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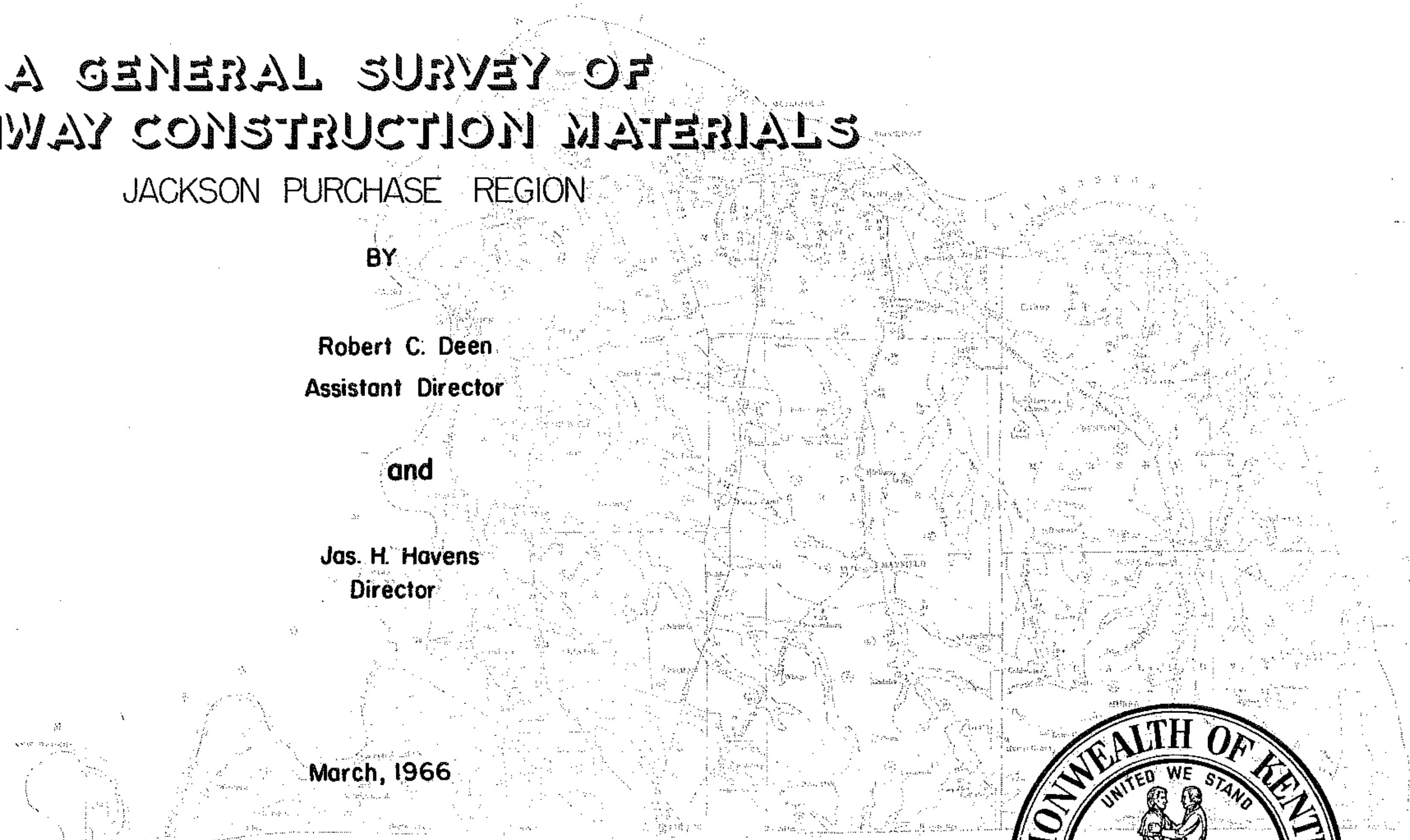
KENTUCKY DEPARTMENT OF HIGHWAYS

RESEARCH REPORT

A GENERAL SURVEY OF HIGHWAY CONSTRUCTION MATERIALS

JACKSON PURCHASE REGION



BY

Robert C. Deen
Assistant Director

and

Jas. H. Havens
Director

March, 1966

Division of Research

LEXINGTON

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

HENRY WARD
COMMISSIONER OF HIGHWAYS

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
DIVISION OF RESEARCH
132 GRAHAM AVENUE
LEXINGTON, KENTUCKY 40506

March 31, 1966

M-3-5

MEMORANDUM

TO: W. B. Drake
Assistant State Highway Engineer

FROM: Jas. H. Havens, Director
Division of Research

SUBJECT: Jackson Purchase Area; Study of Earth Materials in Relation to Purchase Parkway and I 24; Design Consideration

I invite your attention to the report submitted herewith; it was prepared to augment information being obtained from on-site, explorations of surface and subsurface materials and conditions attendant to the proposed routes of the Purchase Parkway and I 24. The information offered therein is purposefully more comprehensive in scope than a route survey. Whereas borings made along the routes should furnish more specific data, this report was compiled largely from geological reconnaissance information and without the benefit of the

highway survey boring data. This information may prove to be helpful in design and construction and in guiding other engineering decisions. Some of the geological information was made available to us by the U.S.G.S. on a privileged basis (for use within the Department only), and I request that all uses of the report be restricted accordingly.

Respectifully Submitted,

Jas. H. Havens

Jas. H. Havens, Director
Division of Research

JHH/em
Attachment

Research Report

A GENERAL SURVEY OF HIGHWAY CONSTRUCTION MATERIALS
Jackson Purchase Region

By
Robert C. Deen
Assistant Director
and
Jas. H. Havens
Director

Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

March, 1966

STRUCTURE AND STRATIGRAPHY

Much information and insight concerning the engineering behavior and characteristics of soils and geologic materials can be obtained by a review of geologic and soil reports available in the literature. This knowledge concerning the engineering behavior of these materials can be quite useful to the design and construction engineers as they proceed with their endeavors with respect to civil engineering structures such as highways. Much of this general and preliminary information is available to the public in the form of county soil survey reports that have been published by the U.S. Department of Agriculture and geologic quadrangle maps that have been published by the U.S. Geological Survey. In recent years there has been an extensive and intensive geological mapping program underway in the State of Kentucky. The USGS field parties have progressed to a very advanced stage in this mapping program in the Jackson Purchase area. Many of the quadrangle maps have already been published. In addition the USGS has made available to the Research Division certain other information concerning those areas for which published geologic maps are not yet available.

The use of such information contained in geologic and soil survey reports should not replace subsurface exploration. The information contained in such reports can be used in preliminary site studies and can be a guide in planning the subsurface exploration program. It is important to realize that this report must be augmented with more detailed information obtained from field soil surveys and subsurface exploration.

A geologic map of the Jackson Purchase is shown in Figure 1. This depicts the general relationships of geologic materials as exposed at the earth's surface. The geologic section in Figure 2 illustrates the vertical relationships of the formations.

PALEOZOIC

The oldest rocks exposed in the Purchase are of the Devonian age and are found in a fault zone along the Little Bear Creek in Marshall County. These Devonian materials, the Camden chert and the Jeffersonville limestone, are exposed to a very minor degree in the region. The Fort Payne chert of the Mississippian age outcrops in a narrow band along the west shore of the Kentucky Lake. The Fort Payne in this region is typically a dark bluish-gray limestone containing dark-blue to black banded chert. This formation ranges between 300 and 500 feet thick and produces some water by wells for this portion of the State.

The Warsaw limestone, also of the Mississippian age, crops out at a few localities along the Kentucky Lake. This is the same limestone formation, for example, which outcrops in Jefferson County. In this region the Warsaw formation is a gray crystalline limestone containing thin beds of chert. The limestone weathers to a nearly white, honeycombed surface. A few wells in Marshall County produce water from these Warsaw limestones. Groundwater is transmitted through solution channels in the factured limestone.

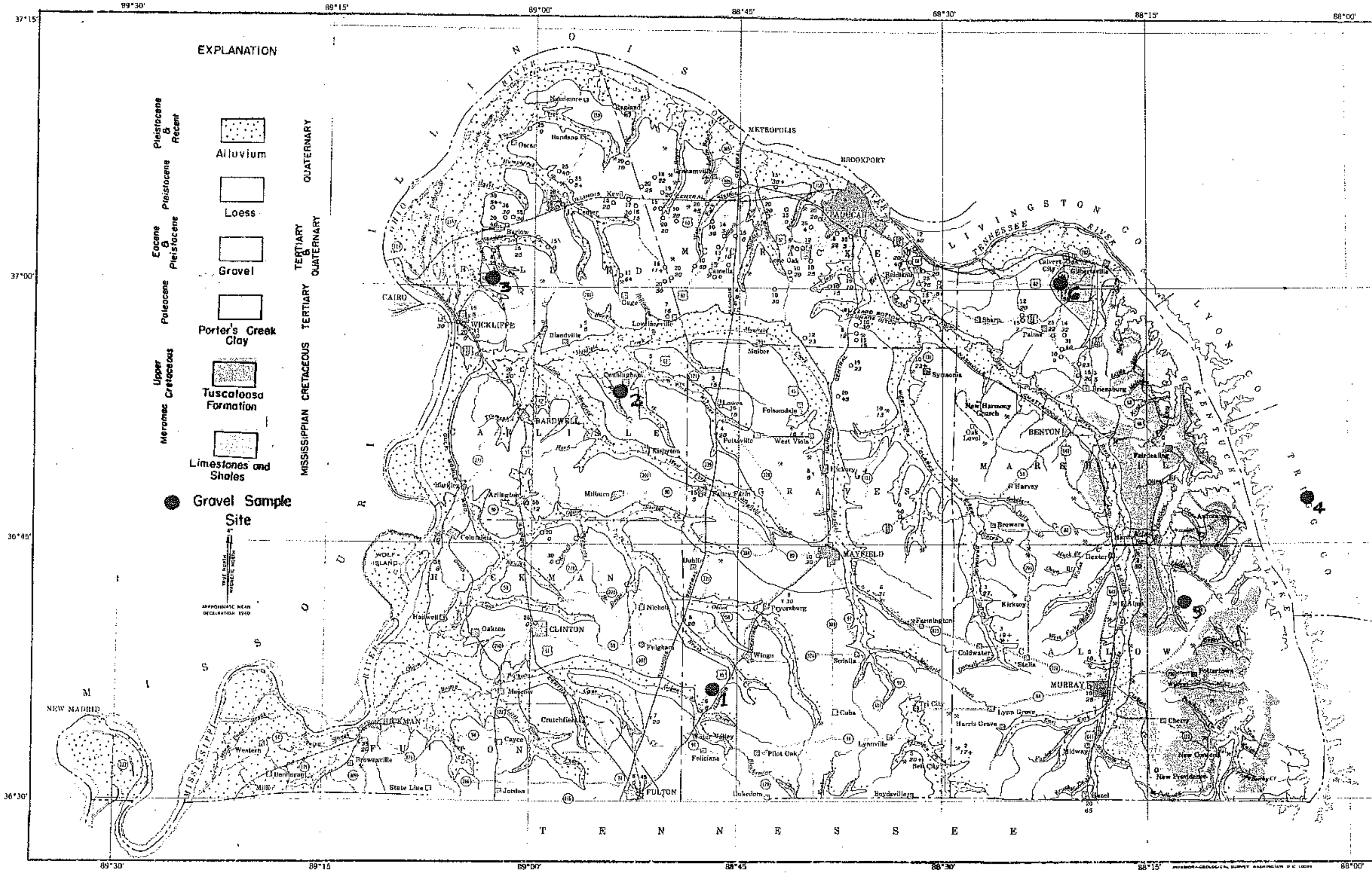


Figure 1. Geologic Map of the Jackson Purchase Region, Kentucky.

SCALE 1:250 000

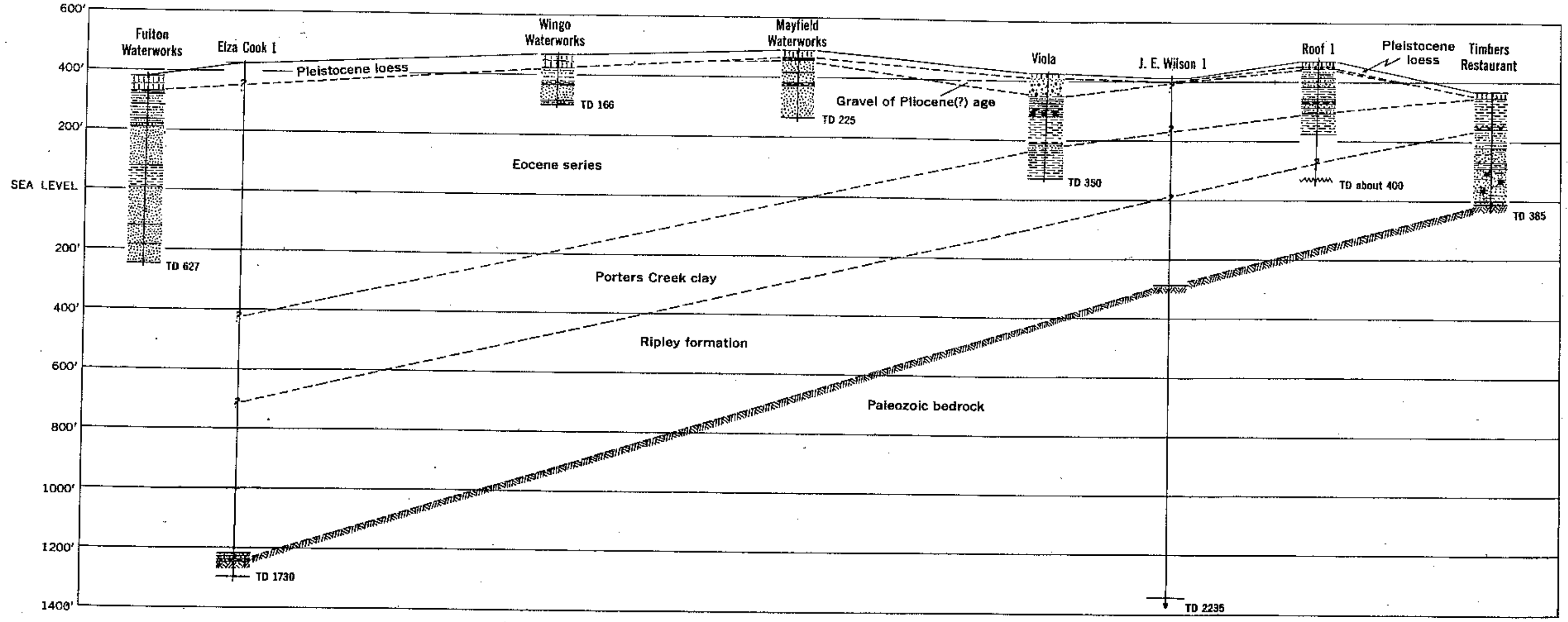


Figure 2. Geologic Section from Paducah to Fulton.

The St Louis limestone of the Mississippian age also outcrops in a few places west of the Kentucky Lake. This is a medium to thick bedded dark-gray to black limestone containing thick beds of yellowish chert. The St.Louis is known to supply water to wells drilled into it in the extreme northeastern portion of the Purchase area.

CRETACEOUS

The Tuscaloosa formation is the oldest Cretaceous deposit in Western Kentucky. It outcrops in exposures on the shores of the Kentucky Lake and is as much as 30 feet thick. The deposit becomes more important to the east of the lake where it has been noted to be as much as 200 feet thick at Golden Pond in Trigg County. The Tuscaloosa is composed of well rounded chert gravels in a matrix of sand and some clay.

The Riply formation, which overlies the Tuscaloosa, is exposed in Calloway and Marshall Counties in a limited belt paralleling the Kentucky Lake. It is generally 20 to 30 feet thick in this area. In the northwestern portion of the Jackson Purchase region, McCracken and Ballard Counties, the formation is covered by a thick mantle of Pliocene gravel and Quarternary alluvium. As much as 400 feet of Riply formation has been penetrated in numerous oil wells drilled in the Jackson Purchase area.

The Riply formation is typically unconsolidated sands and interbedded clays but may contain many thin beds of sand and clay cemented with iron oxide. In Ballard, McCracken, and Marshall Counties the Riply formation is mostly clay and silt. Thin beds of sand are present near the base. Where the Riply is composed mostly of unindurated sand, it yields large quantities of water to wells. In areas where the Riply is composed mostly of clay and silt, it may yield practically no water.

TERTIARY

The Porter's Creek Clay of Paleocene age is exposed in a narrow belt extending from the Tennessee line northward through Calloway County and then northwestward across Marshall and McCracken Counties. There are no exposures in Ballard because the thick deposits of Pliocene age and river alluvium cover this particular formation. The clay is approximately 150 feet thick in the eastern portion of the Jackson Purchase area and thickens to as much as 350 feet in the west. Porter's Creek Clay is a light- to slate-gray clay of very fine texture with beds of fine sand. This formation yields very little water and actually is a barrier to the passage of groundwater. Much groundwater that is contained in the overlaying material does not penetrate this horizon but moves horizontally along the Porter's Creek Clay until it outcrops at the surface as springs.

Sands and clays of the Eocene age underlie most of the Purchase area west and south of the outcrops of the Porter's Creek Clay. There are few exposures of these Eocene deposits because of the presence of a mantle of gravel of Pliocene age and loess of Pleistocene age over most of the western counties. However, as much as 30 feet of Eocene deposits are exposed in road cuts and gulleys. The Eocene deposits have a maximum thickness in the southwest of 700 feet.

They are composed primarily of sand, including some layers indurated by iron oxide cement; clay; and a basal clayey conglomerate. The vertical and lateral ranges in the variations of the Eocene deposits make it extremely difficult to predict the depth to any given type of material. These deposits are in places producers of water.

Much of the upland surface of the Jackson Purchase area is covered by a horizontal mantle of gravel and sand of Pliocene age. The maximum thickness of these deposits is probably more than 50 feet with the average about 25 feet. These gravels consist mostly of subangular to rounded particles of chert with some pebbles of quartzite. The sand is medium to coarse-grained and is composed of quartz and chert and some feldspar and hornblende. The sand may occur as a matrix for the gravel or as separate layers or lenses. The gravels of the Pliocene age yield water to many shallow wells in the Jackson Purchase area. The water moves chiefly through the unconsolidated sands and gravels and in places may be perched or semiperched by beds of clay or indurated sand and gravel.

QUATERNARY

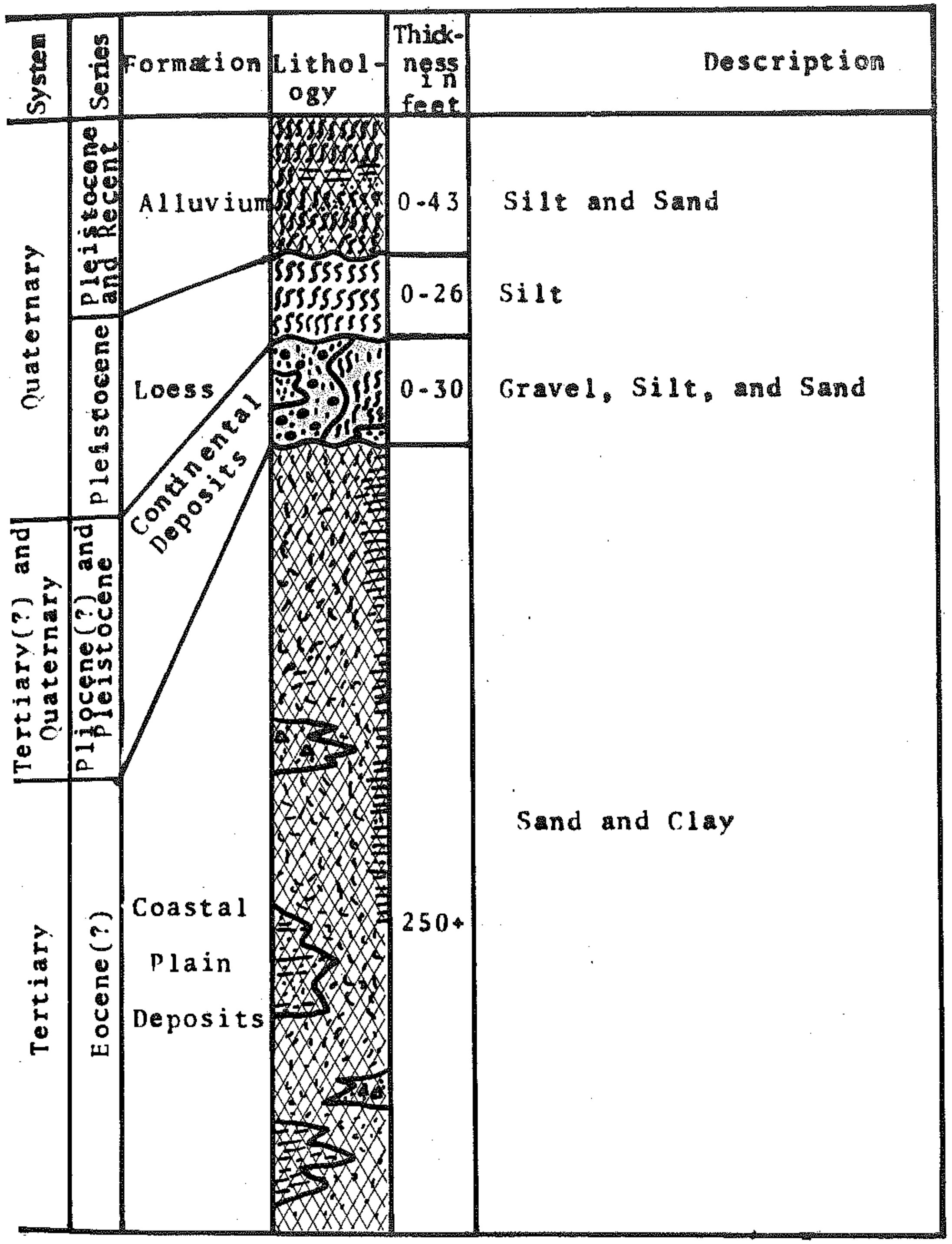
Thick deposits of Pleistocene loess occur along the Mississippi River in the Purchase region. The deposits are approximately 40 feet thick along the Mississippi River and thin to 20 to 25 feet along the Ohio River in McCracken County and to less than 10 feet in Graves County and Calloway County. The loess is composed of angular silt-sized particles of quartz with small amounts of feldspar and mica. The loess is of little importance as an aquifer but is highly susceptible to surface erosion.

Extensive deposits of gravel, sand, and clay occur along the flood plains of the major rivers in the area. Approximately 80 feet of the alluvium has been penetrated in the Tennessee River Valley near Kentucky Dam and 100 feet of alluvium has been encountered in the Ohio River flood plain. In the Mississippi Valley, the alluvium is probably much more than 100 feet thick. Along the large rivers the alluvium ranges from coarse gravel to clay, but along the smaller streams it is mostly fine sand, silt, and clay. The alluvium in the larger stream valleys are important aquifiers and supply quantities of water for domestic use. In the smaller stream valleys the material is more fine-grained and clayey and yields only very small amounts of water.

GENERAL STRATIGRAPHY

Figure 3 and 4 illustrate generalized columnar sections for various portions of the Jackson Purchase region. The pages which follow these columnar sections are more detailed descriptions of the various lithological units which are indicated on the columnar sections.

Reference to Figure 1 indicates that the older formations are exposed along parallel bands west of the Kentucky Lake. The Porter's Creek Clay is exposed further to the west and also outcrops around the rim of the Purchase area to the north. To the south and west, younger and younger materials are exposed. These materials progressively become thicker toward the southwest. In addition one moves from areas in which gravels and sands predominate towards those regions in which fine-grained clays and silts become more predominant in the southwest portion of the region.



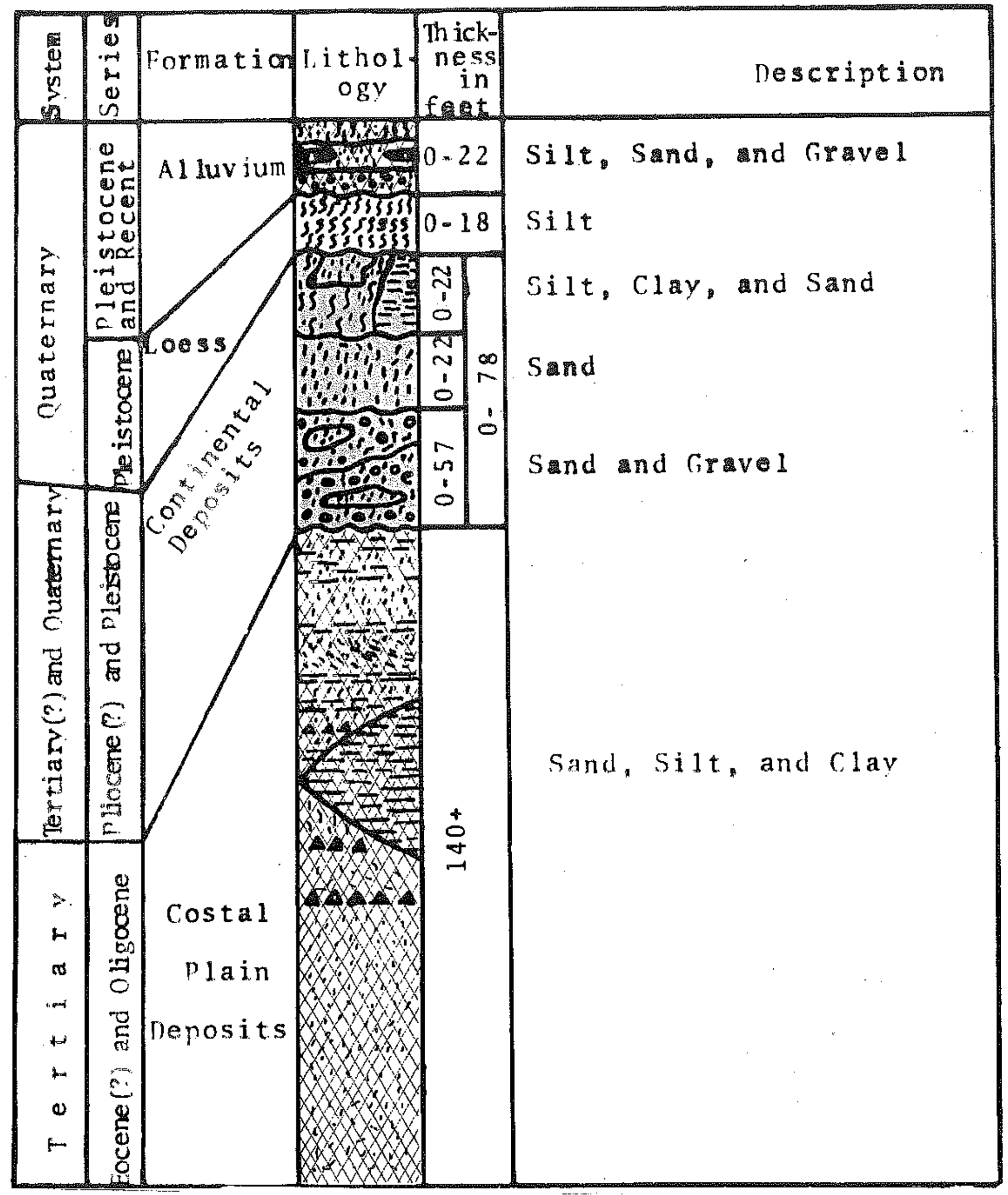


Figure 3. Generalized Columnar Section for Central Portion of Jackson Purchase Area

Generalized Columnar Section for Southern Portion of Jackson Purchase Area

System	Series	Formation	Lithology	Thickness in feet	Description
Quaternary	Pleistocene and Recent	Alluvium		0-125	Clay, Silt, Sand, and Gravel
Quaternay	Pleistocene	Loess		0-15	Silt
Tertiary and Quaternary	Pliocene (?) and Pleistocene	Continental Deposits		0-100	Gravel and Sand
Tertiary	Paleocene	Midway Group: Porters Creek Clay		50	Clay and Sand
Cretaceous and Tertiary (?)	Upper Cretaceous and Paleocene (?)	Midway Group: Clayton (?) and McNairy Formations		200+	Sand, Clay, and Gravel
Cretaceous	Upper Cretaceous	Tuscaloosa Formation		150+	Gravel and Clay

Figure 4. Generalized Columnar Section for Northern Portion of Jackson Purchase Area

Alluvium

Silt: Yellowish- to brownish-gray. Sandy to clayey. Locally pebbly, contains some mica and dark grains. Soft and relatively loose to well-compacted. Locally crossed by gray clayey veinlets at one-half to two foot spacings.

Sand: Brownish-gray. Very fine to very coarse grained quartz. With small amounts of chert and heavy minerals. Generally clayey to silty or pebbly. Locally fairly clean.

Gravel: Brownish-gray. Generally very sandy. Pebbles mostly brown to light-yellowish-gray chert less than two inches across but some cobbles more than five inches across occur.

Uppermost part of the alluvium is very silty. In the highest reaches of small tributaries and locally at edges of large valleys, loess and alluvial silt derived chiefly from loess apparently intergrade and intertongue. In the major valleys the alluvial silt is more sandy or more clayey than the loess and though in part wind deposited, it is chiefly water deposited. The alluvium is up to 40 feet thick in the southern and central portions of the Jackson Purchase area. To the north it increases 80 to 125 feet in thickness.

Loess

Silt: Yellowish-brown to light-brownish-gray. Contains variable amounts of clay and some fine sand. Generally structureless but occasionally displays crude columnar jointing and locally weathers into platy chips roughly parallel to the surface. Locally contains scattered dark-brown ferrguinous concretions.

The loess is separated in places from the underlying sand by a transition zone of red oxidized silty sand or sandy silt as much as 20 feet thick. This transitional zone has been interpreted as a pre-loess weathered zone. The loess is a blanketlike deposit covering much of the Jackson Purchase Area. It lies on ridges and crests of hills. It is generally six to 26 feet in thickness, and is probably of Wisconsin age and of eolian origin, but may include silt of older ages.

Continental Deposits

Gravel: Yellowish-brown. Predominantly subangular to subrounded chert pebbles with small amounts of ellipsoidal quartz pebbles in a sand matrix. Pebbles commonly stained with iron oxide. Locally abundant angular to rounded fragments of sandstone.

Sand: Yellowish-brown, reddish-brown, and brown fine to coarse grained quartz with some chert locally. Poorly sorted, clean to clayey. Interbedded with gravel in irregular lenses as much as five feet thick.

Silt: Dark-gray to brownish-gray. Argillaceous. Unit partly derived colluvially from loess and gravel. Sandy to clayey, micaceous.

Clay: Light- to dark-gray. Sandy and silty. Probably kaolinitic. Occurs in thin seams and lenses as much as ten feet thick. Contains sparse medium grain quartz. Some chert granules and pebbles in lower part. Sparse mica locally.

The Continental Deposits are alluvial in origin. The deposits are generally separated into a three-fold division: an upper silty sand, a middle clean sand, and a lower gravel.

Coastal Plain Deposits

Sand: Predominantly light-yellowish-brown, light-gray and white. In upper portion of unit sand consists mostly of thin layers of silty, very fine grained quartz interlaminated with silt. Contains sparse white mica and abundant black opaque minerals. In the middle portion of the unit the sand consists mostly of fine to medium grained angular quartz. Contains sparse dark-bluish-green and black opaque minerals. Most of the sand is clean and unconsolidated. Where it is indurated it displays prominent cross-beds. Lenticular, thin clay layers and clay pellet and pebble zones are common. The lowest sands consist mostly of well-rounded, well-sorted medium to very coarse grained quartz. Contains sparse bluish-gray and black opaque minerals. Unconsolidated. White clay coats quartz grains locally.

Silt: Gray, yellowish-brown. Thin beds interlaminated with white clay and pink and gray very fine sand.

Clay: White, light to dark and mottled shades of pink, yellow, and brown. Predominantly kaolinitic with minor amount of illite and montmorillonite. Thick, plastic, massive, beds. Weathers hackly and blocky. Slumps badly where thick. Silty in all natural outcrops. Carbonized plant remains and lignitic seams up to five inches thick.

The deposits are better than 250 feet in the southern part of the Purchase area and thins to approximately 140 feet near Mayfield.

Claiborne (?) Formation

Sand: White in fresh exposures (rare) but yellow, orange, red, or light-brown where weathered. Generally poorly sorted very fine to medium grained quartz. Commonly with sparse coarse to very coarse grains and granules of quartz. Beds of coarse to very coarse and granular quartz sand are more common in the lower part. Sparse dark opaque minerals and mica. Angular to sub-rounded. Generally clean but clayey in localities. Locally cemented by iron oxide into concretions. Mostly horizontally thick to thin bedded. Locally contains thin white, pink, and gray seams of clay as well as irregular zones of clay pebbles and balls and blocks of clay.

Clay: Dark-gray to dark-brown, weathering to white, cream, pink, or lavendar. Chiefly kaolonite with small amounts of illite. Locally lignitic, particularly in the upper few feet of thick clay bodies. Occurs in lenses up to 30 or 40 feet thick and as much as several tens of acres of horizontal extent. May contain interbeds of silt or sand.

Silt: Light-gray to white. Clayey to finely sandy. Micaceous. Usually thin-bedded. Common in lower part of formation.

Clay-pebble to clay-boulder conglomerate: Fairly common in the lower part of the formation and locally present higher in the unit. Most pebbles are round to elliptical but larger fragments generally are more angular. The matrix is generally clean sand.

The Clairborne formation is 80 to 100 feet or more in thickness.

Wilcox Formation

Clayey sand: Reddish-brown. Chiefly fine to medium grained quartz, sparse coarse and granular quartz grains.

Sandy clay: Yellowish-brown, approximately 10 percent very fine to fine grained quartz. Sparse white mica.

Clay: Mostly coarse to very coarse light-brown to black. Clay may exceed 50 percent of rock particles. Quartz grains generally fine to medium size and not more than 20 to 40 percent of the rock, which is angular to subangular. Lignitic in part. Sparse iron sulfide nodules.

Sand: Coarse to medium grained sand. Fairly clean. As much as 15 to 25 feet thick.

In areas where the upper member is at or below stream level, the lower member is usually an important aquifer. The formation is 25 to 200 feet or more in thickness.

Porters Creek Clay

Clay: Dark- to light-gray. Montmorillonitic, micaceous. Slightly sandy. Weathers typically into chips and blocks that are moderately resistant to weathering.

Sand: Light-gray, weathers reddish-brown. Micaceous. Ordinarily contains moderate amount of dark minerals in upper reaches.

The upper part consists of 25 to 30 feet of thin-bedded dark-gray micaceous clay and interlaminae of fine to medium grained silty sand layers two to five feet thick. Basal part consist of 20 to 40 feet of interlensing sandy clay and fine to medium grained light-gray, reddish-brown-weathering micaceous quartz sand. At several localities the Porters Creek Clay is intersected by vertical or nearly vertical clastic dikes, commonly less than two feet but in places as much as 15 feet thick. The dikes consist predominantly of sand similar to the bedded sand of the Porters Creek and rarely of clay. The dikes are generally straight for distances of ten to 50 feet but many make sharp angular bends, as much as 90°. Wall rocks of some dikes are slickensided. The unit is from 50 feet thick in the northern portion of the Purchase area to 190 thick northeast of Mayfield.

Clayton (?) and McNairy Formations

Sand: White or light-gray to reddish-brown, weathers to a brick red in lower part of unit. Very fine to medium grained. Micaceous in part. Commonly argillaceous or silty. Contains very fine grains of dark minerals in various quantities. Contains thin lenses of light-colored silty clay. Crossbedding and cut-and-fill structure common. Locally indurated by iron oxide.

Clay: Light-gray to black. Kaolinitic. Micaceous, carbonaceous. Commonly thin-bedded with thin laminae of very fine to fine grained angular quartz sand. Contains scattered ferruginous concretions and fragments of lignite. Interfingered with sand within the upper 90 feet of the formation.

Gravel: Well-rounded white chert pebbles and cobbles in a matrix of quartose sand. Occurs as locally indurated gravel beds and scattered pebbles within the lower 60 feet of the formation.

Where the upper most beds are sand, a zone six inches to two feet thick beneath the Pliocene(?) and Pliestocene Continental Deposits is commonly cemented with a silica or ferruginous material. The formation rests unconformably on older rocks. The formation is 150 to 200 feet or more thick.

GEOLOGIC STRIP MAPS OF JACKSON PURCHASE PARKWAY AND I-24

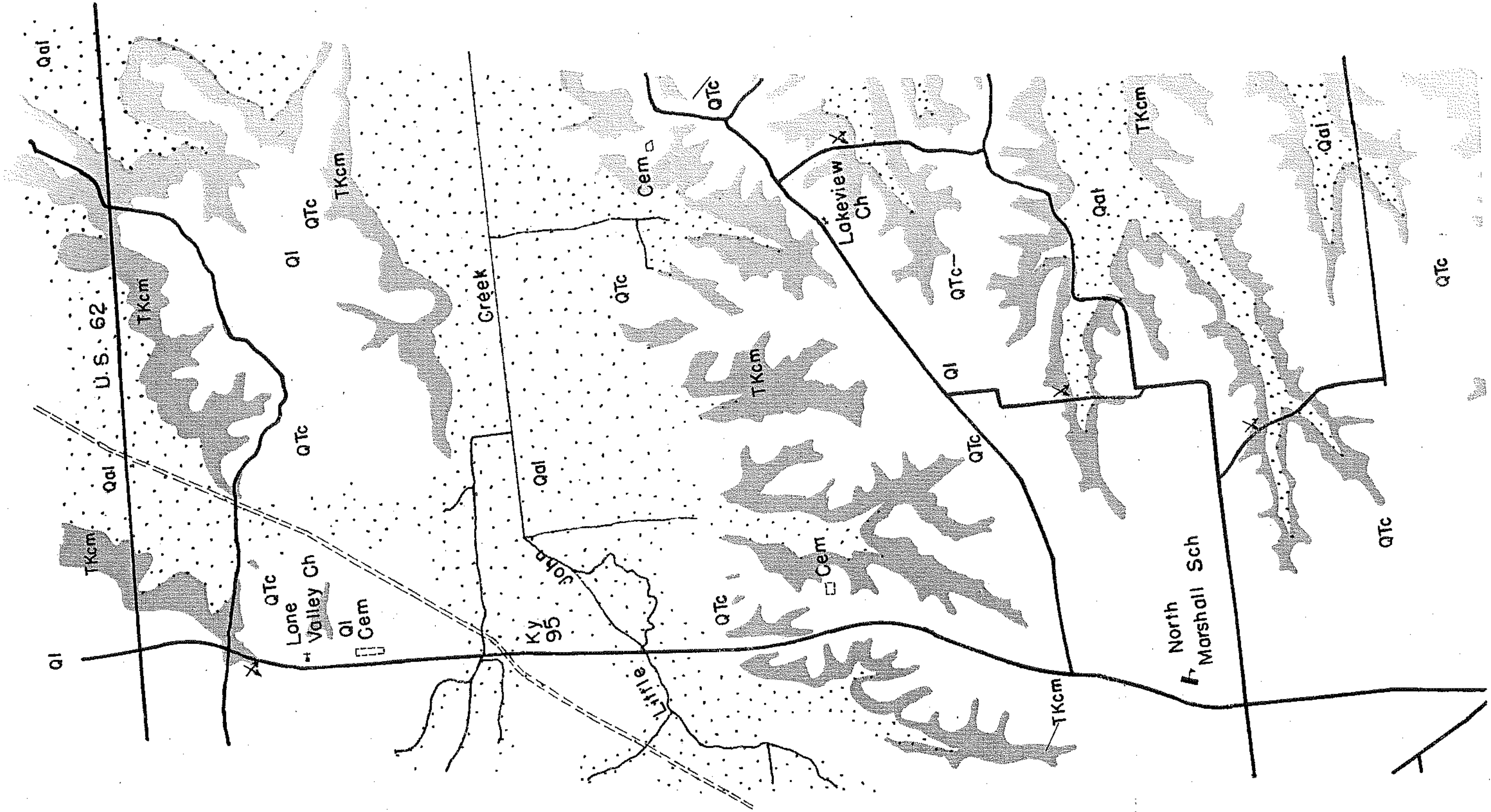
LEGEND
FOR
JACKSON PURCHASE PARKWAY
GEOLOGIC STRIP MAPS

	Qaf	Artificial Fill	
Pleistocene and Recent	Qal	Alluvium	Quaternary
Pleistocene	Ql	Loess	Quaternary
Pliocene(?) and Pleistocene	QTc	Continental Deposits Cl - Clay	Tertiary(?) and Quaternary
Eocene and Oligocene(?)	Tcp	Coastal Plains Deposits Cl - Clay	Tertiary
Eocene	Tc	Claiborne(?) Formation Cl - Clay	Tertiary
Eocene	Tw	Wilcox Formation	Tertiary
Eocene	Te	Claiborne(?) and Wilcox Formations	Tertiary
Paleocene	Tp	Porter's Creek Clay	Tertiary
Cretaceous and Paleocene(?)	TKcm	Clayton and McNairy(?) Formations	Cretaceous and Tertiary(?)

X Gravel Pit
X$_s$ Slump Block
X$_b$ Outcrop of Clay Ball and Pebble Sand
X$_{cl}$ Outcrop of Clay
Spring
Boulders

U/D Fault
Dashed where approximately located.
Dotted where concealed.
U Upthrow side
D Downthrow side
X Outcrop of Silt

Figure 5. Geologic Strip Map for the Jackson Purchase Parkway.



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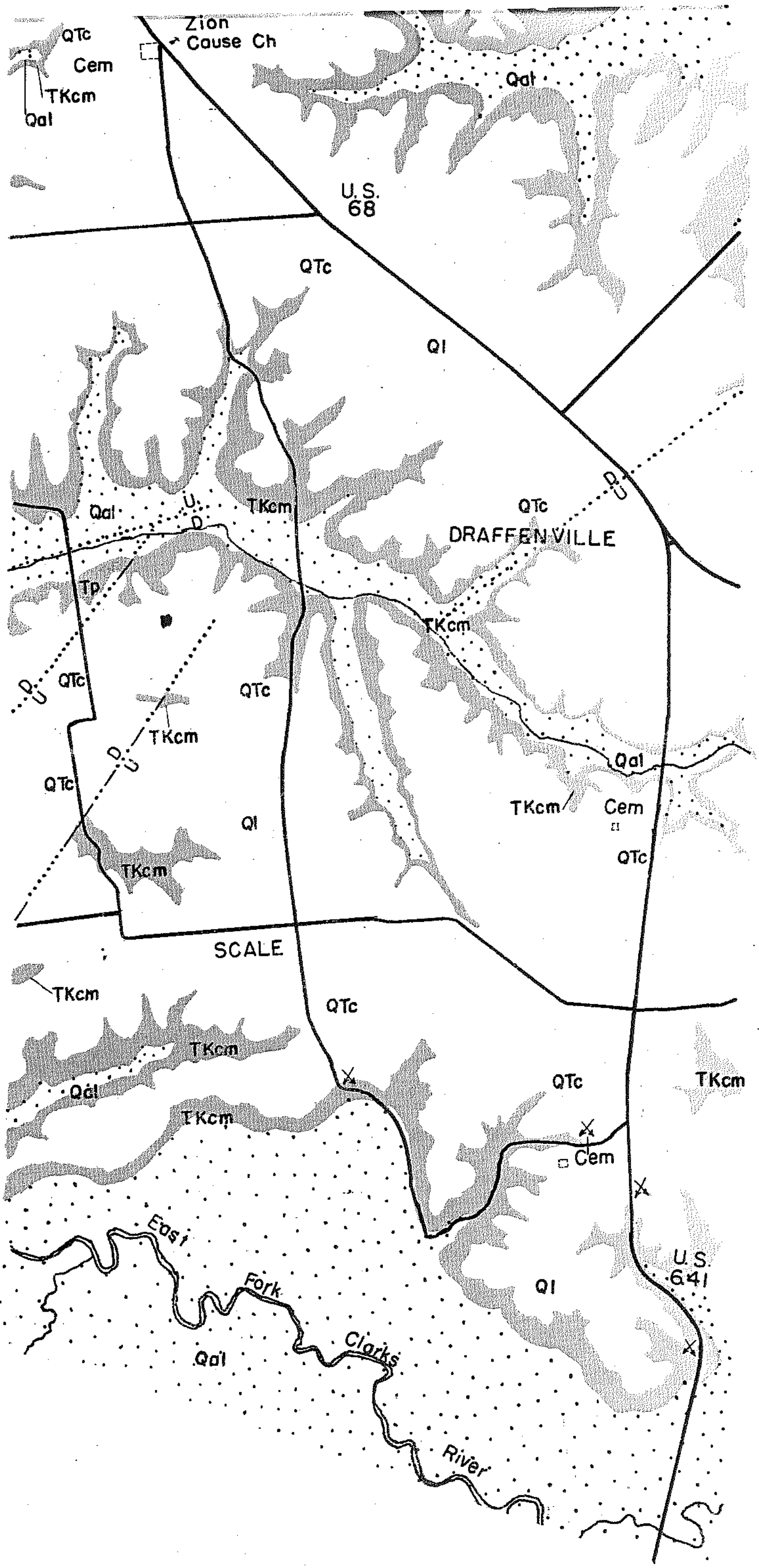

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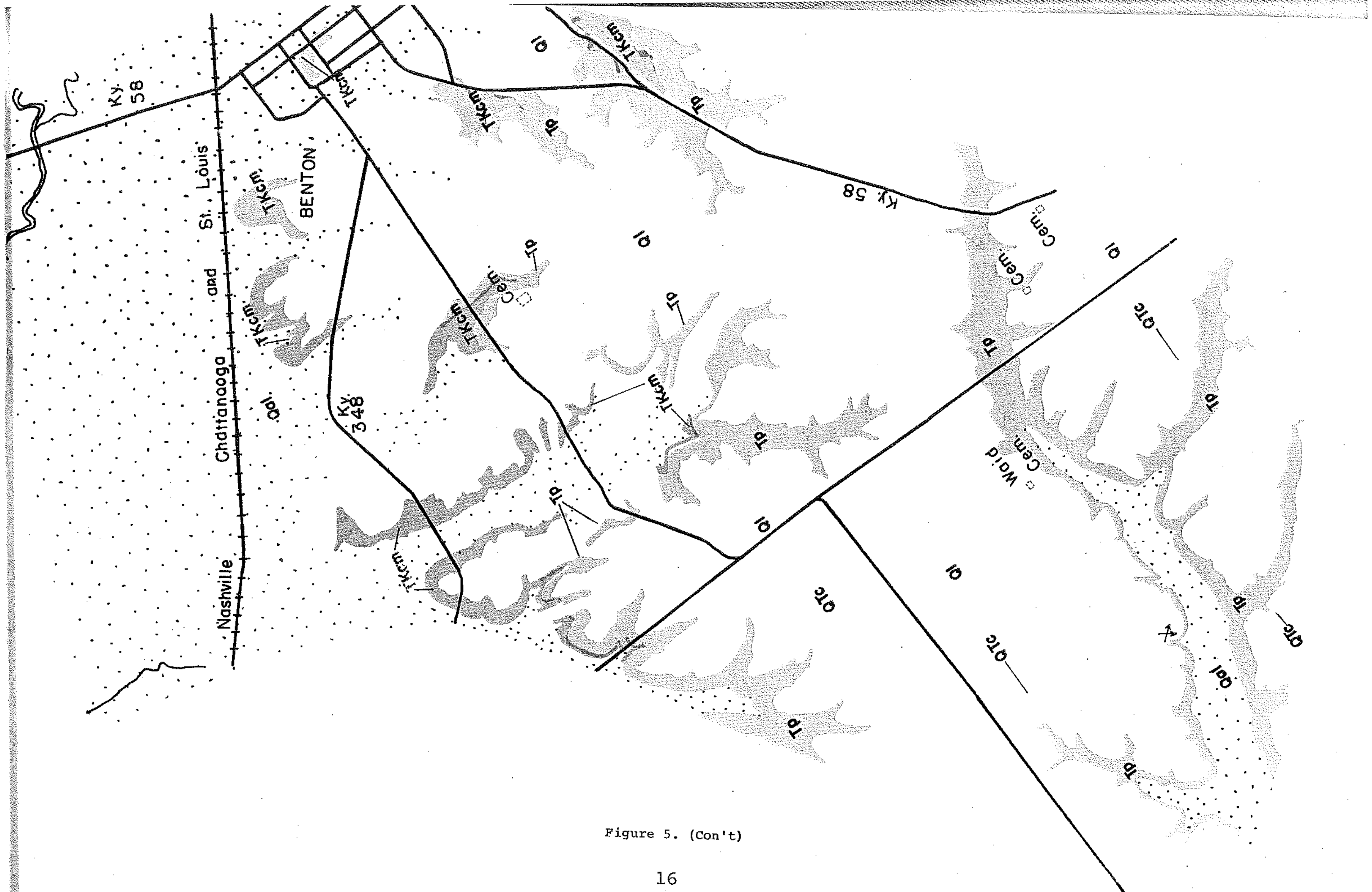

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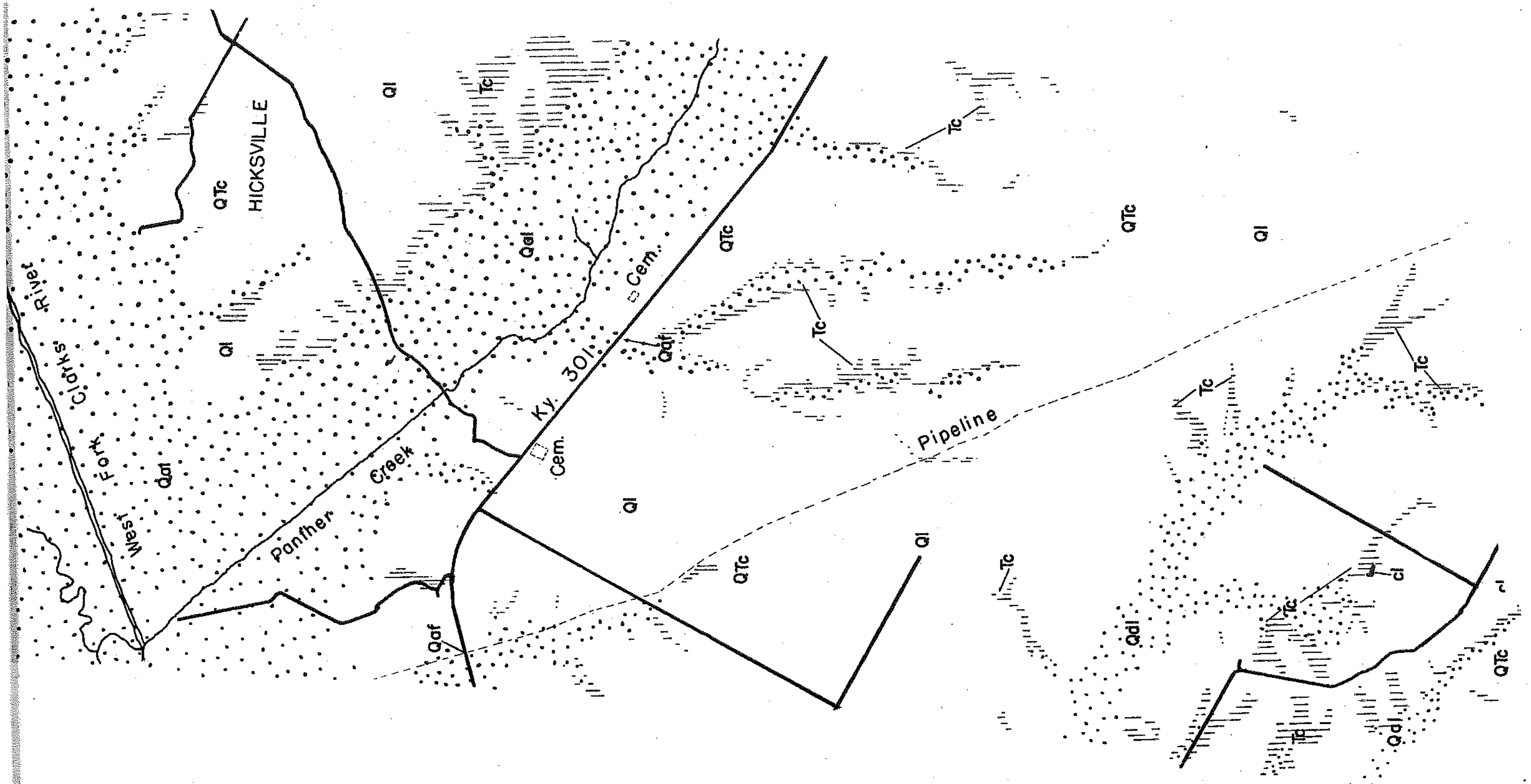

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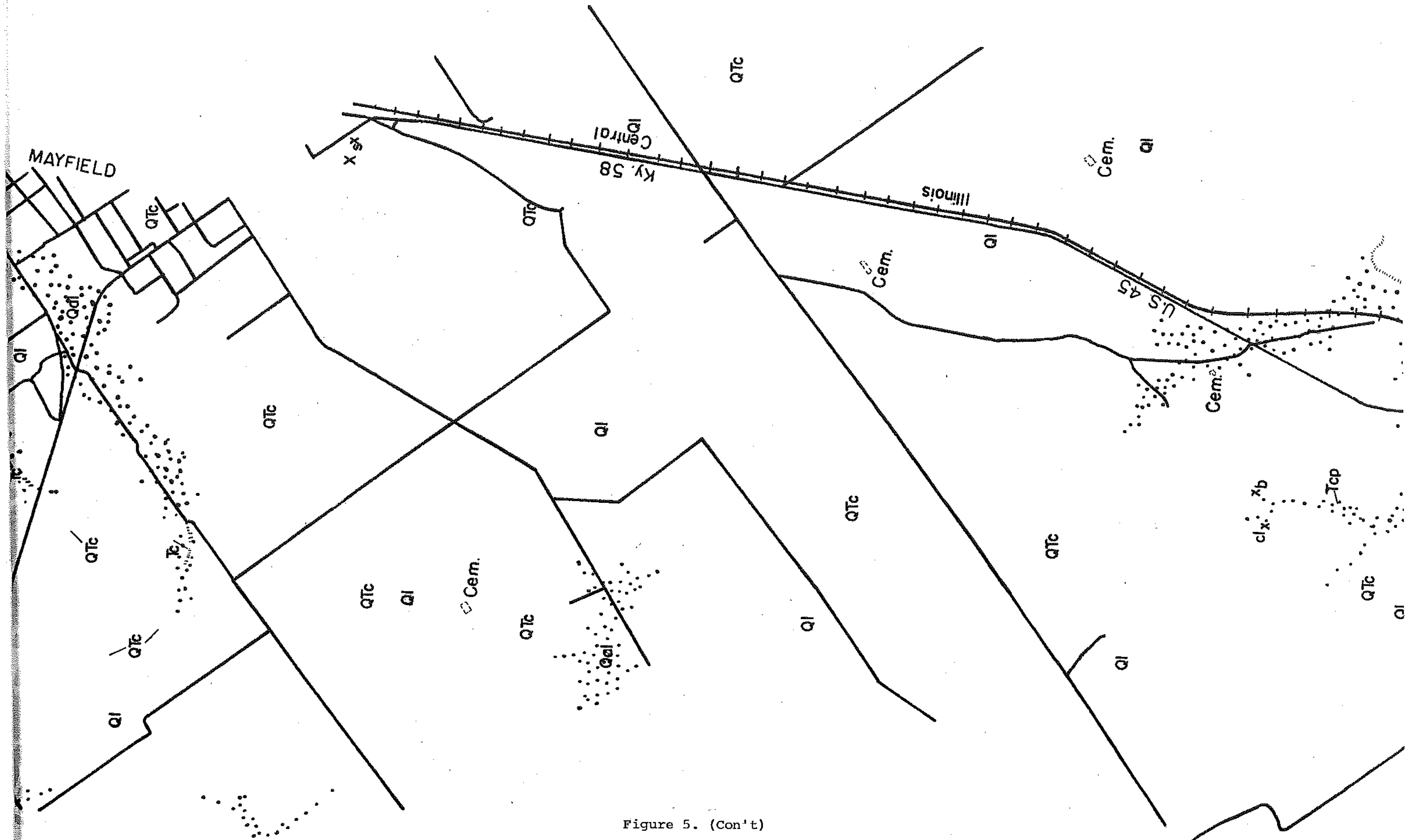

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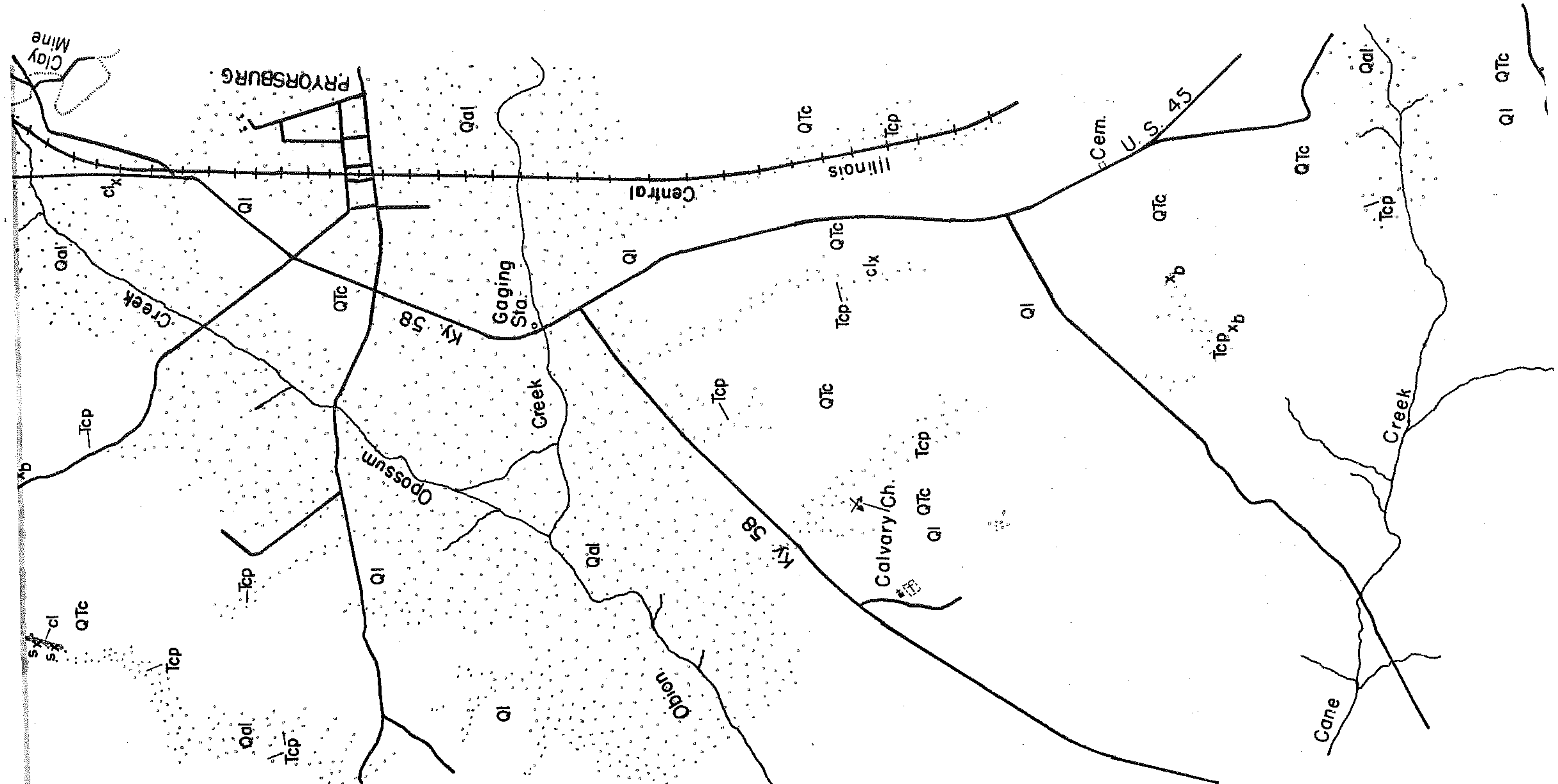

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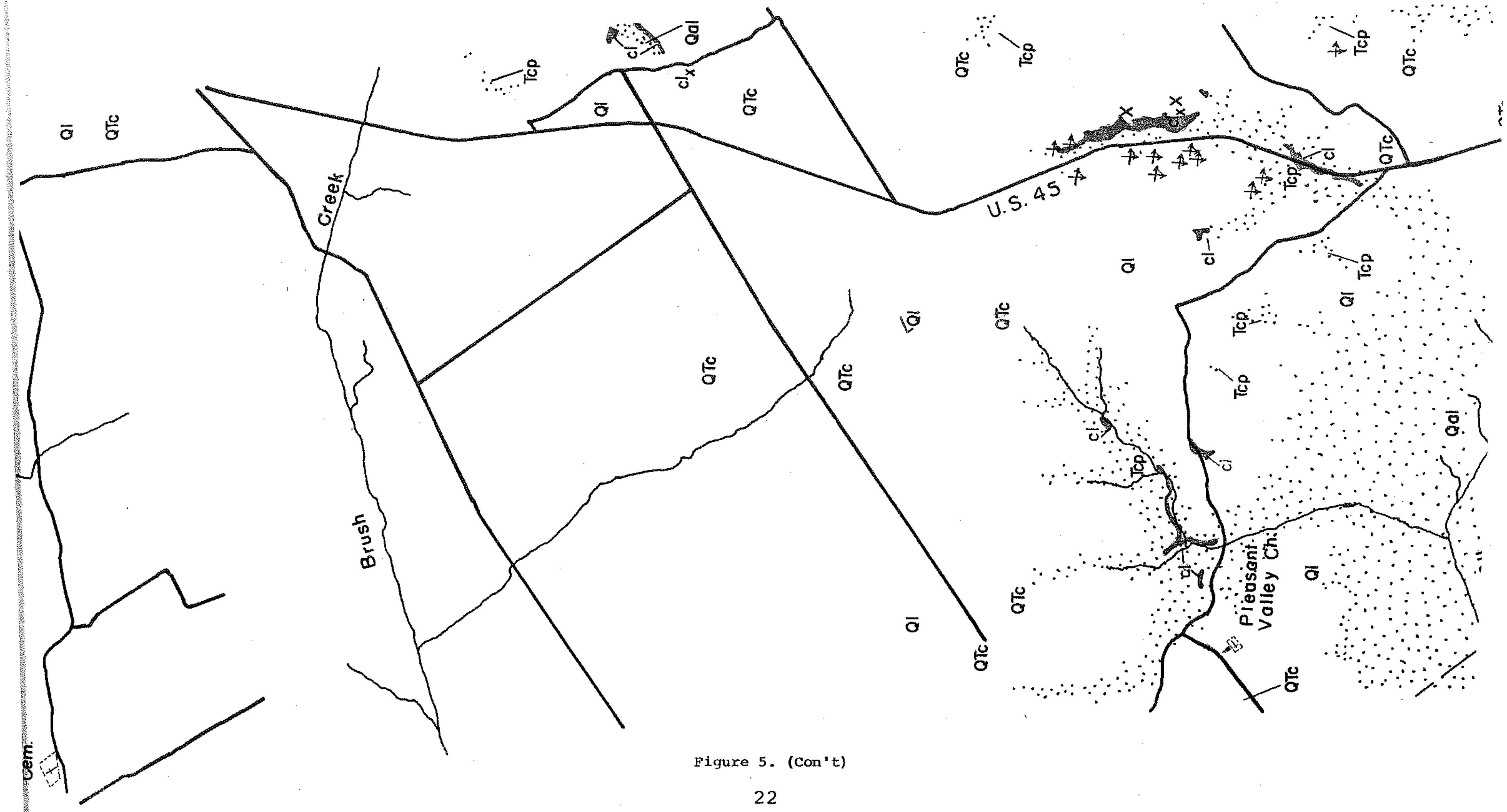

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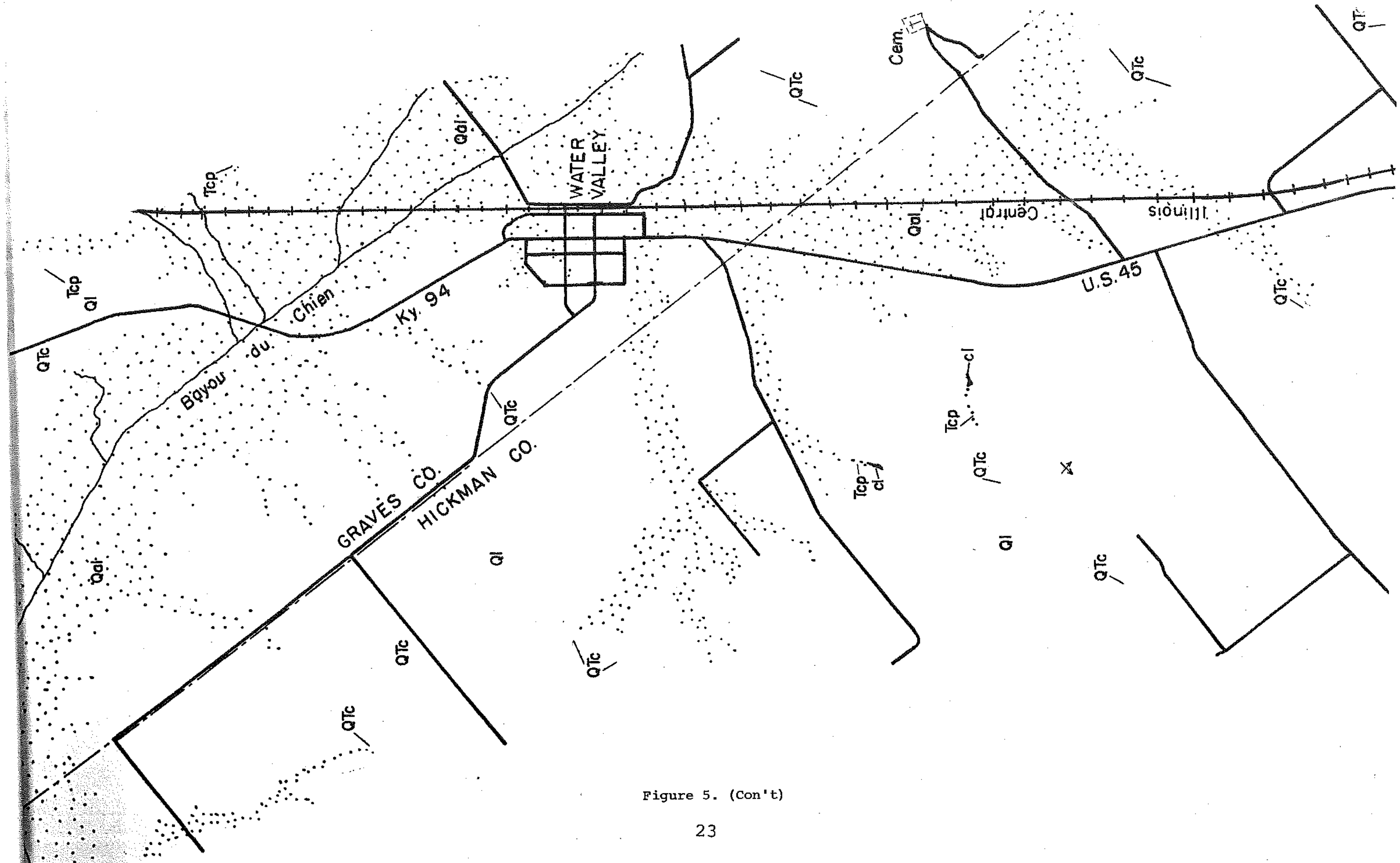

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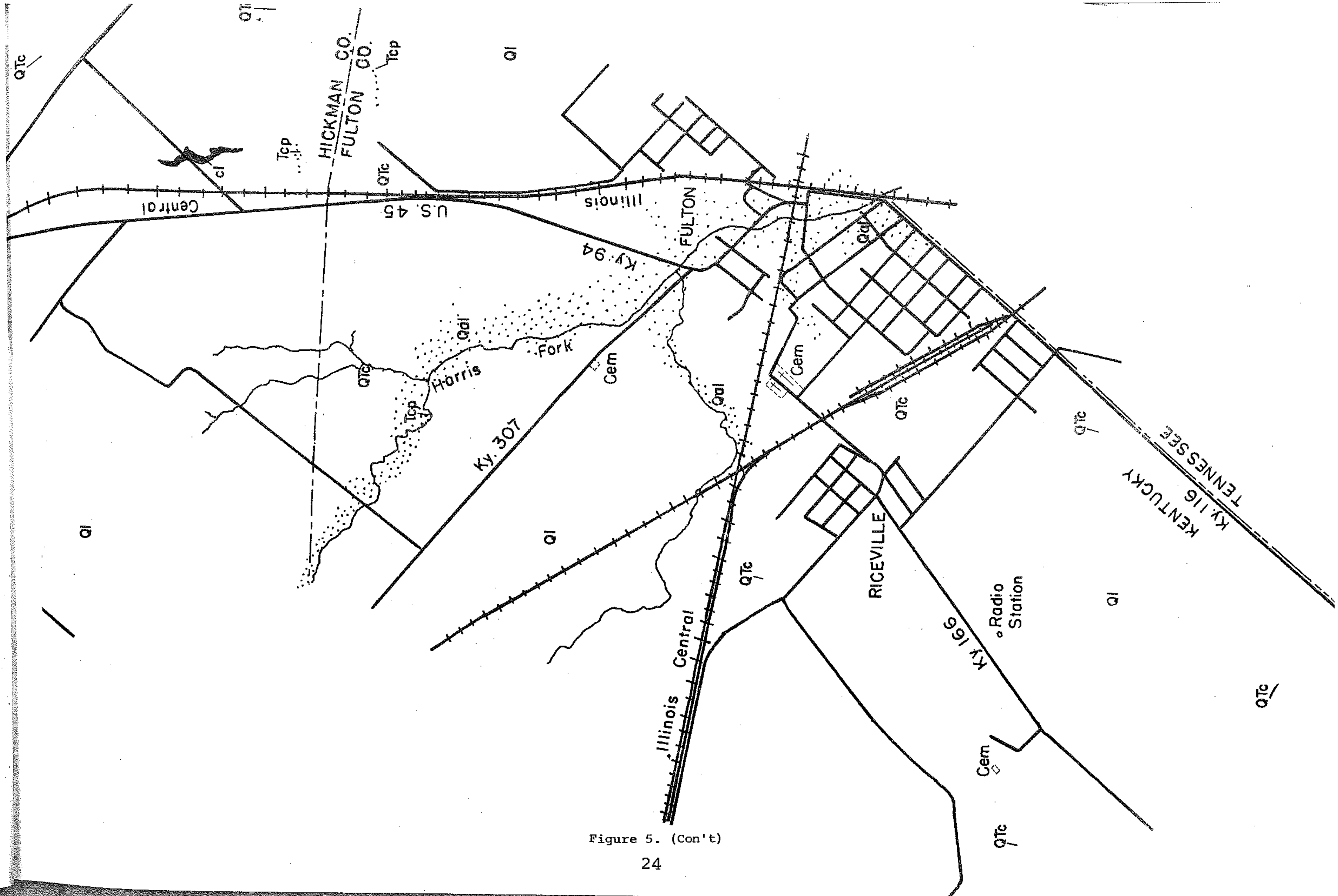


Figure 5. (Con't)

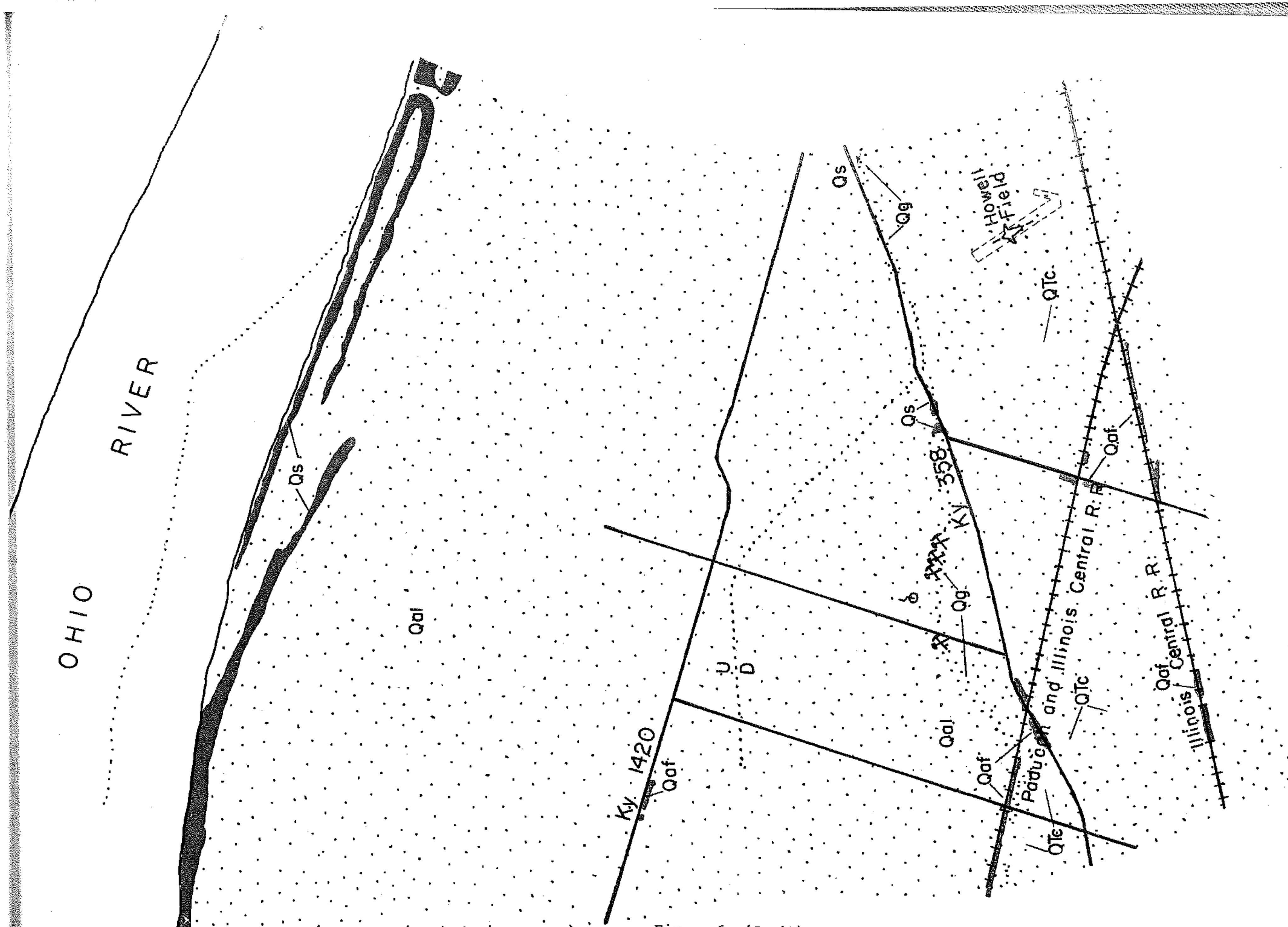
LEGEND
FOR
I-24 (IN THE JACKSON PURCHASE AREA) GEOLOGIC STRIP MAPS

	Qaf	Artificial Fill	
Pleistocene and Recent	Qal	Alluvium Qs – Sand Qg – Gravel	QUATERNARY AND RECENT
Pleistocene	Ql	Loess	QUATERNARY
Pliocene(?) and Pleistocene	QTc	Continental Deposits Cl – Clay	TERTIARY (?) AND QUATERNARY
Eocene	Tc	Claiborne (?) Formation Cl – Clay	TERTIARY
Eocene	Tw	Wilcox Formation	TERTIARY
Eocene	Te	Claiborne (?) and Wilcox Formations Cs – Sandy Clay	TERTIARY
Paleocene	Tp	Porter's Creek Clay	TERTIARY
Cretaceous and Paleocene(?)	TKcm	Clayton(?) and McNairy Formations	CRETACEOUS AND TERTIARY(?)

- X Gravel Pit
- X Slump Block
- X_b Outcrop of Clay Ball and Pebble Sand
- X_{cl} Outcrop of Clay
- Spring
- Boulders

U/D — Fault
Dashed where approximately located.
Dotted where concealed.
U Upthrow side
D Downthrow side
X Outcrop of Silt

Figure 6. Geologic Strip Map for I 24 in the Jackson Purchase Region.



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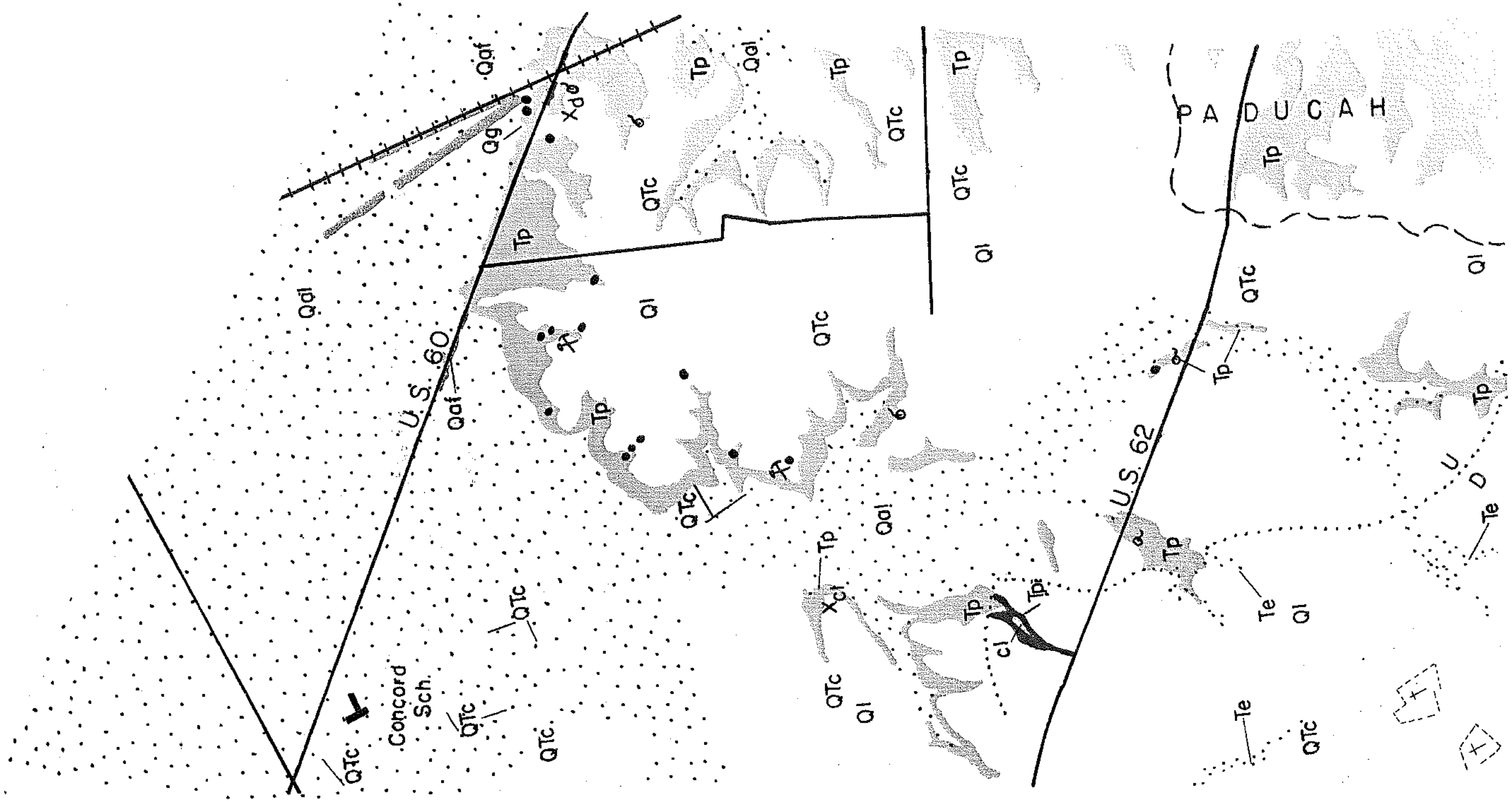

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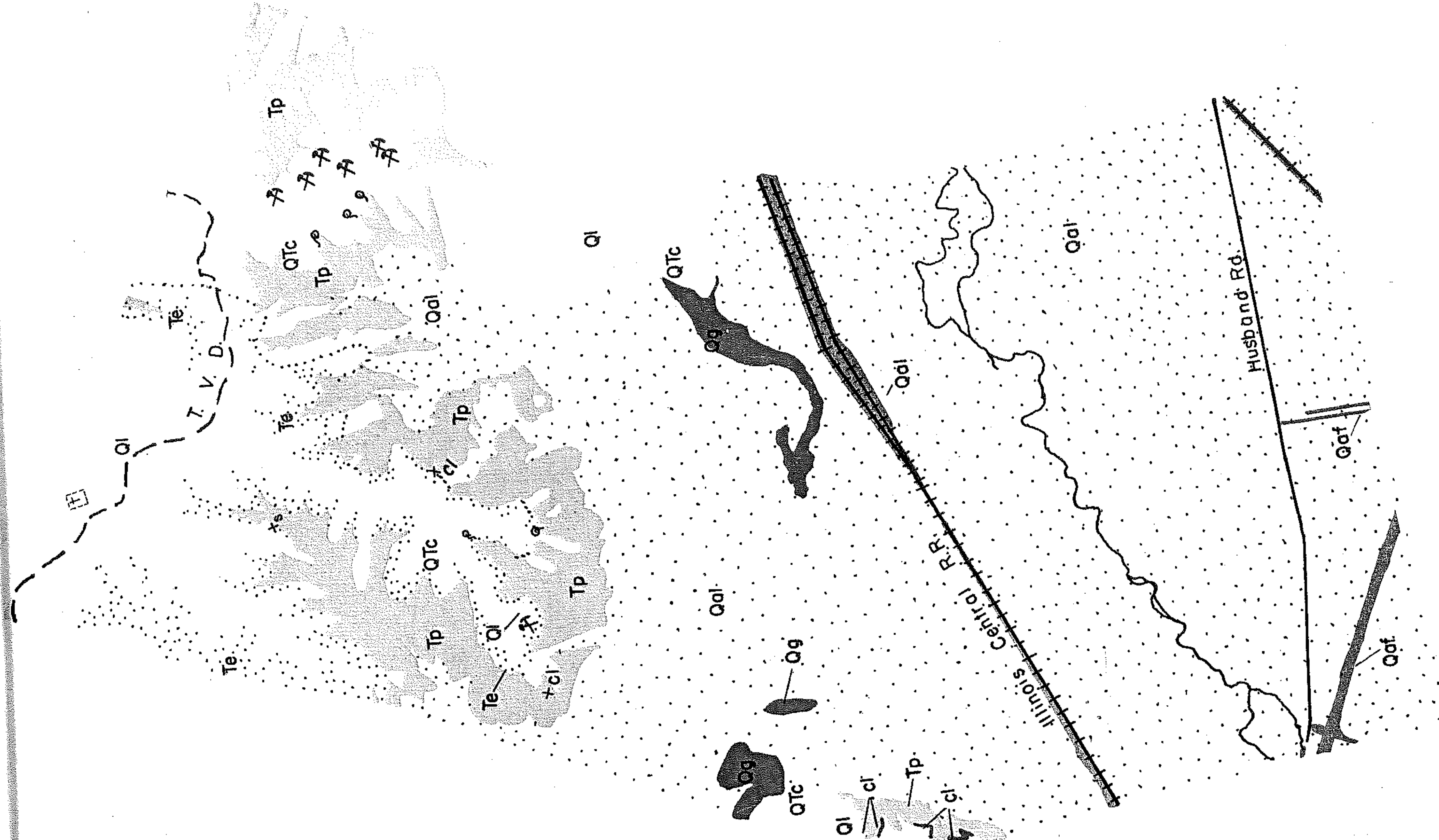

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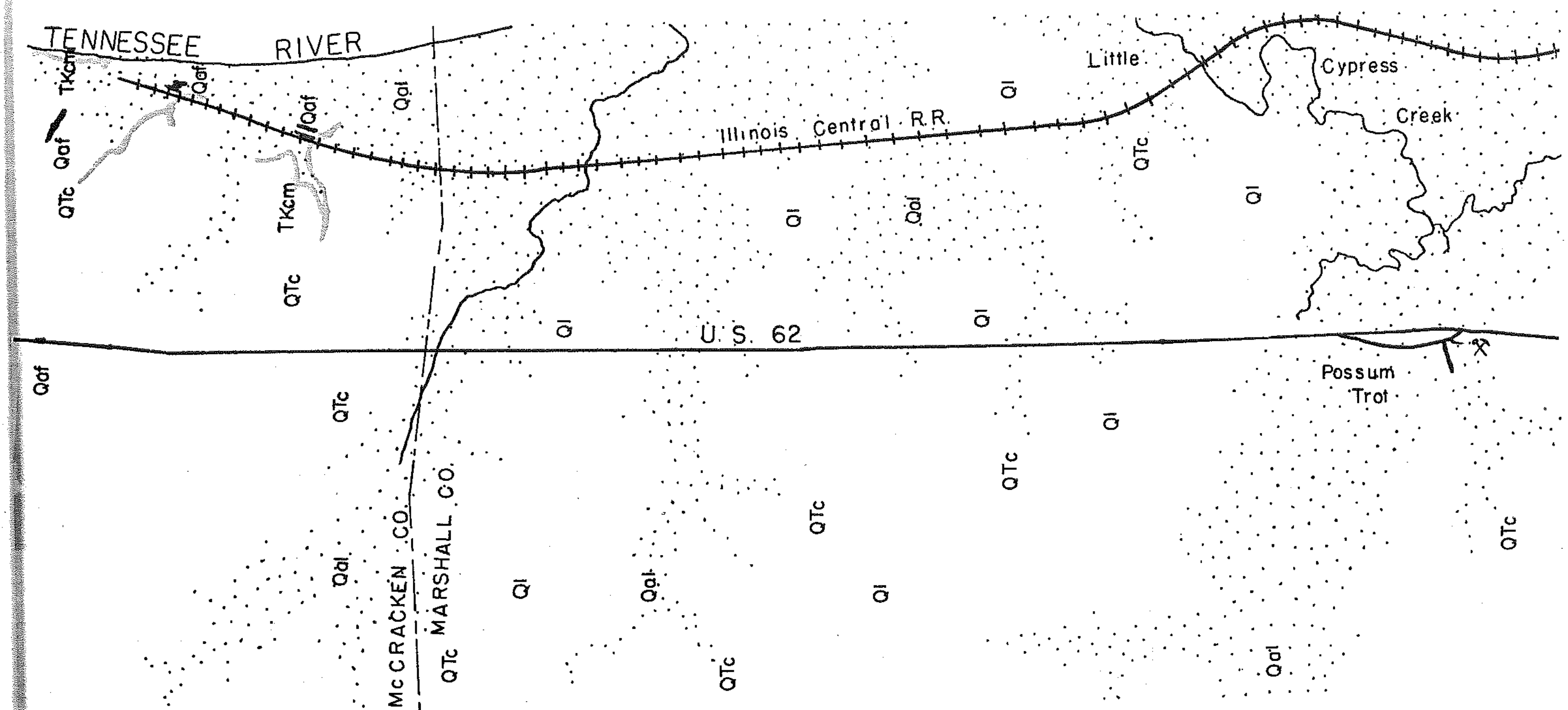

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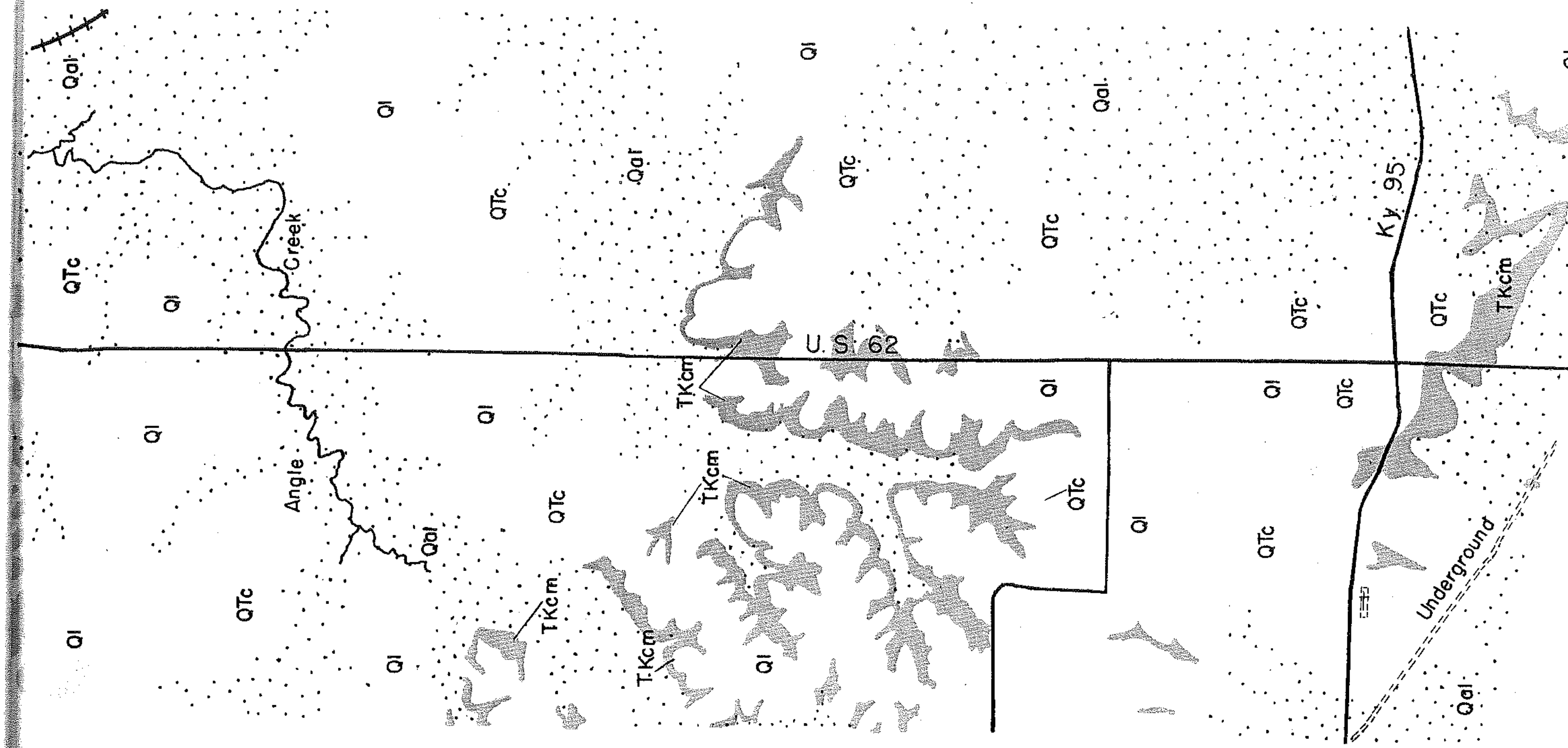

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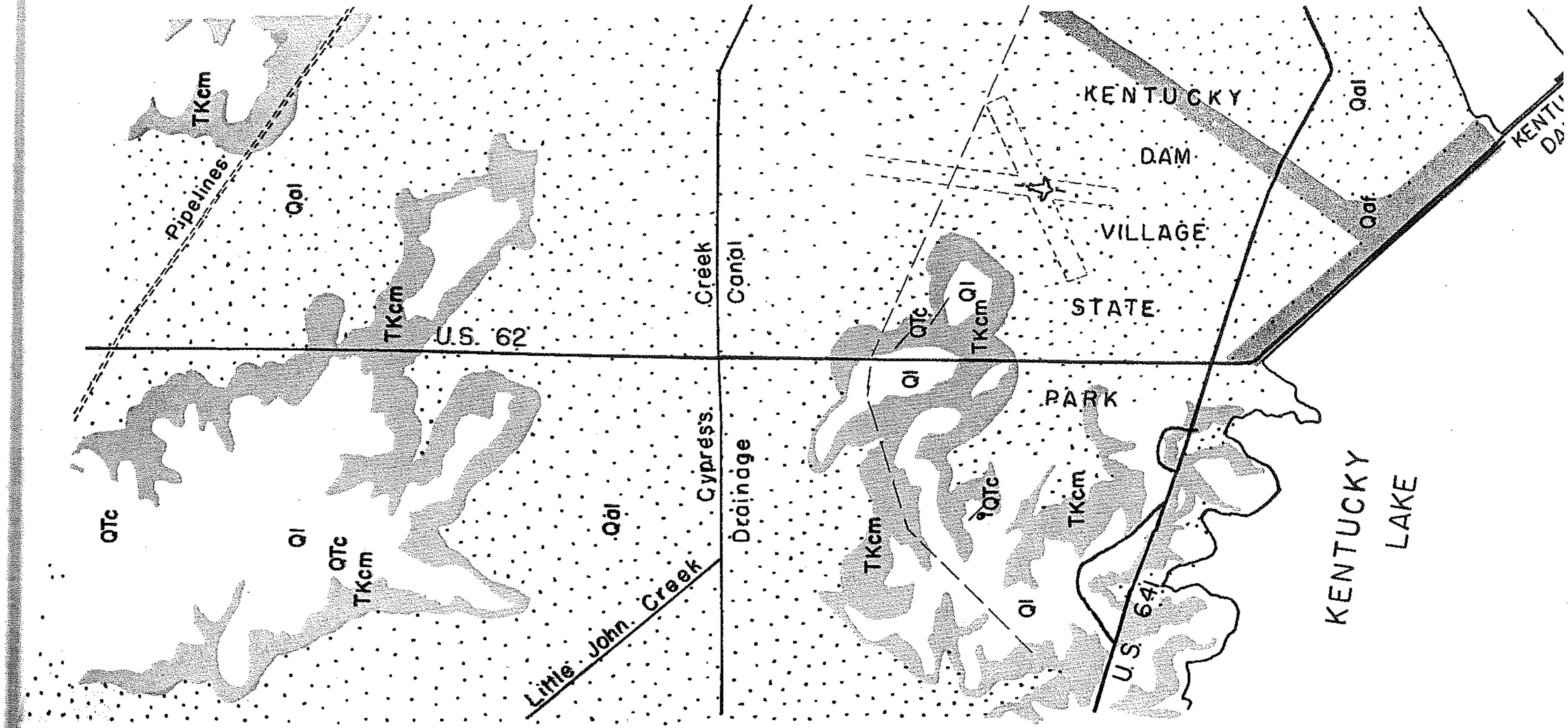

Figure 6. (Con't)

IMPLICATION OF GEOLOGY WITH RESPECT TO HIGHWAY DESIGN AND CONSTRUCTION

With the published geologic maps supplemented by additional information supplied by the U.S. Geological Survey, there is essentially complete geologic coverage of the routes of the Jackson Purchase Parkway and I 24 in the Jackson Purchase region. Strip maps shown in Figures 5 and 6 have been prepared for the proposed corridors of the Jackson Purchase Parkway and I 24 showing detailed geological information. These maps have been drawn to a scale of 1"=1000'. This information might be quite useful in delineating those areas in which difficulties or poor performance might be anticipated. In addition, the geologic information available for the Jackson Purchase region also indicates areas from which highway construction materials might be obtained.

CLAYS

One of the most troublesome geologic materials outcropping in the Jackson Purchase area is the Porter's Creek Clay. As indicated in Figure 1, this formation surfaces in a zone essentially paralleling the Kentucky Lake and Ohio River from the Tennessee line to the Paducah area. Throughout most of its outcrop area, the Porter's Creek Clay is a relative impermeable unit and thus forms a barrier to the downward percolation of groundwater. Perched water tables have developed in many areas where the Porter's Creek Clay is overlain by the porous sand of the Caliborne and Wilcox Formations and the gravels of the Continental Deposits. When vertically percolating water encounters the Porter's Creek Clay, it is forced to move horizontally and often outcrops as springs where the top of the Porter's Creek Clay is exposed. This effect is quite noticeable on several of the highways and county roads in the Jackson Purchase area. Where a highway crosses the outcrop of the Porter's Creek Clay, it has been observed on many occasions to be performing poorly because of the extremely high moisture contents caused by the percolation of water along the top of the formation.

The shallow perched water tables are contributing factors in the development of landslide blocks. The Porter's Creek Clay has become generally saturated as a result of the perched water table and in many places has yielded to the weight of the 25 to 40 feet of overlaying gravel of the Continental Deposits to produce numerous old landslide blocks along the steep valley slopes. These are quite numerous in the corridor of the Jackson Purchase Parkway to the south and west of Benton. Highway construction in this area might reactivate these slides or may trigger new slides.

In some outcrop areas the Porter's Creek Clay is traversed by vertical, variously trending, sandstone dikes which range in thickness from a few inches to as much as 50 feet. Some of these dikes provide avenues along which water moves: and if they are exposed or encountered during construction excavation, they could produce drainage problems.

The unweathered clay of the Porter's Creek consist chiefly of calcium-montmorillonite and has high natural water contents. When exposed at the surface, the clay is subject to rapid desiccation resulting in large volume changes causing the clay to fracture into chips forming talus slopes. Tests on samples on the Porter's Creek Clay indicate that the liquid limit ranges between 40 and 130 percent with the plasticity index ranging from about 15 to 55. Field density tests indicate the natural wet density is 95 to 100 pounds per cubic foot with the natural moisture contents ranging from about 25 to 60 percent.

Clays associated with other deposits and formations in the Jackson Purchase area do not seem to be quite as poor performers as the Porter's Creek Clay. This is probably attributable to the fact that the predominant clay mineral in these other clays is usually of a kalonitic or illitic nature. These clay minerals are generally much more desirable from the engineering performance point of view than the montmorillonite clays.

<u>Recommendation</u>: Because of the shrink-swell nature of most of the Porter's Creek Clay, it is suggested that attempts be made to keep this material out of the highway subgrade and from around bridge abutments and box culverts.

LOESS

As mentioned earlier in the report and as indicated on the geologic strip maps for the Jackson Purchase Parkway and I 24, much of the Jackson Purchase area is covered with a mantle of loess, consisting predominantely of silt-sized particles. The material is extremely susceptible to erosion, and large areas of the Jackson Purchase area show signs of moderate to severe sheet and gulley erosion. These materials are poorly to moderately well drained -- with high moisture contents during the wet seasons and becoming very dry during the dry season. Embankments constructed with this material are susceptible to swelling and settling and the slopes subject to severe erosion. Because of the high silt content of the loess, the control of moisture content during the compaction process of embankments and subgrades is extremely critical. Very slight variations of moisture toward the wet side of optimum can cause a quick condition and severely hamper the compaction procedure. This becomes even more important where the loess is underlain by an impervious material, such Porter's Creek Clay, and the water is maintained at a perched level and is not permitted to drain from the loess. Also because of its high silt content, this material is very susceptible to frost heave, particularly where the drainage is poor or the water table is near the surface. This material has moderate shear strength when dry with the strengths decreasing rapidly as moisture content increases. Swell pressures are negligible in undisturbed material but become noticable in remolded material. Differential consolidation is believed to be significant and quite noticable in highway embankments.

The most abundant clay mineral of the loess mantle is a mixed-layer clay of variable composition consisting predominantely of aluminum-interlayered vermiculite, montmorillonite and kaolinite. This clay is probably the binding material for the silt particles and thus explains the rapid decreases in strength when the material becomes wet. The presence of variable amounts of montmorillonite in the mixed-layer clay is a probable cause of the differential swelling and compaction under loads.

The loess is often suitable for use in soil-cement stabilization. The clays contained in the loess are generally not so heavy or fat that the workability or manipulation characteristics of the material are undesirable. However, the cement contents required for significant improvements are sometimes relatively high.

Recommendation: Where fill or cut slopes of this material are encountered, it is recommended that final dressing be done as quickly as possible following rough grading. It is extremely important that seeding and mulching be done immediately afterwards in order to minimize erosion and sloughing of the slopes.

GRAVELS

There are large quantities of gravels in the Jackson Purchase area. These are often used as aggregate for base construction for highways and road metal for traffic-bound county roads. These gravels are often intermixed with and interbedded with more or less amounts of clays and sometimes are sufficiently "dirty" that they cannot be satisfactorily used in high type base construction without some modification. Some of the gravels contain large quantities of chert and may perform poorly as aggregates in bituminous and portland cement concrete surfaces.

In the fall of 1956, the Division of Research participated in the experimental design and evaluation of a group of ten rural base stabilization projects*. Two of these projects, one in Ballard County and one in Marshall County, involved the stabilization of bank gravels with a bituminous material, AE-200, a mixing-type emulsion. The performance of these bituminous-stabilized gravels has not been entirely satisfactory. Even though there was little tendency for the asphalt to bleed, some sections were deeply marked and remarked by each passing vehicle. It may have been that the addition of the bituminous material served to lubricate rather than cement the gravel particles together.

It was pointed out in the above cited report that Western Kentucky gravels have usually been treated with bituminous materials or calcium cloride in attempted stabilizations with generally unsatisfactory results. It should be pointed out that portland cement, lime, or lime-fly ash might be more successfully used to stabilize these gravels. Gravelly soils, such as those found in the Purchase area, often present most favorable conditions for soil-cement construction and require the least amounts of cements for adequate strengths.

The only significant sources of high quality limestone aggregates would be in the limited exposures of older rock on the east banks of the Kentucky Lake. The nearest commercial limestone aggregate is available from the Reed Crushed Stone Company in Livingston County. This quarry site is actually not in the Jackson Purchase area but is located just to the east of the Kentucky Lake in the Between the Rivers area. With proper selection, gravels found in the Purchase region may be suitable for use in portland cement concrete or in bituminous concrete. Gravels used in these materials must be selected from the non-leached zones that often appear near the top of many gravel pits. These leached gravels are highly porous and cherty and

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*Havens, J. H. and Drake, W. B. "Ten Rural Highway Base Stabilization Projects" Division of Research, Kentucky Department of Highways, August, 1957.

and are completely unsatisfactory in surfacing materials. Gravels used in bituminous concrete mixes perform more satisfactorily if they are crushed.

It is desirable to make maximum use of earth materials located nearest the site of construction. To study the suitability of gravelly soils (bank gravels) for cement-stabilization, a group of six gravels from the Purchase region were sampled and tested in the laboratory during 1961 and 1962. The locations of the sample sites are indicated in Figure 1.

Samples 4 and 6 (See Figures 7 and 8) were obtained from the Tuscaloosa Formation. The Tuscaloosa consists of a cherty gravel in a matrix of quartz sand and some clay. The average size of the gravel particles is about 1 or 2 inches in diameter, but range as high as 10 inches. The gravel particles show the effect of rounding by water, the particles varying from oval to almost spherical. The color of the Tuscaloosa gravel is a light gray.

Samples 1, 2, 3, and 5 (See Figure 9) were obtained from the Lafayette gravels. The Lafayette is apparently derived from Mississippian cherts and represents terraces of the Continential Deposits, which mantles much of the Purchase area. The Lafayette is a cherty gravel averaging 1/2 to 1 inches in diameter in a quartz sand matrix containing very small quantities of clay. The particles are commonly coated with iron oxide, enough in some instances to cement them into a congolomerate, causing the gravel to exhibit a reddish-brown color. The gravel particles of this material generally show less rounding than those of the Tuscallosa gravels. The Lafayette gravels at sites 1, 2, and 3 are overlain by a loess mantle between 10 and 25 feet thick.

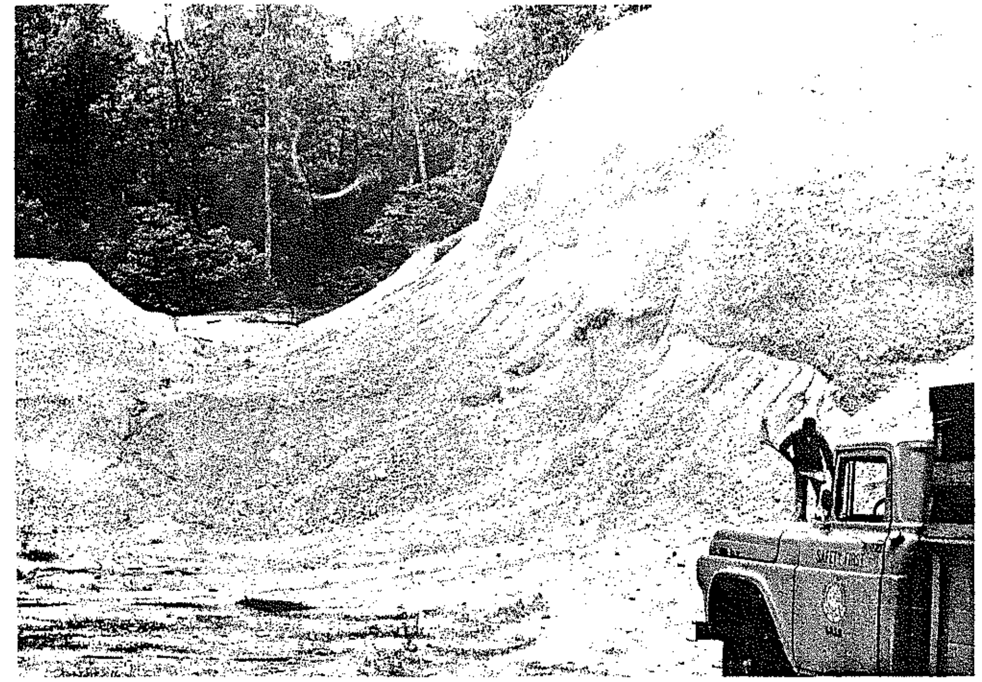


Figure 7. Gravel Pit at Sampling Site 4.

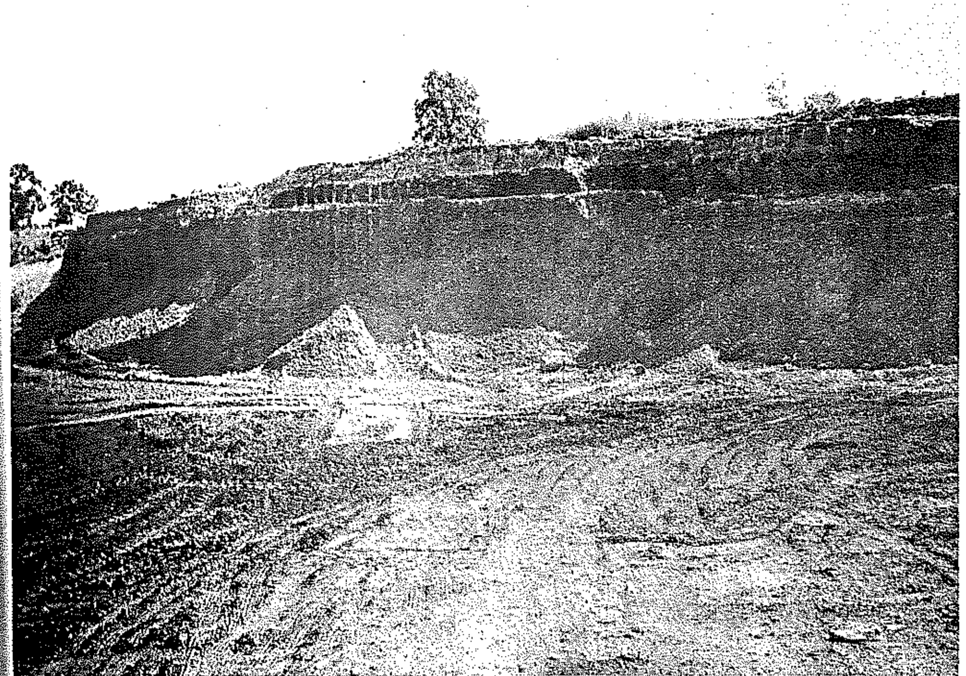


Figure 8. Gravel Pit at Sampling Site 6.

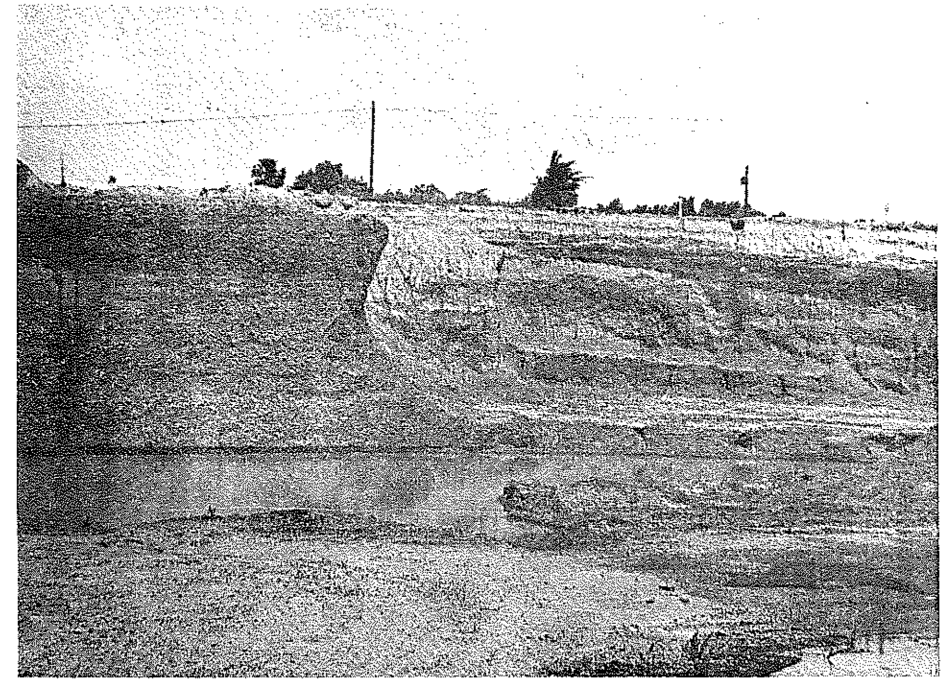


Figure 9. Gravel Pit at Sampling Site 5.

Gain size distribution curves are shown in Figure 10. A mineralogical analysis of the various fractions of selected gravels is given in Tables 1 and 2. Other important laboratory test data that is of significance to soil-cement design is presented in Table 3.

Cylindrical specimens six inches in diameter by seven inches high were prepared at various cement contents. These specimens, three for each cement content and each curing time, were cured for 7, 14, or 28 days in a sealed container. The specimens were then tested in unconfined compression. The results shown in Figure 11 indicate that significant increases in strength do occur, even at the lower cement contents. Photographs of specimens before and after testing are shown in Figure 12.

Laboratory test data for other samples of gravel from the Purchase region is listed in Table 4.

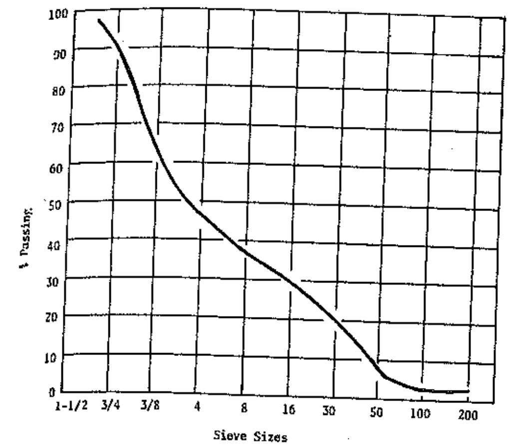
Recommendations: It is suggested that appropriate consideration be given to the use of the Purchase area gravels in soil-cement base stabilization. It is further recommended that, if gravels are used in portland cement concrete or bituminous concrete surfaces, selective measures be taken to insure that leached, porous chert does not make its way into these materials. In addition, gravels which are used in bituminous concrete should be crushed.

Table 1. Mineralogy of the Calloway County Gravel (Lafayette Formation)

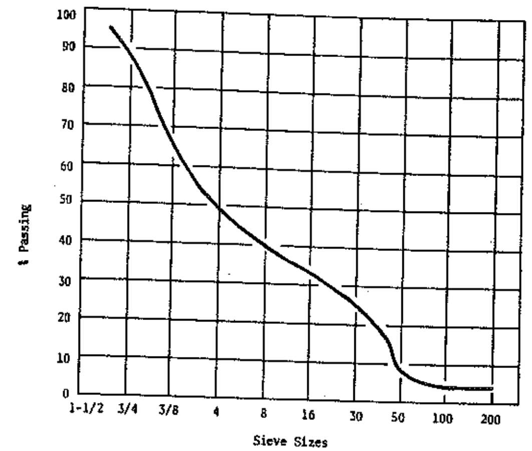
Sieve Size		Constituents (percent)				
Passing	Retained	Chert	Limonite	Quartz	Muscovite	Coal
1-1/2"	1"	100				
1"	3/4"	100				
3/4"	3/8"	97		3		
3/8"	No. 4	94		4		
No. 4	No. 10	85		10		
No. 10	No. 20	42		55		
No. 20	No. 40	7		92		
No. 40	No. 60		1	99		
No. 60	No. 140		39	60	1	Trace
No. 140	No. 200		48	51	1	Trace

Table 2. Mineralogy of the Marshall County Gravel (Tuscaloosa Gravel)

Sieve Size		Constituents (percent)				
Passing	Retained	Chert	Quartzite	Quartz	Muscovite	Coal
1-1/2"	1"	100				
1"	3/4"	100				
3/4"	3/8"	93	2	5		
3/8"	No. 4	68	17	15		
No. 4	No. 10	64	25	11		
No. 10	No. 20	36	14	48	2	
No. 20	No. 40	1		97	2	
No. 40	No. 60			98	2	
No. 60	No. 140			95	5	Trace
No. 140	No. 200			89	11	Trace



Sample No. 1



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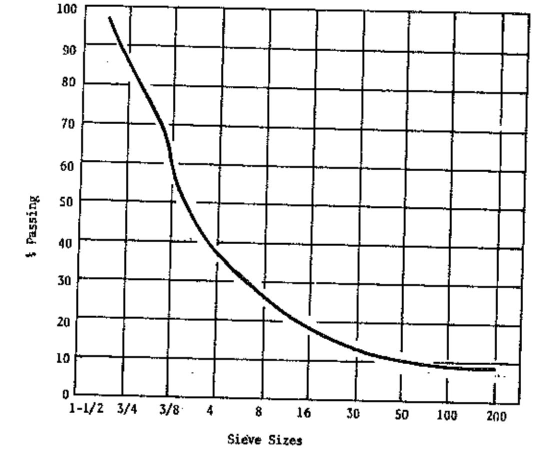

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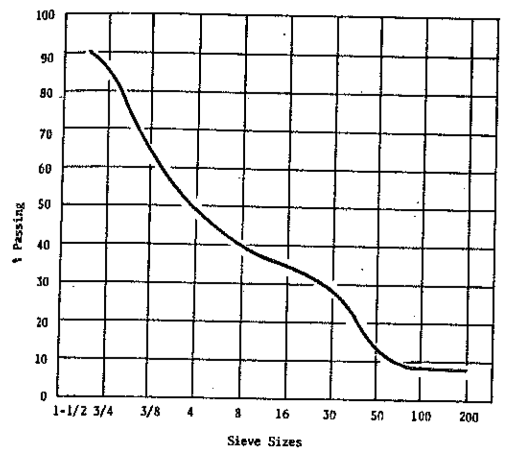
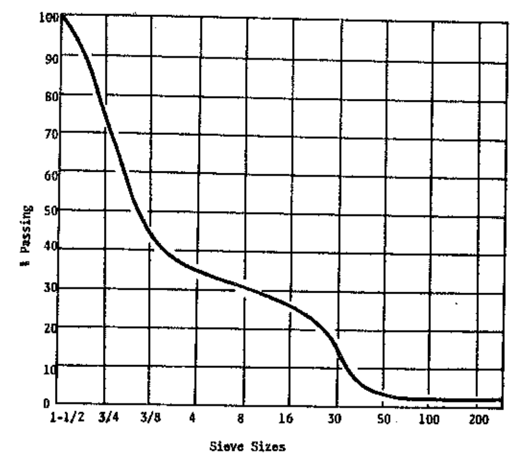
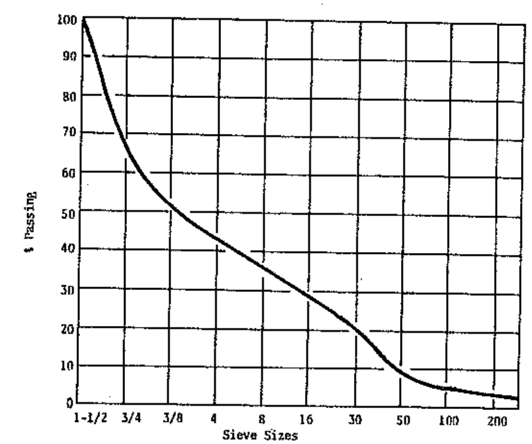


Sample No. 3



Sample No. 5



Sample No. 6

Lafayette Gravels

Tuscaloosa Gravels

Figure 10. Grain Size Distribution Curves.

Table 3. Summary of Laboratory Test Data

Laboratory Test	Graves County Sample 1	Carlisle County Sample 2	Ballard County Sample 3	Trigg County Sample 4	Calloway County Sample 5	Marshall County Sample 6
Plus No. 4 Material[2]						
Apparent Specific Gravity	2.65	2.61	2.60	2.54	2.44	2.52
Saturated Surface Dry Specific Gravity	2.47	2.45	2.40	2.26	2.27	2.35
Bulk Specific Gravity	2.36	2.35	2.28	2.08	2.16	2.23
Percentage Water Absorption	4.6	4.3	5.3	8.7	5.4	5.1
Minus No. 4 Material[3]						
Apparent Specific Gravity	2.68	2.67	2.69	2.64	2.59	2.64
Saturated Surface Dry Specific Gravity	2.60	2.58	2.53	2.39	2.54	2.53
Bulk Specific Gravity	2.56	2.53	2.43	2.24	2.51	2.46
Percentage Water Absorption	1.8	2.1	3.9	6.8	1.4	2.7
Combined Specific Gravity						
Apparent Specific Gravity	2.66	2.64	2.64	2.58	2.49	2.58
Saturated Surface Dry Specific Gravity	2.53	2.51	2.46	2.31	2.34	2.42
Specific Gravity, Minus No. 10 Material[4]					2.65	2.66
Specific Gravity, Minus No. 200 Material[4]	2.90[1]	2.77	2.76	2.63		
Liquid Limit[5]					20	NL
Plastic Limit[6]					20	NP
Plasticity Index[6]					0	NP
Shrinkage Limit[7]					20	22
Shrinkage Ratio[7]					1.68	1.65
Maximun Dry Density (Lbs/cuft)[8]	122	121	120	98	122	127
Optinum Moisture Content (%)	6.3	10.0	10.7	5.5	10.4	8.4

1 Samples contained a large amount of iron oxide
2 ASTM C 127-42
3 ASTM C 128-42
4 ASTM D 854-52
5 ASTM D 423-61 T
6 ASTM D 424-59
7 ASTM D 427-61
8 ASTM D 698-58 T, Method C

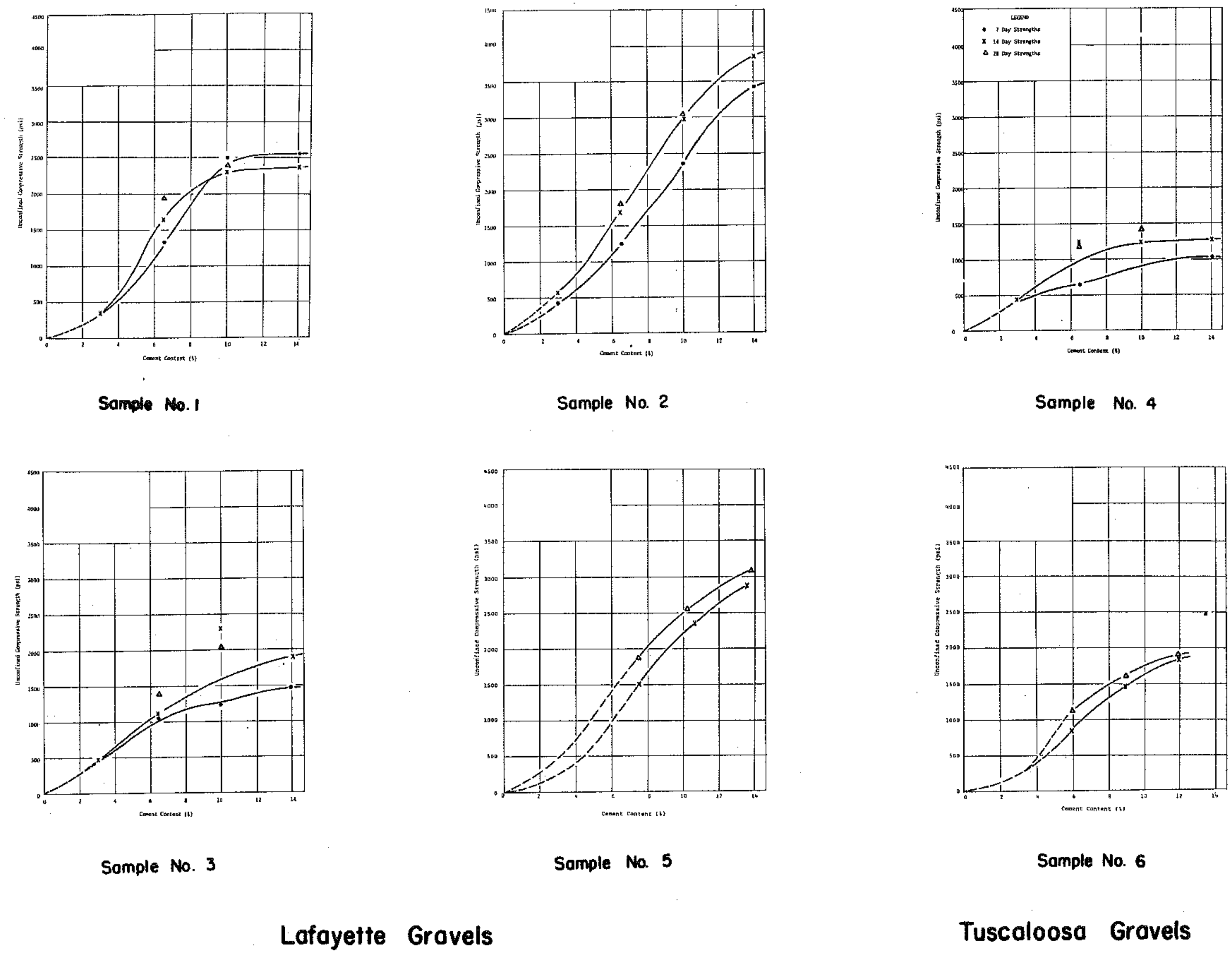


Figure 11. Variation of Unconfined Compressive Strength with Cement Content.

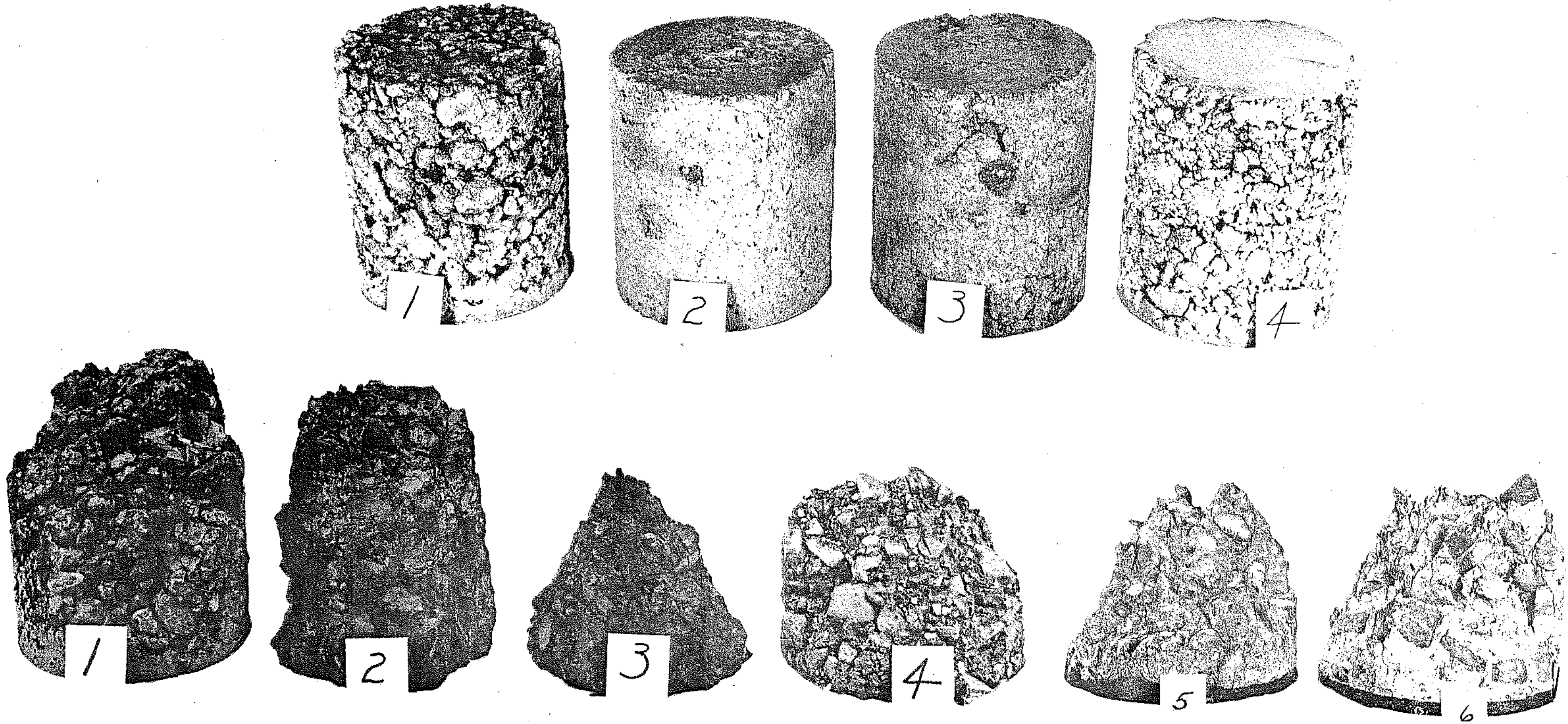


Figure 12. Photograph of Specimens Before and After Compressive Testing.

Table 4. Bank Gravel Test Results (Division of Materials, 1953)

Pit Description	LL	PI	Field Moist. Equiv.	SL	SR	SG	Compaction* Max.Den. (lbs/cuft)	Compaction* OPT.M.C. (%)	CBR*	Wear*	Soundness*	Gradation - Percent Finer 1 1/2"	1"	3/4"	3/8"	No.4	No.10	No.40	No.200	.005mm	.002mm	.001mm
Graves Co., 7 miles south of Mayfield on Mayfield-Farmington Road, Ky 121	22	12	14	25	1.62	2.70	142	3.5	154	27.5	10.2	100	93	76	43	30	24	14	5	4	4	3
	NP	NP	NP	22	1.70	2.70						98	87	77	56	36	25	17	9	4	2	2
Graves Co.,2 miles north of Water Valley on US 45	20	13	15	28	1.55	2.72	135	6.0	37	19.7	3.2	100	98	92	69	54	48	25	9	6	5	4
	25	14	15	30	1.50	2.71						100	99	93	71	52	41	24	10	7	6	6
Livingston Co., 1/2 mile south of US 62 on Ky 917	31	17	20	30	1.49	2.67	150	4.3	139	22.5	1.4	93	83	71	50	38	30	26	12	9		6
	23	10	17	22	1.67	2.64						93	80	67	43	28	20	10	6	3		2
Livingston Co., 1/4 mile west of Ky 917, 2.2 miles south of US 62.	39	22	21	23	1.67	2.68	132	5.9	94	17.5	0.6	92	79	66	45	32	22	15	11	8		4
	44	26	27	30	1.47	2.62						91	79	72	53	37	27	19	15	12		6
Livingston Co., 1/2 mile east of Kentucky Dam on US 62.	35	20	21	25	1.62	2.69	138	3.8	126	18.6	4.0	87	77	67	46	33	25	22	18	14		9
	24	9	18	24	1.62	2.68						89	76	65	40	20	11	9	6	2		1
Calloway Co., 1 1/2 miles east of Elm Grove Church on Ky 94	24	11	17	26	1.58	2.68	140	3.9	103	21.5	3.6	97	88	78	55	37	29	11	6	5		4
	25	11	18	24	1.62	2.68						100	92	79	47	31	24	15	7	5		3
Calloway Co.,south of Ky 732 4 miles east of Ky 94	29	16	17	32	1.46	2.73	137	7.7	65	21.1	1.4	97	81	70	55	43	34	14	7	6		4
	NP	NP	NP	24	1.64	2.69						97	82	71	57	45	34	11	4	3		1
Calloway Co., north of Ky 121 1 mile south of Murray	20	12	16	28	1.55	2.73	140	3.8	135	17.7	0.9	97	88	74	46	32	27	15	6	4		3
	23	10	16	25	1.61	2.70						98	90	79	52	35	26	14	5	3		2
Calloway Co.,3/4 mile north of Fire Points	NP	NP	NP	26	1.59	2.68	138	4.2	90	20.6	2.5	91	77	62	44	35	28	13	5	4		3
	29	13	18	32	1.44	2.70						99	91	80	55	41	31	13	8	6		4
Ballard Co., 2 miles south of Kevil on Kevil-Gage Road, Ky 473	NP	NP	NP	28	1.53	2.68	139	4.7	57	19.8	0.9	100	94	84	61	45	40	23	10	5	4	3
	27	18	13	29	1.51	2.67						100	95	85	61	42	31	15	6	5	4	3
Ballard Co., 5 miles east of Wickliffe on Wickliffe-Mayfield Road, Ky 440	32	20	18	30	1.51	2.76	137	5.1	31	16.2	0.4	100	98	92	60	40	30	10	5	4	3	3
	31	19	17	29	1.51	2.71						100	96	89	65	46	34	11	5	4	3	3
	NP	NP	NP	25	1.50	2.66						100	96	89	65	52	44	14	5	4	3	2
Ballard Co., 4 miles south of New York Store on Old Blandville Road	26	16	15	30	1.49	2.67	136	5.7	37	22.1	0.5	99	95	88	63	50	43	18	8	6	5	5
	26	17	15	27	1.55	2.67						99	96	88	64	51	44	19	8	5	5	4
Hickman Co., 1/4 mile south of Ky 58 1 mile east of Fulgham on the Clinton-Mayfield Road, Ky 58	17	8	13	21	1.71	2.68	139	4.8	35	21.1	3.6	99	98	87	55	41	34	23	9	4	2	2
	NP	NP	NP	25	1.62	2.69						100	100	98	74	49	35	19	3	3	2	2
Carlisle Co., 1 mile north of US 62 3 miles west of Lovelaceville	NP	NP	NP	27	1.56	2.68	134	5.5	38	20.5	0.1	100	98	93	67	46	36	11	3	3	3	2
	NP	NP	NP	27	1.55	2.68						100	99	96	76	53	38	13	4	3	3	2
Carlisle Co.	NP	NP	NP	22	1.68	2.66	135	6.0	29	19.9	0.7	97	88	78	53	39	33	11	2	1	1	1
	NP	NP	NP	31	1.46	2.67						93	85	75	56	44	37	15	5	2	2	2
Fulton Co., 5.2 miles north of Fulton on US 51	NP	NP	NP	26	1.58	2.67	139	4.9	55	22.7	2.4	100	100	99	86	58	42	26	10	4	4	3
	35	21	17	23	1.68	2.72						100	100	99	80	47	34	23	15	9	8	7
McCracken Co., 1/4 mile north of US 62 on McKendree Church Road, Ky 726	NP	NP	NP	26	1.58	2.68	138	4.9	55	17.4	0.7	100	98	88	59	43	34	17	6	3	2	2
	38	25	17	32	1.45	2.70						100	98	90	60	44	36	16	8	5	5	4
McCracken Co.,Bethel Church Road near US Atomic Plant	35	22	18	30	1.51	2.72	138	5.7	69	18.5	0.6	100	93	78	53	40	33	19	10	8	7	5
	NP	NP	NP	29	1.51	2.70						100	99	94	75	57	46	39	11	7	6	5
	31	19	16	30	1.51	2.72						100	97	90	66	44	29	20	8	6	5	5
	32	20	16	30	1.49	2.71						98	98	89	66	44	31	20	10	7	6	5
McCracken Co., 1/4 mile south of Lone Oak Road on Mayfield Cutoff	NP	NP	NP	23	1.68	2.70	141	4.1	74	20.1	3.7	100	97	89	52	33	23	13	5	2	1	1
	NP	NP	NP	28	1.55	2.70						99	93	84	63	49	40	20	7	4	3	3
	NP	NP	NP	27	1.57	2.71						100	98	78	49	38	33	14	4	3	2	2
	19	10	12	18	1.80	2.69						100	100	91	51	31	23	14	7	3	2	1
Graves Co., 1 mile north of Pryorsburg on US 45	NP	NP	NP	28	1.55	2.70	131	6.6	60	24.6	6.3	100	99	94	75	58	47	24	7	5	4	3
Graves Co., 2 miles south of Symsonia on Wadesboro Road	32	19	18	31	1.48	2.72	137	4.9	135	22.5	5.1	99	94	84	53	42	28	11	7	6	5	5
Graves Co., 1/2 mile west of Hollifield Store on Mayfield-Clinton Road, Ky 58	36	22	19	31	1.50	2.80	140	4.6	75	19.9	0.9	100	96	87	55	37	27	11	7	6	4	4
	19	10	13	28	1.57	2.80						100	99	95	71	47	34	15	6	4	3	3
Graves Co., 1 mile west on county road 3 miles north of Mayfield on US 45	NP	NP	NP	26	1.60	2.71	136	5.1	63	19.9	0.6	100	97	87	58	44	37	20	4	3	2	2
	NP	NP	NP	26	1.60	2.71						100	97	86	60	44	36	16	6	4	3	2
Graves Co., 1 mile west of US 45 4 1/2 miles north of Mayfield	23	13	15	27	1.55	2.69	140	4.2	72	20.4	1.2	99	98	94	66	46	34	13	5	5	4	4
	33	19	19	34	1.42	2.77						100	94	80	53	38	27	11	5	5	4	3
Hickman Co., 1 mile east of Crawley on Ky 58	22	14	13	27	1.56	2.70	137	5.4	34	22.2	2.9	100	98	91	66	50	41	18	6	5	4	3
	NP	NP	NP	25	1.62	2.69						100	99	94	64	46	35	18	4	3	2	2
Hickman Co., 4 1/2 miles south of Fulgham on Fulgham-Fulton Road, Ky 307	30	19	17	30	1.51	2.74	137	5.2	52	24.6	4.1	100	100	98	79	57	45	12	6	4	4	3
	35	21	19	24	1.65	2.76						100	100	98	80	55	39	13	8	6	5	4
Lyon Co., 2 1/2 miles east of Eddyville on US 62	23	11	16	22	1.68	2.67	133	6.2	114	20.1	3.1	94	82	76	60	45	33	28	19	8		5
Lyon Co., 2 miles south of US 62 on Mount Zion Church Rd.	22	13	14	27	1.55	2.68	137	4.8	103	18.2	2.9	100	97	90	65	45	36	13	6	5		4
	27	14	18	32	1.44	2.69						97	89	77	50	36	28	21	8	6		4
McCracken Co., 1 mile north of Maxium on Maxium-Mill Rd.	44	29	20	26	1.36	2.68				20.1	4.4	96	88	77	53	32	19	11	5	4	4	3
Carlisle Co., 2 miles south of US 62 on Cunningham-Milburn Road	NP	NP	NP	27	1.58	2.72	137	4.7	96	19.1	0.5	100	97	90	63	45	35	15	6	3	2	2
Marshall Co., 1 mile north of Symsonia-Benton Road, Ky 348, 2 miles east of Graves Co. line	26	14	17	31	1.47	2.70	138	4.4	103	19.8	1.4	96	88	72	52	45	41	13	7	5		3
	19	9	14	27	1.56	2.69						99	86	62	34	27	23	6	4	2		1
Marshall Co., 3 miles east of Graves Co. line on Symsonia-Benton Road, Ky 348	35	20	20	33	1.42	2.69	138	4.6	130	22.1	3.7	96	82	69	50	38	31	14	8	6		5
	24	13	16	30	1.49	2.72						92	75	63	45	37	33	12	6	4		3
Marshall Co., 2.3 miles west of Benton on Benton-Oak Level Road, Ky 408	41	24	22	35	1.39	2.70	132	7.0	77	20.0	2.5	100	96	87	67	51	43	23	12	7		6
	39	23	20	35	1.39	2.72						99	91	80	59	48	40	22	14	7		5
Marshall Co., 1/2 mile south of Benton-Oak Level Road at Hauser's Store	NP	NP	NP	27	1.55	2.68	136	6.2	71	21.1	2.9	97	85	72	51	41	36	18	5	3		2
	NP	NP	NP	26	1.57	2.67						97	80	63	43	36	31	17	3	2		2
Marshall Co., Slickback Road north of Ky 80	23	11	18	29	1.51	2.70	136	5.0	69	24.7	1.5	95	88	77	56	42	37	12	5	3		2
	25	13	17	26	1.59	2.72						100	91	74	49	38	34	15	7	4		3
Marshall Co., at the Graves Co. line on the Tom Lane Rd.	NP	NP	NP	27	1.56	2.67	135	5.1	79	21.7	3.2	99	92	84	64	49	41	14	4	2		2
	30	18	17	32	1.45	2.69						94	86	75	55	40	30	9	5	4		3
Marshall Co., 1/2 mile south of Briensburg	NP	NP	NP	26	1.59	2.70	133	6.1	112	22.0	3.8	95	84	74	55	40	29	19	10	5		4
	21	8	14	23	1.66	2.69						97	92	80	54	38	31	13	8	3		2
	NP	NP	NP	26	1.58	2.69						100	98	93	77	65	57	28	9	4		3

* Composite Sample

OTHER CONSIDERATIONS

The Jackson Purchase area has had a long history of seismic activity. The New Madrid Earthquake of 1811-1812, centered about 50 miles southwest of Paducah, is the only major earthquake of recent times. Even though the occurence of earthquakes has been relatively frequent, destructive ones have been infrequent. On the basis of the history of other seismically active areas, it is reasonable to assume that more major quakes will occur in the future.

In the area to the south and west of Paducah, many large boulders have been observed. These range in size from two to three feet across to as large as automobiles (See Figure 13). The presence of these boulders might lead to a misinterpretation of subsurface data and care should be taken not to assume the rock line at too high elevations.

Because of the extremely thick deposits of unconsolidated materials in the Purchase area, point bearing piles cannot be expected to control settlements and to provide load-carrying capabilities for structures. Except where piles can be driven into dense layers of granular deposits, friction piles, if needed, must be relied upon to provide the load-bearing capabilities for engineering structures.

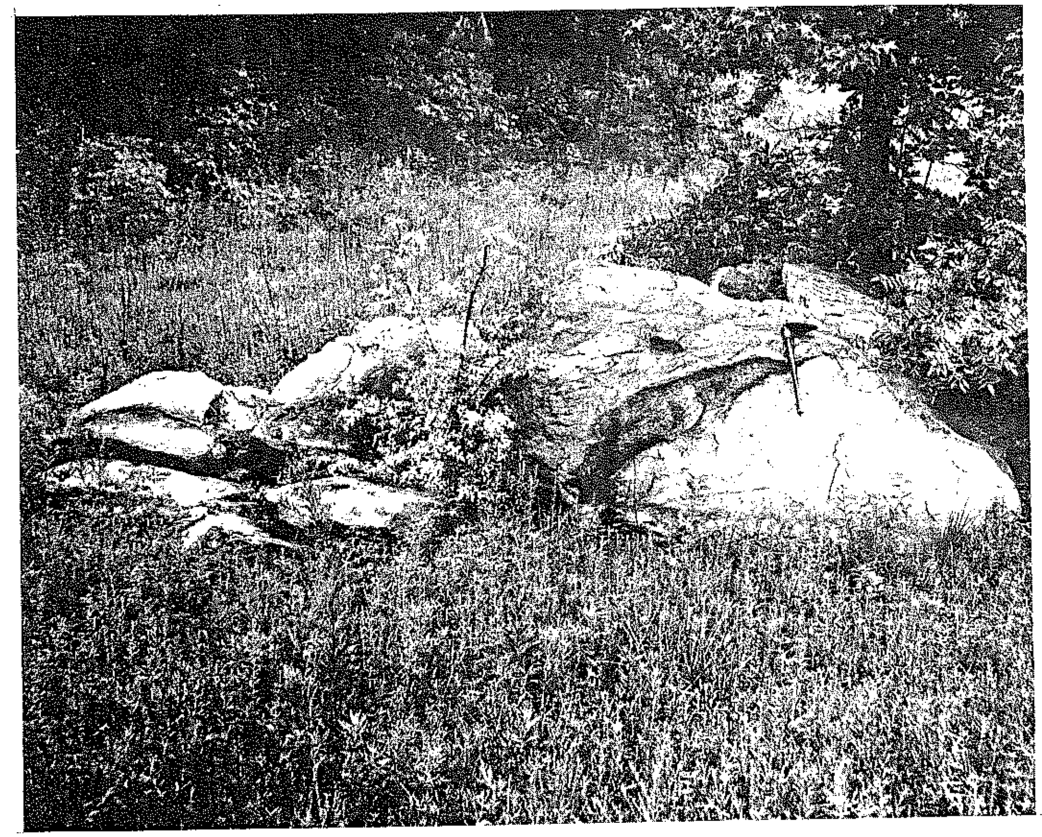


Figure 13. Large Boulders Found in the Paducah Area. This Boulder Has Been Fragmented by Blasting.

CONSIDERATIONS AND RECOMMENDATIONS CONCERNING PAVEMENT DESIGN

The following discussions are specifically directed to the Purchase Parkway route but may be similarly applicable to the I 24 route in the Purchase area.

Pavement design involves considerations of estimated traffic, availability of aggregates and cements, and structural sufficiency. It is recommended that the pavement be designed to carry Kentucky Class VIII traffic (60 million equivalent 5000-pound wheel loads, 20 years). This class of traffic exceeds the preliminary projections for the Parkway but should, judiciously, be considered the median, feasible estimate for pavement design on parkways and most of the primary roads. Surface and structural components of the pavement system are essential factors in determining the adequacy of design. However, economic doctrines should be considered in the selection of types of materials to be employed -- that is to say, aggregates comprise the bulk of paving materials, and local or indigenous resources are inherently exempted from engrossing importation costs. If local aggregates in the Purchase area were equally suitable for high-type portland cement concrete and bituminous concrete paving, typical designs might be employed; however, local gravels, which occur so abundantly along the Parkway route, are not suitable for conventional portland cement concrete paving -- as experience records have shown. These gravels are predominately chert and vary in other qualities from place to place. The upper leached zones are extremely porous; and, although the lower zones are impregnated with iron oxides and are more suitable, precise sorting and control would constitute an overwhelming impost. These refined qualities are not essential in base construction inasmuch as base layers are insulated from the weather. Moreover, inasmuch as the majority of roads in the area are founded on relatively deep gravel bases which are not notably stable and exhibit tendencies to rut when subjected to heavy traffic, stabilized gravel bases merit consideration. Rounded gravels are not as amenable to bituminous stabilization as they are to treatment with portland cement.

The degree of enhancement sought through cement stabilization is optional and ranges upward to conventional concrete base construction. A rule-of-thumb is to consider the mildest degree of stabilization as that which would upgrade the gravel to equal a crushed rock (DGA) base. Further enrichment incurs shrinkage and attendant cracking which tends to reflect through the bituminous layers above. This is an overshadowing detriment unless due safeguards can be contrived. One approach is to interpose a layer of crushed rock between the rigid base and the bituminous layers; another is to merely sand or dust the interface so that the layers will not be bonded together -- i.e. each layer being free to expand or contract independently of the other. Warping and curling of the base (due to temperature and moisture gradients) diminishes with depth of burial. Shrinkage is minimized by compacting the cement-gravel mixture at the optimum moisture content. In order to achieve maximum utilization of local uncrushed gravels, it is recommended that they be relegated to the lower base courses.

A reconciling analysis based on various structural design criteria is offered below.

<u>Kentucky Department of Highways</u> (cf. <u>Bullentin No. 52</u>, Engineering Experiment Station, University of K[illegible] June, 1959)

1. Assumptions: Minimum CBR of subgrade, 5
Traffic, Class VIII.

Design: 20.5 inches total thickness,
5.5 inches bituminous concrete,
15 inches DGA.

2. Assumptions: Minimum CBR of subgrade, 7
Traffic, Class VIII.

Design: 18.5 inches total thickness,
5.5 inches bituminous concrete,
13 inches DGA.

Note: Higher CBR's, if encountered, should not be fully credited because of rutting tendencies.

<u>AASHO Interim Guide</u> (Chart 400-2)

1. Assumptions: Soil Support Value, 3.0
Traffic, 272 18-kip axles per day.

Design: $\overline{SN}$ (Structural Number) = 4.6

$SN = .44\ T_s + .14\ T_b$

$T = T_s + T_b$

T = total thickness in inches

T_s = thickness in inches of bituminous concrete

T_b = thickness in inches of DGA-type base

Structural Coefficient, bituminous concrete = .44

Structural Coefficient, DGA = .14

$\underline{T_s} = T - T_b$

$SN = .44\ T - .44\ T_b + .14\ T_b$

T = 20.5 inches (cf. Example 1, Kentucky Criterion)

Solution:

$$4.60 = .44 \times 20.5 - .44\ T_b + 14\ T_b$$

T_b = 14.7 inches

T_s = 5.8 inches

2. Assumptions: Soil Support Value, 3.0
Traffic, 272 18-kip axle per day.

Structural Coefficients:

Unimproved Gravel -- .07
Cement-treated Gravel (less than 400 psi) -- .15
Cement-Gravel (more than 600 psi) -- .23
Bituminous Concrete -- .44

Design: $\overline{SN}$ = 4.60

Solution: 1) 7 inches butiminous x .44 = 3.08
4.60 - 3.08 = 1.52 (base contribution)

Base Options
(1.52 ÷ .07 = 21.8 inches, unimproved gravel
(1.52 ÷ .15 = 10.1 inches, treated gravel
(1.52 ÷ .23 = 6.7 inches, cement-gravel)

2) 6 inches bituminous concrete x .44 = 2.63

4.60 - 2.63 = 1.97 (base contribution)

Base Options	(1.97 ÷ .15 = 13.1 inches, treated gravel
	(1.97 ÷ .23 = 8.6 inches, cement-gravel

3) 5.5 inches bituminous x .44 = 2.52

4.60 - 2.52 = 2.08 (base contribution)

2.08 ÷ .15 = 13.9 inches, treated gravel

Note: Unimproved gravel was omitted from Solutions 2 and 3, and cement-gravel base was omitted from Solution 3. Only cement-treated gravel in Solutions 2 and 3 is reconcilable with conventional template thicknesses. A template thickness of less than 18 inches is not recommended. The optimum solution appears to be the third one -- i.e., 14 inches of treated gravel and 5.5 inches of bituminous concrete, giving a total thickness of 19.5 inches.

The optimum solution afforded by the AASHO Criterion reflects a strong kinship between the Kentucky criterion and the AASHO structural numbers and structural coefficients. The basic assumption, of course, is that cement-treated gravel (Structural Coefficient = .15) is at least equal to DGA base (Structural Coefficient = .14).

An estimate of the maximum costs of the cement-treated base design is offered below:

* Sand-Asphalt	1"	at .55 per sq. yd. per in.	$ .55
Tack		at .02 per sq. yd.	.02
Bituminous Concrete	5.5"	at .48 per sq. yd. per in.	2.14
Curing Prime Coat and Sand		at .07 per sq. yd.	.07
Cement-Treated Gravel Base	14"	at .11 per sq. yd. per in.	1.54
Total	20.5"		$4.82

* Recommended as a skid-resistant wearing surface not considered to be a structural component.

Note: It is estimated that DGA base would cost in excess of $.25 per sq. yd. per inch of thickness in the Purchase area, hence 15 inches would be $3.75 per square yard.

The suggested design does not require a selected subbase layer nor an especially high-quality subgrade material. It is anticipated that practically all of the materials encountered, except clays, will be suitable for subgrade service.

Gravels are somewhat less favorably located along the southwestern portion of the route; however, haul distances are not expected to exceed 6 miles.

It is further suggested that the treated-gravel base mixture be processed in central mixing-plants and that the construction methods be nominally similar to those required for Dense-Graded Aggregate Base (Section 208, Standard Specifications ...). A proposed draft of special provisions for the cement-treated gravel base (cf. Section 207, Bank Gravel Base; Standard Specifications ...) is included herewith. The suggested proportion of the portland cement admixture is 2.5± 0.5 percent by weight of gravel (dry basis). The compacted dry unit weight of the blend has been estimated to be nominally 125 pounds per cubic foot, and the optimum moisture has been estimated to be 13 percent by weight of dry materials -- i.e., 142.5 pounds per cubic foot, gross (based on AASHO T-99 compaction). The proposed provisions require the base to be constructed to not less than 95 percent of T-99 density. The base should be spread and compacted in two equal courses (lifts); the upper course should not lag behind the first course by more than a few hours. The finished base course should be primed (SS-1h, 0.2 gallon per square yard) before the onset of drying and then sanded immediately (10 pounds per square yard). All non-essential traffic should be prohibited from traveling on the base during the curing period (approximately two weeks). No additional prime should be required in preparation for the first course of bituminous concrete base. Bituminous base courses should be constructed in accordance with current standards. The sand-asphalt surface sourse should be constructed in accordance with the Department's current specification; a tack coat is recommended (SS-1h, diluted half and half, applied at 0.15 gallon per square yard).

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

PROPOSED

SPECIAL PROVISIONS
FOR
CEMENT-STABILIZED BANK-GRAVEL BASE COURSES

These requirements shall be applicable only when indicated on the plans or in the proposal and, when so indicated, shall supersede any conflicting provisions of the Department's Standard Specifications....

I. DESCRIPTION

Cement-stabilized bank-gravel bases shall be constructed upon a prepared subgrade and to the lines, grades, and thicknesses specified or directed -- all in accordance with the provisions set out hereinafter.

II. MATERIALS

A. Bank Gravel. The bank gravel, in its natural deposit, shall consist of coarse aggregate, fine aggregate, and soil fines. The soil fines shall be that portion passing the No. 40 sieve, and shall be nominally free of materials detrimental to its binding qualities.

1. Approval of Source. Prior approval of each source shall be obtained from the Division of Materials before construction operations are begun. The request for approval of the source shall be submitted at least two weeks in advance of operations.

2. Properties. When tested in the laboratory, the bank gravel shall meet the following requirements:

Soundness (5 alternations, max. pct. weighted loss) 15
Wear (L. A. Abrasion, max. pct. loss by weight) 35
Clay, max. pct. (particle size less than .005 mm) 10
Clay plus P. I., max....................................25

The P.I. shall be determined as described in the Division of Materials Soil Manual on material passing the No. 40 sieve.

Gradation:

Sieve Size	Per Cent Passing
2- inch	100
3/4-inch	60-100
No. 4	25-65
No. 40	10-30
No. 100	5-20

3. Sampling and Testing. Two samples per week shall be submitted to the District Materials Engineer for gradation tests. These two samples should represent the materials being used for the base course. Field tests for gradation shall be made and reported two times for each full day of operation or oftener, as deemed necessary by the Engineer to insure control. Sampling and Testing shall be done in accordance with the applicable standards adopted by the Department.

4. Handling and Processing. The approved source shall be completely stripped of all overburden to a sufficient distance from the face of the pit to insure that none of the overburden material will become mixed with the bank gravel. Pockets of unacceptable material, if encountered, shall be removed and wasted before proceeding further with production.

In the event the bank gravel does not comply with the gradation requirements, due to an excess or a dificiency in one or more fractions, then the gravel may be processed by screening, crushing, or by adding approved materials, or both, in a manner satisfactory to the Engineer, so that the processed material will comply with all of the requirements set out herein. No additional compensation will be allowed for any necessary processing of the material. Such work shall be incidental to the unit price bid.

B. Portland Cement. Cement shall satisfy the requirements of Section 601 of the Standards for Type I.

C. Water. Water shall be furnished from a source approved by the Engineer and shall comply with the requirements of Section 603 of the Standards.

III. CONSTRUCTION METHODS

A. Subgrades. Subgrades shall be prepared in accordance with Section 208.3.1 of the 1965 Standard Specifications.

B. Shoulders. Shoulders shall be constructed in accordance with the applicable requirements of Section 109 of the Standards.

C. Base.

1. Proportioning and Mixing. The bank gravel, portland cement and water shall be metered together and uniformly regulated so as to yield a mixture containing the specified proportions. The cement shall be proportioned to yield 2.5 ± 0.5 percent by weight of bank gravel (dry basis). Water shall be proportioned to yield the optimum water content for compaction to maximum density.

The mixer shall be a twin-shaft pugmill or other mixing plant approved by the Engineer. The water-feed system shall be equipped with a flow meter and a regulator. The rate of input shall be adjusted by the Engineer to compensate for indigenous moisture in the gravel supply.

2. Transporting. Cargo boxes of the transport vehicles shall be covered with heavy canvas in order to minimize loss of moisture from the mixture while enroute.

3. Placing, Spreading and Shaping. The mixture shall be placed, spread to a preset, stringlined grade and shaped without causing segregation; powered equipment shall be operated so as to produce the desired compacted depth, grade, and cross-section shown on the plans or in the proposal.

4. Compaction. Each course of the base shall be compacted to not less than 95 percent of maximum density as determined by AASHO T-99. One density test shall be made at each interval

of 1000 feet; additional test may be required. The in-place density shall be determined by the rubber-baloon method, ASTM D 2167.

The compacting equipment shall be subject to the approval of the Engineer and shall be capable of effecting the specified density throughout the depth of the course. The compacted layer-depth shall not exceed 7 inches nominally. Wetting of a course to aid compaction shall not be permitted without re-mixing as directed by the Engineer. Reshaping or other disturbance shall not be allowed after 4 hours have elapsed or after application of asphalt prime coat. Hand tampers may be required at areas inaccessible to larger equipment.

5. Surface Tolerances. The surface of the finished base shall not deviate more than 1/2 inch from the crown template nor more than 3/8 inch in 10 feet when measured longitudinally. Intolerable deviations shall be corrected by the Contractor without additional compensation; such work shall consist of leveling with Class I, Type A, Bituminous Concrete Surface mixture (Section 606 of the Standards) following curing of the base.

6. Application of Prime Coat and Sand. The compacted base shall be primed with not less than 0.20 gallons of SS-1h, asphaltic emulsion per square yard (Section 621.6.0 of the Standards) before the onset of drying and within the day of placement. The prime coat shall be applied in accordance with Section 301 of the Standards, shall be spread immediately thereafter; and the spreader shall conform to Section 302.3.2, E, thereof. The sand shall be applied at a rate of not less than 10 pounds per square yard.

All non-essential traffic shall be prohibited from traveling over the completed base for at least 14 days following placement. Any damage arising from the Contractor's use of the finished base thereafter shall be repaired at his expense prior to paving.

IV. METHODS OF MEASUREMENT

The preparation of the subgrade shall not be measured for payment if the construction of the grade is part of the contract.

Reshaping and Compacting, when included as a contract bid item, shall be measured horizontally along the centerline of the roadway in units of 100-foot stations to the nearest 0.1 station, exclusive of bridges, ramps, and road approaches. When the project is a multiple-lane, divided highway, the measurement shall be made along the centerline of each roadway. When Reshaping and Compacting is done in accordance with Extra Compaction, the entire length of the main line subgrade shall be measured for payment. When Reshaping and Compacting is done in accordance with Standard Compaction, the measurement shall be made only for the portion, or portions, of the project on which the work is actually done.

Water used at the direction of the Engineer for maintaining optimum moisture for subgrade compaction shall be measured by weight or volume and converted to the nearest 1000 gallons. Water used in the mixing of the base shall not be measured for payment.

The plant-mixed base materials shall be measured in tons in accordance with Section 1.9.1-F.

The portland cement admixture shall be measured in barrels (376 pounds per barrel) in accordance with Section 1.9.1-F of the Standards.

The actual quantity of bituminous material applied shall be measured according to Section 621 of the Standards.

Sand aggregate shall be measured in tons in accordance with Section 1.9.1 of the Standards. All material wasted shall be estimated by the Engineer and deducted from the measured quantity.

V. BASIS OF PAYMENT

The quantities thus measured and accepted shall be paid for as follows:

A. Reshaping and Compacting, when included in the contract, shall be at the unit price per 100-foot station -- measured to the nearest one-tenth station.

B. Water used in reshaping and compacting shall be at the unit price per 1000 gallons.

C. Portland cement admixture shall be at the unit price per barrel.

D. Bank Gravel shall be at the unit price per ton of mixture -- less calculated deduction for portland cement admixture.

E. Bituminous material shall be at the contract price per gallon.

F. Sand aggregate shall be at the contract unit price per ton.

Such payments shall be full compensation for preparation of the subgrade, for furnishing and hauling all materials, processing and completing the base, and for furnishing all items incidental thereto.

Note: Excavating and shaping lateral drains and placing aggregate are not included in this specification.

HISTORICAL GEOLOGY

The Jackson Purchase region, eight counties in the extreme western part of Kentucky, was purchased from the Chickasaw Indians in 1818 and divided between the States of Kentucky and Tennessee in 1820 along the 36° 30' parallel. The United States government was represented in these negotiations by General Isaac Shelby of Kentucky and General Andrew Jackson of Tennessee. The name of the latter commissioner has been more popularly associated with the transaction and thus the area has received his name. The region is bounded on the north by the Ohio River, on the west by the Ohio and Mississippi Rivers, and on the east by the Kentucky Lake.

The Jackson Purchase lies in the extreme northeastern part of the Gulf (or Mississippi) embayment, a coastal plain region associated with the large areas of land along the Gulf of Mexico. The rocks exposed in the region range in age from Devonian to Recent. Most of the area is underlain by strata of sand, clay, and gravel of the Tertiary age. Towards the eastern portion of the region, the area is underlain by Cretaceous sands, clays, and gravels and by Paleozoic limestones and shales. These Paleozoic strata are of the same age as those that outcrop in much of the remainder of the State.

Structurally the embayment is a downwarped trough (geosyncline) of Paleozoic rocks which has been filled with Cretaceous and younger sediments. The younger materials which have been deposited in the embayment become progressively thicker to the southwest and the outter rim of the embayment is delineated by outcrops of the Paleozoic rocks along the Kentucky Lake. Dips in the Cretaceous, Paleocene, and Eocene beds are 20 to 30 feet per mile towards the south and west. There is no observable dip in the Pliocene and Quaternary deposits.

Formation of the Mississippi embayment began during the Cretaceous period with a downwarping of the Paleozoic limestones and shales. This allowed the waters of the Gulf of Mexico to move northward into Kentucky. Coarse sands and gravels were deposited near the shores of the embayment and finer sediments were carried off shore and deposited as beds of silt and clay. Toward the end of the Cretaceous period, the sea began to recede and become very shallow. Much of the deposited material was then exposed to wave action which has produced crossbedding in such formations as the Riply.

During the Paleocene epoch the sea began to encroach upon the land again. As before, sands were deposited in the area and, as the sea continued to deepen, the fine-textured marine clays of the Midway group (Porter's Creek Clay) were deposited. As the sea again receded, the surfaces were subjected to erosion and the heavily ladden streams deposited lenses of sands, gravels, and clays as they make their way toward the sea.

In the great ice age of the Pleistocene epoch the northern part of North America was covered by vast continental ice sheets. As these glaciers melted, large amounts of sand, gravel, and rock debris were carried down the rivers and deposited as alluvium. Some of this material has been reworked by water and wind forming the numerous alluvium flood plains along the rivers and streams of the Jackson Purchase area. The materials reworked by the wind have been deposited as thick beds of loess along the east banks of the Mississippi River and as a thin loess mantle over much of the remainder of the Jackson Purchase area.

The Jackson Purchase area is generally an undulating plain with local relief not much in excess of 50 feet, except in the vicinity of major streams. Dissection of this plain is greater to the west in the loess covered region along the Mississippi River bluffs. Most of the area has been covered by a mantle of loess except where it has been locally removed by erosion.

Flood plains of large extent have developed along the Mississippi and Ohio Rivers and to smaller degrees along the lesser streams. Many of these valleys preserve remnants of a higher flood plain approximately 25 to 35 feet above the lower and separated from it by a well marked escarpment. This higher flood plain apparently marks an alluvial plain formed by deposits from overloaded streams during the floods associated with the melting of the Wisconsin ice sheet.