A CHROMATOGRAPHIC APPROACH TO THE DIAGNOSIS OF HUMUS QUALITY AND SOME IMPLICATIONS FOR FOREST MANAGEMENT

by

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ABSTRACT

Understanding forest humus is seen as an important aspect of sound forest management. A method using paper chromatography, developed by Pfeiffer is examined as a diagnostic approach to the nature and dynamics of forest humus. Chromatograms are prepared from a sodium hydroxide extract of humus. On a circular filter paper the radiating extract reacts with silver nitrate producing a characteristic picture or "humus spectrum". Preliminary work relating chromatograms to types of humus and site conditions is presented and discussed. Further comparisons are made between chromatographic features and a range of chemical and site variables of 103 humus form samples. Significant correlations, scattergrams and discriminant function analyses are presented and discussed. It is concluded that the chromatogram allows a network of inferences to be made about the nature of forest humus. Although not quantitatively predictive, the chromatogram reflects in a consistent manner, properties of humus derived from chemical analyses. It supports the classification of humus forms and may provide a method of discrimination when morphological properties are inconclusive as found in clearcuts or other disturbed sites.

Applications for forest management are discussed and a number of examples presented. The potential for monitoring changes as a result of management practises is seen as particularly interesting. The method may provide the field manager with a practical interpretive tool, and the student of humus dynamics

with an interesting bridge between the results of analytical chemistry and field observation of the in-situ humus.

The limitations of the approach are discussed and further studies suggested.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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INTRODUCTION

Humus has proved to be an elusive and complex substance. A good deal of scientific research has taken place, classically in Russia and more recently in North America. Very sophisticated analysis has been used, and is continuing following the approaches developed in Russian schools. Chemical fractionation and analysis are used to elucidate the molecular composition, to attempt to define this substance in form, structure and composition. This approach has been only partially successful on a practical basis, because in spite of the work done to date, and evidence of the importance of humus, very little attention is given to quality and management of humus in agricultural or silvicultural systems. A notable exception is in the "organic movement". However it is surprising how unsophisticated and in a sense unscientific, organic matter management has been . Considering the efforts in the realm of inorganic treatment which has culminated in hydroponics, humus management has been neglected.

The implications of this neglect may prove a severe problem. Most environmental scientists know the problems of erosion, subsidence, pollution of groundwater , decline in quantity and quality of produce, increase in pest damage, etc. These subjects have been explored in workshops such as the Soil Degradation Workshop (Anon. 1983) ,the Agrologist (1975) and by individuals such as Schumacher(1974). Failure to take humus

seriously is a key contributor to these problems. A large part of their "cure" lies in the active, considered management of humus.

Forest systems are used almost exclusively for two major reasons. They provide the most natural system available in which to explore the interactions of site dynamics and humus. More practically the author has worked with them over the last four years as a Pedologist in the Ecological Program of the British Columbia Ministry of Forests. The potential for humus management in British Columbia forests has not been developed to any significant degree. It is suggested that greater attention to humus will provide a good basis for long term forest management.

Forestry practices in B.C. have historically viewed soils and their surface organic matter ("duff") as being of minor importance. Clearcutting, indiscrimimant slashburning and ground skidding have left a legacy of "N.S.R." (not satisfactorily restocked) forest lands. Poor utilization of material has left heavily lignous areas particularly where decadent stands have been harvested. These situations represent , in many cases, degradation of site quality. Ideally, management should enhance quality and productivity on a long term basis.

Recently the Ministry of Forests has provided an improved classification of humus forms (Klinka et al., 1980). Along with description and study of forest ecosystems, a longer term ecological approach to forest management is developing. Present work is primarily descriptive, characterising the chemical and

ecological relationships of humus forms and environmental factors.

Preliminary work with a chromatographic method of studying humus has led to a hypothesis that such an approach can be useful in evaluating the chemical and biological aspects of humus and its relationship to humus form, nutrient status and moisture regime. The chromatogram gives a visual expression of the nature of humus. It also provides a test for the classification of humus forms now used in B.C. A major part of the following thesis is the assessment of this method - is the method practically useful, and what information can be derived from the chromatogram for management decisions?

It is suggested that various kinds of information can be inferred from the chromatogram. Firstly, the chromatogram should reflect something of the chemical constituents of the individual sample. Chromatography separates substances in solution according to molecular weight and size. One would expect smaller molecules to migrate more quickly and therefore be furthest from the origin. Silver likely confounds the migration by forming complexes with humic molecules, precipitating them depending on their structure and activity. However, similar components should react in similar ways in the chromatographic process. The chromatogram should be a "fingerprint" of the chemical constituents in the sample. Secondly, this "fingerprint" should reflect differences of humus formation between two or more

samples, and should express a relationship to the humus form. Thirdly, because humus form is related intimately to the ecosystem, the chromatogram should be an indicator of general site ecology.

This thesis explores the nature of humus and a diagnostic approach to studying humus as a key in soil systems and management of them. The management is emphasized. It is not meant to be a definitive scientific study, but a contribution to a rationale for approaching management decisions, and hopefully improving them.

There is an obvious connection between the natural processes of humus formation in forest systems and the "artificial" composting practiced on farms and industrial composting facilities. The type of input, the temperature, moisture and pH are the major factors that determine the quality of product. The product whether on the farm or in the forest is relatively stable humus. Forest management activities alter light, plant species, temperature, moisture and nutrient cycling. Their effects on humus and site quality need careful consideration. Some of these possibilities are dealt with in "Management Applications".

As mentioned, humus has been neglected to a considerable degree in forest management. There is clearly a need to find practical ways of examining humus to support management decisions. Quantitative analytical approaches have not as yet provided many definitive answers. There is an urgency to better

understand and manage the forest and soil resources. This urgency has provided the impetus to explore the chromatographic method, in spite of its qualitative nature, and in spite of many unknowns regarding its specific relationship to humus chemistry.

The objectives of this study are : to explore the chromatographic approach ; to determine what information can be inferred from the chromatogram and provide some justification for the inferences ; and to examine the usefulness of the method as a diagnostic management tool.

The exploratory nature of this thesis required four stages of development. Each stage followed from the results of the previous study. First, a general survey of soil types was made. Then, apparent relationships were examined between chromatograms and chemical and site characteristics of humus using a well-characterized area - the UBC Research Forest. Thirdly, relationships were examined using 103 humus form samples from the Sayward Provincial Forest. This provided the basis for interpretation of the chromatogram for management application in stage four.

NATURE AND ROLE OF HUMUS

The forested ecosystem in its natural state represents a state of dynamic equilibrium. It is certainly not a closed system, however with a well developed canopy there is a clearly an isolation and protection from climatic variation outside. The source of humus is the rhythmic cycle of litterfall, dying roots, animal products and corpses. The elements of the system pass from the living to the dead and again to the living. Humus occupies a place between these extremes. Little wonder that it is elusive.

Humus may be elusive and difficult to study in its natural environment, but it is of major importance in understanding the forest ecosytem. Sukachev and Dylis (1968) consider it to be the "principal forest biogeocoenose component" because "it is formed from dead organic remains and is a result of the life-activity of organisms and not a product of the soil-forming process as a whole. It is a crucial link between the biological and geological components of an ecosystem.

Humus, "duff" and soil organic matter are terms that are used somewhat loosely to refer to decomposing or decomposed plant and animal remains and their products. Humus does not specifically include undecomposed materials. Practically however, it is intimately associated with unaltered organic materials and with inorganic mineral matter. For the purposes of this thesis, humus refers to the organic products of decomposition of plant

and animal debris, on or in the soil, and involved in soil processes.

Humic substances more specifically refer to isolated fractions or components of the broader concept, humus.

The term humus form refers to " a group of soil horizons at or near the surface of a pedon, which have formed from organic residues, either separate from or intermixed with mineral materials"(Klinka _et al_., 1981).

Much of the analytical work in humus studies has been directed towards humic substances - the isolated fractions. Humic substances have been described as dark coloured, acidic, predominantly aromatic, hydrophilic (in most cases), chemically complex, poly-electrolytic-like substances, with molecluar weights ranging from 100 to many thousands (Schnitzer and Khan, 1978). The formation of these substances has been attributed to the following processes:

1. Plant alteration - where the nature of the plant determines nature of humus.
2. Chemical polymerization - materials are degraded by microbes to small molecules, then microbes synthesize phenols and amino acids which oxidize to form humic substances - so plant nature has little effect on the result.
3. Cell autolysis - autolysis of plant and microbes which condense and polymerize.

4. Microbial synthesis - microbes synthesize humic substances intracellularly.

The consensus appears to be that all four processes may be taking place: chemical and biological degradation of plant and animal residues and synthetic activities of microorganisms, intra and extra cellularly. The process is seen as generally slow with dating techniques giving ages from 50 to 3,000 years (Gjessing,1976).

This variation in results is typical of studies of humic substances and again it must be emphasized that most analytical work is based on an extraction methodology using bases, acids and alcohols. There are relationships between the classic fractions (alcohol soluble waxes and fats; acid and base soluble fulvic acids; base soluble humic acids; and insoluble humins) and soil types (Kononova, 1966), but the relationships are highly variable. Humic and fulvic acids appear to convert to one another and are likely part of a continuum- products of a method and defined by the method. As such these component humic substances may well be partial artifacts and not really participating in natural systems. It may help to explain the lack of firm results and the extreme variability of views on humus. The summary view of humus from a chemical point of view is "that nobody really knows", (Anon., 1972). For example, Lowe and Klinka (1976) report the reverse of a classic assumption that humid conditions favour the production of fulvic acids. The literature contains many such apparent contradictions.

There is a good deal more agreement in regard to the role of humus in soil systems. The importance of humus as a nutrient source is very evident. The biological cycling occuring through humus formation provides a continuous supply of energy to the system.

Humus has a remarkable capacity for linking itself to the inorganic. Organic acids dissolve phosphates and carbonates making them available to plants. Relationships to metals occur as complexation, ion exchange and chelation. The reduction of iron is highly significant in podzolization. Adsorption with clays, bonding with organic compounds such as DDT and urea indicate a wide breadth of involvement in soil processes. It is summarized by the high cation exchange capacity which humus exhibits.

Other major roles include development of soil structure, insulation and protection, and very importantly, the capacity for holding water. The many more subtle roles of humus in growth promotion and antibiotic effects (Sukachev and Dylis ,1968, Kononova,1966) are not well explored, though will likely be important for future management. How humus takes part in these many roles is obscure. Kononova (1966) suggests that "general conceptions and laws of chemistry cannot be applied to phenomena associated with macromolecules". Gjessing (1976) sees the various bonding phenonema as being the same. Humus again is part of dynamic living processes that by their very nature cannot be

understood by inorganic laws. Inorganic systems are predictable and the laws summarize what is observed. Organic systems produce what is observed out of the whole.

In studying humus from a management perspective, it is important to discover trends or behavior of systems so that out of the system itself the direction of processes can be influenced. It is suggested that a broader, more holistic approach to studying humus is required. "As in all other studies and investigations of ecological units, there are no absolute values... the soil type with a special crop ... creates a characteristic microclimate... influences biological activity... which yields a distinct humus spectrum." (Pauli, 1967). The chromatographic method used in this study provides a visual picture of the humus spectrum.

MATERIALS AND METHODS

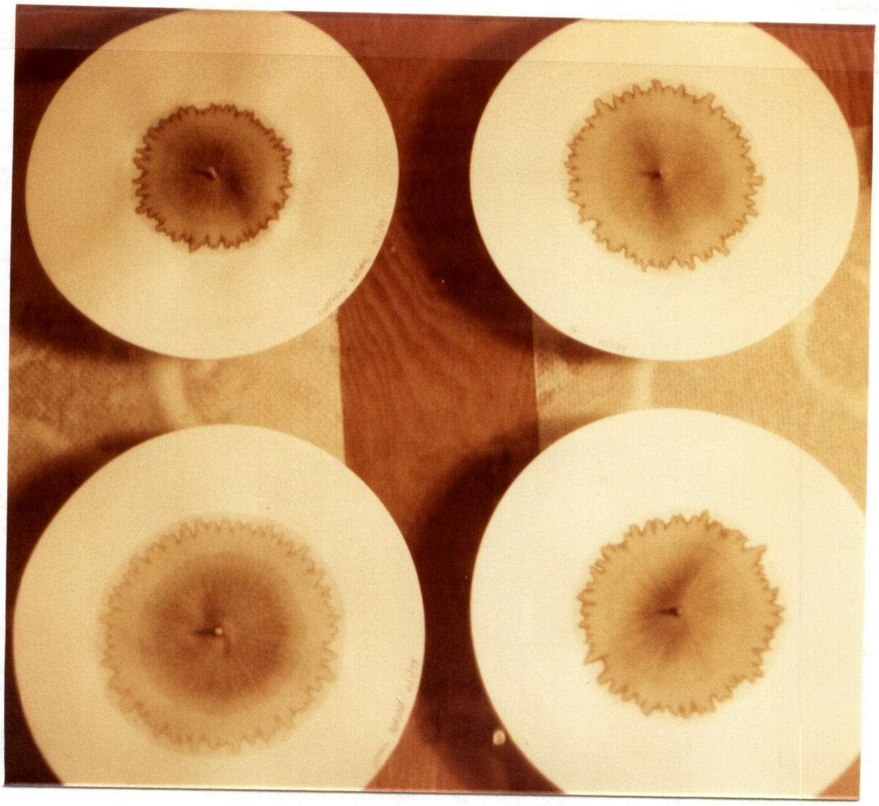
PRELIMINARY STUDY

During field trips in 1979 through British Columbia and Alberta, soil samples of a wide range of soil types and their respective horizons were collected. Samples were air-dried and broken-up by hand to pass a 2-mm screen.

Chromatograms were prepared using an adaptation of the following method. Pfeiffer (1959) developed the following method to evaluate agricultural soils and compost qualilty. Five to seven grams of soil or compost are mixed with 50ml of .25 NaOH and extracted for six hours. The extract is allowed to radiate via a paper wick through a circular filter paper (Whatman no. 1) 15cm in diameter. A closed chamber is used to maintain humidity while the extract radiates. The filter disc has previously been treated by allowing a .5 percent silver nitrate solution to radiate to 75mm , then dried. Figure 1 shows the humus extract as it radiates. When the extract reaches 120mm , the wick is removed and the resulting chromatogram dried and developed in diffuse light for 48 hours. More recently, the method has been described by Koepf(1964) and Brinton(1983) for agricultural and composting applications.

The author first learned of this method in England in the early 70's. During 1979, tests with the method on forest soils indicated some adaptation was required. The extractability of

forest humus required less than the 5 to 7 grams suggested in order that the extract would radiate to the outer area. The chromatograms were prepared by using 2.5 grams of mineral soil sample or 1.25 grams of organic sample.



Chromatography in process. Humus extract radiating after 15 minutes. Moist paper towels maintain humidity in glass top box.

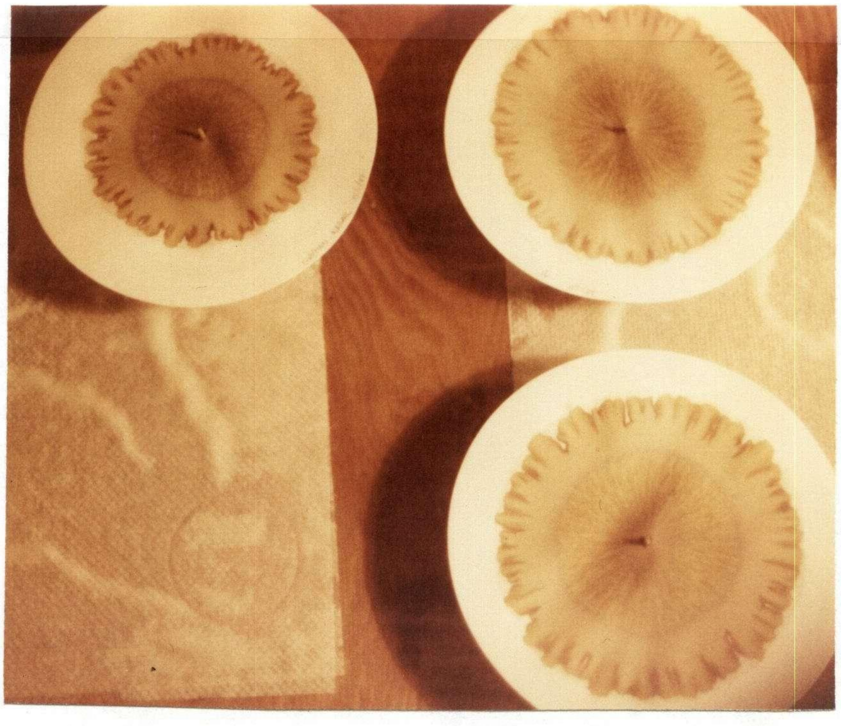


Figure 1 Chromatography in process after 40 minutes.

A generally "naive" approach is taken in regard to the chromatogram. The humus extract used (NaOH extracted) will contain a proportion of the humus fractions mentioned in the introduction. Certainly fulvic and humic acids are represented, as well as soluble components (sugars, salts, etc.). One would expect smaller molecules to migrate more quickly and generally end up at the periphery. This however is confounded by the action of silver. It is obviously critical for the development of zones. Figure 2 shows an LFH extract and Ah extract without using silver nitrate. There is no definition of zones. Silver will form complexes with many components including OH radicals of extracting solution. Silver oxides in combination with the humus colours themselves produce the colours in the chromatogram.

Extractability of humus varies with pH (Konanova 1966). It is expected that the chromatogram will reflect changes in pH. The amount of sample used for extraction was one gram if greater than 17% organic carbon and two grams if less than 17% organic carbon. The intensity of colour varies with the amount of organic matter. As mentioned one would expect the more mobile fulvic acid fraction to migrate to the periphery. However, because it may be expected to complex more rapidly with silver, (Lowe, pers. comm.,1983) it may also concentrate nearer the centre. Generally the wider the zone, the more of a particular substance or complex of substances might be expected. The density of the zone should also reflect the amount of substance.

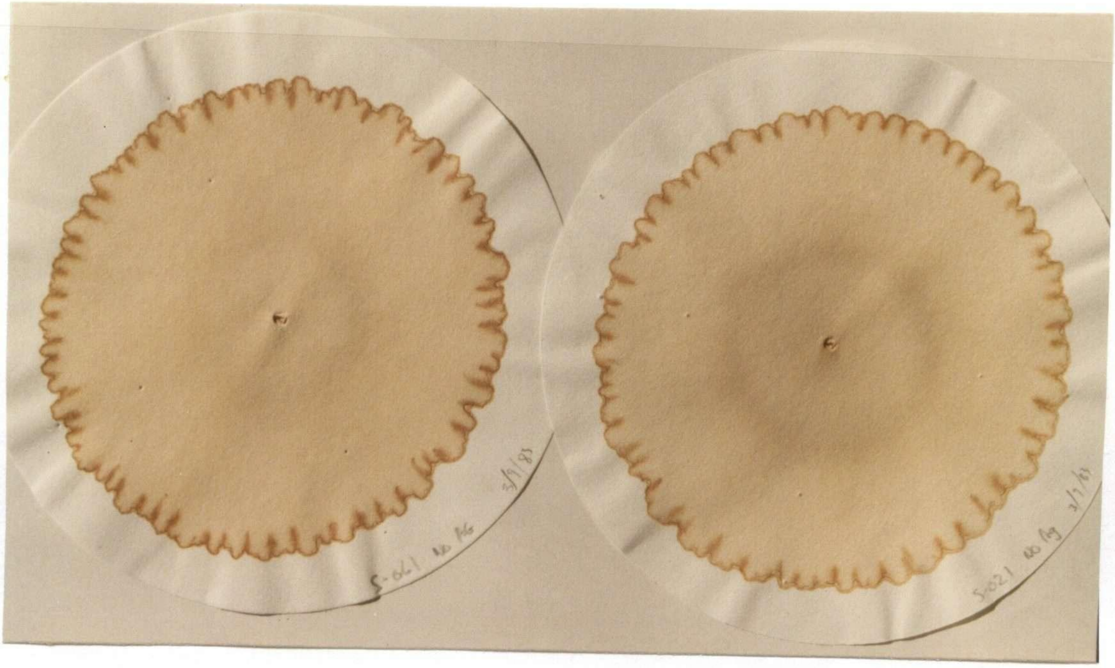


Figure 2 Chromatograms prepared without using Silver Nitrate.

UBC RESEARCH FOREST STUDY

Three plots were selected at the UBC Research Forest representing xeric, mesic and hygric ecosystems for which soil analysis had been done (Klinka and Lowe 1976). Xeric, mesic and hygric refer to moisture regime or hygrotope as used by the Ministry of Forests Staff(Walmsley _et al_. 1980). Simply, they are dry, moist and wet sites with characteristic vegetation. Two samples (25cm by 40cm x the depth of humus form) were taken at each plot. These were air dried and ground. An additional two samples were taken at the mesic site for use in testing the repeatability of the chromatographic method.

Chromatograms were prepared from each H or Hi horizon, Bhf horizon, and an LFH combined sample using a one gram sample for the organic samples and two grams for mineral samples. Eighteen replicate chromatograms were prepared using one gram sub-samples (LFH) from the additional samples taken at the mesic site.

The chromatograms exhibited repeating zones and forms. Measurements of these repeating zones were made using dividers. Four measurements were made of each and the average reported in millimetres. Numbers of lobes and spike formations were counted. Figure 3 shows a schematic diagram of zones and associated measurements.

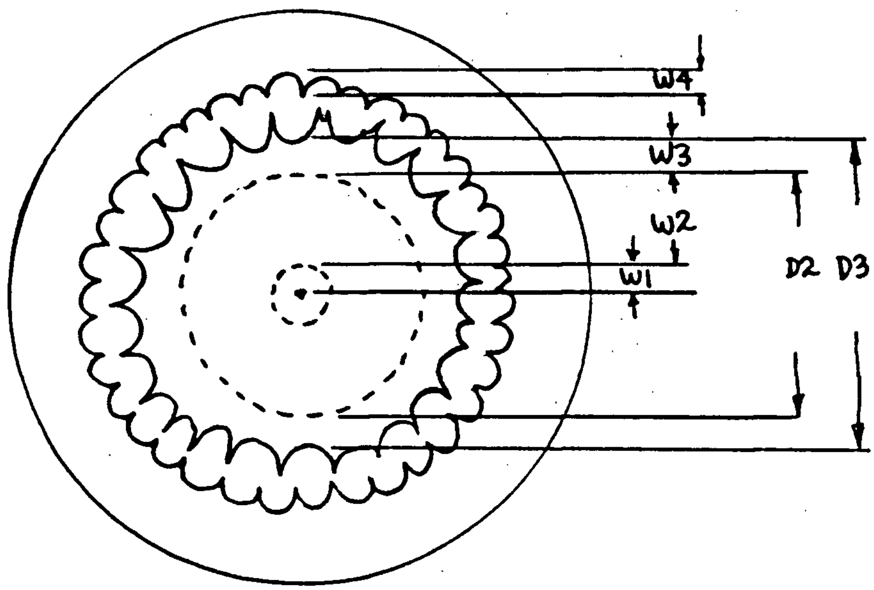


Figure 3 Schematic diagram of chromatogram showing derived variables.

The developed chromatograms were photographed in bright daylight to preserve a record of their colours. A slight darkening was observed in some of the early chromatograms. The original chromatograms are stored in a light-proof container. The photographs presented in this study show the chromatograms at approximately half-size.

SAYWARD PROVINCIAL FOREST STUDY

During 1980 and 1981 extensive sampling of the Sayward Provincial Forest was undertaken by the Ministry of Forests research staff to describe and characterize ecosystems of the area. The Forest is on eastern Vancouver Island near Campbell River, and includes a range of climate, soils and vegetation integrated into several biogeoclimatic subzones. Plots were selected using synecological methods so that the range of associations in each subzone was represented by at least five plots. In all, some 120 plots were sampled and described according to procedures in Describing Ecosystems in the Field (Walmsley et al.,1981). Each 400 square metre plot was described by the above procedures which include vegetation, soils by a modal pit, humus form, mensuration data, wildlife information and general site features. Soils were sampled by horizon. Humus forms were sampled as LFH composites if ectorganic. Endorganic and organic horizons were sampled separately (Ah, Oh) where they occured. Each humus sample was air dried, ground in a blender and then in a Wiley mill and analysed for a wide range of chemical variables.

Analysis was done by Pacific Soil Analysis Inc.. Methods are summarized below:

1. Total Carbon - Walkley-Black.(Black et al.,1965).

2. Total Nitrogen - Sulphuric acid digestion followed by colourimetric analysis.(Black et al.,1965)(Watanabe and Olsen,1965).

3. Total Phosphorus - Sulphuric acid-peroxide digestion followed by colourimetric analysis.(Black et al.,1965)(Watanabe and Olsen,1965).

4. Mineralizable Nitrogen - Waring Method - 2 week 30'C incubation.(Waring and Bremner,1964).

5. CEC and exchangeable cations - one normal ammonium acetate pH=7 method.(Black et al.,1965).

6. Total Cations - Sulphuric acid-peroxide digestion followed by A.A. analysis.(Price,1978).

7. Lipid A fraction - ethanol-benzene extraction.(Lowe,1974).

8. Fraction B - extracted with 0.1 N sulphuric acid. Carbon determined by method 1. Sugars determined by phenol-sulphuric method.(Lowe,1974).

9. Humics and fulvics were extracted with 4 , 200 ml. extractions of 0.2 N NaOH. Carbons were determined by method 1. Nitrogen determined by evaporation followed by method 2. E400 and E600 absorbances measured on a 50 ppm carbon humic extract. Calculated on a 1% carbon basis.(Lowe,1974)(Klinka and Lowe, 1976).

10. Pyrophosphate Fe and Al determined by extraction with 0.1M sodium pyrophosphate.(Bascomb,1978).

The soils component of the Sayward Study is the responsibility of the author. The developed data set includes 146 variables and 114 plots. A report is in progress entitled Humus Forms of the Sayward Forest which is but one part of the Sayward Forest Study.

For the purposes of this thesis, each complete humus form

sample was used to prepare chromatograms. One gram of organic sample was used, two grams for mineral soil (Ah). Only humus forms with one sample i.e., LFH, Ah or O were used because of the difficulty in averaging chromatograms. There is therefore, one chromatogram for one humus form. This allows direct comparison of the chromatographic variables with the chemical, physical and catagorical variables of each plot. The data set used is shown in Appendix I and has 50 variables for 103 plots. Chemical concentration data and site data was selected from the large data set resulting in the use of the 50 variables shown in table 1.

Table 1 List of variables and abbreviations used.

PHH2O - pH in water
TC - total C(%)
TN - total N(%)
CN - TC/TN
TP - total P(%)
MINN - mineralizable N(%)
CEC - cation exchange capacity(meq/100g)
EXCA - exchangeable Ca(meq/100g.)
EXMG - exchangeable Mg(meq/100g.)
EXNA - exchangeable Na(meq/100g.)
EXK - exchangeable K(meq/100g.)
LIPIDA- lipid fraction(%)
CB - Carbon in fraction B (%)
SB - sugars in fraction B(%)
HUMC - Carbon in humic acid fraction(%)
HUMN - Nitrogen in humic acid fraction(%)
CF1 - Carbon in fulvic acid fraction(%)
CHCF - HUMC/CF1 = humic Carbon/fulvic Carbon
E400 - E400 nm for humic acid fraction
E600 - E600 nm for humic acid fraction
E40E6 - E400/E600
TCA - total Calcium(%)
TMG - total Magnesium(%)
TK - total Potassium(%)
TNA - total Sodium(%)
TFE - total Iron(%)
TAL - total Aluminum(%)
TMN - total Manganese(%)
PYFE - pyrophosphate extractable Iron(%)
PYAL - pyrophosphate extractable Aluminum(%)
DTREE - dominant tree species
SUBZ - biogeoclimatic subzone
ELEV - elevation (m)
HYGR - hygrotope
TROPH - trophotope
HFORM - humus form taxa
FDSI - Douglas-fir(Pseudotsuga menziesii(Mirb.)Franco) site index (m./100 yr.)
PLSI - Lodgepole pine(Pinus contortaDougl.) site index
HWSI - Western hemlock(Tsuga heterophylla(Raf.)Sarg.) site index
CWSI - Western red cedar(Thuja plicata Donn) site index
D2 - diameter of 2nd zone (mm)
D3 - diameter of 3d zone (mm)
W1 - width of inner zone (mm)
W2 - width of 2nd zone (mm)
W3 - width of 3d zone (mm)
W4 - width of outer zone (mm)
LO - number of lobes
SP - number of spikes

The chromatographic variables used were all measurements or numbers associated with zones as mentioned previously. These were selected because of simplicity in obtaining them. The colours are clearly important attributes, however to express them as discrete variables would require very elaborate instrumentation, at the least densitometers. As with soils themselves, colour is quite a subjective phenonemon even with the use of Munsell colour charts. Colours then were excluded from the data analysis however, their importance is discussed in later sections.

Both MIDAS (Fox and Guire,1976) and BMDP (Dixon et al.,1981) were used in data analysis. Correlations were examined between the chromatographic variables and chemical and site variables for each sample. Scattergrams were prepared for the significant relationships. Jack-knifed discriminant function analysis (BMDP) was used to examine the relationships of chromatographic variables to the humus form classification, and to groups based on the dominant tree specie in each plot. Stepwise linear regression (MIDAS) was used for productivity relationships.

MANAGEMENT APPLICATIONS

Humus was sampled in two clearcuts and their adjacent stands. Each humus sample was a composite of five LFH samples. Samples from a pure Douglas-fir stand, a mixed Douglas-fir and western hemlock, and a pure western hemlock stand (each 25 sample composites) were used as well as samples from two "problem"

salal(*Gaultheria shallon* Pursh) sites (each 10 sample composites) for which chemical analysis was available.

Chromatograms were prepared from each sample in the collection using one gram for extraction.

RESULTS AND DISCUSSION

PRELIMINARY STUDY

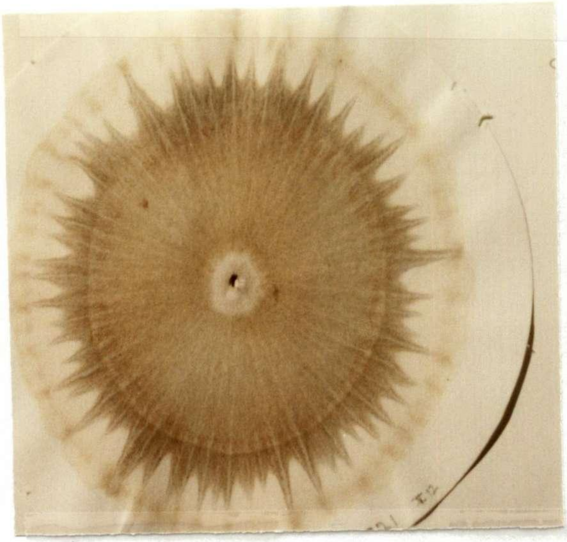
The chromatograms which follow illustrate a range of soil horizon samples. Ah horizons, characteristic of Mull humus forms tended to have a light coloured, outer area and well defined spike formations (figure 4 A and B). LFH horizons tended to darker, lobed outer areas and smaller inner zones. (figure 4 C and D). Organic semi-terrestial horizons (Oh) or saturated H horizons tended to have darker zones with less defined spike formations (figure 4 E and F).

There appeared to be trends in size of the inner zone in relation to soil moisture conditions. The moister the soil, the larger this inner zone. Figure 4 C and D or figure 4 C and figure 5 A are examples.

Pfeiffer (1959) suggested the inner zone gave an indication of mineralization, the presence of soluble inorganic compounds. Figure 6 B, from a cultivated heavily fertilized, drained organic soil does exhibit a larger inner zone and better definition of spike formation than figure 4 E and F. Figure 6 A, a well drained Ah sample shows light outer zone, clear spikes and moderate sized inner zone. Amounts of organic matter and the nature or stability of it were also considered demonstrable by Pfeiffer. Figure 5 A to C shows three horizons from a Ferrohumic Podzol. The Ae shows a faint outer zone, indicative of low organic matter of a less

crude, more stable nature. The Bfl is more stable than the ectorganic F-H. Pfeiffer also suggests that the chromatogram indicates biological factors which cannot be determined by chemical analysis. Two soils of similar chemical properties can be very different in terms of their productivity and quality of product.

These and other observations as well as the experience of describing soils, vegetation and site characteristics and then preparing the chromatogram indicated a potential for the chromatographic approach. The connection between the chromatogram ("humus spectrum") and the site suggested that more specific testing of the interpretations be carried out.



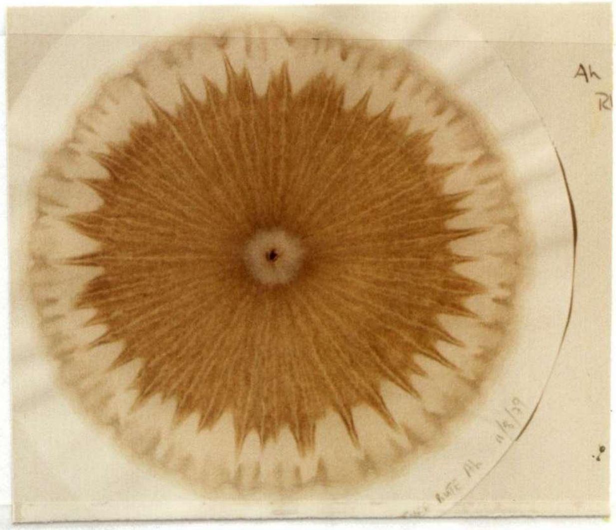
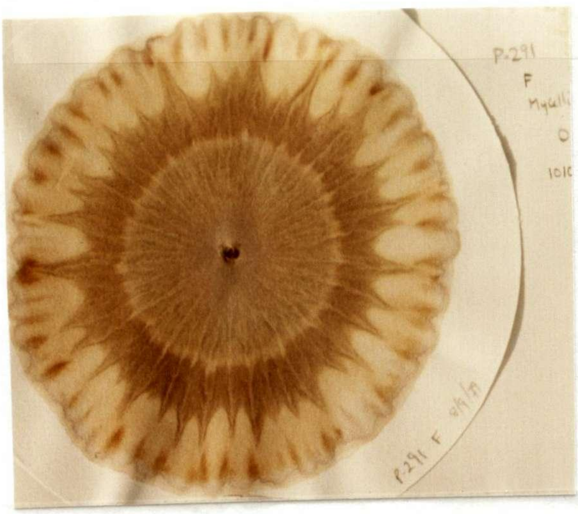


Figure 4 A. Brunisol Mull

Figure 4 B Brunisol Mull



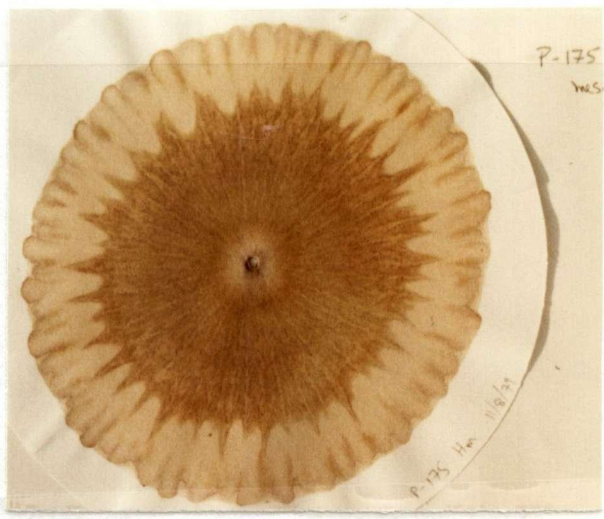
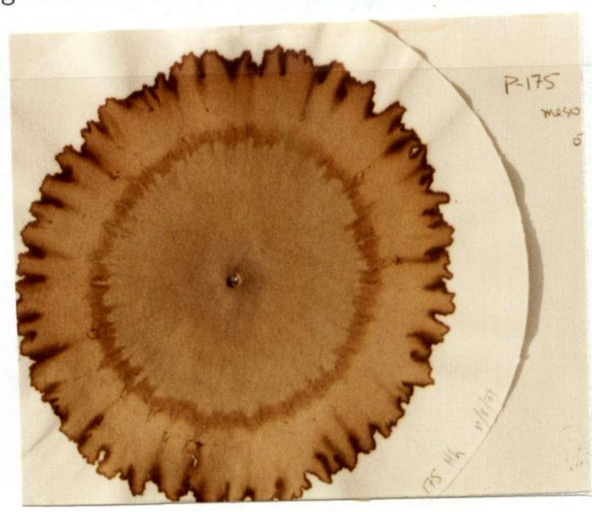


Figure 4 C Podzol(mesic) Mor.

Figure 4 D Gleysol(hygric) Mor.



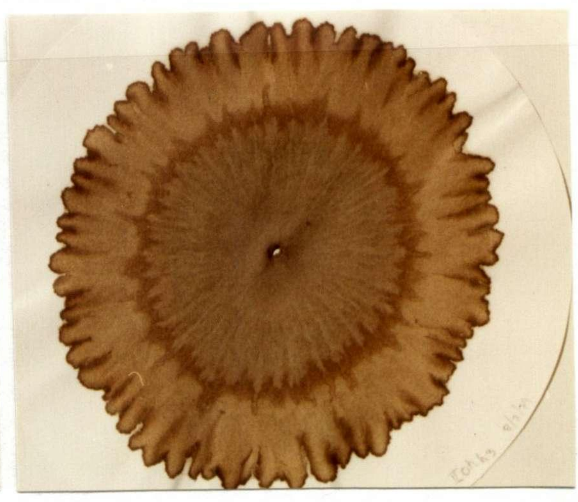


Figure 4 E. H horizon Gleysol. Figure 4 F. Oh horizon Humisol.
Figure 4. Chromatograms of different soil horizon samples.

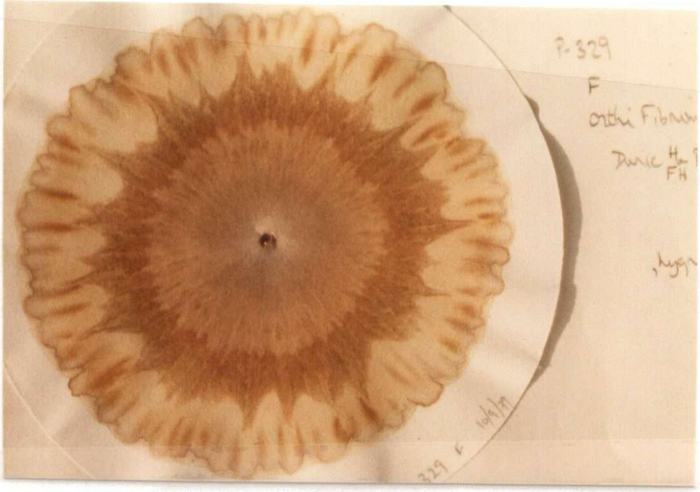


Figure 5 A. F horizon FH Podzol

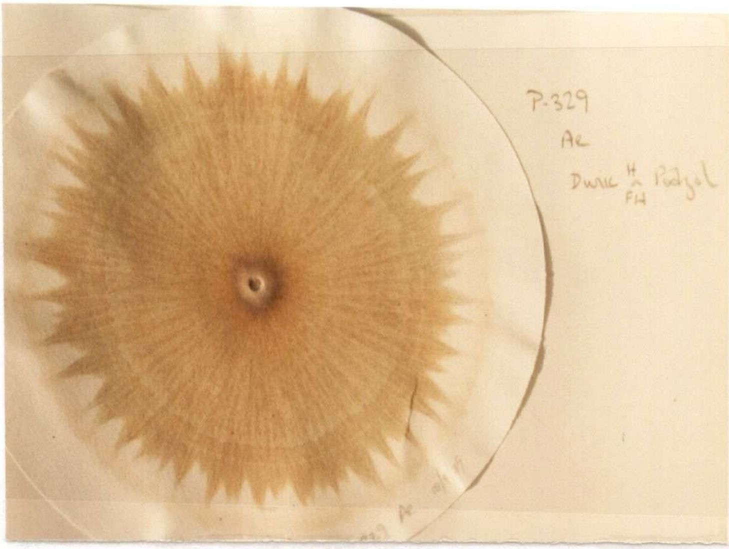


Figure 5 B. Ae horizon.

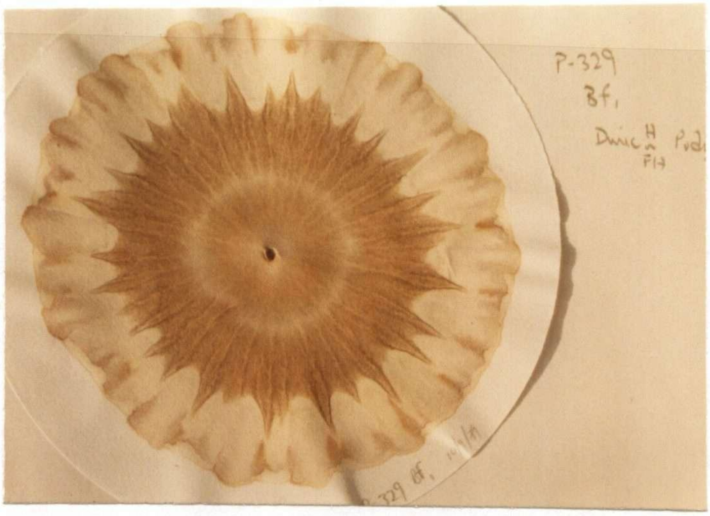


Figure 5 C. Bf horizon.

Figure 5 Chromatograms of horizons of the same soil profile.

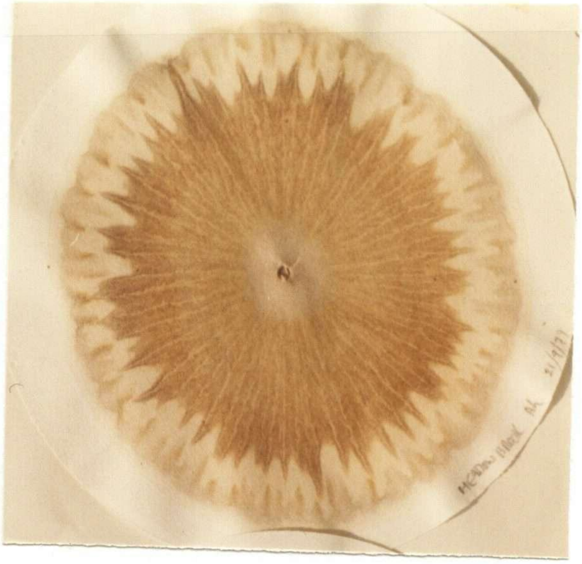


Figure 6 A. Ah horizon. Pasture.

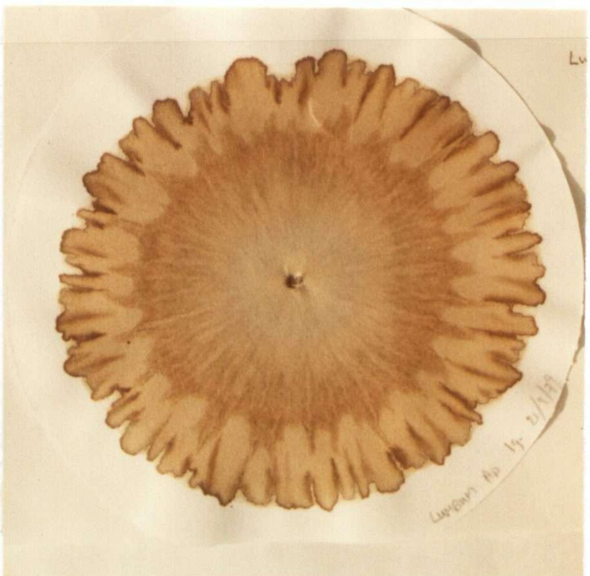


Figure 6 B. Organic. Drained and cultivated.
Figure 6 Chromatograms of two agricultural soils.

UBC RESEARCH FOREST STUDY

Visual examination of figures 7 to 9 shows the following trends. The inner zone (W1) increases in size from xeric to hygric moisture regimes. The diameter of the second zone (D2) also increases with increasing site moisture. The chromatogram from the hygric site sample shows lighter browns and more diffuse outer zones than either the xeric or mesic.

Chemical data from Lowe and Klinka (1976) and measurements of chromatograms of the three plots are shown in Table 2. Relationships were considered to see if consistent trends existed. They are treated only as indications because of the small number of samples. W3 appears related to % organic matter, nitrogen and fulvic carbon. W1 appears related to soil moisture and pH. D2 appears related to % humic carbon. B horizons were examined and similar trends were noted as in LFH or H horizons. It was concluded that a sample of the LFH would provide the simplest method of sampling and present the best overall picture. The indications were such that the chromatographic approach might be diagnostic for a number of humus and site characteristics. The indications support earlier observations and some of Pfeiffer's interpretations.

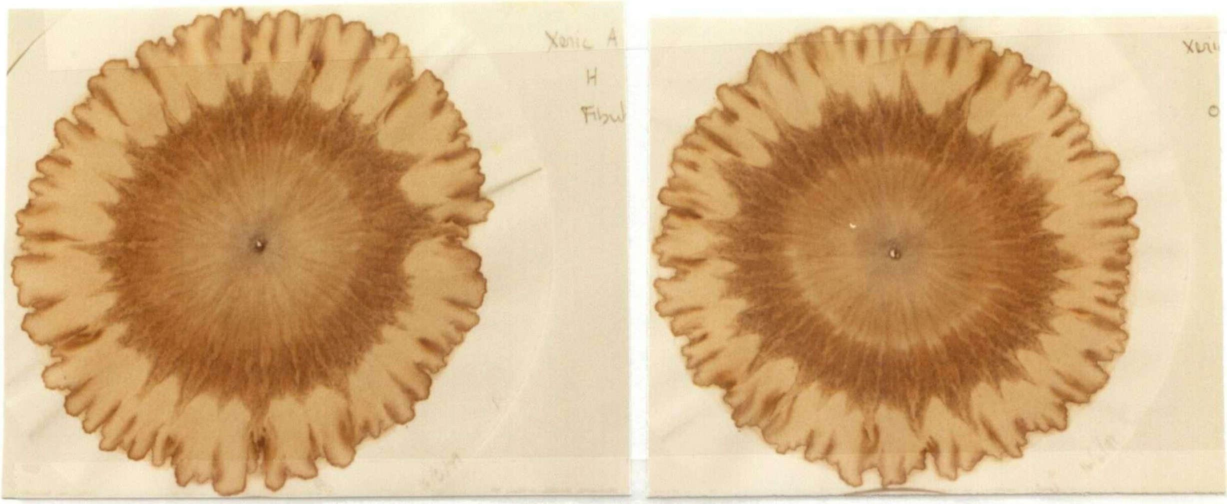


Figure 7 A. Chromatogram of xeric site sample.

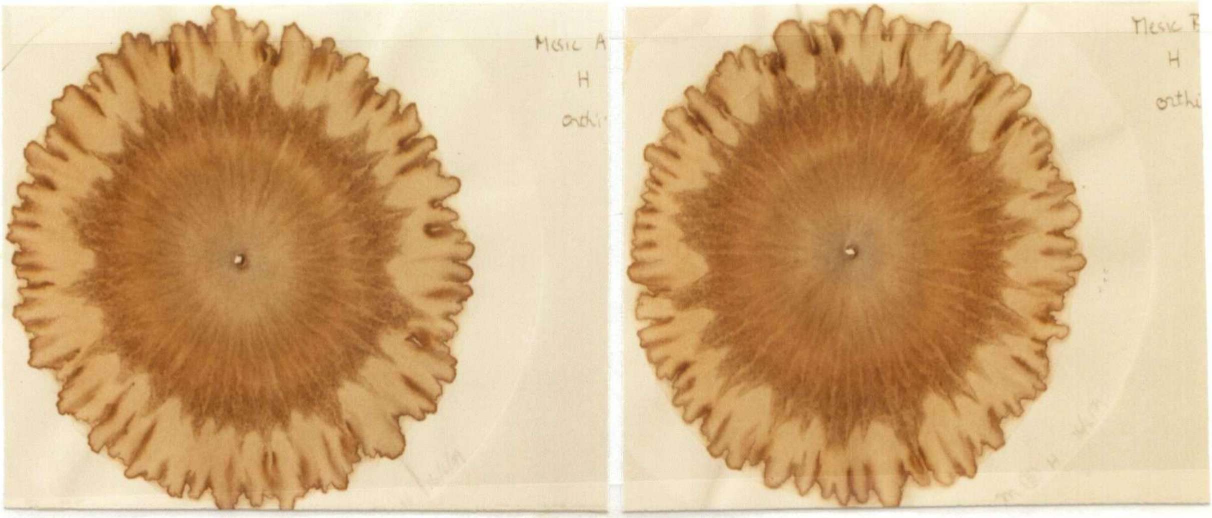


Figure 7 B. Chromatogram of mesic site sample.

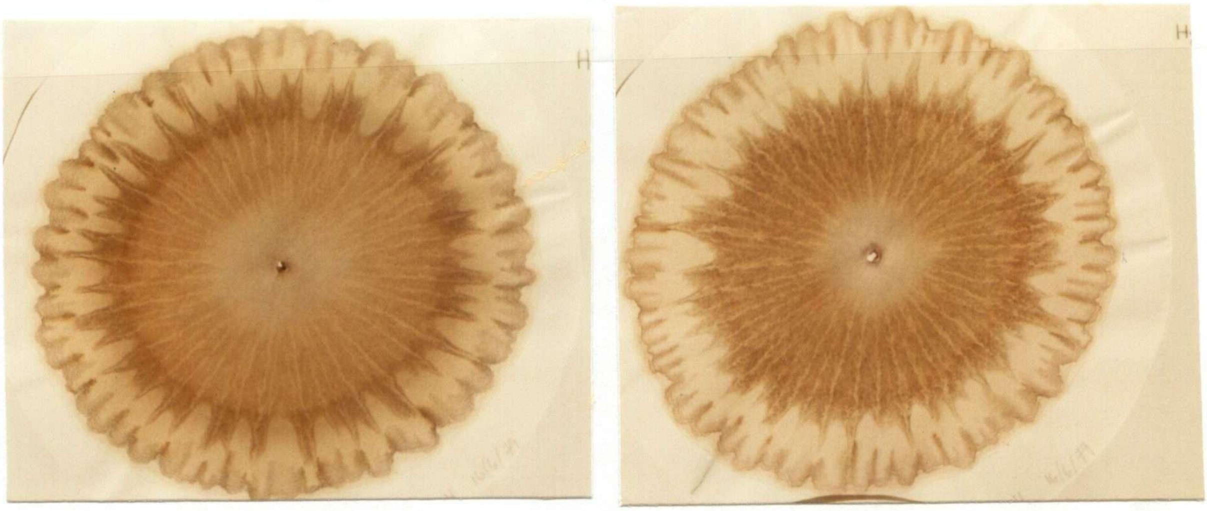


Figure 7 C. Chromatogram of hygric site sample.

Figure 7 Chromatograms of humus samples from three sites in the UBC Research Forest.

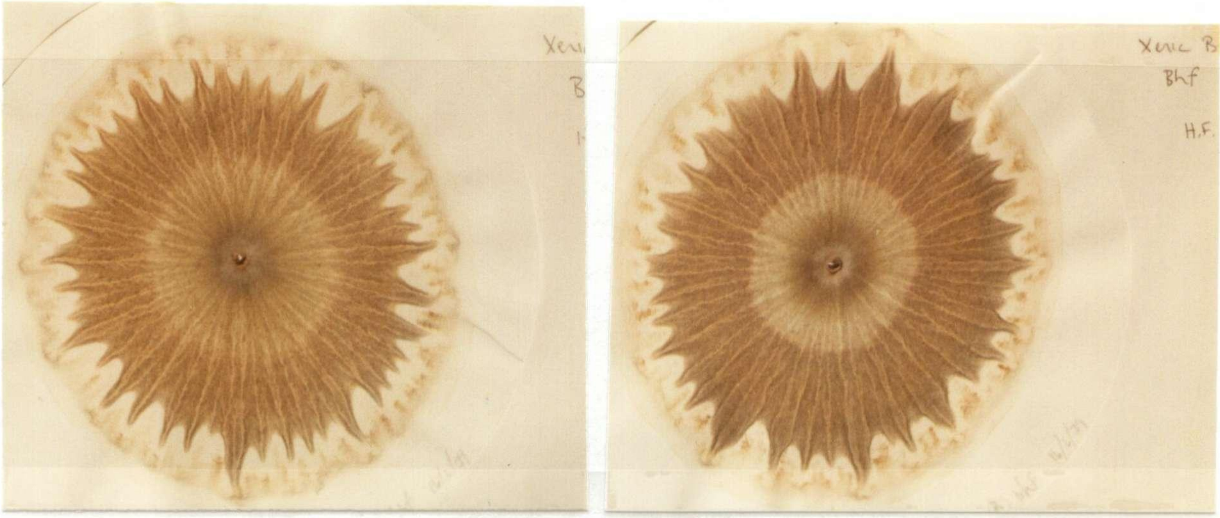


Figure 8 A. Bhf horizon, xeric site.

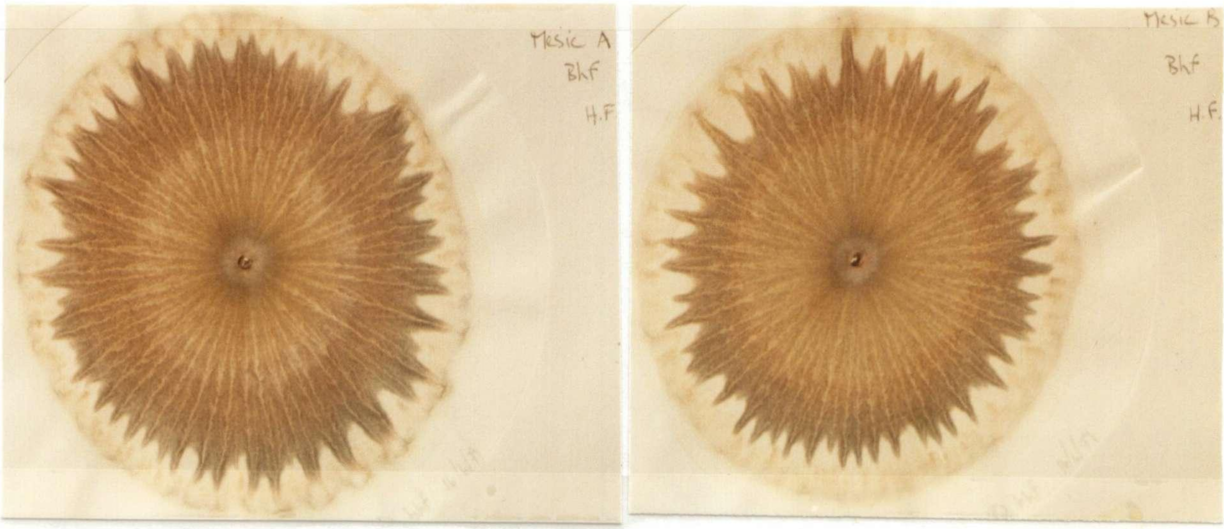


Figure 8 B. Bfh horizon, mesic site.

Figure 8 C. Bfh horizon, hygric site.

Figure 8. Chromatograms of Bhf horizons from three sites in the UBC Research Forest.

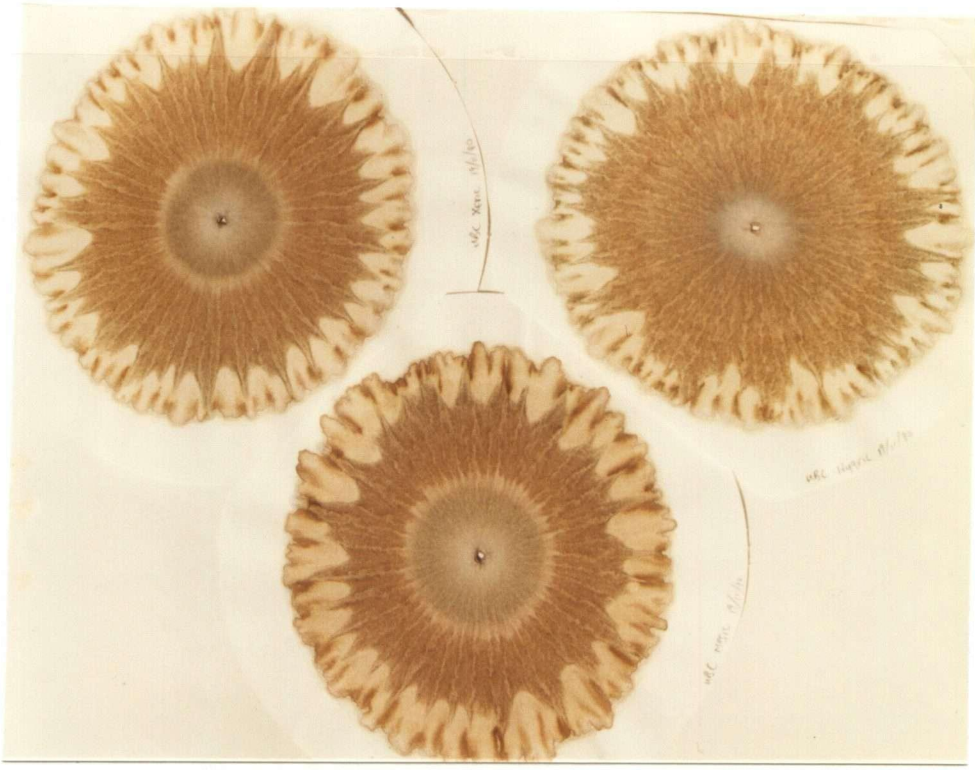


Figure 9. Chromatograms of LFH samples from three sites in the UBC Research Forest.
(LFH xeric upper left, hygric upper right, mesic centre.)

Table 2. Chromatographic variables and associated chemical data from three sites in the UBC Research Forest. (chemical data from Klinka and Lowe,1978.)

	Chromatographic variables (units in mm except LO and SP)							Chemical variables					
Site	D2	D3	W2	W3	W4	LO	SP	PH	%C	%N	CN	%HA	%FA
xeric													
A	46	73	16.5	13.5	10	69	32	3.8	38.4	1.07	36	23	23
B	49	77	16.5	14.0	10	72	36						
LFH	35	80	11.0	22.5	7	65	42						
mesic													
A	47	78	13.5	15.5	10	68	37	3.6	52.6	1.33	40	25	25
B	48	77	15.0	14.5	9	68	41						
LFH	43	80	13.0	22.5	10	59	35						
hygric													
A	75	85	21.5	5.0	9.5	64	46	4.6	15.1	.74	20	37	20
B	72	81	22.5	4.5	10	75	51						
LFH	64	83	22.0	9.5	9	77	47						

Table 3 shows the results of the repeatability study based on eighteen sub-samples from the mesic site LFH samples.

Table 3 Means and standard deviations of chromatographic variables of eighteen replicate chromatograms. (units in mm except for LO and SP)

All Replicates(N=18)	D2	D3	LO	SP	W1	W2	W3	W4
mean	44.9	78.8	54.1	39.6	6.2	15.7	17.0	8.2
standard deviation	2.2	1.3	1.8	1.9	0.2	3.0	1.3	0.6
Sample A (N=9)								
mean	45.8	78.8	53.8	39.8	6.1	16.6	16.5	8.2
standard deviation	2.0	0.8	2.0	2.5	0.2	1.1	0.9	0.6
Sample B (N=9)								
mean	44.0	78.9	54.3	39.4	6.2	15.8	17.4	8.2
standard deviation	2.2	1.6	1.6	1.3	0.3	1.2	1.6	0.6

It is clear that the variables from within sample and within site express a very low degree of variability.

SAYWARD PROVINCIAL FOREST STUDY

CORRELATIONS

Tables 4-1, 4-2, and 4-3 show correlations between measured chromatographic variables and chemical and site variables that are significant at .05 and .01. All humus samples (both organic and mineral) are shown in table 4-1, organics only in table 4-2, and Ah only in table 4-3. Two grams of sample were used for mineral soil (Ah's) and only one gram for organic soil. This was done to increase the extracted substances in mineral soil samples to achieve common characteristics for all humus forms sampled. In particular, lobes did not develop consistently when one gram of Ah samples was used in exploratory studies. This difference will weaken the relationships found for all samples (i.e., table 4-1). However, there is clearly a difference between endorganic humus forms and ectorganic forms - this is why tables 4-2 and 4-3 are presented separately. Differences in results are discussed below. Those scattergrams which showed visually significant relationships are presented in the discussion. Note that asterisks are frequently replaced by numbers which indicate the number of sample points that fall on the same place.

Table 4-1 Significant correlations between chromatographic variables and site and humus sample chemical variables of all samples from the Sayward Forest.

D2	EXMG(+)**, EXK(-)*, LIPIDA(-)*, CB(-)*, SB(-)*, HFORM(+)*
D3	HUMC(-)**, HUMN(-)*, PLSI(-)*, ELEV(-)*
LO	PHH2O(+)*, EXCA(+)*, HUMC(-)**
SP	PHH2O(+)**, TC(-)**, CEC(-)**, LIPIDA(-)**, HUMC(-)**, HUMN(-)**, CF1(-)*, SUBZ(-)**, ELEV(-)*
W1	PHH2O(+)**, TC(-)**, CEC(-)**, EXK(-)**, LIPIDA(-)**, CB(-)**, SB(-)**, HUMC(-)*, CF1(-)**, E400(+)**, E600(+)** E4/E6(-)**, SUBZ(-)**, HYGR(+)**, TROPH(+)**, HFORM(+)**, CN(-)**, ELEV(-)*
W2	PHH2O(-)*, TC(+)*, CEC(+)*, E4/E6(+)*
W3	TN(-)*, EXMG(-)*, EXK(+)**, LIPIDA(+)*, SB(+)*, E400(-)*, E600(-)*, TROPH(-)*, HFORM(-)*, CWSI(-)**
W4	PHH2O(-)**, TC(+)**, CEC(+)**, LIPIDA(+)**, HUMC(+)**, HUMN(+)**, CF1(+)**, E400(-)*, E600(-)*, E4/E6(+)*, SUBZ(+)**, ELEV(+)*

* Significant at .05
** Significant at .01

Table 4-2 Significant correlations between chromatographic variables and site and humus sample chemical variables of organic samples from the Sayward Forest.

D2	TC(-)*, TN(+)*, EXK(-)**, LIPIDA(-)**, SB(-)**, CF1(-)*, E400(+)**, HYGR(+)*, TROPH(+)*, HFORM(+)**
D3	PHH2O(+)*, TC(-)**, CEC(-)**, HUMC(-)**, HUMN(-)*, CF1(-)*, TCA(+)**, TMG(+)*, TNA(+)**, TFE(+)**, SUBZ(-)**, ELEV(-)**
LO	PHH2O(+)*, TC(-)**, EXCA(+)*, LIPIDA(-)**, HUMC(-)**, E600(+)* ,TCA(+)**, TMG(+)*, TNA(+)*, TFE(+)*, SUBZ(-)*, FDSI(+)*, HWSI(+)*, CN(-)**, ELEV(-)*
SP	PHH2O(+)*, TC(-)*, CEC(-)*, HUMC(-)**, HUMN(-)*, TMG(+)**, TK(+)*, TNA(+)**, TFE(+)**, SUBZ(-)*, ELEV(-)**
W1	PHH2O(+)**, TC(-)**, TP(+)**, EXCA(+)**, EXMG(+)*, EXK(-)**, LIPIDA(-)**,CB(-)*, SB(-)**, HUMN(+)**, CF1(-)**, E400(+)**, E600(+)**, TCA(+)**, TMG(+)**, TNA(+)**, TFE(+)**, TAL(+)**, TMN(+)*,SUBZ(-)**, HYGR(+)**, TROPH(+)*,HFORM(+)**, CN(-)**
W2	TP(-)**, TMG(-)**, TFE(-)*, TAL(-)*
W3	TN(-)**, EXK(+)**, LIPIDA(+)*, SB(+)*, HUMN(-)*, E400(-)**, TMG(+)**, TFE(+)*, HYGR(-)*, TROPH(-)*, HFORM(-)**
W4	PHH2O(-)**, TC(+)**, CEC(+)*, LIPIDA(+)**, HUMC(+)**, CF1(+)*, TCA(-)**, TMG(-)**,TK(-)*, TNA(-)**, TFE(-)**, TMN(-)**, SUBZ(+)*, ELEV(+)*

* Significant at .05
** Significant at .01

Table 4-3 Significant correlations between chromatographic variables and site and humus sample chemical variables of Ah samples from the Sayward Forest.

D2	EXMG(+)**, FDSI(-)*, CWSI(+)*
D3	CEC(-)*, SB(-)*, HUMC(-)*, HUMN(-)**, CF1(-)*, PYFE(-)** PYAL(-)*, FDSI(-)*
LO	CEC(-)**, EXMG(+)*, CB(-)*, SB(-)*, HUMC(-)*, HUMN(-)*, PYFE(-)**, PYAL(-)*
W1	TC(+)**, CEC(+)**, HUMC(+)**, HUMN(+)**, CF1(+)*
W2	CEC(-)*, EXMG(+)**, CWSI(+)**
W3	CWSI(-)*, ELEV(+)*
W4	MINN(+)**, CWSI(-)*, CN(-)**

* Significant at .05
** Significant at .01

ALL SAMPLES

The inner zone W1 shows significant correlations with the largest number of variables. Of particular interest are relationships with PHH2O, LIPIDA, EXK and CN (figures 10 to 13). These chemical variables have been shown to have a connection to humus form taxa (Klinka *et al*., 1981). Figure 14 is a scattergram of W1 and HFORM showing an increase in W1 as humus forms change from Mors to Mulls. Increases in PHH2O and decreases in CN, EXK, LIPIDA are expected. Trends between W1 and HYGR,(figure 15) TROPH (figure 16) and SUBZ (figure 17) are also interesting and expected. Generally, as sites become cooler (subzones CDFa>CWHa>CWHb>MHb) PHH2O decreases and CN increases. As W1 decreases, CFI (fulvic carbon) increases. This is also expected as fulvic acids are considered to indicate immature humus. W1 decreases towards Mor humus forms and towards cooler and wetter conditions. W1 is also positively correlated with E400, and shows expected trends with moisture (HYGR), CN, and humus form (Klinka and Lowe ,1976).

W4 also exhibited significant correlations. Scattergrams of PHH2O and HUMC are presented in figures 19 and 20. As this zone increases, PHH2O decreases and HUMC increases. Additional correlations with LIPIDA, CF1 and E400 are also consistent with results of W1 relationships. Cooler wetter subzones show wider W4 zones indicating low pH and E400, high LIPIDA, TC and CF1.

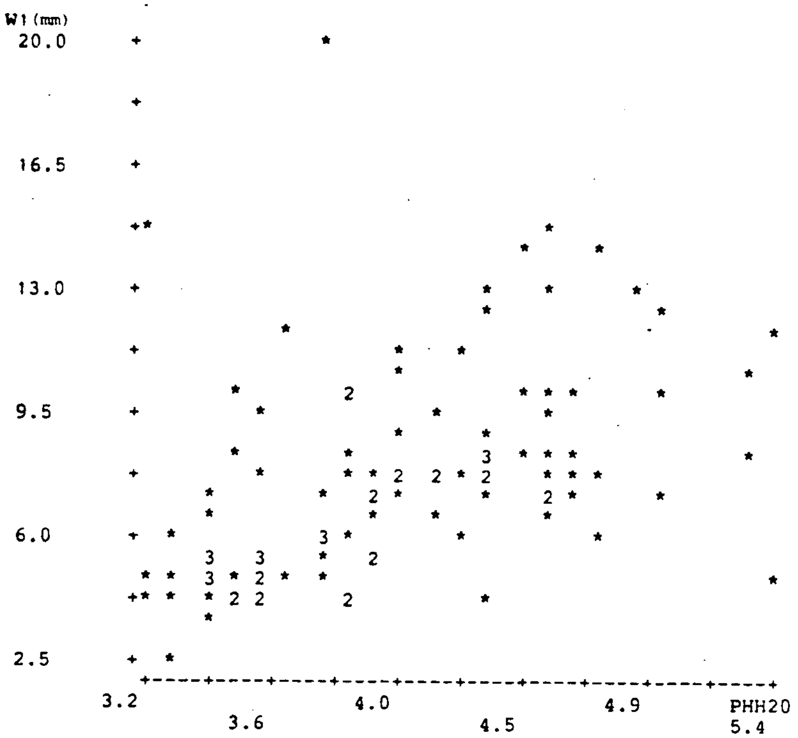


Figure 10. Scattergram showing relationship between W1 and PHH20 using all samples. Numbers indicate the number of sample points that fall in the same place.

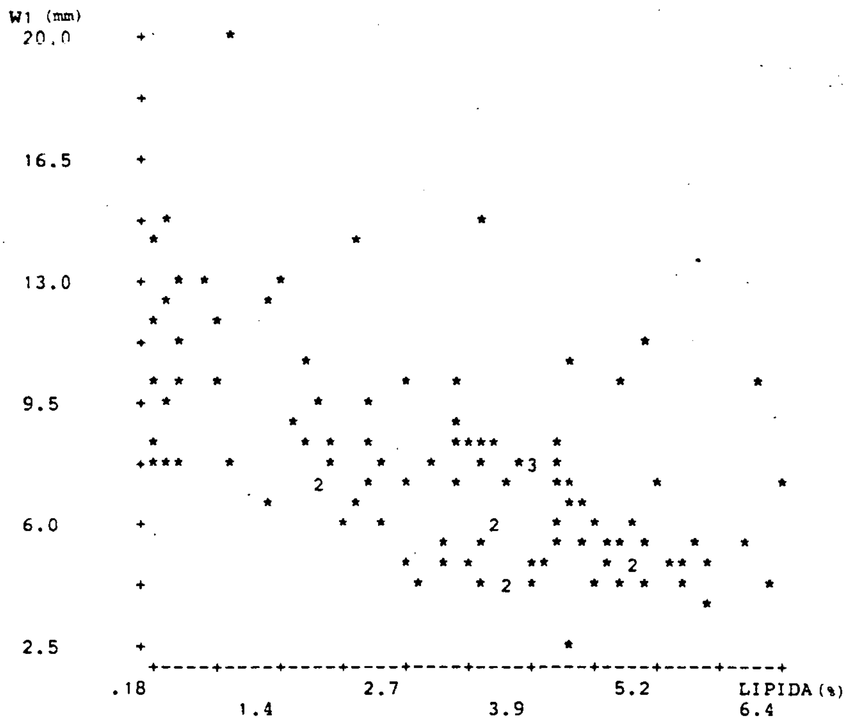


Figure 11. Scattergram showing relationship between W1 and LIPIDA using all samples.

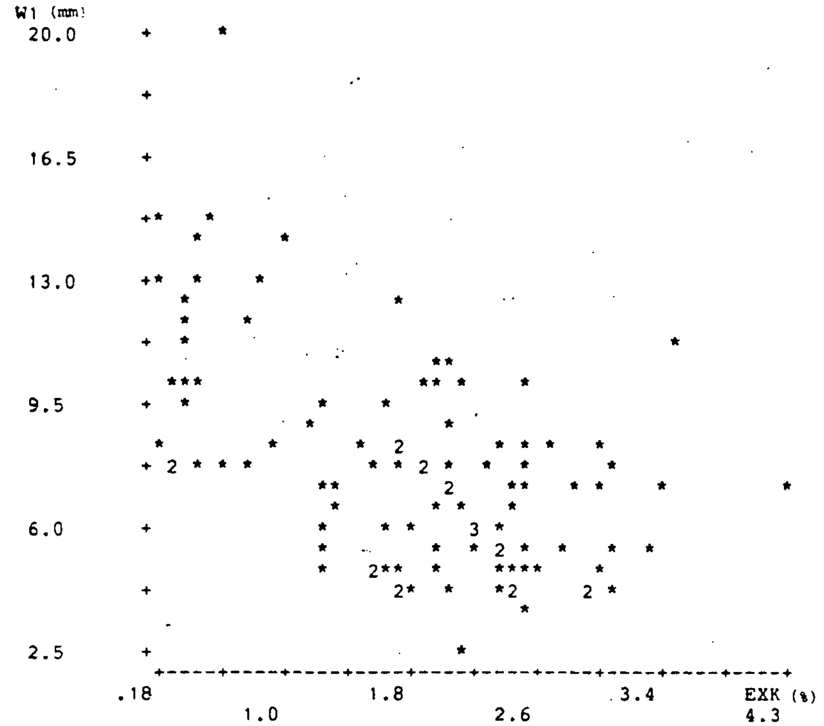


Figure 12. Scattergram showing relationship between W1 and EXK using all samples.

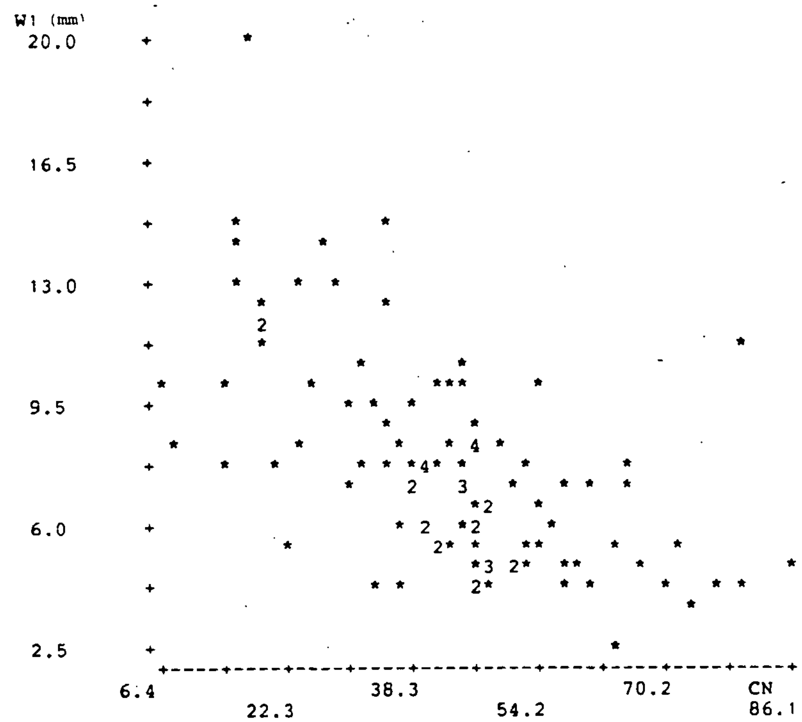


Figure 13. Scattergram showing relationship between W1 and CN using all samples.

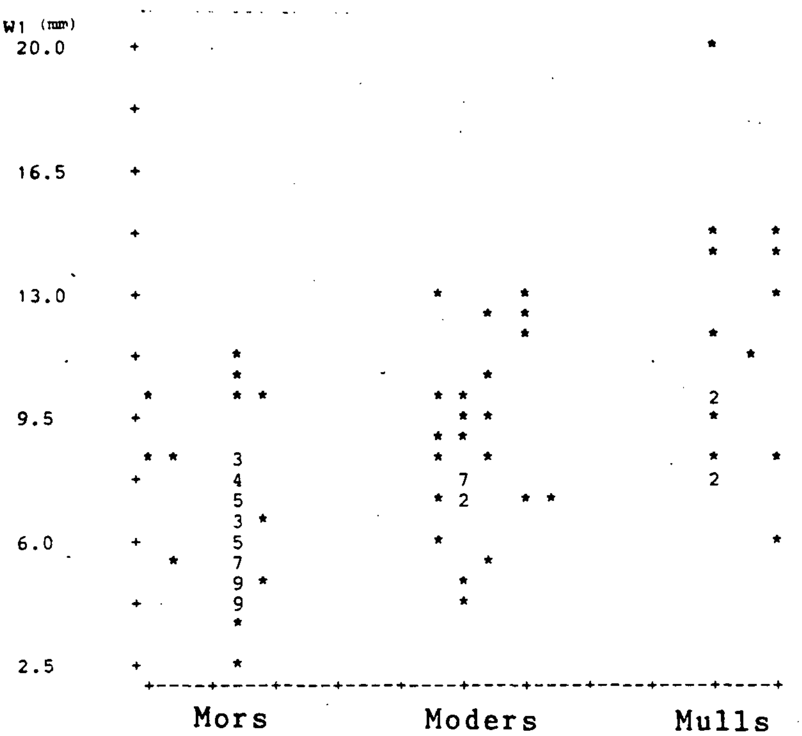


Figure 14. Scattergram showing relationship between W1 and HFORM using all samples.

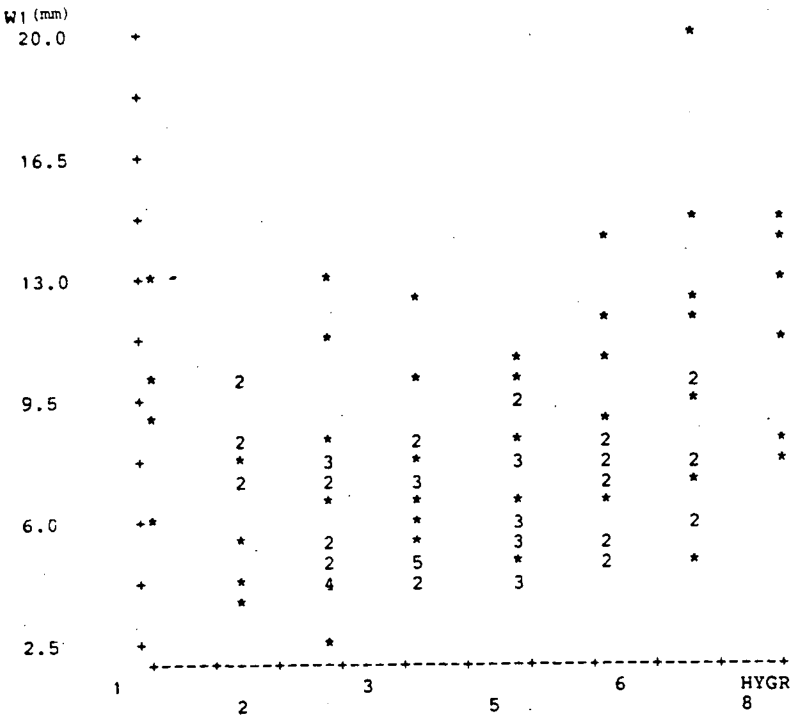


Figure 15. Scattergram showing relationship between W1 and HYGR using all samples.

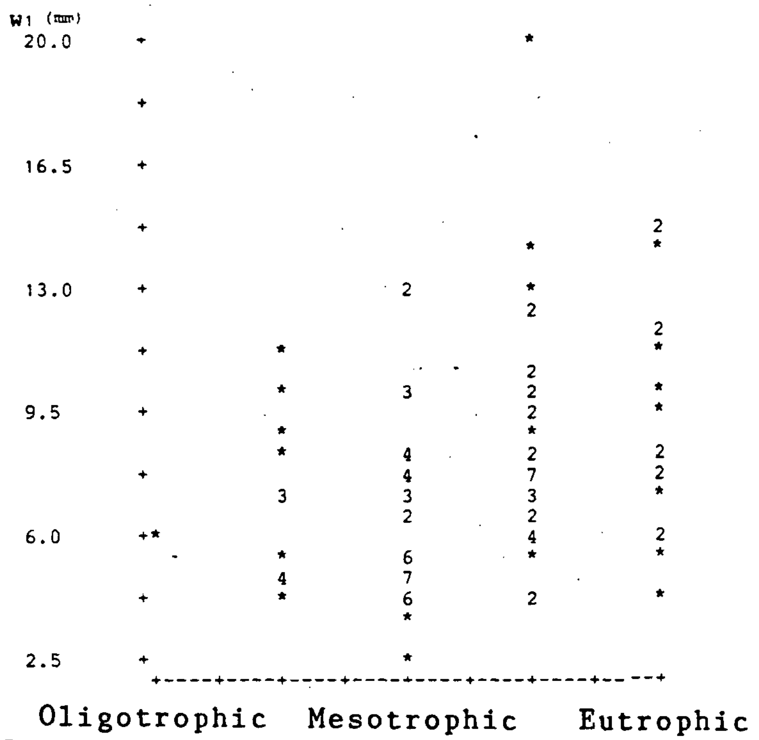


Figure 16. Scattergram showing relationship between W1 and TROPH using all samples.

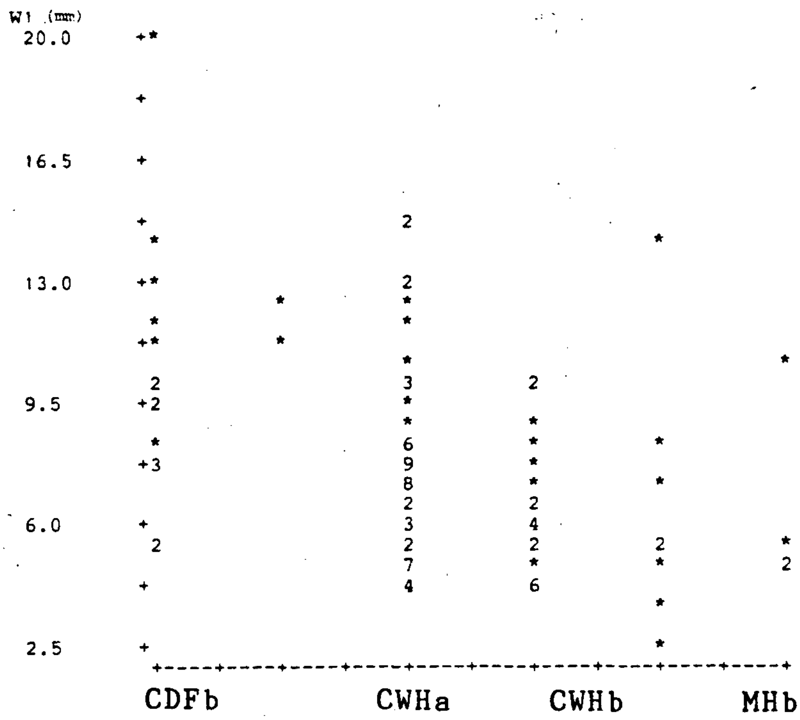


Figure 17. Scattergram showing relationship between W1 and SUBZ using all samples.

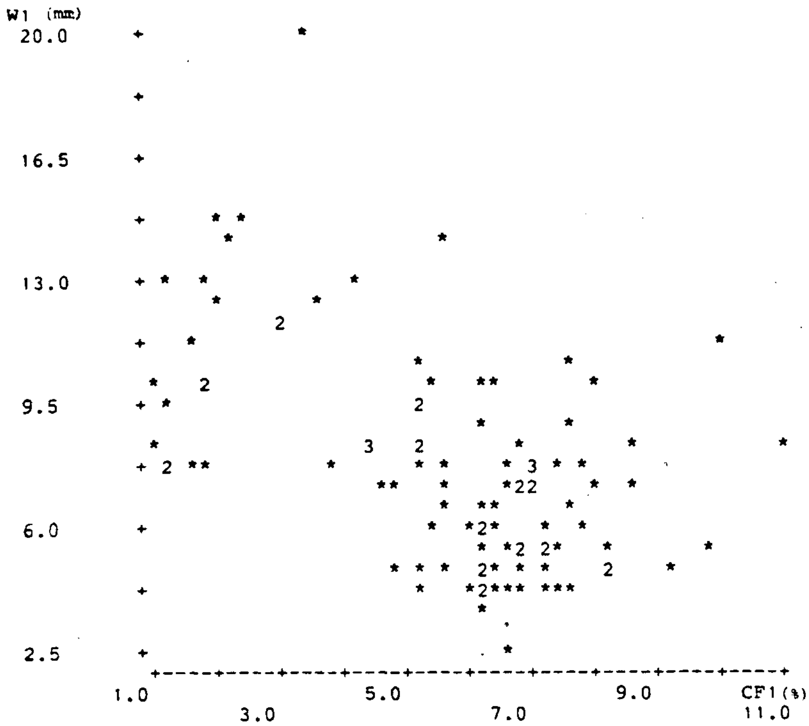


Figure 18. Scattergram showing relationship between W1 and CF1 using all samples.

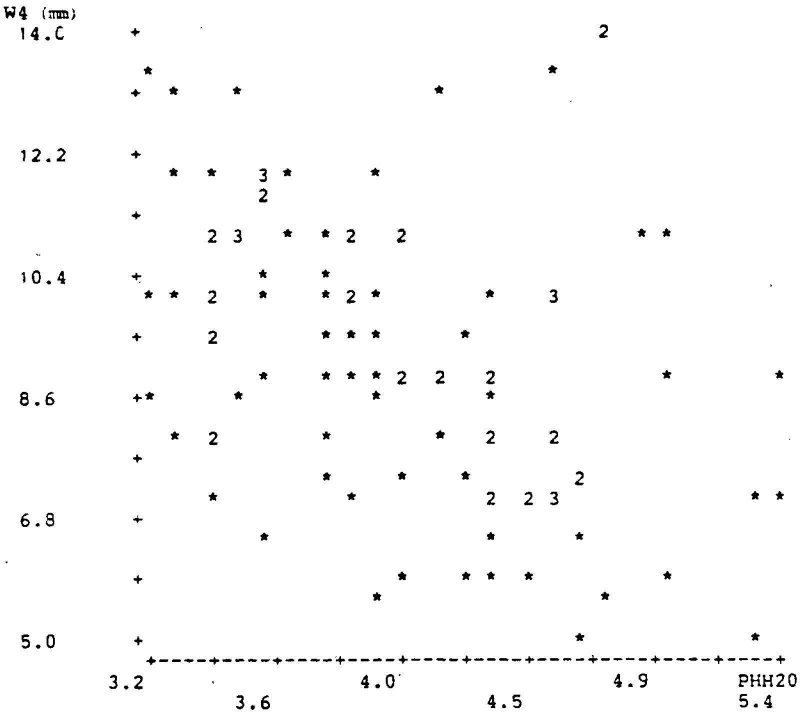


Figure 19. Scattergram showing relationship between W4 and PHH2O using all samples.

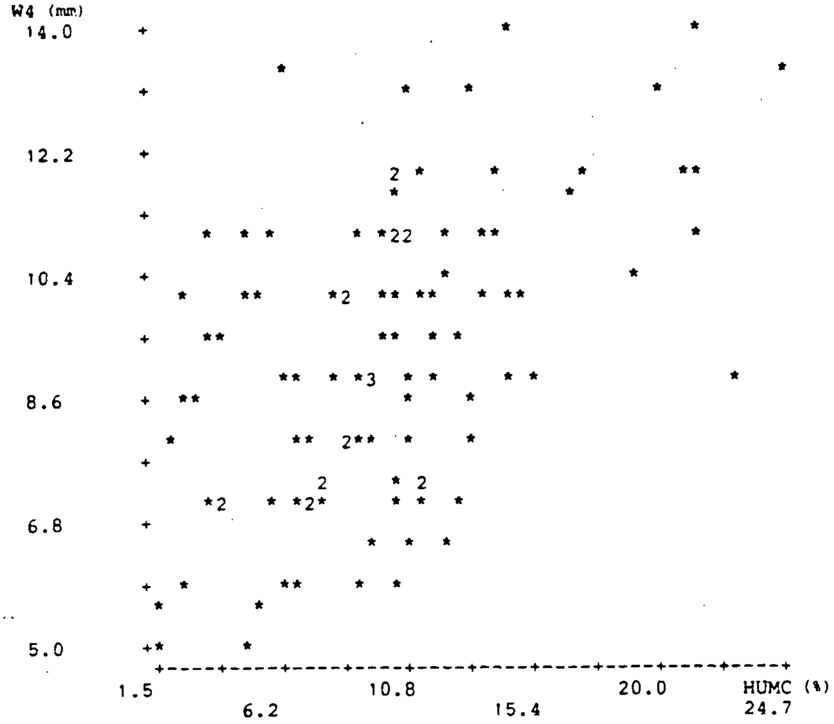


Figure 20. Scattergram showing relationship between W4 and HUMC using all samples.

SP (spikes) also show consistent correlations with PHH2O, TC, CEC, LIPIDA, and CF1. These results would be expected given the relationship between SP and HUMC shown in figure 21.

LO is consistent with SP however it also indicates a relationship with EXCA. This is reasonable because as PH increases and HUMC decreases (i.e. moving from Mor to Mull humus forms) EXCA increases (Klinka et al., 1981).

The second diameter (D2) varies positively from Mor to Mull humus forms, positively with EXMG and negatively with LIPIDA and EXK. Klinka et al. (1981) noted these trends in the UBC Research Forest, Mor humus forms having low EXMG and high LIPIDA and EXK.

W3 also varies significantly with humus form, increasing from Mors to Mulls. Of interest is the relationship with CWSI (site index of Red Cedar) which shows significant negative correlation with W3.

ORGANIC SAMPLES

Relationships of the organic samples show similar patterns as all samples, though there are a greater number of significant correlations (table 4-2). W1 varies positively with PHH2O, HYGR (moisture regime) and humus form, and negatively with LIPIDA and CN (figures 22 to 26). Again, the way W1 changes is consistent and is a reflection of expected chemical and site properties.

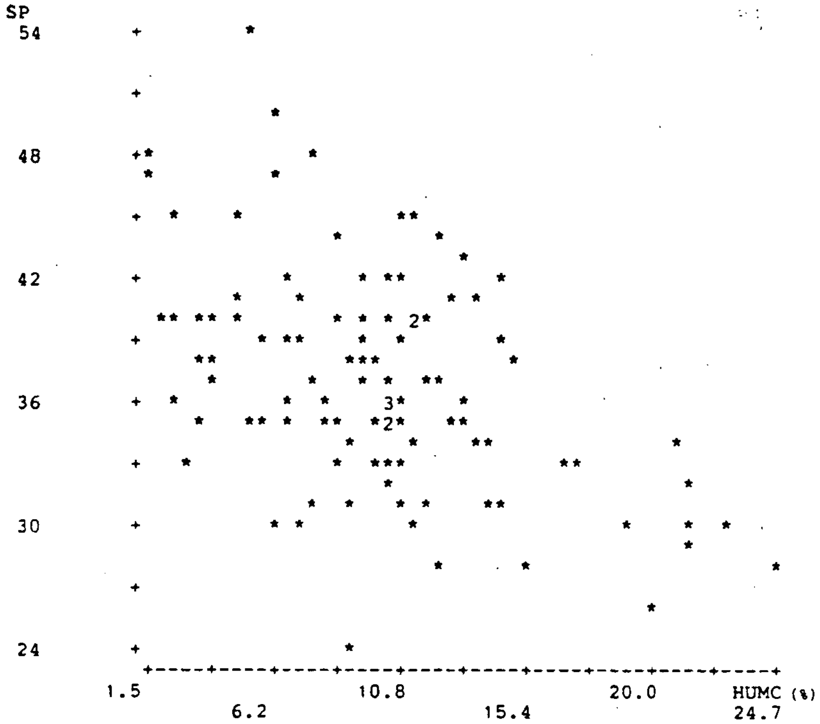


Figure 21. Scattergram showing relationship between SP and HUMC using all samples.

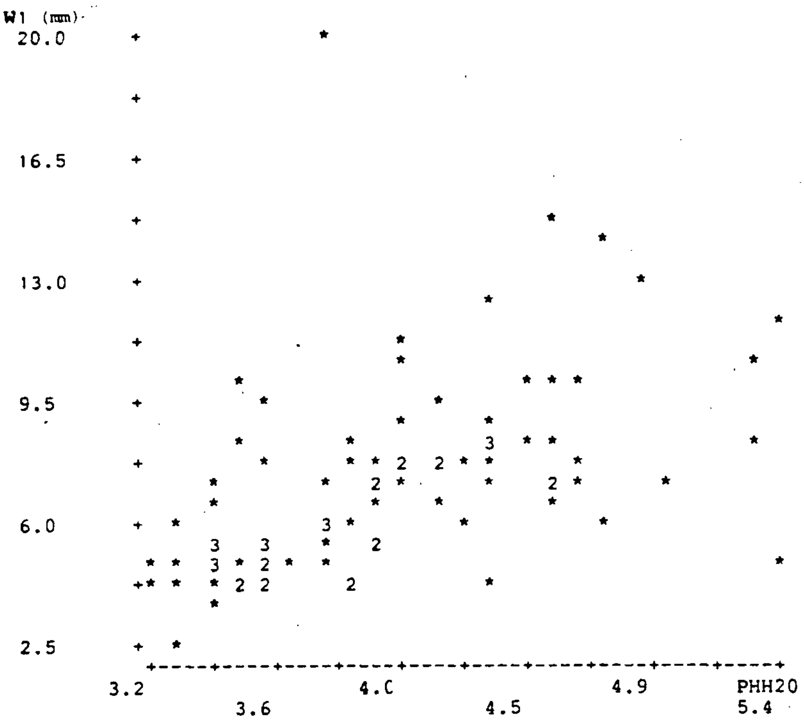


Figure 22. Scattergram showing relationship between W1 and PHH2O using organic samples.

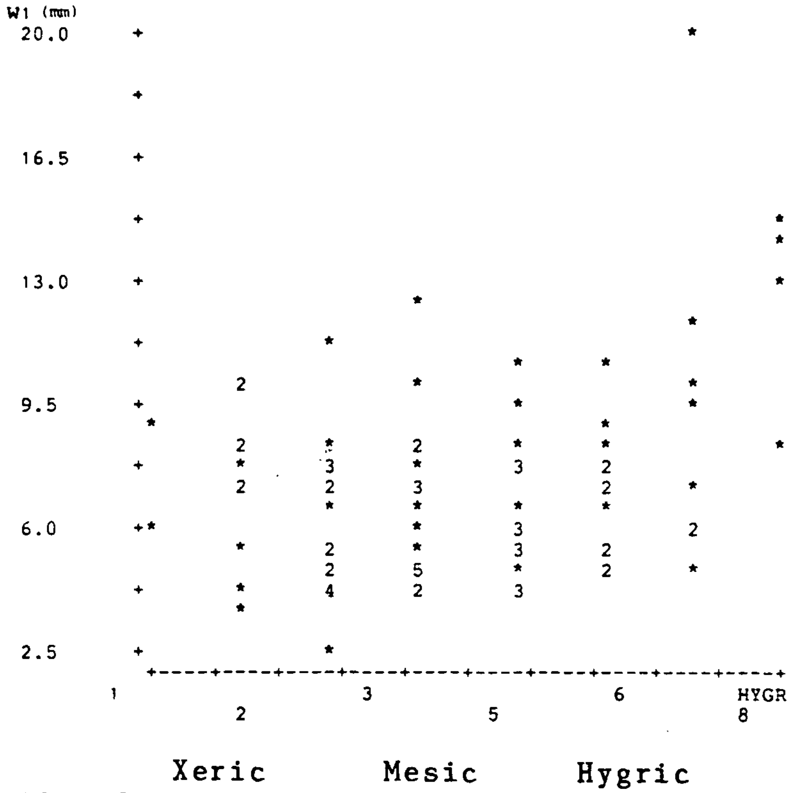


Figure 23 . Scattergram showing relationship between W1 and HYGR using organic samples.

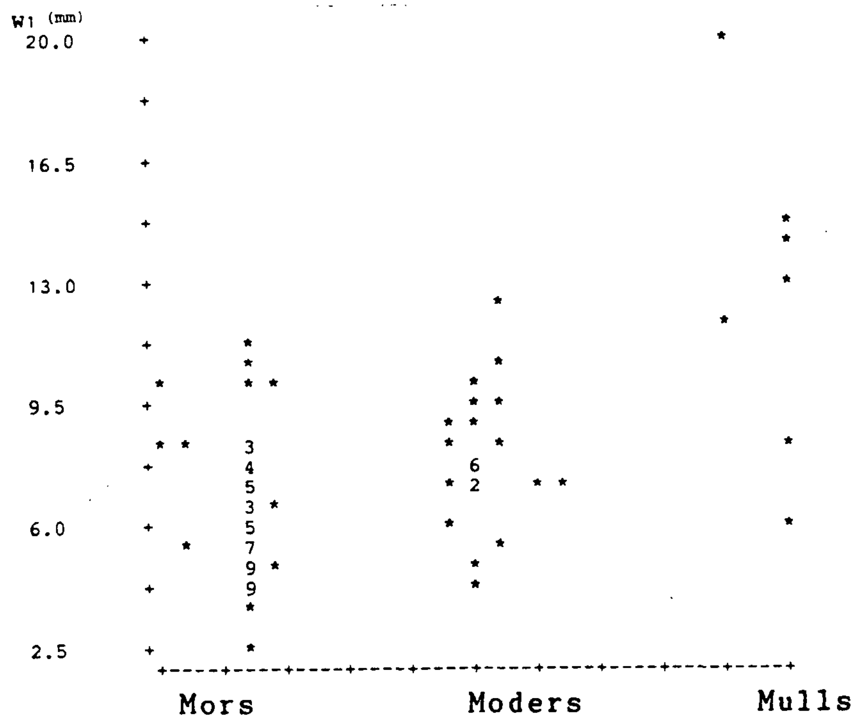


Figure 24. Scattergram showing relationship between W1 and HFORM using organic samples.

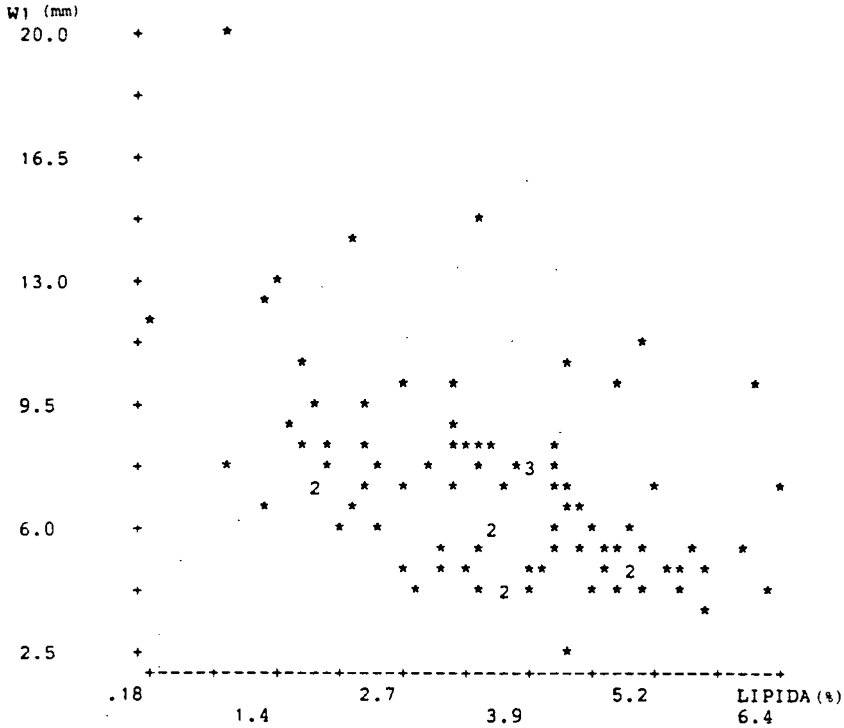


Figure 25. Scattergram showing relationship between W1 and LIPIDA using organic samples.

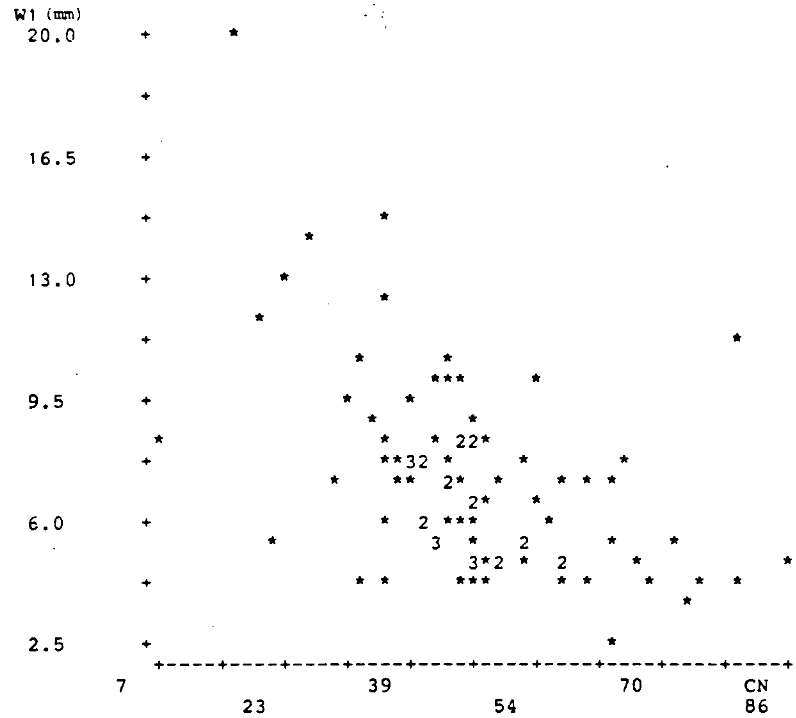


Figure 26. Scattergram showing relationship between W1 and CN using organic samples.

W4 and its relationship to PHH20 and HUMC are shown in figures 27 and 28. Lower values of this outer width indicate higher pH values and lower HUMC and TC.

LO decreases in number with increases in CN (figure 29) and increases with both TCA (figure 30), FDSI (figure 31) and HWSI (figure 32).

AH SAMPLES

When the Ah samples are looked at separately, the number of significant correlations is much reduced. Because of the relatively small sample size (N=15), relationships of chromatographic variables and chemical and site variables are limited.

There are some different relationships expressed. Humus in mineral soil shows different characteristics in the inner zone W1. It shows opposite trends with TC, and CEC as shown in figures 33 and 34. To improve the sample size, additional Ah samples from amphimorphic humus forms were added to the graph. These samples could not be used for the main data set as they represented only part of a humus form. These additional five points conform with the relationships and strengthen their significance.

W4 varies positively with MINN (figure 35). D3 varies negatively with HUMC (figure 36), CEC (figure 37), and as would be expected with FDSI (figure 38). D2 and W2 also vary negatively with FDSI (figure 39).

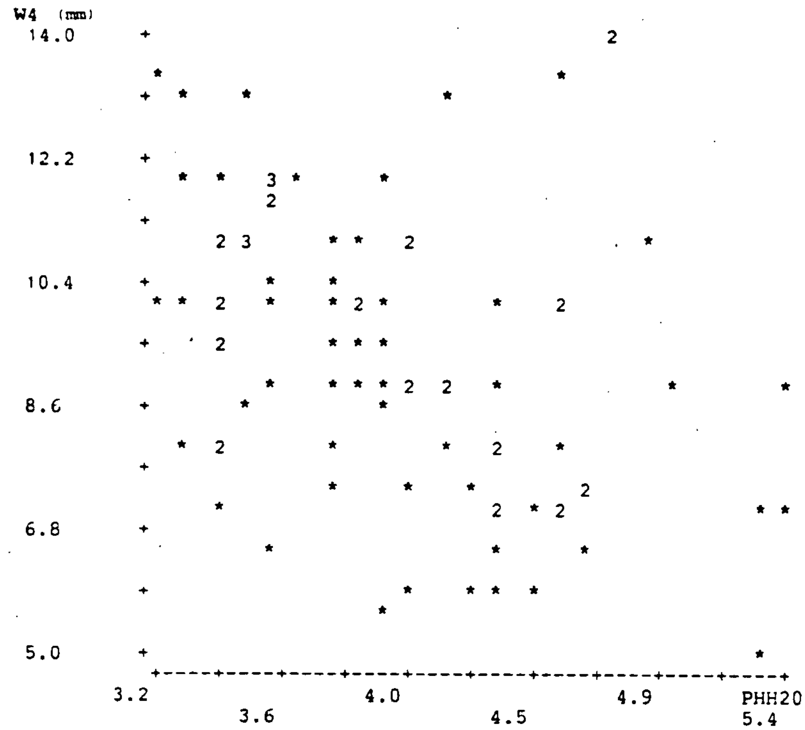


Figure 27. Scattergram showing relationship between W4 and PHH20 using organic samples.

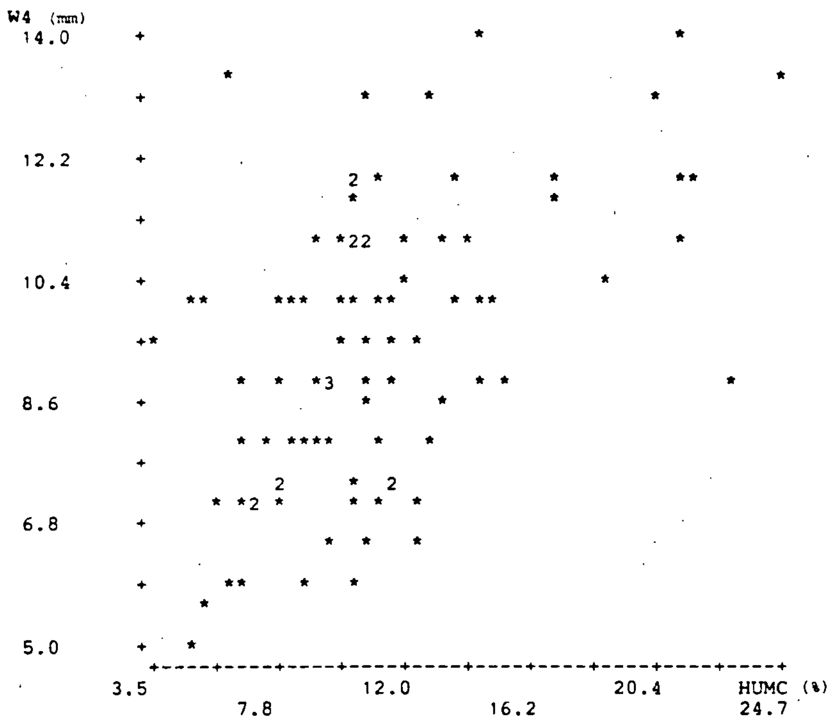


Figure 28. Scattergram showing relationship between W4 and HUMC using organic samples.

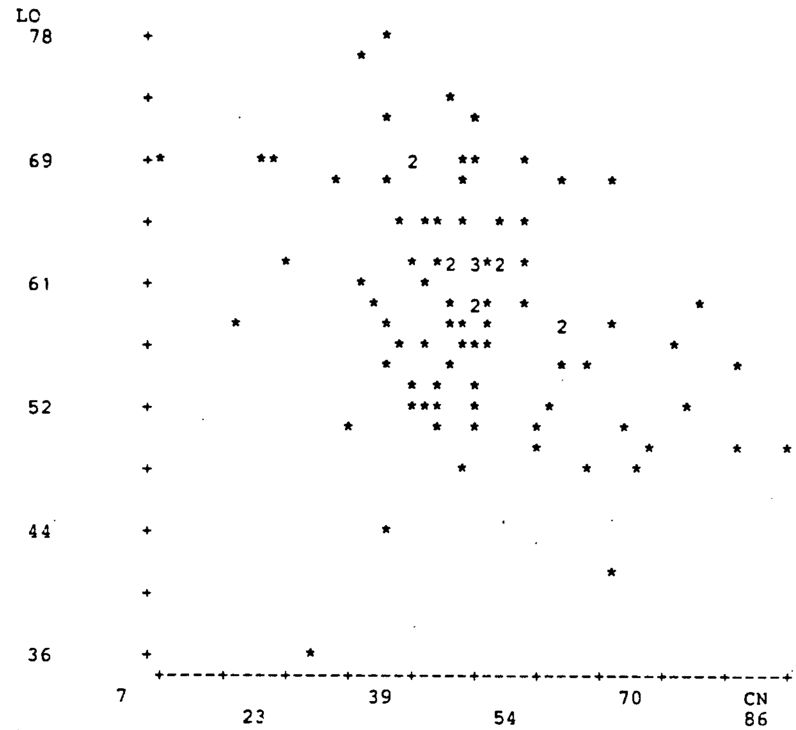


Figure 29. Scattergram showing relationship between LO and CN using organic samples.

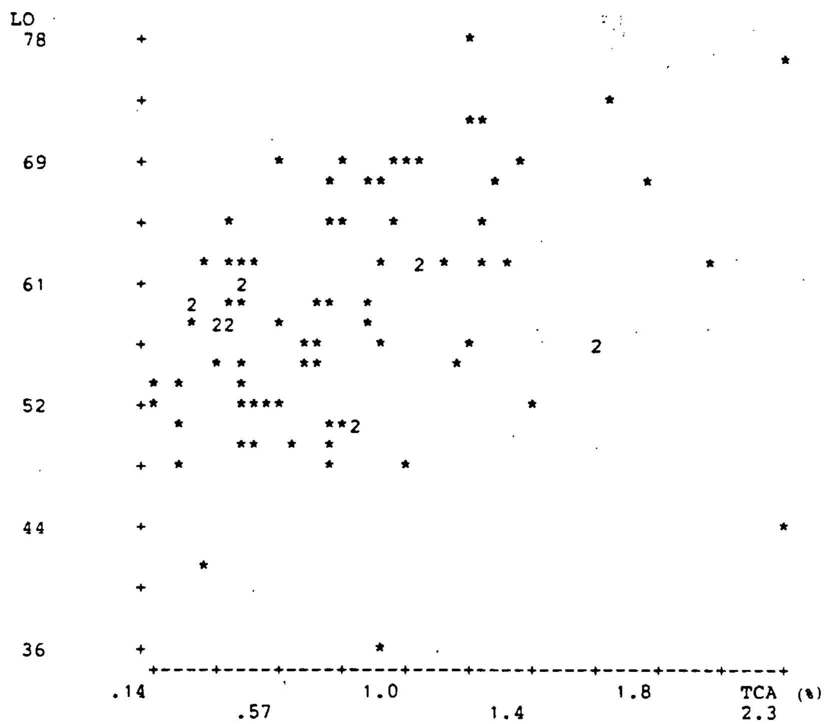


Figure 30. Scattergram showing relationship between LO and TCA using organic samples.

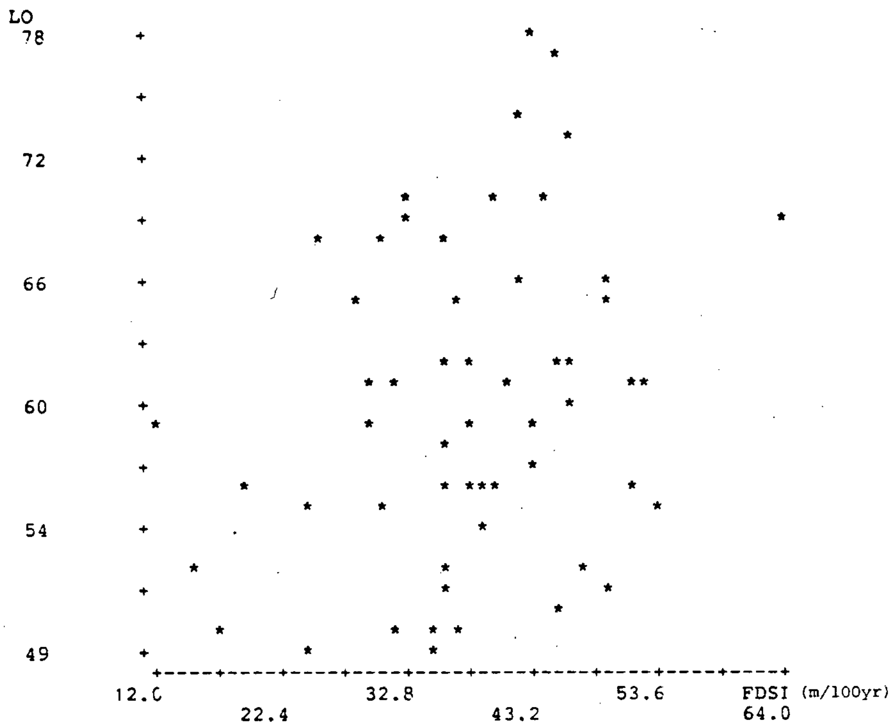


Figure 31. Scattergram showing relationship between LO and FDSI using organic samples.

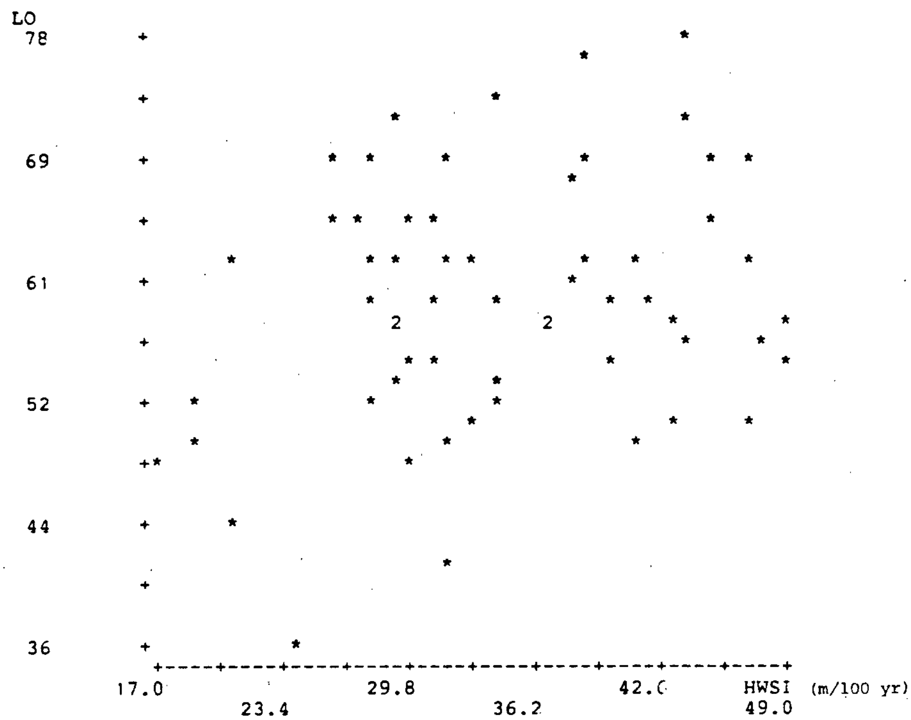


Figure 32. Scattergram showing relationship between LO and HWSI using organic samples.

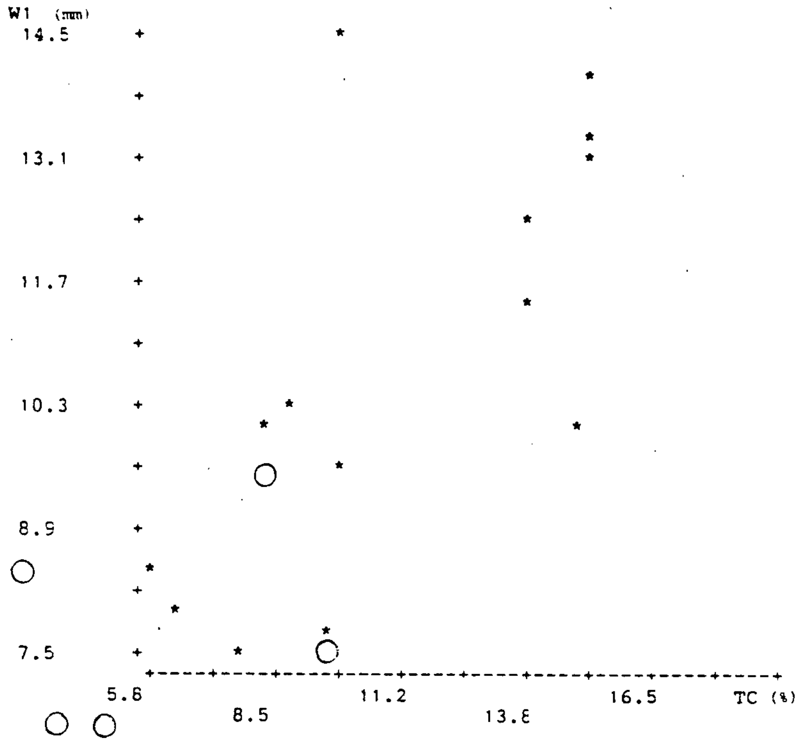


Figure 33. Scattergram showing relationship between W1 and TC using Ah samples.

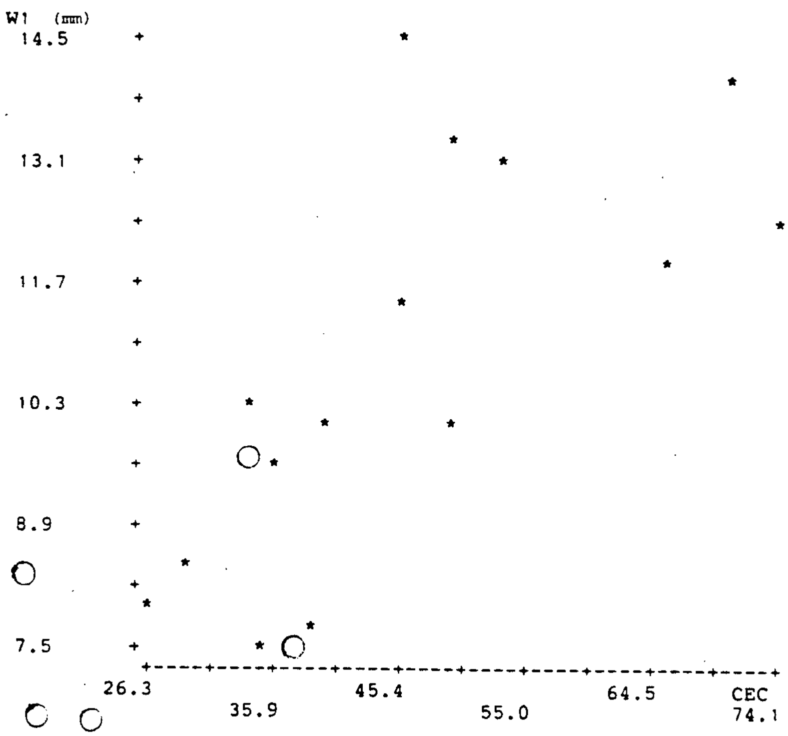


Figure 34. Scattergram showing relationship between W1 and CEC using Ah samples.

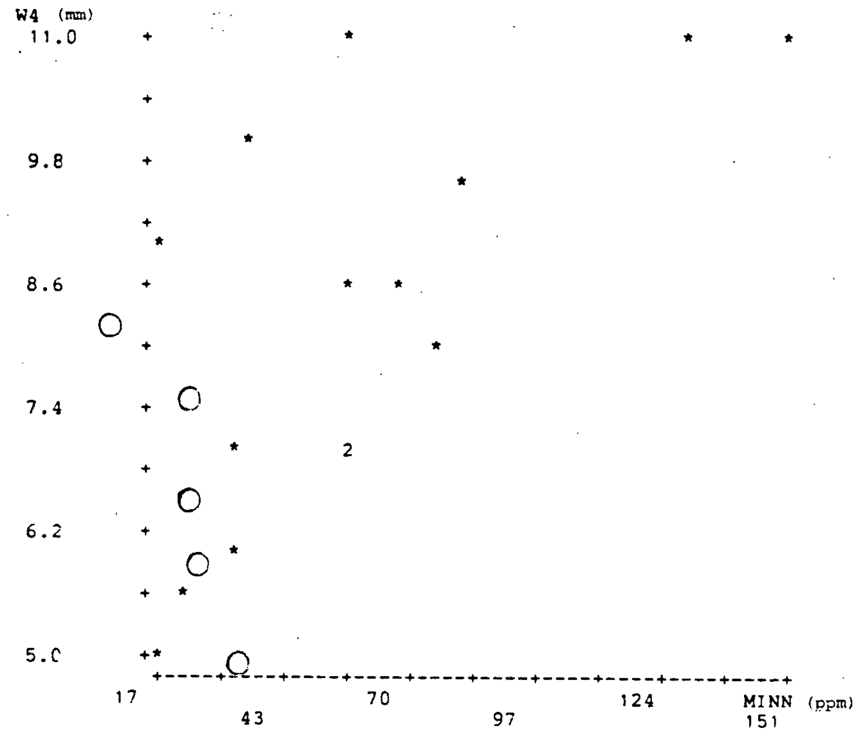


Figure 35. Scattergram showing relationship between W4 and MINN using Ah samples.

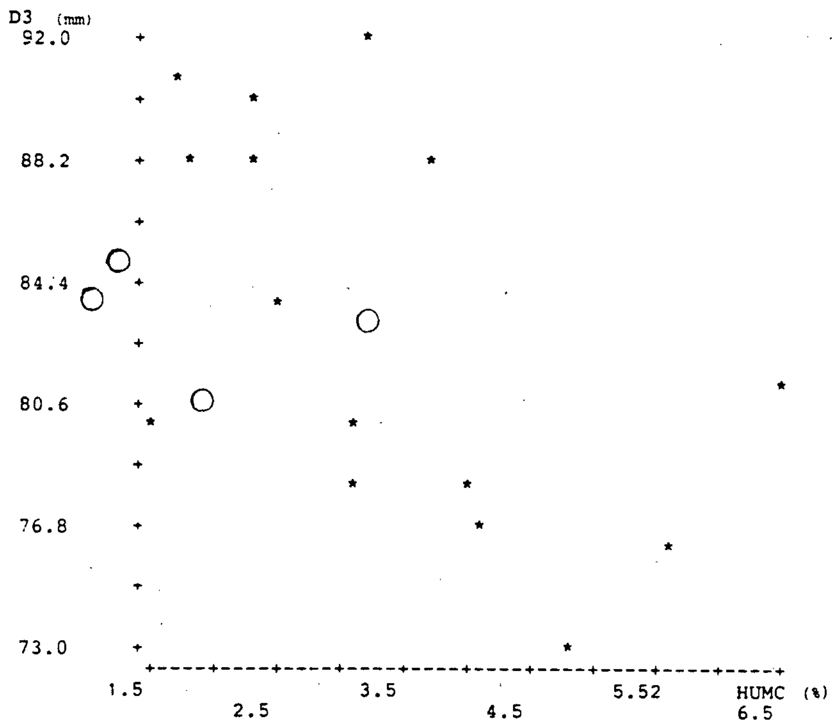


Figure 36. Scattergram showing relationship between D3 and HUMC using Ah samples.

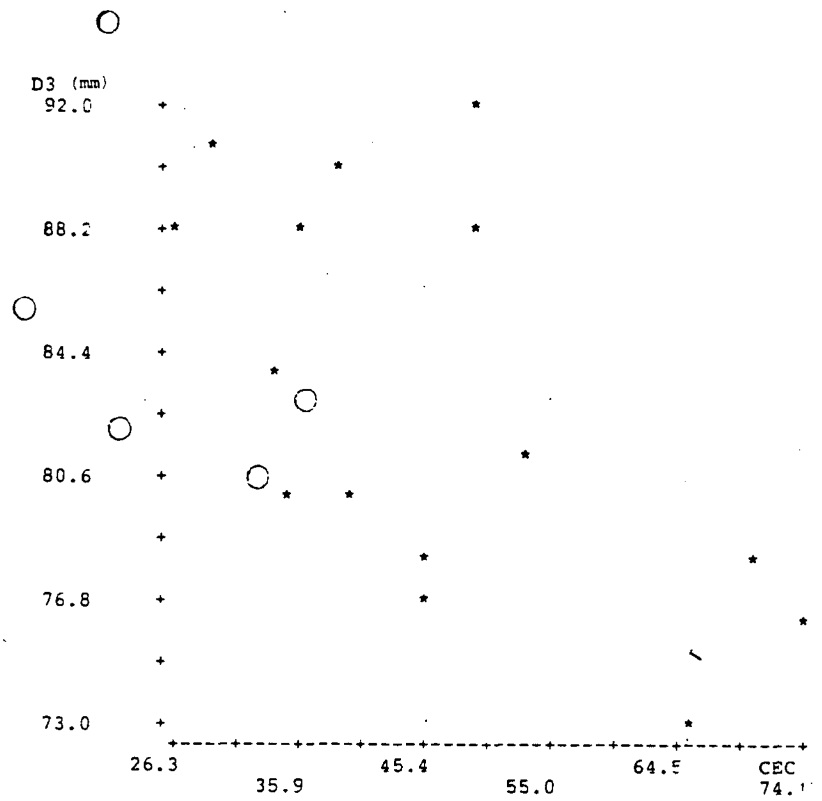


Figure 37. Scattergram showing relationship between D3 and CEC using Ah samples.

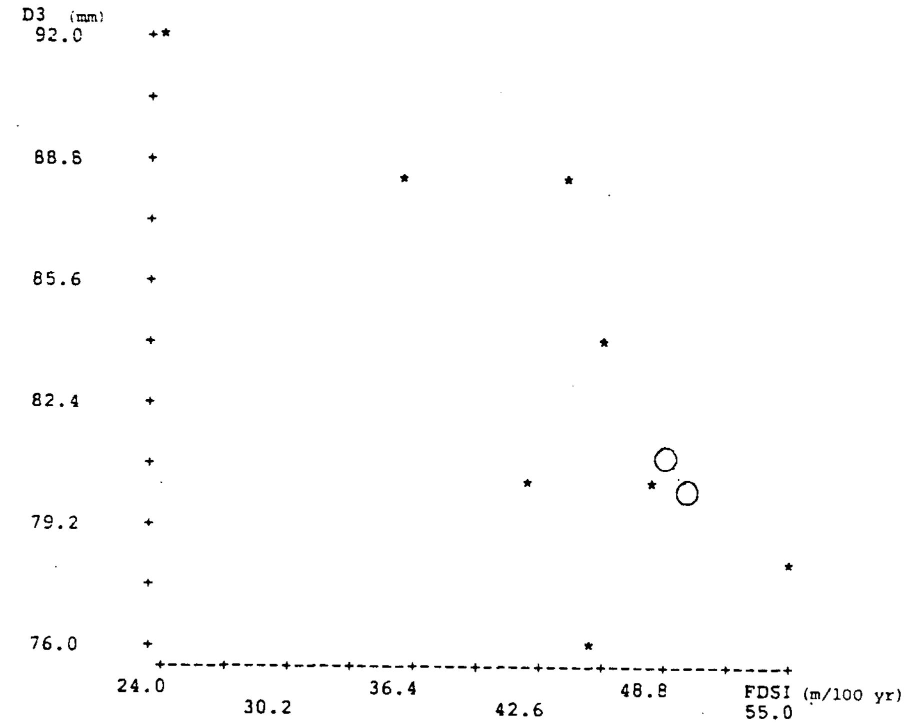


Figure 38. Scattergram showing relationship between D3 and FDSI using Ah samples.

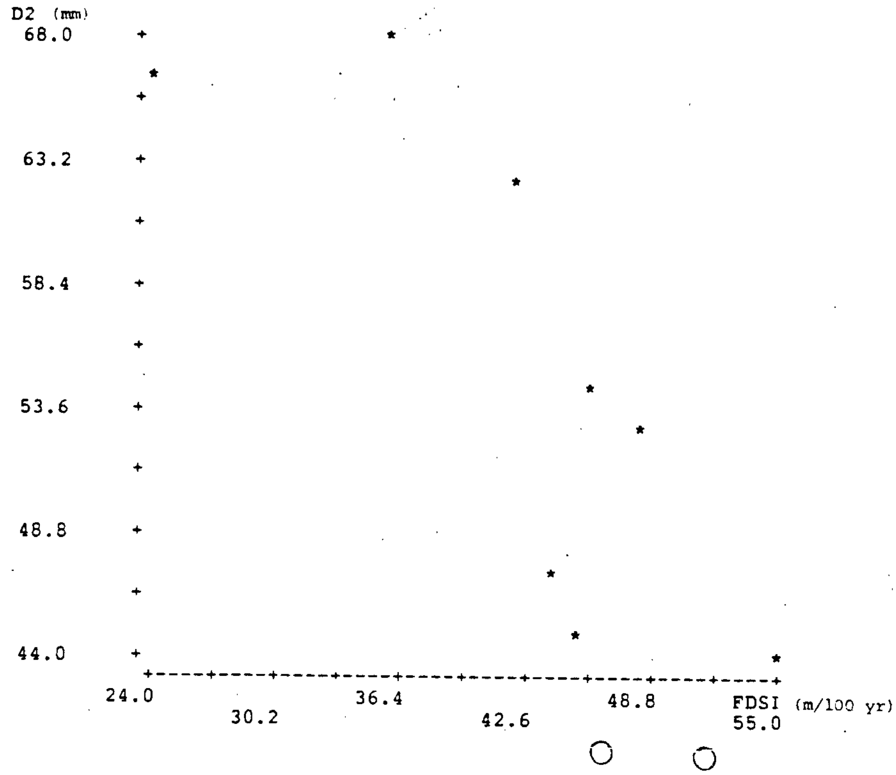


Figure 39. Scattergram showing relationship between D2 and FDSI using Ah samples.

DISCRIMINANT FUNCTION ANALYSIS

Jack-knifed stepwise discriminant function analysis (Dixon <u>et</u> <u>al</u>.,1981) was used to test the ability of measured chromatographic variables to separate humus samples into specified groups.

HUMUS FORM

Humus form	% correct	Mor	Moder	Mull
Mor	75.4	43	9	5
Moder	43.3	9	13	8
Mull	56.3	1	6	9

Approximately 2/3 of the samples were correctly classified using only W1. The poorest separation was with the transitional Moders.

It is interesting that the chromotographic approach though not particularly good, was only slightly poorer than a stepwise discriminant function analysis using only chemical variables and humus form taxa where 70% (Mor 79, Moder 44, Mull 70) were classified correctly. This indicates that the chromatographic approach could be used diagnostically in classifying humus forms.

DOMINANT TREE

When samples were stratified according to whether Douglas-fir or western hemlock were dominant in the plot the results were:

DTREE	%CORRRECT	Fd	Hw
Fd	75.6	34	11
Hw	81.8	4	18

Approximately 4/5 of the samples were correctly classified using only W1. This indicates that the major tree species exerts a large effect on the nature of the humus as reflected by chromatography.

Again, this result was only slightly poorer than when using chemical variables. These showed a 90% correct classification between Douglas -fir and hemlock. Of all relationships tested using chemical data the strongest relationship to humus was the dominant tree species. This can be expected because forested ecosystems are largely detrital and foliage provides the main source of litter. There were not enough plots with other tree species besides Douglas-fir and western hemlock to test the ability of chromatography to discriminate other humus types. In most plots with Douglas-fir or western hemlock dominant, other species were present. Considering this mixture, the results are quite encouraging.

NON-MEASURED OBSERVATIONS ON CHROMATOGRAMS

The above results were obtained by measuring a number of related features of the developed chromatogram. This provided a means to test if the chromatogram expressed significant relationships to chemical data obtained from the same sample. Colour, pattern, and irregularities that could not be quantified are discussed briefly below.

The colours and density of the various zones of the chromatogram are important indicators of the nature of humus. These features could not be quantified in a satisfactory manner. Use of Munsell colour chips was difficult because of variability within each zone and the use of elaborate instruments (densitometers) was rejected as being incompatible with the practical, simple potential of the chromatographic approach.

Figures 40 and 41 show darker browns associated with Mull humus forms and redder browns associated with Mor forms.

Hemlock as dominant on site is associated with redder colours, Douglas-fir with browner colours. Alder(Alnus rubra Bong.) dominance appears related to greenish colours in the middle zone (D2) eg. figure 42 A.

Saturated organic samples (Oh) characteristically showed darker colours throughout and deep irregular lobes (figure 42 B

to D).

There are a number of other features which experience indicates are important. Clean, well expressed zonation and forms are associated with "healthy" productive sites. Undifferentiated colours, dark grey inner zones, and irregularities are associated with "problem" conditions such as high watertables. Balance, strength and clarity are terms that are qualitative, and however subjective, are often appropriate.

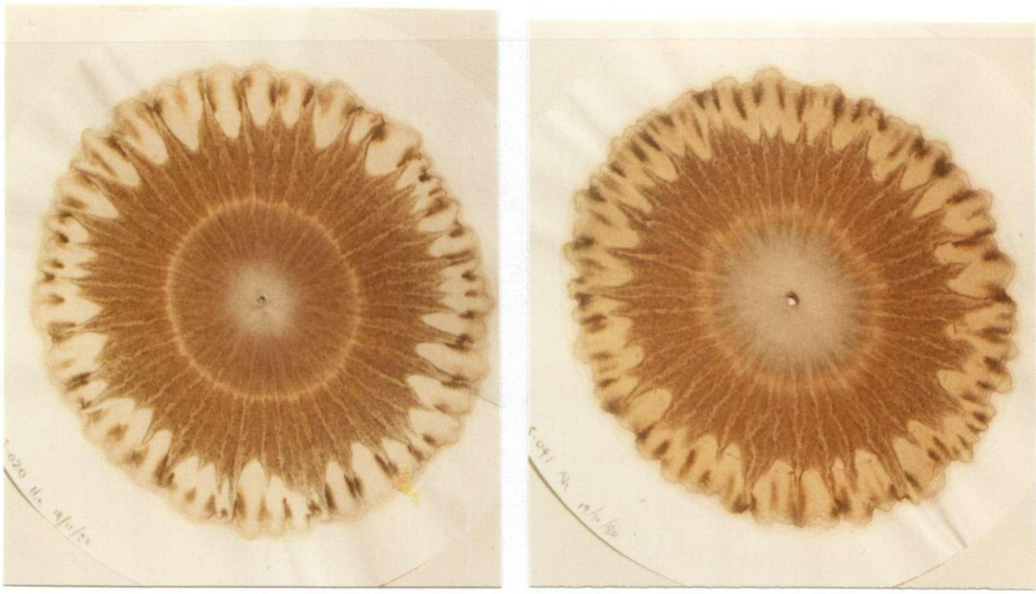


Figure 40. Chromatograms of Mull humus form samples and dark brown colours

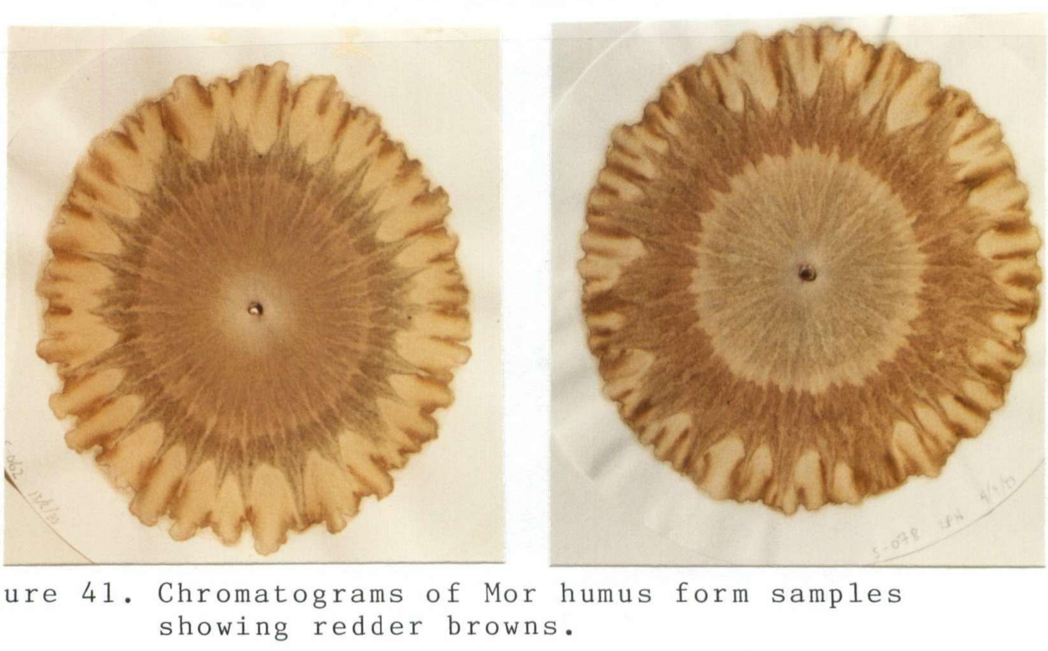


Figure 41. Chromatograms of Mor humus form samples showing redder browns.

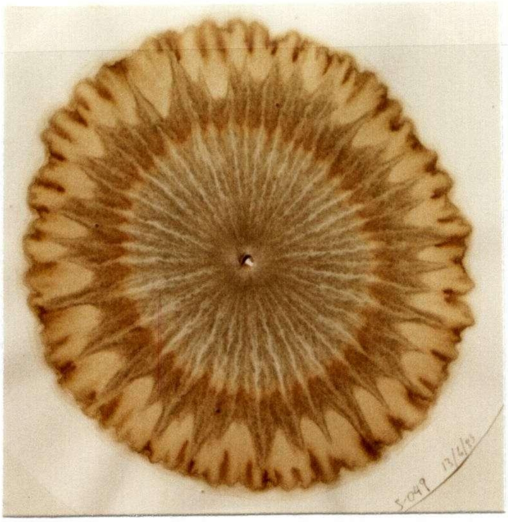


Figure 42 A

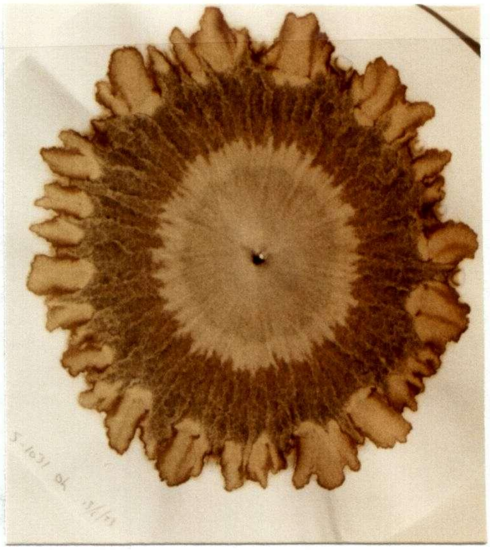


Figure 42 B

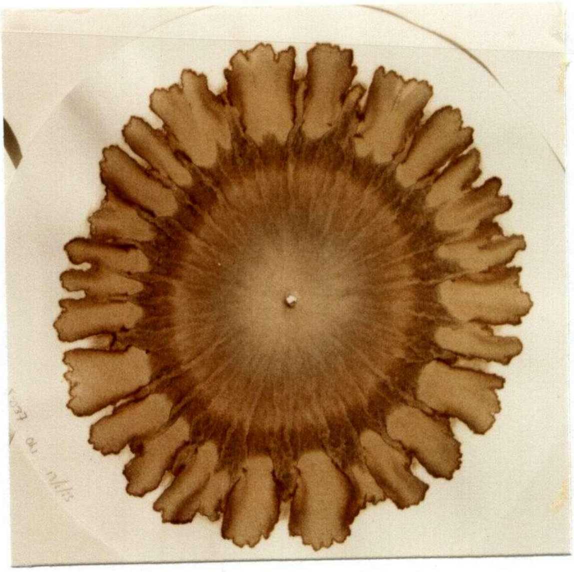


Figure 42 C

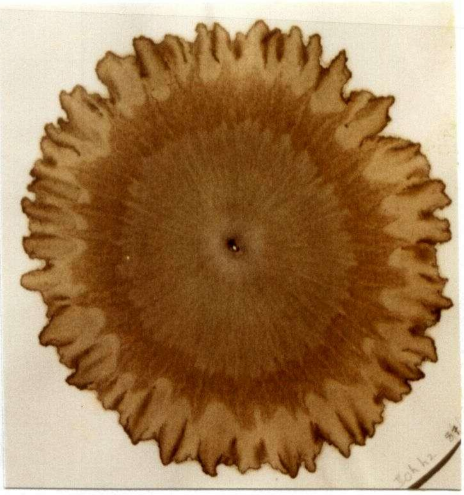


Figure 42 D

Figure 42. Example chromatograms showing colour and form characteristics.

TWO SELECTED PLOTS

Although separate LFH horizons were not chemically analyzed, a number of chromatograms were prepared of F and H samples. Two plots are shown in figures 43 and 44 , representing two different humus forms, climates, and dominant tree species present.

Figure 43 A shows a very thin Fa horizon. Fa horizons have a predominance of faunal activity (Klinka et al.,1981). Note the narrow brown outer zone (W4). This characteristic is associated with active Mull humus forms and Douglas-fir dominated sites. Compare this to figure 44 B, an Fq horizon (fungal activity predominates) with reddish outer zone of hemlock dominated site. Note larger inner zone (W1) in Fa (figure 43 A).

Note the large change from Fa to Ah in figure 43. Note the slow transition from Fq to Hr to Bhf. The overall "picture" of humus is very similar from horizon to horizon, except note the increase in W1 in Bhf.

Compare Ah chromatogram in figure 43 and LFH in figure 44. They show characteristic extremes of inner zone, D2 and W3.

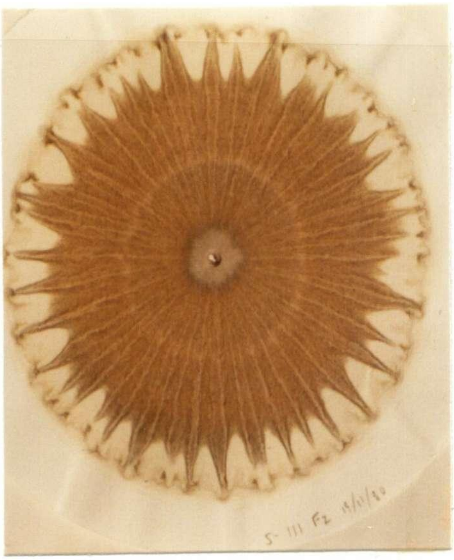


Figure 43 A

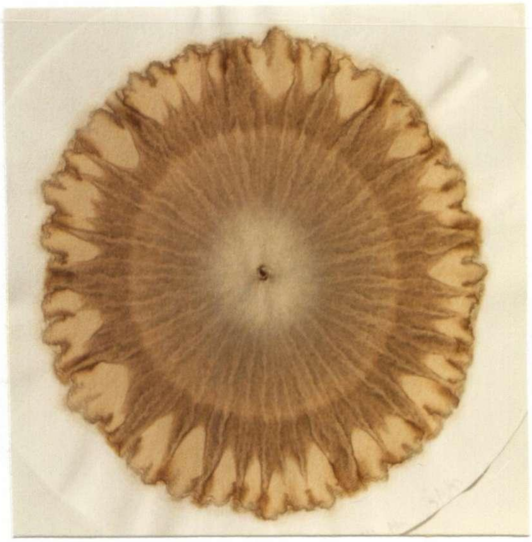


Figure 43 B

Figure 43. Chromatograms of two horizons sampled from a Douglas-fir stand. F horizon and Ah horizon from site on Quadra Island. Vermimull. FDSI 36 m./100yr.

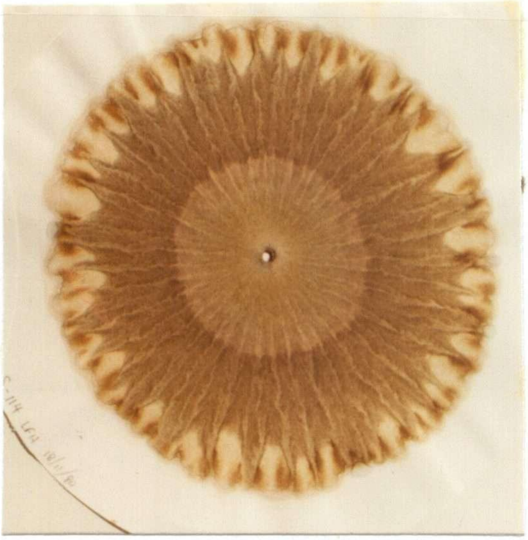


Figure 44 A LFH sample

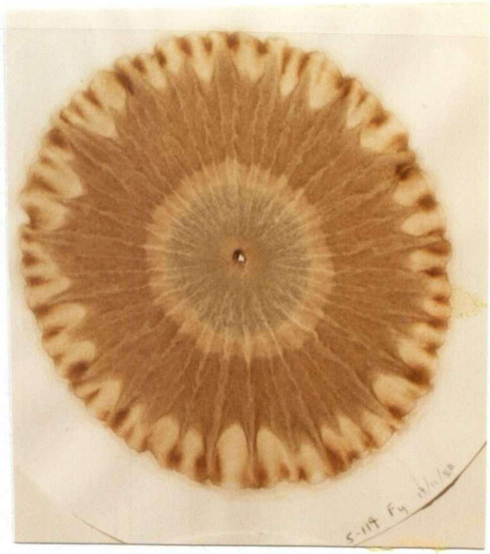


Figure 44 B Fq horizon

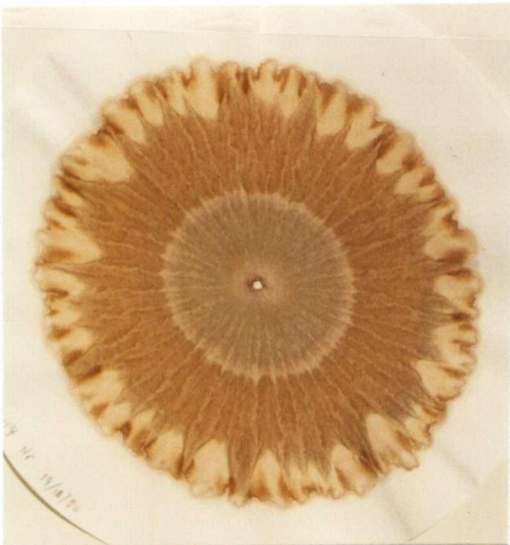


Figure 44 C Hr horizon

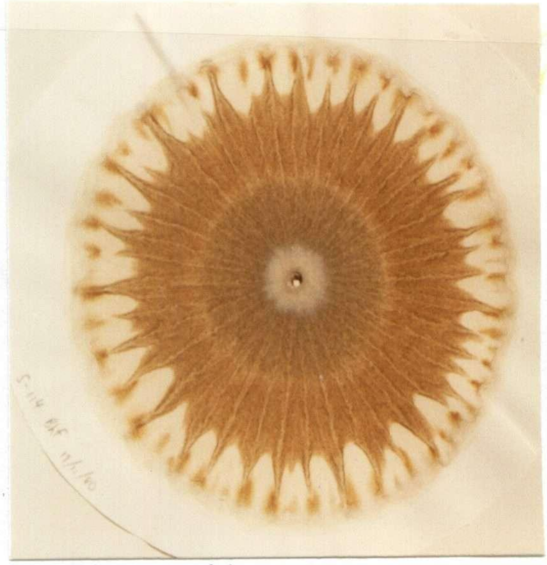


Figure 44 D Bhf horizon

Figure 44. Chromatograms of horizons sampled from a western hemlock stand. Humimor. HWSI 40m./100yr.

SYNTHESIS OF RESULTS

It is apparent that a number of features of chromatograms of humus samples from the Sayward Forest are related to chemical and site properties. None of the relationships can be used in isolation, nor is any considered to be a replacement for precise chemical analysis. Just how the chromatogram is "cause effect" related to humus chemistry has not been explored, though it is clearly necessary before other than corroberative or diagnostic use is made of the method. This is discussed in summary and conclusions.

It is also apparent that humus processes are a continuum and no single factor or single classification will provide a neat separation.

In spite of the above, the results can be summarized as follows:

Table 5 Summary of relationships between chromatographic variables and site and humus sample chemical variables from Sayward Forest study, for organic samples.

"NETWORK OF INFERENCES"

(As chromatographic variables change as shown by arrows in center column, features on the left or right can be inferred. For example, a smaller W1 indicates Mor humus forms with higher TC, lower pH, higher CEC, higher CN and LIPIDA, cooler conditions, poorer productivity.)

	INFERENCE	CHANGE	INFERENCE
Humus form	Mor-less active	↓ W1 ↑	Mull - more active
	Low pH,High TC,		higher pH, low TC,low EXK,
Chemistry	High EXK,high CEC	↓ D2 ↑	lowCEC, low C/n, lower
			lipid
	high HUMC CF1		high EXMg, ExCa, higher TN,
		↓ D3 ↑	higher TNa, TFe, TP, HUMN,
		↓ LO ↑	
	high C/N, low EXMG		TMN,TCA
	high lipid	↓ SP ↑	
Climate	cooler, wetter		dryer, warmer
		↑ W2 ↓	
Elevation	higher		lower
Tree species	Hemlock		Douglas-fir
		↑ W3 ↓	
Hygrotope	dryer		wetter
Trophotope	poorer		richer
		↑ W4 ↓	
Colour	redder		browner
Productivity	poorer		better

It is encouraging that for all eight chromatographic variables, the change of chemical and site variables "fits" accepted relationships of climate, organic matter, humus form, pH, some exchangeable and total cations, and productivity. These results support the diagnostic consistency of the chromatographic method. The precision of the method is another question. Certainly, little quantitative information could be gained without considerably more testing.

Among the Ah samples there is a change in relationships. When the mineral portion of soil predominates,. W1 is larger with increased TC, CEC and HUMC. W2 also shows a reversal of trends - CEC increases as W2 decreases. Productivity relationships of Douglas-fir follow trends of CEC and D3, that is, increase with CEC as one would expect. D2 also shows a reversed relationship with FDSI. Sample size is much lower in Ah relationships (varying from 10 to 20), however the results indicate that Ah (endorganic humus forms) are significantly different from organic humus forms.

MANAGEMENT APPLICATIONS

A question which should be asked more often in forest management is what site changes will be brought about by a certain management activity? It is possible to shift processes to a more active , or a less active state. Long term effects on site productivity need to be considered.

The chromatographic approach is considered useful in indicating directions of change and providing qualitative interpretations about humus conditions.

One goal is to enhance productivity of the site. This requires holding the system in a slightly "adolescent" stage, balanced between inputs of new humus and oxidation / utilization of the old. Once again, organic agricultural management shows that a balanced system is more conservative of energy than one which reduces organic matter and supplies nutrients in a readily available form through inorganic fertilizing. Clearly many silvicultural practises pose problems. Silen (1982) explores some features of maximum yield strategies for Douglas-fir and questions the use of fertilizers and weed control. Feller (1982) explores the effects of slash burning on site ecology. There is a need to understand the effects of such planned or inadvertent practises such as leaving large quantities of woody material on a site, whole tree harvesting, clear-cutting, slash burning and tree species selection.

The examples which follow demonstrate the potential for monitoring humus changes with different management practises. Figure 45 A shows a chromatogram of LFH sample from an old growth hemlock and balsam(<u>Abies amabilis</u>(Dougl.)Forb.) stand, with a Mor humus form. Figure 45 B is from an immediately adjacent felled and bucked site only four to six months after falling. An increase in W1, decrease in W4 and a reduction in

colour intensity indicate more active cycling with inferred decreases in total carbon and CN ratio, in short a shift towards a Moder humus form.

Figure 45 C shows another natural stand - Douglas-fir . Compare with figure 45 A above and note the characteristic "Douglas-fir" brown rather than red of the outer zone in figure 45 A, larger D1, D2, D3 ,slightly smaller W4, and increases in Lobes and Spikes. All these changes fit the summary (table 5). Figure 45 C is a classic Mormoder. Figure 45 D is an immediately adjacent clearcut which was lightly burned. Slight increases in W1 and decreases in W4 and a shift to a lighter brown indicate a reduction in total carbon, and a slight shift towards a Mull humus form. The pale colours and poor definition indicate a reduction in diversity of compounds. It would be interesting to follow this site as it recovers.

Figure 45 A Natural old growth HwBa Stand

Figure 45 B Adjacent area 4 months after clearcutting

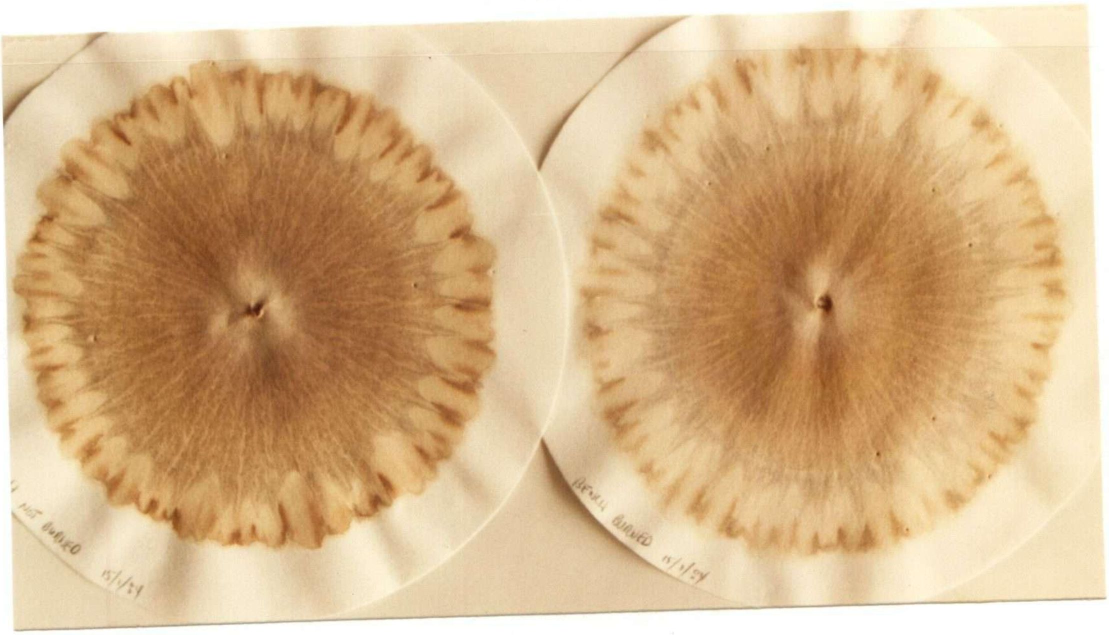


Figure 45 C Douglas-fir stand humus sample

Figure 45 D Adjacent area Cut and light burn

Figure 45 Chromatograms of humus (LFH) sampled from control and treated sites.

Figure 46 A,B,and C are chromatograms from three stands which were intensively sampled for a volume study (Research section, Min. of Forests). They are all adjacent unmanaged second growth stands on similar parent materials. They are of interest because of the intensiveness of the study (25 composited samples of humus (LFH)), accurate productivity data and chemical analysis of humic substances. Table 6 shows variables from chromatograms and chemical data for the three samples.

Table 6. Chromatographic and chemical variables of humus samples from >80% Douglas-fir, mixed, and >80% western hemlock stands.

Stand	Chromatographic variables (units in mm except for LO and SP)								Chemical variables			
	D2	D3	Lo	Sp	W1	W2	W3	W4	Lipid%	HUMC%	Cf1%	CH/CF
Fd	58	80	67	37	9	20	11	9.5	3.14	5.98	3.79	1.58
F&H	54	78	61	38	7	20	12	10.5	4.42	8.37	4.14	2.00
Hw	58	78	52	35	8	21	10	13.0	3.64	7.39	4.19	1.76

(chemical data from Min. of Forests, unpub. data ,Vancouver Research Section)

Figure 46 A and C show characteristic colours of Douglas-fir and hemlock respectively. The mixed stand (figure 46 B) is intermediate. Again, the differences in lobes, spikes and W4 are consistent with correlations from Sayward Forest Study (Table 4-2). The higher lipid content of the mixed stand corresponds with the lowest W1. Two variables, W1 and D2 indicate a slightly poorer productivity for the mixed stand. Site indexes(m. 100 yr)

for the three stands are: Douglas-fir (FdSI 45) ; mixed (FdSI 41, HwSI 42);and hemlock (HwSI 41),(pers. comm. Shishkov, 1984). A paler, less distinct expression in the mixed stand chromatogram also indicates a less dynamic site.

Figure 47 A and B are chromatograms of humus samples from sites where salal is dominant and exclusive in the shrub layer. Table 7 below shows chromatographic and chemical variables for these sites.

Table 7 Chromatographic and chemical variables of humus samples from two "salal" humus sites.

Site	D2	D3	LO	SP	W1	W2	W3	W4	LIPID%	HUMC%	CF1%	CHCF
	(units in mm except for LO and SP)											
SPM	66	80	53	35	6.5	27	7	11	4.50	5.87	3.95	1.4
SNW	64	82	51	36	9.0	23	9	9.5	4.46	5.32	3.78	1.4

(Chemical data from Min. of Forests, unpub. data, Vancouver Research Section)

Both sites show similar results for chemical variables, though the chromatographic variables change with the chemical variables in the same way as demonstrated in the Sayward Forest Study: W1 decreases and W4 increases with increases in HUMC and CF1. But the two chromatograms are quite different. Figure 47 A indicates a "hemlock-type" humus. Figure 47 B indicates a "Douglas-fir-type" humus though has a particularly dark gray inner zone. Dark gray inner zones are often associated with poor growth of Douglas-fir on dry sites, or with sitka spruce(Picea sitchensis(Bong.)Carr.) sites. It is interesting that this similarity occurs in humus from such dissimilar sites. The figure

47 A site is in fact a wet cedar and hemlock site that was logged, burned and planted to sitka spruce 15 years ago. The site brushed in with salal and the spruce has stagnated. The low number of lobes infer poor productivity of Douglas-fir and hemlock (figure 31 and 32), low TCA and high CN. The small W1 also indicates low activity. The figure 47 B site has a 15 year old Douglas-fir stand with minor components of hemlock, red cedar and white pine(Pinus monticola Dougl.) It has a mesic moisture regime and Moder humus form. The relatively small dark gray W1 and low number of lobes indicate poor productivity. This is unusual for a moder humus form. The salal may be contributing to a poorer, less dynamic humus than would be expected.

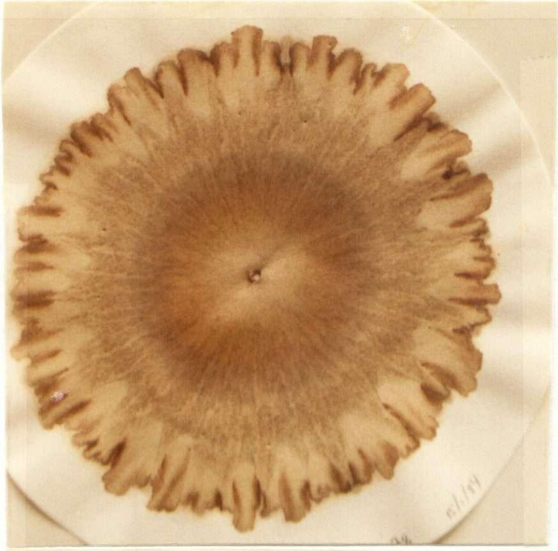


Figure 46 A >80% Douglas-fir

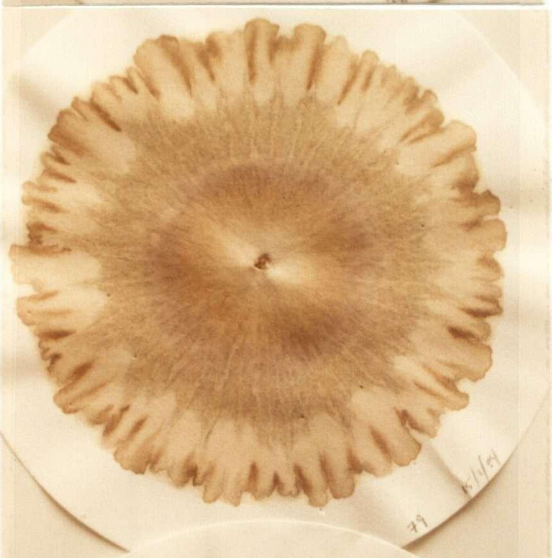


Figure 46 B Mixed hemlock and Douglas-fir

Figure 46 C >80% hemlock

Figure 46 Chromatograms of humus (LFH) sampled from three stands that differ in species composition.

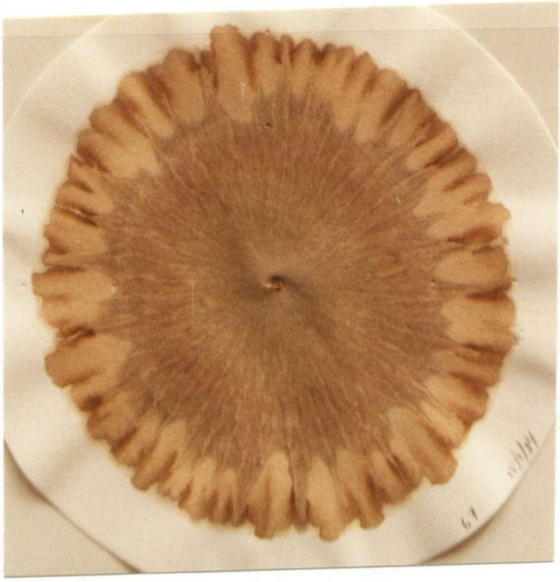


Figure 47 A "Salal humus"   SPM Site

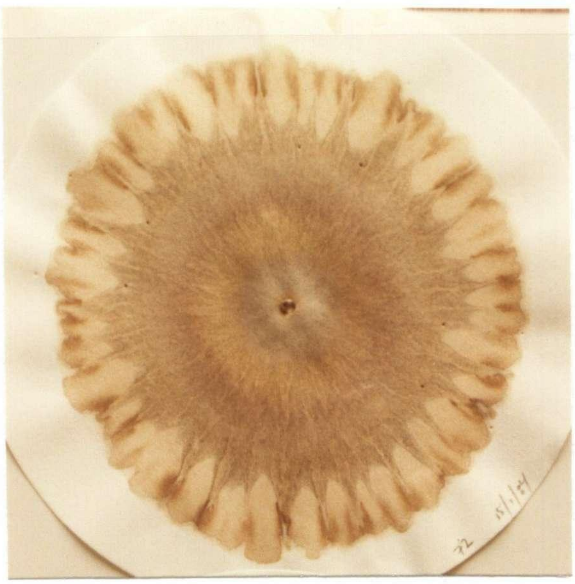


Figure 47 B "Salal humus" SNW Site

Figure 47. Chromatograms of humus (LFH) sampled from two sites where salal is dominant in the shrub layer.

LIMITATIONS OF THE APPROACH AND FURTHER STUDIES

A major limitation is the lack of direct association of the chromatogram and chemical substances in the humus extract. While it appears that fulvic acids, generally more highly coloured radiate to the periphery, it also appears that humic acid fractions also move to the outer zone. Simple tests done with extracts separated into fulvic and humic fractions by acidification are generally inconclusive. Figure 48 shows one example where a fulvic acid fraction yields a chromataogram with darker central zones, and the humic fraction with more defined outer zones. However the chemistry of the chromatographic process cannot be expected to be the same, and the most reasonable method for examining the zones would be as follows: prepare a large number of chromatograms using standard method; cut out the zones and re-extract with .25 N NaOH ; analyze each extract using fractionation techniques and standard chemical analyses. This would establish a "fate map" showing where the classic humus fractions move to on the chromatogram.

While this analysis is seen as a necessary next step, the intent in this thesis was to evaluate the chromatogram as a useful "reflector" of humus conditions for the land manager.

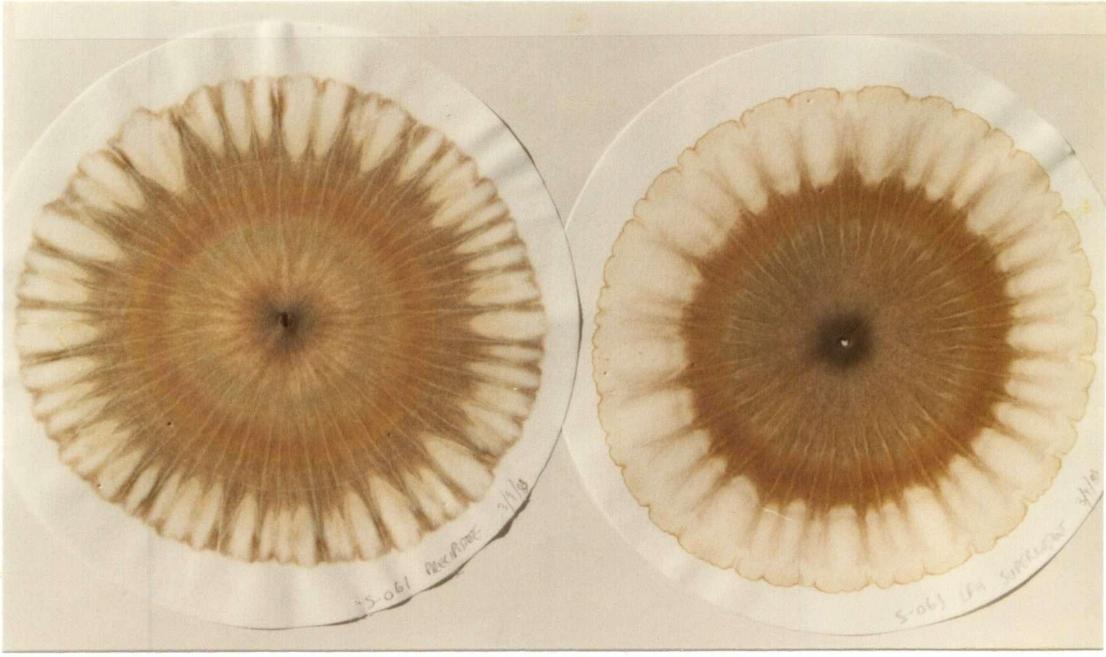


Figure 48 A Humic acid fraction.

Figure 48 B Fulvic acid fraction

Figure 48. Example of chromatograms of separated fractions.

Another significant limitation is the problem of variability of the chemistry of humus. Quesnel (1980) and Carter (1983) have examined this problem in coastal B.C. The Sayward humus data was based on a "modal" pit as representative of a site. This is a shortcoming which weakens the relationships between chemical characteristics of the sample and attributes of the site (i.e. site indices, trophotope, humus form, etc). It does not affect the relationships between the chromatogram and humus chemistry (these were done on the same sample). The relationships between the chromatogram and site attributes, however, are affected. While it is clear that one sample cannot adequately represent a site, given enough samples and sites a good deal of variability must be included. Compositing 5 to 10 samples (as was done for examples in management applications) would have been much preferable.

Productivity relationships are generally weak. This is expected because of the dominant influence of tree species in determining the nature of the humus. It is notable that among the Ah population there is a greater proportion of correlations with productivity than among the organic sample population. In spite of the small number of Ah samples, this suggests that more attention should be given to humic substances in mineral horizons for clues to productivity. Carter (1983) found that chemical properties of humus forms did not show practical significance in assessing Douglas-fir productivity.

Linear regression analysis (MIDAS,stepwise,forward)(Fox and Guire,1976) yeilded only one significant relationship. Using Ah samples, FDSI and D2 had an R squared of .62. Although the sample size is small (n=8) this result is promising. It may have predictive value in site diagnosis.

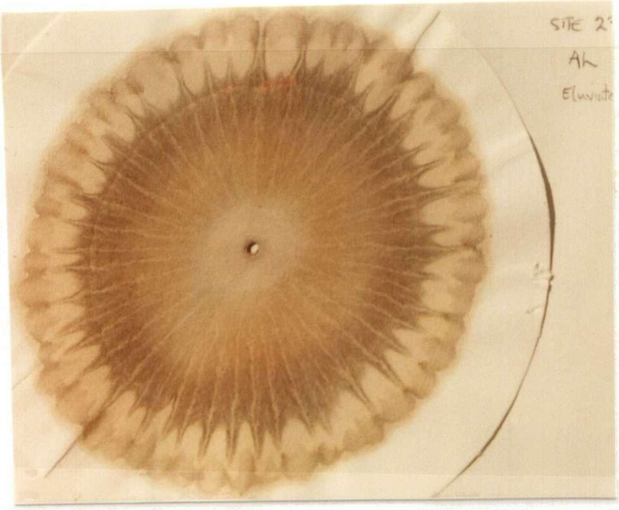
B horizons have not been included in the concept of humus form. In forested ecosystems there is a need to look carefully at the qualities of humic substances in B horizons. Using the analogy in the introduction, in forest ecosystems ectorganic humus can be seen as the "compost" and the upper mineral soil as the "garden". It appears to be of practical importance to examine chromatographically how the products of decomposition enter into association with mineral soil.

It is unfortunate this thesis did not examine B horizons to any extent however some observations can be made. For example, Lowe (1980) demonstrated differences in humus fractions that were related to horizon type. Humic carbon/fulvic carbon ratios were consistently highest in Ah horizons and declined through various B horizon to the lowest in Humoferric Podzols. Figure 49 shows chromatograms of a number of mineral horizons arranged in the order of expected changes in CHCF from top to bottom. The most obvious visual change in the sequence is the shift from brown to red in the outer zone and a general decline in D1 and D3.

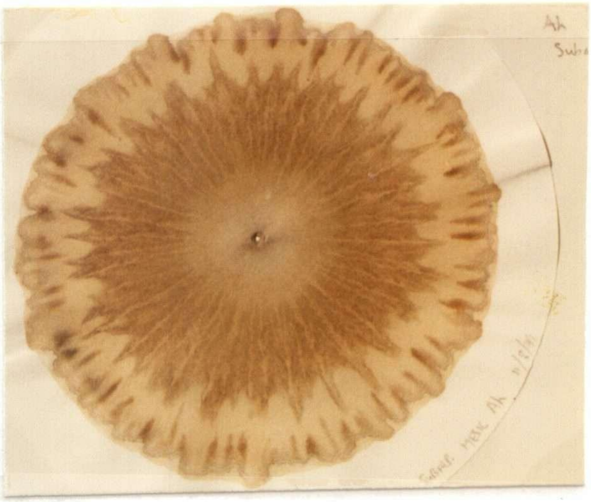
Correlations of Ah sample CHCF with chromatographic variables showed no significant relationships. Perhaps if the sample was

adjusted for organic matter content relationships would be apparent.

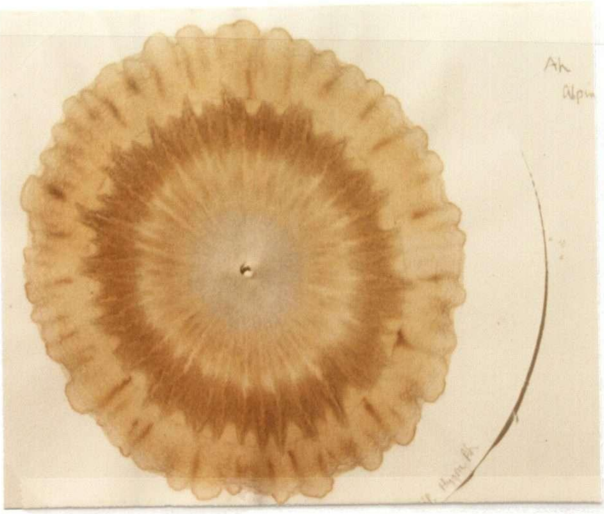
It is suggested that chromatography in relation to humus fractions is worth persuing in B horizons. With a better understanding of what chemical substances the zones represent, chromatography may provide a simple means of examining humus formation in relation to humic and fulvic acid fractions.



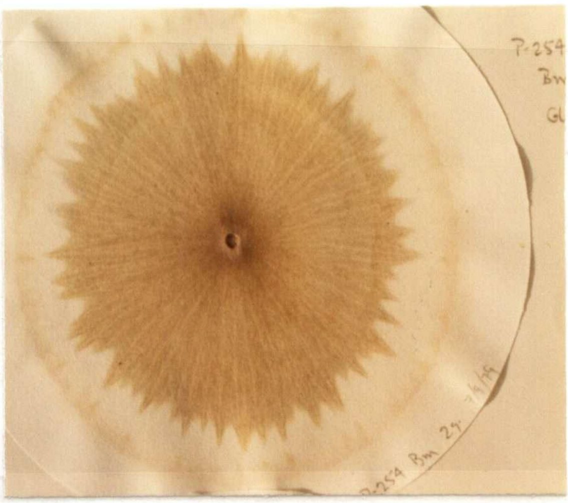
Ah Chernozem



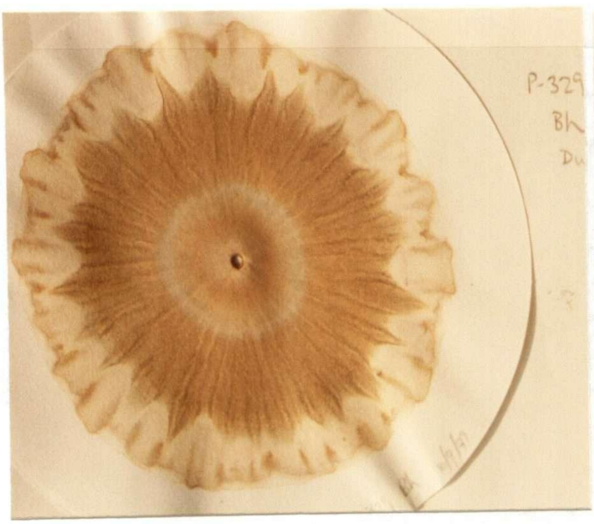
Ah Subalpine Brunisol



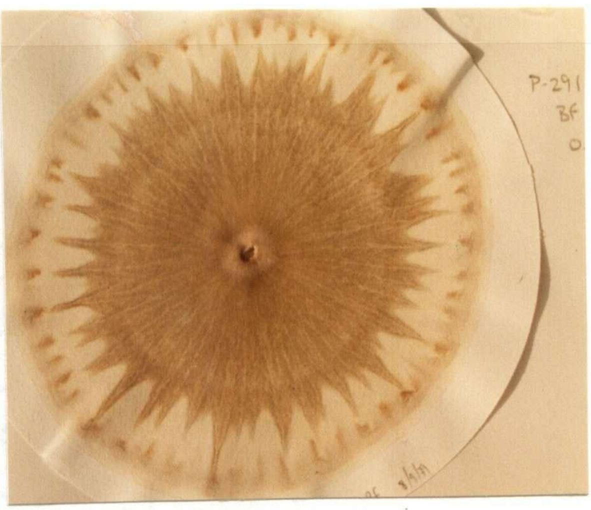
Ah Alpine Brunisol



Bm Luvisol



Bh Podzol



Bf Podzol

Figure 49. Chromatograms of selected mineral soil horizons.

SUMMARY AND CONCLUSIONS

Humus management has been neglected in British Columbia forests. In spite of many years of research into the nature and composition of humus, the results are complex and often contradictory. Little of practical significance has been acheived to aid the land manager in assessing the quality of humus and how management activities affect it.

This study has explored in stages a chromatographic method of investigating humus at various levels of interpretation. At the level of chemical properties of the sample, the chromatogram allows inferences to be made about such properties as pH, CEC, percent organic carbon, some exchangeable and total cations and something regarding the fulvic and humic acid fractions. At the level of humus form or humus type, the chromatogram appears diagnostic for classification of humus form taxa. At the site level, it appears to discriminate between humus formed from differing tree species and under different moisture and nutrient conditions. With further testing, the method may provide sound indications of productivity. At the ecosystem level, the chromatogram reflects more general factors of climate and vegetation. It does so by showing a "fingerprint" of the particular humus component that has formed in the set of conditions and processes that are active in the particular site.

Understanding process is perhaps the most important point. The chromatogram presents an expression of humus/soil

relationships. It does so in a way that is perhaps more natural, less removed from the actual site than many chemical analyses which are often contradictory and difficult to interpret. As such the approach is seen as a bridge between the on-site observations and quantitative chemical analysis.

By using a standard sample, a synthesis of many attributes of humus is portrayed as a diagnostic picture. With the Sayward Forest samples, the elements of the picture are correlated with a range of chemical and site properties. Relationships to humus fractions are evident, however it is suggested that further work take into account extractability of humus and the total carbon content of the sample, so that similar quantities of humus fractions are used with each chromatogram. The Sayward Forest samples are predominantly podzolic soils with a low range in pH. For other areas, a better understanding of the chromatographic process is necessary and specific analysis of the zones is essential.

The primary emphasis in this thesis has been to assess the potential usefulness of this simple approach as an aid to the land manager in making decisions about treatments and effects on long term site quality. This study demonstrates the significant diagnostic value of the approach.

In spite of not knowing the chemical phenomena occuring in the chromatogram, the approach can be used pragmatically. The inferences developed in this thesis regarding the measured

variables D2 to W4 are demonstrated by correlations and scattergrams. There are many other observations which cannot be reasonably measured and which require experience in "reading". While this may be considered a drawback by some, it is suggested that such activity (comparing and questioning why different sites have different expressions of humus) will lead to more rigorous examination of humus processes, which ultimately will contribute to better management of forested ecosystems.

It is possible to conclude that chromatography provides a consistent reflection, based on correlations with chemical and site properties, of the qualitative nature of humus. Chromatographic variables change most with a change in dominant tree species, and to a lesser, though significant degree with humus form, climate, site productivity and moisture regime. This conclusion provides the basis for using the method as a diagnostic tool for studying humus and assessing changes brought about by forest management. Because of the simplicity of equipment and method, it can be used in unsophisticated surroundings, without large capital investments. The method also provides some support for the classification of humus forms and may be of use in separating Fa and Fq horizons which are significant at the order level. These horizons represent the effects of different soil biota and the chromatogram can be seen as an interesting indicator of biological activities. For example, the effects of earthworm populations are evident in the structure of Ah horizons. Earthworm Ah's (vermimulls) have

distinctive chromatograms. Monitoring inoculations, and exploring the association of soil biota with various plant species would be possible with the chromatographic approach. Until further work is done the method can only be considered qualitative. However on a personal note, it does provide a very satisfying, holistic view on what is certainly a key in plant-soil interactions: humus.

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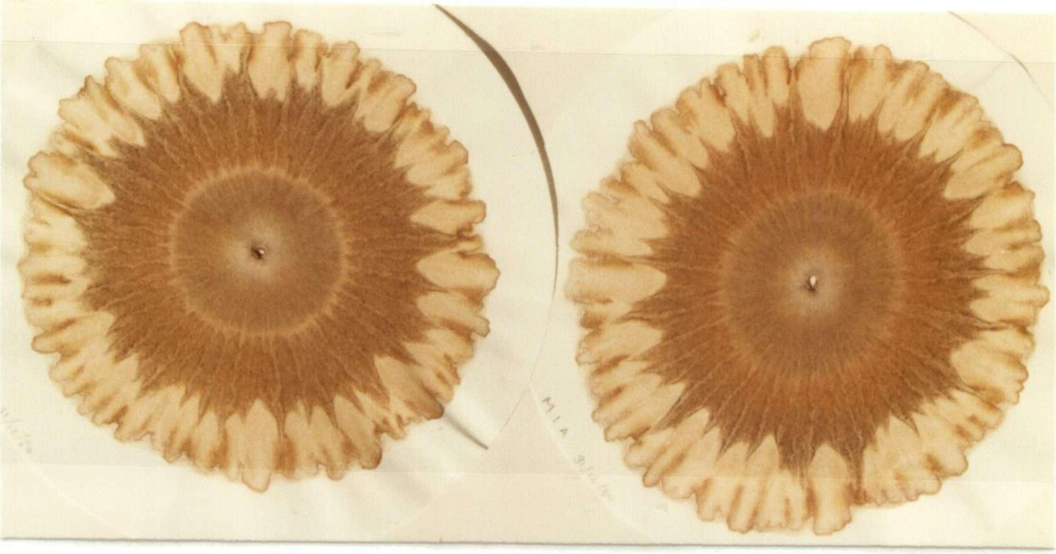
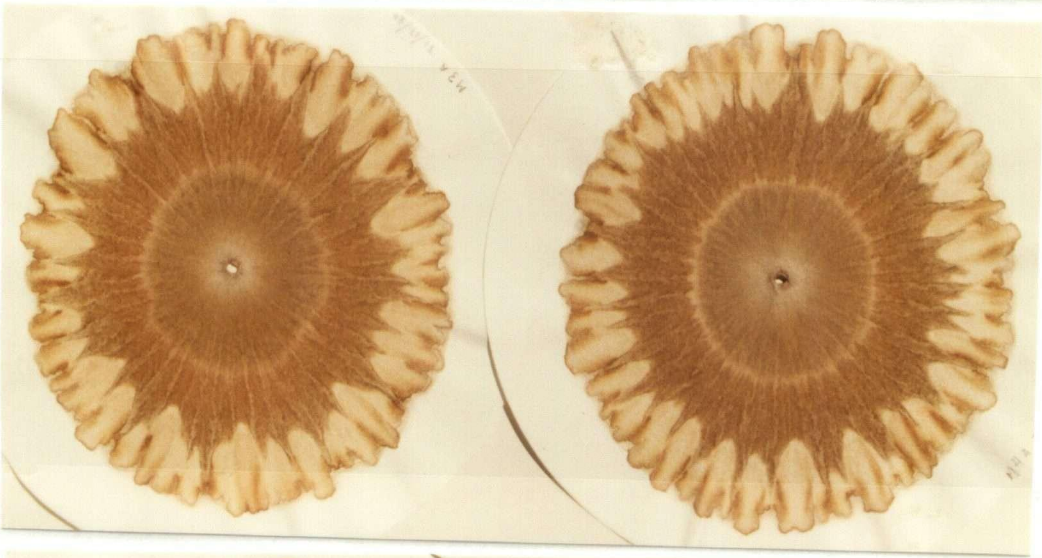
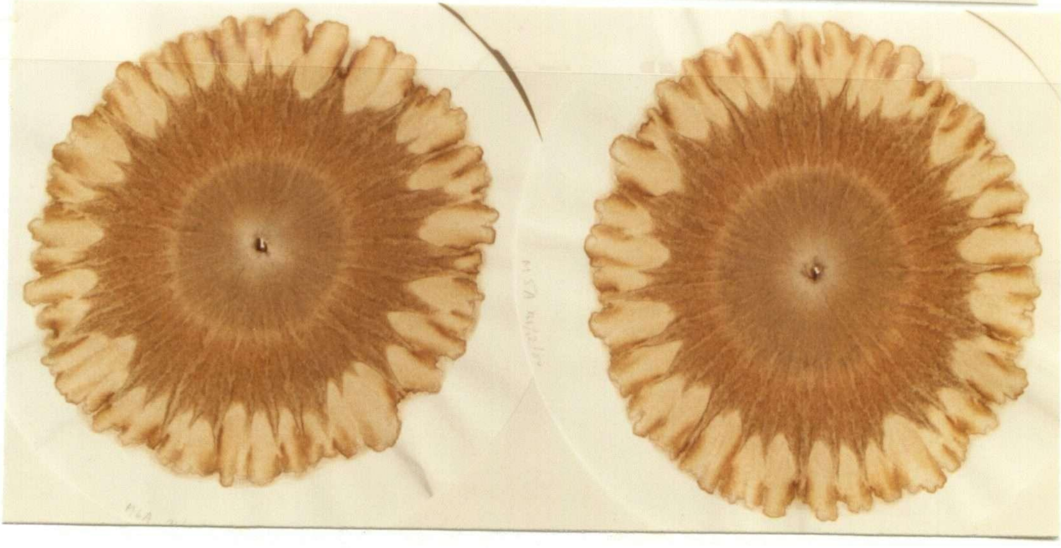
APPENDIX I CHROMATOGRAMS OF REPLICATED HUMUS SAMPLES FROM UBC RESEARCH FOREST

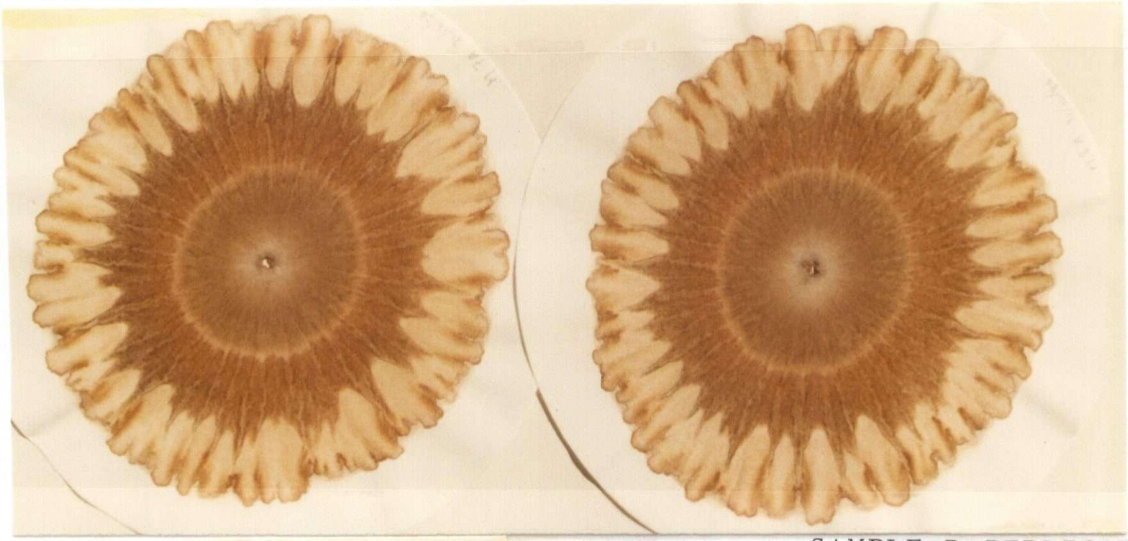
SAMPLE A

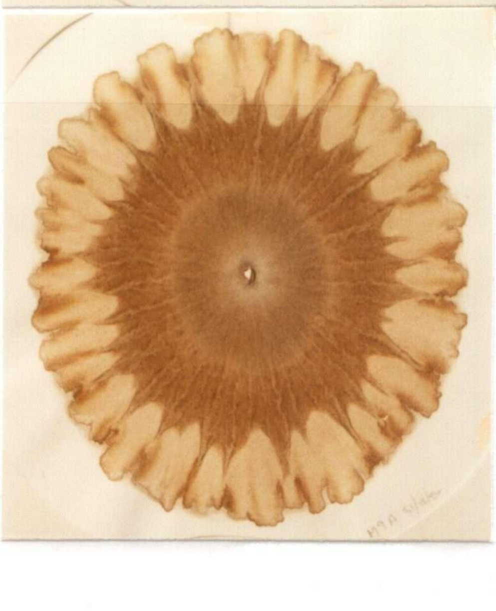




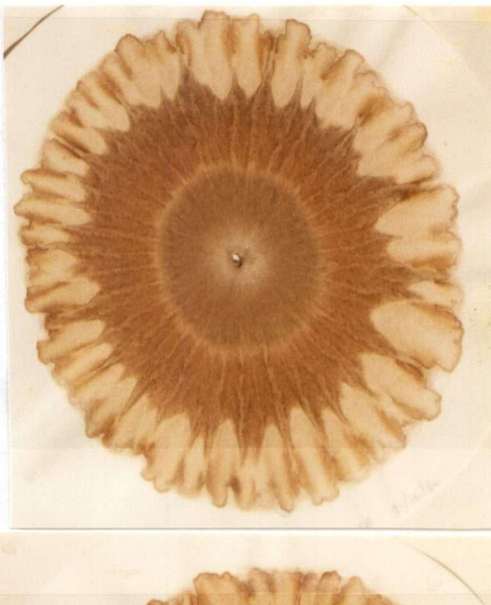


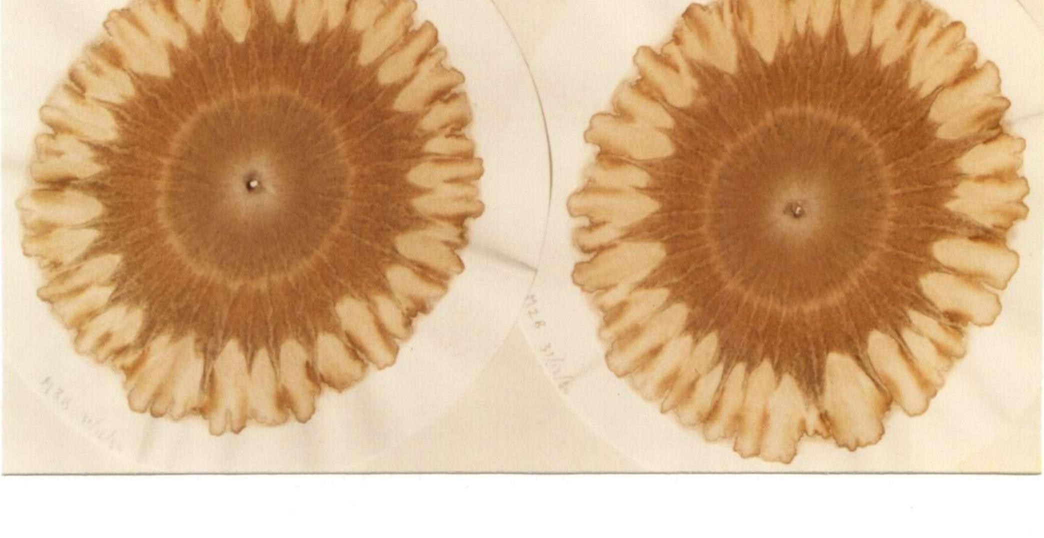
REPLICATES OF SAMPLE A CONTINUED.



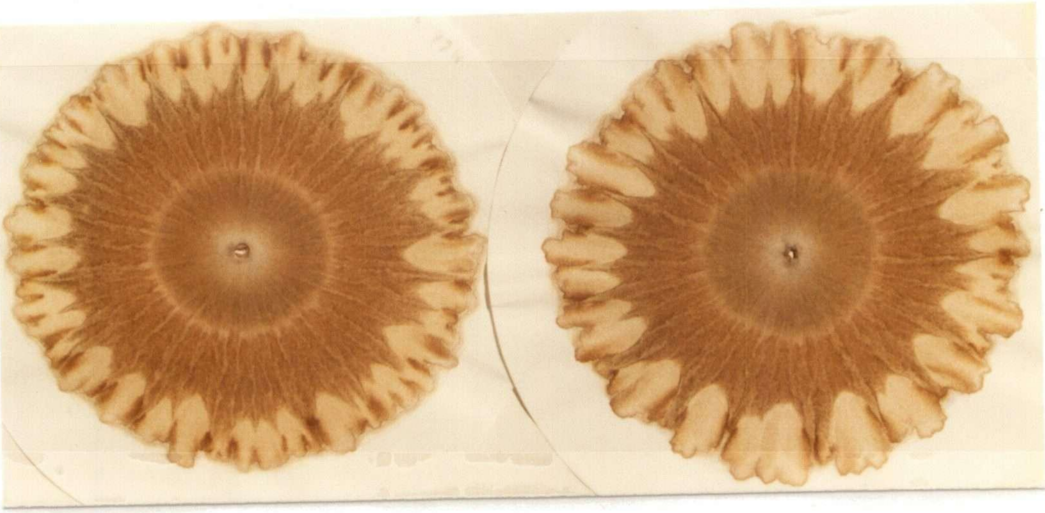


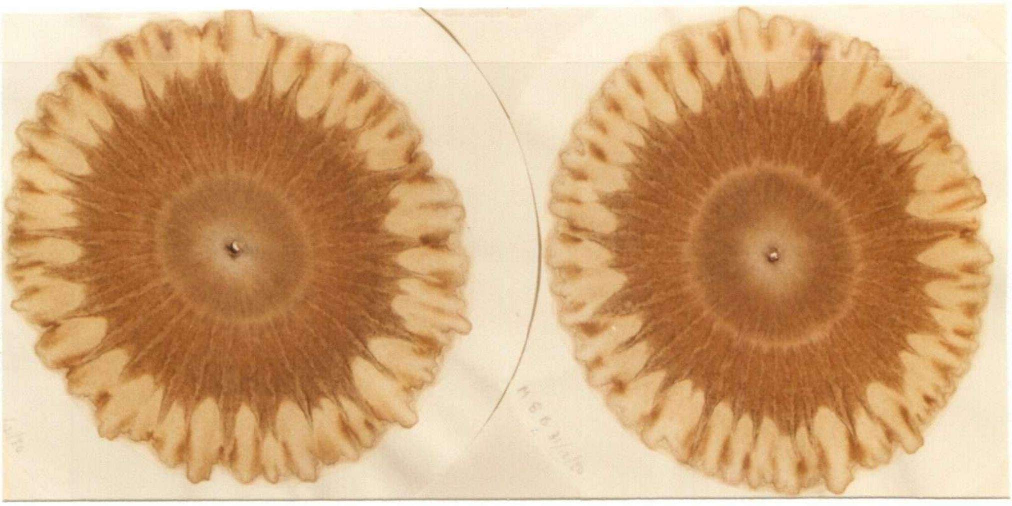
SAMPLE B REPLICATES





REPLICATES OF SAMPLE B CONTINUED.





APPENDIX II DATA SET - SAYWARD PROVINCIAL FOREST STUDY

KEY TO VARIABLES:

0. PLOT	6. PHH2O	7. TC	8. TN	9. TP	11. MINN	12. CEC	13. EXCA	14. EXMG	15. EXNA	16. EXK	17. LIPIDA
18. CB	19. SB	20. HUMC	21. HUMN	22. CF1	23. CF1A	24. E400	25. E600	26. E4OE6	27. TCA	28. TMG	29. TK
30. TNA	31. TFE	32. TAL	33. TMN	34. PYFE	35. PYAL	61. DTREE	64. SUBZ	65. ELEV	66. ASPECT	67. HYGR	68. TROPH
69. HFORM	72. FDSI	74. BGSI	76. HWSI	86. PLSI	90. BASI	92. CWSI	148. D2	149. D3	150. LO	151. SP	152. W1
153. W2	154. W3	155. W4	156. CN	158. CHCF							

VARIABLES:

1	4.4000	33.090	.67000	.11200	147.00	58.460	12.090	3.2500	.35000	3.0900	3.4800
.61000	1.0000	5.2800	.23000	5.2500	2.0400	62.600	10.200	6.1000	.74000	.12000	.15000
.70000 -1	1.3100	.81000	.15000	-0.	-0.	1.0000	3.0000	300.00	3.0000	2.0000	3.0000
12.000	30.000	-0.	28.000	-0.	-0.	27.000	59.000	85.000	60.000	35.000	8.5000
21.000	13.000	10.000	49.388	1.0057							
2	3.6000	56.880	.66000	.74000 -1	92.000	106.98	13.620	2.6300	.39000	1.5800	2.7500
.40000	.57000	16.950	.31000	5.2200	1.6300	60.400	7.6000	7.9000	.48000	.60000 -1	.70000 -1
.40000 -1	.48000	.36000	.20000 -1	-0.	-0.	1.0000	3.0000	280.00	3.0000	4.0000	3.0000
23.000	37.000	-0.	41.000	-0.	-0.	33.000	52.500	82.000	50.000	33.000	4.7500
21.500	14.750	11.500	86.182	3.2471							
3	4.4000	53.290	1.1400	.94000 -1	236.00	106.99	29.030	3.9000	.40000	2.1200	1.5600
.33000	.42000	12.440	.37000	6.3300	2.6600	66.400	11.600	5.7000	1.2100	.26000	.80000 -1
.70000 -1	1.7800	.88000	.60000 -1	-0.	-0.	2.0000	3.0000	150.00	3.0000	6.0000	4.0000
23.000	46.000	49.000	44.000	-0.	-0.	32.000	60.000	93.000	73.000	44.000	9.0000
21.000	16.500	6.5000	46.746	1.9652							
4	3.4000	64.420	1.2700	.81000 -1	141.00	161.44	16.830	5.4900	.53000	1.7600	3.9600
1.2800	.50000	15.030	.49000	6.5300	2.3900	79.200	10.800	7.3000	.47000	.80000 -1	.60000 -1
.20000 -1	.16000	.21000	.10000 -1	-0.	-0.	2.0000	3.0000	140.00	3.0000	6.0000	3.0000
15.000	51.000	-0.	47.000	-0.	-0.	32.000	62.500	87.000	62.000	38.000	5.0000
26.250	12.250	10.000	50.724	2.3017							
5	3.6000	54.820	1.3800	.10700	219.00	137.27	32.200	5.7300	.36000	2.2900	3.4800
.42000	.60000	9.6000	.46000	6.6900	2.2200	88.200	15.000	5.9000	1.0300	.12000	.10000
.40000 -1	.60000	.45000	.80000 -1	-0.	-0.	1.0000	3.0000	240.00	3.0000	3.0000	3.0000
15.000	40.000	-0.	26.000	-0.	-0.	-0.	48.000	87.000	70.000	39.000	8.0000
16.000	19.500	9.0000	39.725	1.4350							
6	3.8000	60.480	1.3500	.10500	200.00	138.02	22.220	4.3000	.44000	2.8700	3.2600
.58000	.70000	13.710	.52000	6.5900	2.1400	74.800	10.000	7.5000	.71000	.80000 -1	.90000 -1
.20000 -1	.50000	.38000	.50000 -1	-0.	-0.	2.0000	3.0000	210.00	3.0000	6.0000	4.0000
15.000	40.000	-0.	44.000	-0.	-0.	27.000	54.000	86.000	57.000	34.000	7.0000
20.000	16.000	10.000	44.800	2.0804							
7	3.5000	64.620	1.1100	.10800	208.00	123.08	12.550	4.4300	.75000	3.1000	4.9800
.66000	.88000	10.750	.37000	8.3100	3.3200	60.600	9.6000	6.3000	.37000	.70000 -1	.12000
.20000 -1	.19000	.23000	.60000 -1	-0.	-0.	2.0000	3.0000	170.00	3.0000	4.0000	3.0000
15.000	43.000	-0.	37.000	-0.	-0.	30.000	58.000	83.000	58.000	33.000	5.0000
24.000	12.500	13.000	58.216	1.2936							
8	3.3000	56.680	.87000	.11600	153.00	109.12	8.7200	3.7600	.45000	2.4700	4.0900
.58000	.64000	11.380	.37000	6.8700	1.9400	66.000	12.600	5.2000	.35000	.11000	.11000
.50000 -1	.66000	.70000	.20000 -1	-0.	-0.	2.0000	3.0000	150.00	3.0000	4.0000	3.0000
15.000	-0.	-0.	43.000	-0.	-0.	-0.	56.000	84.000	58.000	34.000	5.0000
23.000	14.000	12.000	58.433	1.6565							
9	5.3000	36.170	.77000	.14000	168.00	69.710	25.980	3.4200	.15000	1.7800	2.3600
.44000	.51000	4.7700	.22000	4.4600	1.5600	67.000	10.400	6.4000	1.2500	.29000	.14000
.15000	2.6600	1.6900	.14000	-0.	-0.	1.0000	3.0000	210.00	3.0000	4.0000	3.0000
13.000	39.000	-0.	-0.	-0.	-0.	-0	44.000	88.000	57.000	45.000	8.5000
13.500	22.000	5.0000	46.974	1.0695							
10	3.9000	58.570	1.3300	.98000 -1	287.00	111.80	16.690	3.3900	.25000	1.8900	4.1600
.65000	.75000	11.140	.51000	7.1100	2.4100	61.200	8.6000	7.1000	.71000	.15000	.90000 -1
.50000 -1	.80000	.82000	.50000 -1	-0.	-0.	1.0000	3.0000	480.00	3.0000	6.0000	4.0000
23.000	43.000	-0.	40.000	-0.	-0.	23.000	49.000	82.000	60.000	30.000	7.5000
17.000	16.500	10.000	44.038	1.5668							
11	4.7000	52.540	1.2000	.11200	189.00	111.59	40.790	4.8900	.23000	2.0000	3.1800
.54000	.56000	10.860	.46000	6.5300	2.8100	82.400	14.600	5.6000	1.6900	.24000	.10000
.90000 -1	1.8300	1.0700	.13000	-0.	-0.	1.0000	3.0000	470.00	3.0000	4.0000	4.0000
23.000	42.000	-0.	34.000	-0.	-0.	-0.	71.000	85.000	74.000	42.000	10.000
25.500	12.000	6.5000	43.783	1.6631							
12	5.3000	47.440	1.4600	.12600	368.00	137.76	74.420	9.0300	.25000	2.0200	1.7300
.57000	.60000	10.300	.56000	5.2300	2.2200	107.20	17.800	6.0000	2.3200	.20000	.11000
.70000 -1	1.8900	1.1100	.15000	-0.	-0.	1.0000	3.0000	300.00	3.0000	6.0000	4.0000
24.000	45.000	-0.	39.000	-0.	-0.	31.000	74.000	90.000	77.000	37.000	10.500
26.500	8.0000	7.0000	32.483	1.9694							
13	3.9000	62.600	1.0200	.13700	120.00	119.23	13.590	3.9300	.39000	3.0000	4.5800
1.0200	1.0800	6.3400	.28000	6.8700	2.3100	66.400	11.200	5.9000	.70000	.14000	.13000
.50000 -1	1.1300	.82000	.80000 -1	-0.	-0.	2.0000	3.0000	140.00	1.0000	3.0000	3.0000
15.000	39.000	-0.	31.000	-0.	-0.	21.000	50.000	87.000	55.000	50.000	4.5000
20.800	18.500	9.0000	61.373	.96499							
15	4.7000	47.330	1.2100	.11700	248.00	104.30	26.650	8.7700	.84000	2.5200	2.6900
.71000	.79000	7.6400	.39000	6.9800	3.4700	75.400	13.600	5.5000	1.4600	.32000	.13000
.80000 -1	2.2200	1.2500	.14000	-0.	-0.	1.0000	3.0000	85.000	3.0000	4.0000	3.0000
23.000	47.000	-0.	-0.	-0.	-0.	-0.	42.000	86.000	53.000	48.000	7.0000
14.000	22.000	7.5000	39.116	1.0946							

16	4.2000	55.230	1.1400	.12400	218.00	116.17	18.530	4.7500	.76000	1.9900	2.1700
.52000	.57000	10.810	.40000	6.1800	2.3600	66.000	9.4000	7.0000	.91000	.18000	.10000
.60000 -1	1.2500	.84000	.80000 -1	-0.	-0.	1.0000	3.0000	100.00	3.0000	3.0000	3.0000
15.000	36.000	-0	-0.	-0.	-0.	-0.	34.000	79.000	57.000	39.000	6.7500
10.250	32.500	9.0000	48.447	1.7492							
17	4.4000	55.070	1.2400	.15300	269.00	110.18	24.590	6.1500	.78000	3.4700	3.7700
.81000	.82000	9.5400	.41000	6.8700	2.3500	72.200	12.000	6.0000	1.1800	.16000	.15000
.90000 -1	1.1800	.69000	.19000	-0.	-0.	1.0000	3.0000	105.00	3.0000	2.0000	3.0000
15.000	31.000	-0.	-0.	-0.	-0.	-0.	39.000	83.000	56.000	40.000	7.0000
12.500	22.000	8.0000	44.411	1.3886							
18	4.4000	15.340	.97000	-0.	18.000	53.300	1.2500	.28000	.10000	.20000	.38000
.25000	.22000	6.5100	.57000	1.3300	.26000	246.60	59.800	4.1000	-0.	-0.	-0.
-0.	-0.	-0.	-0.	.78000	.86000	-0.	3.0000	105.00	3.0000	1.0000	3.0000
22.000	-0.	-0.	-0.	-0.	-0.	-0.	61.000	81.000	52.000	42.000	13.000
17.500	10.000	9.0000	15.814	4.8947							
19	4.6000	39.620	1.0400	.11400	250.00	92.930	20.000	7.9900	.81000	2.0900	1.7600
.63000	.74000	6.9100	.34000	4.6100	1.4000	77.000	11.800	6.5000	1.6500	.37000	.11000
.12000	2.8400	1.8800	.60000 -1	-0.	-0.	1.0000	3.0000	75.000	1.0000	6.0000	6.0000
25.000	81.000	52.000	48.000	-0.	-0.	-0.	47.000	85.000	87.000	41.000	7.2500
16.250	19.000	7.0000	38.096	1.4989							
21	3.2000	8.8100	.63000	-0.	56.000	45.400	2.0000	5.0000	.11000	.20000	.29000
.34000	.19000	3.1700	.28000	2.1400	.71000	115.40	22.400	5.2000	-0.	-0.	-0.
-0.	-0.	-0.	-0.	.84000	.72000	6.0000	3.0000	70.000	1.0000	7.0000	6.0000
32.000	-0.	-0.	-0.	-0.	-0.	-0.	66.000	78.000	86.000	33.000	14.500
18.500	6.0000	8.5000	15.571	1.4813							
22	5.0000	8.6900	.33000	-0.	33.000	34.290	8.7500	1.5800	.15000	.33000	.18000
.90000 -1	.60000 -1	2.6200	.15000	1.0800	.45000	186.40	46.200	4.0000	-0.	-0.	-0.
-0.	-0.	-0.	-0.	.41000	.57000	1.0000	1.0000	90.000	3.0000	5.0000	4.0000
32.000	46.000	-0.	-0.	-0.	-0.	-0.	54.000	84.000	60.000	40.000	10.250
16.750	15.000	6.0000	26.333	2.4259							
23	3.4000	60.670	2.7800	.11800	339.00	143.72	19.270	5.8100	.46000	1.2800	3.0500
.25000	.34000	11.240	.76000	6.6100	2.1200	72.200	8.8000	8.2000	.57000	.12000	.80000 -1
.20000 -1	.35000	.29000	.30000 -1	-0.	-0.	6.0000	1.0000	80.000	3.0000	6.0000	6.0000
24.000	-0.	-0.	39.000	-0.	-0.	-0.	73.000	89.000	69.000	45.000	5.5000
31.000	8.0000	7.0000	21.824	1.7005							
24	4.8000	62.700	1.5400	.86000 -1	350.00	127.72	16.790	5.3300	.38000	1.2800	2.0700
.26000	.37000	14.430	.48000	7.8100	2.6100	50.600	6.4000	7.9000	.54000	.10000	.60000 -1
.30000 -1	.58000	.31000	.10000 -1	-0.	-0.	3.0000	4.0000	290.00	1.0000	5.0000	6.0000
15.000	-0.	-0.	28.000	-0.	30.000	-0.	52.000	78.000	83.000	42.000	6.2500
19.750	13.000	14.000	40.714	1.8476							
25	4.2000	59.930	1.5200	.12600	321.00	113.96	14.950	2.3600	1.3100	1.7300	3.8800
.29000	.42000	13.050	.54000	7.1200	2.6800	63.800	8.8000	7.3000	.43000	.50000 -1	.80000 -1
.30000 -1	.59000	.38000	.90000 -1	-0.	-0.	3.0000	4.0000	290.00	2.0000	2.0000	6.0000
23.000	-0.	-0.	29.000	-0.	42.000	-0.	53.000	77.000	84.000	35.000	7.5000
19.000	12.000	13.000	39.428	1.8329							
26	3.3000	65.580	1.0200	.79000 -1	193.00	130.67	11.680	2.1900	.85000	2.1900	4.3000
.49000	.71000	20.310	.41000	6.5900	1.4900	49.800	5.2000	9.6000	.33000	.30000 -1	.90000 -1
.20000 -1	.11000	.80000 -1	.40000 -1	-0.	-0.	3.0000	5.0000	600.00	2.0000	3.0000	3.0000
15.000	-0.	-0.	32.000	-0.	24.000	-0.	52.000	80.000	41.000	26.000	2.5000
23.500	14.000	13.000	64.294	3.0819							
27	3.9000	59.760	1.2700	.10000	268.00	121.42	12.120	2.6500	.35000	2.7300	4.2400
.56000	.74000	10.420	.48000	8.6200	2.5700	63.800	10.200	6.3000	.44000	.80000 -1	.12000
.30000 -1	.65000	.31000	.19000	-0.	-0.	3.0000	5.0000	610.00	3.0000	4.0000	3.0000
15.000	-0	-0.	42.000	-0.	26.000	34.000	69.000	86.000	60.000	36.000	8.5000
26.000	8.5000	11.000	47.055	1.2088							
28	3.6000	68.350	1.4600	.11600	290.00	130.67	7.1400	3.1700	.70000	2.2200	5.0500
.32000	.56000	18.960	.62000	7.2100	1.4300	59.600	7.0000	8.5000	.23000	.60000 -1	.11000
.20000 -1	.23000	.23000	.40000 -1	-0.	-0.	3.0000	4.0000	500.00	3.0000	5.0000	4.0000
15.000	-0.	-0.	34.000	-0.	36.000	-0.	43.000	79.000	54.000	30.000	5.5000
16.000	18.000	10.500	46.815	2.6297							
29	3.6000	64.350	1.1900	.11300	180.00	124.04	7.5900	2.9100	.58000	2.4300	4.4200
.57000	.67000	10.290	.35000	6.2900	2.7500	77.600	12.200	6.4000	.27000	.50000 -1	.11000
.30000 -1	.31000	.24000	.60000 -1	-0.	-0.	3.0000	4.0000	500.00	1.0000	3.0000	3.0000
15.000	-0.	-0	34.000	-0.	39.000	-0.	55.000	86.000	60.000	33.000	5.5000
22.000	15.500	12.000	54.076	1.6359							
30	4.1000	45.960	.71000	.85000 -1	34.000	91.900	17.500	4.2000	.64000	1.2600	5.2600
.54000	.70000	11.480	.43000	8.0700	2.5300	62.200	6.0000	7.8000	1.8300	.27000	.60000 -1
.70000 -1	2.0200	1.4400	.80000 -1	-0.	-0.	1.0000	3.0000	190.00	3.0000	2.0000	2.0000
22.000	26.000	-0.	-0.	-0.	-0.	-0.	50.000	93.000	68.000	40.000	7.0000
18.000	21.500	7.5000	64.732	1.4226							
31	3.8000	62.480	.87000	.96000 -1	194.00	108.20	12.330	3.7500	.42000	2.0300	4.2200
.53000	.61000	10.080	.32000	6.7600	2.4300	60.000	9.0000	6.7000	.66000	.70000 -1	.90000 -1
.20000 -1	.42000	.45000	.10000	-0.	-0.	5.0000	3.0000	350.00	1.0000	2.0000	2.0000
15.000	19.000	-0.	-0.	16.000	-0.	-0.	57.000	80.000	57.000	33.000	5.5000
23.000	11.500	11.000	71.816	1.4911							
32	4.4000	35.250	.77000	.18400	18.000	72.230	16.280	2.7100	.33000	2.5800	3.2300
.71000	.67000	5.7500	.30000	5.2800	2.4800	54.600	9.2000	5.9000	1.0300	.24000	.15000
.90000 -1	2.7700	1.3300	.70000	-0.	-0.	1.0000	1.0000	180.00	1.0000	3.0000	2.0000
15.000	24.000	-0	-0.	-0.	-0.	-0.	41.000	80.000	49.000	39.000	8.5000
12.000	19.500	7.0000	45.779	1.0890							
33	4.1000	55.860	.70000	.14000	178.00	112.23	16.990	3.6600	.81000	3.5400	5.1200
.66000	.43000	8.8700	.35000	10.060	4.9200	64.800	8.6000	7.5000	.63000	.10000	.16000
.40000 -1	.61000	.42000	.50000	-0.	-0.	1.0000	1.0000	180.00	1.0000	3.0000	2.0000
15.000	35.000	-0.	19.000	-0.	-0.	19.000	40.000	82.000	80.000	38.000	11.000
9.0000	21.000	11.000	79.800	.88171							
34	4.6000	38.970	.87000	.11700	154.00	87.630	24.620	4.1000	.22000	1.9100	2.6700
.56000	.69000	6.5100	.32000	5.5100	1.9300	82.400	14.400	5.7000	1.3100	.20000	.13000
.10000	1.9200	1.1500	.54000	-0.	-0.	1.0000	3.0000	275.00	3.0000	2.0000	3.0000
15.000	31.000	-0.	-0.	-0.	-0.	31.000	60.000	88.000	68.000	39.000	10.250
19.750	14.000	7.0000	44.793	1.1815							

35	4.4000	48.540	1.1700	.14400	226.00	114.95	31.790	5.2400	.33000	2.5700	4.0200
.66000	.69000	8.9500	.48000	5.5700	1.5500	76.000	12.800	5.9000	1.2900	.20000	.13000
.80000 -1	1.2100	.79000	.39000	-0.	-0.	1.0000	3.0000	270.00	3.0000	3.0000	3.0000
15.000	37.000	-0.	-0.	-0	-0.	-0.	57.000	88.000	65.000	34.000	8.0000
20.500	15.500	8.0000	41.487	1.6068							
36	3.4000	60.490	1.2700	.10500	197.00	136.10	12.990	4.3300	.27000	2.1700	4.4700
.53000	.68000	13.920	.50000	7.6200	2.3600	65.400	8.4000	7.8000	.40000	.70000 -1	.10000
.20000 -1	.19000	.17000	.20000 -1	-0.	-0.	1.0000	4.0000	490.00	3.0000	4.0000	3.0000
15.000	53.000	-0.	39.000	-0.	22.000	37.000	58.000	80.000	62.000	34.000	6.5000
22.500	11.000	12.000	47.630	1.8268							
37	4.8000	48.820	1.8500	.35500	79.000	136.01	30.170	3.1300	.40000	.44000	2.2100
.30000	.24000	21.300	1.0000	5.6100	1.9500	94.700	14.400	6.6000	.92000	.60000 -1	.40000 -1
.30000 -1	.34000	3.6100	.12000	-0.	-0	9.0000	5.0000	640.00	1.0000	8.0000	4.0000
34.000	-0.	-0.	24.000	-0.	-0.	-0.	62.000	77.000	36.000	29.000	14.250
16.750	7.5000	14.000	26.389	3.7968							
38	5.0000	13.940	.73000	-0	56.000	74.130	10.630	1.0500	.17000	.32000	.25000
1.0200	.35000	5.6600	.37000	2.0100	.68000	185.00	44.400	4.2000	-0.	-0.	-0.
-0.	-0.	-0.	-0	1.0000	2.0500	4.0000	3.0000	210.00	3.0000	7.0000	4.0000
25.000	45.000	-0.	38.000	-0.	-0.	38.000	45.000	76.000	41.000	35.000	12.500
10.000	15.500	11.000	19.096	2.8159							
39	4.4000	9.4900	.63000	-0	68.000	38.570	7.0000	1.6800	.13000	.30000	.39000
.17000	.11000	2.3700	.21000	1.7100	.58000	73.600	9.2000	8.0000	-0.	-0.	-0.
-0.	-0.	-0	-0	.10000	.25000	6.0000	3.0000	140.00	1.0000	7.0000	4.0000
32.000	-0.	-0	28.000	-0.	-0	-0.	49.000	90.000	67.000	45.000	7.7500
16.750	20.500	8.5000	15.063	1.3850							
40	4.1000	37.820	.95000	.10800	196.00	78.640	10.300	2.9800	.38000	1.9200	3.9800
.56000	.53000	7.8600	.36000	5.2800	1.6000	76.200	15.800	4.8000	1.0400	.18000	.11000
.90000 -1	2.3100	1.0400	.90000 -1	-0.	-0.	2.0000	3.0000	95.000	3.0000	5.0000	4.0000
15.000	44.000	-0	45.000	-0.	-0.	-0.	61.000	89.000	70.000	36.000	7.5000
23.000	14.000	9.0000	39.811	1.4886							
41	4.5000	15.210	.92000	-0.	58.000	70.040	8.2500	2.4000	.13000	1.0000	.24000
.16000	.13000	4.0900	.35000	2.2900	.90000	131.60	24.000	5.5000	-0.	-0.	-0.
-0.	-0.	-0	-0.	1.1800	1.0400	1.0000	1.0000	20.000	3.0000	6.0000	6.0000
32.000	55.000	61.000	42.000	-0	-0.	-0.	44.000	78.000	51.000	38.000	14.000
8.0000	17.000	7.0000	16.533	1.7860							
42	4.0000	42.860	.81000	.10400	71.000	86.510	17.440	5.0000	.24000	2.3700	3.4600
.50000	.44000	4.7300	.23000	7.2100	3.8800	75.400	12.400	6.1000	.95000	.12000	.11000
.80000 -1	1.0700	.55000	.12000	-0.	-0.	1.0000	1.0000	180.00	1.0000	3.0000	3.0000
15.000	33.000	-0.	32.000	-0.	-0.	-0.	62.000	90.000	69.000	41.000	5.5000
25.500	14.000	10.000	52.914	.65603							
43	4.6000	43.300	.85000	.10300	218.00	85.980	25.410	4.0100	.27000	2.0600	4.3700
.59000	.51000	7.9500	.30000	5.6400	2.2200	71.800	10.800	6.6000	1.2900	.18000	.11000
.70000 -1	1.7100	.86000	.30000	-0	-0.	1.0000	3.0000	250.00	1.0000	4.0000	3.0000
23.000	36.000	-0	28.000	-0.	-0.	-0.	50.000	83.000	63.000	35.000	7.0000
18.000	16.500	10.000	50.941	1.4096							
44	4.7000	52.540	1.3000	.19700	337.00	114.02	39.770	5.8900	.41000	3.1800	4.0100
.47000	.48000	7.6700	.42000	7.7800	3.1600	70.200	11.400	6.2000	1.6500	.17000	.17000
.11000	1.7800	.98000	1.5500	-0.	-0.	1.0000	3.0000	270.00	3.0000	3.0000	3.0000
23.000	38.000	-0	-0.	-0.	-0	35.000	60.000	84.000	57.000	31.000	7.5000
22.500	12.000	7.5000	40.415	.98586							
45	3.6000	58.920	.74000	.64000 -1	126.00	109.39	11.360	5.4500	.97000	2.9800	6.3200
.62000	.66000	21.620	.53000	7.2600	2.9100	68.200	9.0000	7.6000	.34000	.80000 -1	.13000
.30000 -1	.12000	.12000	.10000 -1	-0	-0.	2.0000	4.0000	370.00	3.0000	2.0000	2.0000
15.000	24.000	-0.	30.000	-0.	-0.	31.000	66.000	86.000	56.000	32.000	4.5000
28.500	10.000	12.000	79.622	2.9780							
46	4.1000	55.880	1.5900	.16300	156.00	115.23	12.890	1.2000	.30000	1.1600	3.2100
.75000	.75000	14.080	.74000	7.6200	3.0700	84.800	18.800	4.5000	.26000	.80000 -1	.60000 -1
.20000 -1	1.1100	1.3300	.10000 -1	-0.	-0.	5.0000	4.0000	380.00	2.0000	1.0000	2.0000
22.000	12.000	-0.	-0.	12.000	-0.	-0.	49.000	86.000	60.000	31.000	9.0000
15.500	18.500	11.000	35.145	1.8478							
47	3.9000	8.2900	.58000	-0.	129.00	40.040	30.000	.98000	.10000	.23000	.38000
.15000	.12000	3.2100	.26000	1.8600	.62000	84.400	12.200	6.9000	-0.	-0.	-0.
-0	-0	-0.	-0.	.61000	.39000	6.0000	1.0000	90.000	1.0000	7.0000	6.0000
32.000	48.000	-0.	58.000	-0.	-0.	-0.	53.000	80.000	53.000	35.000	10.000
16.500	13.500	11.000	14.293	1.7258							
48	4.1000	38.030	.58000	.11600	49.000	79.100	10.670	3.0800	.34000	1.5600	2.5000
.44000	.36000	9.5800	.30000	3.9100	1.3600	85.600	14.000	6.1000	.82000	.31000	.12000
.11000	2.5600	1.5400	.90000 -1	-0.	-0.	1.0000	1.0000	160.00	1.0000	4.0000	3.0000
15.000	45.000	-0.	-0.	-0	-0.	-0.	47.000	84.000	51.000	37.000	7.5000
16.000	18.500	9.0000	65.569	2.4501							
50	4.6000	9.8300	.29000	-0.	36.000	35.960	10.750	1.1800	.60000 -1	.33000	.25000
.10000	.60000 -1	2.3900	.13000	1.2800	.51000	171.20	38.000	4.5000	-0.	-0.	-0.
-0	-0.	-0.	-0.	.32000	.36000	1.0000	3.0000	200.00	3.0000	5.0000	4.0000
32.000	44.000	-0.	-0	-0.	-0	-0.	47.000	88.000	63.000	36.000	9.5000
14.000	20.500	10.000	33.897	1.8672							
51	5.4000	53.210	1.0000	.91000 -1	305.00	106.41	30.340	3.7600	.42000	1.9800	5.7600
.35000	.38000	11.710	.40000	4.8900	2.0900	73.800	10.000	7.4000	.97000	.13000	.80000 -1
.40000 -1	.63000	.37000	.80000 -1	-0.	-0.	1.0000	3.0000	240.00	3.0000	4.0000	3.0000
15.000	49.000	-0.	45.000	-0.	-0.	34.000	52.000	87.000	66.000	40.000	5.0000
21.000	17.500	9.0000	53.210	2.3947							
52	4.3000	46.730	1.0000	.12900	160.00	101.06	19.640	3.8600	.38000	2.2400	2.4900
.49000	.45000	10.510	.45000	5.5000	1.6900	91.800	17.200	5.3000	.79000	.12000	.11000
.70000 -1	.86000	.56000	.11000	-0.	-0	1.0000	3.0000	180.00	1.0000	5.0000	4.0000
15.000	64.000	-0	47.000	-0.	-0.	-0.	53.000	90.000	69.000	42.000	6.2500
20.250	18.500	6.0000	46.730	1.9109							
53	4.0000	60.450	1.4500	.13900	316.00	113.55	14.240	2.7300	.33000	3.4100	5.5500
.68000	.62000	10.360	.52000	9.8200	4.2600	61.600	11.400	5.4000	.48000	.50000 -1	.15000
.20000 -1	.24000	.20000	.60000 -1	-0	-0.	2.0000	5.0000	760.00	3.0000	4.0000	3.0000
15.000	36.000	-0.	34.000	-0.	36.000	32.000	36.000	83.000	53.000	36.000	5.2500
12.750	23.500	12.000	41.690	1.0550							
54	4.3000	46.600	.88000	.14400	187.00	96.500	18.180	2.6800	.25000	2.1000	2.8900
.50000	.45000	10.180	.40000	7.0500	3.3000	74.400	12.200	6.1000	1.0600	.24000	.11000
.70000 -1	2.0100	1.2900	.26000	-0	-0.	1.0000	3.0000	200.00	3.0000	5.0000	4.0000
23.000	41.000	-0	41.000	-0.	-0	-0.	45.000	86.000	62.000	40.000	7.5000
15.000	20.500	7.5000	52.955	1.4440							

57	3.8000	23.160	1.2900	-0.	281.00	80.360	6.2500	1.6300	.14000	.58000	.98000
.21000	.20000	6.6100	.57000	3.4800	.76000	125.20	24.400	5.1000	-0.	-0.	-0.
-0.	-0.	-0.	-0	1.3100	.40000	6 0000	1.0000	140.00	1.0000	7.0000	4.0000
32.000	-0.	-0.	-0.	-0.	-0.	-0	76.000	86.000	58.000	36.000	20.000
18 000	5.0000	8 0000	17.953	1.8994							
58	3.9000	47.900	1.0200	.12800	154 00	114.20	17 360	4 1000	.27000	2.4600	3.6600
56000	.46000	10 170	.41000	5.1800	1.4900	76 000	41.600	6.6000	.87000	.10000	.11000
.40000 -1	.76000	.50000	.90000 -1	-0.	-0.	1.0000	3.0000	150.00	3.0000	3.0000	3.0000
15.000	38 000	-0.	-0	-0.	-0.	-0.	49.000	87.000	60.000	35.000	4.5000
20.000	19.000	10.000	46 961	1.9633							
59	4.6000	53.020	1.1400	.12200	313.00	91.820	23.080	4.7800	.34000	2.5200	4.3900
.74000	.52000	8 6300	.45000	6.5400	2.7100	60.000	9.6000	6 3000	1.0600	.18000	.12000
.50000 -1	.94000	.69000	.14000	-0.	-0.	1.0000	3.0000	150.00	3.0000	5.0000	4.0000
15.000	45 000	-0.	33.000	-0.	-0.	-0.	47.000	88.000	63.000	40.000	6.5000
17.000	20.500	10.000	46.509	1.3196							
60	4.0000	54 440	1.2300	.13400	317.00	112 10	22.860	4 0500	.47000	2.5700	4.1600
.51000	.60000	10.630	.52000	7.0000	2.7400	80.400	14.000	5.7000	.86000	.13000	.12000
.50000 -1	.70000	.41000	.29000	-0.	-0.	1.0000	3.0000	40.000	3.0000	4.0000	4.0000
15 000	-0.	-0	49.000	-0.	-0.	-0.	57.000	89.000	58.000	36.000	7.0000
21.500	16 000	8.5000	44 260	1.5186							
61	4.2000	58 680	1.6600	.12000	220 00	166.95	23 630	5.9100	.30000	.79000	1.8900
.74000	.33000	15.300	.83000	7.3500	3.3800	86.800	12.800	6.8000	.66000	.90000 -1	.40000 -1
.20000 -1	.28000	1 6100	.60000 -1	-0.	-0.	1.0000	3.0000	40.000	1.0000	6.0000	4.0000
23 000	54 000	-0.	49.000	-0.	-0.	46 000	65.000	81.000	56.000	28.000	7.5000
25.000	8.0000	9.0000	35.349	2.0816							
62	3.5000	50 550	1 1800	.10400	199.00	121.11	5.8000	3.8700	.51000	1.4900	3.5500
.31000	.34000	10.410	.40000	11.030	6 6500	75.600	10 800	7.0000	.24000	.70000 -1	.70000 -1
.40000 -1	.70000	.46000	.10000 -1	-0	-0.	2 0000	3 0000	50 000	1.0000	6.0000	4.0000
15 000	-0.	-0.	43 000	-0.	47.000	-0.	59.000	74.000	52.000	36.000	8.5000
21 000	7.5000	11.000	42.839	94379							
63	3.8000	58 030	1 0300	.88000 -1	143.00	122 52	15.120	4.8000	.48000	1.8700	4.9500
.53000	51000	8 9500	.32000	6 5100	2 7300	69.200	9 4000	7 4000	.43000	.80000 -1	.90000 -1
.20000 -1	.28000	.19000	.20000 -1	-0.	-0	5.0000	3.0000	50 000	2.0000	1.0000	1.0000
22.000	15 000	-0.	-0	15.000	-0.	-0.	44.000	80.000	53.000	31.000	6.0000
16.000	18.000	9 0000	56.340	1.3748							
64	4.4000	35.930	1.0000	.13600	159.00	94.870	24.750	5.2700	.34000	1.7900	1.3600
.32000	.34000	6.1300	.35000	3.7300	1 1100	117.80	24.600	4.8000	1.2400	.20000	.11000
.10000	1.9100	.97000	.27000	-0	-0.	1.0000	2.0000	70.000	3.0000	4.0000	4.0000
24 000	43 000	-0	44.000	-0.	-0.	-0.	66.000	91.000	78.000	47.000	12.500
20 500	12.500	6 0000	35.930	1.6434							
65	4.6000	53.450	1.5000	.73000 -1	82 000	154 04	72.140	18.110	.28000	.54000	3.4300
.19000	.17000	24 720	.78000	2.4000	.61000	134.80	24 600	5.6000	2.3000	.29000	.40000 -1
.30000 -1	.36000	.69000	.10000 -1	-0.	-0.	6.0000	3.0000	200.00	1.0000	8.0000	6.0000
34.000	-0.	-0.	21 000	-0.	-0	-0.	47.500	74.000	44.000	28.000	15.000
8 7500	13 250	13.500	35.633	10.300							
66	3 6000	49 810	1.6000	.11600	143 00	144 16	21 640	7 2700	.38000	1.2800	2.3600
39000	47000	21.200	.82000	5 3200	1 3800	78 200	11.200	7.0000	.80000	.19000	.70000 -1
.60000 -1	1 0200	.68000	10000 -1	-0.	-0.	1 0000	1.0000	170 00	1.0000	7.0000	6.0000
24 000	49.000	52.000	47 000	-0.	-0.	-0.	44.000	77.000	52.000	34.000	9.2500
12 750	16.500	12 000	31.131	3.9850							
67	3.4000	60 990	1.2100	.87000 -1	182 00	159.80	24.290	5.1200	.39000	2.6400	4.6900
.43000	.61000	12.520	.81000	7 2200	2 9700	95 400	13.200	7.2000	.77000	.10000	.90000 -1
30000 -1	.36000	.26000	.10000 -1	-0.	-0.	4.0000	3.0000	200.00	1.0000	7.0000	2.0000
15 000	-0.	-0	31 000	-0.	-0.	34.000	52.000	84.000	65.000	35.000	5.0000
21.000	16 000	9.5000	50.405	1.7341							
68	3.5000	57.660	1 6000	.12400	192.00	134.32	14 950	4 0900	.83000	1.7800	4.7800
69000	.73000	10 770	.49000	6.2400	1.2700	70.000	10.800	6.5000	.56000	.11000	.80000 -1
.50000 -1	.55000	.34000	.40000 -1	-0.	-0	2 0000	4.0000	260.00	3 0000	4.0000	6.0000
15.000	36 000	-0.	29.000	-0.	37.000	-0.	51.000	81.000	59.000	35.000	4.5000
21 000	15.000	11.000	36.037	1.7260							
69	3.4000	56.160	1 3500	.11200	181.00	143.38	9.6900	4 0700	.62000	3.1600	4.8700
.59000	.65000	13 400	.56000	6.8200	2.0500	84 600	15.000	5.6000	.33000	.70000 -1	.14000
.30000 -1	.47000	.31000	10000 -1	-0.	-0.	2.0000	5.0000	710 00	3.0000	5.0000	3.0000
15 000	32 000	-0.	32 000	-0.	28 000	-0	49 000	80.000	62.000	41.000	5.5000
19 000	15 500	11.000	41 600	1.9648							
70	3.4000	59.260	.98000	95000 -1	153 00	128.78	7.8900	5 1400	.79000	4.3100	6.4800
92000	.74000	9 7900	.51000	6.9300	1 9800	82.000	12.600	6.5000	.22000	.80000 -1	.18000
.30000 -1	.24000	.14000	10000 -1	-0.	-0	9.0000	5.0000	810.00	3.0000	3.0000	2.0000
15 000	-0.	-0	17.000	-0.	16.000	-0.	59.000	79.000	49.000	38.000	7.2500
22 250	10.000	9 5000	60 469	1.4127							
71	3.7000	60.440	.90000	.73000 -1	103.00	126 28	19.640	3 3300	.25000	1.2600	3.3000
.38000	.32000	17.170	.32000	5.6300	2.0200	71.400	9 2000	7.8000	.74000	.10000	.60000 -1
.40000 -1	.62000	.37000	.30000 -1	-0.	-0.	1.0000	3.0000	230.00	3.0000	4.0000	2.0000
15 000	35 000	-0.	30.000	-0.	-0.	-0.	40 000	78.000	49.000	33.000	4.7500
15 250	19.000	12.000	67.156	3 0497							
73	3.8000	48.020	1 0400	.11300	120.00	114.55	20.480	3.6500	.24000	2.2600	4.2300
57000	56000	11.410	.38000	6.2900	1.7700	63.400	9.8000	6.5000	.80000	.12000	.10000
.40000 -1	80000	.46000	.19000	-0.	-0	1.0000	4.0000	450.00	3.0000	4.0000	4.0000
15 000	42 000	-0.	30 000	-0.	-0.	-0.	52.000	85.000	66.000	40.000	6.0000
20 000	16 500	7 5000	46 173	1 8140							

74	4.4000	52.740	1.0900	.11700	203.00	116.39	34.450	5.3900	.28000	2.5300	5.4900
.51000	.43000	9.5900	.42000	6.8300	2.9700	71.000	9.8000	7.2000	1.3800	.22000	.12000
.50000 -1	1.2000	.68000	.18000	-0	-0.	1.0000	4.0000	465.00	3.0000	3.0000	3.0000
23.000	38.000	-0.	-0.	-0.	-0.	32.000	48.000	86.000	63.000	38.000	4.5000
19.500	19.000	9.0000	48.385	1.4041							
75	4.0000	13.170	.35000	-0.	53.000	42.900	4.5300	1.5500	.21000	.62000	.98000
.27000	.15000	3.5700	.13000	1.9200	.69000	122.60	28.800	4.4000	-0.	-0.	-0.
-0.	-0.	-0.	-0.	-0.	-0	1.0000	1.0000	105.00	1.0000	5.0000	4.0000
23.000	49.000	-0	27.000	-0.	-0.	-0.	65.000	90.000	65.000	38.000	8.0000
24.500	12.500	9.5000	37.629	1.8594							
76	4.8000	7.7000	.24000	-0.	22.000	35.380	9.9000	1.4700	.14000	.29000	.28000
.41000	.16000	1.5900	.12000	1.2000	.47000	209.80	56.100	3.9000	-0.	-0.	-0.
-0.	-0.	-0	-0.	-0.	-0.	4.0000	1.0000	100.00	1.0000	7.0000	4.0000
23.000	42.000	-0.	35.000	-0	-0.	42.000	62.000	80.000	52.000	47.000	7.5000
23.500	9.0000	5.5000	32.083	1.3250							
77	3.3000	56.640	1.4000	.10100	208.00	129.48	12.010	3.4100	.27000	2.2600	4.6400
.51000	.43000	11.590	.22000	6.3000	2.3100	70.400	9.8000	7.2000	.46000	.18000	.11000
.60000 -1	.97000	.47000	.20000 -1	-0.	-0.	2.0000	4.0000	400.00	3.0000	5.0000	4.0000
15.000	-0.	-0.	38.000	-0.	36.000	43.000	57.000	84.000	61.000	37.000	6.0000
22.500	13.500	10.000	40.457	1.8397							
78	3.8000	61.070	1.6700	.10000	211.00	145.64	32.530	4.3100	.22000	2.3700	3.5700
.56000	.71000	12.080	.53000	7.3000	1.9700	74.600	10.600	7.0000	.94000	.70000 -1	.80000 -1
.30000 -1	.43000	.20000	.20000 -1	-0.	-0.	2.0000	4.0000	400.00	3.0000	7.0000	4.0000
15.000	-0.	-0.	38.000	-0.	-0	41.000	58.000	86.000	68.000	37.000	6.0000
23.000	14.000	10.500	36.569	1.6548							
79	3.2000	63.850	1.4900	.85000 -1	161.00	169.89	13.020	6.5100	.64000	1.6800	4.4600
.49000	.58000	14.280	.63000	7.9800	3.3900	90.200	12.600	7.2000	.31000	.80000 -1	.70000 -1
.20000 -1	.11000	.90000 -1	.10000 -1	-0.	-0.	3.0000	6.0000	870.00	3.0000	5.0000	3.0000
15.000	-0.	-0.	32.000	-0.	33.000	-0.	-0.	-0.	-0.	-0.	-0.
-0.	-0.	-0.	42.852	1.7895							
80	4.1000	47.470	1.0800	-0.	137.00	129.96	1.9600	.90000	.26000	2.0900	4.3200
.39000	.94000	8.8200	.43000	7.6100	3.2600	88.100	21.700	4.0000	-0.	-0.	-0.
-0.	-0	-0.	-0.	-0.	-0.	3.0000	6.0000	940.00	3.0000	5.0000	4.0000
15.000	-0.	-0.	-0.	-0	22.000	-0	48.000	84.000	62.000	24.000	10.500
13.500	18.000	6.0000	43.954	1.1590							
83	4.6000	6.3700	.31000	-0.	77.000	26.380	7.7500	1.1000	.90000 -1	.43000	.22000
.13000	.90000 -1	1.8600	.11000	1.1900	.45000	78.600	10.600	7.4000	-0.	-0.	-0.
-0.	-0.	-0.	-0.	.36000	.25000	6.0000	3.0000	210.00	3.0000	8.0000	6.0000
32.000	-0.	-0.	-0.	-0.	-0.	-0.	45.000	88.000	67.000	40.000	8.0000
14.500	21.500	8.0000	20.548	1.5630							
84	4.0000	32.520	.56000	.96000 -1	67.000	72.750	16.170	2.2500	.16000	1.3500	2.3300
.41000	.42000	5.3100	.43000	4.9200	2.6700	66.200	9.2000	7.2000	.73000	.12000	.11000
.80000 -1	1.6700	1.1200	.60000 -1	-0.	-0.	1.0000	3.0000	220.00	1.0000	3.0000	2.0000
15.000	36.000	-0.	-0.	-0.	-0.	-0	71.000	93.000	68.000	54.000	7.2500
28.250	11.000	5.5000	58.071	1.0793							
85	3.8000	56.550	1.2000	.94000 -1	128.00	135.55	27.880	2.1900	.22000	1.5500	4.9100
.43000	.46000	11.640	.27000	6.2100	1.9400	69.000	9.2000	7.5000	.82000	.90000 -1	.90000 -1
.20000 -1	1.1200	.56000	.20000 -1	-0.	-0.	7.0000	5.0000	710.00	3.0000	6.0000	2.0000
16.000	36.000	-0.	-0.	-0.	37.000	32.000	54.000	82.000	52.000	31.000	4.7500
22.250	14.000	9.5000	47.125	1.8744							
86	3.4000	60.820	.83000	.66000 -1	104.00	132.72	14.820	2.7100	.27000	2.5400	5.7100
.51000	.68000	8.6400	.46000	6.2000	1.9800	73.200	9.4000	7.8000	.59000	.40000 -1	.10000
.40000 -1	.42000	.25000	.20000 -1	-0	-0.	2.0000	5.0000	750.00	3.0000	2.0000	3.0000
15.000	-0	-0.	19.000	-0.	-0	-0.	52.000	89.000	53.000	35.000	3.5000
22.500	18.500	8.0000	73.277	1.3935							
87	3.6000	64.010	1.5000	.83000 -1	147.00	157.93	5.7600	7.5600	.46000	2.5900	4.7400
.73000	.72000	9.5300	.49000	8.2200	3.0500	72.800	13.400	5.4000	.14000	.11000	.11000
.20000 -1	.24000	.24000	.10000 -1	-0	-0.	2.0000	6.0000	1140.0	3.0000	6.0000	3.0000
15.000	-0.	-0	-0	-0.	12.000	-0.	48.000	83.000	54.000	42.000	5.5000
18.500	17.500	6.5000	42.673	1.1594							
88	3.4000	60.790	1.3100	.13200	92.000	148.80	4.4800	2.6100	1.1400	2.3900	5.4300
.95000	1.0400	12.040	.52000	8.2800	2.9600	78.200	14.800	5.3000	.14000	.40000 -1	.12000
.50000 -1	.30000	.73000	.10000 -1	-0.	-0.	3.0000	6.0000	1140.0	3.0000	5.0000	3.0000
15.000	-0.	-0.	-0.	-0.	15.000	-0.	56.000	76.000	53.000	28.000	5.0000
23.000	10.000	11.000	46.405	1.4541							
89	3.2000	44.640	.92000	.11600	64.000	100.41	4.9600	2.6000	.28000	1.6900	3.0600
.62000	.66000	6.2800	.34000	6.2300	2.1400	73.800	15.600	4.7000	.39000	.70000 -1	.12000
.80000 -1	2.0100	1.0900	.50000 -1	-0.	-0.	9.0000	6.0000	1200.0	2.0000	3.0000	2.0000
15.000	-0.	-0.	-0.	-0	-0.	-0.	50.000	80.000	69.000	30.000	5.0000
20.000	15.000	13.500	48.522	1.0080							
90	3.4000	38.970	.75000	.96000 -1	46.000	85.400	4.3700	1.3400	.21000	.87000	3.8500
.27000	.34000	5.3400	.28000	6.6900	3.1300	93.600	18.600	5.0000	.49000	.10000	.17000
.70000 -1	1.8000	1.7300	.40000 -1	-0.	-0	9.0000	7.0000	1300.0	2.0000	1.0000	2.0000
12.000	-0	-0.	-0	-0	-0	-0	-0.	-0.	-0.	-0.	-0.
-0	-0	-0	51.960	.79821							
91	3.2000	65.930	1.4300	.82000 -1	174.00	153.80	9.4000	4.0500	.31000	2.0400	3.4300
.33000	.55000	14.490	.61000	7.5600	1.9200	80.000	9.8000	8.2000	.26000	.60000 -1	.80000 -1
.20000 -1	.11000	.80000 -1	.10000 -1	-0	-0.	2.0000	3.0000	110.00	3.0000	4.0000	3.0000
15.000	-0.	-0.	37.000	-0.	-0	-0.	53.000	85.000	59.000	31.000	4.5000
22.000	16.000	10.000	46.105	1.9167							
92	3.7000	19.240	1.0300	-0	151.00	65.430	5.2800	1.8800	.12000	.78000	.84000
.23000	.23000	4.8400	.45000	3.1100	.98000	107.90	21.500	5.3000	-0.	-0.	-0.
-0.	-0	-0.	-0.	-0.	-0	8.0000	3.0000	70.000	3.0000	6.0000	6.0000
25.000	-0	-0.	36.000	-0	-0	39.000	47.000	73.000	57.000	40.000	12.000
11.500	13.000	11.000	18.680	1.5563							
93	3.3000	47.650	1.4300	.65000 -1	132.00	137.44	15.110	5.1600	.45000	1.7300	2.8500
.46000	.59000	8.4300	.49000	6.0700	2.2700	72.800	9.4000	7.7000	.43000	.90000 -1	.90000 -1
.30000 -1	.26000	.14000	.10000 -1	-0.	-0.	2.0000	3.0000	60.000	3.0000	5.0000	4.0000
15.000	46.000	51.000	-0.	-0	-0.	36.000	51.000	91.000	61.000	44.000	4.0000
21.500	20.000	8.0000	33.322	1.3888							

94	3.9000	62.770	1.4100	.82000 -1	188.00	159.06	42.770	5.3500	.38000	1.6800	3.8900
.39000	.51000	10.580	.53000	6.1000	2.3200	78.800	9.4000	8.4000	1.1500	.90000 -1	.80000 -1
.20000 -1	.15000	.50000 -1	.10000 -1	-0.	-0.	4.0000	3.0000	210.00	1.0000	7.0000	6.0000
34.000	-0.	-0.	21.000	-0.	-0.	26 000	58.000	88.000	62.000	35.000	6.0000
23.000	15 000	9.5000	44 518	1.7344							
95	4.3000	13.890	.74000	-0	82.000	45.540	6.7500	2 8800	.38000	.33000	.39000
.12000	.80000 -1	4 1200	.33000	1.7500	.54000	86.000	12 600	6.8000	-0.	-0.	-0.
-0.	-0.	-0.	-0	.30000	.31000	6.0000	2.0000	95.000	1.0000	8 0000	6.0000
33.000	-0.	-0	-0	-0.	-0	-0.	48.000	77.000	52.000	40.000	11.500
12.500	14.500	9 5000	18.770	2.3543							
96	3.5000	63.850	1.1600	.89000 -1	96.000	122.38	14.230	4.0300	.38000	2.1300	6.1700
.64000	.85000	13.200	.53000	6 2900	1.4100	75.600	16.200	4.7000	.46000	.90000 -1	.10000
.30000 -1	.53000	.34000	.10000 -1	-0.	-0.	1.0000	4.0000	560.00	3.0000	2.0000	3.0000
12 000	17.000	-0.	-0.	15.000	-0.	-0.	62.000	82.000	50.000	36.000	10.250
20 750	10 000	8.5000	55.043	2 0986							
97	4.5000	62 540	1.4900	.14100	185.00	144.63	14.250	5.3800	.60000	2.5500	4.8700
.88000	.90000	12.580	.64000	8.0300	3.2300	84.800	13.800	6.1000	.40000	.80000 -1	.10000
.20000 -1	.18000	1.3300	.39000	-0.	-0.	4.0000	4.0000	530.00	3.0000	7.0000	2.0000
16 000	29 000	-0.	26.000	-0.	-0.	28.000	49.000	89.000	65.000	41.000	10.000
14.500	20 000	7.0000	41.973	1.5666							
98	3 6000	62.180	1.3200	.14700	112 00	131.65	16 940	4.2400	.47000	2.5400	5.3400
.99000	1.2900	10.300	.53000	9.2400	2 7400	83.200	18.000	4.6000	.46000	.12000	.17000
.70000 -1	.98000	.77000	.40000 -1	-0.	-0.	1.0000	4.0000	540.00	3.0000	3.0000	3.0000
15 000	30.000	-0.	29.000	-0.	-0.	26.000	55.000	81.000	62.000	32.000	5.0000
22.500	13.000	11.500	47.106	1.1147							
9[illegible]	4.7000	5.8800	.24000	-0.	17.000	28.930	9.5000	16.130	.13000	.18000	.19000
.19000	.80000 -1	1.7400	.11000	1.0700	.49000	84.000	14.000	6.0000	-0.	-0.	-0.
-0	-0.	-0.	-0.	.33000	.38000	4.0000	3.0000	60.000	1.0000	6.0000	6.0000
32.000	-0.	58.000	42.000	-0.	-0.	44.000	77.000	91.000	75.000	48.000	8.5000
30 000	7.0000	5.0000	24.500	1.6262							
101	3 5000	57.710	.76000	.65000 -1	111.00	112.42	7.2300	3.9800	.39000	3.1800	3.9800
.17000	.33000	10.830	.33000	6.2700	2.1200	68 200	9.8000	7.0000	.38000	.60000 -1	.80000 -1
.20000 -1	.16000	.12000	.10000 -1	-0.	-0.	2.0000	4.0000	270.00	3.0000	3.0000	3.0000
15.000	-0.	-0.	31.000	-0.	-0.	32.000	64 000	87.000	60.000	31.000	4.5000
27 500	11.500	11.000	75 934	1.7273							
102	3 6000	63.900	.92000	.57000 -1	74.000	167 14	29.570	3.9700	.30000	1.8100	5.1300
.20000	.35000	8 3300	.31000	7.4700	3 3600	72.800	9 2000	7.9000	.77000	.60000 -1	.70000 -1
.10000 -1	.60000 -1	60000 -1	.10000 -1	-0.	-0	2.0000	4.0000	280.00	3.0000	5.0000	4.0000
15 000	32 000	-0.	32 000	-0.	-0.	33 000	62.000	89.000	50.000	33.000	4.0000
27 000	13 500	10 000	69 457	1.1151							
103	4 4000	34 540	.75000	.11500	85.000	73 840	24.350	3.7200	.11000	1.7600	1.8700
.39000	.53000	7.0400	.30000	4.4200	1.3200	70.000	10.600	6 6000	1.4100	.35000	.12000
.15000	2.7600	1.8000	.40000	-0.	-0.	1 0000	3.0000	210.00	3.0000	5.0000	3.0000
24 000	-0.	-0.	-0.	-0.	-0.	-0	58 000	90.000	70.000	39.000	8.5000
20 500	16.000	7.0000	46.053	1.5928							
104	4.2000	37.000	.95000	.96000 -1	111.00	79.470	17.170	3 7800	.32000	1.6500	1.7600
49000	.46000	7.1800	39000	5.2800	2.5200	84 400	15.600	5.4000	.91000	.23000	.14000
.10000	1.4500	.97000	.60000 -1	-0.	-0.	1.0000	1.0000	70.000	3.0000	5.0000	4.0000
23.000	46.000	-0.	-0.	-0.	-0.	-0.	71.000	87.000	63.000	30.000	9.7500
25.750	8 0000	8.0000	38.847	1.3598							
105	4.6000	15.320	.54000	-0	58.000	48.870	10.750	4.8100	.53000	.83000	.67000
.18000	.17000	3.7300	.23000	1 8700	59000	171.30	35 200	5 1000	-0.	-0.	-0.
-0	-0.	-0	-0.	-0.	-0.	1.0000	1.0000	10 000	1.0000	3.0000	3.0000
25 000	36 000	-0	-0	-0.	-0.	-0.	68.000	88 000	66.000	37.000	13.250
20.750	10 000	7.0000	28.370	1.9947							
106	4 3000	64.180	1.4400	.54000 -1	70.000	174.44	45.000	17.030	1.5400	1.3800	2.0100
.14000	20000	15 300	.52000	4.5200	2.1600	101.90	12 800	8.2000	1.2400	.22000	.30000 -1
.40000 -1	.15000	.20000	.20000 -1	-0.	-0.	2 0000	1.0000	40 000	1.0000	8.0000	4.0000
16.000	-0	-0	39.000	-0.	-0	-0	-0.	-0.	-0	-0.	-0.
-0.	-0.	-0	44 569	3.3850							
107	5 4000	29 280	1 4900	-0.	58 000	125.49	38.750	24 250	2.7500	.38000	.18000
.14000	13000	7 6400	47000	3.0700	1.2200	96 000	13 800	7.0000	-0	-0.	-0.
-0	-0.	-0	-0.	.34000	.31000	8 0000	1.0000	10.000	1 0000	7.0000	6.0000
32 000	-0	-0.	28 000	-0.	-0.	-0.	81.000	90 000	69.000	37.000	12.000
28.500	4 5000	7.0000	19.651	2.4886							
108	3 4000	65 790	1.1400	.69000 -1	95 000	169 16	18.030	4.5800	.36000	2.4000	3.7400
.15000	.29000	12.990	.49000	6 5000	2.0000	87.200	10.800	8 1000	.44000	.60000 -1	.10000
10000 -1	.60000 -1	.10000	.20000 -1	-0.	-0.	2 0000	4.0000	310.00	3.0000	5.0000	3.0000
15.000	-0.	-0.	40 000	-0.	38 000	-0.	48.000	90.000	55.000	43.000	4.5000
19.500	21.000	8 0000	57 711	1.9985							
109	4.0000	62 450	1.1400	.63000 -1	89.000	160.81	27.680	5.2500	.38000	1.3400	1.3100
.17000	.21000	22 820	56000	5 6700	1 9900	79.200	9.4000	8.4000	.73000	.80000 -1	.60000 -1
.30000 -1	.25000	.60000	.10000 -1	-0.	-0	4 0000	4 0000	310.00	1.0000	6.0000	4.0000
16 000	-0.	-0.	33.000	-0.	29.000	31.000	70.000	83.000	52.000	30.000	6.5000
28.500	6.5000	9.0000	54.781	4.0247							
110	4.6000	63 970	1 7400	.13000	337.00	142 40	47.990	7 3200	.57000	2.4500	3.3000
.25000	.31000	10 990	55000	6 9000	1.8200	74 400	9 8000	7 6000	1.2700	.10000	.90000 -1
.20000 -1	.33000	.17000	.80000 -1	-0	-0.	4.0000	4.0000	310 00	1.0000	8.0000	6.0000
34 000	-0.	-0.	29 000	-0.	31 000	43 000	59 000	87.000	72.000	45.000	8.5000
21.000	14 000	8 0000	36 764	1.5928							
112	4 5000	27.890	3 5300	-0	158 00	90 800	18 000	2 6000	.30000	.90000	1.6800
37000	.26000	6 6300	.23000	4.3600	1 5200	77 800	10 800	7.2000	-0.	-0.	-0
-0	-0	-0	-0	.70000 -1	.18000	1 0000	3.0000	180.00	2.0000	2.0000	4.0000
22 000	33 000	-0	-0	-0	-0	-0.	69.000	90 000	70.000	35.000	8.5000
26 000	10 500	6.0000	7.9008	1.5206							

113	3.9000	14.970	2.3300	-0.	34 000	49.290	6.7500	2 0000	.18000	.43000	.81000
.11000	.15000	3 2500	17000	1.8600	.71000	122.80	25.000	4.9000	-0.	-0.	-0.
-0.	-0.	-0.	-0	.33000	.23000	1.0000	3 0000	180 00	2.0000	1.0000	3.0000
22 000	24 000	-0.	-0	-0.	-0.	-0.	86.000	92.000	68.000	40.000	10.000
23.000	13 000	7.0000	6.4249	1.7473							
114	4.9000	55 540	2 2900	.11600	114.00	172.40	76.060	6.5900	.38000	.46000	1.4900
.24000	.28000	21 410	1.0800	4.2400	1.4500	109.60	14 600	7.5000	2.0600	.13000	.80000 -1
.50000 -1	.78000	1.1500	.40000 -1	-0.	-0.	4.0000	3.0000	100.00	1.0000	8.0000	4.0000
34 000	-0.	-0.	-0.	-0.	-0.	-0.	65.000	84.000	63.000	30.000	13.000
19.500	9.5000	11 000	24.253	5.0495							
116	8.0000	83 840	1.8200	.18500	173 00	145.05	30.980	8 8500	.49000	3.1000	1.8400
1.0300	.67000	14.380	.74000	8.6300	3.6800	87 800	11.400	7.7000	.88000	.11000	.14000
.30000 -1	.35000	1.6200	.39000	-0.	-0	-0.	4.0000	370.00	3.0000	7.0000	4.0000
26 000	-0.	-0	-0	-0.	-0	-0.	61.000	84.000	68.000	39.000	7.0000
23.500	11.500	8.0000	29 582	1.6663							
117	3.4000	81.290	.95000	.10700	60.000	120.37	10 720	3 8100	.53000	2.8600	6.0800
.75000	.84000	8 8100	35000	7.5300	2 5400	62 200	9 6000	6.5000	.40000	.70000 -1	.12000
.40000 -1	.31000	.27000	.30000 -1	-0.	-0	2.0000	3.0000	175 00	3.0000	5.0000	3.0000
13 000	-0.	-0.	29 000	-0.	-0.	23 000	59.000	88.000	58.000	35.000	5.5000
24 000	14.500	10.000	64.516	1.3028							