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Hilary Thatcher

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Major professor

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THE RELATIONSHIP OF CHROMIUM AND SELECTED HEAVY METALS ON THE MICROBIAL COMMUNITY STRUCTURE IN SEDIMENTS

By

Hilary Thatcher

A THESIS

Submitted to
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ABSTRACT

THE RELATIONSHIP OF CHROMIUM AND SELECTED HEAVY METALS ON THE MICROBIAL COMMUNITY STRUCTURE IN SEDIMENTS

By

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The purpose of this research was to determine if chromium and selected heavy metals have a relationship the microbial community structure in sediments. Soils contaminated with chromium as a result of waste discharge from a former leather tannery afforded an opportunity to study these influences. Sediment samples were taken from diverse environmental settings and analyzed for total metal concentrations, chromium partitioning and microbial community structure. Terminal-Restriction Fragment Length Polymorphism (T-RFLP) analyses was conducted to determine the structure of the microbial community. Multivariate statistical techniques were used to examine the relationships among sediment geochemistry and microbial communities. The results show that the microbial community structure be related to 1) total chromium concentrations, 2) partitioning of chromium among soil phases and 3) total organic matter concentrations. Other elements did not seem to have a relationship with the microbial communities.

For my mother,

Susan R. Richards,

Thank you for all your help,

—H.J.T

ACKNOWLEDGEMENTS

I would like to thank several of my teachers and fellow students who have helped me over the past years. Foremost, among them was my advisor, David T. Long, who was very influential at several critical stages of my academic career. Others include: my thesis committee members, Terence L. Marsh and Graham Larson, and my fellow graduate student Gary Icopini, who provided technical guidance that helped me accomplish the goals of this research. Also, a special thank you to Robert L. Anstey who helped answer a number of statistical related questions. Several others assisted with laboratory work and sample analyses during this research. I thank them all.

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I. INTRODUCTION

In recent years bioremediation has been used as a remediation technique for dealing with contaminated sites. Bioremediation is the use of microorganisms to biotransform or degrade hazardous organic contaminants in soils, subsurface material, water, sludge's and residue to a form that is less toxic or less bioavailable. Although they cannot be destroyed or degraded, bioremediation techniques still can be used to remediate sites contaminated with metals. In such cases, the form of the metal in solutions (e.g., changes in redox state, complexing) can render the metal less toxic or the metal can be made immobile, biostabilized, in sediments and thus less bioavailable. Maintaining the integrity of the microbial population is essential for continued immobilization of metals in sediments. Thus, it is important to understand how the contaminant affects the microbial community in order for biostablization efforts to be successful. The purpose of this research is to examine how or if metal contaminant might influence the structure of a microbial community. The study site is a wetland that received chromium contaminated waste from a former leather tannery and offers a range of chromium concentrations that allows for the study of the relationship between metal contamination and microbial populations.

1.1 – Past Work

There are two aspects in understanding the interaction among metals and microbes; one aspect is the affect that microbes have on metal form and cycling, the other is the influence that metals have on microbial populations. The most studied of these is the specific influence microbes have on a form of metal. Microbes use metals as terminal electron acceptors in anaerobic respiration, which greatly influences the geochemistry of these metals (Lovely, 1995). One example of this influence is the microbial reduction of manganese (IV), which can serve to oxidize organic matter in contaminated aquatic sediments, and has the potential to reduce manganese minerals and the release of trace metals bound to manganese (IV) oxides (Lovely, 1993). Microbial oxidation of organic contaminants coupled to iron (III) reduction removes significant amounts of pollutants from many contaminated aquifers (Lovely, 1997). Some iron (III)-reducing microorganisms also can reduce contaminated metals and metalloids such as uranium, technetium, cobalt, chromium and selenium (Lovely, 1997). It was found that microbes could be used to remove uranium from uranium-contaminated waters and soils. Uranium can potentially be immobilized in subsurface environments by stimulating the activity of U (VI)-reducing bacteria (Lovely, 1997). Besides uranium, the microbial reduction of chromium (VI) to chromium (III) has been documented (Llovera et al., 1993; Shen and Wang, 1994). It is possible to bioremediate sites polluted with chromate or dichromate [chromium (VI)] by stimulating reduction of the chromium (VI) to chromium (III) by bacteria (Wang and Shen, 1995). A variety of bacteria are known to be able to reduce chromium (VI) to chromium (III) enzymatically (DeLeo and Ehrlich, 1994; Wang and Shen, 1995). Chromium (III) may hydrolyze and precipitate as a chromium-hydroxide or it may bind to the remaining soil organic matter (Palmer and Puls, 1994).

Few researchers have investigated the influence of metals on microbial populations. Kolesnikov et al., (1999) studied the effect of copper, zinc, cadmium, mercury and lead on the microbial system in chernozem, a grassland soil with a dark humic horizon more than 25 cm thick. The effect of copper, zinc, cadmium, mercury and lead concentrations on the microbial system in chernozem was studied in vegetative pots 3, 15, 30 and 180 days after contamination (Kolesnikov et al., 1999). They found that contamination by these heavy metals had a significant effect on the populations of the soil microorganisms and the structure of the microbial communities in chernozem, but the influence was not well quantified or understood (Kolesnikov et al., 1999). Ibekwe et al., (1998) tested if the toxicity of metals to plants and microbes depends on the chemical activities of metals in the soil. They found that there was a significant decrease of total cell counts of rhizobia bacteria when coupled with high levels on zinc (II) and cadmium (II).

Meyer et al., (1998) studied the effect of depleted uranium (DU) on soil function and functional diversity of bacterial communities. Depleted uranium, as defined by the Department of Defense, contains less that 0.3% of ^{235}U. Bench topsoil microcosms were used and constructed from 2-quart Mason jars. Mixed-bed ion exchange resin bags were placed in the bottom of each jar. These bags allowed for the indirect estimation of soil nitrogen availability in the microcosms via a LECO CHN-1000 Analyzer. Soil function and functional diversity were determined through the use of Biolog plates. Biolog plates are plates that consist of a number of wells containing tetrazolium dye, supernate from soil samples taken from the microcosms were combined with a potassium phosphate buffer (pH = 7) and placed in the wells. The Biolog plates were incubated in order for color development to occur. An intense color indicates that cell respiration took place. The results showed that DU reduced bacterial functional diversity when DU concentrations were greater then 500ppm.

From the above studies, there seems to be a growing body of evidence that metals can alter microbial community structure. Much of the work has been done in the laboratory. More fieldwork is needed to better understand metal-microbial community relationships. The previous studies also were based on total metal concentrations. The form of the metal and associated geochemical structure of soils and sediments are also likely to play a role in how metals influence microbial community structure. For example, questions that need to be address might include: how do total abundances of other associated elements and organic matter affect the microbial population, how does the partitioning of metals among the various phases of sediments change how metals influence the microbial community structure.

The purpose of this study is to gain insights into these questions by determining if and how the absolute abundances of chromium, the partitioning of chromium among soil phases, chromium's association with selected heavy metals and organic matter influence the microbial community structure in sediments. This is done by quantifying the amount of heavy metals in sediments, examining the microbial community structure and comparing the geochemical data with the microbial analysis through the use of multivariate data analysis (factor and cluster analyses).

II. BACKGROUND INFORMATION

2.1 – Study Site

The study site was located in Sault Ste. Marie, Michigan. This site was home to a leather tannery that operated from the 1890's to the late 1950's. Vegetation was abundant and the entire site was considered to be a wetland, see Figure 1 (Cannelton, 1999). The surface soil was abundant in organic matter and in a number of areas the soils have been described as peat (Cannelton 1992). The site was covered by waste produced from the tannery such as; scrap leather, hair, bricks, concrete, scrap wood, scrap metal, glass and cans (Cannelton, 1999).

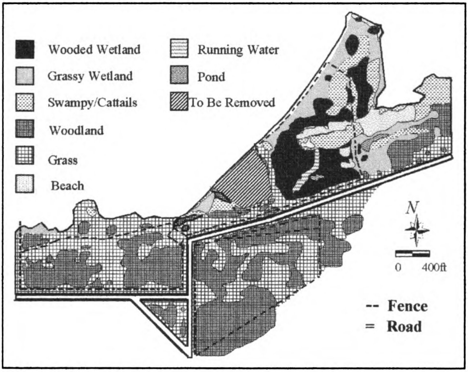


Figure 1. Map of the study site, showing the different vegetation types (modified from Icopini, 2000).

The tanning process used harsh chemicals when processing leather. Chemicals such as hydrochloric acid, dichromate salts and sodium hydroxide were used and resulted in waste containing high concentrations of chromic salts. The vats used were made of galvanized metal, which would result in liquid waste containing heavy metals (Ellis, 1998). Previous investigations at this site have concluded that the disposal of waste generated from leather tanning operations resulted in significant heavy metal contamination, especially chromium, of the near surface soils to a maximum depth of approximately six feet below land surface (Ellis, 1998). These investigations have also found chromium in the form of chromium (III), which is typically very insoluble (Cannelton, 1999). Previous soil speciation studies showed that chromium was predominantly extracted by the moderately reducible (MR) and basic oxidizable extractions (OX1) (Icopini, 2000). This was interpreted to indicate that the most likely form of chromium in the soils was either chromium hydroxide or chromium associated with organic matter (Icopini, 2000). The aqueous phase chromium concentrations in the surface and pore waters at the site were higher than would be predicted by inorganic thermodynamic calculations. These slightly elevated concentrations appear to be related to the formation of $Cr\text{-}DOC_{complexes}$ and the dominant form in the soils were $Cr(OH)_3$ (Icopini, 2000).

2.2 – Site Characteristics

An engineered embankment of boulders was installed along the entire shoreline of the site property in the early 1990's, to eliminate erosion and transport of heavy metals impacted soil from the site by the river flowing adjacent to the site. A 15-foot high ridge, extending east to west across the middle of the site, separates areas of higher elevation and lower elevation. As a result of the embankment and ridge, an extensive wetland, that was generally water-saturated throughout the year, had been created. Wooded and grassy wetland areas make up the bulk of the sampling area (Figure 2).

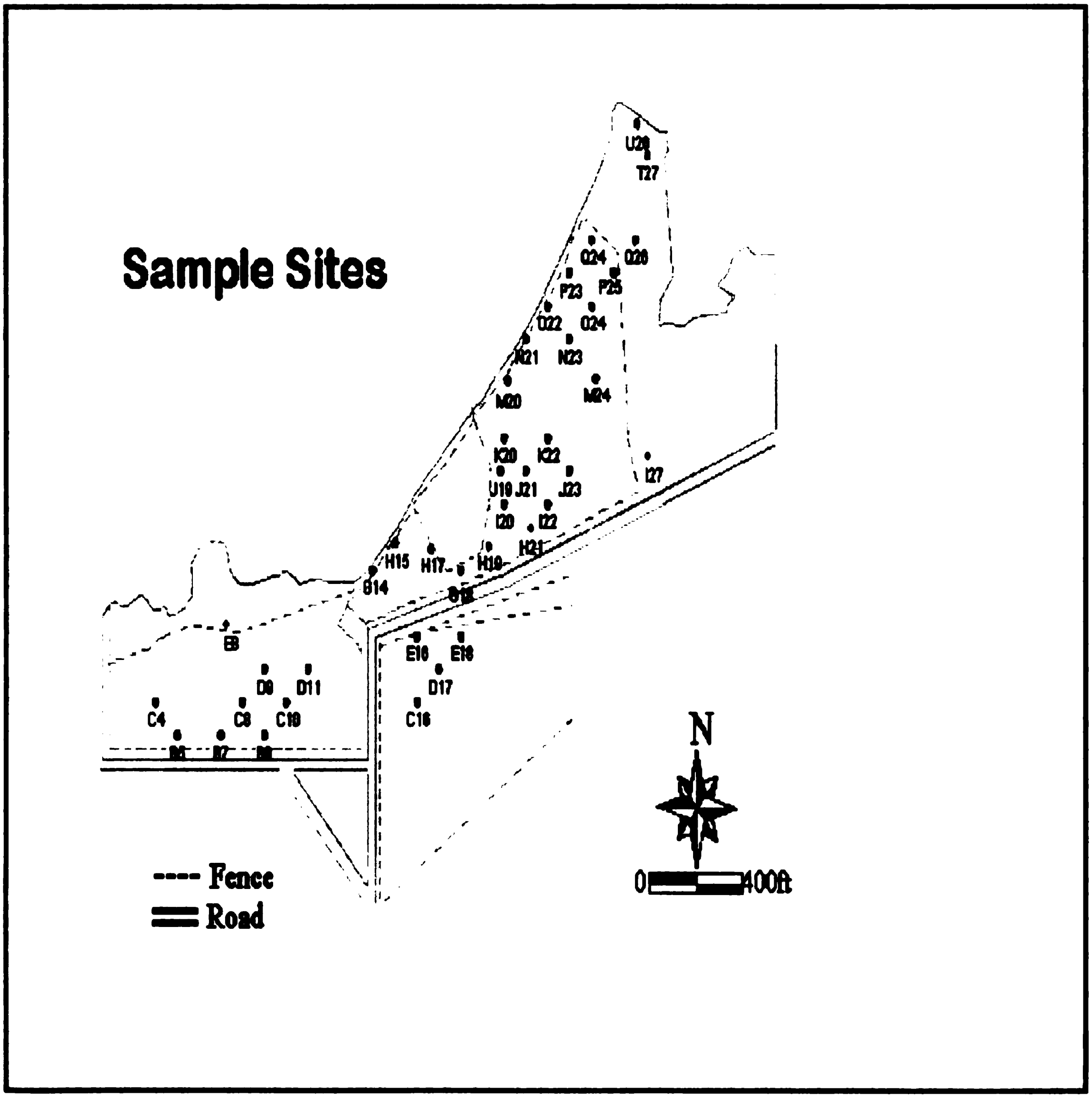


Figure 2. A map of the study site, showing sample sites and locations.

Soil types and textures at the site are spatially heterogeneous (Ellis, 1998). Descriptions of soil at the sample points are given in Table 1. The term soil in this study is used to describe the near surface unconsolidated geologic and detrital organic material in both upland areas and low-lying wetland areas of the site (Ellis, 1998). Soil textures were described in the field during collection of soil samples during the initial site characterization (Ellis, 1998) (Table 2). Samples were collected at the surface and at different depths. Sampling intervals below land surface were taken at depths of 1.0, 1.5, 3.0, 3.5, 4.5 and 6.0 feet. An AMS™ hand auger was used to remove intervening material between the sampling depths (Icopini, 2000). Samples were labeled according to site location and depth. Samples that were collected at the surface are identified by site location only. Some sample sites were collected more than once, these sample sites end in a Roman numeral.

Table 1. Soil descriptions for each sample site.

Site ID	Description	Site ID	Description	Site ID	Description
B5	Dark brown silty sand	**H17(V)1.5**	Saturated Organic matter and silty clay, dark brown	**M24 1.0**	Dark brown silt and decaying organic matter with chips of red brick
B7	Dark brown/black silty sand	**H17(V) 3.5**	Saturated Organic matter and silty clay, dark brown	**M24 3.0**	Tan coarse sand
B9	Dark rusty brown silty sand	**H19**	Black silty sand with clumps of white gravely material	**N21**	Very dark brown silt with lots of roots and other organic matter
C4	Dark brown silty sand, roots and wood chips	**H21**	dark brown silty sand grades to tan sand	**N21(II)1.5**	Very dark brown silt with lots of roots and other organic matter
C8	Black silty sand, with roots	**I20(II)**	Dark, brown organic rich silty sand with hides near bottom	**N23**	Dark brown organic matter with some silt
C10	Dark brown silty sand	**I20(II) 1-1.5**	Dark brown organic rich silty sand with tan and green gray hides with glass fragments and pebbles	**022(II)**	Dark brown organic rich silty sand with hair

Table 1 (cont'd). Soil descriptions for each sample site.

Site ID	Description	Site ID	Description	Site ID	Description
C16	Dark brown silty sand with roots	**I20(II) 3-3.5**	Reddish black gravelly sand with gray green areas and brick	**O22(II)1.5**	Dark brown silty sand with lesser OM and hair
D9	Dark brown silty sand	**I20**	Dark, brown organic rich silty sand with hides near bottom	**O22(II)3.5**	Dark brown silty sand grades to dark gray silty sand with wood. Water in the hole at about 2 ft.
D11	Top 4 in dark brown silty sand - bottom 2 in tan silty sand	**I22**	Very dark brown silt with lots of roots and organic matter	**O22(II)4.5**	Dark gray silty sand
D17	Dark Brown coarse sand w/pebbles, roots present, peat material	**I27**	Black/very dark brown silty sand with lots of organic matter	**O22**	Dark brown organic rich silty sand with hair
E8	Dark brown silty sand	**J19(III)3.5**	Reddish dark brown silty sand and tannery waste	**O24**	Very dark brown, organic rich silty with roots, water in the hole
E16	Dark rich organic coarse sand	**J19(III)6**	Reddish dark brown silty sand and tannery waste	**P23**	Dark brown organic rich silty sand with hair and roots

Table 1 (cont'd). Soil descriptions for each sample site.

Site ID	Description	Site ID	Description	Site ID	Description
E18	1st 4"-dk brown, organic rich coarse sand/pebbles, last 2"-dk green/green silty clay w/organic solvent smell	**J19(IV)**	Dark brown organic rich silty sand	**P25**	Very dark brown decaying organic matter, with some silt
G14	Dark brown silty sand grading into greenish gray silty sand	**J19(IV) 1.5**	Dark brown organic rich silty sand	**P25(II)**	Very dark brown decaying organic matter, with some silt
G18	Dark brown silty sand grading into greenish gray silty sand	**J19(IV)3.5**	Reddish dark brown silty sand and tannery waste	**P25(II) 1-1.5**	Very dark brown decaying organic matter, with some silt and hair
G18(II)	Dark brown silty sand grading into greenish gray silty sand	**J19(IV) 6.0**	Dark brown organic rich silty sand	**P25(II) 3-3.5**	Gray/ brownish sand
G18(II) 1-1.5	Dark brown silty sand grading into greenish gray silty sand	**J21**	Very dark brown organic rich silty sand with rusty tan silty sand	**Q24(II)1.5**	Brown silty sand with a lot of hair and other organic matter
G18(II) 3-3.5	Dark brown silty sand grading into greenish gray silty sand	**J23**	Very dark brown to red brown organic silt with lots of roots	**Q24(II)3.5**	Brown silty sand with a lot of hair and other organic matter

Table 1 (cont'd). Soil descriptions for each sample site.

Site ID	Description	Site ID	Description	Site ID	Description
H15	Black/dark brown silt with lots of organic matter	**K20**	Very dark brown silt with lots of roots and organic matter, wet	**Q24**	Dark Brown organic rich silty sand
H17 (I)	dark brown silt and organic matter, very moist	**K20(II)1.5**	Wood	**Q26**	Black mud, rich detrital clay
H17 (II)	dark brown silt and organic matter, very moist	**K22**	Very dark brown/black organic rich silt with lots of roots, wet	**T27**	Very dark brown silt, organic rich with roots and hair
H17 (III)	dark brown silt and organic matter, very moist	**K22(II)**	Very dark brown/black organic rich silt with lots of roots, wet, hit wood	**U26**	Brown sand
H17(IV)	dark brown silt and organic matter, very moist	**M20**	Dark, brown organic rich silty sand, bottom 2" Rusty tan silty sand	**M20**	Dark, brown organic rich silty sand, bottom 2" Rusty tan silty sand
H17(V)	Dark brown silt and organic matter, very moist	**M24**	Dark brown silt and decaying organic matter	**M24**	Dark brown silt and decaying organic matter

III. METHODS

3.1 – Site Locations and Sample Collection

Soil sampling locations were located by designing a sampling grid that covered the entire site (Ellis, 1998). A GIS analysis was performed on a preexisting data set (Cannelton, 1992; Cannelton, 1995) to determine the optimum spacing between sampling locations and led to the development of the sampling grid used in this study (Icopini, 2000). An existing local datum was used as the starting point for the grid. The sampling locations were then established by measuring distances with surveying equipment and a 200-ft. steel tape from known positions (Icopini, 2000). Once located, each sampling location was marked with a labeled wooden stake. The locations of the 74 sampling sites that resulted are shown in Figure 2.

Soil samples were placed in 125ml specimen sample cups and frozen until analyses. Soil samples were taken at varying depths at each sampling node. In order to accomplish this, soil cores were collected with an AMS™ stainless steel, split spoon, coring device, with two-inch diameter, plastic core liners to contain the sample (Icopini, 2000). Sampling intervals below land surface were taken at depths of 1.0, 1.5, 3.0, 3.5, 4.5 and 6.0 feet.

3.2 – Clean Procedures

The water that was used for preparing solutions, reagents, and washing glassware was distilled deionized water (DDW). All the glassware that was used for making standards and reagents was rinsed three times with DDW, acid-washed in 10 % HCl for

24 hours then rinsed three times with DDW, and soaked in DDW for 24 hours. Items were then placed into containers, which were then placed into a class 100 hood until dry. Nucleopore polycarbonate membrane filters (0.4 micrometer (μm)) were used for filtering extraction leachate from samples. These filters were cleaned in dilute HNO_3 for 24 hours, then rinsed with DDW and soaked in DDW until use.

3.3 – Total Chemical Extractions

Total chromium, iron and manganese concentrations were determined using a Perkin-Elmer 5100 Atomic Absorption Spectrophotomer (AAS) Flame. Other elements were determined by inductively coupled plasma mass spectrometry (ICP-MS). The instrument was a Micromass Platform with hexapole technology. This technology allows for the determination of elements such as arsenic, not easily determined by more traditional ICP-MS technologies. The other elements included potassium (K), chromium (Cr), manganese (Mn), iron (Fe), barium (Ba), magnesium (Mg), vanadium (V), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), strontium (Sr), cadmium (Cd), lead (Pb), aluminum (Al), selenium (Se), scandium (Sc), titanium (Ti), mercury (Hg) and calcium (Ca). Analyses were done in the Geological Sciences Laboratory at Michigan State University.

Calibration standards for sample analyses were prepared using DDW and the extraction chemicals to form the background matrix and certified 1000 milligrams per liter (mg/L) stock solutions. Necessary dilutions of leachate samples were prepared to maintain similar matrices between samples and standards. All chemicals used were analytical metal grade. Analytical precision, in terms of the relative standard deviation, was set at less than 15 % for all AAS. Analytical accuracy was assessed by comparison to National Institute of Standards and Testing (NIST) standard reference materials (SRM). Standard calibration curves were compared to SRM 1643c or 1643d (Trace Elements in Water) values, which were required to be within 15 % of certified values (Ellis, 1998).

The following was the method that was used for total metal analysis, digestions were conducted by Shane Snavley:

1. Dried samples were placed into ceramic mortar and ground into a fine powder with a pestle. Approximately 0.500g of sample was then weighed into a Teflon digestion vessel. This was repeated for each sample. Mortar and pestle were rinsed with DDW in between each grinding of sample in order to prevent cross contamination.
2. Ten milliliters of 15N HNO_3 was added to each Teflon vessel. Caps were screwed onto each Teflon vessel and a pressure monitor was attached to any sample that was not a blank.
3. The vessels were placed into a tray that was then rotated inside a CEM MDS-81D microwave. The microwave was then programmed to run for 15 minutes at 100% maximum power with pressure regulated to a 150 psig maximum followed by a 20 minute (0% power) cool down period to allow pressure in the vessels to fall below 10 psig. A CEM MDS-81D microwave with pressure regulation was used for digestions.

4. After digestion was completed 50ml of DDW was added to each vessel and mixed thoroughly. Samples were then filtered through a 0.4um Nuclepore filter into 60ml acid washed bottle.

3.4 – Solid Phase Organic Carbon Content

The organic carbon content of the soils was determined by a loss on ignition method. Organic matter content was determined on sub-splits of homogenized soil taken prior to the sequential chemical extractions (Icopini, 2000). The method was modified after a procedure developed by researchers from the Department of Soil Science at the University of Wisconsin, Madison, WI (Shulte et al., 1991). Analyses were done in the Plant and Soil Testing Lab at Michigan State University.

3.5 – Sequential Chemical Extractions

Selective chemical extractions were used to remove metals associated with different phases of soils. These extractions are designed to target specific phases within the sediment such as carbonate minerals. Chemical extractants were applied to a soil sample in sequence starting with the least aggressive extractant (Icopini, 2000). The extraction phases are as follows (Table 2): exchangeable (EX) (metals bound to exchange sites on clays), weakly acid soluble (WAS) (metals associated with carbonates), easily reducible (ER) (metals associated with manganese-oxides), moderately reducible (MR) (metals associated with Fe-oxides), basic oxidizible (OX1) (metals associated with organic matter) and acid oxidizible (OX2) (metals associated with sulfides). The sequential chemical extraction procedure (Table 2) used to determine heavy metal speciation in this study was similar to that developed by Tessier et al., (1979), with modifications by Belzile et al., (1989) and Matty (1992).

Chromium concentrations in the sequential chemical extractions were determined using a Perkin Elmer 5100 Atomic Absorption Spectrophotometer. Calibration standards for sample fluid analyses were prepared using DDW and the extraction chemicals to form the background matrix and certified 1000 milligrams per liter (mg/L) stock solutions (J.T. Baker Analyzed). All chemicals, reagents and blanks used were analytical metal grade or better.

Table 2. Sequential Chemical Extractions Procedure.

Extraction Phase	Target Substrate	Solution used in Extraction	Extraction Parameters
Exchangeable (EX)	Exchange Sites On Clay	1.0M $MgCl_2$, pH 7 10 mL	20°C, 1 hour
Weakly Acid Soluble (WAS)	Carbonates Minerals	1.0M NaOAc, pH 5 10 mL	20° C, 5 hours
Easily Reducible (ER)	Manganese- Oxides and Reactive Iron-Oxides	0.1M NH_2OHHCl in 0.1M HNO_3 25 mL	25° C, 5 hours
Moderately Reducible (MR)	Crystalline Iron-Oxides	0.04M NH_2OHHCL v/v 25%HOAc 20 mL	96° C, 6 hours
Basic Oxidizable (OX1)	Organic Matter	NaOCl, pH 9.5 3 times, 6 mL then 3.2M NH_4OAc 5 mL	96° C, 15 min. 25° C, 1 hour
Acid Oxidizable (OX2)	Sulfides	0.02M HNO_3 3 mL 30% H_2O_2, pH2 8mL 3.2M NH_4OAc 5mL then add DDW to make 25mL	85° C, 5 hours 25° C, 1 hour

3.6 – Microbial Analysis

DNA Extraction for T-RFLP:

Community DNA was extracted from soil using Soil DNA Isolation kits from MoBio™ and procedures recommended by the vendor. 0.25--5 g of soil was added to the lysis buffer and incubated at 70°C for 5 minutes. The sample was vortexed for 10 seconds followed by a second incubation at 70°C for 5 minutes. The remainder of the protocol was as described by the vendor. Generally, DNA extracted using this procedure was of sufficient quality for amplification with standard PCR protocols.

Purification of DNA:

If necessary, extracted DNA was further purified on 1% low melting point agarose (Boehringer Mannheim). This step effectively separates humics from genomic DNA and yields DNA of uniform purity. The band containing genomic DNA was excised, the agarose was digested with agarase (Boehringer Mannheim) according to manufacturer's protocol, and the DNA was separated, washed, and concentrated in a Microcon-100 column (Amicon, Inc. Beverly, Mass).

PCR Amplification and Purification of PCR products for T-RFLP:

The primers used for T-RFLP analysis were the 27-forward Hex-labeled "eubacterial" primer; 5'-AGA GTT TGA TCC TGG CTC AG (Operon Inc.), and the 1392 reverse, 5'-ACG GGC GGT GTG TRC (Operon Inc.). PCR amplifications were performed in a final volume of 100 μl under the following conditions; 1.25-2.5 units of Gibco-BRL Taq polymerase and 1x buffer supplied by the vendor, 3mM $MgCl_2$, 0.5 μM EU8F hex, 0.25 μM 1392R, 0.25mM dNTP's, 4ng/μl BSA, and 10ng to 100ng of community DNA per reaction. Amplification was performed in either a PE 9600 or PE

2400 thermocycler programmed with the following parameters; a pre-cycle soak at 94°C for 4 minutes followed by 35 cycles of 94°C for 30 seconds, 60°C for 30 seconds, and 72°C for 1.5 minutes, terminated with a 10 minute extension at 72°C. PCR product was purified with Promega Wizard PCR Preps according to the vendor's protocol. DNA was washed off the column with 60µl of water and quantitated spectrometrically at 260nm.

Restriction digests:

Restriction digests were performed using Rsa I, Hha I, and Msp I from Gibco-BRL according to manufacturer's guidelines. 200-400 ng of PCR product was digested in a 20µl volume with 15 U of enzyme for not more than 3 hours.

Sequencing gel parameters for T-RFLP:

Restriction digests of PCR amplified community DNA were denatured at 94°C, chilled and loaded onto a 36-cm, 6% denaturing polyacrylamide gel. Electrophoresis was for up to 20 hours in an ABI automated sequencer (model 373A, Applied Biosystems Instruments, Foster City, Calif.) run in GeneScan mode with limits of 2,500V and 40 mA. Each lane included both sample and ABI Tamara 2500 size standards (Liu et. al, 1997). The determination of terminal restriction fragment sizes was made with reference to the internal size standards by the vendor provided software (GeneScan 2.1).

T-RFLP data analysis:

Initial analysis of the ABI gels was performed with GeneScan 2.1 software from ABI. In general, the differences in fragment sizing between gel lanes was usually less than 0.5 base although extended reads and gel anomalies could increase differences up to 1.0 base. Lanes were aligned one to another using the terminal fragments common to all lanes as conserved landmarks similar to a conserved sequence island in a gene. Dr. Terence L. Marsh at the Center for Microbial Ecology conducted the T-RFLP analysis.

3.7 – Multivariate Statistical Modeling

Two types of multivariate statistical approaches were used in this study, factor analysis and cluster analysis. Factor analysis was used to establish relationships among the metal concentrations and the microbial communities. The analysis was done on three variations of the data 1) absolute concentrations, 2) logarithmic (data transformed logarithmically in attempt to account for log-normal distributions, and 3) ranked (a non-parametric study). It was considered that absolute differences in metal concentrations might be important in microbial processes; therefore, the results and interpretations of this study are presented in absolute concentrations. Factor analysis is a multivariate statistical technique that is designed to reduce the number of variables in the system and combines variables that behave similarly into "factors" (Rummel, 1968). The two types of factor analysis that were used in this study are Q-mode and R-mode. Q-mode factor analysis was used to analyze the data sets (total metal concentrations and chromium partitioning among the sediment phases) and to divide samples into groups that were similar in terms of their variables. R-mode factor analysis was used to analyze the data sets, which divides variables into similar groups rather than samples. These analyses were done using SAS™ for personal computer and followed techniques outlined by Long et al., (1992).

Cluster analysis was performed on both total and sequential chemical extraction data sets to identify homogenous subgroups within the data set. Hierarchical cluster analysis joins the two "closest" samples as a cluster and continues joining a sample with another sample, a sample with a cluster or a cluster with another cluster until all samples are combined into one cluster. A Ward-Euclidean joining algorithm was used to define how distances between clusters were measured. Ward's method averages all distances between pairs of samples. The Euclidean distance is the "total geochemical difference" between any two samples, the distance matrix is then clustered using an algorithm that searches the matrix for pairs of samples that are most closely related, then iteratively adds samples to these closely related samples by collapsing the matrix as samples are added to clusters. The final result was a tree that groups samples into clusters. The analysis was done using SYSTAT™.

The microbial data were clustered using a program called Paup™ for MacIntosh by Sinauer Publishing. The data entered into Paup™ were in binary form. Maximum likelihood was the statistical approach used for the microbial cluster analysis. This technique searches for and finds the tree that maximizes the probability of observing the tree obtained from the data (Burlage, 1998). This approach was the most analogous to that used by SYSTAT™ for the geochemical cluster analysis.

The geochemical cluster trees were then compared with the microbial cluster trees to determine if clusters could be matched between the two types of data. This posed a slight problem because the two data types were not clustered using the same clustering program due to the differences in the nature of the data sets, the geochemical data was non-binary data, where as, the microbial data was binary. Attempts made to cluster both data sets in one cluster program were unsuccessful. NEXUS™ (Page, 1998) is a program that has the potential to not only cluster both binary and non-binary datasets, but also compare the results. However, formatting the rather complicated binary data from the microbial analysis, to import into the program was unsuccessful. Thus, comparisons of the results from the clustering of the geochemical and microbial datasets were done visually, but informed by study of geochemical trends.

V1. RESULTS AND DISCUSSION

4.1 – Total Extraction Results

Table 3 shows total concentrations of chromium, iron, and manganese and percent organic matter (OM) in the soils. Chemical concentrations for other elements are shown in Table A-1, Appendix . Iron, manganese and organic matter are singled out in Table 3 because they are known to influence the cycling of chromium. Iron oxides and particulate organic matter can sequester chromium (Takacs, 1988). Some iron (III)-reducing microorganisms can reduce chromium (Lovely, 1997). The oxidation of Cr(III) to Cr(VI) by Mn-oxides has also been demonstrated in a number of studies (Schroeder and Lee, 1975; Bartlett and James, 1979; Takacs, 1988; Eary and Rai, 1987). Dissolved organic matter can complex chromium(III), which increases the solubility of chromium(III) in soil environments (James and Bartlett, 1983a,b; Davis et al., 1994; Walsh and O'Halloran, 1994 a and b).

The results of the total concentrations from this study are similar to those from the earlier study at the site (Ellis, 1999). Concentrations for chromium show great variability from sample to sample, ranging from approximately 9 ppm (sample B5) to 282,000ppm (sample H17 (V) top). The average concentration for chromium is 25,000ppm. Sample J19 (III) 3.5 has the lowest concentration of manganese equaling 16.4 ppm and I20 (II) 1-1.5 contains the highest amount at 1,680 ppm. The average concentration for manganese is 307ppm. Sample J19 (III) 6 has the least amount of iron (2,930 ppm) found in the sample set and sample E18 has the highest concentration at 35,800 ppm and an average concentration of 10,600ppm. Organic matter was not obtained for all the samples sites. The sample with the highest percent organic matter is N21(III)1.5 containing 71% and the lowest is G18(II)3.5 with 0.20%. The average for organic matter is 28%.

The relationships among iron, manganese and organic matter with chromium were illustrated in a x-y scatter plot (Figure 3), constructed using the data in Table 3. The figure shows that as organic matter concentrations in the soils increase, chromium concentrations also increase. Chromium concentrations do not appear to be directly related to iron or manganese concentrations in the sediments. The scatter plot show that there is a direct relationship with organic matter and chromium concentrations. It is possible that not only chromium may have an association with the microbial population but a combination of organic matter and chromium.

Table 3. Total concentrations of chromium, iron and manganese in sediment samples. Percent organic matter is given in column four. A dashed line indicates that there are no data for that sample.

Samples	Chromium ppm	Manganese ppm	Iron ppm	Organic Matter (%)
B5	8.88	134.13	4730.00	4.90
B7	22.22	267.87	8909.62	6.10
B9	12.73	76.26	9333.89	1.60
C4	47.27	130.38	7202.92	4.70
C8	47.64	198.15	10642.80	7.40
C10	18.19	200.32	7639.34	6.30
C16	14.95	165.44	9818.63	10.00
D9	49.12	157.89	15622.50	6.60
D11	90.14	188.98	8369.87	-----
D17	5465.07	372.71	25032.81	29.20
E8	170.08	141.00	8710.76	1.80
E16	1192.81	412.46	23576.56	34.00
E18	27830.48	508.90	35832.04	13.80
G14	22134.39	956.78	27936.38	37.10
G18	765.05	278.44	6613.49	-----
G18(II)	493.61	258.91	6888.98	6.90
G18(II) 1.5	20.98	77.74	6082.38	1.10
G18(II) 3.5	12.00	79.76	7652.80	0.20
H15	24715.12	283.87	8463.06	30.50
H17 (I)	137620.87	414.75	7169.78	40.60
H17 (II)	135355.32	410.64	7295.87	-----
H17 (III)	141518.58	379.41	7624.28	-----
H17(IV)	120383.58	909.59	6120.02	-----
H17(V)	281551.80	590.96	3060.67	34.20
H17(V)1.5	237170.11	364.51	4579.17	30.70
H17(V) 3.5	9881.40	542.44	10523.26	25.90
H19	451.87	574.50	9238.98	19.90
H21	29.54	115.94	7276.12	2.00
I20(II)	308.00	532.32	23785.89	34.50
I20(II) 1.5	506.65	1680.50	30630.32	44.00
I20(II) 3.5	1971.33	1555.38	26300.08	50.10
I20	451.60	685.66	30742.01	44.80
I22	20556.33	74.20	8114.47	-----
I27	31660.56	120.32	8423.48	-----
J19 (I)	29137.90	354.33	21484.28	47.40
J19(II)	31543.52	128.82	11568.28	27.20
J19(III)1.5	80186.17	19.03	3421.73	46.00
J19(III)3.5	35000.00	16.43	4063.38	70.60

Table 3 (cont'd). Total concentrations of chromium, iron and manganese in sediment samples. Percent organic matter is given in column four. A dashed line indicates that there are no data for that sample.

Samples	Chromium ppm	Manganese ppm	Iron ppm	Organic Matter (%)
J19(III)6	11001.40	50.29	2926.01	59.20
J19(IV)	23924.00	140.21	13412.54	19.5
J19(IV) 1.5	30479.41	36.88	4031.96	-----
J19(IV)3.5	24917.23	28.82	5081.55	-----
J19(IV) 6.0	31083.28	27.05	4430.81	-----
J21	3795.37	305.54	7748.67	43.50
J23	38640.74	47.78	13184.03	53.40
K20	23589.15	771.49	10031.16	63.80
K20(II)1.5	50494.50	582.76	10488.52	60.40
K22	7149.65	311.57	10635.76	66.40
K22(II)	4027.41	131.14	8370.44	62.80
M20	439.00	127.99	10186.10	1.70
M24 0.5	90.55	141.96	7302.38	3.20
M24 1.0	18.76	116.84	9315.37	1.10
M24 3.0	33.14	652.09	8907.11	11.00
N21	21121.16	607.35	10792.04	55.50
N21(II)1.5	23659.54	284.70	7551.81	72.00
N23	11252.17	268.55	17806.85	58.30
022(II)	13398.74	339.21	7516.48	37.80
O22(II)1.5	32387.79	161.70	9922.20	30.10
O22(II)3.5	5421.46	94.98	5980.26	5.10
O22(II)4.5	697.77	61.64	4698.39	3.00
O22	850.03	47.97	3436.46	1.60
O24	12984.80	700.43	14482.67	46.90
P23	6842.60	177.23	5013.90	22.60
P25	5768.45	161.07	10542.39	51.40
P25(II)	10565.25	182.04	11592.30	55.00
P25(II) 1.5	6127.77	159.83	10777.45	-----
P25(II) 3.5	1646.16	69.12	6263.66	17.90
Q24(II)1.5	16393.91	93.63	6562.50	23.80
Q24(II)3.5	3853.83	60.01	6570.73	5.30
Q24	17536.61	236.63	9912.94	27.80
Q26	638.40	583.86	13907.87	18.30
T27	648.07	117.27	5584.60	0.60
U26	2435.13	180.47	9702.03	9.60
Average	24963.13	307.12	10618.50	27.55

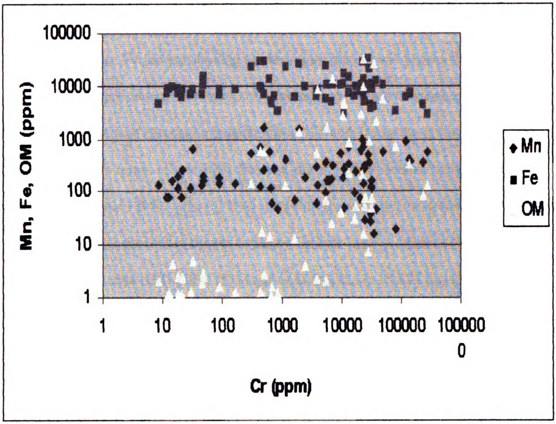


Figure 3. X-Y scatter plot comprised of total concentrations of chromium, iron and manganese. Scales are logarithmic. Organic matter is represent by OM in the legend.

4.2 – Sequential Chemical Extraction Results

The results for the partitioning of chromium among soil phases for samples at each sample site are shown in Table 4. A pie diagram (Figure 4) was constructed using the average percent of chromium in each phase to characterize the general partitioning in the study area. In terms of any other fraction, chromium associates more with the moderately reducible (MR) phase (70%) than with the weakly acid soluble (WAS) phase (14%). Chromium percent in the other phases include basic oxidizable (OX1) phase (7%), easily reducible (ER) phase (5%) and acid oxidizable (OX2) phase (4%). The exchangeable (EX) phase has significantly less chromium associated with it (0.4%).

The results (Table 4) indicate that there is great variation of range for chromium concentrations within each phase. Sample B5 has the lowest amount of concentration of chromium associated with the MR phase that of 2.640 ppm and sample H17 (I) has the highest with 55,500 ppm. The sample containing the least amount of chromium associated with the WAS phase is again B5 (0.182 ppm) and the highest amount is sample J19(IV)3.5 with 27,800 ppm. For the OX1 phase concentrations range for 0.007 ppm (sample C4) to 9,530 ppm [sample H17 (I)] and the ER phase ranges from 0.098 ppm (B9) to 3,000 ppm [H17(V) 1.5]. The EX phase has the least amount of chromium which ranges from 0.025 ppm (sample E8) to 765 ppm [H17 (V) 1.5].

Chromium partitioning results for samples taken two years prior (Ellis, 1999) show similarities when compared with the current study. Results from the previous study also found that very little chromium was associated with the EX and OX2 phases (Icopini, 2000). The earlier study also found that chromium associated more with the MR phase (49%) than the OX1 phase (41%) (Icopini, 2000). Chromium is associated less with the ER and WAS phases, 6% and 3%, respectively (Icopini, 2000). However, there are differences between the data presented here and that of the past study. For example, the MR phase was found to contain a higher percent of chromium then previously found. Another, difference concerns the percent chromium for the MR and OX1 phases. The current study found chromium to associate more to the MR phase (70%), than the WAS phase (14%) followed by the OX2 phase (7%) where as the previous study found chromium associating more with the MR phase (49%) than the OX1 phase (41%) followed by the ER phase (<6%). The WAS phase had twice the amount of chromium (14%) compared to 7% found in the previous study. These differences could be a result of the dataset being a subset of samples from the original dataset, because the original dataset contained additional samples, this could compromise the overall results when compare with the dataset in the current study.

Although the distribution of chromium among the different phases of the sediment can be observed from the results of the extractions, making interactions as to what these fractions are is not necessarily a straightforward procedure. Sequential chemical extractions were intended for systems exposed to oxygen (oxic systems) (Tessier, 1979). For interpreting metal associations with the EX, WAS, and OX1, which theoretically attack metals bound to exchange sites on clays, metals associated with carbonates and organic matter respectively; the knowledge of the oxidation state of the environment is not a factor. However, this is not the case for the MR, ER, and OX2 phases. In oxic systems, redox sensitive metals (iron and manganese) exist in oxidized forms and precipitate out from solution as oxy-hydroxides (Baes and Mesmer, 1976). Many samples in this study were taken from a system that lacks oxygen (anoxic system) in which iron and manganese oxy-hydroxides (ER and MR phases) are thermodynamically unstable. Therefore, it is assumed that iron and manganese oxy-hydroxides do not exist under anoxic conditions. Thus, it is unclear what phase of the sediment is being attacked by the ER and MR leaches.

The geochemical behavior of chromium affords some insight into this problem. In a soil system, such as the study site, the abundance of organic matter and lack of manganese oxy-hydroxides create an environment in which the most common form of chromium will be chromium (III) (Palmer and Puls 1994). Chromium (III) is highly insoluble, precipitating out of solution as $Cr(OH)_3$ (Bartlett and Kimble, 1976; Palmer and Puls, 1994; Rai et al. 1989). This solid however is made soluble with the solutions used in the MR extraction. Considering the chemistry of the solutions used in the selective chemical attacks, and the knowledge of the geochemical behavior of chromium; it can be concluded that a dominant form of chromium in the soils at the study site is a $Cr(OH)_3$ mineral/amorphous solid (Cannelton, 1999). The conclusion that can be drawn from these results is that chromium is associated with the MR phase of the soil. The ER phase contributes only minor amounts of chromium. Previous work could not be found which demonstrates that chromium forms sulfide minerals (the OX2 phase) so little chromium should be found to associate with this phase (Icopini, 2000).

In summary, the major phases controlling the partitioning of chromium in the soils at the study are the MR and OX1, which are most likely chromium hydroxide and chromium associated with organic matter respectively. This is expected and is a pattern that has been shown for other environments (Gephart, 1982; Rezabek, 1988). The role of iron oxides in sequestering chromium in the oxic soils at the site is unclear.

Table 4. Sequential chemical extraction data for chromium. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2). The dashed line indicates that there is no data for that sample.

Sample	EX	WAS	ER	MR	OX1	OX2	Total
	Cr	Cr	Cr	Cr	Cr	Cr	Cr
	ppm	ppm	ppm	ppm	ppm	ppm	
B 5	0.031924	0.18218	0.142656	2.638068	0	--	2.994828
	1.07%	6.08%	4.76%	88.09%	0.00%	--	
B 7	0.073304	0.622206	0.455132	6.298874	0.010601	0.473787	7.933904
	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%	
B 9	0.05159	0.21597	0.098373	3.762425	0	--	4.128358
	1.25%	5.23%	2.38%	91.14%	0.00%	--	
C 4	0.061367	0.844724	0.456575	5.646527	0.007328	0.274974	7.291495
	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%	
C 8	0.061128	0.784006	0.320269	4.869343	0.013122	0.32053	6.368398
	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%	
C 10	0.111688	0.923846	0.585682	9.130438	0.054877	--	10.80653
	1.03%	8.55%	5.42%	84.49%	0.51%	--	
C 16	0.13591	2.89284	4.520062	11.95762	0.034071	0.529566	20.07007
	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%	
D 9	0.054493	1.270878	0.862647	11.93827	0.072296	0.525897	14.72448
	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%	
D11	0.100259	1.126425	1.495744	13.94724	0.0754	0.841288	17.58636
	0.57%	6.41%	8.51%	79.31%	0.43%	4.78%	
D 17	1.415684	21.729	50.71538	1233.836	3.144351	120.5969	1431.437
	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%	
E 8	0.025441	0.935145	1.890918	39.02167	0.128912	0.359704	42.36179
	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%	
E 16	0.277588	3.312904	2.603314	466.8115	0.92945	27.03728	500.972
	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%	
E 18	2.277007	34.80456	94.28317	5333.369	22.27881	504.0278	5991.04
	0.04%	0.58%	1.57%	89.02%	0.37%	8.41%	
G 14	4.281975	274.6354	2448.637	10817.13	4.559789	20.24121	13569.49
	0.03%	2.02%	18.05%	79.72%	0.03%	0.15%	
G 18	0.218475	5.2501	6.248742	303.6426	0.445801	--	315.8057
	0.07%	1.66%	1.98%	96.15%	0.14%	--	
G 18 (II)	0.314323	8.546558	6.903985	271.9403	0.306556	0.779096	288.7908
	0.11%	2.96%	2.39%	94.17%	0.11%	0.27%	
G18(II)1.5	0.058	5.599909	1.678689	17.39124	0	0.5634	25.29124
	0.23%	22.14%	6.64%	68.76%	0.00%	2.23%	

Table 4 (cont'd). Sequential chemical extraction data for chromium. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2). The dashed line indicates that there is no data for that sample.

Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**	**Total**
	Cr	**Cr**	**Cr**	**Cr**	**Cr**	**Cr**	**Cr**
	ppm	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	
G18(III)3.5	0.050797	0.425849	0.409199	4.289532	0	0.800525	5.975902
	0.85%	7.13%	6.85%	71.78%	0.00%	13.40%	
H15	4.985394	140.3759	2406.469	9587.161	4.214198	9.08475	12152.29
	0.04%	1.16%	19.80%	78.89%	0.03%	0.07%	
H17(I)	31.17031	277.8103	306.1469	55467.6	9526.948	1213.336	66823.01
	0.05%	0.42%	0.46%	83.01%	14.26%	1.82%	
H17(II)	26.61341	296.3961	283.5029	53623.98	8950.866	956.6184	64137.98
	0.04%	0.46%	0.44%	83.61%	13.96%	1.49%	
H17(III)	23.96097	283.9987	336.6095	34380.88	8171.495	667.113	43864.06
	0.05%	0.65%	0.77%	78.38%	18.63%	1.52%	
H17(IV)	8.923598	326.9915	273.7736	27519.6	9107.694	119.8424	37356.83
	0.02%	0.88%	0.73%	73.67%	24.38%	0.32%	
H17(V)	21.29106	227.5172	1019.277	40170.44	5646.294	14.3279	47099.15
	0.05%	0.48%	2.16%	85.29%	11.99%	0.03%	
H17(V) 1.5	764.601	7939.782	3000.245	51608.58	4971.693	240.1288	68525.03
	1.12%	11.59%	4.38%	75.31%	7.26%	0.35%	
H17(V) 3.5	0.436777	120.6121	3.382427	6007.706	1668.244	336.1524	8136.534
	0.01%	1.48%	0.04%	73.84%	20.50%	4.13%	
H19	1.456782	2.696951	5.177289	92.92937	0.394462	4.052568	106.7074
	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%	
H21	0.745492	0.288453	0.70091	11.06748	0	0.327474	13.12981
	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%	
I 20	0.247894	5.194509	8.838078	57.93217	0.273078	13.60636	86.09209
	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%	
I 20 (II)	0.240406	5.40855	9.549654	61.14115	0.255322	28.50294	105.098
	0.23%	5.15%	9.09%	58.18%	0.24%	27.12%	
I 20 (II) 1.5	1.577992	18.64033	23.30041	80.44899	0.422149	69.12654	193.5164
	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%	
I 20 (II) 3.5	1.454916	57.50028	72.59037	427.2728	0.796679	178.1651	737.7801
	0.20%	7.79%	9.84%	57.91%	0.11%	24.15%	
I 22	3.666737	138.6424	117.9445	9721.487	5.486339	18.2675	10005.49
	0.04%	1.39%	1.18%	97.16%	0.05%	0.18%	
I 27	0.135518	1.888	0.801194	14.73369	0.016332	0.560392	18.13513
	0.75%	10.41%	4.42%	81.24%	0.09%	3.09%	

Table 4 (cont'd). Sequential chemical extraction data for chromium. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2). The dashed line indicates that there is no data for that sample.

Sample	EX	WAS	ER	MR	OX1	OX2	Total
	Cr	Cr	Cr	Cr	Cr	Cr	Cr
	ppm	ppm	ppm	ppm	ppm	ppm	
J 19 (I)	10.10228	220.5058	137.9256	12988.65	8.386927	352.1262	13717.7
	0.07%	1.61%	1.01%	94.69%	0.06%	2.57%	
J 19(II)	2.158399	188.7063	88.23529	14097.17	4.392996	32.15072	14412.81
	0.01%	1.31%	0.61%	97.81%	0.03%	0.22%	
J19(III)1.5	24.53769	10659.86	220.011	11222.71	3831.293	14.01967	25972.43
	0.09%	41.04%	0.85%	43.21%	14.75%	0.05%	
J19(III)3.5	9.373277	271.9257	287.2895	8439.485	3098.375	670.4327	12776.88
	0.07%	2.13%	2.25%	66.05%	24.25%	5.25%	
J19(III) 6	2.143282	4459.828	229.8016	4261.791	1278.413	310.9614	10542.94
	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%	
J19(IV)	3.358605	14514.28	208.6065	10023.56	3835.69	151.1663	28736.66
	0.01%	50.51%	0.73%	34.88%	13.35%	0.53%	
J19(IV)3.5	5.588125	27815.45	264.1077	8626.129	3111.131	1012.483	40834.89
	0.01%	68.12%	0.65%	21.12%	7.62%	2.48%	
J 21	33.79065	8.94563	31.25	942.0732	1.516972	68.77541	1086.352
	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%	
J23	3.979102	558.3922	180.9191	14524.9	2548.055	3.336393	17819.58
	0.02%	3.13%	1.02%	81.51%	14.30%	0.02%	
K 20	12.51263	345.7912	381.4184	8063.973	11.67424	239.3729	9054.742
	0.14%	3.82%	4.21%	89.06%	0.13%	2.64%	
K20(II)1.5	10.21246	43.54096	818.8082	28125.67	11.43326	279.7214	29289.39
	0.03%	0.15%	2.80%	96.03%	0.04%	0.96%	
K22	3.198718	626.5854	72.37061	1741.907	1042.669	4.299942	3491.031
	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%	
K22(II)	1.295763	458.1907	34.3643	545.5218	278.3188	2.772053	1320.463
	0.10%	34.70%	2.60%	41.31%	21.08%	0.21%	
M 20	2.354567	0.55993	10.8185	366.7596	0.053682	0.448166	380.9944
	0.62%	0.15%	2.84%	96.26%	0.01%	0.12%	
M24	0.185603	101.1459	5.423951	23.46586	23.28683	0.261209	153.7694
	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%	
M24 1.0	0.059993	95.07589	1.185834	16.31502	10.56198	0.653884	123.8526
	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%	
M24 3.0	0.049094	138.2941	1.103933	51.52838	11.75929	5.016618	207.7514
	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%	

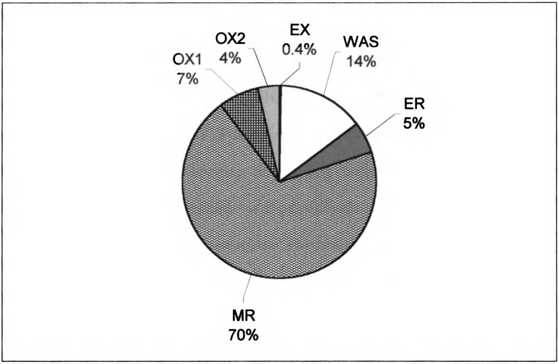
Table 4 (cont'd). Sequential chemical extraction data for chromium. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2). The dashed line indicates that there is no data for that sample.

Sample	EX	WAS	ER	MR	OX1	OX2	Total
	Cr	Cr	Cr	Cr	Cr	Cr	Cr
	ppm	ppm	ppm	ppm	ppm	ppm	
N 21	6.014716	13.41832	171.9713	6193.247	8.140258	120.5653	6513.357
	0.09%	0.21%	2.64%	95.09%	0.12%	1.85%	
N21(II)1.5	5.277671	229.0693	415.5496	7972.424	7.846955	715.9134	9346.081
	0.06%	2.45%	4.45%	85.30%	0.08%	7.66%	
N23	1.747455	3690.62	122.3248	2444.894	2266.492	165.0754	8691.154
	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%	
O22	0.321462	3631.314	90.73745	222.9627	34.91145	0.27371	3980.521
	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%	
O22(II)	4.088538	5843.708	75.66992	5800.78	2821.722	24.99009	14570.96
	0.03%	40.11%	0.52%	39.81%	19.37%	0.17%	
O22(II) 1.5	13.34926	243.2002	2697.09	6576.132	2577.533	2.509218	12109.81
	0.11%	2.01%	22.27%	54.30%	21.28%	0.02%	
O22(II) 3.5	1.363407	120.9767	857.271	1066.772	100.0296	1.466237	2147.879
	0.06%	5.63%	39.91%	49.67%	4.66%	0.07%	
O22(II) 4.5	0.337349	64.86235	88.63441	232.4667	16.03722	0.149183	402.4872
	0.08%	16.12%	22.02%	57.76%	3.98%	0.04%	
O24	6.122982	108.7327	112.4725	4975.545	6.457506	54.44725	5263.778
	0.12%	2.07%	2.14%	94.52%	0.12%	1.03%	
P23	1.912573	25.44574	26.59968	2935.137	2.199459	299.4313	3290.726
	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%	
P25	1.917853	379.9985	35.62486	2279.991	1990.615	33.74387	4721.891
	0.04%	8.05%	0.75%	48.29%	42.16%	0.71%	
P25(II)	2.18787	1492.618	50.41677	1726.42	3049.185	112.2666	6433.094
	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%	
P25(II)1	2.259164	3920.118	48.51146	1563.343	1443.686	10.95673	6988.874
	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%	
P25(II)3	0.47109	1167.798	44.63908	906.6783	323.0643	18.68477	2461.336
	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%	
Q24	6.868371	217.3131	603.0296	11500.53	6.425859	102.2572	12436.42
	0.06%	1.75%	4.85%	92.47%	0.05%	0.82%	
Q24(III)1	6.647517	464.9763	2093.749	9992.268	3.672648	33.54372	12594.86
	0.05%	3.69%	16.62%	79.34%	0.03%	0.27%	
Q24(III) 3	3.48257	154.937	457.2687	2975.376	1.53772	2.084428	3594.686
	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%	

Table 4 (cont'd). Sequential chemical extraction data for chromium. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2). The dashed line indicates that there is no data for that sample.

Sample	EX	WAS	ER	MR	OX1	OX2	Total
	Cr	Cr	Cr	Cr	Cr	Cr	Cr
	ppm	ppm	ppm	ppm	ppm	ppm	
Q26	0.48156	8.116715	8.424054	194.5494	0.484596	2.358735	214.4151
	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%	
T27	0.207966	6.295186	15.76654	409.9302	0.025899	0.410121	432.6359
	0.05%	1.46%	3.64%	94.75%	0.01%	0.09%	
U26	0.322843	21.7749	36.2078	2468.924	0.597608	2.219728	2530.047
	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%	

Figure 4. A summary of the sequential extraction data represented as average percent of chromium extracted from each phase. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2).



4.3 – Microbial Analysis Results

T-RFLP is a culture-independent technique used to assess the structure of microbial communities. Because 90-99% of species in a typical habitat cannot be cultured with current techniques, it is imperative to use culture independent approaches in comparative community analyses. T-RFLP is based on the extensive phylogenetics of bacteria derived from comparative 16S rRNA sequence analysis developed by Woese and colleagues (Woese, 1987). T-RFLP takes advantage of the extensive rRNA sequence database for the design of PCR primers and mapping restriction sites within the sequences. This procedure determines and uses differences in the sizes of terminal restriction fragments ("length polymorphism") to measure the structure of microbial communities. Because all cells require the target molecule, each population (species) can be measured with this metric. This result is a collection of terminal restriction fragments from one community that can be compared to a similar collection derived from a second community.

Table 5 is an example of the results of the Terminal-Restriction Fragment Length Polymorphism (T-RFLP). For the complete table of the results for T-RFLP see Appendix B. Samples are listed in the first column and sample sizes in base pairs (bp) are listed in the columns that remain. For example, sample B5 has a peak height of 65bp for a sample size of 32bp. The number, i.e. 65bp, indicates the presences of a fragment at a peak height for a given sample.

The results of the clustering analysis using the T-RFLP data are shown in Figure 5. The complete dataset of Table 5 was transformed to binary form prior to being entered into the clustering program. Any cell in the spreadsheet containing a number (e.g., containing the number that indicates the presences of a fragment at a peak height for a given sample) was replaced with the letter "A", blank cells were then replaced with the letter "C".

The cluster tree was broken up into four major clusters. The first branch of the cluster tree is divided into two clusters, the first cluster containing one sample, B9, and the second cluster containing the rest of the dataset. This larger cluster was then sub-divided into three clusters as determined by the second branch of the cluster tree. Cluster 2 contains sample site; C4, C16, I20, H19, E16, D17, J21 and O22 (II) 1.5. Cluster 3 contains sample sites; B5, C8, B7, C10, D9 and P23 and the remainder of the 44 sample sites fall into cluster 4.

Table 5. Example of T-RFLP data.

Sample	**Sample Size in base pairs(bp)**															
	32	**36**	**48**	**65**	**67**	**69**	**72**	**73**	**75**	**77**	**78**	**79**	**80**	**82**	**83**	**85**
B5	65									93	67				180	287
B7	75									262		50			80	542
B9											112	51				
C10																
C16					73	52				82						798
C4																
C6																
C8								51		81						183
D17	59										58		60		55	240
D9	56		50		60			56		112	55				219	114
E16	102				55					259					274	413
E18	100				53	53				90	52				66	521
E8						137				50	249		50		144	
G14													60			231
G18										85					126	115
H15																185

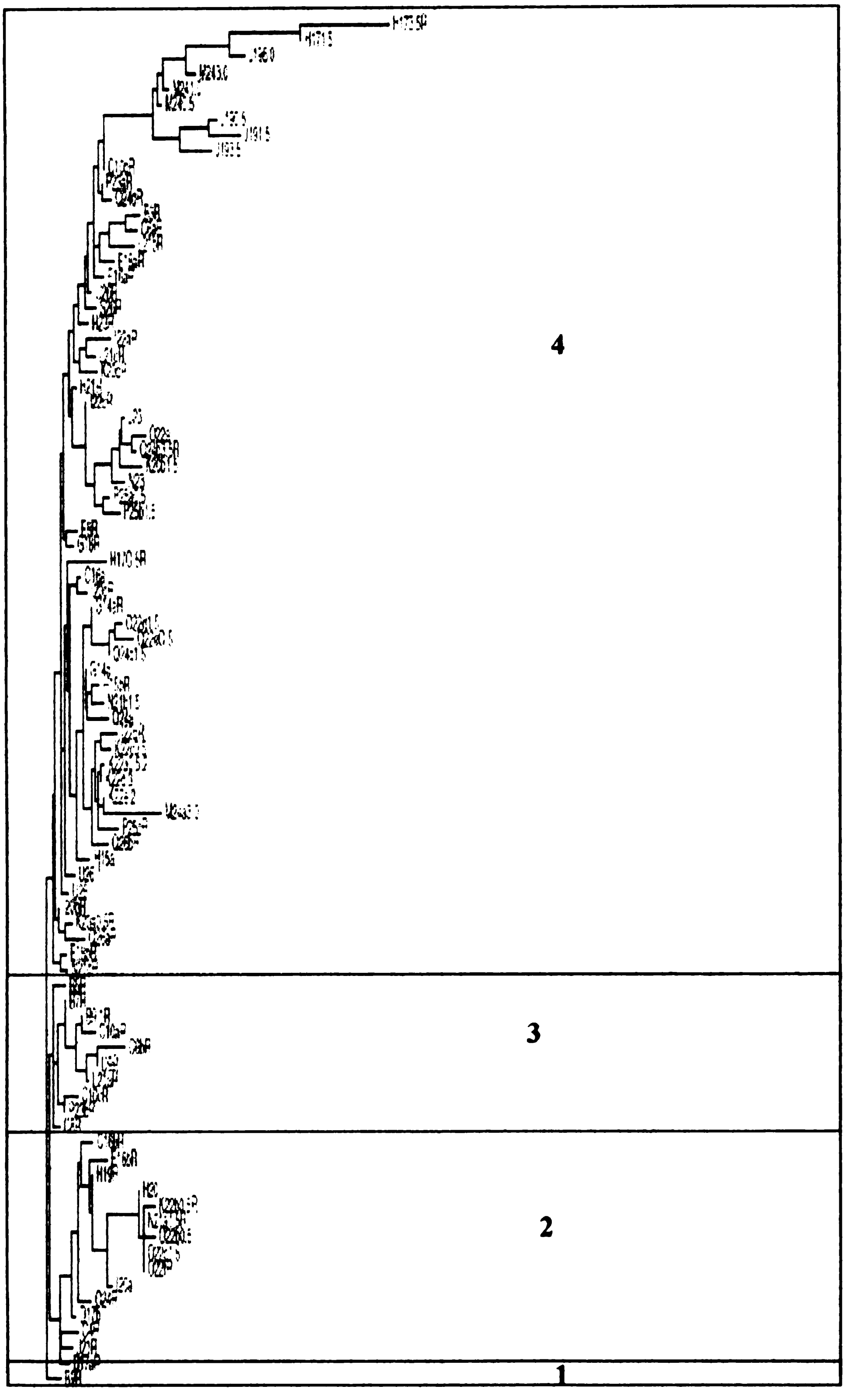


Figure 5. Microbial Cluster Tree produced using data from Table B-1, Appendix B. The cluster tree has been divided into four clusters as indicated by the numbers 1,2,3 and 4. The x-axis is the measurement of the sequence distance.

4.4 – Multivariate Statistical Modeling

Q-MODE Factor Analysis

Q-mode factor analysis, as discussed earlier, was used to determine if individual geochemical populations existed that could then be related to the microbial populations. Data used for this analysis were from Table 3. Twenty-one chemicals were considered in the analysis; potassium (K), chromium (Cr), manganese (Mn), iron (Fe), barium (Ba), magnesium (Mg), vanadium (V), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), strontium (Sr), cadmium (Cd), lead (Pb), aluminum (Al), selenium (Se), scandium (Sc), titanium (Ti), mercury (Hg) and calcium (Ca). The data matrix used for the Q-mode factor analysis had the samples as columns and variables as rows. Factor scores, which are used to estimate the relative importance of the variables in defining the populations, were calculated via a FORTRAN program (Davis 1986; Long et al., 1992). The numbers of factors that can be used to define the data set are interpreted from the relative importance of the eigenvalues describing the data set. The choice of the cut-off used was the default setting of an eigenvalue greater than 1.

The results of the Q-mode factor scores are shown in Table 6. Factor 1 accounts for 77%, factor 2 for 22% and factor 3 less then 0.1% of the variability. The factor scores (Table 6) allow for insight into the variables influencing the individual factors. Examining the values of a variable along a row and choosing its highest value(s) subjectively determined the relative importance of a variable on a factor. Variables that are interpreted to be important in controlling the factors are shown in bold print, and a negative sign denotes there is an inverse relationship between the variable and the factor. Thus, the three factors can be described by the variables listed after the factor at the bottom of Table 6. These three factors can be thought of as sub-populations or end members of the entire data set. The most important population was essentially the one dominated by a majority of the elements (Factor 3).

Q-mode factor analysis was also used to analysis absolute sequential chemical extraction data for chromium from Table 4. Factor 1 and Factor 2 account for 86% and 13% of the variability. Table 7 shows that Factor 1 was dominated by Cr_{EX}, Cr_{ER}, Cr_{MR}, Cr_{OX1} and Cr_{OX2} and Factor 2 contains Cr_{EX}. This shows that one population dominates the system with respect to chromium partitioning.

In conclusion, both the results of the Q-mode factor analysis for total and sequential chemical extractions show that there was one dominant population. Since, the data set was essentially comprised of only one population, R-mode factor analysis was able to be performed to further explore the data set.

Table 6. Factor scores for Q-mode factor analysis for total chemical extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor.

	Eigenvalue	Difference	Proportion	Cumulative
Factor1	56.074472	40.182501	0.7681	0.7681
Factor2	15.891910	14.875606	0.2177	0.9858
Factor3	1.0163643	1.0015764	0.0139	0.9998
FACTOR SCORES				
	Variable	**Factor1**	**Factor2**	**Factor3**
	K	2,887.20	200.87	**12,185.66**
	Cr	**82,134.83**	5,788.85	77,910.43
	Mn	2,115.99	241.19	**3,610.07**
	Fe	92,073.32	13,044.29	**515,357.44**
	Ba	1,891.63	142.96	**2,455.34**
	Mg	11,425.15	1,712.97	**20,918.98**
	V	12.39	18.35	**426.18**
	Co	13.11	1.00	**67.66**
	Ni	82.15	0.89	**99.77**
	Cu	**400.18**	7.03	114.59
	Zn	4,149.96	115.06	**10,230.3**
	As	28.87	4.65	**66.28**
	Sr	296.53	67.51	**-1,097.54**
	Cd	2.2	0.27	**6.33**
	Pb	**871.77**	53.74	398.07
	Al	25,669.55	3,119.69	**165,367.49**
	Se	2.58	0.92	**8.06**
	Sc	3.6	0.64	**6.77**
	Ti	525.04	142.43	**5,157.43**
	Hg	1.3	0.12	**1.80**
	Ca	106,640.18	25,239.31	**-429,512.31**

Factor1: Cr, Cu and Pb
Factor2: None
Factor3: K, Mn, Fe, Ba, Mg, V, Co, Ni, Zn, As, Sr, Cd, Al, Se, Sc, Ti, Hg and Ca

Table 7. Factor scores for Q-mode factor analysis for sequential chemical extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor.

	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	61.0782121	51.1572089	0.8603	0.8603
Factor 2	9.9210033	9.9202197	0.1397	1.0000
Factor Scores				
	Variable	**Factor1**	**Factor2**	
	Cr_{EX}	**6.84**	4.77	
	Cr_{WAS}	58.22	**195.53**	
	Cr_{ER}	**-1,278.8**	-148.46	
	Cr_{MR}	**5,236.57**	4,092.57	
	Cr_{OX1}	**4,213.16**	1,827.54	
	Cr_{OX2}	**-393.19**	39.15	
Factor1: Cr_{EX}, Cr_{ER}, Cr_{MR}, Cr_{OX1} and Cr_{OX2} **Facotr2:** Cr_{WAS}				

R-MODE Factor Analysis

The purpose of R-mode factor analysis was to analyze the dataset, and divide variables into similar groups rather than samples as in Q-mode. The results of the R-mode factor analysis for the entire soil database are shown in Table 8. The same chemicals considered in the Q-mode factor analysis were used in the R-mode analysis. The data matrix used for the R-mode factor analysis had the samples as rows and variables as columns. The eigenvalue measures the amount of variation in the total sample accounted for by each factor (Garson, 1998).

R-mode factor analysis was used to analysis the entire soil database data (Table A-1, Appendix A), results are shown in Table 8. Using the same method as for the Q-mode analysis, the dominant element for each factor are shown in bold print. The resulting factors are shown at the bottom of the table. Manganese, iron, copper, zinc and lead load on Factor 1. Factor 2 had loadings of cadmium, selenium and mercury. Magnesium, strontium, scandium and calcium load on Factor 3. Chromium, vanadium

and arsenic load on Factor 4. Factor 5 had loadings of potassium, cobalt, nickel and titanium and Factor 6 has loadings of barium and aluminum.

R-mode factor analysis was also used to analysis chromium partitioning data from Table 4 and the results can be found in Table 9. The relative amounts of data variance that are explained by the factors and the relative importance of the variables in characterizing a factor can also be found in Table 9. The dominant element for each factor are shown in bold print. The resulting factors are shown at the bottom of the table. Factor 1 had loadings of **Cr_{WAS}, Cr_{MR}, $Cr_{,OX1}$** and **Cr_{OX2}** and Factor 2 had loadings of **Cr_{EX}** and **Cr_{ER}**.

Table 8. Results of R-mode factor analysis on soils from the total extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor. The center of the table shows the loadings of the variables on the factors. The variables that comprise each factor are listed at the bottom of the table.

		Eigenvalue	Difference	Proportion	Cumulative	
	Factor 1	5.167975	1.652159	0.2461	0.2461	
	Factor 2	3.515816	0.917822	0.1674	0.4135	
	Factor 3	2.597994	0.76206	0.1237	0.5372	
	Factor 4	1.835934	0.279468	0.0874	0.6247	
	Factor 5	1.556467	0.428074	0.0741	0.6988	
	Factor 6	1.128393	0.12879	0.0537	0.7525	
Factor Loadings						
	Factor1	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
K	0.48586	0.02388	0.24067	-0.1517	**0.6263**	-0.60392
Cr	0.12986	0.14226	0.12891	**0.93716**	-0.23917	0.19486
M	**0.73479**	-0.17121	0.48172	0.16968	0.18712	-0.28076
Fe	**0.76281**	0.02046	0.42231	-0.20237	0.59254	-0.22743
Ba	0.132	0.11577	0.01632	-0.03226	-0.06669	**0.68382**
Mg	0.3148	-0.02891	**0.79986**	-0.11286	0.54935	-0.26124
V	0.29433	0.46562	0.19627	**0.72495**	0.28995	-0.05892
Co	0.65752	-0.07636	0.36016	-0.09606	**0.80048**	-0.1632
Ni	0.02597	0.13739	-0.07822	0.03817	**0.34772**	-0.07717
Cu	**0.8482**	0.20495	0.14191	0.34758	0.03968	0.06189
Zn	**0.59166**	0.28964	0.28715	0.10756	-0.01905	0.01405
As	0.07603	-0.00155	0.26415	**0.94578**	-0.11293	0.04431
Sr	0.36298	0.21566	**0.79468**	0.49226	-0.02329	0.06946
Cd	0.16868	**0.95626**	0.02387	0.10752	0.00672	0.03292
Pb	**0.738**	0.44372	-0.00696	0.08417	0.00147	0.27003
Al	0.10475	-0.06731	0.03054	-0.13409	0.17379	**-0.57272**
Se	0.18744	**0.96042**	0.05472	0.14765	-0.01843	0.09145
Sc	0.35618	0.01822	**0.69166**	0.32046	0.61509	0.02759
Ti	-0.16806	-0.19467	0.12822	-0.269	**0.83876**	-0.24636
Hg	0.24319	**0.80487**	-0.08469	0.22301	-0.10307	0.48493
Ca	0.18188	-0.03649	**0.91745**	0.19089	0.04956	-0.00329

Table 8 (cont'd). Results of R-mode factor analysis on soils from the total extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor.

Variance Explained by Each Factor Eliminating Other Factors

Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
2.7358352	2.6190525	2.1700363	2.4279608	2.0054061	1.2795492

Factor 1: Mn, Fe, Cu, Zn and Pb
Factor 2: Cd, Se and Hg
Factor 3: Mg, Sr, Sc and Ca
Factor 4: Cr, V, and As
Factor 5: K, Co, Ni and Ti
Factor 6: Ba and Al

Factor Scores

Sample	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
B5	-0.83477	-0.38303	**-1.01741**	-0.42406	-0.77848	-0.08843
B7*	-0.54796	-0.42076	**-0.85648**	-0.41163	-0.27403	-0.33863
B9	**-0.79801**	-0.39801	-1.05233	-0.48177	-0.76747	-0.0872
C4	-0.7479	-0.37062	**-0.8573**	-0.35933	-0.09883	-0.22727
C8	-0.64081	-0.40883	-1.0275	-0.47204	**-0.90629**	-0.25107
C10	-0.6383	-0.45425	**-0.74673**	-0.54703	-0.34439	-0.38273
C16	-0.49235	-0.37767	0.19943	**-0.5915**	0.35843	-0.57764
D9	-0.47115	-0.25766	**-0.79672**	-0.23274	0.26451	-0.51079
D11	**-0.59729**	-0.43781	-0.43839	-0.54967	0.4486	-0.53273
D17	0.93389	-0.36126	0.43818	-0.48259	**1.43826**	-0.53522
E8	-0.47876	-0.49341	-0.29403	-0.678	**0.71803**	-0.41429
E16	0.33505	-0.53157	-0.13894	-0.5774	**0.79014**	-0.35106
E18	2.34793	-0.38456	1.89234	-0.62443	**3.62279**	-1.46332
G14	1.00778	-0.41305	**3.64946**	-0.33988	0.14068	-0.76559
G18	-0.18848	-0.3514	-0.56325	**-0.86195**	-0.153	**-4.35083**
G18(II)0-0.5	-0.53465	-0.27059	**-0.58927**	-0.37308	-0.12792	-0.21555
G18(II)1-1.5	-0.99907	0.08771	-1.31533	-0.07086	**1.81271**	-0.35719
G18(II)3-3.5	-0.61953	-0.40004	-0.14602	-0.35544	**1.48609**	-0.29819
H15	-0.43662	-0.07814	**3.49059**	0.43046	-0.3438	0.35895
H17 (I)	0.13376	0.0479	-0.20431	**3.07802**	-0.12832	-0.35886
H17 (II)	0.16719	0.11237	-0.00394	**3.02842**	0.10235	-0.12379
H17 (III)	0.11457	0.15872	-0.05789	**3.09399**	0.12288	-0.11825
H17(IV)	0.56225	-0.19944	0.42963	**1.91299**	-0.96597	-0.45549
H17(V)	0.51667	0.00577	0.11681	**4.36763**	-0.86694	0.67827
H17(V)1.5	-0.15668	0.01587	1.55436	**3.00836**	-1.0859	0.66362
H17(V) 3.5	-0.5158	-0.62399	**4.09426**	0.8828	0.62745	-0.24905
H19	-0.26933	-0.55436	-0.46349	-0.51414	**-0.64568**	-0.60754

Table 8 (cont'd). Results of R-mode factor analysis on soils from the total extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor. The center of the table shows the loadings of the variables on the factors. The variables that comprise each factor are listed at the bottom of the table.

Factor Scores						
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
H21	-0.68086	-0.46258	-0.24285	-0.61621	**1.13734**	-0.41447
I20(II) 0-0.5	2.31666	-0.07162	0.25689	-0.01153	**1.93824**	-0.27376
I20(II) 1-1.5	**3.48815**	-0.66466	0.63042	-0.2537	0.7359	-0.78849
I20(II) 3-3.5	**3.45429**	-0.50238	0.97982	-0.16564	0.42572	-0.65742
I20	**3.4288**	-0.03015	0.14489	-0.42678	0.87488	-0.01031
I22	0.01281	**3.1856**	0.12805	0.441	-0.17508	-1.17746
I27	-0.58617	-0.39972	-0.40288	-0.29533	**0.73806**	-0.46319
J19 (I)	0.67344	3.0273	0.22612	0.21929	**1.39184**	-0.05259
J19(II)	-0.16365	0.77707	-0.50432	-0.0998	-0.47606	**1.14574**
J19(III)1.5	0.59508	1.11354	-1.49572	0.61488	-1.32165	**3.13398**
J19(III)3.5	-0.12196	-0.07512	-0.92425	-0.08792	**-1.78667**	0.49215
J19(III)6	-0.7541	-0.1901	-0.81879	-0.33165	**-1.52298**	0.22955
J19(IV)0.5	0.22831	0.58507	-0.18132	-0.16893	0.48097	**2.29478**
J19(IV) 1.5	0.59513	0.73042	-1.24193	0.23006	-1.00979	**1.79154**
J19(IV)3.5	-0.09156	-0.07533	**-0.93397**	-0.08667	-1.59586	0.58369
J19(IV) 6.0	-0.26091	-0.08763	-0.91798	-0.04526	**-1.55599**	0.42638
J21	-0.30829	0.01209	-0.55707	-0.512	0.27542	**-1.11304**
J23	1.23089	**6.52411**	0.01612	0.49521	-0.11961	0.84344
K20	0.38244	-0.02825	**0.49505**	-0.19995	-0.44054	-0.45537
K20(II)1.5	**1.70145**	0.43368	0.56317	-0.14984	-1.51724	0.13957
K22	-0.22729	0.34522	0.42437	-0.25864	**-0.90202**	-0.34661
K22(II)top	-0.54234	0.10127	0.10854	-0.36252	**-1.2494**	-0.03864
M20	-0.5162	-0.46988	-0.01623	-0.68326	**1.51824**	-0.35689
M24 0.5	-0.65677	-0.40007	-0.21815	-0.49217	**0.76042**	-0.35838
M24 1.0	**-0.71974**	-0.38524	-0.47839	-0.60921	-0.07841	-0.25664
M24 3.0	-0.02187	-0.44762	**1.22984**	-0.36426	0.96892	-0.70248
N21	0.30384	-0.19135	-0.03466	-0.27155	**-0.5814**	-0.32749
N21(II)1.5	-0.01694	0.03759	0.28721	-0.17841	**-0.96711**	0.7218
N23	0.03985	-0.10094	0.0286	**-0.3633**	-0.14012	-0.05683
022(II) 0.5	-0.38446	-0.20711	-0.15911	-0.2862	**-0.57732**	-0.16358
O22(II)1.5	-0.066	-0.1596	**0.65188**	-0.11162	0.37604	0.8102
O22(II)3.5	**-0.69716**	-0.30599	0.12897	-0.47222	-0.43937	0.25446
O22(II)4.5	**-1.0432**	-0.37666	-0.26126	-0.52644	-0.11121	-0.0105
O22	**-0.99142**	-0.35408	-0.57392	-0.49788	-0.60537	0.06162
O24	0.34427	-0.16514	0.16742	-0.25939	0.11324	**-0.42243**

Table 8 (cont'd). Results of R-mode factor analysis on soils from the total extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor. The center of the table shows the loadings of the variables on the factors. The variables that comprise each factor are listed at the bottom of the table.

Factor Scores						
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
P23	-0.70055	-0.16234	**-0.80899**	-0.36293	-1.40529	0.17462
P25	-0.43685	-0.08504	-0.03427	-0.18651	**0.55181**	0.35158
P25(II) 0-0.5	-0.39057	0.14592	0.12476	-0.01859	**1.00519**	0.54347
P25(II) 1-1.5	-0.70765	-0.14874	0.0933	-0.00966	**1.45634**	0.43378
P25(II) 3-3.5	**-0.98711**	-0.40428	-0.4082	-0.38917	0.5125	0.17862
Q24(II)1.5	-0.34449	-0.25232	-0.0711	-0.34448	**-0.67979**	1.58139
Q24(II)3.5	-0.79855	-0.38483	-0.06988	-0.45224	**-0.98274**	0.32493
Q24*	0.1845	-0.2483	0.21483	-0.48656	-0.06867	**3.88672**
Q26	**-0.37029**	-0.50531	0.16754	-0.34565	1.13775	-0.08472
T27	-0.89515	-0.4635	-0.79108	-0.57217	**-1.04807**	0.0141
U26	**-0.64944**	-0.47091	-0.21718	-0.49931	0.51307	0.07302

Factor 1: B9, D11, I20(II) 1-1.5, I20(II) 3-3.5, I20, K20 (II) 1.5, M24 1.0 O22 (II)3.5, O22(II) 4.5, O22, P25 (II) 3-3.5, Q26 and U26
Factor 2: I22, J23
Factor 3: B5, B7, C4, C10, D9, G14, G18 (II), H15, H17 (V) 3.5, J19(IV) 3.5, M24 3.0, O22(II)1.5 and P23
Factor 4: C16, G18, H17(I), H17(II), H17(III), H17(IV), H17(V), H17(V) 1.5 and N23
Factor 5: C8, D17, E8, E16, E18, G18(II) 1-1.5, G18(II) 3-3.5,H19, H21, I20(II), I27, J19(I), J19(III)3.5, J19(III)6, J19(IV)6, K22, K22(II), M20, M24, N21, N21(II)1.5, O22(II), P25, P25(II), P25(II)1.5, Q24(II)1.5, Q24(II)3.5 and T27
Factor 6: G18,, J19(II), J19(III)1.5, J19(IV), J19(IV)1.5,J21, O24 and Q24

Table 9 . Results of R-mode factor analysis on soils from the sequential chemical extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor. The center of the table shows the loadings of the variables on the factors. The variables that comprise each factor are listed at the bottom of the table.

	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	2.731714	1.382521	0.4553	0.4553
Factor 2	1.349193	0.399842	0.2249	0.6802
Factor 3	0.949352	0.470473	0.1582	0.8384
Factor 4	0.478878	0.090789	0.0798	0.9182
Factor 5	0.388088	0.285312	0.0647	0.9829
Factor 6	0.102777		0.0171	1.0000

	Factor 1	Factor 2
EX	0.28713	**0.84886**
WAS	**0.43760**	0.08449
ER	0.12854	**0.86225**
MR	**0.83789**	0.60268
OX1	**0.88700**	0.32138
OX2	**0.85289**	0.04743

Variance Explained by Each Factor Eliminating Other Factors

Factor1	Factor2
2.1409684	1.5741753

Factor 1: Cr_{WAS}, Cr_{MR}, Cr_{OX1} and Cr_{OX2}
Factor 2: Cr_{EX} and Cr_{ER}

Factor Scores

Sample	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
B7	-0.64024	-0.4173	**-1.01741**	-0.42406	-0.77848	-0.08843
C4	-0.64054	-0.41727	**-0.85648**	-0.41163	-0.27403	-0.33863
C8	-0.64048	-0.41741	-1.05233	-0.48177	**-0.76747**	-0.0872
C16	-0.64029	-0.41385	**-0.8573**	-0.35933	-0.09883	-0.22727
D9	-0.64004	-0.41702	-1.0275	-0.47204	**-0.90629**	-0.25107
E8	-0.63976	-0.41585	**-0.74673**	-0.54703	-	-0.38273
E16	**-0.59087**	-0.42026	0.19943	-0.5915	0.35843	-0.57764
E18	0.21215	-0.49815	-0.79672	-0.23274	0.26451	**-0.51079**
G14	-0.57718	**1.62979**	-0.43839	-0.54967	0.4486	-0.53273
G18II0.5	-0.63385	-0.40697	0.43818	-0.48259	**1.43826**	-0.53522
H15	-0.62383	**1.58735**	-0.29403	-0.678	0.71803	-0.41429
H17I	**3.83175**	0.41475	-0.13894	-0.5774	0.79014	-0.35106
H17II	**3.33073**	0.46456	1.89234	-0.62443	3.62279	-1.46332
H17III	2.34224	0.30503	**3.64946**	-0.33988	0.14068	-0.76559

Table 9 (cont'd). Results of R-mode factor analysis on soils from the sequential chemical extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor. The center of the table shows the loadings of the variables on the factors. The variables that comprise each factor are listed at the bottom of the table.

Factor Scores						
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
H17IV	1.53478	0.35356	-0.56325	-0.86195	-0.153	**-4.35083**
H17V	1.07667	**1.1994**	-0.58927	-0.37308	-0.12792	-0.21555
H17V1	1.82054	**6.44611**	-1.31533	-0.07086	1.81271	-0.35719
H17V3	0.24423	-0.45963	-0.14602	-0.35544	**1.48609**	-0.29819
H19	-0.63315	-0.40713	**3.49059**	0.43046	-0.3438	0.35895
I20	-0.62044	-0.4158	-0.20431	**3.07802**	-0.12832	-0.35886
I20II0	-0.59874	-0.42271	-0.00394	**3.02842**	0.10235	-0.12379
I20II1	-0.53963	-0.42566	-0.05789	**3.09399**	0.12288	-0.11825
I20II3	-0.37567	-0.43795	0.42963	**1.91299**	-0.96597	-0.45549
I22	-0.39402	-0.15787	0.11681	**4.36763**	-0.86694	0.67827
I27	-0.63989	-0.41664	1.55436	**3.00836**	-1.0859	0.66362
J19I	0.17044	-0.22355	**4.09426**	0.8828	0.62745	-0.24905
J19II	-0.26835	-0.1223	-0.46349	-0.51414	**-0.64568**	-0.60754
J19III1	0.67926	0.02676	-0.24285	-0.61621	**1.13734**	-0.41447
J19III3	0.98469	-0.30802	0.25689	-0.01153	**1.93824**	-0.27376
J19III6	0.2827	-0.33239	0.63042	-0.2537	**0.7359**	-0.78849
J19IV0	**1.02388**	-0.20463	0.97982	-0.16564	0.42572	-0.65742
J19IV3	**2.72987**	-0.71158	0.14489	-0.42678	0.87488	-0.01031
J21	-0.51735	-0.24332	0.12805	0.441	-0.17508	**-1.17746**
J23	0.09239	0.01015	-0.40288	-0.29533	**0.73806**	-0.46319
K20	-0.12346	-0.05331	0.22612	0.21929	**1.39184**	-0.05259
K20II1	0.34269	**0.58368**	-0.50432	-0.0998	-0.47606	1.14574
K22	-0.41519	-0.31055	-1.49572	0.61488	-1.32165	**3.13398**
K22IItop	-0.56481	-0.37717	-0.92425	-0.08792	**-1.78667**	0.49215
M20	-0.63266	-0.39196	-0.81879	-0.33165	**-1.52298**	0.22955
M240	**-0.63256**	-0.41299	-0.18132	-0.16893	0.48097	2.29478
M241	-0.63397	-0.41728	-1.24193	0.23006	-1.00979	**1.79154**
M243	-0.62468	-0.41928	-0.93397	-0.08667	**-1.59586**	0.58369
N21	-0.33631	-0.21422	-0.91798	-0.04526	**-1.55599**	0.42638
N23	0.15319	-0.3544	-0.55707	-0.512	0.27542	**-1.11304**
N21II1	0.55845	-0.30296	0.01612	0.49521	-0.11961	**0.84344**
O22	-0.47531	-0.36961	0.49505	-0.19995	-0.44054	-0.45537
O22II0	0.21196	-0.26006	0.56317	-0.14984	**-1.51724**	0.13957
O22II1	-0.33509	**1.83665**	0.42437	-0.25864	-0.90202	-0.34661
O22II3	-0.67356	0.2569	0.10854	-0.36252	**-1.2494**	-0.03864

Table 9 (cont'). Results of R-mode factor analysis on soils from the sequential chemical extractions. At the top of the table are the eigenvalues and proportion of the variance explained by each factor. The center of the table shows the loadings of the variables on the factors. The variables that comprise each factor are listed at the bottom of the table.

Factor Scores						
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**
O22II4	-0.63838	-0.34539	-0.01623	-0.68326	**1.51824**	-0.35689
O24	-0.45105	-0.24675	-0.21815	-0.49217	**0.76042**	-0.35838
P23	-0.13821	-0.48914	-0.47839	**-0.60921**	-0.07841	-0.25664
P25	-0.22441	-0.33612	**1.22984**	-0.36426	0.96892	-0.70248
P25II0	0.08596	-0.36592	-0.03466	-0.27155	**-0.5814**	-0.32749
P25II1	-0.19869	-0.3581	0.28721	-0.17841	**-0.96711**	0.7218
P25II3	**-0.49569**	-0.37998	0.0286	-0.3633	-0.14012	-0.05683
Q23	-0.2719	0.21332	-0.15911	**-0.2862**	-0.57732	-0.16358
Q24III1	-0.53499	1.3506	0.65188	-0.11162	0.37604	**0.8102**
Q24III3	**-0.60451**	-0.00597	0.12897	-0.47222	-0.43937	0.25446
Q26	**-0.63344**	-0.40705	-0.26126	-0.52644	-0.11121	-0.0105
T27	**-0.63219**	-0.39828	-0.57392	-0.49788	-0.60537	0.06162
U26	**-0.58324**	-0.34885	0.16742	-0.25939	0.11324	-0.42243

Factor 1: E16, H17(I), H17(II), J19(IV), J19(IV)3.5, M24, P25(II)3.5, Q24(III)3.5, Q26, T27 and U26
Factor 2: G14, H15, H17(V), H17(V) 1.5, K20 (II) 1.5 and O22(II) 1.5
Factor 3: B7, C4, C16, E8, H17(III), H19, J19(I) and P25
Factor 4: I20, I20(II), I20(II)1.5, I20(II)3.5, I22, I27, P23 and Q23
Factor 5: C8, D9, G18(II), H17(V)3.5, J19(II), J19(III)1.5, J19(III)3.5, J19(III)6, J21, J23, K22, K22(I), M24 3, N21, O22(II)3.5, O22(II) 4, P25(II) and P25(II)1.5
Factor 6: E18, H17(IV), J21, K20(II)1.5, M24 1.0, N23, N21(II)1.5 and Q24(III)1.5

4.5 – Cluster Analysis

Absolute multi-elemental concentrations (Table A-1, Appendix A) were used for the cluster analysis, these results can be found in Figure 6. The first branch in the cluster tree produced two clusters, in order to explore a more detailed relationships among geochemistry/microbial clusters the second set of branches were used in the analysis. The second set of branches breaks off into five major clusters. These five major clusters were labeled numerically 1 thru 5.

The result of the R-mode factor analysis (Table 8) suggests that one population dominates the system. One factor dominates the sample sites, Factor 5, as described by the factor scores at the bottom of Table 8.. Factor 5, from the R-mode factor analysis results, contains a number of the same sample sites that group within cluster 1 of Figure 6 produced by the entire soil database. Another similarity was that almost all the sample sites within clusters 4 and 5 produced by the entire soil database cluster tree group together in Factor 4 from the R-mode factor analysis results (Table 8).

Absolute chromium concentrations for sequential chemical extraction was also clustered, Figure 7. The largest cluster was again identified as cluster 1, followed by cluster 2, 3, 4 and finally cluster 5 being the smallest cluster containing only samples J19(III) 1.5, J19 (IV) 0.5 and J19(IV) 3.5.

When comparing the cluster tree produced using the entire soil database (Figure 6) and the cluster tree for chromium partitioning (Figure 7) the only similarity between the two cluster tree diagrams were that samples H17I, II, III, IV and V cluster near and/or with each other, as do samples J19I, II, J19 (IV) 0.5, J19 (IV) 3.5 and J19III 3.5. Differences among the two figures are that sample site J19 (III) 1.5 does not cluster with the H17's in Figure 7, as in Figure 6. Sample sites M24 surface, 1.0 and 3.0 cluster together in Figure 7 but not in Figure 6. In Figure 6, sample site K20(II) 1.5 clusters in the second largest cluster, cluster 2, but in Figure 7 this sample site clusters in one of the smaller clusters, cluster 4. In conclusion, sample sites H17I, II, III, IV,V J19I, II, J19 (IV) 0.5, J19 (IV) 3.5 and J19III 3.5 cluster near and/or with each other in both the chromium partitioning and the entire soil database cluster tree diagrams. These samples sites (H17I, II, III, IV,V J19I, II, J19 (IV) 0.5, J19 (IV) 3.5 and J19III 3.5), as indicated by both absolute and sequential databases, contain high concentrations of chromium.

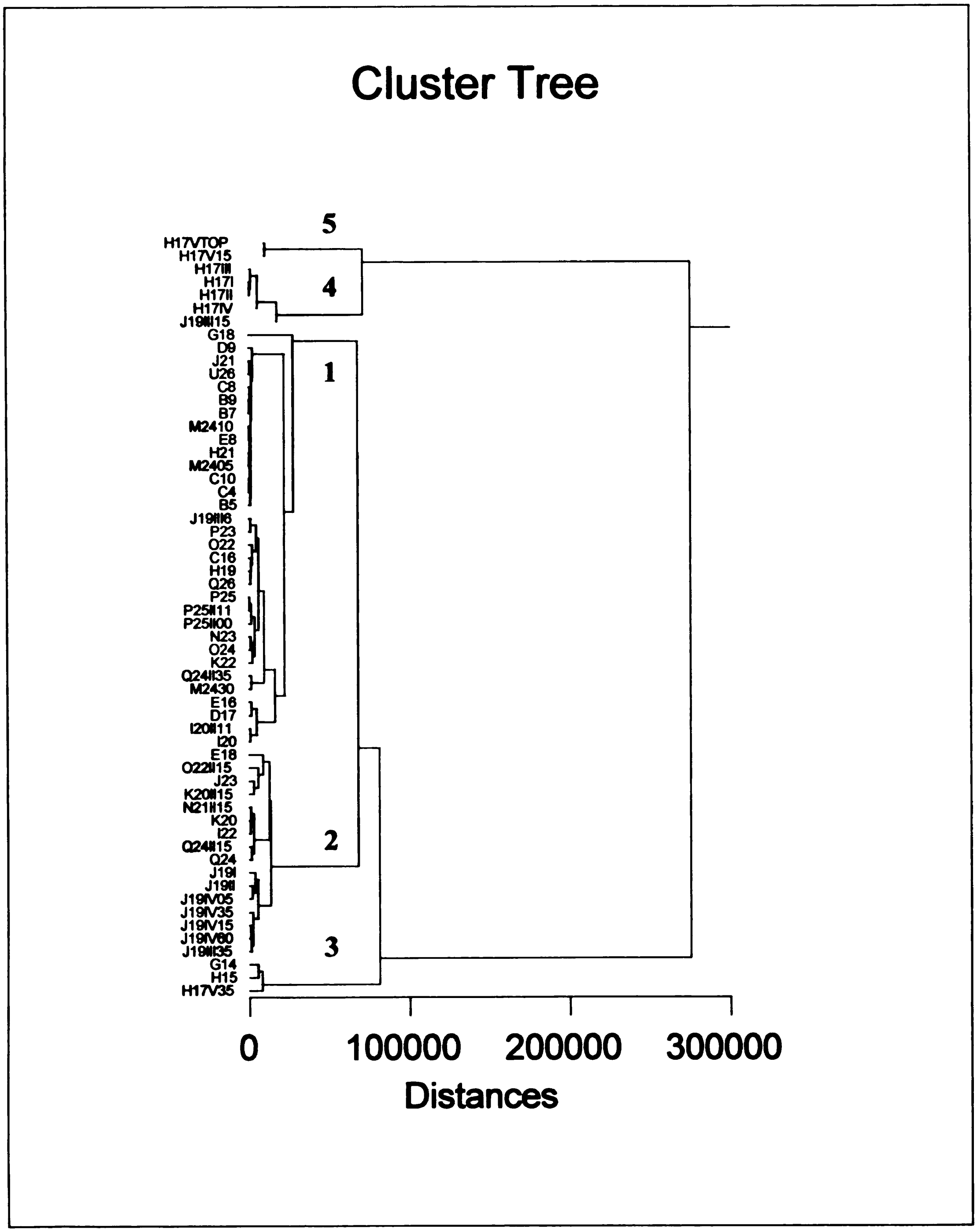


Figure 6. Cluster tree of soils from total chemical extraction data. The cluster tree has been divided into five clusters as indicated by the numbers 1,2,3, 4 and 5.

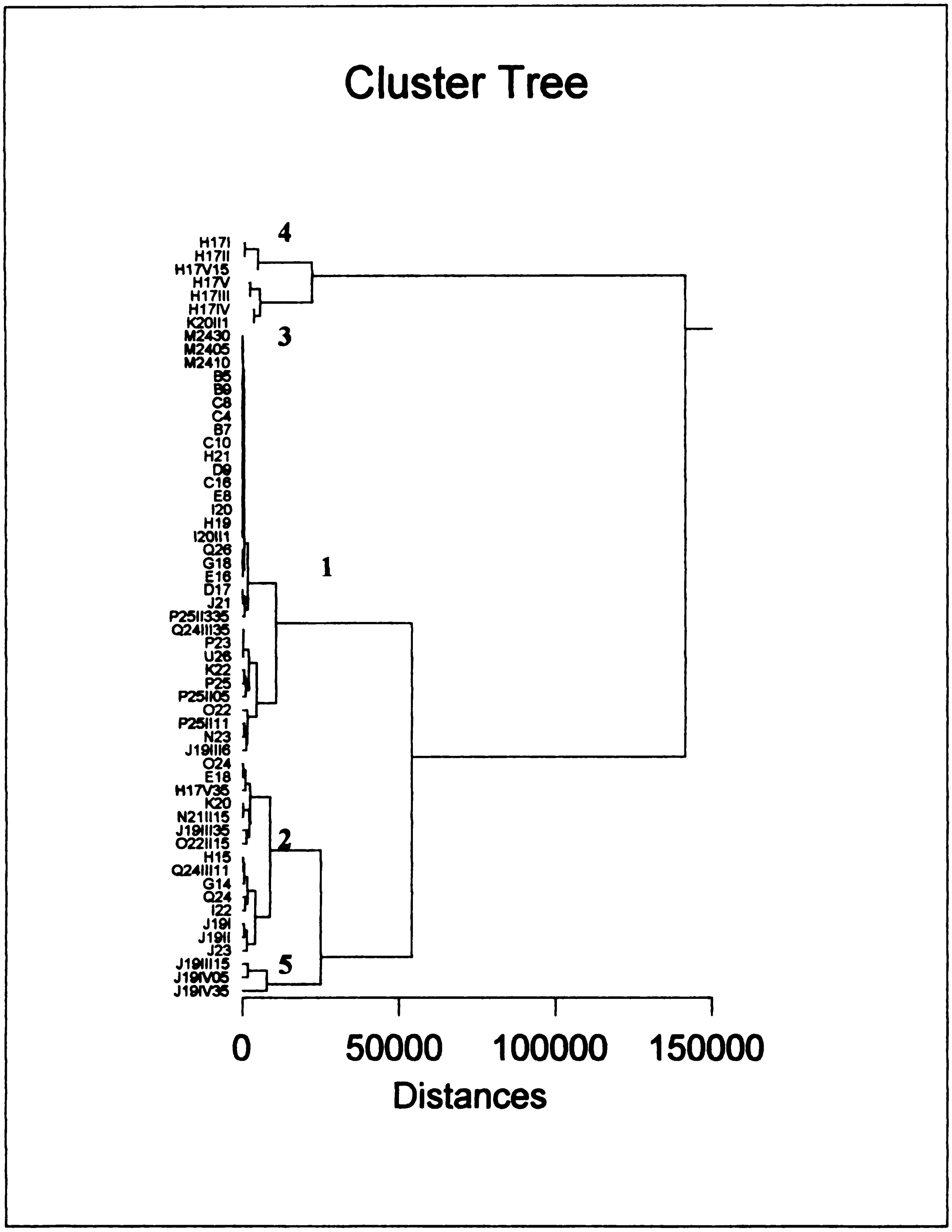


Figure 7. Cluster tree for chromium from sequential chemical extractions. The cluster tree has been divided into four clusters as indicated by the numbers 1,2,3 and 4.

V. GEOCHEMICAL-MICROBIAL COMPARISONS

5.1 – Absolute Chromium Concentrations and Microbial Populations.

This section explores how absolute chromium concentrations, chromium partitioning among sediment phases, selected heavy metal concentrations and organic matter concentrations relate to microbial populations. The first step was to determine if absolute total chromium concentrations could be related to different microbial populations. A t-test was used for this analysis, which is a parametric test that assumes that the data samples are from one population with an asymptotically normal distribution. The microbial clusters were organized into two groups, A and B, in order to determine if absolute chromium concentrations for samples in the lager cluster (A) are different for those samples sites in the smaller clusters (B), (Figure 5). The first group (A) contains sample sites that are within cluster 4. The second group (B) contains sample sites that are within clusters 1, 2 and 3. The t-test then compared chromium concentrations for the sample sites between groups A and B at a 95% confidence level. The test determines if absolute chromium concentrations (Table 3) for sample sites within clusters A and B are the same. If the calculated t-value was greater then the critical t-value, then groups A and B would be different in terms of their chromium concentrations. If the t-value was less then the critical t-value then the chromium concentrations from groups A and B would be considered to be the same. At the 95% confidence level the calculated t-value was slightly larger then the critical t-value (Table 10).

Samples sites that contain high concentrations of chromium tend to group together in absolute geochemical clusters 4 and absolute geochemical cluster 5, these samples sites also group within microbial cluster 4. Microbial cluster 4 also has lower concentrations of chromium that group within absolute geochemical cluster 1. Microbial cluster 1, 2 and 3 tend to have absolute chromium concentrations that are intermediate. This could suggest that neither extremely high nor low absolute chromium concentrations influence the microbial community structure, but that a median range of absolute chromium concentrations may have an effect on microbial populations.

Table 10. t-Test analysis results at a confidence level equal to 95%. Cluster A represents absolute chromium found in sample sites that group within cluster 4 from figure 5. Cluster B represents absolute chromium found in sample sites that group within clusters 1,2 and 3 from figure 5.

Confidence Level = 95%	**Cluster A**	**Cluster B**		
Sample Size	41	15		
Mean	39411.9922	4251.8633	Difference = 35160.1289	
Variance	4.07E+09	7.42E+07	Ratio = 54.8889	
	t-Value	**Probability**	**DF**	**Critical t-Value**
General	2.1141	0.0391	54	2.0049
Paired	2.8964	0.0117	14	2.1448
Co-Variance = -1.8020E+008				
Std Deviation = 24763.0352				
UnPaired	3.4422	0.0013	44	2.0154

5.2 – Chromium Partitioning and Microbial Population.

In section 4.3 the microbial cluster tree was divided into four distinct clusters and in section 4.6 the total and sequential chemical extraction cluster trees were divided into five clusters, these results show that all three types of cluster trees have one dominate cluster. Also, the t-test was used to determine that absolute chromium concentrations are different throughout the microbial population. To further assess the influence chromium has on the microbial population, chromium partitioning and its effects on the microbial community is examined in the following section.

To determine if there is a relationship between chromium partitioning and the microbial population, a table comparing the results from the cluster analysis of the sequential chemical extractions (SCE) and of the microbial populations was prepared (Table 11). The sample sites are listed in column one, the SCE cluster number (Figure 7) in column two. The shaded area indicates the sample sites association within the microbial cluster tree.

Microbial clusters1, 2 and 3 group together within SCE cluster 1. Microbial cluster 4, contains over half of the microbial sample sites, groups within SCE clusters 2, 3, and 4. Only a few microbial sample sites in microbial cluster 4 group within SCE cluster 1. Microbial clusters 1, 2 and 3 group exclusively within SCE cluster 1 and that the majority of microbial sample site (microbial cluster 4) do not group within SCE cluster. This could indicate that there is a relationship between chromium partitioning and the microbial community.

The previous section suggests that there is a potential relationship between SCE clusters and microbial clusters, but further analysis is needed. In order to determine if there is a SCE/microbial relationship a SCE geochemical fingerprint was constructed. Table 11 summarizes the average absolute chromium from the sequential chemical extractions for each of the five clusters in Figure 7 was used to construct the pie diagrams (Figure 8). This approach could then be used to infer why certain microbes' associate with the different SCE clusters was used to examine sample association in each phase.

The pie diagrams (Figure 8) show that except for SCE cluster 5, the MR phase is dominant in sequestering chromium. The most dominant phase sequestering chromium in SCE cluster 5 is WAS phase. The percentage of the absolute chromium concentrations associated with the OX 1 phase decreases from SCE cluster 1 to SCE cluster 5. The pie diagrams also shows that SCE cluster 1 has the highest percent of OX 2. Microbial clusters 1,2 and 3 tend to be confined to SCE cluster 1, while microbial cluster 4 occurs in all SCE cluster, this could indicate that something is unique about microbial clusters 1, 2 and 3. The amount of Cr associated with the OX2 phase appears to be the main difference in Cr partitioning among all SCE clusters. The pie diagrams are averages and there is considerable range of percent for the contribution of each phase in each pie diagram. Therefore, it is not clear how unique the OX2 phase is, so further analysis to determine if high percentage of Cr in the OX2 phase are only associated with SCE cluster 1.

Six tables (Table 12a-f) were constructed to determine if the OX2 phase associates only with SCE cluster 1. The data used to construct the Tables 12a-f was the percent chromium for each SCE phase. Samples associated with microbial cluster 2 are shaded light gray and samples associated with microbial clusters 1 and 3 are dark gray. The data on each table was then sorted by a phase (e.g., EX, WAS, ER, MR, OX1 and OX2). When the samples sites are sorted by the OX2 phase, microbial clusters 1, 2 and 3 group together (e.g., light and dark gray shades line up next to each other). When the sample sites were sorted by the remaining SCE phases the light and dark shades do not line up next to each other as well. It is unclear why the sample sites associated with microbial clusters 1, 2 and 3 group together when sorted by the OX2 phase. It is possible that the OX2 phase is being altered by the microbes or that the OX2 phase may have a more reactive form or Cr.

Table 11. Comparison table showing chromium partitioning versus microbial populations. The results of the sequential chemical extraction cluster tree (Figure 7) are listed in column one along with the cluster number that the sample can be found in. The shaded area indicates what cluster the sample site is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemistry Cluster		**1**	**2**	**3**	**4**
H17 (I)	3				■
H17 (II)	3				■
H17 (V) 1.5	3				■
H17 (V) top	4				■
H17 (III)	4				■
H17 (IV)	4				■
K20 (II) 1.5	4				■
M24 3.0	1				■
M24 0.5	1				■
M24 1.0	1				■
B5	1			■	
B9	1	■			
C8	1			■	
C4	1		■		
B7	1			■	
C10	1			■	
H21	1				■
D9	1			■	
C16	1		■		
E8	1				■
I20	1		■		
H19	1		■		
I20 (II) 1.5	1				■
Q26	1				■
G18	1				■
E16	1		■		
D17	1		■		
J21	1		■		
P25 (II) 3.5	1				■
Q24 (III) 3.5	1				■
P23	1			■	
U26	1				■
K22	1				■
P25	1				■
P25 (II) 0.5	1				■

Table 11 (cont'd). Comparison table showing chromium partitioning versus microbial populations. The results of the sequential chemical extraction cluster tree (Figure 7) are listed in column one along with the cluster number that the sample can be found in. The shaded area indicates what cluster the sample site is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemistry Cluster		**1**	**2**	**3**	**4**
P25 (II) 0.5	1				
O22	1				
P25 (II) 1.5	1				
N23	1				
J19 (III) 6	1				
O24	2				
E18	2				
H17 (V) 3.5	2				
K20	2				
K20 (II) 1.5	2				
N21 (II) 1.5	2				
J19 (III) 3.5	2				
O22 (II) 1.5	2				
H15	2				
Q24 (II) 1.5	2				
G14	2				
Q24	2				
I22	2				
J19 (I)	2				
J19 (II)	2				
J23	2				
J19 (III) 1.5	5				
J19 (IV) 0.5	5				
J19 (IV) 3.5	5				

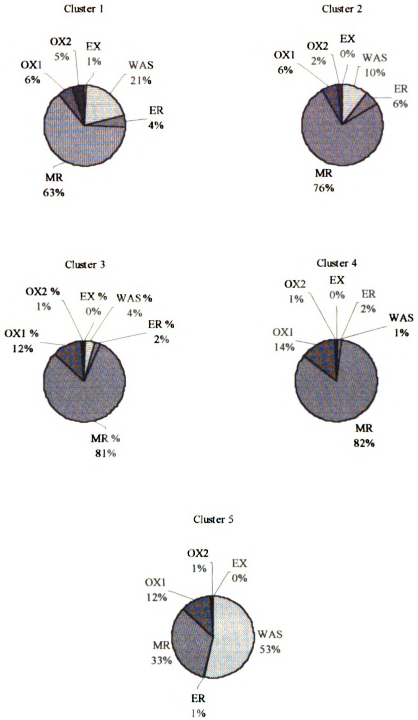


Figure 8. Pie diagrams representing percent chromium for each sequential chemical extraction phase. Cluster 1, 2 and 3 represent geochemical clusters from Table 11. The sequential extraction phases are; exchangeable (EX), weakly acid soluble (WAS), easily reducible (ER), moderately reducible (MR), basic oxidizable (OX1) and acid oxidizable (OX2).

Table 12a. Tables representing the percent chromium associated with each sequential chemical extraction phase. Data below is sorted by exchangeable (EX) phase.

Sorted by EX						
Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**
O22	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%
U26	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%
P25(II)3-3.5	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%
N23	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%
J19(III) 6	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%
M24 3.0	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%
P25(II) 1-1.5	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%
P25(II) 0.5	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%
M24 1.0	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%
E 16	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%
P23	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%
E 8	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%
G 18	0.07%	1.66%	1.98%	95.99%	0.14%	0.17%
K22	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%
Q24(III) 3.5	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%
D 17	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%
M24 0.5	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%
Q26	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%
I 20	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%
D 9	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%
C 16	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%
I 20 (II) 1.5	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%
C 4	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%
B 5	0.90%	5.12%	4.01%	74.18%	0.00%	15.79%
B7	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%
C 8	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%
C 10	0.98%	8.14%	5.16%	80.43%	0.48%	4.81%
B 9	1.12%	4.68%	2.13%	81.60%	0.00%	10.47%
H19	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%
J 21	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%
H21	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%

Table 12b. Tables representing the percent chromium associated with each sequential chemical extraction phase. Data below is sorted by weakly acid soluble (WAS) phase.

Sorted by WAS						
Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**
E 16	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%
P23	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%
J 21	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%
U26	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%
D 17	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%
G 18	0.07%	1.66%	1.98%	95.99%	0.14%	0.17%
H21	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%
E 8	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%
H19	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%
Q26	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%
Q24(III) 3.5	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%
B 9	1.12%	4.68%	2.13%	81.60%	0.00%	10.47%
B 5	0.90%	5.12%	4.01%	74.18%	0.00%	15.79%
I 20	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%
B7	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%
C 10	0.98%	8.14%	5.16%	80.43%	0.48%	4.81%
D 9	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%
I 20 (II) 1.5	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%
C 4	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%
C 8	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%
C 16	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%
K22	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%
P25(II) 0.5	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%
J19(III) 6	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%
N23	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%
P25(II)3-3.5	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%
P25(II) 1-1.5	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%
M24 0.5	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%
M24 3.0	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%
M24 1.0	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%
O22	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%

Table 12c. Tables representing the percent chromium associated with each sequential chemical extraction phase. Data below is sorted by easily reducible (ER) phase.

Sorted by ER						
Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**
E 16	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%
M24 3.0	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%
P25(II) 1-1.5	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%
P25(II) 0.5	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%
P23	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%
M24 1.0	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%
N23	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%
U26	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%
P25(II)3-3.5	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%
G 18	0.07%	1.66%	1.98%	95.99%	0.14%	0.17%
K22	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%
B 9	1.12%	4.68%	2.13%	81.60%	0.00%	10.47%
J19(III) 6	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%
O22	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%
J 21	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%
M24 0.5	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%
D 17	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%
Q26	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%
B 5	0.90%	5.12%	4.01%	74.18%	0.00%	15.79%
E 8	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%
H19	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%
C 8	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%
C 10	0.98%	8.14%	5.16%	80.43%	0.48%	4.81%
H21	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%
B7	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%
D 9	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%
C 4	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%
I 20	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%
I 20 (II) 1.5	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%
Q24(III) 3.5	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%
C 16	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%

Table 12d. Tables representing the percent chromium associated with each sequential chemical extraction phase. Data below is sorted by moderately reducible (MR) phase.

Sorted by MR						
Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**
O22	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%
M24 1.0	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%
M24 0.5	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%
P25(II) 1-1.5	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%
M24 3.0	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%
P25(II) 0.5	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%
N23	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%
P25(II)3-3.5	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%
J19(III) 6	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%
I 20 (II) 1.5	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%
K22	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%
C 16	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%
I 20	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%
B 5	0.90%	5.12%	4.01%	74.18%	0.00%	15.79%
C 8	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%
C 4	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%
B7	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%
C 10	0.98%	8.14%	5.16%	80.43%	0.48%	4.81%
D 9	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%
B 9	1.12%	4.68%	2.13%	81.60%	0.00%	10.47%
Q24(III) 3.5	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%
H21	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%
D 17	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%
J 21	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%
H19	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%
P23	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%
Q26	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%
E 8	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%
E 16	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%
G 18	0.07%	1.66%	1.98%	95.99%	0.14%	0.17%
U26	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%

Table 12e. Tables representing the percent chromium associated with each sequential chemical extraction phase. Data below is sorted by basic oxidizible (OX1) phase.

Sorted by OXI						
Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**
H21	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%
B 9	1.12%	4.68%	2.13%	81.60%	0.00%	10.47%
B 5	0.90%	5.12%	4.01%	74.18%	0.00%	15.79%
U26	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%
Q24(III) 3.5	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%
P23	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%
C 4	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%
B7	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%
J 21	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%
G 18	0.07%	1.66%	1.98%	95.99%	0.14%	0.17%
C 16	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%
E 16	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%
C 8	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%
I 20 (II) 1.5	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%
D 17	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%
Q26	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%
E 8	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%
I 20	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%
H19	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%
C 10	0.98%	8.14%	5.16%	80.43%	0.48%	4.81%
D 9	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%
O22	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%
M24 3.0	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%
M24 1.0	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%
J19(III) 6	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%
P25(II)3-3.5	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%
M24 0.5	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%
P25(II) 1-1.5	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%
N23	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%
K22	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%
P25(II) 0.5	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%

Table 12f. Tables representing the percent chromium associated with each sequential chemical extraction phase. Data below is sorted by acid oxidizible (OX2) phase.

Sorted by OXII						
Sample	**EX**	**WAS**	**ER**	**MR**	**OX1**	**OX2**
022	0.01%	91.23%	2.28%	5.60%	0.88%	0.01%
Q24(III) 3.5	0.10%	4.31%	12.72%	82.77%	0.04%	0.06%
U26	0.01%	0.86%	1.43%	97.58%	0.02%	0.09%
K22	0.09%	17.95%	2.07%	49.90%	29.87%	0.12%
P25(II) 1-1.5	0.03%	56.09%	0.69%	22.37%	20.66%	0.16%
G 18	0.07%	1.66%	1.98%	95.99%	0.14%	0.17%
M24 0.5	0.12%	65.78%	3.53%	15.26%	15.14%	0.17%
M24 1.0	0.05%	76.77%	0.96%	13.17%	8.53%	0.53%
P25(II)3-3.5	0.02%	47.45%	1.81%	36.84%	13.13%	0.76%
E 8	0.06%	2.21%	4.46%	92.12%	0.30%	0.85%
Q26	0.22%	3.79%	3.93%	90.73%	0.23%	1.10%
P25(II) 0.5	0.03%	23.20%	0.78%	26.84%	47.40%	1.75%
N23	0.02%	42.46%	1.41%	28.13%	26.08%	1.90%
M24 3.0	0.02%	66.57%	0.53%	24.80%	5.66%	2.41%
H21	5.68%	2.20%	5.34%	84.29%	0.00%	2.49%
C 16	0.68%	14.41%	22.52%	59.58%	0.17%	2.64%
J19(III) 6	0.02%	42.30%	2.18%	40.42%	12.13%	2.95%
D 9	0.37%	8.63%	5.86%	81.08%	0.49%	3.57%
C 4	0.84%	11.59%	6.26%	77.44%	0.10%	3.77%
H19	1.37%	2.53%	4.85%	87.09%	0.37%	3.80%
C 10	0.98%	8.14%	5.16%	80.43%	0.48%	4.81%
C 8	0.96%	12.31%	5.03%	76.46%	0.21%	5.03%
E 16	0.06%	0.66%	0.52%	93.18%	0.19%	5.40%
B7	0.92%	7.84%	5.74%	79.39%	0.13%	5.97%
J 21	3.11%	0.82%	2.88%	86.72%	0.14%	6.33%
D 17	0.10%	1.52%	3.54%	86.20%	0.22%	8.42%
P23	0.06%	0.77%	0.81%	89.19%	0.07%	9.10%
B 9	1.12%	4.68%	2.13%	81.60%	0.00%	10.47%
B 5	0.90%	5.12%	4.01%	74.18%	0.00%	15.79%
I 20	0.29%	6.03%	10.27%	67.29%	0.32%	15.80%
I 20 (II) 1.5	0.82%	9.63%	12.04%	41.57%	0.22%	35.72%

5.3 – Multi-Elemental Concentrations and Microbial Population

It has been established that there is a relationship between the level of total chromium concentrations in the sediment and microbial populations and between the type of chromium partitioning (particularly the OX2 phase) and microbial populations. It is not necessarily clear however, how important just the chromium concentration is in the associations with the microbial communities. For example, could the concentration of some other chemical work with chromium to cause these relationships. To explore this idea the possible influence of other chemicals on the observed associations of chromium with microbial populations was considered. In this section the possible influences of the 26 chemicals listed in the methods section are examined. In the next section, the specific roles the concentrations of manganese, iron, and organic matters play the associations are studied. These three chemicals were considered because they are ones that have important influences on chromium behavior in the environment [e.g., oxidation of Cr(III) to Cr(VI)] by manganese oxides, adsorption or co-precipitation with iron oxides, and adsorption to organic matter.

A table was prepared to compare the relationships of all of the chemicals (Table 13) using the results from the cluster analyses of the absolute chemical extraction data (Table A-1, Appendix) and of the microbial cluster data (Figure 6). The results of the total chemical extraction clustering (Figure 6) are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree. As with the chromium partitioning data versus microbial population comparison (Table 11) there appears to be a relationship between microbial clusters 1, 2 and 3 and geochemical cluster 1, since microbial clusters 1, 2 and 3 group within geochemical cluster 1. A geochemical fingerprint, which shows general patterns among heavy metal concentrations, was constructed to gain a better understanding of the groupings (Figure 9a-e). The geochemical fingerprint will indicate what chemicals might be characterizing the different groupings so that associations to microbial populations could be determined. In order to construct the geochemical fingerprint the average concentrations for each element was calculated and divided by the average world soil concentration (Reimann et al. 1998) and then converted to log 10. This number was graphed (Figure9a-e). Log10 was used in order to display the data easier and to see how heavy metal concentrations from the current study compared or differed from the average world soil concentration. Five geochemical fingerprints were constructed for each of the five clusters produced in the total chemical extraction cluster tree (Figure 6). The geochemical fingerprinti (Figure 9a) shows that geochemical cluster 1, involving absolute concentrations of elements. It was found to be enriched in such elements as; chromium, arsenic, zinc, cadmium, lead, selenium and mercury. Absolute geochemical cluster 2 (Figure 9b) was enriched in barium, copper, zinc, cadmium, lead, selenium and mercury. Absolute cluster 3 (Figure 9c) was enriched in zinc, mercury, lead and selenium. Absolute geochemical clusters 4 and 5 (Figure 9d and 9e) were enriched in copper, zinc, arsenic, cadmium, lead, selenium and mercury. Chromium concentrations increase from absolute geochemical cluster 1 thru 5, absolute geochemical cluster 5 having the highest concentration. All five of the clusters were depleted in elements such as; potassium, aluminum and titanium. Concentrations for nickel, manganese and copper remain the same throughout clusters 1-5. Arsenic concentrations also increase from absolute geochemical cluster 1 thru 5 similar to chromium. Arsenic, like chromium, can be used by microbes as electron donors or acceptors to metabolism energy (Ehrlich, 1997). Future work would need to be done to determine if arsenic, the form of arsenic, and if arsenic more so then chromium, influences the microbial community.

Table 13. Comparison of multi-elemental concentrations and microbial community structure. The results of the total chemical extraction cluster tree (Figure 6) are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree

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		MICROBE CLUSTER			
Geochemical Cluster		1	2	3	4
H17(V) top	5				■
H17 (V) 1.5	5				■
H17 III	4				■
H17 I	4				■
H17 II	4				■
H17(IV)	4				■
J19 (III) 1.5	4				■
G18	1				■
D9	1			■	
J21	1		■		
U26	1				■
C8	1			■	
B9	1	■			
B7	1			■	
M24 1.0	1				■
E8	1				■
H21	1				■
M24 0.5	1				■
C10	1			■	
C4	1		■		
B5	1			■	
J19 (III) 6	1				■
P23	1			■	
O22	1				■
C16	1				■
H19	1		■		
Q26	1				■
P25	1				■
P25 (II) 1.5	1				■
P25 (II) 0.5	1				■
N23	1				■
O24	1		■		

Table 13 (cont'd). Comparison of multi-elemental concentrations and microbial community structure. The results of the total chemical extraction cluster tree (Figure 6) are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree

		MICROBE CLUSTER			
Geochemical Cluster		1	2	3	4
K22					
Q24 (III) 3.5	1				
M24 3.0	1				
E16	1				
D17	1				
I20 (II) 1.5	1				
I20	1				
E18	2				
O22(II)1.5	2				
J23	2				
K20(II)1.5	2				
N21(II)1.5	2				
K20	2				
I22	2				
Q24(II)1.5	2				
Q24	2				
J19(I)	2				
J19(II)	2				
J19(IV)0.5	2				
J19(IV)3.5	2				
J19)IV)1.5	2				
J19(IV)6.0	2				
J19(III)3.5	2				
G14	3				
H15	3				
H17(V)3.5	3				

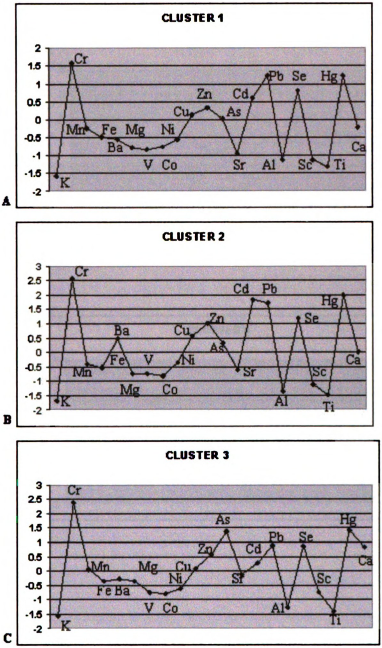
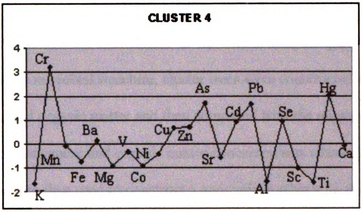


Figure 9a-c. Geochemical fingerprint of multi-elements. The average concentration for each elements was calculated and divided by the average world soil concentration and then converted to log 10, this number was then graphed for the five major clusters that were produced in Figure 6.



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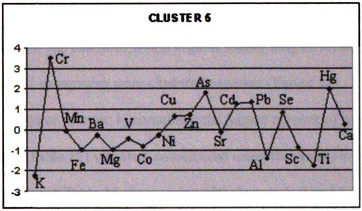

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Figure 9d,e. Geochemical fingerprint of multi-elements. The average concentration for each elements was calculated and divided by the average world soil concentration and then converted to log 10, this number was then graphed for the five major clusters that were produced in Figure 6.

5.4 Chromium, Iron, Manganese and Organic Matter and Microbial Population

To determine how the associations of chromium, iron, manganese and organic matter influence the microbial structure, cluster trees were constructed for chromium, iron, manganese and organic matter and then compared with the microbial cluster tree. Chromium, iron, manganese and organic matter concentrations where clustered (Figure 10). The results were then used to construct a comparison table with the microbial cluster (Figure 5) tree (Table 14). The results of all four variables are combined in the clustering show microbial clusters 1, 2 and 3 still group together in geochemical cluster 1 (Table 14).

To determine the extent to which organic matter may be influencing this pattern; chromium, iron and manganese were clustered together (Figure 12). Figure 12, as with Figure 11, has a cluster (cluster 1) containing the largest number of sample sites. A comparison table (Table 15) was then constructed using the results in Figure 12 and Figure 5. The results of Table 15 shows microbial clusters 1, 2 and 3 no longer group close together within geochemical cluster 1. These results would indicate that since microbial clusters 1, 2 and 3 no longer group close together once organic matter is eliminated from the system, organic matter has an influence on the microbial community structure.

To determine if chromium plays a role influences microbial structure, iron, manganese and organic matter were clustered together (Figure 13). The sample sites that grouped close together within cluster's 1 of Figure's 11 and 12 no longer assemble near each other. When a comparison table (Table 16) was constructed using Figure 5 and

Figure 13, microbial clusters 1, 2 and 3 were no longer found exclusively in geochemical cluster 1 but group within geochemical clusters 2-5. The results of Table 16 indicate that microbial clusters 1, 2 and 3 no longer group close together because chromium is no longer a factor, which means that chromium has an influence on the microbial population.

To determine if chromium and organic matter influence the microbial population, iron and manganese were clustered (Figure 14). The results of Figure 14 show that geochemical cluster 1 is no longer dominated by a majority of the sample sites. A comparison table (Table 17) was constructed using the results of Figure 5 and 14. The results of the comparison table (Table 17) shows that microbial clusters 1, 2, and 3 no longer group close together within the same geochemical cluster, as a result of both chromium and organic matter being removed from the system.

In summary, when chromium, iron, manganese and organic matter are clustered together microbial clusters 1, 2 and 3 group together within chromium, iron, manganese and organic matter cluster 1. When chromium, iron and manganese are clustered and compared with the microbial cluster, microbial clusters 1, 2 and 3 no longer group only in chromium, iron, manganese cluster 1. When iron and manganese are clusters, the iron, manganese geochemical cluster 1 no longer contains a majority of the sample sites and microbial clusters 1, 2 and 3 no longer group together. These results show that chromium and organic matter may play a role in the structure of the microbial community. How these two factors exactly influence the microbial population are unknown and requires further study.

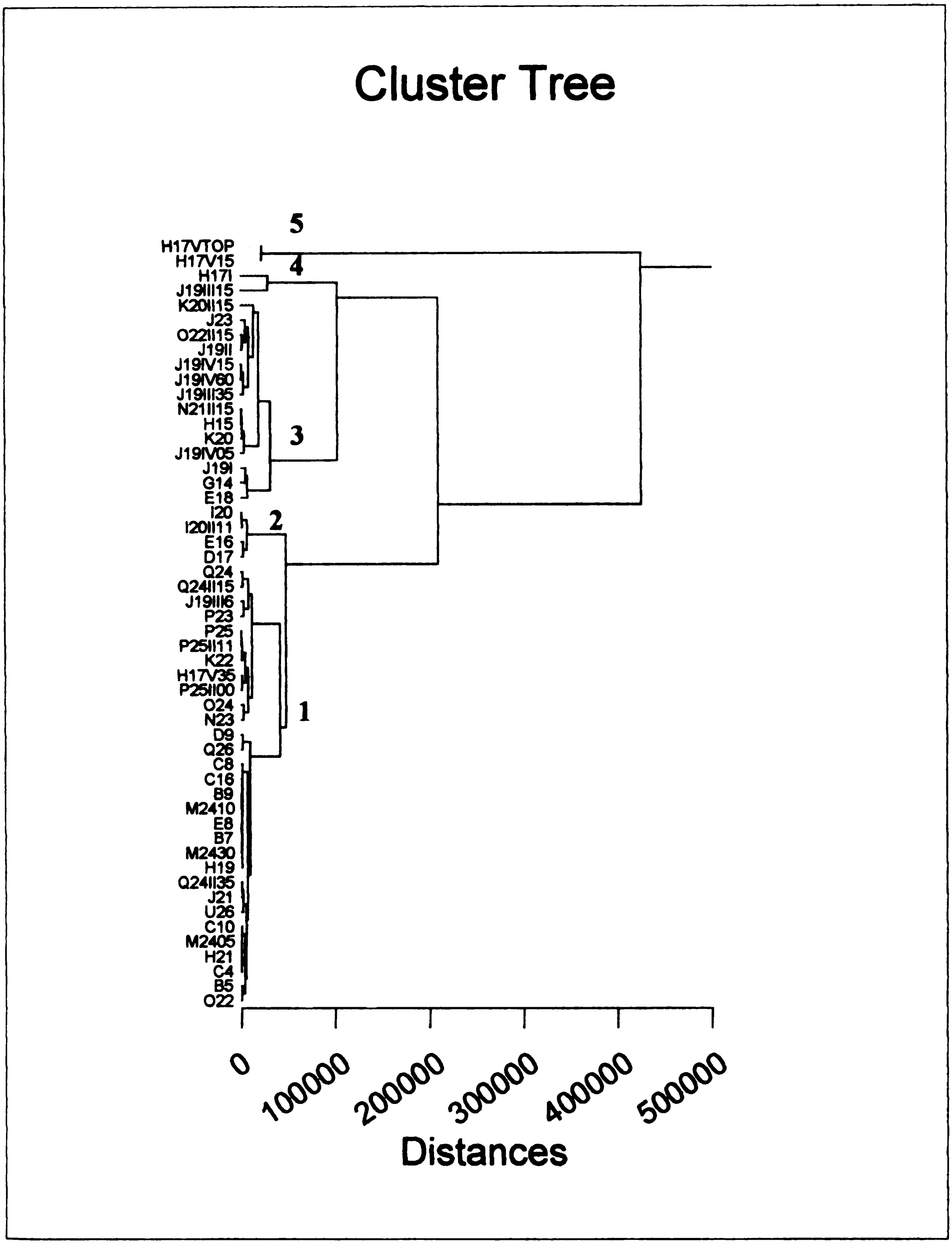

Figure 10. Cluster tree of absolute chromium, iron, manganese concentrations and percent organic matter.

Table 14. Comparison of chromium, iron, manganese and organic matter cluster tree with the microbial cluster tree. The results of the chromium, iron, manganese and organic matter cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemistry		**1**	**2**	**3**	**4**
H17(V) TOP	5				■
H17(V)1.5	5				■
H17(I)	4				■
J19(III)1.5	4				■
K20(II)1.5	3				■
J23	3				■
O22(II)1.5	3		■		
J19(II)	3				■
J19(IV)1.5	3				■
J19(IV)6.0	3				■
J19(III)3.5	3				■
N21(II)1.5	3				■
H15	3				■
K20	3				■
J19(IV)0.5	3				■
J19(I)	3				■
G14	3				■
E18	3				■
I20	2		■		
I20 (II) 1.5	2				■
E16	2		■		
D17	2		■		
Q24	1				■
Q24(II)1.5	1				■
J19(III)6.0	1				■
P23	1			■	
P25	1				■
P25(II)1.5	1				■
K22	1				■
H17(V)3.5	1				■
P25(II)0.5	1				■

Table 14 (cont'd). Comparison of chromium, iron, manganese and organic matter cluster tree with the microbial cluster tree. The results of the chromium, iron, manganese and organic matter cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemical Cluster					
O24	1		■		
N23	1				■
D9	1			■	
Q26	1				■
C8	1			■	
C16	1				■
B9	1	■			
M24 1.0	1				■
E8	1				■
B7	1			■	
M24 3.0	1				■
H19	1		■		
Q24(II)3.5	1				■
J21	1		■		
U26	1				■
C10	1			■	
M24 0.5	1				■
H21	1				■
C4	1		■		
B5	1			■	
O22	1				■

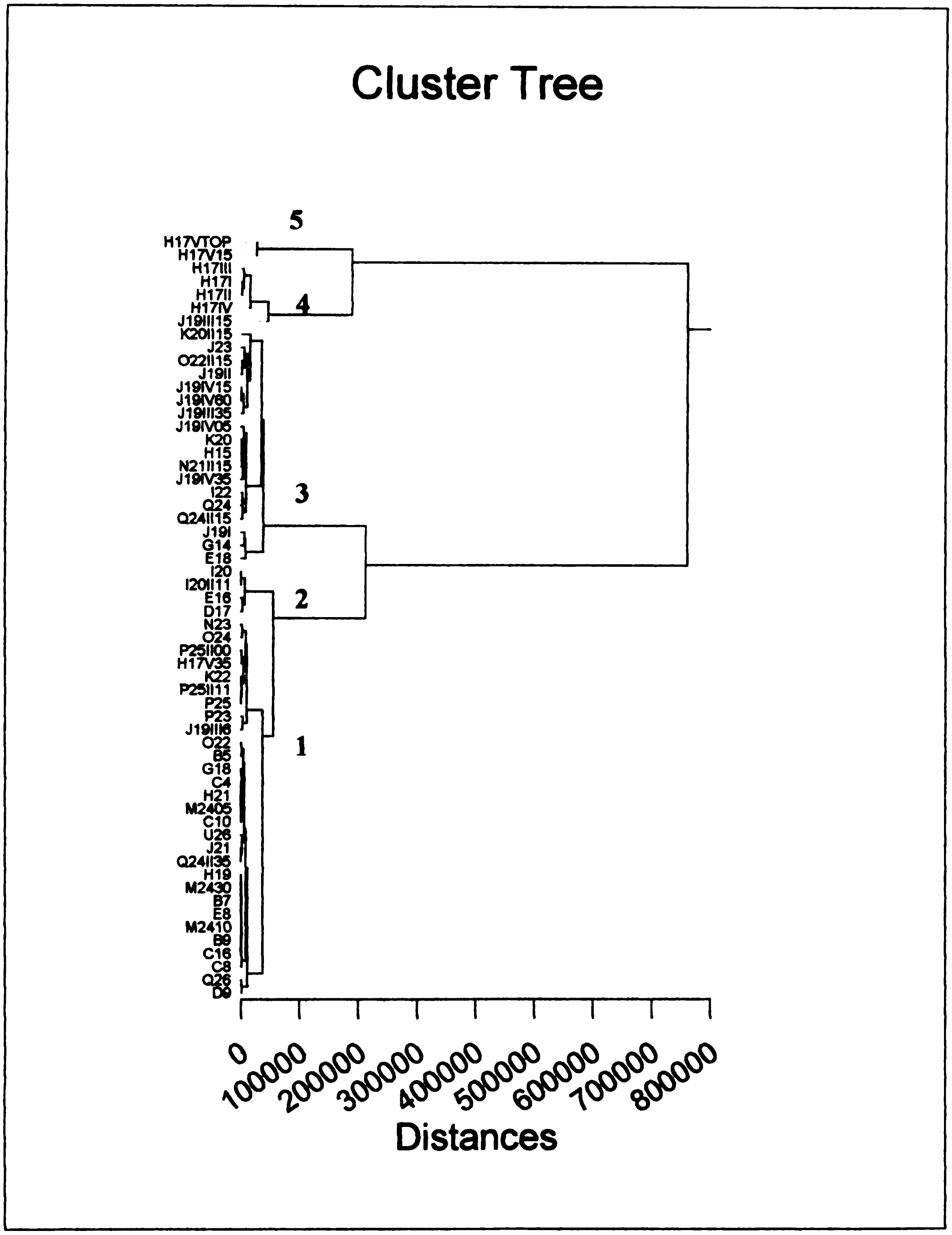

Figure 11. Cluster tree of absolute chromium, iron and manganese concentrations.

Table 15. Comparison of chromium, iron, and manganese cluster tree with microbial cluster tree. The results of the chromium, iron and manganese cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemistry		1	2	3	4
H17(V) TOP	5				
H17(V)1.5	5				
H17(III)	4				
H17(I)	4				
H17(II)	4				
H17(IV)	4				
J19(III)1.5	4				
K20(II)1.5	3				
J23	3				
O22(II)1.5	3				
J19(II)	3				
J19(IV)1.5	3				
J19(IV)6.0	3				
J19(III)3.5	3				
J19(IV)0.5	3				
K20	3				
H15	3				
N21(II)1.5	3				
J19(IV)3.5	3				
I22	3				
Q24	3				
Q24(II)1.5	3				
J19(I)	3				
G14	3				
E18	3				
I20	2				
I20(II)1.5	2				
E16	2				
D17	2				

Table 15. Comparison of chromium, iron, and manganese cluster tree with microbial cluster tree. The results of the chromium, iron and manganese cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemical Cluster					
N23	1				■
O24	1		■		
P25(II)0.5	1				■
H17(V)3.5	1				■
K22	1				■
P25(II)1.5	1				■
P25	1				■
P23	1			■	
J19(III)6.0	1				■
O22	1				■
B5	1			■	
G18	1				■
C4	1		■		
H21	1				■
M24 0.5	1				■
C10	1			■	
U26	1				■
J21	1		■		
Q24(II)3.5	1				■
H19	1		■		
M24 3.0	1				■
B7	1			■	
E8	1				■
M24 1.0	1				■
B9	1	■			
C16	1				■
C8	1			■	
Q26	1				■
D9	1			■	

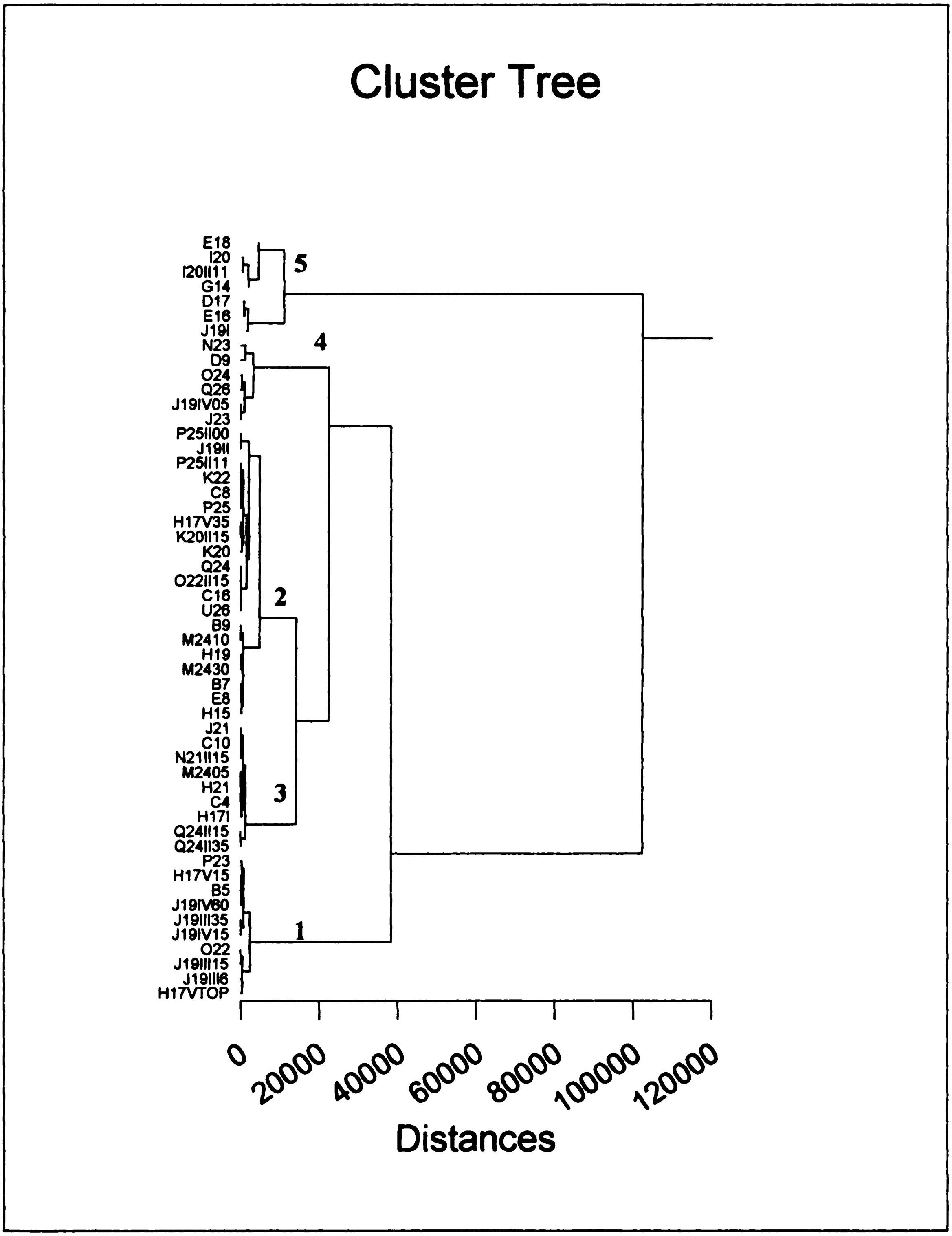

Figure 12. Cluster tree of absolute iron, manganese concentrations and percent organic matter.

Table 16. Comparison of iron, manganese and organic matter cluster tree with microbial cluster tree. The results of the iron, manganese and organic matter cluster are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemical Cluster		1	2	3	4
E18	5				■
I20	5		■		
I20(II)1.5	5				■
G14	5				■
D17	5		■		■
E16	5		■		
J19(I)	5				
N23	4				■
D9	4			■	
O24	4		■		
Q26	4				■
J19(IV)0.5	4				■
J23	4				■
P25(II)0.5	2				■
J19(II)	2				■
P25(II)1.5	2				■
K22	2				■
C8	2			■	■
P25	2				■
H19(V)3.5	2				■
K20(II)1.5	2				
K20	2				■
Q24	2				■
O22(II)1.5	2				■
C16	2				■
U26	2				■
B9	2	■			■
M24 1.0	2				■
H19	2		■		
M24 3.0	2				■
B7	2			■	
E8	2				■

Table 16 (cont'd). Comparison of iron, manganese and organic matter cluster tree with the microbial cluster tree. The results of the iron, manganese and organic matter cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemical Cluster		**1**	**2**	**3**	**4**
H15	2				■
J21	3		■		
C10	3			■	
N21(II)1.5	3				■
M24 0.5	3				■
H21	3				■
C4	3		■		
H17(I)	3				■
Q24(II)1.5	3				■
Q24(II)3.5	3				■
P23	1			■	
H17(IV)1.5	1				■
B5	1			■	
J19(IV)6.0	1				■
J19(III)3.5	1				■
J19(IV)1.5	1				■
O22	1				■
J19(III)1.5	1				■
J19(III)6.0	1				■
H17(V)TOP	1				■

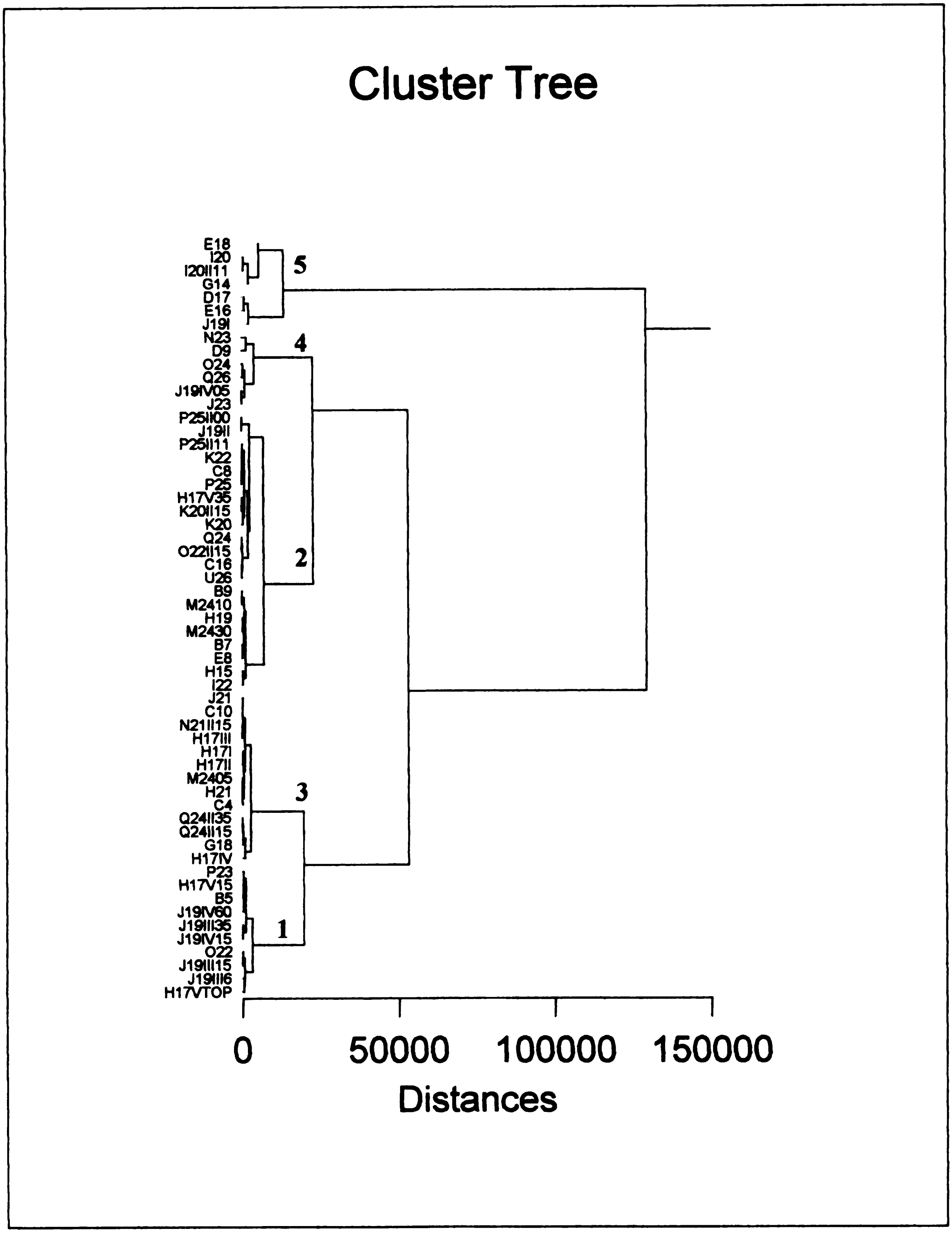

Figure 13. Cluster tree of absolute iron and manganese concentrations.

Table 17. Comparison of iron and manganese cluster tree with the microbial cluster tree. The results of the iron and manganese cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemical Cluster		**1**	**2**	**3**	**4**
E18	5				■
I20	5		■		
I20(II)1.5	5				■
G14	5				■
D17	5		■		
E16	5		■		
J19(I)	5				■
N23	4				■
D9	4			■	
O24	4		■		
Q26	4				■
J19(IV)0.5	4				■
J23	4				■
P25(II)0.5	2				■
J19(II)	2				■
P25(II)1.5	2				■
K22	2				■
C8	2			■	
P25	2				■
H17(IV)3.5	2				■
K20(II)1.5	2				■
K20	2				■
Q24	2				■
O22(II)1.5	2		■		
C16	2				■
U26	2				■
B9	2	■			
M241.0	2				■
H19	2		■		
M243.0	2				■
B7	2			■	

Table 17 (cont'd). Comparison of iron and manganese cluster tree with the microbial cluster tree. The results of the iron and manganese cluster tree are listed in the first column. The shaded area indicates what cluster the sample is associated within the microbial cluster tree.

		MICROBE CLUSTER			
Geochemical Cluster		**1**	**2**	**3**	**4**
E8	2				
H15	2				
I22	2				
J21	3		■		
C10	3			■	
N21(II)1.5	3				
H17(III)	3				
H17(I)	3				
H17(II)	3				
M24 0.5	3				
H21	3				
C4	3		■		
Q24(II)3.5	3				
Q24(II)1.5	3				
G18	3				
H17(IV)	3				
P23	1			■	
H17(V)1.5	1				
B5	1			■	
J19(IV)6.0	1				
J19(III)3.5	1				
J19(IV)1.5	1				
O22	1				
J19(III)1.5	1				
J19(III)6	1				
H17(V)TOP	1				

VI. SUMMARY

6.1 – Summary

Understanding the relationship among heavy metals and the microbial community structure can aid in bioremediation/biostablization efforts in contaminated soils. The purpose of this study was to determine if the concentrations of chromium and selected heavy metals could be related to the microbial community structure in sediments. The study site was a wetland that received chromium contaminated waste from a former leather tannery and provided an ideal environment to study the relationship between contaminants and microbes.

To quantify the-amount of heavy metals in the sediments, samples were collected at the surface and at different depths. Total chemical extractions (chromium plus 19 additional metals) and sequential chemical extractions (chromium) were performed on soil samples taken from the site. Soil samples were also analyzed for organic carbon content. Microbial T-RFLP analysis was used to examine microbial populations and community structure. Factor and cluster analysis was used to establish relationships among the metal concentrations and the microbial population.

Chromium concentrations were found to vary with the concentrations of organic matter, but not with iron or manganese concentrations. Chromium partitioning results indicate that chromium associates more with the moderately reducible (MR) phase than the other sediment phases. The chemicals used to define the MR phase were designed to dissolve iron oxides. However, in this wetland environment, significant portions of the soils are anoxic and iron oxides would not be expected to be stable. In addition, considering the lack of a relationship between chromium concentrations and iron concentrations and knowledge of the low solubility of chromium hydroxides at near neutral pHs, the form of chromium on the MR phase is interpreted to be as chromium hydroxide rather than sorbed to iron oxides.

The results also show that four major microbial populations or clusters could be identified. Five clusters were identified in the sequential chemical extraction geochemical data for chromium. Five clusters were also identified in the data set of the total sediment concentrations for twenty-one elements including chromium. Two of the microbial clusters were found to be associated with chromium partitioned to the OX 2 phase. When chromium, iron, manganese and organic matter were clustered and compared, microbial clusters 2 and 3 grouped together within the geochemical cluster 1. As chromium, iron, manganese and organic matter were removed and re-clustered, microbial clusters 2 and 3 no longer group within microbial cluster 1. Not as many sample sites group in geochemical cluster 1 when chromium and organic matter are removed. These results show that chromium and organic matter play a role in the structure of the microbial community. It has also been found absolute chromium concentrations may also have an influence on the microbial populations. What influence chromium and organic matter have on the microbial community structure is unknown.

This research demonstrated a possible association between chromium concentrations and form and microbial populations. However, various issues arose that still need to be addressed. For example, arsenic concentrations were also found to vary in a similar fashion to chromium. The geochemical fingerprint of mutli-elements indicates that arsenic concentrations increase from cluster 1 thru cluster 5, as does chromium. It is possible that arsenic either acting alone or in combination with chromium plays some role in influencing microbial populations, but this role is unclear. Chromium associated with the OX2 phase of the sediment was found to be related to certain microbial populations. This phase is theoretically related to metals associated with sulfides in the sediments. However, chromium is not known to form sulfides in the environment. Thus, the nature and the form of chromium in this phase is unclear. Perhaps the phase is a more refractory form of organic matter.

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Appendix A

Table A-1: Absolute Concentrations for Multi-Elements.
Concentrations are in mg/L (ppm).

Samples	K	Cr	Mn	Fe	Ba	Mg	V	Co
B5	210.57	8.88	134.13	4730.00	33.06	477.20	7.59	0.86
B7*	306.87	22.22	267.87	8909.62	34.79	739.46	13.30	1.47
B9	143.44	12.73	76.26	9333.89	18.54	516.24	9.86	0.81
C4	259.62	47.27	130.38	7202.92	30.75	874.14	15.88	1.43
C8	245.48	47.64	198.15	10642.80	38.78	390.22	10.16	0.56
C10	371.94	18.19	200.32	7639.34	43.47	1029.30	8.43	1.25
C16	502.46	14.95	165.44	9818.63	72.48	2468.32	11.83	1.69
D9	360.20	49.12	157.89	15622.50	64.75	949.44	29.01	1.35
D11	574.78	90.14	188.98	8369.87	73.83	1415.40	11.67	1.63
D17	738.20	5465.07	372.71	25032.81	359.39	2443.54	17.69	3.22
E8	477.01	170.08	141.00	8710.76	226.06	2405.24	13.37	2.48
E16	480.16	1192.81	412.46	23576.56	63.03	891.92	10.95	3.22
E18	1247.38	27830.48	508.90	35832.04	677.68	4801.35	31.12	6.04
G14	525.48	22134.39	956.78	27936.38	496.75	4305.18	17.63	2.21
G18	961.82	765.05	278.44	6613.49	170.75	1282.83	9.33	0.78
G18(II)	359.70	493.61	258.91	6888.98	141.50	915.70	9.58	1.47
G18(II)1-1.5	400.16	20.98	77.74	6082.38	19.82	1300.68	13.60	1.63
G18(II) 3-3.5	623.50	12.00	79.76	7652.80	33.90	1914.94	17.36	2.52
H15	237.56	24715.12	283.87	8463.06	177.16	2989.32	12.57	1.63
H17 (I)	388.26	137620.87	414.75	7169.78	204.64	1126.13	61.96	1.08
H17 (II)	331.00	135355.32	410.64	7295.87	224.40	1279.84	55.77	1.70
H17 (III)	321.98	141518.58	379.41	7624.28	218.02	1194.72	57.40	1.56
H17(IV)	399.32	120383.58	909.59	6120.02	249.83	1607.82	26.61	1.07
H17(V)top	104.42	281551.80	590.96	3060.67	366.96	805.81	39.75	1.67
H17(V)1.5	51.97	237170.11	364.51	4579.17	178.82	1108.44	24.06	1.64
H17(V) 3.5	398.07	9881.40	542.44	10523.26	123.50	4492.34	18.28	1.18
H19	479.56	451.87	574.50	9238.98	255.67	853.45	7.90	0.67
H21	503.72	29.54	115.94	7276.12	23.43	2333.22	13.39	2.51
I20(II) 0-0.5	1105.74	308.00	532.32	23785.89	387.76	1081.56	24.53	5.48
I20(II) 1-1.5	701.82	506.65	1680.50	30630.32	280.63	1894.55	15.13	4.34
I20(II) 3-3.5	591.94	1971.33	1555.38	26300.08	271.05	3664.73	21.65	3.49
I20	900.09	451.60	685.66	30742.01	369.36	1463.51	18.56	4.20
I22	656.69	20556.33	74.20	8114.47	292.71	1937.83	45.10	0.76
I27	587.40	31660.56	120.32	8423.48	32.37	1662.50	14.11	1.95

Table A-1: Absolute (cont'd)

Samples	K	Cr	Mn	Fe	Ba	Mg	V	Co
J19 (I)	854.30	29137.90	354.33	21484.28	1086.60	1762.51	36.63	2.31
J19(II)	209.87	31543.52	128.82	11568.28	2476.60	1310.12	22.41	1.28
J19(III)1.5	38.20	80186.17	19.03	3421.73	2415.27	411.22	10.58	0.46
J19(III)3.5	42.25	35000.00	16.43	4063.38	347.99	658.09	2.73	0.43
J19(III)6	57.75	11001.40	50.29	2926.01	109.20	745.68	2.74	0.43
J19(IV)0.5	302.98	23924.00	140.21	13412.54	3613.89	1425.39	19.57	2.02
J19(IV) 1.5	104.33	30479.41	36.88	4031.96	860.48	745.35	12.00	0.66
J19(IV)3.5	56.13	24917.23	28.82	5081.55	338.57	799.26	3.74	0.33
J19(IV) 6.0	105.21	31083.28	27.05	4430.81	258.11	780.20	3.52	0.37
J21	1133.61	3795.37	305.54	7748.67	260.66	1048.54	11.68	0.98
J23	286.12	38640.74	47.78	13184.03	350.23	1983.87	46.99	1.93
K20	414.52	23589.15	771.49	10031.16	384.30	2180.53	13.39	1.22
K20(II)1.5	157.63	50494.50	582.76	10488.52	714.31	1817.51	9.19	1.77
K22	268.45	7149.65	311.57	10635.76	268.61	1971.70	16.15	0.79
K22(II)top	96.84	4027.41	131.14	8370.44	157.95	1729.47	11.19	0.57
M20	451.17	439.00	127.99	10186.10	25.66	2888.12	14.87	3.21
M24 0.5	474.18	90.55	141.96	7302.38	32.54	2051.22	13.95	2.07
M24 1.0	320.31	18.76	116.84	9315.37	15.31	1686.42	8.70	1.24
M24 3.0	754.55	33.14	652.09	8907.11	346.43	2652.79	14.49	2.31
N21	612.17	21121.16	607.35	10792.04	913.80	1284.79	12.89	1.16
N21(II)1.5	177.52	23659.54	284.70	7551.81	1401.32	1458.38	9.85	1.09
N23	261.17	11252.17	268.55	17806.85	291.51	1591.40	13.73	1.54
022(II) 0.5	312.55	13398.74	339.21	7516.48	368.05	1261.82	11.23	1.05
O22(II)1.5	367.26	32387.79	161.70	9922.20	1766.61	1484.66	14.87	1.97
O22(II)3.5	252.00	5421.46	94.98	5980.26	584.84	1280.00	7.99	1.13
O22(II)4.5	244.31	697.77	61.64	4698.39	48.33	1381.87	7.69	0.97
O22	160.20	850.03	47.97	3436.46	84.76	1226.73	6.78	0.97
O24	447.09	12984.80	700.43	14482.67	332.64	1570.11	16.65	2.19
P23	17.38	6842.60	177.23	5013.90	129.64	744.03	5.54	0.56
P25	43.05	5768.45	161.07	10542.39	92.66	1814.56	17.90	2.33
P25(II) 0-0.5	67.96	10565.25	182.04	11592.30	150.10	1900.28	20.02	1.90
P25(II) 1-1.5	60.84	6127.77	159.83	10777.45	101.37	1615.72	21.67	2.05
P25(II) 3-3.5	61.30	1646.16	69.12	6263.66	28.09	1601.91	12.36	1.64
Q24(II)1.5	11.44	16393.91	93.63	6562.50	2713.82	1159.84	9.08	1.48
Q24(II)3.5	10.03	3853.83	60.01	6570.73	101.93	1234.36	5.56	1.12
Q24*	34.19	17536.61	236.63	9912.94	7522.57	1547.60	14.07	1.96
Q26	80.21	638.40	583.86	13907.87	80.84	1938.82	18.75	2.08
T27	15.24	648.07	117.27	5584.60	17.34	1325.04	5.04	0.77
U26	56.71	2435.13	180.47	9702.03	54.77	2034.15	12.36	2.33

Table A-1: Absolute (cont'd)

Samples	Ni	Cu	Zn	As	Sr	Cd	Pb
B5	5.96	5.00	43.48	2.33	6.49	0.19	41.04
B7*	2.47	4.84	38.28	5.88	5.73	0.24	24.90
B9	1.31	2.72	25.90	1.42	2.73	0.15	9.42
C4	3.48	5.85	46.76	2.85	6.03	0.23	27.70
C8	0.03	2.27	39.06	1.90	5.65	0.19	16.90
C10	1.84	4.12	41.48	2.59	8.27	0.25	22.47
C16	3.91	18.10	86.98	3.99	38.53	0.23	35.00
D9	3.35	6.04	48.02	3.21	8.30	0.24	24.49
D11	4.93	7.84	67.09	2.81	12.54	0.24	31.10
D17	17.87	115.98	364.99	8.87	41.32	0.85	266.72
E8	3.17	13.75	113.24	1.19	10.64	0.23	57.68
E16	11.14	23.17	86.19	4.56	40.60	0.59	50.40
E18	34.46	156.66	1573.05	5.29	80.25	0.90	321.82
G14	6.26	40.38	556.16	17.84	207.93	0.69	205.15
G18	2.14	8.59	165.71	3.38	18.36	0.20	42.57
G18(II)	2.96	12.88	95.49	10.88	11.73	0.37	34.80
G18(II)1-1.5	252.98	2.87	32.43	4.44	5.85	0.13	2.46
G18(II) 3-3.5	6.88	7.31	27.44	1.04	6.65	0.12	2.56
H15	5.35	22.09	157.02	71.38	215.30	0.57	128.62
H17 (I)	7.05	118.89	341.33	305.07	67.93	1.42	266.69
H17 (II)	9.56	112.69	349.14	323.18	68.82	2.36	259.64
H17 (III)	10.22	111.67	340.71	320.01	69.82	2.02	262.72
H17(IV)	9.76	90.82	675.87	240.24	82.11	2.73	366.03
H17(V)top	12.96	169.19	390.03	408.73	117.90	4.91	464.69
H17(V)1.5	8.63	46.47	340.43	214.61	262.96	6.38	283.12
H17(V) 3.5	2.85	31.96	91.23	265.75	125.05	0.38	58.32
H19	1.02	14.27	158.08	2.31	28.20	0.20	38.60
H21	4.83	9.16	28.21	0.97	8.05	0.13	9.43
I20(II) 0-0.5	15.57	164.82	594.41	15.62	68.86	2.01	1639.05
I20(II) 1-1.5	19.61	284.46	517.71	10.35	73.15	1.07	1833.65
I20(II) 3-3.5	17.53	338.23	512.75	10.09	71.37	0.85	2227.02
I20	9.33	192.73	763.66	17.02	68.99	2.33	4713.85
I22	26.84	132.89	288.74	3.17	86.49	103.36	660.40
I27	6.48	3.62	123.79	1.86	9.51	0.28	20.16
J19 (I)	70.02	51.57	479.59	12.47	89.11	86.47	653.92
J19(II)	7.65	29.37	247.11	6.40	38.28	28.08	321.94
J19(III)1.5	2.46	138.46	45.19	41.29	26.78	3.39	2602.20
J19(III)3.5	3.16	118.62	587.02	13.53	23.04	2.36	441.08

Table A-1: Absolute (cont'd)

Samples	Ni	Cu	Zn	As	Sr	Cd	Pb
J19(III)6	0.60	48.12	60.06	5.50	16.50	0.60	125.70
J19(IV)0.5	6.35	25.32	139.38	6.55	83.74	5.10	1212.06
J19(IV) 1.5	4.39	157.46	50.44	26.40	33.34	5.11	2806.39
J19(IV)3.5	4.82	149.07	327.44	13.02	25.39	1.38	409.93
J19(IV) 6.0	2.12	125.57	256.63	22.51	22.14	1.41	280.62
J21	4.38	12.33	61.00	3.89	17.59	6.19	119.21
J23	9.07	114.70	1202.06	7.32	94.43	143.65	3038.69
K20	6.21	51.79	396.97	6.53	68.65	8.43	643.82
K20(II)1.5	6.14	107.86	3000.66	13.82	76.50	13.69	985.26
K22	12.19	25.39	411.94	4.69	89.33	14.45	152.10
K22(II)top	1.24	17.52	345.44	3.25	70.26	5.12	123.58
M20	5.89	11.02	39.60	1.87	9.65	0.19	43.92
M24 0.5	4.51	4.71	29.98	1.50	9.40	0.23	14.46
M24 1.0	2.17	2.70	13.93	0.59	4.99	0.11	4.34
M24 3.0	5.88	31.88	100.53	2.25	107.38	0.48	36.84
N21	4.36	35.15	512.35	11.37	39.74	1.35	287.11
N21(II)1.5	3.92	39.21	566.60	8.45	84.44	0.92	554.65
N23	6.43	37.59	324.80	11.14	40.14	1.21	236.62
022(II) 0.5	3.35	25.44	201.30	5.48	51.43	4.30	154.64
O22(II)1.5	6.87	44.00	628.62	9.20	74.53	1.48	323.89
O22(II)3.5	2.70	9.48	284.37	1.73	38.06	0.28	197.03
O22(II)4.5	1.50	3.05	30.70	1.17	17.88	0.11	48.68
O22	1.37	3.49	38.39	1.82	10.63	0.14	37.89
O24	7.14	34.55	322.11	11.36	36.26	2.88	181.35
P23	1.25	15.47	186.73	8.03	10.63	0.81	74.87
P25	6.43	28.70	119.75	9.87	26.53	1.08	211.42
P25(II) 0-0.5	8.71	63.87	168.95	10.60	34.98	1.36	119.90
P25(II) 1-1.5	15.51	33.62	86.53	11.92	29.89	0.73	55.55
P25(II) 3-3.5	5.41	9.43	26.45	4.38	10.88	0.22	9.72
Q24(II)1.5	3.73	29.56	455.70	5.63	45.84	0.56	215.50
Q24(II)3.5	1.63	7.89	81.62	2.41	24.38	0.25	80.92
Q24*	5.72	35.07	472.14	8.09	43.33	1.60	282.11
Q26	4.88	11.53	84.79	2.70	32.45	0.49	127.42
T27	2.92	2.16	8.00	0.93	4.90	0.08	7.71
U26	4.39	10.13	49.28	4.40	15.16	0.37	25.90

Table A-1: Absolute (cont'd)

Samples	Al	Se	Sc	Ti	Hg	Ca
B5	2167.54	1.18	0.42	129.96	0.35	1009.35
B7*	3533.30	1.26	0.49	165.20	0.30	1131.29
B9	2421.05	0.93	0.28	129.99	0.24	514.12
C4	3805.65	1.09	0.56	200.60	0.22	996.53
C8	1738.96	0.99	0.25	106.11	0.17	888.65
C10	3491.13	1.01	0.49	162.83	0.16	1672.45
C16	5365.63	1.35	0.87	217.41	0.25	12253.56
D9	4670.30	1.10	0.52	210.38	0.19	1490.23
D11	3811.39	1.10	0.79	260.58	0.17	6173.72
D17	4829.41	2.09	1.48	236.13	0.64	13624.84
E8	4093.70	0.59	0.60	266.79	0.13	2005.15
E16	3712.03	1.74	1.11	196.42	0.66	9263.41
E18	13959.56	0.83	1.79	436.62	0.27	26370.63
G14	4725.53	2.06	1.40	130.72	0.42	78910.09
G18	74996.20	0.41	0.53	184.15	0.12	4670.25
G18(II)	4125.20	2.74	1.00	165.61	0.84	2158.24
G18(II)1-1.5	4717.85	1.45	0.89	250.01	0.44	1198.88
G18(II) 3-3.5	4333.65	1.38	1.86	304.64	0.36	1628.06
H15	3324.45	3.03	2.42	98.12	2.81	91769.68
H17 (I)	2636.88	1.92	1.12	129.09	1.05	12777.97
H17 (II)	2702.68	3.10	1.47	130.52	1.87	13276.37
H17 (III)	2858.62	3.30	1.46	141.65	1.84	12626.39
H17(IV)	1847.10	2.85	0.97	62.97	1.42	18888.74
H17(V)top	2815.94	2.15	1.54	72.53	5.73	17346.18
H17(V)1.5	3206.21	1.86	1.70	79.30	3.51	31331.64
H17(V) 3.5	4621.74	1.29	2.79	235.59	0.89	111813.95
H19	3371.12	0.71	0.42	154.59	0.21	7640.70
H21	4030.21	1.14	0.96	331.49	0.23	2157.30
I20(II) 0-0.5	7443.40	2.90	2.56	141.71	2.72	10894.01
I20(II) 1-1.5	8309.78	1.87	1.43	121.45	1.99	20401.27
I20(II) 3-3.5	4909.05	1.72	1.18	91.84	1.52	22581.96
I20	8461.29	1.78	1.66	114.45	0.59	21483.70
I22	3248.93	14.08	0.79	98.08	1.66	16038.43
I27	4172.30	1.19	1.08	266.63	0.24	2275.37
J19 (I)	3910.82	10.28	1.45	198.17	14.95	12879.33
J19(II)	1707.44	4.23	0.54	88.63	5.05	4723.04
J19(III)1.5	1044.65	2.14	0.79	47.97	20.45	2289.76
J19(III)3.5	549.58	2.14	0.31	16.12	1.52	5200.57

Table A-1: Absolute (cont'd)

Samples	Al	Se	Sc	Ti	Hg	Ca
J19(III)6	672.14	2.64	0.37	35.47	0.80	6975.52
J19(IV)0.5	2829.36	3.75	1.18	211.21	9.24	3255.72
J19(IV) 1.5	1595.76	2.17	0.81	98.68	11.89	3624.02
J19(IV)3.5	595.08	1.65	0.36	37.37	3.35	5399.77
J19(IV) 6.0	707.81	2.10	0.36	39.78	2.82	5459.65
J21	2942.18	3.49	0.79	204.05	1.13	3709.25
J23	3224.74	24.90	1.09	120.45	26.62	13482.49
K20	4370.18	3.40	0.95	125.47	1.33	16241.59
K20(II)1.5	3443.24	2.87	0.67	53.23	2.47	15575.89
K22	1886.24	4.35	0.59	60.15	0.77	17241.14
K22(II)top	1283.83	3.54	0.46	44.98	0.77	14260.96
M20	4074.35	1.37	1.02	350.95	0.29	2545.13
M24 0.5	4078.88	1.44	1.19	254.22	0.29	3186.49
M24 1.0	2582.87	1.55	0.73	176.95	0.30	2263.34
M24 3.0	4785.48	1.84	1.51	291.33	0.63	26079.96
N21	2872.67	2.61	0.72	91.18	1.33	14506.85
N21(II)1.5	2342.21	3.31	0.85	77.61	2.11	19006.69
N23	3264.65	3.24	0.98	127.41	1.41	11922.79
022(II) 0.5	3058.42	2.02	0.63	145.42	0.90	11995.11
O22(II)1.5	4945.58	1.91	1.47	247.97	1.81	31694.82
O22(II)3.5	2509.04	1.45	0.80	183.78	0.84	29290.69
O22(II)4.5	2077.71	1.33	0.74	251.17	0.63	16523.30
O22	1630.37	1.45	0.55	157.82	0.44	8626.71
O24	3094.79	3.90	1.06	143.60	1.20	14344.26
P23	1063.65	2.81	0.39	40.79	1.20	3918.19
P25	4074.72	3.23	1.48	218.19	2.33	8042.78
P25(II) 0-0.5	5636.16	3.49	1.87	312.37	6.01	9461.47
P25(II) 1-1.5	4891.63	2.94	2.07	383.67	2.07	9140.78
P25(II) 3-3.5	4253.05	1.30	1.12	302.25	0.68	2995.75
Q24(II)1.5	1576.421	1.118855	0.734602	72.64645	0.949331	25650.2
Q24(II)3.5	3259.576	1.554276	0.851151	114.0666	1.578947	18503.67
Q24*	3686.179	1.552658	1.107322	134.8285	2.972919	21692.59
Q26	5346.005	1.822258	1.418671	375.8744	0.464737	6460.603
T27	2103.197	0.676779	0.233372	89.49825	0.268378	1017.748
U26	4155.448	1.359535	0.950471	257.9988	0.397032	3801.476

Appendix A

Table A-2: Logarithmic Data for Multi-Elements.

Samples	K	Cr	Mn	Fe	Ba	Mg	V	Co
B5	2.32	0.95	2.13	3.67	1.52	2.68	0.88	-0.06
B7*	2.49	1.35	2.43	3.95	1.54	2.87	1.12	0.17
B9	2.16	1.10	1.88	3.97	1.27	2.71	0.99	-0.09
C4	2.41	1.67	2.12	3.86	1.49	2.94	1.20	0.15
C8	2.39	1.68	2.30	4.03	1.59	2.59	1.01	-0.26
C10	2.57	1.26	2.30	3.88	1.64	3.01	0.93	0.10
C16	2.70	1.17	2.22	3.99	1.86	3.39	1.07	0.23
D9	2.56	1.69	2.20	4.19	1.81	2.98	1.46	0.13
D11	2.76	1.95	2.28	3.92	1.87	3.15	1.07	0.21
D17	2.87	3.74	2.57	4.40	2.56	3.39	1.25	0.51
E8	2.68	2.23	2.15	3.94	2.35	3.38	1.13	0.39
E16	2.68	3.08	2.62	4.37	1.80	2.95	1.04	0.51
E18	3.10	4.44	2.71	4.55	2.83	3.68	1.49	0.78
G14	2.72	4.35	2.98	4.45	2.70	3.63	1.25	0.35
G18	2.98	2.88	2.44	3.82	2.23	3.11	0.97	-0.11
G18(II)	2.56	2.69	2.41	3.84	2.15	2.96	0.98	0.17
G18(II)1-1.5	2.60	1.32	1.89	3.78	1.30	3.11	1.13	0.21
G18(II) 3-3.5	2.79	1.08	1.90	3.88	1.53	3.28	1.24	0.40
H15	2.38	4.39	2.45	3.93	2.25	3.48	1.10	0.21
H17 (I)	2.59	5.14	2.62	3.86	2.31	3.05	1.79	0.04
H17 (II)	2.52	5.13	2.61	3.86	2.35	3.11	1.75	0.23
H17 (III)	2.51	5.15	2.58	3.88	2.34	3.08	1.76	0.19
H17(IV)	2.60	5.08	2.96	3.79	2.40	3.21	1.42	0.03
H17(V)top	2.02	5.45	2.77	3.49	2.56	2.91	1.60	0.22
H17(V)1.5	1.72	5.38	2.56	3.66	2.25	3.04	1.38	0.22
H17(V) 3.5	2.60	3.99	2.73	4.02	2.09	3.65	1.26	0.07
H19	2.68	2.66	2.76	3.97	2.41	2.93	0.90	-0.17
H21	2.70	1.47	2.06	3.86	1.37	3.37	1.13	0.40
I20(II) 0-0.5	3.04	2.49	2.73	4.38	2.59	3.03	1.39	0.74
I20(II) 1-1.5	2.85	2.70	3.23	4.49	2.45	3.28	1.18	0.64
I20(II) 3-3.5	2.77	3.29	3.19	4.42	2.43	3.56	1.34	0.54
I20	2.95	2.65	2.84	4.49	2.57	3.17	1.27	0.62
I22	2.82	4.31	1.87	3.91	2.47	3.29	1.65	-0.12
I27	2.77	4.50	2.08	3.93	1.51	3.22	1.15	0.29
J19 (I)	2.93	4.46	2.55	4.33	3.04	3.25	1.56	0.36
J19(II)	2.32	4.50	2.11	4.06	3.39	3.12	1.35	0.11
J19(III)1.5	1.58	4.90	1.28	3.53	3.38	2.61	1.02	-0.33
J19(III)3.5	1.63	4.54	1.22	3.61	2.54	2.82	0.44	-0.36

Table A-2: Logarithmic (cont'd).

Samples	K	Cr	Mn	Fe	Ba	Mg	V	Co
J19(III)6	1.76	4.04	1.70	3.47	2.04	2.87	0.44	-0.37
J19(IV)0.5	2.48	4.38	2.15	4.13	3.56	3.15	1.29	0.31
J19(IV) 1.5	2.02	4.48	1.57	3.61	2.93	2.87	1.08	-0.18
J19(IV)3.5	1.75	4.40	1.46	3.71	2.53	2.90	0.57	-0.48
J19(IV) 6.0	2.02	4.49	1.43	3.65	2.41	2.89	0.55	-0.43
J21	3.05	3.58	2.49	3.89	2.42	3.02	1.07	-0.01
J23	2.46	4.59	1.68	4.12	2.54	3.30	1.67	0.29
K20	2.62	4.37	2.89	4.00	2.58	3.34	1.13	0.09
K20(II)1.5	2.20	4.70	2.77	4.02	2.85	3.26	0.96	0.25
K22	2.43	3.85	2.49	4.03	2.43	3.29	1.21	-0.11
K22(II)top	1.99	3.61	2.12	3.92	2.20	3.24	1.05	-0.24
M20	2.65	2.64	2.11	4.01	1.41	3.46	1.17	0.51
M24 0.5	2.68	1.96	2.15	3.86	1.51	3.31	1.14	0.32
M24 1.0	2.51	1.27	2.07	3.97	1.19	3.23	0.94	0.09
M24 3.0	2.88	1.52	2.81	3.95	2.54	3.42	1.16	0.36
N21	2.79	4.32	2.78	4.03	2.96	3.11	1.11	0.06
N21(II)1.5	2.25	4.37	2.45	3.88	3.15	3.16	0.99	0.04
N23	2.42	4.05	2.43	4.25	2.46	3.20	1.14	0.19
022(II) 0.5	2.49	4.13	2.53	3.88	2.57	3.10	1.05	0.02
O22(II)1.5	2.56	4.51	2.21	4.00	3.25	3.17	1.17	0.29
O22(II)3.5	2.40	3.73	1.98	3.78	2.77	3.11	0.90	0.05
O22(II)4.5	2.39	2.84	1.79	3.67	1.68	3.14	0.89	-0.01
O22	2.20	2.93	1.68	3.54	1.93	3.09	0.83	-0.01
O24	2.65	4.11	2.85	4.16	2.52	3.20	1.22	0.34
P23	1.24	3.84	2.25	3.70	2.11	2.87	0.74	-0.25
P25	1.63	3.76	2.21	4.02	1.97	3.26	1.25	0.37
P25(II) 0-0.5	1.83	4.02	2.26	4.06	2.18	3.28	1.30	0.28
P25(II) 1-1.5	1.78	3.79	2.20	4.03	2.01	3.21	1.34	0.31
P25(II) 3-3.5	1.79	3.22	1.84	3.80	1.45	3.20	1.09	0.21
Q24(II)1.5	1.06	4.21	1.97	3.82	3.43	3.06	0.96	0.17
Q24(II)3.5	1.00	3.59	1.78	3.82	2.01	3.09	0.75	0.05
Q24*	1.53	4.24	2.37	4.00	3.88	3.19	1.15	0.29
Q26	1.90	2.81	2.77	4.14	1.91	3.29	1.27	0.32
T27	1.18	2.81	2.07	3.75	1.24	3.12	0.70	-0.11
U26	1.75	3.39	2.26	3.99	1.74	3.31	1.09	0.37

Table A-2: Logarithmic (cont'd).

Samples	Ni	Cu	Zn	Cd	Pb	Al	Se	Sc
B5	0.78	0.70	1.64	-0.73	1.61	3.34	0.07	-0.38
B7*	0.39	0.68	1.58	-0.62	1.40	3.55	0.10	-0.31
B9	0.12	0.43	1.41	-0.82	0.97	3.38	-0.03	-0.55
C4	0.54	0.77	1.67	-0.64	1.44	3.58	0.04	-0.25
C8	-1.48	0.36	1.59	-0.73	1.23	3.24	-0.01	-0.61
C10	0.27	0.62	1.62	-0.60	1.35	3.54	0.00	-0.31
C16	0.59	1.26	1.94	-0.63	1.54	3.73	0.13	-0.06
D9	0.53	0.78	1.68	-0.61	1.39	3.67	0.04	-0.28
D11	0.69	0.89	1.83	-0.62	1.49	3.58	0.04	-0.10
D17	1.25	2.06	2.56	-0.07	2.43	3.68	0.32	0.17
E8	0.50	1.14	2.05	-0.63	1.76	3.61	-0.23	-0.22
E16	1.05	1.36	1.94	-0.23	1.70	3.57	0.24	0.05
E18	1.54	2.19	3.20	-0.04	2.51	4.14	-0.08	0.25
G14	0.80	1.61	2.75	-0.16	2.31	3.67	0.31	0.15
G18	0.33	0.93	2.22	-0.70	1.63	4.88	-0.38	-0.28
G18(II)	0.47	1.11	1.98	-0.43	1.54	3.62	0.44	0.00
G18(II)1-1.5	2.40	0.46	1.51	-0.88	0.39	3.67	0.16	-0.05
G18(II) 3-3.5	0.84	0.86	1.44	-0.93	0.41	3.64	0.14	0.27
H15	0.73	1.34	2.20	-0.24	2.11	3.52	0.48	0.38
H17 (I)	0.85	2.08	2.53	0.15	2.43	3.42	0.28	0.05
H17 (II)	0.98	2.05	2.54	0.37	2.41	3.43	0.49	0.17
H17 (III)	1.01	2.05	2.53	0.30	2.42	3.46	0.52	0.16
H17(IV)	0.99	1.96	2.83	0.44	2.56	3.27	0.45	-0.01
H17(V)top	1.11	2.23	2.59	0.69	2.67	3.45	0.33	0.19
H17(V)1.5	0.94	1.67	2.53	0.80	2.45	3.51	0.27	0.23
H17(V) 3.5	0.46	1.50	1.96	-0.42	1.77	3.66	0.11	0.45
H19	0.01	1.15	2.20	-0.69	1.59	3.53	-0.15	-0.38
H21	0.68	0.96	1.45	-0.89	0.97	3.61	0.06	-0.02
I20(II) 0-0.5	1.19	2.22	2.77	0.30	3.21	3.87	0.46	0.41
I20(II) 1-1.5	1.29	2.45	2.71	0.03	3.26	3.92	0.27	0.16
I20(II) 3-3.5	1.24	2.53	2.71	-0.07	3.35	3.69	0.24	0.07
I20	0.97	2.28	2.88	0.37	3.67	3.93	0.25	0.22
I22	1.43	2.12	2.46	2.01	2.82	3.51	1.15	-0.10
I27	0.81	0.56	2.09	-0.55	1.30	3.62	0.07	0.03
J19 (I)	1.85	1.71	2.68	1.94	2.82	3.59	1.01	0.16
J19(II)	0.88	1.47	2.39	1.45	2.51	3.23	0.63	-0.26
J19(III)1.5	0.39	2.14	1.66	0.53	3.42	3.02	0.33	-0.10
J19(III)3.5	0.50	2.07	2.77	0.37	2.64	2.74	0.33	-0.51
J19(III)6	-0.22	1.68	1.78	-0.22	2.10	2.83	0.42	-0.44
J19(IV)0.5	0.80	1.40	2.14	0.71	3.08	3.45	0.57	0.07
J19(IV)3.5	0.68	2.17	2.52	0.14	2.61	2.77	0.22	-0.45

Table A-2: Logarithmic (cont'd).

Samples	Ni	Cu	Zn	Cd	Pb	Al	Se	Sc
J19(IV) 6.0	0.33	2.10	2.41	0.15	2.45	2.85	0.32	-0.44
J21	0.64	1.09	1.79	0.79	2.08	3.47	0.54	-0.10
J23	0.96	2.06	3.08	2.16	3.48	3.51	1.40	0.04
K20	0.79	1.71	2.60	0.93	2.81	3.64	0.53	-0.02
K20(II)1.5	0.79	2.03	3.48	1.14	2.99	3.54	0.46	-0.17
K22	1.09	1.40	2.61	1.16	2.18	3.28	0.64	-0.23
K22(II)top	0.09	1.24	2.54	0.71	2.09	3.11	0.55	-0.34
M20	0.77	1.04	1.60	-0.73	1.64	3.61	0.14	0.01
M24 0.5	0.65	0.67	1.48	-0.64	1.16	3.61	0.16	0.08
M24 1.0	0.34	0.43	1.14	-0.96	0.64	3.41	0.19	-0.14
M24 3.0	0.77	1.50	2.00	-0.32	1.57	3.68	0.27	0.18
N21	0.64	1.55	2.71	0.13	2.46	3.46	0.42	-0.14
N21(II)1.5	0.59	1.59	2.75	-0.03	2.74	3.37	0.52	-0.07
N23	0.81	1.58	2.51	0.08	2.37	3.51	0.51	-0.01
022(II) 0.5	0.52	1.41	2.30	0.63	2.19	3.49	0.30	-0.20
O22(II)1.5	0.84	1.64	2.80	0.17	2.51	3.69	0.28	0.17
O22(II)3.5	0.43	0.98	2.45	-0.56	2.29	3.40	0.16	-0.10
O22(II)4.5	0.18	0.48	1.49	-0.97	1.69	3.32	0.13	-0.13
O22	0.14	0.54	1.58	-0.84	1.58	3.21	0.16	-0.26
O24	0.85	1.54	2.51	0.46	2.26	3.49	0.59	0.02
P23	0.10	1.19	2.27	-0.09	1.87	3.03	0.45	-0.41
P25	0.81	1.46	2.08	0.03	2.33	3.61	0.51	0.17
P25(II) 0-0.5	0.94	1.81	2.23	0.13	2.08	3.75	0.54	0.27
P25(II) 1-1.5	1.19	1.53	1.94	-0.14	1.74	3.69	0.47	0.32
P25(II) 3-3.5	0.73	0.97	1.42	-0.66	0.99	3.63	0.11	0.05
Q24(II)1.5	0.57	1.47	2.66	-0.26	2.33	3.51	0.19	-0.07
Q24(II)3.5	0.21	0.90	1.91	-0.60	1.91	3.20	0.05	-0.13
Q24*	0.76	1.54	2.67	0.20	2.45	3.57	0.19	0.04
Q26	0.69	1.06	1.93	-0.31	2.11	3.73	0.26	0.15
T27	0.46	0.33	0.90	-1.09	0.89	3.32	-0.17	-0.63
U26	0.64	1.01	1.69	-0.43	1.41	3.62	0.13	-0.02

Table A-2: Logarithmic (cont'd).

Samples	Ti	Hg	Ca	As	Sr
B5	2.11	-0.45	3.00	0.37	0.81
B7*	2.22	-0.52	3.05	0.77	0.76
B9	2.11	-0.62	2.71	0.15	0.44
C4	2.30	-0.66	3.00	0.45	0.78
C8	2.03	-0.76	2.95	0.28	0.75
C10	2.21	-0.79	3.22	0.41	0.92
C16	2.34	-0.60	4.09	0.60	1.59
D9	2.32	-0.72	3.17	0.51	0.92
D11	2.42	-0.78	3.79	0.45	1.10
D17	2.37	-0.19	4.13	0.95	1.62
E8	2.43	-0.88	3.30	0.07	1.03
E16	2.29	-0.18	3.97	0.66	1.61
E18	2.64	-0.57	4.42	0.72	1.90
G14	2.12	-0.37	4.90	1.25	2.32
G18	2.27	-0.93	3.67	0.53	1.26
G18(II)	2.22	-0.08	3.33	1.04	1.07
G18(II)1-1.5	2.40	-0.35	3.08	0.65	0.77
G18(II) 3-3.5	2.48	-0.45	3.21	0.02	0.82
H15	1.99	0.45	4.96	1.85	2.33
H17 (I)	2.11	0.02	4.11	2.48	1.83
H17 (II)	2.12	0.27	4.12	2.51	1.84
H17 (III)	2.15	0.26	4.10	2.51	1.84
H17(IV)	1.80	0.15	4.28	2.38	1.91
H17(V)top	1.86	0.76	4.24	2.61	2.07
H17(V)1.5	1.90	0.55	4.50	2.33	2.42
H17(V) 3.5	2.37	-0.05	5.05	2.42	2.10
H19	2.19	-0.67	3.88	0.36	1.45
H21	2.52	-0.64	3.33	-0.01	0.91
I20(II) 0-0.5	2.15	0.43	4.04	1.19	1.84
I20(II) 1-1.5	2.08	0.30	4.31	1.01	1.86
I20(II) 3-3.5	1.96	0.18	4.35	1.00	1.85
I20	2.06	-0.23	4.33	1.23	1.84
I22	1.99	0.22	4.21	0.50	1.94
I27	2.43	-0.61	3.36	0.27	0.98
J19 (I)	2.30	1.17	4.11	1.10	1.95
J19(II)	1.95	0.70	3.67	0.81	1.58
J19(III)1.5	1.68	1.31	3.36	1.62	1.43
J19(III)3.5	1.21	0.18	3.72	1.13	1.36
J19(III)6	1.55	-0.09	3.84	0.74	1.22
J19(IV)0.5	2.32	0.97	3.51	0.82	1.92
J19(IV) 1.5	1.99	1.08	3.56	1.42	1.52
J19(IV)3.5	1.57	0.52	3.73	1.11	1.40
J19(IV) 6.0	1.60	0.45	3.74	1.35	1.35

Table A-2: Logarithmic (cont'd).

Samples	Ti	Hg	Ca	As	Sr
J21	2.31	0.05	3.57	0.59	1.25
J23	2.08	1.43	4.13	0.86	1.98
K20	2.10	0.12	4.21	0.81	1.84
K20(II)1.5	1.73	0.39	4.19	1.14	1.88
K22	1.78	-0.11	4.24	0.67	1.95
K22(II)top	1.65	-0.11	4.15	0.51	1.85
M20	2.55	-0.54	3.41	0.27	0.98
M24 0.5	2.41	-0.53	3.50	0.18	0.97
M24 1.0	2.25	-0.52	3.35	-0.23	0.70
M24 3.0	2.46	-0.20	4.42	0.35	2.03
N21	1.96	0.12	4.16	1.06	1.60
N21(II)1.5	1.89	0.33	4.28	0.93	1.93
N23	2.11	0.15	4.08	1.05	1.60
022(II) 0.5	2.16	-0.04	4.08	0.74	1.71
O22(II)1.5	2.39	0.26	4.50	0.96	1.87
O22(II)3.5	2.26	-0.08	4.47	0.24	1.58
O22(II)4.5	2.40	-0.20	4.22	0.07	1.25
O22	2.20	-0.36	3.94	0.26	1.03
O24	2.16	0.08	4.16	1.06	1.56
P23	1.61	0.08	3.59	0.90	1.03
P25	2.34	0.37	3.91	0.99	1.42
P25(II) 0-0.5	2.49	0.78	3.98	1.03	1.54
P25(II) 1-1.5	2.58	0.32	3.96	1.08	1.48
P25(II) 3-3.5	2.48	-0.17	3.48	0.64	1.04
Q24(II)1.5	2.06	0.20	4.27	0.75	1.66
Q24(II)3.5	1.86	-0.02	4.41	0.38	1.39
Q24*	2.13	0.47	4.34	0.91	1.64
Q26	2.58	-0.33	3.81	0.43	1.51
T27	1.95	-0.57	3.01	-0.03	0.69
U26	2.41	-0.40	3.58	0.64	1.18

Appendix A

Table A-3: Non-Parametric Data for Multi-Elements.

Samples	K	Cr	Mn	Fe	Ba	Mg	V	Co	Ni	Cu	Zn	As
B5	48	73	48	64	63	71	65	58	32	62	59	58
B7*	38	66	31	34	61	68	40	39	59	63	64	37
B9	53	71	61	31	71	70	54	59	68	70	71	67
C4	43	63	50	51	66	60	27	41	50	61	57	53
C8	45	62	35	20	60	73	53	68	73	72	62	61
C10	30	69	34	44	59	56	61	44	64	65	60	56
C16	18	70	40	29	54	8	46	29	48	43	46	47
D9	32	61	44	11	55	57	9	42	51	60	56	51
D11	15	60	36	40	53	38	48	33	38	58	51	54
D17	8	38	21	6	20	9	22	7	6	14	20	29
E8	21	58	46	36	35	10	39	11	53	47	42	68
E16	19	46	18	8	56	59	51	6	12	41	48	43
E18	1	17	16	1	12	1	8	1	3	7	2	41
G14	16	23	3	4	14	3	23	16	29	26	10	12
G18	4	48	29	54	41	44	57	61	62	56	36	49
G18(II)	33	53	32	53	44	58	56	40	55	48	44	23
G18(II)1-1.5	26	67	60	59	70	42	36	35	1	69	65	44
G18(II) 3-3.5	11	72	59	43	62	19	24	9	23	59	69	70
H15	47	19	28	37	40	5	42	34	37	42	38	8
H17 (I)	29	4	17	52	38	52	1	52	22	12	23	4
H17 (II)	34	5	19	49	36	46	3	28	15	16	21	2
H17 (III)	35	3	20	45	37	50	2	36	13	17	24	3
H17(IV)	27	6	4	58	34	29	10	53	14	19	5	6
H17(V)top	55	1	10	72	19	62	6	30	10	4	19	1
H17(V)1.5	65	2	22	66	39	53	12	31	19	24	25	7
H17(V) 3.5	28	33	14	23	46	2	20	47	57	33	45	5
H19	20	54	13	33	33	61	63	64	71	46	37	59
H21	17	65	56	50	69	11	37	10	40	55	68	71
I20(II) 0-0.5	3	57	15	7	15	54	11	2	8	5	7	14
I20(II) 1-1.5	9	52	1	3	28	21	28	3	5	2	11	25
I20(II) 3-3.5	13	44	2	5	29	4	15	5	7	1	12	26
I20	5	55	7	2	17	35	19	4	16	3	4	13
I22	10	25	62	41	26	18	5	63	4	10	29	52
I27	14	12	53	38	65	27	32	24	25	66	40	63
J19 (I)	6	16	23	9	8	24	7	15	2	22	14	18
J19(II)	49	13	51	17	4	41	13	43	20	36	32	36

Table A-3: Non-Parametric (cont'd)

Samples	K	Cr	Mn	Fe	Ba	Mg	V	Co	Ni	Cu	Zn	As
J19(III)1.5	68	7	72	71	5	72	52	69	60	9	58	9
J19(III)3.5	67	10	73	68	22	69	73	70	54	13	8	16
J19(III)6	62	31	66	73	47	65	72	71	72	23	53	39
J19(IV)0.5	39	20	47	14	2	37	17	21	28	40	39	34
J19(IV) 1.5	56	15	69	69	10	66	45	65	44	6	54	10
J19(IV)3.5	64	18	70	62	24	63	70	73	41	8	26	17
J19(IV) 6.0	54	14	71	67	32	64	71	72	63	11	31	11
J21	2	42	26	42	31	55	47	55	45	49	52	48
J23	40	9	68	15	21	15	4	25	17	15	3	33
K20	25	22	5	26	16	12	38	46	30	21	18	35
K20(II)1.5	52	8	12	24	11	22	58	27	31	18	1	15
K22	41	34	25	21	30	16	26	60	11	39	17	42
K22(II)top	57	40	49	39	42	25	50	66	70	44	22	50
M20	23	56	52	25	68	6	30	8	33	51	61	62
M24 0.5	22	59	45	48	64	13	34	19	42	64	67	66
M24 1.0	36	68	55	32	73	26	60	45	61	71	72	73
M24 3.0	7	64	8	35	23	7	31	14	34	34	43	60
N21	12	24	9	18	9	43	41	48	46	29	13	20
N21(II)1.5	50	21	27	46	7	36	55	51	47	27	9	30
N23	42	30	30	10	27	31	35	37	26	28	27	22
022(II) 0.5	37	28	24	47	18	47	49	54	52	38	33	40
O22(II)1.5	31	11	41	27	6	34	29	22	24	25	6	28
O22(II)3.5	44	39	57	60	13	45	62	49	58	53	30	65
O22(II)4.5	46	49	64	65	58	39	64	57	66	68	66	69
O22	51	47	67	70	51	49	66	56	67	67	63	64
O24	24	29	6	12	25	32	25	17	21	31	28	21
P23	70	35	39	63	45	67	68	67	69	45	34	32
P25	66	37	42	22	50	23	21	13	27	37	41	27
P25(II) 0-0.5	59	32	37	16	43	20	16	26	18	20	35	24
P25(II) 1-1.5	61	36	43	19	49	28	14	20	9	32	47	19
P25(II) 3-3.5	60	45	63	57	67	30	43	32	36	54	70	46
Q24(II)1.5	72	27	58	56	3	51	59	38	49	35	16	38
Q24(II)3.5	73	41	65	55	48	48	67	50	65	57	50	57
Q24*	69	26	33	28	1	33	33	23	35	30	15	31
Q26	58	51	11	13	52	17	18	18	39	50	49	55
T27	71	50	54	61	72	40	69	62	56	73	73	72
U26	63	43	38	30	57	14	44	12	43	52	55	45

Table A-3: Non-Parametric (cont'd)

Samples	Sr	Cd	Pb	Al	Se	Sc	Ti	Hg	Ca
B5	66	65	52	57	60	65	44	55	70
B7*	69	54	61	34	58	62	32	57	68
B9	73	66	69	55	68	71	43	64	73
C4	67	59	59	31	65	56	25	66	71
C8	70	64	65	62	67	72	52	69	72
C10	63	51	63	35	66	61	33	71	64
C16	33	56	56	7	54	39	21	62	32
D9	62	53	62	16	64	60	23	68	66
D11	53	55	58	30	63	44	12	70	44
D17	29	35	25	12	31	13	18	45	26
E8	56	57	46	24	72	54	10	72	63
E16	30	41	48	32	41	26	27	44	37
E18	14	34	20	2	69	7	1	61	7
G14	3	39	32	14	32	20	41	52	3
G18	48	62	51	1	73	59	28	73	49
G18(II)	54	48	57	23	23	32	31	38	61
G18(II)1-1.5	68	68	73	15	49	38	16	50	67
G18(II) 3-3.5	65	70	72	19	51	6	7	54	65
H15	2	42	37	38	17	3	54	13	2
H17 (I)	25	25	26	52	34	24	45	34	30
H17 (II)	23	18	28	51	16	15	42	20	28
H17 (III)	20	21	27	48	13	16	39	21	31
H17(IV)	13	17	17	61	21	34	64	27	15
H17(V)top	5	13	14	50	27	10	63	7	17
H17(V)1.5	1	8	22	43	37	8	60	9	5
H17(V) 3.5	4	46	45	17	57	1	19	37	1
H19	41	61	53	37	70	64	35	67	41
H21	64	69	68	28	61	35	5	65	62
I20(II) 0-0.5	22	22	7	5	19	2	38	14	35
I20(II) 1-1.5	17	32	6	4	36	18	48	19	13
I20(II) 3-3.5	18	36	5	10	42	22	56	25	10
I20	21	20	1	3	40	9	50	48	12
I22	10	2	10	41	2	47	55	23	21
I27	60	49	64	21	59	29	11	63	59
J19 (I)	9	3	11	29	3	17	26	3	29
J19(II)	34	4	19	63	5	58	59	8	48
J19(III)1.5	42	15	4	69	29	46	67	2	58
J19(III)3.5	46	19	15	73	28	70	73	26	47
J19(III)6	51	40	39	71	24	67	72	40	42

Table A-3: Non-Parametric (cont'd)

Samples	Sr	Cd	Pb	Al	Se	Sc	Ti	Hg	Ca
J19(IV)0.5	12	12	8	49	7	23	22	5	54
J19(IV) 1.5	38	11	3	65	26	42	53	4	53
J19(IV)3.5	44	27	16	72	43	69	71	10	46
J19(IV) 6.0	47	26	24	70	30	68	70	12	45
J21	50	9	42	46	10	45	24	33	52
J23	7	1	2	42	1	28	49	1	27
K20	24	7	12	18	11	36	47	30	20
K20(II)1.5	15	6	9	36	20	52	66	15	22
K22	8	5	36	60	4	55	65	42	18
K22(II)top	19	10	40	67	8	63	68	41	25
M20	59	63	50	27	52	31	4	59	57
M24 0.5	61	58	66	25	50	21	14	58	55
M24 1.0	71	71	71	53	46	50	30	56	60
M24 3.0	6	45	55	13	38	11	9	47	8
N21	32	29	21	47	25	51	57	29	23
N21(II)1.5	11	33	13	56	12	41	61	17	14
N23	31	30	29	39	14	33	46	28	34
022(II) 0.5	26	14	35	45	33	53	36	36	33
O22(II)1.5	16	24	18	9	35	14	17	22	4
O22(II)3.5	35	50	33	54	48	43	29	39	6
O22(II)4.5	49	72	49	59	55	48	15	46	19
O22	58	67	54	64	47	57	34	51	39
O24	36	16	34	44	6	30	37	31	24
P23	57	37	44	68	22	66	69	32	50
P25	43	31	31	26	15	12	20	16	40
P25(II) 0-0.5	37	28	41	6	9	5	6	6	36
P25(II) 1-1.5	40	38	47	11	18	4	2	18	38
P25(II) 3-3.5	55	60	67	20	56	25	8	43	56
Q24(II)1.5	27	43	30	40	44	40	51	24	16
Q24(II)3.5	45	52	43	66	62	49	62	35	9
Q24*	28	23	23	33	45	27	40	11	11
Q26	39	44	38	8	39	19	3	49	43
T27	72	73	70	58	71	73	58	60	69
U26	52	47	60	22	53	37	13	53	51

Appendix B

Table B-1: Result of T-RFLP Analsys.

Numbers are in Peak Height											
Sample	**32**	**36**	**48**	**65**	**67**	**69**	**72**	**73**	**75**	**77**	**78**
B5	65									93	67
B7	75									262	
B9											112
C10											
C16					73	52				82	
C4											
C6											
C8								51		81	
D17	59										58
D9	56		50		60			56		112	55
E16	102				55					259	
E18	100				53	53				90	52
E8						137				50	249
G14										54	
G18										85	
H15											
H17(I)								382	81	100	77
H17(II)								104			
H17(II)					65			85		165	
H17(IV)								82			
H17(V)top	57							97		59	
H17(V)1.5											
H17(V)3.5											
H19											
H21	83				70					95	93
I20(II)1.5					62			79			
I20											
I22											
J19(I)	54										
J19(II)					68						
J19(III)1.5								96	67		
J19(IV)0.5											
J19(IV)1.5	53							59			
J19(IV)3.5								80	99		
J21	83							50		61	
J23						280				93	
K20	54										

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height											
Sample	**32**	**36**	**48**	**65**	**67**	**69**	**72**	**73**	**75**	**77**	**78**
K20(II)1.5											
K22		55				301				113	
M24 1.0				106	333	706					92
N21	2653		59			51		125		66	
N21(II)1.5	52		53					99		397	
N23					61	236				114	
O22											
O22(II)1.5											
O24										95	
P23										62	54
P25						264					
P25(II)0.5						79				100	
P25(II)1.5						434					
Q24					57					59	
Q24(II)1.5								59		60	
Q26						137				51	
U22										116	86

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**79**	**80**	**82**	**83**	**85**	**87**	**89**	**91**	**93**	**95**	**97**	**99**
B5				180	287		110	1002	586	1478	841	
B7	50			80	542			663	368	967	299	
B9	51						55	344	144	1033	183	
C10							60	188	95	265	120	
C16					798	186		312	150	294	327	
C4								61		132		
C6								103	108	1314		
C8					183			677	536	861		
D17		60		55	240	50		248	143	388	115	
D9				219	114		73	417	410	2084	364	
E16				274	413		105	790	519	1512	2420	
E18				66	521	126	50	1446	622	1082	468	
E8		50		144			143	1223	535	1211	458	
G14					287	122		260	158	309	61	
G18				126	115	183	112	832	367	685	191	
H15					185			273	88	227		
H17(I)				324	340	125	120	1586	776	1916	513	
H17(II)		56			95		75	670	245	841	247	
H17(II)					146		66	557	249	415	89	
H17(IV)				66	767	189	101	1213	491	985	260	
H17(V)top					190		70	396	161	341	100	
H17(V)1.5				4770	1027		287	257	259	259		
H17(V)3.5				1118	137	73	113	306	117		71	
H19				60	71			145	67	285	88	
H21	93			163	300	105	186	1982	942	2134	468	
I20(II)1.5					315	56		615	328	873	319	
I20					87			306	122	312	106	
I22				762	2066	203	189	494	332	336		
J19(I)				831	3259	558	228	1939	781	1240	349	
J19(II)				154	823	142	94	1069	461	772	177	
J19(III)1.5	88			179	123		63	136		599		
J19(IV)0.5	50			53	74		177	1497	570	1058	324	
J19(IV)1.5	78				108	70	162	1117	443	1081	221	
J19(IV)3.5	84				121		85	210	90	376		
J21	164						56	404	247	388	61	
J23					54		105	377	511	412	84	
K20				674	4722	1378		1478	511	732		

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**79**	**80**	**82**	**83**	**85**	**87**	**89**	**91**	**93**	**95**	**97**	**99**
K20(II)1.5				141	1806	580		460	217	416	101	
K22				52	297		147	531	1041	833		
M24 1.0		63			51		698	277	1238	391	160	
N21				146	761		102	1227	873	2130	696	
N21(II)1.5	58			50	215		149	497	374	650		
N23							117	272	781	367		
O22					1079			90	84	94		
O22(II)1.5					75			82	72	313	53	
O24				51	66			499	215	762	279	
P23	58			68	377	68	145	682	608	725	155	
P25							61	149	299	136	50	
P25(II)0.5							83	109	411	559	195	
P25(II)1.5						53	62	71	355	275	75	
Q24					69			134	74	212		
Q24(II)1.5				146	429		133	371	139	683		
Q26				106	2815		133	590	448	434	121	
U22	56			58	332	55	58	789	414	761	152	

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height													
Sample	**123**	**125**	**127**	**128**	**129**	**131**	**133**	**134**	**136**	**137**	**138**	**140**	**141**
B5	65		104			212					303		636
B7	146	56	103	57		136						420	675
B9			66			130					362		406
C10												64	86
C16			172		65	130	51				232		333
C4												79	72
C6			56										1285
C8	72		151	91	51	163					229		663
D17			132		67	132					153		329
D9		127	92			145		54			220		302
E16	76		247		82	74					133		576
E18	134		343		170	276				145	718		887
E8			56			117					381		348
G14			63			78					229		287
G18			94			93					120		355
H15	58		123			338					280		281
H17(I)			316		107	103					218		566
H17(II)			124			152					66		221
H17(II)			354		115	81					354		702
H17(IV)			243		65	155					142		383
H17(V)top			169			98					116		278
H17(V)1.5	105	521	51							68	68		
H17(V)3.5		115											
H19			56			53					51		192
H21			103			122					279		543
I20(II)1.5			87		59						102	77	238
I20			108			67					142		191
I22	53		55			79					61		106
J19(I)	83		174			111					214		592
J19(II)			241		79	156					209		695
J19(III)1.5			220		63	67	90				144	234	219
J19(IV)0.5			106			111	93				180		425
J19(IV)1.5			236			117	169				163		810
J19(IV)3.5					69	200	126				131		188
J21			139	232		106		55			101		2316
J23	282		136			124					408		645
K20			61	94		50							140
K20(II)1.5			64			51							122
K22	177	67	149		77	304					200		332

<u>Table B-1: T-RFLP (cont'd).</u>

Numbers are in Peak Height													
Sample	**123**	**125**	**127**	**128**	**129**	**131**	**133**	**134**	**136**	**137**	**138**	**140**	**141**
M24 1.0	64		110			161		111		89		289	
N21			146		69	105				85		328	
N21(II)1.5	82		155		54	123				138		321	130
N23	166		262		160	324				325		459	181
O22		71	158									77	
O22(II)1.5			122		73	110				134		193	96
O24	77		158			60				161	125	295	131
P23	62		112			50				150		403	
P25	303		86	57		77				81		63	
P25(II)0.5	93		202		80	143				124		340	
P25(II)1.5	122		160		91	76						144	
Q24			206		117	170			77	321		476	284
Q24(II)1.5		50	167		70	303				380		361	302
Q26	87		72			134					129	222	85
U22	50		222			147				389		569	

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height											
Sample	**143**	**145**	**146**	**147**	**150**	**151**	**153**	**155**	**155**	**156**	**157**	**159**
B5		525		271	1329	762					54	
B7		156		429	890	756						
B9		109		131	792	664						
C10		75	93	59	225	126						
C16		135		136	903	326						
C4					164	125						
C6				92	481	406						
C8		132		527	832	790	413					
D17		442		117	666	472						
D9		634		232	1183	715						438
E16		579		200	977	980						
E18		737		356	2038	1006						
E8		1277	538	187	747	331						
G14	142	197		112	415	135						
G18		275		92	817	396						
H15		139	285	102	529	156						
H17(I)		500		386	1127	741					61	
H17(II)	103	280	531	184	431	254						
H17(II)	305	249		196	1004	509	156				92	
H17(IV)	126	429		206	769	386						
H17(V)top	161		176	154	414	414					68	
H17(V)1.5					118	87						
H17(V)3.5					150	118	130					
H19	57	164		50	257	233						
H21		685		194	1085	479						
I20(II)1.5	168	460			442	395					59	75
I20	78	153		64	418	253						
I22			94		252	86						
J19(I)	132	296		222	1107	831						
J19(II)			181	200	1052	1030						
J19(III)1.5	223	196		253	534	1130					168	
J19(IV)0.5		192		151	657	399						
J19(IV)1.5		744		244	1073	699					81	
J19(IV)3.5	131	76		215	322	656					150	
J21		195		369	1008	1112						
J23	199		154	159	427	288						
K20		267		62	265	159	79					97

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**143**	**145**	**146**	**147**	**150**	**151**	**153**	**155**	**155**	**156**	**157**	**159**
K20(II)1.5		147		64	133	97						
K22	159	147		162	410	325						79
M24 1.0		113		126	550	544				58		
N21			445	354	849	680			238	238	142	
N21(II)1.5	130	91		157	410	596					70	
N23	181	99	107	173	654	496	64					
O22					407	344						
O22(II)1.5	96	132		101	260	242						97
O24	131	436	124		424	424						
P23		66		198	723	628					66	
P25					152	161						
P25(II)0.5		199		119	395	550						
P25(II)1.5				62	233	343						
Q24	284	297	249	229	825	597						
Q24(II)1.5	302	239	146	166	437	379					51	102
Q26	85		153	77	250	237						
U22			237	224	1483	774					63	

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**160**	**161**	**163**	**165**	**167**	**175**	**177**	**179**	**182**	**184**	**185**	**186**
B5	85											
B7	68											
B9												
C10												
C16		264	247			100						
C4												
C6									56			
C8				120		66				64	135	
D17			67									
D9			53	758						70	72	
E16	78		52									
E18	71		54	58				64		51		
E8		129	62									
G14		102	187			64						
G18	75		147									
H15		388	907									
H17(I)	194		113	80								
H17(II)	57	120	220									
H17(II)	184	184	115	72		74			53			
H17(IV)	90	60	126									
H17(V)top	111		179			66						
H17(V)1.5			3690				56					
H17(V)3.5			4209									
H19			191									
H21			79									
I20(II)1.5	66		57									
I20			87									
I22		84	53									
J19(I)		92	179									
J19(II)	87		161				64					51
J19(III)1.5	197		250									
J19(IV)0.5	212		50				163					
J19(IV)1.5	718		113	75			99					
J19(IV)3.5	107	107										
J21		62		59								
J23	51	114	620				65					63
K20		109	69									

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**160**	**161**	**163**	**165**	**167**	**175**	**177**	**179**	**182**	**184**	**185**	**186**
K20(II)1.5		59	57									
K22		335	434		257		56					
M24 1.0	287	511	483				171			70		66
N21		1134			58		71				55	
N21(II)1.5	58		399									
N23		250	436									
O22			4938		152		54	254				
O22(II)1.5		101	179									
O24		164	337									
P23	130	130		62								
P25		127	189									
P25(II)0.5	68		221									
P25(II)1.5	56		201	69						59		
Q24	82		133				55					
Q24(II)1.5		71	495					79				
Q26		79	99									
U22	92	85	92				62					

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**188**	**189**	**192**	**194**	**198**	**200**	**202**	**204**	**206**	**207**	**207**	**209**
B5						314			296	399	399	328
B7						504			164	164	170	208
B9						109			94	94	127	141
C10						65				60	95	72
C16						694				71	71	
C4												
C6												
C8				51		190				182	182	188
D17						342			76	76	138	
D9						132	113		83	83	209	394
E16					152	658			333	471		234
E18			62		83	494				618		
E8						168			152	152		
G14						182				72	54	
G18						215	276		250	250	256	140
H15						156				70	70	
H17(I)				61	82	227	50			413	413	
H17(II)						94			105	105	128	
H17(II)				83	211	492			239	239	252	
H17(IV)					58	195			192	192	220	
H17(V)top					84	202				88	110	
H17(V)1.5							271					
H17(V)3.5	57					52						
H19						165				130	130	68
H21						323			390	390	214	82
I20(II)1.5					78	170				182	182	
I20						177				192	192	
I22			65			53			69	69	69	
J19(I)			83			129	139		151	151	365	75
J19(II)						339			191	191	226	
J19(III)1.5			116	74		93				74	74	
J19(IV)0.5						86			175	175	54	
J19(IV)1.5						119	63		184	184		
J19(IV)3.5			122									
J21				271						184		
J23					52	247				89	136	109
K20						570	570		77	100	99	

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**188**	**189**	**192**	**194**	**198**	**200**	**202**	**204**	**206**	**207**	**207**	**209**
K20(II)1.5						72	125			57	57	
K22						168	87			217	217	
M24 1.0		82		170		259			91	91		
N21						146	83			167	167	52
N21(II)1.5						214			163	163	120	
N23					55	304				152	149	77
O22												
O22(II)1.5						164	87					
O24						194			170	170	266	
P23						210	75		147	147	140	60
P25										77		
P25(II)0.5						306				102	80	98
P25(II)1.5						146				86	55	74
Q24					198	543			104	104	126	
Q24(II)1.5				53	162	205			96	96	62	
Q26						127			140	140	132	
U22					232	665			179	179	248	

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**211**	**214**	**215**	**222**	**224**	**227**	**229**	**233**	**235**	**243**	**247**	**263**
B5												73
B7							66					185
B9												
C10												
C16			159					68				
C4												
C6							145					79
C8							78					165
D17			53									
D9			64				83					
E16												
E18		124	124			56	82	137				121
E8			54									
G14												51
G18												65
H15	50											
H17(I)	80											153
H17(II)												
H17(II)			85					56				99
H17(IV)	55											79
H17(V)top		88	50						75			
H17(V)1.5												
H17(V)3.5			77									
H19												
H21	65		77									
I20(II)1.5												
I20												
I22												
J19(I)	120											54
J19(II)	55											
J19(III)1.5					256							
J19(IV)0.5	67											
J19(IV)1.5												
J19(IV)3.5							120			72		
J21			53									3844
J23				54								68
K20	64											
K20(II)1.5												
K22												71

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**211**	**214**	**215**	**222**	**224**	**227**	**229**	**233**	**235**	**243**	**247**	**263**
M24 1.0												
N21	58										93	
N21(II)1.5				53							57	
N23				73								55
O22												
O22(II)1.5									52			
O24												
P23			61									82
P25												
P25(II)0.5					155							
P25(II)1.5					139							
Q24			74				53					
Q24(II)1.5				135					179			
Q26												
U22			176				76					63

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**265**	**267**	**269**	**272**	**273**	**275**	**277**	**279**	**280**	**282**	**283**	**284**
B5	396	97			60							323
B7	1090	256		261	209	436						303
B9	283	131	64		102						65	84
C10	147											110
C16	54											
C4	219											
C6	1097	344			155	80						52
C8	1759	384				67						81
D17	167	56			103							293
D9	444	157		61	197	225						51
E16	498	274			113	119						491
E18	245	63			75							1124
E8	50											999
G14	54											218
G18	294	81				147						433
H15						82						291
H17(I)	507											1173
H17(II)	111	65										595
H17(II)	323	123										382
H17(IV)	223	88										723
H17(V)top	67											169
H17(V)1.5							218					
H17(V)3.5			142									
H19	91					50						144
H21	182	76			63	59						1010
I20(II)1.5	66				63							338
I20	57											153
I22	63											97
J19(I)	513	124										557
J19(II)	650											171
J19(III)1.5	354	146										62
J19(IV)0.5	260				58	75						155
J19(IV)1.5	395			72	72	65						221
J19(IV)3.5	706	213								66	66	148
J21					164	130	57		300	92	92	56
J23	112											87
K20	83	60										201
K20(II)1.5												87
K22	137					61						171

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**265**	**267**	**269**	**272**	**273**	**275**	**277**	**279**	**280**	**282**	**283**	**284**
M24 1.0	110			53	53	76	167	72	94			166
N21	219											188
N21(II)1.5	212	83					74	57	57			78
N23	164											150
O22												
O22(II)1.5	50											135
O24	146	69										322
P23	533	158			82					52	52	150
P25					55							139
P25(II)0.5	57											76
P25(II)1.5	72											119
Q24	93											215
Q24(II)1.5	75	61										340
Q26	103											222
U22	141	53										320

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**286**	**288**	**290**	**292**	**293**	**293**	**295**	**297**	**298**	**299**	**301**	**302**
B5	321			333		233			958			141
B7	154			78		344			114			
B9	66					213			684			
C10	77					83			226			
C16	200				544		117	117	165			
C4						51						
C6			957		344							
C8	130			63		159						
D17	343				454	297	297		398			
D9						253			475			
E16	491	65		522						287	284	
E18	1130				480				831			
E8	755			173					1029			
G14	512				133				53			
G18	309			81		261	189		189		116	
H15	725			119		98	121		55			
H17(I)				304				504				
H17(II)	502					171			259			
H17(II)	430				575				216			
H17(IV)	714					227			344		69	
H17(V)top	211				272				110	57		
H17(V)1.5												
H17(V)3.5				160				289				
H19	127					198			260			
H21	718	249		232		192	192		583			
I20(II)1.5	468		71	64	221				527		54	
I20	199					244			201			
I22	88			421		77						
J19(I)	417					181			293		58	58
J19(II)	153					453			99			
J19(III)1.5	54					168			53			
J19(IV)0.5	147				59				138			
J19(IV)1.5	441				153				236			
J19(IV)3.5												
J21	56		91							50		
J23	95		56			197	66	68	65			
K20	206			113		117			232			
K20(II)1.5	99			53		83	56		101			
K22	375	88	182	109		206	135		90	92		

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**286**	**288**	**290**	**292**	**293**	**293**	**295**	**297**	**298**	**299**	**301**	**302**
M24 1.0	76	188	210			312			194	184		
N21	205	87		173					535			52
N21(II)1.5	66				311				215			
N23		73	79		287				121	102		
O22				97								
O22(II)1.5	123				266				64			
O24	254			52		299			767			
P23	143					241			102			
P25			142	90					59			
P25(II)0.5	67	94	86	77		136			65			
P25(II)1.5		73	120	82		86						
Q24	157			491					215			
Q24(II)1.5	170		93	93	313				146			
Q26	120					231			101	54		
U22	258	60			676				133			

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**304**	**305**	**307**	**308**	**309**	**311**	**316**	**318**	**320**	**323**	**361**	**365**
B5												
B7				73								
B9												
C10												
C16												
C4												
C6				322		66						
C8					172							
D17												
D9					63							
E16					52				68			
E18	169											
E8												
G14												
G18												
H15												
H17(I)												
H17(II)												
H17(II)												
H17(IV)												
H17(V)top	107											
H17(V)1.5							63					
H17(V)3.5												
H19												
H21												
I20(II)1.5												
I20												
I22												
J19(I)												
J19(II)			109									
J19(III)1.5	73		125									
J19(IV)0.5				88								
J19(IV)1.5			156					110				
J19(IV)3.5				164								
J21				322								
J23												
K20												
K20(II)1.5												
K22		50										

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**304**	**305**	**307**	**308**	**309**	**311**	**316**	**318**	**320**	**323**	**361**	**365**
M24 1.0	56	50										
N21			50									
N21(II)1.5			67									
N23												
O22												
O22(II)1.5												
O24								52				
P23				106								
P25												
P25(II)0.5												
P25(II)1.5												
Q24												
Q24(II)1.5												
Q26		66										
U22												

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**385**	**400**	**402**	**404**	**407**	**417**	**420**	**422**	**424**	**426**	**427**	**429**
B5			70	67	77							
B7				76	61							
B9				68	70							
C10												
C16												54
C4												
C6												
C8				128	125							
D17				119	211							
D9				53	63							
E16					109							
E18				154	313							
E8			69	73	69							
G14												
G18					105							
H15				94	80							
H17(I)				177	153							
H17(II)					104							
H17(II)			77	87	51							76
H17(IV)				76	170							
H17(V)top												
H17(V)1.5				51		111						97
H17(V)3.5				99	253			270				
H19												
H21				179								
I20(II)1.5												
I20				55	99							
I22				62								
J19(I)		93		172					112		606	626
J19(II)				50	52							
J19(III)1.5												
J19(IV)0.5				116								
J19(IV)1.5			71	50	66							
J19(IV)3.5												
J21				62	72							
J23												
K20				130						113		295
K20(II)1.5												
K22												123

Table B-1: T-RFLP (cont'd).

Numbers are in Peak Height												
Sample	**385**	**400**	**402**	**404**	**407**	**417**	**420**	**422**	**424**	**426**	**427**	**429**
M24 1.0												
N21					52							
N21(II)1.5												
N23												
O22			82									70
O22(II)1.5												
O24												
P23				76	122							
P25												
P25(II)0.5												
P25(II)1.5												
Q24												
Q24(II)1.5					61							
Q26												
U22				52					55	71	91	101

Appendix C

Table C-1: Sample Site ID Conversion Table

Geochemical Sample ID List	Microbial Sample ID List	**Geochemical Sample ID List**	Microbial Sample ID List
B5	B5R	**J19(III)1.5**	J19 1.5
B7*	B7R	**J19(III)3.5**	J19 3.5
B9	B9R	J19(III)6	J19 6.0
C4	C4R	**J19(IV)0.5**	J19 0.5
C8	C8R	**J19(IV) 1.5**	J19 1.5
C10	C10a	**J19(IV)3.5**	J19 3.5
C16	C16a	**J19(IV) 6.0**	J19 6.0
D9	D9R	**J21**	J21R
D17	D17aR	**J23**	J23
E8	E8R	**K20**	K20a0.5R
E16	E16bR	**K20(II)1.5**	K20b 1.5
E18	E18bR	**K22**	K22d
G14	G14a	**M24 0.5**	M24 0.5
G18	G18R	**M24 1.0**	M24 1.0
H15	H15bR	**M24 3.0**	M24 3.0
H17 (I)	H17a	**N21(II)1.5**	N21a 1.5R
H17 (II)	H17a	**N23**	N23
H17 (III)	H17a	**O22(II)1.5**	O22d 1.5
H17(IV)	H17b	**O22**	O22a
H17(V)top	H17 0.5R	**O24**	O24R
H17(V)1.5	H17 1.5	**P23**	P23R
H17(V) 3.5	H17 3.5R	**P25**	P25cR
H19	H19R	**P25(II) 0-0.5**	P25a 0.5
H21	H21R	**P25(II) 1-1.5**	P25b 1.5
I20(II) 1-1.5	I20bR	**Q24(II)1.5**	Q24c 1.5
I20	I20bR	**Q24(II)3.5**	Q24b 3.5
I22	I20bR	**Q24***	Q24dR
J19 (I)	J19a 0.5	**Q26**	Q26bR
J19(II)	J19b 0.5	**U26**	U26

Appendix D

Table D-1: R-mode Analysis of Logarithmic Multi-Elemental Data

	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	8.39031837	3.19712197	0.3995	0.3995
Factor 2	5.19319640	3.77551331	0.2473	0.6468
Factor 3	1.41768309	0.21538357	0.0675	0.7143
Factor 4	1.20229951	0.24213349	0.0573	0.7716
Factor Loadings				
	Factor1	**Factor2**	**Factor3**	**Factor4**
K	-0.01542	0.41223	-0.01435	0.74759
Cr	0.81094	0.03176	0.53399	-0.30978
Mn	0.42141	0.51889	-0.15203	0.62333
Fe	0.23549	0.49664	0.03715	0.81798
Ba	0.77197	-0.03535	0.50992	0.09871
Mg	0.28704	0.71095	-0.15137	0.39424
V	0.31052	0.70792	0.39065	0.27369
Co	0.11679	0.82576	-0.06821	0.56013
Ni	0.29555	0.64316	0.42551	0.21518
Cu	0.84029	0.15073	0.58481	0.0878
Zn	0.86531	0.11902	0.44286	0.32564
As	0.71505	0.24215	0.36787	-0.28726
Sr	0.92939	0.36425	0.39321	0.12806
Cd	0.6484	-0.00792	0.87951	0.06341
Pb	0.82731	-0.01555	0.65296	0.12853
Al	-0.01444	0.68992	-0.29492	0.61504
Se	0.47502	0.07689	0.86192	-0.03808
Sc	0.43742	0.89873	0.13051	0.15093
Ti	-0.39679	0.71639	-0.3424	0.34334
Hg	0.63517	0.01365	0.82085	-0.33038
Ca	0.85131	0.38337	0.10519	0.10047
Factor Scores				
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**
B5	-1.5922	-1.06847	-0.21772	-0.16454
B7*	-1.43339	-0.46862	-0.46701	0.39123
B9	-2.11244	-1.39732	-0.48103	0.11808
C4	-1.5274	-0.27272	-0.41993	0.14354
C8	-1.45971	-2.28628	-1.13212	0.67339
C10	-1.321	-0.63844	-0.93562	0.50492
C16	-0.42148	0.44589	-1.09353	0.59482

Table D-1: R-mode (cont'd)

Factor Scores				
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**
D9	-1.3544	-0.1321	-0.3667	0.80865
D11	-0.86589	0.18125	-0.92381	0.47117
D17	0.51293	0.94612	0.03811	1.28652
E8	-0.83307	0.01533	-1.06918	0.95379
E16	-0.25518	0.46974	-0.22132	0.88773
E18	1.0251	1.86036	-0.71968	2.22374
G14	1.4877	0.93835	-0.99776	1.269
G18	-0.37615	-0.13307	-1.96389	1.3512
G18(II) 0-0.5	-0.65464	-0.08891	-0.02799	-0.03983
G18(II) 1-1.5	-1.99715	1.04137	0.09724	-0.63835
G18(II) 3-3.5	-1.77337	1.07274	-0.54035	-0.1327
H15	1.27073	1.18054	-0.59151	-0.99934
H17 (I)	0.94768	0.68053	0.36165	-0.65034
H17 (II)	0.95628	1.00163	0.74619	-0.78075
H17 (III)	0.91328	0.99485	0.79441	-0.7811
H17(IV)	1.35207	0.20436	0.35093	-0.38263
H17(V)top	1.42362	0.74533	0.77695	-1.64772
H17(V)1.5	1.44574	0.83031	0.18173	-1.67344
H17(V) 3.5	1.22181	1.78686	-1.60109	-0.8455
H19	-0.13092	-1.0855	-1.45093	1.00822
H21	-1.5421	0.69626	-0.8697	0.15578
I20(II) 0-0.5	0.67873	0.95525	0.86456	1.60742
I20(II) 1-1.5	1.04264	0.74338	0.02301	2.0665
I20(II) 3-3.5	1.22328	0.71551	-0.09456	1.79069
I20	1.05704	0.51097	0.07854	2.18089
I22	0.34659	-0.046	2.63686	0.39048
I27	-0.97635	0.5372	-0.57169	0.03298
J19 (I)	0.64376	0.89394	2.7165	0.94402
J19(II)	0.3148	-0.69258	1.88162	0.26845
J19(III)1.5	0.38715	-1.46942	1.80034	-2.309
J19(III)3.5	0.56102	-2.66035	0.76213	-1.298
J19(III)6	-0.0211	-2.21138	-0.14707	-1.51913
J19(IV)0.5	0.35721	0.14163	1.55198	0.25122
J19(IV) 1.5	0.31263	-0.79251	1.57889	-1.55677
J19(IV)3.5	0.47163	-2.11834	0.69953	-1.29292
J19(IV) 6.0	0.39371	-2.07998	0.61965	-1.30237
J21	-0.50069	-0.36773	0.82656	0.51047
J23	0.70036	0.21843	3.42826	0.2576

Table D-1: R-mode (cont'd)

Factor Scores				
Sample	**Factor1**	**Factor2**	**Factor3**	**Factor4**
K20	0.85772	-0.00058	0.41325	0.82816
K20(II)1.5	1.46195	-0.65735	0.57622	0.88408
K22	0.57272	-0.57984	0.82191	0.55292
K22(II)top	0.43677	-1.33061	0.23783	-0.03917
M20	-1.14088	0.90586	-0.62336	0.25772
M24 0.5	-1.30383	0.66573	-0.70498	-0.00784
M24 1.0	-1.82222	-0.14544	-0.87176	0.01323
M24 3.0	0.14837	0.96544	-0.83994	0.80682
N21	0.77451	-0.49755	0.16311	0.81052
N21(II)1.5	1.04007	-0.53607	0.19653	0.03335
N23	0.46399	0.06553	0.33156	0.51621
022(II) 0.5	0.36707	-0.45108	0.05413	0.30779
O22(II)1.5	0.90551	0.53614	0.06228	0.23127
O22(II)3.5	0.25482	-0.39849	-0.66925	-0.13706
O22(II)4.5	-0.80649	-0.15976	-1.02566	-0.86747
O22	-0.86584	-0.64466	-0.84434	-1.07133
O24	0.50772	0.27331	0.43675	0.77761
P23	-0.05766	-1.75209	0.02013	-1.14597
P25	0.00908	0.86522	0.33869	-0.74762
P25(II) 0-0.5	0.19265	1.17736	0.58258	-0.70027
P25(II) 1-1.5	-0.1541	1.46733	0.29183	-0.99079
P25(II) 3-3.5	-1.09306	0.78536	-0.61833	-1.33187
Q24(II)1.5	0.79231	-0.33268	-0.36799	-0.95267
Q24(II)3.5	0.07978	-0.64407	-1.08139	-1.52369
Q24*	1.02047	0.1007	-0.02508	-0.23326
Q26	-0.2876	0.94103	-0.62434	0.27183
T27	-1.61158	-1.07308	-1.35947	-1.17334
U26	-0.64112	0.65596	-0.78235	-0.49723

Appendix D

Table D-2: R-Mode Analysis of Logarithmic Chromium Partitioning Data

	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	4.44778368	3.75458309	0.7412	0.7413
Factor 2	0.69320059	0.21007208	0.1155	0.8568
Factor 3	0.48312851	0.30087451	0.0805	0.9374
Factor 4	0.18225400	0.05724462	0.0304	0.9677
Factor 5	0.12500938	0.05638553	0.0208	0.9886
Factor 6	0.06862385		0.0114	1.0000
		Factor Loadings		
	EX	0.20160		
	WAS	0.18466		
	ER	0.19835		
	MR	0.21219		
	OX1	0.18924		
	OX2	0.17294		
		Factor Scores		
	Sample	**Factor 1**		
	B7	-2.02751		
	C4	-2.0847		
	C8	-2.09575		
	C16	-1.5612		
	D9	-1.81218		
	E8	-1.74681		
	E16	-0.83028		
	E18	0.36219		
	G14	0.61268		
	G18II0	-0.99603		
	H15	0.51567		
	H17I	1.37328		
	H17II	1.33469		
	H17III	1.27246		
	H17IV	1.04235		
	H17V	1.08438		
	H17V1	1.96631		
	H17V3	0.18051		
	H19	-0.91416		
	I20	-0.97625		
	I20II0	-0.92069		
	I20II1	-0.47478		
	I20II3	-0.08821		

Table D-2: R-Mode (cont'd)

Factor Scores			
	Sample	**Factor 1**	
	I22	0.29191	
	I27	-1.74626	
	J19I	0.67102	
	J19II	0.29297	
	J19III1	1.10968	
	J19III3	1.00782	
	J19III6	0.88811	
	J19IV0	1.07484	
	J19IV3	1.29105	
	J21	0.05754	
	J23	0.6235	
	K20	0.75837	
	K20II1	0.7715	
	K22	0.33977	
	K22IItop	-0.01318	
	M20	-1.03261	
	M240	-0.97763	
	M241	-1.2246	
	M243	-0.99533	
	N21	0.31833	
	N23	0.74218	
	N21II1	0.70494	
	O22	-0.245	
	O22II0	0.77392	
	O22II1	0.82999	
	O22II3	0.13655	
	O22II4	-0.58467	
	O24	0.34661	
	P23	0.03409	
	P25	0.38066	
	P25II0	0.58965	
	P25II1	0.4625	
	P25II3	0.14316	
	Q23	0.65254	
	Q24III1	0.69563	
	Q24III3	0.11427	
	Q26	-0.87541	
	T27	-1.10707	
	U26	-0.51731	

Appendix D

Table D-3: R-Mode Analysis of Non-Parametric Multi-Elemental Data.

	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	9.06435040	3.85243721	0.4316	0.4316
Factor 2	5.21191319	3.84970060	0.2482	0.6798
Factor 3	1.36221259	0.38472411	0.0649	0.7447

Factor Loadings

	Factor1	Factor2	Factor3
K	-0.11637	0.47413	0.66507
Cr	0.85101	-0.02851	-0.07666
Mn	0.29722	0.40115	0.75072
Fe	0.11883	0.61038	0.60937
Ba	0.80634	-0.00427	0.36978
Mg	0.03745	0.66295	0.45708
V	0.40857	0.78611	0.20832
Co	0.01795	0.87845	0.37936
Ni	0.48748	0.75996	0.21909
Cu	0.8736	0.19825	0.26663
Zn	0.80788	0.14262	0.55022
As	0.82942	0.14128	0.0633
Sr	0.81574	0.3093	0.48435
Cd	0.90804	0.08533	0.11075
Pb	0.91322	0.06086	0.24778
Al	-0.18033	0.77732	0.51332
Se	0.78306	0.15556	-0.06396
Sc	0.35155	0.86609	0.23694
Ti	-0.53259	0.65796	0.07168
Hg	0.87857	0.08125	-0.2184
Ca	0.64291	0.20855	0.5542

Factor Scores

Sample	Factor1	Factor2	Factor3
B5	1.18439	1.05029	0.86453
B7*	1.20978	0.4559	0.32726
B9	1.64663	1.16215	0.8023
C4	1.31327	0.18382	0.74778
C8	1.46617	1.51242	0.00207
C10	1.45829	0.83408	-0.24178
C16	0.99837	-0.34542	-1.01905
D9	1.26131	-0.12499	-0.01207

Table D-3: R-Mode (cont'd)

Factor Scores			
Sample	**Factor1**	**Factor2**	**Factor3**
D11	1.20813	-0.04913	-0.50436
D17	-0.29481	-1.35573	-1.22449
E8	1.26017	-0.20755	-0.70906
E16	0.37366	-0.64086	-0.463
E18	-0.27321	-1.59011	-2.24501
G14	-0.54357	-0.67026	-2.16777
G18	1.1837	0.82153	-1.38344
G18(II) 0-0.5	0.45244	0.15246	0.46916
G18(II) 1-1.5	1.28525	-0.84923	1.33835
G18(II) 3-3.5	1.47238	-1.48939	0.84473
H15	-0.7433	-0.43172	-0.0264
H17 (I)	-0.92983	-0.16293	0.17749
H17 (II)	-1.14972	-0.67901	0.5421
H17 (III)	-1.13484	-0.68275	0.61687
H17(IV)	-1.28342	0.17398	-0.49446
H17(V)top	-1.68115	-0.26801	0.56166
H17(V)1.5	-1.37641	-0.31849	0.68795
H17(V) 3.5	-0.06228	-0.72267	-1.03002
H19	1.00172	1.41679	-1.64221
H21	1.62003	-0.82372	0.46872
I20(II) 0-0.5	-0.88832	-1.30856	-0.98768
I20(II) 1-1.5	-0.68394	-1.00692	-1.84089
I20(II) 3-3.5	-0.6954	-0.98757	-1.87556
I20	-0.6875	-0.84446	-2.16666
I22	-1.05789	-0.19803	0.03319
I27	0.99025	-0.79887	0.40599
J19 (I)	-1.30663	-1.31372	-0.4371
J19(II)	-1.07361	0.14348	0.80606
J19(III)1.5	-1.13499	1.31723	1.95755
J19(III)3.5	-0.92848	1.97004	0.94529
J19(III)6	-0.03796	1.89423	1.1045
J19(IV)0.5	-0.93748	-0.7738	0.73042
J19(IV) 1.5	-1.12659	0.84709	1.76982
J19(IV)3.5	-0.83481	1.69966	1.062
J19(IV) 6.0	-0.74685	1.78347	1.12565
J21	0.10457	0.31811	0.04173
J23	-1.51134	-0.7752	0.46981
K20	-0.82654	-0.03412	-1.27832

Table D-3: R-Mode (cont'd)

Factor Scores			
Sample	**Factor1**	**Factor2**	**Factor3**
K20(II)1.5	-1.27194	0.51078	-1.01
K22	-0.74974	0.38419	-0.69876
K22(II)top	-0.33241	1.36696	-0.18509
M20	1.21921	-1.11787	0.332
M24 0.5	1.32221	-0.83359	0.47008
M24 1.0	1.59957	0.38732	0.58929
M24 3.0	0.39525	-0.95459	-1.61004
N21	-0.64759	0.75614	-1.46852
N21(II)1.5	-1.02176	0.95187	-0.59972
N23	-0.56747	-0.19974	-0.17799
022(II) 0.5	-0.27557	0.79552	-0.45215
O22(II)1.5	-0.83473	-0.73814	-0.68199
O22(II)3.5	0.19416	0.99797	-0.32865
O22(II)4.5	1.06633	0.81444	0.60218
O22	0.99008	1.15924	0.91089
O24	-0.61659	-0.56422	-0.57945
P23	-0.04129	1.76542	0.83213
P25	-0.30092	-1.26232	1.17906
P25(II) 0-0.5	-0.50345	-1.64879	0.99969
P25(II) 1-1.5	-0.20417	-1.78553	1.32636
P25(II) 3-3.5	0.98959	-0.70656	1.60423
Q24(II)1.5	-0.4777	0.85253	0.1053
Q24(II)3.5	0.38803	1.35618	0.51839
Q24*	-0.79007	-0.10363	-0.22884
Q26	0.57656	-1.17583	-0.15724
T27	1.51201	1.34613	1.08203
U26	0.84272	-0.63737	0.47315

Appendix D

Table D-4: R-Mode Analysis of Non-Parametric Chromium Partitioning Data.

	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	4.34851723	3.61425128	0.7248	0.7248
Factor 2	0.73426595	0.21953491	0.1224	0.8471
Factor Loadings				
		Factor 1		
	EX	0.89646		
	WAS	0.80765		
	ER	0.87656		
	MR	0.93340		
	OX1	0.83331		
	OX2	0.74738		
Factor Scores				
	B7	1.77999		
	C4	1.82981		
	C8	1.855		
	C16	1.49919		
	D9	1.66585		
	E8	1.63348		
	E16	0.90529		
	E18	-0.31683		
	G14	-0.69203		
	G18II0	1.08837		
	H15	-0.46412		
	H17I	-1.60665		
	H17II	-1.54128		
	H17III	-1.46676		
	H17IV	-1.23627		
	H17V	-1.20631		
	H17V1	-1.75854		
	H17V3	-0.0385		
	H19	1.02927		
	I20	1.10012		
	I20II0	1.01259		
	I20II1	0.64579		
	I20II3	0.31171		
	I22	-0.2537		

Table D-4: R-Mode (cont'd)

Factor Scores			
	I27	1.60923	
	J19I	-0.83872	
	J19II	-0.25651	
	J19III1	-1.17295	
	J19III3	-1.1242	
	J19III6	-0.76426	
	J19IV0	-1.09041	
	J19IV3	-1.2997	
	J21	0.05775	
	J23	-0.75916	
	K20	-0.95432	
	K20II1	-0.91551	
	K22	-0.23566	
	K22IItop	0.14344	
	M20	1.05764	
	M240	1.00056	
	M241	1.11729	
	M243	0.9275	
	N21	-0.32518	
	N23	-0.58009	
	N21II1	-0.79913	
	O22	0.2938	
	O22II0	-0.67451	
	O22II1	-0.86578	
	O22II3	-0.01854	
	O22II4	0.62998	
	O24	-0.26887	
	P23	0.17409	
	P25	-0.25591	
	P25II0	-0.47359	
	P25II1	-0.25654	
	P25II3	-0.03571	
	Q23	-0.78351	
	Q24III1	-0.81257	
	Q24III3	-0.08987	
	Q26	0.98465	
	T27	1.21604	
	U26	0.66381	

Appendix E

Table E-1: Q-Mode Analysis of Logarithmic Multi-Elemental Data

	Eigenvalue	Difference	Proportion	Cumulative
Factor1	69.60580	67.6268	0.9535	0.9535
Factor2	1.979015	1.61207	0.0271	0.9806
Factor3	0.366947	0.12609	0.0050	0.9856
Factor4	0.240857	0.07160	0.0033	0.9889
Factor Loadings				
	Variable	**Factor1**	**Factor2**	
	K	-6.27539	6.37241	
	Cr	-8.19455	6.01094	
	Mn	-1.94088	3.57103	
	Fe	-9.40384	9.70892	
	Ba	-4.63471	4.18813	
	Mg	-8.74391	8.45295	
	V	-2.04416	2.22672	
	Co	-2.80623	1.78467	
	Ni	-7.50985	4.71960	
	Cu	-4.02396	2.76421	
	Zn	-5.25416	4.54533	
	As	4.49015	-2.60248	
	Sr	-1.83794	1.99634	
	Cd	3.92679	-3.45606	
	Pb	1.03603	0.34581	
	Al	-9.26112	9.26792	
	Se	0.39144	-0.27715	
	Sc	-2.20681	1.03351	
	Ti	-8.16477	7.27971	
	Hg	1.91245	-2.03088	
	Ca	-7.52107	7.97225	

Appendix E

Table E-2: Q-Mode Analysis of Logarithmic Chromium Partitioning Data.

	Eigenvalue	Difference	Proportion	Cumulative
Factor1	48.22836	34.54668	0.7307	0.7307
Factor2	13.68168	11.12646	0.2073	0.9380
Factor3	2.555215	1.803815	0.0387	0.9767
Factor Loadings				
	Variable	**Factor1**	**Factor2**	
	Cr_{EX}	0.00974	-0.75460	
	Cr_{WAS}	1.72327	0.15527	
	Cr_{ER}	1.15308	0.33452	
	Cr_{MR}	3.36249	1.44328	
	Cr_{OX1}	0.74440	-1.40377	
	Cr_{OX2}	2.26116	0.22448	

Appendix E

Table E-3: Q-Mode Analysis of Non-Parametric Multi-Elemental

	Eigenvalue	Difference	Proportion	Cumulative
Factor1	58.742293	52.1857689	0.8047	0.8047
Factor2	6.5565237	4.8809548	0.0898	0.8945
Factor3	1.6755689	0.3434371	0.0230	0.9175
Factor4	1.3321318	0.2525628	0.0182	0.9357
Factor5	1.0795690	0.0549844	0.0148	0.9505
Factor6	1.0245846	0.3369709	0.0140	0.9645
Factor Loadings				
	Variable	**Factor1**	**Factor2**	
	K	27.604	-16.316	
	Cr	73.547	-40.308	
	Mn	82.082	-123.345	
	Fe	-26.807	54.196	
	Ba	51.165	-28.781	
	Mg	-176.066	334.337	
	V	45.967	-19.387	
	Co	7.400	25.113	
	Ni	178.747	-97.441	
	Cu	77.010	-80.590	
	Zn	77.144	-77.363	
	As	96.425	-130.797	
	Sr	24.041	33.692	
	Cd	58.627	47.748	
	Pb	89.437	-57.264	
	Al	18.712	-22.807	
	Se	100.308	-91.903	
	Sc	14.238	111.781	
	Ti	-33.353	143.379	
	Hg	60.590	-31.865	
	Ca	-13.867	164.133	

Appendix E

Table E-4: Q-Mode Analysis of Non-Parametric Chromium Partitioning

	Eigenvalue	Difference	Proportion	Cumulative
Factor1	62.738872	57.756104	0.8836	0.8836
Factor2	4.9821683	2.8755384	0.0702	0.9538
Factor3	2.1066299	1.2171417	0.0295	0.9835
Factor Loadings				
Variable	**Factor1**	**Factor2**	**Factor3**	
Cr_{EX}	1370.78	-45.465	-2233.21	
Cr_{WAS}	1399.44	-243.177	-1972.00	
Cr_{ER}	1385.22	-194.605	-1989.91	
Cr_{MR}	1449.44	-179.417	-2151.70	
Cr_{OX1}	962.05	-332.773	-1040.76	
Cr_{OX2}	-403.3	-232.994	1327.04	