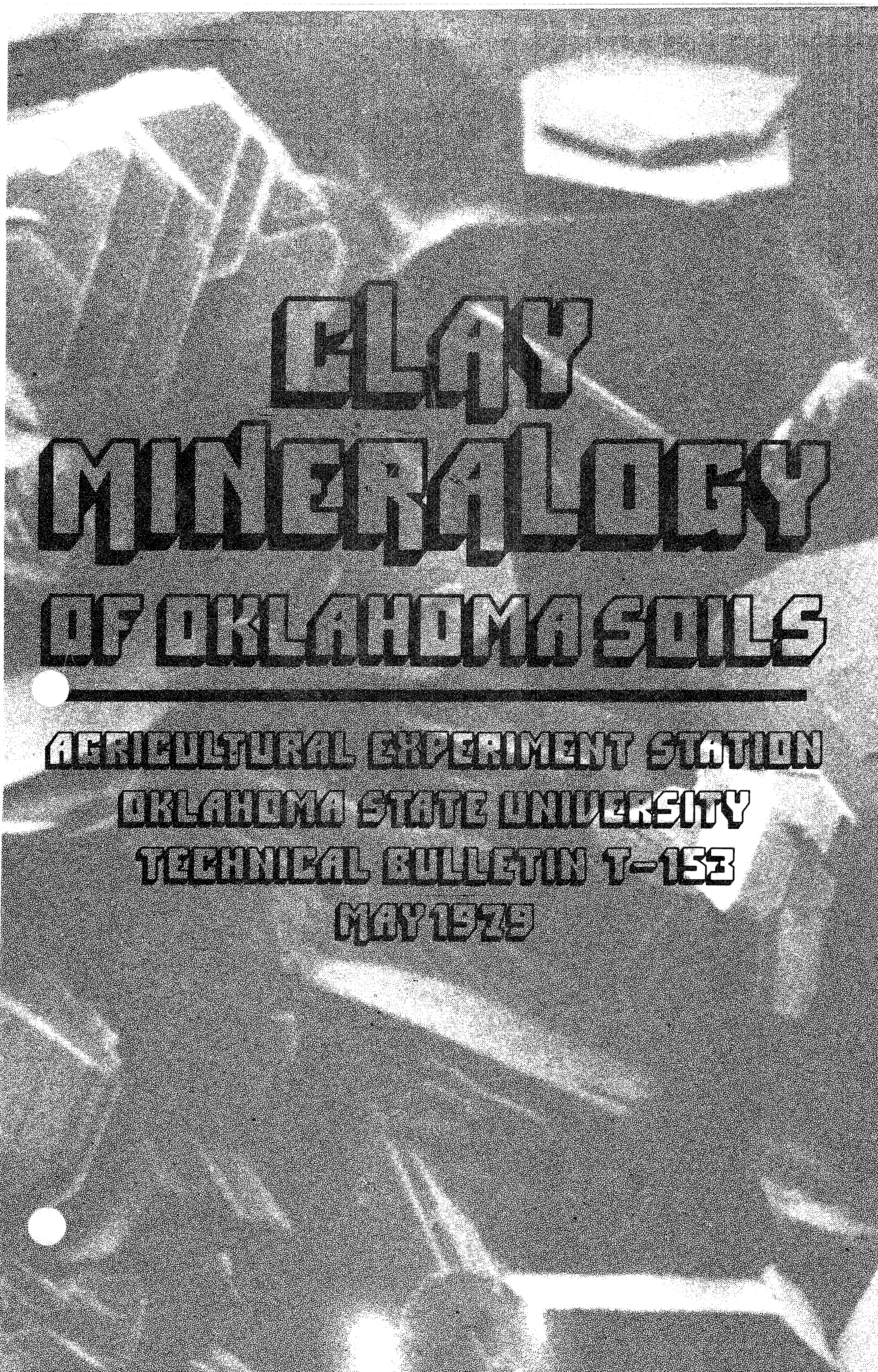

CLAY MINERALOGY OF OKLAHOMA SOILS

AGRICULTURAL EXPERIMENT STATION
OKLAHOMA STATE UNIVERSITY
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Clay Mineralogy of Oklahoma Soils

M. H. Roozitalab and Fenton Gray[1]

Determination of the relative amounts and kinds of clay minerals present in soils is essential. Clay minerals influence (1) physical qualities of soils such as water holding capacity, permeability, shrink-swell potential and plasticity; (2) cation exchange capacity; (3) K and NH_4 fixation potential; (4) K reserve and release rates; and (5) fertility and tillage. Clay minerals also react with natural organic compounds as well as applied herbicides and pesticides.

Clay minerals do not all influence the agricultural and engineering uses of soils in the same way. Montmorillonite is responsible for a large portion of soil cation exchange capacity. The high cation exchange capacity of montmorillonite is available to hold fertilizer cations such as K and NH_4, macronutrients such as Ca and Mg and micronutrients such as Cu and Zn.

Montmorillonite is also responsible for most shrinking and swelling which causes many difficulties in engineering uses of soils, and it has a high adhesive property which prevents soil erosion. However, montmorillonite absorbs large quantities of water, thereby decreasing the strength and stability of the soil, causing destructive landslides and soil creeps. Although montmorillonite increases natural soil fertility, in large amounts it may produce an unfavorable hydraulic condition and restriction of root growth.

Illite has a low cation exchange capacity compared to that of montmorillonite and vermiculite. Through weathering, illite is a potential supplier of K, and it usually contains small amounts of various minor elements, such as Zn and Fe, which may be made available to plants. Micas are known to be nonconductors of heat and electricity; therefore, they are used commercially as insulator materials, particularly muscovite.

Kaolinite has a very low cation exchange capacity; however, it has high reactivity with anions such as phosphate. Soils containing large amounts of kaolinite are naturally acidic and infertile and need to be limed and fertilized more than other soils.

Vermiculite has much less expansion or shrink-swell properties than montmorillonite. It has, however, high capacity to fix K and NH_4 from fertilizers, and the cation exchange capacity is higher than that of montmorillonite.

Clay minerals in soils can originate by different mechanisms: (a) inheritance from soil parent materials; (b) alteration and degradation of soil primary minerals such as biotite and feldspars; and (c) synthesis. These mechanisms, working under different environmental conditions accompanied with the process of translocation in soils, make composition of clay minerals also a function of soil depth. Likewise, weathering with its resulting alteration and synthesis is higher at the soil surface and decreases in intensity with soil depth. Because of the importance of parent materials in the clay mineral composition of soils, soils in Oklahoma can be grouped into five major areas based on the origin of their parent materials (Figure 1). Clay minerals of 49 soils developed in

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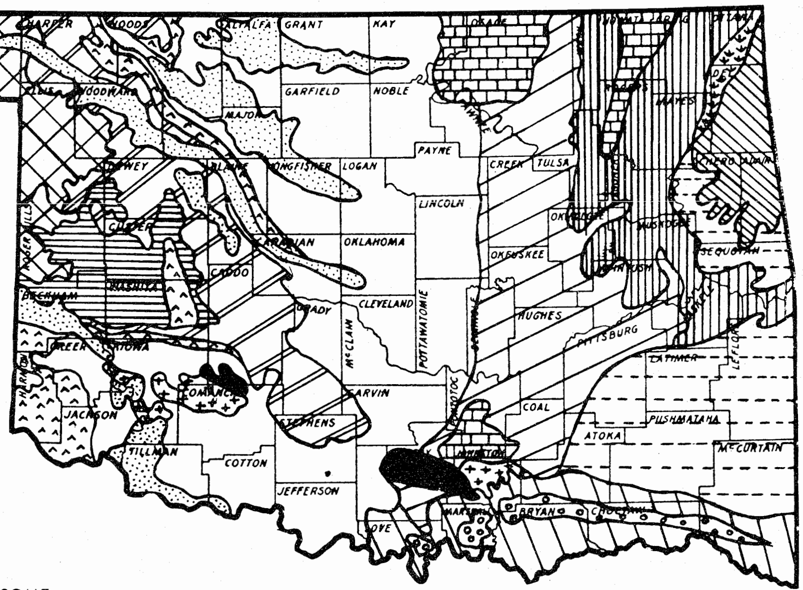

General Geology and Physiography

QUATERNARY

Duney sands and silts

TERTIARY

High Plains: Limy clays, loams, sands

CRETACEOUS

Gulf Coastal Plains: Sands, sandy clays, clays

Limestones, marls, limy clays

PERMIAN

Western Prairie Plains: Clays, sandstones, shales

Rolling Plains: Red sandstones, siltstones

Sandstone Hills: Soft sandstones

Gypsum Hills

PENNSYLVANIAN

Northern Limestone Plains and Hills; Limestones, dolomites, limy shales

Eastern Sandstone Plains and Hills: Sandstones, shales, sandy clays

Eastern Prairie Plains: Shales, sandstones, clays

PENNSYLVANIAN OR MISSISSIPPIAN — SOME OLDER

Ouachita Highlands: Sandstones, shales slates

MISSISSIPPIAN

Ozark Highlands: Cherty limestones and dolomites

Ozark Prairie Lowland: Limestones, clays and shales

DEVONIAN THROUGH PRECAMBRIAN

Arbuckle Plains (mostly Ordovician): Hard limestones

Wichita and Arbuckle Limestone Hills: Hard limestones

Granitic Hills (mostly Precambrian)

Figure 1. General geology and physiographic areas of Oklahoma (Gray and Galloway, 1959).

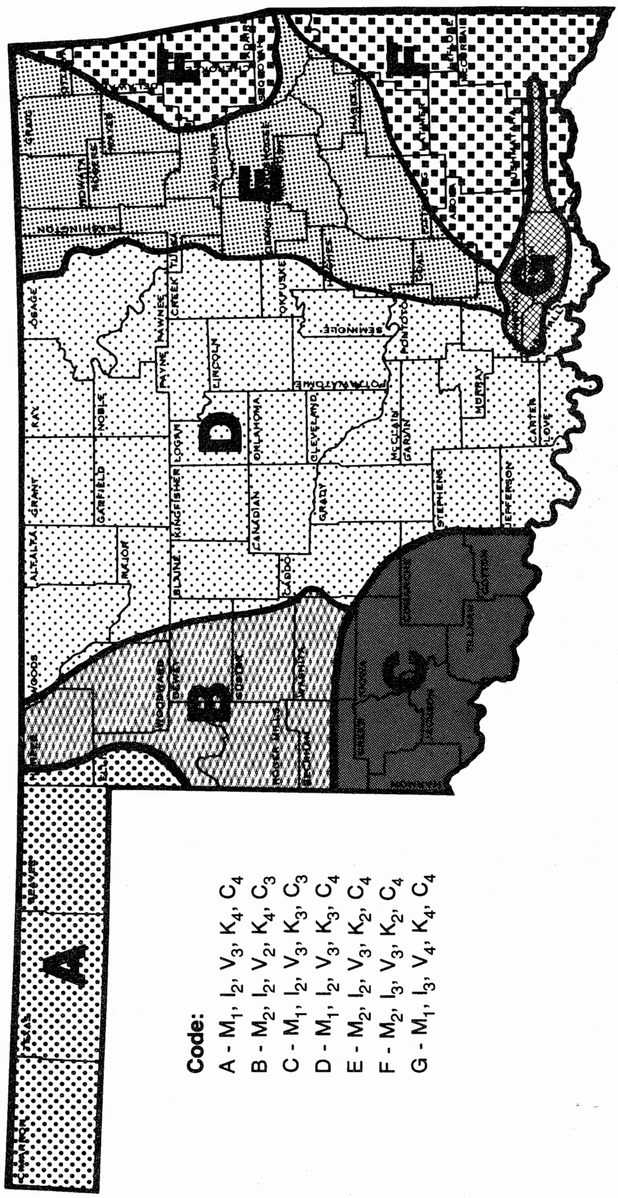

Figure 2. General distribution pattern of clay minerals in Oklahoma: M - montorillonite, I - illite, K - kaolinite, V - vermiculite, C - chlorite, 1 - >35%, 2 - 20-35%, 3 - 10-20%, 4 - <10%.

these major areas are presented in Tables 1 through 5. The generalized clay mine composition of soils from each group and changes which have occurred because of influences of soil-forming factors have been discussed. Figure 2 shows the generalized distribution of clay minerals in Oklahoma soils. This work is based mainly on the study of clay minerals by the authors and other workers (Culver and Gray, 1968; Dawud, 1978; Fanning and Gray, 1959; Gray et al., 1963; Samin, 1971; Stahnke, 1968; Voss, 1974; Wilkinson and Gray, 1954).

Soils Developed in Permian Formations in Central and Western Oklahoma

Most soils in central and western Oklahoma originated from shales, clay redbeds, siltstone or sandstones of Permian age.

Study of soil clay minerals in central Oklahoma suggests montmorillonite and illite are the major components. They are usually the principal components of the coarse clay fraction (2-0.2 micron), but montmorillonite alone dominates the fine clay fraction (less than 0.2 micron).

Shales and clay beds usually contain large amounts of illite. However, strongly developed soils such as Kirkland, Bethany, Grainola and Aydelotte, which have developed in shales and claybeds, contain large amounts of montmorillonite in their solums. Montmorillonite appears to be stable in these soils because of limited leaching and neutral to alkaline pH. Some weathered shales contain mixed layers of illite and montmorillonite which are mostly transformed to montmorillonite in the soil solum.

Small amounts of chlorite have been identified in sub-horizons of several soils; however, cholorite has usually undergone weathering in the soil surface layer. Vermiculite is not usually found as a discrete compound, but as mixed layers with montmorillonite and illite, particularly in the coarse clay fraction. Small amounts of kaolinite are usually present in coarse clays.

Clay mineralogy of soils in southwestern Oklahoma is similar to that in the central part; however, larger amounts of soil chlorite are often identified. Soils such as Foard contain large amounts of montmorillonite. Soils developed in siltstone and sandstone of Permain age in western Oklahoma also show a similar composition to the soils in the central part. Unconsolidated sandstones underlying Dill and Quinlan soils contain large amounts of montmorillonite. This may reflect the relative abundance of volcanic products found in the sedimentary rocks of this area. Vermiculite and chlorite are usually present in relatively larger amounts in the coarse clay fractions of these soils.

Soils Developed in Pennsylvanian Formations in Eastern Oklahoma

Study of soils developed in shales, claybeds and sandstones of Pennsylvanian age in eastern Oklahoma indicates that illite, kaolinite and montmorillonite are the main types of clays. Kaolinite and illite are abundant in the coarse clay fractions while montmorillonite composes large portions of the fine clays. Large amounts of illite are present in the shales in which Enders and Dennis soils developed (Table 2). However, illite has partially weathered to montmorillonite or interstratified illite and montmorillonite in the surface. The presence of hydroxy-Al interlayers is common in 2:1 expansible clays, especially in the coarse clay fractions, in the A and B horizons of these soils.

Table 1. Clay mineralogy of the soils developed in Permian formations in central and western Oklahoma.

Soil	County	Parent Materials	Horizon	X-ray Diffraction† Coarse Clay (2-0.2u)	X-ray Diffraction† Fine Clay (<0.2u)
Zaneis	Payne	stratified sandstone and shale	A1	IKV(Q)	M-V(IK)
			B2t	IKV(Q)	M-V(IK)
			C	IKV-C(Q)	M-V(IK)
Zaneis	Oklahoma	stratified sandstone and shale	A	IKV-C(Q)	M-V(IK)
			B2t	IKV-C(Q)	M-V(IK)
			C	IKV-C(Q)	M-V(IK)
Kingfisher	Kingfisher	shale	A1	IVK(Q)	M-VI(K)
			B2t	IV-CK(Q)	M-VI(K)
			C	IV-CK(Q)	M-VI(K)
Kirkland	Canadian	shale and claybed	AP	IM(Q)	M(IQ)
			B22t	IM(Q)	M(IQ)
Bethany	Canadian	shale and claybed	A11	MI(KQV)	M(IQ)
			B22t	MI(KQV)	M(Q)
Pawhuska-like	Osage	siltstone and sandstone	A1	IV(KQ)	VI(KQ)
			B23t	IV(KQ)	VI(KQ)
			B3	IV(KQ)	VI(KQ)
			C	IM(KQ)	VI(KQ)
Aydelotte	Cleveland	shale and siltstone	A1	IM(KVQ)	M(IKQ)
			B21t	IM(KCVQ)	M(IKCQ)
			Cr	IM(KCQ)	M-I(KCQ)
Grainola	Noble	shale and siltstone	A1	M(IKQ)‡	
			IICr	IM(KQ)	
Waurika	Kay	post-Permain sediment	AP	IK(Q)‡	
			B21t	MI(KQ)‡	
			C2	MI(KQ)	
Waurika	Cotton	reworked Permain shale	A12	IKQ(VMC)	M(IKQC)
			B21	MI(KVCQ)	M(IKQC)
			C3	IKM(VCQ)	M(IKQC)
Windthorst	Pontotoc	hard sandstone and shale	B23t	M-VI(KQ)‡	
Dill	Washita	sandstone	A12	MI(KQ)	M(IK)
			B21	MI(KQ)	M(IK)
			IIC	MI(KQ)	M(I)
Woodward	Harper	soft sandy and silty redbed	A1	I(Q)	MI(Q)
			B2	MI(KQ)	MI(Q)
			B3	IK(Q)	MI(Q)
			C	I(Q)	MI(Q)
Woodward	Washita	stratified sandstone and siltstone	A1	IM-V(KCQ)	M-V(IKC)
			B2	IM-V(KCQ)	M-V(IKC)
			C	IM-V(KCQ)	M-VI(KC)
Quinlan	Washita	stratified sandstone and siltstone	A	IMC(KQ)	MI(K)
			B2	IMC(KQ)	MI(K)
			C	MI(KQ)	M(IK)
Cordell	Washita	siltstone	A1	IM(KQ)	M(I)
			B21	IM(KQ)	M(I)
			R	IM(CKQ)	M(I)
Carey	Custer	siltstone	AP	IVM(KCQ)	MV(ICKQ)
			B22	IV(MKCQ)	MV(ICQ)
			C2	IVC(KQ)	MVC(IQ)
St. Paul	Woodward	silty aeolian and/or alluvial mantle over Permian redbed	A12	IMV(KQ)	M(I)
			B21	IV(MKQ)	M(I)
			C	IV(MKQ)	M(I)
Foard	Cotton	calcareous fine texture redbed	AP	IMV(KCQ)	M
			B22	MVI(KCQ)	M
			C	MV	M
Foard	Comanche	calcerous fine texture redbed	A12	MI(KCVQ)	M(KQ)
			B3Ca	MI(KVQ)	M(KQ)
			C2	MI(KVCQ)	M(KQ)

† Mineral Code: M - montmorillonite, I - illite, K - kaolinite, V - vermiculite, C - chlorite, Q - quartz M/V - mixed layer M and V. Dominant minerals are outside parentheses. ‡ Total clay - less than 2 micron

Table 2. Clay mineralogy of the soils developed in Pennsylvanian formations in eastern Oklahoma.

Soil	County	Parent Materials	Horizon	X-ray Diffraction† Coarse Clay (2-0.2u)	X-ray Diffraction† Fine Clay (<0.2u)
Parsons	Mayes	shale	A1	IK(MQ)	M(IK)
			B21t	IK(MQ)	M(IK)
			C2	KI(MQ)	M(IK)
Dennis	Rogers	shale	A1	IKM(VQ)	M(IKVQ)
			B21	IKM(VQ)	M(IKQ)
			IICr	IKV(Q)	I-M(KVQ)
Dennis	Wagoner	shale	A1	IK(MQ)	M(IKQ)
			B2t	IK(MQ)	M(IVK)
			C	IK(MQ)	M(KI)
Enders	Atoka	shale	A2	MIK(Q)‡	
			B22t	MK(IQ)	
			Cr	MK(IQ)	
Enders	Muskogee	shale	A12	M-IK(Q)‡	
			B21t	M-IK(Q)	
			Cr	I(MKQ)	
Niotaze	Osage	shale and sandstone	A2	IM(KQ)	M(VQ)
			B22t	IM(KQ)	M(VQ)
			C	IM-V(Q)	IM(Q)
Tamaha	Haskell	shale	A12	M-VI(K)‡	
Carnasaw	Pushmataha	shale	A1	MIK(Q)‡	
Collinsville	Haskell	sandstone	B2	M-VIK(Q)‡	

† Mineral Code: M - montmorillonite, I - Illite, K - kaolinite, V - vermiculite, C - chlorite, Q- quartz, M-V - mixed layer M and V. Dominant minerals are outside parentheses. ‡ Total clay - less than 2 micron

Table 3. Clay mineralogy of the soils developed in Cretaceous formations in southeastern Oklahoma.

Soil	County	Parent Materials	Horizon	X-ray Diffraction† Coarse Clay (2-0.2u)	X-ray Diffraction† Fine Clay (<0.2u)
San Saba	Carter	limestone and limey clay	AP	M(KQ)	M(Q)
			A1	M(KQ)	M(Q)
			AC	M(Q)	M(Q)
Burleson	Marshall	calcareous clayey material	AP	M(IKQ)‡	
			AC	M(IKQ)	
			C	M(IKQ)	
Durant	Marshall	calcareous clay bed	A1	M(IKQ)‡	
			B21t	M(IKQ)	
			B23t	M(IKQ)	
Ferris	Marshall	calcareous clayey sediment	A1	M(IKQ)‡	
			AC2	M(IKQ)	
Gasil	Marshall	loamy material and interbedded sand-stone	A2	IMK(Q)‡	
			B22t	MI(KQ)	
			Cr	M(IKQ)	
Bernow	Pushmataha	loamy materials and interbedded sandstone	A1	KIM-V(IQ)	MKI(VQ)
			B22t	KIM-V(IQ)	MKI(VQ)

†Mineral Code: M - montmorillonite, I - illite, K - kaolinite, V - vermiculite, C - chlorite Q - quartz, M-V - mixed layer M and V. Dominant minerals are outside parentheses. ‡ Total clay - less than 2 micron

Table 4. Clay mineralogy of the soils developed in Tertiary sediments in the Oklahoma panhandle.

Soil	County	Parent Materials	Horizon	X-ray Diffraction† Coarse Clay (2-0.2u)	X-ray Diffraction† Fine Clay (<0.2u)
Ulysses	Texas	calcareous loamy loess	AP	IM(KQ)	M(IK)
			B2	IM(KQ)	M(IK)
			C1	IM(KQ)	M(IK)
Richfield	Texas	calcareous loamy loess	AP	IM(KQ)	M(IK)
			B2t	IM-V(KQ)	M(IK)
			C	IM-V(KQ)	M(IK)

†Mineral Code: M - montmorillonite, I - illite, K - kaolinite, V - vermiculite, C - chlorite, Q - quartz, M-V - mixed layer M and V. Dominant minerals are outside parentheses.

Table 5. Clay mineralogy of the soils developed in Quaternary sediments in Oklahoma.

Soil	County	Parent Materials	Horizon	X-ray Diffraction† Coarse Clay (2-0.2u)	X-ray Diffraction† Fine Clay (< 0.2u)
Konawa	Pottawatomie	old alluvium	AP	IKM(VQ)	MI(KQ)
			B22t	IKM(VQ)	MI(KQ)
			C	IKM(VQ)	MI(KQ)
Vanoss	Caddo	old alluvium	AP	MI(KQ)‡	
			B21t	M(IKQ)	
			C1	M(IKQ)	
anfield	Washita	loamy alluvium or aeolian sediment	AP	IM(KQC)	M(IK)
			B22t	IM(KQC)	M(IK)
			C	IM(KQC)	M(IK)
Nobscot	Woodward	wind reworked sandy alluvial deposit	A1	IVKM(CQ)	MV(IC)
			B21	IVK(MCQ)	MV(IC)
			C	IVK(MCQ)	MV(IC)
Kaufman	Atoka	clayey alluvial deposit	A1	M(IKQ)‡	
			AC2g	M(IKQ)	
Asher	Pottawatomie	recent alluvium	B	M(IKQ)‡	
			C	M(IKQ)	
Kamie	McIntosh	sandy alluvium	B22t	MI(KQ)‡	
Vian	Haskell	reworked sediment	B21t	M-VI(KQ)‡	
Neff	Latimer	loamy alluvium	B22t	MI(KQ)‡	
Norge	Canadian	old alluvium	AP	M-VI(KQ)	M(IQ)
			B22t	M-VI(KQ)	M(IQ)
Bonham	Garvin	old alluvium	A1	IM(KQ)‡	
			B2t	MI(KQ)	
Verdigris	Seminole	Alluvium	B2	MI(KQ)‡	

† Mineral Code: M - montmorillonite, I - illite, K - kaolinite, V - vermiculite. C - chlorite, Q - quartz M-V -mixed layer M and V. Dominant minerals are outside parentheses. ‡ Total clay - less than 2 micron

In Ultisols and highly leached Alfisols of eastern Oklahoma, illite is usually degraded and has weathered to 2:1 expansible clays which are partially chloritized by hydroxy-Al. Kaolinite is also abundant in these soils. Amorphous clays of the siliceous or montmorillonitic-type alumino-silicates are usually present in larger amounts than in soils developed in central Oklahoma.

Soils Developed in Cretaceous Formations in Southeastern Oklahoma

Soils developed in limestone and calcareous clayey materials of Cretaceous age in southeastern Oklahoma are dominated by montmorillonite. The presence of large amounts of cations such as Ca and Na, low leaching, neutral to alkaline pH, and slow permeability favor the formation and stability of montmorillonite in soils such as Burleson, Durant, Ferris and San Saba of this area. Illite is the next most abundant clay mineral in these soils.

Study of clay minerals of highly leached and weathered soils, such as Bernow, that developed in sandstone and sandy loams of Cretaceous age in southeastern Oklahoma suggests that montmorillonite and kaolinite are the most abundant clay minerals. Kaolinite is the primary clay mineral in the coarse clay fraction, while hydroxy-Al interlayered montmorillonite composes large portions of the fine clay fraction. Illite is usually present in small amounts.

Soils Developed in Tertiary Materials

Study of soils such as Richfield and Ulysses, that developed in calcareous loamy to clayey material of Tertiary age in the Oklahoma Panhandle, indicates that montmorillonite and illite are the major components of their clay minerals. The coarse clay fraction is composed of large amounts of illite and montmorillonite, while the fine clay is dominated by montmorillonite. Lesser amounts of vermiculite, kaolinite and soil chlorite are identified in these soils. Vermiculite is present mainly in mixed layers with montmorillonite in the coarse clay fraction.

Soils Developed in Quaternary Deposits

Soils developed in alluvial deposits throughout the state contain a varying mixture of montmorillonite, illite, kaolinite and vermiculite. Montmorillonite and illite are usually the most abundant clay minerals in these soils while a lesser amount of kaolinite is usually present.

In central and western Oklahoma, soils such as Norge, Vanoss and Grandfield contain large amounts of montmorillonite in the clay fractions. Montmorillonite is usually interlayered or interstratified with illite or vermiculite. Illite is the second most dominant clay mineral in these soils.

Slowly to very slowly permeable and alkaline soils, such as Kaufman and Asher, which have developed in recent alluvial deposits, are highly montmorillonitic. Illite and kaolinite are present in small amounts in these soils.

Summary and Conclusions

Montmorillonite and illite are the major clay minerals in soils developed in the Permian-aged materials of central and western Oklahoma. Both montmorillonite and illite are usually the principal components of the coarse clay fraction, while montmorillonite alone dominates the fine clay. Vermiculite is not found in large amounts or as a discrete compound, but mainly as mixed layers with montmorillonite and illite in the coarse clay fraction. Small amounts of kaolinite are usually present, mostly in the coarse clays. Chlorite is present in small amounts in the subsurface horizons of some soils; however, chlorite has usually undergone weathering in the surface layers.

Kaolinite and illite are abundant in the coarse clay fractions of soils originated from the Pennsylvanian materials in eastern Oklahoma. Montmorillonite composes a large portion of the fine clay. Hydroxy-Al interlayers are usually present in th terlayer spaces of 2:1 expansible clay minerals, particularly in the coarse clay fractions. Illite is usually degraded in these soils.

Montmorillonite dominates the clay-size fraction of soils developed in limestone or calcareous clayey materials of Cretaceous period in southeastern Oklahoma. Clay minerals of highly leached and weathered soils developed in weakly consolidated sandstones and sandy loam deposits of this region are composed mainly of interlayered 2:1 expansible clay minerals and kaolinite. Illite is present mainly in the coarse clay fraction.

Study of clay minerals of soils developed in calcareous loamy to clayey materials of Tertiary period in the Oklahoma Panhandle suggested that montmorillonite and illite are the major clay minerals in the coarse clays, while montmorillonite dominates the fine clays. Kaolinite is present in small amounts.

Soils derived from alluvial sediments throughout the state contain varying mixtures of montmorillonite, illite, kaolinite and vermiculite. Montmorillonite and illite are usually the most abundant clay minerals. Montmorillonite is usually interlayered and/or interstratified with illite or vermiculite.

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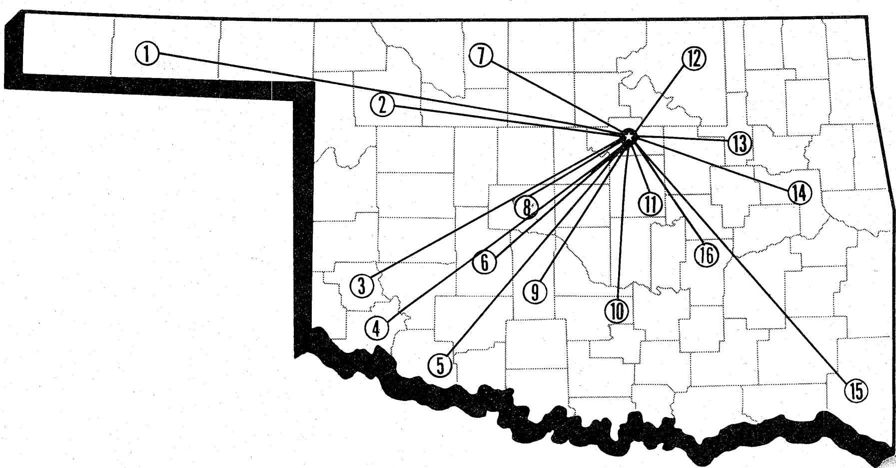
OKLAHOMA

Agricultural Experiment Station

System Covers the State



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