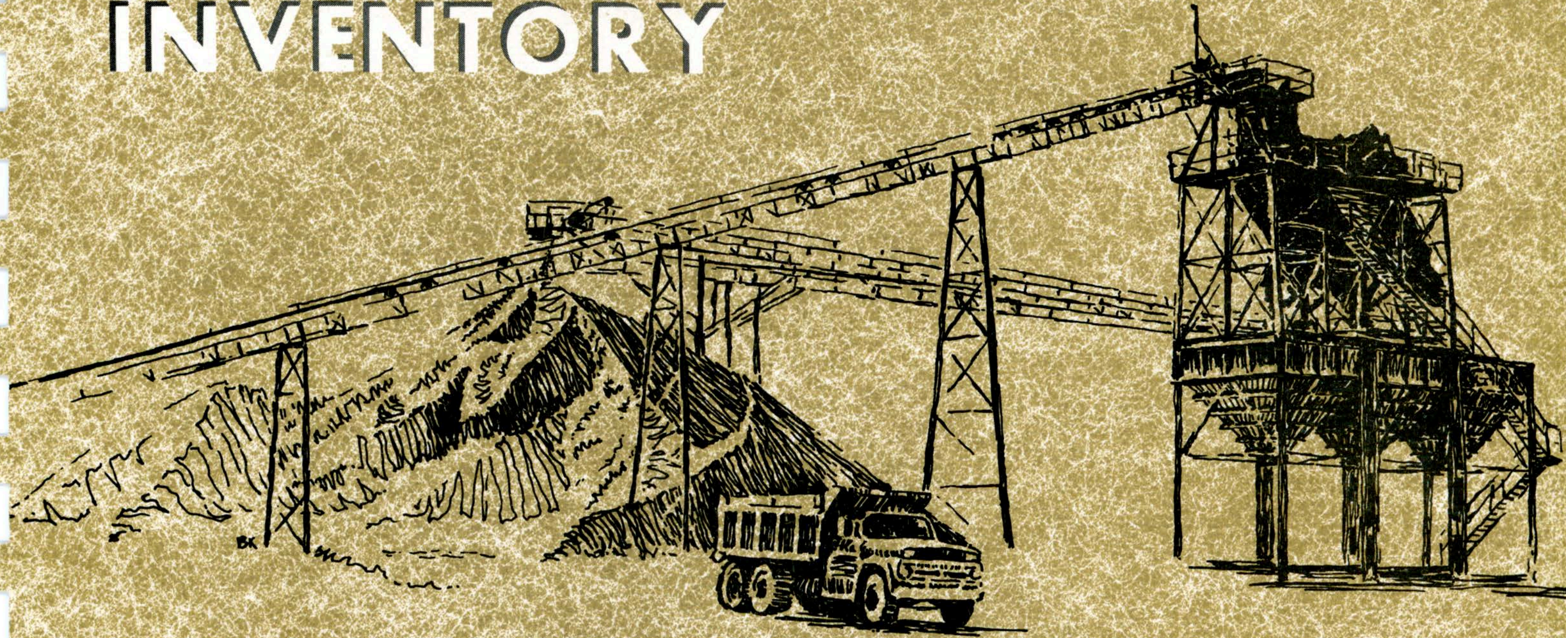
REPORT NO. 30

CONSTRUCTION MATERIALS INVENTORY



CLOUD COUNTY, KANSAS

DEPARTMENT OF TRANSPORTATION KANSAS

Kansas Department of Transportation
Engineering Services Department
Planning and Development Department

CONSTRUCTION MATERIALS INVENTORY

OF

CLOUD COUNTY, KANSAS

by

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Prepared in Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

1978

Construction Materials Inventory Report No. 30

Copies are available from the Planning & Development Department
Kansas Department of Transportation

the WHY?

WHAT?

and HOW?

of This REPORT

This report was compiled for use as a guide for locating construction materials in Cloud County.

Construction materials include all granular material, consolidated rock, and mineral filler suitable for use in highway construction.

Known open and prospective sites, both sampled and unsampled, and all geologic deposits considered to be a source of construction material are described and mapped.

Prospective sites are select geologic locations where construction materials may be found.

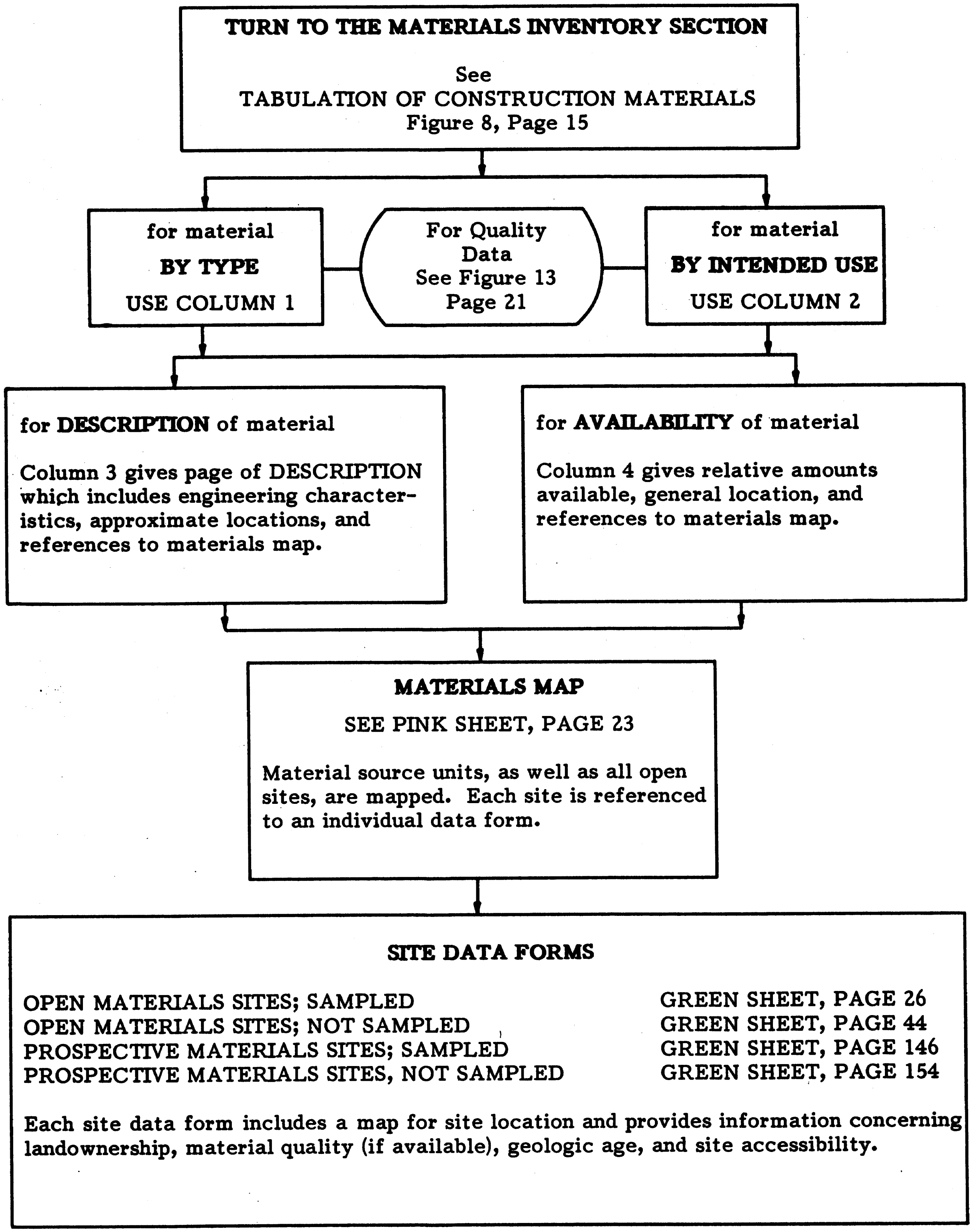
The diagram opposite shows how the MATERIALS INVENTORY SECTION may be used to locate and evaluate *mapped sites.*

Material found in individually mapped sites represents only a small portion of the construction materials resources in the county. Although data used to evaluate the material are based on limited sampling, these can be used to assess the general characteristics of the material source units elsewhere in the county.

Beginning on page 5 is a section explaining the geology of the county. This information (along with the maps, descriptions, and test data) provides the means of evaluating and locating additional construction materials sources in the geologic units throughout Cloud County.

TO LOCATE AND EVALUATE

A MAPPED SITE OF CONSTRUCTION MATERIAL IN CLOUD COUNTY



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PREFACE

This report is one of a series compiled for the Highway Planning and Research Program, "Materials Inventory by Photo Interpretation". The program is a cooperative effort of the Federal Highway Administration and the Kansas Department of Transportation, financed by highway planning and research funds. The objective of the project is to provide a statewide inventory of construction materials, on a county basis, to help meet the demands of present and future construction and maintenance needs.

Publications issued by the State Geological Survey of Kansas, concerning Cloud and surrounding counties, provided the basic geologic information used in this investigation. Detailed geologic and soils data were obtained from geologic profiles and soil surveys prepared for use in the design of major highways in the county by the Kansas Department of Transportation.

This report was prepared under the guidance of Robert R. Jones, P.E., Engineer of Engineering Services, A. H. Stallard, Chief, Environmental Support Section and with assistance from members of the Environmental Support and Special Services Sections.

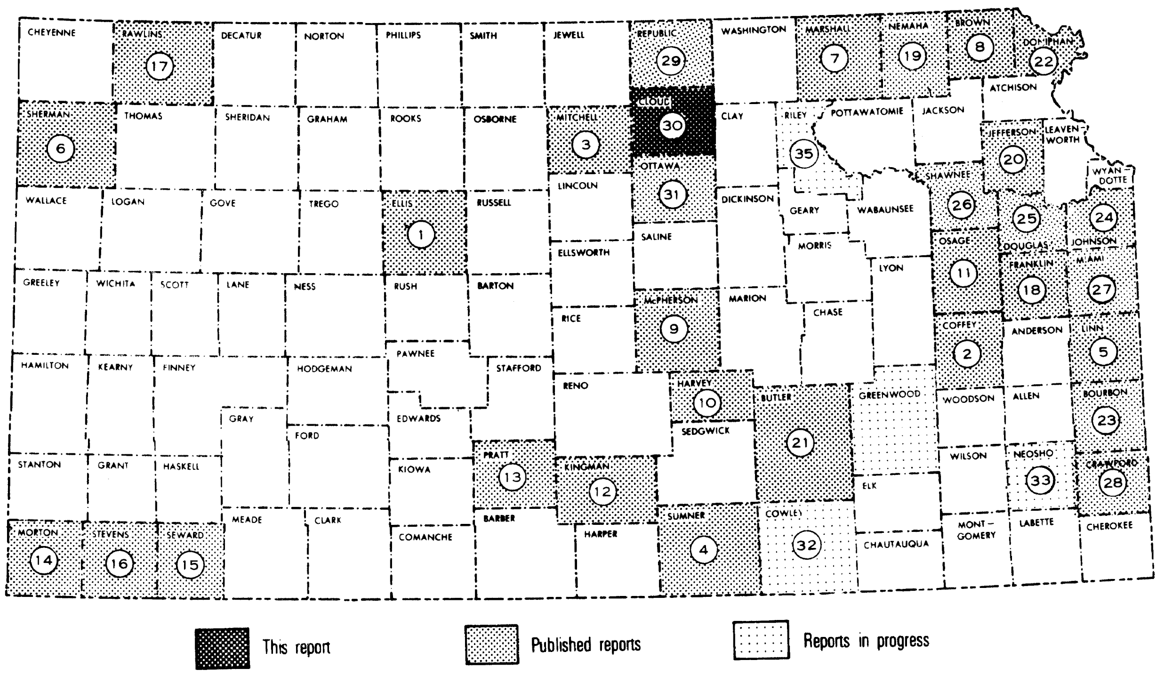


Figure 1. Index map of Kansas showing the location of Cloud County along with the report numbers and location of counties for which reports have been or are being completed.

ABSTRACT

Cloud County lies within the Dissected High Plains portion of the Great Plains physiographic province. Major topographic features of the county include the gently sloping upland plains and steep valley walls formed by erosion of upper Cretaceous limestones and shales along major drainage channels and the moderately rolling land surface formed by erosion of the Dakota Formation.

The Republican River and its tributaries drain most of the county; however, the extreme southern part of the county is drained by the Solomon River and Chapman Creek.

Sources of construction materials in Cloud County are limited to sand and gravel from Wisconsinan Terrace deposits and Quaternary Alluvium in the Republican River valley and Illinoisan Terrace deposits along the Solomon River valley. Untested calcite cemented sandstone was located southeast of Rice, however, the full extent of these deposits is not known.

Moderate to large quantities of water are available in alluvial and terrace deposits along the Republican River valley, however, in the area between Concordia and Ames the water may contain a high chloride content. Limited quantities of water are available from aquifers in other areas, but may contain objectionable concentrations of chlorides or other soluble minerals.

GENERAL INFORMATION SECTION

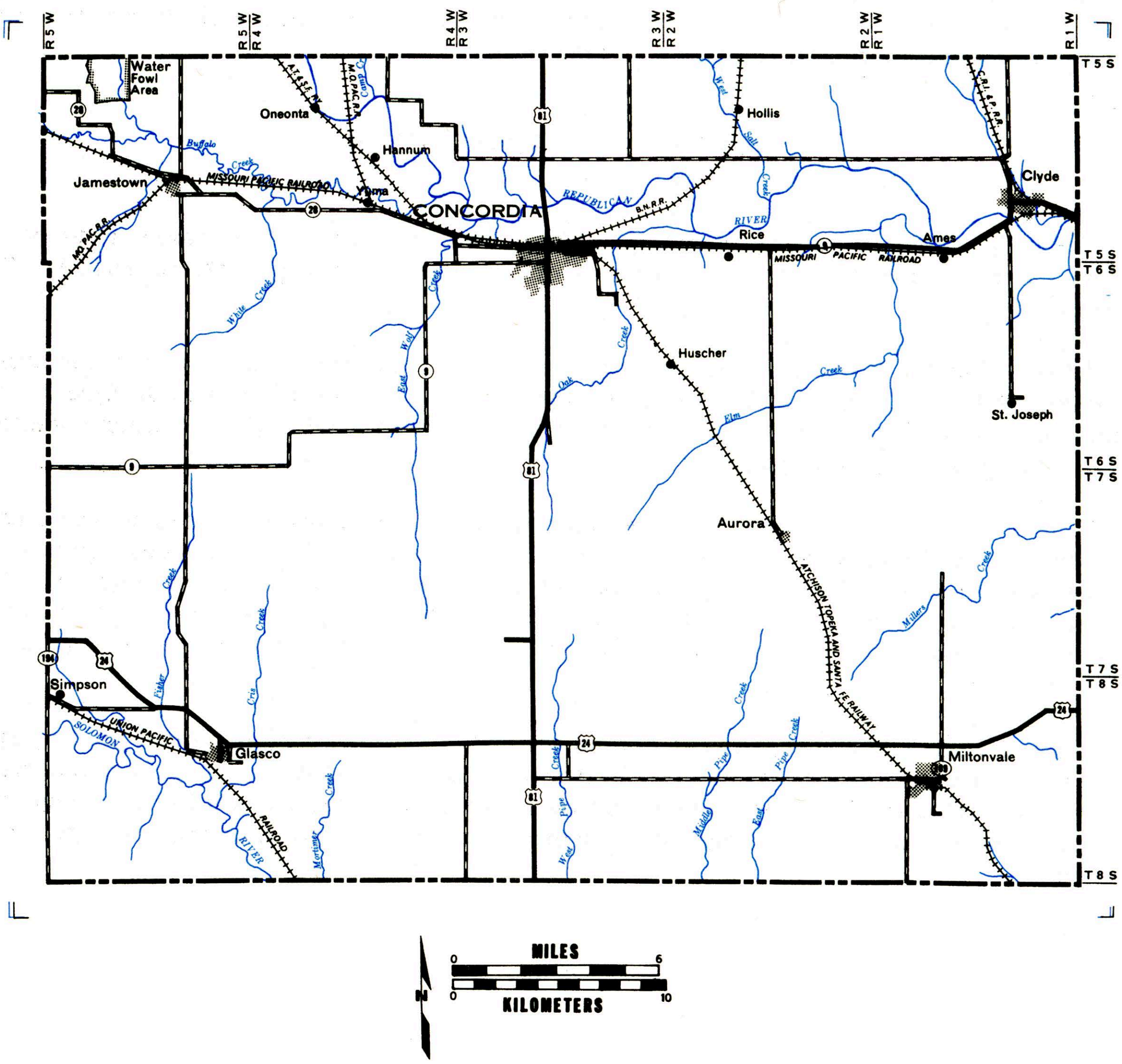


Figure 2. Drainage and Major Transportation facilities in Cloud County.

FACTS ABOUT CLOUD COUNTY

Cloud County is located in north-central Kansas (figure 1, page v), and has an area of 711 square miles (1,841 square kilometers) and a population of 14,090 according to the 1976 records of the Kansas State Board of Agriculture. Elevation of terrain above mean sea level ranges from a high of 1,685 feet (514 meters) in sec. 26, T7S, R3W, to a low of 1,250 feet (381 meters) where the Republican River leaves the county in sec. 1, T6S, R1W.

A primary road system connects all major communities and a well developed secondary road system provides access to small communities. Figure 2 illustrates major drainage and transportation facilities in the county.

METHODS OF INVESTIGATION

Investigation for and preparation of this report consisted of three phases: (1) research and review of available information, (2) photo interpretation, and (3) field reconnaissance.

Phase One: Relevant information concerning geology, soils, and construction materials of the county was reviewed and the general geology determined. Quality test results of samples taken in Cloud County were then correlated with the various geologic units and unconsolidated deposits.

Phase Two: A study and interpretation of aerial photographs taken by the Kansas Department of Transportation at a scale of one inch equals 2,000 feet (1cm = 240 meters) was accomplished. Figure 3 illustrates aerial photographic coverage of Cloud County. Geologic source beds and all open materials sites were mapped and classified on aerial photographs. All materials sites were then correlated with the geology of the county.

Phase Three: This phase was conducted after initial study of aerial photographs. A field reconnaissance was conducted by the author to examine construction materials, to verify doubtful mapping situations, and to acquire supplemental geologic information. Geologic classifications of open sites were confirmed, and prospective sites were observed.

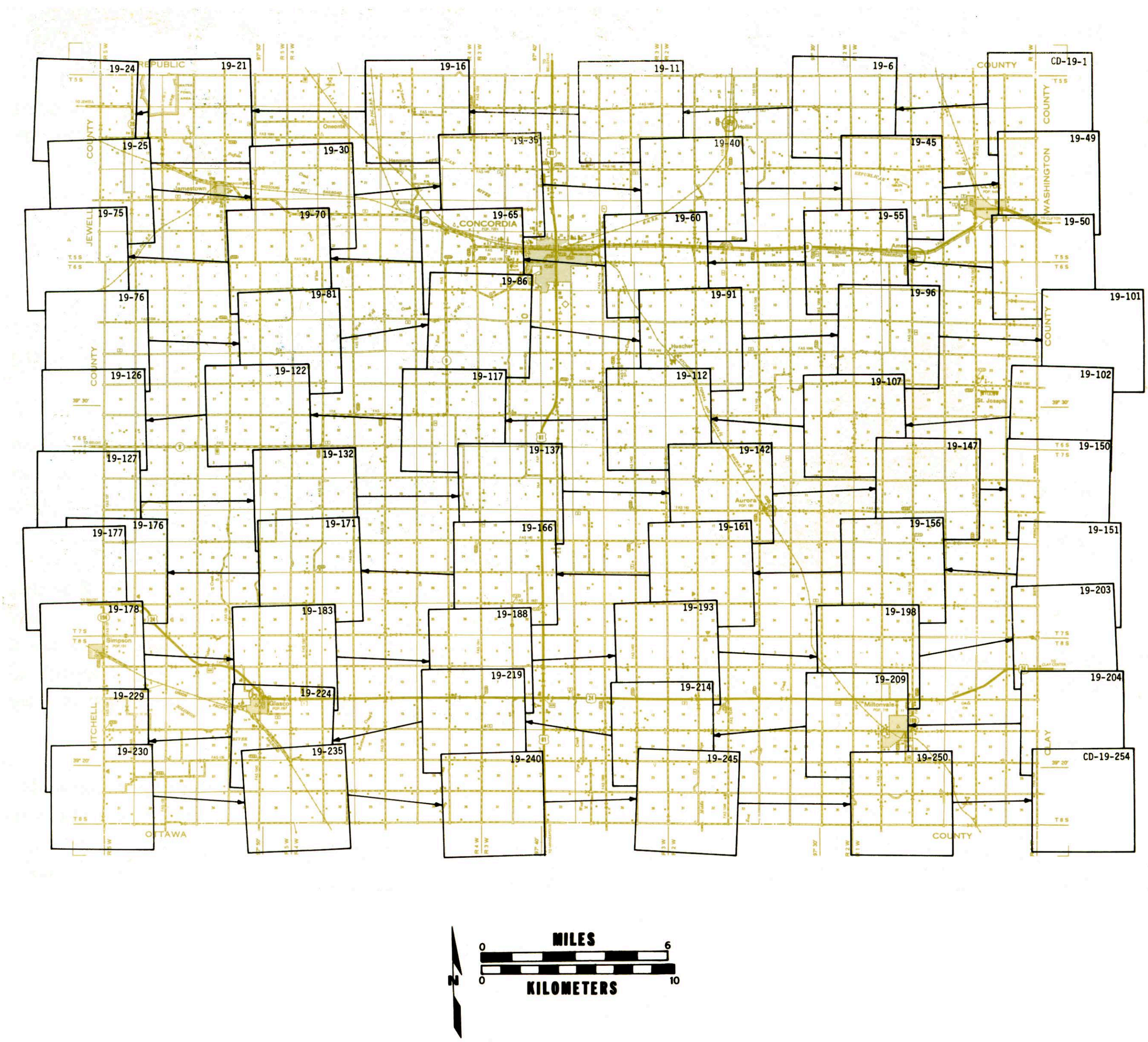
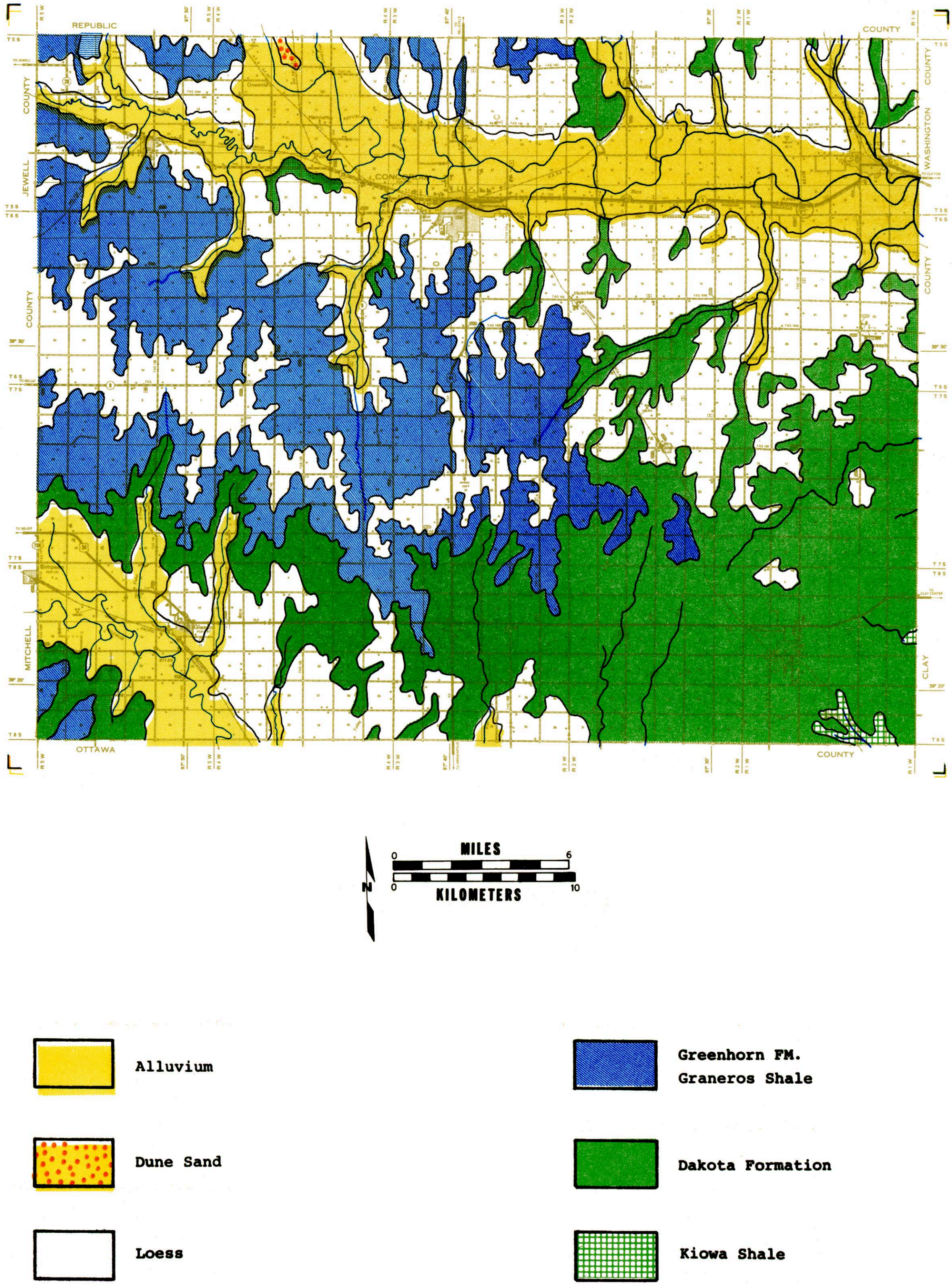


Figure 3. AERIAL PHOTOGRAPHIC COVERAGE MAP for Cloud County. The numbers refer to photographs taken by the Photogrammetry Section, Kansas Department of Transportation, on 11-13-75 at a scale of 1"=2000'. (1 cm. = 240 meters). Aerial photographs are on file in the KDOT's Photogrammetry Laboratory, State Office Building, Topeka, Kansas.

GEOLOGY SECTION



GENERAL GEOLOGY

GEOLOGY is the basis for this materials inventory. Knowledge of the geology makes it possible to: (1) ascertain the general properties of the material source, (2) identify and classify each source according to current geologic nomenclature, and (3) establish a uniform system of material-source-bed classification. By knowing the geologic age, origin, land form, and quality information of the source units, one can derive general information for untested materials sites and prospective locations.

It is important to note that the quality of material from a given source may vary from one location to another, especially in unconsolidated deposits.

This report is based primarily on information obtained from the State Geological Survey of Kansas, Bulletin 139, "Geology and Ground-Water Resources of Cloud County, Kansas," by Bayne and Walters, 1959, 144 pp. Additional information was obtained from Kansas Geological Survey publications relating to Cloud and surrounding counties, reports compiled by the Geology Section of the Kansas Department of Transportation and field observations by the author. The geologic timetable, figure 4, shows in graphic form the major time periods and the approximate duration of each. Figure 5, page 7, illustrates the surface geology and stratigraphic position of each material source unit in Cloud County. Divisions of the Quaternary Period are illustrated in figure 6, page 9.

Subsurface rocks in Cloud County range in age from Precambrian to Permian. Precambrian rocks are marine sedimentary (Merriam, 1963).

Paleozoic sediments composed of limestones, dolomites, sandstones, and shales and ranging in age from Cambrian to Permian overlie the Precambrian basement rocks. Data from surrounding counties indicates that these sediments are approximately 4000 feet (1219 meters) thick. These rocks do not outcrop in the county and are unconformably overlain by Cretaceous deposits.

At the close of Paleozoic time, the seas withdrew and the area was gently tilted towards the Hugoton Embayment located to the southwest. Triassic and Jurassic sediments are absent in the county, indicating a prolonged period of uplift and erosion. During early Cretaceous time, the sea began an advance from the south that eventually inundated the land surface of the mid-continent area. The oldest Cretaceous sediments exposed in the county are outcrops of Kiowa Shale which lie uncomformably on Permian sediments. Throughout the county the Dakota Formation overlies the Kiowa Shale. Mack (1962) places an erosional unconformity between the top of the Kiowa Shale and the base of the Dakota Formation. During the deposition of the Dakota Formation, the sea is thought to have advanced and retreated numerous times throughout the midcontinent area (Twenhofel, 1920). Plummer and Romary (1942) describe the depositional environment of Dakota time as comparable to the existing Mississippi Delta. Characteristics of the sediments such as cross-bedding and sorting are indicative of a near shore or coastal plain environment characterized by sand bars, swampy areas, and lagoons. Mack (1962) compares the ancient environment with those in existence today along the Texas Gulf Coast. The presence of the fossil remains of an ankylosaur, family Nodosauridae (an armored dinosaur) in the Dakota Formation of northeast Ottawa County indicates a warm, temperate deciduous forest existed during at least one part of this period (Eaton, 1960).

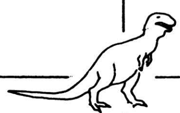
ERAS	PERIODS	ESTIMATED LENGTH IN YEARS	TYPE OF ROCK IN KANSAS	PRINCIPAL MINERAL RESOURCES
CENOZOIC	QUATERNARY (PLEISTOCENE) 	1,800,000	Glacial drift; river silt, sand, and gravel; dune sand; wind-blown silt (loess); volcanic ash.	Sand and gravel; volcanic ash; agricultural soils; water.
	TERTIARY 	63,500,000	Silt, sand, and gravel; fresh-water limestone; volcanic ash; bentonite; diatomaceous marl; opaline sandstone.	Sand and gravel; volcanic ash; diatomaceous marl; water.
MESOZOIC	CRETACEOUS	71,000,000	Chalky shale, dark shale, vari-colored clay, sandstone, conglomerate; outcropping igneous rock.	Concrete and bituminous aggregate, light type surfacing, shoulder and subgrade material, riprap, and building stone; ceramic materials; water.
	JURASSIC	59,000,000	Sandstone and shale, chiefly subsurface.	
	TRIASSIC	30,000,000		
PALEOZOIC	PERMIAN 	55,000,000	Limestone, shale, evaporites (salt, gypsum, anhydrite), red sandstone and siltstone, chert, and some dolomite.	Concrete and bituminous aggregate, light type surfacing, shoulder and subgrade material, riprap, and building stone; natural gas, salt, gypsum, water.
	PENNSYLVANIAN 	40,000,000	Alternating marine and non-marine shale; limestone, sandstone, coal, and chert.	Concrete and bituminous aggregate, light type surfacing, shoulder and subgrade material, riprap, and limestone and shale for cement; ceramic materials; oil, coal, gas, and water.
	MISSISSIPPIAN 	25,000,000	Mostly limestone, predominantly cherty.	Chat and other construction materials; oil, zinc, lead, and gas.
	DEVONIAN	50,000,000	Subsurface only. Limestone and black shale.	Oil.
	SILURIAN	45,000,000	Subsurface only. Limestone.	Oil.
	ORDOVICIAN	60,000,000	Subsurface only. Limestone, dolomite, sandstone, and shale.	Oil, gas, and water.
	CAMBRIAN 	70,000,000	Subsurface only. Dolomite and sandstone.	Oil.
PRE-CAMBRIAN	(Including PROTEROZOIC and ARCHEOZOIC ERAS)	4,600,000,000 +	Subsurface only. Granite, other igneous rocks, and metamorphic rocks.	Oil and gas.

Figure 4. Geologic Timetable.

System	Series	Stage or Group	Graphic Legend	Formations and Members	Map Symbols	Thickness	General Description	Construction Materials
Quaternary	Pleistocene	Recent		Alluvium	Qal	0-130' (0-40m)	Silt, clay, sand and gravel. Arkosic sand and gravel, with some locally derived limestone gravel.	Concrete and bituminous aggregate and light type surfacing.
				Dune Sand	Qds	0-50' 0-15m)	Cross-bedded tan to gray, fine-grained, quartzitic material.	Mortar sand.
		Wisconsinan		Wisconsinan Terrace	Qtw	0-125' (0-38m)	Silt, clay, and sand and gravel. Arkosic sand and gravel with some locally derived limestone gravel.	Light type surfacing.
				Peorian Loess		0-70' (0-21m)		
		Illinoisan		Loveland Loess		0-60' (0-18m)		
				Crete Terrace	Qti	0-30' (0-9m)	Silt, clay, and scattered thin to thick lenses of sand and gravel.	Concrete and bituminous aggregate, and light type surfacing.
		Kansan		Meade Fm.		0-60' (0-18m)	Silt, clay, limestone and sandstone fragments. Erratic sorting and highly variable in thickness and areal extent.	Concrete and bituminous aggregate and light type surfacing.
Tertiary	Pliocene			Ogallala Fm. Kimball Mbr.		0-1' (0-.3m)		
Cretaceous	Upper Cretaceous	Colorado Group		Carlile Sh. Fm. — Fairport Chalk Mbr.		0-30' (0-9m)		
				Greenhorn Limestone Fm. — "Fencepost Bed" Pfeifer Shale Mbr.; "Shellrock Bed" Jetmore Chalk Mbr.; Lincoln -Hartland Mbr.	Kg	80-90' (24-27m)	Alternating thick calcareous shales and thin limestones with scattered seams of bentonite. Tan to gray with abundant fossil clams.	Light type surfacing and building stone.
				Graneros Shale		20-40' (6-12m)		
	Lower Cretaceous			Dakota Fm. — Janssen Clay Mbr.; Terra Cotta Clay Mbr.	Kd	25-400' (8-122m)	Kaolinitic shale with thin to massive layers of cross-bedded sandstone and thin lignite beds. Sandstone is tan to tan gray, brown, and reddish brown with iron or calcite cementation.	Some calcite cemented sandstone appears suitable for construction aggregate. Other types of sandstone suitable only for light type surfacing.

Figure 5. Generalized geologic column of the surface geology in Cloud County.

As the seas gradually transgressed at the close of Dakota time, the non-calcareous black shales of the Graneros were deposited. The depositional environment continued to change and the chalky Greenhorn Limestone and Carlile Shale Formations were laid down.

At the close of the Cretaceous, the seas retreated to the south and a prolonged period of erosion followed. The only Pliocene sediment in the county is a one foot (0.3 m) bed of "Algal" limestone which is regarded as the uppermost portion of the Ogallala Formation (Mack, 1962).

Divisions of the Quaternary Period				
Period	Epoch	Age	Estimated length of age duration in years	Estimated time in years elapsed to present
Quaternary	Pleistocene	Recent		10,000
		Wisconsinan Glacial	80,000	90,000
		Sangamonian Interglacial	160,000	250,000
		Illinoisan Glacial	110,000	360,000
		Yarmouthian Interglacial	160,000	520,000
		Kansan Glacial	280,000	800,000
		Aftonian Interglacial	450,000	1,250,000
		Nebraskan Glacial	550,000	1,800,000 +

Figure 6. Geologic timetable of the Quaternary Period.

The Quaternary (figure 6) marked a time of both degradational and aggradational cycles which were the result of a sequence of glaciers advancing and retreating. Deposition of loess and major drainage development occurred during early Pleistocene time. Streams incised their channels during Nebraskan time and deposits were removed by later erosion. The ancestral Republican River did not flow through the county until Illinoisan time and Kansan (Meade Formation) basal deposits in the valley are largely locally derived material. Illinoisan terrace deposits in the Republican River valley are thick fluvial silts and the Illinoisan Terrace (Crete Member) along the Solomon River is locally derived sand and gravel with some arkosic material from Ogallala outcrops to the west. Loess (Loveland) was deposited over upland areas during and after the fluvial deposition. Streams incised the Illinoisan deposits and deposited silts and clays in the Solomon valley and sand and gravel in the Republican valley during Wisconsinan time. Loess (Peorian) was also deposited in some upland areas during early Wisconsinan time. In early Recent time streams eroded channels in the Wisconsinan deposits and the Republican River backfilled its channel with large amounts of sand and gravel. Dunes derived from alluvium in the Republican River valley and alluvium in active stream channels are the most recent deposits in the county.

GEO-ENGINEERING

This section provides a general appraisal of the geo-engineering problems that may be encountered in Cloud County during highway construction. Potential ground-water problems and the quality of water available for concrete are briefly reviewed along with engineering soil types present in the area. Detailed field investigations will be necessary to ascertain the severity of specific problems and to make recommendations in design and construction procedures.

Geo-engineering problems in Cloud County, which are described in the following paragraphs, are associated with alluvial and terrace deposits of the major drainage channels, sandstone and shale outcrops along valley walls, and in limited areas where limestones and dune sand are located.

The alluvial and terrace deposits encountered in the valleys of the Solomon and Republican Rivers and their tributaries are composed of silt, clay, sand and gravel. Cut-off meanders containing unconsolidated and organic material are located in the flood plains and terraces. The design of fill sections will require detailed study to determine construction procedures that will minimize the effect of differential consolidation. The need for borrow to fill construction in alluvium will also require exploration to acquire sufficient material above the water table. Alluvial deposits are susceptible to seasonal flooding and terraces of Wisconsinan age may be inundated during periods of major flooding. Generally, soils present in the upper part of terrace deposits have a low shear strength and a high shrink-swell potential.

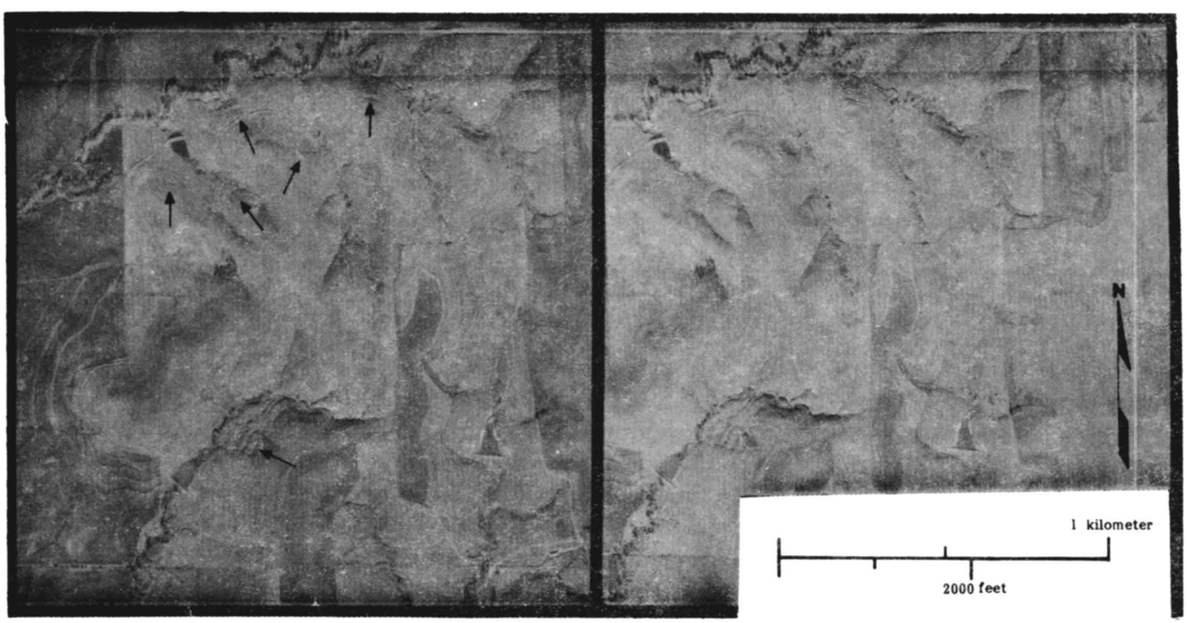


Figure 7. Stereogram of slope failures in Graneros Shale located in sec. 29, T7S, R4W, Cloud County, Kansas.

Rock excavation can be expected in areas where calcite and iron cemented sandstones of the Dakota are encountered. The sandstones tend to case harden upon exposure which will cause difficulty in their removal.

Shales of the Dakota, Graneros, and Greenhorn Formations contain thin seams of bentonite which vary in thickness from .01 to .5 feet (.3 cm to 15.2 cm). Failure to remove bentonite seams may result in slope failure as observed in sec. 29, T7S, R4W, (figure 7). These failures occur when the bentonite hydrates and expands.

Lignite coal in the Dakota Formation has been mined throughout most of Cloud County. These were mostly shaft mining operations which have not been active for over 40 years. The coal deposits occur near the top of the formation but are highly erratic in the thickness and areal extent; however, the possible economic value of any remaining lignite should be considered in proposed construction. Plastic underclays, unconsolidated spoil piles and open mine shafts are potential construction problems that may be encountered.

Greenhorn Limestone outcrops are found in the western three-fourths of the county with a few outliers located southeast of Aurora. These outcrops are composed of alternating thin limestones, thick limy shale beds, shale beds and scattered seams of bentonite. Moderate amounts of rock excavation can be expected in areas where these limestones and shales outcrop.

Sand dunes located north of the Republican River (plates I, II and III) may require special construction techniques to prevent wind erosion when vegetation is removed. Binder material such as soil or asphalt may be needed to provide a stable subgrade for vehicular construction traffic.

Soils overlying the Kiowa Formation in the southeastern part of Cloud County are clayey and exhibit high shrink and swell characteristics. Soil material covering the Dakota Formation displays moderate to high shrink and swell characteristics, low bearing capacity and low shear strength. Thin soils having low shear strength, low bearing capacity and moderate to high shrink and swell potential will be encountered generally south and east of the Greenhorn outcrop shown on plates I, II, IV, V, VI, VII, VIII and IX.

Hydrology problems of a limited nature can be anticipated along bentonite seams, limestones, bedrock-soil mantle contacts and buried soil profiles. Similar problems will be encountered in some sandstones of the Dakota Formation; however, due to the complexity of the formation, these areas will have to be determined by on-site inspection.

Water supplies from less than 1 gpm (.1 l/s) to in excess of 1000 gpm (63.1 l/s) are available from aquifers in Cloud County. The principle aquifers are found in deposits of Pleistocene age and in sandstones of the Dakota Formation. Yields from the Dakota Formation are generally only sufficient for domestic use and deeper wells may produce mineralized water.

Salty water is likely to be encountered in Kansan deposits from a few miles west of Concordia to the east side of Range 2 West near Ames in the Republican River valley. A fairly persistent silt and clay bed in the upper part of these deposits seals salt water from the Dakota Formation within the basal alluvial fill. Wells or exploratory drilling should not penetrate this seal as the mineralized water may be under a hydrostatic head high enough to cause contamination of overlying aquifers.

Water from deposits of Recent and Wisconsinan age along the Republican River may yield in excess of 1000 gpm (63.1 l/s). Those in the Recent Alluvium have a greater thickness of granular material and potentially higher yields.

MATERIALS INVENTORY SECTION

GENERAL INFORMATION

Sand and gravel deposits of Quaternary age make up the major portion of the available construction materials of Cloud County. Deposits of eolian silt found in the upland areas have a low plasticity index which permits their use for certain types of mineral filler. Dune sand found along the north side of the Republican River also appears suitable for mortar sand.

Limestones of Cretaceous age are found in the county; however, the thin nature of the limestone units within the Greenhorn Formation limits their use to light type surfacing and as a minor source of building stone. Deposits of calcite cemented sandstone of the Dakota Formation are found southeast of Rice (sites SS+122 and SS+123). Quality tests have not been run on the material at the time this report was written; however, field observations indicate the material might be suitable as construction aggregate. The full extent of this deposit has not yet been defined.

Construction materials types, their uses, and availability are tabulated in figure 8. Test results from a limited amount of sampling and testing are presented in figure 13, page 21.

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TYPE material and Geologic Source	USE	Page	Availability
SANDSTONE			
Dakota Formation			
"Quartzitic" sandstone	Suitable for concrete and bituminous aggregate, light type surfacing, riprap.	16	Very limited source near Rice, Plate III.
Poorly calcite cemented and limonite cemented.	Light type surfacing only.		Limited source, eastern half of county, Plates II, III, IV, VII, VIII and IX.
LIMESTONE			
Greenhorn Formation	Limited to local use for light type surfacing.	17	Moderate source in western 2/3 of county. Plates I, II, IV, V, VI, VII, VIII and IX.
SAND AND GRAVEL			
Illinoisan Terrace	Concrete and bituminous aggregate and light type surfacing.	18	Limited source along Solomon River valley, Plates IV, VII and VIII.
Wisconsinan Terrace	Concrete and bituminous aggregate and light type surfacing.	19	Moderate source along Republican River valley, Plates I, II and III.
Dune Sand	Mortar sand.	19	Limited source in northern part of county. Plates I, II and III.
Quaternary Alluvium	Concrete and bituminous aggregate and light type surfacing.	19	Good source along Republican River. Plates I, II and III.

Figure 8. Tabulation of the construction materials types and their availability in Cloud County.

Sandstone

Dakota Formation

The Dakota Formation of early Cretaceous age lies unconformably on the Kiowa Formation in the southeastern part of the county and is overlain conformably by the Graneros Shale. The Dakota forms a highly variable topography over the eastern part of the county. In areas where the Graneros caps the Dakota, the thickness of the formation is approximately 400 feet (122 meters); however, the thickness is variable due to the basal unconformity.

According to Bayne and Walters, (1959) the Dakota Formation in Cloud County consists of three primary intergrading units. The upper one-third and lower one-third of the formation are massive lenticular sandstones with intermittent lenses of silt and clay. The middle third is silt and kaolinitic clay interbedded with lenticular sand bodies. Correlation of the beds over more than a short distance is not possible due to the erratic nature of the deposits.

Kaolinitic clays have been utilized for ceramic products, but the study of this type of material is not within the scope of this report.

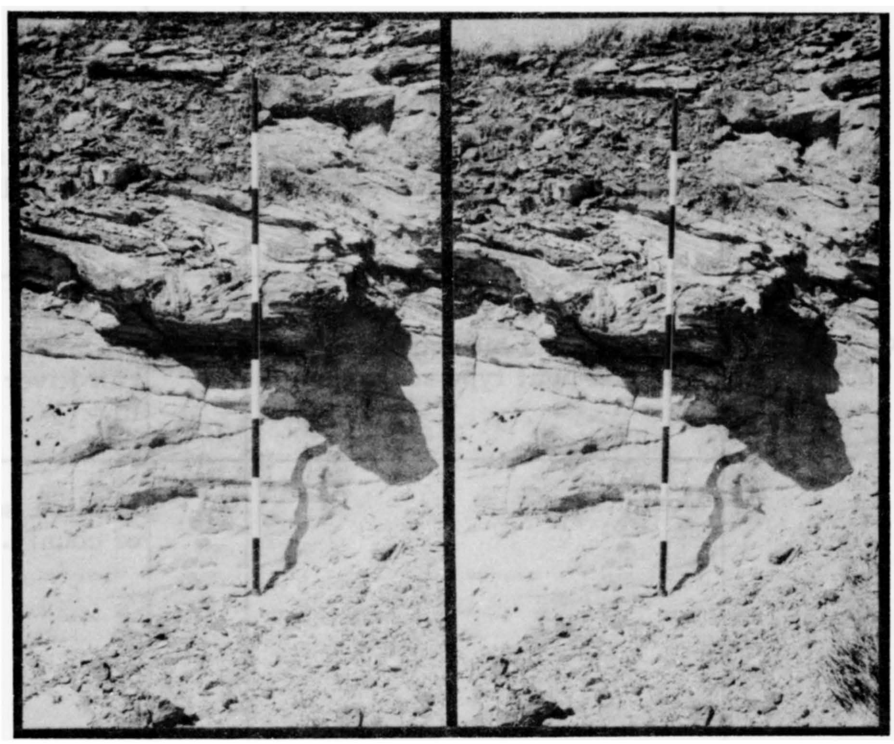


Figure 9. Cross-bedding in Dakota sandstone exposed in north side of road cut in the SE¼, sec. 17, T8S, R2W.

The sandstone lenses are light to tan gray, yellowish brown to brown, and sometimes reddish brown to red in color. The thickness varies from a few inches (centimeters) to many feet (meters) with a highly irregular exposure pattern. They are generally composed of fine to medium, well sorted quartz grains. Cross-bedding is prominent in most of the sandstone lenses. The sand grains are cemented together with iron oxide, calcium carbonate and in some cases silica. The degree of cementation ranges from loose sand to a very dense, hard, cemented sandstone (quartz arenite).

Iron cemented sandstones have been used as light type surfacing in the county; however, due to poor cementation of the stone, it is not suitable for construction aggregate. Calcite cemented sandstone, found southeast of Rice (SS+122 and SS+123), appears to be acceptable as construction aggregate. Field observations indicate this material is similar to that produced by the Quartzite Stone Co. near Lincoln, Kansas, which has been tested and found to be acceptable as construction aggregate. The quartz arenite produced generally has soundness values of .98 or higher, absorption of less than 1%, specific gravity values (dry) near 2.60 and (wet) 2.65 and Los Angeles wear values from 29 to 45%.

The amount of producible aggregate varies from location to location. Test drilling will be needed to delineate the areal extent and thickness of any deposit of cemented sandstone. Quality tests should also be completed on the material before use due to the highly variable nature of the Dakota Formation.

Due to the erratic nature of the sandstone deposits and the fact that much of the Dakota is covered by loess, alluvium, and terrace deposits, members were not mapped. Resistant outcrops observed on the aerial photography were mapped and are shown on plates II, III, IV, VI, VII, VIII and IX.

Limestone

Greenhorn Limestone Formation

The Greenhorn Limestone Formation is exposed in the western two thirds of the county with some outliers south and east of Aurora. Its maximum thickness in Cloud County is approximately 90 feet (27 meters) where the overlying Carlile Shale is present.

The Greenhorn is composed of four members which are, in ascending order, the Lincoln Limestone, Hartland Shale, Jetmore Chalk, and Pfeifer Shale. Due to its limited value as construction aggregate, the formation is mapped as one unit and is shown on plates I, II, IV, V, VI, VII, VIII and IX.

The Greenhorn Formation is composed of chalky shales, thin bedded limestones and scattered, thin beds of bentonite. The basal Lincoln Limestone beds are often distinguished by the petroliferous odor given off on a freshly broken surface. The Lincoln Limestone should not be confused with the term "Lincoln Quartzite" which is a calcite cemented sandstone of the Dakota Formation. The Jetmore Chalk consists of chalky shale and thin beds of limestone including the "Shellrock bed" which contains abundant fossil impressions of *Inoceramus labiatus*, a clam that lived in the Cretaceous seas.

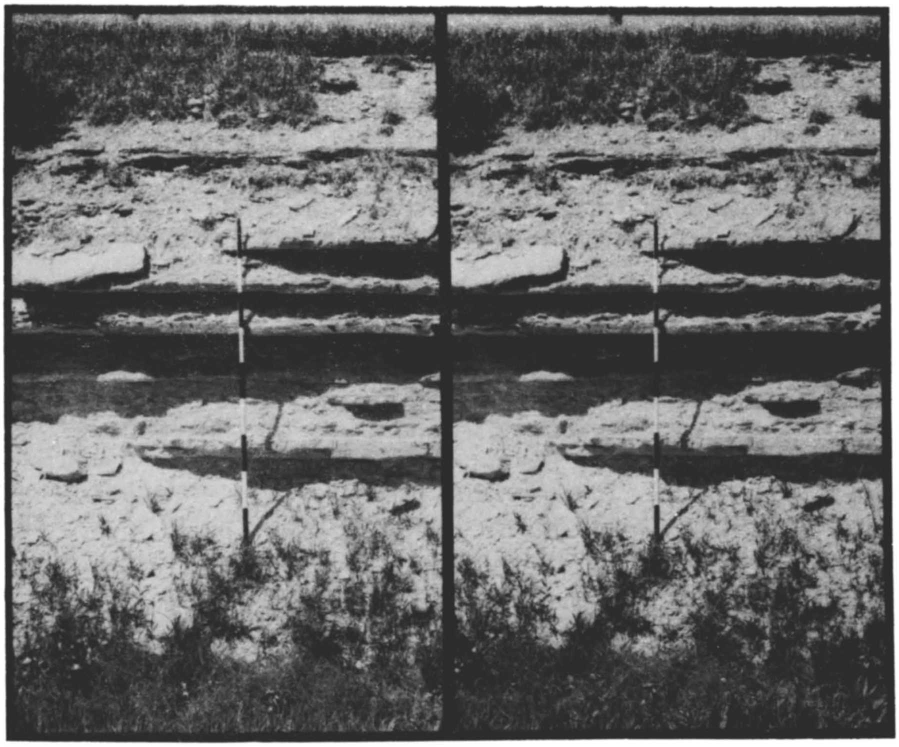


Figure 10. Exposure of a portion of Greenhorn Limestone Formation, SE¼, sec. 7, T8S, R3W (Stereogram).

The uppermost Pfeifer Shale member also consists of thin alternating beds of chalky shale and thinner beds of limestone. The uppermost bed of the Pfeifer is the "Fence-post limestone bed" which serves as the boundary between the Greenhorn and Carlile Formations. The "Fence-post" and the "Shellrock" have been quarried for building stone and fenceposts throughout their outcrop area.

Limited amounts of aggregate for local use can be obtained from the outcrop area of the Greenhorn Formation; however, due to its soft nature, the material will not meet specifications for construction aggregate.

Sand and Gravel

Illinoisan Terrace

Terrace deposits of Illinoisan age are found alongside most of the major drainage valleys in the county. The height of the terraces above the flood plain range from a few feet (meters) to 50 feet (15 meters) (Bayne and Walters) and they have a thickness ranging up to 30 feet (9 meters). The upper material in the terrace deposits is composed of silt and clay sized material while more granular material of sand and gravel is found in the lower portion of the deposit. Along the Republican River these terraces are dominantly silt and clay and are not of value for construction materials. Crete terraces along the Solomon River are suitable for construction aggregate and are composed of reworked arkosic material from the Ogallala Formation located to the west of Cloud County and coarser material derived from locally outcropping rocks. The Illinoisan terrace deposits are mapped on plates I, II, III, IV and VII.

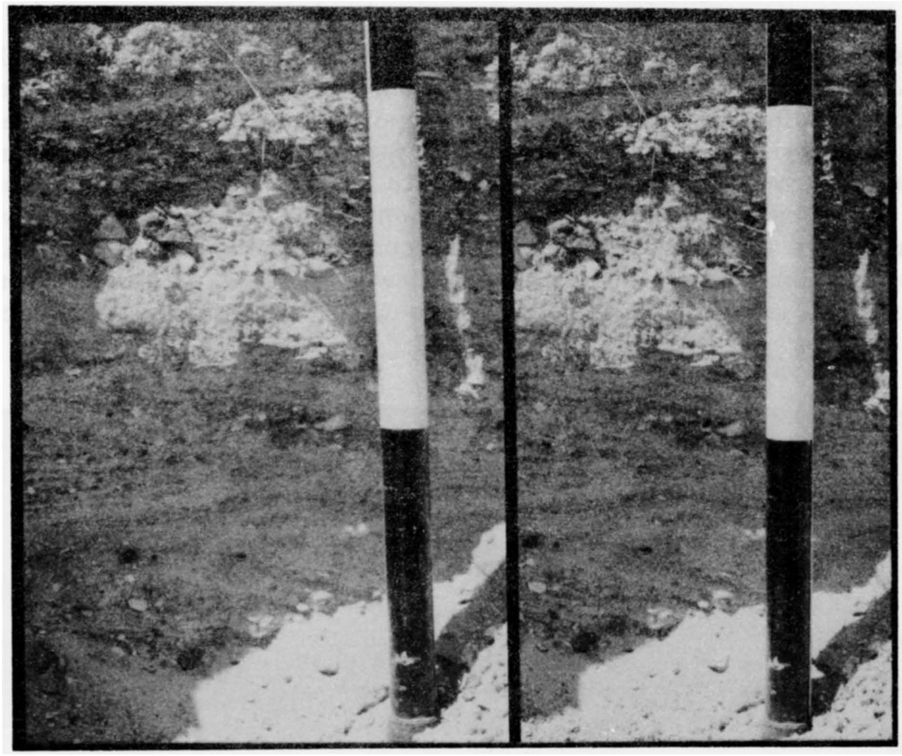


Figure 11. Illinoisan sand and gravel exposed in the E½ sec. 32, T7S, R5W (Stereogram).

Wisconsinan Terrace

Terrace deposits of the Wisconsinan Stage occupy most of the larger stream valleys in Cloud County. The width of these deposits varies from a few feet (meters) in the smaller tributaries to more than 2 miles (3.2 kilometers) along the Solomon River and the thickness may be as great as 125 feet (38 meters) in the Republican River valley. Wisconsinan terraces in the Solomon River valley and along larger streams are composed primarily of silt and clay sized material with thin lenticular sand deposits near the base. These deposits are not of economic value as construction aggregate sources. Deposits along the Republican River are largely arkosic sand and gravel capped by silt and clay up to 20 feet (6.1 meters) thick. They represent large potential resources that are similar to existing sources in the Quaternary Alluvium.

Dune Sand

Sand dunes are found north of the Republican River and are shown on plates I and III. They are composed primarily of fine quartz grains with varying amounts of silt and clay. The dunes are tan colored, crossbedded, and were covered with vegetation at the time of this study. Usually their thickness will not exceed 50 feet (15 meters). The fine dune sand can generally be used as a mortar sand; however, tests should be run before use from any location.

Quaternary Alluvium

Alluvium found along the Republican River is composed of unconsolidated sand, gravel, silt and clay sized material. The thickness of alluvial deposits is as great as 130 feet (40 meters). Granular material is dominantly arkosic sand and gravel with some locally derived material. Silt and clay overburden is generally less than 15 feet (5 meters) thick. Siliceous granular material from alluvial deposits present in the Republican River valley comprise the most important source of aggregate in Cloud County. It is classified as a reactive aggregate by the Kansas Department of Transportation, and concrete made with aggregate from this source is highly susceptible to expansion, cracking, and distress. The cement reacts with the silica which then hydrates to produce a silica gel that causes the concrete to expand and deteriorate. To alleviate these problems prescribed amounts of sweetner such as limestone, sandstone, or specified sand and gravel must be added to meet K.D.O.T. standard specifications.

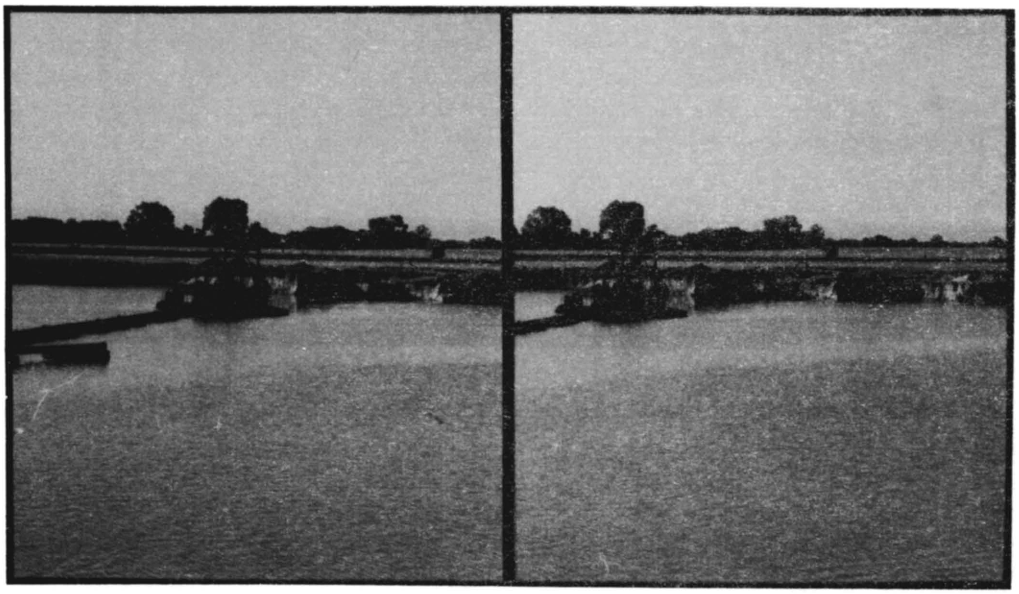


Figure 12. Sand pumping operation located in the W½, sec. 26, T5S, R3W (Stereogram).

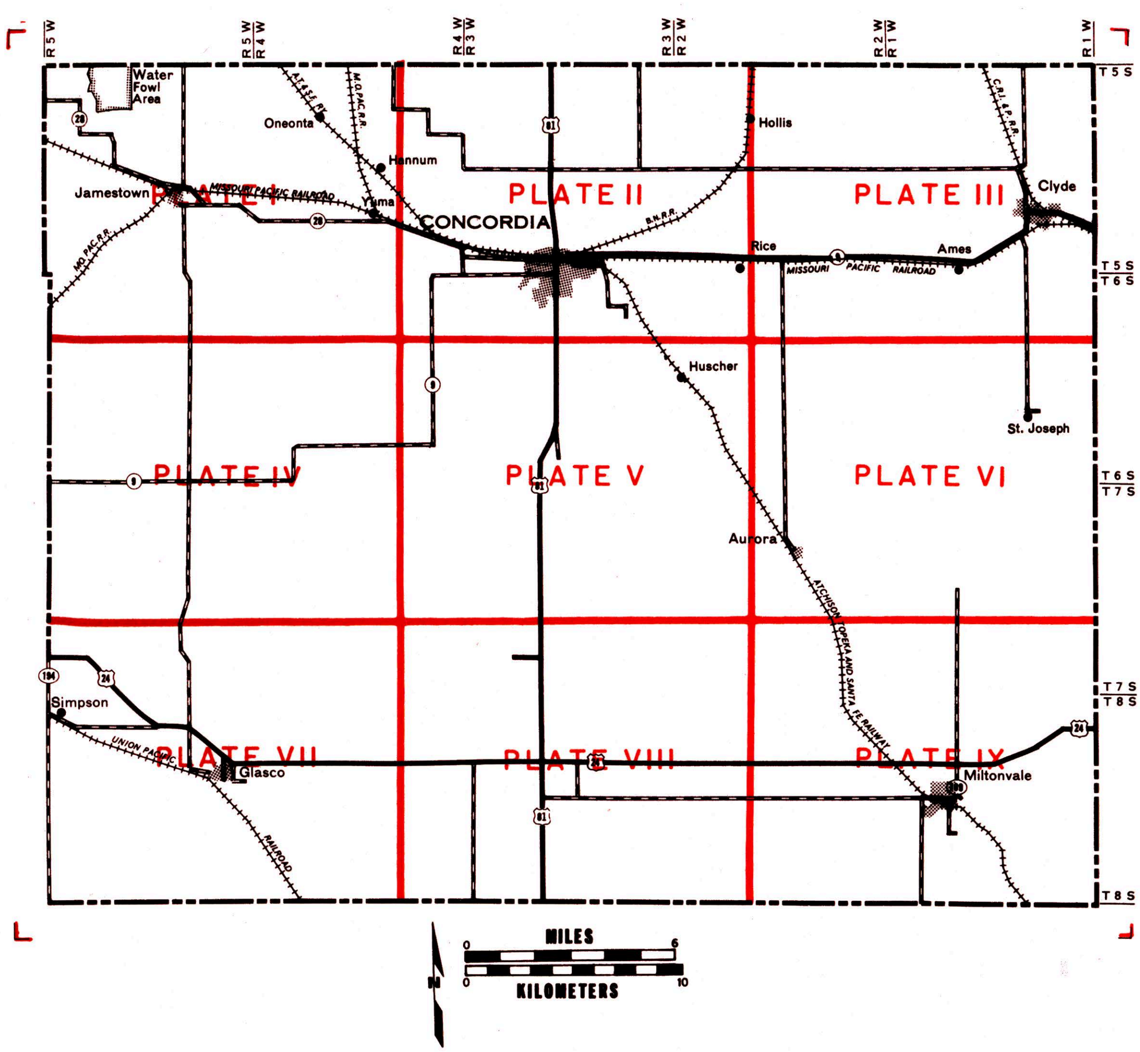
Alluvium in the Solomon River valley is comprised of relatively thick silts and clays deposited over thin lenses of sand and gravel. The thickness of the fine grained overburden is too great to permit economic exploitation of the underlying granular material. Alluvium predominantly of silt and clay sized particles, is also present in many of the smaller stream valleys, but cannot be portrayed on 1" = 1 mile (1 cm = .634 kilometers) maps. Alluvial material is mapped on plates I, II, III and VII.

Site Data Form No.	Material Type	Date of Test	Percent Retained											S.P. Gr. Sat.	% Wear	Soundness	Absorption	Source of Data SHC Lab No.
			1½	3/4	3/8	4	8	16	30	50	100	Wash	G.F.					
SOURCE OF MATERIAL: ALLUVIUM - Qal																		
SG + 1	Sand & Gravel	3-27-68	0	0	5	25	53	79	93	97	99	1.15	4.51	2.58	35.6	0.99	0.60	68-824
SG + 2	Sand & Gravel	3-4-60	0	0	1	3	39	61	87	97	99	1.3	3.87	2.60	39.2	0.98	0.50	10684
SG + 3	Sand & Gravel	2-12-68	0	0	3	19	54	88	96	99	99	1.0	4.58	2.58	35.1	0.97	0.60	68-229
SG + 6	Sand	4-25-67			0	4	16	33	53	79	90	6.7	2.75	2.59	35.9	0.98	0.50	67-1380
					0	3	16	34	55	81	93	3.1	2.82					
					0	2	10	23	38	66	86	7.3	2.25					
					0	5	16	30	48	84	95	3.1	2.79					
SG + 7	Sand & Gravel	6-1-70												2.57	37.0	0.99	0.96	70-1312
SG + 8	Sand & Gravel	2-3-59		0	1	8	26	55	78	97	98	1.14	3.63	2.62	33.2	0.98	0.41	5449
SOURCE OF MATERIAL: DUNE SAND - Qds																		
FS + 5	Fine Sand	4-18-72				0	1	7	17	40	66	15.7	1.31	2.58	36.0	0.99	0.80	72-719
						0	2	6	20	64	80	11.9	1.72					
							0	1	2	11	37	32.5	0.51					
FS-116	Fine Sand	2-54						0	1	25	60	22	0.86					
								1	1	23	65	16	0.90					
								0	2	23	58	24	0.83					
								0	2	29	65	20	0.96					
								0	1	24	63	21	0.88					
SOURCE OF MATERIAL: LOESS - Ql																		
Si + 4	Silt	12-72					0	1	1	2	2	95.8						
							0	1	1	2	2	96.2						
							0	1	1	2	2	96.1						
									0	1	1	97.8						
Si - 117	Silt	4-75						0	1	4	12	76						
									0	3	10	80						
									0	2	10	82						
									0	3	12	76						
									0	3	13	77						
									0	3	13	75						
									0	2	12	80						
Si - 121	Silt	2-55						0	1	6	44	51						
						0	1	1	2	7	51	45						
								0	1	7	47	48						
							0	1	2	8	37	56						
					0	2	4	6	7	13	40	56						
						0	1	1	1	8	36	60						
SOURCE OF MATERIAL: ILLINOISAN TERRACE - Qti																		
SG+ 10	Sand & Gravel	2-30-70		.4	2	5	9	22	50	89	93	6.6	2.70	2.61	28.4	0.95	0.40	70-159
				0	3	9	19	42	74	91	94	5.6	3.32					
				0	2	5	12	32	70	92	95	4.7	3.08					
			0	1	7	14	23	40	70	88	81	8.1	3.34					
			0	2	17	27	36	54	76	90	92	6.8	3.94					
				0	1	2	4	16	50	84	88	9.9	2.45					
				0	3	8	20	47	75	91	93	6.0	3.37					
				0	1	5	12	35	72	93	95	4.0	3.13					
			0	4	9	14	21	36	65	90	92	6.9	3.31					
			0	3	7	10	16	33	65	89	94	5.0	31.7					
			0	.4	4	9	16	34	66	82	85	12.7	29.4					
						0	1	9	59	90	92	6.7	25.1					
			0	2	3	4	10	31	62	78	82	15.5	27.2					
			0	8	17	26	35	51	74	84	86	12.3	38.1					
SG + 11	Sand & Gravel	4-20-62	0	2	5	7	10	29	70	95	96	3	3.14	2.61	28.8	0.95	0.80	21716
			0	2	4	8	11	24	55	92	96	4	2.92					
			0	2	7	11	16	37	71	92	95	4	3.31					
				0	4	6	9	19	49	90	94	6	2.71					
			0	3	6	8	10	24	55	91	93	6	2.89					
			0	1	6	10	15	33	69	92	95	4	3.21					
				0	6	10	13	31	67	96	98	2	3.21					
			0	2	5	8	13	36	71	91	94	5	3.20					
				0	2	6	10	27	63	92	96	3	2.96					
				0	3	7	11	29	60	93	96	4	2.99					
				0	2	5	9	28	63	92	97	2	2.96					
			0	1	5	11	16	40	70	93	96	4	3.32					
				0	5	11	18	38	63	95	98	2	3.28					
FS-12	Fine Sand	3/54	0	1	2	6	9	16	47	91	98	1.0	2.72	2.62	31.2	0.94		82424
SG + 13	Sand & Gravel	3-3-70	0	2	3	4	4	6	10	24	44	44.8	0.97	2.61	30.1	0.93	.70	70-160
				0	1	2	4	13	35	69	82	14.1	2.06					
			0	1	9	14	19	30	51	76	90	7.9	2.90					
				0	3	7	12	25	50	77	90	7.8	2.64					
			0	1	8	15	21	35	57	78	87	12.1	3.02					
			0	1	8	12	18	32	50	76	87	10.6	2.84					
				0	4	7	10	21	42	70	88	8.2	2.42					
			0	5	9	12	16	24	45	78	91	5.8	2.80					
			0	4	12	20	27	44	65	85	92	6.6	3.49					
			0	2	9	17	26	51	53	72	85	11.6	3.15					
			0	2	8	12	17	26	42	71	81	17.5	2.59					
SG + 14	Sand & Gravel	1-13-70	0	5	31	54	67	74	76	78	81	16.3	4.66	2.65	31.2	0.94	2.55	69-3945
			0	13	26	40	50	57	62	67	75	21.5	3.98					
			0	9	17	29	41	49	54	57	63	31.7	3.19					
			0	3	11	25	40	51	58	66	72	24.4	3.26					
			0	6	16	30	45	55	61	66	70	26.1	3.49					
			0	7	23	45	59	67	70	72	75	22.1	4.18					
			0	2	13	34	47	54	57	61	68	25.5	3.36					
			0	10	20	32	43	49	54	59	68	27.0	3.35					
			0	6	15	29	42	51	57	67	75	22.2	3.42					
			0	17	36	52	62	67	70	73	76	21.1	4.53					
			0	7	25	41	54	64	70	75	78	19.4	4.14					
SOURCE OF MATERIAL: WISCONSINAN TERRACE - Qtw																		
Si-118	Silt	4-56								0	1	99						
										0	0	99						
Si-119	Silt	2-55		0	1	1	1	1	1	5	87	6						
									0	3	79	12						
				0	2	4	4	5	5	6	63	21						
										0	1	98						
										0	2	97						
									0	1	4	92						
										0	3	93						
										0	6	90						
										0	1	98						
SOURCE OF MATERIAL: DAKOTA FORMATION - Kd																		
FS + 9	Fine Sand	2-67				0	1	1	5	42	77	12	1.26					
					0	2	2	3	13	68	82	14	1.70					
				0	1	2	3	4	5	42	74	21	1.31					
								0	2	32	81	9	1.15					
							0	1	5	51	88	6	1.45					
								0	7	57	82	9	1.46					
								0	6	72	89	7	1.67					
								0	4	47	82	10	1.33					
							0	1	9	71	87	8	1.68					
							0	1	7	42	84	10	1.34					
							0	1	20	77	89	7	1.87					
									0	17	82	11	0.99					
								0	2	59	86	9	1.47					
								0	2	22	76	14	1.00					
								0	2	38	86	8	1.26					
								0	1	31	82	11	1.14					
								0	3	38	84	10	1.25					
SS + 15	Sandstone	4-18-55						0	1	1	10	47						AA-8947
										0	54	18						
							0	1	1	2	71	13						
										0	61	18						
									0	1	74	12						
									0	10	71	12						
SS + 120	Sandstone	4-55			0	1	2	2	3	3	8	69						AA-8946
						0	1	1	2	2	4	90						
									0	1	46	34						
										0	57	26						
						0	1	1	2	2	31	68						
										0	53	39						
									0	2	86	6						

Figure 13. Results of tests completed on samples of material from the various geologic source beds in Cloud County.

CLOUD COUNTY MATERIALS MAP INDEX

On the following pages are nine plates covering Cloud County as shown below.

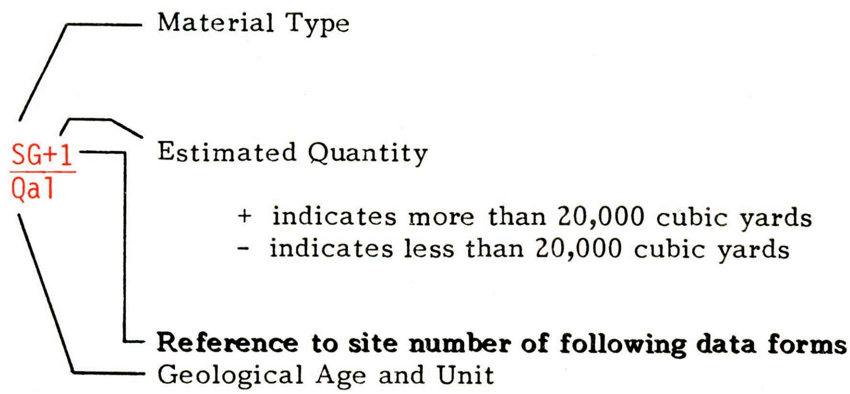


Note: The individual material site data forms follow Plate IX.

LEGEND

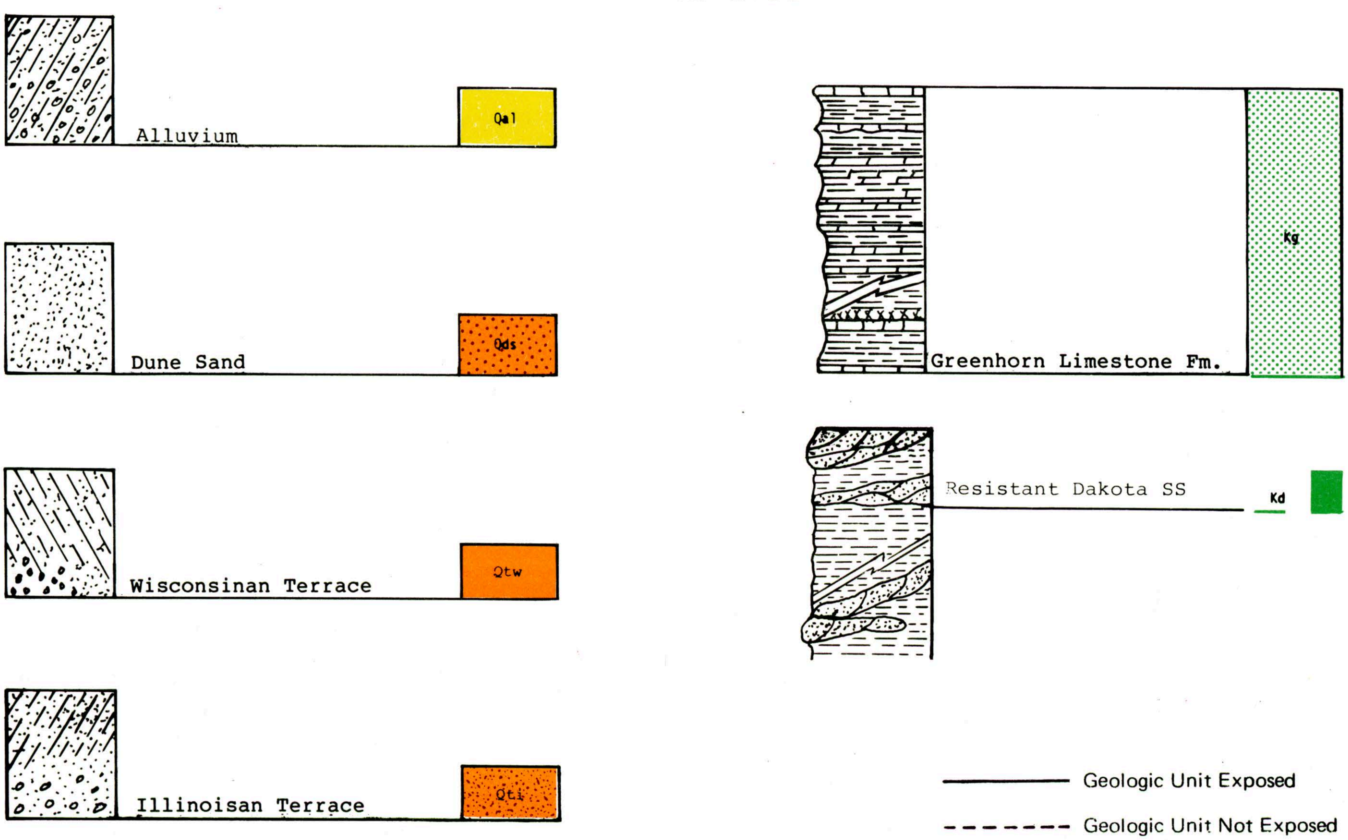
MATERIALS SITE DESIGNATIONS

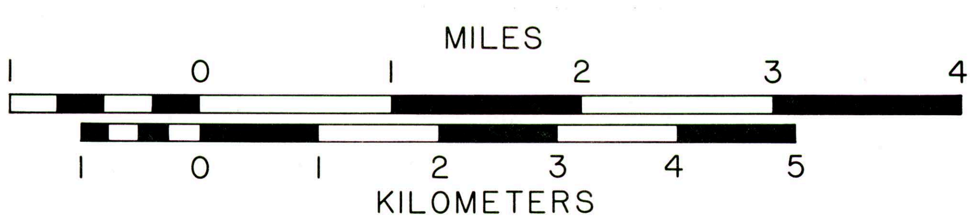
■	Open Materials Sites; Sampled	Page 26
●	Open Materials Sites; Not Sampled	Page 44
▼	Prospective Materials Sites; Sampled	Page 146
⬢	Prospective Materials Sites; Not Sampled	Page 154



SG	Sand Gravel
SS	Sandstone
FS	Fine Sand
Si	Silt
LS	Limestone

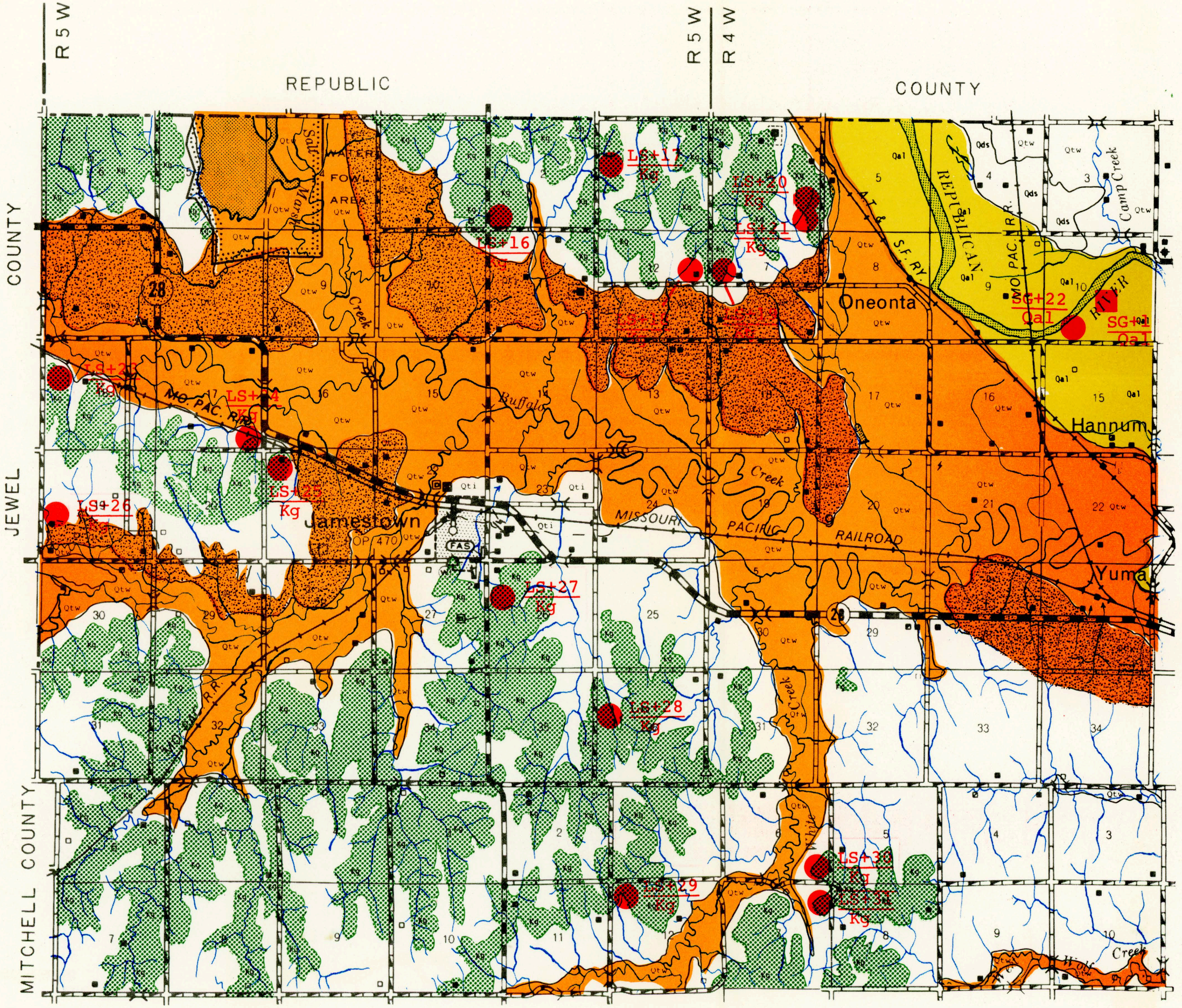
GEOLOGY

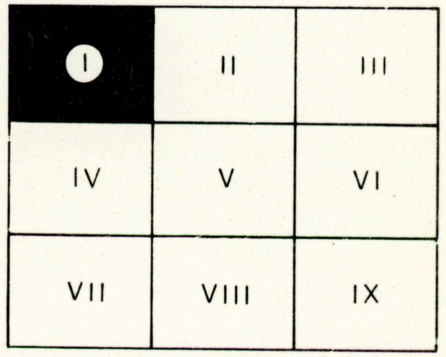




CLOUD COUNTY MATERIALS MAP

PLATE I





CLOUD COUNTY

LEGEND

MATERIALS SITE DESIGNATIONS

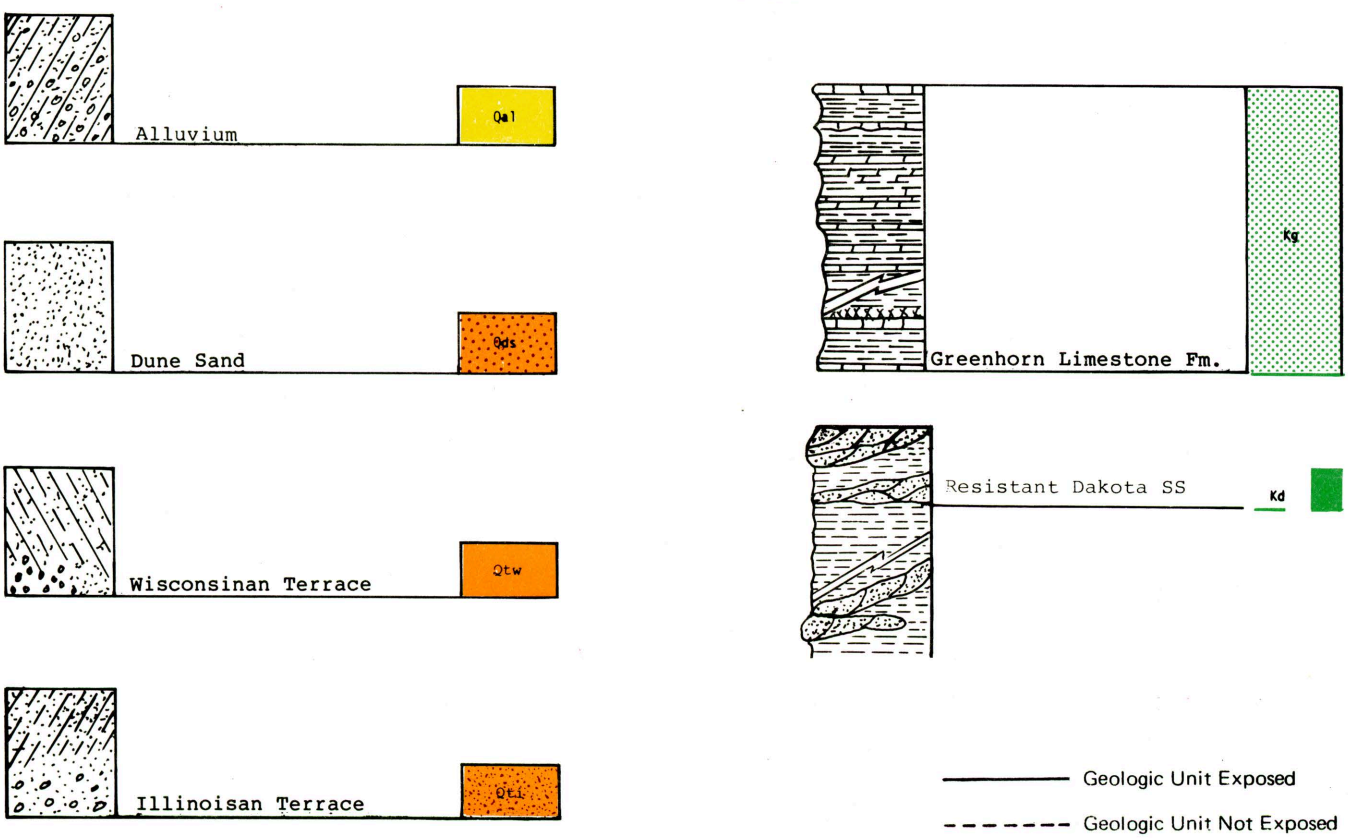
■	Open Materials Sites; Sampled	Page 26
●	Open Materials Sites; Not Sampled	Page 44
▼	Prospective Materials Sites; Sampled	Page 146
⬢	Prospective Materials Sites; Not Sampled	Page 154

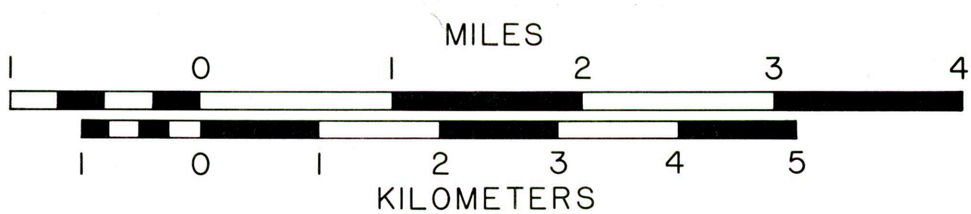
SG+1
Qal

- Material Type
- Estimated Quantity
  - + indicates more than 20,000 cubic yards
  - - indicates less than 20,000 cubic yards
- **Reference to site number of following data forms**
- Geological Age and Unit

SG	Sand Gravel
SS	Sandstone
FS	Fine Sand
Si	Silt
LS	Limestone

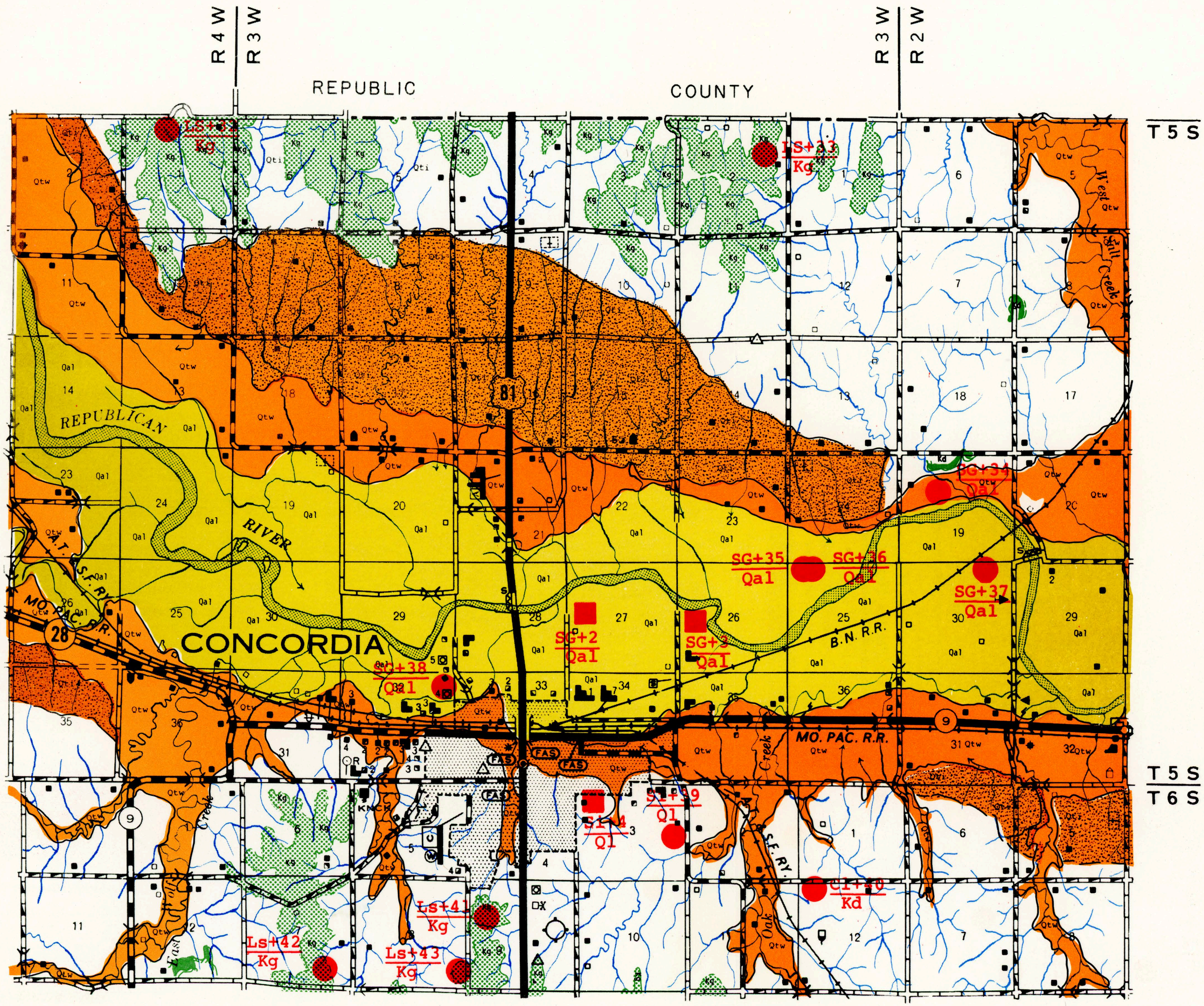
GEOLOGY

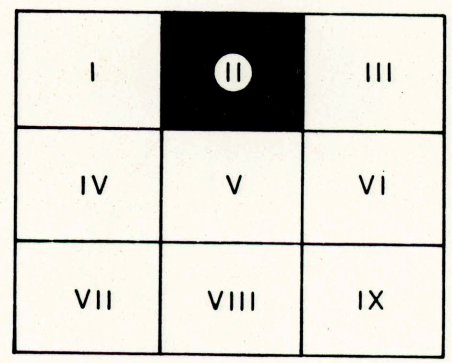




CLOUD COUNTY MATERIALS MAP

PLATE II





CLOUD COUNTY

LEGEND

MATERIALS SITE DESIGNATIONS

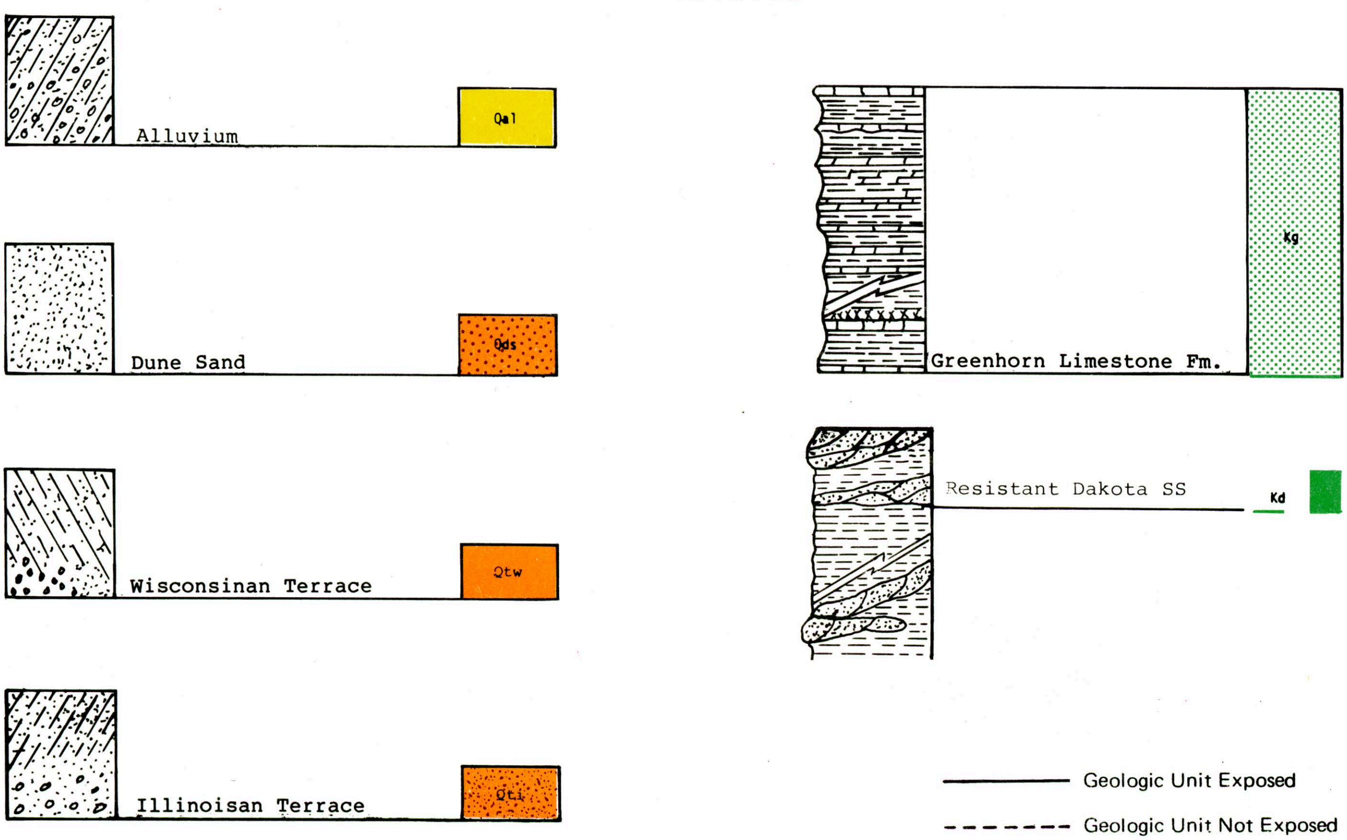
■	Open Materials Sites; Sampled	Page 26
●	Open Materials Sites; Not Sampled	Page 44
▼	Prospective Materials Sites; Sampled	Page 146
⬢	Prospective Materials Sites; Not Sampled	Page 154

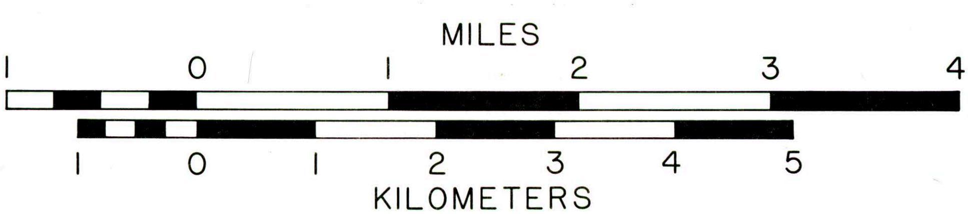
SG+1
Qal

- Material Type
- Estimated Quantity
  - + indicates more than 20,000 cubic yards
  - - indicates less than 20,000 cubic yards
- **Reference to site number of following data forms**
- Geological Age and Unit

SG Sand Gravel
SS Sandstone
FS Fine Sand
Si Silt
LS Limestone

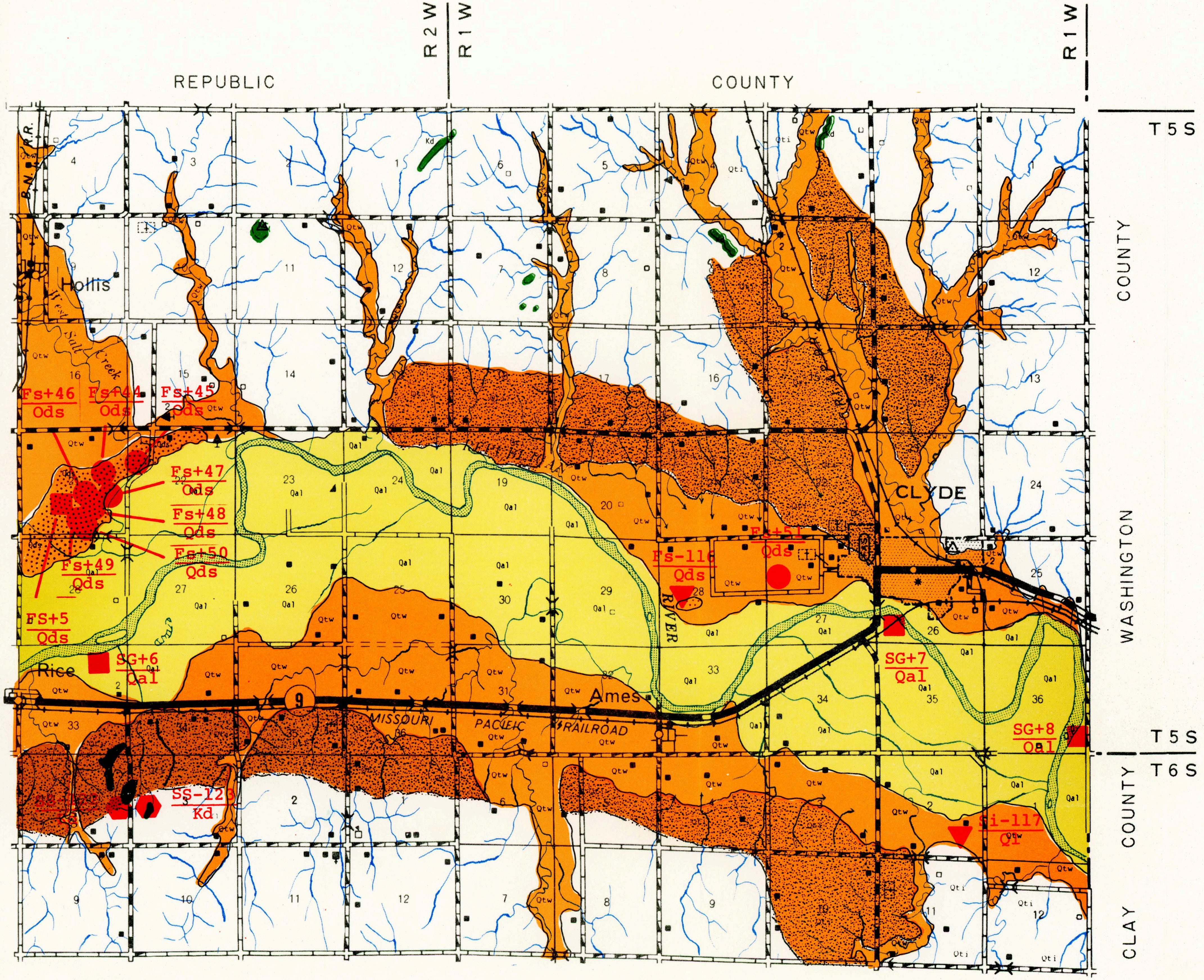
GEOLOGY

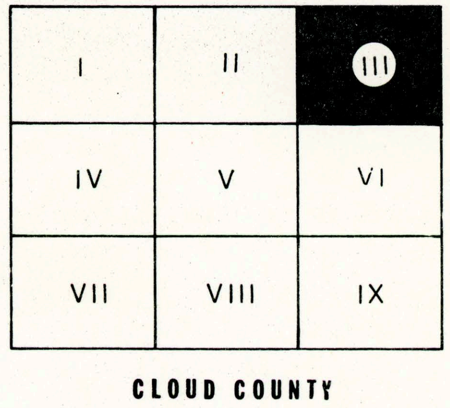




CLOUD COUNTY MATERIALS MAP

PLATE III





LEGEND

MATERIALS SITE DESIGNATIONS

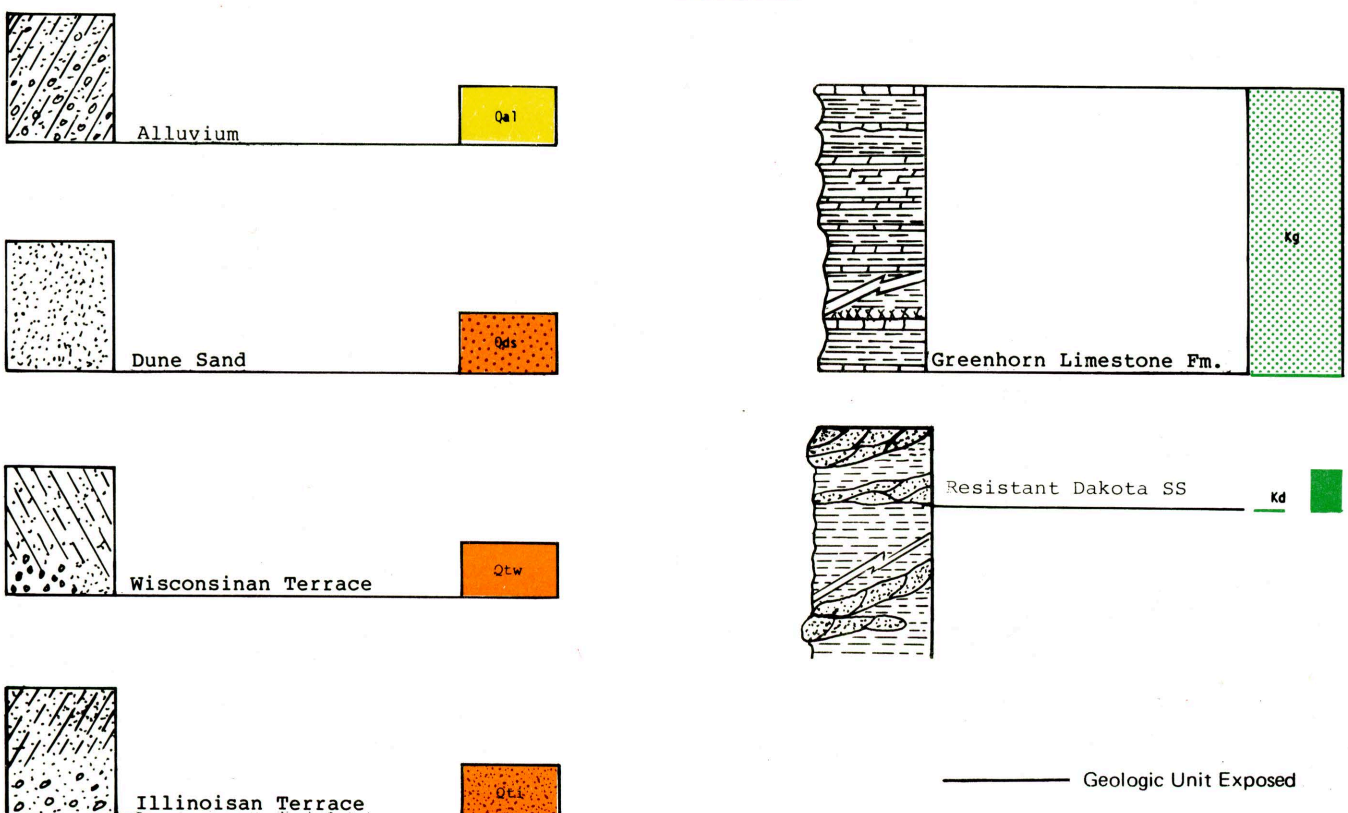
■	Open Materials Sites; Sampled	Page 26
●	Open Materials Sites; Not Sampled	Page 44
▼	Prospective Materials Sites; Sampled	Page 146
⬢	Prospective Materials Sites; Not Sampled	Page 154

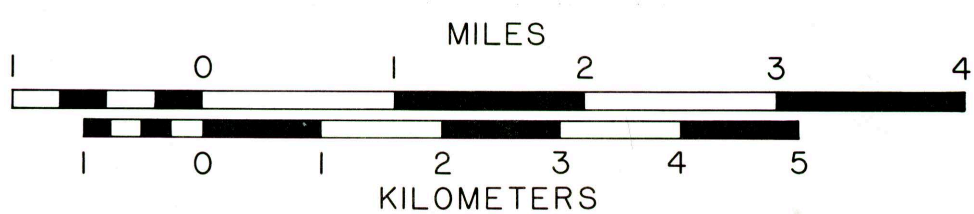
SG+1 / Qal

- SG — Material Type
- +1 — Estimated Quantity
  - \+ indicates more than 20,000 cubic yards
  - \- indicates less than 20,000 cubic yards
- 1 — **Reference to site number of following data forms**
- Qal — Geological Age and Unit

SG Sand Gravel
SS Sandstone
FS Fine Sand
Si Silt
LS Limestone

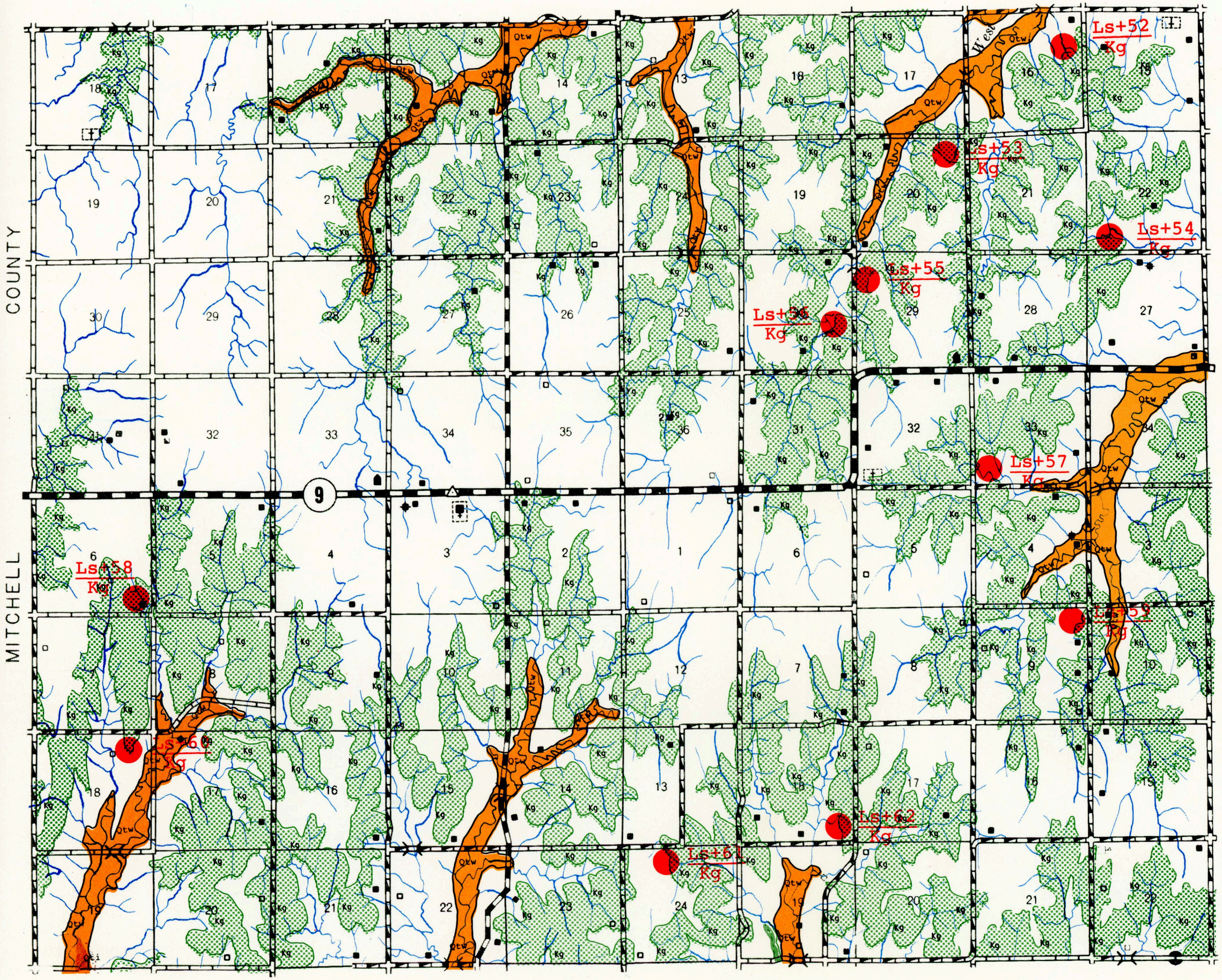
GEOLOGY

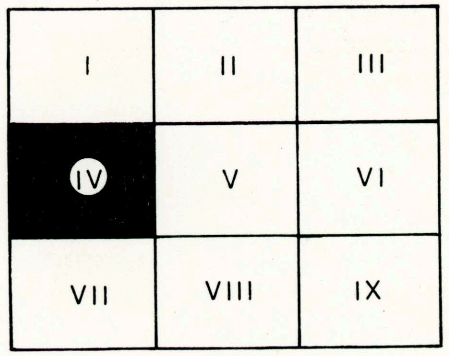




CLOUD COUNTY MATERIALS MAP

PLATE IV





CLOUD COUNTY

LEGEND

MATERIALS SITE DESIGNATIONS

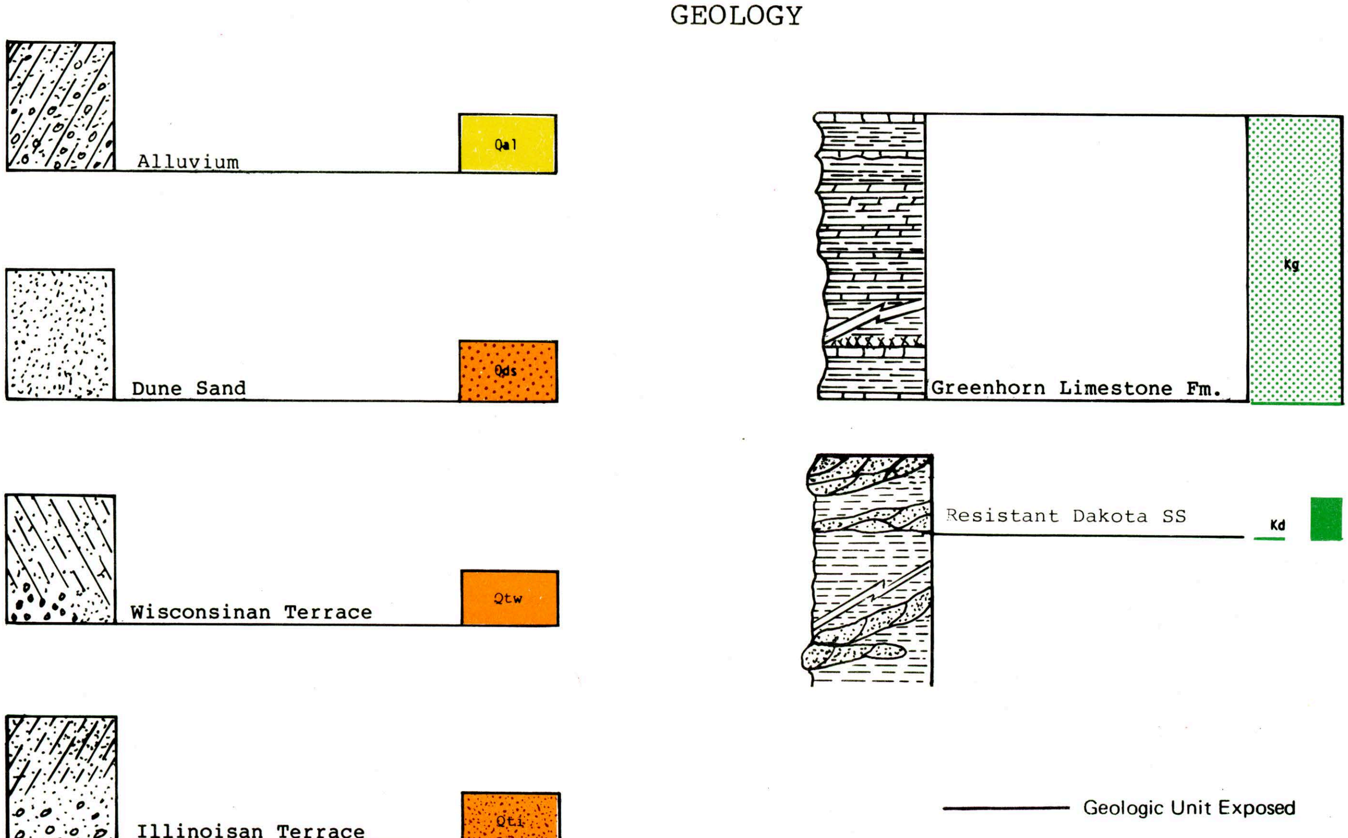
Red square	Open Materials Sites; Sampled	Page 26
Red circle	Open Materials Sites; Not Sampled	Page 44
Red inverted triangle	Prospective Materials Sites; Sampled	Page 146
Red hexagon	Prospective Materials Sites; Not Sampled	Page 154

SG+1
Qal

- Material Type
- Estimated Quantity
  - \+ indicates more than 20,000 cubic yards
  - \- indicates less than 20,000 cubic yards
- **Reference to site number of following data forms**
- Geological Age and Unit

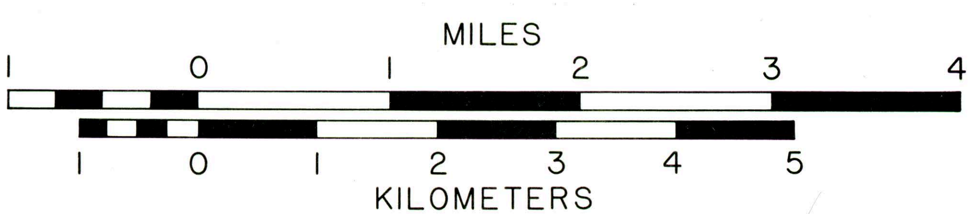
SG Sand Gravel
SS Sandstone
FS Fine Sand
Si Silt
LS Limestone

GEOLOGY



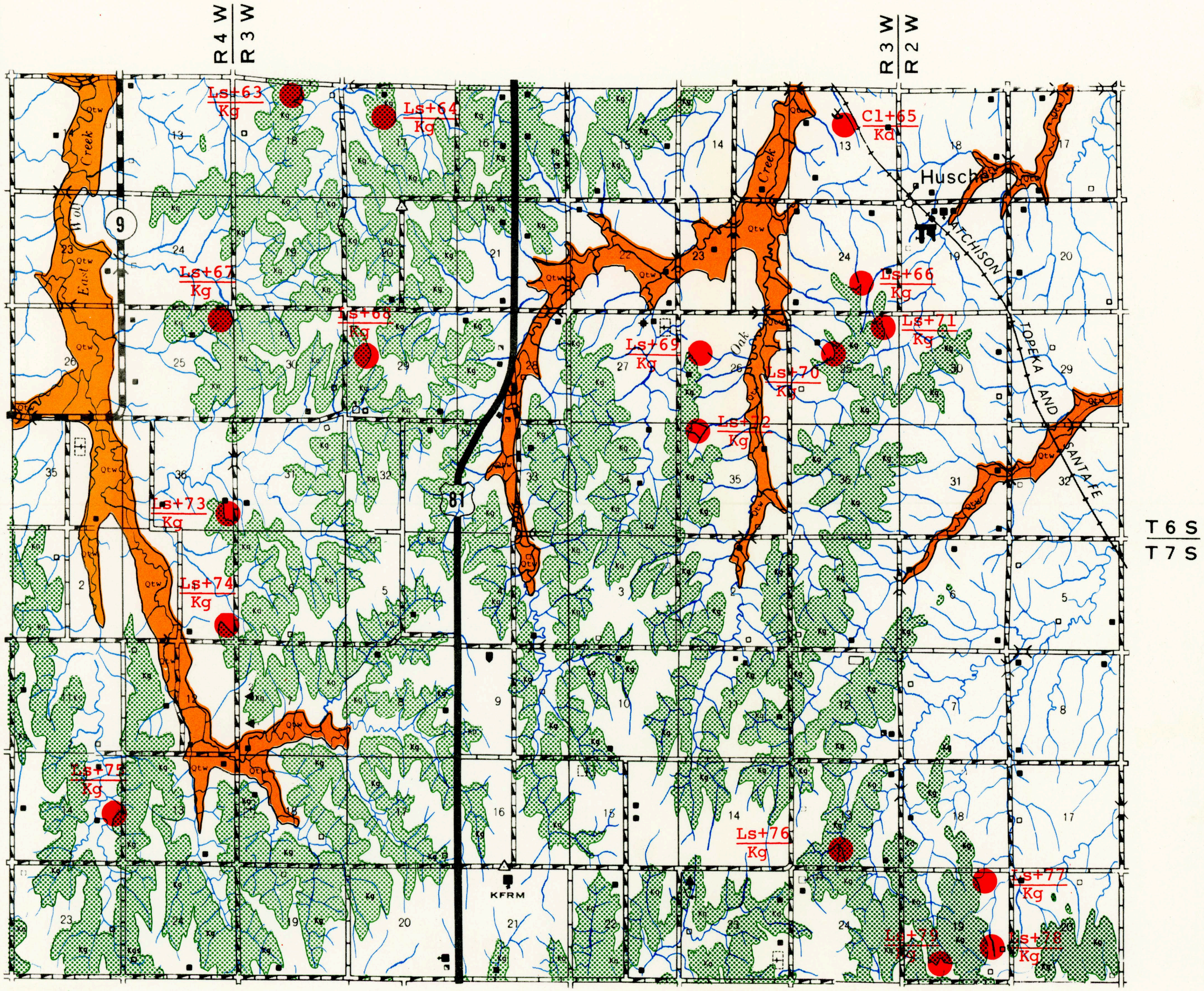
Geologic Unit Exposed

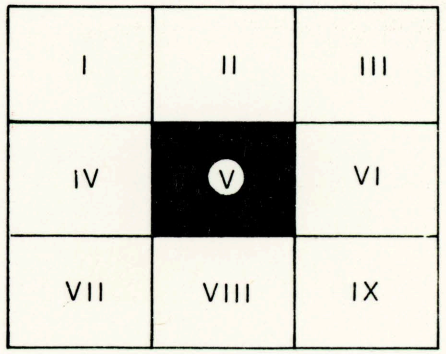
Geologic Unit Not Exposed



CLOUD COUNTY MATERIALS MAP

PLATE V





CLOUD COUNTY

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MATERIALS SITE DESIGNATIONS

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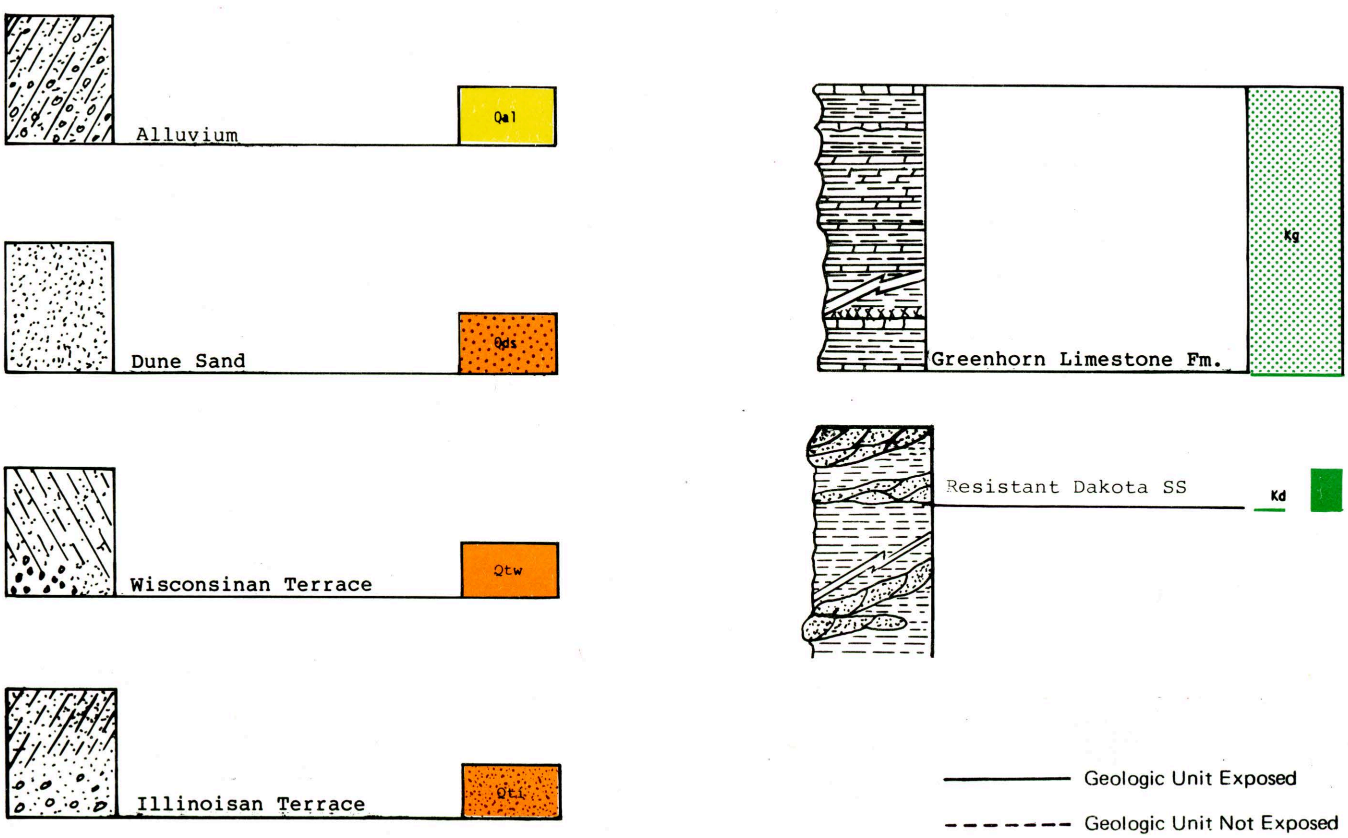
▼	Prospective Materials Sites; Sampled	Page 146
⬢	Prospective Materials Sites; Not Sampled	Page 154

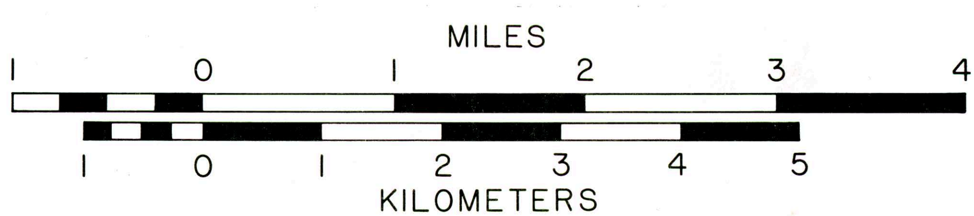
SG+1 / Qal

- Material Type
- Estimated Quantity
  - \+ indicates more than 20,000 cubic yards
  - \- indicates less than 20,000 cubic yards
- **Reference to site number of following data forms**
- Geological Age and Unit

SG	Sand Gravel
SS	Sandstone
FS	Fine Sand
Si	Silt
LS	Limestone

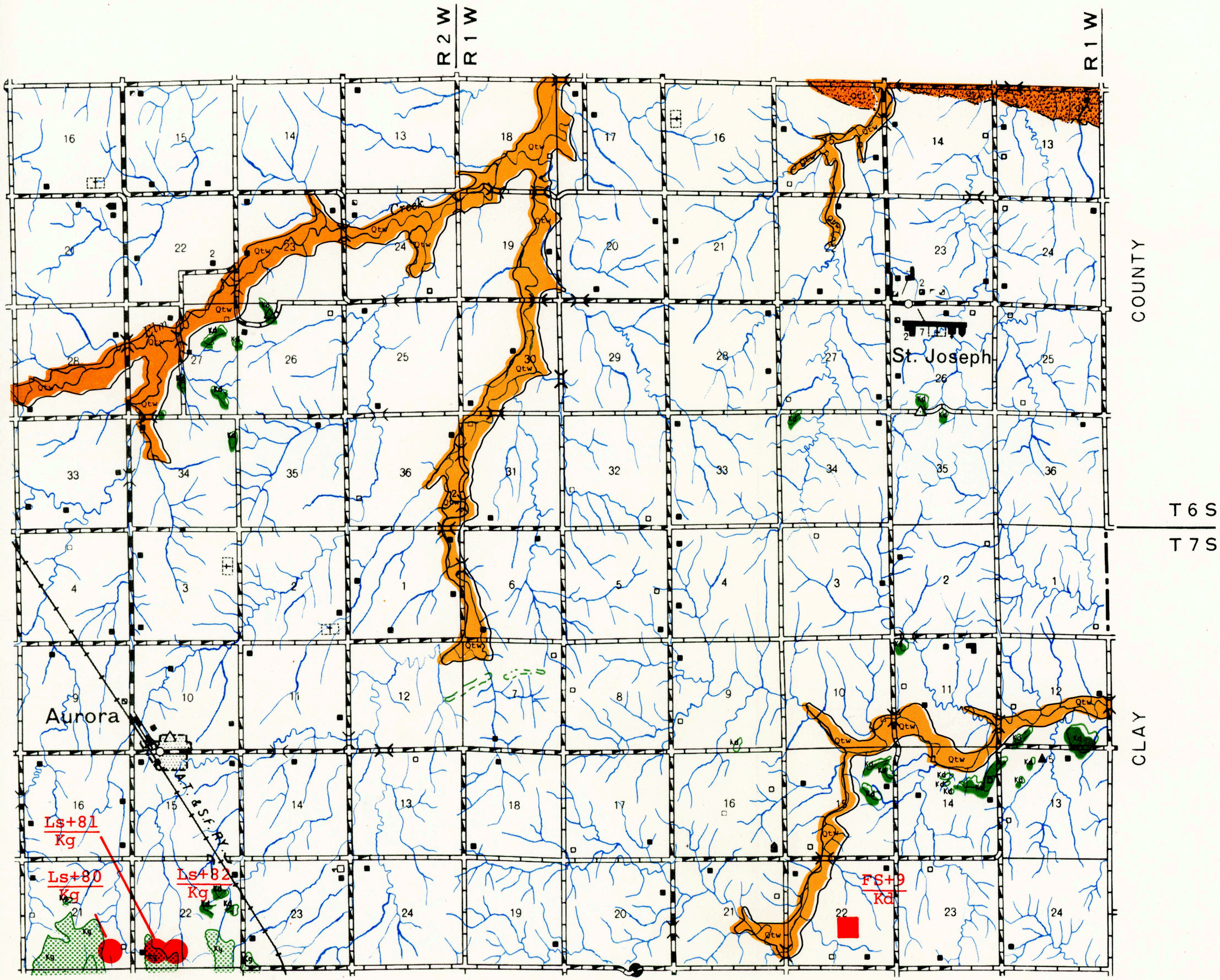
GEOLOGY

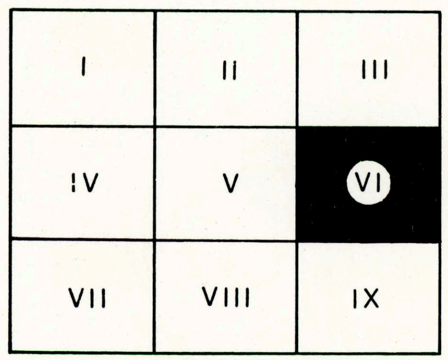




CLOUD COUNTY MATERIALS MAP

PLATE VI





CLOUD COUNTY

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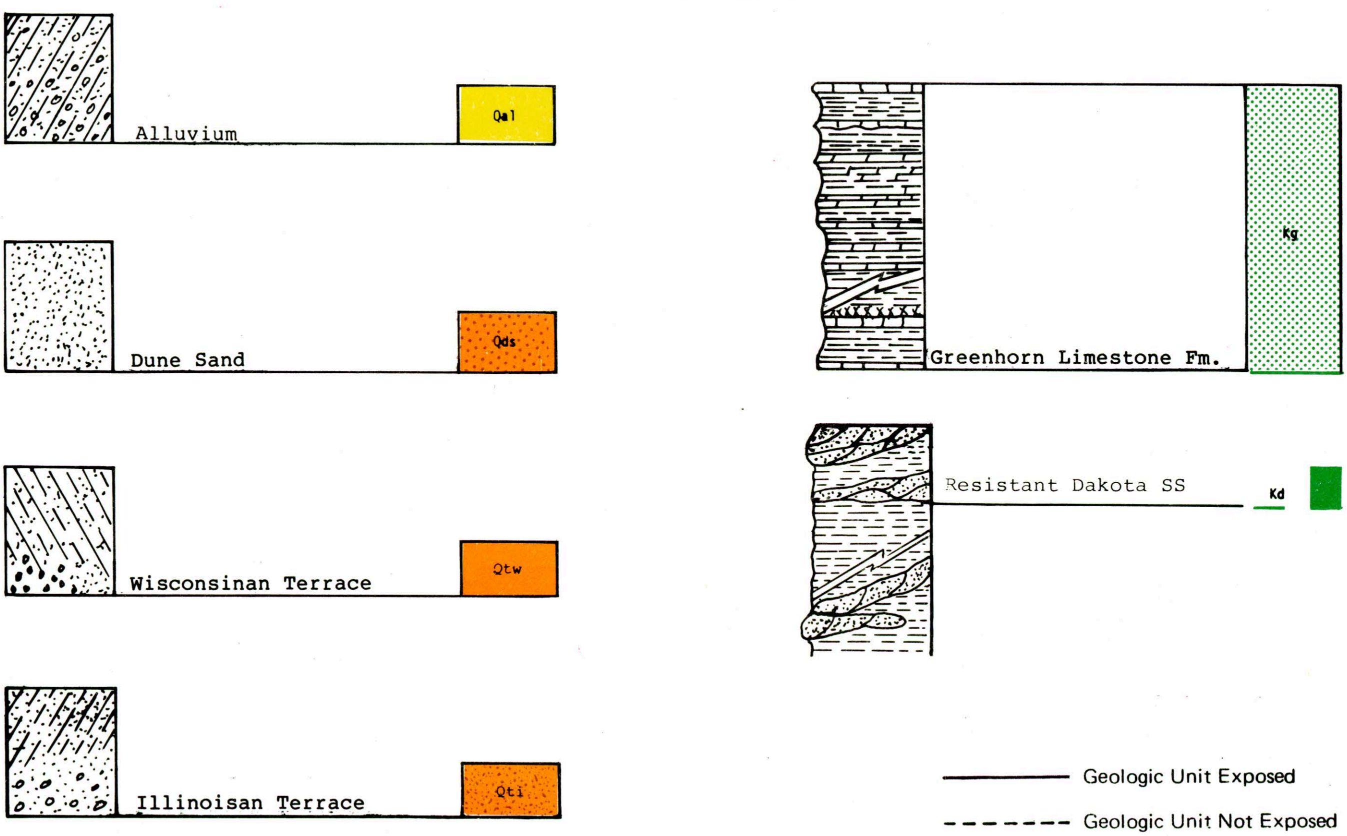
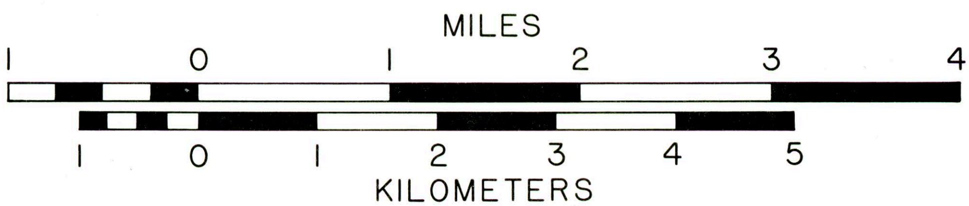
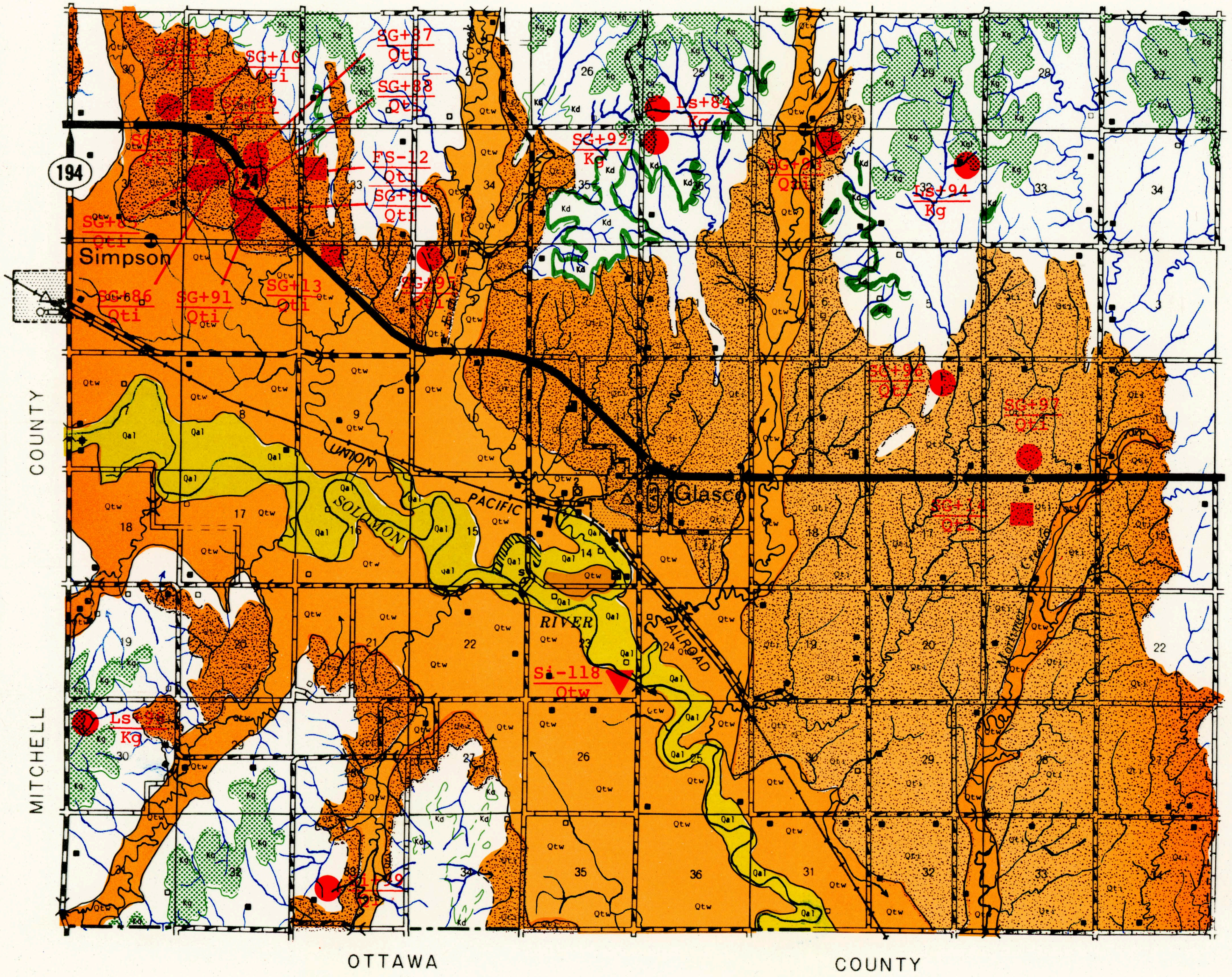
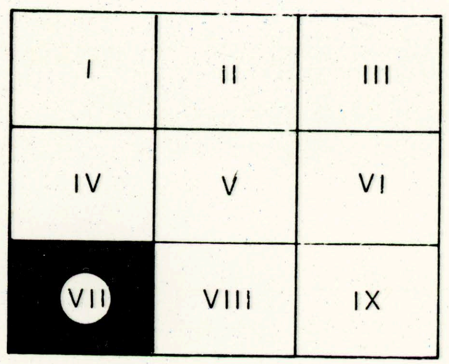




CLOUD COUNTY MATERIALS MAP

PLATE VII





CLOUD COUNTY

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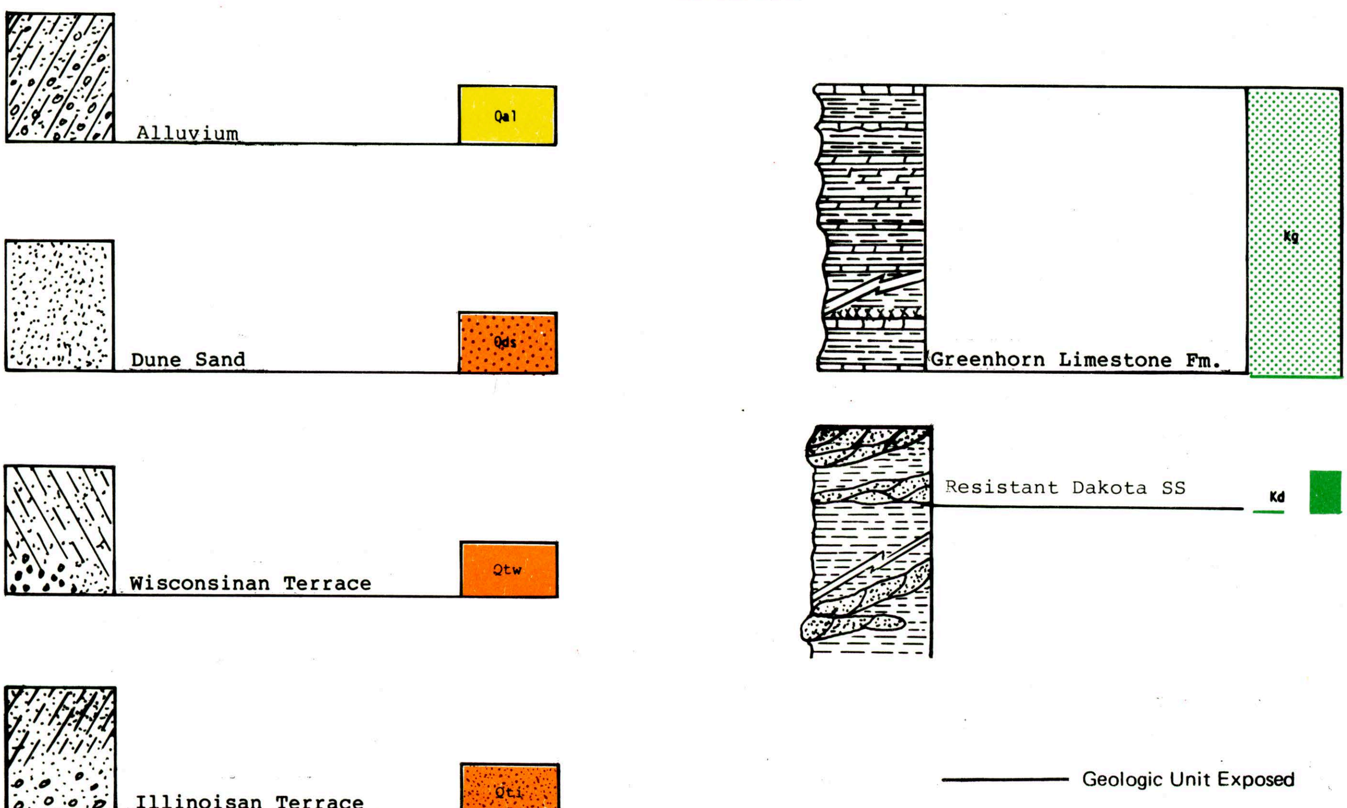
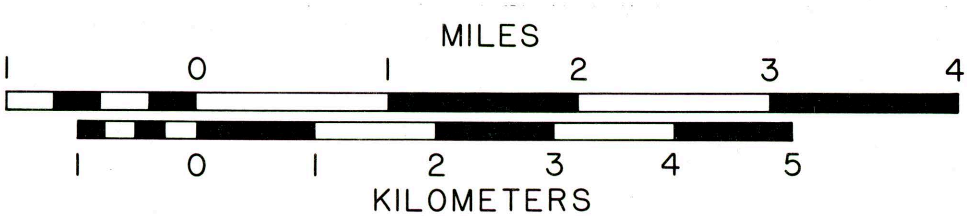


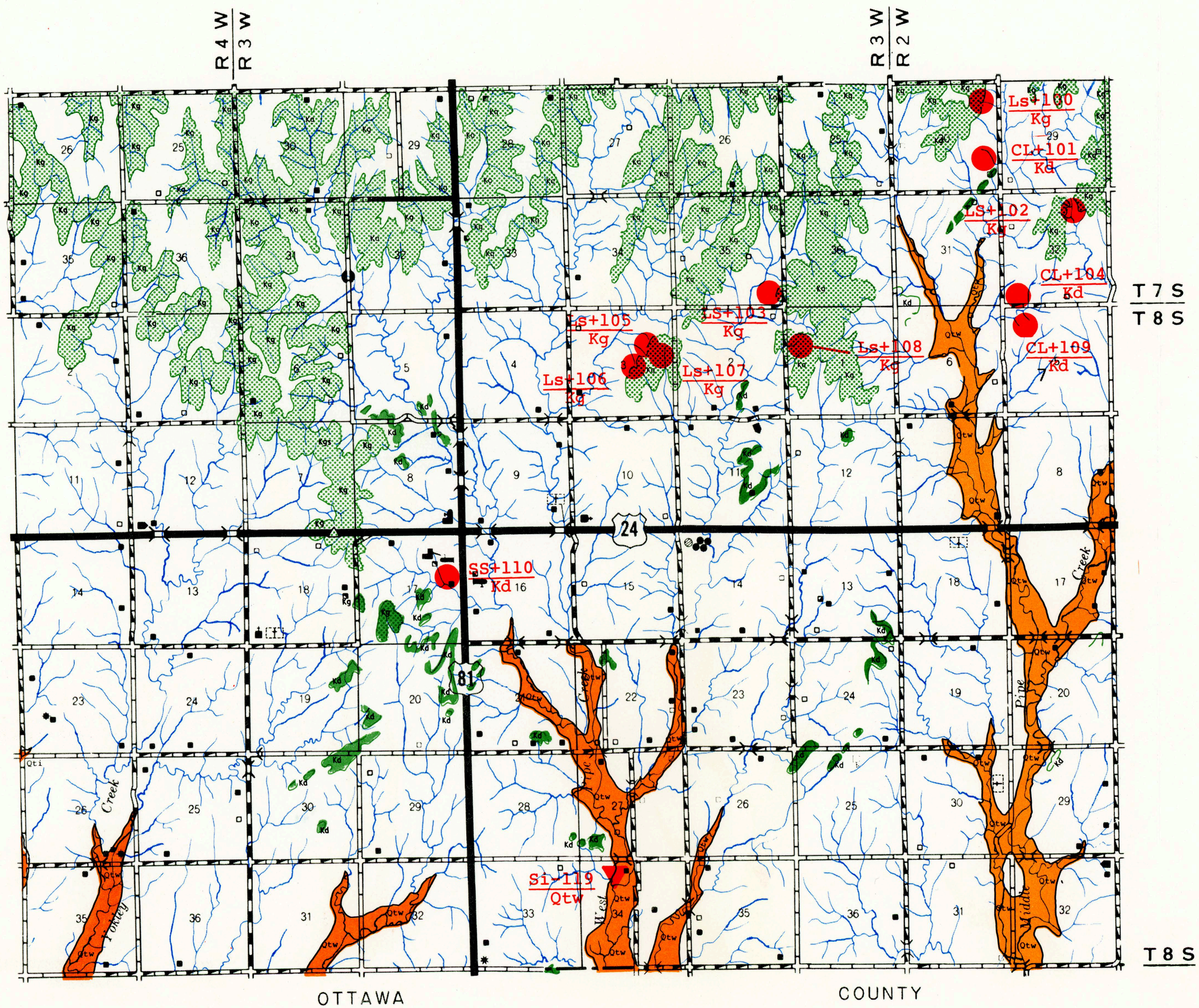
——— Geologic Unit Exposed

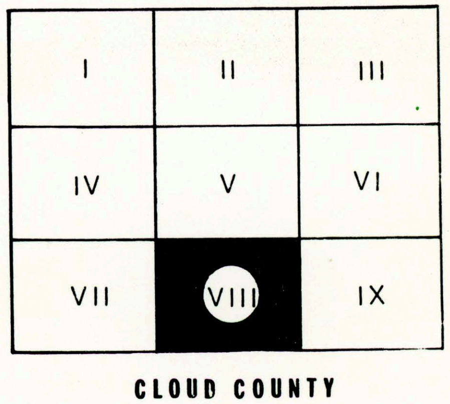
- - - - - - Geologic Unit Not Exposed



CLOUD COUNTY MATERIALS MAP

PLATE VIII





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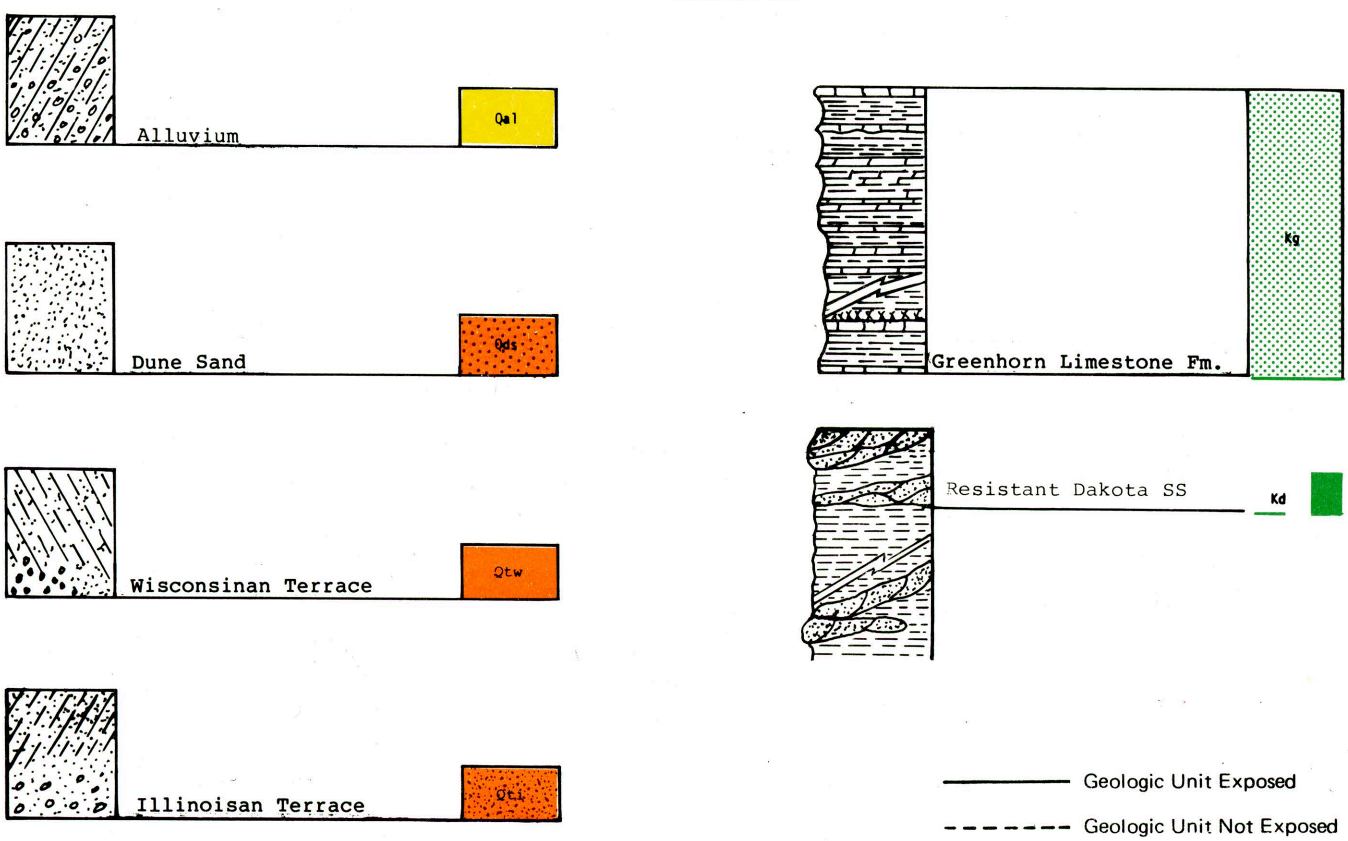
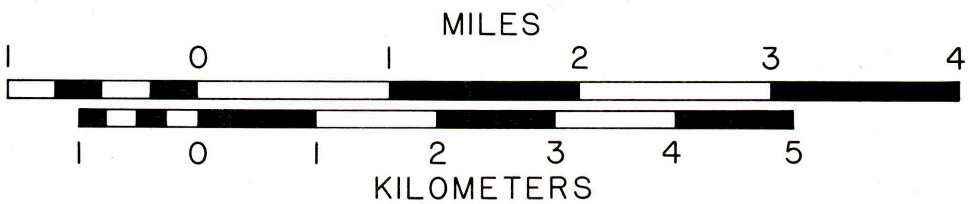
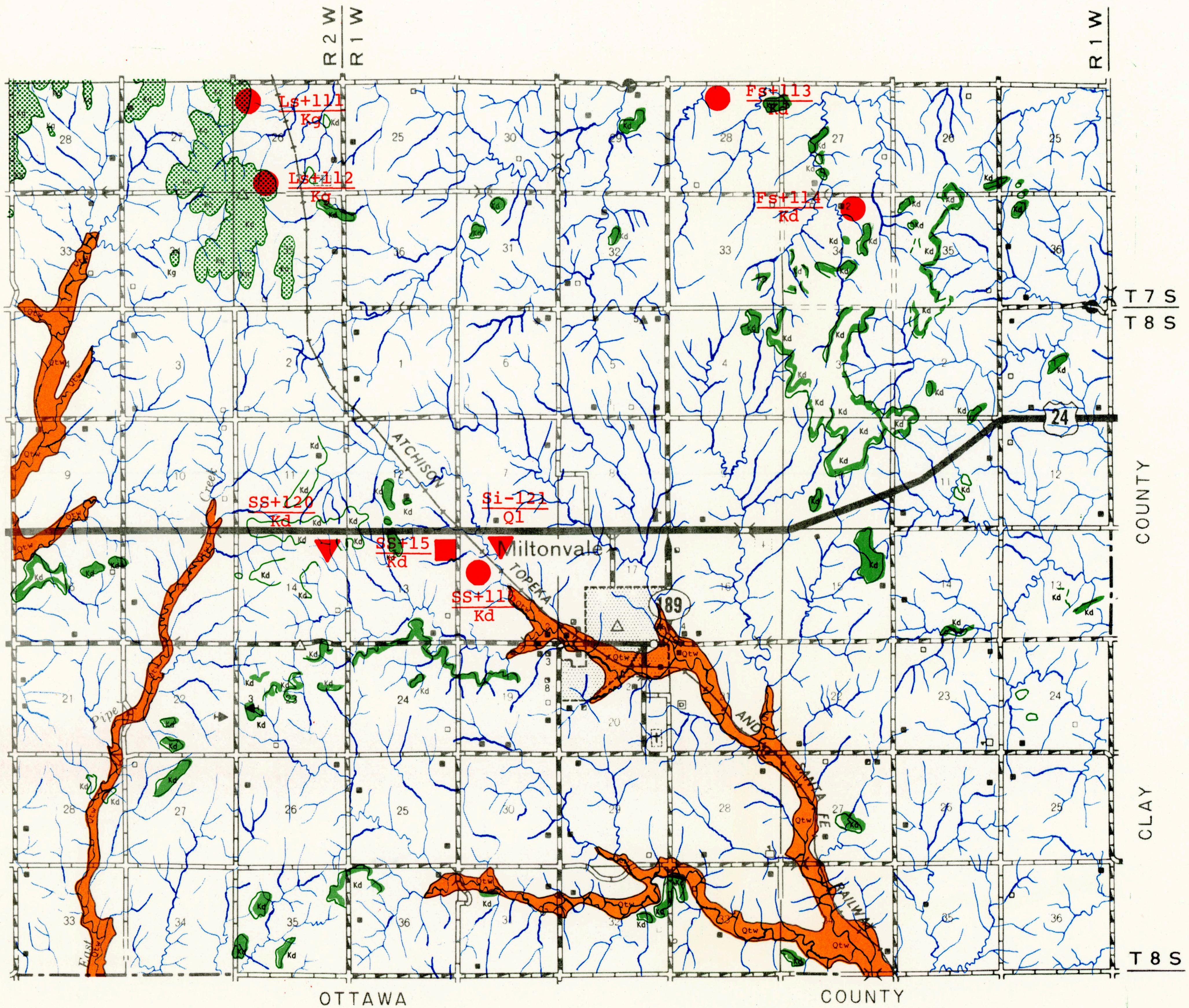
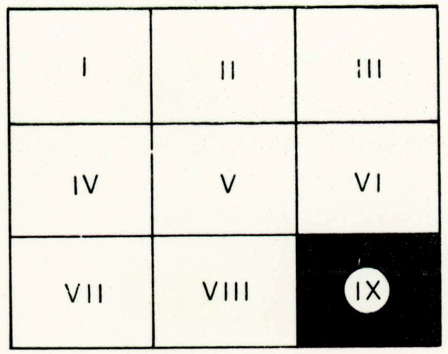




CLOUD COUNTY MATERIALS MAP

PLATE IX





CLOUD COUNTY