**A Progress Report on the Description of the Geology and
Chemical Composition of Soils in Illinois:
Cores 52 through 76**

by

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CONTENTS

PREFACE

This is a progress report to present analytical chemistry data on soil cores 52 through 76 of a total of 137 soil cores. This report is not a final interpretation of the data collected. It is primarily intended to provide our analytical chemistry information to the persons from whose land the soil cores were collected. It will also be useful to others who are interested in learning about the geological background and chemical composition of soils in Illinois.

We wish to thank the landowners who allowed us to collect soil cores from their property. We are grateful for the interest they showed in our research expressed through their questions and their desire to observe the coring and field description operations.

INTRODUCTION

The Illinois State Geological Survey (ISGS) serves the state of Illinois as a depository of geological and chemical information about the geological materials and soils of Illinois. In addition, the ISGS conducts research on important issues that concern the people of the state. In general, these issues deal with the discovery and use of our natural resources, the solution of environmental problems, as well as serving general educational needs about earth science.

The ISGS has a large collection of data gathered in the last 100 years for research projects conducted for many different purposes. Thus, when questions arise about a new subject such as "the chemistry of Illinois soils," we may be able to respond by reviewing available information and reorganizing it in useful formats–for example, data tables, figures and maps–developing a new interpretation based on the available data, and forming a new interpretation. When th available information is insufficient, however, then a new research project must be conducted to address the need. This project was begun in 1998 to address the increasing interest of the general public in the chemical and mineralogical composition of soils in Illinois. To date, three open-file reports on results from samples of cores 1 through 51 have been published (Dreher et al., 2002, 2003a, 2003b).

People are often confused about the differences between soil science and geology. The scopes of these subjects overlap and are interrelated; the two disciplines present results and discussions according to the style and terminology of their specialists. In an agricultural sense, soil is the earth material (geologic unit) that supports agricultural activities. That is, soil is the material in which plants grow and which consequently becomes modified compared with its "parent material" or its original composition and form. In the geological sense, soil is the surficial material that has been modified over time by reactions caused by natural chemical, biological and physical agents that cause the chemistry, mineralogy, and morphology of the original material to change, through processes known as "soil formation." To keep these concepts from becoming confused, one should think of the soil profile as being superimposed on the geologic material; there is both a geologic aspect and a soil aspect of the same volume of material.

For this study we are dealing with both the geologic and the soil science points of view. Therefore, we try to merge the two terminologies in a rational way. In principle, soils (soil profiles) and geologic units (often called material or stratigraphic units) are not separate physical entities. They are terms used for the same "surficial" feature by the two groups of scientists and, in this sense, illustrate the professional preferences or "biases" of the two disciplines.

We considered two approaches to studying the chemistry and mineralogy of Illinois soils. The first was to consider the nature of the existing data and see if they were sufficient to meet our needs. In other words, we considered whether our existing database would be sufficient if we supplemented it with all available data from other sources, such as the U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), engineering companies, water-well and other drillers' reports, and so forth. Our preliminary assessment showed that there

were many data available, but no standard framework or style that could be followed. So we chose to build our own comprehensive database in a universal style that tries to avoid the professional biases of both soil science and geology. Consequently, many parts of the project are still in a developmental stage. Eventually, we plan to incorporate all available data, but initially we chose to start building a database by selecting representative soils to be sampled and analyzed for their chemical and mineralogical composition. Next, we will carry out additional studies to fill gaps in the database following a priority plan determined by needs.

This report presents basic data acquired from soil cores 52 through 76 of a total of 137 coring sites from across the state. These cores were collected in central Illinois during the fall of 2000. We currently have descriptions, identifications of the geologic units and soil horizons, and results from a suite of chemical determinations from a selection of 5 to 6 samples per core. Mineralogical data are not yet available for the samples, but we have made what we believe to be educated guesses in the "Results and Discussion" section of this report about which minerals contain the various elements found in the soils. These educated guesses were based on available knowledge about the chemical compositions of the minerals that are generally found in Illinois soils.

There are several reasons to determine the chemical and mineralogical composition of soils: (1) to provide a coherent geochemical database with which to assess the health of the environment (including assessment of contamination of soils) and to aid in utilizing natural resources (Darnley et al., 1995); (2) "to evaluate the contribution of soil minerals to animal and plant ecology in the State" (Jones, 1986) or stated slightly differently, to determine the effects of soil composition (especially trace elements) on the health of plants, animals, and humans (Esser et al., 1991); (3) to relate the distributions of elemental concentrations in the State to weathering intensity and sorting of particles according to size by action of wind (Jones, 1986); (4) to show the association of trace elements with soil minerals (Esser et al., 1991); (5) to supplement information required to understand the geochemical landscape of Illinois; (6) to provide correlative information for understanding the composition of lake and river sediments; and (7) to provide a well-documented reference collection of cores for other inquiries.

In a previous study conducted by the ISGS (Zhang and Frost, 2002), 94 samples of soil were collected from 54 counties in Illinois. Subsamples were retained from depths of 4 to 8 inches and 28 to 32 inches below the surface. The samples were air-dried, disaggregated, riffle-split, ground, and analyzed for major, minor, and trace element composition using the techniques of X-ray fluorescence spectrometry and instrumental neutron activation analysis. Most of the samples for Zhang and Frost's (2002) study were collected in northern Illinois, with minimal collection of samples from certain other parts of the state.

The purpose of this project is to determine the chemical and mineralogical characteristics of soils and their underlying unlithified parent materials throughout Illinois, and to interpret the derived data in light of the geological processes that have acted upon the soils and their parent materials. In addition, this project will expand upon the previously collected data from other sources. A

database of chemical and mineralogical information will be created which can be used in assessing environmental conditions and to help understand the effects of soils on plant health and productivity. The data collected will contribute to our understanding of the chemical, mineralogical, and geological processes that take place during soil development.

BACKGROUND

Most of the present landscape of Illinois was created during the most recent part of geologic history known as the Ice Age or the Quaternary Epoch (Willman and Frye, 1970; Killey, 1998). All of Illinois was affected directly or indirectly by the continental glaciers that advanced from the north on about six occasions over the last million years (Follmer, 1996). Although large-scale glaciation started earlier in Asia, the glaciers in North America did not grow large enough to advance into the US until about 800,000 years ago. Two of the older glaciations in North America reached to the northern flanks of the Shawnee Hills in southern Illinois during the episode now known as the Illinoian (see Figure 2).

As continental glaciers advanced into the northern US, they crushed large amounts of bedrock into silt, sand and pebbles, dislocated boulders and slabs of bedrock, and transported the debris southward. Along their path they alternated between erosion of the substrate and deposition of their load. The southernmost extent of continental glaciation in North America lies in Illinois. When the glaciers stopped advancing and began melting away, they dropped their remaining load of rock debris. This resulted in most of the glaciated part of the state being covered by sediments formed by the glaciers in one way or another, which are deposits collectively called drift.

The sediment carried by the glaciers tended to level the landscape. Relatively thin veneers of drift were spread across the highlands and thicker deposits filled the pre-glacial bedrock valleys with drift up to 350 feet thick.   Much of the drift is a homogenous mixture of fine-grained material with pebbles and a few boulders. This type of deposit was originally called boulder-clay and is now commonly called till. Interbedded with till in thick sequences of drift is outwash, which is commonly composed of stratified beds of sand and gravel, with some layers of silt and clay in places.

Beyond the margins of the continental glaciers, meltwater flowing from the glaciers coursed down the major valleys such as the Mississippi, Illinois, and many other rivers that drain to the south. Erosion caused by the meltwater greatly widened and deepened the major river valleys and then largely filled them with stratified coarse-grained sediment. The surfaces of many of these deposits in many places are above the levels of the modern streams in terraces underlain by sand and gravel deposits that are commonly over a hundred feet thick. The coarse sediments laid down in former glacial meltwater channels form the excellent aquifers that supply water to many cities in Illinois.

The streams that joined the master meltwater rivers south of the glacial margins were flooded by the rising water in the master rivers during the major glacial events. This caused lakes to form in

the lower reaches of the tributaries. An example of one of the larger flooded valleys that was formed during the last glaciation was in Gallatin and Saline Counties. The rising level of the Wabash River (caused by the flow of meltwater) caused water to back up into the Saline River lowland and flood most of the region. This lake remained for several thousand years and largely filled the lowlands with stratified silt and clay, which is over a hundred feet thick above the original channel of the Saline River. These deposits differ from typical lake deposits and are called slackwater deposits.

Other types of lake deposits commonly are present in glaciated areas. Proglacial lake deposits were formed by advancing glaciers that blocked north-flowing rivers. Another type of lake deposit was laid down in closed basins on till plains after the glaciers stagnated. In these places variable thicknesses of drift and different rates and degrees of settlement and compaction within the drift caused basins to form.

By studying the types of stratified sediment in a basin, a geologist is able to identify the conditions that prevailed during deposition of the sediment. This information provides a valuable tool for tracing the distribution of important deposits and finding the best aquifers.

The rise and fall of the meltwater in rivers according to the seasons exposed their very wide flood plains to wind erosion during winter when melting was at a minimum. Sand and silt was blown out of these valleys onto the adjacent uplands to the east during wind storms. The biggest valley through all of Quaternary time was the Mississippi, and it changed its course several times because of interruptions caused by the glaciers. Large bluffs of eolian (wind-blown) silt accumulated along the eastern margins of the Mississippi's floodplains. This silt is very soft when first formed, but with aging it becomes hard enough to stand in vertical exposures. It was first named by German farmers who called it *loess*, meaning "loose soil" in English.

The term *loess* has become the name used by geologists and soil scientists around the world for eolian silt deposits (Follmer, 1996). Loess covers all of the Midwest except where it has been eroded away (Figure 1). It is thickest along the Illinois and Mississippi Rivers and thinnest in the Chicago region. In the bluffs north of East St. Louis, the total loess thickness is as great as 80 feet in places, but it becomes thinner to the east. Within a mile east of the bluff crest the average thickness is about 25 feet, and the loess blanket gradually thins to the east until it reaches the influence of another meltwater river. The Kaskaskia and many other mid-size rivers in Illinois were minor sources of loess, as indicated by wind-blown dune sand in and along their valleys, but their contributions were relatively small and had little effect on the regional eastward thinning pattern of the loess.

The next master meltwater river to the east of the Mississippi drainage was the Wabash. Within ten miles of the Wabash River the loess begins to thicken and grows to over 10 feet thick in the west bluff of the Wabash. As might be predicted, the loess is even thicker on the east side of the Wabash, again indicating that the Wabash was a major source of loess, and confirming that the prevailing winds blew toward the east. Another important loess source in northwest Illinois was

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from barren till plains that lacked vegetative cover. A large amount of loess came from deflation (wind erosion) of the glacial deposits in central Iowa (Putman et al., 1988). All glaciated landscapes were barren for some time during the main interval of glacial activity and were subjected to wind erosion. Eventually, these landscapes stabilized and became vegetated, that is, landscape disturbance (erosion and sedimentation) slowed enough for vegetation to be reestablished.

In only a few places in Illinois are wind-blown dune sand deposits significant. The largest of these are in Mason County; in the Green River Lowland of Whiteside, Henry, and Lee Counties; and the eastern Kankakee County area. During the peak of the last glaciation favorable conditions allowed "sand seas" to form.   When the climate returned to warmer conditions about 10,000 years ago, the dune-sand deposits were stabilized by vegetation. In geologic terms, this change in conditions marked the beginning of the present geologic interval called the Holocene or "Recent" in common terms.

The dune sand and loess have physical properties and chemical compositions that make them especially good parent materials for agricultural soils. Both materials contain a blend of minerals that, during the early stages of weathering, produce chemicals and byproducts that make fertile soils. Weathering processes, particularly the chemical reactions called hydrolysis and oxidation, cause the dark-colored minerals and the feldspars in rock particles in the sand or loess to be slowly altered, releasing ions (Na, Ca, Fe, Mg, K, P, S, and many others) and forming products (clay minerals) that cause the cation exchange capacity (CEC) of the developing soil to increase over time.   The silt-size particles in loess generally are more altered or weathered than the coarser grains in the dune sands and, because loess deposits can retain significantly more water than dune sand, the water remains available to plants long after a rainfall.

The chemical composition of the Midwestern glacial deposits is near optimum for plant growth. In general, the glacial deposits can be characterized as containing variable proportions of five types of pulverized rocks: igneous and metamorphic rocks of the Canadian shield, and the sedimentary rocks sandstone, limestone, and shale.   The only significant drawback to the glacial deposits as parent materials for soils is the general presence of an excess of limestone in the mixture, causing the youthful soils to be alkaline. After aging for a few thousand years, however, the excess limestone is leached from the upper horizons of the soils, which allows the pH to decrease into the neutral range.

In areas where the glacial sediment is dominated by one rock type or a limited combination of types, the resulting soil developed in this material may be unusually coarse or fine. For example, in areas where the glacier incorporated large amounts of shale or fine-grained lake deposits, the resulting soil will be unusually fine-grained ("clayey") and rich in clay minerals.

Loess deposits cover all the uplands of Illinois except where erosion has removed them. Such erosion was common on slopes along valleys, but the loess is missing in some other places for reasons we do not fully understand. Exceptionally large floods that occurred near the end of the

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glacial conditions scoured away both the loess cover and some of the bedrock in some parts of Illinois. The best example of this is along the Kankakee River west of Kankakee. When a large moraine in northern Indiana that had impounded a large pro-glacial lake was overtopped by the water it caused a catastrophic flood that coursed down the river and overflowed the normal flood plain. The rising water transgressed onto the lower parts of the upland, and removed all the loose material down to solid bedrock over a large area. The height of the water and scope of the erosion caused by the Kankakee Flood (Willman and Frye, 1970) may seem incredible, but they are real.

All major loess deposits were formed in direct response to the glacial environment (Follmer, 1996). As outwash accumulated in the master valleys it was subjected to annual wind storms. Sand dunes on or adjacent to these floodplains provide direct evidence for the wind erosion. The loess deposits are thickest along the bluffs of the main river valleys (Figure 1), which provides further evidence that river floodplains were the main source areas. In Illinois, at least four distinct deposits of loess have been verified in many field studies. At a few locations there are indications that there might be six separate loess units in succession. In many places silt units are commonly found interbedded with other forms of the drift, but it is not yet possible to correlate among them with any confidence. In other words, we have many pieces of the puzzle but do not yet know how they fit together.

The youngest loess is named after Peoria, Illinois, and can be traced across the Midwest from Ohio to Colorado (Follmer, 1996). Most of the accumulation of the Peoria loess [Peoria Silt (Hansel and Johnson, 1996)] occurred during the last glaciation from about 25,000 to 10,000 years ago (commonly called the Late Wisconsinan Age in the Midwest). The Peoria loess formed while a glacier was advancing into northeastern Illinois. Part of this loess was deposited in front of the glacier and was overridden, part was deposited on the glacier and subsequently washed off, and the youngest part was deposited after the glacier melted away. Beyond the limit of the Late Wisconsinan glacier, these intervals of Peoria loess merge and appear as a single uninterrupted geologic unit.

In many parts of Illinois, the Peoria loess overlies another loess unit, the Roxana (Silt) loess. Named after Roxana, Illinois, where it is up to 40 feet thick, this loess is nearly as widespread as the Peoria and has a similar thinning pattern to the east of the major rivers in the Midwest. It formed during the middle portion of the Wisconsinan Age. The reason this loess was deposited is a mystery, because we have not been able to relate it to any glacial record to the north. Presumably the evidence of the southern limit of this glacier's advance is buried beneath the Late Wisconsinan deposits on the north side of the Great Lakes. Numerous radiocarbon dates from the Roxana loess in Illinois show that it formed between 55,000 and 25,000 years ago.

In a few places in southern Illinois, the Peoria and Roxana silts lie directly over a third loess we correlate with the Loveland Loess of Iowa. The Loveland is well known up the Missouri River valley and can be traced down the Mississippi River valley to Louisiana. It formed during the next-to-last glaciation, the Illinoian. On the basis of correlations with ice cores from Greenland

and ocean sediment records around the world (Imbrie and Imbrie, 1979), we believe that the age of the Illinoian can be now constrained to the period from 180,000 to 125,000 years ago. Previous estimates placed the older boundary back to 300,000 years ago, but we believe this age should be rejected because no glacial sediments in this age range have been found in the Midwest (Follmer, 1996).

In southern Illinois near the Mississippi River a fourth loess has been found and was correlated with the Crowley's Ridge loess of Arkansas. Probable correlations are known in Illinois and up the Missouri River valley to Nebraska. Up to two older loesses have been observed in Illinois and in exposures along the Missouri River near St. Charles, Missouri. All across the glaciated part of Illinois, silt units that may be loess have been observed in the older parts of the glacial sequence. These silt units have mostly been observed in areas of thick drift where preglacial valleys have been filled with glacial deposits. At this time, we do not know much about these deposits. The oldest glacial deposits in Illinois are approximately 800,000 years old (Follmer, 1996).

The loess units are distinguished from each other by their physical and mineralogical properties. The most important such distinguishing characteristics are those caused by soil formation. To geologists, the soil at the land surface, which has developed mostly in the Peoria loess, is called the modern soil. Soil profiles, developed in the tops of buried loess units are called paleosols, which means ancient, or fossil soils. The fossil soils' characteristics indicate that the units were once at the ground surface and exposed to active soil formation. Some other buried glacial deposits (for example, tills or outwash deposits) also have paleosols developed in their upper parts. These buried soils are important markers for mapping the distribution of certain units. The classification of the major Quaternary geologic units is based on these key markers (Follmer, 1982)

The Quaternary Deposits Map of Illinois (Figure 2) shows the distribution of the major Quaternary units (Lineback, 1981) as they would appear if they were not buried by loess deposits. The deposits of the last glaciation are named after Wisconsin. In Illinois the deposits of this most recent glaciation are mostly limited to the NE quarter of the State. The next older glaciation is named after Illinois because its deposits cover most of the State. Deposits from some older glaciations have been found in scattered places in Illinois, especially in the lowermost deposits in buried bedrock valleys, but the evidence of their stratigraphic succession and age is limited. Until definitive work is done on these older units, they are grouped into an indefinite time period called pre-Illinoian (Lineback et al., 1979).

Where it has not been eroded, the Peoria loess is the parent material of the modern soil across most of the nearly flat uplands of Illinois. In valleys, the upper part of the alluvium is mostly derived from loess eroded from the surrounding hills in the watershed. Where the Peoria loess is missing, particularly on sloping land where it has been stripped off by erosion, the older loesses are commonly missing, also. At such sites, the soils are formed in other glacial deposits or bedrock.

The distinctive physical characteristics of modern soils from place to place are given soil names by the USDA-NRCS Soil Survey. We use these names in combination with the geologic names of the parent materials assigned by the ISGS when describing the soil cores we collect. In places where the thickness of the Peoria loess is less than the solum thickness, i.e., where the soil horizons have developed into the underlying geologic unit, the soil profile is described as having formed in two materials and, in some places, three. In southern Illinois, the Peoria loess across much of the flat upland on the Illinoian till plain is less than five feet thick and underlain by the Roxana loess. In these situations the modern soil features (roots, and biological traces) commonly extend though the Peoria and into the Roxana, thus blurring the boundary between them. Where such conditions are found we have grouped the two geologic units together and called it Wisconsinan loess after the time interval during which it was deposited.

Soil Development. The important factors that govern the development of a soil are the nature of the parent (geologic) material (loess, in most of Illinois), the geographic relief (the slope of the land surface), climate (temperature and rainfall patterns), organisms (plants, animals, and microorganisms), and time (Jenny, 1941; see also Luxmoore, 1994). On a glaciated landscape, soil quality increases with time until the peak or optimum chemical conditions are attained. Eventually, the quality will decline as continued weathering depletes the minerals that supply nutrients. The application of mineral fertilizers can maintain peak conditions if sufficient inputs are made, but the amount and composition of fertilizer to apply is difficult to determine because the balance of minerals that provides the best soil is not well known. Some plants have special requirements, particularly in the balance of trace elements.

Parent Material. The mineralogical and chemical composition of the parent material governs the chemical composition of the soil (see Figure 3). Certain minerals in the parent material, such as mica, feldspar, and hornblende, are weathered over time to form clay minerals, particularly kaolinite, illite, and smectite (Jackson and Sherman, 1953). Weathering of the primary minerals results from chemical and biochemical reactions of the minerals with water, organic acids, carbon dioxide, and oxygen (Hassett and Banwart, 1992). In general, the chemical elements that make up the primary minerals are simply reconstituted by weathering processes into new minerals. Most elements that were present in trace concentrations in the parent material remain in the resulting soil (Kabata-Pendias, 2001). If the minerals in the soil parent material are easily weathered, then the soil develops rapidly. If, however, the minerals are resistant to weathering, such as quartz sand, then development of the soil will be delayed (Hassett and Banwart, 1992).

Climate. The term "climate" encompasses both temperature and the long-term availability of water. The higher the temperature of the developing soil, the faster the soil will develop through chemical and biological processes. The availability of water is important in determining the types of plants and organisms that can thrive in the developing soil, which chemical and biological reactions will occur, and in the movement of soil particles and dissolved chemical species from one location to another on the landscape or in the soil profile. As water seeps through the soil profile it causes chemical elements to be leached from the surface horizon (eluviation) and to be

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deposited in lower horizons (illuviation) (Hassett and Banwart, 1992), or pass into the groundwater.

Topography. Topography influences the ability of precipitation to infiltrate the soil profile. In steep terrains water is more likely to run off and to erode the soil surface than to infiltrate. In flatter terrains the opposite is true. In enclosed basins, water may stand on the soil surface for long periods if the soil pores have very small diameters or have been plugged by fine particles, as in a pond (Hassett and Banwart, 1992).

Organisms. Organisms in the soil are a major factor in soil formation. Microscopic organisms are the major promoters of the degradation of organic matter. When plants die, it is the soil microorganisms that cause the rapid breakdown of plant tissues. The degraded organic matter is very important, along with minerals, in maintaining soil fertility (Ashman and Puri, 2002; Hassett and Banwart, 1992). Microorganisms also catalyze chemical reactions. That is, a particular chemical reaction would occur even if microorganisms were absent, but because certain types of microorganisms depend on particular chemical elements in the soil, they act as promoters of the reaction—the microorganisms cause the reaction to proceed at a faster rate than it would in their absence (Hassett and Banwart, 1992).

Since the Industrial Revolution, metals have been introduced to the soil surface through atmospheric outfall of particulate matter generated by various industries, by capture of small airborne particles (aerosols) in raindrops, and by the application of fertilizers and other agricultural chemicals to the soils (Kabata-Pendias, 2001). For example, the concentration of molybdenum in soils near a molybdenum processing plant in western Pennsylvania was found to form a plume of contamination in the surface soil in the direction of the prevailing winds. The molybdenum concentration decreased with downwind distance from the plant (Hornick et al., 1976). At about 1 mile from the processing plant the molybdenum concentration was about 30 mg/kg, but at 5 miles it had decreased to about 6 mg/kg. For comparison, in fifteen samples of Illinois loessial surface soils the molybdenum content ranged from 0.75 to 6.40 mg/kg (Kubota, 1977). Prior to the Clean Air Act, emissions from coal burning factories or power generating plants could cause widespread dispersion of metals at large distances from their source (Mattigod and Page, 1983).

Other factors that affect the distribution of metals in soil are churning, or bioturbation, of the soil by earthworms, ants, termites, other invertebrates, and burrowing mammals, such as moles, chipmunks, and gophers (Paton et al., 1995). Plants also accumulate metals during their growth cycles. When the plants die, they are decomposed by microorganisms, which releases the metals back into the soils (Kabata-Pendias, 2001). If the plants are not recycled to the soil, as in many farming operations, then periodic fertilization in greater amounts is required. The leaching of metals and transport of colloidal-sized particles (0.001 to 1 μm diameter) generally causes metals to move downward through the soil, but capillary action can also cause metals dissolved in the soil water to move upward (Simonson, 1978).

Various chemical reactions also operate on metals and the soil parent materials. These include sorption and desorption, dissolution and precipitation, occlusion and coprecipitation, oxidation and reduction, chelation and release by organic chemicals, and fixation and release by biological organisms. The reactions are affected by the pH of the soil, the availability of oxygen, the presence of various types of clay minerals, the rates of various chemical reactions, the presence of and nature of various kinds of animals and microorganisms, and the reaction of organic chemicals with metals and clay minerals. All these variables affect how the metals are held in the soil. For example, these factors determine whether a particular metal is bound to the surface of a clay mineral or an oxide/hydroxide, or whether it is present as a discrete oxide, hydroxide, or other compound (Hassett and Banwart, 1992).

DEFINITION OF TERMS

Sorption and desorption in a soil refer to an interaction between small particles, such as colloidal-sized clay minerals or organic materials, and solutes dissolved in the soil water. The solutes are attracted to the surfaces of the particles because of differences in electrical charge, and tend to become sorbed on the particle surfaces to the point of equilibrium with the concentration of the solute in the soil water.

Equilibrium refers to the condition in which the concentration of an adsorbed species and the concentration of that species in the soil solution have reached a balance; that is, the concentrations remain unchanged. If the concentration of the solute in the soil solution is greater than is necessary to achieve equilibrium, then a sufficient amount of the solute will be adsorbed on soil particles to re-establish equilibrium. If the concentration of the solute in the soil solution is less than required to achieve equilibrium, then the solute will be desorbed, that is, it will be released from the solid particles into the solution until equilibrium is again attained (Hassett and Banwart, 1992).

Dissolution and *precipitation* refer to the processes whereby of solid materials enter into or separate from a solvent. For example, when a small amount of sugar is stirred into water, the sugar enters the solution; that is, the sugar dissolves. If the water is then allowed to evaporate, the sugar eventually separates from the solvent (water) as crystals; that is, the sugar precipitates.

Occlusion refers to the physical enclosure or capture of small amounts of fluid, such as soil solution, in a rapidly growing crystal. *Coprecipitation* refers to the precipitation of a substance that would otherwise be soluble along with an insoluble precipitate (Fisher, 1961).

Oxidation and *reduction* refer to the transfer of one or more electrons between ions in solution. By definition, the ion, or electrically charged atom, from which the electron is removed is oxidized, and the ion which receives the electron is reduced. In soils, iron and manganese commonly undergo oxidation-reduction reactions. Under oxidizing conditions, the soil generally is well-drained and aerated, and both iron and manganese precipitate, commonly as oxides and/or hydroxides (called oxyhydroxides). If the soil becomes saturated with water and oxygen is

excluded (producing reducing conditions), iron and manganese oxides and hydroxides dissolve. In the overall process the iron and manganese gain electrons during reduction and lose electrons during oxidation (Birkeland, 1999).

As plant residues decompose, many organic compounds are formed, some of which will dissolve in the soil solution. Metals, such as cobalt, nickel, iron, and manganese, are readily captured by the organic molecules to form what are known as *chelate compounds* (Fritz and Schenk, 1966). Some microorganisms sometimes accumulate metal ions, effectively removing the ions from the soil solution. However, when the microorganism dies and decomposes, the accumulated ions will be released again (Weatherley et al., 1980).

The reactions described above can all occur at the same time in a soil. Several factors govern the reactions. These factors include: (1) temperature, (2) pH, (3) the depth to which oxygen can penetrate the soil column and the rate at which it can be replaced as it is used in chemical and biological reactions, (4) the degree of saturation of the soil by water, and (5) the number and types of animals and microorganisms in the soil. The various chemical and biological reactions determine how metals are held in the soil.

FIELD METHODS

The sampling plan we adopted was to collect cores of soils at the points of intersection, or nodes, of a rectangular grid, 20 miles on a side, laid on top of a state map. The grid was established in the Universal Transverse Mercator projection by drawing the first node ten miles west of Lake Michigan and 10 miles south of the Illinois-Wisconsin border, in Lake County, in northeastern Illinois. The remainder of the grid was drawn from this starting point using Geographic Information System (GIS) computer software. The grid comprises 137 nodes which we selected as sampling sites (see Figure 4).

The locations of the grid nodes calculated by the GIS were used to locate the target sampling points on appropriate topographic maps, plat maps, soil maps, and highway maps. County assessment supervisors or county clerks were contacted to confirm the current ownership of the various properties upon which the grid nodes were located. Landowners were then contacted by letter to inform them of the research project and to inform them that ISGS personnel would like to visit with them to discuss the project and their willingness to participate by granting permission for a core to be taken from their property. Most landowners we contacted in 2000 were willing to participate. For the few who did not wish to participate, an alternate site was selected from a nearby location which had the same soil type as that at the original target sampling location.

The initial visits with landowners were made during September 2000. Cores were collected at 25 locations during October 2000, after harvest was completed. The black square symbols on the map in Figure 4 indicate the approximate locations of the sampling sites. The core number, the county in which the core was collected, and the final depth of the core are recorded in Table 1.

A Giddings®[1] hydraulically operated coring device mounted on a two-ton pickup truck was used to collect all cores. A combination of unsplit and split core barrels was used, depending on conditions encountered in the soil. The core barrel was pushed into the soil/sediment with no applied rotation. The cores were briefly described in the field as they were collected. Each core segment, approximately two feet long, was wrapped in plastic food wrap, then overwrapped with heavy-duty aluminum foil. The cores were labeled and placed in core boxes for transport and storage.

LABORATORY METHODS

At the ISGS the cores were unwrapped, trimmed to remove any smeared and/or oxidized material from the outer surface, and described in more detail than was possible in the field. Samples were selected from the cores for chemical analysis on the basis of apparent lithologic changes. Samples were dried at 50°C. The dried samples were then disaggregated to approximately <4mm size by passing them through a miniature jaw crusher with ceramic crushing surfaces. The samples were further disaggregated to pass a sieve with 2-mm openings by placing the material between two sheets of clean white paper and crushing the particles with a wooden rolling pin. The samples were then split by the "cone and quarter" method to a reduced sample mass of about 30 grams. This subsample was then ground in a Spex® 8500 Shatterbox® and passed through a 208-µm (No. 65) sieve in preparation for chemical analyses. All analyses were conducted in ISGS laboratories.

Wavelength-Dispersive X-ray Fluorescence Spectrometry

Wavelength-dispersive X-ray fluorescence spectrometry (XRF) was used to determine the concentrations of the following major and minor elements in the samples [silicon (Si), aluminum (Al), iron (Fe), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), titanium (Ti), phosphorus (P), and manganese (Mn)] and trace elements [barium (Ba), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), rubidium (Rb), strontium (Sr), vanadium (V), and zinc (Zn), and zirconium (Zr)].

To prepare the samples for major and minor element determinations, the samples were ground in a Spex® 8500 Shatterbox® with ceramic grinding surfaces to pass a 208-µm sieve. The ground samples were dried at 110°C overnight, and then ignited in platinum-rhodium crucibles at 1000°C for one hour to determine loss on ignition and to ensure complete oxidation of the samples. Loss-on-ignition data provide a measure of the amounts of structural water and organic- and carbonate-carbon in the samples.

Six-tenths gram of the ignited sample was mixed with 5.4 g of a mixture of 1:1 lithium tetraborate:lithium metaborate and fused in a 95% platinum-5% gold crucible in the propane

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[1]The use of trade names does not constitute endorsement by the Illinois State Geological Survey.

flame of a Claisse-bis® Fluxer. The melt was automatically poured into the crucible cover, which also served as a flat circular mold, for cooling. The resulting glass disk was stored in a desiccator prior to analysis.

Pressed pellets of samples were prepared in the following manner for the determination of trace elements, which generally are too diluted to be determined from the fused disk samples.

A portion of the 208-µm sample (6.3 g) was mixed with 0.7 g of Chemplex® X-Ray Mix Powder as a binder. This mixture was placed in a tungsten carbide grinding capsule that contained a tungsten carbide puck. The capsule was then agitated in a Spex Shatterbox® pulverizer to ensure thorough mixing of the sample and binder. The sample mixture was placed in a steel die, a layer of 2 g of cellulose powder was added on top of the sample, and the mass was pressed into a 35-mm diameter disk under a pressure of 20 tons/in² for two minutes. The cellulose provides a reinforcing backing for the disk. The prepared pellets were stored in a desiccator prior to analysis.

Mercury

Total mercury in the sample was determined by cold vapor atomic absorption spectrometry (CVAAS). In CVAAS, mercury is reduced to elemental mercury in the vapor state immediately prior to passing the vapor through a detection cell. Metal ions, including mercury, are dissolved from the sample by mixing the sample with aqua regia, a mixture of concentrated hydrochloric and nitric acids. The mercury dissolved from both inorganic and organic compounds is oxidized in the aqua regia to the mercurous ion (Hg^+) by potassium permanganate. Excess potassium permanganate is reduced by addition of a solution of hydroxylamine hydrochloride prior to analysis. The solution in the sample tube is drawn off by use of a peristaltic pump and combined with an acidic carrier solution. The sample is directed to a reaction chamber where it is combined with a solution of stannous chloride, whereby mercury ions are reduced to elemental mercury. A stream of argon is passed through the reaction solution and the elemental mercury is carried by the argon stream to the detection cell. The amount of mercury in the argon stream is converted by algebraic calculation to content in the original soil sample. The method detection limit is approximately 3 µg of mercury per kg of soil.

Total Carbon and Inorganic Carbon

Total and inorganic carbon were determined in the 208-µm samples using a Coulometrics Inc.® carbon analyzer. For determinations of total carbon, a weighed amount, 10 to 30 mg, of the sample was heated for 10 minutes in a tube furnace at 950°C through which a stream of oxygen was allowed to flow. Carbon in the samples reacted with the oxygen to form carbon dioxide (CO_2) gas. The generated CO_2 was absorbed in a solution of ethanoldiamine, with which it reacts to form acid. The acid thus released was titrated by an electrical current until a neutral pH was attained. The amount of current required to reach the end-point of the titration is an indirect measure of the amount of carbon in the original sample.

The method for the determination of inorganic carbon was similar, except that rather than the sample being heated in a tube furnace as in the determination of total carbon, the sample was submerged in a dilute solution of hydrochloric acid which reacted with the carbonate to generate the CO_2 that was adsorbed by the ethanoldiamine

Soil pH

Five grams of the oven-dried (50°C) <2 mm soil sample was weighed into a 50-mL disposable plastic beaker. Five mL of deionized water was added to the beaker, which was swirled and allowed to stand for 5 to 10 minutes. The pH value of the slurry was determined by a solid-state pH electrode immersed in the slurry. The pH was determined with a Corning® Model 314i ISFET pH meter.

Soil Texture

Soil texture was determined by the method of Indorante et al. (1990). Up to nine samples and a blank were processed at a time. In this method, 10 g of an oven-dried (50°C), <2 mm sample was placed in a 500 mL plastic, wide-mouth, screw-cap bottle. Ten mL of a 10% solution of sodium hexametaphosphate $(NaPO_3)_6$ was added to the bottle followed by 140 mL of deionized water. A blank sample containing only $(NaPO_3)_6$ and deionized water also was prepared. All bottles were sealed and placed on an oscillating shaker and shaken at 120 strokes per minute overnight. After shaking, 250 mL of deionized water was added to each bottle. The bottles were then shaken end-to-end by hand for 25 seconds to dislodge settled sand and silt, then end-over-end for 15 seconds. At the end of the 15-second period, the bottles were immediately placed in a covered, static water bath at 28°C for 3 hours and 18 minutes to allow particles larger than 2 μm to settle from the top 5 cm of the suspension. The shaken samples were placed in the water bath for settling at two-minute intervals to provide ample time between samples to withdraw aliquots for further processing. At the end of the settling period, the bottles were removed from the water bath at two-minute intervals in the same sequence in which they were placed into it. The tip of an Oxford® Macro-Set adjustable pipet was carefully inserted into the suspension to a depth of 5 cm, and exactly 10 mL of the suspension was withdrawn during a 15- to 20-second period. The pipet had been previously calibrated by weighing and averaging 10 replicate volumes of deionized water at the desired volume. The suspension was delivered to a numbered, weighed aluminum weighing pan. When aliquots of all the samples and the blank had been delivered to their respective weighing pans, the pans were placed in an oven to dry overnight at 110°C.

After the aliquots of suspended clay fractions had been withdrawn, the remaining contents of each bottle were poured through a 3.5-inch diameter, 62 μm (No. 230) stainless steel sieve to separate the sand-size particles from the silt- and clay-size particles. Each bottle was thoroughly rinsed with deionized water. Successive rinsates were poured through the sieve until no particulate matter could be observed in the bottle. The sand was rinsed several times to remove all silt-size and smaller particles.

The sand was then backwashed from the sieve with deionized water into a beaker, and the sand was quantitatively filtered through a numbered and weighed circle of Whatman No. 41 filter paper. Each filter paper was rinsed three times with deionized water, folded, and dried overnight in an oven at 110°C.

After drying, both the aluminum weighing pans and the filter papers were weighed. The weight of clay in the weighing pans was corrected for the weight of $(NaPO_3)_6$ in the blank. The clay and sand contents were calculated for each sample. The silt content of the samples was calculated by subtracting the percentages of clay plus sand from 100%.

Organic matter in a soil sample has been found to distort the determination of clay-size content. Therefore, the samples that contained more than 1% organic carbon were treated with 30% hydrogen peroxide (H_2O_2). We also found it necessary to treat the upper two samples from each core with H_2O_2. Ten grams of <2 mm sample was weighed into a 500-mL polymethlypentene bottle, then the bottle, cap, and soil sample were weighed and the weight was noted. Five mL of deionized water, 5 mL of 30% H_2O_2 and one drop of glacial acetic acid were added to the bottle in a fume hood and the bottles were loosely capped. When the reaction subsided, the bottles were transferred to a covered water bath at 60°C. Additional 5-mL aliquots of 30% H_2O_2 were added to the bottles at 15- to 20-minute intervals until a total of 20 mL of 30% H_2O_2 had been added to each bottle. The loosely capped bottles were allowed to stand in the covered water bath overnight. The bottles were allowed to cool to room temperature and then weighed. The amount of water required to bring the total amount of solution to 150 grams was calculated, then that amount of deionized water was added. Soil textures then were determined as described.

RESULTS AND DISCUSSION

Soil Texture

The sand, silt, and clay contents of each sample from each core are listed in Tables 2 through 26, and depicted graphically in odd-numbered figures 7 through 55. The proportion of sand, silt, and clay in a sample was used to determine the textural class of the sample according to the definitions of the USDA Soil Survey Division Staff (1993). The USDA terminology is useful for several reasons: (1) it is popular and used in all U.S. soil survey reports, (2) it is quantitative and easy to determine, and (3) it is based on empirical factors—there is a natural tendency for sediments to occur in these classes and the textural classification has about the maximum practical number of classes to use. Of the 25 cores discussed in this report, the textures of the uppermost or surficial horizon (the plow layer in most cases) of 17 of the cores were silt loam, five were silty clay loam, one was silty clay, one was loamy sand, and one was loam, as indicated in tables 2 through 26. As shown in table 27, the parent materials of the soils at locations 55, 63, and 64 were alluvium, that is, they were deposited as flood plain sediments. The soils of cores 55 and 64 developed in forest, and the soil of core 63 developed on a prairie. Cores 57, 59, 60, 61, 66, and 67 were from upland forest locations, the soil from core 62 developed in windblown

(aeolian) sand, and the remaining 15 cores were collected from areas that were upland prairies during soil development.

The clay contents of the subsamples of all the cores ranged from about 2% to 81%, the silt contents ranged from about 3% to 90%, and the sand from 0.05% to 96%. The soil texture classification, soil type, soil association, and developmental environment of the uppermost soil samples are listed in Table 27. In general, the clay content of the samples increased with depth, as shown in the odd-numbered figures 7 through 55.

The silt-size fraction of a soil is composed principally of quartz (SiO_2), with feldspar and carbonate minerals (where present), plus small amounts of heavy minerals, such as zircon ($ZrSiO_4$). Quartz and zircon are two of the most resistant minerals in soils along with rutile (TiO_2) and ilmenite ($FeTiO_3$), and some other iron-bearing minerals. In addition, quartz and other silicate minerals are resistant to physical abrasion, which means that much energy is required to grind these minerals to the silt-size range. The results of our analyses showed a moderately strong correlation (Table 28) of the sand-plus-silt size fraction with silicon. Quartz grains probably reached a size limit (terminal grade) below which they could not be ground by glacial action. The terminal grade for quartz is between about 31 and 62 µm (Dreimanis and Vagners, 1969, 1971). With artificial grinding, the terminal grade for quartz is about 16 to 32 µm (Gaudin, 1926), slightly finer than that observed by Dreimanis and Vagners, but still in the silt size range of 16 to 62 µm.

Results of Chemical Analyses

Table 28 lists the correlation coefficients between the various chemical constituents in the soil samples. The results of the chemical analyses of the subsamples from each of the 25 cores are presented in Tables 29 through 53 and Figures 7 through 55 (provided at end of report). Major and minor element contents reported as oxides (silicon through manganese in the tables) are listed first, followed by trace element contents (barium through zirconium). Major elements are those whose contents are greater than 1%, minor elements are those whose contents are between 0.1% and 1%, and trace elements are present at less than 0.1%, or 1000 mg/kg. The contents of all major and minor elements, as oxides, are listed as weight percent; trace element contents are listed as mg/kg, except for mercury, which is listed in µg/kg.

Correlation Coefficients A correlation coefficient is a numerical description of the statistical relationship of one constituent with another. If two constituents possess a positive correlation coefficient it means that as the content of one constituent increases from one sample to another, the content of the second constituent is likely to increase also. If the correlation coefficient is negative, then as the content of the one constituent increases, the content of the other is likely to decrease.

For example, the correlation coefficient between alumina (Al_2O_3) and the clay-size fraction is 0.84 (Table 28). That is, in about 84% of the samples, as the content of the clay-size fraction

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increased the alumina content also increased. Because two parameters are positively correlated does not necessarily mean that they are always present in the same ratio, only that they tend to vary together. Therefore, correlation coefficients do not prove conclusively that any particular mineral is present in a sample; they are merely suggestive.

When the data from all 137 cores are available we plan to study regional and state-wide trends, and differences between soil map units in terms of behavior of chemical elements in Illinois soils. For the present report we restrict our interpretations to cores 53 through 76. We calculated correlation coefficients to highlight the general relationships between constituents based on all samples analyzed from this set of cores.

The calculation of correlation coefficients helped confirm soil chemical properties and relationships that were known from previous studies. For example, it is known that silt-sized particles are composed predominantly of silica (SiO_2, Brady and Weil, 1999) and that zirconium (Zr), which occurs principally in the mineral zircon ($ZrSiO_4$) in soils, also occurs predominantly in the silt-size particles. The correlations between silica and the sand-plus-silt size fraction (0.59) and between zirconium and the silt-size fraction (0.82) found for the samples of this study confirm these previous observations.

Titanium oxide (TiO_2) was also correlated (0.72) with the silt-size fraction, but it was also correlated (0.51) with clay-size fraction. A possible explanation for this complex situation is that rutile (TiO_2), ilmenite ($FeTiO_3$), and anatase (TiO_2) were all present in many of the soil samples. Rutile and ilmenite would have been inherited from the parent material and, because of their hardness, had a minimum size in the silt-size fraction. Anatase forms from the degradation of ilmenite; anatase crystals are very small and occur in the clay-size fraction (Milnes and Fitzpatrick, 1989). Therefore, titanium minerals in soils occur in both the silt-size and the clay-size fractions (Steinkoenig, 1914).

Clay minerals are important components of all soils. They occur principally in the clay-size fraction and contain Si as one of the major constituents. Because SiO_2 is the major constituent of the silt- and sand-size fractions, we observed that as the amounts of the sand+silt fraction increased, the amount of SiO_2 in the samples also generally increased. That is, the correlation between Si and the sand+silt fraction was moderately strong. As the silt and sand fractions increased, the clay-size fraction decreased and there was a negative correlation (-0.51) between SiO_2 and the clay-size fraction. Aluminum (as Al_2O_3), another major constituent of clay minerals and other minerals in the clay-size fraction, demonstrated a strong positive correlation with the clay-size fraction (0.84).
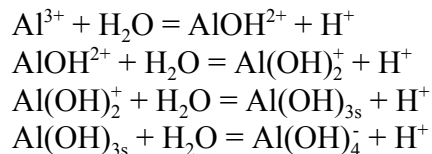
The clay-size fraction was correlated with iron (0.79), copper (0.55), rubidium (0.62), vanadium (0.87), zinc (0.68), and mercury (0.56). Therefore, except for mercury, these elements also correlated with each other. Mercury was correlated only with iron and vanadium. Iron is a common structural member, that is, it is a necessary part of certain clay minerals, although it may also occur as an exchangeable ion on clay minerals. Iron is commonly found in illite and in

coatings of iron oxyhydroxides on other minerals (Wilding et al., 1977) and as concretions in many soils.

The other elements noted above, copper, rubidium, vanadium, zinc, and mercury are known as soil trace elements because they occur at trace concentrations, or less than 1000 mg/kg. These metals are readily adsorbed by, or attached to, clay minerals, or in some cases, become trapped (occluded) within the clay mineral structure. The iron oxyhydroxide minerals are strong adsorbers of many trace elements, as well.

Calcium oxide (CaO) and magnesium oxide (MgO) were strongly correlated with each other (0.95) and with inorganic carbon content (0.99 and 0.96, respectively). These correlations suggest the presence of calcite and dolomite in the soil samples. Titanium oxide and zirconium were correlated with each other (0.58). Each was also correlated with the silt-size fraction (0.72 and 0.79, respectively). The correlation between titanium oxide and zirconium was probably a result of their mutual correlation with the silt-size fraction and not because they form a particular mineral with each other.

Soil pH Soil pH is a measure of the acidity or hydrogen ion (H^+) concentration of the soil solution. Various substances are important in maintaining soil pH, depending on the pH range. At pH values between 4.5 and 5.5, aluminum in the soil solution, which may originate from the dissolution or decomposition of clay minerals, buffers the pH of the soil solution according to the following chemical reactions (Hassett, 1989):

$$Al^{3+} + H_2O = AlOH^{2+} + H^+$$
$$AlOH^{2+} + H_2O = Al(OH)_2^+ + H^+$$
$$Al(OH)_2^+ + H_2O = Al(OH)_{3s} + H^+$$
$$Al(OH)_{3s} + H_2O = Al(OH)_4^- + H^+$$

If small amounts of gibbsite [$Al(OH)_3$] or clay minerals in the soil dissolve to contribute Al^{3+} to the soil solution, the Al^{3+} becomes hydrolyzed to $AlOH^{2+}$, which results in the addition of H^+ to the solution, and this results in greater acidity. If additional H^+ enters the soil solution, the reaction between $AlOH^{2+}$ and Al^{3+} is driven to the left and H^+ is consumed in the formation of H_2O and Al^{3+}. Aluminum, therefore, serves as an acidity buffer for pH between values of about 4.5 and 5.5 (Sparks, 1995). Above pH 5.5, the solubility of Al^{3+} is low enough that it is not effective in buffering soil pH.

In the pH range of 5.5 to 6.8, there are three mechanisms that act to maintain soil solution pH: (1) H^+ and basic cations of the soil exchange-complex buffer the pH, (2) atmospheric carbon dioxide (CO_2) dissolves in and reacts with water, and (3) weak acidic groups of soil mineral matter such as silicate groups of clay minerals (for example, smectite) and organic matter exchange H^+ with the soil solution. (The soil exchange complex is that portion of mineral surfaces which is active in ion exchange.) Soil organic matter is more important than clay minerals in controlling pH and adsorption of various cations in soils (Helling et al., 1964; Yuan et al., 1967)

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If some external source of acid makes the soil solution more acidic, some of the H^+ ions in the soil solution are adsorbed by the soil in exchange for basic cations, which go into solution. Conversely, if the soil solution becomes more alkaline, some of the basic cations become attached to the soil solids in exchange for H^+ ions, which enter the soil solution and make the solution more acidic. In this way, the soil solids act to resist change in the pH of the soil solution.

In the pH range 5.5 to 7.2, weak acidic groups such as –AlOH and –SiOH on the edges of clay minerals and –COOH groups on carboxylic acids in organic matter serve to buffer, or protect, the soil solution against changes in pH by consuming or releasing H^+.

Atmospheric carbon dioxide (CO_2) contributes to the control of soil solution pH by reactions with water to produce carbonic acid and intermediate carbonate and bicarbonate anions, as in the following reactions (Hassett, 1989):

$$CO_{2\,gas} = CO_{2\,aq}$$
$$CO_{2\,aq} + H_2O = H_2CO_3$$
$$H_2CO_3 = HCO_3^- + H^+$$
$$HCO_3^- = CO_3^{2-} + H^+$$
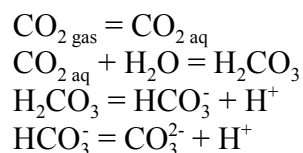
Above pH 7.2 the pH is controlled by the precipitation or dissolution of carbonate minerals such as calcite and dolomite. As calcite dissolves in the soil solution it releases carbonate ion (CO_3^{2-}), which reacts with water to produce bicarbonate ions (HCO_3^-), which, as illustrated in the equations given above, react to produce or consume H^+ ions. The pH value at which calcite or dolomite precipitate depends on the concentration of CO_2 in the gas phase. The greater the amount of carbon dioxide in the gas phase, the lower the solubility of calcite.

The pH values of the samples from the 25 cores ranged from 4.76 (moderately acidic) to 8.30 (moderately alkaline), with a median value of 6.76. Of the 151 samples, 86 had a pH between 4 and 7 and the remaining 66 samples had a pH greater than 7. The approximate pH range of most soils found globally is 3.0 to 8.5 (Baas Becking et al., 1960). As shown in Figure 5 and Tables 29 through 53, the pH value in 13 of the 25 cores became more acidic with increasing depth to about 4 feet or less, then became more alkaline below this depth. Calcareous till that lies under the loess was penetrated at 22 of the 25 coring locations (cores 52-56, 58, 60, and 64-76). In all of these cores the calcium oxide and magnesium oxide contents increased sharply in the sample(s) that were selected from the till. Calcium carbonate in the till imposes an alkaline pH on the deeper samples from these cores.

Means and Ranges of Element Contents The mean and range of the element contents determined in the uppermost samples from the 25 cores in this portion of the project are compared in Table 54 with the results obtained by Shacklette and Boerngen (1984) for loess and silty soils or loamy and clay soils, and Severson and Shacklette (1988), according to the availability of their data. The data from Shacklette and Boerngen (1984) for trace elements were for surface horizons from throughout the U.S., whereas the data for most major and minor

elements were for Illinois soils without regard to soil texture. Our ranges of values were within the ranges observed by Shacklette and Boerngen for similar soil textures for about 48% of the elements determined.

The excursions of concentrations outside the ranges observed by Shacklette and Boerngen did not necessarily mean that the soil sample was deficient or contaminated in an element, nor that plants grown in that soil will absorb any of those elements in toxic amounts. Much depends on how tightly bound the elements are by the clay minerals, iron and manganese oxyhydroxides, and soil organic matter. The pH of the soil solution is also very important in determining the solubility and availability of various elements.

Silicon According to Kabata-Pendias (2001), quartz, or SiO_2, is the most resistant common mineral in soils. Likely, a large portion of the quartz in the source rocks for the glacial deposits in Illinois was originally sand-sized material. Glacial transport would have reduced the size of the quartz grains by grinding them to a size that approached the terminal grade in the silt range. Grinding to terminal grade does not appear to have reached completion during glacial transport, but had there been increased transport distance there would have been an increase in grinding and a consequent increase in the amount of coarse silt (31 to 62 μm) would have been expected (Dreimanis and Vagners, 1971). As already stated, experimental tests by Dreimanis and Vagners (1971) indicated a terminal grade for quartz between 31 and 62 μm (0.031 to 0.062 mm). In the glacial deposits of Illinois, the fraction with the maximum amount of quartz ranges in size from medium silt (0.006 to 0.02 mm) to fine sand (0.125 to 0.250 mm).

In many of the cores the SiO_2 content decreased with depth, especially in cores in which only the modern soil was penetrated, for example cores 52 and 53. In cores in which a paleosol was penetrated, for example cores 58 and 64, the SiO_2 content decreased in the C horizon of the modern soil, then increased in the paleosol sample. This might indicate that the underlying paleosol was subject to weathering conditions similar to those acting upon the modern soil. Certain minerals were degraded during soil development and leached downward in the soil column to accumulate as clay minerals in the paleo B horizon. Quartz, which is not easily degraded, was became more concentrated in the paleo A horizon as other constituents were leached downward.

When the CaO content increased at depth in the profile, the SiO_2 content generally decreased because of dilution of the sample by calcite ($CaCO_3$). When the CaO content increased sharply and the SiO_2 content decreased, it usually occurred in a sample from the C horizon, as in cores 69 and 71.

Aluminum The aluminum content of soils is mostly inherited from the parent materials (Kabata-Pendias, 2001). The concentration of Al in the cores generally increased with depth, although in some cores the concentration passed through a maximum at some depth. These trends reflected the trends in clay content of the subsamples.

The profiles of Al_2O_3 content versus depth were often mirror images of the SiO_2 profiles. When CaO contents increased significantly, usually the Al_2O_3 decreased because of dilution by calcite, as in cores 52 and 53, for example. An exception to this observation was that in the depth profile for core 55, the content of Al_2O_3 increased with an increase in CaO content. In addition to the increase in CaO content, the clay content also increased significantly in the lowermost sample of core 55, compared with the next shallower sample. The content of Al_2O_3 is dependent on the clay content, whereas the SiO_2 content is dependent on the sand+silt content.

Iron Iron in soils occurs principally as oxyhydroxides, most commonly as goethite (FeOOH) in soils of temperate, humid regions. Iron minerals commonly occur as coatings on clay minerals, silt, and sand particles, and cements in concretions. The iron oxyhydroxides typically are very fine-grained, possess large surface areas, and are active adsorbers of other cations, particularly metals such as copper, nickel, vanadium, and zinc (Kabata-Pendias, 2001).

Iron has an affinity for organic molecules and forms complex compounds with them. These organo-iron complexes may be largely responsible for the migration of iron through the soil profile (Kabata-Pendias, 2001). The Fe_2O_3 content in these cores tended to vary within a small range. In all but two cores (55 and 63) the Fe_2O_3 content passed through a maximum with increasing depth, generally in the B horizon, the clay-rich zone in the soil profile. The positive correlation between Fe_2O_3 and clay-size fraction (0.79) upholds that iron oxyhydroxides tend to occur as coatings on clay particles.

In core 55 the Fe_2O_3 content still followed the clay-size fraction. The clay-size content did not go through a maximum in the B horizon, but it did in the underlying paleo C horizon. The Fe_2O_3 content mimicked the behavior of the clay-size fraction.

Potassium Typically, potassium occurs in Illinois soils in the primary minerals, particularly feldspars and micas (Sparks, 1995), and the clay mineral illite, but it can also be held as an exchangeable ion on the soil exchange complex. Because feldspars and micas are quite resistant to weathering, K is not commonly found at high concentrations in the soil solution. In fact, Severson and Shacklette (1988) estimated that 90 to 98 percent of the K in soils is unavailable to plants, which means it occurs in a form that is not readily soluble.

The content of K_2O did not vary appreciably in the cores and remained at approximately 2%. There were, however, noticeable increases in the K_2O contents of the lowermost samples of cores 55 and 71. In both cores the clay-size content increased significantly, especially in core 55. Possibly the illite content of the particular sample was greater than in other samples.

Calcium Calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$] are common sources of calcium in soils, but not all soils contain calcite or dolomite. Calcium can also be held as an exchangeable ion on the soil exchange complex. The content of CaO in cores 61 and 63, was highest in the surface sample and quickly decreased to nearly constant values in samples from greater depths. Core 63 was collected about 15 feet from a "chip and tar" road. The high CaO content of the uppermost

sample might have been caused by road dust that arose when the top dressing was fresh. Core 63 was collected from a field from which soybeans had been harvested. The high CaO content of the uppermost sample possibly resulted from liming of the field. In several other cores (52-55, 58, 64-76), the CaO contents of samples from the C horizon were higher than for other samples selected from the cores. The calcium probably had calcite or dolomite in the parent material as its source. With time, the more reactive minerals in the parent material were affected by many years of contact with water, the atmosphere, plant roots, microorganisms. During weathering, much of the original $CaCO_3$ content of the parent material was dissolved and leached downward, collecting in lower portions of the soil column as secondary minerals.

Magnesium Sedimentary minerals such as dolomite are probably the principal sources of magnesium in Illinois soils.

In most cores in which there was an increase in the CaO content there was also an increase in MgO content, probably because of the presence of dolomite in the samples. Except in core 72, in the sample containing the maximum percentage of CaO, the amount of MgO was also at its maximum, but less than the percentage of CaO. In pure dolomite $[CaO \cdot MgO \cdot (CO_2)_2]$ the mass of MgO is 71.85% of the mass of CaO. In several samples, such as the bottom sample from core 53, or the second sample from the bottom of core 54, this ratio is approximately exhibited. In most cores, however, the MgO content was less than 71.85% of the CaO content. In these cases, part of the CaO could have been derived from dolomite and part from calcite.

Sodium Sodium-rich feldspar is probably the principal source of sodium in soils that are not near either an ocean or a roadway on which de-icing salt is applied (Sparks, 1995). Sodium minerals generally are easily weathered, and once released from the parent mineral, sodium is quite mobile. Sodium forms many water-soluble compounds in soils, and is, therefore, easily leached from the soil column. A small portion of the Na present in the parent materials likely was incorporated onto exchangeable positions on clay minerals, such as smectites, but most Na probably leached from the soil to the groundwater system.

The range of Na_2O content was always narrow, varying less than 1 percent from the minimum to the maximum content. In many of the cores the Na_2O content attained a maximum value in the B horizon or below, suggesting downward leaching of soluble sodium-containing compounds. A small portion of the sodium present in the parent materials probably was incorporated into exchangeable positions on clay minerals, such as smectite, but most Na_2O probably was leached from the soil to the groundwater system.

Titanium The sources of titanium in soils are oxides, such as rutile (TiO_2), and ilmenite ($FeTiO_3$) (Kabata-Pendias, 2001), neither of which is easily weathered. These minerals commonly occur nearly undecomposed in soils. Titanium presents no environmental concerns in soils (Kabata-Pendias, 2001). The titanium content exhibited behavior similar to that of sodium. The range of TiO_2 content was less than 1 percent in all 25 cores.

Phosphorus The content of phosphorus in soils is low, which makes the identification of phosphorus-bearing minerals difficult. Apatite $[Ca_5(F,Cl,OH)(PO_4)_3]$ has been identified in the silt-size fraction of some soils and might be the principal source of phosphorous, but most inorganic phosphate in soils occurs in the clay-size fraction (Lindsay et al., 1989). Phosphorus-containing fertilizers are the most common source of phosphorus in agricultural and residential soils.

Commonly, the content of P_2O_5 was greatest in the uppermost sample or second sample from the top of the core and decreased in deeper samples, such as in cores 69-71. In cores 53, 66, and 72, however, the content of P_2O_5 was greatest in samples from the B horizon.

Manganese The principal source minerals for manganese in soils are amphiboles, pyroxenes, biotite $[K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2]$ (in which Mn can replace iron to a limited extent), and rhodonite $(MnSiO_3)$ (Sparks, 1995). Although manganese occurs in the bulk of the soil as coatings on other minerals (Kabata-Pendias, 2001), it is also commonly found concentrated in nodules of MnO_2 (concretions) accompanied by iron. These nodules seem to form in soil horizons that periodically become waterlogged, so that reducing conditions prevail, and the soil then dries, restoring oxidizing conditions (McKenzie, 1989). In some soils a microscopic layered structure of alternating bands of iron-rich and manganese-rich material has been observed (McKenzie, 1989). However, the lack of correlation between MnO and Fe_2O_3 in the samples from these cores suggests no such intimate association.

In most cores, the MnO content passed through a maximum in the B horizon. In a few cores (57, 58, 64, 68, 73, and 75) the amount of MnO was highest in the A horizon, but there was a secondary maximum in the B horizon. One possible reason for this subsurface maximum is that manganese is sensitive to oxidation and reduction. Oxidized species, such as MnO_2, precipitate where oxygen is readily available, as it normally would be near the surface of the soil, and decrease in content with depth. The solubility of manganese increases as the pH and Eh (the oxidation-reduction potential) decrease (the soil becomes more acidic and less oxidizing) (Lindsay, 1979). Under conditions of increasing acidity and decreasing oxidation potential, manganese would be somewhat easily leached.

Barium Micas and feldspars are sources of barium in soils. These minerals contain potassium, which is commonly replaced by barium because the two atoms are of similar size (Kabata-Pendias, 2001). Barium is strongly adsorbed on clay minerals in soils and, therefore, is not very mobile. Barium has been found in soils as barite ($BaSO_4$, Allen and Hajek, 1989) and hollandite $[Ba(Mn^{4+},Mn^{2+})_8O_{16}$, McKenzie, 1989]. Barium also is concentrated in manganese and phosphorus concretions, and is specifically adsorbed on oxides and hydroxides. Fertilizer can be a secondary source of Ba in agricultural soils to which granular fertilizer has been applied, and in such cases, a steadily increasing load of Ba in the surface horizon is expected. As mentioned above, barium also reacts with sulfate to form the sparingly soluble barium sulfate.

The content of Ba in most cores passed through a maximum in the lower portion of the A horizon or in the AB horizon.

Chromium Chromium is generally present in soils as Cr^{3+} and this is responsible for the element's relative insolubility and immobility in soils (Kabata-Pendias, 2001), because the Cr^{3+} ion is readily adsorbed by clay minerals and oxyhydroxides, such as goethite. As a result of its normally low solubility and strong sorption, Cr generally is not available to plants. The principal sources of Cr in soils are minerals such as chromite ($FeCr_2O_4$) in the parent material (Kabata-Pendias, 2001), and industrial fallout, such as dust and industrial contaminants.

Chromium contents were below the detection limit of 5 mg/kg in some of the samples of cores 52, 55, 62, 67, 68, and 71. In fifteen of the cores (56-58, 61, 62, 64-68, 71-73, 75, and 76) the Cr content was at its maximum in the B horizon, commonly at the top of the horizon, or in a transition zone between the A or E horizon and the B horizon. This behavior is indicative of downward migration of chromium in the soil column. Connor et al. (1957) noted similar behavior in podzols developed on glacial drift in New Jersey and Pennsylvania. Although Cr is relatively immobile in soils because it forms strong bonds with clay minerals, it still can migrate downward in the soil profile. McKeague and St. Arnaud (1969) suggested that clay-sized particles migrate downward from the A horizon and accumulate at the top of the B horizon. If the Cr was adsorbed by colloidal-sized clay minerals in the A horizon, the Cr would be transported downward with the colloidal particles.

Copper Copper readily forms complex compounds with organic molecules, especially of the porphyrin type, but it also is adsorbed readily by clay minerals and iron and manganese oxyhydroxides. Copper precipitates as sulfides and carbonates under reducing conditions and as hydroxides under alkaline conditions (Kabata-Pendias, 2001). Copper is rendered immobile as a result of any of these reactions and its concentration in the soil profile does not vary appreciably (Kabata-Pendias, 2001).

The depth profiles for copper were similar to those for chromium, but the variations in copper content were much more subtle. The maximum Cu content occurred generally in the upper B horizon, but in some cores it occurred in the transition zone between the A or E horizon and the B horizon. The copper contents of the 25 cores were in the range of 15 to 47 mg/kg.

Mercury The most common natural source of mercury in rocks is the mineral cinnabar, HgS, but this mineral is seldom found in detrital material, such as soils and sediments (Kabata-Pendias, 2001). Although some of the mercury in soil is inherited from the parent materials, mercury probably is also deposited on the soil surface as atmospheric fallout of particulate matter from industrial processes or as a dissolved component of rainwater. Applications of phosphate-rock or sewage sludge as fertilizer are other possible sources of mercury.

Competing mechanisms of leaching, sorption, and volatilization determine the fate of mercury in soils. Organic matter (humic material) in soils has a greater capacity to adsorb mercury than the

inorganic soil components (Yin et al., 1997), except that sulfide (S^{2-}) and sulhydryl groups (SH^-) in soils have high affinities for mercury and may form mercuric sulfide (Barnett et al., 1997). Once sorbed, mercury may be desorbed slowly by soil solutions that contain little or no mercury (Yin et al., 1997). If mercuric sulfide is formed, this would tend to fix the mercury in position; however, if the mercury has not reacted with sulfur, it may be leached slowly downward in the soil profile. In contrast to these mechanisms of mercury retention, elemental mercury and methylated mercury compounds are easily volatilized. Methylated mercury has been shown by Rogers (1976, 1977) to be produced abiotically by humic substances in soils. A clay-rich soil produced the most methylmercury, followed by a loam, followed by a sandy soil (Rogers 1976, 1977). The organic matter content of the soils followed the same order: clay>loam>sand.

The mercury content generally attained its maximum in the B, AB, or BA horizon. In a few cores (55, 63, 69) the greatest mercury content occurred in the A horizon. In these three cores the mercury content appeared to follow the organic carbon content. In other cores, the mercury content followed the clay-size content.

Nickel The major source of nickel in soils is the parent material, but, a possible external source is airborne particulate from coal combustion. The highest Ni content typically is found in loamy soils. The Ni that is most available to plants is probably that which is associated with the iron oxyhydroxides. (Kabata-Pendias, 2001).

The nickel content was below the detection limit of 5 mg/kg in a few samples from cores 52, 55, 67, 68, and 71. The Ni content generally passed through a maximum in the upper B horizon or in the transition zone between the A or E horizon and the B horizon. In core 62 the greatest nickel content occurred in a beta (β) horizon. A β horizon is a secondary zone of clay accumulation in a soil profile. This type of concentration profile suggests that Ni was probably leached downward during weathering and followed the accumulation of clay minerals and iron oxyhydroxide compounds.

Lead Lead is adsorbed by clay minerals, iron and manganese oxyhydroxides, and soil organic matter. Hildebrand and Blume (1974) observed that illite was a better sorbent for Pb than other clay minerals, but Kabata-Pendias (1980) did not observe that property of illite.

The Pb content ranged from 9 to 41 mg/kg in the 25 cores. The profile of Pb content as a function of depth generally paralleled the Cu profile, although the Pb content in the soil samples was generally less than the corresponding Cu content. Exceptions to this observation were noted for the uppermost samples from cores 54, 60, 67, 71, and 73, in which the lead content was greatest at the surface or in the next lower sample. This might indicate that lead was deposited on the soil surface by exhaust gases from farm machinery.

Rubidium Because the radius of the rubidium ion (1.49 Å) is approximately the same as that of the potassium ion (1.33 Å), Rb commonly substitutes for K in K-feldspar (Kabata-Pendias, 2001). However, Rb is not as mobile in the soil as K, due to the stronger affinity of Rb to sorb on

clay minerals and iron oxyhydroxides than K (Goldschmidt, 1954). As the soil develops, therefore, Rb concentrations are expected to remain relatively stable whereas K would decrease.

Shacklette and Boerngen (1984) noted that the mean concentration of Rb in alluvial soils of the U.S. is 100 mg/kg, with a range of 55 to 140 mg/kg, and for loess and soils on silt deposits the mean is 75 mg/kg and the range is 45 to 100 mg/kg. The Rb content in all but ten samples fell within these ranges and these samples contained less than 45 mg/kg.

The Rb content in the 25 cores ranged from 36 to 136 mg/kg. In most cores the Rb content was greatest in the upper part of the B horizon, similar to other trace elements, such as Cu, V, and Zn, that are commonly associated with clay minerals.

Strontium Strontium generally is associated with soil organic matter, but it may also precipitate, under alkaline conditions as strontianite ($SrCO_3$), and is commonly associated with calcium geochemically. Strontium is easily mobilized during weathering of soils, especially in acidic oxidizing environments, but it is quickly incorporated in clay minerals and strongly bound by soil organic matter (Kabata-Pendias, 2001).

The Sr contents of these cores did not vary appreciably, falling in the range of 92 to 153 mg/kg. In some cores (53, and 72-75) the strontium content was nearly constant through the depth profile.

Vanadium During weathering, vanadium can be mobile, depending on the host minerals. Once freed by weathering, V tends to be incorporated in clay minerals or iron oxides (Butler, 1953, 1954). Vanadium also may form complex compounds with soil organic matter, for example in porphyrin-type compounds (Kabata-Pendias, 2001). In addition to the rocks in the parent materials, V can be contributed to soils by industrial processes such as smelting or combustion of coal or oil.

The vanadium content in almost every core (range from 25 to 90 mg/kg) followed the clay-size content, reaching a maximum in the B, AB, or BA horizon. The trend of V content with depth generally paralleled that of Rb and Zn.

Zinc Zinc is strongly adsorbed by clay minerals and soil organic matter and, therefore, is commonly present in higher concentrations in the B horizon of the soil profile (Kabata-Pendias, 2001). The atmospheric input of Zn from industrial fallout may be higher than its loss from the soil profile by leaching (Kabata-Pendias, 2001). This lack of balance between input and output can result in an accumulation of Zn in the surface horizon, but formation of soluble species allows Zn to leach downward to the B horizon, where it may be tightly bound by clay minerals and soil organic matter (Lindsay, 1972) and by iron oxyhydroxides (White, 1957). Therefore, the availability of Zn to plants is low.

In these 25 cores the zinc content (range from 36 to 108 mg/kg) was generally greatest in the B horizon or in the transition zone between the A or E horizon and the B horizon. The zinc content followed the vanadium and clay-size contents in almost every core. In a few cores (54, 56, 60, 62, and 74), the Zn content was greatest in the uppermost sample and decreased in the next lower sample of the core. This might indicate an external source of zinc at these five locations.

Zirconium Zirconium generally occurs in soil as the very stable mineral zircon ($ZrSiO_4$). Zircon is very resistant to weathering and zirconium is only very slightly mobile in soils (Hodson, 2002). The Zr content of soils is generally inherited from the parent materials (Kabata-Pendias, 2001).

The minimum Zr content was 185 mg/kg and the maximum was 449 mg/kg. The Zr content closely followed the silt fraction content. The zirconium content followed no particular pattern in these 25 cores with depth. In some cores (55, 60, 63, 64, 67, and 71) the Zr content passed through a maximum, in others (57-59 and 61) it passed through a minimum, in others (53, 62, 68, 70, 72, 75, and 76) the Zr content decreased steadily with depth, and in a few cores (54, 56, 73, and 74) the Zr content was relatively constant with depth.

Carbon Most carbon in the samples was combined in organic residues from biological material. Plant residues are typically plowed into the upper portions of the soil column after harvest each year. Burrowing animals leave waste behind; small insects, worms, and microorganisms die in the soil and their remains are incorporated into the soil column. In each core except cores 67 and 72, the highest organic carbon content occurred in the uppermost sample. The range of total carbon content was 0.06 to 4.38 %, inorganic carbon content ranged from 0.02 to 3.81 %, and organic carbon ranged from 0.04 to 4.01 %. The inorganic carbon content in most cores was low and relatively invariant with depth. In most cores the coring tool penetrated a calcareous till below the modern soil, as indicated by a sharp increase in inorganic carbon content. The inorganic carbon content decreased in the next lower sample of cores 54, 58, and 64 because the coring tool penetrated a paleosol below the till.

CONCLUSIONS

The contents of copper, rubidium, vanadium, zinc and mercury were correlated with the content of clay-sized particles. Each of these metals is easily sorbed by various clay minerals. As the colloidal-sized clay minerals migrate downward through the soil column, any elements attached to the clay particles are also transported.

The sand-plus-silt content is an indicator of the amount of silica in a sample. There is a similar relationship between clay and alumina content.

In twenty cores, the calcareous till beneath the surficial loess was penetrated and in samples selected from the till, dramatic increases in CaO, MgO, and inorganic C and decreases in SiO_2 and Al_2O_3 were observed.

Titanium oxide was correlated with both the silt-size and clay-size fractions, indicating that titanium-bearing minerals occurred in both size fractions. For example, ilmenite and rutile, being resistant to grinding, may have occurred in the silt-size fraction, and anatase, a secondary titanium oxide mineral of small particle size could have occurred in the clay-size fraction.

Some of the mercury content of the soils was probably inherited from the parent materials, but additional amounts probably resulted from atmospheric fallout from industrial sources or other external sources, such as fertilizer application.

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Table 1. Core number, county name, and final depth of core

Core Number	County Name	Final Depth of Core (ft)
52	Douglas	14.0
53	Macon	9.6
54	Christian	18.8
55	Sangamon	22.0
56	Sangamon	20.6
57	Morgan	21.0
58	Pike	22.0
59	Pike	9.0
60	Adams	24.0
61	Brown	17.1
62	Cass	17.3
63	Menard	20.0
64	Logan	19.6
65	Champaign	17.0
66	Douglas	16.6
67	Edgar	17.0
68	Vermilion	15.8
69	Vermilion	14.0
70	Champaign	12.05
71	Champaign	14.5
72	McLean	16.5
73	McLean	10.4
74	Logan	22.0
75	Macon	14.0
76	Champaign	14.0

Table 2. Texture of samples from core 52*

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
52-1	0.0-1.0	Ap	30.59	7.72	61.69	silty clay loam
52-2	1.0-1.6	BA	33.23	6.94	59.83	silty clay loam
52-3	1.6-2.0	Bg	34.20	6.14	59.66	silty clay loam
52-5	2.75-3.4	BCtj	29.99	7.06	62.95	silty clay loam
52-7	4.0-4.6	C	25.83	11.98	62.19	silt loam
52-14	9.3-10.0	2DC	25.40	29.96	44.64	loam

*Percentages in Tables 2 through 26 are weight-percent.

Table 3. Texture of samples from core 53

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
53-1	0.0-0.6	Ap	26.80	4.15	69.05	silt loam
53-2	0.6-1.3	AB	31.35	2.94	65.71	silty clay loam
53-3	1.3-2.0	BAt	40.15	1.50	58.35	silty clay loam
53-4	2.0-2.7	Bt	29.63	2.10	68.27	silty clay loam
53-5	2.7-3.4	CB	24.18	0.92	74.91	silt loam
53-11	7.5-8.0	3C	23.28	38.90	37.82	loam

Table 4. Texture of samples from core 54

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
54-1	0.0-0.8	Ap	24.79	7.13	68.08	silt loam
54-3	1.2-1.8	AB	36.36	1.75	61.89	silty clay loam
54-4	1.8-2.4	B1	34.79	1.99	63.22	silty clay loam
54-5	2.4-3.1	Bt	30.83	1.02	68.15	silty clay loam
54-7	3.5-4.0	C	13.58	0.46	85.96	silt loam
54-14	7.1-8.0	2Ab	21.50	9.19	69.31	silt loam

Table 5. Texture of samples from core 55

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
55-1	0.0-0.7	A	25.12	2.35	72.53	silt loam
55-3	1.1-1.6	A	18.75	9.01	72.24	silt loam
55-6	3.1-3.7	A	19.80	20.52	59.68	silt loam
55-8	4.3-5.0	A	19.38	26.56	54.16	silt loam
55-11	6.8-7.4	Bw	19.04	29.66	51.30	silt loam
55-28	17.0-18.2	2C	80.77	0.05	19.18	clay

Table 6. Texture of samples from core 56

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
56-1	0.0-0.8	A	26.79	1.93	71.28	silt loam
56-2	0.8-1.5	A	28.59	1.33	70.08	silty clay loam
56-3	1.5-2.0	AB	31.08	2.91	66.01	silty clay loam
56-5	2.7-3.4	Bt	33.51	4.39	62.10	silty clay loam
56-7	3.9-4.9	Bt	27.24	2.50	70.26	silty clay loam
56-11	8.4-8.8	C	15.14	0.68	84.18	silt loam

Table 7. Texture of samples from core 57

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
57-1	0.0-0.7	Ap	16.12	1.51	82.37	silt loam
57-2	0.7-1.2	AE	29.83	0.40	69.77	silty clay loam
57-3	1.2-2.0	Btj	33.42	0.42	66.16	silty clay loam
57-5	2.7-3.4	Bt	28.54	0.52	70.94	silty clay loam
57-11	6.6-7.4	CB	15.28	0.64	84.08	silt loam
57-16	10.6-11.1	2A	14.94	2.29	82.77	silt loam

Table 8. Texture of samples from core 58

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
58-1	0.0-0.9	Ap	14.56	2.71	82.73	silt loam
58-2	0.9-1.4	E	17.88	1.61	80.51	silt loam
58-3	1.4-2.0	Bt	39.10	0.68	60.22	silty clay loam
58-4	2.0-2.8	Bt	37.24	0.59	62.17	silty clay loam
58-7	4.0-4.6	Btj	29.32	0.72	69.96	silty clay loam
58-10	5.7-6.4	C	15.98	0.43	83.59	silt loam
58-31	18.2-18.6	2Ab	14.08	0.34	85.58	silt loam

Table 9. Texture of samples from core 59

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
59-1	0.0-0.3	Ap	25.95	0.73	73.32	silt loam
59-2	0.3-1.0	Bt	32.67	0.57	66.76	silty clay loam
59-3	1.0-1.5	Bt	34.35	0.68	64.97	silty clay loam
59-6	2.8-3.4	Bt	30.08	0.60	69.32	silty clay loam
59-13	6.8-7.1	3EB	23.68	2.86	73.46	silt loam
59-16	8.3-8.7	4Bt	24.58	13.50	61.92	silt loam

Table 10. Texture of samples from core 60

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
60-1	0.0-0.4	Ap	14.56	1.86	83.58	silt loam
60-2	0.4-1.2	Ap2	14.44	1.50	84.06	silt loam
60-3	1.2-1.5	E	12.40	3.70	83.90	silt loam
60-6	2.1-2.8	Bt2	45.54	1.56	52.90	silty clay
60-21	11.1-11.6	3Btt	34.50	18.99	46.51	silty clay loam
60-40	23.5-24.0	3C	37.80	30.06	32.14	clay loam

Table 11. Texture of samples from core 61

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
61-1	0.0-0.6	Ap	20.64	8.48	70.88	silt loam
61-2	0.6-1.3	Bt1	38.43	1.08	60.49	silty clay loam
61-3	1.3-2.0	Bt1	35.72	0.32	63.96	silty clay loam
61-4	2.0-2.7	Bt2	32.54	0.96	66.50	silty clay loam
61-10	6.1-6.8	C	17.00	0.58	82.42	silt loam
61-18	11.6-12.2	3Bt	36.06	15.46	48.48	silty clay loam

Table 12. Texture of samples from core 62

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
62-1	0.0-0.8	Ap	2.60	84.06	13.34	loamy sand
62-2	0.8-1.4	AB	2.72	84.99	12.29	loamy sand
62-3	1.4-2.0	AB	3.40	83.33	13.18	loamy sand
62-5	2.75-3.5	BA	2.96	84.26	12.78	loamy sand
62-7	4.25-5.0	Bw	4.88	86.04	9.08	loamy sand
62-17	10.5-11.0	Bβ	7.28	89.78	2.94	sand
62-18	11.0-11.5	C	1.72	95.54	2.82	sand

Table 13. Texture of samples from core 63

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
63-1	0.0-0.8	Ap	16.95	2.59	80.46	silt loam
63-2	0.8-1.4	Ap2	15.28	2.58	82.14	silt loam
63-3	1.4-2.0	A	15.44	3.78	80.78	silt loam
63-6	3.5-4.1	2Ab	16.76	12.30	70.94	silt loam
63-15	8.9-9.4	2Bwg	17.70	16.64	65.66	silt loam

Table 14. Texture of samples from core 64

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
64-1	0.0-0.8	Ap	26.92	0.64	72.44	silt loam
64-2	0.8-1.5	A	28.92	0.38	70.70	silty clay loam
64-3	1.5-2.0	Bt1	25.98	0.71	73.31	silt loam
64-6	3.1-3.7	BC	20.46	0.64	78.90	silt loam
64-8	4.0-4.8	C	14.88	1.04	84.08	silt loam
64-22	13.3-14.0	3BAb	31.72	24.60	43.68	clay loam

Table 15. Texture of samples from core 65

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
65-1	0.0-0.7	Ap	27.00	3.02	69.98	silt loam
65-2	0.7-1.4	A2	31.52	1.72	66.76	silty clay loam
65-3	1.4-2.0	BAt	37.00	1.65	61.35	silty clay loam
65-4	2.0-2.7	Bt	35.34	1.32	63.34	silty clay loam
65-5	2.7-3.5	Btj	27.18	4.36	68.46	silty clay loam
65-11	6.15-6.9	3C	24.18	26.49	49.33	loam

Table 16. Texture of samples from core 66

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
66-1	0.0-1.0	Ap	20.84	14.22	64.94	silt loam
66-2	1.0-1.7	AB	39.67	8.10	52.23	silty clay loam
66-3	1.7-2.2	BA	37.37	10.73	51.90	silty clay loam
66-4	2.2-2.9	Bg	33.04	11.26	56.10	silty clay loam
66-5	2.9-3.6	Bg	27.50	15.56	65.94	silty clay loam
66-6	3.6-4.4	2C	22.34	27.64	50.02	loam

Table 17. Texture of samples from core 67

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
67-1	0.0-0.7	Ap	24.72	25.68	49.60	loam
67-2	0.7-1.2	A	26.72	7.18	66.10	silt loam
67-3	1.2-1.8	A	26.64	4.26	69.10	silt loam
67-5	2.2-2.7	Bt	42.54	2.18	55.28	silty clay
67-7	3.2-4.0	BCt	27.96	9.34	62.70	silty clay loam
67-9	4.65-5.4	2C	19.64	37.60	42.76	loam

Table 18. Texture of samples from core 68

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
68-1	0.0-0.8	Ap	23.84	5.94	70.22	silt loam
68-2	0.8-1.4	AB	38.11	1.18	60.71	silt loam
68-3	1.4-2.0	Btg	39.72	1.24	59.04	silty clay loam
68-4	2.0-2.8	Btg	35.11	1.24	63.65	silty clay loam
68-6	3.3-3.8	2BC	17.44	50.10	32.46	loam
68-9	5.4-6.0	2C	20.62	28.28	51.10	silt loam

Table 19. Texture of samples from core 69

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
69-1	0.0-0.8	Ap	39.86	6.03	54.11	silty clay loam
69-3	1.2-2.0	A	36.47	19.66	43.87	silty clay loam
69-4	2.0-2.8	A	37.70	24.08	38.22	clay loam
69-5	2.8-3.7	AB	31.87	37.12	31.66	clay loam
69-8	4.7-5.8	2C1	26.57	15.99	57.44	silt loam
69-11	7.0-7.7	2C2	25.96	18.42	55.62	silt loam

Table 20. Texture of samples from core 70

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
70-1	0.0-1.2	Ap	29.11	5.47	65.42	silty clay loam
70-2	1.2-2.0	A	33.08	20.40	46.52	clay loam
70-3	2.0-2.8	AB	34.82	24.44	40.74	clay loam
70-4	2.8-3.5	BA	31.88	26.66	41.46	clay loam
70-5	3.5-4.2	Bg	30.06	32.02	37.92	clay loam
70-8	5.7-6.4	B3β	12.30	66.53	21.17	sandy loam

Table 21. Texture of samples from core 71

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
71-1	0.0-0.7	Ap	25.19	7.06	67.75	silt loam
71-2	0.7-1.2	AB	32.70	1.09	66.21	silty clay loam
71-3	1.2-1.8	Btj	28.25	0.69	71.06	silty clay loam
71-4	1.8-2.2	CB	12.78	0.85	86.37	silt loam
71-5	2.2-2.8	C	9.60	0.88	89.66	silt
71-10	5.5-6.1	2C	36.52	12.16	51.27	silty clay loam

Table 22. Texture of samples from core 72

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
72-1	0.0-0.9	Ap	29.03	3.30	67.67	silty clay loam
72-2	0.9-1.5	AB	35.36	4.08	60.56	silty clay loam
72-3	1.5-2.0	Bg	36.77	2.60	60.63	silty clay loam
72-4	2.0-2.8	Bg	33.26	3.24	63.50	silty clay loam
72-6	3.4-4.0	Bg	29.38	7.26	63.36	silty clay loam
72-9	5.6-6.6	2C	23.90	35.36	41.76	loam

Table 23. Texture of samples from core 73

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
73-1	0.0-0.8	Ap	24.71	2.82	72.47	silt loam
73-2	0.8-1.4	AB	33.31	1.47	65.22	silty clay loam
73-3	1.4-2.0	Bt	34.13	1.34	64.14	silty clay loam
73-4	2.0-2.8	Btj	29.90	1.29	68.81	silty clay loam
73-5	2.8-3.4	Btj	25.94	1.17	72.89	silt loam
73-6	3.4-4.0	C	20.82	1.08	78.10	silt loam

Table 24. Texture of samples from core 74

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
74-1	0.0-0.8	Ap	30.72	1.28	68.00	silty clay loam
74-3	1.1-1.6	AB	32.36	1.62	66.02	silty clay loam
74-4	1.6-2.2	Bg	32.39	1.24	66.37	silty clay loam
74-5	2.2-2.9	B	31.96	2.46	65.58	silty clay loam
74-7	3.1-4.0	Bgtj	30.90	1.20	67.90	silty clay loam
74-11	5.4-6.0	C	10.66	4.10	85.24	silt

Table 25. Texture of samples from core 75

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
75-1	0.0-0.7	Ap	25.04	3.14	71.82	silt loam
75-2	0.7-1.3	AB	34.68	2.10	63.22	silty clay loam
75-3	1.3-2.0	Btj	38.69	1.80	59.51	silty clay loam
75-4	2.0-2.6	Bt	34.44	2.50	63.06	silty clay loam
75-6	3.2-3.7	Btj	24.90	9.12	65.98	silt loam
75-10	5.2-5.8	2C	22.30	39.97	37.73	loam

Table 26. Texture of samples from core 76

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
76-1	0.0-0.9	Ap	21.99	9.39	68.62	silt loam
76-3	1.3-2.0	Bt	37.39	4.19	58.42	silty clay loam
76-4	2.0-2.5	Bt	33.33	6.65	60.02	silty clay loam
76-5	2.5-3.3	Btj	26.44	5.32	68.64	silt loam
76-6	3.3-3.8	BC	25.26	8.36	66.38	silt loam
76-8	4.0-4.5	2Cβ	21.65	42.15	36.20	loam

Table 27. Soil texture, soil type, and developmental environment

Core Number	Texture	Soil Type*	Soil Association	Developmental Environment
52	silty clay loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie
53	silt loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie
54	silt loam	Ipava	Tama-Ipava-Sable	upland, prairie
55	silt loam	Radford	Lawson-Sawmill-Darwin	alluvium, prairie
56	silty clay	Sable	Tama-Ipava-Sable	upland, prairie
57	silt loam	Rozetta	Fayette-Rozetta-Stronghurst	upland, forest
58	silt loam	Sable	Tama-Ipava-Sable	upland, prairie
59	silt loam	Fayette	Fayette-Rozetta-Stronghurst	upland, forest
60	silt loam	Keomah	Clinton-Keomah-Rushville	upland, forest
61	silt loam	Rozetta	Fayette-Rozetta-Stronghurst	upland, forest
62	loamy sand	Plainfield	Oakville-Lamont-Alvin	aeolian, prairie
63	silt loam	Arenzvill	Haymond-Petrolia-Karnak	alluvium, forest
64	silt loam	Sawmill	Lawson-Sawmill-Darwin	alluvium, prairie
65	silt loam	Flanagan	Catlin-Flanagan-Drummer	upland, prairie
66	silt loam	Toronto	Dodge-Russell-Miami	upland, forest
67	loam	Wingate	Dodge-Russell-Miami	upland, forest
68	silt loam	Flanagan	Catlin-Flanagan-Drummer	upland, prairie
69	silty clay loam	Elliott	Varna-Elliott-Ashkum	upland, prairie
70	silty clay loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie
71	silt loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie
72	silty clay loam	Ipava	Tama-Ipava-Sable	upland, prairie
73	silt loam	Catlin	Catlin-Flanagan-Drummer	upland, prairie
74	silty clay loam	Sable	Tama-Ipava-Sable	upland, prairie
75	silt loam	Catlin	Catlin-Flanagan-Drummer	upland, prairie
76	silt loam	Flanagan	Catlin-Flanagan-Drummer	upland, prairie

*Designations of soil types in this report are provisional and are subject to change after more detailed examination of the cores. Soil names were those of the map unit in which cores were collected.

Table 28. Correlation coefficients for constituents of cores 27 through 51 (C.I. = 95%)

	Depth	SiO_2	Al_2O_3	Fe_2O_3	K_2O	LOI	Moisture	CaO	MgO
Depth	1								
SiO_2	-0.07	1							
Al_2O_3	-0.13	-0.48	1						
Fe_2O_3	-0.06	-0.44	0.77	1					
K_2O	0.12	-0.62	0.26	0.20	1				
LOI	0.02	-0.81	-0.03	-0.02	0.45	1			
Moisture	-0.33	-0.24	0.82	0.72	-0.09	-0.10	1		
CaO	0.27	-0.69	-0.25	-0.19	0.45	0.85	-0.44	1	
MgO	0.24	-0.80	-0.05	-0.04	0.53	0.83	-0.28	0.95	1
Na_2O	-0.08	0.08	0.23	-0.12	-0.10	-0.27	0.05	-0.21	-0.16
TiO_2	-0.24	-0.26	0.72	0.52	0.14	-0.10	0.58	-0.34	-0.22
P_2O_5	-0.24	-0.08	0.22	-0.02	0.09	-0.02	0.16	-0.14	-0.12
MnO	-0.12	-0.07	0.21	0.33	0.01	-0.11	0.14	-0.13	-0.10
Ba	-0.22	-0.20	0.58	0.15	0.01	-0.11	0.44	-0.18	-0.04
Sr	0.12	0.22	-0.14	-0.06	-0.04	-0.27	-0.22	-0.10	-0.20
Zr	-0.22	0.24	0.07	0.12	-0.26	-0.29	0.08	-0.36	-0.41
Cr	0.13	0.20	0.20	0.15	-0.35	-0.31	0.35	-0.34	-0.29
Cu	-0.13	-0.13	0.30	0.52	0.14	0.02	0.48	-0.20	-0.16
Ni	0.23	0.22	0.06	0.13	-0.38	-0.30	0.18	-0.27	-0.25
Pb	-0.30	-0.19	0.26	0.40	0.11	0.18	0.38	-0.14	-0.13
Rb	-0.10	-0.32	0.30	0.40	0.51	0.25	0.37	-0.01	0.02
V	-0.24	-0.33	0.83	0.87	0.10	-0.09	0.81	-0.37	-0.23
Zn	-0.26	-0.34	0.43	0.58	0.28	0.19	0.57	-0.11	-0.03
Hg	-0.26	-0.08	0.71	0.58	-0.24	-0.25	0.80	-0.44	-0.32
Tot C	-0.16	-0.54	-0.17	-0.26	0.32	0.88	-0.12	0.64	0.56
In C	0.26	-0.67	-0.28	-0.21	0.43	0.83	-0.46	0.99	0.96
Org C	-0.45	0.003	0.06	-0.11	-0.03	0.25	0.30	-0.20	-0.26
Sand	0.26	0.49	-0.66	-0.58	-0.22	-0.19	-0.53	0.06	-0.04
Silt	-0.27	-0.27	0.28	0.25	0.06	0.14	0.17	0.023	0.04
Clay	-0.05	-0.51	0.84	0.79	0.34	0.14	0.77	-0.16	-0.002
Sand+Silt	0.05	0.51	-0.84	-0.79	-0.34	-0.14	-0.77	0.16	0.002
pH	0.30	-0.42	-0.10	-0.02	0.35	0.37	-0.27	0.60	0.61

Table 28, continued

	Na$_2$O	TiO$_2$	P$_2$O$_5$	MnO	Ba	Sr	Zr	Cr	Cu
Na$_2$O	1								
TiO$_2$	0.56	1							
P$_2$O$_5$	0.61	0.51	1						
MnO	0.11	0.253	0.18	1					
Ba	0.58	0.51	0.45	0.31	1				
Sr	0.47	0.18	0.18	-0.03	-0.16	1			
Zr	0.48	0.57	0.32	0.14	-0.006	0.64	1		
Cr	-0.12	-0.10	-0.25	-0.06	0.12	-0.20	-0.22	1	
Cu	-0.19	0.20	0.02	-0.15	-0.28	-0.006	0.02	0.12	1
Ni	-0.10	-0.15	-0.18	-0.03	0.003	-0.14	-0.24	0.47	0.18
Pb	-0.12	0.38	0.28	-0.04	-0.18	-0.07	0.21	-0.13	0.61
Rb	-0.38	0.20	-0.02	-0.23	-0.30	-0.14	-0.11	-0.05	0.70
V	0.05	0.70	0.15	0.23	0.20	-0.007	0.28	0.16	0.60
Zn	-0.21	0.29	0.14	-0.10	-0.16	-0.13	0.02	0.01	0.85
Hg	0.14	0.49	0.13	0.16	0.42	-0.16	-0.02	0.34	0.34
Tot C	-0.17	0.09	0.19	-0.14	-0.07	-0.24	-0.20	-0.32	-0.02
In C	-0.25	-0.38	-0.19	-0.14	-0.20	-0.14	-0.38	-0.33	-0.23
Org C	0.04	0.26	0.42	-0.04	0.11	-0.15	0.14	-0.09	0.20
Sand	-0.40	-0.88	-0.44	-0.22	-0.32	-0.24	-0.63	0.21	-0.25
Silt	0.59	-0.72	0.48	0.19	0.24	0.46	0.79	-0.36	0.007
Clay	-0.21	0.51	0.05	0.12	0.23	-0.30	-0.11	0.22	0.55
Sand+Silt	0.21	-0.51	-0.05	-0.12	-0.23	0.30	0.11	-0.22	-0.55
pH	-0.05	-0.19	-0.13	0.05	0.03	-0.001	-0.18	-0.14	-0.28

Table 28, continued

	Ni	Pb	Rb	V	Zn	Hg	Tot C	In C	Org C
Ni	1								
Pb	-0.06	1							
Rb	-0.08	0.56	1						
V	0.12	0.53	0.56	1					
Zn	0.04	0.76	0.79	0.68	1				
Hg	0.51	0.24	0.08	0.69	0.38	1			
Tot C	-0.34	0.22	0.22	-0.21	0.14	-0.25	1		
In C	-0.26	-0.17	-0.03	-0.39	-0.13	-0.46	0.61	1	
Org C	-0.17	0.42	0.29	0.13	0.30	0.14	0.62	-0.25	1
Sand	0.22	-0.43	-0.26	-0.70	-0.38	-0.39	-0.12	0.10	-0.25
Silt	-0.32	0.25	-0.02	0.36	0.08	0.05	0.14	-0.006	0.18
Clay	0.11	0.48	0.62	0.87	0.68	0.56	-0.006	-0.19	0.18
Sand+Silt	-0.11	-0.48	-0.62	-0.87	-0.68	-0.56	0.006	0.19	-0.18
pH	-0.11	-0.16	-0.16	-0.24	-0.20	-0.29	0.15	0.60	-0.40

	Sand	Silt	Clay	Sand+Silt	pH
Sand	1				
Silt	-0.86	1			
Clay	-0.50	0.00	1		
Sand+Silt	0.50	0.00	-1.00	1	
pH	-0.04	0.02	-0.12	0.12	1

Table 29. Elemental composition of samples selected from Core 52

Subsample	52-1	52-2	52-3	52-5	52-7	52-14	Average
Lab. No.	R22264	R22265	R22266	R22267	R22268	R22269	
Depth Interval (ft)	0.0-1.0	1.0-1.6	1.6-2.0	2.0-3.4	4.0-4.6	9.3-10.0	
Horizon	Ap	BA	Bg	BCtj	C	DC	
SiO_2 (%)	72.40	72.40	72.20	72.30	68.90	57.80	69.33
Al_2O_3 (%)	11.20	12.70	12.50	12.10	13.10	8.80	11.73
Fe_2O_3 (%)	4.11	4.64	4.57	5.81	5.84	3.62	4.77
K_2O (%)	2.33	2.29	2.35	2.62	3.89	2.83	2.72
CaO (%)	1.11	0.73	0.78	0.72	0.84	8.73	2.15
MgO (%)	0.97	1.02	1.06	1.08	1.64	4.39	1.69
Na_2O (%)	0.72	0.74	0.72	0.83	0.64	0.48	0.69
TiO_2 (%)	0.70	0.74	0.71	0.71	0.78	0.42	0.68
P_2O_5 (%)	0.14	0.08	0.10	0.11	0.10	0.07	0.10
MnO (%)	0.05	0.06	0.05	0.14	0.19	0.07	0.09
Barium	382	464	469	403	547	284	425
Chromium	53	--	54	54	41	<5	41
Copper	28	--	30	29	24	26	27
Mercury (µg/kg)	18	27	34	30	14	6	22
Nickel	12	--	14	14	10	<5	11
Lead	22	--	22	19	16	16	19
Rubidium	93	--	91	78	92	83	87
Strontium	111	121	133	134	113	123	123
Vanadium	80	--	92	90	85	58	81
Zinc	79	--	81	74	65	58	71
Zirconium	311	303	296	310	196	152	261
Total C (%)	1.96	0.85	0.97	0.34	0.40	3.08	1.27
Inorganic C (%)	0.09	0.04	0.05	0.05	0.22	2.67	0.52
Organic C (%)	1.87	0.81	0.92	0.29	0.18	0.41	0.75
pH	7.40	7.24	6.91	7.18	7.74	7.81	7.38

Table 30. Elemental composition of samples selected from Core 53

Subsample	53-01	53-02	53-03	53-04	53-05	53-11	Average
Lab. No.	R22270	R22271	R22272	R22273	R22274	R22275	
Depth Interval (ft)	0.0-0.6	0.6-1.3	1.3-2.0	2.0-2.75	2.7-3.4	7.5-8.0	
Horizon	Ap	AB	BAt	Bt	CB	C	
SiO_2 (%)	71.10	70.80	68.10	70.90	66.30	60.30	67.92
Al_2O_3 (%)	10.20	11.70	14.50	13.10	11.60	8.30	11.57
Fe_2O_3 (%)	3.34	3.50	4.80	4.21	3.36	3.33	3.76
K_2O (%)	2.10	2.02	1.92	2.18	2.19	2.67	2.18
CaO (%)	0.88	0.87	0.91	0.97	3.32	7.76	2.45
MgO (%)	0.89	1.15	1.58	1.53	3.37	4.38	2.15
Na_2O (%)	1.04	1.17	1.17	1.44	1.44	0.65	1.15
TiO_2 (%)	0.76	0.88	0.92	0.95	0.93	0.41	0.81
P_2O_5 (%)	0.14	0.15	0.15	0.19	0.19	0.07	0.15
MnO (%)	0.05	0.05	0.06	0.10	0.05	0.08	0.07
Barium	277	937	1000	1019	861	328	737
Chromium	55	120	29	66	86	106	77
Copper	30	29	21	32	27	20	27
Mercury (µg/kg)	48	28	48	36	25	13	33
Nickel	23	19	11	41	19	4	20
Lead	21	22	18	23	19	13	19
Rubidium	73	83	61	76	67	70	72
Strontium	110	98	97	106	102	97	102
Vanadium	90	85	63	103	85	54	80
Zinc	82	73	46	84	79	55	70
Zirconium	305	268	235	253	251	133	241
Total C (%)	4.07	2.68	0.91	0.54	1.34	2.49	2.01
Inorganic C (%)	0.06	0.06	0.06	0.06	1.01	2.37	0.60
Organic C (%)	4.01	2.62	0.85	0.48	0.33	0.12	1.40
pH	5.25	5.60	6.22	7.09	7.68	8.04	6.65

Table 31. Elemental composition of samples selected from Core 54

Subsample	54-01	54-03	54-04	54-05	54-07	54-14	Average
Lab. No.	R22276	R22277	R22278	R22279	R22280	R22281	
Depth Interval (ft)	0.0-0.8	1.2-1.8	1.8-2.4	2.4-3.1	3.5-4.0	7.1-8.0	
Horizon	Ap	AB	B1	Bt	C	2Ab	
SiO_2 (%)	71.80	69.08	69.50	71.90	62.10	76.30	70.11
Al_2O_3 (%)	10.10	13.14	11.90	12.40	8.10	11.50	11.19
Fe_2O_3 (%)	4.03	6.27	7.91	5.72	3.00	2.67	4.93
K_2O (%)	2.08	1.86	1.96	2.09	2.20	2.05	2.04
CaO (%)	1.43	0.78	0.69	0.81	6.74	1.08	1.92
MgO (%)	0.86	1.06	0.99	1.08	4.97	0.75	1.62
Na_2O (%)	0.93	0.77	0.86	1.02	1.00	1.46	1.01
TiO_2 (%)	0.73	0.75	0.76	0.77	0.61	0.79	0.74
P_2O_5 (%)	0.21	0.10	0.09	0.09	0.10	0.10	0.12
MnO (%)	0.09	0.15	0.12	0.09	0.04	0.03	0.09
Barium	551	634	617	548	414	327	515
Chromium	49	115	64	81	12	645	161
Copper	29	32	34	29	20	31	29
Mercury (µg/kg)	32	44	46	41	12	29	34
Nickel	18	25	28	26	9	27	22
Lead	41	21	22	21	15	18	23
Rubidium	65	64	68	66	54	52	62
Strontium	112	90	106	118	117	157	117
Vanadium	77	98	94	89	52	80	82
Zinc	108	73	84	78	57	41	74
Zirconium	299	284	299	304	297	343	304
Total C (%)	2.70	1.04	0.53	0.34	2.44	0.45	1.25
Inorganic C (%)	0.19	0.03	0.03	0.04	2.39	0.04	0.45
Organic C (%)	2.51	1.01	0.50	0.30	0.05	0.41	0.80
pH	7.08	6.36	6.33	6.76	7.87	7.32	6.95

Table 32. Elemental composition of samples selected from Core 55

Subsample	55-01	55-03	55-06	55-08	55-11	55-28	Average
Lab. No.	R22282	R22283	R22284	R22285	R22286	R22287	
Depth Interval (ft)	0.0-0.7	1.1-1.6	3.1-3.7	4.3-5.0	6.8-7.4	17.0-18.2	
Horizon	A	A	A	A	Bw	2C	
SiO_2 (%)	74.60	77.00	77.80	78.60	79.30	46.53	71.85
Al_2O_3 (%)	10.90	10.10	9.48	9.30	9.10	18.75	11.35
Fe_2O_3 (%)	3.54	3.16	2.97	2.91	2.85	6.34	3.65
K_2O (%)	2.29	2.21	2.19	2.17	2.13	4.74	2.69
CaO (%)	0.74	0.83	0.84	0.79	0.75	5.98	1.84
MgO (%)	0.76	0.67	0.66	0.67	0.65	4.73	1.48
Na_2O (%)	1.05	1.19	1.19	1.16	1.16	0.42	1.02
TiO_2 (%)	0.80	0.72	0.66	0.62	0.60	0.76	0.67
P_2O_5 (%)	0.15	0.11	0.14	0.12	0.12	0.14	0.13
MnO (%)	0.09	0.07	0.07	0.07	0.07	0.08	0.07
Barium	659	557	503	524	477	548	522
Chromium	26	61	20	111	106	--	75
Copper	25	22	23	22	19	--	22
Mercury (µg/kg)	23	16	16	12	11	14	14
Nickel	14	15	11	14	12	--	13
Lead	20	15	15	14	14	--	15
Rubidium	78	69	69	66	65	--	67
Strontium	115	137	126	126	127	93	122
Vanadium	74	65	59	59	61	--	61
Zinc	75	63	60	56	57	--	59
Zirconium	287	342	339	330	302	106	284
Total C (%)	1.48	0.98	1.07	0.85	0.61	2.34	1.17
Inorganic C (%)	0.05	0.04	0.03	0.04	0.03	1.57	0.34
Organic C (%)	1.43	0.94	1.04	0.81	0.58	0.77	0.83
pH	5.56	6.15	6.35	6.43	6.56	7.66	6.63

Table 33. Elemental composition of samples selected from Core 56

Subsample	56-01	56-02	56-03	56-05	56-07	56-11	Average
Lab. No.	R22288	R22289	R22290	R22291	R22292	R22293	
Depth Interval (ft)	0.0-0.8	0.8-1.5	1.5-2.0	2.0-3.4	3.9-4.9	8.4-8.8	
Horizon	A	A	AB	Bt	Bt	C	
SiO_2 (%)	72.00	71.80	70.90	67.60	71.10	72.60	71.00
Al_2O_3 (%)	10.00	10.50	12.00	14.10	12.40	11.50	11.75
Fe_2O_3 (%)	3.64	3.74	4.28	6.37	5.87	3.31	4.54
K_2O (%)	2.00	1.96	1.88	1.92	2.14	2.30	2.03
CaO (%)	1.06	1.07	0.91	0.86	0.89	2.03	1.14
MgO (%)	0.70	0.75	0.92	1.24	1.08	1.49	1.03
Na_2O (%)	0.99	0.92	0.98	1.08	1.22	1.74	1.16
TiO_2 (%)	0.71	0.72	0.76	0.75	0.78	0.75	0.75
P_2O_5 (%)	0.16	0.12	0.12	0.17	0.22	0.23	0.17
MnO (%)	0.09	0.07	0.19	0.78	0.36	0.05	0.26
Barium	590	573	684	1315	1079	662	817
Chromium	106	54	63	100	56	63	74
Copper	30	25	21	24	22	24	24
Mercury (µg/kg)	24	17	21	47	35	31	29
Nickel	16	14	16	28	15	11	17
Lead	27	15	15	15	14	15	17
Rubidium	77	81	60	47	47	57	62
Strontium	111	102	102	96	113	173	116
Vanadium	74	73	82	96	84	71	80
Zinc	88	64	56	62	57	62	65
Zirconium	323	314	306	235	305	338	304
Total C (%)	3.20	3.01	2.03	0.64	0.35	0.50	1.62
Inorganic C (%)	0.06	0.04	0.05	0.04	0.04	0.28	0.09
Organic C (%)	3.14	2.97	1.98	0.60	0.31	0.22	1.54
pH	5.55	6.06	6.28	6.82	7.47	7.69	6.65

Table 34. Elemental composition of samples selected from Core 57

Subsample	57-01	57-02	57-03	57-05	57-11	57-16	Average
Lab. No.	R22294	R22295	R22296	R22297	R22298	R22299	
Depth Interval (ft)	0.0-0.7	0.7-1.2	1.2-2.0	2.7-3.4	6.6-7.4	10.6-11.1	
Horizon	Ap	AE	Btj	Bt	CB	2A	
SiO_2 (%)	77.50	73.61	70.20	71.30	75.90	77.40	74.32
Al_2O_3 (%)	9.50	12.26	14.10	13.70	11.00	9.70	11.71
Fe_2O_3 (%)	2.47	4.45	5.04	4.98	4.32	4.12	4.23
K_2O (%)	2.16	2.35	2.28	2.26	2.26	2.28	2.27
CaO (%)	0.59	0.42	0.48	0.53	0.95	0.95	0.65
MgO (%)	0.50	0.77	1.05	1.06	0.69	0.65	0.79
Na_2O (%)	1.18	0.87	0.86	1.05	1.34	1.25	1.09
TiO_2 (%)	0.77	0.76	0.78	0.77	0.79	0.77	0.77
P_2O_5 (%)	0.27	0.14	0.14	0.16	0.16	0.12	0.17
MnO (%)	0.12	0.11	0.09	0.10	0.09	0.11	0.10
Barium	724	465	592	596	194	194	461
Chromium	20	56	68	54	45	98	57
Copper	23	26	31	30	24	24	26
Mercury (µg/kg)	17	14	40	36	19	20	24
Nickel	8	12	19	22	14	11	14
Lead	22	19	22	21	15	14	19
Rubidium	57	82	83	73	62	62	70
Strontium	112	116	95	113	183	194	136
Vanadium	63	88	94	88	73	72	80
Zinc	57	76	89	84	50	50	68
Zirconium	378	318	268	288	421	441	352
Total C (%)	1.06	0.69	0.75	0.48	0.25	0.33	0.59
Inorganic C (%)	0.07	0.05	0.05	0.05	0.03	0.05	0.05
Organic C (%)	0.99	0.64	0.70	0.43	0.22	0.28	0.54
pH	5.36	4.78	4.96	5.49	6.06	7.16	5.64

Table 35. Elemental composition of samples selected from Core 58

Subsample	58-01	58-02	58-03	58-04	58-07	58-10	58-31	Average
Lab. No.	R22300	R22301	R22302	R22303	R22304	R22305	R22306	
Depth Interval (ft)	0.0-0.9	0.90-1.4	1.4-2.0	2.0-2.8	4.0-4.6	5.7-6.4	18.2-18.6	
Horizon	Ap	E	Bt	Bt	Btj	C	2Ab	
SiO_2 (%)	79.80	80.20	71.40	72.20	73.50	61.60	76.20	73.56
Al_2O_3 (%)	7.20	9.20	13.00	12.60	12.00	8.20	10.50	10.39
Fe_2O_3 (%)	2.56	2.87	5.97	5.88	5.36	3.38	3.50	4.22
K_2O (%)	2.08	2.19	1.99	2.01	2.16	2.01	2.26	2.10
CaO (%)	1.34	0.47	0.62	0.51	0.62	6.99	1.26	1.69
MgO (%)	0.37	0.43	0.85	0.86	0.83	4.80	0.75	1.27
Na_2O (%)	0.96	0.95	0.60	0.62	0.85	0.81	1.46	0.89
TiO_2 (%)	0.72	0.75	0.65	0.66	0.65	0.57	0.83	0.69
P_2O_5 (%)	0.16	0.07	0.13	0.13	0.13	0.12	0.15	0.13
MnO (%)	0.16	0.06	0.03	0.03	0.10	0.06	0.03	0.07
Barium	376	320	200	138	171	197	276	240
Chromium	13	47	90	87	75	38	28	54
Copper	18	20	32	34	33	23	26	27
Mercury (µg/kg)	11	25	37	39	39	15	21	27
Nickel	7	5	48	18	26	11	14	18
Lead	18	19	22	23	21	18	15	19
Rubidium	58	76	98	92	75	51	60	73
Strontium	130	139	116	116	128	128	202	137
Vanadium	61	67	114	96	83	59	76	79
Zinc	44	53	96	98	85	61	51	70
Zirconium	449	406	316	328	331	325	446	372
Total C (%)	1.34	0.40	0.42	0.39	0.36	2.59	0.48	0.85
Inorganic C (%)	0.18	0.03	0.06	0.04	0.06	2.39	0.04	0.40
Organic C (%)	1.16	0.37	0.36	0.35	0.30	0.20	0.44	0.45
pH	7.56	7.56	7.18	6.52	6.76	8.22	4.81	6.94

Table 36. Elemental composition of samples selected from Core 59

Subsample	59-01	59-02	59-03	59-06	59-13	59-16	Average
Lab. No.	R22307	R22308	R22309	R22310	R22311	R22312	
Depth Interval (ft)	0.0-0.3	0.3-1.0	1.0-1.5	2.8-3.4	6.8-7.1	8.3-8.7	
Horizon	Ap	Bt	Bt	Bt	3EB	4Bt	
SiO_2 (%)	73.80	71.20	72.10	73.40	77.10	80.50	74.68
Al_2O_3 (%)	11.50	13.70	12.90	11.90	10.20	8.80	11.50
Fe_2O_3 (%)	4.43	5.51	5.98	5.79	4.49	3.81	5.00
K_2O (%)	2.00	2.03	1.99	2.15	2.01	1.46	1.94
CaO (%)	0.56	0.46	0.38	0.51	0.62	0.35	0.48
MgO (%)	0.68	0.93	0.86	0.84	0.60	0.43	0.72
Na_2O (%)	0.86	0.84	0.76	0.90	0.91	0.62	0.82
TiO_2 (%)	0.74	0.74	0.67	0.69	0.79	0.71	0.72
P_2O_5 (%)	0.10	0.14	0.13	0.13	0.09	0.05	0.11
MnO (%)	0.07	0.06	0.11	0.12	0.11	0.12	0.10
Barium	408	471	204	270	163	151	278
Chromium	62	59	66	62	110	41	67
Copper	29	30	30	29	26	23	28
Mercury (µg/kg)	25	30	26	34	28	35	30
Nickel	14	18	18	19	20	23	19
Lead	20	21	21	19	16	15	19
Rubidium	79	82	77	71	68	60	73
Strontium	153	143	161	173	174	119	154
Vanadium	87	101	103	96	80	74	90
Zinc	69	85	81	79	56	52	70
Zirconium	419	358	355	367	402	378	380
Total C (%)	1.16	0.40	0.24	0.20	0.21	0.23	0.41
Inorganic C (%)	0.08	0.07	0.04	0.04	0.03	0.04	0.05
Organic C (%)	1.08	0.33	0.20	0.16	0.18	0.19	0.36
pH	6.41	5.59	5.16	5.47	6.04	6.12	5.80

Table 37. Elemental composition of samples selected from Core 60

Subsample	60-01	60-02	60-03	60-06	60-21	60-40	Average
Lab. No.	R22313	R22314	R22315	R22316	R22317	R22318	
Depth Interval (ft)	0.0-0.4	0.4-1.2	1.2-1.5	2.1-2.8	11.1-11.6	23.5-24.0	
Horizon	Ap	Ap2	E	Bt2	Btt	C	
SiO_2 (%)	77.60	82.30	82.80	69.00	76.60	74.50	77.13
Al_2O_3 (%)	8.20	7.20	7.36	14.40	11.00	8.90	9.51
Fe_2O_3 (%)	2.41	2.44	2.72	6.68	5.30	4.70	4.04
K_2O (%)	1.82	1.85	1.90	1.68	1.08	1.37	1.62
CaO (%)	0.77	0.40	0.34	0.44	0.21	2.64	0.80
MgO (%)	0.32	0.24	0.23	0.97	0.44	1.12	0.55
Na_2O (%)	1.09	0.94	1.00	0.69	0.34	0.49	0.76
TiO_2 (%)	0.72	0.69	0.72	0.63	0.69	0.52	0.66
P_2O_5 (%)	0.13	0.11	0.08	0.10	0.04	0.07	0.09
MnO (%)	0.11	0.09	0.11	0.10	0.10	0.06	0.10
Barium	360	238	253	243	64	64	204
Chromium	10	20	18	80	153	205	81
Copper	20	20	19	32	25	25	24
Mercury (µg/kg)	18	18	11	34	16	20	20
Nickel	8	8	5	18	24	42	18
Lead	27	18	16	22	24	16	21
Rubidium	61	67	61	86	72	63	68
Strontium	144	173	160	138	64	118	133
Vanadium	63	64	69	107	84	72	77
Zinc	69	54	36	96	54	57	61
Zirconium	380	443	440	286	319	205	346
Total C (%)	2.72	1.19	0.62	0.59	0.19	0.80	1.02
Inorganic C (%)	0.05	0.03	0.04	0.03	0.03	0.70	0.15
Organic C (%)	2.67	1.16	0.58	0.56	0.16	0.10	0.87
pH	6.66	5.98	6.12	5.54	6.85	8.16	6.55

Table 38. Elemental composition of samples selected from Core 61

Subsample	61-01	61-02	61-03	61-04	61-10	61-18	Average
Lab. No.	R22329	R22330	R22331	R22332	R22333	R22334	
Depth Interval (ft)	0.0-0.6	0.6-1.3	1.3-2.0	2.0-2.7	6.1-6.8	11.6-12.2	
Horizon	Ap	Bt1	Bt1	Bt2	C	2Bt	
SiO_2 (%)	72.40	71.40	72.10	72.30	75.30	75.40	73.15
Al_2O_3 (%)	7.90	13.00	12.70	12.20	10.20	11.30	11.22
Fe_2O_3 (%)	3.54	5.88	6.11	6.40	5.54	5.83	5.55
K_2O (%)	1.93	2.00	2.07	2.11	2.17	1.33	1.94
CaO (%)	3.70	0.69	0.49	0.47	1.14	0.37	1.14
MgO (%)	0.97	1.00	0.97	0.89	0.70	0.52	0.84
Na_2O (%)	0.83	0.62	0.63	0.68	1.24	0.40	0.73
TiO_2 (%)	0.68	0.69	0.71	0.71	0.78	0.68	0.71
P_2O_5 (%)	0.11	0.12	0.10	0.10	0.16	0.04	0.11
MnO (%)	0.16	0.06	0.05	0.22	0.18	0.15	0.14
Barium	476	288	214	250	333	162	287
Chromium	28	76	83	114	44	101	74
Copper	22	33	36	28	24	22	28
Mercury (µg/kg)	25	30	18	26	27	33	27
Nickel	11	18	21	19	11	19	17
Lead	18	21	24	17	14	19	19
Rubidium	56	92	89	65	58	68	71
Strontium	132	107	128	119	202	108	133
Vanadium	68	108	102	94	78	83	89
Zinc	54	97	101	76	52	52	72
Zirconium	375	309	332	326	432	346	353
Total C (%)	2.12	0.43	0.26	0.28	0.16	0.16	0.57
Inorganic C (%)	0.64	0.07	0.04	0.03	0.04	0.03	0.14
Organic C (%)	1.48	0.36	0.22	0.25	0.12	0.13	0.43
pH	7.60	7.38	7.01	6.48	7.43	7.18	7.18

Table 39. Elemental composition of samples selected from Core 62

Subsample	62-01	62-02	62-03	62-05	62-07	62-17	62-18	Average
Lab. No.	R22335	R22336	R22337	R22338	R22339	R22340	R22341	
Depth Interval (ft)	0.0-0.8	0.8-1.4	1.4-2.0	2.75-3.5	4.25-5.0	10.5-11.0	11.0-11.5	
Horizon	Ap	AB	AB	BA	Bw	Bβ	C	
SiO_2 (%)	91.20	91.60	91.60	92.20	91.60	91.60	93.60	91.63
Al_2O_3 (%)	3.60	3.50	3.40	3.06	3.60	3.70	2.80	3.48
Fe_2O_3 (%)	1.22	1.23	1.25	1.21	1.28	1.30	0.71	1.25
K_2O (%)	1.31	1.32	1.30	1.34	1.27	1.15	1.17	1.28
CaO (%)	0.26	0.25	0.23	0.24	0.20	0.22	0.22	0.23
MgO (%)	0.07	0.07	0.07	0.06	0.10	0.10	0.03	0.08
Na_2O (%)	0.58	0.55	0.52	0.53	0.51	0.46	0.50	0.53
TiO_2 (%)	0.20	0.20	0.20	0.21	0.16	0.10	0.08	0.18
P_2O_5 (%)	0.07	0.07	0.07	0.05	0.05	0.06	0.03	0.06
MnO (%)	0.07	0.07	0.07	0.04	0.03	0.03	0.02	0.05
Barium	203	185	177	238	140	108	89	175
Chromium	<5	285	<5	78	166	161	156	117
Copper	17	17	16	17	19	21	17	18
Mercury (µg/kg)	8	10	14	<7	<5	<5	<5	8
Nickel	9	23	24	17	20	129	28	37
Lead	9	9	9	9	9	8	8	9
Rubidium	36	36	36	37	39	38	34	37
Strontium	96	109	99	108	97	97	100	101
Vanadium	25	29	28	27	30	28	21	28
Zinc	36	28	31	27	29	34	27	31
Zirconium	192	174	166	184	140	86	67	157
Total C (%)	0.44	0.27	0.29	0.15	0.14	0.13	0.06	0.24
Inorganic C (%)	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03
Organic C (%)	0.41	0.24	0.26	0.12	0.12	0.10	0.04	0.21
pH	5.40	6.06	5.81	6.04	6.34	6.08	6.52	5.96

Table 40. Elemental composition of samples selected from Core 63

Subsample	63-01	63-02	63-03	63-06	63-15	Average
Lab. No.	R22342	R22343	R22344	R22345	R22346	
Depth Interval (ft)	0.0-0.8	0.8-1.4	1.4-2.0	3.5-4.1	8.9-9.4	
Horizon	Ap	Ap2	A	Ab	Bwg	
SiO_2 (%)	77.40	79.10	80.70	80.50	80.20	79.58
Al_2O_3 (%)	8.30	7.80	7.30	7.78	7.80	7.80
Fe_2O_3 (%)	3.46	3.26	3.27	3.45	3.55	3.40
K_2O (%)	2.16	2.16	2.16	2.14	2.08	2.14
CaO (%)	1.34	1.21	0.81	0.70	0.89	0.99
MgO (%)	0.92	0.80	0.53	0.46	0.62	0.67
Na_2O (%)	0.85	0.90	0.82	0.89	0.90	0.87
TiO_2 (%)	0.63	0.64	0.63	0.60	0.57	0.61
P_2O_5 (%)	0.11	0.09	0.09	0.11	0.10	0.10
MnO (%)	0.10	0.10	0.10	0.10	0.13	0.11
Barium	140	207	209	208	197	192
Chromium	55	95	42	80	28	60
Copper	26	23	23	23	22	23
Mercury (µg/kg)	12	10	10	11	7	10
Nickel	15	11	8	11	10	11
Lead	16	16	16	15	15	16
Rubidium	60	58	61	64	57	60
Strontium	136	142	154	164	153	150
Vanadium	60	56	59	61	59	59
Zinc	57	53	53	53	54	54
Zirconium	406	458	483	450	372	434
Total C (%)	1.23	0.87	0.84	0.72	0.58	0.85
Inorganic C (%)	0.29	0.21	0.14	0.02	0.12	0.16
Organic C (%)	0.94	0.66	0.70	0.70	0.46	0.69
pH	6.96	7.37	7.34	7.04	7.26	7.19

Table 41. Elemental composition of samples selected from Core 64

Subsample	64-01	64-02	64-03	64-06	64-08	64-22	Average
Lab. No.	R22347	R22348	R22349	R22350	R22351	R22352	
Depth Interval (ft)	0.0-0.8	0.8-1.5	1.5-2.0	3.1-3.7	4.0-4.8	13.3-14.0	
Horizon	Ap	A	Bt1	BC	C	3BAb	
SiO_2 (%)	75.10	74.20	73.00	74.50	62.00	75.60	72.40
Al_2O_3 (%)	9.40	9.90	10.70	10.50	7.50	10.90	9.82
Fe_2O_3 (%)	4.40	4.82	5.32	4.92	3.70	5.53	4.78
K_2O (%)	2.13	2.09	2.16	2.27	2.10	1.80	2.09
CaO (%)	0.75	0.58	0.57	1.01	7.07	0.54	1.75
MgO (%)	0.50	0.56	0.75	0.96	4.67	0.90	1.39
Na_2O (%)	0.70	0.67	0.77	0.97	0.72	0.53	0.73
TiO_2 (%)	0.67	0.66	0.72	0.69	0.52	0.61	0.65
P_2O_5 (%)	0.14	0.12	0.10	0.13	0.10	0.07	0.11
MnO (%)	0.13	0.12	0.11	0.12	0.08	0.03	0.10
Barium	224	241	338	338	173	283	266
Chromium	52	40	144	51	5	160	75
Copper	27	27	30	29	24	26	27
Mercury (µg/kg)	16	16	22	18	9	12	16
Nickel	15	15	19	18	8	28	17
Lead	22	19	21	18	19	22	20
Rubidium	68	72	73	63	54	99	72
Strontium	128	126	102	148	66	94	111
Vanadium	73	77	87	74	55	90	76
Zinc	67	71	78	68	58	85	71
Zirconium	385	388	379	412	320	252	356
Total C (%)	2.07	1.92	1.35	0.54	2.67	0.13	1.45
Inorganic C (%)	0.04	0.03	0.03	0.09	2.35	0.04	0.43
Organic C (%)	2.03	1.89	1.32	0.45	0.32	0.09	1.02
pH	6.38	5.92	5.85	6.74	7.52	7.00	6.57

Table 42. Elemental composition of samples selected from Core 65

Subsample	65-01	65-02	65-03	65-04	65-05	65-11	Average
Lab. No.	R22359	R22360	R22361	R22362	R22363	R22364	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.0-2.7	2.7-3.5	6.15-6.9	
Horizon	Ap	A2	BAt	Bt	Btj	3C	
SiO_2 (%)	74.60	72.30	70.10	71.40	73.20	59.80	70.23
Al_2O_3 (%)	10.10	11.50	12.90	12.10	11.20	9.04	11.14
Fe_2O_3 (%)	4.01	4.59	6.57	6.72	5.57	4.00	5.24
K_2O (%)	1.97	1.98	1.85	1.93	2.22	3.22	2.20
CaO (%)	0.60	0.60	0.48	0.52	0.73	7.26	1.70
MgO (%)	0.59	0.73	0.92	0.89	0.98	4.31	1.40
Na_2O (%)	0.73	0.69	0.49	0.60	0.89	0.45	0.64
TiO_2 (%)	0.78	0.79	0.69	0.67	0.74	0.48	0.69
P_2O_5 (%)	0.11	0.10	0.06	0.06	0.10	0.06	0.08
MnO (%)	0.16	0.15	0.14	0.14	0.12	0.07	0.13
Barium	393	439	194	227	447	138	306
Chromium	60	68	114	137	51	16	77
Copper	22	23	33	32	27	22	27
Mercury (µg/kg)	18	24	45	38	23	5	26
Nickel	12	14	21	35	19	<5	19
Lead	20	19	22	21	19	18	20
Rubidium	64	71	75	71	66	91	75
Strontium	111	110	108	130	135	104	116
Vanadium	78	90	107	99	87	59	87
Zinc	56	63	82	82	74	71	71
Zirconium	373	339	301	335	354	163	311
Total C (%)	1.91	1.68	0.92	0.59	0.59	2.51	1.37
Inorganic C (%)	0.03	0.02	0.03	0.04	0.04	2.23	0.40
Organic C (%)	1.88	1.66	0.89	0.55	0.55	0.28	0.97
pH	5.96	7.09	6.06	6.16	6.80	7.96	6.67

Table 43. Elemental composition of samples selected from Core 66

Subsample	66-01	66-02	66-03	66-04	66-05	66-06	Average
Lab. No.	R22365	R22366	R22367	R22368	R22369	R22370	
Depth Interval (ft)	0.0-1.0	1.0-1.7	1.7-2.2	2.2-2.9	2.9-3.6	3.6-4.4	
Horizon	Ap	AB	BA	Bg	Bg	C	
SiO_2 (%)	78.50	69.40	70.50	72.50	73.20	64.20	71.38
Al_2O_3 (%)	8.70	14.00	13.30	12.10	10.80	8.00	11.15
Fe_2O_3 (%)	3.58	6.05	6.05	5.65	5.12	4.05	5.08
K_2O (%)	2.03	1.96	2.16	2.32	2.54	2.67	2.28
CaO (%)	0.56	0.57	0.60	0.63	1.22	6.17	1.63
MgO (%)	0.61	1.07	1.13	1.11	1.45	3.83	1.53
Na_2O (%)	0.76	0.58	0.63	0.70	0.72	0.44	0.64
TiO_2 (%)	0.71	0.69	0.67	0.67	0.63	0.43	0.63
P_2O_5 (%)	0.10	0.06	0.06	0.10	0.11	0.07	0.08
MnO (%)	0.15	0.14	0.14	0.16	0.13	0.08	0.13
Barium	346	354	389	309	265	72	289
Chromium	109	69	109	119	79	25	85
Copper	27	30	30	26	27	24	27
Mercury (µg/kg)	11	35	38	27	19	8	23
Nickel	22	24	29	22	16	8	20
Lead	19	21	19	19	19	16	19
Rubidium	65	84	79	73	77	77	76
Strontium	105	94	116	128	127	113	114
Vanadium	83	100	97	88	80	62	85
Zinc	73	79	77	74	70	61	72
Zirconium	325	250	274	288	275	186	266
Total C (%)	1.14	0.75	0.52	0.43	0.57	2.32	0.96
Inorganic C (%)	0.04	0.03	0.03	0.03	0.31	1.92	0.39
Organic C (%)	1.10	0.72	0.49	0.40	0.26	0.40	0.56
pH	5.34	6.50	7.05	7.34	7.52	7.92	6.95

Table 44. Elemental composition of samples selected from Core 67

Subsample	67-01	67-02	67-03	67-05	67-07	67-09	Average
Lab. No.	R22204	R22205	R22206	R22207	R22208	R22209	
Depth Interval (ft)	0.0-0.7	0.7-1.2	1.2-1.8	2.2-2.7	3.2-4.0	4.65-5.4	
Horizon	Ap	A	A	Bt	BCt	2C	
SiO_2 (%)	72.00	76.50	74.30	68.40	74.70	60.70	71.10
Al_2O_3 (%)	8.90	8.60	10.50	14.20	10.70	7.00	9.98
Fe_2O_3 (%)	4.42	4.19	4.50	6.91	5.71	3.23	4.83
K_2O (%)	2.39	2.01	2.10	1.99	2.37	2.47	2.22
CaO (%)	2.63	0.55	0.46	0.46	0.44	8.81	2.23
MgO (%)	1.70	0.48	0.60	1.02	0.79	4.37	1.49
Na_2O (%)	0.56	0.57	0.58	0.48	0.67	0.47	0.56
TiO_2 (%)	0.51	0.70	0.75	0.69	0.60	0.34	0.60
P_2O_5 (%)	0.11	0.15	0.12	0.07	0.05	0.07	0.10
MnO (%)	0.12	0.17	0.19	0.15	0.13	0.07	0.14
Barium	65	222	286	225	240	90	188
Chromium	48	48	41	75	68	<5	48
Copper	26	23	22	31	30	20	25
Mercury (µg/kg)	17	25	22	53	25	3	24
Nickel	11	10	11	21	23	<5	14
Lead	20	30	19	22	21	15	21
Rubidium	72	70	72	82	71	69	73
Strontium	119	117	106	96	120	131	115
Vanadium	70	77	85	114	83	50	80
Zinc	67	73	59	91	68	58	69
Zirconium	239	360	328	268	305	151	275
Total C (%)	1.60	1.89	1.58	0.72	0.54	3.00	1.56
Inorganic C (%)	0.83	0.06	0.03	0.05	0.05	2.81	0.64
Organic C (%)	0.77	1.83	1.55	0.67	0.49	0.19	0.92
pH	7.78	7.31	6.84	5.67	6.44	8.22	7.04

ND=Not Determined

Table 45. Elemental composition of samples selected from Core 68

Subsample	68-01	68-02	68-03	68-04	68-06	68-09	Average
Lab. No.	R22377	R22378	R22379	R22380	R22381	R22382	
Depth Interval (ft)	0.0-0.8	0.8-1.4	1.4-2.0	2.0-2.8	3.3-3.8	5.4-6.0	
Horizon	Ap	AB	Btg	Btg	BC	C	
SiO_2 (%)	77.80	70.80	68.80	70.30	80.90	59.70	71.38
Al_2O_3 (%)	8.21	13.20	14.30	13.80	7.86	8.00	10.90
Fe_2O_3 (%)	3.83	6.00	6.73	6.35	4.12	3.73	5.13
K_2O (%)	1.94	1.83	1.86	1.96	2.34	2.99	2.15
CaO (%)	0.66	0.61	0.56	0.65	0.46	8.38	1.89
MgO (%)	0.43	0.90	1.02	1.03	0.67	4.26	1.39
Na_2O (%)	0.61	0.52	0.58	0.75	0.71	0.47	0.61
TiO_2 (%)	0.70	0.74	0.71	0.71	0.43	0.45	0.62
P_2O_5 (%)	0.16	0.08	0.07	0.06	0.06	0.06	0.08
MnO (%)	0.21	0.06	0.17	0.12	0.11	0.08	0.13
Barium	266	333	273	173	226	138	235
Chromium	31	79	109	189	11	<5	71
Copper	20	35	35	35	24	22	29
Mercury (µg/kg)	16	31	45	41	15	<5	26
Nickel	10	17	26	36	11	<5	18
Lead	20	22	24	19	19	19	21
Rubidium	65	90	73	74	64	79	74
Strontium	117	104	105	105	140	108	113
Vanadium	74	108	108	99	56	55	83
Zinc	61	86	85	81	69	66	75
Zirconium	393	307	294	271	226	167	276
Total C (%)	1.75	0.86	0.65	0.47	0.27	2.81	1.14
Inorganic C (%)	0.06	0.04	0.03	0.03	0.04	2.58	0.46
Organic C (%)	1.69	0.82	0.62	0.44	0.23	0.23	0.67
pH	6.22	6.20	5.80	6.60	7.58	8.30	6.78

Table 46. Elemental composition of samples selected from Core 69

Subsample	69-01	69-03	69-04	69-05	69-08	69-11	Average
Lab. No.	R22506	R22507	R22508	R22509	R22510	R22511	
Depth Interval (ft)	0.0-0.8	1.2-2.0	2.0-2.8	2.8-3.7	4.7-5.8	7.0-7.7	
Horizon	Ap	A	A	AB	2C1	2C2	
SiO_2 (%)	98.80	72.10	73.40	77.40	57.90	57.20	72.80
Al_2O_3 (%)	12.60	11.20	11.40	9.60	9.70	9.52	10.67
Fe_2O_3 (%)	4.74	4.20	4.30	4.27	4.53	4.17	4.37
K_2O (%)	2.92	2.60	2.51	2.29	3.62	3.58	2.92
CaO (%)	0.57	0.80	0.82	0.64	6.99	7.36	2.86
MgO (%)	0.88	0.90	0.98	0.84	4.32	4.71	2.11
Na_2O (%)	0.45	0.50	0.56	0.54	0.38	0.35	0.46
TiO_2 (%)	0.71	0.60	0.56	0.47	0.55	0.52	0.57
P_2O_5 (%)	0.19	0.10	0.08	0.08	0.07	0.06	0.10
MnO (%)	0.50	<.05	0.02	0.09	0.14	0.10	0.15
Barium	226	209	220	174	149	118	183
Chromium	81	108	128	114	15	17	77
Copper	47	45	47	34	24	27	37
Mercury (µg/kg)	33	41	39	32	12	11	28
Nickel	10	14	24	20	5	1	12
Lead	28	22	22	18	18	19	21
Rubidium	136	114	110	83	92	98	106
Strontium	92	104	110	119	90	89	101
Vanadium	88	85	86	74	70	67	78
Zinc	108	113	115	90	80	77	97
Zirconium	185	209	210	217	159	158	190
Total C (%)	2.90	2.61	1.64	0.73	2.84	3.05	2.30
Inorganic C (%)	0.05	0.03	0.03	0.02	2.32	2.58	0.84
Organic C (%)	2.85	2.58	1.61	0.71	0.52	0.47	1.46
pH	4.88	5.64	6.33	6.36	8.03	8.04	6.55

Table 47. Elemental composition of samples selected from Core 70

Subsample	70-01	70-02	70-03	70-04	70-05	70-08	Average
Lab. No.	R22512	R22513	R22514	R22515	R22516	R22517	
Depth Interval (ft)	0.0-1.2	1.2-2.0	2.0-2.8	2.8-3.5	3.5-4.2	5.7-6.4	
Horizon	Ap	A	AB	BA	Bg	B3β	
SiO_2 (%)	74.30	71.30	74.30	74.40	76.40	79.40	75.02
Al_2O_3 (%)	9.76	10.10	10.60	12.20	10.60	5.73	9.83
Fe_2O_3 (%)	3.92	4.15	4.28	4.06	3.91	3.03	3.89
K_2O (%)	2.23	2.07	2.06	2.13	2.11	1.89	2.08
CaO (%)	0.55	0.92	0.77	0.74	0.72	2.24	0.99
MgO (%)	0.63	0.76	0.79	0.97	0.86	1.73	0.96
Na_2O (%)	0.63	0.51	0.55	0.78	0.72	0.74	0.66
TiO_2 (%)	0.67	0.55	0.53	0.59	0.56	0.34	0.54
P_2O_5 (%)	0.14	0.16	0.11	0.13	0.10	0.09	0.12
MnO (%)	0.07	0.04	0.05	0.12	0.08	0.03	0.07
Barium	282	256	171	267	426	260	277
Chromium	45	66	102	101	72	4	65
Copper	29	35	32	28	27	31	30
Mercury (µg/kg)	29	31	30	38	28	18	29
Nickel	12	17	14	17	14	7	14
Lead	21	21	21	19	19	19	20
Rubidium	99	107	101	81	84	55	88
Strontium	105	113	118	96	114	104	108
Vanadium	77	82	83	80	77	46	74
Zinc	81	96	97	83	81	84	87
Zirconium	272	215	235	213	218	167	220
Total C (%)	2.46	3.79	1.79	0.81	1.13	1.06	1.84
Inorganic C (%)	0.04	0.03	0.03	0.03	0.03	0.72	0.15
Organic C (%)	2.42	3.76	1.76	0.78	1.10	0.34	1.69
pH	5.19	5.58	6.26	6.61	6.53	8.06	6.37

Table 48. Elemental composition of samples selected from Core 71

Subsample	71-01	71-02	71-03	71-04	71-05	71-10	Average
Lab. No.	R22518	R22519	R22520	R22521	R22522	R22523	
Depth Interval (ft)	0.0-0.7	0.7-1.2	1.2-1.8	1.8-2.2	2.2-2.8	5.5-6.1	
Horizon	Ap	AB	Btj	CB	C	2C	
SiO_2 (%)	67.90	71.00	71.60	59.80	53.60	54.60	63.08
Al_2O_3 (%)	9.60	11.60	12.00	7.40	6.30	11.70	9.77
Fe_2O_3 (%)	4.42	5.44	6.03	3.77	3.03	4.99	4.61
K_2O (%)	2.25	2.16	2.25	1.90	1.71	4.06	2.39
CaO (%)	3.01	0.85	0.74	8.14	12.13	7.37	5.37
MgO (%)	2.09	0.97	0.96	4.76	5.80	4.47	3.18
Na_2O (%)	0.78	0.68	0.78	0.81	0.78	0.32	0.69
TiO_2 (%)	0.63	0.69	0.68	0.50	0.44	0.58	0.59
P_2O_5 (%)	0.20	0.14	0.12	0.13	0.11	0.07	0.13
MnO (%)	0.10	0.10	0.13	0.10	0.08	0.08	0.10
Barium	330	364	295	203	175	186	259
Chromium	30	74	112	14	<5	39	46
Copper	26	28	29	23	23	24	26
Mercury (µg/kg)	36	40	43	21	16	10	28
Nickel	13	18	27	14	8	<5	14
Lead	38	22	19	16	15	18	21
Rubidium	67	77	66	47	40	124	70
Strontium	120	114	137	136	148	88	124
Vanadium	73	91	94	61	53	79	75
Zinc	90	78	78	59	57	83	74
Zirconium	320	343	358	329	286	137	296
Total C (%)	2.70	1.54	0.78	3.20	4.38	2.60	2.53
Inorganic C (%)	0.88	0.08	0.04	2.43	3.81	2.38	1.60
Organic C (%)	1.82	1.46	0.74	0.77	0.57	0.22	0.93
pH	7.48	7.40	7.64	8.16	8.26	8.11	7.84

Table 49. Elemental composition of samples selected from Core 72

Subsample	72-01	72-02	72-03	72-04	72-06	72-09	Average
Lab. No.	R22674	R22675	R22676	R22677	R22678	R22679	
Depth Interval (ft)	0.0-0.9	0.9-1.5	1.5-2.0	2.0-2.8	3.4-4.0	5.6-6.6	
Horizon	Ap	AB	Bg	Bg	Bg	2C	
SiO_2 (%)	72.10	70.20	69.60	69.70	71.30	69.20	70.35
Al_2O_3 (%)	11.30	14.20	15.10	14.40	13.50	11.20	13.28
Fe_2O_3 (%)	3.33	4.33	4.74	5.42	5.02	3.71	4.43
K_2O (%)	2.10	2.15	2.13	2.23	2.47	2.79	2.31
CaO (%)	0.80	0.70	0.72	0.73	0.72	2.71	1.06
MgO (%)	0.74	1.08	1.24	1.24	1.19	2.78	1.38
Na_2O (%)	0.95	0.88	0.90	0.99	1.00	0.66	0.90
TiO_2 (%)	0.76	0.76	0.76	0.75	0.74	0.50	0.71
P_2O_5 (%)	0.15	0.09	0.11	0.15	0.15	0.10	0.13
MnO (%)	0.10	0.08	0.06	0.09	0.11	0.08	0.09
Barium	779	751	991	992	889	497	817
Chromium	83	171	93	222	48	57	112
Copper	18	49	23	24	21	17	25
Mercury (µg/kg)	35	22	56	48	36	18	36
Nickel	10	18	19	21	16	8	15
Lead	17	16	17	16	15	12	16
Rubidium	68	73	71	64	63	64	67
Strontium	107	100	109	109	119	90	106
Vanadium	72	84	95	91	81	59	80
Zinc	64	68	77	72	62	48	65
Zirconium	287	262	273	273	284	168	258
Total C (%)	2.73	1.25	0.61	0.58	0.44	1.19	1.13
Inorganic C (%)	0.08	0.09	0.06	0.09	0.10	1.04	0.24
Organic C (%)	2.65	1.16	0.55	0.49	0.34	0.15	0.89
pH	5.29	6.18	6.66	6.92	7.53	7.98	6.76

Table 50. Elemental composition of samples selected from Core 73

Subsample	73-01	73-02	73-03	73-04	73-05	73-06	Average
Lab. No.	R22680	R22681	R22682	R22683	R22684	R22685	
Depth Interval (ft)	0.0-0.8	0.8-1.4	1.4-2.0	2.0-2.8	2.8-3.4	3.4-4.0	
Horizon	Ap	AB	Bt	Btj	Btj	C	
SiO$_2$ (%)	73.70	69.60	67.70	69.60	70.60	68.20	69.90
Al$_2$O$_3$ (%)	11.50	15.00	16.20	18.90	14.40	12.70	14.78
Fe$_2$O$_3$ (%)	3.26	4.59	5.52	5.21	4.81	4.11	4.58
K$_2$O (%)	2.01	1.98	1.96	2.10	2.16	2.13	2.06
CaO (%)	0.67	0.56	0.51	0.58	0.78	2.49	0.93
MgO (%)	0.64	0.98	1.18	1.21	1.18	2.39	1.26
Na$_2$O (%)	0.94	0.77	0.77	1.02	1.15	1.18	0.97
TiO$_2$ (%)	0.77	0.76	0.74	0.79	0.79	0.73	0.76
P$_2$O$_5$ (%)	0.18	0.10	0.07	0.08	0.14	0.14	0.12
MnO (%)	0.15	0.10	0.10	0.12	0.10	0.10	0.11
Barium	753	884	705	1015	1250	1211	970
Chromium	28	116	77	146	200	51	103
Copper	15	21	24	23	24	19	21
Mercury (µg/kg)	28	39	48	41	34	27	36
Nickel	8	16	21	23	31	15	19
Lead	16	15	16	15	15	13	15
Rubidium	52	62	60	53	52	46	54
Strontium	100	99	99	108	118	116	107
Vanadium	70	84	90	85	80	67	79
Zinc	48	59	66	58	58	52	57
Zirconium	309	280	262	287	200	312	275
Total C (%)	2.05	1.32	0.85	0.62	0.46	1.07	1.06
Inorganic C (%)	0.10	0.08	0.06	0.08	0.09	0.80	0.20
Organic C (%)	1.95	1.24	0.79	0.54	0.37	0.27	0.86
pH	6.26	6.58	6.68	6.90	7.54	7.93	6.98

Table 51. Elemental composition of samples selected from Core 74

Subsample	74-01	74-03	74-04	74-05	74-07	74-11	Average
Lab. No.	R22686	R22687	R22688	R22689	R22690	R22691	
Depth Interval (ft)	0.0-0.8	1.1-1.6	1.6-2.2	2.2-2.9	3.1-4.0	5.4-6.0	
Horizon	Ap	AB	Bg	B	Bgtj	C	
SiO_2 (%)	68.20	69.90	70.90	69.60	69.00	59.20	67.80
Al_2O_3 (%)	13.00	13.70	13.80	14.50	13.40	8.10	12.75
Fe_2O_3 (%)	3.79	4.42	4.38	5.28	4.25	2.47	4.10
K_2O (%)	2.02	2.01	2.06	2.12	2.11	2.04	2.06
CaO (%)	1.37	1.04	0.91	0.88	1.78	7.81	2.30
MgO (%)	1.01	1.14	1.15	1.24	1.81	6.10	2.08
Na_2O (%)	0.97	1.04	1.07	1.10	1.05	1.00	1.04
TiO_2 (%)	0.73	0.76	0.76	0.75	0.73	0.52	0.71
P_2O_5 (%)	0.23	0.14	0.13	0.14	0.14	0.12	0.15
MnO (%)	0.06	0.11	0.05	0.22	0.07	0.08	0.10
Barium	1216	1012	1055	1084	1100	612	1013
Chromium	35	328	140	72	113	4	115
Copper	23	21	20	17	21	15	20
Mercury (µg/kg)	28	29	33	47	32	12	30
Nickel	13	23	32	22	18	7	19
Lead	16	15	16	13	15	11	14
Rubidium	66	58	65	45	64	38	56
Strontium	113	116	118	115	117	117	116
Vanadium	71	78	80	84	75	40	71
Zinc	59	53	61	46	58	37	52
Zirconium	295	295	309	276	297	285	293
Total C (%)	3.13	1.68	1.02	0.73	1.35	3.15	1.84
Inorganic C (%)	0.08	0.04	0.00	0.07	0.42	2.90	0.59
Organic C (%)	3.05	1.69	0.94	0.66	0.93	0.25	1.25
pH	7.10	7.04	7.51	7.74	7.95	8.11	7.58

Table 52. Elemental composition of samples selected from Core 75

Subsample	75-01	75-02	75-03	75-04	75-06	75-10	Average
Lab. No.	R22692	R22693	R22694	R22695	R22696	R22697	
Depth Interval (ft)	0.0-0.7	0.7-1.3	1.3-2.0	2.0-2.6	3.2-3.7	5.2-5.8	
Horizon	Ap	AB	Btj	Bt	Btj	C	
SiO_2 (%)	77.20	69.50	67.10	68.70	72.50	61.40	69.40
Al_2O_3 (%)	12.40	15.20	17.00	15.80	13.20	9.50	13.85
Fe_2O_3 (%)	3.75	4.62	5.65	5.64	4.49	3.11	4.54
K_2O (%)	2.00	1.82	1.83	1.94	2.30	2.59	2.08
CaO (%)	0.66	0.48	0.53	0.52	0.90	7.02	1.69
MgO (%)	0.71	1.05	1.18	1.10	1.18	4.42	1.61
Na_2O (%)	0.93	0.75	0.69	0.82	0.92	0.54	0.78
TiO_2 (%)	0.83	0.78	0.71	0.70	0.67	0.37	0.68
P_2O_5 (%)	0.14	0.09	0.06	0.07	0.11	0.06	0.09
MnO (%)	0.17	0.10	0.09	0.10	0.11	0.05	0.10
Barium	792	971	890	782	574	347	726
Chromium	39	70	165	135	51	4	77
Copper	16	20	22	24	21	16	20
Mercury (µg/kg)	39	37	44	43	26	12	34
Nickel	9	13	20	22	17	6	15
Lead	16	15	16	16	15	11	15
Rubidium	49	62	62	58	51	58	57
Strontium	106	100	102	112	115	98	106
Vanadium	71	89	100	92	73	50	79
Zinc	42	59	70	65	52	46	56
Zirconium	338	281	260	289	278	133	263
Total C (%)	1.75	1.19	0.80	0.70	0.49	2.52	1.24
Inorganic C (%)	0.05	0.05	0.05	0.05	0.18	2.36	0.46
Organic C (%)	1.70	1.14	0.75	0.65	0.31	0.16	0.79
pH	6.26	5.46	5.96	6.58	7.68	8.17	6.69

Table 53. Elemental composition of samples selected from Core 76

Subsample	76-01	76-03	76-04	76-05	76-06	76-08	Average
Lab. No.	R22698	R22699	R22700	R22701	R22702	R22703	
Depth Interval (ft)	0.0-0.9	1.3-2.0	2.0-2.5	2.5-3.3	3.3-3.8	4.0-4.5	
Horizon	Ap	Bt	Bt	Btj	BC	Cβ	
SiO_2 (%)	75.50	67.30	68.90	71.40	71.30	66.90	70.22
Al_2O_3 (%)	10.60	16.00	15.20	13.80	13.60	10.30	13.25
Fe_2O_3 (%)	3.39	5.92	5.37	4.93	5.21	3.32	4.69
K_2O (%)	1.95	1.90	2.04	2.24	2.34	2.77	2.21
CaO (%)	0.43	0.66	0.73	0.77	0.76	3.92	1.21
MgO (%)	0.50	1.24	1.22	1.15	1.14	3.77	1.50
Na_2O (%)	0.78	0.88	1.00	1.13	1.08	0.67	0.92
TiO_2 (%)	0.67	0.76	0.75	0.76	0.75	0.43	0.69
P_2O_5 (%)	0.14	0.09	0.13	0.14	0.14	0.07	0.12
MnO (%)	0.09	0.07	0.13	0.19	0.31	0.11	0.15
Barium	570	922	1397	1267	1467	786	1068
Chromium	47	173	92	50	37	56	76
Copper	17	24	21	21	18	16	20
Mercury (µg/kg)	28	47	43	31	28	12	32
Nickel	9	20	21	16	18	8	15
Lead	16	17	15	13	13	12	14
Rubidium	56	63	52	45	42	54	52
Strontium	114	99	118	140	121	90	114
Vanadium	64	93	86	80	78	51	75
Zinc	50	69	58	49	48	40	52
Zirconium	323	248	272	298	280	144	260.83
Total C (%)	2.00	0.88	0.70	0.52	0.39	1.74	1.04
Inorganic C (%)	0.13	0.05	0.07	0.06	0.06	1.57	0.32
Organic C (%)	1.87	0.83	0.63	0.46	0.33	0.17	0.72
pH	4.76	6.20	6.67	7.40	7.63	8.06	6.79

Table 54. Means and ranges of elemental contents of the uppermost samples from Illinois soil cores 52 through 76 compared with results for surface soils as determined by other researchers

| Element | This Work | | Shacklette and Boerngen[2] | |
	Mean	Range	Mean	Range
Silicon (%)	34.91	31.8-42.6	NR[†]	29-45**
Aluminum (%)	5.17	1.88-6.85	NR	<0.07-8.5**
Iron (%)	2.51	0.85-3.31	2.1[1]	0.1-4.0**
Potassium (%)	1.73	1.09-2.43	1.7[1]	0.22-2.25**
Calcium (%)	0.77	0.18-2.64	0.40[1]	0.3-1.5**
Magnesium (%)	0.46	0.05-1.26	0.30[1]	0.005-1.25**
Sodium (%)	0.62	0.33-0.87	NR	0.6-1.25**
Titanium (%)	0.41	0.12-0.50	0.41	0.05-1.0
Phosphorus (%)	0.07	0.03-0.12	0.065[1]	0.013-0.68**
Manganese (%)	0.09	0.04-0.16	0.052	0.005-0.15
Barium (mg/kg)	456	65-1216	675	200-1500
Chromium (mg/kg)	49	<5-109	55	10-100
Copper (mg/kg)	24	15-47	25	7-100
Mercury (µg/kg)	24	8-48	70***	20-360***
Nickel (mg/kg)	12	7-23	17	5-30
Lead (mg/kg)	21	9-41	19	10-30
Rubidium (mg/kg)	69	36-136	75	45-100
Strontium (mg/kg)	116	92-153	305	20-1000
Vanadium (mg/kg)	71	25-90	87	20-150*
Zinc (mg/kg)	67	36-108	58.5	20-109
Zirconium (mg/kg)	327	185-449	NR	NR

[†]NR = Not reported
***Values for soils on glacial till, U.S., Shacklette and Boerngen, 1984.
**Average concentration in Illinois soils; from Shacklette and Boerngen, 1984.
*Values for loamy and clay soils, U.S.; from Shacklette and Boerngen, 1984.
[1]Values for humid region soils; from Severson and Shacklette, 1988.
[2]Values for loess and silty soils, U.S., unless noted otherwise; from Shacklette and Boerngen, 1984.

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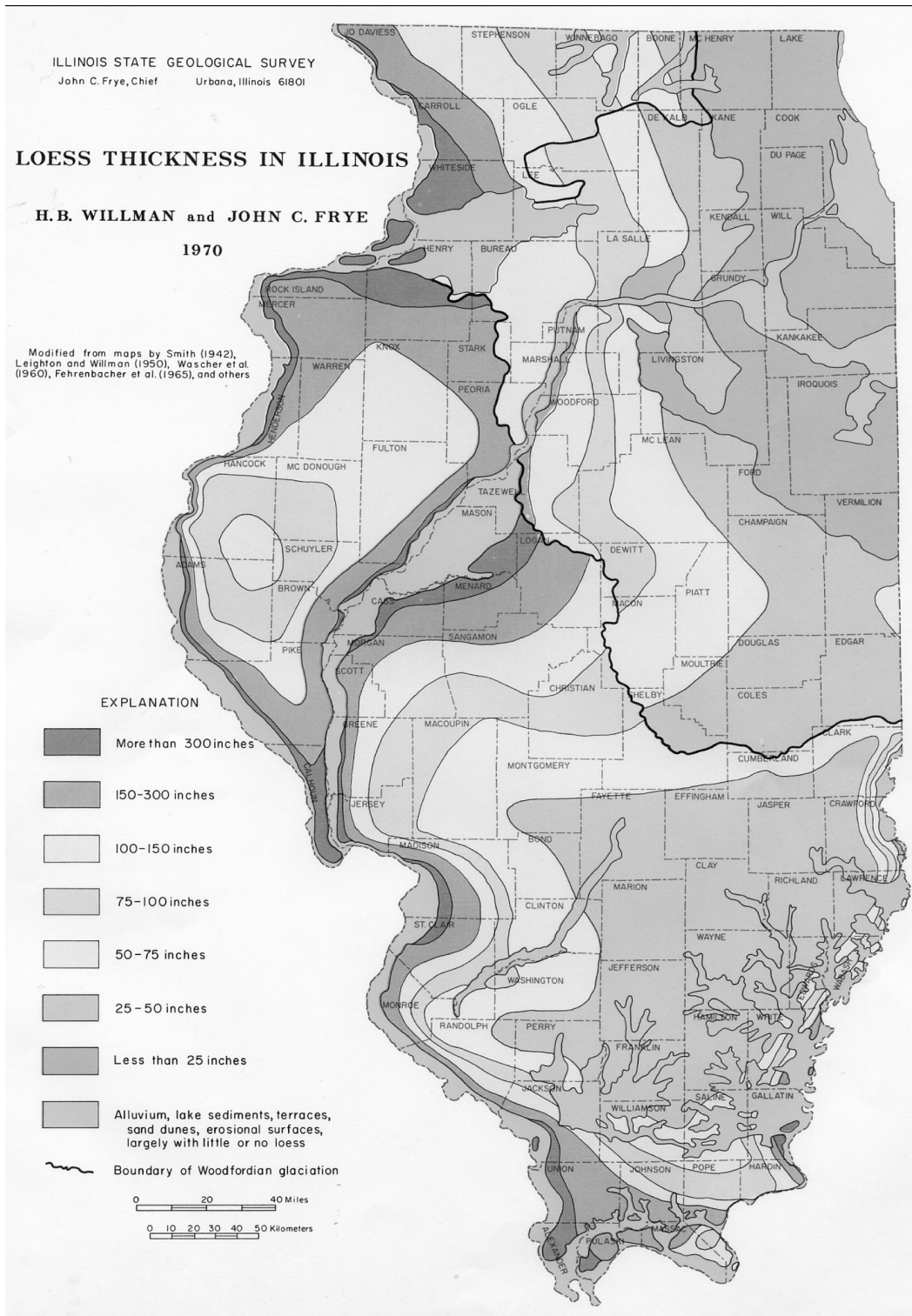
Figure 1. Loess thickness in Illinois (after Willman and Frye, 1970).

QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback
1981

0 ___ 40 mi

0 ___ 50 km

AGE	UNIT
Holocene and Wisconsinan	Cahokia Alluvium, Parkland Sand, and Henry Formation combined; alluvium, windblown sand, and sand and gravel outwash.
Wisconsinan	Peoria Loess and Roxana Silt combined; windblown silt more than 6 meters (20 ft) thick.
	Equality Formation; silt, clay, and sand in glacial and slack-water lakes.
	Moraine / Ground moraine — Wedron and Trafalgar Formations combined; glacial till with some sand, gravel, and silt.
Wisconsinan and Illinoian	Winnebago and Glasford Formations combined; glacial till with some sand, gravel, and silt; age assignment of some units is uncertain.
Illinoian	Glasford Formation; glacial till with some sand, gravel, and silt.
	Teneriffe Silt, Pearl Formation, and Hagarstown Member of the Glasford Formation combined; lake silt and clay, outwash sand, gravel, and silt.
Pre-Illinoian	Wolf Creek Formation; glacial till with gravel, sand, and silt.
	Bedrock.

Figure 2. Quaternary deposits in Illinois (after Lineback, 1981).

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Sources of Trace Elements in Soils

industrial fallout/rainfall

fertilizer

organic matter decomposition

plant uptake and release

leaching

parent material

Reactions
   precipitation⇌dissolution
   adsorption⇌desorption
   fixation⇌release (biota)
   complexation⇌release
   gaseous phase⇌soil (e.g. selenium)

variables
   pH
   Eh
   kinetics
   biological activity
      decomposition
      respiration

Figure 3 Schematic diagram of various input and output functions that affect trace elements, reactions that affect soil chemistry, and variables that affect reactions.
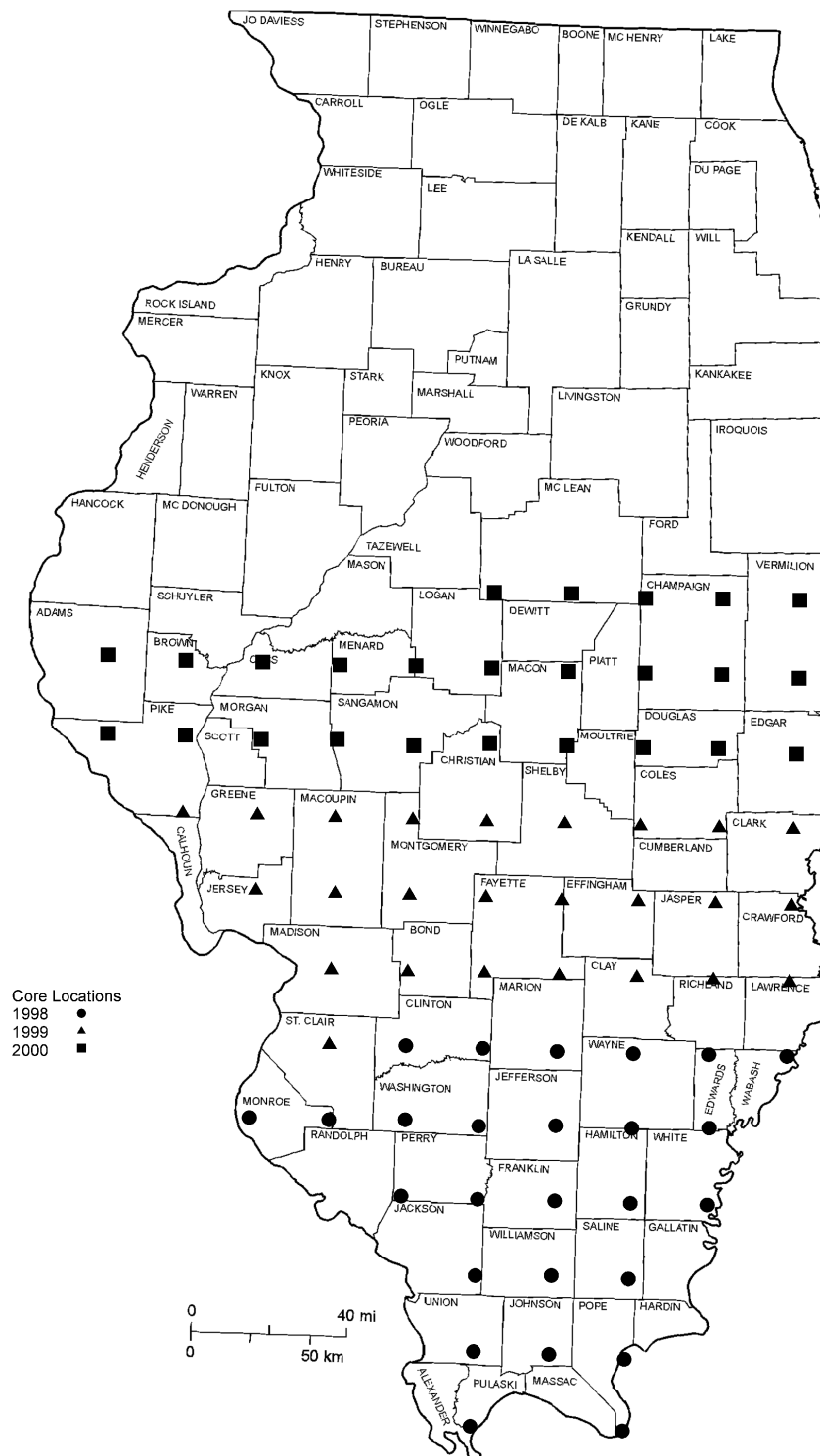
Figure 4. Locations of soil cores collected from 1998 through 2000.

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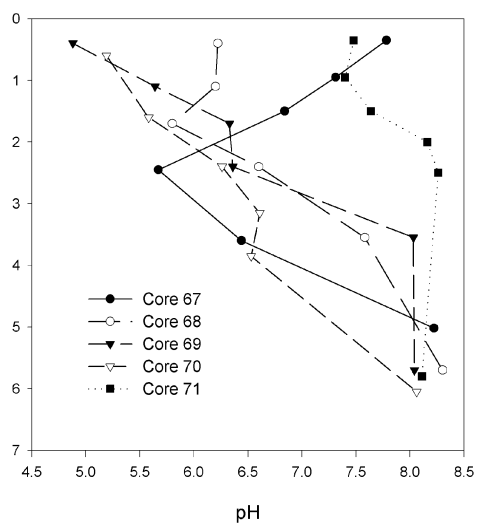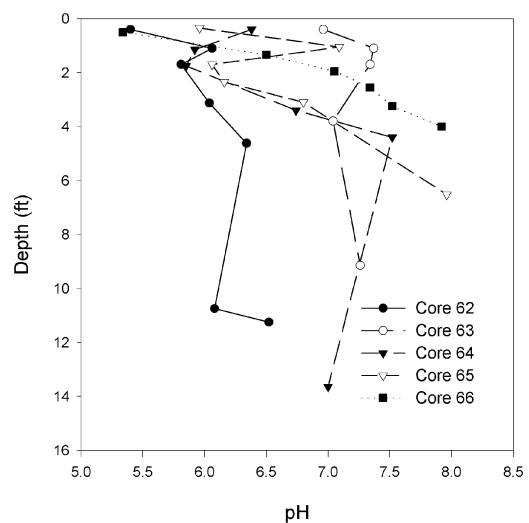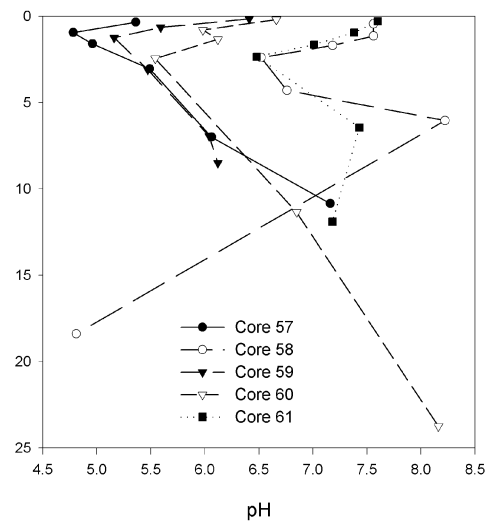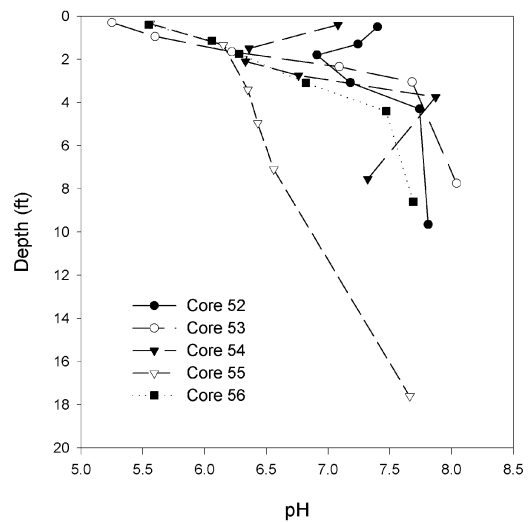
Figure 5. pH versus depth in cores 52 through 76, collected in 2000.

79
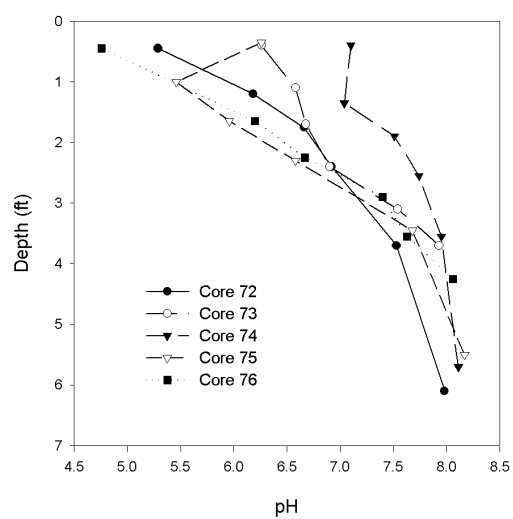
Figure 5. pH versus depth in cores 52 through 76, continued.
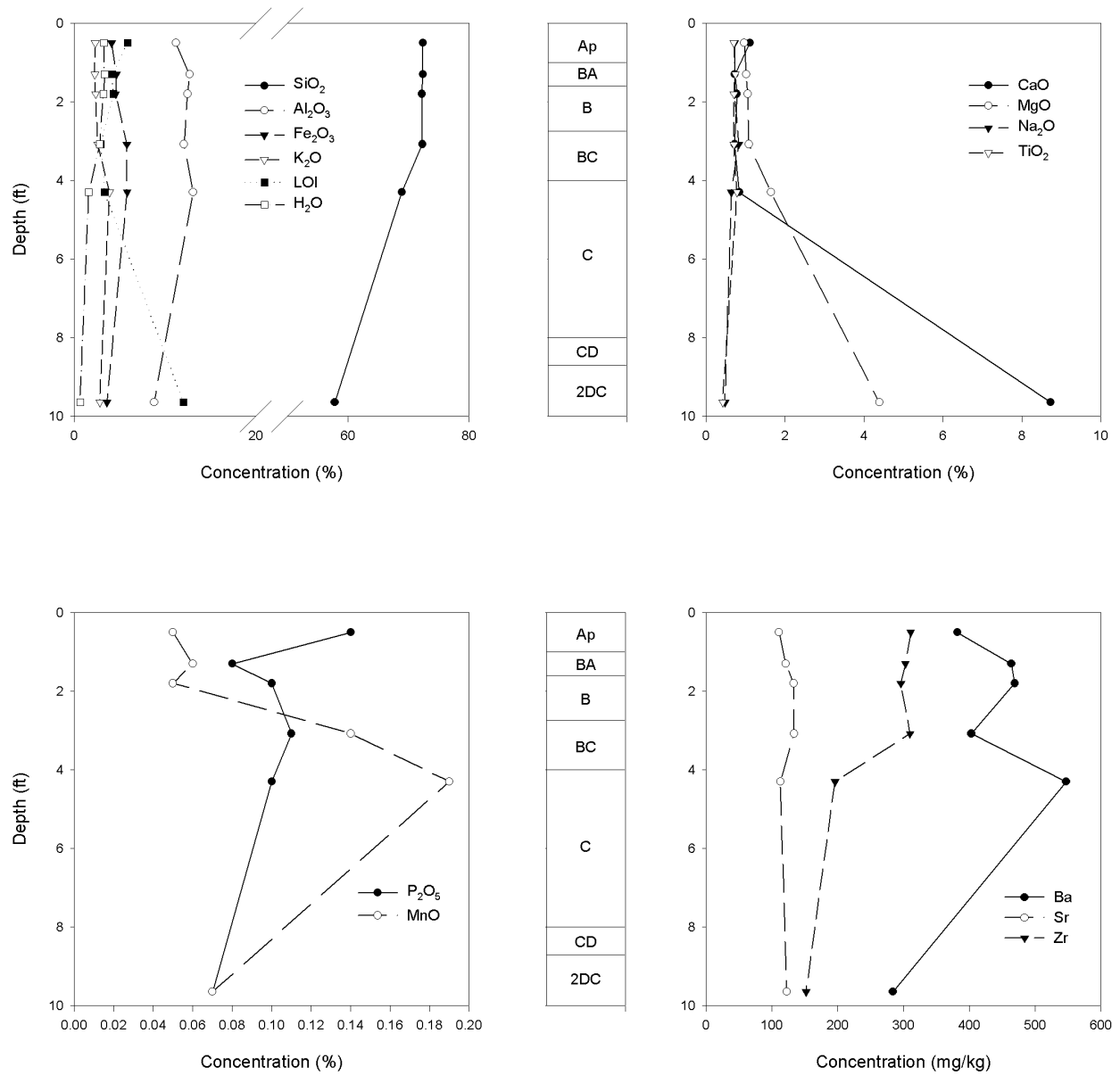
Figure 6. Element concentrations versus depth in core 52.
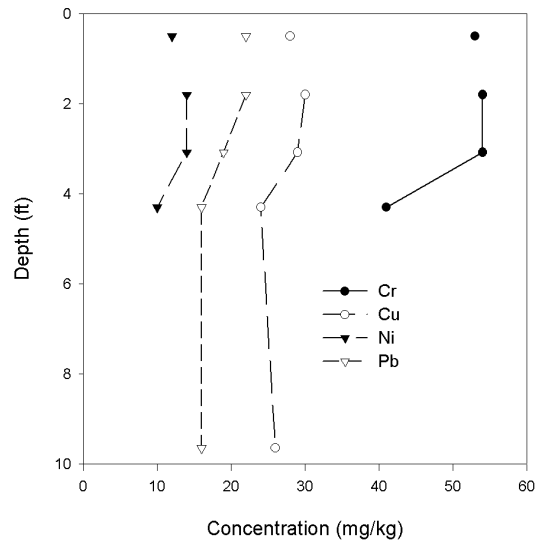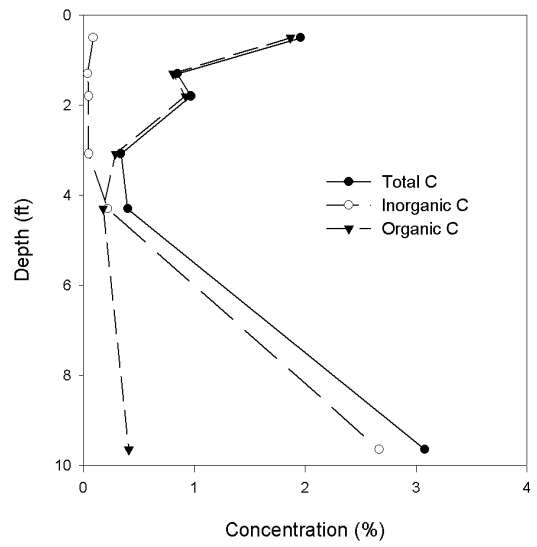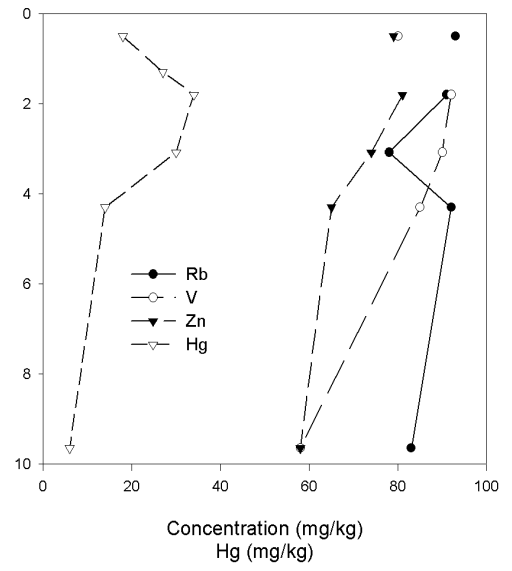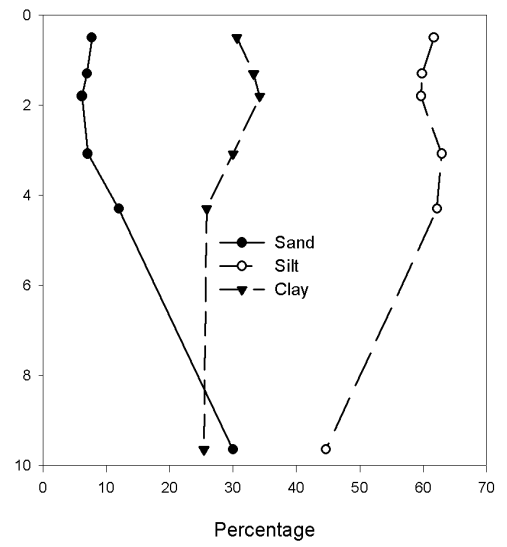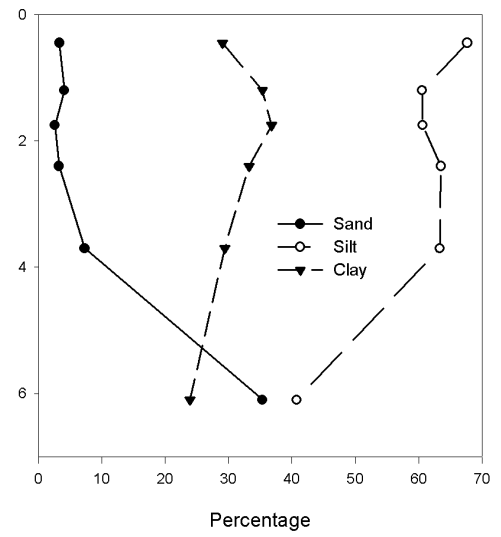
Figure 7. Element Concentrations versus depth in core 52.
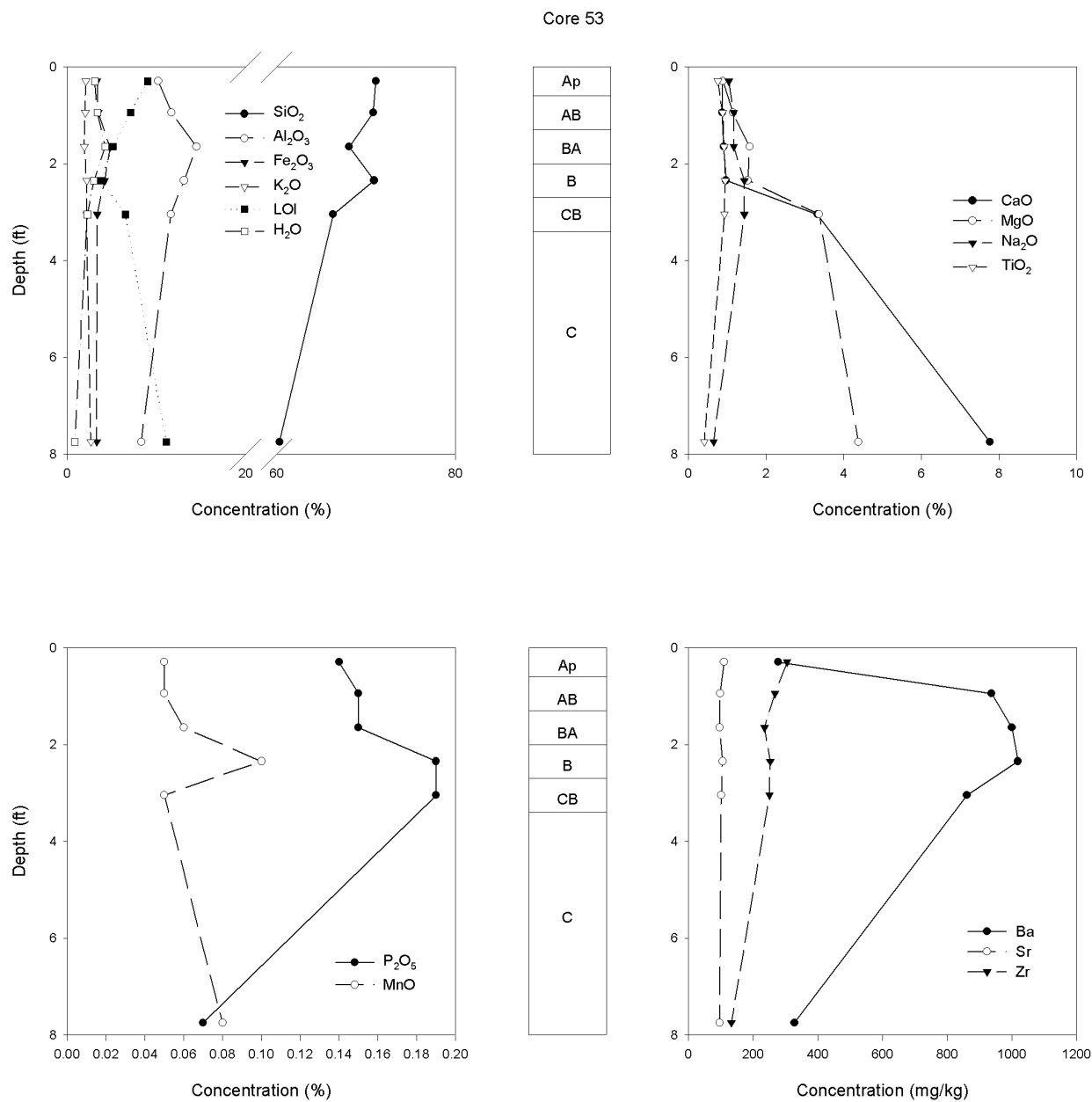
Figure 8. Element concentrations versus depth in core 53.
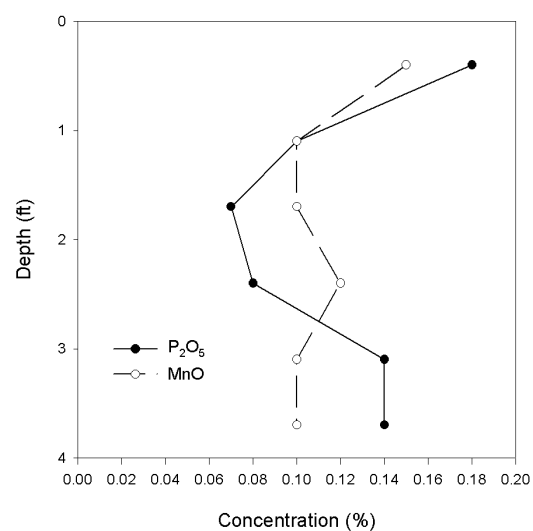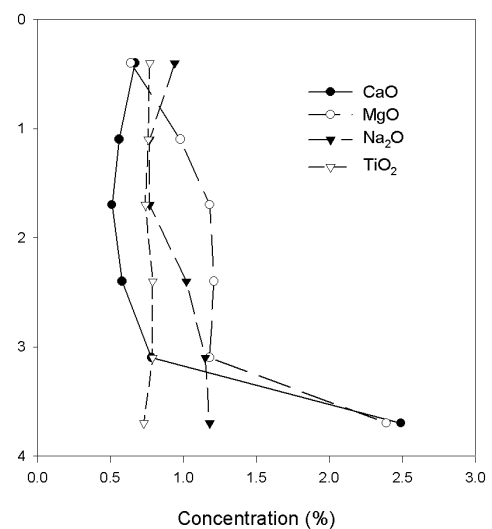
Core 53
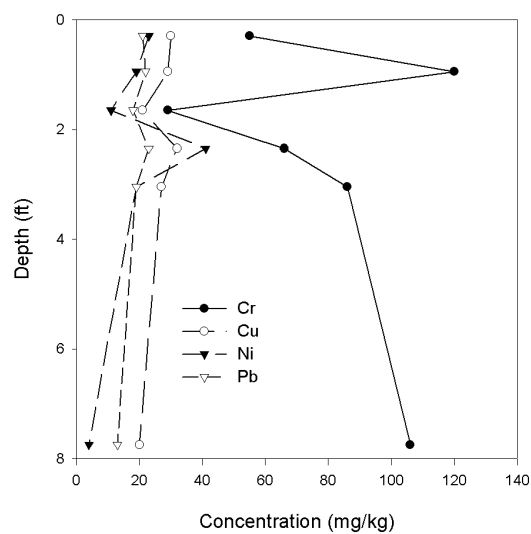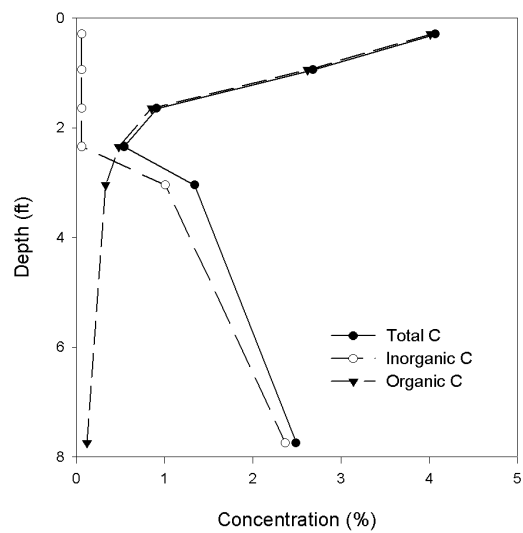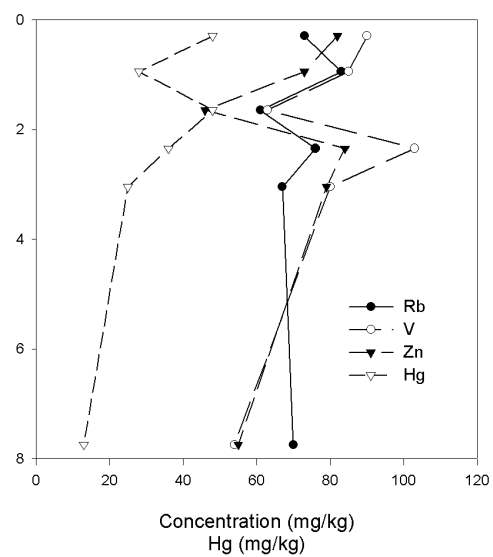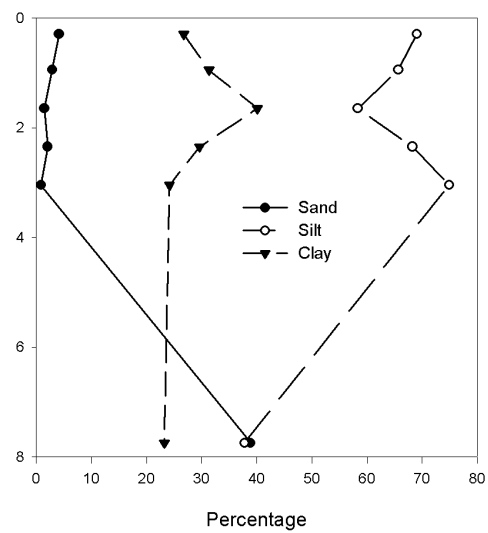
Figure 9. Element concentrations versus depth in core 53.

84
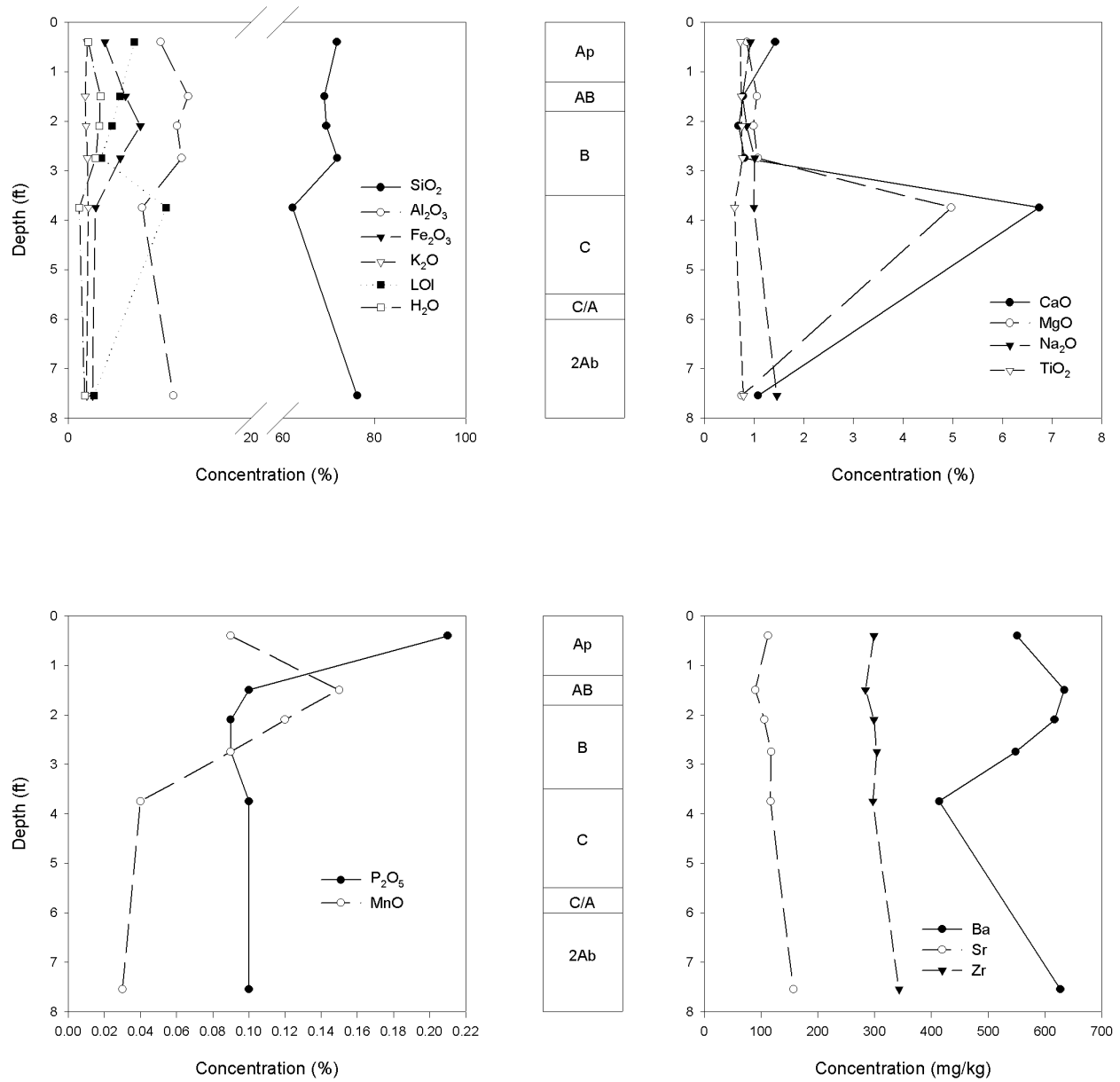
Figure 10. Element concentrations versus depth in core 54.
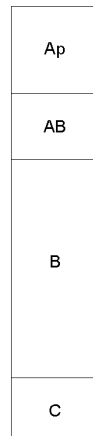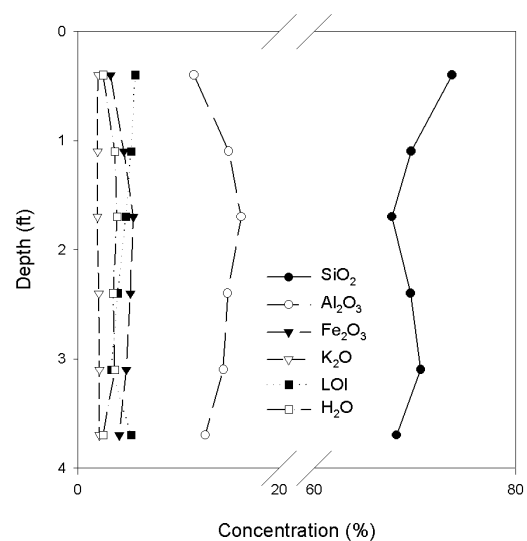
85
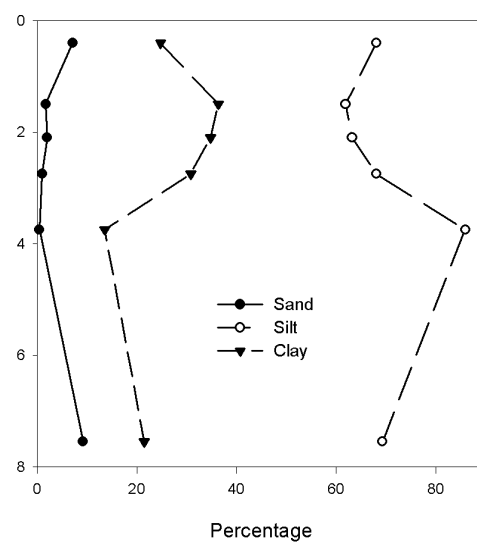
Core 54

Figure 11. Element concentrations versus depth in core 54.

Core 55
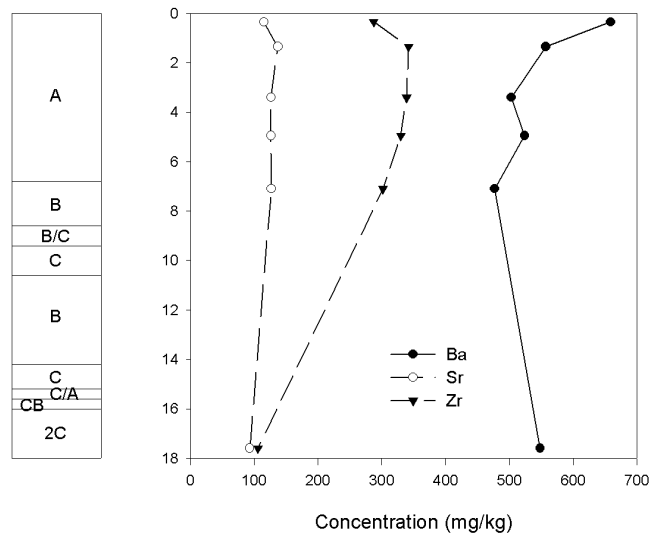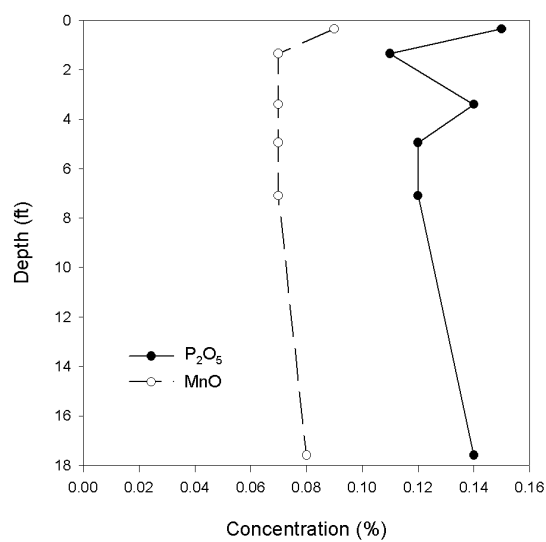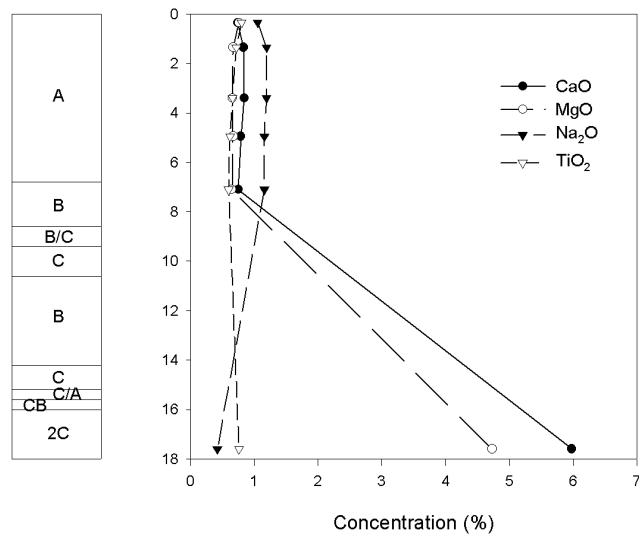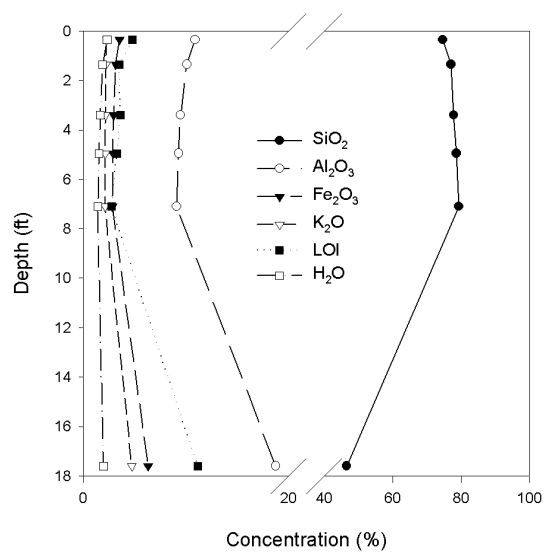
Figure 12. Element concentrations versus depth in core 55.

Core 55
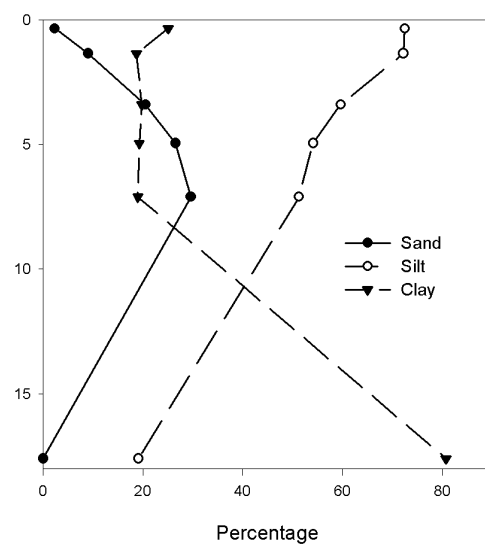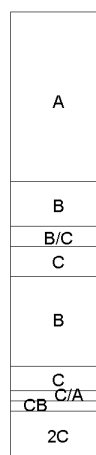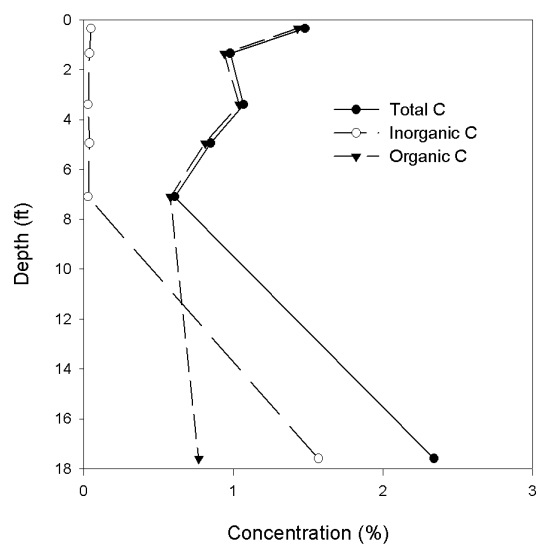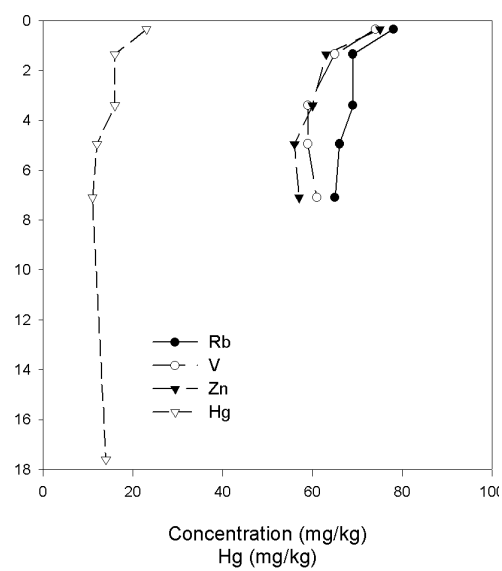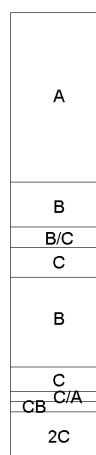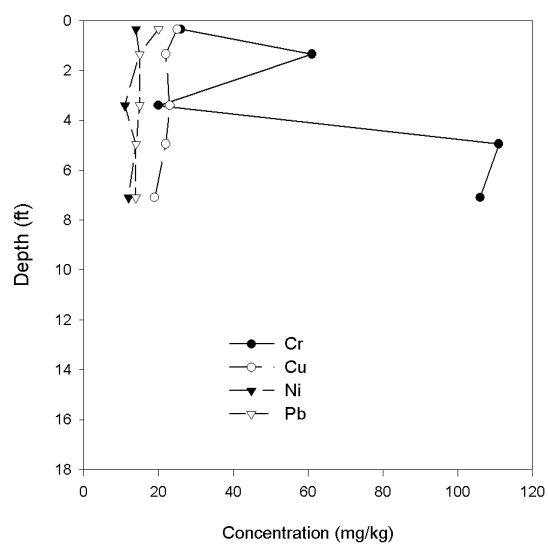
Figure 13. Element concentrations versus depth in core 55.

Core 56
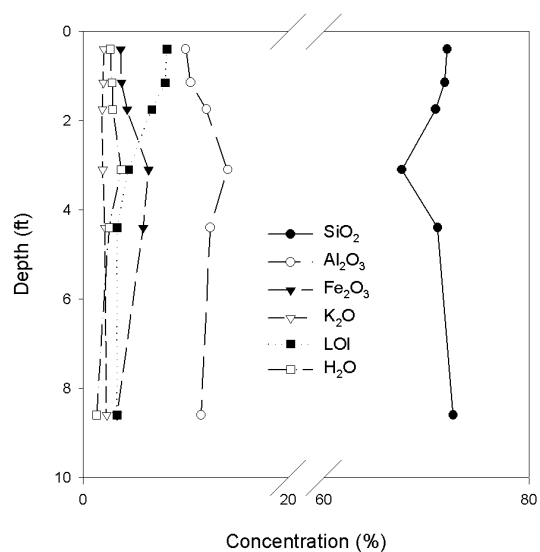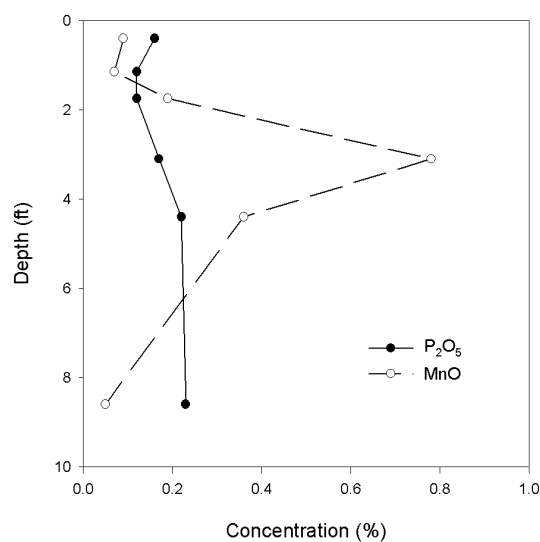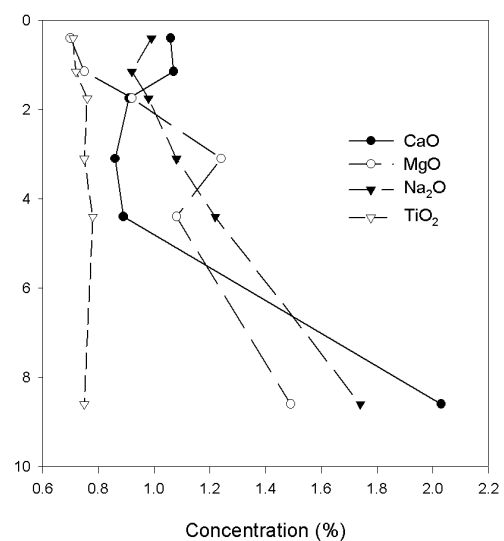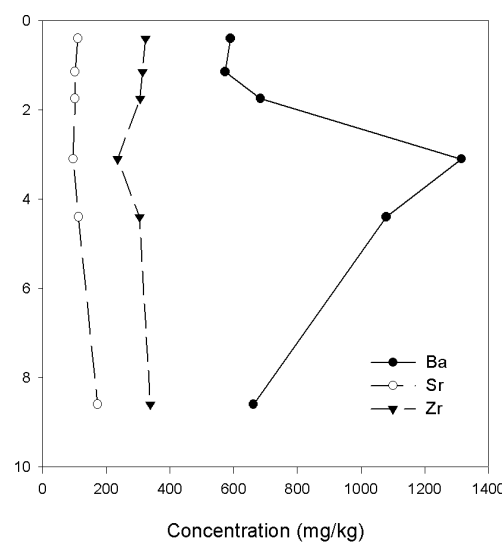
Figure 14. Element concentrations versus depth in core 56.

89
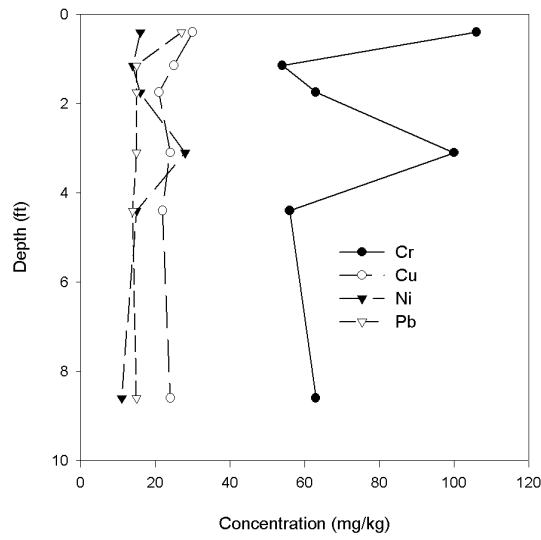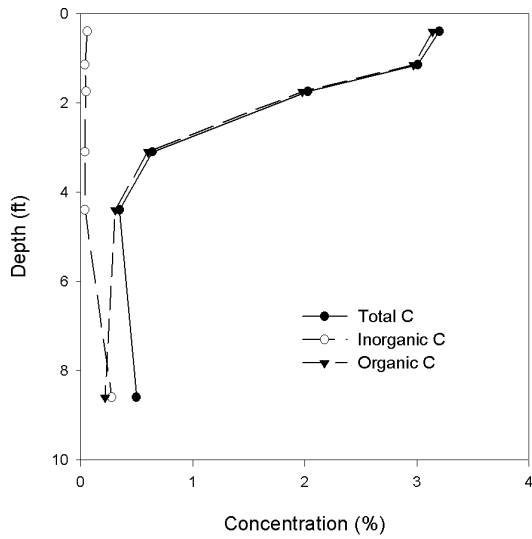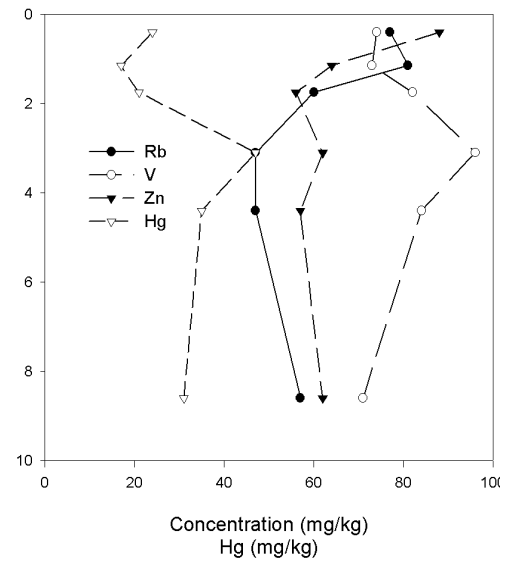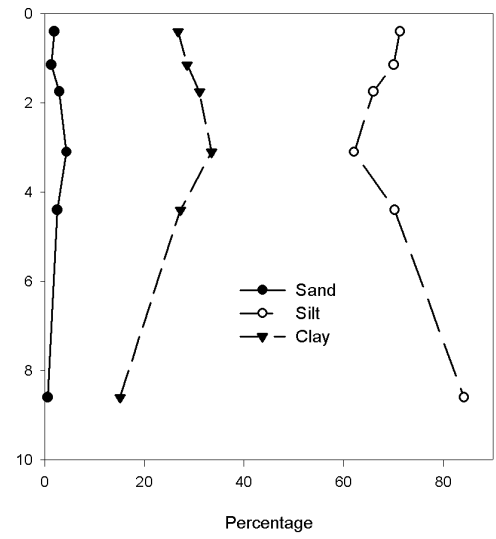
Core 56

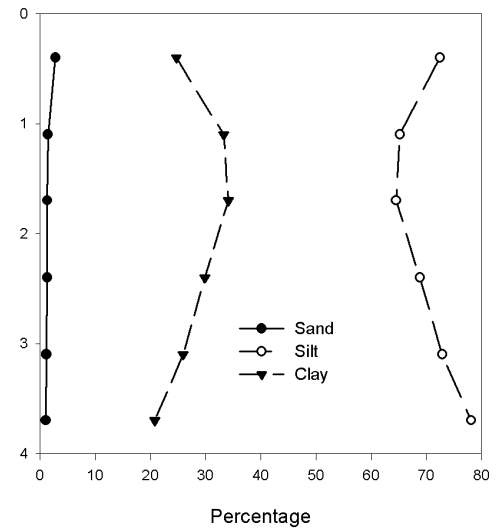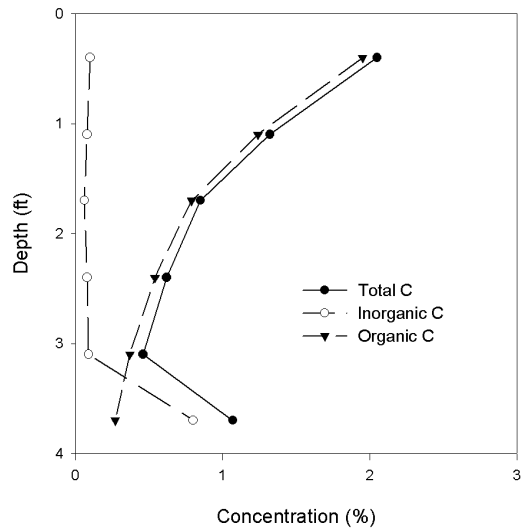**Figure 15.** Element concentrations versus depth in core 56.
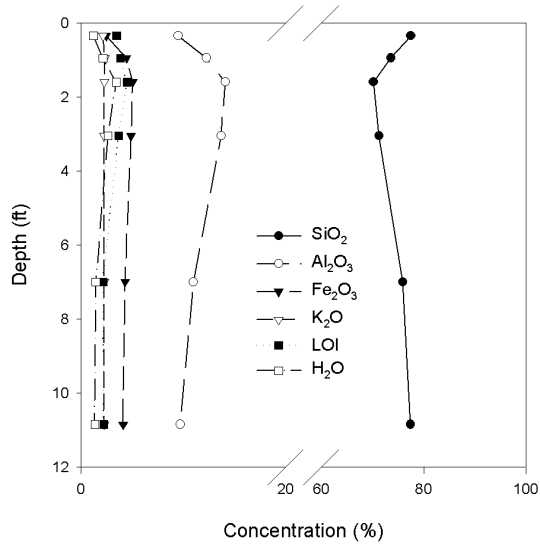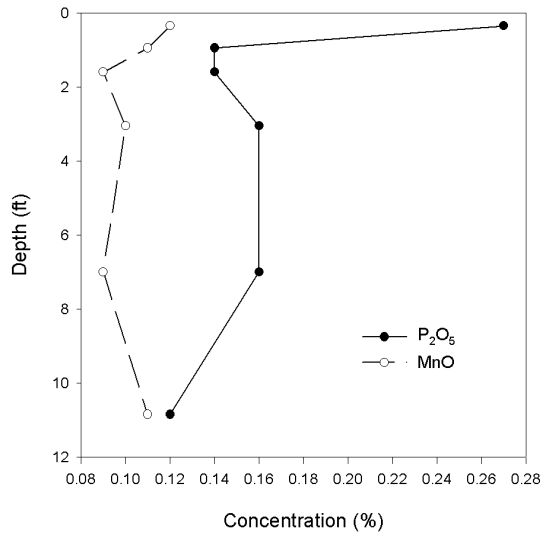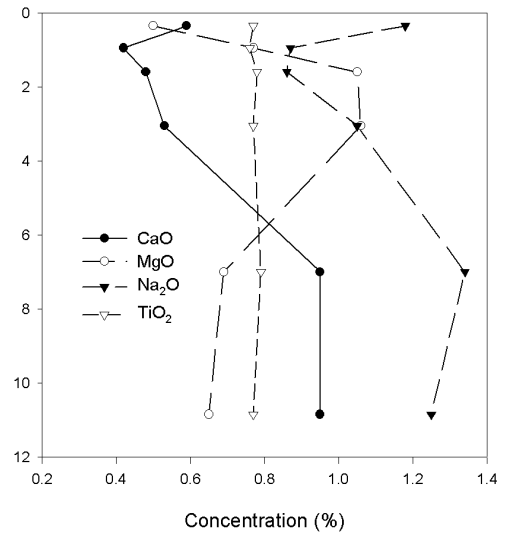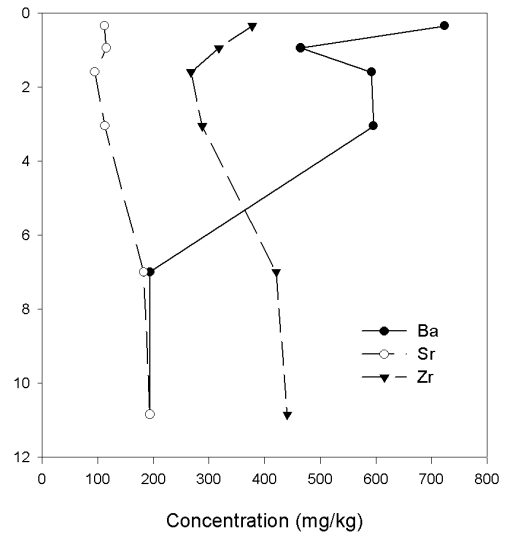
Figure 16. Element concentrations versus depth in core 57.

Core 57
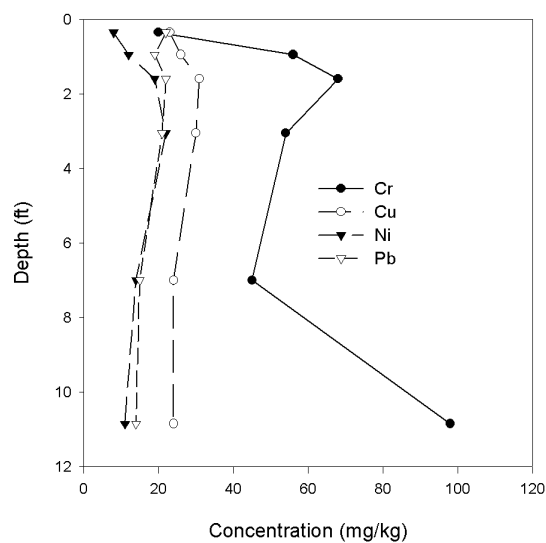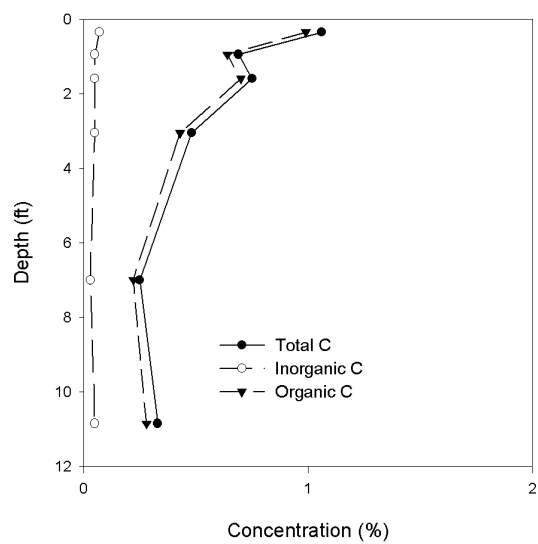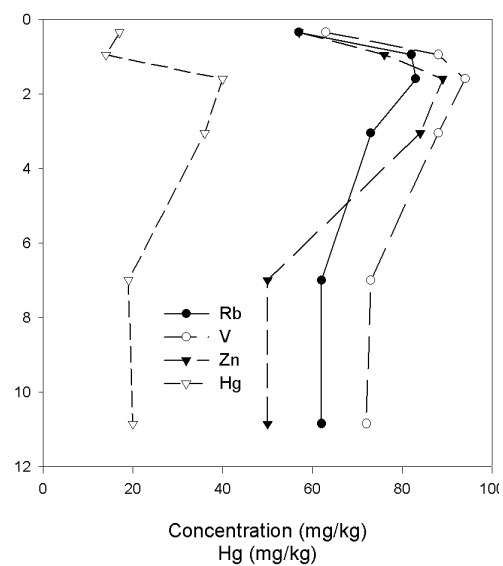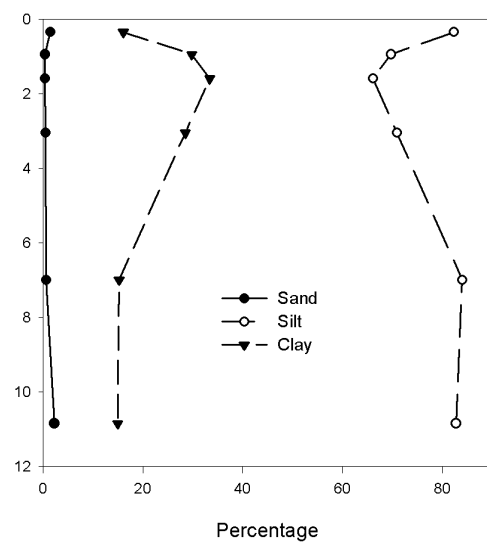
Figure 17. Element concentrations versus depth in core 57.

92
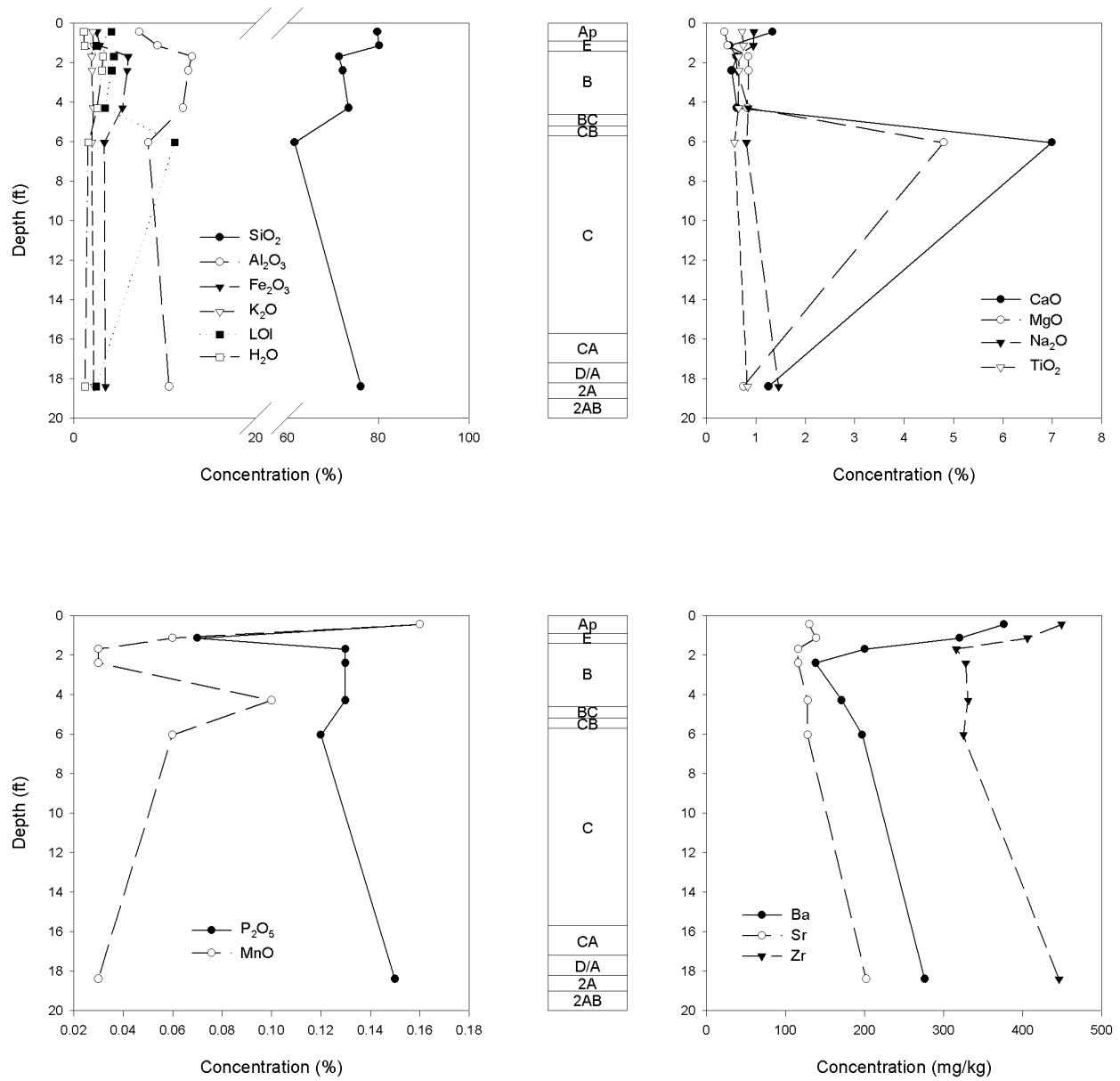
Figure 18. Element concentrations versus depth in core 58.

93
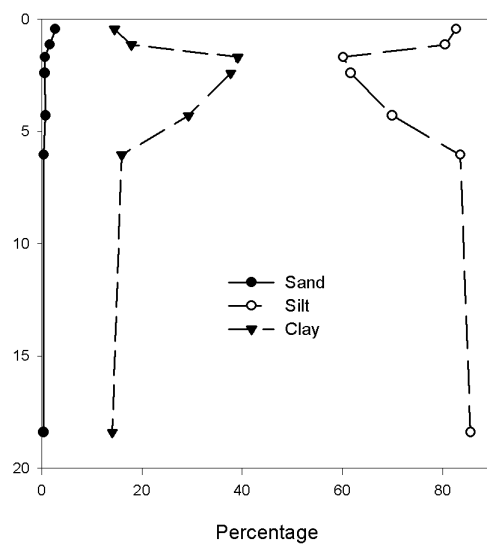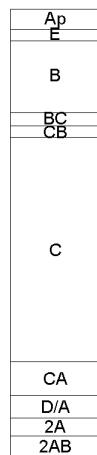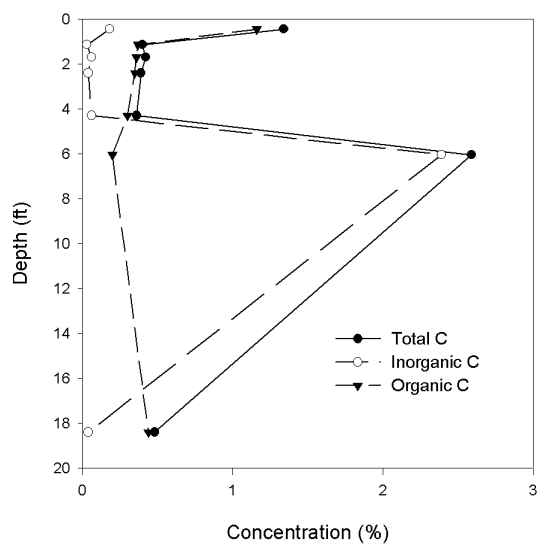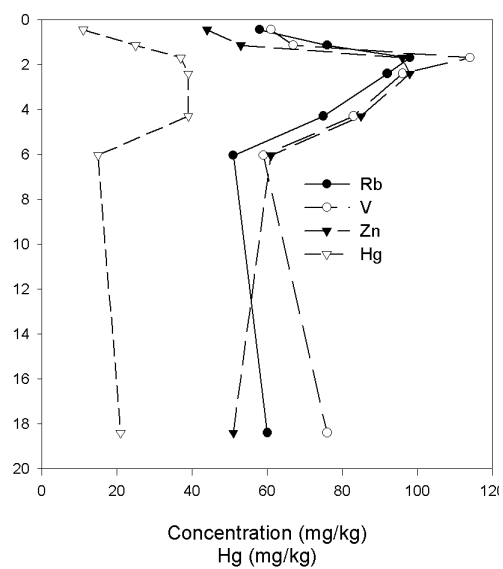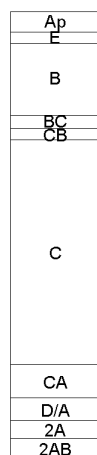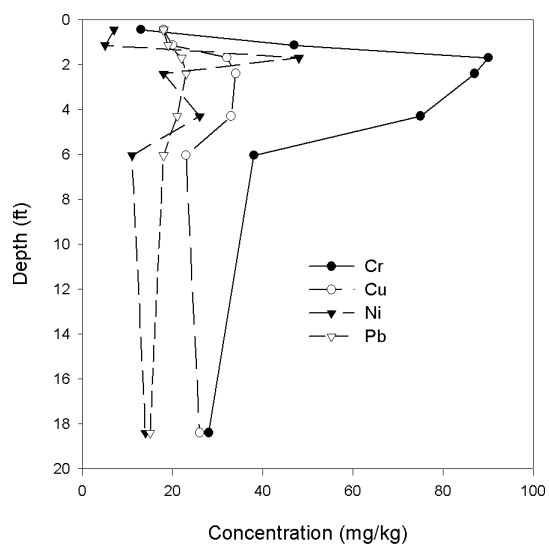
Figure 19. Element concentrations versus depth in core 58.
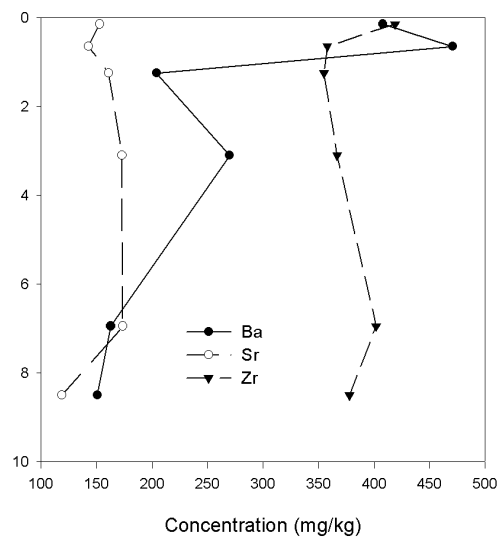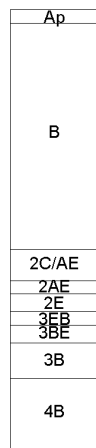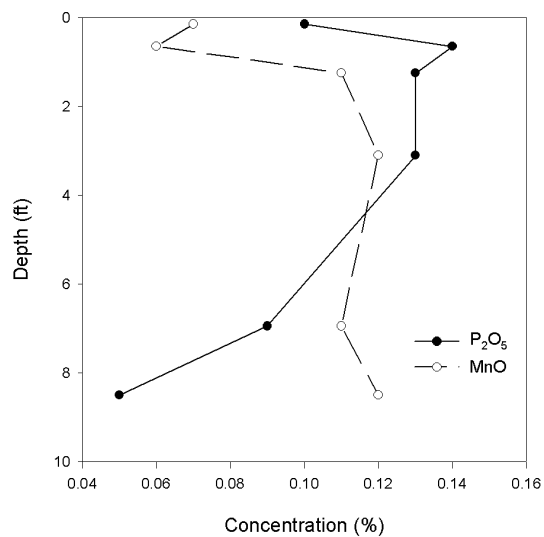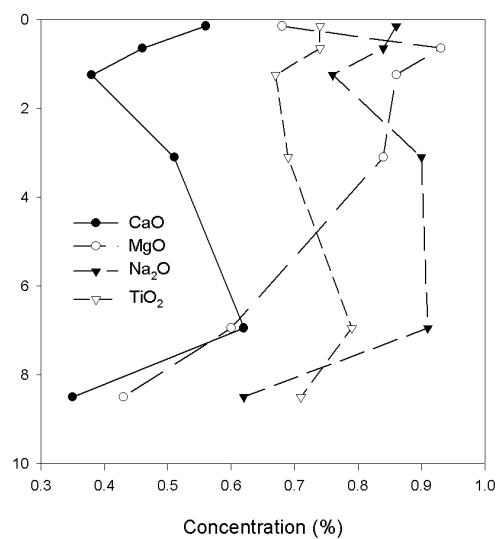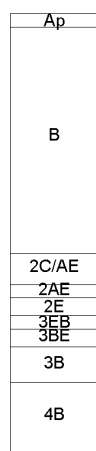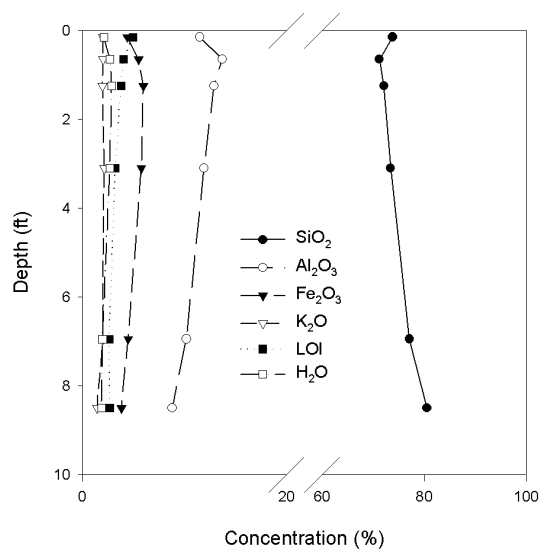
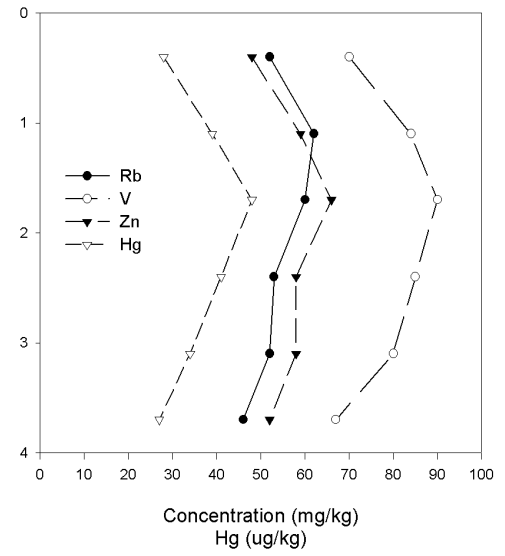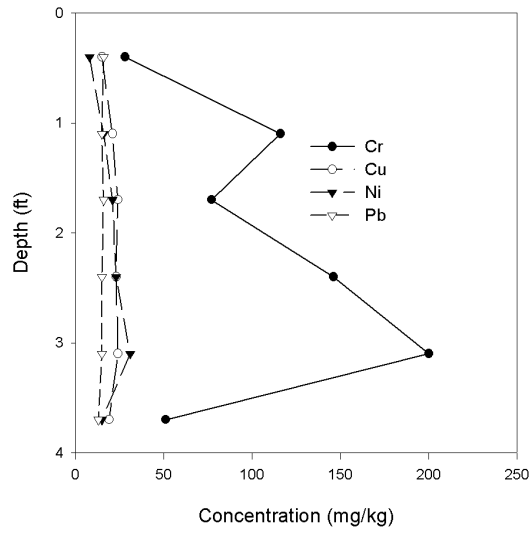**Figure 20.** Element concentrations versus depth in core 59.

95
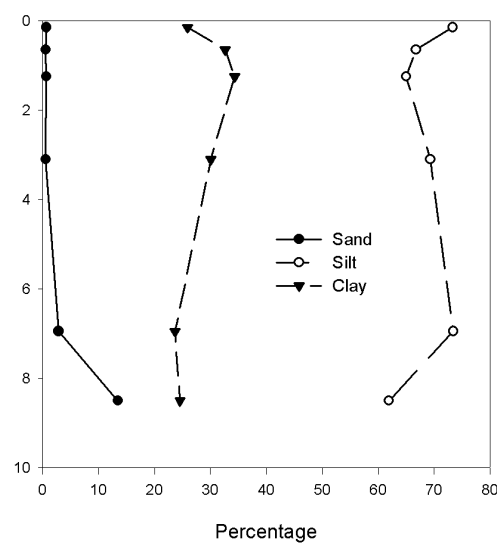
Figure 21. Element concentrations versus depth in core 59.

Core 60
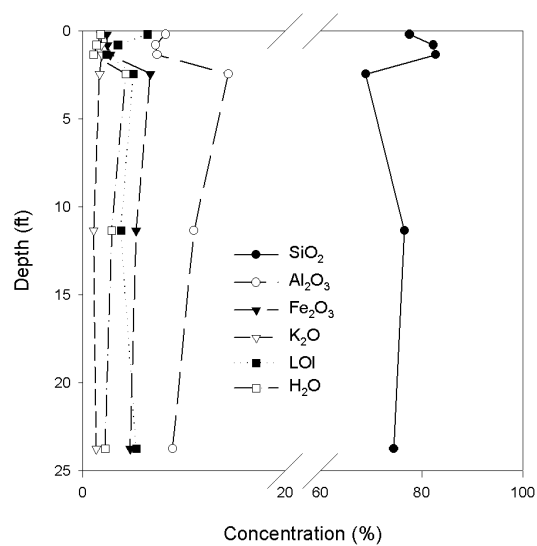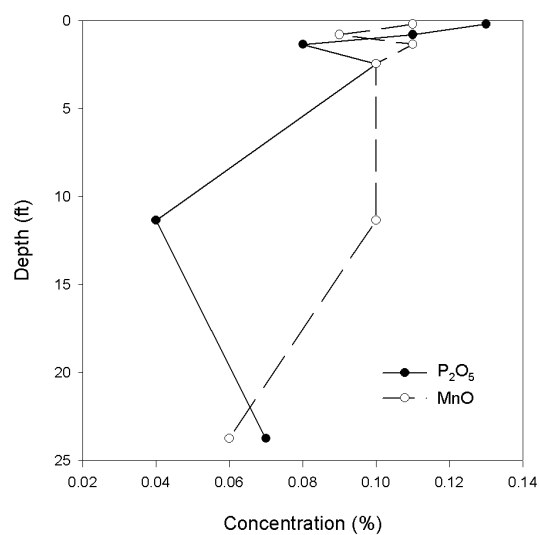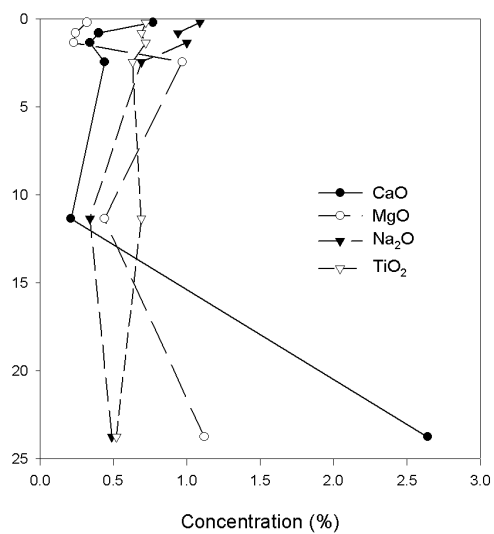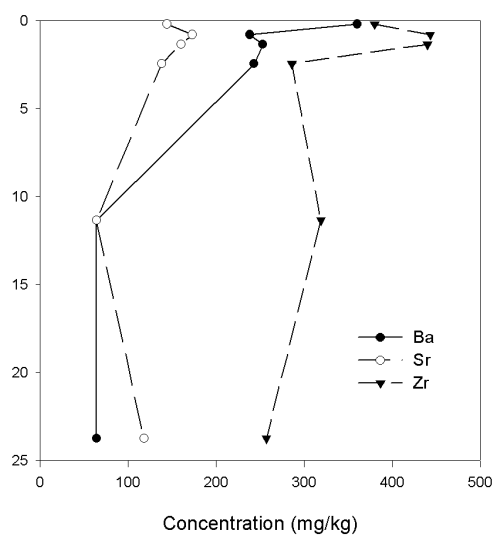
Figure 22. Element concentrations versus depth in core 60.

97
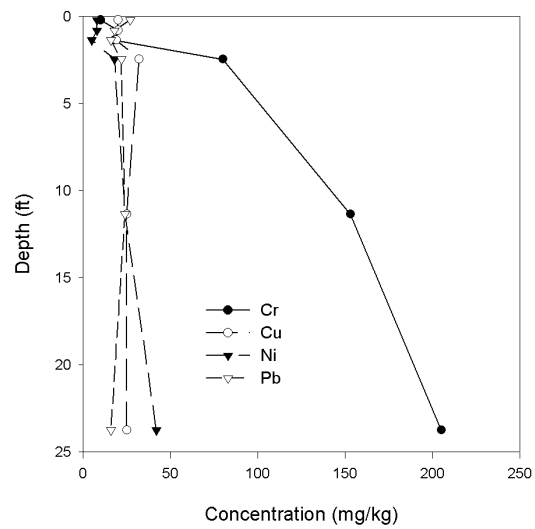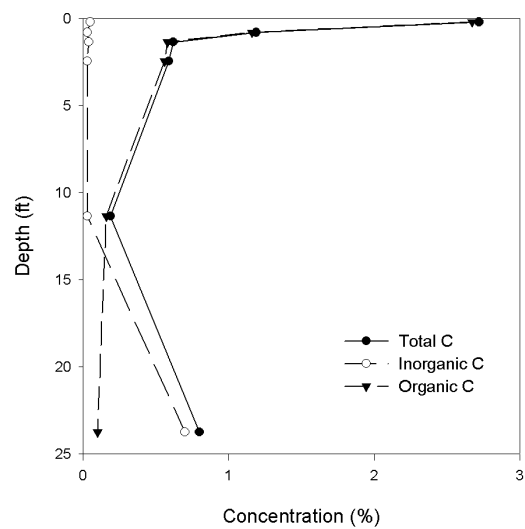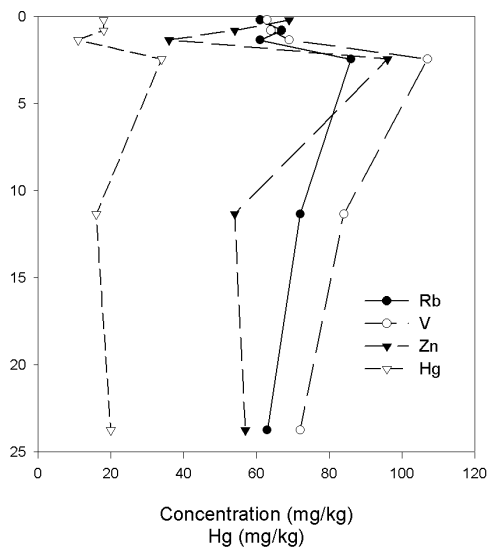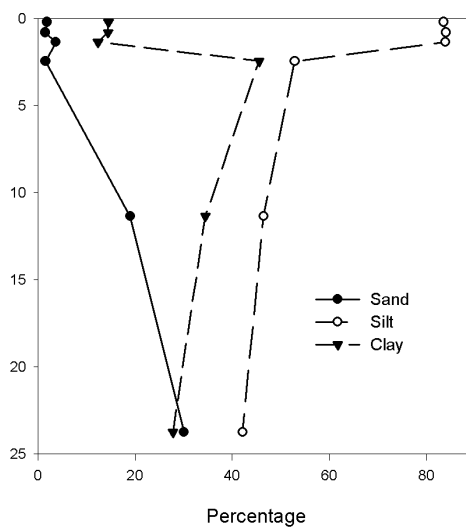
Core 60

Figure 23. Element concentrations versus depth in core 60.

98
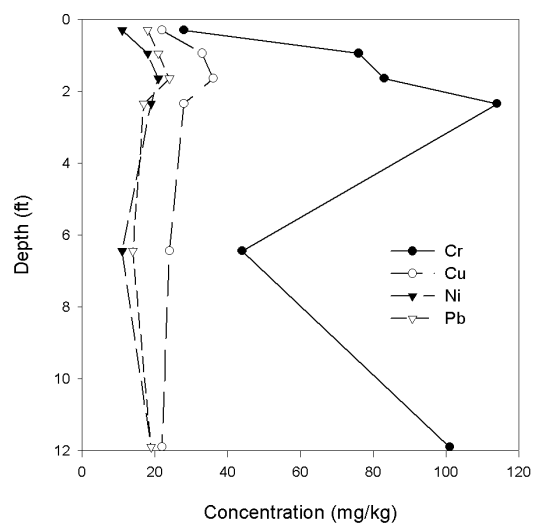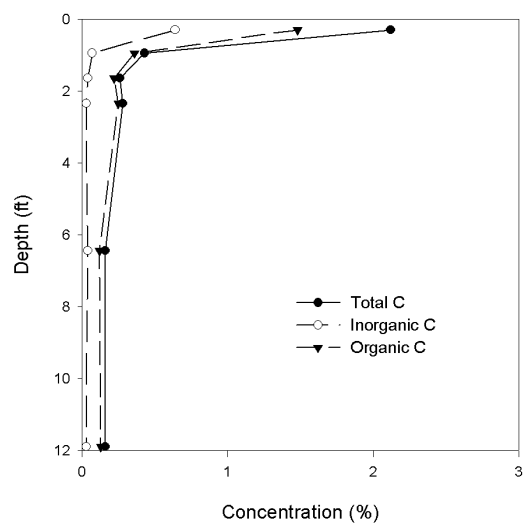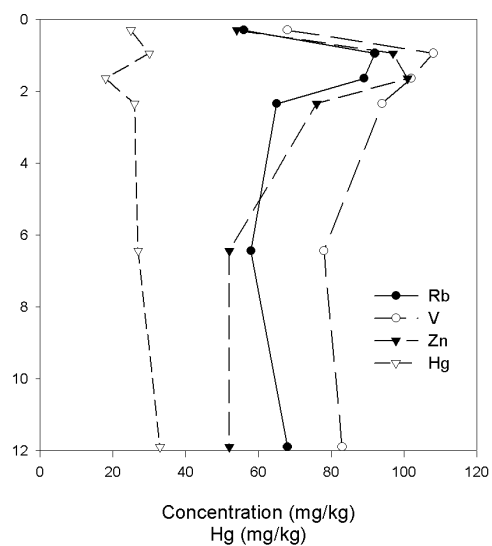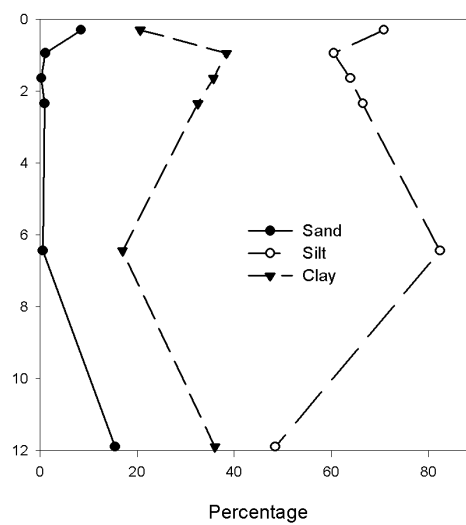
Core 61

Figure 25. Element concentrations versus depth in core 61.

99
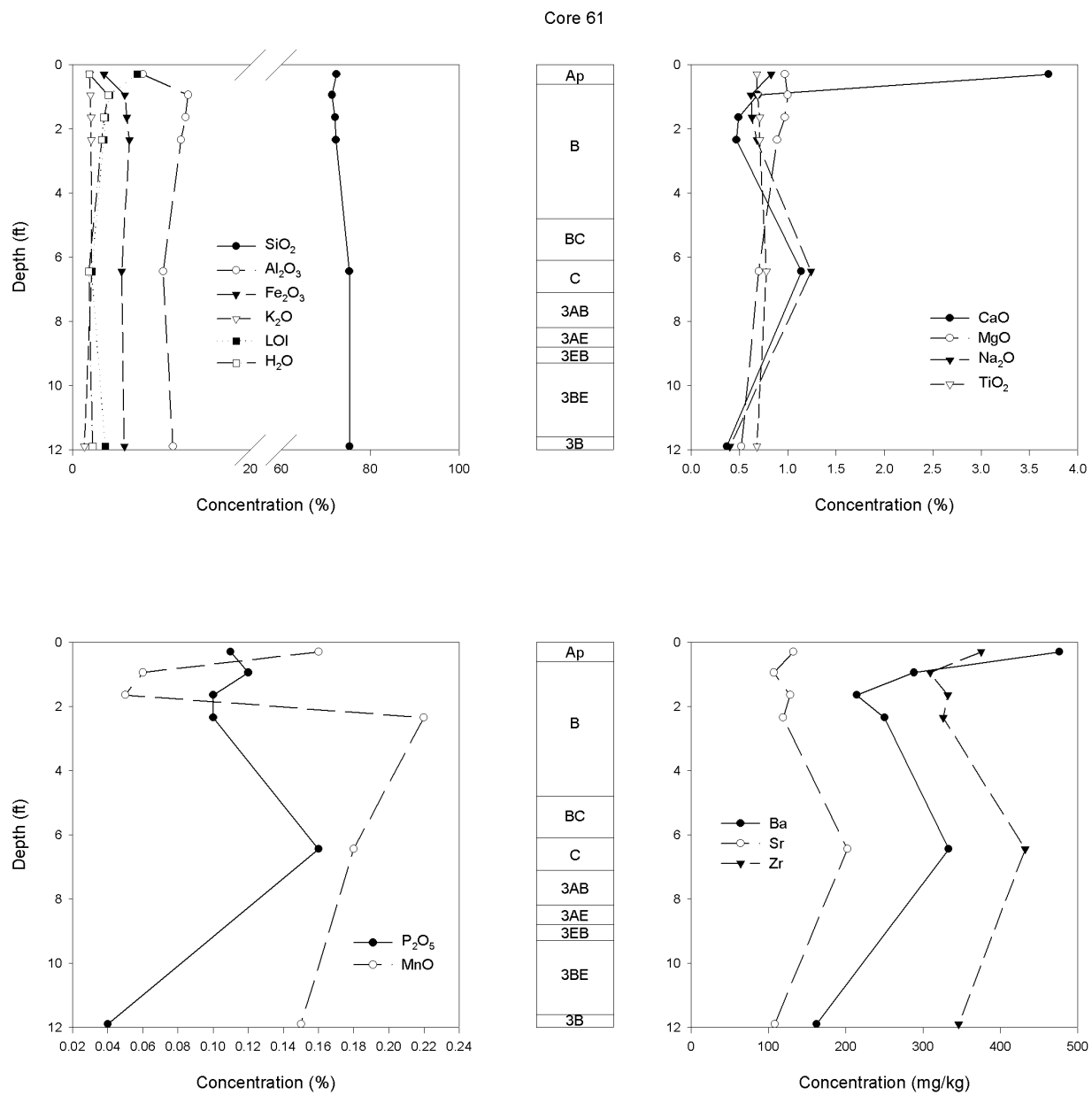
Core 61

Figure 24. Element concentrations versus depth in core 61.

100
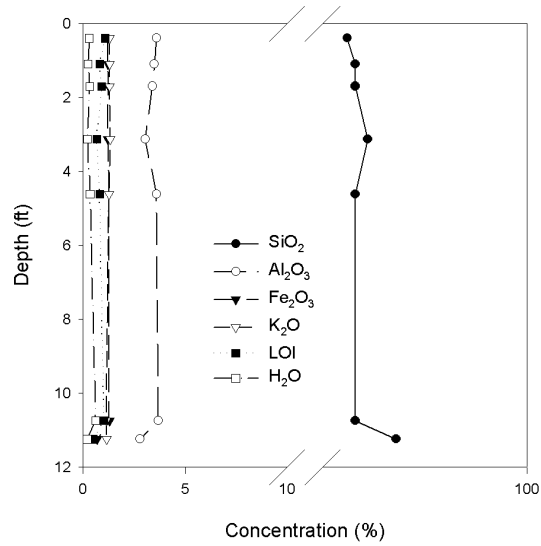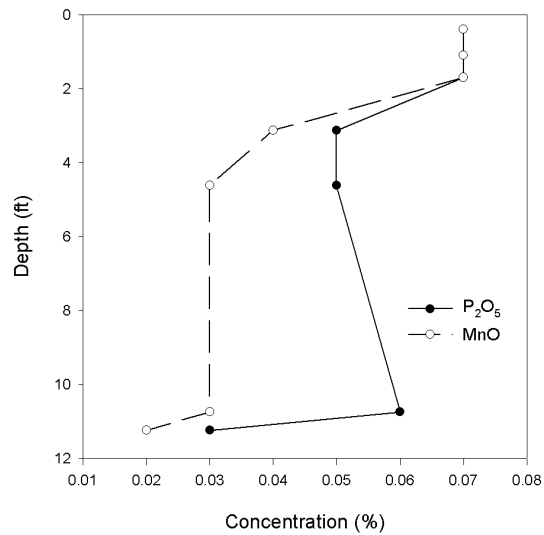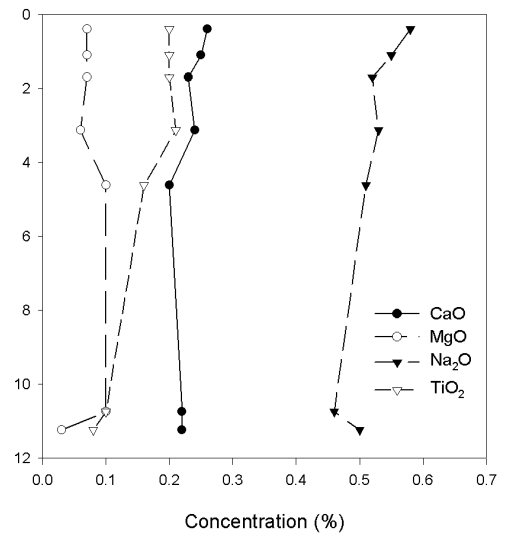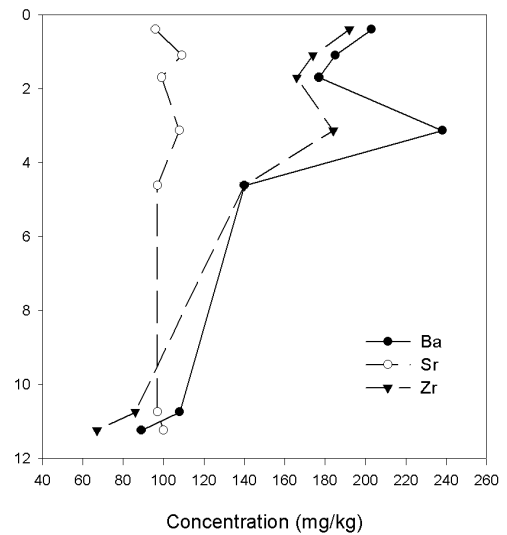
Figure 26. Element concentrations versus depth in core 62.

101
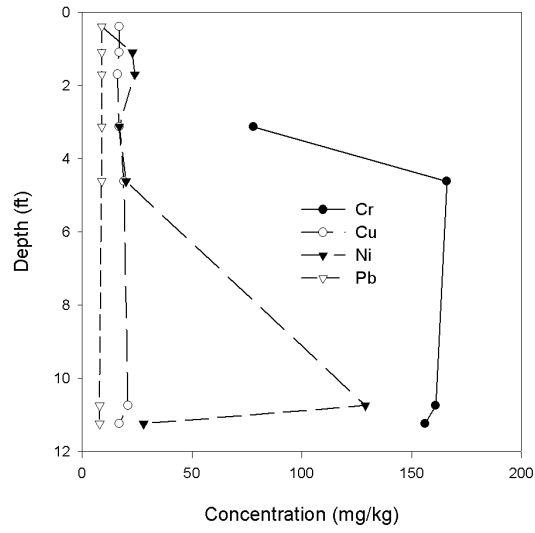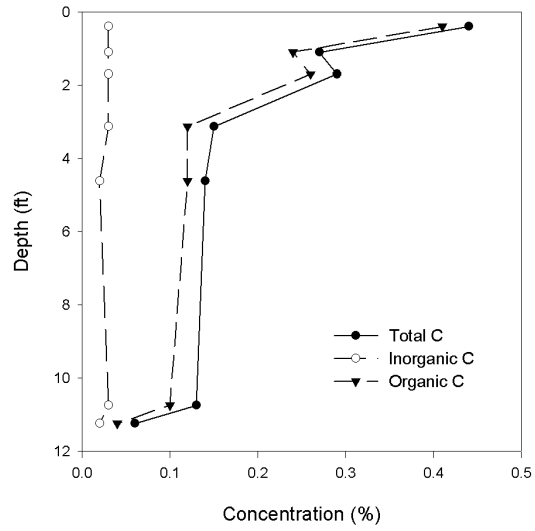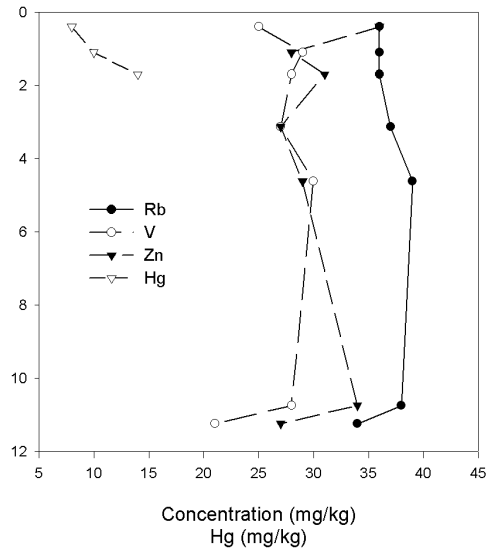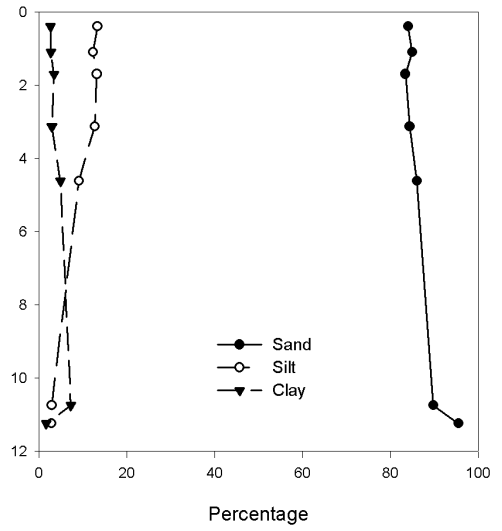
Core 62

Figure 27. Element concentrations versus depth in core 62.

Core 63
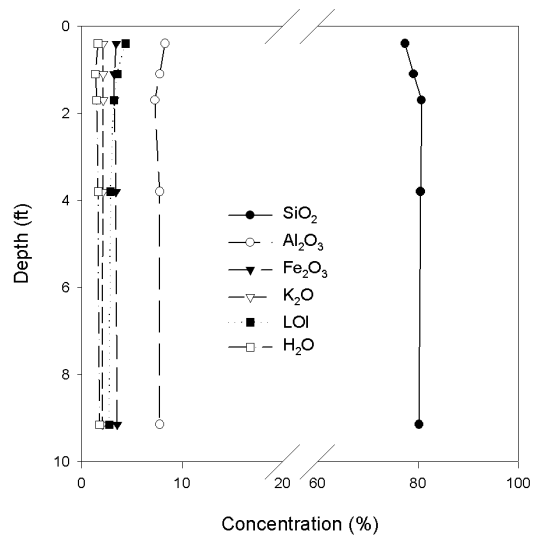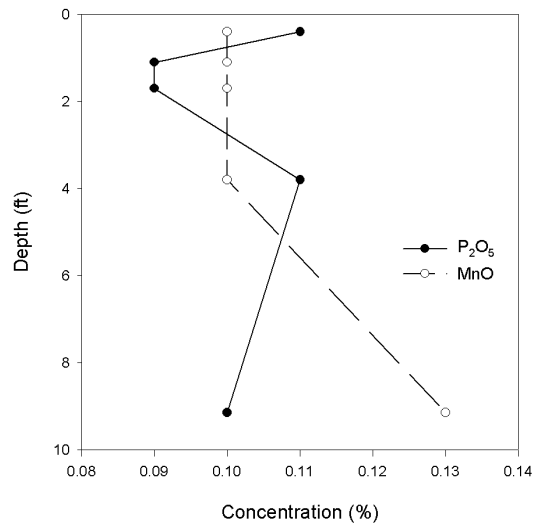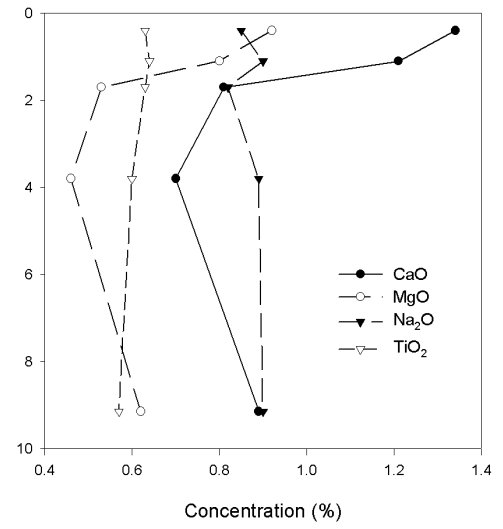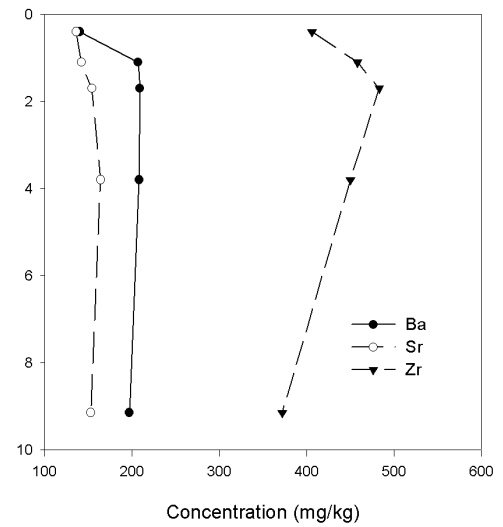
Figure 28. Element concentrations versus depth in core 63.

103
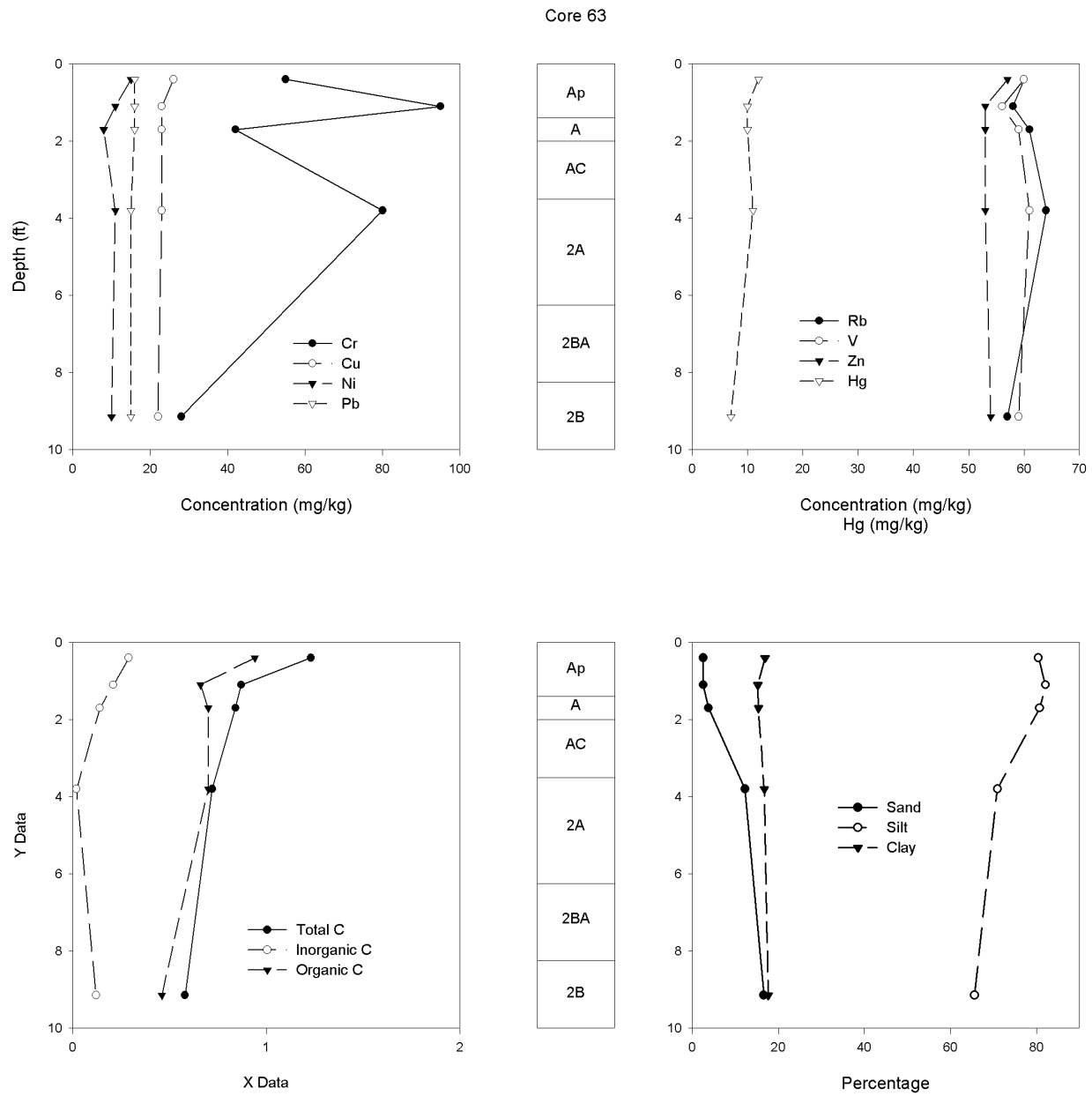
Core 63

Figure 29. Element concentrations versus depth in core 63.

104
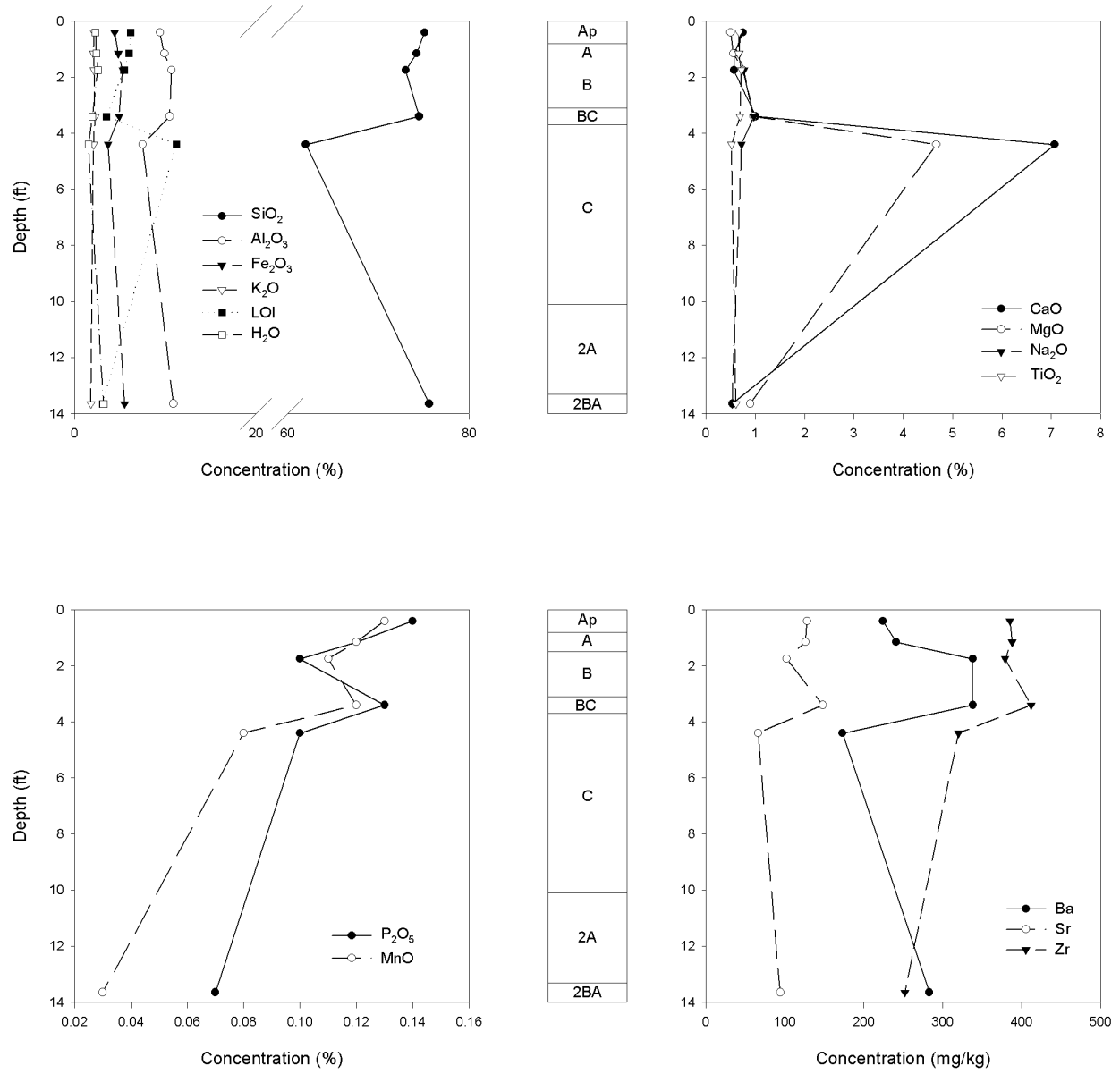
Figure 30. Element concentrations vesus depth in core 64.

Core 64
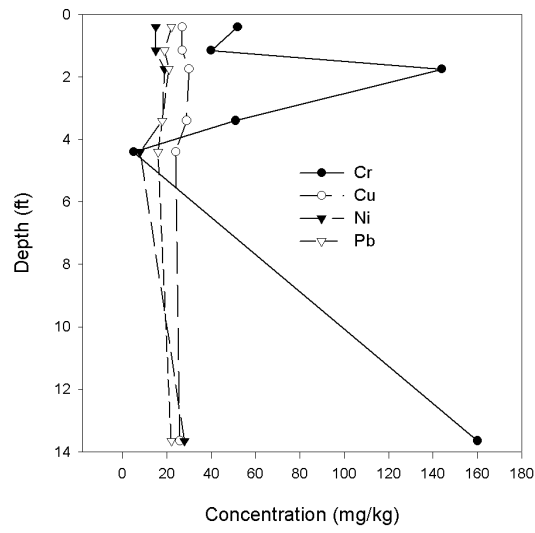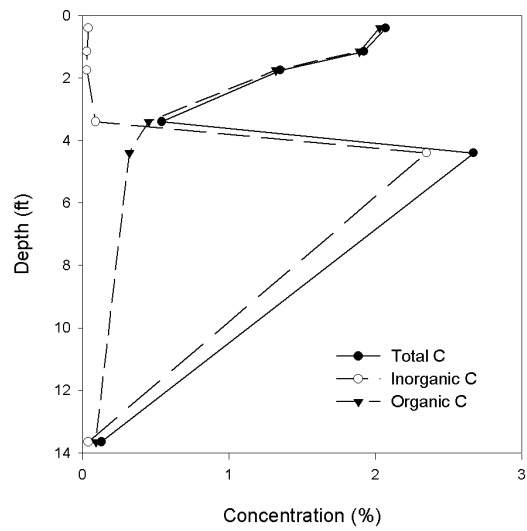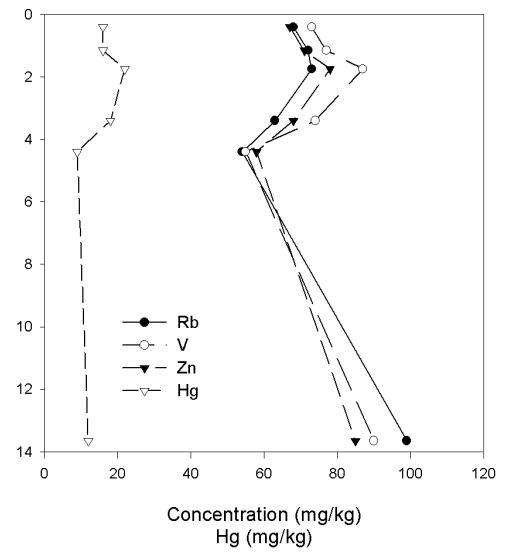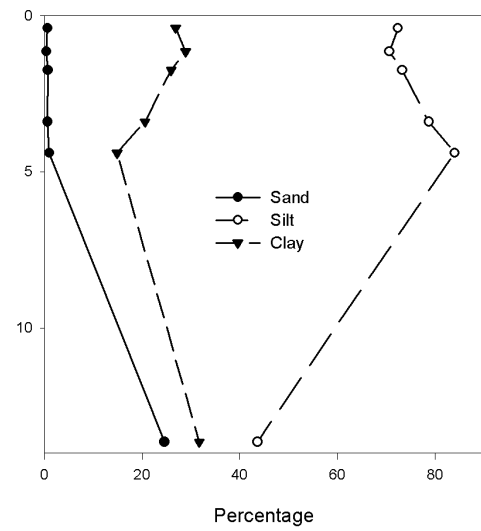
Figure 31. Element concentrations versus depth in core 64.
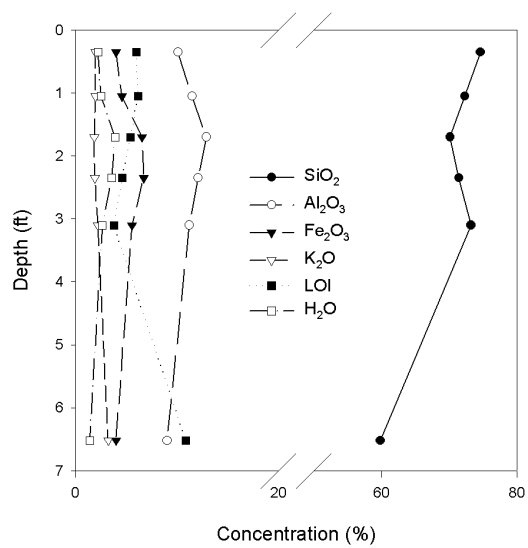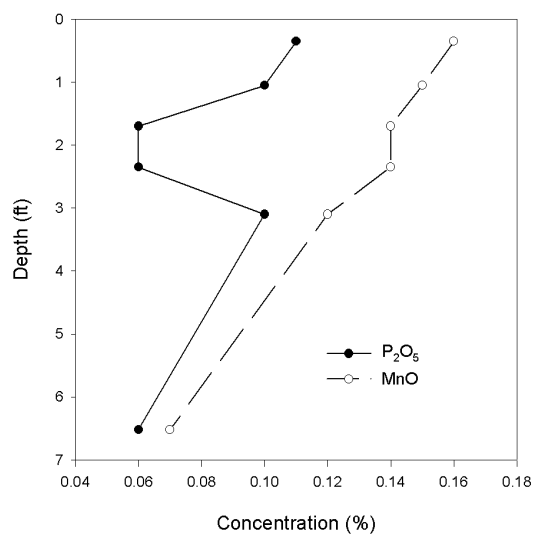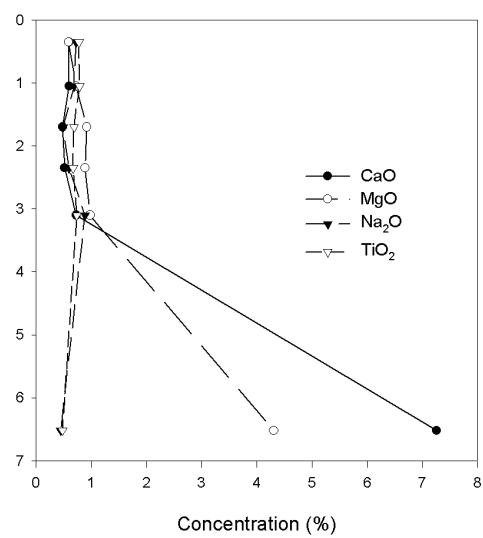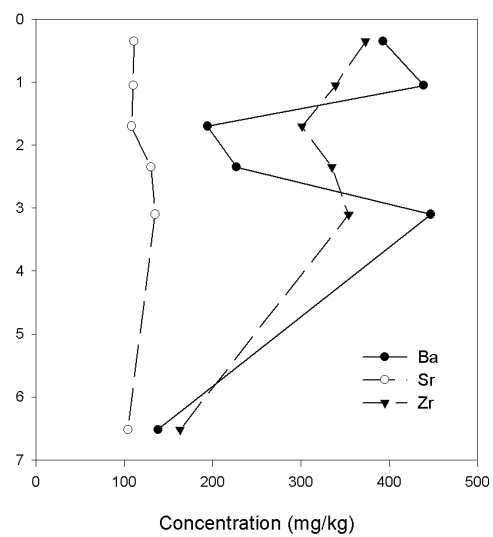
Figure 32. Element concentrations versus depth in core 65.

Core 65
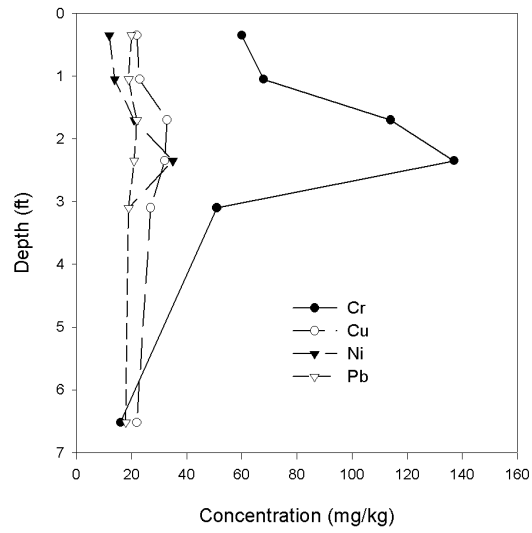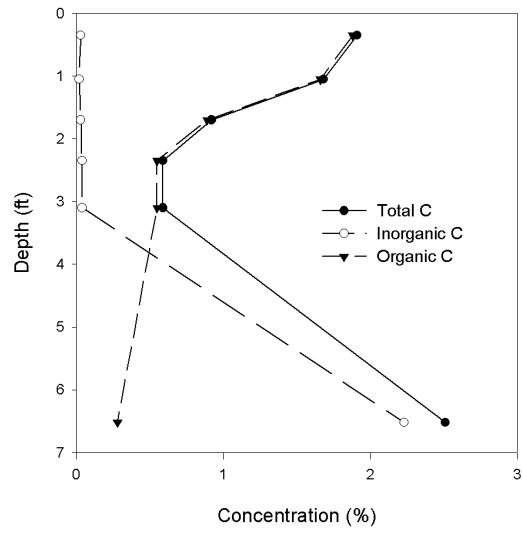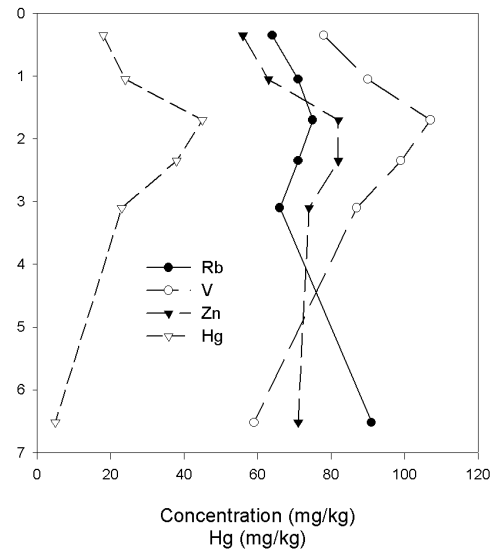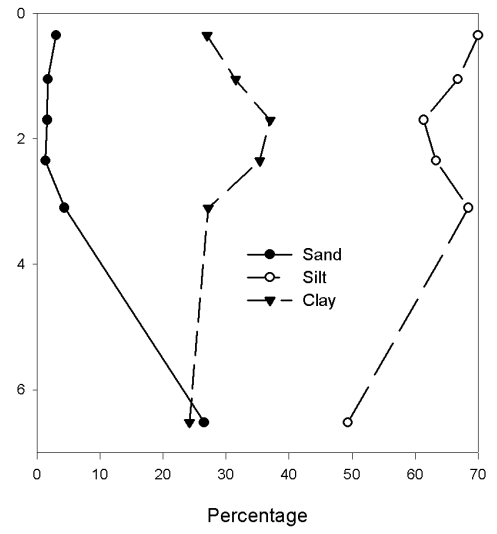
Figure 33. Element concentrations versus depth in core 65.

Core 66
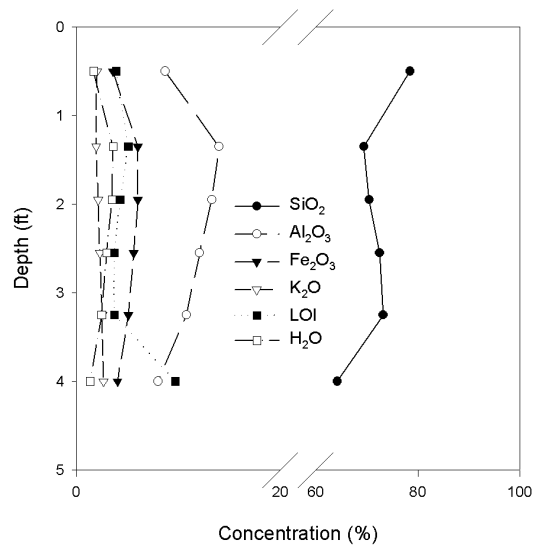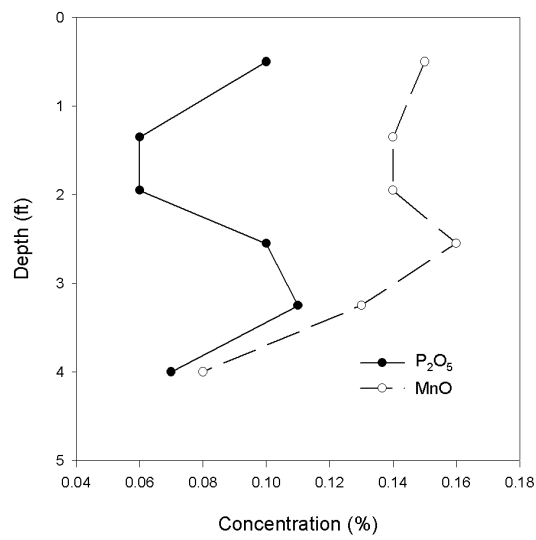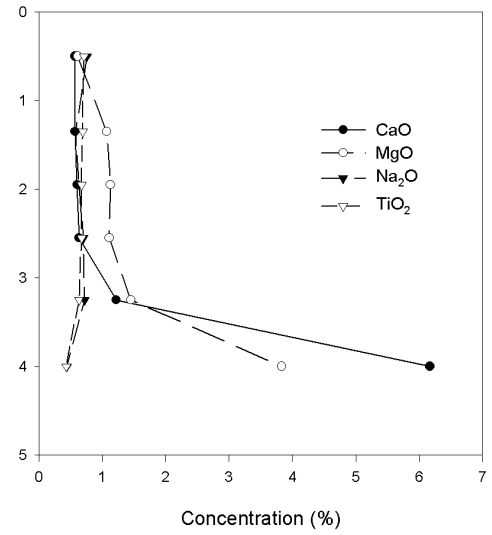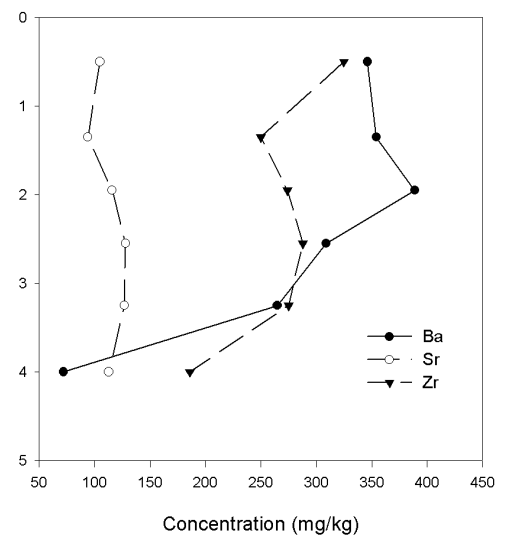
Figure 34. Element concentrations versus depth in core 66.
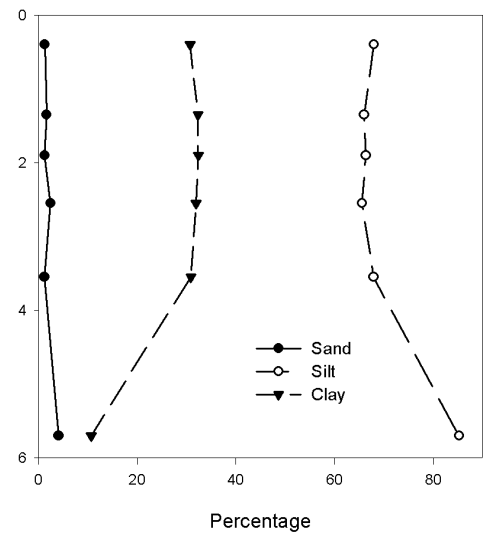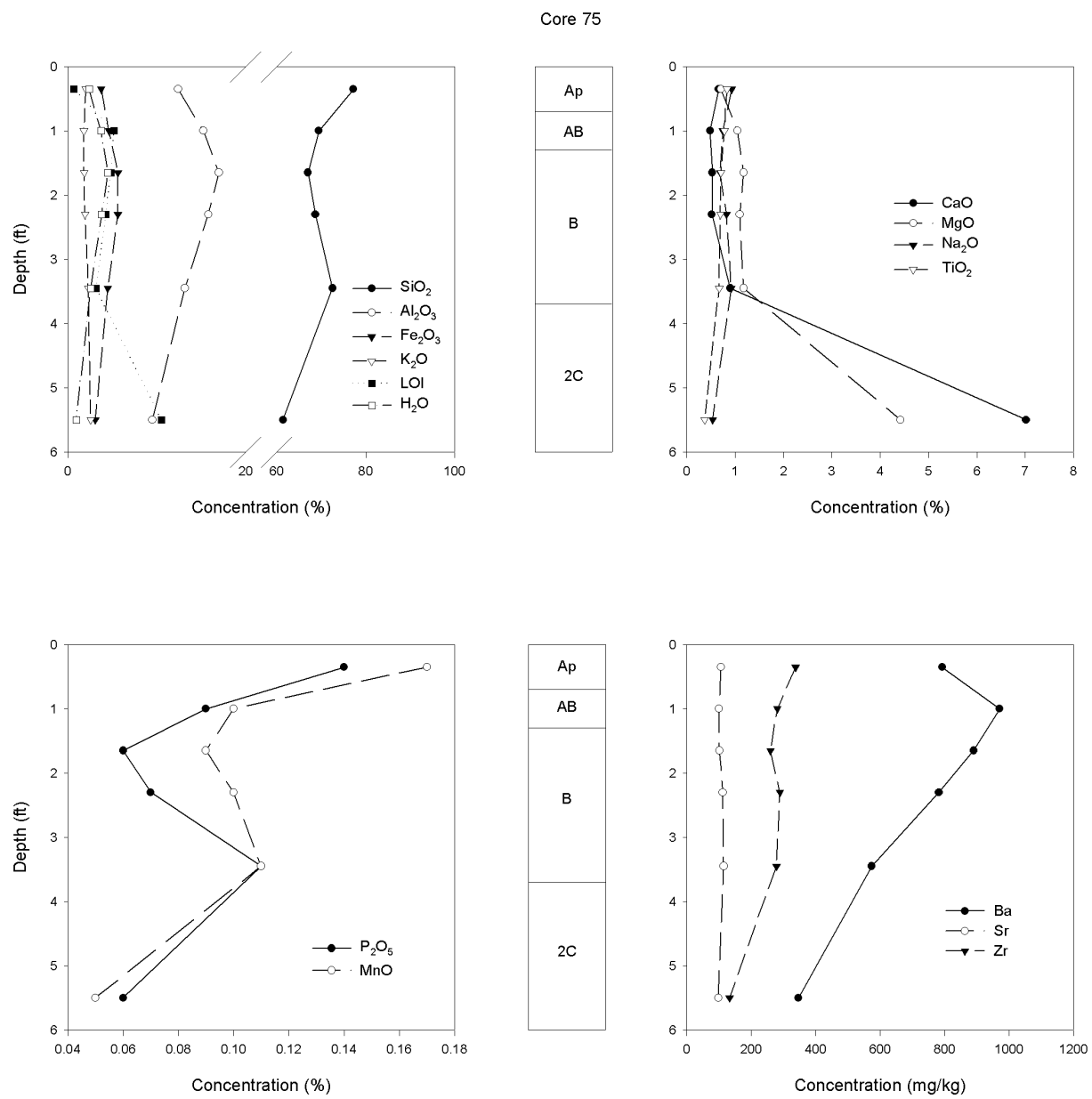
109
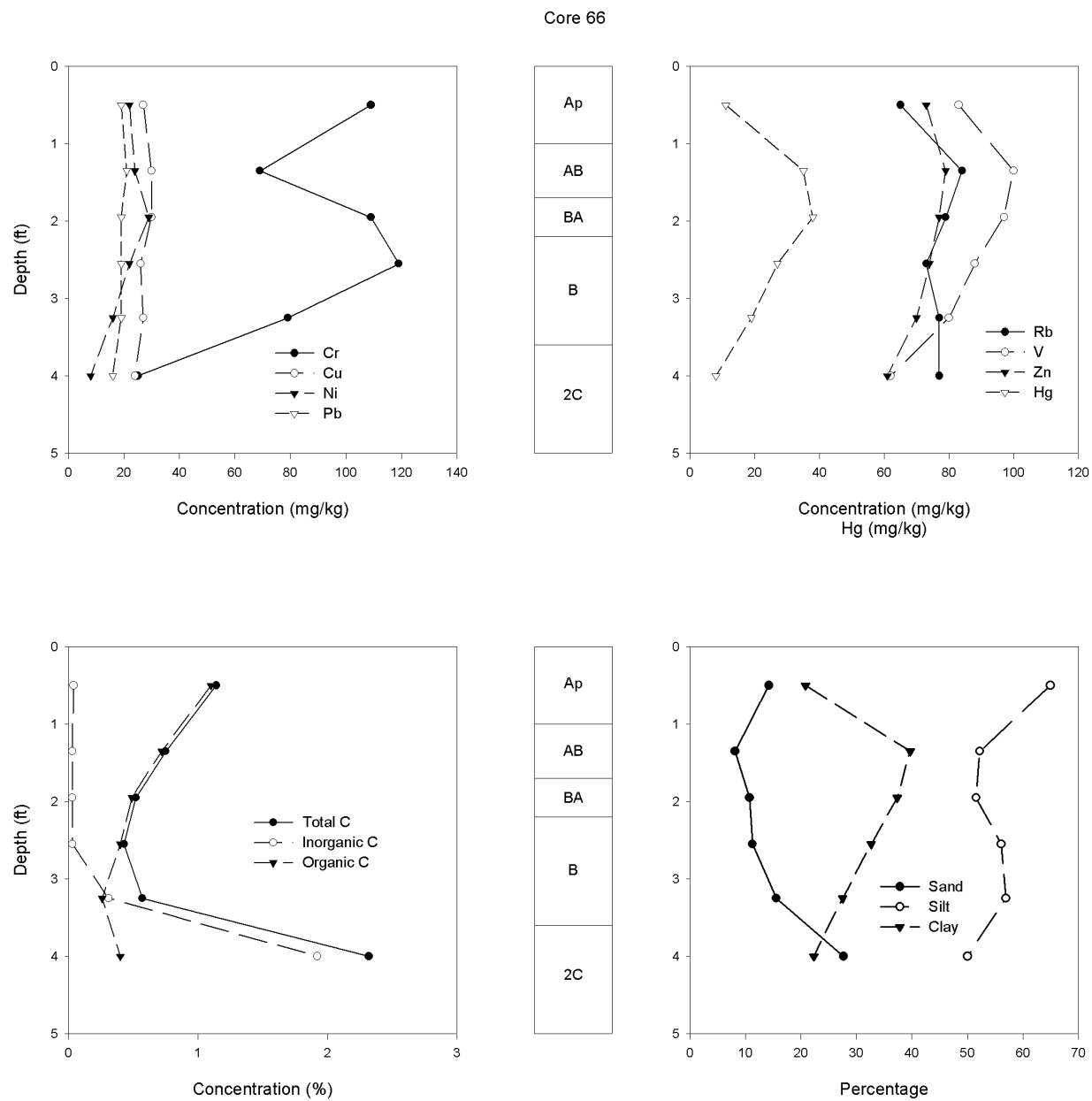
Core 66

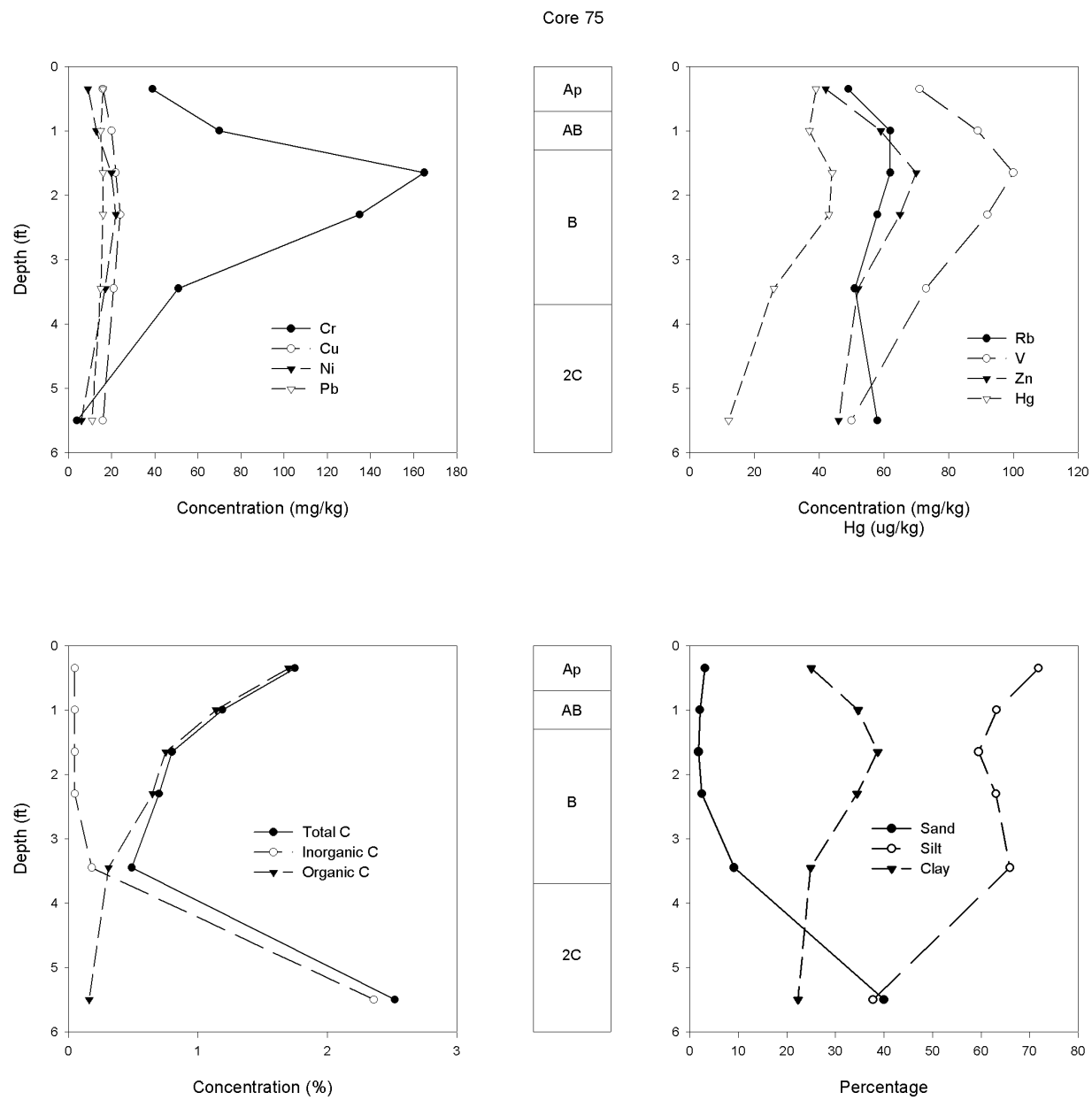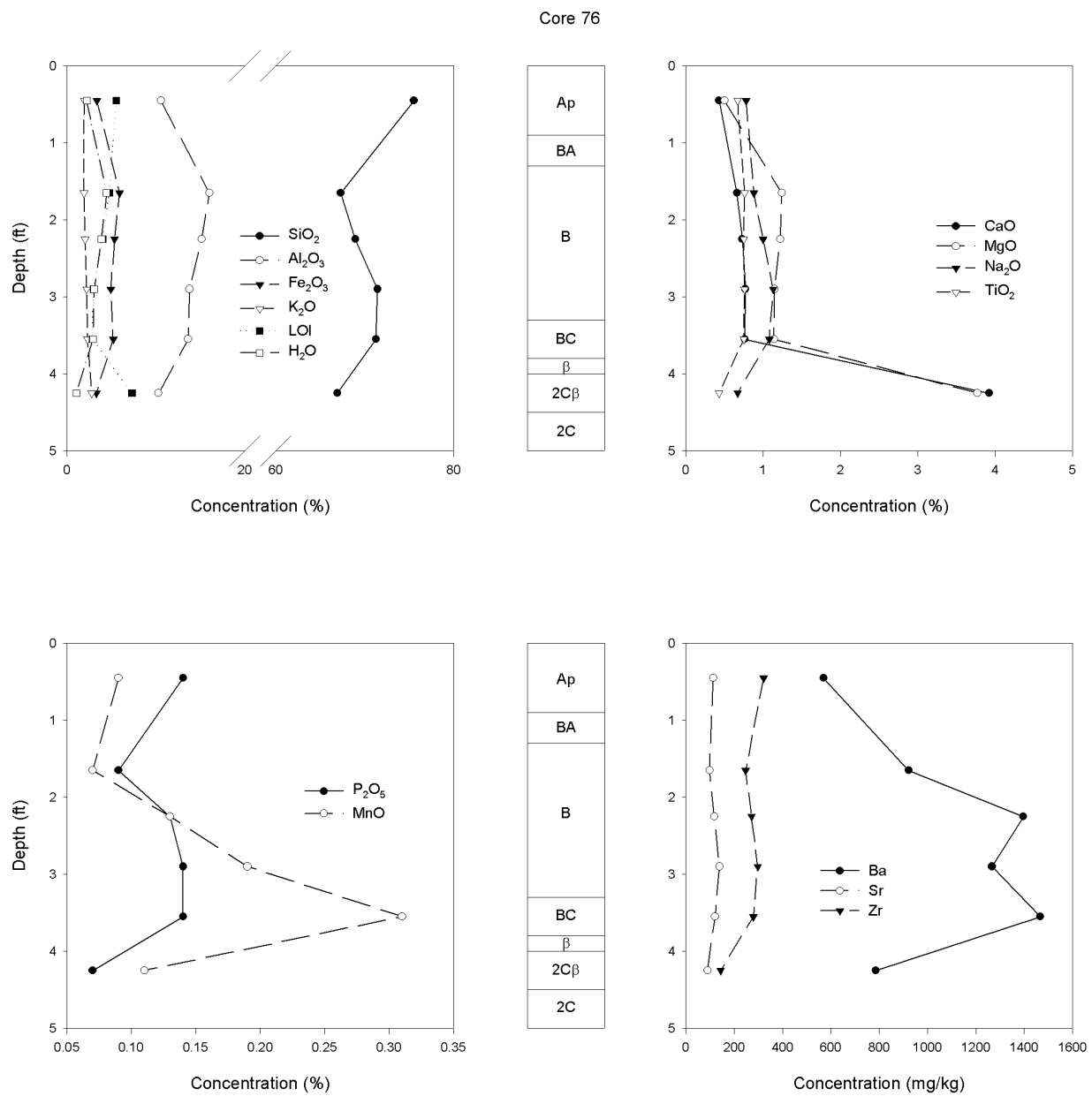**Figure 35.** Element concentrations versus depth in core 66.
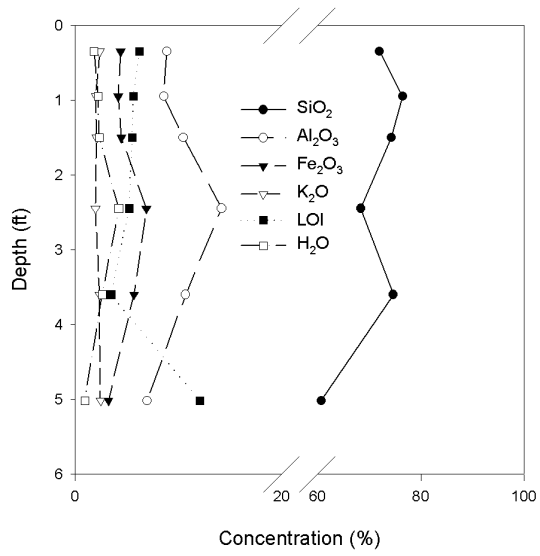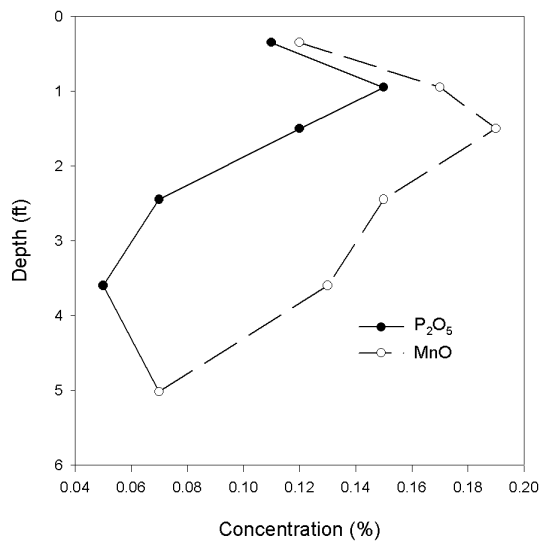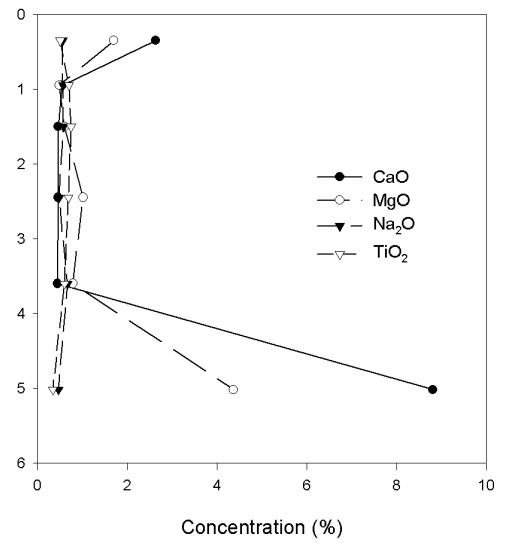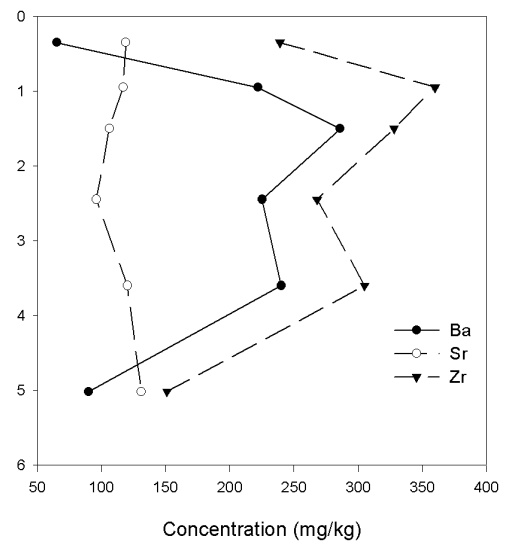
Figure 36. Element concentrations versus depth in core 67.

Core 67
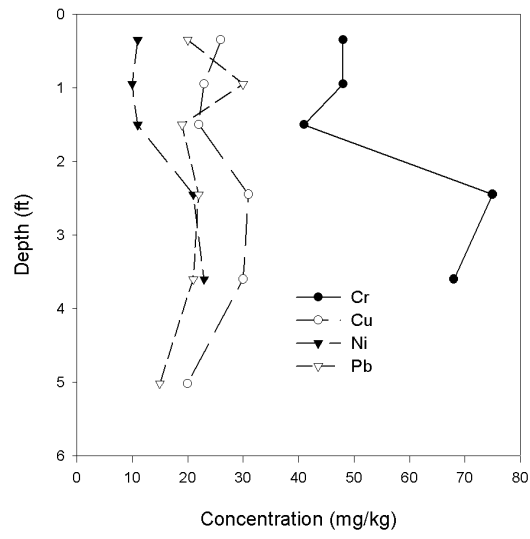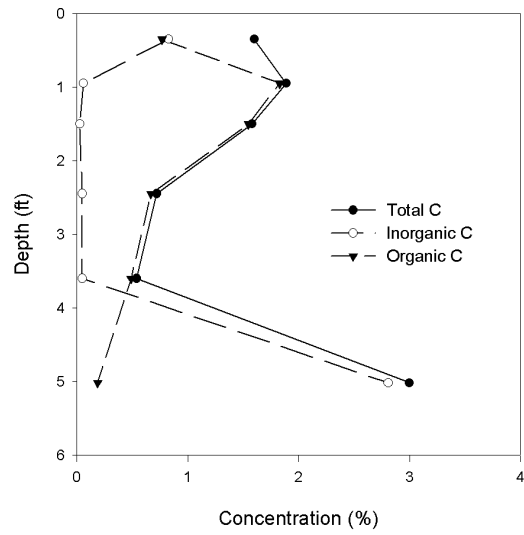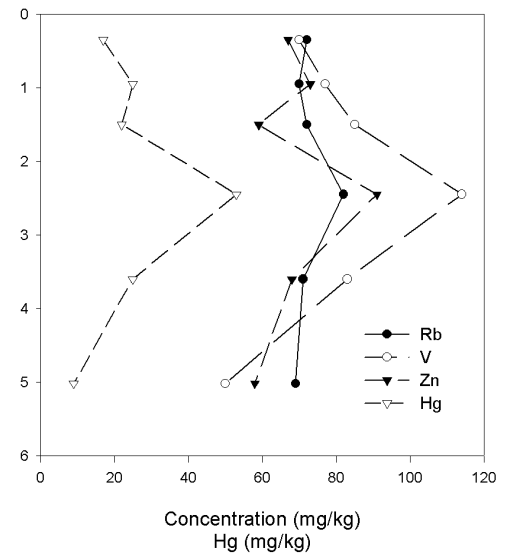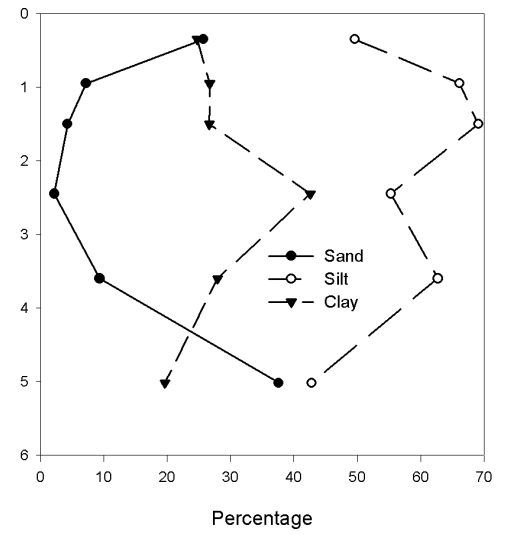
Figure 37. Element concentrations versus depth in core 67.
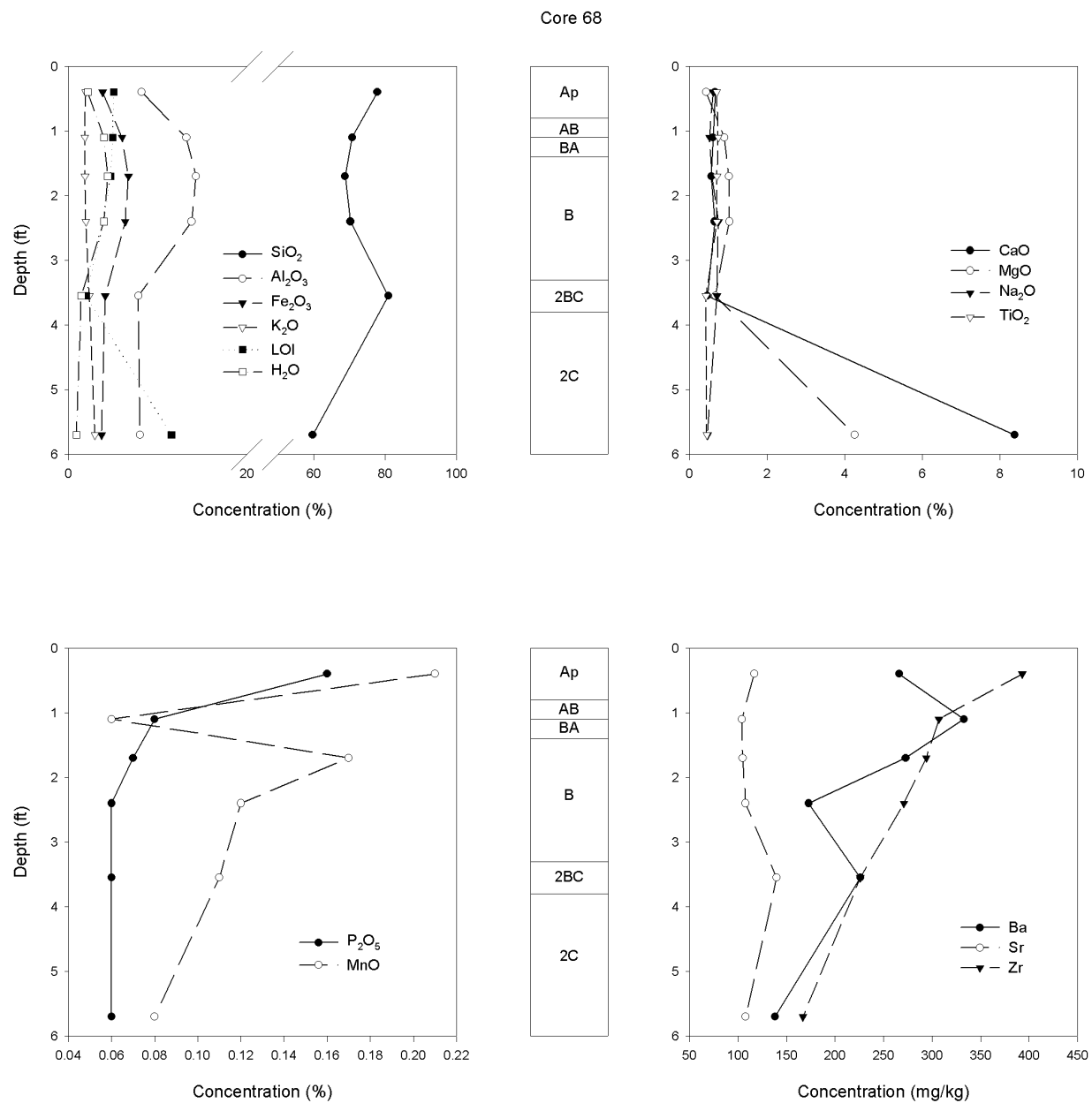
Figure 38. Element concentrations versus depth in core 68.

113
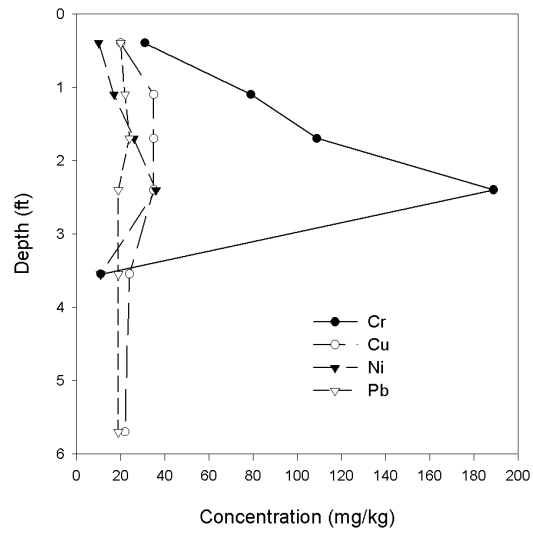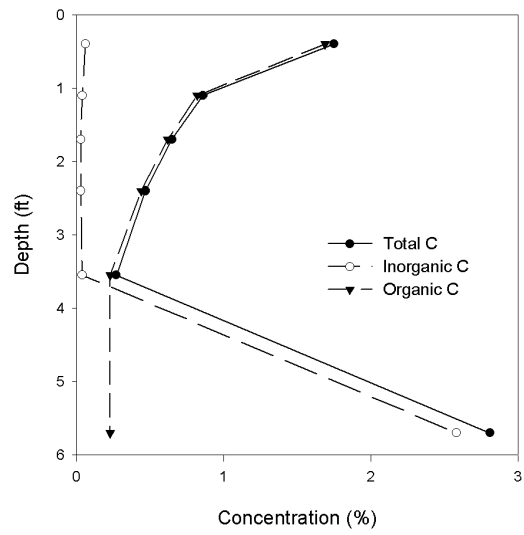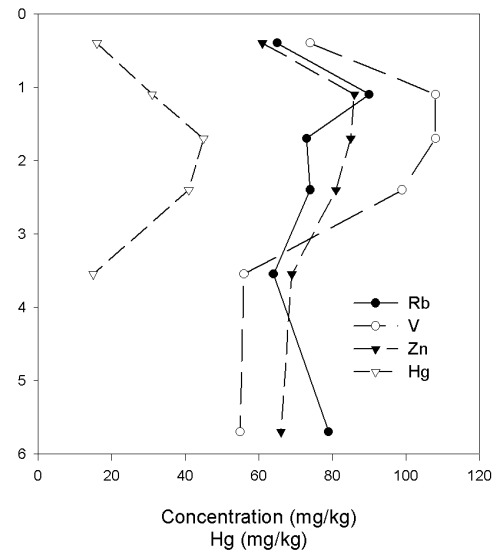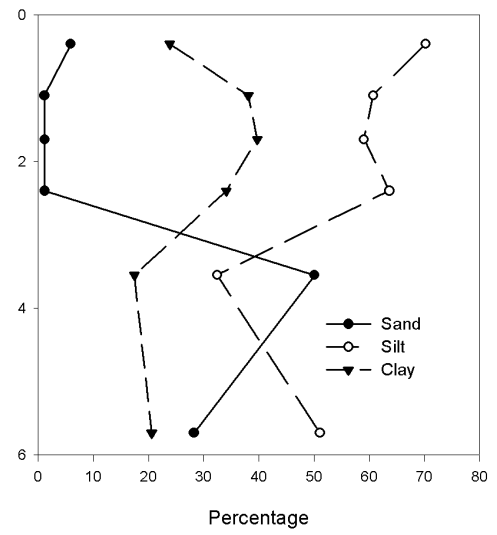
Core 68

Figure 39. Element concentrations versus depth in core 68.

114
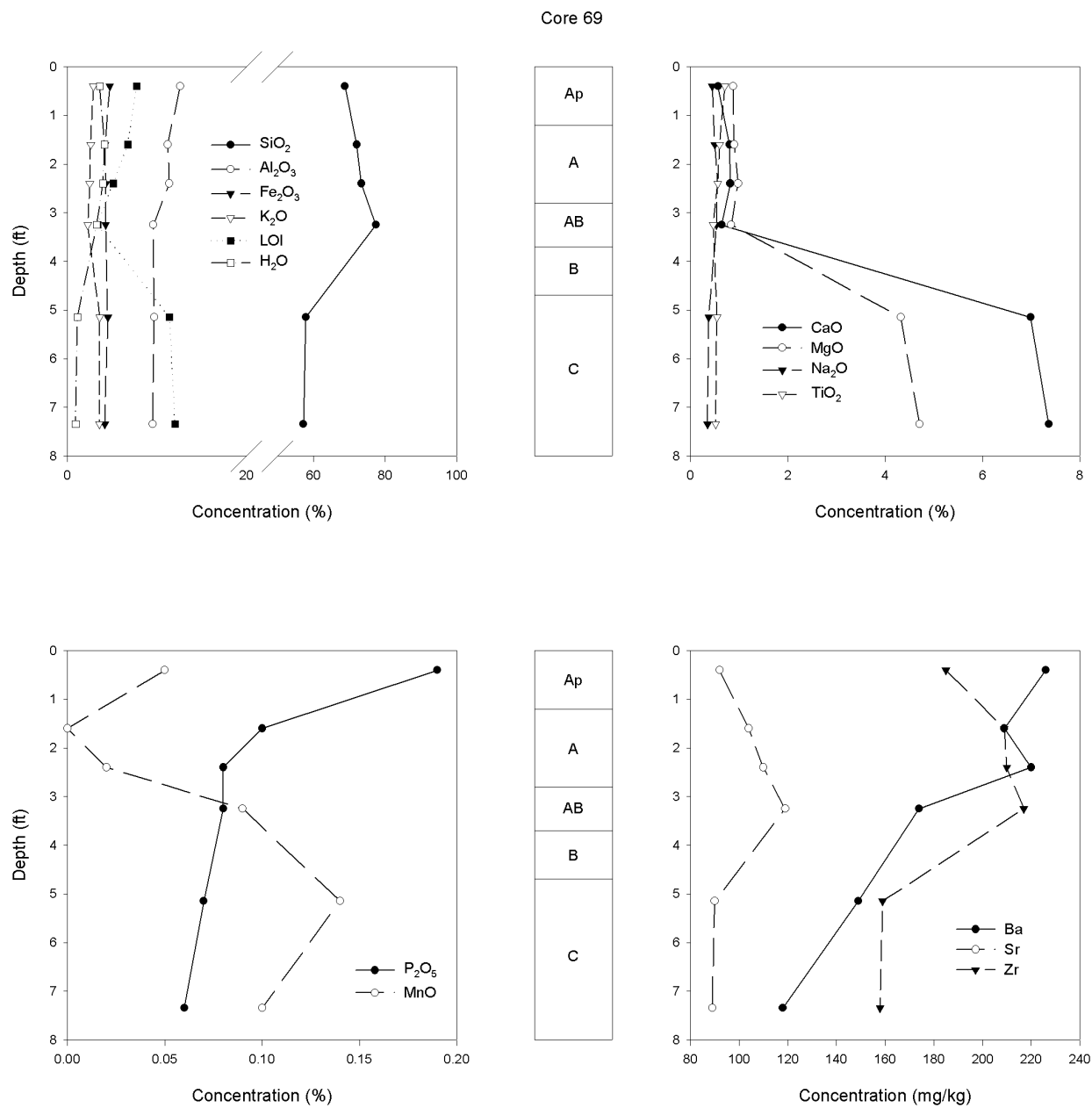
Figure 40. Element concentrations versus depth in core 69.

115
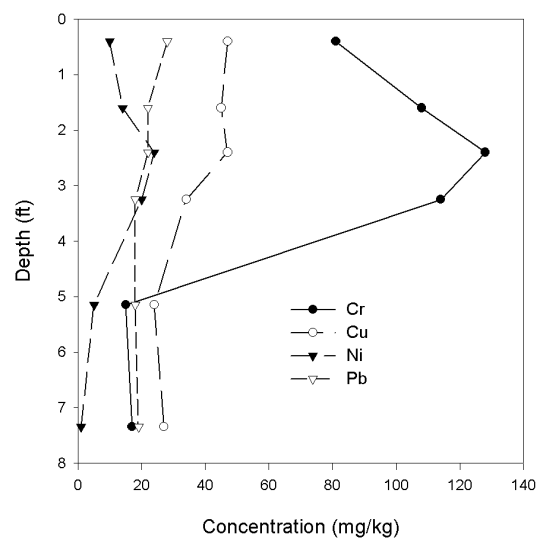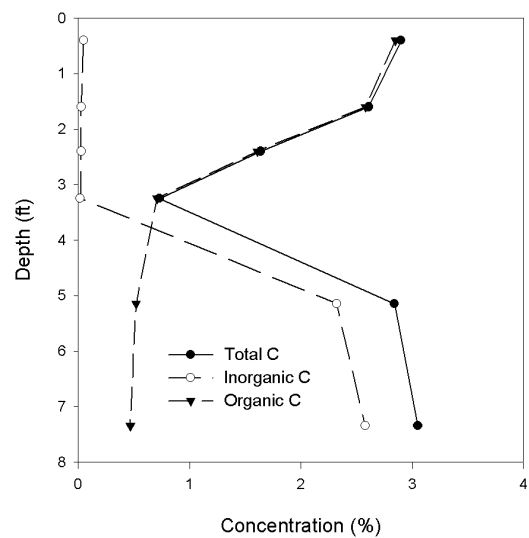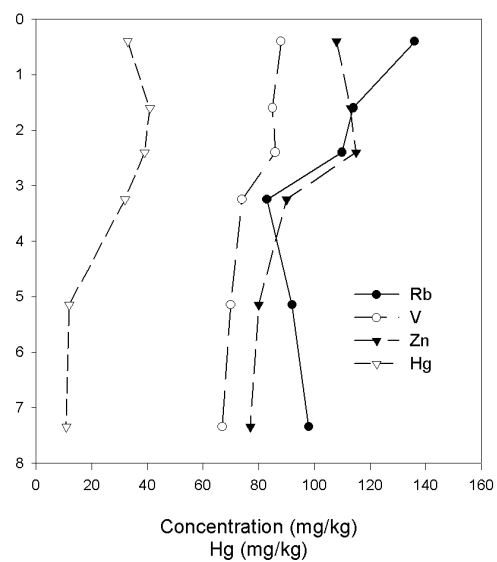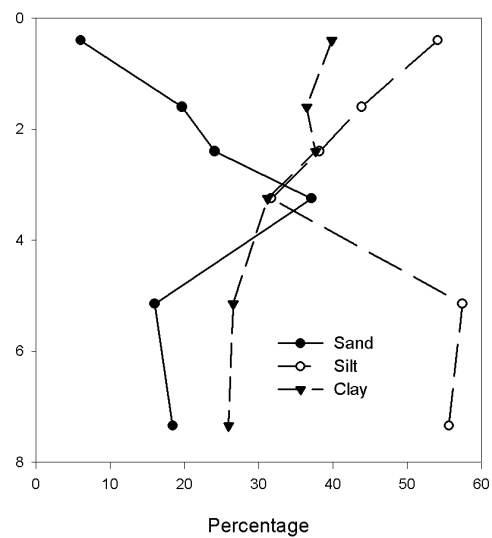
Core 69

Figure 41. Element concentrations versus depth in core 69.

116
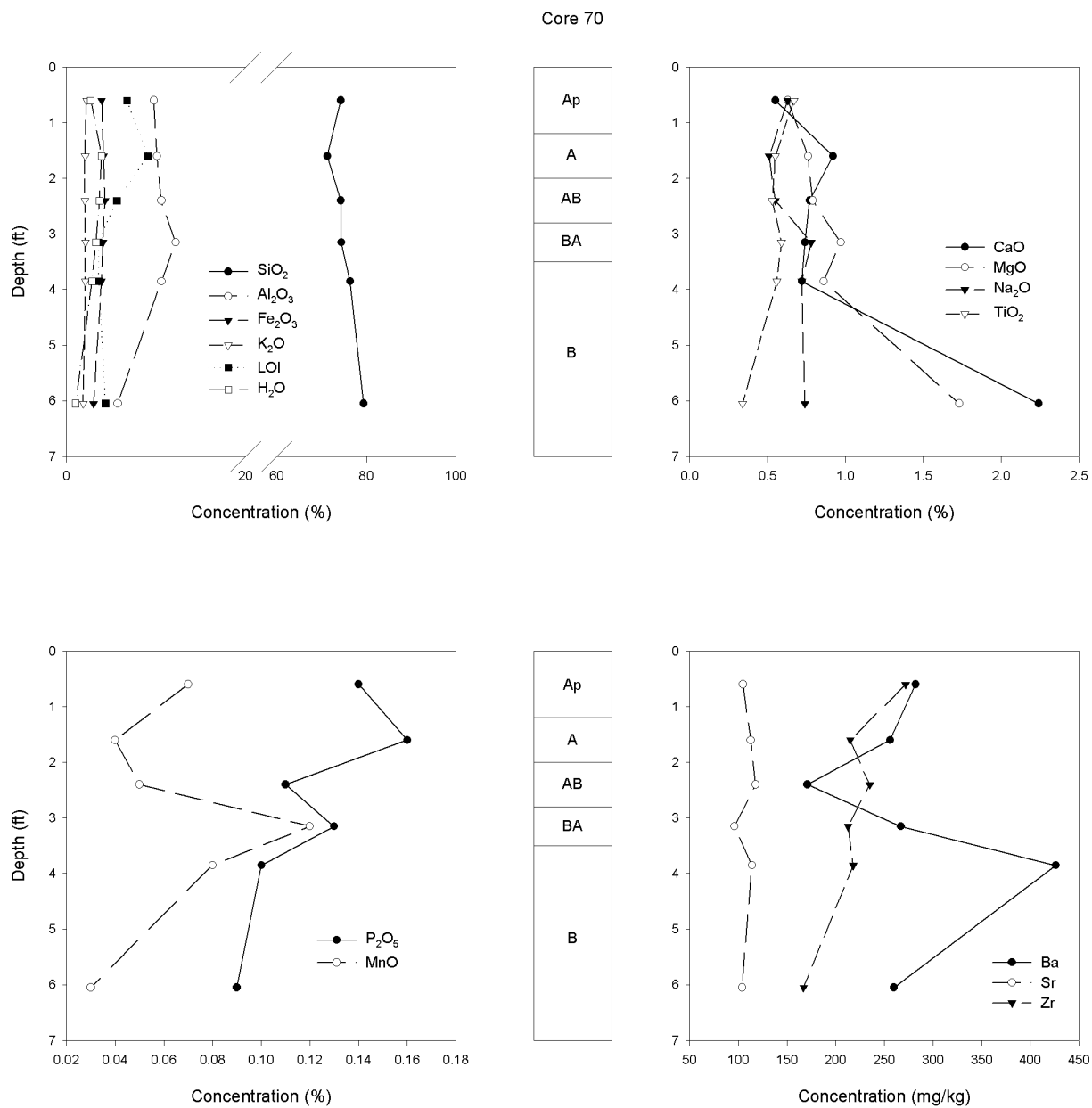
Core 70

Figure 42. Element concentrations versus depth in core 70.
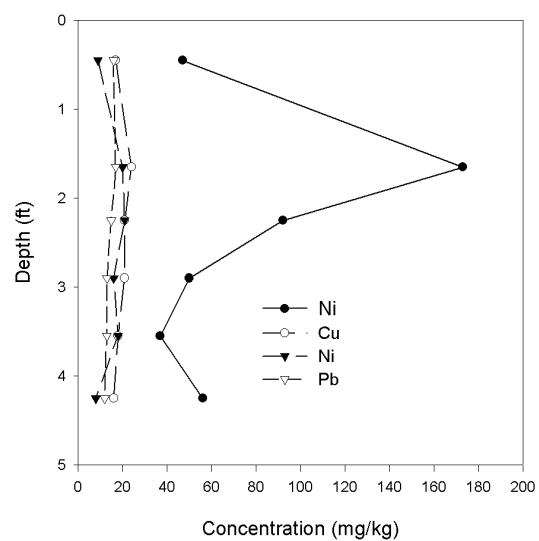
117
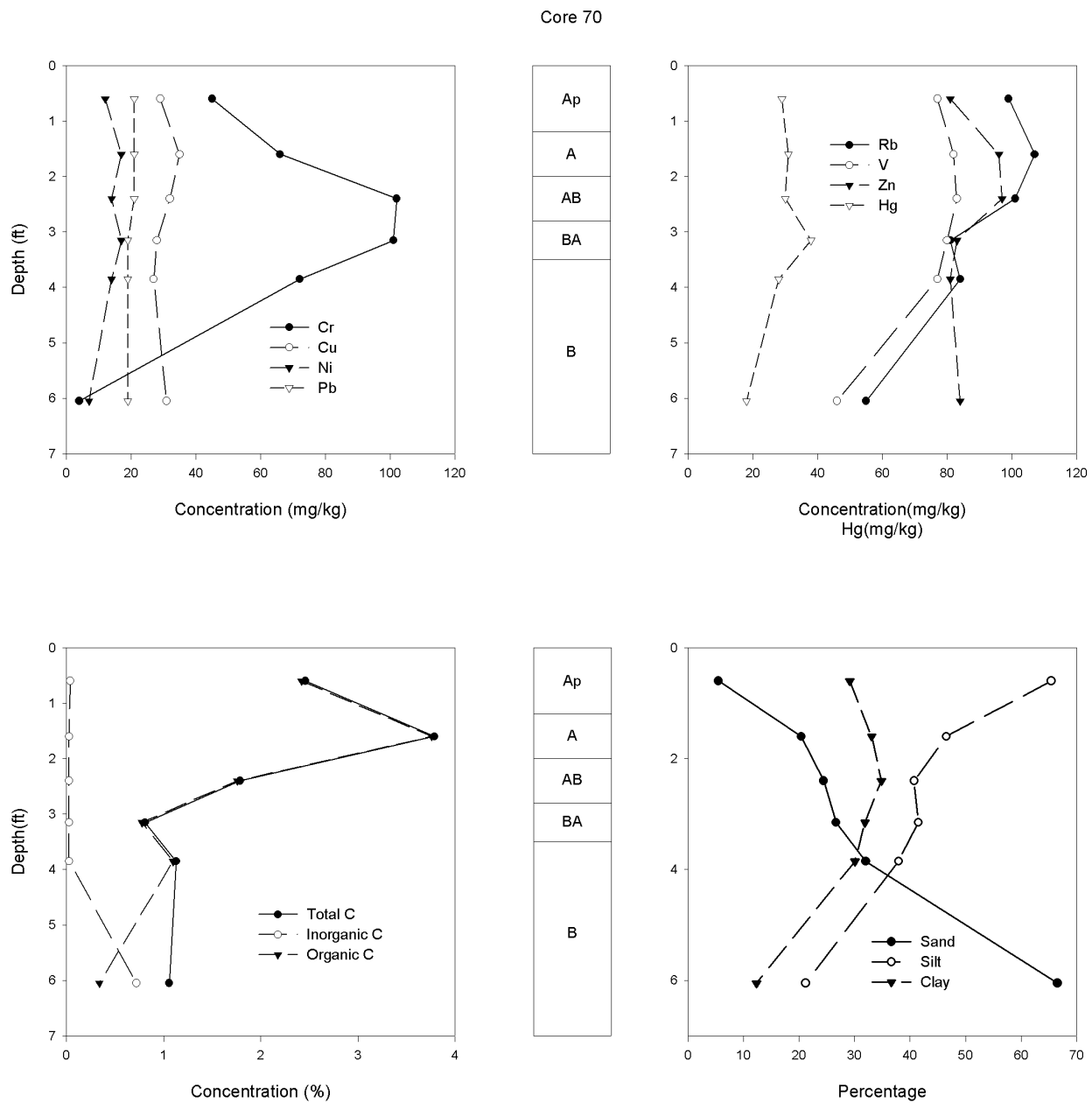
Core 70

Figure 43. Element concentrations versus depth in core 70.

118
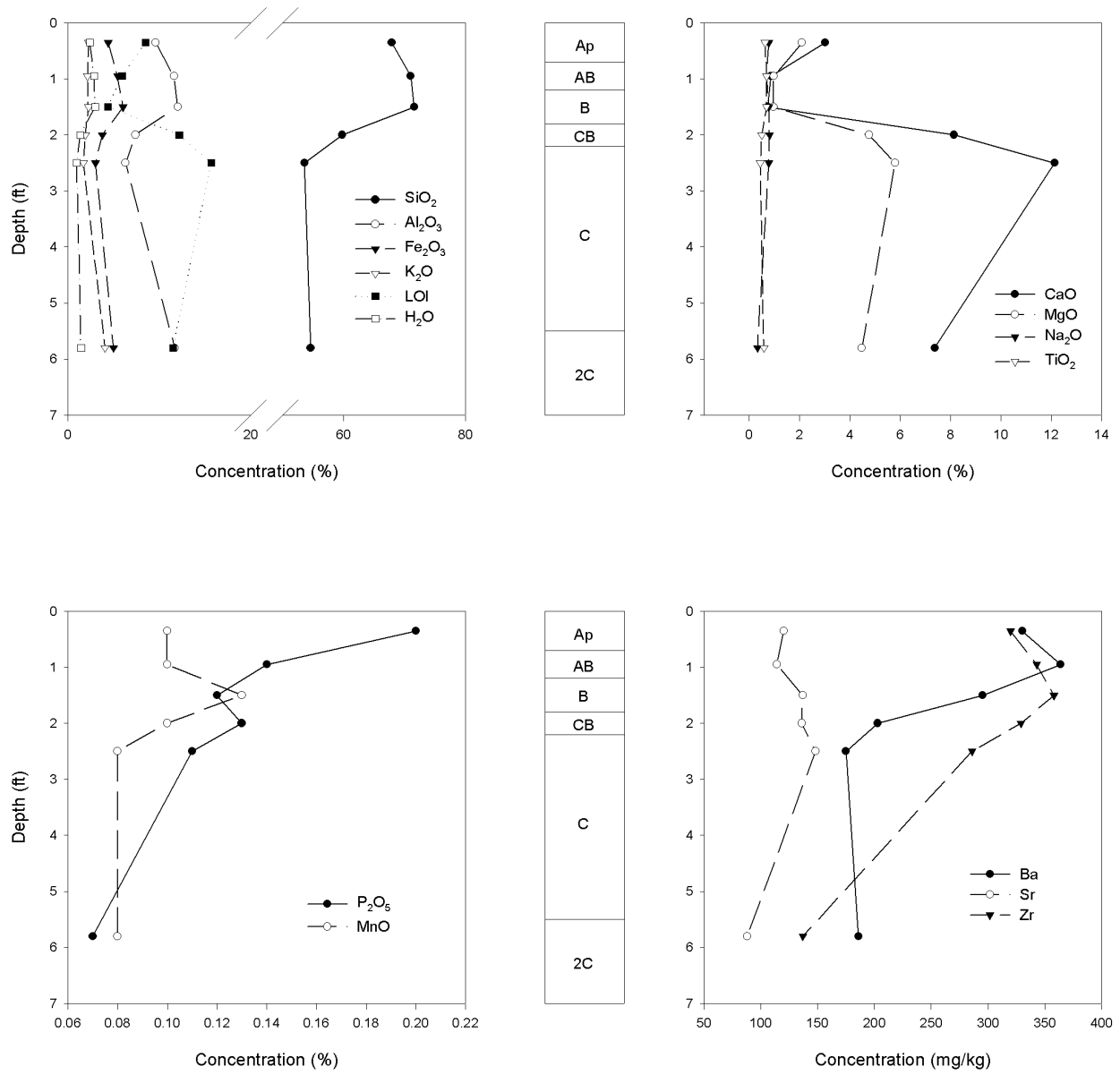
Core 71

Figure 44. Element concentrations versus depth in core 71.

119
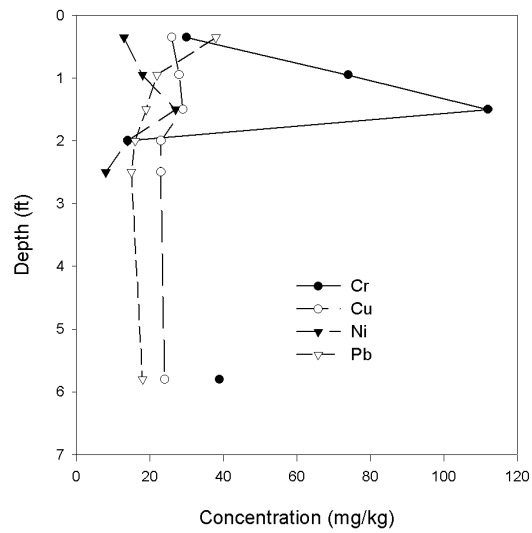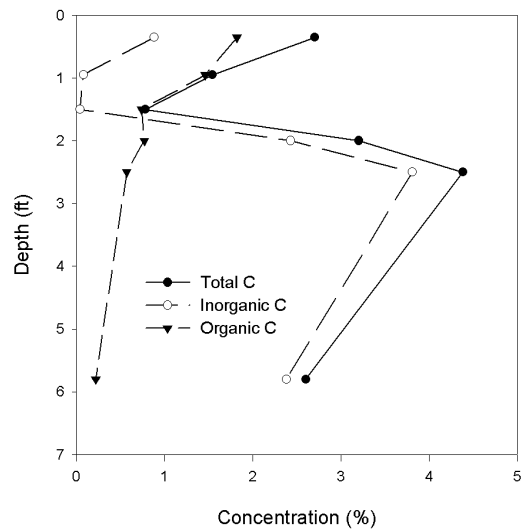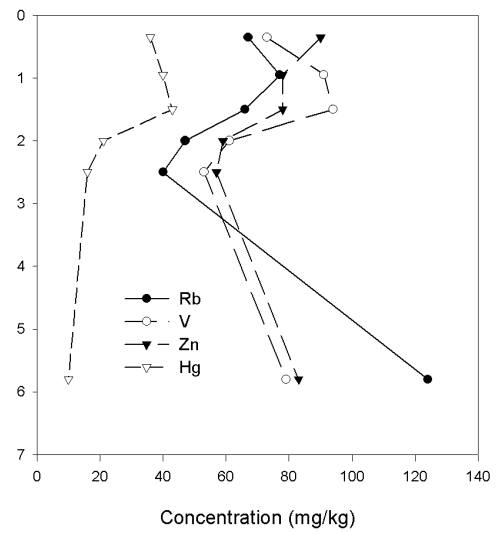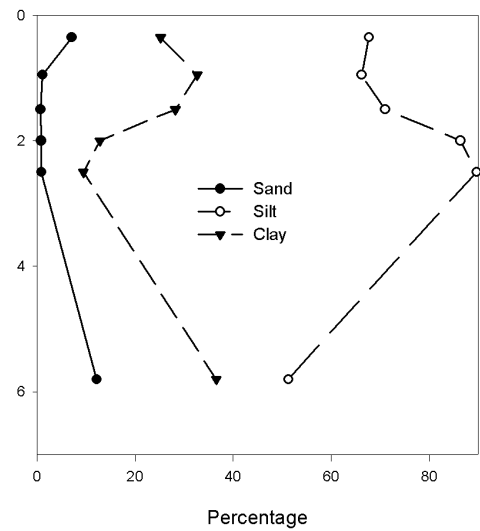
Core 71

Figure 45. Element concentrations versus depth in core 71.

120
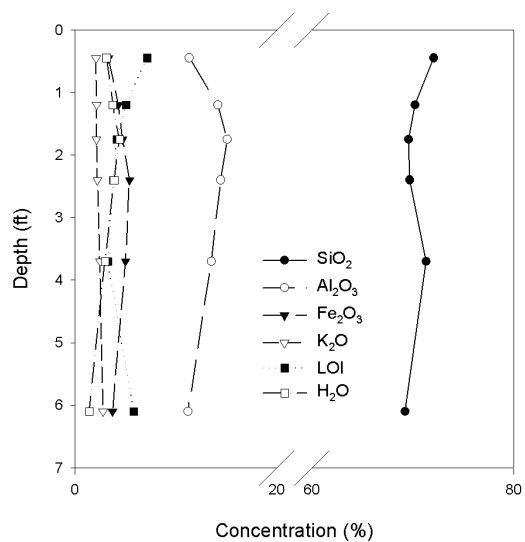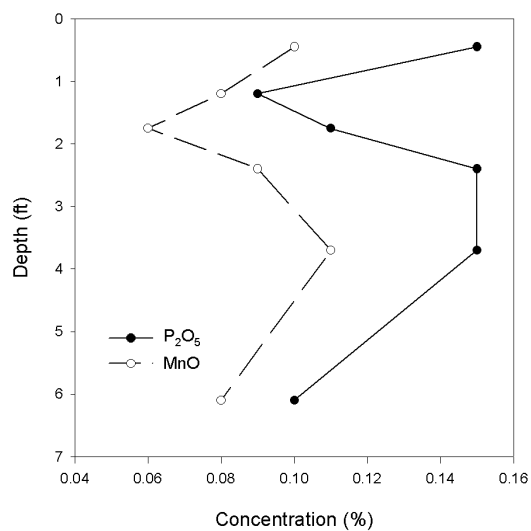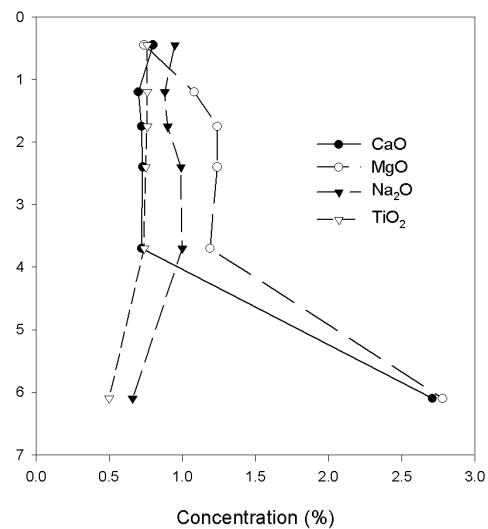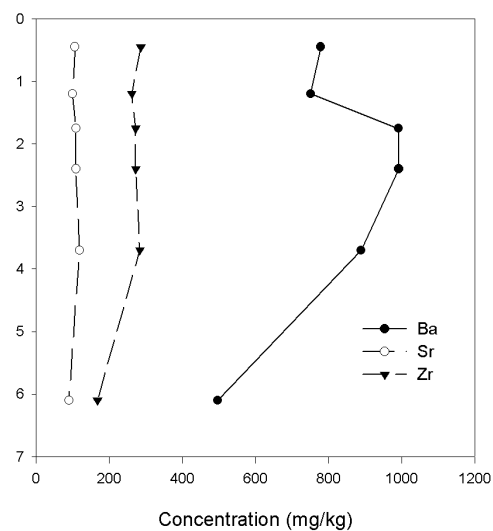
Core 72

Figure 46. Element concentrations versus depth in core 72.

121
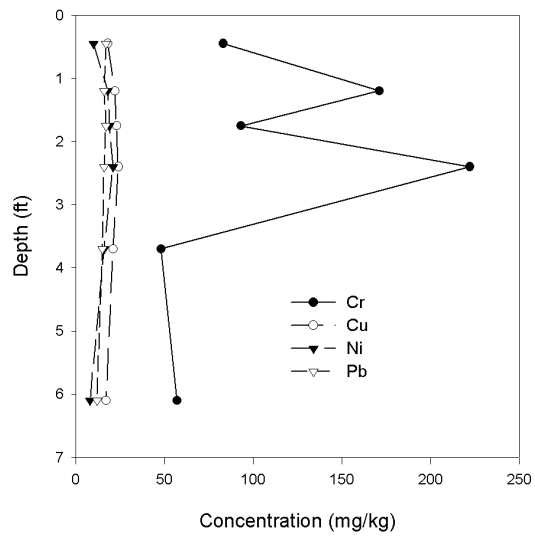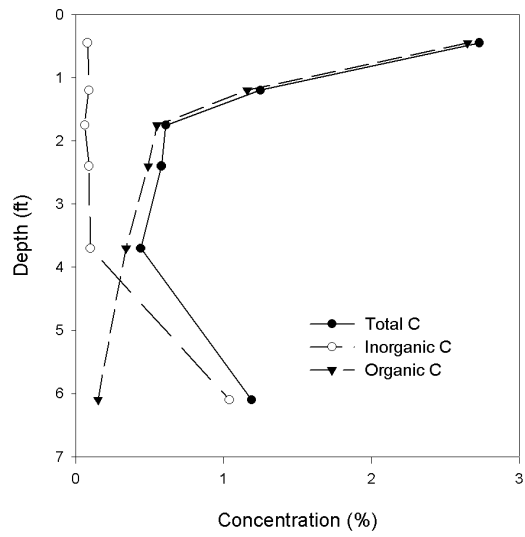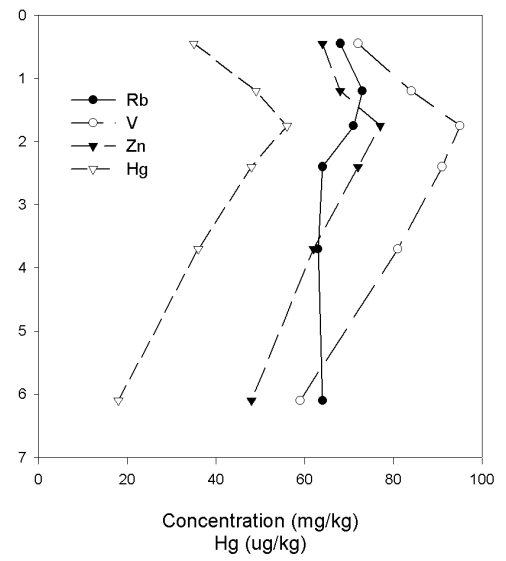
Core 72

Figure 47. Element concentrations versus depth in core 72.

122
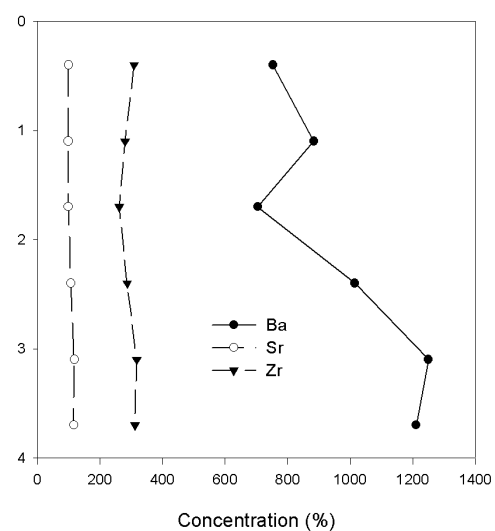
Figure 48. Element concentrations versus depth in core 73.

Core 73

Figure 49. Element concentrations versus depth in core 73.

124
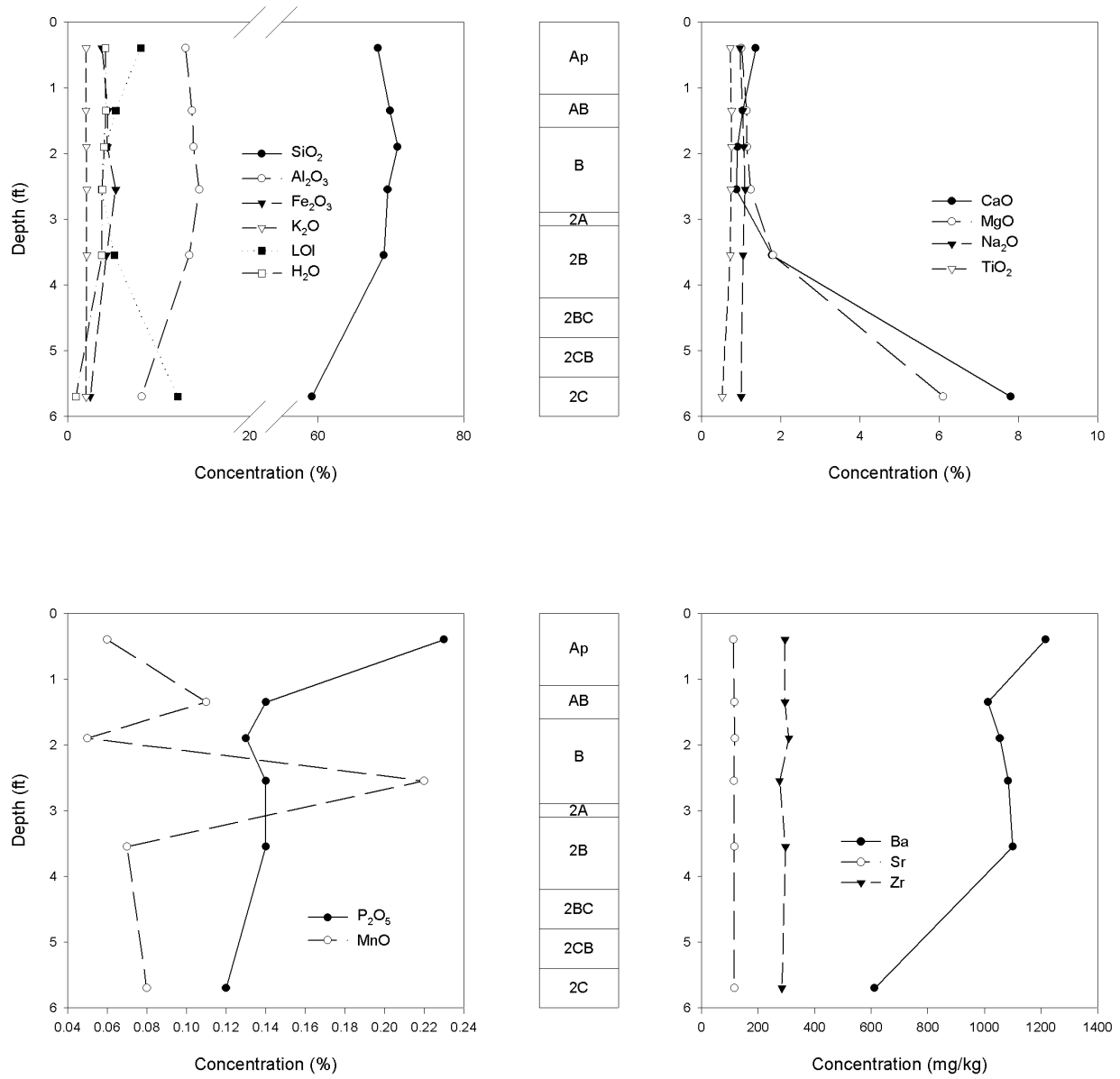
Figure 50. Element concentrations versus depth in core 74.

125
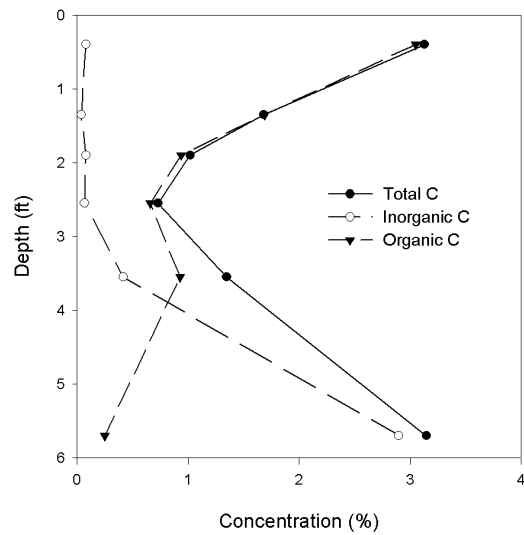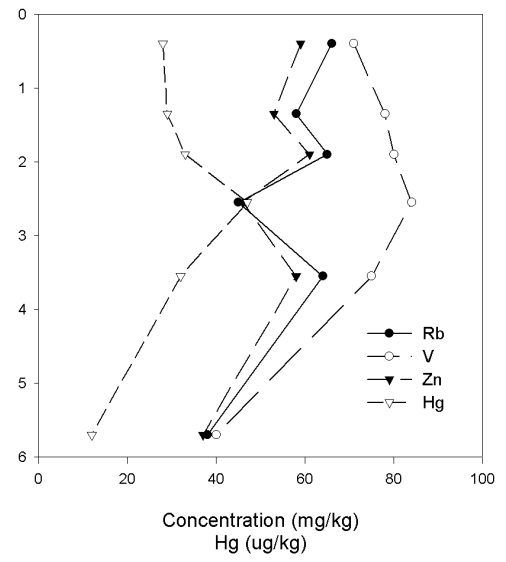
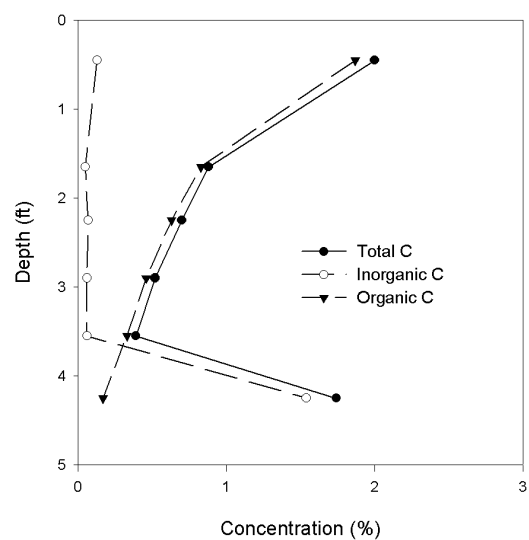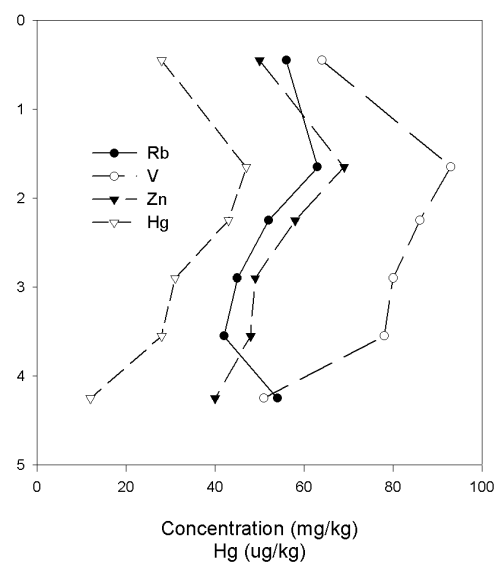**Figure 51.** Element concentrations versus depth in core 74.

Core 75

Figure 52. Element concentrations versus depth in core 75.

127

Core 75

Figure 53. Element concentrations versus depth in core 75.

128

Core 76

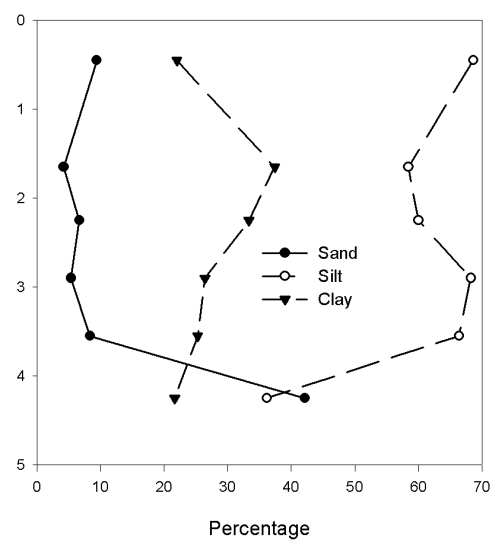**Figure 54.** Element concentrations versus depth in core 76.

Core 76

Figure 55. Element concentrations versus depth in core 76.