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The characterization, genesis and classification of six selected soil profiles of the Kursk Oblast, Russia

Ryan Russell Paul Noble

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To the Graduate Council:

I am submitting herewith a thesis written by Ryan Russell Paul Noble entitled "The characterization, genesis and classification of six selected soil profiles of the Kursk Oblast, Russia." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Michael D. Mullen, Major Professor

We have read this thesis and recommend its acceptance:

John T. Ammons, Michael E. Essington

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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And recommend its acceptance:

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Michael E. Essington

Accepted for the Council:

Vice Provost and Dean of
Graduate Studies

THE CHARACTERIZATION, GENESIS AND CLASSIFICATION OF SIX SELECTED SOIL PROFILES OF THE KURSK OBLAST, RUSSIA

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Ryan Russell Paul Noble
May 2002

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ABSTRACT

Chernozem soils are perhaps one of the most interesting soils in the world; certainly they are well known and worthy of investigation. Chernozemic soils are a very important resource to Russia. Understanding soil properties is essential in maximizing the use and protection of this resource. Creating natural soil standards, with chemical characterization, is critical in delineating the effects of pollution in the soil ecosystem, evaluating risk assessment and devising management schemes. Another aspect of chernozems is the unique genesis dilemma they present. The number of loess depositions, weathering periods and the variability in depth to the underlying geology is not well understood. Soil classification is an integral part of soil science that provides a means to organize knowledge, communicate effectively between researchers and the general public, and aid in research design. The classification of the soils using both U.S. and Russian systems is important to understand key properties of each of the six soil profiles, and also to understand the similarities and differences between the two systems.

Six chernozem soils were selected, sampled and described on the V.V. Alekhin Central-Chernozem Biosphere Reserve, in the Kursk Oblast, Russia. The sites are representative of the Kursk region. Two parent material sequences are present in the study area: loess over Tertiary sands or loess over Cretaceous chalks. Laboratory analyses performed on all sites included pH, cation exchange capacity, exchangeable bases, dry combustion of C, N, and S, total element dissolution analysis, KCl extractable aluminum, particle size, dithionate iron, hydroxylamine easily reducible manganese, Walkley-Black organic carbon, and neutralization potential.

The objectives of this study were to evaluate three soil profiles near Kursk, Russia, for physical characterization, genesis interpretation and classification. Chemical characterization revealed a CEC range of 14-39 cmol$^+$ kg^{-1}, with approximately 100% base saturation that is dominated by calcium. The soils studied all have a high buffering capacity and low concentrations of potentially toxic elements. Phosphorous was the only potentially deficient nutrient with approximately 500 to <50 mg kg^{-1} total P. These soils should make excellent reference standards for future risk assessment of Kursk chernozems.

In regard to genesis, different loess depositions were not evident. Loess appears to be thickest over the Cretaceous Chalk geology. The soils were high in organic carbon and nitrogen and a slight decrease in these compounds was observed in the slightly disturbed soils.

The soils were classified as Pachic Paleudolls, Pachic Hapludolls or Cumulic Hapludolls according to U.S. soil taxonomy. Using Russian soil taxonomy all soils were post lithogenic, humus accumulative soils and considered saturated, leached, segregationary chernozems at the subtype level.

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INTRODUCTION

The Russian chernozem soil is perhaps the most famous soil in the world. The development of soil science is often attributed to V.V. Dokuchaev, and his Russian collegues, who studied chernozems in the 1800's. Chernozemic soils are primarily responsible for most of the agricultural production in Russia. The central chernozemic region, including the Kursk Oblast, is equivalent to the "bread basket" Mollisols of the Midwest, United States. The focus of this research is to characterize six typical chernozem soil profiles from the Kursk Oblast, Russia. A complete chemical and morphological analysis of the profiles was conducted and then classified using both U.S. and Russian soil classification systems. Part 1 is an overview; briefly summarizing each of the parts.

Part 2 focuses specifically on chemical composition of the soil. The goal of this part is to quantify key transition metals, carbon, nitrogen and sulfur, as well as exchangeable cations, and determine pH levels. The information is used with environmental risk assessment in mind and is aimed at presenting future base standards to evaluate other disturbed typic chernozem soils in the Kursk Oblast.

Part 3 builds on the chemical knowledge by investigating the physical properties of the soil, including particle size and the more dynamic soil properties. The dynamic properties of soils include organic matter and compounds that rapidly change under different redoximorphic conditions. Organic carbon, easily reducible manganese, and free iron are quantified as part of the soil analysis in this part. The results are used as additional data for Part 2. The information is discussed with an emphasis on the genesis of the soils.

Part 4 uses the information from Part 2 and 3 to classify the six profiles in both the U.S. and Russian soil taxonomy. Attempts to correlate the different soil classification systems of the world have only been conducted on the broadest level. With the increasing globalization of the world, and the associated global problems such as pollution, resource planning, and climate change, the need for a better understanding of soil classification in other countries is becoming increasingly important. Part 4 uses and compares the two classification schemes, in hope of understanding each system better.

The overlying goal of this thesis is to complete a comprehensive characterization of the six Kursk typic chernozem soils that were sampled, and to gain a better understanding of the soil chemistry, genesis and classification regarding these soils, as well as understanding the techniques and processes involved in conducting a comprehensive soil characterization. Understanding soil genesis, classification, concepts, characteristics, and analysis techniques is the first step to any problem solving regarding soils and the soil ecosystem.

PART 2

CHEMICAL CHARACTERIZATION OF SIX SELECTED SOIL PROFILES OF THE KURSK OBLAST, RUSSIA

INTRODUCTION

Basic chemical characterization is valuable for future land use planning and risk assessment as we move into the 21st century. More emphasis is being placed on the degradation of soil resources, especially chernozemic soils of the central chernozemic region of Russia. Detailed soil descriptions, including sampling, with physical and chemical analysis are needed to develop base line or background soil resource data for future assessment. Standard soil chemical composition can be used to evaluate changes in the soil ecosystem and the effects of pollution and degradation on other Kursk Oblast chernozems, effectively determining rates of chemical build-up and assessing the related risks. Additional knowledge regarding soil fertility, crop selection, and resource planning can be obtained through soil analysis.

The objectives of this study were to evaluate six soil profiles near Kursk, Russia for chemical characterization of central chernozems in the Kursk Oblast. Four of the soils (sites 3-6) were sampled and described on the V.V. Alekhin Central-Chernozem Biosphere Reserve, located approximately N 51°32’ E 36°18’. These soils are in a protected reserve and have not been significantly impacted by human activity, including cultivation for more than 50 years. The soils are considered to be very similar to the virgin native grassland or forest soils. The other two soil profiles (site 1 and 2) were sampled on the edge of quarries next to the reserve, and had been under some cultivation and disturbance (Fig.1 and 2).

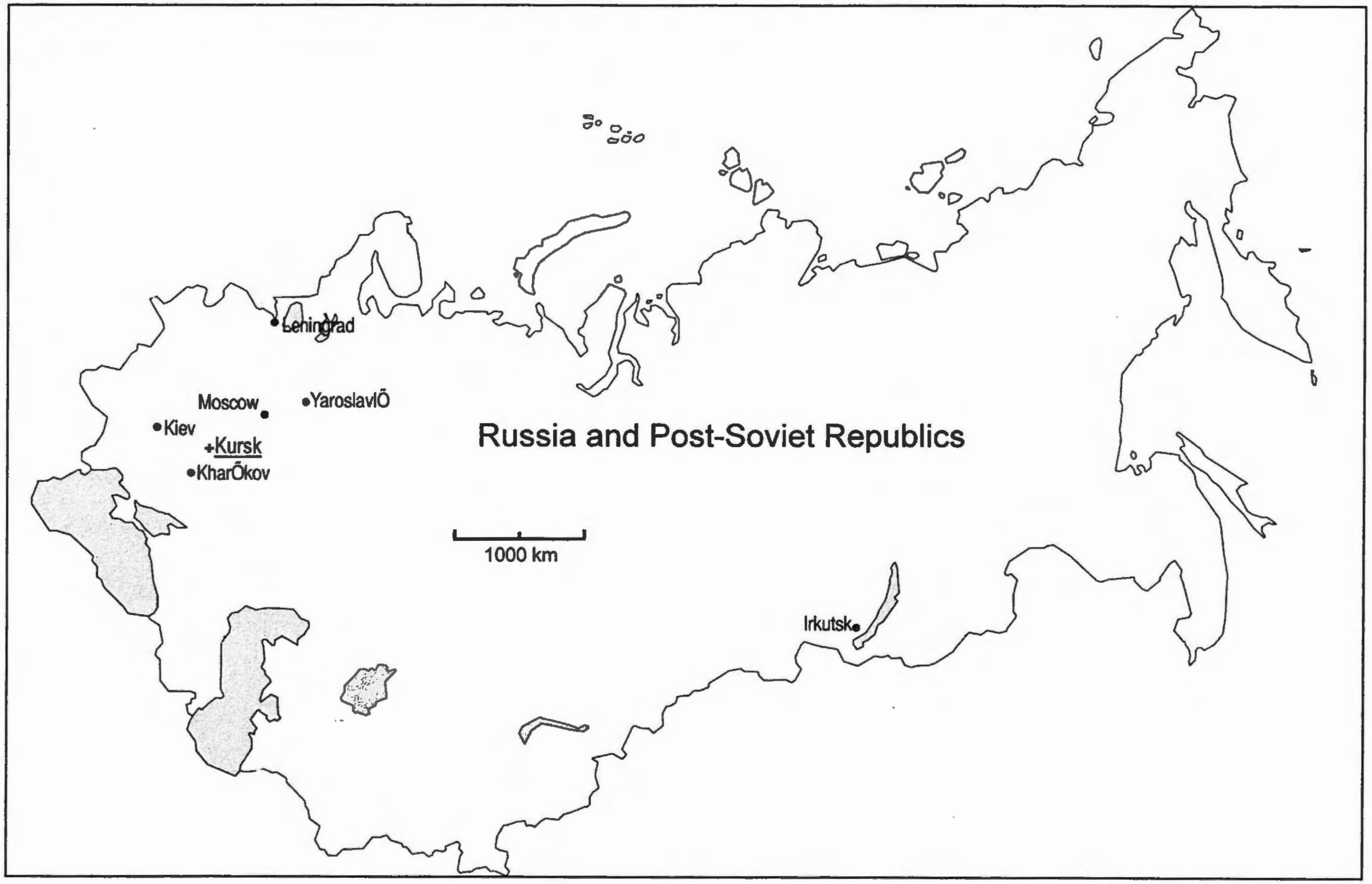

Figure 1. Generalized site location map of Kursk.

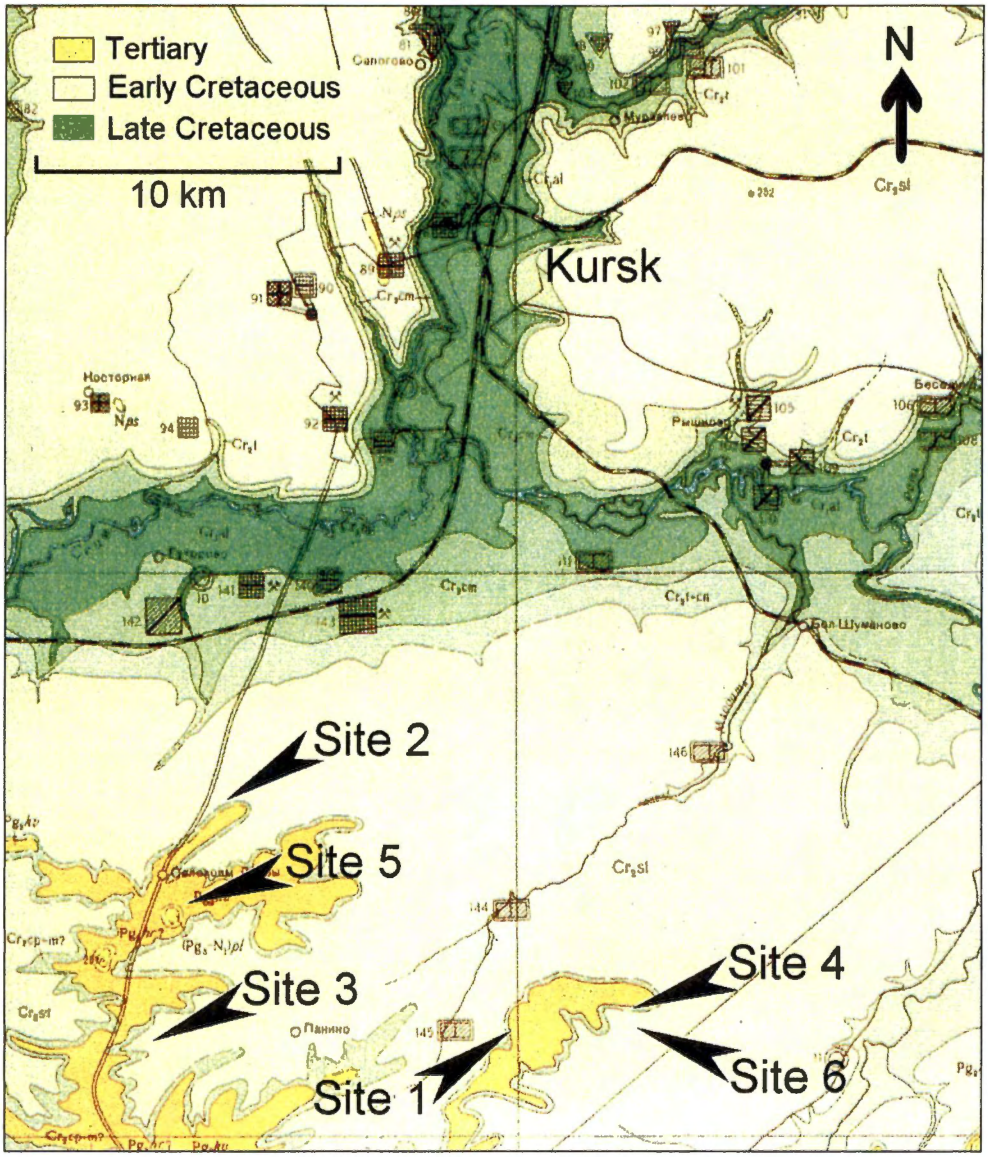

Figure 2. Site locations and geology of the Kursk region.

Two parent material sequences are present in the study area: Loess deposits over Tertiary sands (sites 1 and possibly 5) and loess deposits over Cretaceous chalks (sites 2, 3, 4 and 6). The two combinations of parent material deposits are representative of the Kursk region. The region has a mean annual air temperature of 5.4°C and 587 mm mean annual precipitation (V.V. Alekhin Central-Chernozem Biosphere State Reserve, 1947-1997). The topography is gentle rolling hills, with grasslands dominating the landscape, intersected by groves of deciduous forests.

The six selected sites should prove to be excellent reference soils for future risk assessment and planning in the central chernozemic region of Russia. It is important to realize that these values reported for chemical composition cannot and should not be compared to other non-typic chernozems. For example, the southern chernozems of the Ural mountains contain much higher values of transition metals naturally, than central chernozems (Vazhenin, 1991).

LITERATURE REVIEW

As once stated by V.I. Vernadskii, "the importance of chernozem for soil science is comparable with that of a frog in physiology or calcite in mineralogy" (Shcherbakov and Vasenev, 1999). Chernozem soils will always be a prominent fixture in both basic and applied soil research and teaching.

Agricultural lands account for approximately 27% of the total area of the former Soviet Union (Rozov et al., 1974). Greater than 50% of the arable land consists of chernozems and their complexes with Solonetzes (Rozov et al., 1974). Chernozemic soils make up between 33-50% of all Russian plowland, and generate 80% of domestic crop production for Russia (Shcherbakov and Vasenev, 1999). The importance of these soils to the people of Russia is clearly justified.

The word "chernozem" means black soil. Chernozems are perhaps the most famous of all soil types. V.V. Dokuchaev studied chernozem soils intently, and his later translated work is believed to have started the science of pedology. Cherzozems can take many various forms, however the typic chernozem of the central chernozemic region commonly have a thick, organic A horizons which are generally black, or very dark brown, in color, although color ranges from dark brown to grey, and are granular in structure (U.S.S.R. Ministry of Agriculture, 1977). Typic chernozems exhibit all the characteristic features of chernozem-forming processes, including a large accumulation of humus, nitrogen and other plant nutrients, shallow carbonate leaching, and the lack of textural differentiation (U.S.S.R. Ministry of Agriculture, 1977). The central typic chernozems also have transitional AB horizons, and argillic or cambic subsurface horizons, depending on the distribution of clay accumulation (Ivanova and Rozov, 1970). Lower BC and C horizons can often have high accumulations of carbonates due to the high carbonate loess deposits and the underlying Cretaceous chalk parent materials. Textures, according to this research and Mikhailova (2000b), are often silt loams and silty clay loams with deep moderate granular surface structure and weak to moderate subangular blocky structure in the lower horizons. Chernozems are commonly riddled with passage-ways of burrowing animals, called krotovinas, and are often back-filled by soil of different horizons and appear as large, rounded areas of different colored soil (Glinka, 1927).

The pH values of the central chernozems ranges from 6.5 to 7.0 in the upper horizons, and often much higher than 7.0 in the lower horizons. The central region chernozems do not exhibit salt/soil separations, however this is a feature of many southern chernozems (Shcherbakov and Vasenev, 1999). The base saturation of chernozem soils is high, with calcium dominating the exchange sites. Over 80% of adsorbed bases are Ca, while Mg makes up nearly all the remaining exchange sites (Vilenskii, 1957). Cation exchange capacity of typic chernozems is 35-60 $\text{cmol}^{+}\ \text{kg}^{-1}$ near the surface and 25-30 $\text{cmol}^{+}\ \text{kg}^{-1}$ at lower depths in the soil profile (Ivanova and Rozov, 1970). Mikhailova (2000b) found CEC ranged between 14-38 $\text{cmol}^{+}\ \text{kg}^{-1}$ and base saturation between 66-100% in chernozemic soils in the Kursk region of Russia. Calcium levels were between 16-38 cmol kg^{-1} (Pampura et al., 1993; Mikhailova et al., 2000b). Calcium carbonate separations are characteristic of typic chernozems (Ivanova and Rozov, 1970) with the migration of carbonates through the root zone, precipitating at lower depths.

The central chernozemic area is located in the southern section of the Russian Plain, in the basin of the Oka, Don, and Seym rivers. The Don river valley divides the central chernozemic area into two distinct geographic areas (Protasova and Belyaev, 2000). The elevation of the region is typically between

150-250 m. The climate has a moderately cold short winter with snowfall between 10-40 cm and a long, mild and quite dry summer (Ivanova et al., 1963).

The central chernozem region (comprised of typic chernozems) of Russia is the main agricultural support for many of the Russian people and is often compared to the central breadbasket of the U.S. Subsequently, the soils in these two regions are quite similar, having a thick, dark, highly organic surface horizons. In the U.S. these soils are often classified as Mollisols. The Russian chernozem however, can be broadly classed into many regions. Fridland and Erokhina (1976) loosely map the regions of Illinois, Iowa, Nebraska, Kansas and regions of neighboring states as chernozem-like prairie soils. To the north of the central chernozemic region are grey forest soils, while to the south are steppe chernozems and southern chernozems according to Russian zonal classification (Ivanova et al., 1963).

Chernozems cover a huge section of Russia and have many different climatic conditions and parent materials. The formation of the chernozems varies greatly across the Eurasian region. For this research the majority of discussion will center on the typic chernozems of the central Russian region. Kursk, a city in Russia's southeast, will be my main reference point for discussion.

The Kursk Oblast, including the city of Kursk, is approximately 500 km south of Moscow, near the Ukrainian border. The region was once covered mainly in forests and grassland steppe with rolling topography. Presently, agricultural grasslands with some steppe and forest dominate the land. The region is situated between the Dnieper and Don rivers to the east and west respectively.

The Seym, Oka, and Tuskar rivers flow through the region also. Major industries include machine building, chemical manufacturing, and iron mining. Energy for the region is supplied by a nuclear facility in the city of Kursk. The population of the Kursk Oblast is approximately 1,400,000.

The research was conducted on and around the V.V. Alekhin Central-Chernozem Biosphere State Reserve. The reserve is strictly protected to conserve rare and endangered plants and animals. The reserve is one of the oldest in Russia, created in 1935, specifically to protect the chernozem soil and the native virgin steppe (Maleshin and Zolotuchin, 1994). The reserve covers 5044 ha. and is broken into 6 parts. Four thousand, three hundred and fourteen ha. of the reserve is located in the Kursk region (Maleshin and Zolotuchin, 1994). The reserve also has an additional 3km buffer zone around its perimeter. The reserve is dominated by steppe and meadow (50% of the land area), with 920 species of vascular plants including many flowers, herbs, grasses and trees (Maleshin and Zolotuchin, 1994). English oaks dominate the forested regions with some maple, ash, elm, cherry, linden, and hazel trees (Maleshin and Zolotuchin, 1994). The reserve is managed under four different regimes: periodical mowing, annual mowing, no mowing and pasture (Maleshin and Zolotuchin, 1994).

Chernozem soils are significantly affected by anthropogenic influences. Approximately 55.4 million ha. of Russian soils are contaminated by agrotechnogenic (agricultural mechanical) influences (Shishov, 1996). Plowing can greatly change structure, preferential water flow, and bulk density. Soil temperature was also found to be higher in plowed soils compared to native soils with a decreased frost-free duration and an increase in the soil freezing depth from 30-80 cm (Karavaeva et al., 1998). These differences were observed throughout the plow layer. Moisture differences were also observed. Plowed chernozems exhibit an increased periodic over-moistening in plowed horizons and continuous over-moistening in the deeper horizons (greater than 2m), while soil drought effects increased depths of penetration in plowed soils (Karavaeva, 1998). Conversely to these negative effects of plowing, Podvoyskiy (1972) found that deep plowing or subsoiling resulted in an increased yield over a period of five years. Podvoyskiy's study was conducted on leached, ordinary and calcareous ordinary chernozems. Yield was believed to have increased due to the increase in nutrient supply. Leached chernozems are naturally lower yielding soils than the typic chernozems that were investigated in this study.

Compaction from farm machinery results in the degradation of soil microstructure while the water holding capacity and the soil moisture range favorable for tillage and crop growth decreases (Shcherbakov and Vasenev, 1999). Soil compaction also decreases the ability of plants to assimilate nutrients, particularly N and P. With slight compaction harvest yields are estimated to decrease 5-10%, while moderate compaction results in 20-30% loss of productivity and heavy compaction has a greater than 50% reduction in yield (Shishov, 1996). The opposite of compaction, soil loosening, can also become a problem with changes in water holding capacity, soil temperature, and vulnerability to erosion. Shishov (1996) estimates that 50% of soil loosening is caused by mechanical activity, while 35% is due to shrink-swell action and 15% due to freeze-thaw. The natural influences of loosening would be balanced by the natural soil compaction, structure formation and inorganic/organic binding of soil particles. The mechanical influence has unbalanced the natural equilibrium resulting in excessive loosening of the soil.

Due to the break up of the Soviet Union in 1991, agricultural systems changed from a centrally planned system to a regionally controlled system. The former Soviet government decided which crops should be grown where, based on perceived economic need and climate. Now the decision is based more on consumer demand, and many regions are following capitalist ideals, switching to cash crops and the most economical production. The Kursk Oblast is adopting the cash crop systems to the chernozem soils including wheat, sugar beet, sunflower and alfalfa production (Mikhailova et al., 2000a). Research by Mikhailova (2000a) indicated that the Kursk chernozems showed no significant decrease in soil and forage properties due to hay and pasture use over 50 years. Native grasslands are commonly associated with a high level of natural fertility throughout the world. The desirable fertile land is often converted into high value cropping systems at the eventual demise of the natural fertility of the soils without good management.

Environmental risk assessment refers to many components of a region. Natural soil standards can be used to assess a number of problems including heavy metal content, radioactive elements, and acid rain (Chernova, 1996). With the increase in acid rain over the past few decades, the impact of acidity on the soil system is important. The central chernozem soils are not greatly influenced by acid rain; in fact, chernozem soils with a high humus component have a reasonable buffer-capacity intensity, up to 3.5-4 cmol/kg per pH unit (Bogdanova, 1994). However, the increase in acid rain and the proton release of many fertilizers could eventually harm these soils.

The loss of soil fertility and other important aspects of soil chemistry through agricultural use are also important for understanding risk assessment. The implications of agricultural practices have been shown to reduce cation exchange capacity by 5-10% with a 10-30% reduction of exchangeable magnesium and calcium (Shcherbakov and Vasenev, 1999). The pH values have also been shown to drop up to 2.0 units to depth of 1m or more, however this is more prominent in podzolized (spodic) and leached chernozems (Shcherbakov and Vasenev, 1999). Alkalinization has also been found to be a problem in southern chernozems (Shcherbakov and Vasenev, 1999).

Loss of mobile N in agricultural chernozems has been reduced by 10-20% over the past 25 years due to plowing while P and K levels are also fluctuating but are more influenced by other factors such as texture, topographic position, and degree of degradation (Shcherbakov and Vasenev, 1999). The loss of organic carbon has also been a serious problem and is discussed in more detail in Part 3, along with the changes in soil nitrogen.

Soil erosion is another critical environmental risk. The central region of Russia, including the Kursk Oblast, is losing between 0.5-10 t/ha soil per year on the majority of land (Litfin, 1997). Precipitation amounts can fluctuate greatly between sites due to irregular distribution of snow. Other studies in the Kursk Oblast found that snow varied between 30-100 mm over the soil and was comparable to the mean monthly precipitation (Karavaeva et al., 1998). Oak forests accumulate more snow and consequently have higher annual precipitation than wind-blown prairie regions nearby (Dimo and Rode, 1968). Investigations looking at water flow and related topics have to be particularly selective and account for precipitation variation.

The climatic influences, land use, and topography of plowed land are particularly influential in determining erosion rates. Shcherbakov and Vasenev (1999) state that there has been a progressive increase in gully erosion since the beginning of the 20th century and a wide occurrence of sheet erosion since the 1950's on chernozemic soils. Litfin (1997) indicates that population growth on areas of completely eroded soils will be 5-6%, where an increase of 50-100% is estimated on moderately eroded soils. The population influences are likely to increase erosion rates, posing a significant environmental pollution hazard. The soil loss from arable slopes is 5-7 times higher than in the U.S.A. Soil loss is estimated to have increased 1.5 times over the past 25 years on Russian soils (Shishov, 1996). Many regions of Russia are under threat of serious erosion, primarily due to rainstorm and snowmelt induced soil loss. Soil erosion of fine earth and compaction are major limiting factors in obtaining sustainable, high yield crops on chernozemic soils (Ramazanov and Khaziyev, 1995). Soil conservation practices such as no-till when combined with the natural fertility of the chernozem soils can be a huge, sustainable resource for the people of Russia (Ramazanov and Khaziyev, 1995).

Shcherbakov and Vasenev (1999) note there is a need for research to establish regional soil standards and normal ranges of fertility to facilitate good resource management. Kovda (1966) expresses the same need with regard to fertility and uses chernozem soils from the Kursk region to compare to other Russian soil fertility levels. The average selected microelement content on Kursk chernozems, according to Kovda (1966) are: Ti 4000 mg kg^{-1}; Mn 840 mg kg^{-1} (total), 430 mg kg^{-1} (plant available); Cu 30 mg kg^{-1}; Co 6.1 mg kg^{-1}; Zn 62 mg kg^{-1}; Ni 49 mg kg^{-1}; Mo 4.6 mg kg^{-1}; B 11 mg kg^{-1} (total), 0.5 mg kg^{-1} (water-soluble); and I 5.4 mg kg^{-1}.

Part of a study by Protasova and Belyaev (2000) also investigated macro and microelements in central chernozemic soils. The study of the Kursk Oblast indicates the soils had optimum levels of Ti, Co and Ba; deficiencies of total Al, Be, Ca, Cr, Cu, Fe, I, Mg, Mo, Ni, P, V; sometimes B, Co, I, mobile K, Mn, Mo, P, and Zn; excess B, K, Na, S, and Si (Protasova and Belyaev, 2000). It is important to realize that the soils discussed by Protasova and Belyaev (2000) were generally on Quarternary sand deposits and are more representative of leached and podzolized chernozems, than typic chernozems. Clay levels were particularly influential in element totals (Protosova and Belyaev, 2000).

Chernozems sampled on Cretaceous chalks are expected to have higher values of many nutrients, particularly base cations, and lower acid forming cations such as free Al and Fe. The chernozems in Protosova's and Belyaev's

(2000) study were higher in Al, B, Ba, Be, Ca, Co, Cr, Cu, I, Mn, Mo, Ni, P, Sr, Ti, V, Zn, and Zr than the parent materials alone and gray forest soils; they were lower in Na and Si and had similar values for Fe, K, and Mg (Protosova and Belyaev, 2000). Sulfur content was much higher in the gray forest soils (Protosova and Belyaev, 2000). Soil element composition is presented by the following sequence: Si > Al > Fe > K > Ca > Mg > Na > Ti > S > P > Mn > Ba > Zr > Cr > V > Sr > Zn > B > Ni > Cu > Co > I > Mo > Be (Protosova and Belyaev, 2000).

Protosova and Belyaev (2000) found chernozem soils to contain high levels of I and Zn, however low plant-available, mobile forms of these elements often resulted in an observed deficiency symptoms in plants. Another common deficiency in chernozem soils that effects crop yield is phosphorus (Ivanova and Rozov, 1970). Typic chernozems have mobile P levels of 30-100mg kg^{-1} (Ivanova and Rozova, 1970).

The buffer capacity of chernozems was investigated by Pampura (1993) in regard to Cu and Zn. The central chernozem from the Kursk region was considered a good buffering medium with regard to Cu, as up to 99% of the Cu was sorbed to the soil typically, and only several percent of mobile Cu remained in solution when strong concentration Cu-solutions were used (Pampura et al., 1993). Zinc was not as well sorbed by the chernozem soil, forming weakly bound complexes (both exchangeable and with carbonates), and in turn the amount of mobile Zn increases with an increase in contamination with Zn (Pampura et al., 1993).

The influence of transition metals, pesticides, and oil contamination through industrial processes is another concern for resource management and reclamation. Approximately 10 million ha. of Russian soils are considered to be contaminated with heavy metals (Shishov, 1996). Some transition metals can accumulate in soils rapidly and without prevention large regions of chernozems could be strongly polluted within the next 50-100 years (Shcherbakov and Vasenev, 1999). Creating assessment standards is critical in delineating the effects of pollution and in turn assessing the soil and devising the management scheme.

MATERIALS AND METHODS

Site Selection

The research sites investigated are located in the Kursk Oblast, Russia, to the south of the city Kursk. All sites were located in an upland position (with less than 5% slope), a frigid temperature regime and an udic moisture regime. Site1 is located in an experiment station quarry (N 51°31'54.9"; E 36°14'47.8"). Site 2 is located in another quarry on private land (N 51°36'08.2"; E 36°06'35.8"). The two quarry sites were selected to provide an indication of the depth of loess and the distinctive changes of parent materials and their possible influences. Tertiary sands composed the underlying parent material of site 1 and possibly site 5, while Cretaceous chalks underlie the other sites. All sites had a thick loess covering.

Site 3 and 4 are located on the Central-Chernozem Biosphere reserve at N 51°31’53.7”; E 36°05’01.9”, and N 51°32’20.1”; E 36°18’21.3”, respectively. Site 5 (N 51°34’16.7”; E 36°05’40.6”) and site 6 (N 51°32’04.3”; E 36°18’22.3”) are also located on the Central-Chernozem Biosphere reserve. These sites were selected because they are located on a preserved area. The sites are intended to be used as a standard for future work in evaluating degradation on other central Chernozem sites.

Field Methods

The six sites were sampled and described in the field according to the Soil Survey Manual (Soil Survey Staff, 1993). The soil profiles were broken into horizons and the depths recorded. Site 4 was not separated into horizons, instead it was sampled in 10cm increments to a depth of 250cm, later the soil was broken into horizons based on data. Field texture, color, structure, consistence, “fizz-test” weak acid reactivity, and other significant physical characteristics were recorded. Approximately 1 kg of each soil horizon was placed in a plastic bag for laboratory analysis and shipped to the U.S.

Laboratory Methods

Each sample was placed in a Revco Scientific Model U 2186 A-O-E freezer (Asheville, N.C.) at -75°C for 72 hours in accordance with U.S.D.A quarantine regulations. These samples were then air dried, crushed to pass through a 2mm sieve. Approximately one forth of the sample that was < 2mm was further refined to pass through a 60-mesh sieve (Soil Survey Staff, 1996).

Soil pH was measured using an Orion Research Analog pH meter model 301. A 1:1 soil to water mixture and a 1:2 soil to $CaCl_2$ mixture were used to determine pH on every sample (McClean, 1982). Exchangeable base cations (Na^+, K^+, Mg^{2+}, Ca^{2+}) were removed using the ammonium acetate pH =7 method (Soil Survey Staff, 1996) and analyzed on an atomic absorption spectrophotometer (Perkin-Elmer model AAnalyst 700). Cation exchange capacity (CEC) was calculated via the ammonium acetate rapid distillation method (Chapman, 1968). Percent base saturation was determined mathematically (Soil Survey Staff, 1996).

A Leco CNS 2000 was used to find the total C, N, and S (Matejovic, 1997). Total dissolution analysis using a modified microwave technique (Ammons et al., 1996) was conducted to extract the total soil composition of the following elements Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, Ti, Zn, and Zr. The extraction was then analyzed using inductively coupled argon plasma emission spectroscopy on a Thermo Jarrell Ash ICAP 61.

A KCl extraction was used to determine exchangeable aluminum (Thomas, 1982). Aluminum in the extracts were measured with an atomic absorption spectrophotometer (Perkin-Elmer model AAnalyst 700).

RESULTS AND DISCUSSION

Site 1

Site one is located at N 51° 31’ 54.9” E 36° 14’ 47.8”, on an upland position. The site is located on the edge of a quarry with surrounding grassland vegetation. The site has a slight slope of 1% and an elevation of approximately 261 meters above sea level. The soil was sampled to a depth of 324 cm, with a parent material sequence of loess over Tertiary sands.

The loess is characterized by 10YR hues and silty textures, which rapidly change to 5 and 2.5YR hues and sandy textures below the discontinuity in the Tertiary sands. The soil is considered well drained and showed no redoximorphic features.

This soil has a high base saturation and pH with a moderate cation exchange capacity (CEC), as is common of typic chernozem soils. The pH values (1:1 H_2O) are fairly neutral in the thick surface A horizons and the upper argillic horizon (between 6.8 and 7.3) and then rapidly change to basic conditions with pH 7.9 to 8.3 throughout (Table 1). The $CaCl_2$ pH values all reflect similar change with depth (Table 1). The change in pH is also reflected in the $CaCO_3$ equivalent with a significant increase in carbonates at the lower depths (Table 2). The carbonates act as a strong buffer against acidity, hence the high pH and zero values determined for total acidity (Table 3). Aluminum and H^+ acidity values from the KCl procedure were below detection limits. The fractions of total acidity from these two elements could not be determined, but they are below the

Table 1. Site 1 pH values.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$
Ap	0-22	7.2	6.8
A	22-44	7.3	6.8
AB	44-60	6.8	6.2
Bt1	60-76	7.1	6.8
Bt2	76-106	7.9	7.3
Bt3	106-144	8.1	7.6
2Bw	144-159	8.2	7.6
2C1	159-169	8.2	7.6
2C2	169-202	8.0	7.6
2C3	202-247	8.1	7.6
2C4	247-283	8.1	7.5
2C5a	283-324	8.2	7.6
2C5b	283-324	8.3	7.7

Table 2. Carbon, nitrogen and sulfur data for site 1. Includes total carbon, nitrogen, sulfur, organic C, and calcium carbonate equivalent* ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent
		% of soil				
Ap	0-22	0.27	0.05	3.80	2.90	
A1	22-44	0.23	0.05	3.29	2.02	
AB	44-60	0.11	0.04	1.40	0.86	
Bt1	60-76	0.12	0.02	1.71	0.83	2.59
Bt2	76-106	0.10	0.01	3.07	0.79	14.45
Bt3	106-144	0.05	0.01	2.28	0.54	13.24
2Bw	144-159	0.05	0.01	1.09	0.06	4.79
2C1	159-169	0.08	0.02	0.45	0.20	1.16
2C2	169-202	0.03	0.01	0.42	0.20	0.87
2C3	202-247	0.03	0.02	0.28	0.25	
2C4	247-283	0.02	0.02	0.24	0.24	
2C5a	283-324	0.03	0.02	0.25	0.00	
2C5b	283-324	0.08	0.00	0.06	0.27	

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Table 3. Cation exchange data for site 1. Includes sodium acetate extractable bases, total acidity, and percent base saturation by direct measurement.

Horizon	Depth (cm)	Na	K	Mg	Ca	Total Acidity	CEC pH 7	% Base Saturation
		cmol$^+$ kg^{-1}						
Ap	0-22	0.09	0.29	2.46	35.14	0.00	34.00	100
A	22-44	0.09	0.26	2.69	29.89	0.00	34.83	95
AB	44-60	0.13	0.22	1.43	19.77	0.00	26.95	80
Bt1	60-76	0.15	0.24	1.08	32.86	0.00	23.14	100
Bt2	76-106	0.13	0.23	1.23	38.27	0.00	21.50	100
Bt3	106-144	0.11	0.25	2.22	37.93	0.00	21.16	100
2Bw	144-159	0.05	0.15	1.70	28.05	0.00	12.06	100
2C1	159-169	0.04	0.08	0.98	18.03	0.00	7.07	100
2C2	169-202	0.04	0.07	0.98	14.00	0.00	7.61	100
2C3	202-247	0.01	0.06	0.65	4.54	0.00	5.42	97
2C4	247-283	0.01	0.06	0.94	3.44	0.00	5.54	80
2C5a	283-324	0.02	0.03	0.43	3.90	0.00	2.97	100
2C5b	283-324	0.02	0.01	0.10	3.22	0.00	1.01	100

very low total acidity values. As acid is formed in the soil, base carbonates are dissolved to form free base cations (in most cases Ca^{2+} or Mg^{2+}) and carbonate is able to react to form bicarbonate and then carbonic acid. During the process two protons have been neutralized and eventually the carbonate is cycled (in the presence of oxygen) into water and carbon dioxide. The free base cation is then able to attach to exchange sites. The base saturation of the soil is very high throughout. A minimum base saturation is 80% with most horizons having a base saturation of 100% (Table 3). The results are similar to work by Mikhailova (2000b) with Kursk soils base saturation between 66-100%. In actual fact, the base composition of many Kursk soils is greater than 100% of the CEC due to procedure calculating the free cations in the soil that are not attached to exchange sites.

Calcium was the most dominant base with values between 3.22 and 38.27 $cmol^+ kg^{-1}$ (Table 3). The Ca values seem reasonable when compared to other research on typic chernozems indicate Ca levels were between 16-38 $cmol^+ kg^{-1}$ (Pampura et al., 1993; Mikhailova et al., 2000b). The lowest values were in the sand horizons that also had a very low CEC. Calcium made up approximately 80-90% of all exchangeable bases. Magnesium was the next most prevalent, and finally K^+ and Na^+ were observed in very small amounts between 0.29 to 0.01 $cmol^+ kg^{-1}$ (Table 3). Similar results were also observed by Vilenskii (1957).

The CEC of profile 1 was high in the surface and gradually decreasing with depth. As previously mentioned the Tertiary sand discontinuity is noticeable with a rapid decrease of CEC between the Bt3 to 2Bw horizon interface. The

Tertiary sands have very little clay content and in turn have very little exchange capacity. The highest CEC (34.83 $cmol^+ kg^{-1}$) in the epipedon is due to the high organic content in the soil (Table 2), not higher clay content. The argillic horizons have slightly more clay, but lower CEC. The difference in CEC emphasizes the very high surface area and exchange capacity of organic matter. The CEC values of approximately 35-1 $cmol^+ kg^{-1}$ is similar to values of 38-14 $cmol^+ kg^{-1}$ found by Mikhailova (2000b) in research on Kursk soils.

Total C was high in the upper horizons with a maximum of 3.8% in the Ap horizon and generally decreasing with depth and a minimum of approximately 0% (Table 2). The slight increase in C in the argillic horizons is reflective of loessial secondary carbonate accumulation, a common characteristic in typic chernozems (Ivanova and Rozov, 1970). Sulfur is in very small amounts between 0.05 and 0%, while nitrogen was high and decreased with depth from 0.27 to 0.02% (Table 2).

The previously mentioned data is important in fertility of soils and the effects of acidity, however total elemental analysis data is very beneficial for determining natural metal composition of soils, or the levels of contamination. Table 4 indicates the metal composition of many elements in this soil. Of the heavy metals As, Cd, Cr, and Pb were below detection limits (<50 mg kg^{-1} for As, Cd, Cr; <25 mg kg^{-1} for Pb). All potentially toxic or problematic elements had low concentrations. Cobalt levels ranged from 12 mg kg^{-1} to <3 mg kg^{-1} at lower depths, while Ni levels were from 81-23 mg kg^{-1}. Barium, Cu, Sr, and Zn had

Table 4. Total element analysis for site 1.

Horizon	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	Zn	Zr
	mg kg^{-1}														
Ap	358	11136	12	24	21387	14457	4629	484	4332	55	476	89	2276	52	108
A	365	9807	10	22	22047	14927	4856	477	4697	54	297	85	3808	47	112
AB	401	7375	11	14	25410	17015	5536	492	5282	80	<50	80	2535	48	131
Bt1	386	15094	12	11	24981	16649	5746	459	5088	76	102	91	2471	46	126
Bt2	359	72406	10	10	22725	15553	7331	408	4951	81	<50	142	2245	46	111
Bt3	350	60391	9	10	25440	14314	8466	386	5245	70	<50	168	2344	57	102
2Bw1	198	17763	<3	<2	18798	5865	3560	204	2105	32	<50	57	1325	22	49
2C1	53	5579	<3	<2	9287	1938	1337	57	547	44	<50	25	828	19	29
2C2	51	6110	<3	<2	11546	2038	1444	29	258	54	<50	25	1286	12	49
2C3	37	1834	<3	<2	8947	1243	1043	14	179	37	<50	25	837	<4	25
2C4	32	1045	<3	<2	6654	994	983	15	150	33	<50	25	481	14	17
2C5a	18	1731	<3	<2	5364	498	480	<1	161	37	<50	25	537	<4	25
2C5b	12	932	<3	<2	933	400	117	<1	159	23	<50	25	336	<4	18

* Values for the following elements were all less than the detection limits shown in parentheses: As(<50), Cd(<2), Cr(<50), Mo(<5), and Pb(<25).

ranges of 401-12 mg kg^{-1}; 24-<2 mg kg^{-1}; 168-25 mg kg^{-1}; and 57-<4 mg kg^{-1}, respectively (Table 4).

Research by Protasova and Belyaev (2000) indicates that clay levels influenced element concentrations. Although there are argillic horizons, there was little change in elemental composition with the exception of slight increases in the bases (Na, K, Mg, and Ca), Fe and Sr (Table 4). Soil element composition for Kursk soils according to Protosova and Belyaev (2000) is Si > Al > Fe > K > Ca > Mg > Na > Ti > S > P > Mn > Ba > Zr > Cr > V > Sr > Zn > B > Ni > Cu > Co > I > Mo > Be. The sequence for this profile is estimated to be Si > Al > Fe > K > Ca > Mg > Na > Ti > Mn > Ba > S > P > Zr > Sr > Ni > Zn > Cr > Cu > Co > Mo (Table 4). The two are similar, however V, B, and I were not determined in this research, and Mn and Ba were slightly higher than S, while Ni was in higher amounts than Zn. Chromium was less than detection limits (>50 mg kg^{-1}) however it was less than Sr, Zn, and Ni. Chromium was probably greater than Cu, Co, and Mo. It is important to realize that the soils discussed by Protasova and Belyaev (2000) were generally on Tertiary sand deposits like site 1, but perhaps more representative of leached and podzolized chernozems, than typic chernozems. The element sequence does prove to be remarkably similar between the two analyses.

The average selected microelement content on Kursk chernozems, according to Kovda (1966) are: Ti 4000 mg kg^{-1}; Mn 840 mg kg^{-1} l; Cu 30 mg kg^{-1}; Co 6.1 mg kg^{-1}; Zn 62 mg kg^{-1}; Ni 49 mg kg^{-1}; and Mo 4.6 mg kg^{-1}. This study site indicates lower Ti and Mn values, however the other elements are found in similar concentrations (Table 4). The depth of sampling for the analysis by Kovda (1966) is not discussed and may be a reason for the differences.

For land management regarding plant growth P levels were low with 476 mg kg^{-1} in the surface, but rapidly dropping to <50 mg kg^{-1} while Mo levels were all <5 mg kg^{-1} (Table 4). The levels of plant available P would be significantly lower than these values and perhaps even lower than the generalized levels of 30-100mg kg^{-1} of mobile P for typic chernozems as suggested by Ivanova and Rozova (1970). Although most plants require only very small amounts of Mo, both Mo and P may need to be addressed in future land management on these chenozemic soils.

Site 2

Site two is located at N 51°36'08.2" E 36°06'35.8" on an upland position. Similarly to site 1, site 2 is also located on the edge of a quarry. White birch trees and grasses constitute the vegetation. The site has a slight slope of 2% and an elevation of approximately 258 meters above sea level. The soil was sampled to a depth of 400 cm with a parent material sequence of loess over Cretaceous chalks. The depth of loess was very thick, and the second lower parent material was not apparent in this profile.

The loess is characterized by 10YR hues and silty textures, which change to 7.5YR hues at the lowest depth. The soil is considered well drained and showed no redoximorphic features. Krotovinas were present from burrowing animals.

The soil has a high base saturation and pH, with a moderate CEC. The pH values (1:1 H_2O) are basic throughout with a range from pH 7.2 to 8.3 (Table 5). The $CaCl_2$ pH values all reflect a similar change with depth (Table 5). The change in pH is also reflected in the $CaCO_3$ equivalent, with an increase in carbonates at the lower depths (Table 6). The carbonates act as a strong buffer against acidity, hence the high pH and close to zero values determined for total acidity (Table 7). Aluminum and H^+ acidity values from the KCl procedure were below detection limits. The fractions of total acidity from these two elements could not be determined, but they are below the very low total acidity values.

The base saturation of the soil is very high throughout. A minimum base saturation is 81%, with most horizons having a base saturation of 100% (Table 7). Calcium was the most dominant base with values between 26.59 and 44.44 $cmol^+ kg^{-1}$. The Ca values are slightly higher than other studies on typic chernozems, which indicate Ca levels were between 16-38 $cmol.kg^{-1}$ (Pampura et al., 1993; Mikhailova et al., 2000b). Unlike site 1, this soil does not have a Tertiary sand parent material, and in turn the values for CEC and the amount of bases is much higher in the lower horizons. Calcium made up approximately 90% of all exchangeable bases. Magnesium was the next most prevalent base cation, and K^+ and Na^+ were observed in much smaller amounts (Table 7). Similar results were also observed by Vilenskii (1957).

The CEC of profile 2 was high in the surface, and gradually decreased with depth. The highest CEC (37.31 $cmol^+ kg^{-1}$) in the surface horizon is due to the high organic content in the soil (Table 6), not higher clay content. The argillic

Table 5. Site 2 pH values.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$
Ap	0-25	7.6	7.2
A	25-45	7.4	7
AB	45-85	7.2	6.8
BA	85-135	8	7.6
Bt1	135-195	8.2	7.7
Bt2	195-260	8.2	7.8
Bt3	260-319	8.1	7.8
Bt4	319-368	8.3	7.9
Bt5	368-400	7.7	7.1

Table 6. Carbon, nitrogen and sulfur data for site 2. Includes total carbon, nitrogen, sulfur, organic C, and calcium carbonate equivalent* ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent
		% of soil				
Ap	0-25	0.25	0.06	3.58	2.86	
A	25-45	0.21	0.06	3.01	2.09	
AB	45-85	0.10	0.05	1.31	0.90	11.17
BA	85-135	0.05	0.02	1.85	0.13	5.88
Bt1	135-195	0.08	0.02	1.26	0.07	3.09
Bt2	195-260	0.08	0.03	0.93	0.22	8.62
Bt3	260-319	0.07	0.02	1.60	0.11	5.27
Bt4	319-368	0.07	0.03	1.23	0.25	2.31
Bt5	368-400	0.06	0.03	0.82	0.13	11.17

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Table 7. Cation exchange data for site 2. Includes sodium acetate extractable bases, total acidity, and percent base saturation by direct measurement.

Horizon	Depth (cm)	Na	K	Mg	Ca	Total Acidity	CEC pH 7	% Base Saturation
		cmol$^+$ kg^{-1}						
Ap	0-25	0.22	0.31	2.50	27.19	0.00	37.31	81
A	25-45	0.20	0.28	1.91	26.59	0.00	35.23	82
AB	45-85	0.11	0.31	1.87	18.80	0.01	25.80	82
BA	85-135	0.13	0.29	2.06	34.87	0.03	20.21	100
Bt1	135-195	0.11	0.32	2.64	44.44	0.03	28.60	100
Bt2	195-260	0.26	0.31	2.97	40.00	0.03	27.73	100
Bt3	260-319	0.14	0.24	2.52	37.02	0.03	17.34	100
Bt4	319-368	0.16	0.25	2.46	35.38	0.03	23.19	100
Bt5	368-400	0.17	0.28	2.46	32.99	0.03	24.25	100

horizons have slightly more clay, but lower CEC. The difference in CEC emphasizes the very high surface area and exchange capacity of organic matter.

The CEC values of approximately 37-18 cmol$^+$ kg^{-1} is similar to values of 38-14 cmol$^+$ kg^{-1} found by Mikhailova (2000b) in research on Kursk soils.

Total C was high in the upper horizons with a maximum of 3.58% in the Ap horizon and generally decreasing with depth with a minimum of approximately 0.82% (Table 6). The slight increase in C in the argillic horizons is reflective of loessial secondary carbonate accumulation, a common characteristic in typic chernozems (Ivanova and Rozov, 1970). The carbonate accumulation is not as great as found in site 1. Sulfur is present in very small amounts between 0.06% and 0%, while nitrogen was high and decreased with depth from 0.25 to 0.05% (Table 6).

Total elemental analysis was similar to site 1, however the change in elemental composition due to the Tertiary sands was not observed in this soil profile. Low levels of transition metals were found. Arsenic, Cd, Cr, and Pb were below detection limits (<50 mg kg^{-1} for As, Cd, Cr; <25 mg kg^{-1} for Pb). Cobalt levels ranged from 11 mg kg^{-1} to <3 mg kg^{-1}, while Ni levels were between 63-42 mg kg^{-1}. Barium, Cu, Sr, and Zn had ranges of 448-406 mg kg^{-1}, 13-<2 mg kg^{-1}, 125-80 mg kg^{-1}, and 139-38 mg kg^{-1}, respectively (Table 8).

Research by Protasova and Belyaev (2000) indicates that clay levels influenced element concentrations. Although there are argillic horizons, there was little change in elemental composition, with the exception of slight increases in Mg, Ca, and Fe (Table 8). Soil element composition for Kursk soils is

Table 8. Total element analysis for site 2.

Horizon	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	Zn	Zr
	mg kg^{-1}														
Ap	426	10527	<3	<2	25006	16899	5698	556	5949	50	420	84	2636	56	140
A	414	9835	5	5	24652	16998	5617	529	5953	43	344	80	2669	44	144
AB	438	7862	11	13	26150	17843	6092	536	6310	56	196	88	2796	49	153
BA	431	49823	<3	<2	24473	16501	8869	493	6469	52	98	125	2516	38	132
Bt1	417	30062	9	8	31984	14861	8557	517	6059	63	98	110	2770	57	125
Bt2	421	17723	10	10	33485	15656	8383	517	6260	58	<50	97	2849	95	119
Bt3	448	43715	<3	4	26696	16004	7176	542	5868	54	<50	122	2706	40	138
Bt4	406	27357	11	11	26188	15656	6559	455	5505	42	<50	105	2827	47	141
Bt5	413	17991	7	8	29138	15606	6884	441	5458	57	<50	87	2804	139	141

* Values for the following elements were all less than the detection limits shown in parentheses: As(<50), Cd(<2), Cr(<50), Mo(<5), and Pb(<25).

presented by the following sequence: Si > Al > Fe > K > Ca > Mg > Na > Ti > S > P > Mn > Ba > Zr > Cr > V > Sr > Zn > B > Ni > Cu > Co > I > Mo > Be, according to Protosova and Belyaev (2000). The sequence for soil element composition for this profile is estimated to be Si > Al > Fe > K > Ca > Mg > Na > Ti > Mn > Ba > S > P > Zr > Sr > Zn > Ni > Cr > Cu > Co > Mo (Table 8). The two are similar, but V, B, and I were not determined in this research. Manganese and Ba were slightly higher than S, while Cr is significantly lower. The soils discussed by Protasova and Belyaev (2000) were generally on Tertiary sand deposits like site 1, not Cretaceous chalks, which may influence the slight variation observed. The element sequence does prove to be remarkably similar between the two analyses.

The average selected microelement content on Kursk chernozems, according to Kovda (1966), are: Ti 4000 mg kg^{-1}, Mn 840 mg kg^{-1} I, Cu 30 mg kg^{-1}, Co 6.1 mg kg^{-1}, Zn 62 mg kg^{-1}, Ni 49 mg kg^{-1}, and Mo 4.6 mg kg^{-1}. This study site indicates lower Ti, Mn and Cu values, however the other elements are found in similar concentrations (Table 8). The depth of sampling for the analysis by Kovda (1966) is not discussed and may be a reason for the differences.

Phosphorus levels were low, with 420 mg kg^{-1} in the surface, but rapidly dropping to <50 mg kg^{-1}, while Mo levels were all <5 mg kg^{-1} (Table 8). The levels of plant available P would be significantly lower, perhaps even lower than the generalized levels of 30-100mg kg^{-1} of mobile P for typic chernozems as suggested by Ivanova and Rozova (1970).

Site 3

Site three is located at N 51°31'53.7" E 36°05'01.9" on an upland position. The site is located in the V.V. Alekhin Central-Chernozem Biosphere Reserve, under a thick forest canopy dominated by oak trees. The site has a slight slope of 1% and an elevation of approximately 262 meters above sea level. The soil was sampled to a depth of 315 cm with a parent material sequence of loess over Cretaceous chalks or Tertiary sands. The depth of loess was very thick, and the second lower parent material was not apparent in this profile. The loess is characterized by 10YR hues and silty textures. The soil is considered well drained and showed no redoximorphic features.

Site 3 has a high base saturation and pH with a moderate CEC. The pH values (1:1 H_2O) are basic throughout with a range from pH 7.0 to 8.3 (Table 9). The $CaCl_2$ pH values all reflect similar change with depth (Table 9). The change in pH is also reflected in the $CaCO_3$ equivalent, with an increase in carbonates at the cambic horizons and continuing through the C horizons (Table 10). The carbonates act as a strong buffer against acidity, hence the high pH and close to zero values determined for total acidity (Table 11). Aluminum and H^+ acidity values from the KCl procedure were below detection limits. The fractions of total acidity from these two elements could not be determined, but they are below the very low total acidity values.

The base saturation of the soil is very high with a minimum base saturation of 94% in the surface and 100% base saturation throughout the

Table 9. Site 3 pH values.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$
A1	0-34	7.2	6.8
A2	34-69	7	6.6
AB	69-85	7.2	6.6
Bw1	85-102	7.7	7
Bw2	102-140	8	7.3
Bw3	140-191	8.2	7.4
C1	191-230	8.2	7.4
C2	230-240	8.2	7.5
C3	240-260	8.2	7.6
C4	260-285	8.2	7.5
C5	285-295	8.3	7.5
C6	295-305	8.2	7.6
C7	305-315	8.3	7.7

Table 10. Carbon, nitrogen and sulfur data for site 3. Includes total carbon, nitrogen, sulfur, organic C, and calcium carbonate equivalent* ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent
		% of soil				
A1	0-34	0.30	0.07	4.16	2.61	
A2	34-69	0.15	0.05	1.99	1.48	
AB	69-85	0.11	0.04	1.35	0.83	
Bw1	85-102	0.10	0.02	2.11	0.64	8.01
Bw2	102-140	0.07	0.02	2.85	0.47	15.08
Bw3	140-191	0.06	0.02	1.77	0.29	10.29
C1	191-230	0.04	0.02	1.86	0.15	12.99
C2	230-240	0.04	0.01	1.67	0.13	10.74
C3	240-260	0.06	0.02	2.03	0.15	8.69
C4	260-285	0.04	0.02	1.29	0.15	8.51
C5	285-295	0.04	0.01	1.32	0.15	8.33
C6	295-305	0.04	0.01	1.33	0.15	8.16
C7	305-315	0.04	0.01	1.11	0.15	7.94

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Table 11. Cation exchange data for site 3. Includes sodium acetate extractable bases, total acidity, and percent base saturation by direct measurement.

Horizon	Depth (cm)	Na	K	Mg	Ca	Total Acidity	CEC pH 7	% Base Saturation
		cmol⁺ kg⁻¹						
A1	**0-34**	**0.13**	**0.36**	**2.71**	**29.05**	**0.01**	**34.17**	**94**
A2	**34-69**	**0.12**	**0.28**	**1.51**	**21.41**	**0.00**	**21.13**	**100**
AB	**69-85**	**0.45**	**0.24**	**1.32**	**21.60**	**0.01**	**18.36**	**100**
Bw1	**85-102**	**0.87**	**0.28**	**1.56**	**33.77**	**0.01**	**16.15**	**100**
Bw2	**102-140**	**0.31**	**0.25**	**1.73**	**34.49**	**0.00**	**13.76**	**100**
Bw3	**140-191**	**0.16**	**0.29**	**2.69**	**34.81**	**0.01**	**15.35**	**100**
C1	**191-230**	**0.09**	**0.18**	**2.61**	**30.56**	**0.01**	**8.89**	**100**
C2	**230-240**	**0.09**	**0.22**	**2.96**	**28.48**	**0.01**	**8.15**	**100**
C3	**240-260**	**0.09**	**0.30**	**3.91**	**34.03**	**0.01**	**13.59**	**100**
C4	**260-285**	**0.07**	**0.25**	**3.08**	**29.17**	**0.01**	**9.95**	**100**
C5	**285-295**	**0.09**	**0.28**	**3.06**	**25.29**	**0.01**	**9.42**	**100**
C6	**295-305**	**0.07**	**0.30**	**3.35**	**29.28**	**0.01**	**11.09**	**100**
C7	**305-315**	**0.06**	**0.26**	**3.37**	**29.93**	**0.01**	**10.47**	**100**

remaining profile (Table 11). Calcium was the most dominant base with values between 21.41 and 34.81 cmol$^+$ kg^{-1}. The Ca values are reflective of other studies on typic chernozems, which indicate Ca levels were between 16-38 cmol.kg^{-1} (Pampura et al., 1993; Mikhailova et al., 2000b). Calcium made up approximately 90% of all exchangeable bases. Magnesium was the next most prevalent, and finally K$^+$ and Na$^+$ were observed in much smaller amounts (Table 11). Similar results were also observed by Vilenskii (1957).

The CEC of profile 3 was high in the surface and gradually decreased with depth. The highest CEC (34.17 cmol$^+$ kg^{-1}) in the surface horizon is due to the high organic content in the soil (Table 10). The CEC values of approximately 34-8 cmol$^+$ kg^{-1} is similar to values of 38-14 cmol$^+$ kg^{-1} found by Mikhailova (2000b) in research on Kursk soils. Unlike sites 1 and 2, this profile does not have a significant clay increase, and consequently CEC is lower in the cambic horizons than at similar depths in the previous soils.

Total C was high in the upper horizons, with a maximum of 4.16% in the Ap horizon and generally decreased with depth to a minimum of approximately 1.11% (Table 10). The slight increase in C in the cambic horizons is reflective of loessial secondary carbonate accumulation, a common characteristic in typic chernozems (Ivanova and Rozov, 1970). The carbonate accumulation is greater than both sites 1 and 2. Sulfur is in very small amounts between 0.07 and 0.01%, while nitrogen was high and decreased with depth from 0.30 to 0.04% (Table 10).

Total elemental analysis was similar to site 2. Low levels of transition metals were found. Arsenic, Cd, Cr, and Pb were below detection limits (<50 mg kg^{-1} for As, Cd, Cr; <25 mg kg^{-1} for Pb). Cobalt levels ranged from 11 mg kg^{-1} to <3 mg kg^{-1}, while Ni levels were between 47-26 mg kg^{-1}, slightly lower than the previous two quarry sites. Barium, Cu, Sr, and Zn had ranges of 445-361 mg kg^{-1}; 10-<2 mg kg^{-1}; 140-60 mg kg^{-1}; and 76-26 mg kg^{-1}, respectively (Table 12).

The soil element sequence for this profile is estimated to be Si > Al > Fe > Ca > K > Mg > Na > Ti > Mn > Ba > P > S > Zr > Sr > Zn > Ni > Cr > Cu > Co > Mo (Table 12). Phosphorus levels were generally higher than S. Initially this could be attributes to the increase P cycling in the undisturbed forest setting and decreased human influence. Investigating the actual values indicates that P is lower than sites 1 and 2; yet S values have decreased even more. The increase in biomass from the forest may be providing an above ground nutrient sink for S and P and is more likely to be responsible for the observed element changes.

The average selected microelement content on Kursk chernozems, according to Kovda (1966), are: Ti 4000 mg kg^{-1}, Mn 840 mg kg^{-1} l, Cu 30 mg kg^{-1}, Co 6.1 mg kg^{-1}, Zn 62 mg kg^{-1}, Ni 49 mg kg^{-1}, and Mo 4.6 mg kg^{-1}. This study site indicates significantly lower Ti, Mn and Cu values, while Zn, Ni, and Co were found in slightly lower concentrations (Table 12). The depth of sampling for the anlysis by Kovda (1966) is not discussed and may be a reason for the differences.

Phosphorus levels were low with 350 mg kg^{-1} in the surface, but rapidly dropping to <50 mg kg^{-1}, while Mo levels were all <5 mg kg^{-1} (Table 12). The

Table 12. Total element analysis for site 3.

Horizon	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	Zn	Zr
	mg kg^{-1}														
A1	400	9919	<3	10	21981	14563	5010	559	5606	35	355	75	2466	52	134
A2	413	8424	<3	<2	23642	15606	4327	409	4814	30	237	60	2450	27	121
AB	445	8390	6	5	23821	16600	5523	485	6070	45	157	79	3506	35	158
Bw1	443	39324	11	<2	23647	16799	6822	453	6191	45	141	113	2581	63	148
Bw2	384	79002	<3	<2	22491	15060	8187	387	5913	39	<50	140	2585	33	132
Bw3	345	41014	<3	<2	18555	15109	8237	433	5621	32	89	120	2295	58	109
C1	361	54686	<3	<2	15020	14712	7924	335	6194	39	<50	135	2583	33	159
C2	374	48244	<3	<2	17051	17048	8179	343	5474	26	121	135	2526	26	155
C3	384	48380	8	<2	20940	17197	7845	405	5743	47	<50	140	2169	41	125
C4	384	36090	<3	<2	16790	17594	7305	383	5736	30	<50	116	2224	27	140
C5	393	34406	<3	<2	17569	18191	8164	386	5857	32	<50	116	2322	76	148
C6	402	38991	<3	<2	19005	18290	7568	365	6025	40	<50	130	2327	71	146
C7	399	33601	<3	<2	17506	18340	7204	329	6039	41	<50	125	2338	73	149

* Values for the following elements were all less than the detection limits shown in parentheses: As(<50), Cd(<2), Cr(<50), Mo(<5), and Pb(<25).

levels of plant available P would be significantly lower, perhaps even lower than the generalized levels of 30-100mg kg^{-1} of mobile P for typic chernozems as suggested by Ivanova and Rozova (1970).

The change from quarry grasslands to undisturbed forest vegetation may account for the chemical differences between this site and sites 1 and 2. More emphasis should be placed on using the less disturbed soil profiles (sites 3-6) as soil references for risk assessment in the Kursk Oblast.

Site 4

Site four is located at N 51°32’20.1” E 36°18’21.3” on an upland position. The site is located in the V.V. Alekhin Central-Chernozem Biosphere Reserve in a meadow of grasses and legumes. The site has a slight slope of 1% and an elevation of approximately 250 meters above sea level. The soil was sampled to a depth of 250 cm with a parent material sequence of loess over Cretaceous chalks or Tertiary sands. The depth of loess was very thick, and the second lower parent material was not apparent in this profile. The loess is characterized by 10YR hues and silty textures. The soil is considered well drained and showed no redoximorphic features.

Site 4 has a high base saturation with a moderate CEC. The pH values (1:1 H_2O) are neutral to slightly acidic near the surface and then becoming basic with a range from pH 6.3 to 8.2 (Table 13). The $CaCl_2$ pH values all reflect similar changes with depth (Table 13). The change in pH is also reflected in the $CaCO_3$ equivalent with an increase in carbonates at the argillic horizons (Table

Table 13. Site 4 pH values.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$
A1	0-30	6.3	5.8
A2	30-60	6.8	6.2
Bt1	60-120	7.8	7.5
Bt2	120-150	8.0	7.6
Bt3	150-210	8.2	7.8
Bt4	210-250	8.0	7.6

14). The carbonates act as a strong buffer against acidity, hence the high pH and close to zero values determined for total acidity (Table 15). Aluminum and H^+ acidity values from the KCl procedure were below detection limits. The fractions of total acidity from these two elements could not be determined, but they are below the very low total acidity values.

The base saturation of the soil is very high with 100% base saturation throughout the profile (Table 15). Calcium was the most dominant base, with values between 29.92 and 42.22 $cmol^+ kg^{-1}$. The Ca values are slightly higher than other studies on typic chernozems, which indicate Ca levels were between 16-38 $cmol.kg^{-1}$ (Pampura et al., 1993; Mikhailova et al., 2000b). Calcium made up approximately 80-90% of all exchangeable bases. Magnesium was the next most prevalent, and finally K^+ and Na^+ were observed in much smaller amounts (Table 15). Similar results were also observed by Vilenskii (1957).

The CEC of profile 4 was high in the surface and generally decreased with depth, except for a small increase in the lowest horizon. The increase in the lowest argillic horizon correlates to an increase in clay content. The highest CEC (30.98 $cmol^+ kg^{-1}$) in the surface horizon is due to the higher organic content in the soil (Table 14). The CEC values of approximately 31-18 $cmol^+ kg^{-1}$ is similar to values of 38-14 $cmol^+ kg^{-1}$ found by Mikhailova (2000b) in research on Kursk soils. Similar to sites 1 and 2 this profile has a significant clay increase, and consequently the CEC is higher in the argillic horizons than the site 3 cambic horizons at the same depth.

Table 14. Carbon, nitrogen and sulfur data for site 4. Includes total carbon, nitrogen, sulfur, organic C, and calcium carbonate equivalent* ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent
		% of soil				
A1	0-30	0.37	0.09	5.12	3.36	
A2	30-60	0.28	0.07	3.81	2.37	
Bt1	60-120	0.22	0.02	3.26	1.55	6.14
Bt2	120-150	0.15	0.01	2.84	0.73	9.80
Bt3	150-210	0.07	0.01	2.04	0.12	11.90
Bt4	210-250	0.08	0.01	1.60	0.17	8.21

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Table 15. Cation exchange data for site 4. Includes sodium acetate extractable bases, total acidity, and percent base saturation by direct measurement.

Horizon	Depth (cm)	Na	K	Mg	Ca	Total Acidity	CEC pH 7	% Base Saturation
		$\text{cmol}^{+}\ \text{kg}^{-1}$						
A1	0-30	0.50	0.52	3.07	29.92	0.01	30.98	100
A2	30-60	0.25	0.33	2.00	32.07	0.00	29.01	100
Bt1	60-120	0.27	0.33	1.86	42.22	0.02	23.69	100
Bt2	120-150	0.21	0.29	2.68	40.49	0.03	18.17	100
Bt3	150-210	0.13	0.34	4.66	38.01	0.02	18.25	100
Bt4	210-250	0.16	0.37	6.82	40.66	0.03	22.71	100

Total C was high in the upper horizons with a maximum of 5.12% in the Ap horizon and decreased with depth to a minimum of 1.60% (Table 14). Sulfur is in very small amounts between 0.09 and 0.01%, while nitrogen was high and decreased with depth from 0.37 to 0.07% (Table 14).

Total elemental analysis was similar to previous sites. Low levels of transition metals were found. Arsenic, Cd, Cr, and Pb were below detection limits (<50 mg kg^{-1} for As, Cd, Cr; <25 mg kg^{-1} for Pb). Cobalt levels ranged from 8 mg kg^{-1} to 4 mg kg^{-1}, while Ni levels were between 53-35 mg kg^{-1}. Barium, Cu, Sr, and Zn had ranges of 434-396 mg kg^{-1}; 9-<2 mg kg^{-1}; 162-85 mg kg^{-1}; and 60-41 mg kg^{-1}, respectively (Table 16).

The soil element composition sequence for this profile is estimated to be Si > Al > Fe > Ca > K > Mg > Na > Ti > Mn > Ba > P > S > Zr > Sr > Zn > Ni > Cr > Cu > Co > Mo (Table 16). Calcium is slightly higher than K due the naturally higher Ca levels in loess and the precipitation of calcium carbonates. Chromium was again in significantly lower concentrations than Sr, Zn, and Ni, contradicting the element sequence of Kursk soils by Protosova and Belyaev (2000). Phosphorus levels were generally higher than S. The change could be attributed to the increase P cycling in the undisturbed grassland setting and decreased human influence with no crop and subsequent nutrient removal. The element sequence still proves to be remarkably similar between the two analyses.

The average selected microelement content on Kursk chernozems, according to Kovda (1966) are: Ti 4000 mg kg^{-1}; Mn 840 mg kg^{-1} l; Cu 30 mg kg^{-1}; Co 6.1 mg kg^{-1}; Zn 62 mg kg^{-1}; Ni 49 mg kg^{-1}; and Mo 4.6 mg kg^{-1}. This study

Table 16. Total element analysis for site 4.

Horizon	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	Zn	Zr
	mg kg^{-1}														
A1	416	10377	7	9	24927	17196	5896	567	5693	53	450	85	2265	54	120
A2	417	11121	7	7	25658	17545	6126	545	5753	46	421	85	2385	54	122
Bt1	434	27521	8	8	25139	17802	6547	519	6100	45	362	102	2431	47	126
Bt2	396	47571	4	<2	23847	17379	7396	468	5864	35	292	122	2232	41	120
Bt3	396	53967	8	<2	27322	16510	9682	482	6247	50	<50	162	2358	60	113
Bt4	403	39478	8	9	30718	16463	9781	586	6395	47	80	157	2645	54	116

* Values for the following elements were all less than the detection limits shown in parentheses: As(<50), Cd(<2), Cr(<50), Mo(<5), and Pb(<25).

site indicates significantly lower Ti, Mn and Cu values, while the other elements were found in similar concentrations (Table 16). The depth of sampling for the analysis by Kovda (1966) is not discussed and may be a reason for the differences.

Phosphorus levels were low with 450 mg kg^{-1} in the surface and decreasing with depth, while Mo levels were all <5 mg kg^{-1} (Table 16). The levels of plant available P would be significantly lower, but probably similar to the generalized levels of 30-100mg kg^{-1} of mobile P for typic chernozems as suggested by Ivanova and Rozova (1970). The P levels for site 4 are slightly higher than sites 1, 2 and 3.

The soil profiles of sites 3 to 6 should be considered as natural soil references for risk assessment in the Kursk Oblast.

Site 5

Site five is located at N 51°34'16.7" E 36°05'40.6" on an upland position. The site is located in the V.V. Alekhin Central-Chernozem Biosphere Reserve in a meadow of grasses and small shrubs. The site has a slight slope of 1% and an elevation of approximately 271 meters above sea level. The soil was sampled to a depth of 330 cm with a parent material sequence of loess over Cretaceous chalks or Tertiary sands. The depth of loess was very thick, and the second lower parent material was not apparent in this profile. The loess is characterized by 10YR hues and silty textures. The soil is considered well drained and showed no redoximorphic features.

Site 5 has a high base saturation with a moderate CEC. The pH values (1:1 H_2O) are neutral near the surface to slightly acidic at approximately 1 m and then becoming basic with a range from pH 6.6 to 8.2 (Table 17). The $CaCl_2$ pH values all reflect similar change with depth (Table 17). The change in pH is also reflected in the $CaCO_3$ equivalent with an increase in carbonates at the cambic horizons (Table 18). The carbonates act as a strong buffer against acidity, hence the high pH and close to zero values determined for total acidity (Table 19). Aluminum and H^+ acidity values from the KCl procedure were below detection limits. The fractions of total acidity from these two elements could not be determined, but they are below the very low total acidity values.

The base saturation of the soil is very high with a minimum of 82% at the surface, gradually increasing to 100% base saturation, and then dropping slightly in the deepest horizons (Table 19). Calcium was the most dominant base with values between 11.04 and 40.80 $cmol^+ kg^{-1}$. The Ca values are slightly lower than other studies on typic chernozems, which indicate Ca levels were between 16-38 $cmol.kg^{-1}$ (Pampura et al., 1993; Mikhailova et al., 2000b). The lowest Ca levels were very deep in the site 5 profile and the other investigations may not have calculated Ca abundance to the depths of this study. Calcium made up approximately 90% of all exchangeable bases. Magnesium was the next most prevalent, and finally K^+ and Na^+ were observed in much smaller amounts (Table 19). Similar results were also observed by Vilenskii (1957).

The CEC of profile 5 was high in the surface and generally decreased with depth. The highest CEC (37.21 $cmol^+ kg^{-1}$) in the surface horizon is due to the

Table 17. Site 5 pH values.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$
A1	0-27	7.4	7
A2	27-49	7.3	6.8
A3	49-75	7.2	6.4
AB	75-95	7	6.3
BA	95-112	6.6	6.2
Bw1	112-146	7.9	7.4
Bw2	146-180	8	7.5
C1	180-220	8.1	7.5
C2	220-240	8.2	7.6
C3	240-248	8.2	7.6
C4	248-270	8.1	7.6
C5	270-307	8.1	7.5
C6	307-330	8.1	7.4

Table 18. Carbon, nitrogen and sulfur data for site 5. Includes total carbon, nitrogen, sulfur, organic C, and calcium carbonate equivalent* ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent
		% of soil				
A1	0-27	0.39	0.06	5.22	3.26	
A2	27-49	0.24	0.05	3.36	2.02	
A3	49-75	0.18	0.04	2.45	1.47	
AB	75-95	0.12	0.03	1.48	0.78	
BA	95-112	0.10	0.03	1.02	0.55	
Bw1	112-146	0.07	0.00	2.24	0.29	12.30
Bw2	146-180	0.07	0.01	2.10	0.00	12.30
C1	180-220	0.04	0.00	0.87	0.04	5.28
C2	220-240	0.04	0.01	0.71	0.00	4.17
C3	240-248	0.06	0.00	0.86	0.11	4.22
C4	248-270	0.04	0.00	0.16	0.00	0.42
C5	270-307	0.04	0.01	0.15	0.00	0.60
C6	307-330	0.04	0.01	0.14	0.00	0.32

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Table 19. Cation exchange data for site 5. Includes sodium acetate extractable bases, total acidity, and percent base saturation by direct measurement.

Horizon	Depth (cm)	Na	K	Mg	Ca	Total Acidity	CEC pH 7	% Base Saturation
		$\text{cmol}^+ \text{ kg}^{-1}$						
A1	0-27	0.36	0.44	2.97	26.78	0.00	37.21	82
A2	27-49	0.22	0.30	2.23	26.21	0.00	33.61	86
A3	49-75	0.11	0.27	1.87	23.18	0.01	29.13	87
AB	75-95	0.09	0.27	1.50	20.49	0.01	25.37	88
BA	95-112	0.11	0.25	1.12	18.31	0.01	23.01	86
Bw1	112-146	0.09	0.24	1.19	36.75	0.03	19.19	100
Bw2	146-180	0.10	0.24	1.76	40.80	0.03	21.03	100
C1	180-220	0.08	0.20	1.32	35.42	0.03	15.19	100
C2	220-240	0.07	0.22	1.27	35.18	0.01	14.19	100
C3	240-248	0.07	0.26	1.30	32.83	0.01	19.40	100
C4	248-270	0.06	0.23	1.20	17.46	0.01	14.14	100
C5	270-307	0.06	0.24	1.37	13.69	0.00	15.25	101
C6	307-330	0.05	0.22	1.20	11.04	0.00	12.75	98

higher organic content in the soil (Table 18). The CEC values of approximately 37-13 cmol$^+$ kg^{-1} are very similar to values of 38-14 cmol$^+$ kg^{-1} found by Mikhailova (2000b) in research on Kursk soils. Similar to site 3 this profile does not have a significant clay increase, however the CEC is similar to the argillic horizons of sites 1,2, and 4, and is higher than the other cambic horizons of site 3.

Total C was high in the upper horizons with a maximum of 5.22% in the Ap horizon and decreased with depth to a minimum of 0.14% (Table 18). Sulfur is in very small amounts between 0.06 and 0%, while nitrogen was high and decreased with depth from 0.39 to 0.04% (Table 18).

Total elemental analysis was similar to previous sites. Low levels of transition metals were found. Arsenic, Cd, Cr, and Pb were below detection limits (<50 mg kg^{-1} for As, Cd, Cr; <25 mg kg^{-1} for Pb). Cobalt levels ranged from 23 mg kg^{-1} to <3 mg kg^{-1}, while Ni levels were between 45-27 mg kg^{-1}. Barium, Cu, Sr, and Zn had ranges of 495-394 mg kg^{-1}; 18-<2 mg kg^{-1}; 149-68 mg kg^{-1}; and 61-21 mg kg^{-1}, respectively (Table 20).

Soil element composition for Kursk soils is presented by the following sequence: Si > Al > Fe > K > Ca > Mg > Na > Ti > S > P > Mn > Ba > Zr > Cr > V > Sr > Zn > B > Ni > Cu > Co > I > Mo > Be, according to Protosova and Belyaev (2000). The sequence for this profile is estimated to be Si > Al > Fe > Ca > K > Na > Mg > Ti > Mn > Ba > P > Zr > Sr > S > Zn > Ni > Cr > Co > Cu > Mo (Table 20). The two are similar, however, V, B, and I were not determined in this research, and Mn, Ba, P, Zr, and Sr were slightly higher than a significantly lower

Table 20. Total element analysis for site 5.

Horizon	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	Zn	Zr
	mg kg^{-1}														
A1	403	10051	<3	<2	23460	17772	5264	511	5780	40	432	68	2488	60	136
A2	428	9115	23	18	25031	18436	5301	531	5843	27	486	95	2563	61	131
A3	434	8711	12	5	26587	18550	5593	544	6116	35	397	87	2713	52	143
AB	440	7991	13	4	27625	19635	5946	546	6374	38	332	86	2815	57	152
BA	461	8086	14	4	29092	20263	6448	538	6954	34	283	92	3005	60	166
Bw1	495	63504	11	<2	26161	17865	8333	467	6781	37	248	136	2663	45	133
Bw2	408	57610	<3	<2	26984	17511	8242	485	6303	45	149	149	2678	39	127
C1	394	28040	<3	<2	20103	18187	4492	310	6726	32	<50	124	2662	22	171
C2	410	25319	<3	<2	19959	19200	4306	436	6864	28	79	105	2718	21	178
C3	405	23922	<3	<2	22254	18975	5224	447	7080	41	<50	98	2715	25	168
C4	414	6461	<3	<2	19399	19482	3675	389	6388	32	<50	70	2685	28	174
C5	411	6010	<3	<2	19463	19032	3857	409	6223	34	129	75	2625	40	167
C6	422	6308	<3	<2	20492	19820	4033	414	6456	35	214	70	2721	46	174

* Values for the following elements were all less than the detection limits shown in parentheses: As(<50), Cd(<2), Cr(<50), Mo(<5), and Pb(<25).

S content. Calcium is slightly higher than K due the naturally higher Ca levels in loess and the precipitation of calcium carbonates. Chromium was again in lower concentrations than Sr, Zn, and Ni. The change in decreased S could be attributed to the increase nutrient cycling in the undisturbed grassland setting and decreased human influence, with no crop and subsequent nutrient removal. The element sequence is quite similar between the two analyses. Investigating the S values obtained from the dry combustion method (Tables 2, 6, 10, 14, and 18) the sulfur values for site 5 does not appear to be different from the previous sites. This seems to indicate that one of the methods may not accurately determine S levels, and human laboratory error may also have influenced the decreased S concentrations observed for site 5. In reality the true S values may be greater than Zr and Sr.

The average selected microelement content on Kursk chernozems, according to Kovda (1966) are: Ti 4000 mg kg^{-1}; Mn 840 mg kg^{-1} l; Cu 30 mg kg^{-1}; Co 6.1 mg kg^{-1}; Zn 62 mg kg^{-1}; Ni 49 mg kg^{-1}; and Mo 4.6 mg kg^{-1}. This study site indicates significantly lower Ti and Mn values, while the other elements were found in similar concentrations (Table 20).

Phosphorus levels were low with 486 mg kg^{-1} near the surface and decreasing with depth, while Mo levels were all <5 mg kg^{-1} (Table 20). The levels of plant available P would be significantly lower, but probably similar to the generalized levels of 30-100mg kg^{-1} of mobile P for typic chernozems as suggested by Ivanova and Rozova (1970). The P levels for sites 4 and 5 are slightly higher than sites 1, 2 and 3.

The change from anthropogenically influenced quarry grasslands to undisturbed grassland vegetation may account for the chemical differences between this site and sites 1 and 2. More emphasis should be placed on using the less disturbed soil profiles (sites 3-6) as soil references for risk assessment in the Kursk Oblast.

Site 6

Site six is located at N 51°33'04.3" E 36°18'22.3" on an upland position. The site is located in the V.V. Alekhin Central-Chernozem Biosphere Reserve in a meadow of grasses and legumes. The site has a steeper slope of 5% compared to the previous sites and an elevation of approximately 252 meters above sea level. The soil was sampled to a depth of 250 cm with a parent material sequence of loess over Cretaceous chalks or Tertiary sands. The depth of loess was very thick and the second lower parent material was not apparent in this profile. The loess is characterized by 10YR hues and silty textures. The soil is considered well drained and showed no redoximorphic features. The profile is unusual compared to the previous profiles, with regard to the appearance of both cambic and argillic horizons.

Site 6 has a high base saturation with a moderate CEC. The pH values (1:1 H_2O) are neutral near the surface and then becoming basic with a range from pH 67.0 to 8.3 (Table 21). The $CaCl_2$ pH values all reflect similar change with depth (Table 21). The change in pH is also reflected in the $CaCO_3$ equivalent with an increase in carbonates at the cambic horizons (Table 22).

Table 21. Site 6 pH values.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$
A1	0-40	7	6.6
A2	40-70	7.8	7.3
A3	70-95	8	7.5
A4	95-108	8.1	7.6
AE	108-137	8.2	7.6
E	137-190	8.3	7.7
Bt1	190-230	8.3	7.7
Bt2	230-250	8.3	7.8

Table 22. Carbon, nitrogen and sulfur data for site 6. Includes total carbon, nitrogen, sulfur, organic C, and calcium carbonate equivalent* ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent
		% of soil				
A1	0-40	0.31	0.05	3.99	2.24	
A2	40-70	0.21	0.01	3.41	1.34	7.66
A3	70-95	0.17	0.01	3.35	1.30	9.24
A4	95-108	0.15	0.01	3.20	0.99	11.47
AE	108-137	0.13	0.01	3.06	0.84	6.51
E	137-190	0.06	0.00	2.16	0.18	14.01
Bt1	190-230	0.06	0.01	1.92	0.18	10.84
Bt2	230-250	0.06	0.01	1.29	0.18	7.57

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

The carbonates act as a strong buffer against acidity, hence the high pH and close to zero values determined for total acidity (Table 23). Aluminum and H^+ acidity values from the KCl procedure were below detection limits. The fractions of total acidity from these two elements could not be determined, but they are below the very low total acidity values.

The base saturation of the soil is very high with a minimum of 83% at the surface and 100% base saturation throughout the remaining profile (Table 23). Calcium was the most dominant base with values between 28.94 and 41.76 $cmol^+ kg^{-1}$. The Ca values are higher than other studies on typic chernozems, which indicate Ca levels were between 16-38 $cmol.kg^{-1}$ (Pampura et al., 1993; Mikhailova et al., 2000b). Calcium made up approximately 95% of all exchangeable bases in the upper profile, however an increase in Mg in the lower horizons accounted for 10-30% of all bases and Ca between 70-90%. Magnesium was more prevalent in site 6 than the other sites, however K^+ and Na^+ were observed in small amounts similar to the other sites (Table 23).

The CEC of profile 5 was high in the surface and generally decreased with depth, however the CEC increases in the lower argillic horizons due to the increase in clay content. The highest CEC value (38.90 $cmol^+ kg^{-1}$) was found in the surface horizon due to the higher organic content near the soil surface (Table 22). The CEC values of approximately 39-22 $cmol^+ kg^{-1}$ are slightly higher than the values of 38-14 $cmol^+ kg^{-1}$ found by Mikhailova (2000b) in research on Kursk soils.

Table 23. Cation exchange data for site 6. Includes sodium acetate extractable bases, total acidity, and percent base saturation by direct measurement.

Horizon	Depth (cm)	Na	K	Mg	Ca	Total Acidity	CEC pH 7	% Base Saturation
		$\text{cmol}^+ \text{kg}^{-1}$						
A1	0-40	0.13	0.36	2.77	28.94	0.01	38.90	83
A2	40-70	0.11	0.28	1.67	41.29	0.01	27.11	100
A3	70-95	0.11	0.26	1.30	41.95	0.03	25.14	100
A4	95-108	0.13	0.31	1.93	39.86	0.01	23.72	100
AE	108-137	0.14	0.27	2.20	41.76	0.01	22.42	100
E	137-190	0.17	0.32	5.27	37.53	0.01	22.30	100
Bt1	190-230	0.20	0.33	7.55	34.73	0.01	25.37	100
Bt2	230-250	0.24	0.32	9.40	33.23	0.01	24.61	100

Total C was high in the upper horizons with a maximum of 3.99% in the Ap horizon and decreased with depth to a minimum of 1.29% (Table 22). Sulfur is in very small amounts between 0.05 and 0.01%, while nitrogen was high and decreased with depth from 0.31 to 0.06% (Table 22).

Total elemental analysis was similar to previous sites. Low levels of transition metals were found. Arsenic, Cd, Co, Cr, Cu, and Pb were below detection limits (<50 mg kg^{-1} for As, Cd, Cr; <25 mg kg^{-1} for Pb; <3 mg kg^{-1} for Co; <2 mg kg^{-1} for Cu). Nickel levels were between 48-24 mg kg^{-1}. Barium, Sr, and Zn had ranges of 421-366 mg kg^{-1}; 175-86 mg kg^{-1}; and 51-29 mg kg^{-1}, respectively (Table 24).

The soil element composition sequence for this profile is estimated to be Si > Al > Fe > Ca > K > Na > Mg > Ti > Mn > Ba > P > S > Sr > Zr > Zn > Ni > Cr > Co > Cu > Mo (Table 24). The results slightly oppose the soil composition sequence of Protosova and Belyaev (2000). The two sequences are similar, but Mn, Ba, and P are higher than S in this study. Calcium is slightly higher than K due the naturally higher Ca levels in loess and the precipitation of calcium carbonates. Chromium was again in lower concentrations than Sr, Zn, and Ni. Zirconium was also slightly lower than Sr. The decreased S could be attributed to the increased nutrient cycling in the undisturbed grassland, with S becoming a sink in the surface and above ground biomass.

The average selected microelement content on Kursk chernozems, according to Kovda (1966), are: Ti 4000 mg kg^{-1}, Mn 840 mg kg^{-1} l, Cu 30 mg kg^{-1}, Co 6.1 mg kg^{-1}, Zn 62 mg kg^{-1}, Ni 49 mg kg^{-1}, and Mo 4.6 mg kg^{-1}. This study

Table 24. Total element analysis for site 6.

Horizon	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	Zn	Zr
	mg kg^{-1}														
A1	421	7193	<3	<2	28121	18806	4148	578	8050	40	216	101	3138	45	203
A2	418	26274	<3	<2	27038	17905	6715	537	6385	48	396	86	2504	32	128
A3	386	46181	<3	<2	25027	16216	6903	475	6033	44	344	98	2411	47	122
A4	390	55185	<3	<2	23902	17609	9107	503	15173	24	280	129	2304	51	126
AE	388	56786	<3	<2	24242	17174	7721	455	6056	30	289	124	2323	29	116
E	366	61999	<3	<2	27263	15598	10024	476	6684	42	<50	175	2401	35	108
Bt1	380	46819	<3	<2	29103	14674	9904	532	6022	44	<50	160	2493	37	103
Bt2	373	32249	<3	<2	30950	15000	9422	485	5365	38	<50	134	2469	49	101

* Values for the following elements were all less than the detection limits shown in parentheses: As(<50), Cd(<2), Cr(<50), Mo(<5), and Pb(<25).

site indicates significantly lower Ti, Mn, and Cu values, while the other elements were found in similar concentrations (Table 24).

Phosphorus levels were low with 396 mg kg^{-1} near the surface and decreasing with depth, while Mo levels were all <5 mg kg^{-1} (Table 24). The levels of plant available P would be significantly lower, but possibly lower than the generalized levels of 30-100mg kg^{-1} of mobile P for typic chernozems as suggested by Ivanova and Rozova (1970). The P levels for sites 4 and 5 are slightly higher than sites 1, 2, 3 and 6.

CONCLUSIONS

The differences between the quarry sites do not appear to be very great, indicating that human influence has not significantly impacted the soil chemistry of sites 1 and 2.

Phosphorus levels were low, between 476 - <50 mg kg^{-1}. Mobile P levels would be significantly lower. Phosphorus and possibly Mo deficiencies need to be addressed in future land management.

Cation exchange capacity was moderate, typically between 14 and 39 $cmol^{+}$ kg^{-1}, except in the Tertiary sand parent material and some deep, low clay content loessial C horizons where CEC dropped to between 13 and 1 $cmol^{+}$ kg^{-1}.

With a base saturation of 80-100%, the majority of soil horizons have 100% base saturation. Calcium is the dominant cation, comprising approximately 90% of exchange sites.

The sequence of typical elemental soil composition is Si > Al > Fe > Ca > K > Mg > Na > Ti > Mn > Ba > P > S > Zr > Sr > Zn > Ni > Cr > Cu > Co > Mo for typic chernozems of the Kursk Oblast. In some soils K > Ca, Na > Mg, S > P, Ni > Zn, and Co > Cu.

Inorganic C levels and high calcium carbonate equivalents indicate a high buffering capacity or neutralization potential of these soils against acid damage.

The levels of the following elements As, Cd, Co, Cr, Cu, and Pb were most often below detection limits, indicating a very minimal natural occurrence of these potentially toxic elements. Sulfur levels were also very low.

The soils have low concentrations of transition metals indicating that they are not contaminated and should prove to be excellent reference standards for typic chernozems of the Kursk Oblast for future risk assessment.

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PART 3

SOIL MORPHOLOGY AND GENESIS OF SIX SELECTED SOIL PROFILES OF THE KURSK OBLAST, RUSSIA

INTRODUCTION

Soil science bridges many disciplines of science including geology, biology, chemistry, physics, climatology, geography, agronomy, anthropology, and archeology (Buol et al., 1997). Soil genesis, as a part of soil science, has many important interactions with other sciences and industrial activities.

Soil genesis, according to Buol (1997), deals with soils in three conceptual classes - the influence of factors and processes of soil formation, the geological entity, and a system capable of supporting the functions of soil in ecosystems. To understand soil genesis, physical descriptions, characterization, and interpretation of soil profiles is essential. Soil morphology, including color, physical structure, horizon depths, mineralogical and chemical composition, can provide insight into the history of the soil. Soil analysis increases understanding and leads to interpretation, by making inferences about a soil's development, limitations in use, and productivity (Buol et al., 1997). Using the concept of the five soil forming factors, parent material, climate, relief, organisms, and time, derived by Jenny (1941), chernozem development can be understood in parts and combined to give an overall picture of the genesis of the soil.

Six soils are investigated in the Kursk Oblast, Russia. The Kursk Oblast is approximately 500km southeast of Moscow (Fig. 3). Two parent material sequences are present in the study area. Loess deposits over Tertiary sands (site 1 and possibly 5), and loess deposits over Cretaceous chalks (sites 2, 3, 4, and 6). The two combinations of parent material deposits are representative of

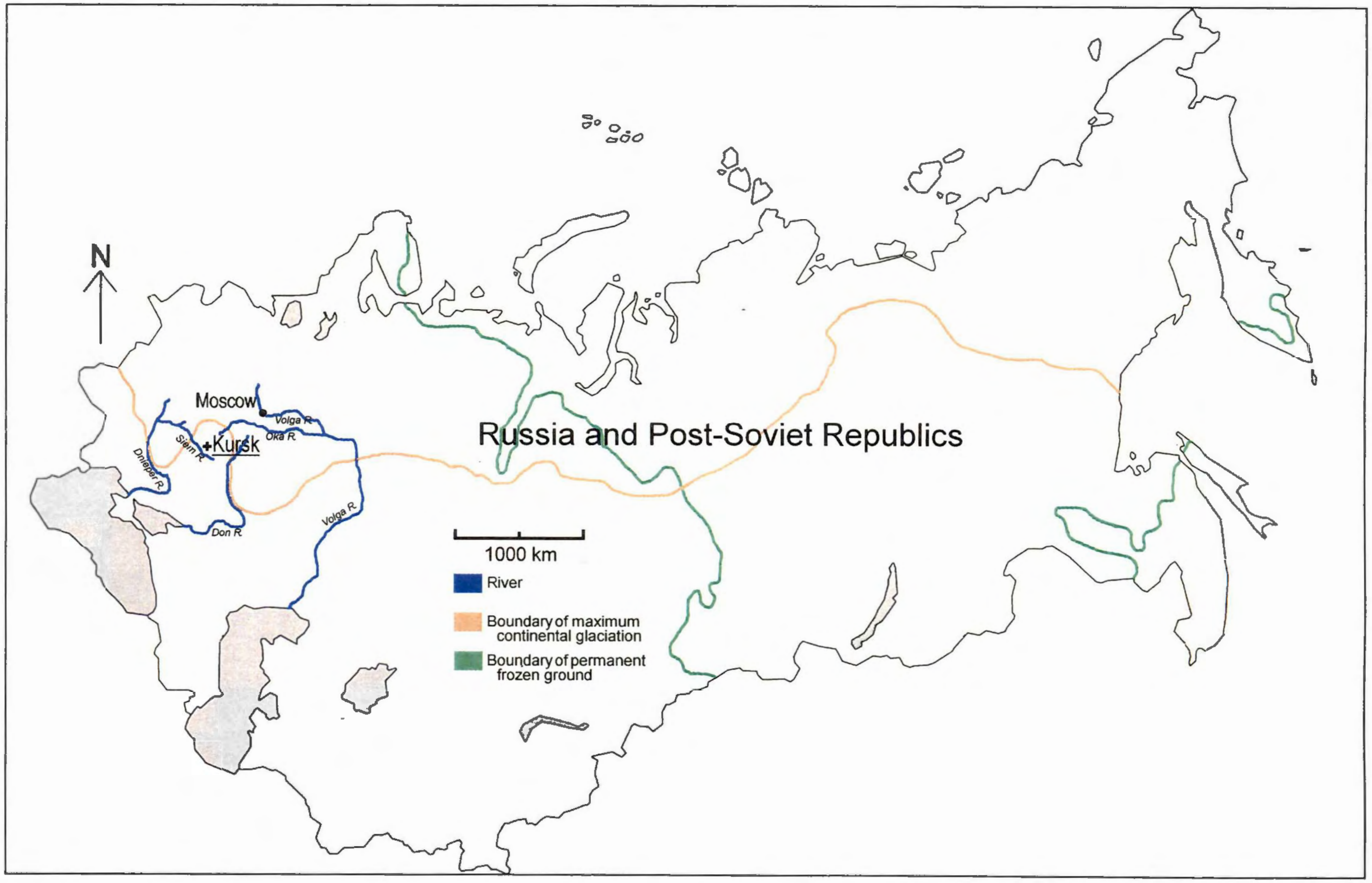

Figure 3. Generalized Kursk location and significant boundaries.

the Kursk region (Fig. 4). The region has a mean annual air temperature of 5.4°C and 587 mm mean annual precipitation (V.V. Alekhin Central-Chernozem Biosphere State Reserve, 1947-1997). The study area is approximately 260 m above sea level. The topography is nearly level with slopes <2° and small depressions due to loess compression in water accumulating regions (Mikhailova, 2000). Grasslands intersected with groves of deciduous forests dominate the landscape.

The objectives of this study were to evaluate six soil profiles near Kursk, Russia for physical characterization and genesis interpretation. Particle size, organic matter, and iron and manganese oxides were used to determine the genesis and of central chernozem soils in the Kursk Oblast.

LITERATURE REVIEW

The central chernozem region is situated on the southeastern portion of the Central Russian Plateau (Vilenskii, 1957), also called the Russian platform, and is fairly typical of a peneplain surface (Nalivkin, 1960). Watercourses forming valleys in the horizontal bedrock deposits primarily determine the topographical relief. The deposition of the Paleozoic, Mesozoic and Tertiary beds have a dip slope usually less than 1°, but can be about 2° in some areas (Nalivkin, 1960). The major rivers of the Kursk oblast include the Dnieper (2285 km in length), Don (1967 km) and Oka (1500 km) (Nalivkin, 1960). The depth to

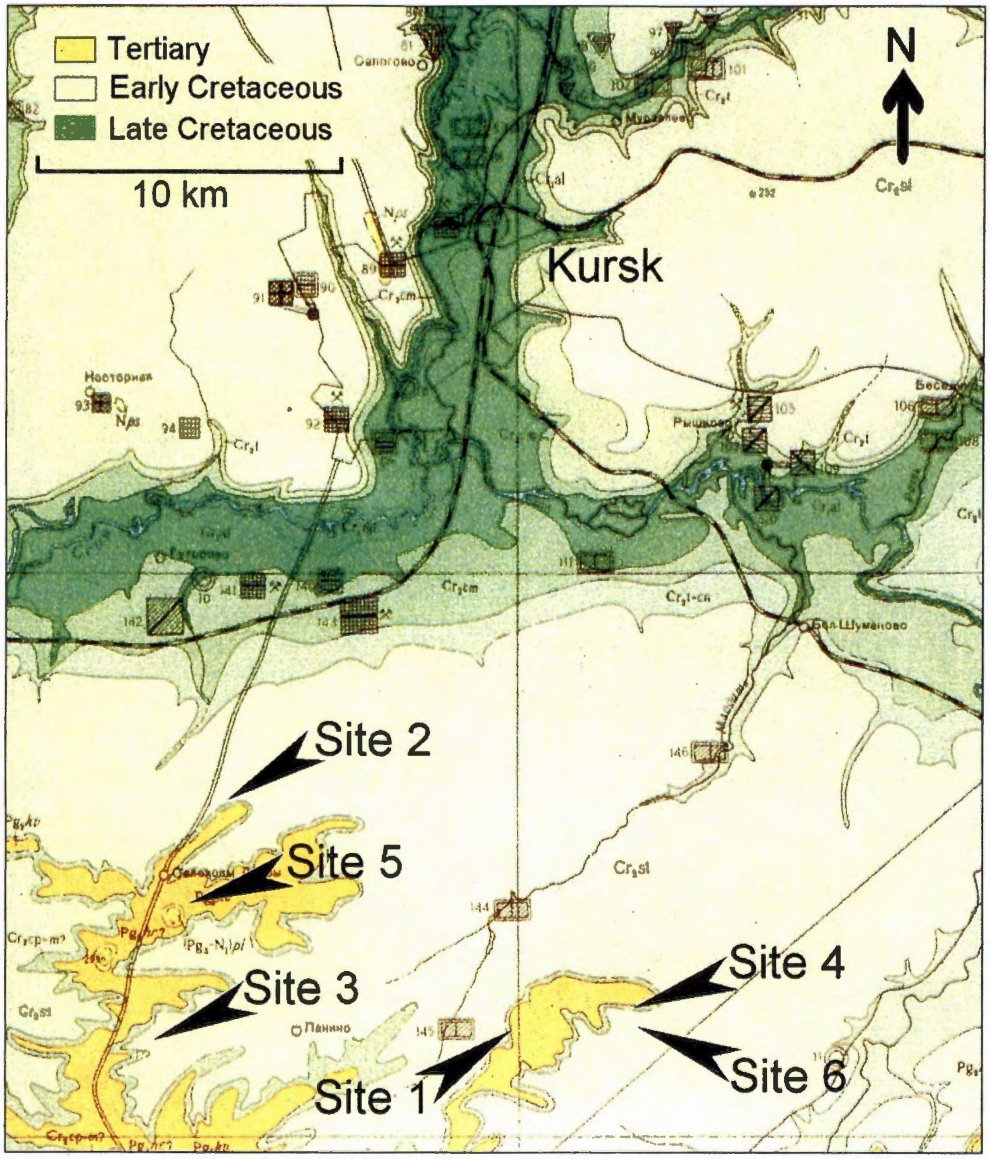

Figure 4. Site locations and geology of the Kursk region.

the crystaline rock-floor is 1500-1800 m and in some areas 2000-2800 m (Nalivkin, 1960).

The base of the Russian platform is comprised of metamorphic and igneous rocks of Archaean, Lower and Middle Proterozoic age (Khain, 1985) with many different depositions and sedimentary rocks closer to the surface (Table 25). Major changes shaped the continent, particularly during the Hercynian movement (Devonian), when the Russian platform subsided (Khain, 1985). The southern sections of the platform sank, while the northern section formed an uplifted, ridge-like, zone (Khain, 1985). Other subsidence events during the Kimmerian (Jurrasic and Triassic) and Alpine also changed the landforms (Khain, 1985) with the east and west edges becoming the higher regions. During subsidence events the lower elevations received erosion depositions, while the sea intruded from the south and deposited coastal sediments.

The Late Cretaceous deposits, in the Kursk region, occurred when the sea depression (the current southern Russian platform) became elongated east-west (Nalivkin, 1973). Previously, the Early Cretaceous basin-sea was oriented north-south. The composition of sediments changed with the formation of the new basin, particularly with an increase in carbonates, and formed the chalk deposits in the southern section of the Russian platform (Nalivkin, 1973). Carbonate deposits, such as chalks and marls, occurred in the deeper regions of the sea (south), while less pure, sandy deposits occurred near the shore (north) (Nalivkin, 1973). The carbonate deposition of the Late Cretaceous sea did not reach as far north as Moscow (Nalivkin, 1960). The sea retreated during the

Table 25. Geologic time.

Orogenic Events (Approximately)	Era	Period	Epoch	Age in millions of years before present
Alpine (0 – 240)	Cenezoic	Quaternary (Anthropocene)	Holocene	0 - 0.01
			Pleistocene	0.01 – 1.6
		Tertiary	Pliocene	1.6 – 5
			Miocene	5 – 25
			Oligocene	25 – 36
			Eocene	36 – 55
			Paleocene	55 - 66
	Mesozoic	Cretaceous		66 – 140
		Jurassic		140 – 210
		Triassic		210 – 250
Hycernian (240 – 380)	Paleozoic	Permian		250 – 290
		Pennsylvanian		290 – 325
		Mississippian		325 – 360
		Devonian		360 – 410
Caledonian (380 – 500)		Silurian		410 –440
		Ordovician		440 – 500
Assyntic (500 – 590)		Cambrian		500 – 590
	Proterozoic			590 – 2500
	Archaen			2500 - 4000

Tertiary period, and sands were deposited in beds overlying the Cretaceous strata, while eroded metamorphosed mountains occur in the north and east of the Russian platform, along with older sedimentary features.

The chernozem region is dominated by a rolling landscape of meandering gullies with deposits in the early Tertiary (Paleocene, Eocene, Oligocene) and the early and late Cretaceous time periods nearest the present day surface (Nalivkin, 1960). Deep beneath the Cretaceous deposits are Jurassic and Devonian age rocks. These older rocks occasionally outcrop on the surface and can vary the topography slightly. A cross section of the geology indicates the typical geologic layering and depths in the Kursk region (Fig. 5).

During the Quaternary the influence of global cooling has affected soil formations. The general trends of the Quaternary can be broken down into the four epochs. Throughout the Miocene the climate was warm over the entire Russian platform, with dense forests and marshes along with an abundance of rivers (Nalivkin, 1973). During the Pliocene the region cooled and the forests gave way to huge steppe lands dominated by herd animals. Towards the end of the Pliocene, and the start of the Anthropogene (Pleistoscene), the cold decreased temperatures further; the northern part of the Russian platform began to rise, and a large continental ice sheet formed (Nalivkin, 1973).

Quaternary geologists debate the actual number of glacial events during the "ice age". Some geologists believe only one glaciation with multiple stages occurred; others believe there were five glacial events, while the majority

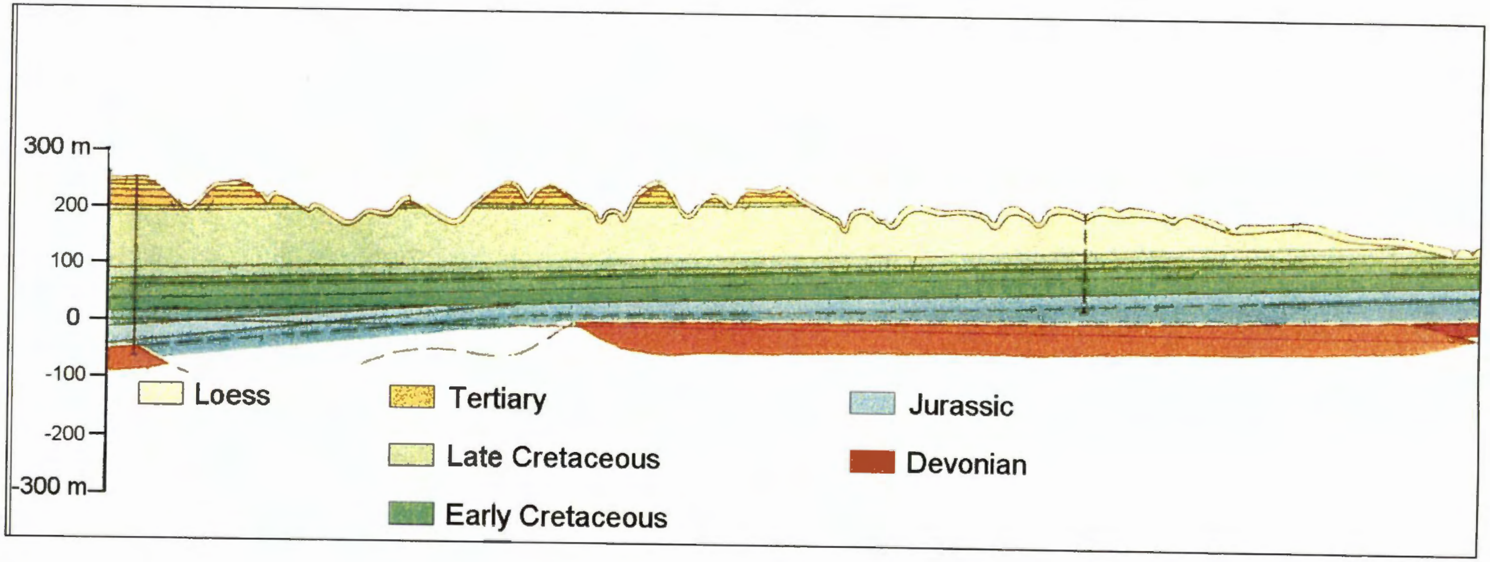

Figure 5. Generalized geologic cross section of the research area.

accept three glaciation events (Nalivkin, 1973). In the U.S. during the "ice age," four divisions of maximum glacial movement were named after their geographical extent. From oldest to youngest these are the Nebraskan, Kansan, Illinoian, and Wisconsin. The names of the glacial periods for the Russian continent are different, depending on how many glacial events are considered correct. Their names do not correspond to geographical extent (Nalivkin, 1973).

During the intermittent dry cold periods (Zolotun, 1974), fine silts from glacier scouring is carried by winds and deposited. The wind blown silt deposition is commonly called loess. Zolotun (1974) believes the loess formation in the Ukraine, a region bordering the Kursk Oblast, was deposited cyclically during glacial epochs. As the Russian ice sheet advanced, it accumulated atmospheric moisture, drying the climate and decreasing vegetation cover. A desert-like climate formed in the periglacial region in front of the ice, and dry southerly winds removed dust from the desert-like zone and deposited it further south in the same direction as the ice sheet growth (Morozova, 1972; Zolotun, 1974).

Ice sheets covered the majority of the Russian platform, however figure 4 shows the Kursk region, including the large area between the Dnieper and Don rivers, was not covered by ice (Nalivkin, 1960). Influence of glacial material in the Kursk Oblast soil is minimal, although the associated climatic changes are important to the soil genesis and morphology.

The Kursk region is dominated with Cretaceous and tertiary deposits intermingled in very short distances. The Tertiary deposits are evident by the sands, while the Cretaceous deposits are characterized by white chalks and marls. The underlying rock beneath the Tertiary deposits is not mapped, being very deep. The Tertiary deposits are from an ancient river valley, as the prehistoric coastline retreated towards the south. Marine sands are characterized by medium and fine-grained particle size, with carbonates and shells, while alluvial sands are sorted and more rounded (Smirnova et al., 1996). The alluvial sands are the most widespread type in Russia (Smirnova et al., 1996). To the north of the Cretaceous deposits are Jurassic aged shales, middle Devonian materials, including some limestone outcrops. The Jurassic and Devonian aged features were covered by ice sheets (Nalivkin, 1960).

The underlying geology and parent materials are often very important in soil formation. The overlying regolith characteristics, particularly the loess, and climatic conditions are more important in chernozem formation. Kursk Oblast chernozem soils have 100-300 cm of loess above the Tertiary coastal plain sand or Cretaceous chalk discontinuity. The discontinuity in the central Russian chernozems is quite similar to the soils of west Tennessee, however other factors of soil formation are different.

Loess, dominated by a silt particle size fraction, covers the underlying geology in the Kursk region. Loess is a controversial topic in soil science. Generally, loess is considered of wind-blown, aeolian, origin. Other scientists will argue that loess is fluvial in origin, as was the initial thoughts on loess prior to the 20th century (Follmer, 1996). Loess is also generally considered to be unconsolidated, homogenous, calcerous, non-stratified material, dominated by the silt particle size fraction.

Separate major loess depositions are believed to have occurred during the Quaternary. Morozova (1972) describes potentially six fossil soil complexes that are inter-layered between loess depositions. The soil forming periods, from oldest to youngest, are: Bryansk time (buried approximately 25,000 y.b.p), the Mikulin-Mezin complex (70,000-120,000 y.b.p), the pre-Dnieprovian I complex (>200,000 y.b.p), and the pre-Dnieprovian II, III, and IV complexes (1,000,000-1,500,000 y.b.p). Many of these paleosol complexes and older loess layers are only seen in specific areas. Erosion has removed many of the older loess layers. In the Kursk region only the most recent loess depositions are observed on the central chernozem soils. The chernozem soils are believed to be 7000-9000 years old when formation began, although they could be 10,000-12,000 years old (Rubilin and Kozyreva, 1974). Upper humus layers (0-80cm) are estimated to be only 3000 years old according to C^{14} dating (Rubilin and Kozyreva, 1974).

The concept of dynamic soil forming processes of the chernozem is correlated to the formation of the grassland steppe, while other processes link chernozem formation as a function of current climatic conditions (Vil'yams, 1968). The development of chernozems varies greatly, however they can be broken into three broad areas: Typic, Northern bog, and Meadow-steppe formations.

Northern chernozems and the related groups form in the colder, wetter regions on watershed bogs in aluminosilicate moraines. Meadow-steppe chernozems, including southern chernozems, are formed in much drier, warmer regions with carbonate moraines dominating the parent material. The Typic chernozems are influenced by the earlier tundra climate (Vil'yams, 1968). Typic and Ordinary chernozems dominate the middle areas between the proceedings two types.

The central chernozem region is a tundra climate formed soil. Of course, the factors of soil formation that developed chernozems are not just based around past climates, but the previous climates were influential in the chernozem formation. Typic chernozems dominate the Kursk Oblast, and in turn the discussion will focus primarily on this type of chernozem.

Most of the typic chernozems began forming after emergence from post-Tertiary glacial cover (Vil'yams, 1968), or strong periglacial influence in the case of the Kursk Oblast. Large plains formed with very little topographic variation. Small depressions marked some variation in the topography. The glacial formations were thick and the bedrock was not significantly dissected, unlike the mountainous regions of Russia. The Kursk region was not covered by ice or glacial till; instead the Kursk region was covered by a thick blanket of loess. Upon the retreat of the glaciers, melt water overflowed and some shallow till soils covered the landscape to the north (Vil'yams, 1968). The climate was still much colder than the present, and tundra dominated the regions that today contain the thick, dark chernozem soils. The scarce, low-lying tundra flora provided little resistance to erosion and many streams dissected the landscape. Boreal forest (taiga) moved northwards with the glacial retreat. Initially, the northward growth occurred in the more protected valleys and along these new stream banks

(Vil'yams, 1968). This phenomenon still exists today, as boreal forest is found at its most northern latitudes in protected river and stream valleys.

The boreal forest changed the soils dramatically. Erosion was reduced, and organic layers began to form. As the forest progressed northwards, the climate was warming, and the grasslands also pushed into the northern regions (Vil'yams, 1968). Eventually, the boreal forest became isolated in pockets, and became mixed forest, as deciduous trees encroached northwards. Birch trees are one of the first invading tree species, followed by alders, oaks, aspens, poplars, and willows along the river floodplains (Vil'yams, 1968). The grassland dominated as vegetative cover in the region, and continues to the present day. The majority of the grasses are native and C_3 photosynthetic (Mikhailova et al., 2000).

The grasslands were subject to erosion and deposition. Sands enveloped the region and layers of various loess deposits have subsequently covered the sands. The loess is the most important deposit of parent material in chernozems, as it supplies high base, calcium enriched, nutrients to the soil. It is important to note that loess is not the only way chernozems can form, but it is the most predominant variety of chernozem soils (Vilenskii, 1957; Vil'yams, 1968). The grasses rapidly recover from the new sediment depositions.

The grasses continue to add dead, vegetative, organic material to the soil until the end of summer; however it is not broken down until the following spring, due very cold temperatures. During the spring thaw the soil remains saturated with water. The anaerobic environment, due to the water saturation, decreases organic decomposition (Ponomareva, 1974), and by summer the cycle continues, with only 50% of the previous years dead material broken down (Vil'yams, 1968). A study by Ganzhara (1974) indicates that 10-15% of the humus formed every year remains in the soil for a long time. The organic cycle allows a high accumulation of organic material in the soil surface.

Chernozems typically have high contents of humus. The humus layer extends to >1 m, with soil organic carbon content of 5-9% near the soil surface (Kogut, 1998). Humic acid is the primary organic acid, with fulvic acid comprising only a very small percentage in most Russian chernozems (Ivanova and Rozov, 1970; U.S.S.R. Ministry of Agriculture, 1977), however Ganzhara (1974) argues that fulvic acids in Kursk chernozems are found at much higher concentrations, with humic acid only 1.5-2 times greater than fulvic acids. In the humic acids, the calcium-bound fraction is dominant (Ivanova and Rozov, 1970).

Soil organic carbon beneath the surface is usually 2-3% of soil. Data indicates that typic chernozems in the Kursk Oblast average 2.9% at a depth of 30-50 cm (Kogut, 1998). The clay fraction strongly binds 40-50% of the organic fraction in organic-clay adsorption complexes, while 25-35% of the organic matter is loosely bound to either humic compounds of complex-salts or of plant, animal, or microbial origin (Kogut, 1998). The loosely bound organic fraction is more easily transformed.

Ponomareva (1974) found typic chernozems from the V.V. Alekhin Biosphere Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. In the same study, nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m, respectively (Ponomareva, 1974). Carbon:Nitrogen ratios are typically between 8:1-12:1 in the upper 1 m and 4:1-10:1 in the lower depths (Ponomerava, 1974; Chuyan et al., 1987).

The carbon sink of the chernozems and grassland soils is considered very important on a global scale, as chernozems and their similar counterparts, such as Mollisols, hold large quantities of organic C in their upper soil horizons. The carbon stored in soils is twice the amount of C in the atmosphere and nearly three times the amount of C stored in aboveground biomass (Eswaran et al., 1993). Chernozems around the world are estimated to cover 230 million ha. (Bryant et al., 2000) with 6,586,470 ha. in Russia alone (Mikhailova et al., 2000). The Russian chernozems are estimated to hold approximately 130 to 160 $t.ha^{-1}$ organic matter in the upper 20cm of soil, providing a large sink of CO_2 (Mikhailova et al., 2000). Carbon loss from chernozems has become a "hot topic" of study with the rise of the global warming phenomenon. Research by Kogut (1998) indicates that the real annual humus loss caused by plowing does not exceed 0.03% in continuously plowed chernozem soils in the Kursk Oblast. The results of the long-term study by Kogut (1998) concluded that humic substances are quite resistant to mineralization. In contrast, Mikhailova (2000) found a significant decline in soil organic matter below plow depth in areas under cultivation. Chimitdorzhiyeva (1991) also found significant loss of humus from soils, including chernozems, which are subject to plowing.

Aspect can affect the amount of humus in soils. Northern facing slopes have higher reserves of humus and total nutrients, however they have less available N, mobile P, and K (Chuyan et al., 1987). Southern slopes are more fertile, having more mobile nutrients and increased mineralization of organic matter and have less pronounced horizonization (Chuyan et al., 1987).

The thick organic carbon layer is generally black or very dark brown in color for the central chernozems, although in different chernozems color ranges from dark brown to grey. The Kursk region chernozems are usually colored (moist) in the 10YR hue with values from 2 near the surface to 6 further below and chromas from 1 at the surface to 6 at lower depths (Mikhailova et al., 2000).

Particle size for the Kursk typic chernozems are usually silt, silt loam, silty clay loam, or silty clay with the clay particle size fraction varying from approximately 15-40% (Kogut, 1998, Mikhailova, 2000). Chernozem formation involves an accumulation of fine clay minerals, particularly 2:1 expanding clays, such as montmorillonite (Ivanova and Rozov, 1970).

The five soil forming factors (Jenny, 1941) are all influential in typic chernozems formation. The development of soil depends on the interactions and influences of parent material, climate, relief, organisms, and time. Although the process of soil formation is a complex series of reactions catalyzed by the five factors. The following discussion briefly focuses on the attributes of each individual factor in the process of chernozems formation.

Parent material provides the ingredients of raw minerals. Typic chernozems have high base saturation, so the influence of high base parent materials is critical. Loess, as stated earlier, contains high levels of carbonates, particularly calcium, as does the Cretaceous chalks and marls that underlie these soils. The wind-blown loess is very influential and is common in the central chernozemic region. The geologic residual parent materials are buried very deep and do not influence soil formation in the present conditions. One could argue that the initial movement to boreal forest and then grassland prairie was facilitated by the prehistoric residual soils and the underlying geology. This argument strengthens the importance of residual parent material to chernozem development.

The integration of the climatic soil-forming factor is also important for chernozems formation. The past climate and present are crucial to typic chernozem development. As stated earlier, past climatic conditions are responsible for the loess deposition and the succession to a prairie ecosystem. Earlier discussion indicates how present climate allows for the accumulation of organic material through the water cycling and the temperature conditions.

Relief, topography and aspect have a less pronounced influence. Aspect does change the chemical and organic composition of the soils slightly; however the changes are not great, and the topography for the central chernozemic regions is quite flat. Some accumulations occur in the lower depressions. The lack of great topography changes does aid the formation of chernozems. If the landscape had larger topographic changes, increased erosion would strip many of the organic accumulations as well as the loess deposition with subsequent carbonate and base cation removal occurring also.

Organisms are also instrumental in the formation of typic chernozems in the Kursk Oblast. The macrofauna, primarily the grasses, provide nutrient cycling and raw organic matter and energy into the soil ecosystem. Macrofauna, like earthworms and moles cause pedoturbation or mixing of the soil. The mixing allows movement of materials, particularly organics, down through the profile. The movement of organics and the natural accumulation, forms the thick, black, high organic horizons that are characteristic of typic chernozems. Microorganisms are very abundant in the soil. The action of microorganisms is responsible for the breakdown of raw organic material into humus and then eventually into the mineral fraction.

Time is the final soil-forming factor, according to the five factors of soil formation (Jenny, 1941). Time is infinite and continuous, however with regard to soil formation this is not true, with time having finite limits. During soil formation, time is reset with major catastrophic events, such as landslides, erosion, volcanic activity, and glaciations.

Time has always been considered important to soils. All reactions, movement of materials into and out of the soil, and horizon development requires time. Some developments can occur quickly, while others take a very long time. The actual age of loess deposits, chernozems, and the development of the thick organic horizons were discussed earlier and takes varying degrees of time. Some early classification schemes used the concept of time and soil development exclusively. Terms such as azonal (young), intrazonal (immature), and zonal (normal) were the key categories.

It is clear that the five soil forming factors can be broken into categories, however only when the five are integrated together into the soil ecosystem, can the genesis of a soil be understood.

MATERIALS AND METHODS

Site Selection

The research sites investigated are located in the Kursk Oblast, Russia, to the south of the city Kursk. All sites were located in an upland position (with less than 5% slope), a frigid temperature regime and a udic moisture regime. Four of the soils in this study (sites 3-6) were sampled and described on the V.V. Alekhin Central-Chernozem Biosphere Reserve. These soils are in a protected reserve and have not been significantly impacted by human activity. Sites 4 and 6 are reserve fallow, without cutting or pasture since 1939. Site 5 is also reserve fallow and under the same management since the 1950's. These three sites are considered similar to the native virgin grassland soils. Site 3 is in a reserve forest. The forest has 80 year-old, 5th generation trees, and has been under this management for more than 300 years. The other two soil profiles (site 1 and 2) were sampled on the edge of quarries next to the reserve, and had been under some disturbance (Fig. 3 and 4).

Site1 is located in an experiment station quarry (N 51°31'54.9"; E 36°14'47.8"). Site 2 is located in another quarry on private land (N 51°36'08.2"; E 36°06'35.8"). The two quarry sites were selected to provide an indication of the depth of loess and the distinctive changes of parent materials and their possible influences. Tertiary sands composed the underlying parent material of site 1, while Cretaceous chalks underlie site 2. Both sites had a thick loess covering. Site 3 and 4 are located on the Central-Chernozem Biosphere reserve at N 51°31'53.7"; E 36°05'01.9", and N 51°32'20.1"; E 36°18'21.3", respectively. Site 5 (N 51°34'16.7"; E 36°05'40.6") and site 6 (N 51°32'04.3"; E 36°18'22.3") are also located on the Central-Chernozem Biosphere reserve. These sites were selected because they are located on a preserved area. The sites are intended to be used as a standard for future work in evaluating degradation on other central Chernozem sites.

Field Methods

The six sites were sampled and described in the field according to the Soil Survey Manual (Soil Survey Staff, 1993). The soil profiles were broken into horizons and the depths recorded. Site 4 was not separated into horizons, but was sampled in 10cm increments to a depth of 250cm. Later this site was broken into horizons based on data. Field texture, color, structure, consistence, "fizz-test" reactivity, and other significant physical characteristics were recorded. Approximately 1 kg of each soil horizon was placed in a plastic bag for laboratory analysis and shipped to the U.S.

Laboratory Methods

Each sample was placed in a Revco Scientific Model U 2186 A-O-E freezer (Asheville, N.C.) at -75°C for 72 hours in accordance with U.S.D.A. quarantine regulations. These samples were then air dried and crushed to pass through a 2mm sieve. Approximately one forth of the sample that was < 2mm was further refined to pass through a 60-mesh sieve (Soil Survey Staff, 1996).

Samples that reacted to weak acid "fizz test" were pretreated to remove carbonates with 1*M* NaOAc (adjusted to pH 5) for particle size analysis. An additional pretreatment of 30% H_2O_2 was used to remove organic matter, when necessary. The pipette method was used to determine particle size (Kilmer and Alexander, 1949) with clay and silt separation times based on the work of Gee and Bauder (1986). Sands were separated into very coarse, coarse, medium, fine, and very fine sands using a CSC™ mechanical shaker and a series of sieves. The sand samples were shaken for 5 minutes to separate the fractions before weighing (Gee and Bauder, 1986). Sand, silt and clay were determined based on the USDA system of textural classification.

The citrate-dithionate method was used to extract iron oxides (Olsen and Ellis, 1982). The hydroxylamine hydrochloride method was used to extract manganese oxides (Gambrell and Patrick, 1982). Atomic absorption spectroscopy (Perkin-Elmer model AAnalyst 700) analyzed the oxide extracts.

The Walkley-Black method was used to determine Organic carbon content in the soil samples (Jackson, 1958). Neutralization potential, a part of acid-base accounting, was used to determine calcium carbonate equivalent and the amount of free carbonates in the soils (Sobek, et al., 1978). Chemical properties data from part 2 will be used where necessary.

RESULTS AND DISCUSSION

Site 1

Site one is located at N 51° 31' 54.9" E 36° 14' 47.8" on an upland position. The site is located on the edge of a sand quarry which has been actively used from the 1960's to the 1980's. The surrounding grassland vegetation is reserve fallow and has not been cut or in pasture since 1939. The site has a slight slope of 1% and an elevation of approximately 261 meters above sea level. The soil was sampled to a depth of 324 cm, with a parent material sequence of loess over Tertiary sands.

Particle size analysis revealed silty textures in the upper 144 cm with a maximum silt content of 58% in the surface horizon, which rapidly changed to sandy textures below 144 cm (Table 26). Clay content ranged typically between 37-14% clay with smaller clay fractions in the lowest sand depths (Table 26). The clay values for this site are similar to the interpretations by Kogut (1998) and Mikhailova (2000) who determined clay fractions between 40-15% for typic chernozems of the Kursk Oblast.

Maximum sand content was 91.78%. The discontinuity between the two parent material sequences is clearly evident with the sharp increase in sand content (Fig. 6). The clay content increases between 60-144 cm forming argillic

Table 26. Particle size distribution for site 1.

Horizon	Depth	% VCoS	% CoS	% MS	% FS	% VFS	% Sand	% Silt	% Clay	% Fine Clay
		USDA Particle Size Class								
Ap	0-22	0.11	0.45	1.02	7.24	2.15	10.97	58.17	30.86	20.34
A	22-44	0.20	0.40	1.79	8.94	1.59	12.91	56.13	30.96	20.94
AB	44-60	0.19	0.48	3.07	9.89	1.15	14.79	54.61	30.60	22.27
Bt1	60-76	0.18	0.44	2.91	9.78	1.15	14.45	48.50	37.04	32.98
Bt2	76-106	0.27	0.73	2.54	9.63	1.27	14.45	50.35	35.20	21.65
Bt3	106-144	1.09	1.00	2.10	9.20	0.00	13.39	51.09	35.52	18.23
2Bw	144-159	0.58	2.75	16.44	39.06	2.84	61.68	17.46	20.86	13.06
2C1	159-169	1.00	3.17	33.25	38.51	2.51	78.44	6.82	14.74	12.12
2C2	169-202	0.00	1.19	18.09	59.29	1.10	79.68	4.45	15.87	10.26
2C3	202-247	0.00	6.44	47.49	33.92	0.34	88.20	4.48	7.32	5.45
2C4	247-283	0.00	1.78	26.24	62.73	0.17	90.92	0.69	8.39	6.24
2C5a	283-324	0.00	2.40	28.33	56.74	0.66	88.12	3.96	7.91	7.55
2C5b	283-324	0.00	0.33	15.36	73.04	3.04	91.78	4.04	4.19	3.11

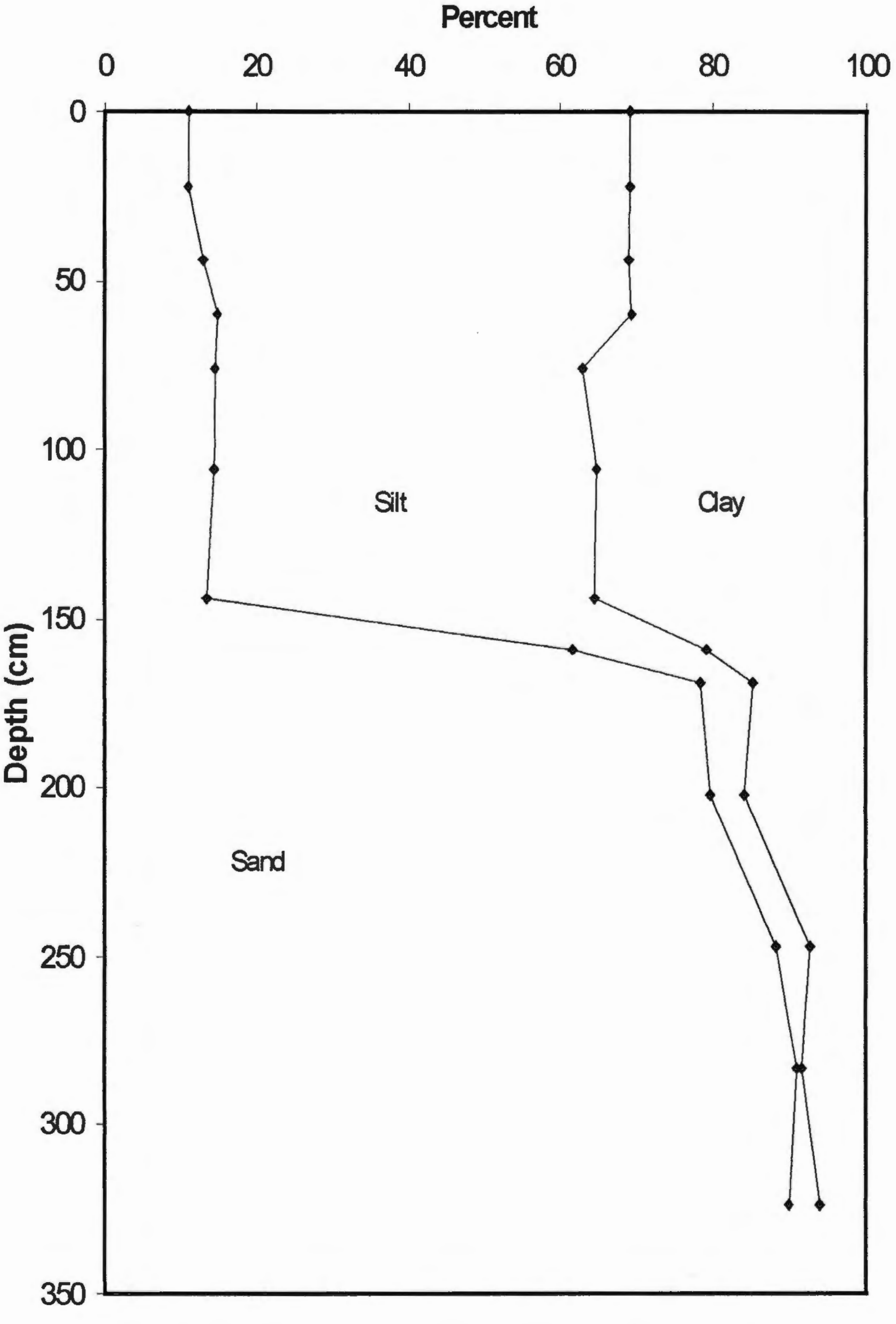

Figure 6. Cumulative particle size plot for Site 1.

horizons through the accumulation of clays from the above eluvial layers. The pedogenic development indicates that the soils have been in place for a significant period of time.

Site one is the only site where the underlying residual parent material is clearly observed. The thinner loess in this region is probably not due to current landscape position. All sites are on flat, broad, uplands. Possibly the loess depths are due to prehistoric vegetation. The Cretaceous chalk parent material is much higher in plant nutrients and was probably succeeded with vegetation before the Tertiary sands in the post-periglacial environment. Subsequent loess depositions may accumulate more rapidly on the prehistoric vegetative structure, and consequently raise the thickness of loess over the Cretaceous chalk parent material compared to the Tertiary sand parent material. Another possibility for the thicker loess deposits over Cretaceous parent material could be attributed to prehistoric landscape positions. The older chalks underlie the sands (Fig. 5). The removal of the horizontally laid sands may have formed ancient landscape depressions. The loess would fill these regions preferentially and form thicker loess deposits over the Cretaceous parent material.

The fine sand content and the Ti:Zr ratio mirror the changes seen in the particle size and the lithologic discontinuity (Fig. 7). Different depositional events within the loess was not evident in the fine sand data, however a peak in the Ti:Zr ratio is evident(Fig.7, Table 27). Titanium and zirconium are highly stable elements and are often used to indicate different parent material sources. The peak may indicate a different loess layer, but may be due to experimental error,

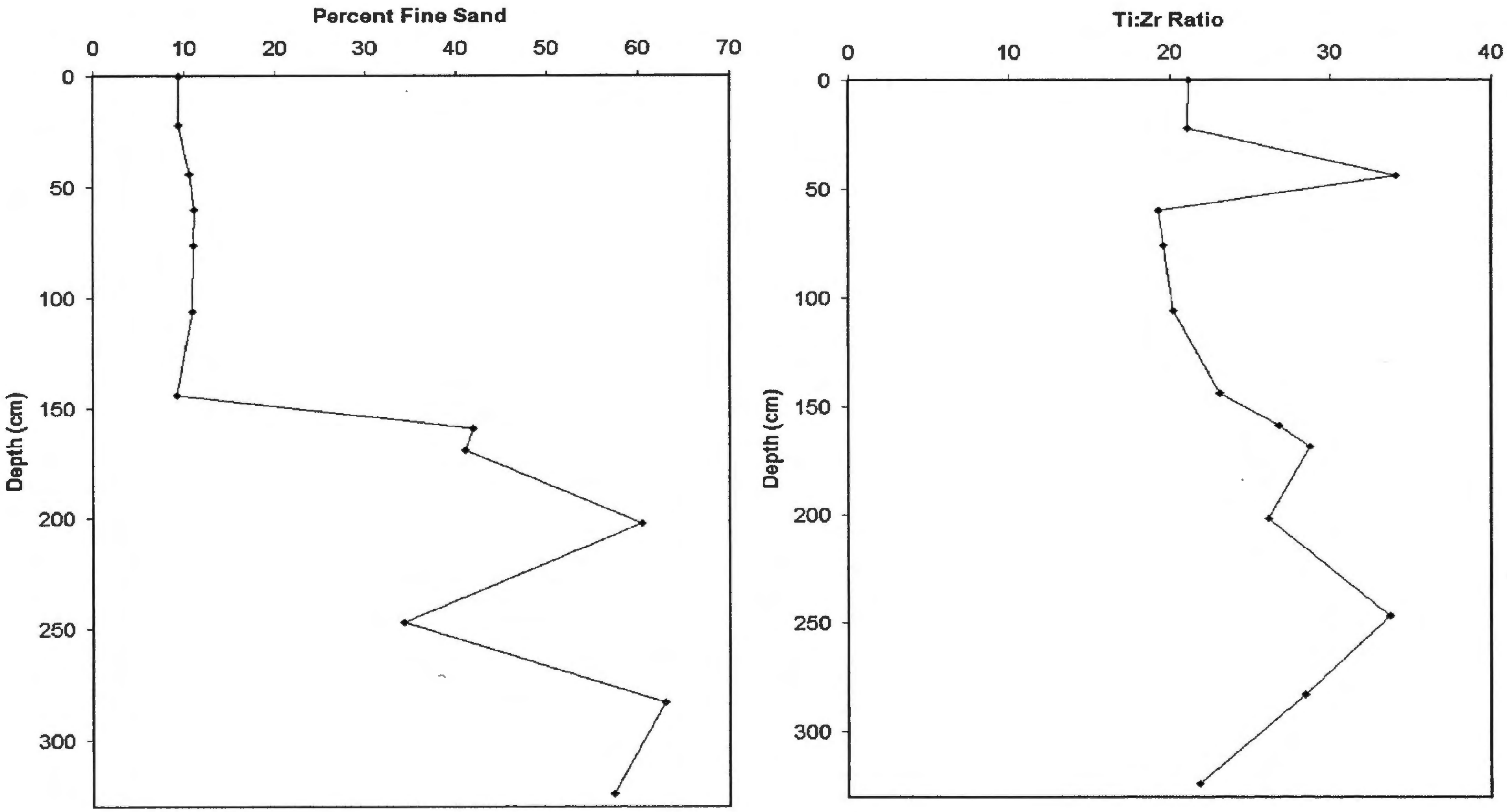

Figure 7. Fine sand and Titanium:Zirconium ratio plots for site 1.

Table 27. Iron, Mn, Ti:Zr, and pH for site 1.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$	Free Fe	Total Fe	Free Mn	Total Mn	Ti:Zr
				------ mg kg^{-1} ------				
Ap	0-22	7.2	6.8	8241	21387	253.75	484	21.14
A	22-44	7.3	6.8	7464	22047	257.18	477	34.08
AB	44-60	6.8	6.2	8833	25410	227.43	492	19.29
Bt1	60-76	7.1	6.8	7856	24981	186.57	459	19.62
Bt2	76-106	7.9	7.3	6748	22725	157.96	408	20.19
Bt3	106-144	8.1	7.6	8294	25440	152.44	386	23.07
2Bw	144-159	8.2	7.6	9893	18798	122.30	204	26.81
2C1	159-169	8.2	7.6	5832	9287	30.93	57	28.73
2C2	169-202	8	7.6	7536	11546	7.46	29	26.13
2C3	202-247	8.1	7.6	7336	8947	1.19	14	33.71
2C4	247-283	8.1	7.5	5255	6654	3.13	15	28.45
2C5a	283-324	8.2	7.6	3773	5364	0.58	<1	21.84
2C5b	283-324	8.3	7.7	354	933	0.45	<1	18.37

since the change is not indicated in any other analysis. Multiple carbonate bulges may indicate the lower extent of different loess depositions. Site 1 has only one carbonate bulge with the accumulation of secondary carbonates occurring between 50-150 cm (Fig. 8).

Free iron oxide concentration was fairly stable throughout the loess layers, while total iron slightly increased with depth (Fig.9, Table 27). The lack of free iron accumulation in the argillic horizons indicates that there has been some minor weathering. The argillic horizons are not much greater in clay accumulation than the above horizons, just managing the 20% increase for Bt classification (Table 26). The change in parent materials to the Tertiary sands is indicated with a rapid decrease in total iron and clay. Free iron nearly accounts for the total iron in this region, and the bright red/orange color (2.5YR hues) of these horizons also indicates that these materials have undergone extensive weathering, oxidation, and exposure to the surface. The paleosol surface was probably removed prior to the loess deposition, creating a truncated soil. A minor clay bulge below the thin 2Bw may be the remnants of ancient clay illuviation.

Redoximorphic features were not obvious in this profile, indicating the profile is well drained, and has not been subject to fluctuating water tables. Evidence of excellent drainage is reflected in the manganese and iron data (Table 27). Easily reducible Mn values are significantly lower than total Mn throughout the profile. The total (Mn^{4+}) and reducible (Mn^{2+}) manganese levels drop with the change in parent materials (Fig.10). The change is due to

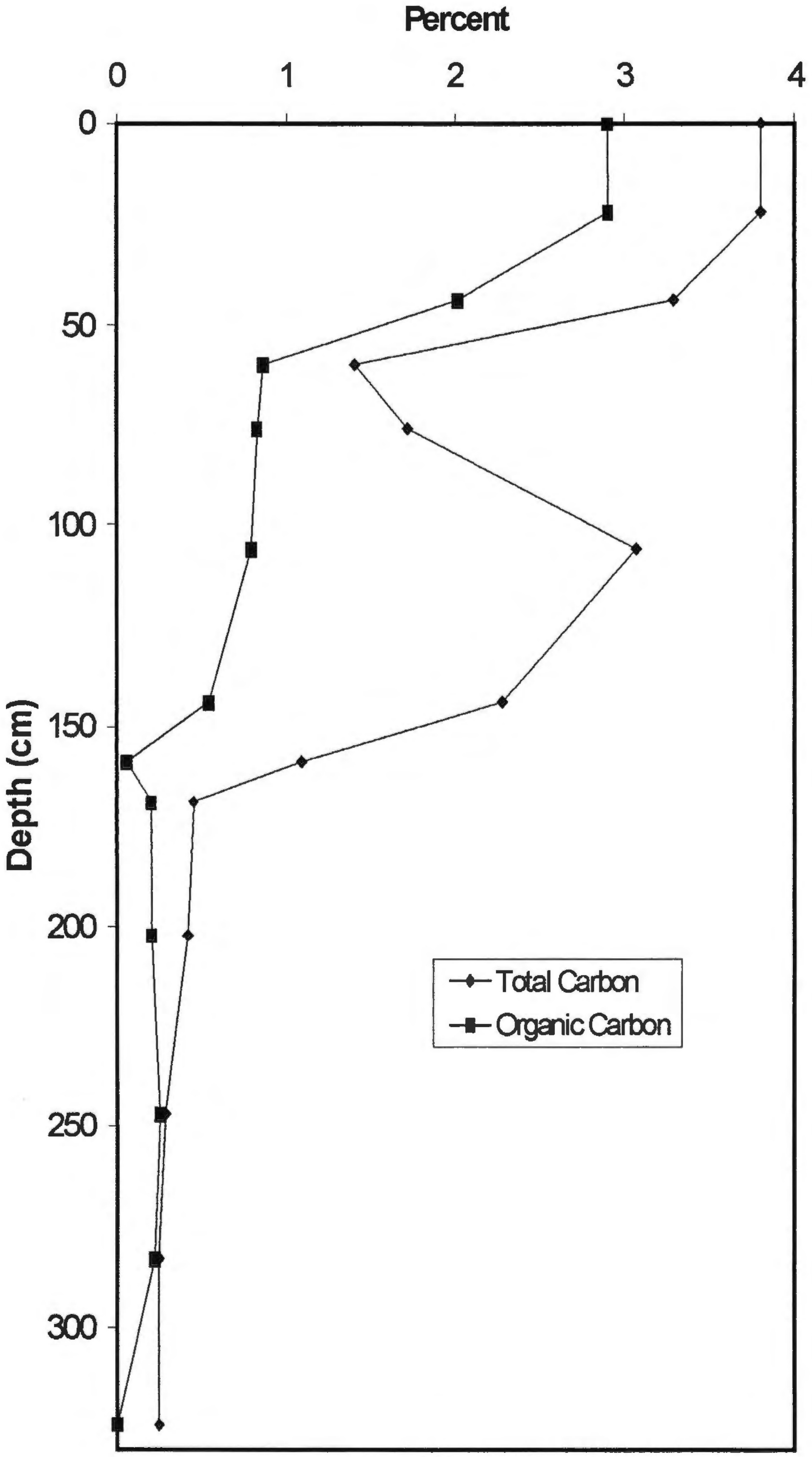

Figure 8. Total and organic carbon plot for site 1.

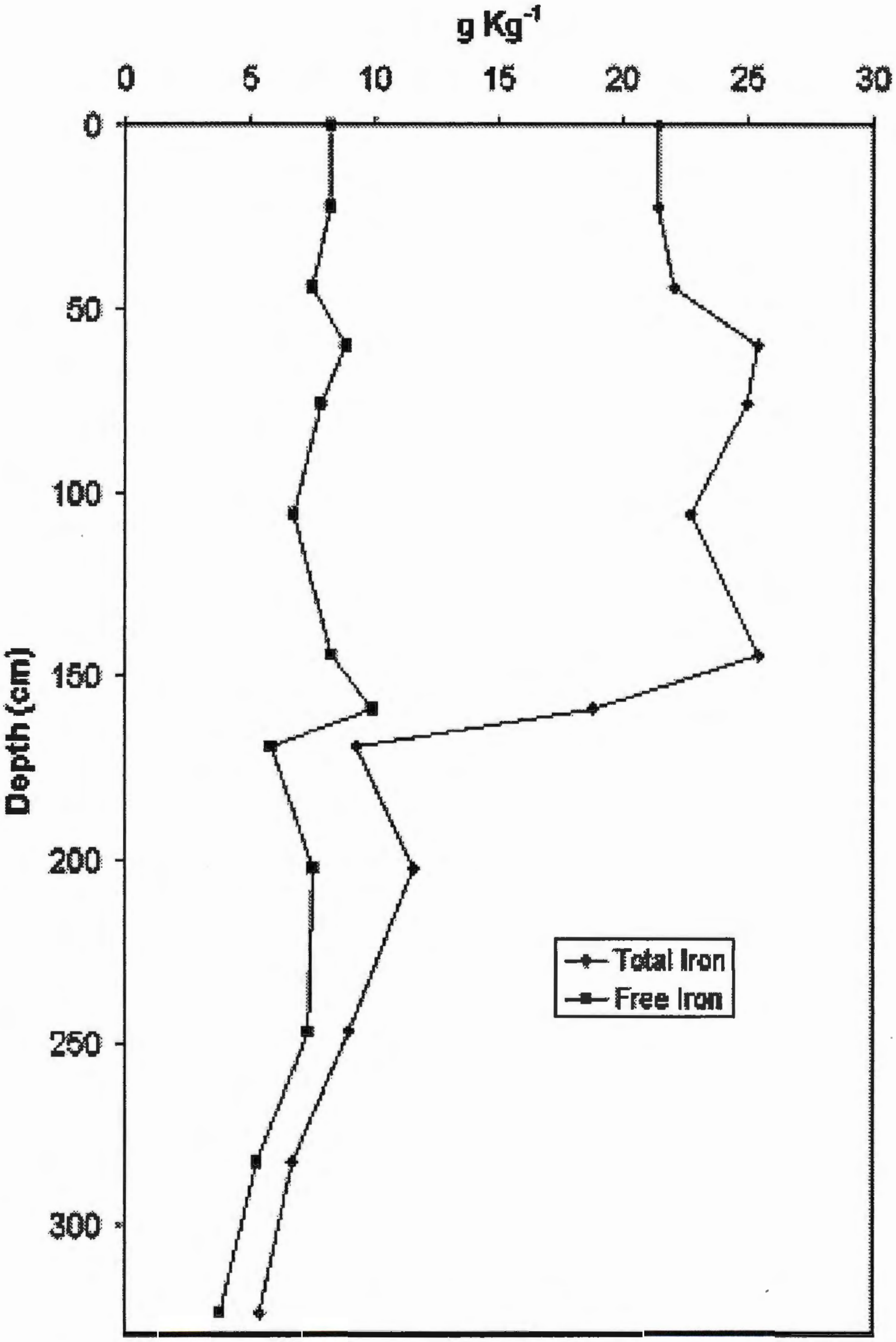

Figure 9. Total and free iron plots for site 1.

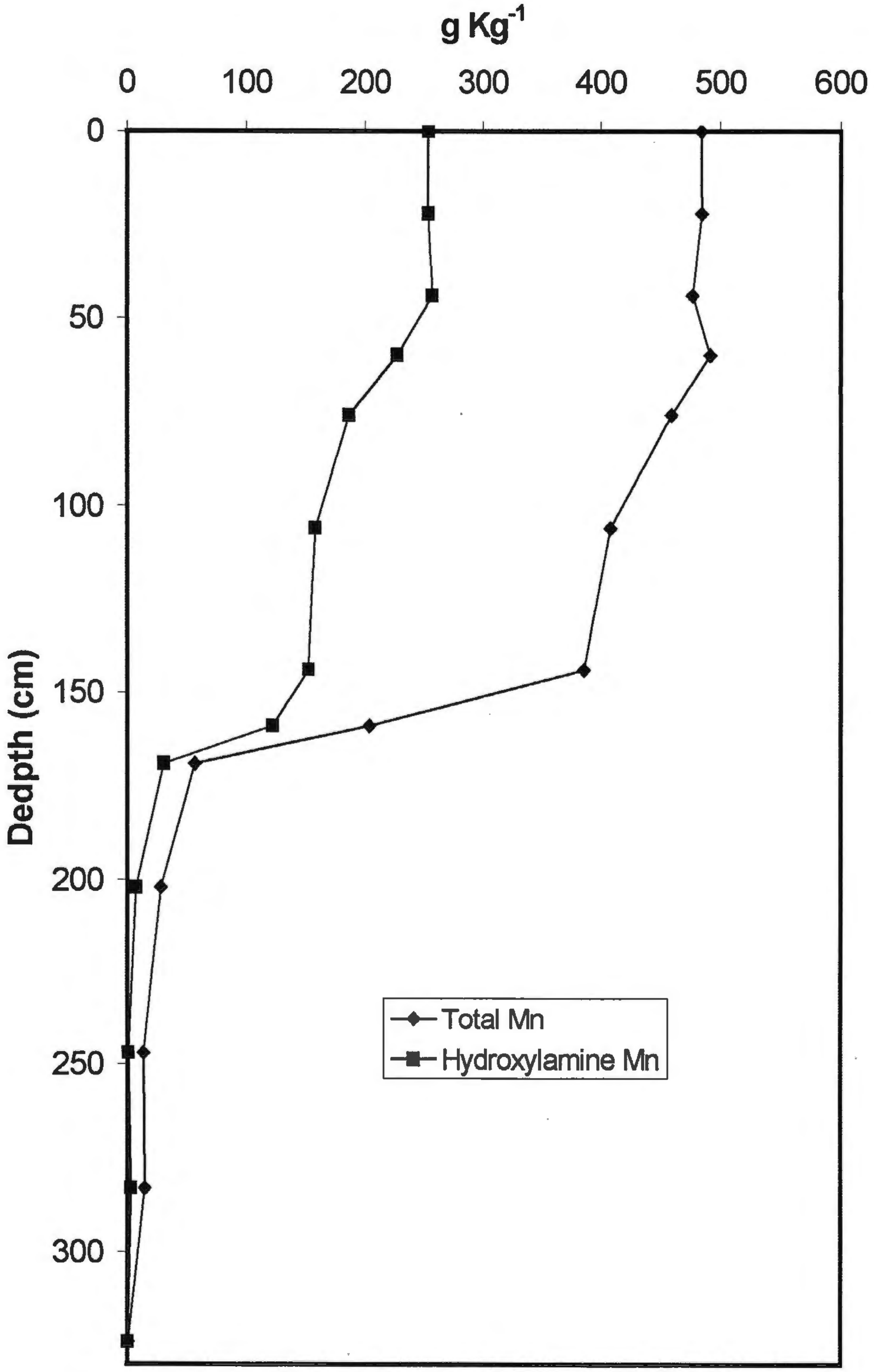

Figure 10. Total and reducible manganese plots for site 1.

mineralogical construction of the Tertiary sands, not a result of drainage changes.

Organic matter accumulation is a key component of chernozem formation. Not surprisingly, organic C is very high in the surface horizon (2.9%) and decreases gradually with depth, forming a typical melanization curve (Table 28, Fig. 8). Humification and melanization of the upper soil horizons is attributed to the breakdown of large quantities of raw organic matter. The two processes are responsible for the formation of the dark, thick, mollic epipedon.

Organic C was lower than the average 2.9% at a depth of 30-50 cm, as determined by Kogut (1998), with an approximate averaged value of 1.5%. Ponomareva (1974) found typic chernozems from the V.V. Alekhin Biosphere Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. The surface of site 1 was not measured; however the other values are very similar with an averaged 0.79% and 0.13% organic C at 1 m and 3 m depths, respectively. In the same study by Ponomareva (1974) nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m, respectively. Nitrogen was also relatively high in this profile with a maximum of 0.27% near the surface and decreasing with depth (Table 28). Average values of 0.10% at 1 m and 0.05% N at 3 m in this research were similarly reflected to Ponomareva (1974). The relatively high nitrogen levels is also reflected in the low C:N ratio. The C:N ratio is typical of chernozemic soils with values of approximately 8:1 to 10:1 in the loess and lower values in the Tertiary sands (Table 27). The results reflect similar findings by Ponomerava (1974) and Chuyan (1987) who estimate

Table 28. Carbon, nitrogen, sulfur data for site 1. Includes totals, organic C, calcium carbonate equivalent*, and C:N ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent	C:N Ratio
		% of soil					
Ap	0-22	0.27	0.05	3.80	2.90		10.60
A1	22-44	0.23	0.05	3.29	2.02		8.77
AB	44-60	0.11	0.04	1.40	0.86		8.23
Bt1	60-76	0.12	0.02	1.71	0.83	2.59	7.13
Bt2	76-106	0.10	0.01	3.07	0.79	14.45	8.14
Bt3	106-144	0.05	0.01	2.28	0.54	13.24	10.17
2Bw	144-159	0.05	0.01	1.09	0.06	4.79	1.26
2C1	159-169	0.08	0.02	0.45	0.20	1.16	2.63
2C2	169-202	0.03	0.01	0.42	0.20	0.87	6.34
2C3	202-247	0.03	0.02	0.28	0.25		9.26
2C4	247-283	0.02	0.02	0.24	0.24		19.53
2C5a	283-324	0.03	0.02	0.25	0.00		0.00
2C5b	283-324	0.08	0.00	0.06	0.27		3.44

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

C:N ratios typically between 8:1-12:1 in the upper 1 m and 4:1-10:1 in the lower depths.

Sites 1 and 2 were more impacted by human activity due to the nearby quarry use. Results from this study indicate that N values were slightly lower, while most other components, including organic C, were very similar to the minimally disturbed profiles. The management and results are similar to the other sites and reflect the lack of difference between the profiles with regard to chemical characterization as discussed in Part 2.

Site 2

Site two is located at N 51°36'08.2" E 36°06'35.8" on an upland position. The site is located on the edge of a clay quarry with surrounding grassland (particularly barley) and birch tree vegetation. The region has had crop rotation of winter wheat, sugar beet, barley, and clover. The clay quarry has been actively used since the 1960's. The site has a slight slope of 2% and an elevation of approximately 258 meters above sea level. The soil was sampled to a depth of 400 cm with a parent material sequence of loess over Cretaceous chalks.

Particle size analysis revealed silty textures with the silt fraction ranging from 69.91% to 57.80% (Table 29). Clay content ranged typically between 38-27% clay (Table 29, Fig.11). The clay values for this site are similar to the interpretations by Kogut (1998) and Mikhailova (2000) who determined clay fractions between 40-15% for typic chernozems of the Kursk Oblast.

Table 29. Particle size distribution for site 2.

Horizon	Depth	% VCoS	% CoS	% MS	% FS	% VFS	% Sand	% Silt	% Clay	% Fine Clay
		USDA Particle Size Class								
Ap	0-25	0.00	0.00	0.16	0.16	1.41	1.72	68.42	29.87	22.46
A	25-45	0.00	0.00	0.00	0.87	0.00	0.87	69.91	29.22	23.01
AB	45-85	0.00	0.83	0.41	2.18	0.00	3.42	69.11	27.47	15.79
BA	85-135	0.00	0.34	0.08	0.25	0.67	1.35	68.64	30.02	12.31
Bt1	135-195	0.00	0.28	0.56	1.21	2.33	4.37	57.80	37.82	15.28
Bt2	195-260	0.00	0.27	0.45	1.16	1.79	3.67	58.93	37.40	15.74
Bt3	260-319	0.10	0.21	0.41	0.62	2.47	3.80	60.81	35.38	14.56
Bt4	319-368	0.11	0.22	0.11	0.56	2.91	3.91	62.36	33.72	12.64
Bt5	368-400	0.00	0.09	0.09	2.50	0.00	2.69	63.92	33.39	13.72

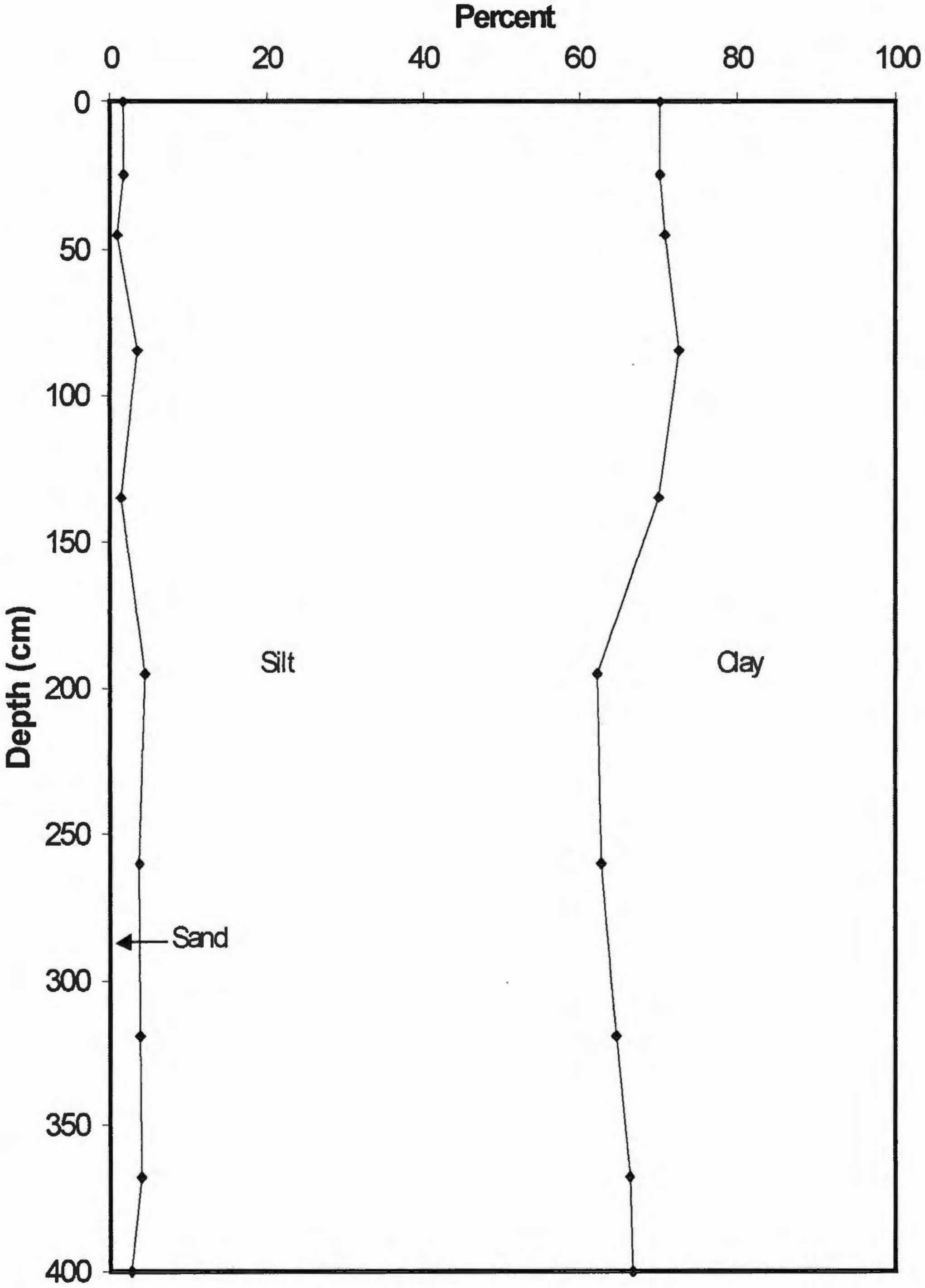

Figure 11. Cumulative particle size plot for Site 2.

Maximum sand content was only 4.37% with fine sand comprising most of the sand fraction (Table 29). No discontinuity was evident in this profile. The fine sand and Ti:Zr ratio increases slightly at approximately 200 cm (Fig. 12) perhaps indicating a different loess deposit, although this is not strong enough evidence to substantiate conclusive loess layers. The depth to Cretaceous chalks was below the sampled depth. As previously discussed, the loess at site 2 is much deeper than site 1. The clay content increases at 135 cm and continues to 400 cm, forming argillic horizons through the accumulation of clays from the above elluvial layers. The pedogenic development indicates that the soils have been in place for a significant period of time.

Multiple carbonate bulges may indicate the lower extent of different loess depositions. Site 2 has two carbonate bulges, with the accumulation of secondary carbonates occurring approximately between 80-175 cm and 300 – 350 cm (Fig. 13). According to the graphs, the boundary between the loess layers is around 175 cm and 350 cm with the third loess deposition continuing past 400 cm. The determination of three loess layers would correspond to the belief that three major glacial movements occurred in the Quaternary period (Nalivkin, 1973). These changes resemble the changes in fine sand and Ti:Zr ratio, but are still inconclusive. Loess from the same source is difficult to distinguish between particularly with chemical composition, so perhaps the carbonate bulges are more conclusive to determine loess depositions.

Free iron oxide concentration was fairly stable throughout the upper horizons, but it increased below approximately 175 cm and 350 cm. Total iron

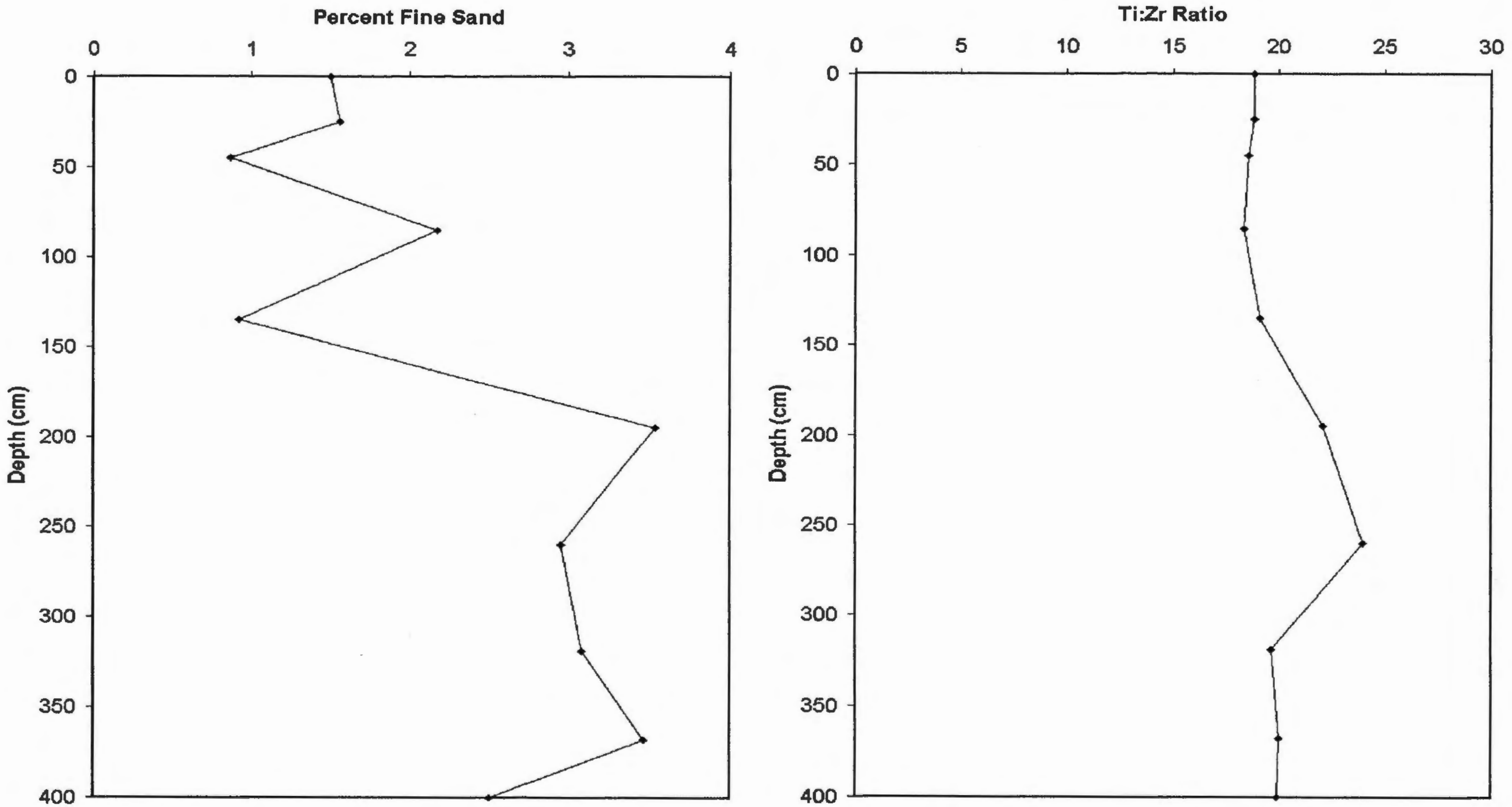

Figure 12. Fine sand and Titanium:Zirconium ratio plots for site 2.

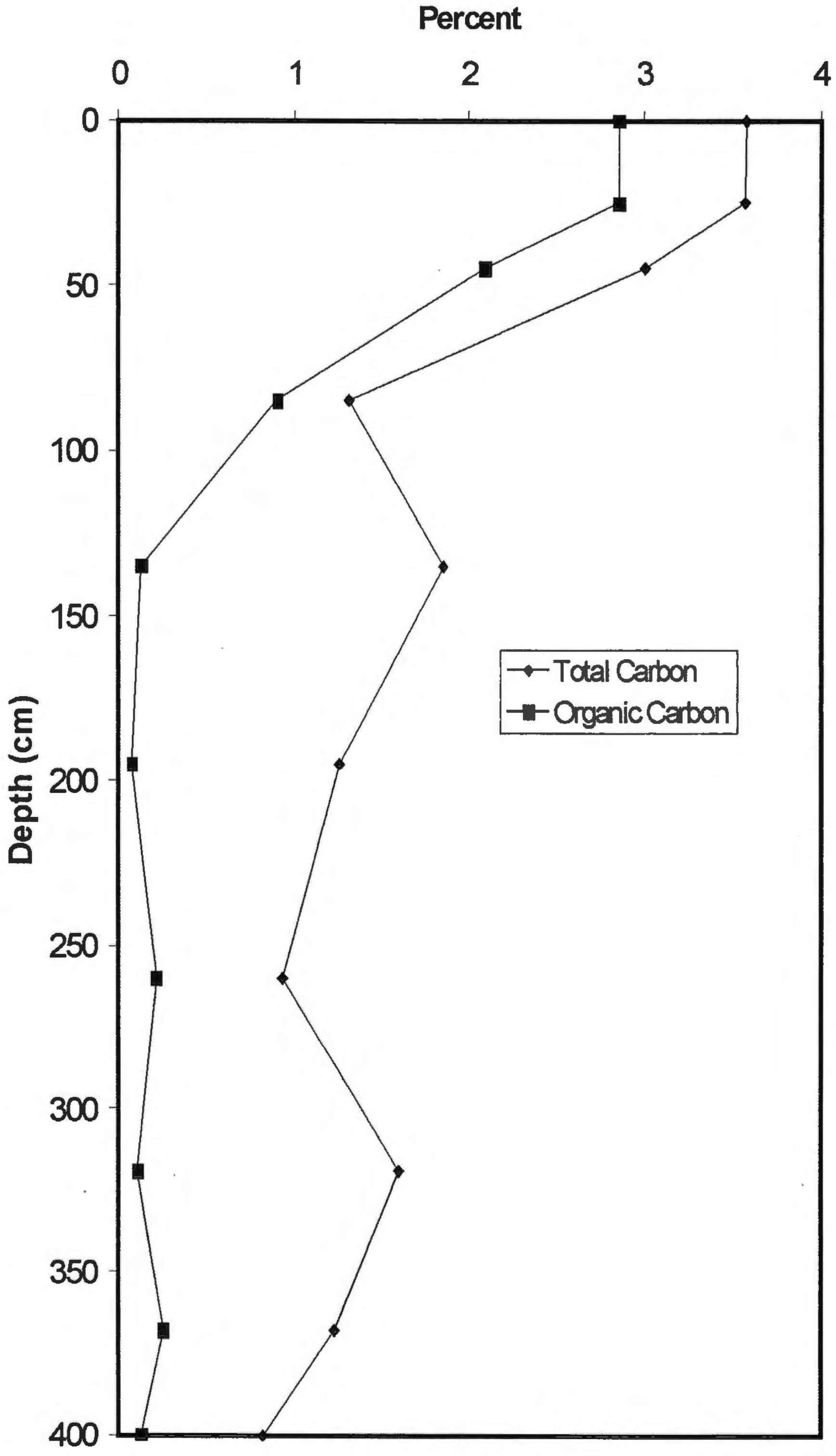

Figure 13.Total and organic carbon plot for site 2.

followed a similar pattern to the free iron (Fig.14, Table 30). The lack of free iron accumulation in the upper argillic horizons indicates that there has been some minor weathering. The depths of increased weathering appear to correspond to the carbonate bulges and the subsequent intermittent periods of weathering between loess depositions.

The argillic horizons have greater clay accumulation than the above horizons, demonstrating the 20% increase required for Bt designation (Table 29). Redoximorphic features were not obvious in this profile, indicating the profile is well drained and has not been subject to fluctuating water tables. Evidence of excellent drainage is reflected in the manganese and iron data (Table 30). Easily reducible Mn values are significantly lower than total Mn throughout the profile. The total (Mn^{4+}) and reducible (Mn^{2+}) manganese levels decrease slightly with depth, except for two small increases at approximately 85 cm and 325 cm (Fig.15).

Organic matter accumulation is a key component of chernozem formation. Not surprisingly, organic C is very high in the surface horizon (2.86%) and decreases gradually with depth, forming a typical melanization curve (Table 31, Fig. 13). Humification and melanization of the upper soil horizons is attributed to the breakdown of large quantities of raw organic matter. The two processes are responsible for the formation of the dark, thick, mollic epipedon.

Organic C was lower than the average 2.9% at a depth of 30-50 cm, as determined by Kogut (1998) with an approximate averaged value of 2.1%. Ponomareva (1974) found typic chernozems from the V.V. Alekhin Biosphere

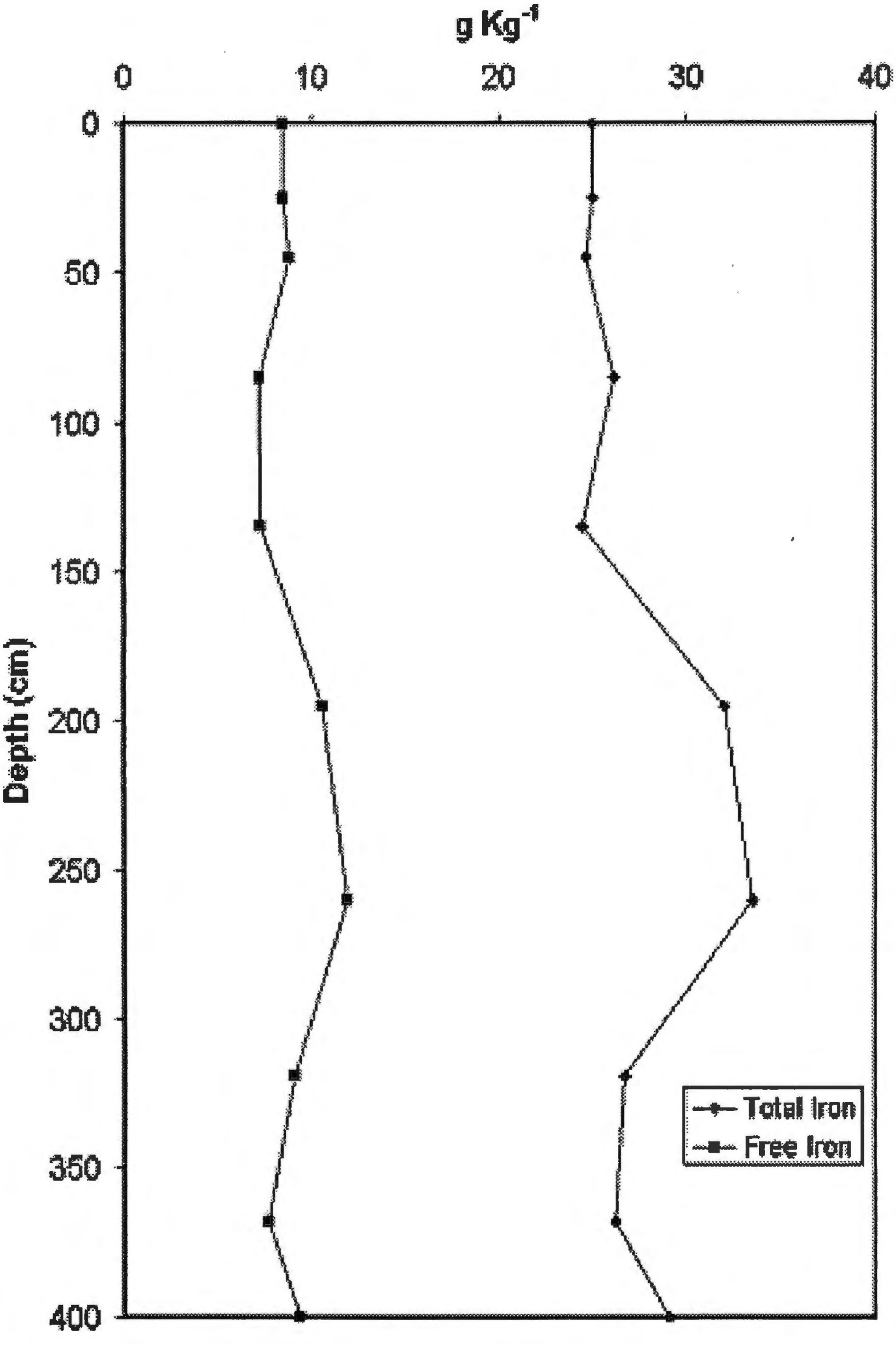

Figure 14. Total and free iron plots for site 2.

Table 30. Iron, Mn, Ti:Zr, and pH for site 2.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$	Free Fe	Total Fe	Free Mn	Total Mn	Ti:Zr
				mg kg^{-1}				
Ap	0-25	7.6	7.2	8433	25006	276.93	556	18.84
A	25-45	7.4	7	8805	24652	271.86	529	18.57
AB	45-85	7.2	6.8	7144	26150	303.74	536	18.33
BA	85-135	8	7.6	7210	24473	249.66	493	19.11
Bt1	135-195	8.2	7.7	10522	31984	219.80	517	22.09
Bt2	195-260	8.2	7.8	11877	33485	190.46	517	23.97
Bt3	260-319	8.1	7.8	9080	26696	298.00	542	19.64
Bt4	319-368	8.3	7.9	7651	26188	214.14	455	20.03
Bt5	368-400	7.7	7.1	9347	29138	169.58	441	19.91

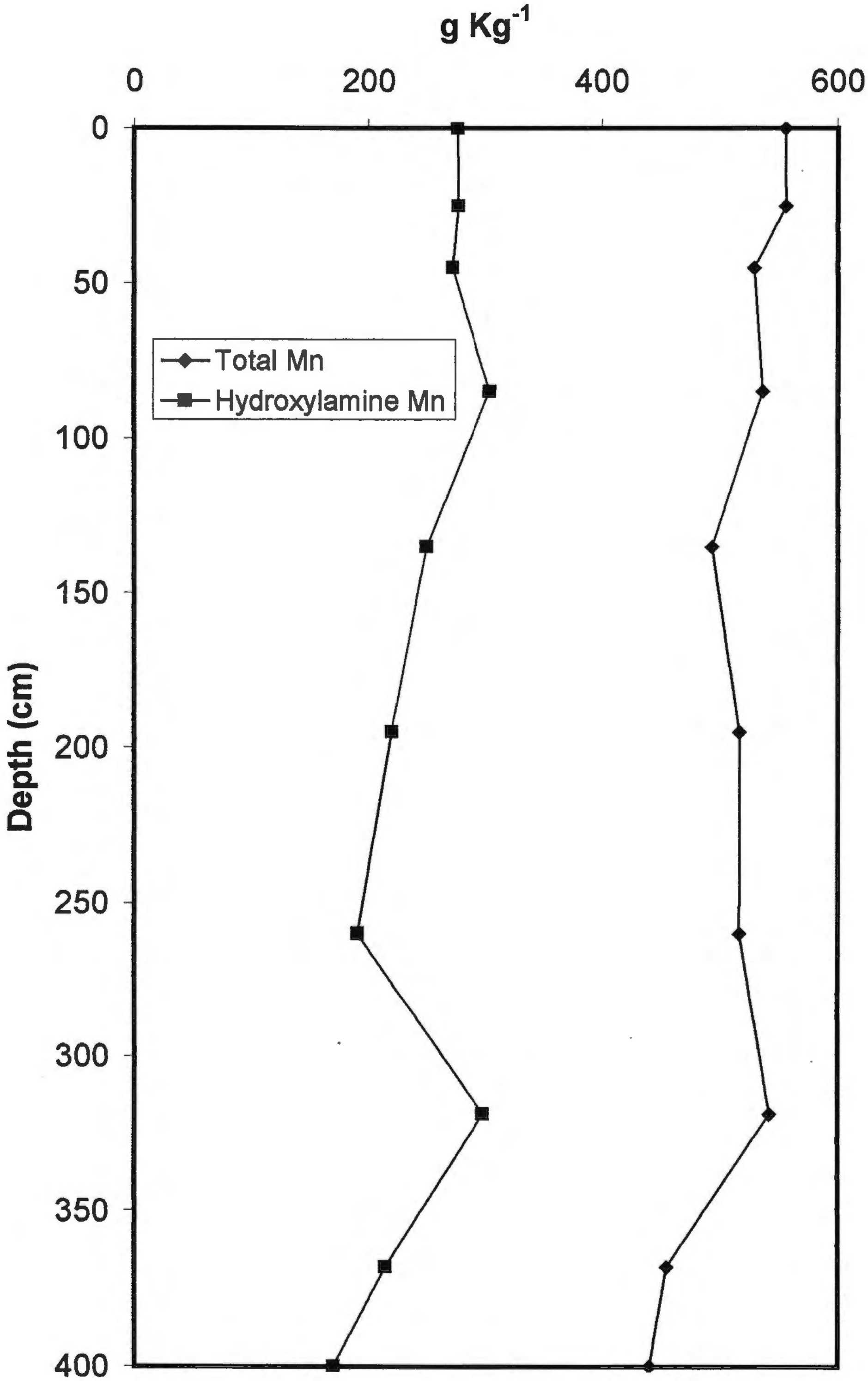

Figure 15. Total and reducible manganese plots for site 2.

Table 31. Carbon, nitrogen, sulfur data for site 2. Includes totals, organic C, calcium carbonate equivalent*, and C:N ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent	C:N Ratio
		% of soil					
Ap	0-25	0.25	0.06	3.58	2.86		11.28
A	25-45	0.21	0.06	3.01	2.09		9.88
AB	45-85	0.10	0.05	1.31	0.90	11.17	8.59
BA	85-135	0.05	0.02	1.85	0.13	5.88	2.52
Bt1	135-195	0.08	0.02	1.26	0.07	3.09	0.93
Bt2	195-260	0.08	0.03	0.93	0.22	8.62	2.61
Bt3	260-319	0.07	0.02	1.60	0.11	5.27	1.62
Bt4	319-368	0.07	0.03	1.23	0.25	2.31	3.59
Bt5	368-400	0.06	0.03	0.82	0.13	11.17	2.02

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. The surface of site 2 was not measured; however site 2 had much lower organic C at 1 m with approximately 0.13%, while 0.11% organic C at 3 m was similar to the other research. In the same study by Ponomareva (1974) nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m, respectively. Nitrogen was also relatively high in this profile with a maximum of 0.25% near the surface and decreasing with depth (Table 31). Values of 0.05% at 1 m were lower than expected, while 0.07% N at 3 m was slightly higher. Anthropogenic influence may be the cause of the slightly lower values compared to the work by Ponomareva (1974). Site 2 does have a crop rotation management regime and this may influence slightly lower N values compared to the reserve fallow of site 1 and other research findings. The relatively high nitrogen levels is also reflected in the low C:N ratio. The C:N ratio is typical of chernozemic soils, with values of approximately 8:1 to 10:1 in the loess (Table 31). The results reflect similar findings by Ponomerava (1974) and Chuyan (1987) who estimate C:N ratios typically between 8:1-12:1 in the upper 1 m and 4:1-10:1 in the lower depths.

Sites 1 and 2 were more impacted by human activity. Results from this study indicate that N values and organic C were slightly lower, while most other components were very similar to the minimally disturbed profiles. These results reflect the similar findings for the lack of difference between the profiles with regard to chemical characterization as discussed in Part 2.

Site 3

Site three is located at N 51°31'53.7" E 36°05'01.9" on an upland position. The site is located in a forest, dominated by oak trees. The trees are up to 80 years old and are considered 5th generation trees. The site has been undisturbed for over 300 years. The site has a slight slope of 1% and an elevation of approximately 262 meters above sea level. The soil was sampled to a depth of 315 cm with a parent material sequence of loess over Cretaceous chalks.

Particle size analysis revealed silty textures with the silt fraction ranging from 76% to 64% (Table 32). Clay content ranged typically between 34-21% clay (Table 32, Fig.16). The clay values for this site are similar to the interpretations by Kogut (1998) and Mikhailova (2000) who determined clay fractions between 40-15% for typic chernozems of the Kursk Oblast.

Maximum sand content was only 5.69% (Table 32). No discontinuity was evident in this profile. The fine sand does increase slightly and erratically as depth increases (Fig. 17), while the Ti:Zr ratio decreases slightly and erratically (Fig.17). The results are not conclusive enough to substantiate loess layers. The depth to Cretaceous chalks was below the sampled depth. Unlike sites 1 and 2, the clay content does not increase more than 20% with depth from the above horizon and has cambic horizons, instead of the argillic horizons. The pedogenic development indicates that site 3 has been subjected to significantly less weathering compared to sites 1 and 2.

Table 32. Particle size distribution for site 1.

Horizon	Depth	% VCoS	% CoS	% MS	% FS	% VFS	% Sand	% Silt	% Clay	% Fine Clay
		USDA Particle Size Class								
A1	0-34	0.00	0.00	0.00	0.00	0.95	0.95	69.81	29.24	21.12
A2	34-69	0.00	0.00	2.31	0.09	0.56	2.96	68.34	28.70	22.11
AB	69-85	0.00	0.00	0.09	0.09	1.24	1.42	69.79	28.80	1.68
Bw1	85-102	0.09	0.09	0.09	0.17	0.96	1.40	69.85	28.75	0.33
Bw2	102-140	0.00	0.10	0.10	0.51	1.82	2.53	65.71	31.77	0.08
Bw3	140-191	0.17	0.08	0.08	0.25	1.35	1.94	64.18	33.89	0.05
C1	191-230	0.13	0.13	0.27	0.27	2.82	3.62	73.36	23.02	0.02
C2	230-240	0.00	0.35	0.00	0.00	3.11	3.46	72.32	24.22	0.02
C3	240-260	0.13	0.00	0.00	0.38	2.15	2.66	67.04	30.30	0.38
C4	260-285	0.73	0.49	0.00	0.12	2.92	4.25	74.15	21.59	0.02
C5	285-295	0.36	0.18	0.18	0.18	4.80	5.69	71.16	23.15	0.21
C6	295-305	0.11	0.44	0.11	0.11	2.86	3.63	73.40	22.97	0.19
C7	305-315	0.13	0.25	0.00	0.13	2.66	3.17	76.05	20.78	0.12

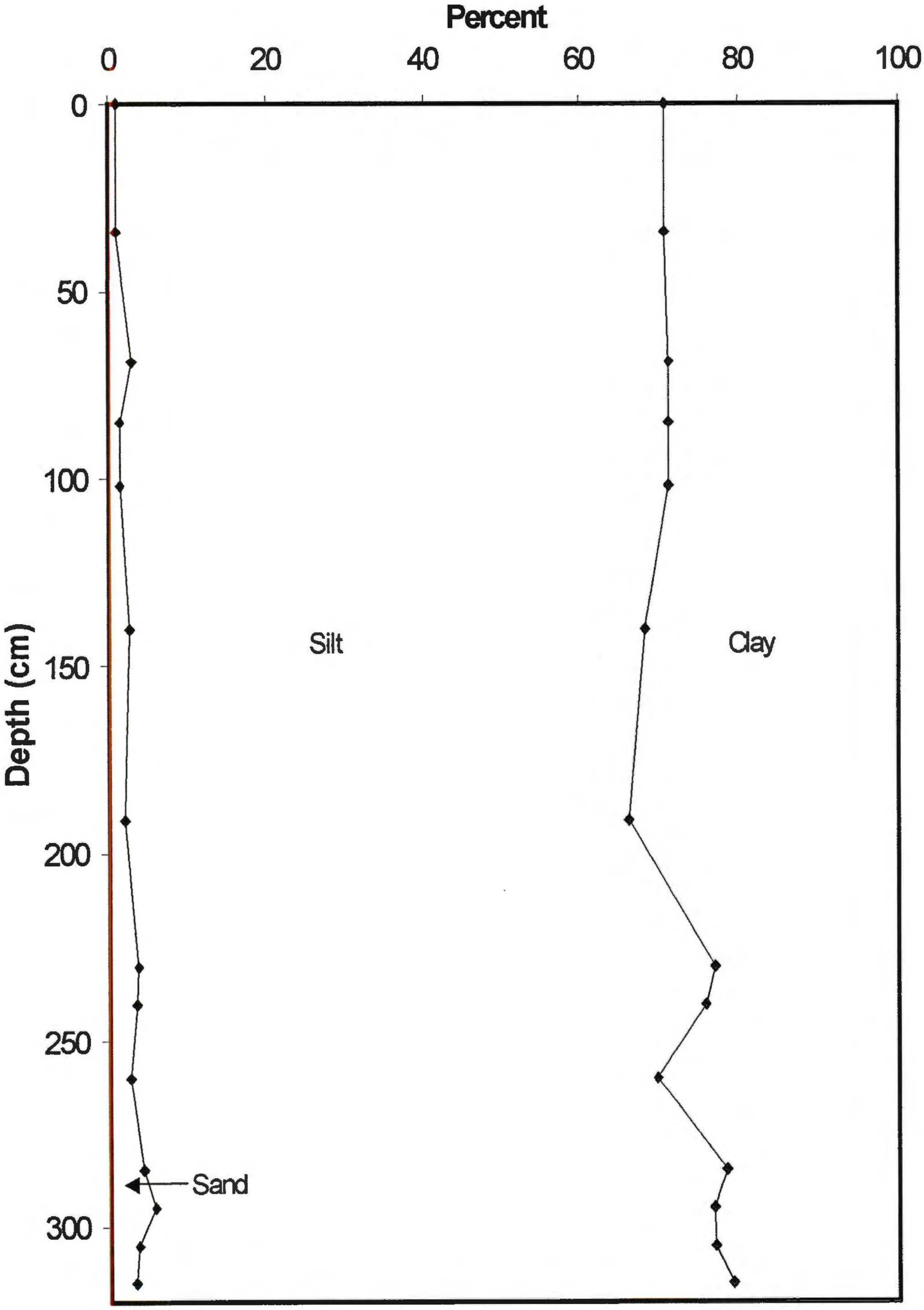

Figure 16. Cumulative particle size plot for Site 3.

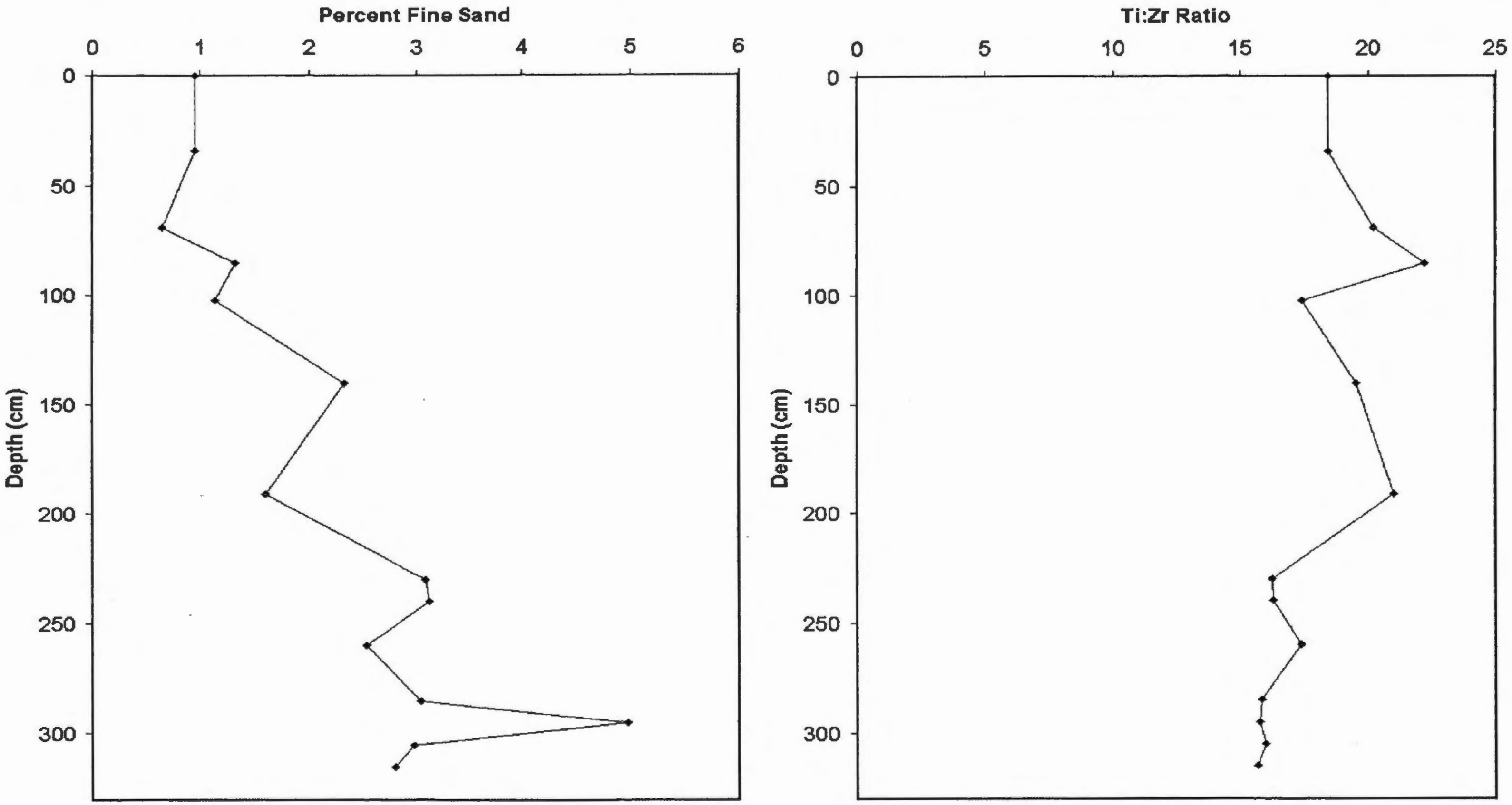

Figure 17. Fine sand and Titanium:Zirconium ratio plots for site 3.

Multiple carbonate bulges may indicate the lower extent of different loess depositions. Site 3 has only one prominent carbonate bulge with the accumulation of secondary carbonates approximately occurring between 80-175 cm (Fig. 18). According to the graph, the boundary between the loess layers is possibly around 175 cm, which is almost identical to site 2. The shallower depth of this site may hide evidence of other loess deposits below. The changes are not reflected in fine sand and Ti:Zr ratio. Loess from the same source is difficult to distinguish between. Carbonate bulges may be more conclusive to determine loess depositions.

Free iron oxide concentration was fairly stable throughout the profile, decreasing slightly with depth. Total iron followed a similar pattern to the free iron, although a little fluctuation exists in the lower horizons (Fig.19, Table 33). The profile shows only minor weathering in the iron data, and this is also reflected in the particle size data and the determination of cambic diagnostic subsurface horizons.

Redoximorphic features were not obvious in this profile, indicating the profile is well drained, and has not been subject to fluctuating water tables. Evidence of excellent drainage is reflected in the manganese and iron data (Table 33). Easily reducible Mn values are significantly lower than total Mn throughout the profile. The total (Mn^{4+}) and reducible (Mn^{2+}) manganese levels decrease slightly with depth, except for some minor increases at approximately 190 cm and 260 cm (Fig.20).

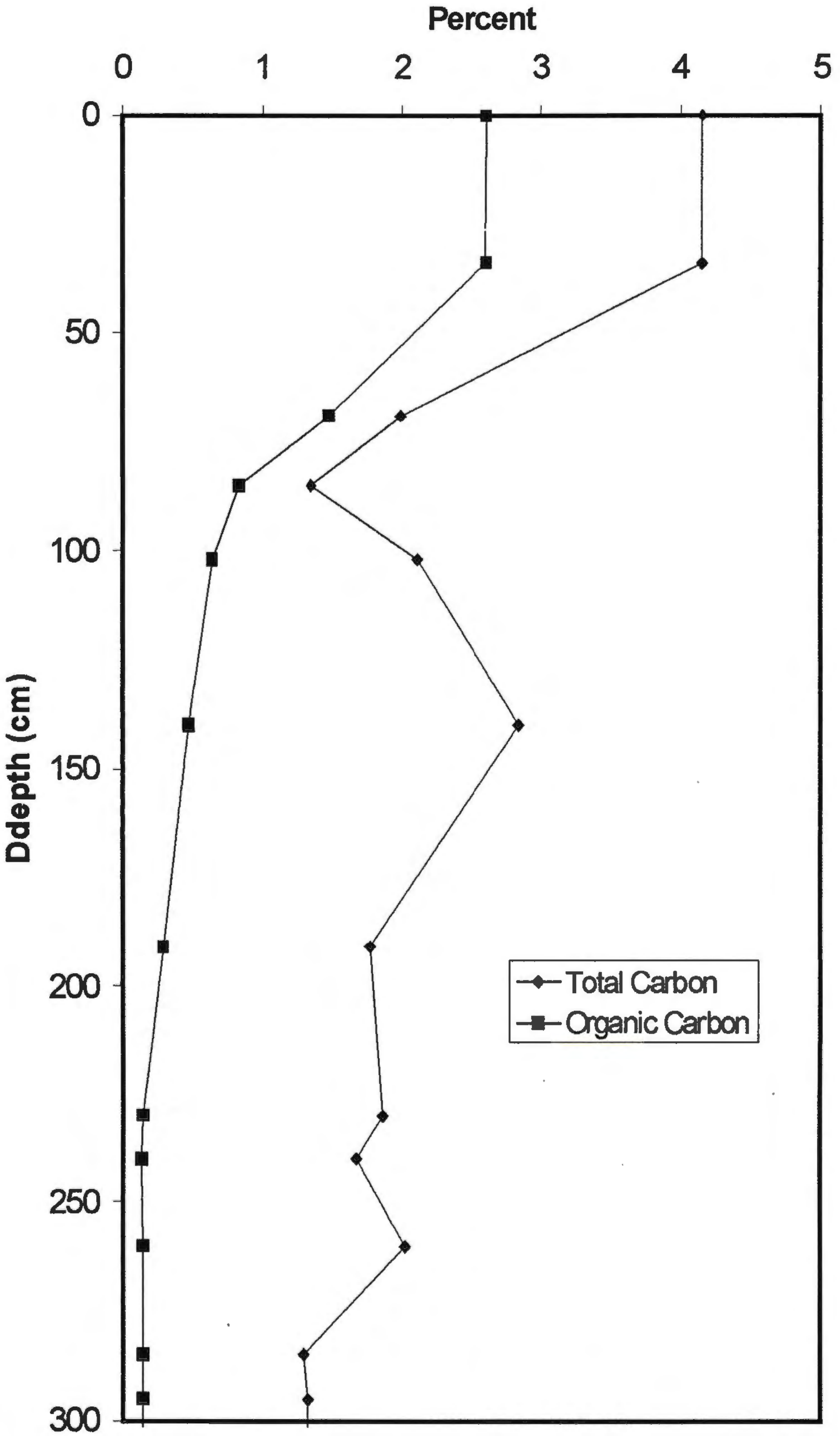

Figure 18. Total and organic carbon plot for site 3.

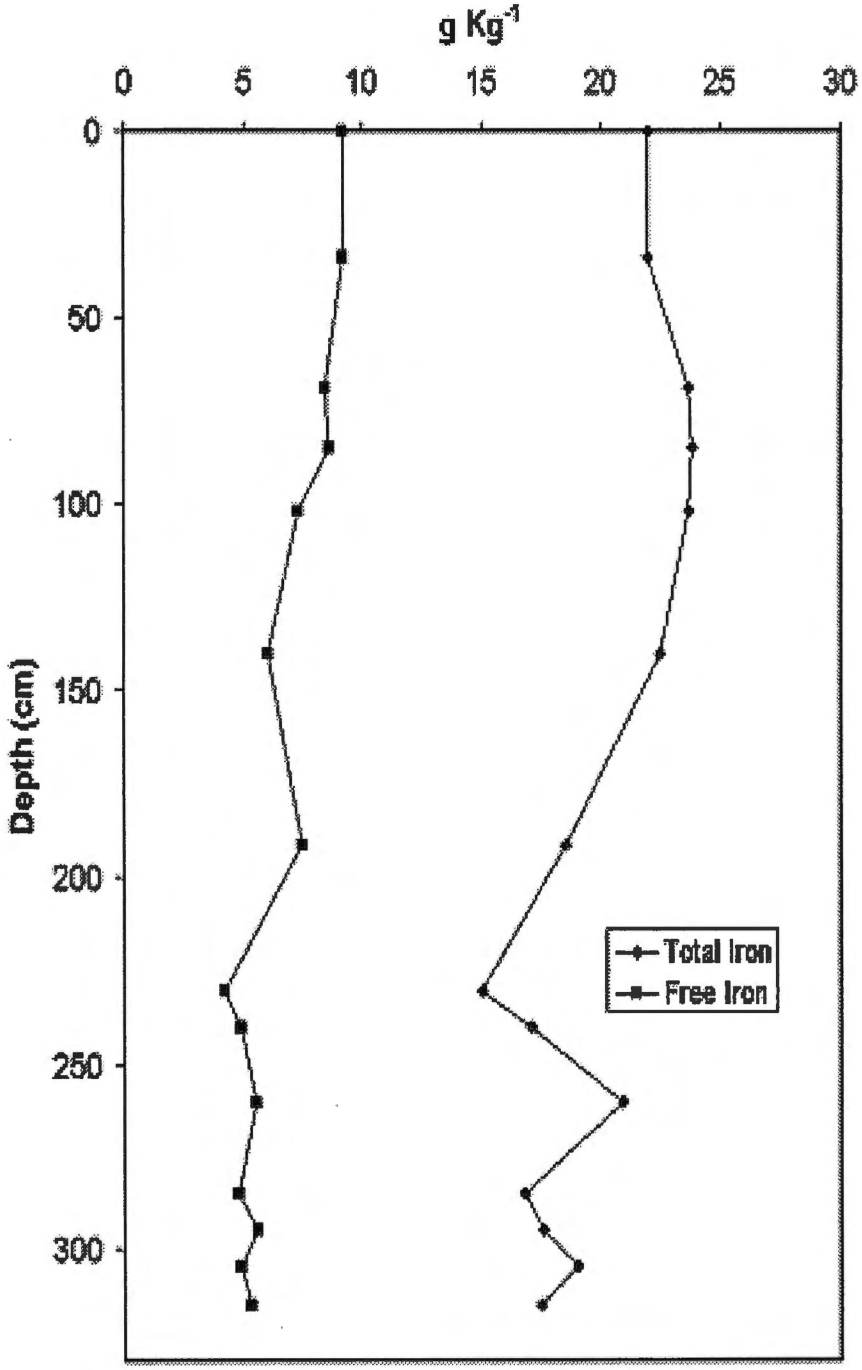

Figure 19. Total and free iron plots for site 3.

Table 33. Iron, Mn, Ti:Zr, and pH for site 3.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$	Free Fe	Total Fe	Free Mn	Total Mn	Ti:Zr
				mg kg^{-1}				
A1	0-34	7.2	6.8	9196	21981	327.56	559	18.41
A2	34-69	7	6.6	8473	23642	233.35	409	20.20
AB	69-85	7.2	6.6	8612	23821	232.91	485	22.17
Bw1	85-102	7.7	7	7269	23647	199.55	453	17.42
Bw2	102-140	8	7.3	6007	22491	182.91	387	19.53
Bw3	140-191	8.2	7.4	7460	18555	240.03	433	20.97
C1	191-230	8.2	7.4	4169	15020	147.70	335	16.23
C2	230-240	8.2	7.5	4857	17051	144.09	343	16.27
C3	240-260	8.2	7.6	5519	20940	182.58	405	17.37
C4	260-285	8.2	7.5	4755	16790	189.51	383	15.83
C5	285-295	8.3	7.5	5556	17569	171.70	386	15.74
C6	295-305	8.2	7.6	4850	19005	148.98	365	15.96
C7	305-315	8.3	7.7	5293	17506	142.40	329	15.66

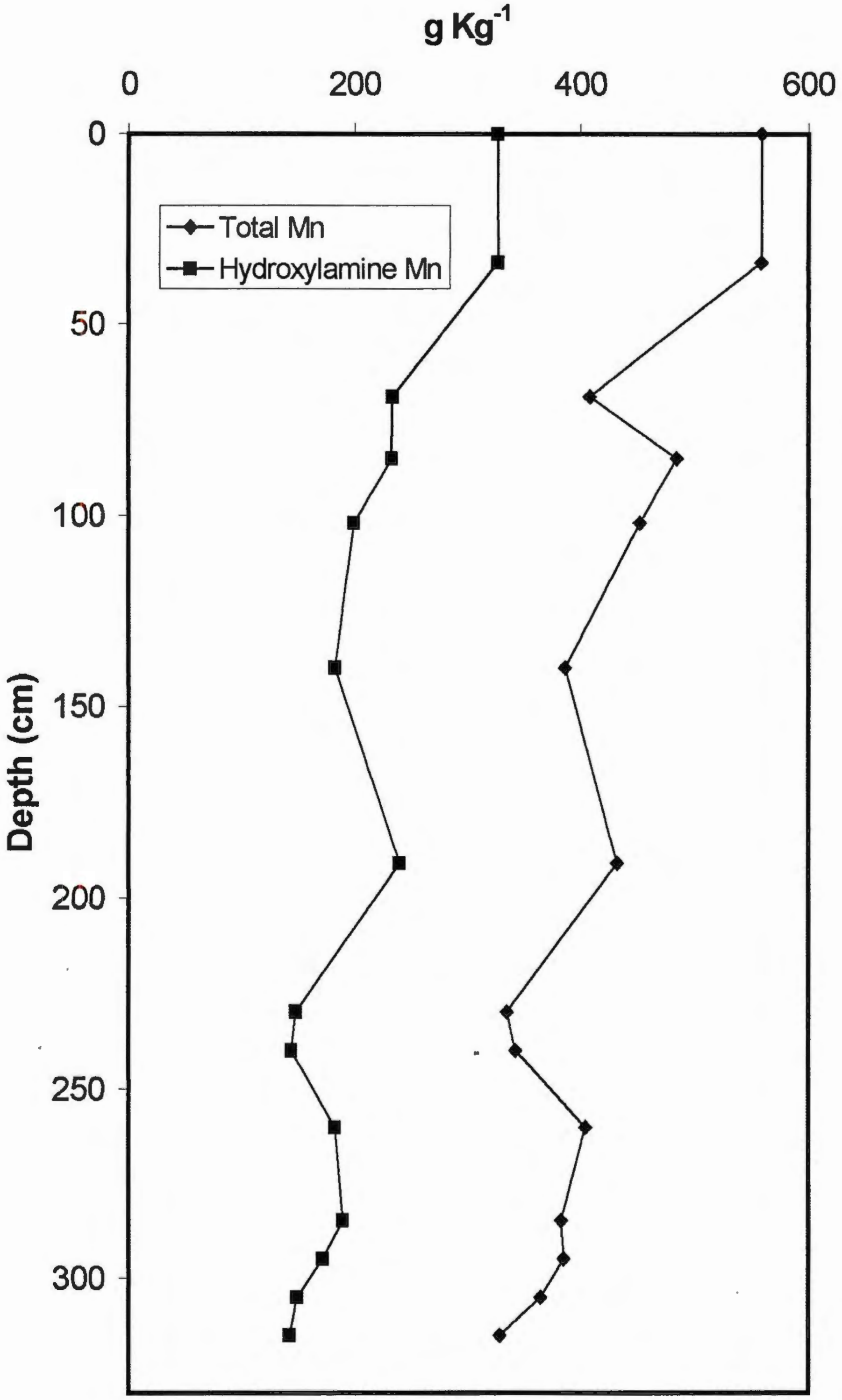

Figure 20. Total and reducible manganese plots for site 3.

Organic matter accumulation is a key component of chernozem formation. Not surprisingly, organic C is very high in the surface horizon (2.61%) and decreases gradually with depth, forming a typical melanization curve (Table 34, Fig. 18). Humification and melanization of the upper soil horizons is attributed to the breakdown of large quantities of raw organic matter. The two processes are responsible for the formation of the dark, thick, mollic epipedon.

Organic C was lower than the average 2.9% determined by Kogut (1998) at a depth of 30-50 cm. The value for this site averaged approximately 1.5% at that depth. Ponomareva (1974) found typic chernozems from the V.V. Alekhin Biosphere Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. The surface of site 3 was not measured; however the other values are similar with an averaged 0.64% and 0.15% organic C at 1 m and 3 m depths, respectively. In the same study by Ponomareva (1974) nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m respectively. Nitrogen was also relatively high in this profile with a maximum of 0.30% near the surface and decreasing with depth (Table 34). Average values of 0.10% at 1 m and 0.05% N at 3 m were similarly reflected in this research to Ponomareva (1974).

The relatively high nitrogen levels is also reflected in the low C:N ratio. The C:N ratio is typical of chernozemic soils with values of approximately 10:1 decreasing to 3:1 at lower depths (Table 34). The results reflect similar findings by Ponomerava (1974) and Chuyan (1987) who estimate C:N ratios typically between 8:1-12:1 in the upper 1 m, and 4:1-10:1 in the lower depths.

Table 34. Carbon, nitrogen, sulfur data for site 3. Includes totals, organic C, calcium carbonate equivalent*, and C:N ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent	C:N Ratio
		----------	----------	% of soil	----------	----------	
A1	0-34	0.30	0.07	4.16	2.61		8.59
A2	34-69	0.15	0.05	1.99	1.48		9.76
AB	69-85	0.11	0.04	1.35	0.83		7.44
Bw1	85-102	0.10	0.02	2.11	0.64	8.01	6.31
Bw2	102-140	0.07	0.02	2.85	0.47	15.08	6.44
Bw3	140-191	0.06	0.02	1.77	0.29	10.29	5.02
C1	191-230	0.04	0.02	1.86	0.15	12.99	3.86
C2	230-240	0.04	0.01	1.67	0.13	10.74	3.63
C3	240-260	0.06	0.02	2.03	0.15	8.69	2.25
C4	260-285	0.04	0.02	1.29	0.15	8.51	3.95
C5	285-295	0.04	0.01	1.32	0.15	8.33	3.53
C6	295-305	0.04	0.01	1.33	0.15	8.16	3.87
C7	305-315	0.04	0.01	1.11	0.15	7.94	3.85

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

Sites 1 and 2 were slightly impacted by human activity. Site 3 does not differ significantly from sites 1 and 2 with regard to organic C and N. The following minimally disturbed, non-forest profiles indicate an increase in both organic C andN, which is not observed in site 3. The grassland ecosystem enhances the incorporation of organic C into the soil compared to the forest and may be the reason for the difference between the other sites on the reserve.

Site 4

Site four is located at N 51°32’20.1” E 36°18’21.3” on an upland position. The site vegetation comprises grasses and legumes in a reserve fallow that has not been subject to cutting or pasture since 1939. The grass cover and soil characteristics are considered similar to virgin grasslands. The site has a slight slope of 1% and an elevation of approximately 250 meters above sea level. The soil was sampled to a depth of 250 cm with a parent material sequence of loess over Cretaceous chalks.

Particle size analysis revealed silty textures with the silt fraction ranging from 67% to 54% (Table 35). Clay content ranged typically between 44-32% clay (Table 35, Fig.21). The clay values for this site are slightly higher than the interpretations by Kogut (1998) and Mikhailova (2000) who determined clay fractions between 40-15% for typic chernozems of the Kursk Oblast.

Maximum sand content was only 2.87% (Table 35). No discontinuity was evident in this profile. The fine sand does increase slightly as depth increases (Fig. 22) while the Ti:Zr ratio increases slightly with depth also. (Fig.22). The

Table 35. Particle size distribution for site 4.

Horizon	Depth	% VCoS	% CoS	% MS	% FS	% VFS	% Sand	% Silt	% Clay	% Fine Clay
		------------------------USDA Particle Size Class------------------------								
A1	0-30	0.00	0.00	0.42	0.22	0.67	1.31	66.24	32.45	22.41
A2	30-60	0.06	0.00	0.00	0.25	0.54	0.85	66.60	32.55	24.14
Bt1	60-120	0.02	0.00	0.02	0.05	0.75	0.84	58.89	40.27	27.00
Bt2	120-150	0.00	0.04	0.04	0.37	0.54	0.98	57.53	41.50	32.44
Bt3	150-210	0.00	0.15	0.18	0.48	1.01	1.81	57.73	40.45	19.98
Bt4	210-250	0.00	0.28	0.42	0.72	1.46	2.87	53.58	43.55	20.50

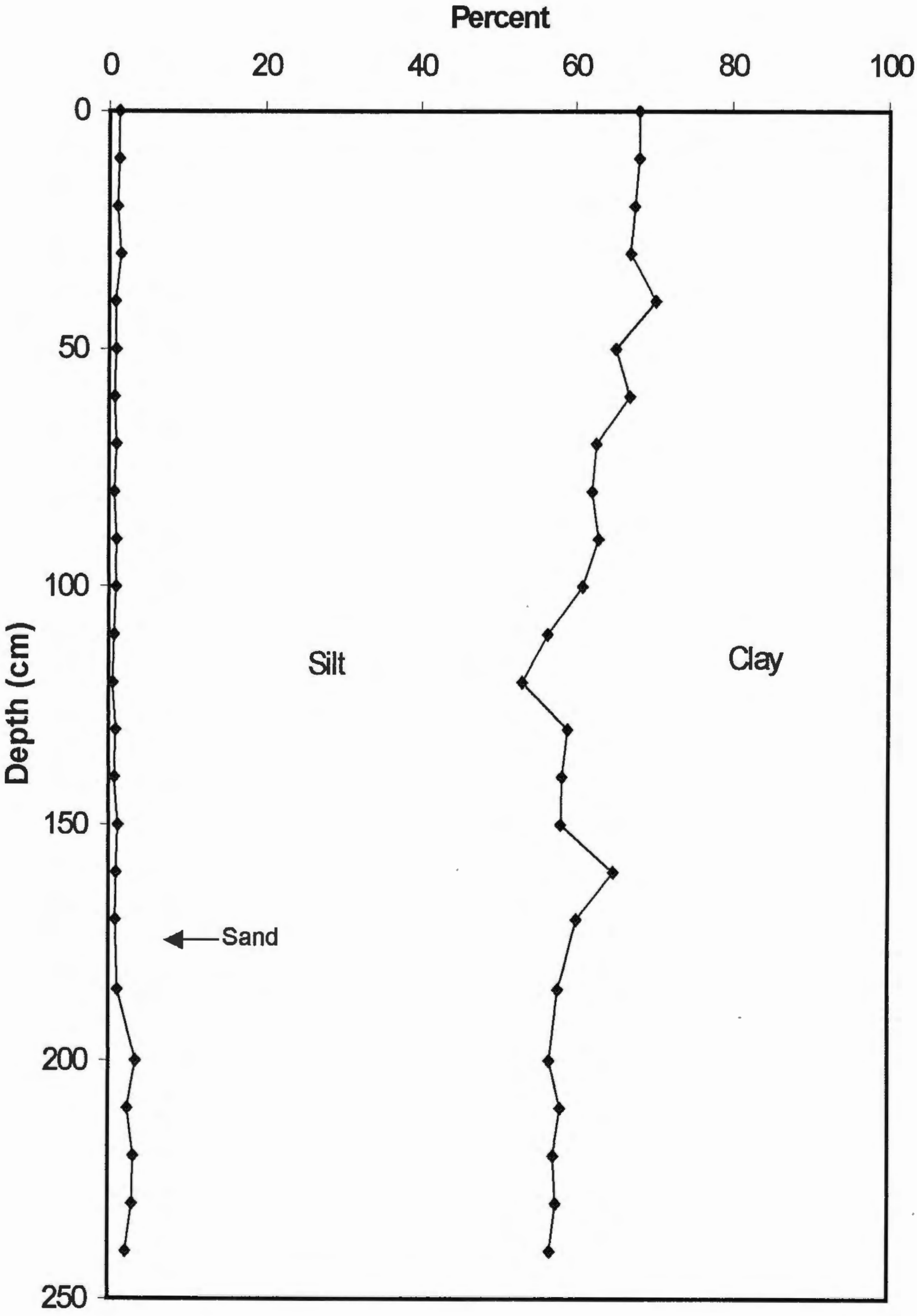

Figure 21. Cumulative particle size plot for Site 4.

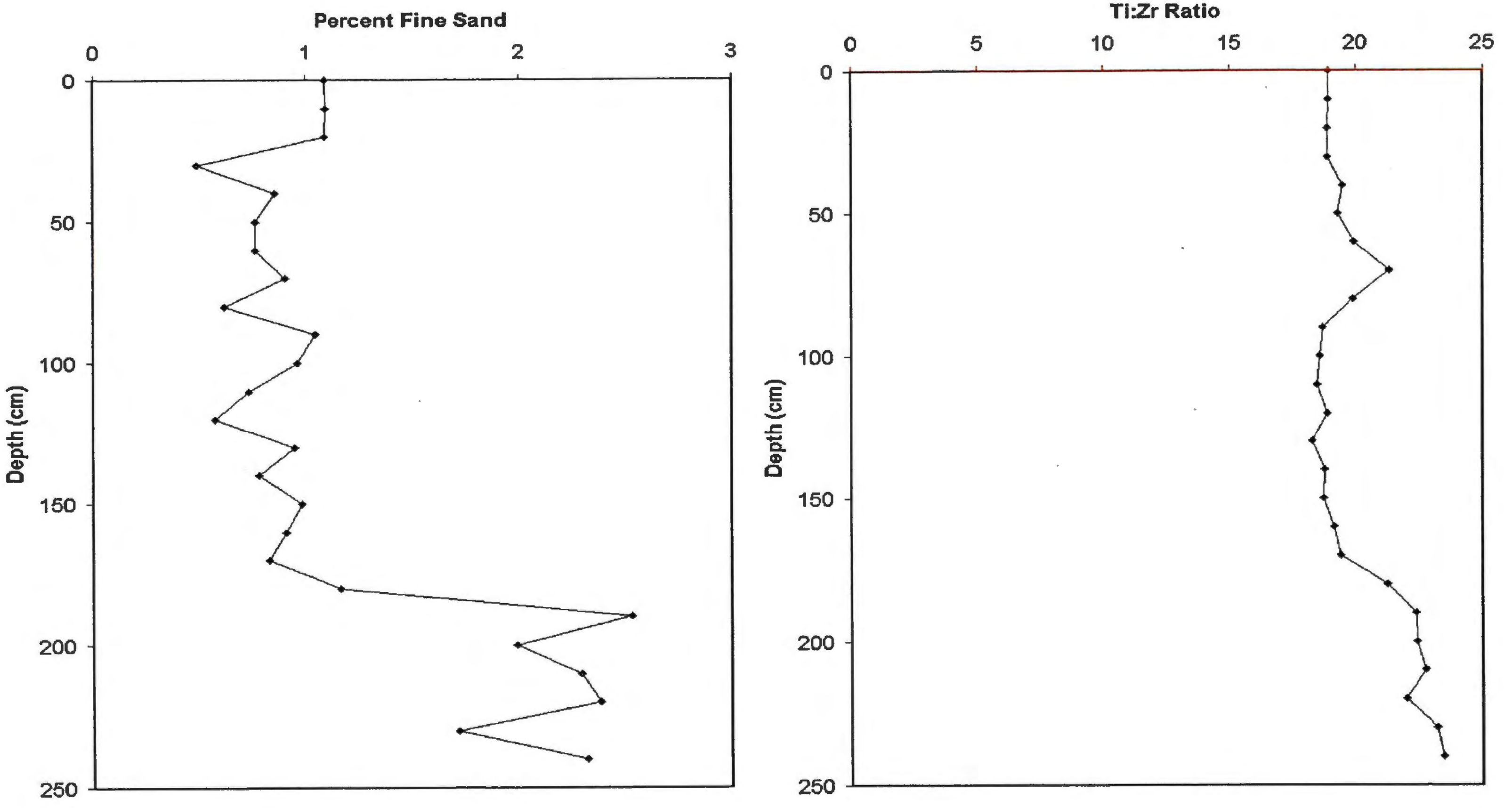

Figure 22. Fine sand and Titanium:Zirconium ratio plots for site 4.

depth to Cretaceous chalks was below the sampled depth. As previously discussed, the loess at sites 2,3, and 4 is much deeper than site 1. Clay content increased more than 20% with depth from the above horizon and has formed argillic horizons. The pedogenic development indicates that site 4, like sites 1 and 2, has been subjected to significantly more weathering than site 3.

Multiple carbonate bulges may indicate the lower extent of different loess depositions. Site 4 does not have a carbonate bulge and has no significant evidence of the accumulation of secondary carbonates (Fig. 23). Some carbonates were present, however they were fairly evenly distributed throughout the lower profiles. This site was the shallowest site sampled. Perhaps data from lower horizons may have indicated other carbonate accumulation zones.

Free iron oxide concentration was fairly stable throughout the profile, increasing slightly at the lowest depths. Total iron followed a similar pattern to the free iron (Fig.24, Table 36). The profile shows only minor weathering in regard to iron data.

Redoximorphic features are not obvious in this profile, indicating the profile is well drained and has not been subject to fluctuating water tables. Evidence of excellent drainage is reflected in the Mn and Fe data (Table 36). Easily reducible Mn values are significantly lower than total Mn throughout the profile. The total (Mn^{4+}) and reducible (Mn^{2+}) manganese levels increase slightly with depth, following similar patterns to the iron graph (Fig.25, Fig. 24).

Organic matter accumulation is a key component of chernozem formation. Not surprisingly, organic C is very high in the surface horizon (3.36%) and

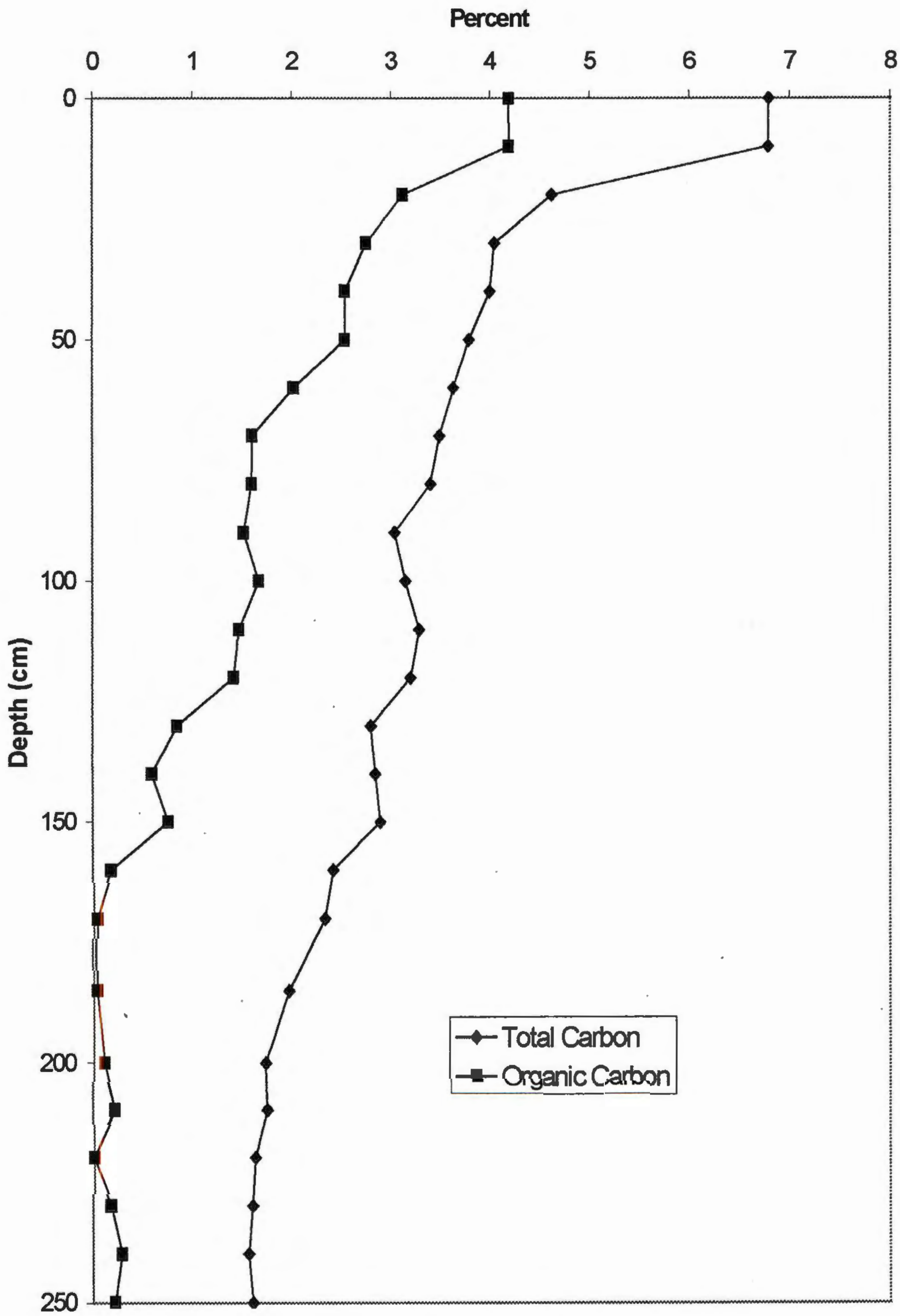

Figure 23.Total and organic carbon plot for site 4.

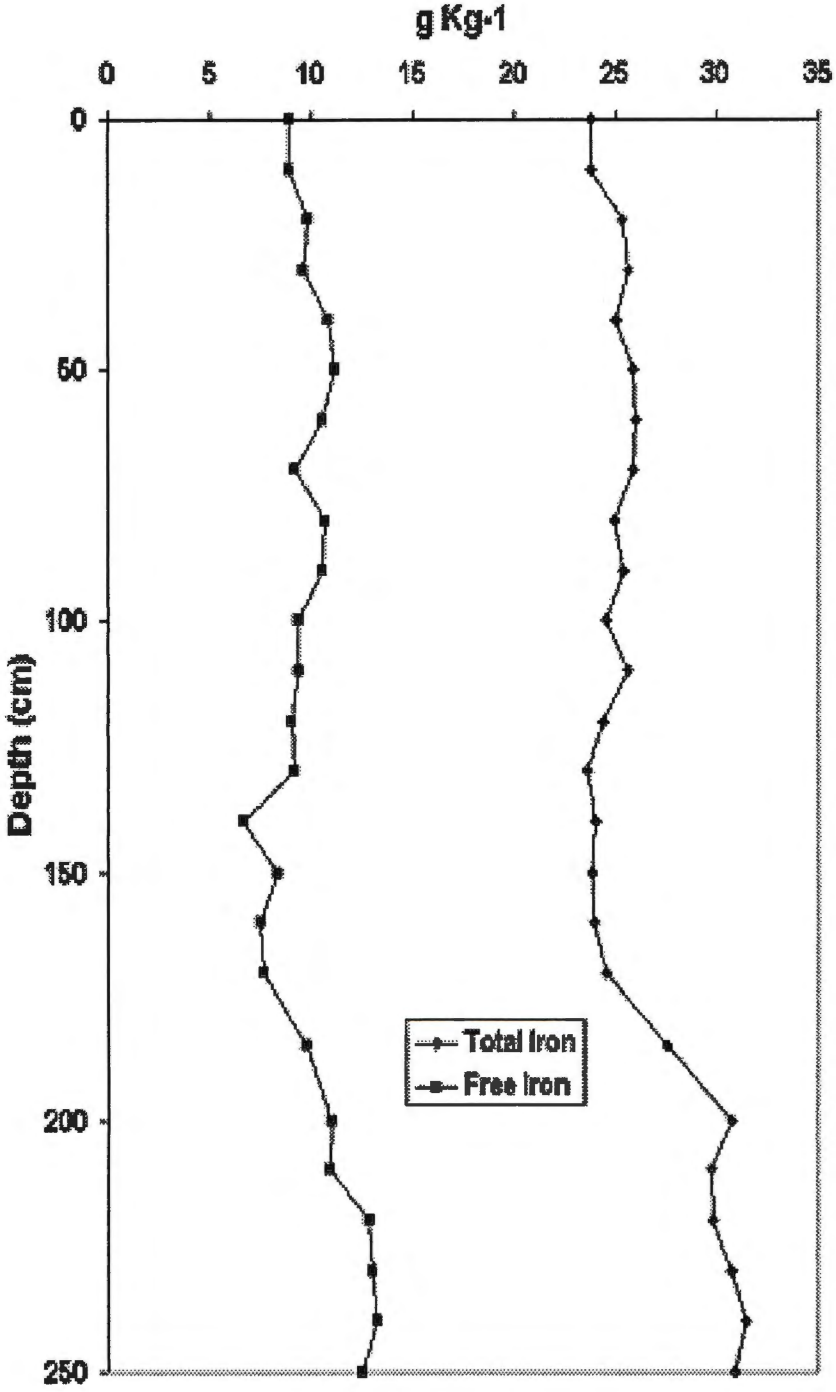

Figure 24. Total and free iron plots for site 4.

Table 36. Iron, Mn, Ti:Zr, and pH for site 4.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$	Free Fe	Total Fe	Free Mn	Total Mn	Ti:Zr
				---- mg kg^{-1} ----				
A1	0-30	6.3	5.8	9410	24927	277.62	567	18.88
A2	30-60	6.8	6.2	10830	25658	29.26	545	19.55
Bt1	60-120	7.8	7.5	9680	25139	241.17	519	19.29
Bt2	120-150	8	7.6	8050	23847	219.47	468	18.60
Bt3	150-210	8.2	7.8	9350	27322	226.02	482	20.87
Bt4	210-250	8	7.6	12880	30718	291.36	586	22.80

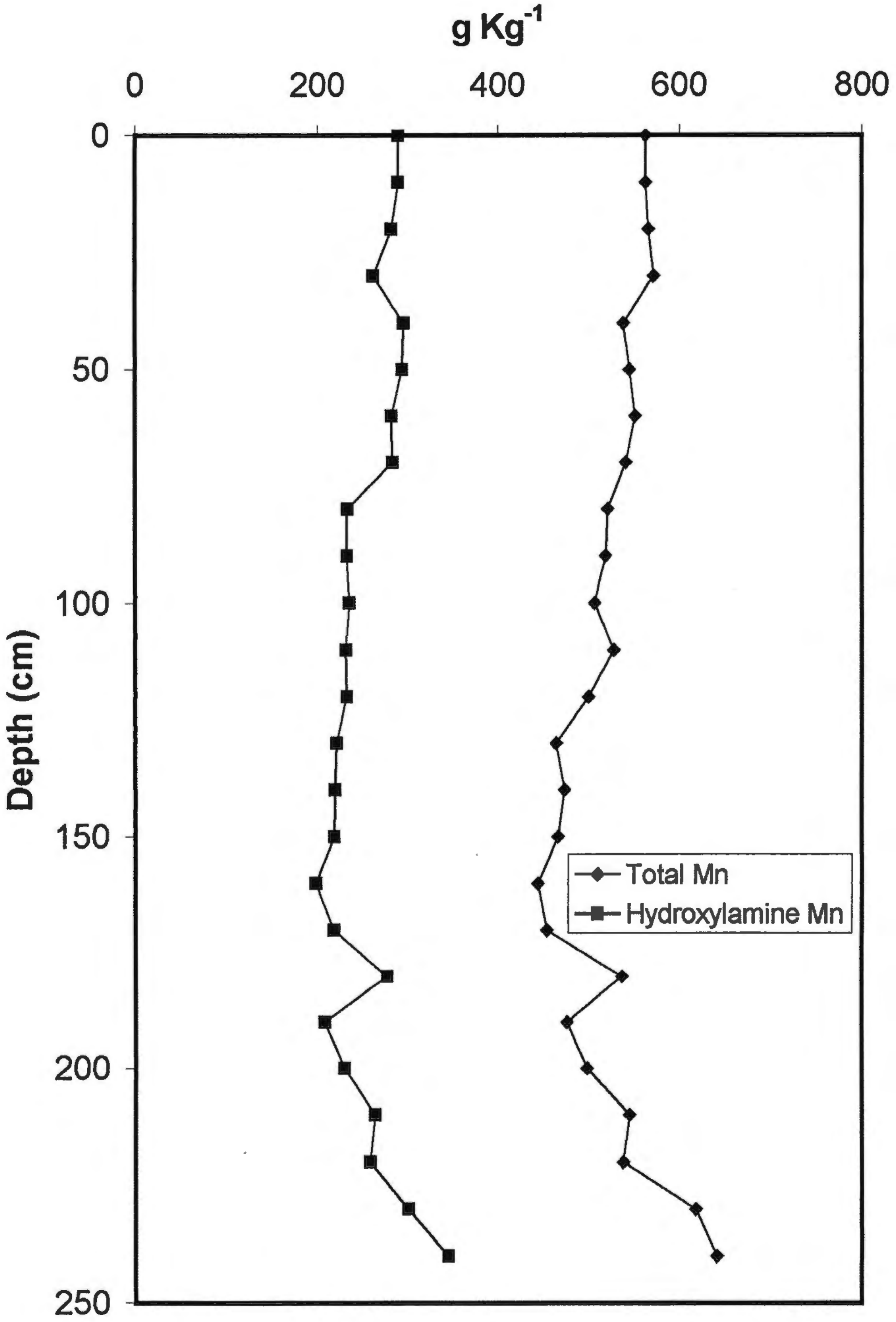

Figure 25. Total and reducible manganese plots for site 4.

decreases gradually with depth, forming a typical melanization curve (Table 37, Fig. 23). Humification and melanization of the upper soil horizons is attributed to the breakdown of large quantities of raw organic matter. The two processes are responsible for the formation of the dark, thick, mollic epipedon.

Organic C was slightly lower than the average 2.9% at a depth of 30-50 cm, as determined by Kogut (1998), with an approximate averaged value of 2.4%. Ponomareva (1974) found typic chernozems from the V.V. Alekhin Biosphere Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. The values for site 4 are slightly lower in the surface, but slightly higher at the other depths. The surface of site 4 was 4.19%, with 1.67% C at 1 m and 0.22% C at 2.5 m. In the same study by Ponomareva (1974) nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m, respectively. Nitrogen was also relatively high in this profile, with a maximum of 0.37% near the surface and decreasing by depth (Table 37). Average values of 0.22% at 1 m and 0.08% N at 2.5 m were slightly higher than the work by Ponomareva (1974). The relatively high nitrogen levels is also reflected in the low C:N ratio. The C:N ratio is approximately 10:1 decreasing to 2:1 at lower depths and is typical of chernozemic soils (Table 34). The results reflect similar findings by Ponomerava (1974) and Chuyan (1987) who estimate C:N ratios typically between 8:1-12:1 in the upper 1 m and 4:1-10:1 in the lower depths.

Site 1 and 2 were more impacted by human activity. Site 4 differs from sites 1 and 2 with regard to organic C and N. The decrease in human activity

Table 37. Carbon, nitrogen, sulfur data for site 4. Includes totals, organic C, calcium carbonate equivalent*, and C:N ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent	C:N Ratio
		% of soil					
A1	0-30	0.37	0.09	5.12	3.36		9.08
A2	30-60	0.28	0.07	3.81	2.37		8.46
Bt1	60-120	0.22	0.02	3.26	1.55	6.14	7.05
Bt2	120-150	0.15	0.01	2.84	0.73	9.80	4.87
Bt3	150-210	0.07	0.01	2.04	0.12	11.90	1.71
Bt4	210-250	0.08	0.01	1.60	0.17	8.21	2.13

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

and the natural accumulation of organics by grasslands explains an increase in both organic C and N.

Site 5

Site five is located at N 51°34'16.7" E 36°05'40.6" on an upland position. The site vegetation comprises grasses and shrubs in a reserve fallow management scheme that has been in place since the 1950's. The site has not been in pasture or cut for approximately 50 years. The site has a slight slope of 1% and an elevation of approximately 271 meters above sea level. The soil was sampled to a depth of 330 cm with a parent material sequence of loess over Tertiary Sands, or possibly Cretaceous Chalks.

Particle size analysis revealed silty textures with the silt fraction ranging from 73% to 65% (Table 38). Clay content ranged typically between 33-21% clay (Table 38, Fig.26). The clay values for this site are within the range of the interpretations by Kogut (1998) and Mikhailova (2000) who determined clay fractions between 40-15% for typic chernozems of the Kursk Oblast.

Maximum sand content was only 6.35% at the lowest horizon (Table 38). No discontinuity was evident in this profile, although the increase in sand at the lowest horizon may be an indication that the Tertiary sands may have been just below the lowest depth sampled. The fine sand also increases dramatically in the lowest depth of the profile (Fig. 27), while the Ti:Zr ratio decreases slightly with depth, much like the region of the Tertiary sand discontinuity in site 1. The depth to Tertiary sand was below the sampled depth. As previously discussed,

Table 38. Particle size distribution for site 5.

Horizon	Depth	% VCoS	% CoS	% MS	% FS	% VFS	% Sand	% Silt	% Clay	% Fine Clay
		USDA Particle Size Class								
A1	0-27	0.00	0.36	0.00	0.00	0.72	1.09	68.59	30.33	19.93
A2	27-49	0.00	0.00	0.00	0.23	0.81	1.04	69.00	29.95	22.47
A3	49-75	0.00	0.13	0.00	0.00	0.78	0.91	65.47	33.62	22.63
AB	75-95	0.00	0.00	0.10	0.00	0.81	0.91	67.89	31.19	18.76
BA	95-112	0.00	0.00	0.00	0.15	0.93	1.08	69.94	28.98	0.96
Bw1	112-146	0.00	0.00	0.00	1.69	0.00	1.69	65.20	33.11	0.02
Bw2	146-180	0.00	0.00	0.00	0.25	1.25	1.50	69.70	28.80	0.02
C1	180-220	0.00	0.00	0.00	0.00	1.88	1.88	70.51	27.61	1.28
C2	220-240	0.00	0.00	0.00	0.00	1.91	1.91	72.36	25.73	1.21
C3	240-248	0.00	0.00	0.00	1.77	0.00	1.77	70.27	27.96	0.86
C4	248-270	0.00	0.00	0.00	0.00	1.56	1.56	73.93	24.51	1.01
C5	270-307	0.00	0.00	0.00	0.00	2.20	2.20	72.69	25.11	0.67
C6	307-330	0.00	0.00	0.00	0.18	6.17	6.35	72.60	21.05	0.62

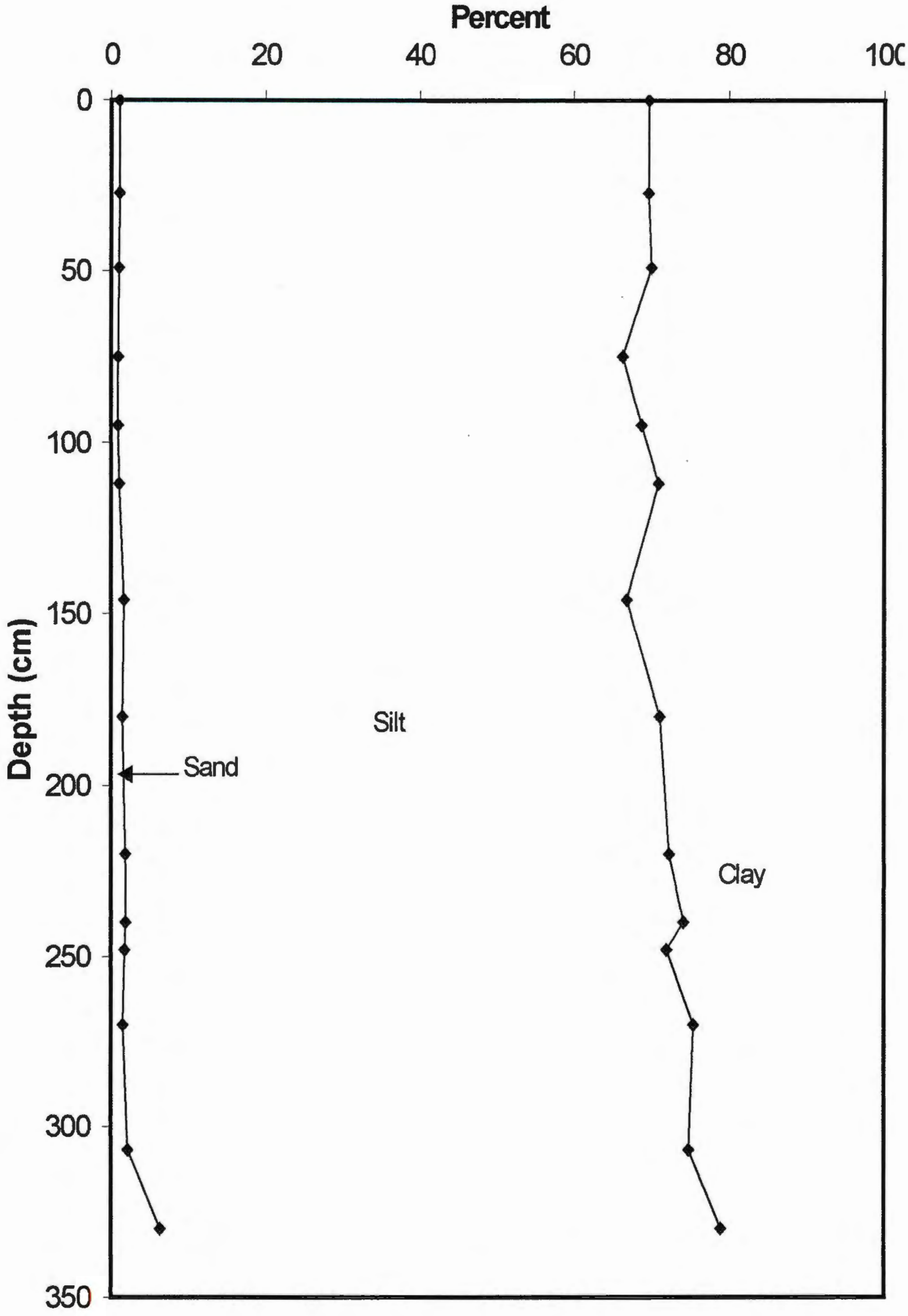

Figure 26. Cumulative particle size plot for Site 5.

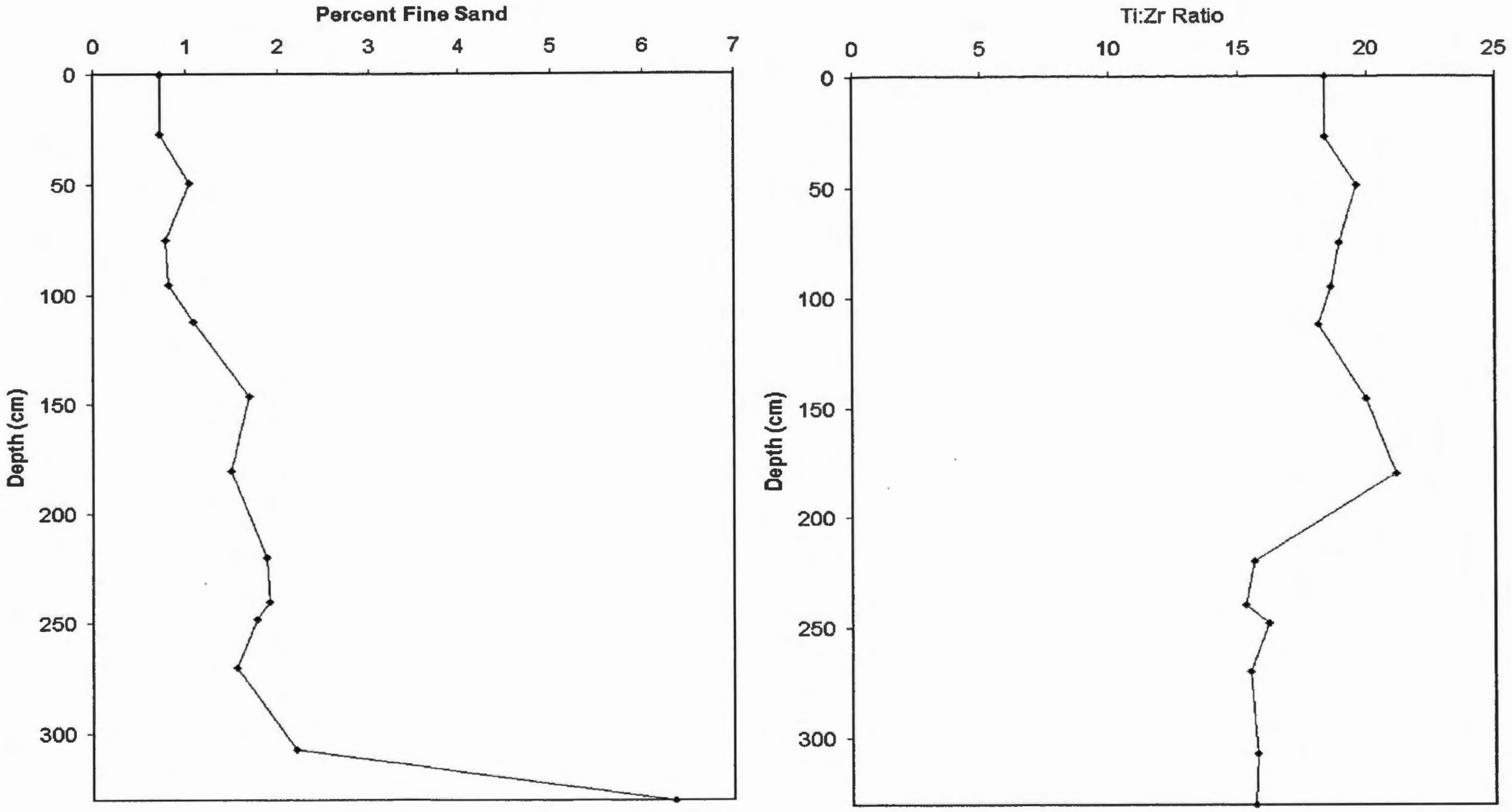

Figure 27. Fine sand and Titanium:Zirconium ratio plots for site 5.

the loess at site 2, 3, and 4 is much deeper than site 1. Site 5 seems to indicate that the interface between parent materials may have been within the next 50 cm, although this assumption would still indicate loess in this region was significantly deeper than the 144 cm observed on site 1. Another possibility is that the underlying parent material was a pocket of Cretaceous Chalks. Possible evidence for this is the difference in the loess particle size between site 1 and 5. Although site 5 has the increase in fine sands and the decrease in Ti:Zr ratio similar to site 1, the amount of total sand in the upper horizons is more similar to sites 2, 3, and 4. These sites had low total sand and were all believed to be above Cretaceous chalk parent material. With the underlying parent material unknown, the depth of loess for site 5 cannot support or refute earlier discussion about the possible influence of the underlying geology on loess deposition.

Unlike sites 1, 2, and 4, the clay content does not increase more than 20% with depth from the above horizon and has cambic horizons instead of the argillic horizons. The pedogenic development indicates that site 5 has been subjected to significantly less weathering compared to the argillic soils.

Multiple carbonate bulges may indicate the lower extent of different loess depositions. Site 5 has one carbonate bulge with accumulation of secondary carbonates (Fig. 28). Interestingly, the shape of the carbonate data is more similar to site 1 with the percent total and organic carbon becoming very small towards the lower extent of the profile.

Total iron concentration increased to a depth of 150 cm and then decreased with depth. Free iron oxide concentration followed a similar pattern to

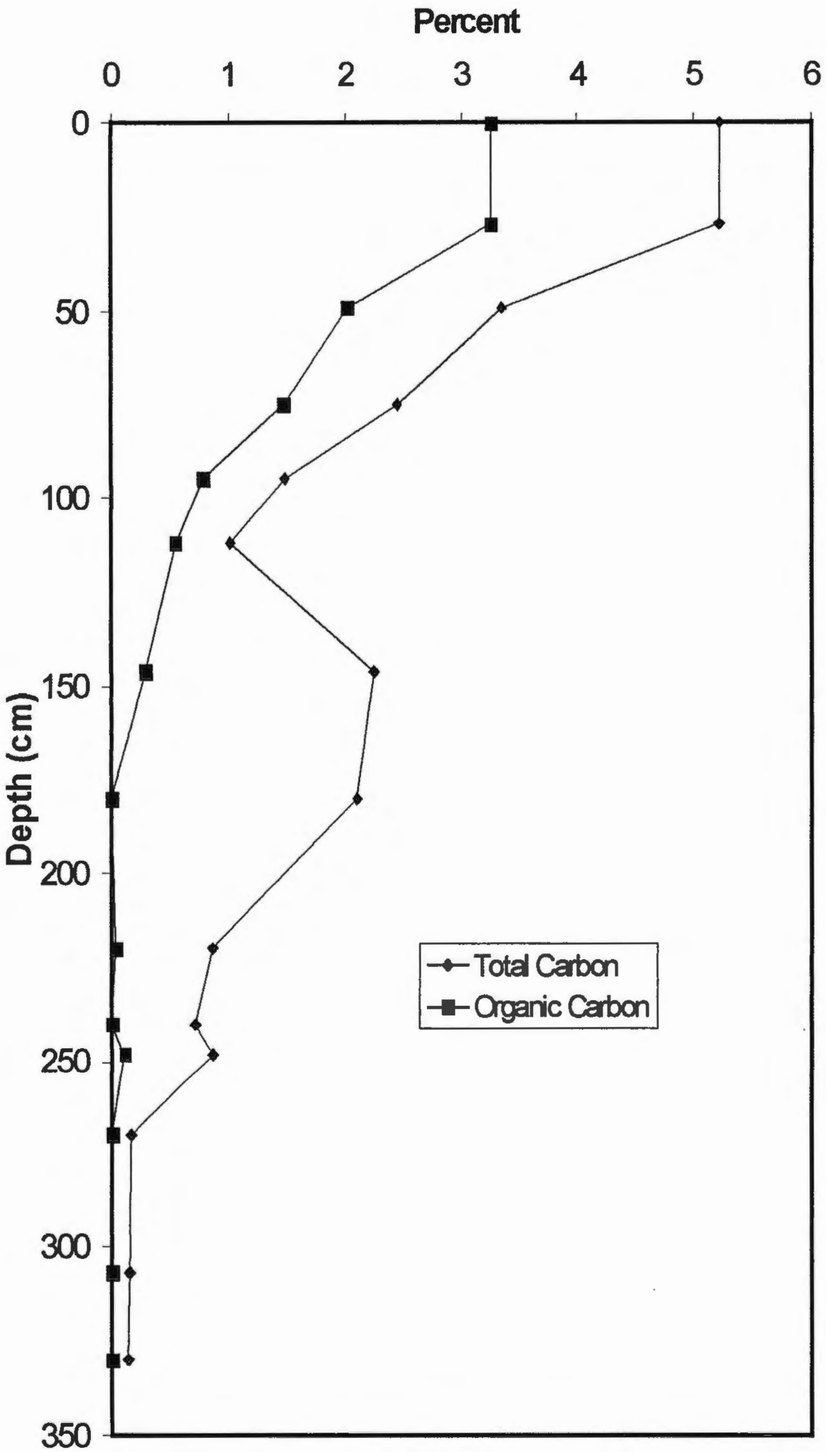

Figure 28. Total and organic carbon plot for site 5.

the total iron (Fig.29, Table 39). The profile shows only minor weathering in regard to iron data.

Redoximorphic features are not obvious in this profile, indicating the profile is well drained and has not been subject to fluctuating water tables. Evidence of excellent drainage is reflected in the manganese and iron data (Table 39). Easily reducible Mn values are significantly lower than total Mn throughout the profile. The total (Mn^{4+}) and reducible (Mn^{2+}) manganese levels are relatively unchanged with depth, except for a decrease at approximately 220 cm in the C1 horizon (Fig.30).

Organic matter accumulation is a key component of chernozem formation. Not surprisingly, organic C is very high in the surface horizon (3.26%) and decreases gradually with depth (Table 40, Fig. 28). Humification and melanization of the upper soil horizons is attributed to the breakdown of large quantities of raw organic matter. The two processes are responsible for the formation of the dark, thick, mollic epipedon.

Organic C was slightly lower than the average 2.9% at a depth of 30-50 cm determined by Kogut (1998). This profile has an approximate averaged value of 2.0%. Ponomareva (1974) found typic chernozems, from the V.V. Alekhin Biosphere Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. The surface of site 5 was not measured; however the other values were lower, with 0.55% and 0% organic C at 1 m and 3 m depths, respectively. In the same study by Ponomareva (1974) nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m, respectively. Nitrogen

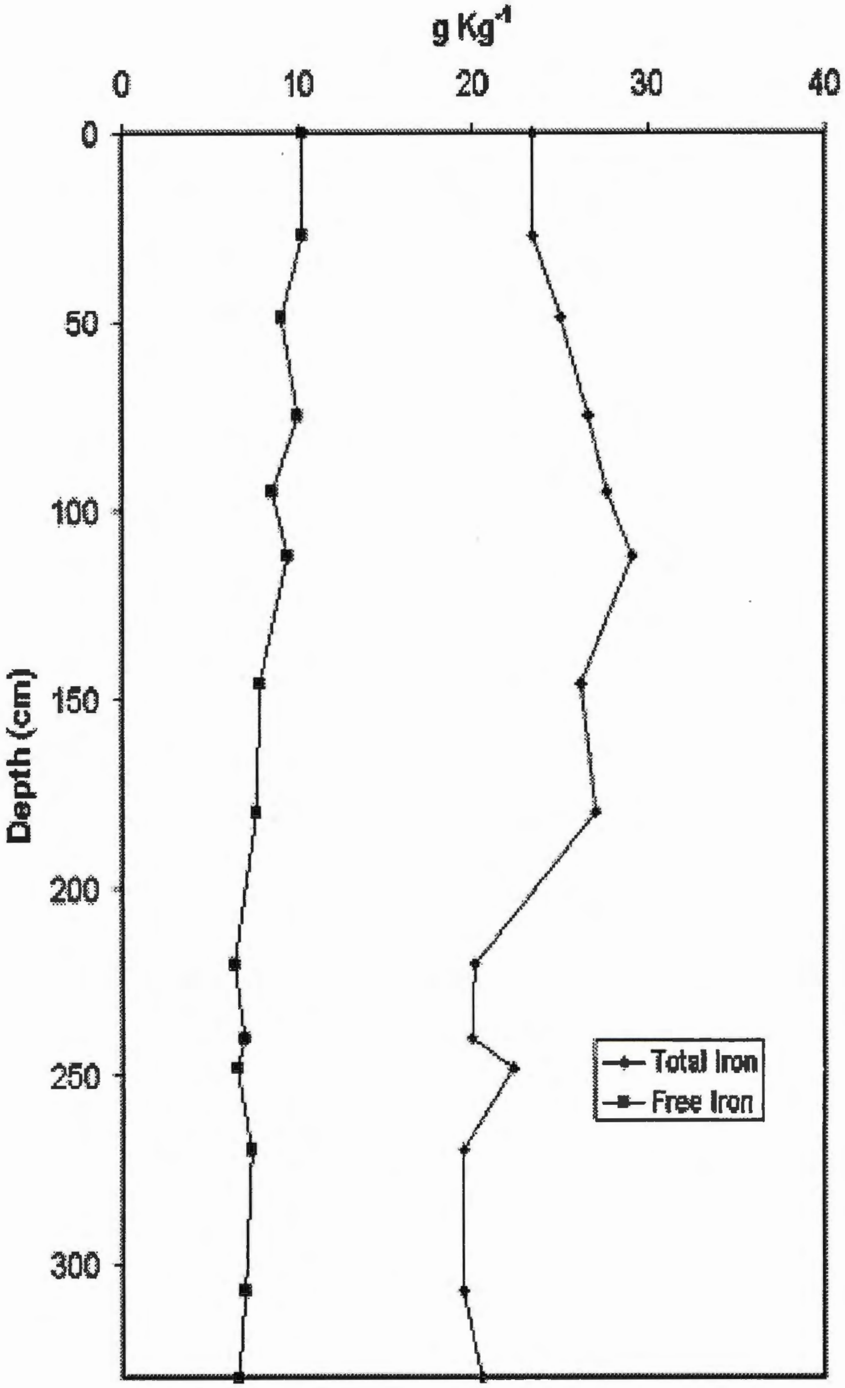

Figure 29. Total and free iron plots for site 5.

Table 39. Iron, Mn, Ti:Zr, and pH for site 5.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$	Free Fe	Total Fe	Free Mn	Total Mn	Ti:Zr
				------- mg kg^{-1} -------				
A1	0-27	7.4	7	279.16	23460	264.63	511	18.35
A2	27-49	7.3	6.8	212.20	25031	243.13	531	19.60
A3	49-75	7.2	6.4	205.44	26587	215.91	544	18.92
AB	75-95	7	6.3	205.40	27625	246.11	546	18.58
BA	95-112	6.6	6.2	196.01	29092	232.98	538	18.10
Bw1	112-146	7.9	7.4	210.00	26161	193.30	467	19.97
Bw2	146-180	8	7.5	274.40	26984	230.63	485	21.12
C1	180-220	8.1	7.5	248.64	20103	125.13	310	15.58
C2	220-240	8.2	7.6	279.16	19959	210.57	436	15.25
C3	240-248	8.2	7.6	212.20	22254	216.51	447	16.14
C4	248-270	8.1	7.6	205.44	19399	196.38	389	15.44
C5	270-307	8.1	7.5	205.40	19463	186.73	409	15.70
C6	307-330	8.1	7.4	196.01	20492	217.93	414	15.64

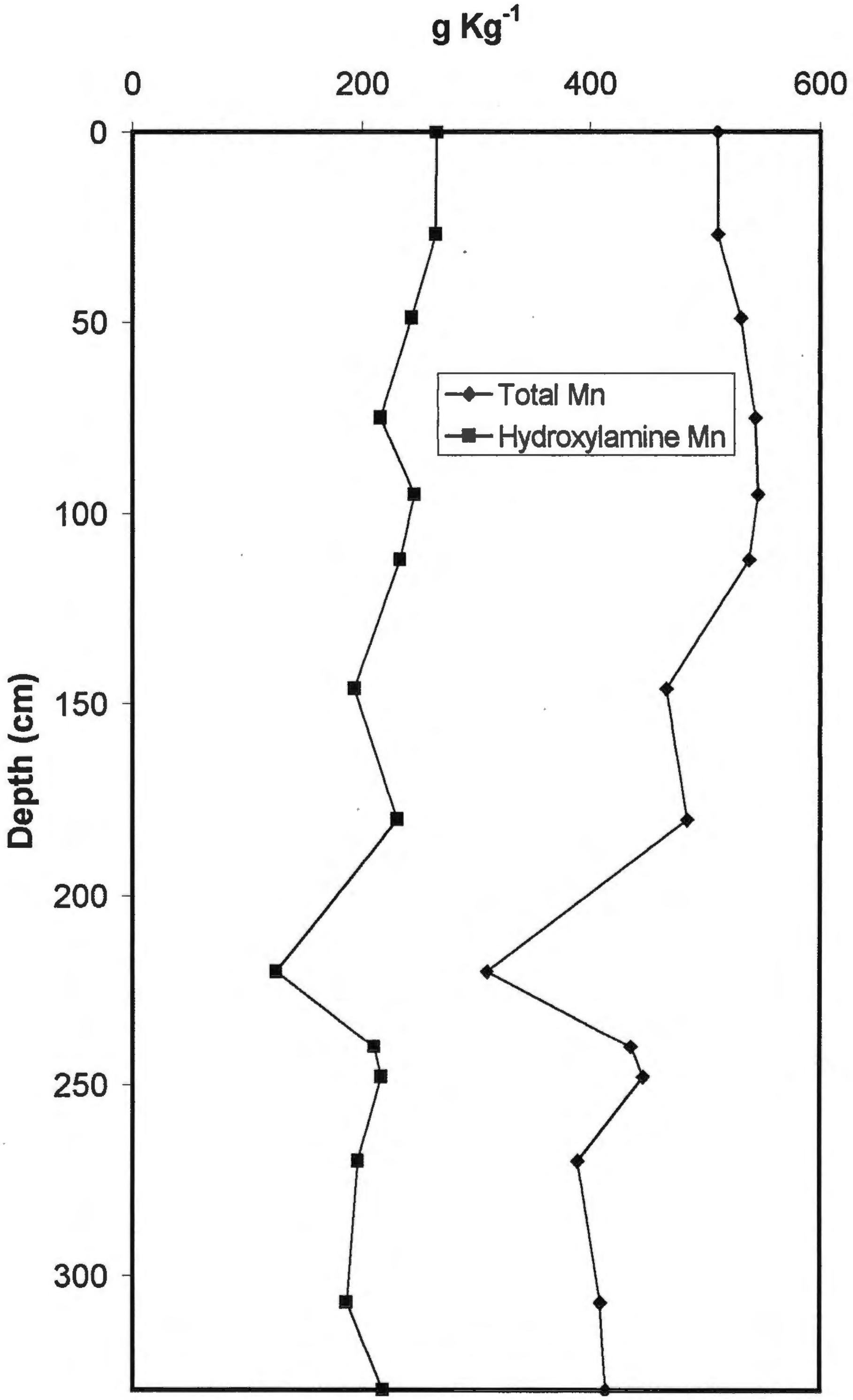

Figure 30. Total and reducible manganese plots for site 5.

Table 40. Carbon, nitrogen, sulfur data for site 5. Includes totals, organic C, calcium carbonate equivalent*, and C:N ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent	C:N Ratio
		% of soil					
A1	0-27	0.39	0.06	5.22	3.26		8.43
A2	27-49	0.24	0.05	3.36	2.02		8.30
A3	49-75	0.18	0.04	2.45	1.47		8.15
AB	75-95	0.12	0.03	1.48	0.78		6.28
BA	95-112	0.10	0.03	1.02	0.55		5.29
Bw1	112-146	0.07	0.00	2.24	0.29	12.30	4.04
Bw2	146-180	0.07	0.01	2.10	0.00	12.30	0.00
C1	180-220	0.04	0.00	0.87	0.04	5.28	0.82
C2	220-240	0.04	0.01	0.71	0.00	4.17	0.00
C3	240-248	0.06	0.00	0.86	0.11	4.22	1.97
C4	248-270	0.04	0.00	0.16	0.00	0.42	0.00
C5	270-307	0.04	0.01	0.15	0.00	0.60	0.00
C6	307-330	0.04	0.01	0.14	0.00	0.32	0.00

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

was also relatively high in this profile with a maximum of 0.39% near the surface and decreasing with depth (Table 40). Average values of 0.10% at 1 m and 0.04% N at 3 m were similarly reflected in this research to Ponomareva (1974).

The relatively high nitrogen levels is also reflected in the low C:N ratio. The C:N ratio is typical of chernozemic soils, with values of approximately 10:1 decreasing to 2:1 at lower depths (Table 40). The results reflect similar findings by Ponomerava (1974) and Chuyan (1987) who estimate C:N ratios typically between 8:1-12:1 in the upper 1 m and 4:1-10:1 in the lower depths.

Site 1 and 2 were possibly impacted by human activity. Site 5 differs from sites 1 and 2 with regard to organic C and N. The decrease in human activity and the natural accumulation of organics by grasslands explains an increase in both organic C and N. The soil is considered similar to the virgin grassland soils and is expected to have a high nutrient base level.

Site 6

Site six is located at N 51°33’04.3” E 36°18’22.3” on an upland position. The site is located in the Central Chernozemic Biosphere Reserve with grasses and legumes dominating the surrounding vegetation. The site is under reserve fallow management and has not been cut or under pasture since 1939. The site has a slight a slope of 5% and an elevation of approximately 252 meters above sea level. The soil was sampled to a depth of 250 cm with a parent material sequence of loess over Cretaceous chalks.

Particle size analysis revealed silty textures with the silt fraction ranging from 84.4% to 51.3% (Table 41). Clay content ranged typically between 44-12% clay (Table 41, Fig.31). The clay values for this site are similar to the interpretations by Kogut (1998) and Mikhailova (2000) who determined clay fractions between 40-15% for typic chernozems of the Kursk Oblast.

Maximum sand content was only 4.3% with fine sand comprising most of the sand fraction (Table 41). A separate loess deposit may be discernable in this profile. The fine sand and Ti:Zr ratio increases at approximately 150 cm (Fig. 32) perhaps indicating a different loess deposit. The depth to Cretaceous chalks was below the sampled depth. The clay content increases at 190 cm and continues to the bottom of the profile (250 cm) forming argillic horizons. Not surprisingly, above the argillic horizon is a highly elluviated E horizon. The lighter color and the low clay content of the soil below 137 cm indicates the soil has been in place for a significant period of time and has pedogenically weathered. Interestingly, the regions above this layer indicate very little clay movement and consequently the upper regions may be a more recent loess deposit positioned above a truncated older loess soil.

Multiple carbonate bulges may indicate the lower extent of different loess depositions. Site 6 has no secondary carbonate accumulations with total carbon decreasing with depth (Fig. 33). If the lower region of this soil is an older loess deposition a carbonate bulge may have occurred below the sampled depth. According to the graphs the boundary between the loess layers is approximately 137 cm. The depth of this loess layer is similar to the hypothesized 175 cm

Table 41. Particle size distribution for site 6.

Horizon	Depth	% VCoS	% CoS	% MS	% FS	% VFS	% Sand	% Silt	% Clay	% Fine Clay
		——USDA Particle Size Class——								
A1	0-40	0.10	0.21	0.00	0.94	0.00	1.26	66.11	32.63	3.69
A2	40-70	0.00	0.00	0.09	0.27	0.63	0.98	63.47	35.55	2.81
A3	70-95	0.00	0.00	0.00	0.14	1.27	1.41	62.70	35.89	1.61
A4	95-108	0.14	0.00	0.00	0.28	0.98	1.40	66.63	31.97	2.38
AE	108-137	0.00	0.00	0.00	0.37	0.98	1.34	74.09	24.57	2.67
E	137-190	0.00	0.20	0.00	3.07	0.00	3.27	84.36	12.37	0.02
Bt1	190-230	0.00	0.00	0.10	1.55	1.66	3.31	58.41	38.27	0.05
Bt2	230-250	0.00	0.00	0.18	4.11	0.00	4.29	51.29	44.42	2.32

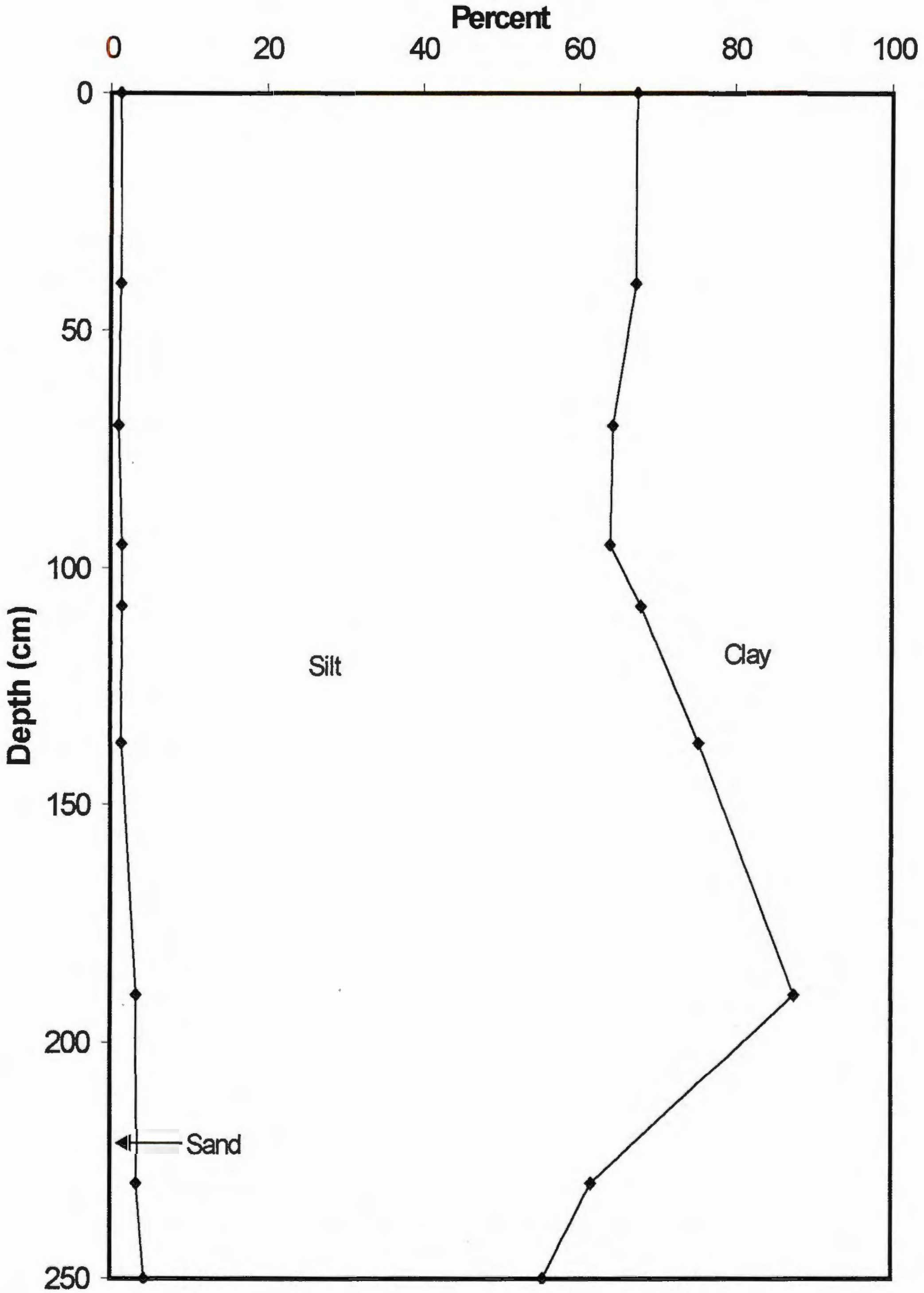

Figure 31. Cumulative particle size plot for Site 6

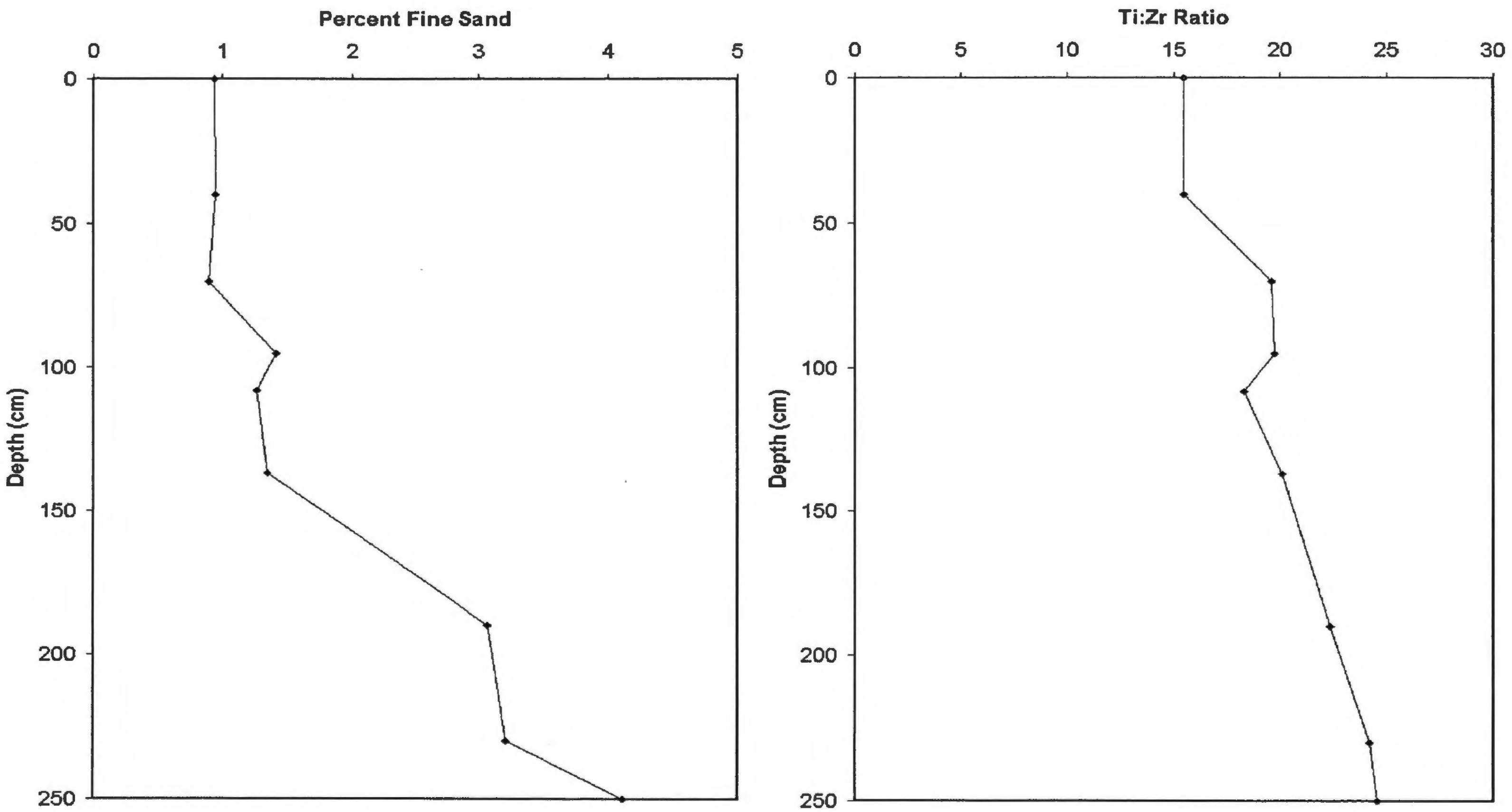

Figure 32. Fine sand and Titanium:Zirconium ratio plots for site 6.

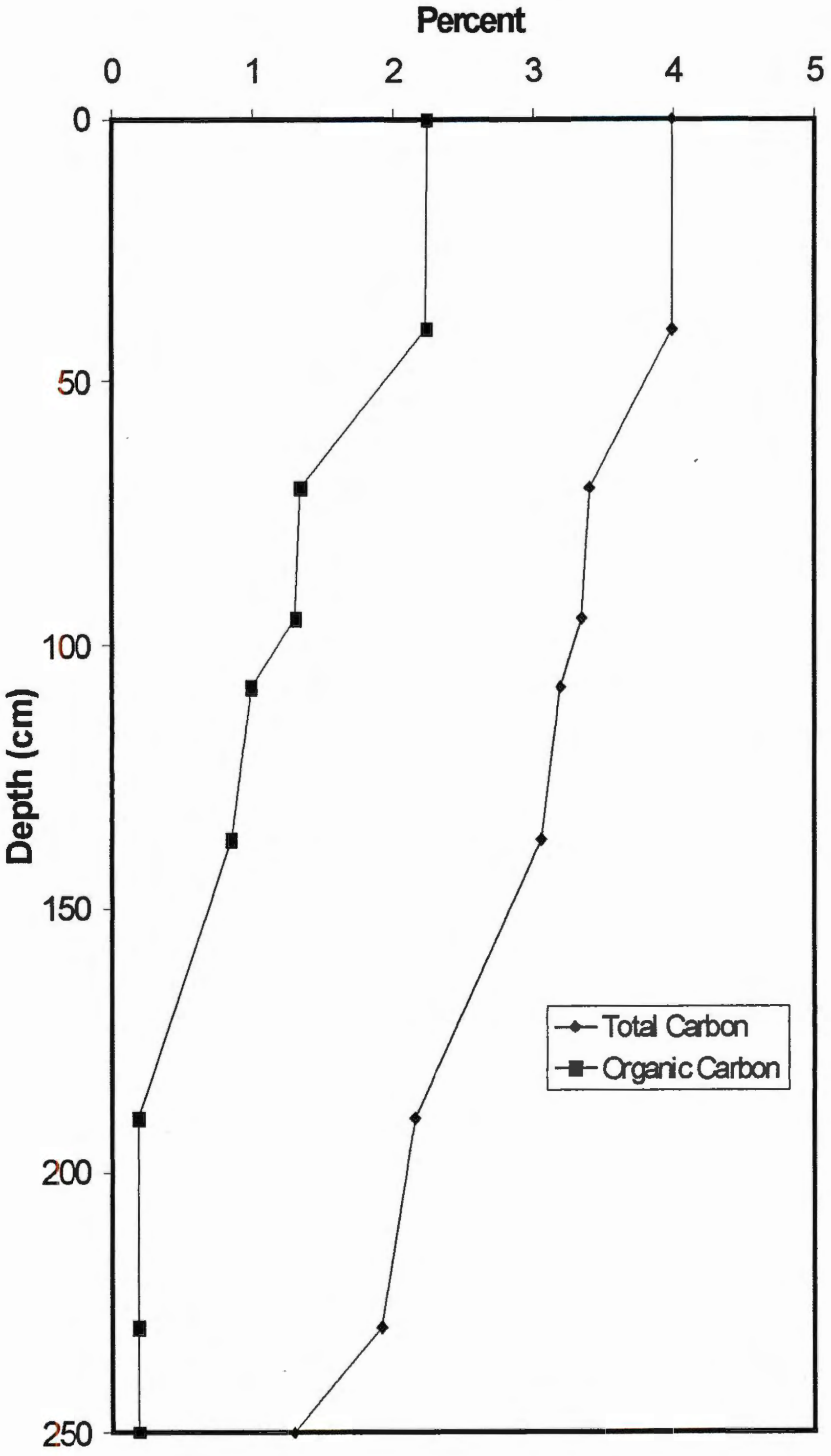

Figure 33. Total and organic carbon plot for site 6.

boundary in Site 2. The slightly shallower depth may be due to the increased slope of Site 5 and the subsequent increased runoff and erosion. Loess from the same source is difficult to distinguish between particularly with chemical composition.

Free iron oxide concentration was fairly stable throughout the profile. Total iron followed a similar pattern to the free iron (Fig.34, Table 42). Redoximorphic features were not obvious in this profile, indicating the profile is well drained, and has not been subject to fluctuating water tables. Evidence of excellent drainage is reflected in the manganese and iron data (Table 42). Easily reducible Mn values are lower than total Mn throughout the profile. The total (Mn^{4+}) and reducible (Mn^{2+}) manganese levels remain quite stable throughout (Fig. 35).

Organic matter accumulation is a key component of chernozem formation. Not surprisingly, organic C is very high in the surface horizon (2.24%) and decreases gradually with depth, forming a normal melanization curve (Table 43, Fig. 33). Humification and melanization of the upper soil horizons is attributed to the breakdown of large quantities of raw organic matter. The two processes are responsible for the formation of the dark, thick, mollic epipedon.

Organic C was lower than the average 2.9% at a depth of 30-50 cm, as determined by Kogut (1998), with an approximate averaged value of 1.3%. Ponomareva (1974) found typic chernozems from the V.V. Alekhin Biosphere Reserve in the Kursk Oblast contained 6.6% C at the surface, 0.82% C at 1 m and 0.14% C at 3 m. The surface of site 6 was not measured; however site 6

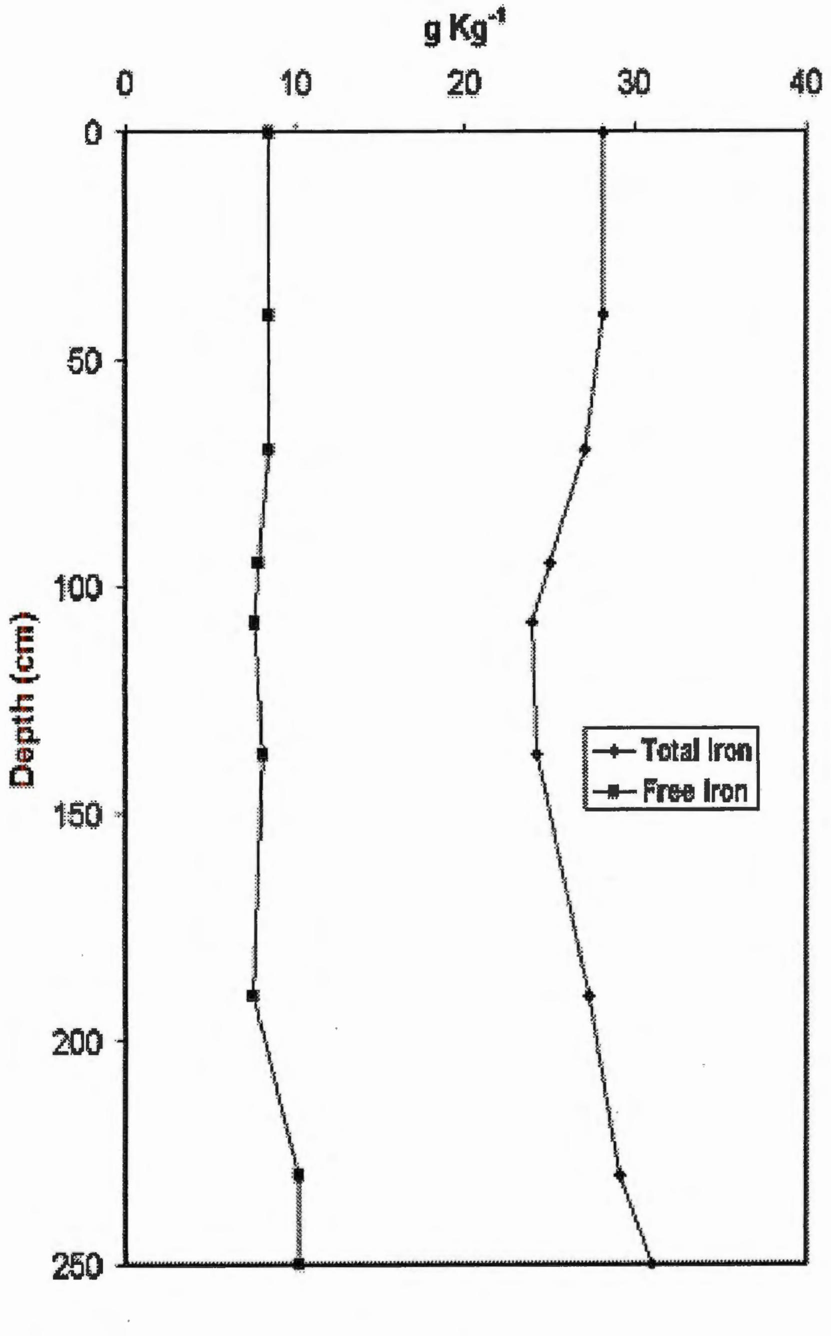

Figure 34. Total and free iron plots for site 6.

Table 42. Iron, Mn, Ti:Zr, and pH for site 6.

Horizon	Depth (cm)	pH 1:1 H_2O	pH 2:1 $CaCl_2$	Free Fe	Total Fe	Free Mn	Total Mn	Ti:Zr
				mg kg^{-1}				
A1	0-40	7	6.6	8413	28121	279.16	578	15.46
A2	40-70	7.8	7.3	8373	27038	212.20	537	19.61
A3	70-95	8	7.5	7834	25027	205.44	475	19.71
A4	95-108	8.1	7.6	7553	23902	205.40	503	18.29
AE	108-137	8.2	7.6	7995	24242	196.01	455	20.08
E	137-190	8.3	7.7	7466	27263	210.00	476	22.34
Bt1	190-230	8.3	7.7	10165	29103	274.40	532	24.19
Bt2	230-250	8.3	7.8	10158	30950	248.64	485	24.55

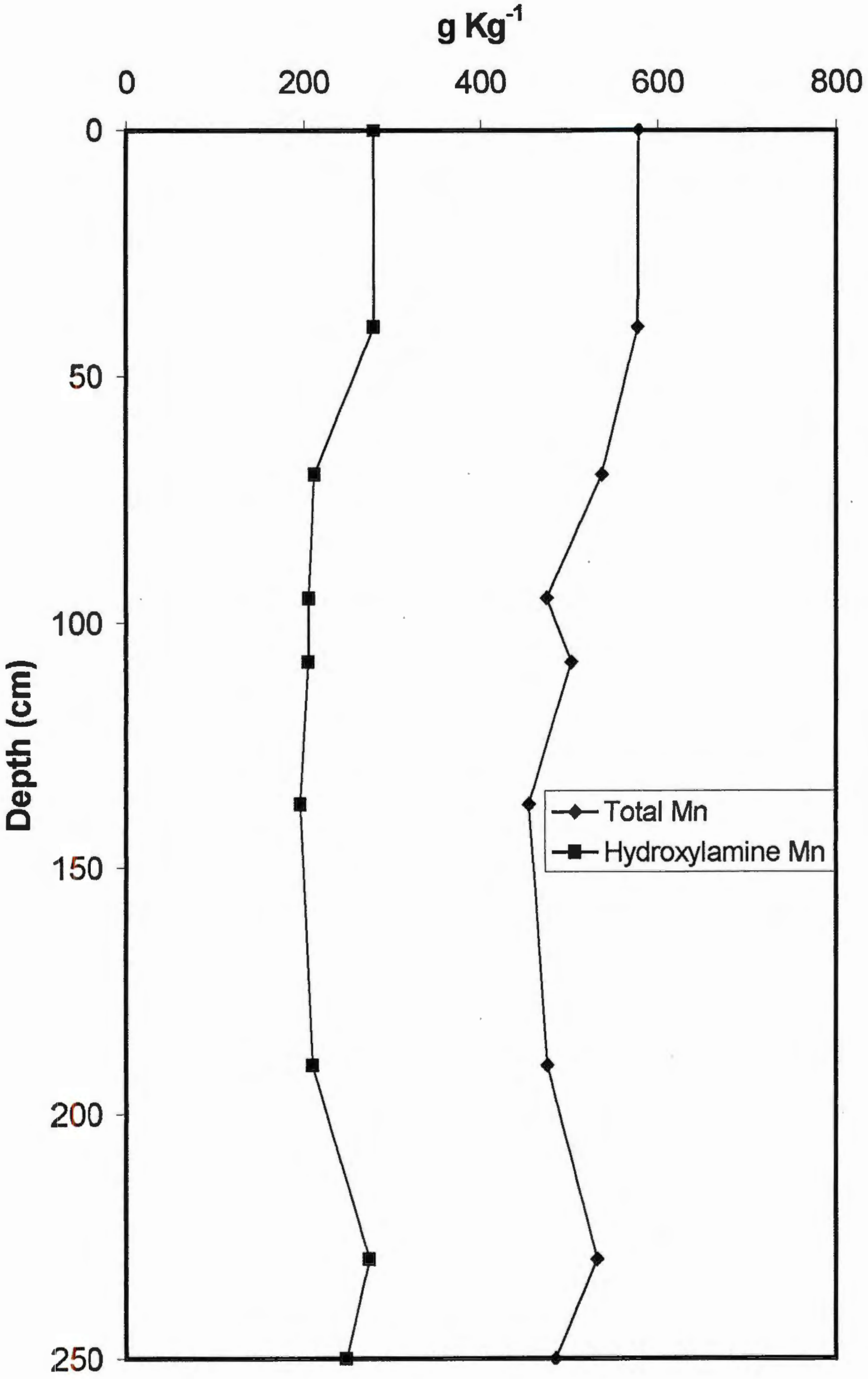

Figure 35. Total and reducible manganese plots for site 6.

Table 43. Carbon, nitrogen, sulfur data for site 6. Includes totals, organic C, calcium carbonate equivalent*, and C:N ratio.

Horizon	Depth (cm)	Total N	Total S	Total C	Organic C	$CaCO_3$ equivalent	C:N Ratio
		% of soil					
A1	0-40	0.31	0.05	3.99	2.24		7.26
A2	40-70	0.21	0.01	3.41	1.34	7.66	6.41
A3	70-95	0.17	0.01	3.35	1.30	9.24	7.57
A4	95-108	0.15	0.01	3.20	0.99	11.47	6.48
AE	108-137	0.13	0.01	3.06	0.84	6.51	6.53
E	137-190	0.06	0.00	2.16	0.18	14.01	3.11
Bt1	190-230	0.06	0.01	1.92	0.18	10.84	2.90
Bt2	230-250	0.06	0.01	1.29	0.18	7.57	2.85

*Calcium carbonate equivalent was only determined for the horizons with weak acid fizz reactivity, indicating the presence of free carbonates.

had similar organic C at 1 m and 2.5 m (lowest depth sampled) with approximately 0.99% and 0.18%, respectively. In the same study by Ponomareva (1974) nitrogen levels were 0.54, 0.13, and 0.02% at the surface, 1 m, and 3 m, respectively. Nitrogen was also relatively high in this profile, with a maximum of 0.31% near the surface and decreasing by depth (Table 43). Values of 0.15% at 1 m and 0.06% N at 2.5 m were similar to work by Ponomareva (1974). The relatively high nitrogen levels are also reflected in the low C:N ratio. The C:N ratio is typical of chernozemic soils with values of approximately 8:1 in the upper horizons to 3:1 lower horizons (Table 43). The results reflect similar findings by Ponomerava (1974) and Chuyan (1987) who estimate C:N ratios typically between 8:1-12:1 in the upper 1 m and 4:1-10:1 in the lower depths.

Site 1 and 2 were possibly impacted by human activity. Site 4, 5, and 6 differ from sites 1 and 2 with regard to organic C and N. The organic C and N levels are higher throughout most of the profile. The decrease in human activity and the natural accumulation of organics by grasslands explains an increase in both organic C and N. The soil is considered similar to the virgin grassland soils and is expected to have a high nutrient base level.

CONCLUSIONS

Different loess depositions were not clearly evident in the profiles. The loess is possibly of one large deposition or more likely multiple depositions from a similar source.

Sites 1, 2 and 5 appear to have a loess layer approximately 1.5 m thick. Site 5 indicates a possible second loess horizon extending to 3.5 m.

Loess appears to be thicker on the underlying Cretaceous chalk geology compared to the Tertiary sand geology. Loess thickness with regard to geology is hypothesized to be due to prehistoric vegetation succession or prehistoric landscape positions.

All soils are well drained with no redoximorphic features and have not been subject to fluctuating water tables.

Particle size, organic C and N are representative of Kursk chernozems and have similar properties to other soils investigated in the Kursk Oblast.

The soils have relatively high nitrogen levels and low C:N ratios. The C:N ratio is approximately 8:1 to 10:1 in the upper loess horizons.

Seasonal organic accumulation, humification and melanization of the upper soil horizons are responsible for the formation of the dark, thick, mollic epipedon observed in all six profiles.

Nitrogen values were slightly lower in the disturbed profiles (sites 1 and 2), while most other components were very similar to the minimally disturbed profiles.

Organic C values were also typically lower in the disturbed profiles (sites 1 and 2). Although site 1 was in reserve fallow management, it was sampled from the face of the quarry, and this region is probably more prone to weathering and nutrient leaching.

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PART 4

A COMPARRISON OF THE MODERN RUSSIAN AND U.S. TAXONOMIC SYSTEMS USING SIX SELECTED SOIL PROFILES OF THE KURSK OBLAST, RUSSIA

INTRODUCTION

Attempts to correlate the different soil classification systems of the world have been conducted on the broadest level. With the globalization of the world and the global problems, such as pollution and climate change, the need for a better understanding of soil classification in other countries is becoming increasingly important. Issues such as global resource planning and carbon sink evaluation are important topics. To address these issues mutual understanding is the most important tool. Differences between the Russian and U.S. soil classification systems are too extensive to create a single system, but it is possible to correlate the systems (Mazhitova et al., 1994). Understanding soil classification and the two systems is required before any significant correlation can be made.

Soil classification according to Buol (1997) is the categorization of soils into groups at varying levels of generalization according to properties and/or genesis. Soil classification is an integral part of soil science. Classification provides a means to organize knowledge, an opportunity for effective communication between researchers and the general public, and aid in research design. Classification can also make it easier to remember key properties, as well as understand the relationships between various soils. A system of classification should be accessible at varying levels, and should easily be used by many different groups for different purposes. Soil classification is often used in agriculture, engineering, resource planning, and ecosystem management, as well as many other applications.

Both the U.S. and Russian classification systems originated from the early works of soil science pioneers, such as Dokuchaev, however each system has evolved quite differently. The U.S. system is based primarily on measurable properties, while the Russian system until recently took a more genetic approach, trying to zone soils based on other key factors like climate and geomorphology. Recently the Russian taxonomic system has under gone a significant change and is using key measurable techniques. Both systems have benefits and both relay valuable information. The classification of the soils using both systems will be used to understand key properties of each of the six soil profiles and also to understand the similarities and differences between the two systems.

Six soils are investigated in the Kursk Oblast, Russia. The Kursk Oblast is approximately 500km southeast of Moscow (Fig. 36). Four of the soils (sites 3-6) were described on the V.V. Alekhin Central-Chernozem Biosphere Reserve, while the other two soil profiles (site 1 and 2) were described on the edge of quarries next to the reserve (Fig. 37).

Two parent material sequences: loess deposits over Tertiary sands (site 1) and loess deposits over Cretaceous chalks (sites 2-6) are present in the study area (Fig. 37). The two combinations of parent material deposits are representative of the Kursk region. The region has a mean annual air temperature of 5.4°C and 587 mm mean annual precipitation (V.V. Alekhin Central-Chernozem Biosphere State Reserve, 1947-1997). The topography is

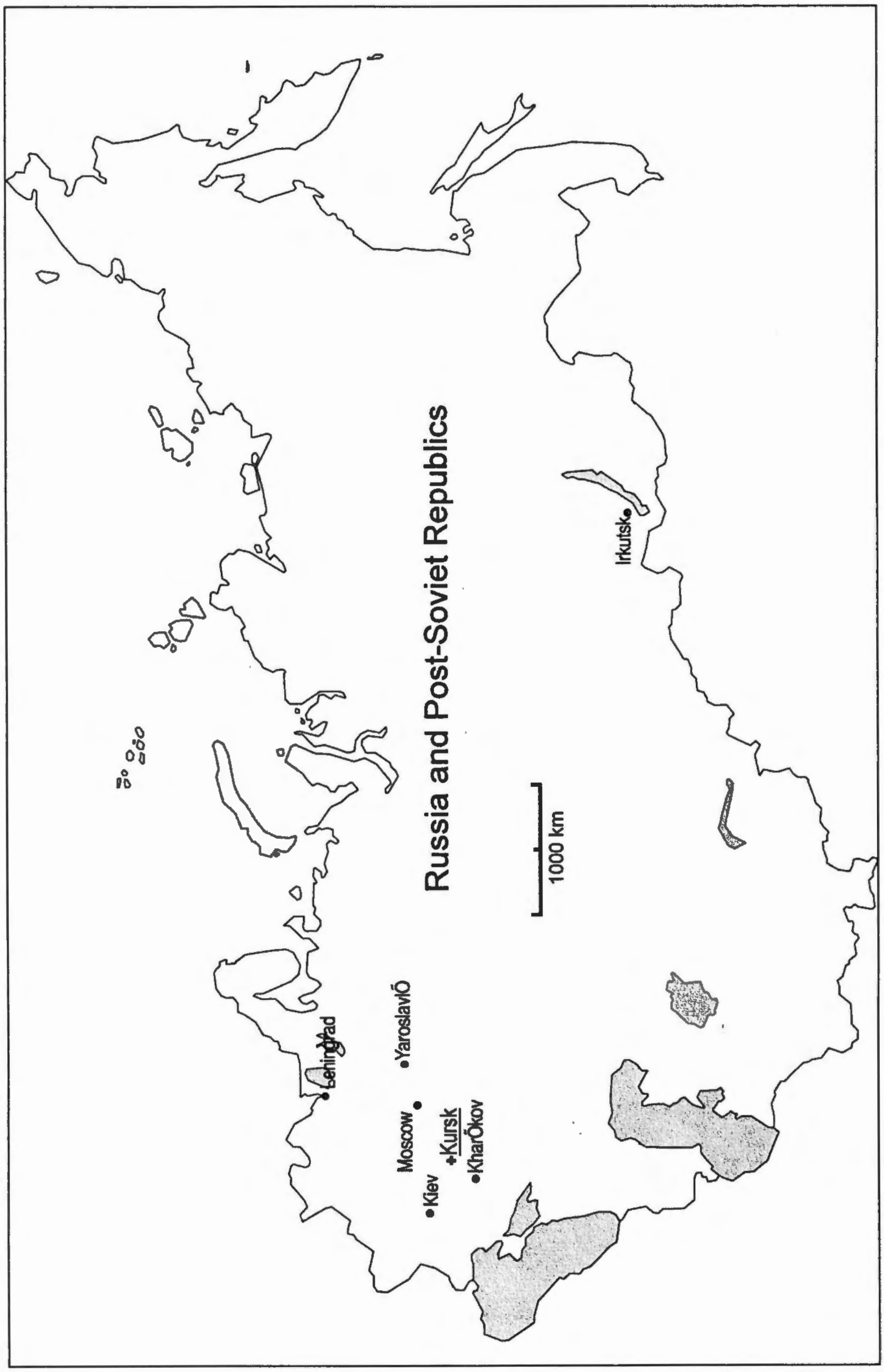

Figure 36. Generalized site location map of Kursk.

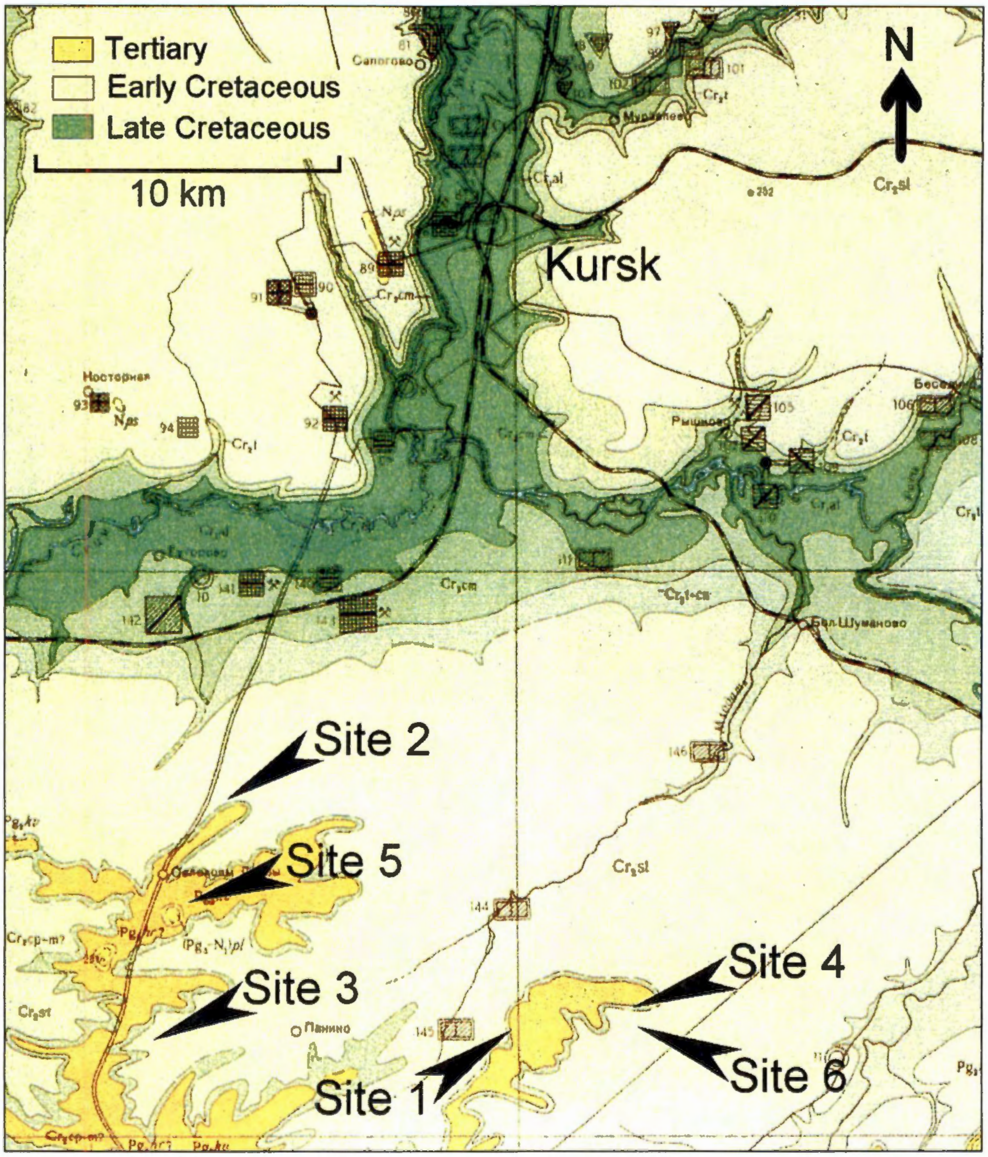

Figure 37. Site locations and geology of the Kursk region.

gentle rolling hills with grasslands intersected with groves of deciduous forests dominating the landscape. The objectives of this study were to evaluate six soil profiles near Kursk, Russia for classification and comparison using both modern Russian and U.S. classification systems.

LITERATURE REVIEW

Chernozem soils have played a predominant role in the development of soil science, particularly the history of Russian soil investigation (Glinka, 1927). Initial soil investigation could be traced back as far as ancient China. During the Yung Dynasty (2357-2261 B.C.) soils were classified into nine classes based on their productivity (Simonson, 1962). In ancient Greece, Aristotle (384-322 B.C.), his pupil Theophrastes, and other Greek philosophers considered the relationships between soil properties and plant nutrition (Vilenskii, 1957). There were not many major contributions to soil science until the 19th century, when the post-Age of Enlightenment scientists began to look more closely at soils.

In 1840 Justus von Liebig published works regarding the use of fertilizers to improve soils, however soil science really gained acceptance as a scientific discipline slightly later through the work of V.V. Dokuchaev (1846-1903). Vasilii Vasilevich Dokuchaev is often considered the "father of pedology". In 1883, Dokuchaev published a report "Russian Chernozem Selected Works Vol. 1" in which he compiled as much data and information as possible on the Russian chernozem soils (Dokuchaev, 1967). Later in 1891 he published "Russian

Steppes in the past and present". Dokuchaev applied morphology to describe major soil groups, and developed sampling techniques to conduct investigations. He was the first to term the word "soil" scientifically, and also investigated relationships between soil and water, air and organisms. Dokuchaev, a supporter of Darwin's "Theory of Evolution" attempted to explain the evolution of soil, as a gradual process, mistakenly missing the concept of rapid change (mutation) and cataclysmic events that can form or remove a soil rapidly, resetting the time framework (Dokuchaev, 1967).

A student of Dokuchaev, K.D. Glinka (1867-1927) translated Dokuchaev's work into German, where it became internationally recognized. Glinka also worked on soils and particularly emphasized surficial geology weathering as the key to soil formation and the correlation of the two concepts to climatic conditions. Dokuchaev's work was later translated into English by C.F. Marbut (1863-1935). Marbut was the U.S. Soil Survey director and proposed a soil classification system of 3 soil orders based on climatic influences.

Prior to Marbut's work in the U.S. E.W. Hilgard (1833-1916), a Mississippi and California geologist wrote about the relationships between soils and climate. G.W. Coffey actually proposed the first U.S. soil classification scheme in 1912, which Marbut worked on. Marbut's successor as director of the U.S. Soil Survey was C.E. Kellogg (1902-1977), who also continued to develop the soil classification system further emphasizing the need for and "open-ended" system.

Hans Jenny made the next major development in soil science when he wrote "Factors of Soil Formation" in 1941. Jenny's formula for soil formation was written S = F(cl, o, r, p, t), where each variable, climate, organisms, relief, parent material, and time, are functions that explain soil formation. The formula allowed soil properties to be expressed as functions of formation and enabled quantitative correlations between soil forming factors and soil formation (Jenny, 1941). Jenny's factors, specifically relating to typic chernozem formation, were discussed in more detail previously in Part 3.

R.W. Simonson (1959) also made considerable contributions to soil genesis with his work that related horizon development to the strength of simultaneously occurring genetic processes. Another major contributor to the U.S. soil classification around the same time was G.D. Smith, who in the 1960's and 70's was the architect for the U.S. Soil Taxonomy. Smith was director of Soil Survey Investigations for the U.S.D.A. Soil Conservation Service (Buol et al., 1997) and with the help of other soil scientists, developed the 7th approximation, a system of classification that was titled "Soil Taxonomy" and published in 1975. Smith also made a key point regarding classification, stating soil genesis is important for taxonomy, but genesis itself cannot be used as a basis for classification because the genetic processes can rarely be quantified or observed (Buol et al., 1997). Since the first publication of "Soil Taxonomy", there have been eight revisions, and it is still used today in the U.S. and in other parts of the world.

The U.S. soil classification is a property-based system that is "open-ended" meaning that new soil types, key features and other factors can be added as they become necessary. A recent example is the addition of the Andisol and

Gelisol soil orders in the past 10 years. The system is developed to embody soils in existence, but allows for new additions and modifications (Soil Survey Staff, 1975). The system is also designed so that it does not separate soils based on human activity, has a hierarchy of classification, and has the same meaning to everyone with specific measurable techniques used to determine classification properties (Soil Survey Staff, 1975).

Presently, the U.S. soil classification system has a hierarchy of six categories. The system proceeds from highest to lowest levels of generalization. The six divisions are: order, sub order, great group, sub group, family, and series. Soil order is the broadest category, differentiated on the presence or absence of major diagnostic horizons. Currently there are 12 orders. Within the orders are approximately 64 suborders. Suborders are differentiated primarily on parent materials or moisture regimes, while the next level, the great group is broken down based on the expression or absence of horizons, moisture regimes and temperature regimes. There are approximately 300 great groups in U.S. soil taxonomy. The sub group divides the great group on the idea of the "central concept" for each soil. The central concept soil is designated as "typic", while other soils are labeled as intergrades to other soil orders, sub orders, and great groups. Sub groups can also be differentiated by other critical properties that were not prominent enough to be at a higher level. The family level of taxonomy uses various components of the soil in combination. The components included are textural class, mineralogy, clay activity, pH, depth, and temperature regime. The soil series is the lowest, and most specific level of classification. Soil series are based on specific horizon sequences and depths, structure, colors, consistence and other properties. Series names are given usually for a location near where they are first described. There are approximately 17,000 soil Series in the U.S. taxonomic system.

Russian soil science history emerged from the same sources, primarily V.V. Dokuchaev. Other significant contributors include P.A. Kostychev, K.D. Glinka, V.R. Vil'yams, and V.M. Fridland. Glinka's work was discussed previously, however Kostychev (1845-1895) worked on soil fertility and the relationships between soils and plants, particularly focusing on agriculture (Vilenskii, 1957). Vil'yams (1963-1939), like Kostychev, worked with fertility as a soil property, but also worked with soil forming processes, chiefly the formation of chernozems from succession of tundra climates to prairie grasslands, and proposed concepts like grassland crop rotation (Vilenskii, 1957). More recently in Russian soil research V.M. Fridland (1919-1983) investigated soil geography with an emphasis on the pattern of soil cover (Buol et al., 1997).

The Russian classification system evolved differently from the U.S. system. Russian research focused on establishing the natural processes, development stages of soil, zones of soil formation, and the use of soil as a work material in social industry, so it should not be surprising that early Russian classification reflected such concepts (Vilenskii, 1957). Dokuchaev classified soils according to features including location, color, origin, and texture (Vilenskii, 1957). The features of zonality in soils were a key feature of this early classification scheme. Glinka developed and then renounced a classification scheme based on climate, before he accepted the new taxonomic subdivision that was introduced by P.S. Kossovich in 1911 (Vilenskii, 1957). Kossovich's genetic linking of soil groups based on weathering from alkaline to acid soils, an error of opinion, was widely accepted and caused many problems later as the Russian classification system evolved (Vilenskii, 1957).

In 1906 G.N. Vysotskii distinguished soils based on water conditions and relief, a useful concept; however, the next major development came from K.K. Gedroits who used soil properties, particularly adsorbed bases, to classify soils in 1925 (Vilenskii, 1957). E.N. Ivanova and N.N. Rozov developed a five-class hierarchal system in 1956 with 12 soil orders and using climatic zones, soil formation factors, vegetation, and water conditions (Vilenskii, 1957). The problem of soil genetics and the lack of human use information lead to the next change in classification.

The U.S.S.R. classification system of 1977 was the most widely used, until the new Russian classification of 1997, and the update of 2000. The 1977 system did not use diagnostic horizons like the U.S. system, but evaluated genesis that examined the horizons of a profile as a whole (Mazhitova et al., 1994).

The 1977 Russian system uses the following breakdown. Core Section, Type, Subtype, Genus, Species, Variety, and Rank (Mazhitova et al., 1994). These class breaks are at similar levels to the U.S. system, but do not correlate easily. Another significant problem with the older Russian soil classification parameters is the lack of an obvious basic unit of study, such as the pedon in the

U.S., and the gradual transition from one soil to another, which is accounted for in the Sub group in U.S. taxonomy (Chernova, 1996). The older Russian classification system (1977) is not as effective as the new system (1997), particularly in regard to determining human impacts, such as erosion, compaction, and dehumification (Ammons and Vassenev, 2000).

"Human use" criteria were added to the most recent Russian soil classification system (V.V. Dokuchaev Soil Science Institute, 2001). In the new Russian system, two groups of anthropogenically-transformed soil are surface transformed soils and multiple-layer transformed soils (Shishov, 1996). Soil classification is a potential tool to indicate disturbances. Soil classification systems should indicate differences between virgin soils and those that have come under significant human influence (Ammons and Vassenev, 2000).

Agricultural practices and degradation of the central chernozem is also evident in color changes (Shcherbakov and Vasenev, 1999) and loss of organic matter. The Kursk region has some areas with significantly degraded chernozems (Shcherbakov and Vasenev, 1999). The U.S. taxonomy system would classify these degraded chernozems as Inceptisols or Entisols, however the Russian taxonomic system differentiates this soil as an eroded chernozem, eventually becoming a brown forest soil or chestnut soil.

The new Russian classification system uses 8 levels of taxonomy (Trunk, Order, Type, Subtype, Genus, Species, Variety, and Phase (V.V. Dokuchaev Soil Science Institute, 2001). The new system uses more measurable concepts, but also incorporates many original concepts developed by early Russian soil scientists. The system still reflects the soil forming processes, and also separates the thermal conditions as a separate section (Mazhitova et al., 1994). The Type is the central classification unit with the Orders grouping some soil Types with similar subsurface diagnostic horizons, while the Trunks are three broad groups relating the soil material (organic or organo-mineral) and time of formation (postlithogenic or synlithogenic) (V.V. Dokuchaev Soil Science Institute, 2001). The modern system is considered the first approximation and will be updated rapidly. Many of the horizons designations have not been given quantitative parameters. Initially there are some problems in assigning one horizon designation over another. The lower levels of the modern classification are not as different as the earlier Russian classification system (V.V. Dokuchaev Soil Science Institute, 2001).

MATERIALS AND METHODS

Site Selection

The research sites investigated are located in the Kursk Oblast, Russia, south of the city Kursk. All sites were located in an upland position (with less than 5% slope), a frigid temperature regime and a udic moisture regime. Site1 is located in an experiment station quarry (N 51°31'54.9"; E 36°14'47.8"). Site 2 is located in another quarry on private land (N 51°36'08.2"; E 36°06'35.8"). The two quarry sites were selected to provide an indication of the depth of loess and the distinctive changes of parent materials and their possible influences. Tertiary sands composed the underlying parent material of site 1, while Cretaceous chalks underlie site 2. Both sites had a thick loess covering. Site 3 and 4 are located on the Central-Chernozem Biosphere reserve at N 51°31'53.7"; E 36°05'01.9", and N 51°32'20.1"; E 36°18'21.3", respectively. Site 5 (N 51°34'16.7"; E 36°05'40.6") and site 6 (N 51°32'04.3"; E 36°18'22.3") are also located on the Central-Chernozem Biosphere reserve. These sites were selected because they are located on a preserved area. The sites are to be used as a standard for future work in evaluating degradation on other central Chernozem sites.

Field Methods

The six sites were sampled and described in the field according to the Soil Survey Manual (Soil Survey Staff, 1993). The soil profiles were broken into horizons and the depths recorded. Site 4 which was not separated into horizons, instead it was sampled in 10cm increments to a depth of 250cm, later this site was broken into horizons based on data. Field texture, color, structure, consistence, "fizz-test" reactivity, and other significant physical characteristics were recorded. Approximately 1 kg of each soil horizon was placed in a plastic bag for laboratory analysis and shipped to the U.S.

Laboratory Methods

Each sample was placed in a Revco Scientific Model U 2186 A-O-E freezer (Asheville, N.C.) at -75°C for 72 hours in accordance with U.S.D.A quarantine regulations. These samples were then air dried and crushed to pass through a 2mm sieve. Approximately one forth of the sample that was < 2mm was further refined to pass through a 60-mesh sieve (Soil Survey Staff, 1996).

The results from the chemical and physical characterization (Part 2 and 3) are used to complete a soil classification to the family level of taxonomy using the 8th edition U.S taxonomic system (Soil Survey Staff, 1999) and to the species level using the modern Russian taxonomic system.

RESULTS AND DISCUSSION

Site 1

The soil has a mollic epipedon (value and chroma ≤ 3 to 106 cm and a base saturation > 50%) and a base saturation >50% throughout the soil profile (Table 44) resulting in this soil being classified as a Mollisol at the order level. The Kursk region has a relatively high rainfall placing these soils in an Udic moisture regime. Site 1 is an Udoll at the Suborder. The Great group is defined by the illuvial clay accumulating argillic diagnostic horizon at a depth of 60 cm or more and a frigid temperature regime, hence the soil is considered a Paleudoll. A mollic epipedon greater than 50 cm and finer than loamy sand texture indicates

Table 44. Soil morphology of site 1.*

Horizon	Depth (cm)	Color Moist	Texture	Structure	Boundary Distinctness	CEC pH 7	% Base Saturation
Ap	0-22	10YR 2/1	SiCL	M Gr	Clear wavy	34.00	100
A	22-44	10YR 2/1	SiCL	M Sbk/Gr	Clear wavy	34.83	95
AB	44-60	10YR 3/2	SiCL	M Sbk	Gradual	26.95	80
Bt1	60-76	10YR 3/1 and 3/3	SiCL	W Pr	Clear	23.14	100
Bt2	76-106	10YR 3/3	SiCL	W Pr	Clear	21.50	100
Bt3	106-144	10YR 6/4	SiCL	M Pr	Clear	21.16	100
2Bw	144-159	5YR 4/6	SCL	M Sbk	Clear	12.06	100
2C1	159-169	2.5YR 5/8	SL	W Sbk	Clear	7.07	100
2C2	169-202	2.5YR 5/8	SL	SLS Ma	Clear	7.61	100
2C3	202-247	2.5YR 5/8	LS	SLS Sg/Ma	Clear	5.42	97
2C4	247-283	7.5YR 8/4 and 5YR 5/8 bands	S	SLS Ma	Clear	5.54	80
2C5a	283-324	5YR 5/8	LS	SLS Sg	Clear	2.97	100
2C5b	283-324	7.5YR 8/2	S	SLS Sg	-	1.01	100

*Abbreviations for morphology designations are given in Appendix A.

a Pachic Paleudoll. The control section has a particle size fraction of 35.8% clay, 14.4% sand and a CEC:clay ratio of 0.62. Mineralogy is assumed mixed. The family level classification of site 1 is a fine-silty, mixed, superactive, frigid Pachic Paleudoll.

Key characteristics for classification according to the U.S. Taxonomy were base saturation and CEC, color, clay acummulation and rainfall. Lower taxonomic classification required soil texture, mineralogy and temperature information. Interestingly, the sand discontinuity did not effect soil classification and indicates a potential weakness in U.S. classification with regard to deeper soil investigation analysis.

The Trunk classification for all 6 sites is Postlithogenic, indicating the soils have formed in prior accumulated rock mineral materials. The Order level of classification is also the same for all 6 sites, being considered humus-accumulative soils.

The new Russian classification allows for distinction between human disturbed soils and the natural state. The soils in this research have been used for agriculture quite a long time ago, however the horizonization and organic accumulation do not appear sufficiently altered from the natural state and are classified the same as their natural counterparts.

The Type for all six sites are Chernozems due to the pronounced dark, deep, humus horizon. This is very similar to the mollic epipedon in U.S. taxonomy. The chernozems characteristically have carbonate accumulation and react with HCl. All six profiles had regions of carbonate accumulation, and although they were not visible, they reacted in accordance to a weak acid "fizz" test.

The Russian classification requires many specific measurable properties to be determined and needs to remove some generalized statements from the specific criteria. The shallow depth measurement of % organic C required is not clear (>3.5% humus in the *upper part* of the dark humus horizon), and there is potential for these six soils to not fit this criteria, although they would clearly be considered chernozems by many soil scientists. The method of humus determination was not calculated by the method designated in the new taxonomy so this may also effect the interpretations. Generalized statements regarding profile trends, general chemical properties, and parent material formation need to be identified as information separate from the specific properties. In this case these six profiles fit the general statements, however it is quite possible to have anomalies to these trends that fit all the Chernozem properties.

The Russian classification system is currently able to account for the clay illuvial argillic horizons (Clay-illuvial Chernozems). However, unlike the U.S. system, the increase required is 1.4 times the above horizon, which these profiles studied do not have that large an increase in clay.

The Subtype is a segregationary Chernozem because of the moderately thick humus profile, the slight overlap of the secondary carbonates, and the lower humus horizons. The carbonates are not present in the near the soil surface and have a distinct maximum below the humus region.

The general classification uses base saturation, carbonate leaching and salinity. Not all aspects are used unless necessary. Site 1 is a saturated, leached segregationary Chernozem. The description indicates a base saturation > 80% and leached indicates that carbonates are not present throughout the entire soil profile.

The species classification is Deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem. The deep modifier refers to the depth of humus (80-120 cm), while low humus infers between 3-6% organic matter. Moderate carbonatic indicates the upper extent of the free carbonates is between 50-120 cm.

The variety of this soil uses surface texture and any fragment modifiers. Site 1 is fully classified as a Loam, deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem. The final phase level of Russian taxonomy is used for depth to hard rock or pan material and is not used on unconsolidated sediments such as loess, glacial till, and glacio-fluvial sand. Since all soils investigated are in loess the phase level classification is not required.

Key characteristics in classifying this soil using the Russian taxonomy were organic matter, color, carbonate accumulation, base saturation and depth. More detailed classification used texture. Clay accumulation was not evident in the classification of this soil using the Russian system.

Site 2

This soil has a mollic epipedon to 41 cm and a base saturation >50% throughout the soil profile resulting in this soil being classified as a Mollisol at the order level (Table 45). The Kursk region has an Udic moisture regime. Site 2 is an Udoll at the Suborder. The Great group is defined by the argillic diagnostic horizon and is considered a Paleudoll. A mollic epipedon greater than 50 cm and finer than loamy sand texture indicates a Pachic Paleudoll. The control section has a particle size fraction of 37.8% clay, 4.4% sand, and a CEC:clay ratio of 0.76. Mineralogy is assumed mixed. The family level classification of site 2 is a fine-silty, mixed, superactive, frigid Pachic Paleudoll.

Key characteristics for classification according to the U.S. Taxonomy were base saturation and CEC, color, clay acummulation and rainfall. Lower taxonomic classification required soil texture, mineralogy and temperature information. Site 2 is classified exactly the same as site 1, even though the soils look very different at lower depths. Using Russian classification site 2 is classified the same as site 1 with two exceptions at the species level. Site 2 is classified as Loam, shallow, low humus, shallow carbonatic, saturated, leached segregationary Chernozem. The difference in this soil is the thinner humus horizon (40-60 cm) and the shallower depth to carbonates (30-50 cm). The change to shallow categories may indicate the increased use of this land for agriculture compared to the other profiles. The humus layer is significantly thinner possibly from the crop rotation that has occurred on this site and the removal of humic materials and nutrients. Other analyses did not indicate any

Table 45. Soil morphology of site 2.*

Horizon	Depth (cm)	Color Moist	Texture	Structure	Boundary Distinctness	CEC ph 7	% Base Saturation
Ap	0-25	10YR 2/1	SiCL	M Gr	Clear	37.31	81
A	25-45	10YR 2/1	SiCL	W/M Sbk	Clear	35.23	82
AB	45-85	10YR 4/3	SiCL	M Sbk	Clear	25.80	82
BA	85-135	10YR 5/4	SiCL	S Pr/M Sbk	Clear Wavy	20.21	100
Bt1	135-195	10YR 4/4	SiCL	M Sbk	Clear Wavy	28.60	100
Bt2	195-260	10YR 5/6	SiCL	M Pr	Clear Wavy	27.73	100
Bt3	260-319	2.5Y 6/4	SiCL	M/W Sbk	Clear Wavy	17.34	100
Bt4	319-368	10YR 5/4	SiCL	W Pl	Clear Wavy	23.19	100
Bt5	368-400	7.5YR 4/6	SiCL	M Sbk	Clear Wavy	24.25	100

*Abbreviations for morphology designations are given in Appendix A.

major change due to land use, however the modern Russian classification may indicate anthrpogenic influences on soil formation.

Site 2 is also considered post lithogenic and a humus accumulative soil. Similar to the U.S. classification scheme, the change in underlying parent materials (from Tertiary sands in site 1 to Cretaceous Chalks in site 2) is not evident. The Russian scheme does not mention parent materials that are unconsolidated, and the U.S. system does not mention parent material at all. The Russian classification does not indicate the increase in clay that is very characteristic in the U.S. classification for this profile.

Site 3

This soil has a mollic epipedon to 69 cm and a base saturation >50% throughout the soil profile (Table 46) resulting in this soil being classified as a Mollisol at the Order level. The Kursk region has an Udic moisture regime. Site 3 is an Udoll at the Suborder. The Great group is defined by the central concept of the Udolls, having cambic diagnostic horizons, and is classified as a Hapludoll. A frigid temperature regime, over-thickened mollic epipedon, fine texture, <25% slope, and >0.3% organic C at 125 cm indicates a Cumulic Hapludoll. The control section has a particle size fraction of 28.8% clay, 2.1% sand, and a CEC:clay ratio of 0.74. Mineralogy is assumed mixed. The family level classification of site 3 is a fine-silty, mixed, superactive, frigid Cumulic Hapludoll.

Key characteristics for classification according to the U.S. Taxonomy were base saturation, CEC, color and rainfall. Lower taxonomic classification required

Table 46. Soil morphology of site 3.*

Horizon	Depth (cm)	Color Moist	Texture	Structure	Boundary Distinctness	CEC pH 7	% Base Saturation
A1	0-34	10YR 2/1	SiCL	M Gr	Clear Wavy	34.17	94
A2	34-69	10YR 3/2	SiCL	M Gr/W Sbk	Clear Wavy	21.13	100
AB	69-85	10YR 4/3	SiCL	M Sbk	Clear Wavy	18.36	100
Bw1	85-102	10YR 5/6	SiCL	M Sbk	Clear Wavy	16.15	100
Bw2	102-140	10YR 6/6	SiCL	M Sbk	Clear Wavy	13.76	100
Bw3	140-191	10YR 6/6	SiCL	M Sbk	Clear	15.35	100
C1	191-230	10YR 6/4	SiL	-	Clear	8.89	100
C2	230-240	10YR 5/4	SiL	-	Clear	8.15	100
C3	240-260	10YR 4/4	SiCL	-	Clear	13.59	100
C4	260-285	10YR 6/4	SiL	-	Clear	9.95	100
C5	285-295	10YR 6/3	SiL	-	Clear	9.42	100
C6	295-305	10YR 3/4	SiL	-	Clear	11.09	100
C7	305-315	10YR 6/4	SiL	-	Clear	10.47	100

*Abbreviations for morphology designations are given in Appendix A.

soil texture, mineralogy and temperature information. Site 3 is classified differently due to the lack of clay accumulation and the over thickened mollic epipedon. Usually cumulic soils are located in receiving positions, however this profile is on a broad, flat upland. The low level of disturbance and the stability of this landform are evident in data from Part 2 and 3, but it is also reflected in the U.S. Soil Taxonomy. Unfortunately, Paleudoll classification does not have a cumulic sub group, as these soils are considered more weathered, but site 1, 4 and 6 would fit the depth, slope and organic C accumulation criteria for cumulic designation. If a large enough area of these soils occurs, which seems probable, Soil Taxonomy may need to be amended to allow for accurate soil mapping of these regions.

Using Russian classification, site 3 is classified the same as site 1 with one exception at the species level. Site 3 is classified as Loam, moderately deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem. The difference in this soil is the thinner humus horizon (60-80 cm). Site 3 is also considered post lithogenic and a humus accumulative soil. The Russian classification, like the U.S. classification accurately indicates no significant clay increase.

Site 4

The soil has a mollic epipedon to more than 60 cm and a base saturation >50% throughout the soil profile (Table 47) resulting in this soil being classified as a Mollisol at the order level. The Kursk region has an Udic moisture regime.

Table 47. Soil morphology of site 4.* **

Horizon	Depth (cm)	Color Moist	Texture	CEC pH 7	% Base Saturation
A1	0-30	10YR 2/2	SiCL	30.98	100
A2	30-60	10YR 2/1	SiCL	29.01	100
Bt1	60-120	10YR 3/3	SiC	23.69	100
Bt2	120-150	10YR 5/3	SiC	18.17	100
Bt3	150-210	10YR 5/6	SiC	18.25	100
Bt4	210-250	10YR 5/4	SiC	22.71	100

*Abbreviations for morphology designations are given in Appendix A.
**Sampled with auger at 10 cm increments. No structure and boundary distinction were determined.

Site 4 is an Udoll at the Suborder. The Great group is defined by the argillic diagnostic horizon and is considered a Paleudoll. A mollic epipedon greater than 50 cm and finer than loamy sand texture indicates a Pachic Paleudoll. The control section has a particle size fraction of 40.3% clay, 0.8% sand, and a CEC:clay ratio of 0.59. Mineralogy is assumed mixed. The family level classification of site 4 is a fine-silty, mixed, active, frigid Pachic Paleudoll.

Key characteristics for classification according to the U.S. Taxonomy were base saturation and CEC, color, clay acummulation and rainfall. Lower taxonomic classification required soil texture, mineralogy and temperature information.

Using Russian classification site 4 is classified the same as site 1. Site 4 is classified as Loam, deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem. Site 4 is also considered post lithogenic and a humus accumulative soil. The Russian classification did not indicate the increase in clay that is very characteristic in the U.S. classification of this profile.

Site 5

The soil is classified as a Mollisol at the Order level because it has a mollic epipedon to 75 cm and a base saturation >50% throughout the soil profile (Table 48). The Kursk region has an Udic moisture regime. Site 5 is an Udoll at the Suborder level. The Great group is defined by the central concept of the Udolls having cambic diagnostic horizons and is classified as a Hapludoll. A mollic epipedon greater than 40 cm and a frigid temperature regime indicates a

Table 48. Soil morphology of site 5.*

Horizon	Depth (cm)	Color Moist	Texture	Structure	Boundary Distinctness	CEC pH 7	% Base Saturation
A1	0-27	10YR 2/1	SiCL	M Gr	Clear	37.21	82
A2	27-49	10YR 2/1	SiCL	M Sbk	Clear	33.61	86
A3	49-75	10YR 2/2	SiCL	M Sbk	Clear Wavy	29.13	87
AB	75-95	10YR 3/4	SiCL	M Sbk	Clear Wavy	25.37	88
BA	95-112	10YR 4/4	SiCL	W Sbk	Clear Wavy	23.01	86
Bw1	112-146	10YR 5/4	SiCL	W Sbk	Clear Wavy	19.19	100
Bw2	146-180	10YR 5/4	SiCL	W Sbk	Clear	21.03	100
C1	180-220	10YR 6/4	SiCL	W Sbk	Clear	15.19	100
C2	220-240	10YR 5/4	SiL	-	Clear	14.19	100
C3	240-248	10YR 5/4	SiCL	-	Clear	19.40	100
C4	248-270	10YR 6/4	SiL	-	Clear	14.14	100
C5	270-307	10YR 7/4	SiL	-	-	15.25	101
C6	307-330	10YR 7/3	SiL	-	-	12.75	98

*Abbreviations for morphology designations are given in Appendix A.

Pachic Hapludoll. Site 5 has 0.29% organic C at 125 cm and does not quite fit the cumulic classification of site 3. The control section has a particle size fraction of 31.5% clay, 1.0% sand, and a CEC:clay ratio of 0.94. Mineralogy is assumed mixed. The family level classification of site 5 is a fine-silty, mixed, superactive, frigid Pachic Hapludoll.

Base saturation, CEC, color and rainfall were key characteristics for classification using U.S. Soil Taxonomy. Lower taxonomic classification required soil texture, mineralogy and temperature information.

Using Russian classification site 5 is classified the same as site 3. Site 5 is classified as Loam, moderately deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem. Site 5 is also considered post lithogenic and a humus accumulative soil. The Russian classification, like the U.S. classification, correctly indicates no significant clay increase.

Site 6

This soil has a mollic epipedon to 108 cm and a base saturation >50% throughout the soil profile (Table 49), determining this soil being classified as a Mollisol at the Order level. The Kursk region has an Udic moisture regime. Site 6 is an Udoll at the Suborder classification. The Great group is defined by the argillic diagnostic horizon, and is considered a Paleudoll. A frigid temperature regime and finer than loamy sand texture indicates a Pachic Paleudoll. There is no cumulic classification for Paleudolls, as this soil would fit the criteria. The control section has a particle size fraction of 39.5% clay, 3.5% sand, and a

Table 49. Soil morphology of site 6.*

Horizon	Depth (cm)	Color Moist	Texture	Structure	Boundary Distinctness	CEC pH 7	% Base Saturation
A1	0-40	10YR 2/1	SiCL	M Gr	Clear	38.90	83
A2	40-70	10YR 3/1	SiCL	W/M Gr	Clear	27.11	100
A3	70-95	10YR 3/2	SiCL	W/M Sbk	Clear	25.14	100
A4	95-108	10YR 3/2	SiCL	M Sbk	Clear	23.72	100
AE	108-137	10YR 4/2	SiL	M Sbk	Clear	22.42	100
E	137-190	10YR 6/4	SiL	S/M Sbk	Clear	22.30	100
Bt1	190-230	10YR 4/4	SiCL	S/M Sbk	Clear	25.37	100
Bt2	230-250	7.5YR 5/4	SiC	S/M Sbk	Clear	24.61	100

*Abbreviations for morphology designations are given in Appendix A.

CEC:clay ratio of 0.65. Mineralogy is assumed mixed. The family level classification of site 6 is a fine-silty, mixed, superactive, frigid Pachic Paleudoll.

Key characteristics for classification according to the U.S. Taxonomy were base saturation and CEC, color, clay acummulation and rainfall. Lower taxonomic classification required soil texture, mineralogy and temperature information. Using Russian classification, site 6 is classified the same as site 1 and 4 with one exception at the species level. Site 6 is classified as Loam, deep, low humus, shallow carbonatic, saturated, leached segregationary Chernozem. The difference in this soil is the shallower depth to carbonates (30-50 cm). Site 6 is also considered post lithogenic and a humus accumulative soil. The Russian classification did not indicate the increase in clay that is very characteristic in the U.S. classification for this profile.

Key characteristics in classifying this soil using the Russian taxonomy were organic matter, color, carbonate accumulation, base saturation and depth. More detailed classification used texture.

CONCLUSIONS

The Russian classification system allows for soil development over time and the return to its natural state, however the changes are very difficult to assess.

The lack of defined properties in the 1st approximation of the modern Russian classification system makes it hard to directly compare the U.S. and the Russian taxonomy.

The Russian classification requires many specific measurable properties to be determined and needs to remove some generalized statements from the specific criteria.

The soils were classified in U.S. Soil Taxonomy as follows:

Sites 1, 2, and 6. Fine-silty, mixed, superactive, frigid Pachic Paleudoll.
Site 3. Fine-silty, mixed, superactive, frigid Cumulic Hapludoll.
Site 4. Fine-silty, mixed, active, frigid Pachic Paleudoll.
Site 5. Fine-silty, mixed, superactive, frigid Pachic Hapludoll.

The soils were classified using Russian Soil Classification as follows:

Site 1 and 4. Loam, deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem.
Site 2. Loam, shallow, low humus, shallow carbonatic, saturated, leached segregationary Chernozem
Site 3 and 5. Loam, moderately deep, low humus, moderate carbonatic, saturated, leached segregationary Chernozem.
Site 6. Loam, deep, low humus, shallow carbonatic, saturated, leached segregationary Chernozem.

The key diagnostic feature for the classification of these soils with both systems was organic matter.

Cumulic criteria may need to be added to the Argiudoll/Paleudoll Sub group classification.

The Russian classification describes the accumulation of non-visible carbonates at the Type level, however the U.S. system does not describe this phenomenon at any level in its classification scheme.

The Russian classification does not describe the clay accumulation that was evident in the U.S. system with the Great group Paleudoll.

The Russian classification clearly separates significantly disturbed soils due to anthropogenic influence, while the U.S. system is still negotiating the placement of disturbed soils in the U.S. Soil Taxonomy.

The Russian taxonomic system does not appear to indicate temperature, moisture, or mineralogy of the soils studied.

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APPENDICIES

Appendix A: Abbreviations used in Soil Morphology

I. Soil Texture

A. Textural Class

S = Sand
LS = Loamy Sand
SL = Sandy Loam
L = Loam
SiL = Silty Loam
Si = Silt
CL = Clay Loam
SiCL = Silty Clay Loam
SCL = Sandy Clay Loam
SC = Sandy Clay
SiC = Silty Clay
C = Clay

II. Soil Structure

A. Strength of Structure

W = Weak
M = Moderate
S = Strong
SLS = Structureless

B. Structure Type

Gr = Granular
Sbk = Subangular blocky
Pr = Prismatic
Sg = Single grained
Ma = Massive
Pl = Platy

III. Consistence

A. Consistence Class

VFr = Very Friable
Fr = Friable
Fi = Firm
VFi = Very Firm

APPENDIX B

Appendix B: Soil Profile Descriptions

Site 1 Soil Profile Description

Landscape position: Upland
Parent Material: Loess/Tertiary Sand
Elevation: 261 m
Slope: 1%
Drainage: Well drained
Latitude and Longitude: N 51°31'54.9" E 36°14'47.8"
Vegetation: Grasses
Classification: Fine, mixed, superactive, frigid Pachic Argiudoll

Ap- 0 to 22 cm; black (10YR 2/1) silty clay loam; moderate granular structure; very friable; clear wavy boundary.

A1- 22 to 44 cm; black (10YR 2/1) silty clay loam; moderate granular and moderate subangular blocky structure; very friable; clear wavy boundary.

AB- 44 to 60 cm; very dark grayish brown (10YR 3/2) silty clay loam; moderate subangular blocky structure; very friable; gradual boundary.

Btk1- 60 to 76 cm; very dark gray and dark brown (10YR 3/1 and 3/3);silty clay loam; weak prismatic structure; friable; clear boundary.

Btk2- 76 to 106 cm; dark brown (10YR 3/3) silty clay loam; weak prismatic structure; friable; clear boundary.

Btk3- 106 to 144 cm; light yellowish brown (10YR 6/4) silty clay loam; moderate prismatic structure; friable; clear boundary.

2Bk- 144 to 159 cm; yellowish red (5YR 4/6) sandy clay loam; moderate subangular blocky structure; friable; clear boundary.

2C1- 159 to 169 cm; red (2.5YR 5/8) sandy loam; weak subangular blocky structure; friable; clear boundary.

2C2- 169 to 202 cm; red (2.5YR 5/8) sandy loam; structureless massive structure; friable; clear boundary.

2C3- 202 to 247 cm; red (2.5YR 5/8) loamy sand; structureless massive and single grained structure; friable; clear boundary.

2C4- 247 to 283 cm; pink and yellowish red bands (7.5YR 8/4 and 5YR 5/8) sand; structureless massive structure; very friable; clear boundary.

2C5a- 283 to 324 cm; yellowish red bands (5YR 5/8) loamy sand; structureless single grained structure; very friable; clear boundary.
2C5b- 283 to 324 cm; pinkish white (7.5YR 8/2) sand; structureless single grained structure; very friable.

Site 2 Soil Profile Description

Landscape position: Upland
Parent Material: Loess
Elevation: 258 m
Slope: 2%
Drainage: Well drained
Latitude and Longitude: N 51°36'08.2" E 36°06'35.8"
Vegetation: White birch trees and grasses
Classification: Fine, mixed, superactive, frigid Pachic Argiudoll

Ap- 0 to 25 cm; black (10YR 2/1) silty clay loam; moderate granular structure; friable; clear boundary.

A1- 25 to 45 cm; black (10YR 2/1) silty clay loam; weak and moderate subangular blocky structure; friable; clear boundary.

AB- 45 to 85 cm; brown (10YR 4/3) silty clay loam; moderate subangular blocky structure; friable; clear boundary.

BA- 85 to 135 cm; yellowish brown (10YR 5/4); silty clay loam; strong prismatic and moderate subangular blocky structure; firm; clear wavy boundary.

Bt1- 135 to 195 cm; dark yellowish brown (10YR 4/4) silty clay loam; moderate subangular blocky structure; firm; clear wavy boundary.

Bt2- 195 to 260 cm; yellowish brown (10YR 5/6) silty clay loam; moderate prismatic structure; friable; clear wavy boundary.

Bt3- 260 to 319 cm; light yellowish brown (2.5Y 6/4) silty clay loam; weak and moderate subangular blocky structure; very friable; clear wavy boundary.

Bt4- 319 to 368 cm; yellowish brown (10YR 5/4) silty clay loam; weak platy structure; very friable; clear wavy boundary.

Bt5- 368 to 400 cm; strong brown (7.5YR 4/6) silty clay loam; moderate subangular blocky structure; friable; clear wavy boundary.

Site 3 Soil Profile Description

Landscape position: Upland
Parent Material: Loess
Elevation: 262 m
Slope: 1%
Drainage: Well drained
Latitude and Longitude: N 51°31'53.7" E 36°05'01.9"
Vegetation: Oak tree forest
Classification: Fine silty, mixed, superactive, frigid Cumulic Hapludoll

A1- 0 to 34 cm; black (10YR 2/1) silty clay loam; moderate granular structure; friable; clear wavy boundary.

A2- 34 to 69 cm; very dark grayish brown (10YR 3/2) silty clay loam; moderate granular and weak subangular blocky structure; friable; clear wavy boundary.

AB- 69 to 85 cm; brown (10YR 4/3) silty clay loam; moderate subangular blocky structure; friable; clear wavy boundary.

Bw1- 85 to 102 cm; yellowish brown (10YR 5/6); silty clay loam; moderate subangular blocky structure; friable; clear wavy boundary.

Bw2- 102 to 140 cm; brownish yellow (10YR 6/6) silty clay loam; moderate subangular blocky structure; friable; clear wavy boundary.

Bw3- 140 to 191 cm; brownish yellow (10YR 6/6) silty clay loam; moderate subangular blocky structure; friable; clear boundary.

C1- 191 to 230 cm; light yellowish brown (10YR 6/4) silt loam; friable; clear boundary.

C2- 230 to 240 cm; yellowish brown (10YR 5/4) silt loam; friable; clear boundary.

C3- 240 to 260 cm; dark yellowish brown (10YR 4/4) silty clay loam; friable; clear boundary.

C4- 260 to 285 cm; light yellowish brown (10YR 6/4) silt loam; friable; clear boundary.

C5- 285 to 295 cm; pale brown (10YR 6/3) silt loam; friable; clear boundary.

C6- 295 to 305 cm; dark yellowish brown (10YR 3/4) silt loam; friable; clear boundary.

C7- 305 to 315 cm; light yellowish brown (10YR 6/4) silt loam; friable; clear boundary.

Site 4 Soil Profile Description

Landscape position: Upland
Parent Material: Loess
Elevation: 250 m
Slope: 1%
Drainage: Well drained
Latitude and Longitude: N 51°32'20.1" E 36°18'21.3"
Vegetation: Grasses and legumes
Classification: Fine, mixed, superactive, frigid Pachic Argiudoll

Ap-	0 to 30 cm; black (10YR 2/1) silty clay loam.
A1-	30 to 60 cm; black (10YR 2/1) silty clay loam.
Bt1-	60 to 120 cm; dark brown (10YR 3/3) silty clay.
Bt2-	120 to 150 cm; brown (10YR 5/3) silty clay.
Bt3-	150 to 210 cm; yellowish brown (10YR 5/6) silty clay.
Bt4-	210 to 250 cm; yellowish brown (10YR 5/4) silty clay.

Site 5 Soil Profile Description

Landscape position: Upland
Parent Material: Loess
Elevation: 271 m
Slope: 1%
Drainage: Well drained
Latitude and Longitude: N 51°34'16.7" E 36°05'40.6"
Vegetation: Grasses and shrubs
Classification: Fine silty, mixed, superactive, frigid, Pachic Hapludoll

A1-	0 to 27 cm; black (10YR 2/1) silty clay loam; moderate granular structure; very friable; clear boundary.
A2-	27 to 49 cm; black (10YR 2/1 silty clay loam; moderate subangular blocky structure; friable; clear boundary.
A3-	49 to 75 cm; very dark brown (10YR 2/2) silty clay loam; moderate subangular blocky structure; friable; clear wavy boundary.
AB-	75 to 95 cm; dark yellowish brown (10YR 3/4); silty clay loam; moderate subangular blocky structure; friable; clear wavy boundary.
BA-	95 to 112 cm; dark yellowish brown (10YR 4/4) silty clay loam; weak subangular blocky structure; friable; clear wavy boundary.
Bw-	112 to 146 cm; yellowish brown (10YR 5/4) silty clay loam; weak subangular blocky structure; friable; clear wavy boundary.
Bw-	146 to 180 cm; yellowish brown (10YR 5/4) silty clay loam; weak subangular blocky structure; friable; clear boundary.
C1-	180 to 220 cm; light yellowish brown (10YR 6/4) silty clay loam; weak subangular blocky structure; friable; clear boundary.
C2-	220 to 240 cm; yellowish brown (10YR 5/4) silty loam; friable; clear boundary.
C3-	240 to 248 cm; yellowish brown (10YR 5/4) silty clay loam; friable; clear boundary.
C4-	248 to 270 cm; light yellowish brown (10YR 6/4) silt loam; friable; clear boundary.
C5-	270 to 307 cm; very pale brown (10YR 7/4) silt loam.

C6-	307 to 330 cm; very pale brown (10YR 7/3) silt loam.

Site 6 Soil Profile Description

Landscape position: Upland
Parent Material: Loess
Elevation: 252 m
Slope: 5%
Drainage: Well drained
Latitude and Longitude: N 51°33'04.3" E 36°18'22.3"
Vegetation: Grasses and legumes
Classification: Fine silty, mixed, superactive, frigid, Cumulic Hapludoll

A1- 0 to 40 cm; black (10YR 2/1) silty clay loam; moderate granular structure; very friable; clear boundary.

A2- 40 to 70 cm; very dark gray (10YR 3/1 silty clay loam; weak and moderate granular structure; very friable; clear boundary.

A3- 70 to 95 cm; very dark grayish brown (10YR 3/2) silty clay loam; weak and moderate subangular blocky structure; friable; clear boundary.

A4- 95 to 108 cm; very dark grayish brown (10YR 3/2); silty clay loam; moderate subangular blocky structure; friable; clear boundary.

AE- 108 to 137; dark grayish brown (10YR 4/2) silt loam; moderate subangular blocky structure; friable; clear boundary.

E- 137 to 190 cm; light yellowish brown (10YR 6/4) silty loam; strong and moderate subangular blocky structure; friable; clear boundary.

Bt1- 190 to 230 cm; dark yellowish brown (10YR 4/4) silty clay loam; strong and moderate subangular blocky structure; friable and firm; clear boundary.

Bt2- 230 to 250 cm; brown (7.5YR 5/4) silty clay; strong and moderate subangular blocky structure; friable and firm; clear boundary.

VITA

Ryan Noble was born on October 5th, 1976, in Rosebud, Victoria, Australia. He attended Traralgon Secondary College where he graduated in December 1994. He entered the University of Melbourne in January 1996 and then transferred to The University of Tennessee in January 1998, graduating with a Bachelor of Science degree in Plant and Soil Science in May 2000. In August 2000, Ryan entered graduate school to work on a Master of Science degree with an emphasis on soil genesis and classification. He received his degree from the University of Tennessee in May 2002.