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DIFFERENCES IN THE COMPOSITION OF SOILS UNDER OPEN AND CANOPY CONDITIONS AT TWO SITES CLOSE-IN TO THE GREAT CANADIAN OIL SANDS OPERATION, FORT McMURRAY, ALBERTA

by

J. BAKER
Northern Forest Research Centre
Canadian Forestry Service

for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Project LS 3.4.1

April 1980

The Hon. J.W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

and

The Hon. John Roberts
Minister of the Environment
Environment Canada
Ottawa, Ontario

Sirs:

Enclosed is the report "Differences in the Composition of Soils Under Open and Canopy Conditions at Two Sites Close-in to the Great Canadian Oil Sands Operation, Fort McMurray, Alberta".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Land System under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

A.H. Macpherson, Ph.D
Member, Steering Committee, AOSERP
Regional Director-General
Environment Canada
Western and Northern Region

DIFFERENCES IN THE COMPOSITION OF SOILS UNDER OPEN AND CANOPY CONDITIONS AT TWO SITES CLOSE-IN TO THE GREAT CANADIAN OIL SANDS OPERATION, FORT McMURRAY ALBERTA

DESCRIPTIVE SUMMARY

Atmospheric emissions from power plants, petroleum and gas plants, and other industrial activities may adversely affect the environment. Sulphur dioxide is a potentially hazardous atmospheric pollutant resulting from oil sands extraction. Although the present levels of emission do now show evidence of being hazardous to the environment (AOSERP Project LS 3.4 by Addison and Baker 1979), detailed studies undertaken in this project revealed that the site closer (2.3 km) to the Suncor plant showed degradation of ground lichens whereas the other site (5.3 km) did not show such degradation.

The soils sampled from these two sites were significantly different in several macronutrients. Also, the jackpine foliage from the closer site contained more sulphur than that from the distant site.

This report has been reviewed and accepted by the Alberta Oil Sands Environmental Research Program.

W.R. MacDonald, Ph.D
Director (1980-81)
Alberta Oil Sands Environmental
Research Program

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Soils sampled at Sites 1 and 2 [2.3 and 5.3 km south of the Great Canadian Oil Sands (GCOS) plant, Fort McMurray, respectively] were found to differ statistically with reference to several macronutrients. Soils under cover of a canopy and those in open areas differed considerably with respect to soil nutrients and pH. Differences in nutrient concentrations under open versus covered soils probably are due mainly to effects of the canopy; however, this may not fully explain soil sulphur and titanium concentrations.

Jack pine foliage sampled at Site 1 was more concentrated in S than that sampled at Site 2, suggesting the possibility that atmospheric sulphur may have played a role. Other foliar nutrient differences more likely are the result of other or natural phenomena.

To date, despite the higher S concentrations in both jack pine foliage and soils under the canopy at Site 1, there is no conclusive evidence that atmospheric pollutants emitted as a result of the overall exploration operation have as yet altered the existing soil nutrient regime of the study area, or are responsible for differences observed between the two sites.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Atmospheric emissions from power plants, petroleum and gas plants, and other industrial activities may adversely affect the environment. A potentially hazardous atmospheric pollutant resulting from the oil sands extraction is sulphur dioxide (SO_2). While as yet there appears to be little damage or danger to the environment from present levels of atmospheric SO_2, the fact that larger extraction plants are soon to be operational could alter markedly this situation.

This study was undertaken to increase the existing baseline information on a specific soil environment within the AOSERP study area (Figure 1) and its response to atmospheric pollutants arising from the oil sands exploration activities.

In view of the fact that Addison and Baker (1979) were unable to demonstrate any detrimental influence to the environment directly attributable to atmospheric pollutants, two sites due south of, and within 5.5 km of the Great Canadian Oil Sands (GCOS)[1] stack, on degraded dystic brunisol soils were studied in greater detail. The closer (2.3 km) of these sites showed some degradation of ground lichens whereas the other (5.3 km) did not. It was felt that, if pollutants arising from the GCOS operation were to demonstrate adverse effects, these would be observed most readily at these close-in sites where higher ambient SO_2 concentrations have been reported (Smith 1979).

Samples of both soils and jack pine foliage were taken and analyzed chemically and the results subjected to statistical analysis. This report records the results and possible explanations of these are offered.

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[1] GCOS amalgamated with Sun Oil Company in August 1979, after the writing of this report was completed, to become Suncor, Inc.

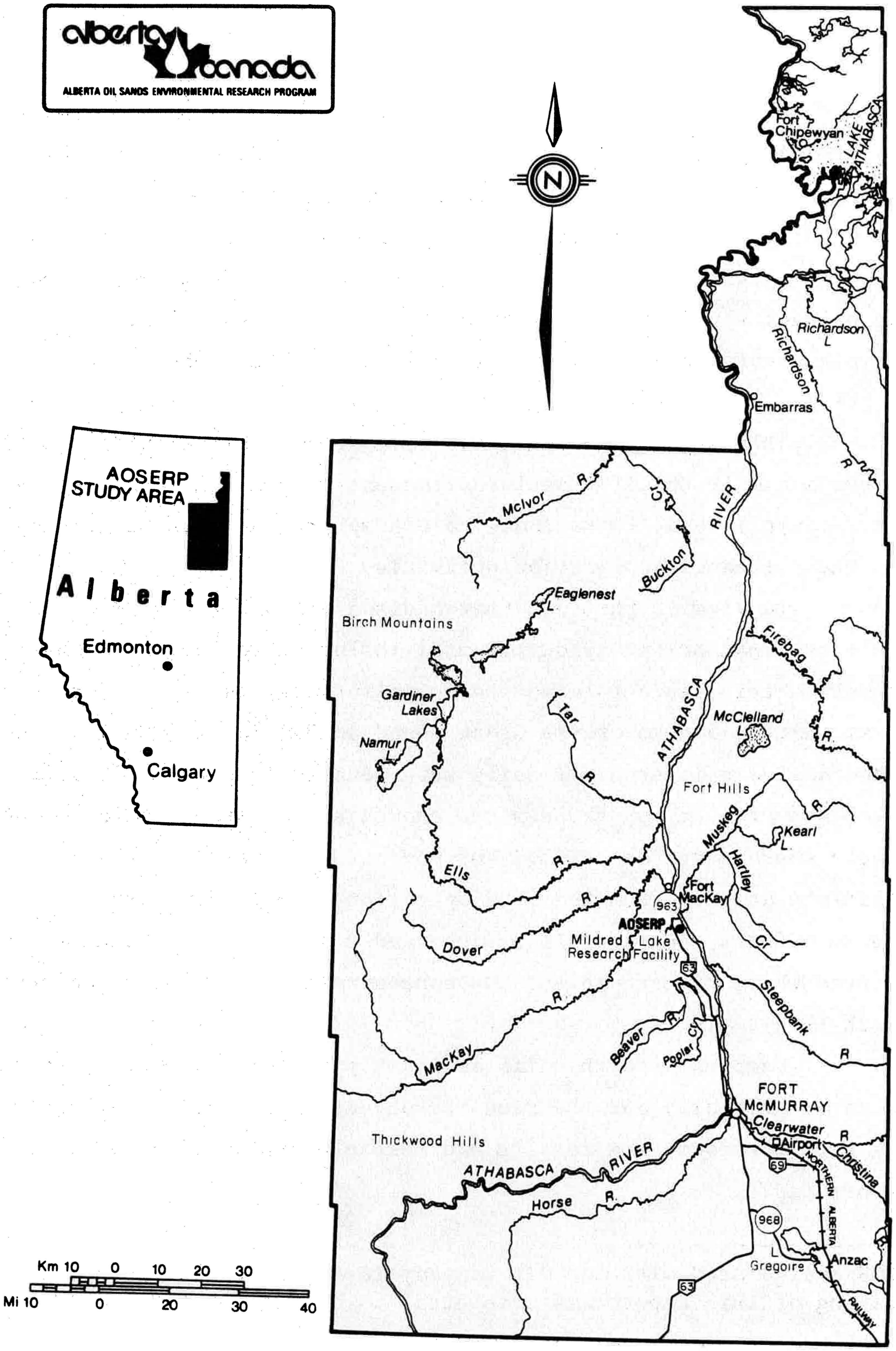

Figure 1. Map of the AOSERP study area.

2. MATERIALS AND METHODS

Two sites (1 and 2, 2.3 and 5.3 km south of the GCOS plant, respectively) were selected and sampled with reference to soil and jack pine foliage. Both soils and vegetative cover were described previously by Addison (1976). Sites 1 and 2 represent Sites A and D, respectively, as described in Addison (1979) (Figure 2). Additional information regarding the soils and the vegetation and the positioning of sites within the study area was supplied by Addison and Baker (1979).

2.1 SOIL SAMPLING

Soil pits 2 x 1.5 x 1 m were dug immediately under a clump of pine trees (about four or five) and in an open space between clumps. The four walls of the pits (north, south, east, and west) were sampled at the litter surface (L-F-H), the surface of the Ae horizon (u-Ae), the lower boundary of the Ae (ℓ-Ae), the upper boundary of the Bm (u-Bm), the lower Bm boundary (ℓ-Bm), and in the mid-C horizon. The sampling depths within the profile corresponded to 6-0, 0-3, 12-15, 15-18, 33-36,and 61 cm at Site 1 and 3-0, 0-3, 7-10, 10-13, 39-42, and 61 cm at Site 2. These profile samples were analyzed separately.

Duplicate 5 and 10 g of field moist L-F-H and mineral soils were extracted for 4 h with 1N ammonia chloride (0.1 N in ethylene diaminetetraacetic acid) immediately followed by a 16 h extraction with 6N hydrochloric acid. All extractions were made by refluxing at 70°C under a partial vacuum of 50 kPa. In principle, the extraction procedure used was essentially that of Janssen (1958), who applied the method to the fractionation of soil nitrogen (N). His assumptions were that the salt extractable N and other soil nutrients were immediately or readily available for plant uptake and at least a portion of the acid extractable nutrients also would be available, arising as they do in part by the hydrolysis of organic matter and easily hydrolyzed mineral matter. However, the emphasis of the extraction technique in this study was not mainly in reference to availability but

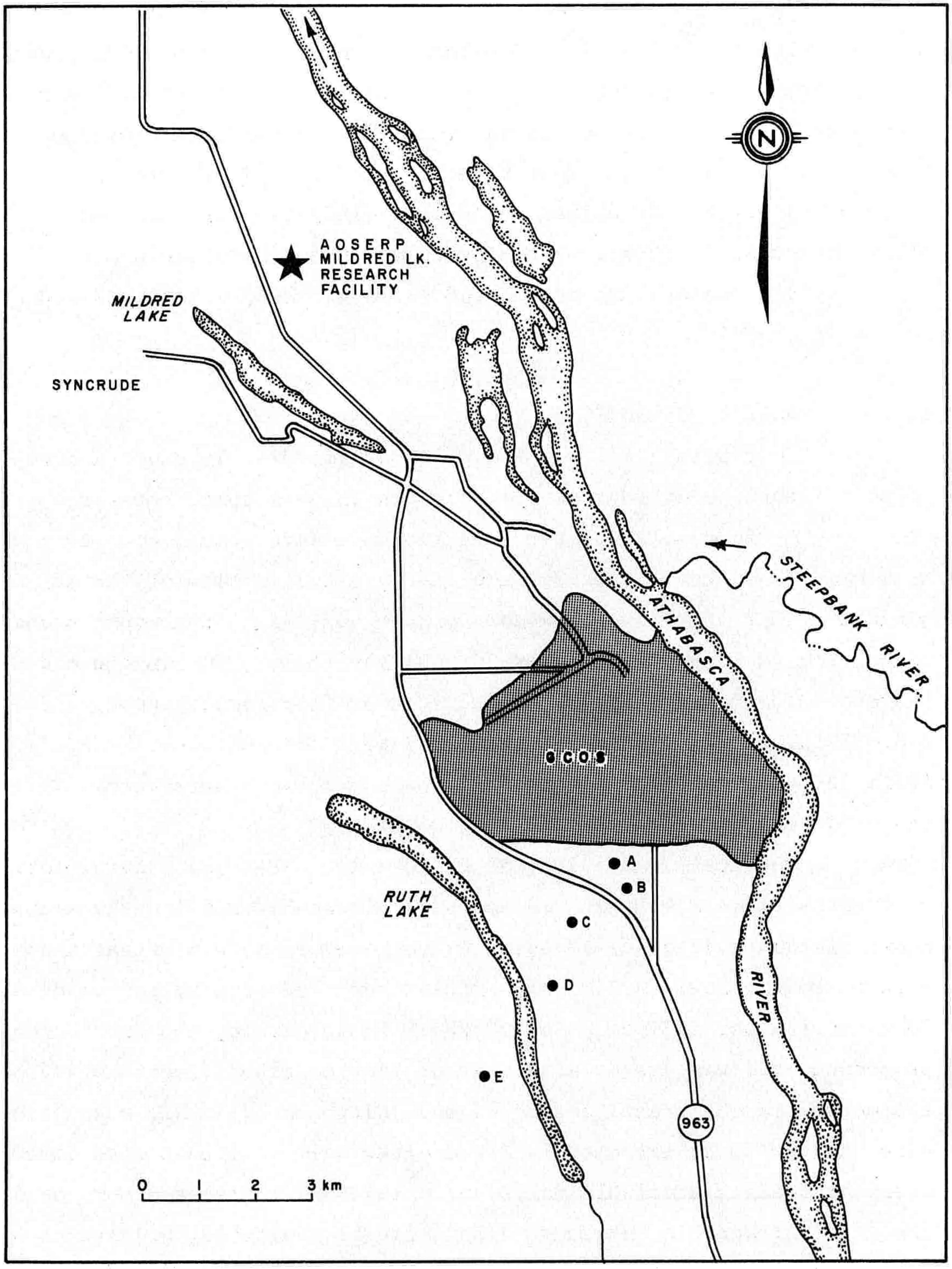

Figure 2. Location of gradient sites in the vicinity of the GCOS operation.

rather was used as a means of demonstrating either natural or induced soil nutrient concentration differences associated with the sites under the several sampling regimes.

Analysis of the extracts included: sulphate-sulphur (SO_4-S) by the Dean modification of the Johnson-Nishita procedure as reported by Carson et al. (1972); phosphorus as the orthophosphate ($H_2PO_4^-$) by the molybdenum blue method (Jackson 1958); cationic species, calcium (Ca), magnesium (Mg), potassium (K), aluminum (Al), iron (Fe), and titanium (Ti), were evaluated by atomic spectrophotometry using an I.L. 251 unit and methods supplied by the manufacturer.

2.2 FOLIAR SAMPLING

Foliar samples were removed from five trees in close proximity to the soil pits at both sites. Current and one-year-old tissues were sampled in late fall from the upper three-whorl branches, washed with distilled water, dried at 75°C, and reduced to 60 mesh in a Wiley mill. Triplicate 0.10 to 0.15 g samples of prepared materials were ashed in a combustion flask which contained 25 mL of 0.5N HCl (0.18% in hydrogen peroxide) as an absorber. The flasks remained stoppered during and for 0.5 h after combustion to minimize loss. Aliquots of the absorbing solution were analyzed for SO_4-S, $H_2PO_4^-$, Ca, Mg, K, Al, Fe, and Mn using methods similar to those used in the soil analyses. Because of the combustion technique used, values recorded are total concentrations.

Since it is well known that vegetative materials can absorb gaseous atmospheric compounds directly through their leaves, the examination of jack pine foliage was included in a predominantly soils study to aid in the determination of the effects, if any, that atmospheric pollutants were having on the nutrient status, balance, and pH of soils in close proximity to the GCOS operation.

Statistical treatment of soil and foliar data was achieved by a 2^2 factorial analysis.

3. RESULTS AND DISCUSSION

3.1 SULPHUR

The factors considered in the experimental design, distance from GCOS stack, and cover, were statistically significant ($P < 0.01$) in the concentration and distribution of both soil S-forms in the profiles at the two sites. Since there was a strong interaction between the two factors ($P < 0.01$), it was apparent that they did not act independently of each other (Snedecor and Cochran 1956). However, data (Tables 1 and 2) indicated that the factors did not act similarly at the two sites. The NH_4Cl--extractable S concentration of the soil under cover at Site 1 was in considerable excess of that observed for the open area. The reverse held true for Site 2. Addison and Baker (1979), using the Huey Plate technique, reported that atmospheric SO_2 concentrations of Site 1 during the period of measurement were greater than those of Site 2. In addition, they reported that the various species checked for S all showed considerably higher concentrations at Site 1 than at Site 2, suggesting that Site 1 was the more heavily impinged. However, this increased atmospheric S concentration was not reflected in soil pH nor in the NH_4Cl--extractable soil S concentrations in samples from the open areas; the more distant Site 2 exhibited lower soil pH values and considerably higher S concentrations throughout the entire sampling depth (Table 1). In other words, despite supposedly greater atmospheric S concentrations, as suggested by the wind direction frequencies (Figure 3) which indicate a stronger impingement at Site 1, the open soils at Site 1 exhibited higher soil pH values and lower S concentrations than those at Site 2. However vegetation at Site 1 showed the higher S concentrations (Addison and Baker 1979). Since four separate profiles were sampled individually and analyzed, this anomaly hardly can be attributed to a sampling inconsistency. Consequently, the only reasonable explanation appeared to be that of a natural soil variation. Thus, the statistical significant difference in S concentration in the open soils of these sites may not exclusively be attributed directly to the GCOS operation.

Table 1. Mean pH values and nutrient concentrations † (ppm) in soils from horizons under jack pine cover and in open areas at Sites 1 and 2 (2.3 and 5.3 km south of the GCOS plant, respectively) extracted by NH_4Cl.[a]

Horizons	Cover	S	P	Ca	Mg	K	Al	Fe	Ti	Ph
Site 1										
L-F-H	Canopy	238.7	111.5	4334.9	495.5	643.2	689.3	1365.0	13.5	4.3
	Open	18.4	98.4	4675.2	541.9	529.6	547.0	1339.9	11.0	4.7
u-Ae	Canopy	9.0	12.0	83.7	10.5	16.8	45.6	340.8	5.8	4.4
	Open	0.6	23.0	149.3	19.1	27.1	122.8	330.2	6.8	4.9
ℓ-Ae	Canopy	9.7	13.9	72.5	9.5	17.6	56.8	392.0	7.0	4.4
	Open	0.3	31.8	130.4	17.6	32.8	151.7	537.2	8.1	4.9
u-Bm	Canopy	24.9	264.3	115.8	18.2	23.5	449.0	3489.9	39.5	4.4
	Open	1.7	23.2	102.8	16.9	36.1	642.6	1668.3	19.9	4.6
ℓ-Bm	Canopy	10.8	122.6	101.6	17.6	17.4	390.4	1299.1	6.6	4.7
	Open	0.1	23.2	102.5	14.3	18.1	206.9	327.5	4.0	4.5
C	Canopy	9.0	10.6	140.6	23.3	15.9	218.6	306.5	1.9	4.9
	Open	0.0	7.0	126.4	19.1	17.2	117.9	90.1	2.5	4.6
Site 2										
L-F-H	Canopy	48.3	57.3	2603.1	205.7	493.2	579.1	1002.5	9.3	4.0
	Open	125.4	76.9	3310.5	343.7	495.4	520.6	794.3	0.0	4.5
u-Ae	Canopy	0.0	6.9	80.6	8.9	14.5	56.4	255.6	2.9	4.1
	Open	22.2	2.6	104.6	9.3	25.5	60.9	51.1	0.0	3.9
ℓ-Ae	Canopy	0.0	8.5	64.4	7.7	15.3	68.9	284.1	7.4	4.0
	Open	21.7	5.3	92.5	10.8	21.2	77.1	87.7	5.0	4.2
u-Bm	Canopy	3.0	9.4	167.1	23.4	29.8	399.4	821.8	4.6	4.6
	Open	42.7	22.0	87.1	21.1	31.4	655.3	836.7	9.0	4.3
ℓ-Bm	Canopy	0.0	3.0	101.5	15.8	20.2	256.7	165.1	0.7	4.7
	Open	22.1	1.7	110.5	22.5	15.2	186.5	127.0	0.0	4.6
C	Canopy	0.0	2.1	76.9	19.8	10.0	45.2	157.1	0.0	4.8
	Open	18.9	3.5	33.0	8.2	6.8	65.0	180.3	1.0	4.4

[a]† each datum represents a mean of 8 replications.

Table 2. Mean nutrient concentrations † (ppm) of soils from horizons under jack pine cover and in open areas at Sites 1 and 2 (2.3 and 5.3 km south of the GCOS plant, respectively) extracted by 6N HCl.

Horizons	Cover	S	P	Ca	Mg	K	Al	Fe	Ti
Site 1									
L-F-H	Canopy	111.6	108.5	2098.2	191.1	184.2	749.7	2126.2	45.6
	Open	69.0	126.0	2253.4	257.6	204.7	1119.5	1882.1	68.6
u-Ae	Canopy	12.9	1.9	26.6	33.1	13.5	223.4	964.6	17.5
	Open	1.6	39.4	43.2	65.2	36.1	483.9	2164.9	22.7
ℓ-Ae	Canopy	12.8	3.6	27.5	36.3	14.3	269.4	1214.4	20.4
	Open	1.8	58.1	68.8	123.1	47.9	812.3	2728.4	31.1
u-Bm	Canopy	14.1	90.2	55.4	188.4	61.1	1251.4	4425.7	22.3
	Open	2.4	185.5	117.2	474.4	100.2	2655.8	6304.0	43.8
ℓ-Bm	Canopy	12.5	86.1	67.4	255.8	73.3	1697.3	6521.5	31.6
	Open	1.9	123.7	86.2	427.2	111.0	2515.4	7609.8	36.9
C	Canopy	12.6	80.8	64.8	284.3	97.6	1782.9	5922.3	32.1
	Open	1.0	64.6	83.6	380.6	106.5	1960.3	7060.1	39.8
Site 2									
L-F-H	Canopy	94.1	72.8	697.6	81.9	38.4	503.3	1306.2	30.5
	Open	58.6	113.6	902.1	133.0	117.6	695.4	989.7	42.4
u-Ae	Canopy	1.1	5.8	19.3	31.7	10.0	243.7	752.4	15.8
	Open	0.6	10.6	18.3	23.1	22.9	220.8	562.8	18.8
ℓ-Ae	Canopy	1.8	9.3	23.6	32.8	11.7	318.6	1230.5	21.9
	Open	0.6	23.6	35.7	57.8	34.6	433.6	1263.8	27.3
u-Bm	Canopy	7.4	201.9	71.9	335.8	80.9	2921.9	10393.1	50.9
	Open	2.8	178.2	81.7	498.7	102.0	4252.4	11010.6	53.6
ℓ-Bm	Canopy	2.8	51.5	53.9	210.8	98.6	2698.1	6503.3	33.5
	Open	2.0	57.4	52.3	390.1	106.0	2639.4	6216.4	34.6
C	Canopy	1.5	25.4	46.8	208.0	66.0	989.7	3513.4	21.1
	Open	0.5	22.8	38.6	193.3	57.1	690.0	1630.5	30.0

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[a]† each datum represent a mean of 8 replications.

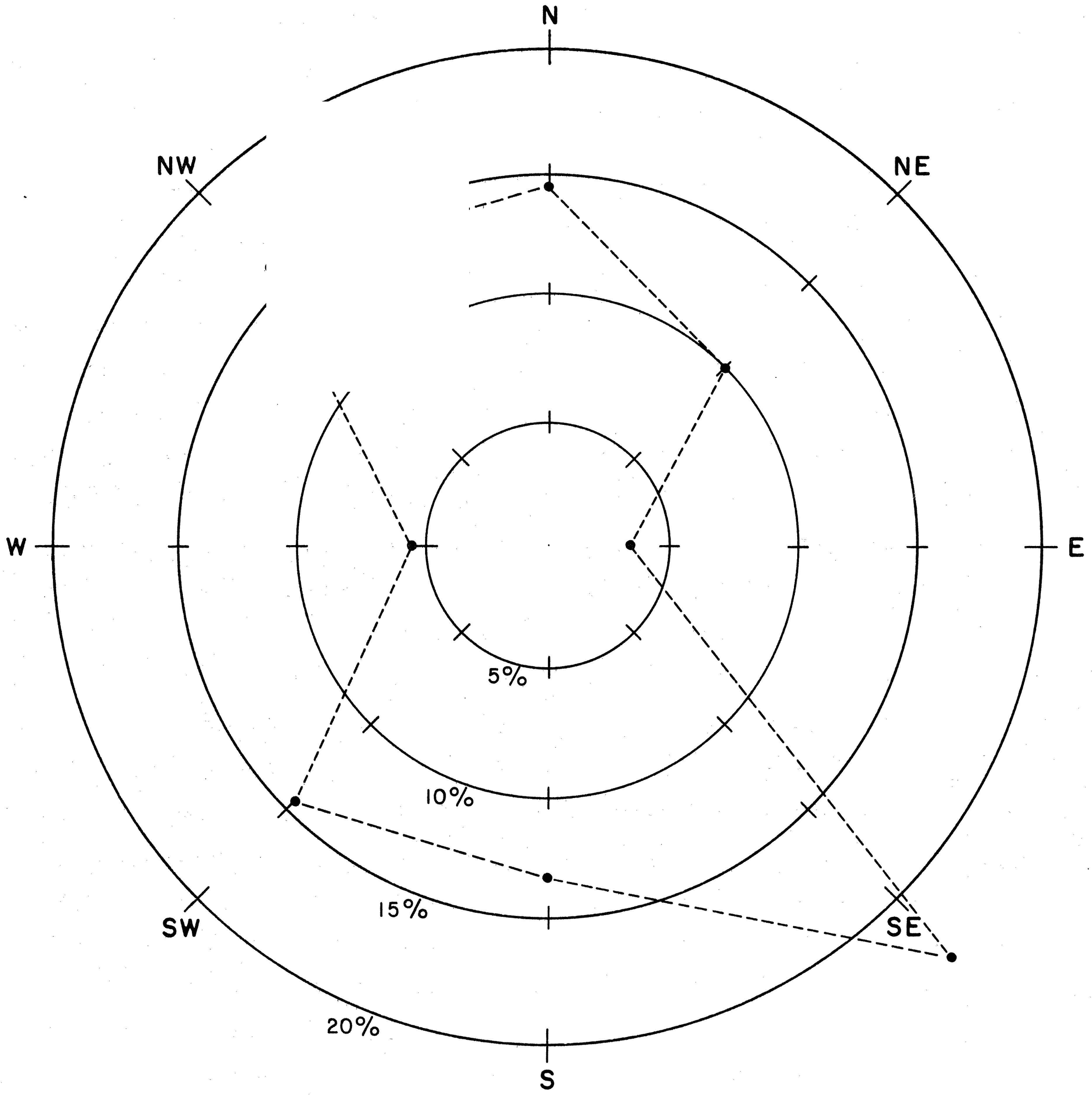

Figure 3. Wind rose of direction frequency for Mildred Lake (from Walmsley and Bagg 1977).

Sulphur concentrations in open soils detected by 6N HCl, although slightly greater at Site 1 and thus more in keeping with the reported atmospheric gradient, were for practical purposes similar. Of the S removed by both extractants from samples from open areas, a slightly greater proportion of that at Site 2 was sensitive to NH_4Cl. This tended to suggest that natural soil variation was responsible for the S concentration differences.

The soil S concentrations removed by both extractants from samples from under the canopy were consistently greater at Site 1 (Tables 1 and 2). This may be explained partly by the fact that atmospheric SO_2 concentrations were greater at Site 1. As a consequence, opportunity for the direct absorption of S may have been enhanced. Mudd (1975) reported the possibility of the entry of SO_2 through the stomata and its conversion to SO_4-S. Probably much of this S subsequently was deposited on the soil surface by stemflow, throughfall, litterfall, etc. (Curlin 1968; Mahendrappa 1974) and redistributed throughout the solum by natural nutrient cycling.

In this study, however, there may be another, perhaps more valid, explanation for the very high S concentrations observed under the canopy at Site 1. In the digging of the soil pit (and this pit only), lens of bitumen were encountered frequently in the C horizon. Consequently, much of, if not all, the elevated S concentrations noted for these soils could have been due to the presence of S-enriched bituminous compounds. Because of the lack of any consistent trend between sites, data (Table 3) tend to confirm the suggestion that soil S concentrations observed at both sites under the two sampling conditions were due mainly to natural soil differences.

3.2 PHOSPHORUS

Concentrations of soil phosphorus detected by the two extractants under both conditions of sampling were usually much greater in the soils of Site 1 (Table 1), the one exception being HCl--extractable P in the u-Bm horizon under the canopy (Table 2). While the statistical analysis indicated that P concentrations throughout the profiles

Table 3. Mean profile concentrations, to the nearest whole numbers (ppm), of nutrients under jack pine cover and in open areas as shown by NH_4Cl and 6N HCl extraction.

	NH_4Cl[a]		6N HCl[a]		Sum	
	Canopy	Open[b]	Canopy	Open[b]	Canopy	Open
Sulphur						
Site 1	51	4	30	13	81	17
Site 2	9	42	18	11	27	53
Calcium						
Site 1	808	881	390	442	1198	1323
Site 2	516	623	152	188	668	811
Magnesium						
Site 1	96	105	165	288	261	393
Site 2	47	69	167	216	214	285
Potassium						
Site 1	123	110	74	101	197	211
Site 2	97	99	51	74	148	173
Phosphorus						
Site 1	89	35	62	100	151	135
Site 2	15	19	62	68	77	87
Iron						
Site 1	1199	716	3529	4625	4728	5341
Site 2	448	346	3951	3612	4399	3958
Aluminum						
Site 1	308	315	996	1591	1304	1906
Site 2	234	261	1279	1489	1513	1750
Titanium						
Site 1	12	9	28	40	40	49
Site 2	4	3	29	35	33	38

[a] Extraction with NH_4Cl or 6N HCl.

[b] Type of cover.

of soils at Site 1, under both sampling regimes and for both extractants, were significantly different ($P < 0.01$) to those observed for the profiles of Site 2, it is hardly expected that this was due to P emissions from the GCOS stack. Addison and Baker (1979) have shown that such emissions are only minimal. A more likely explanation for these concentration differences is the proximity of Site 1 to the highway, which for many years was unpaved. Verry and Timmons (1977) reported a variety of cations and anions, including P, are carried into the atmosphere during soil disturbances either from natural events or man's activity. Consequently, much of the P detected at Site 1 may have come as a result of the deposition of dust during highway construction and use and from the removal of the surface mantle in the extraction of the oil sands. The use of salt on the highway during winter conditions also could be contributory.

An interesting feature of these data was seen in the effect of the canopy on P distribution within the solum. Concentrations of NH_4Cl--extractable P were smaller, although not significantly, in the L-F-H, u- and ℓ-Ae borizons under the canopy, whereas in the u- and ℓ-Bm they were significantly higher ($P < 0.01$:$P < 0.05$). This probably was the result of both increased vegetative uptake, especially from the upper horizons under the canopy, and increased downward movement as a result of increased water movement through these soils arising from foliar drip and stemflow which are normally more acid than incident rainfall (Baker et al. 1977). Data (Table 1) tend to substantiate this view.

The effect of canopy was even more pronounced on the HCl--extractable P concentrations. These were considerably lower in all horizons than comparable samples from open areas, except in the C. Significant differences were observed in the L-F-H and u- and ℓ-Ae ($P < 0.01$) (Table 2). The acid stemflow and throughfall entering the upper soil horizons over a period of time may have slowly solubilized and leached a portion of the soil P normally sensitive to HCl into deeper soil layers bringing about a new distribution within the solum.

3.3 SOIL BASES (Ca, Mg, and K)

With a few exceptions, concentrations of Ca, Mg, and K removed by NH_4Cl were greater in soils at Site 1. These cations usually were more concentrated in soils from open sampling areas than in soils under the canopy (Tables 1 and 2). As with soil P, the concentrations of these cations extractable by NH_4Cl were greater in the lower solum (u- and ℓ-Bm) than in the upper solum (u- and ℓ-Ae). This was not so noticeable in the profiles of the open areas. Probably this situation was brought about by a combination of vegetative uptake and increased leaching in soils under the canopy.

With reference to HCl--extractable bases, the status and distribution of these in the profile were similar to those extractable by NH_4Cl. However the concentrations were considerably higher throughout. Data (Table 1 and 2) reflected the fact that both distance from the GCOS operation and canopy were significant in the distribution and concentrations of soil bases within the soil profiles. These differences, while real, probably were the result of natural phenomena with little relationship to the oil sands extraction processes. Because of the soil surface disturbances in the oil sands area, soil particulates and dust deposition may have been largely responsible for these differences (Integ 1973; Verry and Timmons 1977).

3.4 SOIL SESQUIOXIDES (Al, Fe, and Ti)

With the exception of Ti, these cations are found in very high concentrations as data (Table 1 and 2) clearly show. Consequently, Al and Fe initially are of little value in the assessment of pollutant effects on the soil. If in time pollution is a real danger, especially that associated with SO_2, both of these cations but particularly Al (Hutchinson and Whitby 1976) become significant as they are excellent indicators of the acidic effects of pollution.

Titanium, on the other hand, is an immediately useful indicator of atmospheric pollution effects on soil and vegetation. The relatively low concentrations of both forms in soils make detection of Ti pollution effects more readily apparent.

While both NH_4Cl-- and HCl-- extractable Ti were found in greater concentrations in the profiles of Site 1, in view of the natural site differences already noted, it is impossible at this time to assume that these differences were related directly to pollutant effects of the GCOS operation.

4. JACK PINE FOLIAGE ANALYSIS

While three nutrients, S, Mg, and K, appeared in higher concentrations in current than in one-year growth (Table 4), only K ($P < 0.05$) was statistically significant. In conifer nutritional studies, Miller and Miller (1976) preferred current tissue sampled in late autumn from the topmost branch whorls of dominant and codominant trees. Stated advantages of this sampling location were that it may be precisely defined and resampled in subsequent years and that it was not greatly influenced by sociological factors. Raupach (1975), Lowry and Avard (1969), and Lowry (1968) were in agreement with this view.

Foliar concentrations of S and Mg were significantly different at the two sites ($P < 0.01$) with those at Site 1 being the greater. Foliar K concentrations at this site were significantly lower ($P < 0.05$) than those at Site 2. There did not appear to be any consistent relationship with soil concentrations except in the case of S. The increased S concentrations in tissues sampled at Site 1 may have been responsible for the increased Mg concentrations observed (Wallace 1961).

All other nutrients determined, P, Ca, Al, and Fe, were more concentrated in one-year-old tissues. Of these, Ca, Al, and Fe showed statistically significant differences ($P < 0.01$). Again no consistent trends with soil concentrations were noted. This suggested that factors in addition to soil nutrient concentrations were influential in governing nutrient concentrations in jack pine foliage.

Table 4. Mean † nutrient status (ppm) in current and one-year-old growth of jack pine (needle tissue) from Sites 1 and 2 (2.3 and 5.3 km south of the GCOS plant, respectively).[a]

Site	Age	S	P	Ca	Mg	K	Al	Fe	Mn
1	Current	1705.1	1194.6	2197.8	1920.4	4439.3	530.7	244.5	646.6
1	One-year	1570.4	1355.0	3430.5	1349.5	3700.3	699.5	355.8	881.7
2	Current	1246.0	1200.0	2279.7	1157.5	6136.2	592.2	218.1	535.6
2	One-year	1187.8	1116.1	3351.1	1075.2	4023.6	792.4	317.6	767.9

[a] † each datum represents a mean of three replications from each of five sample trees.

5. CONCLUSIONS

5.1 SOIL ANALYSIS

Detailed soil analysis which included NH_4Cl-- and HCl-- extractable constituents indicated that, to date, atmospheric pollutants arising directly from the development of energy and from the oil sands recovery processes have made little impact on the soils of the study area. Statistically significant differences observed in the concentrations of various nutrients at the two sites appear to have been due mainly to natural variation. Surface mantle disturbances taking place in the oil sands area quite possibly contributed to these differences by soil and dust particulate deposition. Data obtained in this study are part of the baseline information to be used for comparative purposes in future studies.

5.2 FOLIAR ANALYSIS

Foliar concentrations of the various nutrients studied showed no consistent relationship with concentrations in the soil nor with distance from the GCOS plant; S, which is a known stack emission, may be an exception. Jack pine foliage samples from Site 1 exhibited greater S concentrations than those from Site 2. However, the actual cause or causes for this are as yet uncertain. Considerable variability in foliar nutrient concentrations between sample trees emphasized the need for more extensive sampling.

6. RECOMMENDATIONS

Site variability was large and further extensive work will be required before a reasonably accurate evaluation of pollution effects, if any, can be made. An increased sampling base and a more extensive statistical approach under the present field conditions of the study area, while useful, probably will not supply the necessary information required to make such an evaluation.

Soil and vegetative (jack pine) transplants could be introduced with profit into the oil sands area in a manner analogous to lichen transplants. These would have to be of known properties and characteristics and in sufficient numbers for good replication. They would have to be placed at strategic locations and in such a manner that artifact effects were minimal (i.e., effects produced by the methods used, etc.).

In view of the extensive surface mantle disturbances occurring in the oil sands area during the mining of the oil sands, wet and dry particulate gauges (nipher type) also should be employed in addition to the standard precipitation traps and Huey Plates. Particulate deposition arising from the mining and not the oil production processes may be a far more important consideration, especially with reference to soils and conifers.

Periodic examination of these introduced transplants probably would facilitate an early and fairly accurate appreciation of both the degree and advance of atmospheric pollution effects.

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8.

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9820 - 106 Street
Edmonton, Alberta
T5K 2J6

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