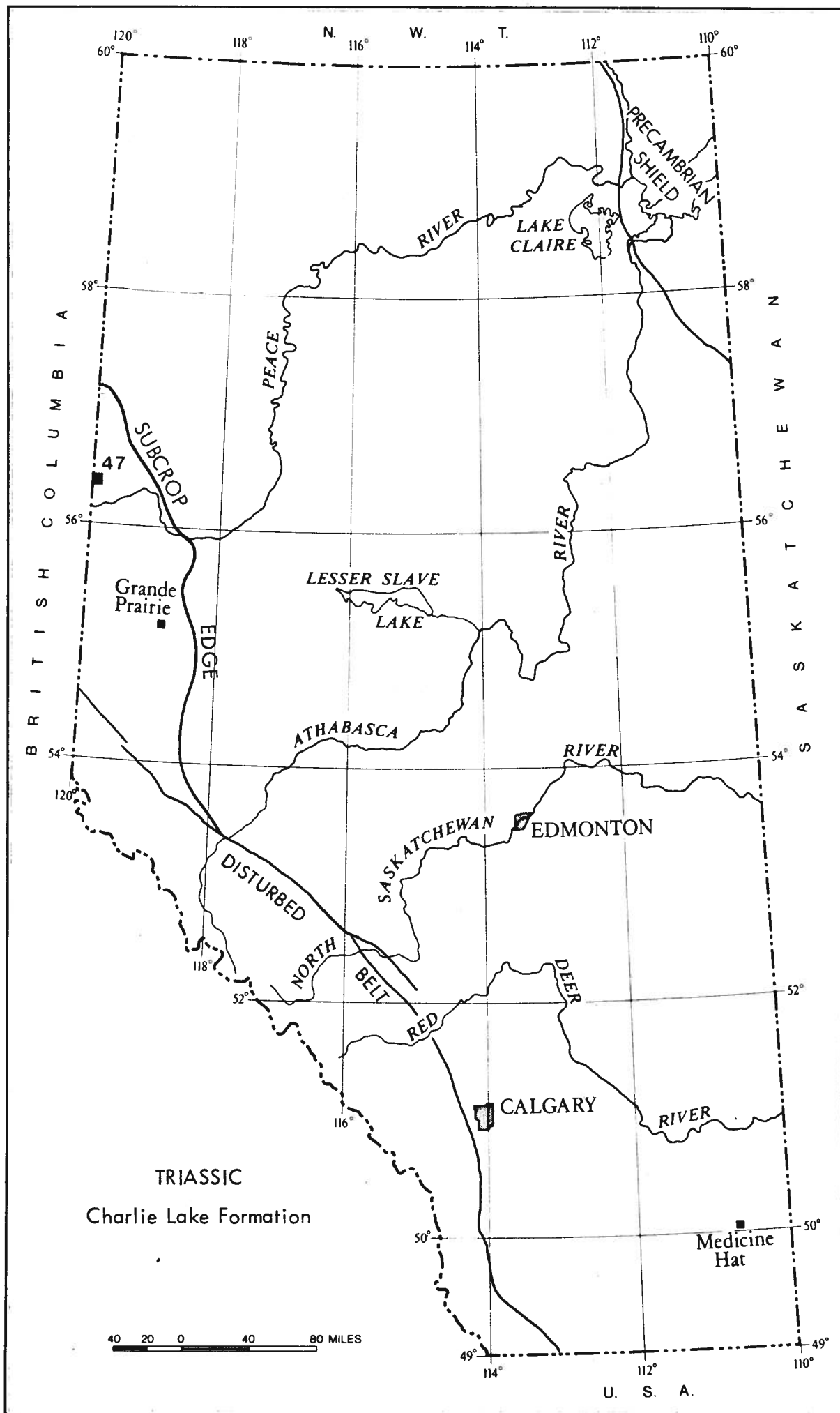
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 46
 Field (pool): Conrad (Ellis)
 Stratigraphic unit: L. Jurassic, Ellis Gp., Sawtooth Fm.
 Well name: Joe Phillips Conrad 7-4-6-15
 Location: Lsd 7 Sec 4 Twp 6 Rge 15 W 4 Mer
 Source of sample: Wellhead - tubing Pressure: _ psig Temperature: _ °F
 Method of production: Flowing Depth: 2990-2992 ft. (perforations)
 Date sampled: 12th August, 1969
 Remarks: Considerable amount of sand and silt in original container.

S	(%)	2.445	(0.224)		
V	(ppm)	71.84	(0.572)		
Cl	(ppm)	10.40	(0.308)		
Na	(ppm)	14.52	(0.2801)		
Fe	(ppm)				
Ni	(ppm)	24.87	(0.296)		
Zn	(ppb)	119.0	(10.6)	Au	(ppb)
Co	(ppb)	16.82	(0.616)	Sb	(ppb)
I	(ppb)	25.37	(6.63)	Cr	(ppb) 98.11 (7.88)
Mn	(ppb)	38.6	(0.931)	Rb	(ppb)
Se	(ppb)	139.8	(7.463)	Sc	(ppb) 0.20 (0.0253)
Hg	(ppb)			Eu	(ppb) 0.571 (0.161)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	40.30	(12.61)		
As	(ppb)	235.4	(9.732)		

* Relative standard deviation (counting statistics) in parenthesis

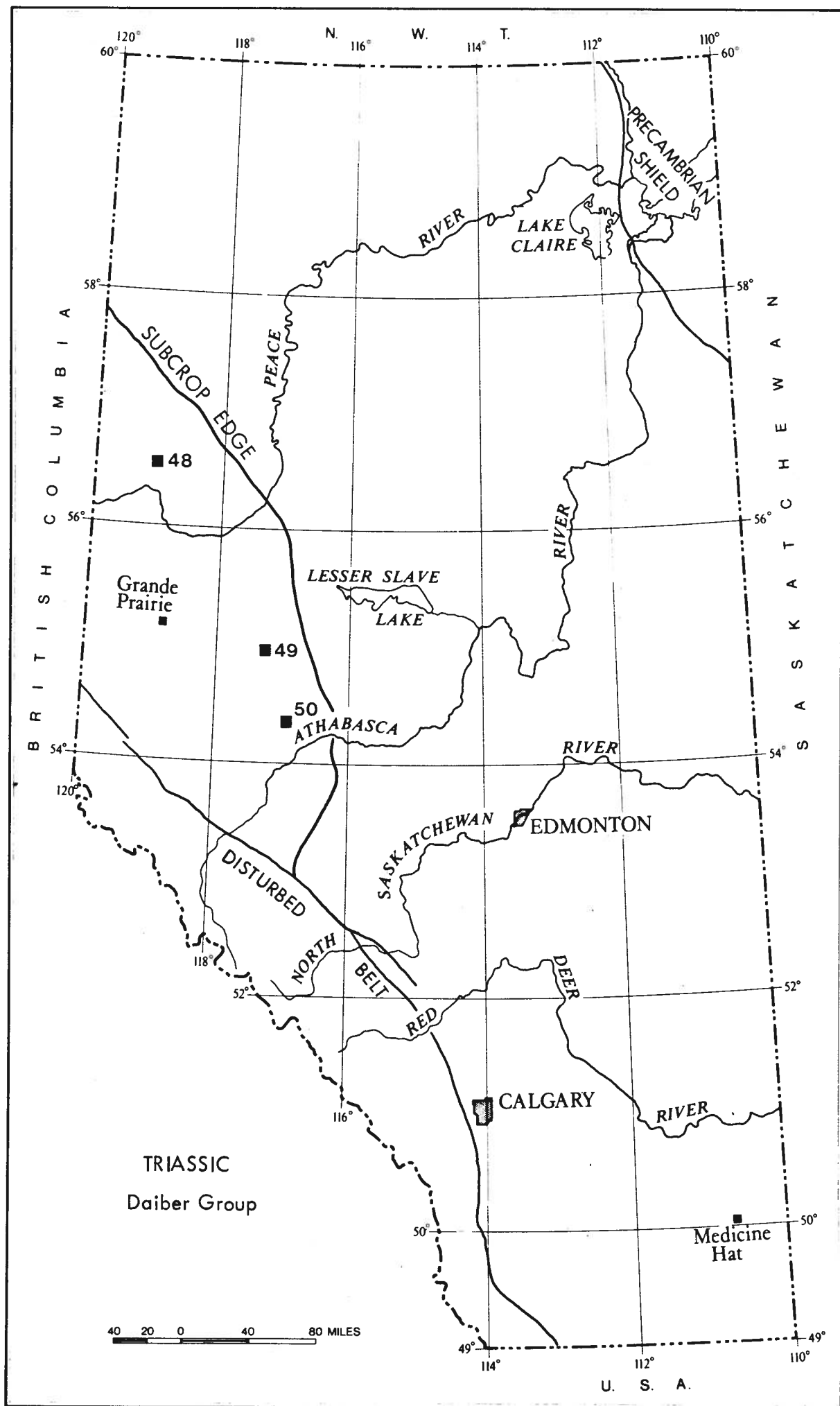


TRACE ELEMENTS IN ALBERTA CRUDE OILS --- DATA SHEET

Sample number: 47
 Field (pool): Boundary Lake South (Triassic E)
 Stratigraphic unit: U. Triassic, Charlie Lake Fm., Boundary Mbr.
 Well name: Imp. Pan Am Bdy Lk S 6-11-85-13
 Location: Lsd 6 Sec 11 Twp 85 Rge 13 W 6 Mer
 Source of sample: Tubing Pressure: 100 psig Temperature: 50 °F
 Method of production: Pump Depth: 4354-4360 ft. (perforations)
 Date sampled: 23rd July 1970
 Remarks:

S	(%)	1.030	(0.0862)		
V	(ppm)	47.39	(0.4054)		
Cl	(ppm)	13.22	(0.4575)		
Na	(ppm)	4.367	(0.0716)		
Fe	(ppm)	2.44	(0.100)		
Ni	(ppm)	14.2	(0.214)		
Zn	(ppb)	924.1	(16.82)	Au	(ppb)
Co	(ppb)	14.50	(0.118)	Sb	(ppb) 1.03 (0.172)
I	(ppb)	99.64	(8.361)	Cr	(ppb) 31.47 (2.09)
Mn	(ppb)	76.35	(1.448)	Rb	(ppb)
Se	(ppb)	161.0	(6.87)	Sc	(ppb) 0.112 (0.010)
Hg	(ppb)			Eu	(ppb) 0.28 0.050
Cs	(ppb)	1.232	(0.261)	Ga	(ppb)
Br	(ppb)	54.15	(3.69)		
As	(ppb)	244.3	(5.20)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 48

Field (pool): Worsley (Triassic A)

Stratigraphic unit: Triassic, Daiber Gp.

Well name: Shell Worsley 6-25-87-7

Location: Lsd 6 Sec 25 Twp 87 Rge 7 W 6 Mer

Source of sample: Treater Pressure: 5 psig Temperature: 60 °F

Method of production: - Depth: 3293-3304 ft. (perforations)

Date sampled: 23rd July 1970

Remarks: The well has been shut-in since February, 1970, so this is a February sample, stored for 5 months in the treater. The following chemicals were added to this oil: Treatolite R25, 1 quart per 50 bbls; Alchem 339, 1 bbl per 250 bbls.

S	(%)	1.397	(0.1164)		
V	(ppm)	23.66	(0.2387)		
Cl	(ppm)	10.48	(0.4518)		
Na	(ppm)	0.203	(0.0047)		
Fe	(ppm)				
Ni	(ppm)	10.78	(0.27)		
Zn	(ppb)	965.5	(28.8)	Au	(ppb)
Co	(ppb)	7.64	(0.723)	Sb	(ppb)
I	(ppb)	59.51	(9.646)	Cr	(ppb) 24.7 (5.531)
Mn	(ppb)	40.94	(1.274)	Rb	(ppb)
Se	(ppb)	70.0	(5.94)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	32.43	(1.26)		
As	(ppb)	5.25	(0.360)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 49

Field (pool): Sturgeon Lake South (Triassic A)

Stratigraphic unit: Triassic, Daiber Gp.

Well name: Amerada HB Union Crown Y 5-12

Location: Tsd 5 Sec 12 Twp 69 Rge 22 W 5 Mer

Source of sample: Treater Pressure: 30 psig Temperature: 80 °F

Method of production: Pump Depth: 4934-4944 ft. (perforations)

Date sampled: 10th July 1969

Remarks:

S	(%)	1.138	(0.11)		
V	(ppm)	26.03	(0.27)		
Cl	(ppm)	7.96	(0.301)		
Na	(ppm)	0.347	(0.0032)		
Fe	(ppm)				
Ni	(ppm)	6.66	(0.077)		
Zn	(ppb)	1274.0	(14.4)	Au	(ppb)
Co	(ppb)	1.53	(0.075)	Sb	(ppb)
I	(ppb)	150.0	(9.1)	Cr	(ppb) 13.0 (1.88)
Mn	(ppb)			Rb	(ppb)
Se	(ppb)	36.9	(2.0)	Sc	(ppb)
Hg	(ppb)	6.34	(1.78)	Eu	(ppb) 0.084 (0.025)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	27.9	(0.867)		
As	(ppb)	8.50	(0.372)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 50

Field (pool): Kaybob South (Triassic A)

Stratigraphic unit: Triassic, Daiber Gp.

Well name: HB Union Kaybob S 10-9-62-20

Location: Lsd 10 Sec 9 Twp 62 Rge 20 W5 Mer

Source of sample: Tubing Pressure: - psig Temperature: 60 °F

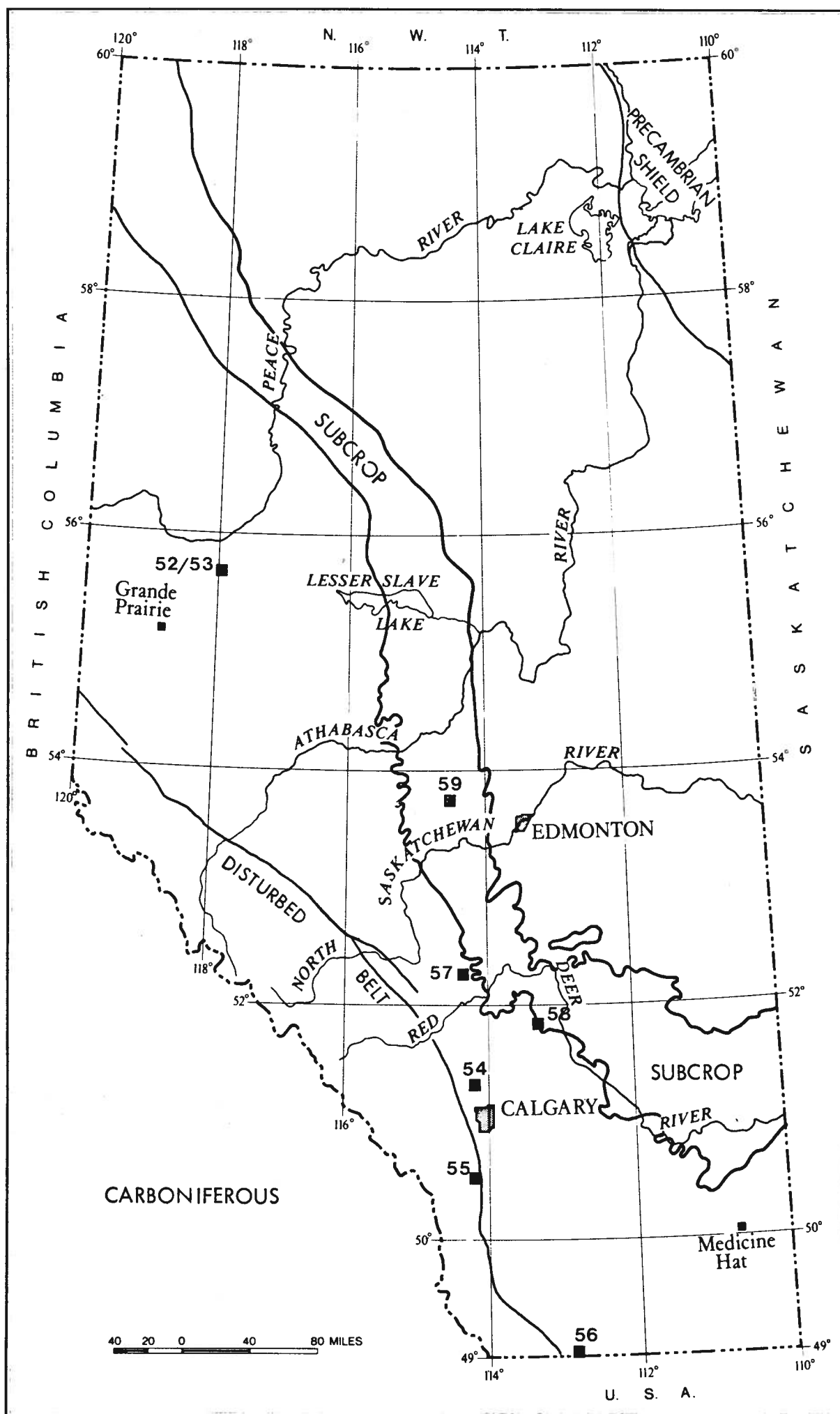
Method of production: Flowing Depth: 6942-6969 ft. (perforations)

Date sampled: 21st July 1970

Remarks:

S	(%)	0.667	(0.0443)		
V	(ppm)	0.185	(0.0046)		
Cl	(ppm)	10.29	(0.236)		
Na	(ppm)	0.119	(0.0026)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	53.0	(7.7)	Au	(ppb)
Co	(ppb)	0.696	(0.261)	Sb	(ppb)
I	(ppb)	14.21	(3.075)	Cr	(ppb)
Mn	(ppb)	24.30	(0.582)	Rb	(ppb)
Se	(ppb)	8.270	(2.122)	Sc	(ppb) 0.150 (0.020)
Hg	(ppb)	3.79	(1.16)	Eu	(ppb)
Cs	(ppb)	1.391	(0.4304)	Ga	(ppb)
Br	(ppb)	4.70	(0.336)		
As	(ppb)	2.443	(0.169)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 52
 Field (pool): Eaglesham (Debolt D)
 Stratigraphic unit: Carboniferous, Rundle Gp., Debolt Fm.
 Well name: HB Union Eaglesham 6-14 MU 77-25
 Location: Lsd 6 Sec 14 Twp 77 Rge 25 W 5 Mer
 Source of sample: Flowline Pressure: 100 psig Temperature: 65 °F
 Method of production: Pump Depth: 4900-4927 ft. (perforations)
 Date sampled: 5th Aug. 1970
 Remarks: Silt at bottom of original container

S	(%)	0.693	(0.0482)		
V	(ppm)	3.871	(0.0385)		
Cl	(ppm)	4.701	(0.1687)		
Na	(ppm)	3.07	(0.029)		
Fe	(ppm)	0.120	(0.041)		
Ni	(ppm)	5.18	(0.066)		
Zn	(ppb)	432.5	(7.83)	Au	(ppb)
Co	(ppb)	0.811	(0.095)	Sb	(ppb)
I	(ppb)	27.50	(3.247)	Ci	(ppb)
Mn	(ppb)	53.26	(1.094)	Rb	(ppb)
Se	(ppb)	13.4	(1.39)	Sc	(ppb) 0.013 (0.006)
Hg	(ppb)	1.9	(0.79)	Eu	(ppb) 0.11 (0.0373)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	76.7	(3.8)		
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 53
 Field (pool): Eaglesham (Debolt C)
 Stratigraphic unit: Carboniferous, Rundle Gp., Debolt Fm.
 Well name: HB Union Eaglesham 6-14-MU-77-25
 Location: Lsd 6 Sec 14 Twp 77 Rge 25 W 5 Mer
 Source of sample: Casing Pressure: 100 psig Temperature: 60 °F
 Method of production: Pump Depth: 4684-4721 ft. (perforations)
 Date sampled: 22nd July 1970
 Remarks: Well shut in at time of sampling; normally produces from tubing

S	(%)	0.382	(0.0752)		
V	(ppm)	1.893	(0.033)		
Cl	(ppm)	13.81	(0.723)		
Na	(ppm)	0.211	(0.004)		
Fe	(ppm)				
Ni	(ppm)	1.14	(0.039)		
Zn	(ppb)	123.0	(9.124)	Au	(ppb)
Co	(ppb)	3.46	(0.292)	Sb	(ppb)
I	(ppb)	174.2	(23.0)	Cr	(ppb)
Mn	(ppb)	5.40	(0.41)	Rb	(ppb)
Se	(ppb)	4.06	(2.02)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	50.2	(1.40)		
As	(ppb)	8.521	(0.374)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 54
 Field (pool): Crossfield (Rundle C)
 Stratigraphic unit: Carboniferous, Rundle Gp., Turner Valley Fm.
 Well name: Triad et al Cross 8-11-27-2
 Location: Lsd 8 Sec 11 Twp 27 Rge 2 W 5 Mer
 Source of sample: Separator Pressure: 30 psig Temperature: 63 °F
 Method of production: Flowing Depth: 8577-8591 ft. (perforations)
 Date sampled: 23rd June 1970
 Remarks:

S	(%)	0.653	(0.0516)		
V	(ppm)	0.068	(0.0029)		
Cl	(ppm)	5.432	(0.2089)		
Na	(ppm)	0.128	(0.0027)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)	29.0	(7.9)	Au	(ppb)
Co	(ppb)	1.016	(0.254)	Sb	(ppb)
I	(ppb)	8.735	(3.169)	Cr	(ppb)
Mn	(ppb)	46.65	(0.8495)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	3.38	(0.394)		
As	(ppb)	7.852	(0.329)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 55
 Field (pool): Turner Valley (Rundle)
 Stratigraphic unit: Carboniferous, Rundle Gp., Turner Valley Fm.
 Well name: Royalite 39
 Location: Lsd 3 Sec 29 Twp 18 Rge 2 W 5 Mer
 Source of sample: Wellhead Pressure: 100 psig Temperature: 40 °F
 Method of production: Pump Depth: 7600-8039 ft. (open hole)
 Date sampled: 12th June 1969
 Remarks:

S	(%)	0.377	(0.0233)	
V	(ppm)	0.028	(0.0022)	
Cl	(ppm)	5.292	(0.214)	
Na	(ppm)	0.065	(0.001)	
Fe	(ppm)			
Ni	(ppm)			
Zn	(ppb)			Au (ppb)
Co	(ppb)			Sb (ppb)
I	(ppb)			Cr (ppb)
Mn	(ppb)	100.7	(1.88)	Rb (ppb)
Se	(ppb)			Sc (ppb)
Hg	(ppb)			Eu (ppb)
Cs	(ppb)			Ga (ppb)
Br	(ppb)	2.26	(0.210)	
As	(ppb)	36.3	(0.426)	

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 56
 Field (pool): Del Bonita (Rundle)
 Stratigraphic unit: Carboniferous, Rundle Gp.
 Well name: National Cordasun Milk River 3
 Location: Lsd 9 Sec24 Twp 1 Rge22 W 4 Mer
 Source of sample: Tubing Pressure: 10 psig Temperature: cold F
 Method of production: Pump Depth: 5143-5196 ft. (perforations)
 Date sampled: 25th March 1970
 Remarks: Formation water in original container

S	(%)	0.72	(0.0528)		
V	(ppm)	0.336	(0.0080)		
Cl	(ppm)	4.252	(0.2630)		
Na	(ppm)	0.160	(0.0027)		
Fe	(ppm)				
Ni	(ppm)	0.136	(0.0265)		
Zn	(ppb)	51.0	(10.6)	Au	(ppb)
Co	(ppb)	0.886	(0.278)	Sb	(ppb) 3.262 (0.785)
I	(ppb)			Cr	(ppb) 13.14 (3.34)
Mn	(ppb)	50.79	(0.8219)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.542 (0.1411)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	7.94	(0.635)		
As	(ppb)	1218.0	(7.20)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 57
 Field (pool): Sylvan Lake (Pekisko B)
 Stratigraphic unit: Carboniferous, Rundle Gp., Pekisko Fm.
 Well name: HB Sylvan Lake 4-16-38-3
 Location: Lsd 4 Sec 16 Twp 38 Rge 3 W 5 Mer
 Source of sample: Wellhead Pressure: 380 psig Temperature: 50 °F
 Method of production: Flowing Depth: 7348-7354 ft. (perforations)
 Date sampled: 24th June 1969
 Remarks:

S	(%)	1.495	(0.127)				
V	(ppm)	17.50	(0.140)				
Cl	(ppm)	15.01	(1.11)				
Na	(ppm)	9.0	(0.180)				
Fe	(ppm)						
Ni	(ppm)	5.64	(0.108)				
Zn	(ppb)	1162.0	(25.8)	Au	(ppb)		
Co	(ppb)	4.484	(0.376)	Sb	(ppb)		
I	(ppb)			Cr	(ppb)		
Mn	(ppb)	5.60	(0.455)	Rb	(ppb)	57.8	(17.3)
Se	(ppb)	67.4	(4.601)	Sc	(ppb)	0.203	(0.0248)
Hg	(ppb)	18.77	(2.76)	Eu	(ppb)	0.335	(0.159)
Cs	(ppb)	1.79	(0.5683)	Ga	(ppb)		
Br	(ppb)	7529.0	(110.8)				
As	(ppb)						

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 58
 Field (pool): Twining North (Rundle)
 Stratigraphic unit: Carboniferous, Rundle Gp., Pekisko Fm.
 Well name: Mic Mac et al Twin N 6-6-33-24
 Location: Lsd 6 Sec 6 Twp 33 Rge 24 W 4 Mer
 Source of sample: Wellhead Pressure: - psig Temperature: cold °F
 Method of production: Pump Depth: 5424-5426 ft. (perforations)
 Date sampled: 6th Nov. 1970
 Remarks: Silt at bottom of original container

S	(%)	1.292	(0.1051)		
V	(ppm)	16.50	(0.1731)		
Cl	(ppm)	13.74	(0.6657)		
Na	(ppm)	4.39	(0.0742)		
Fe	(ppm)				
Ni	(ppm)	7.561	(0.1234)		
Zn	(ppb)	873.0	(22.6)	Au	(ppb)
Co	(ppb)	8.683	(0.5311)	Sb	(ppb)
I	(ppb)	100.9	(24.22)	Cr	(ppb) 19.08 (5.16)
Mn	(ppb)			Rb	(ppb)
Se	(ppb)	57.5	(4.363)	Sc	(ppb) 0.231 (0.0255)
Hg	(ppb)	6.69	(1.2)	Eu	(ppb) 0.417 (0.182)
Cs	(ppb)	2.20	(0.610)	Ga	(ppb)
Br	(ppb)	53.04	(2.73)		
As	(ppb)	5.56	(1.04)		

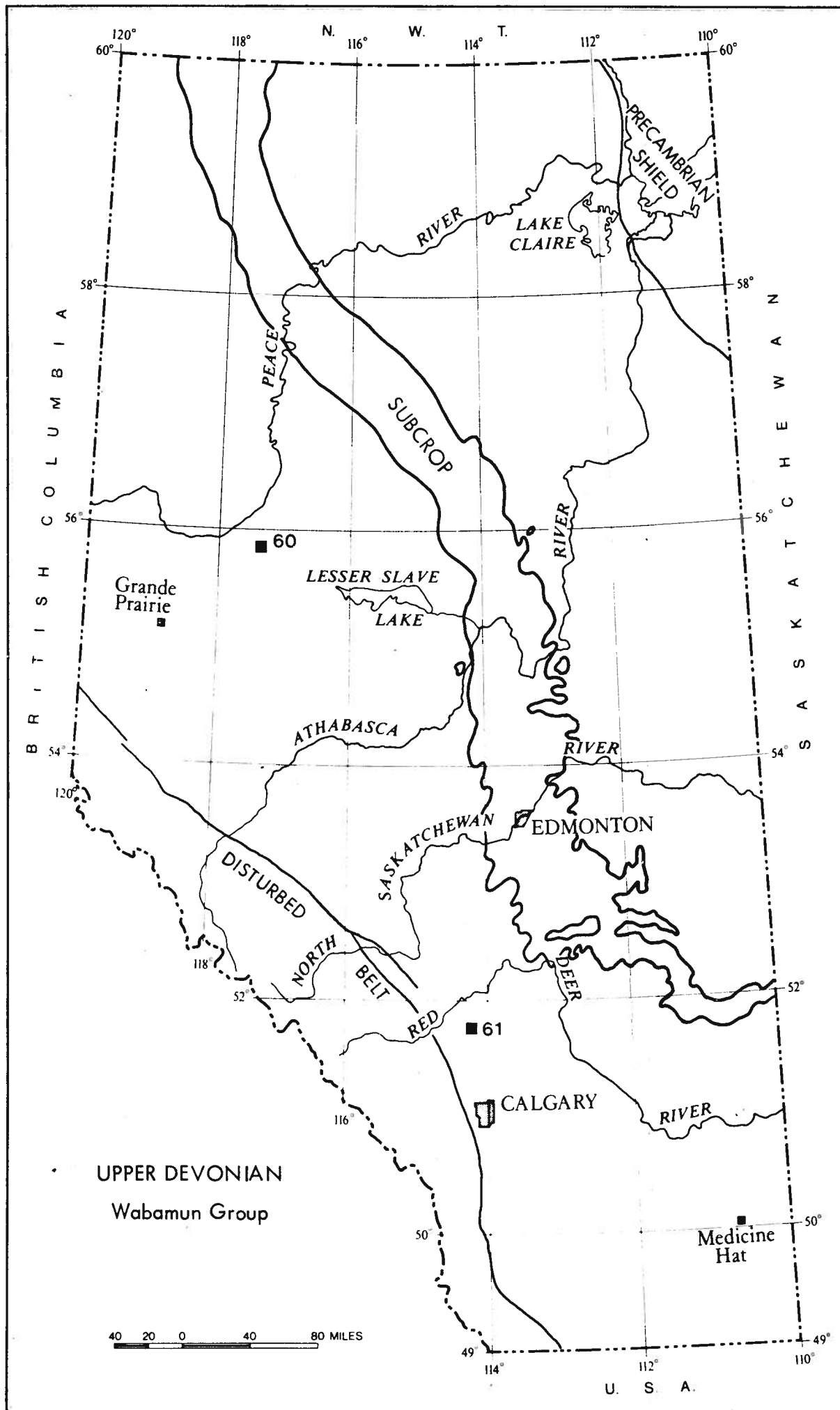
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 59
 Field (pool): Glenevis (Banff)
 Stratigraphic unit: Carboniferous, Banff Fm.
 Well name: Texaco Glenevis 5-35-55-4
 Location: Tsd 5 Sec 35 Twp 55 Rge 4 W 5 Mer
 Source of sample: Test line from header Pressure: - psig Temperature: - °F
 Method of production: Flowing Depth: 4354-4359 ft. (perforations)
 Date sampled: 14th July 1969
 Remarks: Formation water and emulsion at bottom of original container

S	(%)	3.355	(0.8108)		
V	(ppm)	138.8	(1.596)		
Cl	(ppm)	230.3	(3.422)		
Na	(ppm)				
Fe	(ppm)	2.19	(0.202)		
Ni	(ppm)	57.48	(0.870)		
Zn	(ppb)	563.4	(18.84)	Au	(ppb)
Co	(ppb)	60.22	(1.05)	Sb	(ppb) 22.8 (1.29)
I	(ppb)			Cr	(ppb) 78.7 (7.23)
Mn	(ppb)			Rb	(ppb) 28.1 (8.82)
Se	(ppb)	252.3	(14.0)	Sc	(ppb) 0.128 (0.024)
Hg	(ppb)	7.74	(4.32)	Eu	(ppb) 0.493 (0.120)
Cs	(ppb)	9.03	(1.07)	Ga	(ppb)
Br	(ppb)				
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 60
 Field (poci): Normandville (D-1A)
 Stratigraphic unit: U. Devonian, Wabamun Gp.
 Well name: Col OK and Assoc Normand 8-16
 Location: Lsd 8 Sec 16 Twp 79 Rge 22 W 5 Mer
 Source of sample: Tubing Pressure: 20 psig Temperature: 55 °F
 Method of production: Pump Depth: 5762-5802 ft (perforations)
 Date sampled: 22nd July 1970
 Remarks: Well shut in at time of sampling; water at bottom of original container

S	(%)	0.664	(0.0642)		
V	(ppm)	6.828	(0.0703)		
Cl	(ppm)	43.07	(3.001)		
Na	(ppm)	2.589	(0.0416)		
Fe	(ppm)				
Ni	(ppm)	10.94	(0.345)		
Zn	(ppb)	2433.0	(67.6)	Au	(ppb)
Co	(ppb)	44.6	(3.35)	Sb	(ppb)
I	(ppb)	398.7	(11.31)	Cr	(ppb) 15.07 (7.31)
Mn	(ppb)	36.22	(1.176)	Rb	(ppb)
Se	(ppb)	16.33	(4.21)	Sc	(ppb) 0.178 (0.061)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	577.1	(8.18)		
As	(ppb)	23.67	(1.19)		

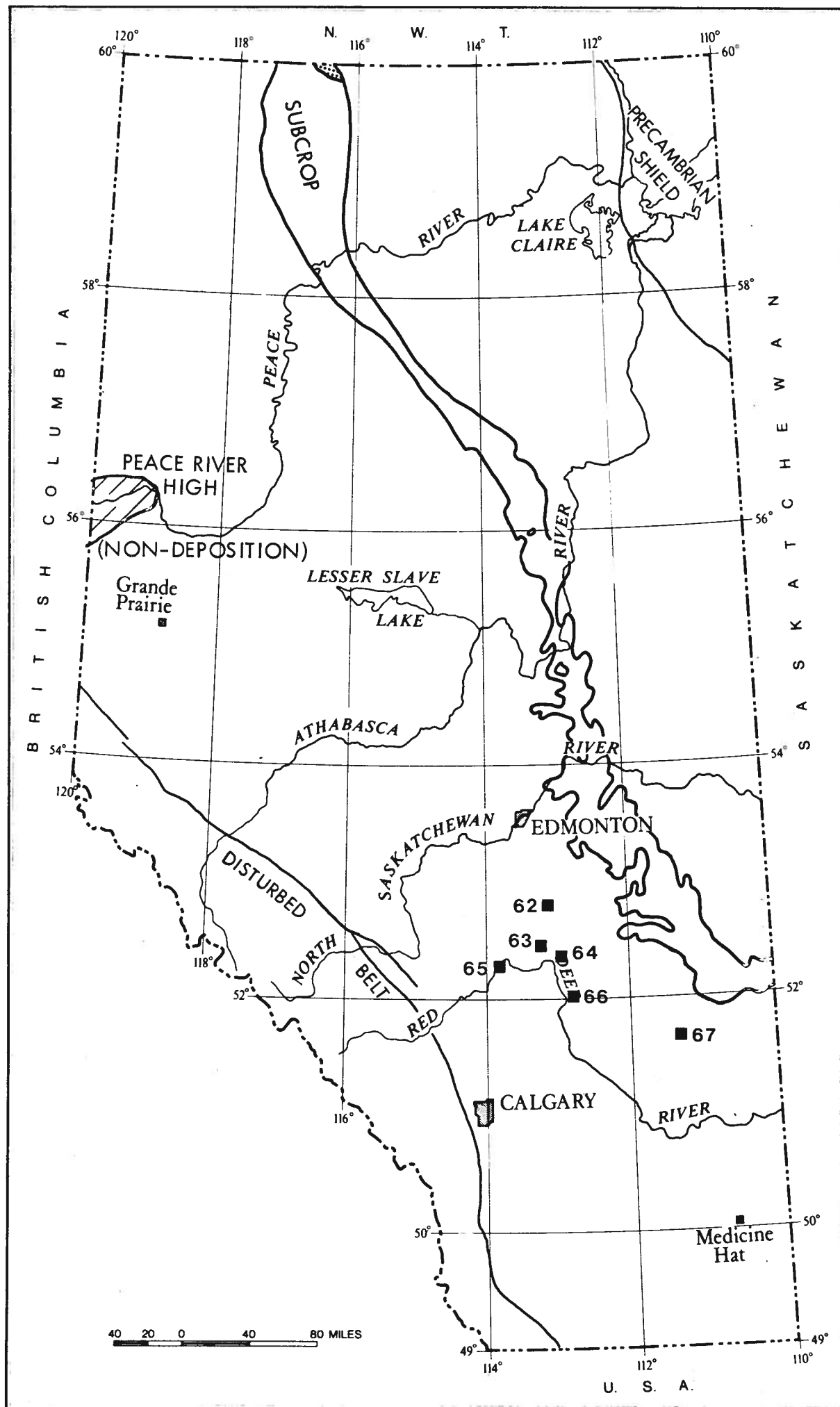
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 61
 Field (pool): Olds (Wabamun A)
 Stratigraphic unit: U. Devonian, Wabamun Gp.
 Well name: Shell Cdn-Sup Olds 10-28W-32-2; Shell Cdn-Sup Olds 10-22W-32-2
 Triad Shell Olds 10-8-33-2
 Location: Lsd 10; 10; Sec 28; 22Twp 32; 32Rge 2 W 5 Mer
 Source of sample: Separator-meter run Pressure: 175 psig Temperature: 82 °F
 Method of production: Flowing Depth: 8953-8984; ft. (perforations)
 8920-8952;
 Date sampled: 8th April 1970 9028-9051
 Remarks:

S	(%)	1.037	(0.0611)		
V	(ppm)	0.015	(0.0015)		
Cl	(ppm)	4.891	(0.1627)		
Na	(ppm)	0.156	(0.0019)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)			Au	(ppb)
Co	(ppb)	0.516	(0.189)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	53.69	(0.9596)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.014 (0.0037)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	0.657	(0.294)	Ga	(ppb)
Br	(ppt)	20.2	(0.585)		
As	(ppb)	10.28	(0.278)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 62
 Field (pool): Malmo (D-2A)
 Stratigraphic unit: U. Devonian, Winterburn Gp., Nisku Fm.
 Well name: Scurry Malmo 5
 Location: Lsd 9 Sec 15 Twp 44 Rge 22 W 4 Mer
 Source of sample: Tubing Pressure: 20 psig Temperature: 35 °F
 Method of production: Pump Depth: 5102-5121 ft. (perforations)
 Date sampled: 22nd May 1970
 Remarks:

S	(%)	0.783	(0.0691)	
V	(ppm)	1.09	(0.0245)	
Cl	(ppm)	15.0	(0.497)	
Na	(ppm)	0.80	(0.0063)	
Fe	(ppm)			
Ni	(ppm)	1.110	(0.0368)	
Zn	(ppb)	40.2	(6.33)	Au (ppb)
Co	(ppb)	2.08	(0.230)	Sb (ppb)
I	(ppb)			Cr (ppb)
Mn	(ppb)	62.36	(0.874)	Rb (ppb)
Se	(ppb)			Sc (ppb)
Hg	(ppb)	5.920	(1.37)	Eu (ppb)
Cs	(ppb)			Ga (ppb)
Br	(ppb)	60.90	(1.473)	
As	(ppb)	21.71	(0.556)	

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 63
 Field (pool): Alix (D-2)
 Stratigraphic unit: U. Devonian, Winterburn Gp., Nisku Fm.
 Well name: Ambass BA Alix 7-7-40-23
 Location: Lsd 7 Sec 7 Twp40 Rge 23 W 4 Mer
 Source of sample: Wellhead Pressure: 390 psig Temperature: 45 °F
 Method of production: Pump Depth: 5974-5981 ft. (perforations)
 Date sampled: 4th Feb. 1970
 Remarks:

S	(%)				
V	(ppm)				
Cl	(ppm)	693.2	(9.364)		
Na	(ppm)	57.76	(0.913)		
Fe	(ppm)	19.77	(0.421)		
Ni	(ppm)	0.531	(0.0474)		
Zn	(ppb)	5921.0	(77.5)	Au	(ppb)
Co	(ppb)	45.04	(0.688)	Sb	(ppb) 34.8 (1.156)
I	(ppb)			Cr	(ppb) 205.8 (4.12)
Mn	(ppb)			Rb	(ppb) 60.0 (9.31)
Se	(ppb)			Sc	(ppb) 0.115 (0.0243)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	12.22	(1.633)	Ga	(ppb)
Br	(ppb)	4.27	(0.165)		
As	(ppb)	1.081	(0.0542)		

* Relative standard deviation (counting statistics) in parenthesis:

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 64
 Field (pool): Erskine (D-2)
 Stratigraphic unit: U. Devonian, Winterburn Gp., Nisku Fm.
 Well name: BA CPR Thom Erskine 8-13-39-21
 Location: Lsd 8 Sec 13 Twp 39 Rge 21 W 4 Mer
 Source of sample: Separator Pressure: 90 psig Temperature: 46 °F
 Method of production: Pump Depth: 5172-5192 ft. (perforations)
 Date sampled: 25th March, 1970
 Remarks:

S	(%)		
V	(ppm)	46.03	(0.4539)
Cl	(ppm)	1014.0	(19.67)
Na	(ppm)	64.70	(1.460)
Fe	(ppm)	1.00	(0.48)
Ni	(ppm)		
Zn	(ppb)	515.6	(30.0)
Co	(ppb)	202.6	(12.3)
I	(ppb)	7335.0	(285.4)
Mn	(ppb)	176.6	(11.30)
Se	(ppb)		
Hg	(ppb)	200.0	(11.2)
Cs	(ppb)	3.0	(0.83)
Br	(ppb)	12470.0	(158.4)
As	(ppb)		
Au	(ppb)		
Sb	(ppb)		
Cr	(ppb)	41.8	(8.25)
Rb	(ppb)		
Sc	(ppb)		
Eu	(ppb)	0.390	(0.100)
Ga	(ppb)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 65
 Field (pool): Joffre (D-2)
 Stratigraphic unit: U. Devonian, Winterburn Gp., Nisku Fm.
 Well name: Imp Joffre 4-36N-38-27
 Location: Lsd 4 Sec 36 Twp 38 Rge 27 W 4 Mer
 Source of sample: Separator Pressure: 74 psig Temperature: 40 °F
 Method of production: Flowing Depth: 7077-7184 ft. (open hole)
 Date sampled: 25th March 1970
 Remarks:

S	(%)	0.354	(0.0216)		
V	(ppm)	0.030	(0.0019)		
Cl	(ppm)	13.34	(0.3865)		
Na	(ppm)	0.091	(0.0011)		
Fe	(ppm)	0.390	(0.123)		
Ni	(ppm)				
Zn	(ppb)	374.0	(15.4)	Au	(ppb)
Co	(ppb)	4.312	(0.261)	Sb	(ppb)
i	(ppb)	727.7	(14.75)	Cr	(ppb) 12.1 (3.0)
Mn	(ppb)	30.58	(3.382)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.067 (0.015)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)	2.17	(0.580)	Ga	(ppb)
Br	(ppb)	16.8	(0.579)		
As	(ppb)	5.34	(0.236)		

* Relative standard deviation (counting statistics) in parentheses

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 66

Field (pool): Fenn-Big Valley (D-2A)

Stratigraphic unit: U. Devonian, Winterburn Gp., Nisku Fm.

Well name: CPR Connor 7

Location: Lsd 7 Sec 23 Twp 35 Rge 20 W 4 Mer

Source of sample: Wellhead - tubing Pressure: 260 psig Temperature: 30 °F

Method of production: Flowing Depth: 5322-5362 ft. (open hole)

Date sampled: 5th Feb. 1970

Remarks:

S	(%)	1.227	(0.0853)		
V	(ppm)	11.80	(0.1)		
Cl	(ppm)	55.9	(1.12)		
Na	(ppm)	0.632	(0.054)		
Fe	(ppm)				
Ni	(ppm)				
Zn	(ppb)			Au	(ppb)
Co	(ppb)			Sb	(ppb)
I	(ppb)	424.7	(23.0)	Cr	(ppb)
Mn	(ppb)	42.4	(1.0)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
					165.0
					(1.873)
Bi	(ppb)	1541.0	(32.6)		
As	(ppb)	392.4	(5.19)		

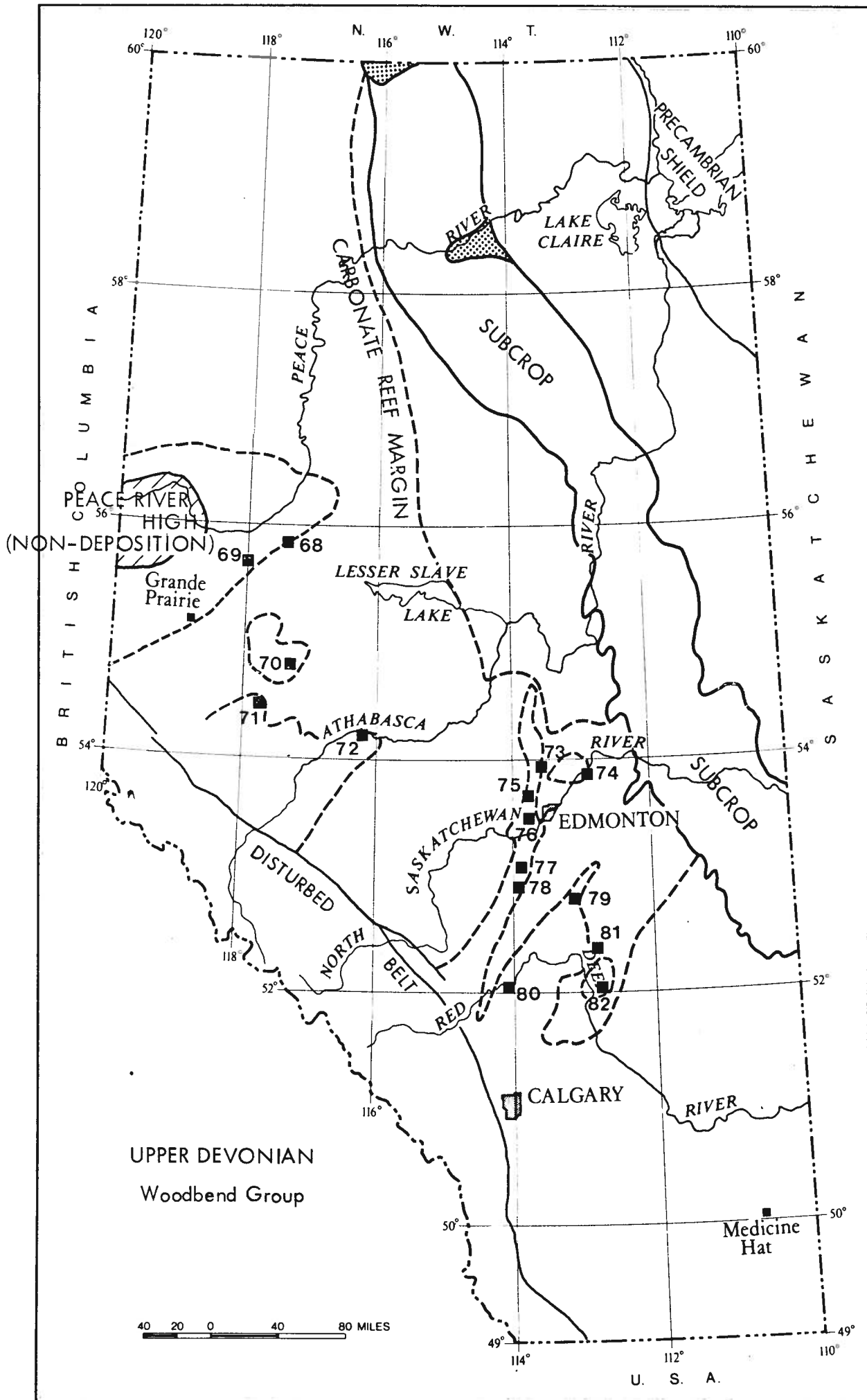
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 67
 Field (pool): Youngstown (Arcs)
 Stratigraphic unit: U. Devonian, Peechee Fm., Ares Mbr.
 Well name: Humber Charter Reist 14-25-31-10
 Location: Lsd 14 Sec 25 Twp 31 Rge 10 W 4 Mer
 Source of sample: Tubing Pressure: - psig Temperature: - °F
 Method of production: Pump Depth: 3708-3720 ft. (open hole)
 Date sampled: 23rd June 1970
 Remarks: Vevsene squeeze job conducted satisfactorily in June, 1978,
 to increase oil production

S	(%)	1.318	(0.1056)		
V	(ppm)	41.27	(0.3747)		
Cl	(ppm)	6.580	(0.2451)		
Na	(ppm)	0.102	(0.0016)		
Fe	(ppm)				
Ni	(ppm)	18.03	(0.240)		
Zn	(ppb)	85.0	(3.8)	Au	(ppb)
Co	(ppb)	15.1	(0.312)	Sb	(ppb) 0.462 (0.160)
I	(ppb)			Cr	(ppb) 29.63 (2.83)
Mn	(ppb)	60.45	(1.0510)	Rb	(ppb)
Se	(ppb)	73.6	(0.270)	Sc	(ppb) 0.10 (0.0074)
Hg	(ppb)	6.89	(0.90)	Eu	(ppb) 0.158 (0.049)
Cs	(ppb)	0.641	(0.262)	Ga	(ppb) 21.2 (0.33)
Br	(ppb)	19.2	(0.700)		
As	(ppb)	25.8	(0.480)		

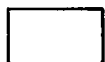
* Relative standard deviation (counting statistics) in parenthesis



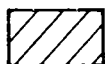
LEGEND



Outcrop



Subcrop



Peace River High (Non-Deposition)

Boundary of Near-Shore Clastics - < - > -

Carbonate Reef Margin - - - - -

Sample Number ■ 28

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 68
 Field (pool): Normandville (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Col OK and Assoc Normand 5-15
 Location: Lsd 5 Sec 15 Twp 79 Rge 22 W 5 Mer
 Source of sample: Tubing Pressure: 400 psig Temperature: 50 °F
 Method of production: Flowing Depth: 6673-6690 ft. (open hole)
 Date sampled: 22nd July 1970
 Remarks:

S	(%)	0.201	(0.029)				
V	(ppm)	1.542	(0.019)				
Cl	(ppm)	39.17	(0.721)				
Na	(ppm)	4.912	(0.0578)				
Fe	(ppm)						
Ni	(ppm)	2.86	(0.051)				
Zn	(ppb)	132.0	(5.5)	Au	(ppb)		
Co	(ppb)	36.5	(0.541)	Sb	(ppb)		
I	(ppb)	2467.0	(35.63)	Cr	(ppb)		
Mn	(ppb)	43.28	(0.983)	Rb	(ppb)		
Se	(ppb)	8.25	(0.062)	Sc	(ppb)	0.094	(0.0093)
Hg	(ppb)			Eu	(ppb)	0.247	(0.06)
Cs	(ppb)			Ga	(ppb)		
Br	(ppb)	847.0	(21.2)				
As	(ppb)						

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 69
 Field (pool): Eaglesham (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: HB Union Eaglesham 10-14-77-25
 Location: Lsd 10 Sec 14 Twp 77 Rge 25 W 5 Mer
 Source of sample: Tubing Pressure: 400 psig Temperature: 60 °F
 Method of production: Flowing Depth: 7552-7564; 7570-7575 ft. (perforations)
 Date sampled: 22nd July 1970
 Remarks:

S (%)	0.216	(0.0466)		
V (ppm)	1.174	(0.0232)		
Cl (ppm)	6.093	(0.2158)		
Na (ppm)	0.112	(0.0018)		
Fe (ppm)				
Ni (ppm)	1.510	(0.060)		
Zn (ppb)			Au (ppb)	
Co (ppb)	7.511	(0.584)	Sb (ppb)	
I (ppb)			Cr (ppb)	
Mn (ppb)	49.33	(0.9963)	Rb (ppb)	
Se (ppb)			Sc (ppb)	0.044 (0.017)
Hg (ppb)			Eu (ppb)	0.424 (0.129)
Cs (ppb)	1.751	(0.376)	Ga (ppb)	1.694 (0.1121)
Br (ppb)	39.40	(1.063)		
As (ppb)	3.98	(0.270)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 71
 Field (pool): Simonette (D-3)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Shell Simonette 12-6-63-25
 Location: Lsd 12 Sec 6 Twp 63 Rge 25 W 5 Mer
 Source of sample: Wellhead Pressure: 1000 psig Temperature: 58 °F
 Method of production: Flowing Depth: 11,536-11,558 ft. (open hole)
 Date sampled: 27th Aug. 1970
 Remarks:

S	(%)	0.340	(0.0356)		
V	(ppm)	0.017	(0.0016)		
Cl	(ppm)	5.43	(0.1496)		
Na	(ppm)	0.183	(0.003)		
Fe	(ppm)	0.216	(0.052)		
Ni	(ppm)				
Zn	(ppb)	16.0	(2.8)	Au	(ppb)
Co	(ppb)	4.09	(0.174)	Sb	(ppb)
I	(ppb)	10.46	(2.9030)	Cr	(ppb) 13.6 (1.31)
Mn	(ppb)	47.70	(0.9142)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.094 (0.0077)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	15.33	(0.572)		
As	(ppb)	1.21	(0.1424)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 72
 Field (pool): Windfall (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Fina Pan Am HB Wind 10-7-60-15
 Location: Lsd 10 Sec 7 Twp 60 Rge 15 W 5 Mer
 Source of sample: Separator Pressure: 1140 psig Temperature: 136 °F
 Method of production: Flowing Depth: 8559-8580 ft. (perforations)
 Date sampled: 18th Dec. 1970
 Remarks:

S	(%)	0.593	(0.0480)				
V	(ppm)	0.014	(0.0017)				
Cl	(ppm)	6.267	(0.2060)				
Na	(ppm)	0.023	(0.0050)				
Fe	(ppm)						
Ni	(ppm)						
Zn	(ppb)			Au	(ppb)		
Co	(ppb)	5.281	(0.247)	Sb	(ppb)		
I	(ppb)	51.98	(5.589)	Cr	(ppb)		
Mn	(ppb)	52.83	(1.003)	Rb	(ppb)	15.58	(3.20)
Se	(ppb)			Sc	(ppb)	0.081	(0.010)
Hg	(ppb)	3.0	(0.785)	Eu	(ppb)	0.255	(0.066)
Cs	(ppb)			Ga	(ppb)		
Br	(ppb)	39.4	(1.107)				
As	(ppb)	7.844	(0.204)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 73
 Field (pool): Fairydell-Bon Accord (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Imperial Fairydell 16-8L-57-24
 Location: Tsd 16 Sec 8 Twp 57 Rge 24 W 4 Mer
 Source of sample: Test treater Pressure: - psig Temperature: 140°F
 Method of production: - Depth: not specified ft. Leduc Fm. 4005;
 Date sampled: 4th Aug. 1970 T. D. 4038 . End casing 4020
 Remarks: May be open hole production

S	(%)	1.244	(0.0631)			
V	(ppm)	6.553	(0.0579)			
Cl	(ppm)	38.74	(0.9333)			
Na	(ppm)	1.975	(0.0343)			
Fe	(ppm)	0.656	(0.0833)			
Ni	(ppm)	11.32	(0.177)			
Zn	(ppb)	329.3	(9.43)	Au	(ppb)	0.149 (0.0621)
Co	(ppb)	33.66	(0.527)	Sb	(ppb)	1.90 (0.272)
I	(ppb)	125.9	(9.151)	Cr	(ppb)	28.76 (3.20)
Mn	(ppb)	36.45	(1.465)	Rb	(ppb)	
Se	(ppb)	63.43	(4.70)	Sc	(ppb)	0.026 (0.010)
Hg	(ppb)	23.0	(4.45)	Eu	(ppb)	0.180 (0.062)
Cs	(ppb)			Ga	(ppb)	127.5 (1.565)
Br	(ppb)	322.5	(11.66)			
As	(ppb)	1219.0	(21.22)			

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 74
 Field (pool): Redwater (D-3)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Imperial Simmons 70
 Location: Lsd 14 Sac 19 Twp 56 Rge 20 W 4 Mer
 Source of sample: Separator Pressure: 375 psig Temperature: 60 °F
 Method of production: - Depth: 3086-3146 ft. (open hole)
 Date sampled: 9th July 1969
 Remarks:

S	(%)	0.474	(0.0516)		
V	(ppm)	6.365	(0.0862)		
Cl	(ppm)	28.61	(0.740)		
Na	(ppm)	0.053	(0.017)		
Fe	(ppm)	0.226	(0.095)		
Ni	(ppm)	14.6	(0.230)		
Zn	(ppb)	151.4	(7.82)	Au	(ppb) 0.204 (0.0243)
Co	(ppb)	60.3	(0.79)	Sb	(ppb)
I	(ppb)	502.8	(15.06)	Cr	(ppb) 16.63 (2.92)
Mn	(ppb)	39.16	(1.479)	Rb	(ppb)
Se	(ppb)	14.54	(2.75)	Sc	(ppb)
Hg	(ppb)	3.13	(1.67)	Eu	(ppb)
Cs	(ppb)			Ga	(ppb) 23.9 (0.422)
Br	(ppb)	460.0	16.22		
As	(ppb)	22.4	0.751		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 75
 Field (pool): Morinville (D-3B)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Oakland Morinv 8-14-54-26
 Location: Lsd 8 Sec 14 Twp 54 Rge 26 W 4 Mer
 Source of sample: Separator Pressure: 20 psig Temperature: 20 °F
 Method of production: Flowing Depth: 5206-5216 ft. (perforations)
 Date sampled: 5th March 1970
 Remarks:

S	(%)	0.237	(0.030)		
V	(ppm)	0.903	(0.0127)		
Cl	(ppm)	19.73	(0.65)		
Na	(ppm)	0.187	(0.0019)		
Fe	(ppm)				
Ni	(ppm)	6.74	(0.12)		
Zn	(ppb)	77.0	(8.4)	Au	(ppb)
Co	(ppb)	15.4	(0.517)	Sb	(ppb)
I	(ppb)			Cr	(ppb) 11.32 (2.85)
Mn	(ppb)	49.2	(1.012)	Rb	(ppb)
Se	(ppb)	14.23	(3.84)	Sc	(ppb) 0.096 (0.014)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb) 1.30 (0.123)
Br	(ppb)	38.8	(1.01)		
As	(ppb)	13.23	(0.343)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 76
 Field (pool): Acheson (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Cal Std Welbourn 8-34
 Location: Lsd 8 Sec 34 Twp 52 Rge 26 W 4 Mer
 Source of sample: Header Pressure: - psig Temperature: - °F
 Method of production: Flowing Depth: Not specified. ft. Leduc Fm. 5038;
 Date sampled: 10 Feb. 1970 TD 5095; End casing 5016
 Remarks: Production may be from open hole

S	(%)	0.3082	(0.037)		
V	(ppm)	0.981	(0.0118)		
Cl	(ppm)	12.86	(0.373)		
Na	(ppm)	0.336	(0.0041)		
Fe	(ppm)	0.312	(0.0754)		
Ni	(ppm)	4.16	(0.071)		
Zn	(ppb)	221.0	(7.2)	Au	(ppb)
Co	(ppb)	14.9	(0.532)	Sb	(ppb)
I	(ppb)	71.010	(6.02)	Cr	(ppb)
Mn	(ppb)	55.4	(1.15)	Rb	(ppb)
Se	(ppb)	16.0	(0.099)	Sc	(ppb) 0.10 (0.01)
Ag	(ppb)	1.34	(0.55)	Eu	(ppb)
Cs	(ppb)	0.870	(0.268)	Ga	(ppb) 0.52 (0.14)
Br	(ppb)	137.3	(3.73)		
As	(ppb)	3.87	(0.273)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 70

Field (pool): Little Smoky (D-3)

Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.

Well name: Little Smoky 10-27

Location: Tsd 10 Sec 27 Twp 67 Rge 22 W 5 Mer

Source of sample: Wellhead- tubing Pressure: 200 psig Temperature: 50 °F

Method of production: Flowing Depth: 8707-8712 ft. (perforations)

Date sampled: 21st July 1970

Remarks:

S	(%)	0.463	(0.0378)		
V	(ppm)	0.099	(0.0034)		
Cl	(ppm)	12.10	(0.2801)		
Na	(ppm)	0.313	(0.040)		
Fe	(ppm)				
Ni	(ppm)	0.120	(0.0155)		
Zn	(ppb)	60.0	(4.9)	Au	(ppb)
Co	(ppb)	4.93	(0.256)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	48.69	(1.044)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.115 (0.0107)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	31.64	(1.10)		
As	(ppb)	2.57	(0.245)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 77
 Field (pool): Bonnie Glen (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Chevron Texaco B Glen 10-7-47-27
 Location: Lsd 10 Sec 7 Twp 47 Rge 27 W 4 Mer
 Source of sample: Flowline Pressure: 590 psig Temperature: - °F
 Method of production: flowing Depth: 7060-7080 ft. (perforations)
 Date sampled: 27th Jan. 1970
 Remarks:

S	(%)	0.309	(0.0193)		
V	(ppm)	0.071	(0.0029)		
Cl	(ppm)	70.62	(0.5705)		
Na	(ppm)	0.0174	(0.0029)		
Fe	(ppm)				
Ni	(ppm)	0.10	(0.014)		
Zn	(ppb)	37.0	(3.5)	Au	(ppb)
Co	(ppb)	8.25	(0.259)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	39.35	(0.0646)	Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)	291.1	(21.2)	Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	21.6	(0.644)		
As	(ppb)	0.63	0.0511		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 78
 Field (pool): Westeros (D-3)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: CPR Christensen 16
 Location: Lsd 16 Sec 33 Twp 45 Rge 28 W 4 Mer
 Source of sample: - Pressure: - psig Temperature: - °F
 Method of production: Flowing Depth: Not given. ft. Leduc 6860;
 Date sampled: 16th April 1970 TD 7372 ft
 Remarks:

S	(%)	0.311	(0.0250)		
V	(ppm)	0.178	(0.0047)		
Cl	(ppm)	6.100	(0.3681)		
Na	(ppm)	0.168	(0.0032)		
Fe	(ppm)	0.429	(0.118)		
Ni	(ppm)				
Zn	(ppb)	13.40	(3.00)	Au	(ppb)
Co	(ppb)	1.57	(0.254)	Si	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	53.08	(0.8579)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.085 (0.014)
Hg	(ppb)	6.57	(1.34)	Eu	(ppb)
Cs	(ppb)			Ga	(ppb) 0.551 (0.143)
Br	(ppb)	19.60	(1.251)		
As	(ppb)	3.843	(0.413)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 79
 Field (pool): Malmo (D-3A)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Fina Pacific Malmo 5-11L-44-22
 Location: Lsd 5 Sec 11 Twp 44 Rge 22 W 4 Mer
 Source of sample: Treater Pressure: 10 psig Temperature: 110°F
 Method of production: Pump Depth: 5233-5250 ft. (perforations)
 Date sampled: 21st Aug. 1970
 Remarks: Visco 1688 injected in ratio 1 pint to ~ 350 bbls fluid; treater temperature given as 150°F.

S	(%)	0.710	(0.0523)		
V	(ppm)	1.469	(0.0180)		
Cl	(ppm)	23.49	(0.4993)		
Na	(ppm)	0.130	(0.0024)		
Fe	(ppm)	4.43	(0.0723)		
Ni	(ppm)				
Zn	(ppb)	63.0	(5.10)	Au	(ppb)
Co	(ppb)	25.75	(0.53)	Sb	(ppb)
I	(ppb)	76.28	(4.0)	Cr	(ppb)
Mn	(ppb)	50.15	(0.9319)	Rb	(ppb)
Se	(ppb)	12.12	(0.123)	Sc	(ppb)
				0.131	(0.0113)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
				20.0	(0.434)
Br	(ppb)	317.8	(8.25)		
As	(ppb)	21.0	(0.577)		

* Relative standard deviation (counting statistics) in parentheses.

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 80
 Field (pool): Innisfail (D-3)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: HB WR C and E Innisfail 11-10-35-1
 Location: Lsd 11 Sec 10 Twp 35 Rge 1 W 5 Mer
 Source of sample: Wellhead-tubing Pressure: 660 psig Temperature: 68 °F
 Method of production: Flowing Depth: 8489-8504 ft. (perforations)
 Date sampled: 26th June 1970
 Remarks:

S	(%)	0.443	(0.0551)				
V	(ppm)	0.017	(0.0023)				
Cl	(ppm)	3.854	(0.1591)				
Na	(ppm)	0.0434	(0.0062)				
Fe	(ppm)						
Ni	(ppm)						
Zn	(ppb)			Au	(ppb)		
Co	(ppb)	6.82	(0.30)	Sb	(ppb)		
I	(ppb)			Cr	(ppb)		
Mn	(ppb)	58.67	(0.901)	Rb	(ppb)		
Se	(ppb)			Sc	(ppb)	0.108	(0.0112)
Hg	(ppb)			Eu	(ppb)	0.20	(0.078)
Cs	(ppb)	0.90	(0.252)	Ga	(ppb)		
Br	(ppb)	8.02	(0.263)				
As	(ppb)	1.47	(0.071)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 81
 Field (pool): Erskine (D-3)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: CPR Clark 6
 Location: Lsd 6 Sec 7 Twp 39 Rge 20 W 4 Mer
 Source of sample: Flow line Pressure: 21 psig Temperature: 30 °F
 Method of production: Flowing Depth: 5379-5382 ft. (perforations)
 Date sampled: 18th February 1970
 Remarks:

S	(%)	2.144	(0.1096)		
V	(ppm)	5.699	(0.0542)		
Cl	(ppm)	27.17	(0.6127)		
Na	(ppm)	2.66	(0.039)		
Fe	(ppm)	1.581	(0.20)		
Ni	(ppm)	7.53	(0.240)		
Zn	(ppb)	114.3	(9.60)	Au	(ppb)
Co	(ppb)	9.07	(0.804)	Sb	(ppb) 5.50 (0.793)
I	(ppb)	350.3	(12.04)	Cr	(ppb) 10.20 (0.578)
Mn	(ppb)	70.86	(1.441)	Rb	(ppb)
Se	(ppb)	18.6	(5.35)	Sc	(ppb) 0.056 (0.026)
Hg	(ppt)			Eu	(ppb) 0.320 (0.130)
Cs	(ppb)	1.63	(0.564)	Ga	(ppb)
Br	(ppb)	622.2	(14.20)		
As	(ppb)	40.0	(2.61)		

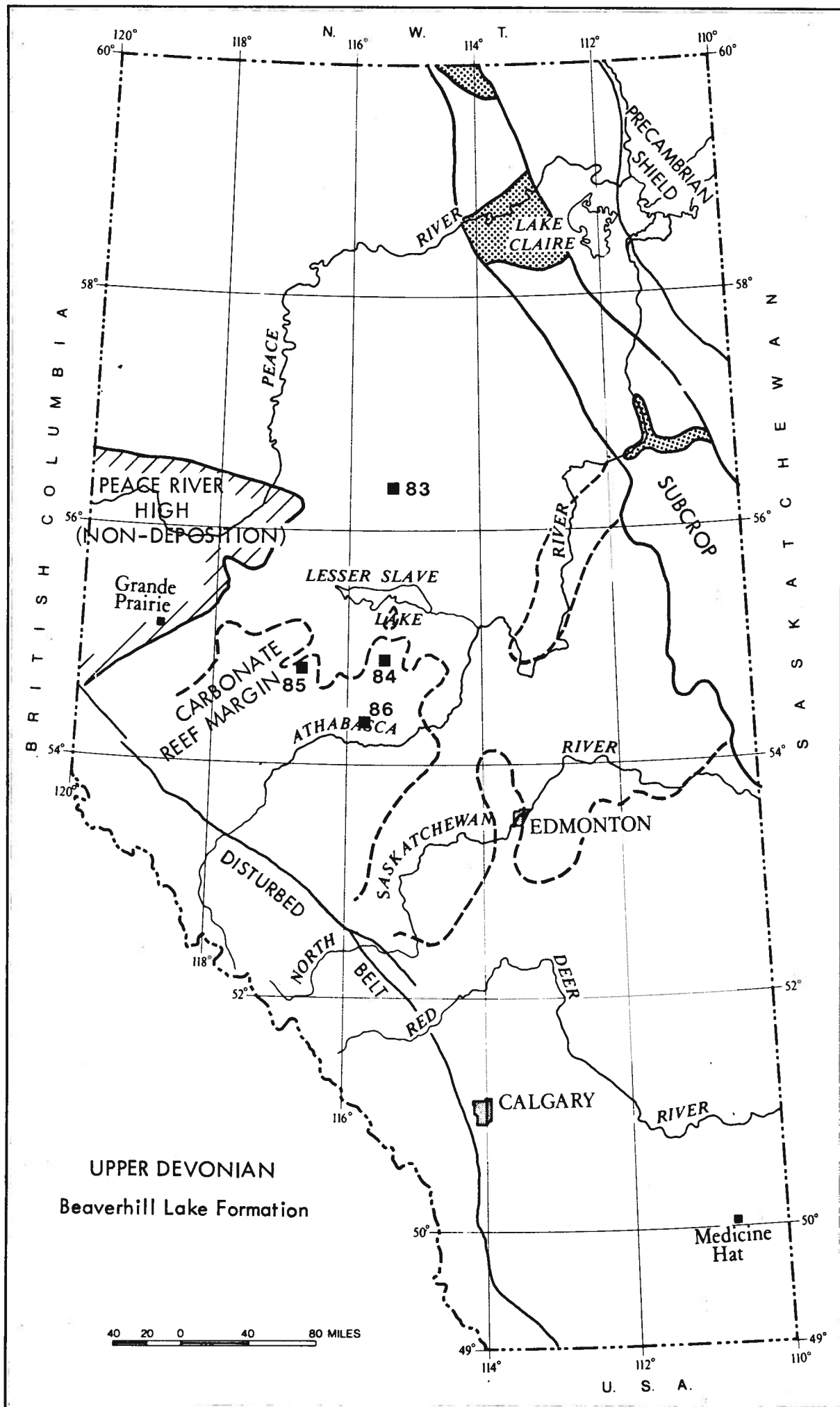
* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 82
 Field (pcol): Fenn-Big Valley (D-3E)
 Stratigraphic unit: U. Devonian, Woodbend Gp., Leduc Fm.
 Well name: Imp HB Caprona 3-26L-36-20
 Location: Lsd 3 Sec 26 Twp 36 Rge 20 W 4 Mer
 Source of sample: Wellhead Pressure: 90 psig Temperature: 30 °F
 Method of production: Pump Depth: 5328-5329 ft. (perforations)
 Date sampled: 5th Feb. 1970
 Remarks: Very heavy oil emulsion which had to be thinned with benzene before centrifuging; analyzed sample contains less than 5% residual benzene.

S	(%)	2.991	(0.2492)		
V	(ppm)	52.67	(5926)		
Cl	(ppm)	250.0	(4.661)		
Na	(ppm)	0.354	(0.0058)		
Fe	(ppm)	0.557	(0.123)		
Ni	(ppm)	70.1	(1.01)		
Zn	(ppb)	940.1	(20.56)	Au	(ppb)
Co	(ppb)	61.0	(0.752)	Sb	(ppb) 2.072 (0.233)
I	(ppb)	7396.0	(91.21)	Cr	(ppb) 83.5 (5.30)
Mn	(ppb)	91.92	(2.583)	Rb	(ppb)
Se	(ppb)	56.1	(5.31)	Sc	(ppb)
Hg	(ppb)	139.8	(12.73)	Eu	(ppb) 0.254 (0.082)
Cs	(ppb)	3.79	(0.591)	Ga	(ppb) 445.0 (11.9)
Br	(ppb)	8406.0	(289.0)		
As	(ppb)	672.9	(18.0)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 83
 Field (pool): Loon (Slave Point A)
 Stratigraphic unit: U. Devonian, Slave Point Fm.
 Well name: Chevron Suptst Dome Loon 10-17-85-9
 Location: Tsd 10 Sec 17 Twp 85 Rge 9 W 5 Mer
 Source of sample: Wellhead Pressure: 50 psig Temperature: 55°F
 Method of production: Pump Depth: 4567-4608 ft.(open hole)
 Date sampled: 15th July 1970
 Remarks:

S (%)	0.2423	(0.0512)		
V (ppm)	1.410	(0.023)		
Cl (ppm)	10.2	(0.366)		
Na (ppm)	0.644	(0.0054)		
Fe (ppm)	0.574	(0.121)		
Ni (ppm)	8.0	(0.13)		
Zn (ppb)	1178.0	(32.0)	Au (ppb)	
Co (ppb)	26.3	(0.584)	Sb (ppb)	4.61 (0.484)
I (ppb)	36.7	(7.81)	Cr (ppb)	
Mn (ppb)	65.1	(1.183)	Rb (ppb)	
Se (ppb)	10.42	(2.54)	Sc (ppb)	0.074 (0.014)
Hg (ppb)	49.0	(6.0)	Eu (ppb)	
Cd (ppb)			Ga (ppb)	1.89 (0.244)
Br (ppb)	69.6	(1.77)		
As (ppb)	124.0	(1.65)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 84
 Field (pool): Swan Hills (Beaverhill Lake A)
 Stratigraphic unit: U. Devonian, Beaverhill Lake Fm.
 Well name: Kewanee A-45 Swan H 12-32-68-10
 Location: Lrd 12 Sec 32 Twp 68 Rge 10 W 5 Mer
 Source of sample: Wellhead Pressure: - psig Temperature: - °F
 Method of production: Pump Depth: 8469 -8489; ft. (perforations)
 Date sampled: 10th July 1969 8500 -8512;
 8535 -8545
 Remarks: Emulsion and formation water at bottom of original sample container

S	(%)	0.156	(0.0259)		
V	(ppm)	0.037	(0.0027)		
Cl	(ppm)	3.789	(0.1849)		
Na	(ppm)	1.169	(0.0113)		
Fe	(ppm)	0.338	(0.118)		
Ni	(ppm)	0.494	(0.033)		
Zn	(ppb)	22.6	(3.49)	Au	(ppb)
Co	(ppb)	1.21	(0.223)	Sb	(ppb)
I	(ppb)	162.7	(8.8720)	Cr	(ppb) 6.05 (1.73)
Mn	(ppb)	43.94	(0.9052)	Rb	(ppb)
Se	(ppb)	9.44	(1.96)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.335 (0.102)
Cs	(ppb)	1.71	(0.190)	Ga	(ppb)
Br	(ppb)	31.66	(1.625)		
As	(ppb)	14.75	(0.664)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 85
 Field (pool): Goose River (Beaverhill Lake A)
 Stratigraphic unit: U. Devonian, Beaverhill Lake Fm.
 Well name: BA Goose River 10-4-67-18
 Location: Lsd 10 Sec 4 Twp 67 Rge 18 W 5 Mer
 Source of sample: Wellhead - line just Pressure: - psig Temperature: - °F
 Method of production: downstream of choke Depth: 9278-9288 ft. (perforations)
 Date sampled: 10th July 1969
 Remarks:

S	(%)	0.126	(0.0297)		
V	(ppm)	0.014	(0.0021)		
Cl	(ppm)	4.664	(0.1642)		
Na	(ppm)	0.789	(0.010)		
Fe	(ppm)				
Ni	(ppm)	0.085	(0.010)		
Zn	(ppb)	148.0	(5.1)	Au	(ppb)
Co	(ppb)	5.43	(0.20)	Sb	(ppb)
I	(ppb)			Cr	(ppb)
Mn	(ppb)	17.93	(0.6306)	Rb	(ppb)
Se	(ppb)	4.0	(0.045)	Sc	(ppb)
				0.091	(0.0072)
Hg	(ppb)			Eu	(ppb)
				0.194	(0.050)
Cs	(ppb)	0.388	(0.156)	Ga	(ppb)
Br	(ppb)	20.3	(0.887)		
As	(ppb)	1.45	(0.26)		

* Relative standard deviation (counting statistics) in parenthesis

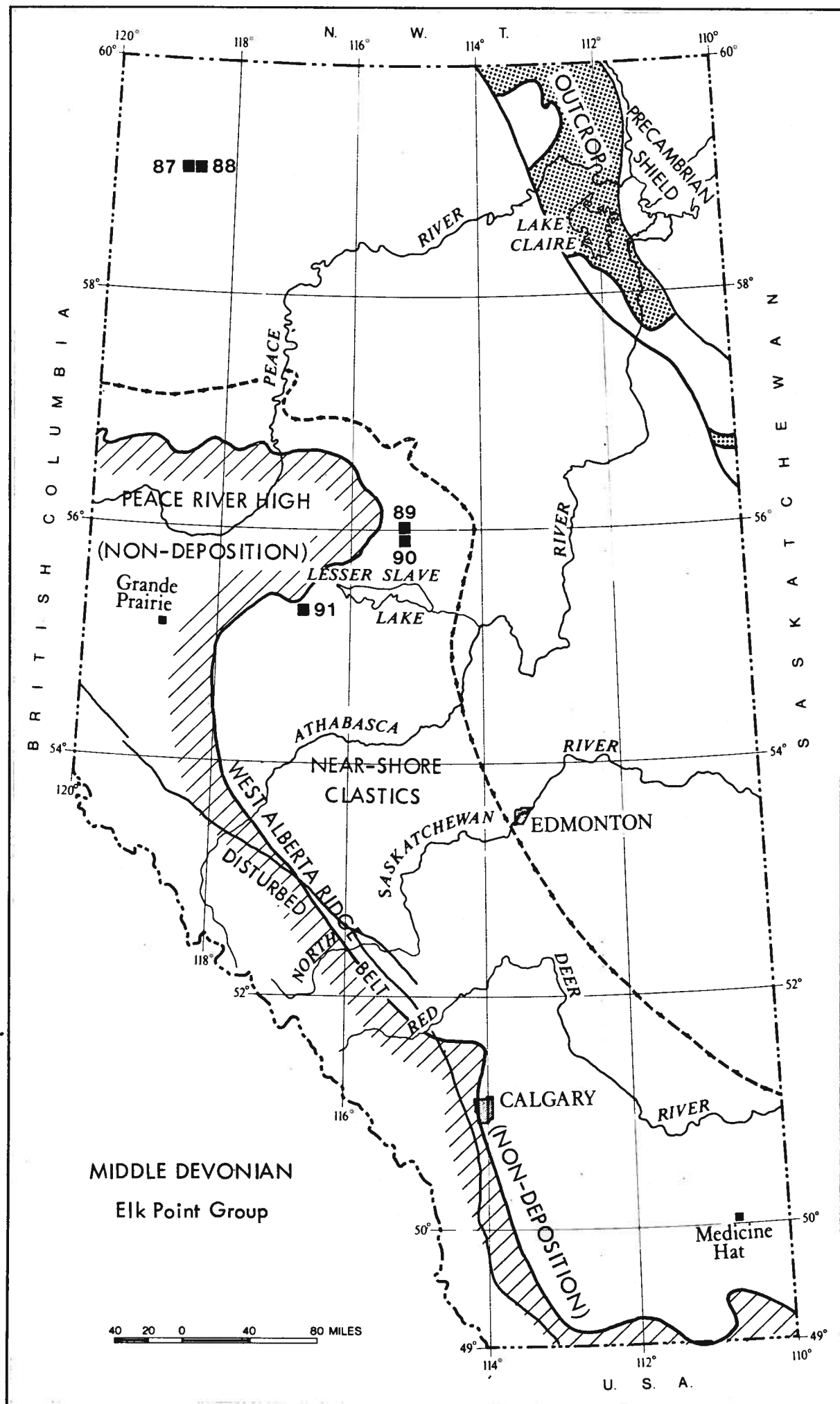
TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 86
 Field (pool): Carson Creek North (Beaverhill Lake A)
 Stratigraphic unit: U. Devonian, Beaverhill Lake Fm.
 Well name: Mobil PR Carson N 6-9MU-62-12
 Location: Lsd 6 Sec 9 Twp 62 Rge 12 W 5 Mer
 Source of sample: Wellhead Pressure: - psig Temperature: - °F
 Method of production: Flowing Depth: 8529-8547; 8556-8582 ft. (perforations)
 Date sampled: 13th Jan. 1971

Remarks:

S	(%)		
V	(ppm)	0.054	(0.0029)
Cl	(ppm)	13.35	(0.4412)
Na	(ppm)	0.735	(0.0089)
Fe	(ppm)		
Ni	(ppm)	0.179	(0.0231)
Zn	(ppb)	90.0	(8.6)
Co	(ppb)	1.28	(0.24)
I	(ppb)	420.3	(11.13)
Mn	(ppb)	22.73	(0.7542)
Se	(ppb)		
Hg	(ppb)	2.0	(0.55)
Cs	(ppb)	19.45	(0.97)
Br	(ppb)		
As	(ppb)		
Au	(ppb)		
Sb	(ppb)		
Cr	(ppb)		
Rb	(ppb)		
Sc	(ppb)	0.111	(0.0141)
Eu	(ppb)		
Ga	(ppb)		

* Relative standard deviation (counting statistics) in parentheses



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 87

Field (pool): Zama (Keg River C)

Stratigraphic unit: M. Devonian, Elk Point Gp., Keg River Fm.

Well name: HB Zama North 3-11-116-5

Location: Lsd 3 Sec 11 Twp 116 Rge 5 W 6 Mer

Source of sample: Separator Pressure: 150 psig Temperature: 32 °F

Method of production: Pump Depth: 4751-4800 ft. (perforations)

Date sampled: 3rd March 1970

Remarks:

S	(%)	1.324	(0.0839)		
V	(ppm)	2.788	(0.0313)		
Cl	(ppm)	42.37	(0.9512)		
Na	(ppm)	3.347	(0.0461)		
Fe	(ppm)	0.842	(0.21)		
Ni	(ppm)	4.66	(0.150)		
Zn	(ppb)	68.23	(10.3)	Au	(ppb)
Cu	(ppb)	35.92	(2.46)	Sb	(ppb)
I	(ppb)	71.72	(6.113)	Cr	(ppb) 14.53 (3.41)
Mn	(ppb)	27.08	(0.9115)	Pb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.30 (0.10)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	1407.0	(23.0)		
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 88

Field (pool): Zama (Muskeg B)

Stratigraphic unit: M. Devonian, Elk Point Gp., Muskeg Fm.

Well name: HB Zama North 8-17-116-4

Location: Tsd 8 Sec 17 Twp 116 Rge 4 W6 Mer

Source of sample: Wellhead Pressure: 100 psig Temperature: 35 °F

Method of production: Pump Depth: 4740-4806 ft. (perforations)

Date sampled: 3rd March 1970

Remarks:

S	(%)	1.506	(0.1120)		
V	(ppm)	9.456	(0.0911)		
Cl	(ppm)	43.70	(0.9778)		
Na	(ppm)	1.945	(0.0330)		
Fe	(ppm)	0.465	(0.104)		
Ni	(ppm)	17.2	(0.263)		
Zn	(ppb)	109.7	(7.83)	Au	(ppb)
Cc	(ppb)	23.2	(0.52)	Sb	(ppb) 3.291 (0.4304)
I	(ppb)	281.2	(12.94)	Cr	(ppb) 7.74 (3.40)
Mn	(ppb)	23.61	(0.8833)	Rb	(ppb)
Se	(ppb)	15.8	(3.24)	Sc	(ppb)
Hg	(ppb)			Eu	(ppb) 0.268 (0.095)
Cs	(ppb)			Ga	(ppb) 15.82 (0.555)
Br	(ppb)	728.0	(25.61)		
As	(ppb)	254.0	(4.94)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 89
 Field (pool): Nipisi (Keg River Sandstone A)
 Stratigraphic unit: M. Devonian, Elk Point Gp., Keg River Ss.
 Well name: Arco IOE Nipisi 12-5-81-8
 Location: Lsd 12 Sec 5 Twp 81 Rge 8 W 5 Mer
 Source of sample: Wellhead Pressure: 50 psig Temperature: 58 °F
 Method of production: Pump Depth: 5760-5763 ft. (perforations)
 Date sampled: 15th July 1970
 Remarks:

S	(%)	0.286	(0.0323)		
V	(ppm)	1.11	(0.0172)		
Cl	(ppm)	17.97	(0.4871)		
Na	(ppm)	2.74	(0.032)		
Fe	(ppm)				
Ni	(ppm)	2.43	(0.050)		
Zn	(ppb)	697.0	(14.3)	Au	(ppb)
Co	(ppb)	9.38	(0.314)	Sb	(ppb)
I	(ppb)	567.1	(14.77)	Cr	(ppb)
Mn	(ppb)	44.25	(0.8502)	Rb	(ppb)
Se	(ppb)	13.1	(0.079)	Sc	(ppb)
				0.066	(0.0089)
Hg	(ppb)	398.6	(29.34)	Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	642.6	(15.2)		
As	(ppb)				

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 90
 Field (pool): Nipisi (Gilwood A)
 Stratigraphic unit: M. Devonian, Watt Mountain Fm., Gilwood Ss. (Elk Point Gp.)
 Well name: Pacific et al Nipisi 10-10-80-8
 Location: Lsd 10 Sec 10 Twp 80 Rge 8 W5 Mer
 Source of sample: Separator Pressure: 40 psig Temperature: 56 °F
 Method of production: - Depth: 5564-5574; ft. (perforations)
 Date sampled: 14th July 1970 5580-5588
 Remarks:

S	(%)	0.187	(0.020)		
V	(ppm)	0.190	(0.0111)		
Cl	(ppm)	0.50	(0.063)		
Na	(ppm)	1.206	(0.0169)		
Fe	(ppm)				
Ni	(ppm)	0.70	(0.07)		
Zn	(ppb)	352.8	(14.4)	Au	(ppb)
Co	(ppb)	4.69	(0.546)	Sb	(ppb)
I	(ppb)			Ci	(ppb)
Mn	(ppb)			Rb	(ppb)
Se	(ppb)			Sc	(ppb)
Hg	(ppb)			Eu	(ppb)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	105.3	(3.96)		
As	(ppb)	12.3	(1.015)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 91

Field (pool): Gilwood (Gilwood A)

Stratigraphic unit: M. Devonian, Watt Mountain Fm., Gilwood Ss. (Elk Point Gp.)

Well name: Gr Pl Triad Musk Gilwood 1-9

Location: Lsd 1 Sec 9 Twp 73 Rge 18 W 5 Mer

Source of sample: Upstream of ^{inlet} treater Pressure: 30 psig Temperature: - °F

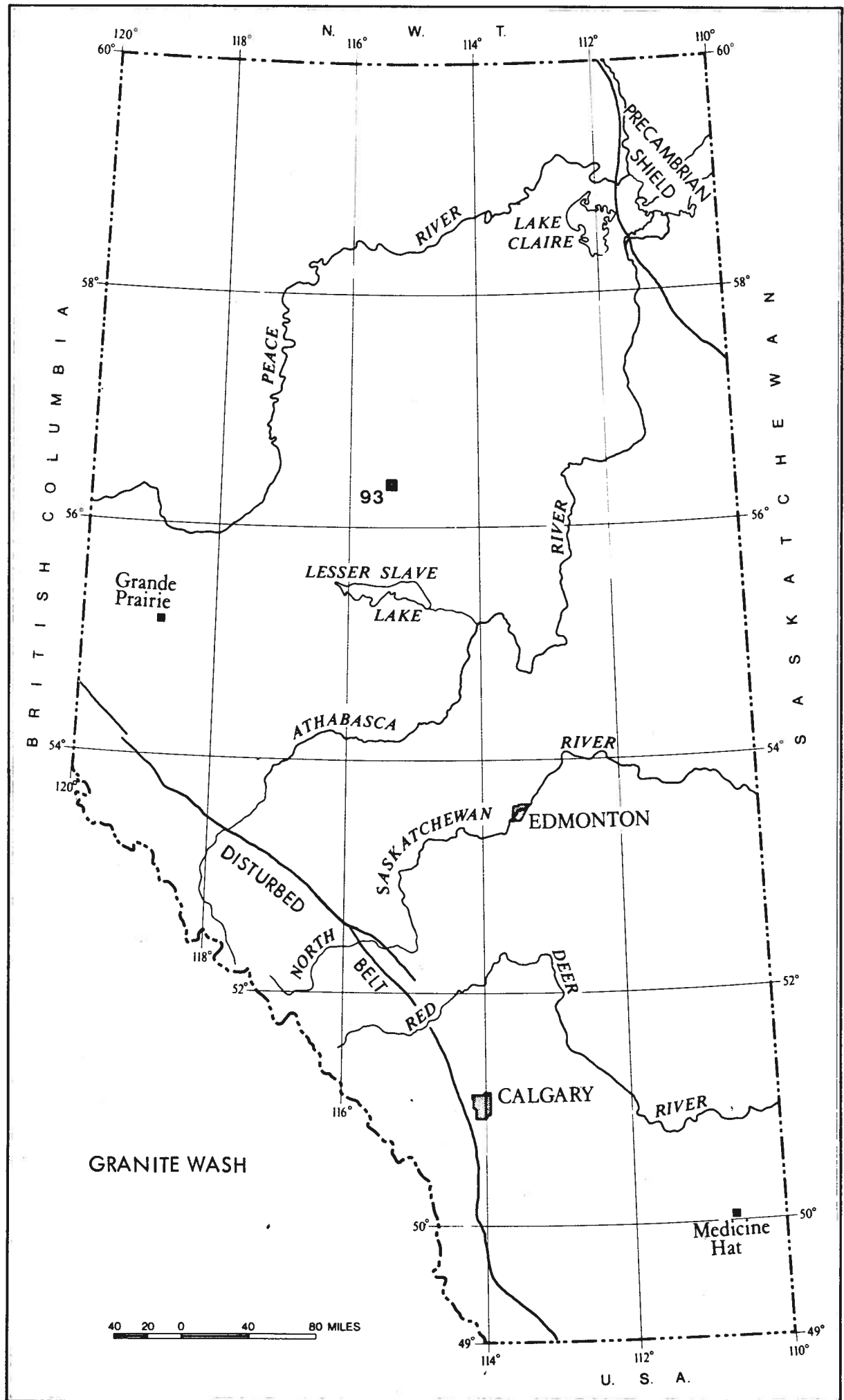
Method of production: - Depth: 8103-8121 ft. (perforations)

Date sampled: 10th July 1969

Remarks:

S	(%)	0.101			
V	(ppm)	0.490	(0.0113)		
Cl	(ppm)	11.070	(0.3097)		
Na	(ppm)	0.347	(3.26)		
Fe	(ppm)	0.876	(0.169)		
Ni	(ppm)	6.74	(0.12)		
Zn	(ppb)	730.0	(23.8)	Au	(ppb)
Co	(ppb)	6.58	(0.340)	Sb	(ppb) 2.55 (0.469)
I	(ppb)	59.44	(4.749)	Cr	(ppb) 21.3 (2.44)
Mn	(ppb)	59.91	(1.170)	Rb	(ppb)
Se	(ppb)			Sc	(ppb) 0.152 (0.019)
Hg	(ppb)	3.02	(0.362)	Eu	(ppb) 0.604 (0.16)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	265.0	(5.86)		
As	(ppb)	2.25	(0.383)		

* Relative standard deviation (counting statistics) in parenthesis



TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 93
 Field (pool): Loon (Granite Wash A)
 Stratigraphic unit: Granite Wash
 Well name: Chevron Suptst Dome Loon S 4-9-85-9
 Location: Lsd 4 Sec 9 Twp 85 Rge 9 W 5 Mer
 Source of sample: Separator Pressure: 70 psig Temperature: 60 °F
 Method of production: Flowing Depth: 5068-5069 ft. (perforations)
 Date sampled: 15th July 1970
 Remarks:

S	(%)	0.203	(0.0285)		
V	(ppm)	0.587	(0.0126)		
Cl	(ppm)	12.19	(0.7810)		
Na	(ppm)	0.889	(0.0084)		
Fe	(ppm)				
Ni	(ppm)	0.900	(0.021)		
Zn	(ppb)	1126.0	(14.41)	Au	(ppb)
Co	(ppb)	3.57	(0.127)	Sb	(ppb) 0.190 (0.095)
i	(ppb)			Cr	(ppb) 3.63 (0.940)
Mn	(ppb)	77.31	(1.183)	Rb	(ppb)
Se	(ppb)	11.6	(0.871)	Sc	(ppb)
Hg	(ppb)	150.1	(8.37)	Eu	(ppb) 0.091 (0.0322)
Cs	(ppb)			Ga	(ppb)
Br	(ppb)	237.0	(6.85)		
As	(ppb)	22.0	(0.585)		

* Relative standard deviation (counting statistics) in parenthesis

TRACE ELEMENTS IN ALBERTA CRUDE OILS -- DATA SHEET

Sample number: 94

Field (pool): Athabasca oil sand deposit

Stratigraphic unit: L. Cretaceous, Mannville Gp., McMurray Fm.

Well name: -

Location: Lsd - Sec - Twp - Rge - W - Mer

Source of sample: - Pressure: - psig Temperature: - °F

Method of production: - Depth: ft.

Date sampled: -

Remarks:

S	(%)	3.881	(0.4426)		
V	(ppm)	176.5	(2.3011)		
Cl	(ppm)	7.961	(1.1630)		
Na	(ppm)	20.78	(0.343)		
Fe	(ppm)	254.2	(4.83)		
Ni	(ppm)	71.88	(1.07)		
Zn	(ppb)			Au	(ppb) 1.316 (0.216)
Co	(ppb)	1998.0	(14.0)	Sb	(ppb) 27.7 (1.65)
I	(ppb)			Cr	(ppb) 1682.0 (12.51)
Mn	(ppb)	3853.0	(35.30)	Rb	(ppb) 720.2 (44.1)
Se	(ppb)	517.1	(22.4)	Sc	(ppb) 190.7 (0.60)
Hg	(ppb)			Eu	(ppb) 23.2 (0.77)
Cs	(ppb)	68.53	(6.41)	Ga	(ppb) 267.0 (7.79)
Br	(ppb)	103.6	(12.81)		
As	(ppb)	320.9	(10.24)		

* Relative standard deviation (counting statistics) in parenthesis

ADDITIONAL DATA - Sample No. 94

Oil sand sample from syncrude Canada Ltd. Extracted in Soxhlet extractor with benzene, centrifuged, and evaporated down using mild heating ($< 80^{\circ}\text{C}$).

Ramsbottom carbon residue: 12.57%

