

**A Progress Report on the Description of the Geology and
Chemical Composition of Soils in Illinois:
Cores 77 through 101**

by

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CONTENTS

PREFACE	ii
INTRODUCTION	1
BACKGROUND	3
DEFINITION OF TERMS	10
FIELD METHODS	11
LABORATORY METHODS	12
RESULTS AND DISCUSSION	15
CONCLUSIONS	28

PREFACE

This report is a progress report to present analytical chemistry data on soil cores 77 through 101 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 for geological and chemical information about the geological materials and soils of Illinois. In addition, the ISGS conducts research on important geology-related 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. When the available information is insufficient to answer a question, 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, four open-file reports, presenting preliminary results from samples of cores 1 through 76, have been published (Dreher et al., 2002, 2003a, 2003b, 2004).

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,” the unweathered rock or sediment with 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 weathering, or “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, reports of water-well and other drillers, 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 77 through 101 of a total of 137 coring sites from across the state. These cores were collected in central Illinois during the fall of 2001. 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 by 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 other parts of the state.

The purpose of this project is to determine the chemical and mineralogical characteristics of soils and their underlying un lithified 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 enclosing 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 sediments. In many places the surfaces of these deposits 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 these former glacial meltwater channels form the excellent aquifers that supply water to many cities in Illinois.

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 these 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 existed 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, which differ from typical lake deposits, 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, geologists are 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 were 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 and east 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 west 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 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 in 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 (soil development), 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 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 for the loess. 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 that 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 through 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 deposited in lower horizons (illuviation) (Hassett and Banwart, 1992), or to 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).

Time 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 and power generating plants could cause widespread dispersion of metals at large distances from their source (Mattigod and Page, 1983).

Other factors 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 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 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 2001 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 2001. Cores were collected at 25 locations during October 2001, after harvest was completed. The “plus” 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), zinc (Zn), and zirconium (Zr)].

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

To prepare samples for major and minor element determinations, aliquots of approximately 2 grams of 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 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 samples 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 the 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 in the <208- μ m samples were determined using a Coulometrics Inc.® carbon analyzer. For determinations of total carbon, a weighed amount, 10 to 30 mg, of the disaggregated, sieved 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 (CO₂) gas. The generated CO₂ 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 CO₂ that was absorbed 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 pH electrode immersed in the slurry. The pH was determined with a Hanna Instruments® model HI9025C pH meter and a ThermoOrion® model 9165BN Sure Flow pH electrode.

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 (NaPO₃)₆ was added to the bottle followed by 140 mL of deionized water. A blank sample containing only (NaPO₃)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 22 minutes to allow particles larger than 2 μ m 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 $(\text{NaPO}_3)_6$ 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 polymethylpentene bottle. 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 65°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 15 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 next morning the bottles were allowed to cool to room temperature. A 10-mL volume of $(\text{NaPO}_3)_6$ solution and 140 mL of deionized water were added to each bottle. 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 the odd-numbered figures 7 through 55. The proportions of sand, silt, and clay in a sample were 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 13 of the cores were silt loam, seven were silty clay loam, two were loam, one was loamy sand, one was sandy loam, and one was clay loam, as indicated in tables 2 through 26. As shown in table 27, the parent material of the soil at location 80 was alluvium, that is, it was deposited as flood plain sediments, and later became covered by forest. The soils of cores 79, 82, 84 through 87, 92, and 93 developed in upland forest, and the soils of cores 89 and 97 developed on a lake bottom which was later covered by prairie. The remaining 14 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 1% to 57%, the silt contents ranged from about 1% to 86%, and the sand contents from 0.2% 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. 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 .

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 the end of the report). Major and minor element contents reported as oxides (silicon through manganese in the tables) are listed first, followed by the 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 those 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 $\mu\text{g/kg}$.

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 0.88 (Table 28). That is, in about 88% of the samples, as the content of the clay-size fraction 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 77 through 101. 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 correlation between silica and the sand-size fraction (0.41) for these 25 cores is low and does not confirm the previous observations. However, in these samples we observed that in several samples the sand- and silt-size fractions included not only silica, but also calcite and/or dolomite particles, especially in the lowermost samples taken from depths at which the core penetrated the underlying calcareous till. When we added the three constituents, SiO_2 , CaO , and MgO and calculated the correlation coefficient with the sand+silt size fraction, the correlation coefficient was 0.70. The correlation coefficient between zirconium and the silt-size fraction was found to be 0.74.

Titanium oxide (TiO_2) was correlated (0.67) with the silt-size fraction, but it was also correlated (0.60) with the clay-size fraction. A possible explanation for this complex situation is that rutile (TiO_2), ilmenite (FeTiO_3), and anatase (TiO_2) may all be present in many of the soil samples. Rutile and ilmenite could 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 may occur in both the silt-size and the clay-size fractions (Steinkoenig, 1914).

Aluminum (as Al_2O_3), a major constituent of clay minerals and other minerals in the clay-size fraction, demonstrated a strong positive correlation with the clay-size fraction (0.88).

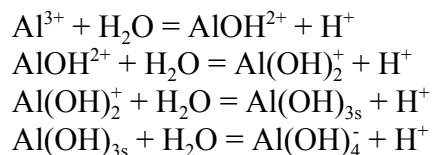
The clay-size fraction also was positively correlated with iron (0.56), potassium (0.56), titanium (0.60), nickel (0.59), rubidium (0.77), vanadium (0.85), and zinc (0.52). Therefore, these elements also correlated with each other. Mercury was correlated with iron (0.52), lead (0.71), and zinc (0.54).

Iron is a necessary element in the crystal structure of certain clay minerals, although it may also occur as a non-structural exchangeable ion in 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 elements nickel, 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 (0.96) and with inorganic carbon content (0.99 and 0.97, respectively). These correlations suggest the presence of calcite and dolomite in the soil samples. Titanium oxide and zirconium were correlated with each other (0.68). Each was also correlated with the silt-size fraction (0.67 and 0.74, 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):



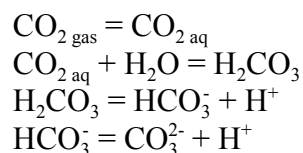
If small amounts of gibbsite, $[Al(OH)_3]$ or clay minerals in the soil dissolve to contribute Al^{3+} to the soil solution, the Al^{3+} becomes hydrolyzed to $AlOH^{2+}$, which results in the addition of H^+ to the solution, and this results in greater acidity. If additional H^+ enters the soil solution, 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 can 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)

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):



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 4.44 (moderately acidic) to 8.71 (moderately alkaline), with a median value of 6.98. Of the 150 samples, 80 had a pH between 4 and 7 and the remaining 70 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). One sample, the lowermost sample of core 78, had a pH of 8.71. As shown in Figure 5 and Tables 29 through 53, the pH value in 15 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 20 of the 25 coring locations (cores 78-80, 82, 85-98, 100, and 101). In all of these cores, except core 80, the calcium oxide and magnesium oxide contents increased sharply in the sample(s) that were

taken from the till. In core 80, only the CaO content increased. Calcium carbonate in the till imposed 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 60% 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).

The most noticeable features about the SiO_2 content versus depth are (1) SiO_2 content decreased when CaO and MgO contents increased, such as in cores 77-79, 85-98, 100, and 101; (2) in nearly every core in which the CaO and MgO contents were low, the appearances of the Al_2O_3 and SiO_2 depth profiles were mirror images.

In several cores (79, 82, 86-88, 90, 91, 93, 95, 98, 100, and 101) the SiO_2 content decreased with depth, especially in cores for which samples were selected only from the modern soil. In cores in which one or more samples were selected from an underlying paleosol (cores 83, 84, 89, and 93), the SiO_2 content decreased or remained steady in the modern soil horizons, 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, became more concentrated in the paleo-A horizon as other constituents were leached downward.

When the CaO and MgO contents increased at depth in the profile, the SiO₂ content generally decreased because of dilution of the sample by calcite (CaCO₃) or dolomite [CaMg(CO₃)₂]. When the CaO and MgO contents increased sharply and the SiO₂ content decreased, this occurred most frequently in samples from the C horizon.

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 Al₂O₃ content versus depth in many cases were mirror images of the SiO₂ profiles. When CaO and MgO contents increased significantly, the Al₂O₃ content commonly decreased because of dilution by calcite or dolomite, as in cores 78, 79, 85-94, 96, 98, 100, and 101. Cores 95 and 97 were exceptions, but in both cores the Al₂O₃ content followed the trends in clay content. The content of Al₂O₃ is largely associated with the clay mineral content of the samples, whereas the SiO₂ content is generally associated with the sand and silt fractions.

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 Fe₂O₃ content in these cores tended to vary within a small range. In all but two cores (80 and 97) the Fe₂O₃ content passed through a maximum with increasing depth, generally in the B horizon, the clay-rich zone in the soil profile. In core 97 the maximum Fe₂O₃ content was in the C horizon, as was the maximum for 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 ion-exchange complex. Because potassium-rich 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.

For most cores, the K₂O content did not vary appreciably and remained between 1 and 2%. There were, however, noticeable increases in K₂O content in samples with more than 30% clay-size

content (for example, cores 97, 100, and 101). Possibly the illite content of these particular samples was greater than in other samples.

Calcium and Magnesium Calcite (CaCO_3) and dolomite [$\text{CaMg}(\text{CO}_3)_2$] 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 ion-exchange complex. Because dolomite is a major component of many rocks in Illinois, it is probably the principal source of magnesium in Illinois soils.

The CaO content in core 80 was greatest in the uppermost sample and quickly decreased to near constant values in samples from greater depths. Limestone pebbles were observed at the surface of the core where the core was collected, and this probably provided the elevated CaO content found in the uppermost sample. In several cores, the lowermost sample or the next-to-lowest sample had elevated CaO and MgO contents (cores 78, 79, 82, 83, 85-98, 100, and 101). Each of these cores apparently penetrated an underlying till with a large content of carbonate minerals.

The lowermost samples of cores collected from the Illinoian till plain (cores 77-85 and 90-92) contained less calcite/dolomite than the lowermost samples of cores collected from the Wisconsinan till plain (cores 86-89 and 93-101). For the cores collected from the Illinoian till plain, the average CaO and MgO contents of the samples of till were $4.16 \pm 1.13\%$ and $2.93 \pm 0.95\%$, respectively. For cores collected from the Wisconsinan till plain, the average CaO and MgO contents in the till samples were $8.06 \pm 4.14\%$ and $5.64 \pm 2.94\%$, respectively. The average contents of both CaO and MgO from Wisconsinan till plain samples were nearly twice those of samples from the Illinoian till plain. The Illinoian till plain samples have been exposed to weathering and leaching for thousands of years longer than the Wisconsinan till plain samples, thus the lower CaO and MgO contents in the samples from the Illinoian till plain. Figure 56 is a scatter plot of the CaO and MgO content data for all samples from cores 77 through 101. The line through the points represents the theoretical composition of dolomite. When the regression line for the points was plotted on the graph it fell directly on top of the theoretical composition line. This indicates that dolomite was the dominant Ca-Mg mineral in the 25 cores.

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 contents in the 25 cores was small, with a difference of only 1.30% between the minimum value of 0.16% and the maximum of 1.46%. In 15 of the 25 cores (77-80, 82, 83, 85, 87, 89-92, 94, 95 and 99) the Na_2O content attained a maximum value in the B horizon or below, suggesting downward leaching of soluble sodium-containing compounds.

Titanium The sources of titanium in soils probably are the minerals 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). Despite the low solubilities of the titanium-rich minerals, the titanium content of the soils 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 it difficult to relate its content to the presence of particular minerals. Apatite [$\text{Ca}_5(\text{F}, \text{Cl}, \text{OH})(\text{PO}_4)_3$] 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 (cores 79, 81, 83, 85, 88, 89, 91, 92, 94, and 95-101) or second sample from the top (cores 77 and 78) of the core. In the remaining cores the greatest content of P_2O_5 was in the B horizon or below.

Manganese The principal source minerals for manganese in soils are the rock-forming minerals amphiboles, pyroxenes, biotite mica [$\text{K}(\text{Mg}, \text{Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$] (in which Mn can replace iron to a limited extent), and rhodonite (MnSiO_3) (Sparks, 1995). Although manganese commonly occurs in soil as coatings on other minerals (Kabata-Pendias, 2001), it is also commonly found concentrated in concretions of MnO_2 accompanied by iron. These concretions 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.

Because of the complex situation of interaction between redox potential, pH, and the possibility of colloidal transport, the depth profiles for MnO are not uniform. In cores 77, 79, 84-87, 92-94, and 101 the MnO content was greatest in the A or E horizon. Oxidized species, such as MnO_2 , precipitate where oxygen is readily available, as it normally would be near the soil surface. In 14 cores (78, 80-83, 88-91, 95-98, and 100) the MnO content passed through a maximum in the B horizon or below. This might indicate that colloidal-sized particles containing Mn migrated from higher positions in the soil profile.

Barium Micaceous and feldspar 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 [$\text{Ba}(\text{Mn}^{4+}, \text{Mn}^{2+})_8\text{O}_{16}$, 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 greater than normal content of Ba in the surface horizon is expected. As mentioned above, barium also reacts with sulfate to form the sparingly soluble barium sulfate.

The Ba content in many of the cores was at a maximum in either the A horizon, such as in core 79, or slightly below the A horizon, as in core 88. In cores 80 and 82 the Ba content achieved its maximum deeper in the core, at depths of 5 feet or below. The propensity of Ba to adsorb on clay minerals might explain the subsurface maxima in the Ba content, commonly in the B horizon. The Ba may have been carried downward as colloidal clay particles, to which the Ba is adsorbed, move downward in the soil profile.

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.

The Cr content was not well correlated with any other constituent for which we analyzed, which suggests multiple modes of occurrence. In cores 77, 78, 80, 87, 89, and 100 Cr generally followed the silt-sized content; in cores 79, 82, 96, and 98 the Cr content generally followed the clay-size content, and in core 97 it followed the sand-size content, especially in the bottom four samples. In 20 of the cores the maximum Cr content occurred in the BA, B, or C horizon, which is indicative of downward migration of Cr in the soil column. In the other five cores (82, 86, 90, 96, and 97), however, the maximum Cr content occurred in the A, AB, or E horizon.

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).

In some cores, for example 77, 79, and 80, the depth profile of the Cu content follows that of Cr. The maximum Cu content commonly occurred in the B horizon or in the transition zone between the A and B horizons. The copper contents of the 25 cores were in the range of <5 to 133 mg/kg.

The Cu content was below the detection limit of 5 mg/kg in one sample from core 77 and two samples from core 78.

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 in the 25 cores ranged from 8 to 147 mg/kg. In all but 8 cores (77, 78, 83, 84, 88, 96, 97, and 98) the maximum Pb content was in the uppermost sample, suggesting accumulation due to an external source. In the eight exceptional cores the maximum Pb content was in or below the B horizon. In 15 of the cores in which the maximum Pb content occurred in the uppermost sample there was a secondary maximum in the B horizon (or CB horizon in one instance), suggesting adsorption and accumulation by clay minerals. Lead was correlated with Zn (0.56) and Hg (0.71).

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 Hg content of the 25 cores was in the range of 3 to 123 $\mu\text{g/kg}$ (parts per billion). In 19 cores the maximum Hg content occurred in or below the B horizon. In the remaining six cores (79, 88, 92, 93, 99, and 100) the maximum Hg content occurred in the A, E, or BE horizon. In cores 88, 92, and 99 there was a secondary maximum of mercury in the BC, BA, or B horizon, respectively. The occurrences of maximum Hg contents in the uppermost sample, as in the noted six cores, suggests an external source.

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 Ni content ranged from 8 to 64 mg/kg in the 25 cores. In all but 5 cores the maximum Ni content occurred in the B horizon and in those exceptional cores the maximum content was in the transitional zone between the B and C horizons. The Ni content was correlated with the clay-size content (0.59), probably due to adsorption of Ni on clay minerals. Nickel content was also correlated with Al_2O_3 (0.57) and Fe_2O_3 (0.54). Alumina is a building block of clay minerals, hence the dual association of Ni with both clay-size content and Al_2O_3 . Iron oxyhydroxides, represented as Fe_2O_3 , occurred in the clay-size range or was adsorbed on clay-size particles, and may have served as a substrate to which Ni could adsorb. In addition, Ni was correlated with Rb (0.61), V (0.68), and Zn (0.58), all of which commonly are adsorbed by clay minerals and/or iron oxyhydroxides.

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 the 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 two of the uppermost samples fell within these ranges, and in both of those samples the content was less than 45 mg/kg.

The Rb content in all samples from the 25 cores ranged from 20 to 179 mg/kg. The correlation coefficient of Rb with SiO_2 was -0.53, with Al_2O_3 it was 0.63, with K_2O it was 0.86, and with clay-size content it was 0.77. These four correlations indicate that Rb was associated with clay minerals. The correlation with K_2O suggests that Rb may have substituted for K in certain minerals. In addition, Rb was correlated with Ni (0.61), V (0.75), and Zn (0.63), an indication that Rb was adsorbed on clay minerals along with Ni, V, and Zn.

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 geochemically with calcium. 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 content varied between 56 and 177 mg/kg. In some cores, such as 87, 91, 100, and 101, the Sr content was nearly constant throughout 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 V content in all but three cores (77, 80, and 97) was at its maximum in the B horizon or the BA transition zone (core 92). In every core the depth profile for V generally followed the clay-size depth profile, more closely in some cores (for example core 79) than in others (for example core 90). This parallelism suggests adsorption of V by clay minerals. The depth profiles of Zn and Hg were often parallel with those for V, indicating that all three elements were adsorbed by clay minerals.

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.

The Zn content of these 25 cores was in the range of 5 to 198 mg/kg, and was greatest in the B horizon or below in 20 cores. In the remaining 5 cores (82, 90, 92, 99, and 100) the maximum Zn content occurred in the A horizon, but there were secondary maxima in the B or CB horizon of three of the five (82, 99, and 100). Both Zn and Pb were at their maximum contents in the uppermost sample of cores 82, 90, 92, and 100. This suggests an external source of Zn and Pb, for example from application of sewage sludge, or from fallout from smelters or other industrial sources.

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 range of Zr contents was 53 to 505 mg/kg in the 25 cores. There was a correlation coefficient of 0.74 between Zr and the silt-size fraction. In some of the cores (79, 81, 87, 88, 90, 93, 96-98, 100, and 101) the Zr content was greatest in the surface sample and decreased with depth. In a few cores the Zr content passed through a maximum below the surface (cores 78, 89, 92, 94, 95, and 99), but in others it passed through a minimum (cores 77, 80, 82-84, and 86). In two cores the Zr content did not vary appreciably with depth (85 and 91).

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 all but three cores (78, 80, and 98) the maximum organic C content occurred in the uppermost sample and decreased with depth. Many of the cores (78, 79, 82, 83, 85-98, 100, and 101) penetrated the underlying calcareous or dolomitic till, as evidenced by a sharp increase in inorganic C and parallel increases in CaO and MgO. Above the till and in the few cores for which till samples were not selected (cores 77, 84, and 99), the inorganic C content was relatively invariant with depth. In cores 80 and 81 the maximum inorganic C content occurred in the uppermost samples. The uppermost samples of cores 80 and 81 contained limestone pebbles or sand. Whether these pebbles or sand particles occurred naturally or were derived from an external source, such as the nearby (within 30 feet) gravel road or driveway is not known.

CONCLUSIONS

The contents of nickel, rubidium, vanadium, and zinc were correlated with the content of clay-sized particles. Each of these metals is easily sorbed by various clay minerals. As colloidal-sized clay minerals migrate downward through the soil column, any elements attached to the clay particles are also transported. The content of Al_2O_3 , a building block of clay minerals, was also correlated with clay-size content.

The calcareous or dolomitic till beneath the surficial loess was penetrated in 19 cores and in samples selected from the till sharp increases in CaO, MgO, and inorganic C and decreases in SiO_2 and Al_2O_3 were observed.

Titanium dioxide 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 came 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)
77	Logan	24.0
78	Mason	14.2
79	Fulton	23.0
80	McDonough	20.0
81	Hancock	14.2
82	Hancock	23.0
83	McDonough	9.6
84	Fulton	9.2
85	Fulton	17.4
86	Tazewell	22.0
87	Woodford	19.2
88	McLean	16.5
89	Ford	22.0
90	Warren	24.0
91	Knox	22.5
92	Peoria	18.2
93	Peoria	12.0
94	Woodford	16.2
95	Livingston	15.0
96	Livingston	13.0
97	Iroquois	20.7
98	Kankakee	4.1
99	Iroquois	6.5
100	Iroquois	9.0
101	Iroquois	14.0

Table 2. Texture of samples from core 77*

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
77-1	0.0-1.0	Ap	22.95	1.98	75.07	silt loam
77-2	1.0-1.7	AB	30.24	1.78	67.98	silty clay loam
77-5	1.7-3.2	Bt	27.64	1.42	70.94	silty clay loam
77-8	4.4-5.0	Bt1	21.20	2.10	76.66	silt loam
77-14	7.3-7.8	C	4.10	88.14	7.769	loamy sand
77-26	12.9-13.6	Ab	15.58	1.85	82.57	silt loam

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

Table 3. Texture of samples from core 78

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
78-1	0.0-1.1	Ap	3.76	81.72	14.52	loamy sand
78-3	1.4-2.0	Bt1	30.52	16.21	53.27	silty clay loam
78-4	2.0-2.4	Bt1	25.00	48.64	26.36	sandy clay loam
78-9	4.3-4.6	C	3.86	95.12	1.02	sand
78-12	5.2-6.0	β	6.62	91.14	2.24	sand
78-17	9.05-9.5	C	1.10	96.04	2.86	sand

Table 4. Texture of samples from core 79

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
79-1	0.0-0.6	Ap	15.50	2.14	82.36	silt loam
79-2	0.6-1.0	E	19.44	1.94	78.62	silt loam
79-3	1.0-1.4	BE	30.84	1.78	67.38	silty clay loam
79-4	1.4-2.0	Bt	28.63	0.84	60.53	silty clay loam
79-6	2.6-3.7	Bt2	30.92	0.64	68.44	silty clay loam
79-11	5.2-6.0	C	18.16	0.69	81.16	silt loam

Table 5. Texture of samples from core 80

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
80-1	0.0-0.5	Ap	13.95	42.01	44.04	loam
80-4	0.95-1.4	C/A	16.96	29.82	43.23	silt loam
80-8	2.5-2.9	CB	16.06	47.25	36.70	loam
80-10	3.5-3.9	2CB	20.42	16.04	63.55	silt loam
80-15	4.8-5.4	4B	20.47	15.64	63.89	silt loam
80-20	7.2-8.0	5Ab	24.52	26.64	48.84	loam

Table 6. Texture of samples from core 81

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
81-1	0.0-0.8	A	22.63	8.71	68.66	silt loam
81-2	0.8-1.8	AB	26.86	4.10	69.04	silt loam
81-3	1.8-2.4	Bt	38.71	3.81	57.48	silty clay loam
81-5	3.0-3.7	Btg	39.84	16.90	43.26	silty clay loam
81-7	4.4-4.9	Btg	42.75	18.23	39.02	clay
81-13	7.3-8.0	Btox	31.63	29.14	29.22	clay loam

Table 7. Texture of samples from core 82

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
82-1	0.0-0.7	A	23.39	1.98	74.63	silt loam
82-2	0.7-1.3	AB	31.85	0.66	67.49	silty clay loam
82-3	1.3-2.0	Bt	21.48	1.48	77.04	silt loam
82-4	2.0-3.2	Bt	32.46	0.97	66.57	silty clay loam
82-9	5.5-6.1	CBgt	26.09	1.10	72.81	silt loam
82-13	8.0-8.75	Cgtj	18.72	0.90	80.38	silt loam

Table 8. Texture of samples from core 83

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
83-1	0.0-0.7	A	30.79	1.08	68.13	silty clay loam
83-2	0.7-1.4	A	33.12	1.26	35.62	silty clay loam
83-4	2.6-3.3	Bgt	35.86	1.64	62.50	silty clay loam
83-5	3.3-4.0	Bgt	32.28	0.58	67.14	silty clay loam
83-10	6.5-7.1	BCtj	19.43	0.84	79.73	silt loam
83-14	8.6-9.3	2Ab	27.90	12.27	59.83	silty clay loam

Table 9. Texture of samples from core 84

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
84-1	0.0-0.6	Ap	22.78	6.42	70.80	silt loam
84-2	0.6-1.3	Btj	32.00	4.67	63.33	silty clay loam
84-3	1.3-2.0	Bt	30.35	8.46	31.19	silty clay loam
84-5	2.7-3.4	Bt	26.90	7.49	65.61	silty clay loam
84-9	4.7-5.4	2Bw	10.24	83.94	5.82	loamy sand
84-14	7.5-8.0	2C	11.60	67.03	21.37	sandy loam

Table 10. Texture of samples from core 85

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
85-1	0.0-0.3	Ap	21.23	2.69	76.08	silt loam
85-2	0.3-1.2	Bt	29.23	1.13	69.64	silty clay loam
85-3	1.2-2.0	Bt	32.15	0.82	67.03	silty clay loam
85-5	2.6-3.4	Bt	31.23	0.85	67.92	silty clay loam
85-9	5.5-6.1	CBt	23.31	2.85	73.84	silt loam
85-13	7.5-8.1	C	16.48	1.54	81.98	silt loam

Table 11. Texture of samples from core 86

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
86-1	0.0-0.7	Ap	16.26	4.10	79.64	silt loam
86-2	0.7-1.4	E	9.71	4.21	86.08	silt
86-3	1.4-2.0	Bt	41.53	1.86	56.61	silty clay
86-5	2.6-3.2	Bt	33.31	2.10	64.59	silty clay loam
86-7	4.0-4.7	B3	28.21	1.47	70.32	silty clay loam
86-12	7.0-7.6	C	17.40	1.98	80.62	silt loam

Table 12. Texture of samples from core 87

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
87-1	0.0-0.7	Ap	17.47	4.45	78.08	silt loam
87-2	0.7-1.4	AE	15.56	4.29	80.15	silt loam
87-3	1.4-2.0	EB	13.36	4.12	82.52	silt loam
87-4	2.0-2.7	Bt	33.54	1.46	65.00	silty clay loam
87-5	2.7-3.4	BC	24.19	1.16	74.65	silt loam
87-6	3.4-4.0	C	18.38	1.04	80.58	silt loam

Table 13. Texture of samples from core 88

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
88-1	0.0-0.6	Ap1	27.44	9.27	63.29	silty clay loam
88-2	0.6-1.4	Ap2	31.82	3.74	64.44	silty clay loam
88-3	1.4-2.0	Btj	34.76	1.82	63.42	silty clay loam
88-5	2.6-3.1	Bt	33.92	7.540	58.54	silty clay loam
88-7	3.6-4.0	2BC	37.81	34.10	28.09	clay loam
88-8	4.0-4.6	2CBt	15.98	44.04	39.98	loam

Table 14. Texture of samples from core 89

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
89-1	0.0-1.0	Ap	27.67	11.72	60.61	silty clay loam
89-2	1.0-1.5	Bg1	31.31	6.15	62.54	silty clay loam
89-3	1.5-2.0	Bgt21	42.74	3.61	53.65	silty clay
89-4	2.0-2.8	Bgt22	37.16	3.78	59.06	silty clay loam
89-5	2.8-3.3	2Bg3	12.44	59.87	29.69	sandy loam
89-7	3.7-4.1	2C	7.84	76.01	16.15	sandy loam

Table 15. Texture of samples from core 90

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
90-1	0.0-1.1	Ap	23.35	2.40	74.25	silt loam
90-2	1.1-1.6	BA	26.47	1.48	72.05	silt loam
90-3	1.6-2.3	Btj	28.66	1.41	69.93	silty clay loam
90-5	3.0-3.6	Bw	29.52	1.61	68.87	silty clay loam
90-7	4.2-4.9	BCtj	25.55	1.24	73.21	silt loam
90-11	6.8-7.5	C	18.96	0.99	80.05	silt loam

Table 16. Texture of samples from core 91

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
91-1	0.0-0.7	Ap1	26.20	0.572	73.22	silt loam
91-2	0.7-1.4	Ap2	27.81	0.55	71.64	silty clay loam
91-3	1.4-2.0	BA	30.46	1.223	68.32	silty clay loam
91-5	2.6-3.2	Btj	32.76	1.366	35.88	silty clay loam
91-7	3.7-4.3	CBtj	25.90	1.316	72.79	silt loam
91-11	6.2-6.8	C	20.06	0.34	79.60	silt loam

Table 17. Texture of samples from core 92

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
92-1	0.0-0.7	Ap	29.39	1.95	68.66	silty clay loam
92-2	0.7-1.1	AB	34.30	0.31	65.39	silty clay loam
92-3	1.1-1.5	BA	33.70	0.57	65.73	silty clay loam
92-4	1.5-1.9	Bt	29.83	0.52	69.65	silty clay loam
92-6	3.3-3.9	BCtj	22.47	0.20	77.33	silt loam
92-9	5.1-5.5	C	17.50	0.22	82.88	silt loam

Table 18. Texture of samples from core 93

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
93-1	0.0-0.6	A/E	17.86	0.99	81.15	silt loam
93-2	0.6-1.0	EB	25.68	0.52	73.80	silt loam
93-3	1.0-1.5	Bt	30.03	1.34	68.63	silty clay loam
93-4	1.5-2.0	Bt	30.74	1.20	68.06	silty clay loam
93-6	2.6-3.3	Bt2	23.98	4.09	71.93	silt loam
93-9	5.5-6.4	2C	24.44	35.30	40.26	loam

Table 19. Texture of samples from core 94

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
94-1	0.0-0.9	Ap	29.58	2.86	67.56	silty clay loam
94-2	0.9-1.5	A	32.45	2.90	24.65	silty clay loam
94-4	1.8-2.6	Bgt	32.79	3.02	64.19	silty clay loam
94-6	3.0-3.7	Bgtj	29.38	2.36	68.26	silty clay loam
94-8	4.1-4.6	C	13.58	2.64	83.78	silt loam
94-12	6.7-7.2	2C	6.70	68.86	24.44	sandy loam

Table 20. Texture of samples from core 95

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
95-1	0.0-0.9	Ap	26.27	18.25	55.48	silt loam
95-2	0.9-1.6	A	27.75	16.66	55.59	silty clay loam
95-3	1.6-2.1	Bgtj	36.30	11.56	21.14	silty clay loam
95-5	2.5-3.1	Bgt2	35.12	6.70	58.18	silty clay loam
95-8	3.8-4.5	2Cgt1	22.36	21.74	55.90	silt loam
95-13	6.5-7.1	3Cg	38.02	11.44	50.54	silty clay loam

Table 21. Texture of samples from core 96

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
96-1	0.0-1.0	Ap	39.73	7.70	52.57	silty clay loam
96-2	1.0-1.6	Bgt	41.68	17.07	41.25	silty clay
96-3	1.6-2.1	2CBtj	25.94	28.29	45.77	loam
96-4	2.1-2.8	2CBtj	28.32	22.10	49.58	clay loam
96-7	3.6-4.6	2C	38.37	8.14	53.49	silty clay loam
96-11	6.7-7.6	4C	38.92	10.98	50.10	silty clay loam

Table 22. Texture of samples from core 97

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
97-1	0.0-0.7	Ap	29.28	20.61	50.11	clay loam
97-2	0.7-1.3	A2	30.09	20.46	49.45	clay loam
97-3	1.3-2.0	Bg	32.52	19.62	47.86	clay loam
97-5	2.7-3.3	Bg	29.44	20.75	49.81	silty clay loam
97-7	4.0-4.8	C	34.62	4.55	60.83	clay loam
97-9	6.0-6.6	C	30.49	2.29	67.22	silty clay loam

Table 23. Texture of samples from core 98

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
98-1	0.0-0.8	Ap	19.99	30.33	49.68	loam
98-2	0.8-1.5	Bt	24.93	44.66	30.41	loam
98-3	1.5-1.9	Ab	19.49	43.59	36.92	loam
98-5	2.1-2.7	Bt	24.84	54.68	20.48	sandy clay loam
98-6	2.7-3.4	Bt	23.05	56.55	20.40	sandy clay loam
98-7	3.4-4.0	Cr	10.04	32.26	57.70	silt loam

Table 24. Texture of samples from core 99

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
99-1	0.0-0.9	Ap	7.28	74.76	17.96	sandy loam
99-2	0.9-1.3	BA	6.47	76.99	16.54	loamy sand
99-3	1.3-2.0	Bw	7.28	80.93	11.79	loamy sand
99-6	2.9-3.5	Bg	10.10	88.36	14.5	loamy sand
99-8	4.2-4.8	CBg	3.50	65.22	1.28	sand
99-9	5.0-5.7	Cg	3.06	65.58	1.36	sand

Table 25. Texture of samples from core 100

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
100-1	0.0-0.6	Ap	21.39	24.77	53.84	silt loam
100-2	0.6-1.1	BAt	31.60	17.39	51.01	silty clay loam
100-3	1.1-1.8	Bt	30.66	11.24	58.10	silty clay loam
100-5	2.0-2.4	B3t	18.43	10.83	70.74	silt loam
100-6	2.6-3.3	C	16.18	11.00	72.82	silt loam
100-8	4.1-4.8	C	13.84	5.62	80.54	silt loam

Table 26. Texture of samples from core 101

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
101-1	0.0-0.8	Ap	37.11	7.02	55.87	silty clay loam
101-2	0.8-1.3	BA	50.72	3.28	46.00	silty clay
101-3	1.3-2.0	Bgtj	56.04	2.88	41.08	silty clay
101-4	2.0-2.5	Bgt	56.85	5.57	37.58	clay
101-5	2.7-3.5	Cgtj	51.28	3.64	45.08	silty clay
101-7	4.2-4.8	Cg	50.51	5.17	44.32	silty clay

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

Core Number	Texture	Soil Type*	Soil Association	Developmental Environment
77	silt loam	Broadwell	Broadwell-Waukegan-Pillot	upland, prairie
78	loamy sand	Onarga	Sparta-Dickinson-Onarga	upland, prairie
79	silt loam	Fayette	Fayette-Rozetta-Stronghurst	upland, forest
80	loam	Wakeland	Haymond-Petrolia-Karnak	alluvium, forest
81	silt loam	Ipava	Tama-Ipava-Sable	upland, prairie
82	silt loam	Atterberry	Fayette-Rozetta-Stronghurst	upland, forest
83	silty clay loam	Ipava	Tama-Ipava-Sable	upland, prairie
84	silt loam	Rozetta	Fayette-Rozetta-Stronghurst	upland, forest
85	silt loam	Hickory	Fayette-Rozetta-Stronghurst	upland, forest
86	silt loam	Stronghurst	Fayette-Rozetta-Stronghurst	upland, forest
87	silt loam	Rozetta	Fayette-Rozetta-Stronghurst	upland, forest
88	silty clay loam	Elkhart	Tama-Ipava-Sable	upland, prairie
89	silty clay loam	Milford	Martinton-Milford	lacustrine, prairie
90	silt loam	Muscatine	Tama-Muscatine-Sable	upland, prairie
91	silt loam	Tama	Tama-Muscatine-Sable	upland, prairie
92	silty clay loam	Rozetta	Fayette-Rozetta-Stronghurst	upland, forest
93	silt loam	Strawn	Dodge-Russell-Miami	upland, forest
94	silty clay loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie
95	silty clay loam	Ashkum	Varna-Elliott-Ashkum	upland, prairie
96	silty clay loam	Ashkum	Varna-Elliott-Ashkum	upland, prairie
97	clay loam	Milford	Martinton-Milford	lacustrine, prairie
98	loam	Plattville	Channahon-Dodgeville-Ashdale	upland, prairie
99	sandy loam	Watseka	Sparta-Dickinson-Onarga	upland, prairie
100	silt loam	Lisbon	Saybrook-Dana-Drummer	upland, prairie
101	silty clay loam	Rutland	Wenona-Rutland-Streator	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 units in which cores were collected.

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

	Depth	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	LOI	Moisture	CaO	MgO
Depth	1								
SiO ₂	-0.13	1							
Al ₂ O ₃	-0.14	-0.36	1						
Fe ₂ O ₃	-0.10	-0.40	0.48	1					
K ₂ O	-0.04	-0.59	0.44	0.40	1				
LOI	0.11	-0.85	-0.05	0.05	0.31	1			
Moisture	-0.35	-0.15	0.77	0.51	0.15	-0.17	1		
CaO	0.31	-0.79	-0.21	-0.06	0.29	0.87	-0.38	1	
MgO	0.30	-0.85	-0.09	-0.06	0.41	0.87	-0.26	0.96	1
Na ₂ O	-0.05	0.40	0.11	-0.23	-0.24	-0.48	0.13	-0.40	-0.45
TiO ₂	-0.20	-0.13	0.68	0.25	0.29	-0.16	0.56	-0.28	-0.22
P ₂ O ₅	-0.22	-0.04	0.02	0.14	0.00	-0.03	0.18	-0.16	-0.18
MnO	-0.34	-0.03	0.10	0.18	0.06	-0.03	0.16	-0.11	-0.11
Ba	-0.22	-0.19	0.25	0.02	-0.02	-0.21	0.31	-0.44	-0.39
Sr	0.12	0.29	0.11	-0.16	0.04	-0.40	0.04	-0.29	-0.29
Zr	-0.22	0.26	0.35	-0.04	-0.14	-0.41	0.32	-0.44	-0.46
Cr	-0.25	0.00	0.35	0.27	0.09	-0.19	0.39	-0.21	-0.18
Cu	0.05	-0.06	0.20	0.27	0.02	-0.02	0.28	-0.12	-0.07
Ni	-0.05	-0.27	0.57	0.47	0.54	-0.12	0.41	-0.04	-0.07
Pb	-0.27	-0.16	0.04	0.43	0.14	0.11	0.14	-0.02	-0.01
Rb	-0.23	-0.53	0.63	0.43	0.86	0.21	0.37	0.13	0.24
V	-0.24	-0.31	0.84	0.50	0.47	-0.11	0.68	-0.18	-0.07
Zn	-0.26	-0.48	0.40	0.67	0.53	0.22	0.38	0.14	0.23
Hg	-0.37	-0.08	0.35	0.52	0.06	-0.08	0.49	-0.16	-0.18
Tot C	-0.04	-0.72	-0.18	-0.05	0.30	0.89	-0.24	0.82	0.78
In C	0.33	-0.78	-0.22	-0.05	0.29	0.88	-0.40	0.99	0.97
Org C	-0.58	0.03	0.05	-0.01	0.04	0.10	0.22	-0.18	-0.22
Sand	0.20	0.41	-0.75	-0.30	-0.41	-0.11	-0.59	0.03	-0.03
Silt	-0.12	-0.30	0.46	0.09	0.22	0.12	0.33	0.05	0.05
Clay	-0.24	-0.42	0.88	0.56	0.56	0.05	0.73	-0.15	0.01
Sand+Silt	0.23	0.36	-0.81	-0.50	-0.51	-0.01	-0.70	0.16	0.02
pH	0.44	-0.53	-0.05	0.10	0.35	0.51	-0.26	0.59	0.57

Table 28, continued

	Na ₂ O	TiO ₂	P ₂ O ₅	MnO	Ba	Sr	Zr	Cr	Cu
Na ₂ O	1								
TiO ₂	0.55	1							
P ₂ O ₅	0.35	0.31	1						
MnO	0.08	0.23	0.27	1					
Ba	0.39	0.48	0.20	0.23	1				
Sr	0.74	0.41	0.28	-0.03	0.37	1			
Zr	0.76	0.68	0.40	0.36	0.41	0.57	1		
Cr	0.11	0.22	0.02	-0.01	0.00	0.10	0.25	1	
Cu	-0.21	-0.06	-0.03	-0.03	0.02	-0.24	-0.18	0.00	1
Ni	-0.08	0.27	-0.06	0.06	-0.15	0.09	0.06	0.40	0.07
Pb	-0.12	0.09	0.41	0.28	0.00	-0.17	0.05	0.04	0.10
Rb	-0.18	0.49	0.07	0.14	-0.01	0.04	0.07	0.23	-0.03
V	0.16	0.71	0.15	0.19	0.13	0.19	0.46	0.39	0.08
Zn	-0.25	0.23	0.32	0.28	-0.18	-0.22	0.01	0.23	0.15
Hg	0.03	0.33	0.36	0.22	0.19	-0.04	0.24	0.19	0.18
Tot C	-0.43	-0.20	0.15	0.03	-0.29	-0.38	-0.35	-0.21	-0.12
In C	-0.45	-0.31	-0.19	-0.10	-0.44	-0.35	-0.48	-0.23	-0.10
Org C	0.02	0.17	0.55	0.22	0.20	-0.10	0.18	-0.01	-0.05
Sand	-0.39	-0.82	-0.32	-0.33	-0.37	-0.31	-0.68	-0.25	-0.03
Silt	0.52	0.67	0.37	0.40	0.32	0.36	0.74	0.16	-0.06
Clay	-0.13	0.60	0.04	0.02	0.21	-0.02	0.13	0.32	0.20
Sand+Silt	0.08	-0.57	-0.03	0.01	-0.22	-0.02	-0.12	-0.26	-0.16
pH	-0.22	-0.12	-0.06	-0.12	-0.34	-0.07	-0.33	-0.12	-0.08

Table 28, continued

	Ni	Pb	Rb	V	Zn	Hg	Tot C	In C	Org C
Ni	1								
Pb	0.06	1							
Rb	0.61	0.21	1						
V	0.68	0.16	0.75	1					
Zn	0.58	0.56	0.63	0.60	1				
Hg	0.23	0.71	0.21	0.40	0.54	1			
Tot C	-0.15	0.23	0.26	-0.14	0.29	-0.05	1		
In C	-0.06	-0.03	0.11	-0.21	0.14	-0.27	0.81	1	
Org C	-0.16	0.43	0.25	0.10	0.27	0.34	0.40	-0.22	1
Sand	-0.32	-0.14	-0.56	-0.75	-0.38	-0.33	-0.06	0.07	-0.20
Silt	0.10	0.11	0.28	0.47	0.20	0.20	0.10	0.00	0.16
Clay	0.59	0.16	0.77	0.85	0.52	0.40	-0.04	-0.15	0.17
Sand+Silt	-0.54	-0.12	-0.71	-0.78	-0.47	-0.34	0.06	0.17	-0.16
pH	0.07	0.06	0.22	-0.06	0.20	-0.18	0.48	0.58	-0.10

	Sand	Silt	Clay	Sand+Silt	pH
Sand	1				
Silt	-0.90	1			
Clay	-0.61	0.23	1		
Sand+Silt	0.56	-0.13	-0.93	1	
pH	0.01	0.02	-0.02	0.05	1

Table 29. Elemental composition of samples selected from Core 77

Subsample	77-1	77-2	77-5	77-8	77-14	77-26	Average
Lab. No.	R22704	R22705	R22706	R22707	R22708	R22709	
Depth Interval (ft)	0.0-1.0	1.0-1.7	1.7-3.2	4.4-5.0	7.3-7.8	12.9-13.6	
Horizon	Ap	AB	Bt	Bt1	C	Ab	
SiO ₂ (%)	69.96	66.21	67.87	71.76	90.17	72.56	73.09
Al ₂ O ₃ (%)	10.87	13.65	14.61	12.54	5.42	12.28	11.56
Fe ₂ O ₃ (%)	3.12	4.07	4.85	4.31	1.05	4.07	3.58
K ₂ O (%)	1.99	1.96	1.98	2.09	1.49	2.21	1.95
CaO (%)	0.56	0.46	0.42	0.59	0.26	1.07	0.56
MgO (%)	0.57	0.84	0.92	0.77	0.14	0.82	0.68
Na ₂ O (%)	0.85	0.73	0.91	1.13	0.72	1.45	0.97
TiO ₂ (%)	0.71	0.71	0.66	0.64	0.13	0.71	0.59
P ₂ O ₅ (%)	0.14	0.12	0.10	0.13	0.05	0.14	0.11
MnO (%)	0.14	0.13	0.10	0.09	0.02	0.04	0.09
Barium	1170	1448	956	1086	428	723	969
Chromium	59	69	70	61	22	64	58
Copper	21	41	39	24	<5	53	31
Mercury (µg/kg)	24	30	36	27	6	29	25
Nickel	8	9	20	14	16	9	13
Lead	13	16	19	19	12	21	17
Rubidium	38	43	57	52	25	41	43
Strontium	112	102	107	137	108	169	123
Vanadium	44	47	45	44	31	50	44
Zinc	12	12	14	12	8	13	12
Zirconium	301	281	286	347	113	357	281
Total C (%)	1.85	1.44	0.45	0.43	0.12	0.35	0.77
Inorganic C (%)	0.09	0.10	0.06	0.06	0.03	0.04	0.06
Organic C (%)	1.76	1.34	0.39	0.37	0.09	0.31	0.71
pH	6.54	6.15	5.90	6.50	7.66	8.17	6.82

Table 30. Elemental composition of samples selected from Core 78

Subsample	78-01	78-03	78-04	78-09	78-12	78-17	Average
Lab. No.	R22710	R22711	R22712	R22713	R22714	R22715	
Depth Interval (ft)	0.0-1.1	1.4-2.0	2.0-2.4	4.3-4.6	5.2-6.0	9.05-9.5	
Horizon	Ap	Bt1	Bt1	C	β	C	
SiO ₂ (%)	89.42	67.50	75.96	92.82	91.08	78.70	82.58
Al ₂ O ₃ (%)	3.80	14.71	11.12	3.32	3.82	2.50	6.55
Fe ₂ O ₃ (%)	1.23	4.28	3.29	0.71	1.07	0.84	1.90
K ₂ O (%)	1.11	1.60	1.32	1.10	1.08	0.72	1.16
CaO (%)	0.18	0.17	0.13	0.12	0.12	3.97	0.78
MgO (%)	0.14	0.86	0.61	0.08	0.14	1.89	0.62
Na ₂ O (%)	0.48	0.44	0.45	0.47	0.52	0.55	0.49
TiO ₂ (%)	0.18	0.57	0.34	0.07	0.09	0.10	0.23
P ₂ O ₅ (%)	0.05	0.06	0.06	0.03	0.04	0.04	0.05
MnO (%)	0.03	0.11	0.07	0.02	0.03	0.03	0.05
Barium	259	467	401	431	414	273	374
Chromium	24	82	61	17	25	16	38
Copper	16	80	23	133	<5	<5	44
Mercury (µg/kg)	10	40	32	5	9	5	17
Nickel	8	18	14	12	13	9	12
Lead	11	17	16	12	14	11	14
Rubidium	24	51	39	22	24	20	30
Strontium	77	88	75	88	99	88	86
Vanadium	26	50	37	24	26	15	30
Zinc	7	13	11	6	8	5	8
Zirconium	134	238	140	59	89	53	119
Total C (%)	0.66	0.55	0.73	0.14	0.17	1.44	0.62
Inorganic C (%)	0.03	0.04	0.07	0.05	0.05	1.39	0.27
Organic C (%)	0.63	0.51	0.67	0.09	0.12	0.05	0.35
pH	6.40	5.13	5.06	5.54	5.86	8.71	6.12

Table 31. Elemental composition of samples selected from Core 79

Subsample	79-01	79-02	79-03	79-04	79-06	79-11	Average
Lab. No.	R23011	R23012	R23013	R23014	R23015	R23016	
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	E	BE	Bt	Bt2	C	
SiO ₂ (%)	79.59	79.94	73.78	69.76	71.37	62.34	72.80
Al ₂ O ₃ (%)	7.71	8.87	12.28	14.64	13.52	10.02	11.17
Fe ₂ O ₃ (%)	2.33	2.68	4.24	5.10	5.17	3.26	3.80
K ₂ O (%)	2.12	2.24	2.22	2.08	2.23	2.04	2.16
CaO (%)	0.50	0.44	0.51	0.55	0.52	5.75	1.38
MgO (%)	0.46	0.57	0.99	1.32	1.19	4.58	1.52
Na ₂ O (%)	1.22	1.24	1.02	0.95	1.13	1.25	1.14
TiO ₂ (%)	0.85	0.88	0.86	0.84	0.86	0.71	0.83
P ₂ O ₅ (%)	0.15	0.10	0.11	0.12	0.12	0.14	0.12
MnO (%)	0.25	0.17	0.10	0.06	0.08	0.08	0.12
Barium	684	619	618	517	457	399	549
Chromium	50	52	78	81	83	72	69
Copper	19	19	25	33	34	27	26
Mercury (µg/kg)	30	25	35	32	33	21	29
Nickel	24	20	24	31	46	29	29
Lead	27	24	24	23	24	19	24
Rubidium	84	89	99	97	87	72	88
Strontium	123	120	114	107	117	143	121
Vanadium	73	82	112	126	113	81	98
Zinc	64	48	74	99	98	63	74
Zirconium	123	120	114	107	117	143	121
Total C (%)	1.54	0.59	0.47	0.39	0.30	2.19	0.91
Inorganic C (%)	0.12	0.09	0.09	0.09	0.11	1.97	0.41
Organic C (%)	1.42	0.50	0.39	0.30	0.19	0.22	0.50
pH	5.00	6.36	6.48	5.50	5.26	7.32	5.99

7.94

Table 32. Elemental composition of samples selected from Core 80

Subsample	80-01	80-04	80-08	80-10	80-15	80-20	Average
Lab. No.	R23017	R23018	R23019	R23020	R23021	R23022	
Depth Interval (ft)	0.0-0.5	0.95-1.4	2.5-2.9	3.5-3.9	4.8-5.4	7.2-8.0	
Horizon	Ap	C/A	CB	2CB	4B	5Ab	
SiO ₂ (%)	72.11	78.03	75.47	76.06	75.73	74.81	76.02
Al ₂ O ₃ (%)	7.28	9.04	8.58	10.50	12.15	11.92	10.44
Fe ₂ O ₃ (%)	2.65	2.85	3.14	3.45	3.08	3.65	3.23
K ₂ O (%)	1.46	1.72	1.55	1.80	1.86	1.82	1.75
CaO (%)	5.85	1.45	3.24	1.30	0.47	0.52	1.40
MgO (%)	1.00	0.82	0.81	0.91	0.57	0.71	0.76
Na ₂ O (%)	0.99	1.18	1.03	1.15	1.04	0.97	1.07
TiO ₂ (%)	0.52	0.68	0.54	0.73	0.82	0.83	0.72
P ₂ O ₅ (%)	0.10	0.10	0.09	0.09	0.13	0.15	0.11
MnO (%)	0.09	0.10	0.11	0.08	0.08	0.09	0.09
Barium	259	361	300	341	483	430	383
Chromium	124	129	68	122	59	64	88
Copper	19	21	20	22	23	23	22
Mercury (µg/kg)	20	19	18	20	27	29	23
Nickel	22	27	26	27	29	33	28
Lead	22	19	20	18	18	19	19
Rubidium	57	68	63	73	81	83	74
Strontium	121	120	120	119	137	157	131
Vanadium	59	73	69	79	83	91	79
Zinc	49	52	48	51	63	74	58
Zirconium	319	363	310	361	367	374	355
Total C (%)	2.16	0.81	1.17	0.56	1.01	1.03	0.92
Inorganic C (%)	1.28	0.38	0.75	0.34	0.09	0.13	0.34
Organic C (%)	0.88	0.43	0.42	0.22	0.92	0.90	0.58
pH	7.55	7.82	7.76	7.88	7.46	7.02	7.59

Table 33. Elemental composition of samples selected from Core 81

Subsample	81-01	81-02	81-03	81-05	81-07	81-13	Average
Lab. No.	R23023	R23024	R23025	R23026	R23027	R23028	
Depth Interval (ft)	0.0-0.8	0.8-1.8	1.8-2.4	3.0-3.7	4.4-4.9	7.3-8.0	
Horizon	A	AB	Bt	Btg	Btg	Btox	
SiO ₂ (%)	71.97	73.11	66.92	72.39	71.45	70.61	71.08
Al ₂ O ₃ (%)	10.03	12.61	16.76	15.64	16.52	14.05	14.27
Fe ₂ O ₃ (%)	2.74	3.58	5.38	3.65	3.83	7.39	4.43
K ₂ O (%)	1.74	1.75	1.76	1.09	1.06	1.42	1.47
CaO (%)	2.67	0.68	0.72	0.54	0.58	0.41	0.93
MgO (%)	0.82	0.73	1.09	0.78	0.82	0.69	0.82
Na ₂ O (%)	1.13	1.21	1.10	0.73	0.60	0.68	0.91
TiO ₂ (%)	0.79	0.87	0.87	0.80	0.77	0.70	0.80
P ₂ O ₅ (%)	0.16	0.09	0.06	0.04	0.06	0.07	0.08
MnO (%)	0.08	0.09	0.12	0.08	0.04	0.05	0.08
Barium	529	594	581	479	471	471	521
Chromium	64	113	109	176	71	140	112
Copper	20	24	32	27	29	27	27
Mercury (µg/kg)	29	26	50	39	45	41	38
Nickel	22	28	49	42	34	47	37
Lead	29	20	26	20	22	23	23
Rubidium	74	77	86	78	87	82	81
Strontium	126	130	132	100	97	94	113
Vanadium	88	98	126	111	112	108	107
Zinc	63	51	69	58	64	89	66
Zirconium	462	468	381	354	333	283	380
Total C (%)	2.65	1.36	0.78	0.35	0.35	0.20	0.95
Inorganic C (%)	0.56	0.11	0.11	0.05	0.08	0.08	0.17
Organic C (%)	2.09	1.25	0.67	0.30	0.27	0.12	0.78
pH	7.24	6.94	6.37	6.62	7.05	7.52	6.96

Table 34. Elemental composition of samples selected from Core 82

Subsample	82-01	82-02	82-03	82-04	82-09	82-13	Average
Lab. No.	R23029	R23030	R23031	R23032	R23033	R23034	
Depth Interval (ft)	0.0-0.7	0.7-1.3	1.3-2.0	2.0-3.2	5.5-6.1	8.0-8.75	
Horizon	A	AB	Bt	Bt	CBgt	Cgtj	
SiO ₂ (%)	74.48	72.54	76.07	71.32	72.26	69.67	72.72
Al ₂ O ₃ (%)	10.09	12.74	10.52	13.28	12.56	10.47	11.61
Fe ₂ O ₃ (%)	2.66	4.38	2.84	4.81	4.58	2.94	3.70
K ₂ O (%)	2.06	2.11	2.09	2.16	2.27	2.05	2.12
CaO (%)	1.12	0.86	0.86	1.00	1.33	3.60	1.46
MgO (%)	0.71	1.02	0.72	1.28	1.32	2.77	1.30
Na ₂ O (%)	1.11	1.06	1.10	1.10	1.46	1.42	1.21
TiO ₂ (%)	0.70	0.73	0.73	0.75	0.85	0.78	0.76
P ₂ O ₅ (%)	0.17	0.11	0.14	0.14	0.18	0.17	0.15
MnO (%)	0.11	0.10	0.10	0.13	0.17	0.06	0.11
Barium	714	689	648	670	769	490	663
Chromium	72	120	58	76	74	58	76
Copper	23	28	22	31	32	21	26
Mercury (µg/kg)	117	43	55	48	34	20	53
Nickel	26	31	24	37	57	24	33
Lead	147	21	29	23	21	17	43
Rubidium	88	90	91	87	82	72	85
Strontium	131	129	132	142	174	166	146
Vanadium	87	111	94	121	117	90	103
Zinc	110	80	72	93	94	60	85
Zirconium	446	384	458	357	360	440	408
Total C (%)	2.60	0.81	1.50	0.41	0.29	1.24	1.14
Inorganic C (%)	0.07	0.08	0.16	0.14	0.10	1.11	0.28
Organic C (%)	2.53	0.73	1.34	0.27	0.19	0.13	0.87
pH	6.61	5.00	5.26	5.45	6.97	7.77	6.18

Table 35. Elemental composition of samples selected from Core 83

Subsample	83-01	83-02	83-04	83-05	83-10	83-14	Average
Lab. No.	R23035	R23036	R23037	R23038	R23039	R23040	
Depth Interval (ft)	0.0-0.7	0.7-1.4	2.6-3.3	3.3-4.0	6.5-7.1	8.6-9.3	
Horizon	A	A	Bgt	Bgt	BCtj	2Ab	
SiO ₂ (%)	72.03	71.49	71.53	73.76	72.12	78.84	73.30
Al ₂ O ₃ (%)	11.11	11.92	13.65	12.79	10.77	11.05	11.88
Fe ₂ O ₃ (%)	2.92	3.34	4.28	3.40	3.92	1.82	3.28
K ₂ O (%)	1.96	1.99	2.03	2.12	2.44	1.43	2.00
CaO (%)	1.32	1.10	1.09	1.17	2.26	0.91	1.31
MgO (%)	0.80	0.94	1.31	1.26	1.85	0.70	1.14
Na ₂ O (%)	1.03	1.03	1.02	1.22	1.27	0.96	1.09
TiO ₂ (%)	0.79	0.82	0.82	0.82	0.85	0.90	0.83
P ₂ O ₅ (%)	0.19	0.14	0.11	0.13	0.15	0.04	0.13
MnO (%)	0.11	0.08	0.12	0.05	0.08	0.01	0.08
Barium	579	742	790	723	594	508	656
Chromium	16	97	84	138	62	84	80
Copper	24	24	27	29	27	21	25
Mercury (µg/kg)	32	34	56	50	28	23	37
Nickel	24	30	39	36	32	26	31
Lead	21	20	24	21	19	18	21
Rubidium	103	102	90	86	80	59	87
Strontium	118	119	127	139	148	108	127
Vanadium	94	109	127	114	97	90	105
Zinc	80	82	90	81	77	31	74
Zirconium	389	387	358	371	438	404	391
Total C (%)	2.87	2.33	0.42	0.30	0.70	0.43	1.18
Inorganic C (%)	0.11	0.10	0.11	0.15	0.61	0.07	0.19
Organic C (%)	2.76	2.23	0.31	0.15	0.09	0.36	0.98
pH	6.16	5.60	6.10	6.42	8.03	7.72	6.67

Table 36. Elemental composition of samples selected from Core 84

Subsample	84-01	84-02	84-03	84-05	84-09	84-14	Average
Lab. No.	R23041	R23042	R23043	R23044	R23045	R23046	
Depth Interval (ft)	0.0-0.6	0.6-1.3	1.3-2.0	2.7-3.4	4.7-5.4	7.5-8.0	
Horizon	Ap	Btj	Bt	Bt	2Bw	2C	
SiO ₂ (%)	76.95	73.20	74.02	75.21	87.53	85.32	78.71
Al ₂ O ₃ (%)	10.46	12.37	11.89	11.60	6.27	7.25	9.97
Fe ₂ O ₃ (%)	2.80	4.62	4.65	4.08	1.53	1.90	3.26
K ₂ O (%)	2.13	2.17	2.12	2.14	1.43	1.65	1.94
CaO (%)	0.89	0.85	0.80	0.85	0.58	0.63	0.77
MgO (%)	0.75	1.08	1.05	0.98	0.41	0.47	0.79
Na ₂ O (%)	1.10	0.97	0.99	1.09	0.57	0.73	0.91
TiO ₂ (%)	0.79	0.80	0.76	0.77	0.26	0.36	0.62
P ₂ O ₅ (%)	0.09	0.12	0.13	0.13	0.07	0.08	0.10
MnO (%)	0.12	0.08	0.07	0.06	0.05	0.05	0.07
Barium	640	569	511	501	232	270	454
Chromium	84	232	88	108	101	48	110
Copper	22	29	31	27	17	20	24
Mercury (µg/kg)	33	72	28	18	16	19	31
Nickel	30	39	40	33	57	24	37
Lead	20	22	21	19	11	13	18
Rubidium	86	88	82	80	50	57	74
Strontium	126	123	124	134	82	94	114
Vanadium	92	116	112	101	48	53	87
Zinc	60	77	76	66	36	42	60
Zirconium	427	376	361	403	116	183	311
Total C (%)	0.94	0.41	0.33	0.23	0.19	0.21	0.39
Inorganic C (%)	0.09	0.10	0.07	0.07	0.07	0.07	0.08
Organic C (%)	0.85	0.31	0.26	0.16	0.12	0.14	0.31
pH	6.36	5.56	4.87	4.44	5.58	5.55	5.39

Table 37. Elemental composition of samples selected from Core 85

Subsample	85-01	85-02	85-03	85-05	85-09	85-13	Average
Lab. No.	R23047	R23048	R23049	R23050	R23051	R23052	
Depth Interval (ft)	0.0-0.3	0.3-1.2	1.2-2.0	2.6-3.4	5.5-6.1	7.5-8.1	
Horizon	Ap	Bt	Bt	Bt	CBt	C	
SiO ₂ (%)	75.80	72.73	71.50	71.52	74.84	62.75	71.52
Al ₂ O ₃ (%)	11.39	13.23	13.50	13.55	11.53	9.95	12.19
Fe ₂ O ₃ (%)	3.38	4.49	5.24	5.12	4.31	3.38	4.32
K ₂ O (%)	2.27	2.21	2.18	2.13	2.42	2.20	2.24
CaO (%)	0.83	0.84	0.83	0.89	0.95	5.62	1.66
MgO (%)	0.65	0.90	0.98	1.04	0.88	3.92	1.40
Na ₂ O (%)	0.94	0.89	0.83	0.93	0.96	0.95	0.92
TiO ₂ (%)	0.69	0.68	0.68	0.66	0.65	0.55	0.65
P ₂ O ₅ (%)	0.15	0.13	0.12	0.12	0.11	0.10	0.12
MnO (%)	0.16	0.09	0.08	0.08	0.10	0.07	0.10
Barium	683	328	509	532	487	330	478
Chromium	119	129	90	378	62	48	138
Copper	19	28	30	33	27	21	26
Mercury (µg/kg)	33	40	31	27	25	16	29
Nickel	34	44	32	51	43	27	39
Lead	27	24	26	20	20	18	23
Rubidium	92	90	86	82	84	74	85
Strontium	135	125	127	136	146	137	134
Vanadium	89	109	116	113	93	74	99
Zinc	88	81	90	94	70	56	80
Zirconium	465	405	400	389	457	376	415
Total C (%)	0.73	0.41	0.36	0.31	0.40	2.36	0.76
Inorganic C (%)	0.08	0.05	0.09	0.07	0.08	2.17	0.42
Organic C (%)	0.65	0.36	0.27	0.24	0.32	0.19	0.34
pH	7.32	7.46	6.98	6.96	7.29	8.26	7.38

Table 38. Elemental composition of samples selected from Core 86

Subsample	86-01	86-02	86-03	86-05	86-07	86-12	Average
Lab. No.	R23053	R23054	R23055	R23056	R23057	R23058	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.6-3.2	4.0-4.7	7.0-7.6	
Horizon	Ap	E	Bt	Bt	B3	C	
SiO ₂ (%)	78.13	75.14	69.01	71.10	72.22	64.26	71.64
Al ₂ O ₃ (%)	9.02	11.43	14.59	13.78	12.94	10.06	11.97
Fe ₂ O ₃ (%)	2.48	4.04	5.78	5.33	5.12	3.38	4.36
K ₂ O (%)	2.01	2.11	1.95	2.06	2.34	2.11	2.10
CaO (%)	1.24	0.72	0.80	0.83	0.92	5.16	1.61
MgO (%)	0.47	0.69	1.08	0.98	1.03	3.67	1.32
Na ₂ O (%)	0.90	0.82	0.63	0.80	0.90	0.90	0.83
TiO ₂ (%)	0.64	0.66	0.61	0.61	0.63	0.54	0.62
P ₂ O ₅ (%)	0.14	0.09	0.08	0.09	0.14	0.11	0.11
MnO (%)	0.21	0.24	0.10	0.11	0.13	0.10	0.15
Barium	564	578	472	474	609	434	522
Chromium	90	223	180	96	70	53	119
Copper	21	23	34	32	37	22	28
Mercury (µg/kg)	31	18	32	38	43	16	30
Nickel	30	32	38	53	50	32	39
Lead	43	31	24	22	23	18	27
Rubidium	87	96	96	89	90	74	89
Strontium	135	115	105	116	146	147	127
Vanadium	77	107	131	112	106	82	103
Zinc	74	63	97	99	104	59	83
Zirconium	452	423	363	387	399	404	405
Total C (%)	1.55	0.66	0.62	0.43	0.23	2.15	0.94
Inorganic C (%)	0.17	0.07	0.06	0.06	0.08	1.93	0.40
Organic C (%)	1.38	0.59	0.56	0.37	0.15	0.22	0.55
pH	7.30	5.64	5.09	6.00	6.26	8.05	6.39

Table 39. Elemental composition of samples selected from Core 87

Subsample	87-01	87-02	87-03	87-04	87-05	87-06	Average
Lab. No.	R23059	R23060	R23061	R23062	R23063	R23064	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.0-2.7	2.7-3.4	3.4-4.0	
Horizon	Ap	AE	EB	Bt	BC	C	
SiO ₂ (%)	77.80	79.40	79.45	70.67	72.60	62.56	73.75
Al ₂ O ₃ (%)	9.35	9.18	9.09	13.52	12.39	10.29	10.64
Fe ₂ O ₃ (%)	3.15	2.70	2.78	5.12	4.86	3.77	3.73
K ₂ O (%)	1.91	1.90	1.89	2.08	2.22	2.01	2.00
CaO (%)	0.79	0.74	0.70	0.94	1.13	5.39	1.62
MgO (%)	0.48	0.42	0.43	1.10	1.06	3.97	1.24
Na ₂ O (%)	0.88	0.88	0.88	0.90	1.10	0.93	0.93
TiO ₂ (%)	0.66	0.66	0.66	0.69	0.70	0.59	0.66
P ₂ O ₅ (%)	0.15	0.12	0.12	0.10	0.14	0.13	0.13
MnO (%)	0.35	0.27	0.27	0.12	0.11	0.19	0.22
Barium	682	606	586	550	538	374	556
Chromium	66	43	51	151	74	87	79
Copper	20	16	17	32	32	27	24
Mercury (µg/kg)	28	28	30	46	39	25	33
Nickel	21	20	20	48	49	31	32
Lead	33	28	27	23	22	19	25
Rubidium	86	83	83	91	82	72	83
Strontium	125	116	126	124	138	137	128
Vanadium	91	81	86	116	100	87	94
Zinc	62	56	60	101	93	76	75
Zirconium	498	490	505	362	444	374	446
Total C (%)	1.27	1.00	0.96	0.51	0.37	2.20	1.05
Inorganic C (%)	0.04	0.05	0.05	0.05	0.03	1.97	0.37
Organic C (%)	1.23	0.95	0.91	0.46	0.34	0.23	0.69
pH	5.86	6.12	5.25	5.42	6.82	7.94	6.24

Table 40. Elemental composition of samples selected from Core 88

Subsample	88-01	88-02	88-03	88-05	88-07	88-08	Average
Lab. No.	R23065	R23066	R23067	R23068	R23069	R23070	
Depth Interval (ft)	0.0-0.6	0.6-1.4	1.4-2.0	2.6-3.1	3.6-4.0	4.0-4.6	
Horizon	Ap1	Ap2	Btj	Bt	2BC	2CBt	
SiO ₂ (%)	71.62	71.50	69.59	70.52	67.22	49.50	66.66
Al ₂ O ₃ (%)	11.48	12.75	14.37	13.98	13.31	7.12	12.17
Fe ₂ O ₃ (%)	3.82	4.23	5.42	5.48	6.91	3.35	4.87
K ₂ O (%)	2.17	2.12	2.08	2.28	2.48	1.81	2.16
CaO (%)	1.08	0.85	0.82	0.80	1.30	10.68	2.59
MgO (%)	0.88	0.90	1.11	1.16	1.59	7.98	2.27
Na ₂ O (%)	0.71	0.75	0.73	0.70	0.53	0.39	0.64
TiO ₂ (%)	0.62	0.66	0.64	0.64	0.44	0.26	0.54
P ₂ O ₅ (%)	0.17	0.10	0.08	0.07	0.11	0.07	0.10
MnO (%)	0.11	0.11	0.10	0.10	0.18	0.11	0.12
Barium	401	511	518	462	352	139	397
Chromium	118	79	84	103	138	50	95
Copper	33	27	33	33	39	26	32
Mercury (µg/kg)	65	31	45	39	49	34	44
Nickel	33	31	40	44	52	22	37
Lead	50	23	23	26	53	54	38
Rubidium	88	92	88	89	88	60	84
Strontium	92	93	95	100	66	75	87
Vanadium	90	102	119	110	102	50	96
Zinc	99	77	92	91	187	108	109
Zirconium	349	372	340	350	161	100	279
Total C (%)	2.59	1.86	0.86	0.53	1.00	4.75	1.93
Inorganic C (%)	0.07	0.04	0.03	0.04	0.30	4.55	0.84
Organic C (%)	2.52	1.82	0.83	0.49	0.70	0.20	1.09
pH	7.05	6.84	6.92	6.82	7.09	7.74	7.08

Table 41. Elemental composition of samples selected from Core 89

Subsample	89-01	89-02	89-03	89-04	89-05	89-07	Average
Lab. No.	R23071	R23072	R23073	R23074	R23075	R23076	
Depth Interval (ft)	0.0-1.0	1.0-1.5	1.5-2.0	2.0-2.8	2.8-3.3	3.7-4.1	
Horizon	Ap	Bg1	Bgt21	Bgt22	2Bg3	2C	
SiO ₂ (%)	72.88	73.95	69.45	71.40	82.67	77.13	74.58
Al ₂ O ₃ (%)	10.88	12.96	15.33	14.51	8.46	6.39	11.42
Fe ₂ O ₃ (%)	3.02	3.41	5.17	4.28	2.49	2.93	3.55
K ₂ O (%)	2.09	2.10	1.98	2.11	1.92	1.82	2.00
CaO (%)	1.27	0.82	0.92	1.04	0.87	2.92	1.31
MgO (%)	0.79	0.85	1.20	1.22	0.65	2.03	1.12
Na ₂ O (%)	0.80	0.80	0.65	0.81	0.79	0.58	0.74
TiO ₂ (%)	0.58	0.64	0.62	0.61	0.40	0.26	0.52
P ₂ O ₅ (%)	0.17	0.05	0.07	0.10	0.09	0.08	0.09
MnO (%)	0.09	0.06	0.05	0.07	0.04	0.30	0.10
Barium	453	497	447	449	282	353	414
Chromium	87	133	83	127	126	32	98
Copper	27	27	37	34	22	27	29
Mercury (µg/kg)	30	31	59	44	15	15	32
Nickel	26	29	38	53	29	38	36
Lead	28	21	26	24	19	21	23
Rubidium	93	92	92	88	60	51	79
Strontium	112	106	96	126	118	86	107
Vanadium	83	107	130	126	61	38	91
Zinc	97	78	99	99	53	57	81
Zirconium	356	356	316	340	384	162	319
Total C (%)	2.83	0.94	0.59	0.39	0.34	1.36	1.08
Inorganic C (%)	0.17	0.08	0.07	0.07	0.06	1.18	0.27
Organic C (%)	2.66	0.86	0.52	0.32	0.28	0.18	0.80
pH	2.74	6.08	6.38	6.72	7.54	8.10	6.26

Table 42. Elemental composition of samples selected from Core 90

Subsample	90-01	90-02	90-03	90-05	90-07	90-11	Average
Lab. No.	R23077	R23078	R23079	R23080	R23081	R23082	
Depth Interval (ft)	0.0-1.1	1.1-1.6	1.6-2.3	3.0-3.6	4.2-4.9	6.8-7.5	
Horizon	Ap	BA	Btj	Bw	BCtj	C	
SiO ₂ (%)	72.18	73.04	72.19	71.88	73.03	66.45	71.46
Al ₂ O ₃ (%)	10.83	11.94	13.28	13.80	13.16	10.71	12.29
Fe ₂ O ₃ (%)	3.22	3.96	4.62	4.77	4.61	3.64	4.14
K ₂ O (%)	1.86	1.90	1.93	1.96	2.02	1.86	1.92
CaO (%)	2.01	0.96	0.89	1.03	1.11	4.42	1.74
MgO (%)	0.78	0.72	0.92	1.01	0.94	3.09	1.24
Na ₂ O (%)	0.84	0.87	0.87	1.01	1.06	1.00	0.94
TiO ₂ (%)	0.56	0.60	0.60	0.55	0.57	0.50	0.56
P ₂ O ₅ (%)	0.14	0.10	0.08	0.12	0.15	0.13	0.12
MnO (%)	0.12	0.17	0.10	0.15	0.14	0.09	0.13
Barium	534	589	515	528	547	397	518
Chromium	106	104	84	74	90	56	82
Copper	23	23	27	30	28	26	27
Mercury (µg/kg)	35	35	46	45	38	20	37
Nickel	24	29	30	42	44	32	35
Lead	44	21	20	21	20	17	20
Rubidium	90	91	82	79	77	70	80
Strontium	130	142	136	156	177	168	152
Vanadium	86	103	111	114	109	90	102
Zinc	101	78	77	66	89	63	79
Zirconium	456	458	417	399	422	401	426
Total C (%)	2.50	1.61	0.77	0.41	0.39	1.69	1.23
Inorganic C (%)	0.36	0.04	0.05	0.04	0.04	1.58	0.35
Organic C (%)	2.14	1.57	0.72	0.37	0.35	0.11	0.88
pH	7.46	6.80	6.60	5.97	6.27	8.15	6.88

Table 43. Elemental composition of samples selected from Core 91

Subsample	91-01	91-02	91-03	91-05	91-07	91-11	Average
Lab. No.	R23083	R23084	R23085	R23086	R23087	R23088	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.6-3.2	3.7-4.3	6.2-6.8	
Horizon	Ap1	Ap2	BA	Btj	CBtj	C	
SiO ₂ (%)	74.26	73.59	71.65	70.08	73.74	69.65	72.16
Al ₂ O ₃ (%)	10.77	10.97	11.79	14.10	11.93	10.75	11.72
Fe ₂ O ₃ (%)	3.19	3.41	4.24	5.04	4.39	3.52	3.97
K ₂ O (%)	1.99	1.99	2.01	2.06	2.12	2.10	2.05
CaO (%)	1.09	0.97	0.90	0.90	1.07	3.16	1.35
MgO (%)	0.67	0.70	0.86	1.06	1.00	2.39	1.11
Na ₂ O (%)	0.93	0.95	0.87	0.86	1.04	1.04	0.95
TiO ₂ (%)	0.60	0.60	0.62	0.62	0.64	0.62	0.62
P ₂ O ₅ (%)	0.13	0.13	0.11	0.08	0.12	0.13	0.12
MnO (%)	0.10	0.11	0.10	0.13	0.12	0.08	0.11
Barium	1046	1033	1006	464	456	372	730
Chromium	160	100	117	190	92	123	130
Copper	27	23	26	30	30	22	26
Mercury (µg/kg)	30	32	31	40	35	20	31
Nickel	37	34	29	44	52	39	39
Lead	24	22	21	23	22	18	22
Rubidium	92	92	94	89	80	78	88
Strontium	122	122	121	118	146	143	129
Vanadium	88	92	111	124	106	88	102
Zinc	78	76	77	87	74	60	75
Zirconium	421	430	457	398	456	439	434
Total C (%)	1.92	1.96	1.78	0.76	0.34	1.15	1.32
Inorganic C (%)	0.06	0.08	0.08	0.10	0.05	1.03	0.23
Organic C (%)	1.86	1.88	1.70	0.66	0.29	0.12	1.09
pH	6.98	5.97	5.60	6.00	7.04	8.05	6.61

Table 44. Elemental composition of samples selected from Core 92

Subsample	92-01	92-02	92-03	92-04	92-06	92-09	Average
Lab. No.	R23089	R23090	R23091	R23092	R23093	R23094	
Depth Interval (ft)	0.0-0.7	0.7-1.1	1.1-1.5	1.5-1.9	3.3-3.9	5.1-5.5	
Horizon	Ap	AB	BA	Bt	BCtj	C	
SiO ₂ (%)	70.72	69.38	69.93	71.80	73.32	65.84	70.17
Al ₂ O ₃ (%)	10.78	13.64	14.31	13.36	13.45	12.31	12.98
Fe ₂ O ₃ (%)	4.10	4.35	5.05	5.00	4.00	3.25	4.29
K ₂ O (%)	2.07	2.14	2.13	2.15	2.34	2.12	2.16
CaO (%)	1.03	0.83	0.88	0.90	1.07	4.05	1.46
MgO (%)	0.77	1.00	0.99	1.02	0.94	2.94	1.28
Na ₂ O (%)	0.81	0.91	0.79	0.90	1.04	1.17	0.94
TiO ₂ (%)	0.62	0.78	0.62	0.64	0.67	0.60	0.66
P ₂ O ₅ (%)	0.34	0.19	0.11	0.10	0.09	0.13	0.16
MnO (%)	0.12	0.10	0.10	0.10	0.09	0.07	0.10
Barium	421	588	464	421	432	317	441
Chromium	96	77	91	97	77	126	94
Copper	37	32	33	32	26	21	30
Mercury (µg/kg)	67	43	48	39	25	24	41
Nickel	31	40	42	43	41	30	38
Lead	69	29	24	22	20	17	30
Rubidium	92	93	89	82	82	78	86
Strontium	112	105	104	124	136	140	120
Vanadium	101	114	117	112	98	85	105
Zinc	138	89	88	82	63	57	86
Zirconium	449	395	407	435	477	382	424
Total C (%)	3.02	1.53	1.01	0.59	0.38	1.69	1.37
Inorganic C (%)	0.11	0.09	0.09	0.09	0.07	1.46	0.32
Organic C (%)	2.91	1.44	0.92	0.50	0.31	0.23	1.05
pH	5.73	5.52	5.62	5.96	6.60	7.87	6.22

ND=Not Determined

Table 45. Elemental composition of samples selected from Core 93

Subsample	93-01	93-02	93-03	93-04	93-06	93-09	Average
Lab. No.	R23095	R23096	R23097	R23098	R23099	R23100	
Depth Interval (ft)	0.0-0.6	0.6-1.0	1.0-1.5	1.5-2.0	2.6-3.3	5.5-6.4	
Horizon	A/E	EB	Bt	Bt	Bt2	2C	
SiO ₂ (%)	77.45	74.34	71.92	71.57	73.56	59.19	71.34
Al ₂ O ₃ (%)	10.24	13.23	14.05	14.17	13.17	10.94	12.63
Fe ₂ O ₃ (%)	2.62	3.73	4.79	5.23	4.71	2.88	3.99
K ₂ O (%)	2.19	2.29	2.29	2.23	2.33	2.58	2.32
CaO (%)	0.76	0.75	0.81	0.82	0.91	6.90	1.83
MgO (%)	0.52	0.72	0.84	0.91	0.82	4.48	1.38
Na ₂ O (%)	0.99	0.91	0.81	0.82	0.95	0.58	0.84
TiO ₂ (%)	0.65	0.63	0.61	0.60	0.59	0.36	0.57
P ₂ O ₅ (%)	0.08	0.06	0.09	0.11	0.10	0.09	0.09
MnO (%)	0.19	0.10	0.10	0.08	0.08	0.05	0.10
Barium	438	470	400	391	395	291	398
Chromium	166	123	137	118	171	103	136
Copper	22	26	32	37	32	22	29
Mercury (µg/kg)	47	29	42	37	33	18	34
Nickel	30	32	37	44	50	29	37
Lead	27	20	24	23	22	14	22
Rubidium	87	97	96	89	83	93	91
Strontium	124	115	107	105	125	106	114
Vanadium	81	99	106	108	94	68	93
Zinc	69	76	91	97	86	56	79
Zirconium	495	451	410	419	482	159	403
Total C (%)	1.43	0.50	0.40	0.36	0.31	2.92	0.99
Inorganic C (%)	0.10	0.08	0.10	0.08	0.09	2.89	0.56
Organic C (%)	1.33	0.42	0.30	0.28	0.22	0.03	0.43
pH	5.40	5.36	5.50	5.74	5.90	8.21	6.02

Table 46. Elemental composition of samples selected from Core 94

Subsample	94-01	94-02	94-04	94-06	94-08	94-12	Average
Lab. No.	R23117	R23118	R23119	R23120	R23121	R23122	
Depth Interval (ft)	0.0-0.9	0.9-1.5	1.8-2.6	3.0-3.7	4.1-4.6	6.7-7.2	
Horizon	Ap	A	Bgt	Bgtj	C	2C	
SiO ₂ (%)	69.22	70.59	69.96	69.97	57.69	52.92	65.06
Al ₂ O ₃ (%)	13.19	12.54	14.85	14.51	11.56	7.76	12.40
Fe ₂ O ₃ (%)	3.52	4.19	4.79	4.78	3.10	2.36	3.79
K ₂ O (%)	2.05	2.03	2.06	2.10	1.78	1.22	1.87
CaO (%)	1.83	1.13	1.04	1.44	6.90	10.56	3.82
MgO (%)	0.82	0.90	1.09	1.36	4.87	6.54	2.60
Na ₂ O (%)	0.85	0.83	0.84	0.95	0.88	0.44	0.80
TiO ₂ (%)	0.57	0.60	0.57	0.57	0.45	0.21	0.50
P ₂ O ₅ (%)	0.17	0.10	0.06	0.12	0.11	0.06	0.10
MnO (%)	0.11	0.12	0.10	0.11	0.08	0.08	0.10
Barium	362	408	451	443	134	<10	301
Chromium	115	68	84	173	124	26	98
Copper	32	31	27	36	28	23	30
Mercury (µg/kg)	28	31	42	36	18	11	28
Nickel	28	30	49	41	30	16	32
Lead	25	22	22	23	18	12	20
Rubidium	104	104	91	87	67	44	83
Strontium	112	102	113	132	98	56	102
Vanadium	92	102	119	110	80	33	89
Zinc	92	83	91	90	67	51	79
Zirconium	325	352	366	368	285	72	295
Total C (%)	3.13	2.51	1.02	0.67	3.05	4.77	2.53
Inorganic C (%)	0.25	0.07	0.06	0.19	3.00	4.76	1.39
Organic C (%)	2.88	2.44	0.96	0.48	0.05	0.01	1.14
pH	7.39	6.99	7.27	7.68	8.07	8.46	7.64

Table 47. Elemental composition of samples selected from Core 95

Subsample	95-01	95-02	95-03	95-05	95-08	95-13	Average
Lab. No.	R23123	R23124	R23125	R23126	R23127	R23128	
Depth Interval (ft)	0.0-0.9	0.9-1.6	1.6-2.1	2.5-3.1	3.8-4.5	6.5-7.1	
Horizon	Ap	A	Bgtj	Bgt2	2Cgt1	3Cg	
SiO ₂ (%)	71.97	72.02	69.25	69.17	67.44	50.78	66.77
Al ₂ O ₃ (%)	12.39	13.04	15.81	16.02	11.10	13.65	13.67
Fe ₂ O ₃ (%)	3.17	3.42	4.82	5.05	3.66	4.55	4.11
K ₂ O (%)	2.00	2.00	1.92	2.04	2.49	3.92	2.40
CaO (%)	1.36	1.05	0.97	1.04	3.57	6.89	2.48
MgO (%)	0.84	0.76	1.06	1.16	2.90	5.50	2.04
Na ₂ O (%)	0.81	0.76	0.72	0.83	0.76	0.38	0.71
TiO ₂ (%)	0.51	0.51	0.55	0.56	0.45	0.53	0.52
P ₂ O ₅ (%)	0.17	0.08	0.05	0.08	0.09	0.06	0.09
MnO (%)	0.09	0.09	0.11	0.12	0.10	0.06	0.10
Barium	67	375	396	407	250	238	289
Chromium	102	121	134	135	219	86	133
Copper	29	28	34	36	27	29	31
Mercury (µg/kg)	27	26	49	45	27	18	32
Nickel	31	31	44	62	39	47	42
Lead	29	21	24	22	22	24	24
Rubidium	94	99	98	90	92	151	104
Strontium	67	110	94	114	106	70	94
Vanadium	84	91	119	120	81	107	100
Zinc	80	72	88	82	72	93	81
Zirconium	239	321	292	313	240	141	258
Total C (%)	2.59	2.28	0.95	0.54	1.90	3.78	2.01
Inorganic C (%)	0.09	0.07	0.08	0.05	1.39	3.05	0.79
Organic C (%)	2.50	2.21	0.87	0.49	0.51	0.73	1.22
pH	7.13	6.72	6.60	6.64	8.18	8.30	7.26

Table 48. Elemental composition of samples selected from Core 96

Subsample	96-01	96-02	96-03	96-04	96-07	96-11	Average
Lab. No.	R23129	R23130	R23131	R23132	R23133	R23134	
Depth Interval (ft)	0.0-1.0	1.0-1.6	1.6-2.1	2.1-2.8	3.6-4.6	6.7-7.6	
Horizon	Ap	Bgt	2CBtj	2CBtj	2C	4C	
SiO ₂ (%)	64.90	63.81	47.85	54.24	50.96	50.32	55.35
Al ₂ O ₃ (%)	14.19	15.07	10.34	11.10	13.88	13.98	13.09
Fe ₂ O ₃ (%)	5.01	8.22	5.29	5.68	4.78	5.64	5.77
K ₂ O (%)	2.65	3.05	2.86	3.31	3.91	3.79	3.26
CaO (%)	2.14	1.13	8.57	6.23	7.06	6.96	5.35
MgO (%)	1.31	1.69	6.85	5.08	4.96	4.66	4.09
Na ₂ O (%)	0.67	0.50	0.27	0.38	0.39	0.41	0.44
TiO ₂ (%)	0.61	0.55	0.38	0.46	0.52	0.53	0.51
P ₂ O ₅ (%)	0.14	0.09	0.06	0.06	0.06	0.06	0.08
MnO (%)	0.07	0.20	0.15	0.12	0.06	0.07	0.11
Barium	385	397	250	252	265	246	299
Chromium	112	92	72	84	97	73	88
Copper	31	47	37	42	29	29	36
Mercury (µg/kg)	39	58	33	37	22	17	34
Nickel	34	64	36	46	48	48	46
Lead	36	40	43	34	24	29	34
Rubidium	126	124	104	119	147	154	129
Strontium	101	76	58	62	79	79	76
Vanadium	117	123	81	94	104	103	104
Zinc	118	198	184	182	108	109	150
Zirconium	257	199	117	142	141	132	165
Total C (%)	2.98	1.33	4.76	3.36	3.17	3.47	3.18
Inorganic C (%)	0.42	0.46	3.98	2.66	2.75	2.84	2.19
Organic C (%)	2.56	0.87	0.80	0.70	0.42	0.63	1.00
pH	7.49	7.74	8.16	8.24	8.14	8.10	7.98

Table 49. Elemental composition of samples selected from Core 97

Subsample	97-01	97-02	97-03	97-05	97-07	97-09	Average
Lab. No.	R23135	R23136	R23137	R23138	R23139	R23140	
Depth Interval (ft)	0.0-0.7	0.7-1.3	1.3-2.0	2.7-3.3	4.0-4.8	6.0-6.6	
Horizon	Ap	A2	Bg	Bg	C	C	
SiO ₂ (%)	72.97	73.66	73.18	73.54	55.25	53.48	67.01
Al ₂ O ₃ (%)	10.73	11.10	10.87	11.16	11.47	10.85	11.03
Fe ₂ O ₃ (%)	3.21	3.23	3.92	3.93	5.68	4.97	4.16
K ₂ O (%)	2.66	2.69	2.71	2.75	3.44	3.24	2.92
CaO (%)	1.24	1.15	1.96	1.06	6.15	7.73	3.22
MgO (%)	1.30	1.32	1.91	1.34	4.69	4.94	2.58
Na ₂ O (%)	0.89	0.90	0.89	0.89	0.62	0.67	0.81
TiO ₂ (%)	0.63	0.64	0.62	0.65	0.66	0.63	0.64
P ₂ O ₅ (%)	0.14	0.12	0.11	0.09	0.12	0.12	0.12
MnO (%)	0.04	0.03	0.05	0.04	0.08	0.10	0.06
Barium	468	483	517	585	468	295	469
Chromium	70	271	160	154	71	76	134
Copper	26	26	24	20	24	26	24
Mercury (µg/kg)	27	29	33	31	15	18	26
Nickel	36	41	62	39	43	50	45
Lead	23	21	20	18	24	22	21
Rubidium	113	113	116	111	130	123	118
Strontium	140	150	153	160	126	125	142
Vanadium	94	93	104	94	112	102	100
Zinc	82	79	77	76	92	94	83
Zirconium	309	324	316	330	261	241	297
Total C (%)	2.19	1.69	0.87	0.91	2.86	3.57	2.02
Inorganic C (%)	0.20	0.16	0.12	0.53	2.54	2.97	1.09
Organic C (%)	1.99	1.53	0.75	0.38	0.32	0.60	0.93
pH	7.00	7.00	7.08	7.88	7.97	8.00	7.49

Table 50. Elemental composition of samples selected from Core 98

Subsample	98-01	98-02	98-03	98-05	98-06	98-07	Average
Lab. No.	R23141	R23142	R23143	R23144	R23145	R23146	
Depth Interval (ft)	0.0-0.8	0.8-1.5	1.5-1.9	2.1-2.7	2.7-3.4	3.4-4.0	
Horizon	Ap	Bt	Ab	Bt	Bt	Cr	
SiO ₂ (%)	75.62	67.15	74.56	76.34	66.28	28.44	64.73
Al ₂ O ₃ (%)	8.32	8.62	7.40	7.90	7.20	4.07	7.25
Fe ₂ O ₃ (%)	3.68	12.66	3.65	7.48	16.40	2.23	7.68
K ₂ O (%)	2.05	2.19	1.80	2.05	1.94	1.70	1.96
CaO (%)	1.18	1.11	2.01	0.68	0.65	19.12	4.13
MgO (%)	1.07	1.33	1.61	1.04	0.97	13.71	3.29
Na ₂ O (%)	0.70	0.51	0.63	0.50	0.47	0.16	0.50
TiO ₂ (%)	0.53	0.44	0.41	0.40	0.39	0.24	0.40
P ₂ O ₅ (%)	0.32	0.20	0.32	0.10	0.16	0.05	0.19
MnO (%)	0.12	0.12	0.10	0.13	0.11	0.06	0.11
Barium	415	337	383	383	403	121	340
Chromium	54	203	53	80	111	20	87
Copper	28	37	28	31	40	16	30
Mercury (µg/kg)	44	63	36	41	101	29	52
Nickel	26	39	23	37	27	12	27
Lead	40	47	43	30	107	13	47
Rubidium	84	78	73	72	69	51	71
Strontium	120	94	109	94	75	64	93
Vanadium	72	82	66	77	66	33	66
Zinc	116	162	126	101	152	41	116
Zirconium	286	197	228	218	131	71	189
Total C (%)	2.63	1.14	3.17	0.72	1.14	8.24	2.84
Inorganic C (%)	0.27	0.33	0.63	0.16	0.10	7.88	1.56
Organic C (%)	2.36	0.81	2.54	0.56	1.04	0.36	1.28
pH	6.85	7.20	7.30	7.04	7.25	8.28	7.32

Table 51. Elemental composition of samples selected from Core 99

Subsample	99-01	99-02	99-03	99-06	99-08	99-09	Average
Lab. No.	R23147	R23148	R23149	R23150	R23152	R23153	
Depth Interval (ft)	0.0-0.9	0.9-1.3	1.3-2.0	2.9-3.5	4.2-4.8	5.0-5.7	
Horizon	Ap	BA	Bw	Bg	CBg	Cg	
SiO ₂ (%)	85.61	86.77	87.76	86.01	88.70	88.57	87.24
Al ₂ O ₃ (%)	5.68	6.02	5.78	6.77	5.39	5.46	5.85
Fe ₂ O ₃ (%)	1.44	1.49	1.34	1.67	1.22	1.17	1.39
K ₂ O (%)	1.41	1.49	1.56	1.72	1.63	1.71	1.59
CaO (%)	0.70	0.69	0.66	0.76	0.80	0.87	0.75
MgO (%)	0.65	0.66	0.65	0.71	0.67	0.70	0.67
Na ₂ O (%)	0.79	0.75	0.80	0.90	0.94	0.97	0.86
TiO ₂ (%)	0.25	0.28	0.28	0.25	0.19	0.20	0.24
P ₂ O ₅ (%)	0.12	0.04	0.03	0.05	0.04	0.05	0.06
MnO (%)	0.03	0.02	0.02	0.03	0.02	0.03	0.03
Barium	430	415	436	449	386	413	422
Chromium	33	196	62	111	47	46	83
Copper	10	10	10	13	9	10	10
Mercury (µg/kg)	17	12	11	16	7	3	11
Nickel	30	33	19	47	13	18	27
Lead	12	9	10	9	8	8	9
Rubidium	48	47	47	51	46	47	48
Strontium	122	126	134	143	145	167	140
Vanadium	34	38	34	41	19	20	31
Zinc	28	16	11	19	12	12	16
Zirconium	187	242	258	220	174	167	208
Total C (%)	1.33	0.48	0.26	0.32	0.17	0.14	0.45
Inorganic C (%)	0.09	0.09	0.04	0.07	0.09	0.08	0.08
Organic C (%)	1.24	0.39	0.22	0.25	0.08	0.06	0.37
pH	5.06	5.08	4.76	4.84	6.97	7.44	5.69

Table 52. Elemental composition of samples selected from Core 100

Subsample	100-01	100-02	100-03	100-05	100-06	100-08	Average
Lab. No.	R23153	R23154	R23155	R23156	R23157	R23158	
Depth Interval (ft)	0.0-0.6	0.6-1.1	1.1-1.8	2.0-2.4	2.6-3.3	4.1-4.8	
Horizon	Ap	BAt	Bt	B3t	C	C	
SiO ₂ (%)	74.28	70.25	69.75	58.41	52.99	54.08	63.29
Al ₂ O ₃ (%)	9.72	12.55	12.62	9.65	8.78	8.94	10.38
Fe ₂ O ₃ (%)	3.96	5.38	5.92	4.25	3.70	3.75	4.49
K ₂ O (%)	2.51	3.07	3.46	3.09	2.95	3.05	3.02
CaO (%)	0.92	0.79	0.73	6.73	9.85	8.94	4.66
MgO (%)	1.10	1.43	1.54	4.61	5.43	5.58	3.28
Na ₂ O (%)	0.76	0.64	0.64	0.59	0.58	0.56	0.63
TiO ₂ (%)	0.64	0.68	0.69	0.54	0.49	0.51	0.59
P ₂ O ₅ (%)	0.16	0.08	0.07	0.08	0.07	0.06	0.09
MnO (%)	0.10	0.10	0.11	0.09	0.08	0.08	0.09
Barium	552	563	562	399	227	330	439
Chromium	63	79	74	69	66	61	69
Copper	28	31	31	28	24	26	28
Mercury (µg/kg)	123	41	37	23	18	17	43
Nickel	32	51	54	42	34	34	41
Lead	47	28	29	27	24	23	30
Rubidium	96	113	117	100	94	100	103
Strontium	129	113	112	106	105	104	112
Vanadium	77	98	99	77	68	67	81
Zinc	128	110	127	114	112	108	117
Zirconium	313	244	253	195	157	174	223
Total C (%)	2.32	1.35	0.94	3.24	4.00	3.87	2.62
Inorganic C (%)	0.10	0.09	0.08	2.41	3.50	3.34	1.59
Organic C (%)	2.22	1.26	0.86	0.83	0.50	0.53	1.03
pH	7.06	7.16	7.10	8.18	8.33	8.28	7.69

Table 53. Elemental composition of samples selected from Core 101

Subsample	101-01	101-02	101-03	101-04	101-05	101-07	Average
Lab. No.	R23159	R23160	R23161	R23162	R23163	R23164	
Depth Interval (ft)	0.0-0.8	0.8-1.3	1.3-2.0	2.0-2.5	2.7-3.5	4.2-4.8	
Horizon	Ap	BA	Bgtj	Bgt	Cgtj	Cg	
SiO ₂ (%)	68.57	64.28	63.29	56.93	55.24	51.76	60.01
Al ₂ O ₃ (%)	12.51	16.23	17.29	17.08	15.82	15.61	15.76
Fe ₂ O ₃ (%)	4.62	5.97	6.29	6.20	5.67	5.34	5.68
K ₂ O (%)	2.66	2.83	3.16	4.53	4.28	4.75	3.70
CaO (%)	1.16	0.89	0.87	2.52	4.18	5.45	2.51
MgO (%)	1.56	1.83	2.11	3.69	4.03	4.66	2.98
Na ₂ O (%)	0.68	0.64	0.63	0.45	0.53	0.45	0.56
TiO ₂ (%)	0.79	0.81	0.80	0.80	0.74	0.71	0.78
P ₂ O ₅ (%)	0.13	0.06	0.07	0.07	0.08	0.07	0.08
MnO (%)	0.11	0.09	0.07	0.09	0.08	0.06	0.08
Barium	583	673	617	631	494	465	577
Chromium	94	108	92	90	79	79	90
Copper	22	26	31	30	26	24	27
Mercury (µg/kg)	26	36	55	24	24	18	31
Nickel	31	38	43	64	52	48	46
Lead	33	26	27	24	24	22	26
Rubidium	129	148	150	177	168	179	159
Strontium	128	138	140	130	128	125	132
Vanadium	112	138	142	136	128	122	130
Zinc	82	88	96	96	91	92	91
Zirconium	310	249	224	176	174	152	214
Total C (%)	2.27	1.31	0.75	1.43	2.08	2.56	1.73
Inorganic C (%)	0.12	0.07	0.08	1.00	1.61	2.03	0.82
Organic C (%)	2.15	1.24	0.67	0.43	0.47	0.53	0.92
pH	7.30	7.35	7.45	7.86	8.12	8.25	7.72

Table 54. Means and ranges of elemental contents of the uppermost samples from Illinois soil cores 77 through 101 compared with results for surface soils as determined by other researchers

Element	This Work		Shacklette and Boerngen ⁽²⁾	
	Mean	Range	Mean	Range
Silicon (%)	34.79	30.3-41.8	NR [†]	29-45**
Aluminum (%)	5.35	2.01-7.51	NR	<0.07-8.5**
Iron (%)	2.18	0.86-3.50	2.1 ⁽¹⁾	0.1-4.0**
Potassium (%)	1.70	0.92-2.21	1.7 ⁽¹⁾	0.22-2.25**
Calcium (%)	0.96	0.13-4.18	0.40 ⁽¹⁾	0.3-1.5**
Magnesium (%)	0.48	0.08-0.94	0.30 ⁽¹⁾	0.005-1.25**
Sodium (%)	0.64	0.36-0.90	NR	0.6-1.25**
Titanium (%)	0.37	0.11-0.51	0.41	0.05-1.0
Phosphorus (%)	0.07	0.02-0.15	0.065 ⁽¹⁾	0.013-0.68**
Manganese (%)	0.09	0.02-0.27	0.052	0.005-0.15
Barium (mg/kg)	533	67-1170	675	200-1500
Chromium (mg/kg)	90	24-166	55	10-100
Copper (mg/kg)	24	10-37	25	7-100
Mercury (µg/kg)	40	10-123	70***	20-360***
Nickel (mg/kg)	27	8-37	17	5-30
Lead (mg/kg)	35	11-147	19	10-30
Rubidium (mg/kg)	86	24-129	75	45-100
Strontium (mg/kg)	118	67-140	305	20-1000
Vanadium (mg/kg)	81	26-117	87	20-150*
Zinc (mg/kg)	79	7-138	58.5	20-109
Zirconium (mg/kg)	365	134-498	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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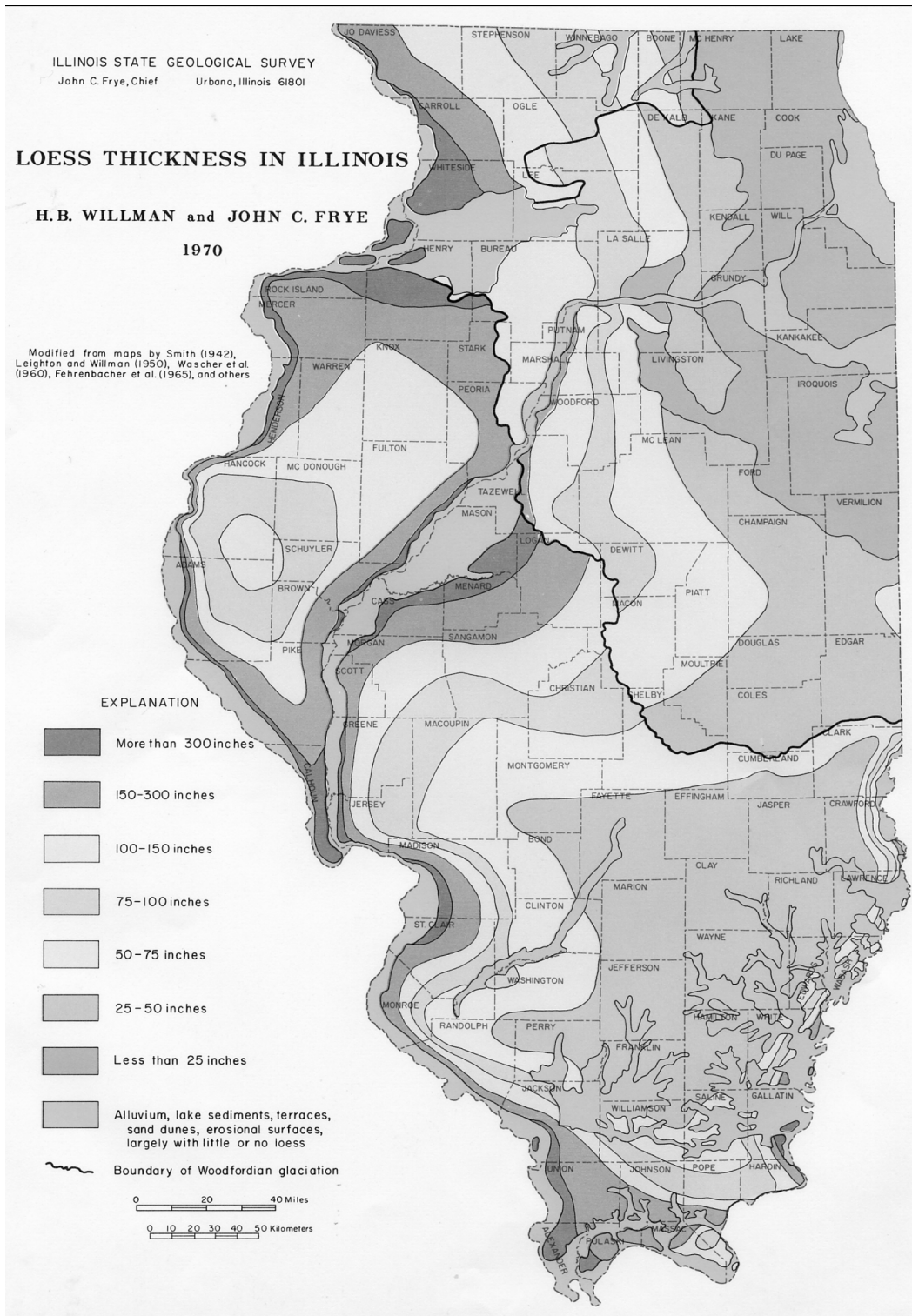


Figure 1. Loess thickness in Illinois (after Willman and Frye, 1970).

QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback
1981

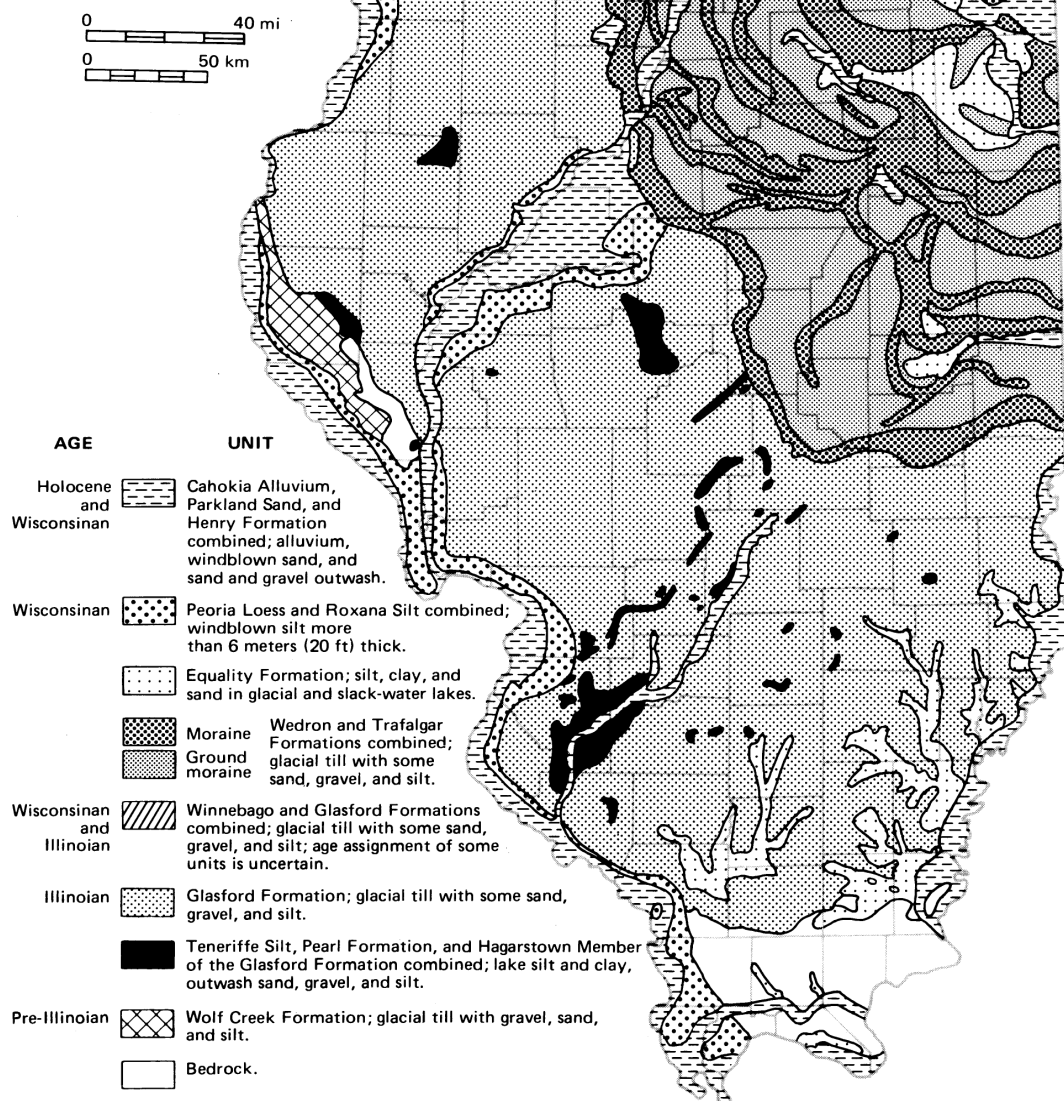


Figure 2. Quaternary deposits in Illinois (after Lineback, 1981).

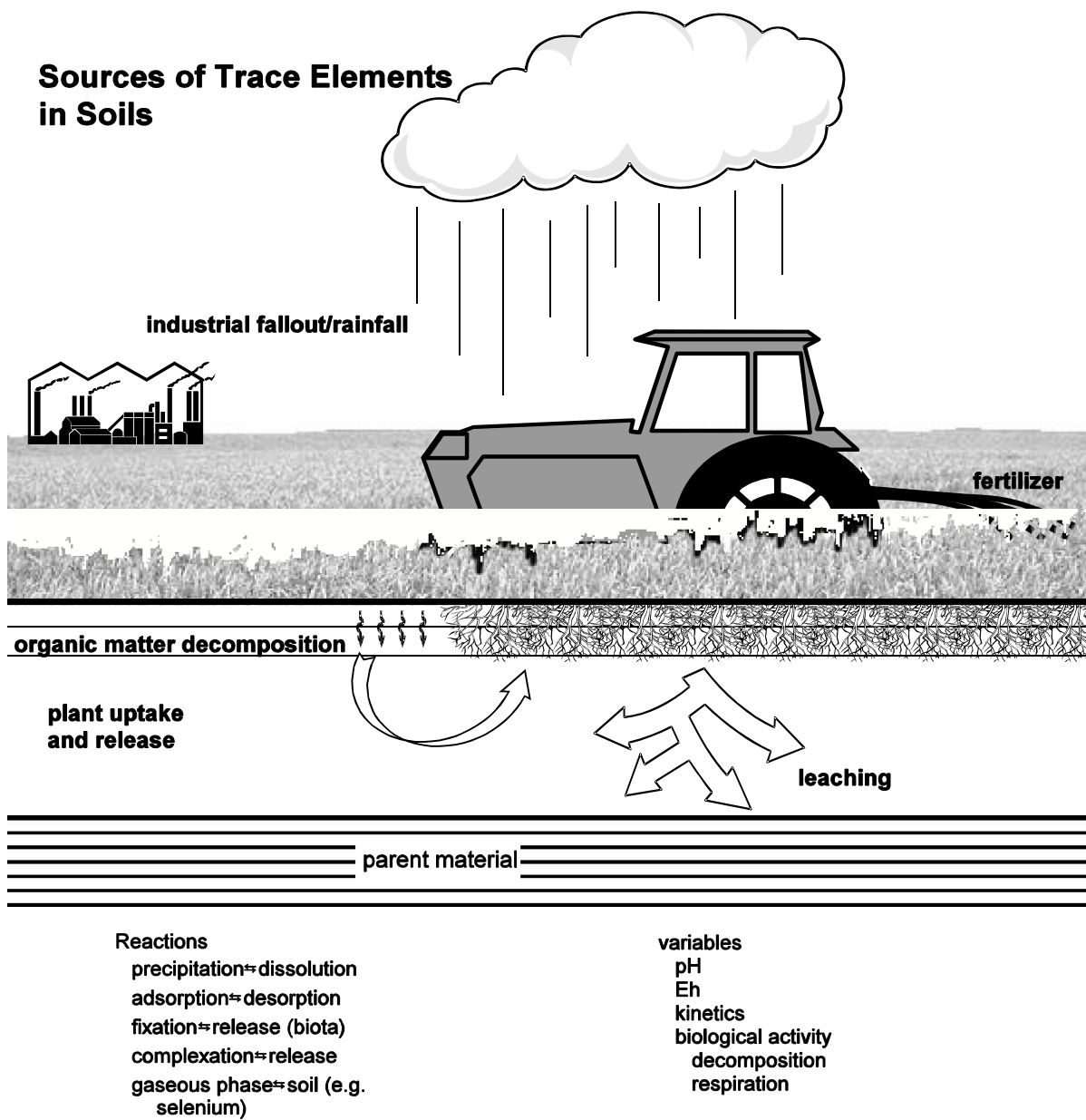


Figure 3 Schematic diagram of various input and output functions that affect trace elements, reactions that affect soil chemistry, and variables that affect reactions.

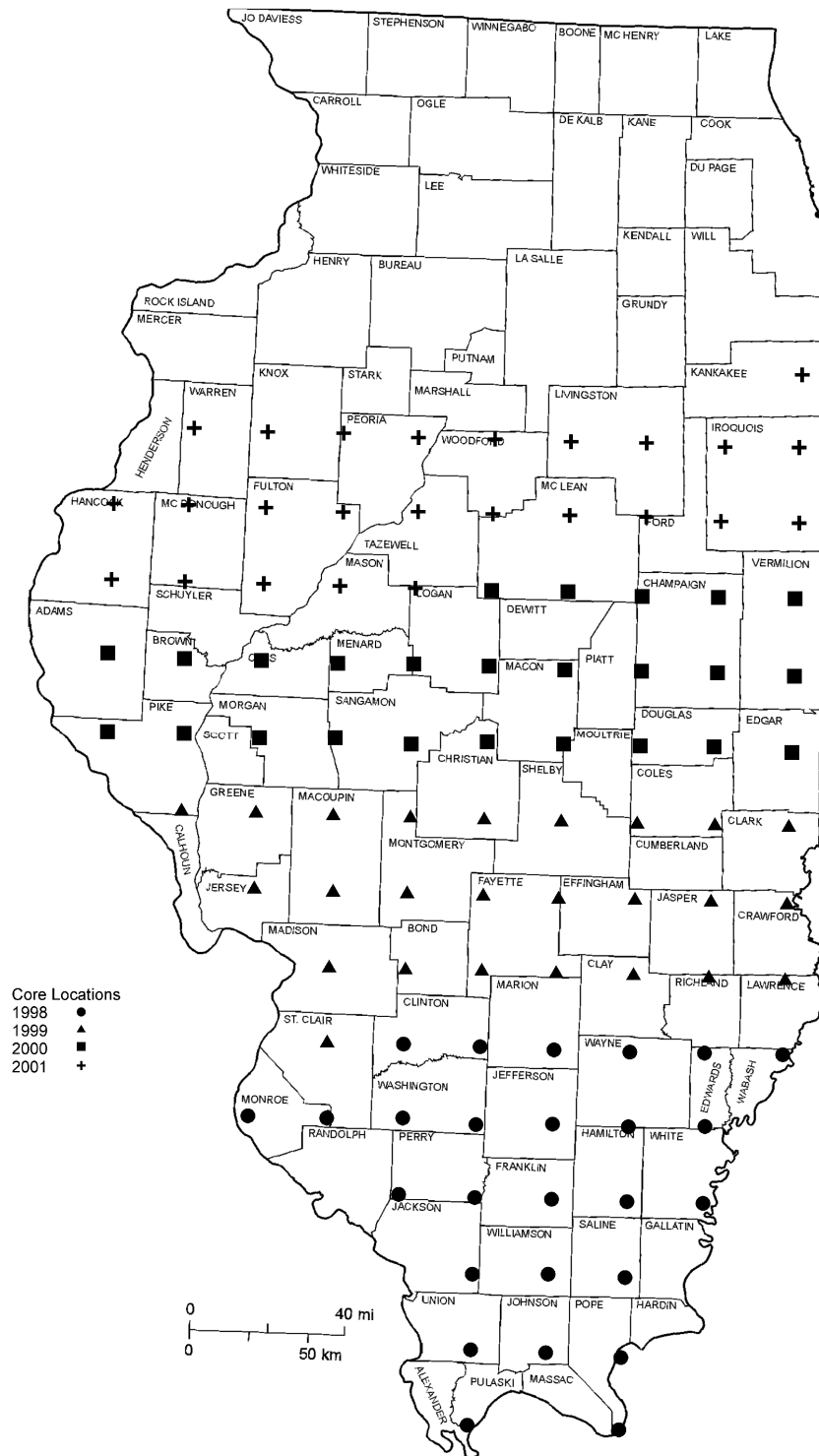


Figure 4. Locations of soil cores collected from 1998 through 2001.

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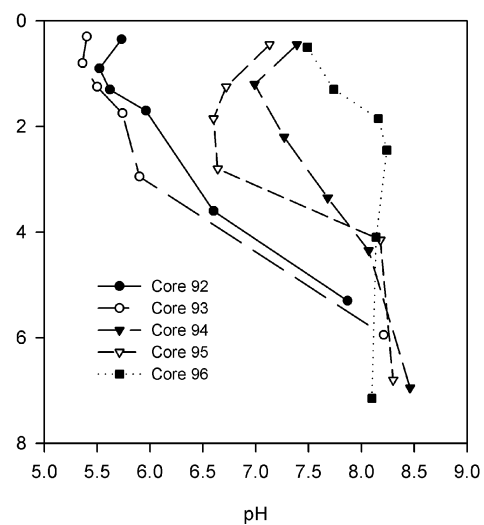
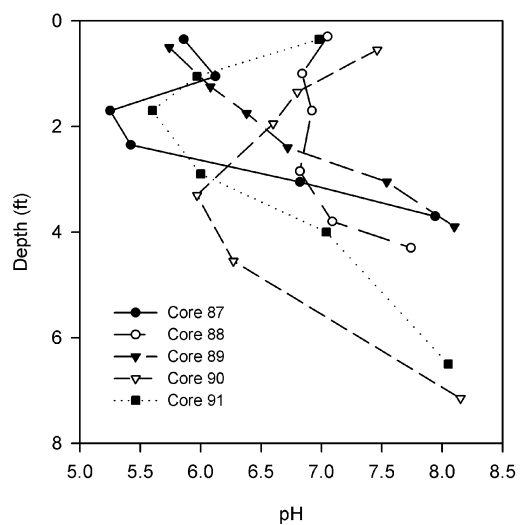
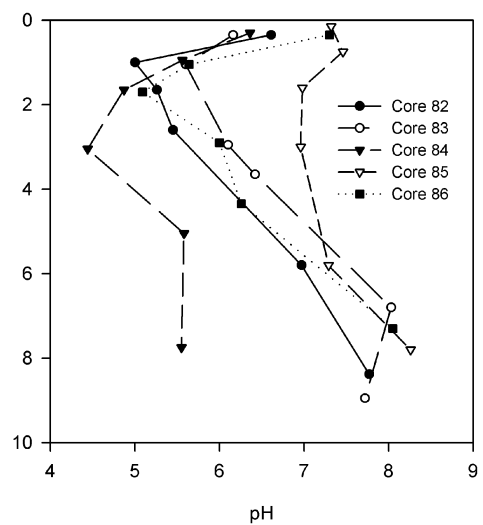
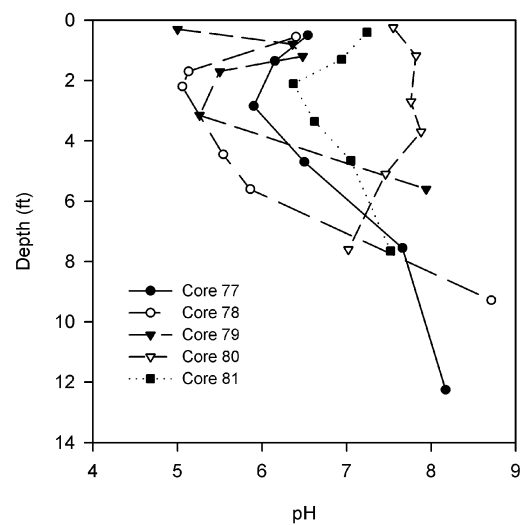


Figure 5. pH versus depth in cores 77 through 101.

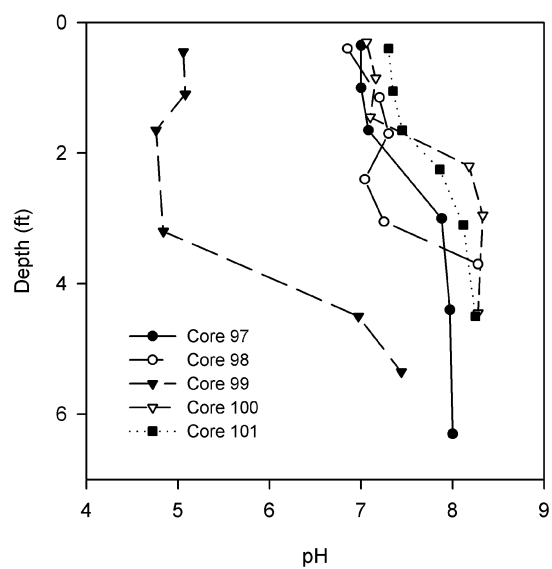


Figure 5. pH versus depth in cores 77 through 101, continued.

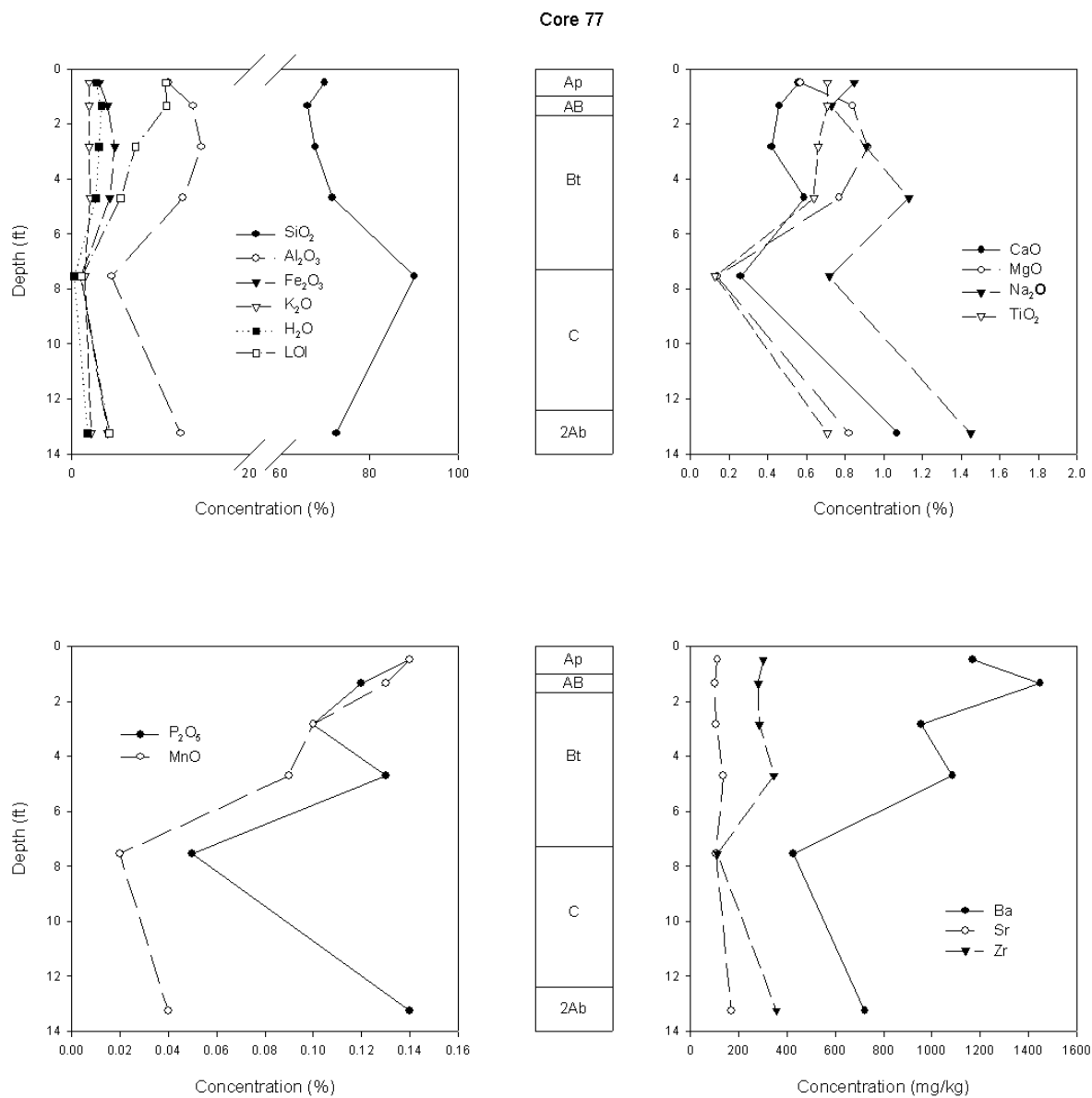
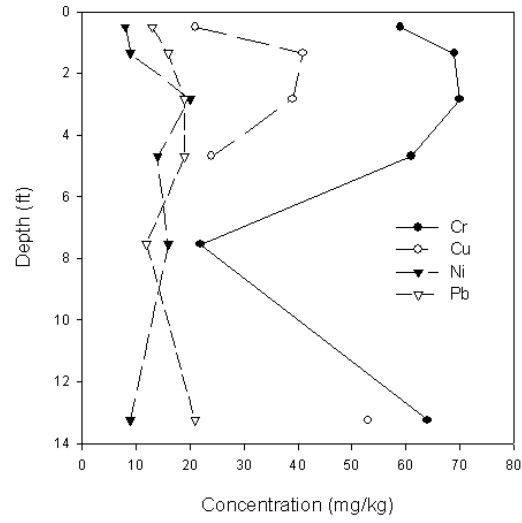
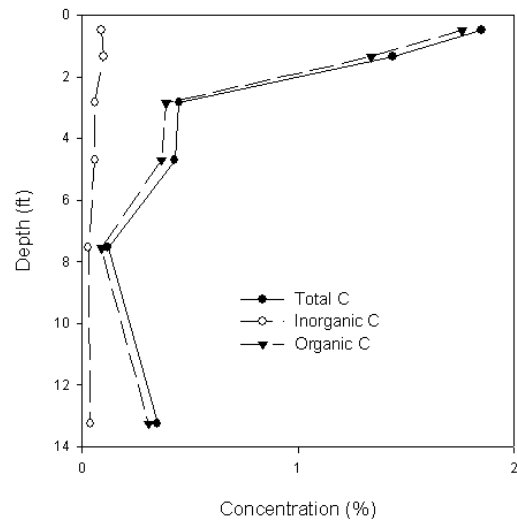
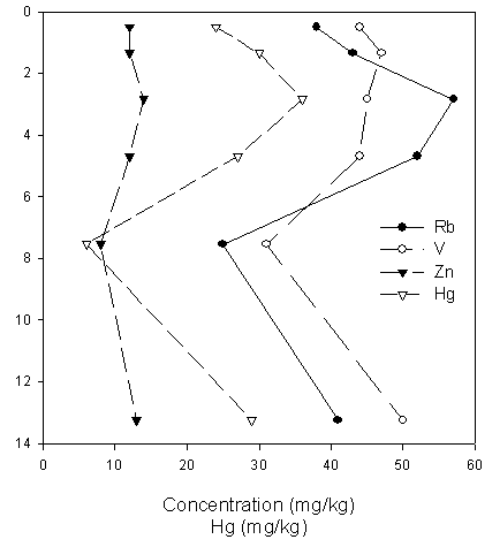


Figure 6. Elemental concentrations versus depth in core 77.

Core 77



Ap
AB
Bt
C
2Ab



Ap
AB
Bt
C
2Ab

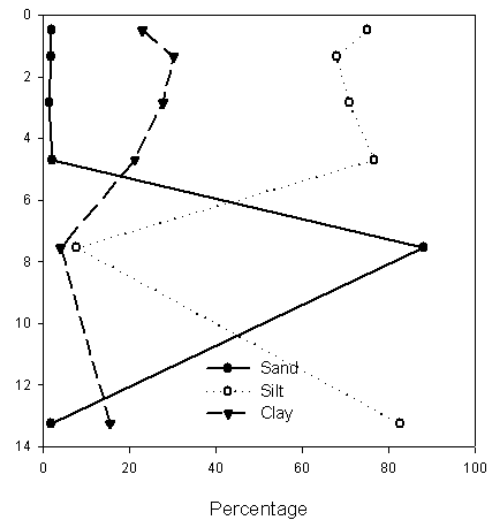


Figure 7. Elemental concentrations versus depth in core 77.

Core 78

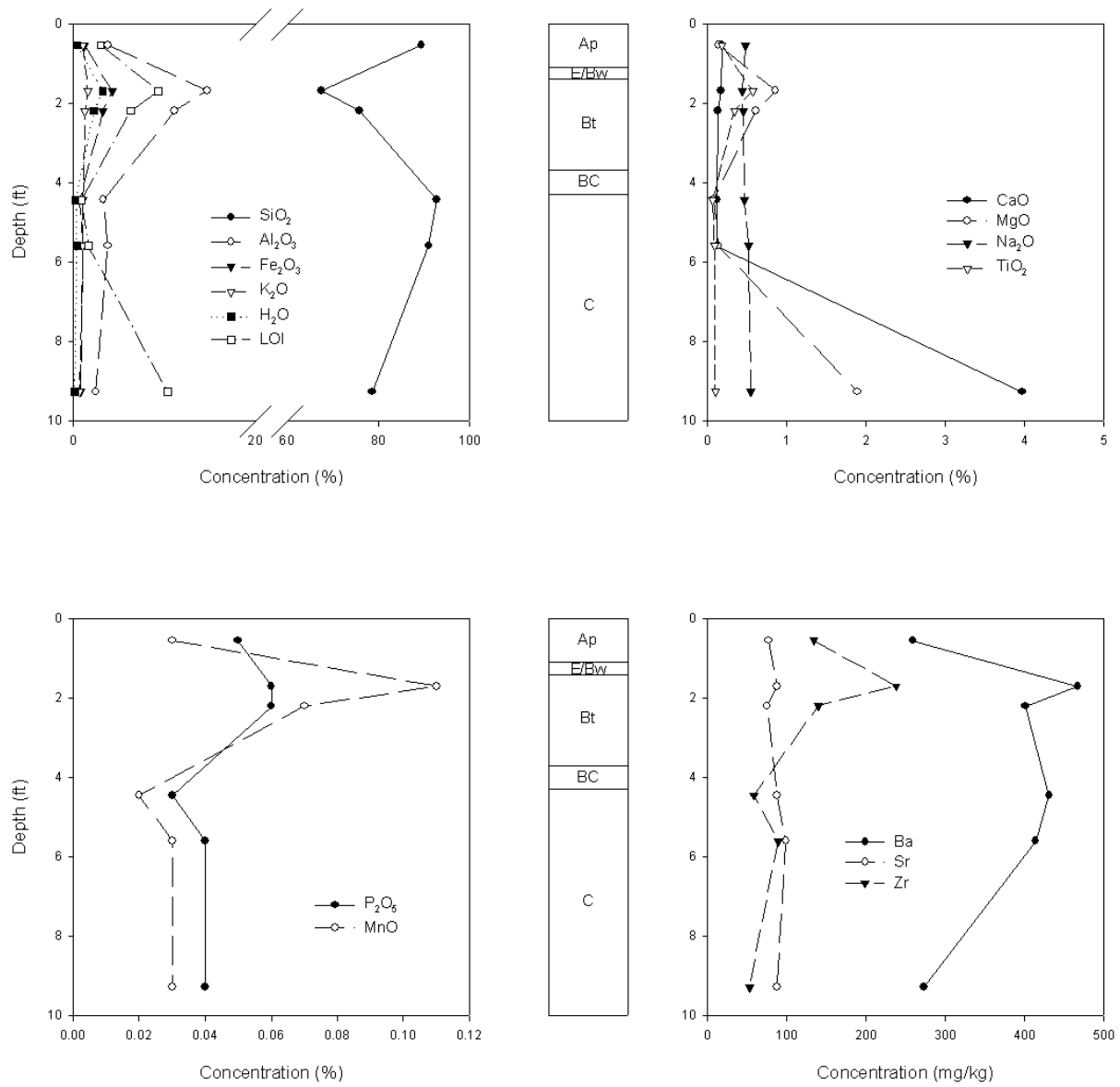


Figure 8. Elemental concentrations versus depth in core 78.

Core 78

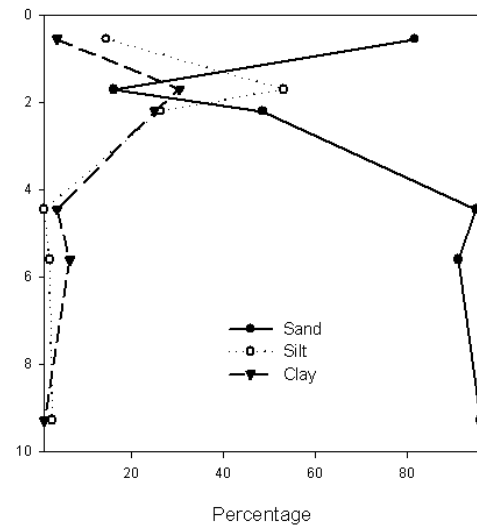
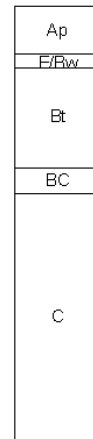
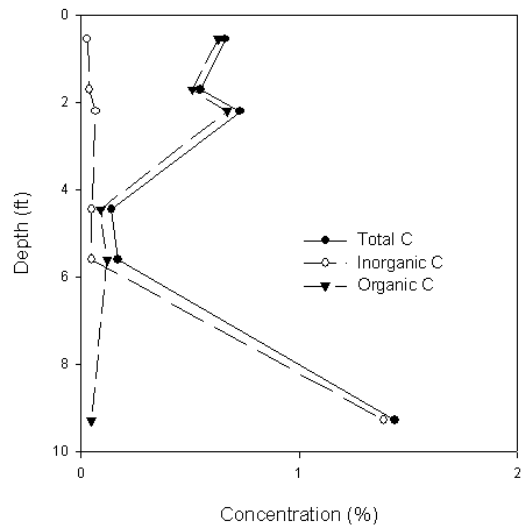
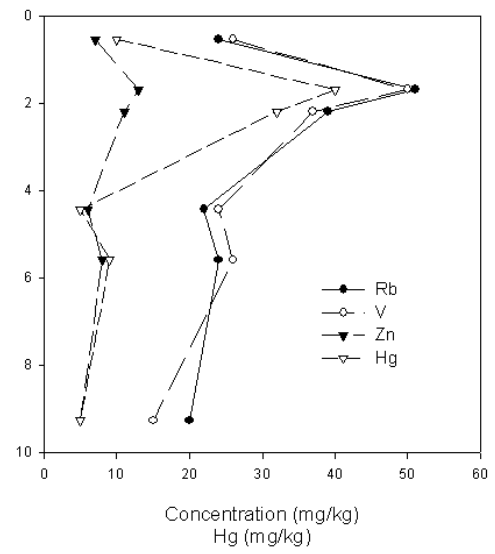
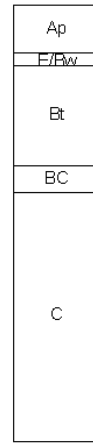
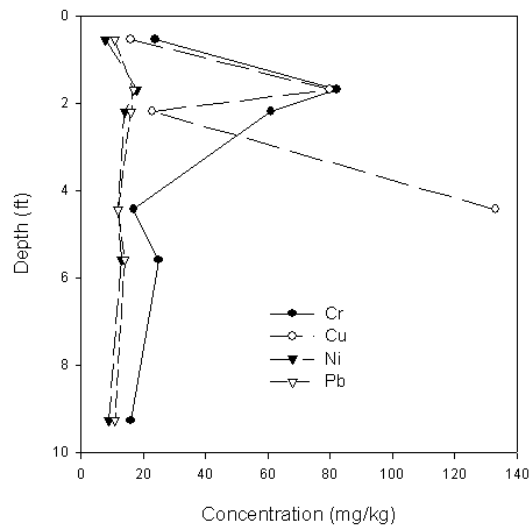
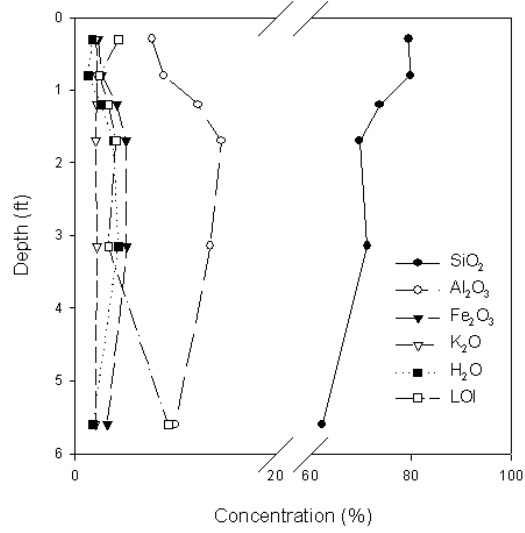
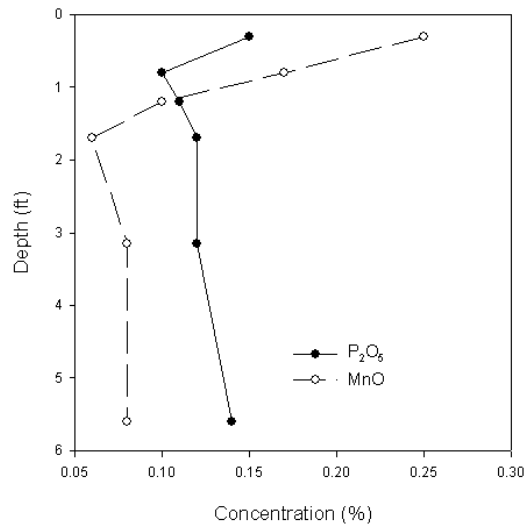
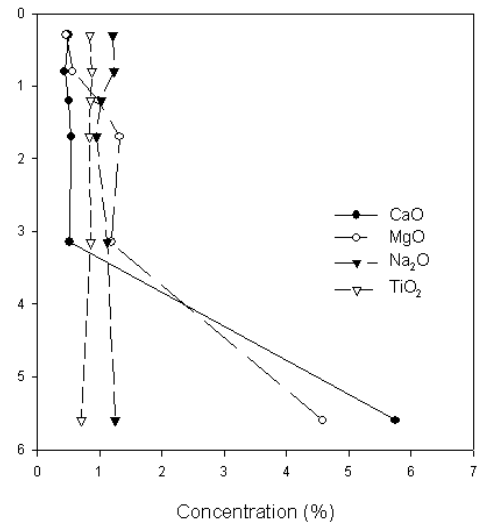


Figure 9. Elemental concentrations versus depth in core 78.

Core 79



Ap
E
BE
Bt
BC
CB
C



Ap
E
BE
Bt
BC
CB
C

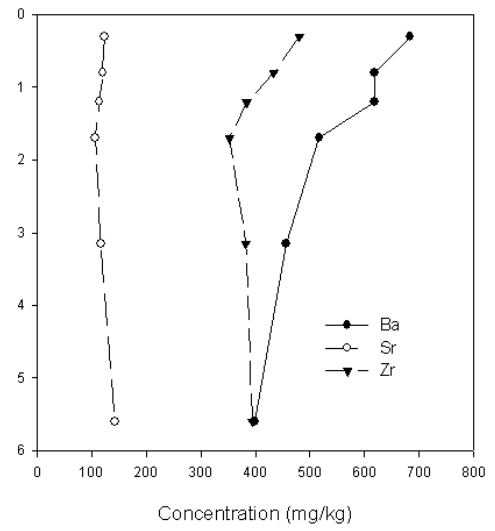
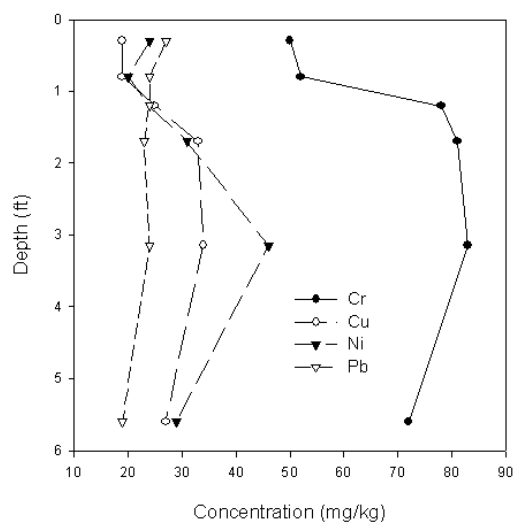
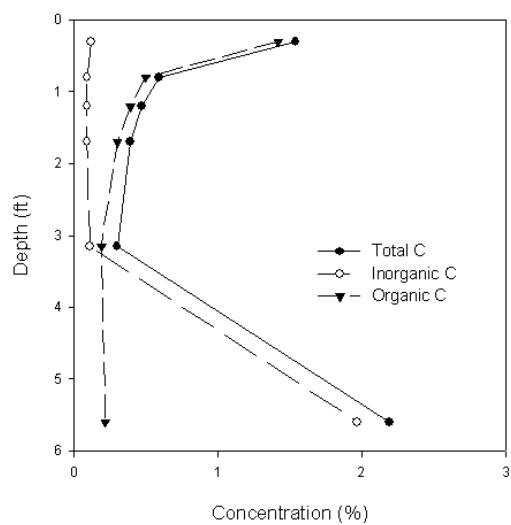
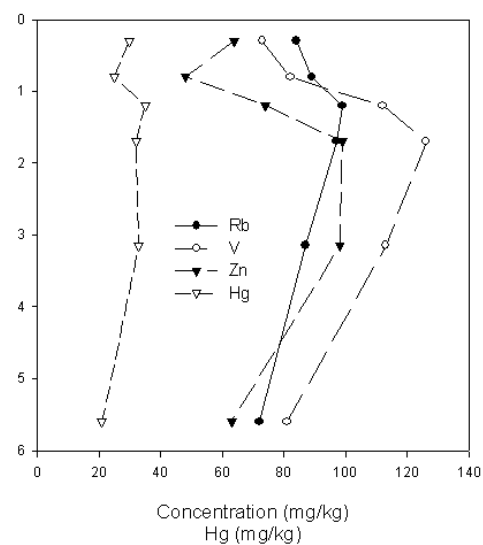


Figure 10. Elemental concentrations versus depth in core 79.

Core 79



Ap
E
BE
Bt
BC
CB
C



Ap
E
BE
Bt
BC
CB
C

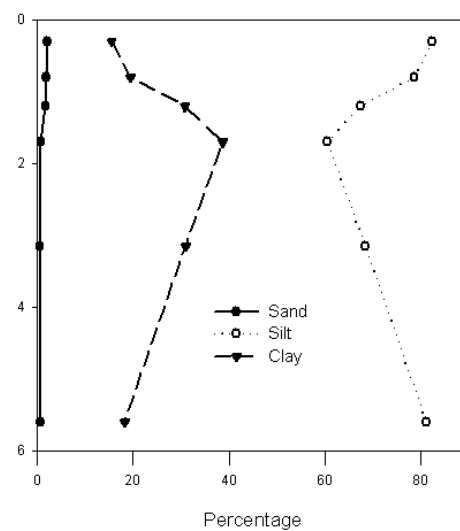


Figure 11. Elemental concentrations versus depth in core 79.

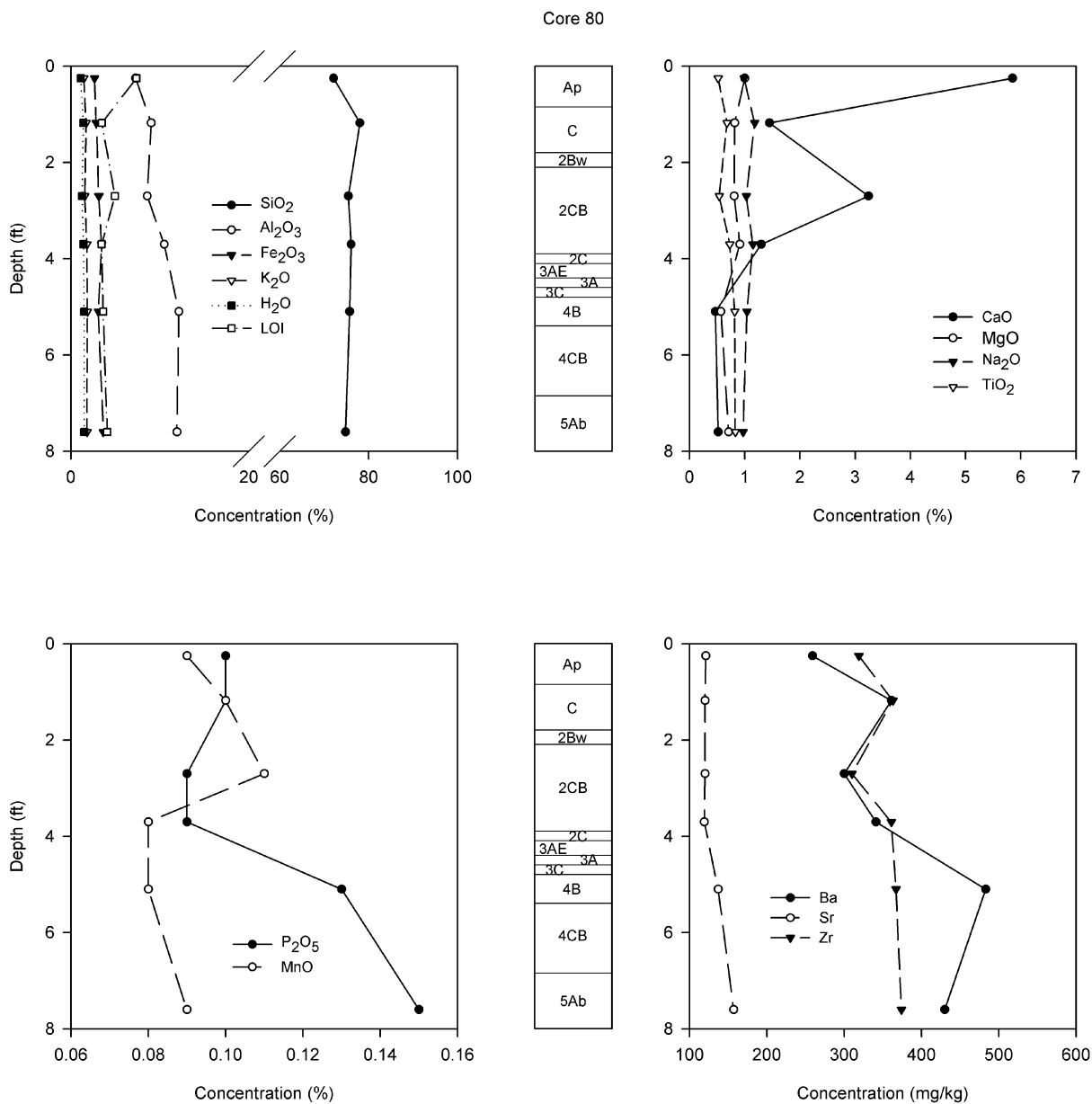
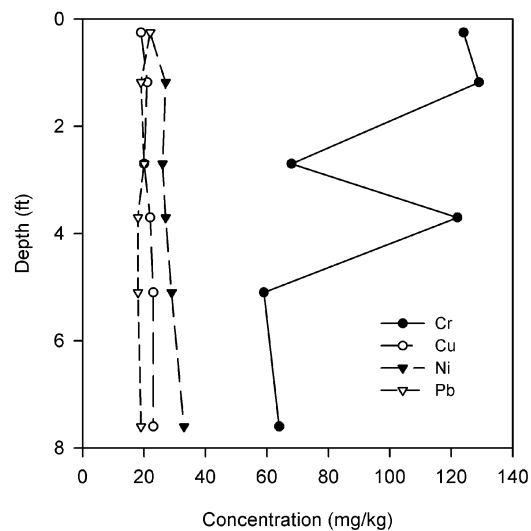
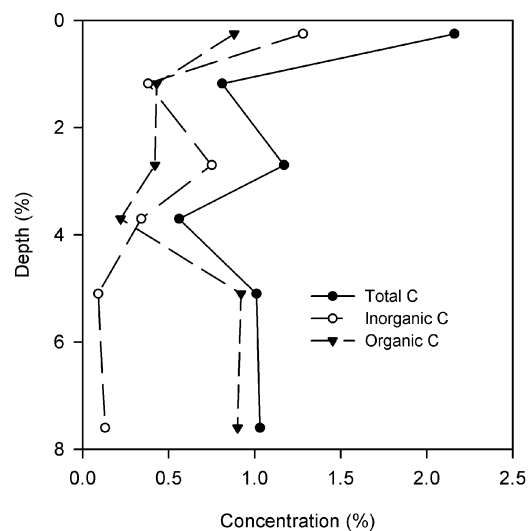
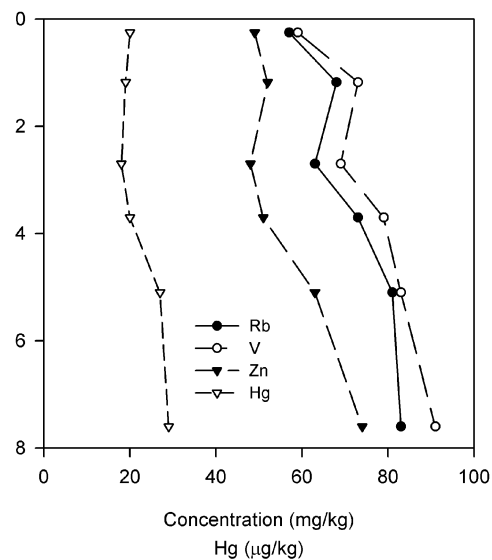


Figure 12. Element concentrations versus depth in core 80.

Core 80



Ap
C
2Bw
2CB
2C
3AE
3A
3C
4B
4CB
5Ab



Ap
C
2Bw
2CB
2C
3AE
3A
3C
4B
4CB
5Ab

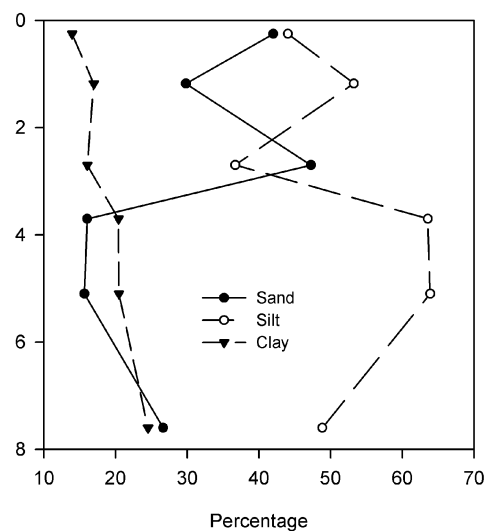


Figure 13. Element Concentrations versus depth in core 80.

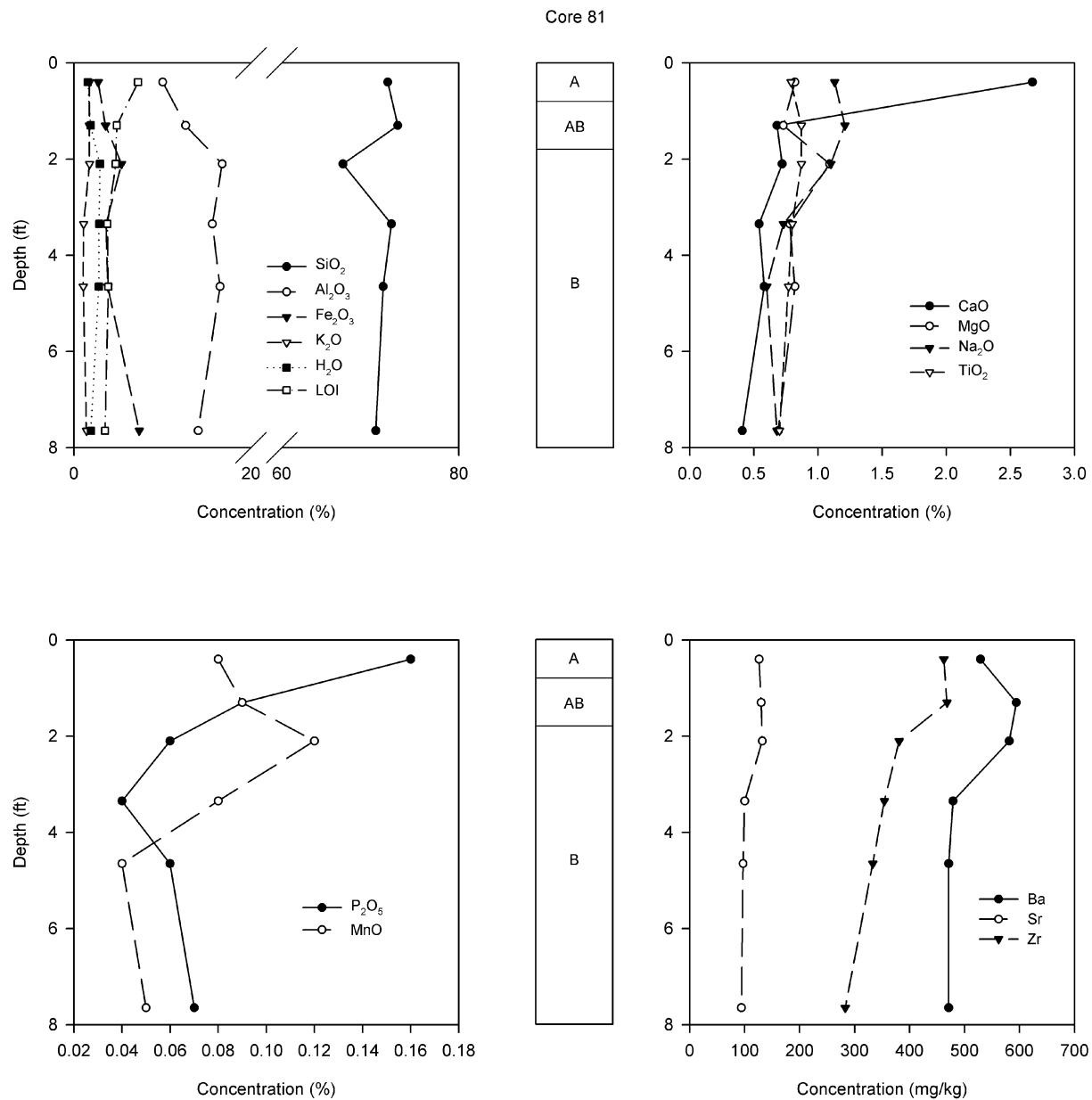


Figure 14. Element Concentrations versus depth in core 81.

Core 81

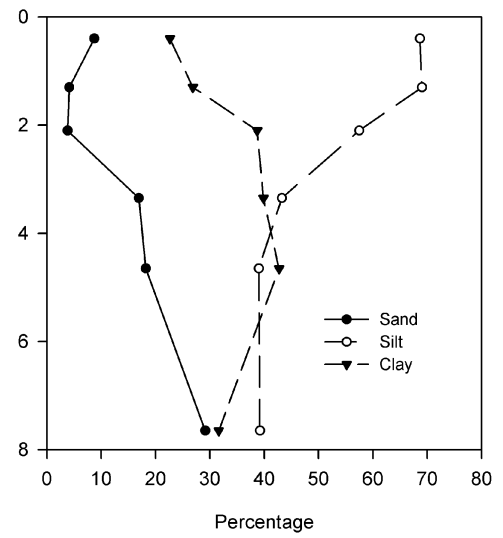
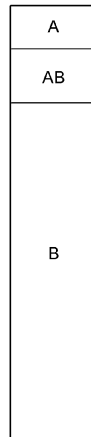
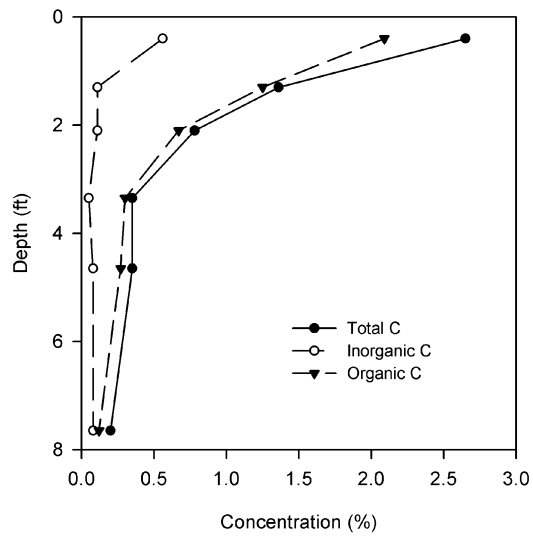
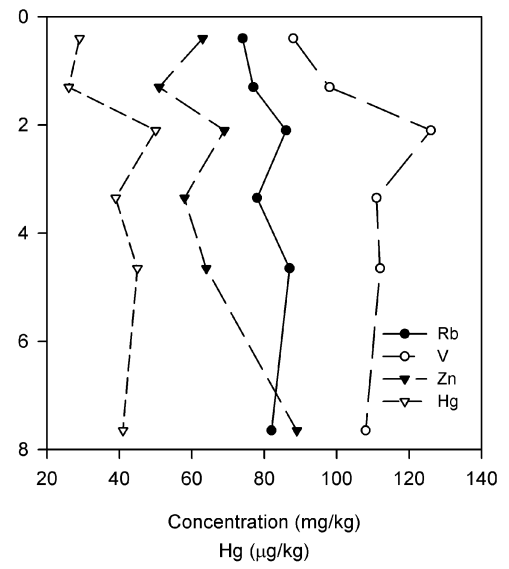
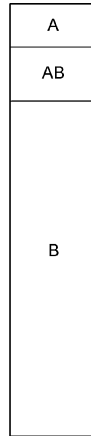
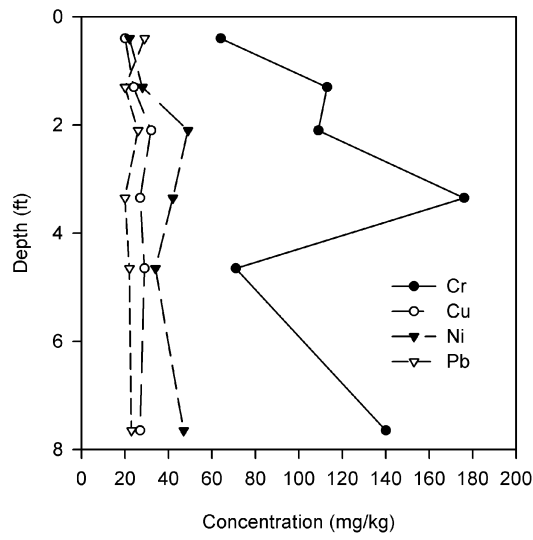


Figure 15. Element Concentrations versus depth in core 81.

Core 82

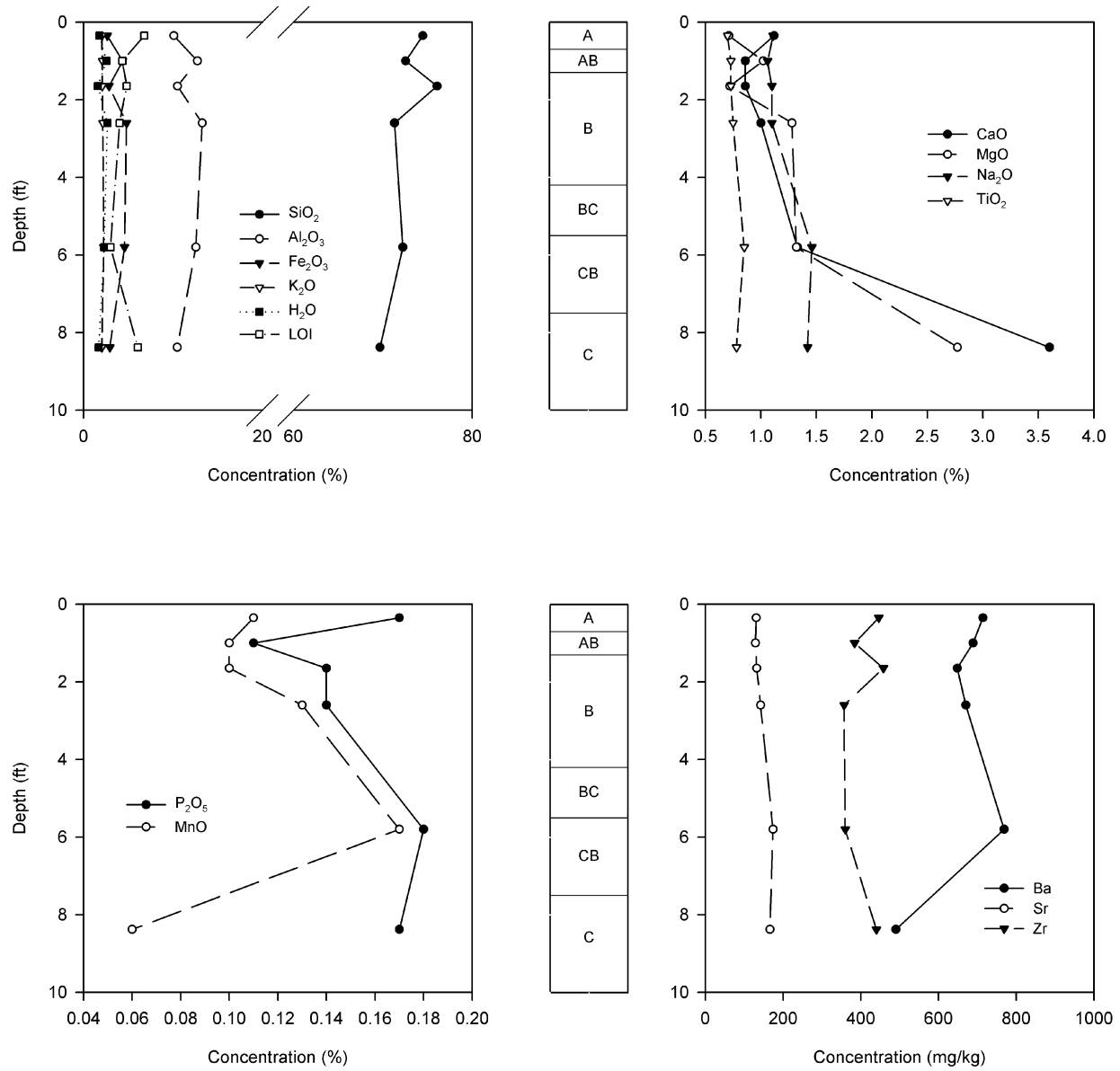


Figure 16. Element concentrations versus depth in core 82.

Core 82

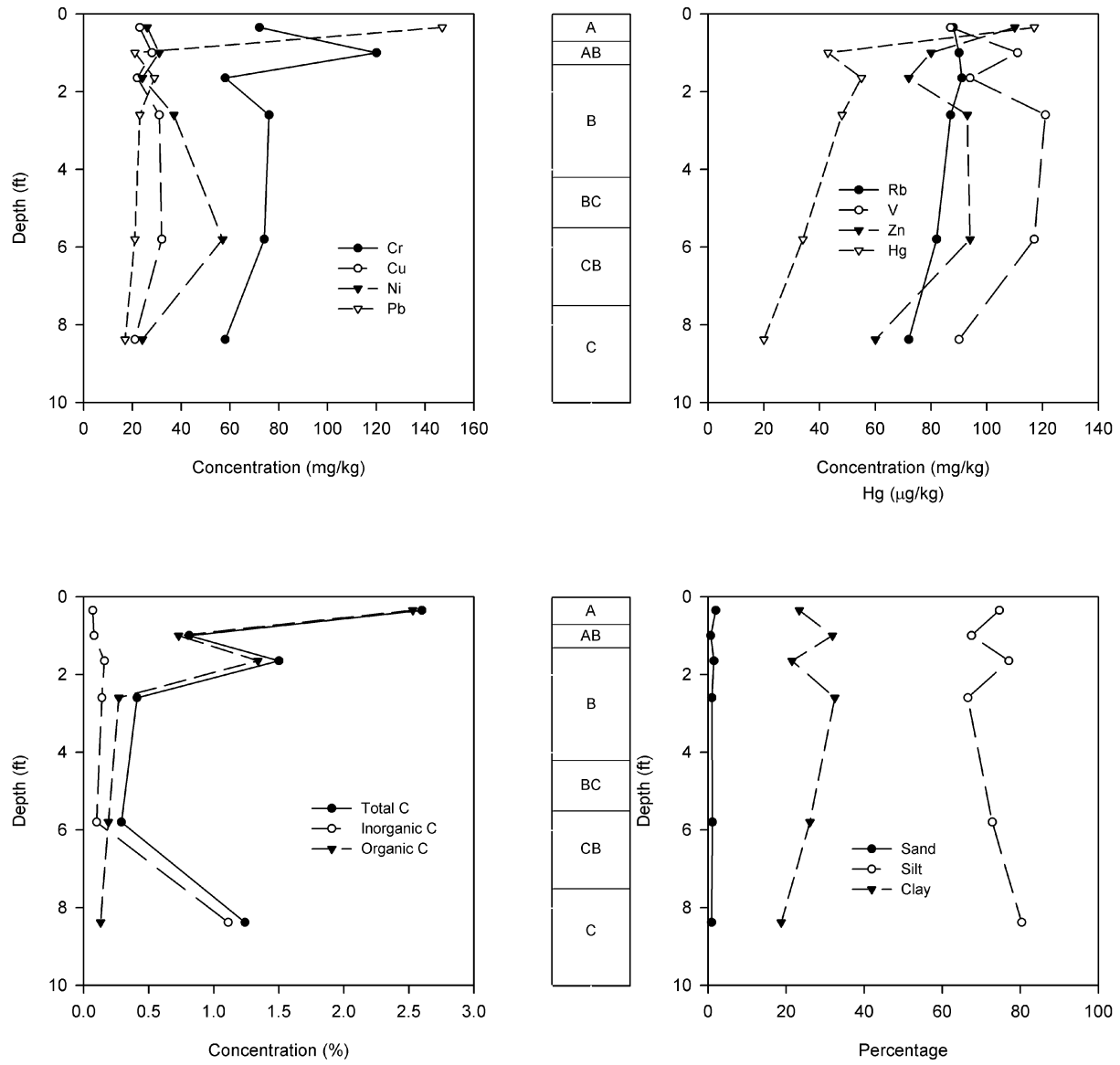


Figure 17. Element concentrations versus depth in core 82.

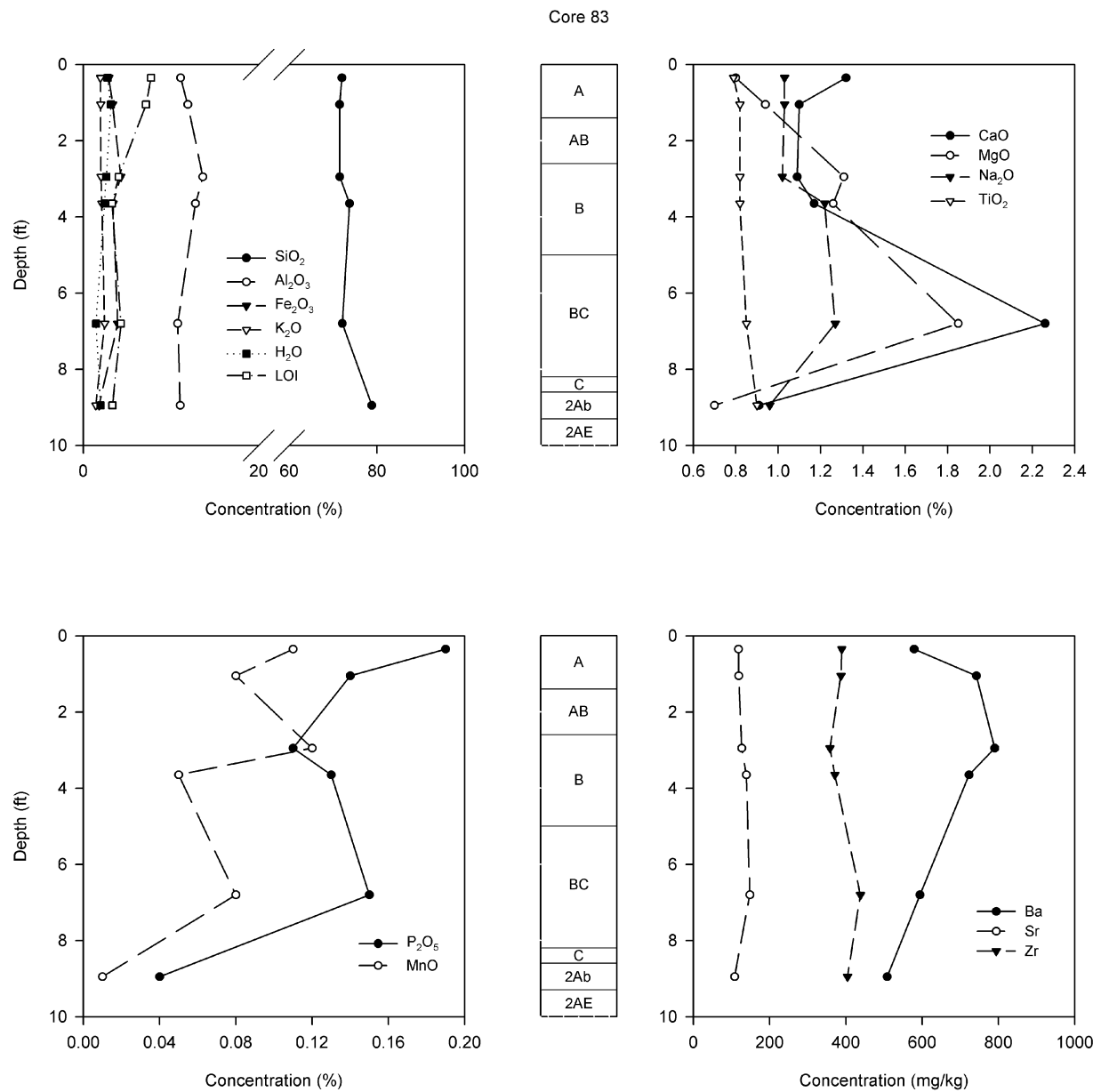
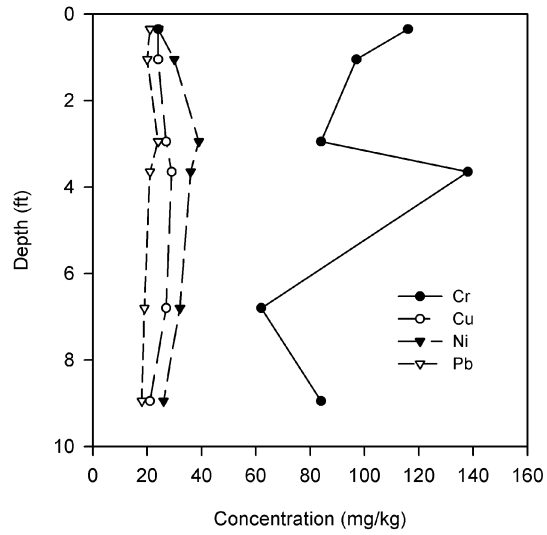
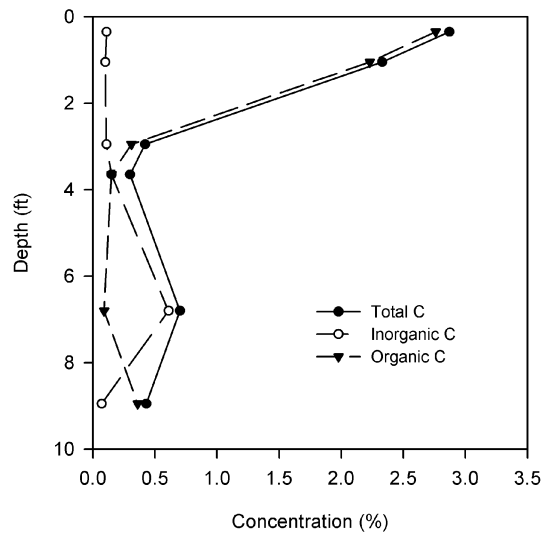
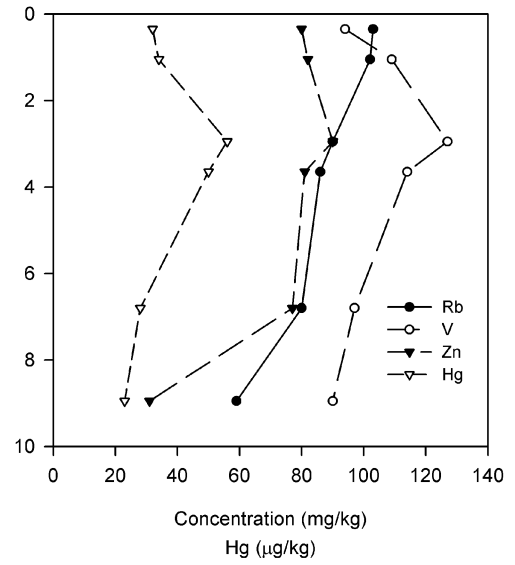


Figure 18. Element concentrations versus depth in core 83

Core 83



A
AB
B
BC
C
2Ab
2AE



A
AB
B
BC
C
2Ab
2AE

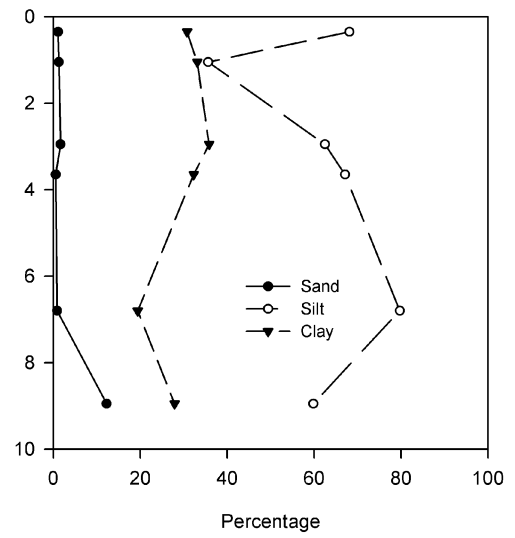
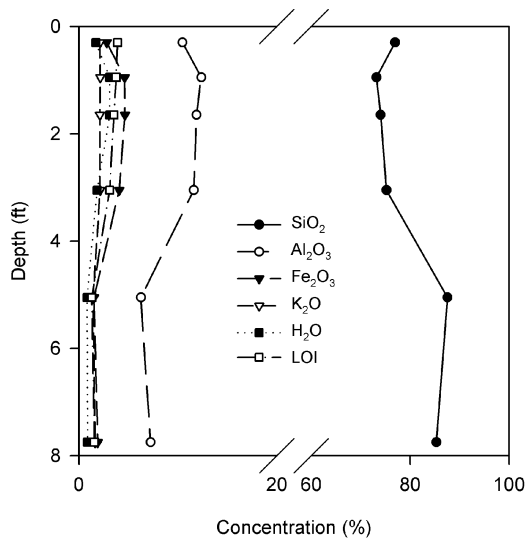
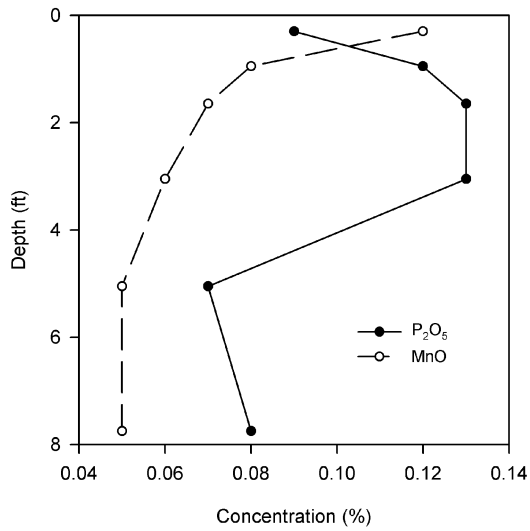
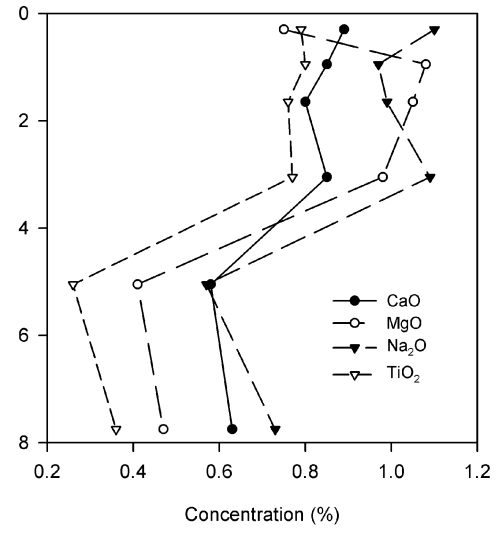


Figure 19. Element concentrations versus depth in core 83.

Core 84



Ap
B
2E
2B
2CB
2C



Ap
B
2E
2B
2CB
2C

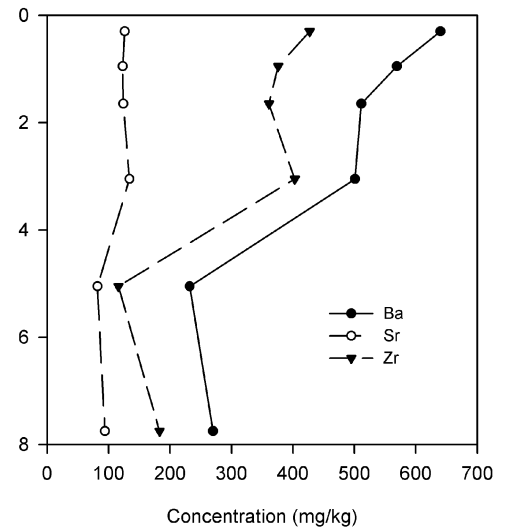
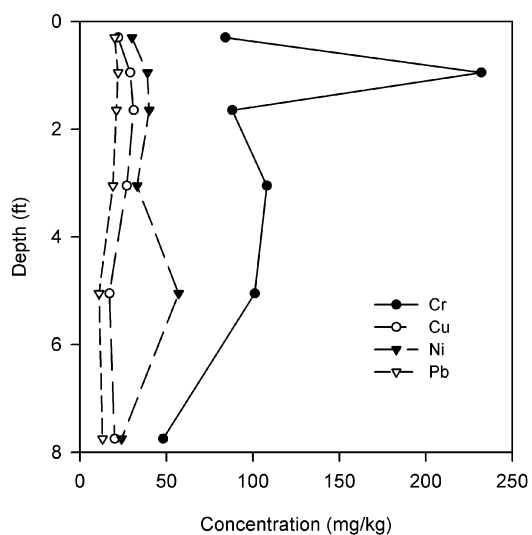
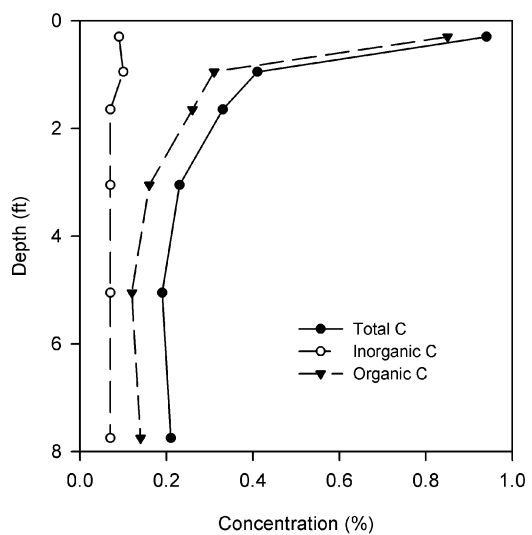
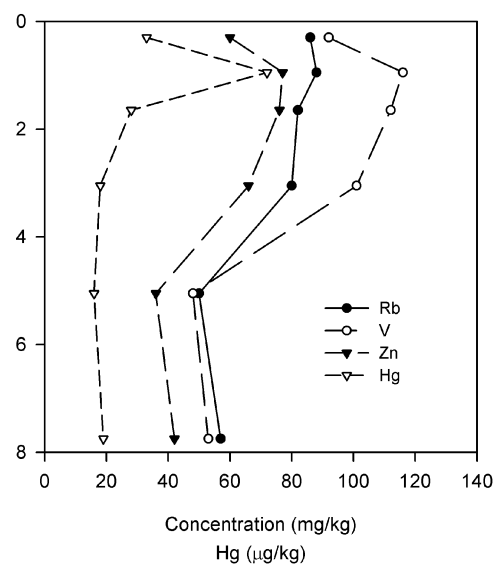


Figure 20. Element concentrations versus depth in core 84.

Core 84



Ap
B
2E
2B
2CB
2C



Ap
B
2E
2B
2CB
2C

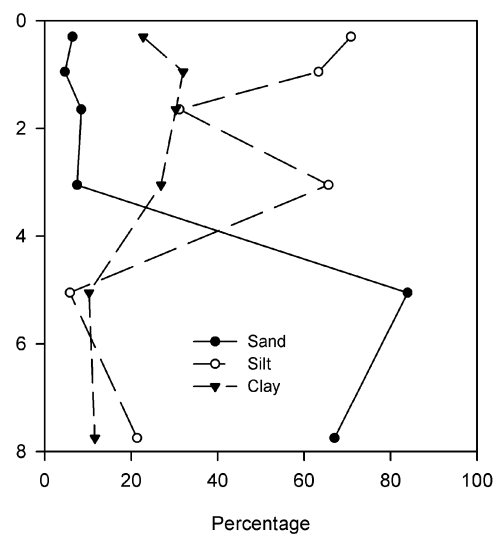


Figure 21. Element concentrations versus depth in core 84.

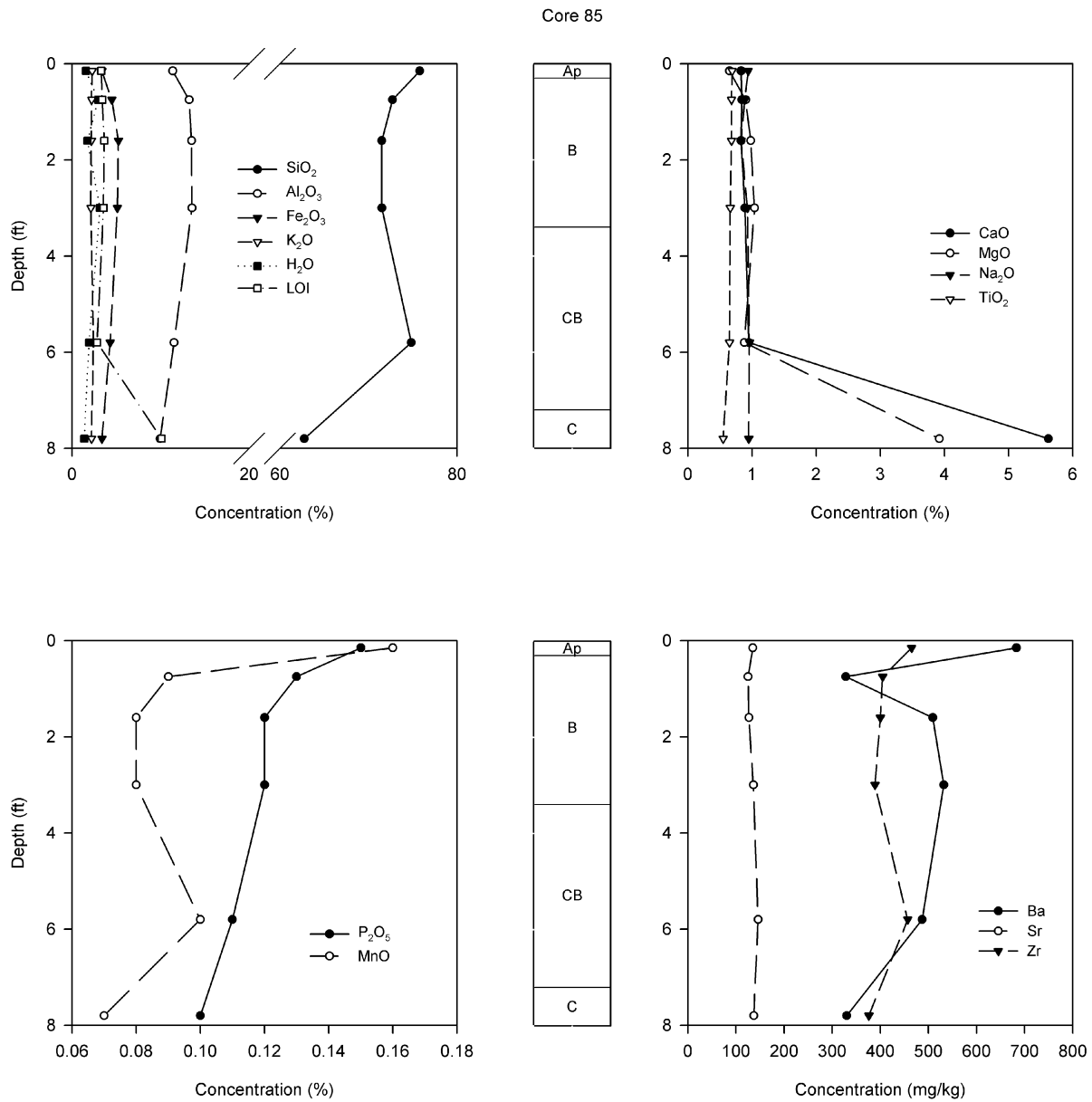


Figure 22. Element concentrations versus depth in core 85.

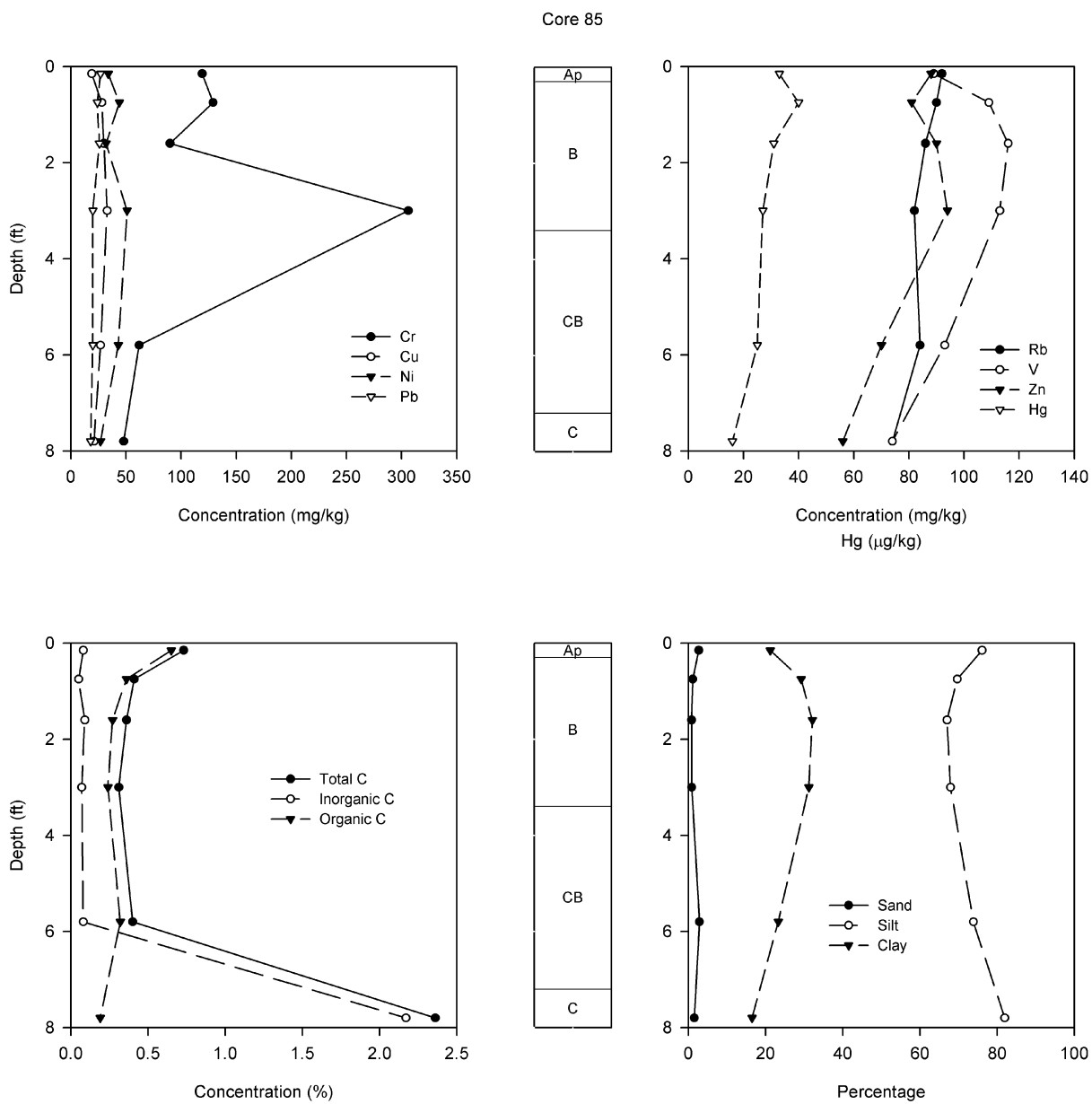


Figure 23. Element concentrations versus depth in core 85.

Core 86

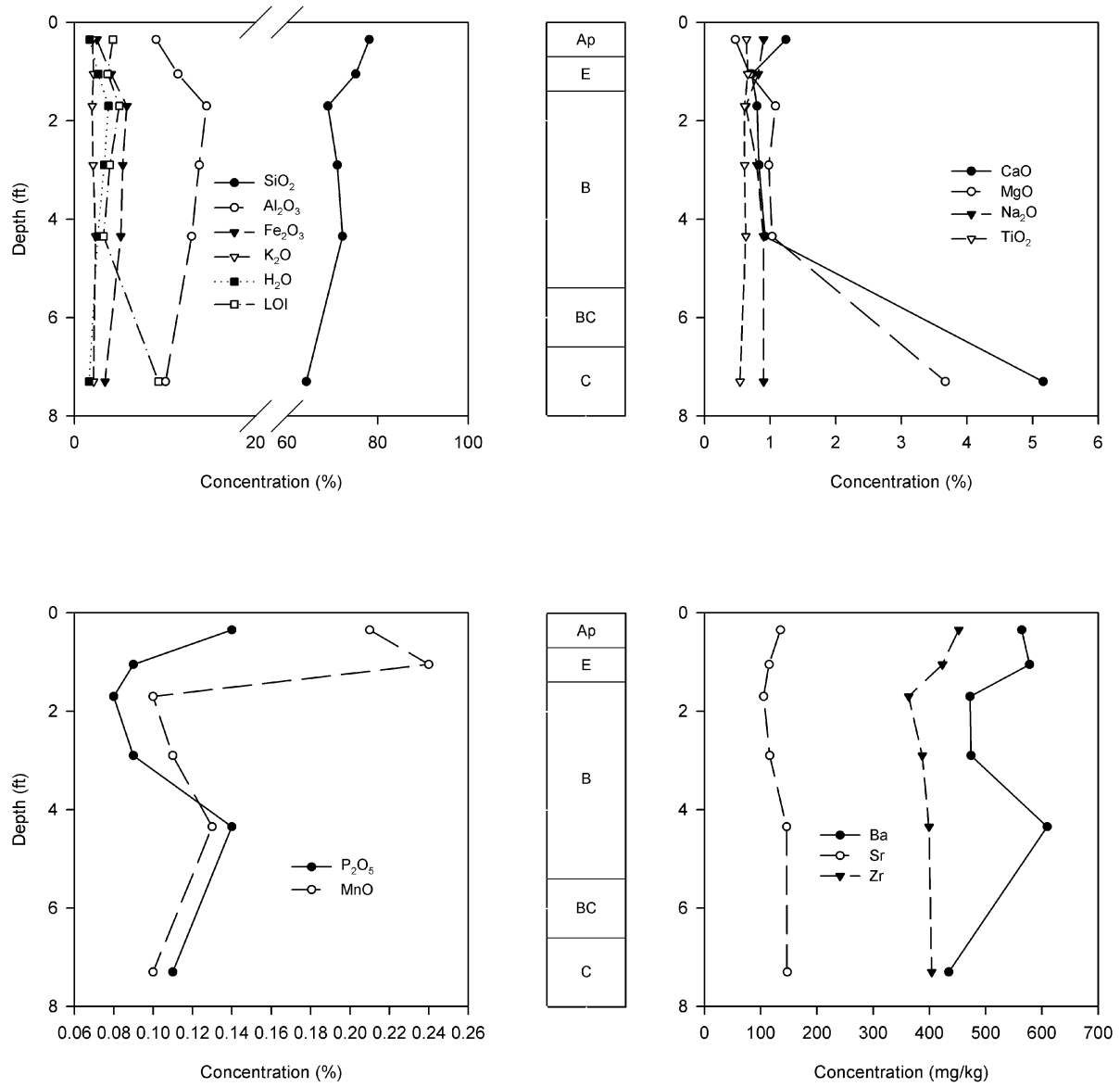
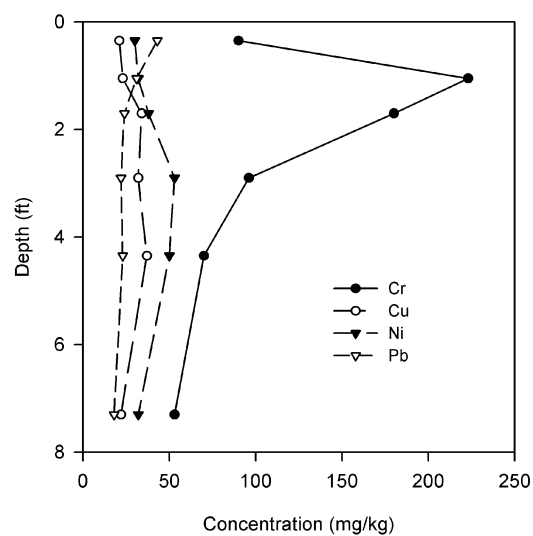
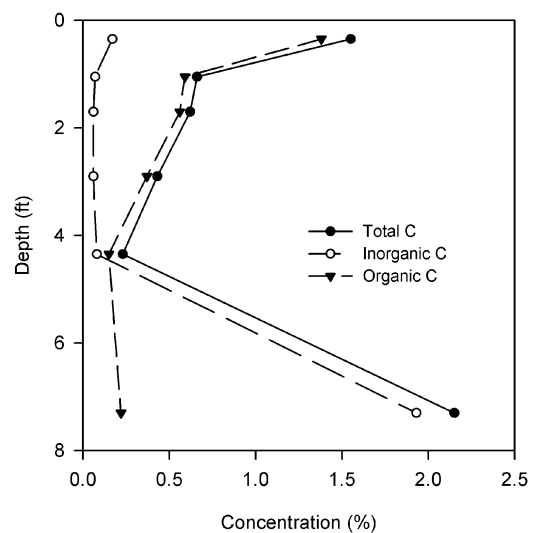
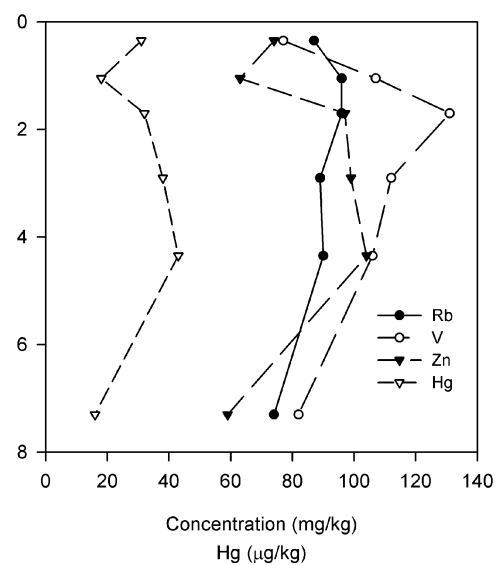


Figure 24. Element concentrations versus depth in core 86.

Core 86



Ap
E
B
BC
C



Ap
E
B
BC
C

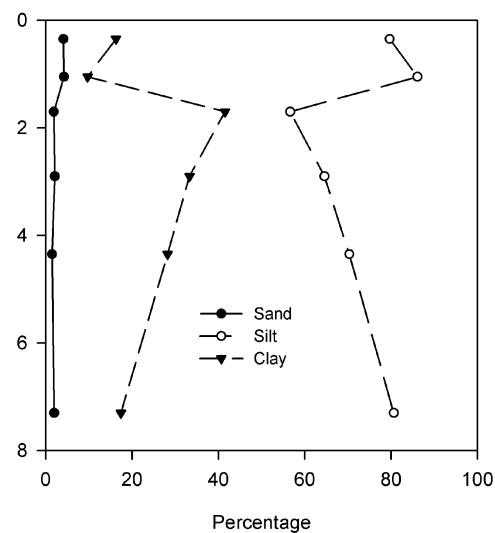


Figure 25. Element concentrations versus depth in core 86.

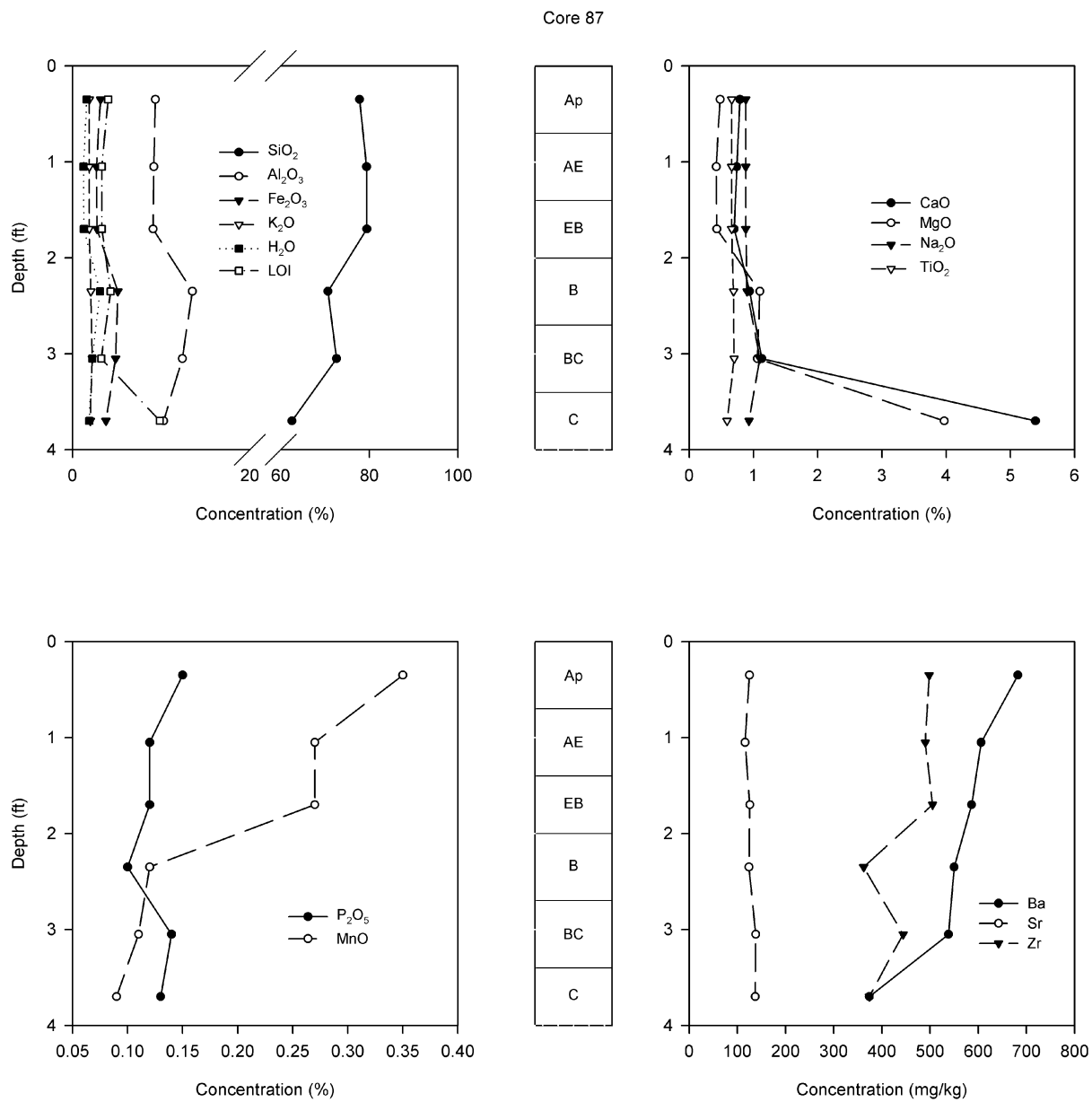
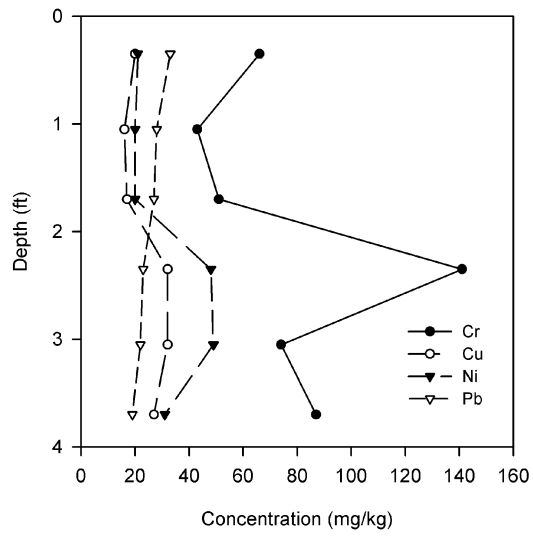
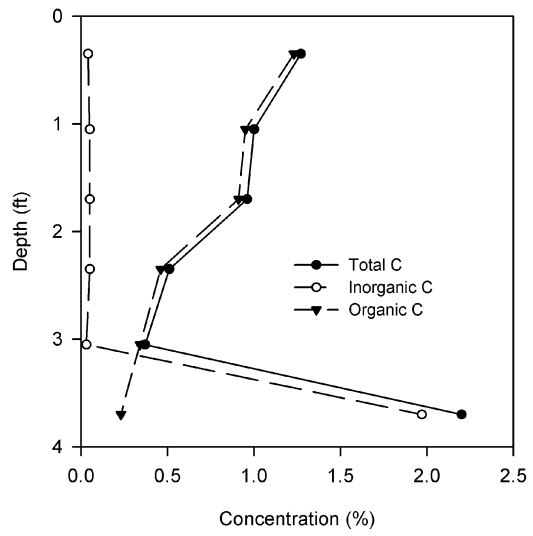
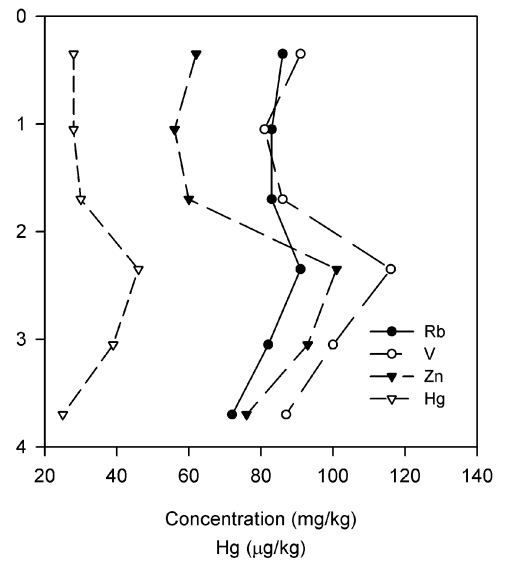


Figure 26. Element concentrations versus depth in core 87.

Core 87



Ap
AE
EB
B
BC
C



Ap
AE
EB
B
BC
C

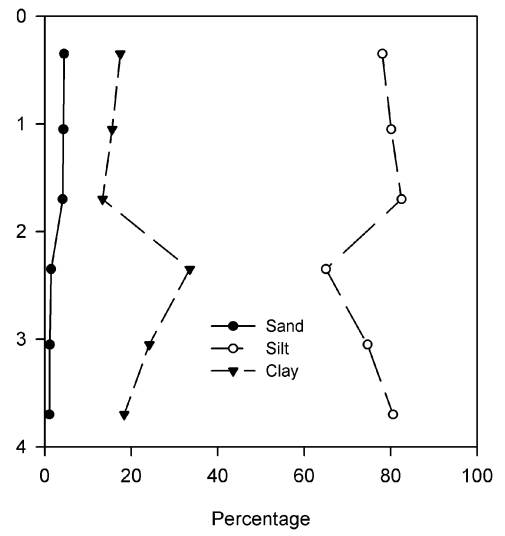


Figure 27. Element concentrations versus depth in core 87

Core 88

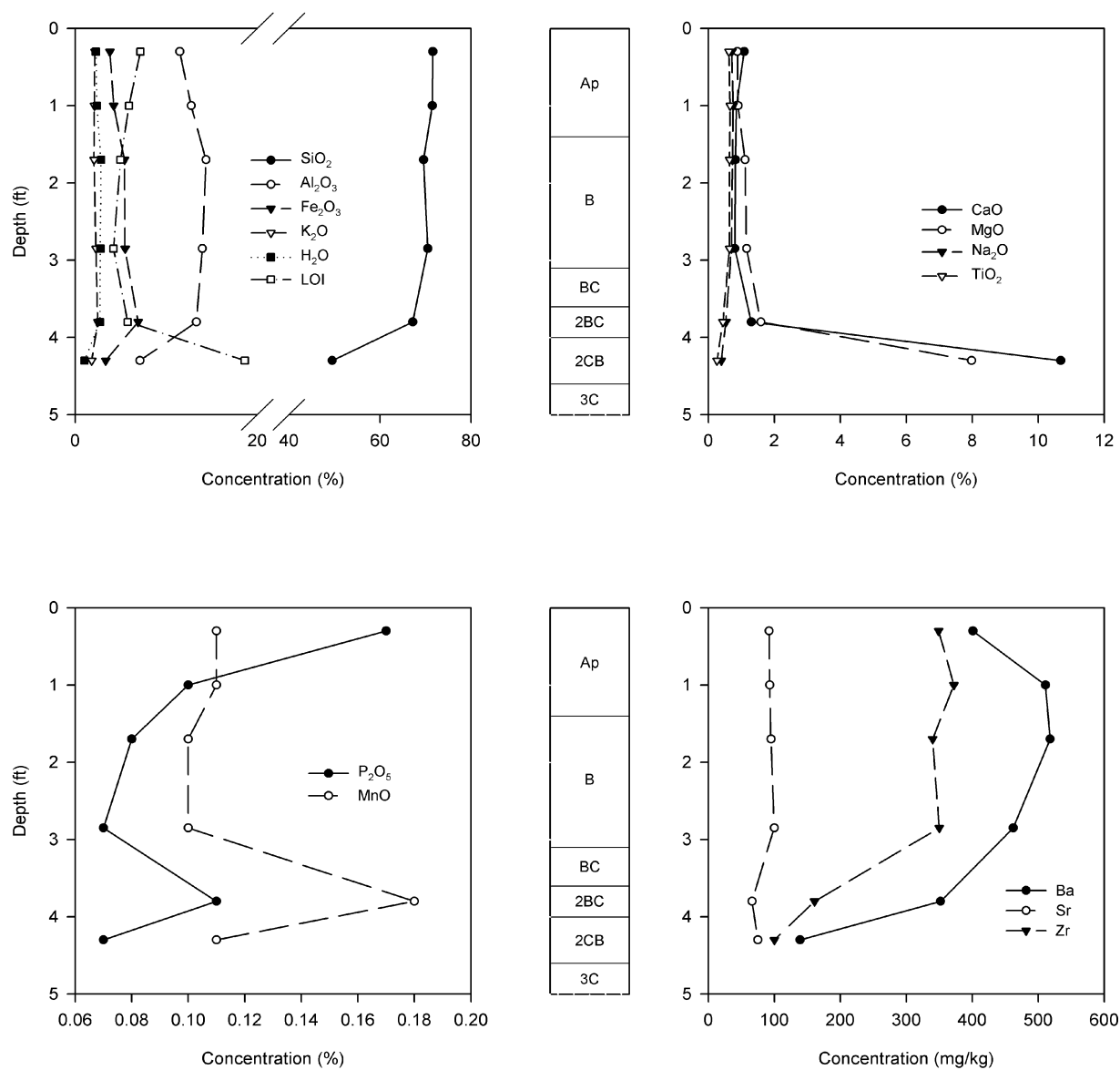


Figure 28. Element concentrations versus depth in core 88.

Core 88

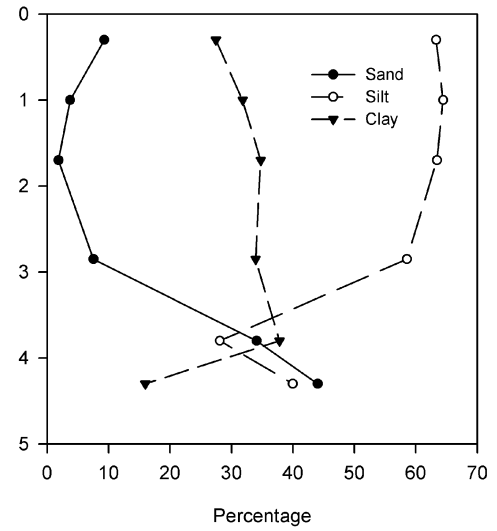
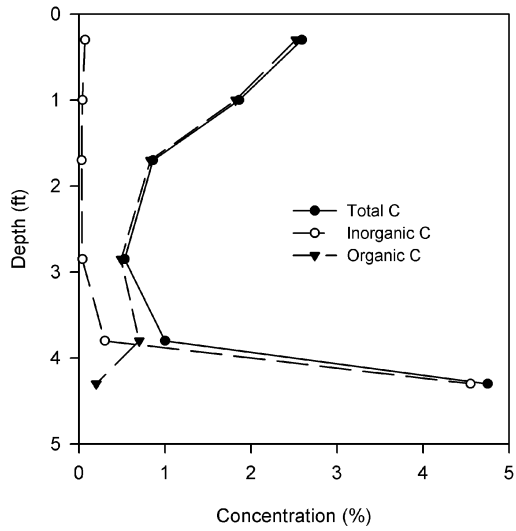
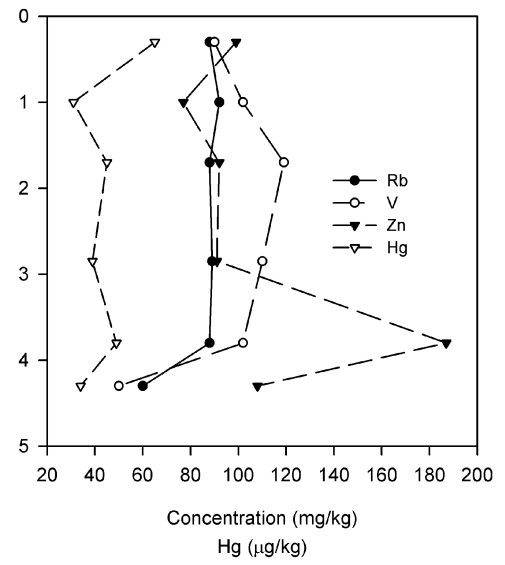
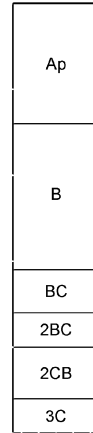
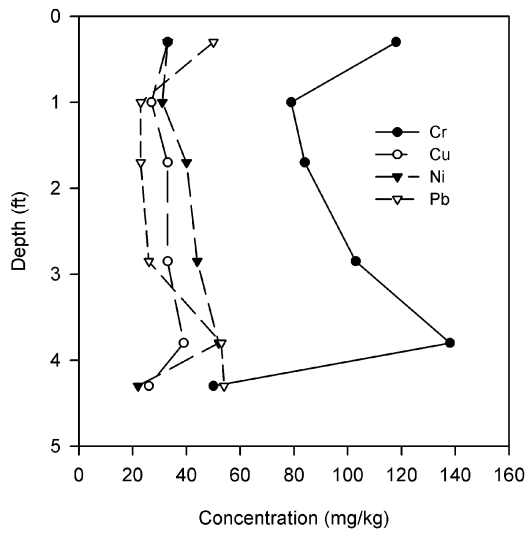


Figure 29. Elemental concentrations versus depth in core 88.

Core 89

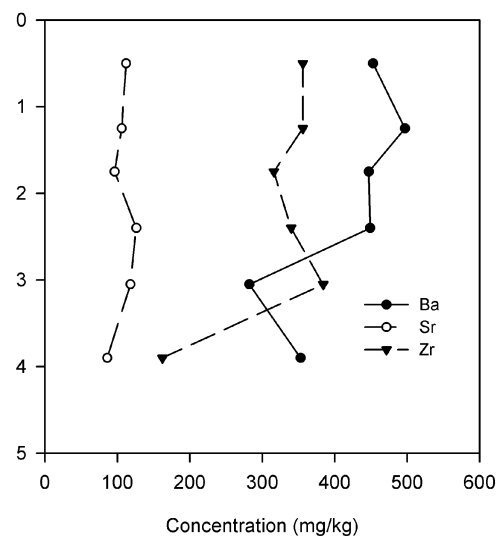
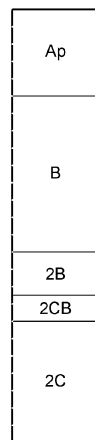
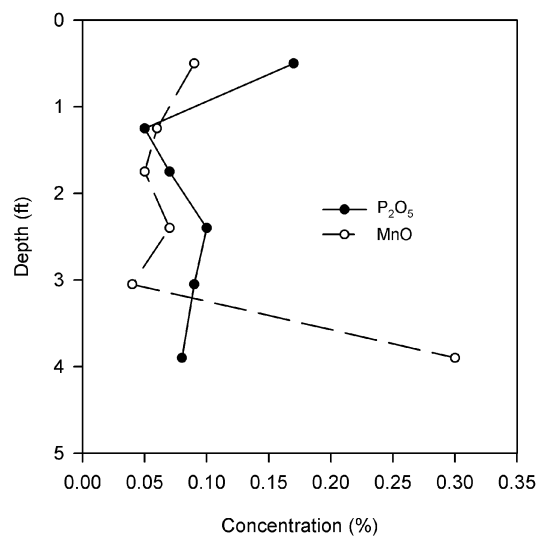
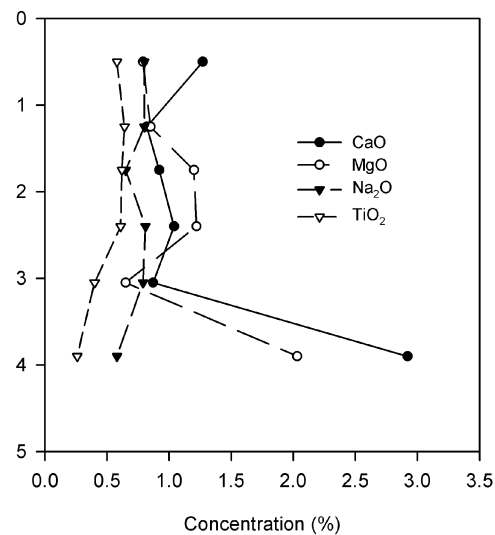
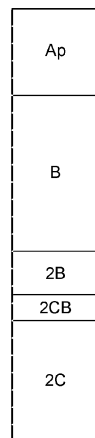
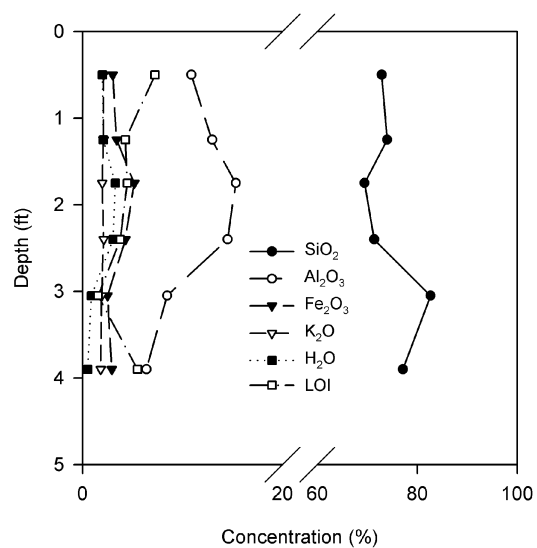


Figure 30. Element concentrations versus depth in core 89.

Core 89

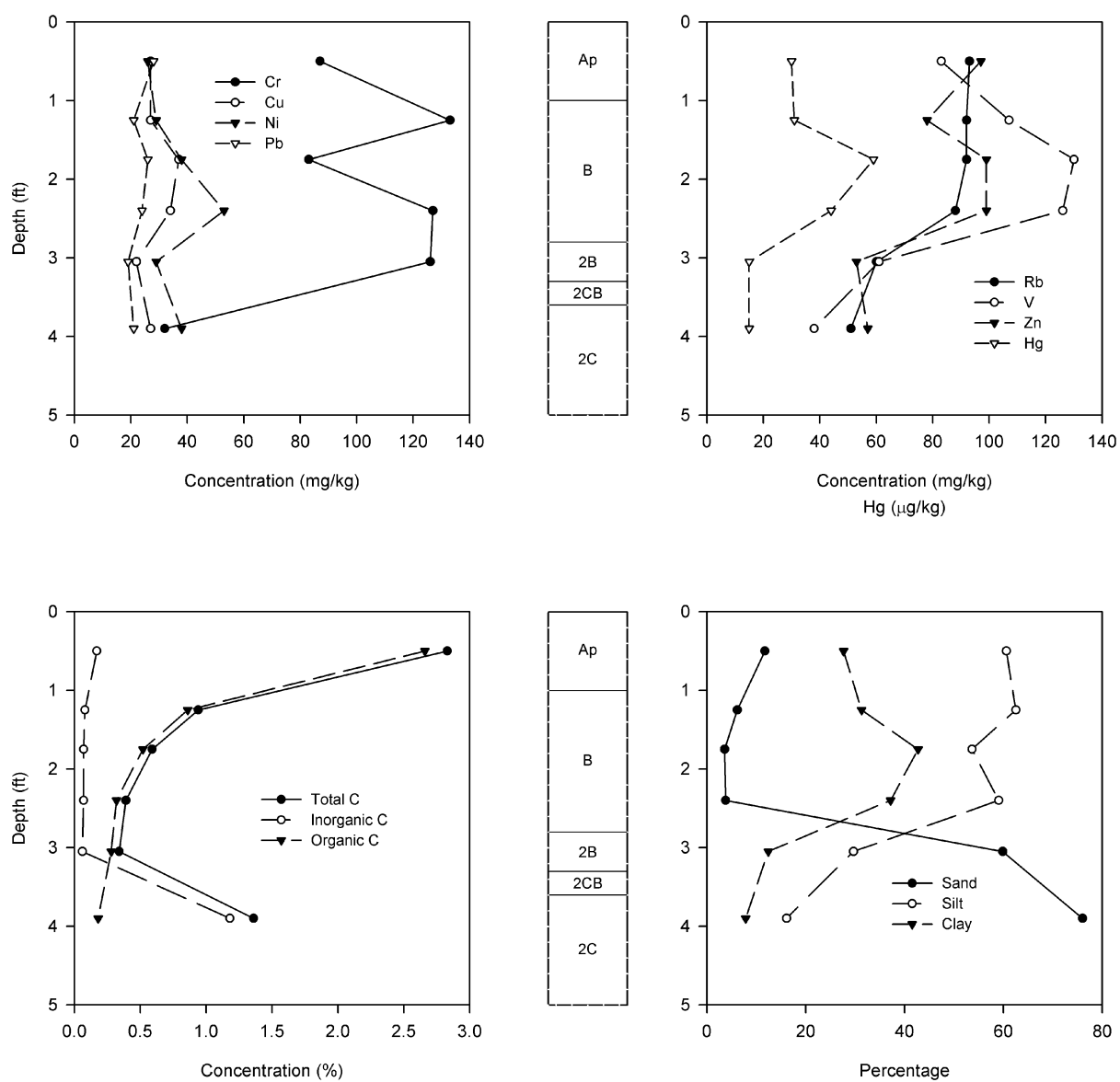


Figure 31. Element concentrations versus depth in core 89.

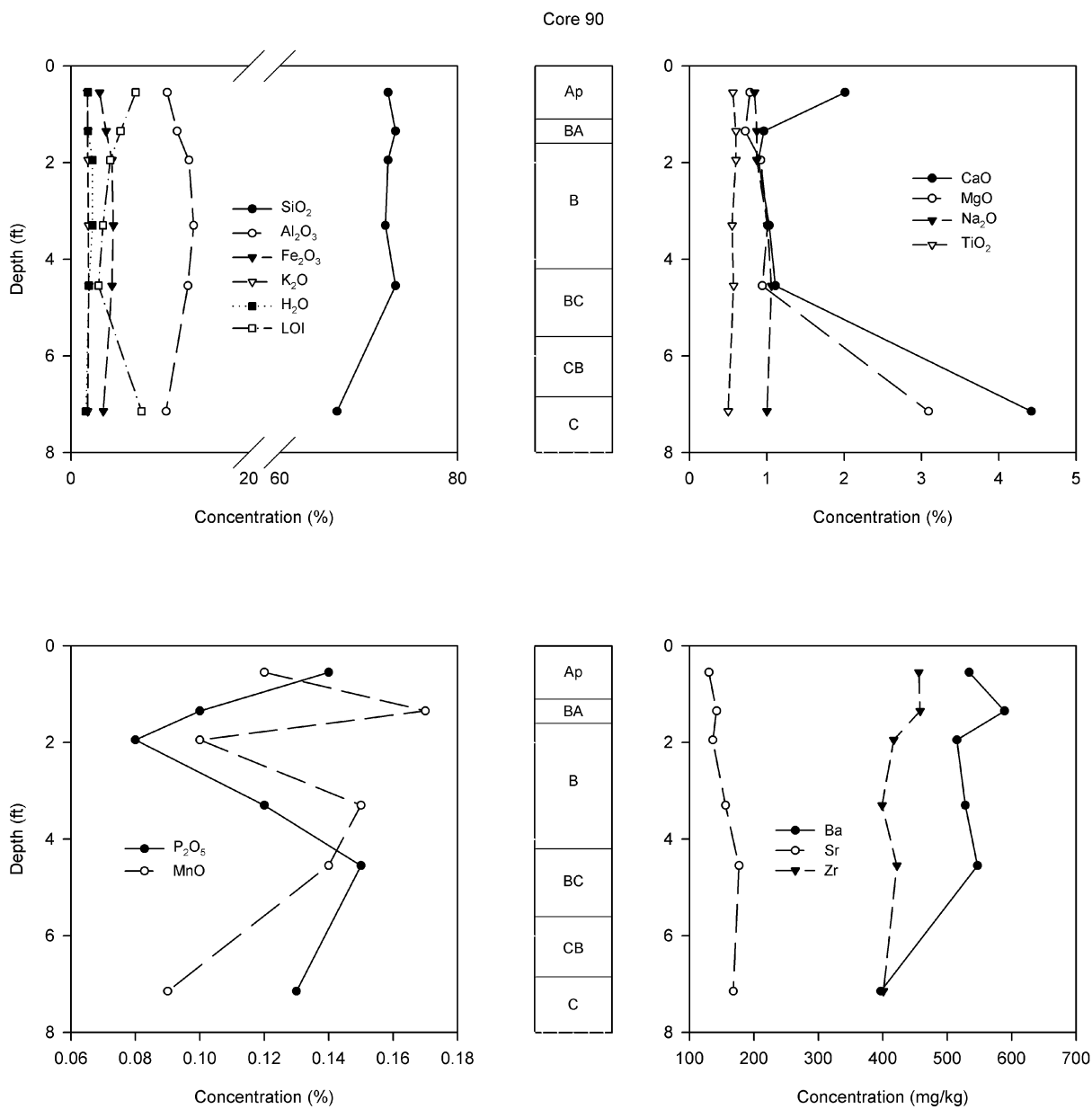


Figure 32. Element concentrations versus depth in core 90.

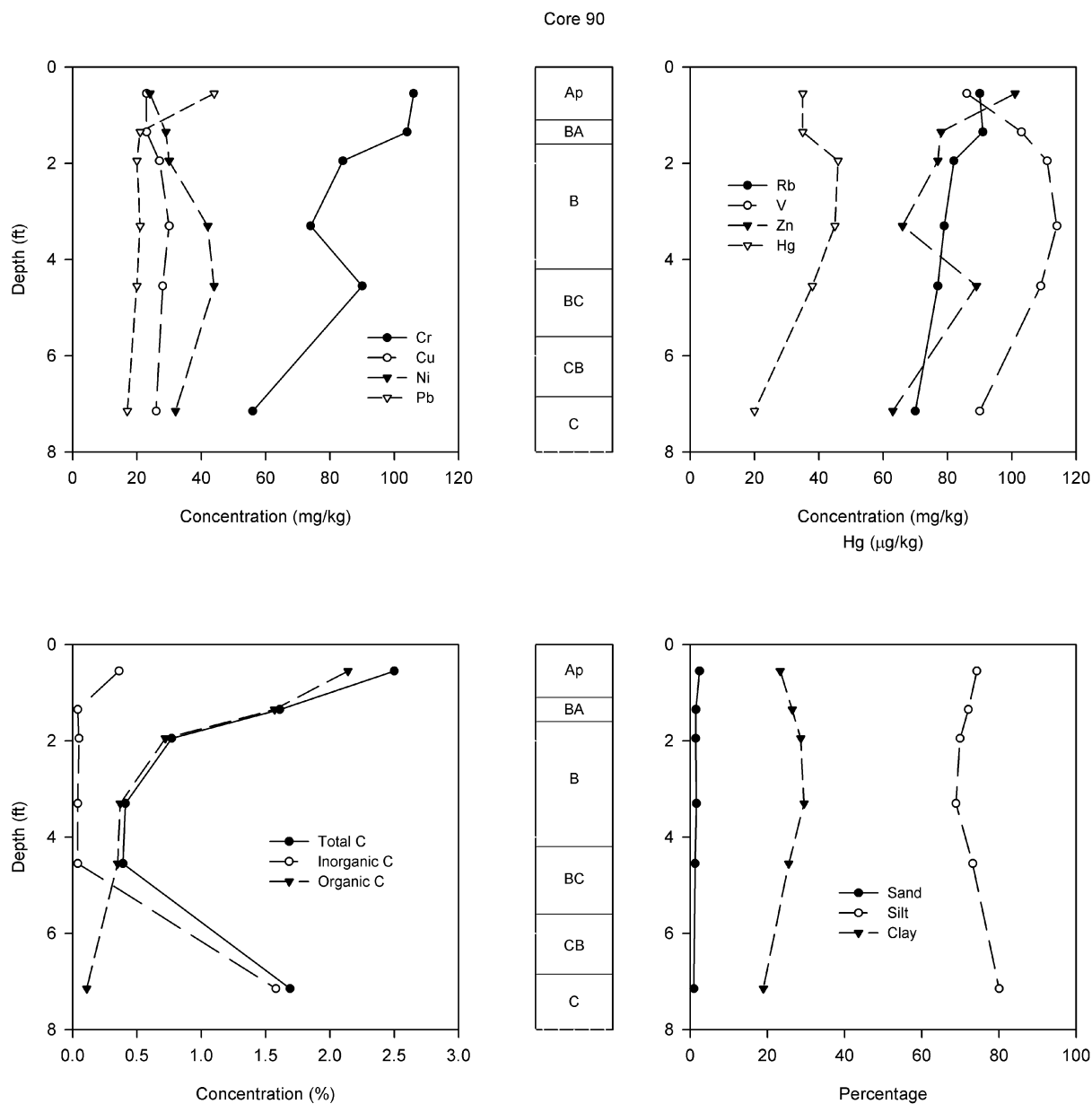


Figure 33. Element concentrations versus depth in core 90.

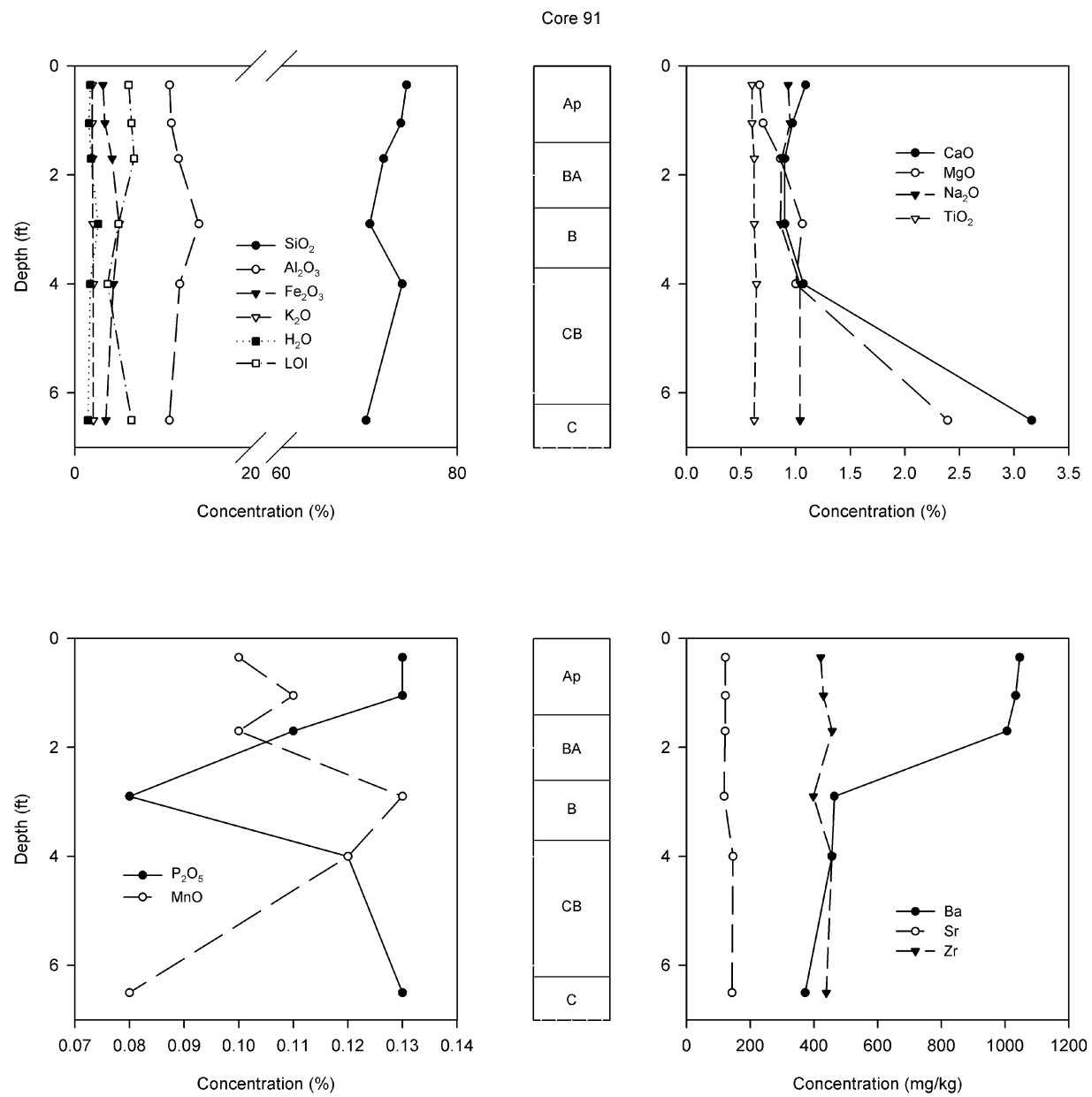


Figure 34. Element concentrations versus depth in core 91.

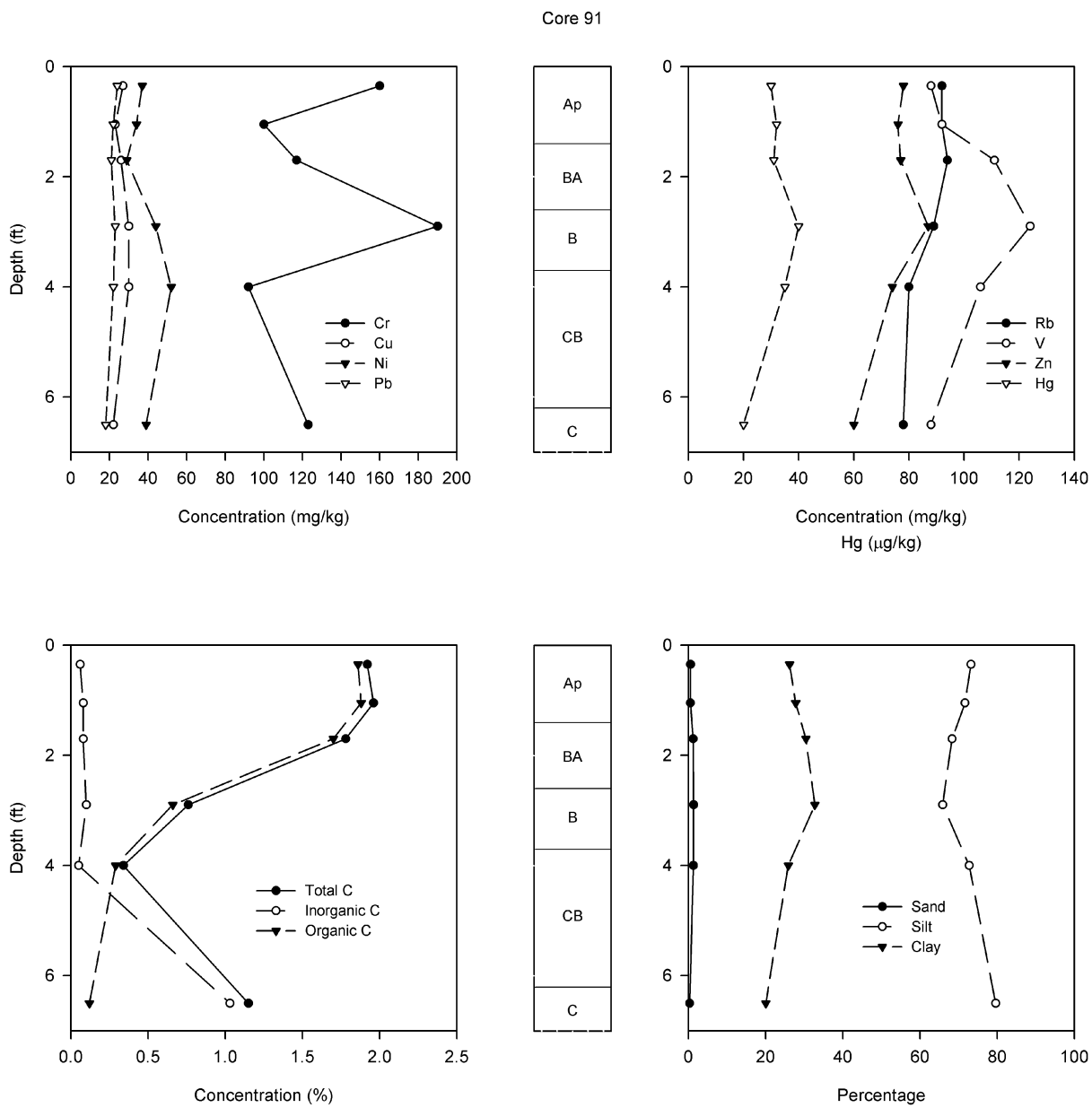


Figure 35. Element concentrations versus depth in core 91.

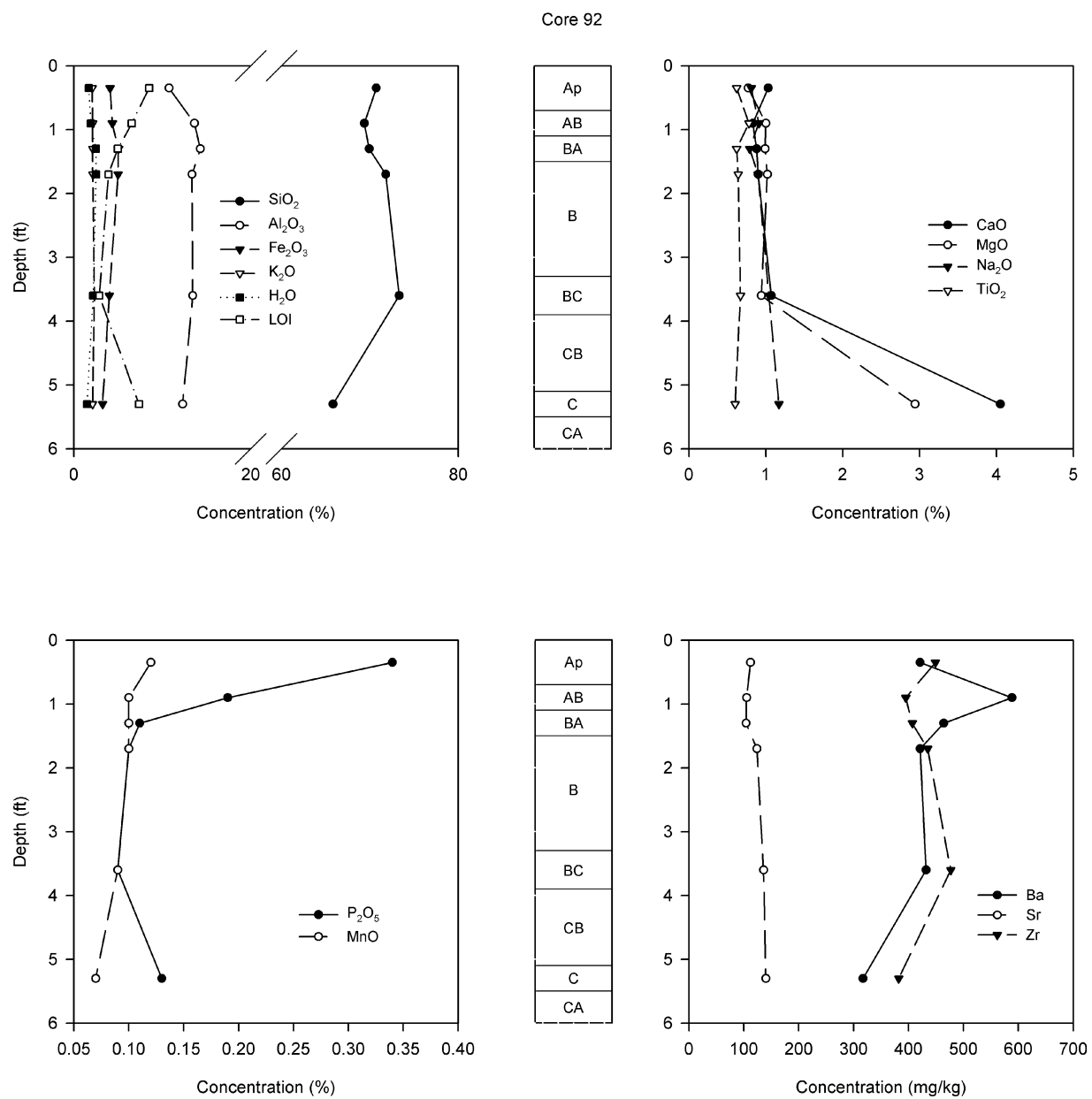
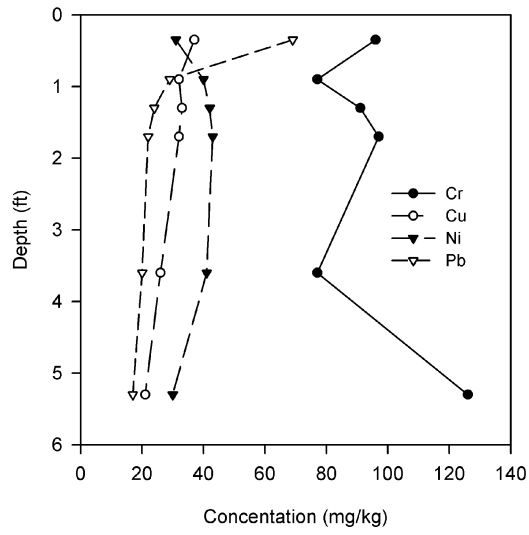
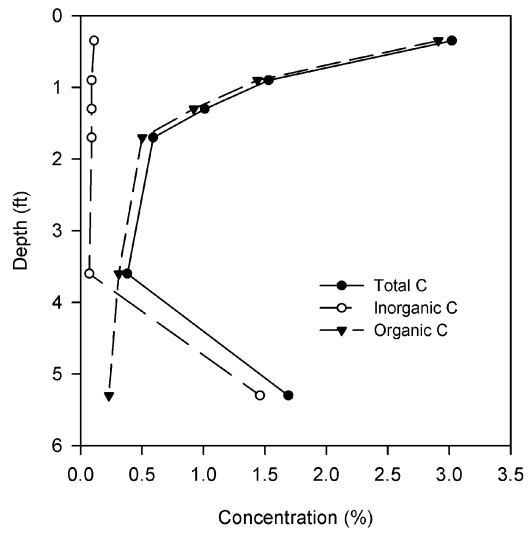
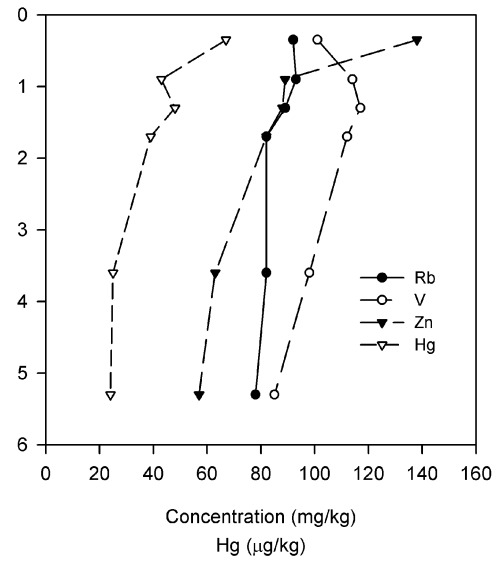


Figure 36. Element concentration versus depth in core 92.

Core 92



Ap
AB
BA
B
BC
CB
C
CA



Ap
AB
BA
B
BC
CB
C
CA

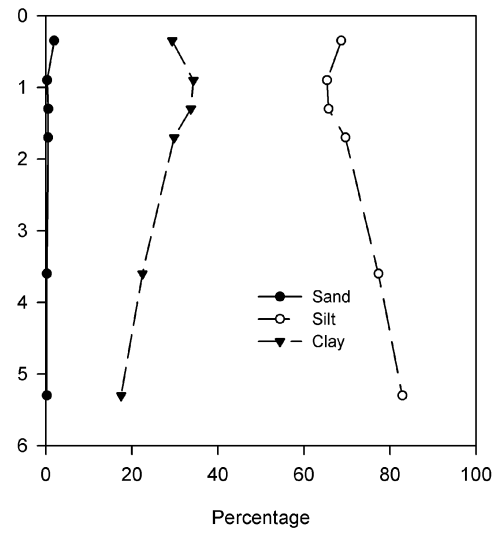


Figure 37. Element concentrations versus depth in core 92.

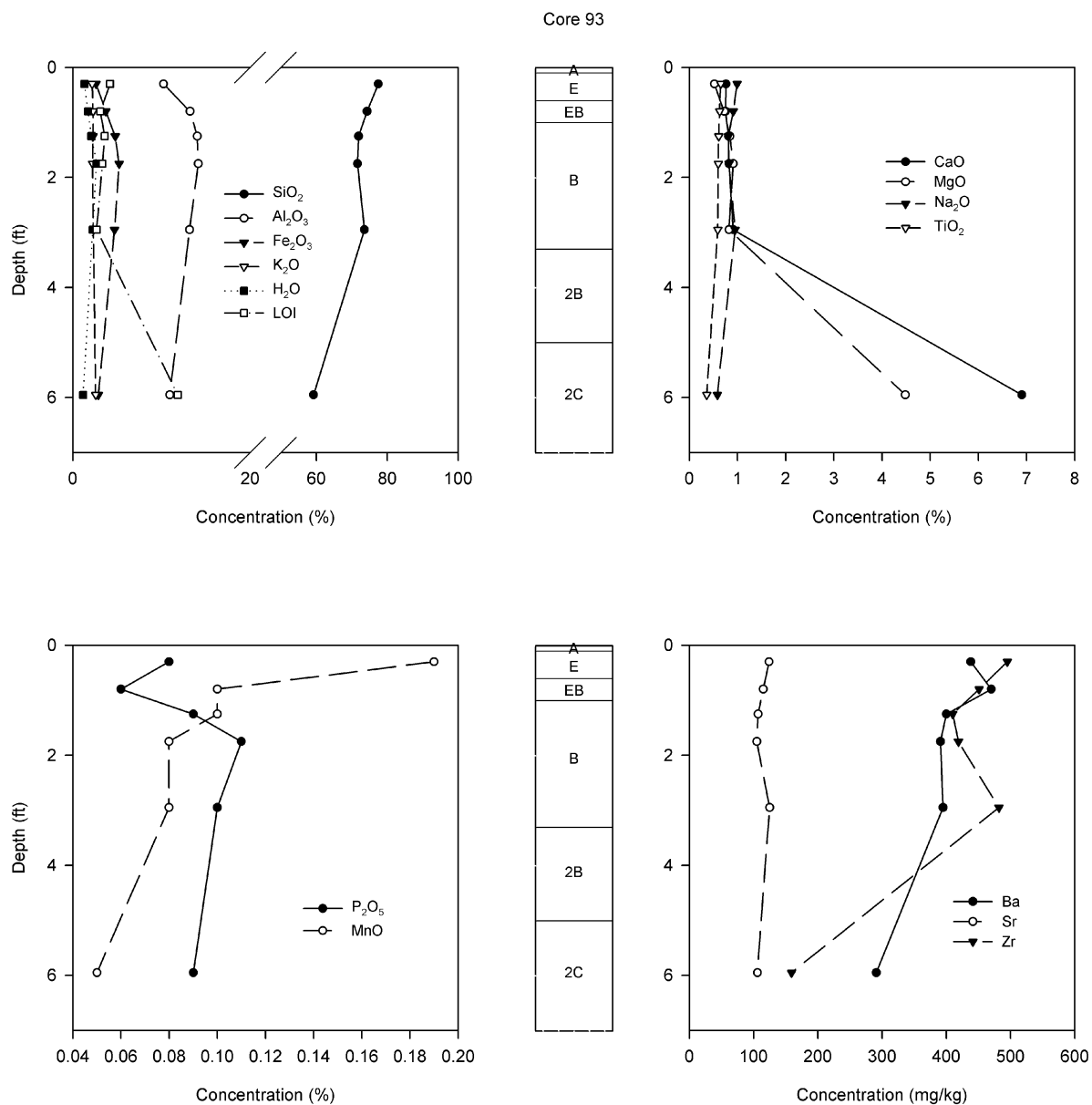


Figure 38. Element concentrations versus depth in core 93.

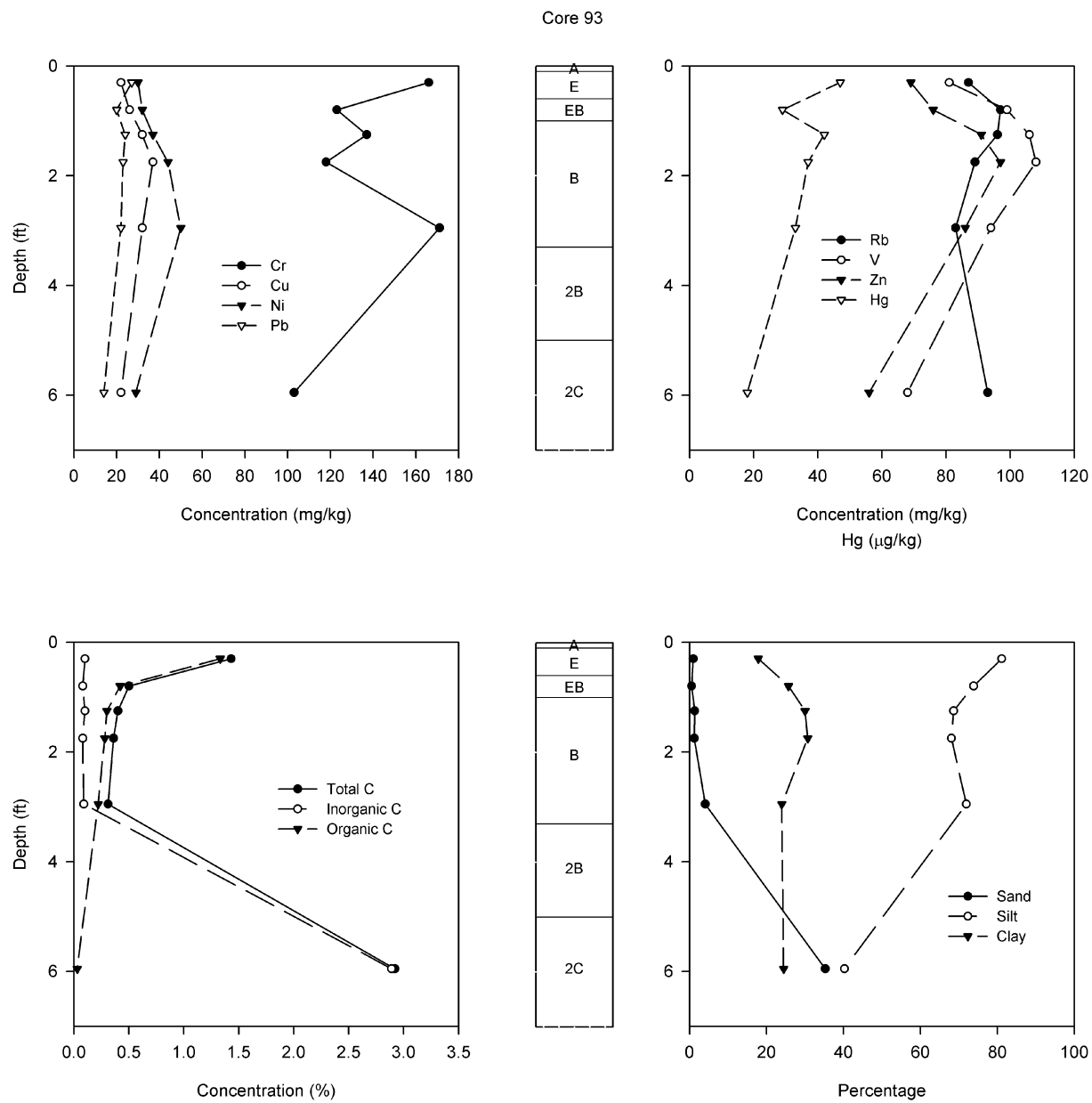


Figure 39. Element concentrations versus depth in core 93.

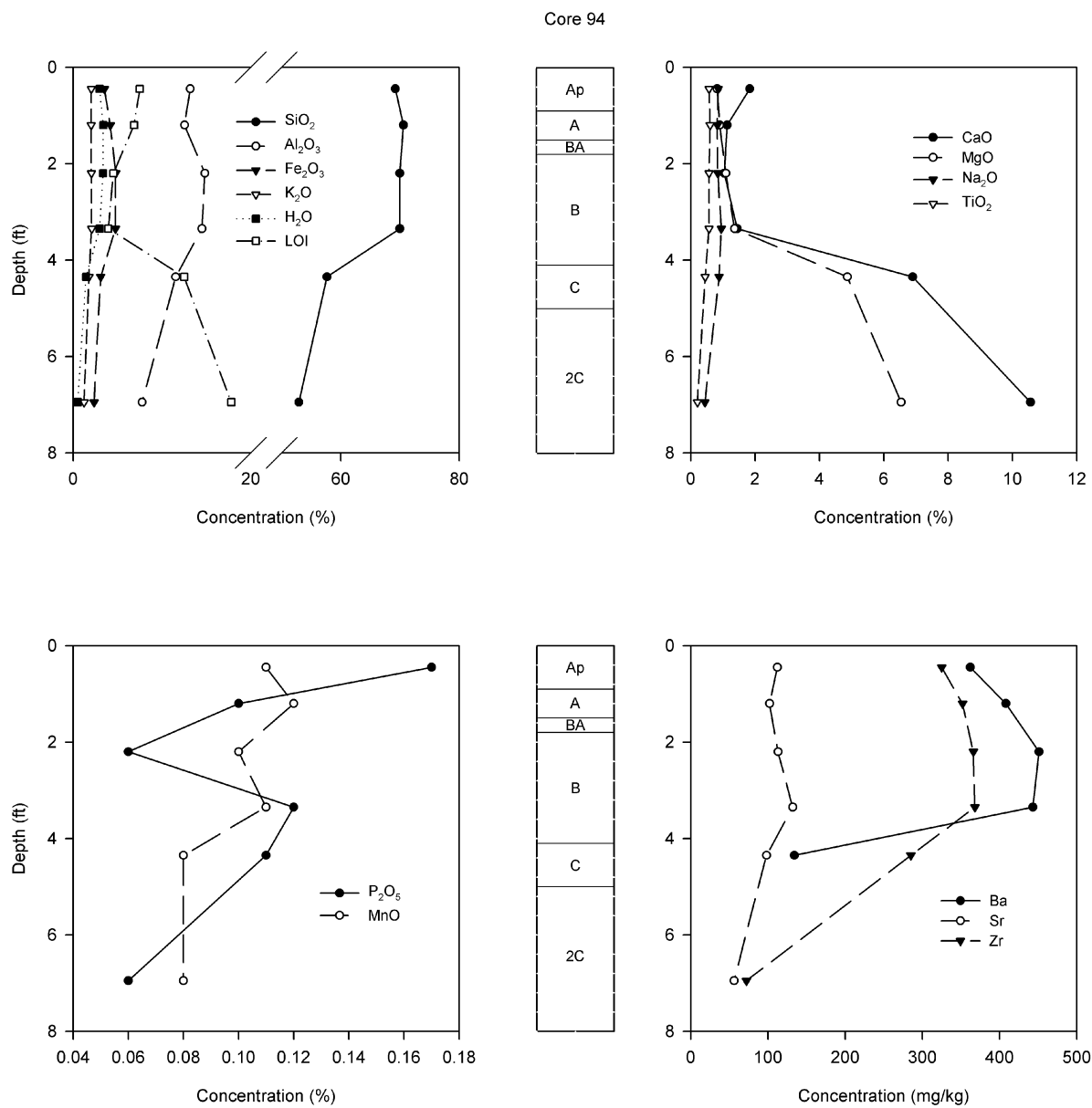


Figure 40. Element concentrations versus depth in core 94.

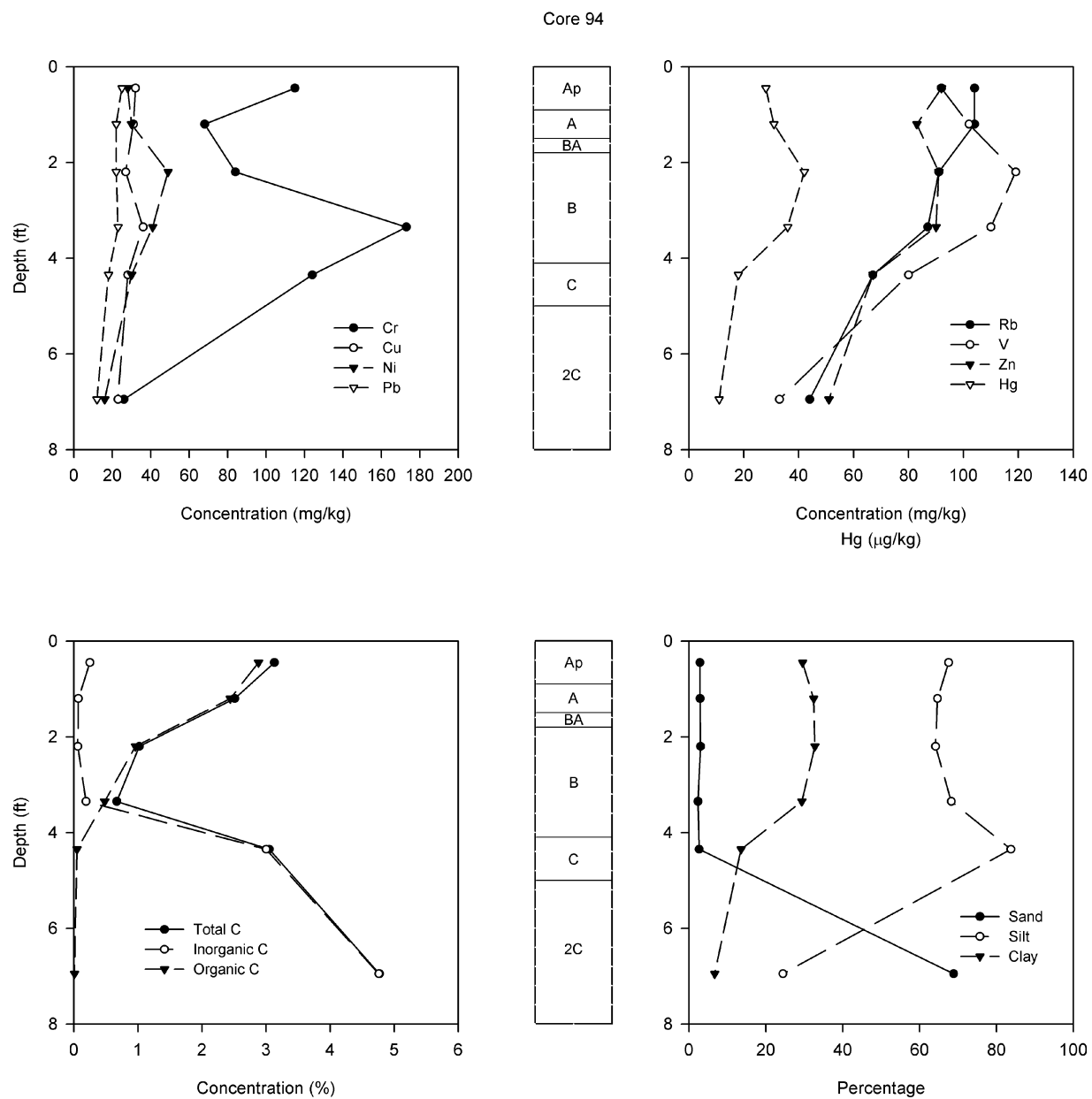


Figure 41. Element concentrations versus depth in core 94.

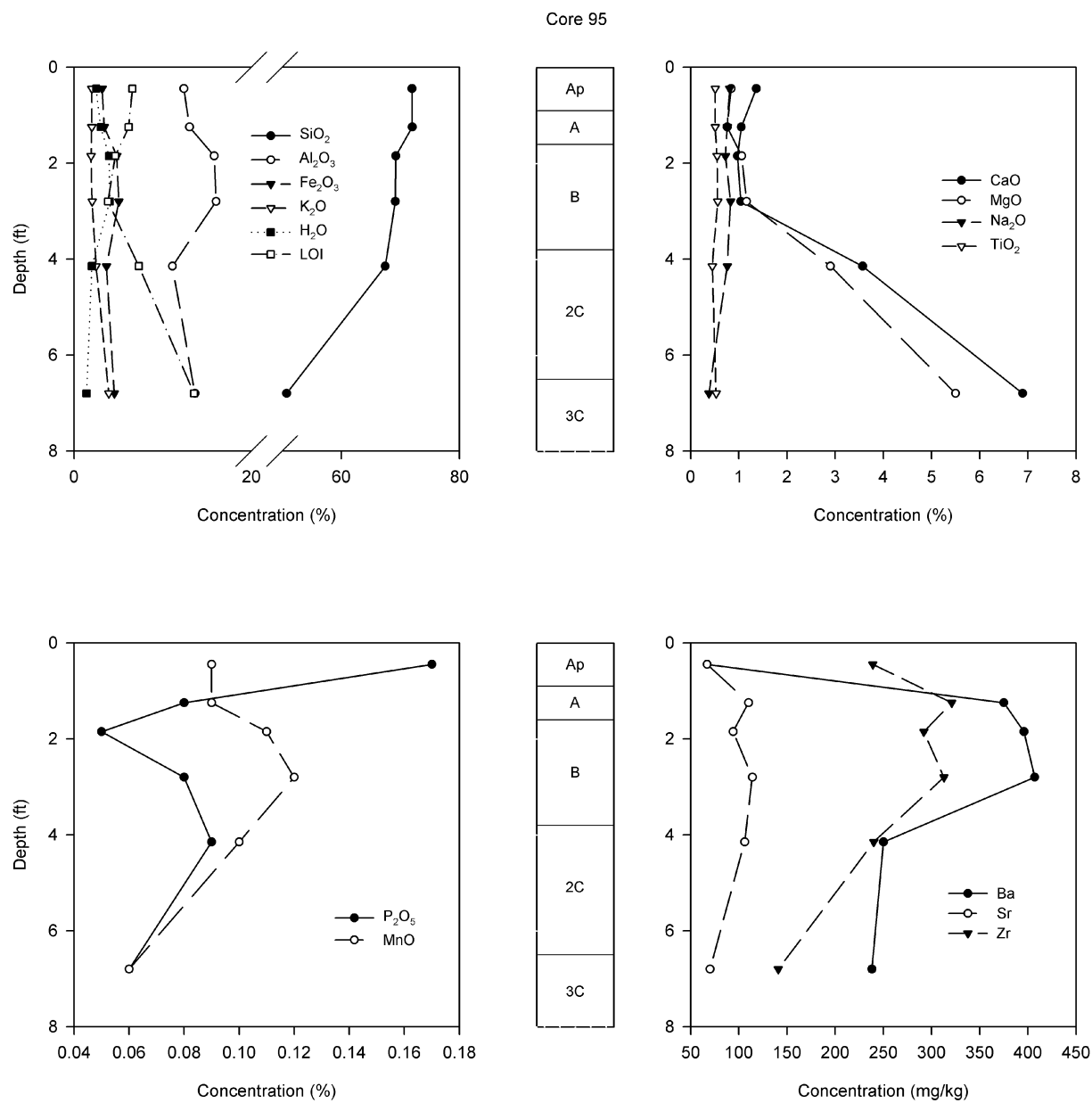


Figure 42. Element concentrations versus depth in core 95.

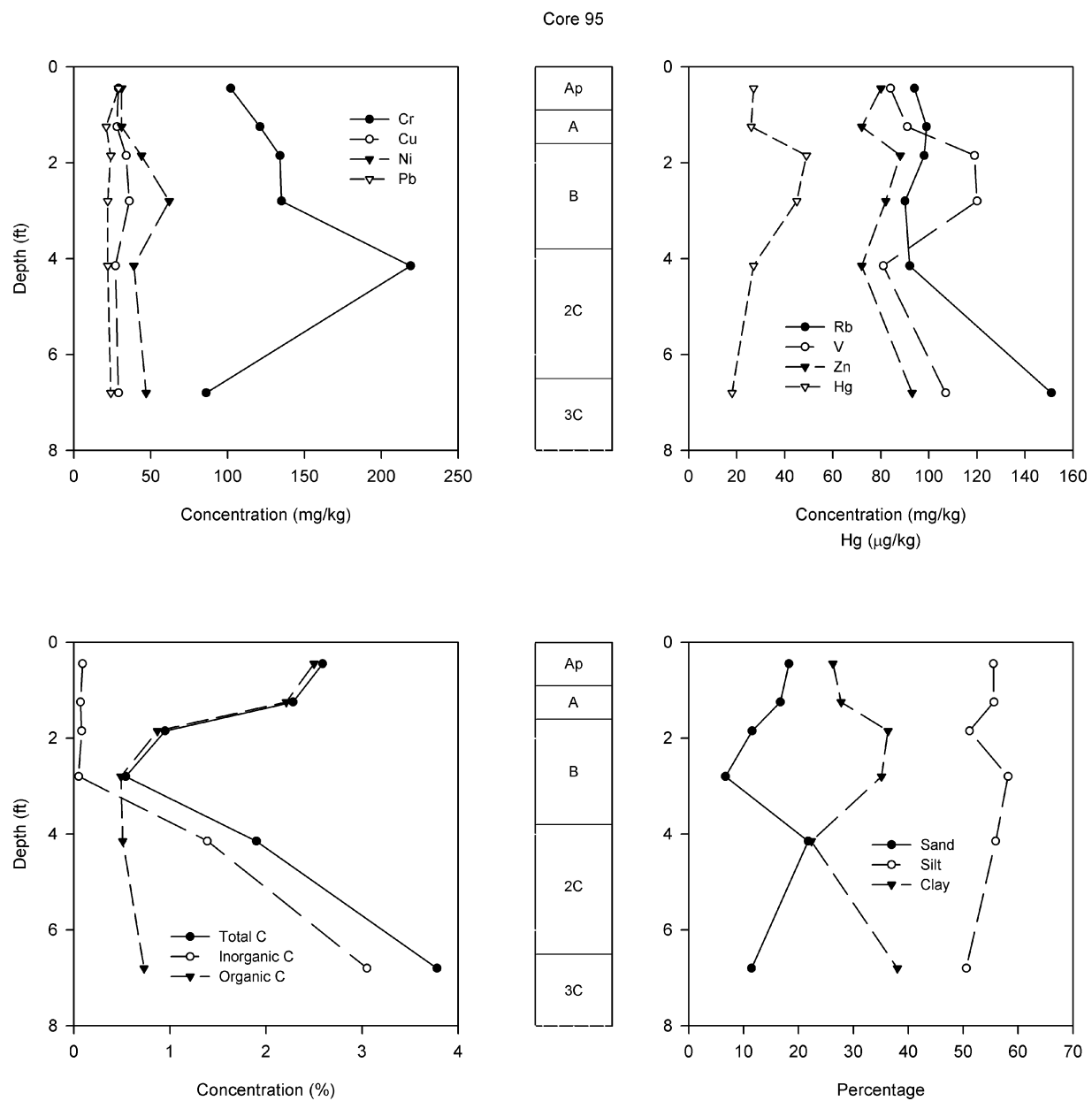


Figure 43. Element concentrations versus depth in core 95.

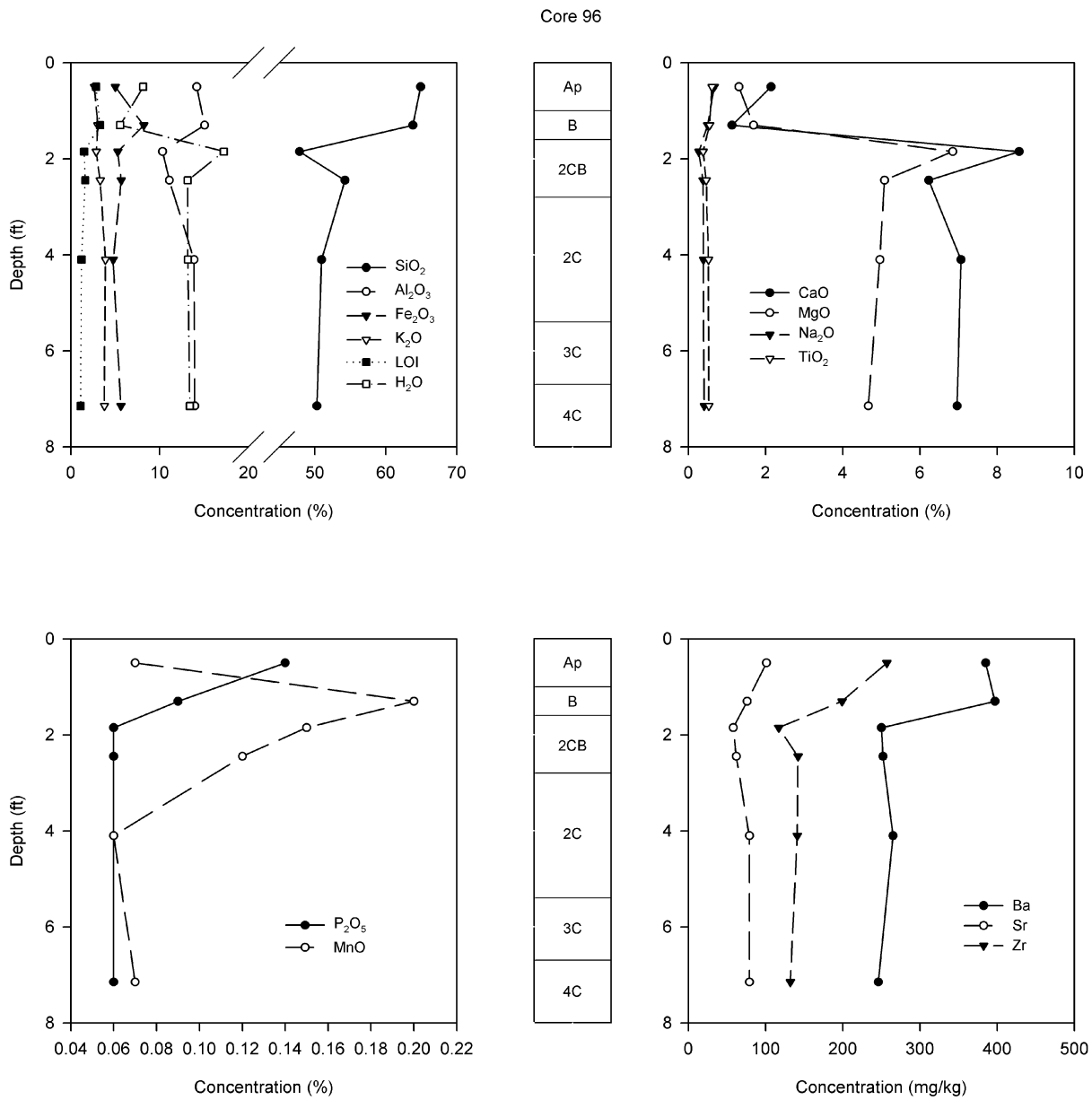


Figure 44. Element concentrations versus depth in core 96.

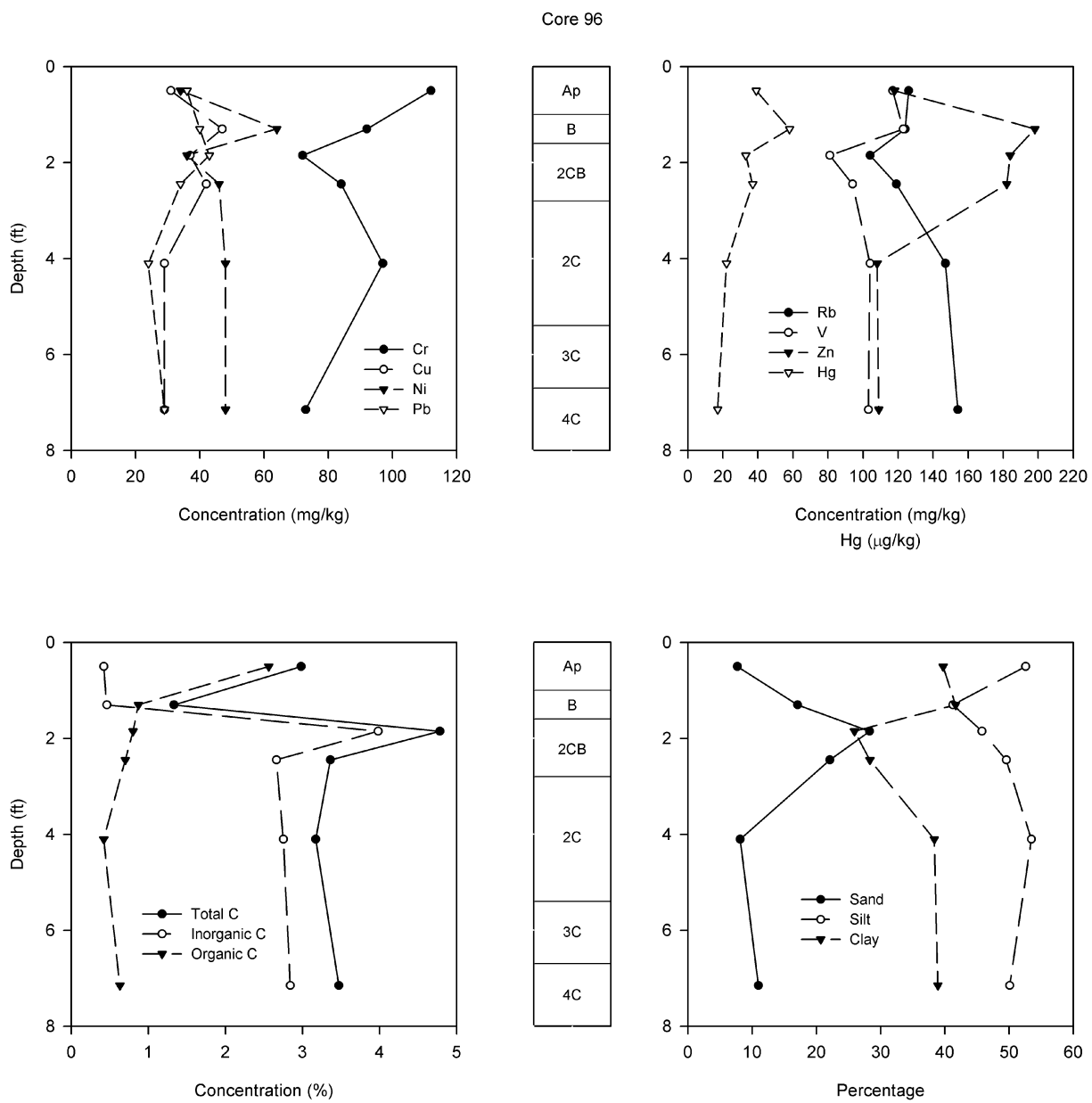


Figure 45. Element concentrations versus depth in core 96.

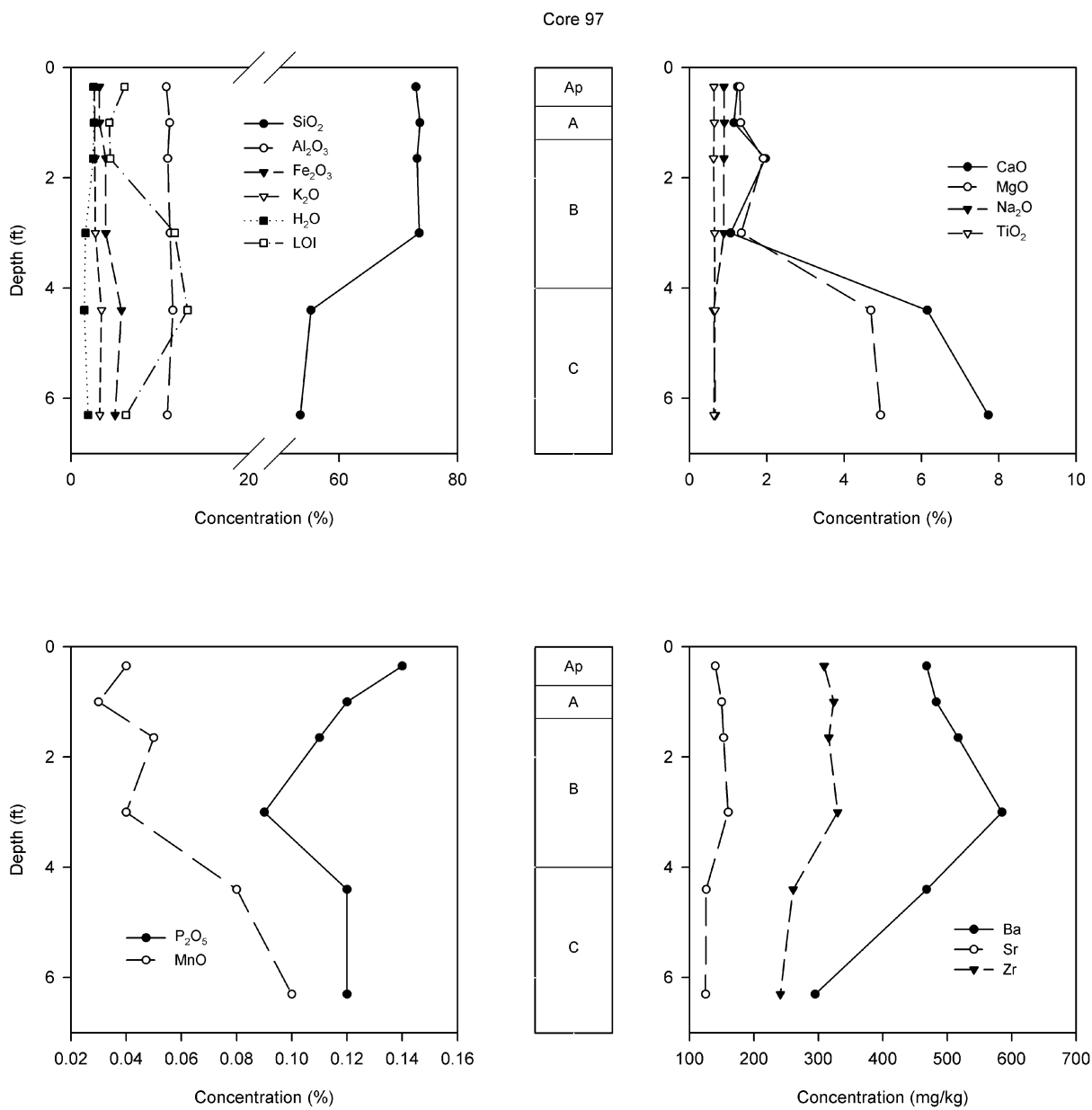


Figure 46. Element concentrations versus depth in core 97.

Core 97

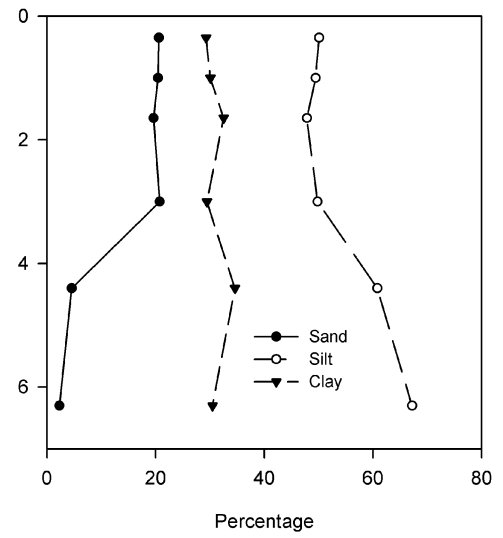
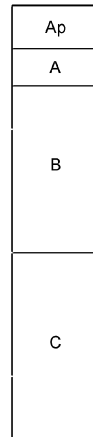
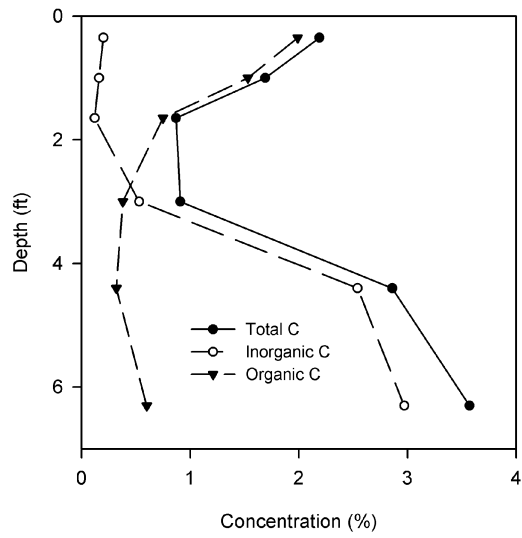
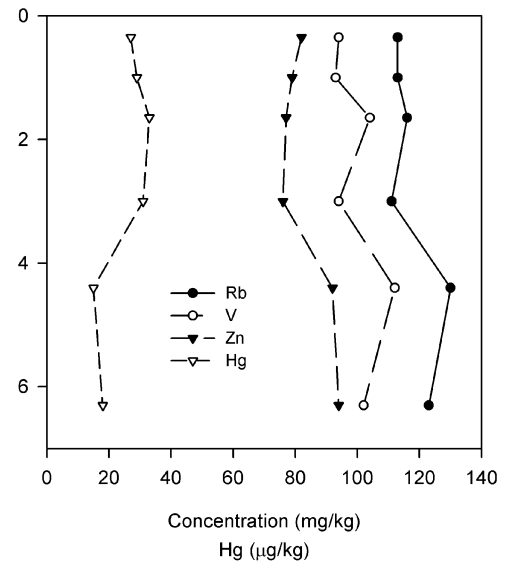
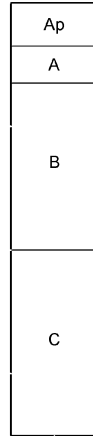
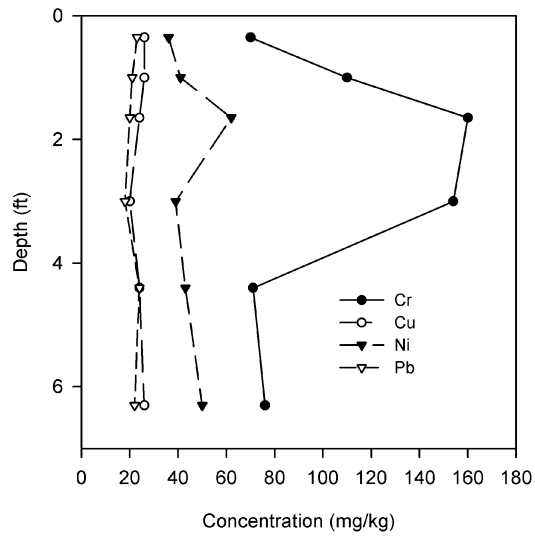


Figure 47. Element concentrations versus depth in core 97.

Core 98

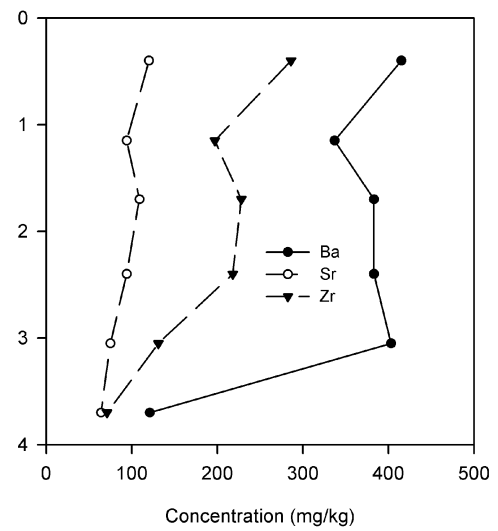
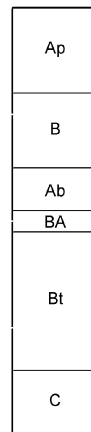
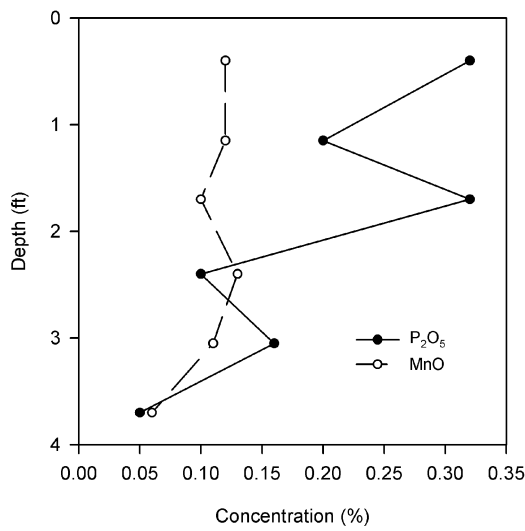
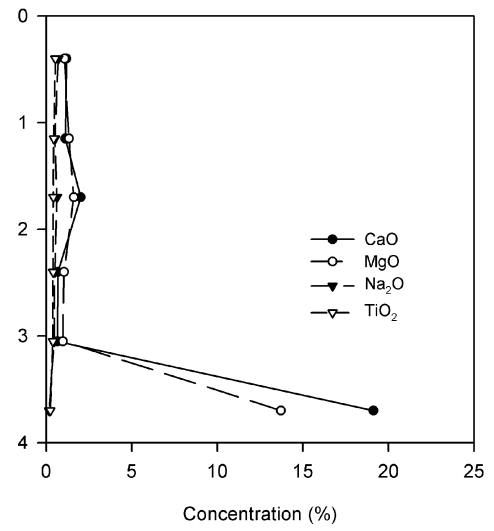
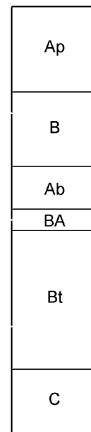
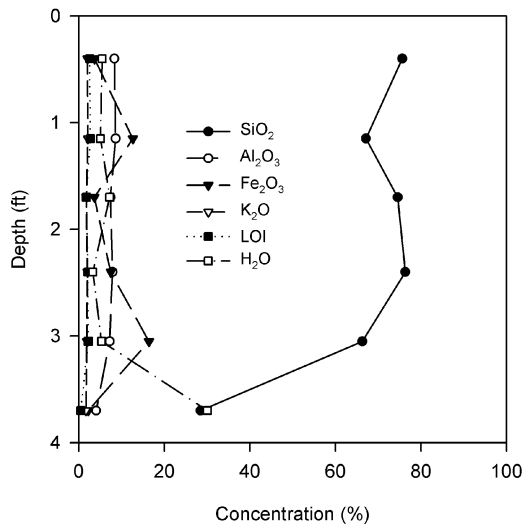


Figure 48. Element concentrations versus depth in core 98.

Core 98

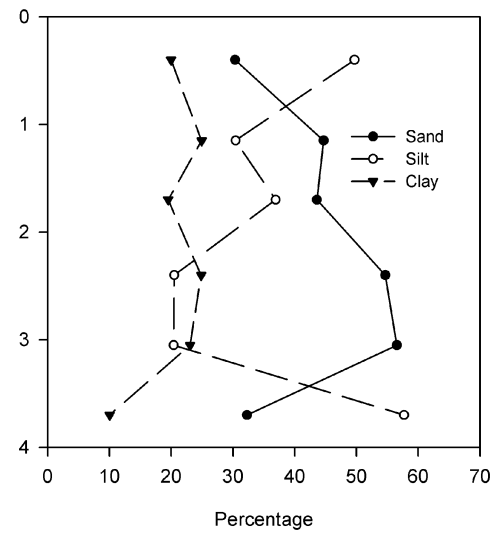
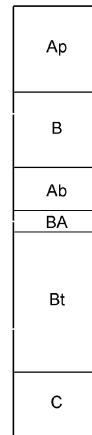
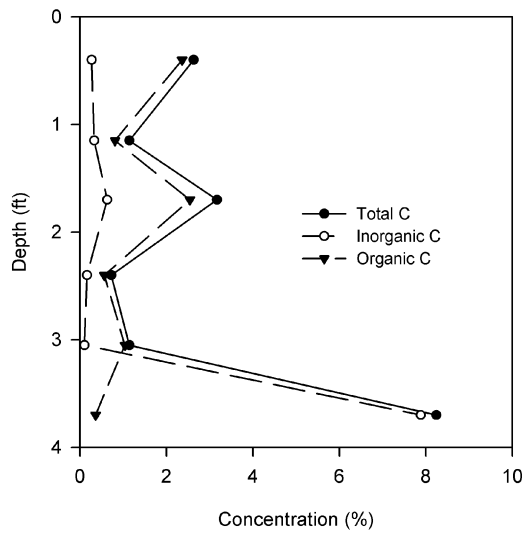
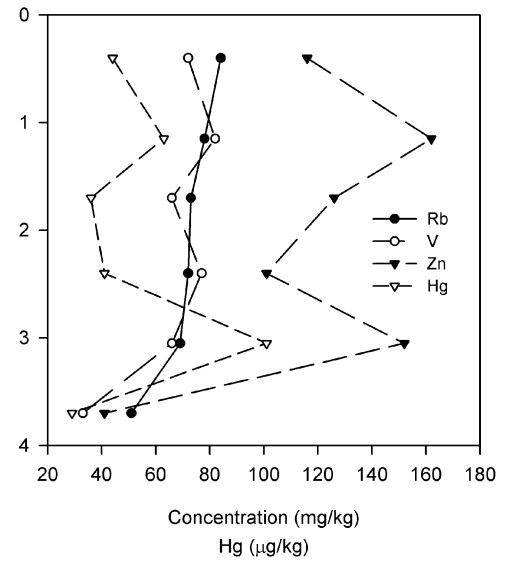
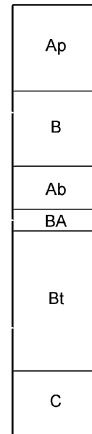
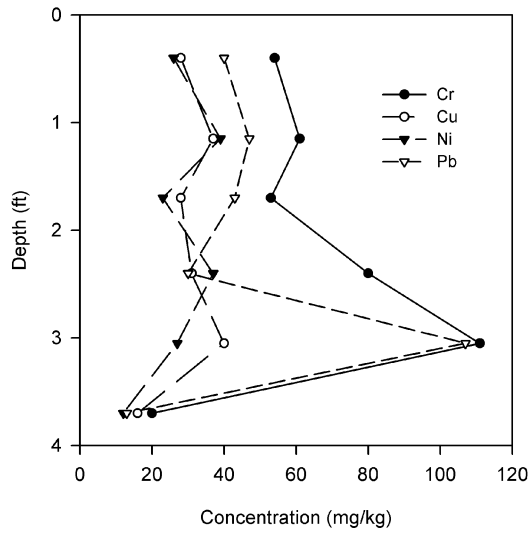


Figure 49. Element concentrations versus depth in core 98.

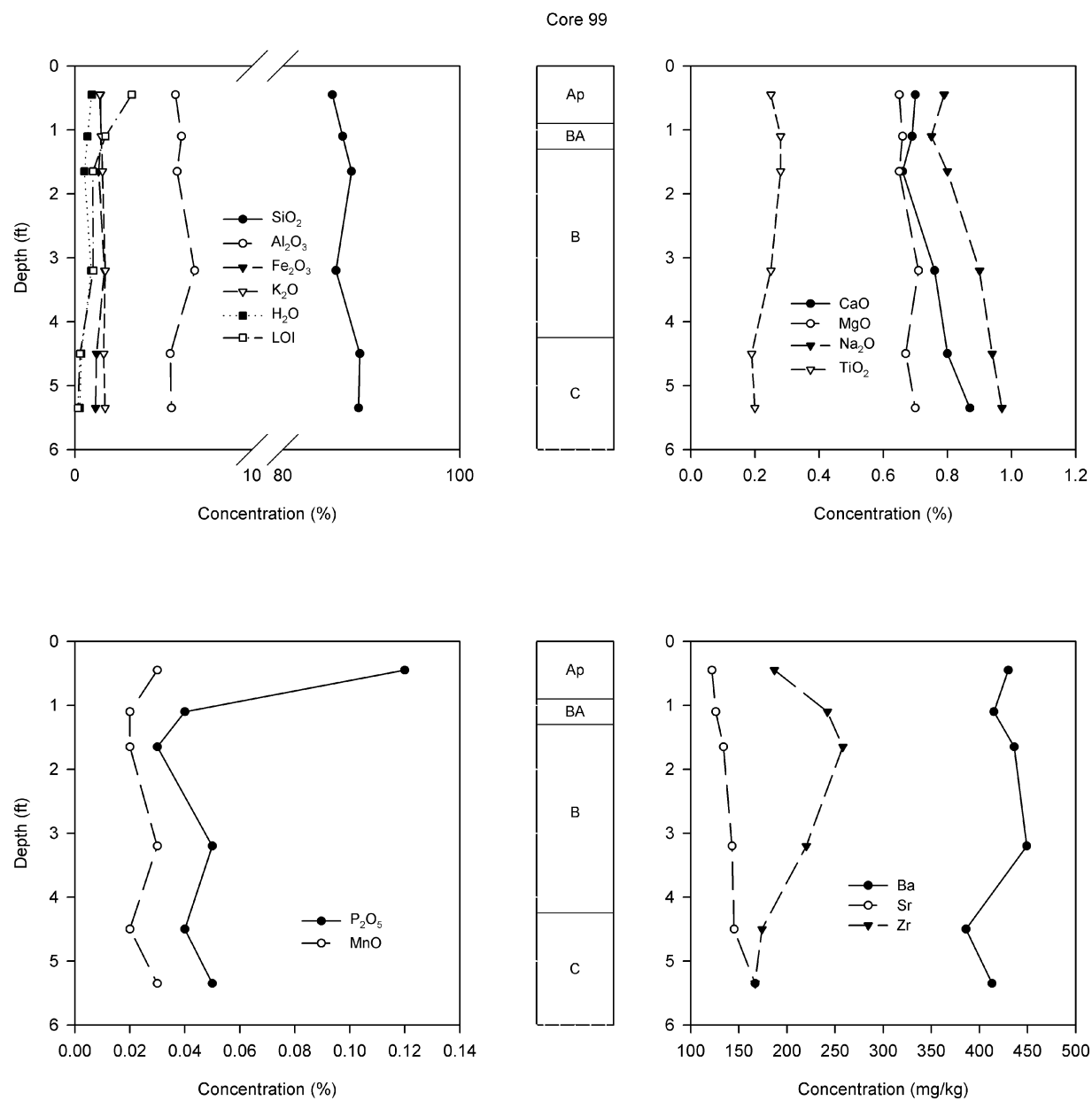


Figure 50. Element concentrations versus depth in core 99.

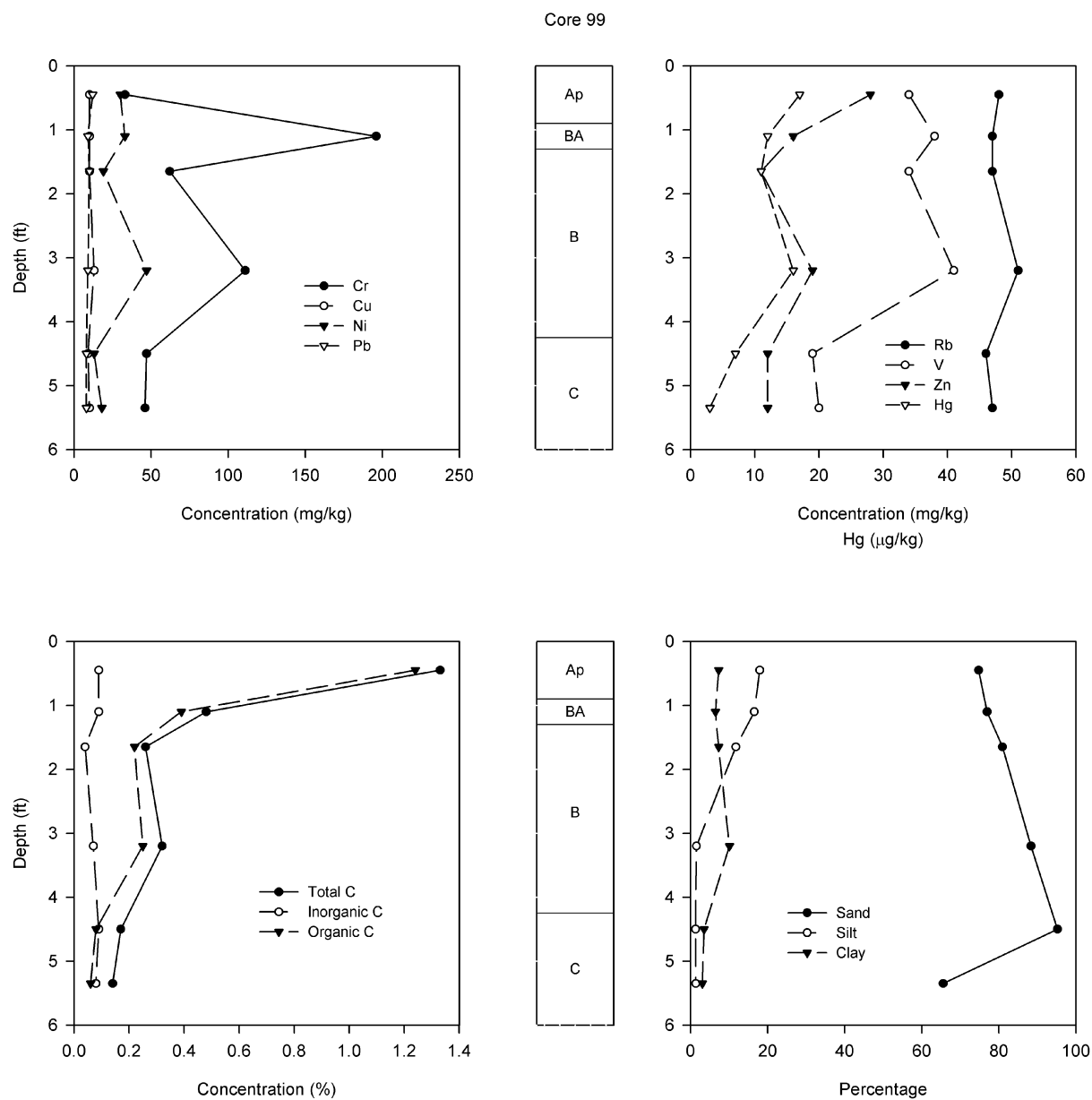


Figure 51. Element concentrations versus depth in core 99.

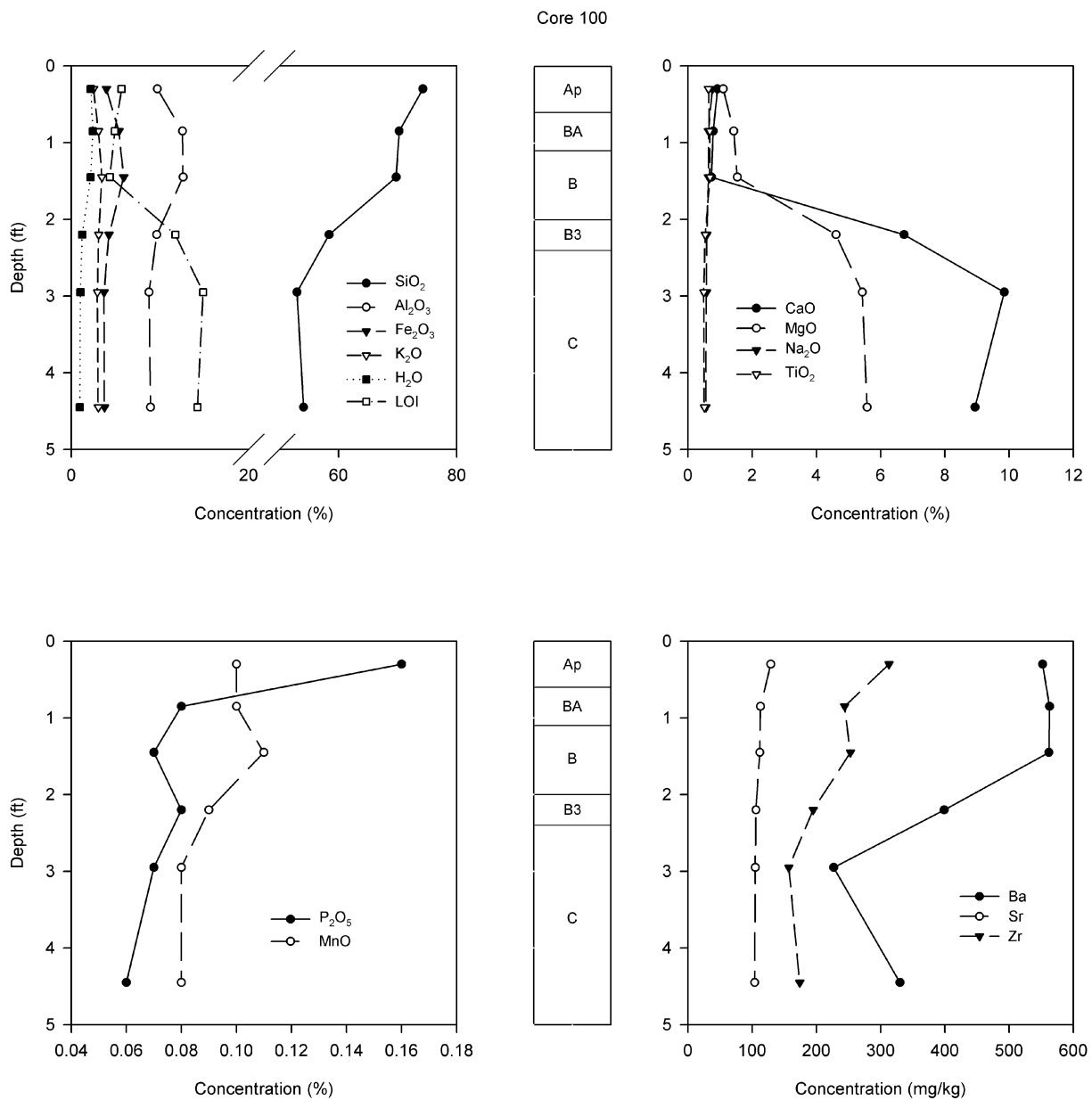
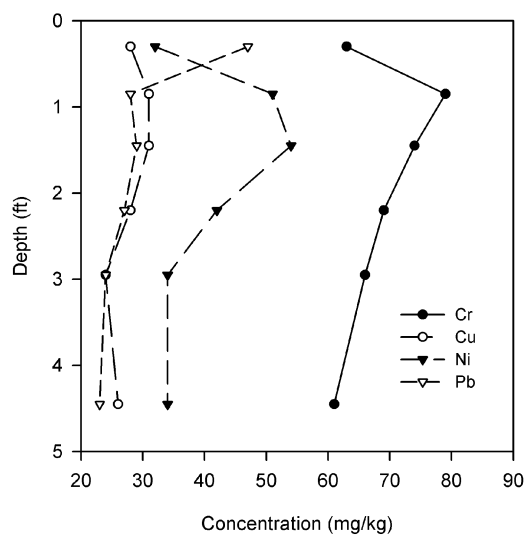
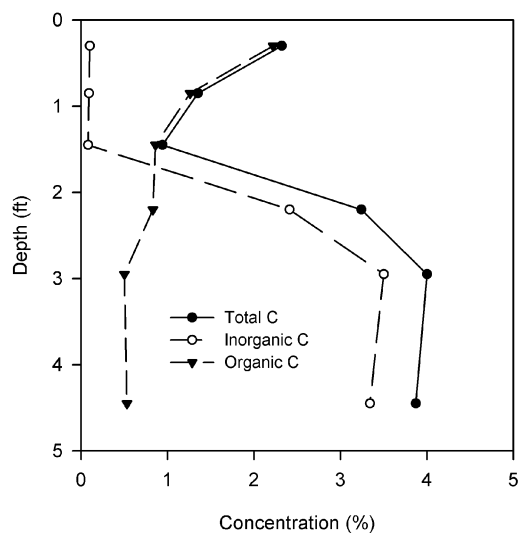
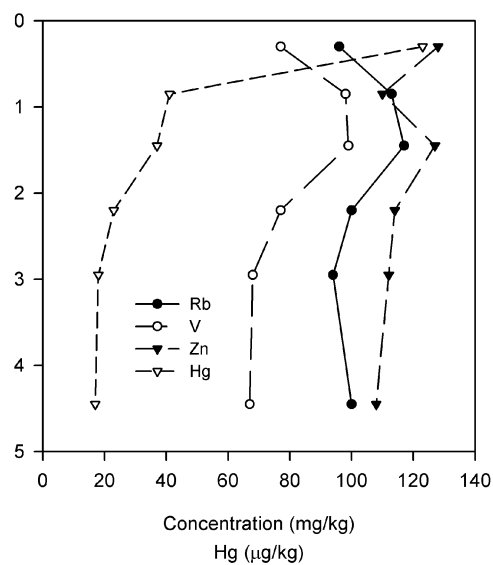


Figure 52. Element concentrations versus depth in core 100.

Core 100



Ap
BA
B
B3
C



Ap
BA
B
B3
C

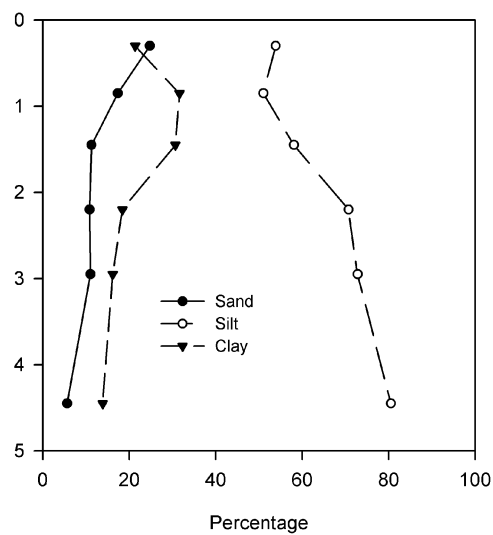


Figure 53. Element concentrations versus depth in core 100.

Core 101

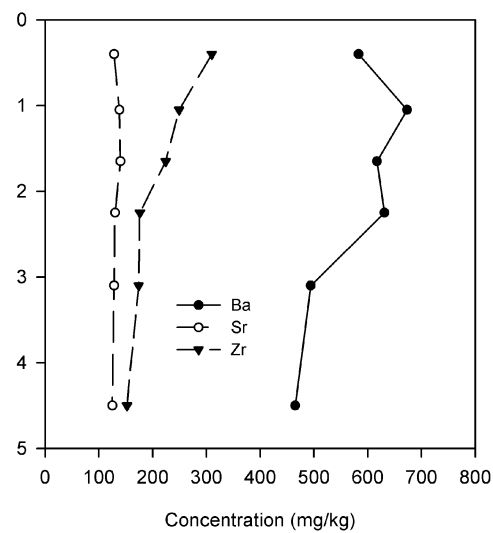
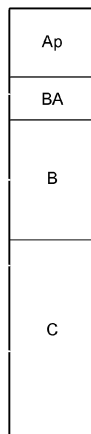
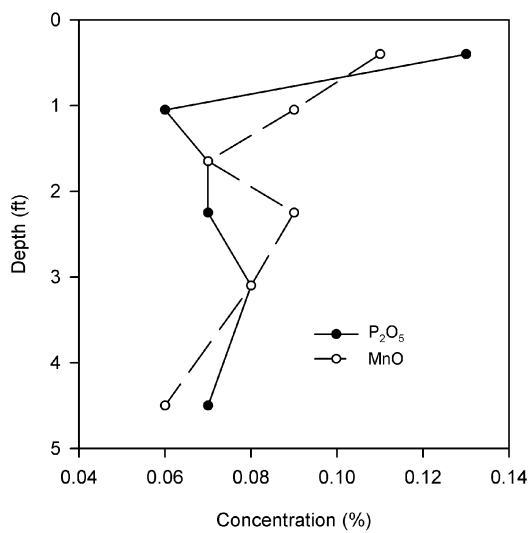
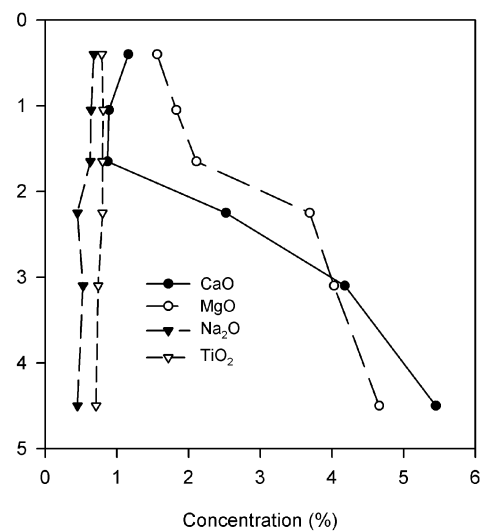
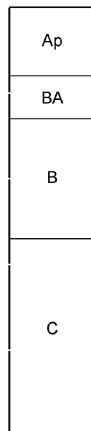
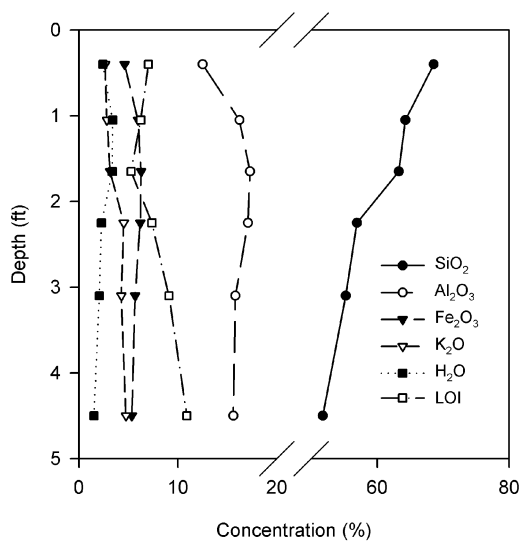


Figure 54. Element concentrations versus depth in core 101

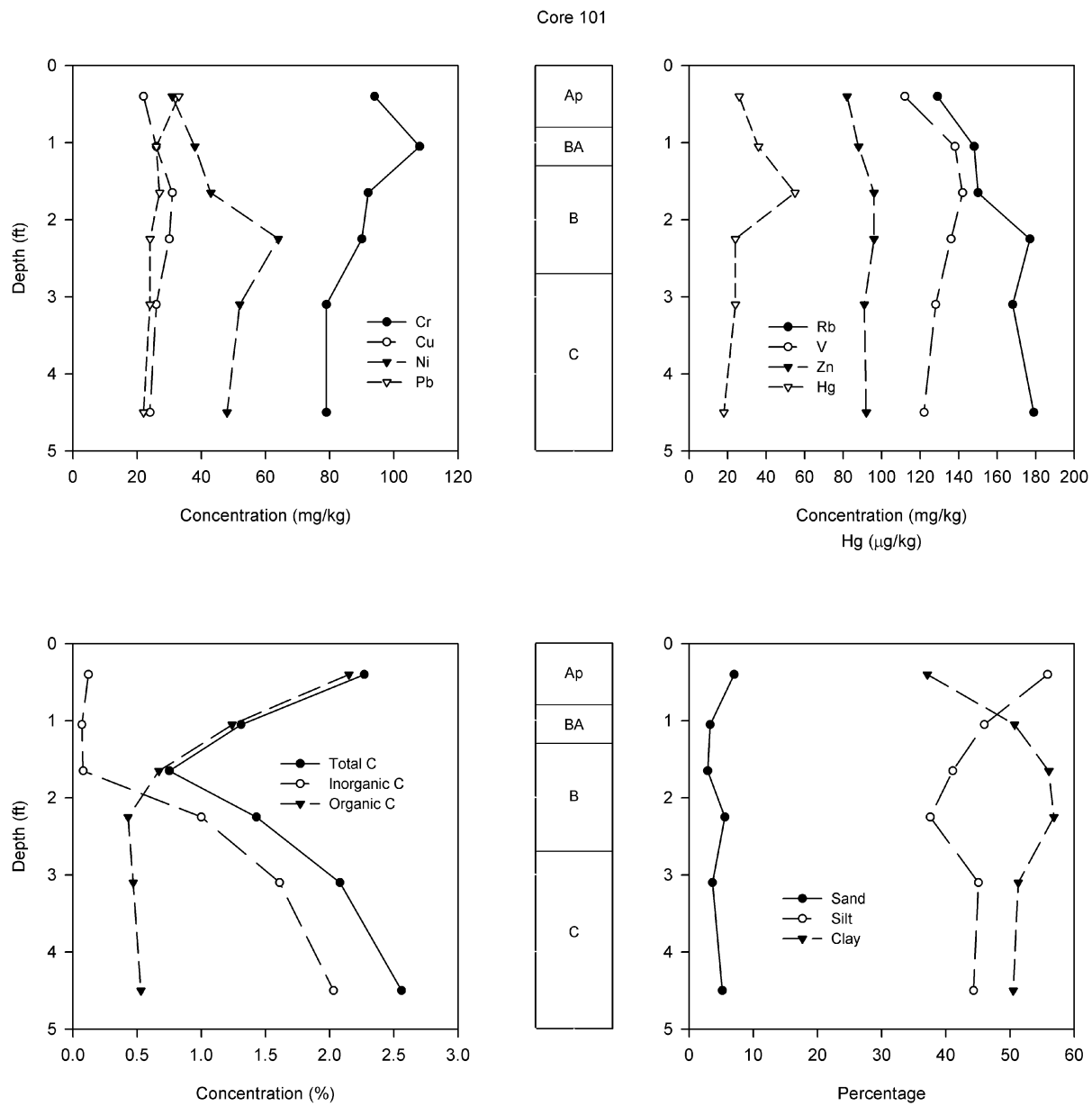


Figure 55. Element concentrations versus depth in core 101.

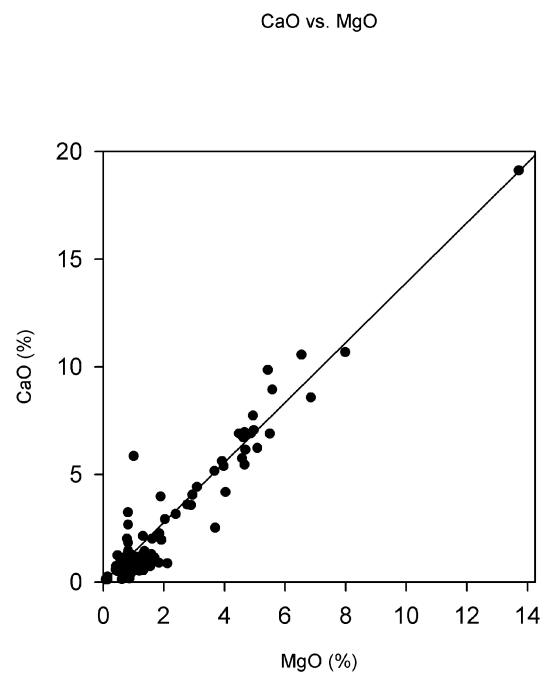


Figure 56. Calcium oxide content versus magnesium oxide content of cores 77 through 101.

