GEOLOGY OF THE YALE SOUTHWEST QUADRANGLE,
PAYNE COUNTY, OKLAHOMA

By

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GEOLOGY OF THE YALE SOUTHWEST QUADRANGLE,

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PREFACE

This thesis is a study of the geology of the Yale Southwest Quadrangle, Payne County, Oklahoma. Detailed study of both the Pennsylvanian sedimentary bedrock and the Quaternary deposits was accomplished by the preparation of a surficial geologic map, a bedrock geologic map, a structure-contour map, a composite stratigraphic section, longitudinal profiles of terrace surfaces, and geologic cross sections.

I would like to thank Dr. John E. Stone, Thesis adviser, for suggesting the problem, assisting in field work, providing helpful suggestions, and editing the manuscript. Thanks are extended to Mrs. Dolores Behrens for the typing of the final draft. Advisory committee members, Dr. Douglas C. Kent and Dr. John D. Naff, made helpful comments and criticisms. Appreciation is expressed to the Oklahoma Geological Survey and the Oklahoma State University, Department of Geology for partial funding of the field work.

Very sincere thanks are extended to my parents, Gerald and Arleen Robbins, and my wife's parents, Kenneth and Ruth Rarey, for their understanding, guidance, and financial support. Finally, I would like to express special thanks to my wife, Elaine, for her patience, understanding, and support throughout my graduate work.

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ABSTRACT

This thesis presents detailed information both on the near-surface Lower- to Middle-Pennsylvanian geology and on the overlying Quaternary geology in the Yale Southwest Quadrangle of eastern Payne County, Oklahoma. The area of study includes approximately 60 square miles, including the Cimarron River Valley from three miles west of Yale, Oklahoma eastward to the Creek County line.

The main objectives of this study are to resolve differences in stratigraphic usage in the area, to map bedrock and Quaternary geology, to reconstruct the geologic history, to provide brief descriptions of oil fields occurring within the area, and to evaluate the possibilities of expanding commercial mineral usage in the area. A few of the problems which may be encountered in future urban and regional planning and development within the Yale Southwest Quadrangle also are discussed.

Geologically, the study area is located in the Central Oklahoma Platform and geomorphically it is located in the Northern Limestone Cuesta Plains Region. The Cimarron River has dominated the development of the topography of the Yale Southwest Quadrangle since the early Pleistocene Epoch, eroding through west-sloping cuestas, depositing six alluvial deposits (represented today by five separate deposits of terrace alluvium and recent flood-plain alluvium), and providing the main source for the extensive eolian deposits present in the area.

Alluvial deposits along the Cimarron River in the study area in order of decreasing age are: the Van Ness Terrace Alluvium, the Paradise Terrace Alluvium, the Summit View Terrace Alluvium, the Perkins Terrace Alluvium, the Lawrie Terrace Alluvium, and flood-plain alluvium. Eolian deposits mapped include dune deposits, which have been divided into two age groups, and an eolian sheet sand. Colluvium is present on the riverward edge of most terrace deposits and on essentially all of the hillslopes underlain by bedrock.

Bedrock stratigraphic nomenclature has been revised somewhat in this study, but new names have not been proposed in order to minimize future complications in the much-needed correlation of some bedrock units with type sections in Kansas.

An attempt has been made to present the basic interpretations reached in this study in such a manner as to be of benefit to geologists, planners, engineers, public servants, builders, and others, who have an interest in the physical environment.

INTRODUCTION

With increasing population and increasing urbanization more emphasis must be given to maximizing the usage of natural resources. Detailed surficial geologic studies usually are very useful and sometimes vital in urban and regional planning and development. This type of study gives insight into the suitability of various areas as locations of towns, subdivisions, farms, sanitary landfills, and construction materials. In addition to this, mapping of sedimentary bedrock may help to explain the distribution of oil and gas wells from deeper horizons. It is hoped that this study will be useful to planners from a variety of professions.

Objectives

The main objectives of this study are to resolve differences in stratigraphic usage in the area, to map bedrock and Quaternary geology in far more detail than has been done heretofore, to reconstruct the geologic history of the surficial geologic units, to provide brief descriptions of oil fields occurring within the area, and to evaluate the possibilities of expanding commercial mineral usage within the area. A few of the problems which may be encountered in urban and regional planning and development within the Yale Southwest Quadrangle also are briefly discussed.

The information and interpretation obtained from this study is presented in such a manner as to be of benefit to civil engineers and soil scientists, as well as to geologists.

Location

The Yale Southwest Quadrangle is located in eastern Payne County. The study area encompasses approximately 60 square miles, including the Cimarron River Valley from three miles west of Yale eastward to the Creek County line (Figure 1). Communities within the area include Yale, Gano, Norfolk, and Schlegel. The area is accessible in the north from the east-west Oklahoma Highway 51 and in the south from the east-west Oklahoma Highway 33, which passes one mile south of the study area. Unpaved section-line roads extend throughout most of the study area except near the Cimarron River and along parts of the Creek County-Payne County line.

Previous Investigations

The bedrock of southeastern and northeastern Payne County has been mapped by Nakayama (1955) and Fenoglio (1957) respectively, on base maps prepared from aerial photographs. Regional bedrock studies have been done by Miser and others (1954) and by the Oklahoma Water Resources Board (1972). All of these studies, however, have been at relatively small scales with little or no emphasis given to Quaternary geology. These studies also showed a lack of consistent stratigraphic usage and inconsistencies in mapped units between differing study areas (see "Bedrock Stratigraphy", p. 23).

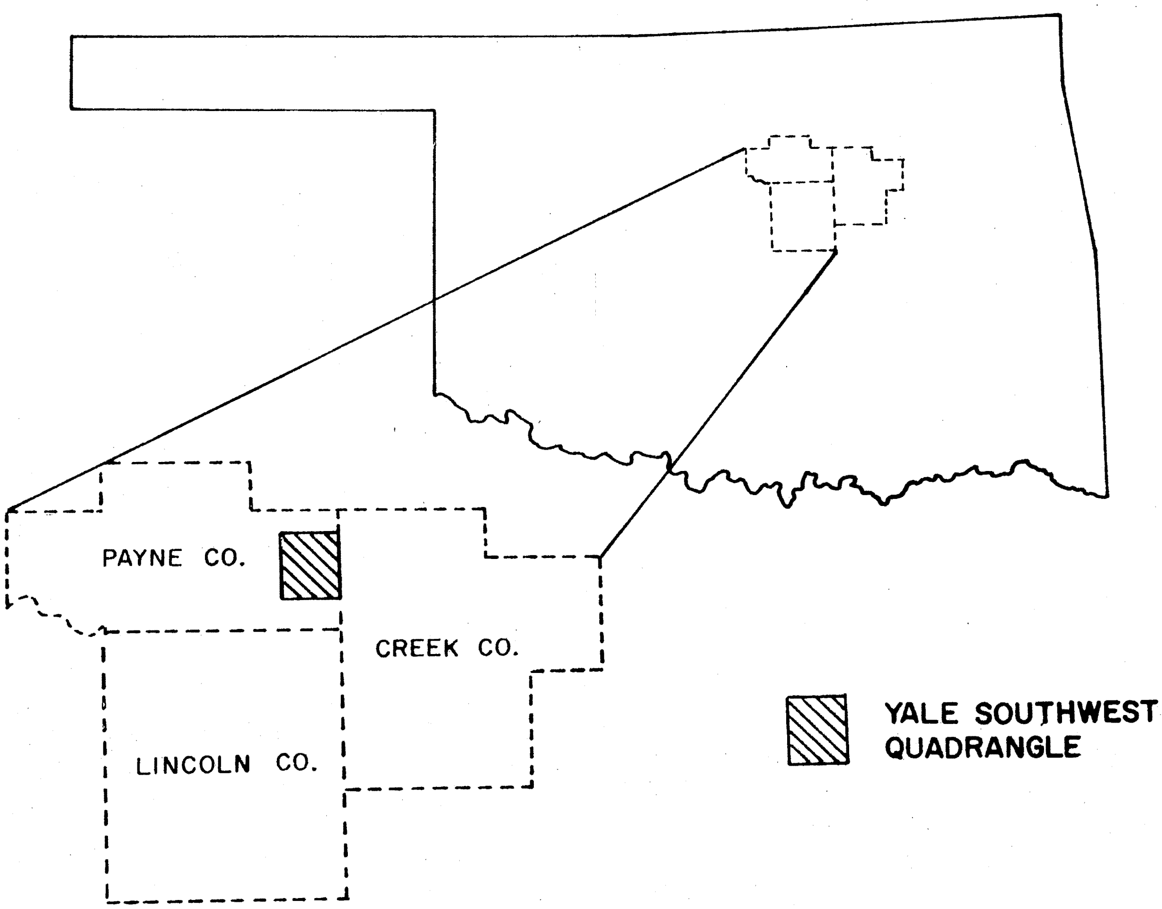

Figure 1.--Map showing location of Payne County and the Yale Southwest Quadrangle in Oklahoma.

Blair (1975) mapped Quaternary deposits along the Cimarron River Valley in western Payne County from Interstate 35 to Perkins, Oklahoma 13 miles upstream from the study area. These deposits have been correlated to the Yale Southwest Quadrangle by the use of longitudinal profiles and surficial geologic mapping. Mapping of the Quaternary deposits between Perkins, Oklahoma and the Yale Southwest Quadrangle is presently being done by an Oklahoma State University Masters' degree candidate, Cyrus Nayyeri.

The soils of the study area have been mapped by Cobb and Hawker (1918) on a relatively small scale. The Soil Conservation Service presently is completing work on a more detailed soils map of Payne County (Mayhugh and Henley, 1979).

Methods of Study

Bedrock formations were mapped by the use of aerial photographs, field observation along section-line roads and stream valleys, the measuring of sections, and the use of a shallow subsurface map drawn on the base of the Lecompton Limestone Member. Mapping of bedrock units in the Yale Southwest Quadrangle proved to be extremely difficult because of the numerous faults, rapid facies changes, and extensive Quaternary cover throughout the area.

Although most of the bedrock units which crop out in this part of Oklahoma long have been "correlated" with bedrock units from northeastern Oklahoma and eastern Kansas, most actually have not been physically correlated with their type sections in Kansas. Thus, many of the formation names routinely used in north-central Oklahoma may not actually correspond to the type sections in Kansas. To minimize future complications in the correlation of bedrock units, formation names used herein are those which have been consistently used in other studies near the Yale Southwest Quadrangle and unnamed units have been left unnamed. Obviously there is an urgent need to carefully correlate various units and subunits in north-central Oklahoma with presumed type sections in eastern Kansas and to change the formal rock-stratigraphic names when necessary. In the author's opinion, unnamed units should not be named until this is done.

Formerly, several sections of sandstones and limestones intermixed with shale have been referred to strictly as shale units (e.g., the Pony Creek, Gano, Harveyville, Auburn, and Severy-Aarde Shales). In this study, these have been referred to as formations or members, and the mappable sandstones and limestones present within them have been referred to as unnamed units and subunits even though they have been mapped. Traditionally, of course, rock-stratigraphic units have been defined on the basis of mappable boundaries. In many cases such units have included more than one lithology which have not been differentiated. In this study a major effort has been made to map major lithologic subdivisions within rock-stratigraphic units.

Quaternary deposits were mapped by the use of aerial photographs, topographic maps, longitudinal profiles, and field work. Topographic maps and aerial photographs were especially useful in delineating flood-plain deposits, the Lawrie Terrace, recent dune deposits, and colluvial deposits. Longitudinal profiles greatly facilitated the correlation of terrace surfaces. Deposits were differentiated on the basis of texture, sorting, structure, coating on grains, and sedimentary structures. Clayey textures generally indicate primary deposition of clays through the settling of suspended particles, or secondary deposition of clays by meteoric water percolation during weathering. Sorting helps, in a general way, to determine the relative distance and mode of transport of the sediments in question. Coating on grains and structure give insight into the amount of chemical and physical weathering which the sample in question has undergone. Sedimentary structures aid in the determination of the direction and mode of transport of Quaternary sediments during deposition.

Detailed mapping of Quaternary deposits helped in the mapping of sedimentary bedrock. For example, several anomalous flood-plain gradients appear to be related to faults in bedrock. The mapping of colluvium, being directly related to the bedrock from which it was derived, occasionally helped in mapping buried bedrock units.

A structure-contour map was drawn on the base of the Lecompton Member of the Pawhuska Formation to establish the regional surface dip (about 40 ft. per mile) and local variations thereof. This map proved to be useful only in a general way, however, because of the "thinning and thickening" nature of Upper Pennsylvanian cyclothemic sediments (see p. 58).

A virtually complete advanced sheet of the Yale Southwest 7½ minute Quadrangle available on special order from the U.S. Geological Survey has been used as the base for the surficial geologic map, the bedrock geologic map, and the structure-contour map.

REGIONAL GEOLOGY

The Yale Southwest Quadrangle is an area of low undulating hills, most of which are capped by sandstone or more rarely by limestone. Shales, underlying the sandstones and limestones, are highly susceptible to weathering and erosion and therefore, underlie most of the shallow valleys. Geologically, the study area lies within the Central Oklahoma Platform, west of the Ozark Province and east of the Nemaha Ridge (Fambrough, 1962) and geomorphically it lies in the southern part of the Northern Limestone Cuesta Plains (Curtis and Ham). The Northern Limestone Cuesta Plains region is described as an area of limestones capping west-dipping cuestas that rise above broad shale plains. The cuestas were formed by erosion of a westward dipping homocline. Present dip on this homocline in eastern Payne County averages 40 ft. per mile or about $.4^{\circ}$ west (Nakayama, 1955). Bedrock at the surface in the study area consists of Upper Pennsylvanian sedimentary rocks.

The Cimarron Valley, two to four miles wide, dominates the topography of the Yale Southwest Quadrangle. Alluvial deposits of the Cimarron River include five terrace deposits and flood-plain alluvium. These deposits are expressed geomorphically in places by smooth, low-gradient depositional surfaces. Eolian deposits are widespread within the study area and cover terrace deposits and bedrock.

STRUCTURAL GEOLOGY

Bedrock at the surface in the Yale Southwest Quadrangle strikes approximately north-south and generally dips westward about 40 feet per mile. The study area is located within the Prarie Plains Homocline, a regional post-Permian structure west of the Ozark dome. Within parts of Pawnee, Payne, and Lincoln Counties the homocline is interrupted by a north-trending belt of en echelon faults and gentle- to moderate- folds. Most of the faults within the en echelon zone trend northwest-southeast (see Plate 5).

Faulting within the western half of the study area has resulted in a general shallowing of dips except in the area of secs. 1, 2, 11, and 12, T. 18 N., R. 5 E. where an anticlinal structure is present. The extreme southeastern part of the study area is characterized by beds which dip sharply to the west forming the west flank of the Cushing oil field in Creek County, Oklahoma (see p. 71). The anticlinal structure, which forms the Cushing oil field, plunges to the north causing beds within the easternmost part of the study area to have a northward dip as well as a westward dip. In the central part of the study area the dip is westward being locally interrupted by gentle folds, characteristic of the regional Prarie Plains Homocline.

Powers (1931) described the gentle anticlinal structures within central Oklahoma, similar to the one in the south-central part of the study area (sec. 20 and 21, T. 18 N., R. 6 E.) as having increasing closure with depth (see Plate 1). He attributed this to the older beds having been uplifted a larger number of times than younger beds. Surface mapping and well data from the top of the Pink Limestone (Lower Pennsylvanian) and Lecompton Limestone Member (Upper Pennsylvanian) show an apparent increasing closure with depth in the structure which forms the Norfolk oil field. This structure (sec. 1, 2, and 11, T. 18 N., R. 5 E. and sec. 35, T. 19 N., R. 5 E.) has a maximum closure of approximately 60 feet within one-half mile on the Lecompton structural horizon (see Plate 1). The large amount of closure appears to be partially influenced by a northwest trending fault which truncates the northeast edge of the structure.

The north-south trending en echelon fault zone, which appears to be related to the Norfolk structure,[1] presently is known to extend from central Lincoln County to northern Pawnee County. Fath (1920) described these faults as being normal faults whose individual trends are at about N.20°W. to N.45°W. with the largest stratigraphic throw being about 130 feet and the greatest length about 3¼ miles. Displacements along this fault zone in Pawnee County have been reported by Greig (1959) to range up to 90 feet. Within the Yale Southwest Quadrangle the largest amount of displacement measured was 40 feet (E½ NE¼ sec. 30, T. 19 N., R. 6 E.). Most faults within the study area, however, displaced the geologic section by only 15 to 25 feet.

Explanations on the origin of this en echelon fault zone have been proposed by Fath (1920), Sherrill (1929), Levorsen (1930), Melton

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[1]Norfolk structure--The name Norfolk structure is being used herein to refer to the anticlinal structure forming the structural trap of the Norfolk oil field (secs. 1, 2, and 11, T. 18 N., R. 5 E. and sec. 35, T. 19 N., R. 5 E.).

(1930), and Tanner (1956). Fath (1920), recognizing a close relationship between regional faulting and folding, attributed the structure to horizontal movement in the basement along pre-existing planes of weakness. Sherrill (1929), Levorsen (1930), and Tanner (1956) attempted to relate the faulting to torsion produced by the Prarie Plains Homocline. Melton (1930) correlated the faulting with Permian Ouachita thrusting. Although Fath (1920) offered the most reasonable explanation, all of these hypotheses were based on torsion theories without consideration of modern tectonic theories.

According to Greig (1959, p. 128), the youngest beds affected by en echelon faulting are of late Wolfcampian age indicating the most recent age of faulting to be at least post-Wolfcampian (Permian). Though no direct evidence of Quaternary faulting was observed within the study area, it is believed that slight recent movement along this fault zone may have occurred. Displacements of 15 to 20 feet in a fault zone active since the Lower Pennsylvanian Period would result in a negligible amount of displacement occurring since the deposition of the oldest terrace (Paradise Terrace). Therefore a lack of recognizable displacements in terrace surfaces corresponding to fault displacements (see Plates 1 and 3) does not necessarily refute the possibility of recent faulting.

GEOMORPHOLOGY

Eastern Payne County is typified by low, undulating hills which are capped by resistant bedrock forming east-facing escarpments. Formation of these cuestas occurred from the erosion of bedrock within the Prarie Plains Homocline.

Topography near the Cimarron River and its tributaries has been drastically modified by the formation of extensive terraces, flood plains, and sand dunes. Deposition of large amounts of alluvium by the Cimarron River at various times formed a source of sand for the formation of the extensive eolian deposits that occur within the study area.

The Cimarron River has characteristics of both a braided and a meandering stream, being characteristically braided during periods of low water flow and characteristically meandering during periods of high water flow (Figure 2).

Erosional Topography

Many bedrock lithologies within the study area erode to produce characteristic landforms recognizable on aerial photographs and topographic maps.

On the topographic map the large shale sections, in particular the Harveyville Member, are represented by characteristic wavy topographic contour lines and on the aerial photographs by deep erosional scars which parallel the hill slopes. Good examples of wavy contour

A. High water level at the W½ of sec. 10, T. 18 N., R. 5 E. during May 1978.

B. Low water level at the N½ of sec. 35, T. 19 N., R. 5 E. during August 1978.

Figure 2.--Photographs of the Cimarron River during high and low water levels.

lines characteristic of the Harveyville Member can be seen on Plates 1 and 5 (NW$\frac{1}{4}$ NE$\frac{1}{4}$ NE$\frac{1}{4}$ of sec. 29, T. 19 N., R. 6 E. and at the W$\frac{1}{2}$ E$\frac{1}{2}$ of sec. 30, T. 19 N., R. 6 E.). Hills capped by large sandstone units form areas of rugged topography which are recognizable on aerial photographs as smooth, irregular grayish surfaces flanked by steep eroded valleys. Vegetation in these regions is primarily concentrated within or around these valleys because of the larger amount of moisture retained within these valleys and the lack of a need for plowing such areas.

Areas of bedrock exposure sometimes can be identified in areas largely covered by Quaternary deposits by the use of both topographic maps and aerial photographs. Drainages within bedrock areas have formed deep eroded valleys, while drainages within areas largely covered by Quaternary deposits have formed shallower, smoother eroded channels. This variation in erosive character is a function of the length of time over which erosion has occurred and of the difference in texture between sedimentary bedrock and unconsolidated Quaternary deposits.

Because drainage systems develop along paths least resistant to erosion, fault and joint patterns play an important role in drainage orientation. Obvious examples within the Yale Southwest Quadrangle include: the fault in sec. 24 and 25, T. 19 N., R. 5 E., which appears to at least partially control the orientation of the Salt Creek tributary; the fault extending from the center of sec. 29 to the center of sec. 30, T. 19 N., R. 6 E. which apparently controls the southern part of the Mud Creek tributary; and the possible fault which extends through sec. 12, T. 18 N., R. 5 E., and sec. 17, 18, and 20, T. 18 N.,

R. 6 E. which may partially control the southern extent of the Cimarron River within the south-central part of the study area.

Intrenched meanders have been well preserved within the Yale Southwest Quadrangle because of the presence of resistant bedrock. In areas west of the study area, intrenched meanders have been destroyed by lateral migration and subsequent erosion of less resistant bedrock.

Meanders within the study area reflect at least two periods of formation, an older period of high-discharge Pleistocene erosion which resulted in the formation of the intrenched meanders encompassed by the present flood-plain and the Lawrie Terrace, and a recent period reflecting the present discharge of the Cimarron River resulting in the development of meanders on the flood plain.

Terraces

Stream-terrace surfaces are recognized on aerial photographs and topographic maps as smooth, low-gradient surfaces. In areas of extensive colian cover, terraces usually cannot be so recognized, and therefore, must be identified in the field. Longitudinal profiles of alluvial surfaces greatly aids in the search for eolian covered terraces (see Plate 2). The distribution of terrace surfaces in the study area is shown on the alluvial surface map of the Yale Southwest Quadrangle (Figure 3). The formally-named terraces within the Yale Southwest Quadrangle are from the oldest to youngest: the Van Ness Terrace, the Paradise Terrace, the Summit View Terrace, the Perkins Terrace, and the Lawrie Terrace.

The author named the Van Ness Terrace for the owners of the land on which the terrace was first identified (S½ E½ SE¼ sec. 28, T. 19 N.,

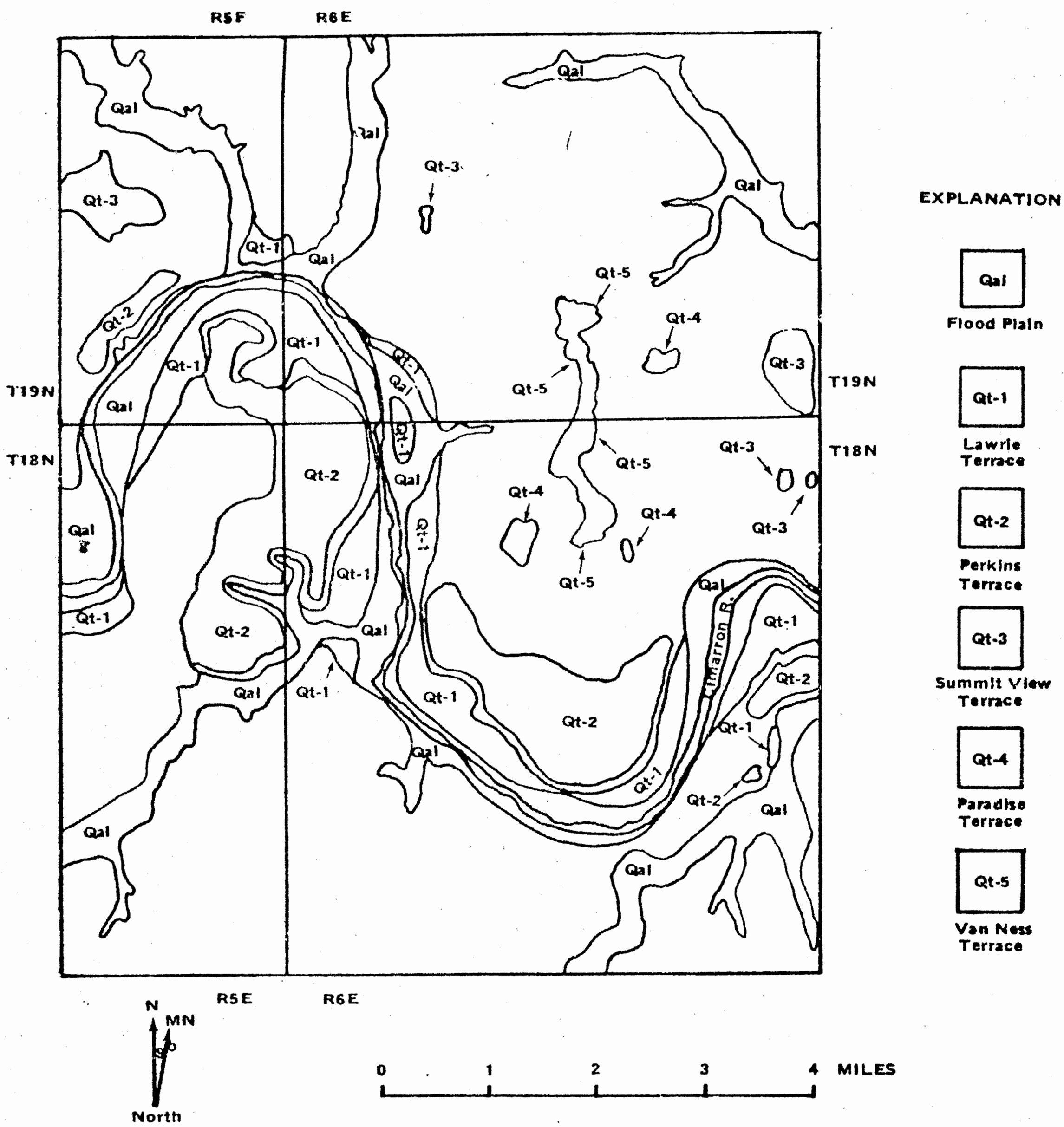

Figure 3.--Alluvial surface map, Yale Southwest Quadrangle, Oklahoma

R. 6 E.). Blair (1975) named the Paradise Terrace for the Paradise Cemetery located three miles northeast of Coyle, Oklahoma and the Perkins Terrace for the town of Perkins, Oklahoma. The Summit View and Lawrie Terraces were named by Meyer (1975) for the Summit View Cemetery northeast of Guthrie, Oklahoma and for Lawrie Creek four miles north of Guthrie.

Van Ness Terrace

The Van Ness Terrace is the highest and oldest terrace within the study area. It is present only within the eastern part of the area where it is expressed by a broad, flat surface extending two miles in a north-south direction (see Figure 3). This terrace has not been recognized upstream from the study area. The large bedrock outcrops west, south, and southeast of the terrace have protected it from erosion within the Yale Southwest Quadrangle (i.e., it can be called a rock-defended terrace; Thornbury, 1969, p. 158).

Paradise Terrace

The Paradise Terrace is the second highest and second oldest terrace within the study area (Figure 3). It is preserved only in the eastern part of the study area, apparently because there it is rock defended as is the Van Ness Terrace (Thornbury, 1969; p. 158). On the south and west it is protected from erosion by 250 ft.-high outcrops of relatively resistant units (the Elmont Limestone Member, the Reading Limestone Member, the Harveyville sandstones, and the Auburn sandstones). On the east it is protected by the Auburn sandstones, the Wakarusa Limestone, and the Bird Creek Limestone (Plate 4). The surficial distribution of the Paradise Terrace is shown in Figure 3.

Summit View Terrace

The Summit View Terrace is the third highest and third oldest terrace along the Cimarron River. It is largely covered by eolian sand and is well exposed only in the northwest part of the Yale Southwest Quadrangle where it covers an area of approximately one-half square mile.

Projection of the Summit View Terrace to the base line used for Plate 2 results in a distorted apparent gradient between base line numbers 20 and 30. This occurs because the axis of the flood plain in Summit View time is different from the axis of the present-day flood plain (and the base line used for Plate 2). Projection of the Summit View Terrace surface onto a base line more closely related to the path of its paleo flood plain results in a gradient similar to other terrace surfaces shown on Plate 2.

Perkins Terrace

The Perkins Terrace is the next-to-lowest and the next-to-youngest terrace recognized along the Cimarron River. It is the most widespread terrace within the study area (see Figure 3). It is well expressed in eight to nine square miles of the Yale Southwest Quadrangle. Sand dunes cover much of this terrace forming a slightly undulating surface or a hummocky surface interrupted by areas of smooth low-gradient slopes.

The gradient of the Perkins Terrace is 2-3 ft. per mile, approximately the gradient of the present flood plain (see Plate 2). A 10 ft. riser borders the riverward side of the Perkins Terrace. This change in slope, which separates the Perkins Terrace from the younger, lower Lawrie Terrace and/or the flood plain, is easily identified on both aerial photographs and topographic maps.

Blair (1975) recognized paleosols representing at least three periods of alluvial deposition within the Perkins Terrace in western Payne County. If these paleosols acted as resistant strata during rejuvenation, thus protecting part of the underlying terrace from erosion, anomalous elevations in terrace surfaces could have resulted. This may provide an explanation for the anomalous terrace in the western part of the study area (sec. 36, T. 19 N., R. 5 E.).

Lawrie Terrace

The Lawrie Terrace is the youngest and lowest terrace within the Yale Southwest Quadrangle. It is the second most widely distributed terrace within the study area, occupying an area of about five to six square miles (see Figure 3).

Distinguishing the Lawrie Terrace from the Cimarron flood plain sometime is difficult because unless the riser between the alluvial surfaces is steep, the six to eight ft. difference in elevation between them is not easily noticed. Generally the riser can be recognized on aerial photographs but usually is not obvious on topographic maps, which have a ten-ft. contour interval. Soil development also helps to distinguish the Lawrie Terrace from the flood plain. The Lawrie Terrace has a fairly well developed soil profile whereas soils on the flood plain either are very poorly developed or are nonexistent.

Sand dunes cover much of the Lawrie Terrace in the southeast quarter of the study area. These dunes are relatively young in age and form ridges on top of the terrace (see Figure 3 and Plate 3).

The Cimarron River has eroded through part of the Lawrie Terrace leaving an isolated section of terrace in NW¼ sec. 5, T. 18 N., R. 6 E. In this area, instead of migrating slowly, the river has completely abandoned a small channel to arrive at its present course.

The gradient of the Lawrie Terrace shown by the longitudinal profile (Plate 2) is essentially the same as the present flood-plain gradient, being approximately two ft. per mile within the quadrangle.

Flood Plain

The width of the Cimarron River flood plain in the Yale Southwest Quadrangle varies from less than one-eighth mile in areas of resistant bedrock to more than one mile in areas of less resistant bedrock. The gradient on the present flood plain is approximately two ft. per mile within most of the study area.

Dunes on the flood plain are generally elongate parallel to the direction of winds which deposited them. Most elongate sand dunes are oriented southwest-northeast, having been deposited by southwest prevailing winds, except in areas protected by huge sandstone and limestone escarpments where deposition apparently was caused by crosswinds.

Distinct changes in the gradients of the flood plains of several streams tributary to the Cimarron are apparent on the longitudinal profile (Plate 2). These appear to represent areas where faulting has resulted in the juxtaposition of a resistant bedrock unit into contact with a less resistant bedrock unit. Four faults apparently have caused gradient changes in the Skull Creek flood plain, and one fault appears to have caused a change in the Mud Creek flood plain (see Plates 1, 2, and 5).

Sand Dunes

Sand dunes have been deposited on all alluvial units within the study area. Young dunes are present on the Cimarron River flood plain and the Lawrie Terrace and relatively old dunes are present on the Perkins Terrace, the Summit View Terrace, the Paradise Terrace, and the Van Ness Terrace.

Topographically sand dunes usually display characteristic rounded, hummocky shapes though some may be considerably more elongate than others. Old dunes above the Summit View Terrace level (sec. 35, T. 19 N., R. 6 E. and sec. 2, T. 18 N., R. 6 E.) generally appear to be more rounded and much larger than those on the edge of the Perkins Terrace (sec. 15, 21, and 22, T. 18 N., R. 6 E.). It is possible that these two groups of dunes were formed during different time periods. Many young dunes present in the study area appear to be noticably more elongate than others. These dunes may have been formed by wind erosion of elongate channel-edge sand bars with redeposition occurring only a short distance downwind (see Plate 3; NW¼ sec. 11 and SW¼ sec. 2, T. 18 N., R. 5 E.; and SW¼ sec. 17 and NW¼ sec. 21, T. 18 N., R. 6 E.).

BEDROCK STRATIGRAPHY

Bedrock stratigraphic nomenclature within north-central Oklahoma has been misused and is widely inconsistent. Bedrock units containing significant amounts of sandstone and limestone have been referred to as shale formations; conflicting local names have been used for regionally consistent, previously named limestones; names have been used to refer to groups of lithologies without designation of rank; and probably most significant of all is the fact that most of the limestones have not been adequately correlated with their presumed type sections in Kansas.

Rock-stratigraphic names for the Upper Pennsylvanian geology used within this study is in accord with that proposed by Branson (1956, p. 122-126 and 1962, p. 431-460). Rock-stratigraphic units containing significant amounts of variable lithologies, however, have been referred to within this study simply as members or formations. For example, the sandstone-shale sequence formerly referred to as the Gano Shale is referred to herein as the Gano Formation. Names have not been proposed for unnamed units in this study in order to minimize future complications in the correlation of bedrock units to type sections in Kansas.

Former studies within eastern Payne County have been primarily concerned with the mapping of marker beds for the purpose of determining structural trends. It is the purpose of this study to describe all of the lithologies observed within the study area and to map all lithologies of significant thicknesses which appear to be continuous within the Yale Southwest Quadrangle.

All of the bedrock in the Yale Southwest Quadrangle is in the Virgilian Series of the Pennsylvanian System. This series contains three groups, the Douglas Group, the Shawnee Group, and the Wabaunsee Group. Within the study area bedrock of the Wabaunsee Group is the most extensive, the Shawnee Group being restricted to a small area in the southeasternmost part of the Yale Southwest Quadrangle. Bedrock of the Douglas Group does not crop out within the study area (see Plate 6 for the rock-stratigraphic classification of the bedrock).

Shawnee Group

The name Shawnee was first applied to beds of lower Virgilian age in Shawnee County, Kansas by Haworth (1898, p. 93). Later, this name was raised to group status by Moore (1932, p. 93).

The Shawnee Group is divided into the Vamoosa and Pawhuska Formations. The Vamoosa Formation is not present within the Yale Southwest Quadrangle and the Pawhuska Formation is present only within the easternmost part of the study area.

Pawhuska Formation

The Pawhuska Formation contains the oldest rocks exposed in the Yale Southwest Quadrangle. Two limestone members are included within the Pawhuska Formation, the Lecompton Member and the Turkey Run Member.

Mappable units cropping out within the study area are the Turkey Run Limestone Member and a lower unnamed, mappable sandstone.

Lecompton Limestone Member.--The Lecompton Limestone Member of the Pawhuska Formation crops out just east of the study area and is not actually exposed within the Yale Southwest Quadrangle. The base of this unit is distinct on electric logs throughout the Yale Southwest Quadrangle and it, therefore, was used as the structural horizon for the structure-contour map of the study area (Plate 1).

The type locality of the Lecompton Limestone Member is near the town of Lecompton in Douglas County, Kansas, where it was originally described by Haworth (1895, p. 278) as being "four closely associated limestones which with the included shale have a thickness of 35 to 40 ft." Descriptions of selected Lecompton outcrops near the Yale Southwest Quadrangle have been made by Shelton and Rowland (1974), Mistretta (1975), and Morganelli (1976). It is described as a carbonate consisting of sequences of limestone, dolomitized limestone, and dolomite with crossbeds and wavy beds.

In north-central Oklahoma the thickness of the Lecompton Member varies from less than one to 35 ft. with areas of local thickening caused by the development of algal mounds (Morganelli, 1976). Areas in which the subsurface elevations on the Lecompton Limestone structure-contour map (Plate 1) do not agree stratigraphically with the bedrock geologic map (Plate 5), may represent areas of local thickening or thinning of the limestone. Examples of such areas are secs. 11 and 14, T. 18 N., R. 5 E.; and sec. 2, T. 18 N. R. 5 E. (see Plates 1 and 5).

Unnamed Member.--This member contains approximately three ft. of yellowish-brown, fissile shale directly underlying the Turkey Run Limestone Member, a 50 ft. section of sandstone which is poorly exposed in western Creek County, and 10 ft. of light gray shale which overlies the Lecompton Limestone Member.

Turkey Run Limestone Member.--This limestone has been classified by Heald and Mather (1919, p. 153) as the uppermost unit of the Pawhuska Formation and was named from exposures in Osage County, Oklahoma. They reported the base of the Turkey Run Limestone Member as being 65 to 70 ft. above the Lecompton Limestone Member, separated primarily by sandstones and described it as "a dark-gray limestone one to three ft. thick... fine grained, thin bedded, hard, and brittle and weathers into smoothly rounded slabs... The weathered surface is generally light gray... On fresh fracture the color is a much darker bluish gray, at some localities almost black".

The Turkey Run Member has been reported east of the Yale Southwest Quadrangle in west-central Creek County by Oakes (1959) as a limestone that weathers brown, is sandy, fossiliferous, and is stratigraphically located approximately 60 ft. above the top of the Lecompton Member. Greig (1959) reported the base of the Turkey Run in Pawnee County to be approximately 75 ft. from the top of the Lecompton and described it as a "single bed of dense gray fossiliferous limestone with subconcoidal fracture and locally well developed vertical joints striking northwest". He reported the thickness of the Turkey Run

Member within Pawnee County to range from 1.5 to 3 ft. Greig (1959) and Russell (1955, p. 37) both reported the occurrence of a thin bed of lignitic coal beneath this limestone in Pawnee and Osage Counties which may be continuous throughout north-central Oklahoma.

Wabaunsee Group

The name Wabaunsee was first used by Prosser (1895, p. 686) in reference to a formation of sedimentary rocks in Wabaunsee County, Kansas. Later, the name was raised to group rank by Moore (1932, p. 94) in reference to the stratigraphic section between the Turkey Run Member of the Pawhuska Formation and the Americus Limestone of the Foraker Formation. Condra (1935, p. 9) restricted the Wabaunsee Group to the section between the top of the Turkey Run Member and the top of the Brownville Limestone Member of the Woodsiding Formation following the lowering of the Pennsylvanian-Permian contact to the top of the Brownville by Moore and Moss (1933, p. 100). Since 1933 many workers have proposed further changes in this contact. Among the most recent of these are Branson (1962, p. 431), Wilson and Rashid (1971), and Clendening (1971) who propose raising this contact to the base of the Wellington Formation.

Severy-Aarde Formation

The name Severy was first proposed by G. I. Adams for a shale section below the Howard Limestone near Severy, Greenwood County, Kansas (Haworth 1898, p. 67). Moore (1936) redefined the Severy as the basal formation of the Wabaunsee Group which extends upward to the base of the Howard Limestone and concurrently proposed the use of the name Severy-Aarde in areas where the Howard Limestone is not present.

In the Yale Southwest Quadrangle, this formation consists of gray shale at the top which grades downward to a yellowish-brown shale. Three sandstones occur within the shale, two of which are 10-13 ft. thick and one of which is 4-5 ft. thick (see Plate 6 for stratigraphic position). The upper sandstone, 40 ft. above the Turkey Run Member, appears to be continuous within the study area.

Bird Creek Limestone Formation

The Bird Creek Limestone Formation, which was named by Heald (1919, p. 216), crops out within the eastern part of the Yale Southwest Quadrangle. It is the lowest marker bed in the Wabaunsee Group.

Within the Yale Southwest Quadrangle the Bird Creek Limestone is a dense, dark-grayish, micritic limestone. Large horizontal burrows occur on the upper weathered surfaces (see Figure 4). Freshly broken surfaces have a "metallic" sheen and subconcoidal fracture with calcite-replaced crinoid stems displaying prominent calcite cleavage. In the northeast quarter of the study area, the limestone becomes oolitic and contains well-developed northeast-southwest and northwest-southeast oriented joints (see Figure 5). Within this part of the study area the Bird Creek Limestone occurs in ledges about three inches thick and is underlain by laminated light-brown silty shale. Limestone within this part of the study area was mapped as the Turkey Run Limestone Member by Fenoglio (1957) but has been called the Bird Creek Limestone in this study because of its stratigraphic relationship to upper and lower

Figure 4.--Typical burrowing in the Bird Creek limestone at E½ E½ E½ section 27, T. 18 N., R. 6 E.

Figure 5.--Photograph of the oolitic facies within the Bird Creek limestone at SW¼ SE¼ section 23, T. 19 N., R. 6 E.

marker beds. Nakyama (1955) also mapped the limestone cropping out in the N½ of sec. 11 and S½ of sec. 2, T. 18 N., R. 6 E., as the Turkey Run. In this study however, it also has been referred to as the Bird Creek Limestone because of its stratigraphic relationship to upper and lower marker beds and its obvious similarity in appearance to the Bird Creek outcrops in the southeastern part of the study area.

Stratigraphically, the Bird Creek Limestone is located about 50 ft. above the Turkey Run Limestone Member and is underlain by the Severy-Aarde Formation which is a gray fissile shale containing three massive bedded sandstones.

The Bird Creek Limestone has been described by Grieg (1959) in Pawnee County, 2½ miles north of the study area, as "a single bed of dense, gray to dark-gray limestone. Weathered exposures are light-brown to gray and have smooth, rounded surfaces. Freshly broken surfaces show a subconcoidal fracture". The limestone ranges "from 1.5 ft.... to less than one ft" in thickness. Within the study area the Bird Creek generally is 1.5 ft. thick.

Hallett Formation

The Hallett Formation was named by Branson (1956, p. 122) for the town of Hallett in Pawnee County, Oklahoma. He defined the formation as "the predominately shale sequence from the top of the Bird Creek Limestone to the base of the Wakarusa Limestone". Within the Yale Southwest Quadrangle, this formation contains two 10-15 ft. channel sandstones separated by reddish-brown and whitish-green shale. The lower sandstone is underlain by reddish-brown shale which grades downward into gray shale (see Plate 6 for stratigraphic position).

Wakarusa Limestone Formation

The Wakarusa Limestone was named by Beede (1898, p. 30) from an exposure along Wakarusa Creek southwest of Topeka, Kansas. This limestone crops out within the eastern part of the Yale Southwest Quadrangle.

Locally, the upper part of the Wakarusa Limestone is a light- to medium-gray, crystalline limestone with some beds of calcareous sandstone containing abundant fusulinids. The central section contains thin ledges of limestone about four inches to one ft. thick underlain by a lower section of thick, nodular, bedded limestone which has surfaces that appear "wrinkled". The Wakarusa is underlain by the Hallett Formation containing reddish-brown and whitish-green shale which weathers to buff-white shale containing numerous small calcareous nodules. Overlying the Wakarusa Limestone is a 10 ft. crossbedded channel sandstone of the Auburn Formation. In the northeast part of the study area (S½ SW¼ SW¼ of sec. 23, T. 19 N., R. 6 E.), a well preserved 1½ ft. tree branch was found within the central part of the Wakarusa. Fusulinids were found in the upper and lower parts of the limestone but not within the central part. This may indicate that the central part of the limestone was deposited nearest to the paleo-shoreline.

Fenoglio (1956) reported the distance from the top of the Bird Creek Limestone to the base of the Wakarusa Limestone to be approximately 35 ft. in eastern Payne County and Greig (1959) reported this distance to be approximately 90 ft. in Pawnee County, Oklahoma. It is the writers' belief that the distance between the base of the Wakarusa and the top of the Bird Creek in the Yale Southwest Quadrangle is

85 ft. In the northeast part of the study area, it appears that much of what was mapped by Fenoglio (1956) as the Bird Creek Limestone in sec. 14, 15, 22, 23, and 26, T. 19 N., R. 6 E. actually is part of the Wakarusa Limestone.

Auburn Formation

The Auburn Formation was named by Beede (1898, p. 30) for exposures in southern Shawnee County, Kansas and later was applied to the section between the Wakarusa Limestone and the Reading Limestone Member of the Emporia Formation by Condra (1927, p. 78). Locally, this formation includes two large channel sandstones about 10 ft. thick, two 1½-2 ft. sandstones, a discontinuous one ft. cornstone ledge, and medium-brown, reddish-brown, greenish-white, and whitish-gray shales (see Plate 6 for stratigraphic position). The sandstone which occurs 20 to 25 ft. below the Reading Member appeared to be continuous within the southern part of the study area and was mapped.

Emporia Limestone Formation

The name "Emporia Limestone" generally has been used informally to represent the section between the top of the Elmont Limestone Member to the bottom of the Reading Limestone Member (Kirk, 1896; Moore and Mudge, 1956). The name does not refer to a clearly defined type section but was applied to a shale-limestone sequence in the vicinity of Emporia, Kansas. Within this study, the term "Emporia Limestone" will be used as a formation name referring to the section of bedrock from the top of the Elmont Member down to the base of the

Reading Member. The section between the base of the Elmont down to the top of the Reading generally has been referred to as the Harveyville Shale (Moore, 1936) and will be referred to herein as the Harveyville Member.

The Harveyville Member contains two mappable subunits, an unnamed limestone located 23 ft. above the top of the Reading Member (designated as Peh-1) and an unnamed sandstone extending from 8 to 15 ft. above the Reading Member (see Plate 6). The unnamed limestone is a discontinuous unit and, therefore, was mapped only where it was observed in the field (see Plate 5).

Reading Limestone Member.--The Reading Limestone Member crops out within the central part of the study area. It is a continuous unit which has been mapped from Kansas through Oklahoma by Robert Faye of the Oklahoma Geological Survey, whose map has been published by the Oklahoma Water Resources Board (1972, p. 20). This limestone was named by Smith (1905, p. 150) for exposures near the town of Reading in Lyon County, Kansas.

The Reading is a reddish-purple, nodular limestone. Fossils weather out on the surface of the rock leaving a thin buff-white coating. Large burrows occur on surfaces within the area near the NE¼ NE¼ sec. 19, T. 18 N., R. 6 E. (Figure 6). In the NE¼ of sec. 5, T. 18 N., R. 6 E., the Reading Member becomes a grayish micrite which weathers dark-gray to black with localized areas of reddish staining. Fossils weather out on the surface of the rock assuming a whitish color.

Brown shale of the Auburn Formation underlies the Reading. This shale is poorly bedded and contains numerous small calcareous nodules.

Figure 6.--Typical burrowing in the Reading limestone at SE¼ SE¼ section 18, T. 18 N., R. 6 E.

In the north-central part of the study area, the Reading Limestone Member is overlain by a calcareous sandstone of the Harveyville Member which is about one ft. thick. The Reading Member lies about 70 ft. above the top of the Wakarusa Limestone. Within the study area, the limestone is consistently about 1½ ft. thick. Greig (1959) reported the thickness of the Reading Member in Pawnee County, Oklahoma to range from 15 to 26 ft. He described this limestone as having a base of "mottled red to gray-green sandy limestone... commonly crinoidal and partly algal", which "becomes markedly more sandy to the south". The top, being separated from the base by two feet of red and gray shale, was described as "gray fusulinid limestone containing interbedded gray shale". Within the Yale Southwest Quadrangle, no limestone ledge was observed two ft. below the Reading. The only unit in the study area which may be correlated to this marker is a sandy, white cornstone bed approximately 5 ft. below the Reading Member at the SW¼ SW¼ SW¼ sec. 21, T. 18 N., R. 6 E. Cornstone forms under evaporitic conditions which would indicate that the lower ledge of the Reading was deposited in increasingly shallower water southward from Pawnee County to the Yale Southwest Quadrangle.

Detailed mapping of the Reading Member in the Yale Southwest Quadrangle indicates the presence of gross inconsistencies in earlier geologic maps of the area. Fenoglio (1956) shows the Bird Creek Limestone, the Wakarusa Limestone, the Reading Limestone Member and the Elmont Limestone Member all to crop out within the NE¼, sec. 29, T. 19 N., R. 6 E. In order for this to be true, approximately 220 ft. of section would have to be contained within 80 ft. of topographic relief which is a structural impossibility (see Plates 5 and 6). Therefore, the rocks in secs. 28 and 32, T. 19 N., R. 6 E. and secs. 5 and 8, T. 18 N., R. 6 E. were mapped as part of the Emporia Formation. It appears that a major facies change occurs within this area, resulting in a change from a nodular, reddish-purple limestone in sec. 29, T. 19 N., R. 6 E. southward to a less nodular and more grayish limestone with only localized areas of reddish-purple staining in sec. 5, T. 18 N., R. 6 E. Surfaces of the limestone within this area generally weather to a black color with fossils weathering out on the surface to a white color.

Harveyville Member.--The Harveyville Member was named by Moore (1936, p. 226) for exposures in southeastern Wabaunsee County, Kansas. It is defined as being the section of shale, sandstones, and thin limestones which extends upward from the top of the Reading Limestone Member to the base of the Elmont Limestone Member. Within the Yale Southwest Quadrangle the Harveyville Member includes two discontinuous limestones one to 1½ ft. thick, two thin sandstones less than two ft. thick, an eight ft. sandstone, and a 13 ft. sandstone (see Plate 6).

Elmont Limestone Member.--The Elmont Limestone Member was named by Beede (1898, p. 30) for the town of Elmont in Shawnee County, Kansas. Moore (1949, p. 185) described the Elmont of southern Kansas as a dense, hard, dark-blue rock, typically a single massive bed, in which fusulinids are prominent.

Within the Yale Southwest Quadrangle the upper part of the Elmont Member contains a gray crystalline limestone about one ft. thick, which sometimes contains large burrows on its surface. The central section of the Elmont is a nodular, reddish-purple limestone which weathers to a buff-white color. The lowest part of the Elmont contains another gray crystalline limestone ledge about one ft. thick. At the NW¼ NW¼ NW¼ sec. 33, T. 19 N., R. 6 E., the entire limestone section is more resistant to weathering, more grayish in color, less nodular and contains only localized areas of red staining. Generally overlying the Elmont Member is a large yellowish-brown to reddish-brown channelized sandstone which cuts into buff-white, reddish-brown, and grayish shale. The Elmont is underlain by about 3-4 ft. of brownish-gray shales and 10 ft. of maroon shale of the Harveyville Member.

Greig (1959) reported the thickness of the Elmont Limestone Member in Pawnee County, Oklahoma to range from 20 to 35 ft. The Elmont is five ft. thick within the north-central and south-central parts of the study area but thins and apparently was not deposited within the southwestern part of the study area.

Earlier mapping of the Elmont Member proved to be consistent throughout most of the study area. What was mapped by Fenoglio (1956) in the SW½ sec. 20, T. 19 N., R. 6 E. as the Reading Member however, actually appear to be the Elmont Member. This limestone outcrop is lithologically similar to other Elmont outcrops and is overlain by a characteristically large channel sandstone of the Gano Formation and underlain by brownish-gray shale of the Harveyville Member. Mapping of the Elmont in sec. 28, T. 19 N., R. 6 E. by Fenoglio (1956) also showed discrepancies similar to those discussed in the previous section on the Reading Limestone Member (see p. 36).

Gano Formation

The Gano Formation was named by Branson (1956, p. 123) for a sandstone-shale sequence northeast of the town of Gano located in the extreme southwest part of the Yale Southwest Quadrangle. This section includes three 1-2 ft. discontinuous limestones, a 1½-2 ft. limestone containing abundant Myalina shells, two 15 ft. channel sandstones, a 3-ft. sandstone, and approximately 30 ft. of shale which grades downward from grayish to buff-white and reddish-brown.

The Gano Formation contains two mappable units, the "Myalina zone" and a lower unnamed sandstone which extends upward from 10 ft. above the Elmont Limestone Member to approximately 25 ft. above the Elmont (see Plates 5 and 6).

"Myalina zone". The term "Myalina zone" was used informally by Nakayama (1955) to refer to the uppermost, poorly consolidated limy mudstone between the Elmont and the Grayhorse Members. The "Myalina zone" has not been mapped in adjacent counties and may be a localized unit.

The thickness of the "Myalina zone" ranges from 2 ft. thick (SW¼ SW¼ SW¼ sec. 11, T. 18 N., R. 5 E.), to less than one-half ft. thick in the northwest part of the study area (NW¼ NW¼ NW¼ sec. 19, T. 19 N., R. 6 E.). This limestone is a poorly consolidated limy mudstone which weathers rapidly. It is light-brown to light-gray in color, with yellowish-brown shells which typically weather out of the limestone (Figure 7). This type of lithology and fossil assemblage is probably indicative of deposition in shallow, muddy water (Wilson; 1975, p. 209).

Figure 7.--Orthomyalina fossils from the "Myalina zone". Collected from the NW¼ NW¼ of sec. 19, T. 19 N., R. 5 E.

Shales underlying the "*Myalina* zone" include a section of medium-gray shale, which in turn is underlain by a section of reddish-brown buff-white, and light-green shale with numerous small calcareous nodules. The "*Myalina* zone" is stratigraphically located 55 ft. above the Elmont Limestone Member (see Plate 6).

Woodsiding Formation

The Woodsiding Formation is the uppermost formation within the Yale Southwest Quadrangle. The name "Woodsiding" was first used by Condra and Reed (1943, p. 43) to refer to the section in southeastern Nebraska extending upward from the base of the Nebraska City Limestone Member to the base of the Brownville Limestone Member. Moore and Mudge (1956, p. 2273) redefined the Woodsiding Formation in Kansas as containing five members, the Nebraska City Limestone, the Plumb Shale, the Grayhorse Limestone, the Pony Creek Shale, and the Brownville Limestone. Branson (1956, p. 122) modified the Kansas definition of the Woodsiding Formation for usage in Oklahoma, including only the interval from the top of the Brownville Limestone Member to the base of the Grayhorse Limestone Member.

Only two members of the Woodsiding Formation are present within the study area, the Grayhorse Limestone Member and the Pony Creek Member.

Grayhorse Limestone Member.--The Grayhorse Limestone Member is continuous within north-central Oklahoma. It has been mapped regionally by Robert Faye of the Oklahoma Geological Survey. His map has been published by the Oklahoma Water Resources Board (1972). Within the Yale Southwest Quadrangle outcrops of the Grayhorse are restricted to the northwest and southwest parts of the area (see Plate 5).

The type section was described and named by Bowen (1918, p. 138) near Ralston in Osage County, Oklahoma. Bowen described the Grayhorse as "a dark brownish-gray, crystalline conglomeratic limestone", containing "numerous small pebbles". He stated that "In most places it contains numerous large fossils of the species _Myalina subquatrata_". In Pawnee County, Oklahoma the limestone ranges in thickness from two to six ft.

Within the study area, the Grayhorse Member consists of an upper thin-bedded, gray, pure micritic limestone with burrowed surfaces and a lower dense, medium- to light-gray micritic limestone with nodular to smooth surfaces. Some localized parts of the Grayhorse become sandy and some contain abundant fusulinids. The Grayhorse Member is generally about five to six ft. in thickness and occurs stratigraphically 15 ft. above the "_Myalina_ zone" within the study area.

Earlier mapping of the Grayhorse proved to be reliable and only minor changes were made by the author.

Pony Creek Member.--The Pony Creek Member was named by Condra (1927, p. 74) for the town of Pony Creek south of Falls City, Nebraska. This member contains bluish-gray and reddish shale and is exposed only in the extreme southwest and northwest parts of the study area. The total thickness of this member was not measured.

QUATERNARY STRATIGRAPHY

Quaternary deposits within the Yale Southwest Quadrangle include fluvial deposits of several ages, eolian deposits of several ages, colluvial deposits of quite different textures, and a few anthropic deposits. These are described herein in their approximate chronological order of deposition (see Plate 2 for relative time relationships).

The geologic names of Quaternary units in this study are in accord with the "Policy of the Minnesota Geological Survey on Nomenclature and Classification for the Quaternary of Minnesota" (Stone and others, 1966). The author named the Van Ness Terrace Alluvium for the owners of the land on which the deposit was first identified (S½ E½ SE¼ sec. 28, T. 19 N., R. 6 E.). Other formal names of terrace alluvial deposits used in this study are from similar theses by Blair (1975) and by Meyer (1975) from farther up the Cimarron Valley. Blair (1975) named the Paradise Terrace Alluvium for the Paradise Cemetery northeast of Coyle, Oklahoma and the Perkins Terrace Alluvium for the town of Perkins, Oklahoma. Meyer (1975) named the Summit View Terrace Alluvium for the Summit View Cemetery northeast of Guthrie, Oklahoma and the Lawrie Terrace Alluvium for Lawrie Creek north of Guthrie, Oklahoma. The type localities of the Paradise, Summit View, Perkins and Lawrie terrace deposits are approximately 30, 40, 16, and 40 miles respectively west of the Yale Southwest Quadrangle.

Quartzite Pebbles and Cobbles

Iron-stained, highly weathered, quartzite pebbles and cobbles are relatively common on the bedrock uplands in the Yale Southwest Quadrangle. These have been reported in western Payne County by Blair (1975) to range up to 10 inches in diameter.

According to Johnson (1971, p. 14), the Pliocene Ogallala and Laverne Formations may have extended into central Oklahoma during the Tertiary Period (Figure 8). Stone (1979), Meyer (1975), and Blair (1975) believe that the Ogallala probably extended entirely across Oklahoma in Pliocene time and that the weathered, iron-stained quartzite pebbles and cobbles are lag from the Ogallala left behind during the long episode of weathering and erosion of the Pleistocene, which eroded away the Ogallala and much underlying bedrock east of the present-day High Plains.

Van Ness Terrace Alluvium

The Van Ness Terrace Alluvium is the highest and oldest terrace deposit recognized within the study area. This deposit is highly weathered and largely dissected.

The relatively unweathered part of this deposit is a dark-brown, to a dark-reddish brown, fine- to medium-grained sand. Mineralogically it is composed principally of quartz, with lesser amounts of feldspar and quartzite. Sedimentary structures within this part of the deposit include horizontal laminae, small scale crossbedding, and fining and coarsening sequences.

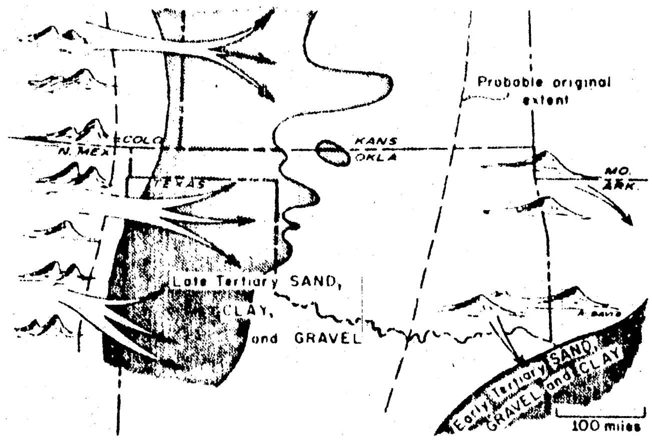

Figure 8.--Map showing the original extent of the Ogallala Formation in Oklahoma according to Johnson (1971). Stone (1979), Meyer (1975), and Blair (1975) believe that the Ogallala originally extended entirely across Oklahoma.

The highly weathered upper part of the Van Ness Terrace Alluvium is a clayey, silty, very fine- to fine-grained sand which has been highly modified by weathering. Mineralogically it is composed principally of quartz with lesser amounts of feldspar and quartzite and contains thin clayey black manganese oxide layers. Carbonate has been leached from the upper 20 to 30 ft. of the deposit. Highly weathered horizontal laminae were the only sedimentary structures observed in the upper 10 ft. of the deposit.

The total thickness of this terrace deposit may be as much as 250 ft.

Paradise Terrace Alluvium

The Paradise Terrace Alluvium is the second highest and second oldest terrace deposit recognized within the study area. It is present only in the eastern half of the study area north of the river where it has been protected from lateral erosion of the Cimarron River by resistant bedrock south, west, and southeast of the deposit.

No deep, relatively unweathered outcrops of the Paradise Terrace Alluvium are exposed in the Yale Southwest Quadrangle. The upper, weathered part of the deposit is a dark-brown to dark reddish-brown clayey, silty, fine- to medium-grained sand which originally was moderately well sorted. The alluvium is composed principally of quartz with lesser amounts of feldspar and quartzite. Carbonate has been leached from the upper 15 to 20 ft. of the deposit which is highly weathered and contains substantial amounts of secondary clay and manganese oxide staining.

The original texture of this deposit has been significantly modified and sedimentary structures essentially destroyed by weathering. The Paradise Terrace Alluvium is so clayey because of weathering that it is quite hard when it is dry. The thickness of this terrace deposit ranges up to 60 ft. in the Yale Southwest Quadrangle.

Summit View Terrace Alluvium

The Summit View Terrace Alluvium is exposed within the easternmost and westernmost parts of the Yale Southwest Quadrangle. It is the third highest terrace deposit in the study area. The upper part appears to be almost as highly weathered as the Paradise Terrace Alluvium.

The relatively unweathered lower part of this deposit is a medium-brown to reddish-brown, fine- to medium-grained calcareous sand, which is moderately well sorted. Mineralogically it is composed principally of quartz, with lesser amounts of feldspar. Horizontal laminae were the only type of sedimentary structures observed in the lower part of the Summit View Terrace Alluvium.

The highly weathered upper part of the Summit View Terrace Alluvium is a clayey, silty, medium-brown to reddish-brown, fine- to medium-grained sand, which has been highly modified by weathering. Mineralogically it is very similar to the lower part being composed principally of quartz, with lesser amounts of feldspar and significant amounts of manganese oxide staining.

The total thickness of the Summit View Terrace Alluvium in the Yale Southwest Quadrangle ranges up to 50 ft.

Perkins Terrace Alluvium

The Perkins Terrace Alluvium is the second lowest terrace deposit along the Cimarron River. This deposit is well exposed because it is the most widespread terrace deposit in the study area and was formed recently enough to be well preserved.

The lower relatively unweathered part of the terrace deposit contains dark reddish-brown to light reddish-brown, medium- to coarse-grained calcareous sand. The upper more weathered part of the Perkins Terrace Alluvium is a dark reddish-brown, silty, fine-grained sand with only sparse occurrences of carbonate within the upper 60 to 80 inches of the deposit. Mineralogically, the upper and lower part of the alluvium is quite similar, both being principally composed of quartz with lesser amounts of feldspar and quartzite.

Excellent exposures of this terrace deposit are located in the sanitary landfill at N½, NW¼, sec. 35, T. 19 N., R. 5 E. and along the road at SE¼, SE¼, sec. 26, T. 19 N., R. 5 E. Sedimentary structures, which include horizontal laminae, small scale cross-bedding, fining and coarsening sequences, and clay drapes are well preserved within these exposures. The thickness of the Perkins Terrace Alluvium in the Yale Southwest Quadrangle ranges up to at least 25 ft. In western Payne County, Blair (1975) reported the Perkins Terrace to range up to 60 ft. thick.

Blair (1975) recognized paleosols representing at least three periods of alluvial deposition followed by prolonged periods of weathering within the Perkins Terrace Alluvium in western Payne County. If these paleosols acted as a resistant stratum during rejuvenation, thus protecting part of the underlying terrace alluvium, they may be responsible for an anomalously low terrace-like area within the Perkins Terrace Alluvium mapped south of the Cimarron in sec. 36, T. 19 N., R. 5 E.

Lawrie Terrace Alluvium

The Lawrie Terrace Alluvium is the lowest terrace deposit in the Yale Southwest Quadrangle. Because the deposit is relatively young and is only slightly weathered, its alluvium is very similar to flood-plain alluvium along the Cimarron River.

The Lawrie Terrace Alluvium is a light reddish-brown to dark reddish-brown, fine- to coarse-grained sand which is composed principally of quartz with lesser amounts of feldspar, quartzite, and some other silicate minerals. The Lawrie Terrace Alluvium has been leached of carbonate only in the upper 20 to 40 inches. No deep exposures of this deposit were observed in the study area.

Sedimentary structures observed in the upper part of the Lawrie Terrace Alluvium are well preserved. They include horizontal laminae, cross-bedding, fining and coarsening sequences, and clay lenses. The thickness of this terrace deposit ranges up to 15 ft.

Flood-Plain Alluvium

Flood-plain alluvium occurs adjacent to the Cimarron River and most of its tributaries in the Yale Southwest Quadrangle. In areas where fine colluvium is present, the Cimarron and its tributaries have a wider flood plain than in areas bounded by heterogeneous colluvium. This is because heterogeneous colluvium is derived from resistant bedrock which hinders the lateral development of flood plains.

Flood-plain alluvium along the Cimarron River consists of light-brown to light reddish-brown, fine- to coarse-grained sand, composed principally of quartz with lesser amounts of feldspar, quartzite, and dark mineral grains. Carbonate has been leached from the upper 5 to 10 inches of the deposit.

Flood-plain alluvium along the major tributaries of the Cimarron consists of light-brown to light-reddish-brown, silty, fine- to coarse-grained sand which is much more poorly sorted than the flood-plain alluvium along the Cimarron River. Minor tributaries, being less competent than either the Cimarron River or the major tributaries, deposit flood-plain alluvium which is still more poorly sorted, and contains more clay and bedrock fragments than the major tributaries.

Sedimentary structures observed within the Cimarron River flood-plain alluvium include medium and small scale cross-bedding, horizontal laminae, coarsening and fining sequences, scour and fill, heavy mineral laminae, and clay drapes. Observed sedimentary structures in tributary flood plains include horizontal laminae and small scale cross-bedding.

Old Dune Sand

Generally, old dune sands are found on the north side of the river and are widely developed within the eastern half of the study area. The positions of these dune sands relative to their presumed alluvial source materials seems to indicate that the prevailing wind direction throughout the Quaternary Period has been essentially the same as it is today, namely southwest. Old dune sand deposits tend to be larger than young dune sand deposits, having accumulated to a maximum thickness of 30 to 35 ft.

Old dune sands are composed of reddish-brown to yellowish-brown, well sorted, fine- to medium-grained sand. This sand presumably has been derived from the Perkins Terrace Alluvium, the Summit View Terrace Alluvium, the Paradise Terrace Alluvium, and older eolian deposits during various phases of eolian activity during the Quaternary. Old dune sand overlies terrace deposits as young as the Perkins Terrace Alluvium and as old as the Van Ness Terrace Alluvium. The Lawrie Terrace Alluvium and the Cimarron River flood-plain alluvium are not overlain by old dune sand. Old dune sand is deeply weathered and sedimentary structures, specifically eolian crossbedding, usually are found only at considerable depth. Secondary structures in old dune sand include filled animal burrows, lamellae, and skeletans. Lamellae probably are formed by the downward movement of water through dune sand causing the migration of clays, finely divided iron oxide, and the like resulting in secondary reddish-brown deposits between the original grains of the sediments. Finely divided iron oxide and clay probably were blown from sediment derived from Permian red beds immediately west of the study area. According to Mayhugh (1979) clays in lamellae within the upper part of eolian deposits are darker and denser than clays in lamellae within the lower part of the deposits. He explains this as the ineffectiveness of average rainfall to saturate the lower part, resulting in a concentration of migrating clays in the upper parts of deposits.

Texture, mineralogy, sedimentary structures, amount of weathering, and morphology of old dune sands indicate at least two ages of deposition. Deep weathering and poor exposures make it impossible to differentiate them consistently in the field at this time. Dune sand on the riverward edge of the Perkins Terrace Alluvium at the W½ W½ W½ sec. 2, T. 18 N., R. 5 E. and the E½ SW½ sec. 15, T. 18 N., R. 6 E. appears to have a much different texture, mineralogy, and morphology than eolian sand on higher terraces. Compared to eolian sand on higher terraces, this dune sand is much less weathered and contains fewer lamellae. Dune sand within the area of sec. 2 and 3, T. 18 N., R. 6 E. appears to have a texture, mineralogy, and overall morphology different from that overlying the Perkins Terrace Alluvium. The division of old and young dune sand into subgroups will require careful consideration of texture, mineralogy, clay mineralogy, weathering, sedimentology (including paleo-wind analysis), and geomorphology.

Young Dune Sand

Young dune sand is most extensive within the easternmost and westernmost parts of the study area, occurring on the north side of the river. The configuration of the Cimarron Valley has had an enormous impact on the deposition of young dune sand within the study area. In the southwest part of the area a northeast facing bedrock escarpment with a topographic relief of approximately 100 feet parallels the present Cimarron River and in the western and central part of the study area, west-facing bedrock escarpments with topographic reliefs of approximately 100 and 150 ft. respectively, parallel the river. These large bedrock escarpments apparently have diverted the prevailing southwest winds causing deposition in preferred areas. Young dune sand generally has accumulated into dunes less than 25 ft. in height.

Young dune sand is composed of light-brown to yellowish-brown, clean, well sorted, fine- to medium-grained sand which has been derived from the present flood plain and the Lawrie Terrace Alluvium. Young dune sands lack well-developed soil profiles and lamellae. These dune sands have been deposited so recently that weathering has been relatively insignificant. Primary sedimentary structures are well preserved consisting mainly of small-scale eolian cross-bedding. Secondary sand-filled animal burrows are fairly common.

Young dune sand deposition appears to have been restricted to the flood plain and the Lawrie Terrace. Thus, no young dune sand can be older than the Lawrie Terrace Alluvium and some probably is only a few years old at most, having been mobilized during recent periods of drought.

It is possible that two or more distinct ages of young dune sand may exist in the study area, but no obvious differences in texture, mineralogy, weathering, sedimentology, or geomorphology were observed in the field.

Eolian Sheet Sands

Eolian sheet sands are tan, very fine- to fine-grained sands which are well sorted and appear to be structureless. These sands generally overlie alluvium of Perkins Terrace age or older. The sheet sand in the southeast part of the study area ($S\frac{1}{2}$ sec. 11, T. 18 N., R. 6 E.) which covers the Lawrie Terrace has been explained by Mayhew (1979) as sand which originally was deposited as sand dunes and later has been redistributed through frequent flooding of the Cimarron River. It is probable that all other sand sheets mapped in the area originally were deposited with remarkably smooth surfaces (i.e., without dune morphology). Most eolian sheet sands appear to have been formed after the deposition of the Perkins Terrace. These sands probably were derived from the uppermost part of the Perkins Terrace Alluvium, which consists of a very fine, reddish-brown to tan sand. Deposition of these eolian sheet sands generally occurred on bedrock and the Perkins Terrace. The thickness of this deposit within the study area ranges from 1 to 10 ft.

Colluvium

Colluvium is material that has moved downslope by creep and sometimes by slope wash. It almost invariably has undergone a significant amount of chemical weathering and usually is extremely weathered. The fine material in colluvial deposits appears "cruddy", contains iron oxide concretions and manganese oxides, has a well-developed platy structure, and sometimes contains bedrock fragments. Usually an extremely fine-grained "shiny" matrix appears to fill the pores between sand grains.

In this study, only colluvial deposits greater than one foot in thickness were mapped (Plate 3). The upslope boundary of terrace colluvium is shown as a dotted contact on the surficial geologic map because of the difficulty in determining how far upslope on terrace edges, colluvium has developed. Three types of colluvium were mapped: heterogeneous colluvium (Qc-1) and fine colluvium (Qc-2) having been derived from bedrock material upslope, and terrace colluvium (Qc-3) having been derived from terrace alluvium and eolian sand upslope.

Heterogeneous colluvium (Qc-1), is a reddish-brown, clayey, silty sand with discrete shale, sandstone, and/or limestone fragments, commonly larger than a few inches in diameter and occassionally larger than 2 ft. in diameter. The fine matrix fraction of heterogeneous colluvium has been derived from alternating sandstone and shale by weathering and mixing of the various components during downslope movement. The coarse fraction is derived from the erosion of shale, and large sandstone and limestone blocks. Heterogeneous colluvium (called blocky colluvium by other workers) is found on steep slopes and on gentler slopes beneath resistant sandstones. Colluvium of this type is highly variable containing from less than 5% cobbles and boulders to as much as 50% cobbles and boulders.

Fine colluvium (Qc-2) is a reddish-brown, clayey, silty sand. Usually all bedrock fragments within this deposit have been completely disaggregated during downslope movement, but occassionally a few fragments of shale and sandstone not greater than 2 inches in diameter have survived. Colluvium of this type is common in areas dominated by alternating thin sandstones and shale in areas of low- to moderate-slopes.

Terrace colluvium (Qc-3) is a brownish, fine- to coarse-grained sand with a trace of silt and clay. Terrace colluvium is primarily derived from upslope terrace alluvium, but often is derived in part, from eolian sand. This type of colluvium commonly occurs on slopes eroded into the older terrace deposits.

Paleosols

Paleosols have been observed underlying alluvium, colluvium, and eolian materials. Such buried soils, of course, are evidence of extended humid periods when the materials from which the soils were developed were exposed at the surface. Thus, paleosols are an important part of the geologic record. Paleosols are so few and so poorly exposed in the study area, however, that they have been considered beyond the scope of this study.

Thin Unmapped Eolian Deposits

Thin unmapped eolian deposits ranging from silty, very fine-grained sand to medium-grained sand occur irregularly at the surface throughout the study area. Such deposits are unmapped where there are largely less than one ft. thick. In some cases these deposits are so recent as to be easily distinguished from the soil and other material underneath. In other cases such deposits undoubtedly have been incorporated into soil and/or colluvium so that they are essentially indistinguishable as eolian.

Anthropic Deposits

Anthropic deposits include community sanitary landfills, private dumps, construction fills, and any other deposits emplaced by Man. Within the Yale Southwest Quadrangle, there are two dumps which service the city of Yale and one large public sanitary landfill west of Yale. Construction fills include dams for small lakes, highway fills, and railroad fills. Only the largest of these were mapped to avoid over-complication of the map (Plate 3). Many hundreds of small anthropic deposits could have been mapped.

PALEOGEOGRAPHY OF THE LATE PENNSYLVANIAN

The Yale Southwest Quadrangle contains at least five cyclic sequences which may be regarded as transgressive-regressive couplets (Shelton, 1973, p. 3, 87, 99, and 102). Trangressive-regressive sequences occur on a much larger scale in the Pennsylvanian sediments of Kansas where they originally were referred to as "cyclothems" (Moore, 1936 and 1949). Cyclothems within the study area appear to be similar to those in Kansas described by Heckel (1977, p. 1047) with the exception of a lack of phosphatic shales and thin coal beds (see Figure 9). The limestone sequences in the study area also are generally thinner than sequences described in Kansas, owing to a regional thinning of limestone southward from there (Heckel; 1977, p. 1061).

A typical example of a transgressive-regressive couplet is represented by the section between the Elmont and Grayhorse Limestone Members (see Plate 6). The middle part of the Elmont Limestone Member is a thoroughly burrowed, thin- to medium-bedded, nodular, reddish-purple limestone, similar to that described by Wilson (1975, p. 26) as being deposited on an open marine neritic shelf and by Heckel (1977) as being deposited in an offshore environment of intermediate water depth (see Figure 9). The lower part of the Elmont of the Yale Southwest Quadrangle is not separated from the upper part by a deep water, phosphatic black shale as described in Kansas cyclothems (see Figure 9), since transgressive sequences probably did not result in water depths

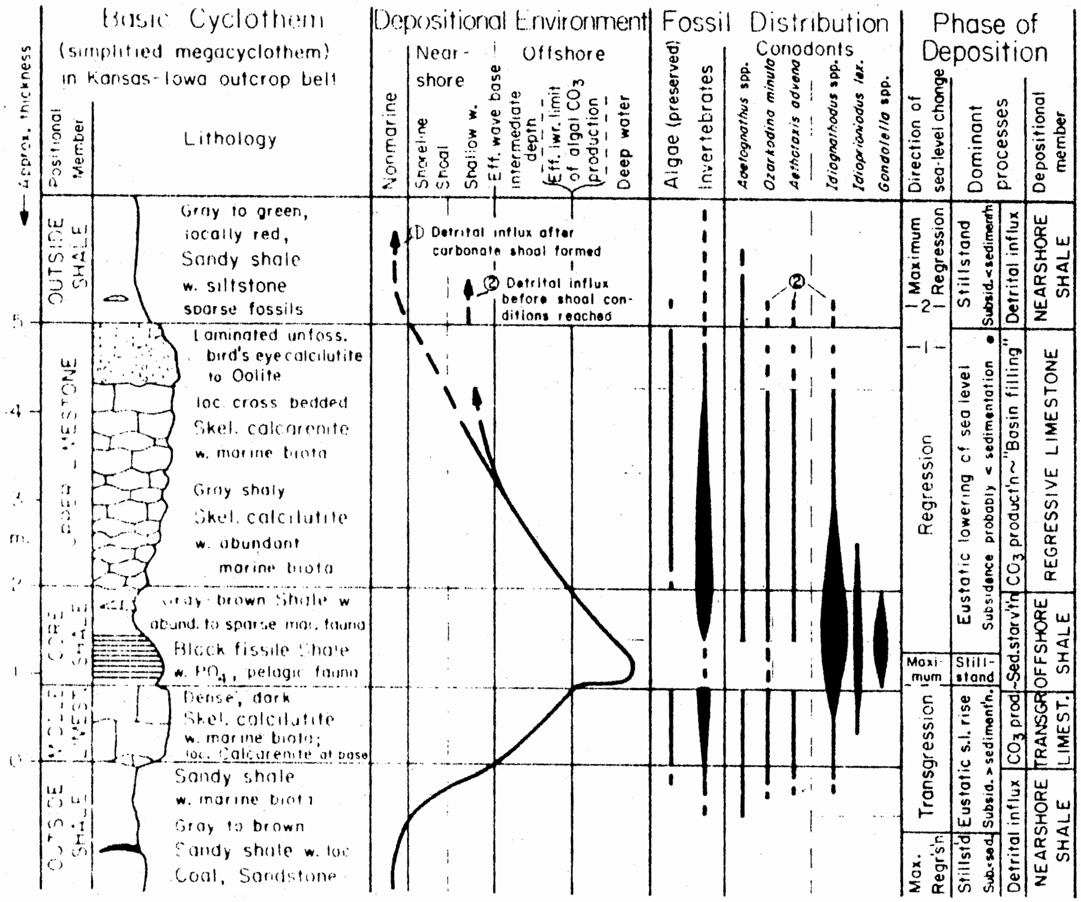

Figure 9.--Basic Upper Pennsylvanian individual Kansas cyclothem sequence (Heckel, 1977, p. 1047).

great enough for the deposition of this facies within the study area. The lower part of the Elmont Limestone Member contains a 1½ ft. dense, resistant limestone which apparently represents the lower transgressive marker (see Figure 9). Below the lower ledge is a 1½ ft. section of brownish-gray shale and a lower 3-4 ft. section of maroon shale which probably was deposited in a shallow marine environment. The sandstone section approximately 10 ft. above the Elmont Member, which contains small-scale crossbedding, massive bedding, and channel-fill sandstone may have been deposited in a nonmarine environment.

The "Myalina zone" is located approximately 55 ft. above the Elmont Limestone Member and 15 ft. below the Grayhorse Limestone Member. This limestone is a limy light-brown to gray mudstone which contains numerous well preserved pelecypod shells (Orthomyalina). Wilson (1975, p. 209) described this type of limestone as being deposited in shallow, muddy water.

The lower part of the Grayhorse Limestone Member, a grayish, dense, medium- to thick-bedded limestone (locally arenaceous) represents the upper transgressive marker (see Figure 9). As in the Elmont Member, the upper and lower parts of the Grayhorse are not separated by a deep water, phosphatic, black fissile shale typical of the Kansas sequences.

Local thinning and thickening of units, and facies changes are numerous within the study area. In the southwest part of the study area, the Elmont Limestone Member changes from a 3 ft. thick, nodular bedded, reddish-purple limestone (SE¼, SW¼ of sec. 18, T. 18 N., R. 6 E.) westward to a 1½ ft. thick, medium-gray to brownish-gray, iron-stained, arenaceous limestone (SW¼ of sec. 13, T. 18 N., R. 5 E.). South of this area, the Elmont Limestone Member apparently was not deposited. Within the north-central part of the study area, the Elmont changes from a reddish-purple, nodular limestone southward to a medium- to dark-gray, more resistant and less nodular limestone. South of the Cimarron River, the Elmont is a reddish-purple limestone similar to that in the north part of the study area.

The Reading Limestone Member changes from a reddish-purple limestone with a thin buff-white coating in the north and south parts of the study area, to a grayish micrite containing a black coating with localized areas of red staining, in the central part of the study area.

The Bird Creek Limestone changes from a dense, dark gray, thoroughly burrowed limestone underlain by a gray-fissile shale in the southeast part of the study area (N½ N½ N½ sec. 11, T. 18 N., R. 6 E.), to a light brown, oolitic limestone underlain by brown silty shale in the northeast part of the study area indicating deposition in a higher energy and shallower water environment in the northeast part of the study area (S½ S½ S½ sec. 23, T. 19 N., R. 6 E.; see Figure 6).

GEOLOGIC HISTORY

Displacements along the north-south trending en echelon fault zone in the western part of the study area were initiated at least as early as early Pennsylvanian time. Verish (1978) recognized an abrupt thinning and thickening of Lower Pennsylvanian units along the en echelon fault zone in Lincoln County, immediately south of Payne County. An increase in closure with depth in north-central Oklahoma structures has been reported by Powers (1931), suggesting that anticlinal folding and faulting may have occurred concurrently in the study area.

In late or post-Permian time, the Mid-Continent region was tilted sligFtly westward forming the Prarie Plains Homocline (Greig, 1959). Truncation of the homocline by erosion followed, resulting in a topography probably quite similar to the present-day topography but developed higher in the stratigraphic section and probably at a higher elevation.

Development of the present east-flowing drainage system throughout Oklahoma initially occurred during the Tertiary. The Ogallala Formation, a thick blanket of sand and gravel, was deposited by east-flowing streams which were eroding sediments from the Rocky Mountains during the Pliocene. During this period the Rockies were virtually buried in their own debris and most of the bedrock surface from the Rockies to the Gulf of Mexico (including the Yale Southwest Quadrangle) probably was covered.

Early in the Pleistocene the overloaded streams depositing the Ogallala apparently became large meandering degrading streams (e.g., the Cimarron River) which were superposed through the Ogallala deposits onto the underlying bedrock producing large intrenched meanders reflecting the very high discharges of the streams. During this period the Ogallala was largely eroded away except in the area of the High Plains of today stretching from Texas to South Dakota. In the study area pebbles and cobbles derived from the Ogallala lagged behind on the evolving bedrock erosion surface. Only the quartz and quartzite pebbles and cobbles, however, have survived the long period of weathering since that time. Such lag usually is found on the bedrock surface in interfluvial areas or beneath younger eolian deposits.[2]

After the Cimarron River was intrenched its valley was completely filled with the Van Ness Terrace Alluvium. The Van Ness, Paradise, Summit View, Perkins, and Lawrie Terraces were formed during the Pleistocene. Distribution of these terraces and their related deposits within the Yale Southwest Quadrangle generally show a gradual southward shift from the oldest (Van Ness) to the youngest (Lawrie). Cyclic, humid-arid climatic fluctuations related to the cyclic cool-warm fluctuations during the Pleistocene Epoch probably account for the periodic rejuvenations along the Cimarron Valley.

Periodic development of large, broad flood plains and strong southwest winds favored the periodic development of sand dunes mostly

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[2]An alternative explanation is that the quartz and quartzite pebbles and cobbles may be lag from early Pleistocene terrace alluvium deposited earlier and higher than any recognized so far.

north and east of the Cimarron during the Quarternary Period. Dunes, though believed to be of at least three separate ages, have been divided into two age groups in this study. The younger group was formed sometime between the deposition of the Lawrie Terrace Alluvium and the present Cimarron River flood-plain alluvium, while the older group was formed between the deposition of the Van Ness Alluvium and the Perkins Terrace Alluvium. Since the deposition of Pleistocene dune sands, prevailing winds apparently have not shifted significantly.

Most of the eolian sheet sands were formed after the deposition of the Perkins Terrace Alluvium. The formation of sheet sands apparently occurred on large, relatively flat slopes such as some of the remarkably smooth colluviated slopes developed on shales or old, highly weathered terrace alluvium. Even under such conditions the slopes must have been virtually free of all vegetation.

The formation of the recent Cimarron River flood plain and its tributaries occurred during the Holocene. Relatively broad flood plains have been developed in areas underlain by less resistant rock such as shale, and relatively narrow flood plains have been developed in areas underlain by resistant rock such as sandstone or limestone.

ENVIRONMENTAL GEOLOGY

Consideration of environmental parameters is important in agricultural, hydrologic, and engineering endeavors. The number and area of man-made structures in the Yale Southwest Quadrangle undoubtably will increase in the future due to population growth and the expansion of urban areas.

The following section presents some of the problems which planners, engineers, politicians, and even the average citizen may encounter in the Yale Southwest Quadrangle in the future and briefly discusses a few of the factors which should be considered when dealing with these problems.

It should be stressed that all mapping done in this study is at a relatively small scale and that the comments made in this section are generalized. Environmental endeavors and construction of all kinds normally would require a detailed site investigation.

Engineering Geology

With increased urbanization in the Yale Southwest Quadrangle, urban and regional planning will become increasingly necessary. Problems with flooding, the leaching of effluents from sanitary landfills, the instability of foundational materials, and the need for construction materials must be recognized and planned for to minimize their environmental impact.

Problems Along Streams

Because of the relatively frequent flooding of the Cimarron River and its tributaries, considerable planning should be undertaken before roads, bridges, railways, and pipelines are to be built near the river. Normal migration of stream channels and catastrophic changes in channels during floods often threaten the works of Man. For example, eastward migration of the river has resulted in partial erosion of the north-south road at the rivers' edge, 3½ miles south of the city of Yale at sec. 32, T. 19 N., R. 6 E. Bridges over the Cimarron River, which have failed since 1955 due to flooding, include an east-west bridge which was located at the south line of sec. 26, T. 19 N., R. 5 E. and a north-south bridge located at the west line of sec. 21, T. 18 N., R. 6 E.

Waste Disposal

Sites of waste disposal in the Yale Southwest Quadrangle should be more carefully chosen than they have been in the past. The Yale sewage lagoon and trash dump both are located on the flood plain of Mud Creek which drains directly into the Cimarron River. A large sanitary landfill is located in terrace alluvium and eolian sand, adjacent to a small tributary which drains directly into the Cimarron River one-fourth mile from the landfill in the NW¼, sec. 35, T. 19 N., R. 5 E. Terrace alluvium and eolian sand are very permeable so that effluent readily pollutes ground water and commonly finds its way into surface streams.

The most satisfactory site for a future sanitary landfill within the Yale Southwest Quadrangle would be within a highly impermeable shale unit above the water table or zone of saturation, and located as far from stream drainages as possible. Because of the numerous permeable channel sandstones within the shale sections of the study area, no really excellent locations for sanitary landfills exist within the Yale Southwest Quadrangle.

Foundation of Structures (Including Highways)

Factors such as slope stability, the rippability of bedrock, the shrink-swell potential of clayey materials (especially colluvium and shales), and frequency of flooding must be considered before selecting sites for structures of any kind. The engineering characteristics of Quaternary units in the Cimarron Valley in western Payne County have been reported by Blair (1975, p. 56-58). In most cases these units correspond to equivalent units in the Yale Southwest Quadrangle. Thus, if care is used, the environmental and engineering judgements made by Blair (1975) can be applied to the study area.

Soils

Soils underlain by terrace and flood plain alluvium are the most fertile and agriculturally productive soils within the study area (Oakes; 1906, p. 10). The formation of steep, resistant bedrock escarpments by erosion and the deposition of extensive eolian sands on the top of terrace alluvium, has produced soils of relatively low agricultural productivity.

A soil map of Payne County presently is being completed by Mayhugh and Henley of the Soil Survey of the Soil Conservation Service (USDA) which among other things will show the productivities of soils within the study area. This map is scheduled to be published in 1982.

Hydrogeology

Because of the probability of population growth in rural areas such as eastern Payne County, new water resources for agricultural, commercial, and private use will have to be developed in the future. Further development of ground water and the building of pipelines to large surface reservoirs appear to be plausible. Regional studies on the development of future water resources have been published by the Oklahoma Water Resources Board (1972 and 1975).

Surface Water

Surface water within the Yale Southwest Quadrangle area, in general, is too poor for irrigation or municipal use. The Cimarron River usually contains more than 1,000 ppm dissolved solids, more than 250 ppm sulfate, and above 250 ppm chloride (Oklahoma Water Resources Board, 1972, p. 107). The nearest suitable source of surface water is Cushing Lake, which covers an area of approximately one square mile and is located approximately seven miles south and ten miles west of Yale, Oklahoma. Presently, there are no pipelines from this lake to Yale.

Subsurface Water

The most favorable areas for ground-water supplies in the Yale

Southwest Quadrangle are found within terrace and flood-plain alluvium. These wells yield from 1,000 gallons of water per minute to less than 50 gallons per minute, the average being between 100 and 300 gallons of water per minute (Oklahoma Water Resources Board; 1972, p. 95).

The public water supply for Yale, Oklahoma is supplied from wells in the Vanoss, Ada, and Vamoosa Formations, and from wells in alluvial deposits (Havens and Bergman; 1976, p. 73 and 74). Chemical analyses of public water supplies done by the Oklahoma Water Resources Board (1972) in July 1964 indicated that the Yale public water supply contained an average of 97 ppm calcium, 264 ppm chloride, 23 ppm sulfate, and 610 ppm total dissolved solids. The U. S. Public Health Service (1962) recommends that drinking water contain less than 250 ppm chloride, less than 250 ppm sulfate, and less than 500 ppm total dissolved solids.

Gould (1905, p. 12 and 13) reported the occurrence of two natural springs in the vicinity of the study area, one being within the southwest part of the quadrangle in sec. 23, T. 18 N., R. 5 E., and the other 1½ miles north of the study area in sec. 9, T. 19 N., R. 6 E. These springs are too small for municipal use but may be large enough for some private purposes.

Temporary contact springs probably are very common in the Yale Southwest Quadrangle. Erosion or even wetting of subbase material by springs can be extremely detrimental to both paved and unpaved roads. Roads should be constructed in such a way that the effect of springs will be minimized.

ECONOMIC GEOLOGY

Petroleum is the most important geologic resource in the Yale Southwest Quadrangle. Other possible economic resources occurring within the study area include limestone for building stone and crushed rock, and sand with minor amounts of gravel for construction use.

Petroleum Resources

Major oil fields within the Yale Southwest Quadrangle include the Yale-Quay, Cushing, Norfolk, Gano, North Schlegel, and Northwest Schlegel oil fields. Brief descriptions of each of these fields are presented in Table 1.

Most fields in the Yale Southwest Quadrangle appear to have been formed either by a combination of stratigraphic and structural entrapment or simply by structural entrapment (see Table 1). The north-south trending en echelon fault zone and localized gentle to moderate folds have formed the necessary requirements for the development of structural traps. Lateral variations in Lower Pennsylvanian sediments probably are very similar in character to Upper Pennsylvanian rocks which crop out at the surface in the Yale Southwest Quadrangle. Thinning and thickening of sandstones, the localized depositon of sandstone lenses, and lateral variations in permeability, all common characteristics of the Pennsylvanian sediments mapped in the study area, would provide numerous locations favorable for the entrapment of oil within

FIELD	LOCATION	DISCOVERY YEAR	PRODUCING FORMATIONS	PROBABLE TRAPPING MECHANISM	CUMULATIVE OIL PRODUCTION TO 1/1/76
Cushing Field (major part of field located in Creek Co.)	Sec. 14, 23, and 26, T.18N., R.6E. (Extends eastward into Creek Co.)	1912	Layton sand, Jones sand, Cleveland sand, Wheeler sand, Prue sand, Skinner sand, Red Fork sand, Bartlesville sand, Tucker sand, Dutcher sand, Misener sand, Wilcox sand, Arbuckle limestone	Anticlinal Structure	465, 745, 542 barrels
Norfolk Field	Sec. 35, 36, T.19N., R5E and Sec.1, 2, 3, 10, 11, 12, T.18N., R.5E.	1916	Prue sand (1916) Wilcox sand (1916) Cleveland sand (1955) Red Fork sand (1955) Cottage Grove sand (1963)	En Echelon fault zone truncating Anticlinal Structure	2, 518, 066 barrels
Yale–Quay Field	Sec. 23, 24, 25, and 26, T.19N., R.5E. (Extends northward to Pawnee Co.)	1914 (Southward extent near Yale discovered in 1944)	Bartlesville sand (1944) Prue sand Red Fork sand (1949) Lower Skinner sand (1951)	Faults, small structures, and lateral variation in reservior rocks.	2, 518, 066 barrels
North Schlegel and Northwest Schlegel Field	Sec. 2 and 3, T. 18N., R.6E., and Sec. 34 and 35, T.19N., R.6E.	1951	Prue sand Skinner sand Red Fork sand Mississippi limestone Wilcox sand	Small structures and lateral variation in reservior rocks.	1,087, 796 barrels
Gano Field	Sec. 23, 24, 25 26, and 27, T.18N., R.5E.	1952	Misener sand Cleveland sand	Faults, small structures, and lateral variation in reservoir rocks.	78,170 barrels

Table 1.--Brief descriptions of oil fields within the Yale Southwest Quadrangle.

the subsurface extension of this part of the geologic section.

Limestone and Sand Resources

Limestones within the study area are generally not consistently thick enough for use as commercial building stone. The Turkey Run Limestone is 3½ ft. thick, the Bird Creek Limestone is 1½ ft. thick, the Wakarusa Limestone is 6 ft. thick, the Reading Limestone is 1½ ft. thick, the Elmont Limestone is 5 ft. thick, the "Myalina zone" Limestone is 2 ft. thick, and the Grayhorse is 5 ft. thick. In some areas, the Wakarusa and Grayhorse Limestones may be consistently thick enough for use as building stone, but other limestones such as the Lecompton, which is 12 to 13 ft. thick in Creek County and the Neva, ranging up to 21 ft. thick in northern Pawnee County immediately northeast of the study area, are consistently thicker and are therefore more desirable for development. Many of the thin limestones within the study area, however, could be used as crushed rock for the surfacing of roads, providing they occur near enough to the surface for stripping to be economically feasible.

The purest deposits of sand are young eolian dune sand deposits. Old dune sands have previously been mined commercially in the W½, W½, W½, sec. 2, T. 18 N., R. 5 E. and young dune sands have been mined commercially in the NW¼, NW¼, sec. 11, T. 18 N., R. 5 E. Unmined dune sand deposits which appear to be most favorable for future commercial development are located in sec. 15, 21, and 22, T. 18 N., R. 6 E.

Though flood-plain alluvium is a good source for sand and gravel, it apparently has not been used commercially in the Yale Southwest Quadrangle. Flood-plain alluvium contains coarse-grained sand and gravel not present in dune sand. It is also somewhat more clayey than dune sand, but it can be washed after dredging to produce sand cleaner than dune sand. This method presently is being used commercially in other areas in north-central Oklahoma along the Cimarron River (Blair, 1975 and Meyer, 1975).

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