A Progress Report on the Description of the Geology and Chemical Composition of Soils in Illinois:
Cores 27 through 51

by

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PREFACE

This report is a progress report to present analytical chemistry data on soil cores 27 through 51 of an anticipated total of 137 soil cores. There are presently insufficient data to allow exhaustive interpretations of the analytical chemistry results. As more data become available throughout this project we will be better able to make final interpretations and to increase our confidence in the correctness of our inferences from the data. The report is primarily intended to provide our analytical chemistry information to the persons from whose land the soil cores were collected. It will also be useful to others who are interested in learning about the geological background and chemical composition of soils in Illinois.

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

INTRODUCTION

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

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 data, and presenting the new interpretation in a variety of ways. When sufficient information is not available, however, then new research projects must be conducted to address the need. This project was begun to address the increasing concerns from the general public about the chemical and mineralogical composition of soils in Illinois.

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

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

We considered two approaches to studying the chemistry and mineralogy of Illinois soils. The first was to consider the nature of the existing data and see if they were sufficient to meet our needs. In other words, we considered whether our existing database would be sufficient if we supplemented it with all available data from other sources, such as the U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), engineering companies, water-well and other drillers' reports, and so forth. Our preliminary assessment showed that there were many data available, but no standard framework or style that could be followed. So we chose to build our own comprehensive database in a universal style that tries to avoid the professional biases of 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 subsequent studies to fill gaps in the database following a priority plan determined by needs.

This report presents basic data acquired from soil cores 27 through 51 of an anticipated 137 coring sites from across the state. These cores were collected in southern Illinois during the fall of 1999. We currently have limited 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 in utilizing natural resources (Darnley et al., 1995); (2) "to evaluate the contribution of soil minerals to animal and plant ecology in the State" (Jones, 1986) or stated slightly differently, to determine the effects of soil composition (especially trace elements) on the health of plants, animals, and humans (Esser et al., 1991); (3) to relate the distributions of elemental concentrations in the State to weathering intensity and sorting of particles according to size by action of wind (Jones, 1986); (4) to show the association of trace elements with soil minerals (Esser et al., 1991); (5) to supplement information required to understand the geochemical landscape of Illinois; (6) to provide correlative information for understanding the composition of lake and river sediments; and (7) to provide a well-documented reference collection of cores for other inquiries.

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

The purpose of this present research project is to determine the chemical and mineralogical characteristics of soils and underlying unconsolidated 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 general 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

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). Large-scale glaciation started earlier in Asia, but the glaciers did not grow large enough in North America 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 to the south. 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 glacial deposits, which are 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 thick deposits filled the pre-glacial bedrock valleys with drift up to 350 feet thick. Much of the drift is a homogenous mixture of fine-grained material with pebbles and a few boulders. This type of deposit was originally called boulder-clay and is now commonly called till. Interbedded with till in thick sequences of drift is outwash, which is commonly composed of stratified beds of sand and gravel, with some layers of silt and clay in places.

Beyond the margins of the continental glaciers, meltwater from the glaciers filled 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 deposits. The surfaces of many of these deposits commonly 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 deposits in former glacial meltwater channels form the excellent aquifers that supply water to many cities in Illinois.

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

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

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

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

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

The next master meltwater river to the east of the Mississippi drainage was the Wabash. Within ten miles of the Wabash River the loess begins to thicken and grows to over 10 feet thick in the west bluff of the Wabash. As might be predicted, the loess is even thicker on the east side of the Wabash, again indicating that the Wabash was a major source of loess, and confirming that the prevailing winds blew toward the east. Another important loess source in northwest Illinois was 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 are wind-blown dune sand deposits significant. The largest of these are in Mason County; in the Green River Lowland of Whiteside, Henry, and Lee Counties; and the eastern Kankakee County area. During the peak of the last glaciation favorable conditions allowed “sand seas” to form. When the climate changed back to a warmer condition about 10,000 years ago, the dune-sand deposits were stabilized by vegetation. In geologic terms, this change in conditions marked the beginning of the present geologic interval called the Holocene or “Recent” in common terms.

The dune sand and loess have physical properties and chemical compositions that make them especially good parent materials for agricultural soils. Both materials contain a blend of minerals that, during the early stages of weathering, produce chemicals and byproducts that make fertile soils. Weathering processes, particularly the chemical reactions called hydrolysis and oxidation, cause the dark-colored minerals and the feldspars in rock particles in the sand or loess to be slowly altered, releasing ions (Na, Ca, Fe, Mg, K, P, S, and many others) and forming products (clay minerals) that cause the cation exchange capacity (CEC) of the developing soil to increase over time. The silt-size particles in loess generally are more altered or weathered than the coarser grains in the dune sands and, because loess deposits can retain significantly more water than dune sand, the water is 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 in Illinois 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 surfaces provide direct evidence for the wind erosion. The loess deposits are thickest along 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 [formally called 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 glacier to the north. Presumably the evidence of the southern limit of this glacier's advance is buried beneath the Late Wisconsinan deposits on the north side of the Great Lakes. Numerous radiocarbon dates from the Roxana loess in Illinois show that it formed between 55,000 and 25,000 years ago.

In a few places in southern Illinois, the Peoria and Roxana silts lie directly over a third loess we correlate with the Loveland Loess of Iowa. The Loveland is well known up the Missouri River valley and can be traced down the Mississippi River valley to Louisiana. It formed during the next-to-last glaciation, the Illinoian. On the basis of correlations with ice cores from Greenland and ocean sediment records around the world (Imbrie and Imbrie, 1979), we believe that the age of the Illinoian can be now constrained to the period from 180,000 to 125,000 years ago. Previous estimates placed the older boundary back to 300,000 years ago, but we believe this age should be rejected because no glacial sediments in this age range have been found in the Midwest (Follmer, 1996).

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

The loess units are distinguished from each other by physical and mineralogical properties. The most important such distinguishing characteristics are those caused by soil formation. In geologic terms, 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 soil's characteristics indicate that the unit was once at the ground surface and exposed to active soil formation. Some other buried glacial deposits also have a paleosol, developed in their upper part; that is, there are soil features in the upper parts of some important geologic units. 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 almost always missing also. At such sites the soils are formed in other glacial deposits or bedrock.

The important variations in the 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 so forth) 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.

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 (physical and chemical properties are optimum for plant growth) 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.

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 rearranged 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).

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 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).

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 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).

Exposure of the soil profile to weathering factors for long periods allows the other soil formation factors to act more fully on the soil (Hassett and Banwart, 1992).

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

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

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 process of solid materials entering into or separating 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). Microorganisms sometimes accumulate metal ions, effectively removing the ions from the soil solution. However, when the microorganism dies and decomposes, the accumulated ions will be released again (Weatherley et al., 1980).

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

FIELD METHODS

The sampling plan we adopted was to collect cores of soils at the points of intersection, or nodes, of a rectangular grid, 20 miles on a side, laid on top of a state map. The grid was established in the Universal Transverse Mercator projection by drawing the first node ten miles west of Lake Michigan and 10 miles south of the Illinois-Wisconsin border, in Lake County, 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 1999 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 1999. Cores were collected at 25 locations during October and November 1999, after harvest was completed. The gray triangular 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 lithologic changes. Samples were dried at 50˚C. The dried samples were then disaggregated to approximately <4mm size by passing them through a miniature jaw crusher with ceramic crushing surfaces. The samples were further disaggregated to pass a sieve with 2-mm openings by placing the material between two sheets of clean white paper and crushing the particles with a wooden rolling pin. The samples were then split by the “cone and quarter” method to a reduced sample mass of about 30 grams. This subsample was then ground in a Spex® 8500 Shatterbox® and passed through a 208-µm (No. 65) sieve in preparation for chemical analyses. All analyses were conducted in ISGS laboratories.

Wavelength-Dispersive X-ray Fluorescence Spectrometry

Wavelength-dispersive X-ray fluorescence spectrometry (XRF) was used to determine the concentrations of the following major and minor elements in the samples [silicon (Si), aluminum (Al), iron (Fe), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), titanium (Ti), phosphorus (P), manganese (Mn), and sulfur (S)] 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 the samples for major and minor element determinations, the samples were ground in a Spex® 8500 Shatterbox® with ceramic grinding surfaces to pass a 208-µm sieve. The ground samples were dried at 110˚C overnight, and then ignited in platinum-rhodium crucibles at 1000˚C for one hour to determine loss on ignition and to ensure complete oxidation of the samples. Loss-on-ignition data provide a measure of the amounts of structural water and organic- and carbonate-carbon in the samples.

Six-tenths gram of the ignited sample was mixed with 5.4 g of a mixture of 1:1 lithium tetraborate:lithium metaborate and fused in a 95% platinum-5% gold crucible in the propane 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 for the determination of trace elements, which generally are too diluted to be determined in the fused disk samples.

In this preparation, 10 g of the as-received sample was ground in a tungsten carbide grinding container and then ground in a Spex® 8500 Shatterbox® for three minutes. A portion of the ground sample (6.3 g)

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

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 placed 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 2g of cellulose powder was added on top of the sample, and the mass was pressed into a 35-mm diameter disk under a pressure of 20 tons/in2 for two minutes. The cellulose provides a reinforcing backing for the disk. The prepared pellets were stored in a desiccator prior to analysis.

Mercury

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

Total Carbon and Inorganic Carbon

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

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

Soil pH

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

Soil Texture

Soil texture was determined by the method of Indorante et al. (1990). Up to nine samples and a blank were processed at a time. In this method, 10 g of 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. The blank contained $(NaPO_3)_6$ and deionized water only. 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 25˚C for 3 hours and 36 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 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 fraction had been withdrawn, the 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. The 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. Silt content was calculated by subtracting the percentages of clay and sand from 100%.

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

RESULTS AND DISCUSSION

Soil Texture

The sand, silt, and clay contents of each sample from each core are listed in Tables 2 through 26, and depicted graphically in odd-numbered figures 7 through 55. The proportion of sand, silt, and clay in a sample was used to determine the textural class of the sample according to the definitions of the USDA

Soil Survey Division Staff (1993). The USDA terminology is useful for several reasons: (1) it is popular and used in all U.S. soil survey reports, (2) it is quantitative and easy to determine, and (3) it is based on empirical factors—there is a natural tendency for sediments to occur in these classes and the textural classification has about the maximum practical number of classes to use. Of the 25 cores discussed in this report, the textures of the uppermost or surficial horizon (the plow layer in most cases) of 20 of the cores were silt loam, three were silt, one was clay loam, and one was silty clay. The parent materials of the soils at locations 28, 42, and 47 were alluvium, and were deposited as flood plain sediments. Cores 29, 33, 38, 41-43, and 48-50 were from upland prairie locations, and the remaining cores were collected from areas that were upland forests during soil development.
The clay contents of the subsamples of all the cores ranged from about 10% to 48%, the silt contents ranged from about 13% to 86%, and the sand from 0.4% to 77%. The soil texture classification, soil type, 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 odd-numbered figures 7 through 55.

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

Results of Chemical Analyses

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

Correlation Coefficients

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

For example, the correlation coefficient between alumina (Al_2O_3) and the clay-size fraction is 0.90 (Table 28). That is, in about 90% 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 from the 25 cores reported here, and from cores 1 through 26 (Dreher et al., 2002a, 2002b) are not sufficient to allow us to draw conclusions about similarities or differences between cores, and certainly not to make any suggestions about regional trends. It is, however, our goal, when we do have sufficient data, to study similarities and differences in constituent trends relative to soil horizons and to study regional or state-wide patterns. We calculated correlation coefficients to highlight the general relationships between constituents based on all samples analyzed from cores 26 through 51.

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

Clay minerals are important components of all soils. They occur principally in the clay-size fraction and contain Si as one of the major constituents. Because SiO_2 is the major constituent of the silt- and sand-size fractions, we observed that as the amounts of the sand+silt fraction increased, the amount of SiO_2 in the samples also generally increased. That is, the correlation between Si and the sand+silt fraction was moderately strong. As the silt and sand fractions increased, the clay-size fraction decreased and there was a negative correlation (-0.56) between SiO_2 and the clay-size fraction. Aluminum (as Al_2O_3), another major constituent of clay minerals and other minerals in the clay-size fraction, demonstrated a strong positive correlation with the clay-size fraction (0.90).

The clay-size fraction was correlated with iron (0.80), chromium (0.62), copper (0.71), nickel (0.67), rubidium (0.69), vanadium (0.83), and zinc (0.66). Therefore, these elements also correlated with each other. Iron is a common structural member, that is, it is a necessary part of certain clay minerals, although it may also occur as an exchangeable ion on clay minerals. Iron is commonly found in illite and in coatings of iron oxyhydroxides on other minerals (Wilding et al., 1977) and as concretions in many soils.

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

Calcium oxide (CaO) and magnesium oxide (MgO) were strongly correlated with each other (0.95) and with inorganic carbon content (0.99 and 0.94, respectively). These correlations suggest the presence of calcite and dolomite in the soil samples. Barium (Ba) and titanium oxide (TiO_2) were correlated with each other (0.68), but they were also correlated with the percent silt-size fraction (0.54 and 0.74, respectively). The correlations between Ba and TiO2 probably are simply a result of their common correlation with the silt-size fraction. Titanium oxide was also correlated with Zr (0.63), which is known to reside in the silt-size fraction.

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 clay minerals, buffers the pH of the soil solution according to the following chemical reactions (Hassett, 1989):

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

If small amounts of gibbsite, $Al(OH)_3$, or clay minerals in the soil dissolve to contribute Al^{3+} to the soil solution, the Al3+ becomes hydrolyzed to $AlOH^{2+}$, which results in the addition of H^+ to the solution, which results in greater acidity. If additional H^+ enters the soil solution, the reaction between $AlOH^{2+}$ and Al^{3+} is driven to the left and H^+ is consumed in the formation of H_2O and Al^{3+}. Aluminum, therefore, serves as an acidity buffer for pH between values of about 4.5 and 5.5 (Sparks, 1995). Above pH 5.5, the solubility of Al^{3+} is low enough that it is not effective in buffering soil pH.

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

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):

$CO_{2\ gas} = CO_{2\ aq}$
$CO_{2\ aq} + H2O = H_2CO_3$
$H_2CO_3 = HCO + H^+$
$HCO = CO^- + H^+$

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 3.57 (very acidic) to 8.02 (moderately alkaline), with a median value of 6.17. Of the 149 samples, 146 had a pH between 4 and 7. The approximate pH range of most soils found globally is 3.0 to 8.5 (Baas Becking et al., 1960). As shown in Figure 5 and Tables 29 through 53, the pH value in 18 of the 25 cores became more acidic with increasing depth to about 4 feet, then became more alkaline below this depth. Calcareous till lies under the loess at several of the 25 coring locations (cores 27, 31, 32, 35, 37, 41, 43, 44, 50, and 51). Calcium carbonate in the till imposes an alkaline pH on the deeper samples from these cores.

Means and Ranges of Element Contents

The mean and range of the element contents determined in the uppermost samples from the 25 cores in this portion of the project are compared in Table 54 with the results obtained by Shacklette and Boerngen (1984) for loess and silty soils or loamy and clay soils, and Severson and Shacklette (1988), according to the availability of their data. The data from Shacklette and Boerngen (1984) for trace elements were for surface horizons from throughout the U.S., whereas the data for most major and minor elements were for Illinois soils without regard to soil texture. Our ranges of values were within the ranges observed by Shacklette and Boerngen for similar soil textures for about 70% of the elements determined.

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

Silicon

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

The silica content generally decreased from the surface to the B horizon, then increased, in some cases to a level that was higher than in the surface samples (cores 29, 30, 34, 36, 41, 42, 46, 48, and 49). In cores 31 and 33, however, the SiO_2 content increased with depth and then decreased. The SiO_2 content, in general, increased as the sand+silt fraction increased (the clay fraction decreased). We also noted that in the ten cores that penetrated the underlying calcareous till, the SiO2 content decreased as the CaO content increased (cores 27, 31, 32, 35, 37, 41, 43, 44, 50, and 51).

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 mirror images of the SiO_2 profiles, with a few exceptions. In those cores that penetrated the underlying calcareous till, the Al_2O_3 content decreased as the CaO content increased.

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 pass through a maximum with increasing depth, generally in the B horizon, which is the clay-rich zone in the soil profile.

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

The content of K_2O did not vary appreciably in the cores and remained at approximately 2%.

Calcium

Calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$] are common sources of calcium in soils, but not all soils contain calcite or dolomite. Calcium can also be held as an exchangeable ion on the soil exchange complex. The content of CaO in several cores, for example, cores 29 and 30, was highest in the surface sample and quickly decreased to nearly constant values in samples from greater depths. In ten cores (27, 31, 32, 35, 37, 41, 43, 44, 50, and 51) the CaO content increased in deeper samples because the calcareous till underlying the soil was penetrated.

Calcium may be present in soils because of human activities such as the recent use of limestone or dolomite in road building or for agricultural liming to reduce soil acidity. The latter activity might explain the unusually high CaO content in the surface samples of cores 38 and 45.

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

The MgO content of several cores (34-41, 45, 46, 48, and 49) increased with depth to a maximum in the B horizon. The maximum MgO content in core 27 was observed in the sample from the C horizon. Once released from its source mineral, Mg compounds are somewhat soluble in water and leaching of Mg from high in the soil profile to deeper positions and might explain the observed concentration maxima. In cores that penetrated the underlying calcareous till there was a sharp increase in the MgO content, similar to the change in CaO content.

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.

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

Titanium

The sources of titanium in soils are oxides, such as rutile (TiO_2), and ilmenite ($FeTiO_3$) (Kabata-Pendias, 2001), neither of which is easily weathered. These minerals commonly occur nearly undecomposed in soils. Titanium presents no environmental concerns in soils (Kabata-Pendias, 2001). In almost every core the TiO_2 content increased to depths of one to two feet then decreased. In seven of the ten cores that penetrated the underlying calcareous till, there was a sharp decrease in TiO_2 content compared with the shallower samples in the profiles.

Phosphorus

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

The P_2O_5 content in the cores generally decreased or remained relatively constant with depth. Where the P_2O_5 content of the uppermost sample or two was much higher than the lower samples (cores 31, 32, 35, 37, and 49, for example), there might have been a recent application of P-containing fertilizer.

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

In more than half the cores the MnO content was highest in the surface samples and decreased with depth. One possible reason for this is that manganese is sensitive to oxidation and reduction. Oxidized species, such as MnO_2, precipitate where oxygen is readily available, as it normally would be near the surface of the soil, and decrease in content with depth. The solubility of manganese increases as the pH and Eh (the oxidation-reduction potential) decrease (the soil becomes more acidic and less oxidizing) (Lindsay, 1979).

Under conditions of increasing acidity and decreasing oxidation potential, manganese would be somewhat easily leached. In the remaining cores (28, 31-33, 37-39, 43, 46, 48, and 49) the MnO content increased below the surface.

Barium

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

The content of Ba in most cores passed through a maximum in the B horizon. In core 30 the Ba content decreased from the surface downward, and in core 39, the Ba content passed through a minimum in the B horizon. In a few of the cores that penetrated the underlying calcareous till (32, 41, 43, 44, 50, and 51) there were notable decreases in the Ba content of the lowermost samples.

Chromium

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

Chromium contents were below the detection limit of 5 mg/kg in some of the samples of cores 28, 29, 32, 34, 42, 44, 50, and 51. For a few samples in cores 42 and 49, proper analytical samples could not be prepared for trace element determinations. In all but a few of the cores the Cr content was at its maximum in the B horizon, commonly at the top of the horizon, or in a transition zone between the A or E horizon and the B horizon. The maximum Cr content was 192 mg/kg. 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. This hypothesis is supported by the previously mentioned correlation between Cr and clay-sized 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 (Kabata-Pendias, 2001).

The depth profiles for copper were similar to those for chromium. The maximum Cu content occurred generally in the upper B horizon, but in some cores it occurred in the transition zone between the A or E horizon and the B horizon. Copper was not determined in one sample from core 42 and three samples from core 49 because of sample preparation difficulties. The copper contents of the 25 cores were in the range of 17 to 38 mg/kg.

Mercury

The most common natural source of mercury in rocks is the mineral cinnabar, HgS, but this mineral is seldom found in detrital material, such as soils and sediments (Kabata-Pendias, 2001). Although some of the mercury in soil is inherited from the parent materials, in the Midwest, most is deposited on the soil surface as atmospheric fallout of particulate matter from industrial processes or as a dissolved component of rainwater.

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 does not react 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.

With a few exceptions, the Hg profiles paralleled those for clay content. The Hg content was commonly highest in the B horizon, attaining a maximum of 124 µg/kg in core 33. This suggests downward migration of mercury and sorption by clay minerals or iron and manganese oxyhydroxides.

Nickel

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

The nickel content was below the detection limit of 5 mg/kg in a few samples from cores 32, 35, 43, 44, 50, and 51. Nickel was not determined in one sample from core 42 and three samples from core 49 because of sample preparation difficulties.

The Ni content generally passed through a maximum in the upper B horizon or in the transition zone between the A or E horizon and the B horizon. This type of concentration profile suggests that Ni was probably leached downward during weathering and followed the accumulation of clay minerals and iron oxyhydroxide compounds.

Lead

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

The Pb content ranged from 12 to 30 mg/kg in the 25 cores. The profile of Pb content as a function of depth generally paralleled the Cu profile, although the Pb content in the soil samples was almost always less than the corresponding Cu content. Exceptions to this observation were noted for the uppermost samples from cores 29, 39-41, 44, and 45. In many cores the lead content of the soil was greatest at the surface and decreased with depth to the B horizon, where the content increased, then again decreased with depth. This behavior is indicative of input to the soil surface, probably by products from the combustion of leaded gasoline in vehicles and machinery, and from coal combustion. It appears that lead was leached from the surface and accumulated in the B horizon by adsorption on clay minerals and iron and manganese oxyhydroxides. Organic matter is also known to strongly adsorb lead, as might be reflected in those surface samples that contained elevated lead contents. Lead was not determined in one sample from core 42 and three samples from core 49 because of sample preparation difficulties.

Rubidium

Because the radius of the rubidium ion (1.49 Å) is approximately the same as that of the potassium ion (1.33 Å), Rb commonly substitutes for K in K-feldspar (Kabata-Pendias, 2001). However, Rb is not as mobile in the soil as K, due to the stronger affinity of Rb to sorb on clay minerals and iron oxyhydroxides than K (Goldschmidt, 1954). As the soil develops, therefore, Rb concentrations are expected to remain relatively stable whereas K would decrease.

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

The Rb content in the 25 cores ranged from 40 to 106 mg/kg. In most cores the Rb content was greatest in the upper part of the B horizon, similar to other trace elements, such as Cr, Cu, Ni, V, and Zn, that are commonly associated with clay minerals.

Strontium

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

The Sr contents of these cores did not vary appreciably, falling in the range of 65 to 193 mg/kg.

Vanadium

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

The V content in the cores (range from 38 to 120 mg/kg) generally was greatest in the upper B horizon. The trend of V content with depth generally paralleled that of Rb and Zn.

Zinc

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

In these 25 cores the zinc content (range from 32 to 150 mg/kg) was generally greatest in the B horizon or in the transition zone between the A or E horizon and the B horizon.

Zirconium

Zirconium generally occurs in soil as the very stable mineral zircon ($ZrSiO_4$). Zircon is very resistant to weathering and zirconium is only very slightly mobile in soils (Hodson, 2002). The Zr content of soils is generally inherited from the parent materials (Kabata-Pendias, 2001).
The minimum Zr content was 120 mg/kg and the maximum was 542 mg/kg. The Zr content closely followed the silt fraction content. The Zr content was generally greatest at the surface and decreased with depth. There were a few exceptions to this, such as core 38, in which the maximum Zr content occurred n the E horizon. This was not the case in other cores that possessed an E horizon. In core 42 the maximum Zr content occurred in the D horizon, and in core 49 it occurred in the transition zone between the B and C horizons, about 4 feet below the surface.

Carbon

Most carbon in the samples was combined in organic residues from biological material. Plant residues are typically plowed into the upper portions of the soil column after harvest each year. Burrowing animals leave waste behind; small insects, worms, and microorganisms die in the soil and their remains are incorporated into the soil column. In each core except cores 12 and 16, the highest total carbon content occurred in the uppermost sample and it was almost entirely organic carbon. The range of total carbon content was 0.13 to 3.77 %, inorganic carbon content ranged from 0.02 to 3.08 %, and organic carbon ranged from <0.01 to 3.60 %. The inorganic carbon content in most cores was low and relatively invariant with depth. In cores in which the underlying calcareous till was penetrated, however, the content of inorganic carbon increased in response.

CONCLUSIONS

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

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

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

As more cores are analyzed and more data become available, we expect that some regional trends in soil composition may emerge. Presently, the data are too few to make such inferences reliably. With more data we may be able to distinguish between various mechanisms for the addition and removal of material. For example, we noted the possible input of Pb content to the surface from particulate matter carried and deposited by wind versus the increase in content due to weathering.

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

Core Number	County Name	Final Depth of Core (ft)
27	St. Clair	21.0
28	Madison	22.0
29	Bond	20.0
30	Fayette	20.7
31	Fayette	16.0
32	Clay	20.0
33	Richland	15.1
34	Lawrence	13.3
35	Crawford	16.0
36	Clark	12.3
37	Coles	16.0
38	Jasper	17.8
39	Effingham	16.0
40	Fayette	16.2
41	Fayette	22.6
42	Montgomery	18.9
43	Macoupin	21.0
44	Jersey	20.3
45	Pike	20.0
46	Greene	22.0
47	Macoupin	20.3
48	Montgomery	20.1
49	Christian	16.0
50	Shelby	19.0
51	Coles	22.0

Table 2 Texture of samples from core 27*

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
27-1	0.0-0.5	Ap	11.71	1.91	86.38	silt
27-2	0.5-1.0	A2	16.04	1.88	82.08	silt loam
27-3	1.0-1.7	B	25.03	1.74	73.23	silt loam
27-4	1.7-2.6	B2	30.99	1.36	67.65	silty clay loam
27-9	6.1-6.85	C2	17.38	1.07	81.55	silt loam
27-13	11.8-12.8	2A	14.42	0.65	84.93	silt loam

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

Table 3 Texture of samples from core 28

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
28-1	0.0-1.0	A	14.75	16.58	68.67	silt loam
28-2	1.0-2.3	B1	29.87	2.01	68.12	silty clay loam
28-3	2.3-3.5	B2	20.18	4.12	75.70	silt loam
28-4	3.5-4.45	B3	23.84	5.04	71.07	silt loam
28-10	9.5-10.3	C3	14.19	21.02	64.79	silt loam
28-15	15.9-16.8	D3	14.08	18.20	67.72	silt loam

Table 4 Texture of samples from core 29

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
29-1	0.0-0.5	Ap	18.16	10.27	71.57	silt loam
29-2	0.5-1.0	A1	19.14	6.82	74.04	silt loam
29-3	1.0-1.40	Ae	17.22	5.28	77.50	silt loam
29-4	1.4-2.4	E	30.06	2.90	67.04	silty clay loam
29-9	7.0-8.0	C1	12.56	35.10	52.34	silt loam
29-14	12.0-12.65	2A	17.14	64.61	18.25	sandy loam

Table 5 Texture of samples from core 30

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
30-1	0.0-0.6	Ap	13.95	10.45	75.60	silt loam
30-2	0.6-1.4	AE	18.44	6.62	74.94	silt loam
30-3	1.4-1.65	E	24.79	4.60	70.61	silt loam
30-4	1.65-3.0	B1	31.40	7.08	61.52	silty clay loam
30-8	5.15-6.0	2B	21.24	42.00	36.76	loam

Table 6 Texture of samples from core 31

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
31-1	0.0-0.4	Ap	28.58	24.83	46.59	clay loam
31-2	0.4-1.4	Bt1	36.27	20.61	43.12	clay loam
31-3	1.4-2.4	Bt2	31.44	25.97	42.59	clay loam
31-4	2.4-3.7	Bt3	29.08	33.43	37.49	clay loam
31-8	3.7-6.4	B7	16.18	52.20	31.62	loam
31-20	12.5-16.0	2A	21.37	23.94	54.69	silt loam

Table 7 Texture of samples from core 32

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
32-1	0.0-0.7	Ap	17.87	16.73	65.40	silt loam
32-2	0.7-1.7	Eg1	20.91	15.72	63.37	silt loam
32-3	1.7-2.5	Eg2	21.56	16.12	62.32	silt loam
32-4	2.5-4.5	Btg	37.00	12.60	50.40	silty clay loam
32-6	4.7-7.0	C1	30.37	23.72	45.91	clay loam
32-11	14.0-16.0	C6	16.85	43.50	39.65	loam

Table 8 Texture of samples from core 33

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
33-1	0.0-0.5	Ap	23.22	12.10	64.98	silt loam
33-2	0.5-1.0	A2	25.16	10.07	64.77	silt loam
33-3	1.0-1.5	AB	17.58	7.79	74.63	silt loam
33-4	1.5-1.8	B1	18.92	7.04	74.04	silt loam
33-6	2.4-4.2	B3	32.98	10.99	56.03	silty clay loam
33-10	8.15-8.8	C3g	38.97	17.76	43.27	silty clay loam

Table 9 Texture of samples from core 34

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
34-1	0.0-0.5	Ap	15.32	5.45	79.23	silt loam
34-2	0.5-0.85	A2	15.00	4.99	80.01	silt loam
34-3	0.85-1.25	E	16.46	4.92	78.62	silt loam
34-4	1.25-1.70	B1	22.55	2.60	74.85	silt loam
34-10	4.0-5.0	2Btx4	15.46	28.12	56.42	silty clay
34-13	6.0-6.6	3A	14.88	45.43	39.69	loam

Table 10 Texture of samples from core 35

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
35-1	0.0-0.7	Ap	13.24	13.52	73.24	silt loam
35-2	0.7-1.25	E	18.40	11.00	70.60	silt loam
35-3	1.25-1.6	BE	29.92	6.22	63.86	silty clay loam
35-4	1.6-2.9	Bt1	32.80	4.96	62.24	silty clay loam
35-6	4.0-5.15	Bt3	17.06	6.46	76.48	silt loam
35-9	8.0-8.9	B6	21.69	24.50	53.81	silt loam

Table 11 Texture of samples from core 36

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
36-1	0.0-0.9	Ap	16.51	5.81	77.67	silt loam
36-2	0.9-1.4	EB1	22.71	3.76	73.53	silt loam
36-3	1.4-2.3	EB2	27.38	2.08	70.54	silty clay loam
36-4	2.3-3.0	B1	27.26	2.64	70.10	silty clay loam
36-6	4.5-5.2	Btx2	14.04	30.98	54.98	silt loam
36-8	7.0-8.0	C1	27.95	43.18	28.87	clay loam

Table 12 Texture of samples from core 37

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
37-1	0.0-0.6	Ap	18.60	18.32	63.08	silt loam
37-2	0.6-1.3	A	31.39	13.61	55.00	silty clay loam
37-3	1.3-1.7	AB	42.24	8.37	49.39	silty clay
37-4	1.7-2.6	Bt1	37.47	6.78	55.75	silty clay loam
37-8	5.0-6.0	C2	20.42	46.84	32.74	loam
37-11	7.35-8.0	Cg5	23.16	17.20	59.64	silt loam

Table 13 Texture of samples from core 38

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
38-1	0.0-0.6	Ap	16.48	12.79	70.55	silt loam
38-2	0.6-1.15	AE	17.72	12.84	69.44	silt loam
38-3	1.1-1.8	E	17.24	11.89	70.87	silt loam
38-5	2.0-2.8	Bt1	48.02	2.84	49.14	silty clay
38-8	4.75-6.0	2A1	25.54	29.88	44.58	loam
38-13	12.0-12.5	2Bt4	31.20	39.56	29.24	clay loam

Table 14 Texture of samples from core 39

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
39-1/2	0.0-0.9	A	15.92	15.15	68.93	silt loam
39-3	0.9-1.4	E	35.73	5.17	59.10	silty clay loam
39-4	1.4-2.7	B1	38.60	3.46	57.94	silty clay loam
39-5	2.7-2.9	B2	29.23	4.83	65.94	silty clay loam
39-7	3.4-4.1	2B1	22.96	24.56	52.48	silt loam
39-13	8.9-9.55	3Bt4	31.71	35.88	32.41	clay loam

Table 15 Texture of samples from core 40

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
40-1	0.0-0.4	Ap	14.63	15.20	70.17	silt loam
40-2	0.4-1.3	E	17.56	10.17	72.27	silt loam
40-3	1.3-1.65	B1	28.58	7.04	64.38	silty clay loam
40-4	1.65-2.35	B2	31.86	5.91	62.23	silty slay loam
40-7	3.45-4.0	2B1	34.72	5.32	59.96	silty clay loam
40-14	9.1-10.2	3Bt1	28.13	35.14	36.73	clay loam

Table 16 Texture of samples from core 41

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
41-1	0.0-0.9	Ap	16.68	5.13	78.19	silt loam
41-2	0.9-1.15	E1	21.16	4.20	74.64	silt loam
41-3	1.15-1.7	E2	22.06	3.48	74.46	silt loam
41-4	1.7-2.35	EB	31.45	4.97	67.58	silty clay loam
41-9	6.0-7.8	C1	15.36	23.47	61.17	silt loam
41-23	17.0-18.0	3C2	22.74	30.25	47.01	loam

Table 17 Texture of samples from core 42

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
42-1	0.0-0.7	Ap	11.84	36.14	52.02	silt loam
42-2	0.7-1.3	A	15.56	35.56	48.88	loam
42-4	2.0-2.7	AB	17.26	39.72	43.02	loam
42-6	3.3-4.0	Bw	13.08	56.45	30.47	sandy loam
42-16	9.2-10.0	CA	10.10	76.70	13.20	loamy sand
42-23	14.0-15.1	D/A	22.20	11.17	66.63	silt loam

Table 18 Texture of samples from core 43

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
43-1	0.0-0.8	Ap	9.96	4.24	58.80	silt
43-3	1.1-1.7	E	20.56	5.66	73.78	silt loam
43-5	2.0-2.85	Bt	37.45	2.90	59.65	silty clay loam
43-8	4.25-4.8	C	17.98	0.64	81.38	silt loam
43-12	6.3-6.9	3A	28.18	20.78	51.04	clay loam
43-27	16.1-16.8	3CD	16.96	42.74	40.30	loam

Table 19 Texture of samples from core 44

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
44-1	0.0-1.0	Ap	10.32	3.74	85.94	silt
44-2	1.0-1.5	EB	19.15	3.27	77.58	silt loam
44-3	1.5-2.0	B	35.85	1.94	62.21	silty clay loam
44-4	2.0-2.8	Btj	33.35	2.20	64.45	silty clay loam
44-13	8.0-8.9	2Ab	24.72	11.77	63.51	silt loam
44-29	17.8-18.2	2C	17.26	37.38	45.36	loam

Table 20 Texture of samples from core 45

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
45-1	0.0-0.9	Ap	13.64	1.12	85.24	silt loam
45-2	0.9-2.0	E1	21.83	0.89	77.28	silt loam
45-3	2.0-2.8	E2	29.68	1.04	69.28	silty clay loam
45-5	3.3-3.95	Bt	31.11	1.37	67.52	silty clay loam
45-9	5.9-6.5	C	18.92	1.32	79.76	silt loam
45-17	12.2-13.0	2Bt	47.63	0.80	51.57	silt loam

Table 21 Texture of samples from core 46

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
46-1	0.0-0.7	Ap	18.88	0.38	80.74	silt loam
46-2	0.7-1.4	A	19.80	0.41	79.79	silt loam
46-4	2.0-2.4	AB	27.44	0.86	71.70	silty clay loam
46-5	2.4-2.85	B/Ab	33.88	0.56	65.56	silty clay loam
46-8	4.0-5.0	Bg	29.80	1.12	69.08	silty clay loam
46-33	18.6-19.2	2DC	18.68	45.10	36.22	loam

Table 22 Texture of samples from core 47

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
47-1	0.0-0.6	Ap	13.72	17.27	69.01	silt loam
47-2	0.6-2.1	C1	15.48	12.32	72.20	silt loam
24-4	2.4-3.55	C3	13.18	37.51	49.31	loam
24-5	3.55-3.9	C4	15.12	14.70	70.18	silt loam
47-8	6.0-6.7	2Bt1	16.98	32.52	50.50	silt loam
47-16	14.2-14.9	2C7	19.98	39.36	41.66	loam

Table 23 Texture of samples from core 48

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
48-1	0.0-0.7	Ap	18.92	3.74	77.34	silt loam
48-3	0.95-1.5	Bt1	27.16	3.20	69.64	silty clay loam
48-4	1.5-2.0	Bt2	37.96	2.66	59.38	silty clay loam
48-6	2.5-3.2	Bt4	36.42	2.48	61.10	silty clay loam
48-9	4.25-5.25	C	25.22	2.51	72.27	silt loam
48-16	10.3-11.3	2C1	19.02	43.16	37.82	loam

Table 24 Texture of samples from core 49

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
49-1	0.0-0.7	Ap	23.51	3.66	72.93	silt loam
49-2	0.7-1.4	Ap2	31.72	3.11	65.17	silty clay loam
49-3	1.4-2.0	BAt	36.04	2.36	61.60	silty clay loam
49-5	2.6-3.3	Bgt2	28.34	4.90	66.76	silty clay loam
49-7	4.1-4.7	CBtj	18.91	0.54	80.55	silt loam
49-21	12.45-13.0	Bg	25.75	30.08	44.17	loam

Table 25 Texture of samples from core 50

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
50-1	0.0-0.75	Ap	27.16	5.44	67.40	silty clay loam
50.2	0.75-1.3	AB	33.03	3.16	63.81	silty clay loam
50.3	1.3-2.0	BA	34.82	4.73	60.45	silty clay loam
50.5	2.7-3.5	Bt	31.77	23.68	44.55	clay loam
50.7	4.0-5.0	C	24.68	29.98	45.34	loam
50.16	10.2-11.0	D	22.66	30.09	47.25	loam

Table 26 Texture of samples from core 51

Sample	Depth Interval (ft)	Horizon	Clay (%)	Sand (%)	Silt (%)	Texture
51-1	0.0-0.7	Ap	20.35	6.75	72.90	silt loam
51-2	0.7-1.3	Ap2	24.60	5.40	70.00	silt loam
51-3	1.3-2.0	BA	40.43	2.67	56.90	silty clay
51-4	2.0-2.7	Bt	38.78	3.30	57.92	silty caly loam
51-6	3.5-4.0	B/C	25.40	24.11	40.49	loam
51-21	13.3-13.76	D	21.45	31.60	43.48	loam

Table 27 Soil texture, soil type, and developmental environment

Core Number	Texture	Soil Type*	Soil Association	Developmental Environment
27	silt	Fayette	Fayette-Rozetta-Stronghurst	upland, forest
28	silt loam	Beaucoup	Lawson-Sawmill-Darwin	alluvial, prairie
29	silt loam	Darmstadt-Oconee	Oconee-Cowden-Piasa	upland, prairie
30	silt loam	Bluford	Ava-Bluford-Wynoose	upland, forest
31	clay loam	Atlas	Fayette-Rozetta-Stronghurst	upland, forest
32	silt loam	Wynoose	Ava-Bluford-Wynoose	upland, forest
33	silt loam	Cisne	Hoyleton-Cisne-Huey	upland, prairie
34	silt loam	Ava	Ava-Bluford-Wynoose	upland, forest
35	silt loam	Muren	Alford-Muren-Iva	upland, forest
36	silt loam	Stoy	Hosmer-Stoy-Weir	upland, forest
37	silt loam	Xenia	Dodge-Russell-Miami	upland, forest
38	silt loam	Hoyleton	Hoyleton-Cisne-Huey	upland, prairie
39	silt loam	Bluford	Ava-Bluford-Wynoose	upland, forest
40	silt loam	Bluford	Ava-Bluford-Wynoose	upland, forest
41	silt loam	Oconee	Oconee-Cowden-Piasa	upland, prairie
42	silt loam	Ross	Lawson-Sawmill-Darwin	alluvial, prairie
43	silt	Harrison	Herrick-Virden-Piasa	upland, prairie
44	silt	Keomah	Clinton-Keomah-Rushville	upland, forest
45	silt loam	Fayette	Fayette-Rozetta-Stronghurst	upland, forest
46	silt loam	Muscatine	Tama-Muscatine-Sable	upland, prairie
47	silt loam	Wakeland	Haymond-Petrolia-Karnak	alluvial, forest
48	silt loam	Herrick	Herrick-Virden-Piasa	upland, prairie
49	silt loam	Virden	Herrick-Virden-Piasa	upland, prairie
50	silty clay	Dana	Saybrook-Dana-Drummer	upland, prairie
51	silt loam	Toronto	Dodge-Russell-Miami	upland, forest

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

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

	Depth	SiO_2	Al_2O_3	Fe_2O_3	K_2O	CaO	MgO	Na_2O	TiO_2
Depth	1								
SiO_2	-0.29	1							
Al_2O_3	-0.07	-0.54	1						
Fe_2O_3	-0.07	-0.47	0.74	1					
K_2O	0.10	-0.37	0.14	0.00	1				
CaO	0.51	-0.69	-0.18	-0.18	0.32	1			
MgO	0.52	-0.84	0.08	0.04	0.40	0.95	1		
Na_2O	-0.21	0.22	-0.03	-0.26	0.28	-0.20	-0.23	1	
TiO_2	-0.60	0.09	0.40	0.19	0.03	-0.50	-0.43	0.49	1
P_2O_5	-0.25	0.03	-0.07	-0.10	0.28	-0.04	-0.07	0.53	0.29
MnO	-0.29	0.05	-0.08	0.18	-0.02	-0.13	-0.16	0.04	0.21
Ba	-0.39	0.12	0.23	0.06	0.04	-0.37	-0.33	0.48	0.68
Cr	0.09	-0.39	0.60	0.51	0.03	-0.18	0.09	-0.17	0.11
Cu	-0.01	-0.39	0.73	0.56	0.06	-0.13	0.08	-0.05	0.24
Hg	-0.29	-0.15	0.40	0.33	-0.09	-0.22	-0.12	0.02	0.30
Ni	0.19	-0.39	0.57	0.52	-0.24	-0.10	0.14	-0.37	-0.07
Pb	-0.36	-0.16	0.46	0.47	-0.08	-0.33	-0.21	-0.02	0.50
Rb	0.05	-0.43	0.70	0.40	0.34	-0.04	0.16	-0.08	0.26
Sr	0.02	-0.09	0.00	-0.09	0.36	0.15	0.11	0.67	0.10
V	-0.27	-0.37	0.87	0.74	-0.01	-0.33	-0.10	-0.00	0.56
Zn	-0.05	-0.49	0.68	0.58	0.18	-0.05	0.15	-0.05	0.24
Zr	-0.52	0.40	-0.12	-0.18	-0.08	-0.41	-0.50	0.56	0.63
LOI	0.27	-0.81	0.03	0.00	0.20	0.86	0.86	-0.31	-0.28
Moisture	-0.18	-0.37	0.84	0.74	-0.06	-0.29	-0.07	-0.13	0.34
Tot C	0.05	-0.43	-0.30	-0.30	0.11	0.66	0.54	-0.13	-0.20
In C	0.51	-0.68	-0.20	-0.18	0.29	0.99	0.94	-0.25	-0.51
Org C	-0.47	0.14	-0.19	-0.21	-0.15	-0.15	-0.26	0.08	0.26
Clay	-0.07	-0.56	0.90	0.80	-0.03	-0.12	0.12	-0.34	0.24
Sand	0.56	0.18	-0.47	-0.25	-0.21	0.24	0.16	-0.53	-0.86
Silt	-0.54	0.16	-0.02	-0.18	0.22	-0.22	-0.26	0.73	0.74
Sand+Silt	0.03	0.59	-0.85	-0.75	0.01	0.04	-0.18	0.35	-0.20
pH	0.39	-0.17	-0.31	-0.27	0.30	0.49	0.42	-0.02	-0.51

Table 28 continued

	P_2O_5	MnO	Ba	Cr	Cu	Hg	Ni	Pb	Rb
P_2O_5	1								
MnO	0.19	1							
Ba	0.31	0.42	1						
Cr	-0.14	-0.03	0.05	1					
Cu	-0.07	-0.44	-0.01	0.43	1				
Hg	0.02	0.09	0.21	0.27	0.27	1			
Ni	-0.30	-0.12	-0.06	0.53	0.44	0.27	1		
Pb	0.12	0.05	0.15	0.25	0.52	0.34	0.18	1	
Rb	-0.17	-0.43	0.02	0.46	0.72	0.20	0.29	0.38	1
Sr	0.34	-0.01	0.04	-0.06	0.00	-0.14	-0.13	-0.07	-0.05
V	-0.05	-0.01	0.32	0.52	0.72	0.45	0.47	0.61	0.61
Zn	0.06	-0.13	0.08	0.43	0.69	0.33	0.39	0.66	0.59
Zr	0.30	0.29	0.39	-0.29	-0.14	0.03	-0.37	0.26	-0.22
LOI	-0.02	-0.05	-0.24	0.02	0.03	0.01	0.05	0.01	0.11
Moisture	-0.13	-0.07	0.15	0.64	0.72	0.39	0.64	0.53	0.58
Tot C	0.19	0.07	-0.20	-0.31	-0.23	-0.04	-0.27	0.03	-0.18
In C	-0.08	-0.12	-0.38	-0.20	-0.15	-0.22	-0.11	-0.32	-0.04
Org C	0.33	0.21	0.13	-0.23	-0.16	0.17	-0.23	0.37	-0.19
Clay	-0.23	-0.10	0.06	0.62	0.71	0.40	0.67	0.49	0.69
Sand	-0.34	-0.17	-0.54	-0.09	-0.32	-0.30	0.06	-0.52	-0.31
Silt	0.47	0.24	0.54	-0.27	-0.07	0.11	-0.42	0.26	-0.08
Sand+Silt	0.22	0.13	0.00	-0.59	-0.68	-0.34	-0.62	-0.44	-0.68
pH	0.12	0.01	-0.18	-0.13	-0.34	-0.26	-0.03	-0.39	-0.22

Table 28 continued

	Sr	V	Zn	Zr	LOI	Moisture	Tot C	In C	Org C
Sr	1								
V	-0.06	1							
Zn	0.01	0.62	1						
Zr	0.42	0.09	-0.15	1					
LOI	-0.03	-0.07	0.19	-0.35	1				
Moisture	-0.05	0.77	0.70	-0.09	-0.06	1			
Tot C	0.04	-0.36	0.05	-0.06	0.82	-0.27	1		
In C	0.08	-0.33	-0.07	-0.43	0.87	-0.31	0.66	1	
Org C	-0.03	-0.13	0.14	0.36	0.18	-0.04	0.63	-0.16	1
Clay	-0.18	0.83	0.66	-0.26	0.14	0.88	-0.21	-0.12	-0.15
Sand	-0.36	-0.59	-0.34	-0.66	-0.03	-0.39	0.01	0.27	-0.26
Silt	0.47	0.14	-0.02	0.83	-0.15	-0.07	0.06	-0.25	0.35
Sand+Silt	0.19	-0.77	-0.62	0.28	-0.21	-0.80	0.13	0.03	0.14
pH	0.20	-0.52	-0.16	-0.29	0.31	-0.32	0.32	0.45	-0.05

	Clay	Sand	Silt	Sand+Silt	pH
Clay	1				
Sand	-0.31	1			
Silt	-0.23	-0.83	1		
Sand+Silt	-0.93	0.29	0.29	1	
pH	-0.30	0.38	-0.22	0.29	1

Table 29 Elemental composition of samples selected from Core 27

Subsample	27-1	27-2	27-3	27-4	27-9	27-13	Average
Lab. No.	R22098	R22099	R22100	R22101	R22102	R22103	
Depth Interval (ft)	0.0-0.5	0.5-1.0	1.0-1.7	1.7-2.6	6.1-6.85	11.8-12.8	
Horizon	Ap	A2	B	B2	C2	0.08	
SiO_2 (%)	81.10	80.10	75.90	71.70	70.20	74.00	75.83
Al_2O_3 (%)	8.00	8.90	10.90	12.70	9.90	10.20	10.10
Fe_2O_3 (%)	1.97	2.40	3.54	5.15	4.05	2.57	3.28
K_2O (%)	1.97	2.09	2.03	1.97	2.07	2.26	2.07
CaO (%)	0.71	0.72	0.76	0.72	3.11	2.54	1.43
MgO (%)	0.35	0.48	0.69	1.03	2.43	1.73	1.12
Na_2O (%)	1.20	1.23	1.05	0.90	1.36	1.54	1.21
TiO_2 (%)	0.73	0.73	0.75	0.70	0.69	0.71	0.72
P_2O_5 (%)	0.12	0.10	0.10	0.14	0.18	0.16	0.13
MnO (%)	0.17	0.14	0.18	0.08	0.11	0.03	0.12
Barium	745	758	828	658	741	620	725
Chromium	9	18	43	70	39	26	34
Copper	19	21	24	32	27	24	25
Mercury (µg/kg)	27	21	28	37	31	25	28
Nickel	6	6	9	18	15	8	10
Lead	19	17	16	18	17	16	17
Rubidium	55	62	72	78	57	64	65
Strontium	138	129	129	120	176	179	145
Vanadium	62	71	87	106	86	78	82
Zinc	48	48	61	84	65	57	61
Zirconium	478	416	377	324	380	381	393
Total C (%)	1.15	0.65	0.57	0.46	0.98	0.69	0.75
Inorganic C (%)	0.05	0.03	0.03	0.03	0.79	0.57	0.25
Organic C (%)	1.10	0.62	0.54	0.43	0.19	0.12	0.50
pH	6.11	6.42	6.41	5.60	7.64	7.61	6.63

Table 30 Elemental composition of samples selected from Core 28

Subsample	28-01	28-02	28-03	28-04	28-10	28-15	Average
Lab. No.	R22104	R22105	R22106	R22107	R22108	R22209	
Depth Interval (ft)	0.0-1.0	1.0-2.3	2.3-3.5	3.5-4.45	9.5-10.3	15.9-16.8	
Horizon	A	B1	B2	B3	C3	D3	
SiO_2 (%)	80.00	73.10	77.90	76.50	80.80	80.50	78.13
Al_2O_3 (%)	8.60	12.00	10.20	11.00	9.00	9.10	9.98
Fe_2O_3 (%)	2.25	3.51	2.55	3.78	2.59	1.80	2.75
K_2O (%)	2.04	2.25	2.24	2.31	2.11	2.14	2.18
CaO (%)	0.74	0.77	0.64	0.63	0.67	0.67	0.69
MgO (%)	0.45	0.80	0.53	0.69	0.51	0.53	0.59
Na_2O (%)	1.09	0.92	1.05	1.05	1.14	1.13	1.06
TiO_2 (%)	0.65	0.83	0.80	0.81	0.66	0.66	0.74
P_2O_5 (%)	0.10	0.13	0.09	0.12	0.11	0.06	0.10
MnO (%)	0.06	0.05	0.05	0.10	0.12	0.03	0.07
Barium	562	679	638	637	582	600	616
Chromium	<5	40	20	36	39	17	26
Copper	19	21	24	32	27	24	25
Mercury (µg/kg)	27	21	28	37	31	25	28
Nickel	6	6	9	18	15	8	10
Lead	19	17	16	18	17	16	17
Rubidium	55	62	72	78	57	64	65
Strontium	129	109	131	122	129	138	126
Vanadium	59	87	74	78	65	67	72
Zinc	56	77	57	62	44	55	59
Zirconium	396	281	366	328	416	369	359
Total C (%)	1.16	1.34	0.74	0.47	0.22	0.71	0.78
Inorganic C (%)	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Organic C (%)	1.12	1.30	0.70	0.43	0.18	0.67	0.73
pH	6.82	6.58	6.51	6.35	7.14	3.57	6.16

Table 31 Elemental composition of samples selected from Core 29

Subsample	29-01	29-02	29-03	29-04	29-09	29-14	Average
Lab. No.	R22110	R22111	R22112	R22113	R22114	R22115	
Depth Interval (ft)	0.0-0.5	0.5-1.0	1.0-1.40	1.4-2.4	7.0-8.0	12.0-1265	
Horizon	Ap	A1	AE	E	C1	0.08	
SiO_2 (%)	78.40	78.40	78.50	72.40	84.40	84.90	79.50
Al_2O_3 (%)	8.40	9.10	9.50	12.80	7.10	6.20	8.85
Fe_2O_3 (%)	2.43	2.51	2.59	4.68	2.26	4.07	3.09
K_2O (%)	1.87	2.00	2.06	1.97	1.68	1.24	1.81
CaO (%)	0.76	0.69	0.60	0.55	0.48	0.23	0.55
MgO (%)	0.47	0.53	0.55	1.07	0.35	0.18	0.52
Na_2O (%)	0.97	1.03	1.05	0.88	0.90	0.37	0.87
TiO_2 (%)	0.71	0.77	0.79	0.79	0.60	0.26	0.65
P_2O_5 (%)	0.15	0.12	0.10	0.11	0.06	0.05	0.10
MnO (%)	0.12	0.13	0.13	0.09	0.04	0.08	0.10
Barium	693	703	745	665	541	380	621
Chromium	20	21	24	59	62	<5	32
Copper	20	19	19	28	18	18	20
Mercury (µg/kg)	28	20	17	22	13	15	19
Nickel	7	9	6	16	25	7	12
Lead	28	20	17	22	13	15	19
Rubidium	53	57	56	70	52	40	55
Strontium	123	119	120	109	117	65	109
Vanadium	71	78	79	108	62	56	76
Zinc	65	55	43	65	37	32	49
Zirconium	368	383	386	310	308	148	317
Total C (%)	2.13	1.34	0.93	0.53	0.24	0.14	0.89
Inorganic C (%)	0.07	0.04	0.04	0.06	0.05	0.04	0.05
Organic C (%)	2.06	1.30	0.89	0.47	0.19	0.10	0.84
pH	6.56	6.65	6.49	5.41	7.10	7.02	6.54

Table 32 Elemental composition of samples selected from Core 30

Subsample	30-01	30-02	30-03	30-04	30-08	Average
Lab. No.	R22116	R22117	R22118	R22119	R22120	
Depth Interval (ft)	0.0-0.6	0.6-1.4	1.4-1.65	1.65-3.0	5.15-6.0	
Horizon	Ap	AE	E	B1	2B	
SiO_2 (%)	81.10	79.30	74.90	72.90	84.10	78.46
Al_2O_3 (%)	7.70	9.50	11.30	13.00	7.50	9.80
Fe_2O_3 (%)	2.52	3.23	4.61	4.81	1.97	3.43
K_2O (%)	1.64	1.86	1.93	1.87	1.26	1.71
CaO (%)	0.50	0.35	0.32	0.40	0.38	0.39
MgO (%)	0.32	0.51	0.77	0.93	0.33	0.57
Na_2O (%)	0.90	0.95	0.97	0.97	0.62	0.88
TiO_2 (%)	0.77	0.82	0.87	0.78	0.40	0.73
P_2O_5 (%)	0.13	0.10	0.11	0.11	0.02	0.09
MnO (%)	0.21	0.10	0.06	0.06	0.02	0.09
Barium	627	605	557	555	303	529
Chromium	13	31	49	57	12	32
Copper	20	20	28	34	25	25
Mercury (µg/kg)	20	18	21	20	15	19
Nickel	10	9	9	15	22	13
Lead	20	18	21	20	15	19
Rubidium	48	61	74	72	49	61
Strontium	98	102	102	109	115	105
Vanadium	64	79	100	100	68	82
Zinc	45	45	58	65	39	50
Zirconium	430	400	353	309	219	342
Total C (%)	1.19	0.50	0.34	0.27	0.19	0.50
Inorganic C (%)	0.04	0.04	0.04	0.04	0.03	0.04
Organic C (%)	1.15	0.46	0.30	0.23	0.16	0.46
pH	6.20	4.52	4.42	4.20	5.70	5.01

Table 33 Elemental composition of samples selected from Core 31

Subsample	31-01	31-02	31-03	31-04	31-08	31-20	Average
Lab. No.	R22121	R22122	R22123	R22124	R22125	R22126	
Depth Interval (ft)	0.0-0.4	0.4-1.4	1.4-2.4	2.4-3.7	3.7-6.4	12.5-16.0	
Horizon	Ap	Bt1	Bt2	Bt3	B7	0.08	
SiO_2 (%)	76.50	74.20	77.70	78.50	81.80	67.20	75.98
Al_2O_3 (%)	10.60	12.90	10.70	8.00	8.00	9.00	9.87
Fe_2O_3 (%)	3.31	4.09	4.02	7.26	2.19	2.74	3.94
K_2O (%)	1.43	1.38	1.40	1.48	1.83	1.80	1.55
CaO (%)	0.56	0.59	0.68	0.57	1.32	5.17	1.48
MgO (%)	0.52	0.72	0.70	0.57	0.59	2.96	1.01
Na_2O (%)	0.71	0.71	0.74	0.67	0.88	0.91	0.77
TiO_2 (%)	0.69	0.72	0.62	0.45	0.41	0.59	0.58
P_2O_5 (%)	0.12	0.05	0.04	0.09	0.06	0.08	0.07
MnO (%)	0.02	0.02	0.03	0.03	0.03	0.05	0.03
Barium	425	439	647	325	289	416	424
Chromium	50	63	34	31	7	6	32
Copper	27	34	26	30	25	25	28
Mercury (µg/kg)	31	48	39	22	20	19	30
Nickel	19	20	29	19	13	12	19
Lead	18	21	20	22	17	15	19
Rubidium	60	75	64	66	58	59	64
Strontium	108	101	106	115	124	121	113
Vanadium	72	94	81	79	62	70	76
Zinc	57	74	67	74	56	52	63
Zirconium	334	293	248	220	237	269	267
Total C (%)	1.38	0.60	0.24	0.20	0.29	2.36	0.85
Inorganic C (%)	0.03	0.04	0.03	0.04	0.20	1.64	0.33
Organic C (%)	1.35	0.56	0.21	0.16	0.09	0.72	0.52
pH	4.38	4.44	6.08	6.82	7.61	7.28	6.10

Table 34 Elemental composition of samples selected from Core 32

Subsample	32-01	32-02	32-03	32-04	32-06	32-11	Average
Lab. No.	R22138	R22139	R22140	R22141	R22142	R22143	
Depth Interval (ft)	0.0-0.7	0.7-1.7	1.7-2.5	2.5-4.5	4.7-7.0	14.0-16.0	
Horizon	Ap	Eg1	Eg2	Btg	C1	C6	
SiO_2 (%)	80.90	79.80	80.50	72.50	77.30	64.30	75.88
Al_2O_3 (%)	7.50	8.70	9.70	13.80	11.70	7.70	9.85
Fe_2O_3 (%)	2.33	2.83	3.17	5.48	2.70	2.94	3.24
K_2O (%)	1.63	1.70	1.75	1.79	1.66	1.99	1.75
CaO (%)	0.94	0.45	0.37	0.55	0.73	6.76	1.63
MgO (%)	0.29	0.31	0.41	0.88	0.69	3.97	1.09
Na_2O (%)	0.81	0.83	0.84	0.80	0.92	0.88	0.85
TiO_2 (%)	0.75	0.80	0.82	0.79	0.75	0.41	0.72
P_2O_5 (%)	0.19	0.10	0.09	0.12	0.06	0.10	0.11
MnO (%)	0.12	0.13	0.11	0.40	0.06	0.09	0.15
Barium	606	640	593	771	841	481	655
Chromium	21	23	30	71	53	<5	34
Copper	19	19	24	23	27	20	22
Mercury (µg/kg)	23	23	21	35	36	12	25
Nickel	<5	<5	6	18	23	6	11
Lead	18	16	17	16	15	14	16
Rubidium	55	63	72	66	77	58	65
Strontium	112	104	105	114	115	116	111
Vanadium	66	78	81	101	87	62	79
Zinc	46	38	44	59	59	57	51
Zirconium	382	348	354	295	257	158	299
Total C (%)	1.41	1.02	0.65	0.32	0.22	2.57	1.03
Inorganic C (%)	0.13	0.13	0.03	0.06	0.10	2.57	0.50
Organic C (%)	1.28	0.89	0.62	0.26	0.12	<0.01	0.53
pH	6.72	5.28	4.22	4.30	6.34	7.93	5.80

Table 35 Elemental composition of samples selected from Core 33

Subsample	33-01	33-02	33-03	33-04	33-06	33-10	Average
Lab. No.	R22144	R22145	R22146	R22147	R22148	R22149	
Depth Interval (ft)	0.0-0.5	0.5-1.0	1.0-1.5	1.5-1.8	2.4-4.2	8.15-8.8	
Horizon	Ap	A2	AB	B1	B3	C3g	
SiO_2 (%)	75.20	76.80	80.50	80.20	74.30	71.00	76.33
Al_2O_3 (%)	9.10	9.40	8.50	8.80	12.50	13.90	10.37
Fe_2O_3 (%)	3.02	3.30	2.80	3.35	4.12	5.41	3.67
K_2O (%)	1.42	1.41	1.46	1.60	1.58	1.66	1.52
CaO (%)	0.77	0.50	0.75	0.32	0.45	0.51	0.55
MgO (%)	0.50	0.43	0.39	0.37	0.68	0.78	0.52
Na_2O (%)	0.96	0.96	1.01	1.09	1.02	0.84	0.98
TiO_2 (%)	0.86	0.77	0.82	0.91	0.82	0.79	0.83
P_2O_5 (%)	0.15	0.09	0.08	0.05	0.07	0.04	0.08
MnO (%)	0.08	0.05	0.02	0.02	0.07	0.09	0.06
Barium	733	586	679	594	1040	752	730
Chromium	26	32	20	29	83	70	43
Copper	27	31	27	28	29	25	28
Mercury (µg/kg)	30	124	19	19	31	28	42
Nickel	14	15	6	5	23	26	15
Lead	21	22	18	20	18	18	20
Rubidium	61	70	67	74	78	106	76
Strontium	93	99	147	102	109	107	110
Vanadium	78	84	78	88	95	99	87
Zinc	60	62	45	47	59	61	56
Zirconium	310	342	385	371	283	224	319
Total C (%)	3.77	2.56	0.62	0.33	0.31	0.16	1.29
Inorganic C (%)	0.23	0.07	0.07	0.09	0.07	0.06	0.10
Organic C (%)	3.54	2.49	0.55	0.24	0.24	0.10	1.19
pH	5.84	4.73	4.27	4.28	4.48	6.54	5.02

Table 36 Elemental composition of samples selected from Core 34

Subsample	34-01	34-02	34-03	34-04	34-10	34-13	Average
Lab. No.	R22150	R22151	R22152	R22153	R22154	R22155	
Depth Interval (ft)	0.0-0.5	0.5-0.85	0.85-1.25	1.25-1.70	4.0-5.0	6.0-6.6	
Horizon	Ap	A2	E	B1	2Btx4	0.13	
SiO_2 (%)	80.90	82.30	81.10	77.10	82.00	85.10	81.42
Al_2O_3 (%)	7.20	7.50	8.30	10.30	7.90	6.50	7.95
Fe_2O_3 (%)	1.90	1.95	2.59	3.79	2.99	2.66	2.65
K_2O (%)	1.95	2.02	2.12	2.14	1.71	1.41	1.89
CaO (%)	0.55	0.42	0.38	0.36	0.41	0.28	0.40
MgO (%)	0.31	0.33	0.43	0.71	0.49	0.34	0.44
Na_2O (%)	0.94	0.95	0.93	0.92	0.88	0.49	0.85
TiO_2 (%)	0.86	0.90	0.90	0.91	0.64	0.57	0.80
P_2O_5 (%)	0.12	0.09	0.07	0.08	0.06	0.05	0.08
MnO (%)	0.23	0.21	0.13	0.06	0.05	0.04	0.12
Barium	907	958	886	848	651	592	807
Chromium	<5	37	15	44	27	13	24
Copper	20	21	21	29	24	24	23
Mercury (µg/kg)	40	38	42	44	14	14	32
Nickel	9	18	6	8	17	9	11
Lead	19	17	16	19	17	15	17
Rubidium	61	61	64	83	61	55	64
Strontium	105	98	99	97	114	71	97
Vanadium	62	61	74	92	66	64	70
Zinc	48	45	48	67	51	42	50
Zirconium	401	408	389	353	282	265	350
Total C (%)	1.54	0.74	0.41	0.24	0.16	0.15	0.54
Inorganic C (%)	0.11	0.32	0.04	0.03	0.02	0.05	0.10
Organic C (%)	1.43	0.42	0.37	0.21	0.14	0.10	0.45
pH	6.09	6.30	6.28	5.14	4.58	5.03	5.57

Table 37 Elemental composition of samples selected from Core 35

Subsample	35-01	35-02	35-03	35-04	35-06	35-09	Average
Lab. No.	R22156	R22157	R22158	R22159	R22160	R22161	
Depth Interval (ft)	0.0-0.7	0.7-1.25	1.25-1.6	1.6-2.9	4.0-5.15	8.0-8.9	
Horizon	Ap	E	BE	Bt1	Bt3	B6	
SiO_2 (%)	61.40	80.20	73.20	70.90	70.30	79.80	72.63
Al_2O_3 (%)	7.40	8.80	11.80	12.70	9.40	9.50	9.93
Fe_2O_3 (%)	2.31	2.95	4.74	5.38	3.47	2.81	3.61
K_2O (%)	1.99	2.06	2.11	2.10	2.15	1.80	2.04
CaO (%)	0.67	0.56	0.64	0.67	3.24	0.68	1.08
MgO (%)	0.36	0.56	0.97	1.12	2.59	0.64	1.04
Na_2O (%)	1.07	1.01	0.88	0.92	1.21	0.91	1.00
TiO_2 (%)	0.76	0.81	0.81	0.80	0.71	0.67	0.76
P_2O_5 (%)	0.26	0.11	0.11	0.11	0.14	0.08	0.13
MnO (%)	0.12	0.08	0.08	0.10	0.07	0.05	0.08
Barium	727	752	755	778	697	659	728
Chromium	10	24	58	66	23	5	31
Copper	22	21	34	34	27	25	27
Mercury (µg/kg)	27	16	20	39	25	28	26
Nickel	7	<5	9	12	9	14	9
Lead	16	19	22	22	16	15	18
Rubidium	54	66	83	77	63	59	67
Strontium	121	115	97	104	128	106	112
Vanadium	61	79	101	105	73	70	82
Zinc	46	52	77	80	64	52	62
Zirconium	364	354	298	294	298	264	312
Total C (%)	0.96	0.38	0.42	0.40	1.12	0.16	0.57
Inorganic C (%)	0.04	0.03	0.04	0.02	0.95	0.08	0.19
Organic C (%)	0.92	0.35	0.38	0.38	0.17	0.08	0.38
pH	5.99	6.07	5.98	6.03	7.53	6.76	6.39

Table 38 Elemental composition of samples selected from Core 36

Subsample	36-01	36-02	36-03	36-04	36-06	36-08	Average
Lab. No.	R22162	R22163	R22164	R22165	R22166	R22167	
Depth Interval (ft)	0.0-0.9	0.9-1.4	1.4-2.3	2.3-3.0	4.5-5.2	7.0-8.0	
Horizon	Ap	EB1	EB2	B1	Btx2	C1	
SiO_2 (%)	80.40	78.00	74.70	73.60	83.90	77.60	78.03
Al_2O_3 (%)	8.10	9.90	11.10	11.90	7.20	10.70	9.82
Fe_2O_3 (%)	2.42	3.33	4.51	4.86	2.56	4.27	3.66
K_2O (%)	2.02	2.17	2.27	2.37	1.68	1.68	2.03
CaO (%)	0.48	0.47	0.41	0.40	0.37	0.30	0.41
MgO (%)	0.40	0.63	0.91	0.99	0.41	0.60	0.66
Na_2O (%)	0.96	0.89	0.91	1.08	0.82	0.46	0.85
TiO_2 (%)	0.90	0.90	0.88	0.89	0.70	0.58	0.81
P_2O_5 (%)	0.11	0.08	0.08	0.09	0.04	0.04	0.07
MnO (%)	0.24	0.12	0.05	0.06	0.04	0.08	0.10
Barium	890	905	803	787	554	527	744
Chromium	25	39	58	65	17	48	42
Copper	21	22	32	32	22	25	26
Mercury (µg/kg)	33	30	31	28	18	34	29
Nickel	12	7	11	8	10	18	11
Lead	20	18	22	23	13	19	19
Rubidium	60	69	87	83	60	75	72
Strontium	98	97	98	98	113	74	96
Vanadium	71	87	100	99	66	87	85
Zinc	52	54	76	73	43	53	59
Zirconium	388	343	321	313	310	194	312
Total C (%)	0.91	0.39	0.25	0.16	0.17	0.19	0.35
Inorganic C (%)	0.05	0.04	0.04	0.04	0.03	0.04	0.04
Organic C (%)	0.86	0.35	0.21	0.12	0.14	0.15	0.31
pH	5.92	6.22	4.50	4.30	4.66	5.22	5.14

Table 39 Elemental composition of samples selected from Core 37

Subsample	37-01	37-02	37-03	37-04	37-08	37-11	Average
Lab. No.	R22173	R22174	R22175	R22176	R22177	R22178	
Depth Interval (ft)	0.0-0.6	0.6-1.3	1.3-1.7	1.7-2.6	5.0-6.0	7.35-8.0	
Horizon	Ap	A	AB	Bt1	2A1	2Bt4	
SiO_2 (%)	78.00	72.60	68.50	68.80	77.60	71.00	72.75
Al_2O_3 (%)	8.90	12.40	14.60	14.10	9.80	11.20	11.83
Fe_2O_3 (%)	2.66	4.12	5.22	5.53	3.65	3.29	4.08
K_2O (%)	2.12	2.12	2.08	2.21	2.75	2.66	2.32
CaO (%)	0.73	0.75	0.83	0.86	0.62	2.21	1.00
MgO (%)	0.52	0.95	1.35	1.43	0.99	2.24	1.25
Na_2O (%)	1.05	0.93	0.82	0.90	0.90	1.04	0.94
TiO_2 (%)	0.84	0.85	0.84	0.85	0.55	0.73	0.78
P_2O_5 (%)	0.17	0.09	0.08	0.12	0.12	0.12	0.12
MnO (%)	0.15	0.13	0.07	0.16	0.13	0.07	0.12
Barium	763	761	784	829	614	665	736
Chromium	55	37	76	181	130	42	87
Copper	19	22	31	28	22	26	25
Mercury (µg/kg)	28	41	58	56	22	30	39
Nickel	7	11	19	34	11	14	16
Lead	18	16	22	19	15	16	18
Rubidium	66	80	99	75	70	87	80
Strontium	103	86	90	95	109	102	98
Vanadium	64	77	105	106	64	69	81
Zinc	54	81	107	89	57	75	77
Zirconium	292	231	156	163	120	137	183
Total C (%)	1.49	0.91	0.75	0.49	0.24	0.89	0.80
Inorganic C (%)	0.04	0.05	0.05	0.04	0.04	0.61	0.14
Organic C (%)	1.45	0.86	0.70	0.45	0.20	0.28	0.66
pH	6.24	6.11	6.17	6.46	7.00	7.39	6.56

Table 40 Elemental composition of samples selected from Core 38

Subsample	38-01	38-02	38-03	38-05	38-08	38-13	Average
Lab. No.	R22179	R22180	R22181	R22182	R22183	R22184	
Depth Interval (ft)	0.0-0.6	0.6-1.15	1.15-1.8	2.0-2.8	4.75-6.0	12.0-12.5	
Horizon	Ap	AE	E	Bt1	2A1	2Bt4	
SiO_2 (%)	79.00	80.00	80.90	66.20	80.40	77.90	77.40
Al_2O_3 (%)	8.20	8.90	8.10	16.20	9.50	10.80	10.28
Fe_2O_3 (%)	2.56	2.85	3.14	6.36	3.12	3.53	3.59
K_2O (%)	1.72	1.76	1.77	1.73	1.48	1.99	1.74
CaO (%)	1.32	0.48	0.34	0.44	0.47	0.52	0.59
MgO (%)	0.39	0.40	0.39	1.27	0.53	0.80	0.63
Na_2O (%)	1.09	1.08	0.95	0.69	0.78	0.68	0.88
TiO_2 (%)	0.87	0.92	0.81	0.78	0.61	0.50	0.75
P_2O_5 (%)	0.17	0.09	0.08	0.08	0.06	0.07	0.09
MnO (%)	0.08	0.06	0.08	0.11	0.03	0.03	0.07
Barium	601	613	602	693	469	371	558
Chromium	25	27	35	117	87	141	72
Copper	22	23	22	34	25	25	25
Mercury (µg/kg)	23	23	20	56	27	28	30
Nickel	7	8	9	24	17	18	14
Lead	20	19	19	24	18	18	20
Rubidium	58	65	65	92	74	94	75
Strontium	105	105	122	102	115	105	109
Vanadium	63	72	72	120	72	70	78
Zinc	47	46	46	91	48	65	57
Zirconium	233	239	386	249	249	190	258
Total C (%)	1.22	0.60	0.53	0.55	0.20	0.13	0.54
Inorganic C (%)	0.18	0.04	0.03	0.03	0.03	0.03	0.06
Organic C (%)	1.04	0.56	0.50	0.52	0.17	0.10	0.48
pH	6.81	5.16	4.70	4.37	6.57	7.18	5.80

Table 41 Elemental composition of samples selected from Core 39

Subsample	39-1/2	39-03	39-04	39-05	39-07	39-13	Average
Lab. No.	R22185	R22186	R22187	R22188	R22189	R22190	
Depth Interval (ft)	0.0-0.9	0.9-1.4	1.4-2.7	2.7-2.9	3.4-4.1	8.9-9.55	
Horizon	A	E	B1	B2	2B1	3Bt4	
SiO_2 (%)	81.20	72.20	71.30	75.30	79.80	70.00	74.97
Al_2O_3 (%)	7.30	12.30	13.50	10.50	9.20	11.10	10.65
Fe_2O_3 (%)	3.12	5.03	5.59	5.00	3.74	9.77	5.38
K_2O (%)	1.57	1.62	1.82	2.09	1.54	1.60	1.71
CaO (%)	0.49	0.26	0.30	0.36	0.38	0.47	0.38
MgO (%)	0.46	0.86	1.00	0.88	0.51	0.70	0.74
Na_2O (%)	0.85	0.77	0.80	1.03	0.81	0.57	0.81
TiO_2 (%)	0.80	0.81	0.81	0.83	0.71	0.58	0.76
P_2O_5 (%)	0.09	0.06	0.09	0.10	0.08	0.06	0.08
MnO (%)	0.22	0.04	0.04	0.06	0.03	0.43	0.14
Barium	610	483	444	534	596	705	562
Chromium	73	89	62	56	44	86	68
Copper	18	32	37	32	26	18	27
Mercury (µg/kg)	34	89	28	11	11	38	35
Nickel	8	13	15	11	15	18	13
Lead	20	22	24	23	18	15	20
Rubidium	50	89	91	82	67	41	70
Strontium	103	93	104	126	115	103	107
Vanadium	69	101	100	89	75	75	85
Zinc	42	76	80	69	52	45	61
Zirconium	422	306	312	340	334	207	320
Total C (%)	0.88	0.42	0.43	0.34	0.31	0.24	0.44
Inorganic C (%)	0.07	0.04	0.04	0.03	0.03	0.03	0.04
Organic C (%)	0.81	0.38	0.39	0.31	0.28	0.21	0.40
pH	6.24	4.02	3.98	4.24	4.38	6.50	4.89

Table 42 Elemental composition of samples selected from Core 40

Subsample	40-01	40-02	40-03	40-04	40-07	40-14	Average
Lab. No.	R22191	R22192	R22193	R22194	R22195	R22196	
Depth Interval (ft)	0.0-0.4	0.4-1.3	1.3-1.65	1.65-2.35	3.45-4.0	9.1-10.2	
Horizon	Ap	E	B1	B2	2B1	3Bt1	
SiO_2 (%)	76.50	80.90	76.30	74.70	72.20	77.80	76.40
Al_2O_3 (%)	7.50	8.30	10.80	11.80	12.60	10.80	10.30
Fe_2O_3 (%)	4.17	3.08	4.36	4.89	5.88	3.73	4.35
K_2O (%)	1.67	1.74	1.92	1.79	2.02	1.56	1.78
CaO (%)	0.53	0.30	0.29	0.24	0.36	0.42	0.36
MgO (%)	0.38	0.40	0.64	0.80	0.96	0.69	0.65
Na_2O (%)	0.83	0.90	0.91	0.87	1.00	0.66	0.86
TiO_2 (%)	0.77	0.84	0.82	0.83	0.79	0.60	0.78
P_2O_5 (%)	0.11	0.10	0.09	0.09	0.13	0.04	0.09
MnO (%)	0.27	0.26	0.10	0.06	0.06	0.06	0.14
Barium	314	651	569	542	703	530	552
Chromium	20	27	43	73	75	82	60
Copper	19	18	23	29	36	22	26
Mercury (µg/kg)	37	28	27	62	14	36	34
Nickel	9	7	8	10	12	15	10
Lead	30	19	19	22	25	16	20
Rubidium	47	56	73	87	87	82	77
Strontium	119	102	123	105	141	93	114
Vanadium	69	76	89	98	100	69	84
Zinc	150	51	63	78	90	57	82
Zirconium	376	355	341	314	319	202	318
Total C (%)	3.65	0.61	0.43	0.37	0.29	0.21	0.93
Inorganic C (%)	0.05	0.05	0.04	0.03	0.04	0.03	0.04
Organic C (%)	3.60	0.56	0.39	0.34	0.25	0.18	0.89
pH	5.84	4.38	4.53	4.24	4.19	6.52	4.95

Table 43 Elemental composition of samples selected from Core 41

Subsample	41-01	41-02	41-03	41-04	41-09	41-23	Average
Lab. No.	R22197	R22198	R22199	R22200	R22201	R22202	
Depth Interval (ft)	0.0-0.9	0.9-1.15	1.15-1.7	1.7-2.35	6.0-7.8	17.0-18.0	
Horizon	Ap	E1	E2	EB	C1	3C2	
SiO_2 (%)	78.90	77.60	75.00	72.00	81.60	60.20	74.22
Al_2O_3 (%)	7.60	8.80	10.90	12.80	8.50	13.20	10.30
Fe_2O_3 (%)	3.91	3.98	4.59	4.87	2.60	2.66	3.77
K_2O (%)	1.69	1.79	1.85	1.68	1.62	1.89	1.75
CaO (%)	0.60	0.44	0.38	0.34	0.48	6.04	1.38
MgO (%)	0.37	0.45	0.66	0.87	0.47	3.58	1.07
Na_2O (%)	0.95	0.94	0.95	0.91	0.97	0.88	0.93
TiO_2 (%)	0.78	0.81	0.84	0.88	0.75	0.55	0.77
P_2O_5 (%)	0.10	0.09	0.08	0.08	0.06	0.09	0.08
MnO (%)	0.39	0.30	0.22	0.04	0.06	0.04	0.18
Barium	672	628	596	628	534	862	653
Chromium	37	29	46	62	24	21	37
Copper	19	20	20	31	24	26	23
Mercury (µg/kg)	34	28	27	22	33	17	27
Nickel	9	10	9	13	10	9	10
Lead	23	20	20	21	15	18	20
Rubidium	51	60	60	88	59	71	65
Strontium	141	141	113	93	110	119	120
Vanadium	75	78	89	103	64	66	79
Zinc	46	45	49	78	43	66	55
Zirconium	542	487	380	289	297	190	364
Total C (%)	1.15	1.07	0.84	0.73	0.27	2.21	1.05
Inorganic C (%)	0.05	0.04	0.04	0.03	0.02	1.80	0.33
Organic C (%)	1.10	1.03	0.80	0.70	0.25	0.41	0.72
pH	6.98	6.74	5.22	4.54	6.87	8.02	6.40

Table 44 Elemental composition of samples selected from Core 42

Subsample	42-01	42-02	42-04	42-06	42-16	42-23	Average
Lab. No.	R22204	R22205	R22206	R22207	R22208	R22209	
Depth Interval (ft)	0.0-0.7	0.7-1.3	2.0-2.7	3.3-4.0	9.2-10.0	14.0-15.1	
Horizon	Ap	A	AB	Bw	CA	D/A	
SiO_2 (%)	82.60	80.00	81.80	83.80	87.10	76.10	81.90
Al_2O_3 (%)	7.10	8.00	8.20	7.50	6.20	12.10	8.18
Fe_2O_3 (%)	2.29	2.80	2.78	2.74	1.94	2.89	2.57
K_2O (%)	1.85	1.85	1.80	1.56	1.20	2.16	1.74
CaO (%)	0.52	0.58	0.48	0.40	0.46	0.79	0.54
MgO (%)	0.39	0.45	0.46	0.43	0.34	0.90	0.50
Na_2O (%)	0.84	0.87	0.83	0.75	0.73	1.21	0.87
TiO_2 (%)	0.53	0.56	0.56	0.45	0.29	0.83	0.54
P_2O_5 (%)	0.10	0.11	0.07	0.08	0.09	0.11	0.09
MnO (%)	0.11	0.13	0.12	0.12	0.03	0.03	0.09
Barium	502	527	496	472	353	663	502
Chromium	60	6	ND	28	<5	89	38
Copper	26	23	ND	20	20	31	24
Mercury (µg/kg)	28	28	26	22	15	27	24
Nickel	8	10	ND	10	13	12	11
Lead	16	15	ND	14	13	20	16
Rubidium	53	56	ND	46	43	89	57
Strontium	106	96	94	86	86	119	98
Vanadium	52	57	ND	54	38	81	56
Zinc	53	49	ND	44	46	839	206
Zirconium	270	278	240	180	121	306	233
Total C (%)	1.36	1.61	0.66	0.39	0.26	0.30	0.76
Inorganic C (%)	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Organic C (%)	1.33	1.58	0.63	0.37	0.23	0.27	0.74
pH	6.06	6.32	6.53	6.50	6.77	5.78	6.33

ND=Not Determined

Table 45 Elemental composition of samples selected from Core 43

Subsample	43-01	43-03	43-05	43-08	43-12	43-27	Average
Lab. No.	R22210	R22211	R22212	R22213	R22214	R22215	
Depth Interval (ft)	0.0-0.8	1.1-1.7	2.0-2.85	4.25-4.8	6.3-6.9	16.1-16.8	
Horizon	Ap	E	Bt	C	3A	3CD	
SiO_2 (%)	82.10	75.50	69.70	76.70	77.90	60.70	73.77
Al_2O_3 (%)	7.60	10.50	13.60	10.90	11.20	6.80	10.10
Fe_2O_3 (%)	2.05	4.70	6.57	3.05	2.91	1.99	3.55
K_2O (%)	1.76	1.81	1.82	2.15	1.74	2.04	1.89
CaO (%)	0.56	0.55	0.57	0.98	0.66	9.34	2.11
MgO (%)	0.27	0.59	1.06	0.76	0.71	5.01	1.40
Na_2O (%)	1.17	1.08	0.92	1.55	0.90	0.65	1.05
TiO_2 (%)	0.83	0.87	0.76	0.81	0.68	0.36	0.72
P_2O_5 (%)	0.14	0.12	0.12	0.11	0.05	0.06	0.10
MnO (%)	0.14	0.52	0.15	0.07	0.03	0.05	0.16
Barium	738	1126	631	647	523	339	667
Chromium	15	52	106	49	192	7	70
Copper	18	23	32	26	27	24	25
Mercury (µg/kg)	18	33	53	38	37	14	32
Nickel	8	9	19	16	18	<5	13
Lead	18	18	21	18	18	15	18
Rubidium	53	50	68	61	73	58	61
Strontium	109	118	105	179	126	102	123
Vanadium	57	84	102	78	77	47	74
Zinc	43	50	83	69	58	51	59
Zirconium	411	328	287	388	300	136	308
Total C (%)	1.09	0.53	0.42	0.27	0.17	3.07	0.93
Inorganic C (%)	0.05	0.06	0.04	0.03	0.03	3.02	0.54
Organic C (%)	1.04	0.47	0.38	0.24	0.14	0.05	0.39
pH	5.32	5.40	4.70	5.66	5.94	7.86	5.81

Table 46 Elemental composition of samples selected from Core 44

Subsample	44-01	44-02	44-03	44-04	44-13	44-29	Average
Lab. No.	R22216	R22217	R22218	R22219	R22220	R22221	
Depth Interval (ft)	0.0-1.0	1.0-1.5	1.5-2.0	2.0-2.8	8.0-8.9	17.8-18.2	
Horizon	Ap	EB	B	Btj	2AB	2C	
SiO_2 (%)	81.50	78.40	71.60	71.70	78.20	60.80	73.70
Al_2O_3 (%)	7.80	9.50	13.20	13.00	10.80	7.10	10.23
Fe_2O_3 (%)	2.27	3.40	5.22	5.36	2.86	2.43	3.59
K_2O (%)	2.05	2.10	2.00	2.06	1.89	2.07	2.03
CaO (%)	0.67	0.60	0.64	0.62	0.70	9.69	2.15
MgO (%)	0.38	0.60	1.04	1.04	0.59	4.63	1.38
Na_2O (%)	1.23	1.20	0.92	0.93	1.05	0.60	0.99
TiO_2 (%)	0.77	0.80	0.76	0.76	0.74	0.40	0.71
P_2O_5 (%)	0.10	0.10	0.11	0.10	0.07	0.07	0.09
MnO (%)	0.21	0.10	0.08	0.12	0.04	0.06	0.10
Barium	667	704	593	579	492	279	552
Chromium	15	40	60	55	53	<5	38
Copper	18	20	32	29	26	23	25
Mercury (µg/kg)	24	30	55	35	36	22	34
Nickel	7	7	14	15	14	<5	10
Lead	20	19	21	19	18	15	19
Rubidium	58	62	87	73	67	62	68
Strontium	136	125	115	116	125	113	122
Vanadium	61	78	99	94	77	52	77
Zinc	44	52	94	83	49	58	63
Zirconium	423	357	306	299	319	140	307
Total C (%)	0.83	0.40	0.42	0.32	0.20	2.87	0.84
Inorganic C (%)	0.05	0.04	0.04	0.03	0.03	2.77	0.49
Organic C (%)	0.78	0.36	0.38	0.29	0.17	0.10	0.35
pH	6.33	5.40	4.60	4.58	5.74	7.86	5.75

Table 47 Elemental composition of samples selected from Core 45

Subsample	45-01	45-02	45-03	45-05	45-09	45-17	Average
Lab. No.	R22222	R22223	R22224	R22225	R22226	R22227	
Depth Interval (ft)	0.0-0.9	0.9-2.0	2.0-2.8	3.3-3.95	5.9-6.5	12.2-13.0	
Horizon	Ap	E2	E2	Bt	C	2Bt	
SiO_2 (%)	79.10	78.10	73.10	72.30	75.90	70.00	74.75
Al_2O_3 (%)	7.90	10.20	12.60	12.70	10.80	15.00	11.53
Fe_2O_3 (%)	2.21	3.51	5.08	5.56	4.10	6.24	4.45
K_2O (%)	1.98	2.09	2.06	2.15	2.32	1.21	1.97
CaO (%)	2.12	0.54	0.47	0.56	0.99	0.43	0.85
MgO (%)	0.64	0.64	0.97	1.05	0.83	0.85	0.83
Na_2O (%)	1.14	1.07	0.99	1.03	1.47	0.40	1.02
TiO_2 (%)	0.77	0.81	0.79	0.80	0.85	0.88	0.82
P_2O_5 (%)	0.10	0.08	0.09	0.12	0.13	0.04	0.09
MnO (%)	0.13	0.09	0.09	0.09	0.10	0.02	0.09
Barium	622	673	555	604	686	432	595
Chromium	22	37	69	66	70	88	59
Copper	20	26	33	35	27	38	30
Mercury (µg/kg)	24	30	33	19	31	6	24
Nickel	8	9	14	16	12	32	15
Lead	18	18	22	23	16	28	21
Rubidium	59	72	76	76	67	84	72
Strontium	144	144	124	134	193	85	137
Vanadium	62	82	100	99	79	108	88
Zinc	45	57	79	82	57	100	70
Zirconium	478	423	325	326	386	395	389
Total C (%)	1.24	0.45	0.33	0.16	0.20	0.64	0.50
Inorganic C (%)	0.05	0.05	0.05	0.05	0.05	0.06	0.05
Organic C (%)	1.19	0.40	0.28	0.11	0.15	0.58	0.45
pH	6.33	5.40	4.60	4.58	5.74	7.86	5.75

Table 48 Elemental composition of samples selected from Core 46

Subsample	46-01	46-02	46-04	46-05	46-08	46-33	Average
Lab. No.	R22228	R22229	R22230	R22231	R22232	R22233	
Depth Interval (ft)	0.0-0.7	0.7-1.4	2.0-2.4	2.4-2.85	4.0-5.0	18.6-19.2	
Horizon	Ap	A	AB	B/Ab	Bg	2DC	
SiO_2 (%)	78.10	78.20	75.90	73.50	73.20	81.00	76.65
Al_2O_3 (%)	8.90	9.00	10.50	12.00	12.10	8.30	10.13
Fe_2O_3 (%)	2.48	2.53	3.45	4.22	5.07	2.90	3.44
K_2O (%)	2.11	2.12	2.07	2.02	2.18	2.41	2.15
CaO (%)	0.83	0.81	0.83	0.87	0.86	0.46	0.78
MgO (%)	0.49	0.52	0.75	0.98	1.11	0.73	0.76
Na_2O (%)	1.09	1.09	1.07	1.01	1.08	0.84	1.03
TiO_2 (%)	0.75	0.76	0.76	0.76	0.77	0.54	0.72
P_2O_5 (%)	0.14	0.11	0.07	0.07	0.14	0.10	0.11
MnO (%)	0.06	0.06	0.04	0.03	0.10	0.02	0.05
Barium	583	637	651	629	650	455	601
Chromium	30	20	31	155	90	15	57
Copper	27	27	30	33	32	30	30
Mercury (µg/kg)	24	23	21	25	41	27	27
Nickel	7	9	9	13	15	11	11
Lead	20	18	18	19	21	20	19
Rubidium	76	79	90	93	74	84	83
Strontium	132	143	142	141	143	107	135
Vanadium	66	68	79	88	96	66	77
Zinc	67	64	70	84	83	66	72
Zirconium	357	352	359	338	316	194	319
Total C (%)	1.73	1.66	1.27	0.99	0.31	0.14	1.02
Inorganic C (%)	0.06	0.05	0.05	0.05	0.06	0.04	0.05
Organic C (%)	1.67	1.61	1.22	0.94	0.25	0.10	0.97
pH	6.20	6.26	6.06	6.17	6.25	6.23	6.20

Table 49 Elemental composition of samples selected from Core 47

Subsample	47-01	47-02	47-04	47-05	47-08	47-16	Average
Lab. No.	R22234	R22235	R22236	R22237	R22238	R22239	
Depth Interval (ft)	0.0-0.6	0.6-2.1	2.4-3.55	3.55-3.9	6.0-6.7	14.2-14.9	
Horizon	Ap	C1	C3	C4	2Bt1	2C7	
SiO_2 (%)	80.90	80.10	82.50	80.10	81.00	78.20	80.47
Al_2O_3 (%)	8.30	8.70	7.80	8.80	8.70	9.90	8.70
Fe_2O_3 (%)	2.43	2.59	2.25	2.59	2.89	3.72	2.75
K_2O (%)	2.04	2.06	1.90	2.08	1.93	2.00	2.00
CaO (%)	0.67	0.73	0.62	0.73	0.55	0.65	0.66
MgO (%)	0.48	0.57	0.45	0.60	0.52	0.73	0.56
Na_2O (%)	1.06	1.07	1.00	1.09	0.98	0.94	1.02
TiO_2 (%)	0.71	0.76	0.58	0.72	0.63	0.66	0.68
P_2O_5 (%)	0.11	0.10	0.09	0.10	0.09	0.11	0.10
MnO (%)	0.09	0.09	0.08	0.08	0.10	0.06	0.08
Barium	557	575	552	599	547	524	559
Chromium	20	14	23	15	25	112	35
Copper	24	24	20	23	23	30	24
Mercury (µg/kg)	21	22	19	22	13	9	18
Nickel	8	8	8	9	10	18	10
Lead	16	16	15	16	15	20	16
Rubidium	60	64	58	66	61	76	64
Strontium	124	124	133	105	115	129	122
Vanadium	57	62	55	60	62	74	62
Zinc	49	52	45	50	53	65	52
Zirconium	386	393	324	361	317	300	347
Total C (%)	0.91	0.77	0.61	0.70	0.44	0.41	0.64
Inorganic C (%)	0.05	0.07	0.04	0.07	0.03	0.06	0.05
Organic C (%)	0.86	0.70	0.57	0.63	0.41	0.35	0.59
pH	6.94	7.48	7.30	4.57	6.80	6.87	6.66

Table 50 Elemental composition of samples selected from Core 48

Subsample	48-01	48-03	48-04	48-06	48-09	48-16	Average
Lab. No.	R22240	R22241	R22242	R22243	R22244	R22245	
Depth Interval (ft)	0.0-0.7	0.95-1.5	1.5-2.0	2.5-3.2	4.25-5.25	10.3-11.3	
Horizon	Ap	Bt1	Bt2	Bt4	C	2C1	
SiO_2 (%)	78.50	75.10	70.40	70.70	73.70	80.00	74.73
Al_2O_3 (%)	8.50	10.90	13.40	13.20	11.70	8.80	11.08
Fe_2O_3 (%)	2.55	3.74	5.31	5.61	4.76	3.94	4.32
K_2O (%)	2.05	1.97	1.84	1.96	2.16	2.25	2.04
CaO (%)	0.85	0.72	0.75	0.78	1.02	0.46	0.76
MgO (%)	0.44	0.73	1.10	1.15	0.90	0.60	0.82
Na_2O (%)	1.03	0.90	0.80	0.90	1.27	0.73	0.94
TiO_2 (%)	0.78	0.81	0.78	0.79	0.82	0.51	0.75
P_2O_5 (%)	0.13	0.08	0.07	0.09	0.17	0.11	0.11
MnO (%)	0.07	0.05	0.04	0.10	0.05	0.03	0.06
Barium	615	609	625	695	627	420	599
Chromium	41	73	72	59	42	14	50
Copper	26	30	38	33	31	28	31
Mercury (µg/kg)	19	20	33	49	33	17	29
Nickel	9	11	20	21	13	11	14
Lead	20	19	24	22	21	19	21
Rubidium	67	81	91	79	77	81	79
Strontium	131	122	112	122	152	96	123
Vanadium	67	85	102	102	88	65	85
Zinc	57	71	92	86	78	61	74
Zirconium	382	328	298	300	342	201	309
Total C (%)	1.70	1.15	0.93	0.52	0.41	0.20	0.82
Inorganic C (%)	0.04	0.04	0.04	0.04	0.03	0.03	0.04
Organic C (%)	1.66	1.11	0.89	0.48	0.38	0.17	0.78
pH	6.51	5.85	6.08	6.39	6.55	7.41	6.47

Table 51 Elemental composition of samples selected from Core 49

Subsample	49-01	49-02	49-03	49-05	49-07	49-21	Average
Lab. No.	R22246	R22247	R22248	R22250	R22251	R22252	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.6-3.3	4.1-4.7	12.45-13.0	
Horizon	Ap	Ap2	BAt	Bgt2	CBtj	Bg	
SiO_2 (%)	76.90	73.60	72.10	72.40	75.80	75.70	74.42
Al_2O_3 (%)	9.70	11.90	13.20	11.60	11.30	10.30	11.33
Fe_2O_3 (%)	2.92	4.20	4.52	6.44	3.68	5.65	4.57
K_2O (%)	2.01	1.80	1.78	2.04	2.17	2.22	2.00
CaO (%)	0.90	0.92	0.94	0.86	1.13	0.70	0.91
MgO (%)	0.55	0.84	1.09	0.95	0.79	0.88	0.85
Na_2O (%)	1.03	0.94	0.96	1.01	1.43	0.83	1.03
TiO_2 (%)	0.79	0.79	0.81	0.80	0.87	0.59	0.78
P_2O_5 (%)	0.16	0.07	0.10	0.13	0.15	0.10	0.12
MnO (%)	0.06	0.07	0.08	0.18	0.06	0.09	0.09
Barium	608	690	723	748	688	531	665
Chromium	ND	ND	ND	56	37	48	47
Copper	ND	ND	ND	25	26	27	26
Mercury (µg/kg)	21	25	42	43	37	28	33
Nickel	ND	ND	ND	17	18	16	17
Lead	ND	ND	ND	18	16	19	18
Rubidium	ND	ND	ND	54	63	71	63
Strontium	131	131	131	133	182	123	139
Vanadium	ND	ND	ND	84	76	75	78
Zinc	ND	ND	ND	66	60	64	63
Zirconium	346	317	310	322	401	237	322
Total C (%)	1.59	1.07	0.60	0.32	0.16	0.17	0.65
Inorganic C (%)	0.03	0.04	0.04	0.04	0.04	0.03	0.04
Organic C (%)	1.56	1.03	0.56	0.28	0.12	0.14	0.62
pH	6.50	6.19	6.22	6.58	6.55	6.81	6.48

Table 52 Elemental composition of samples selected from Core 50

Subsample	50-01	50-02	50-03	50-05	50-07	50-16	Average
Lab. No.	R22252	R22253	R22254	R22255	R22256	R22257	
Depth Interval (ft)	0.0-0.7	0.7-1.4	1.4-2.0	2.6-3.3	4.1-4.7	12.45-13.0	
Horizon	Ap	AB	BA	Bt	C	D	
SiO_2 (%)	74.70	71.60	70.60	72.00	57.90	56.60	67.23
Al_2O_3 (%)	10.70	12.70	13.20	12.80	8.60	8.30	11.05
Fe_2O_3 (%)	3.83	5.03	5.57	5.09	3.33	3.12	4.33
K_2O (%)	2.03	2.02	2.14	2.89	2.72	2.65	2.41
CaO (%)	0.57	0.58	0.57	0.69	9.14	9.24	3.47
MgO (%)	0.71	1.03	1.15	1.26	4.56	4.81	2.25
Na_2O (%)	0.77	0.70	0.74	0.66	0.51	0.52	0.65
TiO_2 (%)	0.81	0.83	0.81	0.59	0.40	0.38	0.64
P_2O_5 (%)	0.09	0.07	0.07	0.07	0.07	0.08	0.08
MnO (%)	0.15	0.09	0.09	0.09	0.07	0.06	0.09
Barium	596	640	587	349	244	197	436
Chromium	44	51	57	44	<5	<5	34
Copper	22	30	32	27	22	23	26
Mercury (µg/kg)	24	31	37	28	13	15	25
Nickel	11	17	20	15	<5	<5	12
Lead	21	21	21	18	16	13	18
Rubidium	64	76	76	89	79	79	77
Strontium	102	93	102	123	141	122	114
Vanadium	83	92	98	79	57	59	78
Zinc	53	75	78	67	61	56	65
Zirconium	326	297	307	226	150	141	241
Total C (%)	1.56	1.02	0.78	0.42	2.94	3.35	1.68
Inorganic C (%)	0.05	0.05	0.04	0.10	2.84	2.96	1.01
Organic C (%)	1.51	0.97	0.74	0.32	0.10	0.39	0.67
pH	5.24	5.29	5.55	7.01	7.97	7.62	6.45

Table 53 Elemental composition of samples selected from Core 51

Subsample	51-01	51-02	51-03	51-04	51-06	51-21	Average
Lab. No.	R22258	R22259	R22260	R22261	R22262	R22263	
Depth Interval (ft)	0.0-0.7	0.7-1.3	1.3-2.0	2.0-2.7	3.5-4.0	13.3-13.76	
Horizon	Ap	Ap2	BA	Bt	B/C	D	
SiO_2 (%)	78.90	77.00	68.70	68.60	74.20	57.00	70.73
Al_2O_3 (%)	8.60	9.70	14.00	14.60	11.10	8.20	11.03
Fe_2O_3 (%)	3.32	3.84	6.30	6.38	4.53	3.00	4.56
K_2O (%)	1.98	1.92	1.90	1.98	2.65	2.55	2.16
CaO (%)	0.40	0.40	0.65	0.72	0.99	9.34	2.08
MgO (%)	0.43	0.54	1.14	1.17	1.30	4.81	1.57
Na_2O (%)	0.70	0.80	0.72	0.72	0.72	0.54	0.70
TiO_2 (%)	0.75	0.76	0.76	0.75	0.54	0.38	0.66
P_2O_5 (%)	0.11	0.09	0.06	0.06	0.09	0.07	0.08
MnO (%)	0.12	0.14	0.12	0.14	0.10	0.06	0.11
Barium	430	356	589	578	417	195	428
Chromium	31	30	66	71	22	<5	38
Copper	22	23	31	31	26	20	26
Mercury (µg/kg)	25	27	54	57	30	17	35
Nickel	8	9	21	29	9	<5	14
Lead	20	20	22	21	18	13	19
Rubidium	64	65	78	71	77	68	71
Strontium	123	118	110	120	122	11	101
Vanadium	69	78	106	103	71	51	80
Zinc	50	50	78	76	63	51	61
Zirconium	399	377	289	299	234	149	291.17
Total C (%)	1.38	1.25	0.84	0.57	0.46	3.36	1.31
Inorganic C (%)	0.06	0.06	0.04	0.06	0.21	3.08	0.59
Organic C (%)	1.32	1.19	0.80	0.51	0.25	0.28	0.73
pH	4.85	4.89	5.72	6.42	7.32	7.63	6.14

Table 54 Means and ranges of elemental contents of the uppermost samples from Illinois soil cores 27 through 51 compared with results for surface soils as determined by other researchers

	This Work		Shacklette and Boerngen	
Element	Mean	Range	Mean	Range
Silicon (%)	37.07	34.9-38.6	NR[†]	29-45**
Aluminum (%)	4.38	3.74-5.64	NR	<0.07-8.5**
Iron (%)	1.88	1.38-2.92	2.1(1)	0.1-4.0**
Potassium (%)	1.55	1.17-1.76	1.7(1)	0.22-2.25**
Calcium (%)	0.53	0.28-1.52	0.40(1)	0.3-1.5**
Magnesium (%)	0.26	0.16-0.43	0.30(1)	0.005-1.25**
Sodium (%)	0.72	0.52-0.91	NR	0.6-1.25**
Titanium (%)	0.46	0.32-0.54	0.41	0.05-1.0
Phosphorus (%)	0.06	0.04-0.11	0.065(1)	0.013-0.68**
Manganese (%)	0.11	0.01-0.30	0.052	0.005-0.15
Barium (mg/kg)	643	425-907	675	200-1500
Chromium (mg/kg)	30	<5-73	55	10-100
Copper (mg/kg)	21	18-27	25	7-100
Mercury (µg/kg)	28	18-59	70***	20-360***
Nickel (mg/kg)	9	<5-19	17	5-30
Lead (mg/kg)	20	16-30	19	10-30
Rubidium (mg/kg)	58	47-76	75	45-100
Strontium (mg/kg)	117	93-144	305	20-1000
Vanadium (mg/kg)	66	52-83	87	20-150*
Zinc (mg/kg)	55	42-150	58.5	20-109
Zirconium (mg/kg)	381	233-542	NR	NR

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

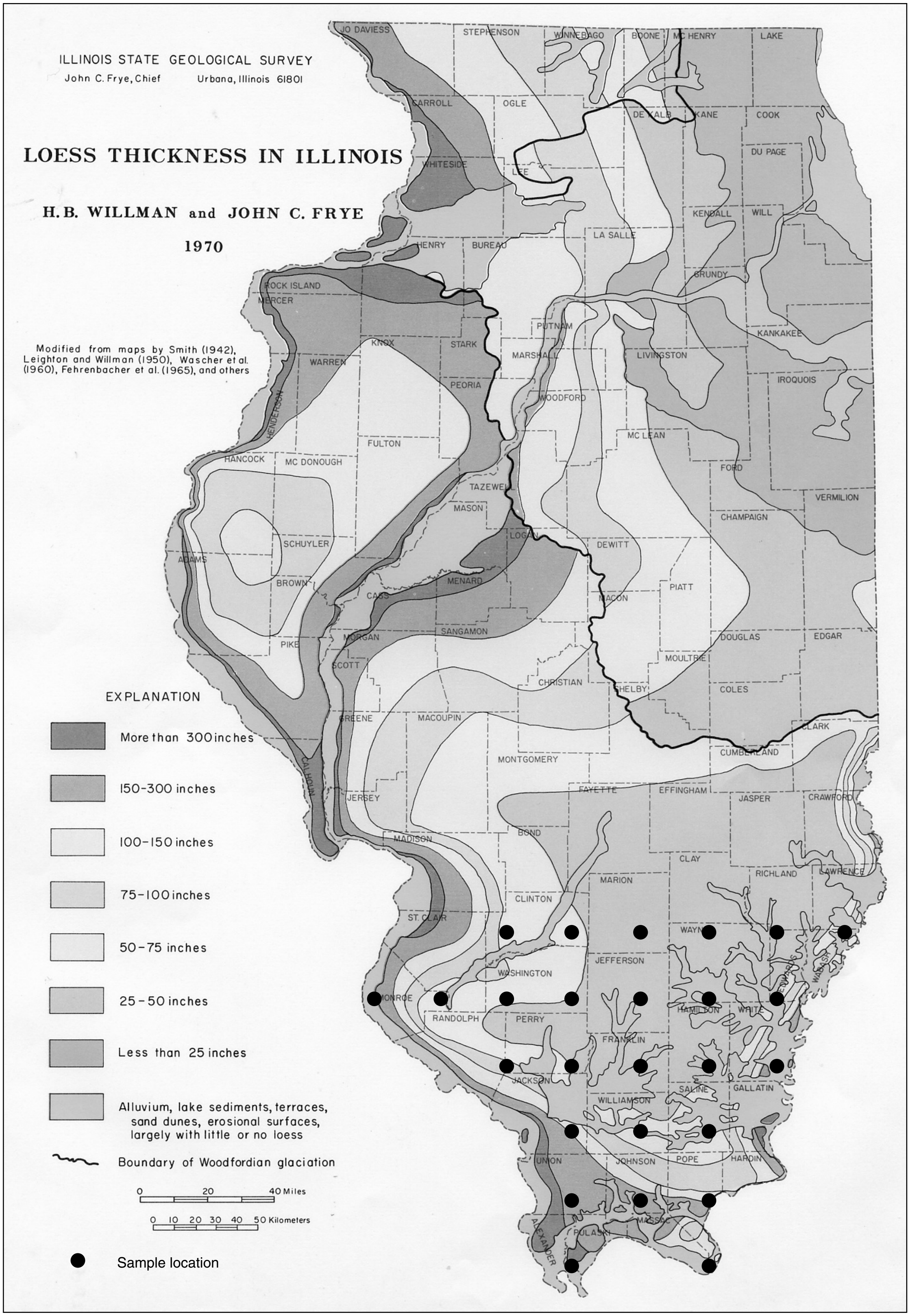


Figure 1 Sample locations related to loess thickness in Illinois (after Willman and Frye 1970).

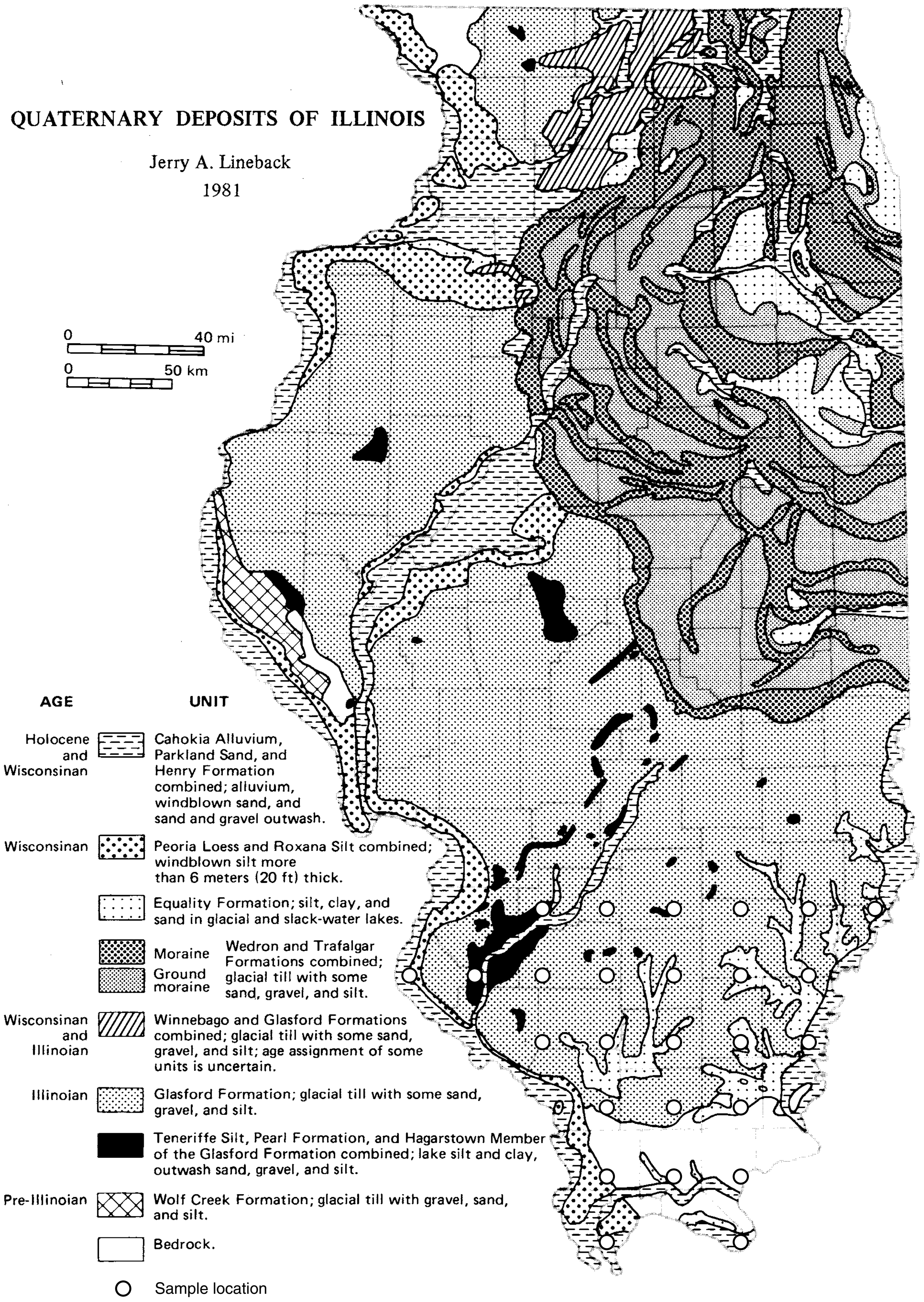
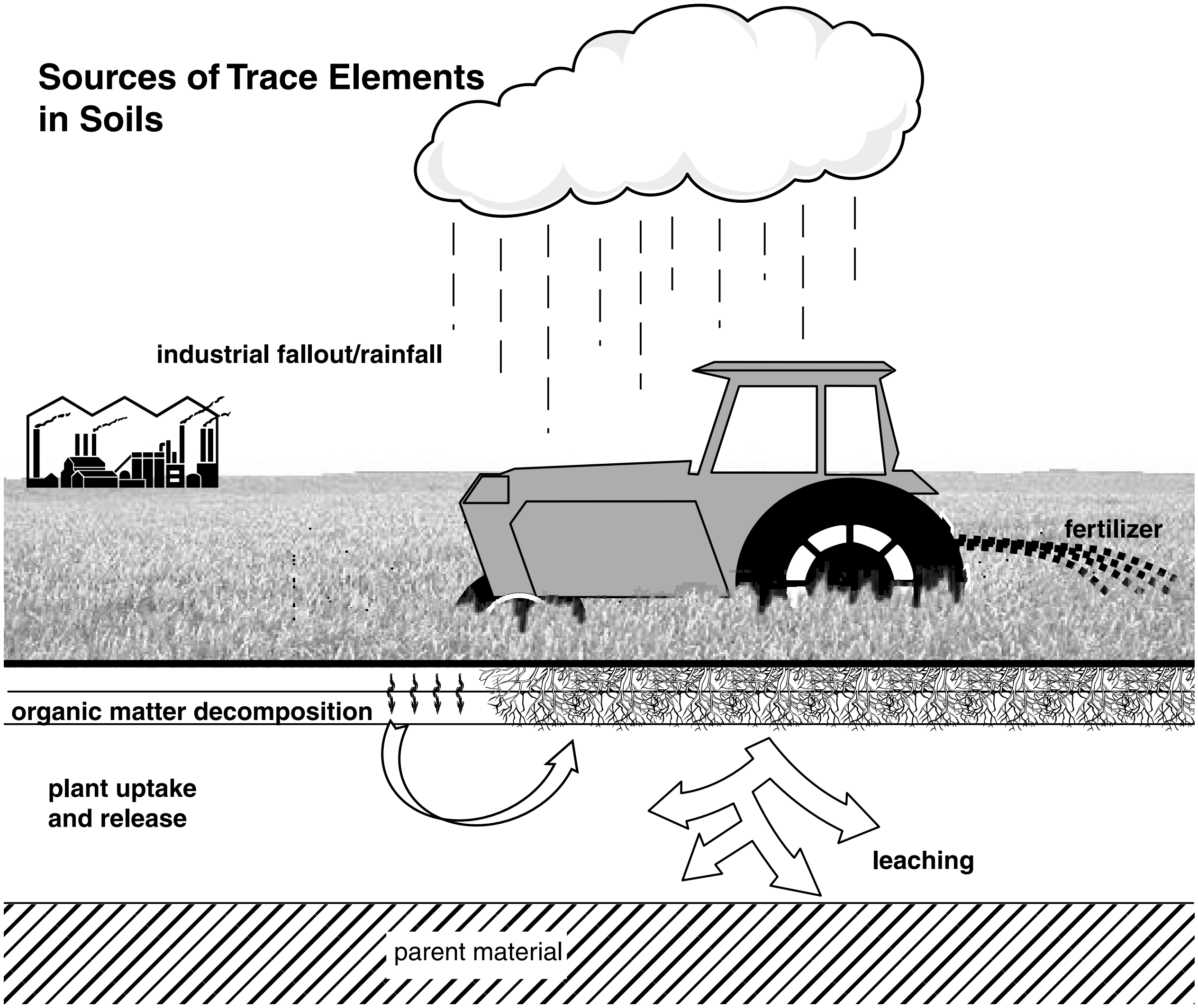


Figure 2 Sample locations related to Quaternary deposits in Illinois (after Lineback 1981).



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

variables
  - pH
  - Eh
  - kinetics
  - biological activity
    - decomposition
    - respiration
  - organics on clays, oxides

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

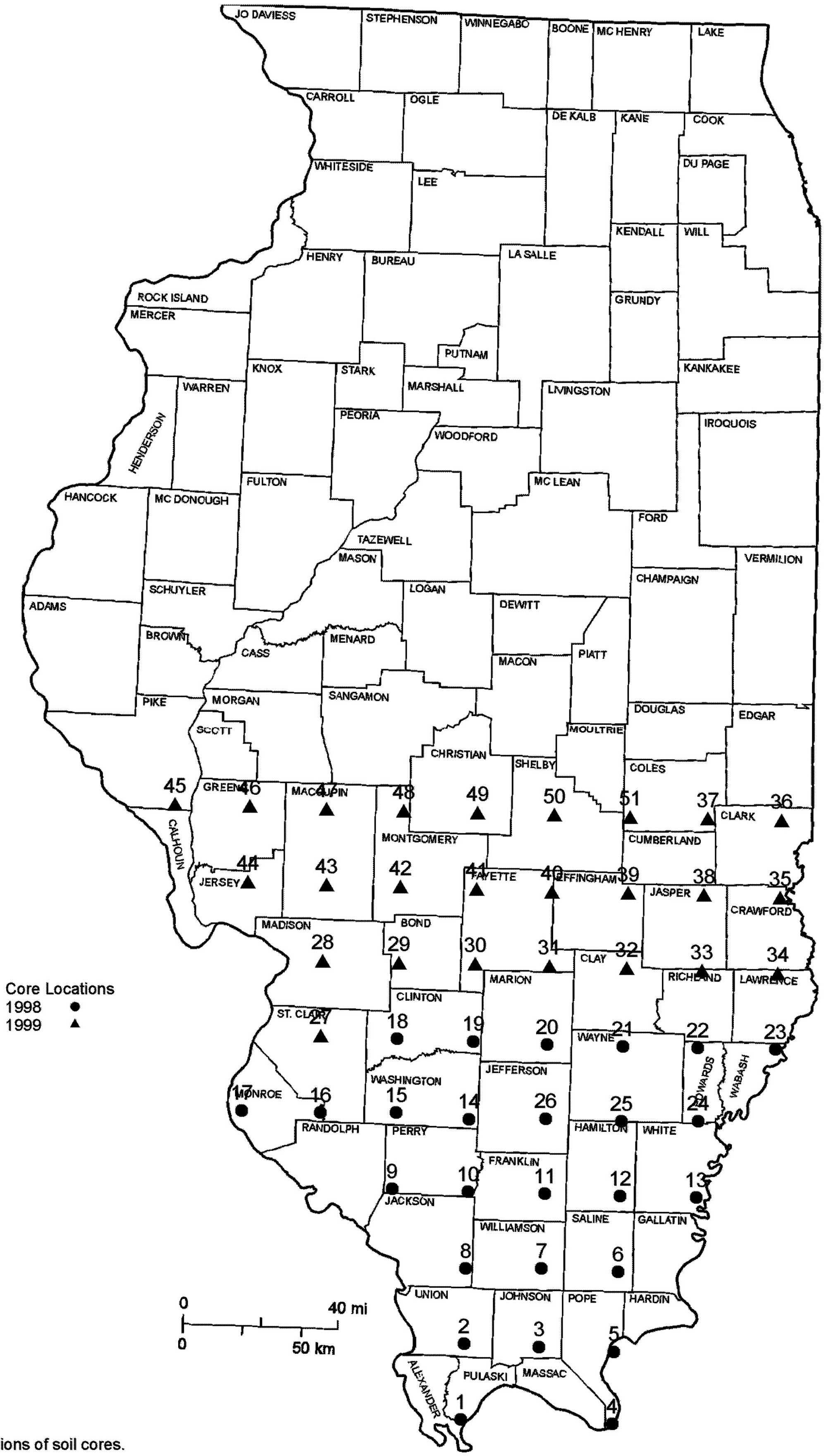


Figure 4. Locations of soil cores.

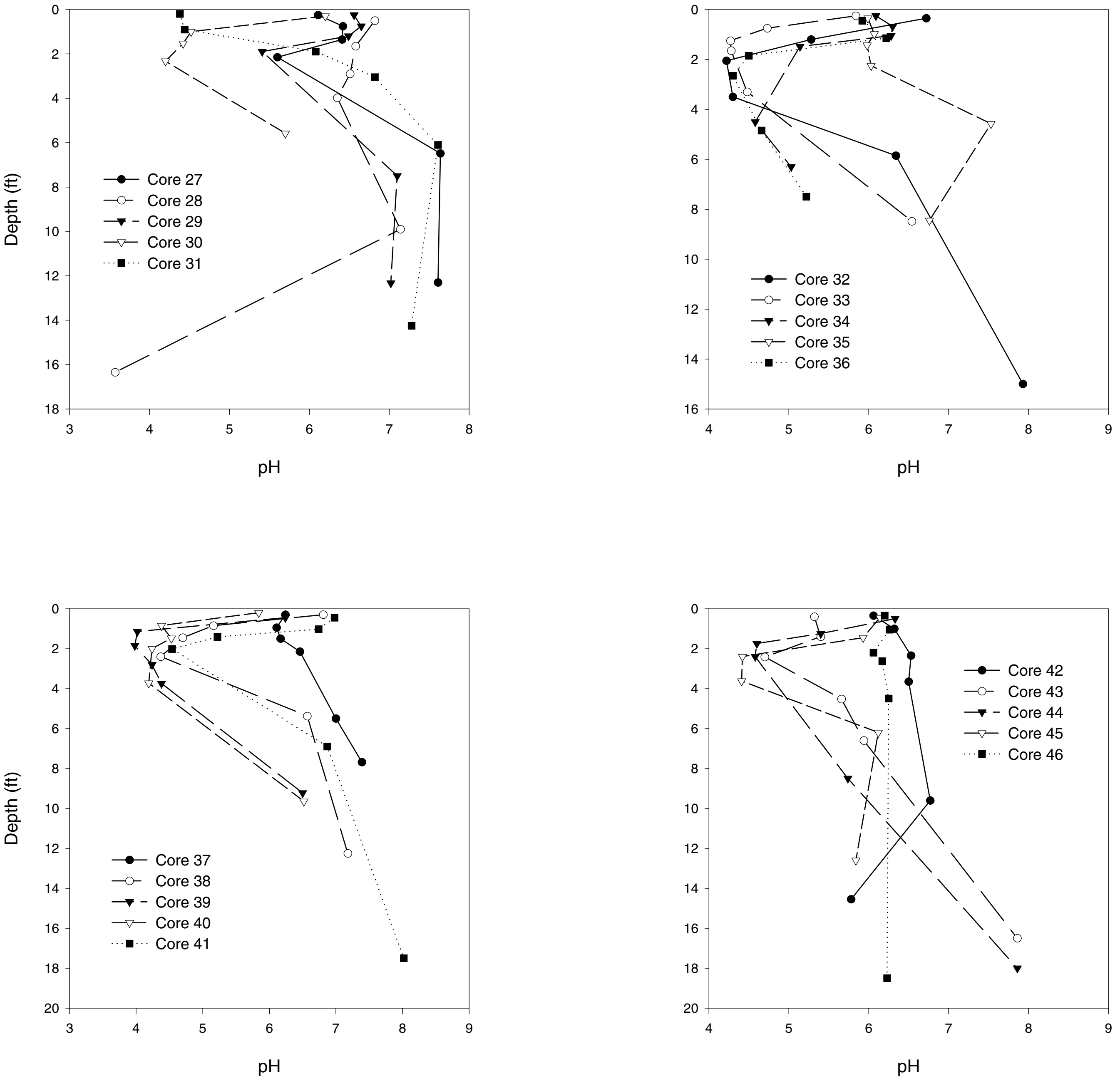


Figure 5 pH versus depth in cores 27 through 51.

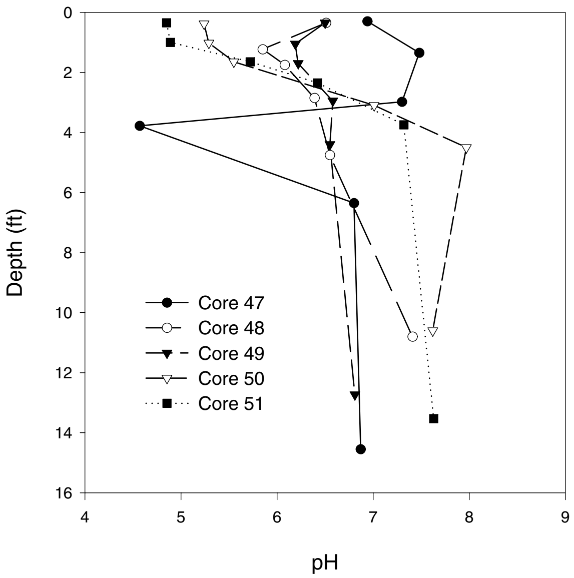


Figure 5. pH versus depth in cores 27 through 51, continued.

Core 27

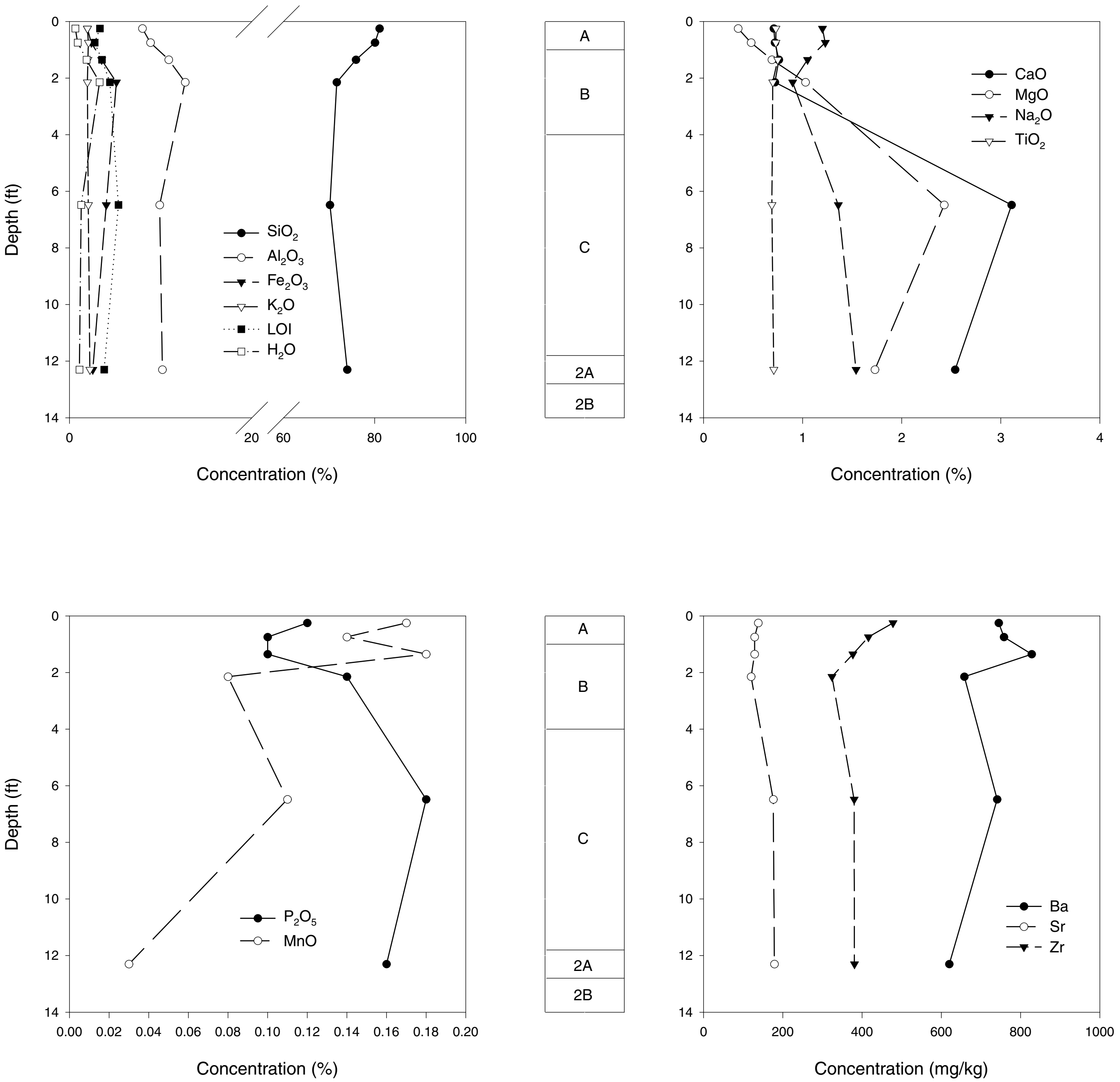


Figure 6. Elemental concentrations versus depth in core 27.

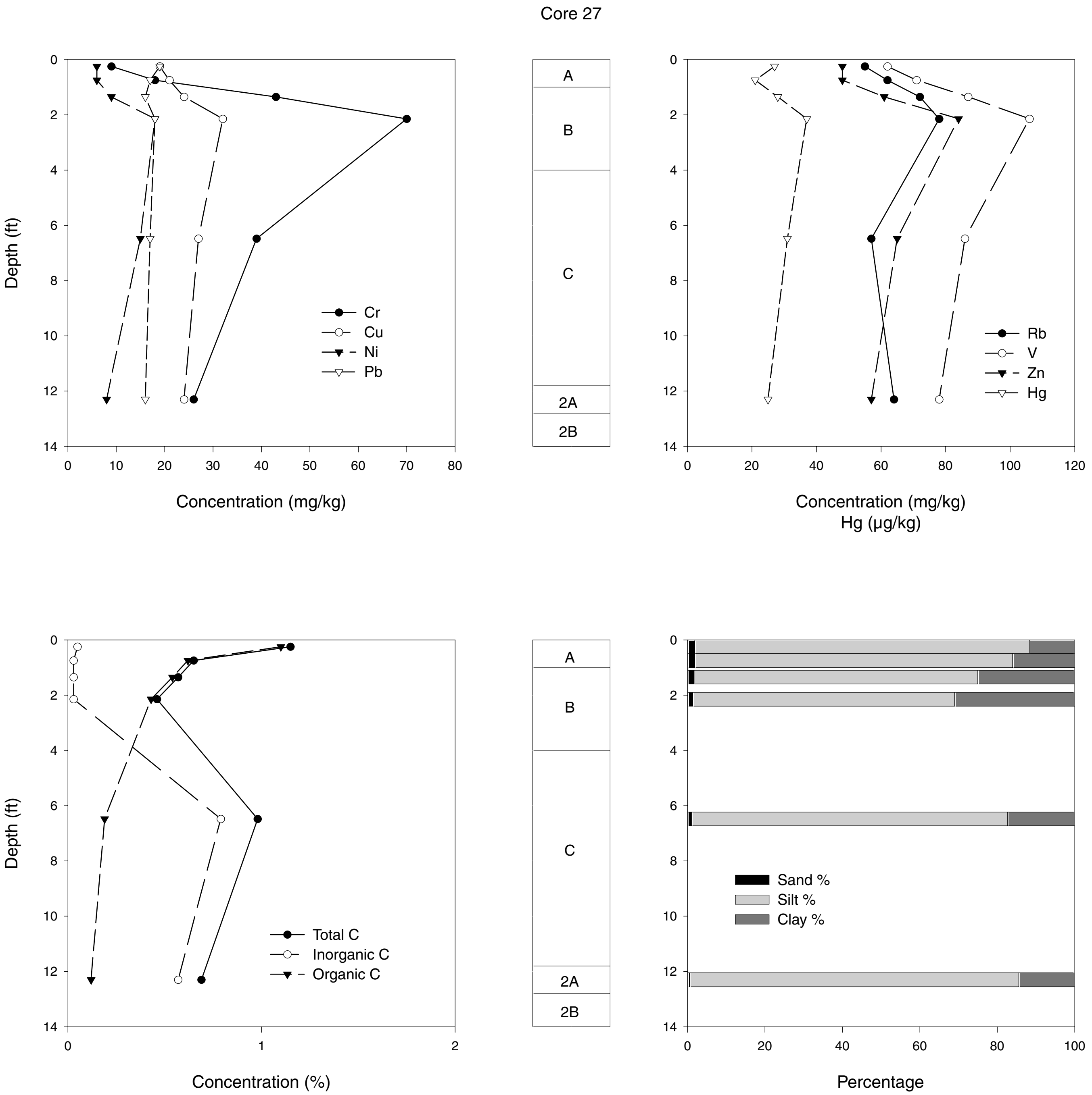


Figure 7 Elemental concentrations versus depth in core 27.

Core 28

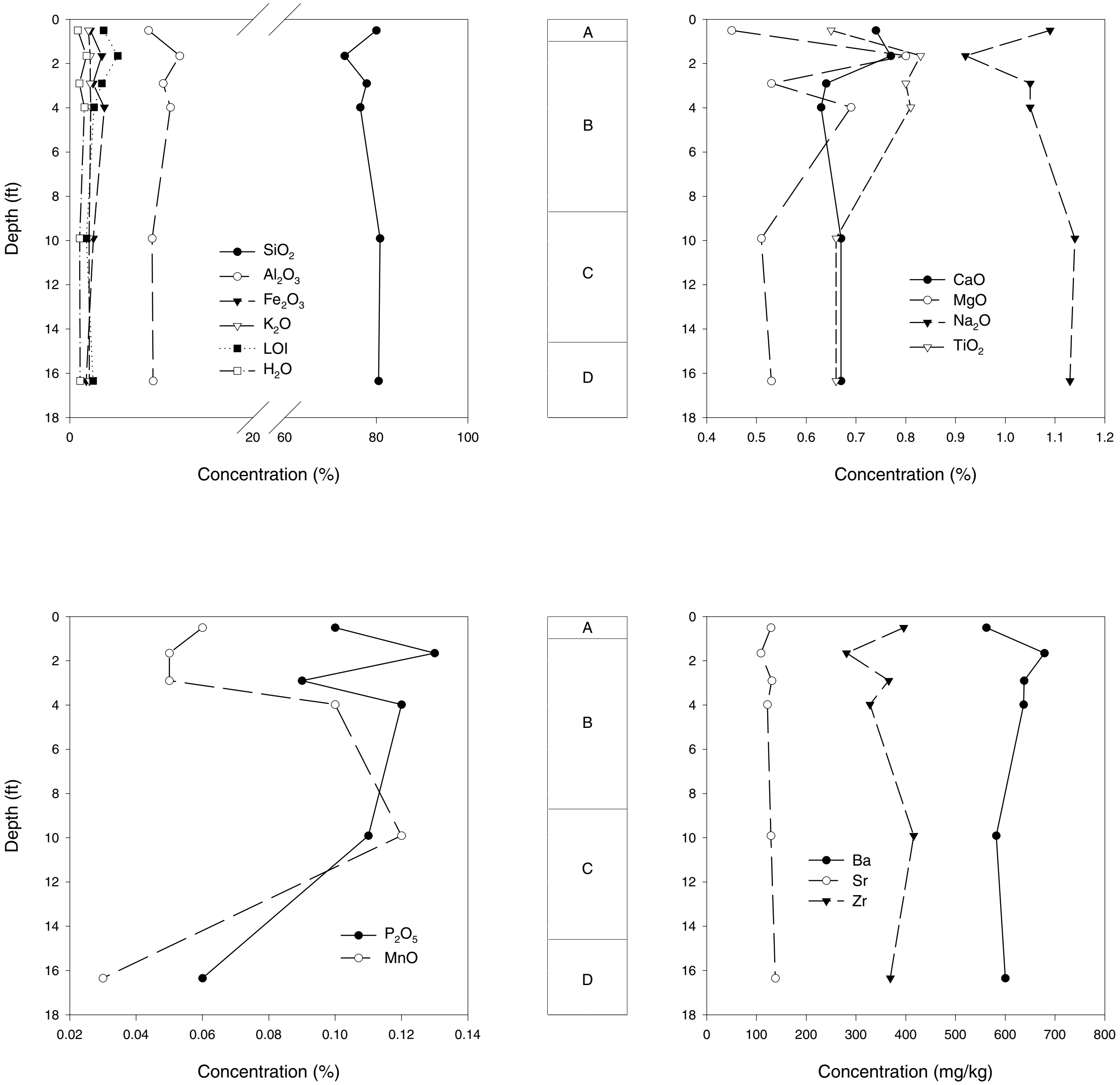


Figure 8 Elemental concentrations versus depth in core 28.

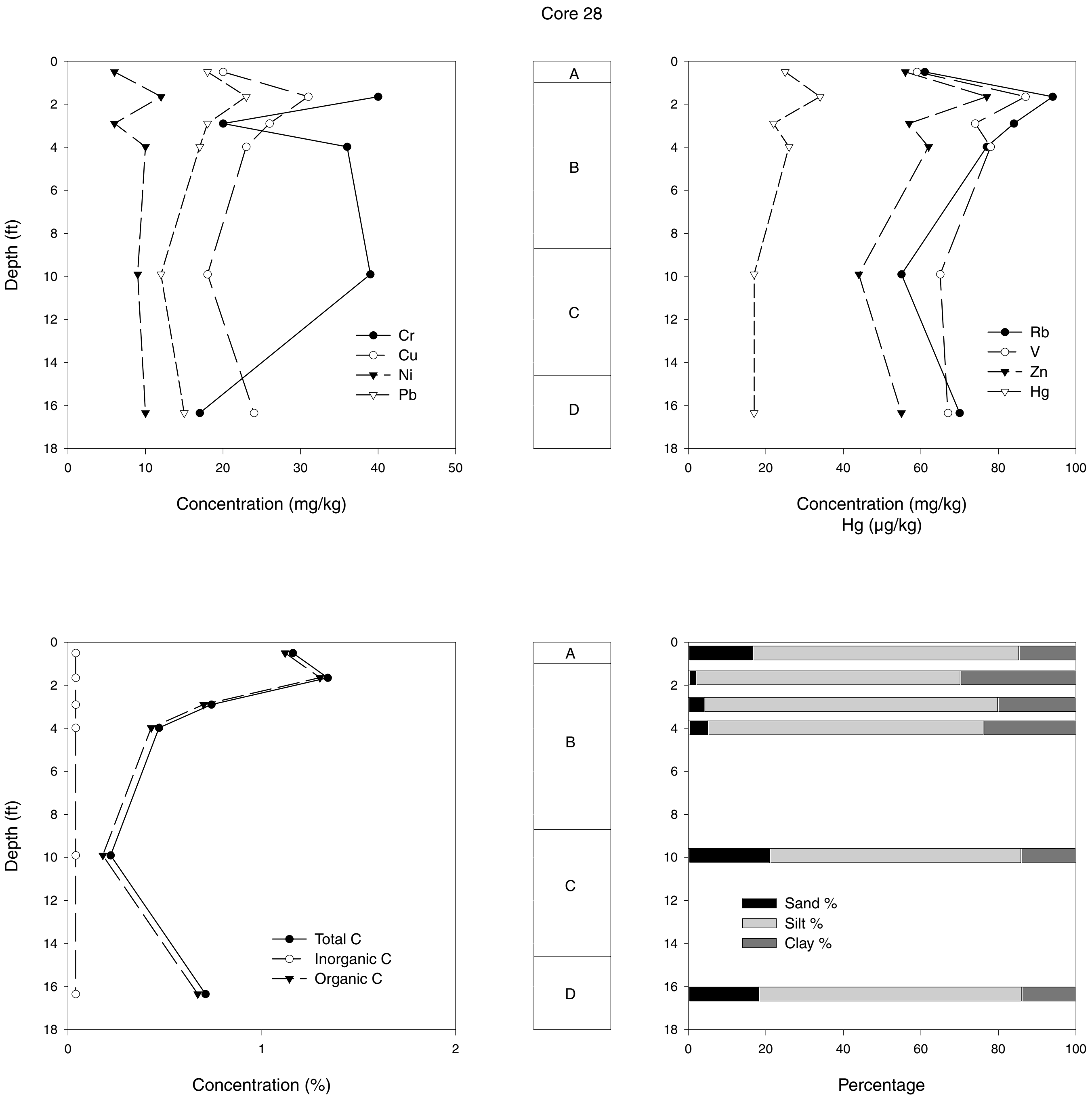


Figure 9 Elemental concentrations versus depth in core 28.

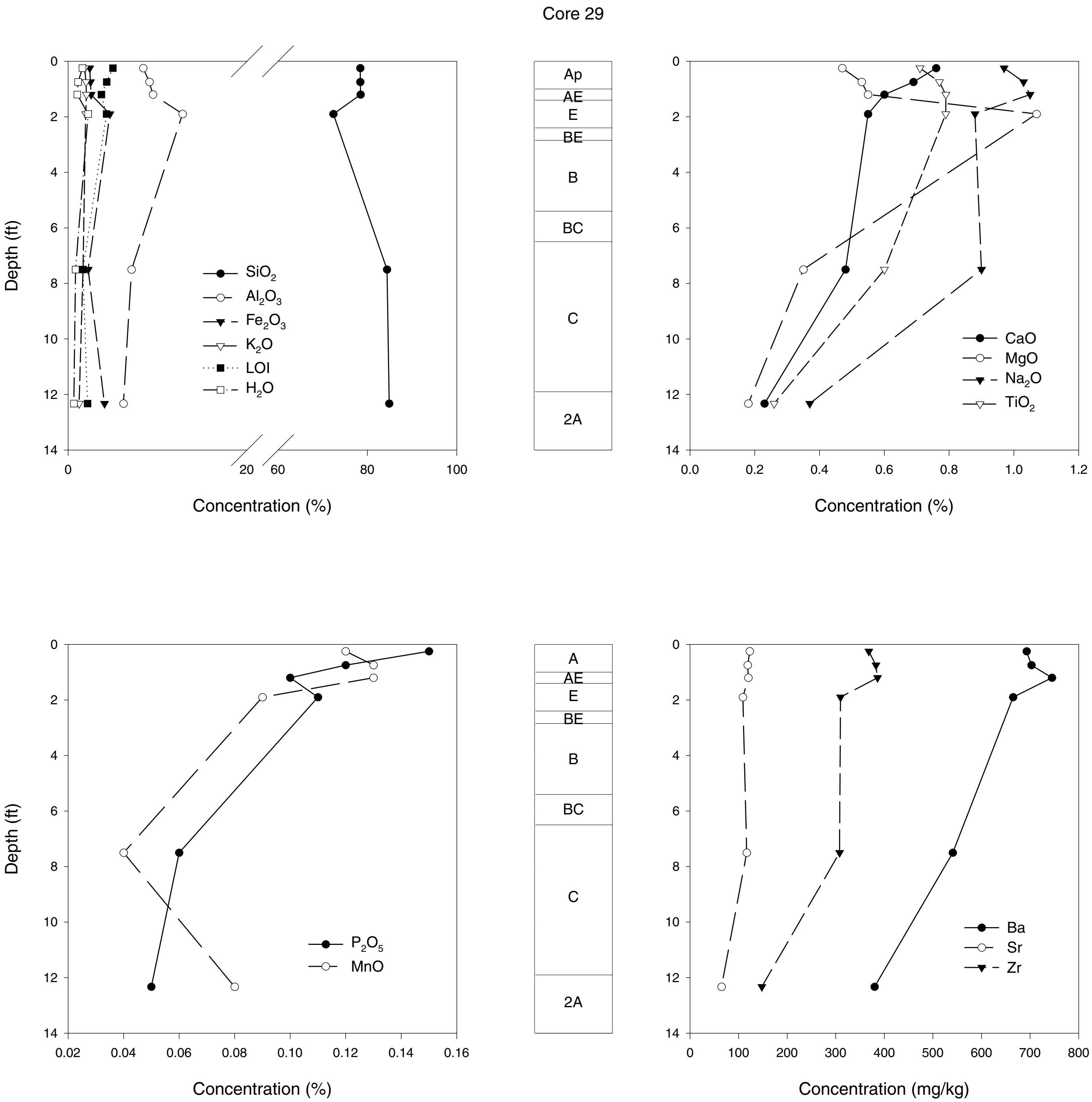


Figure 10 Elemental concentrations versus depth in core 29.

Core 29

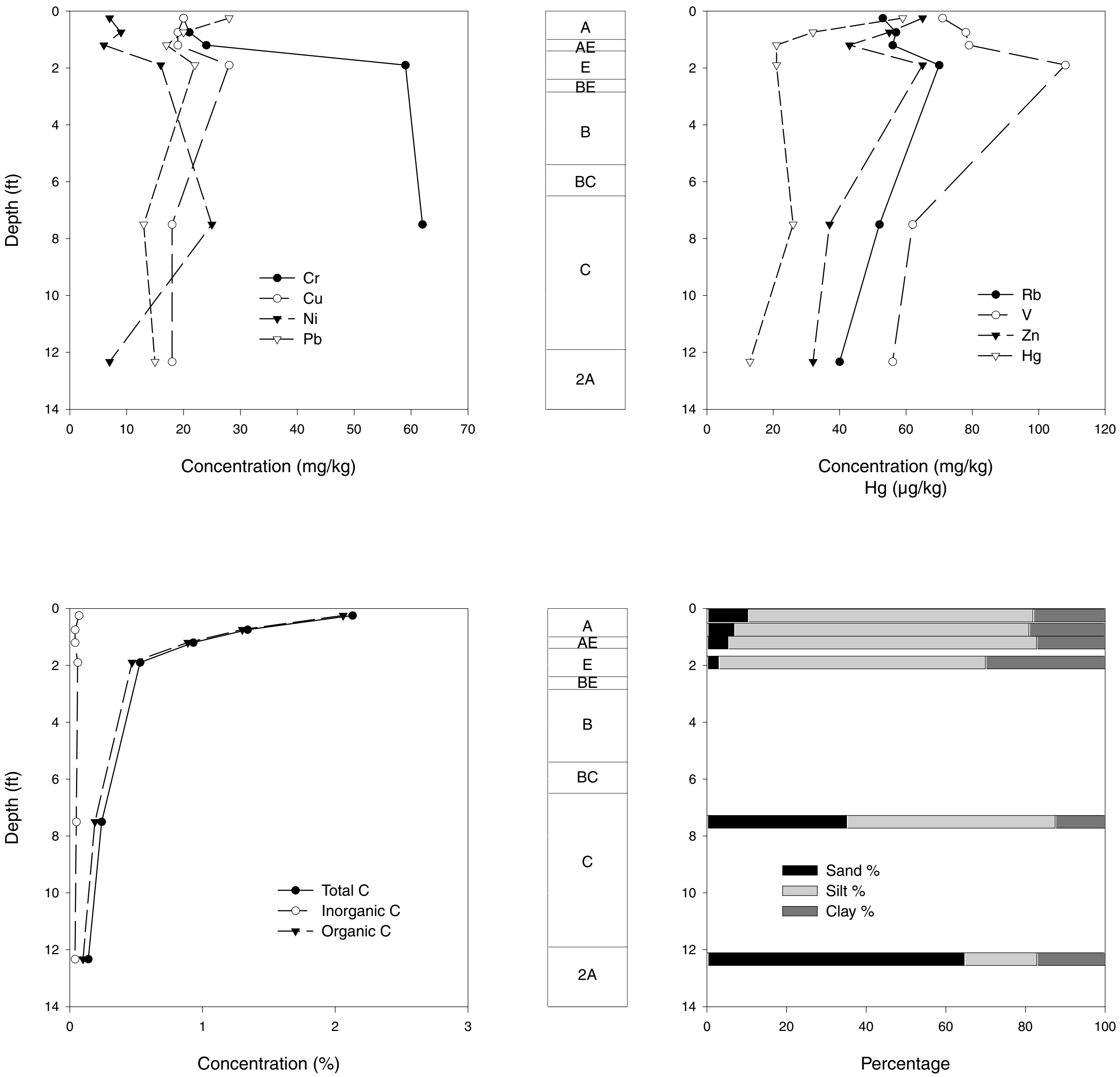


Figure 11 Elemental concentrations versus depth in core 29.

Core 30

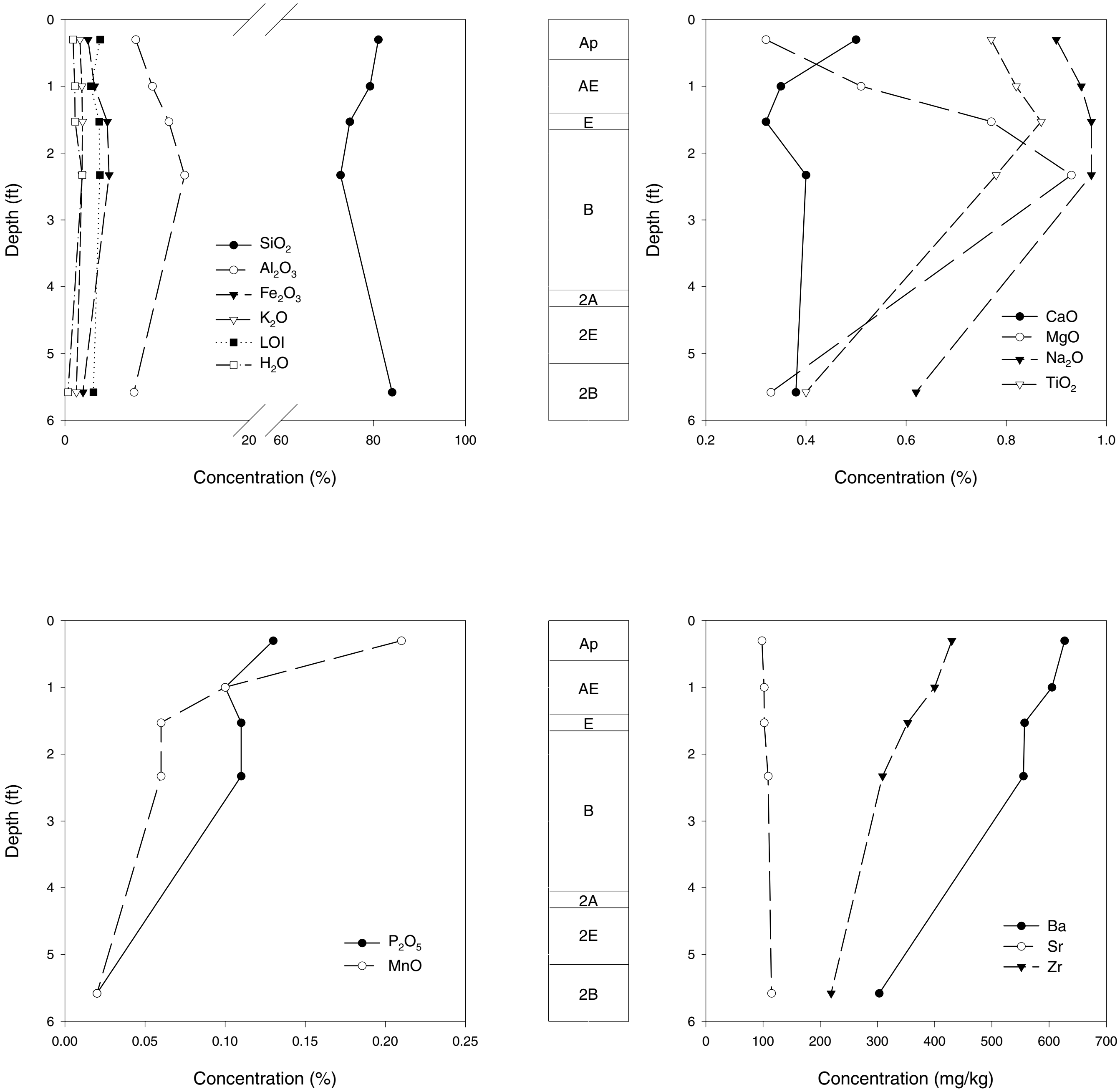


Figure 12 Elemental concentrations versus depth in core 30.

Core 30

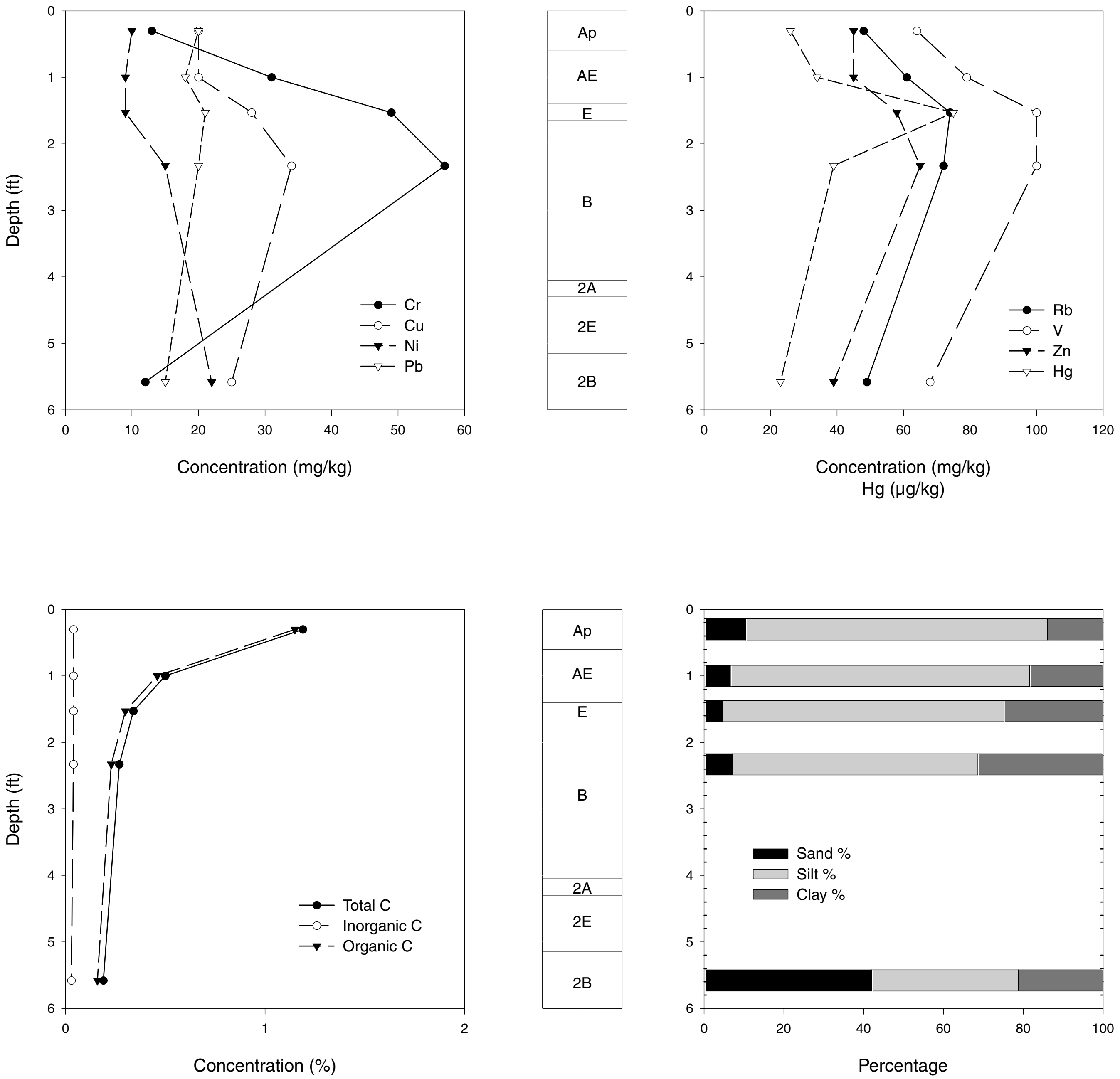


Figure 13 Elemental concentrations versus depth in core 30.

Core 31

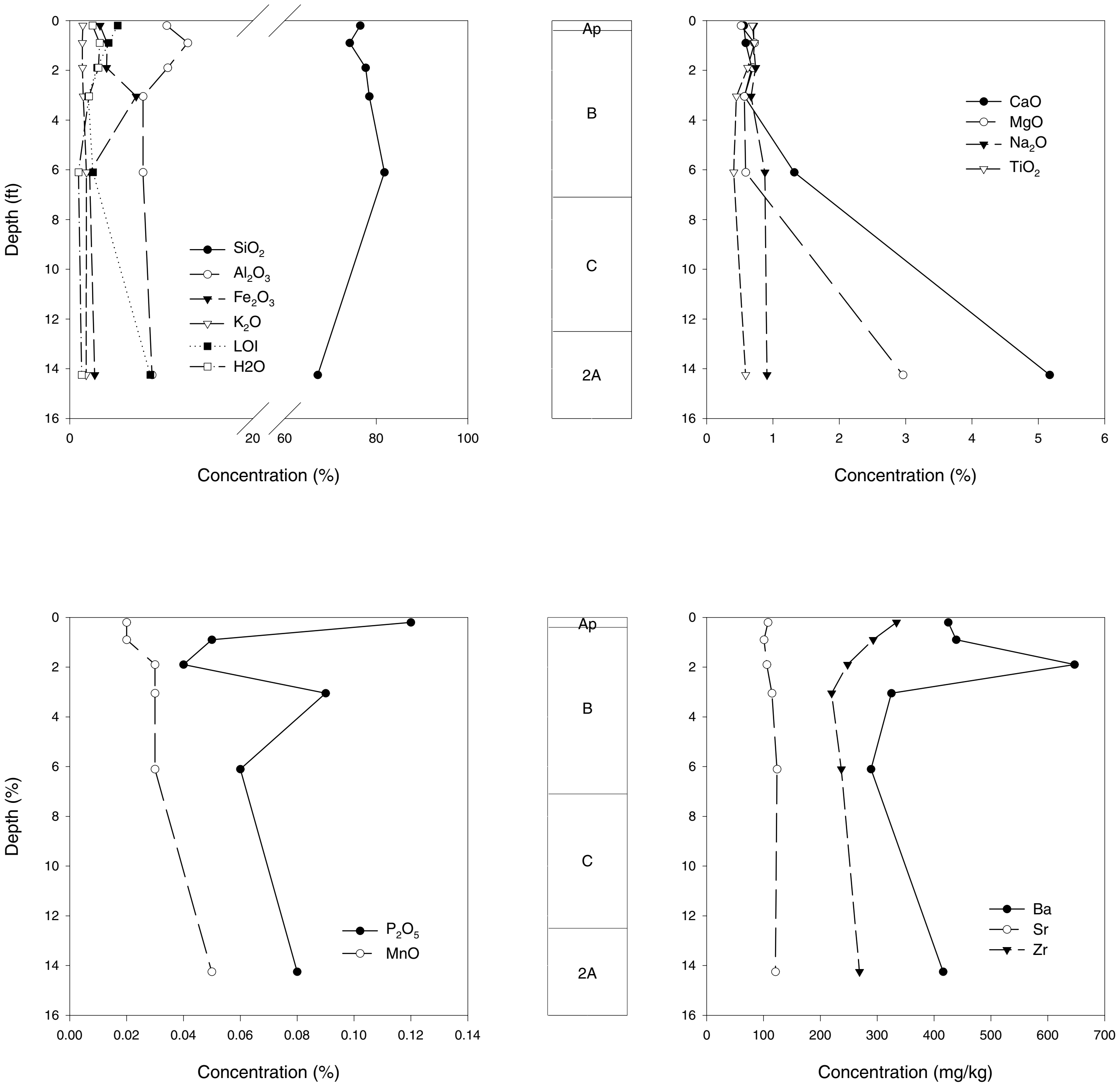


Figure 14 Elemental concentrations versus depth in core 31.

Core 31

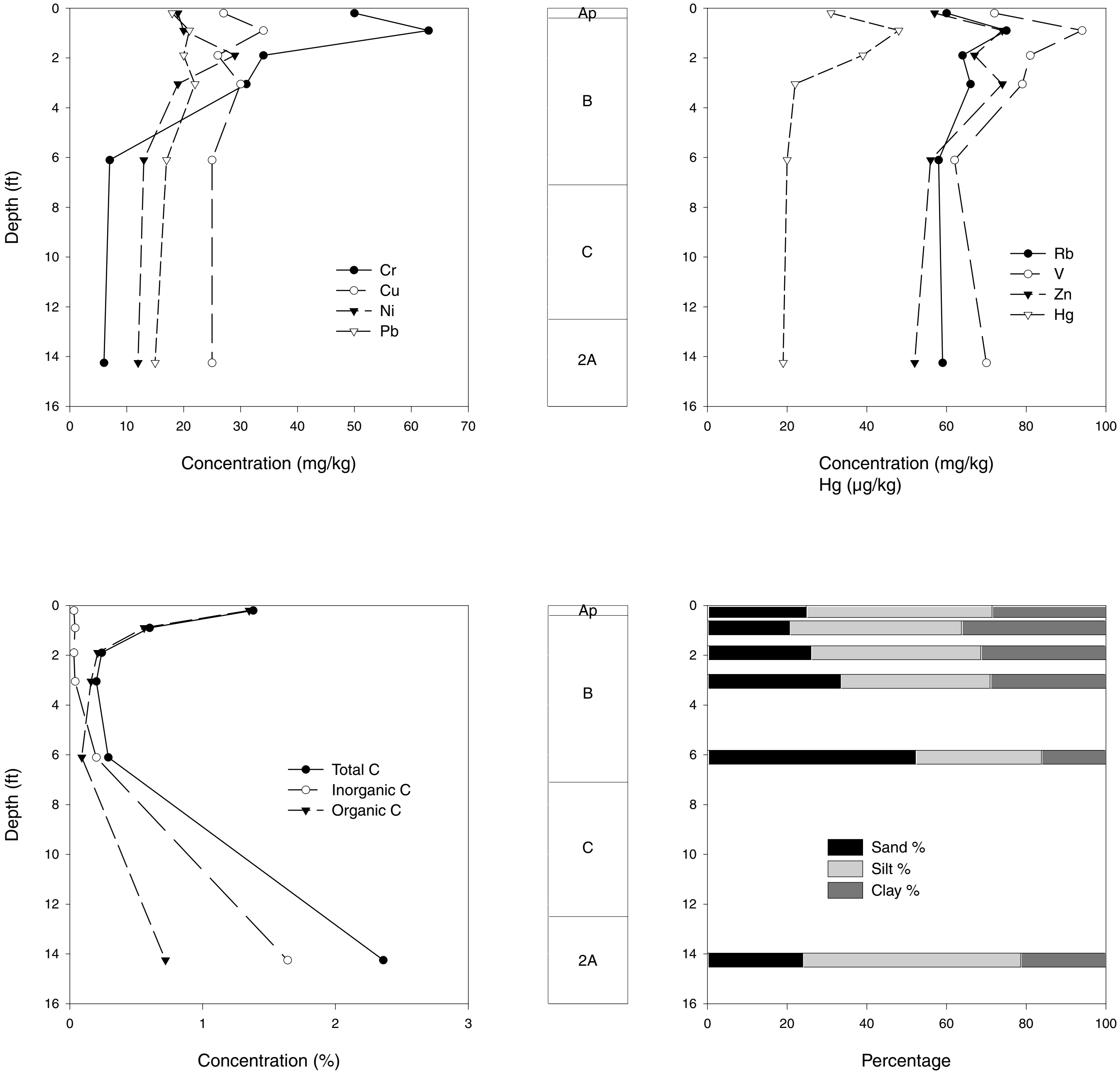


Figure 15 Elemental concentrations versus depth core 31.

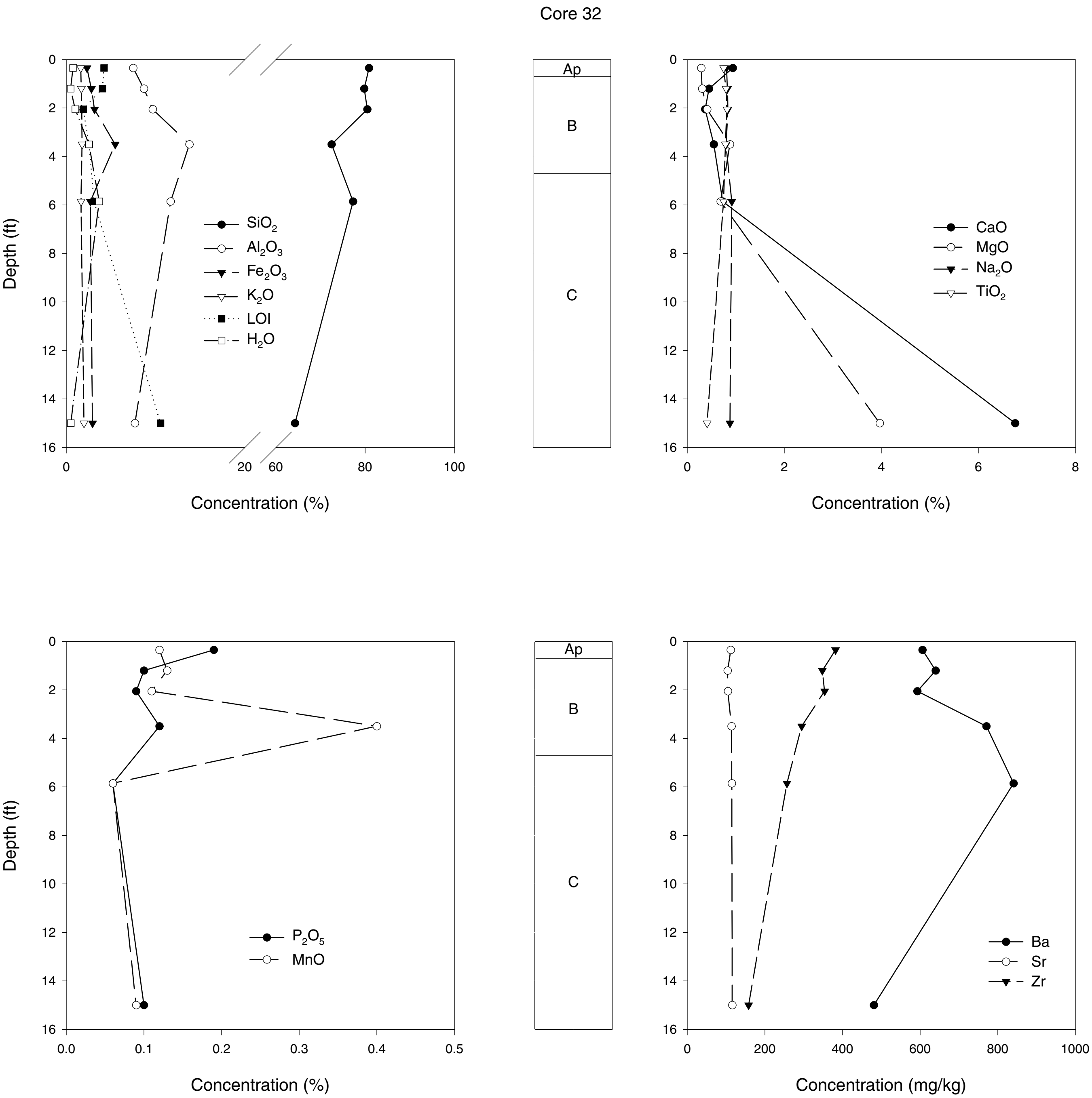


Figure 16 Elemental concentrations versus depth in core 32.

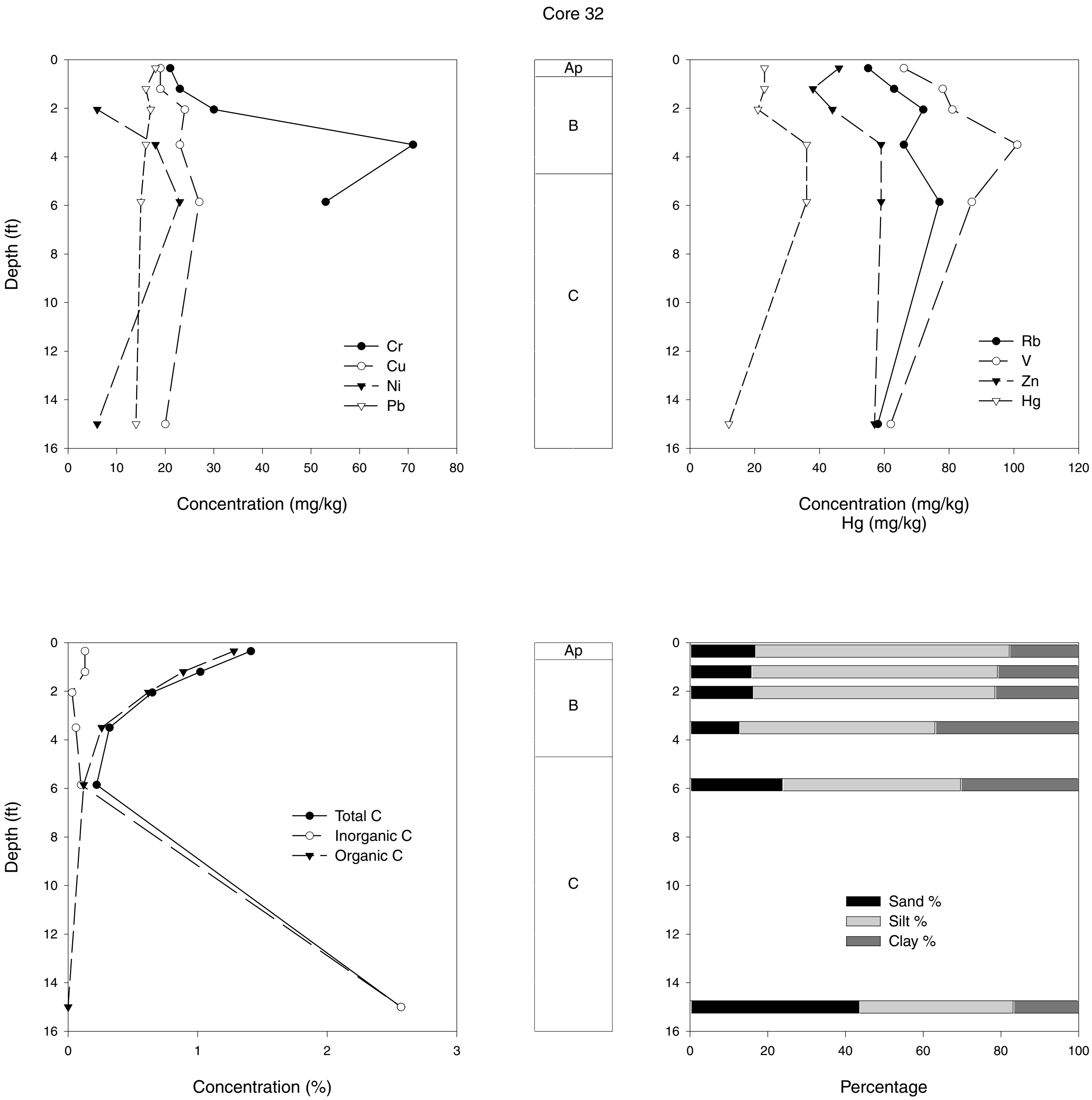


Figure 17 Elemental concentrations versus depth in core 32.

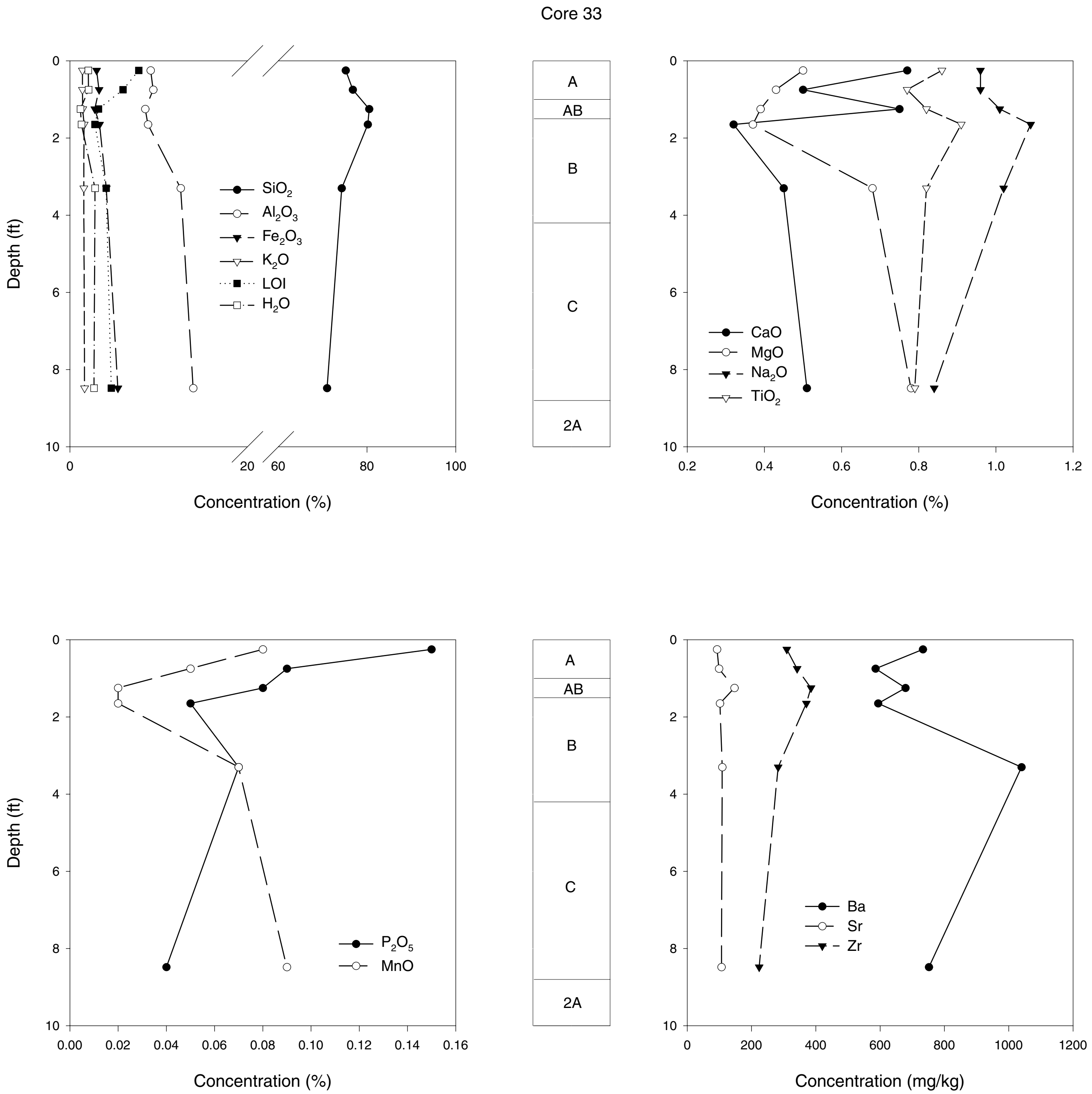


Figure 18 Elemental concentrations versus depth in core 33.

Core 33

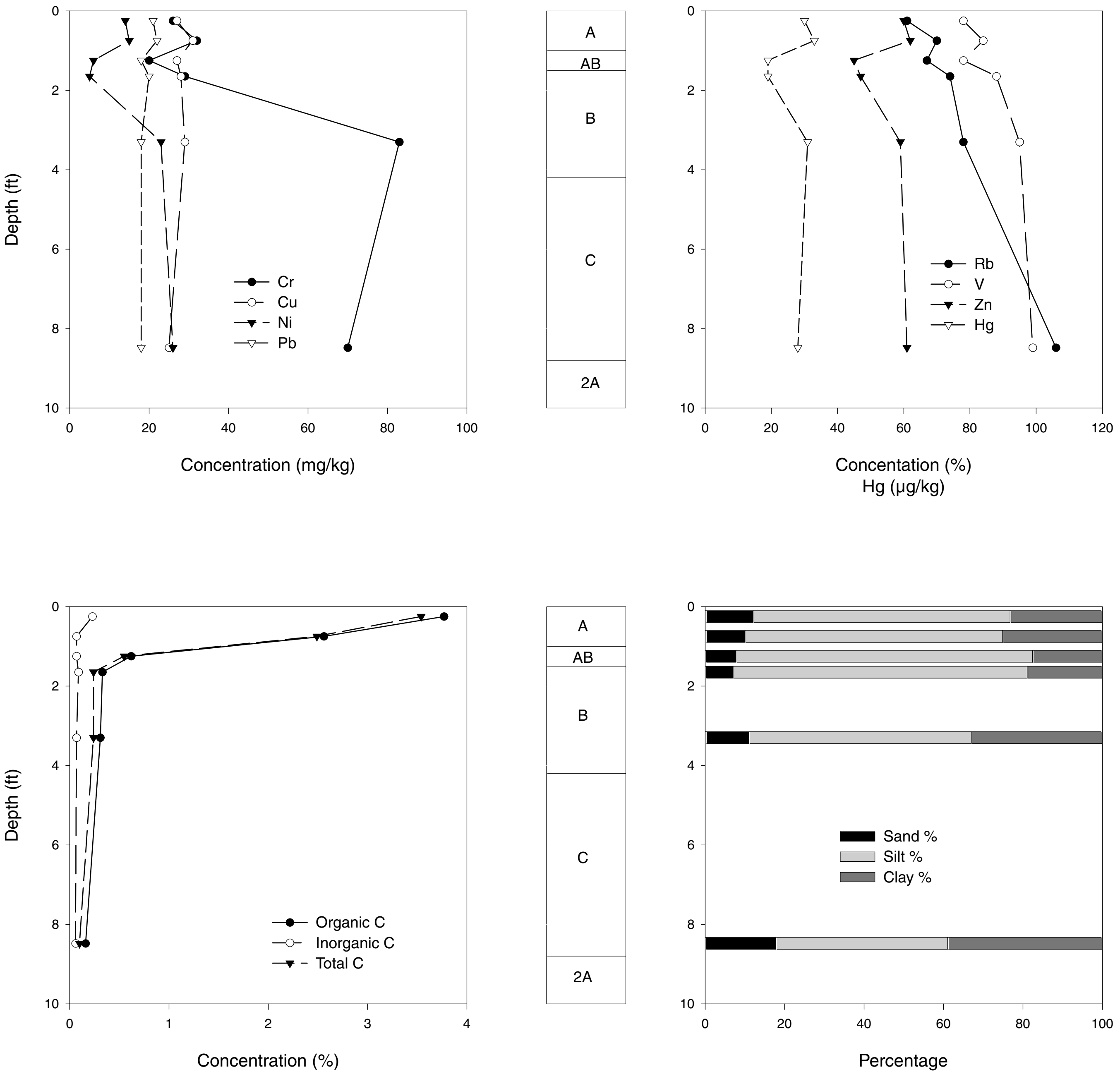


Figure 19 Elemental concentrations versus depth in core 33.

Core 34

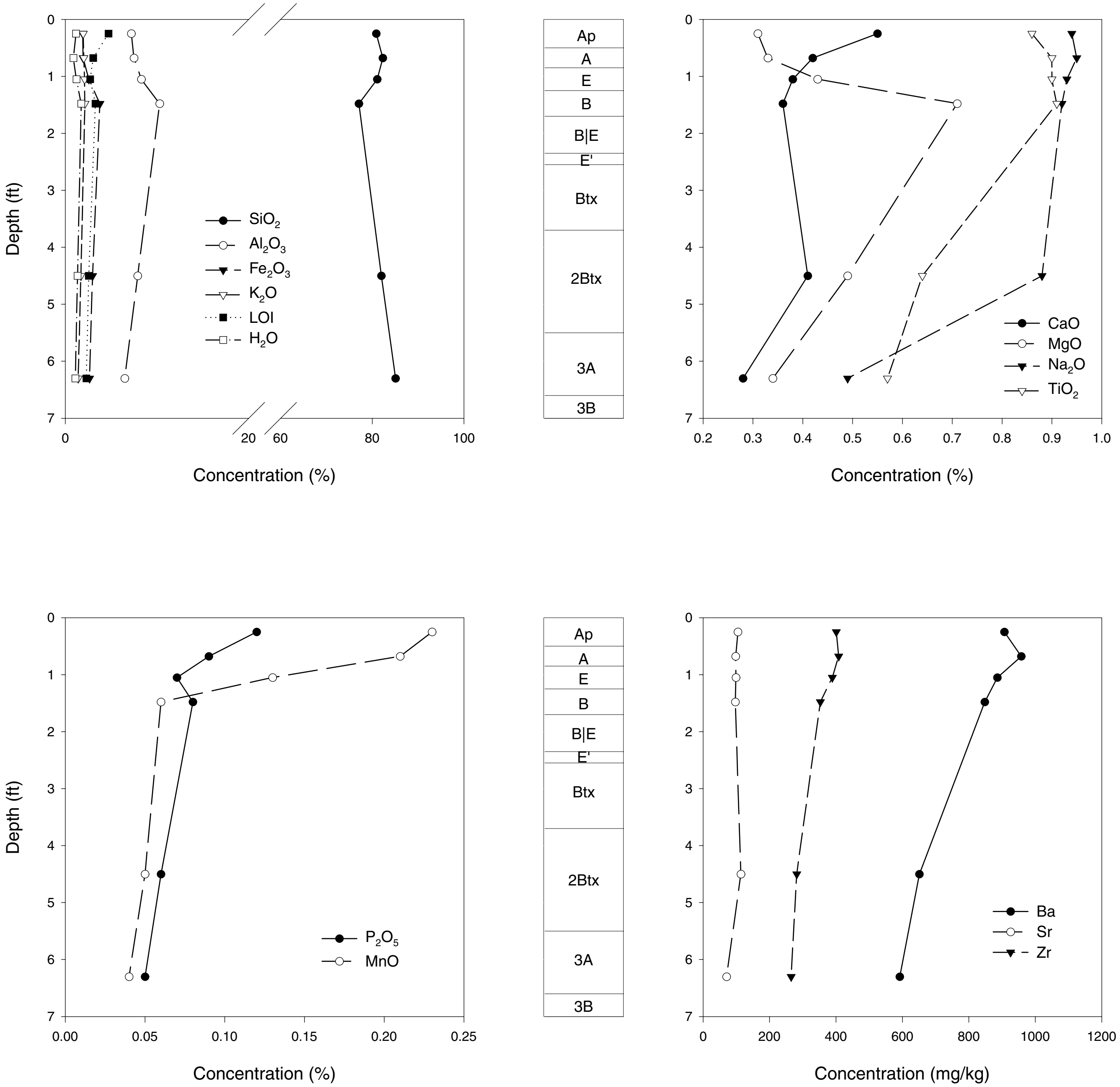


Figure 20 Elemental concentrations versus depth in core 34.

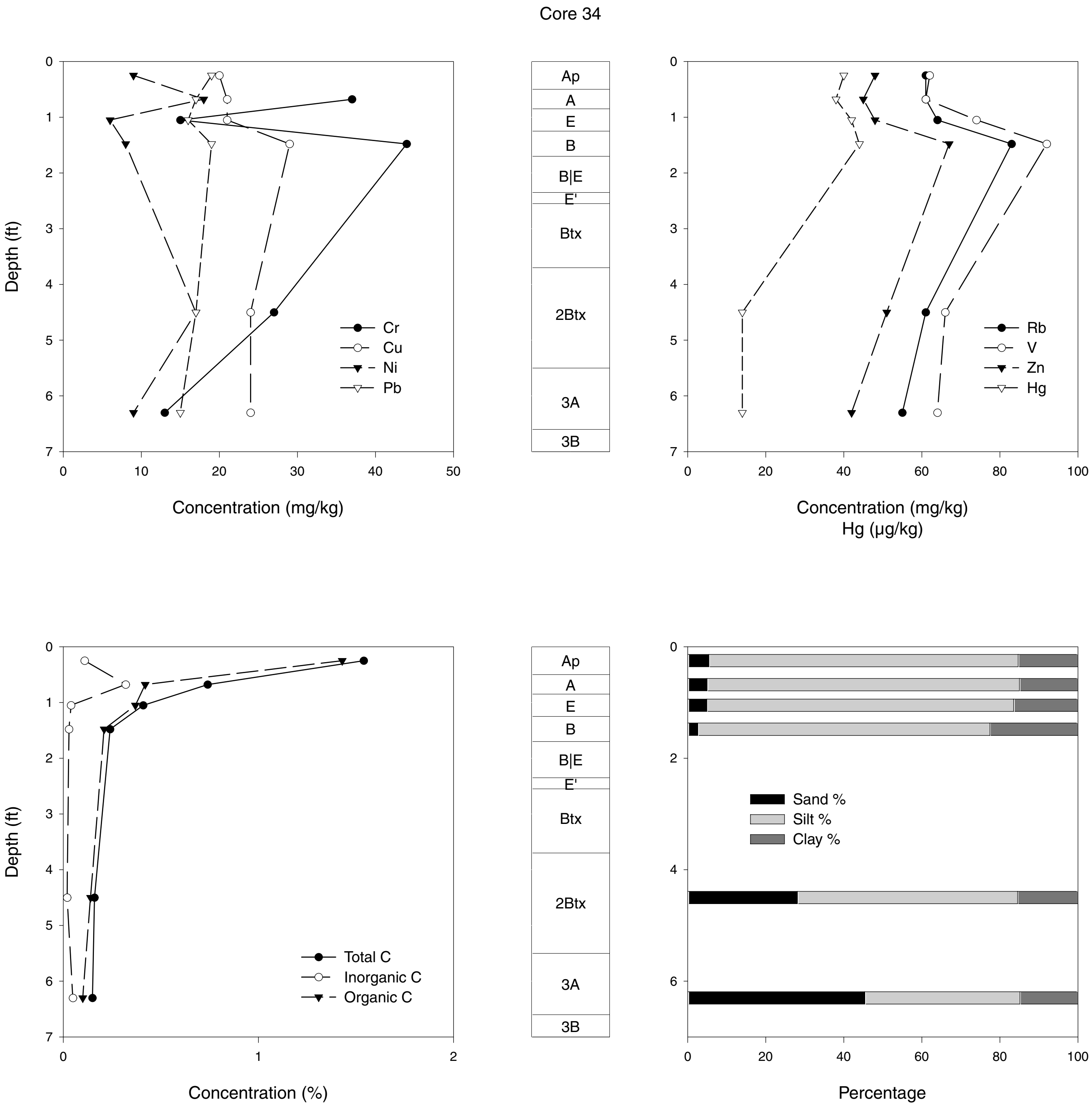
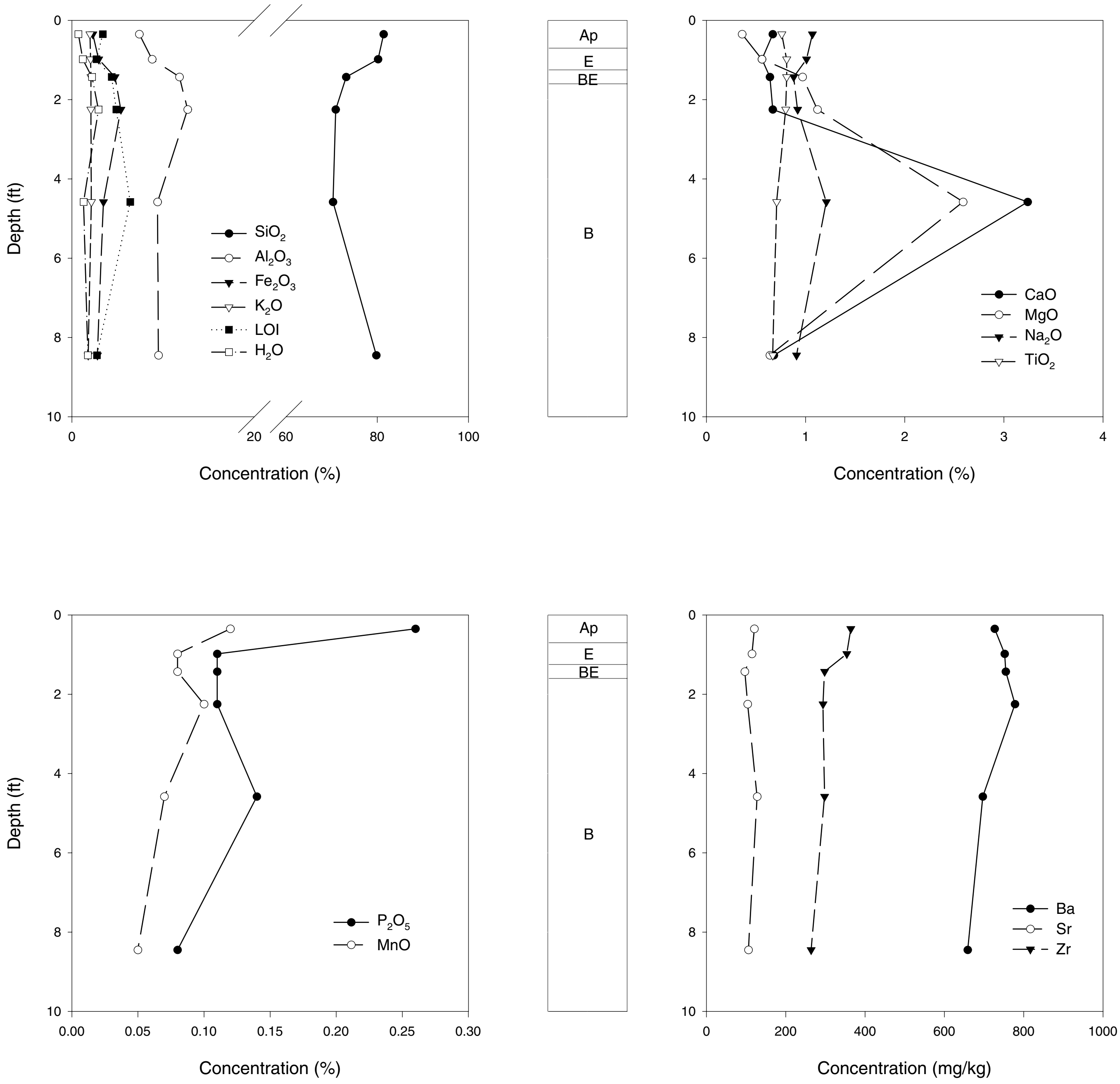


Figure 21 Elemental concentrations versus depth in core 34.



Core 35

Figure 22 Elemental concentrations versus depth in core 35.

Core 35

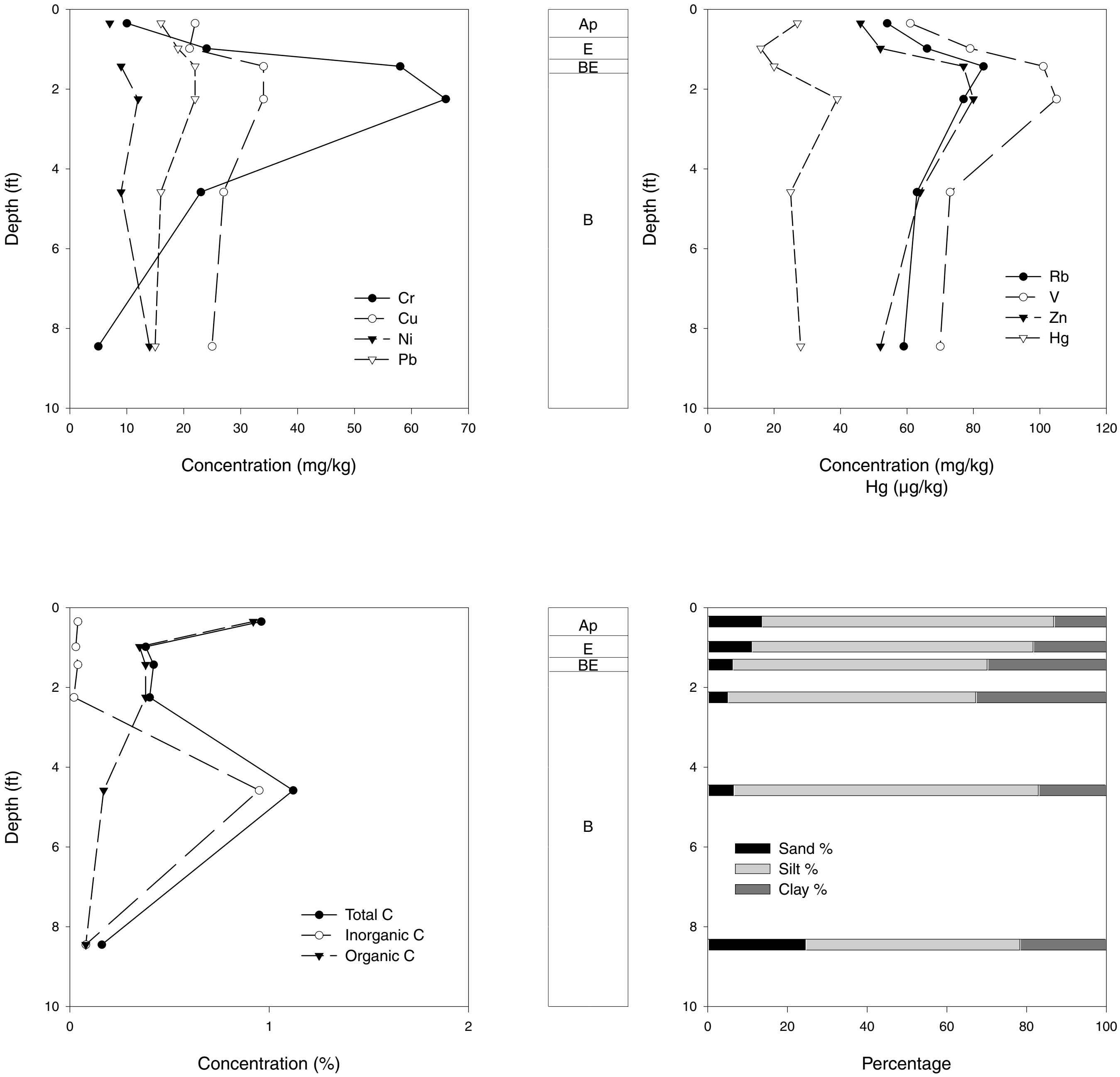


Figure 23 Elemental concentrations versus depth in core 35.

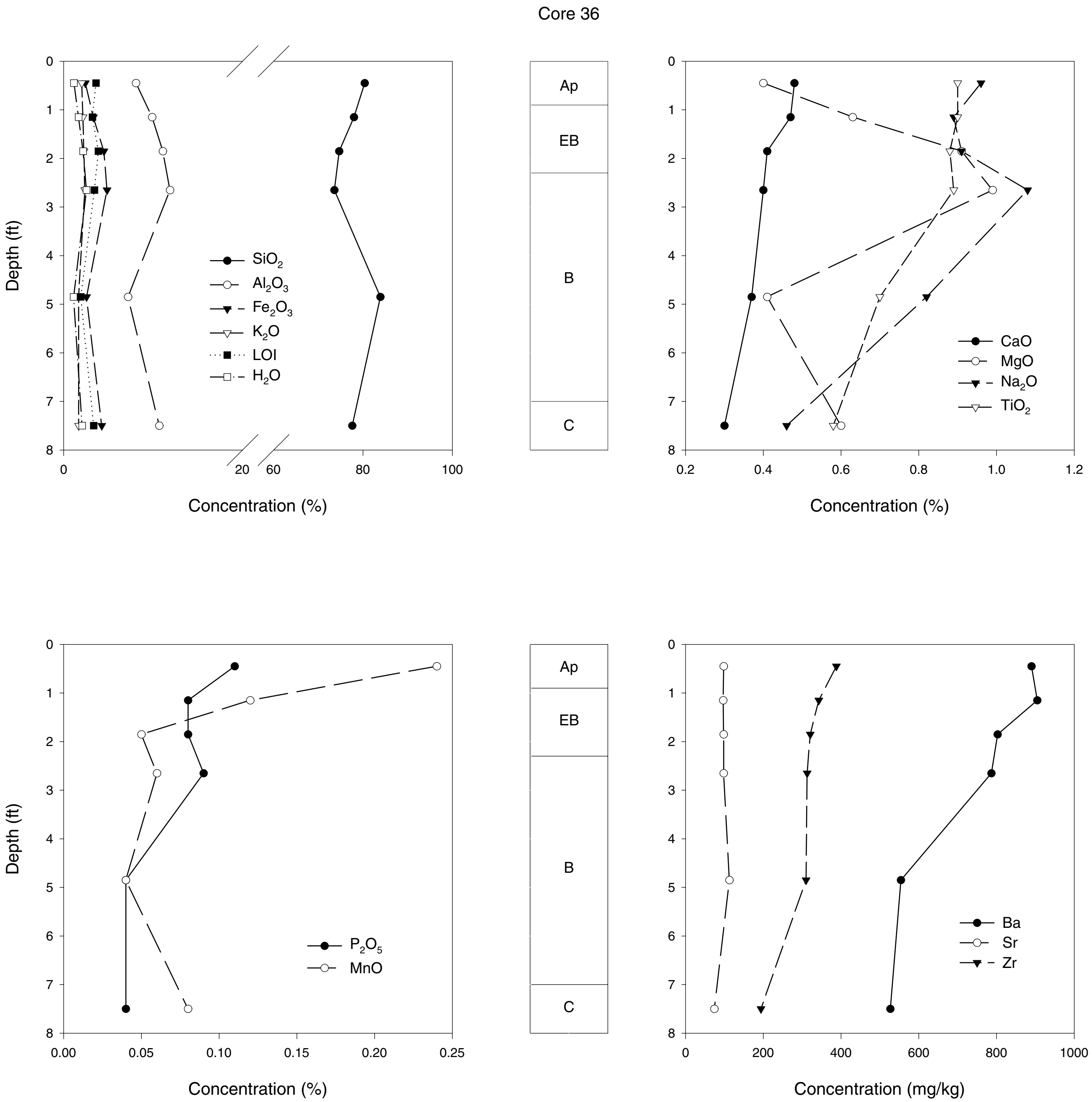


Figure 24 Elemental concentrations versus depth in core 36.

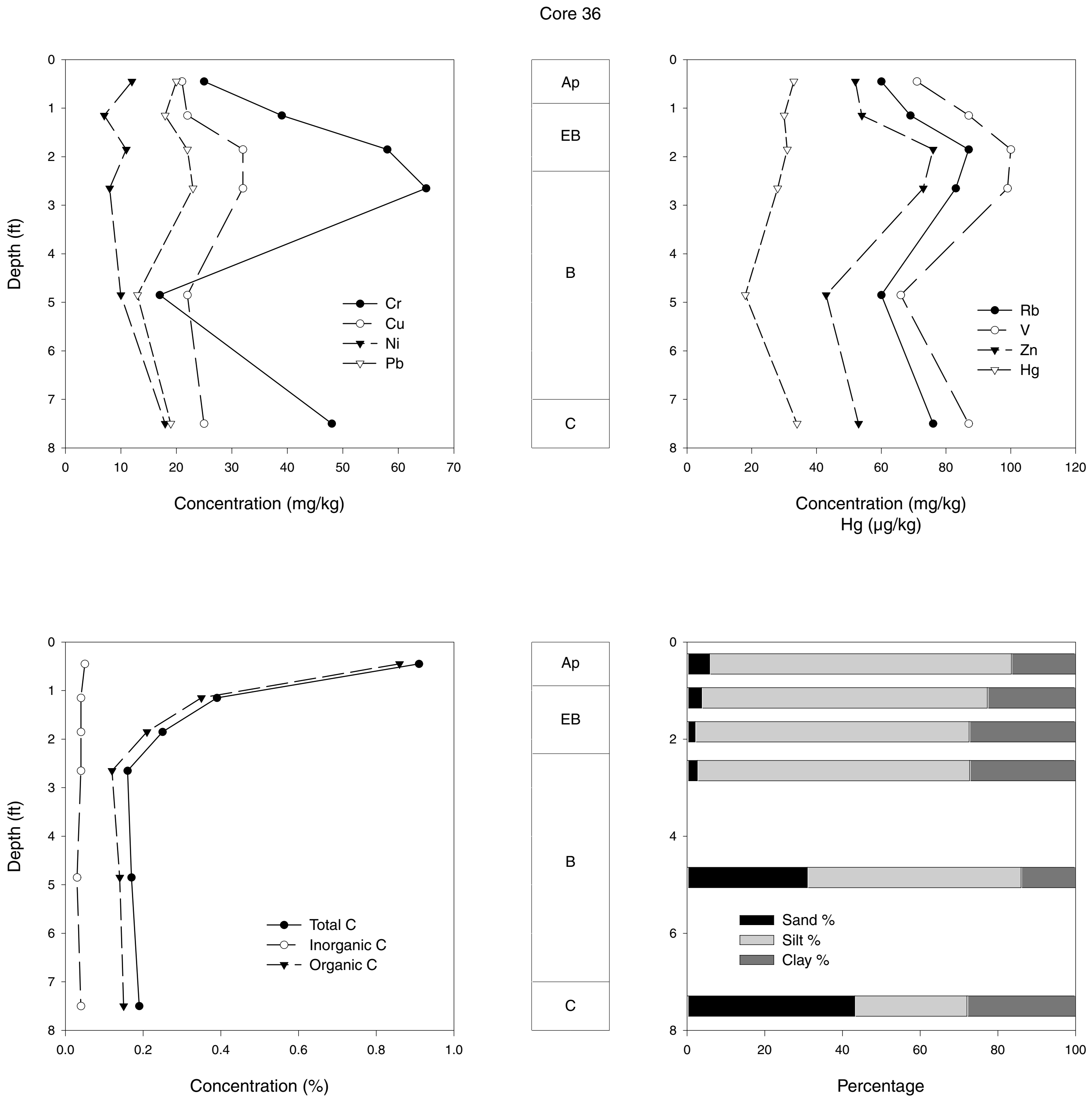


Figure 25 Elemental concentrations versus depth in core 36.

Core 37

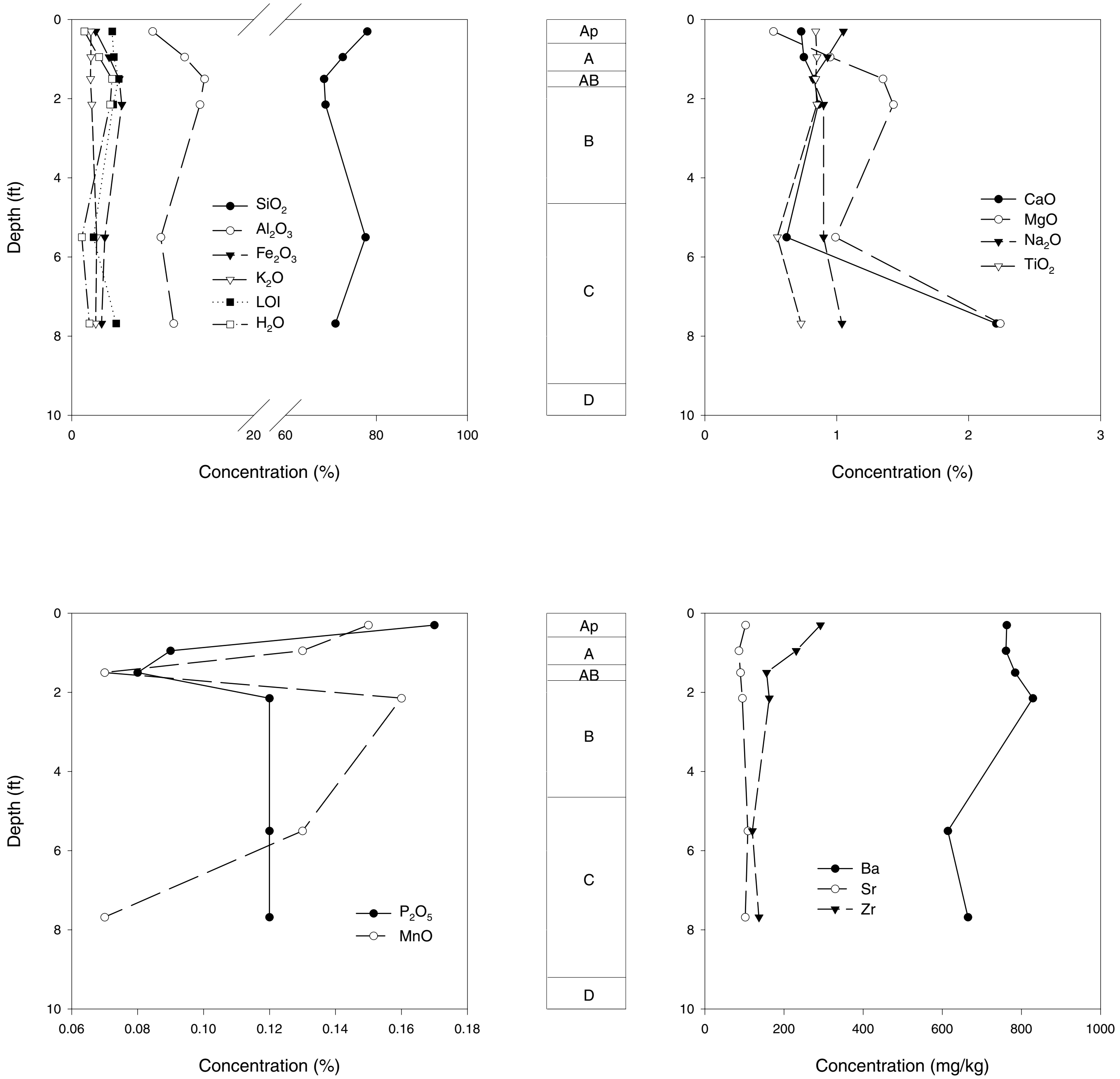


Figure 26 Elemental concentrations versus depth in core 37.

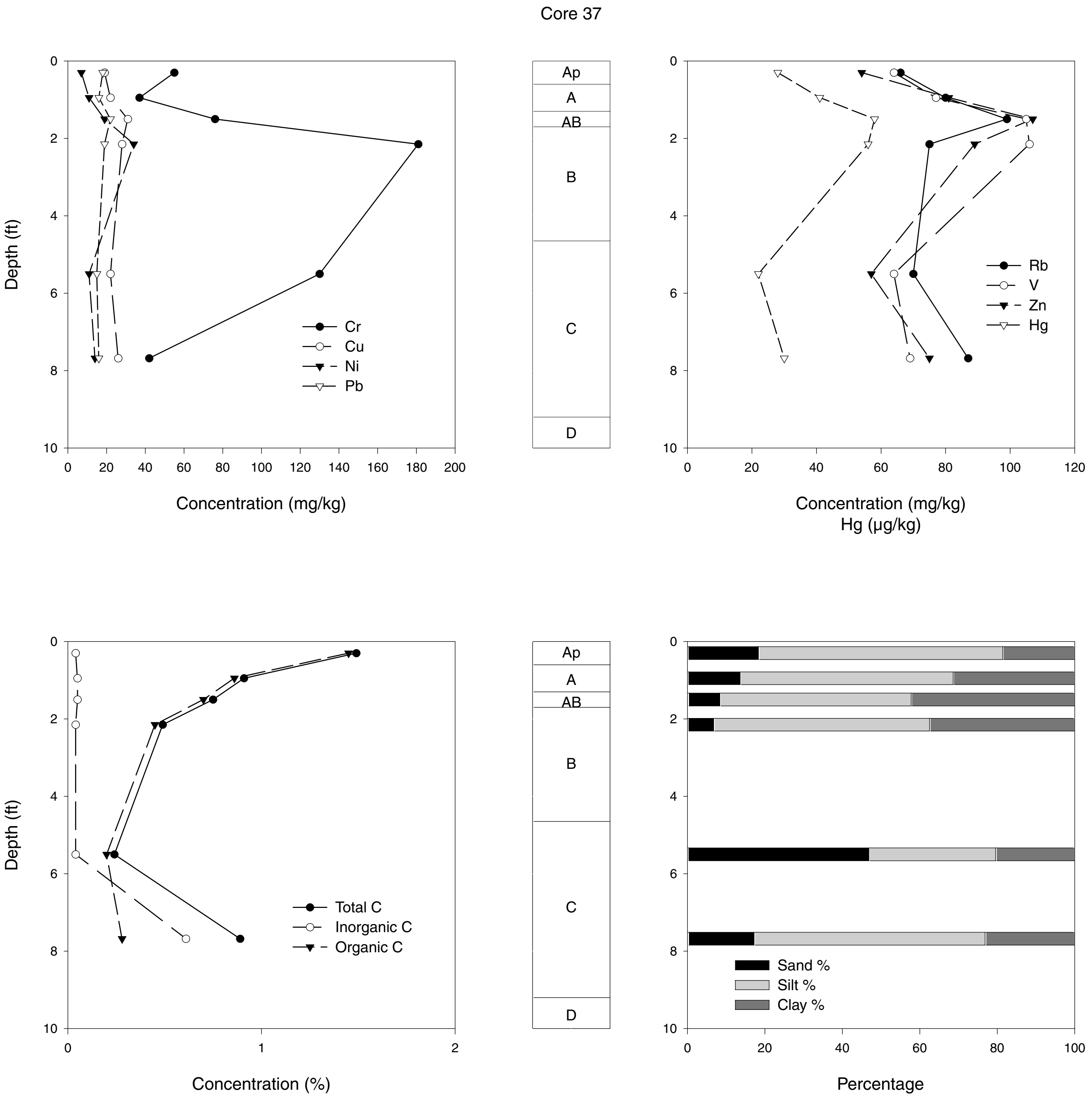
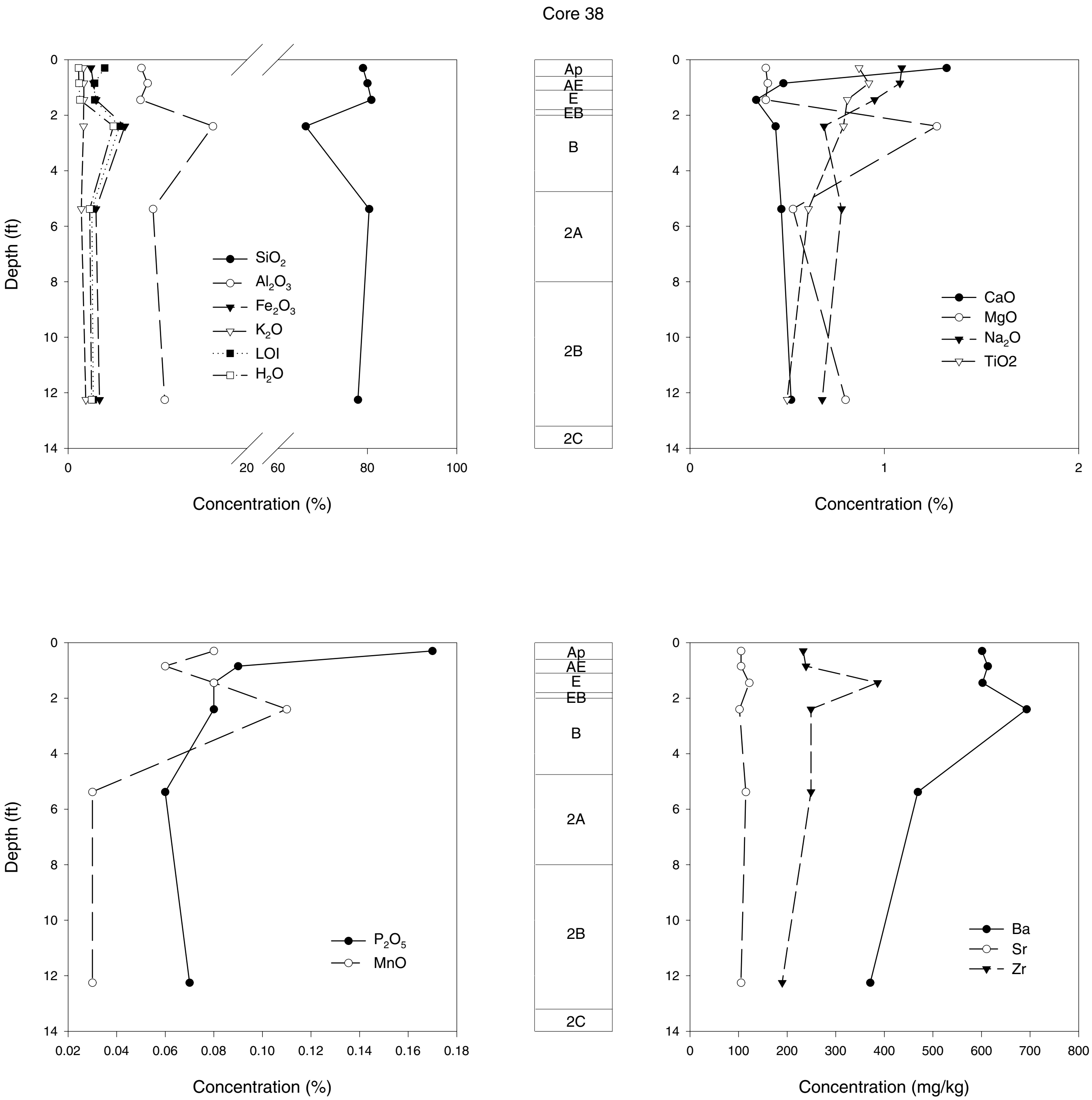


Figure 27 Elemental concentrations versus depth in core 37.



Core 38

Figure 28 Elemental concentrations versus depth in core 38.

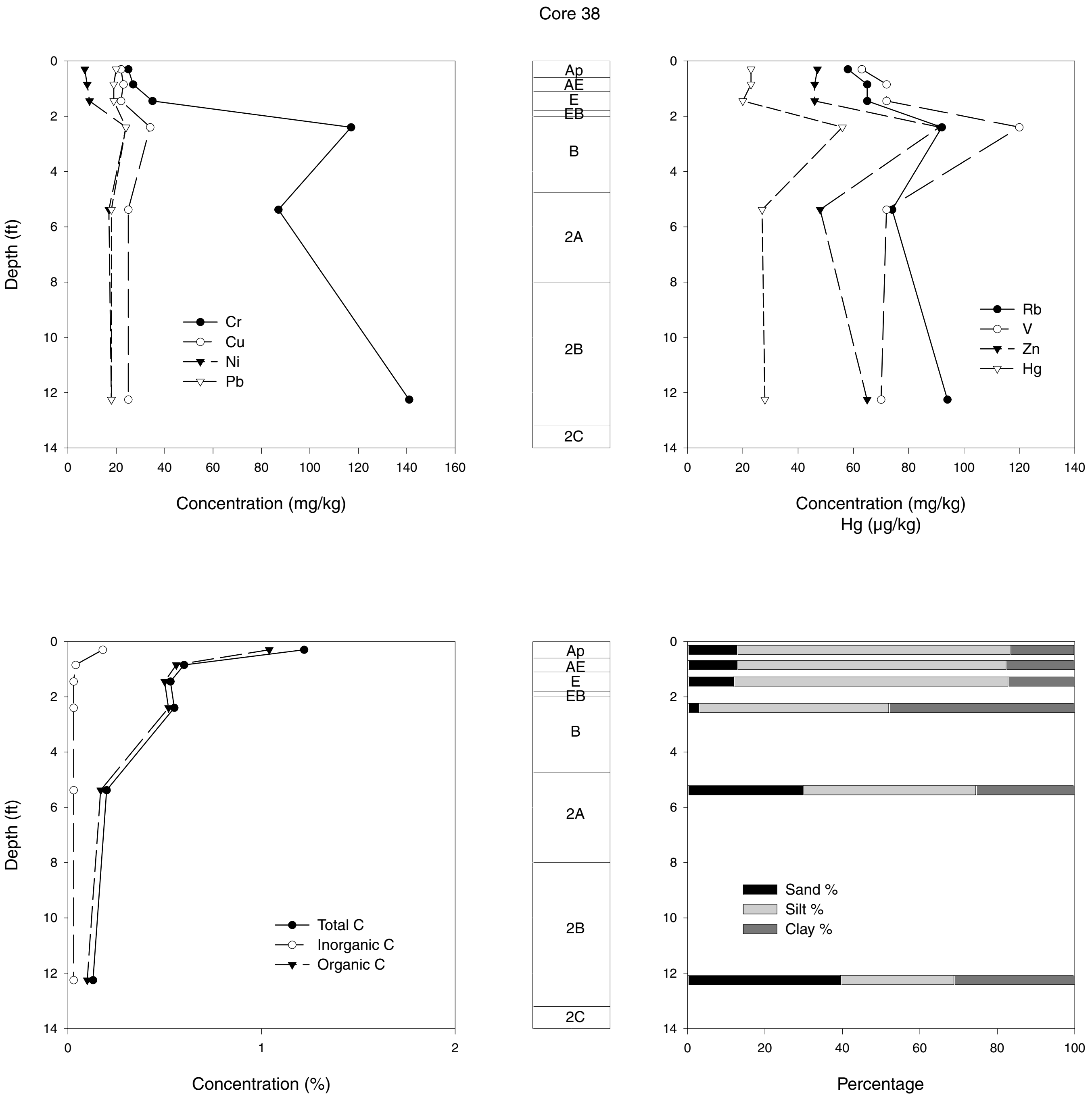


Figure 29 Elemental concentrations versus depth in core 38.

Core 39

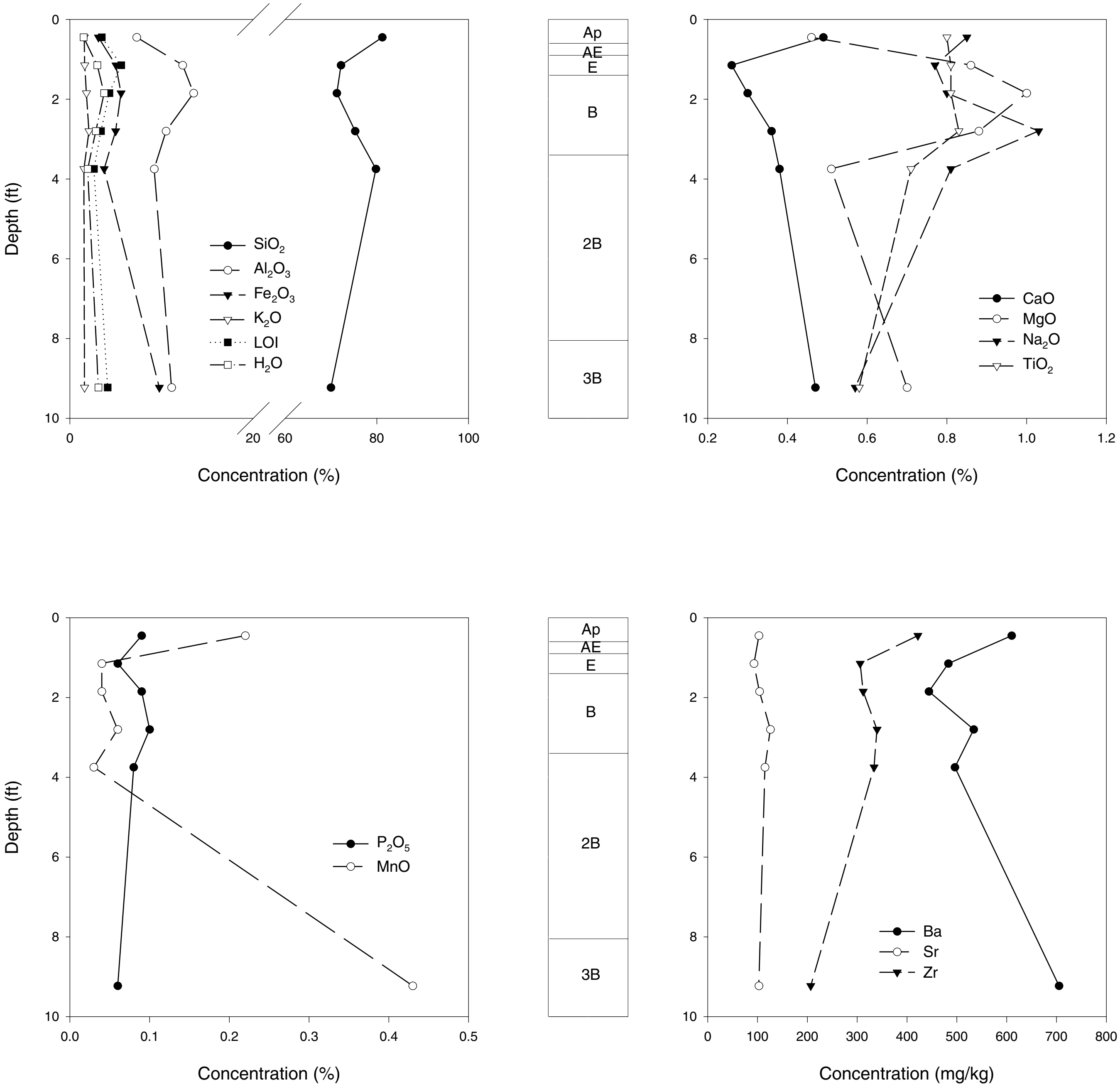


Figure 30 Elemental concentrations versus depth in core 39.

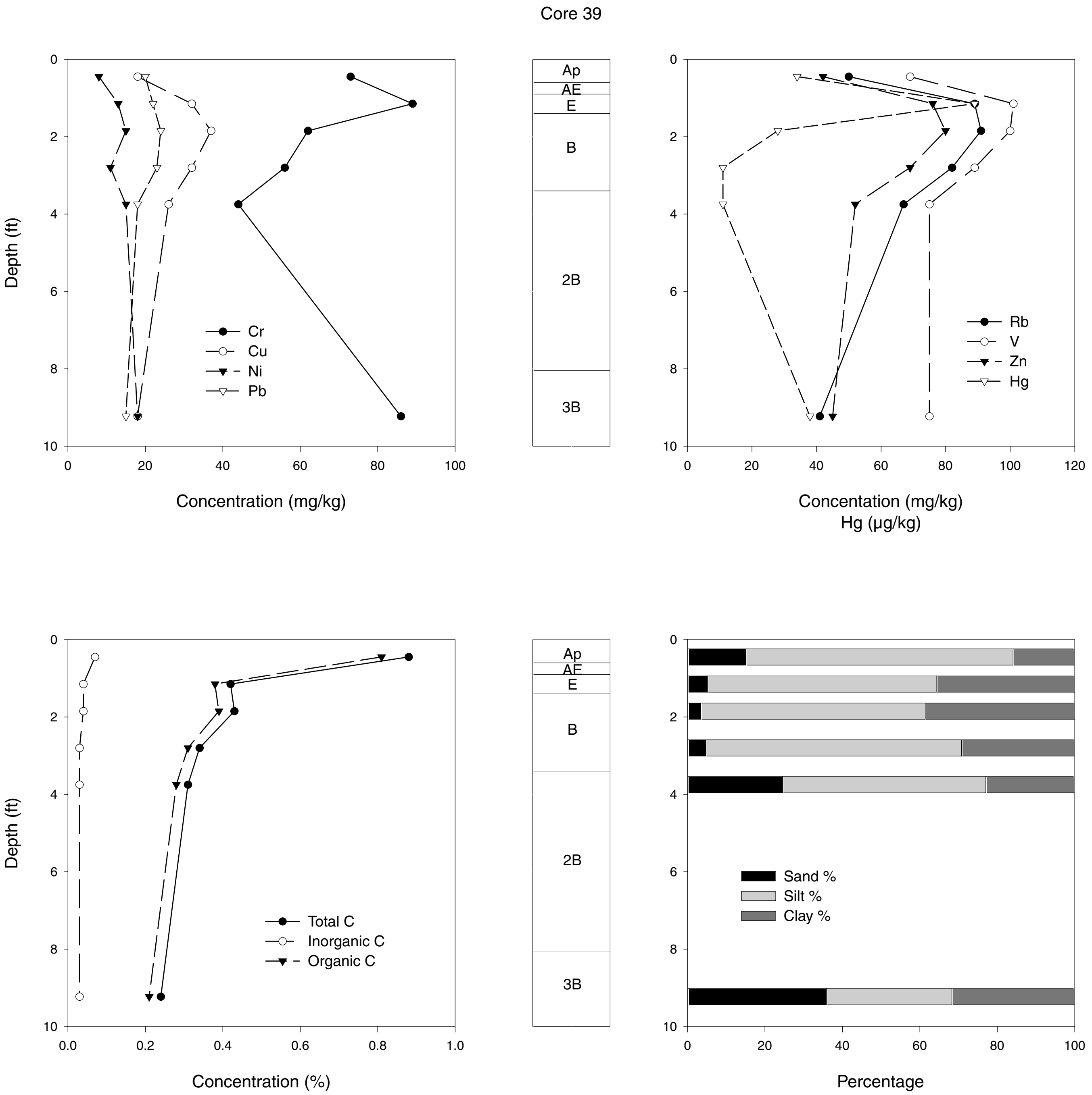


Figure 31 Elemental concentrations versus depth in core 39.

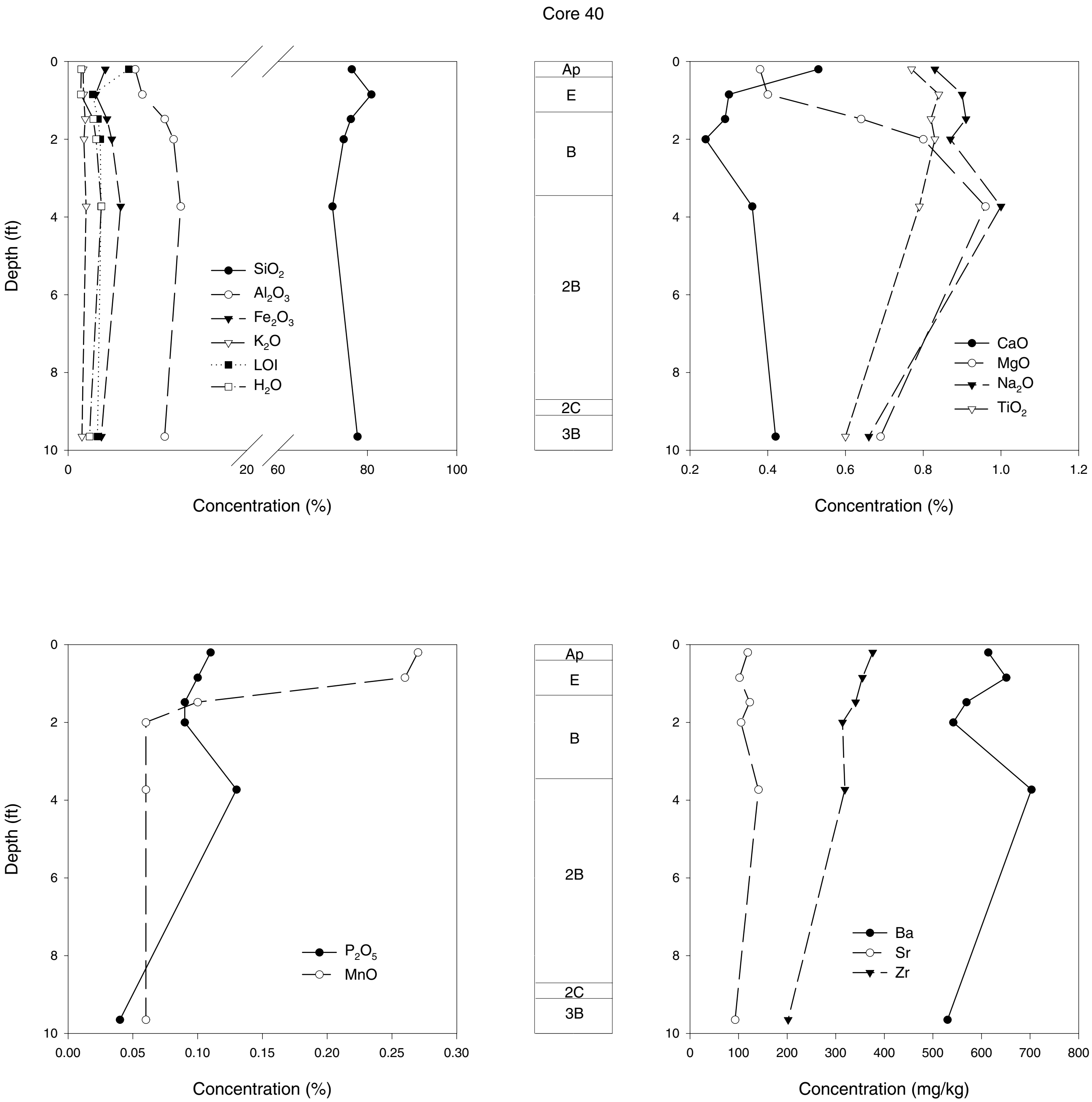


Figure 32 Elemental concentrations versus depth in core 40.

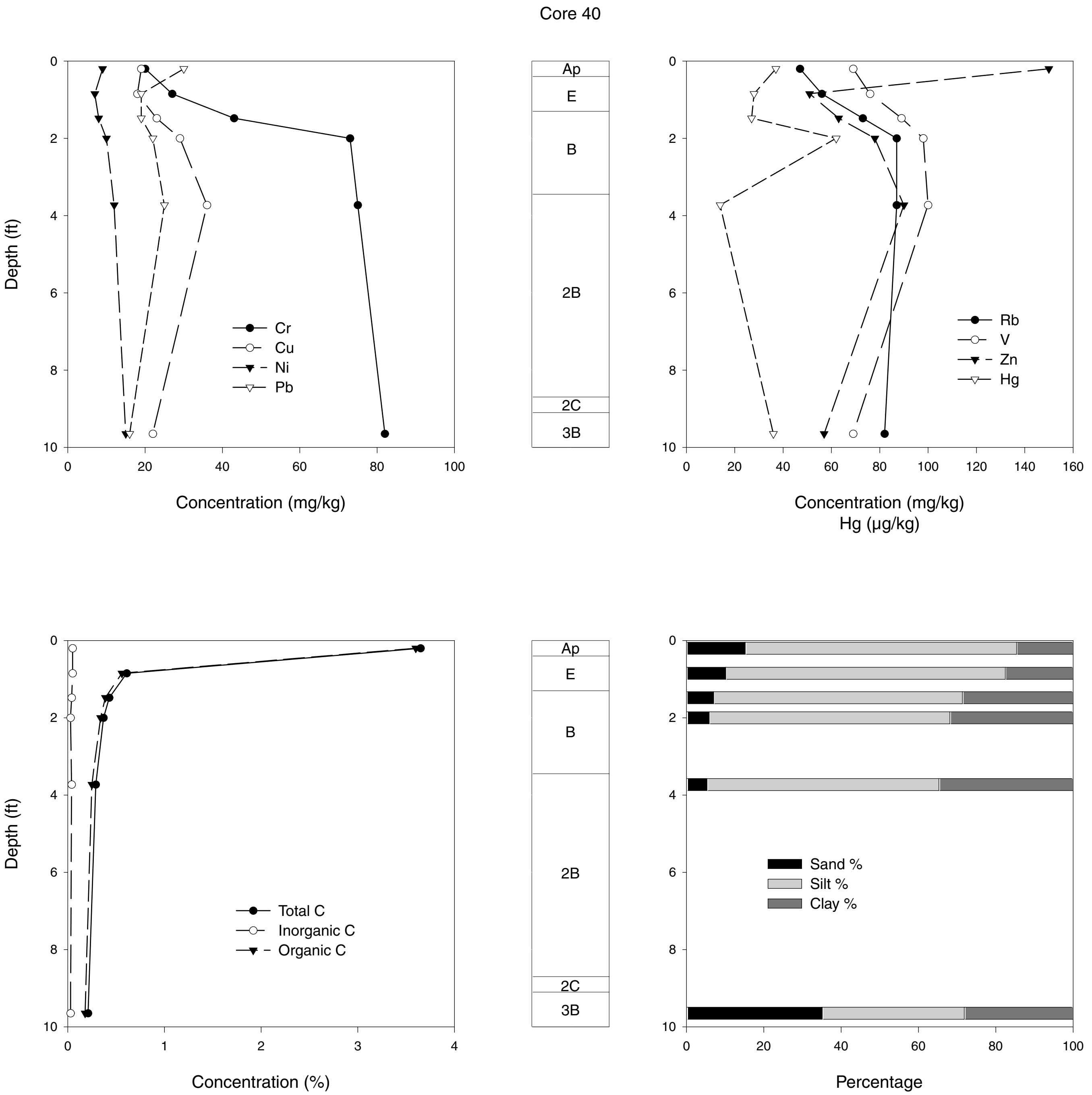


Figure 33 Elemental concentrations versus depth in core 40.

Core 41

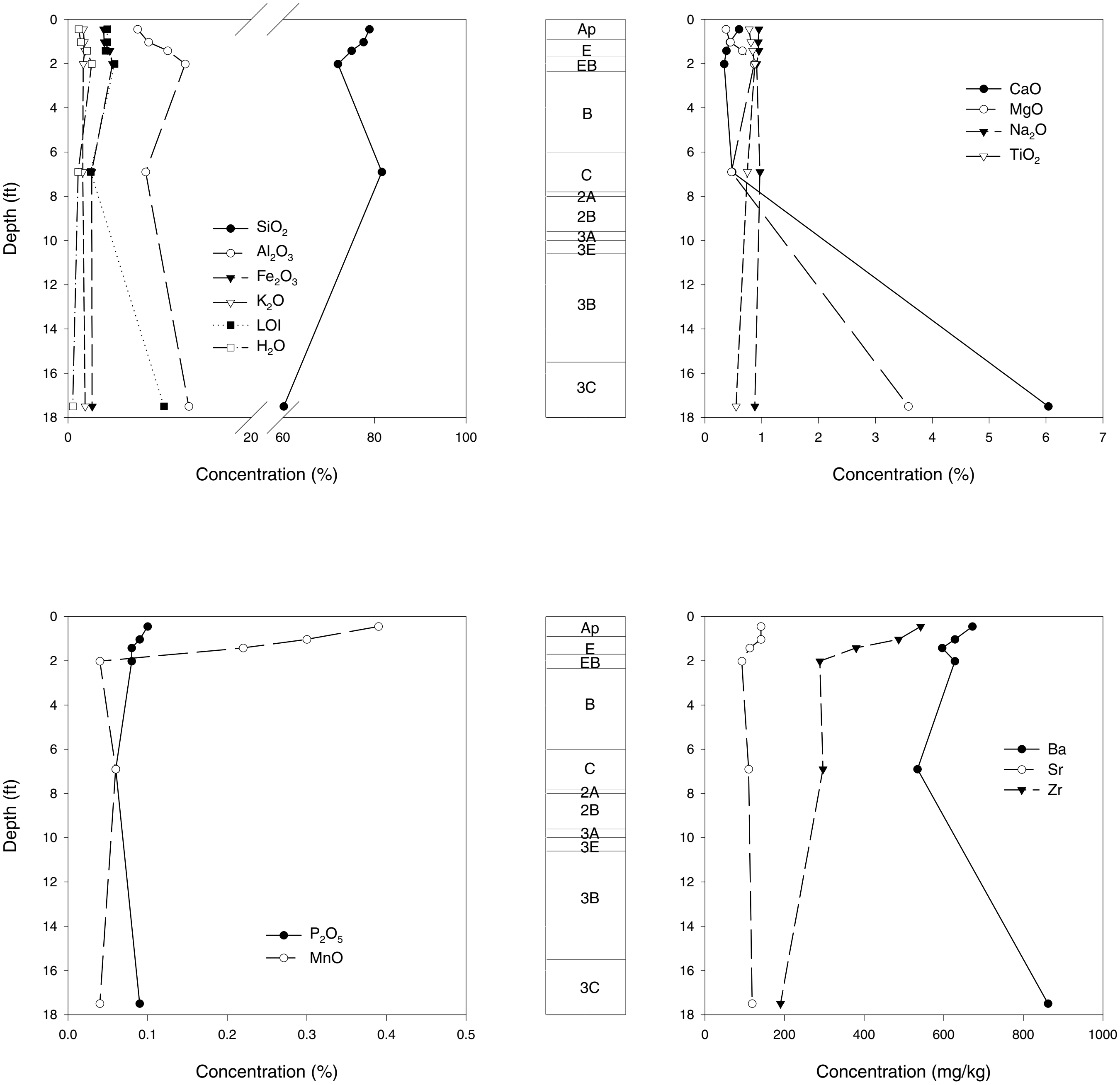


Figure 34 Elemental concentrations versus depth in core 41.

Core 41

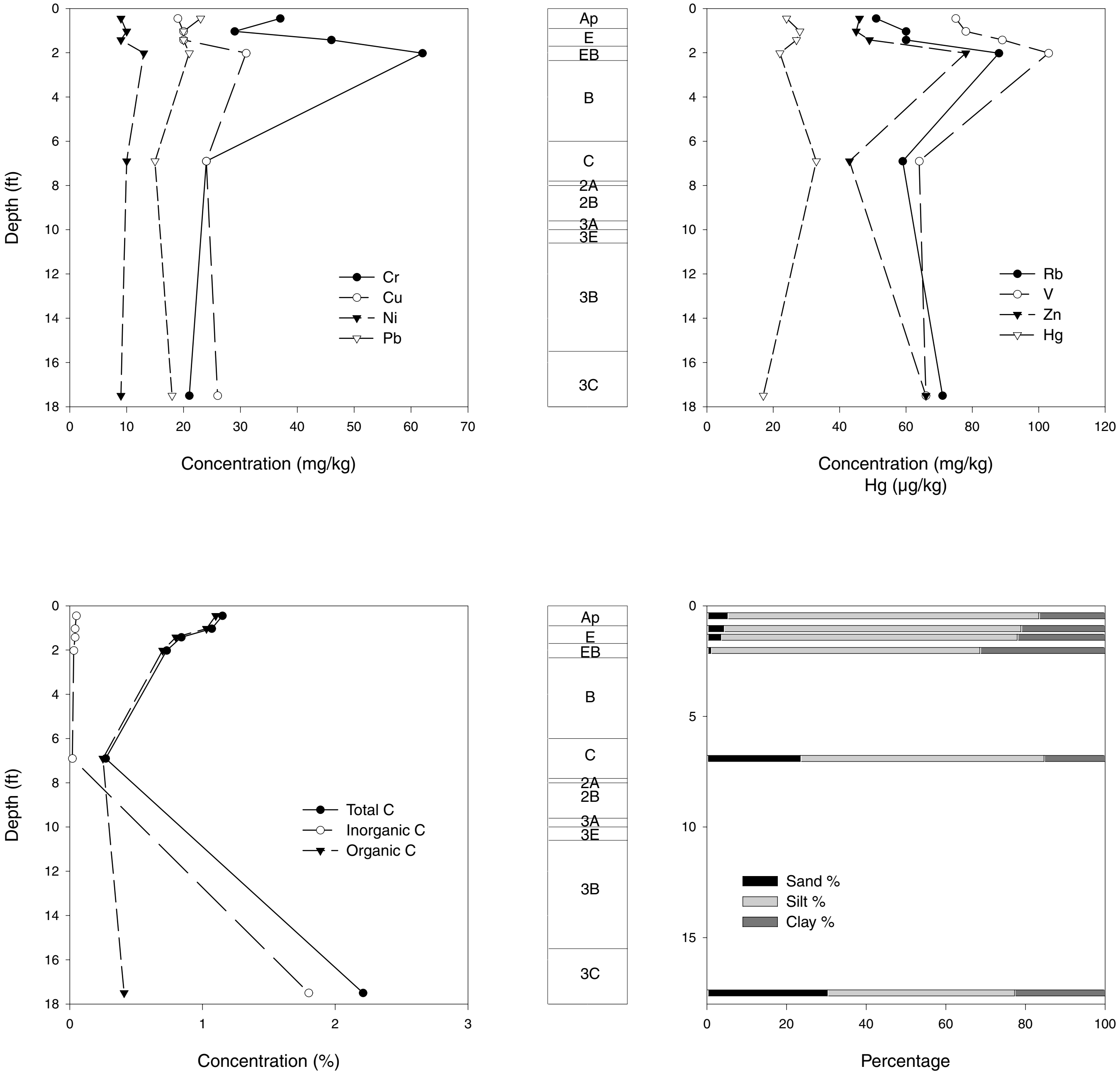


Figure 35 Elemental concentrations versus depth in core 41.

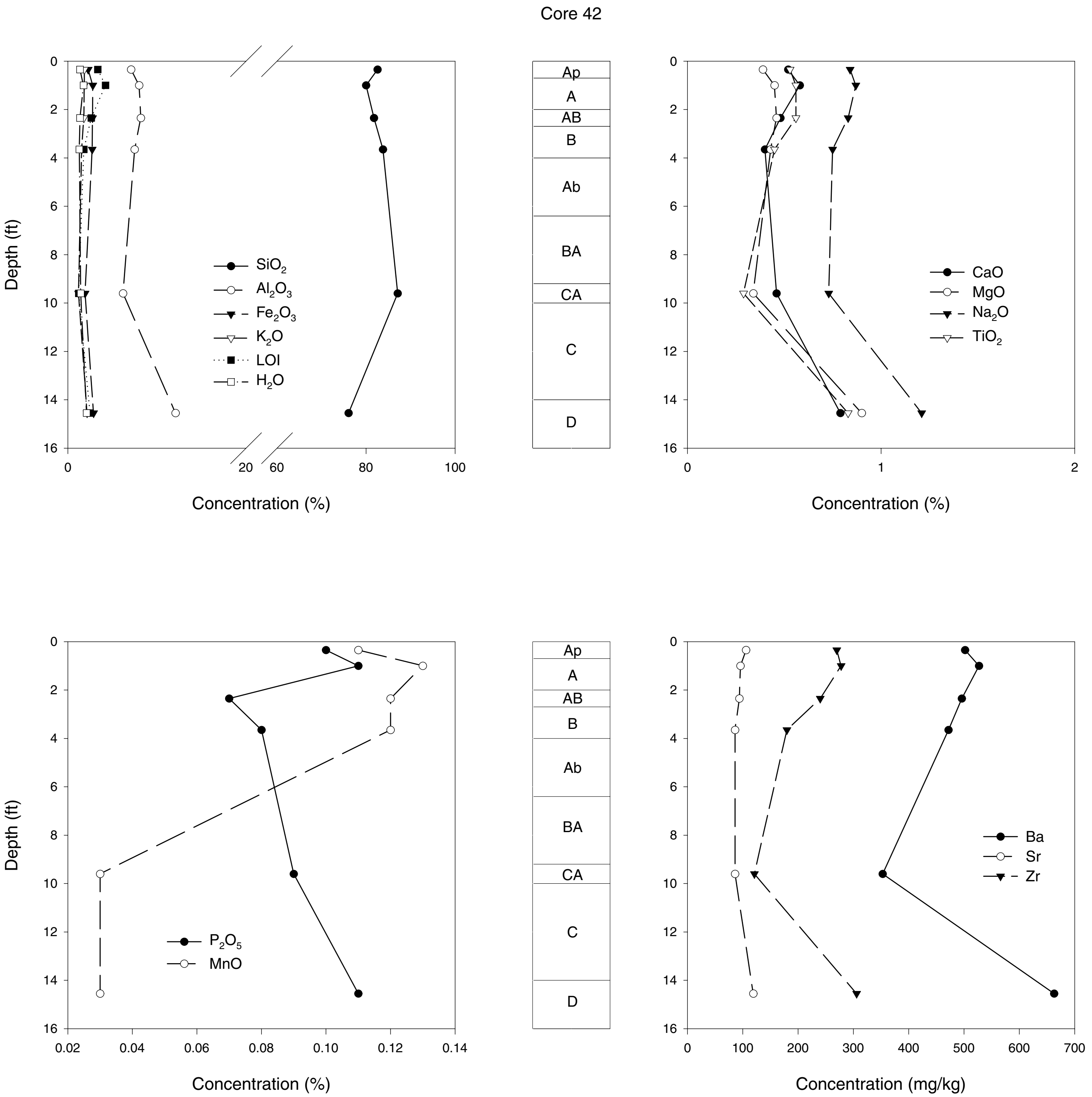


Figure 36 Elemental concentrations versus depth in core 42.

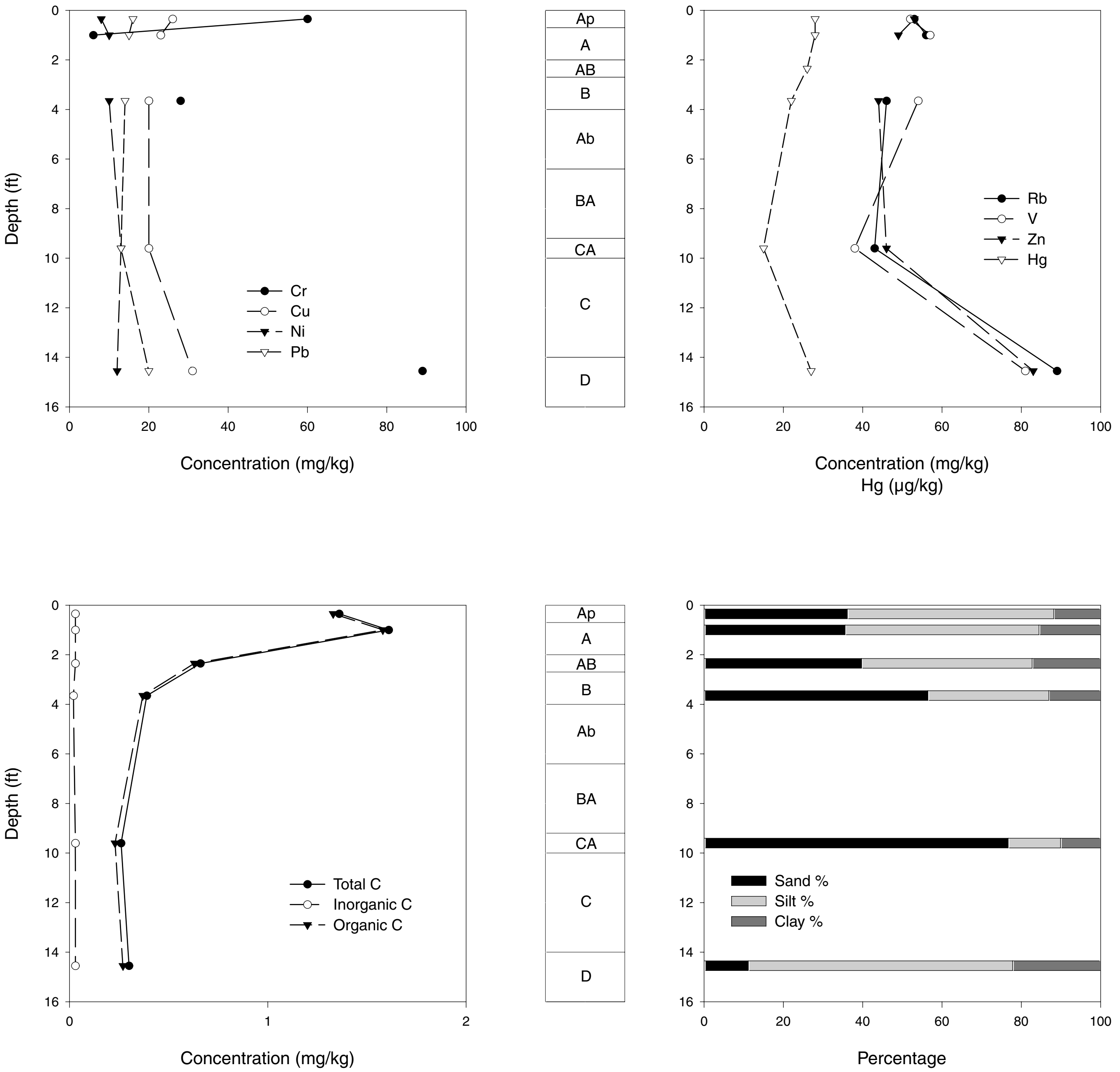

Core 42

Figure 37 Elemental concentrations versus depth in core 42.

Core 43

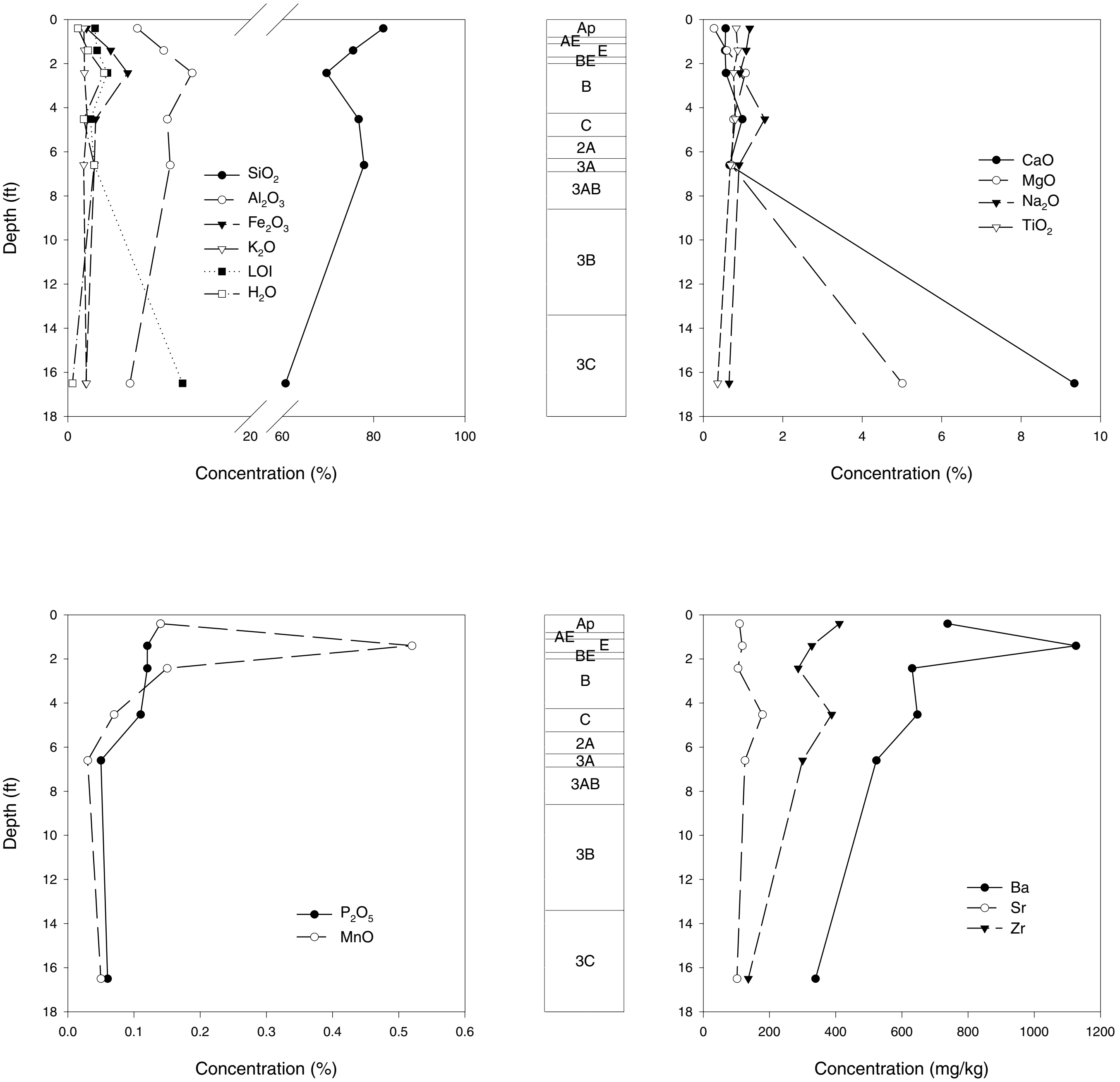


Figure 38 Elemental concentrations versus depth in core 43.

Core 43

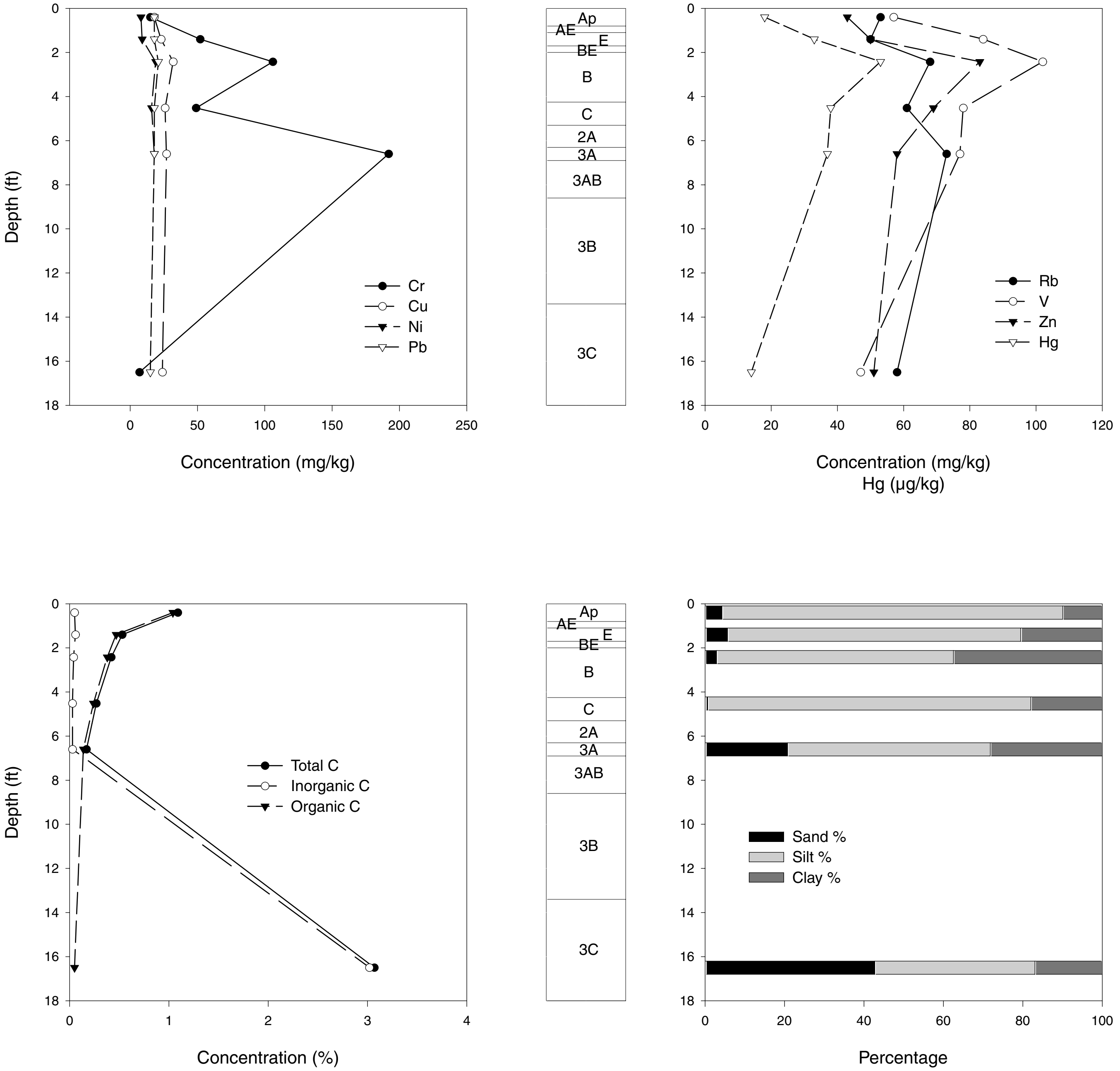


Figure 39 Elemental concentrations versus depth in core 43.

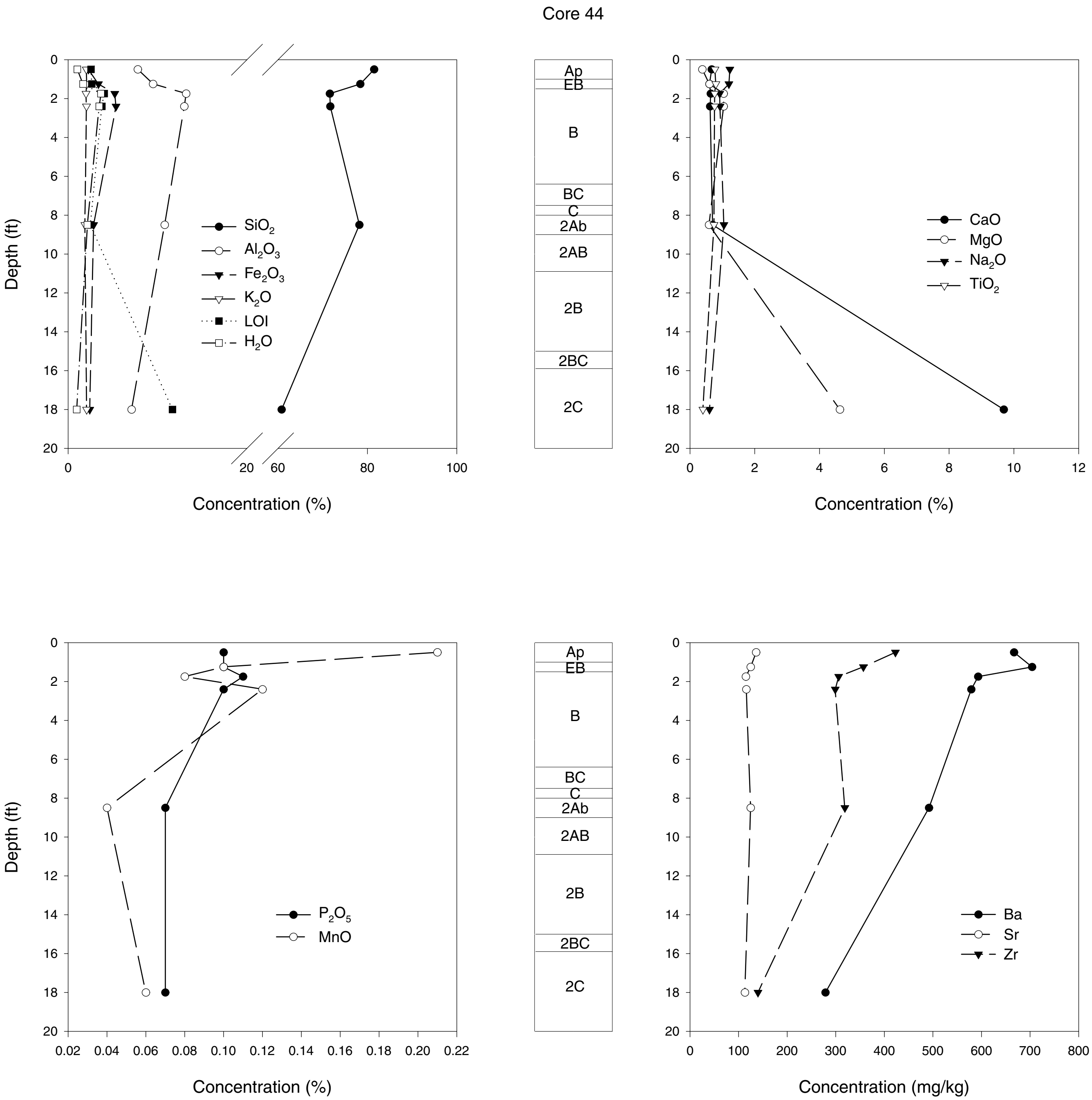

Core 44

Figure 40 Elemental concentrations versus depth in Core 44.

Core 44

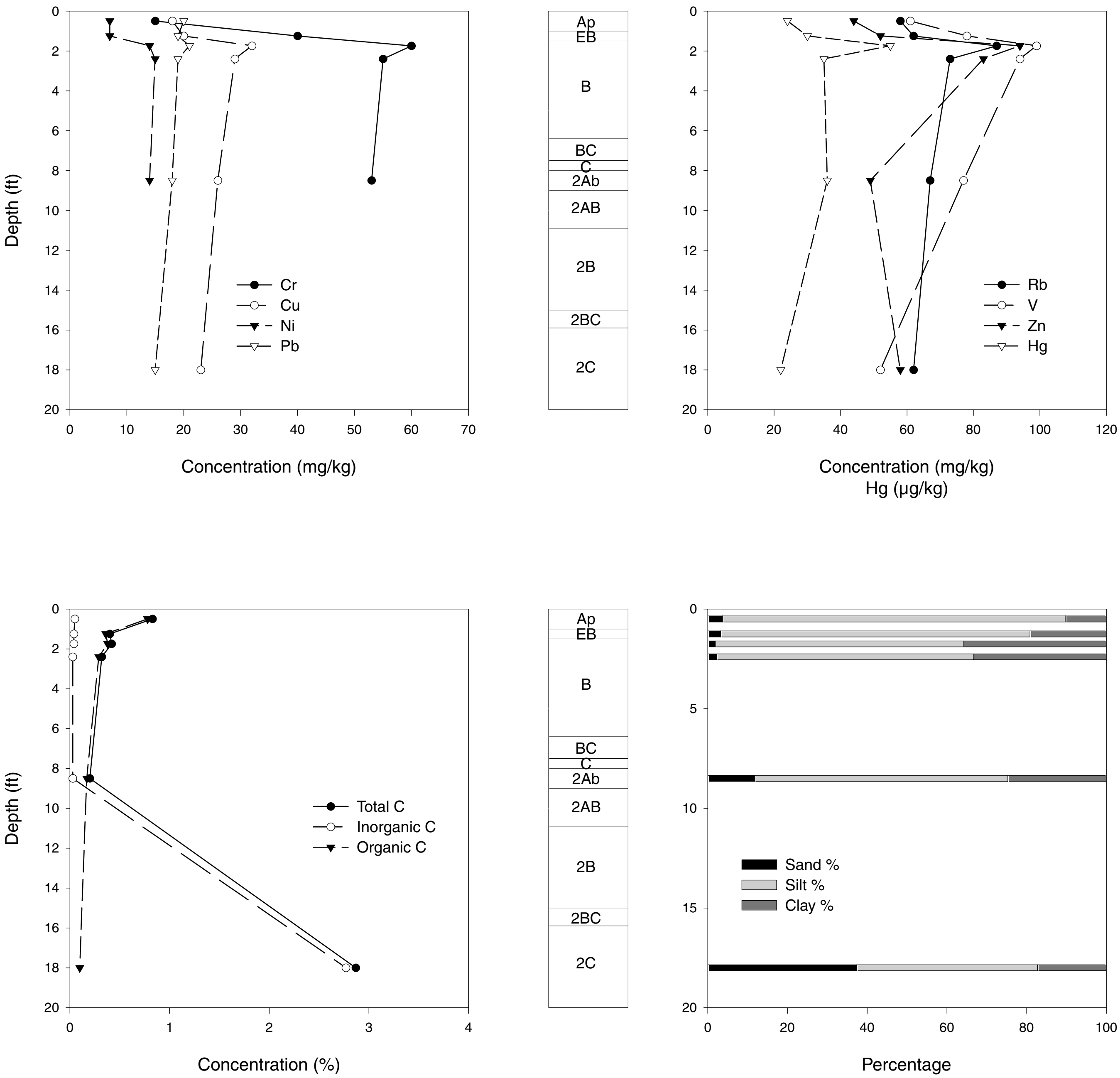


Figure 41 Elemental concentrations versus depth in core 44.

Core 45

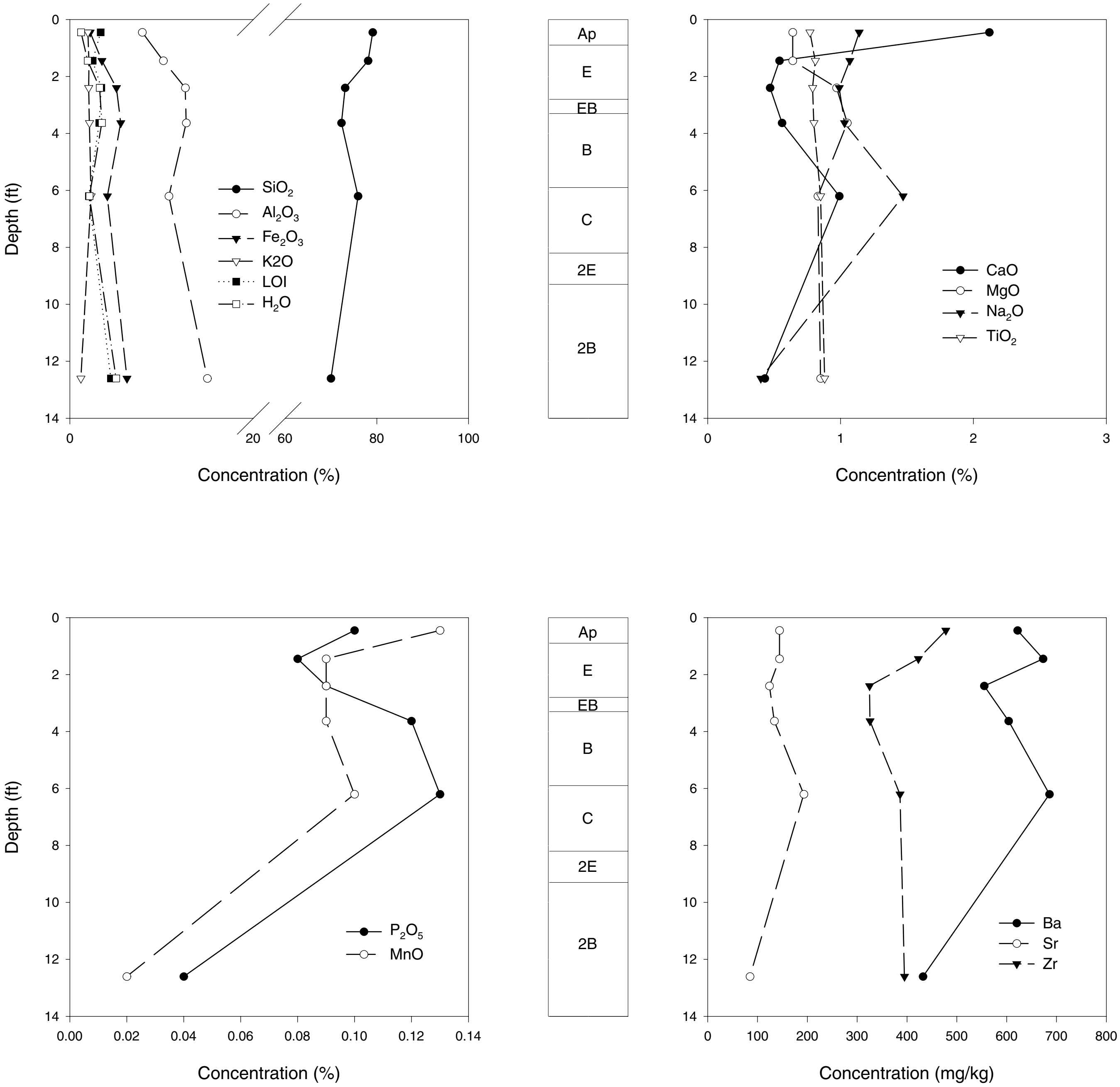


Figure 42 Elemental concentrations versus depth in core 45.

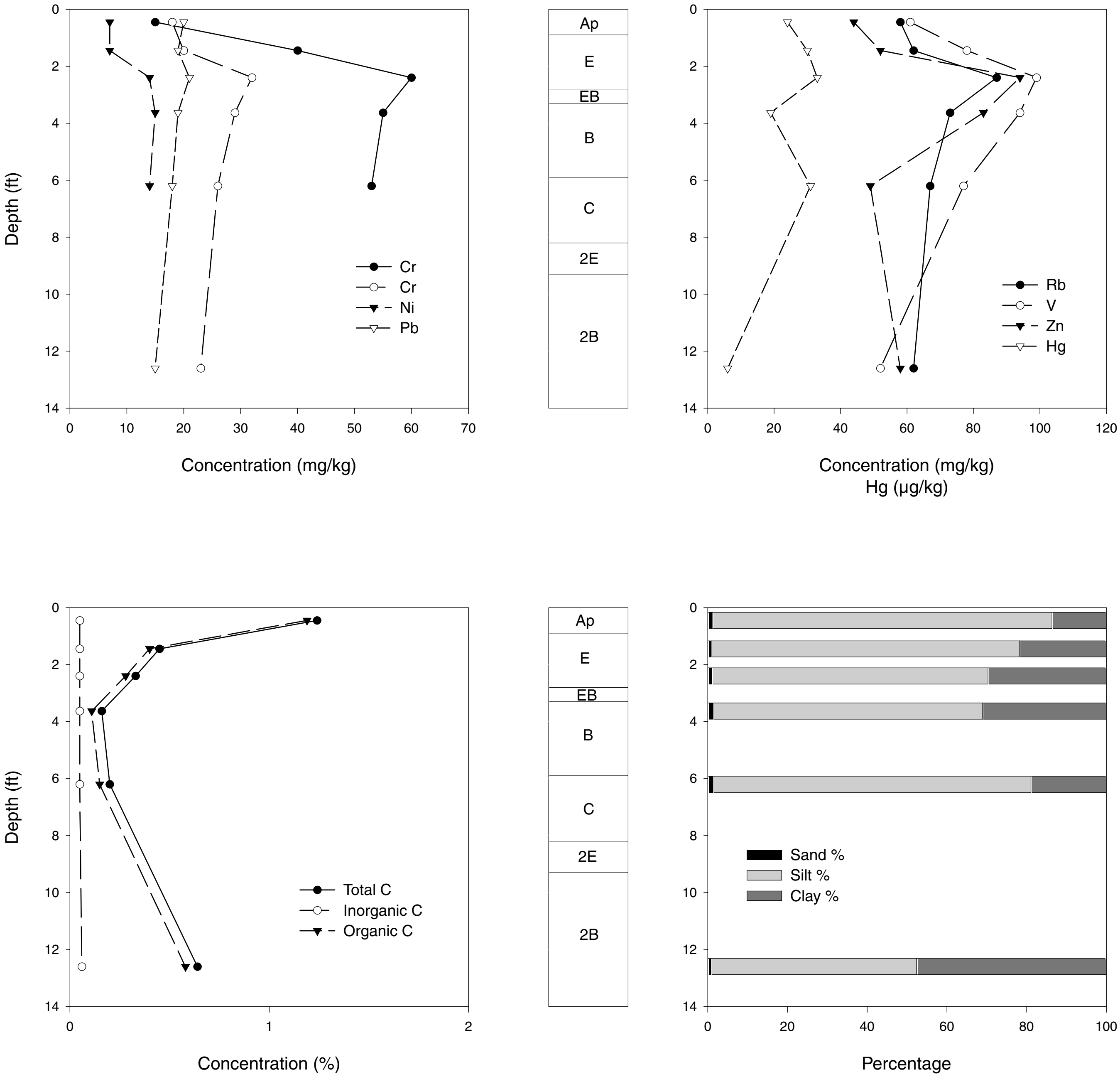

Core 45

Figure 43. Elemental concentrations versus depth in core 45.

Core 46

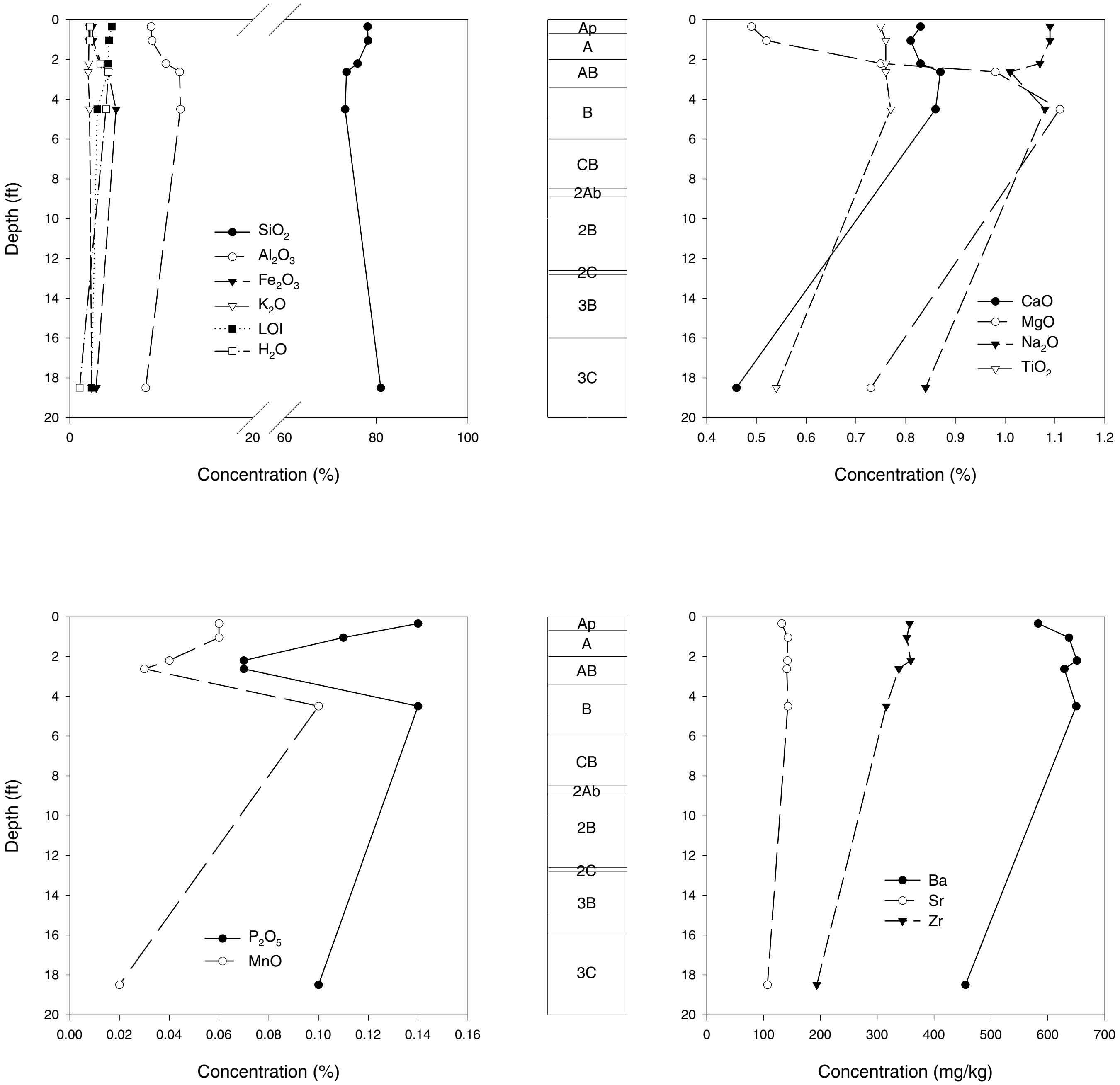


Figure 44 Elemental concentrations versus depth in core 46.

Core 46

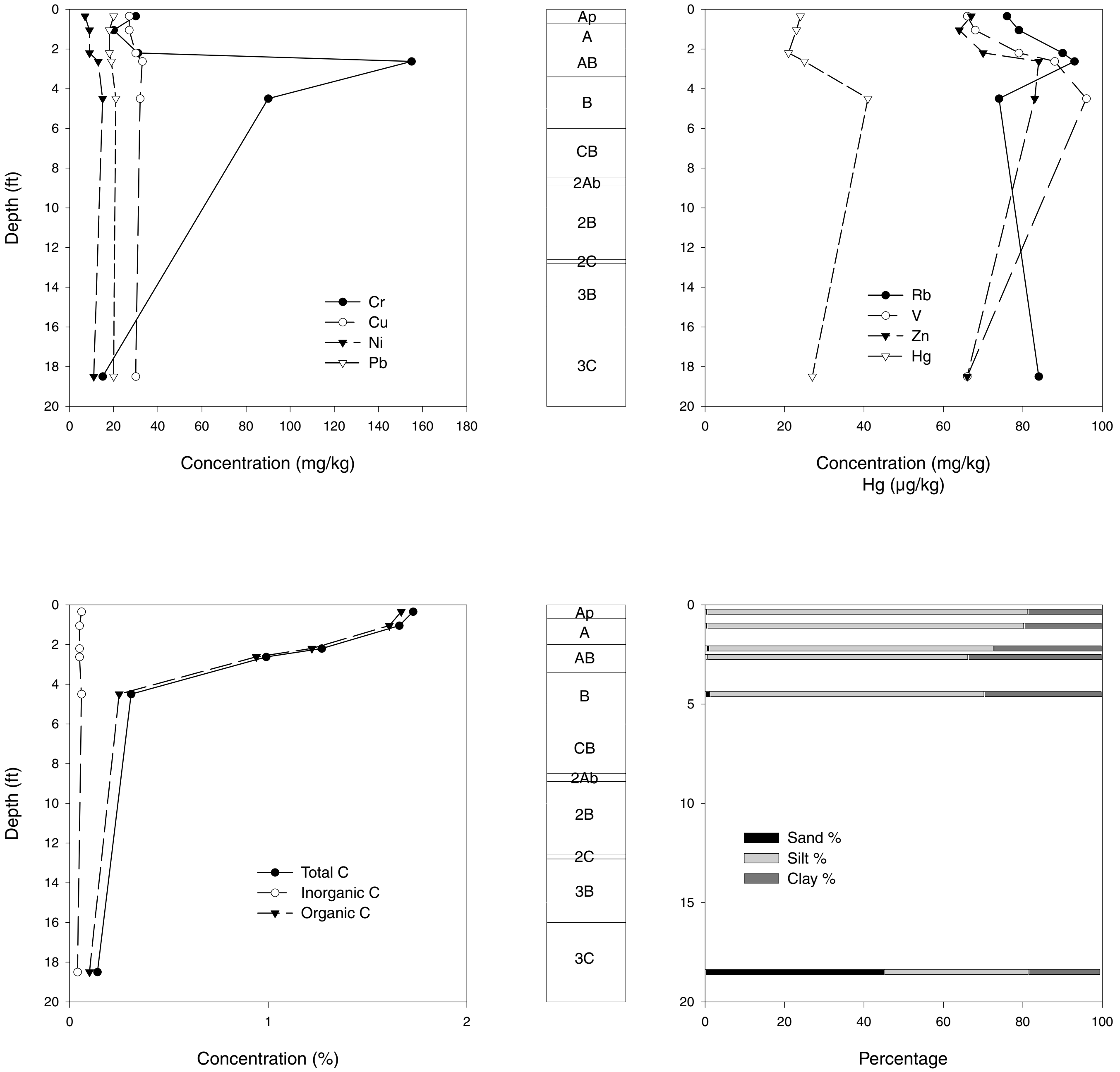


Figure 45 Elemental concentrations versus depth in core 46.

Core 47

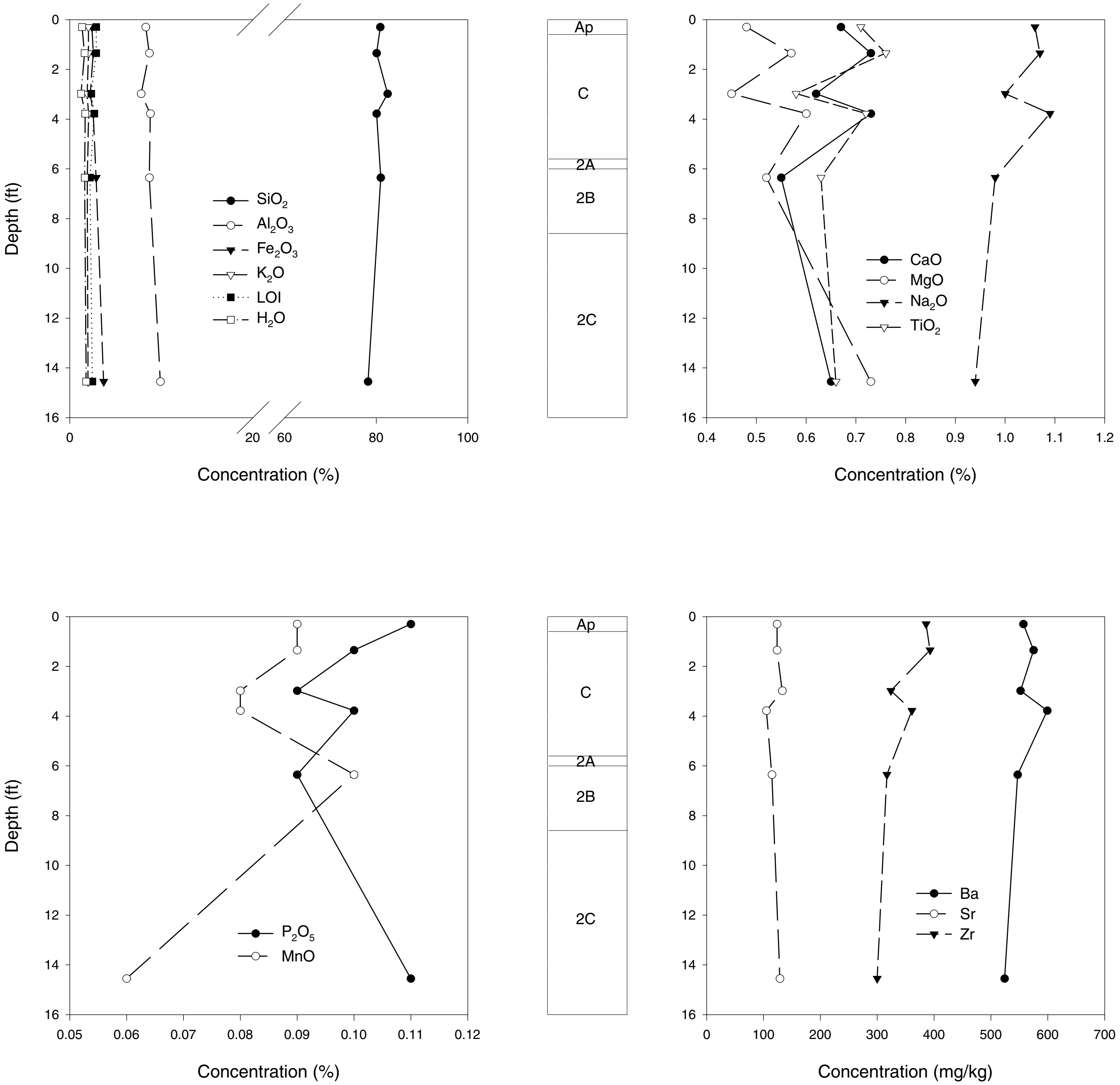


Figure 46 Elemental concentrations versus depth in core 47.

Core 47

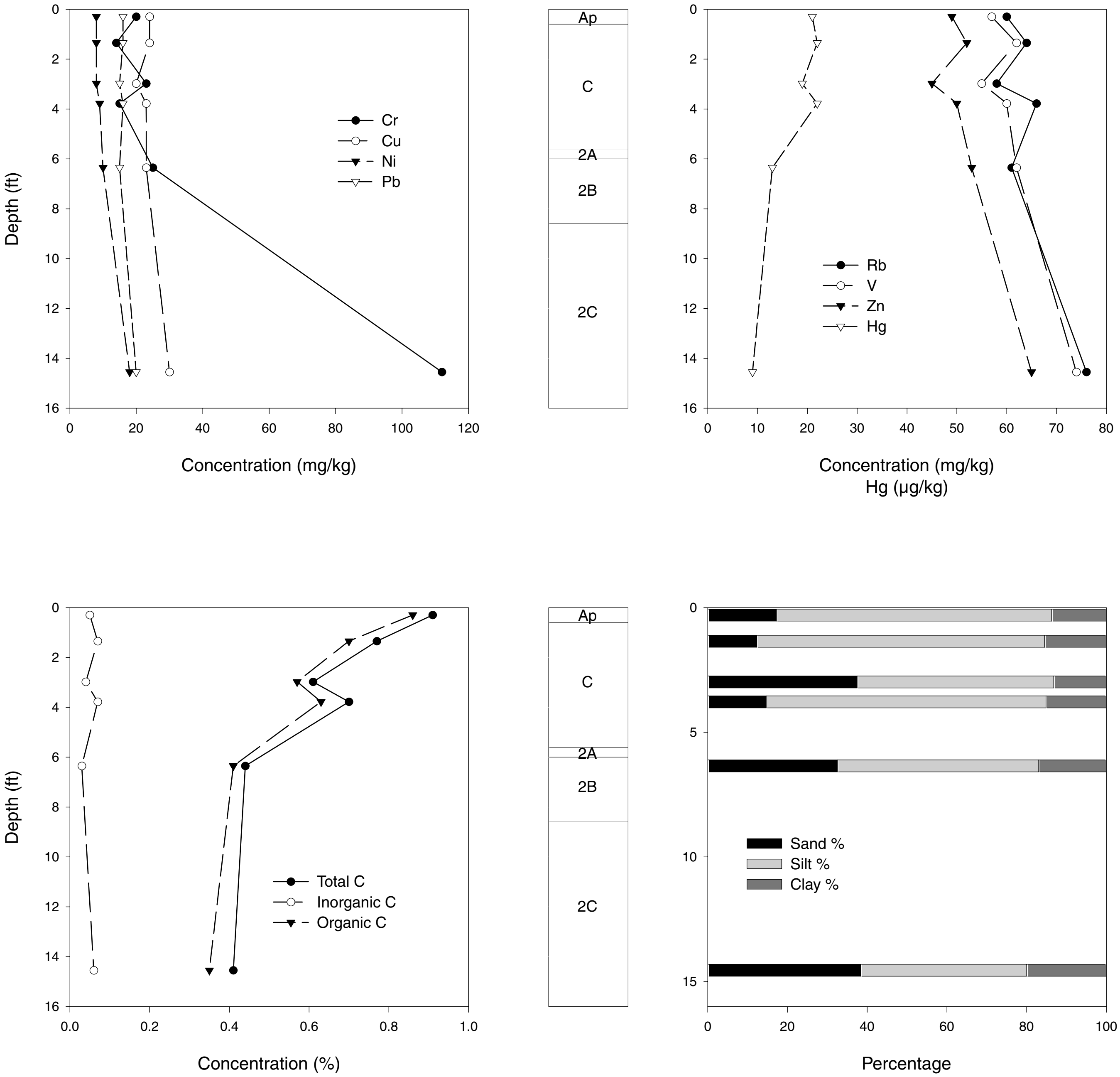


Figure 47 Elemental concentrations versus depth in core 47.

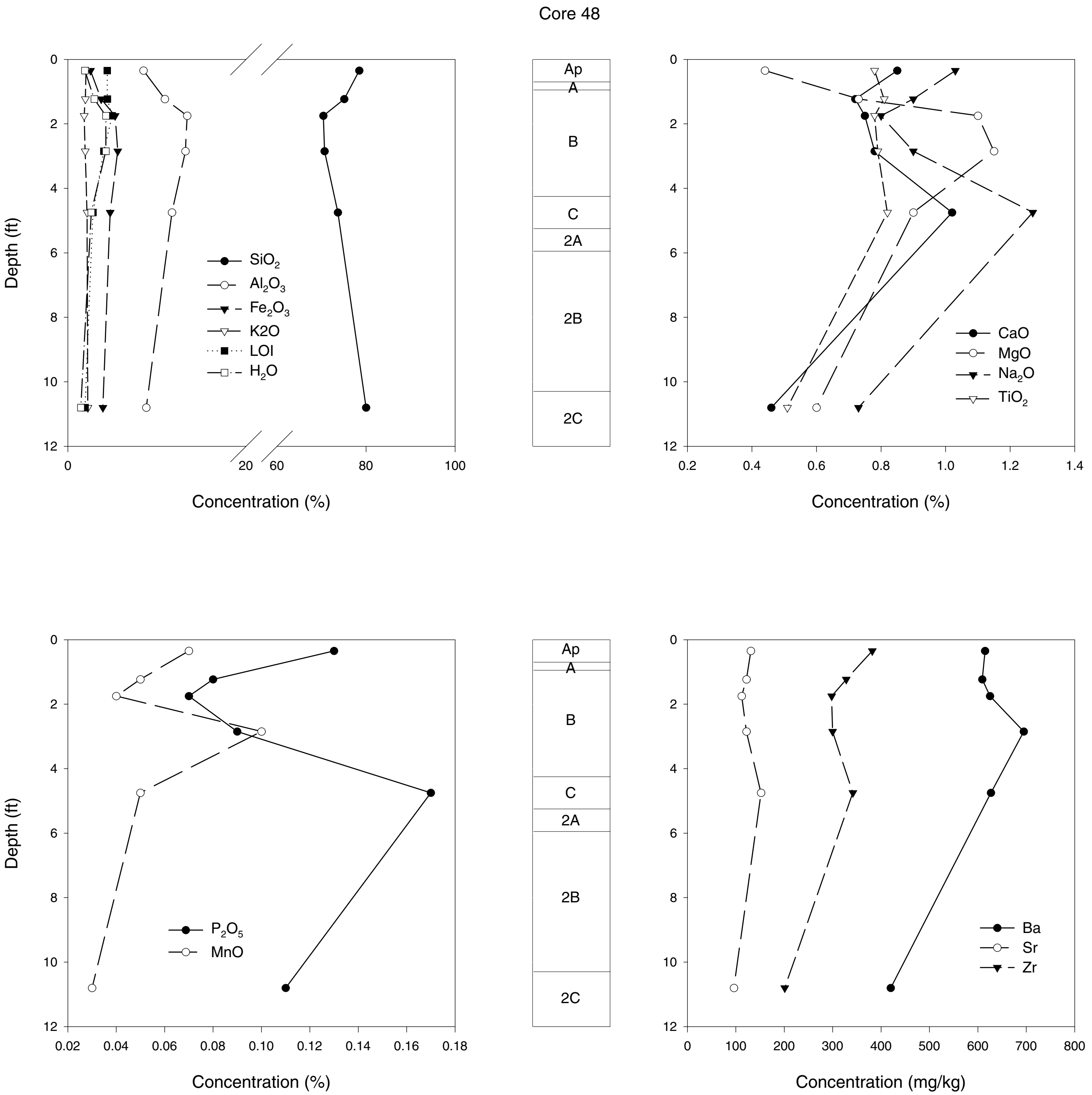


Figure 48 Elemental concentrations versus depth in core 48.

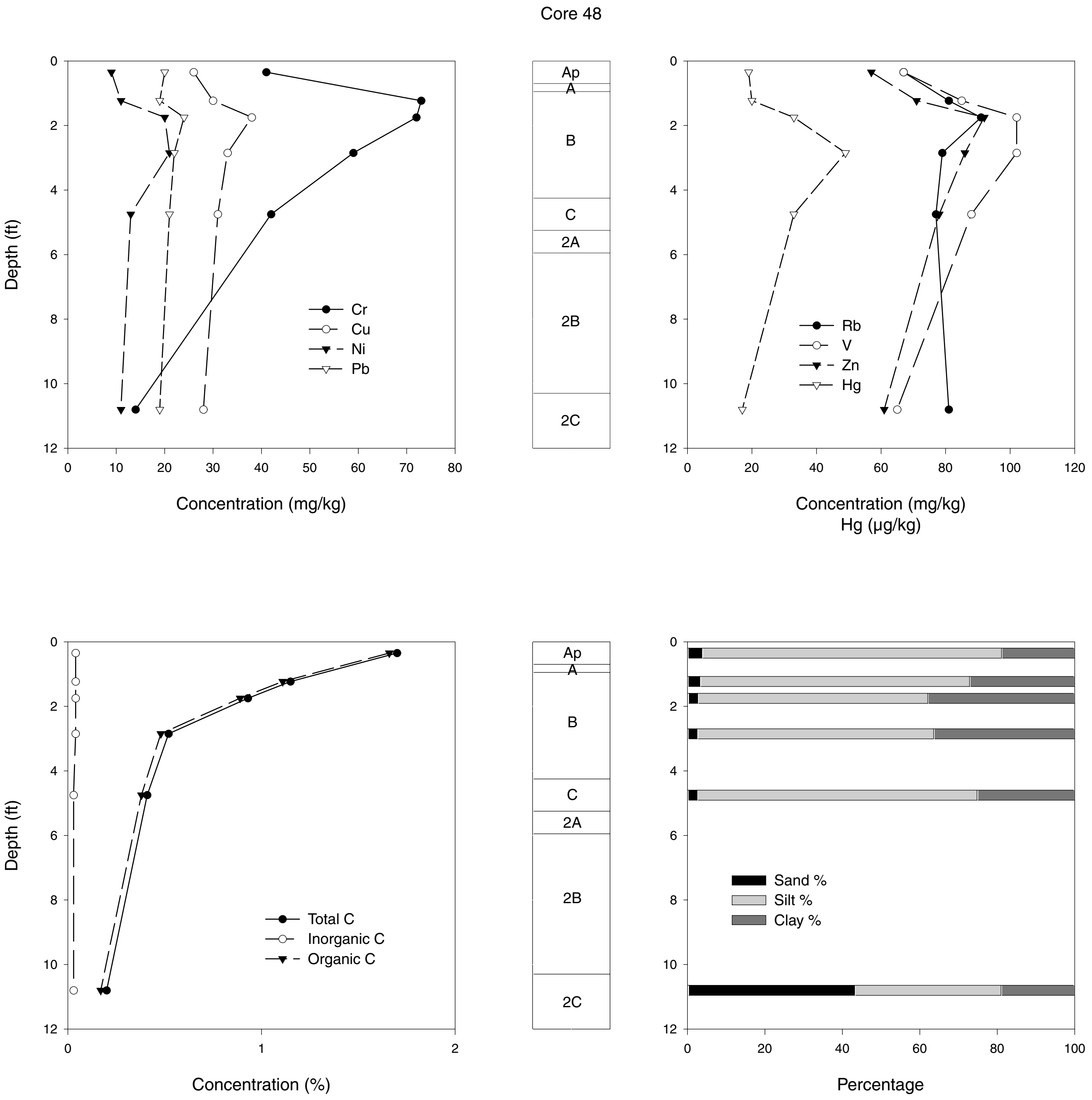


Figure 49 Elemental concentrations versus depth in core 48.

Core 49

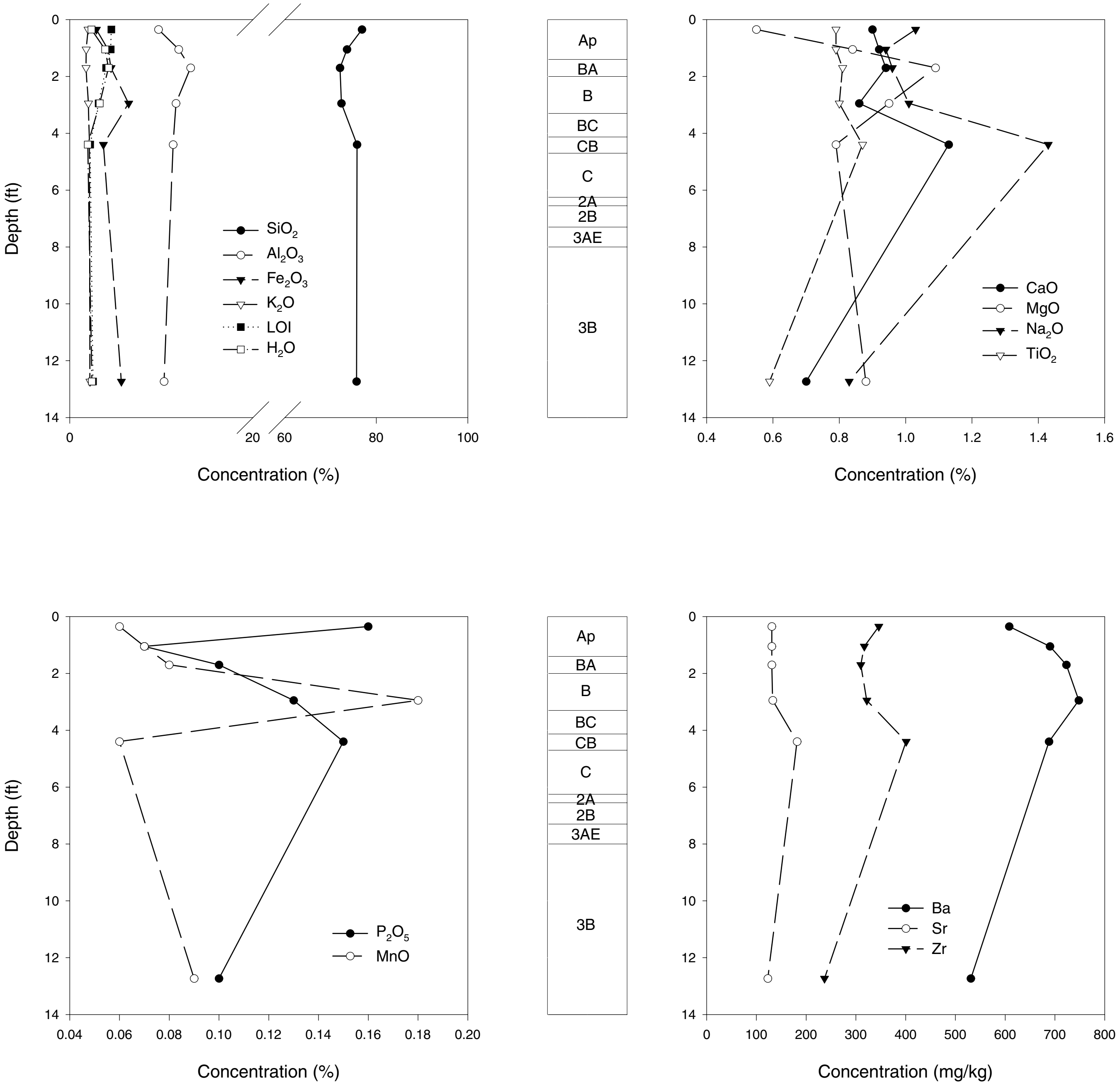


Figure 50 Elemental concentrations versus depth in core 49.

Core 49

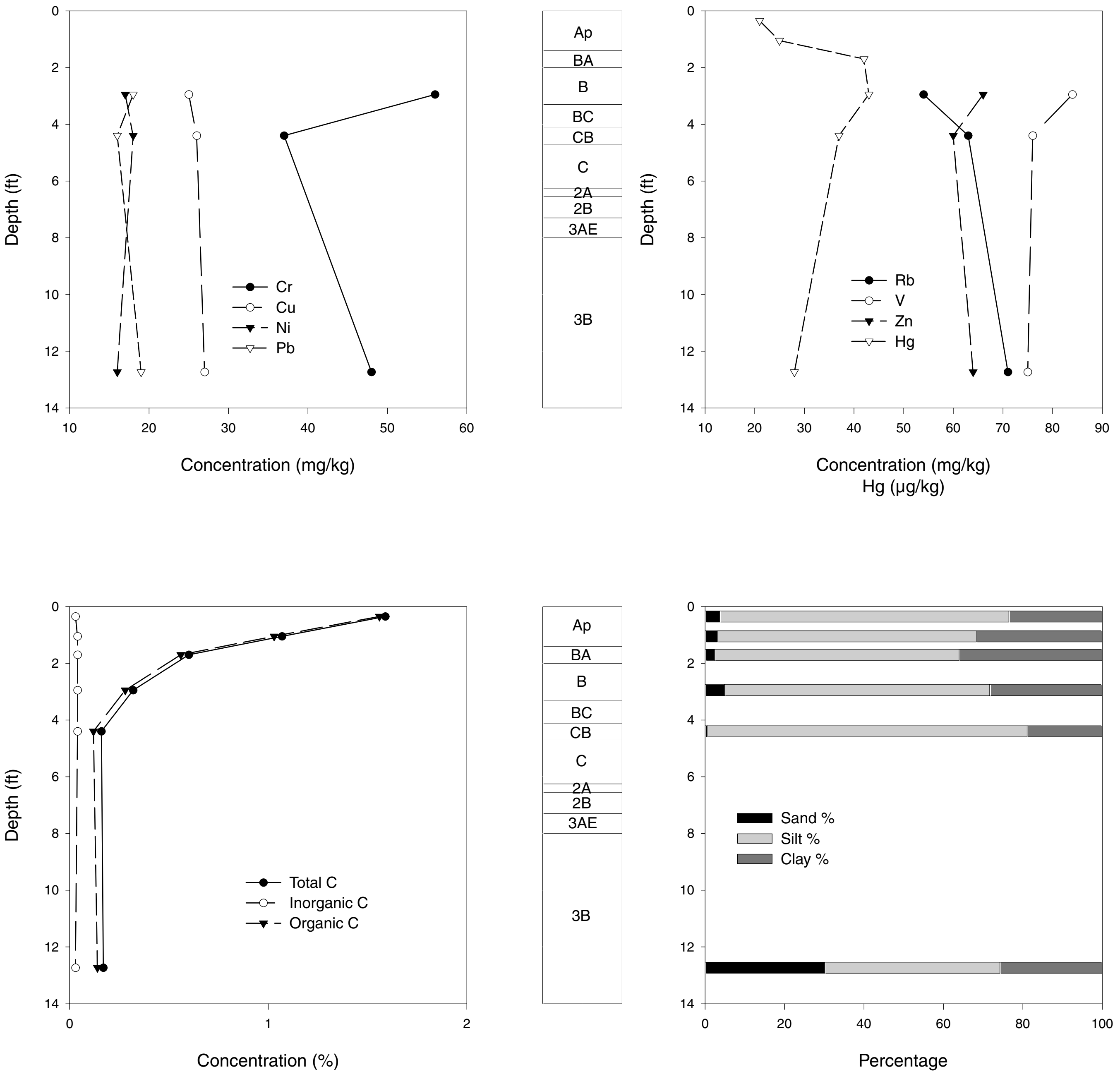


Figure 51 Elemental concentrations versus depth in core 49.

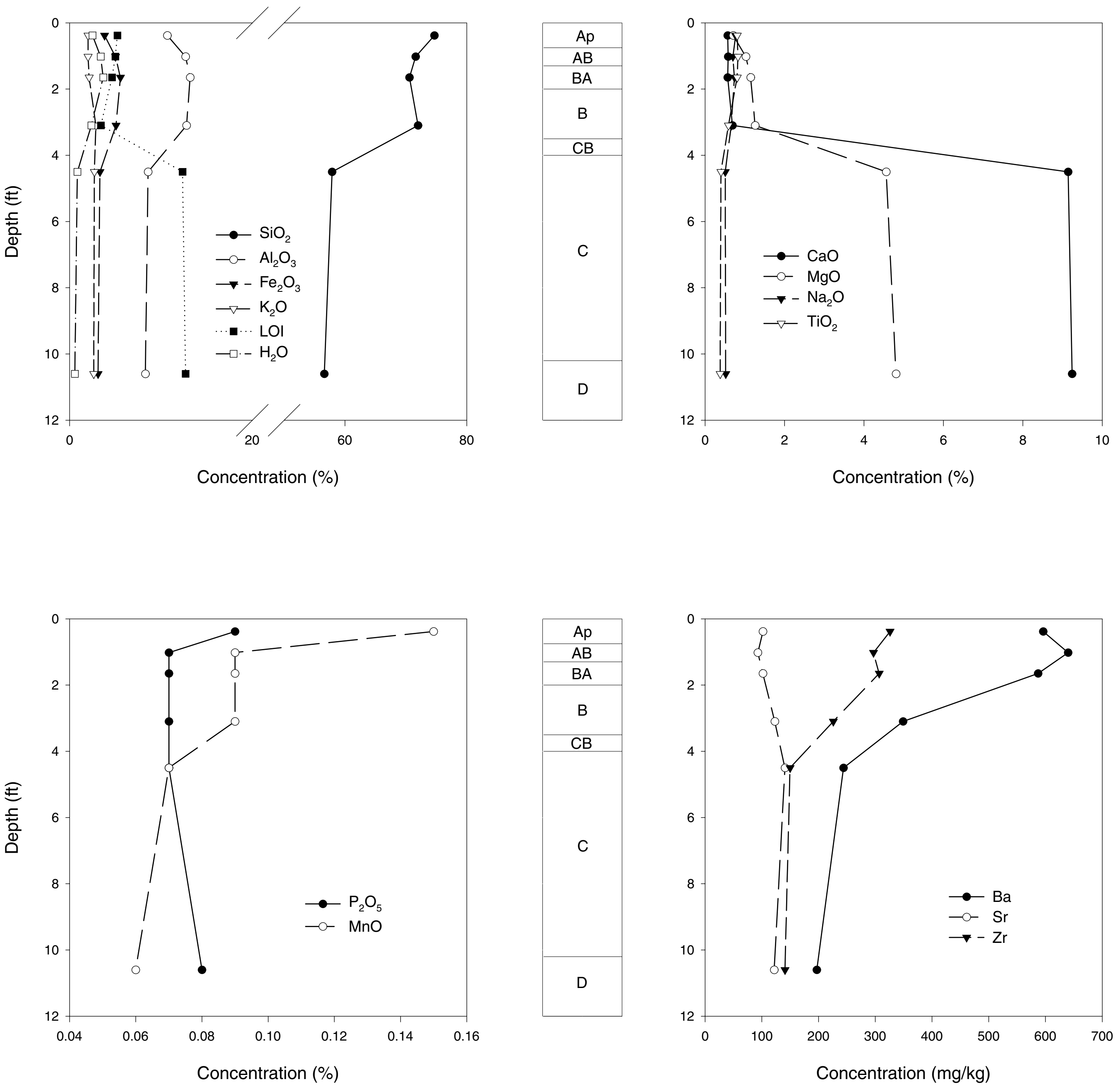

Core 50

Figure 52 Elemental concentrations versus depth in core 50.

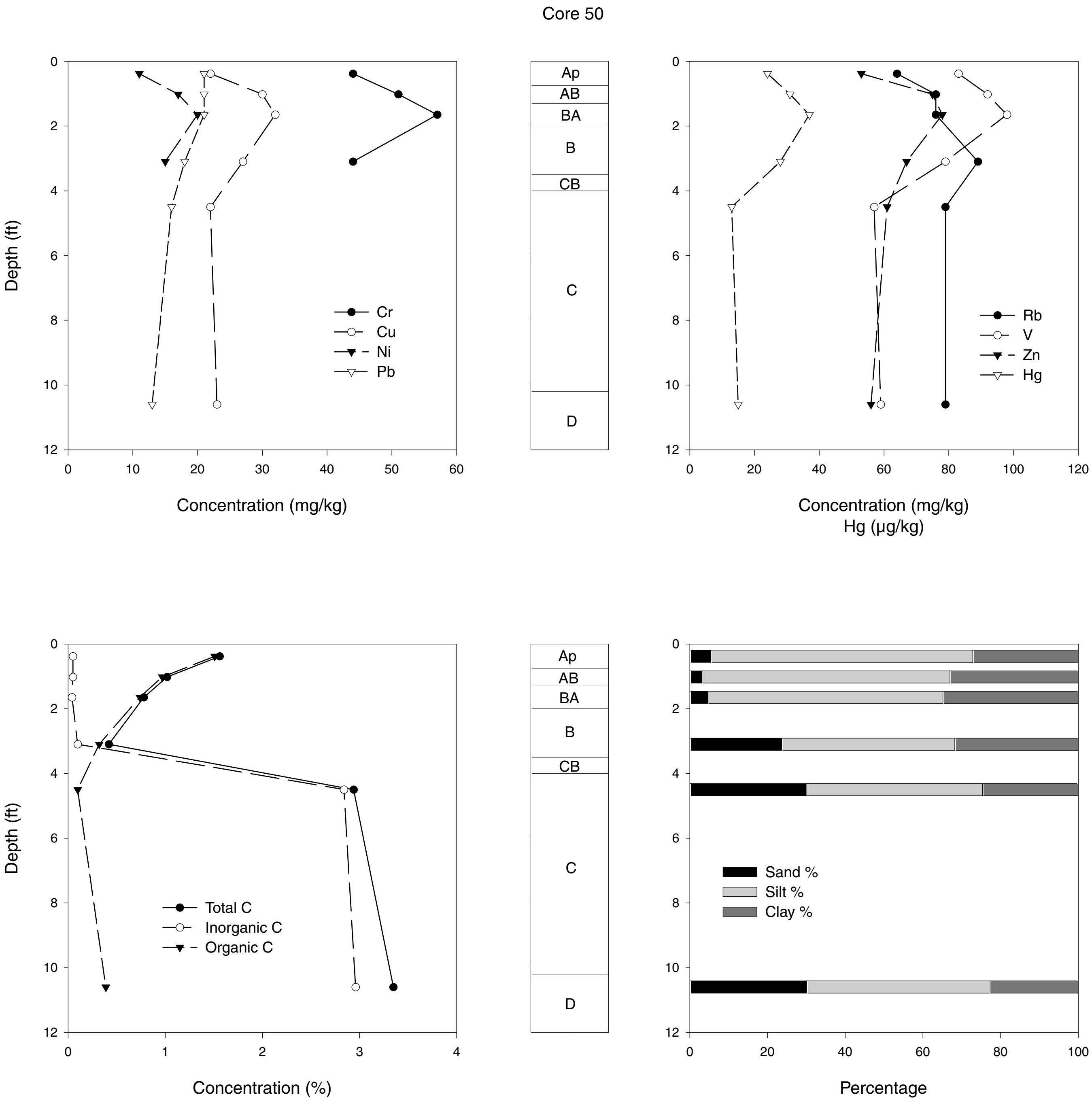


Figure 53. Elemental concentrations versus depth in core 50.

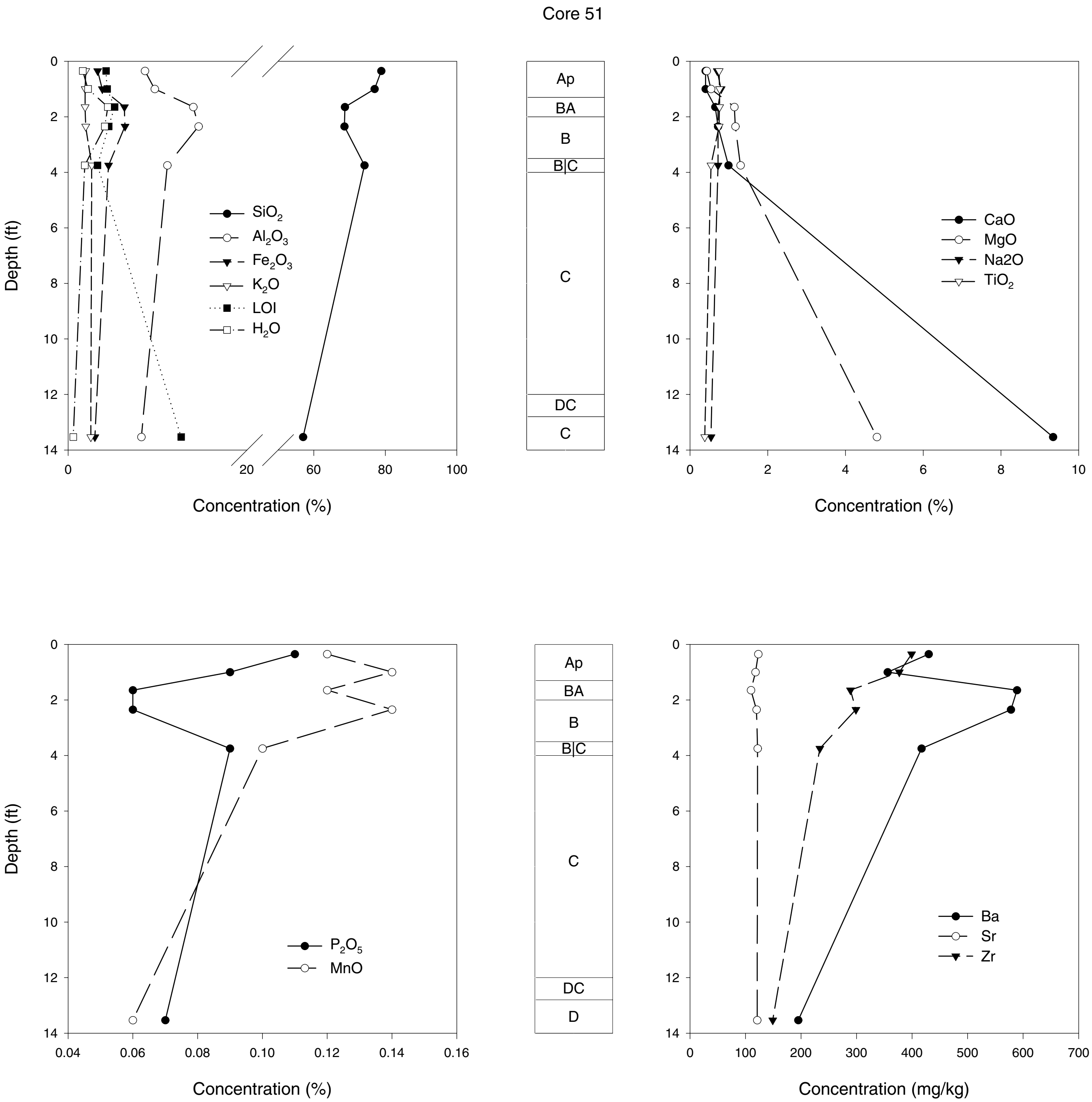


Figure 54 Elemental concentrations versus depth in core 51.

Core 51

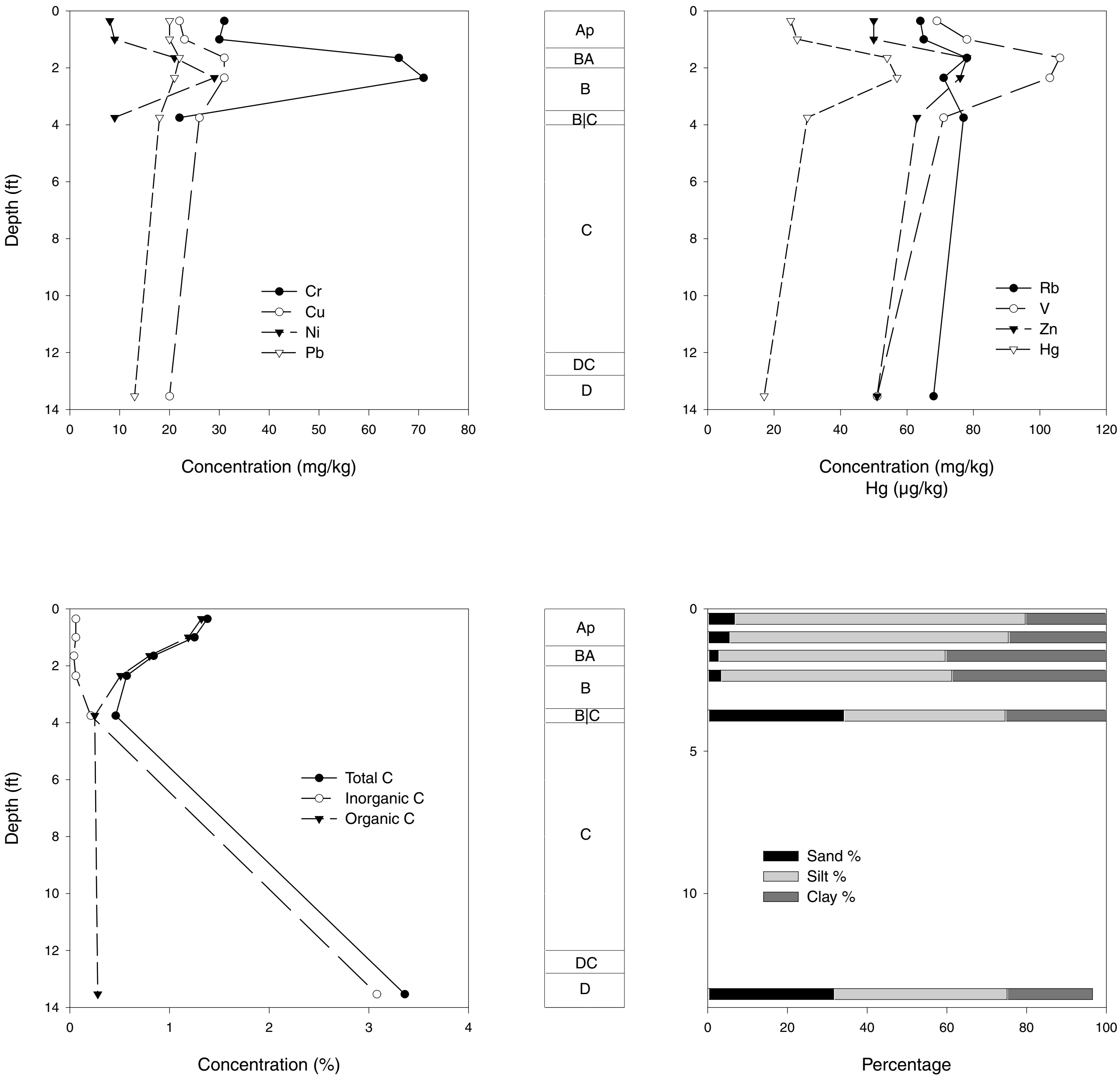


Figure 55 Elemental concentrations versus depth in core 51.