A Progress Report on the Description of the Geology and Chemical Composition of Soils in Illinois:
Cores 102 through 126

by

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PREFACE

This report is a progress report to present analytical chemistry data on soil cores 102 through 126 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. Core 122 was collected at the end of an abandoned roadbed. The top two samples from this core contained unusually large contents of several elements, including mercury, lead, zinc, organic carbon, and therefore, total carbon. For this reason, core 122 was excluded from some of the considerations in this discussion. The exclusion of core 122 has been noted in the appropriate sections.

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, five open-file reports, presenting preliminary results from samples of cores 1 through 101 have been published (Dreher et al., 2002, 2003a, 2003b, 2004a, 2004b).

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 102 through 126 of a total of 137 coring sites from across the state. These cores were collected in central Illinois during the fall of 2002. 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 unlithified parent materials throughout Illinois, and to interpret the derived data in light of the geological processes that have acted upon the soils and their parent materials. In addition, this project will expand upon the previously collected data from other sources. A database of chemical and mineralogical information will be created which can be used in assessing environmental conditions and to help understand the effects of soils on plant health and productivity. The data collected will contribute to our understanding of the chemical, mineralogical, and geological processes that take place during soil development.

BACKGROUND

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

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

The sediment carried by the glaciers tended to level the landscape. Relatively thin veneers of drift were spread across the highlands and thicker deposits filled the pre-glacial bedrock valleys with drift up to 350 feet thick. Much of the drift is a homogenous mixture of fine-grained material 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 weathering), produce chemicals and byproducts that make fertile soils. Weathering processes, particularly the chemical reactions called hydrolysis and oxidation, cause the dark-colored minerals and the feldspars in rock particles in the sand or loess to be slowly altered, releasing ions (Na, Ca, Fe, Mg, K, P, S, and many others) and forming products (clay minerals) that cause the cation exchange capacity (CEC) of the developing soil to increase over time. The silt-size particles in loess generally are more altered or weathered than the coarser grains in the dune sands and, because loess deposits can retain significantly more water than dune sand, the water remains available to plants long after a rainfall.

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

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

Loess deposits cover all the uplands of Illinois except where erosion has removed them. Such erosion was common on slopes along valleys, but the loess is missing in some other places for reasons we do not fully understand. Exceptionally large floods that occurred near the end of the 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 though the Peoria and into the Roxana, thus blurring the boundary between them. Where such conditions are found we have grouped the two geologic units together and called it Wisconsinan loess after the time interval during which it was deposited.

Soil Development

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

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

Climate The term “climate” encompasses both temperature and the long-term availability of water. The higher the temperature of the developing soil, the faster the soil will develop through chemical and biological processes. The availability of water is important in determining the types of plants and organisms that can thrive in the developing soil, which chemical and biological reactions will occur, and in the movement of soil particles and dissolved chemical species from one location to another on the landscape or in the soil profile. As water seeps through the soil profile it causes chemical elements to be leached from the surface horizon (eluviation) and to be deposited in lower horizons (illuviation) (Hassett and Banwart, 1992), or pass into the groundwater.

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

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

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 2002 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 2002. Cores were collected at 25 locations during October 2002, after harvest was completed. The "diamond" 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.

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)].

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 two hours 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/in^2 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 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 unignited portion of the -208-µm 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 (CO_2) gas. The generated CO_2 was absorbed in a solution of ethanoldiamine, with which it reacts to form acid. The acid thus released was titrated by an electrical current until a neutral pH was attained. The amount of current required to reach the end-point of the titration is an indirect measure of the amount of carbon in the original sample.

The method for the determination of inorganic carbon was similar, except that rather than the sample being heated in a tube furnace as in the determination of total carbon, the sample was submerged in a dilute solution of hydrochloric acid which reacted with the carbonate to generate CO_2 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 $(NaPO_3)_6$ was added to the bottle followed by 140 mL of deionized water. A blank sample containing only $(NaPO_3)_6$ and deionized water also was prepared. All bottles were sealed and placed on an oscillating shaker and shaken at 120 strokes per minute overnight. After shaking, 250 mL of deionized water was added to each bottle. The bottles were then shaken end-to-end by hand for 25 seconds to dislodge settled sand and silt, then end-over-end for 15 seconds. At the end of the 15-second period, the bottles were immediately placed in a covered, static water bath at 28°C for 3 hours and 22 minutes to allow particles larger than 2 µm to settle from the top 5 cm of the suspension. The shaken samples were placed in the water bath for settling at two-minute intervals to provide ample time between samples to withdraw aliquots for further processing. At the end of the settling period, the bottles were removed from the water bath at two-minute intervals in the same sequence in which they were placed into it. The tip of an Oxford® Macro-Set adjustable pipet was carefully inserted into the suspension to a depth of 5 cm, and exactly 10 mL of the suspension was withdrawn during a 15- to 20-second period. The pipet had been previously calibrated by weighing and averaging 10 replicate volumes of deionized water at the desired volume. The suspension was delivered to a numbered, weighed aluminum weighing pan. When aliquots of all the samples and the blank had been delivered to their respective weighing pans, the pans were placed in an oven to dry overnight at 110°C.

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

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

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

Organic matter in a soil sample has been found to distort the determination of clay-size content. Therefore, the samples that contained more than 1% organic carbon were treated with 30% hydrogen peroxide (H_2O_2). We also found it necessary to treat the upper two samples from each core with H_2O_2. Ten grams of <2 mm sample was weighed into a 500-mL polymethlypentene bottle. 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 $(NaPO_3)_6$ 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 12 of the cores were silt loam, eight were silty clay loam, three were loam, and two were loamy sand, as indicated in tables 2 through 26. As shown in table 27, the parent materials of the soils at locations 117 and 121 were alluvium, that is, they were deposited as flood plain sediments, and which later became covered by prairie. The soils of cores 107, 109, 110, and 118 through 120 developed in upland forest. The remaining 17 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 54%, the silt contents ranged from about 3% to 86%, and the sand contents from 0.4% 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 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 1% and 0.1%, 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 µg/kg.

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

For example, the correlation coefficient between alumina (Al_2O_3) and the clay-size fraction is 0.86 (Table 28). That is, in about 86% 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. The data for core 122 were excluded from the calculations of correlation coefficients because core 122 was collected at the end of an abandoned roadbed and had unusually elevated contents of several elements. Therefore, it was not representative of a natural soil.

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 102 through 126. 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 (0.44) for 24 cores (excluding core 122) is low and does not confirm the previous observations. However, 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 0.59. The correlation coefficient between zirconium and the silt-size fraction was 0.77.

Titanium oxide (TiO_2) was correlated with the silt-size fraction (0.83), but it was also correlated with the clay-size fraction (0.68). 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. The 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 (0.86).

The clay-size fraction also was positively correlated with iron (0.74), potassium (0.58), titanium (0.68), barium (0.55), copper (0.60), rubidium (0.80), vanadium (0.85), zinc (0.70) and mercury (0.57). Therefore, these elements also correlated with each other. Nickel was correlated with iron (0.53), copper (0.51), and vanadium (0.60).

Iron is a necessary element in the crystal structure of certain clay minerals, although it may also occur as a non-structural 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 copper, 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 (such as FeOOH) are strong adsorbers of many trace elements, as well.

Calcium oxide (CaO) and magnesium oxide (MgO) were strongly correlated with each other (0.97) and with inorganic carbon content (0.99 and 0.98, respectively). These correlations suggest the presence of calcite and dolomite in the soil samples. Titanium oxide and zirconium were correlated with each other (0.80). Each was also correlated with the silt-size fraction (0.83 and 0.77, 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):

$$\begin{aligned} &Al^{3+} + H_2O = AlOH^{2+} + H^+ \\ &AlOH^{2+} + H_2O = Al(OH) + H^+ \\ &Al(OH) + H_2O = Al(OH)_{3s} + H^+ \\ &Al(OH)_{3s} + H_2O = Al(OH) + H^+ \end{aligned}$$

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):

$$CO_{2\ gas} = CO_{2\ aq}$$
$$CO_{2\ aq} + H_2O = H_2CO_3$$
$$H_2CO_3 = HCO + H^+$$
$$HCO = CO^- + H^+$$

Above pH 7.2 the pH is controlled by the precipitation or dissolution of carbonate minerals such as calcite and dolomite. As calcite dissolves in the soil solution it releases carbonate ion (CO^-), which reacts with water to produce bicarbonate ions (HCO), 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 4.98 (moderately acidic) to 8.54 (moderately alkaline), with a median value of 7.08. Of the 155 samples, 69 had a pH between 4 and 7 and the remaining 86 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 124, had a pH of 8.54. As shown in Figure 5 and Tables 29 through 53, the pH value in 9 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 16 of the 25 coring locations (cores 102-106, 108, 109, 111, 113-115, 119, 122, and 124-126). In all of these cores the calcium oxide, magnesium oxide, and inorganic C contents increased sharply in the sample(s) that were selected from the till. Carbonaceous minerals 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 24 of the 25 cores from 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 65% of the elements determined. The data for core 122 are not included in Table 54 because core 122 was collected at the end of an abandoned roadbed and the upper two samples from this core do not represent a natural soil. The contents of several elements, including mercury, lead, and zinc, as well as organic carbon, and therefore, total carbon, were abnormally elevated.

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 the particular minerals present in the soil and 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 102-106, 108, 109, 113-115, 119, 122, and 124-126; (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.

When the CaO and MgO contents increased at depth in the profile, the SiO_2 content generally decreased because of dilution of the sample by calcite ($CaCO_3$) or dolomite [$CaMg(CO_3)_2$]. When the CaO and MgO contents increased sharply and the SiO_2 content decreased, it usually occurred in a sample 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 Al_2O_3 content versus depth were in many cases mirror images of the SiO_2 profiles. When CaO and MgO contents increased significantly, the Al_2O_3 content commonly decreased because of dilution by calcite or dolomite, as in cores 102-106, 108, 109, 113-115, 122, and 122-126. Exceptions to this behavior were cores 115 and 119. In core 119 the Al_2O_3 content followed the trends in clay particle-size content. The Al_2O_3 content is generally associated with the clay mineral content of the samples, whereas the SiO_2 content is commonly 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 Fe_2O_3 content in these cores tended to vary within a small range. In all cores the Fe_2O_3 content passed through a maximum with increasing depth, generally in the B horizon, the clay-rich zone in the soil profile. The maximum Fe_2O_3 content of the modern soil was in the C horizon in cores 103 and 115, in the A horizon in cores 121 and 122, and in the underlying ancient soil in core 119.

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 K_2O content did not vary appreciably and remained between 1 and 2%.
In core 119 the K_2O content of the lowermost sample attained a value of 4.82% and the clay content reached its maximum value of 54.50% for this core. This might indicate the presence of potassium-containing clay minerals in this core.

Calcium and Magnesium Calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$] are common sources of calcium in soils, but not all soils contain calcite or dolomite. Calcium can also be held as an exchangeable ion on the soil 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 was at its maximum value in the uppermost sample of cores 112, 118, 120, 121, and 123, and in core 122 the CaO content would have been at its maximum value in the uppermost sample except that the lowermost sample was selected from the underlying calcareous till. Possibly cores 112 and 118 had been recently limed. Lime streaks were observed in the uppermost sample of core 120, indicating possible liming. Core 121 was collected from a location that was within 100 feet southeast of the intersection of two limestone gravel roads. Limestone dust probably drifted across the field and settled onto the surface. Core 122 was collected at the end of an abandoned roadbed and contained limestone pebbles in the uppermost sample.

The lowermost samples of cores collected from the Illinoian till plain that penetrated the underlying calcareous till (cores 108 and 109) contained less calcite/dolomite than the lowermost samples of cores collected from the Wisconsin till plain (cores 102, 104-106, 113-115, 122, and 124-126). For the two cores collected from the Illinoian till plain, the average CaO and MgO contents of the lowermost samples were 5.78±0.77% and 3.04±0.95%, respectively. For cores collected from the Wisconsin till plain, the average CaO and MgO contents in the till samples were 8.00±1.56% and 5.02±0.85%, respectively. Only two of the cores collected on the Illinoian till plain penetrated the underlying till, so the averages and standard deviations for CaO and MgO of the two cores are not very strong compared with data from 10 cores collected from the Wisconsin till plain. However, similar differences between cores from the Illinoian and Wisconsin till plains were observed for cores 77 through 101. Among these cores, 12 from the Wisconsin and 8 from the Illinoian till plain penetrated the underlying till. In these eight Illinoian till plain cores the average CaO and MgO contents in the lowermost samples were 4.16±1.13% and 2.93±0.95%, respectively. In the lowermost samples from the 12 Wisconsin till plain cores the average CaO and MgO contents were 8.06±4.14% and 5.64±2.94%, respectively.

The Illinoian till plain was exposed to weathering and leaching for thousands of years longer than the Wisconsin till plain, thus the CaO and MgO contents were less 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 102 through 126. The solid line through the points represents the theoretical composition of dolomite, that is, the weight-percent ratio of CaO/MgO is 1.39, or the molar ratio is 1. The dashed line represents the best-fit (linear regression) line through the points. The regression line is close to the theoretical line, which 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 content in the 25 cores was small, with only 1.28% between the minimum value of 0.22% and the maximum of 1.50%. In 16 of the 25 cores (103, 105, 106, 108, 110-114, 118, 120-124, and 126) 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 teh low solubility 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, with a minimum of 0.12% and a maximum of 0.82%.

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

In all but two cores (109 and 110) the content of P_2O_5 was elevated in the surface soil sample and decreased in at least the next deeper sample. In the remaining 23 cores the content of P_2O_5 was at its maximum in the surface sample in all cores except 113 and 119. Possibly P_2O_5 was contributed to the surface soil as a result of plowing plant debris into the soil or by application of phosphate fertilizer to the soil. In core 109 the maximum P_2O_5 content increased from the surface to near the bottom of the thick A horizon, and in core 110 the P_2O_5 content increased from the surface to the upper B horizon.

Manganese The principal source minerals for manganese in soils are the rock-forming minerals amphiboles, pyroxenes, and biotite mica [$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$] (in which Mn can replace iron to a limited extent), and rhodonite ($MnSiO_3$) (Sparks, 1995). Although manganese commonly occurs in soil as coatings on other minerals (Kabata-Pendias, 2001), it is also commonly found concentrated in nodules of MnO_2 (concretions) accompanied by iron. These nodules seem to form in soil horizons that periodically become waterlogged, so that reducing conditions prevail, and 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 16 cores (104-106, 108, 109, 111, 112, 115-121, 123, and 124) the MnO content was greatest in the A horizon. In 9 cores (102, 103, 107, 110, 113, 114, 122, 125, and 126) the MnO content passed through a maximum in the B horizon or below. There was a secondary maximum in MnO content, however, in cores 105-108, 112, 118, and 120 in the B horizon or below. These behaviors might indicate that colloidal-sized particles containing Mn migrated from higher positions in the soil profile to lower positions.

Barium Micas and feldspars are sources of barium in soils. These minerals contain potassium, which is commonly replaced by barium because the two atoms are of similar size (Kabata-Pendias, 2001). Barium is strongly adsorbed on clay minerals in soils and, therefore, is not very mobile. Barium has been found in soils as barite ($BaSO_4$, Allen and Hajek, 1989) and hollandite [$Ba(Mn^{4+},Mn^{2+})_8O_{16}$, McKenzie, 1989]. Barium also is concentrated in manganese and phosphorus concretions, and is specifically adsorbed on oxides and hydroxides. Fertilizer can be a secondary source of Ba in agricultural soils to which granular fertilizer has been applied, and in such cases, a 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 11 cores (105, 107, 109, 111, 113, 115-117, 119, 122, and 123) was at its maximum in the A horizon. In the remaining cores the Ba content achieved its maximum in the B horizon 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 (11 cores). Barium may have been carried downward as adsorbed species on colloidal clay particles.

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 in the 25 cores ranged from 37 to 633 mg/kg and was erratic in several cores, for example, 102, 106, 114, and 121. The Cr content was not well correlated with any other constituent for which we analyzed, which suggests multiple modes of occurrence. In cores 107, 108, 110, 111, 113-115, 118-120, 122, 125, and 126 the Cr content reached a maximum value in the AB horizon or below, which is indicative of downward migration of Cr in the soil column. In cores 103, 105, and 109, however, the maximum Cr content occurred in the A 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 16 cores the maximum Cu content occurred in the B horizon or below and in six cores the maximum Cu content was in the A horizon. In the remaining three cores there were dual maxima in the A and B horizons. The range of Cu content was 11 to 43 mg/kg.

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 of the 24 cores (excluding core 122) ranged from 2 to 46 mg/kg. Core 122 was collected at the end of an abandoned roadbed. The greatest lead contents in the 25 cores, 308 and 110 mg/kg were observed in the two uppermost samples of core 122, respectively. In every core except two (107 and 109), the maximum Pb content was in the uppermost sample. In core 107 the maximum Pb content of 23 mg/kg occurred in the lowermost sample, but the uppermost sample contained 22 mg/kg. All other samples in core 107 contained less Pb. In core 109 the maximum Pb content occurred about 2.4 feet below the surface, in the A horizon.

The accumulation of Pb in the uppermost samples suggests that Pb was contributed by an external source, such as fallout from industrial activities or the use of leaded fuel in vehicles that passed over or nearby the coring location. In 14 cores in which tthe maximum Pb content occurred in the uppermost samples, there was a secondary maximum in the B horizon (AB transition zone in 1 core) or below, indicating adsorption of Pb by clay minerals. Lead was correlated with TiO_2 (0.71), P_2O_5 (0.53), Ba (0.57), Zr (0.60), Cu (0.57), Rb (0.50), V (0.59), Zn (0.85), organic C (0.57), and silt-size fraction (0.60). The Pb content was negatively correlated with the sand-size fraction (-0.69).

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 22 to 471 µg/kg (parts per billion, as opposed to parts per million for other trace elements), including the amount from the uppermost sample of core 122. If this core is not included, the range was 8 to 98 µg/kg. In 11 cores the maximum Hg content was in the B horizon or below (BA transition zone in core 111). In cores 103, 107, 109, 115, 117, and 122 the maximum Hg content was in the uppermost sample except in core 109, in which mercury had its maximum content in the second sample from the surface. Mercury was correlated with Al_2O_3 (0.54), Cu (0.51), V (0.59), Zn (0.50), and clay-size fraction (0.57).

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 11 to 68 mg/kg in the 25 cores. In all cores except 109, 115, and 117, the maximum Ni content occurred in the B horizon or below. In ten cores (102, 104, 105, 107, 109, 110, 114, 118, 121, and 124) the maximum Ni content occurred in the horizon that had the greatest clay-size content. The Ni content was correlated with Fe_2O_3 (0.53), copper (0.51), and V (0.60), which suggests adsorption of Ni by iron oxyhydroxides, represented by Fe_2O_3.

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 23 to 176 mg/kg. Rubidium was correlated with Al_2O_3 (0.72), Fe_2O_3 (0.53), K_2O (0.80), TiO_2 (0.65), Pb (0.50), V (0.66), Zn (0.65), clay-size content (0.80), and negatively with sand-size content (-0.64). All correlations suggest that Rb was adsorbed by clay minerals. The correlation of Rb with K_2O suggests that Rb may have substituted for K in certain minerals.

Strontium Strontium generally is associated with soil organic matter, but it may also precipitate under alkaline conditions as strontianite ($SrCO_3$). The element 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 77 and 219 mg/kg. In most cores the variation of Sr content through the profile was small. Strontium was correlated with Na_2O (0.85) and Zr (0.62).

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 range of V content in all 25 cores was 17 to 128 mg/kg. The V content in all but four cores (107, 111, 117, and 123) was at its maximum in the B horizon or the BA transition zone (cores 103, 106, and 115). In every core the depth profile for V generally followed the clay-size depth profile, more closely in some cores (for example core 113) than in others (for example core 121). This parallelism suggests adsorption of V by clay minerals. The depth profile for Hg was often parallel with that for V, indicating that both elements were adsorbed by clay minerals. Vanadium was correlated with Al_2O_3 (0.87), Fe_2O_3 (0.86), TiO_2 (0.83), Ba (0.72), Zr (0.51), Cu (0.71), Ni (0.60), Pb (0.59), Rb (0.66), Zn (0.70), Hg (0.59), silt-size fraction (0.62), and clay size fraction (0.85). Vanadium content was negatively correlated with sand-size fraction (-0.81)

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 the 24 cores not including core 122 was in the range of 11 to 161 mg/kg. The range was 11 to 519 when core 122 was included. The greatest Zn content was in the A or AB horizon in 20 of the cores, suggesting an external source of Zn such as fertilizer or industrial fallout. In the remaining five cores (102, 108, 110, 118, and 125) the maximum zinc content occurred in the B horizon or below. Zinc was correlated with Al_2O_3 (0.60), Fe_2O_3 (0.59), TiO_2 (0.68), P_2O_5 (0.58), Ba (0.55), Cu (0.64), Pb (0.85), Hg (0.50), Rb (0.65), V (0.70), organic C (0.51), silt-size content (0.58), and clay-size content (0.70). The Zn content was negatively correlated with sand content (-0.72).

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 58 to 569 mg/kg in the 25 cores. The Zr content was correlated with Na_2O (0.77), TiO_2 (0.80), MnO (0.53), Ba (0.72), Sr (0.62), Pb (0.60), V (0.51) and silt-size fraction (0.77). The Zr content was negatively correlated with the sand-size fraction (-0.71). The Zr content was greatest in the surface sample and decreased with depth in cores 104, 105, 110, 114, 116, 119, 123, and 124. In a few cores (102, 106-109, 111, 113, 115, 117, 121, 122, 125, and

126) the Zr content passed through a maximum below the surface. In the remaining four cores (103, 112, 118, and 120) the Zr content did not vary appreciably.
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 (109, 117, and 121) the maximum organic C content occurred in the uppermost sample and decreased with depth. In cores 109 and 117, the A horizon was unusually thick (2.75 and 5.0 feet, respectively). The soil at site 117 was alluvial, collected from within 100 feet of a creek. The sediment probably accumulated relatively quickly. At the location of core 121, liquefied hog manure was knifed into the soil to a depth of about 1 foot and then the field was chisel plowed to a depth of 1.5 to 2 feet in the autumn of each year. The core was collected just off the end of a dry, grassy waterway, in the plowed field. Possibly organic C was leached downward during rain events.

Many of the cores penetrated the underlying calcareous till, as evidenced by a sharp increase in inorganic (carbonate) C and the parallel increases in CaO and MgO. Above the till and in the cores which either did not penetrate the till or for which a till sample was not selected (cores 107, 110, 112, 116-118, 120, 121 and 123), the inorganic C content was relatively invariant with depth. In cores 110, 116, 118, and 120-123 the maximum inorganic C content occurred in the uppermost sample. In the core from site 120 there were lime streaks in the uppermost sample, and in core 122, taken at the end of an abandoned roadbed, there were limestone pebbles and particles of coal or asphalt in the uppermost sample.

CONCLUSIONS

The content of Al_2O_3 was correlated with clay-size content. Aluminum is a building block of clay minerals and this correlation was expected. The correlation between Fe_2O_3 and clay-size content suggests that iron oxyhydroxides coated clay minerals. K_2O was correlated with clay-size content. Potassium is a structural component of the clay mineral, illite. Copper, rubidium, vanadium, zinc, and mercury were also correlated with clay-size content, suggesting adsorption of these trace elements on clay minerals. Copper, nickel, rubidium, vanadium, zinc, and mercury were also correlated with Fe_2O_3 content, an indication that these trace elements were sorbed by iron oxyhydroxides. Iron oxyhydroxides often occur as coatings on other particles, but can also occur as concretions or nodules in soil.

The calcareous or dolomitic till or limestone beneath the surficial loess was penetrated by at least 16 cores. 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.

Because of the unusual nature of core 122 (collected at the end of an abandoned roadbed), data from this core were excluded from the calculation of correlation coefficients and the data for the means and ranges of element contents in the uppermost samples, Table 54. The contents of Pb, Zn, Hg, and inorganic C, and thus total C, were at their greatest in the uppermost sample from this core, probably due to the occurrence of coal and/or asphalt in the sample.

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(Footnotes)

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

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

Core Number	County Name	Final Depth of Core (ft)
102	Kankakee	3.6
103	Grundy	3.7
104	LaSalle	16.0
105	Putnam	16.0
106	Bureau	21.0
107	Henry	16.5
108	Henry	24.0
109	Mercer	17.0
110	Henry	19.6
111	Henry	12.8
112	Bureau	14.4
113	Bureau	19.5
114	LaSalle	13.0
115	Lee	12.5
116	Lee	20.3
117	Whiteside	20.0
118	Carroll	26.8
119	Jo Daviess	10.7
120	Jo Daviess	13.0
121	Stephenson	10.0
122	Ogle	20.6
123	Ogle	16.6
124	Winnebago	6.7
125	Boone	17.0
126	DeKalb	19.0

Table 2. Texture of samples from core 102*

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
102-1	0.0-0.8	A	14.86	43.17	41.97	loam
102-2	0.8-1.4	E	13.28	52.36	34.36	silt loam
102-3	1.4-2.0	Bt	19.54	52.12	28.36	silt loam
102-4	2.0-2.4	Bt	27.92	50.14	21.94	silty clay loam
102-5	2.4-3.0	Btβ	33.23	43.60	23.17	clay loam
102-6	3.0-3.5	Cr	9.64	63.24	27.12	silt loam

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

Table 3. Texture of samples from core 103

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
103-1	0.0-0.8	Ap	31.35	18.89	49.76	silty clay loam
103-2	0.8-1.5	A	32.01	17.37	50.62	silty clay loam
103-3	1.5-2.0	BA	30.21	18.94	50.85	silty clay loam
103-4	2.0-2.4	Btj	14.74	49.31	35.95	loam
103-5	2.4-3.0	Ctj	27.74	21.78	50.48	clay loam

Table 4. Texture of samples from core 104

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
104-1	0.0-0.9	Ap	28.00	3.18	68.82	silty clay loam
104-2	0.9-1.5	AB	30.05	2.45	67.50	silty clay loam
104-3	1.5-2.0	Bt	36.12	1.18	62.70	silty clay loam
104-4	2.0-2.5	Bt	34.56	1.22	64.22	silty clay loam
104-6	3.0-3.5	C	20.20	1.47	78.33	silt loam
104-8	4.0-4.8	C	20.60	2.32	77.08	silt loam

Table 5. Texture of samples from core 105

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
105-1	0.0-0.9	Ap	26.32	1.88	71.80	silt loam
105-2	0.9-1.5	AB	34.11	1.15	64.74	silty clay loam
105-3	1.5-2.0	Bt	35.22	1.61	63.17	silty clay loam
105-5	2.6-3.2	Bt2	26.10	2.69	71.21	silt loam
105-7	3.8-4.5	2C	33.98	19.34	46.68	silty clay loam
105-12	7.1-7.7	2C	33.50	20.58	45.92	clay loam

Table 6. Texture of samples from core 106

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
106-1	0.0-0.7	Ap	29.24	1.45	69.31	silty clay loam
106-2	0.7-1.2	BA	31.95	0.78	67.27	silty clay loam
106-3	1.2-2.0	Bt	27.78	1.27	70.95	silty clay loam
106-4	2.0-2.7	Bt	26.86	2.56	70.58	silt loam
106-6	3.4-4.0	B2tj	16.71	3.17	80.12	silt loam
106-8	4.3-4.8	C	9.76	4.42	85.82	silt

Table 7. Texture of samples from core 107

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
107-1	0.0-0.5	Ap	29.98	0.51	69.51	silty clay loam
107-2	0.5-1.1	Bt1	26.96	0.40	72.64	silt loam
107-3	1.1-1.8	Bt2	24.04	0.70	75.26	silt loam
107-4	1.8-2.4	Bt3	21.53	0.60	77.87	silt loam
107-6	2.6-3.1	2Ab	20.60	7.83	71.57	silt loam
107-9	4.0-4.7	3BtA	38.30	21.82	39.88	clay loam

Table 8. Texture of samples from core 108

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
108-1	0.0-0.8	Ap	32.80	1.11	66.09	silty clay loam
108-2	0.8-1.3	A2	35.24	1.28	63.48	silty clay loam
108-3	1.3-2.0	Bt	36.09	1.49	62.42	silty clay loam
108-5	2.7-3.4	Bt	32.86	0.86	66.28	silty clay loam
108-7	4.0-4.6	BCtj	24.45	0.90	74.65	silt loam
108-10	6.0-6.6	C21	18.14	0.52	81.34	silt loam

Table 9. Texture of samples from core 109

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
109-1	0.0-0.6	Ap	26.39	7.87	65.74	silt loam
109-3	1.3-2.0	A11	22.70	2.61	74.69	silt loam
109-4	2.0-2.75	A12	16.02	4.74	79.24	silt loam
109-5	2.75-3.5	Btj	26.11	17.16	56.73	silt loam
109-7	4.0-4.5	Bk	24.63	32.14	43.23	loam
109-9	5.3-6.0	2C2	21.40	37.26	41.34	loam

Table 10. Texture of samples from core 110

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
110-1	0.0-0.5	Ap	13.26	56.38	30.36	sandy loam
110-2	0.5-1.1	Btj	19.70	23.90	26.40	sandy loam
110-3	1.1-1.7	Bt	20.50	56.65	22.85	sandy clay loam
110-5	2.2-2.7	Bt	13.99	78.62	7.39	sandy loam
110-7	3.0-3.4	E	4.22	87.71	8.07	sand
110-9	4.0-4.6	C	1.14	95.68	3.18	sand

Table 11. Texture of samples from core 111

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
111-1	0.0-0.9	Ap	22.96	41.14	35.90	loam
111-2	0.9-1.4	A12	22.14	41.95	35.91	loam
111-3	1.4-2.0	A13	20.26	46.84	32.90	loam
111-4	2.0-2.65	BA	22.66	39.93	37.41	loam
111-5	2.65-3.3	AB	15.50	56.68	27.82	sandy loam
111-6	3.3-3.7	C1	4.98	87.77	7.25	sand

Table 12. Texture of samples from core 112

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
112-1	0.0-0.9	Ap1	19.32	3.26	77.42	silt loam
112-3	1.1-1.8	Btj	25.95	1.72	72.33	silt loam
112-4	1.8-2.4	Btj	26.02	2.50	71.48	silt loam
112-6	2.9-3.3	Btj	21.82	4.04	74.14	silt loam
112-8	4.0-4.6	BCtj	18.26	7.68	74.06	silt loam
112-10	4.9-5.5	C	19.28	11.28	69.44	silt loam

Table 13. Texture of samples from core 113

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
113-1	0.0-0.6	Ap	28.98	1.19	69.83	silty clay loam
113-2	0.6-1.2	Btj	35.20	0.99	63.81	silty clay loam
113-3	1.2-1.8	Bt	30.60	1.30	68.10	silty clay loam
113-4	1.8-2.4	Bt	23.76	1.960	74.29	silt loam
113-5	2.4-3.1	BCtj	15.72	2.32	81.96	silt loam
113-6	4.5-5.2	C	11.98	6.52	81.50	silt

Table 14. Texture of samples from core 114

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
114-1	0.0-0.6	Ap	27.83	2.72	69.45	silty clay loam
114-2	0.6-1.4	A2	33.67	1.62	64.71	silty clay loam
114-3	1.4-2.0	Bt	34.98	1.40	63.62	silty clay loam
114-4	2.0-2.6	Bt	31.14	1.70	67.16	silty clay loam
114-5	2.6-3.2	Btj	25.33	1.69	73.18	silt loam
114-6	3.2-4.0	Ctj	18.70	2.88	78.42	silt loam

Table 15. Texture of samples from core 115

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
115-1	0.0-1.1	Ap	25.24	8.70	65.06	silt loam
115-2	1.1-1.8	AB	27.22	7.28	65.50	silty clay loam
115-3	1.8-2.3	BAg	26.16	8.20	65.64	silt loam
115-5	2.8-3.5	Cg	26.34	7.10	66.56	silt loam
115-7	4.0-4.5	Cg	17.02	5.60	77.38	silt loam
115-9	5.0-5.6	Cg	12.60	30.92	56.48	silt loam

Table 16. Texture of samples from core 116

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
116-1	0.0-0.8	Ap	15.90	39.96	15.90	loam
116-3	1.0-1.5	Btj	18.04	37.98	18.04	loam
116-4	1.5-2.0	Btj	18.74	42.82	18.74	loam
116-5	2.0-2.5	Btj	14.60	58.44	14.60	sandy loam
116-6	2.5-3.0	BC	8.73	77.63	8.73	sandy loam
116-9	3.6-4.4	C	4.26	91.66	4.26	sand

Table 17. Texture of samples from core 117

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
117-1	0.0-0.6	Ap	20.99	25.94	53.07	silt loam
117-2	0.6-1.4	A2	13.59	37.24	49.17	loam
117-3	1.4-2.0	Ab	11.60	41.06	47.34	loam
117-5	2.8-3.5	Ab	10.64	50.59	38.77	loam
117-6	3.5-4.1	Ab	9.88	54.74	33.38	sandy loam
117-8	5.0-5.6	AB	8.59	57.07	34.34	sandy loam

Table 18. Texture of samples from core 118

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
118-1	0.0-0.9	Ap	16.10	3.68	80.22	silt loam
118-2	0.9-1.5	Btj	23.90	0.96	75.14	silt loam
118-3	1.5-2.0	Btj	26.58	1.56	71.86	silt loam
118-5	2.6-3.3	Bt	26.82	3.76	69.42	silt loam
118-8	4.5-5.1	Bt	26.62	3.00	70.38	silt loam
118-11	6.6-7.5	Ctj	16.96	1.36	81.68	silt loam

Table 19. Texture of samples from core 119

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
119-1	0.0-0.7	Ap	16.34	5.19	78.47	silt loam
119-2	0.7-1.4	Ap	20.15	2.72	77.18	silt loam
119-3	1.4-2.0	BA	24.64	3.13	72.23	silt loam
119-5	2.2-2.8	Bt	29.02	1.55	69.43	silty clay loam
119-6	2.8-3.4	Bt	24.85	0.53	74.59	silt loam
119-11	5.3-6.1	2Cr	54.50	2.32	43.18	silty clay

Table 20. Texture of samples from core 120

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
120-1	0.0-0.45	Ap	26.50	3.69	69.81	silt loam
120-2	0.45-0.9	Bt	29.71	2.13	68.16	silty clay loam
120-4	1.4-2.0	Bt	33.20	0.86	65.94	silty clay loam
120-5	2.0-2.5	Btg	33.25	1.22	65.53	silty clay loam
120-8	3.0-3.6	C	26.45	0.62	72.93	silt loam
120-15	4.6-5.2	2Ab	33.67	1.46	64.93	silty clay loam

Table 21. Texture of samples from core 121

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
121-1	0.0-0.8	Ap	23.62	3.74	72.64	silt loam
121-2	0.8-1.3	C	20.04	0.96	79.00	silt loam
121-3	1.3-2.0	2A1	21.80	1.24	76.96	silt loam
121-5	2.7-3.4	3Ab	21.62	1.94	76.44	silt loam
121-8	4.3-4.8	3BA	32.00	1.71	66.29	silty clay loam
121-10	5.5-6.2	3CB	28.98	0.94	70.08	silty clay loam

Table 22. Texture of samples from core 122

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
122-1	0.0-0.8	Ap	25.58	14.66	59.76	silt loam
122-2	0.8-1.3	AB	29.93	3.69	66.38	silty clay loam
122-3	1.3-2.0	Btj	27.08	2.40	70.52	silty clay loam
122-5	2.8-3.4	Btj	31.08	1.84	67.08	silty clay loam
122-8	5.0-5.8	Bt	24.53	1.00	74.47	silt loam
122-9	5.8-6.7	C	16.42	1.42	82.16	silt loam

Table 23. Texture of samples from core 123

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
123-1	0.0-0.8	Ap	24.96	2.93	72.11	silt loam
123-2	0.8-1.3	AB	33.69	1.25	65.06	silty clay loam
123-3	1.3-1.8	Btj	31.36	2.68	65.96	silty clay loam
123-4	1.8-2.5	E’	24.18	1.84	73.98	silt loam
123-7	3.1-3.7	2Bg	49.48	2.85	47.67	silty clay
123-8	3.7-4.2	3AB	45.70	14.66	39.64	clay

Table 24. Texture of samples from core 124

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
124-1	0.0-0.6	Ap	14.43	61.47	24.10	sandy loam
124-2	0.6-0.9	Btj	15.80	61.73	22.47	sandy loam
124-3	0.9-1.5	C	11.58	60.32	28.10	sandy loam
124-4	1.5-2.0	C	10.71	60.26	29.03	sandy loam
124-5	2.0-2.6	C	11.05	57.30	31.65	sandy loam
124-7	3.3-4.0	C	10.20	58.52	31.28	sandy loam

Table 25. Texture of samples from core 125

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
125-1	0.0-0.9	Ap1	22.46	8.31	69.23	silt loam
125-2	0.9-1.3	Ap2	25.10	12.30	62.60	silt loam
125-3	1.3-2.0	Bg	26.88	3.60	69.52	silt loam
125-4	2.0-2.6	Bg	35.36	5.10	59.52	silty clay loam
125-6	3.3-3.6	BCg	16.46	64.59	18.95	silt loam
125-10	6.0-7.0	3C	17.54	43.92	38.54	loam

Table 26. Texture of samples from core 126

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
126-1	0.0-1.0	Ap	32.14	2.27	65.59	silty clay loam
126-2	1.0-1.5	A2	39.89	2.84	57.27	silty clay loam
126-3	1.5-2.0	AB	39.18	3.67	57.15	silty clay loam
126-5	2.6-3.2	Bg	35.72	3.23	61.05	silty clay loam
126-7	4.0-4.7	Bg	31.37	4.24	64.39	silty clay lam
126-11	6.0-6.6	2C	17.71	39.16	43.13	loam

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

Core Number	Texture	Soil Type*	Soil Association	Developmental Environment
102	loam	Kankakee	Channahon-Dodgeville-Ashdale	upland, prairie
103	silty clay loam	Reddick	Symerton-Andres-Reddick	upland, prairie
104	silty clay loam	Elburn	Plano-Proctor-Worthen	upland, prairie
105	silt loam	Catlin	Catlin-Flanagan-Drummer	upland, prairie
106	silty clay loam	Catlin	Catlin-Flanagan-Drummer	upland, prairie
107	silty clay loam	Hickory	Fayette-Rozetta-Stronghurst	upland, forest
108	silty clay loam	Ipava	Tama-Ipava-Sable	upland, prairie
109	silt loam	Hickory	Fayette-Rozetta-Stronghurst	upland, forest
110	sandy loam	Dickinson	Fayette-Rozetta-Stronghurst	upland, forest
111	loam	Selma	Jasper-LaHogue-Selma	upland, prairie
112	silt loam	Port Byron	Port Byron-Joy	upland, prairie
113	silty clay loam	Catlin	Catlin-Flanagan-Drummer	upland, prairie
114	silty clay loam	Muscatine	Tama-Muscatine-Sable	upland, prairie
115	silt loam	Hartsburg	Tama-Ipava-Sable	upland, prairie
116	loam	Dakota	Lorenzo-Warsaw-Wea	upland, prairie
117	silt loam	Otter	Lawson-Sawmill-Darwin	alluvium, prairie
118	silt loam	Fayette	Fayette-Rozetta-Stronghurst	upland, forest
119	silt loam	Fayette	Fayette-Rozetta-Stronghurst	upland, forest
120	silt loam	Atterberry	Fayette-Rozetta-Stronghurst	upland, forest
121	silt loam	Huntsville	Lawson-Sawmill-Darwin	alluvium, prairie
122	silt loam	Tama	Tama-Muscatine-Sable	upland, prairie
123	silt loam	Assumption	Tama-Muscatine-Sable	upland, prairie
124	sandy loam	Winnebago	Winnebago-Durand-Ogle	upland, prairie
125	silt loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie
126	silty clay loam	Drummer	Catlin-Flanagan-Drummer	upland, prairie

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

Table 28. Correlation coefficients for constituents of cores 102 through 126 (C.I. = 95%)

	Depth	SiO_2	Al_2O_3	Fe_2O_3	K_2O	LOI	H_2O	CaO	MgO
Depth	1								
SiO_2	-0.31	1							
Al_2O_3	-0.01	-0.37	1						
Fe_2O_3	0.01	-0.34	0.72	1					
K_2O	0.22	-0.57	0.65	0.47	1				
LOI	0.20	-0.84	-0.13	-0.10	0.22	1			
H_2O	-0.31	-0.11	0.61	0.59	0.18	-0.15	1		
CaO	0.43	-0.76	-0.28	-0.19	0.14	0.90	-0.39	1	
MgO	0.44	-0.81	-0.16	-0.13	0.24	0.89	-0.32	0.97	1
Na_2O	-0.05	0.09	0.33	0.32	0.09	-0.35	0.19	-0.31	-0.35
TiO_2	-0.21	-0.16	0.78	0.67	0.49	-0.23	0.58	-0.43	-0.36
P_2O_5	-0.25	-0.19	0.17	0.20	0.18	0.17	0.21	-0.04	-0.09
MnO	-0.15	-0.07	0.33	0.43	0.22	-0.13	0.29	-0.22	-0.18
Ba	-0.23	-0.05	0.67	0.56	0.37	-0.30	0.47	-0.45	-0.41
Sr	0.13	0.10	0.18	0.25	0.11	-0.30	0.05	-0.20	-0.27
Zr	-0.24	0.10	0.40	0.37	0.15	-0.33	0.30	-0.43	-0.43
Cr	-0.06	0.31	-0.26	-0.12	-0.24	-0.20	0.11	-0.15	-0.16
Cu	-0.14	-0.16	0.58	0.59	0.26	-0.13	0.60	-0.29	-0.23
Ni	-0.08	0.01	0.47	0.53	0.22	-0.31	0.60	-0.33	-0.26
Pb	-0.41	-0.12	0.49	0.42	0.22	-0.04	0.56	-0.33	-0.31
Rb	-0.05	-0.44	0.72	0.53	0.80	0.14	0.45	0.11	-0.01
V	-0.13	-0.25	0.87	0.86	0.48	-0.21	0.73	-0.38	-0.28
Zn	-0.25	-0.32	0.60	0.59	0.38	0.09	0.66	-0.20	-0.15
Hg	-0.31	-0.06	0.54	0.41	0.02	-0.14	0.74	-0.34	-0.28
Tot C	-0.02	-0.63	-0.27	-0.25	0.09	0.91	-0.11	0.73	0.68
In C	0.43	-0.74	-0.30	-0.23	0.13	0.89	-0.42	0.99	0.98
Org C	-0.58	0.08	0.01	-0.05	-0.04	0.10	0.38	-0.27	-0.31
Sand	0.11	0.44	-0.78	-0.69	-0.55	-0.05	-0.52	0.13	0.08
Silt	-0.05	-0.42	0.61	0.53	0.49	0.10	0.31	-0.02	0.00
Clay	-0.11	-0.37	0.86	0.74	0.58	-0.02	0.71	-0.25	-0.15
S+Si	0.18	0.27	-0.78	-0.72	-0.42	0.08	-0.72	0.30	0.22
pH	0.35	-0.44	-0.28	-0.19	0.05	0.56	-0.35	0.68	0.64

Table 28, continued

	Na_2O	TiO_2	P_2O_5	MnO	Ba	Sr	Zr	Cr	Cu
Na_2O	1								
TiO_2	0.57	1							
P_2O_5	0.33	0.32	1						
MnO	0.38	0.51	0.25	1					
Ba	0.60	0.81	0.34	0.64	1				
Sr	0.85	0.38	0.29	0.29	0.47	1			
Zr	0.77	0.80	0.35	0.53	0.72	0.62	1		
Cr	-0.13	-0.35	-0.13	-0.11	-0.24	-0.06	-0.34	1	
Cu	0.30	0.58	0.29	0.23	0.38	0.19	0.31	-0.03	1
Ni	0.20	0.37	0.02	0.36	-0.32	0.17	0.16	0.21	0.51
Pb	0.36	0.71	0.53	0.46	0.57	0.17	0.60	-0.22	0.57
Rb	0.02	0.65	0.24	0.28	0.46	-0.02	0.24	-0.23	0.37
V	0.38	0.83	0.20	0.46	0.72	0.25	0.51	-0.16	0.71
Zn	0.24	0.68	0.58	0.45	0.55	0.12	0.45	-0.20	0.64
Hg	0.11	0.43	0.15	0.17	0.35	-0.06	0.19	0.07	0.51
Tot C	-0.29	-0.23	0.35	-0.12	-0.28	-0.25	-0.24	-0.15	-0.16
In C	-0.37	-0.46	-0.10	-0.23	-0.49	-0.27	-0.47	-0.15	-0.32
Org C	0.07	0.27	0.59	0.14	0.24	0.00	0.26	0.00	0.19
Sand	-0.54	-0.91	-0.42	-0.52	-0.76	-0.36	-0.71	0.42	0.59
Silt	0.63	0.83	0.45	0.53	0.69	0.45	0.77	-0.46	0.43
Clay	0.02	0.68	0.18	0.25	0.55	-0.05	0.21	-0.16	0.60
S+Si	-0.07	-0.66	-0.15	-0.26	-0.54	-0.02	-0.24	0.12	-0.65
pH	-0.24	-0.40	0.01	-0.20	-0.39	-0.16	-0.36	0.01	-0.28

Table 28, continued

	Ni	Pb	Rb	V	Zn	Hg	Tot C	In C	Org C
Ni	1								
Pb	0.27	1							
Rb	0.24	0.50	1						
V	0.60	0.59	0.66	1					
Zn	0.35	0.85	0.65	0.70	1				
Hg	0.47	0.49	0.27	0.59	0.50	1			
Tot C	-0.40	0.09	0.12	-0.31	0.15	-0.12	1		
In C	-0.35	-0.36	-0.12	-0.41	-0.24	-0.36	0.71	1	
Org C	-0.09	0.57	0.31	0.09	0.51	0.29	0.45	-0.30	1
Sand	-0.31	-0.69	-0.64	-0.81	-0.72	-0.38	0.00	0.17	-0.23
Silt	0.17	0.60	0.49	0.62	0.58	0.20	0.07	-0.07	0.18
Clay	0.44	0.49	0.80	0.85	0.70	0.57	-0.11	-0.28	0.20
S+Si	-0.47	-0.55	-0.68	-0.85	-0.69	-0.59	0.15	0.33	-0.21
pH	-0.16	-0.36	-0.22	-0.37	-0.27	-0.29	0.42	0.67	-0.28

	Sand	Silt	Clay	S+Si	pH
Sand	1				
Silt	-0.94	1			
Clay	-0.66	0.40	1		
S+Si	0.65	-0.35	-0.92	1	
pH	0.21	-0.11	-0.28	0.32	1

Table 29. Elemental composition of samples selected from Core 102

Subsample	102-1	102-2	102-3	102-4	102-5	102-6	Average
Lab. No.	R23165	R23166	R23167	R23168	R23169	R23170	
Depth Interval (ft)	0.0-0.8	0.8-1.4	1.4-2.0	2.0-2.4	2.4-3.0	3.0-3.5	
Horizon	A	E	Bt	Bt	Btβ	Cr	
SiO_2 (%)	81.21	83.74	81.63	77.28	73.67	57.42	75.83
Al_2O_3 (%)	7.51	7.12	8.27	10.38	10.83	5.20	8.22
Fe_2O_3 (%)	2.21	1.94	2.45	3.58	4.59	1.82	2.77
K_2O (%)	1.73	1.69	1.68	1.67	1.85	1.37	1.67
CaO (%)	0.74	0.73	0.75	0.81	1.16	9.91	2.35
MgO (%)	0.78	0.76	0.89	1.08	1.38	6.85	1.96
Na_2O (%)	0.71	0.73	0.70	0.62	0.52	0.47	0.63
TiO_2 (%)	0.49	0.46	0.45	0.43	0.44	0.22	0.42
P_2O_5 (%)	0.09	0.06	0.06	0.06	0.09	0.08	0.07
MnO (%)	0.07	0.03	0.03	0.08	0.09	0.04	0.06
Barium	452	530	436	499	446	203	428
Chromium	52	311	89	258	147	203	177
Copper	16	13	18	21	23	11	17
Mercury (μg/kg)	36	30	32	81	70	38	48
Nickel	40	27	24	38	49	18	33
Lead	20	13	16	19	19	11	16
Rubidium	71	64	66	71	84	52	68
Strontium	113	133	133	122	114	110	121
Vanadium	62	57	70	94	98	40	70
Zinc	57	40	53	77	94	42	61
Zirconium	330	379	332	302	256	186	298
Total C (%)	1.76	0.85	0.76	0.82	1.13	4.42	1.62
Inorganic C (%)	0.08	0.08	0.10	0.08	0.22	4.09	0.78
Organic C (%)	1.68	0.77	0.66	0.74	0.91	0.33	0.85
pH	4.98	5.92	5.94	6.00	7.11	8.21	6.36

Table 30. Elemental composition of samples selected from Core 103

Subsample	103-1	103-2	103-3	103-4	103-5	Average
Lab. No.	R23190	R23191	R23192	R23193	R23194	
Depth Interval (ft)	0.0-0.8	0.8-1.5	1.5-2.0	2.0-2.4	2.4-3.0	
Horizon	Ap	A	BA	Btj	Ctj	
SiO_2 (%)	68.12	69.80	71.62	53.87	68.73	66.43
Al_2O_3 (%)	10.75	11.97	12.46	6.83	11.79	10.76
Fe_2O_3 (%)	3.84	4.07	4.44	3.11	4.49	3.99
K_2O (%)	2.03	1.98	2.02	1.50	1.96	1.90
CaO (%)	1.99	1.47	1.28	9.72	2.58	3.41
MgO (%)	1.34	1.32	1.40	6.72	2.28	2.61
Na_2O (%)	0.83	0.90	0.98	0.63	0.95	0.86
TiO_2 (%)	0.59	0.62	0.66	0.38	0.61	0.57
P_2O_5 (%)	0.22	0.15	0.12	0.08	0.13	0.14
MnO (%)	0.05	0.05	0.07	0.06	0.14	0.07
Barium	465	538	587	333	606	506
Chromium	633	218	181	149	297	296
Copper	31	22	23	18	28	24
Mercury (µg/kg)	80	72	54	43	56	61
Nickel	38	39	59	23	44	41
Lead	21	18	18	10	20	17
Rubidium	89	88	78	50	70	75
Strontium	134	137	149	108	147	135
Vanadium	88	96	100	68	99	90
Zinc	77	70	74	42	71	67
Zirconium	277	282	317	258	312	289
Total C (%)	4.04	2.79	1.39	4.49	1.38	2.82
Inorganic C (%)	0.20	0.12	0.14	4.24	0.74	1.09
Organic C (%)	3.84	2.67	1.25	0.25	0.64	1.73
pH	7.47	7.22	7.50	8.02	7.81	7.60

Table 31. Elemental composition of samples selected from Core 104

Subsample	104-1	104-2	104-3	104-4	104-6	104-8	Average
Lab. No.	R23195	R23196	R23197	R23198	R23199	R23200	
Depth Interval (ft)	0.0-0.9	0.9-1.5	1.5-2.0	2.0-2.5	3.0-3.5	4.0-4.8	
Horizon	Ap	AB	Bt	Bt	C	C	
SiO_2 (%)	70.85	71.30	68.28	68.09	61.27	54.14	65.66
Al_2O_3 (%)	10.85	12.81	15.80	15.69	11.78	11.03	12.99
Fe_2O_3 (%)	3.26	3.64	4.56	5.32	3.74	3.43	3.99
K_2O (%)	1.98	1.96	1.92	2.01	2.05	2.17	2.02
CaO (%)	1.88	1.17	1.12	1.17	5.33	8.80	3.25
MgO (%)	1.31	1.14	1.41	1.45	3.93	4.81	2.34
Na_2O (%)	1.00	0.99	0.88	0.99	1.00	0.79	0.94
TiO_2 (%)	0.67	0.71	0.71	0.69	0.56	0.47	0.64
P_2O_5 (%)	0.12	0.09	0.07	0.09	0.12	0.11	0.10
MnO (%)	0.08	0.09	0.07	0.09	0.08	0.08	0.08
Barium	664	597	625	547	494	438	561
Chromium	206	126	104	133	139	108	136
Copper	28	22	26	33	26	26	27
Mercury (µg/kg)	45	70	87	95	63	29	65
Nickel	27	29	39	67	36	30	38
Lead	23	22	22	21	20	18	21
Rubidium	90	92	90	83	71	79	84
Strontium	135	128	129	139	150	149	138
Vanadium	83	92	117	119	90	76	96
Zinc	84	68	80	80	67	66	74
Zirconium	368	358	331	343	326	221	325
Total C (%)	2.76	1.93	0.95	0.66	2.38	3.48	2.03
Inorganic C (%)	0.29	0.13	0.07	0.13	2.12	3.31	1.01
Organic C (%)	2.47	1.80	0.88	0.53	0.26	0.17	1.02
pH	7.78	7.40	7.42	7.35	7.97	7.40	7.55

Table 32. Elemental composition of samples selected from Core 105

Subsample	105-1	105-2	105-3	105-5	105-7	105-12	Average
Lab. No.	R23201	R23202	R23203	R23204	R23205	R23206	
Depth Interval (ft)	0.0-0.9	0.9-1.5	1.5-2.0	2.6-3.2	3.8-4.5	7.1-7.7	
Horizon	Ap	AB	Bt	Bt2	2C	2C	
SiO_2 (%)	72.31	69.73	68.24	70.76	52.72	49.95	62.28
Al_2O_3 (%)	12.37	14.32	16.01	14.60	13.29	13.11	14.27
Fe_2O_3 (%)	3.53	4.61	5.00	4.61	4.25	3.93	4.48
K_2O (%)	2.09	2.03	1.99	2.15	3.27	3.36	2.56
CaO (%)	0.87	0.90	0.92	1.03	7.31	8.37	3.71
MgO (%)	0.97	1.18	1.33	1.23	5.00	5.41	2.83
Na_2O (%)	0.97	0.80	0.84	1.11	0.49	0.44	0.74
TiO_2 (%)	0.69	0.66	0.65	0.66	0.50	0.48	0.59
P_2O_5 (%)	0.24	0.11	0.09	0.11	0.08	0.07	0.09
MnO (%)	0.14	0.11	0.10	0.12	0.06	0.06	0.09
Barium	574	574	604	613	446	318	511
Chromium	191	89	97	120	140	58	101
Copper	26	28	32	28	27	26	28
Mercury (µg/kg)	54	47	61	36	28	18	38
Nickel	28	36	43	40	40	38	39
Lead	31	22	20	21	20	19	20
Rubidium	92	90	82	77	120	122	98
Strontium	137	134	137	158	107	100	127
Vanadium	92	108	116	99	92	84	100
Zinc	96	77	78	69	76	78	76
Zirconium	419	380	348	409	146	126	282
Total C (%)	1.97	1.25	0.79	0.63	3.10	3.75	1.90
Inorganic C (%)	0.14	0.16	0.15	0.12	2.84	3.45	1.34
Organic C (%)	1.83	1.09	0.64	0.51	0.26	0.30	0.56
pH	5.13	5.62	5.76	6.81	8.29	8.39	6.97

Table 33. Elemental composition of samples selected from Core 106

Subsample	106-1	106-2	106-3	106-4	106-6	106-8	Average
Lab. No.	R23338	R23339	R23340	R23341	R23342	R23343	
Depth Interval (ft)	0.0-0.7	0.7-1.2	1.2-2.0	2.0-2.7	3.4-4.0	4.3-4.8	
Horizon	Ap	BA	Bt	Bt	B2tj	C	
SiO_2 (%)	71.80	71.06	71.23	72.43	75.78	60.10	70.40
Al_2O_3 (%)	11.67	12.93	12.80	12.48	10.56	8.17	11.44
Fe_2O_3 (%)	4.25	4.88	5.01	5.08	4.40	3.06	4.45
K_2O (%)	2.12	2.03	2.10	2.10	2.26	1.91	2.09
CaO (%)	1.09	0.95	0.97	1.01	1.22	7.36	2.10
MgO (%)	1.27	1.32	1.32	1.33	1.17	4.96	1.90
Na_2O (%)	0.91	0.90	1.48	1.07	1.23	1.00	1.10
TiO_2 (%)	0.72	0.73	0.71	0.70	0.70	0.53	0.68
P_2O_5 (%)	0.15	0.10	0.09	0.10	0.14	0.11	0.12
MnO (%)	0.12	0.11	0.09	0.11	0.10	0.08	0.10
Barium	768	672	668	576	554	406	607
Chromium	116	120	172	97	163	122	132
Copper	24	29	30	41	31	24	30
Mercury (µg/kg)	44	47	45	47	25	17	38
Nickel	33	33	40	32	42	32	35
Lead	31	22	21	18	19	17	21
Rubidium	90	86	80	66	72	60	76
Strontium	137	129	130	151	172	138	143
Vanadium	100	114	108	88	89	68	95
Zinc	89	82	80	77	72	59	77
Zirconium	411	377	381	397	521	381	411
Total C (%)	1.65	1.05	0.61	0.47	0.28	3.21	1.21
Inorganic C (%)	0.11	0.04	0.08	0.07	0.06	3.09	0.58
Organic C (%)	1.54	1.01	0.53	0.40	0.22	0.12	0.64
pH	7.11	6.76	6.76	6.51	7.14	8.36	7.11

Table 34. Elemental composition of samples selected from Core 107

Subsample	107-1	107-2	107-3	107-4	107-6	107-9	Average
Lab. No.	R23344	R23345	R23346	R23347	R23348	R23349	
Depth Interval (ft)	0.0-0.5	0.5-1.1	1.1-1.8	1.8-2.4	2.6-3.1	4.0-4.75	
Horizon	Ap	Bt1	Bt2	Bt3	2Ab	3BtA	
SiO_2 (%)	70.84	73.62	74.59	74.70	76.17	72.94	73.81
Al_2O_3 (%)	12.70	11.28	11.13	10.98	10.45	12.11	11.44
Fe_2O_3 (%)	4.74	4.99	4.61	4.52	4.03	5.50	4.73
K_2O (%)	2.13	2.22	2.23	2.46	2.20	1.96	2.20
CaO (%)	0.95	0.95	0.97	1.06	1.05	0.81	0.97
MgO (%)	1.25	1.26	1.20	1.21	1.12	1.28	1.22
Na_2O (%)	0.92	0.94	1.08	1.16	1.17	0.55	0.97
TiO_2 (%)	0.74	0.75	0.76	0.77	0.80	0.65	0.75
P_2O_5 (%)	0.15	0.10	0.09	0.10	0.09	0.06	0.10
MnO (%)	0.09	0.08	0.08	0.09	0.09	0.05	0.08
Barium	629	547	602	604	562	411	559
Chromium	146	162	93	86	79	132	116
Copper	33	33	29	30	28	30	31
Mercury (µg/kg)	42	39	35	33	22	39	35
Nickel	34	38	34	34	35	43	36
Lead	22	21	20	19	18	23	21
Rubidium	83	81	78	80	86	100	85
Strontium	128	154	173	185	175	115	155
Vanadium	106	104	99	94	94	103	100
Zinc	76	71	62	59	47	72	65
Zirconium	392	470	520	487	427	277	429
Total C (%)	1.42	0.56	0.45	0.50	0.47	0.40	0.63
Inorganic C (%)	0.11	0.07	0.08	0.06	0.10	0.09	0.09
Organic C (%)	1.31	0.49	0.37	0.44	0.37	0.31	0.55
pH	5.79	6.62	6.62	6.44	6.52	6.14	6.36

Table 35. Elemental composition of samples selected from Core 108

Subsample	108-1	108-2	108-3	108-5	108-7	108-10	Average
Lab. No.	R23350	R23351	R23352	R23353	R23354	R23355	
Depth Interval (ft)	0.0-0.8	0.8-1.3	1.3-2.0	2.7-3.4	4.0-4.6	6.0-6.6	
Horizon	Ap	A2	Bt	Bt	BCtj	C21	
SiO_2 (%)	69.69	69.84	69.75	72.19	74.78	64.27	70.09
Al_2O_3 (%)	10.55	11.64	12.63	12.43	11.42	9.07	11.29
Fe_2O_3 (%)	3.86	4.65	5.32	4.97	4.13	2.67	4.27
K_2O (%)	2.03	2.03	2.04	2.12	2.10	1.92	2.04
CaO (%)	1.30	1.13	1.09	1.12	1.23	6.32	2.03
MgO (%)	1.15	1.19	1.35	1.43	1.28	3.72	1.69
Na_2O (%)	0.90	0.90	0.85	1.01	1.20	1.04	0.98
TiO_2 (%)	0.66	0.69	0.70	0.70	0.71	0.60	0.68
P_2O_5 (%)	0.17	0.12	0.10	0.11	0.13	0.12	0.13
MnO (%)	0.12	0.15	0.11	0.10	0.13	0.04	0.11
Barium	606	674	695	651	647	434	618
Chromium	60	81	116	114	79	94	91
Copper	28	28	32	36	31	22	30
Mercury (µg/kg)	30	40	54	46	33	21	37
Nickel	26	29	31	40	46	21	32
Lead	24	23	23	22	20	17	22
Rubidium	122	113	100	84	72	69	93
Strontium	136	148	141	163	183	172	157
Vanadium	97	110	119	121	103	76	104
Zinc	92	84	84	94	79	60	82
Zirconium	362	369	357	383	463	416	392
Total C (%)	4.13	2.59	1.50	0.55	0.54	2.67	2.00
Inorganic C (%)	0.15	0.09	0.06	0.10	0.17	2.45	0.50
Organic C (%)	3.98	2.50	1.44	0.45	0.37	0.22	1.49
pH	5.84	5.68	5.76	5.92	7.10	8.50	6.47

Table 36. Elemental composition of samples selected from Core 109

Subsample	109-1	109-3	109-4	109-5	109-7	109-9	Average
Lab. No.	R23384	R23385	R23386	R23387	R23388	R23389	
Depth Interval (ft)	0.0-0.6	1.3-2.0	2.0-2.75	2.75-3.5	4.0-4.5	5.2-6.0	
Horizon	Ap	A11	A12	Btj	Bk	2C2	
SiO_2 (%)	74.67	74.97	75.34	75.79	76.17	68.79	74.29
Al_2O_3 (%)	9.70	8.71	8.72	10.20	8.73	8.45	9.09
Fe_2O_3 (%)	3.94	3.15	3.16	4.51	4.51	3.81	3.85
K_2O (%)	1.97	1.99	2.00	1.96	1.89	1.77	1.93
CaO (%)	1.28	1.34	1.29	0.97	1.33	5.23	1.91
MgO (%)	1.05	0.95	0.92	1.02	1.20	2.37	1.25
Na_2O (%)	0.93	1.02	1.00	0.84	0.78	0.76	0.89
TiO_2 (%)	0.72	0.71	0.71	0.70	0.60	0.51	0.66
P_2O_5 (%)	0.11	0.13	0.14	0.09	0.09	0.10	0.11
MnO (%)	0.09	0.17	0.16	0.07	0.08	0.07	0.11
Barium	497	646	694	570	457	513	563
Chromium	174	98	63	110	106	84	106
Copper	28	26	26	28	26	23	26
Mercury (µg/kg)	35	44	44	32	35	22	35
Nickel	33	31	31	30	31	30	31
Lead	19	28	29	21	20	17	22
Rubidium	82	86	86	80	76	71	80
Strontium	141	166	166	152	156	159	157
Vanadium	88	77	80	92	86	74	83
Zinc	64	112	102	67	64	63	79
Zirconium	478	517	542	446	370	261	436
Total C (%)	1.75	2.69	2.77	0.81	1.10	1.90	1.84
Inorganic C (%)	0.18	0.17	0.16	0.08	0.26	1.70	0.43
Organic C (%)	1.57	2.52	2.61	0.73	0.84	0.20	1.41
pH	7.20	7.26	7.40	7.25	7.57	8.20	7.48

Table 37. Elemental composition of samples selected from Core 110

Subsample	110-1	110-2	110-3	110-5	110-7	110-9	Average
Lab. No.	R23390	R23391	R23392	R23393	R23394	R23395	
Depth Interval (ft)	0.0-0.5	0.5-1.1	1.1-1.7	2.2-2.7	3.0-3.4	4.0-4.6	
Horizon	Ap	Btj	Bt	Bt	E	C	
SiO_2 (%)	82.22	80.18	79.50	83.38	87.58	88.80	83.61
Al_2O_3 (%)	6.99	8.23	8.72	7.10	5.50	5.06	6.93
Fe_2O_3 (%)	2.43	3.65	3.89	2.86	1.62	1.38	2.64
K_2O (%)	1.93	1.79	1.80	1.75	1.53	1.36	1.69
CaO (%)	0.97	0.87	0.90	0.91	0.87	0.90	0.90
MgO (%)	0.85	0.98	1.02	0.87	0.70	0.70	0.85
Na_2O (%)	0.88	0.74	0.76	0.89	1.00	0.93	0.87
TiO_2 (%)	0.42	0.43	0.42	0.25	0.20	0.17	0.32
P_2O_5 (%)	0.07	0.08	0.09	0.07	0.06	0.05	0.07
MnO (%)	0.07	0.07	0.08	0.05	0.03	0.03	0.06
Barium	471	493	432	493	344	392	438
Chromium	219	228	142	441	583	326	323
Copper	18	26	28	21	16	16	21
Mercury (µg/kg)	28	22	29	26	13	12	22
Nickel	28	37	36	42	27	20	32
Lead	17	14	16	11	8	6	12
Rubidium	62	67	66	59	44	38	56
Strontium	163	145	155	184	157	167	162
Vanadium	61	87	88	69	38	23	61
Zinc	34	47	48	38	19	13	33
Zirconium	337	261	233	135	108	108	197
Total C (%)	1.15	0.60	0.46	0.28	0.18	0.21	0.48
Inorganic C (%)	0.15	0.06	0.07	0.06	0.06	0.06	0.08
Organic C (%)	1.00	0.54	0.39	0.22	0.12	0.15	0.40
pH	7.16	7.00	6.97	6.72	6.43	5.46	6.62

Table 38. Elemental composition of samples selected from Core 111

Subsample	111-1	111-2	111-3	111-4	111-5	111-6	Average
Lab. No.	R23396	R23397	R23398	R23399	R23400	R23401	
Depth Interval (ft)	0.0-0.9	0.9-1.4	1.4-2.0	2.0-2.65	2.65-3.3	3.3-3.7	
Horizon	Ap	A12	A13	BA	AB	C1	
SiO_2 (%)	78.54	79.88	79.92	78.32	81.39	83.81	80.31
Al_2O_3 (%)	7.92	7.68	8.39	8.13	6.78	3.96	7.14
Fe_2O_3 (%)	3.00	3.49	3.16	5.13	2.35	1.13	3.04
K_2O (%)	1.62	1.59	1.66	1.69	1.53	1.16	1.54
CaO (%)	1.26	1.18	1.28	1.27	1.77	2.78	1.59
MgO (%)	0.94	0.93	0.99	1.05	1.31	1.92	1.19
Na_2O (%)	0.84	0.83	0.88	0.92	0.80	0.52	0.80
TiO_2 (%)	0.42	0.41	0.45	0.45	0.33	0.12	0.36
P_2O_5 (%)	0.13	0.11	0.11	0.13	0.09	0.05	0.10
MnO (%)	0.03	0.02	0.02	0.03	0.02	0.02	0.02
Barium	508	438	482	452	401	291	429
Chromium	147	152	72	220	461	299	225
Copper	29	25	22	19	22	16	22
Mercury (µg/kg)	34	30	29	38	25	8	27
Nickel	23	22	19	22	28	33	25
Lead	17	13	13	13	11	7	12
Rubidium	61	60	58	60	56	37	55
Strontium	151	143	154	164	143	103	143
Vanadium	71	72	69	69	56	22	60
Zinc	52	48	43	47	37	13	40
Zirconium	245	238	260	279	210	66	216
Total C (%)	2.24	1.40	1.02	0.77	1.27	1.40	1.35
Inorganic C (%)	0.12	0.16	0.09	0.08	0.42	1.14	0.34
Organic C (%)	2.12	1.24	0.93	0.69	0.85	0.26	1.02
pH	6.26	6.97	7.34	7.80	7.90	8.14	7.40

Table 39. Elemental composition of samples selected from Core 112

Subsample	112-1	112-3	112-4	112-6	112-8	112-10	Average
Lab. No.	R23402	R23403	R23404	R23405	R23406	R23407	
Depth Interval (ft)	0.0-0.9	1.1-1.8	1.8-2.4	2.9-3.3	4.0-4.6	4.9-5.5	
Horizon	Ap1	Btj	Btj	Btj	BCtj	C	
SiO_2 (%)	75.45	72.72	73.24	74.38	76.14	75.97	74.65
Al_2O_3 (%)	9.15	12.76	12.01	11.74	11.03	11.11	11.30
Fe_2O_3 (%)	2.93	4.09	4.60	4.20	3.68	3.74	3.87
K_2O (%)	2.08	2.08	2.02	1.97	1.99	2.01	2.03
CaO (%)	1.46	1.00	1.11	1.35	1.40	1.41	1.29
MgO (%)	1.14	1.17	1.26	1.19	1.11	1.14	1.17
Na_2O (%)	1.15	1.15	1.22	1.48	1.50	1.50	1.33
TiO_2 (%)	0.69	0.72	0.67	0.62	0.61	0.59	0.65
P_2O_5 (%)	0.19	0.09	0.09	0.14	0.15	0.15	0.14
MnO (%)	0.14	0.10	0.10	0.10	0.12	0.10	0.11
Barium	754	748	812	779	743	668	751
Chromium	79	139	76	129	66	90	97
Copper	22	26	27	27	22	20	24
Mercury (µg/kg)	30	34	42	38	32	29	34
Nickel	21	27	27	31	36	32	29
Lead	22	20	18	18	17	16	19
Rubidium	86	83	73	67	63	66	73
Strontium	158	158	179	219	219	210	191
Vanadium	78	103	106	99	81	83	92
Zinc	71	61	64	60	50	54	60
Zirconium	512	446	453	485	543	486	488
Total C (%)	2.10	1.11	0.66	0.62	0.37	0.49	0.89
Inorganic C (%)	0.23	0.10	0.12	0.09	0.06	0.10	0.12
Organic C (%)	1.87	1.01	0.54	0.53	0.31	0.39	0.78
pH	7.00	6.86	6.58	6.38	6.60	6.94	6.73

Table 40. Elemental composition of samples selected from Core 113

Subsample	113-1	113-2	113-3	113-4	113-5	113-6	Average
Lab. No.	R23408	R23409	R23410	R23411	R23412	R23413	
Depth Interval (ft)	0.0-0.6	0.6-1.2	1.2-1.8	1.8-2.4	2.4-3.1	4.5-5.2	
Horizon	Ap	Btj	Bt	Bt	BCtj	C	
SiO_2 (%)	72.10	70.11	71.20	71.20	60.00	54.68	66.55
Al_2O_3 (%)	11.86	13.88	13.39	12.25	9.73	8.39	11.58
Fe_2O_3 (%)	3.88	5.08	4.93	4.40	3.29	3.05	4.11
K_2O (%)	1.98	1.89	1.96	2.09	1.87	1.82	1.94
CaO (%)	1.15	1.21	1.27	1.96	7.02	9.57	3.70
MgO (%)	1.15	1.40	1.35	1.68	4.27	5.37	2.54
Na_2O (%)	1.09	1.05	1.20	1.23	1.09	0.96	1.10
TiO_2 (%)	0.71	0.68	0.67	0.65	0.53	0.42	0.61
P_2O_5 (%)	0.11	0.08	0.08	0.13	0.13	0.11	0.11
MnO (%)	0.09	0.08	0.08	0.12	0.10	0.08	0.09
Barium	767	748	713	750	599	452	672
Chromium	79	197	146	102	84	37	108
Copper	23	31	28	28	27	23	27
Mercury (µg/kg)	41	61	46	40	22	15	38
Nickel	27	33	41	46	29	18	32
Lead	24	20	18	21	16	14	19
Rubidium	86	78	72	70	61	57	71
Strontium	146	148	176	176	165	153	161
Vanadium	99	117	108	94	73	59	92
Zinc	87	78	72	68	59	58	70
Zirconium	429	378	417	445	356	290	386
Total C (%)	1.97	0.94	0.66	0.93	3.09	4.10	1.95
Inorganic C (%)	0.15	0.10	0.13	0.43	2.75	3.85	1.24
Organic C (%)	1.82	0.84	0.53	0.50	0.34	0.25	0.71
pH	5.67	5.82	6.15	7.07	8.22	8.29	6.87

Table 41. Elemental composition of samples selected from Core 114

Subsample	114-1	114-2	114-3	114-4	114-5	114-6	Average
Lab. No.	R23414	R23415	R23416	R23417	R23418	R23419	
Depth Interval (ft)	0.0-0.6	0.6-1.4	1.4-2.0	2.0-2.6	2.6-3.2	3.2-4.0	
Horizon	Ap	A2	Bt	Bt	Btj	Ctj	
SiO_2 (%)	70.55	70.29	68.69	69.58	69.88	60.71	68.28
Al_2O_3 (%)	11.28	13.37	14.92	14.78	13.97	11.78	13.35
Fe_2O_3 (%)	3.27	4.30	5.19	4.82	4.44	3.59	4.27
K_2O (%)	2.10	2.09	2.19	2.34	2.43	2.21	2.23
CaO (%)	1.43	1.10	1.07	1.16	1.59	5.56	1.99
MgO (%)	1.17	1.22	1.37	1.38	1.62	3.88	1.77
Na_2O (%)	0.99	0.96	0.97	1.13	1.18	1.07	1.05
TiO_2 (%)	0.66	0.67	0.66	0.66	0.65	0.55	0.64
P_2O_5 (%)	0.34	0.20	0.14	0.16	0.18	0.16	0.20
MnO (%)	0.10	0.07	0.12	0.14	0.14	0.09	0.11
Barium	664	674	763	722	710	484	670
Chromium	89	58	86	126	78	119	93
Copper	30	29	32	30	30	26	30
Mercury (µg/kg)	58	46	59	53	37	24	46
Nickel	23	20	36	53	44	29	34
Lead	46	23	21	22	21	19	25
Rubidium	99	76	81	78	74	68	79
Strontium	142	126	145	156	157	141	145
Vanadium	86	90	117	112	101	81	98
Zinc	161	90	88	83	74	64	93
Zirconium	381	386	381	386	369	334	373
Total C (%)	3.25	1.65	0.98	0.59	0.66	2.62	1.63
Inorganic C (%)	0.22	0.14	0.09	0.13	0.30	2.07	0.49
Organic C (%)	3.03	1.51	0.89	0.46	0.36	0.55	1.13
pH	6.60	6.72	7.22	7.41	7.76	8.42	7.36

Table 42. Elemental composition of samples selected from Core 115

Subsample	115-1	115-2	115-3	115-5	115-7	115-9	Average
Lab. No.	R23437	R23438	R23439	R23440	R23441	R23442	
Depth Interval (ft)	0.0-1.1	1.1-1.8	1.8-2.3	2.8-3.5	4.0-4.5	5.0-5.6	
Horizon	Ap	AB	BAg	Cg	Cg	Cg	
SiO_2 (%)	65.60	68.09	65.97	58.74	59.98	61.47	63.31
Al_2O_3 (%)	9.66	10.07	9.81	9.34	8.59	7.07	9.09
Fe_2O_3 (%)	3.18	3.26	4.91	7.78	3.13	3.55	4.30
K_2O (%)	1.97	1.93	1.87	1.91	1.97	1.87	1.92
CaO (%)	2.94	3.82	5.15	6.77	8.24	7.63	5.76
MgO (%)	1.82	2.08	1.98	2.87	4.38	4.41	2.92
Na_2O (%)	1.01	1.07	1.05	0.98	1.01	0.95	1.01
TiO_2 (%)	0.56	0.59	0.58	0.52	0.50	0.40	0.53
P_2O_5 (%)	0.36	0.24	0.21	0.20	0.14	0.14	0.22
MnO (%)	0.03	0.04	0.05	0.09	0.08	0.05	0.06
Barium	634	625	587	568	536	398	558
Chromium	1311	164	71	116	77	136	113
Copper	43	32	26	15	22	18	23
Mercury (µg/kg)	62	46	47	33	22	16	38
Nickel	47	28	27	38	26	21	28
Lead	33	20	18	18	14	14	17
Rubidium	71	71	66	68	67	57	66
Strontium	165	181	165	162	178	159	168
Vanadium	83	84	88	88	76	56	79
Zinc	110	68	71	72	53	47	70
Zirconium	356	398	358	280	330	318	340
Total C (%)	5.31	2.88	2.17	2.51	3.20	3.26	3.22
Inorganic C (%)	0.57	0.97	1.27	2.22	3.14	3.09	1.88
Organic C (%)	4.74	1.91	0.90	0.29	0.06	0.17	1.35
pH	7.56	8.03	8.06	8.13	8.32	8.26	8.06

Table 43. Elemental composition of samples selected from Core 116

Subsample	116-1	116-3	116-4	116-5	116-6	116-9	Average
Lab. No.	R23443	R23444	R23445	R23446	R23447	R23448	
Depth Interval (ft)	0.0-0.8	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.6-4.4	
Horizon	Ap	Btj	Btj	Btj	BC	C	
SiO_2 (%)	82.57	82.03	81.70	85.72	89.48	92.61	85.69
Al_2O_3 (%)	6.83	7.84	8.21	6.36	4.85	3.49	6.26
Fe_2O_3 (%)	2.18	2.57	2.84	2.23	1.43	0.83	2.01
K_2O (%)	1.50	1.48	1.44	1.19	1.02	0.81	1.24
CaO (%)	0.88	0.76	0.76	0.67	0.61	0.56	0.71
MgO (%)	0.85	0.89	0.96	0.84	0.69	0.60	0.81
Na_2O (%)	0.61	0.59	0.59	0.48	0.39	0.30	0.49
TiO_2 (%)	0.45	0.47	0.46	0.32	0.22	0.13	0.34
P_2O_5 (%)	0.12	0.09	0.10	0.09	0.07	0.05	0.09
MnO (%)	0.08	0.08	0.07	0.06	0.04	0.02	0.06
Barium	489	484	428	380	240	212	372
Chromium	118	52	122	174	68	158	115
Copper	17	21	23	19	17	16	19
Mercury (µg/kg)	22	24	30	26	19	71	32
Nickel	21	23	27	27	34	28	27
Lead	18	13	14	11	8	4	11
Rubidium	58	59	57	44	34	23	46
Strontium	113	104	114	95	86	77	98
Vanadium	56	68	73	56	41	17	52
Zinc	47	42	40	30	18	11	31
Zirconium	310	303	257	190	115	58	206
Total C (%)	1.30	0.90	0.70	0.43	0.24	0.30	0.65
Inorganic C (%)	0.29	0.11	0.10	0.07	0.07	0.06	0.12
Organic C (%)	1.01	0.79	0.60	0.36	0.17	0.24	0.53
pH	7.25	7.32	7.48	7.42	7.48	7.20	7.36

Table 44. Elemental composition of samples selected from Core 117

Subsample	117-1	117-2	117-3	117-5	117-6	117-8	Average
Lab. No.	R23449	R23450	R23451	R23452	R23453	R23454	
Depth Interval (ft)	0.0-0.6	0.6-1.4	1.4-2.0	2.8-3.5	3.5-4.1	5.4-5.6	
Horizon	Ap	A2	Ab	Ab	Ab	AB	
SiO_2 (%)	74.77	78.02	77.64	80.82	81.99	82.86	79.35
Al_2O_3 (%)	9.39	8.32	7.84	7.79	7.62	7.55	8.09
Fe_2O_3 (%)	3.18	2.68	2.50	2.36	2.27	2.28	2.55
K_2O (%)	1.90	1.78	1.68	1.68	1.68	1.69	1.74
CaO (%)	1.47	1.70	1.61	1.33	1.27	1.28	1.44
MgO (%)	1.14	1.16	1.00	0.86	0.85	0.85	0.98
Na_2O (%)	1.11	1.16	1.19	1.23	1.22	1.26	1.20
TiO_2 (%)	0.55	0.51	0.50	0.47	0.45	0.44	0.49
P_2O_5 (%)	0.18	0.14	0.17	0.15	0.12	0.11	0.15
MnO (%)	0.08	0.08	0.07	0.05	0.07	0.06	0.07
Barium	544	584	515	509	485	449	514
Chromium	94	122	80	81	139	97	102
Copper	24	19	14	16	18	16	18
Mercury (µg/kg)	47	34	32	13	13	11	25
Nickel	26	22	20	33	22	22	24
Lead	20	16	16	11	11	10	14
Rubidium	74	62	58	56	52	52	59
Strontium	166	179	184	189	190	201	185
Vanadium	70	62	49	48	50	48	55
Zinc	69	52	44	37	33	30	44
Zirconium	350	406	460	462	390	402	412
Total C (%)	2.36	1.58	2.42	1.32	0.90	0.57	1.53
Inorganic C (%)	0.15	0.26	0.15	0.08	0.08	0.07	0.13
Organic C (%)	2.21	1.32	2.27	1.24	0.82	0.50	1.39
pH	7.06	7.42	7.31	7.30	7.28	7.34	7.29

Table 45. Elemental composition of samples selected from Core 118

Subsample	118-1	118-2	118-3	118-5	118-8	118-11	Average
Lab. No.	R23455	R23456	R23457	R23458	R23459	R23460	
Depth Interval (ft)	0.0-0.9	0.9-1.5	1.5-2.0	2.6-3.3	4.5-5.1	6.6-7.5	
Horizon	Ap	Btj	Btj	Bt	Bt	Ctj	
SiO_2 (%)	75.68	75.00	73.73	73.07	71.66	75.13	74.05
Al_2O_3 (%)	8.96	11.53	12.16	12.51	14.02	11.59	11.80
Fe_2O_3 (%)	2.70	3.79	4.35	4.60	4.42	3.97	3.97
K_2O (%)	2.11	2.20	2.14	2.05	2.13	2.30	2.16
CaO (%)	1.73	1.02	1.02	1.18	1.16	1.31	1.24
MgO (%)	1.33	1.11	1.23	1.27	1.28	1.16	1.23
Na_2O (%)	1.21	1.16	1.16	1.29	1.30	1.41	1.26
TiO_2 (%)	0.71	0.74	0.73	0.66	0.65	0.72	0.70
P_2O_5 (%)	0.16	0.11	0.10	0.12	0.15	0.13	0.13
MnO (%)	0.18	0.12	0.08	0.07	0.12	0.09	0.11
Barium	695	687	763	741	821	610	720
Chromium	56	82	79	102	103	68	82
Copper	20	22	24	27	29	27	25
Mercury (µg/kg)	26	23	39	48	42	30	35
Nickel	29	32	28	29	38	36	32
Lead	21	18	18	18	19	17	19
Rubidium	82	91	84	74	79	76	81
Strontium	169	153	160	188	194	188	175
Vanadium	70	96	100	104	102	87	93
Zinc	68	66	68	67	72	68	68
Zirconium	545	439	452	479	436	497	475
Total C (%)	1.64	0.51	0.37	0.29	0.24	0.31	0.56
Inorganic C (%)	0.42	0.11	0.09	0.07	0.10	0.11	0.15
Organic C (%)	1.22	0.40	0.28	0.22	0.14	0.20	0.41
pH	6.86	7.02	7.32	7.06	5.84	5.96	6.68

Table 46. Elemental composition of samples selected from Core 119

Subsample	119-1	119-2	119-3	119-5	119-6	119-11	Average
Lab. No.	R23461	R23462	R23463	R23464	R23465	R23466	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.2-2.8	2.8-3.4	5.3-6.1	
Horizon	Ap	Ap	BA	Bt	Bt	2Cr	
SiO_2 (%)	74.65	74.69	72.43	70.87	71.89	45.68	68.37
Al_2O_3 (%)	10.34	11.28	12.88	14.29	14.06	18.95	13.63
Fe_2O_3 (%)	2.64	2.96	3.97	4.41	3.79	5.03	3.80
K_2O (%)	1.93	1.96	2.00	2.06	2.32	4.82	2.52
CaO (%)	1.45	1.18	1.16	1.28	1.29	6.17	2.09
MgO (%)	1.14	1.00	1.16	1.33	1.32	5.12	1.85
Na_2O (%)	1.20	1.21	1.20	1.17	1.22	0.22	1.04
TiO_2 (%)	0.68	0.71	0.71	0.73	0.74	0.60	0.70
P_2O_5 (%)	0.11	0.10	0.08	0.10	0.12	0.16	0.11
MnO (%)	0.15	0.18	0.15	0.08	0.06	0.06	0.11
Barium	635	866	791	734	773	621	737
Chromium	60	54	110	94	89	56	77
Copper	18	21	19	21	20	14	19
Mercury (µg/kg)	33	37	38	35	31	12	31
Nickel	21	27	36	37	36	26	31
Lead	32	26	24	19	19	2	20
Rubidium	71	76	80	77	83	176	94
Strontium	163	173	164	165	175	117	160
Vanadium	70	78	96	102	92	101	90
Zinc	69	51	58	66	62	61	61
Zirconium	562	510	500	496	414	101	431
Total C (%)	2.24	1.62	0.99	0.59	0.40	2.89	1.46
Inorganic C (%)	0.26	0.11	0.10	0.07	0.07	2.62	0.54
Organic C (%)	1.98	1.51	0.89	0.52	0.33	0.27	0.92
pH	6.88	6.76	6.98	7.28	7.48	8.32	7.28

Table 47. Elemental composition of samples selected from Core 120

Subsample	120-1	120-2	120-4	120-5	120-8	120-15	Average
Lab. No.	R23467	R23468	R23469	R23470	R23471	R23472	
Depth Interval (ft)	0.0-0.45	0.45-0.9	1.4-2.0	2.0-2.5	3.0-3.6	4.6-5.2	
Horizon	Ap	Bt	Bt	Btg	C	2Ab	
SiO_2 (%)	68.36	68.98	68.77	68.09	69.95	69.36	68.92
Al_2O_3 (%)	13.07	14.70	16.08	16.33	15.43	15.80	15.24
Fe_2O_3 (%)	3.57	3.98	4.75	4.87	4.35	4.39	4.32
K_2O (%)	2.16	2.12	2.11	2.14	2.65	2.50	2.28
CaO (%)	1.99	1.39	0.99	1.07	1.18	1.08	1.28
MgO (%)	1.73	1.51	1.44	1.47	1.34	1.30	1.47
Na_2O (%)	0.98	0.96	1.02	1.11	1.16	0.94	1.03
TiO_2 (%)	0.67	0.68	0.67	0.68	0.74	0.82	0.71
P_2O_5 (%)	0.22	0.13	0.12	0.14	0.15	0.12	0.15
MnO (%)	0.13	0.12	0.07	0.13	0.08	0.04	0.10
Barium	710	666	686	706	680	799	708
Chromium	57	91	90	99	94	71	84
Copper	21	22	27	27	25	20	24
Mercury (µg/kg)	40	46	51	52	27	39	43
Nickel	26	26	30	37	39	28	31
Lead	23	20	19	20	20	17	20
Rubidium	98	94	79	80	88	107	91
Strontium	142	138	153	163	175	144	153
Vanadium	92	101	114	119	94	106	104
Zinc	79	73	77	78	60	52	70
Zirconium	390	400	370	362	395	368	381
Total C (%)	2.00	1.20	0.48	0.56	0.45	0.51	0.87
Inorganic C (%)	0.58	0.28	0.07	0.06	0.08	0.09	0.19
Organic C (%)	1.42	0.92	0.41	0.50	0.37	0.42	0.67
pH	7.51	7.22	6.72	6.74	6.98	6.83	7.00

Table 48. Elemental composition of samples selected from Core 121

Subsample	121-1	121-2	121-3	121-5	121-8	121-10	Average
Lab. No.	R23498	R23499	R23500	R23501	R23502	R23503	
Depth Interval (ft)	0.0-0.8	0.8-1.3	1.3-2.0	2.7-3.4	4.3-4.8	5.5-6.2	
Horizon	Ap	C	2A1	3Ab	3BA	3CB	
SiO_2 (%)	71.40	77.09	74.60	72.18	71.13	71.62	73.00
Al_2O_3 (%)	9.63	9.52	10.42	10.81	13.00	13.13	11.09
Fe_2O_3 (%)	3.37	3.11	3.50	3.72	4.80	4.82	3.89
K_2O (%)	1.99	1.99	2.04	2.01	2.04	2.12	2.03
CaO (%)	1.97	0.97	0.98	1.01	0.95	1.08	1.16
MgO (%)	1.66	0.99	1.05	1.07	1.36	1.38	1.25
Na_2O (%)	0.87	0.97	0.91	0.87	0.93	1.08	0.94
TiO_2 (%)	0.68	0.70	0.71	0.70	0.72	0.71	0.70
P_2O_5 (%)	0.25	0.09	0.11	0.15	0.10	0.12	0.14
MnO (%)	0.13	0.11	0.14	0.14	0.13	0.13	0.13
Barium	728	774	820	911	844	860	823
Chromium	68	59	100	76	97	77	80
Copper	23	14	17	18	23	24	20
Mercury (µg/kg)	29	28	28	34	41	38	33
Nickel	20	22	27	27	33	39	28
Lead	22	19	19	20	21	19	20
Rubidium	70	74	82	90	82	76	79
Strontium	136	149	138	144	139	163	145
Vanadium	76	74	86	88	104	106	89
Zinc	94	54	60	70	72	73	71
Zirconium	509	569	488	451	427	438	480
Total C (%)	2.65	1.43	1.78	2.49	0.93	0.40	1.61
Inorganic C (%)	0.52	0.08	0.09	0.08	0.08	0.08	0.16
Organic C (%)	2.13	1.35	1.69	2.41	0.85	0.32	1.46
pH	6.99	6.89	6.74	6.52	6.13	6.70	6.66

Table 49. Elemental composition of samples selected from Core 122

Subsample	122-1	122-2	122-3	122-5	122-8	122-9	Average
Lab. No.	R23504	R23505	R23506	R23507	R23508	R23509	
Depth Interval (ft)	0.0-0.8	0.8-1.3	1.3-2.0	2.8-3.4	5.0-5.8	5.8-6.7	
Horizon	Ap	AB	Btj	Btj	Bt	C	
SiO_2 (%)	58.61	68.98	71.08	70.54	71.98	63.19	67.40
Al_2O_3 (%)	9.89	12.44	12.90	14.01	13.25	11.02	12.25
Fe_2O_3 (%)	6.10	5.04	4.18	4.80	4.44	3.49	4.68
K_2O (%)	1.90	2.12	2.17	2.17	2.24	2.19	2.13
CaO (%)	2.91	1.22	1.09	1.11	1.39	5.00	2.12
MgO (%)	2.03	1.21	1.18	1.36	1.36	3.73	1.81
Na_2O (%)	0.76	0.97	1.01	1.07	1.33	1.15	1.05
TiO_2 (%)	0.58	0.69	0.72	0.68	0.69	0.62	0.66
P_2O_5 (%)	0.28	0.18	0.14	0.11	0.17	0.12	0.17
MnO (%)	0.11	0.14	0.15	0.13	0.10	0.10	0.12
Barium	761	890	863	801	868	622	801
Chromium	61	71	121	138	88	60	90
Copper	37	29	21	24	23	19	26
Mercury (µg/kg)	471	248	56	48	32	29	147
Nickel	30	29	30	32	41	26	31
Lead	308	110	26	21	18	16	83
Rubidium	88	98	101	79	72	68	84
Strontium	147	148	154	166	196	160	162
Vanadium	82	99	99	107	99	73	93
Zinc	348	519	83	99	73	48	195
Zirconium	303	389	400	423	429	346	382
Total C (%)	7.46	2.70	1.53	0.55	0.34	2.25	2.47
Inorganic C (%)	0.93	0.10	0.06	0.09	0.11	2.01	0.55
Organic C (%)	6.53	2.60	1.47	0.46	0.23	0.24	1.92
pH	6.94	7.04	7.13	6.40	7.20	7.92	7.11

Table 50. Elemental composition of samples selected from Core 123

Subsample	123-1	123-2	123-3	123-4	123-7	123-8	Average
Lab. No.	R23510	R23511	R23512	R23513	R23514	R23515	
Depth Interval (ft)	0.0-0.8	0.8-1.3	1.3-1.8	1.8-2.5	3.1-3.7	3.7-4.2	
Horizon	Ap	AB	Btj	E’	2Bg	3AB	
SiO_2 (%)	71.28	69.66	69.91	71.10	67.71	70.50	70.03
Al_2O_3 (%)	11.78	14.32	14.55	15.05	18.16	15.99	14.98
Fe_2O_3 (%)	3.27	4.55	4.69	3.28	2.87	3.16	3.64
K_2O (%)	2.08	2.02	2.05	2.31	2.25	2.30	2.17
CaO (%)	1.51	1.00	0.97	1.04	0.97	0.96	1.08
MgO (%)	1.32	1.31	1.30	1.11	1.38	1.40	1.30
Na_2O (%)	0.93	0.87	0.93	1.18	0.80	0.58	0.88
TiO_2 (%)	0.69	0.71	0.71	0.79	0.75	0.73	0.73
P_2O_5 (%)	0.29	0.13	0.09	0.06	0.05	0.05	0.11
MnO (%)	0.11	0.10	0.10	0.06	0.02	0.02	0.07
Barium	748	834	803	822	653	609	745
Chromium	71	83	67	69	71	86	75
Copper	23	26	30	29	32	34	29
Mercury (µg/kg)	41	42	45	98	85	43	59
Nickel	23	36	29	48	31	37	34
Lead	26	21	19	20	22	21	22
Rubidium	81	79	63	70	99	107	83
Strontium	143	144	135	155	136	118	139
Vanadium	82	107	99	108	104	91	99
Zinc	93	70	60	30	76	91	70
Zirconium	463	422	415	402	281	263	374
Total C (%)	2.10	1.06	0.72	0.60	0.72	0.69	0.98
Inorganic C (%)	0.33	0.08	0.10	0.07	0.06	0.08	0.12
Organic C (%)	1.77	0.98	0.62	0.53	0.66	0.61	0.86
pH	7.08	6.86	6.82	6.74	6.40	6.44	6.72

Table 51. Elemental composition of samples selected from Core 124

Subsample	124-1	124-2	124-3	124-4	124-5	124-7	Average
Lab. No.	R23516	R23517	R23518	R23519	R23520	R23521	
Depth Interval (ft)	0.0-0.6	0.6-0.9	0.9-1.5	1.5-2.0	2.0-2.6	3.3-4.0	
Horizon	Ap	Btj	C	C	C	C	
SiO_2 (%)	81.32	81.26	67.52	61.79	60.52	60.52	68.82
Al_2O_3 (%)	7.16	7.65	6.20	5.77	5.72	5.66	6.36
Fe_2O_3 (%)	2.76	2.86	2.04	1.81	1.66	1.66	2.13
K_2O (%)	2.01	2.20	1.92	1.78	1.80	1.79	1.92
CaO (%)	1.01	1.08	5.98	8.53	9.26	9.35	5.87
MgO (%)	1.02	1.15	4.35	5.14	5.21	5.25	3.69
Na_2O (%)	0.60	0.68	0.60	0.56	0.56	0.57	0.60
TiO_2 (%)	0.38	0.36	0.28	0.25	0.24	0.24	0.29
P_2O_5 (%)	0.11	0.07	0.07	0.07	0.06	0.06	0.07
MnO (%)	0.06	0.06	0.04	0.04	0.04	0.03	0.05
Barium	396	529	388	353	361	310	390
Chromium	183	340	59	40	47	58	121
Copper	21	20	17	13	14	11	16
Mercury (µg/kg)							0
Nickel	24	27	18	12	12	11	17
Lead	16	12	11	8	9	8	11
Rubidium	61	66	56	51	50	50	56
Strontium	113	113	115	112	120	120	116
Vanadium	54	56	39	30	28	28	39
Zinc	46	41	31	26	26	24	32
Zirconium	207	180	141	120	120	103	145
Total C (%)	1.17	0.64	2.90	3.85	4.01	3.97	2.76
Inorganic C (%)	0.17	0.17	2.64	3.61	3.85	3.91	2.39
Organic C (%)	1.00	0.47	0.26	0.24	0.16	0.06	0.37
pH	7.10	7.60	8.14	8.38	8.50	8.54	8.04

Table 52. Elemental composition of samples selected from Core 125

Subsample	125-1	125-2	125-3	125-4	125-6	125-10	Average
Lab. No.	R23522	R23523	R23524	R23525	R23526	R23527	
Depth Interval (ft)	0.0-0.9	0.9-1.3	1.3-2.0	2.0-2.6	3.3-3.6	6.0-7.0	
Horizon	Ap1	Ap2	Bg	Bg	BCg	3C	
SiO_2 (%)	78.76	74.53	75.18	71.56	85.24	57.39	73.78
Al_2O_3 (%)	9.92	9.52	11.00	12.14	6.89	6.94	9.40
Fe_2O_3 (%)	3.16	3.26	4.09	5.67	1.75	3.16	3.52
K_2O (%)	2.22	1.99	2.18	2.10	1.66	2.26	2.07
CaO (%)	1.18	1.25	1.07	1.24	0.91	8.42	2.35
MgO (%)	1.09	1.08	1.22	1.48	0.90	5.34	1.85
Na_2O (%)	1.01	0.93	1.00	0.93	0.63	0.52	0.84
TiO_2 (%)	0.70	0.65	0.73	0.69	0.34	0.34	0.58
P_2O_5 (%)	0.16	0.14	0.07	0.10	0.06	0.08	0.10
MnO (%)	0.16	0.13	0.07	0.28	0.02	0.04	0.12
Barium	719	648	719	904	428	336	626
Chromium	80	91	88	268	269	73	145
Copper	21	21	18	26	16	14	19
Mercury (µg/kg)							0
Nickel	31	32	38	38	39	20	33
Lead	23	20	20	19	12	13	18
Rubidium	84	78	80	79	52	70	74
Strontium	165	157	163	162	125	112	147
Vanadium	73	82	96	111	53	50	78
Zinc	71	72	59	77	30	50	60
Zirconium	418	380	460	409	260	138	344
Total C (%)	2.64	2.50	0.61	0.43	0.27	4.13	1.76
Inorganic C (%)	0.11	0.08	0.11	0.06	0.05	3.69	0.68
Organic C (%)	2.53	2.42	0.50	0.37	0.22	0.44	1.08
pH	5.47	5.96	6.50	6.97	7.68	8.28	6.81

Table 53. Elemental composition of samples selected from Core 126

Subsample	126-1	126-2	126-3	126-5	126-7	126-11	Average
Lab. No.	R23528	R23529	R23530	R23531	R23532	R23533	
Depth Interval (ft)	0.0-1.0	1.0-1.5	1.5-2.0	2.6-3.2	4.0-4.7	6.0-6.6	
Horizon	Ap	A2	AB	Bg	Bg	2C	
SiO_2 (%)	70.31	68.94	70.25	69.54	72.23	58.75	68.34
Al_2O_3 (%)	10.67	12.03	12.78	12.51	12.44	7.71	11.36
Fe_2O_3 (%)	3.67	4.16	4.87	6.26	4.49	2.75	4.37
K_2O (%)	2.04	1.93	1.96	2.12	2.25	2.43	2.12
CaO (%)	1.28	1.53	1.39	1.42	1.44	8.01	2.51
MgO (%)	1.20	1.38	1.47	1.56	1.52	5.24	2.06
Na_2O (%)	0.86	0.88	0.93	0.96	1.08	0.64	0.89
TiO_2 (%)	0.69	0.69	0.70	0.69	0.68	0.35	0.63
P_2O_5 (%)	0.21	0.16	0.14	0.14	0.17	0.10	0.15
MnO (%)	0.10	0.03	0.05	0.37	0.18	0.07	0.13
Barium	686	771	733	936	832	420	730
Chromium	77	81	78	290	279	60	144
Copper	25	28	31	32	27	17	27
Mercury (µg/kg)							0
Nickel	28	33	37	66	38	21	37
Lead	24	21	22	21	20	10	20
Rubidium	100	92	84	80	80	71	85
Strontium	144	154	150	162	190	131	155
Vanadium	90	103	117	128	110	51	100
Zinc	100	108	98	97	87	39	88
Zirconium	352	354	348	363	400	175	214
Total C (%)	3.48	2.87	1.19	0.49	0.39	3.66	2.01
Inorganic C (%)	0.15	0.13	0.06	0.05	0.06	3.42	0.65
Organic C (%)	3.33	2.74	1.13	0.44	0.33	0.24	1.37
pH	6.22	6.51	6.68	7.34	7.59	8.31	7.11

Table 54. Means and ranges of elemental contents of the uppermost samples from Illinois soil cores 102 through 126 compared with results for surface soils as determined by other researchers[a]

	This Work		Shacklette and Boerngen(2)	
Element	Mean	Range	Mean	Range
Silicon (%)	34.53	30.7-38.6	NR[†]	29-45**
Aluminum (%)	5.31	3.61-6.91	NR	<0.07-8.5**
Iron (%)	2.30	1.52-3.31	2.1(1)	0.1-4.0**
Potassium (%)	1.65	1.25-1.85	1.7(1)	0.22-2.25**
Calcium (%)	1.01	0.53-2.10	0.40(1)	0.3-1.5**
Magnesium (%)	0.72	0.47-1.09	0.30(1)	0.005-1.25**
Sodium (%)	0.70	0.45-0.90	NR	0.6-1.25**
Titanium (%)	0.37	0.23-0.44	0.41	0.05-1.0
Phosphorus (%)	0.08	0.03-0.16	0.065(1)	0.013-0.68**
Manganese (%)	0.08	0.02-0.14	0.052	0.005-0.15
Barium (mg/kg)	617	396-768	675	200-1500
Chromium (mg/kg)	133	52-633	55	10-100
Copper (mg/kg)	25	16-43	25	7-100
Mercury (µg/kg)	40	22-80	70***	20-360***
Nickel (mg/kg)	28	20-47	17	5-30
Lead (mg/kg)	24	16-46	19	10-30
Rubidium (mg/kg)	82	58-122	75	45-100
Strontium (mg/kg)	143	113-169	305	20-1000
Vanadium (mg/kg)	80	54-106	87	20-150*
Zinc (mg/kg)	78	34-161	58.5	20-109
Zirconium (mg/kg)	392	207-562	NR	NR

[a] Not including values for core 122

[†] 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.FFigure 1. Loess thickness in Illinois (after Willman and Frye, 1970)

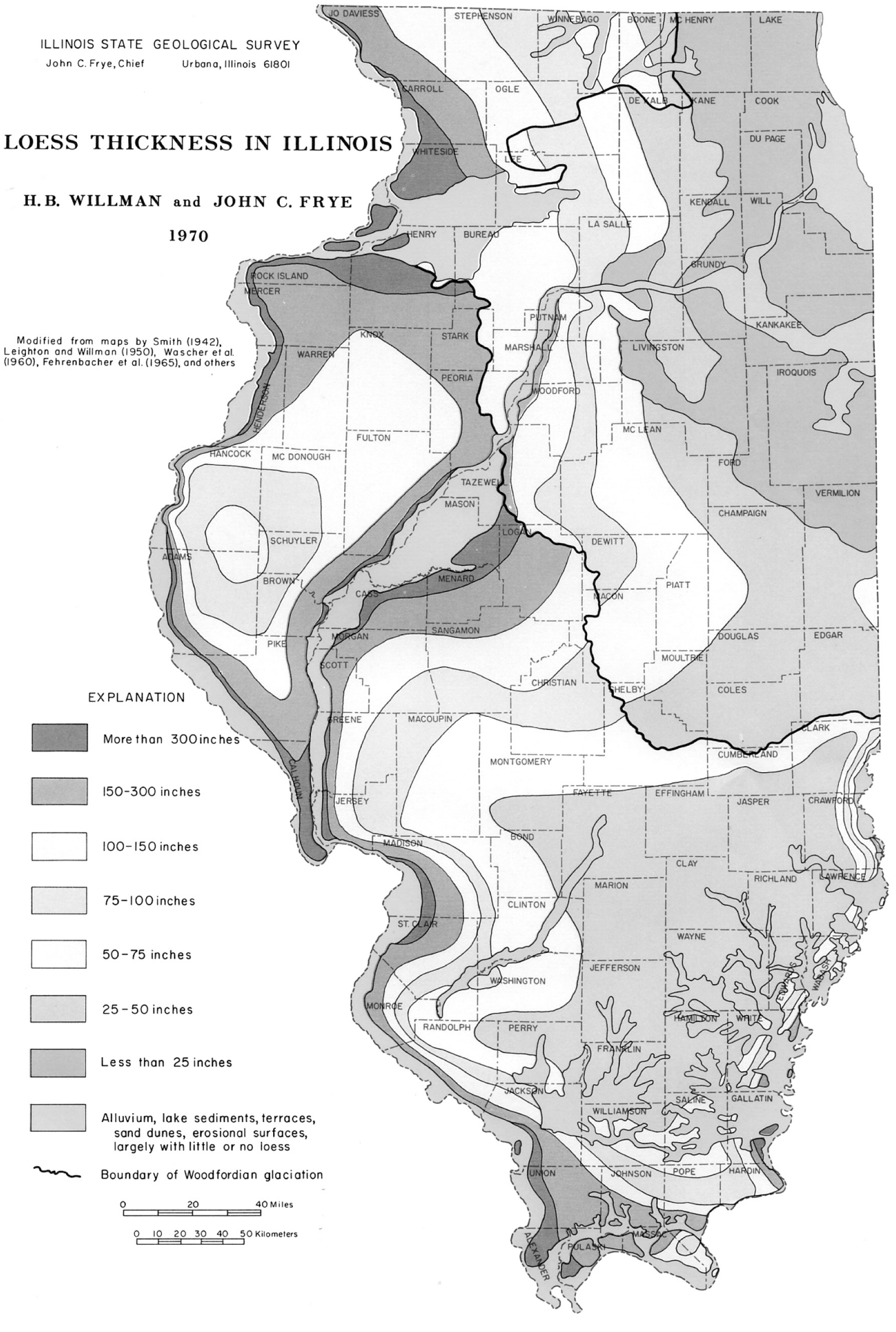


Figure 1. Loess thickness in Illinois (after Willman and Frye, 1970).

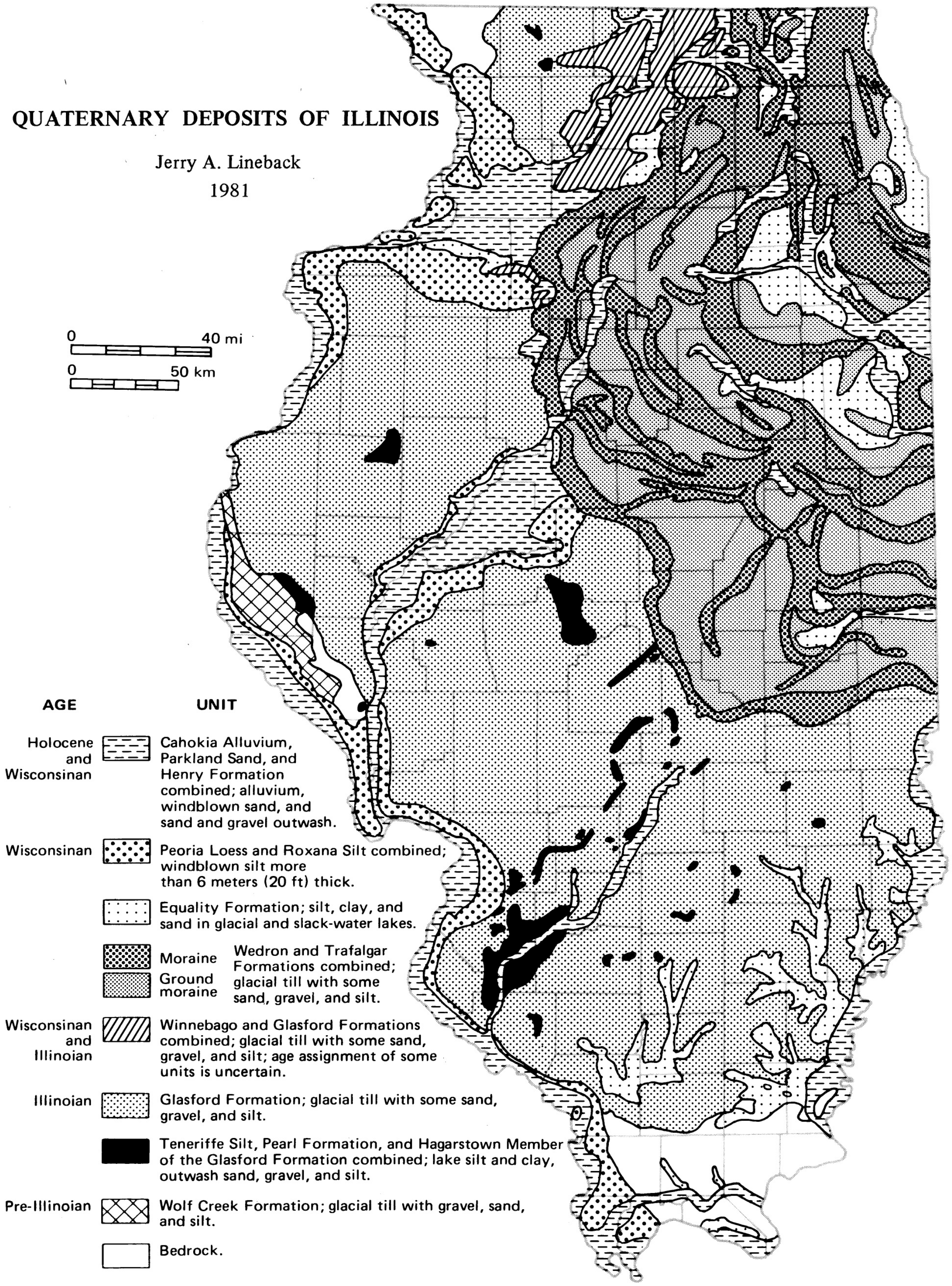


Figure 2. Quaternary deposits in Illinois (after Lineback, 1981).

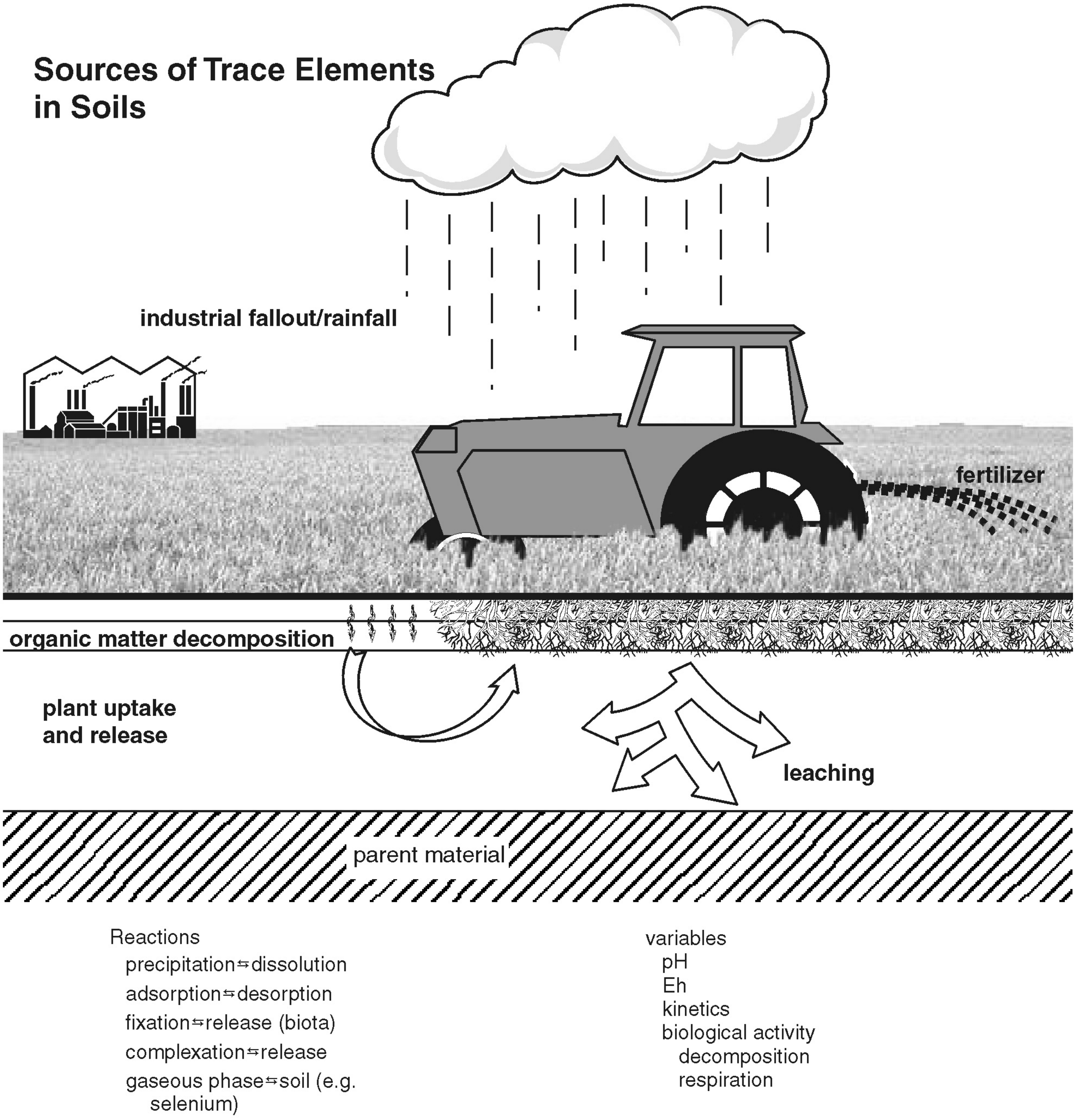


Figure 3. Schematic diagram of various input and ouput functions that affect trace elements, reactions that affect soil chemistry, and variables that affect reactions.

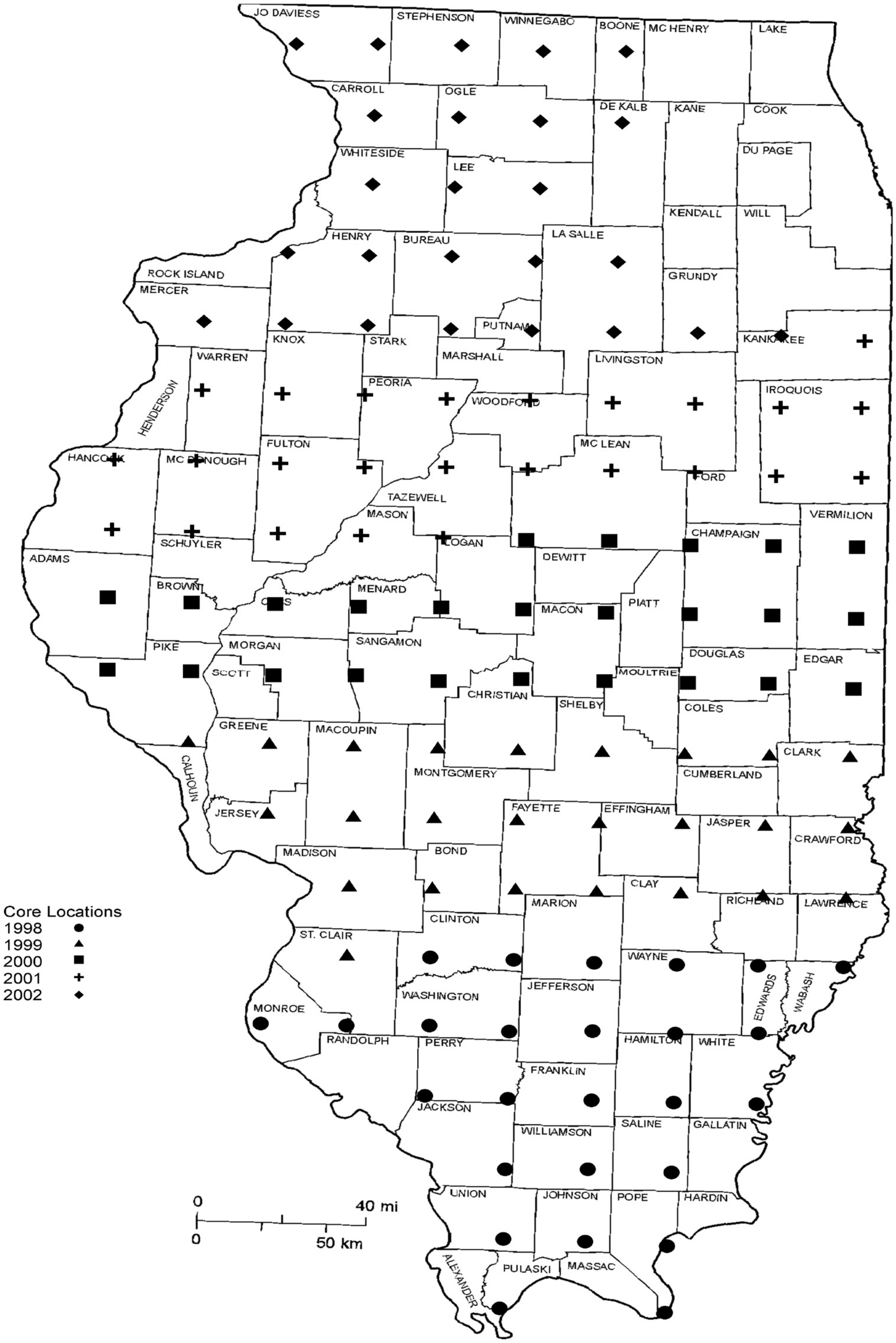


Figure 4. Locations of soil cores collected from 1998 through 2002.

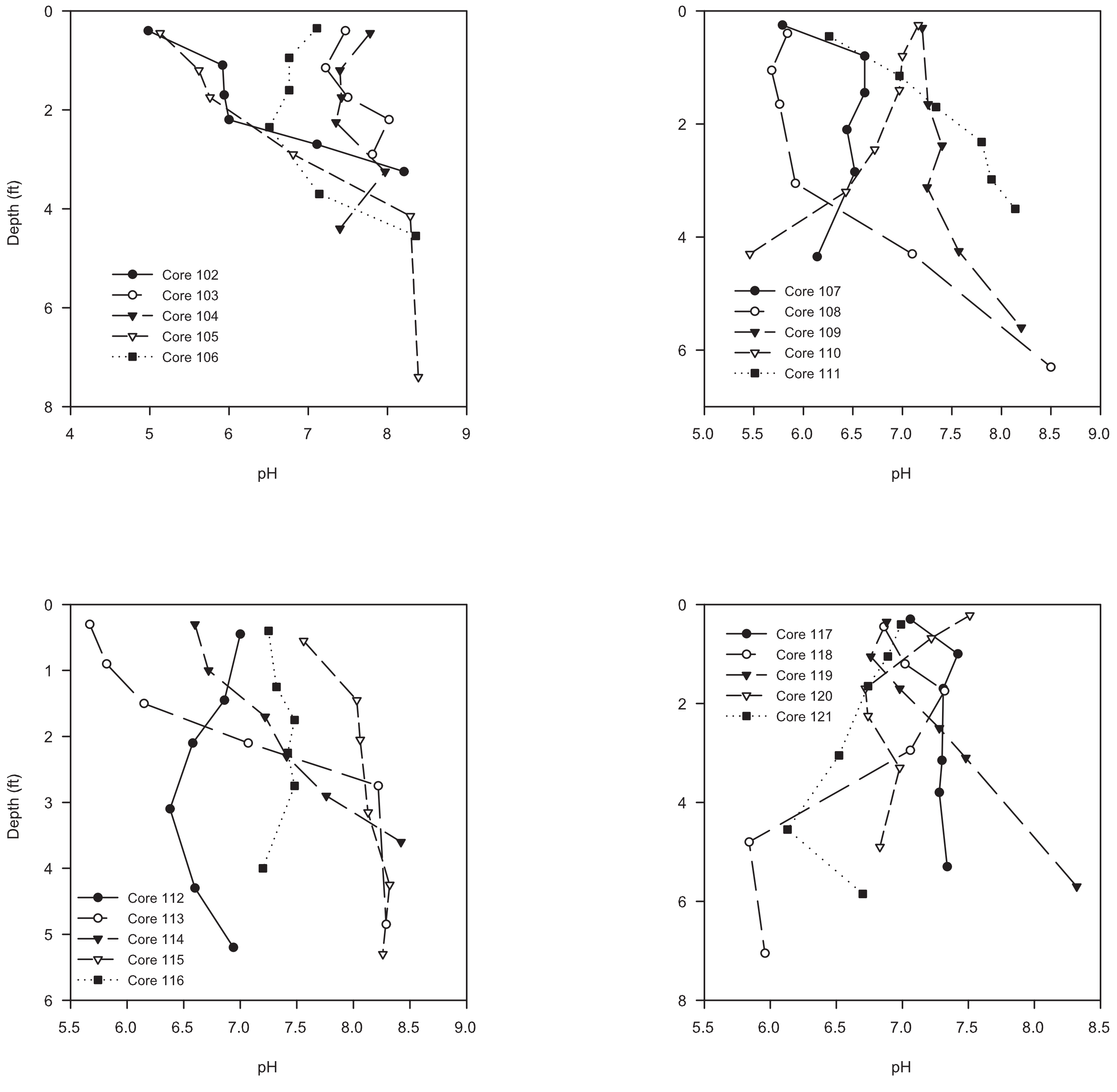


Figure 5. pH versus depth in cores 102 through 126, collected in 2002.

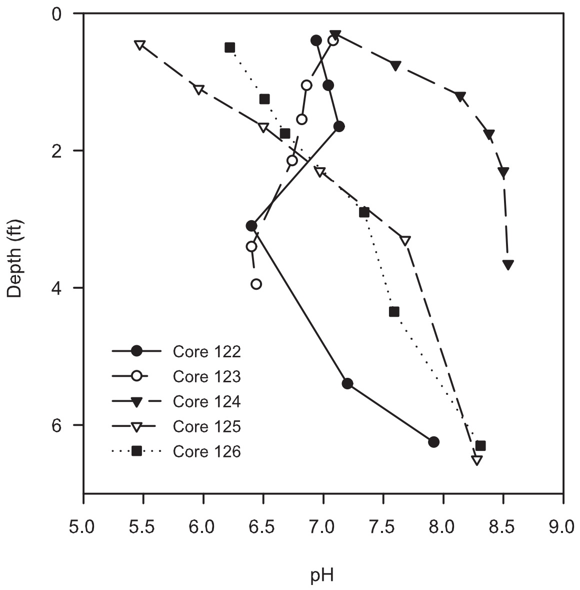


Figure 5. pH versus depth in cores 102 through 126, continued.

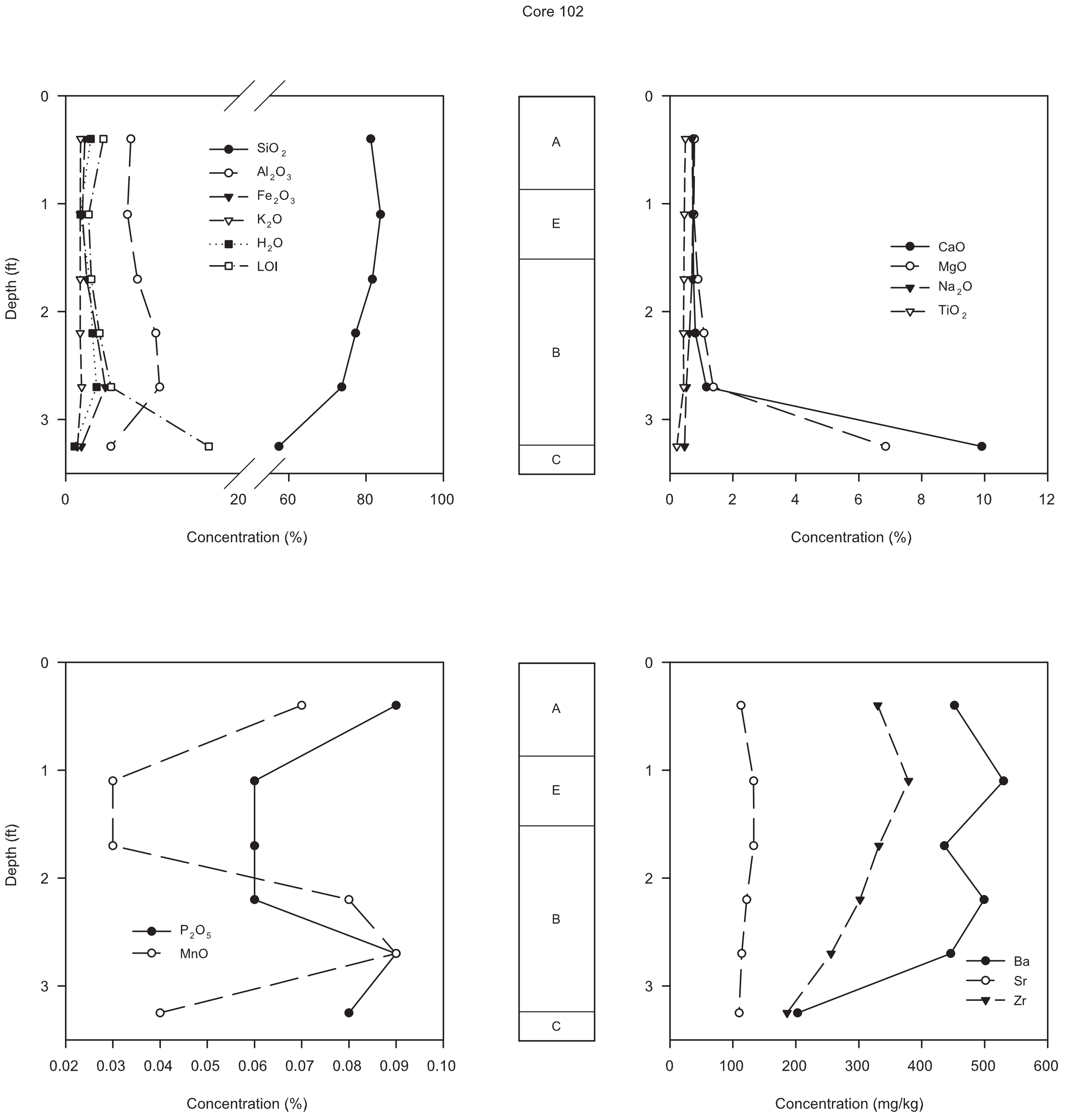


Figure 6. Element concentrations versus depth in core 102.

Core 102

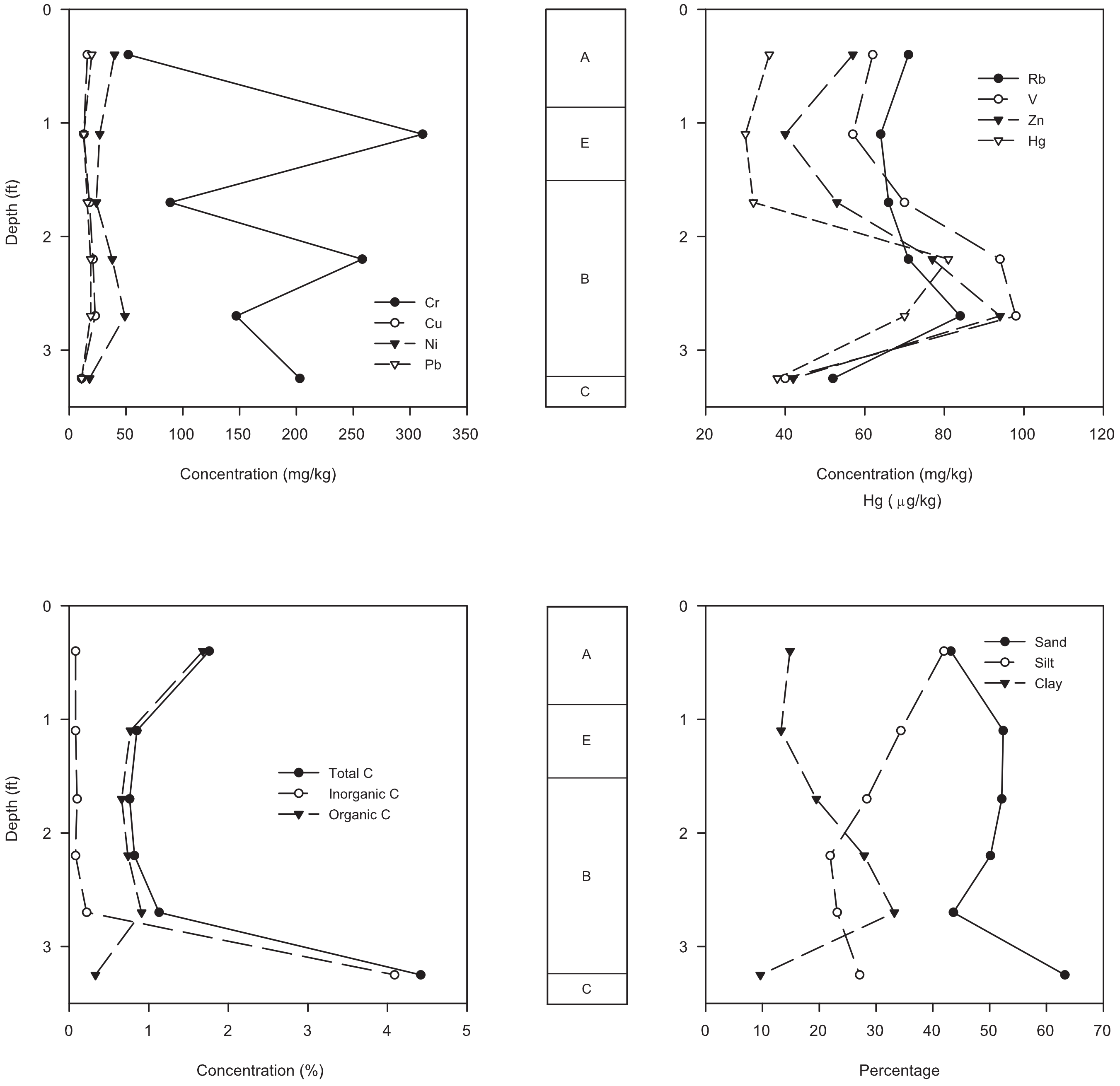


Figure 7. Element concentrations versus depth in core 102.

Core 103

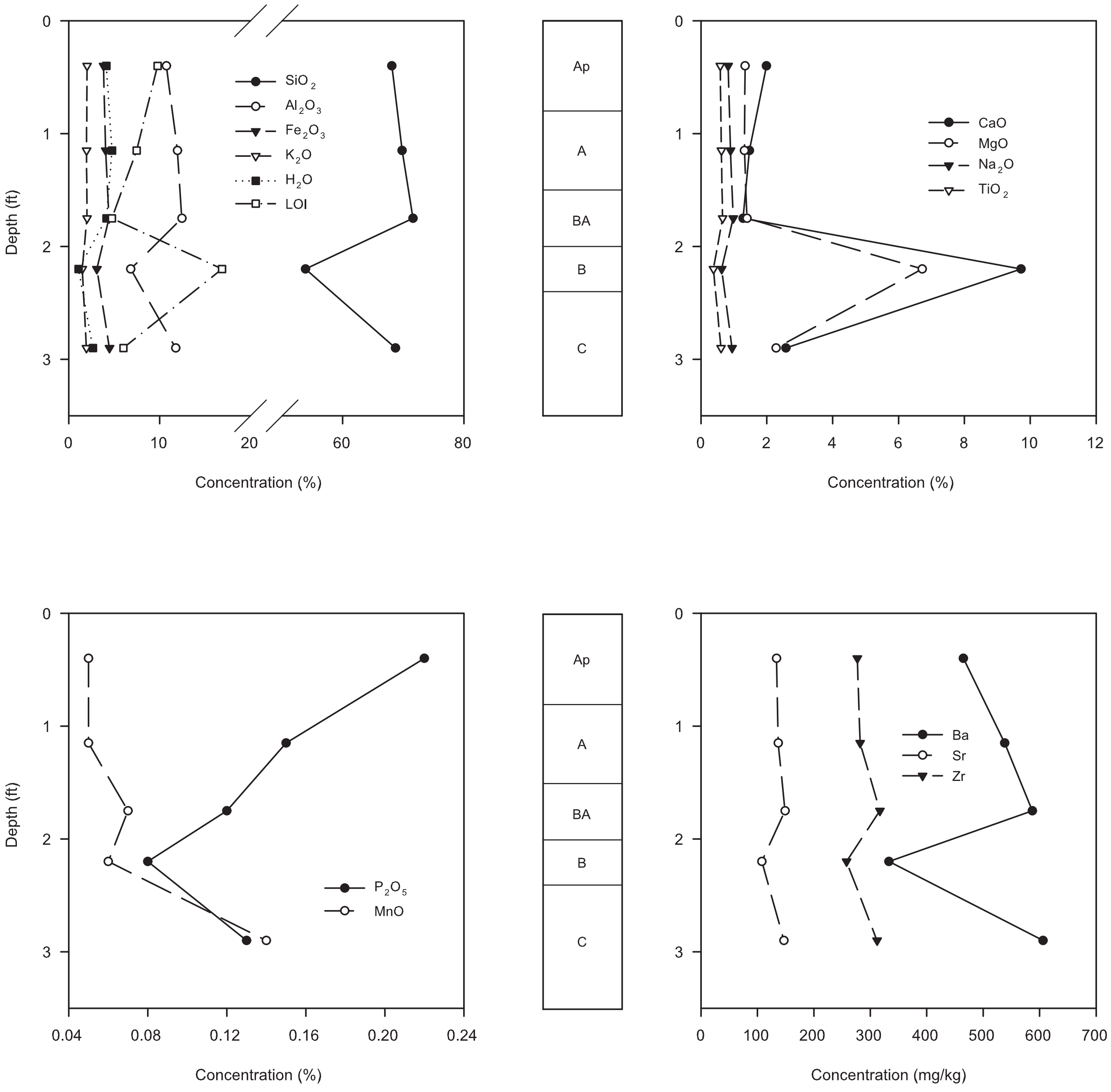


Figure 8. Element concentrations versus depth in core 103.

Core 103

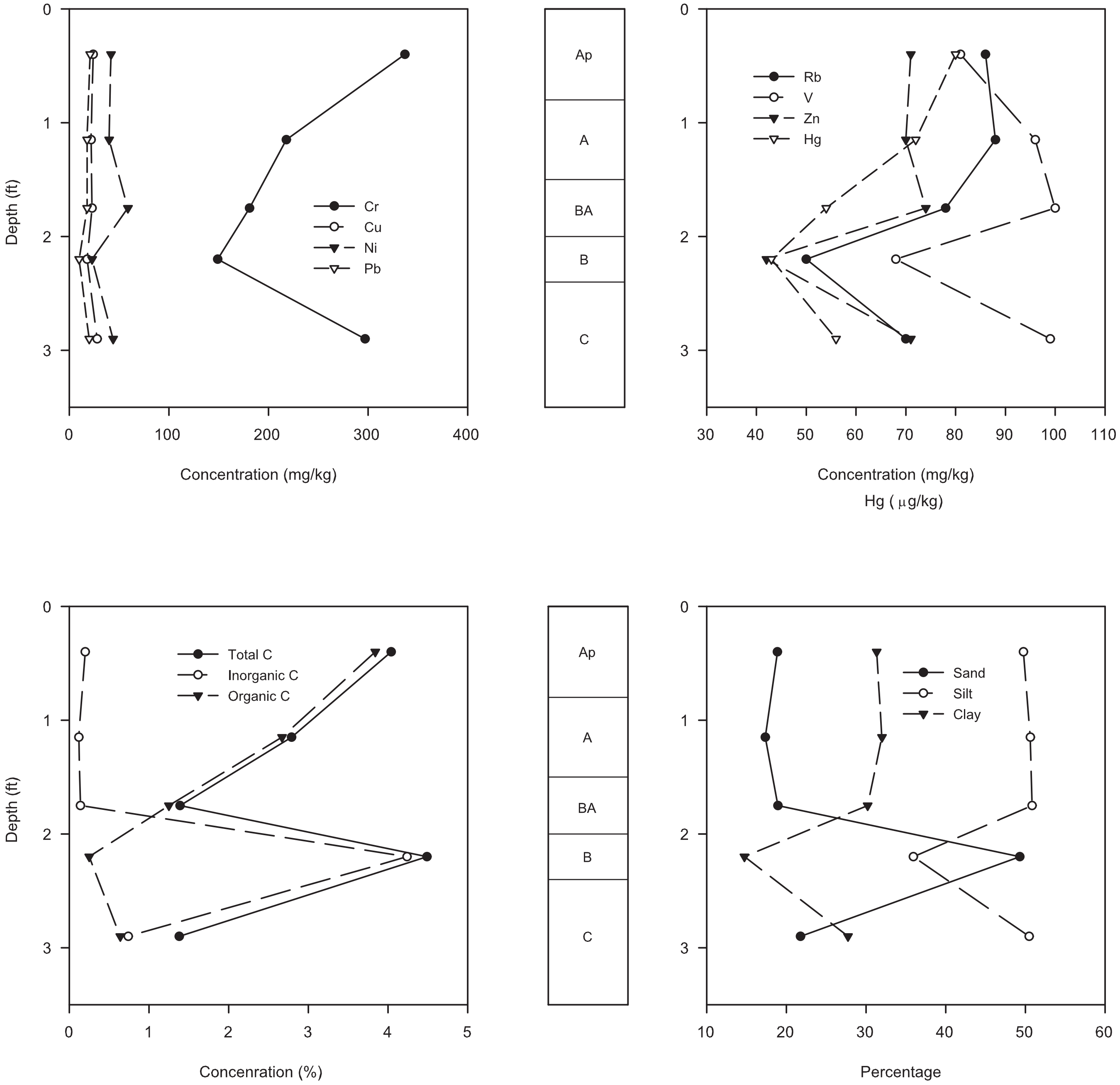


Figure 9. Element concentrations versus depth in core 103.

Core 104

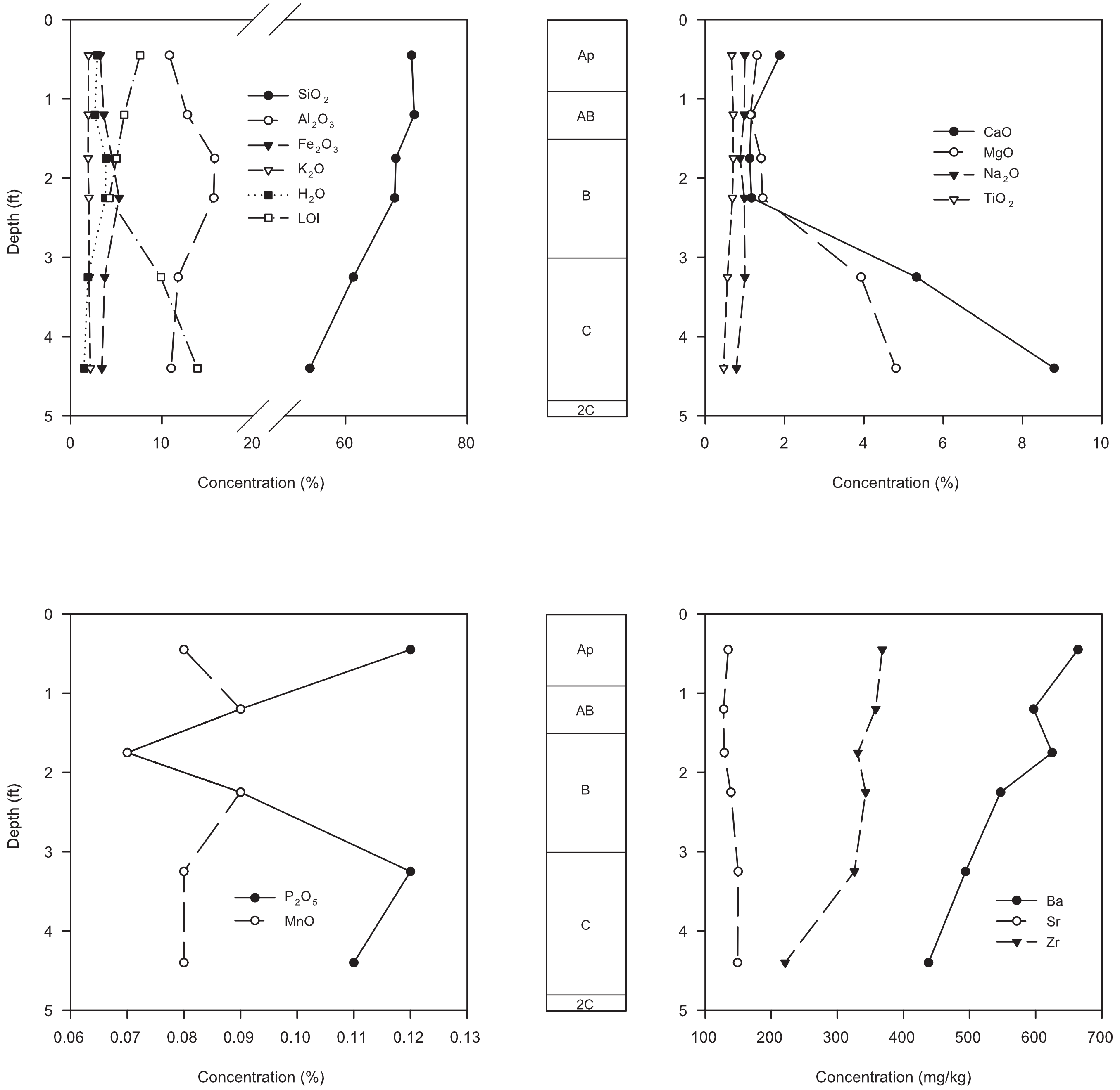


Figure 10. Element concentrations versus depth in core 104.

Core 104

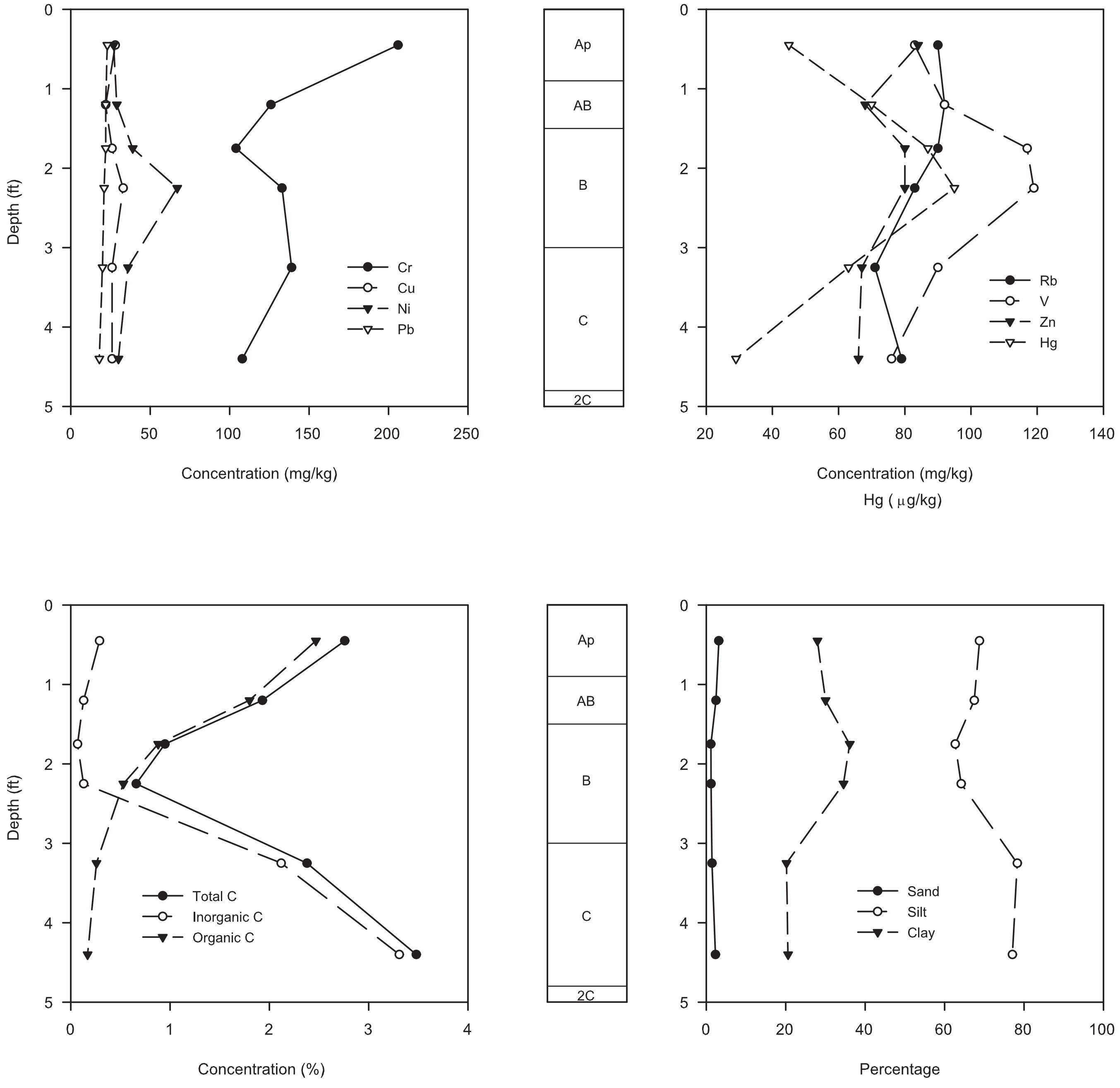


Figure 11. Element concentrations versus depth in core 104.

Core 105

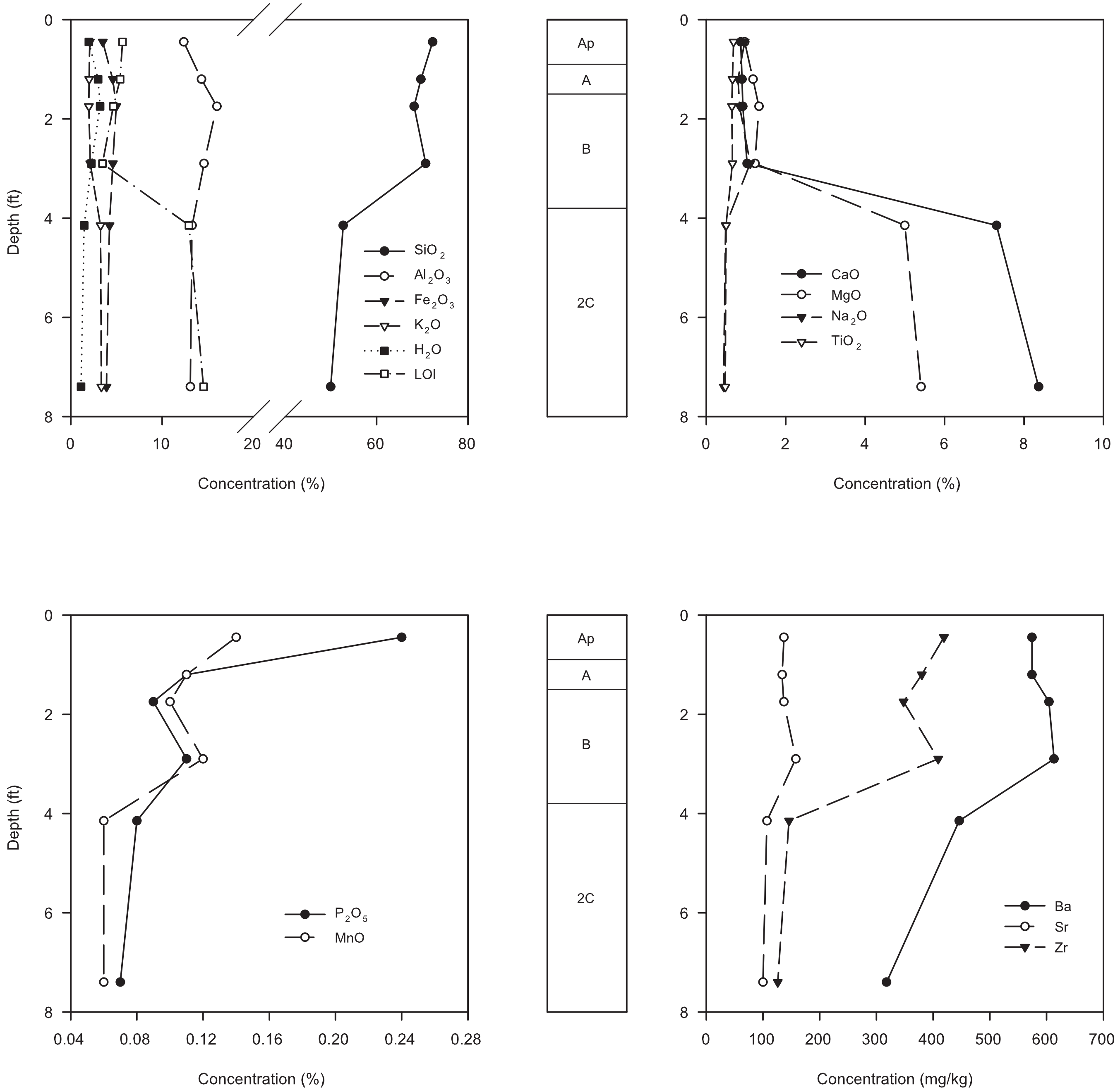


Figure 12. Element concentrations versus depth in core 105.

Core 105

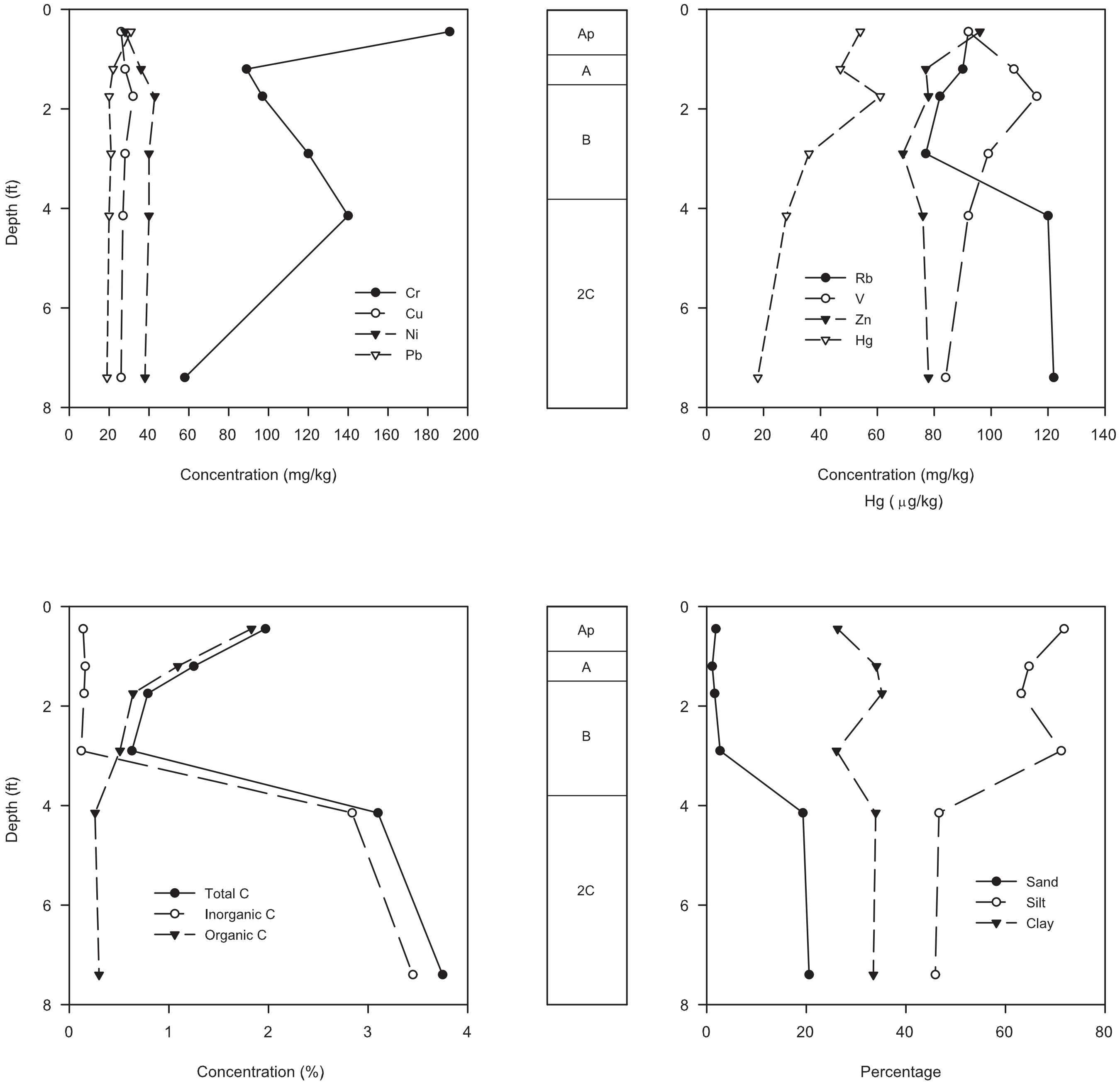


Figure 13. Element concentrations versus depth in core 105.

Core 106

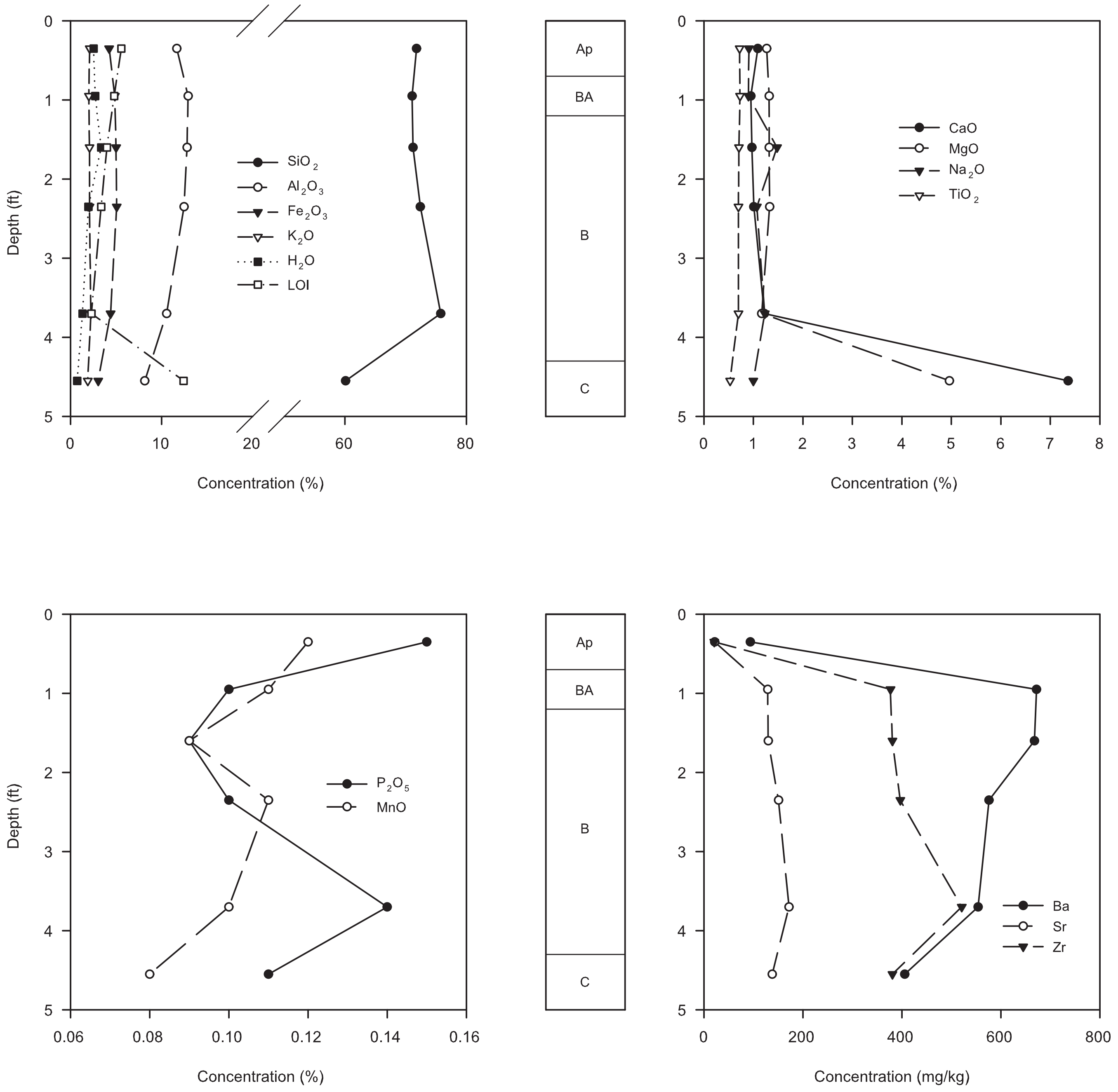


Figure 14. Element concentrations versus depth in core 106.

Core 106

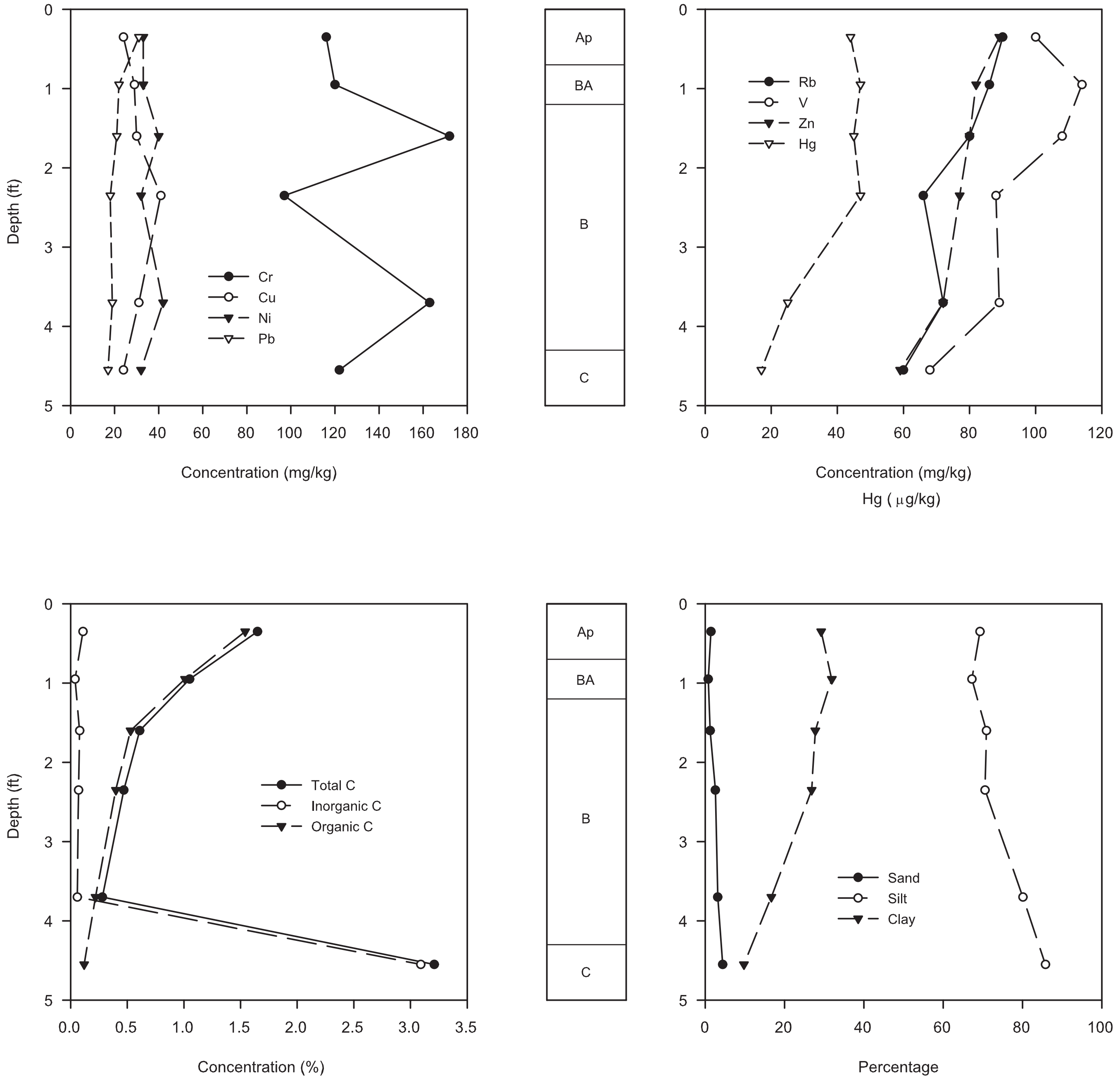


Figure 15. Element concentrations versus depth in core 106.

Core 107

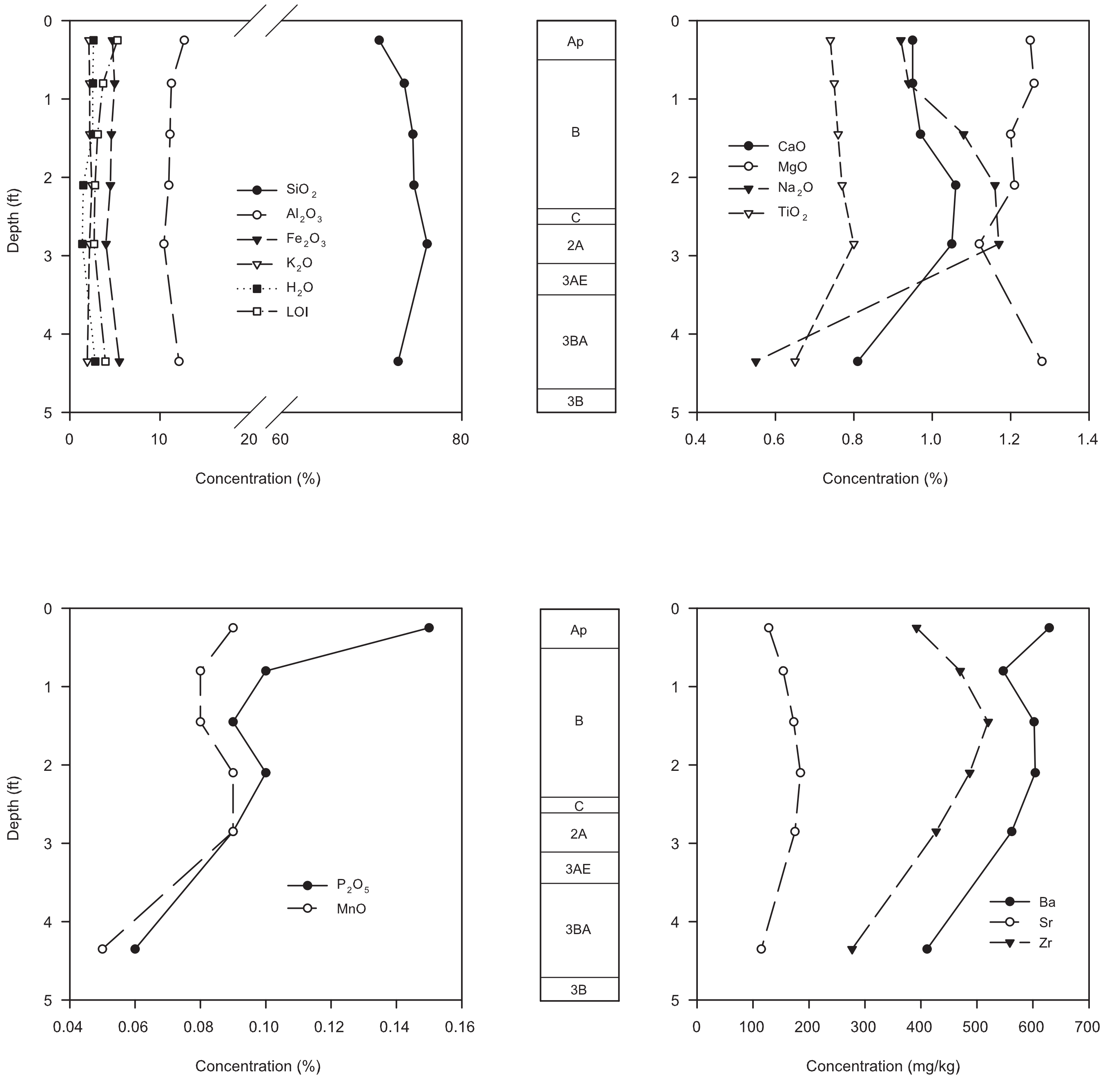


Figure 16. Element concentrations versus depth in core 107.

Core 107

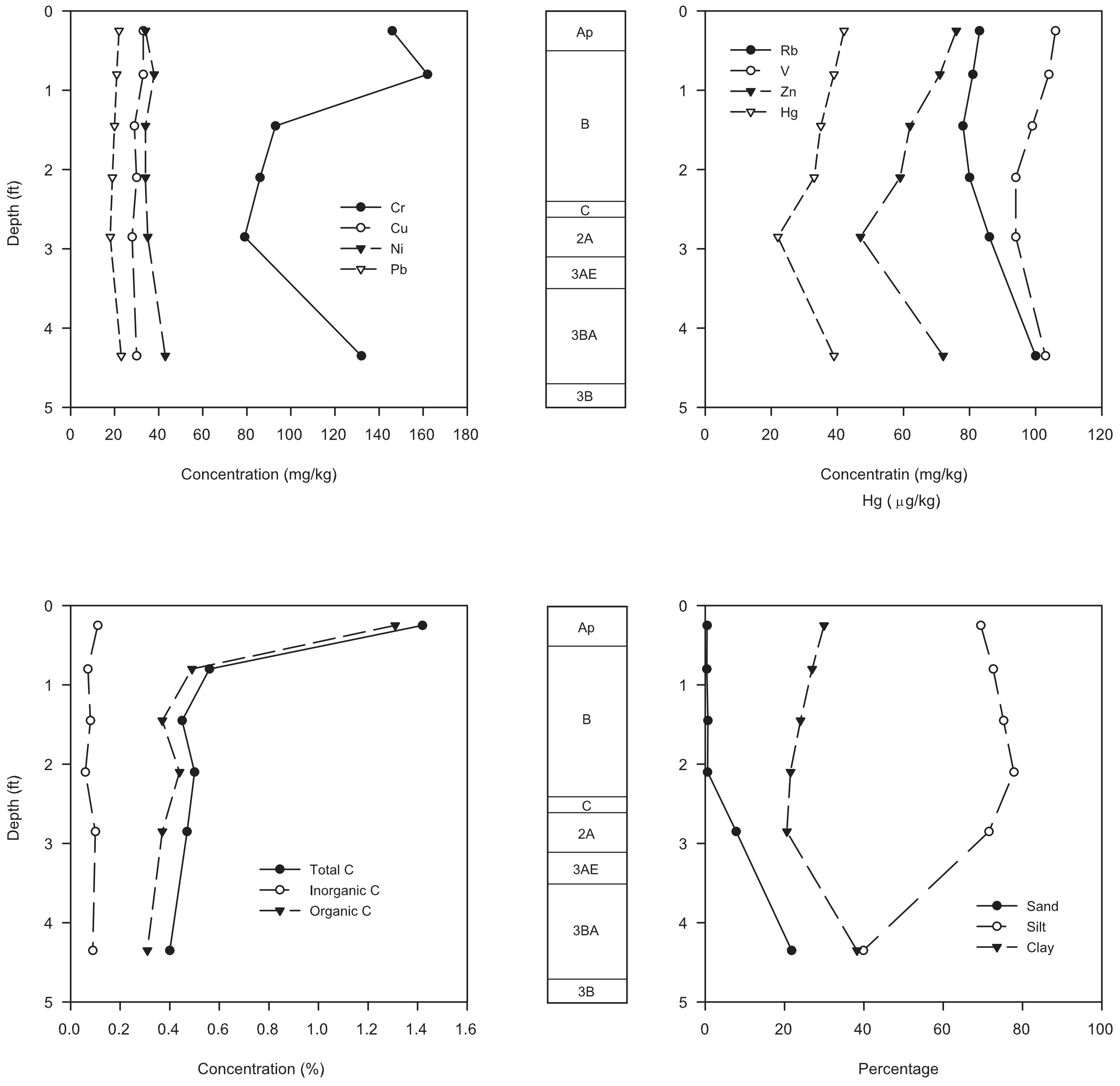


Figure 17. Element concentrations versus depth in core 107.

Core 108

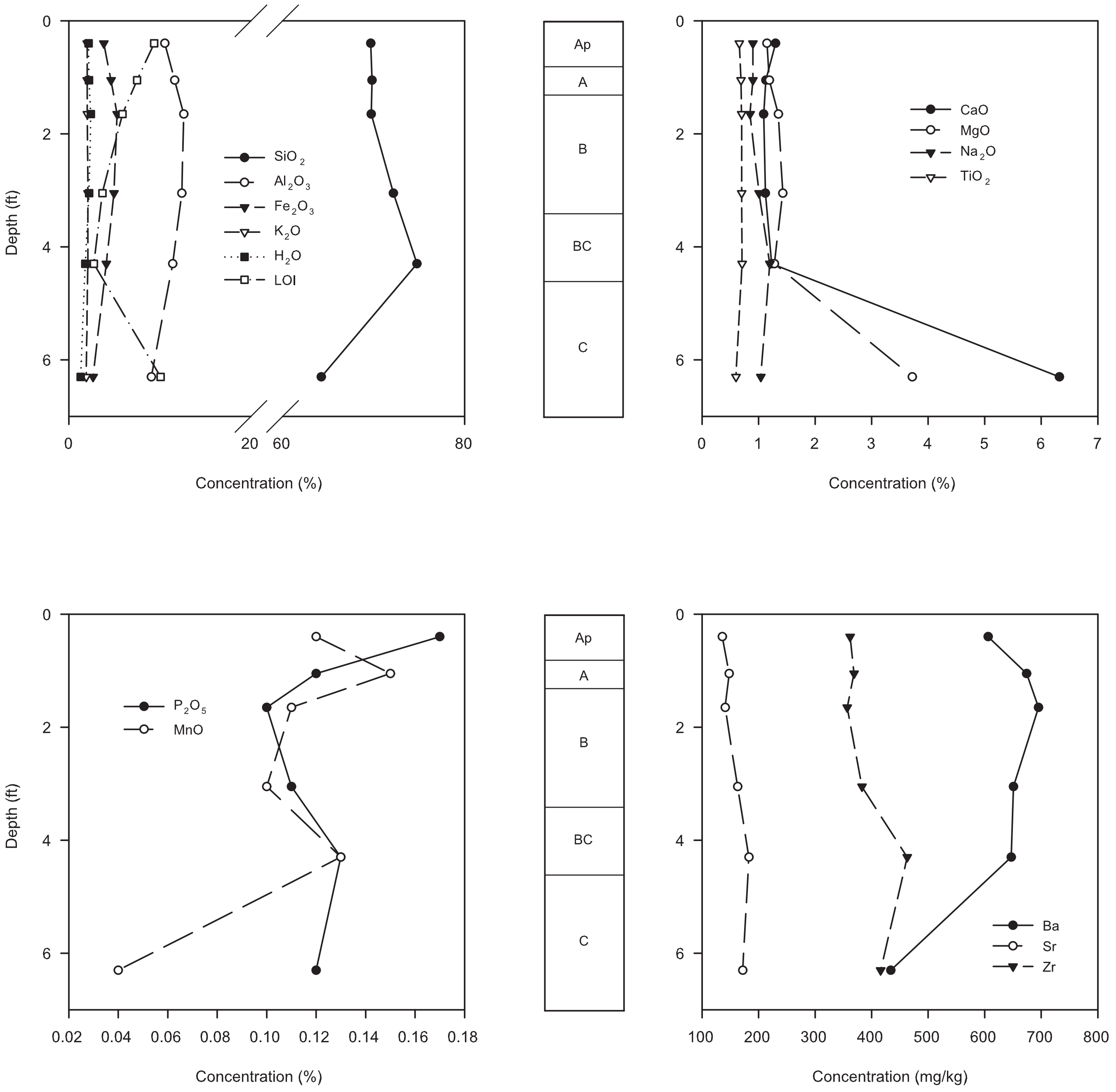


Figure 18. Element concentrations versus depth in core 108.

Core 108

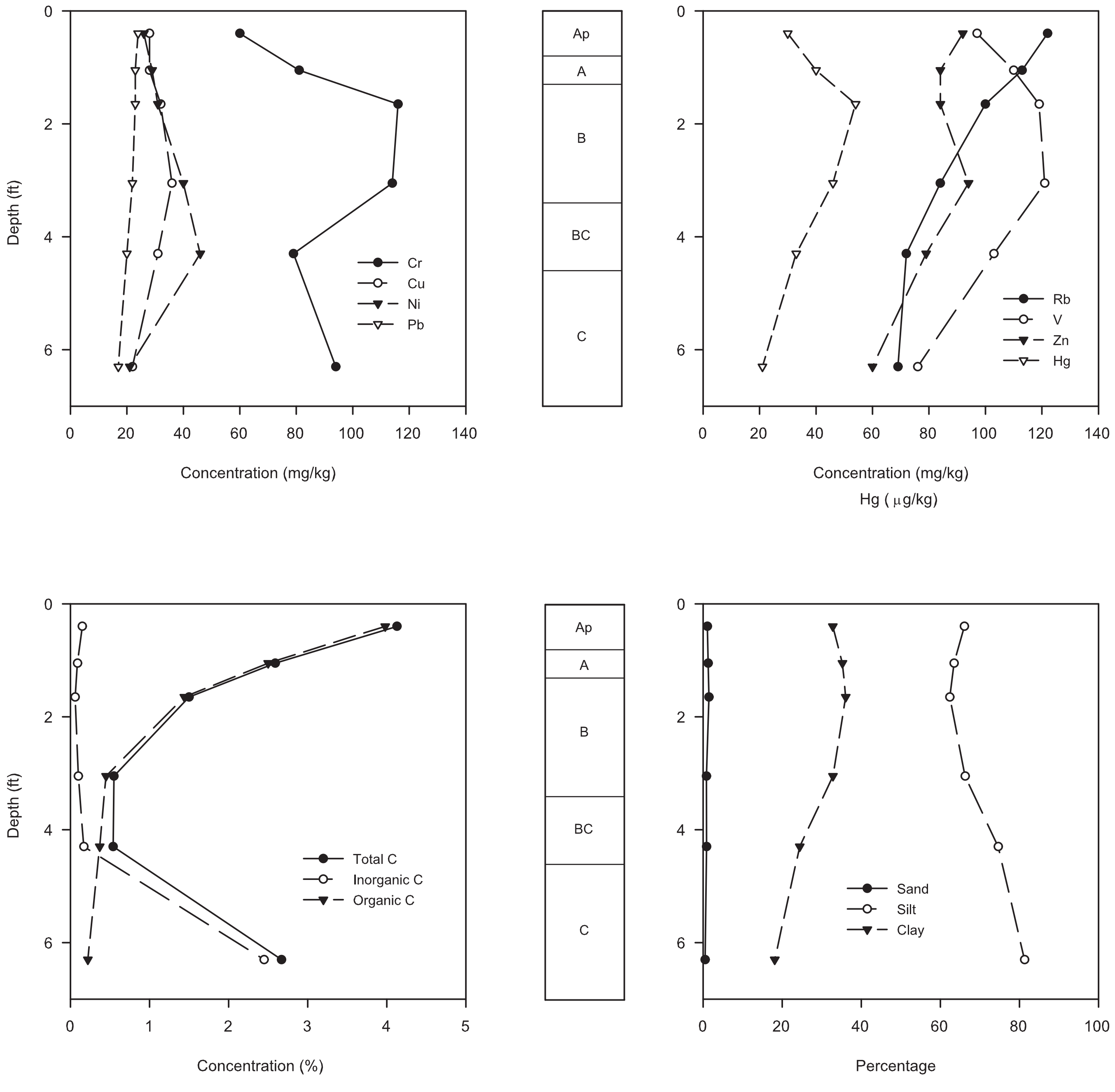
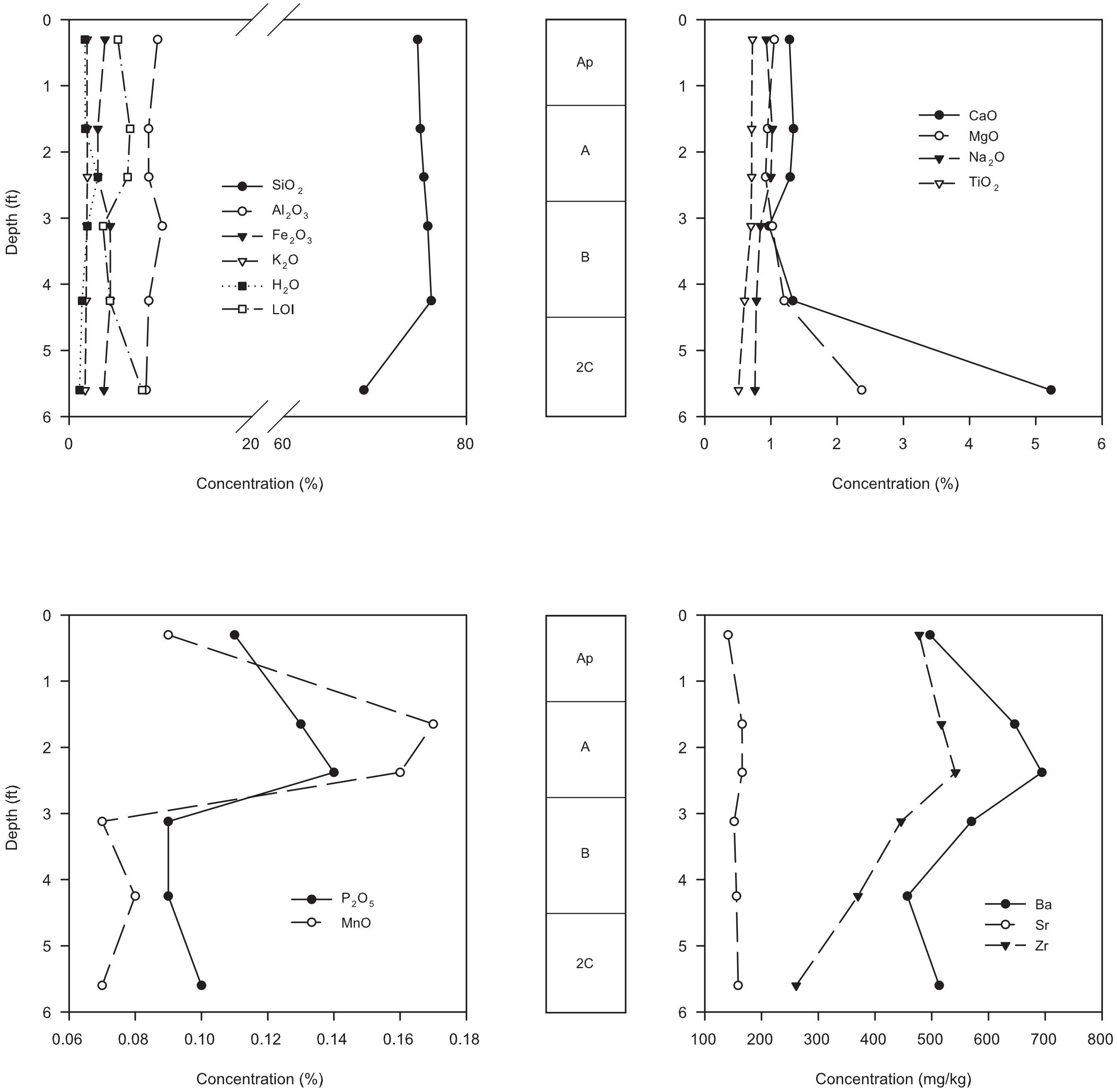


Figure 19. Element concentrations versus depth in core 108.



Core 109

Figure 20. Element concentrations versus depth in core 109.

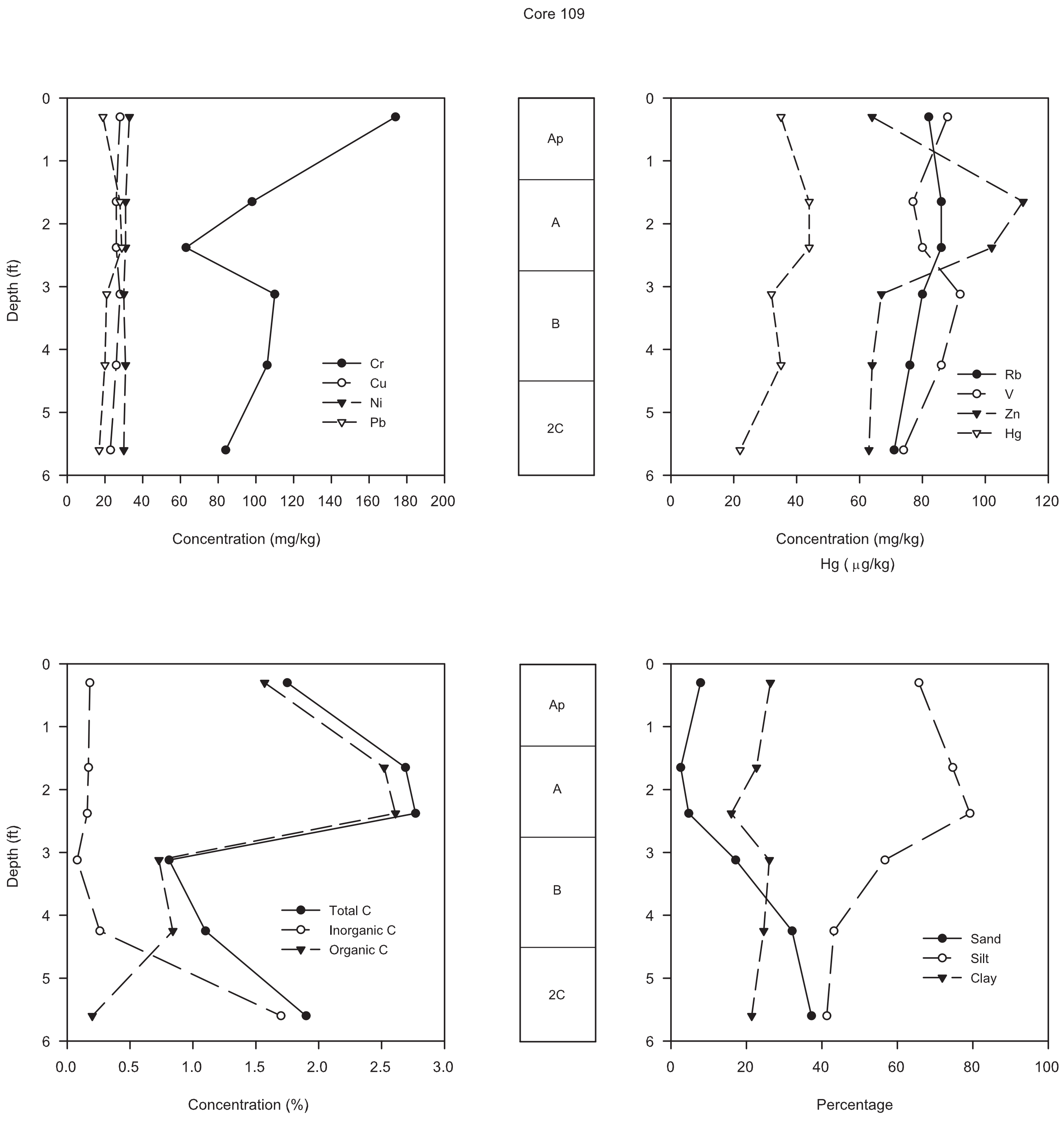


Figure 21. Element concentrations versus depth in core 109.

Core 110

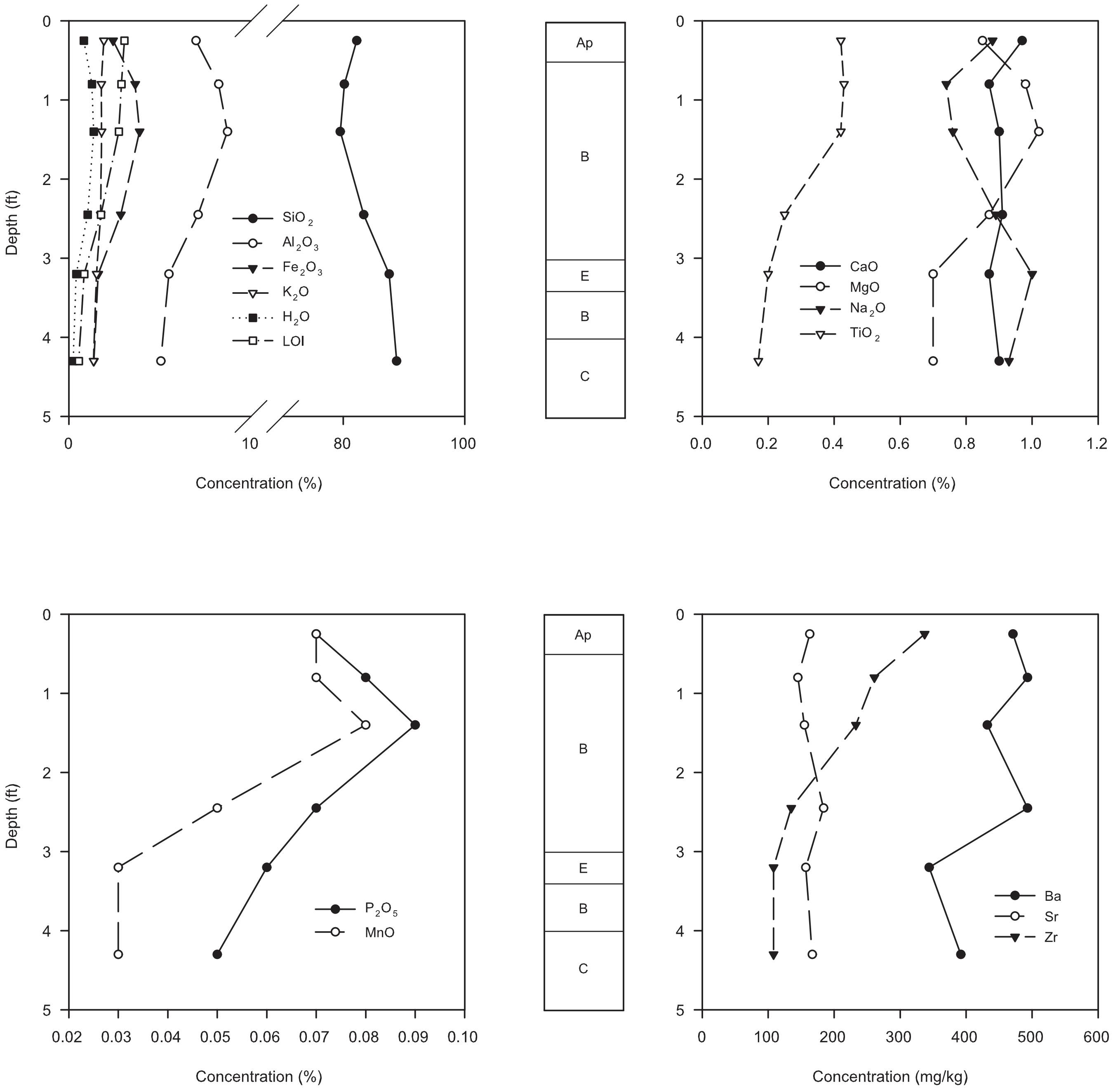


Figure 22. Element concentrations versus depth in core 110.

Core 110

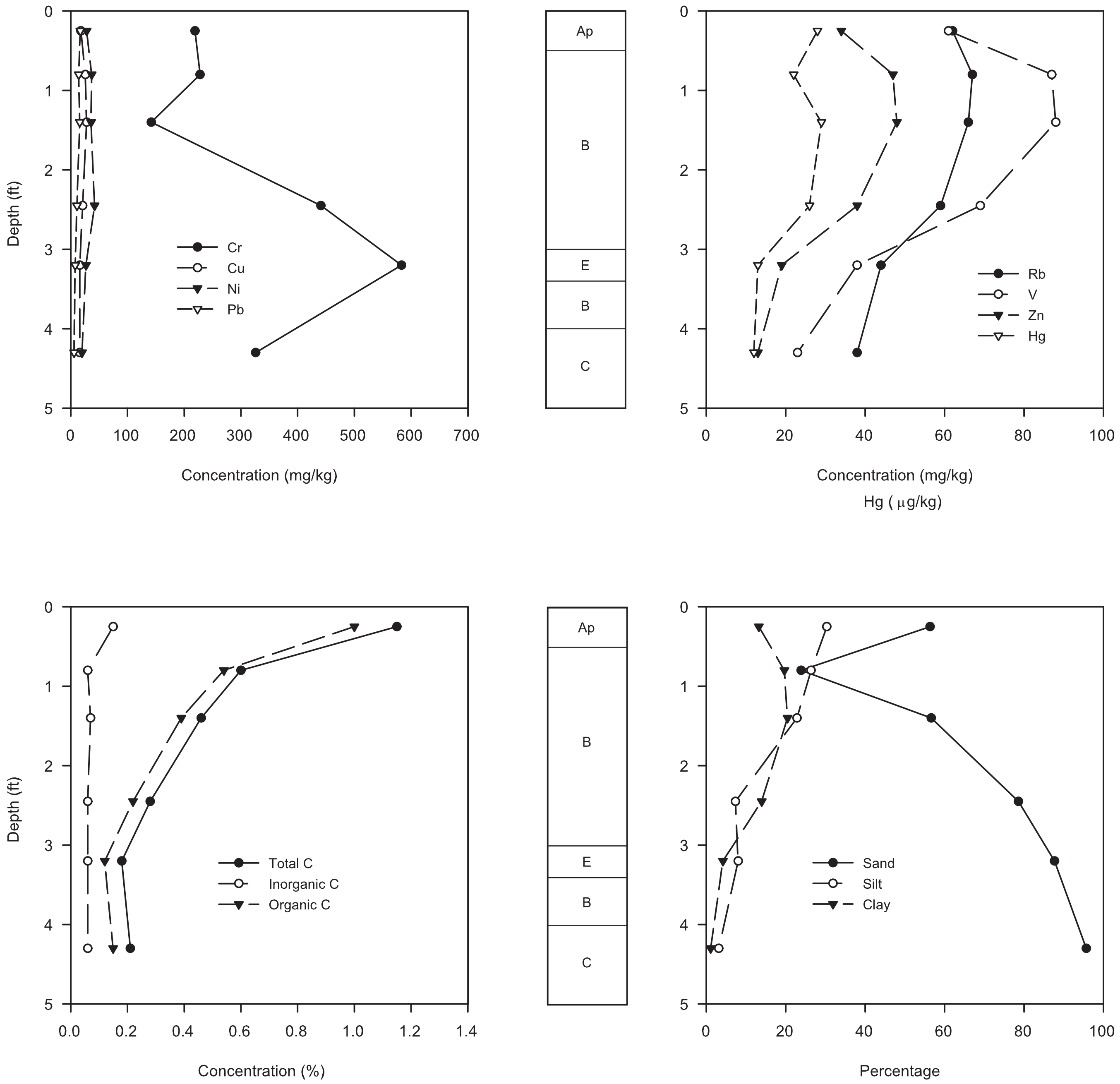


Figure 23. Element concentrations versus depth in core 110.

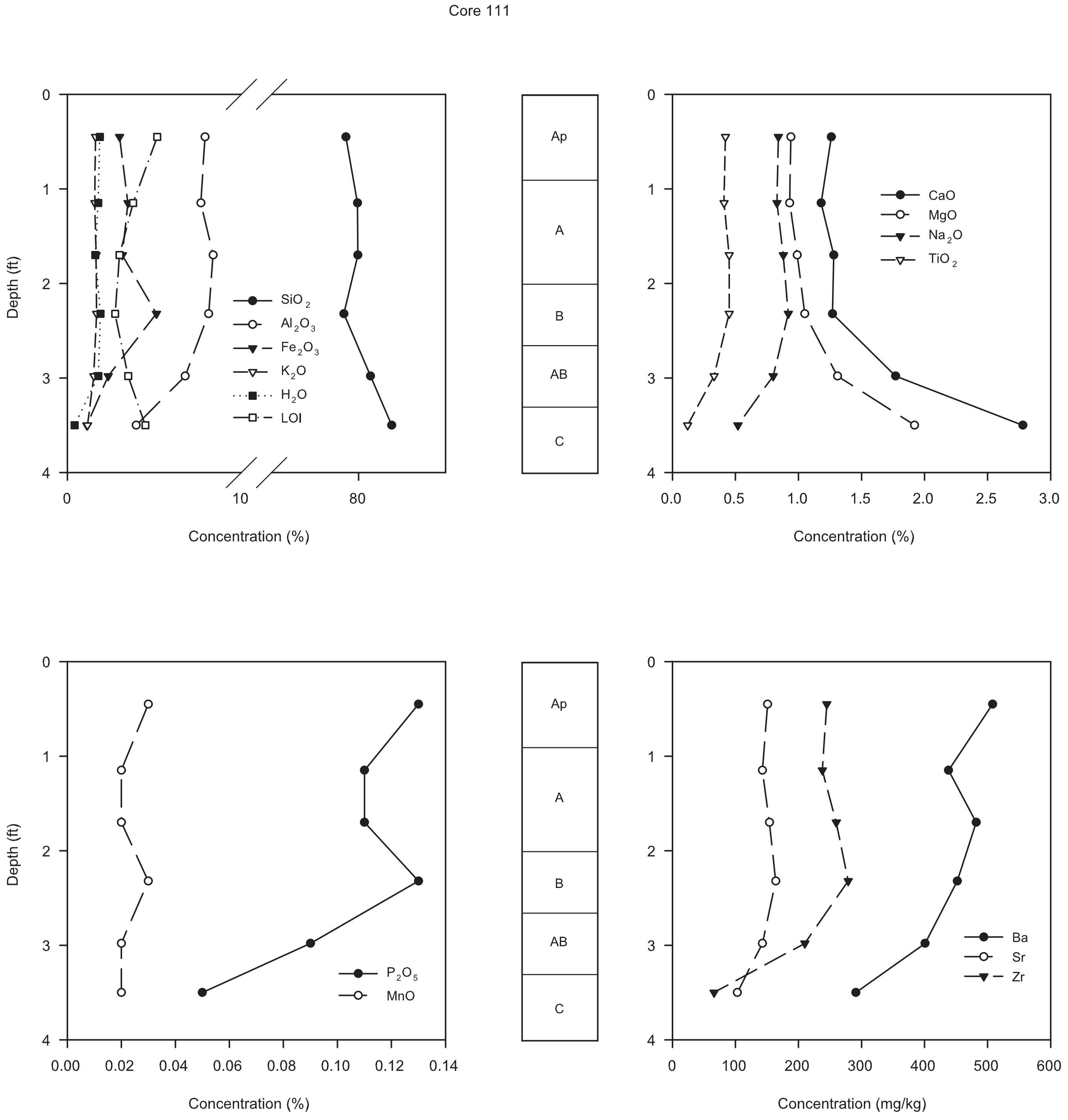


Figure 24. Element concentrations versus depth in core 111.

Core 111

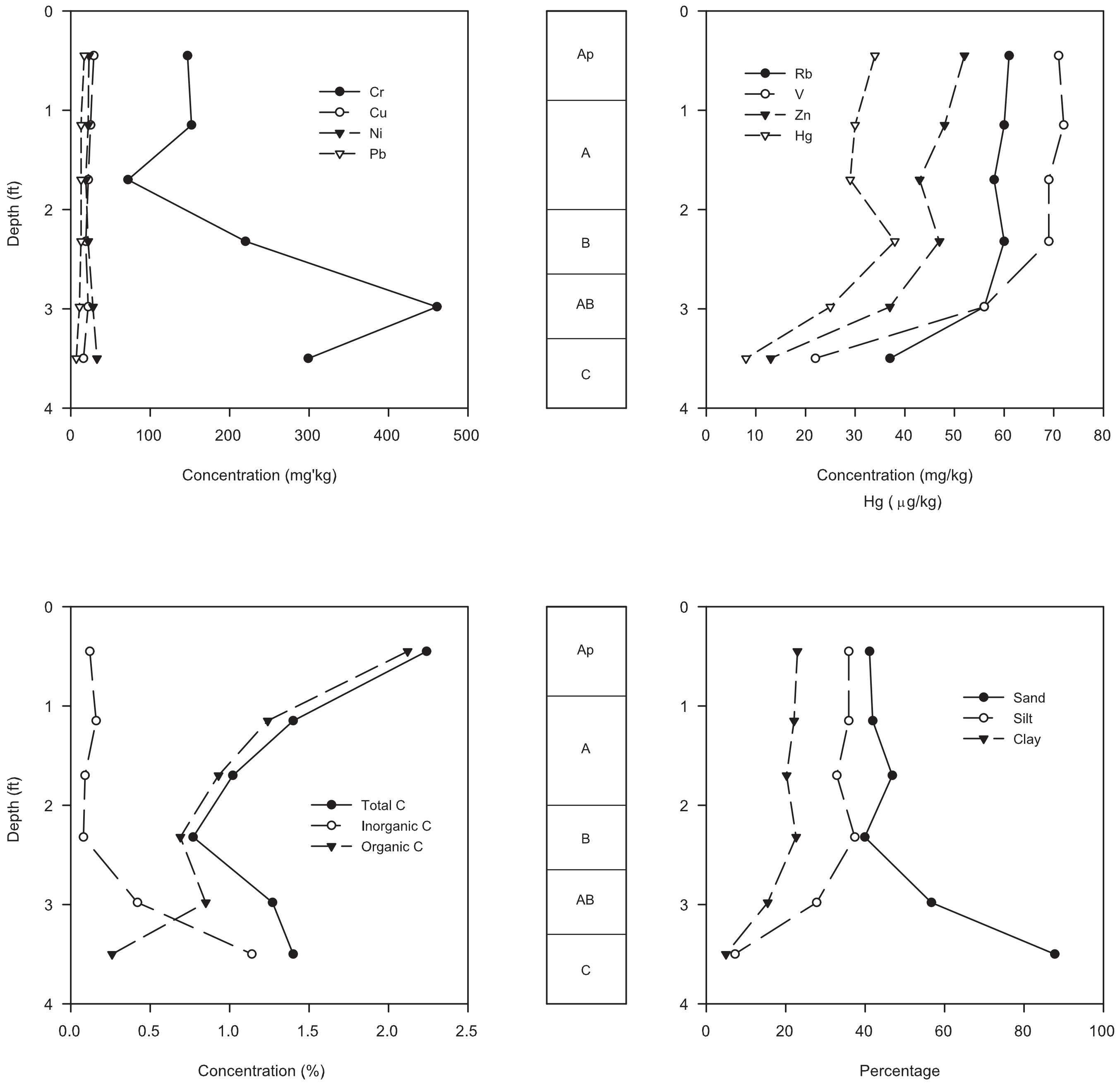


Figure 25. Element concentraitons versus depth in core 111.

Core 112

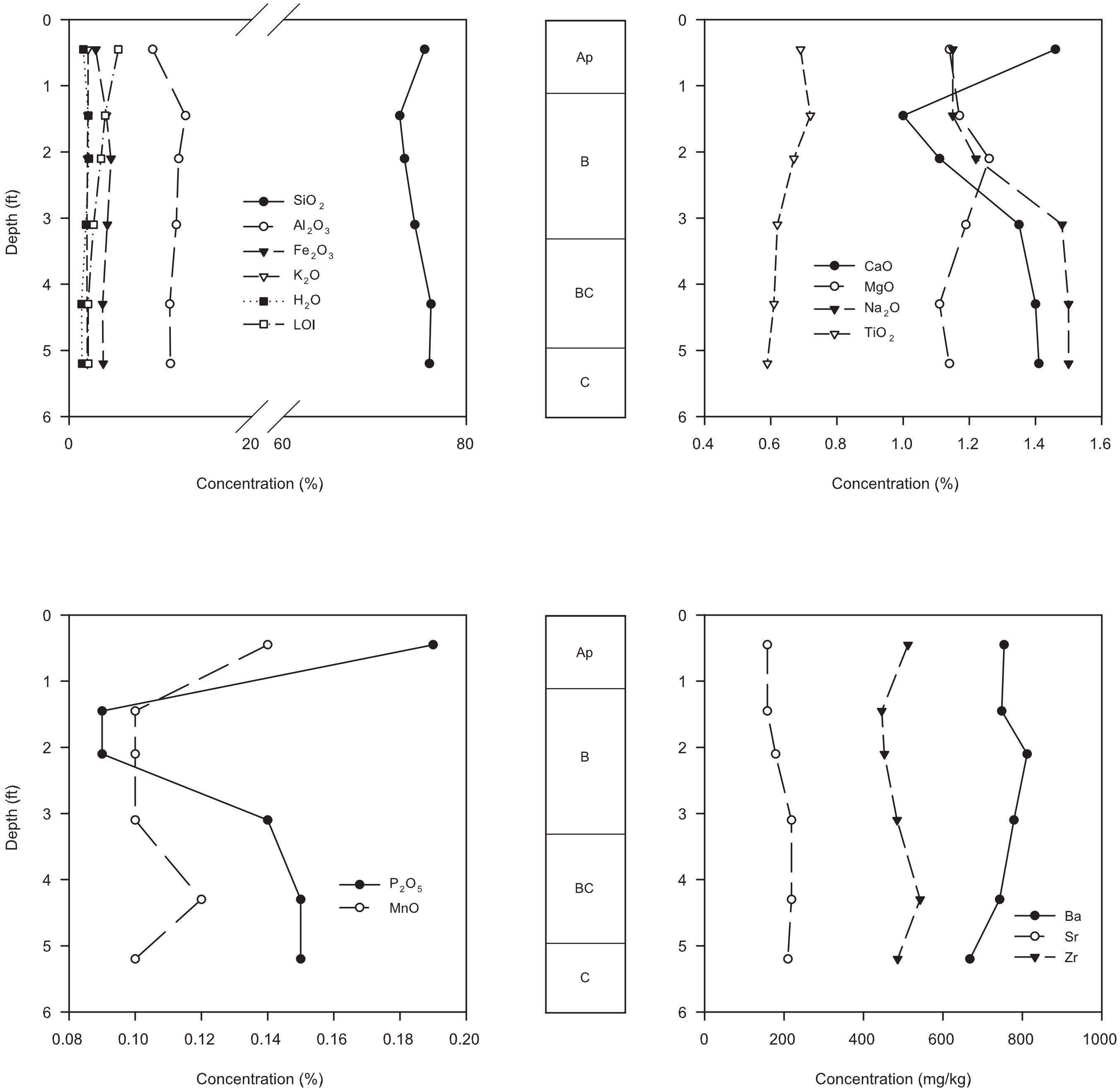


Figure 26. Element concentrations versus depth in core 112.

Core 112

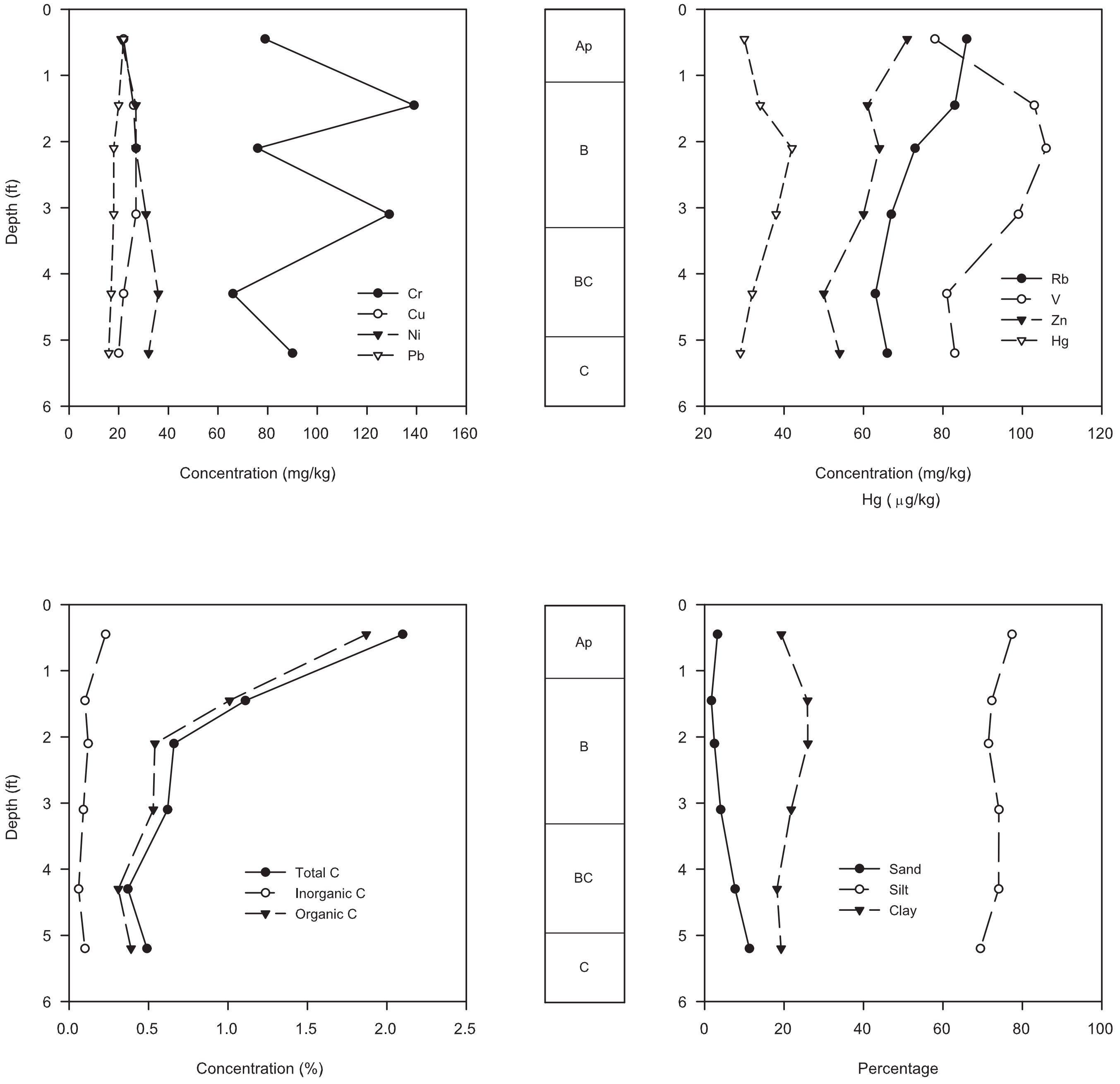


Figure 27. Element concentrations versus depth in core 112.

Core 113

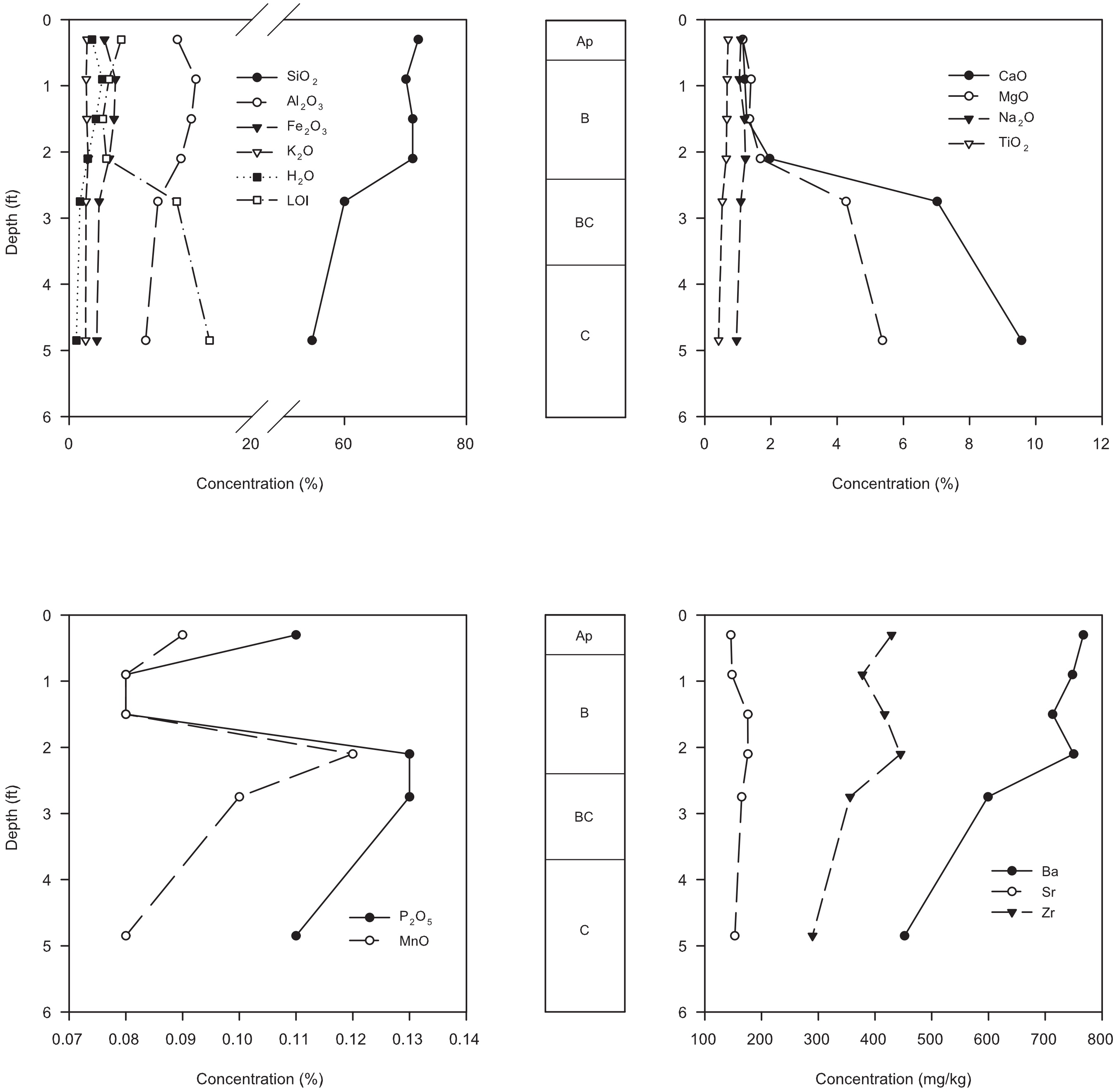


Figure 28. Element concentrations versus depth in core 113.

Core 113

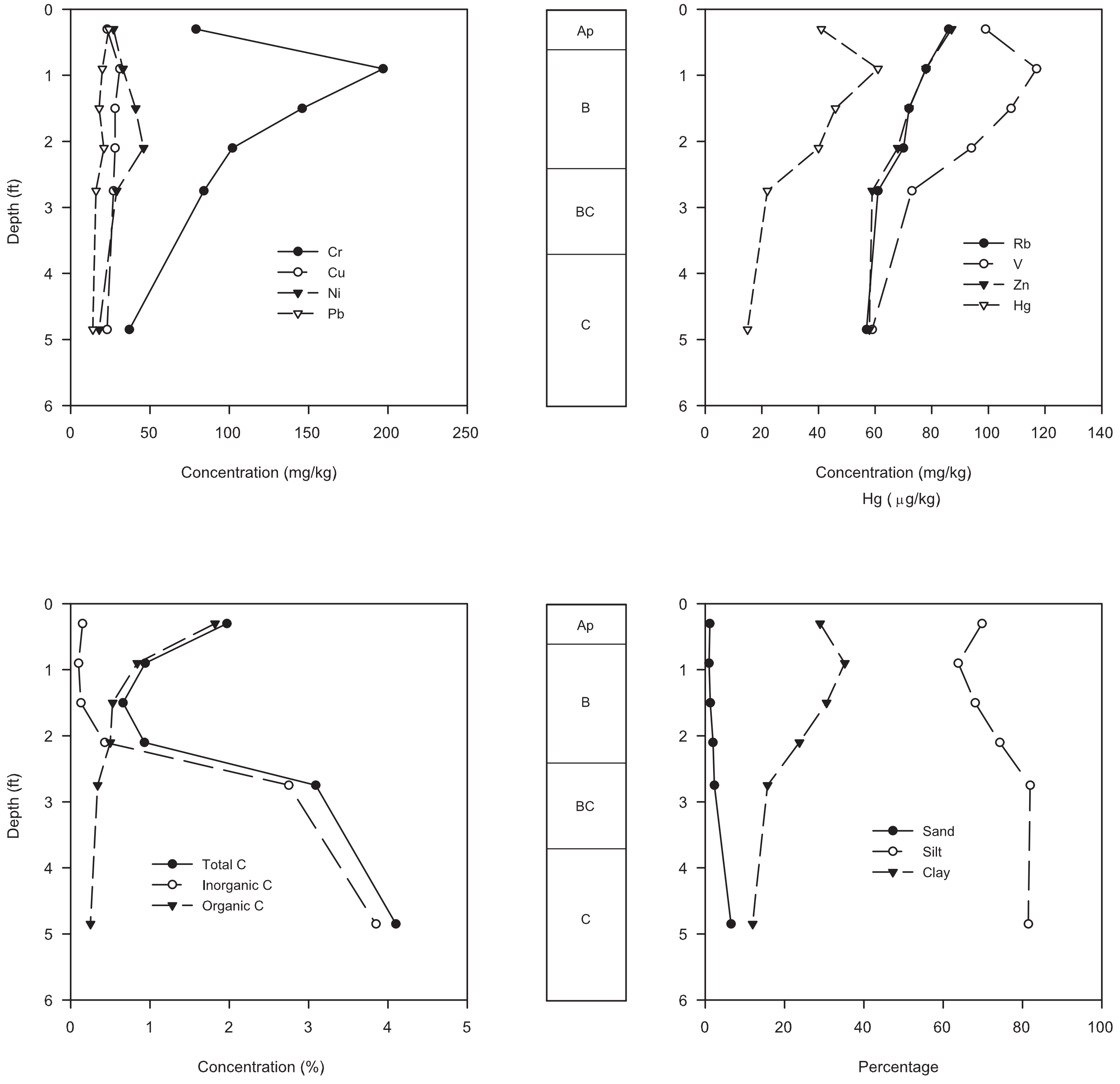


Figure 29. Element concentrations versus depth in core 113.

Core 114

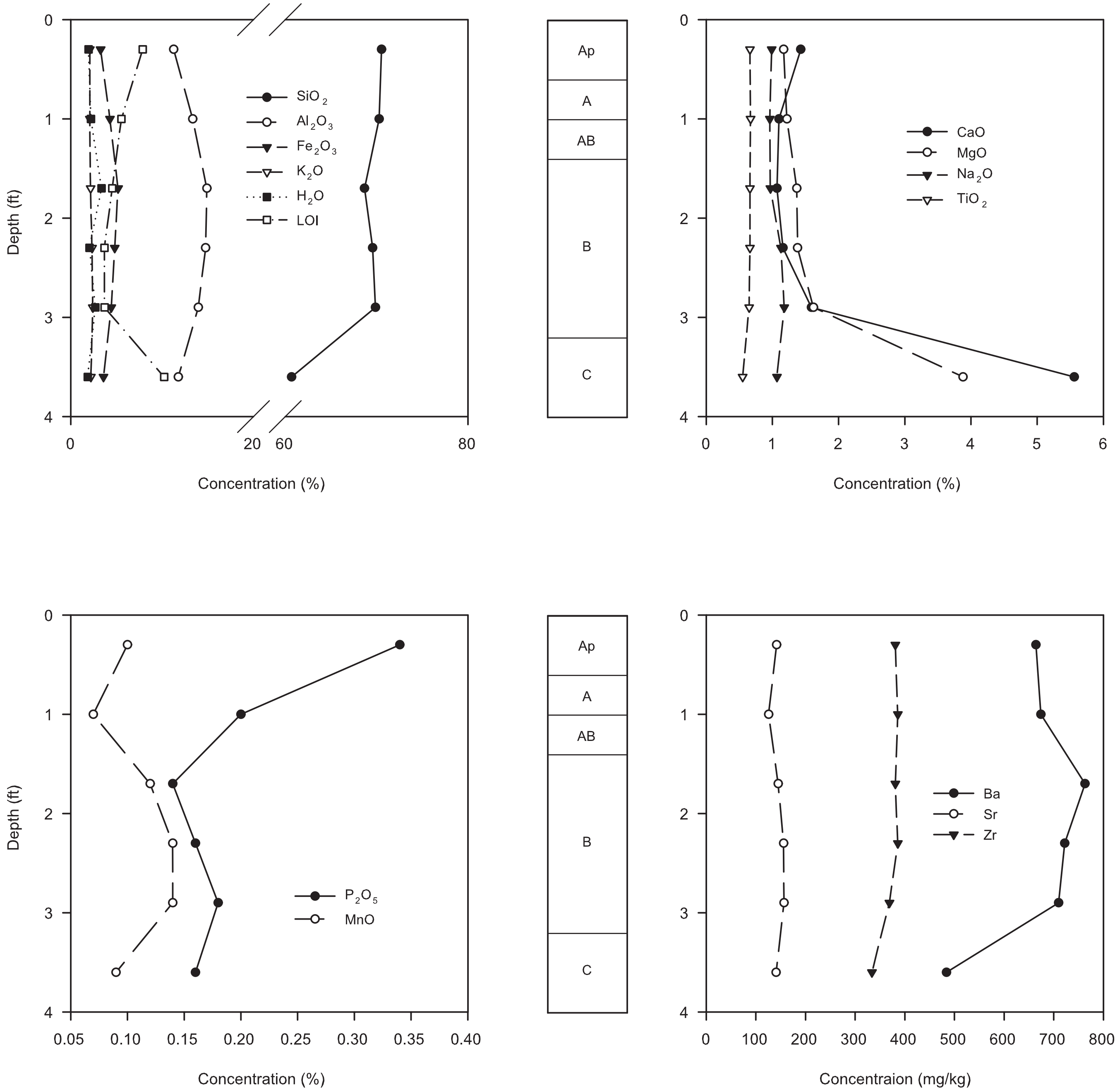


Figure 30. Element concentrations versus depth in core 114.

Core 114

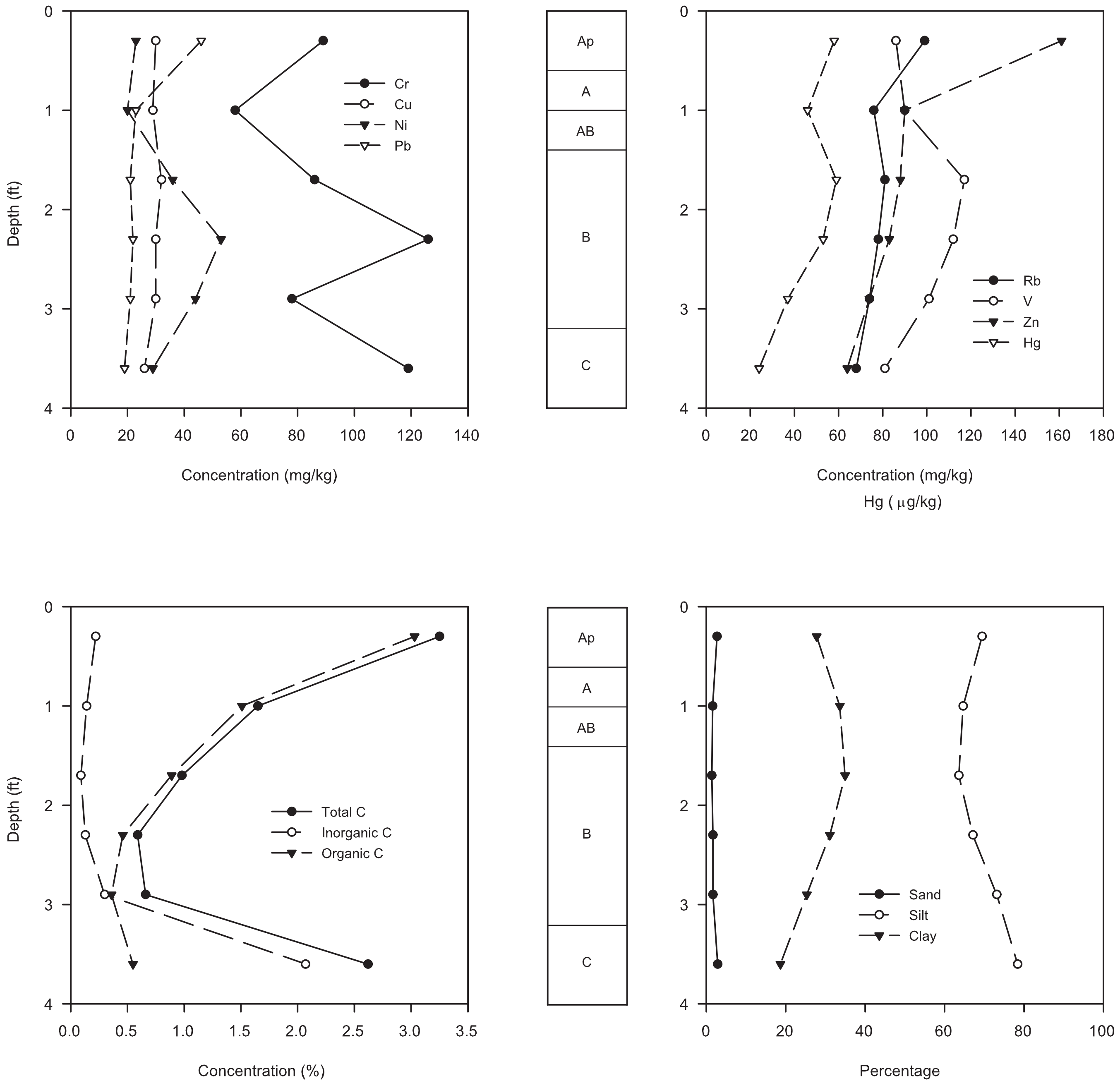


Figure 31. Element concentrations versus depth in core 114.

Core 115

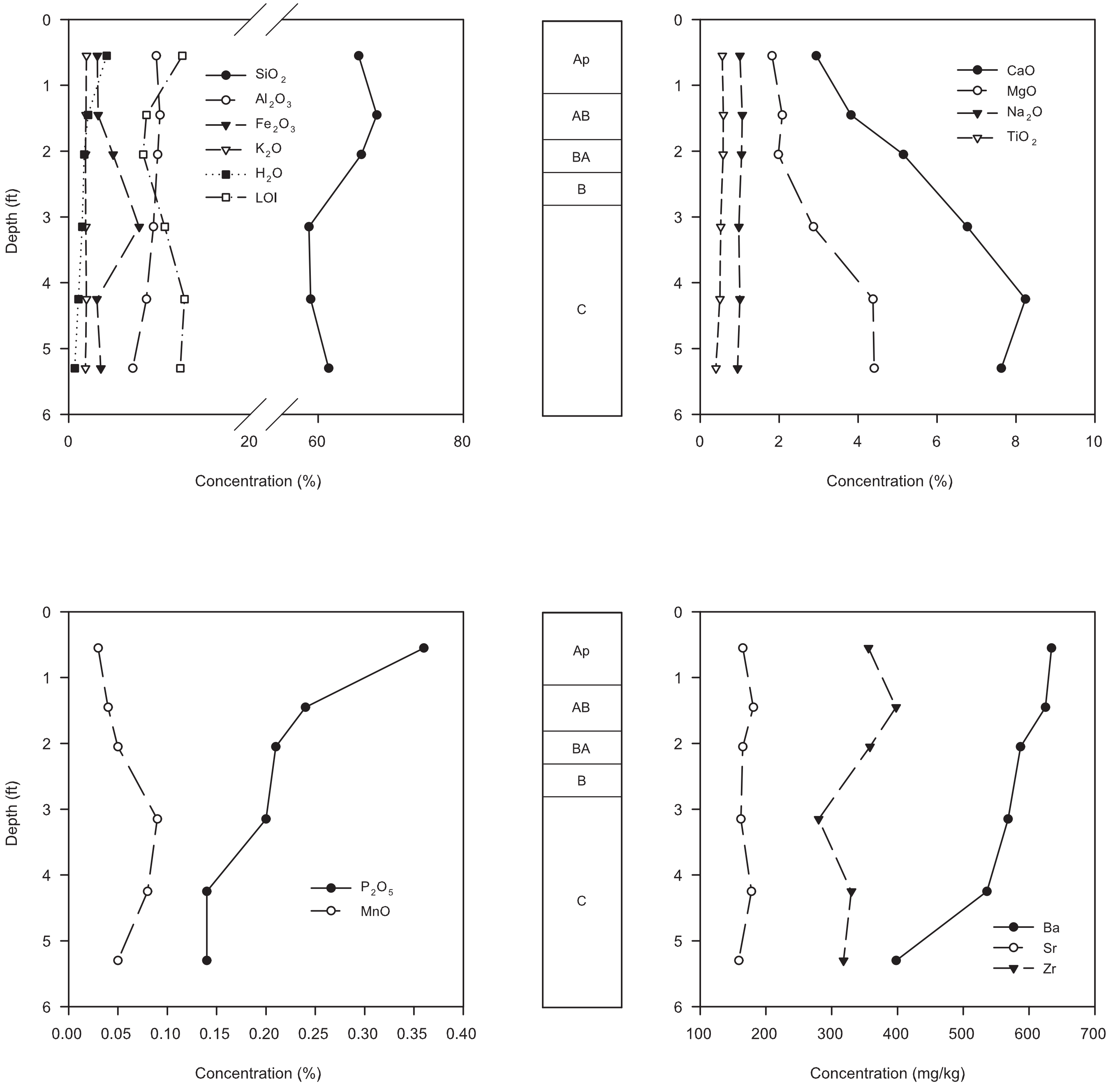


Figure 32. Element concentrations versus depth in core 115.

Core 115

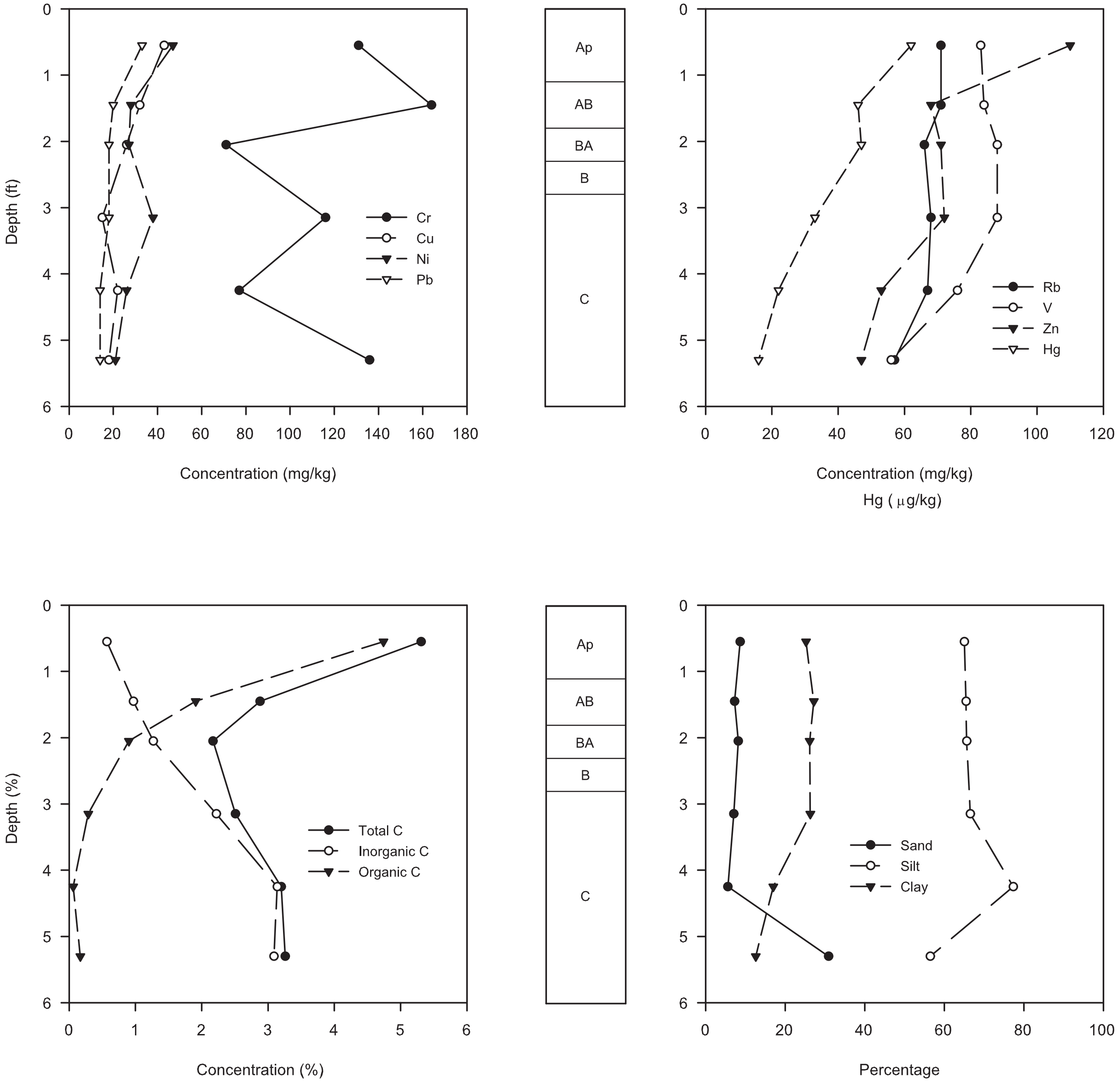


Figure 33. Element concentrations versus depth in core 115.

Core 116

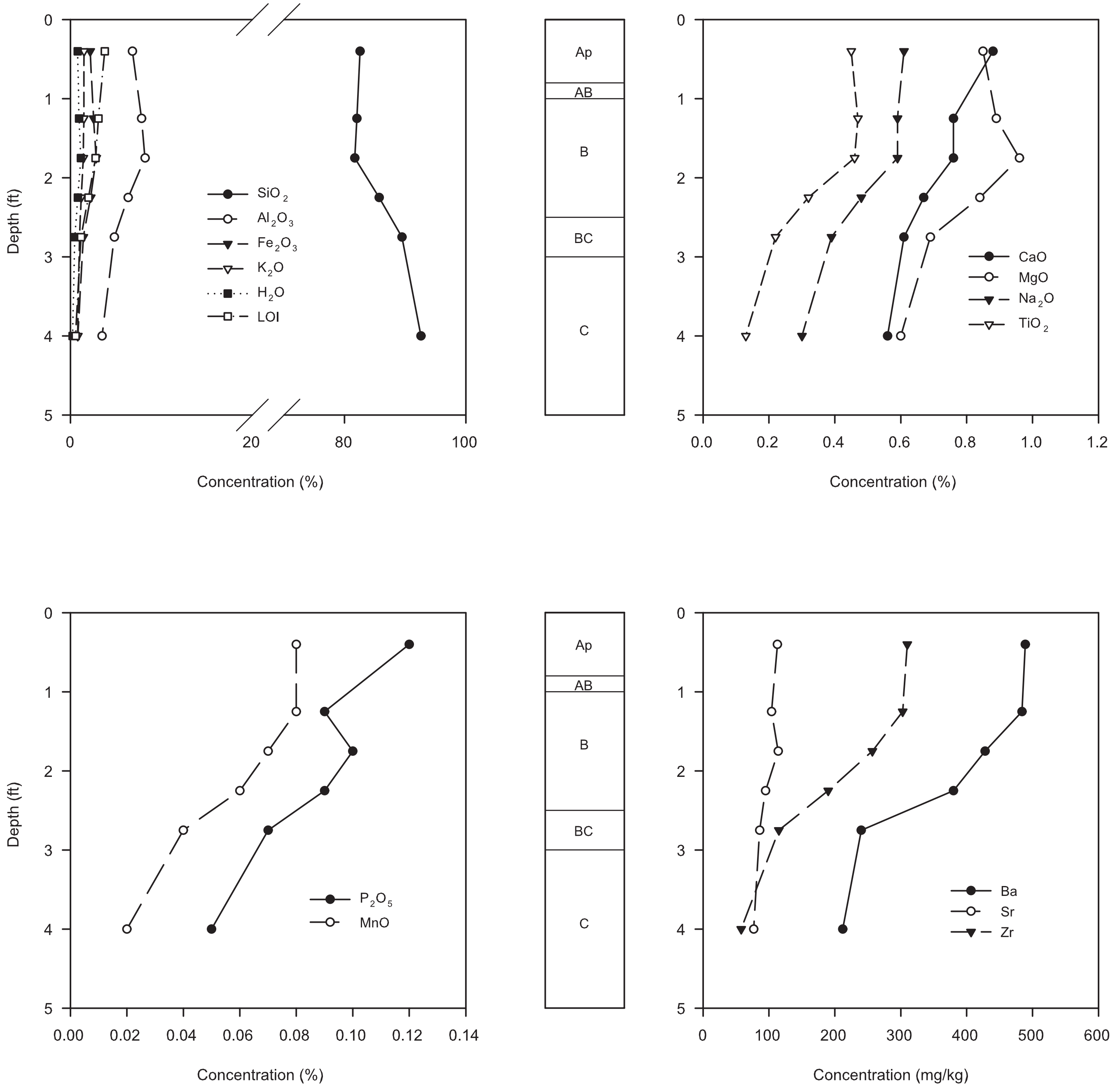


Figure 34. Element concentrations versus depth in core 116.

Core 116

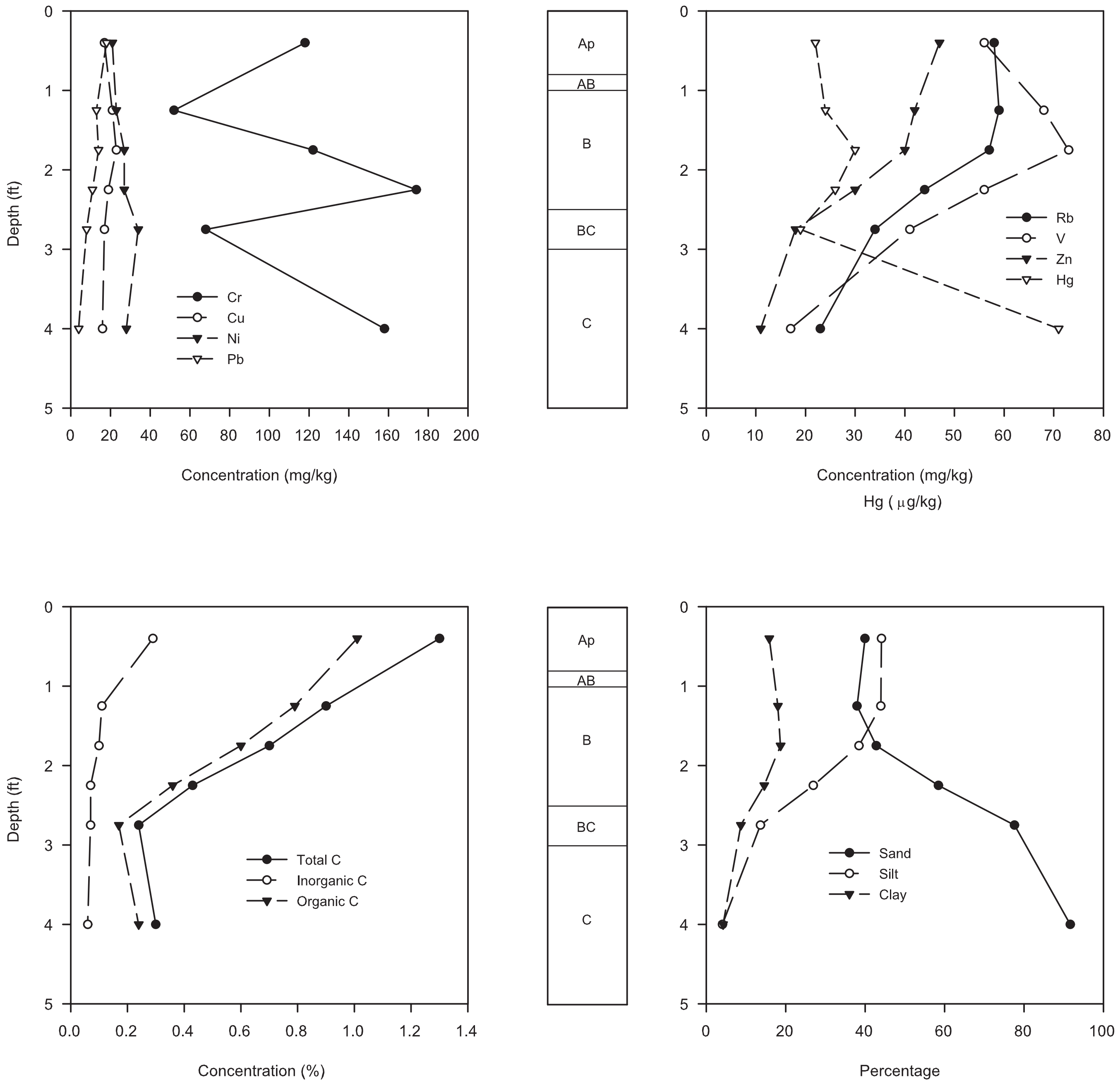


Figure 35. Element concentrations versus depth in core 116.

Core 117

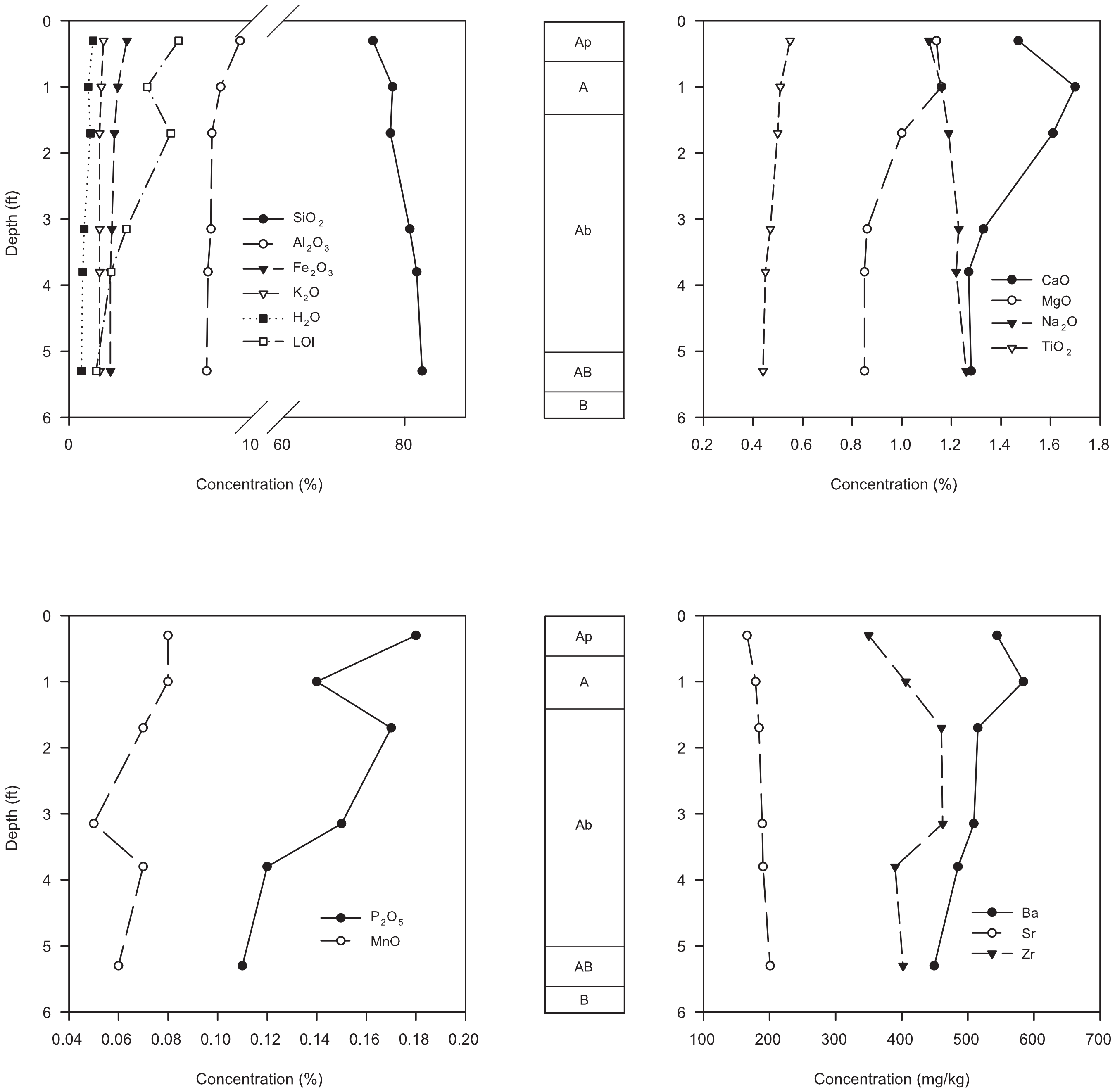


Figure 36. Element concentrations versus depth in core 117.

Core 117

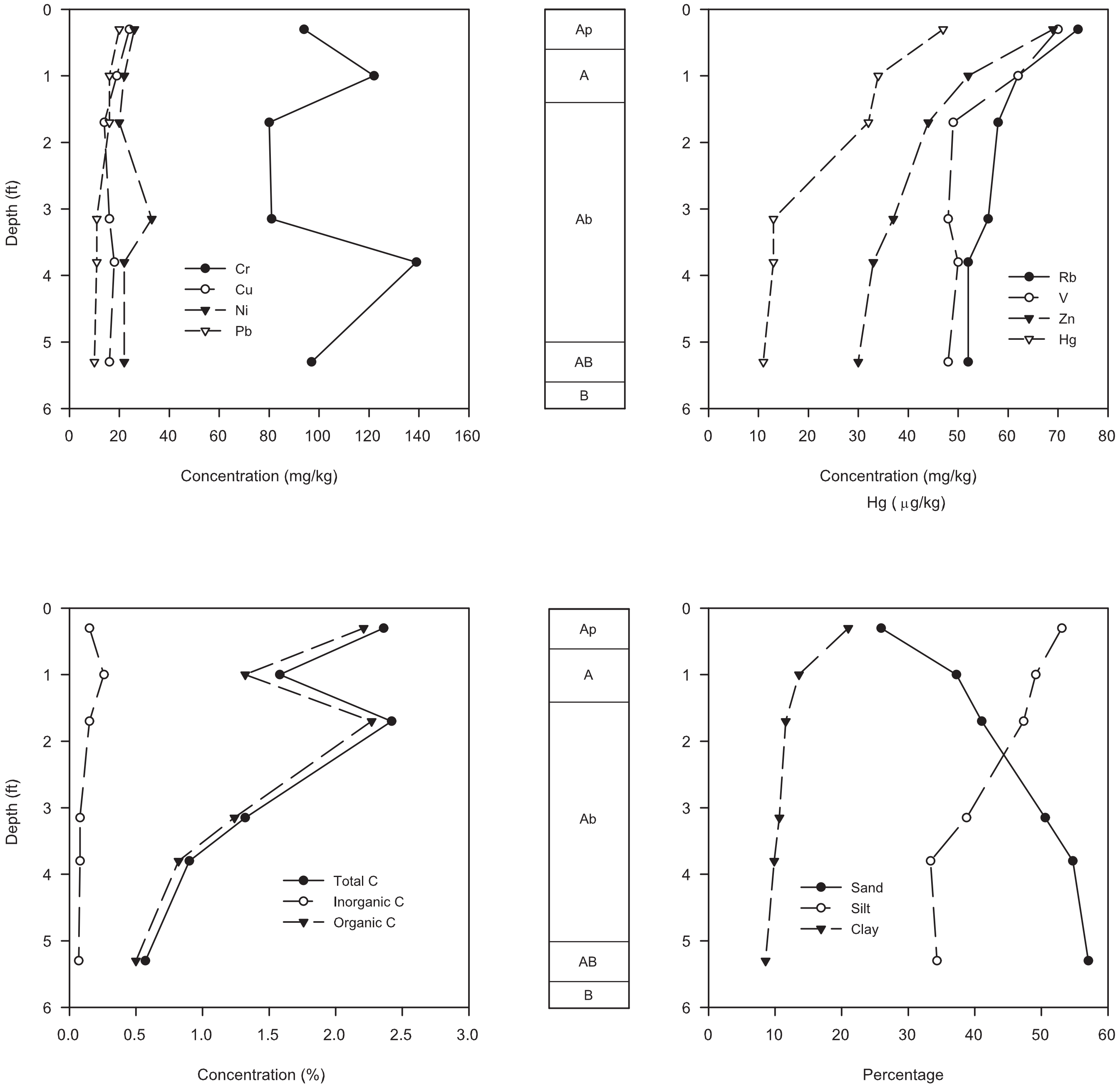


Figure 37. Element concentrations versus depth in core 117.

Core 118

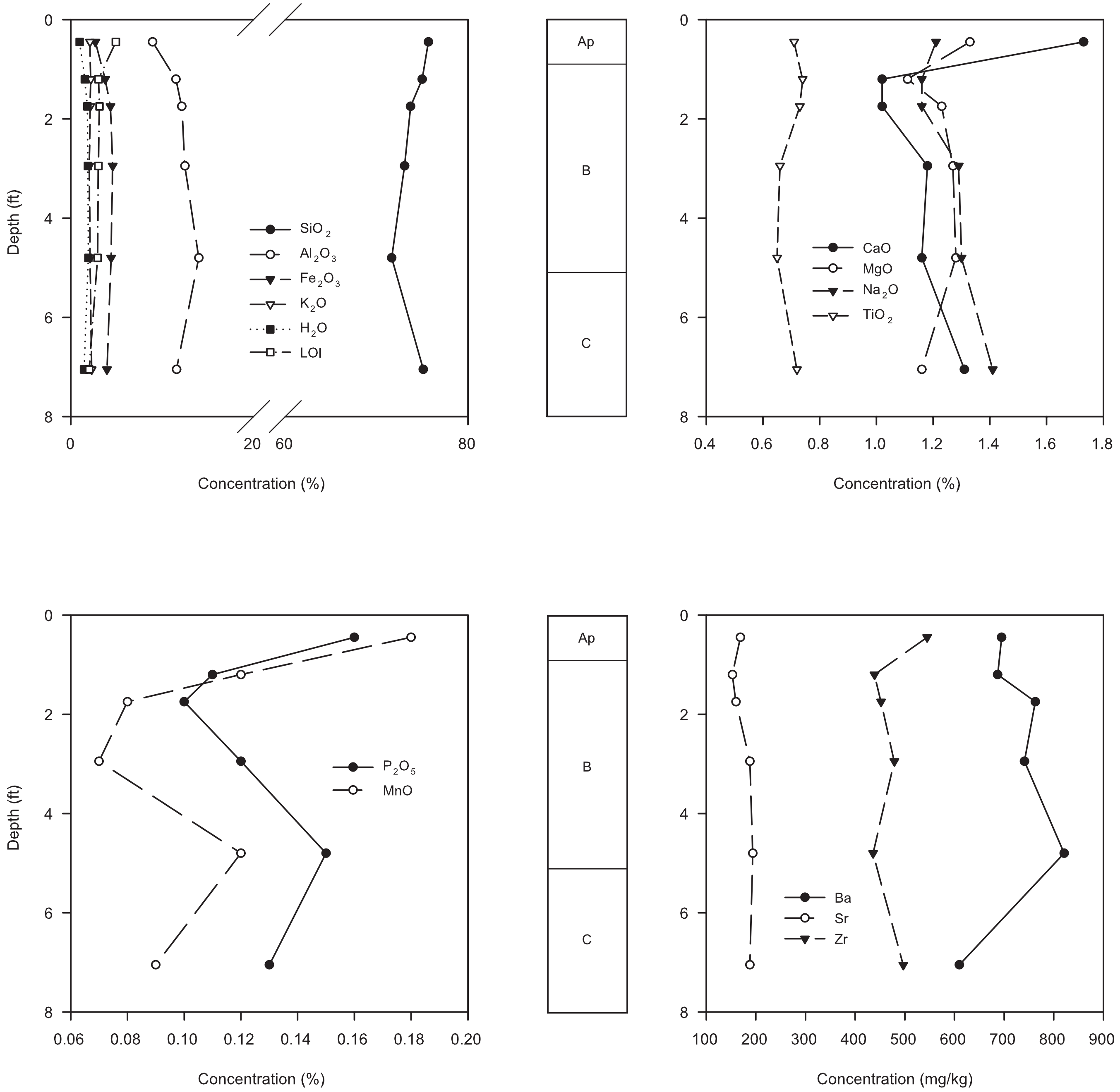


Figure 38. Element concentrations versus depth in core 118.

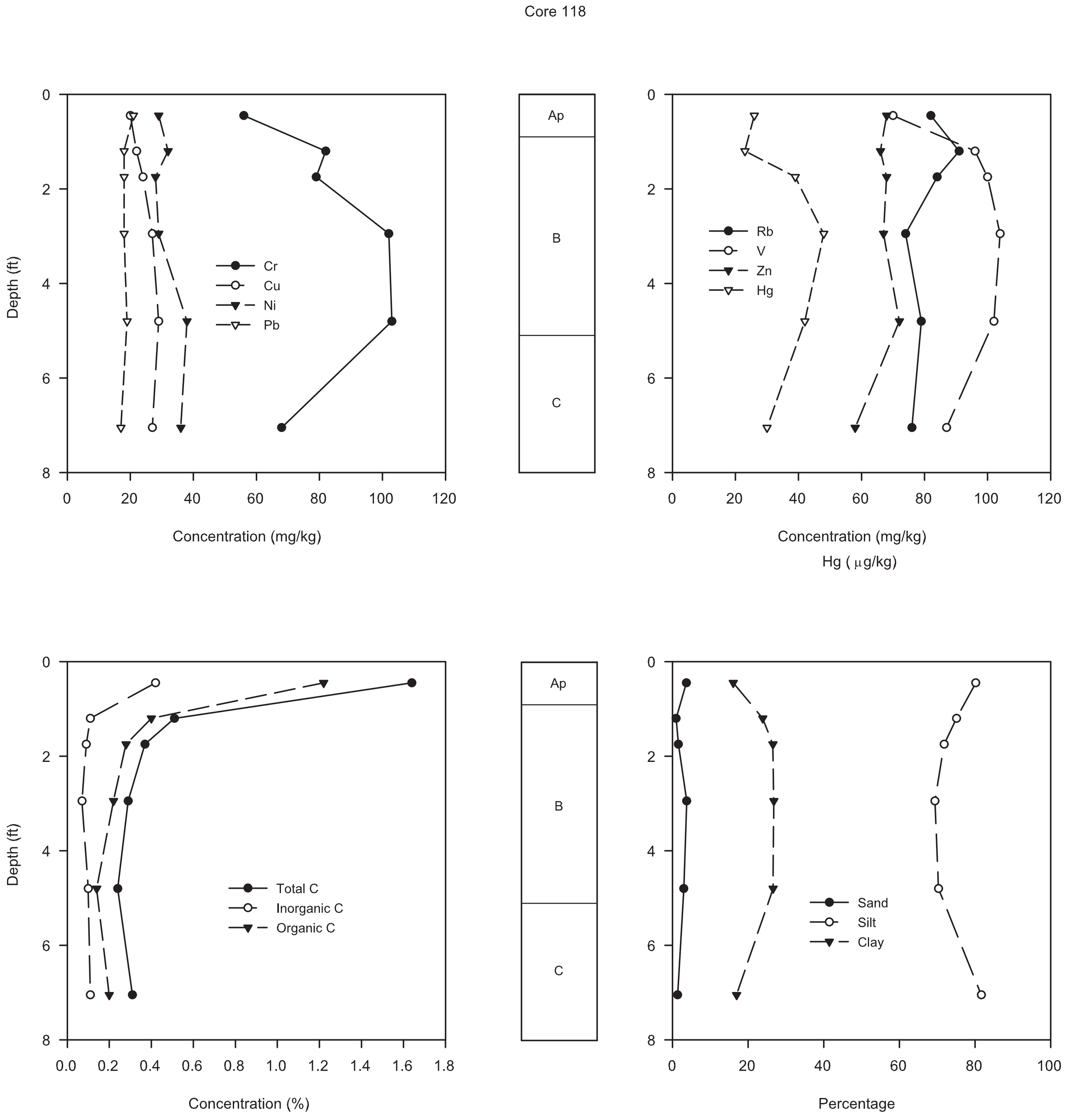


Figure 39. Element concentrations versus depth in core 118.

Core 119

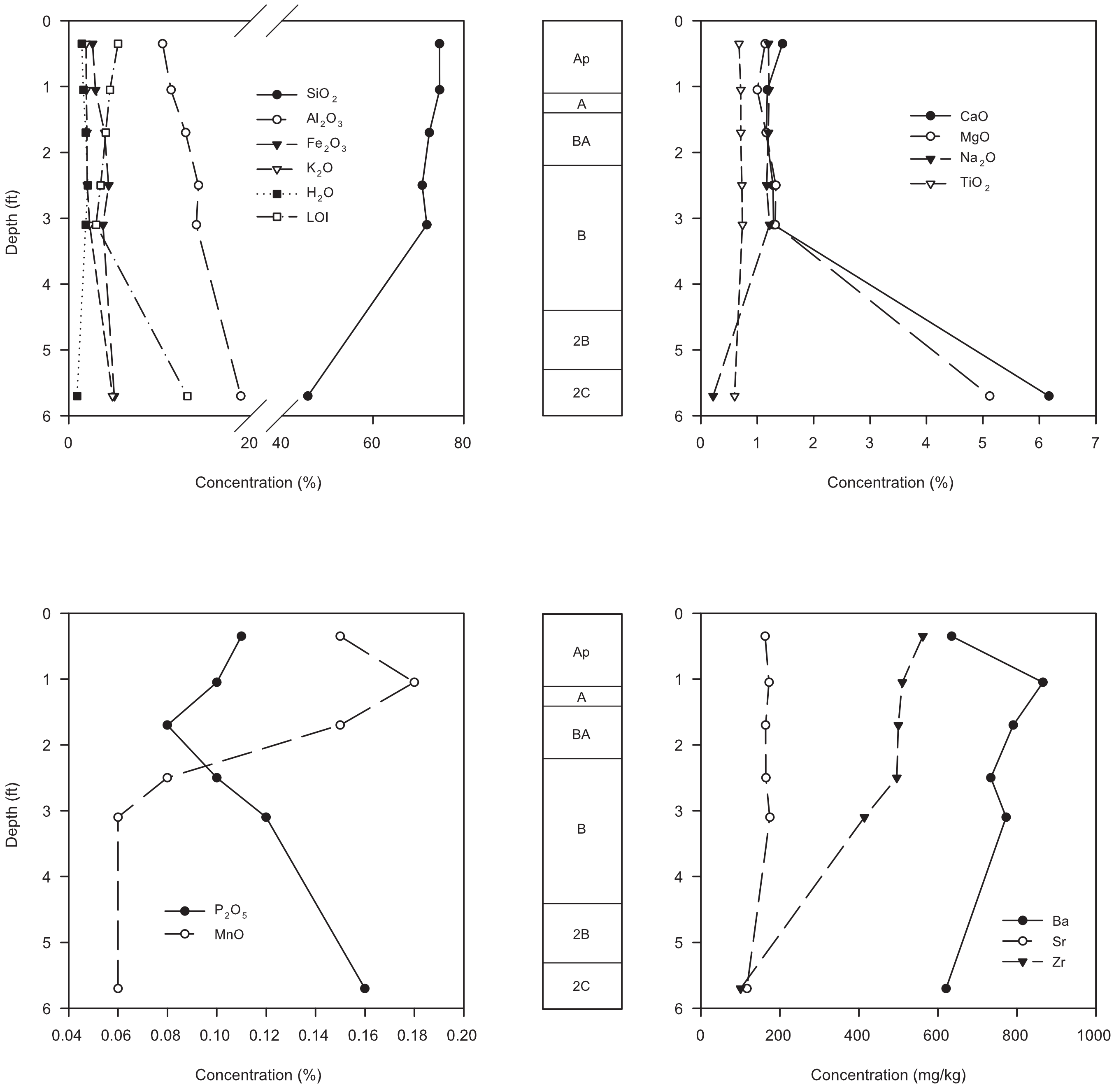


Figure 40. Element concentrations versus depth in core 119.

Core 119

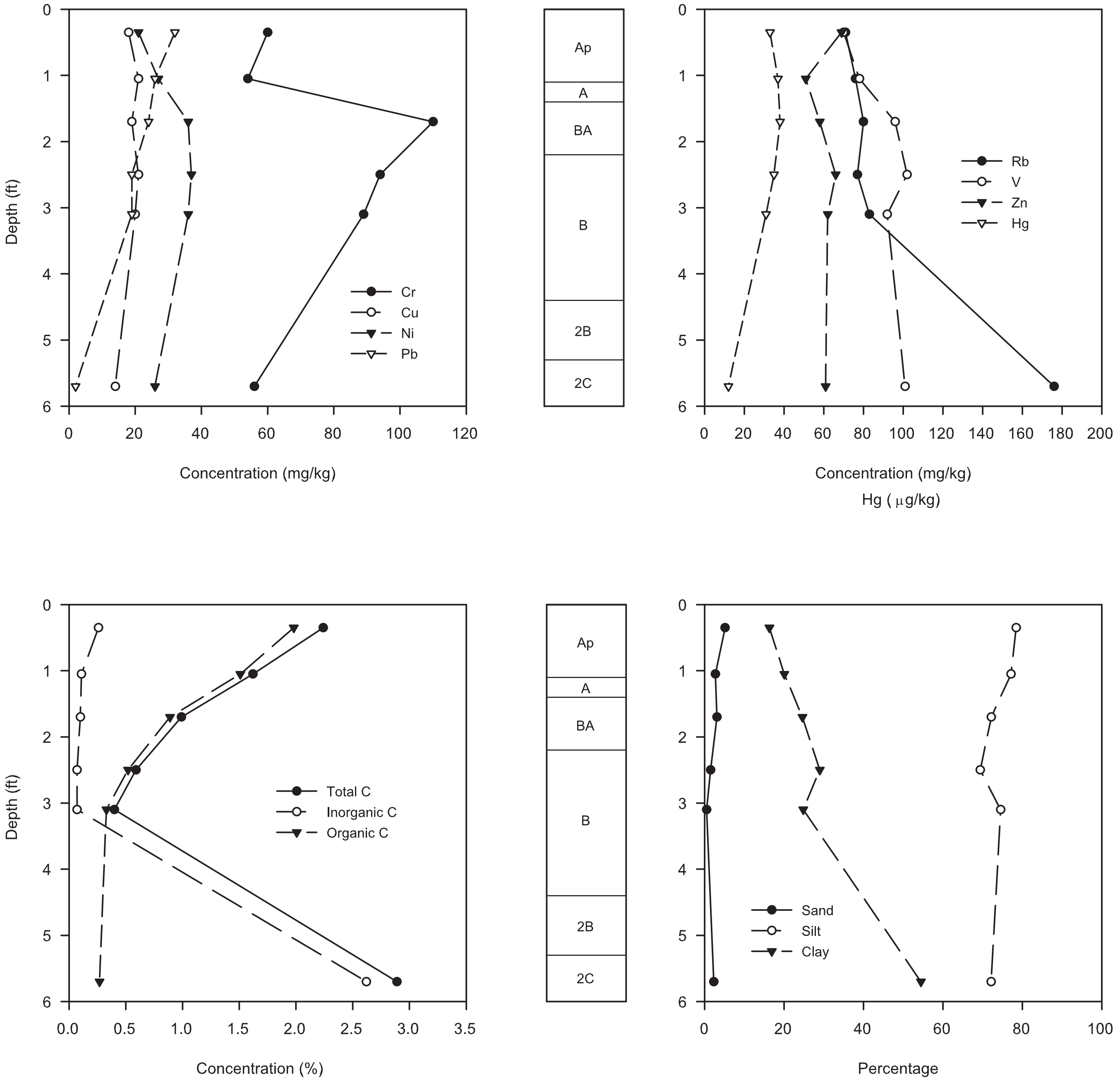


Figure 41. Element concentrations versus depth in core 119.

Core 120

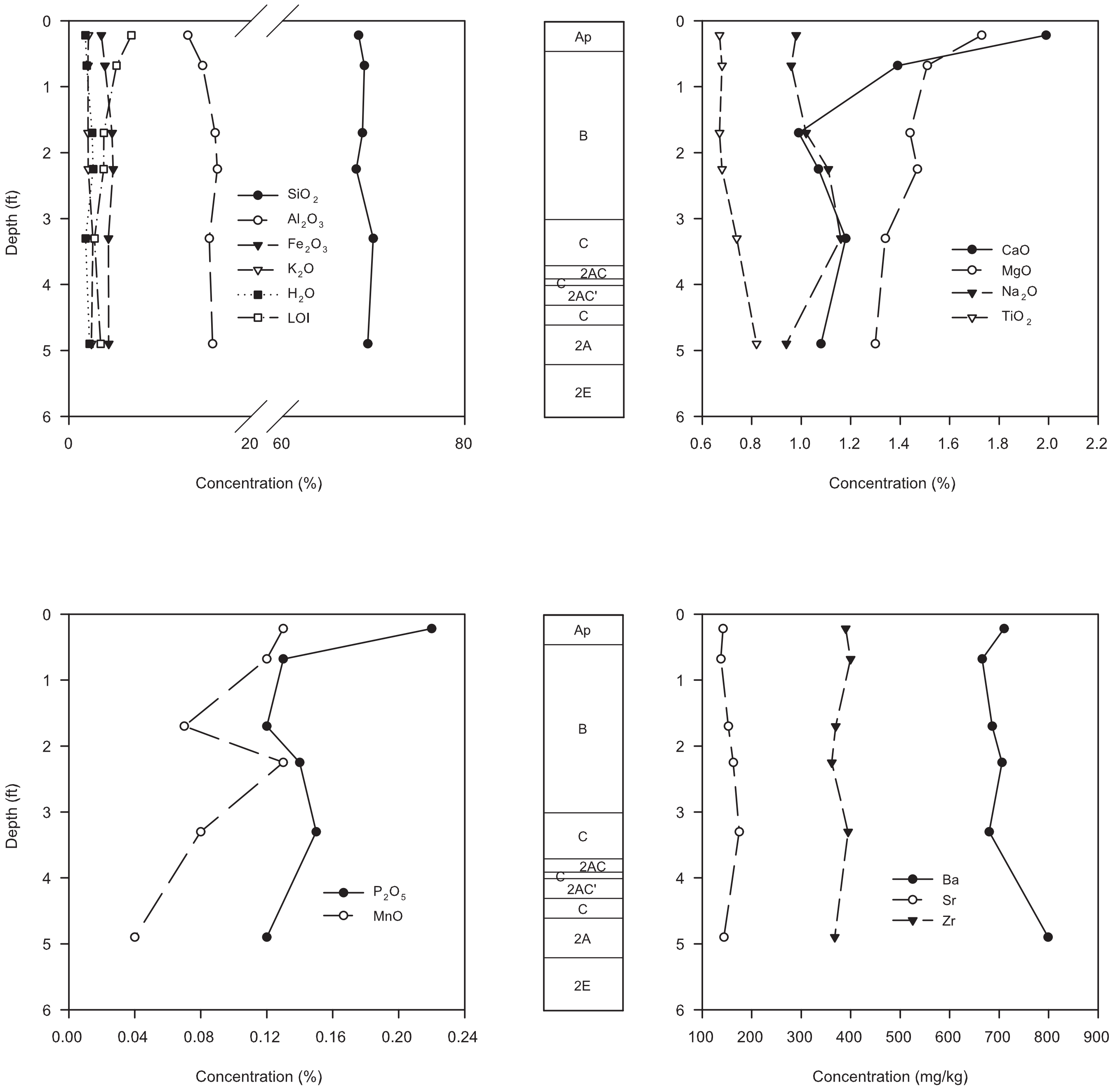


Figure 42. Element concentrations versus depth in core 120.

Core 120

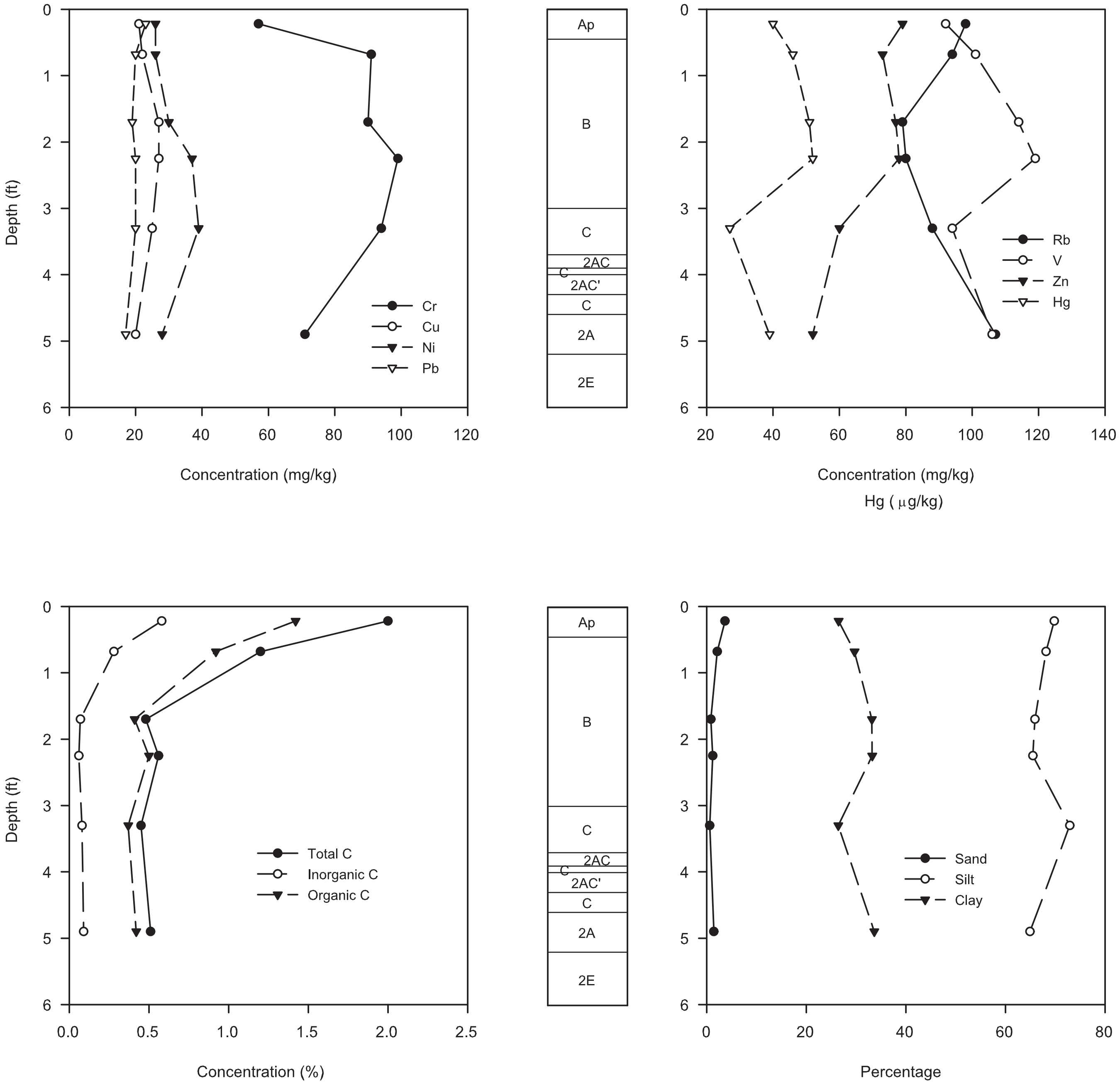


Figure 43. Element concentrations versus depth in core 120.

Core 121

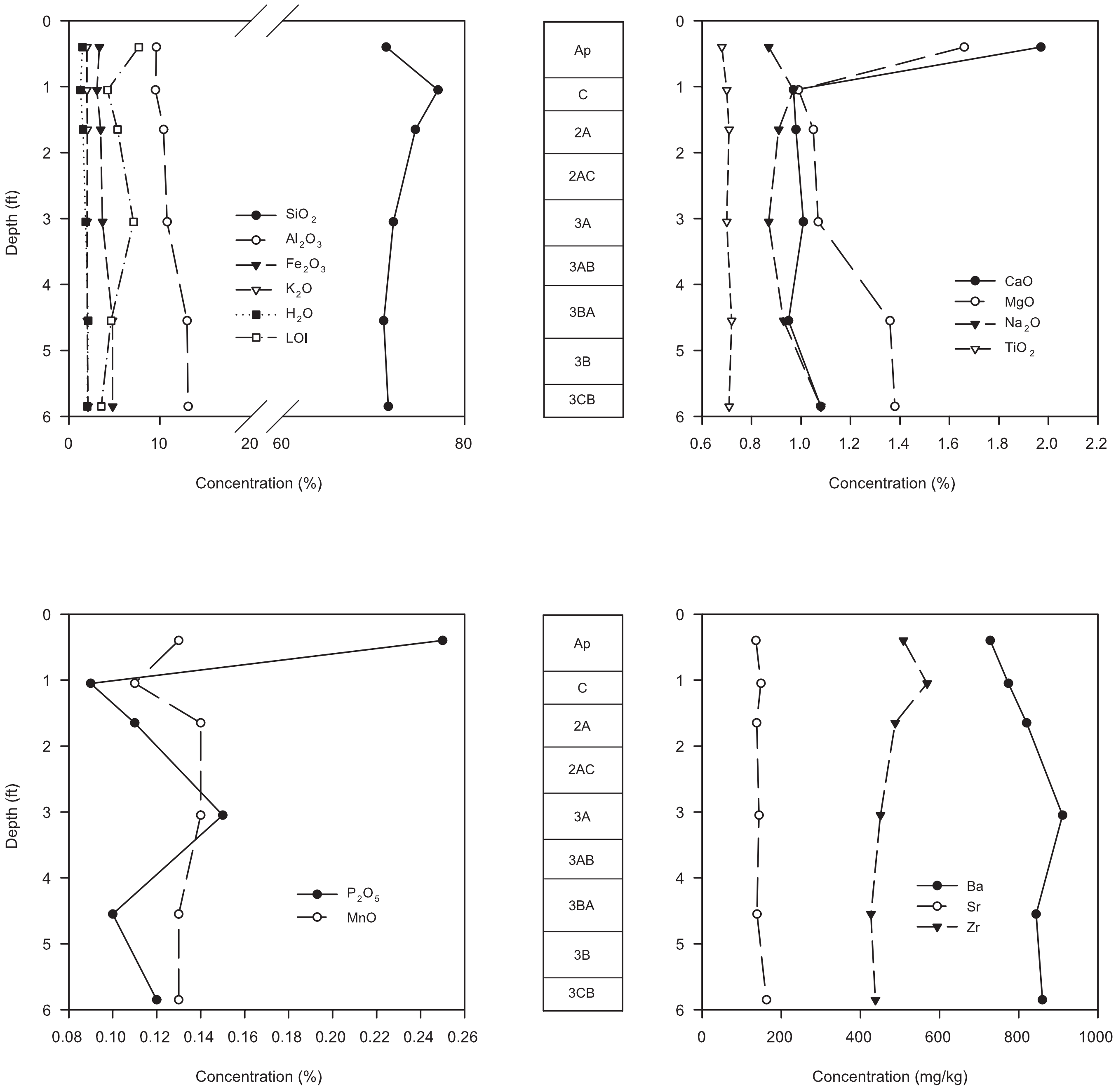


Figure 44. Element concentrations versus depth in core 121.

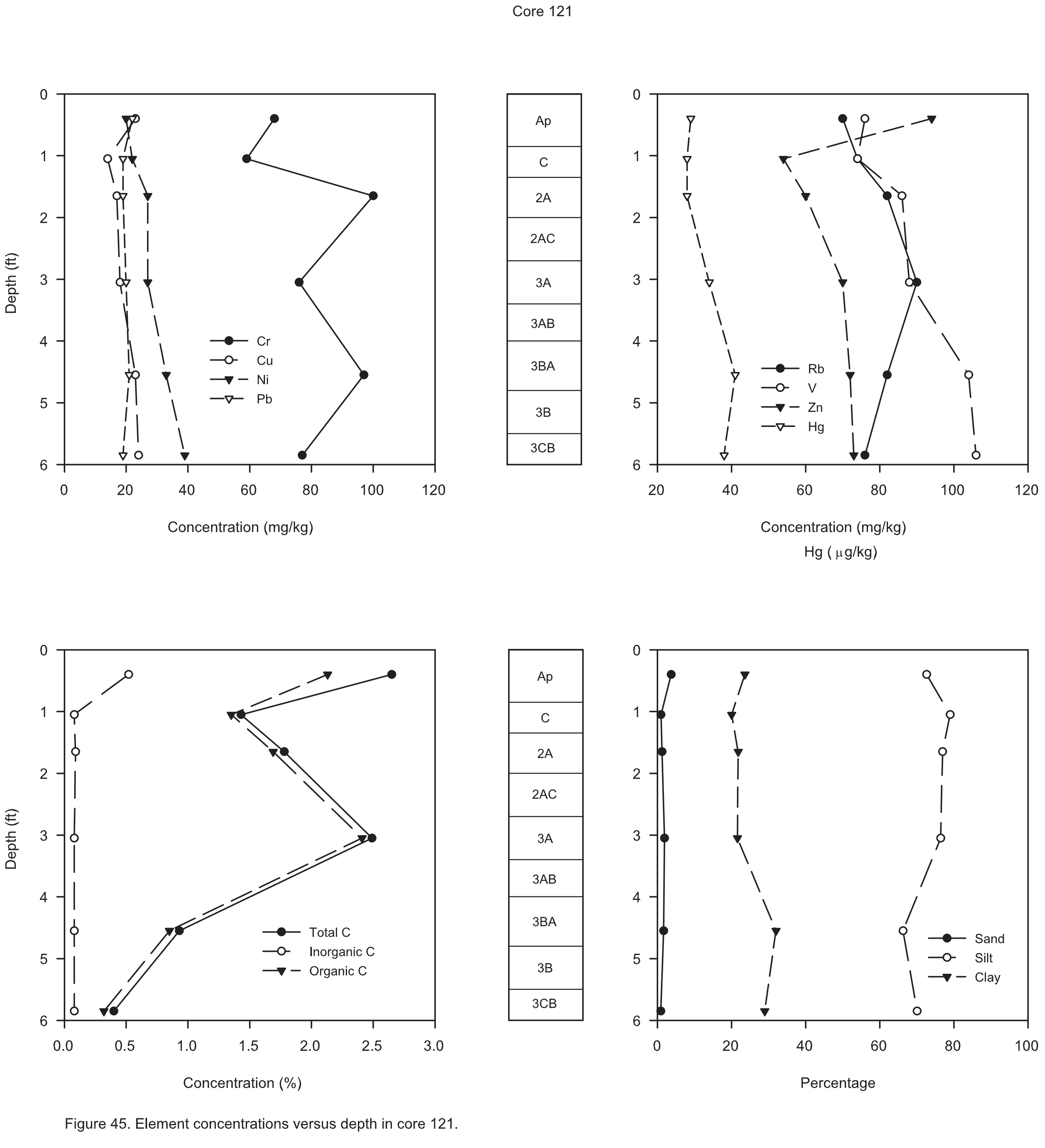


Figure 45. Element concentrations versus depth in core 121.

Core 122

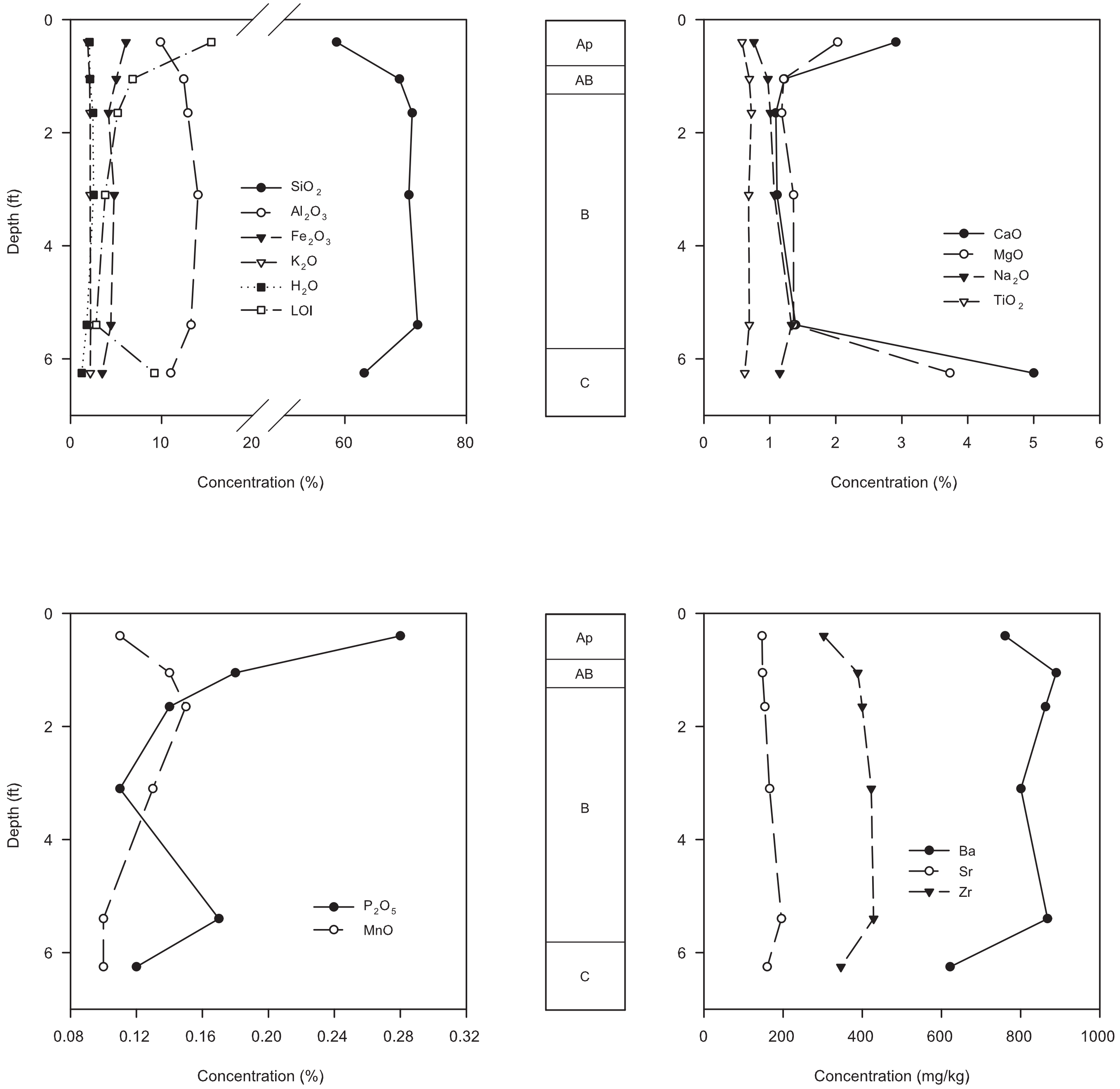


Figure 46. Element concentrations versus depth in core 122.

Core 122

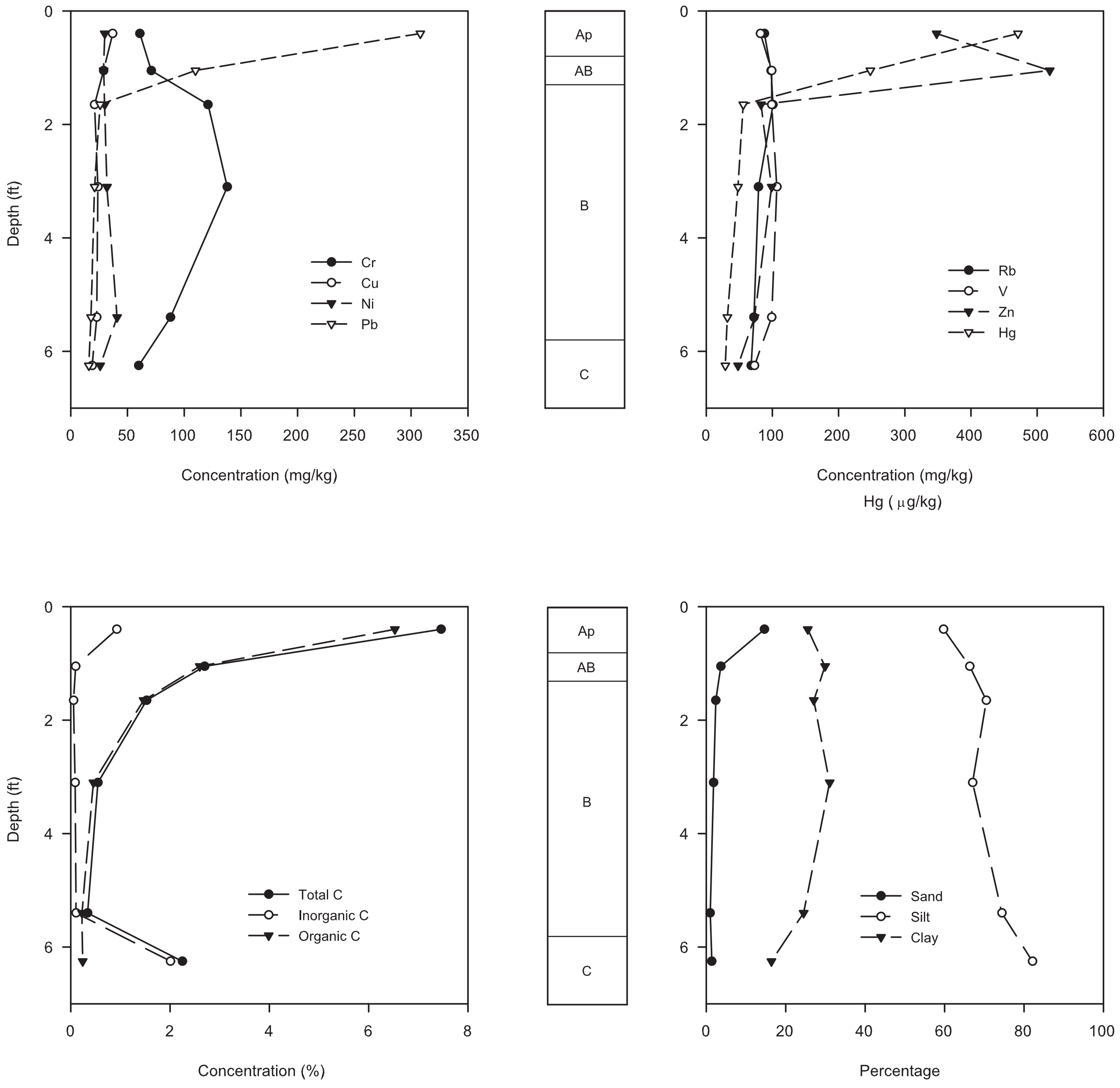


Figure 47. Element concentrations versus depth in core 122.

Core 123

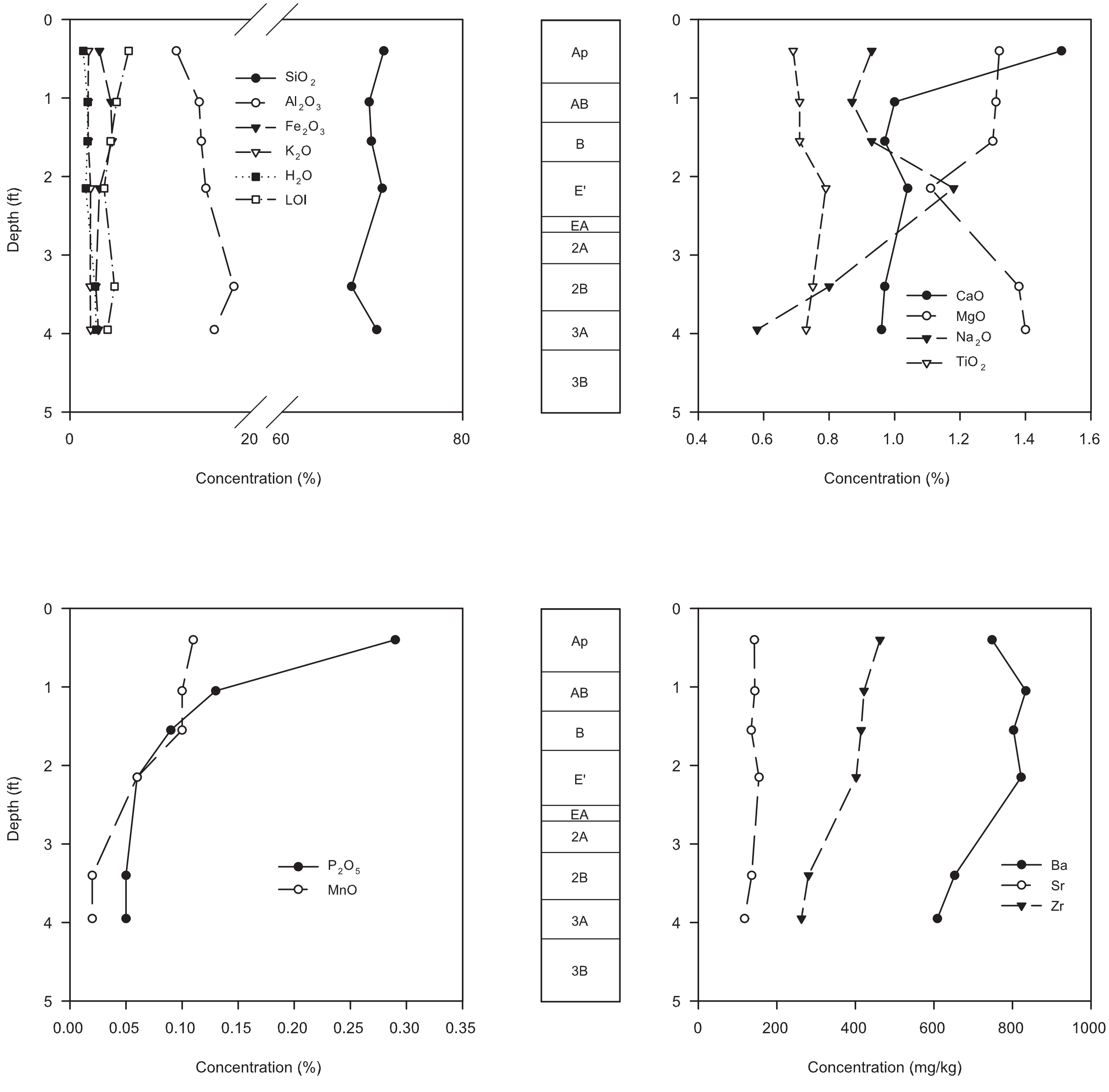


Figure 48. Element concentrations versus depth in core 123.

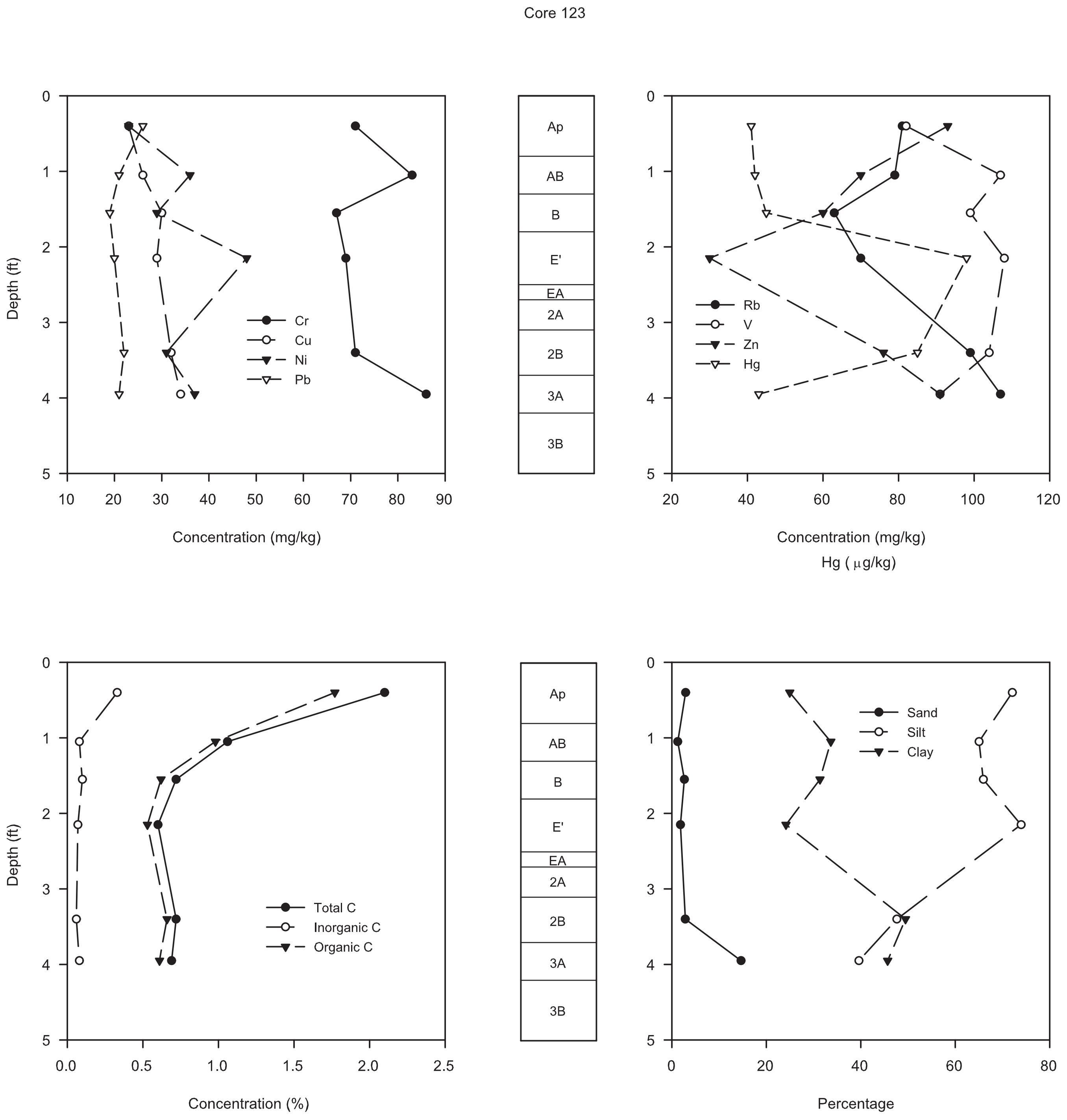


Figure 49. Element concentrations versus depth in core 123.

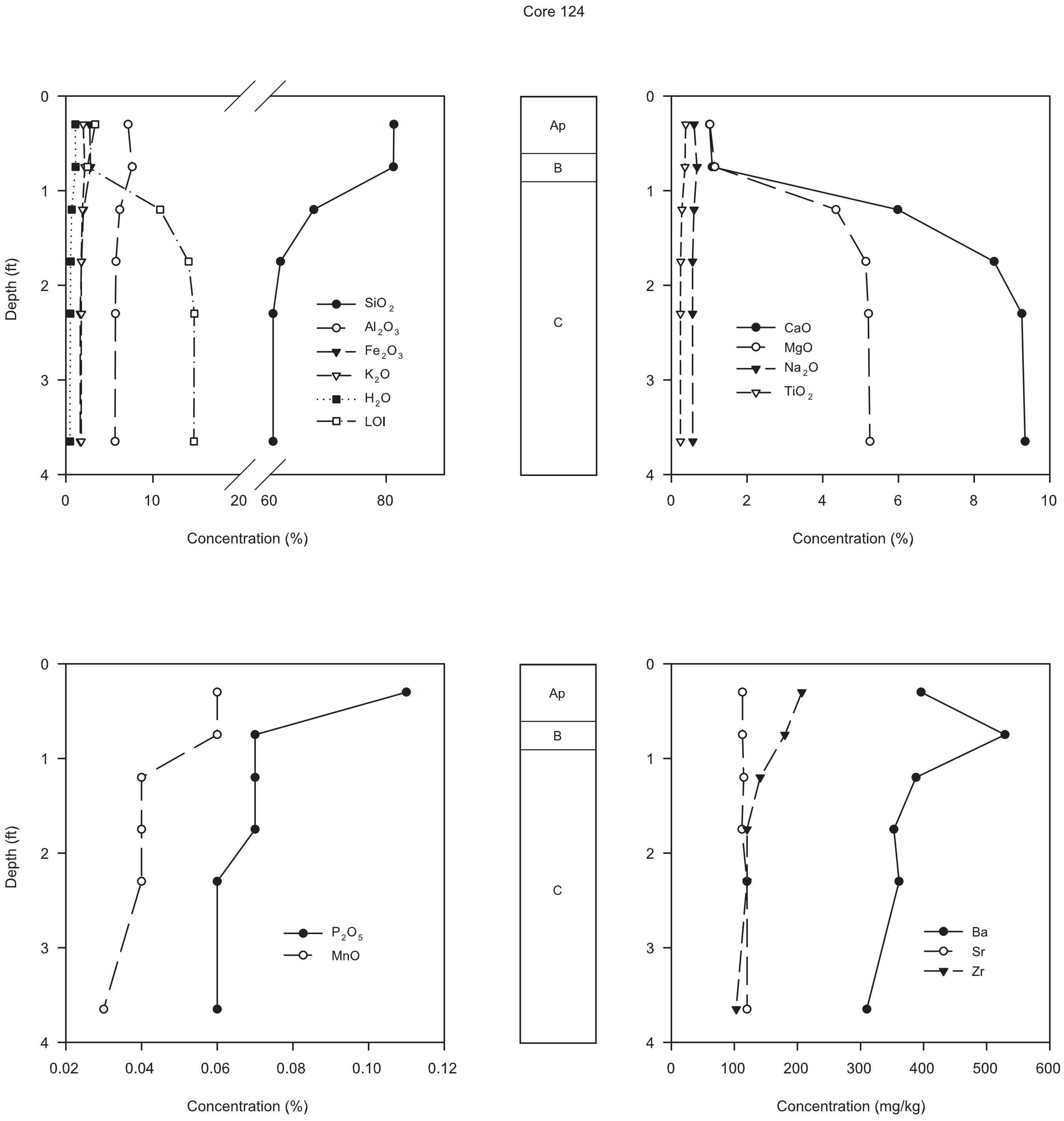


Figure 50. Element concentrations versus depth in core 124.

Core 124

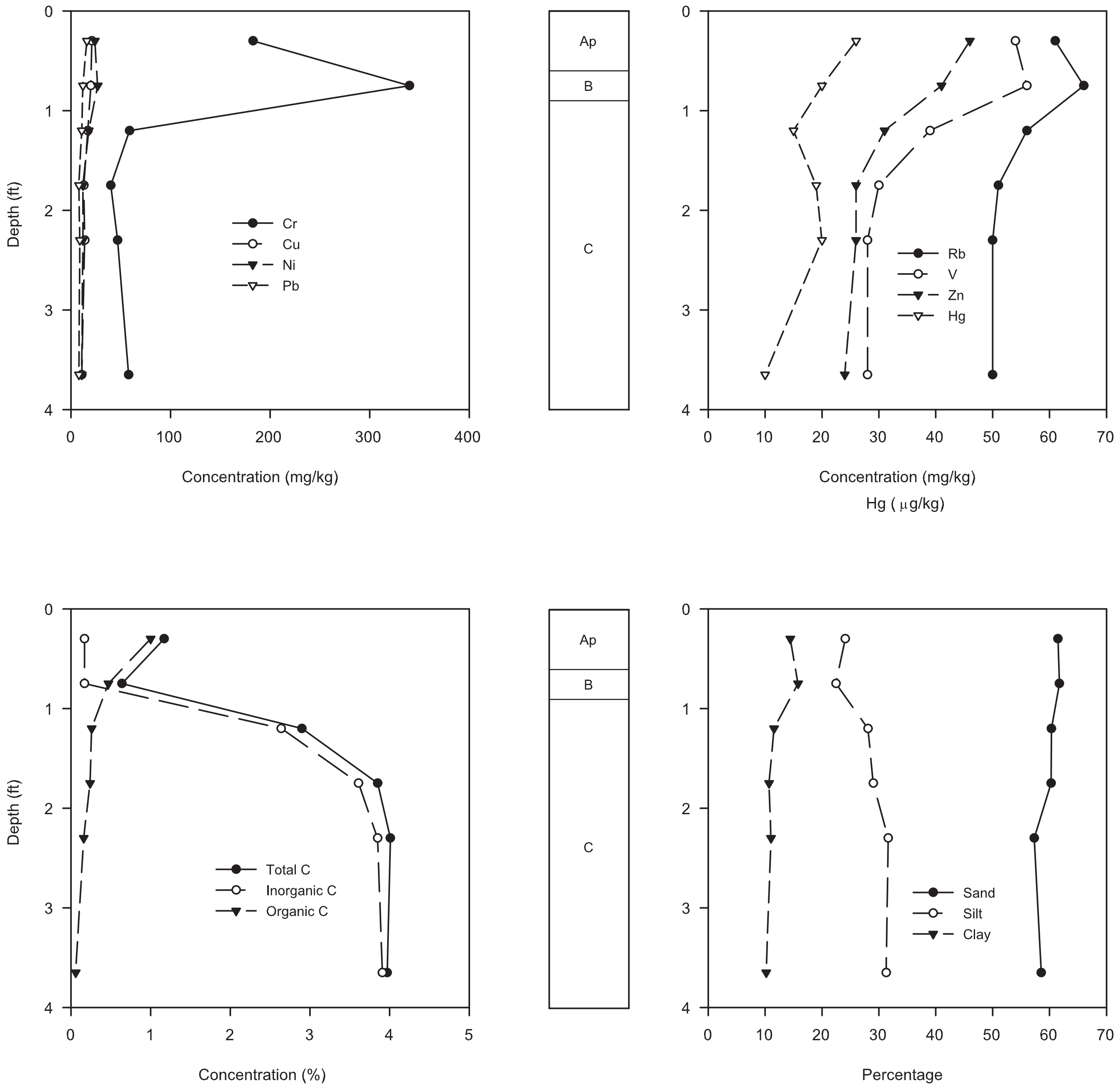


Figure 51. Element concentrations versus depth in core 124.

Core 125

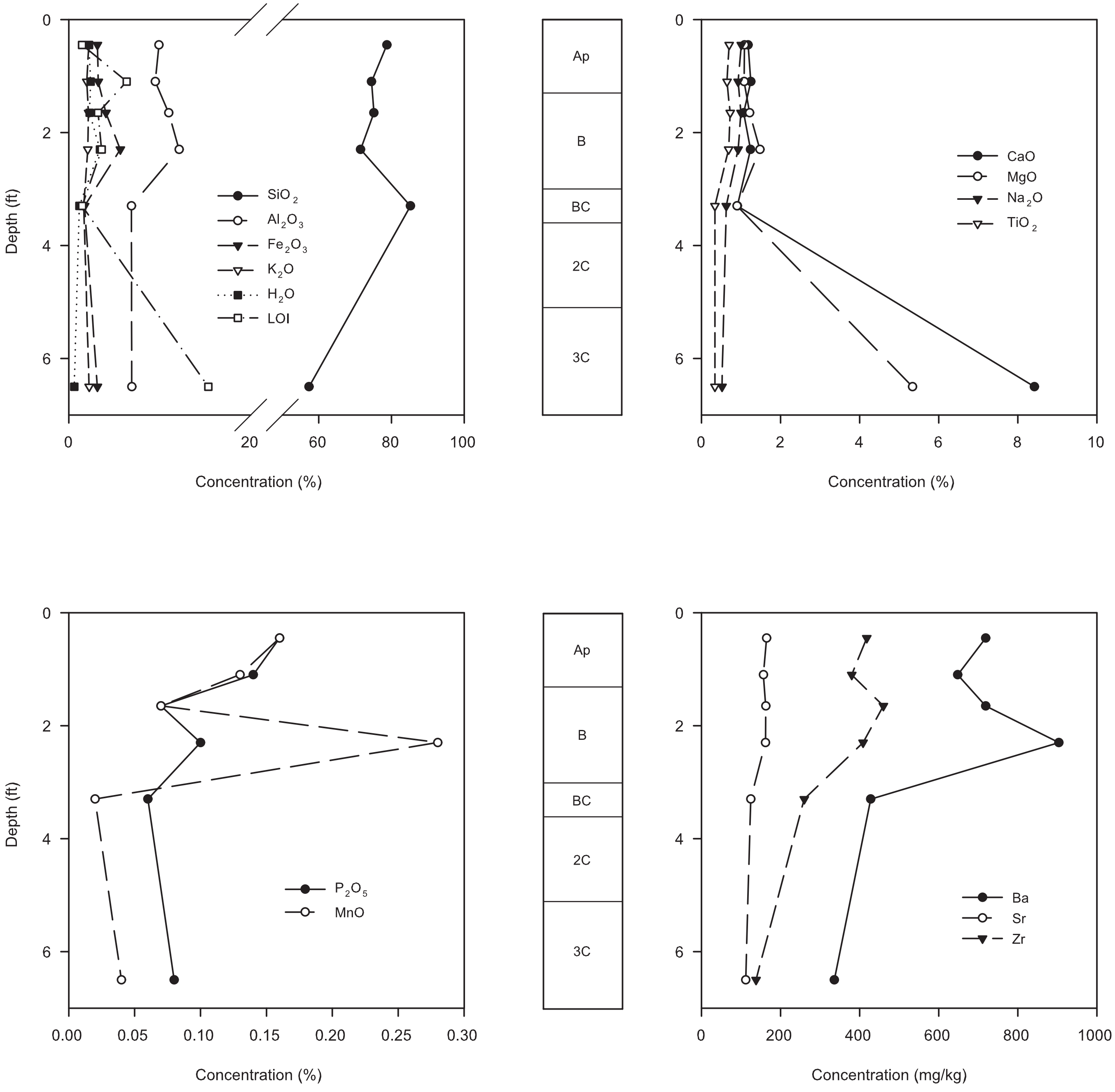


Figure 52. Element concentrations versus depth in core 125.

Core 125

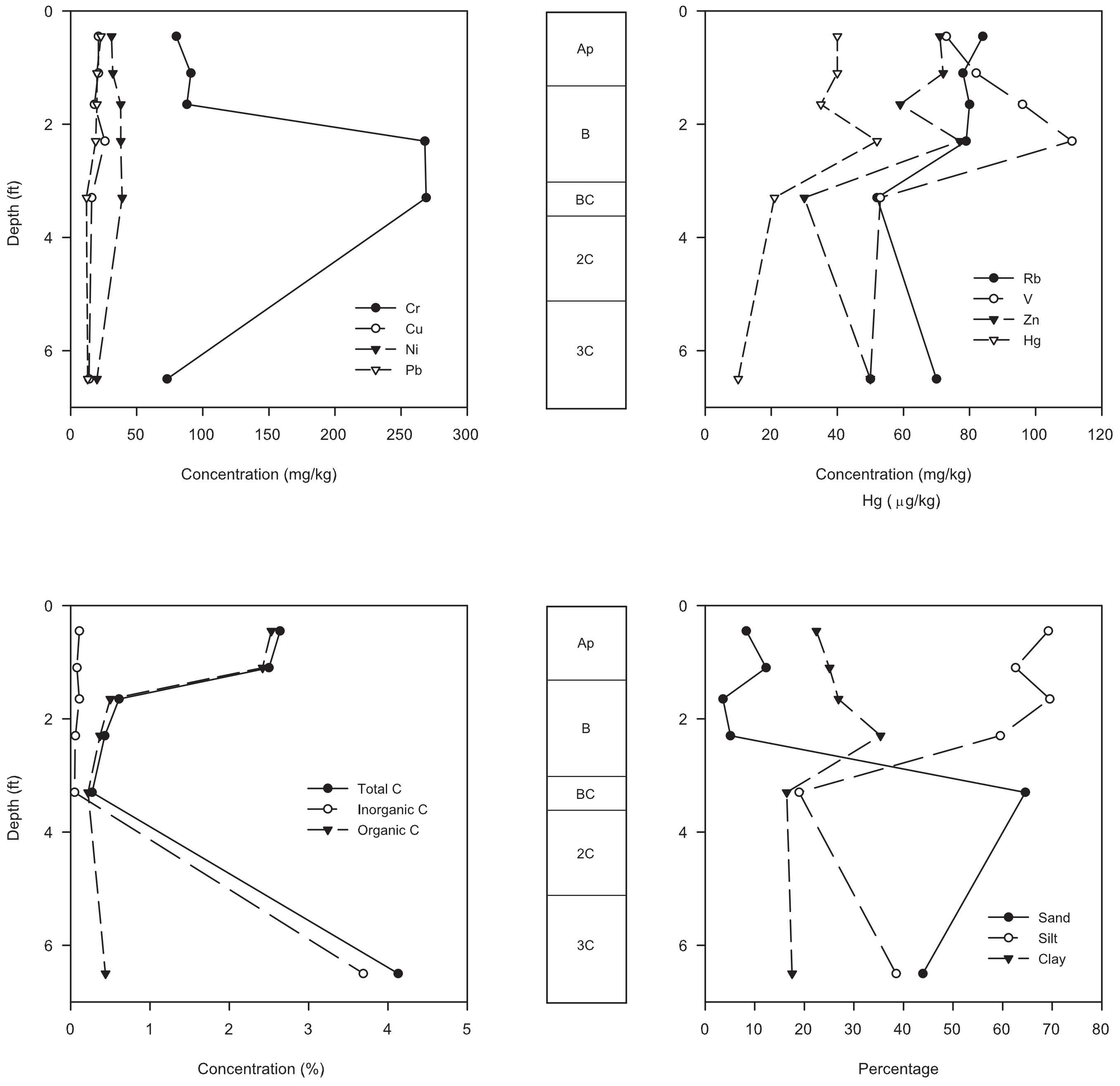


Figure 53. Element concentrations versus depth in core 125.

Core 126

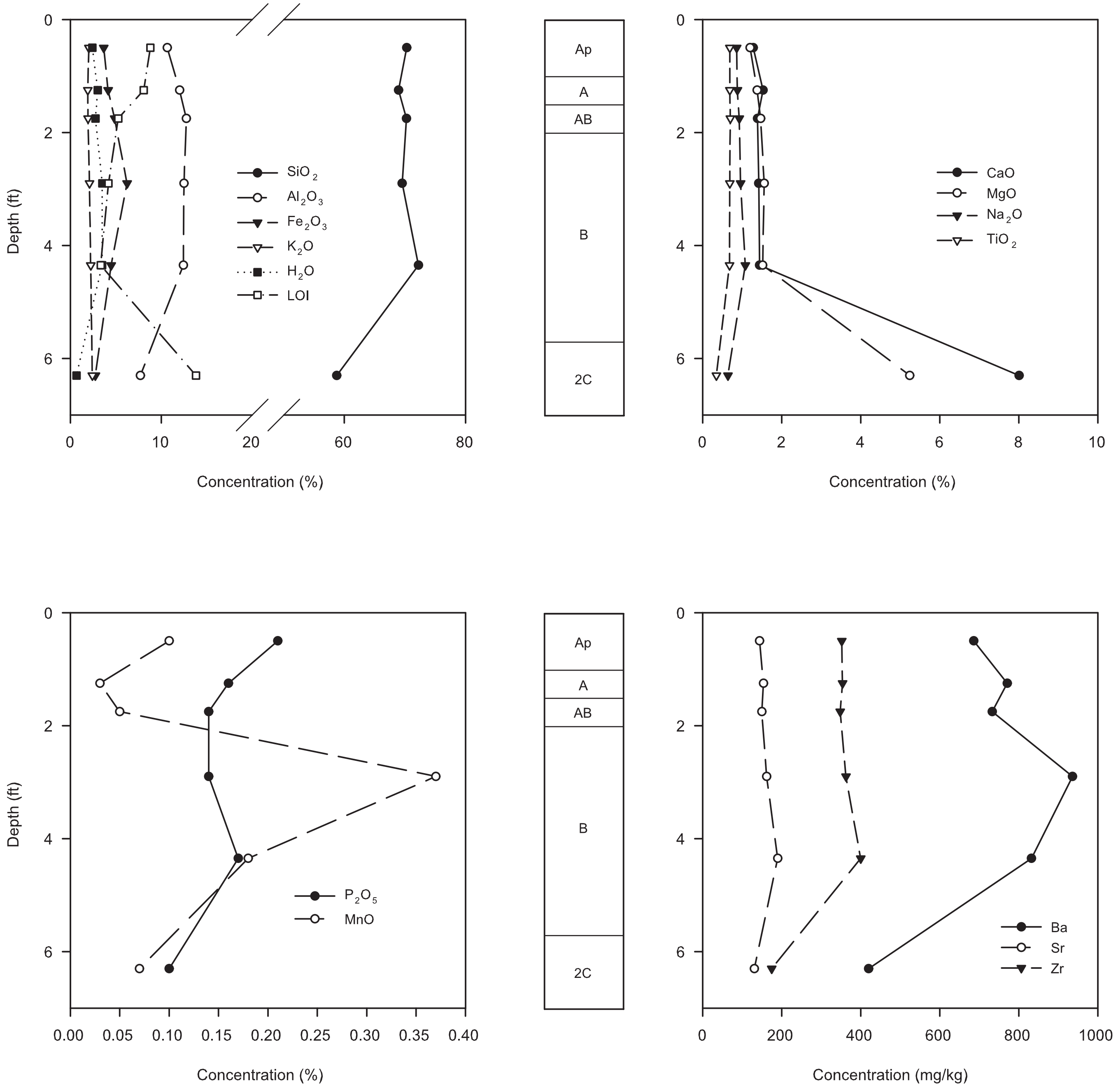


Figure 54. Element concentrations versus depth in core 126.

Core 126

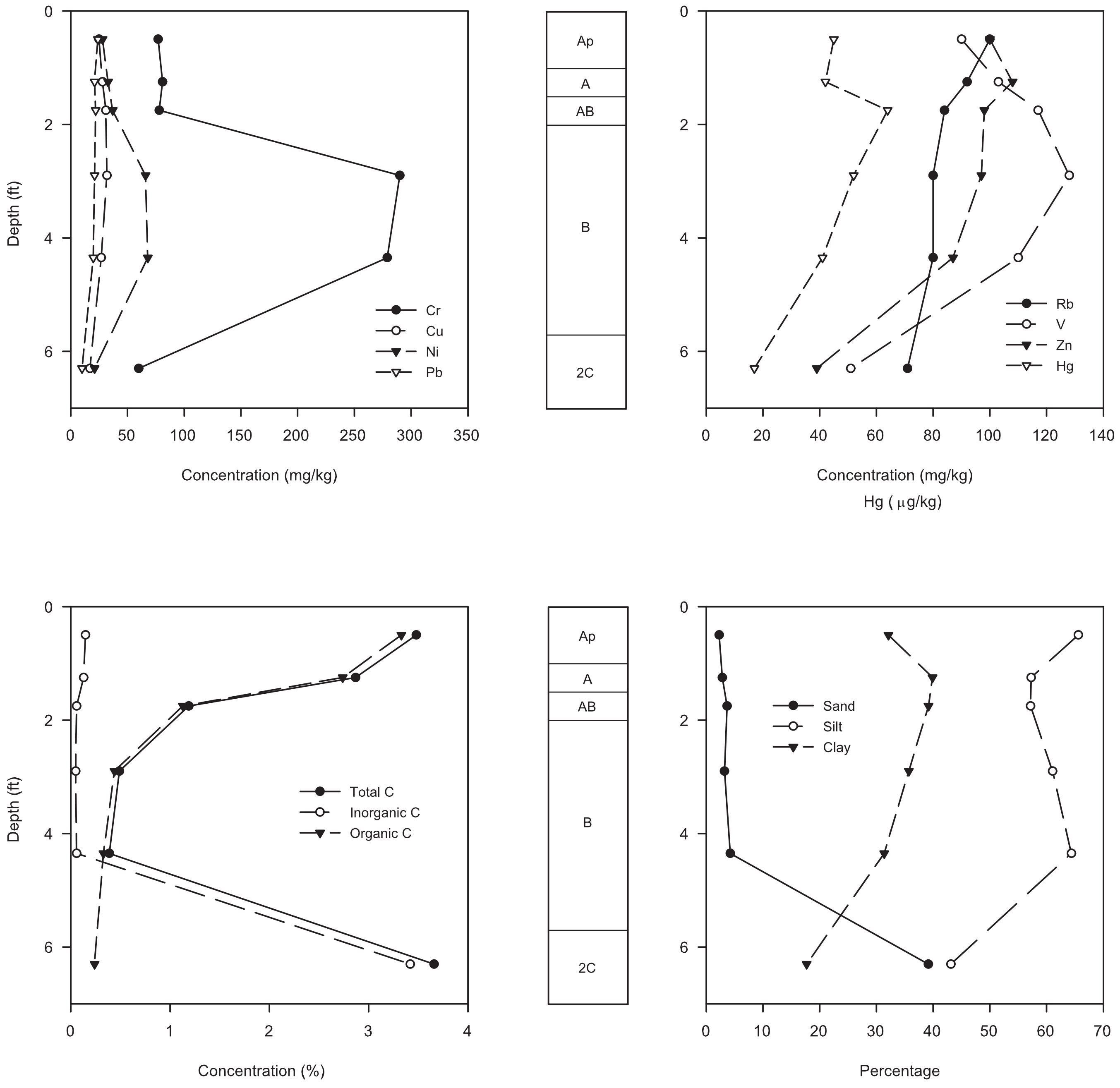


Figure 55. Element concentrations versus depth in core 126.

CaO vs. MgO

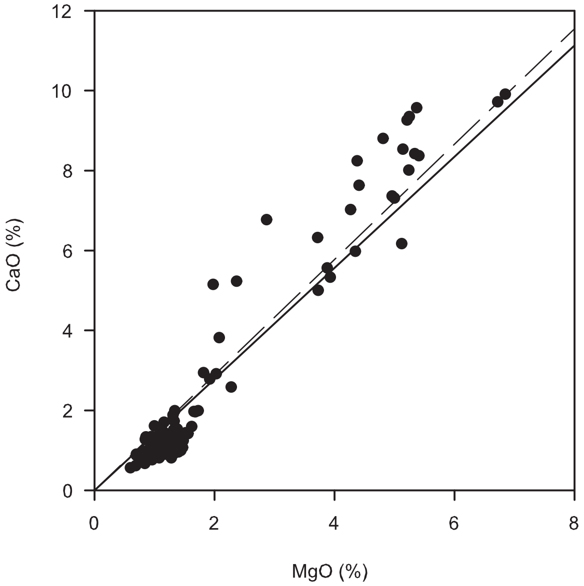


Figure 56. Calcium oxide content versus magnesium oxide content of cores 102 through 126.