GEOLOGY FOR LAND-USE PLANNING OF THE MUSKOGEE AREA, MUSKOGEE COUNTY, OKLAHOMA

By

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AREA, MUSKOGEE COUNTY, OKLAHOMA

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ABSTRACT

The purpose of this study is to contribute to efficient land-use by documenting the geology of the Muskogee, Oklahoma area in a manner that will allow the geologic information to be understood and used by the public. Five maps show the existing geologic elements of the area and the factors that will effect the planning and development of the area: (1) an Environmental Geology Map, (2) a Land-resource Capability Map, (3) a Current Land-use Map, (4) a Relief Map, and (5) a Flood-prone Areas Map. The study area is in the northeastern corner of Muskogee County; it incorporates about 120 square miles.

The Environmental Geology Map is a map of rock units: shale, sandstone, limestone, interbedded sandstone and shale, interbedded limestone and shale, terrace deposits and flood-plain alluvium. This method of mapping, as compared to mapping of formal stratigraphic units, is considered to be more useful to the public. The map represents what rock one should find in outcrops and what rock may be expected to be encountered beneath the soil.

The Land-resource Capabilities Map incorporates soil units and man-made units along the rock units and presents a realistic description of the field situation. The mapping units are classified according to thickness, engineering properties, chemical properties and physical properties of the soil. From these classifications the units are rated for specific uses of the land.

The Current Land-use Map shows the current general uses of the

area's land, and the Relief Map shows the major features of the topography. The Flood-prone Area Map shows the 100-year floodplains; it will be useful as urban development extends along the streams.

These five maps are intended for use in a broad, regional study of the Muskogee area. They are not of sufficient detail to be used in making the final commitment of a tract of land.

INTRODUCTION

Location of the Study Area

The study area is located a short distance to the west and south of the city of Muskogee, in Muskogee County, Oklahoma (Fig. 1). The Arkansas River constitutes the northern boundary of the study area. The study area is bounded on the east by longitude 95^{o} 15' and the Arkansas River (Fig. 1). The area includes Townships 14 and 15 North, Ranges 18 and 19 East.

Previous Work

The earliest published geological work concerning the Muskogee area was by Drake (1864), who discussed the coal fields of the Indian Territory. The United States Geological Survey Folio 132 (Taff, 1906) of Muskogee (sic) County was the most complete geologic description of the area for a long time. A geologic map of the Muskogee-Porum district (Wilson, 1937) and mapping within the study area by Gregware (1958) and Bell (1959) were sources of much information used in this report.

Base Map

The scale of the base map is 1:62,500 (approximately 1 inch to 1 mile). The base map was constructed from advance film positives of unpublished 7½-minute topographic maps of the Muskogee area, (Fig. 2) made by the U.S. Geological Survey. The film positives were joined and

INDEX MAP OF OKLAHOMA

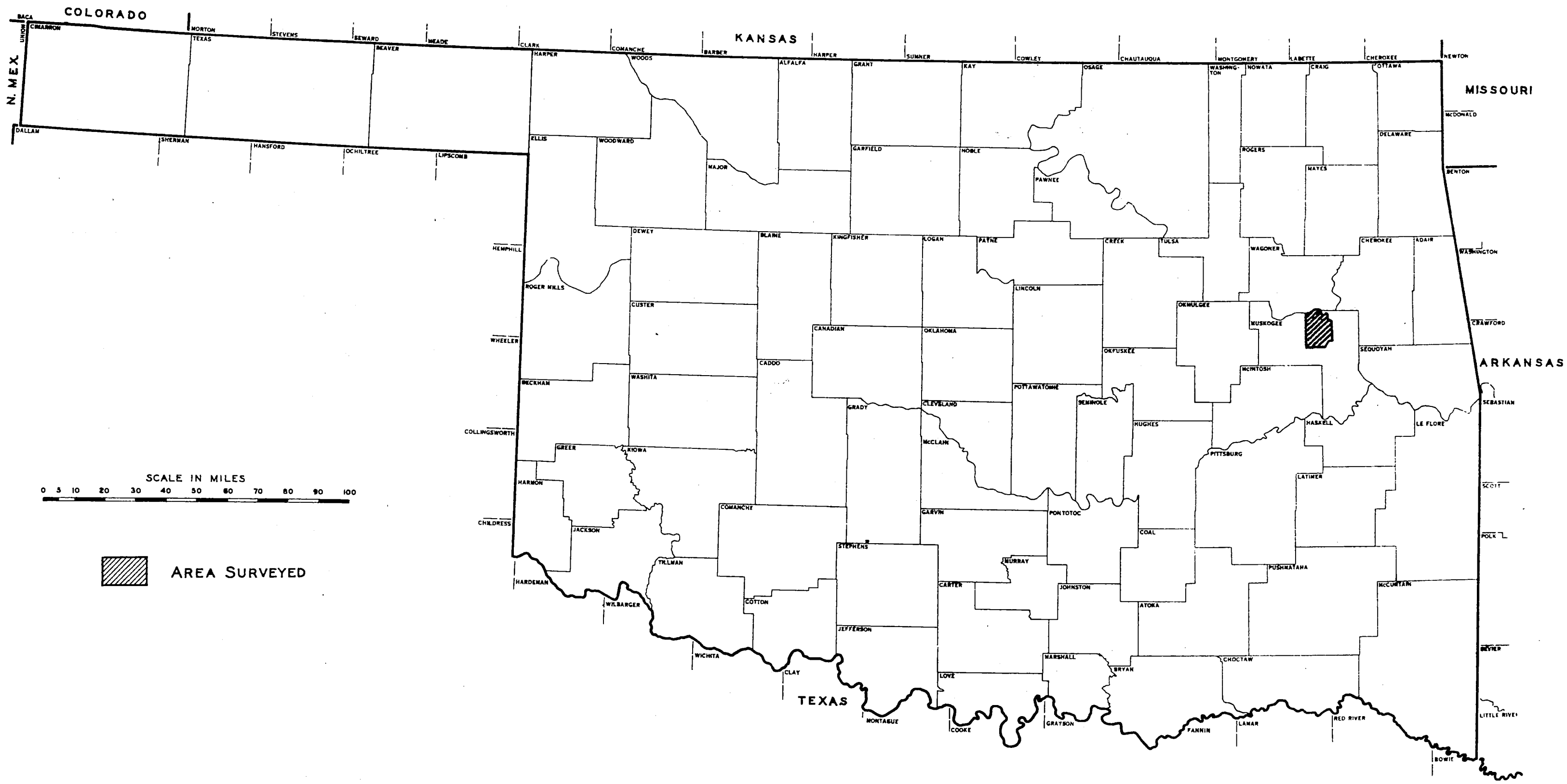

Figure 1.--Location of the study area.

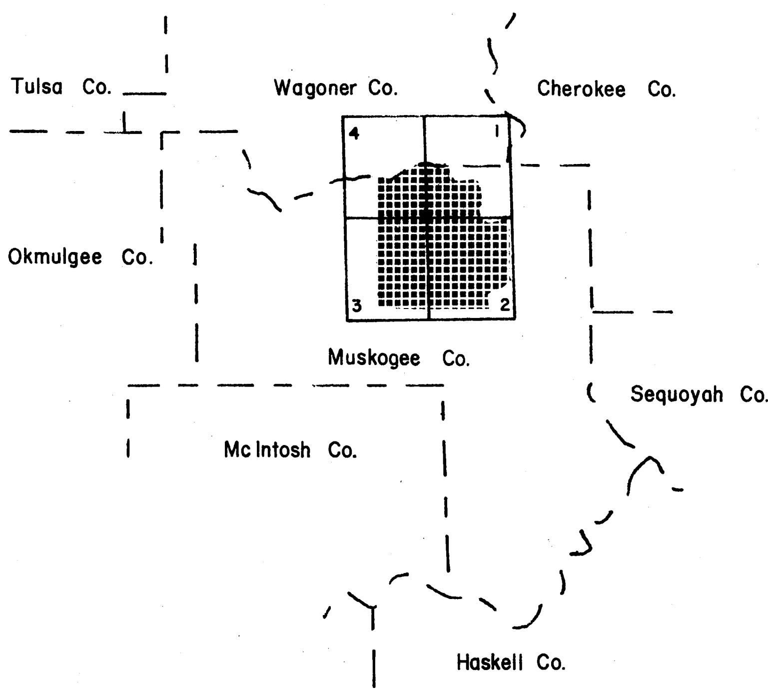

Figure 2.--Locations of advanced line prints of topographic maps used for construction of the base map (modified from U.S. Geological Survey, 1972).

reduced photographically to 1:62,500.

Acknowledgements

The author is grateful to many people who have given encouragement and help during the study. The author is especially grateful to Dr. Gary F. Stewart who supervised the investigation and made it the most satisfying learning experience of the author's life. Dr. Douglas C. Kent, and Dr. John W. Trammell, Department of Geology, and Dr. T.H. Silker, Department of Forestry were gracious in serving on the author's committee. Sincere thanks is extended to Dr. Silker, who unselfishly assisted in the field work, and to Paul Droll who did the drafting on many of the illustrations and plates.

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The greatest thanks goes to Susan, my wife. She provided love, faith, encouragement, hard work and our beautiful daughter, Melissa, who made this effort meaningful.

Geographical Information of the Muskogee Area

In 1970 the population of Muskogee County was 59,542; the population of the city of Muskogee was 37,331. Estimates of the population of Muskogee County in 1970 vary from 59,200 to 69,200 (Muskogee Chamber of Commerce Population Potential, 1970).

The city of Muskogee is approximately 50 miles southeast of Tulsa, Oklahoma; it is served by U.S. Highways 62, 64, and 69, and Oklahoma Highway 16. The Muskogee Turnpike connects with Interstate 44 at Tulsa and Interstate 40 at Webbers Falls, Oklahoma.

During the period of research for this study, the transportation system in the region east of the study area was not well developed. This, plus the constraint of a single bridge across the Arkansas River, are the chief reasons why the eastern boundary of the study area is the west bank of the Arkansas River. The study was concentrated in the townships discussed herein, because it was believed that rapid development would take place here, where the transportation network is good.

The average annual temperature is 61.5^{o} F. (Table 1). Extremes of temperature occur in August, with a mean daily maximum temperature of 94.5^{o}F., and January, with a mean daily maximum temperature of 49.2^{o} F. The mean annual precipitation is 42.02 inches (Table 1). The most precipitation is in May, 5.75 in., and the least is in January, 2.3 in.

The Muskogee area is served by three railroads: St. Louis-San Francisco Railway Company (Frisco), Missouri Pacific and Texas Pacific Railroad Company (Mo-PAC), and the Missouri-Kansas-Texas Railroad (Katy).

The McClellan-Kerr Arkansas River Navigation System provides opportunity for Muskogee to become an inland port. Muskogee is located above the Webbers Falls lock and dam, which is the 15th lock in the system of 17 locks and dams (Fig. 3). Several industries are located in Muskogee (Table 2) but the navigation system should attract large industries to the Muskogee area - especially industries that require cheap transportation to deliver large quantities of raw materials.

Table 1.-Average temperature and rainfall of the Muskogee area (modified from Oklahoma Water Resources Board, 1971, p. 55)

	MEAN TEMPERATURES (^{o}F)			PRECIPITATION (INCHES)
	DAILY MAX	DAILY MIN	MONTHLY	MEAN
JANUARY	49.2	29.0	39.3	2.30
FEBRUARY	54.2	32.7	43.0	2.63
MARCH	62.4	39.5	51.3	3.23
APRIL	72.8	50.2	61.4	4.54
MAY	79.7	58.6	69.1	5.75
JUNE	88.7	67.4	77.8	5.48
JULY	94.1	71.0	82.1	3.15
AUGUST	94.5	70.4	82.3	2.89
SEPTEMBER	87.2	62.8	75.0	3.49
OCTOBER	76.0	51.4	63.8	3.42
NOVEMBER	61.9	39.4	50.8	2.79
DECEMBER	51.6	31.9	41.6	2.35

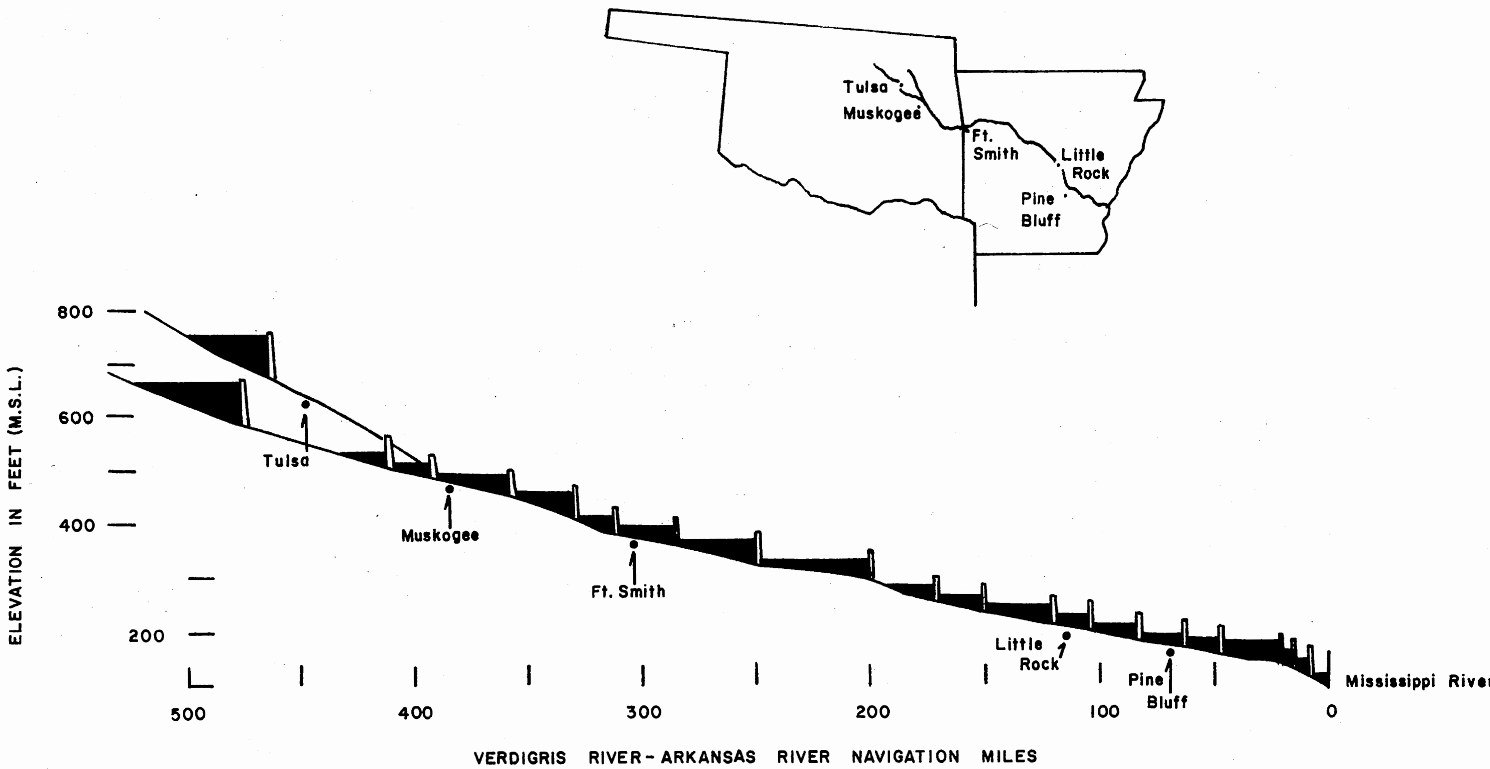

Figure 3.--McClellan-Kerr Navigation System, channel and lock locations (U.S. Army Corps of Engineers, 1973b, p. 23).

Table 2.-Industries of Muskogee that employ 100 people or more.

Company	Product	Employees
Corning Glass Works	Pyrex glass	652
Acme Engineering and Manufacturing Corporation	Ventilations equipment	409
Coborn Optical Industries, Inc.	Optical equipment	360
Brockway Glass Company	Glass containers	352
Muskogee Iron Works	Structural steel	278
H.B. Egan Manufacturing Company	"Camel" auto products	160
Griffin Grocery Company	Food processing	154
Container Corporation of America	Corrugated boxes	145
Fansteel Metals	Metal alloys and compounds	132
Swift and Company	Poultry processing	130
Pet, Inc. Funsten Nut Division	Shelled pecans	110
Zapata Industries Incorporated	Brewing and soft-drink metal closures	107
Blytheville Canning Company	Canned vegetables	107
Love Bottling Company	Soft drinks	103

The Fort Gibson Reservoir, located 12 mi. northeast of Muskogee, is the source of the city's water supply. The water from this reservoir is considered to be good, as it has a normal dissolved-solids count of less than 200 ppm; the standard for "good" water is dissolved-solid content of less than 500 ppm (Oklahoma Water Resources Board, 1971, p. 105). The city water plant has capacity for treatment of 23 million gallons per day, but average daily use is 9 million gallons in winter and 15 million gallons in summer.

The industry of Muskogee is diversified. Corning Glass Works, with 652 employees, is the largest employer (Muskogee Chamber of Commerce, personal communication). Table 2 shows the industries that employ 100 people or more.

The Muskogee area offers abundant opportunity for outdoor activities. Eufaula, Fort Gibson, Greenleaf and Tenkiller reservoirs are within a 45-minute drive of Muskogee.

Objective of the Study

Because the population and industry of the Muskogee area will grow in the near future, it is wise to document the geology of the area in a manner that would allow the geologic information to be understood and used by the public, in general, and by persons responsible for land development, in particular. This information will be useful in avoiding costly mistakes, in terms of money and time, in planning for underground utilities and excavations, highway construction, septic-tank installations, foundations, and related structures and activities.

Five maps show the existing geologic elements of the area and many of the factors that will affect planning and development in the area.

These maps are an environmental geology map, a land-resource capability map, a current land-use map, a topographic relief map and a flood-prone-area map.

The study, although geologic, should be understandable to the general public; it is not excessively technical by design. Also, because the report will be used by land-use planners, most of whom are not geologists, it includes discussion of some social aspects.

GENERAL GEOLOGY

Bedrock of the study area includes the Morrowan, Atokan and Desmoinesian Series of the Pennsylvanian System. Among the three series, only six formations have been named. The formation generally consist of shales that contain units of sandstone and limestone which are lenticular, and therefore not persistent throughout the formation (Fig. 4). The surficial materials of the Quaternary System consist of colluvial deposits, flood-plain alluvium and terrace-alluvium.

The Environmental Geology Map (Pl. 1) shows types of bedrock rather than the formal geologic units that are used in traditional geologic mapping. This method was used because, in general, the interpretation of traditional geologic maps is difficult for nongeologists, and only small amounts of usable information may be recovered.

Stratigraphy of the Pennsylvanian System

Morrowan Series

Hale and Bloyd Formations.-The Morrowan Series crops out in T15N, R19E (Fig. 5; see also Gregware, 1958, Pl. 1). The uppermost 40 to 50 ft. may be equivalent to the Bloyd Formation. The remainder, of course, is believed to correlate with the Hale Formation (after Bell, 1959, p. 8).

The Hale Formation consists of shale interbedded with limestone. Shale and limestone strata vary from a few feet thick to as much as 20

Figure 4.--Depositional margin of a channel-fill sandstone showing example of irregular bedding in some rock units.

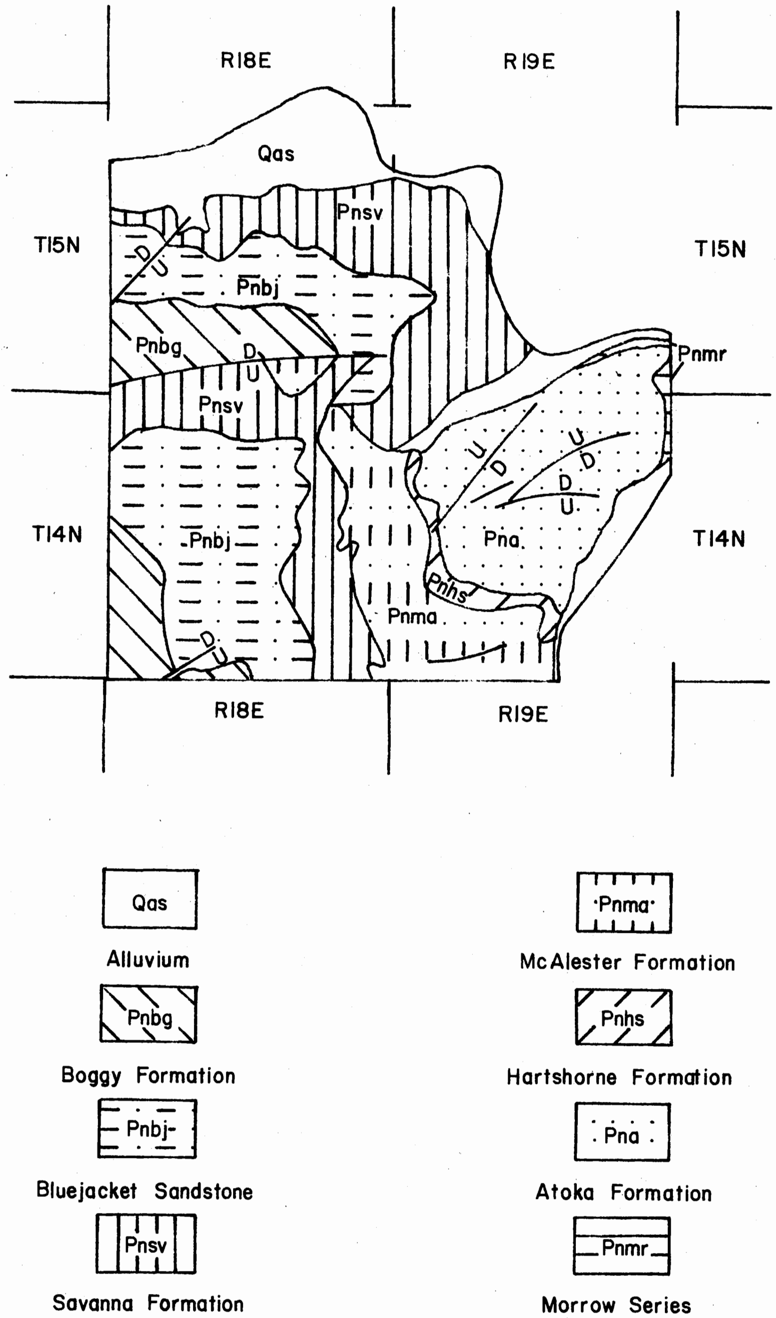

Figure 5.--Generalized geologic map of the study area (modified from Hartronft and others, 1970).

feet thick. Much of the limestone is crinoidal, and the shale generally is rather fissile (Fig. 6).

The Bloyd Formation consists of interbedded shale and sandy limestone, and one calcareous sandstone unit. These strata, which are somewhat sandier than the Hale Formation, tend to weather a little faster and deeper.

In the study area, the Hale and Bloyd underlie mostly forested hills, some with moderately steep slopes. At some places where the Hale and Bloyd are mostly shale, slopes are gentle and the land is used for farming.

Atokan Series

Atoka Formation.-In the study area, thickness of the Atoka Formation varies considerably from north to south. For example, in the northern part of the study area the Atoka is as thin as 304 feet (Bell, 1959, p. 11) whereas to the south, in T14N, R19E the formation may be as thick as 610 feet (Gregware, 1958, p. 14).

The Atoka crops out in the eastern part of the study area, chiefly in T14N, R19E. It is exposed at localities in these areas (Fig. 5; also Gregware, 1958, Pl. 1): (a) sections 1 through 12, 14 through 17, 20 through 23 and 27 through 29, T14N, R19E, and (b) sections 24, 25, 34, 35 and 36, T15N, R19E (Bell, 1959, Pl. 1).

The Atoka is composed chiefly of shale; lenticular beds of sandstone, siltstone, and limestone also are included. Shale underlies stream valleys and hillsides, whereas siltstone and sandstone units tend to underlie hills and low ridges. Shale of the Atoka varies from light gray to dark gray; it ranges from calcareous and fossiliferous

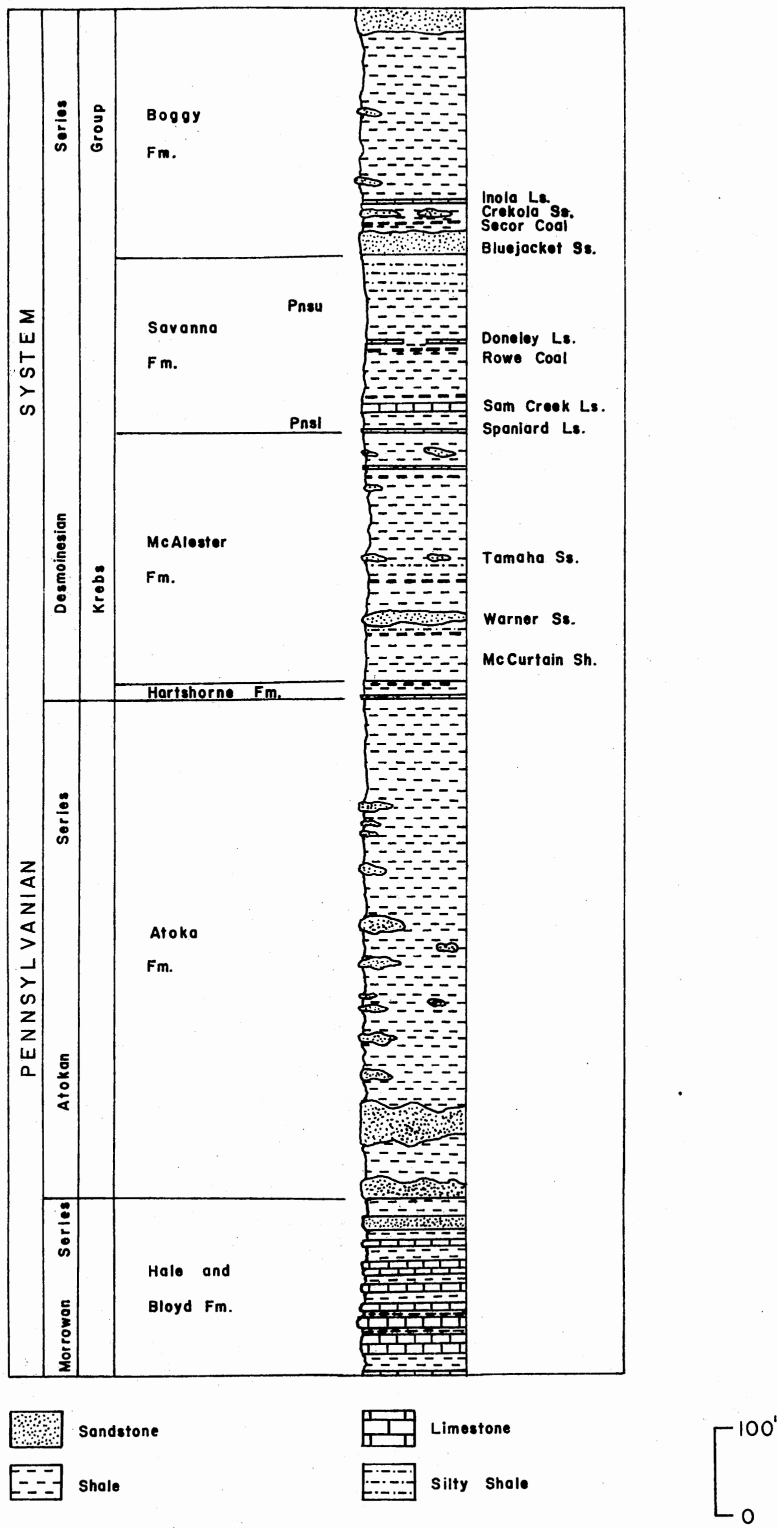

Figure 6.--Diagrammatic stratigraphic section, Muskogee area. (Modified from Bell, 1958, Gregware, 1958, and Coleman, 1958.)

to silty and micaceous. The shale contains nodules and concretions at many localities.

Lenticular strata of shale account for the observable variations in thickness, as do the "pinching out" of sandstone units and siltstone units. Within large bodies of sandstone and siltstone, the more nearly massive units are generally hard and compact. Most of the beds are cemented by calcite and where the sandstone or siltstone is deeply weathered, it is friable.

The limestone beds of the Atoka that crop out in section 16, T15N, R19E (Bell, 1959, Pl. 1) and sections 14, 22, 23, 24 of T14N, R19E (Gregware, 1958, Pl. 1) are hard and fossiliferous. Thickness of the limestones ranges from 18 to 24 inches.

Desmoinesian Series

Krebs Group

Hartshorne Formation.-The Hartshorne Formation is only about 17 feet thick in the study area (Gregware, 1958, p. 28; Bell, 1959, p. 20). The formation chiefly is shale that contains calcareous nodules at some localities. A coal bed about 1 ft. thick is contained in the upper part of the Hartshorne (Fig. 6).

McAlester Formation.-The McAlester predominantly is shale interbedded with lenticular strata of sandstone and limestone (Fig. 4; Fig. 6). The McAlester contains several beds of coal, but none is thick enough to be of commercial value under present economic conditions. In the northern part of the study area the McAlester is about 190 ft. thick (Bell, 1959, p. 22), whereas in the southern part it is as thick as 310 ft. (Gregware, 1958, p. 32). Within the McAlester are these units: the McCurtain Shale Member, the Warner Sandstone Member, and the Tamaha Sandstone Member.

In the outcrop belt of the McAlester, thick shale units underlie stream valleys, whereas the resistant strata of sandstone and limestone underlie hilly terrain. The shales range from light gray to dark gray or black. The light gray shales are generally micaceous and silty; darker shales tend to be fissile. Commonly, the shales contain ironstone concretions.

Sandstones of the McAlester Formation, of which beds in the Warner and Tamaha Members are the most significant, are lenticular. These beds will cause problems in construction of unpaved roads, in excavations, and in construction of foundations.

A limestone bed is in the uppermost part of the McAlester Formation (Fig. 6) but its outcrops are insignificant from an environmental geologic point of view. Therefore, the limestone is not shown on the Environmental Geology Map (Pl. 1).

Savanna Formation.-The Savanna Formation is predominantly shale. It includes three limestone members (Spaniard, Sam Creek and Doneley) and three coal beds. The lowermost coal is unnamed; it lies about 1 ft. above the Spaniard Limestone Member (Fig. 6) and is about 1 in. thick. The middle unit, also unnamed, lies about 10 ft. above the Sam Creek Limestone Member (Fig. 6). This coal ranges from 7 to 12 in. thick and is not mined. Of the three coal units, this middle unit is the most extensive. The Rowe Coal underlies the Doneley Limestone Member (Fig. 6) and is about 1 ft. thick in the Muskogee area. Although it is not mined in the study area, one strip mine in Rogers County

(Sec. 34, T19N, R3E) produced the Rowe Coal. The total thickness of the Savanna in the study area is approximately 200 ft. (Oklahoma Water Resources Board, 1971, p. 27).

The Savanna can be divided into an upper and lower unit. The lower unit (Pnsl, Fig. 6) is underlain by the Spaniard Limestone Member and overlain by the Sam Creek Limestone Member. The upper unit (Pnsu, Fig. 6) lies above the Sam Creek and below the Bluejacket Sandstone, the oldest member of the Boggy Formation (Fig. 6).

The lower shale unit of the Savanna is grayish brown and silty. It commonly is jointed and contains clay-ironstone concretions. The upper member is a grayish brown, concretionary shale near the base; it grades upward through dark gray, fissile, jointed shale into silty to sandy shale and siltstone that is concretionary and crossbedded.

The Spaniard Limestone Member is hard, dark gray, jointed and fossiliferous. The limestone is thin-bedded and ranges from about 18 in. to about 3 feet thick. The Sam Creek Limestone Member is only about 6 to 8 in. thick. It is medium to dark gray, compact and fossiliferous. The Doneley Limestone Member is only a few inches thick, and is not known to extend throughout the outcrop of the Savanna Formation (Bell, 1969, p. 26-44).

Boggy Formation.-Only part of the Boggy Formation crops out in the study area, but exposures of the Boggy probably are the most abundant exposures in the entire study area.

The Bluejacket Sandstone Member, the lowermost unit of the Boggy, caps many of the hills in T14N, R18E (Fig. 6). This sandstone is silty to fine-grained, cemented by iron oxide, and weathers to tan or light gray reddish brown. Crossbedding is common, especially in the lower units. Thickness of the member ranges from about 10 to about 65 ft.

The predominant rock type of the formation is grayish-brown, micaceous silty shale and dark gray shale with ironstone concretions. The sandstones in the section above the Bluejacket Sandstone Member are lenticular. The Boggy also includes the Inola Limestone Member and the Secor coal bed (Fig. 6).

The Crekola Sandstone Member (Fig. 6) is lenticular and varies from 4 to 20 ft. thick. It is thin-bedded, silty and micaceous at some places; elsewhere it is massive, friable, and porous (Bell, 1959, p. 48).

The Inola Limestone Member is 6 in. to 1 ft. thick, hard, dense and dark gray. It overlies the Crekola Sandstone Member (Fig. 6). It does not crop out in the study area.

The other two sandstone units of the Boggy Formation are unnamed (Fig. 6). Both are silty and thick-bedded.

Geology of the Quaternary System

Geology of the Quaternary System has not been studied extensively in Muskogee County, and to do so is beyond the scope of this study. However, some observations should be mentioned.

Rounded pebbles in some of the soils of the area indicate that the Arkansas River was at a higher level and parts of the study area probably were covered by extensive terrace alluvium. The area covered (Pl. 1) is more widespread than previously believed (Bell, 1959, Pl. 1). In particle size the deposits range from clay to pebbles. Because of the extensive area of the dissected terrace materials it is difficult to map them precisely, so they are shown (Pl. 1) as undifferentiated alluvium or as shale.

Alluvium of the creeks in the area ranges from clay to fine-grained sand. Alluvium of the Arkansas is predominantly silt and sand with minor proportions of clay. Terrace alluvium of the Arkansas consists of clay, silt, sand, and gravel. This unit is mapped (Pl. 1) simply as terrace material.

Structural Geology

Structural geology deals with the folding, jointing and faulting of rock strata. Although a structural geologic map is not included in this study, some structural features can be inferred from patterns shown on the Environmental Geology Map (Pl. 1). In the Muskogee area strata dip about 2^{o} southwestward. Within this general pattern are many local folds and faults (Bell, 1959, Plate 1; Gregware, 1958, Plate 1).

The structural geology of an area that is growing in population and industry, such as Muskogee, is important because faults cause abrupt changes in rock types, joints can be passageways for considerable amounts of ground water to travel, and folds can cause subtle or extreme changes in dips of strata. As cities grow, often there is a time lag between urbanization of an area and installation of utilities such as sewers, in which case septic tanks commonly are used for waste disposal. Septic tanks should be used only in areas where the subsurface conditions permit their use. This means not only that soil conditions must be acceptable, but also the rock under the soil must be acceptable. Use of septic tanks in areas of impermeable soil or bedrock leads to contamination of ground water, pollution of streams and lakes and eventually, individual septic-tank failures.

Although bedrock is faulted at some places in the Muskogee area, there is no evidence of consequences of recent earthquakes (Halacy, 1974, p. 150). A joint system is present in some shales and sandstones with the joints trending northeastward and northwestward. The joints contribute to the weakening of rock because, in addition to being structural discontinuities, they commonly transmit ground water and thus weathering of rock is accelerated along the joints. These weathered zones often contribute to slumping and gliding of rock units on steep slopes.

Soils

The physical properties of soils is an important consideration in any development, for the obvious reason that foundations of most buildings are not placed on sound bedrock but are seated in the soil.

In principle, use of information about soils in land-use planning is strongly similar to the use of geologic information. First the soils of an area should be studied to determine the types of soils present, and also to determine the patterns of soils. This enables approximation of areas where soil imposes limitations, hazards and restrictions. As a development progresses, more detailed evaluation of soils is necessary for local areas of interest. Finally, when specific sites are considered for specific uses, one must carry out detailed on-site studies.

While field work for this thesis was being conducted, the mapped soil series in the Muskogee area numbered 19 (Table 3).

Table 3.-Soils of the Muskogee area and their basic properties.

SOIL SERIES	BEDROCK OR PARENT MAT.	SOIL ABOVE "C" HOR. (IN.)	UNIFIED SOIL CLASSIFICATION	TOPOGRAPHIC POSITION	PERMEABILITY (IN./HR)	SHRINK-SWELL POTENTIAL	pH
BATES	SANDSTONE	33	ML, CL	UPLANDS	0.6-2.0	LOW-MOD	5.1-6.5
CHOSKA	TERRACE ALLUVIUM	14	ML, CL	LOW TERRACES	0.6-2.0	LOW	6.1-7.8
CHOTEAU	TERRACE ALLUVIUM	65	CL	UPLANDS OR TERRACES	0.2-0.6	MOD	4.5-6.0
COLLINSVILLE	SANDSTONE	8	SM, CL	UPLANDS	2.0-6.0	LOW	5.1-6.5
COMMERCE	STREAM	25-36	CL	FLOOD PLAINS	0.2-0.6	MOD	6.1-8.4
DENNIS	SHALE	68	CL, MH	UPLANDS	0.1-0.2	HIGH	5.1-8.4
ENDERS	SHALE	46	MH, CH	UPLAND SLOPES	0.1	HIGH	3.6-5.5
HARTSELLS	SANDSTONE	36	CL, ML	UPLANDS	0.6-2.0	LOW	4.0-5.5
HECTOR	SANDSTONE	15	SM, ML	UPLAND SLOPES	2.0-6.0	LOW	4.1-5.5
KIOMATIA	STREAM ALLUVIUM	4	SM	FLOOD PLAINS	0.6-2.0	LOW	6.0-8.4

Table 3 (Continued)

SOIL SERIES	BEDROCK OR PARENT MAT.	SOIL ABOVE "C" HOR. (IN.)	UNIFIED SOIL CLASSIFICATION	TOPOGRAPHIC POSITION	PERMEABILITY (IN./HR)	SHRINK-SWELL POTENTIAL	pH
LELA	STREAM ALLUVIUM	75	CL, CH	FLOOD PLAINS	0.1	HIGH	6.1-8.4
LIGHTNING	STREAM ALLUVIUM	51	CH, CL	FLOOD PLAINS	0.1	HIGH	4.5-7.3
LINKER	SANDSTONE	35	CL, SC	UPLAND SLOPES	0.6-2.0	LOW	3.6-5.5
MORELAND	STREAM ALLUVIUM	64	CH	FLOOD PLAINS	0.1	HIGH	6.1-8.4
PARSONS	TERRACE ALLUVIUM	58	CL, CH	UPLANDS	0.1	HIGH	5.1-7.8
RADLEY	STREAM ALLUVIUM	23	ML, CL	FLOOD PLAINS	0.6-2.0	MOD	5.6-7.3
STIGLER	SANDSTONE-SHALE	85	CL, CH	UPLANDS	0.1	HIGH	4.5-7.8
TALOKA	TERRACE ALLUVIUM	78	CL, CH	UPLANDS	0.1	HIGH	5.1-8.4
VERDIGRIS	STREAM ALLUVIUM	39	ML, CL	FLOOD PLAINS	0.6-2.0	MOD	5.6-7.3

Bedrock or Parent Material

The terms "bedrock" or "parent material" imply the type of material that would be penetrated beneath a specific soil. This information permits more efficient planning for design and construction of foundations, or for excavations for pipelines and utility lines. Some bedrock - such as soft shale - can be excavated at low cost, but it has low bearing capacity. Other kinds of bedrock, such as well-cemented sandstone, may have high bearing capacity, but be quite expensive to excavate. Information about bedrock also gives insight as to the texture, permeability, composition and pH of the soil, especially if the soil has been derived from the bedrock.

Thickness of the Soil Above the "C" Horizon

The position of the top of the "C" horizon is considered to define the lower boundary of the soil, rather than the actual top of the bedrock. The "C" horizon is the part of the soil profile that is similar to the material from which the overlying soil horizons are presumed to have formed. The "C" horizon may have been weathered chemically, which could have resulted in cementation, brittleness, or accumulation of salt, but it has not been subjected to major biological activity and thus could still be dense and hard enough to constitute an excavation problem.

Unified Soil Classification

Classification of soils implies some important engineering properties and descriptive properties. The Unified Soil Classification System, shown in Table 4, commonly is used in civil engineering practice.

Table 4.-Unified soil classification system (modified from Peck and others, 1974, p. 28).

	GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines.
	GP	Poorly graded gravels and gravel-sand mixtures, little or no fines.
	GM	Silty gravels, gravel-sand-silt mixtures.
	GC	Clayey gravels, gravel-sand-clay mixtures.
	SW	Well-graded sands and gravelly sands, little or no fines.
	SP	Poorly graded sands and gravelly sands, little or no fines.
	SM	Silty sands, sand-silt mixtures.
	SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
	OL	Organic silts and organic silty clays of low plasticity.
	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.
	CH	Inorganic clays of high plasticity, fat clays.
	OH	Organic clays of medium to high plasticity.
	PT	Peat, muck and other highly organic soils.

Topographic Position of the Soil

The physical location of a soil can be as important to a planner as all other properties of a soil. Two sites with soils of similar thickness and texture may be under consideration and the deciding factor may be their topographic positions. For example, one of the sites may be on an moderately sloping upland that will be well drained, whereas the other may be on a steep slope where drainage is good, but it could lead to severe erosion if the soil cover were disturbed.

Permeability

Permeability of a soil is a property of major importance in many engineering problems. For instance, settlement of compressible soils is dependent upon permeability. By definition, permeability of less than 0.05 in./hr. is considered to be very slow, 0.05 to 0.2 in./hr. is slow, 0.2 to 5 in./hr. is moderate, and more than 5 in./hr. is rapid.

Shrink-Swell Potential

The shrink-swell potential of soils indicates whether soils shrink markedly when dried and swell when wetted. Shrinking and swelling are characteristic of clayey soils that gain or lose pore water. The volume changes that occur can be large enough to cause foundation-stability problems if the foundations are not designed properly. One of these problems could be loss of foundation support during dry periods when shrinkage occurs and at some places soil is not the direct contact with the foundation. If a foundation is not rigid enough to withstand such a state of non-support, cracking of the foundation will occur. During wet periods abnormal pressures could be transferred to the foundation by swelling soil, these pressures can cause cracking of foundations.

Acidity

The unit of measurement of acidity is pH. Acidity of soil is important in estimating the probability that steel or concrete will corrode. The more acidic a soil, the higher the probability of serious corrosion.

ENVIRONMENTAL GEOLOGY

A note of explanation as to what the term "environmental geology" means is warranted at this point. As Legget (1973, p. 49) points out, "Sound information about the ground in the area being planned, and for the region immediately adjoining, is a prime essential of the basic data that must be assembled for even the overall general planning that will always precede the more detailed planning of individual facilities."

Bedrock-geologic mapping units are defined here as (1) limestone, (2) shale, (3) sandstone, (4) interbedded sandstone, siltstone, and shale, and (5) interbedded limestone and shale. Also included as mapping units are alluvium of creeks and rivers, terrace alluvium, and a category made up of an undifferentiated complex of terrace alluvium and shale. This classification is simplified but acceptably accurate, allowing mapping and discussion of bedrock geology without use of traditional stratigraphic nomenclature - a property of the classification that nongeologists should find helpful. Users of the information shown about bedrock will develop ideas about the types of problems that might be encountered in development of terrain; therefore they should be more able to determine the testing problems that can be used to help solve some of the problems caused by bedrock.

Environmental Geology Map

One of the most efficient ways of conveying information about environmental geology is use of a map. Information shown on the Environmental Geology Map (Pl. 1) was derived from geologic maps (Bell, 1959; Gregware, 1958), from aerial photographs, and from field observations.

The Environmental Geology Map does not represent surface conditions everywhere in the field, because soil cover has been ignored in the environmental geology mapping. The map does show the types of rock that would be found at most outcrops and what rock may be expected to be penetrated first in drilling within the area mapped. If information about soil thickness is also needed, the Environmental Geology Map can be cross-referenced with the Land-use Capabilities Map.

Limestone

Limestone beds that are thicker than about 1 ft. are considered to be a stable and competent bedrock, especially if the limestone is not densely jointed and/or extensively weathered. Limestone is strong and can withstand pressures in the range of 40 to 100 T/ft. (Peck, 1973, p. 362), depending on the conditions of the rock, such as absence of jointing, cavities, faults, and random fractures.

Limestone causes some problems in construction and development, and many of these problems are related to jointing and to the solubility of limestone in water (Fig. 6). Joints commonly are passageways for ground water and the passage of the water will lead to enlargement of joints by dissolution. A widened joint may be an area where soil can accumulate to depth greater than that of the nearby soil.

Therefore, thickness of soil above limestone may be quite variable. The soil should be thoroughly investigated in cases where piles are to be driven to the top of limestone. This is to insure that a pile would not be driven into a joint that contains thick soil, and thereby not have the bearing capacity predicted.

Because limestone commonly is jointed, it is subject to creep, especially in areas where beds crop out on steep slopes. If such a condition is suspected, an investigation should be carried out to determine whether the limestone is in place and stable, or whether it is actually a detached limestone block that actually is in motion.

If excavation of limestone is necessary, the excavation could be difficult and expensive where limestone beds are about 1 foot thick or thicker. This possibility should be given consideration when excavation costs are estimated.

In areas where limestone beds are extensive, sinkholes may be problems. A sinkhole develops when limestone is dissolved by ground water. Collapse of the roof of a sinkhole could cause severe structural damage to structures nearby.

Specialized structures with light foundations - such as plants for manufacture of materials that are sensitive to motion - should not be located on limestone beds that are being quarried nearby. Limestone is an excellent transmitter of energy and foundations or interiors of buildings on limestone may be damaged by energy of blasting, translated through the limestone.

Sandstone

Sandstone generally is resistant to erosion and commonly underlies areas of higher elevation in terrain where topography is due to stream erosion and bedrock is sedimentary. In many such hilly areas, sandstone is overlain by thin, sandy, residual soils that are of limited use in agriculture. Tracts of residual sandy soils therefore are often left as woodlands; in the study area, the trees on these sites are predominantly blackjack oak and post oak.

Sandstone, even though it is generally a sound and stable foundation material, can cause some problems in construction activities. In fact, sandstone beds commonly are jointed. Thus, blocks are subject to down-slope movement due to forces of gravity and frost heaving. In areas of sandstone outcrops, testing procedures may be necessary to determine whether the sandstone is stationary or in motion.

Many sandstones are permeable, and in some localities, such as places where shale underlies a sandstone or where the soil mantle thins over sandstone, seeps develop. In planning for development of terrain, areas where seeps occur should be located so that measures can be taken to prevent the problems associated with excessive ground water.

Difficulties also may arise if excavation of large blocks of sandstone is necessary, because a thick massively bedded sandstone unit probably would not be rippable. Under these circumstances, the rock must be drilled, blasted and removed, all expensive measures.

Unpaved roads across sandstone terrains and outcrops may be difficult to maintain, especially if the road cuts through sandstone of different weathering characteristics. A rough "washboard" effect often is developed within a relatively short period of time, requiring scraping or grading in order to re-establish a usuable surface. Figure 7 shows such a road on a sandstone outcrop. Loose fragments of

Figure 7.--Example of a deteriorating road on an outcrop of sandstone.

sandstone can be seen easily and the road, which probably was only about 1 yr. old at the time of the inspection, was very uneven.

Shale

Whereas sandstones generally underlie elevated terrains, shales generally underlie valleys and lowlands of the study area (Pl. 1). Shale, when weathered, composes a residual clayey soil that is generally valuable agricultural soil. These residual soils retain moisture and nutrients better than sandy soils; therefore they are usually not left in forest or grasslands, but are cleared for pasture or crop farming.

The problems that shales present vary in character and severity due to variation in mineralogy of the clays that compose the shale, chemical composition, hardness and geologic history. Some of the clays absorb water readily, causing increase in volume. Likewise, such clays shrink when they dry.

One problem that occurs in areas underlain by swelling clayey soil results from differential drying or wetting of the soil caused by the physical placement of a structure.

When the area outside a foundation is subjected to a great deal of wetting, clay, being almost impermeable, transmits water slowly (Table 5). The coefficient of permeability (Table 5) is the discharge velocity of water through soil under a hydraulic gradient of unity (Means and Parcher, 1963, p. 151). Table 5 shows that the coefficient of permeability of clayey soils is equal to or less than 10^{-7} cm/sec, as compared to "K" of clean sand which is 1.0 cm/sec. Because clays are only slightly permeable, water would not quickly migrate from the

Table 5.-Coefficients of permeability of various soils. Coefficient of permeability = K. (From Means and Parcher (1963, p. 200).)

k (cm/sec)	DRAINAGE	SOIL TYPE
10^2	Good	Clean gravels
10^1	Good	Clean gravels
1.0	Good	Clean sands
10^{-1}	Good	
10^{-2}	Good	
10^{-3}	Good	Clean sand and gravel mixtures
10^{-4}	Good	
10^{-5}	Poor	Very fine sands
10^{-6}	Poor	Mixtures of sand silt and clay
10^{-7}		
10^{-8}	Almost impervious	Impervious soils
10^{-9}		

edges of a foundation. Therefore, the clays near the edges would expand, exerting an upward force while soil under the central part of the mat would be unchanged (Fig. 8a). Thus, the foundation would be lifted at the edges, leaving the center unsupported.

The converse of the preceding situation occurs when, at the center of a foundation mat, evaporation from the soil is decreased, whereas evaporation at the edges of teh mat is not affected. The soil under the center of the mat remains wetter and tends to swell, while soil at the edge of the mat is drier and tends to shrink. The foundation is subjected to an upward force at the center of the mat while the shrinking soil leaves the edges unsupported (Fig. 8b).

The likelihood of both situations should be recognized before construction begins so that foundations can be designed to tolerate swelling soils. Some common foundation designs used in these situations are reinforced concrete mats, belled-pier and cap foundations, and pile-and-cap foundations.

When first uncovered in an excavation, shale may appear to be solid and firm; but after being exposed to rain, wind and sun for a short time, shale may slake and become soft, flakey, and unusable as good foundation material. If such shale must be exposed, the surfaces should be protected with materials such as concrete or asphalt. It would also be advantageous to avoid final excavation into these shales until just before concreting.

Because shales are so nearly impermeable drainage in terrain underlain by shale can be problematic. If a sanitary landfill is to be located in such an area, drainage of the area should be checked to insure that pollutants are not dispersed into the surface water.

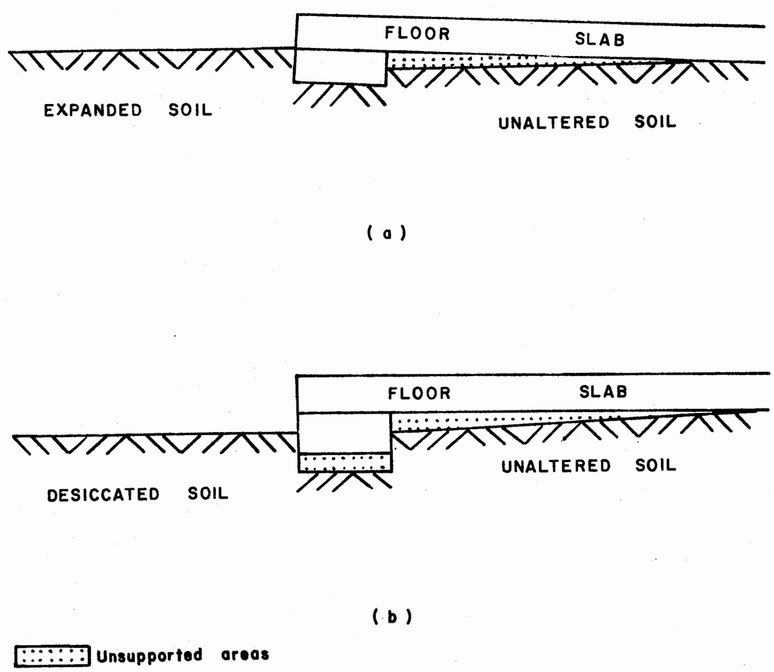

Figure 8.--Examples of lack of support of foundations, caused by clays that shrink and swell. Stippled patterns show unsupported portions of foundations.

Shales and their associate soils are quite variable in their physical properties. As stated above, some soils shrink and swell more than others; some clayey soils contain more sand than others and thus are more permeable. Some shales do not slake upon exposure. Because of these varied reactions to environmental changes, areas of clayey soils should be outlined carefully. Field observations should be made and samples of shale and related soils should be gathered for laboratory analyses. Results should be studied carefully and used in design of foundations and for other pertinent construction.

Interbedded Siltstone, Shale, and Sandstone

Of the three units in this grouping (Pl. 1), sandstone is the most resistant to weathering and, as stated above, where the sandstone is of sufficient thickness it forms ridges and acts as a protective "cap" for the siltstone and shale (Pl. 1). This situation can be somewhat misleading because although sandstone is resistant, if it is underlain by thick shale, performance of the shale in construction may be more important than that of the sandstone. Shale weathers markedly along the contact with overlying sandstone, in joints, and along faults. This weathering is associated with transmission of ground water. Weathering can severely diminish the load that shale can support, and settlement or slippage may occur along these weathered areas. Steep slopes, where strata dip toward the slope, are places where slippage is likely to occur along contacts of sandstone-above-shale.

Interbedded Limestone and Shale

Where limestone is interbedded with shale (Pl. 1), beds of limestone commonly form ledges and cliffs. On such slopes limestone weathers along joints, and joint blocks tend to creep down slope. Because limestone ordinarily is not permeable, water generally drains along joints or the basal contacts of the limestone beds. This can result in differential weathering of the underlying shale due to the fact that runoff may be concentrated at the joints, but the shale beneath unjointed limestone is weathered less.

Current Land-Use Map

The Current Land-use Map (Pl. 2) shows seven primary classes of land: (1) agricultural lands, (2) forested areas, (3) timbered lands, (4) urban areas, (5) industrial areas, (6) oil fields, and (7) man-made lands. Four secondary features include major pipelines, major power-transmission lines, railroads and major transportation routes. These data were compiled from aerial photographs, topographic maps and field observations. Locations of pipelines were obtained from the Oklahoma Resources Board (1971, p. 136).

Agricultural land, which makes up a large portion of the Muskogee area, includes a few basic uses. This classification comprises cultivated lands, pasture lands and lands that show evidence of past agricultural use. No attempt was made to divide the classification of agricultural lands further, due to the frequent changes of land-use by farmers.

Forested areas are defined here as areas of extensive upland forests, not as areas of flood-plain forests. Within the study area parts of some flood plains are heavily timbered, but these timberlands, as such, are not considered potentially to be problematic in development of the land. Forested areas, as mapped here indicate areas that would require extensive clearing projects for the land to be readied for use.

The category of "urban areas" was defined chiefly on population density, as shown by the number of dwellings within a given area. Mapping was based on the author's judgment and although qualitative, is considered to be not seriously in error. The urban areas mapped show locations of the more expensive urban land, potential work forces, housing and supplies.

Areas classed as oil fields are problematic because of collector pipelines. Some pipelines lie on the ground, and buried lines are shallow. These pipelines are small and are not included under the heading of "major pipelines." Because collector pipelines are abundant and commonly unmarked, care should be taken before excavating in the areas mapped as oil fields.

In brief, the Current Land-use Map shows background information about distribution of urban areas and the services that are available, relative land costs (urban cf. agricultural land or forested land), major highways, power sources, and railroads. Because Muskogee is growing and changing, errors will develop in this map; however, the inaccuracies should not overshadow its usefulness in pointing out major social and agricultural features.

Land-Resource Capability Map

The Land-resource Capability Map (Pl. 3) is based on data about soils and geology of the bedrock. At most places within the study area, bedrock is covered by soil. Where soil is 30 in. thick or less, most foundations will be based at least partly on bedrock. Therefore, at places where soil above the "C" horizon, or the weathered upper part of the bedrock is 30 in. deep or less, the area is classified as "bedrock-dominant." Where soil is thicker than 30 in., the land is classed as "soil-dominant." This classification would enable one to make such basic decisions as whether pipelines could perhaps be buried, because soil deeper than 30 in. would be required.

Areas of sufficiently thick soil were classified further into "sediment-dominant" and "soil-dominant" systems. These classifications are related to the history of the soil. Residual soil, which forms from weathering of the bedrock, is included in the soil-dominant system. The soil has not been transported by water or wind to any great extent. Reliable inferences generally can be drawn about residual soils. First, if the type of bedrock is known from reliable geologic mapping, texture of the soil can be inferred and lateral extent of the soil is not likely to vary much from the extent of the bedrock.

Whereas the soil-dominant system is based on residual soils, the sediment-dominant system is based on soils that have been carried by water and, in some instances, wind. Because these soils have been transported, they overlie many different types of bedrock. Moreover, they vary greatly in horizontal and vertical extent, both in texture and thickness. Because of such variation, terrain of sediment-dominant systems generally will require more investigation in planning than will terrain of bedrock and residual soils.

The three systems - soil-dominant, sediment-dominant, and bedrock-dominant systems - are classified further for specific circumstances. The subclasses are described in the explanation of the Land-resource

Capabilities Map (Pl. 3).

An official soils report for Muskogee County has not been published. Figure 9 shows parts of the thesis area where information was secured from the Soil Conservation Service from work in progress. In some areas no information was available; the data shown in these places is based on interpretations of aerial photographs, distribution of vegetation, and upon general field observation. The varying degree of accuracy is a reflection of the author's confidence in the interpretations.

No information was available on the flood-plain soils of the Muskogee area. Surrounding areas were studied to determine what soils might be expected in the flood plain, but no attempt was made to map individual soil series. Soil series believed to be in the flood plain are listed in Table 3, along with their properties.

Relief Map

The Relief Map (Pl. 4) shows general topography of the area. Plates 1, 2 and 3 are constructed on topographic base maps, but contour lines are obscured by map patterns. The Relief Map is accurate within standards prescribed by the U.S. Geological Survey. The map was developed from unpublished, advance line prints of 7½-minute topographic maps of the Muskogee area. They were purchased from the U.S. Geological Survey.

Steep slopes are shown by "dark" areas of very closely spaced contour lines, the result of the medthod of construction of the final map. The original maps, which are at the scale of 1:24,000, were reduced to 1:62,500, and contour lines along steep slopes were made much closer.

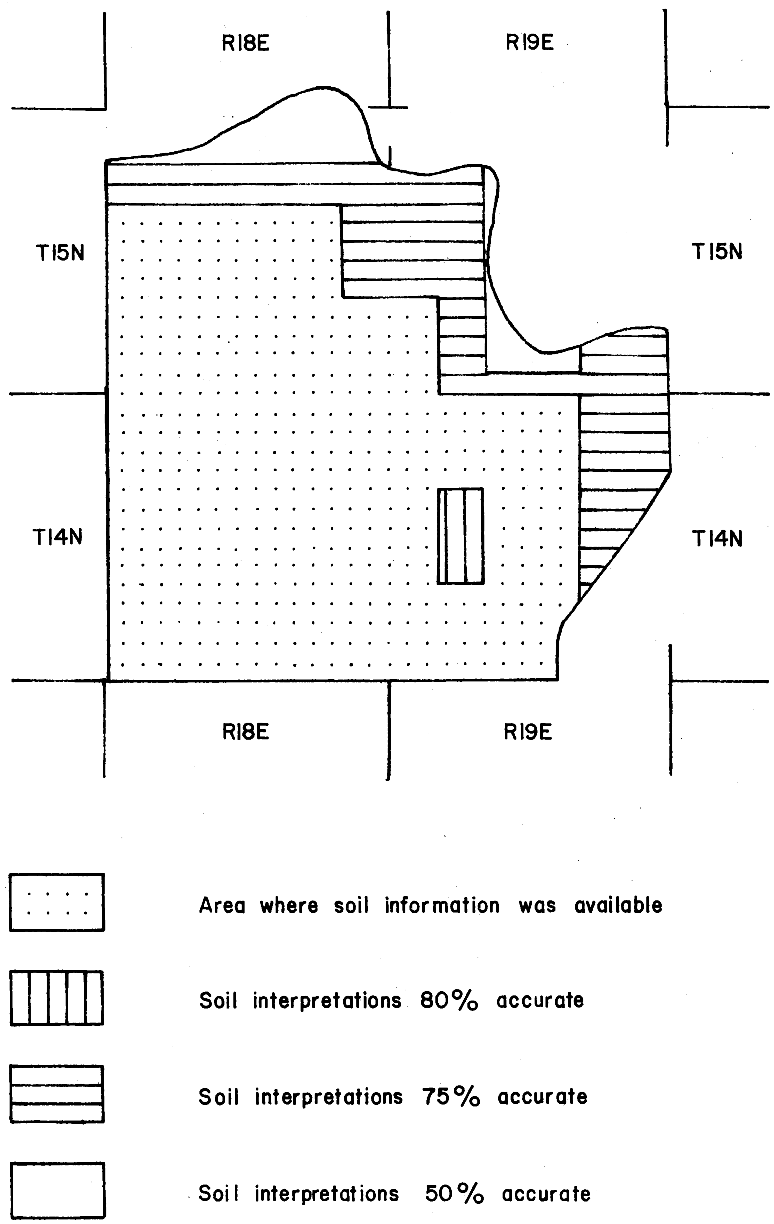

Figure 9.--Location map showing areas where information about soil was available. In the thesis area, in T15N, R18 and 19E, areas that show no patterns are areas where properties of the soil were estimated by the author.

Consequently, at some places individual contour lines are indistinguishable.

Flood-Prone Area Map

Because of recent legislative acts requiring flood insurance for dwellings located in the flood-plains of rivers, there is need to define the areas of periodic flooding. This is especially true in flood-prone terrain that is being developed for housing or business. Many streams that flow through farmlands or woodlands have flooded in the past and not caused a great amount of hardship to anyone. As the area around a stream is developed, the stream becomes more likely to flood because of greater runoff into the stream due to roofs, driveways, streets, parking lots, and other impermeable areas that cover the ground.

The streams under study (Pl. 5) are Coody Creek, Corta Creek and Sam Creek, in the path of the current urbanization trend south or southeast of Muskogee. Corta Creek and Sam Creek are tributaries to Coody Creek.

The information was developed by two methods. The 100-year flood plain of Coody Creek was mapped by the U.S. Army Corps of Engineers (1973). The flood plain of Corta Creek and Sam Creek was defined by the method of Thomas (1975). The generalized formula for estimation of depths of floods is: $Dx = a\,A^{b}I^{c}$ R.F. (from Thomas, 1975, p. 13, 17 ff).

Where

Dx = peak flood-plain depth in feet
A = contributing drainage area in miles
I = 2-year 24-hour rainfall in inches
a = regression constant
b, c = regression coefficients

R.F. = regional factor based on topography

Some additional adjustment was made so that calculations based on the method described above would be consistent with calculations of the Corps of Engineers.

The author points out that the flood plains shown in Plate 5 are approximated, and that no responsibility is accepted for consequences of action taken on the basis of these data.

SUMMARY

This study documents several aspects of geology, soils and bedrock of the Muskogee area that will be useful in regional planning. Five maps with explanatory legends and descriptive text show:

(1) environmental geology, which presents the distribution of bedrock units and sediments,

(2) current land-use,

(3) land-resource capabilities, which includes mapping units described according to their capabilities,

(4) relief, and

(5) flood-prone areas, which could become more troublesome.

Land-resource Capabilities units are delineated according to parent material, bedrock geology, soil thickness and texture, and other physical and chemical properties of the soil and the bedrock. These should aid in preliminary evaluation of the area for specific uses.

Growth potential of the study area is dependent on development of the Port of Muskogee and the McClellan-Kerr Arkansas River Navigation System, and development of the Camp Gruber area as a possible atomic power plant site. As it is necessary for planners to have information about the area to properly plan the development, I believe that this study provides basic information for an efficient land-use program.

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APPENDICES

At the beginning of the study, I knew little about the Muskogee area. Interviewing some of the city officials was judged to be a good way to become familiar with the area, and also to learn about some of the geologic problems of the area.

Two questionnaires were developed one designed for the interviewing of politicians and public-relations persons, and the other questionnaire directed more toward engineers and designers. Copies of the questionnaires are included as Appendix I, and transcripts of three of the interviews as Appendix II.

APPENDIX I

Questionnaire 1, For Engineers And Designers

1) What are some of the common problems related to soil that occur in Muskogee?

2) Do shrinking and swelling soils cause problems in some areas? If so, are the problems bad enough to require lime-stabilization or other modification?

3) Are seeps, wet-weather springs and intermittent streams problems in some areas?

4) Are some buildings, streets or highways in the area prone to fracturing?

5) Does the Muskogee airport have any persistent geology-related maintenance problems?

6) Do some areas in Muskogee flood and if so, where are these areas?

7) Do zoning problems exist in the city?

8) Are there any areas of truck farming near Muskogee?

9) Where does the city dispose of refuse? Is it a public or private facility? Do you have difficulty in maintaining it properly?

10) Where are there areas of landfills in Muskogee County? Are there any restrictions on the type of fill and the amount of compaction?

11) How does Muskogee dispose of its sewage? Is treatment primary, secondary and tertiary? Are ponds used or is the sewage just treated with chemicals? What happens to the sludge?

12) Where does the city get its public water supply? How large a population will it maintain? What is the relative quality of the water?

13) Has there been in the past or is there now any type of mining or oil and gas production in the area? Are there any problems that can be directly related to these industries?

14) What construction materials are available? Where are they available and what are their approximate costs?

15) Have Keystone Dam and Tenkiller Dam affected the amounts and quality of sand available from the Arkansas River?

16) Are foundation failures a severe problem in Muskogee and if so are they localized?

17) Are there any maps showing hazardous locations?

18) Do contractors have access to information (from the city) about soils and bedrock before they bid on a project?

19) What engineering firm or firms get the majority of the contracts for the work in the Muskogee area? Architectural firm?

Questionnaire 2, For Persons In Political Offices

1) What is the estimated growth potential of Muskogee in the next 10 to 20 years?

2) In what directions is growth most likely to occur?

3) What are the major industries of the area?

4) What types of industries does the city hope to entice in the future?

5) What effect is the Port of Muskogee having on bringing industry into the area?

6) What energy sources are available?

7) Can these energy sources be expanded to accommodate the growth?

8) What possible effects will the development of the Camp Gruber complex bring?

9) What areas are proposed to be preserved as historical and scenic sites?

10) Does Muskogee have zoning problems related to flooding and other geological phenomena?

11) What type of geologically oriented data would be most beneficial in a series of maps for this area?

APPENDIX II

Interview With Mr. Bob Wright,

Chamber of Commerce, Industries Branch,

Muskogee, October, 1974. (Based on Questionnaire 2.)

Muskogee's port is attracting large industries because industries can use the port to keep shipping costs down. The Fort Howard Paper Company of Green Bay, Wisconsin has been very close to a decision to build a plant in Muskogee. Muskogee was the only city under consideration. The biggest potential advantage of moving to Muskogee was that a good supply of natural gas could be assured. The plant, which would be located near the southeastern corner of the city, would be for making tissue products.

Other types of plants that may be built in Muskogee are a chemical plant, a food-processing plant, a steel mill, two plants for manufacture of steel products, an automobile assembly plant, and a grain brokerage.

The effect that a nuclear power plant at Camp Gruber will have on Muskogee is conjectural at this point. A great building boom would start and 1000 to 2000 jobs could be generated, but the amount and type of related industry is still in question.

Mr. Wright believes that there are no geologic problems in the area. Coody Creek is a problem, from the standpoint of flooding and pollution, but the stream is being cleaned up. Mr. Wright believes that the restrictions of the 100-year flood plain of the Arkansas River are no longer applicable, due to the construction of the dam upstream. The heavy rains of 1973 caused no serious flooding. He would like to have seen industrial lands identified in the course of the study - lands that are high, dry, and near the channel of the waterway. Also, the soil-bearing factors interested Mr. Wright. He would prefer that the soils be discussed in layman's terms. Knowledge of the locations of buried cables and pipes would be quite useful.

Nearby lakes are a great advantage to Muskogee in being a recreational center. Industries seem to like this selling point, because employers are giving more serious consideration to the use of leisure time.

Interview With Mr. W.C. Smith
City Engineer, Muskogee, Oklahoma
October, 1974. (Based On Questionnaire 1.)

Muskogee has a problem with "stratified rock." It is expensive to excavate and it "shifts." It has a "rock-soil-rock-soil" pattern vertically (due to interbedding of thin strata of sandstone and shales, I infer). Construction of piers is necessary to support loads and to stabilize "rock." According to Mr. Smith, Muskogee has no problems with shrinking and swelling of soils.

The stratified condition of the shallow bedrock leads to wet-weather springs. It is difficult to keep basements dry, and underground structures require French drains.

Buildings in the area are prone to crack unless designs are made to compensate for wet-weather conditions. (Note: This seems to contradict the earlier statement about swelling soils not being a problem.) Houses in the area develop few problems with cracking, because they commonly are seated on bedrock. Mr. Smith noted that structures which were to be seated deeper than 2 ft. usually had to be designed for potential cracking.

Mr. Smith did not know of any problems at the Davis Field Airport or the Hatbox Airport, although he stated that he was just guessing at this because the airports are controlled by a different department.

Coody Creek is the stream in the Muskogee area that causes the most problems with flooding. In 1973, the Corp of Engineers completed a study of Coody Creek, aimed at providing information to help in the planning for the flood-prone area.

The Muskogee sewage plant is located on Hancock Street, about 5 mi. from the downtown district. Recently a $2.7 million enlargement program changed the treatment capabilities from primary to secondary. (As of the date of this interview, the plant was not fully in use because Muskogee had just received a permit to begin discharging water into the Arkansas River.)

The city maintains a solid-waste landfill in the southwestern section of the city, an area of about 160 acres. The incoming material and the landfill itself is monitored to prevent burial of dead animals, development of ground water with abnormal pH, and other undesirable agents. The city has the right to say how much fill will be accepted from an industry and to insist on having the fill pretreated by the industry before being dumped. (Mr. Smith suggested that Buster Sayler of Public Services be contacted if more information about the landfill was needed.)

The city water supply comes directly from Fort Gibson Reservoir. Muskogee also has the option of using water from Tenkiller Reservoir. The water is of good quality, but is somewhat turbid. During fiscal 1974 the city pumped 3,081,000,000 gal. of water. The water is treated with alum, lime, chlorine and fluoride.

Sand and gravel are available from the Arkansas River alluvium, from which they are recovered by Arkola Sand Company, and limestone is available from the Fort Gibson area. Supplies are plentiful; they are adequate for shipment of materials to neighboring cities.

According to Mr. Smith, failure of foundations is not common. Instances of failure probably are related to ages of the buildings and to poor construction. Specifications for contracts generally require investigation of the subsoil by the contractor, which is paid for by the city.

Many of the utility contracts are let to Holloway Engineering Company, Muskogee. Horstman, Richter and Mott, Architects, Muskogee, designs many of the large buildings. Hudgins, Thompson, Ball and Associates, Tulsa, Oklahoma is designing the Columbus Street Overpass.

Interview with Mr. Jim Thompson, Manager
Chamber of Commerce, Muskogee, October, 1974.
(Based on Questionnaire 2.)

Mr. Thompson was rather optimistic about the growth of Muskogee. He favored the Eastern Oklahoma Development District report, which was by far the most optimistic of the several reports cited. EODD took into consideration the development of Muskogee's industrial parks, the possible Gruber atomic power plant, and the recreational facilities that the Muskogee area has to offer. Mr. Thompson believes that the good work sites and convenient recreational areas are what employers are looking for today. The Arkansas Navigation System also is a big factor in Muskogee's advantageous position.

Mr. Thompson believes that Muskogee will grow northeastward up to the location of the port facilities, but development probably will not extend across the river - at least until the transportation bottle-neck of only one bridge across the Arkansas River is solved. Good industrial growth is expected along the Shawnee Bypass and also north of the town between the Arkansas River and the Muskogee Turnpike.

The eastern part of Muskogee is expected to be enhanced in its development by the completion of the Southeast Bypass, which will connect U.S. Highway 69 and the Muskogee Turnpike.

Mr. Thompson said that Muskogee is trying to attract some moderately heavy industry, such as manufacturers of glass and steel. Muskogee also is being considered by grain and paper industries. Mr. Thompson believes that Muskogee is a better port than the Port of Catoosa, because the navigation channel into Muskogee is better.

Mr. Thompson said that the Port of Muskogee has not yet had as much effect upon Muskogee as one might expect. One industry is located in the Port industrial park, but more time is required for full development. In fact, the number of industries that need port facilities is not large.

The energy supply seems to be good. Oklahoma Gas and Electric Company is building two 550,000 k.w. plants. The plants will use coal from Wyoming. Oklahoma Natural Gas recently signed a contract to supply Muskogee with natural gas for 30 years.

Water facilities are equally good, as 21 million gals/day could be delivered to the city and current use is only about 9 million gallons per day.

Development of the Camp Gruber complex could have a "stupendous" effect on the city. The full-time staff might number 3,000 and the total annual expenditure in the millions of dollars. The complex would affect greatly a seven county area; it would call for a great reorganization in the city to meet the need of maintaining the quality of life in the Muskogee area.

The only designated historical site in the area is Fort Gibson. Mr. Thompson believes that there are some parts in the Camp Gruber area that should be reserved as historical sites.

Mr. Thompson knows of no areas prone to flooding. The Port of Muskogee will not allow any industry to build below the 100-year flood plain.

VITA

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Candidate for the Degree of

Master of Science

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Personal Data: Born in Barberton, Ohio, September 6, 1946, the son of Mr. and Mrs. Thomas E. Mileff.

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