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GEOLOGICAL AND STRUCTURAL ANALYSIS OF THE SURFACE GEOLOGY OF ELLIS COUNTY, KANSAS

By

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GEOLOGICAL AND STRUCTURAL ANALYSIS
OF THE SURFACE GEOLOGY OF
ELLIS COUNTY, KANSAS

being

A Thesis Presented to the Graduate Faculty
of the Fort Hays State University in
Partial Fulfillment of the Requirements for
the Degree of Master of Science

by

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ABSTRACT

A detailed surficial geologic map of Ellis County, Kansas was produced as a pilot study in the Kansas Geological Survey's (KGS) effort to remap the entire state. This study determined the efficiency, reliability, and financial suitability of mapping with published soil survey data. If the parent material of a soil type is determined, a surficial geologic map of the existing rock units underlying the soils may be produced. Generally, the soil survey data proved to be an accurate reflection of the underlying bedrock and provided the means of producing an extremely detailed geologic map. The final geologic map was produced by computer-aided cartography using the GIMMAP (Geodata Interactive Management Map Analysis and Production) system developed at the KGS.

Three-point solution methods indicated that the surficial strata in Ellis County are essentially horizontal. Lineament analyses of a black and white aerial photographic mosaic and a series of color infrared aerial photographs suggested that the lineament features in Ellis County are stream-related.

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INTRODUCTION

The Department of Earth Sciences at Fort Hays State University received funding from the Kansas Geological Survey (KGS) to remap the geology of Ellis County, Kansas. The remapping of Ellis County is the basis for this thesis. This project provides the first known geologic map of Ellis County since the 1964 KGS geologic map of Kansas. This study is a pilot project to determine the efficiency, reliability, and financial suitability of mapping with published soil survey data. The remapping of Ellis County is the basis for this thesis. Also, it is part of a comprehensive plan by the KGS for the regional remapping of the state of Kansas.

Emphasis is placed on the use of data in the Soil Survey of Ellis County, Kansas (Glover and others, 1975). The survey provides detailed descriptions of the soil types. Bedrock or various parent materials weather to different types of soil. If a researcher can determine the parent materials of the soil types, he can produce a surficial geologic map of the existing rock units beneath the soils. Published geologic maps, infrared aerial photographs, and field reconnaissance were also used to produce the geologic map of Ellis County. In addition to remapping the county, I conducted a study of surficial structural elements. This included measuring seven representative stratigraphic sections. An alidade and topographic maps were used to determine elevations of specific strata in order to determine strike and dip.

PREVIOUS WORK

Many geological studies have been conducted in Ellis County, Kansas, but only a few have been mapping projects. Bass (1926) produced a surficial reconnaissance geologic map of Ellis County that served as a comparison for the project map. Byrne and others (1949) conducted a survey of construction materials within the county that includes general outcrop patterns of several formations and members within the study area. A structural analysis and outcrop patterns of the Fort Hays Limestone in Ellis County are found in an unpublished thesis (Drees, 1974). Hattin's (1962, 1965) work on the stratigraphy of the Carlile and Graneros shales of Kansas provided basic outcrop patterns within Ellis County. Hattin's and Siemers's (1978) detailed study on the stratigraphy and depositional environments of western Kansas provided basic stratigraphic relationships within the county. Jewett's (1951) study of geologic structures of Kansas provided a general outline of the subsurface structure in Ellis County. Leonard and Berry (1961) reported general outcrop patterns of the Greenhorn and Fairport limestones of southern Ellis County. Siemers (1971) completed a detailed stratigraphic, paleoecologic, and environmental analysis of the Dakota in central Kansas that supports the presence of the Dakota Sandstone in the southeastern corner of the county. Stallard and others (1963) provided a material inventory of Ellis County that furnished outcrop localities and a brief geologic overview. Frye (1945, 1945b, 1946, 1968) and Frye and Leonard (1951, 1952) employed many studies on Kansas Pleistocene stratigraphy dealing with soils, loesses, terraces, and the Ogallala Formation. Glover and others (1975) provided the soil survey of Ellis County. The rock units represented on the geologic map in this study were determined by studying the detailed soil descriptions.

METHODS OF INVESTIGATION

Producing the geologic map of Ellis County involved a variety of sequential methods. The first, and most crucial, step was becoming familiar with the Soil Conservation Service's (SCS) soil survey of the county. I outlined and studied soil types and their related associations and matched them to their corresponding lithologies. Uncertain contacts were field checked and compared to color infrared photographs, elevations on topographic quadrangles, and previously published geologic maps. A mosaic of soil maps was then color coded, contacts traced according to lithologies, and reduced to a more desirable three foot by three foot working size. The first rough draft of the map showed subtle scale variations with the KGS's existing base map. A more detailed digitized base map was then provided by the KGS and the entire map was redrafted. This final copy was submitted to the KGS for the purpose of digitizing the final geologic map.

The second part of the project involved the location of seven stratigraphic sections that represent all the lithologies cropping out in the county. I used plane table and alidade to establish exact elevations of a certain marker horizon. This information was used to study the surficial structure within the county. Also, a black and white mosaic and color infrared photographs were used to perform a lineament study.

LOCATION AND STRATIGRAPHIC REVIEW

Ellis County, Kansas is located in the north-central portion of the state along the western edge of the Smoky Hills Physiographic Province (Figure 1). The county covers nearly 900 sq. mi. (2,330 sq. km.) and borders Rooks County to the north, Rush County to the south, Russell County to the east, and Trego County to the west. Cretaceous limestones, shales, and sandstones and late Cenozoic alluvial and loess deposits dominate the nearly level surface geology of Ellis County. The Smoky Hill River, the Saline River, Big Creek, and numerous intermittent streams throughout the county dissect the geologic units.

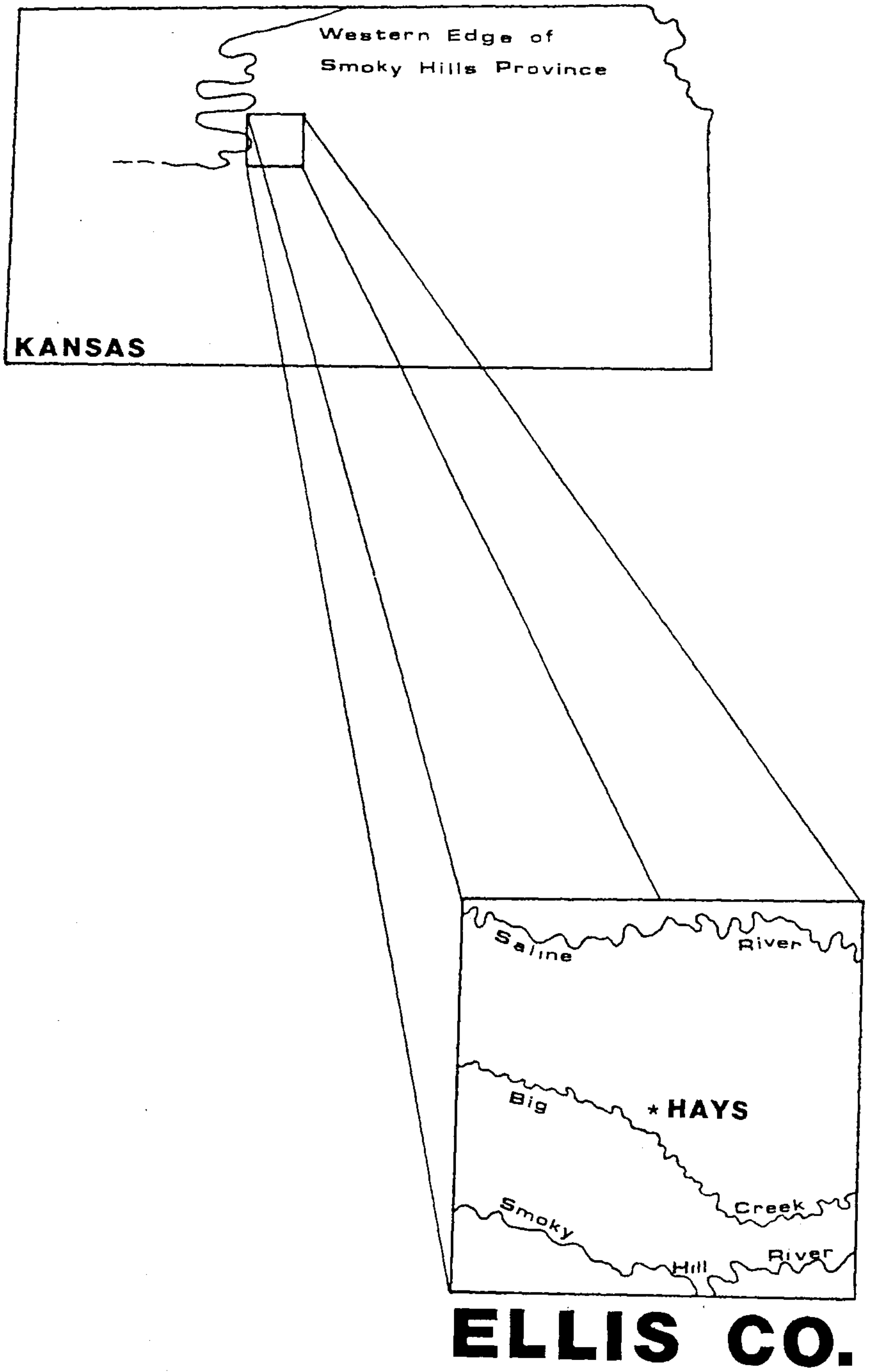

Figure 1. Map showing location of Ellis County in Kansas with inset showing major drainages in the county.

The stratigraphic column in Figure 2 reveals the general relationships between the lithologic units that crop out within Ellis County. The following section is a brief lithologic description of the rock units. The references provide a more detailed account of the stratigraphy, biostratigraphy, and depositional environments.

The oldest unit exposed in Ellis County is the Dakota Sandstone, found only in the extreme southeastern corner along the Smoky Hill River. Twelve feet (3.7 m) of a medium-grained, subangular to subrounded, thinly laminated sandstone is exposed. The color of the weathered surface is dark yellow brown (10 YR 4/2) and the fresh surface is yellow gray (5 Y 8/1). The sandstone is friable and contains abundant carbonaceous flakes along the laminations. It also contains a laterally continuous seven inch (17.8 cm) thick layer of soft-sediment deformation nine feet (2.7 m) below the contact with the overlying Graneros Shale. Scattered iron stained and spherical iron nodules up to two inches (5.1 cm) in diameter occur within the top three feet (0.9 m). Siemers (1971) suggested that westerly to southwesterly meandering streams in an environmentally diverse, marginal-marine setting deposited the sediments comprising the uppermost Dakota in central and western Kansas. The contact between the Dakota and

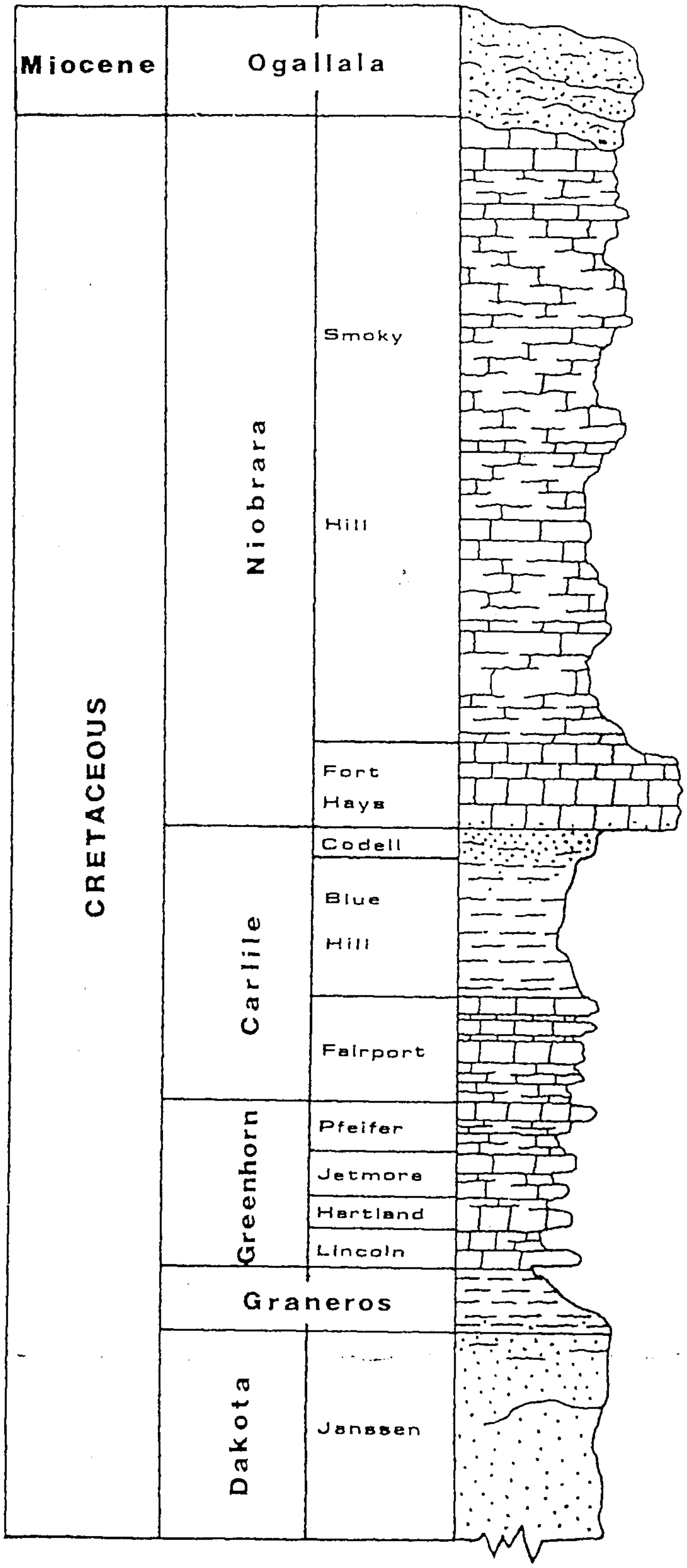

Figure 2. Representative stratigraphic section of the lithologic units that crop out in Ellis County.

Graneros Shale in Ellis County is transitional between alternating beds of sandy shale, shale, and thin sandstone, and is typical of these units in central Kansas (Hattin, 1965).

The Graneros Shale, likewise only exposed in the southeastern corner, is 26 feet (7.9 m) thick. This slope-forming shale is fissile and noncalcareous. The weathered surface is light olive gray (5 Y4/1) and the fresh surface is dusky yellow brown (10 YR 2/2). The unit contains carbonaceous debris and gypsum flakes and crystals up to two inches (5.1 cm) in length, plus numerous laminae of fine sand throughout. Iron-stained shale and dark red brown (10 R 3/4), laterally-persistent clay-ironstone layers up to one foot (0.3 m) thick occur throughout the unit. The Graneros suggests shallow-water, open-marine deposition and represents the start of the transgressive phase of the Greenhorn cyclothem. Loess and alluvium cover the contact between the Graneros and overlying Greenhorn Limestone in Ellis County; however, in central Kansas the contact is easily distinguished by an abrupt change in color and lithology. These abrupt changes suggest a stratigraphic hiatus because the contact at most places separates rocks deposited in a low-energy environment from those of a high-energy environment of deposition (Hattin, 1965).

The Greenhorn Formation crops out in the southeastern, south-central, and northeastern portions of the county. The Lincoln, Hartland, Jetmore, and Pfeifer members comprise the formation. The soil survey of the county does not distinguish different soil types for each member; therefore, the rock unit was mapped as a formation. The general lithology ranges from cross-bedded and cross-laminated skeletal limestone in the Lincoln to a more dominant lithology of laminated chalk and chalky limestone in the upper members. Many bentonite layers occur in the upper three members. The Greenhorn attains a maximum thickness of 90 feet (27.4 m) in Ellis County and the upper Pfeifer represents the transgressional peak of the Greenhorn cyclothem (Hattin and Siemers, 1978). The Pfeifer and the lowermost part of the overlying Fairport Member of the Carlile Shale are indistinguishable. However, the Fencepost limestone bed at the top of the Pfeifer is used as an arbitrary contact because the bed is geographically widespread and easily identified in the field.

The Carlile Shale crops out in all of Ellis County except the southeastern corner. Three members make up the formation. The Fairport Member attains a maximum thickness of 100 feet (30.5 m) in Ellis County and consists chiefly of olive-gray chalk with beds of chalky limestone in the lower part. Beds of marly chalk and bentonite are characteristic of the middle and upper parts. Lenses of skeletal limestone and a moderate amount of terrigenous detritus in the upper Fairport reflects deposition in a higher energy environment than during Greenhorn deposition, suggesting regressive movement of the shoreline (Hattin and Siemers, 1978). The overlying Blue Hill Shale Member is easily distinguished from the Fairport based on lithology and fossil content. The Blue Hill attains a maximum thickness of 200 feet (61 m) in the county. The member consists of dark gray, silty, fissile, noncalcareous shale that becomes sandy near the top. Zones of septarian concretions are common, and the shale contains very fine carbonaceous matter scattered throughout. The presence of fine-grained, noncalcareous sediment reflects an influx of terrigenous detritus, suggesting regression of the sea. The boundary between the Blue Hill and overlying Codell Sandstone Member is gradational. The Codell attains a maximum thickness of 25 feet (7.6 m) in Ellis County. The unit consists chiefly of well-sorted, fine quartzose sand, small quantities of feldspar, and a limited assemblage of stable heavy minerals (Hattin and Siemers, 1978). The presence of intensive bioturbation suggests slow sedimentation during the final stages of regression of the Greenhorn cyclothem. The Codell does not weather into a specific soil type. Also, the stratigraphic position of the Codell directly below the Fort Hays Limestone does not allow the Codell to be easily mapped on a surficial map. As a result, the Codell was not placed on the map of Ellis County.

The Fort Hays Limestone and Smoky Hill Chalk members comprise the overlying Niobrara Formation. The lower Fort Hays unconformably overlies the Carlile and represents the beginning of the Niobrara transgression. The Fort Hays crops out in Ellis County except in the southeastern corner and attains a maximum thickness of approximately 70 feet (21.3 m). Thick, massive beds of resistant chalky limestone that are light to medium gray, commonly weathering to pale grayish orange or white, are characteristic of this unit. The Fort Hays is almost pure calcium carbonate except for the reworked Codell sediments in the basal portion. Thin beds of shale and bentonite separate many of the limestone beds. The Fort Hays grades into the overlying Smoky Hill Member. The Smoky Hill crops out in northwestern Ellis County and attains a maximum thickness of 100 feet (30.5 m). Gray, shaly chalk and interbedded shale and chalk that weather white, yellow, and orange are characteristic of the Smoky Hill. Limonitic concretions and local massive chalk beds are common (Zeller, 1968). The Niobrara fauna suggests that the Smoky

Hill period of deposition consisted of deeper and less well-circulated waters than during Fort Hays deposition. Quartz silt becomes evident in the upper Smoky Hill, suggesting an influx of terrigenous detritus as the eastern shoreline approached western Kansas. Generally, the lithology and faunal makeup of the Smoky Hill and Fairport Member of the Carlile Formation are similar in that both units represent the regressive carbonate phase of their respective depositional cycles (Hattin and Siemers, 1978).

The Pierre Shale is absent in Ellis County. Therefore, the Smoky Hill in the study area is overlain by the Ogallala Formation. Zakrzewski (1988) showed that vertebrate faunas from the Ogallala in Ellis County range in age from early Clarendonian to early Hemphillian and, therefore, a major part, if not all, of the Ogallala is late Miocene in age. However, for this study, I have temporarily adhered to the KGS's request of assigning a Pliocene age to the Ogallala until the KGS's rules committee decides to adopt Miocene. The Ogallala attains a maximum thickness of 75 feet (22.9 m) in Ellis County and crops out in the northern and western portions. The unit is massive to cross-bedded and is generally composed of arkosic gravel, sand, and silt that are locally cemented with calcium carbonate (Zeller, 1968). Streams flowing eastward from the Rocky Mountains deposited the Ogallala on the plains of western Kansas.

There are three Quaternary deposits in Ellis County. The Saline, Big Creek, and Smoky Hill River valleys contain stream-deposited sand, gravel, and silt that now form terraces. These deposits may reach a thickness of 100 feet (30.5 m) in some places. Loess deposits are located on isolated topographic high and broad, flat-lying areas. Loess covers a moderate amount of the Cretaceous units in Ellis County and may reach over 30 feet (9.1 m) in thickness. Stream-deposited alluvium, ranging from coarse sand and gravel to clay, occurs along the major rivers and most of the intermittent streams across the county. The alluvium may be as thick as 60 feet (18.3 m).

REVIEW OF THE SOIL SURVEY

The general intent of this survey is to show what kinds of soils are in Ellis County, where they are located, and how they can be used. The survey also provides general historical information about the county and basic knowledge of the environment.

A soil series or soil phase define most of the soils in Ellis County. Soils that have very similar profiles make up a soil series. All the soils of one series are similar in thickness, topographic location, and other important characteristics. However, there may be differences in texture of the surface layer, slope, stoniness, or other features. Based on such differences, a soil series is divided into soil phases. In Ellis County, there are 26 soil series and 42 soil phases.

After determining the soil types of Ellis County, soil scientists drew boundaries of the individual soils on aerial photographs of the county. The photographs are at a scale of 1:20,000 and a single photograph covers 4.5 miles (2.8 km) east-west and 3 miles (1.9 km) north-south. The soils boundaries incorporate an area called a mapping unit. In most instances, a mapping unit is nearly equivalent to a soil phase. However, some mapping units are made up of soils of different series or phases. These mapping units are soil complexes and consist of two or more soils so intricately mixed or so small that they cannot be shown separately. There are ten soil complexes in Ellis County. Also, descriptive names are given to land types representing areas that are rocky or severely eroded. There are five land types in Ellis County.

After reviewing the information in the soil survey, the soil photographs were carefully trimmed and taped together into five separate strips. Each strip consisted of 14 aerial photographs and covered six miles (3.7 km) in a north-south direction and the entire width of the county in an east-west direction. Working with the individual strips helped to avoid the awkwardness of working with all 70 photographs at one time. The soils boundaries matched well from one photograph to another, although some subtle discrepancies did exist.

RELATIONSHIPS BETWEEN PARENT MATERIAL AND SOILS

The next and most important step was to classify and summarize the soil types which developed from each rock unit. To begin this procedure, each soil series, phase, complex, and land type was extensively studied by reviewing the descriptions provided in the soil survey. An outline of each soil was then produced. This provided easily accessible information about the topographical location of a particular soil, and also showed the presence of rock outcrops, depressions, erosional features, and mining operations. Because of the generalized descriptions of some of the soils, it was not possible to determine the parent material for each soil by simply studying the soil survey. Therefore, Bass's (1926) geologic map of Ellis County, Stallard and others' (1963) materials inventory of the county, and Byrne and others' (1949) location maps of construction materials were also studied. These publications provided outcrop patterns that could be studied and compared with the soil mapping unit patterns on the aerial photographs.

The first unit studied was the Fort Hays Limestone. The Fort Hays is easily identified by its outcrop pattern and white color. The distribution of the Heizer-Armo soil complex (HI) perfectly matches the outcrop pattern of the Fort Hays. This soil complex occurs on uplands, consists of five to fifteen percent barren geologic material, and forms in material weathered from chalky limestones. By examining Bass's and Stallard and others' outcrop locations of the Fort Hays, it was deduced that the Heizer-Armo complex corresponded only to the Fort Hays outcrops. This correlation removed any doubt that the chalky limestone parent material of the Heizer-Armo complex could be one of the other chalky limestones present in Ellis County. At this point, I traced and color coded all the Heizer-Armo complex mapping units on the soil survey's aerial photographs.

After tracing and color coding the Fort Hays, I listed and studied all the soils adjacent to the Fort Hays. The Brownell gravelly loam soil phase (Br) of the Brownell series occurs only adjacent to the Heizer-Armo complex. An examination of topographic quadrangles showed that the Brownell soil phase is topographically lower than the Heizer-Armo complex. The soil description states that the Brownell series occurs on uplands and side slopes and forms in colluvium derived from chalky limestone. Therefore, I included the Brownell gravelly loam soil as part of the Fort Hays Limestone. The Brownell mapping unit was color coded the same as the Heizer-Armo complex.

The Bogue clay soil phase (Bg) and the Bogue-Armo complex (Bo) of the Bogue series also occur adjacent to the Fort Hays in a topographically lower position. However, the soil description states that the Bogue soils have a clay shale parent material. I compared the location of the Blue Hill Shale on Bass's map to the location of the Bogue soils on the aerial photographs. A good correlation suggested the Bogue soils formed in material weathered from the Blue Hill. The Bogue clay and Bogue-Armo complex were then traced and color coded.

Rough broken land (Ro) is a soil land type that also borders the Fort Hays. However, rough broken land occurs in a topographically higher position than the Fort Hays. The soil description of rough broken land states that this land type is about 45 percent shallow soils over chalk, 12 percent moderately deep soils over chalk, 23 percent chalk outcrops, and 20 percent deep soils that formed in colluvial and alluvial sediment on the floor of drainageways (Glover and others, 1975). The chalk outcrops are very evident on the aerial photographs. In comparing Bass's map to the mapping unit location of rough broken land, it is obvious that this soil land type formed in material weathered from the Smoky Hill Chalk. This soil type was traced and color coded.

With the Blue Hill, Fort Hays, and Smoky Hill color coded, it was easy to discern many of the intermittent drainageways that dissect these rock units. I listed and studied four different soil types associated with these drainageways. The most common of the four is the frequently-flooded Roxbury silt loam soil phase (Rf) of the Roxbury series. The soil description states that this soil phase occurs on flood plains along the smaller creeks and drainageways. It is somewhat stratified with thin layers of loam, sandy loam, or silty clay loam. The aerial photographs show that the frequently-flooded Roxbury silt loam mapping units closely follow the path of most of the intermittent streams. Alluvial Land describes the other three soil types derived from alluvium. Broken Alluvial Land (Ab) is a soil land type located on the channel and banks of Big Creek. The descriptive term, broken, defines the moderately steep to vertical banks along Big Creek. The soil on the banks is loamy. The narrow flood plain along the channel consists of nearly level to gently sloping loamy soils and sandbars. Clayey Alluvial Land (Ac) consists of nearly level to gently undulating clayey soils on narrow flood plains along meandering intermittent streams. The clay present in these soils is probably derived from the Blue Hill Shale. Wet Alluvial Land (Ad) consists of clayey, loamy, and sandy soils. This soil occurs just above the water table along the smaller drainageways. I traced and color coded these four soil types as alluvium on all five strips of aerial photographs.

Many different soil types occur near and adjacent to the major streams in Ellis County. Alluvium is the parent material, but the soils occur in a terrace position. KGS personnel indicated that it was not necessary to determine high or low terraces for this project.

The Detroit silt loam soil phase (De) of the Detroit series is a deep, well-drained soil that forms in silty calcareous alluvium along major drainageways. The underlying material is a light-gray, calcareous silt loam.

The Eltree series contains four soil phases. Each soil phase has a soil profile similar to the one described for the series. These phases consist of deep, well-drained soils that form in calcareous, silty, colluvial-alluvial sediment. The Eltree silt loam soil phase (Ee) with zero to one percent slopes occurs on smooth, old, high terraces on valley sides along the major streams. The Eltree silt loam soil phase (Ef) with one to three percent slopes occurs on old, high alluvial terraces and valley sides. The Eltree silt loam soil phase (Eg) with three to seven percent slopes also occurs on old alluvial terraces and valley sides. The soil profile is similar to that for the series, but the surface layer is slightly thinner. The

Eltree silt loam soil phase (Eh) with seven to fifteen percent slopes also occurs on old, high alluvial terraces and valley sides. Compared with the profile for the series, this soil has a thinner surface layer and the subsoil contains less clay.

One of the most common soils located in a terrace position is the Hord silt loam soil phase (Hr) of the Hord series. This phase consists of a deep, well-drained soil that forms in calcareous silty alluvium. The soil occurs on a nearly level to gently undulating topography. The underlying material is a pale-brown, calcareous silt loam.

The McCook fine sandy loam soil phase (Mc) and the McCook silt loam soil phase (Md) form the McCook series. Both of these soils occur on low terraces and bottom lands closer to the streams. They are both composed of deep, well-drained soils that form in calcareous, medium-textured alluvium. The McCook fine sandy loam is slightly sandier in the surface layer.

The New Cambria series contains the New Cambria silty clay soil phase (Nc). This soil forms in clayey, calcareous alluvium and occurs on a nearly level to gently sloping topography. The New Cambria soil phase occurs in a terrace position interrupted in places by small, narrow drainageways that advance into the uplands.

Lastly, the Roxbury silt loam soil phase (Rb) of the

Roxbury series forms in calcareous silty alluvium. Like most of the other soils located in a terrace position, the Roxbury silt loam lies on a nearly level to gently undulating surface. The other soil phase of the Roxbury series was previously mapped as alluvium along the smaller drainageways. This is one of the few instances where different phases of the same series were mapped as different geologic units. The reason is mainly because of their respective topographic positions. I traced and color coded all the soils located in a terrace position.

Loess covers approximately 35 to 40 percent of Ellis County. The soil descriptions plainly state what soils form in loess. The next step in this study involved color coding all loess deposits. This process eliminated seventeen different soil types and made it easier to work with the remaining soils later in the project. The soil descriptions of the loess deposits and remaining soils are more detailed to show the subtle differences between the different soil types.

The Crete series is made up of two soil phases that form in loess deposits. The Crete silty clay loam soil phase (Cr) occurs on uplands and contains areas of small depressions and eroded spots. The Crete silty clay loam (Ct) with a thin variant surface occurs in somewhat depressional areas on uplands. Both phases are deep, moderately well-drained soils. The subsoil has a clayey character. The representative profile for the Crete series shows the depth of the solum averages 37.5 inches (95.3 cm). The underlying loess is a pale-brown (10 YR 6/3) silty clay loam.

The Mento series consists of deep, well-drained soils that form in thin loess deposited over chalky limestone. Mixing of loess and material eroded from the chalky limestone occurred at the time of loess deposition. The representative profile for the Mento series shows that depth to the bottom of the solum averages 26 inches (66 cm). Underlying the solum is 36 inches (91.4 cm) of loess. Pale-brown (10 YR 6/3), silty clay loam comprises the upper 11 inches (27.9 cm). The lower 25 inches (63.5 cm) consist of white (10 YR 8/2) clay loam and contain coarse fragments of chalky limestone. Level-bedded chalky limestone underlies the loess. The Mento series contains four phases. The Mento silt loam (Me) with zero to one percent slopes has the profile described as representative for the series. This phase occurs on narrow tablelands and level ridgetops. This soil includes small areas of rock outcrops. The Mento silt loam soil phase (Mf) with one to three percent slopes occurs on ridgetops and tablelands. This soil has a profile similar to the one described for the series, but the chalky limestone is at a depth of 55 inches (139.7 cm). This phase contains small eroded areas and rock outcrops. The Mento silty clay loam soil phase (Mg) is on ridgetops, on slopes, and along narrow, shallow drainageways in upland areas. The surface layer is moderately eroded and has a finer texture than that seen in the profile for the series. The eroded Mento soil phase (Mo) with three to seven percent slopes occurs on sides of drainageways and narrow ridgetops. In most places, the surface layer is approximately seven inches (17.8 cm) thinner than that in the series profile. Tilling of this soil allows the mixing of the surface layer with part of the subsoil, giving the surface layer a silty clay loam texture.

The Holdrege soil series consists of deep, well-drained soils that form in calcareous silty loess and occur on loess-covered valley sides. The representative profile shows that the surface layer is dark grayish-brown silt loam about 10 inches (25.4 cm) thick. Depth to the bottom of the subsoil is approximately 30 inches (76.2 cm). The underlying loess varies from pale-brown (10 YR 6/3) silt loam to brown (10 YR 5/3) silty clay loam. The Holdrege silt loam soil phase (Ho) with zero to one percent slopes occurs on old, high alluvial terraces covered by silty loess. This phase has a profile similar to the one described as representative for the series. Several areas of Eltree soils, which were previously determined to be associated with terrace deposits, occur frequently with this phase. The Holdrege silt loam soil phase (Hp) with one to three percent slopes occurs on loess-covered valley sides and has a profile similar to that for the series. Soils associated with terrace deposits also occur rather frequently with this soil.

The Harney series represents most of the loess in the study area. This series is made up of four phases and five complexes. Generally, the series consists of deep, well-drained soils that form in calcareous, medium-textured loess on nearly level to sloping areas and on uplands. A representative profile for the series shows the surface layer to be nearly 10 inches (25.4 cm) thick. The underlying subsoil is nearly 30 inches (76.2 cm) thick and ranges from calcareous, silty clay loam to silty clay. Loess is at a depth of 40 inches (101.6 cm). The upper 19 inches (48.3 cm) of loess is brownish-gray (10 YR 6/2) silty clay loam and the lower 15 inches (38.1 cm) is light-gray (10 YR 7/2) silt loam.

The Harney silt loam soil phase (Ha) with zero to one percent slopes occurs on tablelands and has the profile described as representative for the series. This phase occurs in areas of small depressions and eroded land. The Harney silt loam soil phase (Hb) with one to three percent slopes is on ridgetops and broad tablelands. The surface layer is slightly thicker and the subsoil is nearly three inches (7.6 cm) thinner than that for the series. This phase contains small eroded areas. The Harney silt loam soil phase (Hc) with three to seven percent slopes occurs on convex slopes. The surface layer may be as thick as 16 inches (40.6 cm) where soil material has eroded from higher lying areas. In other areas, the surface layer may be as thin as 8 inches (20.3 cm). The distribution of this phase includes small eroded areas and some rock outcrops. The Harney silty clay loam (Hd) occurs on rounded hills along drainageways in upland areas. In most places, the surface layer averages four inches (10.2 cm) in thickness; however, in some places the surface layer has been completely removed by erosion, and the present surface layer consists entirely of subsoil material. Depth to calcareous material is nearly four inches (10.2 cm) less than in the representative profile.

The Harney series includes five soil complexes. The Harney-Armo soil complex (He) with three to seven percent slopes occurs along sloping drainageways on tablelands where thin deposits of loess cover calcareous limestone colluvium. Harney soils comprise about 45 percent of this complex, Armo soils comprise about 45 percent, and minor included soils make up the remaining 10 percent. Nearly 40 percent of the acreage of the Harney soils is moderately eroded. In some small areas, Harney soils are underlain by chalky limestone or chalky shale at an average depth of 48 inches (121.9 cm). About 55 percent of the acreage of Armo soils is moderately eroded. Small, severely eroded spots and rock outcrops are present in this complex. The Harney-Carlson silt loam soil complex (Hf) with zero to one percent slopes occurs on uplands. The complex consists of 40 to 60 percent Harney soils, 25 to 40 percent Carlson soils, and five to 15 percent minor included soils. The soil profile for the Harney soils is similar to the one described as representative for the series, but in a few small areas the soils are underlain by sandy loam or are noncalcareous below a depth of 30 inches (76.2 cm). The Carlson soils have a profile similar to the one described as representative for the Carlson series. Small depressions, eroded areas, and rock outcrops are present in this complex. The Harney-Carlson silt loam soil complex (Hg) with one to three percent slopes occurs on ridgetops and tablelands. Areas of this complex are about 40 to 55 percent Harney soils, 35 to 45 percent Carlson soils, and 10 to 20 percent minor included soils. In some areas, the surface layer of the Harney soils is five inches (12.7 cm) thinner than that of the representative profile, and in other areas the soils have a sandy loam layer below the subsoil and are noncalcareous to a depth of more than 30 inches (76.2 cm). The Carlson soils are similar to that described as representative for the Carlson series. Small depressions, eroded areas, and rock outcrops are present in this complex. The Harney-Wakeen silt loam soil complex (Hh) with zero to one percent slopes is present on tablelands and ridgetops. Harney soils comprise 40 to 50 percent of this complex, Wakeen soils comprise 20 to 25 percent, soils similar to Harney soils comprise 20 to 30 percent, and minor included soils make up nearly 10 percent. The soils that are similar to Harney soils have a higher lime content below the subsoil and chalky limestone or calcareous shale are at an average depth of four feet (1.2 m). Wakeen and Harney soils are similar to their respective soil profiles. Small depressions and eroded spots are present in this complex. The Harney-Wakeen silt loam soil complex (Hk) with one to three percent slopes occurs on ridgetops and tablelands. Areas of this complex are 30 to 40 percent Harney soils, 25 to 30 percent Wakeen soils, 20 to 30 percent soils similar to Harney soils, and 10 to 15 percent minor included soils. The soils similar to Harney soils have a layer below the subsoil that is higher in lime content, and they are underlain by bedded chalky limestone or calcareous shale at an average depth of four feet (1.2 m). In a few small areas, the Wakeen soils have a slightly thinner surface layer than that described as representative for the series. Small depressions, eroded spots, and areas of rock outcrops are present in this complex.

The Ogallala was the next rock unit studied. Bass's surficial geologic map of the county revealed a more extensive outcrop pattern for the Ogallala than I anticipated. Also, the soil descriptions in the soil survey did not conclusively distinguish what soils were weathered from the Ogallala. Therefore, I used field reconnaissance to verify the extent of the Ogallala, and also to determine what soils weathered from this lithologic unit.

Bass's geologic map revealed the approximate outcrop areas of the Ogallala. Field checking these outcrops revealed the location of several Ogallala exposures. All the Ogallala outcrops that I studied occurred in the mapping units associated with the Campus series and the Canlon series.

The Campus soil series consists of moderately deep, calcareous, well-drained soils that form in caliche and unconsolidated colluvium. These soils occur on ridgetops, slopes, and along drainageways in upland areas. A representative profile for the series shows the surface layer to be a dark grayish-brown (10 YR 4/2) loam about nine inches (22.9 cm) thick. This layer contains many fragments of caliche up to one inch (2.5 cm) in diameter. The solum continues to a depth of 19 inches (48.3 cm) and is underlain by 14 inches (35.6 cm) of white (10 YR 8/2) to light gray (10 YR 7/2) loam containing many caliche fragments and masses of segregated lime. The underlying material consists of white (10 YR 8/2) caliche. The Campus series is made up of two soil complexes. The Campus-Carlson soil complex (Cc) is on erosional uplands and is comprised of approximately 55 percent Campus soils, 26 percent Carlson soils, and 19 percent minor included soils. The Campus soils occur on knolls and ridgetops and the Carlson soils occur on ridgetops and along shallow drainageways. Both major soils have profiles similar to the profiles of their respective series. The Campus-Penden soil complex (Cd) occurs on erosional uplands, sides of small valleys, and in drainageways. About 44 percent of this complex is Campus soils, 35 percent is Penden soils, and 21 percent is minor included soils. This complex contains small areas of rock outcrops.

The Canlon soil series consists of shallow, well-drained soils that form in residuum derived from caliche. The soils occur on narrow ridgetops and sides of ridges above or below ledges of outcropping caliche. In a representative profile for the series, the surface layer is grayish-brown (10 YR 5/2) to very dark grayish-brown (10 YR 3/2) loam about four inches (10.2 cm) thick. It is calcareous and contains a few scattered fragments of caliche. The solum continues down to a depth of eight inches (20.3 cm) and is underlain by five inches (12.7 cm) of white (10 YR 8/2) to light gray (10 YR 7/2) loam that is calcareous and contains small to large fragments of caliche. The underlying rock material consists of white (10 YR 8/2) caliche. The Canlon series contains the Canlon soil complex (Ce). This complex occurs on the narrow rims of bluffs of outcropping caliche. Approximately 42 percent of this complex is Canlon loam, 20 percent is Campus loam, and 38 percent is included soils. Mapping these soils included small areas of Penden soils, outcrops of caliche, soils of the Alluvial Land complex, and loamy alluvial soils in small drainageways. Also included are soils similar to Canlon soils except that the surface layer is seven inches (17.8 cm) or more in thickness. There are also small areas where caliche is at a depth of 10 inches (25.4 cm) or less. I determined that the Campus and Canlon series weather from the Ogallala and color coded these soils on the aerial photographs.

I determined that the Corinth soil series forms from the Fairport Member of the Carlile Formation. The soil description states that this series consists of moderately deep, well-drained soils that form from calcareous shale. The soils are on ridgetops and sides of ridges on uplands. In a representative profile the surface layer is grayish-brown (2.5 Y 5/2) to dark grayish-brown (10 YR 4/2) silty clay loam about nine inches (22.9 cm) thick. The upper seven inches (17.8 cm) of the B horizon is light brownish-gray (2.5 Y 6/3) firm silty clay loam, and the lower six inches (15.2 cm) is light yellowish-brown (2.5 Y 6/3) firm silty clay loam. The C horizon consists of eight inches (20.3 cm) of brownish-yellow (10 YR 6/6) heavy silty clay loam that contains platy fragments of calcareous shale and several flat pieces of calcite. The underlying rock material is light yellowish-brown (10 YR 6/4) to brown (10 YR 4/3) platy shale with numerous thin seams of light gray (N 7/0) gypsum.

Three soil phases comprise the Corinth series. The Corinth silty clay loam soil phase (Cm) with one to three percent slopes occurs on ridgetops and sides of ridges in upland areas. The profile for this phase is similar to the one described as representative for the series, but the surface layer is slightly thicker. Also included in this phase were soils similar to Corinth soils except that the surface layer and subsoil form in loess and are noncalcareous. The Corinth silty clay loam soil phase (Cn) with three to seven percent slopes is on ridgetops and sides of small drainageways in upland areas. The Corinth silty clay loam soil phase (Co) with seven to fifteen percent slopes is on sides of drainageways. The surface layer is nearly three inches (7.6 cm) thinner than that in the series. This soil is moderately eroded, exposing the subsoil in some areas. The distribution of the Fairport on Bass's geologic map confirmed that the Corinth series forms from the Fairport. The Fairport was color coded on the aerial photographs.

The Greenhorn Limestone weathers into soils belonging to the Nibson soil series. The series consists of shallow soils that form in material weathered from interbedded chalky shale and chalky limestone. The soils are on erosional uplands. In a representative profile the surface layer is dark grayish-brown (10 YR 4/2) to very dark grayish-brown (10 YR 3/2) silt loam about seven inches (17.8 cm) thick. The upper three inches (7.6 cm) of the subsoil is grayish-brown (2.5 Y 5/2), friable silty clay loam and the lower four inches (10.2 cm) is light yellowish-brown (2.5 Y 6/4), friable silty clay loam. The subsoil is calcareous and contains many limestone fragments up to one inch (2.5 cm) in diameter. The underlying C horizon consists of five inches (12.7 cm) of pale yellow (2.5 Y 7/4) to light yellowish-brown (2.5 Y 6/4) silty clay loam that contains weathered shale and limestone fragments up to four inches (10.2 cm) in length in the lower two inches (5.1 cm). The underlying rock material consists of alternating pale-yellow (2.5 Y 7/4) shale and limestone layers. The Nibson silt loam soil phase (Nn) is characteristic of the series and contains areas of rock outcrops. As before, the Greenhorn was color coded on the aerial photographs.

Other than a few soil types not matched with a specific lithology, the only rock units not color coded on the aerial photographs were the Graneros Shale and Dakota Sandstone. Bass's geologic map and a study of the geology of southern Ellis County by Leonard and Berry (1961) show that these two rock units crop out in the extreme southeastern corner of the county. The soil survey did not describe any soils that weather directly from the Graneros or Dakota. I conducted field reconnaisance in sections 26, 27, 34, and 35 of T.15 S., R.16 W. to verify the extent of the units. Field checking proved that these units are present, but not to the extent as shown by Bass. This difference occurs because Bass did not show terrace deposits on his map. Terrace deposits, as shown by Leonard and Berry, overlie much of the Graneros and Dakota in the southeastern corner.

The outcrop pattern of the two units were roughly outlined on the soil survey's aerial photograph of this area. The Graneros and Dakota crop out in a soil mapping unit called hilly land. Hilly land is a land type that consists of loamy, well-drained soils along the valley sides of the Saline and Smoky Hill rivers. The soils have a surface layer that varies from dark grayish-brown sandy loam to silt loam. The subsoil is grayish-brown sand clay loam that is underlain by sandy loam, loamy sand, or sand. Besides rock outcrops, hilly land contains several areas of sand and gravel mined for construction. Using the previously published maps and the outline of hilly land on the aerial photograph, I labeled and color coded the approximate locations of the Graneros and Dakota.

At this point in the study all the rock units exposed in Ellis County were represented on the soil survey's aerial photographs. However, all the soil types were not color coded. As previously stated, I used hilly land to define the Graneros and Dakota; however, the hilly land soil mapping unit occurs quite often along the entire extent of the Saline and Smoky Hill rivers. Therefore, knowing that the Graneros and Dakota crop out only in the southeastern corner, it is not reasonable to presume that soils of hilly land weather only from the Graneros and Dakota.

Hilly land was extensively field checked in areas of accessibility. In areas close to the rivers and along intermittent streams flowing into the rivers, this land type consists of medium to coarse sand and gravel. Most of these areas were color coded as alluvium. In stratigraphically higher areas, terrace deposits enclose the hilly land soil mapping units. These areas are less well exposed, consist of much finer sand, and seem to be part of the stairstep topography indicative of terraces. These hilly land deposits were color coded as terraces based on their topographical location and composition. Still other areas of hilly land consist almost entirely of rock outcrops. These areas border previously determined rock units and I included them as part of those rock units. In areas where I could not gain access, I approximated the hilly land soils to specific lithologies by their topographic position and by comparison with previously determined areas of hilly land.

The Wann soil series was another soil type not yet color coded, primarily because of its rarity. The series consists of deep soils that form in calcareous, stratified, loamy alluvium along the major streams. The soils are on flood plains where the water table fluctuates between depths of two feet (0.61 m) and six feet (1.83 m). In a representative profile the surface layer is dark-gray (10 YR 4/1) loam about 12 inches (30.5 cm) thick. The solum continues down to 24 inches (61 cm) and is underlain by grayish-brown (10 YR 5/2) loam that has common distinct mottles. The series contains the Wann loam soil phase (Wn). This phase has a profile similar to the one described as representative for the series and is present in only a few areas along the major rivers. The Wann loam was color coded as alluvium.

The Munjor series consists of deep, well-drained soils that form in moderately sandy, calcareous alluvium. The soils occur on flood plains and in a few places on low terraces. The representative profile shows the surface layer to consist of grayish-brown (10 YR 5/2) sandy loam about seven inches (17.8 cm) thick. The upper 37 inches (94 cm) of the underlying material is light brownish-gray (10 YR 6/2), very friable sandy loam stratified with thin layers of finer-textured and coarser-textured material. The lower 16 inches (40.6 cm) is pale-brown (10 YR 6/3), calcareous, medium-grained sand. The Munjor sandy loam soil phase (Mu) has a profile similar to the one described as representative for the series. This phase occurs often near the major rivers and was color coded as alluvium and/or terrace deposits, depending on its topographical location and its occurrence with other soil types.

The Inavale series consists of deep, well-drained soils that form in coarse-textured alluvium. The soils are on flood plains and foot slopes of terraces. In a representative profile the surface layer is grayish-brown (10 YR 5/2) loamy sand about nine inches (22.9 cm) thick. The solum continues down to a depth of 14 inches (35.6 cm). The upper 17 inches (43.2 cm) of the underlying material is light brownish-gray (10 YR 6/2) sand, the next eight inches (20.3 cm) is light brownish-gray loamy sand, and the lower part is light brownish-gray (10 YR 6/2) loamy sand stratified with thin layers of medium-grained sand and coarse silt loam. The Inavale loamy sand soil phase (In) has a profile similar to the one described as representative for the series. As with the Munjor sandy loam soil phase, the Inavale loamy sand soil phase was color coded as alluvium or terrace deposits.

The two remaining soil types to be color coded were the Armo series and Wakeen series. It was difficult to work with these soils for several reasons. First, the soil descriptions are not very informative concerning the underlying rock units. Second, these two soil series occur adjacent to several different rock units. Third, the lack of outcrops within the soil mapping units prevents field checking. Finally, both soil series occur together just as often as they occur separately.

The Armo series consists of deep, well-drained soils that form in medium-textured local colluvium derived from chalky limestone. The soils occur on slopes, tablelands, and along drainageways on uplands. In a representative profile the surface layer is about 15 inches (38.1 cm) thick. The upper 10 inches (25.4 cm) is dark grayish-brown (10 YR 4/2) loam and the lower five inches (12.7 cm) is grayish-brown (10 YR 5/2) silt loam with scattered fragments of chalk up to two cm in diameter. The subsoil is pale-brown (10 YR 6/3), friable clay loam about 13 inches (33 cm) thick. The upper 13 inches (33 cm) of the C horizon is pale-brown (10 YR 6/3) clay loam with thin lenses of loamy sand. The lower 10 inches (25.4 cm) is pale-brown (10 YR 6/3) silt loam and is made up of about 40 percent of interbedded gravelly loam sand. The underlying rock material contains chalk fragments up to two inches (5.1 cm) in diameter. The Armo loam soil phase (Am) with one to three percent slopes, the Armo loam soil phase (An) with three to seven percent slopes, the eroded Armo loam soil phase (Ao) with three to seven percent slopes, and the Armo loam soil phase (Ar) with seven to fifteen percent slopes make up the Armo series. All the phases have profiles similar to the one described as representative for the series except for slight differences in the thickness of the surface layer. The phases of the Armo series occur with soil types derived from the Smoky Hill, Fort Hays, Blue Hill, Fairport, and Greenhorn. Except for the Blue

Hill, these rock units are made up partially or wholly of chalky limestone. Therefore, the Armo phases do not weather from one specific lithology.

The absence of rock outcrops and the need to determine the rock units beneath the colluvium led me to use topographic maps and the principle of stratigraphic succession, along with knowing the average thicknesses of the rock units and observing the location and elevation of the Armo soils, to determine the bedrock beneath these soils. The resulting data were then compared with previously published maps of the county and revealed a very good correlation. The Armo soils were color coded the same as their inferred parent materials.

The Wakeen series consists of moderately deep, well-drained soils that form in colluvium derived from chalky limestone. The soils occur on uplands. In a representative profile the surface layer is 17 inches (43.2 cm) thick. The upper five inches (12.7 cm) is dark grayish-brown (10 YR 4/2) silt loam, the next five inches (12.7 cm) is dark grayish-brown (10 YR 4/2) silty clay loam, and the lower seven inches (17.8 cm) is grayish-brown (10 YR 5/2) silty clay loam. The subsoil is very pale brown (10 YR 8/4), friable silty clay loam about 12 inches (30.5 cm) thick. The C horizon is seven inches (17.8 cm) of very pale brown (10 YR 8/4) silty clay loam that contains very friable, thinly bedded chalk. The underlying rock material is brownish-yellow (10 YR 6/6) thinly bedded chalk. The Wakeen silt loam soil phase (Wa) with one to three percent slopes, the eroded Wakeen silt loam soil phase (We) with one to three percent slopes, the Wakeen silt loam soil phase (Wh) with three to seven percent slopes, and the Wakeen silt loam soil phase (Wk) with five to fifteen percent slopes make up the Wakeen series. As in the Armo series, all the Wakeen phases have profiles similar to the one described as representative for the series except for slight differences in the thickness of the surface layer. Topographic maps and the other previously mentioned methods were again used to determine the bedrock beneath the Wakeen soils. The soils were color coded the same as their inferred parent materials.

REDUCTION PROCEDURE

At this point in the study, all five strips of the soil survey's aerial photographs were color coded. The next step involved the reduction of the eight foot by eight foot mosaic into a more desirable working size. In order to do this, I traced all the geologic units onto mylar tracing paper. The mylar was cut into pieces the size of a township, resulting in 25 separate sheets of mylar. All the lithologic units, towns, highways, railroads, rivers, and intermittent streams were then traced and labeled on the mylar. The sheets of mylar were then submitted to the print shop at Fort Hays State University. The print shop reduced each mylar sheet using the Photo Mechanical Transfer (PMT) Process. This procedure reduced the scale to approximately 1:54,000; however, all the detail was preserved remarkably well.

I mosaicked the PMT copies into a single three foot by three foot map. The next step was to trace PMT data onto regular tracing paper to produce a preliminary map. However, at this scale too much detail existed. For example, some of the loess deposits occur in very small isolated areas. Upon reduction, these areas were too small to be well represented. Therefore, I did some generalizing during the preparation of the preliminary map, but most of the detail was preserved. After I drafted all the data onto the tracing paper, the geologic units were color coded for the ease of differentiating the individual units. I included a representative stratigraphic column and descriptions of the exposed rock units. I then submitted the preliminary geologic map of Ellis County to the KGS.

REVIEW AND REDRAFTING OF PRELIMINARY MAP

The KGS evaluated the preliminary map for the purpose of digitizing. However, before the digitizing process began, KGS personnel noticed that the density of intermittent streams on the preliminary map was greater than that on their existing base map of Ellis County. The KGS's existing base map was produced from United States Geological Survey (USGS) topographic maps at a scale of 1:500,000. The 1:54,000 preliminary map was obviously more detailed. This prompted the KGS to produce a more detailed base map using the USGS topographic maps at a scale of 1:24,000. The KGS supplied me with the new base map at a scale of 1:53,870 along with a set of stereoscopic color infrared aerial photographs of the entire county. The KGS suggested I redraft the preliminary map onto the new base to verify the density of intermittent streams. This method would also put the final geologic map at the same scale required by the KGS for future mapping endeavors.

Before I redrafted the preliminary map, I used the stereoscopic color infrared photographs to check the accuracy of some questionable areas on the preliminary map. One such area was where the Dakota and Graneros cropped out in the southeastern corner of the county. Although this area was extensively field checked, some doubt existed about the exact distribution of these units. This doubt existed because the two units did not correlate with a specific soil type, the area was not easily accessible for field reconnaisance, and previously published information on this area was somewhat contradictory. Aerial reconnaisance supported the study of the color infrared photographs. Several photographs were taken of the questionable area in the southeastern corner and provided new data on the exact location of the Graneros and Dakota. The outcrop pattern of these two rock units was slightly revised on the final draft of the geologic map. Small problem areas related to the Wakeen and Armo soils were also studied by aerial reconnaissance and the color infrared photographs; however, these methods of investigation were nearly useless because of the lack of outcrops.

Another step undertaken before the redrafting of the preliminary map involved locating and studying any surficial structural features that might be large enough to add to the final map at the given scale. Bass (1926) mapped 76 small-scale normal surface faults in the Niobrara Formation located in the northwestern part of the county. The faults are commonly marked by veins of slickensided calcite and may be traced for considerable distances. The lack of closely spaced marker beds in the chalk makes it difficult to determine the amount of displacement, but the greatest noted is about 80 feet (24.4 m). Two of these faults are large enough to map at the scale of 1:54,000. One occurs in sections 11 and 12 of T.12 S., R.20 W., and the other in section 13, T.12 S., R.20 W. Other surficial structure features added to the final map include two slump blocks located in section 18 of T.11 S., R.17 W. just south of the Saline River. At this time I redrafted the preliminary map on to the newly revised base map. The density of intermittent streams on the preliminary map matched well with the density of intermittent streams on the base map; however, I did some generalizing in areas where the streams did not exactly coincide. This was due to the slight differences in scale between the two maps. The lithologic units were color coded, and the redrafted map was submitted to the KGS for purposes of digitizing.

DIGITIZING PROCEDURE

The geologic map was produced by computer-aided cartography using the GIMMAP (Geodata Interactive Management Map Analysis and Production) system developed at the KGS. The digitizing process involves the transfer of data on the geologic map into a computer as X-Y coordinates on a graph. Michael Wong, a graduate student at the University of Kansas, was one of the key people responsible for this task. The digitizing instrument consists of a graphics cursor connected by a cord to a computer terminal. The cursor is simply a small rectangular piece of plastic containing a cross hair in one end. The cross hair is located in an area of the cursor that magnifies the information on the map. The person conducting the digitizing centers the cross hair on a lithologic contact, and moves the cross hair along the trace of the contact. The location of the contact line is then recorded in the computer terminal as X-Y coordinates. Two problems arose in digitizing the contacts. First, the graphics cursor magnified the contact lines by a considerable amount. KGS personnel noted that the person doing the digitizing needed to be consistent about tracing the right side, left side, or middle of the line. Second, tracing all the contact lines was very tedious work, and human error surely accounted for small discrepancies. However, the editing process corrected this problem. Once the contacts were in the computer as X-Y coordinates, the computer operator could call up certain segments of the map onto the computer screen. The image on the screen graphically showed the contact lines as they would appear on the final map. The computer operator could then edit the contact lines by "smoothing out" areas where the contact lines were not completely connected.

After editing was completed, the computer operator stored the data in the main-frame computer at the KGS. KGS personnel then made several decisions on how they wanted the final product to appear. These decisions included how much cultural detail should be shown and how detailed the descriptive legend should be. The next step involved printing the information by using the Xynetics 1100 printer, and color coding the lithologic units by using the KGS's Calcomp electrostatic color plotter. Several computer-related problems occurred at this point. After several months of painstaking work by KGS personnel to rectify these problems, the KGS produced the final surficial geologic map of Ellis County (Plate 1). Table 1 shows the approximate amount of time needed to perform each step.

SURFICIAL STRUCTURAL ELEMENTS IN ELLIS COUNTY

The remaining portion of this thesis involves the study of surficial structural elements present in Ellis County. Merriam (1963) stated that in western Kansas surface mapping is unreliable for determining structure at depth because the structural pattern of the Tertiary and Cretaceous rocks differs significantly from that of buried Permian, Pennsylvanian, and older rocks. Therefore, the surficial structure elements in Ellis County are probably unrelated to subsurface structural elements. Also, Jewett (1951) stated that many small anticlinal and synclinal features complicate the regional structure of Cretaceous beds.

As previously mentioned, Bass mapped 76 small-scale normal surface faults in the northwestern part of the county. The faults are present in the Smoky Hill Member of the Niobrara Formation. The faults show no preferential

TIME TABLE OF MAPPING PROJECT

STEPS	TIME (HRS.)
Review of soil survey	32
Preparation of aerial photograph mosaic	16
Determining parent material/color coding	168
Field checking/topo. work	136
Reduction procedure	112
Drafting of preliminary map	176
Study of infrared photos/revising	80
Drafting of final map	150 +
Digitizing/editing	240 +
TOTAL	1,110 +

trend, dip steeply, and seem to die out downward (Merriam, 1963). Twenhofel (1925) postulated four possible causes for these small faults: (1) differential settling of the brittle chalk due to the underlying incompetent shales adjusting to the unconformable Cretaceous-Permian surface; (2) surficial slumping along present stream valleys; (3) slumping into solution features that formed within the chalk; (4) faulting as a result of regional structure movement. By studying a cross section through the area of faulting, Merriam noted that there was no evidence of solution features in even the most soluble formations. Twenhofel (1925) stated, in a very broad sense, that regional movement would be largely adjusted in the shales, and that the effects in the chalk would be similar. Therefore, it seems most likely that surficial faults in this area are the result of differential settling of the brittle chalk beds or by surficial slumping along the intermittent stream valleys.

Neuhauser (1988) studied five slump block structures in northern Ellis County. Slump blocks C and D in Neuhauser's study are the ones shown on the geologic map in this study. Both slump blocks offset the Fort Hays Limestone, Codell Sandstone, and Blue Hill Shale. Neuhauser stated that the Fort Hays and Codell are in fault contact with brecciated fault-zone material. The fault breccia consists of Codell, Blue Hill, and minor amounts of Fort Hays. The fault zone is curved and covered by colluvium and soil. The Blue Hill is below the fault plane and is not a coherent part of these blocks. The strike and dip of the west (C) and east (D) blocks are N 42° E, 38° S and N 75° W, 70° S, respectively. Neuhauser's kinematic analysis of these structural features revealed that block C moved vertically downward 45 feet (13.5 m) and 395 feet (119 m) horizontally along a line trending N 15° E, and rotated 70 degrees. Block D moved vertically downward 100 feet (30 m) and 505 feet (152 m) horizontally along a line trending N 15° E, and rotated 70 degrees. Neuhauser suggested that initial deformation of the rocks involved the development of joints. The next stage of deformation involved headward erosion of the valley escarpment and seasonal ice wedging on joints that generated slope instability. Once separated from the escarpment, the blocks began a vertical, downward translation under the force of gravity. The ductility of the underlying Blue Hill Shale created a valley-ward bulge caused by reduced lateral support. The blocks continued to rotate along the fault plane, and once they were out of the plane of rotation they continued to move downward through creep. The remaining three slump blocks studied by Neuhauser, in addition to several others in north-central and northeastern Ellis County, were too small to be shown on the geologic map.

Neuhauser (1986) also conducted a detailed analysis of the joints in the Fort Hays. He discovered two dominant joint systems, one striking N 70° W and the other striking N 25° E with both joint systems dipping greater than 78 degrees. Neuhauser suggested that the origin of the joints is a result of a nearly horizontal compressive deformation along an east-west line that occurred during the late Laramide Revolution (early Tertiary). Drees (1974) also studied these joint systems and mentioned another possible explanation for the jointing. Drees suggested that deformation of western Kansas took place from late Cretaceous time through the Tertiary and Quaternary. The result of deformation was the tilting of the rocks northward into a deep, unnamed structural basin in Nebraska. This created a tension-like stress in a north-south line. In turn, this stress aided in the formation of the joint patterns in Ellis County along with compressive forces in an east-west line.

Another surficial structural element present in Ellis County is the Chrysler sinkhole located in the N 1/2, SW 1/4, Sec. 28, T.11 S., R.16 W. just south of the Saline River. The elliptical feature formed by sudden collapse of the overlying sediment and it has been naturally filled by water. Several large surficial cracks are currently forming just west of the sinkhole. A leaking oil-disposal well that dissolved the subsurface strata is the cause of the sinkhole (N. Windholz, per. comm.). The omission of the sinkhole on the geologic map was partially due to time constraints, but KGS personnel will add it in the future. I was informed of a possible sinkhole near Yocemento (J. Ratzlaff, per. comm.), but no additional information was obtained on this feature.

I conducted a study of possible lineament features by observing a black and white 1:20,000 aerial photograph mosaic of the county and the color infrared photographs provided by the KGS. SLAR images were not available at the time of this study. All the linear features are stream related. The intermittent streams flowing into the Saline River, Smoky Hill River, and Big Creek define many of the linear elements. A high percentage of these streams trend in a north-south direction. In the western half of the county, especially along the Saline River and Big Creek, the streams show headward erosion into the Fort Hays Limestone. Merriam (1963) indicated that drainage patterns in northwest Kansas trend approximately N 45° W, N 25° W, and N 55° E and suggests that these drainage patterns are controlled by the joint systems in the Fort Hays. Although Merriam's trends do not coincide exactly with the trends for the joints within the Fort Hays in Ellis County, I believe the joint systems effect the patterns of drainage in Ellis County.

Several other intermittent streams show linear characteristics. A group of streams that begin in T.14 S., R.19 W. flow almost parallel in a southeasterly direction until they join just before entering the Smoky Hill River. A prominent stream that begins in the NE 1/4 of T.12 S., R.18 W. shows a curvilinear trend before reaching the Saline River. Big Creek and the North Fork of Big Creek flow nearly parallel in a southeasterly direction until Big Creek changes flow to the northeast and joins the North Fork of Big Creek. Turner (1983) suggested that stream maturity and variable lithologies may account for some of the stream patterns in Ellis County.

Regional strikes and dips were calculated by the three-point method using a specific datum at each of the seven stratigraphic sections that represent all the exposed lithologies in Ellis County (Figure 3). Appendix B contains the location of and road logs to each section. Topographic quadrangles were used in locating easily identifiable benchmarks, such as oil wells, that I used as reference points. The recorded elevation at each outcrop was of a lithologic contact.

Section # 1 consists of the Ogallala and the Smoky

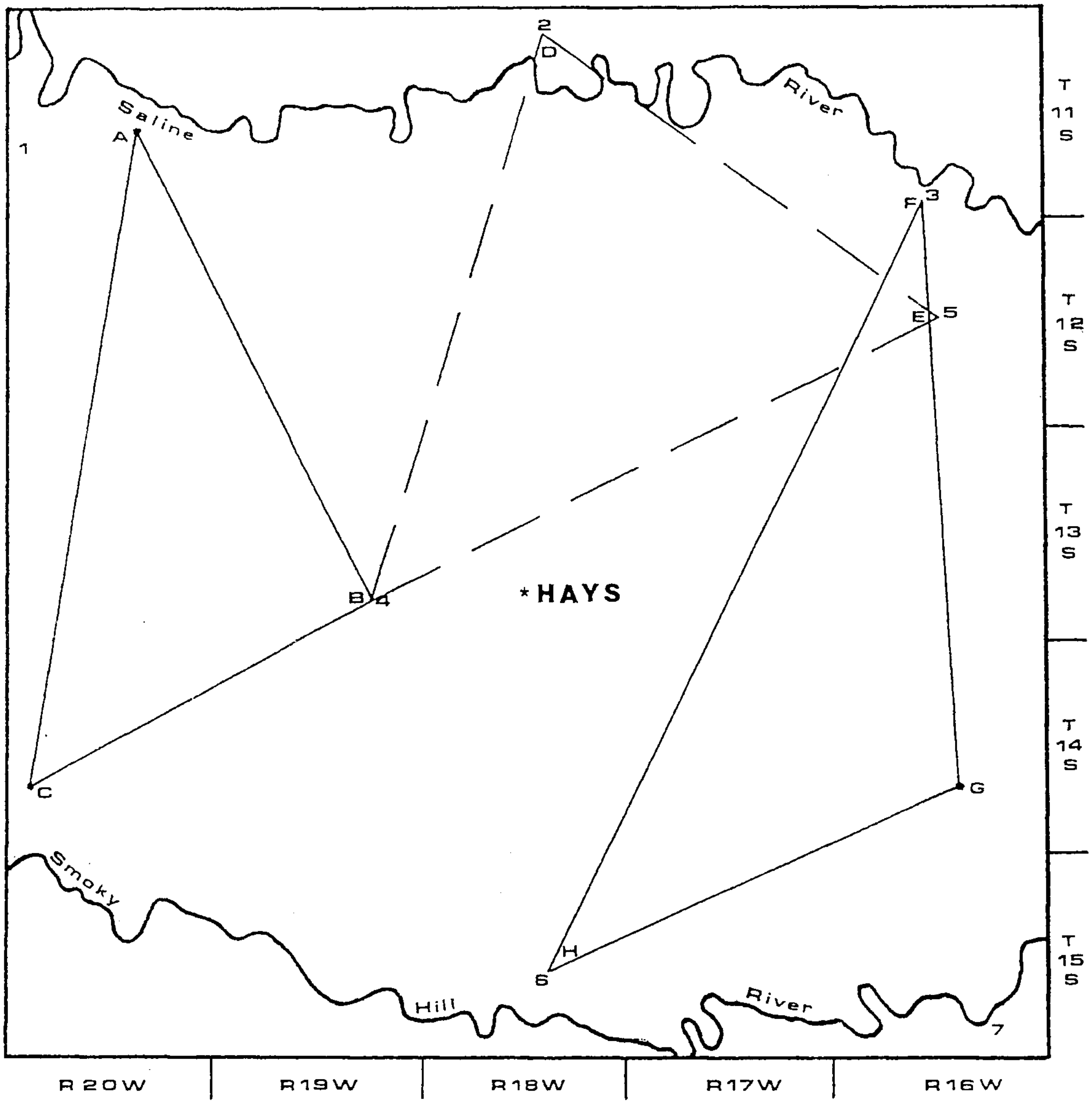

Figure 3. Location of representative stratigraphic sections in Ellis County (1-7) and triangular areas used to determine strike and dip.

Hill Member of the Niobrara Formation. I used an oil well as a benchmark and the elevation of the contact between the two units is 2216 feet (675 m) above sea level. I placed an arbitrary contact at a break in slope where Smoky Hill colluvium seemed to begin. Section # 2 includes the Fort Hays Limestone, Codell Sandstone, and Blue Hill Shale. I again used an oil well as a benchmark and the elevation at the bottom of the Fort Hays is 2004 feet (610 m) above sea level. I used the elevation of a bridge for a benchmark during the survey of section # 3. The Fencepost limestone is usually considered the contact between the Greenhorn and Fairport. The elevation at the top of the Fencepost is 1753 feet (534 m) above sea level. Section # 4 consists of the Fort Hays, Codell, and Blue Hill. I used the elevation of an intermittent stream at the base of the outcrop as a benchmark. The elevation at the base of the Fort Hays is 2138 feet (652 m) above sea level. Section # 5 includes the Fort Hays and Codell. I used the elevation at the intersection of two roads as a benchmark and the elevation of the contact between the two rock units is 2091 feet (637 m) above sea level. Section # 6 consists of the Greenhorn and Fairport. I used the elevation of the base of an intermittent stream as a benchmark. A resistant layer of limestone in this outcrop has the physical characteristics of the Fencepost limestone and I determined the layer to be this marker bed. The elevation at the top of the Fencepost is 1950 feet (594 m) above sea level. The last section is made up of the Graneros and Dakota. I used the elevation of an oil field disposal well as a benchmark. I placed the contact between these two units at a major break in slope where alternating layers of shale and sandstone became the dominant lithology. The contact elevation is 1816 feet (553 m) above sea level.

The strike and dip of a lithologic contact can be determined if the contact elevation of three localities is known (Aber, 1988). This principle was used to determine the strike and dip of three areas in the county. Points A, B, and C and D, E, and B (Figure 3) define two areas where I used the elevation at the base of the Fort Hays to obtain strike and dip measurements. Points F, G, and H define an area where I used the elevation of the Greenhorn/Fairport contact. In the western triangular area (Fig. 3), I determined the elevation at point B by using plane table and alidade. I estimated the elevations at points A and C from 1:24,000 topographic quadrangles. In the center triangular area, I determined all three elevations by plane table and alidade. I determined the elevations of points F and H in the eastern triangular area by plane table and alidade, and I estimated the elevation at point G by using

1:24,000 topographic quadrangles.

Appendix A shows the graphic solutions for each strike and dip. In the western area, the planar feature defined by the three elevations at the base of the Fort Hays strikes N 79° E and dips 0.060° northwest. The center area strikes N 74.5° E and dips 0.097° northwest. The strike values are comparable with the general trend of the exposed Fort Hays in Kansas. Both dip values are less than one degree and are less than the variable 2° -4° north-northwest regional dip values obtained by Drees for the Fort Hays in Ellis County. Drees and other researchers measured dip values at exposed sections of the Fort Hays. Although their dip values may be accurate, the rock exposures may tend to supply false readings due to the fact that these exposed areas are highly eroded and the Fort Hays, as seen in many outcrops, tends to tilt and slump because of the underlying incompetent Blue Hill Shale. The method of determining dip in this study uses the elevation at a specific point and looks at the outcrops in a more regional sense.

In the eastern area of the county, the contact between the Greenhorn and Fairport strikes N 45° W and dips 0.094° northeast. Again, the dip is minimal and towards the north. The strike direction is to the northwest in contrast to the northeast for the base of the Fort Hays. However, variable strike directions are common when dip values are very low. The strike and dip calculations provided no information on the presence of any structural trends in the surface geology of Ellis County.

CONCLUSIONS

The information in the soil survey proved to be beneficial in mapping the surface geology of Ellis County. The information is accurate and reliable and provides the means to produce a very detailed surficial geologic map. Mapping by this method also proves to be time efficient. This project took over 1,110 working hours to complete; however, since this was a pilot project, the KGS and I encountered several problems that can be eliminated in future mapping projects of this type. For example, if I had been supplied with the updated base map earlier in the study, I could have eliminated a second drafting of the geologic map. Also, the KGS encountered several computer-related problems. To the best of my knowledge, the KGS corrected these problems and therefore many hours will be saved in similar mapping projects. This method of mapping also proved to be relatively inexpensive. In addition to drafting supplies and wages for the researcher, the only other expense is the time and use of the computers, digitizer, printer, and plotter at the KGS.

I noticed that loess deposits occur in irregular patterns. For example, in the northeastern corner of the county near the Saline River, I mapped an area of loess located in the middle of a terrace deposit. Also, I encountered several very small loess areas that are located along small drainageways in topographically low areas. Although the data in the survey may have been misleading or misinterpreted, future researchers should consider studying loess distribution.

The surficial structural analysis provided some interesting relationships. Future researchers may be inclined to further delineate how variable lithologies and structural features effect stream patterns in Ellis County. The strike and dip values obtained in this study demonstrated that the bedrock geology in Ellis County is essentially horizontal. However, variance in the degree of dip, as compared with previous studies, may provide future research in this area. Also, the lineament analysis conducted in this study showed that all lineament features in Ellis County are stream-related.

Mapping with soil survey information eliminated much field reconnaisance. Field reconnaissance done in this study was performed simply to test the accuracy of the soil survey information and check uncertain areas. However, field reconnaissance may be a bigger factor in future mapping projects of this type where the surface geology is more complex.

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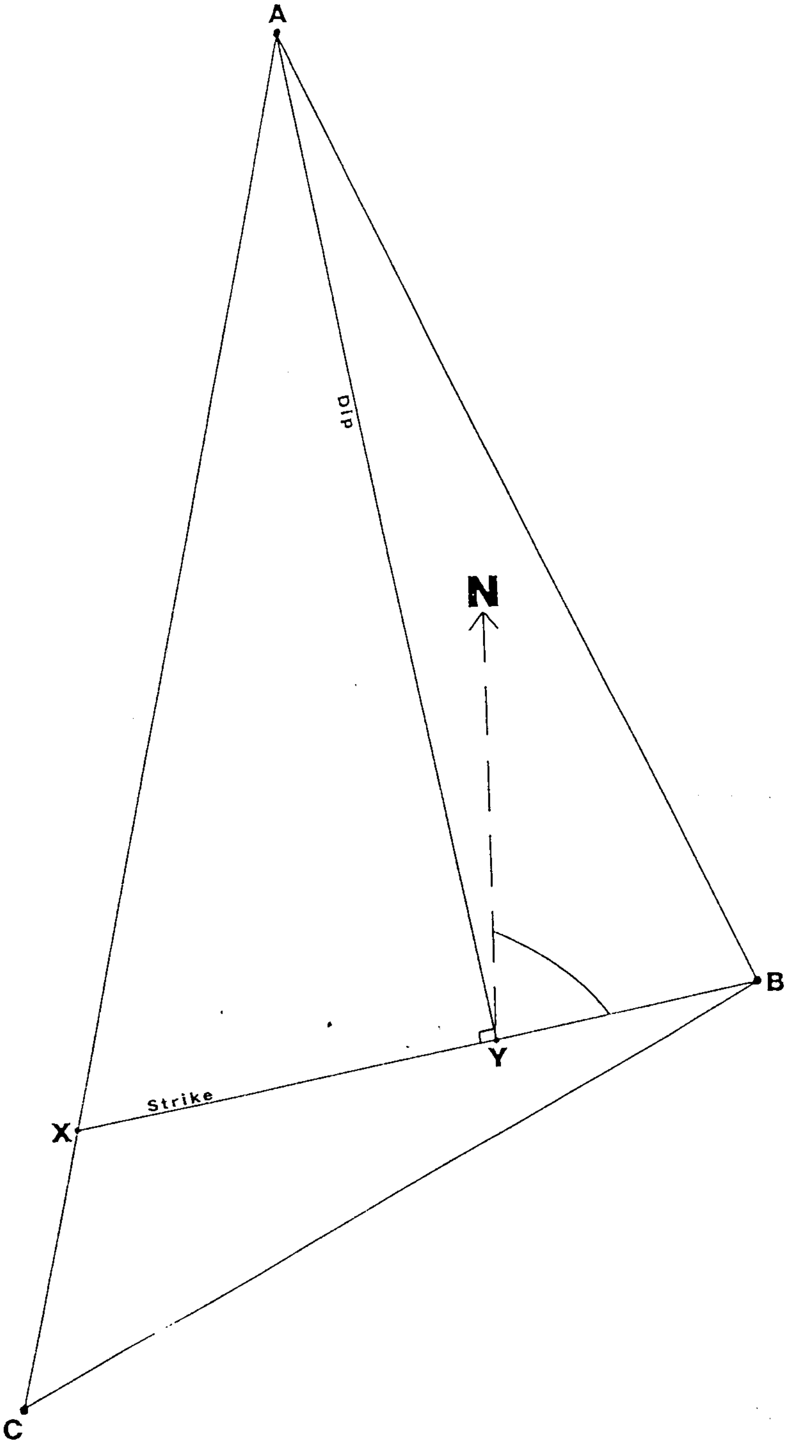
APPENDIX A



Western Triangular Area (see Fig. 3)

1) Points A, B, and C represent three elevations at the base of the Fort Hays:

Elevation at A: 2050'
Elevation at B: 2138'
Elevation at C: 2160'

The points are connected to form a triangle.

2) Point B serves as one end of the strike line; the other end will be point X located somewhere along line AC. The location of X is found by:

$$\frac{\text{Elevation B - Elevation A}}{\text{Elevation C - Elevation A}} = \frac{\text{Distance AX}}{\text{Distance AC}}$$

$$\frac{2138' - 2050'}{2160' - 2050'} = \frac{\text{AX}}{98761'}$$

$$\frac{88'}{110'} = \frac{\text{AX}}{98761'} \qquad \text{AX} = 79009'$$

By scale conversion, point X is then located on line AC, and since X is equal in elevation to point B, line BX is the strike of the base of the Fort Hays.

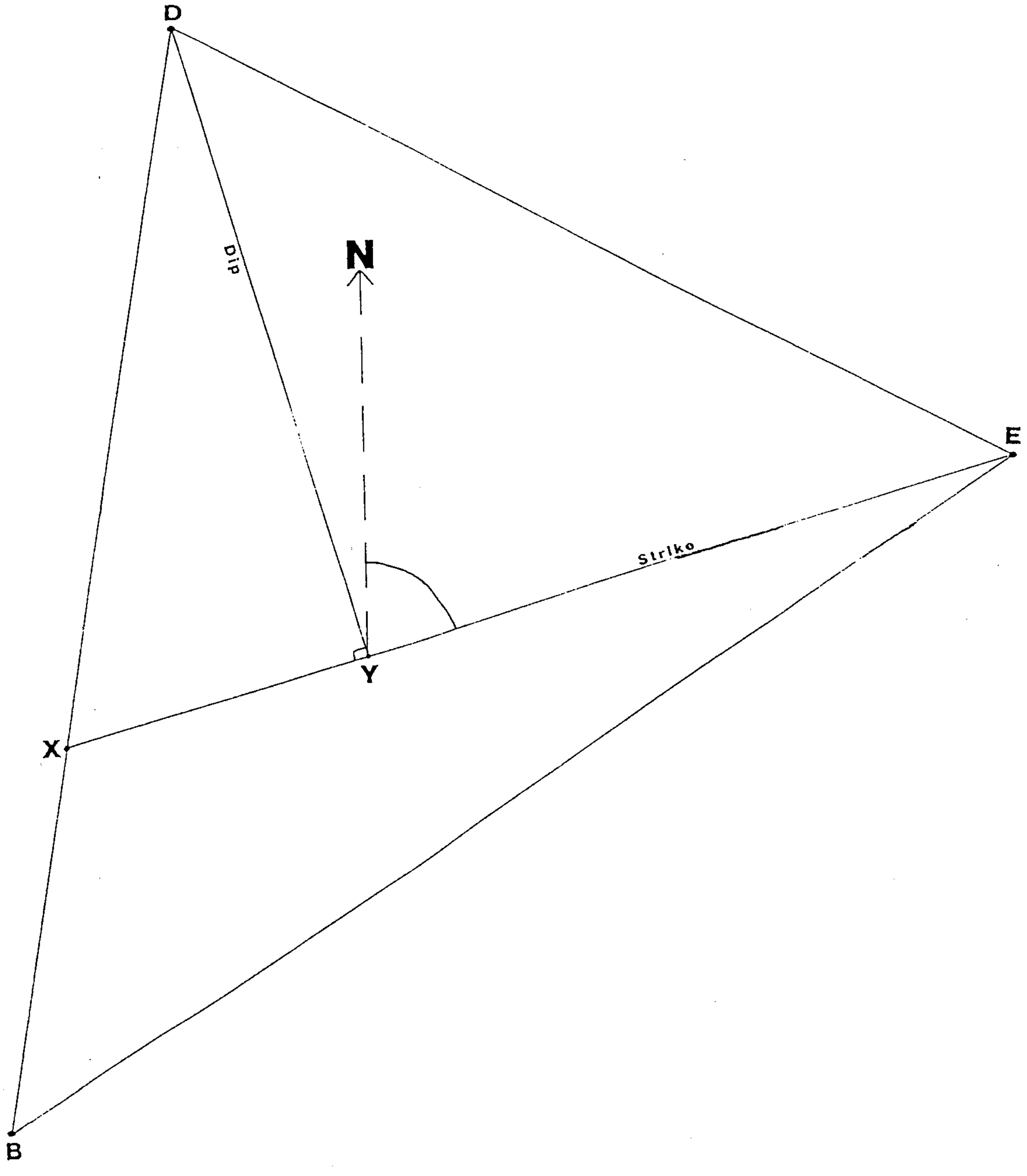
3) A line that passes through A and is perpendicular to line BX is drawn to find point Y.

4) The dip is computed by:

$$\frac{\text{Elevation Y - Elevation A}}{\text{Distance AY}} = \text{tan (dip angle)}$$

$$\frac{88'}{72816'} = 0.0012 \qquad \text{Inverse tan } (0.0012) = 0.060^{\circ}$$

5) A line representing north is drawn through point Y and the degree of strike is then measured. In this example, the base of the Fort Hays is striking N 79° E and is dipping 0.060° N-NW.



Central Triangular Area (see Fig. 3)

1) Points D, E, and B represent three elevations at the base of the Fort Hays:

Elevation at D: 2004'
Elevation at E: 2091'
Elevation at B: 2138'

The points are connected to form a triangle.

2) Point E serves as one end of the strike line; the other end will be point X located somewhere along line DB. The location of X is found by:

$$\frac{\text{Elevation E - Elevation D}}{\text{Elevation B - Elevation D}} = \frac{\text{Distance DX}}{\text{Distance DB}}$$

$$\frac{2091' - 2004'}{2138' - 2004'} = \frac{DX}{86551'}$$

$$\frac{87'}{134'} = \frac{DX}{86551'} \qquad DX = 56193'$$

By scale conversion, point X is then located on line DB, and since X is equal in elevation to point E, line EX is the strike of the base of the Fort Hays.

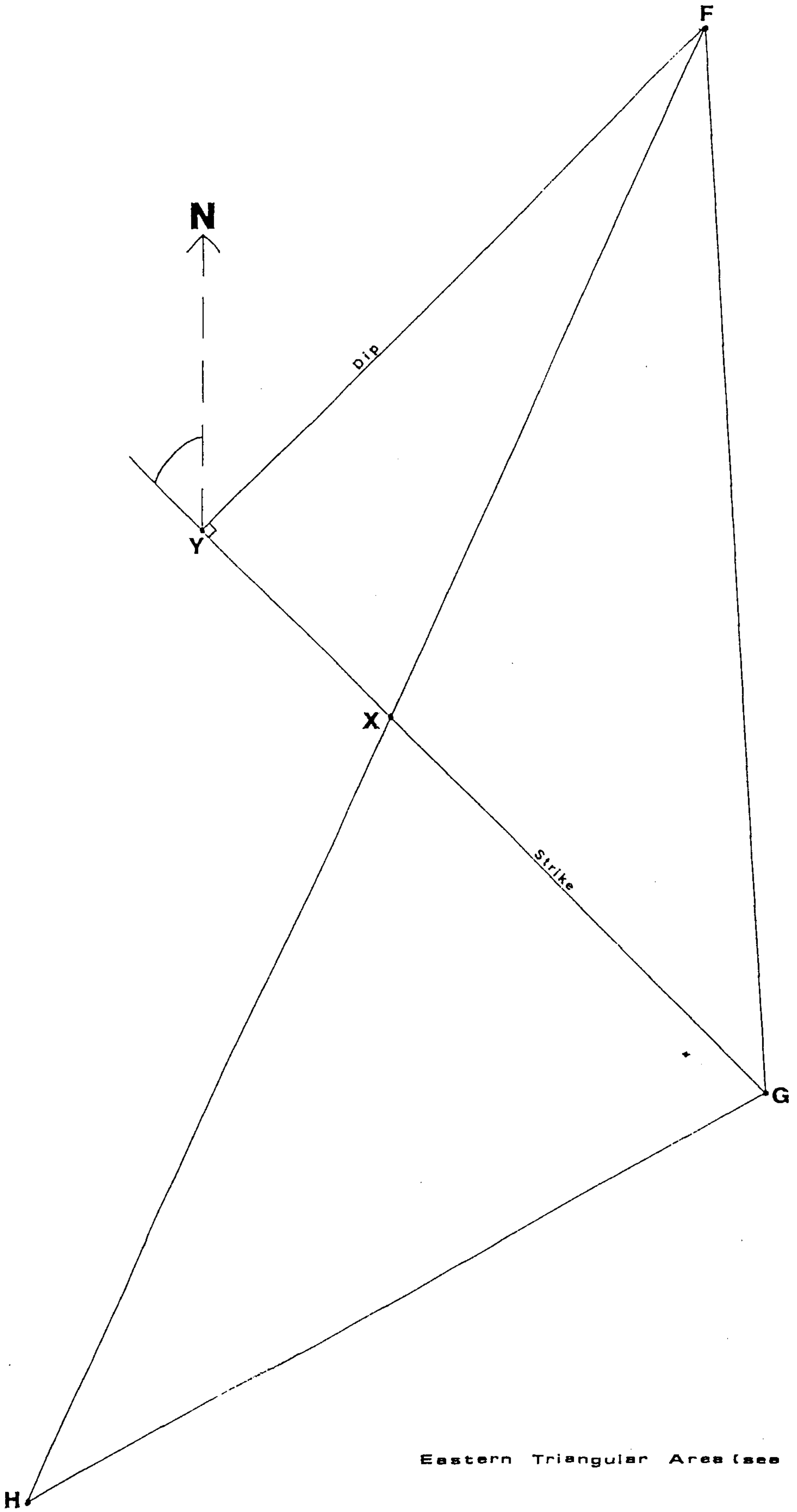
3) A line that passes through D and is perpendicular to line EX is drawn to find point Y.

4) The dip is computed by:

$$\frac{\text{Elevation Y - Elevation D}}{\text{Distance DY}} = \tan\text{(dip angle)}$$

$$\frac{87'}{50900'} = 0.0017 \qquad \text{Inverse tan } (0.0017) = 0.097^{\circ}$$

5) A line reprsenting north is drawn through point Y and the degree of strike is then measured. In this example, the base of the Fort Hays is striking N 74.5° E and is dipping 0.097° N-NW.



Eastern Triangular Area (see Fig. 3)

1) Points F, G, and H represent three elevations at the contact between the Greenhorn and Fairport:

Elevation at F: 1753'
Elevation at G: 1850'
Elevation at H: 1950'

The points are connected to form a triangle.

2) Point G serves as one end of the strike line; the other end will be point X located somewhere along line FH. The location of X is found by:

$$\frac{\text{Elevation G - Elevation F}}{\text{Elevation H - Elevation F}} = \frac{\text{Distance FX}}{\text{Distance FH}}$$

$$\frac{1850' - 1753'}{1950' - 1753'} = \frac{FX}{134675'}$$

$$\frac{97'}{197'} = \frac{FX}{134675'} \qquad FX = 66312'$$

By scale conversion, point X is then located on line FH, and since X is equal in elevation to point G, line GX is the strike of the contact between the Greenhorn and Fairport.

3) A line that passes through F and is perpendicular to line GX is drawn to find point Y.

4) The dip is computed by:

$$\frac{\text{Elevation Y - Elevation F}}{\text{Distance FY}} = \tan\text{ (dip angle)}$$

$$\frac{97'}{58677'} = 0.0016 \qquad \text{Inverse tan } (0.0016) = 0.094^{\circ}$$

5) A line reprsenting north is drawn through point Y and the degree of strike is then measured. In this example, the contact between the Greenhorn and Fairport is striking N 45° W and is dipping 0.094° NE.

APPENDIX B

ROAD LOG TO SECTION # 1

NW 1/4, SW 1/4, Sec. 19, T. 11 S., R. 20 W.

Miles	
0.0	Intersection of Highway 40 and 27th street on the western edge of Hays, Kansas. Proceed 11.0 miles west to Ellis on Highway 40.
11.0	Turn north and take the main road out of Ellis under the I-70 underpass for 0.5 miles.
11.5	Turn west and go 1.0 mile.
12.5	Turn north and go 7.0 miles.
19.5	Turn west and go 1.0 mile to Trego County line.
20.5	Turn north and proceed around first curve to the lease road just at the start of the second curve.
22.0	Take lease road and make a direct right just after crossing the cattle guard. Proceed until the road ends at an oil well located in a small tributary valley.
22.5	Outcrop is approximately 500 feet due east.

ROAD LOG TO SECTION # 2

W 1/2, SE 1/4, Sec. 3, T. 11 S., R. 18 W.

Miles	
0.0	Intersection of Highway 183 and I-70 in Hays, Kansas. Proceed north on 183 for 15.5 miles to a large roadcut.
15.5	Outcrop is located on both sides of the highway.

ROAD LOG TO SECTION # 3

NW 1/4, NW 1/4, Sec. 34, T. 11 S., R. 16 W.

Miles	
0.0	Intersection of Highway 183 and I-70 in Hays, Kansas. Go east on I-70 for 9.0 miles and take the Victoria exit.
9.0	Turn north and go 5.5 miles.
14.5	Turn east and go 3.0 miles.
17.5	Turn north and go 6.75 miles until the road crosses the Saline River.
24.75	Outcrop is located in the ditch on the east side of the road just south of the river.

ROAD LOG TO SECTION # 4

Private Property--Must Obtain Permission

Mr. Al Schenk, Jr.--Hays, KS

SE 1/4, NW 1/4, Sec. 26, T. 13 S., R. 19 W.

Miles	
0.0	Intersection of Highway 40 and 27th street on the western edge of Hays, Kansas. Go under overpass and proceed west for approximately 3.0 miles or until 0.75 miles east of Yocemento.
3.0	Turn south and go 0.25 miles to a house on the west side of the road.
3.25	Turn east and go 1/8 mile to a gate in the fence on the south side of the road.
3.375	Go through gate and proceed south to the firing range.
3.625	Outcrop is approximately 60 feet due east across the stream.

ROAD LOG TO SECTION # 5

Private Property--Must Obtain Permission

Ruder farm--Rural Route, Hays, KS

NW 1/4, SW 1/4, Sec. 22, T. 12 S., R. 16 W.

Miles	
0.0	Intersection of Highway 183 and I-70 in Hays, Kansas. Go east on I-70 for 9.0 miles and take the Victoria exit.
9.0	Turn north and go 5.5 miles.
14.5	Turn east and go 3.0 miles.
17.5	Turn north and go 2.25 miles.
19.75	Outcrop is located on the east side of the road approximately 300 feet into the pasture.

ROAD LOG TO SECTION # 6

NW 1/4, SE 1/4, Sec. 27, T. 15 S., R. 18 W.

Miles	
0.0	Intersection of Highway 183 and Highway 40 in Hays, Kansas. Proceed 9.0 miles south on 183 or until 1.0 mile north of Schoenchen.
9.0	Turn east and go approximately 0.75 miles to a house on the south side of the road.
9.75	Turn in private drive and proceed south through gate into the pasture for approximately 0.25 miles.
10.0	Outcrop is located down in a tributary valley approximately 60 feet to the west.

ROAD LOG TO SECTION # 7

NE 1/4, NE 1/4, Sec. 34, T. 15 S., R. 16 W.

Miles	
0.0	Intersection of Highway 183 and Highway 40 in Hays, Kansas. Proceed 8.0 miles south on 183 to truck dealership on the west side of the highway.
8.0	Turn east and go 12.0 miles.
20.0	Turn south and go 3.0 miles to Rush County line.
23.0	Turn east and go 0.75 miles (do not take the main road that curves north after 0.5 miles).
23.75	Cross cattle guard and follow lease road approximately 0.25 miles north and 0.25 miles east.
24.25	Cross cattle guard and follow lease road north approximately 0.5 miles until the road ends.
24.75	Outcrop is approximately 150 feet straight north along the southern bank of the Smoky Hill River.