SOIL AND GEOMORPHIC EVOLUTION WITHIN THE ROLLING RED PLAINS USING PLEISTOCENE VOLCANIC ASH DEPOSITS

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CHAPTER 1

INTRODUCTION

The alluvium of major river systems from the Arkansas River south to the Brazos River contains early to middle Pleistocene volcanic ash deposits. This drainage area includes tributaries originating in the High Plains, the Raton volcanic field and the Rocky Mountain Front Range within the states of Oklahoma, Colorado, New Mexico, Kansas, and Texas (Figure 1).

Thirteen ash deposits are dated (Ward and Carter, 1989) from within the High Plains of Kansas and Texas eastward in to central Oklahoma to understand the geomorphic history and improve soil and geologic mapping. Time is an important factor in the formation of soil (Jenny, 1941) and geomorphology (Davis, 1889). Dating soil parent materials which are older than 70,000 yr B.P. constitutes a major improvement in the understanding of soil formation and geomorphology because these dates are rare.

Within the study area unconsolidated Tertiary and Quaternary sediments deposited in a west to east direction overlie Triassic, Permian, and Pennsylvanian bedrock. Volcanic ash deposits are predominantly early to middle Pleistocene age (dated by the fission-track method on shards; Boellstorff, 1976). The ash deposits are contained within five land resource regions, the Southern and Central High Plains, the High Plains Breaks, the Rolling Red Plains, and the

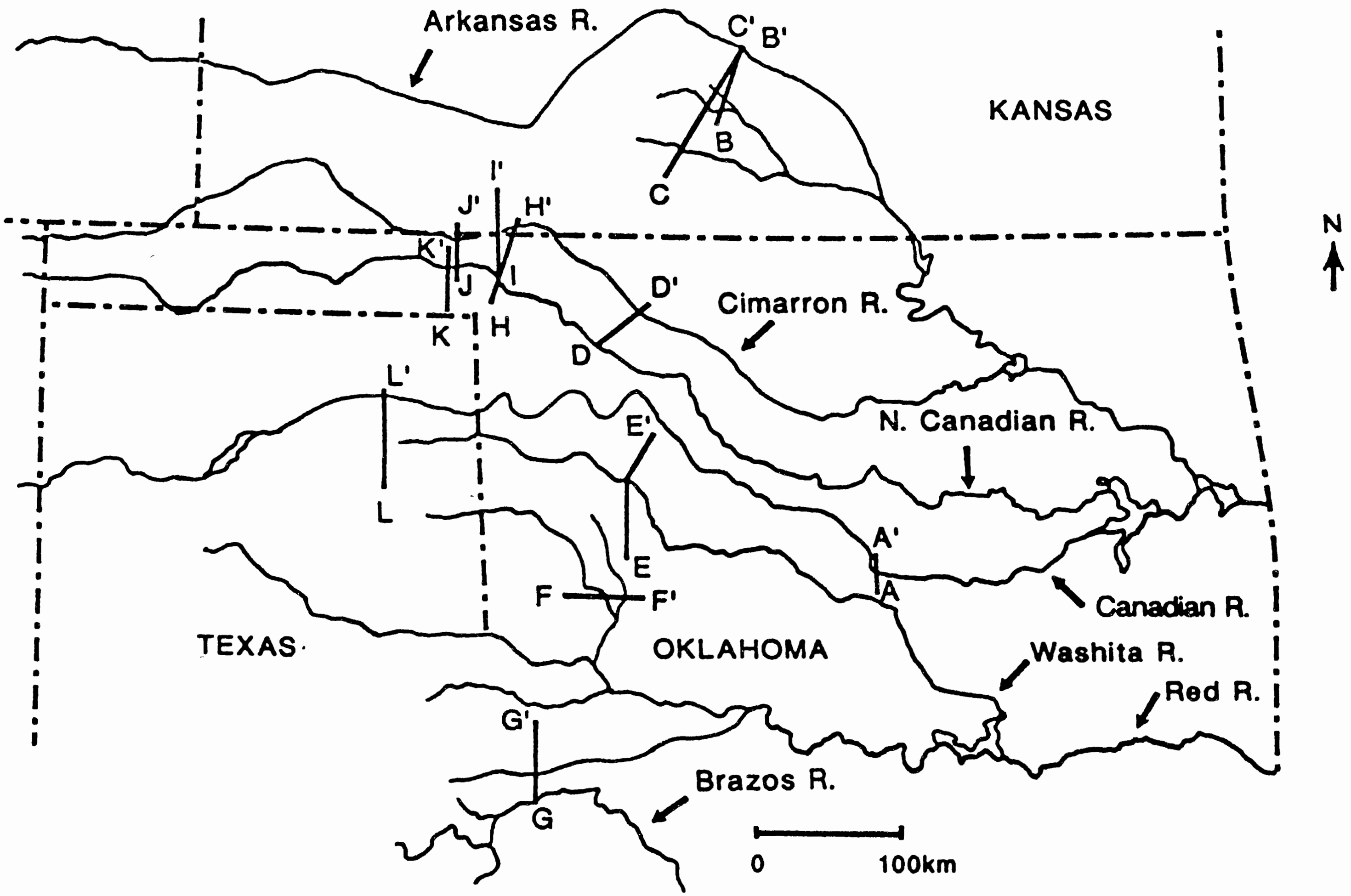

Figure 1. Transect locations along major rivers across the study area in Kansas, Oklahoma, and Texas

Reddish Prairies (Figure 2). Extensive middle Pleistocene constructional stream terrace surfaces occur within the Rolling Red Plains. Multiple stream terrace surfaces were recognized across the study are by Frye and Leonard (1963) with the highest level being dated early Pleistocene to Pliocene and the lowest bordering the Holocene floodplains.

Objectives

The objective of this research was to use dated volcanic ash deposits as time markers to interpret soil formation and geomorphic evolution of the Rolling Red Plains. River floodplains and terraces provide an excellent setting in which to examine soils and pedological processes. When the terraces are dated, the soils can then be placed in a realistic chronology and conclusions reached on rate of soil formation. Geomorphologists can use the properties of the soils to study past climatic regimes in the history of the landscape. Knowledge of soils found on floodplains and river terraces is especially important because these are some of the most densely populated and intensively cultivated areas.

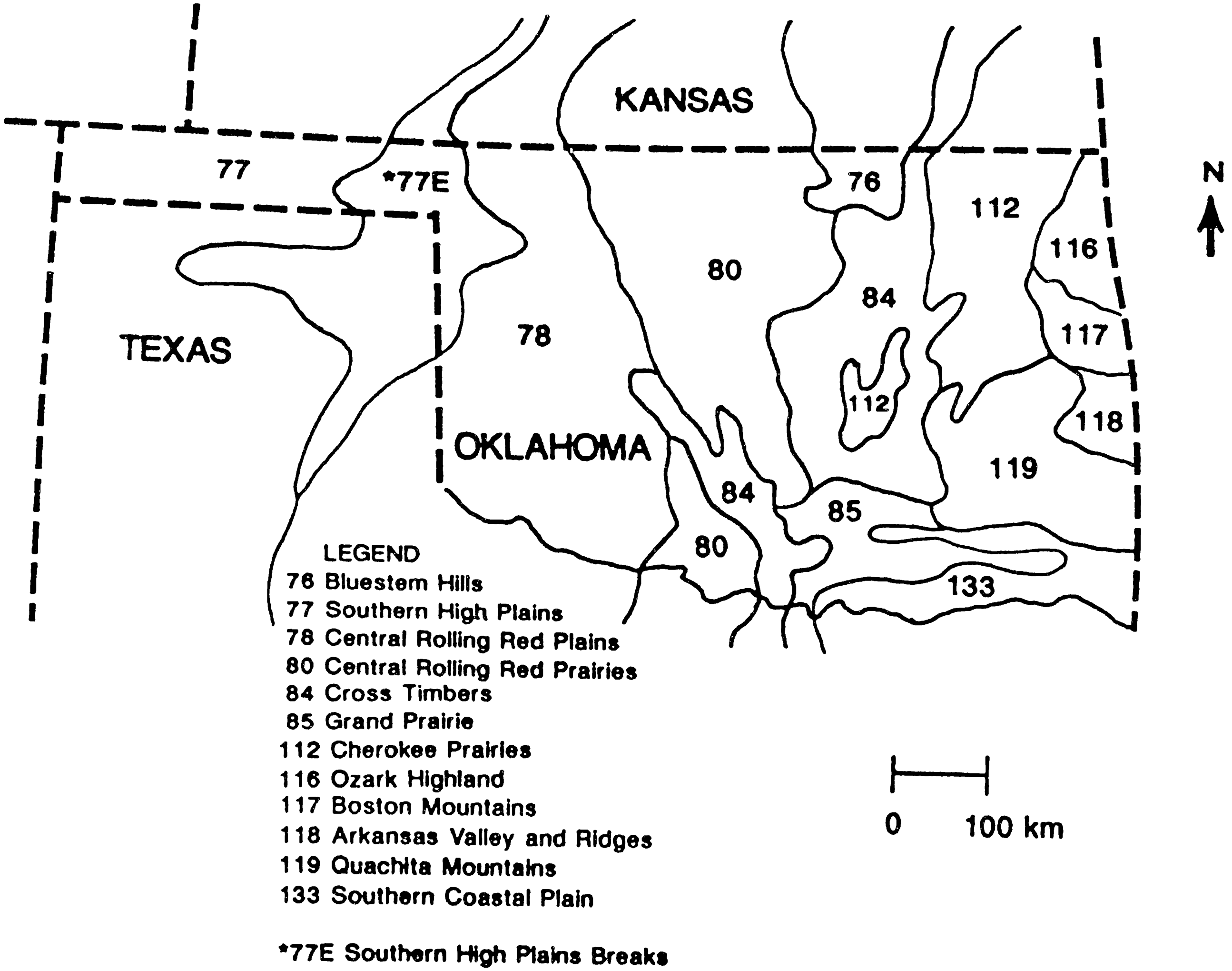

Figure 2. Land resource areas across the study area in Kansas, Oklahoma, and Texas

CHAPTER II

LITERATURE REVIEW

Volcanic ash as time marker bed

Volcanic ash deposits have been located and identified in the Central Great Plains since the 1800's (Buttram, 1914; Frye et al., 1948; Burwell and Hamm, 1949; Boellstorff, 1976; Izett, 1981; Izett and Wilcox, 1982). Early studies considered the deposits as one ash and applied the stratigraphic name "Pearlette ash" to deposits in Meade County, Kansas. Later investigations in Oklahoma, Texas, Nebraska, and Kansas, (Frye et al, 1948), revealed the presence of several ashes of a single middle-Pleistocene age in their study of Great Plains and glacial geologic deposits. They used the ashes as time marker beds to distinguish between Pleistocene and Pliocene deposits. The more recent studies by Boellstorff (1976), Izett et al., (1970), and Izett (1981) have shown that the ash beds in the Great Plains are of widely differing ages and have different volcanic source areas. Izett and Wilcox (1982) identified the source areas for the major ash falls as the Yellowstone caldera, the Long Valley caldera of California and the Toledo and Valles calderas of New Mexico. The ash deposits have been used as time marker beds to make regional correlations of geologic deposits because they can be dated (Boellstorff, 1976; Naeser and Naeser, 1988) and they have widespread occurrence. Karas (1987) used relative topographic position and degree of soil development in alluvial deposits to correlate alluvial deposits and assign relative ages to them. The age of the Blackwater Draw Formation of the Texas Panhandle was determined by Holliday (1988 and 1989) using volcanic ash as time markers and soil-geomorphic indicators. Holliday (1989) also uses the presence of two ashes in the Blackwater Draw formation of Texas and New Mexico to show that the wide-spread eolian deposit accumulated throughout most of the Quaternary.

Glass shards taken from volcanic ash deposits have been fission-track dated (Ward and Carter, 1989, in review; Boellstorff, 1976; Boellstorff and Steinck, 1975). Fission-track dating, classified as a radiogenic method of dating according to Colman et al, (1987), is a recognized tool in recent research focusing on Quaternary landforms, deposits, and geologic events.

The Rolling Red Plains and Southern High Plains Border regions of western Oklahoma, southcentral Kansas, and the eastern edge of the Texas Panhandle are covered by a soil mantle of alluvial and eolian origin. Reeves and Haynes (1976) describe the Southern High Plains surface as being mantled by Quaternary eolian, fluvial, and lacustrine deposits. In west-central Oklahoma, early Pleistocene deposits are thought to be part of a continuous plain (Carter, 1985) incised by the major rivers flowing through the area, namely the Arkansas, Cimarron, North Canadian, Canadian, Washita and Red. Ages of the alluvial and eolian deposits in that area may be estimated using the volcanic ashes found there.

Pleistocene alluvial deposits

Pleistocene alluvial deposits have been identified throughout the study area. Kitts (1959, 1965) studied terraces along the Canadian

River in Roger Mills and Ellis counties in western Oklahoma and used faunal assemblages and volcanic ash deposits to assign ages. Hibbard (1944) and Stephens (1960) identified Pleistocene deposits in southwestern Kansas and northwestern OK, respectively, using stratigraphy and vertebrate paleontology. Fay (1959) noted broad constructional surfaces associated with Pleistocene deposits. He identified five discernible terrace levels in the Canadian River basin of west central Oklahoma. Volcanic ash was found only in the highest terrace. Myers (1959, 1962) describes constructional terrace surfaces and Pleistocene terrace deposits in a long, wide band between the North Canadian and Cimarron Rivers throughout most of northwestern Oklahoma (excluding the Panhandle). These deposits are discontinuous because parts have been removed by Late Pleistocene and Recent erosion (Myers, 1962). Volcanic ash is also noted in these deposits (Fay, 1959).

Soil surveys have identified the terrace deposits along the major streams and the soil landscapes that are associated with them (Gray and Galloway, 1969). Soil landscapes are first identified by aerial photography. Percent slope is a major consideration, hillslope components (Ruhe and Walker, 1968) are used to differentiate expected differences in soil type. These soil landscape mapping units are then field checked for soil and geologic characteristics. In this way soil surveys become a powerful tool in understanding regional soil geomorphologic relationships. Soil mapping units are based on land use and can include one or more soil series. Soil series are soils that have profiles almost alike. They may differ in texture in surface layers but horizons are similar in thickness, arrangement and other important characteristics (Soil Survey Staff, 1975). The system of soil classification used by the National Cooperative Soil Survey has six categories. They are order, suborder, great group, subgroup, family, and series. Classification is based on soil properties observed in the field or inferred from those observations or from laboratory measurements. To date all but two counties in Oklahoma, most of Kansas, and about half of Texas is soil mapped.

Soil development and topography

Many studies have been made involving soil development and topography. Ruhe (1956) showed that specific soils or soil associations can be related to each delineated geomorphic surface. Ruhe et al. (1967) identifies erosion as the key factor in shaping the landscapes of southwestern Iowa and affecting the soil development.

Bilzi and Ciolkosz (1977) cite time as a major factor in soil development. They studied the genesis of four alluvial soils in central Pennsylvania to evaluate the importance of time in relation to the soils' pedologic age. Radiocarbon methods were used to determine age deposits and soils (Birkeland, 1984).

A field morphology rating scale was used by Bilzi and Ciolkosz (1977) to show the distinctness of the horizons in each soil profile. The rating scale indicated the similar ages of the first three soils, whereas the fourth soil was rated pedologically older. These relationships agreed with the findings of the radiocarbon dating or chronologic age. Bilzi and Ciolkosz (1977) found that morphological properties are effective in distinguishing chronological age differences and concluded that pedologic age differences were best identified by the relative distinctness of horizons evaluated by a field morphology rating scale, their in situ weathering of clay minerals, and the volume of illuvial clay films in the B horizons.

Soil-landscape studies combined with reasonably accurate methods of dating events indicate that soil development can be much more rapid than originally thought (Hall et al, 1982). The first indication of soil formation is usually considered to be when organic matter is incorporated in the surface of a parent material (mollic epipedon), with the A horizon forming in as little as 24 years (Hall et al, 1982). Clay translocation and accumulation in the B horizon generally takes longer (> 2000 years) but Hall et al (1982) indicate that under ideal conditions the process may be relatively rapid (450 years). Cambic horizon or color B horizon formation depends on all the soil forming factors (Hall et al, 1982) and are thought to be the first stages of subsoil development.

Gile et al. (1981) stated that soil age was the most important factor affecting soil morphology and occurrence at stable locations. In the stepped sequence of geomorphic surfaces along the Rio Grande valley border, the soils of stable sites are progressively older, thicker, and more prominent with increasing elevation of the steps. The horizon of carbonate accumulation in desert conditions is the soil horizon that exhibits the morphological change and that is best related to soil age (Gile et al., 1981). The stages of carbonate accumulation are useful as chronological and stratigraphic markers for the soils. Carbonate can accumulate in any desert soil if moisture can enter and there is a source of carbonate, in either dust or the soil parent material (Gile et al, 1981). Increasing soil development is also shown by increasing thickness of the carbonate horizon with age. Harden and Taylor (1983) applied the comparative techniques of the soil development index to determine whether certain soil properties develop systematically with depth and age, and whether they develop similarly in different environments. The five properties that correlated most significantly with age in the four chronosequences that Harden and Taylor studied were total texture, rubification, clay films, dry consistence, and moist consistence. It is their conclusion, that if samples are separated and grouped according to soil-forming factors and described according to Soil Survey Staff (1951, 1982) procedures, the development of soil properties is found to be highly correlative with age, and quantitative comparisons of development rates can be made. Birkeland (1984) suggests that the relative importance of time as a soil forming factor will vary from soil to soil.

CHAPTER III

METHODS AND MATERIALS

Land resource areas

The study area encompasses parts of Kansas, Oklahoma and Texas. Figure 2 is a map showing resource areas studied. Land resource areas (Soil Survey Staff, 1979) studied were Southern and Central High Plains, Central Rolling Red Plains, and Central Rolling Red Prairies, (Figure 2). These areas are differentiated for resource inventory and separated by land use, elevation and topography, climate, water, soils, and potential natural vegetation Soil Survey Staff (1951, 1982). This study area has layers of unconsolidated alluvial and eolian sediments, which contain volcanic ashes as marker beds. Volcanic ashes had previously been collected from 13 localities in the study area and ages assigned to them using the radiometric fission-track method on glass shards (Ward and Carter, 1989).

Terrace levels associated with the ashes were identified by topographic cross-sections constructed perpendicular to the major river systems intersecting the ash deposits. Transects were viewed looking upstream in order to maintain uniform perspective. The river basins included were: Arkansas, Cimarron, North Canadian, Canadian, Washita, Red, and Brazos (Figure 1). Large scale (1:250,000) United States Geological Survey topographic quadrangle maps were used to align the transects.

Topographic transect construction

The transects were constructed at a scale of 1:24,000 using the 7.5 min. topographic quadrangles. The lengths of the transects ranged from 60-120 km. After identifing terrace levels on the transects, the transects were scanned into a computer using Hewlett-Packard ScanJet Plus scanner with the software program, Scanning Gallery Plus, (Version A.03.00 Hewlett-Packard Co., 1988). This process reduced the multiple pages of the transects, typically 8 to 17 pages (21.5 x 27 cm), to one page each per transect. Twelve transects are included (Figures 3-14, Appendix A).

County soil surveys

Soils along the transects were identified using the county soil survey maps (Allgood et al., 1962; Fisher, 1968; Frie et al., 1967; Henson, 1978; Hoffman and Glaum, 1979; Koos and Dixon, 1964; Lamar, 1979; Lofton et al, 1972; Mayhugh, 1977; Moebius and Sparwasser, 1979; Moffatt and Conrad, 1979; Mowery et al., 1961; Nance et al., 1960; Rockers et al., 1966; Rogers and Risinger, 1979; Wheeler, 1973; Williams and Welker, 1966; and Wyrich and Williams, 1981). These soil maps were prepared from aerial photographs at a scale of 1:20,000 or 1:24,000. The topographic transect locations were transferred to the county soil surveys. Soils along the transects were identified. Soil mapping units were then transferred from the county soil survey to the transects. Terraces were identified by either 1) soils with 0-1% slopes or 2) soils with profile descriptions within the soil surveys indicating alluvium as their parent material.

Table 1 (Appendix B) represents the terrace data for the transects. Starting on the left side of each transect, the following information concerning each terrace was determined and noted: elevation (m), width (km), distance from river (km), and height from river (m). This same information, except width, is also given for the volcanic ash localities. The location north or south of the river, the terrace number, and the name of the major river are listed. For example, in Table 1, Transect C, Ash 10, on page 23, TS9 Arkansas refers to the ninth terrace south of the Arkansas River. This terrace can be seen on Transect C, page 41, on the left hand side of the transect. Ash 10 is in terrace TS4. Floodplains are also indicated. Table 2 shows the ash terrace levels, the corresponding ash ages from fission-track methods (Ward and Carter, 1989), and height above river for each transect. This data is listed by drainage basin, i.e., Arkansas River, Cimarron River, etc. The soil series mapped on the ash-dated terraces of each transect are given in Table 3 along with their soil classification which was taken from the soil surveys. Table 4 contains the soil series and its classification of every soil found on the floodplains and the terraces. Special notation is made of the terrace containing the ash. Table 5 identifies soil characteristics that are produced by major soil forming processes in the study area. These processes are partly dependent on time and will be used to evaluate the age of the terrace. Generally the thickest solum and the thickest calcic and mollic horizons represent the most development.

CHAPTER IV

RESULTS AND DISCUSSION

Terrace Characterization

Stream terraces identified by soil series and landscape form were present along all major west to east flowing drainages within the study area. Terraces were as high as 204 m above current stream level, however, the majority of terraces occurred less than 100 m (Table 1). The highest terraces capped the divides between major streams (Table 1, Figures 3-14). Coalescing fans or rock divides were consumed by erosion. Middle Pleistocene (0.60 to 1.0 m.y., Table 2) volcanic ash deposits are found within alluvial sediments underlying the terrace surfaces. Six ash deposits (Ash 34, Transect A; Ash 15, Transect D; Ash 23, Transect I; Ash 8, Transect B; Ash 13, Transect E; Ash 25, Transect K) were contained within terraces that capped divides between drainages. Middle Pleistocene terraces which contained the ash deposits ranged from 14 to 119 m above river level. An early Pleistocene to late Tertiary ash deposit (2.15 ± 0.24 m.y.) occurred within a terrace 155 m above the Canadian River (Table 2 and Figure 7). The oldest ash deposit (2.15 ± 0.24 m.y.) was contained within the highest ash-dated terrace (155 m). The youngest ash deposit (0.60 ± 0.07) was not found within the lowest ash-dated terrace. Relatively old ash deposits; 1.0 ± 0.11 Ma, 0.89 ± 0.09, 0.88 ± 0.09, and 0.74 ± 0.08 were found within the lowest ash-dated terraces, 30 m (Kiowa Creek), 21 m (Elk Creek), 21 m (Arkansas

River), and 14 m (Arkansas River), respectively. Lower terrace levels, however, contained younger ash deposits within the same river system (Table 2). All river systems do not necessarily have the same rate of incision and it is likely that they don't especially with changing stream bed lithology. This is controlled by several factors including stream capture, resistant underlying geology and sediment load (Gerrard, 1981). Stream capture was first presented by Fay (1959 and 1965) to support the fact that in some areas accelerated erosion has subdued divides and captured sediments and water from an adjacent river. From ash dates in the Rosston area (Transect H) it appears about 1 million years ago the Cimarron River captured part of the N. Canadian River at Rosston. This was probably caused by dissolution of gypsum and halite beds (Gustavson, 1986) which accelerated the rate of erosion within the Cimarron River drainage basin.

The widest terrace sequence (84.1 km) was found in Transect C on the south side of the Arkansas River (Table 1, Figure 3). This sequence included 9 terraces up to 79 m above the Arkansas River. The range in the length of terrace sequences within all transects (length includes distance from river to terrace-capped divide or highest terrace level) was 1.2 to 84.1 km. Generally the distance from stream to the highest terrace was between 5 to 30 km. Within 7 out of the 12 transects the widest terraces were also the highest terrace (Transects A, D, E, G, H, I, and L) Maximum terrace width for these high terraces ranged from 2.9 to 17.7 km. For four out of the remaining five transects the widest terraces occurred within the middle to lower portion of the sequence (Transects B, C, F, and J). Maximum terrace width for these low terraces ranged from 1.2 to 14.2 km. The ash deposits were found on the broad terraces. This indicates that the middle Pleistocene was a period of wide-spread alluviation in Oklahoma compared to the late Pleistocene. There was little difference in terrace width within Transect K which averaged 0.8 km.

Statistics

The variables terrace width, distance from river, elevation above river, height above river and drainage basin size were plotted and fitted to linear regression curves to determine if significant trends existed. No trends were evident. Statistical analysis was limited by the relatively few ash locations compared to the large size of the study area. Each basin will exhibit unique characteristics because of possible stream capture, temporal and spatial variations in climate, lithology and sediment load. More ash locations are needed within different terrace levels, along the entire length of a drainage basin, and within several drainage basins before meaningful statistical analysis can be achieved.

Soil classification

Major soil components of mapping units having a high proportion of single series occur on landscapes that are undissected or only slightly dissected and that lack substantial deposition by wind; particle size does not differ greatly; and discontinuous argillic, calcic, or petrocalcic horizons are not present. These soils occur mostly in the basin floors. The most complex patterns of soil distribution and the largest number of soils in a given area are found in dissected landscapes (Gile et al., 1981). The study area featured landscapes that were undissected, slightly dissected and dissected.

Twenty-five different soil series were found on terrace surfaces dated by ash deposits (Table 3). Five different soil orders were represented within these 25 soil series. Twenty soil series were identified as Mollisols, 2 soil series identified as Alfisols, 1 soil series identified as an Inceptisol and 1 soil series identified as an Entisol. The Entisol, Otero, usually present in floodplains, was found in a higher terrace because of recent wind erosion. All Mollisols were identified as Ustolls at the suborder level. All Alfisols were identified as Haplustalfs at the great group level. The majority of the soils found on the ash-dated terraces contained argillic horizons (Argiustolls, Paleustolls, and Haplustalfs). Only a few soils contained calcic horizons (Calciustolls and Calciorthidic Paleustolls). This results from a current relatively moist climate which promotes leaching of salts and movement of clay. The dominant climate during middle Pleistocene was moist, similar to today as is evidenced by the large number of Argiustolls present. Argiustolls are indicators of subhumid and humid regions with alternating wet and dry periods (Hall, 1983). Precipitation amounts average 50-90 cm and correlate to ustic to udic soil moisture regimes respectively (Pettyjohn et al., 1983). Precipitation is not high enough to support forest vegetation, therefore, Mollisols were the dominant soil order formed. Soil textures within ash-dated terraces were predominantly sandy clay loam, clay loam, and loam; however, there was a wide distribution of textures indicating fluvial origin instead of eolian origin which has similar texture throughout. Clay- textured soils containing greater than 60% clay were not present. Although soil series generally had a similar classification at the group suborder and order levels across the entire study area, the difference between drainage basins, within the study area was apparent because of the differences in bedrock lithologies within each basin. Soil series mapped on ash-dated terraces within the same basin were similar, i.e., transects B, C, D, H, I, J, and K.

Soil orders found across terrace and floodplain sequences included Entisols, Inceptisols, Alfisols, Mollisols, and Vertisols (Table 4). Mollisols were the most numerous soil order mapped on terraces followed by Alfisols, Entisols, and Inceptisols. Vertisols were only represented by one soil series within TS2 (Transect A, Canadian River). Entisols were the most abundant soil order mapped within floodplains (Table 4). Mollisols, especially Haplustolls, were also mapped within floodplains, but were much less abundant. Haplustolls are slightly more developed than Entisols because Haplustolls contain a mollic epipedon and cambic horizon while Entisols do not. The majority of the soil series that were recognized within this study were formed on the floodplain and terrace constructional surfaces. Argiustolls, Paleustolls, and Calciustolls were major soil groups that occurred on terrace surfaces. Where terrace surfaces have been eroded and where wind-blown sand has reworked the terrace surfaces, soils often lack one or more of the following: mollic epipedons, argillic horizons, and calcic horizons. Eroded terrace surfaces are mapped as Ustochrepts and Haplustolls. Eolian sands are recognized by dune form. Soil series formed within eolian sands overlying terrace surfaces are Tivoli, Pratt, Nobscot, Enterprise, and Devol. These soils were classified as either Psammentic, Haplustalfs, Typic Ustipsamments, Arenic Paleustalfs, Typic Ustochrepts, or Udic Haplustolls.

Soils within terrace transects

In Transect A the thickest solum is found in the Durant soil on the uppermost terrace of the Canadian River. This is also the soil series which contains an ash, dated at 0.87 ± 0.13 Ma. The parent material of the Durant soil is Pleistocene alluvium overlying Cretaceous shale and although it has the thickest solum, it does not have the thickest mollic horizon which is found in the Clarita soil. Both the Durant and Clarita are classified as having a fine family particle size class. The Pratt soil on the Arkansas River floodplain of Transect B formed in sand dunes of probable Holocene age. The Bethany soil is in the fine family and found on the uppermost terrace of the Arkansas River. The Bethany soil has the thickest Bt horizon and the thickest solum. The Farnum found on all terraces above the floodplain has the thickest calcic and mollic horizons. The ash is found in the highest terrace dated 0.74 ± 0.08 Ma. Transect C is also on the Arkansas River. The thickest solum again is found in the fine textured Bethany soil. It also has the thickest Bt horizon, between 2-7 times that of the other soils on the terraces. Calcic thickness is greatest in the Clark soil which is derived from calcareous alluvium. Eolian soils, Tivoli, Elsmere, Pratt, Carwile and Enterprise are found in Transect D in Woodward County, OK. Landforms are marked by dune fields. The Nobscot soil from Pleistocene loamy/sandy eolian sediments has the thickest solum. The fine-silty textured St. Paul soil contained the thickest mollic colors while the fine-loamy textured Mansker formed from calcareous material had the thickest calcic horizon. Transect E contained Pratt and Devol soils which formed in eolian deposits. The Cordell and Dill soils formed on rock or strath terraces. The

Grandfield and the Carey soils, both formed in Pleistocene alluvium, have very thick solums while the Carey also has a thick calcic horizon (the only calcic in the transect). Mollic colors are thickest in the Pond Creek and the St. Paul which are both of fine-silty texture. The fine textured Tillman soil formed from clayey alluvium has the thickest solum of Transect F, along with the thickest calcic horizon. The Hollister soil also fine textured contained the thickest mollic. Transect G contained windblown sediments with Hardeman soils formed within them. The Sagerton soil has the thickest solum and thickest Bt development. The Wichita soil is fine textured with the thickest calcic horizon and no mollic horizon. Mollic color thickness is found in the Rotan which also has a very thick solum and Bt horizon. The Mansker of Transect H has the thickest solum along with the thickest calcic and Bt horizon. The Pratt, a sandy soil of eolian origin, is present adjacent to the North Canadian floodplain. Transect I contained no soils formed in windblown deposits. The Mansker soil has the thickest solum, Bt and calcic horizons. The fine-loamy textured Tipton soil has the thickest mollic. The parent materials of the soils on Transect J are calcareous Tertiary deposits. The Richfield and Ulysses formed from calcareous loess. The Bt thickness is negligible in all soils but the Richfield. The thickest solum is found in the Mansic along with the thickest mollic and calcic horizons. Transect K also reflects the calcareous Tertiary parent materials. Free carbonate is at the surface in most terraces. There are no windblown deposits. The Mansker soil has the thickest solum, Bt, mollic, and calcic thickness. The fine textured Darrouzett soil and the fine textured Olton soil have the thickest solums on Transect L which contains very calcareous soils. Estacado has the thickest calcic horizon. The Darrouzett, Olton and Estacado all have thick Bt horizons. No windblown deposits are present as evidenced by the lack of dunes.

Terrace soils within a transect are similar as a result of similar geomorphological processes, the parent materials and pedologic processes. Soils on terraces differ from transect to transect as parent materials reflect the characteristics unique to the drainage basin.

Paleosols

Evolution of landscapes can be determined by studying the soils. Since soil development takes time, a soil represents a part of the geomorphological history (Gerrard, 1981). Soils indicate periods of stability within cycles of erosion and deposition. While the nature of the soil may give insight into environmental conditions during the period of soil formation, the correlations between soil properties and environments are still not sufficiently established (Birkeland, 1984). The soils of greatest use in this respect are those that have been buried under later deposits and have had their characteristics "fossilized". Buried soils (or buried paleosols) play a vital role in the study of the Quaternary because they provide a record of time discontinuities in the stratigraphic record. Paleosols are not identified by the soil surveys in the study area but this does not mean they are not present. To date, only the upper 150 cm of the soils have been extensively described by the Soil Conservation Service. Paleosols buried at a depth greater than 150 cm may be present. Buried soils can also be difficult to recognize in the field by common methods like changes in color, decalcification, structure, cementation, clay accumulation and iron-oxide accumulation. Laboratory characterization is being used more frequently to make identification. With increasing interest in paleosols and better analytical technique more buried soils will be recognized.

CHAPTER V

CONCLUSIONS AND RECOMMENDATION

Terraces within the study area were predominantly Pleistocene age; however, some surfaces may be as old as late Tertiary. Surprisingly, little difference was observed in the development of soils on these constructional terrace surfaces. The predominant soil group mapped across terrace surfaces was the Argiustoll. Terrace surfaces often capped stream divides, making it difficult to associate the terrace deposits with a particular stream system. Terrace surfaces extend from the High Plains of Texas, Oklahoma, and Kansas into the Rolling Red Plains and Reddish Prairies. The Rolling Red Plains of Oklahoma, Texas, and Kansas are composed of multiple Pleistocene terraces. Within the Rolling Red Plains and Reddish Prairies the terrace deposits can be easily distinguished on sand and gravel lithologies. Within the Rolling Red Plains and Reddish Prairies terrace deposits are composed of reworked Ogallala materials which overlie Permian "redbed" bedrock. Within the High Plains and High Plains Breaks, where the Ogallala is found in situ, terrace deposits are difficult to distinguish on the basis of soil particle lithology. Soil series are distinguished by the amount of incorporation of underlying Permian bedrock. Stream terraces located within the southeastern section of the study area contain a higher percentage of Permian "redbed" lithologies. This inherited red color from bedrock lithologies is often confused with soil-developed color (braunification). Eolian sand deposits also modified constructional terrace surfaces across several transects. Loess deposits are not recognized across the study area but should be associated with source-area stream drainages. Paleosols are not identified but should exist at depths greater than soil survey investigative procedures now allow (1.5 to 2.0 m). Paleosols should increase the ability to interpret past changes in climate and corresponding periods of eolian and alluvial deposition.

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APPENDIX A

FIGURES 3-14

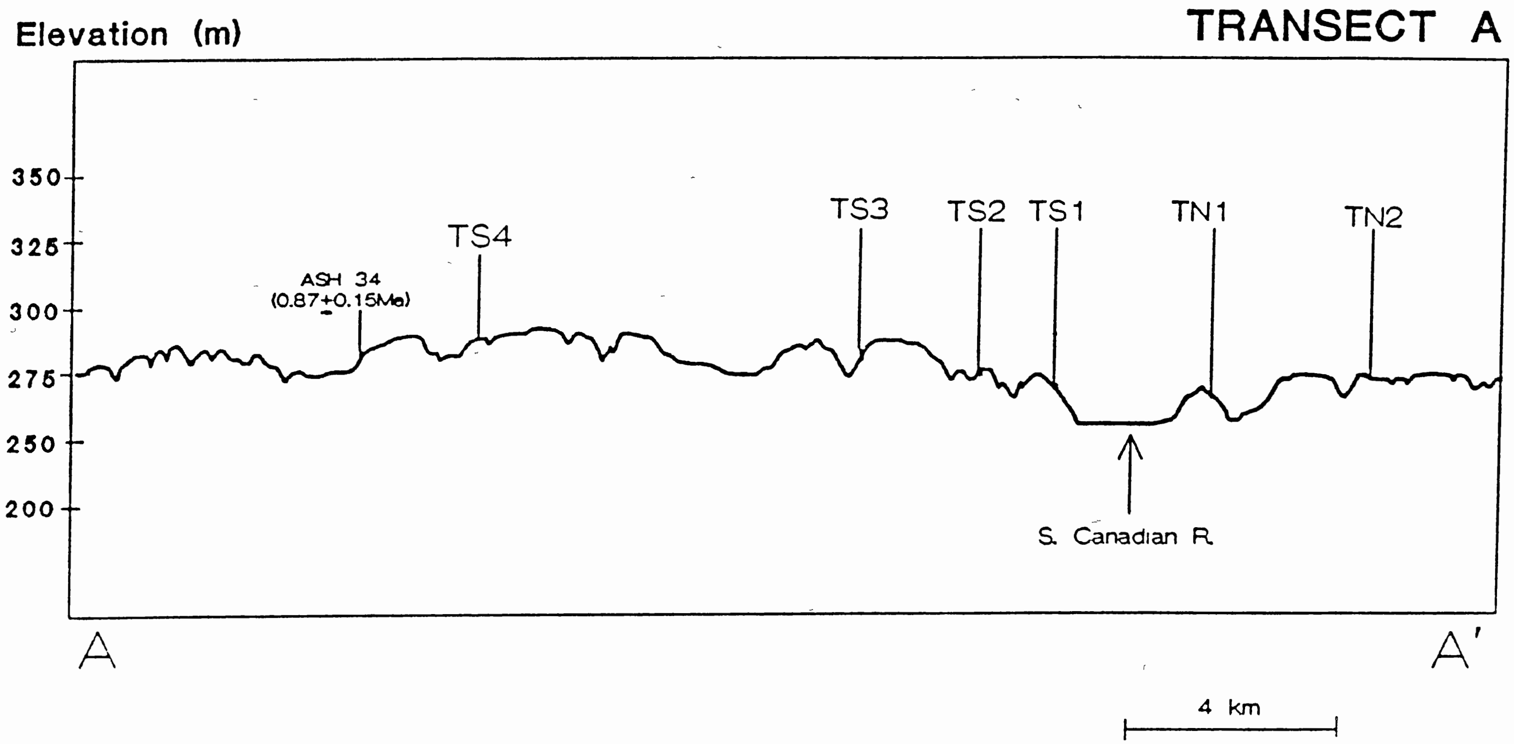

Figure 3. Topographic Transect A Including Location of Ash 34 and Terrace Sequences

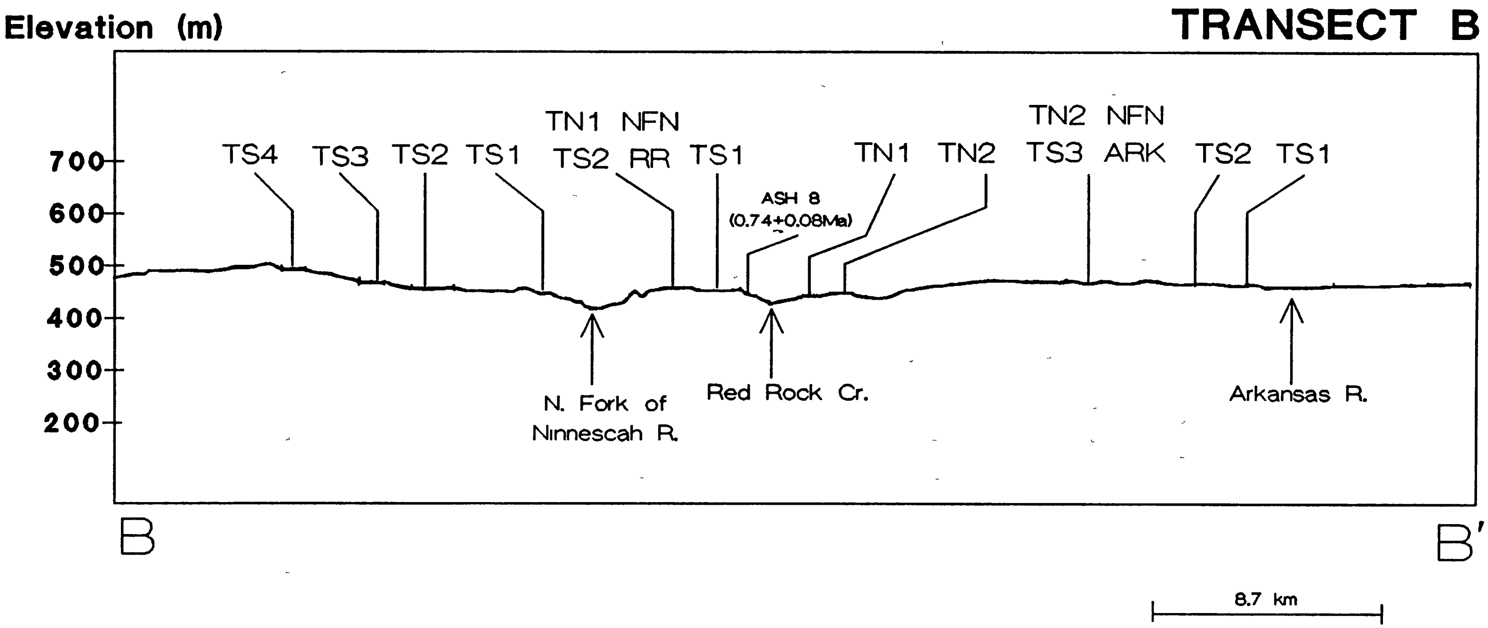

Figure 4. Topographic Transect B Including Location of Ash 8 and Terrace Sequences

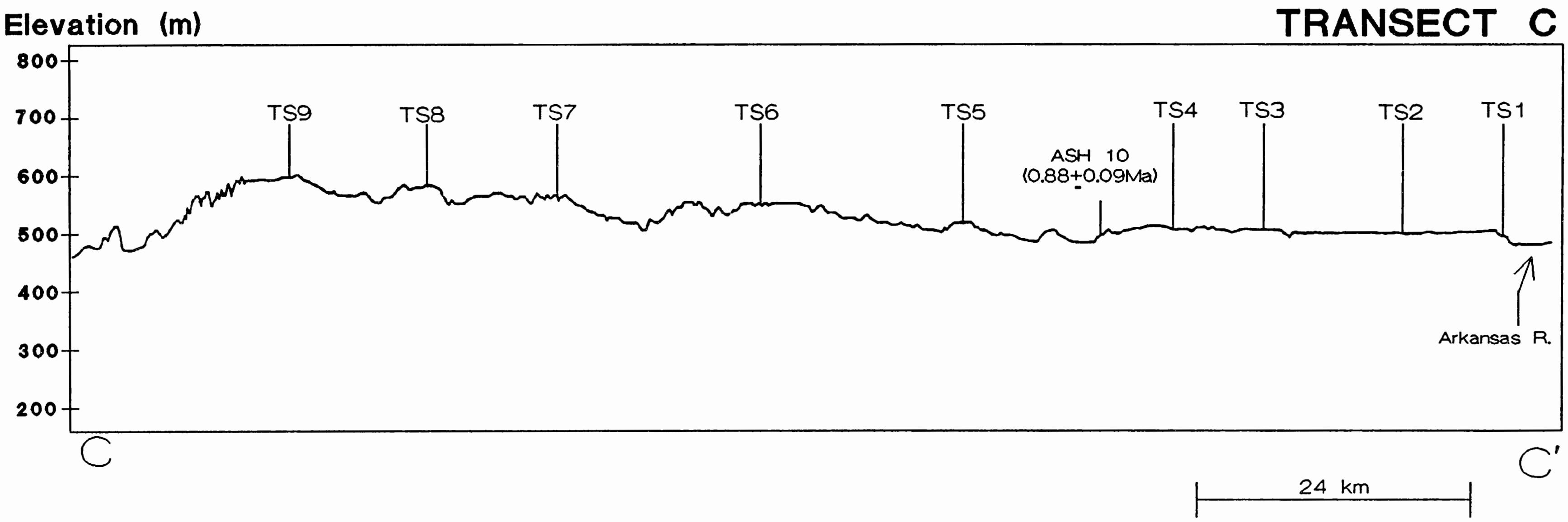

Figure 5. Topographic Transect C Including Location of Ash 10 and Terrace Sequences

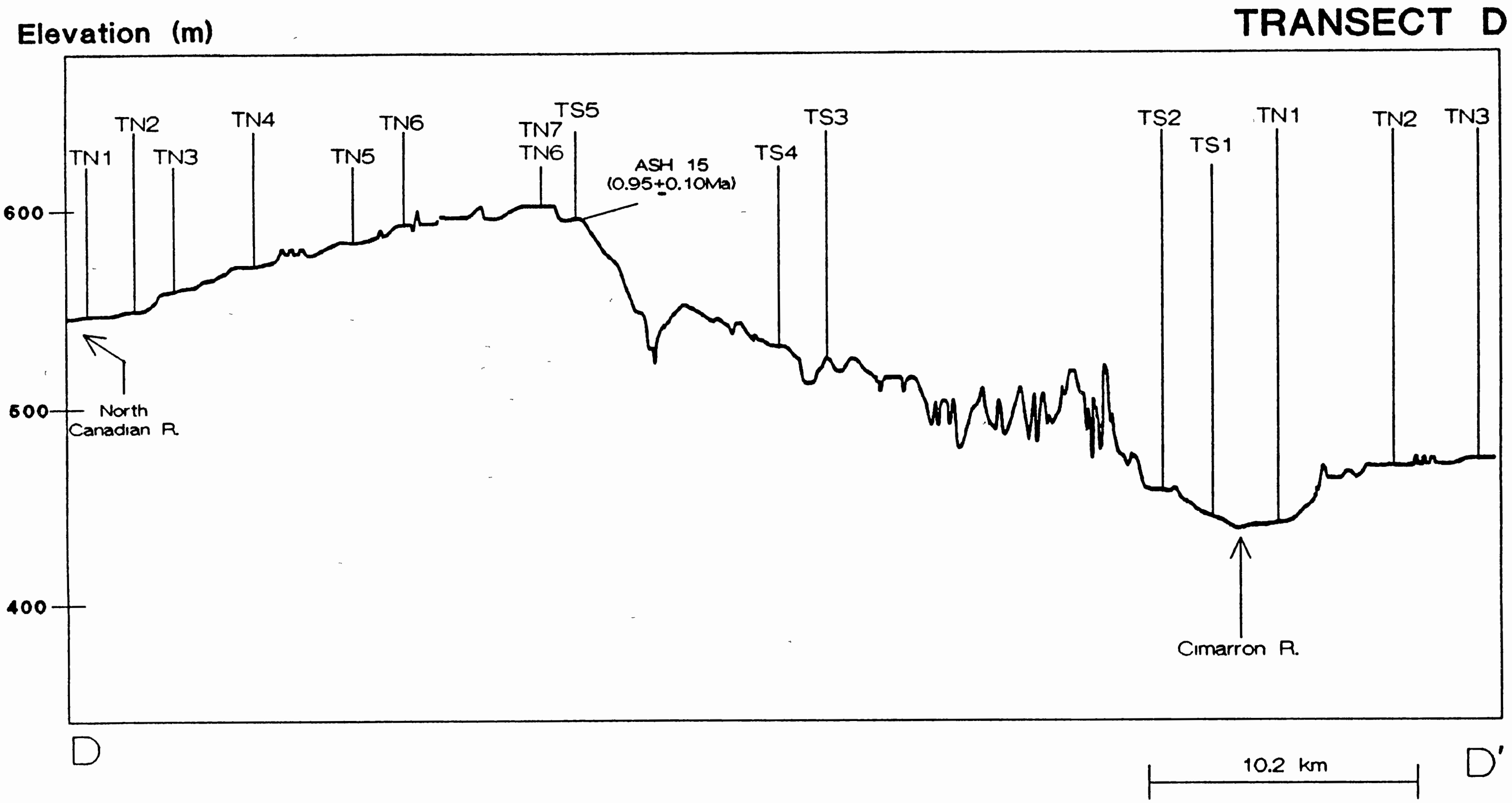

Figure 6. Topographic Transect D Including Location of Ash 15 and Terrace Sequences

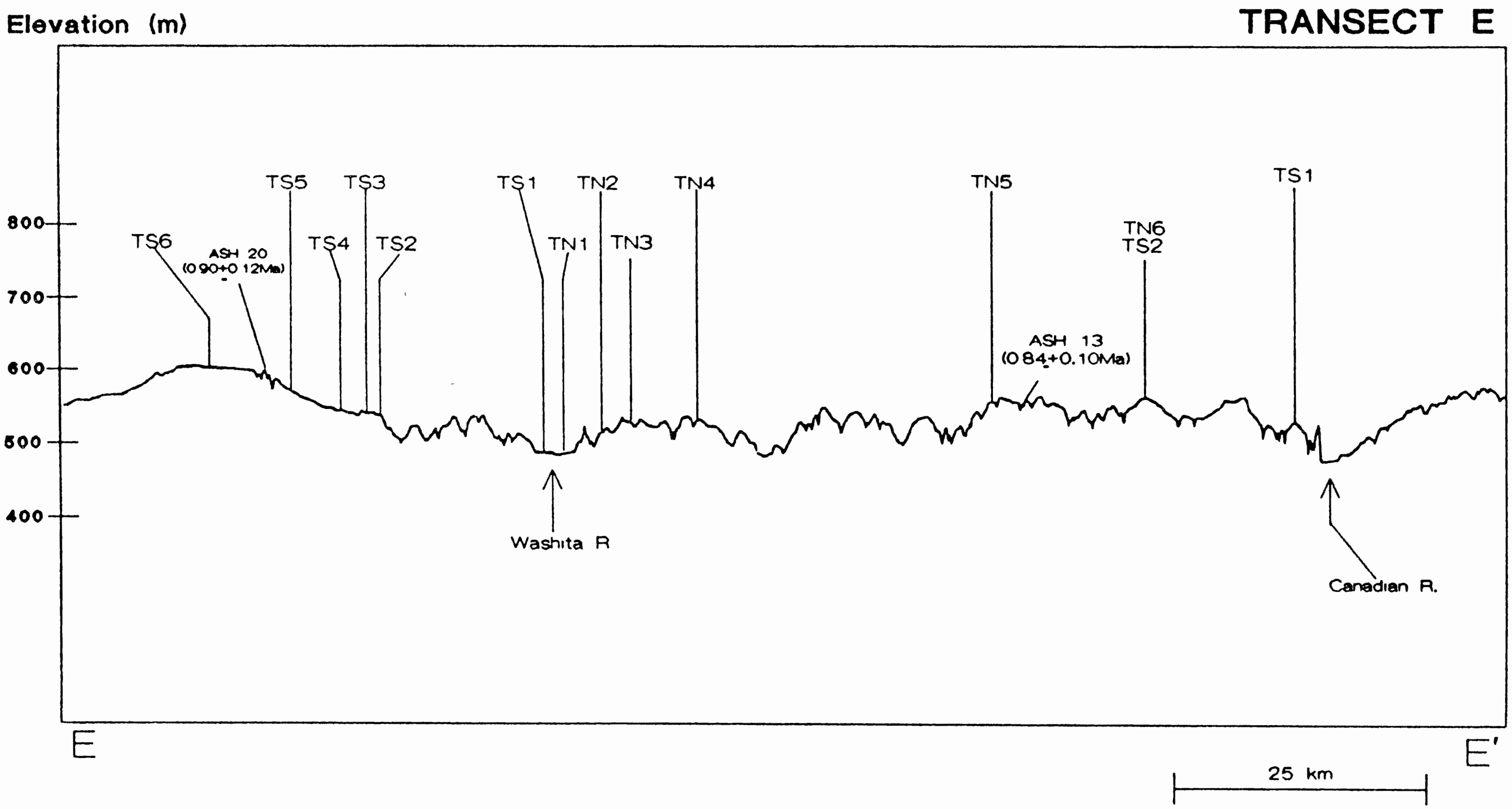

Figure 7. Topographic Transect E Including Location of Ashes 13 and 20 and Terrace Sequences

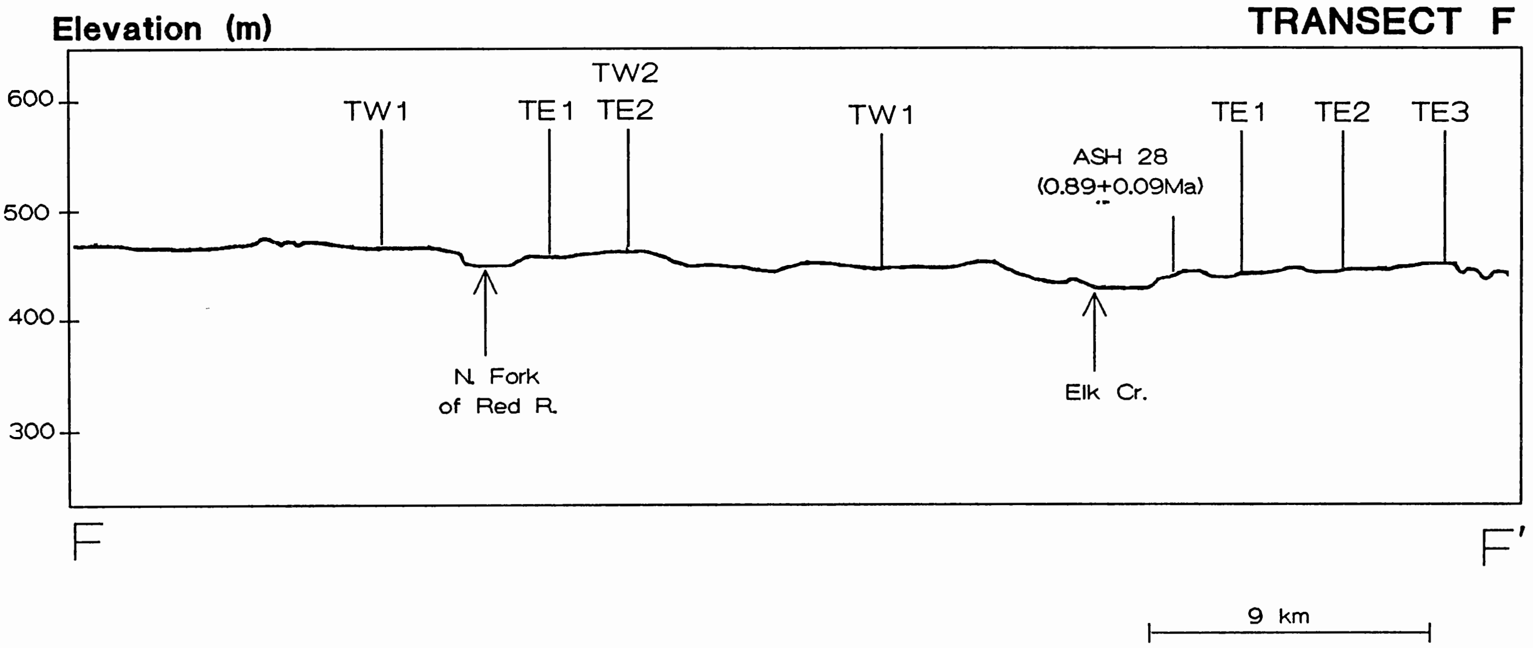

Figure 8. Topographic Transect F Including Location of Ash 28 and Terrace Sequences

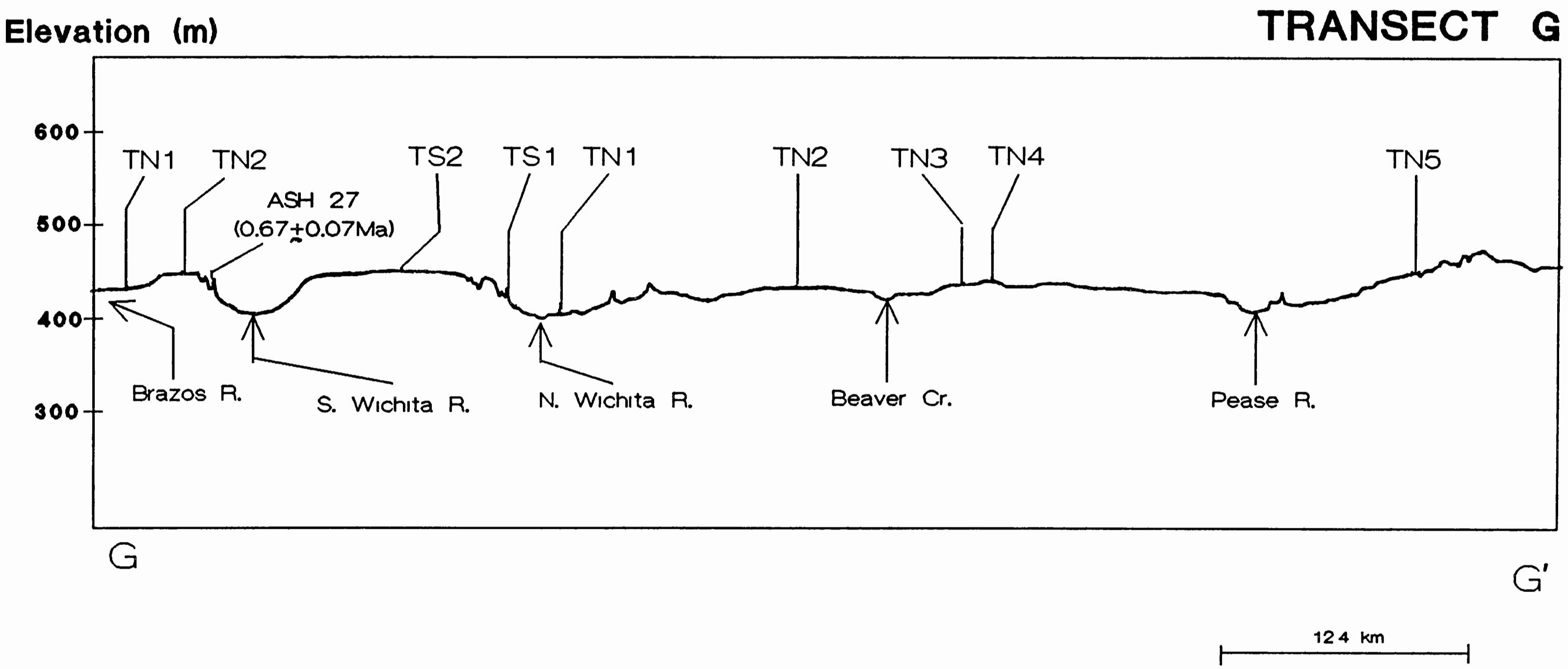

Figure 9. Topographic Transect G Including Location of Ash 27 and Terrace Sequences

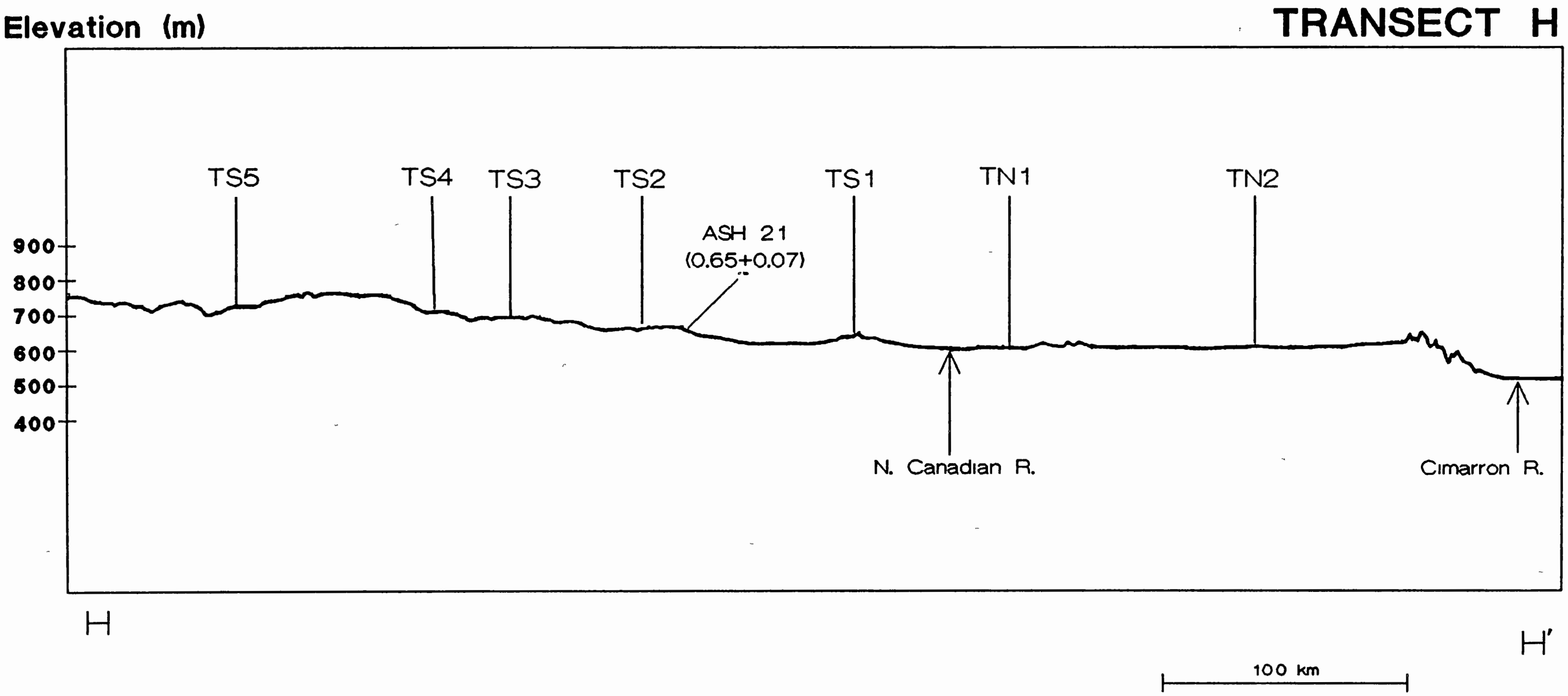

Figure 10. Topographic Transect H Including Location of Ash 21 and Terrace Sequences

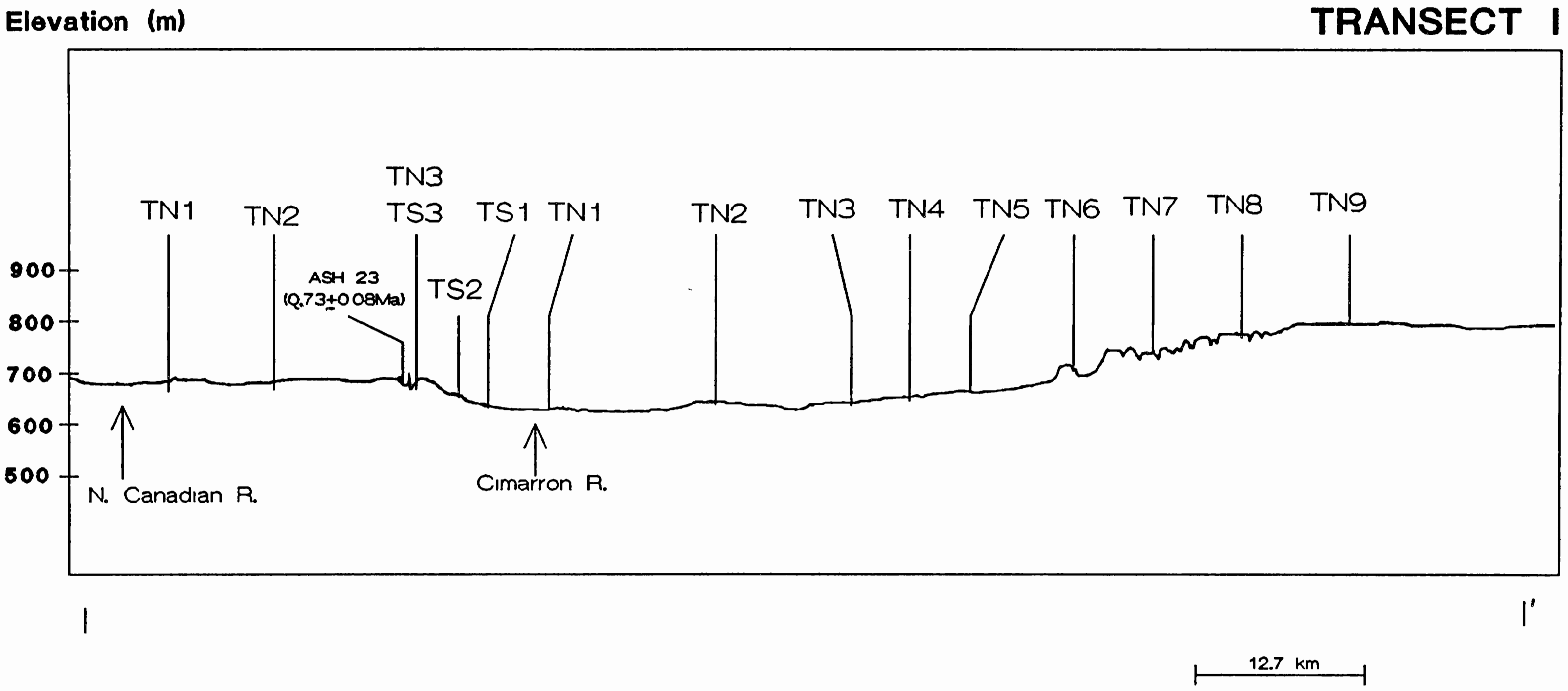

Figure 11. Topographic Transect I Including Location of Ash 23 and Terrace Sequences

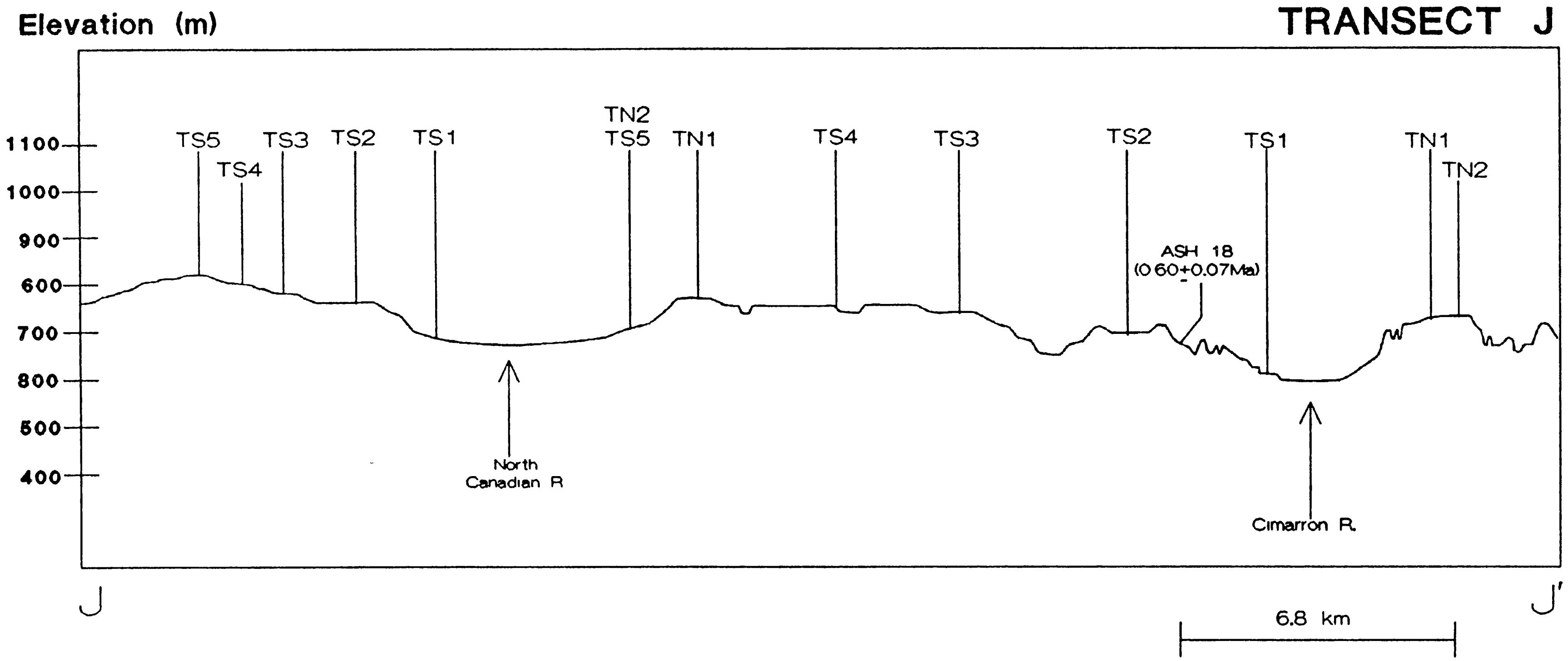

Figure 12. Topographic Transect J Including Location of Ash 18 and Terrace Sequences

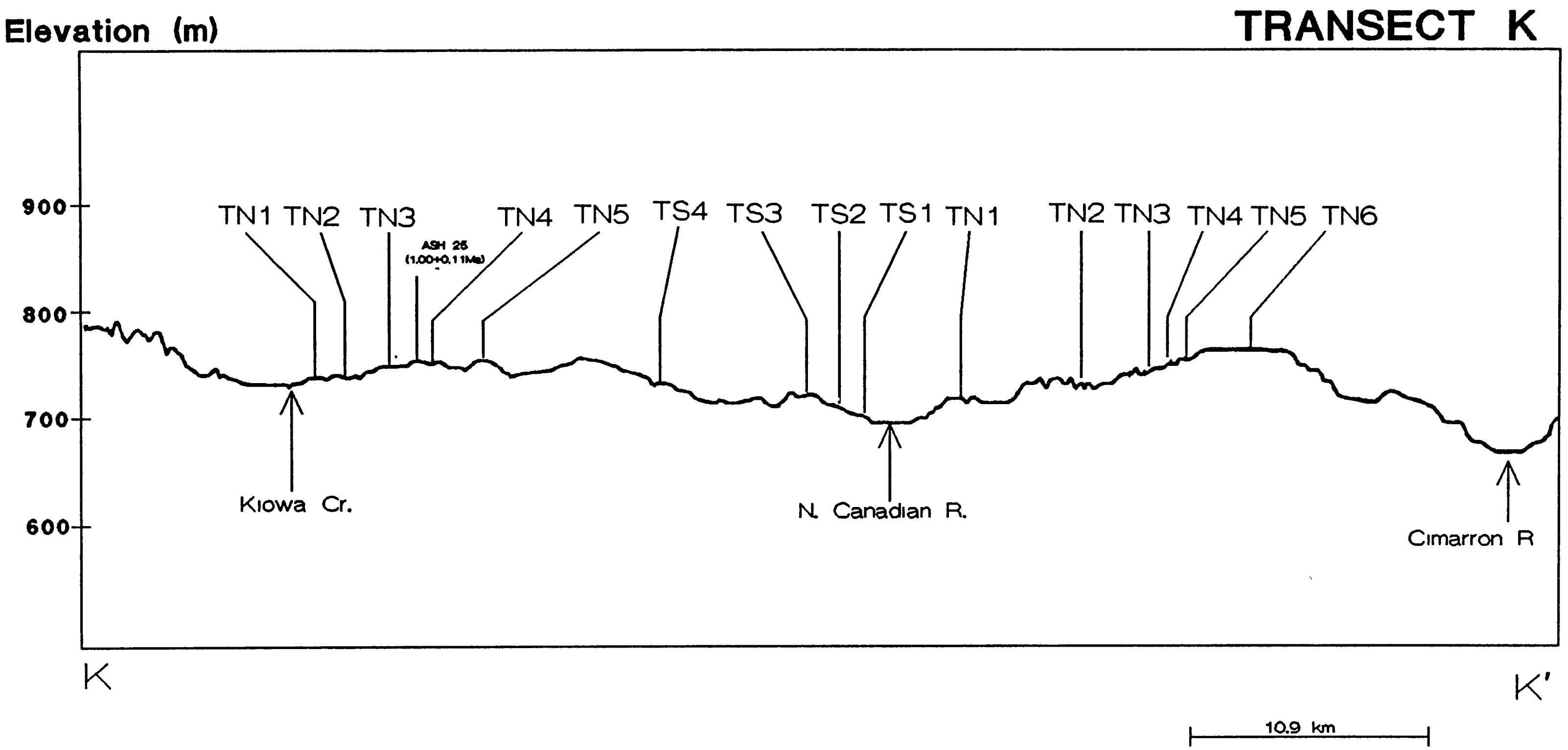

Figure 13. Topographic Transect K Including Location of Ash 25 and Terrace Sequences

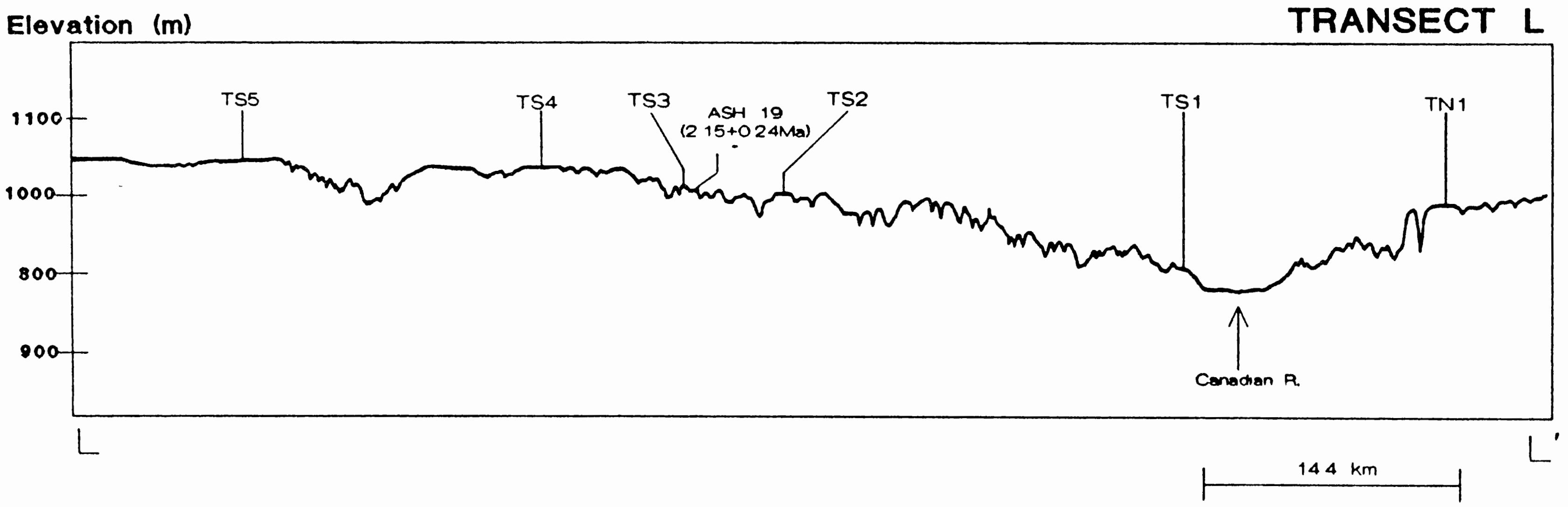

Figure 14. Topographic Transect L Including Location of Ash 19 and Terrace Sequences

APPENDIX B

TABLES I-V

TABLE I

TERRACES DENOTED FROM TRANSECTS

Terrace	Terrace elevation (m)	Terrace width (km)	Terrace distance from river (km)	Terrace height above river (m)
		Transect A, Ash 34		
(Ash 34)	(335)	---	(12.8)	(52)
TS4 Canadian River (CAR)	351	5.9	9.8	67
TS3 (CAR)	341	3.6	4.0	58
TS2 (CAR)	320	0.7	1.8	36
TS1 (CAR)	317	0.8	0.6	34
CAR Floodplain	283	1.9	---	--
		Transect B, Ash 8		
TS4 Arkansas River (ARK), TS4 North Fork of the Ninnescah River (NFN)	493	0.8	32.3 (Ark) 9.8 (NFN)	26 (Ark) 43 (NFN)
TS3 (NFN)	479	0.8	7.3	27
TS2 (NFN)	472	1.4	4.9	21
TS1 (NFN)	466	0.3	1.5	15
NFN Floodplain	451	0.3	---	--
TN1 (NFN), TS2 Red Rock Creek (RR)	476	0.9	2.9 (NFN) 3.0 (RR)	24 (NFN) 18 (RR)
TS1 (RR)	472	0.2	1.5	15
(Ash 8)	(466)		(16.9 (Ark)) (5.5 (NFN)) (0.4 (RR))	(<-1 (Ark)) (15 (NFN)) (19 (RR))
RR Floodplain	457	0.2	---	--
TN1 (RR)	466	0.6	1.4	9
TN2 (RR)	470	0.8	2.4	12
TN3 (RR)	482	5.2	10.4 (RR)	24 (RR)
TN2 (NFN), TS3 (Ark)			16.5 (NFN) 5.5 (Ark)	30 (NFN) 14 (Ark)
TS2 (Ark)	474	1.4	2.4	6
TS1 (Ark)	472	0.9	0.9	4
Ark Floodplain	468	1.7	---	--
		Transect C, Ash 10		
TS9 Arkansas River (Ark)	552	1.4	84.1	79
TS8 (Ark)	543	2.1	75.3	70
TS7 (Ark)	530	1.4	67.1	58
TS6 (Ark)	521	8.5	54.2	49
TS5 (Ark)	497	1.2	38.4	24
(Ash 10)	(482)	---	(29.3)	(9)

TABLE I (Continued)

Terrace	Terrace elevation (m)	Terrace width (km)	Terrace distance from river (km)	Terrace height above river (m)
		Transect C, Ash 10 (con't)		
TS4 (Ark)	493	4.6	23.8	21
TS3 (Ark)	491	2.7	18.9	18
TS2 (Ark)	488	14.0	9.4	15
TS1 (Ark)	482	0.8	2.0	9
Ark Floodplain	472	1.2	---	--
		Transect D, Ash 15		
N. Canadian River NCR Floodplain	552	0.3	---	--
TN1 (NCR)	553	0.9	0.7	1
TN2 (NCR)	555	0.6	1.8	3
TN3 (NCR)	564	0.9	3.2	12
TN4 (NCR)	573	1.1	5.0	21
TN5 (NCR)	585	0.8	8.7	34
TN6 (NCR)	594	0.4	10.2	43
TN7 (NCR), TS6 Cimarron River (CI)	604	4.1	13.6 (NCR) 22.6 (CI)	52 (NCR) 174 (CI)
(Ash 15)	(585)	---	(20.1 (CI)) (14.9 (NCR))	(155 (CI)) (34 (NCR))
TS5 (CI)	598	0.8	20.1	165
TS4 (CI)	530	0.6	14.3	101
TS3 (CI)	524	1.8	12.8	94
TS2 (CI)	451	0.9	2.4	21
TS1 (CI)	436	0.3	0.6	6
CI Floodplain	430	1.5	---	--
		Transect E, Ashes 13 + 20		
TS6 Washita River (WAR)	591	5.1	23.2	119
(Ash 20)	(573)	---	(20.3)	(101)
TS5 (WAR)	561	1.5	18.9	88
TS4 (WAR)	534	0.6	15.5	61
TS3 (WAR)	530	0.8	13.4	58
TS2 (WAR)	527	0.6	12.8	55
TS1 (WAR)	476	1.2	0.4	3
WAR Floodplain	472	1.1	---	--
TN1 (WAR)	488	0.3	1.2	15
TN2 (WAR)	494	1.8	2.4	21
TN3 (WAR)	500	0.9	5.8	27
TN4 (WAR)	520	2.4	8.8	52
TN5 (WAR)	543	0.6	31.7	70

TABLE I (Continued)

Terrace	Terrace elevation (m)	Terrace width (km)	Terrace distance from river (km)	Terrace height above river (m)
Transect E, Ashes 13 + 20 (con't)				
(Ash 13)	(536)	--- ---	(33.8 (WAR)) (29.3 (CAR))	(64 (WAR)) (73 (CAR))
TN6 (WAR)	549	3.0 (WAR)	33.8 (WAR)	76 (WAR)
TS2 Canadian River (CAR)		17.7 (CAR)	15.2 (CAR)	85 (CAR)
TS1 (CAR)	509	3.6	3.0	46
CAR Floodplain	463	1.2	---	--
Transect F, Ash 28				
TW1 North Fork of the Red River (NFR)	488	2.1	2.7	18
NFR Floodplain	470	1.2	---	--
TE1 (NFR)	478	1.1	1.8	9
TE2 (NFR), TW2 Elk Creek (Elk)	485	1.4	4.6 (NFR) 15.2 (Elk)	15 (NFR) 40 (Elk)
TW1 (Elk)	476	6.1	6.7	30
Elk Floodplain	445	1.7	---	--
TE1 (Elk)	466	2.7	2.7	21
(Ash 28)	(466)		(2.4 (Elk))	(21 (Elk))
TE2 (Elk)	470	3.2	7.3	24
TE3 (Elk)	476	0.8	11.0	30
Transect G, Ash 27				
Brazos River (BRR) Floodplain	412	1.2	---	--
TN1 (BRR)	439	1.7	2.4	27
TN2 (BRR), TS2 N. Wichita River (NWR)	457	7.7	17.6 (BRR) 6.1 (NWR)	46 (BRR) 61 (NWR)
(Ash 27)	448	---	7.3	36 (BRR)
TS1 (NWR)	412	0.2	1.5	15
NWR Floodplain	396	0.3	---	--
Transect H, Ash 21				
TS5 N. Canadian River (NCR)	768	11.0	25.6	115
TS4 (NCR)	732	0.9	18.9	79
TS3 (NCR)	719	2.3	16.5	67
TS2 (NCR)	698	2.7	11.3	46

TABLE I (Continued)

Terrace	Terrace elevation (m)	Terrace width (km)	Terrace distance from river (km)	Terrace height above river (m)
Transect H, Ash 21 con't				
(Ash 21)	(719)	---	(9.9)	(46)
TS1 (NCR)	679	1.2	3.6	27
NCR Floodplain	652	1.2	---	--
TN1 (NCR)	655	1.2	1.2	3
TN2 (NCR),	680	11.0	10.4	27
TS1 Cimarron River (CI)	604	0.8	1.2	6
CI Floodplain	598	1.8	---	--
Transect I, Ash 23				
N. Canadian River (NCR) Floodplain	655	1.8	---	--
TN1 (NCR)	658	0.8	0.9	3
TN2 (NCR)	665	8.5	6.7	9
TN3 (NCR),	670	2.9	15.2 (NCR)	15 (NCR)
TS3 Cimarron River (CI)			5.8 (CI)	67 (CI)
(Ash 23)	(662)	---	(6.4 (CI)) (14.7 (NCR))	(58 (CI)) (6 (NCR))
TS2 (CI)	631	0.8	3.4	30
TS1 (CI)	613	1.7	2.4	9
CI Floodplain	604	2.3	---	--
Transect J, Ash 18				
TS5 N. Canadian River (NCR)	726	0.4	6.7	61
TS4 (NCR)	720	0.6	5.8	55
TS3 (NCR)	710	0.4	5.5	46
TS2 (NCR)	701	1.2	3.4	36
TS1 (NCR)	671	0.4	2.0	6
NCR Floodplain	665	0.9	---	--
TN1 (NCR)	680	0.6	3.0	15
TN2 (NCR)	701	0.9	4.0 (NCR)	36 (NCR)
TS5 Cimarron River (CI)			13.2 (CI)	73 (CI)
TS4 (CI)	695	4.3	10.4	67
TS3 (CI)	689	0.6	7.6	61
TS2 (CI)	677	1.8	3.6	43

TABLE I (Continued)

Terrace	Terrace elevation (m)	Terrace width (km)	Terrace distance from river (km)	Terrace height above river (m)
Transect J, Ash 18 (con't)				
(Ash 18)	(658)	---	(2.6)	(30)
TS1 (CI)	634	0.3	0.9	6
CI Floodplain	628	1.2	---	--
Transect K, Ash 25				
Kiowa Creek (KIC) Floodplain	726	1.2	---	--
TN1 (KIC)	735	0.6	0.9	9
TN2 (KIC)	738	1.1	2.1	12
TN3 (KIC)	750	1.1	4.0	24
(Ash 25)	(753)	---	(4.6)	(27)
TN4 (KIC)	756	1.2	5.2	30
TN5 (KIC)	759	0.4	7.0	34
TS4 N. Canadian River (NCR)	735	0.6	8.5	46
TS3 (NCR)	722	1.1	3.4	34
TS2 (NCR)	710	0.6	2.4	21
TS1 (NCR)	701	0.6	1.2	12
NCR Floodplain	689	1.4	---	--
Transect L, Ash 19				
TS5 Canadian River (CAR)	957	10.2	47.6	204
TS4 (CAR)	942	8.8	31.1	189
TS3 (CAR)	908	1.4	23.2	155
(Ash 19)	(896)	---	(23.2)	(143)
TS2 (CAR)	902	3.6	19.8	149
TS1 (CAR)	786	0.6	1.8	34
CAR Floodplain	753	2.6	---	--
TN1 (CAR)	890	1.2	9.8	137

TABLE II

TERRACE LEVEL AND VOLCANIC ASH AGE

Transect	Ash No.	Ash Age (m.y.)	Terrace height above river, (m)
		Arkansas River	
C	10	0.88±0.09	21
B	8	0.74±0.08 (or Red Rock 15m)	14
		Cimmarron River	
I	23	0.73±0.08 (or N. Canadian 15m)	67
J	18	0.60±0.07	43
		North Canadian River	
D	15	0.95±0.10 (or Cimmarron 174m)	52
H	21	0.65±0.07	46
		Canadian River	
L	19	2.15±0.24	155
A	34	0.87±0.13 (or Washita 64m)	67
		Washita River	
E	20	0.90±0.12	119
E	13	0.84±0.09 (or Canadian 85m)	76
		Kiowa Creek	
K	25	1.00±0.11 (or N. Canadian 46m)	30
		Elk Creek	
F	28	0.89±0.09	21
		Brazos River	
G	27	0.67±0.07	46

TABLE III

TERRACE SURFACE DATED BY VOLCANIC ASHES AND SOILS MAPPED ON TERRACES.

Tran-sect	Ash No.	Ash age (m.y.)	County	Soil series on terrace	Soil Classification
A	34	0.87±0.13	Garvin, OK	Durant	Fine, montmorillonitic, thermic Argiustoll
				Teller	Fine-loamy, mixed, thermic Udic Argiustoll
				Konowa	Fine-loamy, mixed, thermic Ultic Haplustalf
B	8	0.74±0.08	Reno, KS	Bethany	Fine, mixed, thermic Pachic Paleustolls
				Farnum	Fine-loamy, mixed, thermic Pachic Argiustoll
C	10	0.88±0.09	Reno, KS	Clark	Fine-loamy, mixed, thermic Typic Calciustoll
				Ost	Fine-loamy, mixed, thermic Typic Argiustoll
				Farnum	Fine-loamy, mixed, thermic Pachic Argiustoll
				Shellabarger	Fine-loamy, mixed, thermic Udic Argiustoll
D	15	0.95±0.10	Woodward, OK	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustoll
				Enterprise	Coarse, silty, mixed thermic Typic Ustochrept
				Pratt	Sandy, mixed, thermic Psammentic Haplustalf
E	20	0.90±0.12	Washita, OK	Grandfield	Fine-loamy, mixed, thermic Udic Haplustalf
				Altus	Fine-loamy, mixed, thermic Pachic Argiustoll
	13	0.84±0.09	Custer, OK	St. Paul	Fine-silty, mixed thermic Pachic Argiustoll
				Minco	Coarse-silty, mixed, thermic Udic Haplustoll
				Pond Creek	Fine-silty, mixed, thermic Pachic Argiustoll
				Grant	Fine-silty, mixed, thermic Udic Argiustoll
F	28	0.89±0.09	Kiowa, OK	Tillman	Fine, mixed, thermic Typic Paleustoll
				Hollister	Fine, mixed, thermic Pachic Paleustoll
G	27	0.67±0.07	Knox, TX	Sagerton	Fine, mixed, thermic Typic Paleustoll
H	21	0.65±0.07	Harper, OK	Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthent
				Pratt	Sandy, mixed, thermic Psammentic Haplustalf
I	23	0.73±0.08	Harper, OK	Tipton	Fine-loamy, mixed, thermic, Pachic Argiustoll
				Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustoll
J	18	0.60±0.07	Beaver, OK	Richfield	Fine, montmorillonitic, Mesic Aridic Argiustoll
				Mansic	Fine-loamy, mixed, thermic, Typic Calciustoll
K	25	1.00±0.11	Beaver, OK	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustoll
				Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthent
				Mansic	Fine-loamy, mixed, thermic, Aridic Calciustoll
L	19	2.15±0.24	Roberts, TX	Estacado	Fine-loamy, mixed, thermic Calciorthidic Paleustoll
				Paloduro	Fine-loamy, mixed, thermic Aridic Haplustoll

TABLE IV

SOILS ON TERRACES

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
Transect A, Ash 34			
Canadian River	--	Gaddy	Sandy, mixed, thermic Typic Ustifluvents
(CAR) Floodplain		Yahola	Coarse-loamy, mixed (calcareous) thermic Typic Ustifluvents
TS1 (CAR)	34	Minco	Coarse-silty, mixed, thermic Udic Haplustalfs
TS2 (CAR)	36	Clarita	Fine, montmorillonitic, thermic Udic Pellusterts
TS3 (CAR)	58	Konowa	Fine-loamy, mixed, thermic Ultic Haplustalfs
TS4 (CAR)	67	Durant	Fine, montmorillonitic, thermic Vertic Argiustolls
Ash 34 in		Teller	Fine-loamy, mixed, thermic Udic Argiustolls
this terrace		Konowa	Fine-loamy, mixed, thermic Ultic Haplustalfs
Transect B, Ash 8			
Arkansas River		Platte	Sandy, mixed, mesic Mollic Fluvaquents
(ARK) Floodplain	--	Lesho	Sandy, skeletal, mixed thermic Fluvaquentic Haplustolls
		Wann	Coarse-loamy, mixed, mesic Fluvaquentic Haplustolls
TS1 (ARK)	4	Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
TS2 (ARK)	6	Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
TS3 (ARK)	14	Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
Ash 8 in this		Bethany	Fine, mixed, thermic Pachic Paleustolls
terrace			
TS4 (ARK)	26	Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
		Albion	Coarse-loamy, mixed, thermic Udic Argiustolls
Transect C, Ash 10			
Arkansas River (Ark)	--	Wann	Coarse-loamy, mixed, mesic Fluvaquentic Haplustolls
Floodplain		Platte	Sandy, mixed, mesic mollic Fluvaquents
		Lesho	Sandy-skeletal, mixed, thermic Fluvaquentic Haplustolls
TS1 (Ark)	9	Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
TS2 (Ark)	15	Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
		Tabler	Fine, montmorillonitic, thermic Vertic Argiustolls
		Vanoss	Fine-silty, mixed, thermic Udic Argiustolls

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
			Transect C, Ash 10 (con't)
		Bethany	Fine, mixed, thermic Pachic Paleustolls
		Naron	Fine-loamy, mixed, thermic Udic Argiustolls
		Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
TS3 (Ark)	18	Naron	Fine-loamy, mixed, thermic Udic Argiustolls
		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
		Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
TS4 (Ark)	21	Clark	Fine-loamy, mixed, thermic Typic Calciustolls
Ash 10 in		Ost	Fine-loamy, mixed, thermic Typic Argiustolls
this terrace		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
		Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
TS5 (Ark)	24	Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
TS6 (Ark)	49	Albion	Coarse-loamy, mixed, thermic Udic Argiustolls
		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
		Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
TS7 (Ark)	58	Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
		Albion	Coarse-loamy, mixed, thermic Udic Argiustolls
TS8 (Ark)		Albion	Coarse-loamy, mixed, thermic Udic Argiustolls
		Farnum	Fine-loamy, mixed, thermic Pachic Argiustolls
		Clark	Fine-loamy, mixed, thermic Typic Calciustolls
TS8 (Ark)	70	Blanket	Fine, mixed, thermic Pachic Argiustolls
		Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
TS9 (Ark)	79	Attica	Coarse-loamy, mixed, thermic Udic Haplustalfs
		Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
		Tivoli	Sandy, mixed, thermic Typic Ustipsamments
			Transect D, Ash 15
N. Canadian River (NCR) Floodplain	--	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
TN1 (NCR)	1	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
		Las Animas	Coarse-loamy, mixed (calcareous) mesic Typic Fluvaquents

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
		Tansect D, Ash 15 (con't)	
TN2 (NCR)	3	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
		Las Animas	Coarse-loamy, mixed (calcareous) mesic Typic Fluvaquents
TN3 (NCR)	12	Tivoli	Sandy, mixed, thermic Typic Ustipsamments
		Elsmere	Sandy, mixed, Mesic Aquic Haplustolls
		Las Animas	Coarse-loamy, mixed (calcareous) mesic Typic Fluvaquents
TN4 (NCR)	21	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
TN5 (NCR)	34	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
		Carwile	Fine, mixed, thermic Typic Argiaquolls
TN6 (NCR)	43	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
TN7 (NCR)	52	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
Ash 15 in this terrace		Carwile	Fine, mixed, thermic Typic Argiaquolls
		Nobscot	Loamy, mixed, thermic Arenic Paleustalfs
		Mansker	Fine-loamy, carbonatic thermic Calciorthidic Paleustolls
		Enterprise	Coarse-silty, mixed, thermic Typic Ustochrepts
Cimarron River (CI) Floodplain	--	No survey completed for Woods Co., OK	
TS1 (CI)	6	No survey completed for Woods Co., OK	
TS2 (CI)	21	No survey completed for Woods Co., OK	
TS3 (CI)	94	St. Paul	Fine-silty, mixed, thermic Pachic Argiustolls
TS4 (CI)	101	St. Paul	Fine-silty, mixed, thermic Pachic Argiustolls
		Vernon	Fine, mixed, thermic Typic Ustochrepts
TS5 (CI)	168	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Enterprise	Coarse-silty, mixed, thermic Typic Ustochrepts
TS6 (CI)	174	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
		Carwile	Fine, mixed, thermic Typic Argiaquolls
		Nobscot	Loamy, mixed, thermic Arenic Haplustalfs
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Enterprise	Coarse-silty, mixed, thermic Typic Ustochrepts

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
Transect E, Ashes 13 + 20			
Washita River (WAR) Floodplain	--	Yahola	Coarse-loamy, mixed (calcareous) thermic Typic Ustifluvents
		Clairemont	Fine-silty, mixed (calcareous) thermic Typic Ustifluvents
TS1 (WAR)	3	Crisfield	Coarse-loamy, mixed, thermic Udic Haplustolls
		Yahola	Coarse-loamy, mixed (calcareous) thermic Typic Ustifluvents
		Clairemont	Fine-silty, mixed (calcareous) thermic Typic Ustifluvents
TN1 (WAR)	15	Crisfield	Coarse-loamy, mixed, thermic Udic Haplustolls
TN2 (WAR)	21	Crisfield	Coarse-loamy, mixed, thermic Udic Haplustolls
		Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
		Devol	Coarse-loamy, mixed, thermic Udic Haplustalfs
		Shellabarger	Fine-loamy, mixed, thermic Udic Argiustolls
TN3 (WAR)	27	Carey	Fine-silty, mixed, thermic Typic Argiustolls
TN4 (WAR)	52	St. Paul	Fine-silty, mixed, thermic Pachic Argiustolls
TS2 (WAR)	55	Cordell	Loamy, mixed, thermic Lithic Ustochrepts
TS3 (WAR)	58	Cordell	Loamy, mixed, thermic Lithic Ustochrepts
TS4 (WAR)	61	Dill	Coarse-loamy, mixed, thermic Udic Ustochrepts
TN5 (WAR)	70	Carey	Fine-silty, mixed, thermic Typic Argiustolls
TN6 (WAR)	76	St. Paul	Fine-silty, mixed, thermic Pachic Argiustolls
Ash 13 in this terrace		Minco	Coarse-silty, mixed, thermic Udic Haplustolls
		Pond Creek	Fine-silty, mixed, thermic Pachic Argiustolls
		Grant	Fine-silty, mixed, thermic Udic Argiustolls
TS5 (WAR)	88	Grandfield	Fine-loamy, mixed, thermic Udic Haplustalfs
TS6 (WAR)	119	Grandfield	Fine-loamy, mixed, thermic Udic Haplustalfs
Ash 20 in this terrace		Altus	Fine-loamy, mixed, thermic Pachic Argiustolls
Canadian River (CAR) Floodplain	--	Gracemore	Sandy, mixed, thermic Aquic Udifluvents
TS1 (CAR)	46	Minco	Coarse-silty, mixed, thermic udic Haplustolls
		Grant	Fine-silty, mixed, thermic Udic Argiustolls
		Pond Creek	Fine-silty, mixed, thermic Pachic Argiustolls
TS2 (CAR)	85	Minco	Coarse-silty, mixed, thermic Udic Haplustolls
Ash 13 in this terrace		Pond Creek	Fine-silty, mixed, thermic Pachic Argiustolls
		St. Paul	Fine-silty, mixed, thermic Pachic Argiustolls
		Grant	Fine-silty, mixed, thermic Udic Argiustolls

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
Transect F, Ash 28			
Elk Creek (Elk) Floodplain	--	Clairemont	Fine-silty, mixed (calcareous), thermic Typic Ustifluvents
		Lugert	Coarse-silty, mixed, thermic Fluventic Haplustolls
		Port	Fine-silty, mixed, thermic Cumulic Haplustolls
TE1 (ELK) Ash 28 in this terrace	21	Tillman	Fine-mixed, thermic Typic Paleustolls
TE2 (ELK)	24	Tillman	Fine-mixed, thermic Typic Paleustolls
		Hollister	Fine, mixed, thermic Pachic Paleustolls
TE3 (ELK)	30	Hollister	Fine, mixed, thermic Pachic Paleustolls
TW1 (ELK)	30	Hollister	Fine, mixed, thermic Pachic Paleustolls
		Tillman	Fine-mixed, thermic Typic Paleustolls
TW2 (ELK)	40	Devol	Coarse-loamy, mixed, thermic Udic Haplustalfs
		Grandfield	Fine-loamy, mixed, thermic Udic Haplustalfs
Transect G, Ash 27			
Brazos River (BRR) Floodplain	--	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
		Mangum	Fine, mixed (calcareous), thermic Vertic Ustifluvents
		Yahola	Coarse-loamy, mixed (calcareous), thermic Typic Ustifluvents
		Hardeman	Coarse-loamy, mixed, thermic Typic Ustochrepts
TN1 (BRR)	27	Sagerton	Fine, mixed, thermic Typic Paleustolls
		Wichita	Fine, mixed, thermic Typic Paleustalfs
		Rotan	Fine, mixed, thermic Pachic Paleustolls
TN2 (BRR) Ash 27 in this terrace	46	Sagerton	Fine, mixed, thermic Typic Paleustolls
Transect H, Ash 21			
N. Canadian River (NCR) Floodplain	--	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
		Las Animas	Coarse-loamy, mixed (calcareous), mesic Typic Fluvaquents
TN1 (NCR)	3	Lincoln	Sandy, mixed, thermic Typic Ustifluvents

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
		Transect H, Ash 21 (con't)	
TN2 (NCR)	27	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
		Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
		Dalhart	Fine-loamy, mixed, mesic Aridic Haplustalfs
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
TS1 (NCR)	27	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
TS2 (NCR)	46	Pratt	Sandy, mixed, thermic Psammentic Haplustalfs
Ash 21 in this terrace		Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthents
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
TS3 (NCR)	67	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthents
TS4 (NCR)	79	Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
TS5 (NCR)	115	Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Alluvial and broken land	----------
		Transect I, Ash 23	
Cimarron River (CI) Floodplain	--	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
TS1 (CI)	9	Spur	Fine-loamy, mixed, thermic Fluventic Haplustolls
TS2 (CI)	30	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
TS3 (CI)	67	Tipton	Fine-loamy, mixed, thermic Pachic Argiustolls
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
Ash 23 in this terrace			

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
		Transect J, Ash 18	
Cimarron River (CI) Floodplain	--	Las Animas	Coarse-loamy, mixed (calcareous), mesic Typic Fluvaquents
TS1 (CI)	6	Canadian	Coarse-loamy, mixed, thermic Udic Haplustolls
TS2 (CI)	43	Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
Ash 18 in this terrace		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
TS3 (CI)	61	Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
TS4 (CI)	67	Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
		Ulysses	Fine-silty, mixed, mesic Aridic Haplustolls
		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
		Alluvial and broken land	
TS5 (CI)	73	Richfield	Fine, montmorillonitic, mesic Aridic Argiustolls
		Transect K, Ash 25	
Kiowa Creek (KIC) Floodplain	--	Likes	Sandy, mixed, thermic Typic Ustipsamments
TN1 (KIC)	9	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthents
TN2 (KIC)	12	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthents
		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
TN3 (KIC)	24	Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
TN4 (KIC)	30	Otero	Coarse-loamy, mixed (calcareous), mesic Ustic Torriorthents
Ash 25 in this terrace		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls
TN5 (KIC)	34	Mansic	Fine-loamy, mixed, thermic Aridic Calciustolls

TABLE IV (Continued)

Terrace	Terrace height above stream (M)	Soil series mapped on terrace	Classification
			Transect L, Ash 19
Canadian River (CAR) Floodplain	--	Lincoln	Sandy, mixed, thermic Typic Ustifluvents
TS1 (CAR)	34	Mobeetie	Coarse-loamy, mixed, thermic Aridic Ustocreepts
TN1 (CAR)	137	Paloduro	Fine-loamy, mixed, thermic Aridic Haplustolls
		Estacado	Fine-loamy, mixed, thermic Calciorthidic Paleustolls
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls
		Pullman	Fine, mixed, thermic Torrertic Paleustolls
TS2 (CAR)	149	Olton	Fine, mixed, thermic Aridic Paleustolls
		Estacado	Fine-loamy, mixed, thermic Calciorthidic Paleustolls
		Paloduro	Fine-loamy, mixed, thermic Aridic Haplustolls
TS3 (CAR)	155	Paloduro	Fine-loamy, mixed, thermic Aridic Haplustolls
Ash 19 in this terrace		Estacado	Fine-loamy, mixed, thermic Calciorthidic Paleustolls
TS4 (CAR)	189	Pullman	Fine, mixed, thermic Torrertic Paleustolls
		Olton	Fine, mixed, thermic Aridic Paleustolls
		Estacado	Fine-loamy, mixed, thermic Calciorthidic Paleustolls
		Darrouzett	Fine, mixed, thermic Pachic Paleustolls
TS5 (CAR)	204	Pullman	Fine, mixed, thermic Torrertic Paleustolls
		Mansker	Fine-loamy, carbonatic, thermic Calciorthidic Paleustolls

TABLE V

SELECTED SOIL CHARACTERISTICS FOR TERRACES ALONG TRANSECTS CONTAINING ASHES

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free CaCO$_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
			TRANSECT A -- ASH 34 (0.87 ± 0.13 Ma)-Average Annual Precipitation (in cm)-91						
Canadian R. (CAR) Floodplain	Gaddy	Sandy	Recent sandy alluvium	surface	none	none	none	51	none
	Yahola	coarse-loamy	Permian/Pleistocene loamy alluvium	surface	none	none	none	28	none
TS1 (CAR)	Minco	coarse-silty	Loamy eolian deposits	140	none	38	none	140	none
TS2 (CAR)	Clarita	fine	Cretaceous/Permian clays	25	none	56	none	127	none
TS3 (CAR)	Konawa	fine-loamy	Pleistocene sandy/ loamy alluvium	none	none	none	61	137	none
TS4 (CAR)*	Durant	fine	Cretaceous shale	119	none	28	135	163	none
	Teller	fine-loamy	Pleistocene loamy sediments	none	none	38	102	152	none
	Konawa	fine-loamy	Pleistocene sandy/ loamy alluvium	none	none	none	61	137	none
			TRANSECT B -- ASH 8 (0.74 ± 0.08 Ma)-Average Annual Precipitation (in cm)-66						
Arkansas R. (ARK) Floodplain	Pratt	Sandy	Sandy eolian deposits	none	none	none	71	102	none
	Lesho	fine-loamy over sandy	Alluvium	surface	none	46	none	46	none
	Wann	coarse-loamy	Recent alluvium	surface	none	41	none	41	none
TS1 (ARK)	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
TS2 (ARK)	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
TS3 (ARK)*	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Bethany	fine	Pleistocene loess or alluvium	91	none	91	158	203	none
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
	Albion	coarse-loamy	Loamy sediments	none	none	41	20	69	none

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT C -- ASH 10 (0.88 ± 0.09 Ma)-Average Annual Precipitation (in cm)-66									
Arkansas R. (ARK) Floodplain	Wann	coarse-loamy	Recent alluvium	surface	none	41	none	41	none
	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Lesho	fine-loamy over sandy	Alluvium	surface	none	46	none	46	none
TS1 (ARK)	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
TS2 (ARK)	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Tabler	fine	Calcareous loamy Clayey alluvium	76	none	112	51	112	none
	Vanoss	fine-silty	Pleistocene loamy alluvium	none	none	38	89	127	none
	Bethany	fine	Pleistocene loess or alluvium	91	none	91	158	203	none
	Naron	fine-loamy	Loamy eolian deposits	>152	none	91	51	137	none
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
TS3 (ARK)	Naron	fine-loamy	Loamy eolian deposits	>152	none	91	51	137	none
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
TS4(ARK)*	Clark	fine-loamy	Calcareous old alluvium	25	114	38	none	38	none
	Ost	fine-loamy	Calcareous old alluvium	36	76	36	36	112	t,tk,k
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
TS5 (ARK)	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
TS6 (ARK)	Albion	coarse-loamy	Loamy sediments	none	none	41	20	69	none
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
TS7 (ARK)	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Albion	coarse-loamy	Loamy sediments	none	none	41	20	69	none
TS8 (ARK)	Albion	coarse-loamy	Loamy sediments	none	none	41	20	69	none
	Farnum	fine-loamy	Loamy old alluvium	152	41	112	79	152	t,k
	Clark	fine-loamy	Calcareous old alluvium	25	114	38	none	38	none

*Ash 10 in this terrace.

TABLE V (Continued)

TRANSECT C -- ASH 10 (0.88 ± 0.09 Ma)-Average Annual Precipitation (in cm)-66 (Con't)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TS8 (ARK)	Blanket	fine	Calcareous sediments	107	none	76	61	127	none
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
TS9 (ARK)	Attica	coarse-loamy	Eolian sediments	>76	none	25	28	99	none
	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Tivoli	sandy	Sandy eolian sediments	none	none	none	none	18	none

TRANSECT D -- ASH 15 (0.95 ± 0.10 Ma)-Average Annual Precipitation (in cm)-61

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
N. Canadian R. (NCR) Floodplain	Lincoln	sandy	Sandy recent	surface	none	none	none	28	none
TN1 (NCR)	Lincoln	sandy	Sandy recent	surface	none	none	none	28	none
	Las Animas	coarse-loamy	Loamy calcareous alluvium	surface	114	none	none	46	none
TN2 (NCR)	Lincoln	sandy	Sandy recent	surface	none	none	none	28	none
	Las Animas	coarse-loamy	Loamy calcareous alluvium	surface	114	none	none	46	none
TN3 (NCR)	Tivoli	sandy	Sandy eolian sediment	none	none	none	none	18	none
	Elsmere	sandy	Eolian sands or sandy alluvium	none	none	41	none	76	none
	Las Animas	coarse-loamy	Loamy calcareous alluvium	surface	114	none	none	46	none
TN4 (NCR)	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
TN5 (NCR)	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Carwile	fine	Loamy alluvium or eolian sediments	89	none	none	51	114	none
TN6 (NCR)	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
TN7 (NCR)*	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Carwile	fine	Loamy alluvium or eolian sediments	89	none	none	51	114	none
	Nobscot	loamy	Pleistocene loamy/ sandy sediments	none	none	none	122	203	none
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
	Enterprise	coarse-silty	Loamy eolian sediments	46	none	none	none	102	none

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT D -- ASH 15 (0.95 ± 0.10 Ma)-Average Annual Precipitation (in cm)-61 (Con't)									
Cimarron R. (CI) Floodplain	no survey								
TS1 (CI)	no survey								
TS2 (CI)	no survey								
TS3 (CI)	St. Paul	fine-silty	Pleistocene silty sediments or weathered Permian sandstone	86	none	114	69	142	none
TS4 (CI)	St. Paul	fine-silty	Pleistocene silty sediments or weathered Permian sandstone	86	none	114	69	142	none
TS5 (CI)	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
	Enterprise	coarse-silty	Loamy eolian sediments	46	none	none	none	102	none
TS6 (CI)	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Carwile	fine	Loamy alluvium or eolian sediments	89	none	none	51	114	none
	Nobscot	loamy	Pleistocene loamy/ sandy sediments	none	none	none	122	203	none
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
	Enterprise	coarse-silty	Loamy eolian sediments	46	none	none	none	102	none
TRANSECT E -- ASH 13 (0.84 ± 0.09 Ma), ASH 20 (0.90 ± 0.12 Ma)-Average Annual Precipitation (in cm)-66									
Washita R (WAR) Floodplain	Yahola	coarse-loamy	Calcareous loamy alluvium	surface	none	none	none	28	none
	Clairemont	fine-silty	Calcareous silty alluvium	surface	none	none	none	20	none
TS1 (WAR)	Crisfield	coarse-loamy	Sandy alluvium	none	none	41	none	114	none
	Yahola	coarse-loamy	Calcareous loamy alluvium	surface	none	none	none	28	none
	Clairemont	fine-silty	Calcareous silty alluvium	surface	none	none	none	20	none

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT E -- ASH 13 (0.84 ± 0.09 Ma), ASH 20 (0.90 ± 0.12 Ma)-Average Annual Precipitation (in cm)-66 (Con't)									
TN1 (WAR)	Crisfield	coarse-loamy	Sandy alluvium	none	none	41	none	114	none
TN2 (WAR)	Crisfield	coarse-loamy	Sandy alluvium	none	none	41	none	114	none
	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Devol	coarse-loamy	Pleistocene loamy and sandy sediments	none	none	none	33	101	none
	Shellabarger	fine-loamy	Old alluvium	none	none	48	48	97	none
TN3 (WAR)	Carey	fine-silty	Permian silty or sandy redbeds	36	81	36	86	173	t,tk,k
TN4 (WAR)	St. Paul	fine-silty	Pleistocene silty sediments; Permian sandstone	86	none	114	69	142	none
TS2 (WAR)	Cordell	loamy	Permian calcareous siltstone	surface	none	none	none	36	none
TS3 (WAR)	Cordell	loamy	Permian calcareous siltstone	surface	none	none	none	36	none
TS4 (WAR)	Dill	coarse-loamy	Permian sandstone	none	none	none	none	81	none
TN5 (WAR)	Carey	fine-silty	Permian silty or sandy redbeds	36	81	36	86	173	t,tk,k
TN6 (WAR)*	St. Paul	fine-silty	Pleistocene silty sediments; Permian sandstone	86	none	114	69	142	none
	Minco	coarse-silty	Loamy eolian deposits	140	none	38	none	140	none
	Pond Creek	fine-silty	Loamy loess/alluvium	none	none	117	61	152	none
	Grant	fine-silty	Permian silty sandstone or shale	119	none	41	41	119	none
TS5 (WAR)	Grandfield	fine-loamy	Pleistocene calcareous loamy/ sandy sediments	122	none	none	76	178	none
TS6 (WAR)**	Grandfield	fine-loamy	Pleistocene calcareous loamy/ sandy sediments	122	none	none	76	178	none
	Altus	fine-loamy	Pleistocene calcareous loamy/ sandy sediments	158	none	89	61	158	none
Canadian R. (CAR) Floodplain	Gracemore	sandy	Recent calcareous sandy alluvium	31	none	none	none	31	none

*Ash 13 in this terrace; ** Ash 20 in this terrace

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT E -- ASH 13 (0.84 ± 0.09 Ma), ASH 20 (0.90 ± 0.12 Ma)-Average Annual Precipitation (in cm)-66 (Con't)									
TS1 (CAR)	Minco	coarse-silty	Loamy eolian deposits	140	none	38	none	140	none
	Grant	fine-silty	Permian silty sandstone or shale	119	none	41	41	119	none
	Pond Creek	fine-silty	Loamy-loess/alluvium	none	none	117	61	152	none
TS2 (CAR)*	Minco	coarse-silty	Loamy eolian deposits	140	none	38	none	140	none
	Pond Creek	fine-silty	Loamy loess/alluvium	none	none	117	61	152	none
	St. Paul	fine-silty	Pleistocene silty sediments; Permian sandstone	86	none	114	69	142	none
	Grant	fine-silty	Permian silty sandstone or shale	119	none	41	41	119	none
TRANSECT F -- ASH 28 (0.89 ± 0.09 Ma)-Average Annual Precipitation (in cm)-66									
Elk Cr. (ELK) Floodplain	Clairmont	fine-silty	Calcareous silty alluvium	surface	none	none	none	20	none
	Lugert	coarse-silty	Alluvial sediments	51	none	41	none	107	none
	Port	fine-silty	Recent calcareous loamy alluvium	69	none	69	none	107	none
TE1 (ELK)*	Tillman	fine-mixed	Clayey alluvium	surface	81	36	178	206	t,tk,k
TE2 (ELK)	Tillman	fine-mixed	Clayey alluvium	surface	81	36	178	206	t,tk,k
	Hollister	fine-mixed	Permian calcareous clay	15	46	81	147	178	t,tk
TE3 (ELK)	Hollister	fine-mixed	Permian calcareous clay	15	46	81	147	178	t,tk
TW1 (ELK)	Hollister	fine-mixed	Permian calcareous clay	15	46	81	147	178	t,tk
	Tillman	fine-mixed	Clayey alluvium	surface	81	36	178	206	t,tk,k
TW2 (ELK)	Devol	coarse-loamy	Pleistocene loamy, sandy sediments	none	none	none	33	102	none
	Grandfield	fine-loamy	Pleistocene calcareous loamy sandy sediments	122	none	none	76	178	none

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT G -- ASH 27 (0.67 ± 0.07 Ma)-Average Annual Precipitation (in cm)-66									
Brazos R. (BRR) Floodplain	Lincoln	sandy	Recent sandy material	surface	none	none	none	28	none
	Mangum	fine	Calcareous clayey alluvium	surface	none	none	none	61	none
	Yahola	coarse-loamy	Permian and Pleistocene calcareous loamy alluvium	surface	none	none	none	28	none
	Hardeman	coarse-loamy	Eolian materials	25	none	none	none	91	none
TN1 (BRR)	Sagerton	fine	Calcareous clayey loamy sediments	64	66	38	196	213	t,tk,t
	Wichita	fine	Loamy clayey alluvium	56	112	none	142	168	t,tk
	Rotan	fine	Quaternary calcareous loamy alluvium	36	51	64	168	203	t,tk,t
TN2 (BRR)*	Sagerton	fine	Calcareous clayey loamy sediments	64	66	38	196	213	t,tk,t
TRANSECT H -- ASH 21 (0.65 ± 0.07 Ma)-Average Annual Precipitation (in cm)-56									
N. Canadian R. (NCR) Floodplain	Lincoln	sandy	Recent sandy material	surface	none	none	none	28	none
	Las Animas	coarse-loamy	Loamy calcareous alluvium	surface	114	none	none	46	none
TN1 (NCR)	Lincoln	sandy	Recent sandy material	surface	none	none	none	28	none
TN2 (NCR)	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
	Dalhart	fine-loamy	Pleistocene loamy eolian deposits	71	31	23	74	127	t,k
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
TS1 (NCR)	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT H -- ASH 21 (0.65 ± 0.07 Ma)-Average Annual Precipitation (in cm)-56 (Con't)									
TS2 (NCR)*	Pratt	sandy	Sandy eolian deposits	none	none	none	71	102	none
	Otero	coarse-loamy	Alluvial sediments	surface	117	none	none	36	k
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
TS3 (NCR)	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
	Otero	coarse-loamy	Alluvial sediments	surface	117	none	none	36	k
TS4 (NCR)	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TS5 (NCR)	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
TRANSECT I -- ASH 23 (0.73 ± 0.08 Ma)-Average Annual Precipitation (in cm)-56									
Cimarron R. (CI) Floodplain	Lincoln	sandy	Recent sandy material	surface	none	none	none	28	none
TS1 (CI)	Spur	fine-loamy	Loamy alluvial sediments	surface	none	38	none	97	none
TS2 (CI)	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk,tk
TS3 (CI)*	Tipton	fine-loamy	Pleistocene calcareous loamy silty alluvium	102	none	86	48	168	none
	Mansker	fine-loamy	Calcareous loamy	surface	137	31	137	168	tk,tk

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT J -- ASH 18 (0.60 ± 0.07 Ma)-Average Annual Precipitation (in cm)-51									
Cimarron R. (CI) Floodplain	Las Animas	coarse-loamy	Calcareous alluvium	surface	114	none	none	46	none
TS1 (CI)	Canadian	coarse-loamy	Pleistocene loamy alluvium	76	none	38	none	76	none
TS2 (CI)*	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TS3 (CI)	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TS4 (CI)	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
	Ulysses	fine-silty	Calcareous loess	25	51	25	none	46	k
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TS5 (CI)	Richfield	fine	Calcareous loess	41	36	41	25	51	t,k
TRANSECT K -- ASH 25 (1.00 ± 0.11 Ma)-Average Annual Precipitation (in cm)-51									
Kiowa Cr. (KIC) Floodplain	Likes	sandy	Unconsolidated sandstones, alluvial and eolian sands	surface	none	25	none	25	none
TN1 (KIC)	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk,tk
	Otero	coarse-loamy	Alluvial sediments	surface	117	none	none	36	k
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk,tk
	Otero	coarse-loamy	Alluvial sediments	surface	117	none	none	36	k
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TN3 (KIC)	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk,tk

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT K -- ASH 25 (1.00 ± 0.11 Ma)-Average Annual Precipitation (in cm)-51 (Con't)									
TN4 (KIC)*	Otero	coarse-loamy	Alluvial sediments	surface	117	none	none	36	k
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk,tk
	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TN5 (KIC)	Mansic	fine-loamy	Tertiary calcareous alluvium	31	104	48	none	76	k
TRANSECT L -- ASH 19 (2.15 ± 0.24 Ma)-Average Annual Precipitation (in cm)-51									
Canadian R. (CAR) Floodplain	Lincoln	sandy	Recent sandy material	surface	none	none	none	28	none
TS1 (CAR)	Mobeetie	coarse-loamy	Sandy calcareous sediments	surface	41	none	none	66	k
TN1 (CAR)	Paloduro	fine-loamy	Calcareous loamy sediments	surface	none	31	none	203	none
	Estacado	fine-loamy	Calcareous loamy materials	surface	211	41	211	252	tk
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk
	Pullman	fine	Calcareous clayey materials	61	66	61	183	198	t,tk
TS2 (CAR)	Olton	fine	Calcareous loamy materials	56	112	38	231	252	t,tk,t
	Estacado	fine-loamy	Calcareous loamy materials	surface	211	41	211	252	tk
	Paloduro	fine-loamy	Calcareous loamy sediments	surface	none	31	none	203	none
TS3 (CAR)*	Paloduro	fine-loamy	Calcareous loamy sediments	surface	none	31	none	203	none
	Estacado	fine-loamy	Calcareous loamy materials	surface	211	41	211	252	tk

*Ash in this terrace.

TABLE V (Continued)

Terrace	Soil Series	Family Particle Size Class	Parent Material	Depth to free $CaCO_3$ (cm)	Calcic Thickness (cm)	Mollic Colors Thickness (cm)	Bt Thickness (cm)	Solum Thickness (cm)	t/k
TRANSECT L -- ASH 19 (2.15 ± 0.24 Ma)-Average Annual Precipitation (in cm)-51 (Con't)									
TS4 (CAR)	Pullman	fine	Calcareous clayey materials	61	66	61	183	198	t,tk
	Olton	fine	Calcareous loamy materials	56	112	38	231	252	t,tk,t
	Estacado	fine-loamy	Calcareous loamy materials	surface	211	41	211	252	tk
	Darrouzett	fine	Loamy, calcareous, eolian materials	58	64	89	239	254	t,tk
TS5 (CAR)	Pullman	fine	Calcareous clayey materials	61	66	61	183	198	t,tk
	Mansker	fine-loamy	Calcareous loamy material	surface	137	31	137	168	tk

*Ash in this terrace.

VITA

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Candidate for the Degree of

Master of Science

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