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A Preliminary Report on Backfill Material from Kansas Shales

This report is a prefatory study of the information available which pertains to the clay mineralogy of shales in Kansas. Emphasis is placed upon data that concerns the clay fraction and especially such clay minerals as montmorillonite, mixed-layer montmorillonite, vermiculite, and mixed-layer vermiculite. A mixed-layer clay is one which has the combined structural properties of two or more clay minerals ~~species~~. The above mentioned clay minerals will expand appreciably in the presence of water and contract when dried. It is necessary for the expandable clay to exceed 5% of the clay fraction before the expansive properties of the clay mineral or minerals cause any swelling in a shale. It is also necessary for the clay mineral to exceed 5% so that it can be detected with any certainity on an X-ray pattern.

How about swelling Illite

perhaps we could simplify this

Data was collected from the following sources: the Department of Geology at Kansas State University, the Geological Survey of Kansas, the Research Laboratory of the State Highway Commission, and published professional papers. Particularly helpful were discussions with Ada Swineford, Paul Franks, and Norman Plummer of the Kansas Geological Survey and Carl Crumpton of the Highway Research Laboratory.

The data as presented in this report is separated into the shales of Cretaceous, Permian, and Pennsylvanian ages. Each group is further subdivided into the different formations and members for which information was available. Each shale has a table containing the major clay minerals found, the source ref-

erence, the method of obtaining the clay composition, and a plot by county of the locations described in the reference. Most of the information listed is the result of X-ray analyses, but some DTA (differential thermal analysis) data also appears. The most reliable information is gained from X-ray diffraction studies, and where DTA studies are found alone, caution should be exercised when quoting the data. If the author of a reference showed a stratigraphic section, the section was reproduced, and the sample locations within the section were plotted along the left side of the column. It should be kept in mind, however, that the shale units thick and thin both laterally and vertically as one moves away from any given outcrop.

Most mixed-layer clays appear to be a product of degradation or aggradation of pre-existing clay minerals. Since degradation is generally associated with weathering, it is not surprising to find that soils are usually high in swelling clay minerals. For example, illite degrades to a mixed-layer illite-montmorillonite. The result is that the Permian shales in Kansas, which are high in illite for the most part, produce soils with an undesirable swelling characteristic. The expansion property of the soil is not, therefore, a desirable trait of a backfill. If at all possible, soil should be wasted and not used in highway backfill or stabilization considered.

Glacial tills in Kansas contain a high content of montmorillonite and mixed-layer expandable clay minerals. Till should also be avoided in subgrades if at all feasible. Crushed limestone

or ~~unweathered~~ non-swelling shales will produce a much better backfill and are highly recommended. The problem here may be one of economics.

Shales of Cretaceous age

Pierre shale

The only information found on the Pierre shale in Kansas comes from Wallace County where Ada Swineford found that the major clay minerals are montmorillonite, illite, and kaolinite. She indicated that the many locations sampled by her gave the same results.

Blue Hill and Graneros shales

Both of these shales are loaded with montmorillonite and/or mixed-layer expandable clay. Merriam et.al(1959) indicate a sample which produced a clay analysis of 100 per cent montmorillonite.

Dakota shale member and Kiowa? shale

With the exception of one or two zones in the Dakota shale member these two shales are comparatively high in illite and kaolinite and low in montmorillonite.

Shales of Permian age.

All of the Permian shales contain expandable clay minerals. Some of the shales, however, contain rather large amounts. For instance, large quantities of montmorillonite are found in the upper Permian redbeds from the shale partings in the Blaine gypsum to the top of the Taloga shale. The redbeds above the Flowerpot shale should not be used for topping backfill if at all possible.

The following lists are a breakdown of the lower Permian shales in Kansas. The lists should be used with some reservation, since the references do not indicate, in most cases, what percent of the whole sample is represented by the clay fraction.

The shales were placed in the bad column if 1.) more than one expandable clay was present or 2) the expandable clay was indicated as being major. In all cases at least 5% of the expandable clay had to be present in order to pick it up on the X-ray. Where X-ray data was absent a question mark appears after the name.

Good	Bad
Ninnescah ?	Pearl (Wellington)
Odell?	Paddock - ? 3. Sswell
Holmesville (except certain zones)	Grant - ?
Oketo?	Gage
Blue Springs (except top and bottom)	Havensville
Wymore (except top and bottom)	Blue Rapids
Speiser (except top and bottom)	Easly Creek
Legion (except bottom)	Hooser
Hughes Creek??	Stearns
Towle?	Eskridge -?
	Florena - ?
	Salem Point
	Roca
	Bennett
	Johnson
	Oaks

Shales of Pennsylvanian age

Not too much information was available on the Pennsylvanian shales of Kansas. The following lists were compiled as the Permian shales above.

Good	Bad
Vilas	Wathena
Holdenville (except top)	Robbins
	Vinland
	Hepler
	Weston

Recommendations for Future Study

This preliminary study points out that materials are currently used which cause concrete pavement to move differentially under alternately wet and dry conditions. The net result is cracked and uneven pavement. The study of backfill materials in Kansas, therefore, is a very important step in improving highway stability.

It is recommended that a program be initiated immediately to systematically sample and study the shales and limestones in light of their importance as highway fill materials. These investigations could most proficiently be carried out at qualified universities under the direction of trained personnel. The State Highway Commission would necessarily need to provide funds for such studies. The field samples should be collected by the investigators accompanied by geologists from the Highway Commission who are familiar with the freshest and most complete geologic sections.

The first results from such a study should not be expected in less than a period of two years.

Submitted: October 2, 1964

By: Paul S. Wingard

Paul S. Wingard
Department of Geology
Kansas State University

References Cited

Asmussen, Loris E., 1958, Clay Mineralogy of Some Permian Shales and Limestones, KSU Thesis.

Ball, Stanton M., 1964, Stratigraphy of the Douglas Group (Pennsylvanian, Virgilian) in the Northern Midcontinent Region, KU Ph.D. Thesis.

Bryson, William R., 1959, Clay Mineralogy and Clay Paragenesis of the Upper Chase and Lower Sumner Limestones and Shales in North and East Central Kansas, KSU Thesis.

Dalton, James A., 1958, Clay Minerals at a Pennsylvanian Disconformity; Reprint from Publication 566 of National Academy of Science.

Franks, Paul C., 1962, Personal Communication (Baldwin Hill).

Hargadine, Gerald D., 1959, Clay Mineralogy and Other Petrological Aspects of the Grenola Limestone Formation in the Manhattan, Kansas, Area. KSU Thesis.

Hartig, Robert L., 1954, Minor Petrographic Constituents of Some Permian Rocks. KSU Thesis.

Hattin, Don E., 1962, Stratigraphy of the Carlile Shale, Kansas Geological Survey Bulletin 156.

Johnson, Wendell B., 1949, The Mineralogy of Some Shales of the Lower Permian System of Riley County, Kansas. KSU Thesis.

Kineil III, Carl B., 1964, Clay Mineralogy of the Vilas Shale (Upper Pennsylvanian) in Wilson and Montgomery Counties. KU Masters Thesis.

Matthews, Claude W., 1949, The Mineralogy of Some Soils and Shales from Saline County, Kansas. KSU Thesis.

McPherron, Donald S., 1956, Clay Mineralogy of Some of the Permian Shales. KSU Thesis.

Merriam, D.F. et.al., 1959, Description of Dakota (Cretaceous) Core From Cheyenne County, Kansas. Bull. 134, Part I, Kansas Geological Survey.

State Highway Commission of Kansas, , Investigation of Clay Minerals in Blue Hills Shale on Thomas Holden property and Vicinity Used for the Manufacture of Drilling Mud.

Swineford, Ada, 1953, Personal Communication (Tuttle Creek).

Swineford, Ada, 1955, Petrography of Upper Permian Rocks in South-Central Kansas, Bull. III, Kansas Geological Survey.

Waterman, Willis D., 1951, Factors Determining the Colors of Red and Green Shales. KSU Thesis.

Copied from letter to John D. McNeal from Ada Swinford dated October 1, 1952

in reference to clay mineral analysis of samples of Blue Hill shale collected from Holden pit (Cobri-Sol works) in Ness County (SHC #10)

The clay-sized minerals identified in the minus 0.6 μ Cobr.-Sol are, in rough order of abundance, montmorillonite, kaolinite, illite, quartz and feldspars

Blue Hill

partly or wholly surrounded by this mineral. Very small grains of crystalline pyrite are disseminated in the shale locally. At nearly all exposures the shale is stained along joints and bedding planes by pale-yellow, powdery iron sulfate. Limonitic staining along joints and bedding planes is common also, and is generally concomitant with the iron sulfate stains; indeed, the limonite undoubtedly originated by oxidation of the iron sulfate. At a few places, especially at locality 32, a strong melanterite taste can be detected locally in the gray shale. Calcium sulfate in the form of selenite is especially abundant at many exposures, occurring as minute aggregates along planes of fissility, as coarsely crystalline platy masses in partly weathered shells of *Inoceramus,* and as large individual or fishtail-twinned crystals several inches in length. At a few places, slopes of the shale glitter by reflection of sunlight from thousands of large selenite crystals. Gypsum and barite occur locally as fossil-replacement minerals.

X-ray study was made of five representative samples of the Blue Hill Shale Member from selected exposures along the Saline River valley. Two additional samples from Jewell County were studied because the field appearance of the rock is not "typical" for the member. Despite the different appearance of the last two samples, the mineral content is harmonious with other analyzed samples. In all samples, quartz is the dominant mineral, and in all but two samples nonclay constituents exceed the total clay-mineral content. In the field, all of the samples were described as being very slightly to slightly silty clayey shale, except sample 28-L, which is very sandy. Thus, most of the quartz is seemingly of very fine silt size or smaller. Kaolinite is the dominant clay mineral in five of the samples and is present in the other two. Montmorillonite, or illite and montmorillonite are dominant in the two samples where kaolinite is not, and occur in nearly equal quantities in all samples. Results of x-ray study of the Blue Hill samples are summarized below. According to Swineford and others (1954, p. 163), minerals in the upper part of the Blue Hill of Ness County are, "in rough order of abundance, montmorillonite, quartz, kaolinite, illite, feldspar, muscovite, and traces of chlorite and gypsum". Except for dominance of montmorillonite, rather than quartz, the Ness County analysis is in accord with those of the present report. The upper part of the Blue Hill is seemingly more bentonitic in Ness County than where the tabulated samples were collected.

Beginning as much as 75 feet or as little as 15 feet below the Niobrara, the Blue Hill Member becomes, progressively upward, more silty and finally very sandy at the top. In the lower part of this transition to the overlying Codell Sandstone Member, the quantity of silt

Clay mineral analyses of clayey shale

Sample	Clay minerals			Nonclay		Dominant mineral assemblage	Domi min
	Dominant	Moderate	Minor	Dominant	Minor		
H-1	Kaolinite	Montmorillonite Illite	Chlorite	Quartz	Dolomite	Nonclay	Qua
H-2	Kaolinite	Illite Montmorillonite	Chlorite	Quartz	Feldspar Gypsum	Nonclay	Qua
H-3	Montmorillonite	Illite Chlorite	Kaolinite	Quartz	Mica	Clay	Qua
H-4	Illite Montmorillonite	Kaolinite	Chlorite	Quartz	Mica	Nonclay	Qua
H-5	Kaolinite	Illite Montmorillonite		Quartz	Feldspar	Nonclay	Qu
H-6	Kaolinite	Illite Montmorillonite		Quartz		Clay	Qu
H-7	Kaolinite	Illite Montmorillonite		Quartz	Calcite	Nonclay	Qu

grains disseminated in the shale gradually increases. Upward, th shale is interbedded with thin to thick laminae and lenses of ligh olive-gray (5Y6/1), very fine grained quartz sand and silt. The sma lenses of sand commonly impart a mottled appearance to this part the shale. Still higher, thin to very thin beds of very fine grained quar sand or silt alternate with thicker layers of silty or very fine sand shale. As the quantity of sand increases, the blocky structure of th shale is less prominent, and the weathered rock is only partly flak The predominant color of this part of the section is medium dark gra on fresh surfaces, medium gray where weathered. The thickness rang of the sandy upper part of the Blue Hill Member in part reflects inte grading facies at the Codell-Blue Hill boundary. Rocks in stratal co tinuity are assigned to one member or the other, depending on t percentage of coarse silt and sand content. Where the Codell is thic est, the part of the Blue Hill Member that is sandy is generally mu thinner than at places where the Codell is poorly developed. X-r analysis of a sandy shale sample (28-L) is given above.

At several localities in Finney, Ness, Ellis, Hamilton, Osborne, a Mitchell Counties one or two thin beds of hard, resistant sandstone sandy siltstone lie just above or just below the base of the sandy upp portion of the Blue Hill Member. The beds are generally no more th

Blue Hill Shale

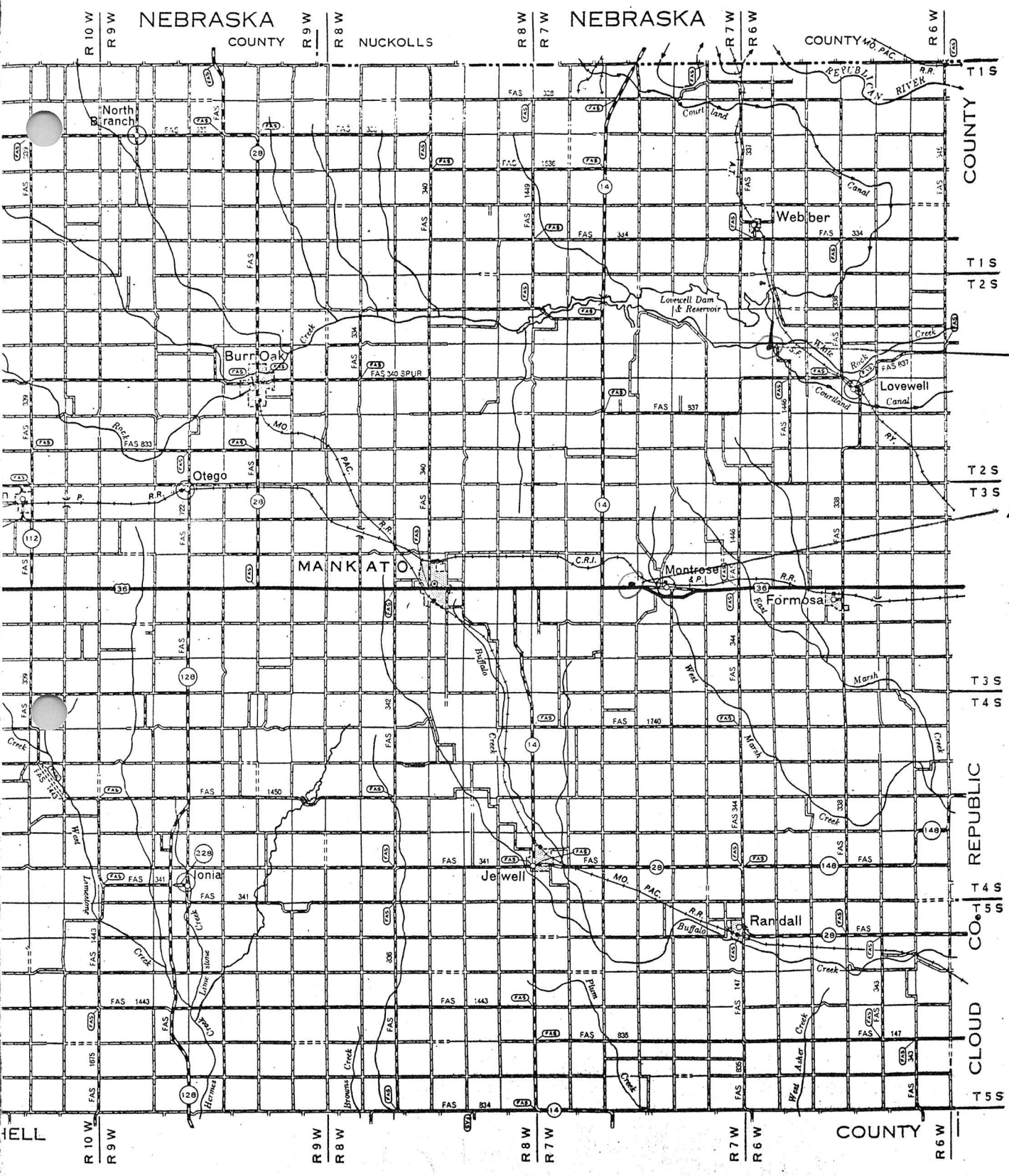
Clay Mineral

Sample #	Dominant	Moderate	minor
H 1	Kaolinite	Montmorillonite Illite	chlorite
H 2	Kaolinite	Illite Montmorillonite	chlorite
H 3	Montmorillonite	Illite chlorite	Kaolinite
H 4	Illite Montmorillonite	Kaolinite	chlorite
H 5	Kaolinite	Illite Montmorillonite	
H 6	Kaolinite	Illite Mont.	
H 7	Kaolinite	Illite Mont.	

Location	Method	Source
Cut bank & bluff N trib. to Saline river SE¼ SE¼, sec 9, T11S, R18W Ellis County	X-Ray	Hattin, Donald E SGS Bul 156
Cut banks S Trib to Saline R. E½ Sec 21, T11S, R17W Ellis County	X-Ray	Same as above
Gullies & S. bank Saline River SW¼ Sec 29 & SE¼ SE¼ Sec 30 T11S, R16W Ellis County	X-Ray	Same as above
Gullies & Road cut NE¼ Sec 3, T11S, R17W Ellis County	X-Ray	Same as above
Same as above	X-Ray	Same as above
Bluff at S. end of Lovewell Dam NE¼ Sec 18 T2S R6W Jewell County	X-Ray	Same as above
Rd cut N. Side US 36 SE¼ SE¼ Sec 16 T3S, R7W Jewell County	X Ray	Same as above

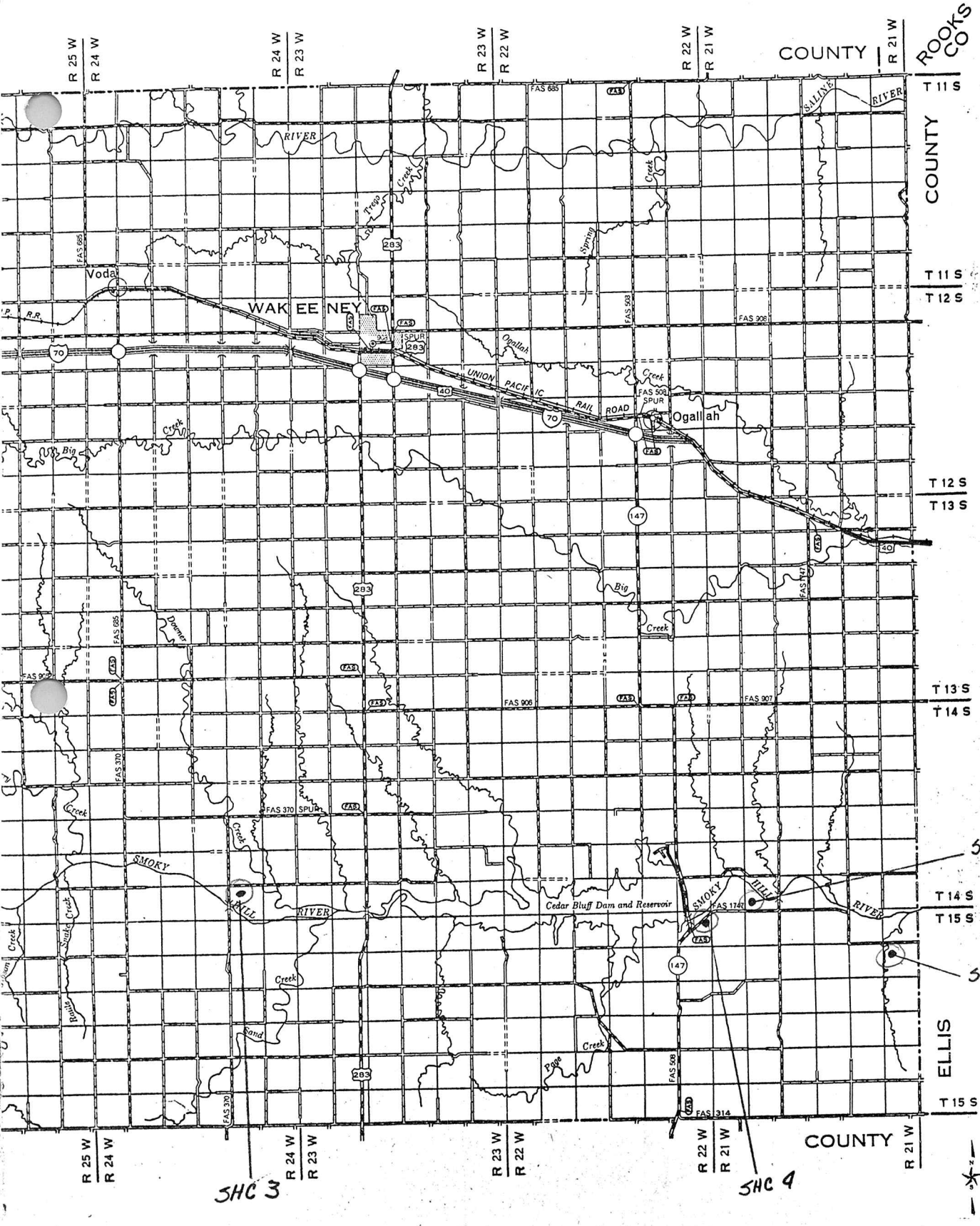
ELLIS COUNTY
KANSAS

1961



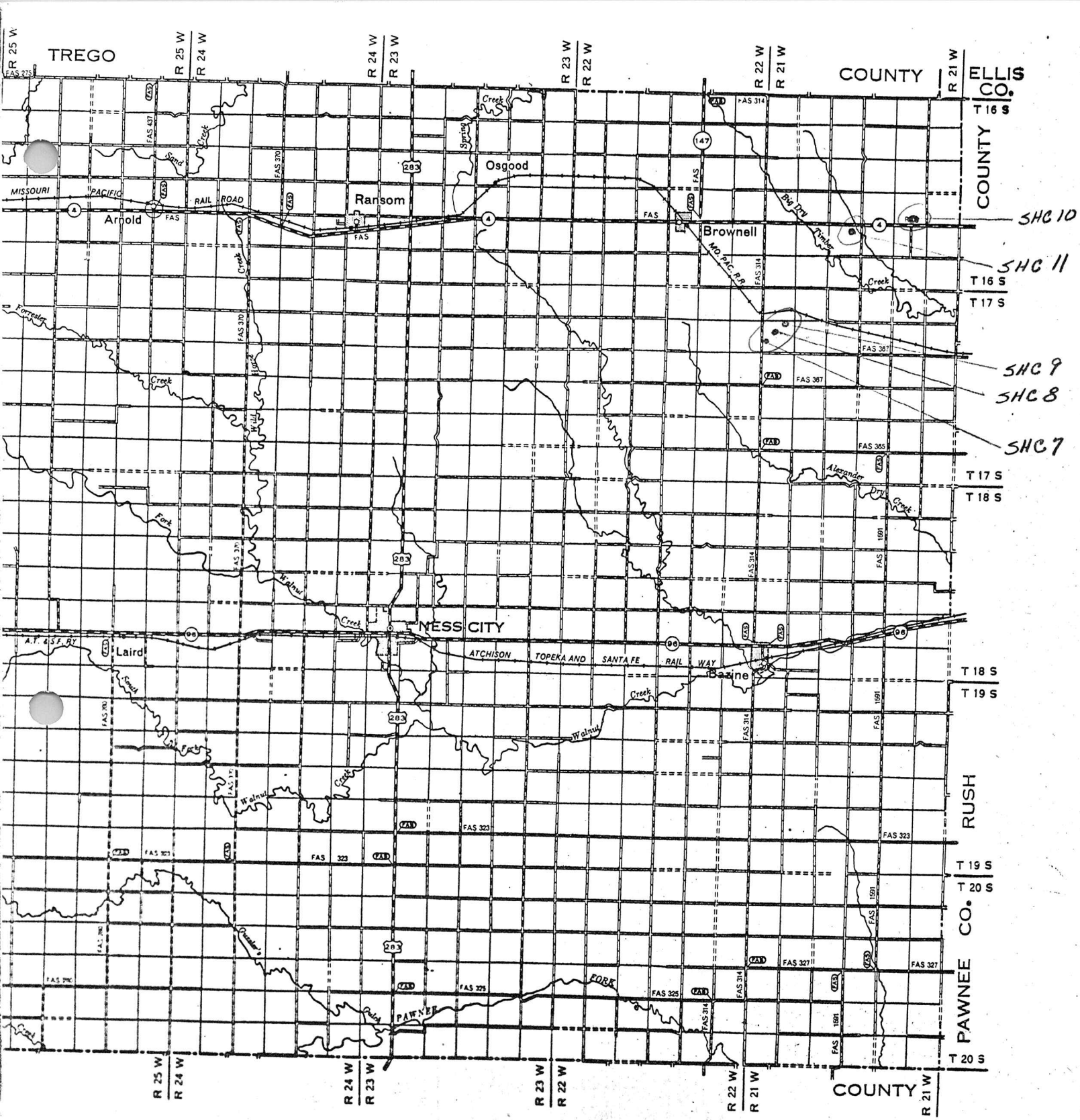
JEWELL COUNTY
KANSAS

1961



TREGO COUNTY
KANSAS

1959

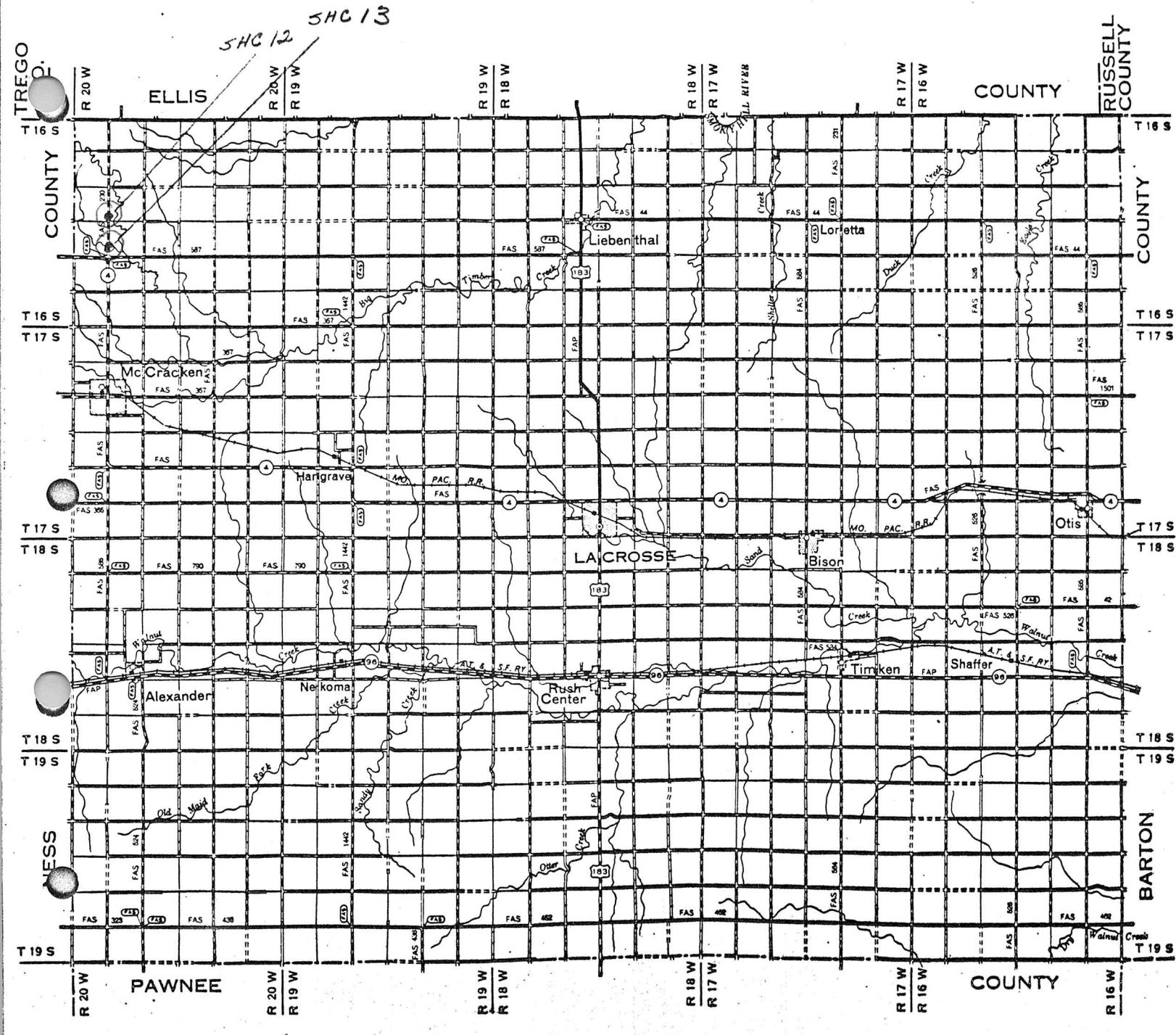


NESS COUNTY
KANSAS

1960

5HC 12

5HC 13



RUSH COUNTY
KANSAS

1962

SCALE

have decomposed illite to produce montmorillonite-like clay. In this respect, it should be noted that low-temperature endothermic water peaks in the differential thermal analysis curves of samples from the same sequence are weak in comparison with those from mudstone samples from other parts of the Dakota Group. The coal in the Cruise member contains mainly kaolinite and mixed-layer clay, a composition totally unlike other rocks in the Dakota Group.

Differential-thermal-analysis curves for samples from the Dakota Group show minor variations, but there are no consistent features common to any one of the stratigraphic units that distinguish it from the others. As noted above, however, absorbed-water peaks of mudstone samples between depths of 2,190 and 2,234 feet are weak in comparison with those of samples from

TABLE 7.—*Clay-mineral composition of selected core samples.*

		Depth (feet)	Lithology	Percentage of clay minerals in samples				
				Illite	Kaolinite	Chlorite	Montmorillonite	Mixed layer
GRANEROS SHALE		2,001	Bentonite				100	
		2,017	Claystone	15	15		70	
DAKOTA FM. OMADI FORMATION	Gurley member	2,034.5	Mudstone	60	30	10		
		2,039	Sandstone	45	35	20		
		2,074	Mudstone	55	15	20	5	5
		2,082	Sandstone	40	40	10	10	
		2,095	Sandstone	50	30	20		
	Huntsman member	2,118	Mudstone	60	25	15		
	Cruise member	2,146	Sandstone	40	30		20	10
		2,166	Mudstone	60	25	15		
		2,176	Mudstone	60	20	20		
		2,189	Coal		40			60
		2,191	Siltstone	65	35			
		2,193	Mudstone	65	35			
		2,206	Mudstone	70	30			
		2,226	Mudstone	65	25	10		
		2,233.5	Mudstone	70	30			
		2,239	Sandstone	55	40		5	
		2,254	Mudstone	60	30	10		
		2,259	Sandstone	45	40	7	1	7
		2,304	Sandstone	30	30	25	5	10
KIOWA SHALE		2,308	Mudstone	70	30			
		2,341	Mudstone	65	20	5	5	5
CHEYENNE SANDSTONE		2,421	Sandstone	15	25	15	45	
		2,425	Mudstone	65	20	—15—		
		2,440	Sandstone	35	30	25	10	
		2,473	Sandstone	35	35	25	5	

TAKEN FROM MERRIAM, D.F. 1959. DESCRIPTION OF A DAKOTA (CRETACEOUS) CORE FROM CHEYENNE CO, KANS. KANS. GEOL. SURV. BULL 134 PT. 1

GRANEROS

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TAKEN FROM MERRIAM, D.F. et.al, 1959 - Ks. Geol. Surv. Bull. 134, pt 1. DESCRIPTION OF A DAKOTA (CRETACEOUS CORE FROM CHEYENNE Co. KANS.

Dakota

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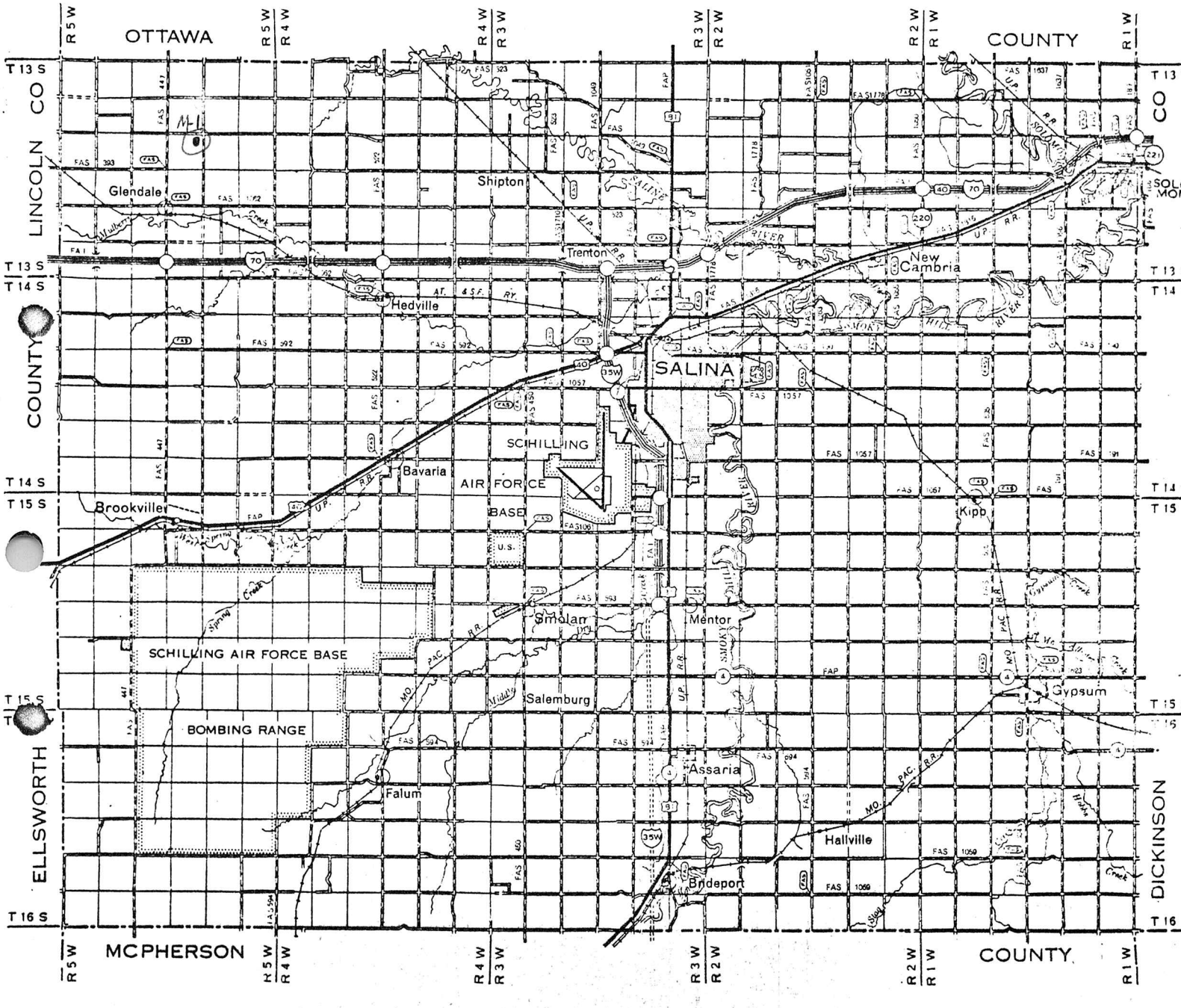
DAKOTA FM

KIOWA

MATTEWS FOUND BY DTA THAT THE CHIEF CLAY MINERAL NEAR THE TOP OF THE FORMATION IS ILLITE. MORE INFORMATION IS NEEDED, HOWEVER, BEFORE A DEFINITE STATEMENT CAN BE PRESENTED.

LOCATION	METHOD	SOURCE
M-1 NE¼ NE¼ Sec 15 T13S R5W	DTA	MATTHEWS, C.W.



SALINE COUNTY
KANSAS

1963

part of the section, have a bright polished appearance; many of these grains are light orange in color. Surface textures of some of the heavy minerals are discussed in the section on mineralogy.

SUMMARY OF COMPOSITION

Mineral Composition

Major constituents.—Detrital minerals in the typical sandstone consist of approximately 80 percent quartz, 20 percent feldspar (at least three-fourths of which is without multiple lamellar twinning), and less than 2 percent mica (predominantly muscovite, but some chlorite and traces of biotite). The typical siltstone contains a somewhat larger proportion of mica; in some argillaceous siltstones the mica content may reach more than 5 percent, but such a large proportion is not common. Most of the sandstones contain less than 5 percent of clay minerals (many are nearly free from clay), and the normal siltstones contain 10 to 30 percent. The clay minerals as such are not regarded as 100 percent detrital constituents.

The typical clay shale is silty, with approximately 20 percent quartz, 4 percent feldspar, and 3 percent micas in the silt fraction. The clay fraction (as shown by x-ray diffration data) also contains quartz, feldspar, and micas, with a somewhat lower proportion of feldspar. It also contains a few percent of hematite which is responsible for the common red color. Most of the clay shales also contain dolomite or calcite or both.

The major constituents of the clay fraction are (besides quartz, feldspar, and hematite) illite, chlorite, montmorillonite, and kaolinite. Of these minerals the typical clay shale contains essentially only illite and chlorite, in the proportion of about 4:1. Some noncalcareous clays contain small quantities of kaolinite, and some clays near the top of the section are chiefly montmorillonite.

The predominant chemical minerals among the major constituents include dolomite, calcite, anhydrite, gypsum, and halite. Each of these occurs in thin essentially monomineralic beds or lenses. Calcite, dolomite, anhydrite, and gypsum are also common cementing materials in sandstones and siltstones, in some sandstones constituting about 50 percent of the rock. Calcite, dolomite, and gypsum occur as veins in some sandstones and silty shales, and as disseminated particles and crystals in many shales.

Sandstones in some zones are characterized by the presence of small unworn overgrowths on some of the quartz and orthoclase grains. One of the dolomite units—the Day Creek—commonly contains nodules and stringers of secondary chert. The time of origin of this chert is not clear; it has been postulated to be Tertiary or younger in age (Norton, 1939, p. 1811) but the presence of greenish-gray Permian montmorillonite clay immediately above it suggests that the silica may have been leached from the overlying bed. A primary origin is of course possible.

Accessory minerals.—Accessory heavy minerals are neither abundant nor varied in the upper Permian sandstones. The quantity is everywhere less than 1 percent (not including the micas) and commonly less than 0.4 percent of the total sample. A sample from the base of the Cedar Hills formation was found to contain 0.38 percent heavy minerals, most of which were finer than sand size (less than 62 microns). A sample from the Relay Creek member of the Whitehorse sandstone contains only 0.15 percent heavy minerals, most of which are in the very fine sand sizes.

Except for the micas, there are no obvious stratigraphic variations in mineral suites. The only variations observed by me can be attributed to differences in particle size of the deposit, and perhaps to selective destruction of certain minerals, notably staurolite, after deposition.

The opaque minerals (ilmenite, "leucoxene," magnetite) make up from 40 to 65 percent of the heavy residues (micas excluded). The nonopaque minerals apatite, epidote, garnet, rutile, staurolite, titanite, tourmaline, and zircon form the remainder. Tourmaline, garnet, and staurolite are particularly abundant in the coarser fractions, whereas zircon and the opaque minerals predominate in the finer.

The nonopaque heavy minerals seem to be essentially unaltered, but all the staurolite is corroded. Much of the garnet is pitted; these pits may be vacuoles exposed on surface planes by fracturing (Krynine, personal communication dated April 4, 1954). Many staurolite grains are so delicately etched that they seem to have been corroded after deposition. However, it is conceivable that such grains could have survived transport in suspension load.

the clay minerals observed in a sediment are in large part a function of the cations present, and that kaolinite is not likely to grow in the presence of calcium ion. Magnesium ion, on the other hand, leads to the growth of chlorite minerals. Millot (1953) notes that illite and chlorite (but not kaolinite) are typical of the deposits of large supersaline lakes more or less linked with the sea. According to him, the mechanism of inheritance would appear inadequate to explain such a general phenomenon, and he considers it necessary to postulate the building up of the micaceous network in a basic milieu. Rivière (1953), on the other hand, believes that most clay minerals are transported and deposited without alteration. He writes that the lagoonal milieu of evaporation corresponds to a relatively dry climate in which the evolution of the soils of the watersheds scarcely passes the illitic stage. The presence of deeply weathered feldspars and the abundance of hematite, together with the paucity of unstable minerals in the Kansas Permian redbeds do not support Rivière's hypothesis.

The abundance of chlorite and illite, rather than kaolinite, is the factor which places the argillaceous siltstones in the low-rank graywacke field of Krynine's (1948) diagram (Fig. 10). This is seemingly a matter of diagenesis and therefore does not have the implied tectonic significance, except in so far as the Kansas area can be called part of a mild autogeosyncline.

Van Houten (1948, p. 2100) reports illite as the predominant clay mineral in various western redbeds, including the Chugwater, Spearfish, and Chinle formations, and does not find even subordinant kaolinite in these redbeds. In a study of clay minerals of sedimentary rocks and derived soils, Van Houten (1953) reported illite and some montmorillonite as the predominant clay mineral groups in Permian "Cimarron" (term discarded by Kansas Geological Survey) red sandstones and siltstones from Sumner, Harper, and Barber Counties, Kansas. The fact that chlorite was not mentioned by Van Houten does not necessarily indicate that it is not present. The importance of chlorite in the fine fractions of sediments has only recently been recognized by clay mineralogists, and it is quite possible that this mineral was not recognized as such at the time the work was done. Preliminary treatment of Van Houten's (1953, p. 70) samples with HCl may also have destroyed any chlorite present. Van Houten (1953, pp. 72-73) suspected the presence of a colloidal magnesium silicate

mineral in two of his Kansas redbed sediments because he found high MgO content coupled with low CO_2. He suggested indirectly that this colloid might be related to attapulgite or sepiolite.

The point to be stressed is that illite rather than kaolinite is the predominant clay mineral in the redbeds. This is in direct opposition to the observation of kaolinite and gibbsite in the Triassic of Connecticut by Krynine (1950). In my opinion this merely points out the environmental difference between terrestrial redbeds and those deposited under water in a broad saline basin.

The presence of large quantities of montmorillonite in the Whitehorse and Taloga formations may be related to volcanic activity in Mexico during Guadalupian? time. Bentonites are common in the Guadalupian rocks of west Texas. Adams and Frenzel (1950, p. 296) report that bentonite is common in the Grayburg (upper Guadalupian) formation, and they suggest that it is derived from a volcanic area in Mexico. Adams and Frenzel (1950, p. 304) also state that bentonite "was probably widely distributed over the southern Permian Basin, but it is seldom recognized in the anhydrite and salt sections."

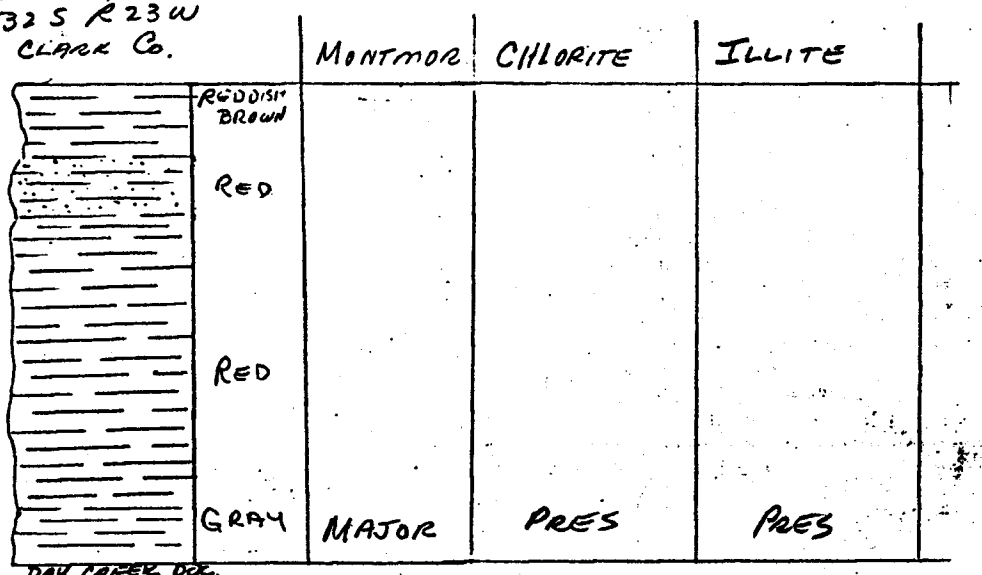
Present-day soils developed on the Kansas redbeds have approximately the same clay mineralogy as do the redbeds themselves (Van Houten, 1953). During the interval between the close of Permian deposition and the beginning of Cretaceous deposition in the area, however, kaolinite developed in the now-buried zone of alteration formed on the Permian redbeds.

TEXTURE

The fine particle size of most of the grains in the Kansas redbeds suggests low energy levels of transportation, an only moderate supply of clastics, and great distance from source areas. The large rounded quartz and chert grains which are scattered among the finer sediments in the upper part of the section obviously had a different source or sources and are believed to have been derived from isolated mountain uplifts to the south within the basin; their coarseness increases markedly into Oklahoma. The large quartz and chert grains are typical of second-cycle orthoquartzites, and they seem to have been derived from erosion of Cambro-Ordovician rocks. Adams and Frenzel (1950, pp. 299, 304) describe similar large quartz grains from the upper Guad-

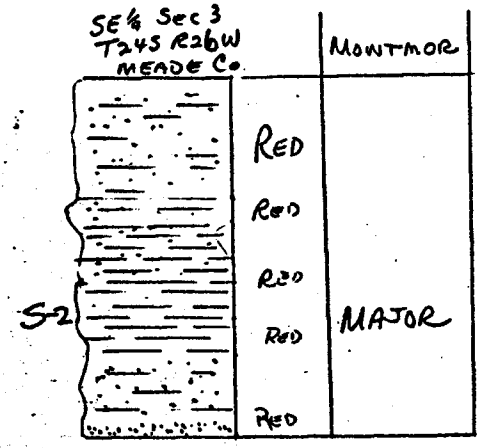
TALOGA SHALE

CEN SEC 14
T32S R23W
CLARK CO.



	MONTMOR	CHLORITE	ILLITE
S-1	MAJOR	PRES	PRES

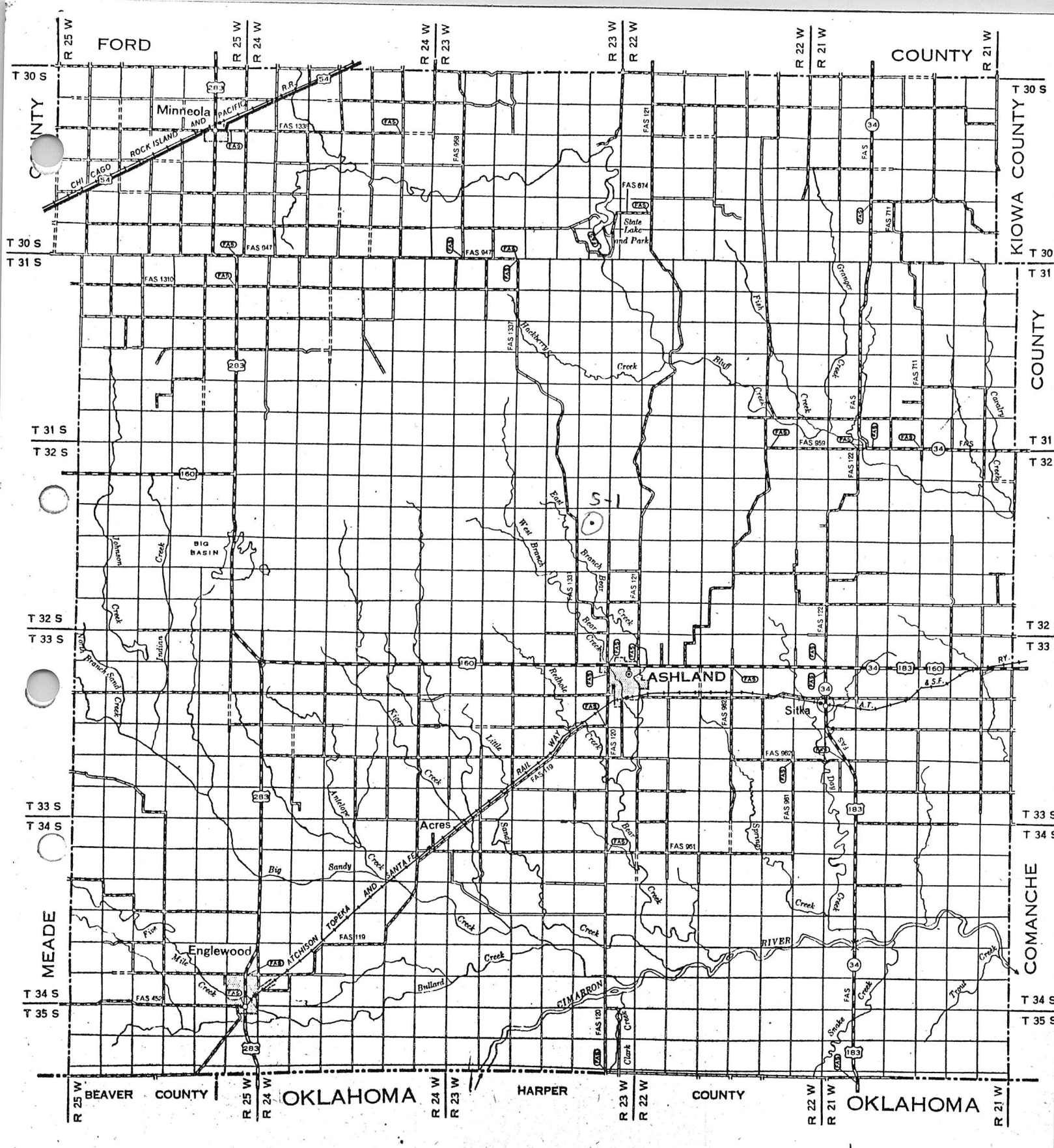
SE¼ SEC 3
T24S R26W
MEADE CO.



	MONTMOR
S-2	MAJOR

TALOGA OR BIG BASIN FM. IS HIGH IN MONTMORILLONITE.

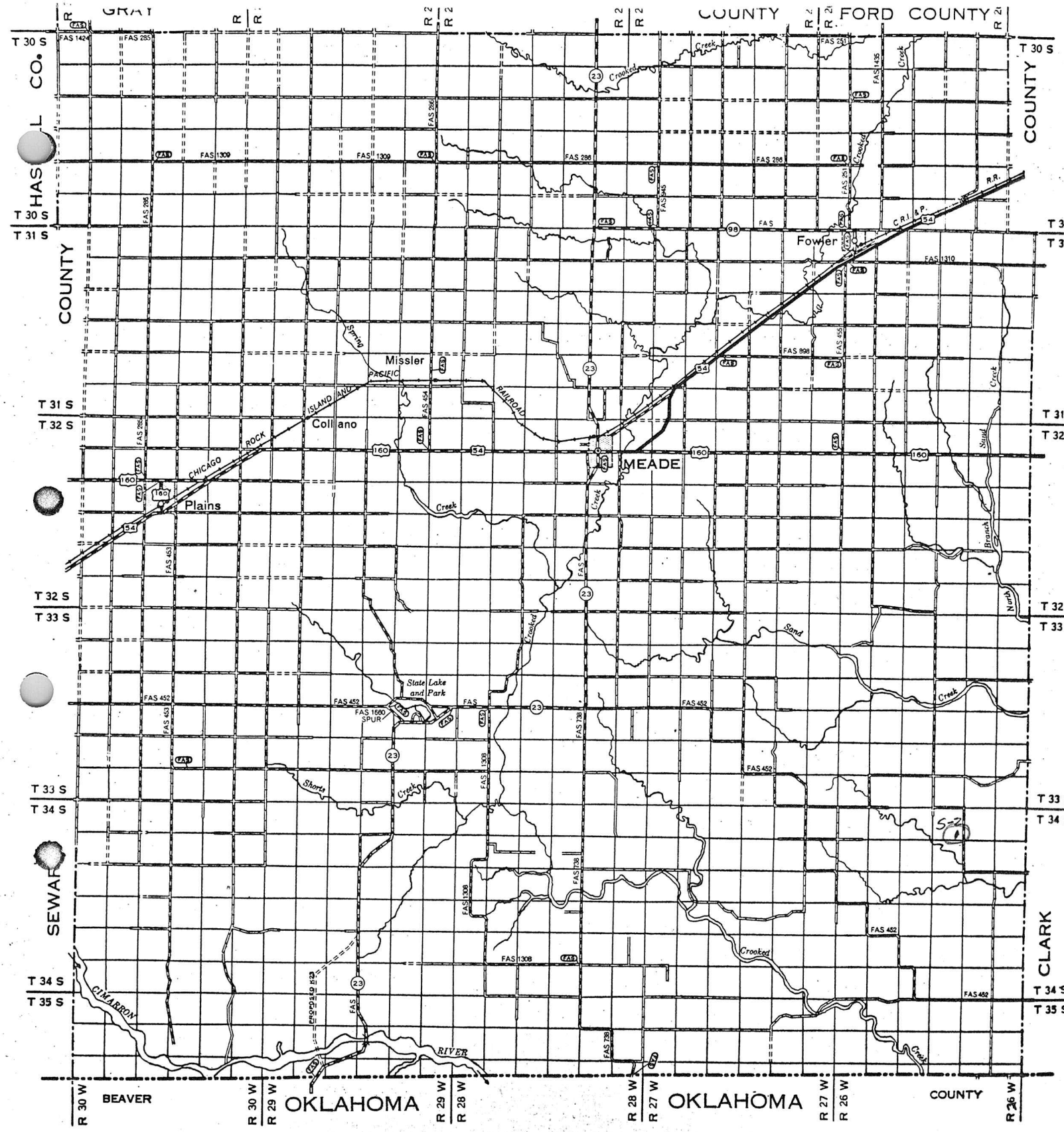
S-1	CEN SEC 14 T32S R23W CLARK CO.	X-RAY	SWINEFORD, A - 1955
S-2	SE¼ SEC 3 T24S R26W MEADE CO.	X-RAY	SWINEFORD, A. - 1955



CLARK COUNTY
KANSAS

1960

SCALE



MEADE COUNTY
KANSAS

1960

CHARACTER OF END MEMBERS

As stressed by Krynine (1948, p. 137), sedimentary rocks may be regarded as mixtures of three textural elements: grains, matrix, and cement.

The end members of the Kansas Permian redbeds are (1) feldspathic sands and silts; (2) clayey matrix which is at least in part authigenic and chiefly red; (3) carbonates and sulfates (predominantly dolomite and gypsum); and (4) salt.

The grains in the redbeds are characteristically of silt or very fine sand size with the following average mineral composition.

	Percent, grains
Quartz	75 to 80
Feldspar	
Orthoclase	15
Microcline	5
Plagioclase	1
Micas and detrital chlorites	<2

The matrix is generally illite clay with significant quantities of chlorite, fine-grained quartz and feldspar, and hematite stain. A few sandstones contain a silt matrix. The clay in some specimens is predominantly montmorillonite, but this is not typical except in the upper part of the section. Some matrix contains no hematite. The typical clayey matrix has approximately the following mineral composition.

	Percent
Illite and sericite	50
Chlorite	15
Kaolinite and montmorillonite	<10
Hematite	5
Quartz and feldspar	>20

The characteristic cement is dolomite or calcite, or both; some gypsum cement also occurs.

The type of mixture of these three textural elements (and the depositional environment) depends upon degree of activity in the source areas, or, more probably, degree of warping between the source and the site of deposition, character of water from which the sediments were deposited, depending on such factors as effectiveness of barrier to open sea, and degree of rainfall, and possibly diagenesis. The controlling genetic factor seems to be

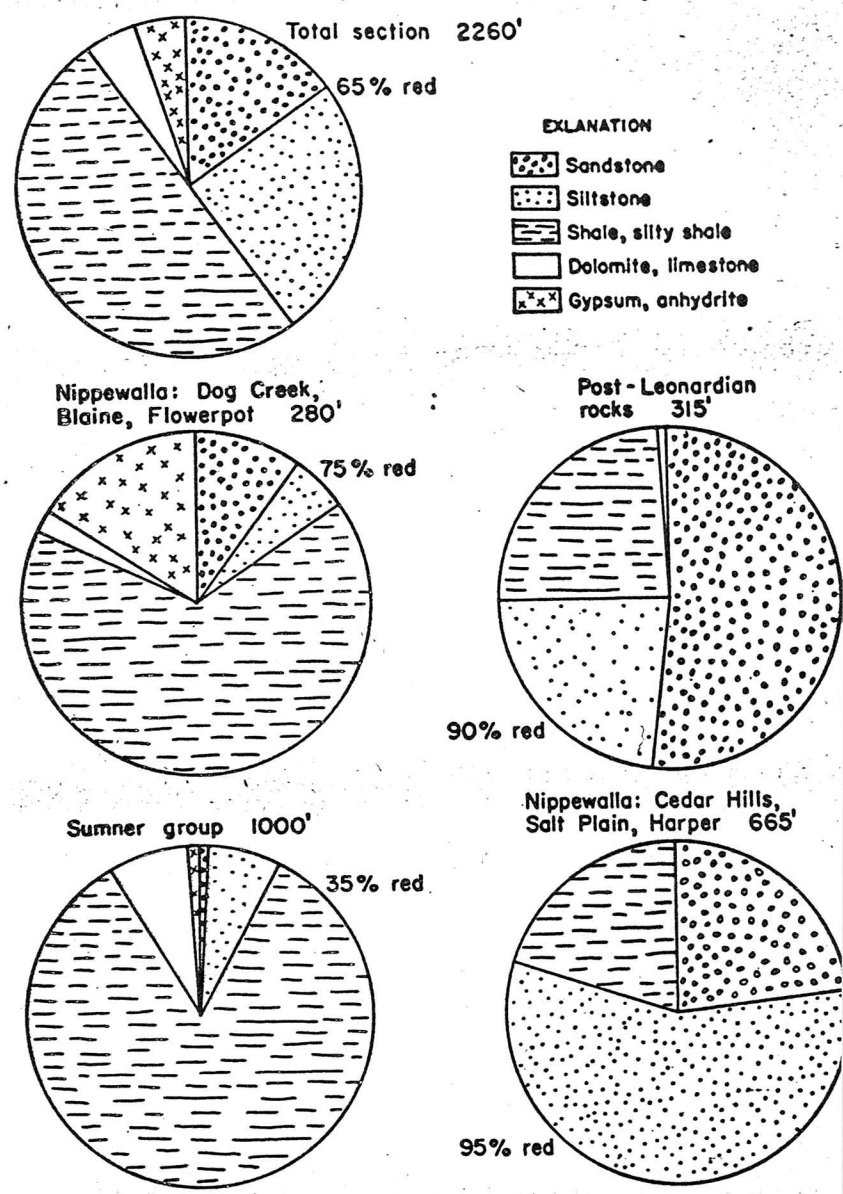


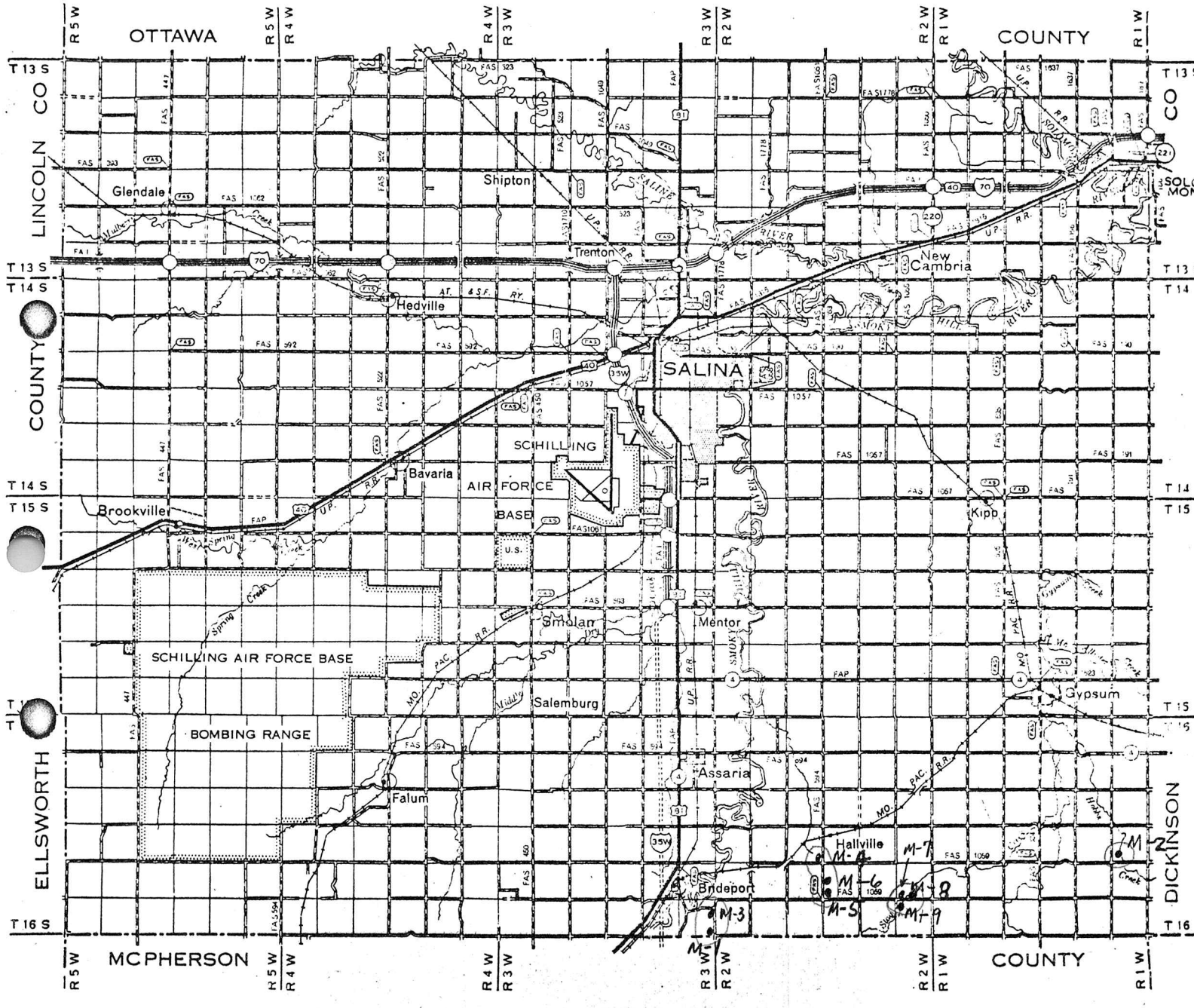
FIG. 7.—Stratigraphic distribution of lithologic types and of redbeds.

NINNESCAH

MATHEWS INDICATES ILLITE AS THE DOMINANT CLAY MINERAL BY DTA. THIS NEEDS X-RAY CONFIRMATION.

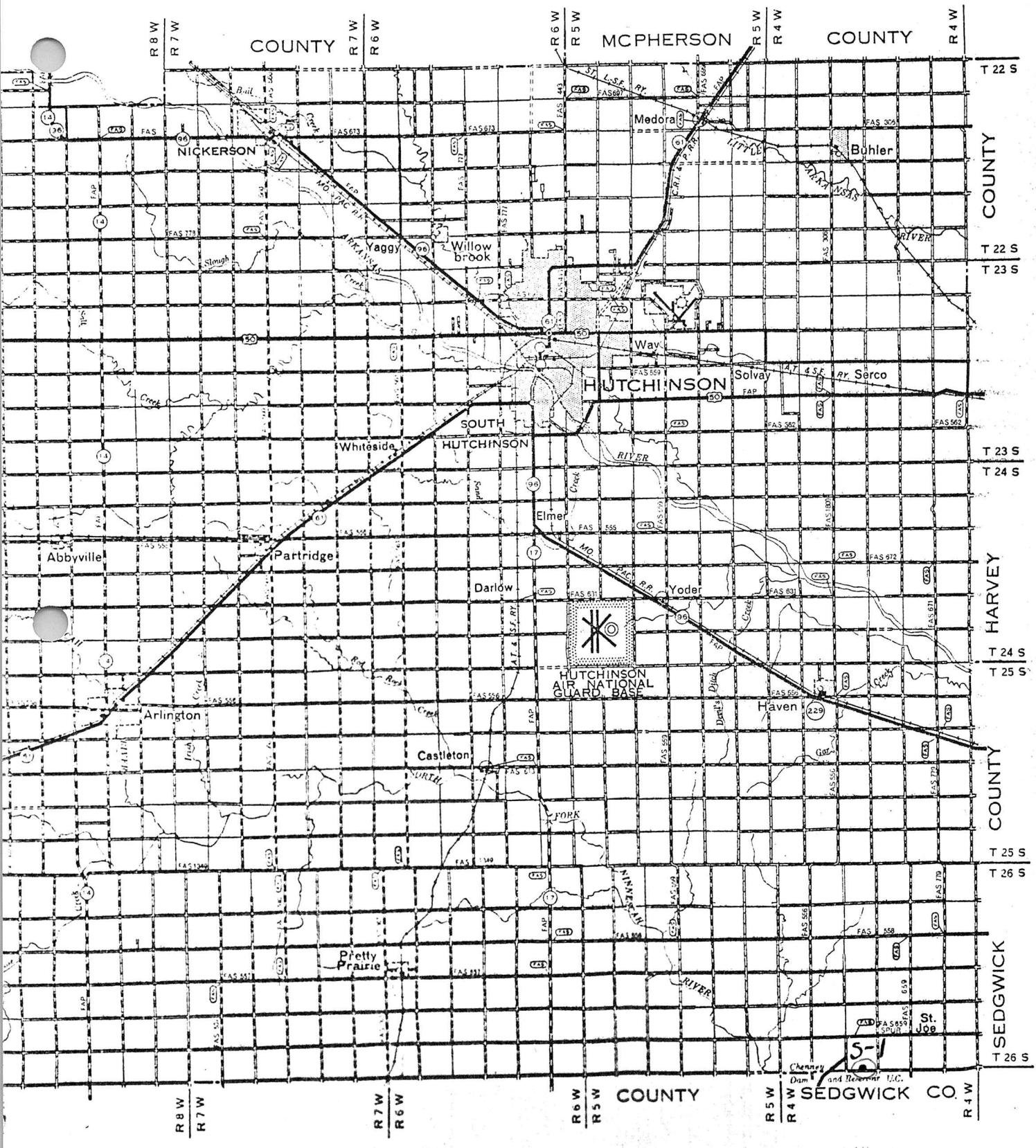
(S-1) SWINEFORD INDICATES FOR THIS LOCALITY THAT THE CLAY MINERALS ARE PREDOMINATELY ILLITE AND CHLORITE.

LOCATION	METHOD	SOURCE
M-1 SALINE CO. SE¼ SE¼ SEC 36 T16S R3W ROAD CUT	DTA	MATTHEWS, C.W.
M-2 SALINE CO. SW¼ SW¼ SEC 29 T16S R1W STREAM BANK BELOW 1st PARTING	DTA	MATTHEWS, C.W.
M-3 SALINE CO. SE¼ NE¼ SEC 36 T16S R 3W RED SHALE IN ROAD CUT	DTA	MATTHEWS, C.W.
M-4 SE¼ SE¼ SEC 21 T16S R2W SALINE CO.	DTA	MATTHEWS, C.W.
M-5 SW¼ SW¼ SEC 27 T16S R2W SALINE CO	DTA	MATTHEWS, C.W.
M-6 SALINE CO. NW¼ SW¼ SEC 27 T16S R2W ROAD CUT 30' LOWER THAN M-5	DTA	MATTHEWS, C.W.
M-7 SALINE CO. SW¼ SW¼ SEC 25 T16S R2W ROAD CUT	DTA	MATTHEWS, C.W.
M-8 SALINE CO. NW¼ NW¼ SEC 36 T16S R2W STREAM CUT 20' BELOW M-7	DTA	MATTHEWS, C.W.
S-1 RENO CO. CEN S LINE SEC. 33 T26S R4W	X-RAY	SWINEFORD, AOA 1955



SALINE COUNTY
KANSAS

1963



RENO COUNTY
KANSAS

1963

SCALE MILES

PEARL

	LOCATION	METHOD	SOURCE
B-1	NW¼ SEC 16 T2S R4E	X-RAY	BRYSON, W.R.
B-2	CW LINE SEC 1 T6S R4E	X-RAY	BRYSON, W.R.
B-3	SEC SEC 31 T9S R3E	X-RAY	BRYSON, W.R.
B-4	SEC SEC 30 T10S R3E	X-RAY	BRYSON, W.R.
B-5	NE¼ SEC 30 T11S R3E	X-RAY	BRYSON, W.R.
B-6	SE¼ SEC 5 T14S R4E	X-RAY	BRYSON, W.R.
B-7	CS LINE SEC 21 T17S R5E	X-RAY	BRYSON, W.R.
B-8	NW¼ SEC 3 T22S R6E	X-RAY	BRYSON, W.R.

Pearl
(lower Wellington)

PEARL

THESE FIGURES ARE IN PERCENT. PARENTHESIS FIGURES ARE RATIOS FOR MIXED LAYERS.

SAMPLES ARE ARRANGED WITH LOWEST AT THE BOTTOM

		ILLITE	MONTMOR	VERMICULITE	CHLORITE	ILLITE-MONTMOR	ILLITE CHLORITE	CHLORITE MONTMOR	VERMICULITE CHLORITE	VERMICULITE MONTMOR	MONTMOR. SWELLING CHLOR *
B-1	Sh	77	18		4	1 (3:2)					
	Dol-Sh	97	T		3	T					
B-2	Dol-Sh	95	2	T	3	T		T	T		
	Dol-Sh	91	4	T	5	T	T (1:1)				
	Sh	84	18	—	5	T	—	T	—		
	Dol-Sh	95	T	—	5	—	—	—	—		
	Sh	94	1	T	5	—	—	T	—		
	Dol-Sh	84	9	T	7	T	—	—	—		
	Dol-Sh	90	—	—	2	—	—	8(1:9)	—		
	Dol-Sh	93	4	—	3	T	—	—	—		
B-3	Ls	24			2			68(1:1)	—		—
	Sh	34			—			52(1:1)	—		14(1:1)
	Sh	47			1			52(1:1)	—		—
	Sh	40			1			59(1:1)	T		—
B-4	Sh	51			1	—		46(1:1)	—		2(1:1
	Sh	45			—	—		55(2:3)	—		—
	Sh	43			—	T		56(1:1)	1(7:3)		—
	Sh-Ls	59			3	T		38(4:9)	—		T
	Sh	46			2	T		46(4:9)	—		6(1:1)
B-5	Dol-Sh	90		1	3	T		6(1:1)			
	Dol-Sh	88		T	3	—		9(1:1)			
	Dol-Sh	77		—	4	—		19(1:1)			
B-6	Sh-Dol	90	T	7	3					—	
	Sh	94	—	—	1					5(5:3)	
B-7	Sh	85	—	3	3	4(7:3)				8(1:1)	
	Dol-Ls	90	-	2	2	T				8(1:2)	
	Sh	96	-	4	4	T				—	
	Sh	97	-	3	3	T				—	
	Sh	98	1	1	1	—				—	
	Sh	97	—		3	—				—	
B-8	Ls-Sh	30								66(1:9)	4(1:1)

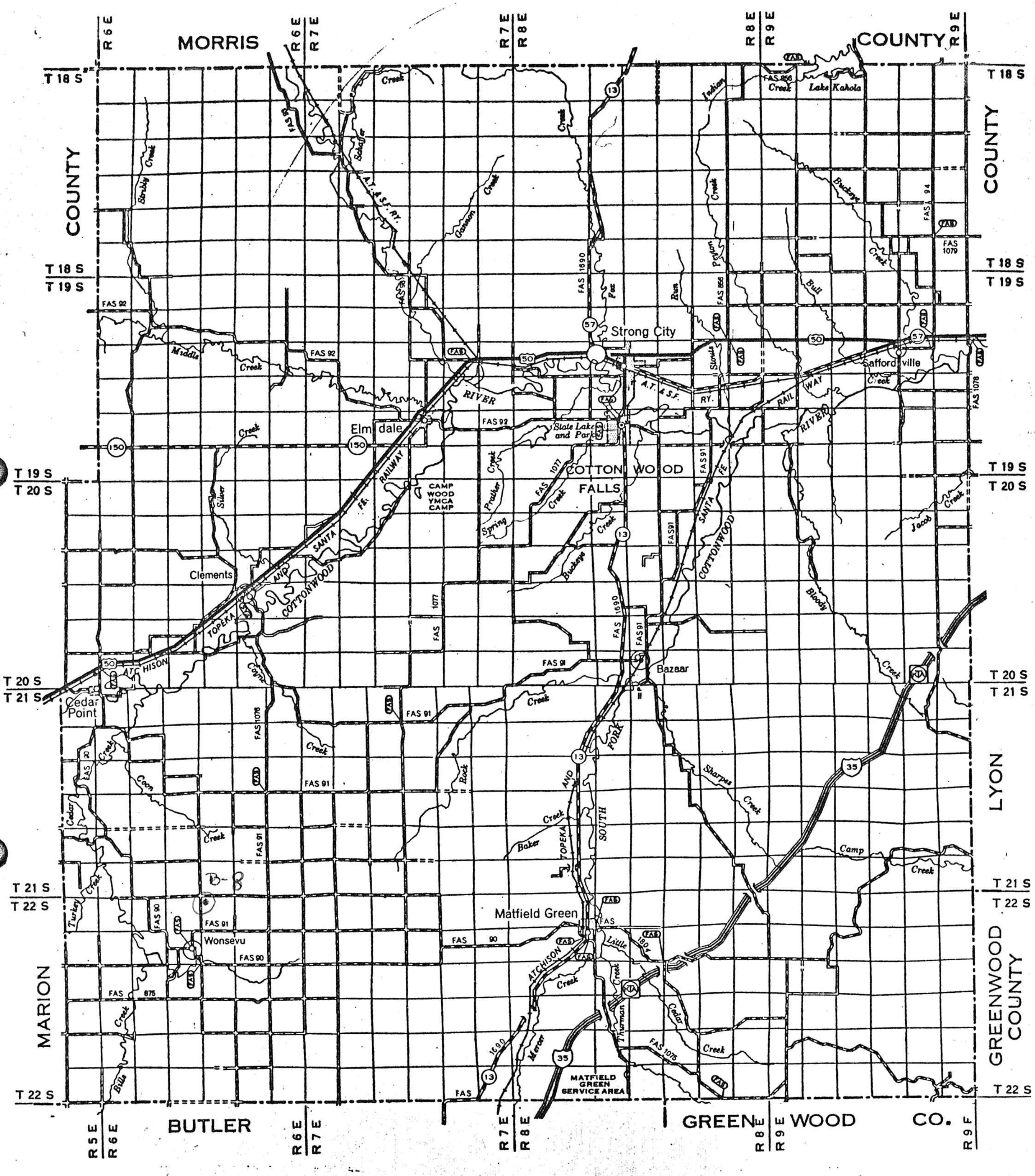
WELLINGTON (PERRY)

MATTHEWS INDICATES ILLITE AS THE DOMINANT CLAY MINERAL BY D.T.A. METHODS. THIS INFORMATION NEEDS TO BE SUPPLEMENT BY X-RAY WORK.

(S-1) SWINEFORD INDICATES FOR A GREENISH-GRAY BED: POORLY CRYSTALLINE ILLITE (MAJOR), MINOR CHLORITE, AND DETECTABLE QUANITIES OF MONTMORILLONITE AND/OR MIXED LAYER CLAY.

LOCATION	METHOD	SOURCE
M-1 NW¼ NW¼ (LOWER PORTION) SEC 21 T16S R3W	DTA	MATTHEWS, C.W.
M-2 NW¼ NW¼ SEC 36 T14S R1W	DTA	MATTHEWS, C.W.
M-3 NW¼ NW¼ SEC 18 T14S R1W	DTA	MATTHEWS, C.W.
S-1 NE¼ NE¼ SEC 17 T33S R2W SUMNER CO.	X-RAY	SWINEFORD, ADA 1955

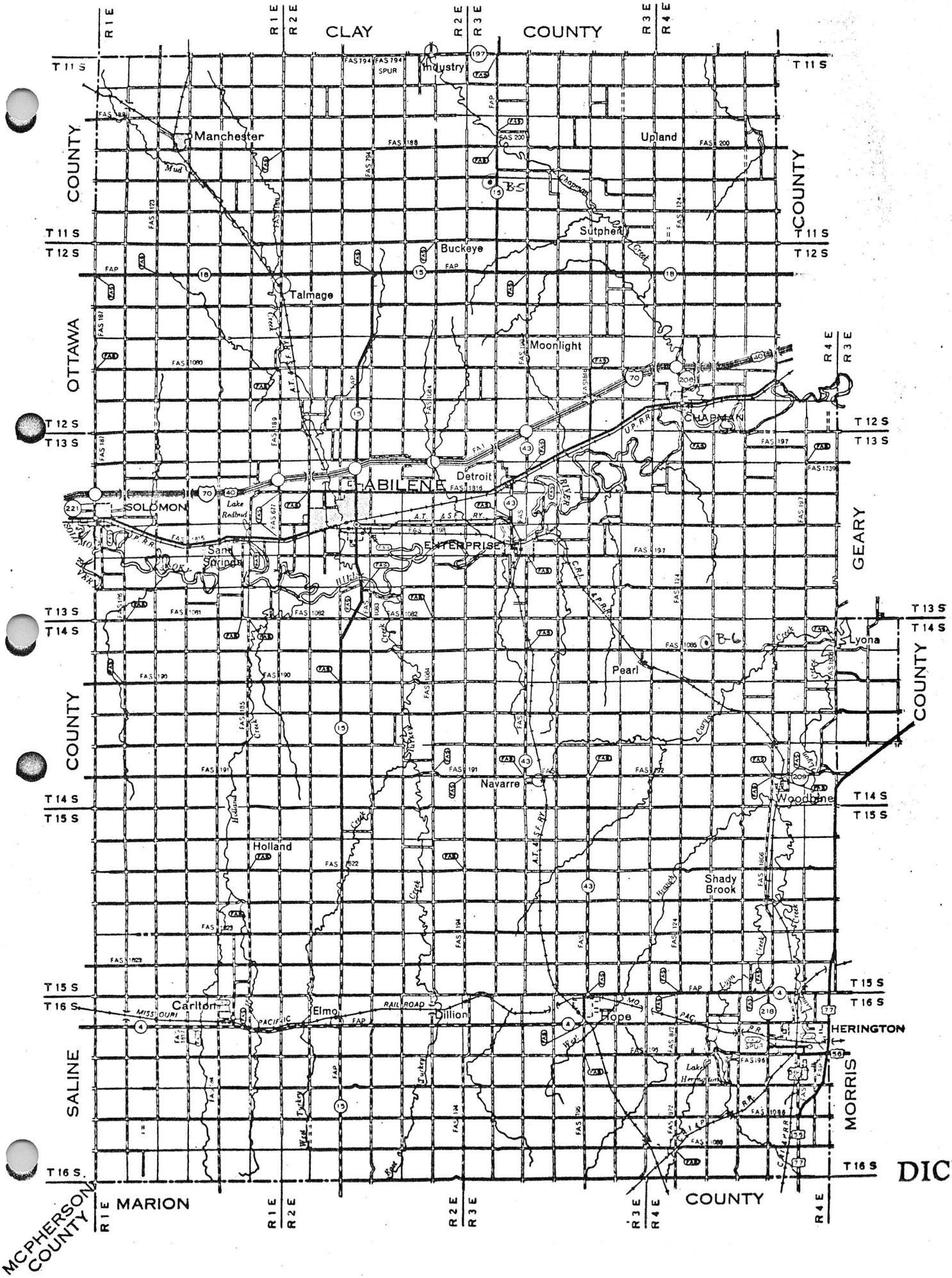
↖ prob. road cut (AS)

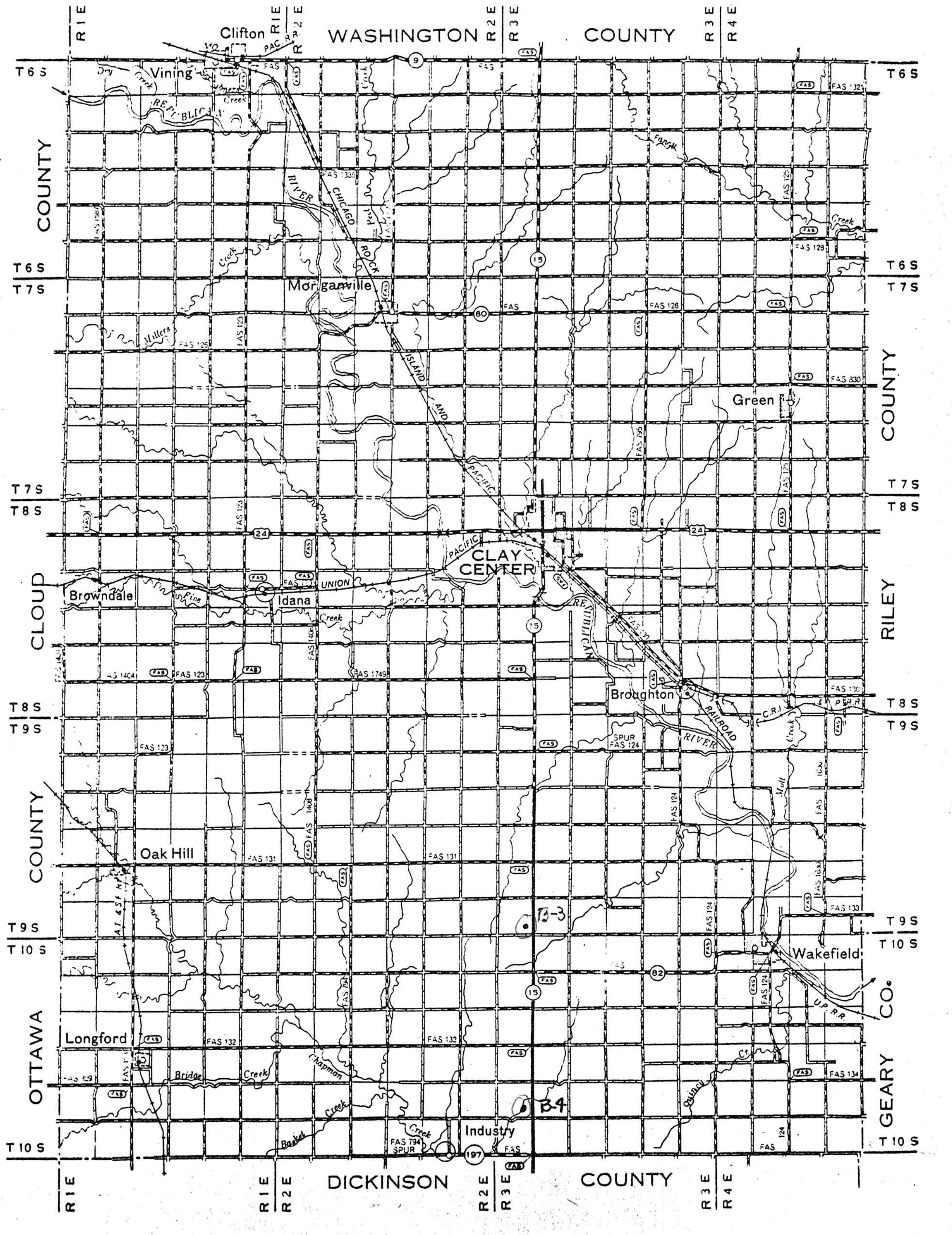


CHASE COUNTY
KANSAS

1959

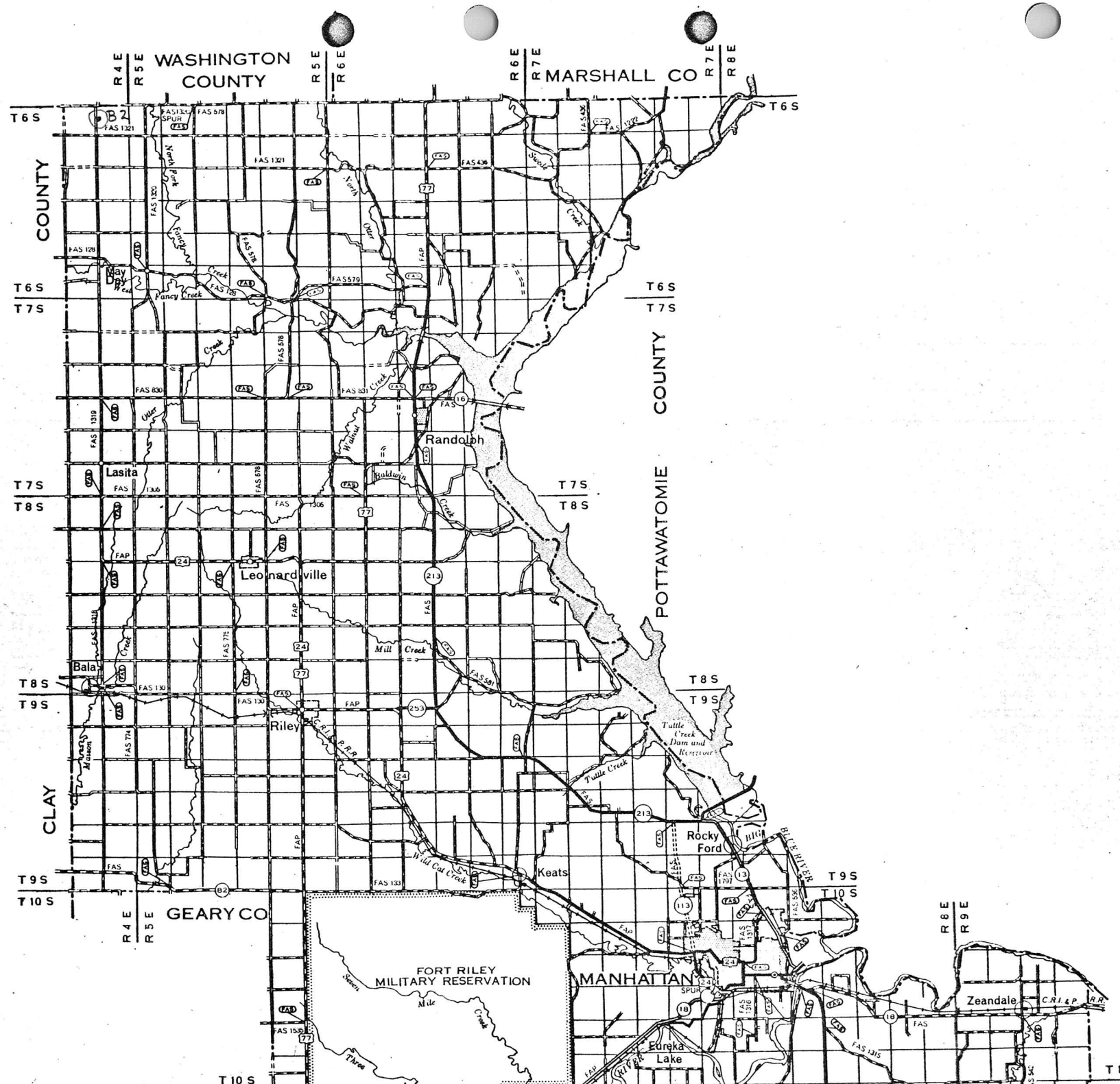
MORRIS COUNTY
KANSAS
1963
GEARY COUNTY
WABAUNSEE COUNTY
DICKINSON CO
MARION CO.
CHASE COUNTY
LYON COUNTY
Skiddy
Dwight
White City
Parker ville
Latimer
Kelso
HERINGTON MUNICIPAL AIRPORT
Council Grove Dam and Reservoir
Council Grove Lake
COUNCIL GROVE
Delavan
Willsey
Helmick
Burdick
Diamond Springs
Dunlap
Lake Kahola
R5E
R6E
R7E
R8E
R9E
T14S
T15S
T16S
T17S


CLAY COUNTY
OTTAWA COUNTY
GEARY COUNTY
SALINE COUNTY
MORRIS COUNTY
MARION COUNTY
DICKIN
MCPHERSON COUNTY
Industry
Manchester
Upland
Buckeye
Sutphen
Talmage
Moonlight
CHAPMAN
ABILENE
Detroit
SOLOMON
Lake Redbud
Sand Springs
ENTERPRISE
Lyona
Pearl
Navarre
Woodbine
Holland
Shady Brook
Carlton
Elmo
Dillion
Hope
HERINGTON
Lake Herrington
Mud Creek
Chapman Creek
Turkey Creek
Lyon Creek
Cottonwood Creek
Missouri Pacific Railroad
A.T. & S.F. Ry.
U.P.R.R.
C.R.I. & P.R.R.
R1E
R2E
R3E
R4E
T11S
T12S
T13S
T14S
T15S
T16S

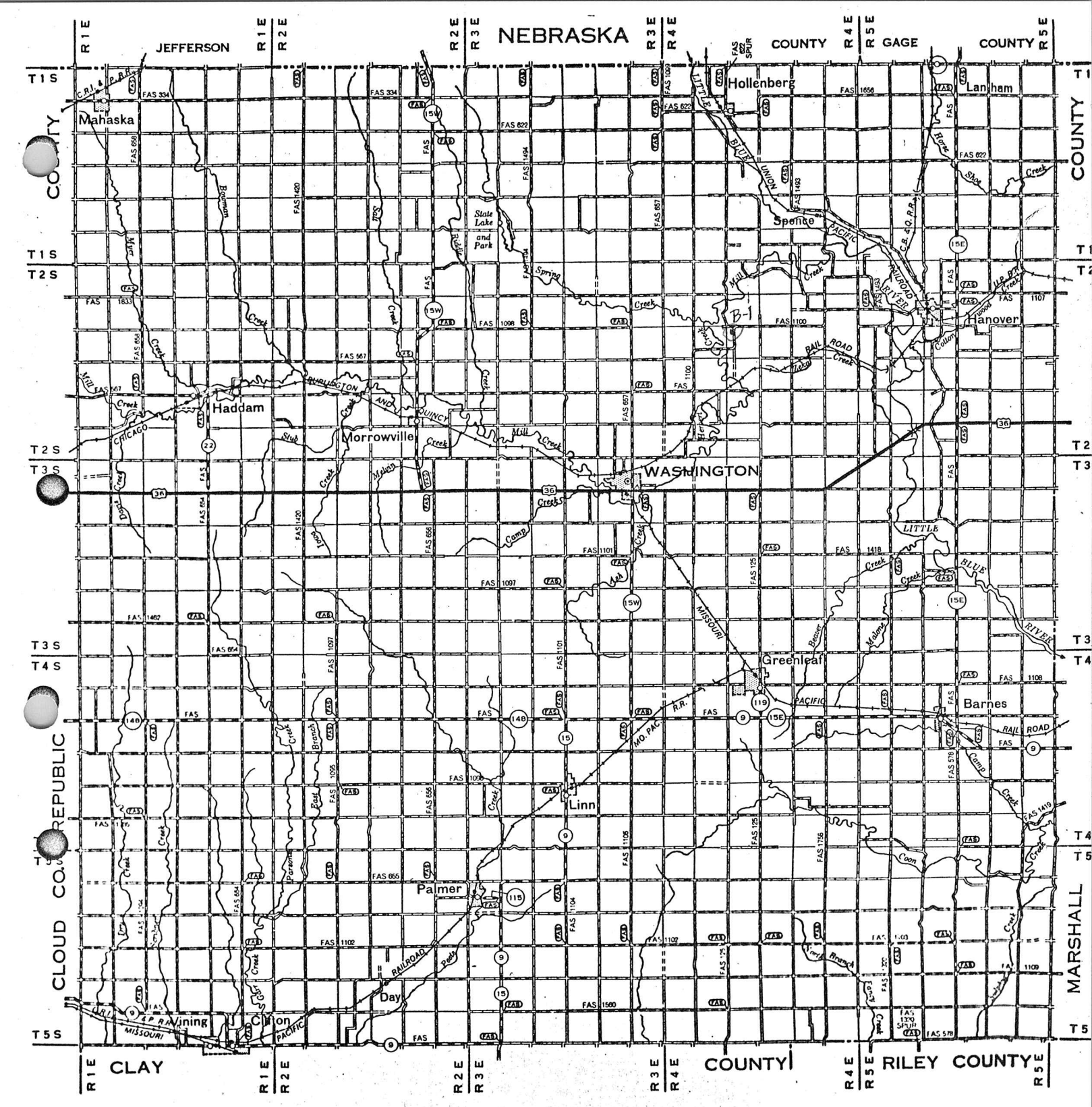


CLAY COUNTY
KANSAS

1961

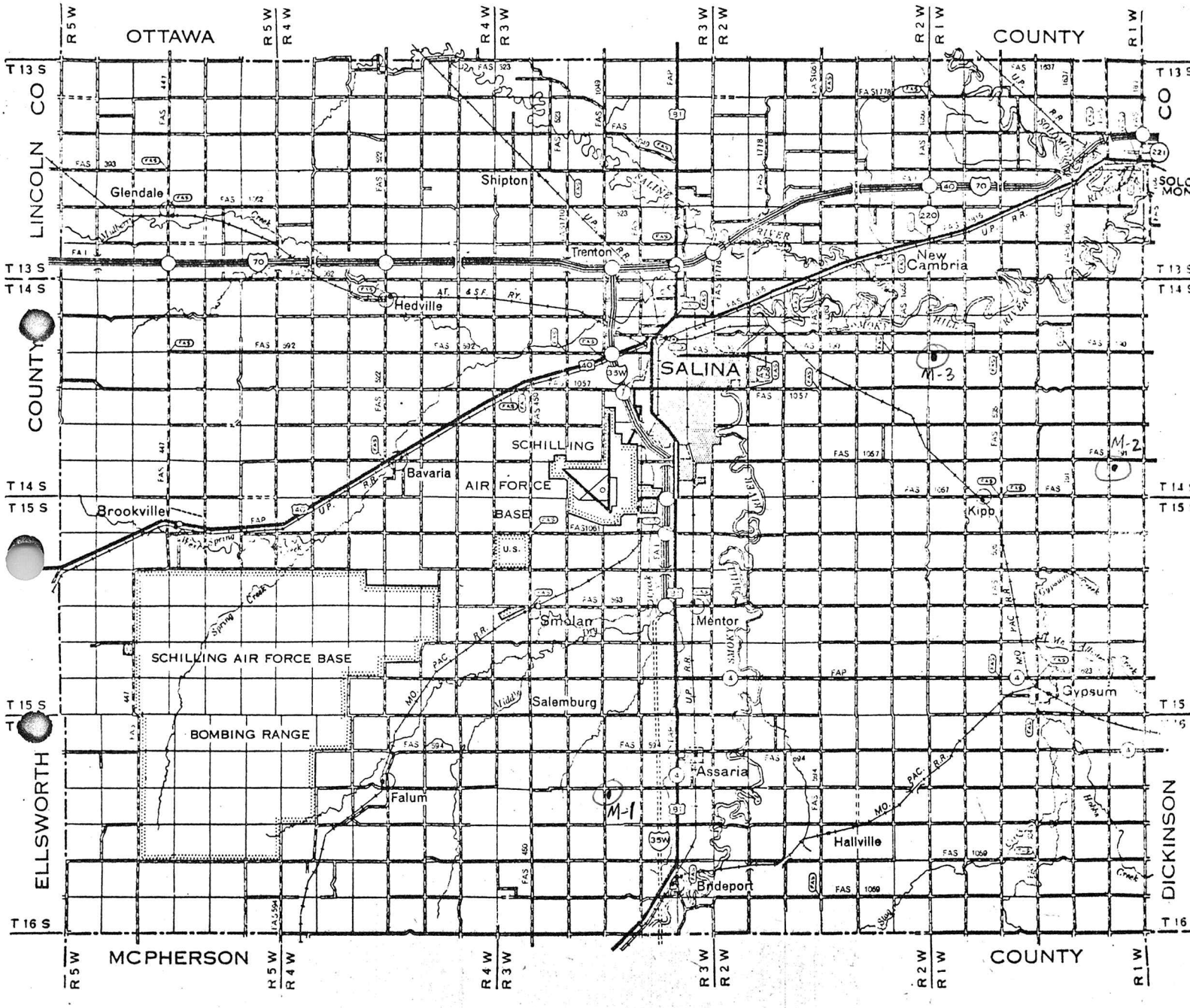


RILEY COUNTY



WASHINGTON COUNTY
KANSAS

1961



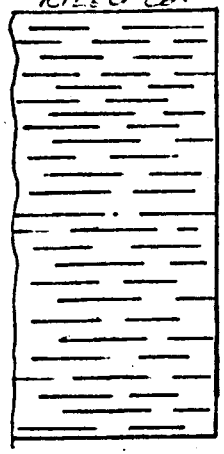
SALINE COUNTY
KANSAS

1963

SCALE

PADDOCK

NE¼ NE¼ SEC 12
T6S R4E
RILEY CO.



	COLOR	ILLITE-MONTMOR.
J-1	GRAY	P

SCALE 1"=5'

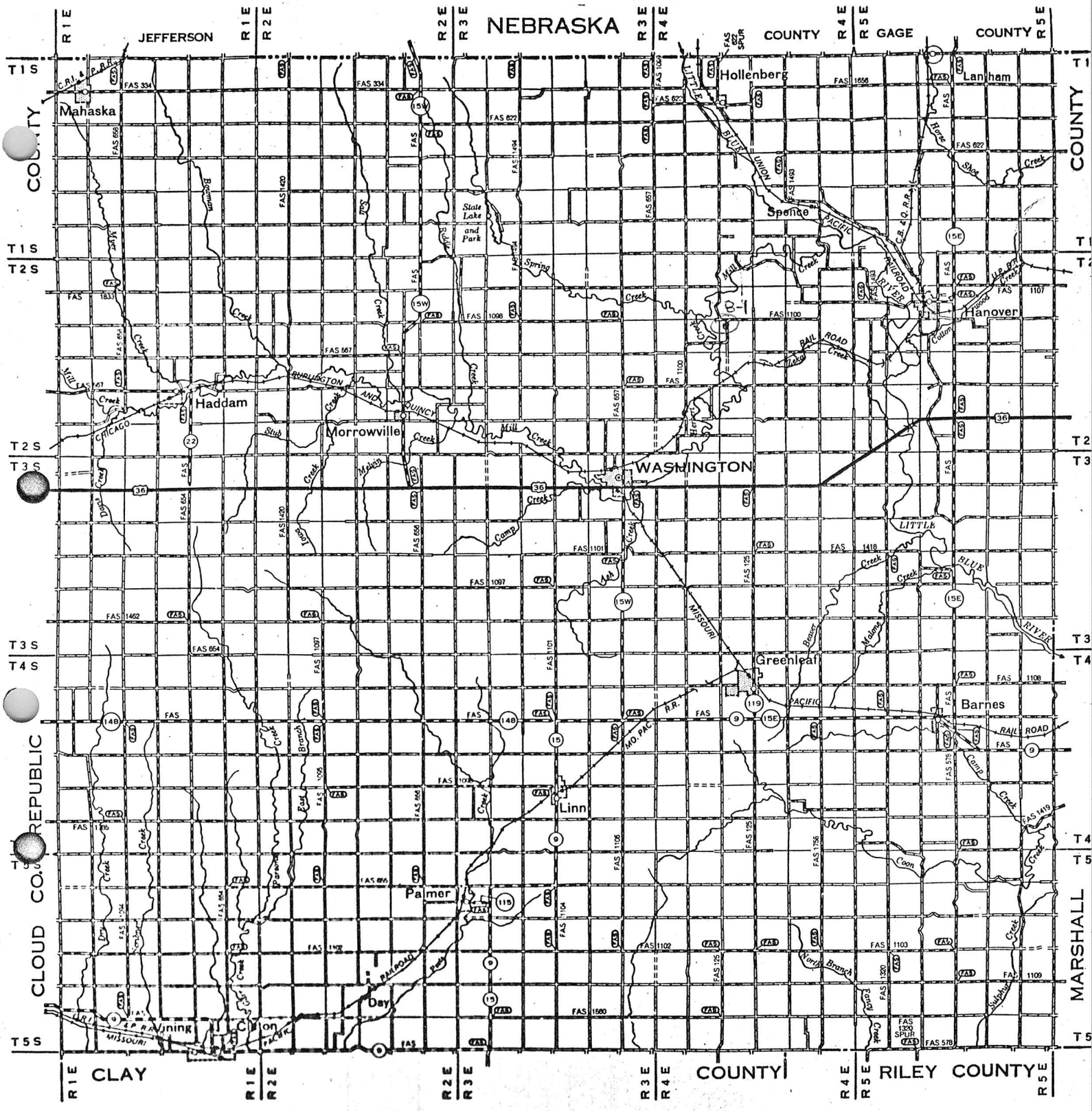
LOCATION	METHOD	SOURCE
J-1 QUARRY NE¼ NE¼ SEC 12, T6S, R4E CHANNEL SAMPLE	DTA	JOHNSON, W.B. [illegible]
B-1 NW¼ SEC 16 T2S R4E	X-RAY	BRYSON, W. R
B-2 SW¼ SEC 13 T7S R5E	X-RAY	"
B-3 SE¼ SEC 36 T7S R5E	X-RAY	"
B-4 SE¼ SEC 25 T7S R4E	"	"
B-5 S LINE SEC 4 T12S R3E	"	"
B-6 CS LINE SEC 13 T15S R5E	"	"
B-7 NW¼ SEC 31 T15S R5E	"	"
B-8 NE¼ SEC 28 T21S R6E	"	"
B-9 SW¼ SEC 26 T18S R4E	"	"

PADDOCK

PADDOCK

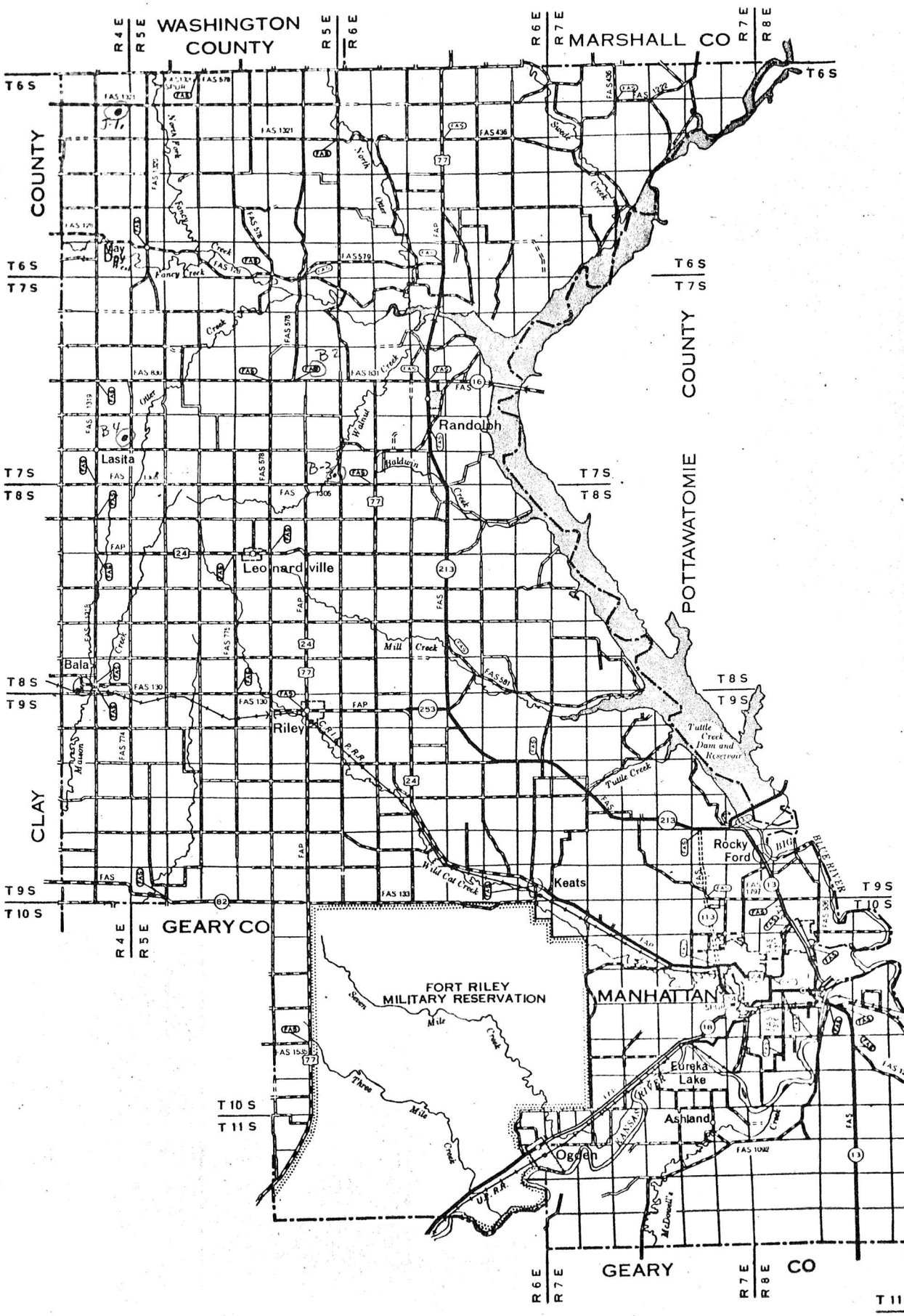
FIGURES IN PERCENT, LOWEST SAMPLE AT BOTTOM. (1:1) RATIO OF INTERLAYERS

		ILLITE	MONTMOR	VERM	CHLORITE	ILLITE MONTMOR	VERM MONTMOR	CHLORITE MONTMOR.	VERMIC CHLORITE	* MONT SWELLING CHL.	
J-1	Sh					Peak					
B-1	Dol-Sh	92	T		7	T		1 (1:5)			
B-2	Dol Sh	83		2	1			14 (1:1)			
	Dol Sh	84		–	3			13 (7:6)			
B-3	Sh	85		T	5	T		6 (3:5) 4 (3:7)			
B-4	Sh	90		1	5			4 (5:7)			
	Sh	91		T	4			7 (3:2)			
B-5	Dol-Sh	73			5	T		22 (1:1)			
B-6	Dol-Sh	82		T	6	T		12 (1:2)			
	Sh	86		–	1	T		13 (1:1)			
	Sh	86		T	2	T		12 (1:1)			
B-7	Sh-Dol	82		T	7	T (7:3)		6 (1:1)			
	Sh	82		–	3	T		15 (1:9)			
B-8	Dol-Sh	51		T	3			45 (3:7)		1	
B-9	Sh	94			2	T	2 (1:1)	2 (1:1)			



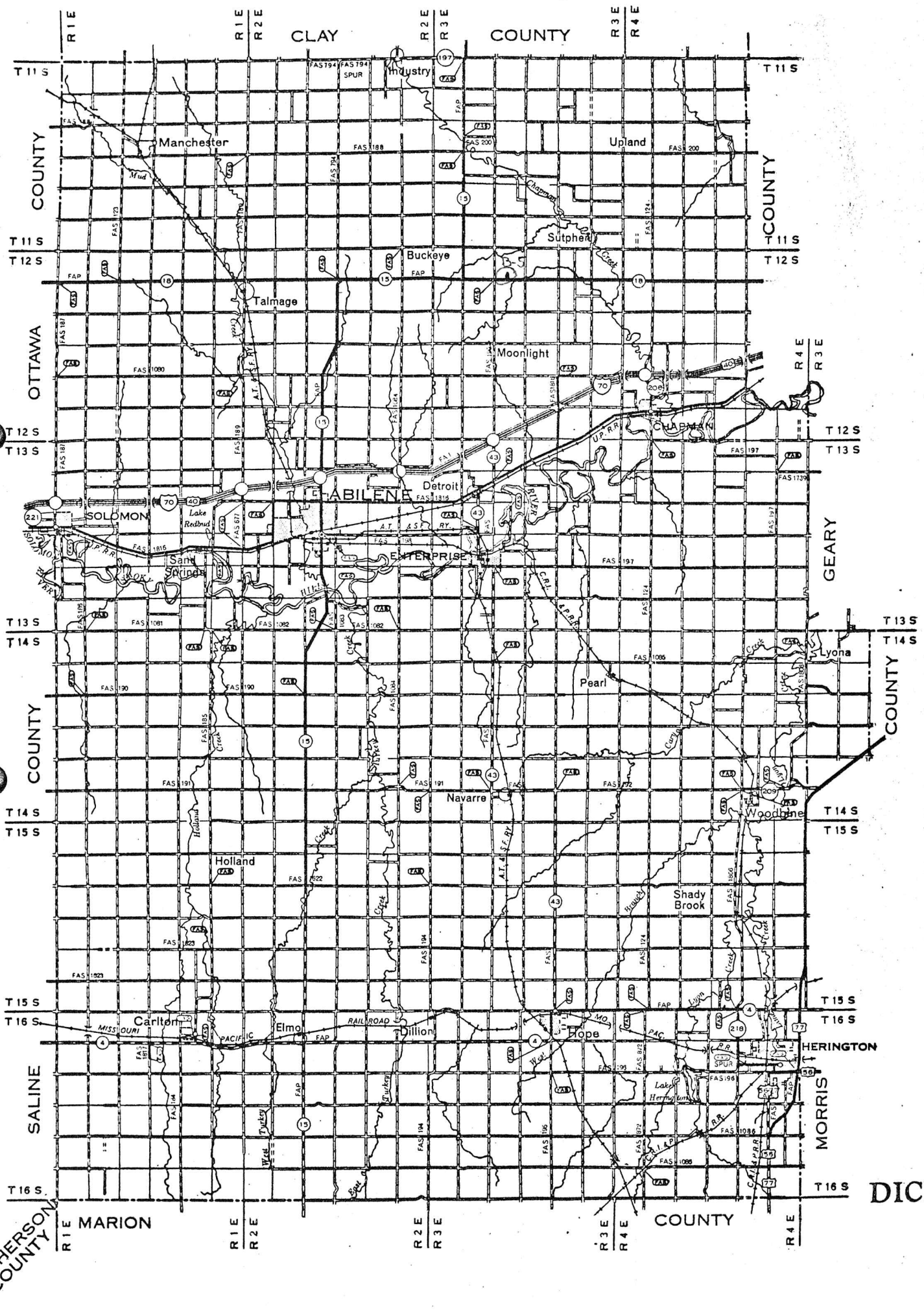
WASHINGTON COUNTY
KANSAS

1961

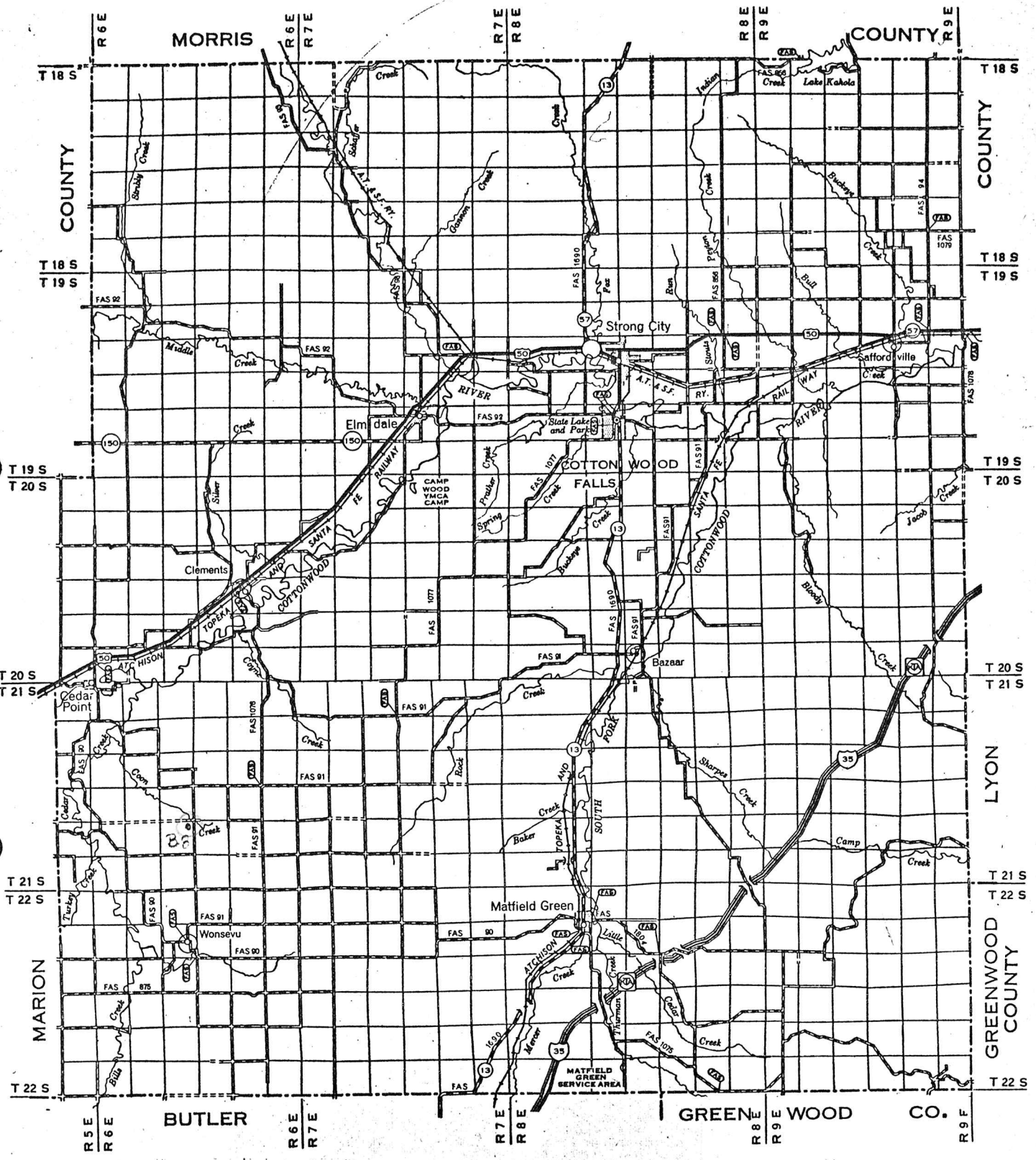


RILEY COUNTY
KANSAS

1963


CLAY COUNTY
OTTAWA COUNTY
GEARY COUNTY
SALINE COUNTY
MARION COUNTY
MORRIS COUNTY
DICKIN
MCPHERSON COUNTY
R1E
R2E
R3E
R4E
T11S
T12S
T13S
T14S
T15S
T16S
Industry
Manchester
Upland
Sutphen
Buckeye
Talmage
Moonlight
CHAPMAN
ABILENE
Detroit
SOLOMON
Lake Redbud
Sand Springs
ENTERPRISE
Lyona
Pearl
Navarre
Woodbine
Holland
Shady Brook
Carlton
Elmo
Dillon
Hope
HERINGTON
Lake Herrington
Mud Creek
Chapman Creek
Holland Creek
Turkey Creek
West Fork
Lyon Creek
Curtis Creek
Shady Brook
Spring Creek
Dry Creek
Rock Creek
Missouri Pacific Railroad
U.P.R.R.
A.T. & S.F. Ry.
C.R.I. & P.R.R.
K.P. Ry.
M.O. P.A.C.
FAS 1794
FAS 1794 SPUR
FAS 188
FAS 200
FAS 124
FAS 197
FAS 1739
FAS 1816
FAS 1080
FAS 1081
FAS 1082
FAS 1084
FAS 1085
FAS 1086
FAS 190
FAS 191
FAS 192
FAS 1522
FAS 1523
FAS 194
FAS 196
FAS 198
FAS 1872
FAS 1806
FAS 1423
FAS 181
FAS 189
FAS 185
FAS 105
FAS 677
FAP
15
18
70
40
43
77
56
218
209
206
221
197

MORRIS COUNTY
KANSAS
1963
GEARY COUNTY
WABAUNSEE COUNTY
DICKINSON COUNTY
MARION CO.
CHASE COUNTY
LYON COUNTY
Skiddy
Dwight
White City
Parkerville
Latimer
Kelso
HERINGTON MUNICIPAL AIRPORT
Council Grove Dam and Reservoir
Council Grove Lake
COUNCIL GROVE
Delavan
Willsey
Helmick
Burdick
Diamond Springs
Dunlap
Lake Kahola
T14S
T15S
T16S
T17S
R5E
R6E
R7E
R8E
R9E

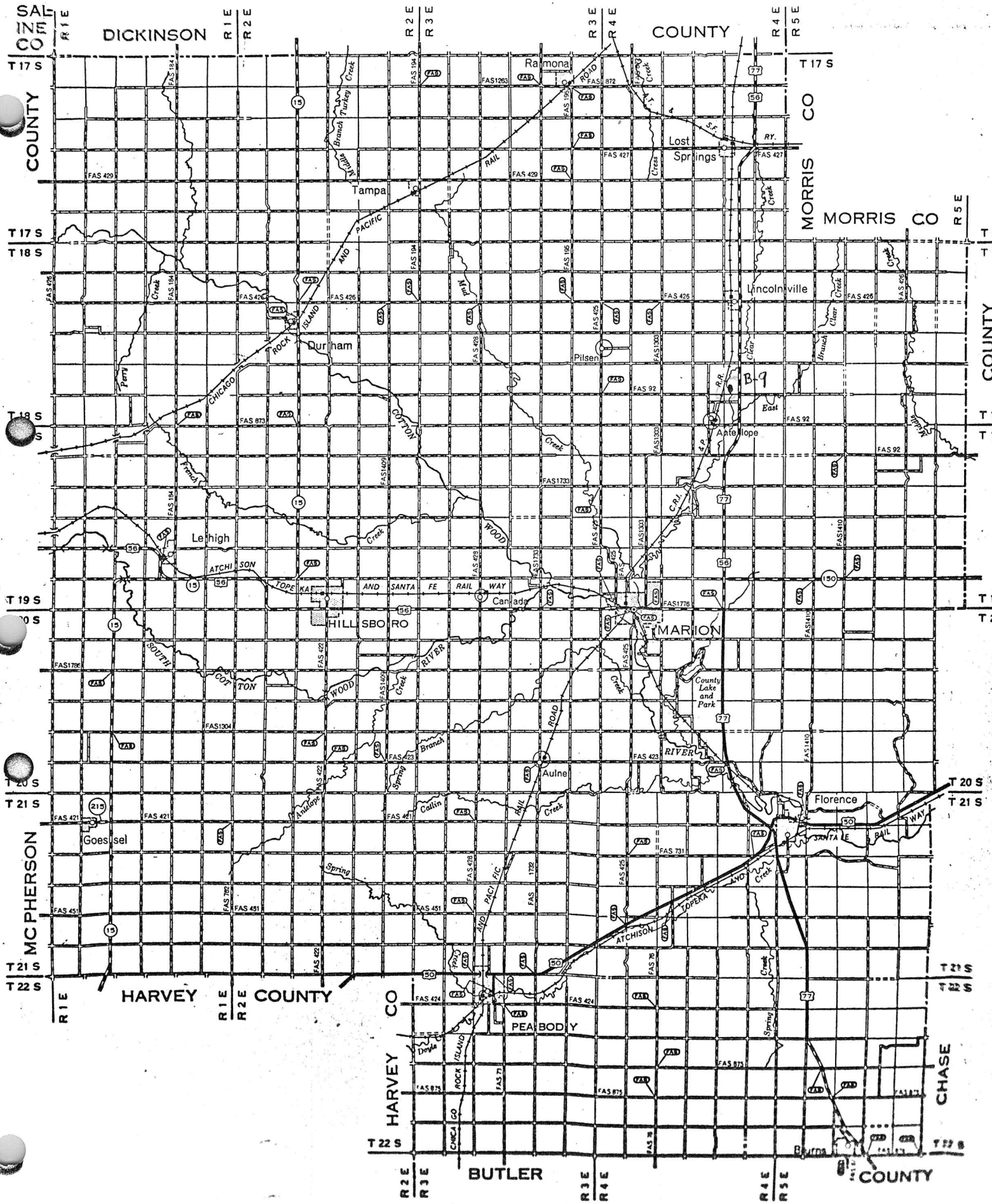


CHASE COUNTY
KANSAS

1959

SCALE

MARION COUNTY



ODELL

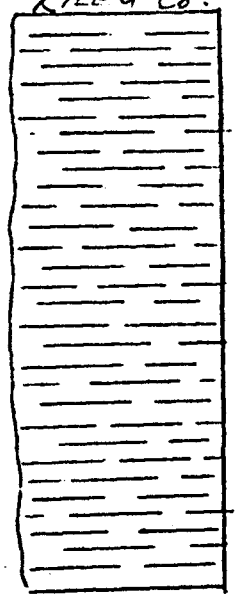
FIGURES IN PERCENT. OLDEST AT BOTTOM. (1:1) RATIO OF INTERLAYERED CLAYS.

		ILLITE	MONTMOR	VERM.	CHLORITE	ILLITE MONT	VERM. MONT	CHLORITE MONT.	* MONT SWELLING CHL
B-1	Dol Sh	79			2 —	T —		6 (1:1) 5 (2:3) 3 (3:7)	5 (1:1)
B-2	Ls-Sh Sh	98 80	T —		1 4		1 (2:3)	16 (1:5	
B-3	Sh Dol-Sh	98 96	— 1		2 3	— T			

ODELL

ODELL

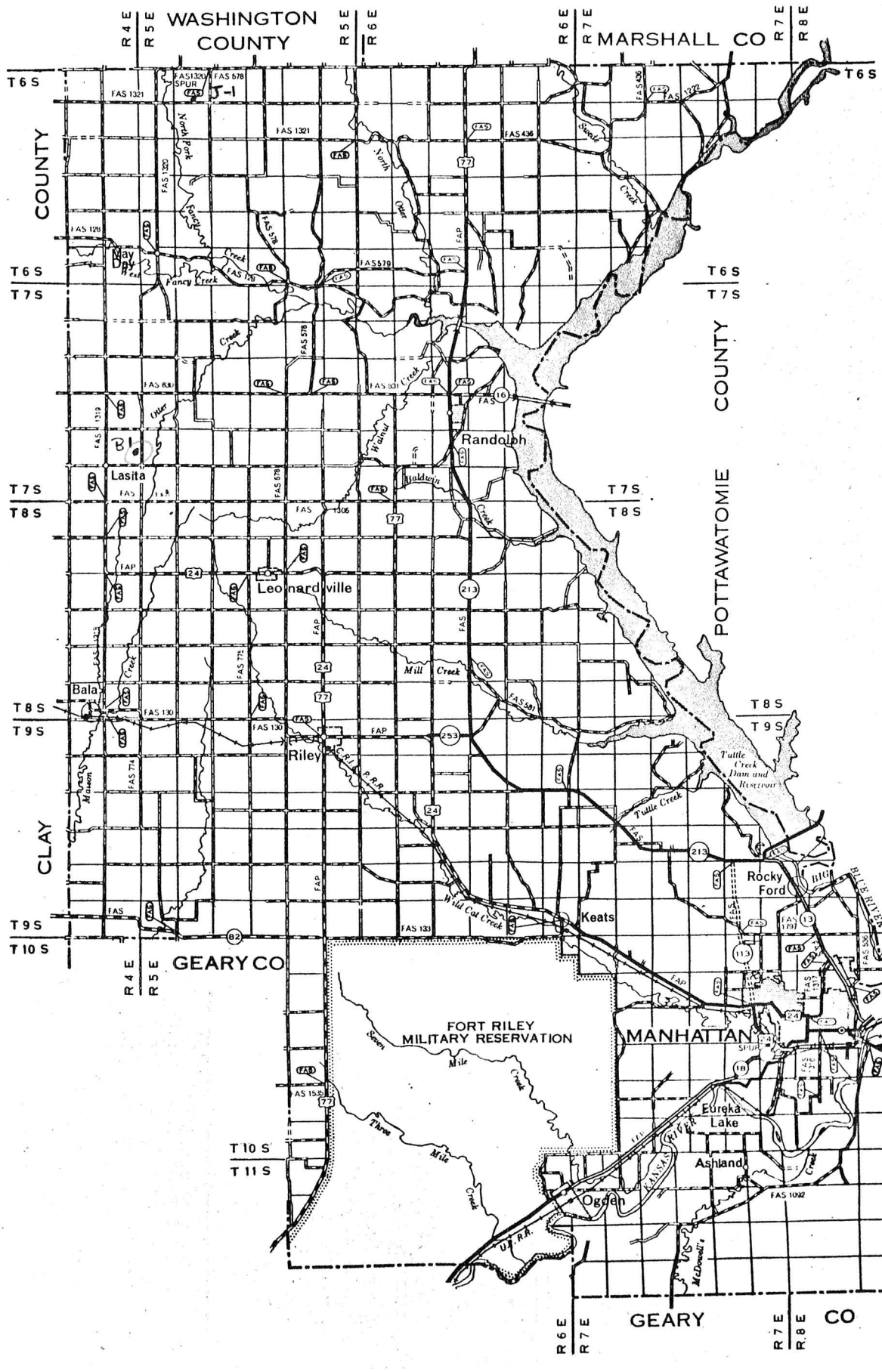
SW¼ SE¼ SEC 5
T6S R5E
RILEY CO.



	COLOR	ILLITE
J-1	RED	MAJOR
	RED	
	GRAY OR YELLOW	

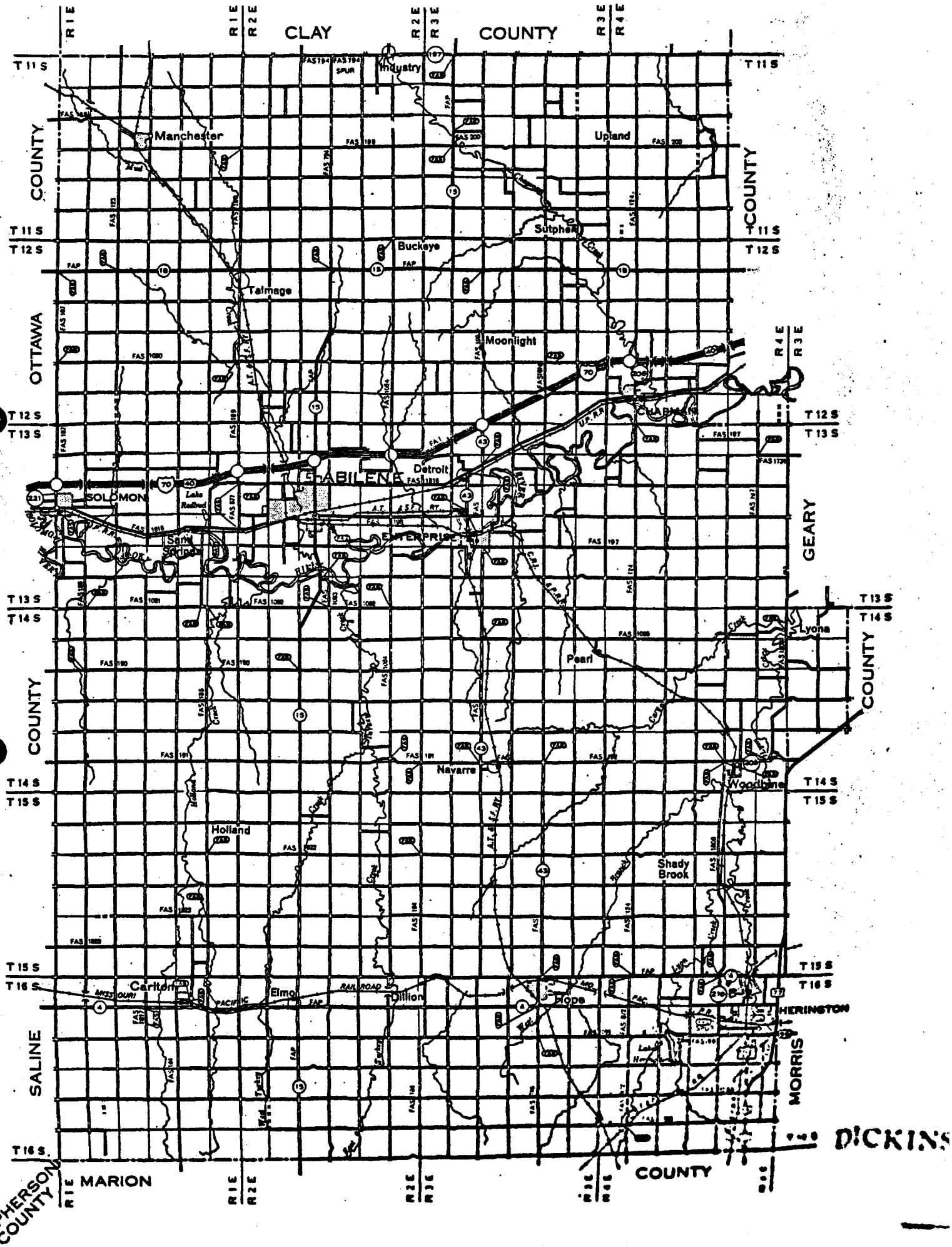
SCALE 1" = 10'

	LOCATION	METHOD	SOURCE
J-1.	ROAD CUT SW¼, SE¼, SEC. 5, T6S, R5E	DTA	JOHNSON, W.B., THE MINERALOGY OF SOME SHALES OF THE KANSAS SYSTEM OF RILEY CO., KS., 1917, 154 THESIS
B-1	SE¼ SEC 25 T7S R4E	X-RAY	BRYSON, W.R.
B-2	NW¼ SEC 2 T16S R4E	X-RAY	"
B-3	NW¼ SEC 14 T15S R6E	X-RAY	"



RILEY COUNTY
KANSAS

1963


CLAY COUNTY
OTTAWA COUNTY
GEARY COUNTY
SALINE COUNTY
MORRIS COUNTY
MARION COUNTY
MCPHERSON COUNTY
DICKINSON COUNTY
R1E
R2E
R3E
R4E
T11S
T12S
T13S
T14S
T15S
T16S
Manchester
Industry
Upland
Sutphen
Buckeye
Talmage
Moonlight
Detroit
ABILENE
SOLOMON
Lake Redbed
Smoky Hill River
Saint Scholastica
ENTERPRISE
CHAPMAN
U.P.R.R.
Lyona
Pearl
Navarro
Woodbine
Holland
Shady Brook
Carlton
Elmo
Dillion
Hope
HERINGTON
Union Pacific Railroad
Missouri Pacific Railroad
A.T. & S.F. RY.

MORRIS COUNTY
KANSAS
1963
GEARY COUNTY
WABAUNSEE COUNTY
DICKINSON CO
MARION CO.
CHASE COUNTY
LYON COUNTY
Skiddy
Dwight
White City
Parkerville
Latimer
Kelso
HERINGTON MUNICIPAL AIRPORT
Council Grove Lake
COUNCIL GROVE
Delavan
Willsey
Helmick
Burdick
Diamond Springs
Dunlap
T 14 S
T 15 S
T 16 S
T 17 S
R 5 E
R 6 E
R 7 E
R 8 E
R 9 E

GRANT

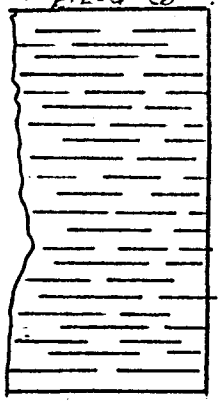
FIGURES IN PERCENT. LOWEST SAMPLE AT BOTTOM. (1:1) RATIO OF INTERLAYERED CLAYS.

		ILLITE	MONT	VERM	CHLORITE	ILLITE MONT.	VERM MONT	CHLORITE MONT	VERM CHLORITE	*MONT SWELLING CHL.
B-1	Sh-Ls	74		1	4	—	2:(1:)	21(1:1)		
	Ls-Sh	78		—	3	T		19(2:3)		
	Ls-Sh	78		—	2	T		16(1:1)	2(1:1)	2(1:1)
B-2	Sh-Doc	74		—	5	T		18(1:1)		3(1:1)
	Doc-Sh	79		1	6	T		14(3:2)		
	Doc Sh	79		1	3	T		14(3:2)		
B-3	Sh Ls	61			1	T	32(2:3)			6(1:1)
B-4	Sh	89	4		4	T		3(2:1)		

GRANT

GRANT

NE¼ NE¼ Sec 1 T9S R4E Pulaski Co



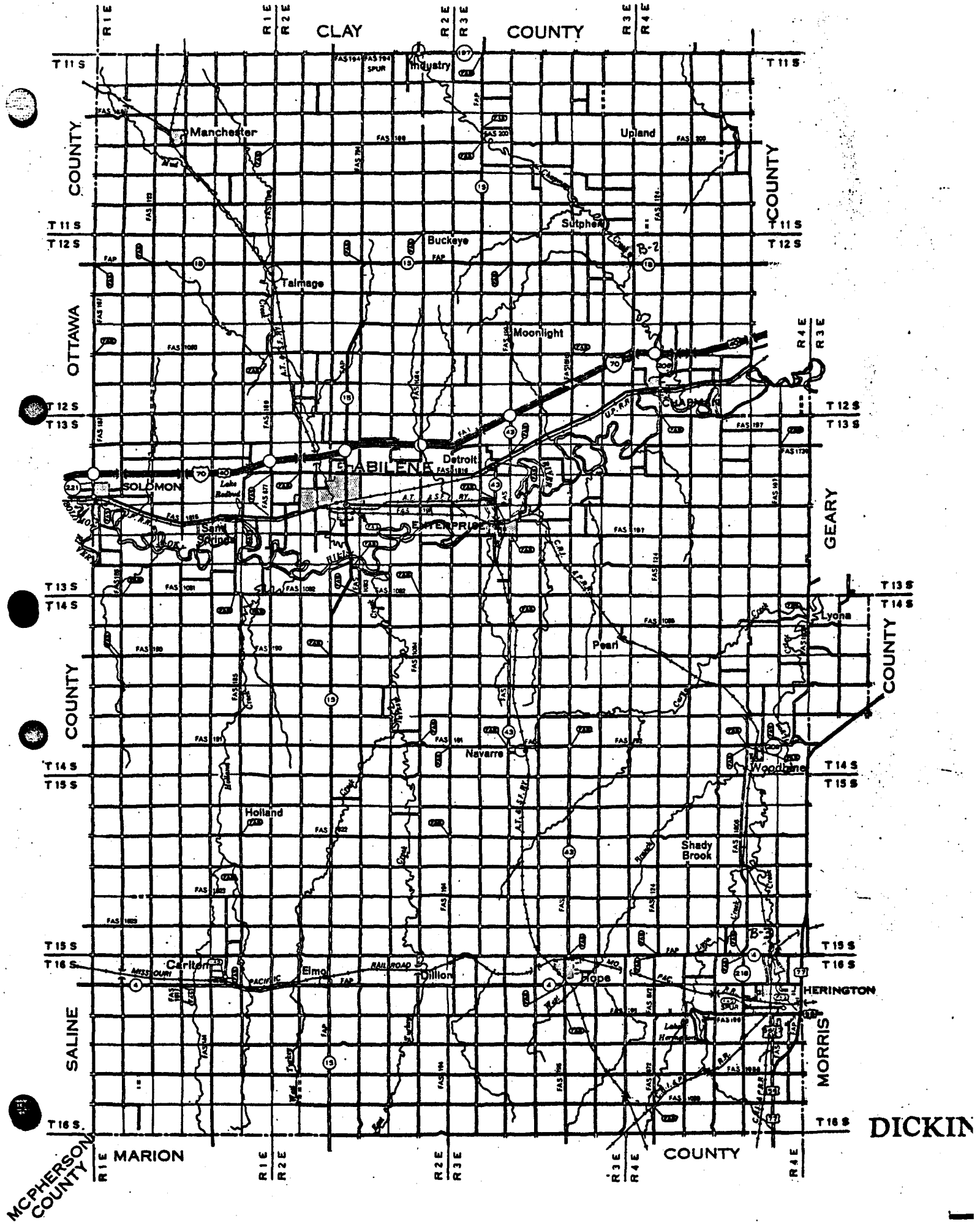
COLOR	ILLITE-MONTMOR.
GRAY	P

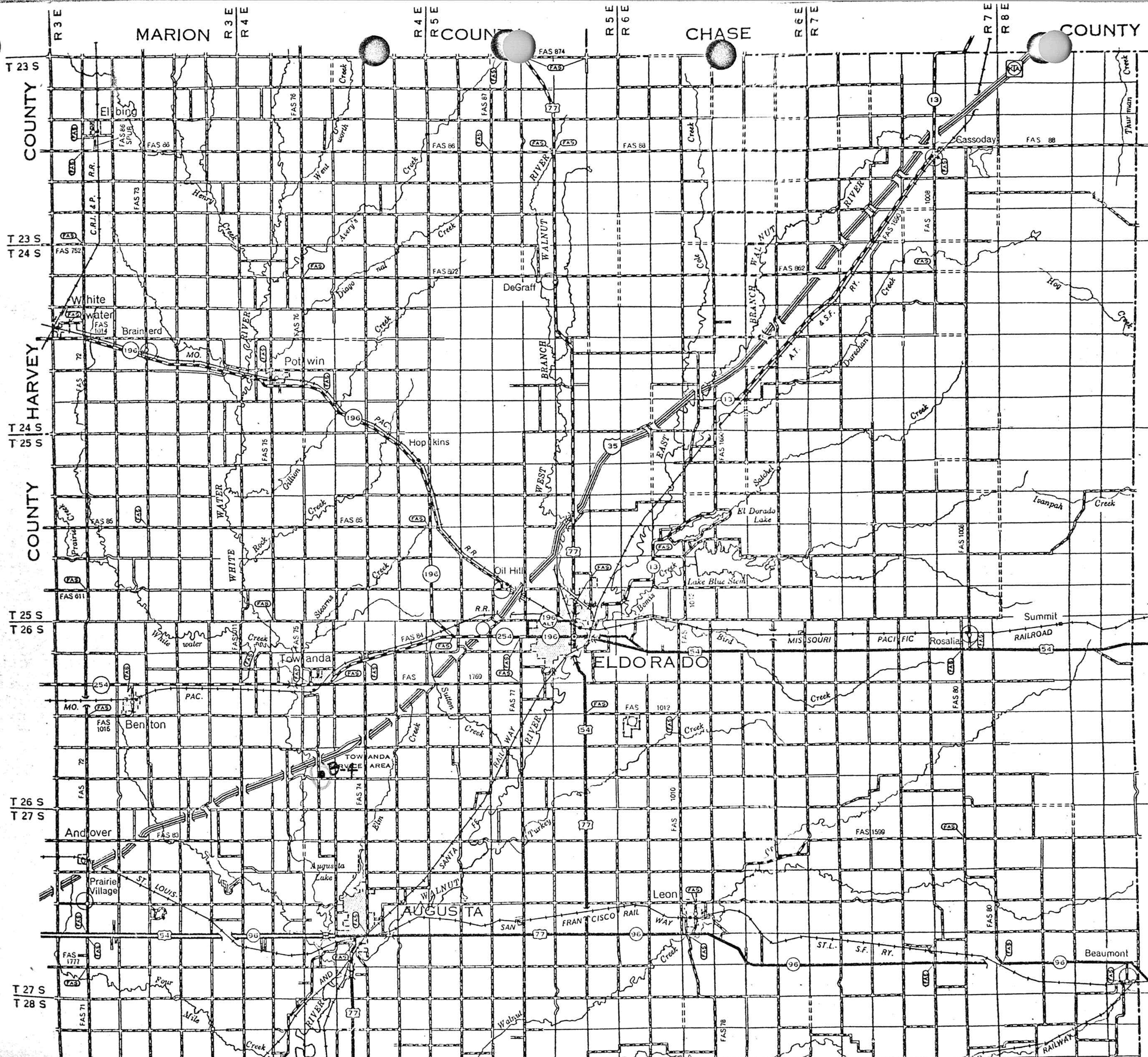
SCALE 1" = 5'

LOCATION	METHOD	SOURCE
J-1 RAILROAD CUT NE¼ NE¼, SEC 1, T9S R4E CHANNEL SAMPLE	DTA	JOHNSON, W.B., [illegible]
B-1 CN LINE SEC 1 T9S R4E	X-RAY	BRUSON, W.R.
B-2 SE ¼ SEC 1 T12S R3E	"	"
B-3 SE ¼ SEC 35 T15S R4E	"	"
B-4 CS LINE SEC 28 T26S R4E	"	"

RILEY COUNTY
KANSAS

18


CLAY COUNTY
Industry
Manchester
Upland
Sutphen
Buckeye
Talmage
Moonlight
OTTAWA COUNTY
ABILENE
Detroit
SOLOMON
Lake Bedford
Saint Springs
ENTERPRISE
Pearl
Lyons
GEARY COUNTY
Navarre
Woodbine
Holland
Shady Brook
Carlton
Elmo
Dillon
Hope
HERINGTON
SALINE COUNTY
MORRIS COUNTY
MARION COUNTY
MCPHERSON COUNTY
DICKIN
T11S
T12S
T13S
T14S
T15S
T16S
R1E
R2E
R3E
R4E



BUTLER COUNTY

GAGE

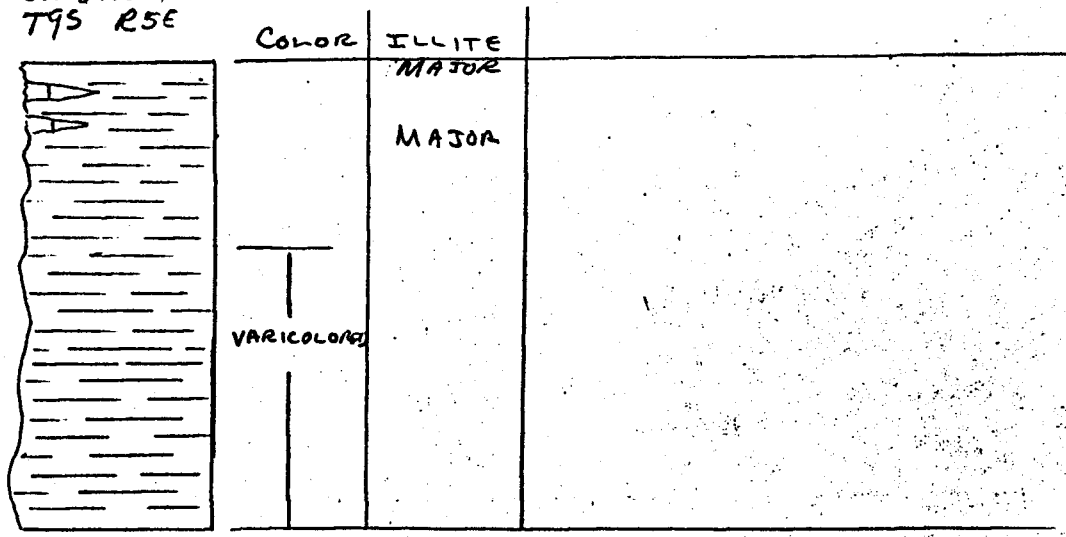
FIGURES IN PERCENT. LOWEST SAMPLE AT BOTTOM.. RATIO OF INTERLAYERED CLAYS (1:3)

		ILLITE	MONT	VERM	CHLORITE	ILLITE MONT	VERM MONT	CHLORITE MONT	VERM CHLORITE	MONT SWELLING CHL.
B-1	Sh	75	—	1	5	T		14(4:5)	6(1:7)	
	Sh	81	4	—	4	T		10(1:1)	—	
B-2	Sh	81			2	T		18(1:1)		
B-3	Sh Dol	79			3			16(1:1)		2(1:1)
B-4	Ls Sh	44	—	—	—	T	—	—	—	56(1:1)
	Ls Sh	88	—	—	1	T	11(2:7)	—	—	—
	Dol	83	15	T	2	T	T	—	—	—
	Ls Sh	73	3	2	2	7(7:2)	16(1:7)	—	—	—
	Ls Sh	86	10	1	3	—	—	T	T	—
	Ls Sh	85	10	T	4	T		1(1:7)	—	—
B-5	Sh	97	1		2	T		—		
	Sh	52	—		3	—		45(2:1)		

GAGE

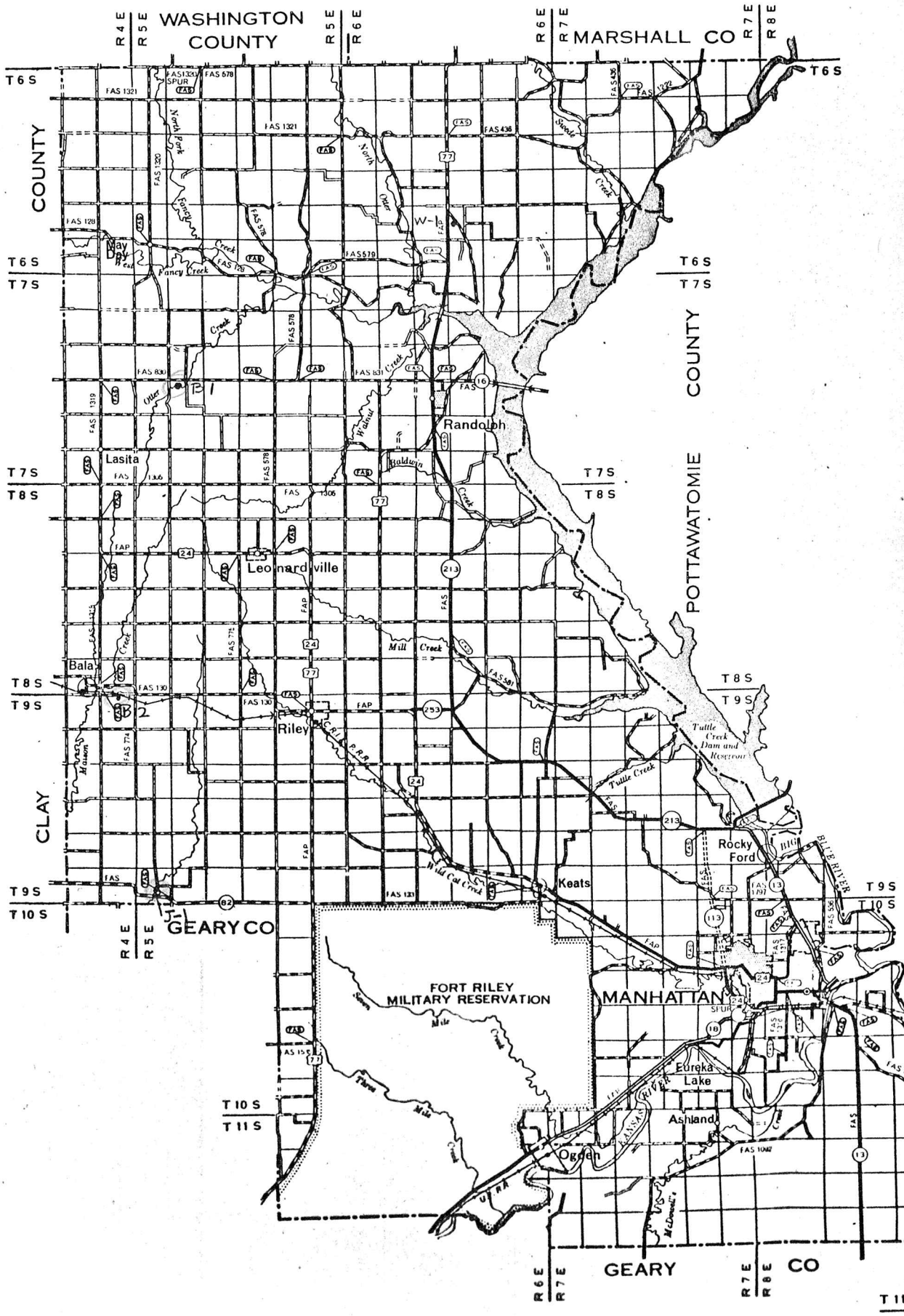
GAGE

SW¼ NE¼ Sec 31
T9S R5E



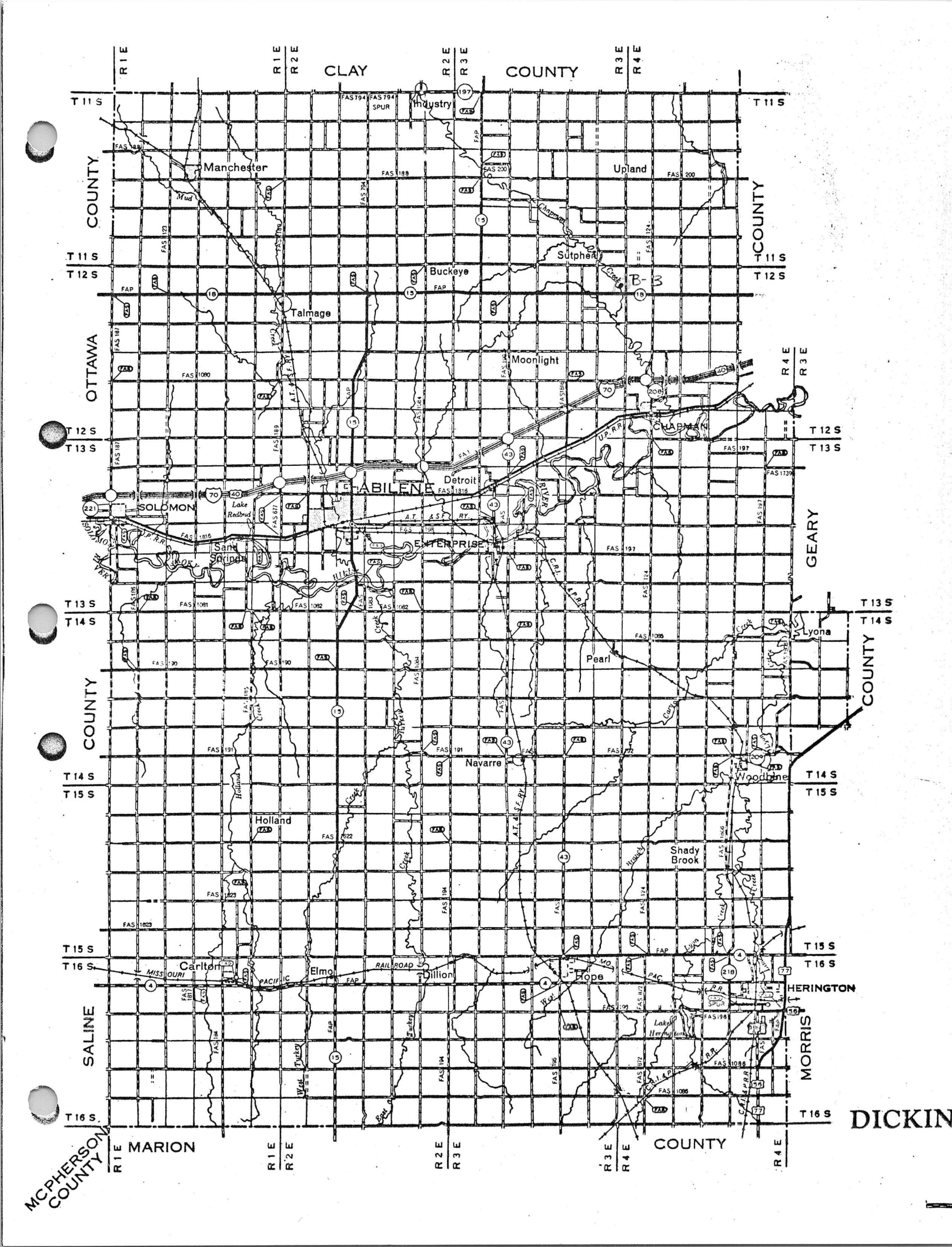
SCALE 1"=20'

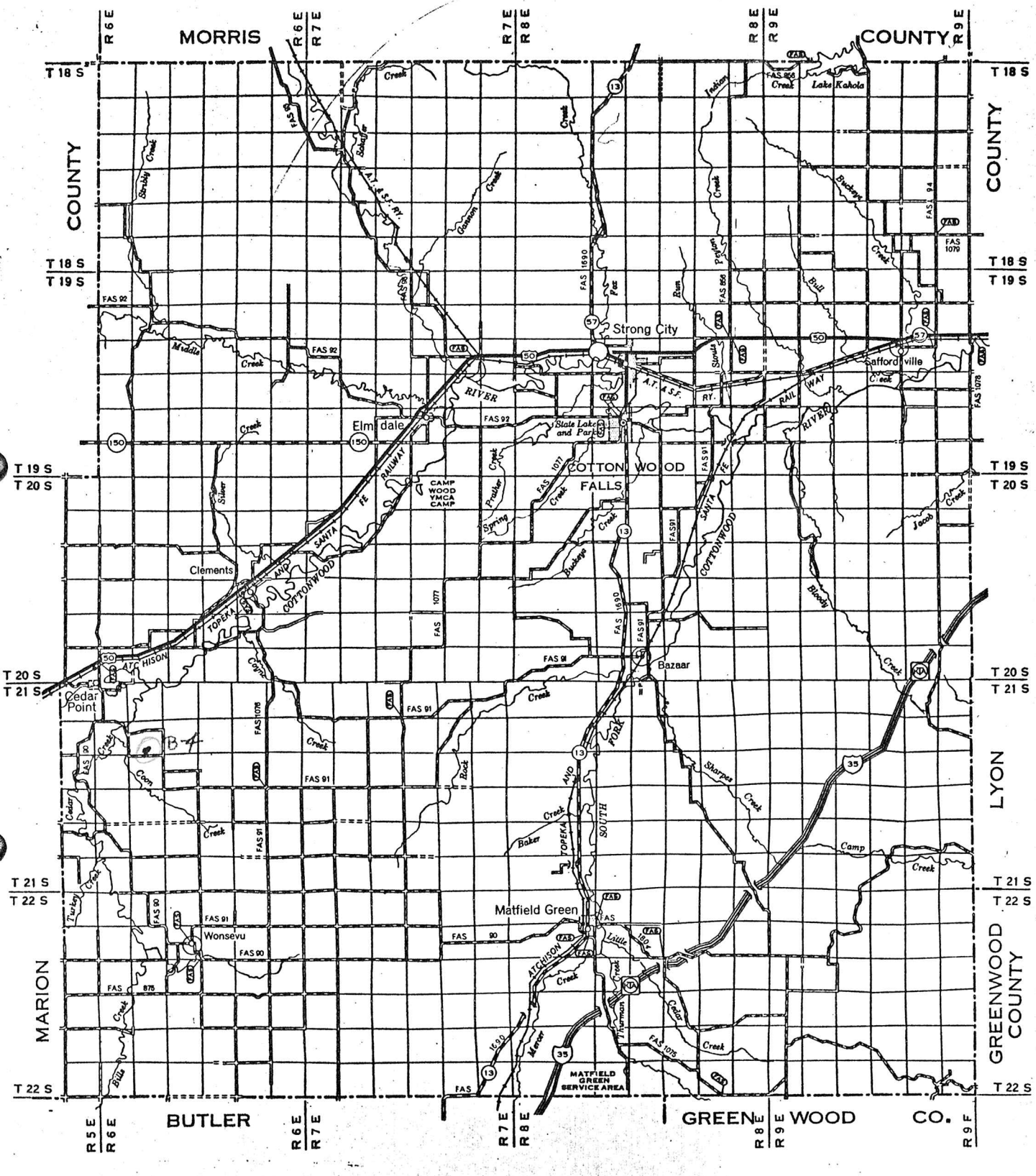
	LOCATION	METHOD	SOURCE
J-1	ROAD CUT SW¼, NE¼, SEC. 31, T9S, R5E	DTA	JOHNSON, W.B.
W-1	NW¼ SW¼ SEC 27 T6S R6E	DTA	WATERMAN, W.D.
B-1	NW¼ SEC 20 T9S R5E	X-RAY	BRYSON, W.E.
B-2	CN LINE SEC 1 T9S R4E	"	"
B-3	SE¼ SEC 1 T12S R3E	"	"
B-4	CS LINE SEC 8 T21S R6E	"	"
B-5	CS LINE SEC 28 T26S R4E	"	"



RILEY COUNTY
KANSAS

1963

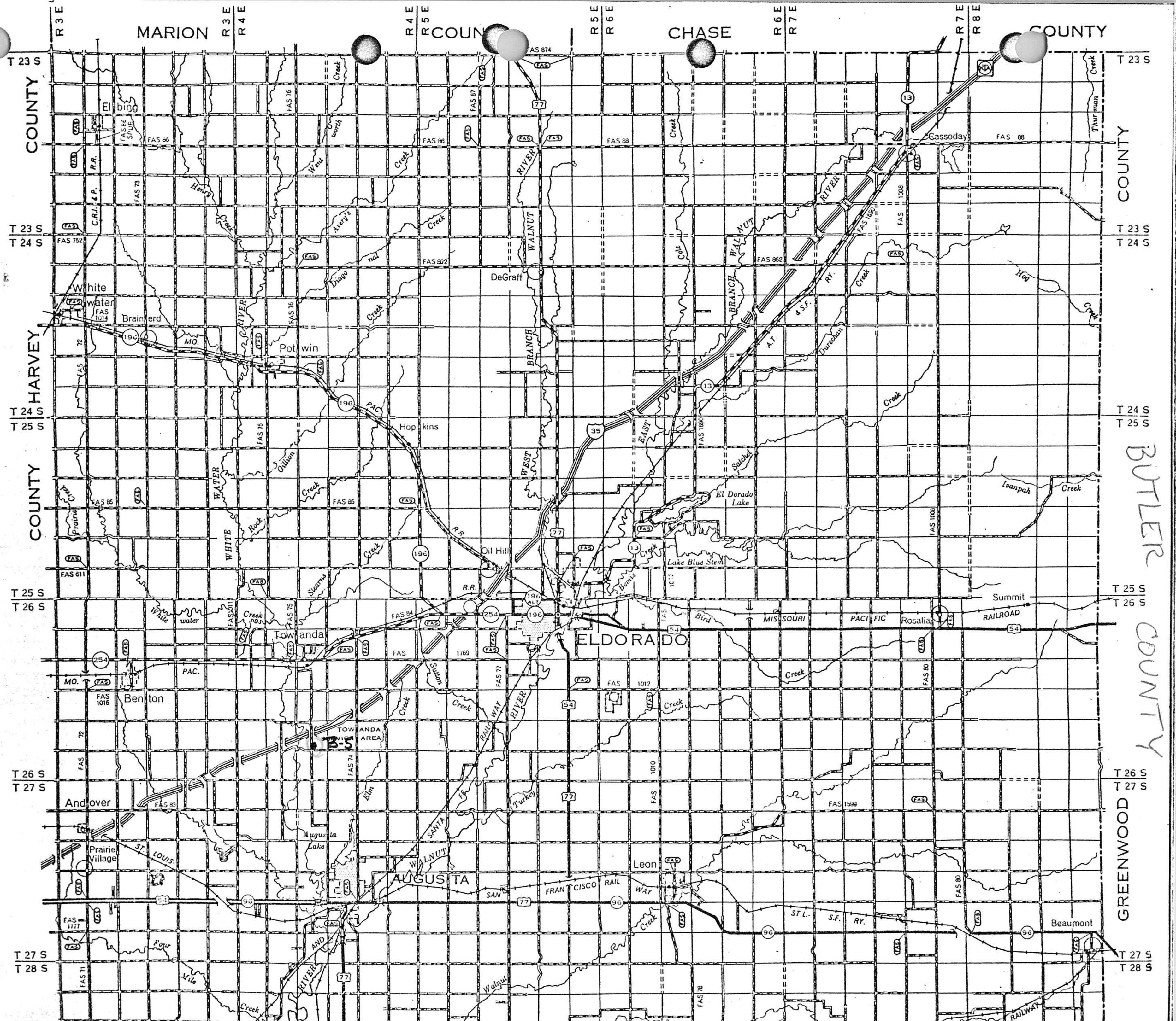

CLAY COUNTY
OTTAWA COUNTY
GEARY COUNTY
SALINE COUNTY
MORRIS COUNTY
MARION COUNTY
MCPHERSON COUNTY
DICKIN
Industry
Manchester
Upland
Sutphen
Buckeye
Talmage
Moonlight
CHAPMAN
Detroit
ABILENE
SOLOMON
Lake Redbud
Sand Springs
ENTERPRISE
Lyona
Pearl
Navarre
Woodbine
Holland
Shady Brook
Carlton
Elmo
Dillon
Hope
HERINGTON
Lake Herington
Mud Creek
Chapman Creek
Turkey Creek
Holland Creek
Lyon Creek
Shady Creek
Curtis Creek
Stranger Creek
Missouri Pacific Railroad
Union Pacific Railroad
U.P. R.R.
A.T. & S.F. RY.
C.R.I. & P. R.R.
T11S
T12S
T13S
T14S
T15S
T16S
R1E
R2E
R3E
R4E
B-3



CHASE COUNTY
KANSAS

1959

SCALE


MARION COUNTY
CHASE COUNTY
HARVEY COUNTY
GREENWOOD COUNTY
BUTLER COUNTY
R 3 E
R 4 E
R 5 E
R 6 E
R 7 E
R 8 E
T 23 S
T 24 S
T 25 S
T 26 S
T 27 S
T 28 S
Elbing
White water
Brainerd
Potwin
Hopkins
DeGraff
Cassoday
Oil Hill
Towanda
Benton
Andover
Prairie Village
Augusta Lake
AUGUSTA
ELDORADO
El Dorado Lake
Lake Blue Stem
Summit
Rosalia
Leon
Beaumont
TOWANDA SERVICE AREA
B-5
MISSOURI PACIFIC RAILROAD
ST. LOUIS SAN FRANCISCO RAILWAY
ST.L.-S.F. RY.
A.T. & S.F. RY.
SANTA FE RAILWAY
C.R.I. & P. R.R.
MO. PAC.
WALNUT RIVER
WEST BRANCH WALNUT RIVER
EAST BRANCH WALNUT RIVER
WHITE WATER RIVER
Henry Creek
Wentworth Creek
Avery's Creek
Diagonal Creek
Cole Creek
Durechan Creek
Hog Creek
Thurman Creek
Satchel Creek
Ivanpah Creek
Gillion Creek
Rock Creek
Prairie Creek
Stearns Creek
Sutton Creek
Elm Creek
Turkey Creek
Bemis Creek
Bird Creek
Four Mile Creek
Walnut
FAS 874
FAS 87
FAS 86
FAS 86 SPUR
FAS 88
FAS 73
FAS 76
FAS 752
FAS 862
FAS 1014
FAS 72
FAS 75
FAS 85
FAS 611
FAS 84
FAS 1769
FAS 77
FAS 1016
FAS 74
FAS 83
FAS 1012
FAS 1010
FAS 1599
FAS 1008
FAS 1006
FAS 1680
FAS 80
FAS 1777
FAS 71
FAS 78
KTA
13
35
77
196
196 ALT
254
54
96

HOLMESVILLE

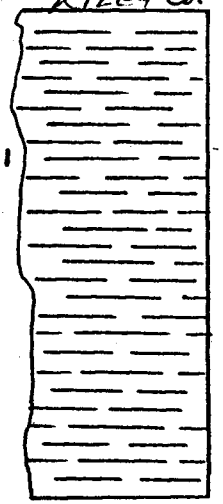
FIGURES ARE IN PERCENT. LOWEST SAMPLES AT BOTTOM. RATIO OF INTERLAYERED CLAYS (I:I)

		ILLITE	MONT	VERM	CHLORITE	ILLITE MONT.	VERM MONT	ILLITE CHLORITE		
B-1	Sh Ls	89	9	2	—	T	T			
	Sh	97	1	—	1	T	2(3:7)			
	Sh	98	T	2	T	T	—			
	Sh	98	—	T	2	T	—			
B-2	Sh	87	—	—	—	1 (7:1)	7(4:3)	5(1:1)		
	Sh	95	T	T	5	T	—	T		
	Sh	98	—	—	2	T	—	—		
B-3	Sh	58	42	—	—	T	—			
	Sh	93	—	2	1	—	4			
	Ls	94	1	2	3	—	T			
	Sh	98	—	T	2	—	—			
B-4	Dol-Sh	75	19		6	—				
	Sh-Dol	87	9		2	2(7:1)				
B-5	Sh	84	12	2	1	1(8:1)				

HOLMESVILLE

HOLMESVILLE

SE¼SW¼ SEC18
T7S R6E
RILEY Co.



	COLOR	ILLITE-MONTMOR	ILLITE
W-1	GRAY TO VARI-COLORED	P	MAJOR

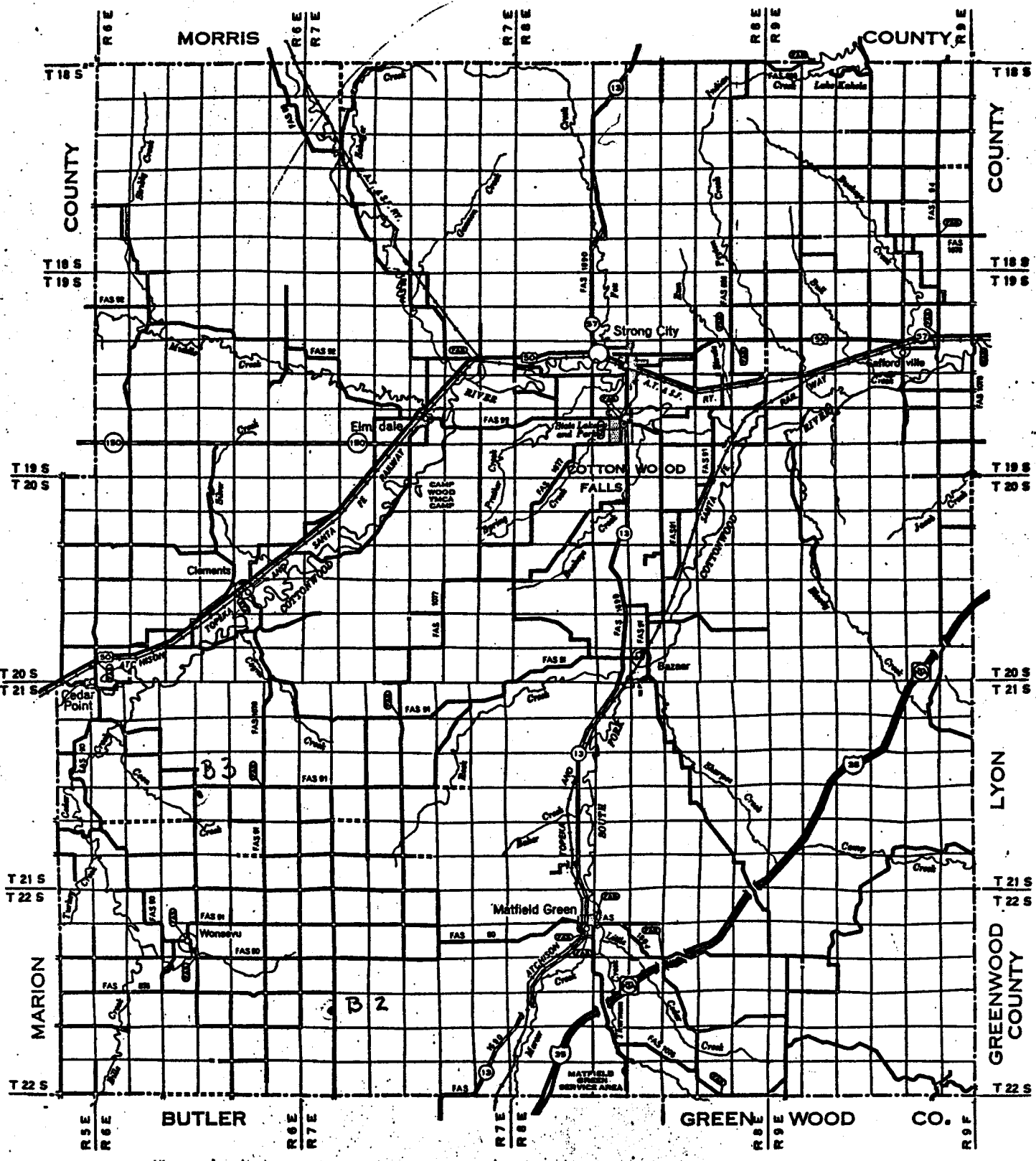
SCALE 1" = 10'

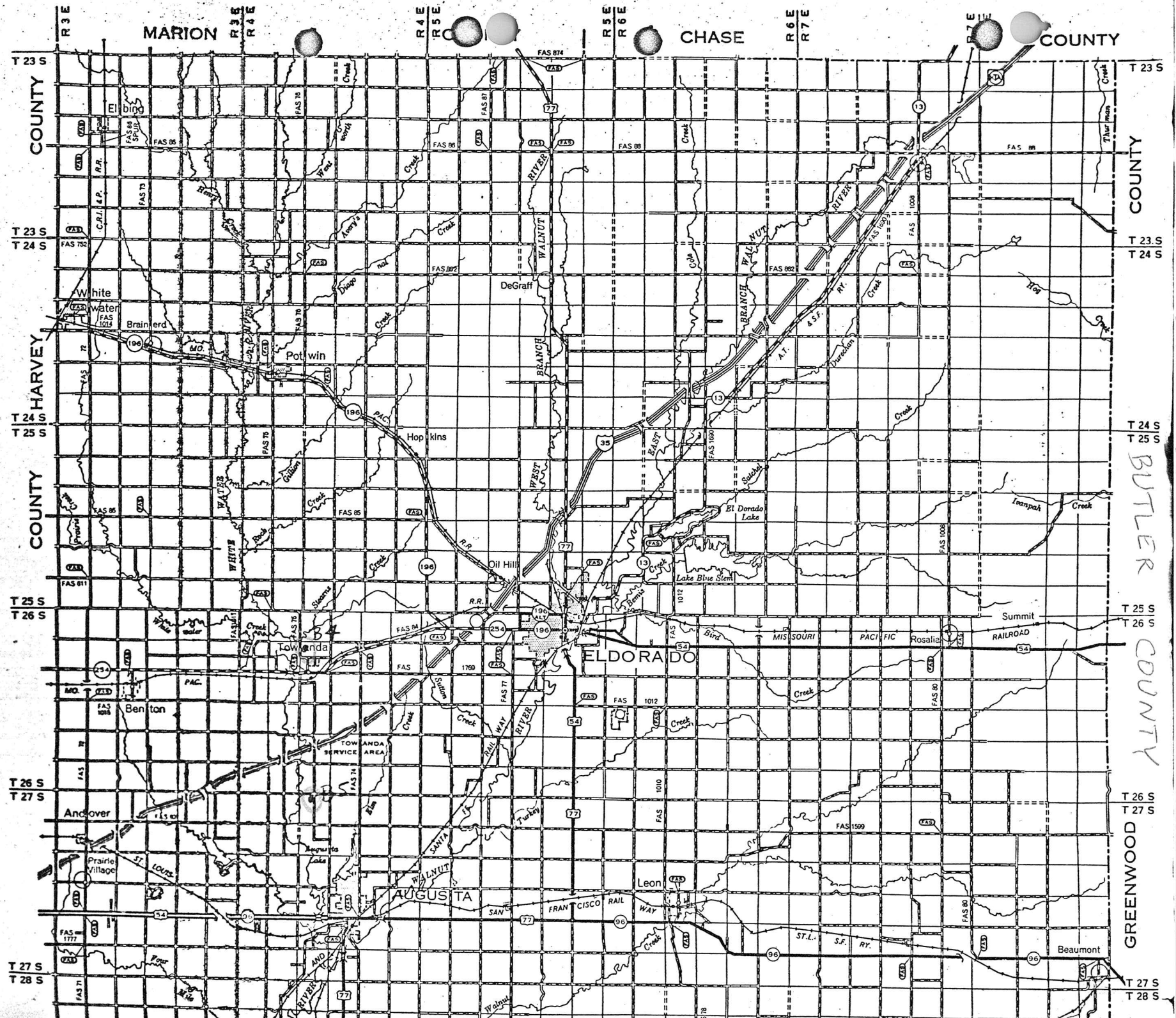
	LOCATION	METHOD	SOURCE
J-1	ROAD CUT SE¼, SW¼, SEC 18, T7S, R6E CHANNEL SAMPLE	DTA	JOHNSON, W.D. The Mineralogy of Some Shales of the [illegible] System of Riley Co. Ks, 1949 KU Thesis
W-1	NW¼ NE¼ SEC 22 T9S R6E	DTA	WATERMAN, W.D.
B-1	C SEC 17 T9S R5E	X-RAY	BRYSON, W.R.
B-2	CE LINE SEC 19 T22S R7E	"	"
B-3	NW¼ SEC 23 T21S R6E	"	"
B-4	NW¼ SEC 9 T26S R4E	"	"
B-5	NE¼ SEC 4 T27S R4E	"	"

RILEY COUNTY
KANSAS

1961

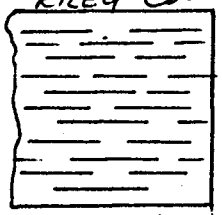
18


MORRIS COUNTY
COUNTY
COUNTY
LYON COUNTY
GREENWOOD COUNTY
MARION COUNTY
BUTLER COUNTY
GREEN WOOD CO.
R5E
R6E
R7E
R8E
R9E
R9F
T 18 S
T 19 S
T 20 S
T 21 S
T 22 S
Strong City
Elmdale
COTTONWOOD FALLS
Clements
Cedar Point
Bazaar
Matfield Green
Wonsevu
B1
B2
B3
MATFIELD GREEN SERVICE AREA
CHASE COUNTY
KANSAS
1959


MARION COUNTY
CHASE COUNTY
HARVEY COUNTY
BUTLER COUNTY
GREENWOOD COUNTY
R3E
R4E
R5E
R6E
R7E
T 23 S
T 24 S
T 25 S
T 26 S
T 27 S
T 28 S
Elbing
White water
Brainerd
Potwin
DeGraff
Hopkins
Oil Hill
Towanda
ELDORADO
El Dorado Lake
Lake Blue Stem
Summit
Rosalia
Benton
Andover
Prairie Village
AUGUSTA
Leon
Beaumont
MISSOURI PACIFIC RAILROAD
SANTA FRANCISCO RAILWAY
ST.L.-S.F. RY.
WALNUT RIVER
WHITE WATER
BRANCH
Duran
Ivanpah Creek
Thurman Creek
Hog Creek
Bemis Creek
Stucker Creek
Gilson Creek
Diamond Creek
Avery's Creek
Prairie Creek
Turkey Creek
Augusta Lake
TOWANDA SERVICE AREA
FAS 874
FAS 86
FAS 88
FAS 752
FAS 1014
FAS 892
FAS 1600
FAS 1599
FAS 1008
FAS 1012
FAS 1010
FAS 1769
FAS 1777
FAS 611
FAS 84
FAS 85
FAS 80
FAS 71
FAS 73
FAS 76
FAS 77
FAS 87
FAS 88 SPUR
FAS 1008 SPUR
77
13
35
254
196
54
96
MO. PAC.
A.T. & S.F. RY.
C.R.I. & P. R.R.

OKETO

NE¼ NE¼ Sec 12
T9S R6E
Riley Co.

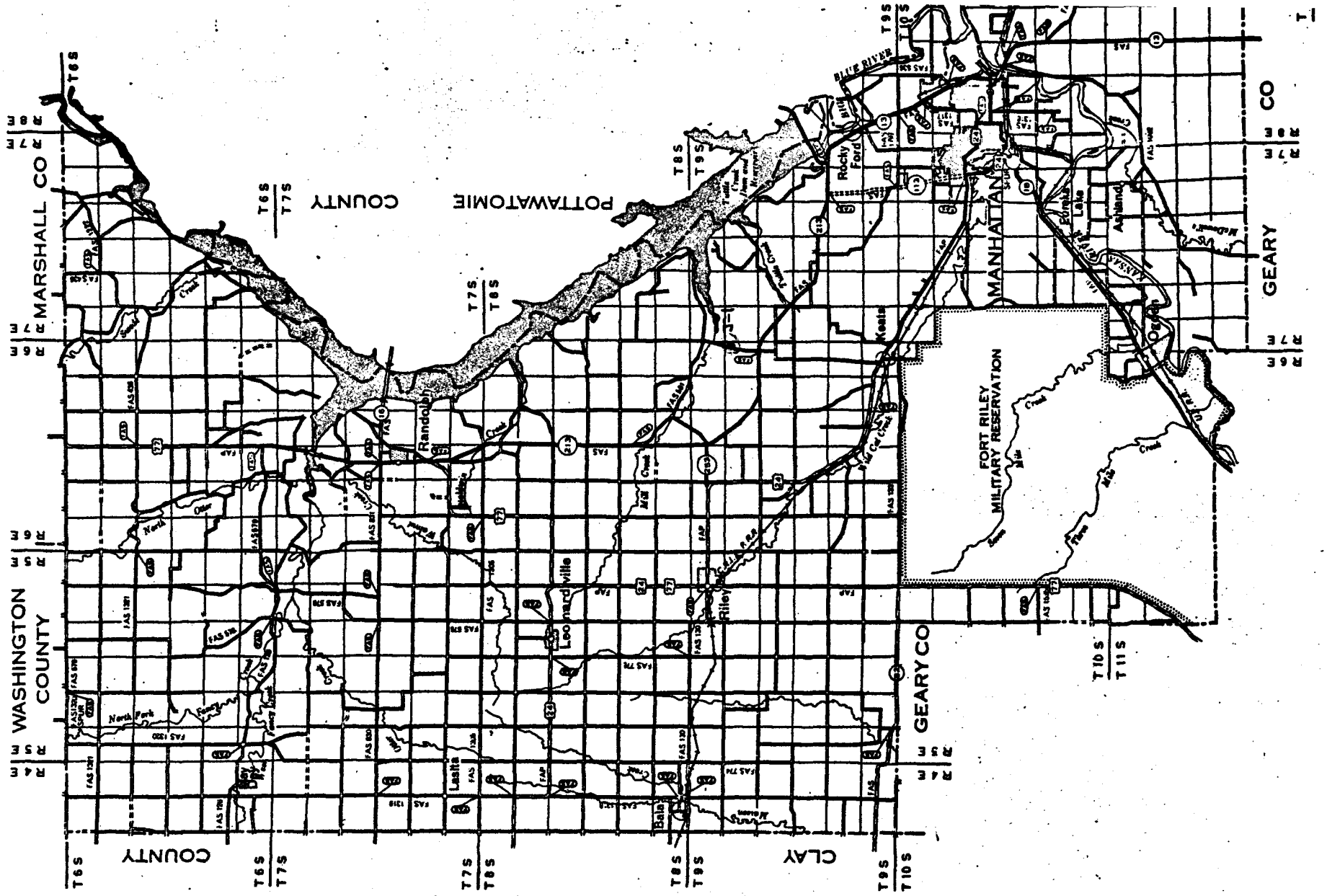


Color	Illite	
Gray	Major	

Scale 1"=5'

	Location	Method	Source
J-1	Road Cut NE¼, NE¼ Sec. 12, T9S, R6E Channel Sample	DTA	Johnson, W.B. The mineralogy of some shales of the lower Permian System of Riley Co., Ks. [illegible]

OKETO

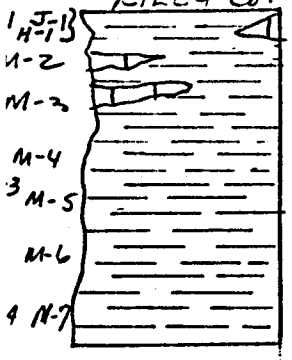


RILEY COUNTY
KANSAS

1963

BLUE SPRINGS

NW¼ NW¼ Sec 26 T9S R6E Riley Co.

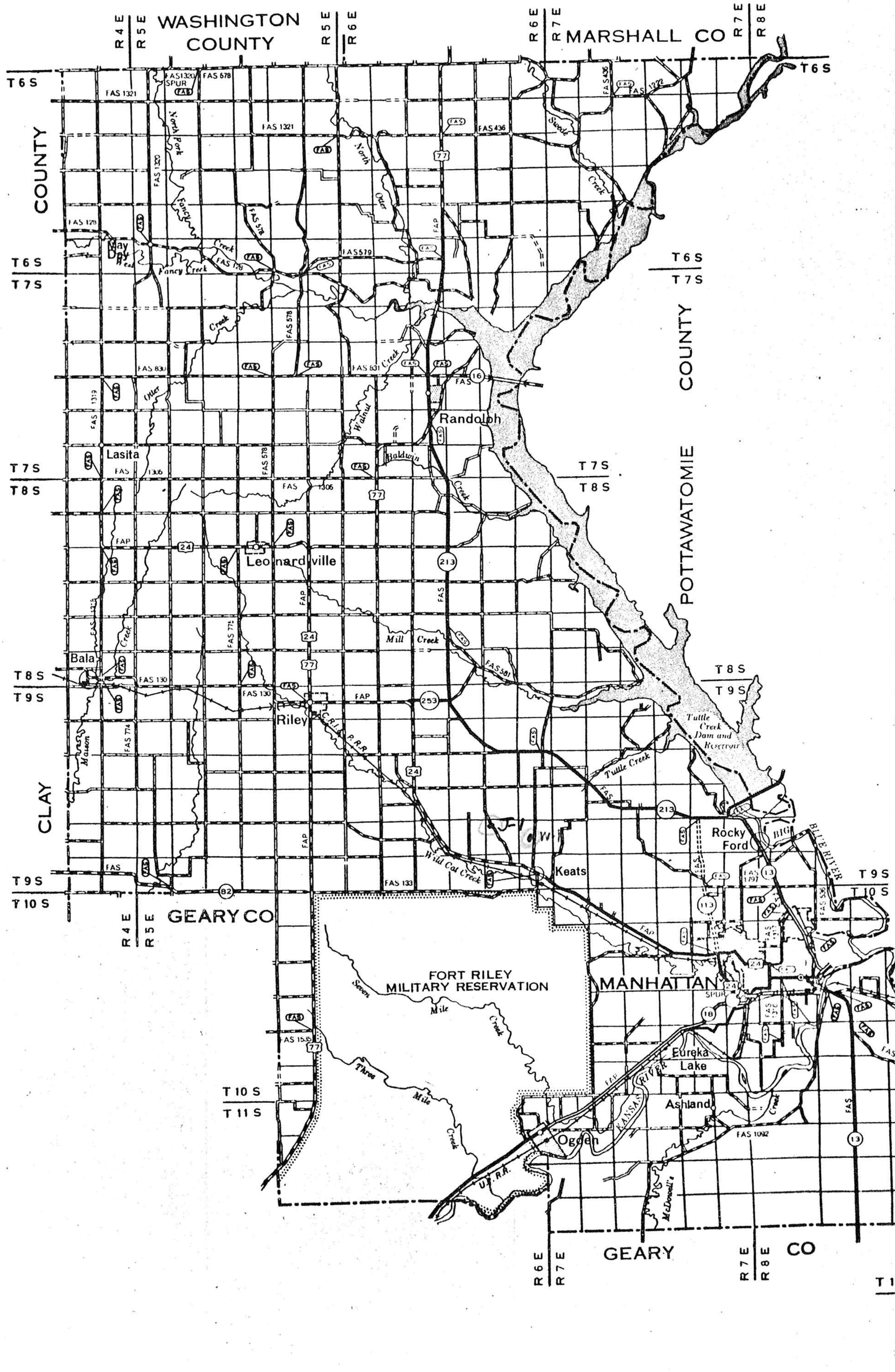


Color	Illite-Mintmor	Illite	Chlorite	Chlorite Illite	Chlorite Vermiculite C/V	Chlorite Vermiculite V/C	Montmor.
GRAY	P	MAJOR	ABUNDANT	P	P	P	P?
GREEN		MAJOR	MINOR			P	
RED		MAJOR	ABUNDANT? KAOLIN?	P		P	
GREEN		MAJOR				P	
GREEN		MAJOR	ABUNDANT	P	P	P	
GRAY	P	MAJOR	MAJOR	P	P		
GRAY	P	MAJOR	MAJOR		P		P?

SCALE 1" = 20'

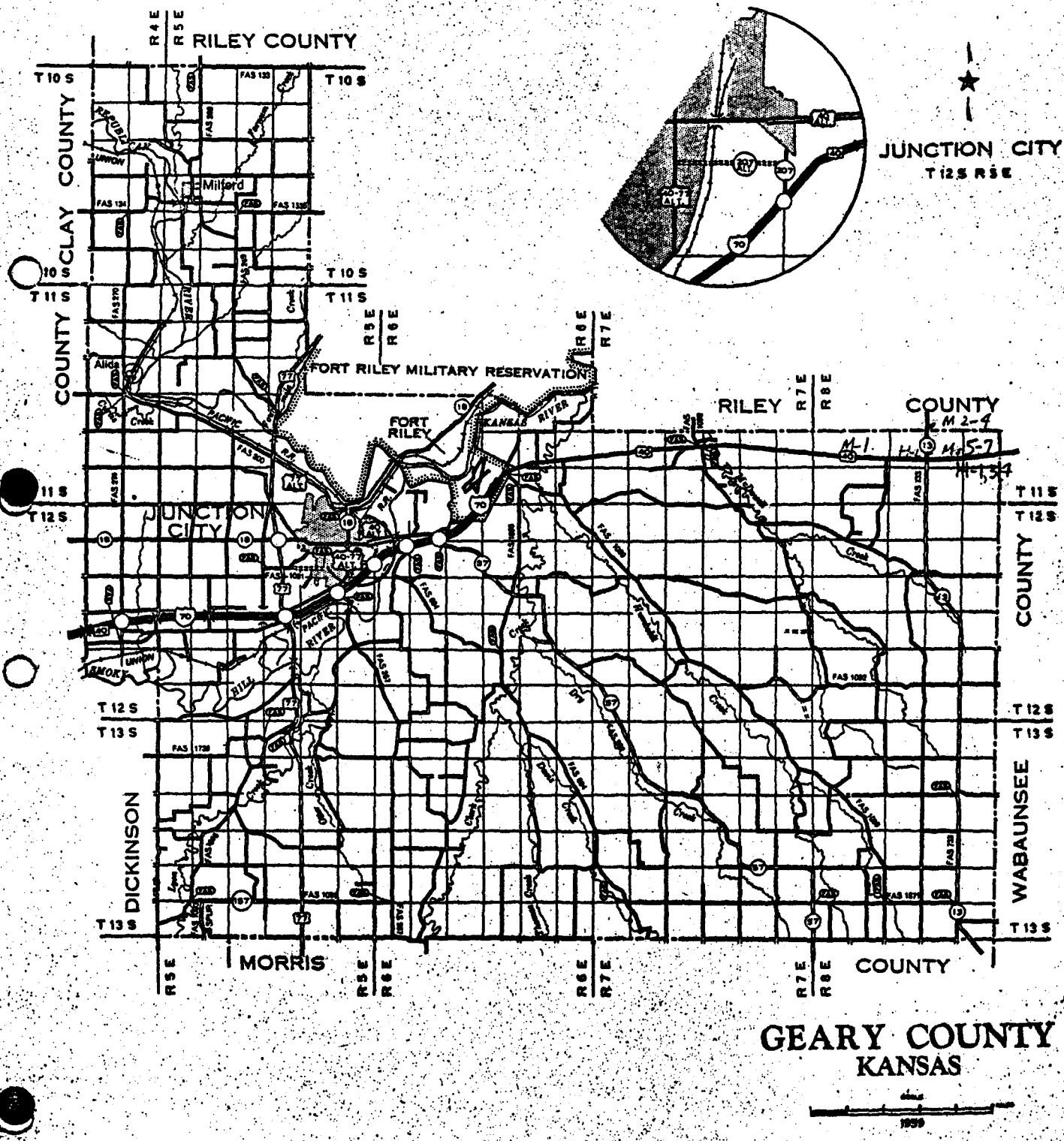
Location	Method	Source
J-1 NW¼ NW¼ SEC 26 T9S R6E	DTA	JOHNSON, W.B.
M-1 SEC 30 T11S R8E	X-RAY	Mc PHERRON, D.S.
M 2-4 NW¼ NW¼ SEC 28 T11S R8E	X-RAY	Mc PHERRON, D.S.
M 5-7 SE¼ SEC 28 T11S R8E	X-RAY	Mc PHERRON, D.S.
W-1 SE¼ NW¼ SEC 25 T9S R6E	DTA	WATERMAN, W.D.
H 1,3,4 SEC 28 T11S R8E	DTA	HARTIG, R.L.
H 2 SWSW SEC 28 T11S R8E	DTA	HARTIG, R.L.

BLUE SPRINGS



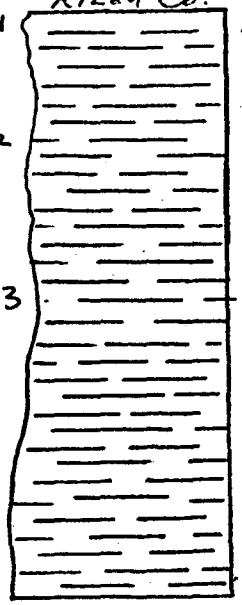
RILEY COUNTY
KANSAS

1963


RILEY COUNTY
CLAY COUNTY
Milford
Alida
FORT RILEY MILITARY RESERVATION
FORT RILEY
KANSAS RIVER
JUNCTION CITY
RILEY COUNTY
DICKINSON
MORRIS
COUNTY
WABAUNSEE
COUNTY
T10S
T11S
T12S
T13S
R4E
R5E
R6E
R7E
R8E
JUNCTION CITY
T12S R5E
M-1
M-2-4
M-5-7
M-13-14
GEARY COUNTY
KANSAS
1939

WYMORE

SW¼ SE¼ Sec 7 T6S R6E Riley Co.

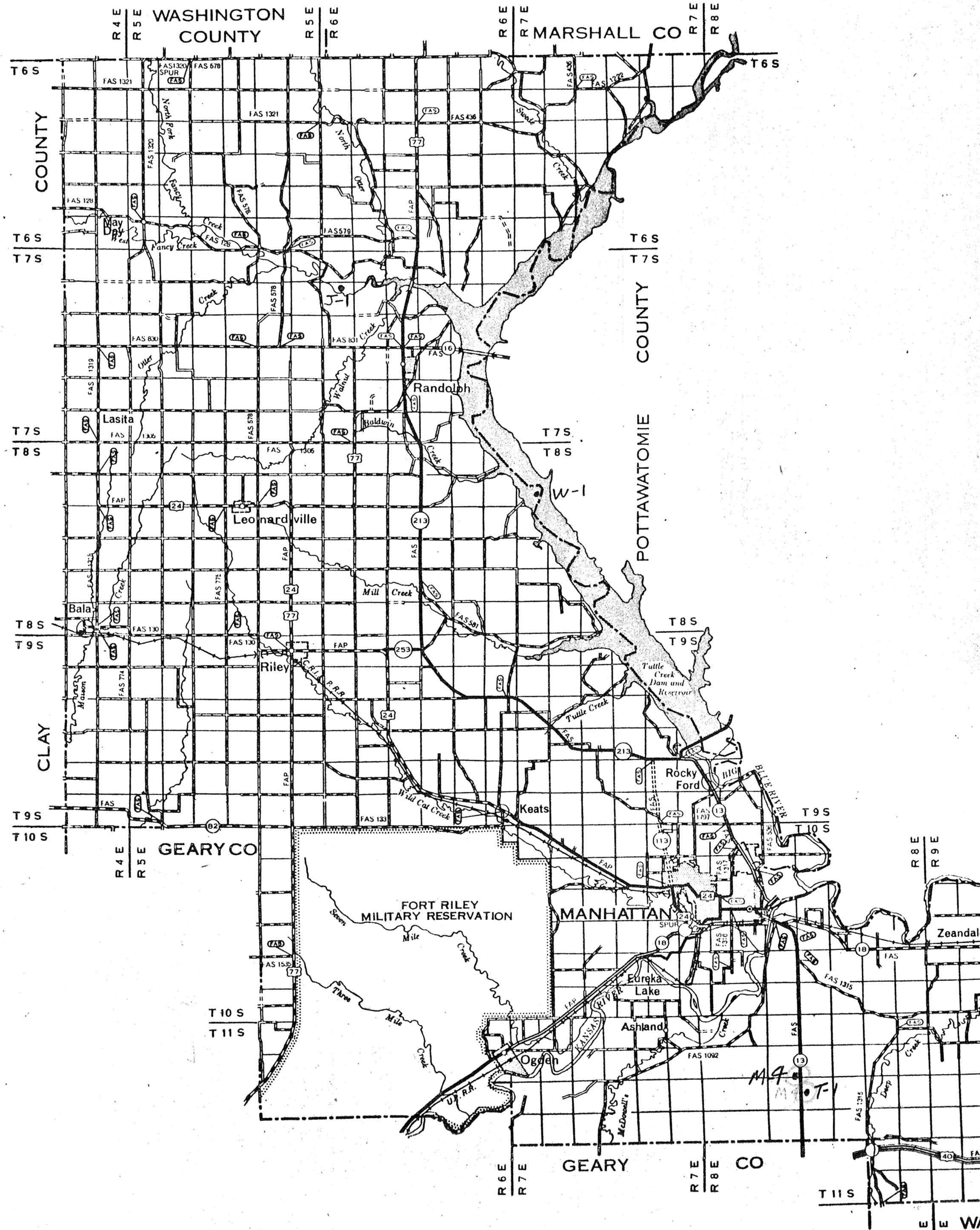


SCALE 1" = 10'

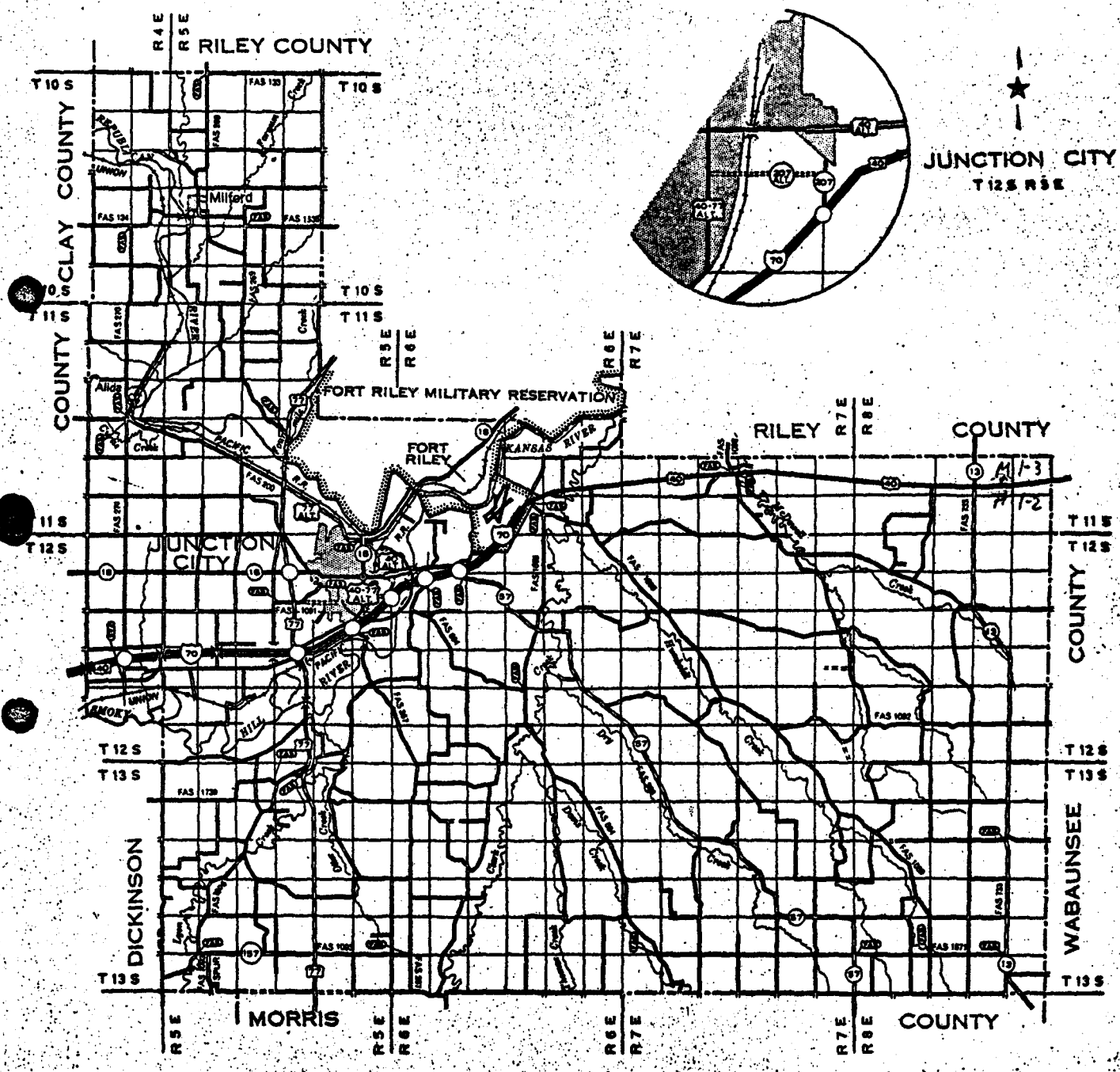
	COLOR	ILLITE - MONTMOR	ILLITE	CHLORITE	CHLORITE ILLITE	CHLORITE VERMICULITE C/V	CHLORITE VERMICULITE V/C
M-1	BUFF	P	MAJOR	MAJOR		P	
M-2	BUFF		MAJOR	MAJOR	P	P	
M-3	BUFF		MAJOR	MAJOR		P	
M-4	BUFF	P	MAJOR				P

LOCATION	METHOD	SOURCE
J-1 SW¼ SE¼ Sec 7 T6S R6E STREAM CUT BANK	DTA	JOHNSON, W.B. THE MINERALOGY OF SOME SOILS OF THE LOWER ARKANSAS SYSTEM OF RILEY CO., KS., 1979, KSU THESIS
M-1-3 SE¼ SE¼, Sec 8, T11S, R8E	X-RAY	McPHERRON, D.S.
M 4 SE¼ Sec. 28, T11S, R8E	X-RAY	McPHERRON, D.S.
W-1 NE¼ SW¼, Sec. 7, T8S, R7E	DTA	WATERMAN, W.D.
H 1-2 Sec 28 T 11S R8E	DTA	HARTIG, R.L.
T-1 W½ Sec 21 T11S R8E	X-RAY	TWISS, P.C. PERSONNAL COMMUNICATION

WYMORE



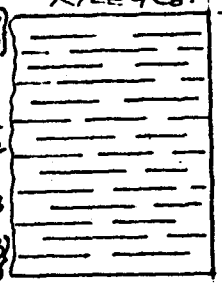
RILEY COUNTY
KANSAS
1963



GEARY COUNTY
KANSAS

HAVENSVILLE

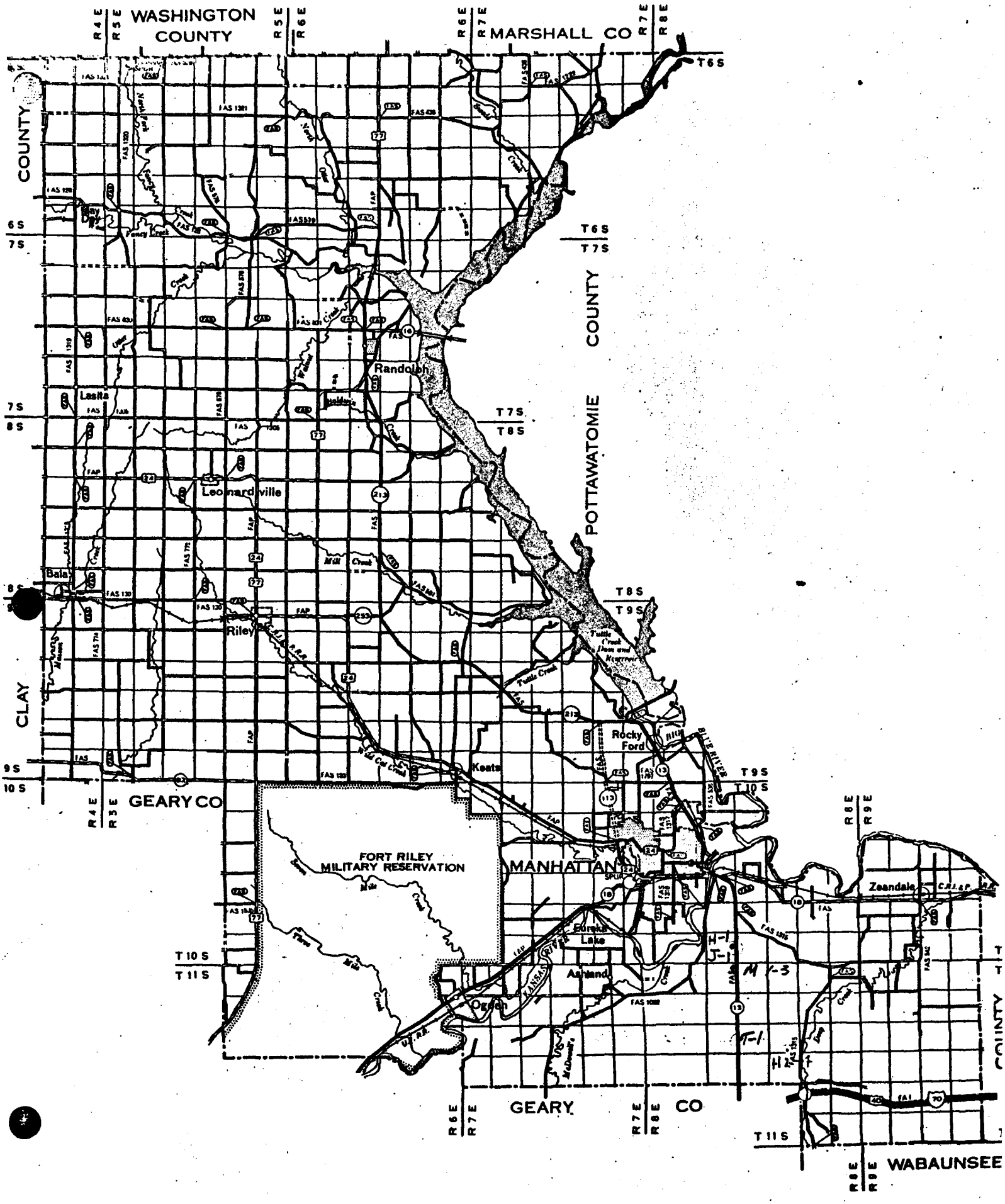
SE¼ NE¼ Sec 32 T10S R8E Riley Co.



SCALE 1" = 10'

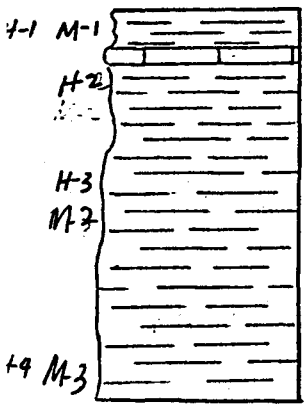
	COLOR	ILLITE	CHLORITE	CHLORITE VERMICULITE C.V. V/C	MONTMOR-ILLITE	CHLORITE MONTMOR
M-1 H-1	BUFF	MAJOR	MINOR	P	P	P
M-2 H-2	GRAY	MAJOR	MINOR	P	P P	
H-3		MAJOR				
M-3 H-4	TUFF	MAJOR	TRACE	P	P	

	LOCATION	METHOD	SOURCE
J-1	ROAD CUT SE¼, NE¼, SEC 32, T10S, R8E CHANNEL SAMPLE	DTA	JOHNSON, W.B. [illegible]
M 1-3	NE¼ NE¼ Sec 5 T11S R8E	X-RAY	McPHERRON, D.S.
H-1	SE¼ NE¼ SEC 32 T10S R8E	DTA	HARTIG R.L.
H 2-4	SW¼ SE¼ SEC 21 T11S R8E	DTA	HARTIG R.L.
T-1	W½ SEC 21 T11S R8E	X-RAY	TWISS, P.C. PERSONNAL COMMUNICATION


WASHINGTON COUNTY
MARSHALL CO
POTTAWATOMIE COUNTY
CLAY
GEARY CO
GEARY
WABAUNSEE
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Ogden
Wild Cat Creek
Mill Creek
Tuttle Creek
Big Blue River
Kansas River
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S

S PEISER

SW¼ NE¼ Sec 36
T9S R6E
RILEY Co

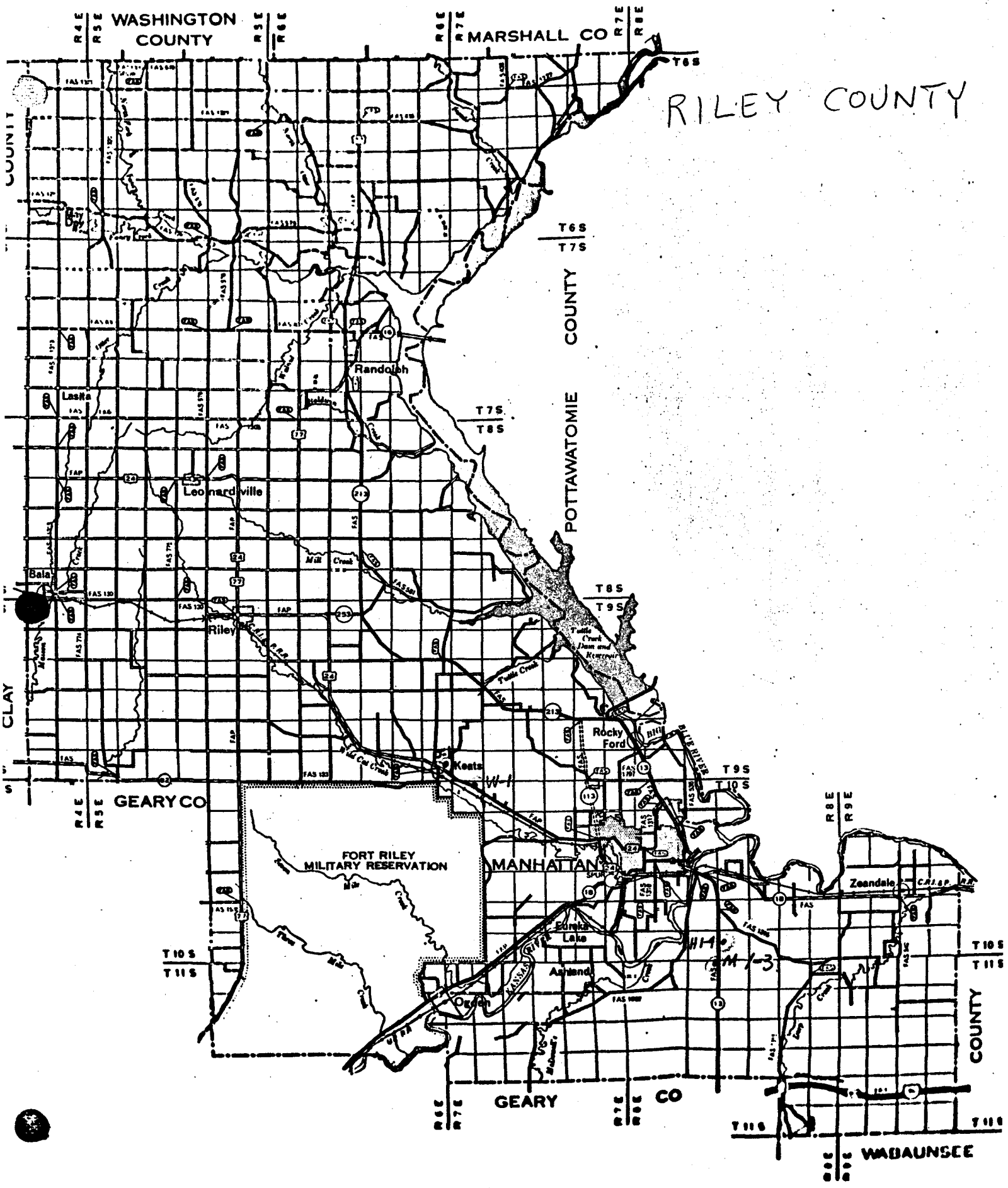


SCALE 1"=10'

	COLOR	ILLITE-MONTMOR.	ILLITE	CHLORITE	CHLORITE ILLITE	CHLORITE VERMICULITE CHL	CHLORITE VERMICULITE VTC	MONTMOR.
J-1 M-1	GRAY	P (CHLORITE-SMECTITE)	MAJOR	TRACE	P	P	P	
H-2								
H-3								
M-2	RED		MAJOR	MINOR + KAOLIN?		P		
H-4 M-3	BUFF		MAJOR			P		P?

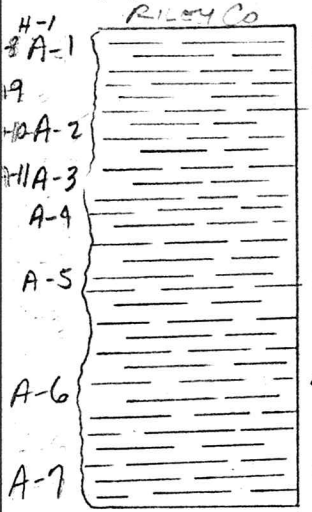
LOCATION	METHOD	SOURCE
J-1 [illegible] SW¼NE¼ Sec 36 T9S R6E STREAM BANK CUT (CHANNEL SAM)	DTA	JOHNSON, W.B. [illegible] CHASE CO., KANS., Co., 1960 PSU
M 1-3 NE¼NE¼ SEC 5 T7S R8E	X-RAY	McPHERRON, D.S.
W-1 NW¼ NE¼ Sec 6 T10S R 7E	DTA	WATERMAN, W.D.
H 1-4 SW¼ NW¼ Sec 33 T10S R 8E	DTA	HARTIG, R.L.

SPEISER


RILEY COUNTY
WASHINGTON COUNTY
MARSHALL CO
POTTAWATOMIE COUNTY
CLAY COUNTY
GEARY CO
GEARY COUNTY
WABAUNSEE COUNTY
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Lasita
Leonardville
Bala
Riley
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Ogden
Tuttle Creek Dam and Reservoir
Tuttle Creek
Mill Creek
Wild Cat Creek
Blue River
Kansas River
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S

BLUE RAPIDS

Sec 19
T8S R7E
Riley Co

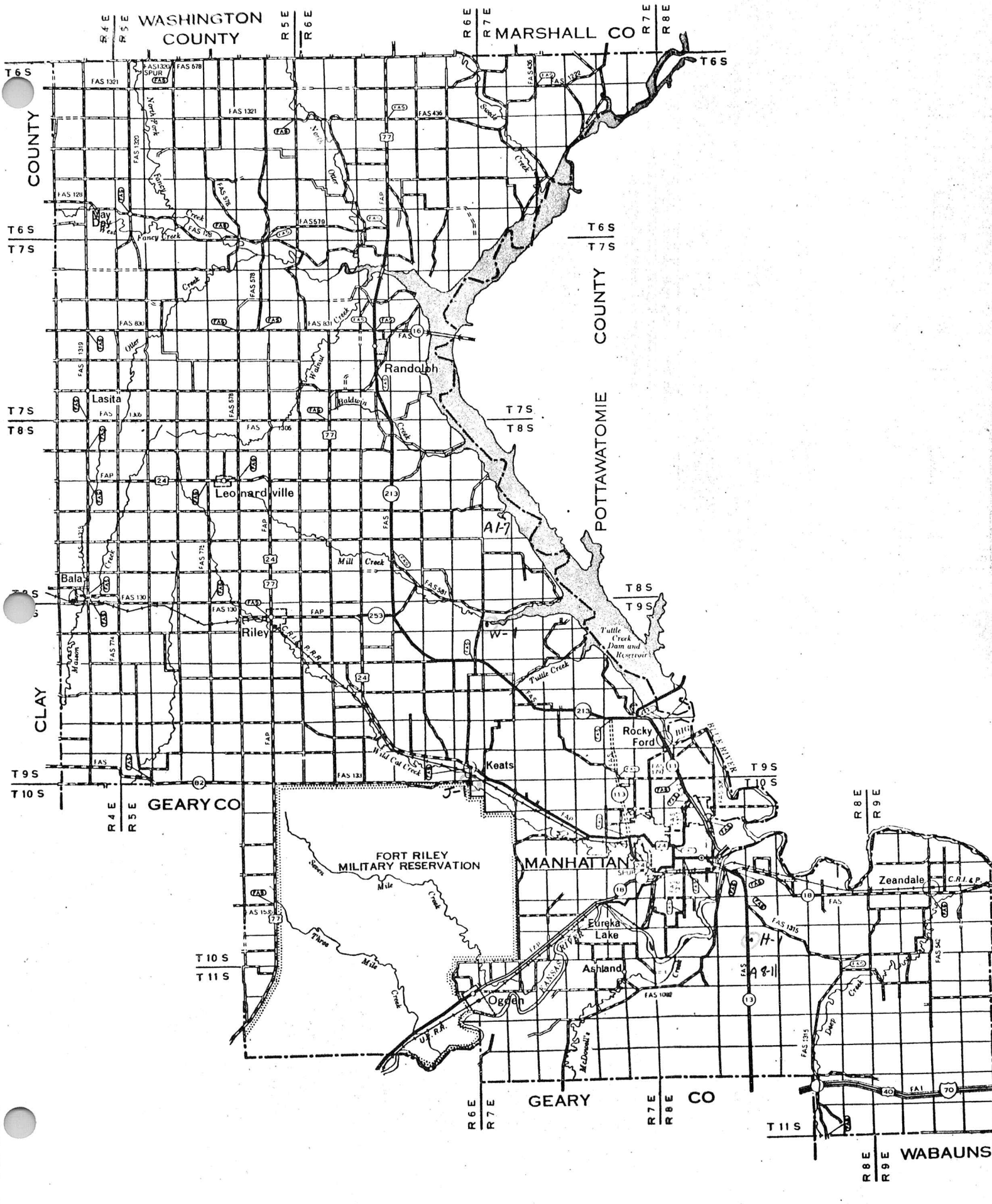


Scale 1" = 20'

	Color	Illite	Chlorite	Chlorite Illite	Chlorite Vermiculite C/V V/C	Montmor Illite	Mont Chlorite Ill	Mont. Chlorite
H-1								
A-1	Gray	Major	P			P	P	P
	Black	Major	P			P	P	P
A-2	Red	Major	P			P	P	P
A-3	Gray	Major	P			P	P	P
A-4	Gray	Major	P			P	P	P
A-5	Green	Major	P			P	P	P
A-6	Red	Major	P			P	P	P
A-7	Green	Major	P			P	P	P

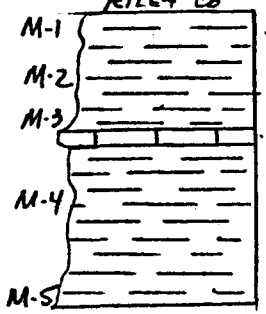
Location		Method	Source
A 1-7	Sec 19 T8S R7E	X-Ray	Asmussen, L.E.
A 8-11	Sec 4 T11S R8E	X-Ray	
J-1	SW¼ SE¼, Sec 36, T9S, R6E Stream Cut on Ft. Riley Channel Sample	DTA	Johnson, W.B. The clay mineralogy of some lower [illegible] shales of Clay Co. Ks., 1979 Kan. Mineral Symp.
W-1	SW¼ SW¼ Sec 6 T9S R7E	DTA	Waterman, W.D.
H-1	SW¼ NW¼ Sec 33 T10S R8E	DTA	Hartig, R.L.

BLUE RAPIDS


WASHINGTON COUNTY
MARSHALL CO
CLAY COUNTY
POTTAWATOMIE COUNTY
GEARY CO
GEARY CO
WABAUNS
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S
Randolph
Lasita
Leonardville
Bala
Riley
Keats
Rocky Ford
MANHATTAN
Zeandale
Eureka Lake
Ashland
Ogden
FORT RILEY MILITARY RESERVATION
Tuttle Creek Dam and Reservoir
Mill Creek
Wild Cat Creek
Three Mile Creek
Seven Mile Creek
Walnut Creek
Fancy Creek
Blue River
C.R.I.&P.
U.P.R.R.
A1-7
W-1
J-
H-1
A8-11
RILEY COUNTY

EASLY CREEK

NW¼ NW¼ Sec 33 T8S R7E Riley Co

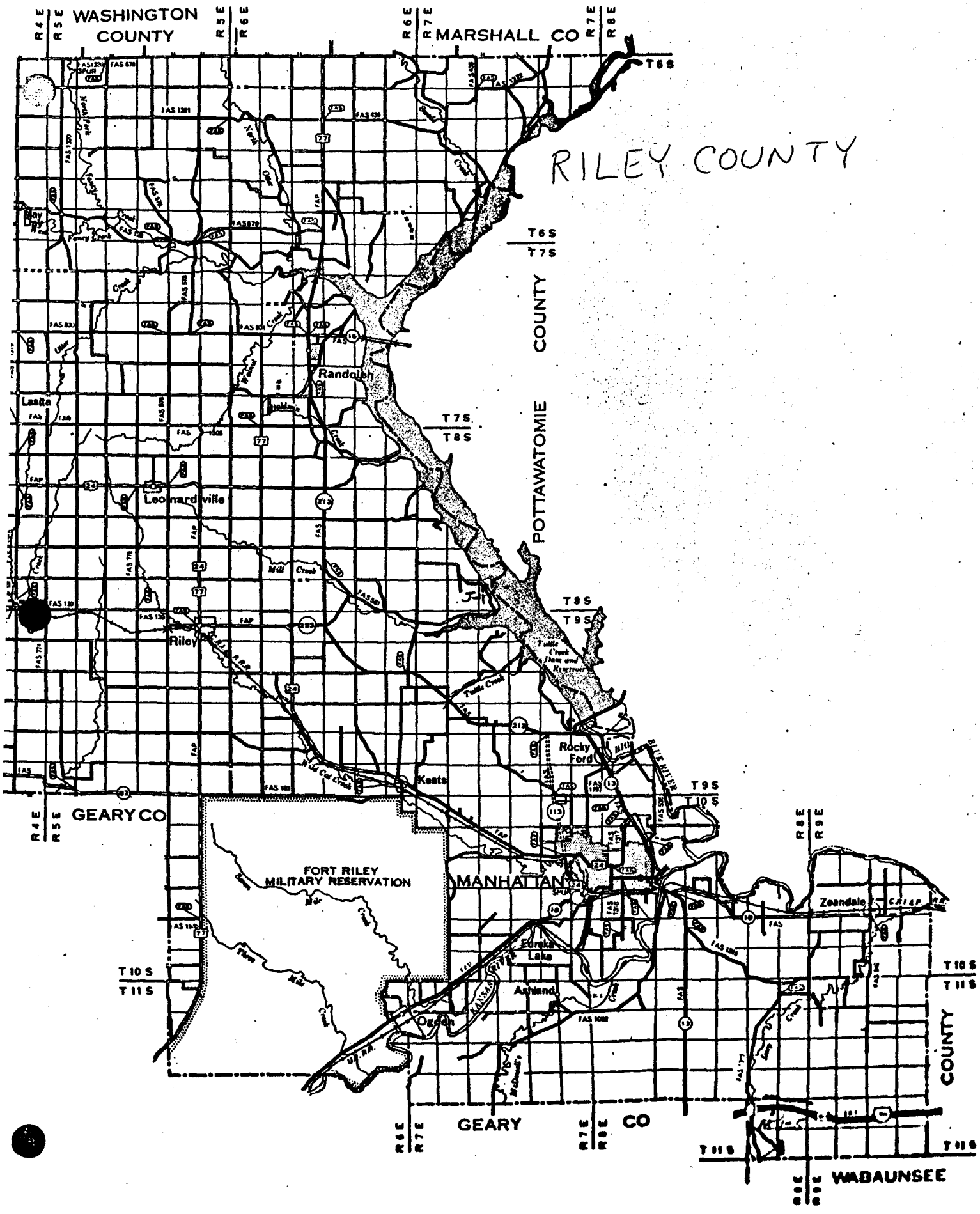


SCALE 1" = 10'

	Color	Illite	Chlorite	Chlorite Illite	Chlorite Vermiculite C/V	Chlorite Vermiculite V/C	Mintmor. Illite
M-1	Buff	Major		P		P	P
M-2	Buff	Major	Minor	P	P		P
M-3	Green	Major	Abundant	P	P		
M-4	Red	Major	Minor + Kaolin?	P	P	P	
M-5	Buff	Major	Minor	P		P	

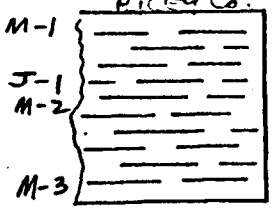
	Location	Method	Source
J-1	NW¼ NW¼ Sec 33 T8S R7E Road Cut Channel Sample	DTA	Johnson, W.B. The Mineralogy of some Surface Rocks of the Eastern Portion of Riley Co., Kans. 1971 KSU Thesis
M 1-5	Sec 26 T11S R8E	X-Ray	McPherron, D.S.

EASLY CREEK


WASHINGTON COUNTY
MARSHALL CO
RILEY COUNTY
POTTAWATOMIE COUNTY
GEARY CO
GEARY COUNTY
WABAUNSEE COUNTY
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Rocky Ford
Zeandale
Fancy Creek Reservoir
Tuttle Creek Dam and Reservoir
Milford Reservoir
Ogden
Ashland
Funke Lake
Lasita
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S

HOOSER

SE¼ SW¼ Sec 28 T10S R8E Pickens Co.

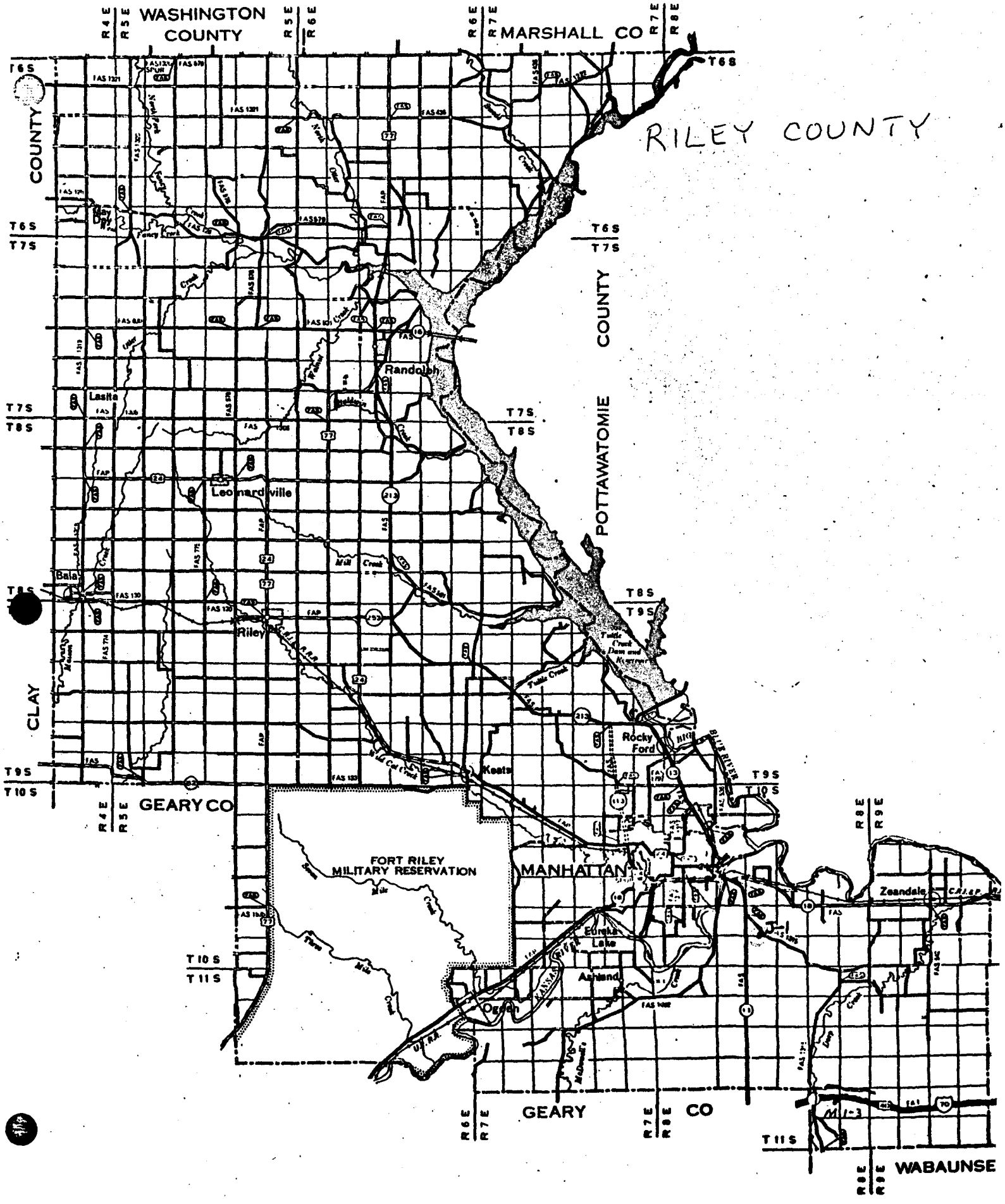


SCALE 1"=10'

	COLOR	ILLITE-MONTMOR	ILLITE	CHLORITE	CHLORITE ILLITE	CHLORITE VERMICULITE C/V	CHLORITE VERMICULITE V/C
M-1	GRAY		MAJOR	ABUNDANT	P	P	P
J-1 M-2	RED	P ?	MAJOR	ABUNDANT + KAOLIN?		P	P
M-3	GREEN		MAJOR	MINOR	P	P	P

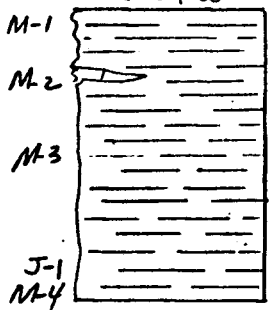
	LOCATION	METHOD	SOURCE
J-1	SE¼ SW¼ SEC 28 T10S R8E ROAD CUT	DTA	JOHNSON, W.B.
M1-3	SEC 26 T11S R8E	X-RAY	MCPHERRON, D.S.

HOOSER


WASHINGTON COUNTY
MARSHALL CO
RILEY COUNTY
POTTAWATOMIE COUNTY
CLAY COUNTY
GEARY CO
GEARY CO
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Ogden
WABAUNSEE
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S

STEARNS

SE ¼ NW ¼ Sec 33 T8S R7E Riley Co

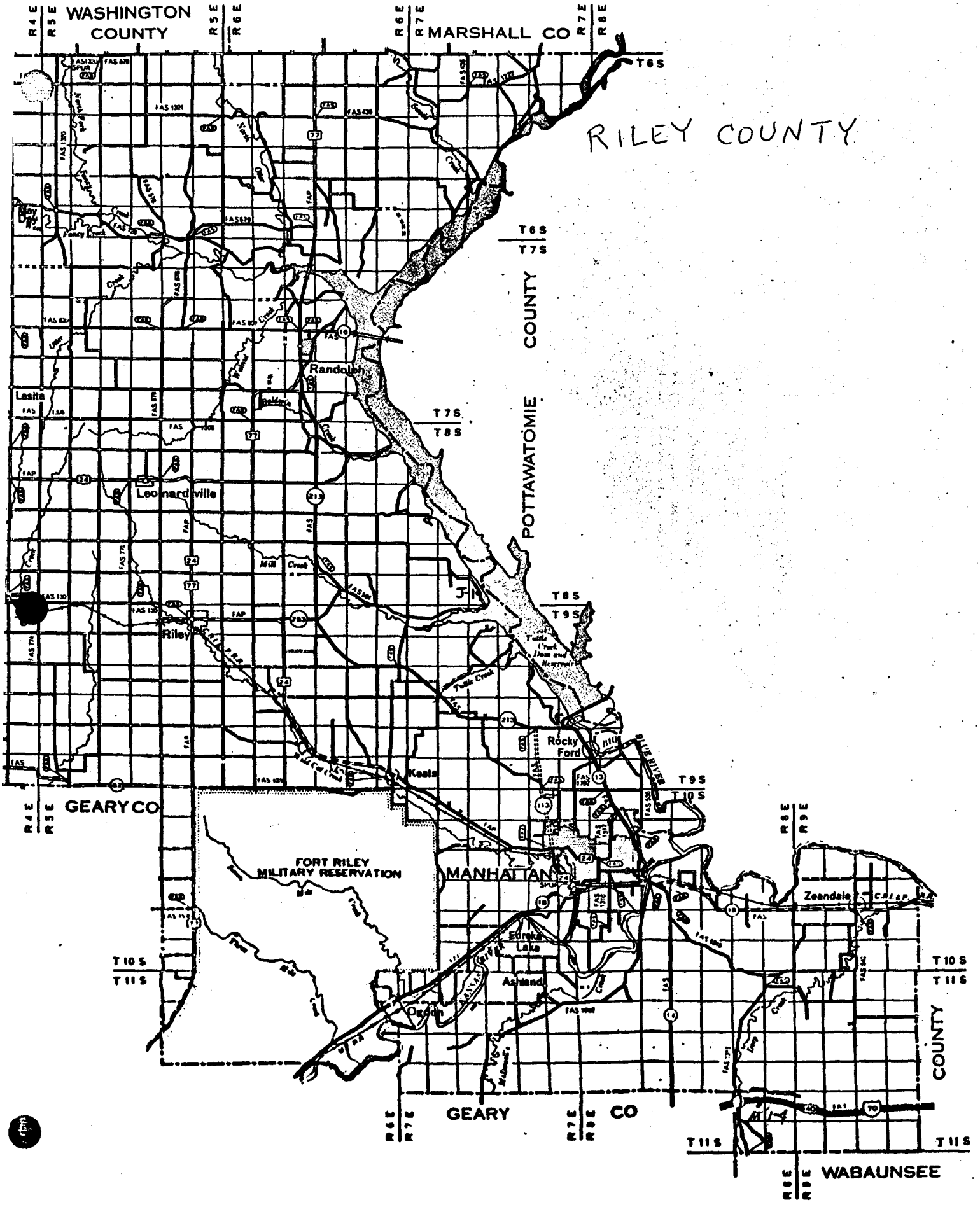


SCALE 1"=10'

	COLOR	ILLITE - MONTMOR	ILLITE	CHLORITE	CHLORITE ILLITE	CHLORITE VERMICULITE C/V	V/C
M-1	GRAY		MAJOR	ABUNDANT	P	P F	P
M-2	GRAY		MAJOR	ABUNDANT	P	P P	P
M-3	GRAY		MAJOR	ABUNDANT	P		P
	RED						
J-1 M-4	BUFF	N. P?	MAJOR	MINOR		P P	

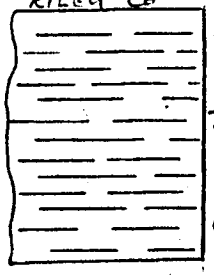
	LOCATION	METHOD	SOURCE
J-1	SE ¼ NW ¼ Sec 33 T8S R7E Road Cut	DTA	JOHNSON, W.B. The Mineralogy of Some Shales of the Lower Permian of Riley Co. Kansas Thesis
M 1-4	Sec 26 T11S R8E	X-RAY	McAHERON, D.S.

STEARNS


WASHINGTON COUNTY
MARSHALL CO
RILEY COUNTY
POTTAWATOMIE COUNTY
GEARY CO
GEARY COUNTY
WABAUNSEE COUNTY
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Deegan
Lasita
R4E
R5E
R6E
R7E
R8E
T6S
T7S
T8S
T9S
T10S
T11S

FLORENA

SE¼ SE¼ Sec 23 T10S R7E RILEY Co



SCALE 1" = 8'

	COLOR	ILLITE - MONTMOR.	ILLITE	CHLORITE	CHLORITE ILLITE	CHLORITE VERMICULITE C/V V/C
M-1	GRAY		MAJOR		P	P
M-2	BUFF	P	MAJOR	ABUNDANT	P	P
J-1	GRAY	P	MAJOR	ABUNDANT	P	P

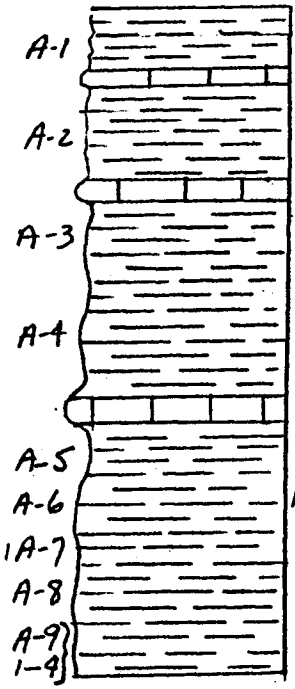
	LOCATION	METHOD	SOURCE
J-1	SE¼ SE¼ Sec. 23, T10S, R7E OLD ROAD CUT	DTA	JOHNSON, W.B. [illegible]
M1-3	Sec 26 T11S R8E	X-RAY	McPHERRON D.S

FLORENA

RILEY COUNTY
KANSAS
CLAY
POTTAWATOMIE COUNTY
GEARY CO
GEARY CO
WABAUNSEE COUNTY
FORT RILEY
MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Ogden
T7S
T8S
T9S
T10S
T11S
R4E
R5E
R6E
R7E
R8E
R9E

ESKRIDGE

SEC 32
T10S R8E
RILEY Co.



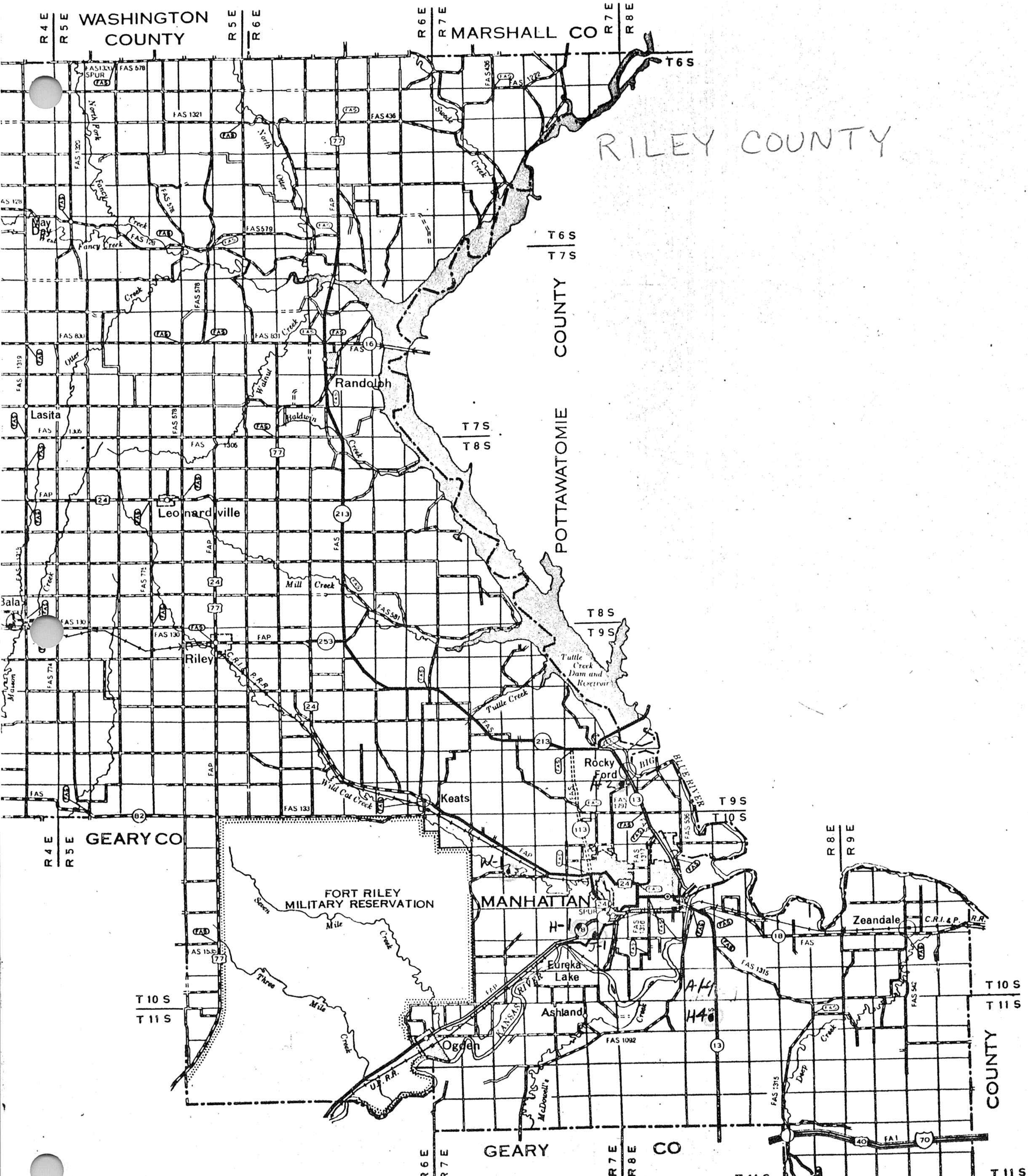
	COLOR	ILLITE	CHLORITE	MONTMOR CHLORITE Mg C/M	MONTMOR ILLITE	MONTMOR CHLORITE ILLITE	SUPER LATTICE MONT-ILL	MONTMOR
A-1	BROWN	MAJOR	P	P	P	P		
A-2	GRAY	MAJOR	P	P	P	P		
A-3	GREEN	MAJOR	P	P P	P	P	P	
A-4	BROWN	MAJOR	P	P P	P	P		
A-5	TAN	MAJOR	P	P	P			P
A-6	PURPLE	MAJOR	P	P P	P	P		
A-7	GRAY	MAJOR	P	P P	P	P		
A-8	GRAY	MAJOR	P	P	P	P		
A-9 I-9	RED	MAJOR	P	P	P	P		P

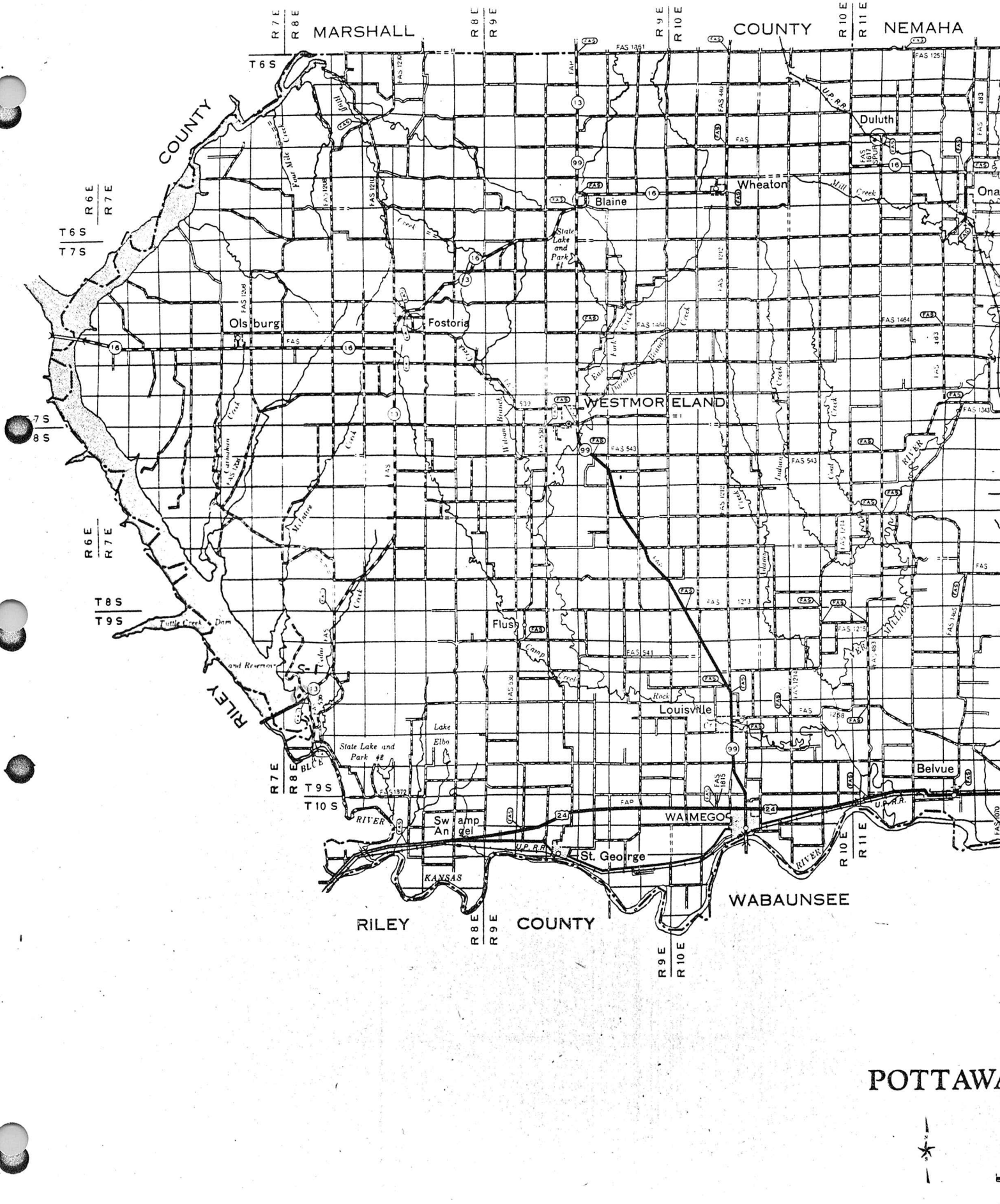
SCALE 1" = 10'

LOCATION	METHOD	SOURCE
A 1-9 SEC 32 T10S R8E	X-RAY	ASMUSSEN, L.E. CLAY MINERALOGY OF SOME PENNSYLVANIAN SHALES OF RILEY COUNTY, 1958 KSU MASTERS THESIS
J 1. SE¼ SE¼ SEC 23 T10S R7E OLD ROAD CUT CHANNEL SAMPLE OF LOWER HALF	DTA	JOHNSON, W.B. THE MINERALOGY OF SOME SHALES OF THE LOWER PERMIAN OF RILEY COUNTY, KS. KSU THESIS
N-1 SE¼ SW¼ SEC 10 T10S R7E	DTA	WATERMAN, W.D.
H-1 NE¼ SW¼ SEC 23 T10S R7E ROADCUT	X-RAY	HARGADINE, G.D.
H-2 NE¼ NE¼ SEC 36 T9S R7E ROADCUT	X-RAY	HARGADINE, G.D.
H-3 SW¼ NE¼ SEC 19 T9S R8E TUTTLE CREEK SALLYWAY	X-RAY	HARGADINE, G.D.
H-4 NE¼ SW¼ SEC 5 T11S R8E ROADCUT	X-RAY	HARGADINE, G.D.
S-1 W½ SEC 19 T9S R8E	X-RAY	SWINEFORD, ADA

ESKRIDGE

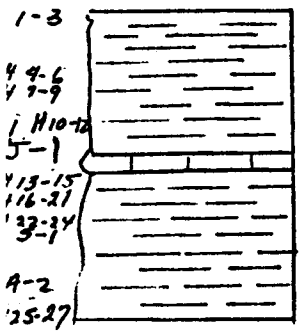
RILEY COUNTY




MARSHALL COUNTY
NEMAHA COUNTY
RILEY COUNTY
WABAUNSEE COUNTY
R7E
R8E
R9E
R10E
R11E
T6S
T7S
T8S
T9S
T10S
Blaine
Wheaton
Duluth
Olsburg
Fostoria
WESTMORELAND
Flush
Louisville
Belvue
WAMEGO
St. George
Swamp Angel
State Lake and Park #2
Lake Elbo
Tuttle Creek Dam
KANSAS RIVER
BLUE RIVER
U.P.R.R.
POTTAWA

SALEM POINT

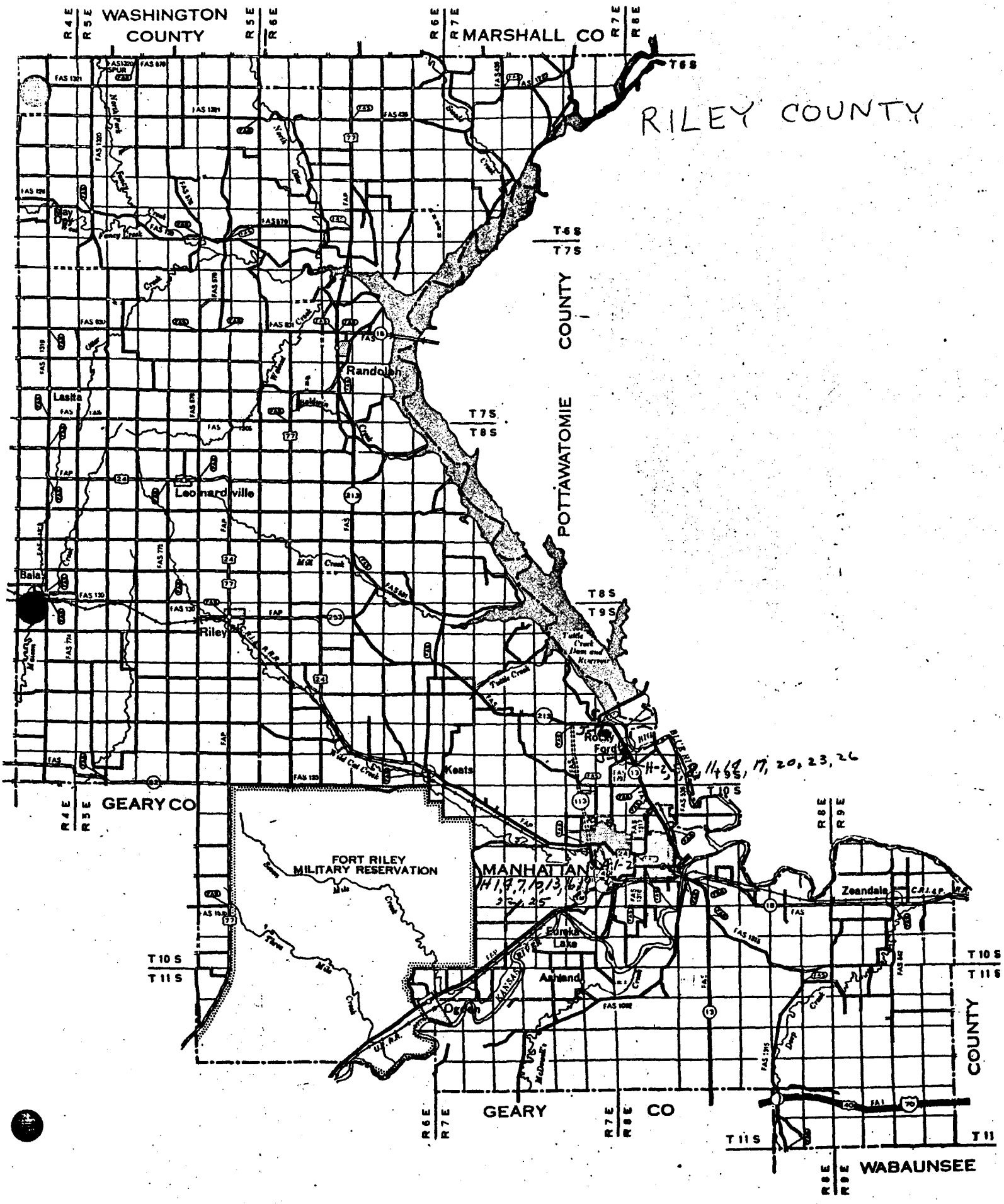
SEC 13 T10S R8E
RILEY CO.

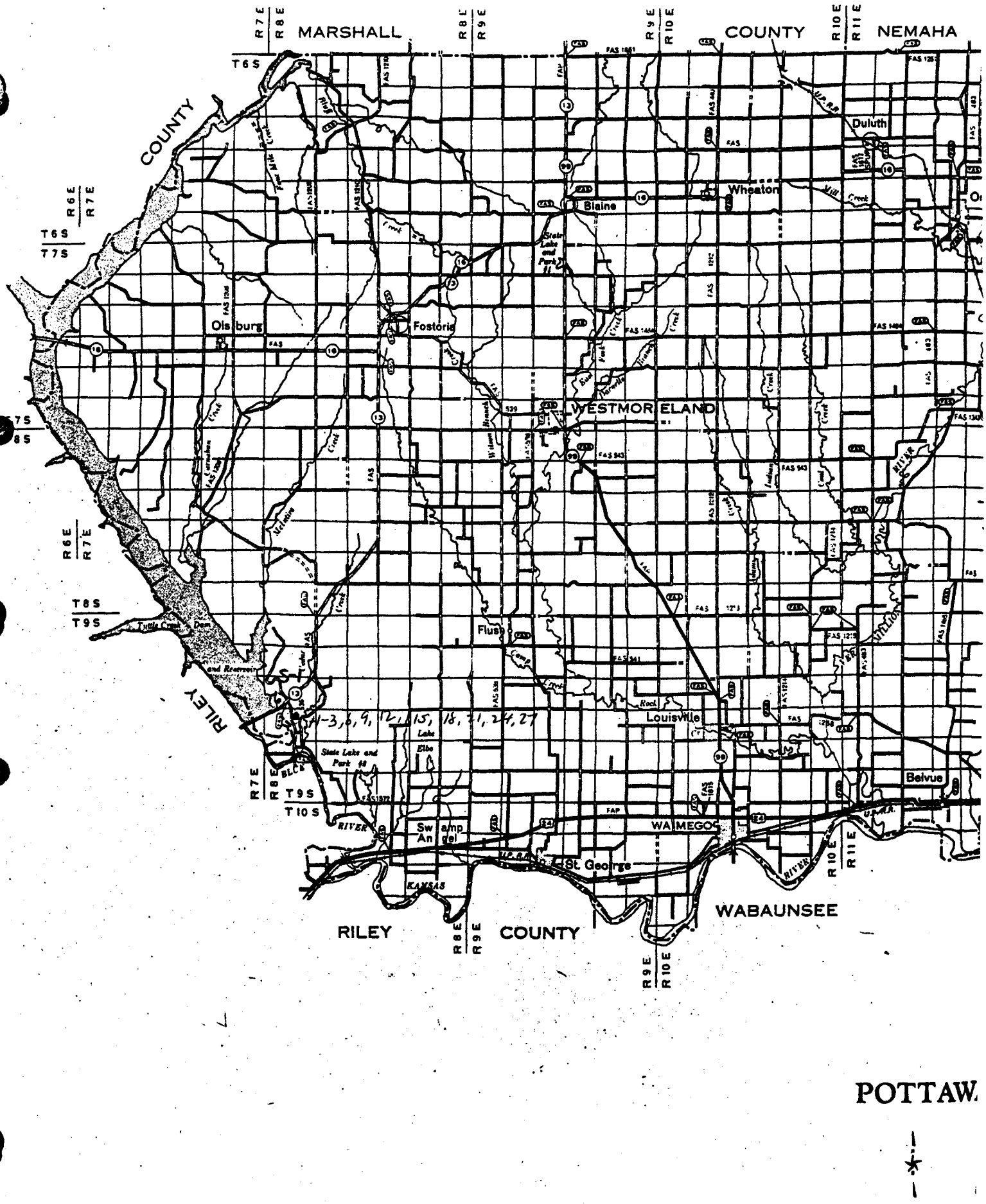


	COLOR	ILLITE	CHLORITE	MONTMOR CHLORITE M/C C/M	MONTMOR ILLITE	MONT CHLORITE ILLITE	SUPER LATTICE MONT-ILL
1-3		MAJOR	MOD.	P	MINOR		
4 4-6		MAJOR	MINOR	MODERATE	MINOR	P	
7-9		MINOR	MINOR	P	MINOR		
H10-12	GRAY	MAJOR	PRES.	P P	P	P	
J-1							
13-15		MAJOR	MOD	MOD	MINOR		
16-21		MAJOR	MOD	MOD	MINOR		
22-24		MAJOR	MOD	MOD	MINOR		
3-1		MAJOR	IOT				
A-2	GRAY	MAJOR	PRES.	P P	P	P	P
25-27							

1" = 5'

LOCATION	METHOD	SOURCE
A 1-2 SEC 13 T10S R8E	X-RAY	ASMUSSEN, L.E., [illegible]
J 1 - SE¼SE¼SEC 25 T9S R7E ROAD CUT	DTA	JOHNSON, W.B. — [illegible]
J 2 NW¼SE¼ SEC 25 T9S R7E CHANNEL SAMPLE OF LOWER SECTION ROAD CUT	DTA	SAME
1, 4, 7, 10, 13, 16, 19, 21, 24, 27 NE¼ SW¼ SEC 23 T10S R7E ROADCUT	X-RAY	HARGADINE, G.D.
2, 5, 8, 11, 14, 17, 20, 23, 26 NE¼ NE¼ SEC 36 T9S R7E ROADCUT	X-RAY	HARGADINE, G.D.
3, 6, 9, 12, 15 18, 21, 24, 27 SW¼ NE¼ SEC 19 T9S R8E TUTTLE CREEK SPILLWAY	X-RAY	HARGADINE, G.D.
S-1 W½ SEC 19 T9S R8E TUTTLE CREEK	X-RAY	SWINEFORD, ADA

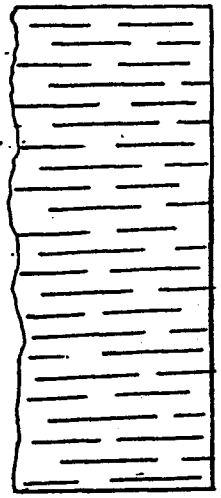

WASHINGTON COUNTY
MARSHALL CO
RILEY COUNTY
POTTAWATOMIE COUNTY
GEARY CO
GEARY CO
WABAUNSEE COUNTY
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Zeandale
Eureka Lake
Ashland
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S
T11


MARSHALL COUNTY
NEMAHA COUNTY
RILEY COUNTY
WABAUNSEE COUNTY
Duluth
Blaine
Wheaton
Olsburg
Fostoria
WESTMORELAND
Flush
Louisville
Belvue
WAMEGO
St. George
KANSAS RIVER
Tuttle Creek Dam and Reservoir
State Lake and Park #1
State Lake and Park #2
Elbo Lake
Sw Amp
R7E R8E R8E R9E R9E R10E R10E R11E
T6S T7S T7S T8S T8S T9S T9S T10S
R6E R7E R6E R7E R7E R8E R8E R9E R9E R10E
1-3, 6, 9, 12, 15, 18, 21, 24, 27

POTTAW

LEGION

NE¼ SW¼ Sec 23 T10S R7E Riley Co.



SCALE 1"=2'

	ILLITE	CHLORITE	ILLITE-MONTMOR.	CHLORITE MONTMOR
H 1-2	MAJOR	MOD.	MINOR	MINOR
H 3-4	MAJOR	MOD	MINOR	MINOR
H 5-6	MAJOR	MOD	MINOR	MINOR
H 7-8	MAJOR	MOD	MOD	MINOR

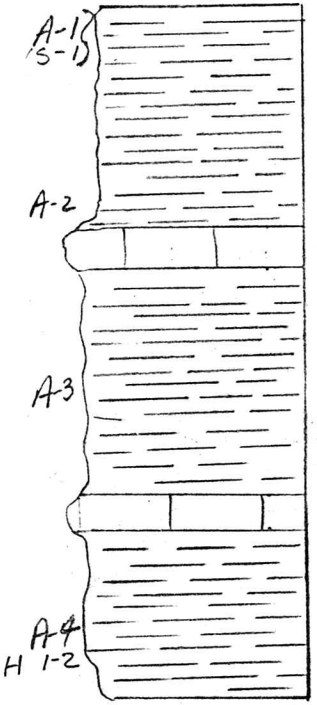
LOCATION	METHOD	SOURCE
H 1,3,5,7 NE¼ SW¼ Sec 23 T10S R7E ROADCUT	X-RAY	HARGADINE, G.D.
H 2,4,6,8 NE¼ NE¼ Sec 36 T9S R7E ROADCUT	X-RAY	HARGADINE, G.D.

LEGION

COUNTY
POTTAWATOMIE
CLAY
GEARY CO
T6S
T7S
T8S
T9S
T10S
T11S
R4E
R5E
R6E
R7E
Randolph
Leonardville
Riley
Keats
Rocky Ford
MANHATTAN
Zeandale
Eureka Lake
Ashland
Ogden
FORT RILEY
MILITARY RESERVATION
Mill Creek
Wild Cat Creek
Tuttle Creek
H 2,4,6,8
H 1,3,5,7
RILEY C

ROCA

SEC 32
T10S R8E
RILEY Co.

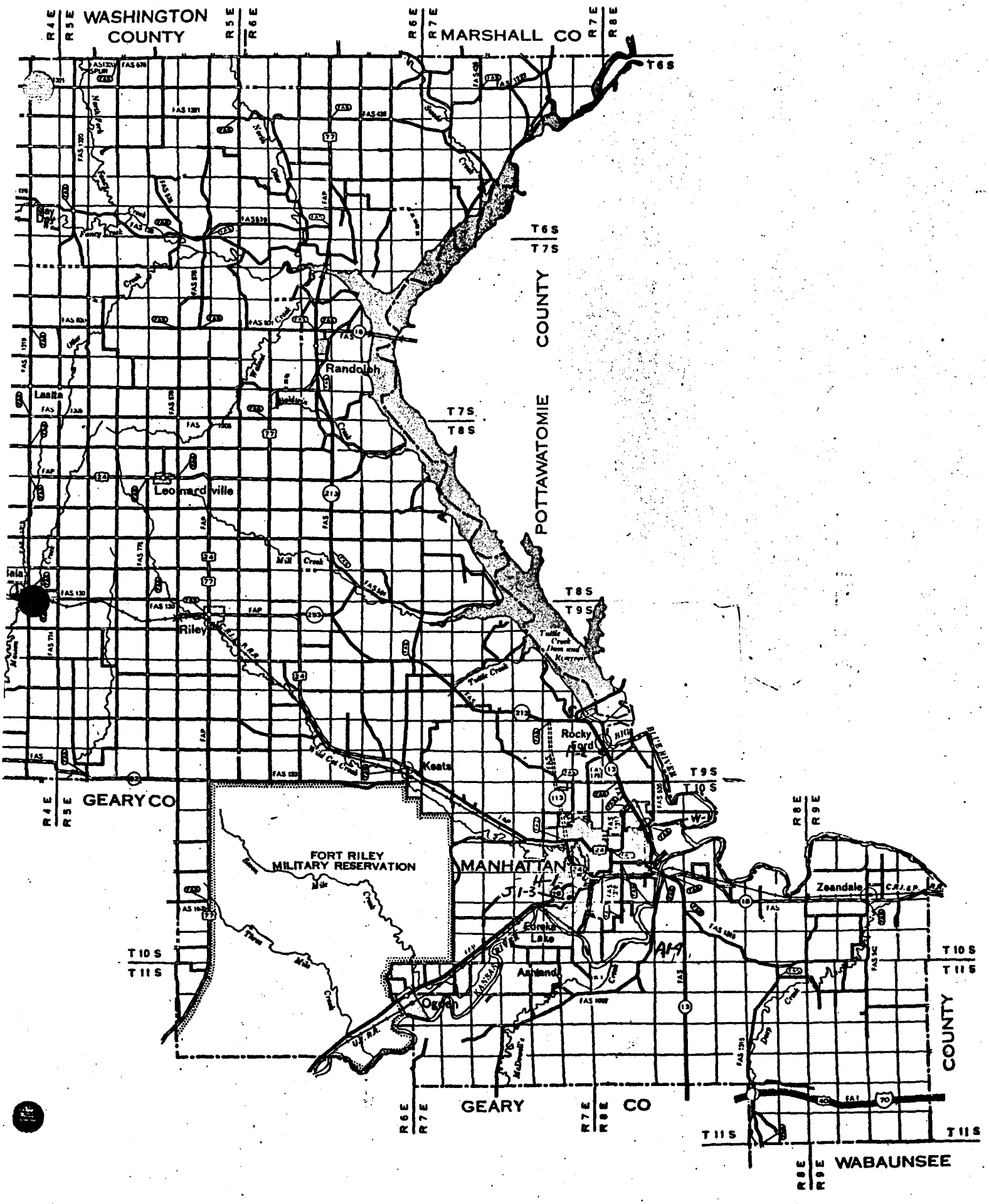


1" = 5'

	COLOR	ILLITE	CHLORITE	MONTMOR. CHLORITE M/C C/M	MONTMOR. ILLITE	MONTMOR ILLITE CHLORITE	SUPER LATTICE MONT-ILL
A-1 S-1	GREEN	MAJOR	10+	P	P	P	
A-2	RED	MAJOR	P	P	P	P	P
A-3	RED	MAJOR	P	P	P	P	
A-4 H 1-2	GREEN	MAJOR MAJOR	P MINOR	P MINOR	P MINOR	P	

	LOCATION	METHOD	SOURCE
S-1	W1/4 SEC 19 T9S R8E	X-RAY	SWINGFORD - ADA
A 1-4	SEC 32 T10S R8E	X-RAY	ASMUSSEN, LE.
J 1	SE¼SE¼ SEC 23 T10S R7E CHANNEL SAMPLE OF UPPER SHALE SEGMENT	DTA	JOHNSON, W.B.
J-2	SE ¼ SE ¼ SEC 23 T10S R7E CHANNEL SAMPLE OF MIDDLE SHALE SEGMENT	DTA	JOHNSON, W.B.
J-3	SE ¼ SE ¼ SEC 23 T10S R7E CHANNEL SAMPLE OF LOWER SHALE SEGMENT	DTA	JOHNSON, W.B.
W-1	SE¼ SE¼ SEC 7, T10S, R8E.	DTA	WATERMAN, W.D.
H-1	NE¼ CW¼ SEC 23 T10S R7E ROADCUT	X-RAY	HARGADINE, G.D.
H-2	NE¼ NE¼ SEC 36 T9S R7E ROADCUT	X-RAY	HARGADINE G.D.

ROCA


WASHINGTON COUNTY
MARSHALL CO
POTTAWATOMIE COUNTY
GEARY CO
FORT RILEY MILITARY RESERVATION
MANHATTAN
GEARY CO
WABAUNSEE COUNTY
Randolph
Leonardville
Riley
Keats
Rocky Ford
Ogden
Ashland
Eureka Lake
Zeandale
R4E
R5E
R6E
R7E
R8E
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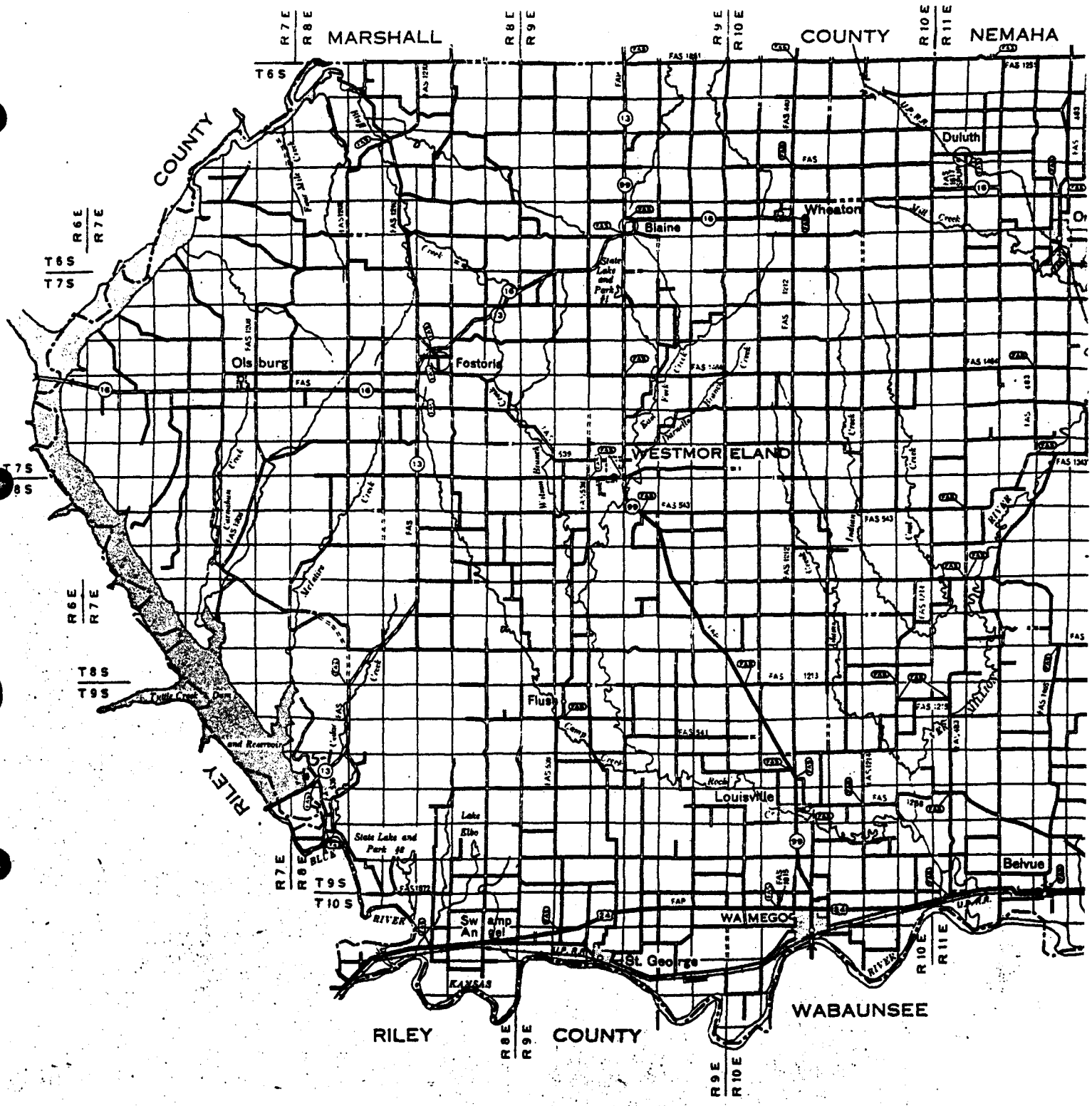
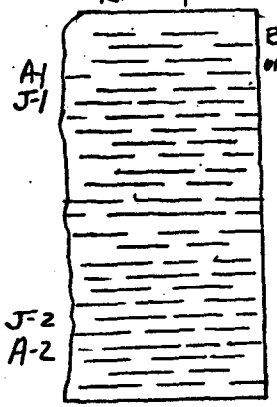
T9S
T10S
T11S


MARSHALL COUNTY
NEMAHA
COUNTY
RILEY COUNTY
WABAUNSEE
Duluth
Wheaton
Blaine
Olsburg
Fostoria
WESTMORELAND
Flush
Louisville
WAMEGO
St. George
Belvue
RILEY
R7E R8E R8E R9E R9E R10E R10E R11E
T6S
T7S
T8S
T9S
T10S
R6E R7E

POTTAW

BENNETT

SEC 13
T10S R7E
RILEY Co.

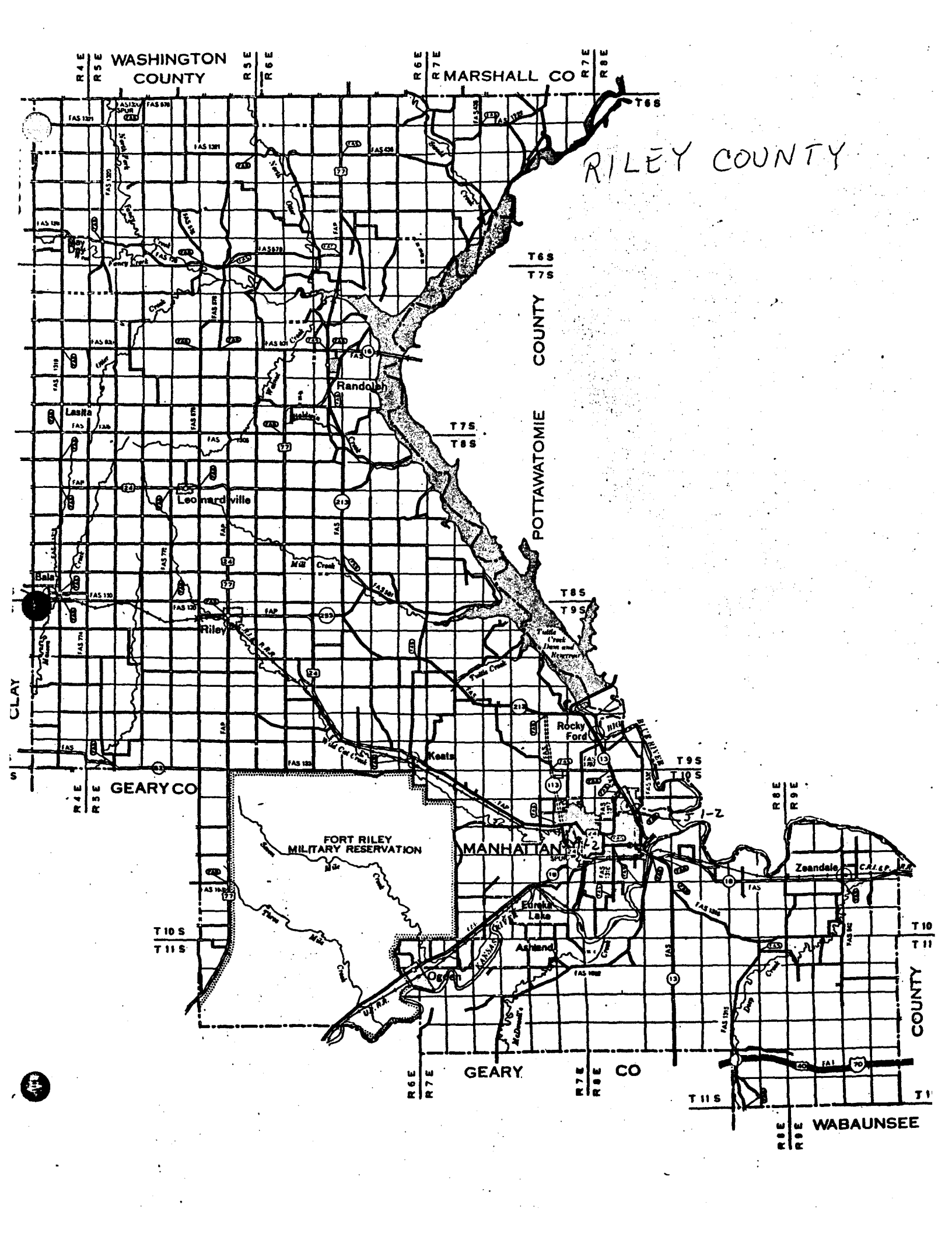


COLOR	ILLITE	CHLORITE	MONTMOR CHLORITE M/C C/M	MONTMOR ILLITE	MONTMOR CHLORITE ILLITE	SUPER LATTICE MONT-ILL.	MONTMOR.
BOTTOM OF BLACK	MAJOR	P	P	P	P		Ab
	MAJOR						
GREEN	MAJOR MAJOR	P	P	P	P	P	Ab

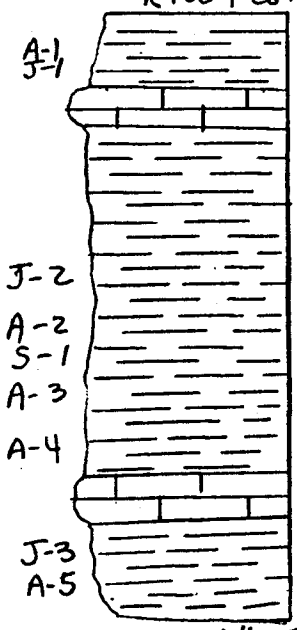
SCALE 1"=5'

LOCATIONS	METHOD	SOURCE
A 1-2 Sec 13 T10S R7E	X-RAY	ASMUSSEN, L.E.
J-1-2 NW¼ NE¼ SEC 7 T10S R8E BLUEMOUNT HILL ROAD CUT	DTA	JOHNSON, W.B.

BENNETT


RILEY COUNTY
WASHINGTON COUNTY
MARSHALL CO
POTTAWATOMIE COUNTY
CLAY
GEARY CO
GEARY CO
WABAUNSEE COUNTY
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Bala
Riley
Keats
Rocky Ford
Zeandale
Elmhurst Lake
Ashland
Ogden
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S

SEC 13
T10S R7E
RILEY Co.

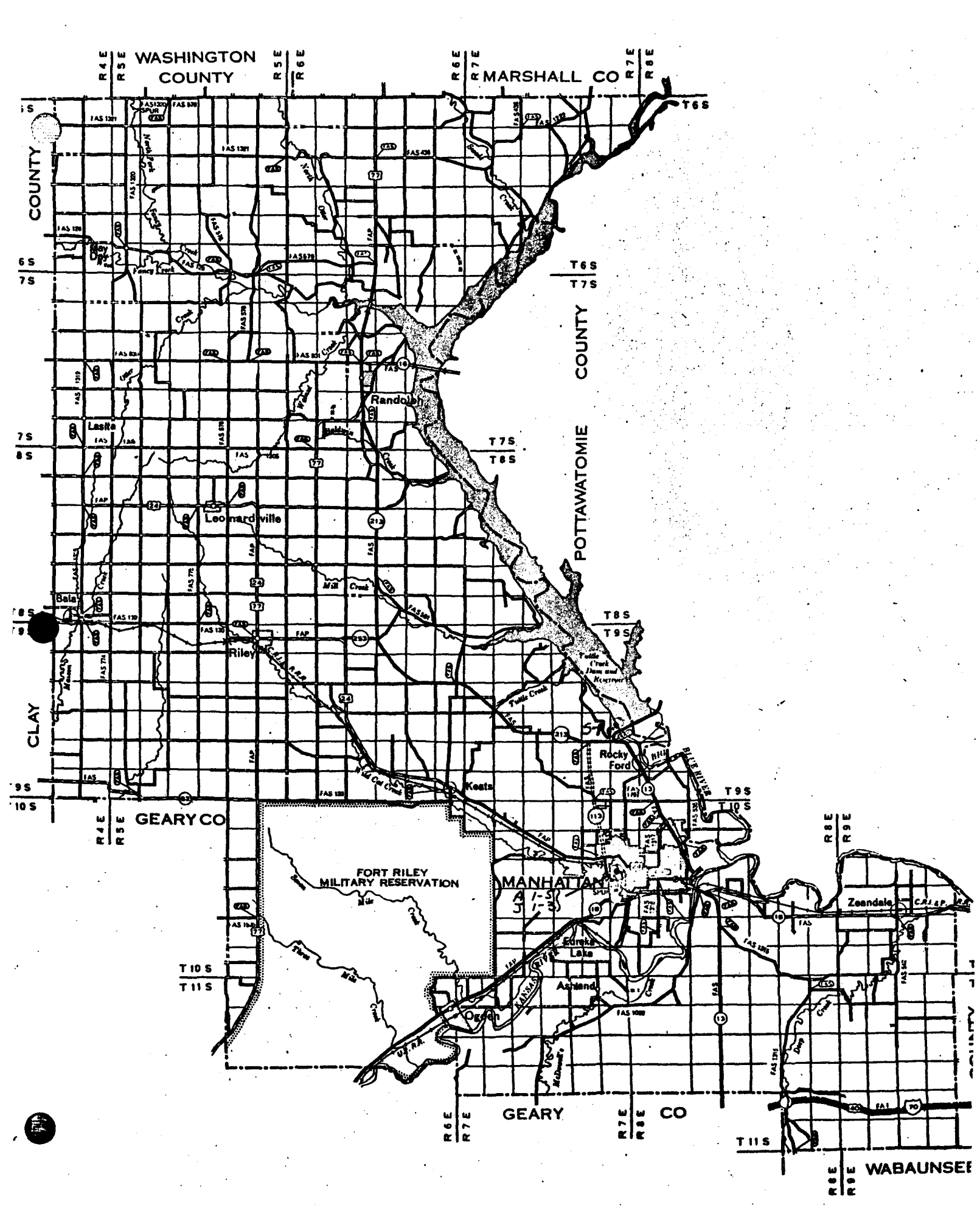


SCALE 1" = 5'

	COLOR	ILLITE	CHLORITE	MONTMOR. CHLORITE M/C C/M	MONTMOR ILLITE	MONTMOR CHLORITE ILLITE	SUPER LATTICE MONT-ILL	MONTMOR.
A-1 J-1	GRAY	MAJOR MAJOR	P	P	P	P		Ab
J-2		MAJOR						
A-2	BROWN	MAJOR	P	P	P	P	P	Ab
S-1		MAJOR	10+	P	P	MAJOR	P	Ab
A-3	BROWN	MAJOR	P					
A-4	TAN	MAJOR		P	P	P	P	Ab
J-3		MAJOR						
A-5	BLACK	MAJOR	P	P	P	P	P	Ab

LOCATIONS	METHOD	SOURCE
A 1-5 Sec 13, T10S, R7E	X-RAY	ASMUSSEN, L.E.
J1-3 SE¼ NW¼ SEC 13 T10S R7E WILDCAT CREEK	DTA	JOHNSON, W.B.
S-1 Sec 29 T9S R7E	X-RAY	, SWINEFORD ADA

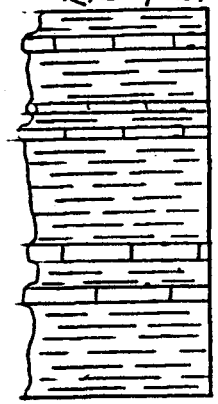
JOHNSON


WASHINGTON COUNTY
MARSHALL CO
POTTAWATOMIE COUNTY
CLAY
GEARY CO
GEARY CO
WABAUNSEE
FORT RILEY MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Bala
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Ogden
Lasita
R4E
R5E
R6E
R7E
R8E
R9E
T6S
T7S
T8S
T9S
T10S
T11S

HUGHES CREEK

SE¼ NW¼ Sec 13 T10S R7E RILEY Co.

J-1

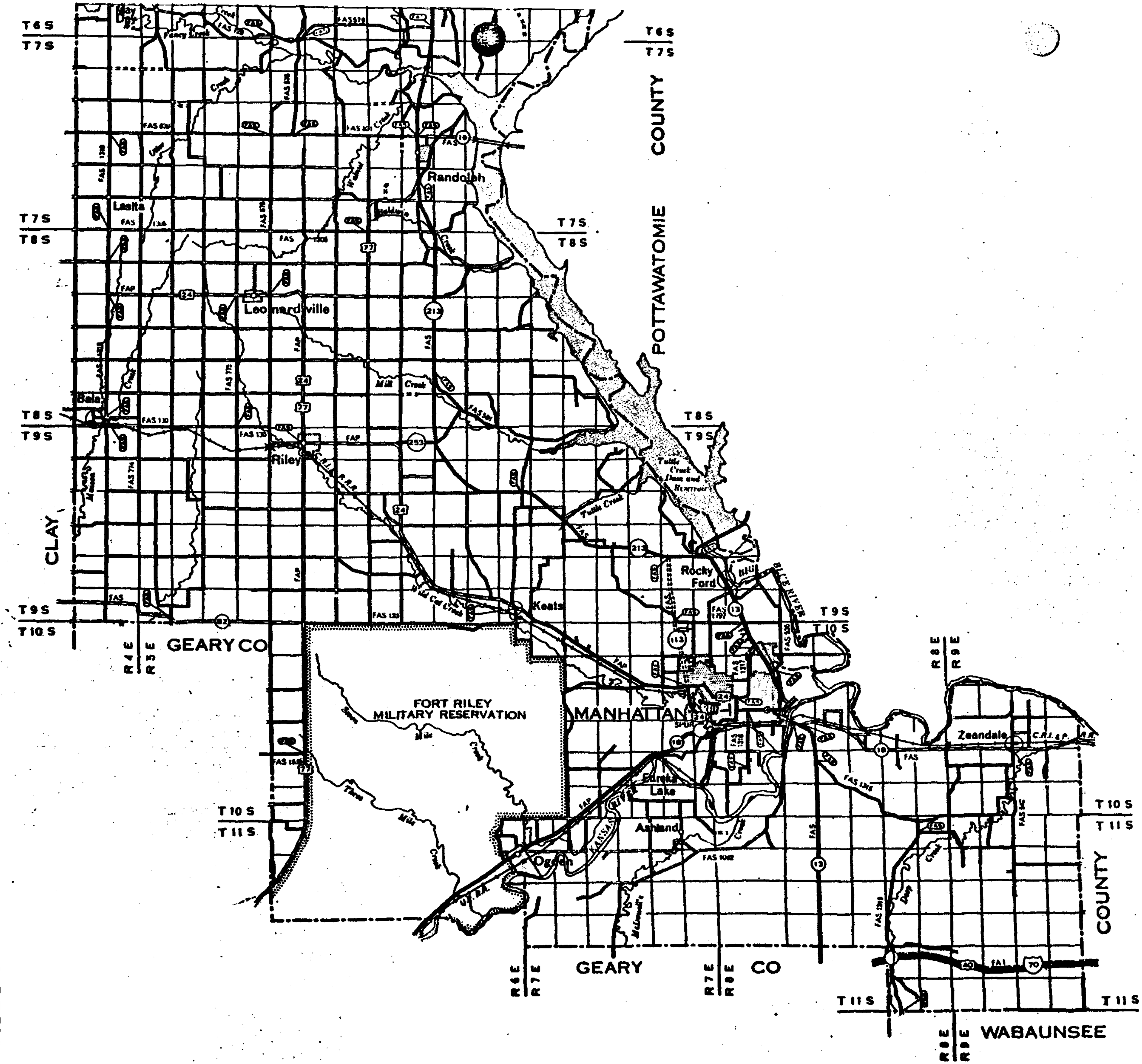


COLOR	ILLITE
GRAY	MAJOR

SCALE 1" = 20'

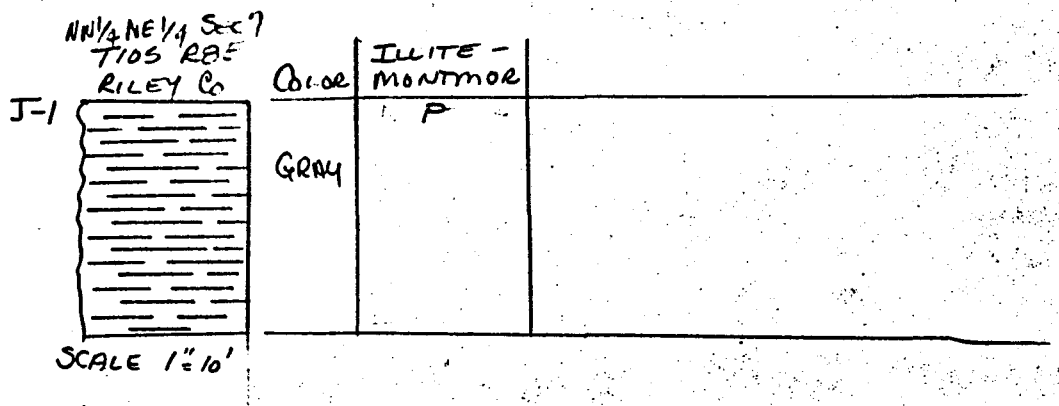
	LOCATION	METHOD	SOURCE
J-1	SE¼ NW¼ Sec 13 T10S R7E WILDCAT CREEK	DTA	JOHNSON, WB.

HUGHES CREEK



RILEY COUNTY
KANSAS

OHKS



LOCATION	METHOD	SOURCE
J-1 NW¼NE¼ SEC 7 T10S R8E BLUEMOUNT HILL RR. CUT	DTA	JOHNSON W.B.

OAKS

RILEY COUNTY
KANSAS
POTTAWATOMIE COUNTY
CLAY
GEARY CO
GEARY CO
WABAUNSEE COUNTY
FORT RILEY
MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Riley
Keats
Rocky Ford
Zeandale
Eureka Lake
Ashland
Ogden
T7S
T8S
T9S
T10S
T11S
R4E
R5E
R6E
R7E
R8E
R9E

TOWLE (INDIAN CAMP SANDSTONE MEMBER)

THICKNESS 0-120'

CLAY - INTERMEDIATE BETWEEN ILLITE AND KAOLIN

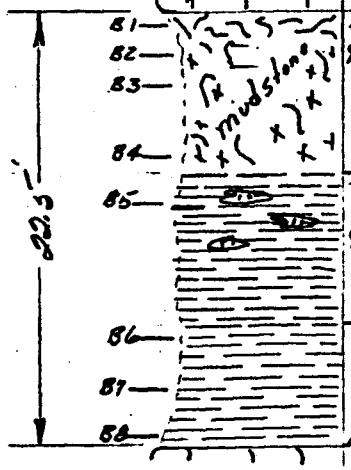
LOCATION	METHOD	SOURCE
J-1 SW¼ NE¼ SEC 30 T10S R9E ROAD CUT - 8' BELOW TOP OF CUT	DTA	JOHNSON, W.B.

TOWLE

RILEY COUNTY
KANSAS
1963
CLAY
POTTAWATOMIE
COUNTY
GEARY CO
GEARY
CO
WABAUNSEE
COUNTY
FORT RILEY
MILITARY RESERVATION
MANHATTAN
Randolph
Leonardville
Lasita
Bala
Riley
Keats
Rocky
Ford
Zeandale
Eureka
Lake
Ashland
Ogden
T6S
T7S
T7S
T8S
T8S
T9S
T9S
T10S
T10S
T11S
T11S
R4E
R5E
R6E
R7E
R8E
R9E

Wathena Shale Member

Sec 33-3-22E
Doniphon Co.



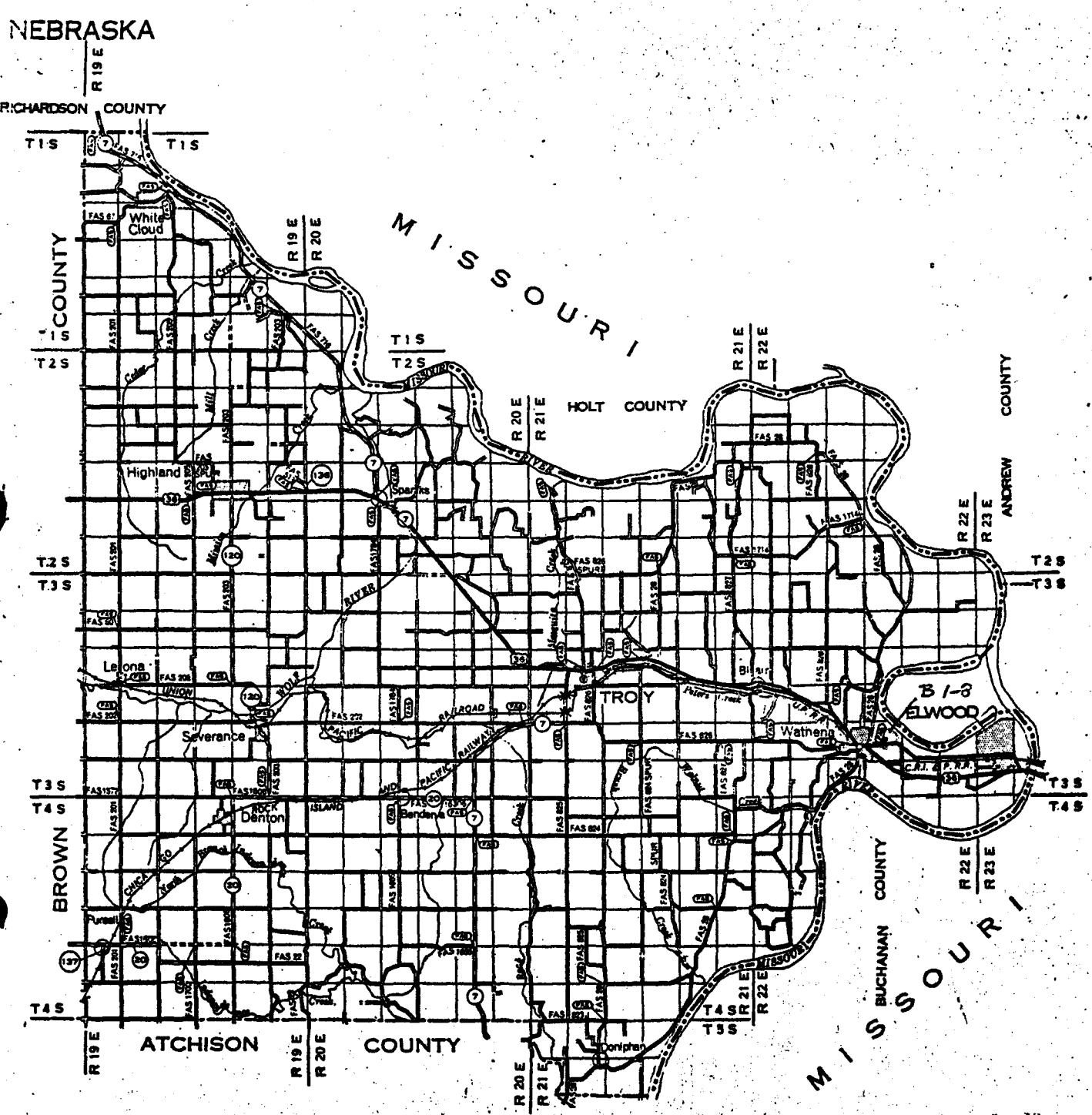
	Color	Illite	Illite Mixed-layer	Koolin	Verm
B1	Pale olive	major	P	T	P(?)
B2	greenish gray	major	P	T	P(?)
B3		major	P	T	P(?)
B4	grayish red	major	P	T	P(?)
B5	light greenish gray	major	P	P	P(?)
B6	Yellow green to greenish gray	major	P	P	P(?)
B7		major	P	P	P(?)
B8	light olive gray	major		P	P(?)

Scale 1" = 10'

* Illite content [illegible] samples from below [illegible]

	Location	Method	Source
1-8	Abandoned Quarry near center Sec 33, T3S, R22E Doniphan County.	X-Ray	Ball, Stanton, M.
9	[illegible] Sec 31, T3S, R22E Doniphan County	X-Ray	Ball, Stanton M.
10	[illegible] Sec 21, T12S, R19E Douglas County	X-Ray	Ball, Stanton M.
11	Road cut [illegible] Sec 25, T12S, R19E Douglas County	X-Ray	Ball, Stanton M.

WATHENA

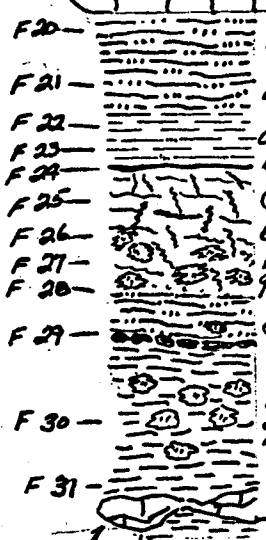


DONIPHAN COUNTY
KANSAS

1958

Wathena Shale Member

SE-SW-Sec 25-12-19E
Douglas County



Scale 1" = 10'

Color	Illite	Mont.	Verm	Chlorite	Kaolinite	Chlorite Verm	Illite Mont.
Yellowish gray	major		P		P		P
					moderately abundant		P
Light gray	major				major		major(?)
Light gray	major				P		T
Black (Coal)					T	P	major
Gray-green					T(?)		mixed layer nearly absent
Grayish-green	major				sparse		P
mottled	major				T		P
grayish-red	major				T(?)		P
Greenish gray							Limestone nodules
Light gray	major				sparse		P
to grayish green	major				sparse		P

Note: All but trace minerals exceed 5% of Clay fraction.

	Location	Method	Source
1-20	near Center east line SE¼ SW¼ Sec 25, T12S, R19E 6th St & Iowa Douglas Co.	X-Ray	FRANKS, Paul C.
	[illegible] Douglas County	X-Ray	[illegible]

Douglas County

Wathena Shale Member

	Color	Illite	Chlorite	Mont	Chlorite Verm	Kaolin	Illite Mont.	Kaolin Chlorite Verm	Verm
F 8	grayish orange	P				P	major		P
F 9	greenish gray	P	P			P	major		P
F 10		P			* P	P	major		P
F 11	light gray	major	P		P	P	P		
F 12	black	P	P			P	P		
F 13	mottled grayish red	P	P		P	P	P		
F 14		P	P			T	major		
F 15		P	P			T	major		P
F 16	med. gray	P	P			T	major		
F 17		Major	P			P	major		
F 18		Major	P		P			P	
F 19	greenish gray	Major	P			P	P	P	

Note: All but trace minerals exceed 5 percent of clay fraction

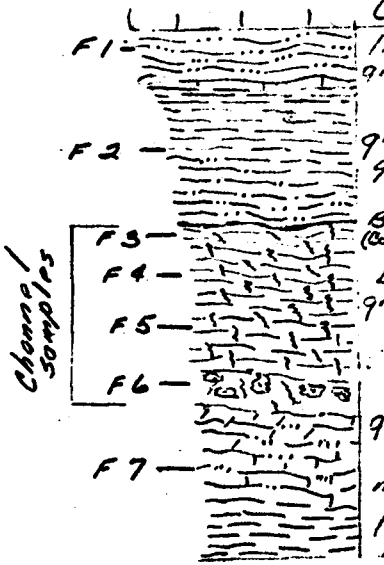
Scale 1" = 10'

* Slightly expandable

Road Cut NE¼ NW¼ Sec 21, T12S, R19E Turnpike Douglas County	X-Ray	FRANKS, PAUL C.

Douglas County

WATHENA SHALE MEMBER



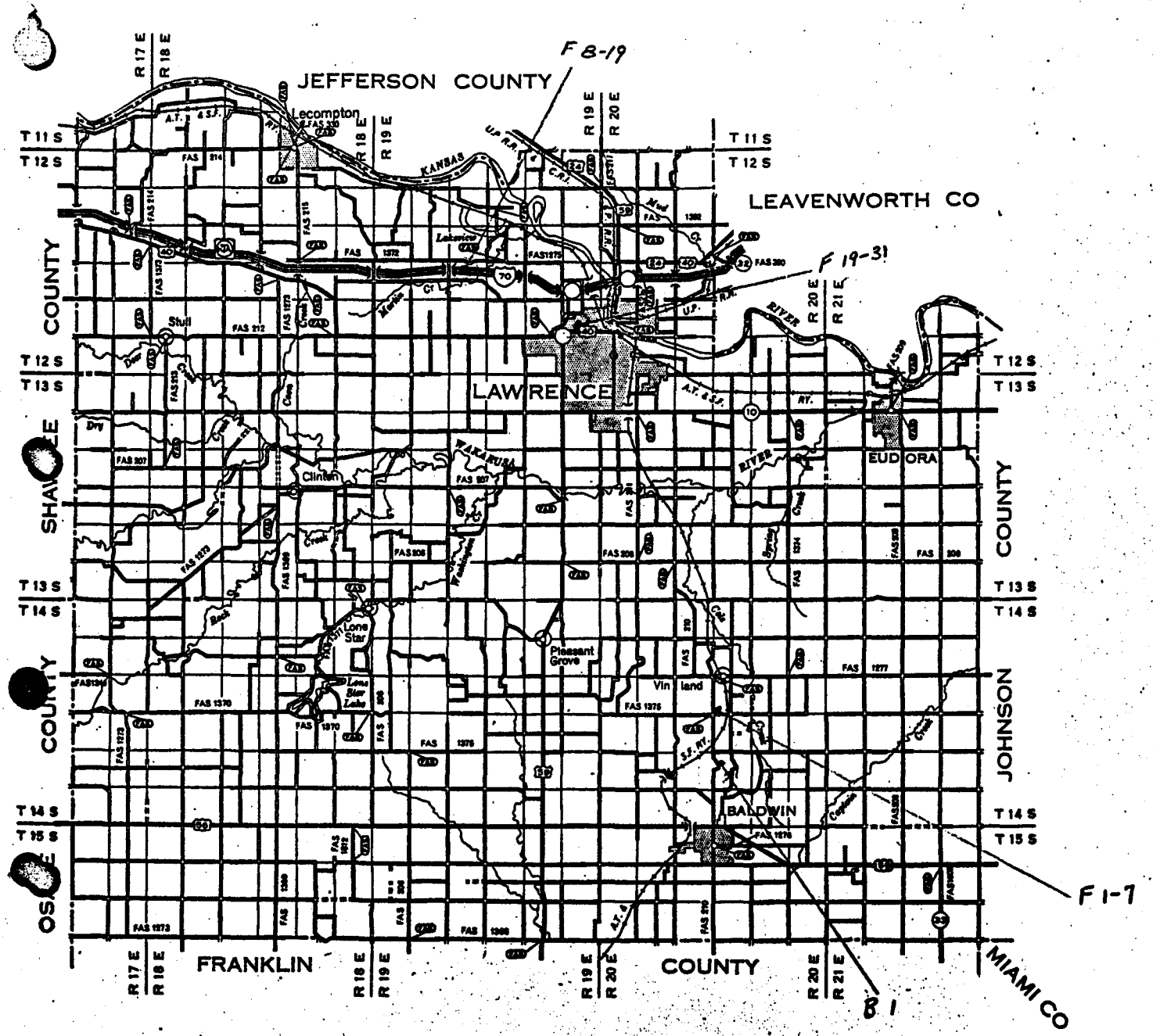
	Color	Illite	Mont	Verm	Chlorite	Kaolinite	Illite Mont	Calcite	Chlorite Verm	Chlorite Mont	
F1	light greenish gray	major		P	T (?)	P	P				
F2	greenish gray	major		P		T	P				
F3	Black (Coal mud)	MAJOR					P				
F4	Dark greenish gray	major					P				
F5		MAJOR			P		P			P	
F6	w/ grayish red mottling in lower part	major		P(?)		T(?)	P		P	P	
F7		major				T(?)	P		P(?)		

Note: All but trace minera exceed 5% of clay fract

Scale 1" = 10'

	Location	Method	Source
F1-1	SW Cor. Sec 15, T14S, R20E "Baldwin Hill" Douglas Co.	X-RAY	Frank, Paul C.
B1	Road Cut Con. S. line NW-SW-NW Sec 27, T14S, R20E Douglas Co.	X-RAY	BALL, Stanton 19

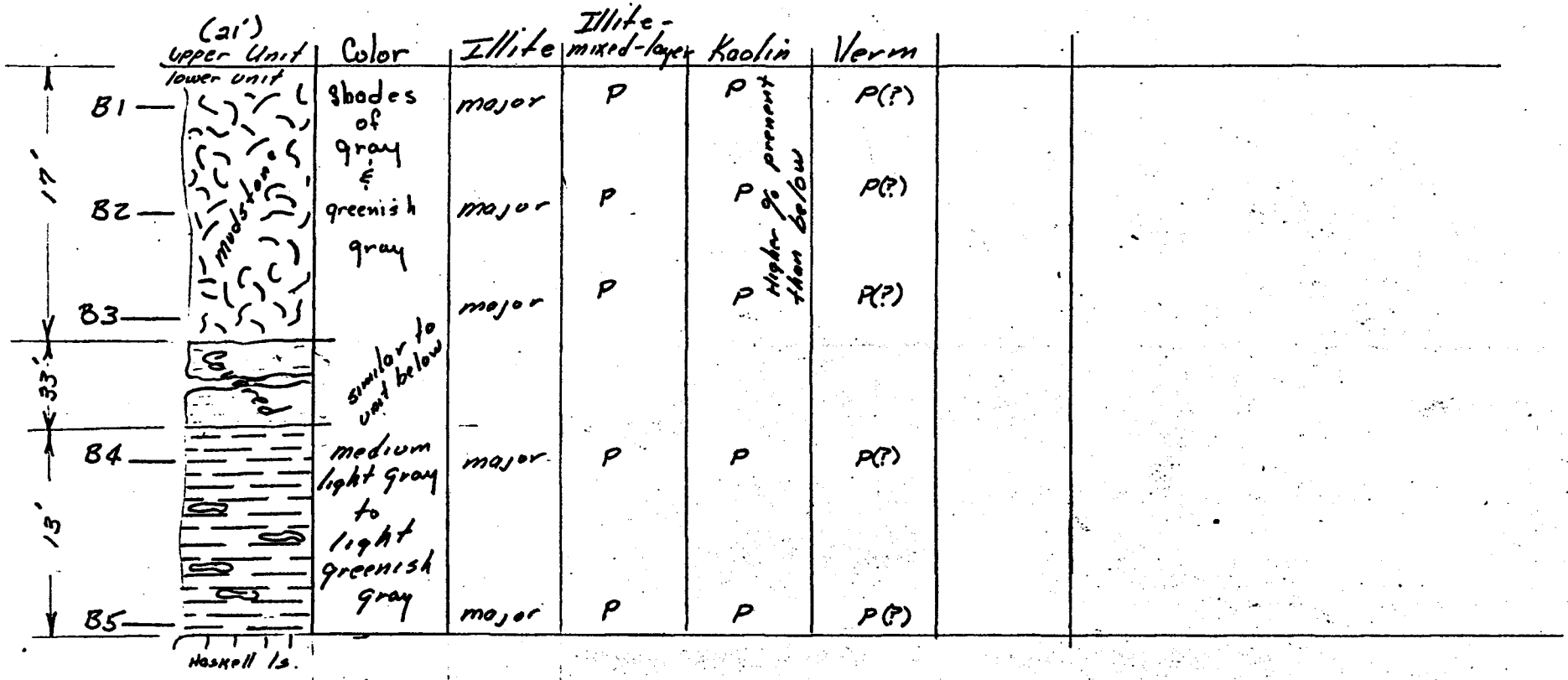
Douglas County



DOUGLAS COUNTY
KANSAS

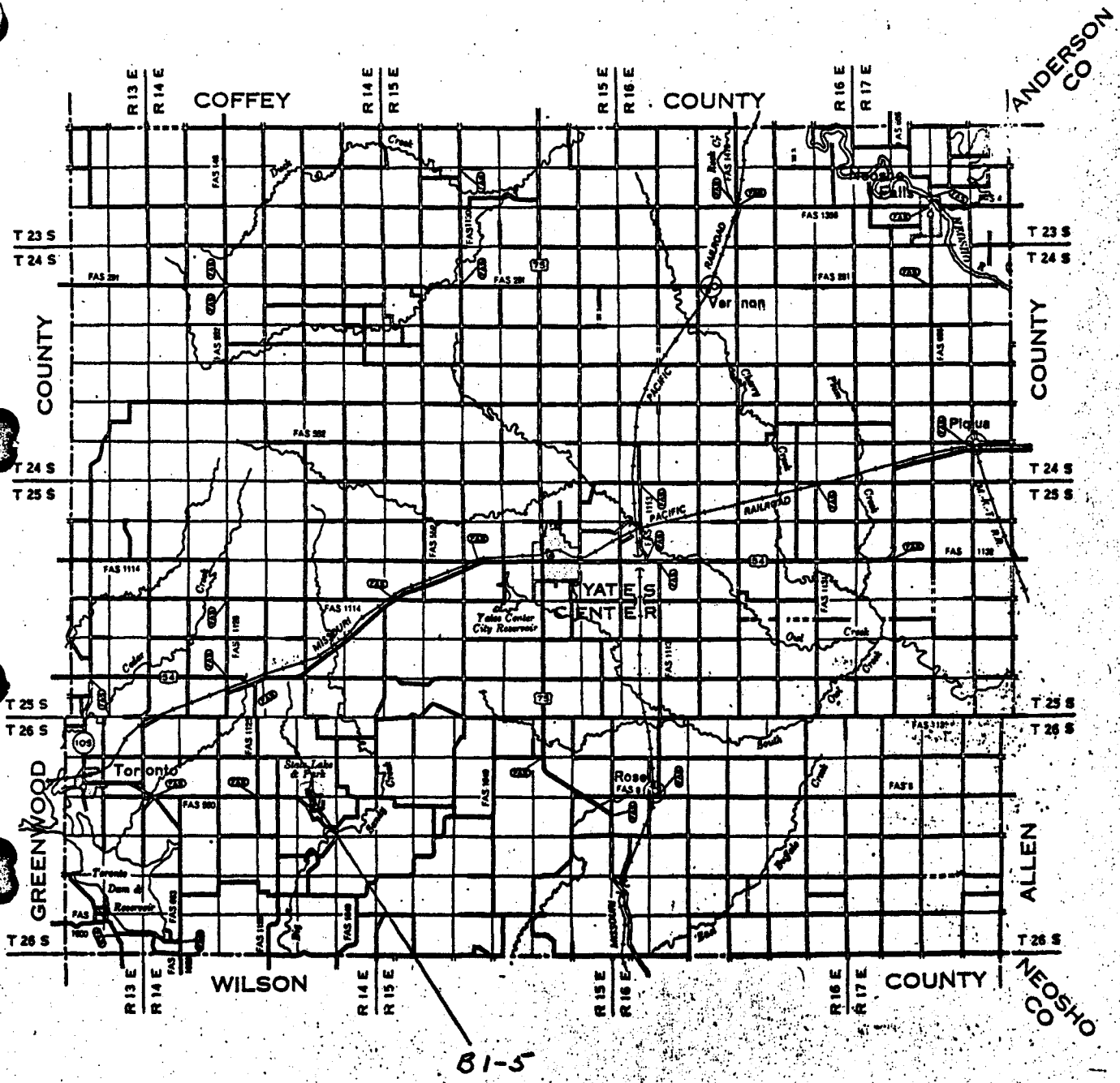
1958

Robbins Shale



Location	Method	Source
Spillway Cutbank of Lake Fegan SE¼, SW¼, SE¼ Sec 11, T26S, R14E Woodson County	X-Ray	Ball, Stanton M.

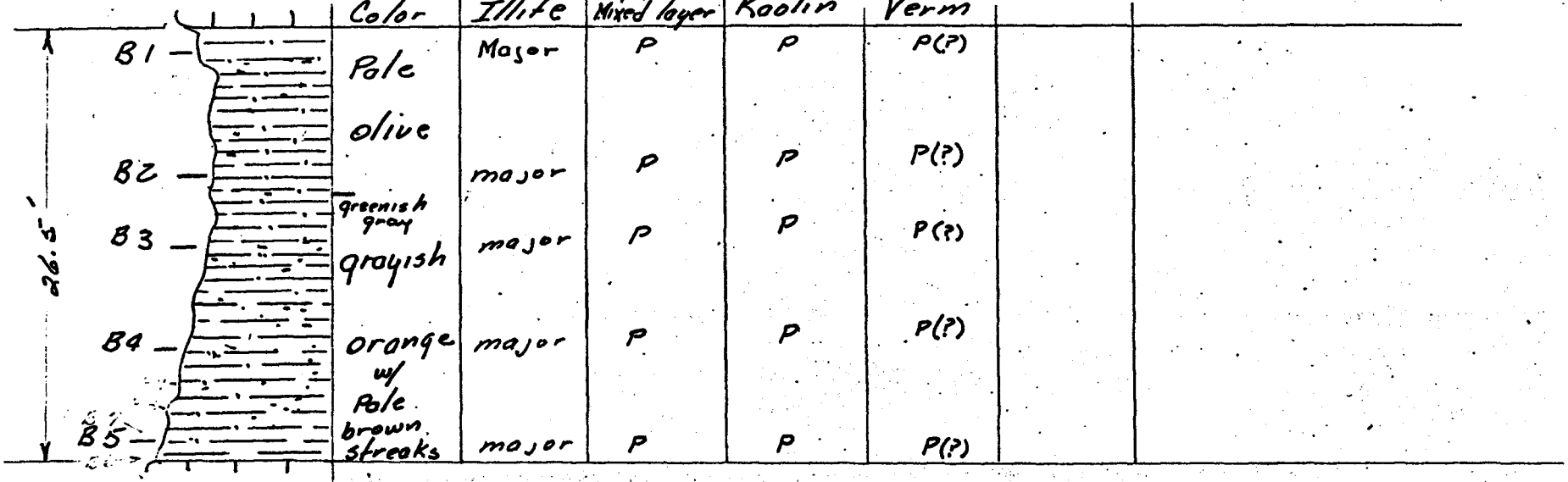
ROBBINS



WOODSON COUNTY
KANSAS

1960

VINLAND SHALE MEMBER

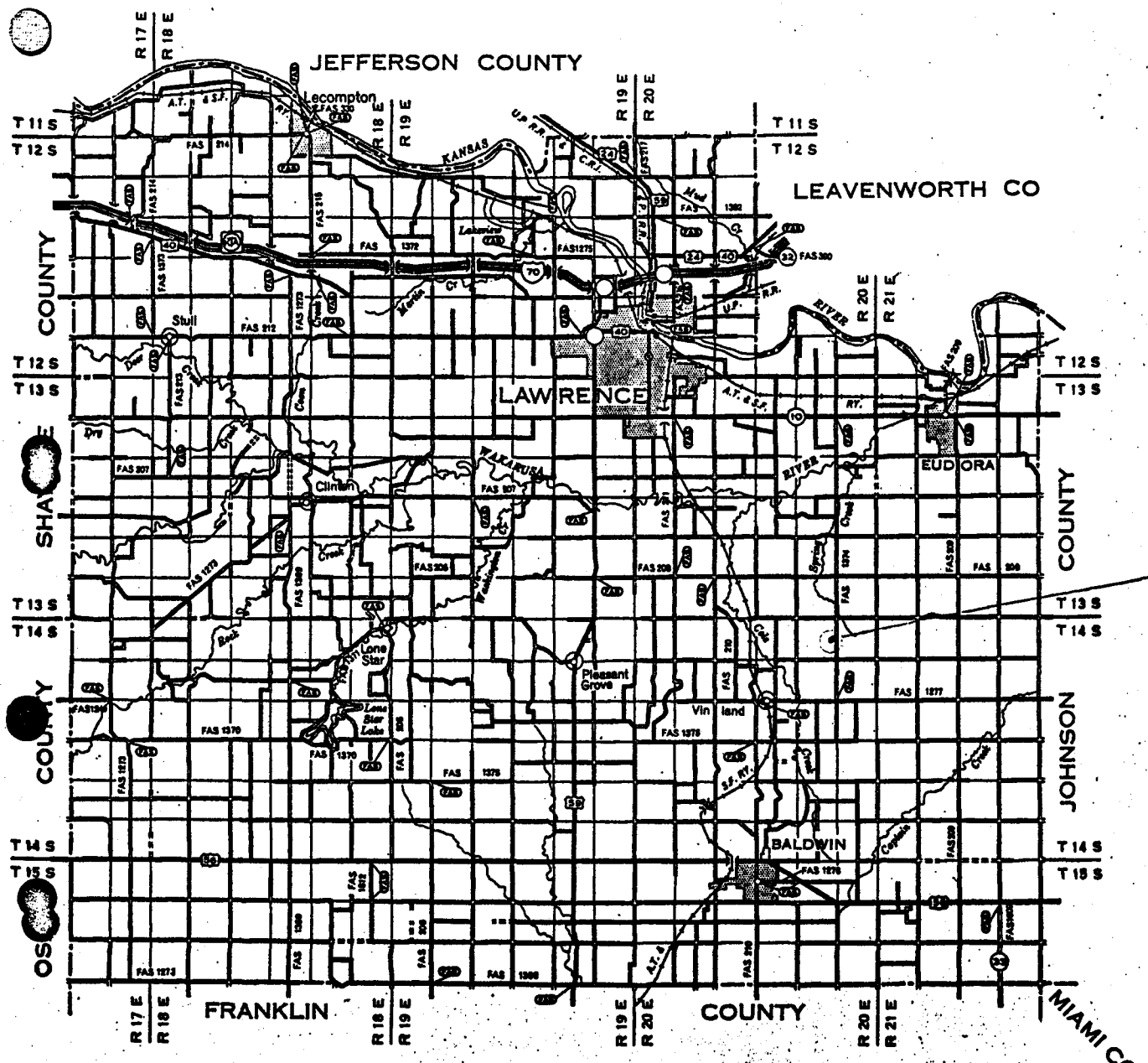


Scale 1" = 10'

	Color	Illite	Illite-Mixed layer	Kaolin	Verm		
B1	Pale olive	Major	P	P	P(?)		
B2		major	P	P	P(?)		
B3	greenish gray grayish	major	P	P	P(?)		
B4	orange w/ Pale	major	P	P	P(?)		
B5	brown streaks	major	P	P	P(?)		

	Location	Method	Source
B1-5	Road cut near Center east line SE¼, Sec 2 T14S, R20E Douglas County	X-Ray	Ball, Stanton M.
		X-Ray	Ball, Stanton M.

VINLAND

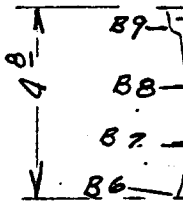


DOUGLAS COUNTY
KANSAS

1958

Vinland shale Member

Sec 11-26-18E
Woodson Co.

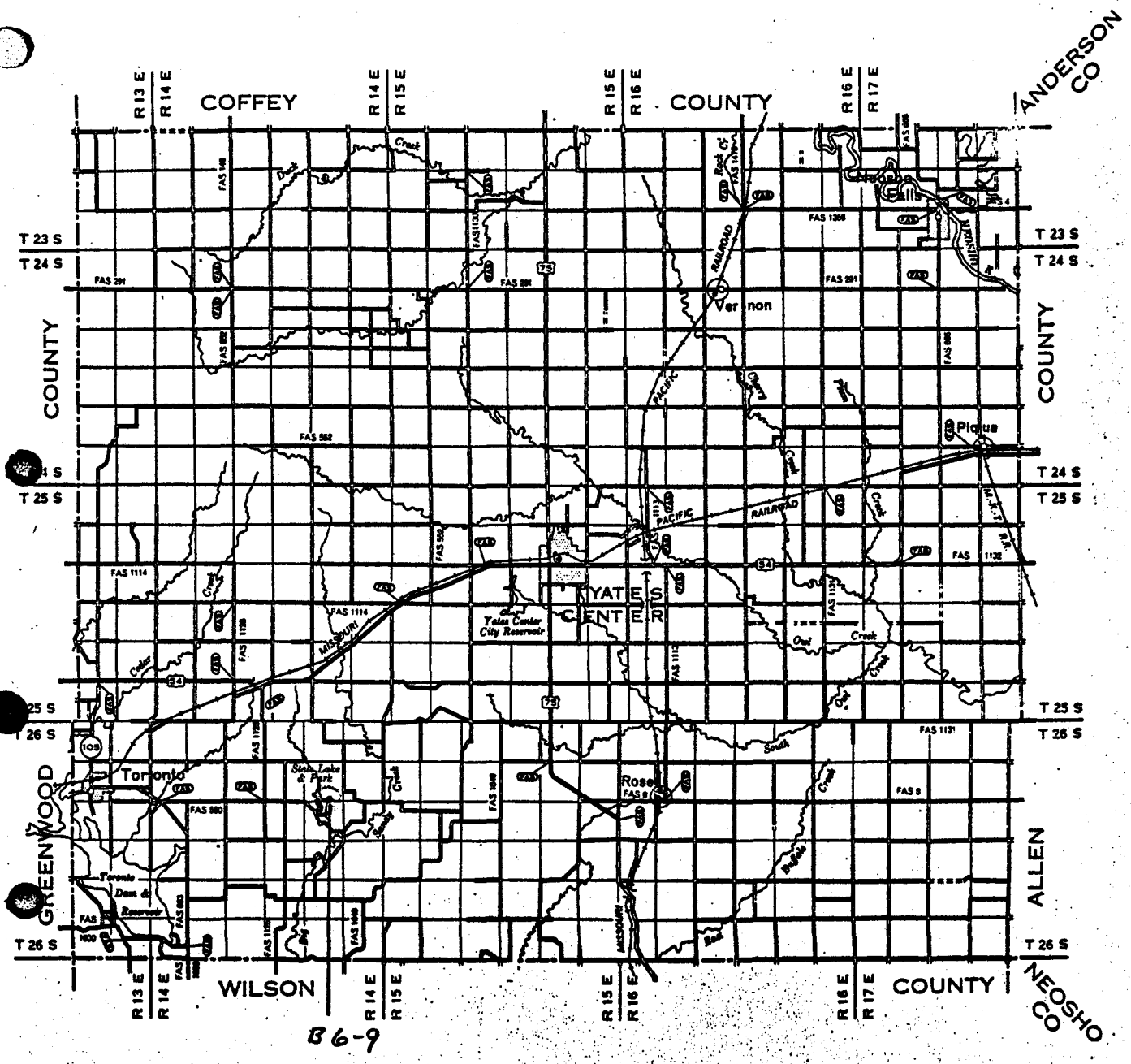


Haskell	Color	Illite	Illite mixed-L	Kaolin	Verm
B9	greenish gray	major	P	P	P(?)
B8	greenish gray	major	P	* P	P(?)
B7	to light brownish gray	major	P	P	P(?)
B6	to light brownish gray	major	P	P	P(?)

Scale 1" = 5'

* Kaolin Content increases

Stream bank & Spillway Cut SE-SW-SE Sec 11, T26S, R18E Woodson County	X-Ray	Ball, Stanton M.



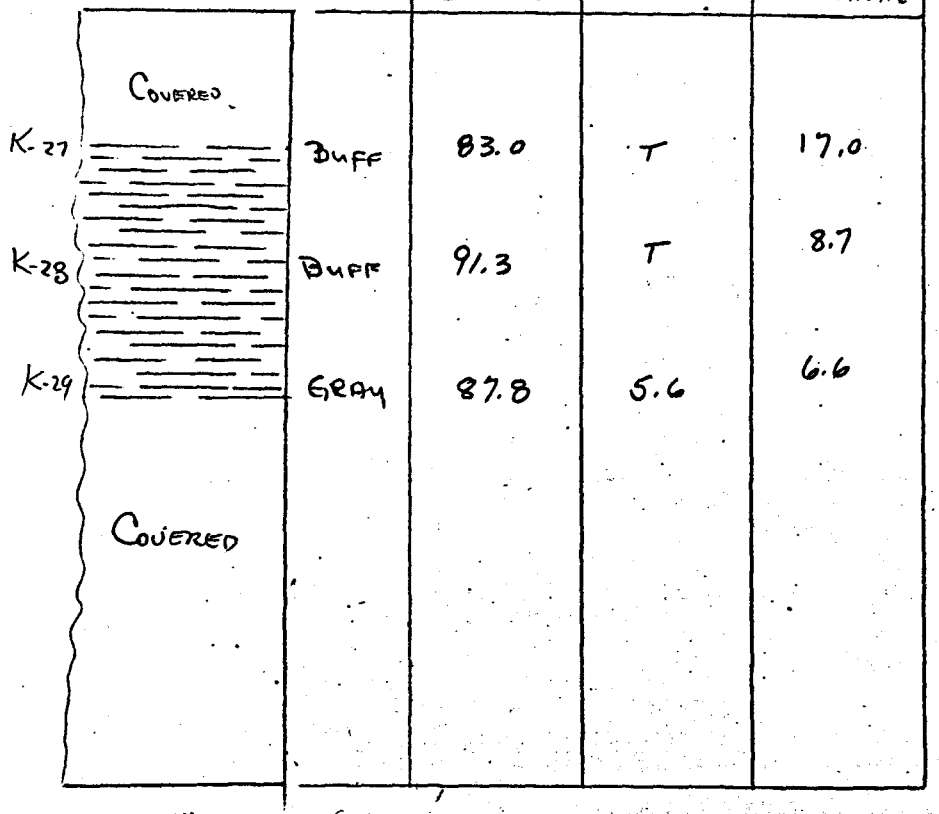
WOODSON COUNTY
KANSAS

1960

VILAS

FIGURES ARE FOR % OF CLAY FRACTION ONLY

SE 1/4 SEC 9
T 32S RISE

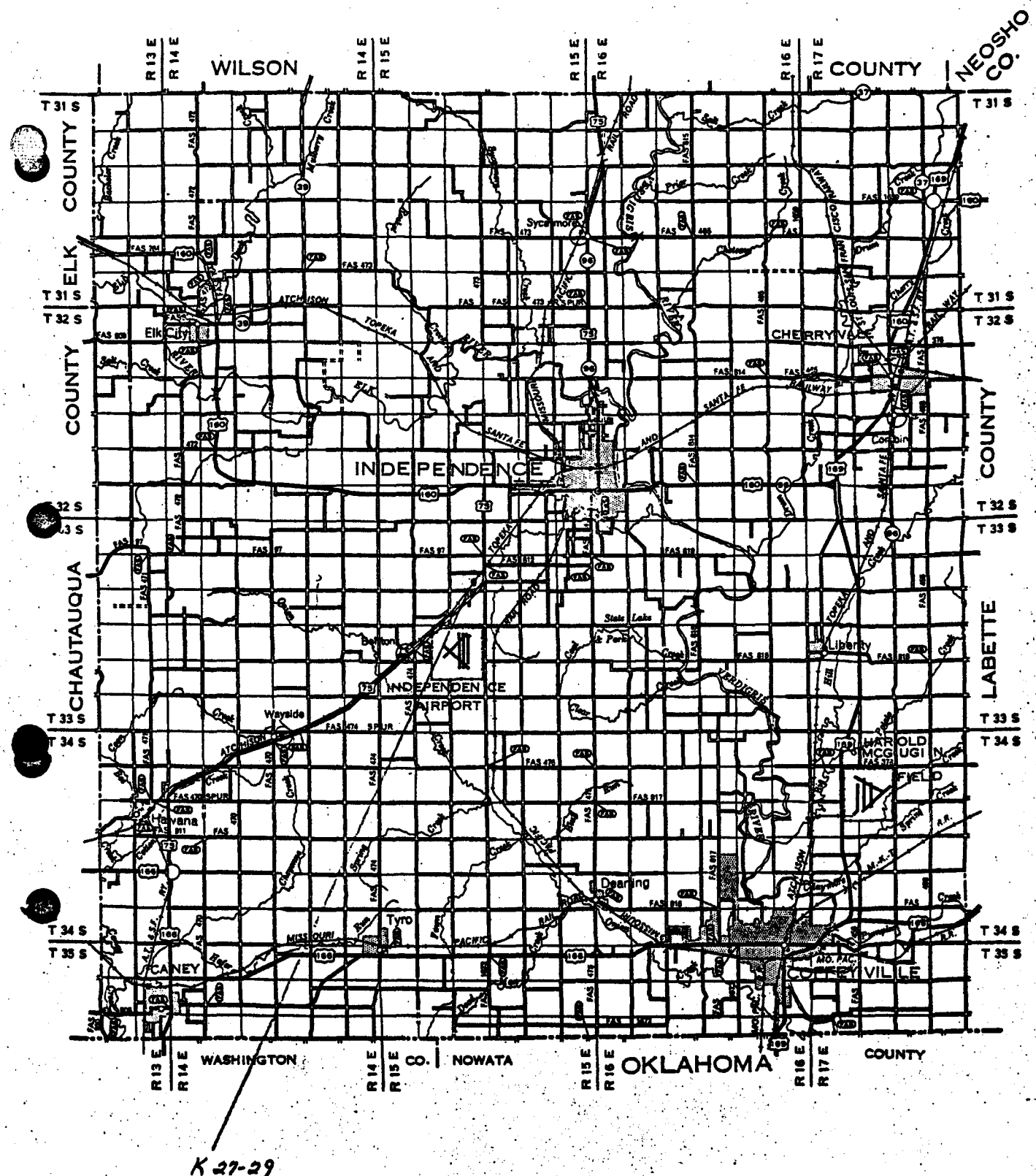


SCALE 1" = 25'

		ILLITE	CHLORITE	KAOLINITE
K-27	BUFF	83.0	T	17.0
K-28	BUFF	91.3	T	8.7
K-29	GRAY	87.8	5.6	6.6

K 27-29 SE4 SEC. 9 T 32S RISE STREAM BANK	X-RAY	KINELL III, C.B.

VILAS



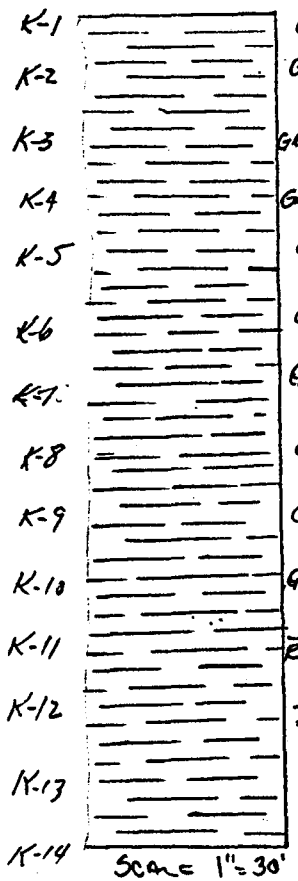
K 27-29

MONTGOMERY COUNTY
KANSAS

1959

VILAS SHALE

FIGURES ARE FOR CLAY FRACTION ONLY.

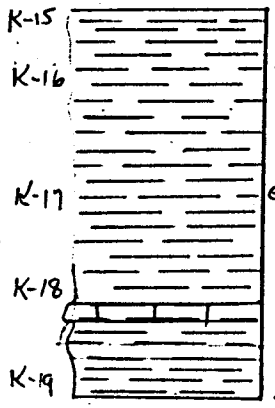


		Illite	Chlorite	Kaolinite
K-1	Gray	79.7		20.3
K-2	Gray-Buff	83.8		16.2
K-3	Gray-Buff	90.4		9.6
K-4	Gray-Buff	88.2		11.8
K-5	Gray	91.3		8.7
K-6	Gray	86.3	T	13.7
K-7	Gray	88.5	5.3	6.2
K-8	Gray	79.6	T	20.4
K-9	Gray	75.6	15.1	9.3
K-10	Gray-Buff	83.7	T	16.3
K-11	Buff-Gray	74.3		25.7
K-12	Buff			
K-13	Buff	80.3	10.0	9.7
K-14	Buff	76.4	9.10	14.5

K-14	NW¼ NW¼ Sec 26 T28S R15E (ROADCUT)	X-RAY	KINELL, C.B.

VILAS

FIGURES REFER TO % OF CLAY FRACTION ONLY



		ILLITE	CHLORITE	KAOLINITE
K-15	BUFF	87.5		12.5
K-16	BUFF	89.4	T	10.6
K-17	GRAY-BUFF	71.5	11.9	16.6
K-18	GRAY	78.6	10.9	10.5
K-19	GRAY	79.1	13.2	7.7

SCALE 1" = 10'

	METHOD	
K-15-19 NW¼ SEC 18 T 29S R 1 E ROADCUT ON K-77	X-RAY	KINELL, III, C.B.

FIGURES REPRESENT % OF CLAY FRACTION ONLY

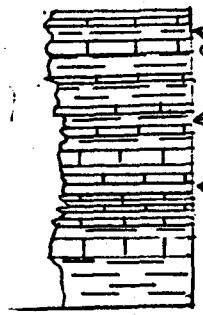
		ILLITE	CHLORITE	KAOLINITE	
K-20	BUFF	90.4	TT	9.60	
K-21	GRAY	90.0		10.0	
K-22	GRAY	89.3		10.7	

Scale 1" = 5'

NW¼, SEC 18, T30S, R16E, CAPE LIMESTONE QUARRY	X-RAY	KINGLE III, C.B.

VILAS

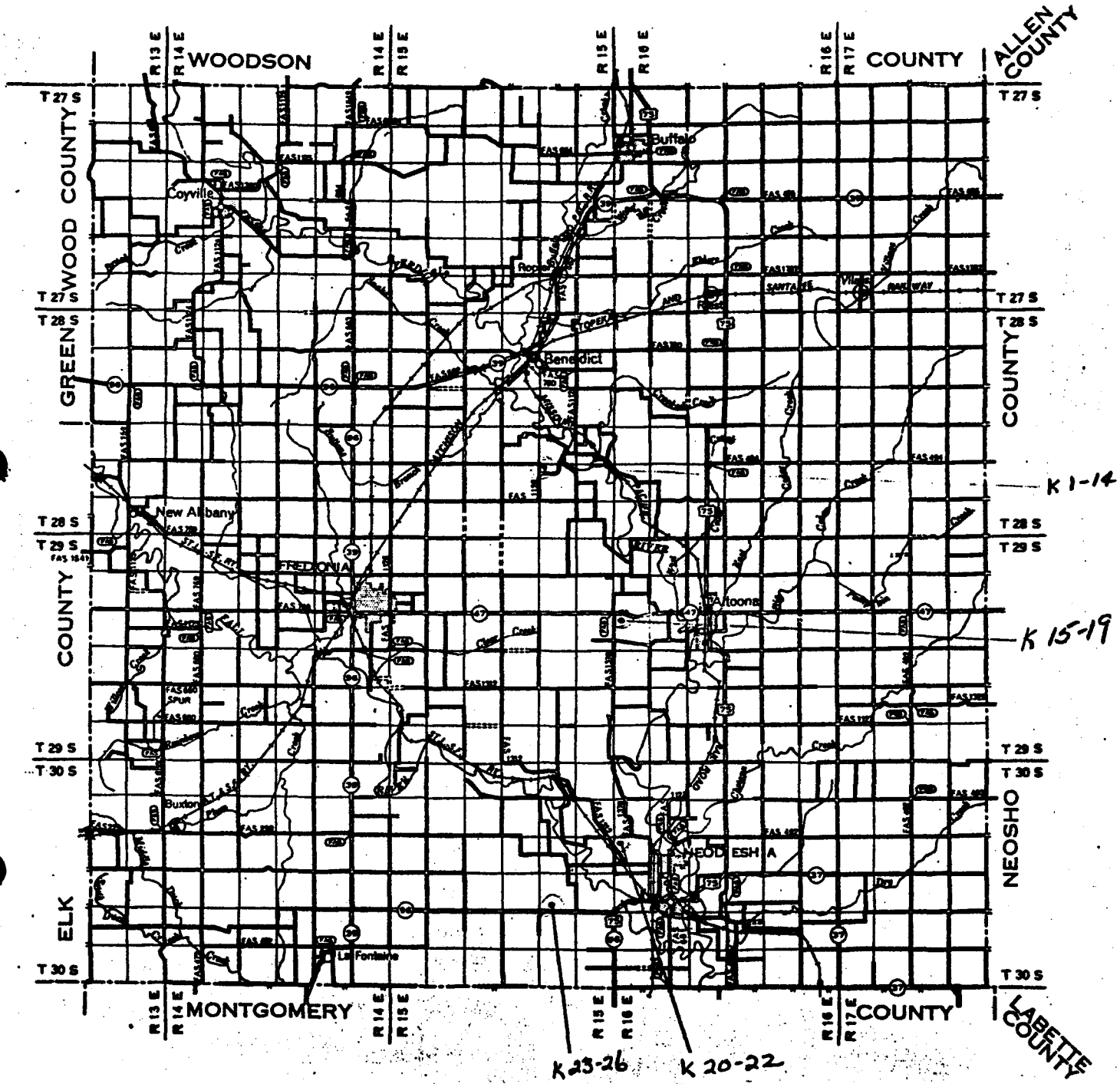
FIGURES REPRESENT % OF CLAY FRACTION ONLY



SCALE 1"=10'

	ILLITE	CHLORITE	KAOLINITE	
GRAY-TAN	87.6	T	12.4	
GRAY	78.0	11.8	10.2	
GRAY	76.4	11.9	11.7	
GRAY	81.6	11.3	7.05	

K 23-26 SE¼SW¼ Sec 23, T30S R5E ROADCUT - K 96		X-RAY	KINELL, III, C.B.



WILSON COUNTY
KANSAS

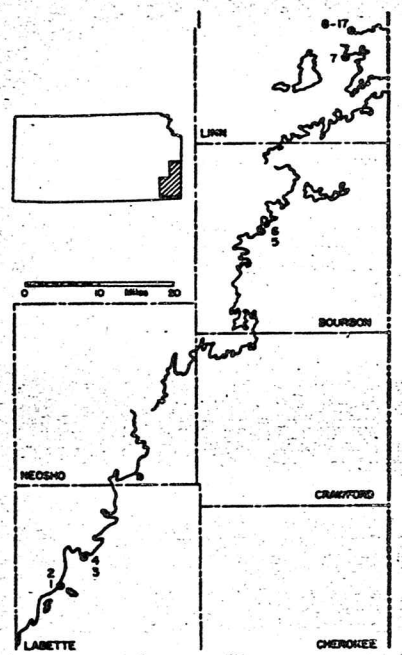


FIGURE 2. — Sample localities and trace of Hepler-Holdenville boundary in southeast Kansas.

and sample 6, from just below the disconformity, were made in the geochemistry laboratories of the State Geological Survey under the direction of Russell Runnels. The results are reported in Table 2.

HEPLER SANDSTONE AND SHALE

The clay minerals were examined from one sample (7) of basal Hepler sandstone and two samples (8, 9) of basal Hepler shale.

The sandstone sample is represented by diffractometer patterns in Figure 3. The minerals present are kaolinite, slightly hydrated illite, a small quantity of quartz, and a nonexpanding 14.5A mineral. This 14.5A spacing, although slightly broad, is in part stable after heating to 450°C, but it shifts to 11.9A after the clay is heated to 575°C. It is attributed to a vermiculite mineral, probably mixed-layer chlorite-vermiculite. The symmetry of the illite 001 reflection improves with glyceration and also with heating to 450°C, so it is thought that the illite has no chloritic (Nelson, 1956, p. 120) or vermiculitic component. No feldspar reflections were observed.

The basal Hepler shale samples contain kaolinite, illite, and normal chlorite. They are described in a later section.

TABLE 1. — LOCATIONS OF SAMPLES DESCRIBED; PARTICLE SIZE AND SORTING

No.	Location	Depth Below Hepler	Height Above Lenapah	Phi Mean Diameter	S D
1	NE 11-33-18E, Labette Co.	10 ft	8 ft	8.64	
2	do	9	9		
3	Cen. N line 20-32-19 E, Labette Co.	5.3		7.32	
4	do	0.5		7.53	
5	SE SE 18-25-23E, Bourbon Co.	.5-1		8.30	
6	do	0-.5		8.66	
7	Cen. 19-21-25E, Linn Co.	—[1]			
8	Cen. 5-21-25E, Linn Co.	—[2]			
9	do	—[3]			
10	do	1.5	25		
11	do	2.5	24		
12	do	3.5	23	7.03	
13	do	4.5	22		
14	do	5.5	21		
15	do	6.5	20		
16	do	7.5	19	9.22	
17	do	13.5	13	9.56	

[1] Basal Hepler sandstone
[2] 1.5 feet above base of 7-foot Hepler shale section
[3] 0.5 foot above base of Hepler shale

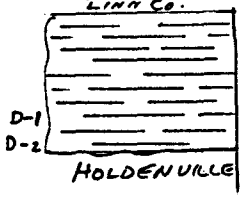
TABLE 2. — CHEMICAL ANALYSES OF TWO SAMPLES FROM THE HOLDENVILLE SH
(by Russell Runnels, State Geological Survey of Kansas)

	16[1]		6[2]	
	Whole Shale	—2μ	Whole Shale	—
SiO_2	54.21	47.43	50.97	48.
Al_2O_3	21.89	25.72	22.10	25.
Fe_2O_3[3]	8.20	9.17	6.20	8.
TiO_2[4]	1.19	0.93	1.47	0.
CaO	0.31	0.28	4.47	1.
MgO	2.79	2.88	2.13	2.
P_2O_5	0.09	ND	1.89	N
SO_3	nil	ND	0.05	N
K_2O	4.39	5.57	4.14	5.
Na_2O	0.81	0.45	0.37	0.
Sulfide S	0.05[5]	ND	tr	N
LOI 140-550°	1.05	3.34	2.92	3.
LOI 550-600°	2.62	2.45	1.42	2.
LOI 1000°	1.90	1.05	1.72	1.
Total	99.45	99.27	99.73	99.

[1] 7.5 feet below Hepler
[2] Less than 6 inches below Hepler
[3] Total iron expressed as ferric oxide
[4] Includes V_2O_5 and ZrO_2 if present
[5] Not included in total

HEPLER - BASAL SHALE

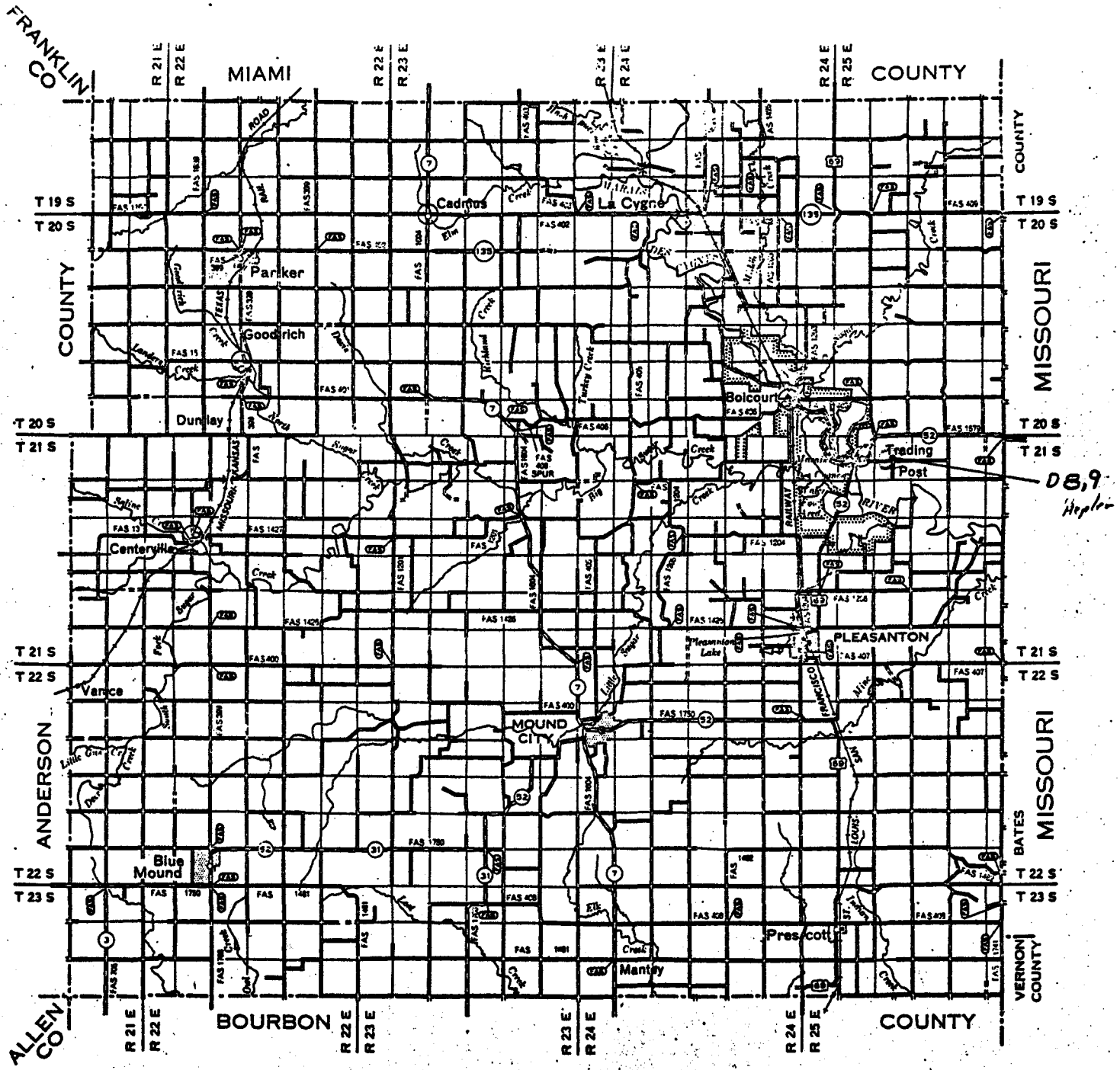
CEN S T21S R25E LINN Co.



SCALE 1" = 10'

	ILLITE	ILLITE-MONTMOR	CHLORITE	VERMICULITE	DEGRADED ILLITE
GRAY	MAJOR	T P	P	P	MAJOR

D1-2	CEN S T21S R25E LINN Co.	X-RAY	DALTON et.al.



GENERAL HIGHWAY MAP

LINN COUNTY

KANSAS

1960

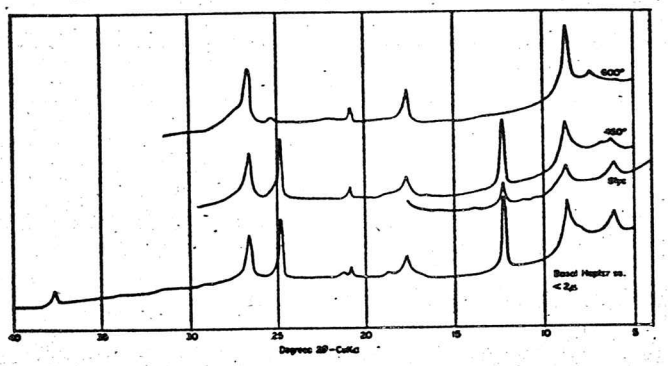


FIGURE 3. — X-ray diffractometer patterns of –2 micron fraction, basal Hepler sandstone (sample 7).

TYPICAL HOLDENVILLE SHALE

Four of the samples analyzed and described herein (1, 2, 16, 17) are believed to be characteristic of the essentially unmodified Holdenville. These range in position from about 8 to 19 feet above the base of the formation, and are 7 to 13 feet below the base of the Hepler sandstone. Two of them (1 and 2) contain abundant marine fossils, particularly bryozoans and corals, in the coarser fractions.

The minerals present in the fraction finer than 2 microns, as shown by x-ray diffractometer patterns, are illite, chlorite, quartz, and feldspar, and very small quantities of kaolinite and illite-montmorillonite. The 14.5, 10, and 7A basal reflections are sharp and well defined (Fig. 4), but there is slight asymmetry in the 10A reflection. Feldspar is identified by a reflection at about 3.2A in the oriented samples. The 14.5A reflection and higher-order basal chlorite reflections (7.13A, 4.77A, 3.56A, 2.84A) in all four samples are unmodified by heating the sample to 450°C, but after the clay was heated at 575°C for one-half hour all but the 14.5A reflection were destroyed. The intensity of this peak increased and its spacing shifted to 14.2A.

Treatment of the oriented clay with glycerol increased the symmetry of the 10A reflection in all samples; the diffraction patterns were otherwise unmodified. Destruction of the chlorite with hot HCl revealed the presence of a minute quantity of kaolinite. Typical Holdenville diffractometer patterns are shown in Figure 4.

CHARACTER OF HOLDENVILLE CLAY MINERALS NEAR DISCONFORMITY

Five changes are observed in the various samples of Holdenville shale from near the base of the Hepler: (a) destruction or modification of the chlorite; (b) formation or addition of either a kaolin mineral or "soil" chlorite or both; (c) decrease in feldspar; (d) broadening of the illite basal reflections;

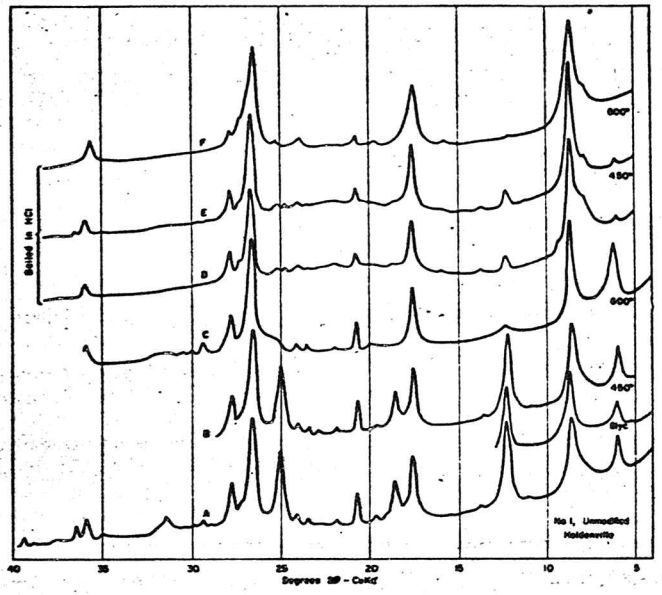


FIGURE 4. — X-ray diffractometer patterns of –2 micron fraction, unmodified Holdenville shale (sample 1).

and (e) increase in mixed-layer minerals. There is also a trend toward poor sorting with respect to particle-size distribution.

The clay minerals in a single outcrop will first be described and tabulated. Each of five samples from other localities will then be described individually, in order of decreasing distance below the Hepler contact.

Section Below Basal Hepler Shale

In a stream bank near the center of sec. 5, T. 21 S., R. 25 E., Linn County, is a complete section of Hepler sandstone and Holdenville shale. Inasmuch as the basal few feet (about 7 feet) of the Hepler at this locality is predominantly shaly and hence relatively impermeable to percolating ground water, this section was chosen for detailed study. Samples were taken at one-foot intervals from the gray Holdenville shale upward through increasingly yellowish limonitic zones, and across the disconformity into the dark gray basal Hepler shale. The clay mineral assemblages are shown in Table 3.

This is the only locality from which a "soil" chlorite was identified. Otherwise, the general picture is similar to that at other localities: illite becomes degraded, illite-montmorillonite increases, and normal chlorite gives way to vermiculite.

Description of Individual Samples

The clay-mineral content of each of five samples from localities in Linn,

TABLE 3. — CLAY MINERALS IN BASAL HEPLER SHALE AND UPPER HOLDENVILLE SHALE IN THE CEN. SEC. 5, T. 21 S., R. 25 E., LINN COUNTY

Distance Above or Below Disconformity	Clay Minerals
1.5 ft above	Kaolinite, illite, chlorite[1]
0.5 ft above	Kaolinite, illite, chlorite
— — — — — — — —	DISCONFORMITY — — — — — — — —
0.5 ft below	Illite (degraded), "soil" chlorite, illite-montmorillonite, vermiculitic mineral, trace kaolinite (?)
1.5 ft below	Same, but no kaolinite
2.5 ft below	Illite, "soil" chlorite, chlorite, vermiculitic mineral, trace illite-montmorillonite
3.5 ft below	Same as above, but chlorite more heat-resistant, trace kaolinite
4.5 ft below	As above, but no vermiculite. Chlorite and illite reflections strong
5.5 ft below	As above
6.5 ft below	As above, but no "soil" chlorite. Chlorite and illite reflections very strong, nearly symmetrical
7.5 ft below	As above
13.5 ft below	As above

[1] The term *chlorite* here refers to normal chlorite having a 14A basal spacing that is retained after heating to 575°C. *"Soil" chlorite* refers to chlorite whose basal spacings are destroyed at 450°C.

Bourbon, and Labette counties are described in order of decreasing distance below the disconformity.

Sample 3 (5.3 feet below base of Hepler).—The diffraction pattern from the unheated oriented clay is identical with those from the unmodified Holdenville, except that the illite reflections are slightly broader and the 001 illite reflection is markedly asymmetrical. However, a portion of the 14.5A spacing (vermiculite in part?) decreases to about 13.3A after the clay is heated to 450°C, and to 12.1A after heating to 575°C. This sample also contains a small quantity of calcite and only a suggestion of kaolinite (small 003 reflection at 37.8° 2θ). The asymmetrical illite 001 reflection is made symmetrical by glyceration and also by heating (as in the unmodified Holdenville). A diffraction pattern from sample 3 is shown in Figure 5.

Sample 12 (3.5 feet below base of Hepler).—This sample was collected from 3 feet above sample 15 (Table 1), which is near the top of the typical unmodified Holdenville. It is from the locality for which the clay minerals are shown in Table 3. The chlorite is still heat-resistant, as in 15, but other strong basal reflections (including 3.59 and 2.38A) are also present. These reflections are attributed to a "soil" chlorite (for the most part, although kaolinite is also present), because the spacings are almost entirely destroyed when the sample is heated to 450°C. Another spot sample from this locality at the same depth contained slightly less "soil" chlorite than the first. Quartz and feldspar are present, but the 3.2A feldspar reflection is less pronounced than in typical

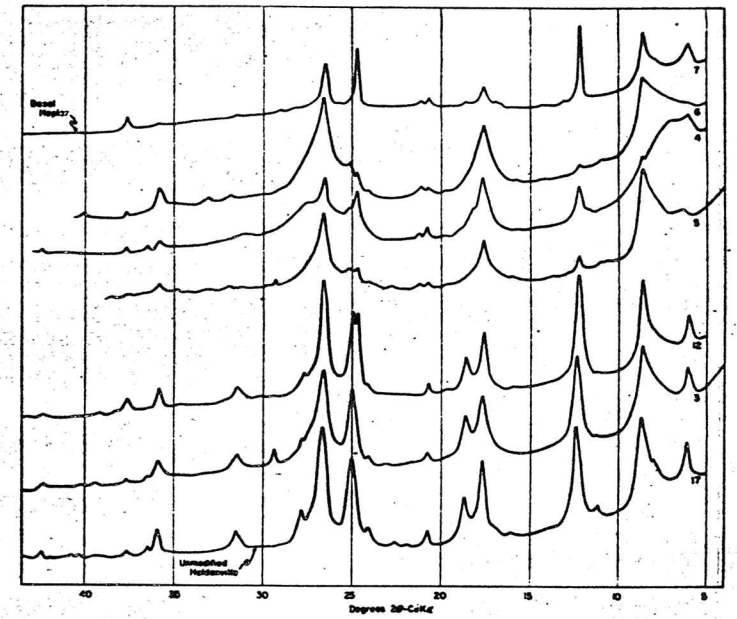


FIGURE 5. — X-ray diffractometer patterns of air-dried samples from various locali order of depth of sample below disconformity.

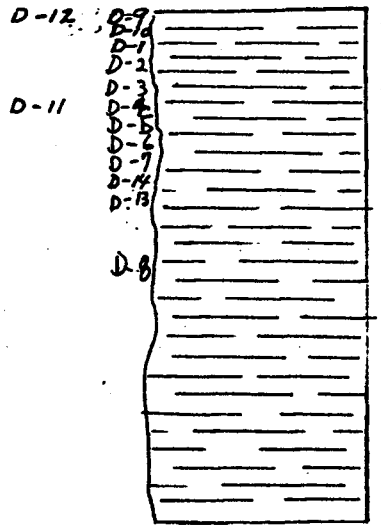
Holdenville samples. A diffractometer pattern of sample 12 is shown in F 5. The illite 001 peak in this clay is somewhat asymmetrical, but the sym is increased by glyceration and by heating. Boiling the clay fraction minutes in HCl decreases the chlorite reflections, making the kaolinite tions more prominent.

Sample 5 (0.5 to 1.0 foot below Hepler).—The clay consists chie hydrated illite (asymmetrical 001 reflection, very broad 002 and 003 tions), kaolinite, some quartz, and a mineral that expands to 14.5A. Aft sample was heated to 450°C, this 14.5A basal spacing shrank to 12.6A. heating at 550° to 600°C, the basal spacing was 11.3A, and other spacin this mineral (which may be chlorite-vermiculite) were destroyed. No fe was observed, but it may be obscured by the broad illite 003 reflecti weak 8A spacing was observed in all the patterns (Fig. 6).

Sample 4 (0.5 foot below Hepler).—Diffraction patterns from this s which is taken from about 5 feet above sample 3, show further broaden the illite reflections and degradation of the chlorite. A broad band ff mixed-layer mineral is also present at about 11.5A (Fig. 5). There is indication that this spacing expands to 14.5A when the clay is glycerated 11.5A spacing is reduced in intensity but not changed in position by h the sample to 450°C. In the glycerated clay there is a broad spacing at

OLDENVILLE SHALE

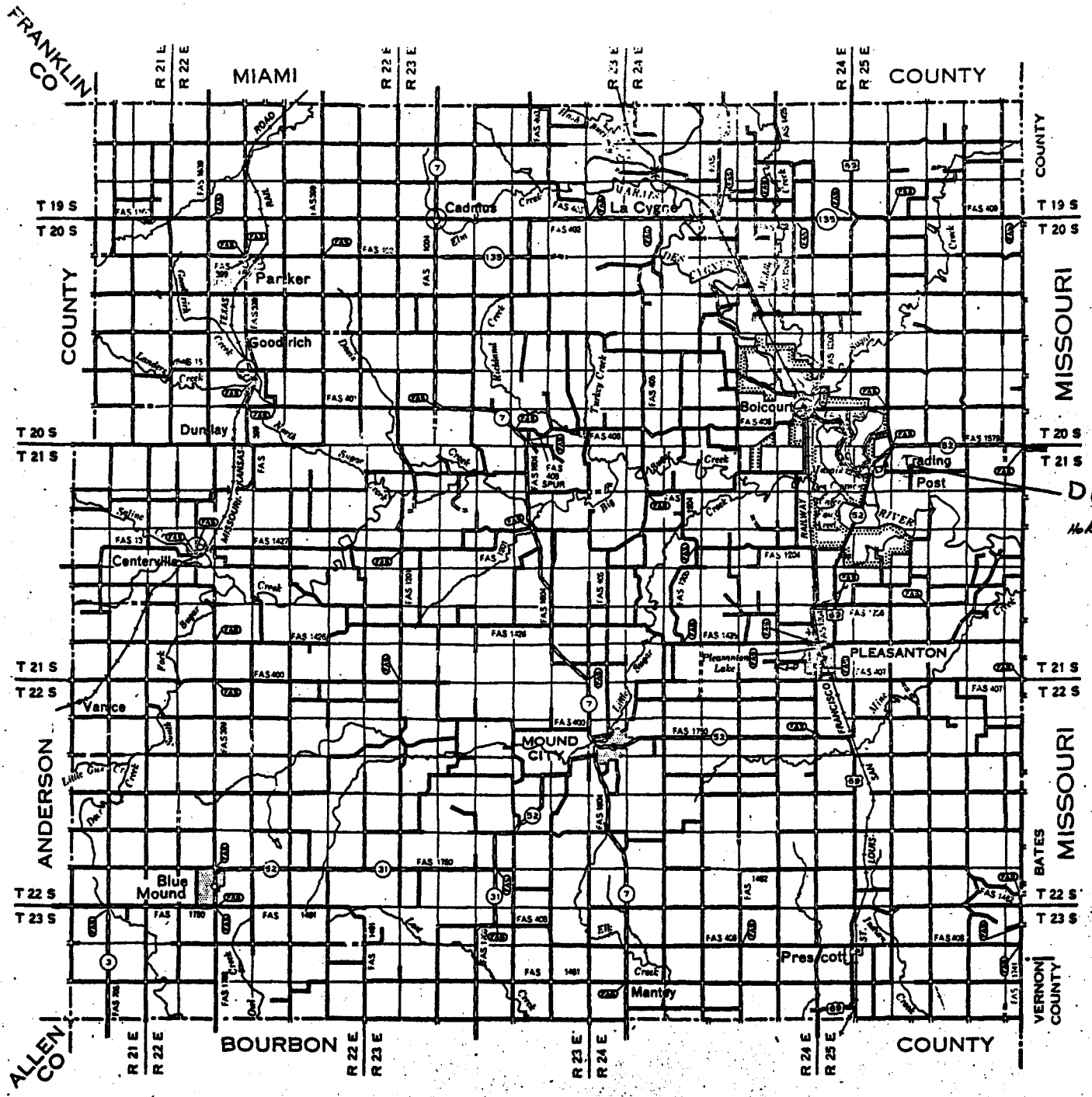
CEN S-21-25E
LINN Co.



SCALE 1" = 10'

	ILLITE	ILLITE MONTMOR	VERM	KAOLINITE	CHLORITE	ILLITE DEGRADED
				P	PRES	MAJOR
		PRES	PRES	P	PRES	MAJOR
	MAJOR	T	PRES		PRES	MAJOR
	MAJOR	T	PRES	I	PRES	
	MAJOR	T		I	MAJOR	
	MAJOR	T		T	MAJOR	
	MAJOR	T		T	MAJOR	
	MAJOR	T		T	MAJOR	
	MAJOR	T		T	PRES	
	MAJOR	T		T	MAJOR	

	LOCATION		
D 1-8	CEN 5 SEC 21 T21S R25E LINN Co	X-RAY	DALTON et al
D-9,10	SE¼ SE¼ Sec 18 T25S R23E BOURBON Co.	X-RAY	DALTON et al
D 11-12	CEN. N. LINE SEC 20 T32S R19E LAFAYETTE Co.	X-RAY	DALTON et al
D 13-14	NE¼ SEC 11 T33S R 18E LAFAYETTE Co.	X-RAY	DALTON et al

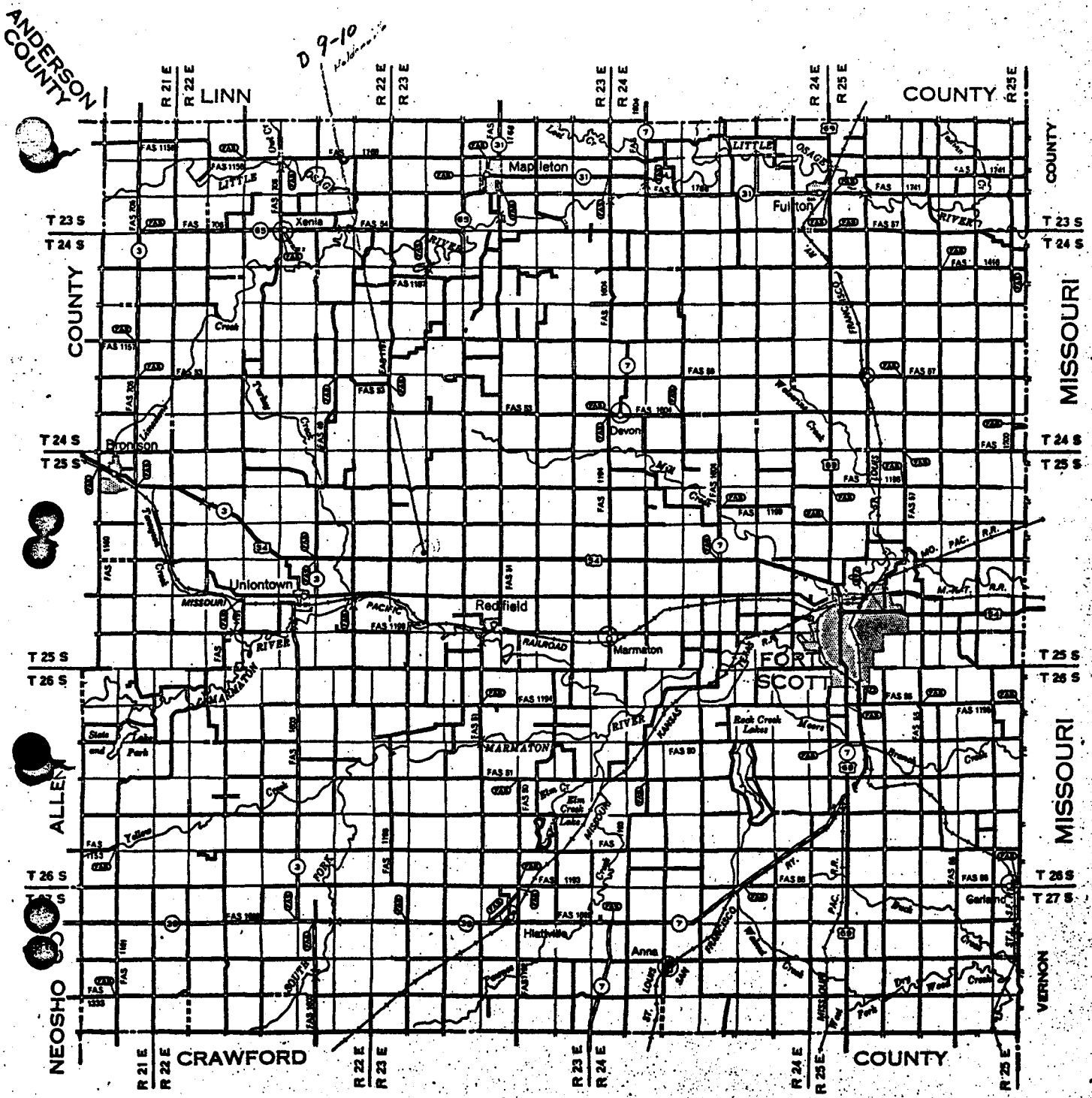


GENERAL HIGHWAY MAP

LINN COUNTY

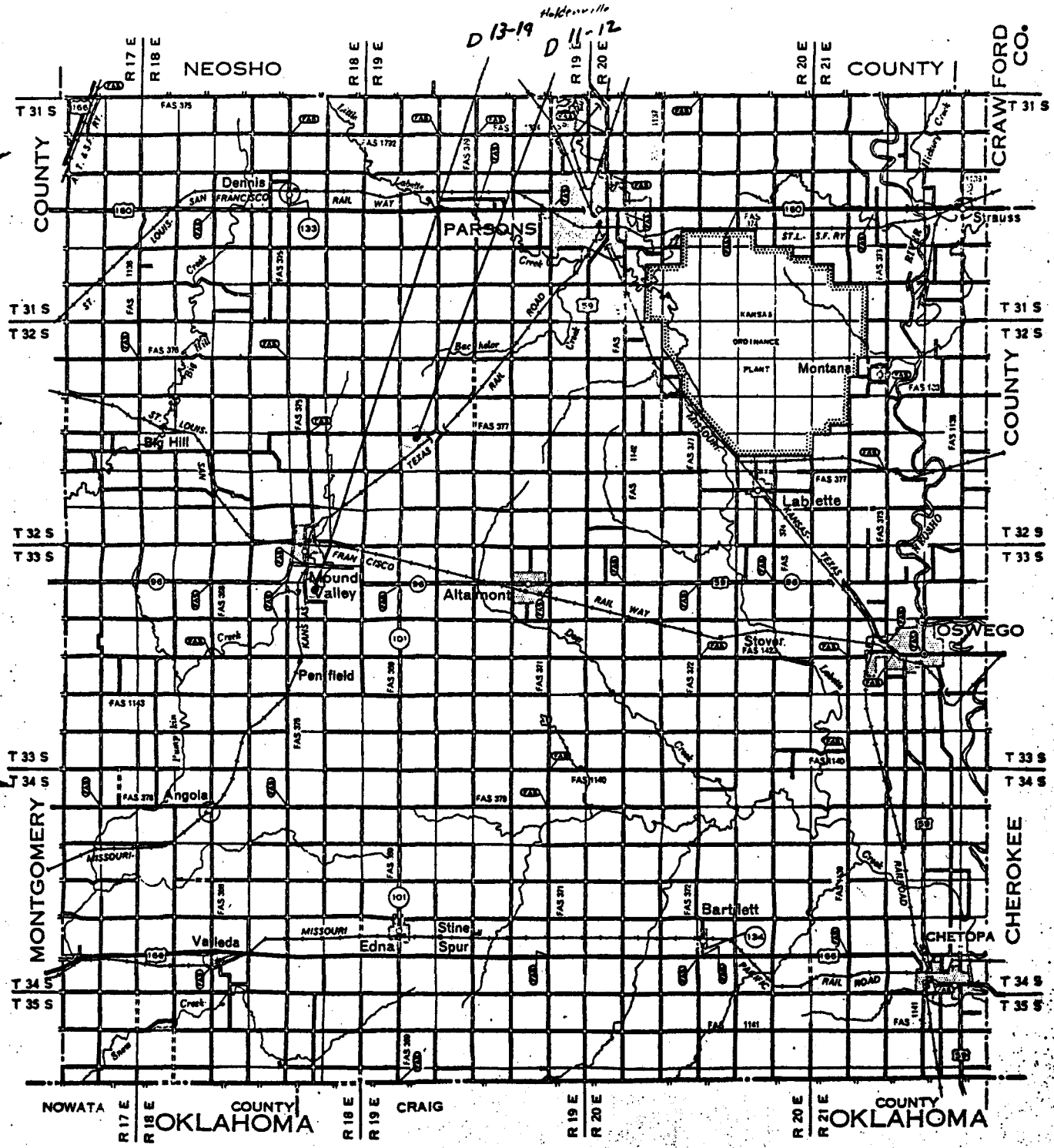
KANSAS

1960



BOURBON COUNTY
KANSAS

1959

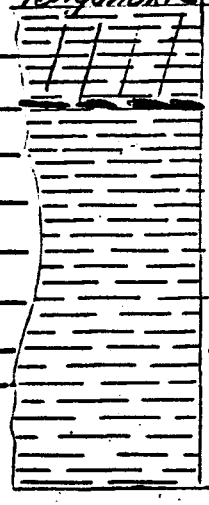


LABETTE COUNTY
KANSAS

1960

Weston Shale Mbr

Road cut
Cow W. line
swk Sec 14-17-19E
Franklin Co.

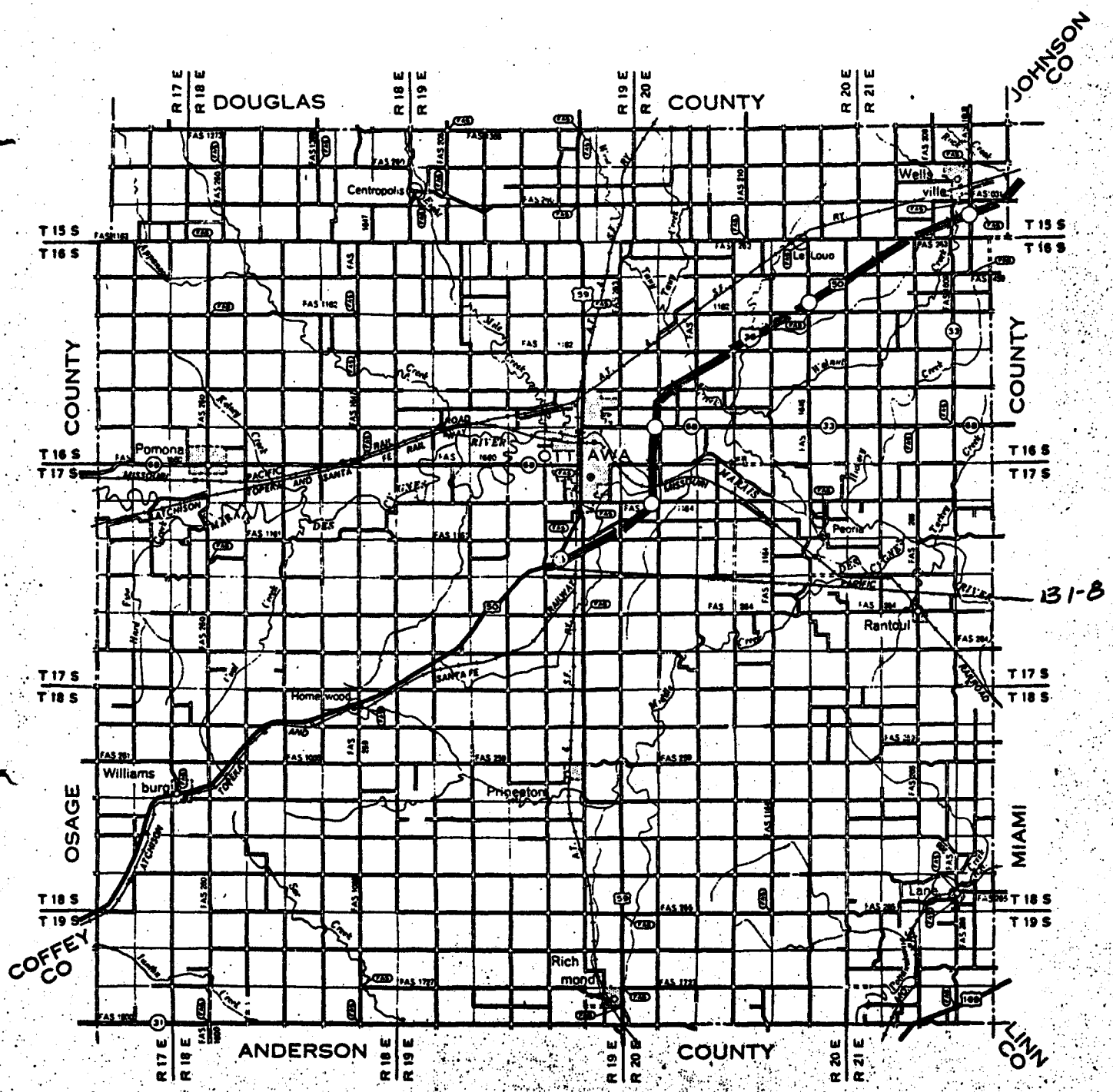


Tonganoxie	Color	Illite	Illite Mixed-layer	Kaolin	Verm	ment
B1	light gray to greenish gray to med bluish gray	major	P	P ↑ P increases	P(?) P(?)	Present in place of Verm in samples from Platte Co. Missouri. (upper 10')
B2		major	P			
B3		major	P	P	P(?)	
B4		major	P	P	P(?)	
B5		major	P	P	P(?)	
B6		major	P	P	P(?)	
B7		major	P	P	P(?)	
B8		major	P	P	P(?)	

Scale 1" = 20'

Location		
Road Cut Center W. line swk Sec 14, T17S, R19E Franklin Co.	X-Ray	Ball, Stanton 17.

WESTON



FRANKLIN COUNTY
KANSAS

Kansas Geological Survey
Open-file Report

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