SURFICIAL GEOLOGY OF THE CIMARRON VALLEY FROM INTERSTATE 35 TO PERKINS, NORTH-CENTRAL OKLAHOMA

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ABSTRACT

This thesis presents the results of a study of the surficial geology of the Cimarron Valley from Interstate 35 to Perkins, north-central Oklahoma. Objectives of the study are to describe the stratigraphy of the area, to map the distributions of geologic units, to reconstruct the geologic history, and to determine the engineering characteristics of the stratigraphic map units. Because previous investigations in the area have been limited primarily to bedrock geology and to pedologic examinations of soils, particular emphasis is given to Quaternary geollogy. An attempt has been made to present the results of this study in a manner that provides the non-geologist with an appreciation of the importance of geology in environmental problems.

Situated in the Central Redbed Plains Geomorphic Province, the study area is one of gently rolling hills underlain by Permian red shales and sandstones. Widespread Quaternary fluvial, colluvial, eolian, and anthropic deposits occur along the valley.

Stream terraces in the area, from oldest to youngest are the Paradise Terrace, the Summit View Terrace, the Perkins Terrace, and the Lawrie Terrace. Flood plains border the Cimarron River and its large tributaries. Sand dunes overlie terraces and bedrock in much of the area.

Permian bedrock units in the study area are designated informally in this report as units 1, 2, 3, and 4. Units 1 and 3 consist primarily

of sandstones interbedded with shale; unit 2 consists predominantly of shales with some discontinuous sandstones, and unit 4 consists of shales and limey sandstones interbedded. Bedrock units are defined according to lithology and engineering characteristics rather than according to traditional stratigraphic criteria.

Fluvial deposits include the Paradise Terrace Alluvium, the Summit View Terrace Alluvium, the Perkins Terrace Alluvium, the Lawrie Terrace Alluvium, and recent flood-plain alluvium. Overlying some of these deposits are eolian deposits including eolian sand, old and young dune sand, and loess. Colluvial deposits mantle the sides of hills, and anthropic deposits occur wherever Man has emplaced materials to suit his own purposes.

The structural geology of the study area is very simple; the Permian bedrock units dip 30 to 40 ft./mi. to the west. Gentle anticlinal and synclinal flexures are present. No faults were found at the surface. Drainage appears to be influenced by the bedrock joint system which consists of four sets of joints.

The study area has a record of sedimentation in every geologic period from Precambrian to Permian. Deposition also took place during Mesozoic and Tertiary times. Sometime before the end of the Tertiary Period, uplift and erosion took place so that rocks of Mesozoic and/or Tertiary age were eroded away. During late Tertiary time, the Ogallala Formation possibly was deposited in this area. Subsequent to the possible deposition of the Ogallala Formation, erosion took place and the Cimarron River established its present course. Since that time, alternating periods of humid and arid climatic conditions have controlled the formation of terrace deposits, flood plains, dune sands, loess, and colluvium. Finally, Man has been active in forming anthropic deposits, in building structures, and in making cuts.

Geology is a vital part of Man's environment in the Cimarron Valley. Ground water suitable for most purposes occurs in terrace deposits. Ground water of highly variable quality and quantity occurs in sandstone bedrock. Surface waters, other than those of the Cimarron River, generally are good for most purposes. Earthquake susceptibility within the area is a factor that merits special consideration for many construction projects. Other geologic parameters that should be considered in engineering projects include shrinking and swelling soils, permeability, erodibility, position of the water table, seepage, ripping potential, slope stability, flood potential, and depth to bedrock. Awareness of these properties and knowledge of criteria for engineering will enable the geologist or non-geologist to use this report for planning purposes.

INTRODUCTION

Geology is important in the activities of Man from the day he is born until he expires. His food and clothing often are grown in soils derived by geologic processes from geologic units. Soil provides food for the animals he eats. Fuel to heat his home generally comes from geologic sources. Water, the substance of life, is found in the pores of rocks and sediments. Ultimately, Man is buried in the earth.

This report attempts to show the relation of Man to his geologic environment. The report describes how the landscape came to be. Geologic units are described in terms of their environmental characteristics. Geologic processes are described not only in terms of earth history, but also in relation to Man. It is hoped that this report will provide a realistic guide for planners, civil engineers, geologists, and others who want to interact in a realistic way with the environment.

Objectives

The objectives of this study are to determine the stratigraphy within the project area with emphasis on Quaternary units, to map the distribution of stratigraphic units, to reconstruct the geologic history of the area, to evaluate stratigraphic map units with respect to the activities of Man, and to give the layperson an appreciation for the importance of geology in his everyday life.

Location

The project area extends along the Cimarron Valley from approximately 1¼ mi. west of Interstate 35 to approximately 1½ mi. east of Perkins, Oklahoma, and extends from 3 to 6 mi. north of the Cimarron River and from 3 to 4 mi. south of the river in Lincoln, Logan, and Payne Counties, north-central Oklahoma (see Figure 1). Communities within the area include Coyle, Langston, Perkins, Perkins Station, and Vinco Post Office. The main north-south corridors within the area are Interstate Route 35 in the west and U. S. Route 177 in the east. State Route 33 is the main east-west corridor within the project area. Unpaved roads extend along section lines throughout the area.

Methods of Study

Geology was mapped in the field as it was revealed in hand auger borings, in shoveled-out holes, in road cuts, and along stream banks. Much mapping was accomplished along section line roads. Other points not visible on section-line roads were checked along stream embankments, along cliffs, and in fields. Aerial photographs and soils maps proved to be valuable aids for the mapping of geologic units.

Prior to field work, a base map was assembled, using the Langston 7½' Quadrangle (1970), the Stillwater South 7½' Quadrangle (1967), the Stillwater Southwest 7½' Quadrangle (1967), the Perkins 15' Quadrangle (1907), and the Mulhall 15' Quadrangle (1893). The absence of 10 ft. contours on some maps, poor representation of the landscape on some

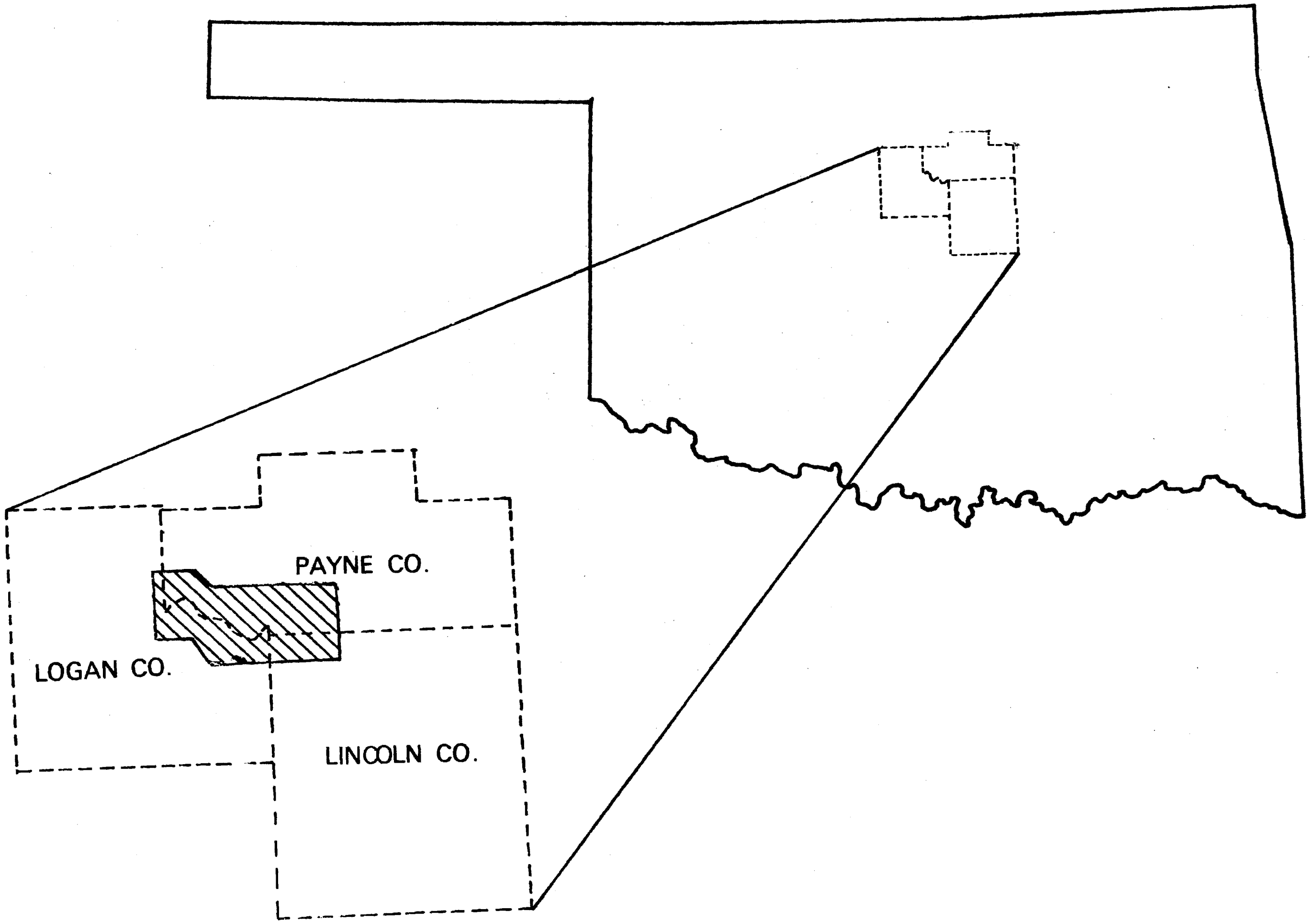

Figure 1. Location map of area of study

maps, differences of scale, and gross errors in topographic mapping made detailed interpretations of the geology from the Perkins and Mulhall Quadrangles difficult. For example, the Mulhall Quadrangle contained a contour labeled 1200 ft. instead of 1100 ft., Section 12, T18N, R1W. Portions of the Langston, Stillwater South, and Stillwater Southwest Quadrangles were reduced from 1:24,000 to 1:62,500. Reduction caused contours in places to merge and to appear as heavy lines.

Differentiation of geologic units in the field is difficult because of the similarities of lithologies. At some localities, weathered bedrock could be misinterpreted as a terrace deposit because some Permian sandstone units weather into a residual soil with coloration and structure similar to terrace deposits. A general lack of fossils in terrace deposits combined with lithologic similarities of terrace deposits makes the longitudinal profile (Plate 2) the most reliable tool for correlation of those units. Terrace deposits also have lithologies similar to some colluvium. Some loess deposits were difficult to distinguish from the "A" horizon in soils.

In this kind of study it would have been desirable to map bedrock lithologies in detail because lithology is the most important engineering parameter of bedrock. Bedrock in the study area is extremely difficult to map lithologically, however, because sandstones and shales are lenticular, and because colluvial deposits, alluvial deposits, eolian deposits, and pedologic soils conceal bedrock in most areas.

Ross (1972) and Garden (1973) handled the problem of bedrock correlation in Payne County by making structural contours on a known stratigraphic horizon in the subsurface and then correlating surface units on the basis of equal thickness of stratigraphic intervals. For purposes of this study, the units of Ross and Garden were modified into four more generalized stratigraphic units with similar engineering and lithologic characteristics. These units then were projected along strike to Lincoln and Logan counties.

Correlation of terrace alluvium were made using a longitudinal profile (Plate 2) and lithology. Construction of the longitudinal profile began with the laying out of a base line roughly down the middle of the Cimarron Valley (see Plate 1). Terrace surfaces then were projected at right angles onto a plane perpendicular to the earth and passing through the base line. The geometrical relationships are depicted in Figure 2 and the resultant profile is shown on Plate 2.

Eolian deposits were mapped on the basis of well-sorted texture, geomorphology, and weathering. Colluvium was delineated by examination for heterogeneous texture, erratic structure, thorough weathering, its "cruddy" aspect of colluvium and its topographic position on the sides of hills.

Joint orientations were measured with a Brunton Compass. Orientations of drainage segments were determined by drawing straight lines down obviously straight drainage segments on aerial photographs and measuring the bearings of the lines with a protractor.

Previous Investigations

Most of the geologic investigations of the study area made previous to this study emphasized bedrock geology and virtually ignored Quaternary geology. Patterson (1933) attempted to subdivide the Permian units in the area. Pownell (1957) mapped bedrock geology in northwestern

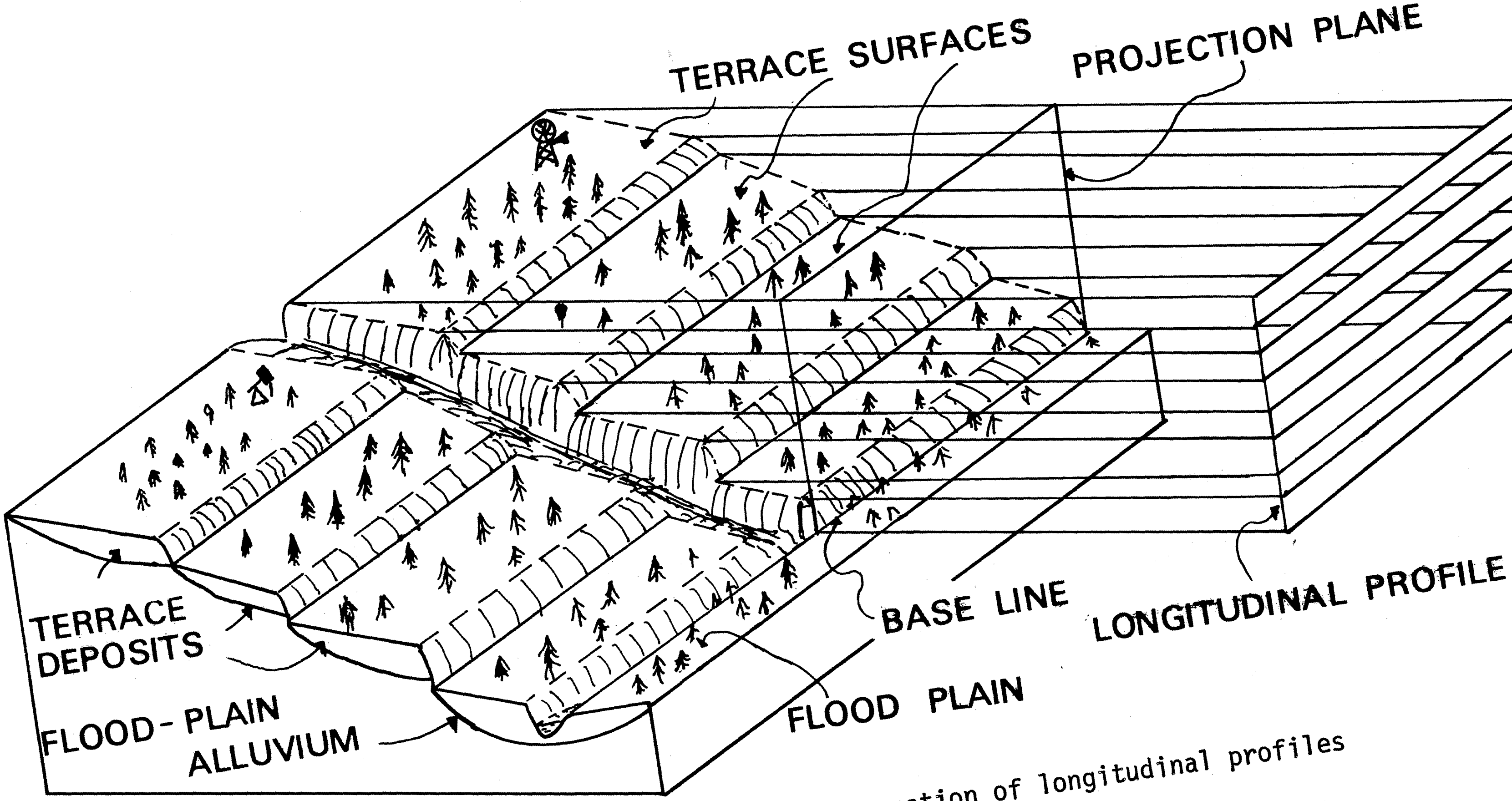

Figure 2. Diagram illustrating construction of longitudinal profiles

Lincoln County. Ross in central Payne County (1972) and Garden in western Payne County (1973) traced out individual sandstone units within the Permian System and made contour maps on shallow subsurface limestones. Subsurface reports on the Stillwater-Chandler area by Heinzelman (1964) and in the area of the Cimarron River by Shipley (1975) together with a paleogeographic study by Gould (1927) provide valuable information on the geologic history of the area.

A report by Hays and McCasland (1967) describes some engineering characteristics of various bedrock and soil units in the area. Franks (1974) described the environmental geology of Payne County by using land-resource-capability units derived from both geologic and pedologic data. Several Oklahoma State University theses served as models for environmental sections of this report including those by Ireland (1973), McGuire (1974), Kemmerly (1973), Cohoon (1974), and Cook (1973). Other studies of environmental significance include studies by Snider (1911) on clays, by Gould (1905) on water, and by Gould (1911) on structural materials.

Soils reports for Payne County (Cobb and Hawker, 1918), for Logan County (Galloway, 1961), and for Lincoln County (Williams and Bartolina, 1970) have been published. Ford (1972) produced a detailed soils map of the Oklahoma State University Farm in the map area near Perkins.

Maps of the Quaternary deposits along the Cimarron River in Oklahoma have been made by Fay (1962 and 1965) in Blaine County and Woods County, and by Meyer (1975) in Logan County. Meyer named some of the Quaternary units used by the author, and vice versa. Noble (1973) did detailed work on channel changes of the Cimarron River near Perkins.

GENERAL GEOLOGY

The study area lies in the Central Redbed Plains Geomorphic Province (Curtis and Ham, 1972). Topographically, the region is an area of relatively low relief with rounded, colluviated hills broken in many places by stream terraces and in a few places by sharp cliffs of sandstone.

The bedrock stratigraphy of the area consists of Permian shales, sandstones, nodular dolomites, and limestones. The most common bedrock type is a blocky shale which is extensively colluviated on slopes. Second in importance are lenticular sandstones, mostly in the upper two-thirds of the bedrock column. Nodular dolomite beds are distributed irregularly throughout the column.

Overlying the bedrock units in most places are Quaternary deposits including the alluvia of four terraces and the flood plain, dune sand, other eolian sand, loess, colluvium, and anthropic deposits.

The structural geology of the area is relatively simple. The area lies on the Central Oklahoma Platform 30 to 40 miles east of the Nemaha Ridge (Arbenz, 1956). Although there is a series of minor anticlinal and synclinal flexures, the area is dominated by a homocline with a gentle westward dip of approximately 40 ft./mi. No faults have been recognized at the surface in the area, but four sets of joints are found throughout the area.

Running water, wind, gravity, and Man are the predominant geologic agents active in the area today. Wind erosion is especially evident during dry times, usually in the Spring and Summer. Sheet wash, mass wasting, and water erosion are especially evident after heavy rains. Man's activities and his effect on the terrain are especially visible in cultivated fields, along highways, around buildings, in landfills, along bridges and channel straightening projects, around oil wells, and in rock quarries and sand pits.

GEOMORPHOLOGY

Local relief within the study area is approximately 295 ft. Elevation above sea level ranges from approximately 1110 ft. in the northwestern part of the area near Clarkson Cemetery to approximately 815 ft. in the eastern part of the area near Perkins, where the Cimarron River flows out of the project area.

Erosional Topography

In many parts of the area, characteristic erosional landforms are associated with lithologies. In addition to underlying smoothly rounded hills, the easily eroded shales seem to be associated with stream valleys broader than the valleys associated with erosion-resistant sandstones. Erosion-resistant sandstone is associated with the rugged topography from the Lincoln County-Logan County line to Coyle on the south side of the valley. Porous terrace deposits such as those north of Perkins contain fewer drainage channels than sandstone or shale, because much water seeps through the terrace deposits instead of running across the surface to cause erosion.

Drainage Patterns

The drainage in the study area appears to be influenced by joints. Rose diagrams made of 190 drainage segments and nearly 200 joints shows preferred orientation of joints and drainage segments that appeared to coincide in four directions (see Figure 3). The most likely explanation for this coincidence is that the streams tend to erode along paths of least resistance. Joints, of course, tend to channelize the movement of water and concentrate weathering processes.

Terraces

Stream terraces are recognized by their smooth, low-gradient surfaces that are underlain by alluvial deposits. If a terrace has been undisturbed by tectonic activity since its formation, all remnants of the original surface should have a topographic gradient that will fit into a smooth continuous longitudinal profile. Such profiles are shown on Plate 2. (See Figure 2 for the geometry of profile construction.) Four terraces exist in the project area: the Paradise Terrace, the Summit View Terrace, the Perkins Terrace, and the Lawrie Terrace. Only the Lawrie Terrace is large enough to be shown up tributary streams at the present map scale.

Paradise Terrace

The Paradise Terrace is the highest and oldest terrace in the project area. This terrace is named herein for the Paradise Cemetry approximately three miles northeast of Coyle. The terrace is well preserved in the northwestern part of the map area because it is rock-defended in this area. Figure 4 shows the general configuration of the terrace surface; Plate 1 shows the general distribution of the terrace deposit associated with this terrace, and Plate 2 shows the gradient of the terrace. Alluvial deposits beneath this terrace are thin. Surficial features such as sand dunes, oxbow lakes, blowouts, meander scars,

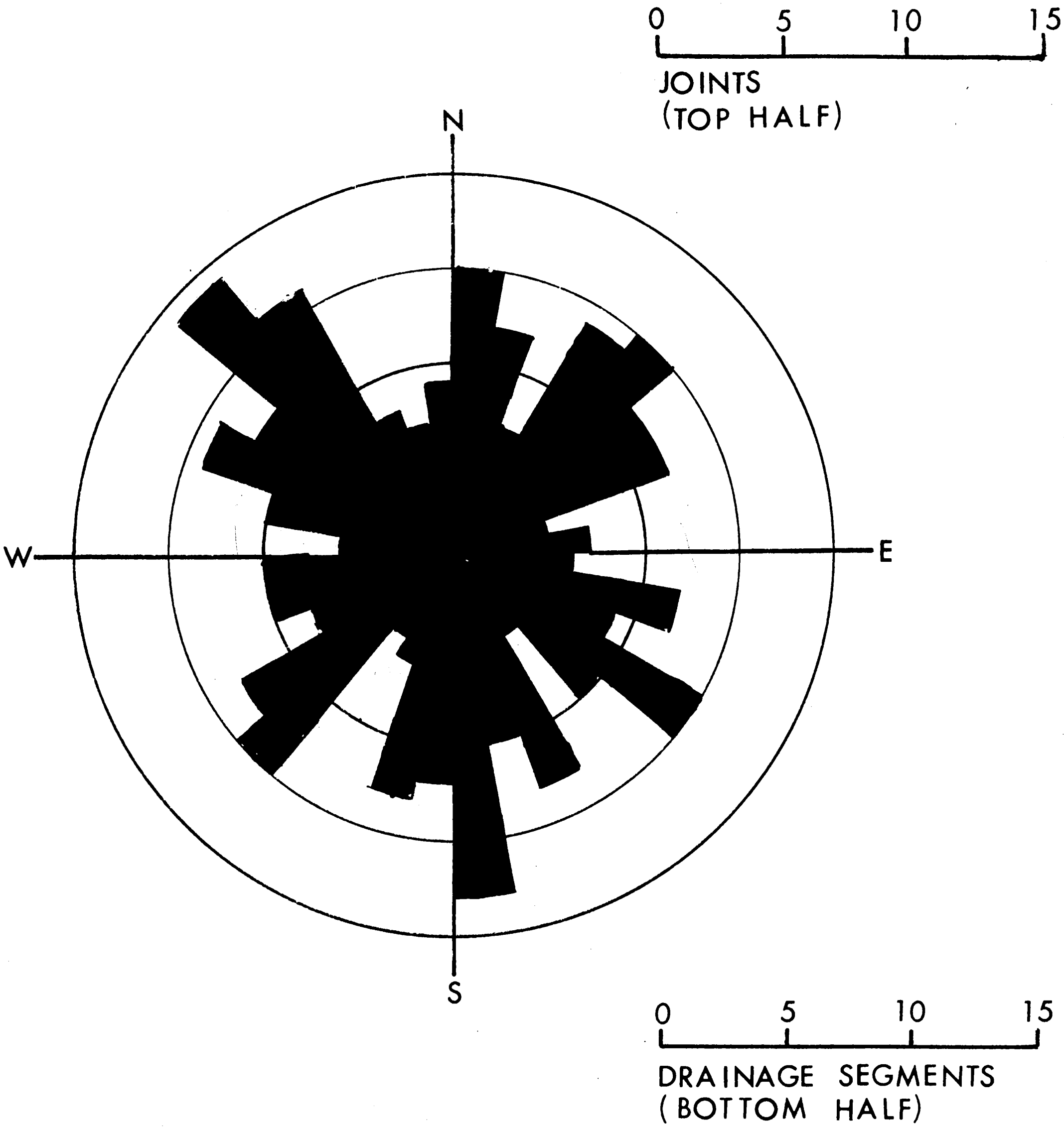

Figure 3. Rose diagrams of bedrock joint orientations and of drainage segment orientations along the Cimarron Valley from Interstate 35 to Perkins, north-central Oklahoma

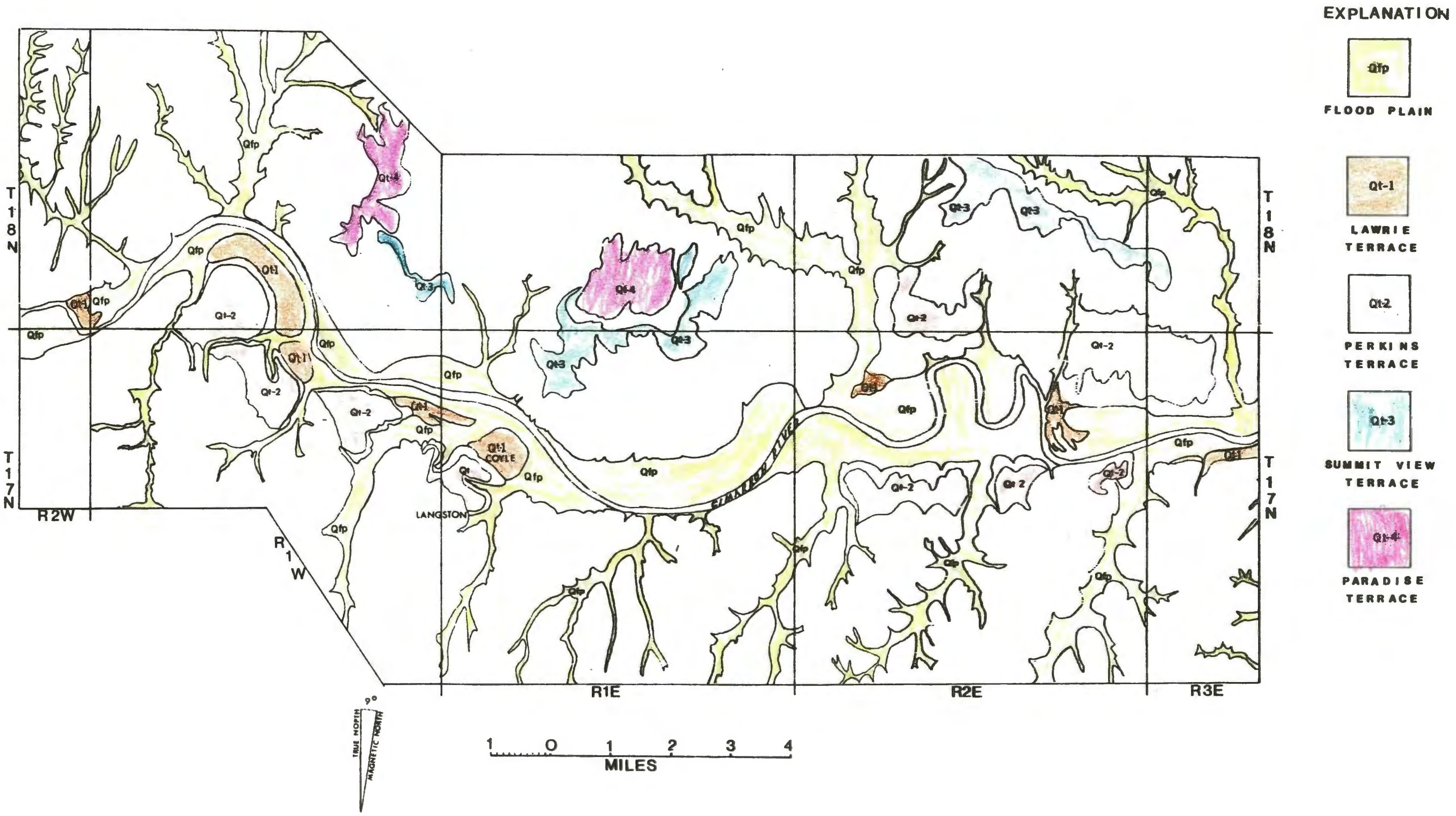

Figure 4. Alluvial surface map of the Cimarron Valley from Interstate 35 to Perkins, north-central Oklahoma

and point bars have not been preserved on this surface. In general, this ancient terrace occurred at elevations 170 to 230 ft. above the present river due to the differences in gradients of the Paradise Terrace and of the Cimarron River.

Summit View Terrace

At levels 140 to 190 ft. above the present level of the Cimarron is the Summit View Terrace. This terrace, named for the Summit View Cemetery northeast of Guthrie, Oklahoma (Meyer, 1975), is exposed throughout the project area in a position generally north of the river. Figure 4 shows the general configuration of this surface, and Plate 1 shows the distribution of the associated Summit View Terrace Deposit. Deposits beneath this terrace generally are thicker than those deposits beneath the Paradise Terrace. Sand dunes are found on this terrace in contrast to the absence of dunes on the higher Paradise Terrace. Nonetheless, this terrace is still old enough so that most surficial features have been eroded away. (See Plate 2 for gradient of this terrace.)

Perkins Terrace

At elevations of about 45 to 85 ft. above the Cimarron lies the Perkins Terrace, named for the town of Perkins in the eastern part of the map area. This is one of the best preserved terraces in the project area. Figure 4 shows the general configuration of this surface, Plate 1 shows the distribution of the associated Perkins Terrace Deposit, and Plate 2 shows the gradient of this terrace. Large expanses of the terrace are found on both sides of the valley. Many of the characteristic flood plain features of this terrace are obscured by sand dunes. Nevertheless, some features are preserved on the terrace surface, including possible oxbow lakes and blowouts near Perkins.

Lawrie Terrace

Lying at elevations 20 to 30 ft. above the Cimarron River is the Lawrie Terrace, named for Lawrie Creek approximately 4 mi. north of the town of Guthrie (Meyer, 1975). This terrace is the youngest terrace mapped within the project area. Figure 4 shows the general configuration of this surface, Plate 1 shows the distribution of the associated Lawrie Terrace Deposit, and Plate 2 shows the gradient of the terrace. The Lawrie Terrace extends up a few tributaries of the Cimarron River. Because the Lawrie Terrace lies immediately adjacent to the present flood plain of the Cimarron River and because the riser of the Lawrie Terrace is so low (only about 5 ft. in some places), it sometimes is difficult to distinguish the Lawrie Terrace from the flood plain.

Flood Plain

The flood plain of the Cimarron River is 1 to 2 mi. wide, narrowing where sandstone is the predominant bedrock type and broadening where shale is predominant. Surficial features of the flood plain include meander scars, oxbow lakes, point-bar deposits, ripple marks, and young sand dunes. As is the case with the Lawrie Terrace, most sand dunes on the flood plain are on the north side of the river.

Gradients of Alluvial Surfaces

The longitudinal profile shows that the gradients of the younger terraces are steeper than the gradients of the older terraces. Figure 4 shows that the younger terraces are generally to the south of the older terraces. Ross (1972) and Garden (1973) both state that formations in the area contain more sandstone toward the south. A possible explanation for steeper gradients is that steeper gradients evolve as the river cuts through sandstone. Sandstone at lower elevations may also cause steeper gradients.

Cimarron River

If we believe the principle of uniformitorianism--namely that the present is the key to the past--then the Cimarron River is a very important key to the understanding of the Cimarron River Valley. Noble (1973) has described in great detail the present, ever-changing course of the Cimarron River. He came to the conclusion that the Cimarron has a dual character because it is a braided stream at times of low flow and a meandering stream at times of high flow. Because the course of the river is ever-changing, the base map used for Plate 1 has not been changed to show the present course of the Cimarron River.

Most changes in the course of the Cimarron have been caused by Nature, but Man also has changed the course of the Cimarron River. Keller jacks in the extreme western part of the area on the south side of the river apparently have caused a point bar to form. At Coyle and Perkins, rip rap has been used to keep the river on course. Groins used at Perkins have caused sedimentation upstream from the Perkins Bridge. Within the last 20 years, drainageways have been constructed for the wandering river at Interstate 35.

Sand Dunes and Eolian Sheets

In addition to those dunes found on terraces, there is a series of smooth eolian sand sheets and sand dunes between the Perkins Terrace and the Summit View Terrace. The sand sheets seem to be made up of thin deposits of sand lying directly on colluvial material derived from Permian bedrock. Both the sand sheets and the sand dunes appear to be continuations of eolian geomorphic landforms found on the Perkins Terrace.

Sand dunes can be recognized by their irregular hummocky topography. Drainage within tracts of sand dunes is mostly internal because the dunes generally have no interconnected drainageways and because the sand making up the dunes is so porous.

Within the project area, sand dunes of two ages were recognized. Soil on the older dunes has generally formed a recognizable soil profile, whereas soil within the younger dunes generally has formed no profile.

BEDROCK STRATIGRAPHY

Bedrock in the project area consists of Permian sandstones, shales, mudstones, and dolomites. Strata of sandstone mostly are lenticular. No marker beds occur in the shales, and fossils are rare. Dolomite beds are nodular, poorly exposed, and probably lenticular in some parts of the study area. For these reasons, many of the conventional means of correlating and mapping bedrock units are not applicable.

Ross (1972) and Garden (1973) defined, correlated, and mapped such discontinuous bedrock units, however. Their methods were based on the following procedure: The stratigraphic section to be mapped at the surface was defined down-dip in the shallow subsurface by using electric logs. Marker beds (chiefly strata of limestone underlain and overlain by shale) were correlated. These beds were used as strata of reference. Sandstone units, although chiefly multistoried*, multilateral*, and lenticular, nonetheless are moderately consistent in positions above the subsurface marker beds. This fact and the fact that some of the limestone beds crop out, comprise a set of working assumptions that is useful in mapping bedrock units at the surface. For example, a sandstone unit generally occurs about 40 ft. above the Neva Limestone, a unit mappable at the surface (Ross, 1972, p. 19 and Figure 2). The sandstone can be traced across the countryside by

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*Units made up of sandstone channel-fill deposited side by side and one on top or within another.

locating exposures, by observing patterns of vegetation, topography, and land use, and by reference to the outcrop of the Neva Limestone.

This basic method was used in the study area to extend southward the mapping units of Ross and Garden. Their units were combined into sets of strata defined as Permian bedrock unit 1 (chiefly units below the Wellington Shale), Permian bedrock unit 2 (approximately the first 200 ft. of the Wellington Shale), Permian bedrock unit 3 (from 200 to 600 ft. above the base of the Wellington), and Permian bedrock unit 4 (from 600 ft. above the base of the Wellington to the western boundary of the area). These four mapping units clearly are informal and *ad hoc*. Nevertheless, these units do serve as a basis for mapping surficial bedrock.

Permian Bedrock Unit 1

Permian bedrock unit 1 consists of sandstones, shales, and carbonates. Within the project area, this unit contains mostly reddish-brown to maroon sandstones with some interbeds of maroon shale, and thin, discontinuous, nodular dolomites and limestones. This unit crops out only in the northeastern part of the project area (see Plate 1). The topographic relief developed upon this unit is more rugged than in most of the area, because the erosion-resistant sandstones often stand out as cliffs. In some places, the sandstone units are delineated by the presence of blackjack oaks, post oaks, and junipers, because these trees are particularly adapted to the types of soil developed on this unit. Soil on this unit generally is not cultivated because bedrock is near the surface and the topography is rugged. Thickness of the unit is approximately 180 ft. (Ross, 1972, p. 34-39).

Permian Bedrock Unit 2

Permian bedrock unit 2 consists primarily of maroon mudstone and shale with some discontinuous scour and channel-fill sandstone lenses. In general, the topographic relief on this unit is more rounded and subdued than the topography found on units containing more sandstone. Unit 2 is poorly exposed because it is overlain by considerable amounts of colluvium. Cultivation of soil derived from this unit is common. Within the project area, this unit is exposed from a locality just east of Perkins to a short distance just east of Goodnight (see Plate 1). The unit is approximately 200 ft. thick (Garden, 1973, p. 13-15).

Permian Bedrock Unit 3

Permian bedrock unit 3 is composed primarily of 180 ft. of buff to maroon carbonate cemented sandstone beds with mudstone and shale. Because many sandstones within the unit are of multilateral, multistoried complexes, many sandstone units can be traced for many miles (Garden, 1973, p. 13-15). Exposures of this unit are found primarily west of Wildhorse Creek and east of Fitzgerald Creek in the western part of the area (see Plate 1).

In the field and on aerial photographs, unit 3 can be recognized by its rugged topography, its lack of cultivation, and its extensive tree cover. Sandstone near the surface limits cultivation, and topography developed on it is rugged. Trees consist mainly of blackjack oaks, post oaks, and junipers.

Permian Bedrock Unit 4

Permian bedrock unit 4 consists dominantly of red shales, about 180 ft. thick, with some extensive carbonate-cemented sandstone beds as much as 30 ft. thick (Garden, 1973, p. 13-15). Most of the sandstones are multilateral and multistoried, and they can be traced for long distances within the area. Texture of the sandstones ranges from very fine-grained to medium-grained. In addition, a few thin conglomeratic layers that contain pebbles of dolomite occur within unit 4.

Unit 4 extends from the vicinity of Fitzgerald Creek to the western edge of the map area (see Plate 1). More cultivated fields are developed on the outcrop of this unit than on Permian bedrock unit 3. Soils associated with this unit are basic (pH ranges above 7.0), a property caused by the presence of carbonate minerals in the soils. Consequently, soils derived from this unit provide a favorable environment for the production of some kinds of crops.

STRUCTURAL GEOLOGY

In rocks exposed at the surface, the structural geology of the study area is relatively simple. The area lies on the Central Oklahoma Platform just east of the Nemaha Ridge (Arbenz, 1956). Beds strike generally north-south and dip approximately 40 ft./mi. to the west. Gentle anticlinal and synclinal flexures are shown on subsurface structural contour maps by Garden (1973) and Ross (1972).

A rose diagram of the bearings of 200 joints (see Figure 3) shows four major joint directions with strikes of N65W, N45W, N5E, and N45E. Only joints visible in sandstone units were measured. Nelson (1975, p. 221) stated that fracture orientations are generally coincident with paleo-current directions in fluvial sediments. A comparison of joint data in Figure 3 with paleo-current data for sandstones from work by Garden (1973, p. 32) appears to show this coincidence in the Cimarron Valley (see Figure 5). A possible explanation for this phenomenon would be that ancient drainage was influenced by joints in the same manner that present day drainage is influenced. Shale and precipitated limestone would not be subject to this phenomenon.

No major faults were found within the project area. Subsurface data generally indicate scarcity of faults within rock units deposited from the Pennsylvanian to the present (Shipley, 1975; Heinzelman, 1965).

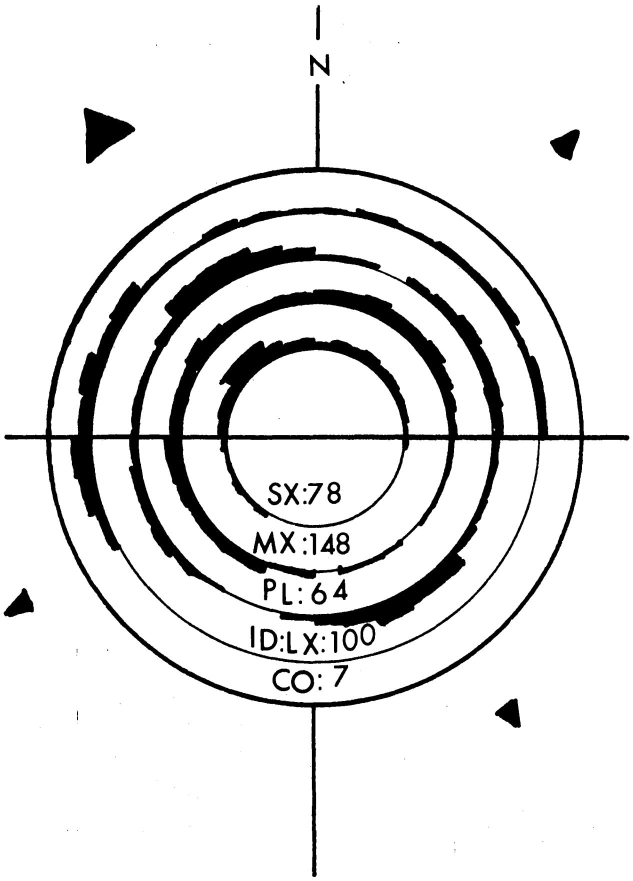

Figure 5. Composite paleocurrent diagram of the Wellington sandstones of western Payne County (from Garden, 1973)

SX = small-scale cross-bedding
PL = parting lineation
ID = initial dip
LX = large-scale cross-bedding
CO = cut-out trend

QUATERNARY STRATIGRAPHY

Quaternary deposits of the Cimarron River Valley include fluvial deposits, eolian deposits, and gravity deposits. In this report, these deposits are classified texturally according to their principal constituents as follows: The textural class making up the most of the sediment is a noun; the second most common constituent is described by an adjective modifying the noun; other constituents are described in order of their quantity by the terms "some," "little," and "trace." "Some" implies 20 to 35 percent of a minor constituent; "little" implies 10 to 20 percent of a minor constituent, and "trace" implies 0 to 10 percent of a minor constituent (modified from Burmister, 1970). For example, sandy clay with little silt implies a mixture with more than 50 percent clay, greater than 35 percent sand, and 10 to 20 percent silt.

Geologic names of Quaternary units are in accord with the "Policy of the Minnesota Geological Survey on Nomenclature and Classification for the Quaternary of Minnesota" (Stone and others, 1966). Quaternary units are herein described approximately in the chronological order of formation.

Quartzite Pebbles and Cobbles

At many places in and near the project area, iron oxide-coated quartzite pebbles and cobbles with diameters up to 10 in. occur. These pebbles are probably the only remnants remaining from a former deposit which possibly was the Tertiary Ogallala formation. Sand, silt, and clay from the Ogallala may have been reworked into present day sediments of the Cimarron River terraces and floodplain.

Paradise Terrace Alluvium

The oldest Quaternary deposit recognized within the project area is the Paradise Terrace Alluvium, a dark brown, fine-grained silty sand with thin horizontal laminae, cross-bedding, and a few layers of convolute bedding. A few lenses and layers of clay and silt are also present.

In the map area, this deposit is in a 5 square-mile area west and south of Wildhorse Creek and north of the Cimarron River (see Plate 1). Preservation of the deposit is attributed to a sandstone which originally was beveled out by the Cimarron and which has been preserved because of its resistance to erosion. Thickness of the unit varies from <1 to 25 ft. Because the deposit is generally thinner than 25 ft., there is a close correlation between the outcrop pattern of this deposit and the remnants of the terrace surface.

Summit View Terrace Alluvium

The Summit View Terrace Alluvium is the next-to-oldest terrace deposit in the map area. A small portion of this deposit is exposed just south of the river and one mile east of Interstate 35, but most of the deposit is found north of the river and south of the Paradise Terrace Alluvium (see Plate 1).

The Summit View Terrace Alluvium consists of a dark brown to yellowish-brown, fine- to medium-grained, well-sorted sand with some deposits of red-brown and gray-green mottled silty clay. Sedimentary structures found within the alluvium include horizontal laminae, ripple marks, clay drape, cross-bedding, and some convolute bedding. Deposits of gravel including quartz pebbles are on bedrock in the western part of the map area. The Summit View Terrace deposit is <1 to 25 ft. thick.

Perkins Terrace Alluvium

The Perkins Terrace Alluvium lies generally to the south of the Summit View Terrace Alluvium and north of the Cimarron in a band one to two miles wide. This unit generally is well exposed because it formed recently enough in the past to be well perserved. It now is located at a position far enough away from the river so that it will not be destroyed within the near future by fluvial erosion.

The Perkins Terrace Alluvium consists of a light brown to dark brown, very fine- to fine-grained silty sand. In some locations on the Perkins Terrace, silt and clay have accumulated in blowouts and abandoned oxbow lakes. Sedimentary structures within the deposit include scour-and-fill structures, horizontal bedding, cross-bedding, clay drape, and horizontal laminations. Near Coyle on the north side of the river is an exposure of the Perkins Terrace Alluvium that contains two paleosols and fossil snails and mammals (see Figure 6). These paleosols indicate at least three periods of deposition of alluvium. The thickness of this deposit is highly variable, due to the varying configuration of the underlying surface on which it was deposited. Thickness varies from <1 to 60 ft.

Figure 6. Photograph of the Perkins Terrace Alluvium showing modern soil No. 1 and two paleosols Nos. 2 and 3, evidence of three cycles of deposition

Lawrie Terrace Alluvium

The Lawrie Terrace Alluvium lies parallel to and on both sides of the Cimarron River. This deposit can be traced both along the Cimarron River and up some tributaries of the river.

The Lawrie Terrace Alluvium consists of a reddish-brown to yellowish-orange very fine-grained silty sand with lenses and layers of clay and silt. Sedimentary structures within the unit include cross-bedding, cross-laminations, and horizontal laminae. Some laminae within the deposit are clay. The deposit is <1 to 40 ft. thick.

Flood-plain Alluvium

Flood-plain alluvium extends along the Cimarron River and up the tributaries of most streams in the area (see Plate 1).

Flood-plain alluvium is a reddish-brown to yellowish-brown, very fine- to fine-grained sand with some silt and some clay. Laminae of clay are common as a result of frequent overflow within the Cimarron flood plain. Deposits of silt and clay also occur in blowouts and in oxbow lakes along the river. Gravel- and cobble-size mudballs and rock fragments are present and are more abundant at depth. Within the alluvium are found cross-bedding, horizontal bedding, eolian ripple marks, and point bar deposits. Flood-plain alluvium on the tributaries of the Cimarron River contains more silt and clay than the alluvium of the Cimarron River flood plain because these deposits are derived locally from silty and clayey rocks, whereas deposits along the Cimarron are made up of reworked Ogallala sediments. Flood-plain deposits along the Cimarron River are <1 to 30 ft. thick, whereas flood-plain deposits along tributaries are 1 to 15 ft. thick.

Depth measurements have been made by the U. S. Geological Survey at the Perkins crossing of the Cimarron River (Thomas, written communication, 1974). These measurements show variations in elevation of the river bottom through time of as much as 25.5 ft. Borings made by the Oklahoma State Highway Department in 1953 show that the river alluvium at Perkins was approximately 26.0 ft. deep. In addition, Noble (1973) showed that the river has changed its channel considerably within the last 75 years.

Old Dune Sand

Generally, this deposit is found on the north side of the Cimarron River on the Perkins and Summit View Terraces. Old dune sands within the project area consist of white fine- to medium-grained, well-sorted clean sand which is highly weathered in the uppermost 10 ft. and which has been stabilized by vegetation. The weathering takes the form of alternating layers of clean sand and secondarily clay-enriched sand. This weathering is known in soil science as the multiple "B" horizon. The deposit is <1 to 30 ft. thick.

Young Dune Sand

Young dune sand consists of white to yellow fine- to medium-grained, fairly well-sorted clean sands. In general, these sands show no soil profile development and they may be subject to wind erosion where they are not vegetated. This deposit is <1 to 20 ft. thick. These deposits lie mostly on the north side of the river on the flood plain and the Lawrie Terrace.

Eolian Sand

The eolian sand is a white to yellow well-sorted fine-to-fine-grained sand. This sand is distinguished by its lack of sand dune surface morphology and a lack of cohesive material. This deposit is <1 to 6 ft. thick. In general, this deposit is developed on a very smooth slope. The very fine grain size of these deposits suggests that this material may have been deposited in the same manner as loess with the thickest part of the material exposed near the source. Sand dunes probably did not form in these sediments because of the thinness of the deposit.

Colluvium

Colluvium is material that is deposited by gravity and sheetwash. For the purposes of this report, colluvium was considered significant if it were 1.0 ft. or more thick. Two different kinds of colluvium have been distinguished within the project area.

Fine-grained colluvium consists mostly of maroon-to-buff silty clay with some sand and traces of pebbles or gravels up to 1 in. in diameter. Within the deposit are concretions of iron and manganese oxides. These oxides stain much of the deposit. Shale fragments are abundant. This unit is distinguished by platy structure, heterogeneous mixtures of grain sizes, and a characteristic "cruddy" aspect. The unit is <1 to 15 ft. thick.

Coarse-grained colluvium consists of maroon-to-buff sand, silt, and clay mixed with boulders, cobbles, and gravels. Concretions of iron and manganese oxides are within the deposit. These oxides also stain other parts of the deposit. Boulders, cobbles, and pebbles may constitute 50 percent or more of the deposit. In general, this deposit occurs where sandstone forms a significant part of the bedrock. Coarse-grained colluvium is <1 to 15 ft. thick.

Loess

Overlying nearly all of the project area is a thin deposit of clayey and sandy eolian silt, known as loess. For purposes of this project, only those deposits of loess 2.0 ft. thick or thicker were mapped. In general, these deposits consist of gray-black silt 2.0 to 3.0 ft. thick, which has been organically stained with decayed plant material. The thickest deposits of loess are found downwind near the source materials.

Anthropic Deposits

Anthropic deposits are those deposits emplaced by Man. Included within these deposits are the artificial fills along highways, fills for buildings, approaches to bridges, sanitary landfills, protective rip rap, and stockpiles of sand and gravel. The nature of these deposits ranges from locally derived soil and rock material to natural materials transported from afar to rubble, trash, and garbage. The texture, thickness, and distribution of these deposits are highly variable.

DISCUSSION

Distribution of Terrace Deposits

The geologic map (Plate 1) shows that most terrace deposits are on the north side of the Cimarron. Two possible explanations for this distribution are considered. First, did glacio-eustatic rebound cause tilting of the entire area to the south? Second, did wind erosion play a role?

Glacio-eustatic rebound is essentially the process of uplift of a section of the earth's crust after the retreat of a glacier. Such rebound is the cause of tilted strand lines in North America, the British Isles, and Fennoscandia (Flint, 1970, p. 343-344). Unfortunately, however, this phenomenon does not help explain the southern migration of terraces in the Cimarron Valley because the outer limits of glaciations are in northeastern Kansas more than 200 mi. away (Flint, 1970, p. 545), and the limits of known upwarpings in Fennoscandia (Flint, 1970, p. 391 and 594), North America (Flint, 1970, p. 369 and 389), and the British Isles (Flint, 1970, p. 365 and 594) lie inside the known limits of glaciation.

Eolian activity provides a better explanation for the asymmetric distribution of terrace deposits on the northern side of the river. The geologic map shows more eolian deposits on the northern side of the river than on the southern side of the river, reflecting the predominant wind direction from the south. During dry times, the sands of the Cimarron flood plain probably were blown onto the northern side of the dried out river channel. Subsequently, precipitation increased and the course of the river was diverted south of the northern channels which by this time were filled with the eolian material.

Division of Dune Sands

In this report, dune sands were differentiated on the basis of soil-profile development. Older dune sand shows considerable weathering, while younger dune sand shows little or none. Young dune sand lies mostly on the flood plain and the Lawrie Terrace, while old dune sand lies mostly on the Perkins and Summit View Terraces. Old dune sand may have been deposited intermittently from Summit View time to Perkins time, but it could not be subdivided in this investigation. Absence of the old dune sand on the Paradise Terrace indicates that all old dune sand is younger than the Paradise Alluvium.

Age of Loess

Loess deposits (most of which are less than 2 ft. thick) occur on the Perkins Terrace, all higher terraces, and the bedrock. Little or no loess is on the Lawrie Terrace or the flood plain. For these reasons, most loess deposits are believed to be younger than the Perkins Terrace, but older than the Lawrie Terrace. The continuous nature of the loess as well as its uniform texture indicate that all of the loess was deposited at the same time. The Lawrie Terrace Alluvium may have been the source area of the loess (Meyer, 1975). It is interesting to note that most of the erosional topography of the area and most (if not all) of the colluvium was developed pre-loess.

Age of Colluvium

Some colluvium situated higher than the Paradise Terrace and overlain by loess was found in the northernmost part of the area, 7 mi. east of the western boundary. This colluvium may have formed concurrently with the formation of the Paradise Terrace. Colluviation can occur whenever increased precipitation takes place. Therefore, colluvial deposits of many ages are present in the Cimarron Valley. Nonetheless, most colluvium is older than the loess deposits.

Causes of Rejuvenation

Thornbury (1969, p. 139-141) lists three basic causes for rejuvenation: dynamic rejuvenation, a rejuvenation caused by regional uplift without important deformation; eustatic rejuvenation, a rejuvenation produced by worldwide lowerings of sea level; and static rejuvenation which may come about without lowering of sea level or epeirogenic uplift. Thornbury lists three possible causes of static rejuvenation, including increased runoff because of increased rainfall, decreased load, and increase in stream volume by acquisition of new drainage by stream diversion or derangement (Thornbury, 1969, p. 140).

All of the above causes were considered as possible causes of rejuvenation in the Cimarron Valley. Epeirogenic uplift may be responsible for part of the incision of streams, although such uplift alone cannot explain the periodicity necessary to produce the terraces. Stewart (1973, p. 59-83) pointed out that eustatic sea levels could not cause entrenchment of the Arkansas River in Kansas because knickpoints caused by lowering of sea level would not be translated headward across so great a distance. Consequently, the Cimarron River which flows into the Arkansas River upstream from Arkansas would not be affected by eustatic changes in sea level. The one remaining hypothesis to explain rejuvenation in the Cimarron Valley is static rejuvenation. Very little evidence for acquisition of drainage from other sources is found within the map area. The Cimarron River appears to have formed its drainage parallel to the present drainage as early as time of deposition of the Paradise Terrace. Two possible hypotheses by Thornbury remain, including decreased load and increased runoff. Both hypotheses are feasible. Both hypotheses would imply changes of climate. In most east-flowing rivers of Oklahoma, these changes of climate might be related to glaciations in the Rockies. The Cimarron River, however, is the only major east-flowing river in Oklahoma not originating in the Rockies. Therefore, the terraces of the Cimarron directly reflect changes from humid to arid climates. Increases in precipitation would cause the establishment of vegetation which, in turn, would stabilize deposits of sand, silt, clay, and gravel; thus, the load in the Cimarron River would be decreased. Concurrently, increased amounts of precipitation would supply more water for down-cutting by the Cimarron River. Thus, the form of the Cimarron Valley reflects alternating humid and arid climates (see Garner, 1974, p. 381-447).

GEOLOGIC HISTORY

Rocks of every geologic system from the Precambrian to the Permian are represented either at the surface or in the subsurface within the project area (Gould, 1927). All of the bedrock within this sequence is marine or near-marine. The surficial Permian bedrock units were deposited in deltaic and other marginal marine environments with elongate sandstone bodies cutting through shales. Studies of these bedrock units have revealed that the dominant direction of water flow within this deposit was to the northwest (Ross, 1972, p. 70; Garden, 1973, p. 47).

During Mesozoic time, sediments possibly were deposited over Permian strata, but if so, they have been destroyed by erosion. It is probable that during Pliocene time the ancestral Cimarron and other streams deposited the Ogallala Formation, remnants of which still occur in western Oklahoma. During the Pleistocene, the Ogallala was eroded from all except western Oklahoma. Today, a few quartzite pebbles and cobbles survive as lag in the study area. Uplift, tilting, and minor folding occurred some time between the Permian and the Pleistocene.

Relatively early in the Pleistocene erosional phase and by the time the Paradise Terrace Alluvium had started to form, the Cimarron River established a course parallel to the present drainage directions of the area. After a period of time, the river increased its erosive power and began to cut down into its own floodplain. The most likely reason for the increased erosive power of the river was increase in the amount of precipitation caused by a change in climatic conditions from arid to humid. This increased precipitation also helped accelerate the process of colluviation by providing moisture for freeze-thaw action, shrink-swell action, softening of shales, and chemical weathering.

Later, the climate became arid, and the Cimarron became an agent of deposition. Sand, silt, and clay were reworked into a broad flat plain, colluvial processes slowed down, and the river eroded a broad valley. Thus was formed the Summit View Terrace. Sometimes the valley was so dry that alluvium could be picked up and blown into sand dunes.

Subsequently, precipitation within the area began to increase, and a new valley was incised. Colluvial processes began to speed up. Sand dunes began to stabilize with the formation of soils and the establishment of vegetative cover.

Later, when the climate again became arid, a new flood plain which would later become the Perkins Terrace, began to form. New dunes formed on the Perkins Terrace and some migrated up the riser of the Summit View Terrace. Old dunes on the Summit View Terrace were reactivated. Those colluvial processes requiring water began to slow down.

Deposits and sedimentary features within the Perkins Terrace Alluvium reveal that transitions from one climate to another were not always smooth. The paleosols within the Perkins Terrace Alluvium demonstrate at least three different periods of deposition, each of which represents minor climatic fluctuations between arid and humid periods (see Figure 6).

After the Cimarron River had formed the Perkins Terrace, two more cycles of downcutting and infilling produced the Lawrie Terrace and the flood plain. During each cycle, sand dunes formed while relatively arid climatic conditions prevailed and colluvium formed during times of relatively humid conditions.

Throughout the Quaternary Period, eolian activity has produced not only sand deposits, but also deposits of loess, a wind-deposited silt. It is probable that loess has been deposited periodically throughout the time of the formation of the valley, but most has been removed by erosion. The loess in the valley represents one episode of loess deposition--one probably occurring during Lawrie time.

Although natural geologic processes have been at work in this area throughout the history of the valley, Man has acted as an important geologic agent since settlement by whites in the later 1800s. Roads throughout the project area are sources of sediment for the Cimarron River and its tributaries. Gullies in the project area have resulted from poor farming practices (e.g., cultivation stripped vegetation). Restoration of the landscape has been attempted in many places by means of terrace building, land filling, and contour plowing. In the extreme western part of the area, keller jacks have slowed down the flow of the Cimarron and have caused a point bar to form. At Perkins, groins have caused sediment to be deposited. Rip rap has been used to keep the river in its place at Coyle and at Perkins. A segment of Walnut Creek has been straightened out to provide more fields for cultivation. Bridges along this creek are washed out as new meanders begin to form.

ENVIRONMENTAL GEOLOGY

Some people propose the building of subdivisions without any regard to environmental problems. Indeed, trailer homes have been built without tiedowns in tornado-prone areas, houses have been built on soils that cause foundation failures, and many structures have been built on flood plains without due regard for consequences. On the other hand, some people oppose the building of any structure that might encounter any environmental problems. The answer lies neither in a carefree attitude nor in an overly cautious attitude. Instead, the answer lies in planning with due consideration of the risks and costs involved.

The following section is a brief discussion of the factors that should be considered when Man interacts with the environment in the study area. This presentation is not intended to provide substitutes for on-site inspections, but is designed for preliminary planning and site selection. If significant problems seem to be present, then a specialist such as a civil engineer, soils scientist, or engineering geologist should be consulted.

Ground Water

Ground water within the project area occurs in bedrock units, in terrace deposits, and in flood plain alluvium. Ground water is that water which saturates all of the pores, cracks, and fissures of a geologic unit. The surface below which the ground water occurs under a pressure of 1 atmosphere is known as the water table. Usually, underground water rises some inches or feet above the water table because of capillarity. This water can be an important factor in shrinking and swelling of soils and in plant growth.

Ground water within the bedrock is distributed erratically due to the lenticular nature of sandstone lenses. These lenses cause seeps to form where the water from a permeable sandstone may flow to the surface along a shale-sandstone interface. Yields of wells within the sandstone are likely to be on the order of 10 gallons per minute (gpm) or less, due to the presence of cement, silt, and clay within the pores of the bedrock. Water quality generally is fair to good, although there may be problems of salt water pollution from old, uncased oil wells. Hardness also is a problem in some cases (Oklahoma Water Resources Board, 1972, 0. 96).

The Perkins, Summit View, and Paradise terrace deposits are relatively good aquifers with high yields of water. Yields of wells in these aquifers range from 50 to 1000 gpm with an average yield of 200 gpm (Oklahma Water Resources Board, 1972, p. 96). The water quality in the terraces generally is good, although it may be hard, and it sometimes is contaminated by salt water from old oil wells (Oklahoma Water Resources Board, 1972, p. 95). Certain parts of the alluvial deposits are less permeable than others, so that perched ground water is likely to be found near the surface in areas of topographic depressions underlain by clay.

Water from the Lawrie Terrace Alluvium and from flood plain alluvium is likely to be abundant, just as it is in the upper three terrace deposits of the river. Unfortunately, however, there is danger of contamination of the ground water of these deposits when overpumping causes cones of depression in the water table to develop immediately adjacent to the Cimarron River. The ground water flow reverses and flows toward a pumping well from the Cimarron River, which is contaminated by salt, pesticides, and fertilizer from upstream.

Surface Water

The water quality of tributaries to the Cimarron River generally is good, although the water may be hard due to the presence of calcareous deposits within most of the drainage basins. Water quality of the Cimarron River generally is unfit for most uses because of the presence of over 1000 parts per million (ppm) dissolved solids, 250 ppm chloride (Oklahoma Water Resources Board, 1972, p. 105-107). Sources of the pollution lie far upstream of the project area.

Many good sites for small reservoirs exist within the project area due to the presence of impermeable shales near the surface and favorable topography.

Earthquake Susceptibility

Algermission (1966) has rated the project area as Zone II on the map of the United States, indicating that the area has a higher probability of earthquakes than 80 percent of the United States. The probability of major earthquakes, however, is quite low. Nonetheless, all large structures should be designed to resist seismic stresses.

Environmental Evaluations of Map Units

One of the main objectives of this report is to present geologic data in a manner so that possible correlations can be made between those properties desired and the properties of the geologic materials. Three tables (Tables I, II, and III) present the author's evaluations of the map units in the study area. These tables are by no means complete, and they are not intended to be substitutes for engineering evaluations of critical situations. In the following paragraphs, engineering characteristics of stratigraphic units and their relation to specific purposes are discussed.

Engineering Characteristics

Shrink-swell. "Shrinking" refers to the volumetric contraction of certain clays when they are dried out, and "swelling" refers to the volumetric expansion of clays when they are wetted. Shrinking and swelling can be a serious problem, especially when the process takes place at unequal rates that will cause man-made structures to undergo differential stresses. These stresses may cause cracked foundations, cracked walls, or in extreme cases, collapse of structures.

Permeability. Permeability is a measure of the rate at which a fluid can move through a substance. In general, the permeability of a unit depends on its texture. Coarser materials such as sand and sandstone are more permeable than finer material, such as clay and shale. Materials that are well-sorted are more permeable than materials that are poorly sorted. High permeability is needed when it is desirable for water to flow. Low permeability is desirable when water needs to be held back. Rates of permeability can be classified as follows (modified from USDA, 1971, p. 12): low, less than 0.06 - 0.2 inches per hour (iph); moderate, 0.2 - 6.0 iph, and high, greater than 6.0 iph.

Erodibility. Erodibility is a measure of the rate of which geological units are worn down or removed by mechanical processes (e.g., by running water, wind, or gravity). In this report, geologic materials are rated according to ease of erodibility. High erodibility means that erosion severe enough to cause damage to an artificial structure is possible whenever precipitation exceeds 2 in./day. High erodibility also means that a geologic unit is subject to wind erosion whenever vegetation is removed. Low erodibility would imply that no erosion of any significance is likely to occur within the 50-year lifespan of an artificial structure.

Water Table Position. The water table is that surface below which all pores in soil or rock are filled and the water is under 1 atmosphere of pressure.

The water table is generally closest to the surface when the amount of precipitation is highest and the amount of loss from evaporation and transpiration is lowest. The highest water table in the year is known as the seasonally high water table. For certain projects, encountering the water table is undesirable, and for that reason geologic units are rated according to their seasonally high water tables. A seasonally high water table with a depth of 5.0 ft. or less is considered shallow; a seasonally high water table with a depth of 5.0 - 11.0 ft. is considered moderate, and a seasonally high water table with a depth of 11.0 ft. or more is considered to be deep.

Seepage. Seepage is a flow of water that occurs when the ground water table intersects the ground surface. Seepages can cause landslides, potential landslide conditions, softening of unpaved road surfaces, failure of pavement on hard surface roads, and pollution. Seepage generally occurs where the contact between overlying permeable materials and underlying impermeable materials intersects the ground surface. A high rate of seepage is used in this report to mean that seepage was observed in the field. A low rate means that no seepage was observed in the field.

Rippability. Rippability is the relative ease with which a bulldozer (Caterpillar D-9 or equivalent) can excavate rock by means of a ripper (a steel tooth attached to the rear of the machine)(Hayes and McCasland, 1967, O. 23). A rock becomes more rippable when the strata are thinner, less cohesive, and/or more jointed. A high (H) rippability means that the rock can be ripped easily. Moderate (M) rippability means that some difficulty may be encountered. Low (L) rippability indicates that blasting may be required in some instances.

Slope Stability. The term "slope stability" refers to the tendency of a slope to stand without failure. Slope failure can be caused by one or more of at least 15! combinations of factors (Sowers and Sowers, 1970, p. 506). In operation, these factors can lead either to increased stresses on materials underlying the slope or to decreased strengths of the materials. These factors which might cause failure within the Cimarron Valley include: removal of the toes of slopes by stream erosion and man-made cuts, seepage, removal of stabilizing vegetation, weathering of cementing materials, and undercutting of erosion-resistant sandstone blocks by weathering and erosion of underlying shales.

Effective evaluation of slope stability requires that each slope be studied independently. Nonetheless, on the basis of field observations, general inferences can be made about stabilities of slopes in the Cimarron Valley. At some localities, colluvium underlies hummocky topography. This occurrence suggests former landslides. Sandstone blocks overlying shale commonly are undercut and fail. Seeps and springs which were observed at several places can lower the shear-strengths of materials that underlie them. In the tables that follow, evidence of this kind is used to rate geologic units as to the tendencies toward failures of slopes. Units which were considered to have the highest observed failure potential are rated lowest; those with the lowest failure potential are rated highest.

Flood Potential. Flood potential is a measure of the frequency with which floods are likely to occur. Evaluation of this frequency is difficult to make within the map area. Flood potential depends on rate of precipitation, the permeability of soils, the elevation of land, the size of the drainage basin, presence or absence of frozen ground, and depth to the water table. Only the flood plains and the Lawrie Terrace are likely to flood regularly within the Cimarron Valley. A few local depressions in other geologic units are likely to flood during periods of intense precipitation. In the tables accompanying this report, the Lawrie Terrace and the flood plain are given low (L) ratings because of their tendency to flood. Every other unit is given a high (H) rating with the exception of those deposits which may flood only in local depressions. These latter units are given a moderate (M) rating.

Compressibility. The term "compressibility" refers to the tendency of a geologic unit to contract volumetrically under stress. Compressibility is more pronounced in clayey soils rather than in sandy soils. In sandy soils, compression generally takes place quickly, while in clayey soils, compression requires a relatively long period of time. Instant compression presents no problems once it takes place although it may cause problems of differential stress when it occurs. Slow compressibility can cause differential stresses in structures.

Many soils in the Cimarron Valley already have been precompressed by stresses from previous overburden or desiccation. Some of these soils actually will expand under light loads (see discussion of shrink-swell). Some clayey alluvia and some organic materials in oxbow lakes may have compressible clays. Sandstone bedrock units and terrace alluvia in general pose no problems, although terrace alluvia may contain buried silt and clay.

Bearing Capacity. The term "bearing capacity" refers to the ability of a soil to support a structure without failure. Evaluating the bearing capacity of a soil depends not only on the substrate upon which the structure is built, but also on the size and shape of the foundation used. Bearing capacities must be evaluated individually. Nonetheless, geologic units within an area can be evaluated according to which formations may have the most bearing capacity problems. For example, a loose, well-sorted eolian sand will not have the bearing capacity of a well-compacted, poorly-sorted terrace deposit. A high water table can lower the bearing capacity of some soils. Organic soils will have a very poor bearing capacity in contrast to poorly-sorted sandy deposits.

With factors such as these in mind, the author has attempted to determine which of the observed geologic units observed have minimum, moderate, and maximum bearing capacity problems.

Depth to Bedrock. Depth to bedrock refers to the amount of unconsolidated materials overlying bedrock. Shallow bedrock is sometimes undesirable because it costs more to excavate. Shallow bedrock is also undesirable for septic systems. On the other hand, bedrock is desirable for end bearing piles. Bedrock serves well as a foundation for most structures. In the environmental tables, "shallow" bedrock is less than 5 ft. deep, "moderate" bedrock is 5 to 10 ft. deep, and "deep" bedrock is deeper than 10 ft.

Building Materials

Aggregate. The term "aggregate" refers to the filler material in concrete. The U. S. Bureau of Reclamation states that aggregate should be composed of "clean, uncoated, properly shaped particles, of strong durable materials" (U. S. Bureau of Reclamation, 1959, p. 57-60). The cleaner an aggregate is, the easier it is to control its quality. Properly shaped particles containing a minimum number of long and elongate particles help increase the workability of the concrete. The strength and durability of the particle making up the concrete is important because the strength of the concrete itself may depend ultimately on the strength of the aggregate particles.

In the environmental tables, materials are rated according to their suitability as aggregate sources. Ratings range from high for suitable aggregates to low for those materials which are unsuitable.

Fill Material. Fill material is material moved onto a site to provide a base for a foundation. In general, a fill material should be poorly sorted, so that fine materials will fill the interstices between coarse grains and give the fill a higher density. A slight amount of clay is desirable to give the fill a good binder. Low shrink-swell is desirable for fills so that no differential stresses will be set up in the structure. Ideally, bedrock should be deep so that it is possible to excavate the material more easily. If bedrock material is used for fill, the bedrock should be easily rippable. Low erodibility of the fill material is desirable after emplacement.

Materials most suitable for use as a fill are given high (H) ratings in the environmental tables. Materials that are least desirable are given low (L) ratings.

Base Course. The term "base course" refers to that material immediately below the wearing surface of a pavement. Base material under a rigid pavement is used to prevent pumping, to protect against frost action, to drain the subbase, to prevent volume change of the subgrade, to increase structural capacity, and to expedite construction (Yoder, 1959, p. 283).

Prevention of pumping is accomplished by a well graded soil that is well compacted and free of excessive fines. For drainage, the soil should contain little or no fines. Frost action is avoided if the material is free draining. For adequate structural capacity, a soil should be well graded and it should resist deformation (Yoder, 1959, p. 283-284).

The prime purpose of base courses and subbase under flexible pavements is to increase the load capacity by distributing the load through a finite thickness of pavement. Drainage and prevention of frost heave also are important under these pavements (Yoder, 1959, p. 284).

Materials in the Cimarron Valley have been rated according to their suitability as base course material in the environmental geology table (Table I). The highest rating (H) has been given to those materials that are most suitable for base course material. The lowest rating (L) has been given to those materials with the least suitability. A moderate rating (M) has been given materials with only moderate restrictions on their use.

Activities

Light Construction. The term "light construction" refers to most one or two-story buildings without heavy loads inside the buildings. Low shrink-swell potential is desirable for light construction because building loadings generally are not heavy enough to counteract the stresses produced by shrinking and swelling. Bearing capacities may be moderate or high. A small building with a basement should be built in areas where the seasonally high water table is 10 or more feet below the surface. A considerable depth of overburden or high rippability of bedrock is also desirable for light construction with basements. If a building has no basement, seasonal high water tables can be as near to the surface as 4.0 ft. (below the footings). Other requirements for light construction include slope stability for the sides of any excavation, low flood potential to prevent loss of the building, and low seepage potential to prevent problems of excavation, slope stability or drainage, and low erodibility to prevent undermining of the structure.

Heavy Construction. Heavy construction includes factories, heavy industrial plants, and structures three or more stories high. Some structures are heavy enough to counteract moderate or even severe shrink-swell problems. Bearing capacity problems are more critical for heavy construction than for light construction. Other requirements of geologic materials for heavy construction are the same as for light construction (see light construction section).

Excavation. Ease of excavation or the removal of natural materials can be evaluated on the basis of water table position, rippability, flood potential, seepage, depth to bedrock, and slope stability. The occurrence of a high water table, seepage, or flooding can increase excavation costs by 35 to 50 percent or even more. Bedrock requiring blasting can increase costs by four or five times (Way, 1973, p. 69).

Highway Location. Geologic conditions most favorable for highway location include underlying materials with low shrink-swell potential to prevent rapid mechanical deterioration of pavements; low flood potential so that traffic will be able to flow at all times; low erodibility so that highway shoulders will not be washed or blown away; minimal bedrock exposure so that blasting can be kept to a minimum; a water table below grade so that seepage will not be a problem; good slope stability not only for integrity of the highway, but also for minimizing maintenance; and availability of natural building materials near the site of the highway. The ideal highway is designed so that the amount of material excavated is equivalent to the amount of material needed for fills.

Underground Installations. Underground installations include basements, underground garages, or even tornado shelters. Material in which underground installations are located should have low shrink-swell potential to minimize stress on the structure. Moderate permeability is desirable so that water will not pond in the underground installation. A deep water table will minimize problems of drainage from the structure. If bedrock is encountered above the bottom of the excavation, it should be rippable. Flood potential should be minimal. Good slope stability is desirable so that the excavation will require minimum bracing.

Buried Cables and Pipes. Favorable conditions for buried cables and pipes include low shrink-swell potential to minimize movement or disruption of utilities; moderate permeability to provide good drainage away from the pipes; low erodibility so that the utilities will remain buried; deep bedrock or bedrock with a high rippability to minimize excavation difficulties; good slope stability so that trenches for utilities need a minimum of artificial support; and low potential for chemical reaction with the surrounding soil and rock to minimize corrosion and subsequent replacement.

Reservoir or Pond Location. A good pond or reservoir location is usually located in an area of low permeability so that water can be held back and will not seep through the bottom of the reservoir. Generally, a narrow valley for the dam is desirable along with adequate upstream drainage to supply water for filling the reservoir (Case, 1973). A ready supply of relatively impervious borrow material should be nearby for dam construction. The side slopes which will form the embankments of the dam should be very stable to minimize the possibility of dam failure. Materials around the reservoir should have low erodibility so that silt will not fill up the pond.

Solid Waste Disposal. The term "solid waste disposal" refers to the disposal of solid waste in a sanitary landfill. A sanitary landfill consists of an area wherein garbage and refuse are buried daily so that a minimum of pollution results. Sites for a sanitary landfill should be relatively impermeable with a deep water table so that contamination of ground water will be minimized. Relatively impermeable cover material should be available from nearby sites. Seepage into the landfill should not be permitted because such seepage could react with waste to form toxic leachates. If bedrock is present in the landfill, it must be rippable. Preferably, the depth to bedrock should be below the base of the landfill. Flood potential should be minimal because floods could possibly damage the landfill and even float away waste. Slope stability should be good so that the sides of the landfill will not collapse or that the landfill itself might not collapse.

Septic Systems. Septic systems are those systems designed for disposal of domestic waste waters. Septic systems should be in soils with moderate permeability so that waste flows into the ground, though not so permeable that contamination of the ground-water supply results. For the same reason, the water table should be deep. Flood potential should be minimal to prevent contamination of streams. Bedrock should be deep so that contaminated water will not flow to the surface along the soil-bedrock interface.

TABLE I

ENGINEERING CHARACTERISTICS OF STRATIGRAPHIC UNITS ALONG THE CIMARRON VALLEY FROM INTERSTATE 35 TO PERKINS, NORTH-CENTRAL OKLAHOMA

	Parameters										
Geologic Units	Shrink-swell	Permeability	Erodibility	Water-table position	Seepage	Rippability	Slope stability	Flood potential	Compressibility	Bearing capacity	Depth to bedrock
Anthropic deposits	V	V	V	V	V	V	V	V	V	V	V
Loess	L	H	H	NA	L	NA	NA	L		L	V
Colluvium	M-H	L-H	M-H	S-D	M	NA	L	M	M	L-M	S-M
Eolian sands	L	H	H	D	L	NA	H	L	L	L-M	D
Young dune sand	L	H	H	LD	L	NA	H	L	L	L-M	D
Old dune sand	L	M-H	H	D	L	NA	H	L	L	L-M	D
Flood-plain Alluvium along Cimarron	L-D	H	H	S	L	NA	L	H	L-M	L-M	D
Flood-plain Alluvium along tributaries	L-M	M-H	H	S	L-M	NA	L	H	L-M	L-M	D
Lawrie Terrace Alluvium	L	M-H	H	M	L	NA	M	M	L	L-M	D
Perkins Terrace Alluvium	L	M-H	H	M	L	NA	M	L	L	L-M	D
Summit View Terrace Alluvium	L	M-H	H	M	L	NA	M	L	L	L-M	D
Paradise Terrace Alluvium	L	M-H	H	M	L	NA	M	L	L	L-M	D
Permian bedrock Unit 4	L-M	L-M	M	M-D	H	M	M	L	L	M	S
Permian bedrock Unit 3	M	L-M	L	M-D	H	L	M	L	L	H	S
Permian bedrock Unit 2	H	L	M	M-D	M	M	M	L	L	M	M
Permian bedrock Unit 1	L-M	L-M	M	M-D	H	L-M	M	L	L	H	S

H = high
M = moderate
L = low
S = shallow
D = deep
NA = not applicable
V = uncommonly variable

TABLE II

IDEAL ENGINEERING CHARACTERISTICS OF GEOLOGIC UNITS FOR SPECIFIED ENGINEERING PURPOSES

	Parameters										
Uses of geologic materials	Shrink-swell	Permeability	Erodibility	Water-table position	Seepage	Rippability	Slope stability	Flood potential	Compressibility	Bearing capacity	Depth to bedrock
Aggregate	L	NA	NA	NA	L	M-H	NA	NA	L	NA	S
Fill material	L	M	L	NA	NA	M-H	NA	NA	L	NA	D
Base course	L	M	L	NA	NA	M-H	NA	NA	L	NA	S-D
Light construction	L	M	L	M-D	L	M-H	H	L	L	M-H	M-D
Heavy construction	L-M	M	L	M-D	L	M-H	H	L	L	M-H	S-D
Highway location	L	M-H	L	M-D	L	M-H	H	L	L	M-H	M-D
Underground installation	L	M	L	D	L	M-H	H	L	L	M	D
Buried cables and pipes	L	M	L	M-D	L	M-H	H	L-M	L-M	M	M-D
Reservoir or pond location	L	L	L	L-M	L	M-H	H	L	L	H	M-D
Solid waste disposal	L	L	L	D	L	H	H	L	L	H	D
Septic systems	L	M	L	D	L	NA	NA	L	L	NA	D

H = high
M = moderate
L = low
S = shallow
D = deep
NA = not applicable

TABLE III

SUITABILITY OF STRATIGRAPHIC UNITS ALONG THE CIMARRON VALLEY FROM INTERSTATE 35 TO PERKINS, NORTH-CENTRAL OKLAHOMA FOR SPECIFIED ENGINEERING PURPOSES (See Table II for ideal characteristics)

	Uses of geologic materials									
Geologic Units	Aggregate	Fill material	Base course	Light construction	Heavy construction	Underground installations	Buried cables and pipes	Reservoir or pond locations	Solid waste disposal	Septic systems
Anthropic Deposits	V	V	V	V	V	V	V	V	V	V
Loess	-	-	-	0	-	-	-	-	-	-
Colluvium	-	0	-	-	-	-	-	-	-	-
Eolian sand	-	0	-	0	-	0	-	-	-	-
Young dune sand	-	0	-	-	-	0	0	-	-	-
Old dune sand	-	0	-	0	-	0	0	-	-	-
Flood-plain Alluvium along Cimarron	-	0	0	-	-	-	-	0	-	-
Flood-plain Alluvium along tributaries	-	0	0	-	-	-	-	0	-	-
Lawrie Terrace Alluvium	-	0	0	0	0	-	-	0	-	-
Perkins Terrace Alluvium	-	0	0	+	0	0	0	0	-	0
Summit View Terrace Alluvium	-	0	0	+	0	0	0	0	-	0
Paradise Terrace Alluvium	-	0	0	+	0	0	0	0	-	0
Permian bedrock Unit 4	-	0	0	0	0	-	0	0	0	-
Permian bedrock Unit 3	-	0	0	+	+	-	-	-	-	-
Permian bedrock Unit 2	-	0	0	0	0	-	0	0	0	-
Permian bedrock Unit 1	-	0	0	+	+	-	-	0	-	-

V = uncommonly variable
+ = good
0 = fair
- = poor

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