APPORTIONMENT OF VARIANCE ANALYSIS LICHEN DATA FROM THE ATHABASCA OIL SANDS REGION

STATISTICAL REPORT

Prepared for

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by

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STATISTICAL REPORT

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II. EXECUTIVE SUMMARY

This is a report of statistical analysis of the apportionment of variance within the Lichen Data from the Athabasca Oil Sands Region. The report answers three questions of interest. They are:

1. What is the relative error due to laboratory analysis, as measured with laboratory replicates?
2. What is the error due to field collections, as measured by field replicates?
3. What is the error due to pollution deposition among sites?

The report includes an introduction to the analysis, a description of the statistical procedures, and the results of the analyses.

The results are presented in three chapters, one dealing with each question of interest.

III. INTRODUCTION

Lichens are a unique life form, consisting of a relationship between a fungus and a photosynthetic partner, a cyanobacterium or a green alga. The association is said to be symbiotic, such that the fungus provides moisture and shelter for the algal cells allowing them live even in places that otherwise would be unsuitable for them. Due to this symbiotic relationship, lichens are able to live in some of the harshest habitats on earth. Lichens are extremely widespread in nature; they occur from arid desert regions to the Arctic and grow on bare soil, tree trunks, and rocks. Lichens grow very slowly, often less than a millimeter per year.

Lichens lack any outside covering, or cuticle, and consequently are directly exposed to the atmosphere, which they depend upon for their nutrients and water. Moistened lichen tissues act as blotters, soaking up chemicals or materials deposited on their surfaces. This feature has also made them highly susceptible to air pollutants; and lichens are perhaps the plant species most susceptible to sulfur dioxide, heavy metals, and acid rain.

Since lichens are very sensitive to pollutants, they are sometimes used as indicators of air and water pollution. Lichens are investigated at a number of locations surrounding a point or area pollution source, or at a number of locations within an area of interest. Appropriate lichen metrics are recorded at each location and are related to known or inferred pollution levels. The metrics include distribution of individual

indicator species, frequency or abundance of individual species, species richness (total number of different species) at each study location, total lichen cover, and element content of lichen samples.

When assessing pollution with lichens it is appropriate to apportion the variance of the data into its various sources. Variability in element content is dependent upon the ability to collect a representative sample, the precision of laboratory measurement, and the natural variability among sites due to environmental variables such as air pollution, rainfall, temperature, and substrate.

Questions of Interest

1. What is the relative error due to laboratory analysis, as measured with laboratory replicates?

2. What is the error due to field collections, as measured by field replicates?

3. What is the error due to pollution deposition among sites?

Species of Interest

Element content was measured from three lichen species:

1 – Clamit = *Cladina mitis*

2 – Evemes = *Evernia mesomorpha*

3 – Hypphy = *Hypogymnia physodes*

Elements

Twenty-nine elements were detected in laboratory analysis:

Percent Nitrogen, Percent Sulfur, parts per million (ppb for Hg) of Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, Si, Sr, Ti, V, Zn.

IV. STATISTICAL PROCEDURES

The data were compiled and delivered to Pacific Analytics on April 23, 2003 for analysis. The element content of three lichen species were delivered in spreadsheet format with columns for Lab ID #, Site #, Direction to Mine, Distance to Mine, Species acronym, and replicate code.

Using various forms of the variance formula

$$\sum_{i=1}^{Samples} \sum_{j=1}^{Sites} (y_{ij} - y_{i.})^2$$

where y_{ij} is the replicate value and $y_{i.}$ is the mean for the site or sample.

To calculate the variance due to field replicates and laboratory replicates, the sample mean was calculated from the replicates for each site or sample. The deviation from the mean was calculated by subtracting the mean from the measured value of each replicate. This was squared and summed to arrive at the sum of squared deviations. The mean squared deviation (variance) was calculated by dividing the sum of squared deviations by one less than the number of sample replicates. The standard deviation was calculated by taking the square root of the variance.

The apportioned variance for among site pollution deposition was determined by first calculating the overall variance and the total sums of squares for all replicates. In this case the formula used was

$$\sum_{i=1}^{Samples} \sum_{j=1}^{Sites} (y_{ij} - y_{..})^2$$

where $y_{..}$ is the grand mean for all replicates.

The difference between the total sums of squares and the field sums of squares is the variance due to among site variation (reported as the sum of squares sites).

V. FIELD REPLICATE VARIATION

Presented in Tables V-1, V-2, and V-3 are the variances in field replication. For each element, the Sums of Squared Deviations, the Mean Squared Deviation (variance), and Standard Deviation are reported. The Standard Deviation is a measure of the variation within the sites.

Table V-1. Field Replicate Variation of *Cladina mitis* lichen.

CLADINA MITIS									
ELEMENT	**N (%)**	**S (%)**	**Al (ppm)**	**As (ppm)**	**B (ppm)**	**Ba (ppm)**	**Be (ppm)**	**Ca (ppm)**	**Cd (ppm)**
SUM OF SQUARED DEVIATIONS	0.144	0.003	75718.302	0.074	11.913	78.733	0.000	459335.658	3.299
MEAN SQUARED VARIATION	0.002	0.000	958.460	0.001	0.151	0.997	0.000	5814.375	0.042
STANDARD DEVIATION	0.043	0.006	30.959	0.031	0.388	0.998	0.001	76.252	0.204

ELEMENT	**Co (ppm)**	**Cr (ppm)**	**Cu (ppm)**	**Fe (ppm)**	**K (ppm)**	**Li (ppm)**	**Mg (ppm)**	**Mn (ppm)**	**Mo (ppm)**
SUM OF SQUARED DEVIATIONS	0.002	1.480	18.141	62758.066	777728.282	0.050	31667.856	9829.668	0.060
MEAN SQUARED VARIATION	0.000	0.019	0.230	794.406	9844.662	0.001	400.859	124.426	0.001
STANDARD DEVIATION	0.004	0.137	0.479	28.185	99.220	0.025	20.021	11.155	0.027

ELEMENT	**Na (ppm)**	**Ni (ppm)**	**P (ppm)**	**Pb (ppm)**	**Si (ppm)**	**Sr (ppm)**	**Ti (ppm)**	**V (ppm)**	**Zn (ppm)**
SUM OF SQUARED DEVIATIONS	310.065	3.040	137783.849	0.295	106658.034	6.950	18.085	1.219	128.034
MEAN SQUARED VARIATION	3.925	0.038	1744.099	0.004	1350.102	0.088	0.229	0.015	1.621
STANDARD DEVIATION	1.981	0.196	41.762	0.061	36.744	0.297	0.478	0.124	1.273

ELEMENT	**Hg (ppb)**
SUM OF SQUARED DEVIATIONS	1284.928
MEAN SQUARED VARIATION	16.265
STANDARD DEVIATION	4.033

Table V-2. Field Replicate Variation of *Evernia mesomorpha* lichen.

EVERNIA MESOMORPHA

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
SUM OF SQUARED DEVIATIONS	0.123	0.003	167281.824	0.244	3.263	4.154	0.000	9210069.425	0.145
MEAN SQUARED VARIATION	0.003	0.000	3801.860	0.006	0.074	0.094	0.000	209319.760	0.003
STANDARD DEVIATION	0.053	0.008	61.659	0.074	0.272	0.307	0.003	457.515	0.058

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
SUM OF SQUARED DEVIATIONS	0.000	0.980	27.373	229941.202	589556.305	0.184	18249.124	1468.494	0.131
MEAN SQUARED VARIATION	0.000	0.022	0.622	5225.936	13399.007	0.004	414.753	33.375	0.003
STANDARD DEVIATION	0.000	0.149	0.789	72.291	115.754	0.065	20.365	5.777	0.055

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
SUM OF SQUARED DEVIATIONS	12993.799	2.263	63048.264	2.249	119561.184	8.091	50.299	5.859	141.767
MEAN SQUARED VARIATION	295.314	0.051	1432.915	0.051	2717.300	0.184	1.143	0.133	3.222
STANDARD DEVIATION	17.185	0.227	37.854	0.226	52.128	0.429	1.069	0.365	1.795

ELEMENT	Hg (ppb)
SUM OF SQUARED DEVIATIONS	49522.302
MEAN SQUARED VARIATION	1125.507
STANDARD DEVIATION	33.549

Table V-3. Field Replicate Variation of *Hypogymnia physodes* lichen.

HYPOGYMNIA PHYSODES								
ELEMENT	**N (%)**	**S (%)**	**Al (ppm)**	**As (ppm)**	**B (ppm)**	**Ba (ppm)**	**Be (ppm)**	**Ca (ppm)**
SUM OF SQUARED DEVIATIONS	0.160	0.002	679702.947	1.984	5.043	1254.336	0.002	615471347.042
MEAN SQUARED VARIATION	0.002	0.000	8603.835	0.025	0.064	15.878	0.000	7790776.545
STANDARD DEVIATION	0.045	0.005	92.757	0.158	0.253	3.985	0.005	2791.196

ELEMENT	**Cd (ppm)**	**Co (ppm)**	**Cr (ppm)**	**Cu (ppm)**	**Fe (ppm)**	**K (ppm)**	**Li (ppm)**	**Mg (ppm)**
SUM OF SQUARED DEVIATIONS	1.194	0.207	4.493	144.510	1370653.835	2204291.055	0.438	349730.775
MEAN SQUARED VARIATION	0.015	0.003	0.057	1.829	17350.049	27902.418	0.006	4426.972
STANDARD DEVIATION	0.123	0.051	0.238	1.352	131.720	167.040	0.074	66.535

ELEMENT	**Mn (ppm)**	**Mo (ppm)**	**Na (ppm)**	**Ni (ppm)**	**P (ppm)**	**Pb (ppm)**	**Si (ppm)**	**Sr (ppm)**
SUM OF SQUARED DEVIATIONS	39782.237	0.423	1301.266	4.493	486855.809	22.558	359597.609	1698.899
MEAN SQUARED VARIATION	503.573	0.005	16.472	0.057	6162.732	0.286	4551.868	21.505
STANDARD DEVIATION	22.440	0.073	4.059	0.238	78.503	0.534	67.468	4.637

ELEMENT	**Ti (ppm)**	**V (ppm)**	**Zn (ppm)**	**Hg (ppb)**
SUM OF SQUARED DEVIATIONS	183.130	46.157	2718.825	14757.223
MEAN SQUARED VARIATION	2.318	0.584	34.416	186.800
STANDARD DEVIATION	1.523	0.764	5.866	13.667

VI. LABORATORY REPLICATE VARIATION

Presented in Tables VI-1, VI-2, and VI-3 are the variances in laboratory replication. For each element, the Sums of Squared Deviations, the Mean Squared Deviation (variance), and Standard Deviation. The Standard Deviation is a measure of the precision of the laboratory measurements.

Table VI-1. Laboratory Replicate Variation of *Cladina mitis* lichen.

Cladina mitis

ELEMENT	N%	S%	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
SUM OF SQUARED DEVIATIONS	0.029	0.000	27470.561	0.012	4.476	0.519	0.000	4421.640	0.271
MEAN SQUARED VARIATION	0.001	0.000	722.910	0.000	0.118	0.014	0.000	116.359	0.007
STANDARD DEVIATION	0.036	0.003	26.887	0.018	0.343	0.117	0.001	10.787	0.085

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
SUM OF SQUARED DEVIATIONS	0.001	0.348	0.142	15002.480	14197.008	0.010	1207.181	34.104	0.012
MEAN SQUARED VARIATION	0.000	0.009	0.004	394.802	373.605	0.000	31.768	0.897	0.000
STANDARD DEVIATION	0.006	0.096	0.061	19.870	19.329	0.016	5.636	0.947	0.018

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
SUM OF SQUARED DEVIATIONS	23.215	1.684	1506.634	0.085	34731.065	0.052	4.139	0.296	3.445
MEAN SQUARED VARIATION	0.611	0.044	39.648	0.002	913.975	0.001	0.109	0.008	0.091
STANDARD DEVIATION	0.782	0.211	6.297	0.047	30.232	0.037	0.330	0.088	0.301

ELEMENT	Hg (ppb)
SUM OF SQUARED DEVIATIONS	9.615
MEAN SQUARED VARIATION	0.874
STANDARD DEVIATION	0.935

Table VI-2. Laboratory Replicate Variation of *Evernia mesomorpha* lichen.

Evernia mesomorpha

ELEMENT	N%	S%	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)
SUM OF SQUARED DEVIATIONS	0.001	0.000	116885.007	0.745	31.764	1.496	0.002	116210.329
MEAN SQUARED VARIATION	0.000	0.000	6493.612	0.041	1.765	0.083	0.000	6456.129
STANDARD DEVIATION	0.016	0.003	80.583	0.203	1.328	0.288	0.010	80.350

ELEMENT	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)
SUM OF SQUARED DEVIATIONS	0.033	0.065	0.612	0.144	8538.242	14342.152	0.106	1827.172
MEAN SQUARED VARIATION	0.002	0.004	0.034	0.008	474.347	796.786	0.006	101.510
STANDARD DEVIATION	0.043	0.060	0.184	0.089	21.780	28.227	0.077	10.075

ELEMENT	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)
SUM OF SQUARED DEVIATIONS	2.834	0.067	52.249	0.688	931.660	3.925	219620.194	0.130
MEAN SQUARED VARIATION	0.157	0.004	2.903	0.038	51.759	0.218	12201.122	0.007
STANDARD DEVIATION	0.397	0.061	1.704	0.196	7.194	0.467	110.459	0.085

ELEMENT	Ti (ppm)	V (ppm)	Zn (ppm)	Hg (ppb)
SUM OF SQUARED DEVIATIONS	94.744	1.635	3.550	112.500
MEAN SQUARED VARIATION	5.264	0.091	0.197	22.500
STANDARD DEVIATION	2.294	0.301	0.444	4.743

Table VI-3. Laboratory Replicate Variation of *Hypogymnia physodes* lichen.

Hypogymnia physodes

ELEMENT	N%	S%	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
SUM OF SQUARED DEVIATIONS	0.072	0.000	114267.568	0.385	25.648	67.951	0.000	42456029.408	0.017
MEAN SQUARED VARIATION	0.002	0.000	3174.099	0.011	0.712	1.888	0.000	1179334.150	0.000
STANDARD DEVIATION	0.050	0.002	56.339	0.103	0.844	1.374	0.003	1085.972	0.022

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
SUM OF SQUARED DEVIATIONS	0.011	0.402	0.911	124191.741	92772.172	0.041	28098.907	3408.654	0.041
MEAN SQUARED VARIATION	0.000	0.011	0.025	3449.771	2577.005	0.001	780.525	94.685	0.001
STANDARD DEVIATION	0.017	0.106	0.159	58.735	50.764	0.034	27.938	9.731	0.034

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
SUM OF SQUARED DEVIATIONS	35.438	0.571	3462.419	1.502	107643.340	3.449	41.258	3.697	96.910
MEAN SQUARED VARIATION	0.984	0.016	96.178	0.042	2990.093	0.096	1.146	0.103	2.692
STANDARD DEVIATION	0.992	0.126	9.807	0.204	54.682	0.310	1.071	0.320	1.641

ELEMENT	Hg (ppb)
SUM OF SQUARED DEVIATIONS	909.890
MEAN SQUARED VARIATION	43.328
STANDARD DEVIATION	6.582

VII. POLLUTION DEPOSITION VARIATION AMONG SITES

Presented in Tables VII-1, VII-2, and VII-3 are the apportioned variances for pollution deposition among sites for each of the detected elements. For each element, the overall mean, variance, and standard deviation are reported. Also reported are the Total Sums of Squares, the Sums of Squares Error (due to on-site variation), and Sums of Squares Sites, the variation of pollution deposition after accounting for on-site error.

In the accompanying Excel Workbook, AOSlichendata, the data are summarized by Direction from Mine and by Distance from Mine. Given are the means, variances, and standard deviations for each species. These summaries can be found on the Dep *Species* worksheet for each of the three species.

Table VII-1. Pollution Deposition Variation Among Sites of *Cladina mitis* lichen.

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
MEAN	0.517	0.057	420.624	0.829	2.439	5.911	0.042	1075.636	0.175
VARIANCE	0.008	0	197790.512	0.028	1.706	12.169	0	210548.168	0.084
STANDARD DEVIATION	0.089	0.017	444.736	0.168	1.306	3.488	0.011	458.855	0.29
SUM OF SQUARES TOTAL	0.627	0.022	15625450.48	2.237	134.738	961.377	0.01	16633305.27	6.634
SUM OF SQUARES ERROR	0.144	0.003	75718.302	0.074	11.913	78.733	0	459335.658	3.299
SUM OF SQUARES SITES	0.483	0.02	15549732.18	2.164	122.826	882.644	0.01	16173969.61	3.335
MEAN SQUARE VARIATION SITES	0.012	0.001	388743.304	0.054	3.071	22.066	0.000	404349.240	0.083

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
MEAN	0.241	0.979	1.313	433.995	1491.368	0.512	365.759	69.087	0.323
VARIANCE	0	0.32	0.702	207309.513	80249.707	0.064	32883.751	1167.002	0.026
STANDARD DEVIATION	0.007	0.566	0.838	455.313	283.284	0.252	181.339	34.161	0.162
SUM OF SQUARES TOTAL	0.004	25.271	55.491	16377451.55	6339726.82	5.021	2597816.3	92193.154	2.085
SUM OF SQUARES ERROR	0.002	1.48	18.141	62758.066	777728.282	0.05	31667.856	9829.668	0.06
SUM OF SQUARES SITES	0.002	23.791	37.349	16314693.49	5561998.53	4.97	2566148.5	82363.486	2.025
MEAN SQUARE VARIATION SITES	0.000	0.595	0.934	407867.337	139049.963	0.124	64153.711	2059.087	0.051

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
MEAN	24.47	1.001	546.051	1.746	502.766	3.515	5.608	1.462	14.68
VARIANCE	146.209	0.352	14311.193	0.025	62043.694	11.378	7.494	1.202	12.08
STANDARD DEVIATION	12.092	0.594	119.629	0.158	249.086	3.373	2.738	1.096	3.476
SUM OF SQUARES TOTAL	11550.498	27.832	1130584.242	1.965	4901451.85	898.852	592.049	94.919	954.317
SUM OF SQUARES ERROR	310.065	3.04	137783.849	0.295	106658.034	6.95	18.085	1.219	128.034
SUM OF SQUARES SITES	11240.434	24.792	992800.393	1.67	4794793.82	891.902	573.964	93.699	826.283
MEAN SQUARE VARIATION SITES	281.011	0.620	24820.010	0.042	119869.845	22.298	14.349	2.342	20.657

Table VII-2. Pollution Deposition Variation Among Sites of *Evernia mesomorpha* lichen.

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
MEAN	0.963	0.115	918.582	1.013	4.512	6.755	0.05	3995.734	0.215
VARIANCE	0.085	0.002	709633.206	0.148	3.813	7.928	0	43116808.63	0.012
STANDARD DEVIATION	0.291	0.042	842.397	0.384	1.953	2.816	0.021	6566.339	0.112
SUM OF SQUARES TOTAL	3.727	0.078	31223861.07	6.495	167.751	348.853	0.019	1897139580	0.548
SUM OF SQUARED ERROR	0.123	0.003	167281.824	0.244	3.263	4.154	0	9210069.425	0.145
SUM OF SQUARES SITES	3.603	0.075	31056579.25	6.251	164.488	344.699	0.018	1887929510	0.402
MEAN SQUARE VARIATION SITES	0.129	0.003	1109163.545	0.223	5.875	12.311	0.001	67426053.942	0.014

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
MEAN	0.241	1.942	2.429	934.844	2118.333	0.885	337.035	38.99	0.669
VARIANCE	0	1.037	1.974	721508.557	185048.122	0.582	19367.817	221.461	0.203
STANDARD DEVIATION	0.004	1.018	1.405	849.417	430.172	0.763	139.168	14.882	0.45
SUM OF SQUARES TOTAL	0.001	45.641	86.856	31746376.49	8142117.38	25.589	852183.95	9744.303	8.913
SUM OF SQUARED ERROR	0	0.98	27.373	229941.202	589556.305	0.184	18249.124	1468.494	0.131
SUM OF SQUARES SITES	0.001	44.66	59.483	31516435.29	7552561.08	25.405	833934.83	8275.809	8.782
MEAN SQUARE VARIATION SITES	0.000	1.595	2.124	1125586.975	269734.324	0.907	29783.387	295.565	0.314

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
MEAN	39.395	2.211	557.716	2.208	713.469	5.448	13.276	4.371	29.972
VARIANCE	650.921	1.36	19683.511	0.318	44530.337	23.288	26.185	9.837	38.492
STANDARD DEVIATION	25.513	1.166	140.298	0.564	211.022	4.826	5.117	3.136	6.204
SUM OF SQUARES TOTAL	28640.527	59.831	866074.463	13.978	1959334.83	1024.655	1152.141	432.829	1693.638
SUM OF SQUARED ERROR	12993.799	2.263	63048.264	2.249	119561.184	8.091	50.299	5.859	141.767
SUM OF SQUARES SITES	15646.729	57.568	803026.199	11.729	1839773.64	1016.563	1101.842	426.969	1551.871
MEAN SQUARE VARIATION SITES	558.812	2.056	28679.507	0.419	65706.202	36.306	39.352	15.249	55.424

Table VII-3. Pollution Deposition Variation Among Sites of *Hypogymnia physodes* lichen.

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)
MEAN	0.749	0.095	1049.643	1.573	4.206	29.559	0.069	18126.885
VARIANCE	0.02	0.001	718209.66	0.746	4.266	151.626	0.002	143708200
STANDARD DEVIATION	0.142	0.026	847.473	0.864	2.065	12.314	0.049	11987.836
SUM OF SQUARES TOTAL	1.601	0.053	56738563.18	58.956	337.008	11978.482	0.187	11352947801
SUM OF SQUARED ERROR	0.16	0.002	679702.947	1.984	5.043	1254.336	0.002	615471347
SUM OF SQUARED SITES	1.441	0.051	56058860.23	56.973	331.966	10724.147	0.185	10737476454
MEAN SQUARE VARIATION SITES	0.034	0.001	1303694.424	1.325	7.720	249.399	0.004	249708754.751

ELEMENT	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)
MEAN	0.425	0.326	2.27	4.33	1383.42	2661.98	0.788	857.21
VARIANCE	0.033	0.036	1.835	13.362	1367652.29	277409.578	0.395	183435.969
STANDARD DEVIATION	0.181	0.189	1.354	3.655	1169.467	526.697	0.628	428.294
SUM OF SQUARES TOTAL	2.583	2.823	144.926	1055.581	108044531	21915356.6	31.178	14491441.59
SUM OF SQUARED ERROR	1.194	0.207	4.493	144.51	1370653.84	2204291.06	0.438	349730.775
SUM OF SQUARED SITES	1.389	2.616	140.433	911.072	106673877	19711065.6	30.74	14141710.81
MEAN SQUARE VARIATION SITES	0.032	0.061	3.266	21.188	2480787.830	458396.874	0.715	328876.996

ELEMENT	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)
MEAN	215.74	0.694	37.572	3.785	736.049	4.699	766.064	24.4
VARIANCE	16062.902	0.194	957.101	5.559	55574.897	1.664	61852.723	372.387
STANDARD DEVIATION	126.74	0.44	30.937	2.358	235.743	1.29	248.702	19.297
SUM OF SQUARES TOTAL	1268969.2	15.287	75610.968	439.193	4390416.87	131.417	4886365.1	29418.541
SUM OF SQUARED ERROR	39782.237	0.423	1301.266	4.493	486855.809	22.558	359597.61	1698.899
SUM OF SQUARED SITES	1229187	14.864	74309.702	434.7	3903561.06	108.859	4526767.5	27719.643
MEAN SQUARE VARIATION SITES	28585.744	0.346	1728.133	10.109	90780.490	2.532	105273.664	644.643

ELEMENT	Ti (ppm)	V (ppm)	Zn (ppm)
MEAN	15.326	6.027	58.848
VARIANCE	42.441	11.413	161.790
STANDARD DEVIATION	6.515	3.378	12.720
SUM OF SQUARES TOTAL	3352.815	901.626	12781.404
SUM OF SQUARED ERROR	183.130	46.157	2718.825
SUM OF SQUARED SITES	3169.685	855.468	10062.579
MEAN SQUARE VARIATION SITES	73.714	19.895	234.013

	CLAMIT	EVEMES	HYPPHY
ELEMENT	Hg (ppb)	Hg (ppb)	Hg (ppb)
MEAN	13.145	106.209	91.611
VARIANCE	49.674	2950.284	534.163
STANDARD DEVIATION	7.048	54.317	23.112
SUM OF SQUARES TOTAL	3924.278	129812.516	42198.860
SUM OF SQUARED ERROR	1284.928	49522.302	14757.223
SUM OF SQUARED SITES	2639.350	80290.214	27441.637
MEAN SQUARE VARIATION SITES	65.984	2867.508	638.178

Summary Tables: Comparison of Mean Squared Variation for each Source.

Cladina mitis

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
MEAN SQUARED VARIATION FIELD	0.002	0.000	958.460	0.001	0.151	0.997	0.000	5814.375	0.042
MEAN SQUARE VARIATION SITES	0.012075	0.0005	388743.3	0.0541	3.07065	22.0661	0.00025	404349.2	0.083375
MEAN SQUARED VARIATION LAB	0.001278	7.64E-06	722.9095	0.000311	0.117789	0.013656	8.42E-07	116.3589	0.007141

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
MEAN SQUARED VARIATION FIELD	0.000	0.019	0.230	794.406	9844.662	0.001	400.859	124.426	0.001
MEAN SQUARE VARIATION SITES	0.00005	0.594775	0.933725	407867.3	139050	0.12425	64153.71	2059.087	0.050625
MEAN SQUARED VARIATION LAB	3.71E-05	0.009147	0.003736	394.8021	373.6055	0.000266	31.76792	0.897484	0.000311

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
MEAN SQUARED VARIATION FIELD	3.925	0.038	1744.099	0.004	1350.102	0.088	0.229	0.015	1.621
MEAN SQUARE VARIATION SITES	281.0109	0.6198	24820.01	0.04175	119869.8	22.29755	14.3491	2.342475	20.65708
MEAN SQUARED VARIATION LAB	0.610918	0.044328	39.64826	0.002244	913.9754	0.001374	0.10891	0.007782	0.09067

Summary Tables: Comparison of Mean Squared Variation for each Source.

Evernia mesomorpha

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
MEAN SQUARED VARIATION FIELD	0.003	0.000	3801.860	0.006	0.074	0.094	0.000	209319.760	0.003
MEAN SQUARE VARIATION SITES	0.129	0.003	1109163.545	0.223	5.875	12.311	0.001	67426053.942	0.014
MEAN SQUARED VARIATION LAB	0.000	0.000	6493.612	0.041	1.765	0.083	0.000	6456.129	0.002

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
MEAN SQUARED VARIATION FIELD	0.000	0.022	0.622	5225.936	13399.007	0.004	414.753	33.375	0.003
MEAN SQUARE VARIATION SITES	0.000	1.595	2.124	1125586.975	269734.324	0.907	29783.387	295.565	0.314
MEAN SQUARED VARIATION LAB	0.004	0.034	0.008	474.347	796.786	0.006	101.510	0.157	0.004

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
MEAN SQUARED VARIATION FIELD	295.314	0.051	1432.915	0.051	2717.300	0.184	1.143	0.133	3.222
MEAN SQUARE VARIATION SITES	558.812	2.056	28679.507	0.419	65706.202	36.306	39.352	15.249	55.424
MEAN SQUARED VARIATION LAB	2.903	0.038	51.759	0.218	12201.122	0.007	5.264	0.091	0.197

Summary Tables: Comparison of Mean Squared Variation for each Source.

Hypogymnia physodes

ELEMENT	N (%)	S (%)	Al (ppm)	As (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)
MEAN SQUARED VARIATION FIELD	0.002	0.000	8603.835	0.025	0.064	15.878	0.000	7790776.545	0.015
MEAN SQUARE VARIATION SITES	0.034	0.001	1303694.424	1.325	7.720	249.399	0.004	249708754.751	0.032
MEAN SQUARED VARIATION LAB	0.002	0.000	3174.099	0.011	0.712	1.888	0.000	1179334.150	0.000

ELEMENT	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Li (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)
MEAN SQUARED VARIATION FIELD	0.003	0.057	1.829	17350.049	27902.418	0.006	4426.972	503.573	0.005
MEAN SQUARE VARIATION SITES	0.061	3.266	21.188	2480787.830	458396.874	0.715	328876.996	28585.744	0.346
MEAN SQUARED VARIATION LAB	0.000	0.011	0.025	3449.771	2577.005	0.001	780.525	94.685	0.001

ELEMENT	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Si (ppm)	Sr (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)
MEAN SQUARED VARIATION FIELD	16.472	0.057	6162.732	0.286	4551.868	21.505	2.318	0.584	34.416
MEAN SQUARE VARIATION SITES	1728.133	10.109	90780.490	2.532	105273.664	644.643	73.714	19.895	234.013
MEAN SQUARED VARIATION LAB	0.984	0.016	96.178	0.042	2990.093	0.096	1.146	0.103	2.692

Summary Tables: Comparison of Mean Squared Variation for each Source.

MERCURY (Hg)

SPECIES	CLAMIT	EVEMES	HYPPHY
ELEMENT	Hg (ppb)	Hg (ppb)	Hg (ppb)
MEAN SQUARED VARIATION FIELD	16.265	1125.507	186.800
MEAN SQUARE VARIATION SITES	65.984	2867.508	638.178
MEAN SQUARED VARIATION LAB	0.874	22.50	43.328