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TERTIARY OUTLIER STUDIES: RECENT INVESTIGATIONS IN THE SUMMERLAND BASIN, SOUTH OKANAGAN AREA, B.C.
(82E/12)

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INTRODUCTION

The Tertiary basins in the interior of British Columbia present opportunities for the development of geothermal resources but not without appropriate regard for environmental considerations such as the dispersion of heavy metals, the radioactivity of country rocks and the quality of groundwater.

The main object of this project was to test the geothermal potential of the Summerland basin with a view to locating a low-grade thermal source for space heating (mainly the local greenhouses). To this end the first phase of a drilling, Hole No. EPB/GSC 495, began in March 1990 at Summerland, sponsored by the South Okanagan – Similkameen Community Futures Group (based in Penticton), the Geological Survey of Canada and the British Columbia Ministry of Energy, Mines and Petroleum Resources.

The weakly lithified beds, characteristic of the Tertiary basins, are poor thermal conductors that commonly blanket older more conductive crystalline basement rocks. The natural dissipation of heat from the earth's interior is impeded by this blanket, causing thermal accumulation. Combined with this, the inherent structural weakness of these young cover rocks facilitates faulting and fracturing allowing the entry of groundwater into the strata and the possible development of warm-water reservoirs at depth (Nevin, Sadlier-Brown, Goodbrand Ltd., 1987).

The mixing of mineral-laden ground waters from deep sources with surface waters may present environmental concerns in ranching and urban areas. For example specific concerns were expressed by Bates *et al.* (1979, page 4):

> "A problem exists at Eneas Creek west of Summerland, where uranium in creek water at the present time appears to be naturally in excess of the proposed public drinking water standard (20 ppb uranium)".

Elevated uranium in surface water in the area, up to 2.5 ppm, was also noted by Church, 1980. The ultimate source of the uranium is believed to be groundwater from surrounding hills.

GEOLOGICAL SETTING

The Summerland basin is an Eocene volcanic caldera that was once part of a larger contiguous mass of volcanic and sedimentary rocks known as the "Penticton Tertiary outlier" (Church, 1982). The rocks in the Summerland basin consist of several major units of the Penticton Group such as the basal conglomerates (Kettle River Formation), massive volcanic beds (Marron Formation), feldspar porphyry trachyandesite lavas (Kitley Lake member), fine-grained trachytic lavas and ash flows (Nimpit Lake member), dome-forming dacitic lava and breccia (Marama Formation) and fluvial and lacustrine sedimentary rocks (White Lake Formation). The total stratigraphic thickness of this assemblage is in excess of 1000 metres (Figures 2-1-1 and 2-1-2). A drill hole through to the keel of the basin in a central location would be expected to encounter most of the stratigraphic units.

Rifting and graben development caused by crustal extension along the Okanagan valley occurred about 50 million years ago (Church, 1973). At this time, and subsequently, the rocks of the Summerland area were tilted and folded into an elliptical 5 by 10 kilometre synclinal trough, forming a natural catchment area for resupply of groundwater. Down dip on the beds the lateral movement of groundwater is impeded (and ponded?) along the Summerland fault at the southeast margin of the basin where down-faulted strata are juxtaposed against impervious massive granite.

Eneas Creek enters from the north, through the breached rim of the basin. It becomes intermittant and marshy toward the centre of the basin and eventually disappears into the glacial overburden. Elsewhere there are few streams; a number of ponds and marshes in closed depressions receive drainage directly from adjacent slopes.

At depth, groundwater is channelled along joints, bedding planes and faults, becoming trapped in permeable units such as conglomerate and sandstone beds and lenses of breccia in fault zones. In the clastic beds permeability is greatly reduced because of carbonate cement and abundant interstitial volcanic ash. Consequently much of the available groundwater is believed to be contained in the fractures. Slippage, as the result of folding, between the individual beds and along formational contacts, is believed to be the most promising mechanism for the formation of aquifers at depth.

DRILLING

The search for renewable energy sources began prior to the energy crisis of the mid-70s. To this end, Energy Mines and Resources Canada and the British Columbia Ministry of Energy, Mines and Petroleum Resources have supported a number of geothermal energy projects. The Geothermal Potential Map of British Columbia (Church *et al.*, 1983)

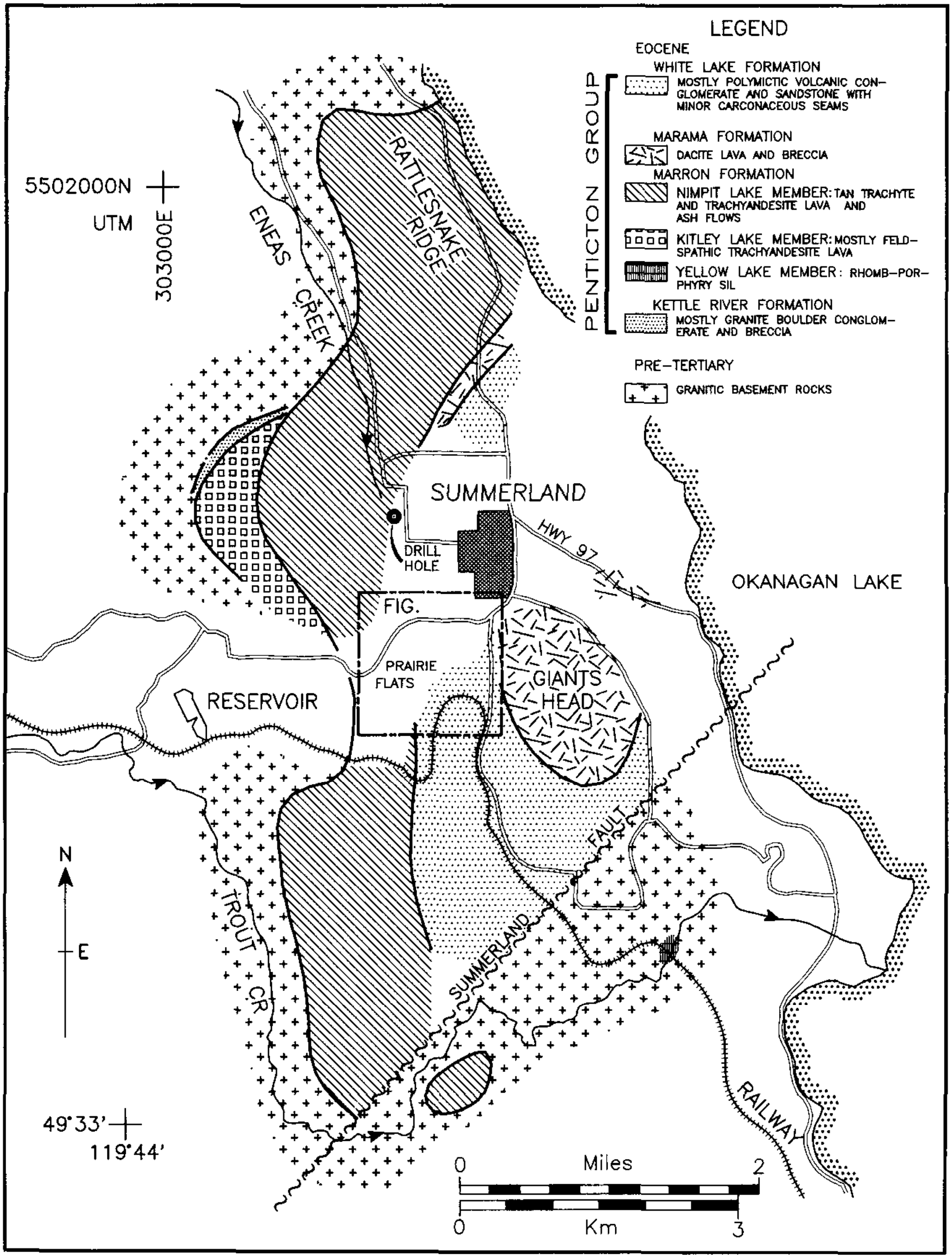

Figure 2-1-1. Location of geothermal drill hole in the Summerland basin.

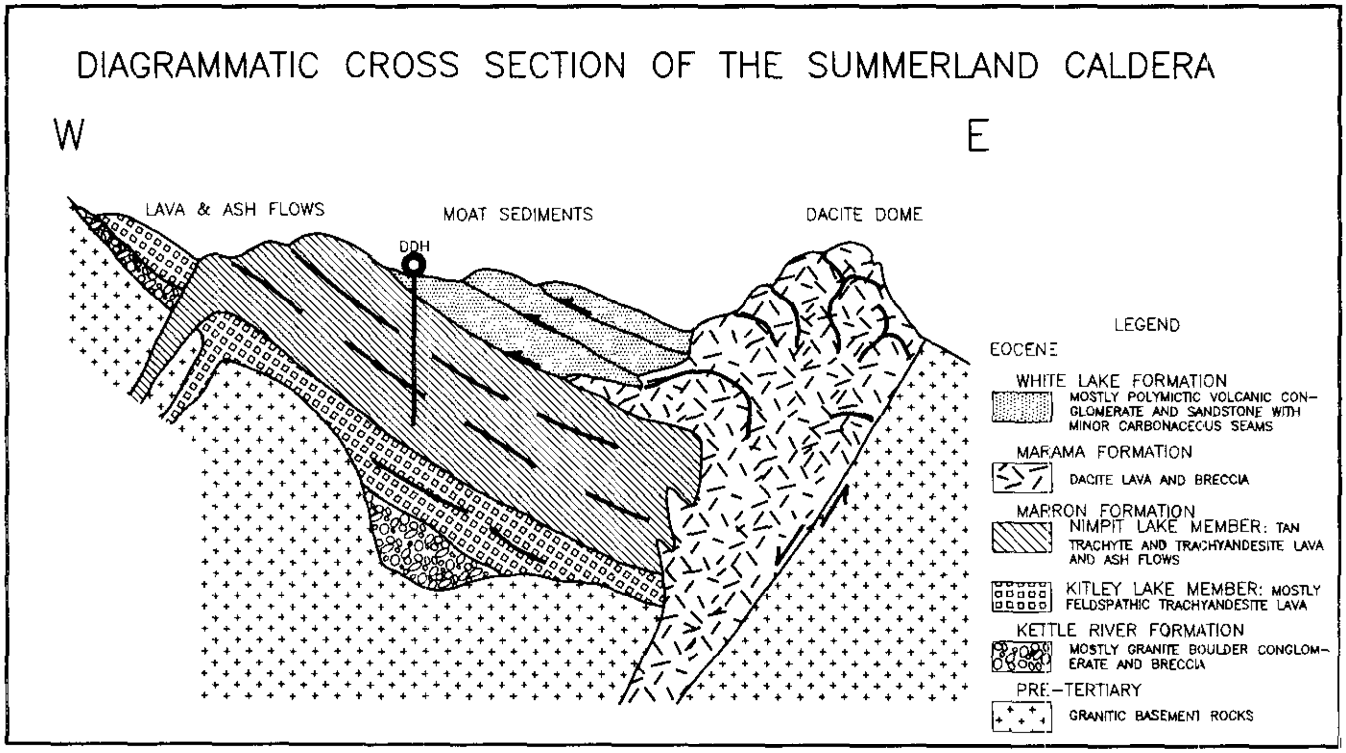

Figure 2-1-2. Diagrammatic cross-section of the Summerland basin.

was preceded by more detailed investigations suggesting geothermal potential in the White Lake basin and other Tertiary outliers in south-central British Columbia (Church, 1973; Jessop and Judge, 1971).

The first borehole in the area was sponsored by the federal government as part of the Geothermal Energy Program (Lewis and Werner, 1982). This was a diamond-drill hole intended to test the geophysical and geological properties of granitic rocks just south of the Summerland basin. Later, a second hole, the "Mraz well", was drilled to a depth of 200 metres to test the bedded Tertiary rocks in the southern part of the basin.

Lewis (1984) confirmed a regional high heat-flow and suggested targets for further research. He concluded that a more quantitative evaluation of the geothermal reserve required additional test wells.

The most recent hole (EPB/GSC 495) is located on the Boreboon farm (Mountain View Farms), just south of Eneas Creek, approximately 1 kilometre northwest from the centre of Summerland (Plate 2-1-1): (latitude 49°36'30", longitude 119°41'18"; elevation 505 metres). The location of this hole was chosen based on geology and proximity to a potential customer. The Boreboon farm proved to be well positioned on the west limb of the basin where a drill hole of reasonable depth could penetrate to the base of the Tertiary pile. This optimized the blanket effect and increased the possibility of intercepting a warm-water aquifer at the contact of the Tertiary beds with the underlying granite. The farm is a large user of natural gas for heating greenhouses and the owner was clearly interested in a cheaper source of energy.

Plate 2-1-1. Logging geothermal well at Summerland (Giant's Head in background)

The new well began as a 6-inch (15.2 cm) diameter rotary hole. It was drilled (March 10 to May 15th) to a depth of 544 metres, penetrating 56 metres of gravel and glacial till before entering bedrock. The hole was completed by BQ diamond drilling (July 2nd to July 31st) to a depth of 712 metres.

The geological profile of the bed-rock in this hole shows mostly alternating ash flows and lava flows typical of the Nimpit member of the Marron Formation, that is tan to dark grey trachyte/trachyandesite with small phenocrysts of diopsidic pyroxene and microlites of plagioclase and alkali feldspar in a fine-grained matrix. Quartz is rarely seen. Some admixture of shale and coal with the volcanic fragments recovered from the rotary drilling suggests penetration of part of the White Lake Formation or intercalation of similar sedimentary rocks in the volcanic pile.

The petrography of the lower, cored section of the drill hole is consistent with the chip samples obtained above. Most of this section appears to be Nimpit tuff-breccia with a few interlayered lava flows and crosscutting dikes. Flattening and welding of pumice fragments is seen at several levels. The angle between bedding and core axis averaged 45°.

A temporary water-flow of about 100 litres per minute was reported at approximately 150 metres depth; a geophysical log of the hole indicated possible water movement at 523 metres and other disturbances at 50 and 350 metres. Water movement is also believed to have been responsible for hematization in shear zones such as between 569 and 573 metres and by the local abundance of calcite and laumontite-filled fractures between 554 and 557 metres.

Preliminary results (Jessop, unpublished) gives a bottom hole temperature of slightly more than 33°C (at 706 metres) and a uniform thermal gradient close to 34 microkelvins per metre in the lower part of the hole.

ENVIRONMENTAL CONSIDERATIONS

The first caution regarding the environmental hazard of uranium in the Summerland area was from Bates *et al.* (1979, page 4): "A recent intensification of exploration and drilling in this area might have the effect of further increasing the uranium content in this (Eneas Creek) and other creeks".

In this regard it is noteworthy that testing rock samples and water from hole EPB/GSC 495 has shown no anomalous uranium concentrations nor high radioactive levels (Leaming, personal communication, 1990). However, accumulation of young uranium in the peat of nearby Prairie Flats was noted by Culbert (1980) and Culbert and Leighton (1988).

The Prairie Flats area is marshland on the edge of Summerland (Figures 2-1-1 and 3). According to Culbert *et al.* (1984) concentration of uranium in peat samples from Prairie Flats locally exceeds 1000 ppm in the surface layer; a maximum of value of 623 ppm uranium was obtained by the writer from a suite of 28 samples collected from the same general area (Table 2-1-1). The total accumulation of U_3O_8, to a depth of 1 to 3 metres, is estimated to be 230 tonnes (Culbert *et al.*, 1984). It is believed that this uranium was deposited since the last ice age and mostly within the last 2000 years (Levinson *et al.*, 1984).

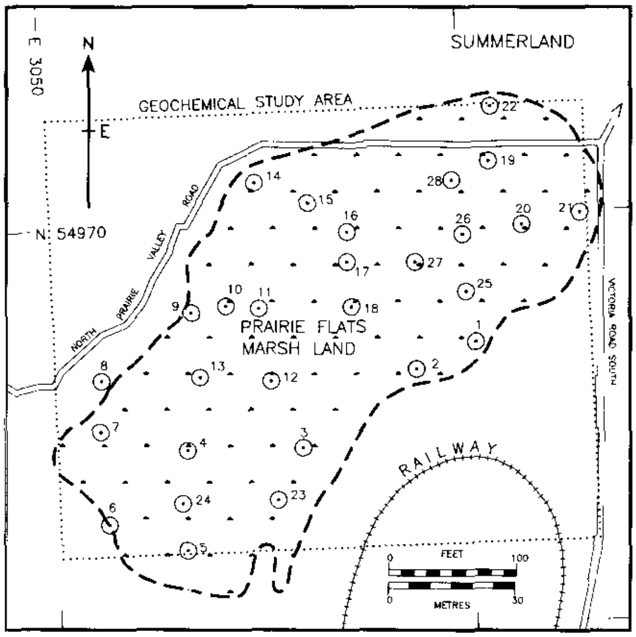

Figure 2-1-3. Sample locations, Prairie Flats marshland.

Young uranium with few gamma-active daughter products occurs in semi-arid regions of the southern interior of British Columbia and northeastern Washington State. The uranium was leached from felsic igneous rocks and fixed in organic-rich sediments. In the Flodelle Creek area of Washington uranium has been recovered from organic-rich sediments in a series of old beaver ponds — the source is a nearby uranium-rich granodiorite (Johnson *et al.*, 1987). Similarly, in the Eneas Creek area near Summerland the source of uranium appears to be groundwater feeding from fractured granitic rocks underlying the upper course of the stream.

The semi-arid climate of the Okanagan region has facilitated transport of uranium in streams. Evaporation has resulted in an increase in the alkalinity and bicarbonate content of these waters, both of which are important local factors for the solution of uranium at surface (Culbert and Leighton, 1978; Church and Johnson, 1978). Uranium was concentrated initially by evaporation and held by adsorption and ion exchange such as occurred in the Flodelle Creek deposit (Johnson *et al.*, 1987). Zielinski and Meier (1988) indicate that uranium at Flodelle Creek may be held loosely on organic matter as uranyl carbonate and phosphate complexes, then fixed, together with other metals, by the reducing action of bacteria. However, no specific uranium-bearing minerals have been identified and the exact mechanism of metal fixation on organic matter is not completely understood.

These young deposits are not readily detectable by conventional scintillometer surveys because of the lack of significant radioactive daughter products. They are of environ-

TABLE 2-1-1
ANALYSES OF PRAIRIE FLAT PEAT SAMPLES

No.	EASTING	NORTHING	LOI %	SIO$_2$ %	Ba PPM	Ce PPM	Cs PPM	La PPM	Mo PPM	Sc PPM	Th PPM	U PPM	V PPM
1	30603	549670	27.47	46.04	1106	58	6	34	39	8.8	8	106	267
2	30588	549663	23.12	50.99	979	58	4	26	82	9.3	18	222	214
3	30560	549644	17.64	51.75	997	47	2	28	7	10.6	5	10	153
4	30531	549643	20.97	52.53	1054	48	4	24	24	8.9	12	172	127
5	30530	549620	12.85	56.78	1050	48	4	43	7	8.0	5	2	77
6	30502	549621	13.80	55.33	874	50	1	30	7	7.4	5	8	61
7	30510	549650	35.33	31.78	402	1	13	1	3	18.7	17	25	32
8	30511	549662	6.82	63.53	1193	72	0	39	1	5.1	5	7	81
9	30533	549679	21.20	45.83	724	39	4	27	7	12.1	5	6	69
10	30543	549680	30.47	35.80	764	23	12	24	5	18.2	5	21	10
11	30550	549679	22.00	47.45	903	41	6	24	1	11.8	5	17	84
12	30552	549661	25.82	48.61	937	56	3	37	5	7.7	2	34	111
13	30536	549661	14.81	51.91	868	57	5	38	3	13.1	5	16	96
14	30551	549709	40.16	37.69	509	30	6	19	13	9.6	5	34	168
15	30562	549704	18.70	55.86	708	31	6	20	7	7.2	5	58	134
16	30573	549698	49.23	30.93	609	28	7	15	72	7.5	11	577	184
17	30572	549690	61.02	22.31	558	13	8	4	54	6.7	1	623	179
18	30572	549678	50.77	25.69	657	16	10	9	36	10.3	2	133	161
19	30609	549712	19.95	54.00	949	51	1	26	4	6.7	12	30	106
20	30617	549698	17.01	52.96	908	46	3	30	27	8.5	5	80	134
21	30630	549700	28.12	44.61	773	46	3	12	4	7.4	5	46	125
22	30610	549726	12.22	60.92	1019	50	0	21	7	5.9	5	10	72
23	30552	549632	14.18	55.55	916	37	1	15	7	7.8	5	2	67
24	30530	549632	18.26	54.89	1145	56	2	32	7	7.7	5	46	99
25	30600	549682	34.17	42.22	712	24	5	8	68	6.9	0	187	135
26	30601	549697	33.20	41.43	684	28	5	15	49	8.4	0	193	109
27	30588	549690	47.17	28.81	532	11	6	15	66	8.7	10	393	139
28	30599	549708	19.72	56.49	969	46	2	8	3	6.9	3	33	78

mental concern because they contain significant concentrations of poorly fixed uranium and some other elements such as molybdenum, and inadvertant cultural disruption may generate transient, perhaps harmful, levels of dissolved uranium in local ground and surface waters (Zeilinski *et al.*, 1987).

ANALYTICAL RESULTS

Table 2-1-1 gives the results of analyses of 28 samples of peat from Prairie Flats (Figure 2-1-3). Eleven chemical variables were chosen to characterize the deposit, the main variables being loss on ignition (LOI) representing organics (mostly carbon), silica (SiO_2) representing the clastic sedimentary fraction; and uranium (U) representing chemical precipitate. Other elements analysed are barium (Ba), cerium (Ce), lanthanum (La), molybdenum (Mo), scandium (Sc), thorium (Th) and vanadium (V).

Loss on ignition is the weight loss of the sample after heating to 550°C. This is an indication of its organic content.

Silica ranges from 22.3 to 63.5 per cent and is generally the most abundant component in the peat. It is concentrated in the silty layers as detrital quartz and in silicates such as feldspar, the clay minerals and mica.

Other major oxides and LOI constituents comprise much of the remainder. These include alumina (Al_2O_3), carbon (C), carbon dioxide (CO_2), water (H_2O), and probably minor amounts of lime (CaO), magnesia (MgO), potash (K_2O), soda (Na_2O) and phosphate (P_2O_5), although these variables have not been individually determined for this report. The LOI ranges from 6.8 to 61.0 per cent.

The minor element values are mostly elevated compared to other sediments. It is well known that peatbogs and marshlands can be sites for anomalous concentrations of metals, especially heavy metals (Zeilinski *et al.*, 1987). This is especially true for uranium, molybdenum (Mo), and vanadium which are concentrated up to two or three magnitudes above the levels in source rocks. The exception is thorium which averages 5 ppm, a value lower than some of the source rocks in the region (Church and Johnson, 1978).

TABLE 2-1-2
CORRELATION MATRIX OF CHEMICAL DATA*

VARIABLE	LOI	SiO_2	Ba	Ce	Cs	La	Mo	Sc	Th	U	V
LIO	1	**−.909**	−.754	−.57	**.742**	−.567	**.611**	.284	−.196	**.742**	.237
SiO_2		1	**.798**	**.684**	−.736	**.617**	−.501	−.33	.201	−.61	−.087
Ba			1	**.829**	−.652	**.728**	−.302	−.389	.077	−.395	.059
Ce				1	−.592	**.868**	−.138	−.495	−.07	−.248	.274
Cs					1	−.428	.361	**.629**	−.064	.508	−.014
La						1	−.15	−.23	.118	−.325	.124
Mo							1	−.125	−.134	**.75**	**.542**
Sc								1	.264	−.098	−.483
Th									1	−.109	−.073
U										1	**.519**
V											1

* *Based on log transformation of data in Table 2-1-1.*

Molybdenum is commonly associated with uranium and enrichment of vanadium is noted in some deposits (Levinson *et al.*, 1984). In the sedimentary cycle, under oxidizing conditions, molybdate ions are mobile and travel together with vanadium. Under strongly reducing conditions, such as found in peat bogs and carbonaceous sedimentary rocks, molybdenum may precipitate as molybdenite (MoS_2) if hydrogen sulphide (H_2S) is available.

Thorium can also be adsorbed by organic material, however, this element is relatively insoluble in most surface and groundwaters and its presence can usually be explained by silicate variations in the silt fraction.

Table 2-1-2 presents the correlation matrix (r-coefficients) for the elements listed in Table 2-1-1 (log transformed). It can be seen that the abundances of uranium and molybdenum are positively correlated with LOI as is cesium (Cs), which is a heavy alkali metal absorbed in clays. Scandium adsorbs on clay explaining the positive correlation of this element with cesium — it may also substitute to some extent for ferrous iron, especially in micas. The association of clay and organic material in the peat deposit suggested by these data, is not surprising and the strong negative correlation of silica (representing clastic material) and LOI (that includes organics), $r=-0.909$, fits a

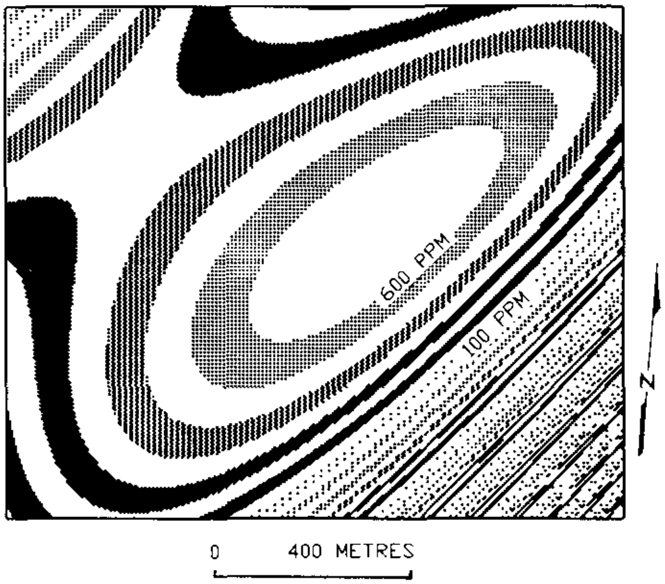

Figure 2-1-4. Trend surface map of uranium (U), Prairie Flats area (6th order polynomial surface)

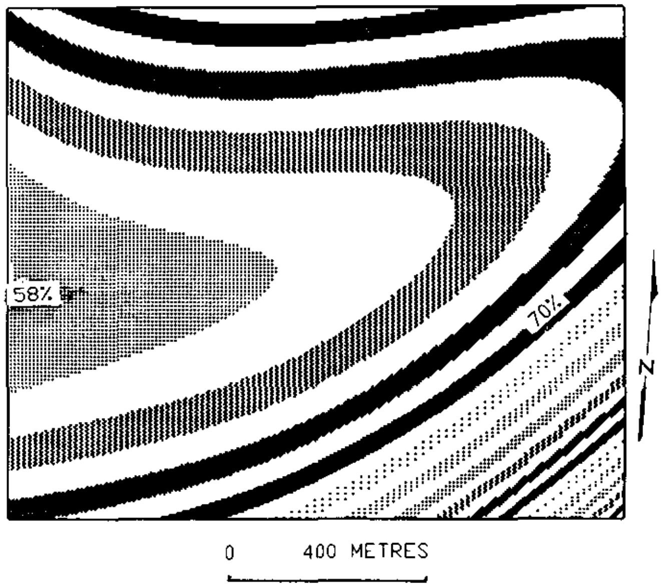

Figure 2-1-5. Trend surface map of SiO_2, Prairie Flats area (6th order polynomial surface).

model indicating that some of the peat is relatively free of clastic input, perhaps distal from the source area. The alkaline-earth and lanthanide elements, barium, lanthanum and cerium, are positively correlated with silica suggesting transportation in clastic minerals, perhaps in alkali feldspar. Lanthanum and cerium are also known to concentrate in apatite which may survive transport as a clastic component, together with quartz.

Figure 2-1-4 is a trend-surface map of uranium content based on the random array of sampling stations in the Prairie Flats area (Figure 2-1-3). The contours form an assymetric elliptical bull's eye rising abruptly on the southeast side of the deposit from 100 to more than 600 ppm over a distance of 200 metres. This is a 6th order polynomial surface (coefficient $r=0.57$); the procedure for preparation of trend-surface maps is described in detail by Krumbein, 1959. The general shape of the contours coincides with the northeast elongation of the marshland, with the highest concentration of uranium in the east-central part. Possible erosion or leaching of the deposit along the southeast side may account for the rapid change in uranium values here. Alternatively, the uranium may already have migrated from the centre of peat accumulation farther to the west.

Figure 2-1-5 is the result of trend-surface analysis of normalized silica data for the Prairie Flats area. The silica is normalized to a LOI-free basis to better reflect the distribution of the clastic sedimentary fraction in the area. This assumes that the coarse clastic fraction is mainly quartz. Normalized silica ranges from 51.49 to 70.37 per cent, with the highest values peripheral to much of the marshland area. The map contours have a parabolic outline with values diminishing from the maximum of about 70 per cent on the north and southeast margins of the Prairie Flats area to about 50 per cent on the west. This is also a 6th order polynomial surface (coefficient $r=0.61$). It appears that these contours are roughly parallel to the original margin or strand line of the peat basin which evidently had a northeast-southwest elongation.

In conclusion, variations in the abundance of selected elements show the influence of a combined clastic and chemical depositional environment on the formation of the Prairie Flats marshland — an environment where alkalinity and oxidizing/reducing conditions were important.

The original geometry of the basin is suggested by the shape of the trend-surface contours for normalized silica. These contours are parabolic in outline and open to the west possibly defining the strand line of the original marsh. This suggests that the centre of the marshland may have been farther west (prior to erosion) than the present Prairie Flats location.

The highest concentration of uranium, over 600 ppm, is in the east-central part of the Prairie Flats area. Steep uranium contours on the southeast side suggest some chemical remobilization of uranium in the marshland to the southeast.

This may have been caused by inadvertent cultural disturbance such as farming or urban activities at the outer Summerland town limits. However, further studies in the area are necessary to confirm these conclusions.

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