MINERALOGY AND PROPERTIES OF TYPICAL TEXAS CLAYS

Approved:

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Dean of the Graduate School

MINERALOGY AND PROPERTIES OF TYPICAL TEXAS CLAYS

DISSERTATION

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of the Requirements

For the Degree of

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BY

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PREFACE

The author wishes to acknowledge the interest, suggestions and encouragement of F. K. Pence, who for a number of years has had an interest in the study of clays by means of X-Rays and under whose direction the work was performed.

The author wishes to thank Dr. M. Y. Colby for his cooperation, which made this research possible.

Also, the author wishes to thank each of the following for their contributions to this research: Dr. G. H. Fancher and R. M. Darling for furnishing drilling mud samples and making it possible for the author to get some clay samples fractionated according to different particle sizes; W. L. Pondrom for his assistance in the operation of the X-Ray machine; R. Anwyl for the plastograph data; J. E. Stullken for making the chemical analysis; and Paul Crawford for his help on particle size.

CONTENTS

INTRODUCTION

The standard practice of classifying clays is according to the working and firing properties of the clay and not according to the minerals and soluble salts present. Two clays may have the same mineral composition, but, unless the soluble salts and the organic matter are the same, the two clays will probably be classified differently. There are other factors which may influence the working behavior of a clay, in addition to the ones just given.

The five factors given by Grim[1] are a good summary of the factors which may influence the working behavior of a clay and determine its classification. The factors are:

1. Clay-mineral composition--the relative abundance of the clay-mineral components and their particle-size distribution.
2. Non-clay-mineral composition--the relative abundance of each mineral and the size grade distribution of its particles.
3. Electrolytic content--quantitative determinations of the individual exchangeable bases and any water soluble salts.
4. Organic content--amount and kind.
5. Miscellaneous textural characteristics such as shape of quartz grains, degree of parallel orientation of the clay-mineral particles, silication, etc.

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[1] Grim, Jour. of Geology, University of Chicago Press, Vol. L, No. 3, p. 230, 1942.

At present, a manufacturer of clay products, having once adjusted his machinery for the use of a particular clay, will continue to use clay from the same pit as long as it is available, because, in changing clays, he usually encounters difficulties in treating a new clay or adjusting his machinery for the same. However, in case the manufacturer is compelled to change clays, such information about a number of clays studied from the angles given by Grim would be a great aid in locating a new clay or in adjusting another clay for his machinery.

Some ceramists in the northeastern states have noted the unique nature of the Texas clays, particularly their gelatinous quality. If the information obtained by a study of the Texas clays by means of the five points of Grim was available, the question about the unique nature of the Texas clays would be solved. Also, if this information was available, it would serve as a starting point for the development of Texas clays for industrial uses. Since some brick manufacturers are losing a high percentage of bricks in the drying stage, this information would serve as a starting point for eliminating this loss.

From the previous discussion and since the University of Texas is doing research on the development of Texas clays for industrial uses, it appears that the most logical research to be performed by the University at present is to study the Texas clays from the angles given by Grim in his five points, for very little work of this type has been done on Texas clays. This information is of a general nature. It is not adapted to the immediate needs of any particular manufacturer and, if carried out on a large number of clays, it will give a general picture of the clays of the state as a whole. If a sufficient number of clays are studied from these angles, some general conclusions can be drawn as to the effect of soluble salts, organic matter, particles size, etc. on the properties of clays. This type of research would be too expensive for any manufacturer to undertake, but it is a good research problem for a University because it is general and not limited to any certain clay manufacturer.

To make this study on all Texas clays would be a very large undertaking for a single person. Of all the Texas clays on hand only four kaolins, two volcanic ashes, and eleven clays were selected and studied, with emphasis placed upon the mineral composition. From the eleven clays five were selected and special work was done on particle size, working behavior, organic material and soluble salts.

Chemical analysis, thermal analysis, microscopic analysis and x-ray analysis are the methods used to determine the minerals in a clay. One method alone is not sufficient for identifying the clay minerals. Sometimes when there is more than one clay mineral present in a clay, there may be an intergrowth between the minerals or, if organic material is present, there may be an intergrowth between the organic material and the clay mineral. Grim made the following statement about such intergrowths:

> The existence of such intergrowths vastly complicates the complete identification of all the clay minerals in a given clay material. Frequently, the use of a single criterion for identification of the mineral constituents will not reveal all the components of the interstratification. Only a combination of optical, x-ray, chemical and thermal data will provide the complete picture.[2]

Chemical analyses alone are not sufficient for mineral identification, because a mixture of several chemicals giving the same chemical analysis of a clay mineral will not give an x-ray diffraction pattern corresponding to that of a clay, nor will it have the physical properties of a clay. In addition, some clay minerals have the same chemical composition but have different structures. However, a chemical analysis will serve as a check on the other methods of identifying minerals.

Recent studies[3] have indicated that the size of some clay particles approach unit cell dimensions and, for this reason, the petrographic analysis cannot be used with certainty

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[2] Grim, op. cit.

[3] Ibid., p.229

because, according to Nagelschmidt,[4] the identification of crystals less than two microns in diameter is not absolutely positive.

Chemical, x-ray and thermal analyses were used for identifying the minerals in the Texas clays.

In order to identify the minerals in a clay, the minerals which are clay minerals must be known. Ross and Kerr[5] have made a table which includes most of the clay minerals. This table appears on the following page.

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[4] Nagelschmidt, G., Zeit. Kryst., Vol. 87, p. 120, 1933.

[5] Ross, C. S. and Kerr, P. F., Jour. of Amer. Ceram. Soc., Vol. 21, p. 55, 1938.

Group	Mineral	Chemical Constituent	Structure
Kaolin			
	Nacrite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	Nacrite
	Dickite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	Dickite
	Kaolinite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	Kaolinite
	Anauxite	$Al_2O_3 \cdot 3SiO_2 \cdot 2H_2O$	Kaolinite
	Halloysite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	Halloysite
	Allophane	$Al_2O_3 \cdot NSiO_2 \cdot MH_2O$	No Regular
Montmorillonite			
	Montmorillonite	$(Mg,Ca) \cdot O \cdot Al_2O_3 \cdot 5SiO_2MH_2O$	Montmorillonite
	Beidellite	$Al_2O_3 \cdot 3SiO_2 \cdot MH_2O$	Montmorillonite
	Montronite	$(Al\ Fe)O_3 \cdot 3SiO_2MH_2O$	Montmorillonite
	Saponite	$2Mgo \cdot 3SiO_2 \cdot MH_2O$	Montmorillonite
Alkali Bearing			
	Meta Bentonite	$K_2O \cdot Mgo \cdot Al_2O_3 \cdot SiO_2 \cdot H_2O$ in Variable Amounts	Modified Mica

The following are minerals which sometimes occur in clays, but are often not classified as clay minerals: muscovite,[6,7] phlogopite, biotite, lepidolite, zinnwaldite, leuchenbergite,[8] sheridanite, chlorite, prochlorite, amesite, talc,[9] pyrophyllite, attapulgite,[10] meta-halloysite,[11] and illite.[12]

A brief knowledge of the structures assigned to the different clay minerals is very essential for identifying clay minerals, therefore, the next chapter is given to a brief discussion of the different clay minerals. With the exception of allophane, all the clay minerals are crystals. The physicists define a crystal as a substance which gives a definite diffraction pattern. If the powder diffraction data of known crystals are

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[6] Bragg, W. L., Atomic Structure of Minerals, pp.203-4, 1937.

[7] Maegdefrau and Hofmann, Zeit. Kryst., Vol. 99, pp. 31-59, 1937-38.

[8] McMurchy, R. C., Zeit. Kryst., Vol. 88, pp. 422-424, 1934.

[9] Grunner, Zeit. Kryst., Vol. 88, p. 412, 1934.

[10] Bradley, Amer. Min., Vol. 25, pp. 404-409, 1940.

[11] Mehmel, R. C., Zeit. Kryst., Vol. 90, pp. 35-43, 1935.

[12] Grim, Bradley and Bray, Amer. Min., Vol. 22, pp. 813-816, 1937.

available, powder diffraction patterns of unknown crystals can be made and the diffraction data of the unknown crystal can be compared to that of the known crystals. If a known powder diagram* is found which corresponds to that of the unknown, then the unknown crystal has the same structure as that of the known. In this way unknown crystals can be identified.

The powder diagram for a crystal is a recording of lattice distances with their intensities for each line given on the powder diffraction picture. The lattice distances are calculated by means of the Bragg equation $n\lambda = 2d \sin\theta$

λ = x-ray wave length

n = order of diffraction

θ = angle of diffraction

d = distance between atomic planes

In the Bragg equation, d is the only unknown and it can be calculated after θ has been determined from measurements made on the diffraction picture.

When clay minerals are heated, exothermic reactions occur at certain temperatures and endothermic reactions occur at other temperatures. If the temperatures at which the exothermic and endothermic reactions occur for a clay mineral are known, they will serve as an aid in identifying the clay mineral.

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* Some writers refer to powder diffraction data as powder diagram.

THE STRUCTURES OF CLAY MINERALS

As pointed out in the introduction, most clay mineral crystals are less than one micron in diameter; therefore, the crystals are too small to be used for Laue or rotation pictures. With the exception of one case, all information about the structure of clay minerals is based upon powder diffraction patterns and the five rules of Pauling.[13] Ksanda and Barth[14] of Carnegie Institute of Washington isolated a crystal of dickite .4 mm by .04 mm by .02 mm while making an optical study of a dickite sample and succeeded in making two rotation and two Laue pictures of the crystal. Their results corresponded to the results obtained by Gruner[15] from the powder diffraction data in the dimensions of the unit cell and the value of the β angle, but their space group differed from that obtained by Gruner.

With the information obtained from powder pictures and by applying the rules of Pauling, the men studying the clay mineral crystals have set up some tentative structures for the clay minerals. These tentative structures picture the

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[13] Pauling, L., J.A.C.S., Vol. <u>51</u>, p. 1010, 1929.

[14] Ksanda, C. J. and Barth, T.F.W., Amer. Min., Vol. <u>20</u>, pp. 631-637, 1935.

[15] Gruner, J. W., "The Crystal Structure of Dickite",

clay mineral crystals as made up of alternate layers of gibbsite or brucite and of silicon-oxygen layers.

Figure 1* shows side views of the clay mineral structures. The following discussion deals with the structure of the clay mineral structures from a top view of the crystals.

SILICON-OXYGEN RING

Determinations of crystal structures of clay minerals indicate that the clay mineral silicon-oxygen layer is composed of a hexagon ring of six silicon atoms at the corners of a hexagon in the same manner as the carbon atoms in a benzene ring. Each silicon atom is surrounded by four oxygen atoms forming a tetrahedron. Between every two silicon atoms is one oxygen atom. All the oxygens except one in the tetrahedron are in the silicon ring. Each Si_4O_{10} joined to the silica ring adds another hexagon to the silica layer.

BRUCITE[16] $Mg(OH)_2$ a = 3.12A, b = 5.38A, c = 4.73A, z = 1.

Brucite is made up of two layers of hexagonal OH ions with a magnesium ion layer between the OH layers. The OH ions are arranged in hexagonal closest packing. Each OH links three magnesium ions in the magnesium layer and three OH ions in the other OH layer. From a top view, six OH ions

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*Figure 1 is a photostat taken from page 137 of Norton's book on Refractories, McGraw-Hill Book Co., New York, N. Y.

[16] Bragg, W. L., Atomic Structures of Minerals, pp. 107-108, 1937.

FIG. 40a.—Structural data of the clay minerals.* First column is schematic drawings (not to scale) of the atoms in a unit cell projected into one plane. Second column gives number and type of atoms in each lattice plane and third column gives the corresponding valence charges. Where (+) and (−) charges are equal, lattice is neutral; where unequal, the charge is equal to the algebraic difference. (*From E. A. Hauser, J. Am. Ceram. Soc.*)

Fig. I.

Figure I

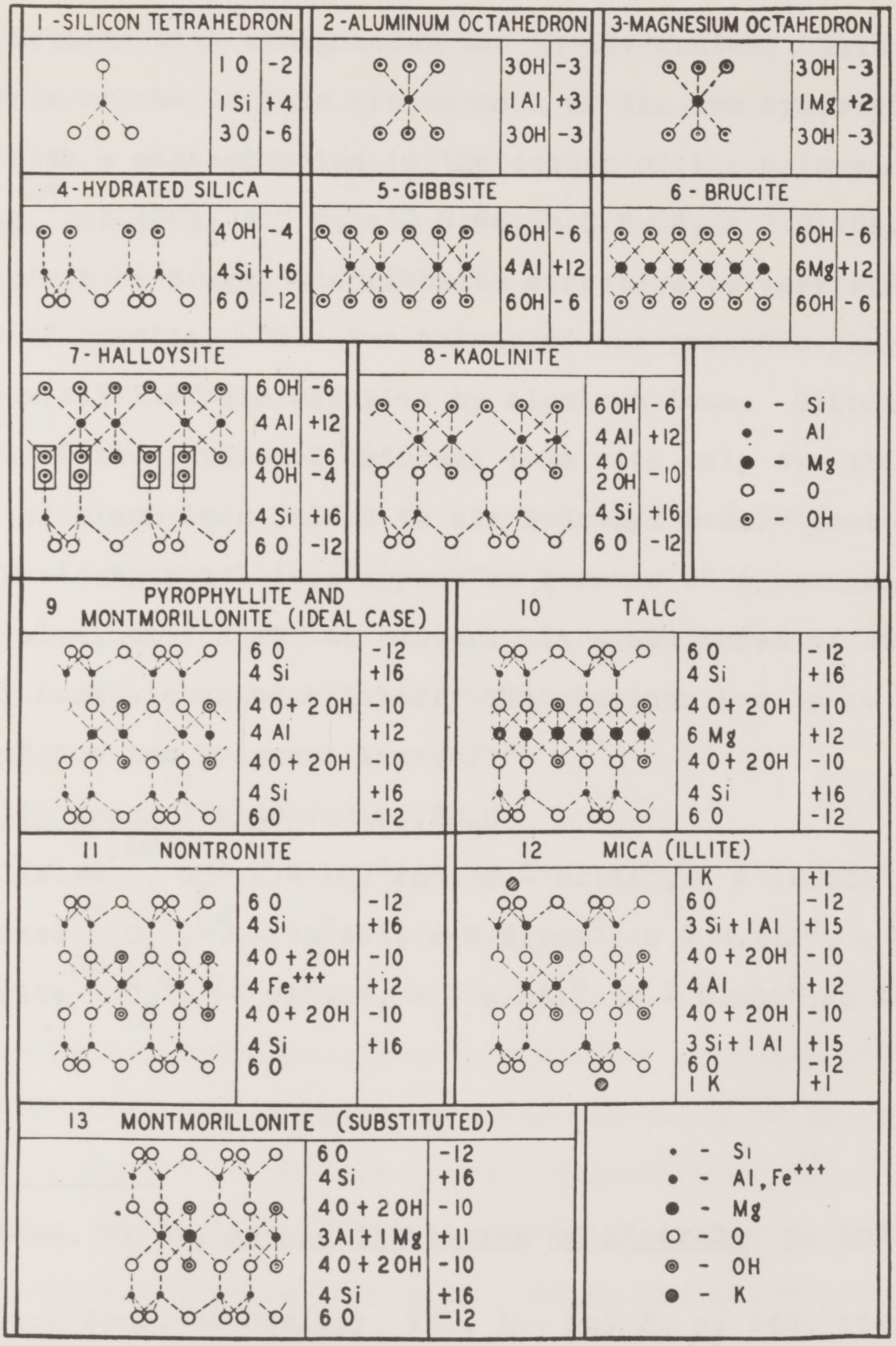

Fig. 40*a*.—Structural data of the clay minerals.* First column is schematic drawings (not to scale) of the atoms in a unit cell projected into one plane. Second column gives number and type of atoms in each lattice plane and third column gives the corresponding valence charges. Where (+) and (−) charges are equal, lattice is neutral; where unequal, the charge is equal to the algebraic difference. (*From E. A. Hauser, J. Am. Ceram. Soc.*)

Fig. 1

form a hexagon with a magnesium ion in the center. This means that three of the OH ions are on each of the two hydroxyl layers with a magnesium ion in the center of these ions.

Gibbsite[16] $Al(OH)_3$ z = 8, a = 8.62, b = 5.06, c = 9.70A.

As given by Bragg, the gibbsite structure is very similar to that of brucite. Only two thirds of the possible places for the metal ions are occupied by aluminum ions. Gibbsite consists of two layers of hydroxyl ions with only two thirds as many aluminum ions joined to six hydroxyl ions. From a top view six hydroxyl ions appear as corners of a hexagon with an aluminum ion at the center. In space three of the hydroxyl ions are on each layer. The aluminum ion is at the center of the two hydroxyl layers.

The Kaolin Group[17] $Al_2O_3.2SiO_2.2H_2O$

Kaolinite[18] C_s^4, β = 100°12', a = 5.14A°, c = 14.51A°

Dickite[19] C_s^4, β = 96°50', a = 5.14A°, b = 8.94A°, c = 14.42A°

Nacrite[20] C_x^4, β = 91°43', a = 5.16A°, b = 8.93A°, c = 28.66A

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[16] Bragg, W. L., Atomic Structures of Minerals, p. 107-108, 1937.

[17] Grim, Jour. of Geology, Vol. L., No. 3, p. 245, 1942.

[18] Gruner, J. W., Zeit. Kryst. Vol. 83, p. 394ff, 1931.

[19] Ibid., pp. 75-88, 1932.

[20] Ibid., Vol. 85, pp. 354ff, 1933.

These three minerals have very similar structures. Their chemical compositions are the same. Their structures are built of alternate silicon oxygen layers and gibbsite layers. The three minerals differ only in the stacking and rotation positions of the different layers. In each of these minerals the c direction corresponds to the stacking direction of the silicon and gibbsite layers.

Anauxite - $Al_2O_3.3SiO_2.2H_2O$

Anauxite gives a powder diffraction pattern which is almost identical with kaolinite. The ratio of SiO_2 to Al_2O_3 is 3 to 1. It is thought that a portion of the aluminum atoms of kaolin are replaced by silicon atoms.

Halloysite

Halloysite, $Al_2O_3.2SiO_2.4H_2O$

$n = 2$, C_s^3, $a = 5.20$, $b = 8.92$, $c = 10.20$, $\beta = 100^\circ$

Meta-Halloysite, $Al_2O_3.2SiO_2.4H_2O$

$n = 2$, C_s^3, $a = 5.15$, $b = 8.9$, $c = 7.57$, $\beta = 100^\circ$[20]

M. Mehmel recognizes two halloysites -- halloysite and meta-halloysite. Halloysite has four molecules of water and when it is heated to 50°C it loses 2 molecules of water and transforms into meta-halloysite. Mehmel believes that halloysite is made up of alternate layers of $H_2Si_2O_5$ and $Al(OH)_3$. But Hendricks[21] objects to Mehmel's structure, because he believes that a temperature greater than 50°C would be required to re-

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20 Mehmel, M., Zeit. Kryst. Vol. 90, p. 35ff, 1935.

21 Grim, op. cit., p. 247

move the 2 molecules of water from the crystal if the $2H_2O$ were in the form of hydroxyl ions. Hendrick believes that the two extra molecules of water are in the form of water placed between the silicon-oxygen and gibbsite layers as in kolinite, but it differs from kaolinite only in the symmetry of its atoms.

Mica Group

Muscovite $KAl_2(AlSi_3O_{10}).(OH)_2$

$C_2{}^6h$, a= 5.18, b= 9.02, c= 20.04, β= 95°30'

Biotite $K(MgFe)_3\ (Al\ Si_3O_{10})\ (OH)_2$

Lepidolite $KLi_2\ Al(Si_3O_{10})\ (OH,F)_2$

Zinnwaldite $KLiFeAl.(AlSi_3O_{10})(OH)_2$

Pragonite $Na\ Al_2.(AlSi_3O_{10})\ (OH)_2$

Margarite $CaAl_2(Al_2Si_2O_{10})\ (OH)_2$

Chlorite $Mg_5\ Al\ (Al_2Si_2O_{10})\ (OH)_8$[22]

According to Bragg and from the powder diffraction data[23,24] gathered from the literature, these minerals appear to have very closely related structures. Muscovite is the only mineral discussed here, since the other members of the mica group have similar structures. From a study of the published data of the diffraction patterns, it is obvious that a purified mineral with chemical analysis is essential for positive identification of one mineral from the other of this group. The unit

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[22] Bragg, W. L., Atomic Structure of Clay Minerals, pp. 203-219, 1937.

[23] Maegdefrau and Hofmann, Zeit. Kryst., Vol. 98, p. 31ff, 1938.

[24] McMurchy, R. C., Zeit. Kryst., Vol. 88, pp. 422-424, 1934.

cell of muscovite is made by the stacking of two silicon layers and one aluminum - hydroxyl layer in the "c" direction. The free oxygens of the silicon-oxygen layer join to the aluminum-hydroxyl ring. The potassium atoms are located on the other side of the silicon-oxygen ring and between the two silicon-oxygen rings. For the other members of this group, the silicon atoms are replaced by some other metal atoms, or the aluminum atoms are replaced by other metal atoms, or the potassium atoms are replaced by other alkali atoms.

Talc Group

Talc, $Mg_3(Si_4O_{10})(OH)_2 C_2^6 b \beta = 100^o$

$a = 5.26A, b = 9.10A, c = 18.81A^o$

Pyrophyllite, $Al_2(Si_4O_{10})(OH)_2, C_2^6 b, \beta = 99^o 55'$

$a = 5.14A, b = 8.90A, c = 18.55A$

Gruner[25] believes that pyrophyllite has a structure similar to that of muscovite with the exception that the former has no alkali between the two silicon-oxygen layers. Another difference between pyrophyllite and muscovite is that a part of the silicon in the silicon-oxygen ring of muscovite is replaced by aluminum to give a ring of $(AlSi_3O_{10})$ while pyrophyllite does not have this substitution--its silicon-oxygen ring is made of (Si_4O_{10}) units. Talc and pyrophyllite powder diffraction patterns are nearly alike. Thus Gruner

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[25] Gruner, F. W., Zeit, Kryst., Vol. 88, p. 412, 1934.

drew the conclusion that talc had the same structure as pyrophyllite, except that in the place of aluminum atoms in the aluminum-hydroxyl layer, the talc had magnesium atoms. The magnesium layer contains 50% more magnesium atoms and this gives a brucite layer for talc and a gibbsite layer for pyrophyllite.

Illite $2K_2O.3MO.8R_2O_3.24SiO_2.12H_2O$

A few quotations from an article written by Grim are self-explanatory.

> Other investigators have noted apparently the same mineral in similar sediments describing as resembling muscovite, but as differing from it by containing less potash and more water. It has been called hydromica or sericite, the latter term being used because some of its physical properties appear to be similarly associated with the mineral sericite.[26]

> It is possible that the mineral described by Ross and Kerr for indices of refraction and birefringes are somewhat lower than those of the mineral here studied, but the presence of small amounts of impurities such as beidellite and quartz would account for these variations and for the very high silica alumina ratio shown by their formula approximately representing one sample. Thus there is no doubt that a mineral belonging to the mica group is a common constituent of argillaceous sedimentation (purest sample .1 micron to .06 micron).[27]

> Sericite may indicate, therefore, a white mica with certain attributes of physical properties, chemical composition or origin depending upon the user of the term.

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[26] Grim, R. E., Amer. Min., Vol. __22__, p. 813, 1937.

[27] Grim, R. E., __op__. __cit__., p. 814

> There remains only the alternative of giving a new name to the mica occurring in argillaceous sediments and the term illite, taken from the state of Illinois is here proposed. It is not proposed as a specific mineral name but as a general term for the clay mineral constituent of argillaceous sediments belonging to the mica group.[28]

Montmorillonite Group

Montmorillonite $(MgCa).O.Al_2O_3.5SiO_2.nH_2O$

Nontronite $(AlFe)O_3.3SiO_2.NH_2O$

Saponite $2MgO.3SiO_2.NH_2O$

Beidellite $Al_2O_3.3SiO_2.NH_2O$

The montmorillonite group of clay minerals has a property of swelling when water is added to the crystals. Montmorillonite[29] consists of one gibbsite layer between two silica layers, similar to the structure of pyrophyllite. These layers are stacked in the "c" direction without orientation and the layers are loosely held together in the "c" direction by the presence of water. The ideal formula for montmorillonite is $(OH)_4Al_4Si_8.nH_2O$. The c dimension of the montmorillonite is variable; it has the lengths 9.6A, 12.4A, 15.4A, and 21.4A - depending upon the amount of water absorbed in the crystal lattice. The water is absorbed in the crystal lattice between the two silicon-oxygen layers. The amount of water absorbed in the crystal lattice may

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28 Ibid., p. 815, 1937

29 Hofmann, Endell and Wilm. Zeit. Kryst., Vol. 98, P.299f, 1937.

reach 51.8 grams per 100 grams of water free substance. There is a difference of opinion about whether the montmorillonite is monoclinic[30] or orthorhombic.

Grim[31] thinks that the amount of expansion of montmorillonite is related to the character of the exchangeable bases carried by the mineral.

Grim[32] says, "It is a well known fact that completely electro-dialyzed montmorillonite expands only very slightly". He also says, "There is a considerable body of data to indicate that, before all the adsorbed cations are replaced by H^+ some Al^{+++} is removed from the lattice to occupy exchange positions. An explanation for the non-swelling of the so-called 'H - montmorillonite clays' is that they are not pure H - montmorillonite but also contain multivalent cations that serve to bind the layers together."

Nontronite[33] has properties similar to montmorillonite, e.g., the swelling property. Nontronite has a structure similar to montmorillonite in which half the aluminum atoms are replaced by iron atoms (Fe^{++}).

Saponite is similar to montmorillonite in its swelling

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[30] Grim, Jour. of Geology, Vol. L, No. 3, p. 239, 1942.

[31] Ibid., p. 240.

[32] Ibid., p. 272.

[33] Amer. Min., Vol. 20, p. 475ff, 1935.

property and in its structure. In place of aluminum atoms as in montmorillonite, saponite has magnesium atoms in the form of a brucite layer.

For a long time, it was believed that there was another member of the montmorillonite group, and this member was called beidellite. Now, it is believed that beidellite is a mixture of clay minerals. Grim gives the following statement about beidellite.

> Unpublished work by the writer and his colleagues indicates that some so-called beidellite is a mixture of montmorillonite and limorite and that some others have a non-expanding lattice which, together with other properties, suggests that they are clay mineral mixtures containing large amounts of illite.[34]

Attapulgite $(OH_2)_4(OH)_2Mg_5Si_8O_{20}4H_2O$

Bradley[35] gives the above formula for this mineral, but he believes that some of the magnesium is replaced by aluminum. Bradley believes that attapulgite is made up of two silica tetrahedra layers with a brucite layer. He believes that the direction of the brucite and silica layers extend in one direction only, instead of two directions as in the other clay minerals. Bradley thinks that the attapulgite has a fiber diagram.

Conclusion from Clay Mineral Discussion:

Since clay minerals are built of common units and their a and b dimensions are approximately the same, one can expect

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[34] Grim, op. cit., p. 233

[35] Bradley, Amer. Min., Vol. 25, pp. 405-410, 1940.

their powder diffraction patterns to be very similar. Since clay minerals particles are very small, they will give broad lines on the powder pictures. The best identifications for clay minerals will be by the value of the lines giving the 00L indices - especially the 001 or 002 index. One can see that for the identification of a mineral in a group a chemical analysis is essential and, in some cases, a purification of the mineral followed by a chemical analysis is necessary.

LITERATURE DATA

Identifying crystals by means of the powder diffraction method is limited by the number of standard powder diagrams available and by the number of powder diffraction pictures on file in the laboratory. Tables 1 through 8 give chemical analyses taken from the literature of standard clay minerals, and Tables 9 through 26 give the powder diagrams of standard minerals taken from the literature.

GENERAL NOTATIONS FOR LINE INTENSITIES

Very strong	=	V.H.	or	S.St.
Strong	=	H	or	St.
Medium	=	M		
Weak	=	Sch.	or	W
Very Weak	=	S. Sch.	or	V.W.

TABLE 1

Chemical	Grim Sericite Like Mica[35]	Sarospatah Mica[35]	New Jersey Glankonite[35]	Seladonite Vesuvius[35]
SiO_2	50.10%	50.30%	49.10%	55.30%
TiO_2	0.50	trace		
Al_2O_3	25.12	32.80	19.30	10.90
Fe_2O_3	5.12	0.00	7.52	6.90
FeO	1.52	0.00	2.87	3.54
MgO	3.92	1.95	2.71	6.56
CaO	0.45	0.55	0.98	0.47
K_2O	6.90	6.72	7.50	9.38
Na_2O	0.05	0.52	0.00	0.00
$-H_2O$	6.85	6.98	6.07	5.21
Total	100.54	99.82	96.05	98.31
$+H_2O$	1.90	3.60	3.10	1.30

[35] Zeit. Kryst., Vol. 98, p. 41, 1937-38.

TABLE 2

Chemical Analysis

Chemical	Gruner Kaolin[36]	Gruner Dickite[37]	Gruner Nacrite[38]
SiO_2	45.73%	46.35%	44.75%
Al_2O_3	38.77	39.59	39.48
TiO_2	1.35		
Fe_2O_3	.40	.11	.53
CaO	.56		.13
SO_3	.16		
MgO			.19
H_2O	13.66	13.93	15.00
Total	100.26	100.13	100.09

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[36] Zeit. Kryst., Vol. 87, p. 75, 1933.

[37] Ibid., p. 395.

[38] Ibid., p. 345.

TABLE 3

Chemicals	Hydro Muscovite[39]	Lepidolite[39]	Phlogopite[39]	Lepido-melane[39]	Zinn-Waldite[39]
SiO_2	46.54%	52.26%	43.27%	33.07%	41.78%
TiO_2	.17			3.84	
Al_2O_3	36.37	22.31	13.76	16.32	22.76
Fe_2O_3	.72	1.3	.32	5.97	.98
FeO	.36	.37	.72	22.46	14.28
CaO	.22	.18	.36	.26	---
MgO	.50	.21	27.64	5.85	.55
K_2O	8.06	11.18	8.73	7.92	10.51
Na_2O	.46	1.07	.39	.87	.67
Li_2O	tr.	5.47	---	---	2.42
H_2O	6.83	1.20	1.18	3.87	1.41
F	.02	8.64	5.41	---	6.48
Total	100.25	100.56	99.40	100.43	100.09

[39] Zeit. Kryst., Vol. 97, p. 514ff, 1937.

TABLE 4

Chemical	Nontronite[40] 2	Nontronite[40] 3	Nontronite[40] 6
SiO_2	45.74%	41.60%	36.45%
TiO_2	trace	.13	.02
Al_2O_3	1.98	22.68	6.03
Fe_2O_3	29.68	15.22	34.24
FeO	.83	.54	---
MgO	3.99	.11	.97
CaO	1.61	.60	1.91
MnO	trace	---	.04
K_2O	.20	.22	.35
Na_2O	.10	.16	---
H_2O-	8.80	5.76	11.01
H_2O+	5.02	13.02	9.20
FeS	.66	---	---
P_2O_5	.18	.21	.31
Total	98.89	100.20	100.53

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[40] Amer. Min., Vol. 20, p. 478, 1935.

TABLE 5

Chemicals	Smectite or Montmorillonite[41] I	II	France Montmorillonite
SiO_2	51.21%	52.43%	48.60%
Al_2O_3	12.25	15.95	20.03
Fe_2O_3	2.07	1.42	1.25
FeO		.10	---
MgO	4.89	5.02	5.24
CaO	2.13	2.97	1.72
MnO		---	.16
TiO_2		.08	---
SO_3		.22	
P_2O_5		.08	
C		.30	
H_2O	27.87	21.50	21.52
Total	100.44	100.13	98.52

41 Amer. Min., Vol. 17, p. 196, 1932.

TABLE 6

Chemical	Pyrophyllite[42]	Attapulgite[43]
SiO_2	65.96%	53.64%
TiO_2	trace	.60
Al_2O_3	28.25	8.76
Fe_2O_3	.18	3.36
FeO		.23
MnO		.03
MgO		9.05
CaO		2.02
Na_2O		.83
K_2O		.75
P_2O_5		.79
H_2O+	5.27	10.89
H_2O-	.14	9.12
Total	99.81	100.07

[42] Amer. Min., Vol. 20, p. 478, 1935.

[43] Amer. Min., Vol. 25, p. 405, 1940.

TABLE 7

Chemical	Prochlorite[44]	Chlorite[44]	Amesite[44]
Insoluble		4.28%	
SiO_2	23.69%	21.28	20.95%
TiO_2	---	trace	---
Al_2O_3	21.26	22.40	35.21
Fe_2O_3	26.52	---	---
FeO		33.20	8.28
CaO	3.32	1.12	.58
MnO	.43	---	trace
MgO	17.60	6.52	22.80
H_2O-			.23
H_2O+	7.63	6.09	13.02
S		.56	
B_2O_3		trace	
Total	100.45	99.45	101.15

44 Zeit. Kryst., Vol. 88, p. 422, 1934

TABLE 8

Chemical	Leuchtenbergite[45]	Sheridanite[45]	Chlorite[45]
SiO_2	31.44%	27.78%	29.87%
Al_2O_3	17.62	24.30	14.48
Fe_2O_3		1.43	5.52
FeO	trace	.35	1.93
Cr_2O_3			1.53
CaO	trace	trace	
MgO	37.60	32.71	33.06
NiO			.17
H_2O-		.06	
H_2O+	13.19	13.01	13.60
Total	99.89	99.64	100.19

45 Zeit. Kryst., Vol. 88, p. 422, 1934.

TABLE 9

Kaolinite from Saxony[50]		Kaolinite Data: Gruner[50]		Kaolinite Data of Ross & Kerr[50]	
d	I	d	I	d	I
7.14	s.st.	7.06	10	4.46	10
4.45	st.	4.39	6	4.19	10
4.16	st.	4.21	3	3.87	5
3.83	m.	3.76	4	3.61	6
3.60	st.	3.57	10	3.42	5
3.37	sch.	3.35	1	3.07	2
3.11	s.sch.	3.08	.5	2.789	1
2.780	s.sch.	2.760	1	2.515	9
2.54	st.	2.556	5	2.344	10
2.32	st.	2.491	5	2.305	4
2.208	s.sch.	2.373	2	2.205	1
1.997	m.	2.341	8	2.005	4
1.950	s.sch.	2.272	5	1.860	1
1.850	sch.	2.200	.5	1.666	6
1.793	sch.	1.983	4	1.621	2
1.666	st.	1.930	1	1.549	2
1.625	st.	1.893	1	1.487	6
1.586	s.sch.	1.839	2	1.455	2
1.549	sch.	1.785	1	1.382	1
1.493	st.	1.658	7	1.347	5
1.396	s.sch.	1.610	4	1.303	2
1.375	s.sch.	1.585	1	1.283	3
1.344	m.	1.536	3	1.233	4
1.311	m.	1.486	8		
1.287	m.	1.452	2		
1.243	m.	1.430	1		
		1.389	.5		
		1.371	.5		
		1.340	3		
		1.306	4		
		1.284	3		
		1.264	1		
		1.235	3		

[50] Zeit. Kryst., Vol. 87, p. 128, 1934.

TABLE 10

Dickite of Gruner[51]		Dickite of Ross & Kerr[51]		Dickite of Hendricks & Fry[51]	
d	I	d	I	d	I
7.12	10				
4.43	4	4.471	8	4.49	m
4.15	3	4.201	5	4.16	m
3.79	2	3.846	5	3.816	m.sch.
3.578	10	3.631	9	3.605	st.
3.439	.5-1	3.491	2	3.446	s.sch.
3.011	.5	3.336	.5	3.276	s.sch.
2.828	1	3.161	.5	3.080	s.sch.
2.781	1	2.981	2	2.960	s.sch.
2.566	3-4	2.741	2	2.802	sch.
2.514	4	2.591	5	2.574	m.st.
2.384	5	2.526	8	2.509	m.
2.328	5	2.408	1	2.329	s.st.
2.180	.5	2.346	10	2.221	sch.
2.099	.5	2.225	2	1.976	m.st.
1.976	.4	1.995	8	1.88	s.sch.
1.898	.5	1.910	1	1.725	s.sch.
1.859	1	1.870	2	1.651	st.
1.792	3	1.800	1	1.56	s.sch.
1.649	4	1.659	9	1.489	m.st.
1.555	3	1.564	5	1.424	m.sch.
1.490	5	1.494	8	1.315	m.st.
1.455	2	1.459	2		
1.431	2	1.434	.5		
1.391	1	1.409	1		
1.374	1	1.383	1		
1.317	4	1.323	8		
		1.291	3		
		1.234	4		
		1.190	3		

[51] Zeit. Kryst., Vol. 87, p. 126, 1934.

TABLE 11

Nacrite of Freidberg, Sachsen[52]		Nacrite Near Augustusberg, Sachsen[52]		Nacrite Data of Ross & Kerr[52]	
d	I	d	I	d	I
7.15	s.st.	7.15	s.st.	4.71	8
4.42	st.	4.40	st.	4.201	5
4.16	m.	4.15	sch.	3.621	9
3.59	s.st.	3.57	s.st.	3.371	4
3.38	sch.	3.38	sch.	3.101	3
3.07	sch.	3.06	sch.	2.541	5
2.540	m.	2.538	m.	2.425	10
2.416	s.st.	2.413	st.	2.335	4
2.305	s.sch.	2.095	sch.	2.100	4
2.100	m.	1.915	m.	1.980	5
1.922	m.	1.795	m.	1.920	5
1.798	m.	1.672	s.sch.	1.820	2
1.740	s.sch.	1.610	s.sch.	1.671	5
1.676	sch.	1.486	st.	1.480	9
1.618	sch.	1.462	sch.	1.450	3
1.489	st.	1.366	sch.	1.368	4
1.466	sch.	1.272	sch.	1.318	1
1.372	m.			1.273	4
1.282	s.sch.				
1.270	sch.				

[52] Zeit. Kryst., Vol. 87, p. 125, 1934.

TABLE 12

Halloysite Argentina[53]

d	I
7.49	sch.
4.42	s.st.
3.60	sch.
2.59)	st.
2.53)	
2.019	s.sch.
1.70)	m.
1.62)	
1.289	sch.
1.236	sch.

Halloysite Data Kelley, Dore & Brown[53]

d	I
4.45	s.st.
3.65	m.
2.60)	m.
2.35)	
1.69	sch.
1.29	s.sch.
1.24	s.sch.

Halloysite Data Hendrick & Fry[53]

d	I
4.41	
2.56	st.
2.508	m.st.
2.337	m.st.
1.64	m.sch.
1.29	m.sch.
1.23	m.

Halloysite I[53]

d	I
7.48	m.
4.44	s.st.
3.62	sch.
3.35	sch.
2.60)	st.
2.33)	
1.70)	m.
1.64)	
1.290	sch.
1.237	sch.

Halloysite II[53]

d	I
7.48	s.sch.
4.42	s.st.
3.72)	m.
3.31)	
2.59)	st.
2.33)	
2.22	s.sch.
1.70)	m.
1.63)	
1.289	sch.
1.236	sch.

Halloysite III[53]

d	I
7.43	m.
4.44	s.st.
3.61	st.
2.57	st.
2.36	st.
2.23	s.sch.
2.013	sch.
1.71)	st.
1.63)	
1.291	m.
1.239	m.

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[53] Zeit. Kryst., Vol. 87, p. 131, 1934.

TABLE 13

Montmorillonite France[54]		Montmorillonite Data of Hendricks & Fry[54]		Montmorillonite Data of P.F.Kerr[54]	
d	I	d	I	d	I
5.06	m.	4.92	st.	4.49	
4.46	s.st.			4.05	
4.25	sch.	3.063	s.sch.		
3.57	m.	2.551	s.st.	2.48	
3.05	m.	2.478	s.sch.		
2.536	s.st.	1.685	M.	1.67	
2.340	sch.	1.286	m-sch.	1.29	
2.188	s.sch.	1.238	m-sch.	1.25	
1.698) 1.648)	m.			.976	
1.285	m.				
1.239	m.				
.972	m.				

[54] Zeit. Kryst., Vol. 87, p. 133, 1934.

TABLE 14

Nontronite[55] No. 2 d	I	Nontronite[55] No. 3 d	I	Nontronite[55] No. 6 d	I
12.4	3	13.9	4	13.4	5-8
7.00	ind.	7.1	ind.	4.99	.5
4.95	.5	4.87	.5	4.51	3
4.48	2-3	4.44	3	4.18	1
4.14	1	3.94	.5 ind.	2.82	.5
3.55	1	3.54	2	2.68	.5
2.88	.5	2.79	.5	2.577	2
2.61	1	2.588	1-2	2.436	2
2.573	1-2	2.507	1 ind.	2.18	.5-1vb
2.501	1-2	2.272	.5	1.888	.5-1
2.437	1-2	1.720	.5-1	1.708	1-2
2.259	.5-1	1.678	1	1.665	1-2
2.180	.5-1	1.632	.5-1	1.556	.5
2.071	5	1.519	2	1.505	4
1.995	.5-1	1.481	2	1.444	.5
1.884	.5	1.307	.5	1.299	.5
1.771	1-2	1.281	.5	1.254	1
1.659	1	1.261	.5-1		
1.560	.5	1.251	.5-1		
1.506	2-3				
1.449	.5				
1.391	5				
1.253	.5-1				

[55] Amer. Min., Vol. 20, p. 481, 1935.

TABLE 15

Muscovite[56] Norway d	I	Biotite[56] Norway d	I	Seladonite[56] Vesuvius d	I
9.93	5	9.93	5	10.00	4
5.02	1	4.88	1	4.99	1
4.46	5	4.44	5	4.52	4
3.92	1	4.09	1	4.32	3
3.71	1	3.86	3	4.11	3
3.49	2	3.58	3	3.62	4
3.32	4	3.31	5	3.31	4
3.19	2	3.07	3	3.08	4
2.98	3	2.86	4	2.89	2
2.86	1	2.56	5	2.67	3
2.78	1	2.46	2	2.57	5
2.57	5	2.38	3	2.48	1
2.46	1	2.25	.5	2.39	4
2.39	2	2.19	.5	2.25	2
2.25	1	2.12	3	2.20	2
2.18	1	2.04	.5	2.13	2
2.13	3	2.02	2	1.99	2
1.99	3	1.86	.5	1.95	2
1.53	3	1.76	.5	1.82	1
1.50	4	1.64	3	1.71	1
1.35	1	1.61	.5	1.65	3
1.30	2	1.54	.5	1.59	2
1.27	.5	1.50	3	1.51	4
1.25	1	1.34	2	1.34	2
		1.30	2	1.30	3
		1.25	1	1.28	1
				1.25	2

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[56] Zeit. Kryst., Vol. 98, pp. 38-39, 1937-38.

TABLE 16

Mica of Sarospatak[57]		Glaukonite New Jersey[57]		Grim's Sericite-Like Mica[57]	
d	I	d	I	d	I
10.09	3	9.70	5	10.15	5
5.01	2	4.50	5	4.92	2
4.45	5	3.64	2	4.45	5
3.64	2	3.31	3	3.67	.5
3.31	3	3.07	2	3.31	3
3.07	2	2.58	5	3.05	.5
2.56	5	2.39	4	2.57	5
2.46	1	2.25	1	2.47	1
2.38	2	2.14	4	2.37	2
2.24	1	1.99	.5	2.25	1
2.13	2	1.65	1	2.13	1
2.00	.5	1.51	5	2.1	1
1.69	1	1.30	3	1.7	1
1.63	1			1.64	2
1.50	4			1.50	4
1.29	2			1.30	2
1.24	1			1.25	1

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[57] Zeit. Kryst., Vol. 98, pp. 38-39, 1937-38.

TABLE 17

Muscovite[58] East Africa d	I	Hydro Muscovite[58] Whales d	I	Lepidolite[58] Saxony d	I
9.98	s	9.98	s	10.1	s
4.98	s	5.02	s	5.05	s
4.48	s	4.51	m	4.78	m
3.92	m	3.62	s	4.47	s
3.73	m	3.34	vs.br.	3.93	w
3.50	m	3.09	s	3.56	s
3.34	vs	2.89	s	3.36	vs
3.20	m	2.59	vs	3.17	vw
3.00	m	2.47	m	2.84	s
2.91)	m	2.390	s	2.58	vs
2.77)	m	2.27)	w	2.52	w
2.57)	m	2.18)		2.42	vw
2.48	w	2.135	s	2.32	m
2.39	m	1.994	vs	2.25)	vw
2.28)	w	1.715	vw	2.09)	
2.18)		1.648	s	2.012	vs
2.132	s	1.505	s	1.970	w
1.995	vs	1.416	vw	1.695	s
1.723	vw	1.380	vw	1.634	s
1.652	s	1.350)	m	1.537	vw
1.547	vw	1.336)		1.492	vs
1.520	vw	1.297	m	1.416	vw
1.500	s	1.245	w	1.380	vw
1.450	vw			1.350)	m
1.421	vw			1.336)	
1.356)	m			1.297	m
1.377)				1.245	w
1.296	m				
1.296	m				
1.247	m				

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58 Zeit. Kryst., Vol. 97, p. 514ff, 1937.

TABLE 18

Phlogopite[59] Rossie, America		Lepidomelane[59] Ural		Zinnwaldite[59] Saxony	
d	I	d	I	d	I
10.0	vs	10.1	vs	10.0	vs
5.02	vw	5.04	vw		
4.57	w	4.57	w	4.57	vw
3.35	vs	3.36	vs	3.34	vs
3.13	vw	3.14	vw	3.13	vw
2.89	vw	2.88	vw	2.89	vw
2.62	s	2.65	s	2.62	s
2.510	w	2.507	w	2.482	w
2.435	s	2.452	s	2.432	s
2.285	vw	2.279	vw	2.184	s
2.175	s	2.186	s	1.995	s
1.998	s	2.00	s	1.915	vw
1.906	vw	1.911	vw	1.672	s
1.742	vw	1.746	vw	1.540	s br.
1.669	s	1.676	s	1.470	vw
1.533	s	1.548	s br.	1.425	vw
1.475	vw	1.477	vw	1.358	m
1.432	vw	1.435	vw	1.330	vw
1.358	m	1.364	m	1.302	w
1.333	vw	1.335	vw		
1.305	w	1.314	vw br.		

[59] Zeit. Kryst., Vol. 97, p. 514ff, 1937.

TABLE 19

Pro-Chlorite[60] Conn.		Chlorite[60] Bolivia		Amesite[60] Chester, Mass.	
d	I	d	I	d	I
13.621	4	13.791	7	6.927	8
6.898	8	6.927	10		
5.124	1	5.155	.5	4.529	1
4.646	6	4.627	6	3.832	3
3.852	2	3.854	3	3.469	10
3.480	10	3.490	10	2.733	1
2.797	5	3.047	.5	2.605	2
2.546	6 br.	2.791	5	2.467	6
2.442	4	2.551	5	2.315	3
2.373	4	2.446	3	2.112	3
2.259	3	2.380	2	1.995	1
2.206	1	2.256	2	1.920	7
2.061	1	2.202	.5	1.748	4
1.996	8	2.067	.5	1.685	1
1.873	4	1.999	8	1.596	3
1.814	3	1.876	3	1.529	5
1.700	2	1.817	3		
1.653	2	1.703	2		
1.558	7	1.653	2		
1.539	7	1.560	7		
		1.543	7		

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[60] Zeit. Kryst., Vol. 88, p. 423, 1934.

TABLE 20

Leuchtenbergite[61] Philipsburg, Montana		Sheridanite[61] Miles City, Montana		Chlorite[61] Westchester, Pa.	
d	I	d	I	d	I
13.138	6	13.678	7	13.848	10
6.970	9	7.040	8	7.014	8
4.678	9	5.250	2	4.685	8
3.893	2	4.680	9	3.907	3
3.515	10	3.922	2	3.533	8
2.824	5	3.509	10	3.109	.5
2.523	8 br.	3.129	1	2.831	6
2.431	5	2.828	7	2.648	5
2.369	1	2.712	.5	2.546	6
2.251	3	2.578	7	2.400	6 br.
2.171	1	2.542	5	2.243	.5
1.998	8	2.430	6	2.017	4
1.880	3	2.370	3	1.743	.5
1,818	3	2.247	4	1.698	1
1.728	2	2.215	.5	1.668	1
1.688	2	2.064	1	1.537	9 br.
1.655	2	2.021	7		
1.563	7	1.998	6		
1.531	9	1.881	4		
		1.825	4		
		1.731	3		
		1.706	3		
		1.659	2		
		1.562	10		
		1.534	10		

[61] Zeit. Kryst., Vol. 88, p. 423, 1934.

TABLE 21

Talc[62]

d	I
8.94	5
5.05	1
4.57	3
3.87	1
3.38	3
3.06	10
2.702	1
2.56	1 br.
2.449	5
2.312	1
2.188	2 br.
2.081	1 br.
2.039	1
1.920	.5
1.850	3
1.701	1 br.
1.664	3 br.
1.652	1-2
1.544	2
1.632	1 br.
1.515	4
1.499	1
1.461	1
1.446	.5
1.405	2
1.375	3-4 br.
1.327	1-2
1.313	1
1.289	2 br.
1.263	.5
1.230	1
1.179	.5
1.165	.5
1.112	.5

Pyrophyllite[62]

d	I
8.97	3
4.97	.5
4.53	4
4.12	2)
3.85	.5)
3.34	2-3
3.037	8
2.761	.5
2.655	1
2.524	2 br.
2.400	3 br.
2.281	2
2.142	1-2 br.
2.071	1
2.044	1
2.013	.50
1.8813	.5
1.828	3
1.681	.5-1
1.801	.5
1.636	2-3
1.621	1
1.567	.25 br.
1.522	1
1.503	.5
1.485	2-3
1.463	.5-1
1.432	.5
1.419	.5
1.377	3
1.362	3
1.344	.5
1.328	.5
1.307	1-2
1.283	1
1.264	1-2
1.254	.5-1
1.236	1
1.206	.5-1
1.142	.5

[62] Zeit. Kryst., Vol. 88, pp. 414-415, 1934.

TABLE 22

Kaolinite[63]		Halloysite[63]		Metahalloysite[63]		Montmorillonite[63]	
d	I	d	I	d	I	d	I
7.16	m.st.	10.1	st.	7.46	st.	13.-15.	st.
4.39	m.st.					4.32-4.37	st.
4.17	m.	4.46	st.	4.41-4.45	st.		
3.56	st.			3.63	m.	3.12-3.14	m.
3.36	st.	3.40	st.			2.92	m.s.
2.55	m.st.	2.56		2.55	m.	2.58	m.s.

NaCl[64]
Salt

d	I
3.25	.05
2.81	1.00
1.99	.73
1.697	.02
1.626	.33
1.407	.13
1.290	.01
1.260	.33
1.150	.20
1.080	.01
.997	.30
.941	.05
.892	.03
.852	.03
.813	.01
.782	.01
.755	.01

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63 Zeit. Kryst., Vol. 94, p.344, 1936.

64 Ind. Eng. Chem.(anal. ed.), Vol. 10, p. 469, 1938.

TABLE 23

Attapulgite[65] d	I	Chrysotile[66] d	I	Antigorite[67] d	I
10.50	ss	7.073	2	7.16	6
6.44	ms	4.565	2	4.66	.5
5.42	m	4.380	1 ind.	3.96	2
4.49	s	3.974	2	3.588	7
4.18	w	3.588	6	3.480	.5
3.69	m	2.706	.5	2.791	1
3.50	w	2.588	1	2.521	4
3.23	ss	2.549	1	2.401	1
3.03	ww	2.446	3	2.152	1b
2.61	s	2.299	.5	1.986	.5
2.55	w	2.176	ind.	1.846	.5
2.38	m	2.085	1	1.808	1
1.82	ww	1.807	1	1.723	.5
1.62	ww	1.736	1	1.695	.5
1.56	w	1.680	1	1.562	3
1.50	m	1.519	3	1.538	2
		1.450	1	1.529	1
		1.300	1	1.509	1
		1.209	.5	1.478	.5
		1.187	ind.	1.442	1
				1.417	.5
				1.342	.5

[65] Amer. Min., Vol. 25, p. 409, 1940.

[66] Amer. Min., Vol. 22, p. 98, 1937.

[67] Amer. Min., Vol. 22, p. 99, 1937.

TABLE 24

Bauxite[68] $Al_2O_3.2H_2O$		- Alumina[68] $Na_2O.11Al_2O_3$		Sillimanite[68] Al_2SiO_5	
d	I	d	I	d	I
4.88	1.00				
4.39	.50				
3.33	.12	11.8	.53	5.3	.25
3.18	.07	5.7	.13	3.40	1.00
2.45	.32	4.46	.09	2.88	.20
2.38	.32	4.08	.05	2.68	.30
2.29	.03	3.78	.01	2.54	.45
2.25	.08	2.79	.17	2.41	.13
2.17	.12	2.67	.40	2.28	.15
2.05	.24	2.50	.27	2.20	.75
1.99	.12	2.40	.27	2.11	.30
1.92	.10	2.23	.27	1.97	.03
1.81	.20	2.13	.27	1.88	.13
1.75	.20	2.08	.03	1.84	.15
1.69	.20	2.02	.40	1.69	.25
1.64	.03	1.93	.27	1.59	.20
1.59	.06	1.83	.13	1.52	.75
1.460	.12	1.74	.12	1.440	.20
1.410	.12	1.69	.01	1.395	.08
1.361	.05	1.65	.04	1.328	.25
1.321	.05	1.59	.53	1.275	.20
1.273	.01	1.56	.20	1.265	.20
1.251	.03	1.480	.20		
1.215	.04	1.400	1.00		
		1.340	.33		
		2.238	.17		
		1.210	.11		
		1.190	.01		
		1.170	.03		
		1.153	.03		
		1.135	.03		
		1.113	.03		
		1.098	.03		
		1.051	.11		
		1.041	.13		
		1.017	.12		
		.993	.13		
		.968	.12		

[68] Ind. Eng. Chem. (Anal. Ed.), Vol. 10, p. 469, 1938.

TABLE 25

Quartz [69]		Calcite [70]		Diaspore $AlHO_2$ [71]	
<u>d</u>	<u>I</u>	<u>d</u>	<u>I</u>	<u>d</u>	<u>I</u>
4.24	st.	3.84	m		
3.35	s.st.	3.02	s.st.	4.70	.09
2.45	m	2.49	st.	3.99	1.00
2.285	m	2.272	st.	3.20	.08
2.236	sch.	2.082	st.	2.55	.33
2.129	m	1.914	s.st.	2.37	.05
1.981	m	1.866	s.st.	2.31	1.00
1.814	st.	1.618	sch.	2.12	.67
1.667	m	1.595	m	2.06	.67
1.539	st.	1.515	st.	1.81	.07
1.447	sch.	1.470	sch.	1.71	.20
1.412	s.sch.	1.437	m	1.63	.83
1.376	st.	1.420	sch.	1.60	.05
1.284	sch.	1.355	s.sch.	1.52	.08
1.253	m	1.333	sch.	1.477	.33
1.225	s.sch.	1.293	m	1.422	.27
1.196	m	1.176	m	1.400	.08
1.178	m	1.153	m	1.370	.20
1.150	sch.	1.139	sch.	1.330	.10
1.078	m	1.043	m	1.290	.08
1.044	sch.	1.010	m	1.260	.05
1.011	s.sch.	.963	m	1.240	.07
.916	sch.			1.215	.03
.897	s.sch.			1.200	.05
				1.170	.09
				1.140	.03
				1.090	.08
				1.063	.07
				1.037	.04
				1.00	.03

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69 Zeit. Kryst., Vol. <u>87</u>, p. 123, 1933.

70 Zeit. Kryst., Vol. <u>87</u>, p. 136, 1933.

71 Ind. Eng. Chem. (Anal. Ed.), Vol. <u>10</u>, p. 469, 1938.

TABLE 26

Indices for Muscovite	Typical Illite[73] d	Typical Illite[73] Intensity	Goose Lake Clay[72] d	Goose Lake Clay[72] Intensity
002	9.98	s	9.9	m
004	4.97	w	4.95	ww
110,111	4.47	s	4.47	s
022	4.11	ww	3.9	very diffuse
023	3.7	ww		
114	3.4	ww	3.4	
006	3.31	m	3.29	w
114	3.20	ww	3.1	very diffuse
025	2.98	ww		
115	2.84	ww		
131, 202	2.56	s	2.56	s
133	2.44	w	2.44	w
204, 133	2.38	m	2.38	m
221	2.24	m	2.2	ww
223	2.18	w	2.1	ww
135, 136	2.11	w		
0010	1.98	m	1.98	m
2010	1.65	w	1.65	w
312, 0012	1.64	m	1.64	w
060,331	1.50	s	1.50	s
20.12, 1312	1.34	ww	1.34	ww
400,068, 339	1.29	m	1.29	m
	1.24	w	1.24	ww

[72] Jour. Amer. Ceram. Soc., Vol. 22, No. 5, p. 157, 1939.

[73] Grim, R.E., Amer. Min., Vol. 22, p. 820, 1937.

PROCEDURE

As mentioned in the introduction, x-ray, chemical, and thermal analyses were used in identifying the minerals in the Texas clays. And since these methods are standard, no detailed descriptions of the methods are necessary because the details can be found in textbooks. So only reference to textbooks about the details of the x-ray and thermal analyses are given.

For more detailed discussions of the powder diffraction procedure, the reader should consult the textbooks written by Davey[74] and Wykoff[75].

For a detailed discussion of the thermal analyses method, the reader should consult Norton[76], Pask[77] and Davies, Berkelhamer[78] and Speil[79].

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[74] Davey, W. P., A Study of Crystal Structure and its applications, McGraw-Hill Book Co., Inc., New York, 1934.

[75] Wykoff, R.W.G., The Structure of Crystals, 2d ed., Chemical Catalog Co., Inc., New York, 1931.

[76] Norton, Refractories, 2d ed., McGraw-Hill Book Co., Inc., New York, 1942.

[77] Pask, J. A. and Ben Davies, Bulletin Bureau of Mines, R. I. 3737, Dec., 1943.

[78] Berkelhamer, L. H., An Apparatus for Differential Thermal Analysis, Bureau of Mines Bulletin R. I. 3762, July, 1944.

[79] Speil, S., Applications of Thermal Analysis to Clays and Aluminous Minerals, Bulletin Bureau of Mines, R. I. 3764, July, 1944.

A new X. R. D. General Electric copper target x-ray machine was used to make the powder diffraction pictures. Figure 2 contains a picture of the x-ray machine with the diffraction camera mounted in the operating position.

For an electro-dialysis apparatus, an apparatus as shown in the lower picture of figure 2 was built. A voltage doubler rectifier using four 117-Z6 tubes was built for a source of D.C. power. The dialysis cell was made from three U-shaped pieces of building tile as shown in figure 2. Parchment paper was used for the membranes between the center cell and two outside cells. The ends of the cells were covered with two flat pieces of tile and the whole apparatus was held together by means of wood blocks on each end fastened together with three tie rods. Carbon was used for the cathode electrode and copper was used for the anode electrode. The approximate dimensions of each cell were 2-1/2" by 2-1/2" by 1".

An apparatus patterned after a Brabender plastograph* was built. The apparatus records the torque produced on two shafts containing cross rods as the rods are rotated in a clay-sand mixture as water is added - the arrangement of the rods and shafts in the plastograph is similar to the arrangement of the shafts and knives in a pug mill.

The procedure developed by Oliphant[80] for fractionating

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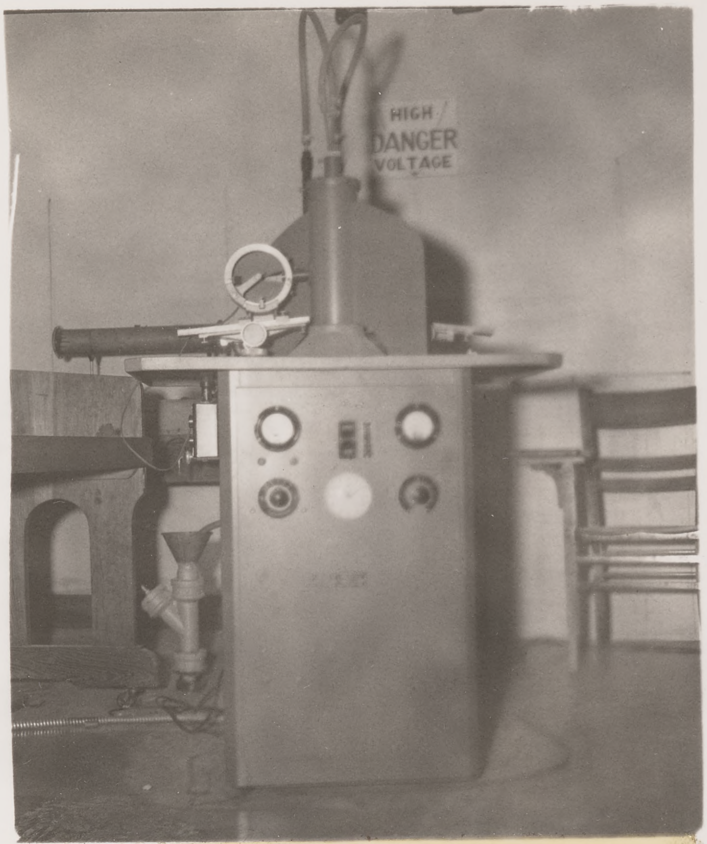
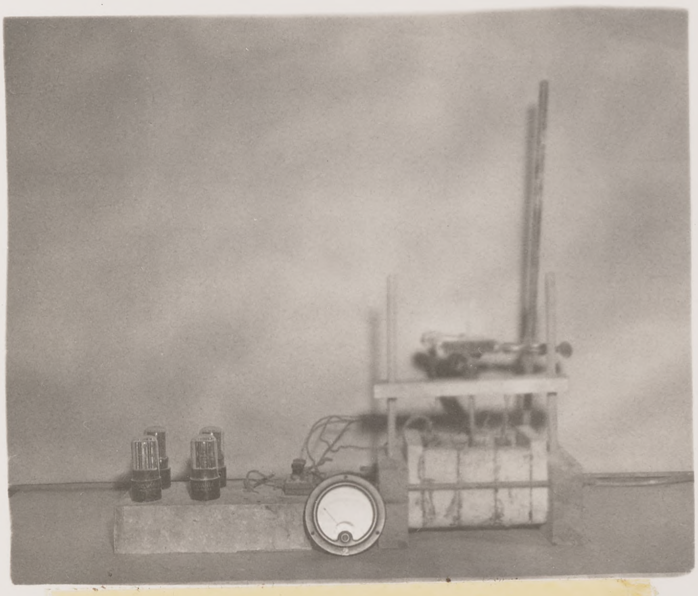
* Made by Brabender Corporation, Rocelle Park, New Jersey

[80] Oliphant, S. C., Thesis, University of Texas, pp. 30-52, 1941.

Figure 2



General Electric XRD X-Ray Unit



Electro-Dialvsis Apparatus

Fig. 2

clays according to particle sizes was used in fractionating five clays according to particle sizes. The procedure consisted of a series of settlings of clay suspensions, followed by a series of ultra-centrifugalizations of the suspended portions from the settlings at various speeds.

The procedure for preparing the samples for the x-ray camera was as follows: The samples were ground in an agate mortar fine enough to pass through a 200 mesh screen; in the center of a pyrex capillary tube approximately 1-1/2 inches long and one millimeter in diameter was placed a small plug of cotton; on each side of the cotton plug were placed powdered samples to be analyzed; the ends of the capillary tubes were then sealed with paraffin or cotton plugs. Then the capillary was placed in the x-ray camera in such a way that a clay sample was on each side of the partition in the camera. In this position, two different powder diffraction patterns were made on the same film from the two different samples in the capillary tube.

The time of exposure was two hours when using Eastman films and 20 to 30 minutes when using Agfa non-screen films.

Figures 3 through 10 show contact prints of some of the powder diffraction patterns made--only one half of the film was used in making the contact prints.

Since the films were bent in a circle around the capillary tubes containing the samples, each unit on the film corresponded to a certain number of degrees. The diffraction angles were calculated from measurements made on the film from the place, which was in front of the camera slit, to the lines made by the diffracted rays. For calibration purposes sodium chloride was used as one of the samples in the capillary tubes, because the angle of diffraction for each line on the salt pattern is known, and from the known angles of diffraction for salt, a factor for converting the measurements on the unknown to angles of diffraction was calculated. By knowing the diffraction angle for each line on the unknown pattern, the distances of the atomic planes in the unknown crystal can be calculated by means of the Bragg equation $n\lambda = 2d \sin \theta$.

λ = wave length of x-ray

n = order of diffraction

θ = angle of diffraction

d = distance between atomic planes

Samples of montmorillonite, kaolinite, halloysite, and pyrophyllite were obtained from Wards Natural Science Establishment, Inc., Rochester, New York, and samples of Wyoming bentonite, Tatatila montmorillonite, dickite, kaolinite, halloysite, pyrophyllite, illite and attapulgite were obtained from the State Geological Survey Division, Urbana, Illinois, for the purpose of making standard patterns. Each of the samples received from the two places was not pure, but contained some impurities. According to a letter received with the samples from the Illinois State Geological Survey, the Wyoming bentonite contained 10% to 15% quartz; the Tatatila montmorillonite contained some gibbsite; the

the kaolin contained 2 or 3% anatase and some coarse mica flakes; the halloysite sample contained some kaolinite and gibbsite; the illite contained some quartz and kaolinite; the attapulgite contained some montmorillonite; and the pyrophyllite contained some rutile.

Bradley* stated in a letter the following quotation:

> Very few ceramic minerals occur in nature in a state of purity such that they could be thought of as standard samples. For purposes of x-ray diffraction studies, however, we have made a practice of using admittedly impure materials and depending on experience to tell which features of the diffraction diagram derive from the mineral in question and which from extraneous material.

Powder diffraction patterns were made for each of the minerals received from the Wards Natural Science Establishment, Inc. and from the Illinois State Geological Survey Division. The d values for each line on each pattern were calculated and recorded with the relative intensities of the lines. The relative intensities of the lines were estimated with the naked eyes. The following notations were used for estimating the relative intensities:

h = strong line

m = medium line

d = dim line or weak line

v.d. = very weak line

v.v.d. = scarcely visible line

The powder diagrams of these standard minerals were compared to

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* Bradley, W. F., Chief Chemist for the State Geological Survey Division of Illinois, Urbana, Illinois.

the powder diagrams taken from published articles, in order to check the methods used in calculating the distances of the atomic planes.

Diffraction patterns of talc, salt, quartz, gypsum, feldspar, barite, calcite, anhydrite, nepheline syenite, and silica jel were made for comparison purposes. The powder diagrams were determined for the salt and quartz patterns.

There follows a table which contains the name and location of the clays studied in this research. Powder diagrams were made for each of the clays given in the table and their powder diagrams were determined.

Five clays were selected from the twelve clays given in Table A and each clay was fractionated* by Oliphant procedure[80] into nine different fractions according to particle size. Powder diffraction patterns and powder diagrams were made for each fraction of the five clays.

Powder diffraction patterns were made for eight drilling muds** which had been fractionated according to particle size. These diffraction patterns were compared with standard patterns to check for the presence of barium sulfate, quartz, salt, clay minerals, calcite, anhydrite and gypsum.

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* The work was done under the direction of Richard Darling of the petroleum engineering laboratory.

[80] Oliphant, S. C., lit. cit.

** See University of Texas Thesis by Richard Darling, June, 1944 for locations of the drilling muds.

Table A

TABLE OF CLAY SAMPLES

Name	Location
I. Kaolins	
1) Pink Davis Mountain)	Medley Ranch
2) White Davis Mountain)	Jeff Davis County
3) White Davis Mountain from deposit No. 2)	16 miles northwest of Marfa, Texas
4) White Plastic Leakey	Section 16, 5 miles west of Leakey, Texas
II. Volcanic Ash	
1) Gonzales	Max B. Nieler Co's Mines, 7 miles S. E. of Gonzales, Texas
2) Falls City	J. R. Martin Lease, 1½ miles south of Cestahona
III. Clays	
1) Acme Black	Acme Brick Company Denton, Texas
2) Elgin Black)	Elgin Standard Brick Co.
3) Elgin Bank Run)	Elgin, Texas
4) Brownwood Shale	Texas Brick Company Brownwood, Texas

TABLE OF CLAY SAMPLES (Continued)

Name	Location
5) Seguin	Seguin Brick and Tile Co., McQueeney, Texas
6) Troup	7 miles east of Troup Thermo-Fire Brick Co., Sulphur Spring, Texas
7) Rainey and Seiler	Rainey Ranch, Bexar Co., 16 miles south of San Antonio, Texas
8) Elmendorf	Alamo Clay Products Co. of Elemendorf, Texas
9) Bremond	5 miles south east of Bremond, Robertson County, Texas
10) Athens	Harbison-Walker Refractory Plant, Athens, Texas
11) Medina	Adams Ranch, 10 miles north west of Devine, Medina County, Texas
12 Smithwick Shale	Out crop along Colorado River, 5 miles down river from Marble Falls, Burnet County, Texas

A thermal analysis was made for each of the five clays as a whole and a thermal analysis was made for each .05 - .15u fraction. A thermal analysis and a powder diffraction pattern were made for a mixture of 11.2% Arizona montmorillonite, 44.4% illite and 44.4% halloysite.

Settling tests were made for the 1u to 44 fractions of the five clays and the particle size versus percent finer than curves were made.

The organic material was determined for each of the five clays by means of the hydrogen peroxide method.[81]

Fifty grams of each of the five clays were placed separately in 500 cc bottles with 300 cc of distilled water. The bottles were shaken equally for short intervals over a period of two weeks. At the end of the shaking, the bottles were allowed to set undisturbed for a month; then clear liquid was analyzed for chloride and sulfate ions.

Plastograph curves were made for each of the five clays. 200 grams clay with 800 grams sand was the clay-sand mixture.

Chemical analyses were made for the clays, kaolins, and volcanic ashes used in this research.

In order to get an estimate of the adsorbed ions in each of the five clays, each clay was subjected to electro-dialysis from 40 to 70 hours. After electro-dialysis, each clay was analyzed for sodium and potassium ions by the Lawrence Smith method.[82]

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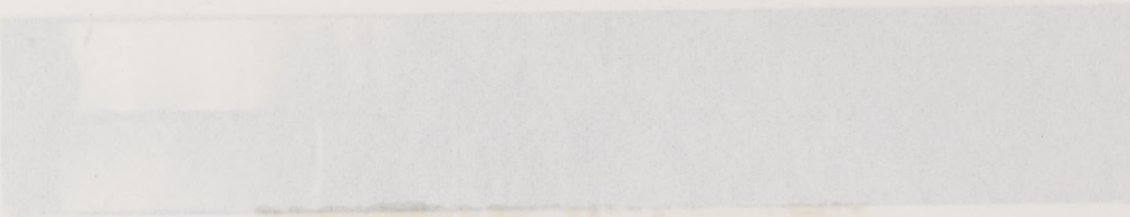
[81] Russell, R. and Mohr. W. C., Casting Characteristics of Clays, Jour. Amer. Ceram. Soc., Vol. 27, pp. 101-102, 1944.

[82] Ries, H., Clays, Their Occurrences, Properties and Uses, 3rd Edition, pp. 108-109, 1927.

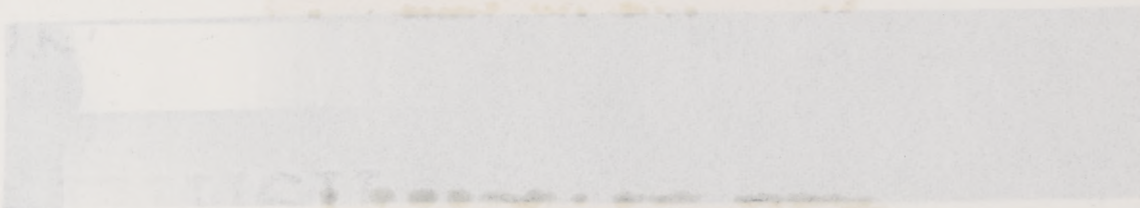
CONTACT PRINTS

Figures 3, 4 and 5 are contact prints of the standard powder diffraction patterns.

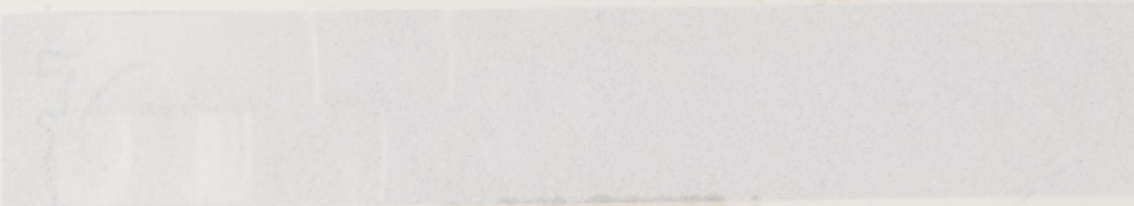
Figures 6, 7, 8, 9 and 10 are the contact prints of the fractions of the five selected clays.



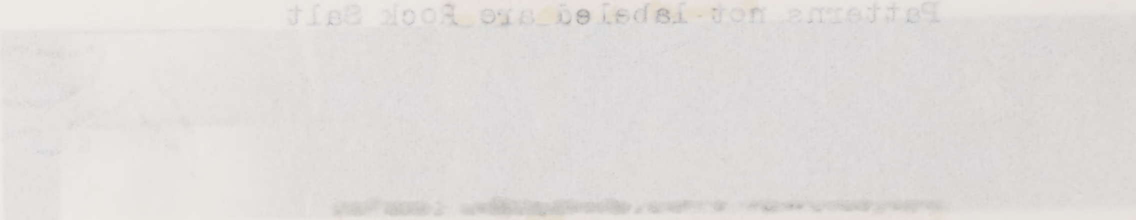
1. Georgia Kaolin 2. Salt



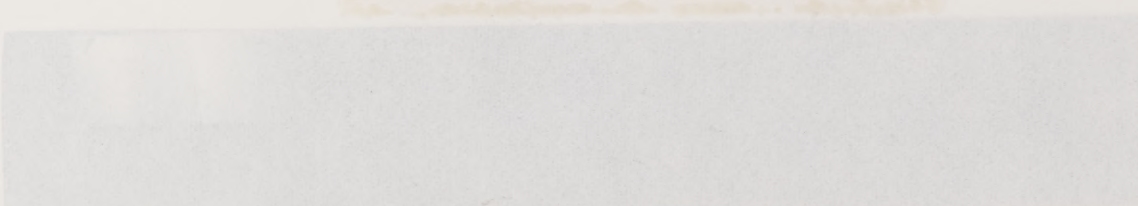
1. North Carolina Kaolin



2. Dickite



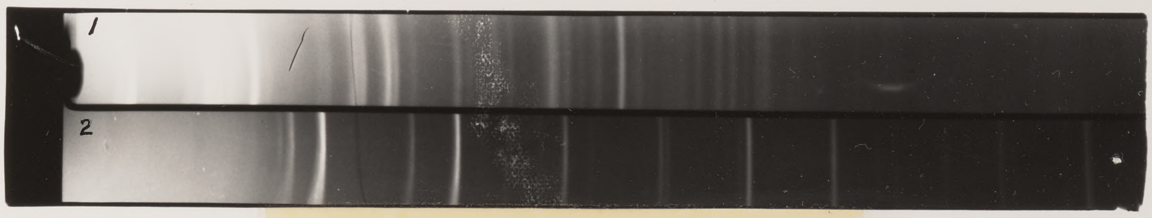
2. Halloysite Var Indianite



1. Utah Halloysite

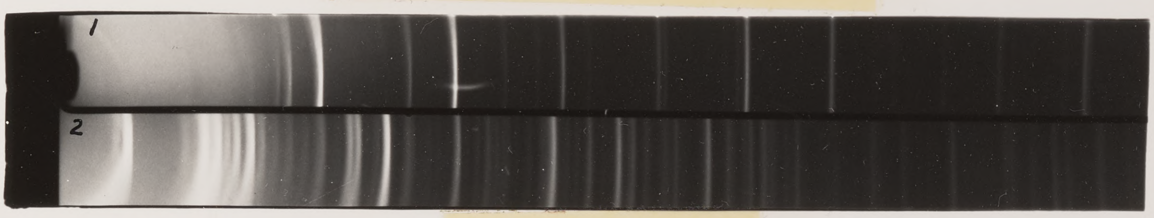
Figure 3

Patterns not labeled are Rock Salt



1. Georgia Kaolin 2. Salt

1. North Carolina Kaolin

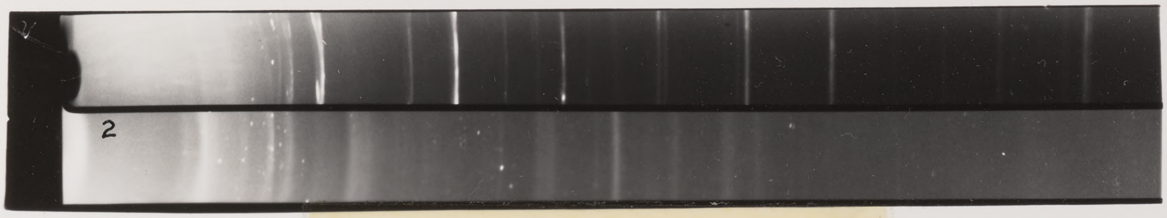


2. Dickite

2. Halloysite Var Indianite

1. Utah Halloysite

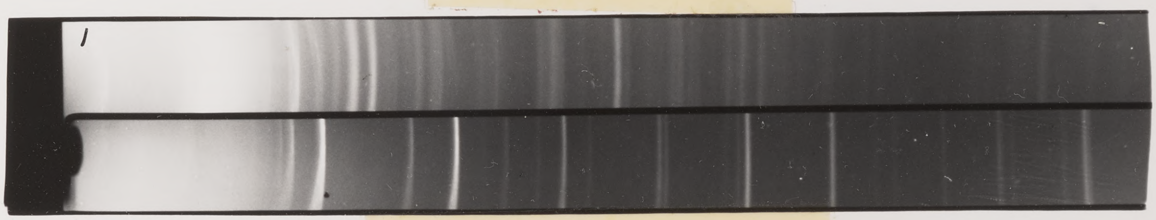
Figure 4



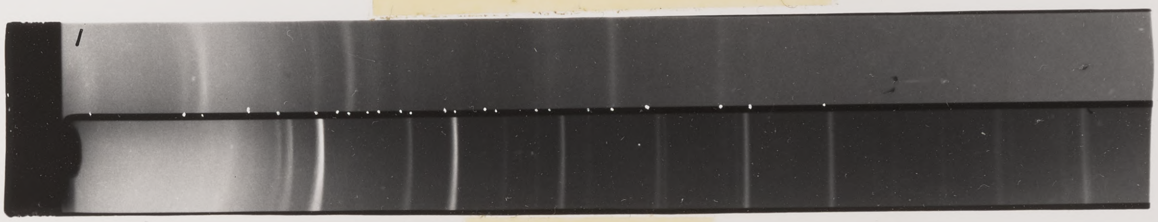
2. Wyoming Montmorillonite

1. Arizona Montmorillonite

1. Pyrophyllite

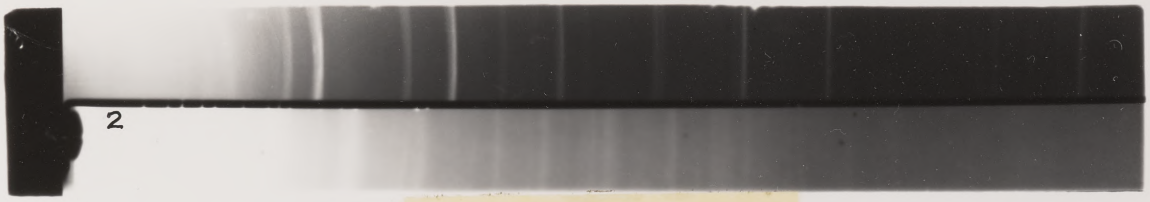


1. N.C. Pyrophyllite



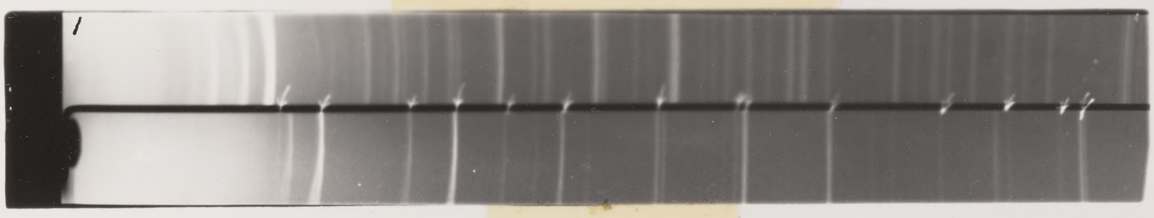
1. Illite

Figure 5



2. Attapulgulite

2. Nepheline Syenite



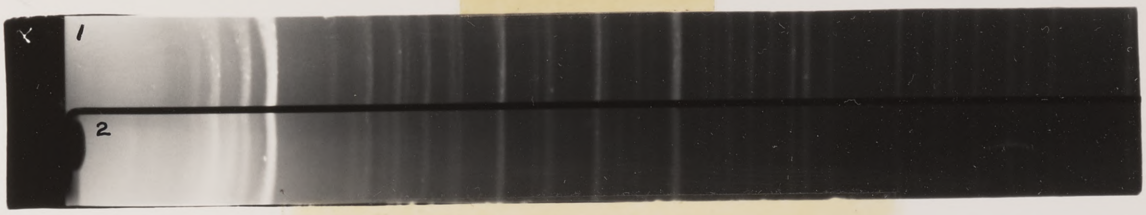
1. Quartz

1. Calcite 2. Feldspar

1. Anhydrite 2. Gypsum

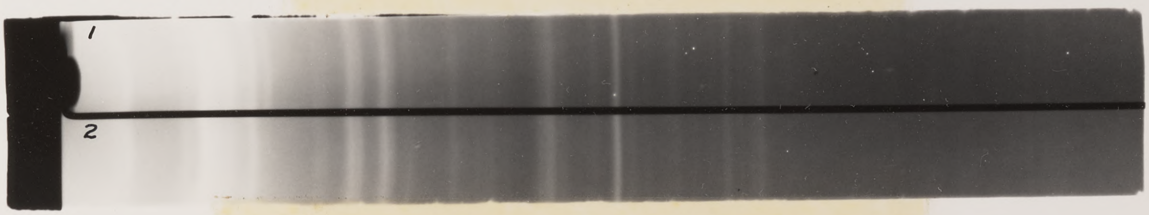
Figure 6

TROUP CLAY

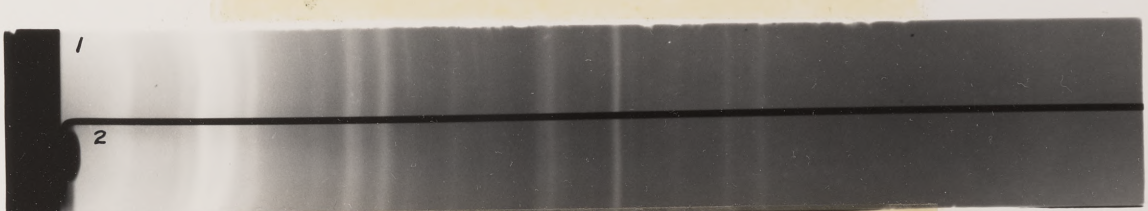


1. Plus 44μ 2. 2μ ---44μ

1. 1μ ---2μ 2. .8μ ---1μ



1. .5μ ---.8μ 2. .25μ ---.5μ

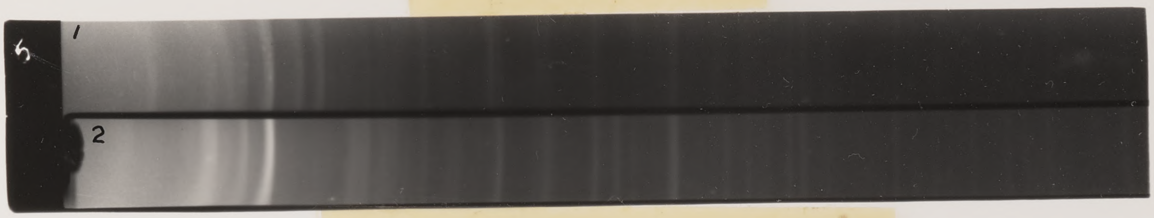


1. .15 ---.25   2. .05μ ---.15μ

1. Troup < .05μ 2. Elgin Black < .05 μ

Figure 7

ACME BLACK CLAY

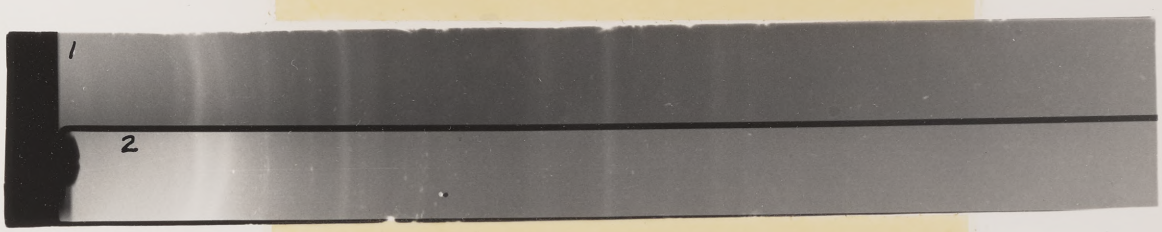


1. Plus 44μ   2. 2μ--44μ

1. 1μ--2μ   2. .8μ--1μ

1. .5μ--.8μ   2. .25μ--.5μ

1. .15μ--.25μ   2. .05μ--.15μ



1. Acme < .05μ   2. Seguin < .05μ

Figure 8

BROWNWOOD SHALE

1. Plus 44μ 2. 2μ --44μ

1. 1μ --2μ 2. .8μ --1μ

1. .5μ --.8μ 2. .25μ --.5μ

1. .15μ --.25μ 2. .05μ --.15μ

1. Illite 2. Purified Illite

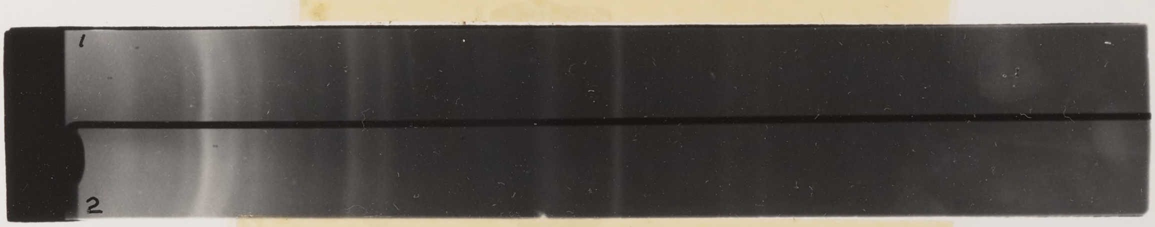
Figure 9

ELGIN BLACK CLAY

1. Plus 44μ 2. 2μ---44μ

1. 1μ---2μ 2. .8μ---1μ

1. .5μ---.8μ 2. .25μ---.5μ

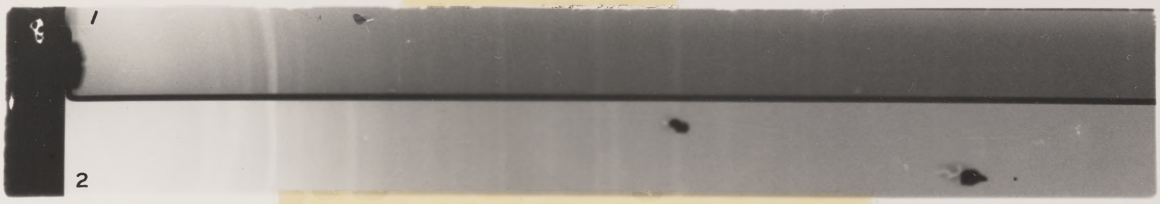


1. .15μ---.25μ 2. .05μ---.15μ

1 Vera Cruz Montmorillonite

Figure 10

SEGUIN CLAY

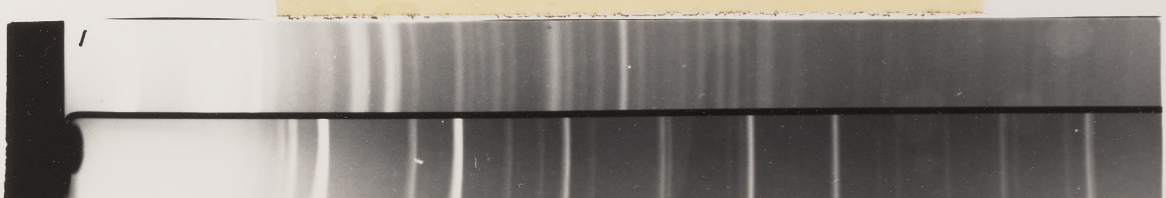


1. Plus 44μ 2. 2μ ---44μ

1. 1μ ---2μ 2. .8μ ---1μ

1. .5μ ---.8μ 2. .25μ ---.5μ

1. .15μ ---.25μ 2. .05μ ---.15μ



White Davis Mt. Kaolin

DISCUSSION RESULTS

Standard Clay Samples

Tables 27 through 41 give the powder diagrams for the following clay minerals taken as standards: Georgia kaolin, South Carolina kaolin, dickite, halloysite var. Indianite, Utah halloysite, Arizona montmorillonite, illite, Florida attapulgite, pyrophyllite, North Carolina pyrophyllite. Only the lines belonging to the clay minerals were identified on these powder diagrams in order to compare them to the values of the lines of clay minerals found in the literature. This served as a check on the methods used in calculating atomic distances of clay minerals. The variations for lines calculated for these standard samples were not greater than the variations given by different writers for the same mineral found in the literature.

TABLE 27

Dry Branch Georgia Kaolin

Reading in mm.	Intensity	d_{hkl}	Kaolin
13.9	D	7.98	-
15.3	H	7.24	+
22.5	V.V.D.	4.94	-
25. Br.	H	4.46	-
26.5	H	4.22	+
27.8Br.	m	4.02	-
31.1	H	3.58	+
32.8	V.D.	3.41	+
35.5	V.V.D.	3.16	+
39.4)	V.D.	2.85	-
40.5)	V.D.	2.77	+
43.3)	m	2.60	+
45.1)	m	2.50	+
48.0	H	2.35	+
49.1	m	2.30	+
51.3	V.V.D.	2.21	+
57.	m	1.996	+
58.4	V.D.	1.95	+
61.6	D	1.86	+
63.8	D	1.79	+
69.2Br.	m	1.67	+
71.0	D	1.63	+
72.8	V.D.	1.59	+
75.	V.D.	1.55	+
78.	H	1.49	+
80.2	V.D.	1.46	+
81.5	V.V.D.	1.43	+
83.8Br.	V.V.D.	1.41	-
86. Br.	V.V.D.	1.37	+
88.	V.D.	1.34	+
90.5	V.D.	1.31	+
92.2	V.D.	1.29	+
94.	V.V.D.	1.27	+
95.5)	V.D.	1.25	+
96.5)	V.D.	1.24	+

TABLE 28

South Carolina Kaolin

Reading in mm.	Intensity	d_{hkl}	Kaolinite
13.5	m	8.22	-
15.2	H	7.20	+
25.0 Br.	H	4.46	+
26.3	m	4.23	+
28.0	m	3.99	+
31.0	H	3.60	+
32.6	V.V.D.	3.42	-
33.7	V.V.D.	3.32	+
35.5	V.D.	3.16	+
43.5)	m	2.59	+
44.6)	m	2.53	+
47.6)	m	2.37	+
49.0)	m	2.33	+
51.1	D	2.22	+
56.5	m	2.02	+
59.9	V.V.D.	1.90	+
61.6	V.V.D.	1.86	+
63.0	V.D.	1.82	+
69.5 Br.	D	1.65	+
71.0	m	1.63	+
72.0	V.V.D.	1.60	+
75.0	V.V.D.	1.547	+
78.0	m	1.491	+
80.1	V.V.D.	1.46	+
83.3	V.V.D.	1.41	+
88.5	V.V.D.	1.33	+
90.5	V.V.D.	1.31	+
92.5	V.D.	1.28	+
94.5	V.D.	1.26	+
96.5 Br.	V.D.	1.24	+

TABLE 29

Dickite

Reading in mm.	Intensity	d_{hkl}	Dickite
15.5 mm.	H	7.18	+
25.3	H	4.42	+
27.0	H	4.14	+
29.5	m	3.76	+
31.2	H	3.58	+
32.5	V.D.	3.45	+
34.5	V.V.D.	3.25	-
36.2	V.D.	3.11	+
38.2	V.D.	2.95	+
40.2	D	2.81	+
43.8	m	2.58	+
45.	m	2.51	+
47.2	V.V.D.	2.40	+
48.5	H	2.34	+
51.3 Br.	V.D.	2.21	+
54.1	V.V.D.	2.10	+
55.3	V.V.D.	2.06	+
57.7	m	1.98	+
59.	V.V.V.D.	1.93	-
60.1	V.V.V.D.	1.89	+
61.5	V.D.	1.86	+
63.5	V.D.	1.80	+
64.2	V.V.D.	1.79	+
65.3	V.V.D.	1.76	-
66.9 Br.	V.D.	1.72	-
68.3 Br.	V.D.	1.69	-
70.1	H	1.64	+
71.8	V.D.	1.61	-
73.	V.V.D.	1.59	-
74.6	m	1.55	+
76.6	V.V.V.D.	1.52	-
78.2) Br.	H	1.49	+
80.2)	D	1.46	+
81.9	V.D.	1.43	+
84.3	V.D.	1.39	+
85.6	V.D.	1.38	+
89.8	m	1.32	+

TABLE 30

Halloysite Var. -- Indianaite

Reading in mm.	Intensity	d_{hkl}	Halloysite
10.2 Br.	m	10.98	-
11.6 Br.	m	9.55	-
22.8 Br.	D	4.88	-
25.2 Br.	H	4.43	+
28.1	m	3.98	-
30.8	D	3.62	+
34.1	V.V.D.	3.29	-
40.0	D	2.81	-
44.1 Br.	D	2.56	+
45.6 Br.	V.D.	2.48	-
47.2 Br.	V.D.	2.40	+
51.3	V.D.	2.21	+
56.0	V.D.	2.04	+
57.1	V.D.	1.998	-
63.6	V.V.D.	1.800	-
66.1	V.V.D.	1.74	-
68.1	V.V.D.	1.70	+
70.8	V.V.D.	1.64	+
78.3	D	1.49	-
83.2	V.V.D.	1.41	-
84.1	V.V.D.	1.399	-
92.5	V.V.D.	1.287	+
94.3	V.V.D.	1.265	-
96.3	V.V.D.	1.242	+
105.3	V.V.D.	1.154	+

TABLE 31

Eureka, Utah Halloysite

Reading in mm.	Intensity	d_{hkl}	Halloysite
15.	m	7.400	+
23.1	D	4.81	-
25.1	H	4.43	+
31.0 Br.	D	3.59	+
44.1	V.V.D.	2.55	+
47.8 Br.	V.V.D.	2.36	+
69.	V.D.	1.67	+
71.	V.D.	1.63	+
78.4	m	1.49	-
92.9	V.V.D.	1.28	+
96.8	V.V.D.	1.22	+

TABLE 32

<u>Arizona</u> <u>Montmorillonite</u>

No.	Reading in mm.	Intensity	d_{hkl}	Montmorillonite
1.	22.0	m	5.07	+
2.	24.5	H	4.54	+
3.	36.2	V.V.V.D.?	3.095	+
4.	39.5	V.V.V.D.?	2.850	-
5.	43.5 Br.	m	2.590	+
6.	51.0	D	2.214	+
7.	67.)) Br.	D	1.715	+
8.	69.1)		1.668	+
9.	77.2	m	1.506	-
10.	88.5	V.V.D.	1.335	-
11.	91.))	V.D.	1.302	-
12.	92.2)		1.288	+
13.	95.	V.V.D.	1.257	+
14.	108.5	V.V.V.D.	1.125	-

TABLE 33

Vera Cruz, Mexico Montmorillonite

No.	Reading in mm.	Intensity	θ	Sin θ	d_{hkl}	Montmorillonite
1.	7.5	H	2.985	.05205	14.78	+
2.	22.2	D	8.82	.1533	5.02	+
3.	24.5	m	9.74	.1691	4.54	+
4.	38.0	D	15.11	.2608	2.945	-
5.	39.5	V.D.	15.7	.2706	2.838	-
6.	43.6 Br.	D	17.33	.298	2.578	+
7.	50.6	V.V.D.	20.15	.3445	2.228	+
8.	68.0) Br.)	V.D.	27.01	.4543	1.694	+
9.	70.0)		27.81	.4667	1.646	+
10.	77.9	m	30.95	.5143	1.496	-
11.	92.2	V.D.	36.62	.5965	1.287	+
12.	96.0	V.V.D.	38.15	.6177	1.243	-

TABLE 34

Upton, Wyoming Montmorillonite

No.	Reading in mm.	Intensity	d_{hkl}	Montmorillonite
1.	9.0	H	12.36	+
2.	22.5	m	4.94	+
3.	24.9	H	4.46	+
4.	30.2	D	3.802	-
5.	33.6	m	3.33	-
6.	35.5	m	3.15	-
7.	39.5))	V.D.	2.836	-
8.	42.)		2.674	-
9.	43.6))	m	2.582	+
10.	45.8)	D	2.462	+
11.	49.5	V.V.D.	2.284	-
12.	50.5	V.V.D.	2.242	-
13.	63.1	V.D.	1.817	
14.	68.0))	D	1.693	+
15.	69.7)	D	1.656	+
16.	75.5	D	1.535	-
17.	77.6	m	1.499	-
18.	85.5	D	1.375	-
19.	92. Br.	D	1.295	+
20.	96.	D	1.244	+
21.	10.04	V.V.D.	1.196	-
22.	10.21	V.V.D.	1.179	-

TABLE 35

Illite

Reading in mm.	Intensity	d_{hkl}	Illite
10.3	D	10.3	+
22.3	D	4.96	+
24.5	H	4.54	+
30.8	V.D.	3.62	+
34.5	V.D.	3.31	+
39.3	V.V.D.	2.90	-
42.1	V.V.D.	2.67	+
46.	V.V.D.	2.45	+
47.3	V.V.D.	2.38	+
50.3	V.V.D.	2.25	-
51.5	V.V.D.	2.20	+
55.8	V.V.D.	2.03	+
57.1	V.V.D.	1.99	+
61.0	V.V.D.	1.87	-
62.4	V.V.D.	1.83	-
67.5	V.V.D.	1.70	-
69.3 Br.	V.V.D.	1.66	+
74.2	V.V.D.	1.56	-
77.3	m	1.51	+
81.8	V.V.D.	1.34	+
91.3	V.D.	1.30	+
95.1	V.D.	1.26	+
104.6	V.V.D.	1.16	+

TABLE 36

Florida Attapulgite

Reading in mm.	Intensity	d_{hkl}	Attapulgite
10.5	H	10.41	+
17.0	m	6.44	+
20.1	D	5.46	+
24.5	D	4.49	+
26.1	m	4.32	+
29.8	m	3.70	+
33.0	m	3.35	-
34.4	H	3.21	+
35.8	V.D.	3.09	+
39.6	V.V.D.	2.79	+
42.2)	V.V.D.	2.63	+
) 44.2)	V.D.	2.52	+
52.1	V.V.D.	2.15	+
53.5	V.V.D.	2.091	+
62.5	V.D.	1.81	+
68.6	V.V.D.	1.67	-
74.9	V.V.D.	1.54	+
76.)Br.	V.V.D.	1.52	-
) 77.4)	V.V.D.	1.50	+
85.0	V.V.D.	1.37	+
90.0	V.V.D.	1.31	+
92.5	V.V.D.	1.28	+
94.9	V.V.D.	1.25	+

TABLE 37

Pyrophyllite

Reading in mm.	Intensity	d_{hkl}	Pyrophyllite
11.4	H	9.66	-
22.1	m	4.98	+
24.5)	H	4.52	+
26.8)	H	4.13	+
32.5	D	3.42	+
34.1	V.V.D.	3.17	+
36.0	H	3.09	+
37.5	V.V.D.	2.96	-
39.5	D	2.82	+
41.3	D	2.70	+
43.5	H	2.57	+
46.0	H	2.43	+
48.3 Br.	V.D.	2.32	+
50.6	D	2.22	+
52.2	D	2.15	+
54.3	D	2.07	+
56.3 Br.	V.D.	1.88	+
60.2 Br.	V.D.	1.83	+
68.0	m	1.68	+
69.0	m	1.66	+
70.8	m	1.62	+
73.0	V.V.D.	1.58	+
75.5	V.V.D.	1.53	+
77.7	m	1.49	+
82.0	V.V.D.	1.42	+
84.4	V.D.	1.38	+
85.8	V.D.	1.36	+
87.6	V.V.D.	1.34	+
90.0	V.V.D.	1.31	+
92.0	V.D.	1.28	+
93.8	V.D.	1.26	+

TABLE 38

Pyrophyllite from North Carolina

Reading in mm.	Intensity	d_{hkl}	Pyrophyllite
11.3	H	9.81	-
22.5	m	4.92	+
25.0	H	4.36	+
26.5	m	4.12	+
33.0	D	3.36	+
36.5	m	3.07	+
39.5	D	2.84	+
41.5	D	2.71	+
44.0	H	2.56	+
46.5	H	2.43	+
48.3)	V.D.	2.34	+
49.2)	V.D.	2.30	+
52.3	V.D.	2.17	+
54.0)	V.D.	2.10	+
55.0)	V.D.	2.06	+
56.5	V.V.D.	2.01	+
60.3	V.D.	1.89	+
62.3	V.D.	1.84	+
67.8	D	1.70	+
69.5)	D	1.66	+
70.8)	V.D.	1.63	+
73.3	V.V.D.	1.58	+
75.6	V.V.D.	1.53	+
77.6	m	1.50	+
79.1	V.D.	1.48	+
85.0	V.D.	1.39	+
86.0	V.D.	1.37	+
87.0)	V.V.D.	1.35	+
88.1)	V.V.D.	1.34	-
92.0	V.D.	1.29	+
93.7	D	1.27	+
96.2	D	1.24	+
97.7	V.V.D.	1.23	-
99.3	V.V.D.	1.21	+

TABLE 39

Nepheline Syenite

Reading in mm.		Intensity	d_{hkl}
17.5		V.D.	6.36
25.2		V.V.D.	4.32
26.2		V.D.	4.26
27.7		D.	4.02
29.		V.D.	3.85
30.5		V.D.	3.66
31.8		V.D.	3.51
35.0		H.	3.19
37.0		D.	3.03
38.5	Br.	D.	2.91
43.6		V.D.	2.58
46.0		V.D.	2.45
48.0		V.D.	2.35
49.0		V.D.	2.30
53.5	Br.	V.D.	2.12
57.1		D.	1.99
59.		V.D.	1.93
60.2		D.	1.89
61.5		V.V.D.	1.86
62.6		V.D.	1.83
63.5		D.	1.800
66.	Br.	V.D.	1.74
68.	Br.	V.D.	1.70
69.	Br.	V.D.	1.67
71.		V.V.D.	1.63
74.		D.	1.57
75.8		V.V.D.	1.53
77.2		V.V.D.	1.51
79.5	Br.	V.D.	1.47
81.6		V.D.	1.43
84.5		V.V.D.	1.39
85.5		V.V.D.	1.38
87.3		V.D.	1.35
88.9		V.V.D.	1.33
89.7		V.V.D.	1.32

TABLE 40

Quartz (Known)

Reading in mm.	Intensity	d_{hkl}	Quartz
23.5	V.D.	4.59	-
26.2	m	4.13	+
30.2	m	3.68	-
33.5	H	3.23	+
41.5	V.V.D.	2.68	-
43.0	V.V.D.	2.60	-
44.9	D	2.50	-
46.0	D	2.44	+
48.1	V.V.D.	2.34	-
49.6	D	2.28	+
50.7	V.D.	2.23	+
53.6	D	2.12	+
56.6	D	2.01	-
57.6	D	1.97	+
63.1	m	1.81	+
67.6	V.D.	1.70	-
69.1	m	1.66	+
75.5	m	1.54	+
76.5	D	1.51	-
80.5	D	1.45	+
82.1	V.V.D.	1.42	+
85.2	m	1.38	+
90.5	V.D.	1.31	-
91.3	V.D.	1.298	-
92.4	D	1.28	+
95.2	m	1.26	+
97.5	V.D.	1.22	+
100.5	m	1.19	+
102.	m	1.18	+
105.1	D	1.15	+
112.2	V.V.D.	1.10	-
113.9	m	1.08	+

TABLE 41

NaCl

Reading in mm.	Intensity	d_{hkl}
34.5	V.V.D.	3.25
40.	H	2.81
57.	m	1.99
63.6	V.V.D.	1.70
71.1	m	1.63
83.2	V.V.D.	1.41
94.6	m	1.26
105.3	m	1.50
120.	V.V.D.	1.08
128.1	V.V.D.	.998
137.6	m	.938
150.	D	.890
163.	V.D.	.848

Chemical Analyses

Tables 42 through 44 give the chemical analyses for the Texas clay minerals.

Texas Kaolins

Table 45 is a powder diagram of the white plastic Leakey kaolin deposite. The diagram shows that the kaolin contains a large percentage of montmorillonite and some quartz besides being largely kaolinite. The montmorillonite was identified by a medium line corresponding to a lattice distance of 15.6 A^{o} which is the 001 line of montmorillonite.

The white Davis Mountain kaolin appeared to be the purest of the four samples of kaolin examined, but it contained traces of quartz and possibly traces of mica. The pink Davis Mountain kaolin sample contained more quartz than the white kaolin. The sample of Davis Mountain kaolin taken from deposit No. 2 of the Medley ranch had a large percentage of calcite present besides quartz. Tables 46, 47 and 48 are the powder diagrams of the three Davis Mountain kaolins.

TABLE 42

Chemical	Elemendorf	Bremond Washed	Rainey & Seiler	St. Hedrick
SiO_2	69.72	57.04	69.60	66.20
Al_2O_3	15.88	27.26	15.47	17.16
Fe_2O_3	3.16	1.96	2.48	3.94
CaO	1.30	.81	.45	.80
K_2O	1.70	.70	1.94	1.16
Na_2O	.92	2.76	2.58	2.80
Ig. Loss.	7.79	10.36	7.50	8.90
MgO		.18	Tr.	Tr.
Total	100.49	100.80	100.02	100.96

Chemical	Smithwick Shale	Broonwood Shale	Butler Clay Tile	Llano Shale
SiO_2	62.42	63.45	59.90	55.10
Al_2O_3	16.32	15.28	21.86	18.47
Fe_2O_3	7.10	7.49	3.60	8.68
CaO	.70	.82	.84	1.10
MgO	1.60	2.03		.94
K_2O	2.52	2.58	3.00	2.59
Na_2O	2.82	2.54	2.52	2.89
H_2O	6.89	6.62		10.28
Total	100.37	100.81	100.83	100.04

TABLE 43

Chemical	Lee Hubbard	Seguin	Medina (Washed)	Elgin Stand. White
SiO_2	47.34	58.20	64.26	61.99
Al_2O_3	30.58	15.53	18.59	19.53
Fe_2O_3	2.70	3.16	3.11	3.38
CaO	.93	4.58	.80	.91
MgO	.57	1.94	.18	
K_2O	.88	1.46	1.88	1.64
Na_2O	1.50	2.28	2.28	3.39
SO_3	.24	1.06	.41	
BaO		.33		
H_2O	14.84	10.93	9.36	9.15
Total	99.60	99.47	100.87	99.99

Chemical	Davis Mts. Great Face	Harbison Walker	Plastic Thermo Fire Clay Co.	Sulphur Springs Fire Clay
SiO_2	61.14	58.31	55.30	73.46
Al_2O_3	25.02	26.85	29.64	15.45
Fe_2O_3	1.18	2.48	2.11	1.58
CaO	.20	.50	.38	1.15
MgO	.04			.39
K_2O	.24	.02	.27	.84
Na_2O	1.21	1.19	1.72	1.64
SO_3	.61			
H_2O	10.60	10.79	10.64	6.07
Total	100.24	100.14	100.06	100.58

TABLE 44

Chemical	Elgin Standard Black	Elgin Standard Bank	Acme Black
SiO_2	54.74	59.56	52.61
Al_2O_3	25.19	24.15	24.00
Fe_2O_3	2.37	1.54	3.28
TiO_2	.10	.20	
CaO	.88	.82	1.80
MgO	.60		
K_2O	1.50	.59	1.54
Na_2O	1.71	1.30	2.18
Ig. Loss	13.04	11.90	14.85
Total	100.13	100.06	100.26

TABLE 45

Leakey Kaolin

Reading mm.	Intensity	d	Quartz	Kaolinite	Mica
15.4	m	7.21	-	+	-
22.7	m	4.90	-	-	+
25.2) Br.	H	4.31	-	+	+
28.2)	m	3.91	-	-	+
31.5	D.	3.53	-	+	-
34.0	D.	3.36	+	+	+
37.7	m	3.22	-		+
43.8)	D.	2.56	-	+	+
46.1)	D.	2.46	+	+	+
48.3	m	2.34	-	+	-
51.1	m	2.21	+	+	+
60.3	D.	1.88	-	-	-)
61.5	V.V.V.D.	1.87	-	-	-)
62.5	V.V.V.D.	1.83	+	+	+
66.0	V.D.	1.74	-	+	+
67.4)	V.D.	1.70	+	-	-
69.6)	V.D.	1.65	-	+	+
70.8	m	1.63	-	+	-
78.1	m	1.49	-	+	+
80.	V.D.	1.45	-	-	-)
82.9 Br.	V.D.	1.41	-	-	-)
85.9 Br.	V.D.	1.37	+	+	+
92.6	V.D.	1.28	+	-	+
94.3	D.	1.26	+	-	-
95.6)	V.V.V.D.	1.25	+	-	+
96.8)	V.V.V.D.	1.23	+	-	-
100.	V.V.D.	1.20	+	-	-
105.2	D.	1.15	+	-	-

Strong Line at d = 15.4 A

TABLE 46

White Davis Mountain

Reading mm.	Intensity	d	Kaolinite	Quartz	Mica
15.5	H	7.16	+	-	-
22.9	V.D.	4.90	-	-	+
25.2	H	4.43	+	-	+
26.5	H	4.22	+	+	-
28.5 Br.	V.D.	4.06	-	-	-
31.2	H	3.89	-	-	+
33.1	D	3.35	+	+	+
35.5)	V.V.D.	3.15	+	-	-
37.5)	V.V.D.	2.99	-	-	+
40. Br.	m	2.84	-	-	+
43.7	m	2.58	+	-	+
45.2	m	2.50	+	-	+
48.2	H	2.36	+		+
49.3	m	2.29	+	-	-
51.4	V.D.	2.20	-	-	+
57.1	D.	1.99	+	-	+
58.6	V.D.	1.95	-	-	-
60.1	V.D.	1.90	-	-	-
62.1	D.	1.84	+	-	-
64.	V.D.	1.79	+	-	-
68.4 Br.	m	1.67	+	-	-
71.2	D.	1.63	+	-	+
73.2	V.D.	1.58	-	-	+
75.1 Br.	V.D.	1.54	+	-	-
78.2	m	1.49	+	-	+
80.4	V.D.	1.45	-	+	-
82.	V.V.D.	1.42	-	+	-
83.6) Br.	V.V.D.	1.40	-	-	-
85.6)	V.V.D.	1.37	-	+	+
88.1	V.D.	1.34	+	-	+
90.5	V.D.	1.31	-	-	-
92.5	V.D.	1.29	+	+	+
94.1	V.V.D.	1.27	-	+	-
95.6)	D.	1.25	-	-	+
96.7)	D.	1.24	-	-	-

TABLE 47

Pink Davis Mountain Kaolin

Reading mm.	Intensity	d	Quartz	Kaolin	Mica
13.5	m	8.23	-	-	
15.3	H	7.34	-	+	
22.5	V.V.D.	4.96	-	-	+
24.2)	H	4.58	-	-	+
27.1)	H	4.12	-	+	-
30.8	m	3.62	-	+	-
33.2	H	3.35	+	+	-
35.1)	V.V.D.	3.19	-	-	+
37.2)	V.V.D.	3.01	-	+	-
40 Br.	V.D.	2.80	-	+	-
43.5)	D	2.58	-	+	-
45)	D	2.50	+	+	-
48.1	D	2.35	-	+	-
49.1	D	2.30	+	+	-
51.3	V.D.	2.22	+	+	-
53.0	m	2.14	+	-	-
57.0	m	1.99	+	+	-
59.2	V.V.D.	1.92	-	-	-
60.0	V.V.D.	1.90	-	-	-
62.5	m	1.831	+	+	-
66.7	V.V.D.	1.70	-	-	-
68.6	m	1.68	+	+	-
70.9	V.D.	1.63	-	-	-
71.5	V.D.	1.615	-	+	-
73.1	V.V.V.D.	1.59	-	+	-
75.0 Br.	m	1.54	+	+	-
78.0	m	1.49	-	+	-
80.2	D	1.46	-	+	-
81.6	V.V.D.	1.44	+	-	-
85.1	m	1.38	+	+	-
88.	V.V.D.	1.34	-	+	-
90.	V.D.	1.33	-	-	+
92.2	V.D.	1.29	+	+	-
95.	m	1.26	+	-	-
96.5 Br.	V.D.	1.24	-	+	-
101.	m	1.19	+	-	-
101.6	m	1.18	+	-	-

TABLE 48

Davis Mountain Kaolin
From Deposit No. 2

Reading mm.	Intensity	d	Kaolin	Quartz	Calcite
15.5	m	7.08	+	-	-
25.0	H	4.33	+	+	-
27.6	H	4.02	+	-	-
31.2	m	3.56	+	-	+
33.3	m	3.33	+	+	-
37.0	H	3.00	+	-	+
39.3)	D	2.84	+	-	-
40.7)	D	2.74	+	*	-
43.5)	m	2.57	+	-	-
45.3)	m	2.47	+	+	+
48.2	H	2.33	+	-	-
49.5	H	2.27	+	-	+
51.5	m	2.18	+	-	-
54.2	m	2.08	-	-	+
57.2	m	1.98	+	+	-
58.8)	D	1.93	-	-	-
59.6)	D	1.90	-	-	+
61.0	D	1.86	+	-	+
62.0	V.D.	1.83	-	+	-
64.2	V.D.	1.77	-	-	-
69.5 Br.	m	1.65	+	+	-
70.9	D	1.62	+	-	-
72.1	V.D.	1.59	-	-	+
73.1	V.V.D.	1.57	-	-	-
75.1	V.D.	1.53	-	+	-
76.1	V.D.	1.52	-	-	+
78.1	m	1.49	+	-	+
80.5)	V.D.	1.43	-	+	+
82.4)	V.D.	1.414	-	+	-
85.5 Br.	D	1.37	-	+	+
88.1	V.D.	1.33	+	-	+
90.1	V.D.	1.30	+	-	+
92.5	V.D.	1.28	+	+	-
94.1	V.V.D.	1.26	-	-	-
95.6)	D	1.24	+	-	-
96.6)	D	1.23	-	+	-
100.3)	V.D.	1.19	-	+	-
101.5)		1.15	-	+	+

Texas Montmorillonites

The Falls City montmorillonite x-ray powder picture corresponded very much to the powder picture of Arizona montmorillonite. It showed that the Falls City montmorillonite was a purer grade of montmorillonite than the Gonzales montmorillonite. The Gonzales montmorillonite powder picture contained some kaolin lines.

The Falls City thermal analysis curve indicated a large endothermic at 150°C and a small endothermic reaction at 700°C which are characteristics of the montmorillonite mineral. The Gonzales montmorillonite thermal curve indicated the two endothermic reactions (at 150°C and 700°C) of montmorillonite, the endothermic reaction at 600°C of kaolin and the exothermic reaction of kaolin at 950°C.

Texas Clays

Tables 49 through 59 give the powder diagrams of the minus 100 mesh fractions of eleven Texas clays. Tables 42, 43 and 44 give the chemical analyses of these clays. The powder diagrams indicate that there is free quartz present in all the clays. Kaolinite is the preponderate clay mineral present in Elgin bank run, Elmendorf, Troup, Sulphur Springs, Medina, Lee Hubbard, and Eastland clays. The presence of kaolinite as the preponderate mineral in these clays was also verified by the thermal analysis curves of these minerals which gave an endothermic peak at 600°C and an exothermic peak at 950°C. The powder diagrams indicate that illite may be present in these clays. The only lines on the powder diagrams, which correspond to illite lines and are not kaolin lines are the lines which correspond to the lattice distances of 4.97A^{o}, 3.68A^{o} and 1.56A^{o}, but these lines could be K_{β} lines for the lines which correspond to lattice distances of 4.24A^{o}, 3.34A^{o} and 1.52A^{o} respectively, because a piece of nickel foil was not available to be used as a filter for the copper K_{β} rays.

Acme black, Elgin black, and Rainey and Seiler contain halloysite as the preponderate clay mineral. The thermal analysis curves indicated the presence of an endothermic reaction for each of these clays at 550^{o}C which is characteristic of halloysite.

Seguin and Brownwood clays have illite present as the preponderate mineral and each contains a trace of halloysite. Seguin has some calcite present.

TABLE 49

Acme Clay (Through 100 Mesh)

No.	Reading mms.	Intensity	θ	Sin θ	d	Quartz	Halloy-site
1.	15.1	V.D.	5.88	.1028	7.48	-	+
2.	23.0	V.D.	8.95	.1620	4.92	-	-
3.	25.1)	H	9.75	.1694	4.54	-	-
4.	26.2)	H	10.2	.1771	4.26	+	-
5.	28.3	V.D. Br.	10.99	.1905	4.03	-	-
6.	30.3	m+	11.79	.2045	3.76	-	-
7.	31.8	V.D.	12.38	.2145	3.58	-	+
8.	33.8	H	13.15	.2275	3.38	+	-
9.	44.1)	D	17.3	.2974	2.59	-	+
10.	46.1)		18.1	.3107	2.48	+	+
11.	48.3	V.D.	18.99	.3254	2.37	-	+
12.	49.8	V.D.	19.55	.3346	2.30	+	-
13.	51.0	V.D.	20.01	.3423	2.25	+	-
14.	52.1)	V.D.	20.44	.3497	2.20	-	+
15.	53.6)	V.D.	21.05	.3592	2.14	+	-
16.	58.0	V.D.	22.80	.3875	1.99	+	-
17.	61.3	V.V.D.	24.1	.4083	1.88	-	-
18.	63.6	D	25.05	.4234	1.816	+	-
19.	69.2)	V.V.D.	27.20	.4571	1.681	-	+
20.	70.4)		27.70	.465	1.66	+	+
21.	76.0	V.D.	30.0	.500	1.54	H	-
22.	77.1	V.V.D.	30.5	.5075	1.52	-	-
23.	78.6	D	31.01	.5150	1.49	-	-
24.	81.0	V.V.V.D.	31.94	.529	1.46	+	-
25.	83.0	V.V.V.D.	32.75	.541	1.42	+	-
26.	86.0	D	33.95	.5585	1.38	H	-
27.	92.9	V.V.D.	36.55	.5955	1.29	+	+
28.	95.3	V.V.V.D.	37.50	.609	1.26		-
29.	96.6)	V.V.D.	38.00	.6157	1.25	+	-
30.	98.1)		38.6	.6240	1.23	V.D.	-
31.	101.	V.D.	39.6	.6401	1.20	m	-

TABLE 50

Athens Clay

No.	Reading Mms.	Intensity	θ	Sin θ	d	Kaolinite	Quartz
1.	15.5	m	6.17°	.1074	7.16	+	-
2.	23.3	D	8.28	.1441	5.33	-	-
3.	25.0	H	9.96	.1731	4.44	+	+
4.	28.0 Br.	D	11.14	.1934	3.98	+	-
5.	30.0 Q	D	11.95	.2045	3.75	+	-
6.	31.2	m	12.44	.2153	3.58	+	-
7.	33.2 Q	H	13.22	.2287	3.36	+	+
8.	40.0 Br.	V.D.	15.93	.2745	2.79	+	-
9.	43.5)	m	17.32	.2979	2.58	+	-
10.	45.1)	D	17.94	.3079	2.50	+	-
11.	48.0	H	19.10	.3272	2.35	+	+
12.	49.5 Q	m	19.72	.3374	2.28	+	+
13.	50.7	V.D.	20.14	.3445	2.23	-	+
14.	51.5	V.D.	20.50	.3502	2.19	+	-
15.	53.0 Q	V.D.	21.1	.3600	2.14	-	+
16.	57.1 Br.	D	22.73	.3867	1.986	+	+
17.	58.5	V.D.	23.3	.3956	1.943	+	-
18.	60.0	V.D.	23.9	.4051	1.895	+	-
19.	61.9	V.D.	24.65	.4171	1.841	+	-
20.	62.6 Q	m	24.93	.4216	1.820	-	+
21.	63.6	V.D.	25.35	.4282	1.796	+	-
22.	68.5)	V.D.	27.28	.4584	1.676	-	+
23.	69.6)		27.75	.4656	1.65	+	-
24.	71.0	V.D.	28.28	.4738	1.623	+	-
25.	75.1 Q	m	29.90	.4985	1.542	+	+
26.	78.1	H	31.15	.5173	1.485	+	-
27.	80.2	V.D.	31.95	.5292	1.454	+	+
28.	82.1	V.D.	32.70	.5402	1.421	+	+
29.	85.1 Q	m	33.93	.5582	1.376	+	+
30.	88.1	V.D.	35.10	.5750	1.336	+	-
31.	90.0	V.D.	35.85	.5857	1.311	+	-
32.	92.1	D	36.70	.5976	1.287	+	+
33.	95.0	D	37.82	.6131	1.254	+	+
34.	96.5	D	38.45	.6218	1.235	+	+
35.	101. Q	D	40.30	.6468	1.188	+	+
36.	101.5 Q	D	40.50	.6495	1.183	+	+

TABLE 51

Bremond Clay (Washed)

No.	Reading mm.	Intensity	θ	Sin θ	d	Quartz	Kaolinite
1.	13.8	V.D.	5.5	.09585	8.02	-	-
2.	15.5	H	5.97	.1040	7.38	-	+
3.	22.8	V.V.D.	6.51	.1135	6.775	-	-
4.	25.0)	H	9.98	.1731	4.43	+	+
5.	26.5)		10.56	.1834	4.185	-	+
6.	28.4	m	11.31	.1962	3.91	-	+
7.	30.1	m	11.98	.2073	3.71	-	+
8.	31.5	m	12.56	.2176	3.53	-	+
9.	33.3	H	13.26	.2292	3.35	+	+
10.	39.3)	V.V.D.	15.65	.2698	2.85	-	+
11.	41.0)		16.33	.2812	2.73	-	+
12.	44.0)	m	17.53	.3013	2.55	+	+
13.	45.2)		18.00	.30902	2.49	-	+
14.	48.2	m	19.22	.3291	2.33	-	+
15.	49.3	m	19.64	.3360	2.29	+	+
16.	51.3	D	20.45	.3494	2.20	-	+
17.	53.2	D	21.15	.3608	2.13	+	-
18.	57.2	m	22.80	.3875	2.03	+	-
19.	58.5	V.V.D.	23.30	.3956	1.941	+	+
20.	60.2	V.V.D.	24.00	.4067	1.888	-	+
21.	62.1)	V.D.	24.72	.4181	1.838	-	+
22.	62.5)		24.90	.4210	1.826	+	-
23.	67.2	V.V.D.	26.75	.4501	1.705	-	-
24.	68.5)	m	27.26	.4579	1.678	+	-
25.	70.0)		27.90	.4679	1.642	-	+
26.	71.5	V.D.	28.50	.4772	1.610	-	+
27.	75.3	m	30.00	.5000	1.536	+	-
28.	78.2	m+	31.18	.5176	1.484		+
29.	80.4	V.D.	32.02	.5300	1.448	+	+
30.	85.5	D	34.06	.5602	1.372	+	+
31.	88.0	V.V.V.D.	35.12	.5752	1.336	-	+
32.	90.8	V.V.D.	36.18	.5901	1.302	-	+
33.	92.4	V.D.	36.80	.5990	1.284	+	+
34.	95.)	V.D.	37.70	.6115	1.256	+	++
35.	97.)		38.70	.6252	1.227	+	+
36.	100.1	V.D.	39.90	.6415	1.197	+	
37.	102.1	V.D.	40.75	.6528	1.177	+	-
38.	105.1	V.V.D.	41.85	.6672	1.151	+	-

TABLE 52

Brownwood Shale

No.	Reading Mms.	Intensity	θ	Sin θ	d	Quartz	Musco-vite
1.	22.5	V.V.D.	8.96	.1556	4.94	-	+
2.	24.8	m	9.875	.1714	4.48	-	+
3.	26.2	m	10.44	.1811	4.23	+	-
4.	28.5	m	11.35	.1968	3.90	-	+
5.	30.1	m	11.97	.2073	3.70	-	+
6.	31.5	V.D.	12.54	.2173	3.53	-	+
7.	33.3	H	13.26	.2295	3.34	+	+
8.	35.1	D	13.97	.2414	3.18	-	+
9.	37.1	V.V.D.	14.77	.2549	3.01	-	+
10.	39.2	V.D.	15.23	.2628	2.92	-	+
11.	43.6	m	17.36	.2985	2.57	-	+
12.	45.6	D	18.17	.3118	2.46	+	+
13.	47.2	V.D.	18.82	.3225	2.38	-	+
14.	49.6	V.D.	19.76	.3379	2.27	+	+
15.	51.5	V.D.	20.52	.3505	2.19	-	+
16.	53.2	V.D.	21.18	.3611	2.13	+	+
17.	56.)all	V.D.	22.32	.3800	2.02	+	+
18.	57.5)		22.92	.3994	1.922	-	
19.	60.1	V.V.V.D.	23.95	.4059	1.892	-	+
20.	63.1	m	25.15	.4250	1.805	+	-
21.	67.3	V.D.	26.83	.4514	1.699	-	+
22.	69.0	D	27.52	.4620	1.663	+	+
23.	75.1	D	29.90	.4985	1.544	+	-
24.	77.3	D	30.83	.5125	1.495	-	+
25.	80.3	V.D.	31.95	.5292	1.453	+	-
26.	81.3	V.V.D.	32.4	.5358	1.433	-	-
27.	85.5	m	34.1	.5606	1.368	+	+
28.	90.5)Br.	V.D.	36.1	.5892	1.304	-	-
29.	92.)		36.7	.5976	1.285	+	-
30.	95.	V.D.	37.86	.6138	1.254	+	+
31.	97.2	V.V.D.	38.72	.6257	1.225	+	-
32.	100.1	V.D.	39.95	.6421	1.196	+	-
33.	101.6	V.D.	40.45	.6488	1.183	+	-
34.	113.6	V.D.	45.25	.7102	1.078	+	-

TABLE 53

Elgin Standard Bank Run

No.	Reading Mms.	Intensity	θ	Sin θ	d	Quartz	Kaolin
1.	15.6	V.D.	6.21	.1083	7.12	-	+
2.	22.6 Br.	V.V.D.	8.98	.1562	4.93	-	+
3.	26.0	m	10.34	.1797	4.28	+	
4.	28.0 Br.	V.V.D.	11.13	.1931	3.98	-	+
5.	30.0	m	11.93	.2068	3.71	-	+
6.	31.5	m	12.53	.2170	3.54	-	+
7.	33.2	H	13.19	.2283	3.37	+	+
8.	39.5)	V.V.D.	15.69	.2706	2.84	-	+
9.	41.0)		16.29	.2807	2.74	-	+
10.	43.5)	D	17.31	.2974	2.59	-	+)
11.	45.6)		18.14	.3115	2.47	+	+)
12.	47.6)	V.D.	18.94	.3245	2.37	-	+
13.	49.5)		19.67	.3366	2.28	+	+
14.	50.5	V.D.	20.07	.3431	2.24	+	+
15.	51.6	V.V.D.	20.52	.3505	2.19	-	+
16.	53.2	D	21.15	.3608	2.13	+	-
17.	56.5)	D	22.47	.3822	2.01	-	+
18.	57.5)		22.88	.3891	1.976	+	+
19.	63.0	m	25.08	.4239	1.815	+	+
20.	67.2	V.D.	26.75	.4501	1.706	-	+
21.	69.1	D	27.48	.4615	1.665	+	+
22.	71.2	V.V.V.D.	28.33	.4746	1.623	-	+
23.	73.2	V.V.V.D.	29.10	.4863	1.584	-	+
24.	75.1	m	29.90	.4985	1.543	+	+
25.	76.2	V.V.D.	30.30	.5045	1.525	-	-
26.	78. Br.	V.D.	31.04	.5154	1.491	-	+
27.	80.2	V.D.	31.90	.5284	1.455	+	+
28.	81.8	V.V.D.	32.55	.5380	1.429	+	+
29.	85.2	H	33.87	.5573	1.378	+	-
30.	88.6	V.V.D.	35.30	.5779	1.331	-	+
31.	90.4	V.V.D.	35.94	.5868	1.308	-	+
32.	92.1	V.D.	36.62	.5965	1.288	+	+
33.	95.0	V.D.	37.75	.6122	1.255	+	-
34.	96.5)	V.D.	38.37	.6207	1.237	-	+
35.	97.4)		38.72	.6255	1.228	+	+
36.	100.1	D	39.90	.6415	1.197	+	+
37.	101.8	D	40.55	.6501	1.182	+	-
38.	105.0	V.D.	41.75	.6659	1.154	+	-

TABLE 54

Elmendorf Clay

No.	Reading mm.	Intensity	θ	Sin θ	d	Quartz	Kaolinite
1.	15.5	V.V.D.	6.175	.1074	7.16	-	+
2.	23.5	V.D.	9.36	.1628	4.72	-	+
3.	26.2	m	10.44	.1811	4.23	+	-
4.	28.2	V.D.	11.24	.1951	3.94	-	+
5.	30.1	m	11.98	.2076	3.70	-	+
6.	31.5	V.D.	12.55	.2173	3.53	-	+
7.	33.2	H	13.23	.2289	3.36	+	+
8.	39.6	V.V.D.	15.76	.2714	2.83	-	+
9.	41.3	V.V.D.	16.46	.2835	2.71	-	+
10.	43.6	D	17.38	.2990	2.57	-	+
11.	45.7	D	18.21	.3126	2.46	+	-
12.	48.1	V.D.	19.15	.3280	2.35	-	+
13.	49.4	D	19.64	.3360	2.29	+	+
14.	50.5	V.D.	20.12	.3439	2.24	+	-
15.	51.5	V.D.	20.50	.3502	2.19	-	+
16.	53.2	D	21.22	.3619	2.12	+	-
17.	56.3	V.D.	22.45	.3819	2.02	-	+
18.	57.3	V.D.	22.85	.3883	1.981	+	+
19.	62.9	m	25.07	.4237	1.816	+	+
20.	67.2	V.D.	26.75	.4501	1.708	-	+
21.	68.6	D	27.35	.4594	1.675	+	
22.	71.3	V.V.D.	28.42	.4759	1.615	-	+
23.	73.2	V.V.V.D.	29.14	.4868	1.579	-	+
24.	75.1	m	29.93	.4990	1.542	+	+
25.	76.1	V.D.	30.33	.5050	1.523	-	-
26.	78.0	V.D.	31.10	.5165	1.488	-	+
27.	80.1	V.D.	31.90	.5284	1.457	+	+
28.	82.1	V.V.D.	32.70	.5402	1.424	-	+
29.	84.9)	m	33.60	.5548	1.387	+	+
30.	85.7)		34.15	.5614	1.368		+
31.	88.6	V.V.D.	35.30	.5779	1.333	-	+
32.	90.3	V.V.D.	35.95	.5871	1.311	-	+
33.	92.1	D	36.70	.5976	1.287	+	+
34.	94.6	D	37.70	.6115	1.257	+	-
35.	97.3	V.D.	38.75	.6259	1.228	+	-
36.	100.	m	39.81	.6401	1.201	+	-
37.	101.8	m	40.60	.6508	1.182	+	-
38.	105.	D	41.80	.6665	1.135	+	-

TABLE 55

Rainey & Seiler

No.	Reading mm.	Intensity	θ	Sin θ	d	Quartz	Kaolinite
1.	15.5	V.D.	6.17	.1074	7.16		+
2.	25.1	V.V.V.D.	9.97	.1731	4.44		+
3.	26.2	m	10.42	.1808	4.26	+	+
4.	28.5	V.D.	11.33	.1965	3.91		+
5.	30.2	D	11.96	.2073	3.71		+
6.	31.5 Br.	V.D.	12.53	.2173	3.53		+
7.	33.3	H	13.24	.2292	3.36	+	+
8.	39.4	V.D.	15.67	.2700	2.85		+
9.	43.6	D	17.35	.2982	2.58		+
10.	45.7	D	18.17	.3118	2.47	+	+
11.	48.0	V.D.	19.11	.3275	2.42		+
12.	49.5	D	19.68	.3368	2.28	+	+
13.	50.5	V.V.D.	20.10	.3437	2.24	+	
14.	51.5	V.D.	20.48	.3499	2.19		+
15.	53.0	D	21.10	.3600	2.13	+	
16.	56.1	D	22.32	.3800	2.02	-	-
17.	57.2	D	22.75	.3867	1.99	+	+
18.	59.3	V.V.D.	23.55	.3996	1.925		+
19.	60.0	V.V.D.	23.87	.4046	1.902		+
20.	62.8	m	24.95	.4218	1.824	+	+
21.	67.2	V.D.	26.72	.4498	1.712		
22.	69.0 Br.	V.D.	27.50	.4618	1.665	+	+
23.	71.2	V.V.D.	28.30	.4741	1.621		+
24.	75.0	m	29.85	.4977	1.545	+	
25.	76.1	V.V.D.	30.30	.5045	1.525		+
26.	78.0	V.V.D.	31.023	.5153	1.488		+
27.	80.2	V.D.	31.90	.5284	1.455	+	+
28.	81.6	V.V.D.	32.50	.5373	1.432	+	+
29.	85.0	m	33.80	.5563	1.382	+	+
30.	88.7	V.V.D.	35.30	.5779	1.329		+
31.	90.5	V.D.	36.10	.5892	1.306		+
32.	92.0	D	36.60	.5962	1.289	+	+
33.	94.8	D	37.70	.6115	1.257	+	+
34.	97.2	V.D.	38.70	.6252	1.228	+	+
35.	99.8	m	39.70	.6388	1.203	+	+
36.	101.6	m	40.40	.6481	1.185	+	-

TABLE 56

Troup Clay

No.	Reading mm.	Intensity	θ	Sin θ	d	Quartz	Kaolinite
1.	15.5	D	6.17	.1074	7.16		+
2.	23. Br.	V.D.	9.16	.1593	4.92		-
3.	25.5	H	10.14	.1762	4.36	+	+
4.	27.)	V.D.	10.74	.1865	4.12		+
5.	28.6)		11.37	.1971	3.90		+
6.	30.2	D	12.00	.2079	3.70		+
7.	31.3	D	12.44	.2153	3.58		+
8.	33.5	H	13.33	.2343	3.28	+	+
9.	40.)	V.D.	15.91	.2742	2.80		+
10.	41.)		16.31	.2807	2.74		+
11.	43.6)	D	17.34	.2979	2.58		+
12.	45.2)		17.95	.3082	2.49		+
13.	46.0	V.D.	18.30	.3140	2.45	+	-
14.	48.2	m	19.16	.3283	2.34		+
15.	49.5	D	19.68	.3366	2.29	+	+
16.	50.6	V.D.	20.10	.3437	2.24		
17.	51.6	V.D.	20.51	.3502	2.19		+
18.	53.1	D	21.11	.3603	2.13	+	
19.	56.2)	V.D.	22.34	.3800	2.02	-	-
20.	57.3)		22.80	.3875	1.985	+	+
21.	60.1	V.D.	23.90	.4051	1.895	+	+
22.	62.9	D	24.95	.4218	1.821	+	+
23.	67.3) Br.	V.D.	26.75	.4501	1.705	-	-
24.	69.1)	D	27.48	.4692	1.638	-	+
25.	71.2	V.D.	28.33	.4746	1.623	-	+
26.	75.2	D	29.90	.4985	1.541	+	+
27.	78.0	m	31.02	.5053	1.520	-	+
28.	80.2	V.D.	31.90	.5284	1.456	+	+
29.	82.0	V.V.D.	32.64	.5395	1.427	+	+
30.	85.2	m	33.88	.5575	1.378	+	+
31.	88.2	V.V.D.	35.10	.5750	1.335	-	+
32.	90.5	V.V.D.	36.00	.5878	1.308	-	+
33.	92.1	V.D.	36.64	.5967	1.288	+	+
34.	94.6	V.V.D.	37.65	.6107	1.258	+	+
35.	96.1)	V.D.	38.20	.6184	1.243	-	+
36.	97.2)		38.64	.6243	1.233	+	+
37.	100.2	D	39.80	.6401	1.202	+	+
38.	101.7	D	40.45	.6488	1.185	+	-
39.	105.	V.D.	41.75	.6659	1.153	+	-

TABLE 57

Sulphur Springs

No.	Reading Mms.	Intensity	θ	Sin θ	d	Quartz	Kaolinite
1.	15.1	m	6.02	.1048	7.34	-	+
2.	22.5 Br.	D	8.95	.1556	4.94	-	-
3.	25.5 Br.	H	10.14	.1762	4.37	+	+
4.	28.1 Br.	D	11.18	.1937	3.98	-	+
5.	30.0	D	11.94	.2068	3.72	-	+
6.	31.2 Br.	D	12.41	.2150	3.58	-	+
7.	33.2	H	13.21	.2286	3.36	+	+
8.	39.5)	V.D.	15.7	.2706	2.84	-	+
9.	40.6)		16.15	.2782	2.76	-	+
10.	43.5	m	17.30	.2974	2.59	-	+
11.	45.2	D	18.02	.3093	2.49	-	+
12.	50.2	V.D.	19.85	.3396	2.27	+	+
13.	51.2	V.D.	20.35	.3478	2.21	-	+
14.	53.1	V.D.	21.12	.3603	2.13	+	-
15.	56.5)	V.D.	22.44	.3816	2.02	+	+
16.	57.5)		22.88	.3886	1.977	-	+
17.	62.5	D	24.84	.4200	1.833	+	+
18.	67.2	V.D.	26.73	.4498	1.711	-	-
19.	69.0 Br.	D	27.48	.4615	1.665	+	+
20.	75.1	D	29.9	.4985	1.545	+	+
21.	78.1	m	31.1	.5165	1.488	-	+
22.	80.4	V.D.	31.95	.5292	1.458	-	+
23.	81.2	V.D.	32.30	.5344	1.442	+	+
24.	82.1	V.V.D.	32.66	.5398	1.428	+	+
25.	85.2	m	33.90	.5578	1.379	+	+
26.	88.2	V.V.D.	35.10	.5750	1.338	-	+
27.	90.4	V.V.D.	35.95	.5871	1.311	-	+
28.	92.1	D	36.63	.5967	1.288	+	+
29.	95.0	V.D.	37.75	.6122	1.256	+	+
30.	96.7 Br.	V.D.	38.46	.6225	1.236	-	+
31.	100.2	V.D.	39.90	.6415	1.198	+	+
32.	102.1	V.D.	40.70	.6521	1.181	-	-
33.	105.0	V.V.D.	41.75	.6659	1.172	+	+

TABLE 58

Medina (Washed)

No.	Reading mm.	Intensity	θ	Sin θ	d	Quartz	Kaolinite
1.	15.	V.D.	5.98	.1042	7.37	-	+
2.	23.2	V.D.	9.23	.1605	4.78	-	-
3.	25.0	V.D.	9.96	.1731	4.44	-	+
4.	26.0	H	10.35	.1797	4.28	+	
5.	28.2	D	11.24	.1950	3.94	-	+
6.	30.1	m	11.98	.2076	3.71	-	+
7.	31.3	D	12.47	.2159	3.56		+
8.	33.2	H	13.24	.2289	3.35	+	-
9.	39.5	V.V.D.	15.74	.2712	2.83	-	+
10.	41.2	V.V.D.	16.41	.2826	2.63	-	+
11.	43.5	V.D.	17.34	.2979	2.58	-	+
12.	45.6	V.D.	18.17	.3118	2.46	+	+
13.	47.6	V.D.	18.97	.3250	2.37		+
14.	49.2	D	19.58	.3352	2.29	+	+
15.	50.3	V.D.	20.05	.3428	2.24	+	
16.	51.5	V.D.	20.48	.3499	2.20	-	+
17.	53.1	D	21.15	.3608	2.13	+	-
18.	56.2	V.D.	22.35	.3803	2.02	-	-
19.	57.2	V.D.	22.80	.3875	1.985	+	+
20.	62.6	m	24.93	.4216	1.821	+	+
21.	67.2	V.D.	26.75	.4501	1.708	-	-
22.	68.6	m	27.30	.4587	1.676	+	-
23.	75.1	m	29.95	.4992	1.540	+	+
24.	76.1	V.D.	30.30	.5045	1.526	-	+
25.	78.0	D	31.10	.5165	1.488	-	+
26.	80.2	D	31.95	.5292	1.455	+	+
27.	82.1	V.D.	32.70	.5402	1.422	+	+
28.	85.1	m	33.92	.5578	1.378	+	+
29.	88.9	V.D.	35.39	.5792	1.328	-	+
30.	90.5	V.D.	35.99	.5876	1.308	-	+
31.	92.1	V.D.	36.66	.5972	1.288	+	+
32.	94.6	V.D.	37.70	.6115	1.256	+	+
33.	97.3	V.D.	38.80	.6266	1.226	+	+
34.	100.0	m	39.82	.6403	1.200	+	+
35.	102.	m	40.70	.6521	1.180	+	+

TABLE 59

Lee Hubbard

No.	Reading Mms.	Intensity	θ	Sin θ	d	Quartz	Kaolin
1.	15.2	V.D.	6.08	.1060	7.24	-	+
2.	23.0	V.D.	9.20	.1599	4.81	-	-
3.	25.1	D	10.03	.1742	4.42	+	+
4.	28.1	V.D.	11.24	.1951	3.94	-	+
5.	29.5	D	11.82	.2048	3.75	-	+
6.	31.2	V.D.	12.47	.1988	3.87	-	+
7.	33.0	H	13.21	.2286	3.36	+	+
8.	39.5)	V.D.	15.82	.2726	2.82	+	+
9.	40.6)	V.D.	16.25	.2798	2.75	-	+
10.	43.5	D	17.41	.2991	2.57	-	+
11.	45.0	D	18.00	.3090	2.49	+	+
12.	47.5	D	19.04	.3261	2.36	-	+
13.	49.1	D	19.65	.3363	2.28	+	+
14.	50.2	V.D.	20.13	.3442	2.23	+	+
15.	51.3	V.D.	20.50	.3502	2.19	-	+
16.	52.7	V.D.	21.08	.3597	2.14	+	+
17.	56.0	D	22.41	.3811	2.02	-	
18.	57.2	D	22.86	.3886	1.976	+	+
19.	61.2	D	24.50	.4147	1.903	-	+
20.	62.6	D	25.10	.4242	1.813	+	
21.	66.6	D	26.66	.4488	1.713	-	+
22.	68.5	D	27.40	.4602	1.667	+	-
23.	71.1	V.D.	28.45	.4764	1.613		+
24.	74.5	D	29.82	.4922	1.561	+	+
25.	75.8	D	30.35	.5053	1.521	-	+
26.	77.6	D	31.10	.5165	1.487	-	+
27.	79.6	V.D.	31.86	.5279	1.455	+	+
28.	81.6	V.V.D.	32.70	.5402	1.421	+	+
29.	84.6	m	33.90	.5578	1.377	+	+
30.	88.0	V.D.	35.26	.5772	1.332	-	+
31.	89.7	V.D.	35.90	.5864	1.311	-	+
32.	91.6	m	36.63	.5967	1.287	+	+
33.	94.5	D	37.82	.6131	1.254	+	+
34.	96.5 Br.	V.V.D.	38.60	.6239	1.233	+	+
35.	99.7	D	39.90	.6415	1.197	+	+

Drilling Muds

Tables 60 through 63 give the interpretations of drilling muds* made by comparing their powder pictures to standard powder pictures. No attempt to identify feldspar was made. The results of the drilling mud patterns are given in the data section with the results given by Dow. The writer used a letter system to estimate the relative abundance of each mineral based upon observations with the naked eye. Dow used an intensity method of estimating the percentages of the minerals present in each mud fraction.

Considering the methods used, both results were in fairly close agreement. There was a little disagreement in the presence of calcite and barium sulfate in the Hackberry mud. The estimations for the presence of calcite was checked with hydrochloric acid.

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* Darling, R. Thesis University July 1944; see the thesis for more information.

TABLE 60

Big Hill Davidson - 10, 114

Size	Quartz	Calcite	Illite	$BaSO_4$
Plus 44u	A75%	B		25%
44 - 2u	C 20	C	D	C 80
2 - 1u	C 20	D	C	B 80
1 - .8u	20		B 20	B 60
.8 - .5u	20		B 20	B 60
.5 -2.5u	10		A 40	C 50
.25-.15u	5		A 85	C 10
.15-.05u			A 95	5
< .05u			A100	

Big Hill Davidson 5877'

	Quartz	Illite	Calcite	NaCl	$BaSO_4$
Plus 44u	A 95%		C 5%		
44 - 2u	B 40	30%	B 20		5%
2 - 1u	C 25	D 50%	B 25		
1 - .8u	D 15	C 70	C 15		
.8 - .5u	15	A 70	D 15		
.5 - .25u	5	A 95			
.25 - .15u	5	A 95			
.15 - .05u		A100			
.05u		A 95		D 5%	

TABLE 61

Fairbank Jahnki

Size	Quartz	Calcite	Illite	Spar
Plus 44u	A 100%	D		
44 - 2u	A 60'	D 10%	25%	5%
2 - 1u	C 20	D 10	A 70	
1 - .8u	C 20	D 10	A 70	
.8 - .5u	D 10	5	A 80	D 5
.5 - .25u	2		A 98	
.25 - .15u	1		A 99	
.15 - .05u	1		A 99	
< .05u			A100	

Hackberry Sand Fraction

Size	Quartz	Calcite	Illite	$BaSO_4$
Plus 44u	A 90%	C 5%		
44 - 2u	B 40	B	60%	
2. - 1u	B 20	B	C 70	10
1 - .8u	B 10	D	B 80	10
.8 - .5u	D 10	D	A 80	10
.5 - .25u	5	D	A 85	5
.25- .15u	5		A 85	10
.15- .05u	10		A 90	5
< .05u			A100	

TABLE 62

Theo Richards (6357 ft.)

Size	Quartz	Calcite	Illite
Plus 44u	A 100%	D	
44 - 2u	A 75	D	25%
2 - 1u	C 20	D 5%	C 75%
1 - .8u	D 15	D 3	B 82
.8 - .5u	D 5		A 95
.5 - .25u	2		A 98
.25- .15u	2		A 98
.15- .05u	2		A 98
$<$ .05u	1		A 99

Theo Richards 10,250 ft.

Size	Quartz	$BaSO_4$	Illite	Calcite
Plus 44u	A 95%			C 5%
44 - 2 u	B 25%	B 25%	50%	B
2 - 1 u	C 20	B 15	A 65	C
1 - .8u	C 15	B 15	A 70	D
.8 - .5u	10	10	A 80	
.5 - .25u	5	5	A 90	
.25- .15u	2	2	A 96	
.15- .05u	2		A 96	
$<$ .05u			A100	

TABLE 63

Vandenburg and Hill 6877 ft.

Size	Quartz	$BaSO_4$	Illite	Calcite
Plus 44u	A 90%			C 5%
44 - 2u	B 60	?	20	C 10
2 - 1u	C 40	?	C 50	C 10
1 - .8u	D 25	?	B 70	C 5
.8 - .5u	15		A 82	3
.5 - .25u	10		A 90	
.25- .15u	10		A 90	
.15- .05u	10		A 90	
< .05u			A	

Vandenburg and Hill 3674 ft.

	Quartz	Calcite	Illite
Plus 44u	A 90%	C 10%	20%
44 - 2u	A 40	B 40	B 50
2 - 1u	B 20	C 30	B 75
1 - .8u	C 10	C 15	A 90
.8 - .5u	5	D 5	A 90
.5 - .25u	2	D 2	A 96
25 - .15u			A100
15 - .05u			A100
< .05u			A100

The Five Selected Clays

Five clays were selected from the general group of clays. Each of the five clays selected is being used at present in Texas brick plants and each of the five clays is known to have a different working quality. The minerals of each clay were separated into groups according to particle sizes. The clays selected were Troup, Elgin black, Acme black, Seguin, and Brownwood shale. Troup and Brownwood shale were the most ideal of the five clays selected as far as working and drying properties were concerned for the production of brick. Acme black, Elgin black, and Seguin caused increased power cost and trouble in the pug and extrusion machines and these clays gave a higher percentage of cracking in the dryers.

Troup Clay

Tables 65 through 73 give the powder diagrams of the different fractions of the Troup clay. Table 74 gives the particle size data for the Troup clay and the color of each fraction. Figure 11 gives the thermal analysis curve for the Troup clay containing all fractions, but Figure 12 gives a thermal analysis curve of the .05u - .15u fraction. Table 77 gives an estimate of the mineral compositions of each fraction of the Troup clay.

The powder diagrams indicate that a trace of illite may be present. The only two lines which belong to the illite and not to the kaolin are the 4.94 and 3.68 but these could be

K_β lines for 4.24 and 3.34 respectively.

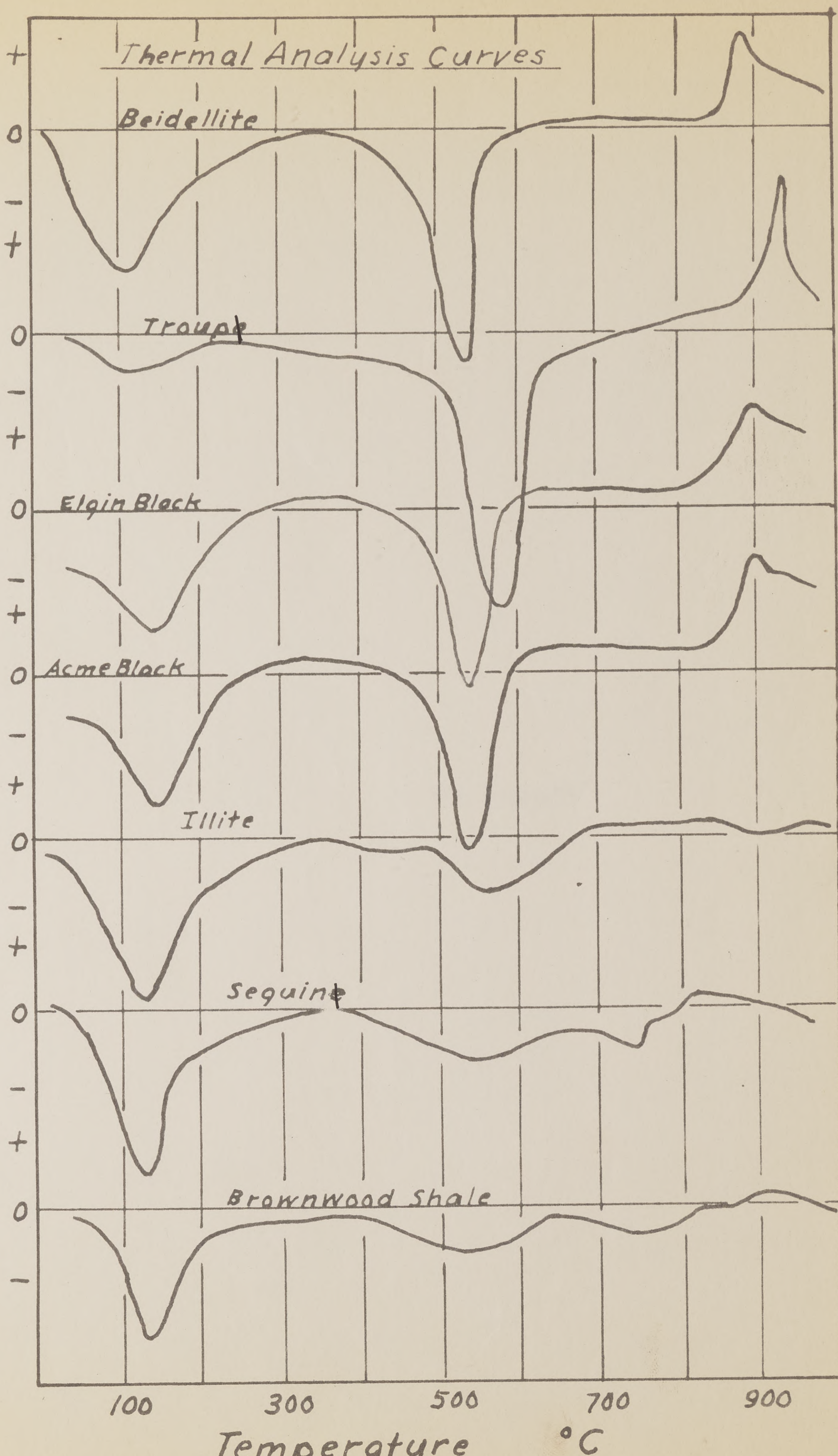
Table 78 gives the dialysis data for the clays. During dialysis the K_2O content of the Troup decreased from .27% to .21% and the Na_2O decreased from 1.72% to .477% . Sodium ions are removed faster than potassium during dialysis. This low value of K_2O after dialysis indicates that the Troup clay contains either a little feldspar or illite.

The thermal analysis curve of the .05 -.15u fraction shows an endothermal reaction at 550°C which is characteristic of halloysite. So, in the smaller particle size fractions, halloysite is present.

The reddish color of the plus 44u fraction indicated that it contained a large percentage of ferric oxide.

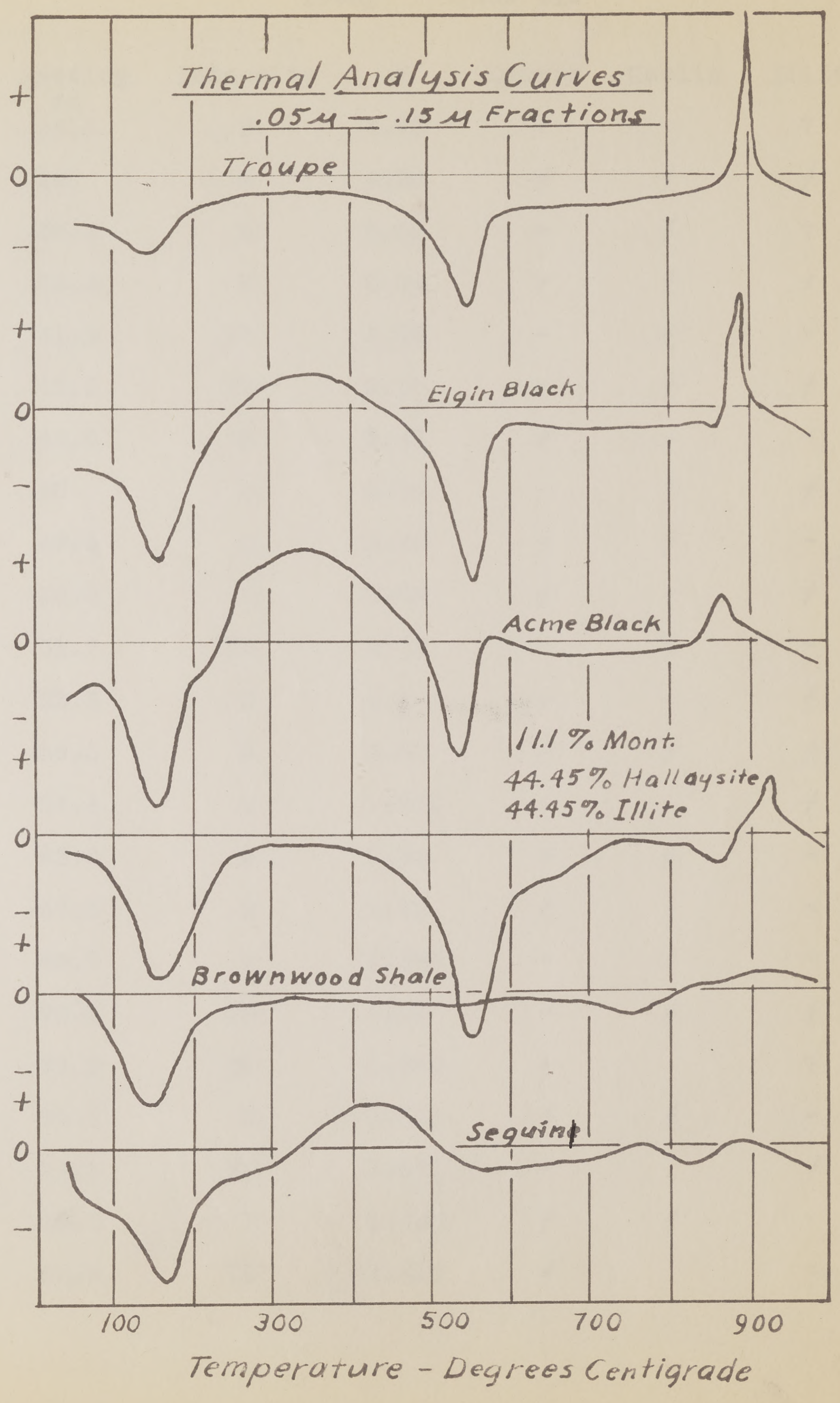
The hydrogen peroxide test only showed .49% organic matter.

Figure 11



Thermal Analysis Curves
Beidellite
Troupe
Elgin Black
Acme Black
Illite
Sequine
Brownwood Shale
+
0
−
100
300
500
700
900
Temperature °C

Figure 12



Thermal Analysis Curves
.05μ — .15μ Fractions
Troupe
Elgin Black
Acme Black
11.1 % Mont.
44.45 % Hallaysite
44.45 % Illite
Brownwood Shale
Seguine
+
0
−
100
300
500
700
900
Temperature - Degrees Centigrade

TABLE 65

Troup Plus 44u

	Reading mm	Intensity	d	Quartz	Kaolin	Illite	K
1.	23.5	D	4.90	-		?	?
2.	26	M	4.24	+	+	+	
3.	30.2	M	3.68	-	+	?	?
4.	33.4	H	3.34	+	+	+	
5.	41.2	VD	2.73	-	-	-	
6.	43.5	VD	2.58	-	+	+	
7.	46.0	M	2.44	+	-	-	
8.	48	D	2.36	-	+	+	
9.	49.5	D	2.28	+	+	-	
10.	50.8	D	2.26	+	-	+	
11.	51.7	VD	2.79	-	+	-	
12.	53.5	D	2.12	+	-	+	
13.	56.5	D	2.03	+	+	+	
14.	57.6	D	1.975	-		+	
15.	63.0	M	1.80	+	+	-	
16.	67.5	D	1.70	+		-	
17.	68.8	M	1.682	-	+	-	
18.	72.2	VD	1.60	-	+	+	
19.	73.8	VD	1.560	-		?	
20.	75.5	M	1.531	+	+	-	
21.	76.5	VD	1.511	-		+	
22.	80.6	D	1.440	+	+	-	
23.	82.5	VD	1.415	+		-	

TABLE 65 (Cont'd)

	Reading	Intensity	d	Quartz	Kaolin	Illite	K
24.	85.5	H	1.365	+	+	+	
25.	89.2	VD	1.30	-	+	-	
26.	90.8	VD	1.29	-	-	+	
27.	92.5	D	1.280	+	-	-	
28.	95.2	M	1.260	+	-	-	
29.	97.6	D	1.225	-	-	-	
30.	100.5	M	1.190	+	-	-	
31.	102.5	M	1.178	+	-	-	
32.							
33.							
34.							
35.							
36.							
37.							
38.							
39.							
40.							
41.							
42.							
43.							
44.							
45.							
46.							

TABLE 66

Troup 2u - 44u

	Reading mm	Intensity	d	Quartz	Kaolinite	Illite
1.	15.5	VD	7.20	-	+	
2.	23.5	D	4.96	-		+
3.	26	M	4.24	+	+	+
4.	28.2	D	3.94	-	+	+
5.	29.8	D	3.70	-	+	+
6.	33.2	H	3.34	-		-
7.	41.2	VD	2.73	-	-	-
8.	43.5	VD	2.58	-	+	+
9.	45.5	M	2.44	+	-	+
10.	47.5	VD	2.36	-	+	+
11.	49.2	D	2.28	+	+	-
12.	50.5	VD	2.24	+	-	+
13.	53.3	D	2.12	+	-	+
14.	56.)	D	2.03	+	-	
	) BR.					
15.	57)		1.98	-	+	+
16.	62.5	M	1.80	+	+	-
17.	67.1	VD	1.70	-	+	-
18.	68.8	D	1.682	+	+	-
19.	75.0	M	1.530	+	-	-
20.	78.	D	1.490	-	+	+
21.	80	D	1.440	+	-	-
22.	85	H	1.365	+	-	+
23.	89.	D	1.300	-	-	+

TABLE 66 (Cont'd)

	Reading	Intensity	d	Quartz	Kaolinite	Illite
24.	90.5	VD	1.290	-	+	+
25.	92.	D	1.280	+	+	-
26.	94.8	D	1.260	-	-	-
27.	97.3	D	1.225	+	-	-
28.	100.	D	1.190	+	-	-
29.	102.	D	1.178	+	-	-
30.	105.0	VD	1.150	+	-	-
31.						
32.						
33.						
34.						
35.						
36.						
37.						
38.						
39.						
40.						
41.						
42.						
43.						

TABLE 67

Troup 1u - 2u

	Reading mm	Intensity	d	Quartz	Kaolinite	Illite
1.						
2.	15.5	H	7.21	-	+	-
3.	23	D	4.97	-	-	+
4.	25.5	H	4.24	+	+	+
5.	28.5	D	3.94	-		+
6.	30.0	D	3.70	-		+
7.	31.5	M	3.56	-	+	-
8.	33.5	H	3.34	+	+	+
9.	40.5 BR	D	2.76	-	+	-
10.	44	M	2.58	-	+	+
11.	45.3	D	2.44	+		+
12.	48.2	M	2.35	-	+	+
13.	49.5	D	2.28	+	+	+
14.	51.5	D	2.20	-	+	+
15.	53.2	D	2.12	-	-	+
16.	57.2	M	1.97	+	-	+
17.	60.2	VD	1.89	-	-	-
18.	63.1	D	1.80	+	+	-
19.	69.5 BR	M	1.66	+	+	+
20.	71.1	VD	1.63	-	+	+
21.	73	VD	1.58	-	+	-
22.	75.2	D	1.534	+	-	-

TABLE 67 (Cont'd)

	Reading	Intensity	d	Quartz	Kaolinite	Illite
23.	78.1	H	1.490	-	+	+
24.	80.3	VD	1.440	+	-	-
25.	81.5	VD	1.430	-	-	-
26.	85.3	D	1.365	+	+	+
27.	88.2	VD	1.312	-	+	-
28.	90.4	VD	1.290	-	+	+
29.	92.3	D	1.281	+	+	-
30.	96.8 BR	D	1.226	+	-	-
31.	100.5	D	1.190	+	-	-
32.	100.1	D	1.178	+	-	-
33.						
34.						
35.						
36.						
37.						
38.						
39.						
40.						

TABLE 68

Troup 8u - 1u

	Reading mm	Intensity	d	Quartz	Kaolinite	Illite
1.	15.6	H	7.20	-	+	-
2.	23.2	D	4.97	-	-	+
3.	25.5	H	4.24	+	+	-
4.	28.5	H	3.90	-	+	+
5.	31.5	M	3.56	-	+	-
6.	33.5	D	3.34	+	+	+
7.	40 Br	VD	2.76	-	+	-
8.	43.8	M	2.57	-	+	+
9.	45.4	D	2.44	+	-	+
10.	48.2	M	2.34	-	+	+
11.	49.5	D	2.28	+	+	+
12.	51.5	D	2.20	-	+	+
13.	57.2	D	1.98	+	+	+
14.	60.2	D	1.89	-	-	-
15.	62.5 Br	VD	1.84	+	+	-
16.	69.5 Br	M	1.66	+	+	+
17.	71.2	D	1.634		+	-
18.	75.3	D	1.534	+	+	-
19.	78.0	H	1.490		+	+
20.	80.2	VD	1.440	+	+	-
21.	81.8	VD	1.430	-		-
22.	85.5	D	1.365	+	+	-

TABLE 68 (Cont'd)

	Reading mm	Intensity	d	Quartz	Kaolinite	Illite
23.	88.	D	1.312	-	+	-
24.	90.8	VD	1.290	-	+	+
25.	92.3	D	1.281	+	+	-
26.	97.0	VD	1.226	+	-	-
27.				-	-	-
28.	100.2	VD	1.191	+	-	-
29						
30.						
31.						
32.						
33.						
34.						
35.			Slight trace of Illite			
36.			Mostly Kaolinite & Quartz			
37.						
38.						
39.						
40.						

TABLE 69

Troup .5u - .8u

	Reading mm	Intensity	d	Quartz	Kaolinite	Illite
1.	15.5	H	7.21	-	+	-
2.	23.5	D	4.97	-	-	+
3.	25.2	H	4.25	+	+	-
4.	28.3	H	3.92	-		+
5.	31.2	M	3.56	-	+	-
6.	33.2	D	3.34	+	+	+
7.	40 Br	VD	2.76	-	+	-
8.	43.6)	M	2.58	-	+	+
9.	44.5)	D	2.48	+	-	+
10.	48.0)	M	2.35	-	+	+
11.	49.0)	D	2.29	+	+	+
12.	51.1	VD	2.20	-	+	+
13.	57.	VD	1.97	+	-	+
14.	60.1	VD	1.89	-	+	-
15.	63.	VD	1.80	+	+	-
16.	69.5 Br	M	1.66	+	+	+
17.	78.0	H	1.490	-	+	+
18.	80.3	VVD	1.440	+	-	-
19.	82.	VVD	1.430	-	-	-
20.	85.2	VD	1.365	+	+	+
21.	88.	VD	1.312	-		

TABLE 70

Troup .5u - .25u

Reading mm	Intensity	d	Quartz	Kaolinite	Illite
15.5	H	7.21	-	+	
23.4	D	4.97	-	-	+
25.2	H	4.25	+	+	-
28.3	H	3.92	-	-	+
31.2	M	3.56	-	+	-
40. Br	VD	2.76	-	+	-
43.6)	M	2.58	-	+	+
44.5)	D	2.48	+	-	+
48.0)	M	2.35	-	+	+
49.0)	D	2.29	+	+	+
51.1	VD	2.20	-	+	+
57.	VD	1.97	+	-	+
60.1	VD	1.89	-	+	-
63.	VD	1.80	+	+	-
69.3 Br	M	1.66	+	+	+
78.0	H	1.49	-	+	+
80.3	VD	1.44	+	-	-
82	VVD	1.43	-	-	-
85.2	VD	1.37	+	+	+

Mostly Kaolinite with little Illite and very little Quartz

TABLE 71

Troup .15u - .25u

Reading mm	Intensity	d	Kaolinite	Illite
15.6	H	7.21	+	-
23.1	D	4.97	-	+
25.4	H	4.25	+	+
28.3	M	3.92	-	+
31.5	H	3.56	+	-
40 Br	D	2.76	+	+
44.)	M	2.58	+	+
45.2)	D	2.48	+	+
48)	M	2.35	+	+
49.2)	D	2.29	+	+
51.5	D	2.20	+	+
57.3	D	1.97	+	+
60.5	D	1.89	-	-
68.0	D	1.69	-	-
70.0	M	1.66	+	+
71.4	VD	1.61	+	+
78.2	H	1.490	+	+
80.0	VD	1.440	+	-
92.5	VD	1.280	+	+
94.2	VD	1.260	-	-
95.4	VVD	1.235	+	+
97	D	1.231	+	-

TABLE 72

Troup .05u - .15u

Reading mm	Intensity	d	Kaolinite	Illite
15.6	H	7.21	+	-
23.1	D	4.97	-	+
25.4	H	4.20	+	-
28.3	M	3.92	-	+
31.5	H	3.56	+	-
40. Br	D	2.76	+	+
44)	M	2.58	+	+
45.2)	D	2.48	+	+
48)	M	2.35	+	+
49.2)	D	2.29	+	+
57.3	D	1.98	+	+
68.	D	1.69	-	-
70	M	1.66	+	+
78.2	H	1.490	+	+
80.0	VD	1.44	+	-
92.5	VD	1.28	+	+
94.2	VD	1.26	-	+
95.4	VVD	1.24	+	+
97	D	1.23	-	-

TABLE 73

Troup .05u

	Reading mm		Intensity	d	Kaolinite	Illite
1.	15.6		D	7.21	+	-
2.	23.0		VD	4.97	-	+
3.	25		H	4.25	+	-
4.	28	Br	VD	3.92	-	-
5.	31.5		VD	3.56	+	-
6.	40.		VD	2.76	+	-
7.	44)		M	2.58	+	+
8.	44.5)		D	2.48		+
9.	48.2		D	2.35	+	+
10.	51.5		D	2.20	+	+
11.	60.1			1.89	+	-
12.	68.5		VD	1.80	+	-
13.	70.0		D	1.66	+	+
14.	78.2		M	1.49	+	+
15.	85.5		VVD	1.36	+	+
16.	92.0		VD	1.28	+	+
17.	97.0		VD	1.23	-	-

TABLE 74

Troup

Fraction	Per Cent	Color
On 325	-	Reddish Sandy
44 - 2u	22.45%	White
2u - 1u	19.25	White
1u - .8u	27.60	White
.8u- .5u	12.53	White
.5u- .25u	13.58	White
.25u-.15u	3.25	Gray
.15u-.05u	.81	Dark Gray
Below .05u	.55	Black

Brownwood Shale

Fraction	Per Cent	Color
On 325		Reddish Green
44 - 2u	68.15%	Green - Gray
2u - 1u	11.76	Light-Green Gray
1u - .8u	10.42	Light-Green Gray
.8u- .5u	5.45	Medium-Gray Green
.5u- .25u	2.49	Medium-Gray Green
.25u-.15u	.38	Medium-Gray Green
.15u-.05u	.92	Black Green
Less than .05u	.46	Black

TABLE 75

Elgin Black

Fraction	Per Cent	Color
Plus 325 mesh	-	Reddish Brown
44u - 2u	45.50%	Light Black Brown
2u - 1u	29.50%	Medium Black Brown
1u - .8u	9.35%	Heavy Black Brown
.8u- .5u	7.48%	Black
.5u- .25u	4.12%	Black
.25u-.15u	1.40%	Black
.15u-.05u	1.54%	Black
Less than .05u	.77%	Light Black Brown

Acme Black

Fraction	Per Cent	Color
Plus 325	-	Black and White
44u - 2u	68.75%	Light-Black Brown
2u - 1u	10.05%	Light-Black Brown
1u - .8u	11.49	Medium-Black Brown
.8u - .5u	5.47	Medium-Black Brown
.5u - .25u	2.59	Heavy-Black Brown
.25u- .15u	.73	Black
.15u - .05u	.47	Black
Below .05	.36	Light-Black Brown

TABLE 76

Seguin Clay

Fraction	Per Cent	Color
Plus 325	34.88	Light Gray
2u - 44u	29.12	Light Gray
1u - 2u	5.2	Medium-Dark Gray
.8u - 1u	12.13	Medium-Dark Gray
.5u - .8u	7.14	H-Black Gray
.25u - .5u	5.86	Black
.15u - .25u	1.51	Black
.05u - .15u	3.04	Black
Less than .05u	1.12	Black
	100.00	

TABLE 77

Troup Clay Analysis

Size	Kaolin	Quartz	Fe_2O_3
Plus 325	C	A	B
2u - 44u	B	A	
1u - 2u	A	B	
.8u- 1u	A	B	
.5u- .8u	A	B	
.25u- .5u	A	C	
.15u- .25u	A		
.05u- .15u	A		
Less than 05u	A		

TABLE 78

Alkali Analysis

	Before Dialysis K_2O	Before Dialysis Na_2O	After Dialysis K_2O	After Dialysis Na_2O
Troup	.27%	1.72%	.21%	.477%
Acme Black	1.54	2.18	1.06	1.02
Elgin Black	1.50	1.71	.76	.55
Brownwood Shale	2.52	2.82	2.52	1.09
Seguin	1.92	3.14	1.15	1.20

Dialysis Data

T	Wt. Sample	Current Peak	Current Steady	Time
Troup	5 grams	.2 Amp.	.1 Amp.	40 hours
Acme Black	5 grams	.5 Amp.	.1 Amp.	72 hours
Elgin Black	5 grams	.4 Amp.	.1 Amp.	56 hours
Brownwood Shale	5 grams	.3 Amp.	.1 Amp.	48 hours
Seguin	5 grams	.6 Amp.	.1 Amp.	40 hours

Elgin Black

Tables 79 through 86 give the powder diagrams of the Elgin black clay. Table 75 gives the particle size data of the Elgin black. The reddish brown color of the plus 325 mesh fraction indicates the presence of Fe_2O_3. The 2 to 44 micron, 1 to 2 micron and .8 to 1 micron fractions contained preponderately quartz with some halloysite. The .5 to .8 micron, .25 to .5 micron and .15 to .25 micron fractions contained preponderately halloysite with traces of quartz. The .05 to .15 micron and less than .05 micron fractions contained halloysite with very little quartz. As in the case of the Troup clay, no lines were found which could be taken as positive proof for illite.

Table 78 gives the dialysis data for the Elgin black. During dialysis the Na_2O decreased from 1.71% to .55% and the K_2O decreased from 1.50% to .76%. The thermal analysis curve in Figure 11 for Elgin black shows by the endothermic reactions at 150°C and 550°C that the preponderate clay mineral is halloysite. The thermal analysis curve of the .05 - .15 micron fraction of the Elgin black showed halloysite and possibly a trace of montmorillonite by the large endothermic reaction at 150°C and the slight endothermic reaction at 750°C and 850°C, in addition to the thermal analysis curve indicated by the presence of organic material by the exothermic peak at 350°C.

A concentric circle type powder diffraction pattern of a mixture of the .15 to .25u and less than .05u fractions of the Elgin black failed to bring out the 001 line of illite or the 001 line of montmorillonite.

The Elgin black contains approximately 20% quartz, 70% clay minerals, 2.3% Fe_2O_3, 1.35% calcite, .462% organic material determined by the hydrogen peroxide method, .52% free chlorides calculated as sodium chloride, and .032% sulfates calculated as sodium sulfate.

Table 87 gives a relative estimate of the minerals for each particle size fraction.

TABLE 79

Elgin Black on 325 Mesh

	Reading mm	Intensity	d	Quartz	Illite
1.	28.5	VVD	3.91		+
2.	34	VVD	3.34	+	+
3.	37.2	VVD			
4.	40.8	D			
5.	48.8	VD	2.27	+	
6.	51.5	VD			
7.	58.0	VD	2.22	+	
8.	60.0	VD	1.980	+	
9.	64.2	VD			
10.	66.8	VD	1.699	+	
11.	77.5	VD	1.485	+	
12.	82.5	VD			
13.	84.5	VD	1.355	+	
14.	88.0	VD			
15.	93.2	VD	1.280	+	
16/	10.05	VD	1.198	+	

TABLE 80

Elgin Black 1u-2u

	Reading mm	Intensity	d	Quartz	Illite	Halloysite	Kaolinite
1.	15.3	M	7.40		-	+	
2.	23.2	D	4.93	-	+	-	
3.	25.2	M	4.44	-	+	+	
4.	28.5	M	3.91	-	+	-	
5.	30.	D	3.70	-	+	-	
6.	31.4	D	3.66	-	-	-	+
7.	33.2	H	3.34	+	+	+	+
8.	39.5	VD	2.83	-	+	-	
9.	43.5	D	2.56	-	+	-	+
10.	48.3	D	2.36	-	+	+	+
11.	51.	VD	2.23	-	+	-	
12.	53.	VD	2.12	+	+	-	
13.	57. Br	VD	1.99	+	+	-	+
14.	60.	VVD	1.90	-		-	
15.	63.0	D	1.81	+		-	+
16.	69.5 Br	D	1.66	+	+	+	
17.	75.0	D	1.54	+		-	+
18.	78.	M	1.485	-	+	+	
19.	80.	VVD	1.445	+	-	-	
20.	81.9	VVD	1.375	+	-	-	
21.	85	D	1.355	-	-	-	
22.	92	D	1.280	+	+	+	
23.	94.5	D	1.255	+	-	-	
24.	96.5	VD	1.24	-	+	+	

TABLE 80 (Cont'd)

	Reading mm	Intensity	d	Quartz	Illite	Halloysite	Kaolinite
25.	100.	VD	1.198	+	-		
26.	102.0	VD	1.180	+	-		

TABLE 81

Elgin Black 2u-44u

1.	Reading mm	Intensity	d	Quartz	Halloysite	Illite
2.	15.1	VVD	7.41	-	+	-
3.	17.5	VVD	6.31	-	-	-
4.	23.	VD	4.93	-	-	+
5.	25.5 Br	M	4.24	+	+	+
6.	28. Br	D	3.91	-	-	+
7.	30.	D	3.70	-	-	+
8.	33.	H	3.34	+	+	+
9.	43.5	D	2.56	-	+	+
10.	45.5	VD	2.46	+	-	+
11.	47.5	VD	2.36		+	+
12.	49.	VD	2.27	+	-	
13.	50.5	VD	2.22	+	-	+
14.	53.0	VD	2.12	+	-	+
15.	56.5	VD	1.998	-	-	+
16.	57.5	VD	1.980	+	-	
17.	62.5	M	1.81	+	-	-
18.	67.6	D	1.699	+	-	+
19.	69.4	M	1.660	-	+	-
20.	75.0	M	1.540	+	-	-
21.	78.	D	1.485	-	-	-
22.	80.	VD	1.445	+	-	-
23.	85.	H	1.355	+	-	-
24.	90.6	VD	1.300	+	-	-

TABLE 81 (Cont'd)

	Reading mm	Intensity	d	Quartz	Halloysite	Illite
25.	92.	D	1.280	+	+	+
26.	95.	D	1.255	+	-	-
27.	97.2	VD	1.228	+	+	-
28.	1002	D	1.198	+	-	-
29.	1018	VD	1.180	+	-	-

TABLE 82

Elgin Black .5u-.8u

Reading mm	Intensity	d	Quartz	Halloysite	Illite
15.5	D	7.39		+	-
22.5	VD	4.95			+
25	H	4.45		+	+
31.3	D	3.67		-	+
33.0	D	3.34	+	+	+
40.	VD	2.80		-	+
43.5 Br	M	2.56		-	+
48. Br	D	2.36	+	+	+
51.	VD	2.24	-	-	+
56.5	VVD	1.99	+	-	+
60.0	VVD	1.90		-	-
62.8	VVD	1.81	+	-	-
68.	VD	1.69		+	+
69.5	D	1.66	+	+	-
75	D	1.54		-	-
77.5	H	1.49		+	+
80	VVD	1.445	+	-	-
81.2	VVD	1.38	+	-	-
85	D	1.36		-	-
88	VVD	1.34		-	+
92	D	1.280	+	-	+
96.	VD	1.27	-	+	-
99.5	VD	1.198	+	-	-

Probably Trace of NaCl

TABLE 83

Elgin Black .25u-.5u

	Reading mm	Intensity	d	Quartz	Halloysite	Illite
1.	15.1	M	7.40	-	+	
2.-	22.6	D	4.95	-	-	+
3.	25.	H	4.45	-	+	+
4.	28.4	D	3.91	-	-	+
5.	31.2	M	3.67	-	-	+
6.	33.0	D	3.34	+	+	+
7.	40.	D	2.80	-		+
8.	44.	M	2.58	-	+	+
9.	48.	D	2.36	+	+	+
10.	51.1	D	2.24	-	-	+
11.	57.2	VVD	1.99	+	-	+
12.	60.	VD	1.90	-	-	-
13.	63.0	VVD	1.81	+	-	-
14.	68.)Br	D	1.69	-	+	+
15.	69.5)		1.66	-	+	-
16.	78	M	1.49	-	+	+
17.	85.4	VVD	1.36	-	-	
18.	89.	VVD	1.34	-	-	+
19.	92	D	1.28	+	-	-
20.	96.2	D	1.27	-	+	

TABLE 84

Elgin Black .15u-.25u

	Reading mm	Intensity	d	Quartz	Halloysite	Illite	NaCl
1.	1.51	M	7.40	-	+	-	
2.	22.6	D	4.95	-	-	+	
3.	25.	H	4.45	-	+	+	
4.	28.4	D	3.91	-	-	+	
5.	31.	M	3.67	-	-	+	
6.	33.5	D	3.34	+	+	+	
7.	39.6	D	2.80	-	-	+	+
8.	44.	M	2.56	-	+	+	
9.	48	D	2.36	+	+	+	
10.	51.5	VD	2.24	-	-	+	
11.	57.2	VVD	1.99	+	-	+	
12.	60.	VVD	1.90	-	-	-	
13.	68)Br)	VD	1.69	-	+	+	
14.	69.5)	D	1.66	-	+	-	
15.	78.	M	1.49	-	+	+	
16.	85.4	VVD	1.36	-	-	-	
17.	89.	VVD	1.34	-	-	+	
18.	92.	D	1.28	+	-	-	
19.	96.2	D	1.27	-	+	-	

TABLE 85

Elgin Black .05u-.15u

	Reading mm	Intensity	d	Quartz	Halloysite	Illite
1.	15.4	D	7.40	-	+	-
2.	22.5	D	4.95	-	-	+
3.	25.	H	4.45	-	+	+
4.	28.0	D	3.91	-	-	+
5.	31.4	D	3.67	-	-	+
6.	35.	VVD	3.18	-	-	+
7.	39.6	VD	2.80	-	-	+
8.	43.6	M	2.57	-	+	+
9.	48.	D	2.36	-	+	+
10.	51.5	D	2.24	?	-	+
11.	60.2	VD	1.90	-	-	+
12.	67.5	VD	1.69	-	-	-
13.	69.4	D	1.66	?	+	+
14.	77.8	M	1.49	-	+	+
15.	92.0	VD	1.28	-	+	+
16.	96.0	VD	1.22	-	+	+

Quartz is questionable.

TABLE 86

Elgin Black Less Than .05u

	Reading mm	Intensity	d	Quartz	Halloysite	Illite
1.	15.4	D	7.40	-	+	-
2.	22.5	D	4.95	-	-	+
3.	25.	H	4.45	-	+	+
4.	28.0	D	3.91	?	-	+
5.	31.4	D	3.67	?	-	+
6.	35.	VVD	3.18	?	-	+
7.	39.6	VD	2.80	?	-	+
8.	43.7	M	2.57		+	+
9.	48.	D	2.36	-	+	+
10.	67.5	VD	1.69	-	-	-
11.	69.5	D	1.66	-	+	+
12.	77.8	M	1.49	-	+	+
13.	92.0	VD	1.28	-	+	+
14.	96.0	VD	1.22	-	+	+

TABLE 87

Elgin Black Analysis

Fraction	Halloysite	Quartz	Fe_2O_3
Plus 325	?	B	A
2u - 44u	B	A	
1u - 2u	B	A	
.8u - 1u	B	A	
.5u - .8u	A	B	
.25u - .5u	A	C	
.15u - .25	A	C	
.05u - .15u	A	?	
Less than .05u	A	?	

Acme Black

Tables 88 through 96 give the powder diagrams for the particle size fractions of Acme black. The plus 325 mesh fraction of the Acme black contained quartz and an unidentified white substance with diffraction lines which corresponded neither to calcite, anhydrite, feldspar nor gypsum. The 2 to 44 micron and 1 to 2 micron fractions contained quartz preponderately with some halloysite. The .8 to 1 micron, .5 to .8 micron, .25 to .5 micron, .15 to .25 micron and .05 micron fractions contained halloysite preponderately and traces of quartz. The less than .05 micron fraction contained halloysite preponderately and some traces of montmorillonite.

The thermal analysis curve of Acme black in Figure 11 shows by the endothermic reactions at 150°C and 550°C that halloysite was the preponderate mineral. The thermal analysis curve of the .05 to .15u fraction in Figure 12 shows the presence of halloysite, montmorillonite and organic matter. The organic material is indicated by the large exothermic peak at 350°C; the halloysite is indicated by the endothermic peak at 550°C; and the montmorillonite by the large endothermic reaction at 150°C and the endothermic reaction between 650°C and 750°C.

The concentric circle type powder diffraction pattern showed the 001 line of montmorillonite at 15.7A° for a mixture of the .15 to .25u and less than .05 fractions.

Table 97 gives the relative mineral content for each fraction.

The electro dialysis data for the Acme black is found in Table 78. The Na_2O decreased from 2.18% to 1.02% on dialysis and the K_2O decreased from 1.54% to 1.06% on dialysis. The large decrease in alkali content during electro-dialysis and the large current required for electro-dialysis indicated a large percent of adsorbed alkali ions.

An approximate mineral analysis is 74% clay minerals, 18% quartz, 3.23% Fe_2O_3, .102% organic matter (determined by means of hydrogen peroxide), .78% free chlorides calculated as sodium chloride, and .35% sulfates calculated as sodium sulfate.

TABLE 88

Acme Black on 325 Screen

Reading mm	Intensity	d	Quartz	Illite
18.9	M	5.88	-	-
26.3	VD	4.23	+	-
28.5	VD	3.91	-	+
30.3	VD	3.68	-	+
33.6	H	3.34	+	+
37.5	D	2.99	-	+
40.3	D	2.78	-	+
46.1	VD	2.44	+	-
50.1	VD	2.26	+	-
51.6	VD	2.19	+	-
53.5	D	2.12	+	-
56.0	VVD	2.03	+	-
60.3	VD	1.89	-	-
62.2	VD	1.84	-	+
63.5	VD	1.80	+	-
68.5	D	1.68	-	+
69.5	D	1.66	+	-
75.6	D	1.53	+	-
76.6	VD	1.51	-	+
81.1	VVD	1.44	+	-
86.0	D	1.37	+	-
91.4	VD	1.29	-	+
92.8	VVD	1.28	+	-
95.0	VVD	1.26	+	-
99.6	VVD	1.21	+	-

TABLE 89

Acme Black 2u - 44u

Reading mm	Intensity	d	Quartz	Halloysite	Illite
15.0	VD	7.41	-	+	-
21.1	VD	5.36	-	-	-
25.5	D	4.43	-	+	-
30.0	D	3.70	-	-	+
33.5	M	3.34	+	+	+
38.0	VVVD	2.95	-	-	+
40.0	VVVD	2.80	-	-	-
44.1	VD	2.57	+	+	+
46.1	VD	2.44	+	+	-
48.0	VD	2.37	-	+	+
50.0	VD	2.26	+	-	-
50.8	VVD	2.22	+	-	-
53.1	VD	2.12	+	-	-
56.5	VD	2.03	-	-	-
57.5	VD	1.98	+	-	-
63.1	D	1.81	-+	-	-
67.8	VVD	1.70	+	-	-
70.0	D	1.64	-	-	-
75.5	D	1.54	+	-	-
78.1	VD	1.49	-	-	-
80.6	VVD	1.45	+	-	-
85.6	D	1.36	+	-	-
92.5	VD	1.29	+	-	-
95.2	VD	1.26	+	-	-
97.6	VVD	1.23	+	-	-
100.5	D	1.198	+	-	-

TABLE 90

Acme Black 1.0-.8u

Reading mm	Intensity	θ	sin θ	d	Quartz	Halloysite	Illite
15.1	D			7.42		+	
21.8	VVVD			5.33		-	
25.	D			4.44		+	
28.0	VVD			3.97		-	+
30.0	VVD			3.70		+	
31.8	VVD			3.40			
33.5	M			3.34	+	+	+
39.5	VD			2.81		-	
44. Br	D			2.56		+	
48.	D			2.36		+	
57.	VVD			1.98	+		
62.8	VD			1.81	+		
69.5	VD			1.66	+	-	+
75.	D			1.54	+		
78.	M			1.485		-	?
85.4	VD			1.370	+		
92.	VD			1.29		+	
96.0	VVD			1.25	+		
100.	VVD			1.198	+		

TABLE 91

1u-2u fraction

Reading mm	Intensity	d	Quartz	Meta-Halloysite	Illite
15.1	VVVD	7.42	-	+	
22.5	VVD	4.93	-		+
25.1	D	4.44	+	+	+
28.0	VD	3.97	-		
30.0	VVD	3.70	-		+
31.8	VVD	3.40	-		+
33.3	D	3.34	+	+	+
44.0 Br	VD	2.56	-	+	+
48. Br	VD	2.36	-	+	
57.	VVD	1.98	+		+
63.	D	1.80	+		
69.8	VD	1.66	+	+	+
75.3	VD	1.53	+		
78.	D	1.485	-		-
85.6	VD	1.370	+		
91.8	VD	1.280	-	+	+
97.0	VVD	1.230	+	+	+
100.5	VVD	1.197	+		
102.1	VVD	1.190			-
53. ?	VVVD	2.13			+

TABLE 92

Acme Black .8-.50u

Reading mm	Intensity	d	Quartz	Halloysite	Illite
15.1	VVD	7.42	-	+	-
22.5	VVD	4.93		-	+
25.	M	4.44	+	-	+
28.	D	3.97	-		-
33.1	VD	3.34	+	+	
39.5	VVD	2.81	-		-
43.5	D	2.56	-	+	+
48.0	VD	2.36	-	+	-
51.3	VVD	2.20		-	
57.5	VVVD	1.98	+		+
62.9	VVVD	1.81	+		-
69.4	VD	1.66	+	+	+
78.	M	1.485	-		+
85.1	VD	1.370	+		
92.0	VD	1.29	-	+	+
96.3	VD	1.245	+	-	

TABLE 93

Acme Black .5-.25u

Reading mm	Intensity	d	Quartz	Halloysite	Illite
15.1	VVD	7.42	-	+	-
22.5	VVD	4.93	-	-	+
28.	D	3.97	-	+	-
31.5	VD	3.40	-	+	+
33.1	VD	3.34	+	+	
39.1	VVD	2.81	-	-	-
43.5	D	2.56	-	+	+
48.0	VD	2.36	-	+	
51.3	VVD	2.20	+	-	-
57.5	VVVD	1.98	+	-	
62.9	VVVD	1.81	+	-	-
69.4	VD	1.66	+	+	+
78.0	M	1.485	+	-	+
85.1	VD	1.370	+	-	-
92.0	VD	1.29		+	+
96.3	VD	1.245	+	-	-
25.0	M	4.44	+	-	-

TABLE 94

Acme Black .25-.15u

	Reading mm	Intensity	d	Quartz	Halloysite	Illite	NaCl
1.	15.1	VVVD	7.41	-	+		
2.	25.0	H	4.43	+	-	+	
3.	28.3	M	3.92	-	-	+	
4.	32.	D	3.40	-	-	+	
5.	33.5	VD	3.34	+	+		
6.	40.	VD	2.81	-	-		+
7.	44.	M)	(2.56	-	+	+	
8.	48.2	D)	(2.36	-	+	+	
9.	51.5	D	2.20	-	-		+
10.	68.	VD	1.81	+	-		
11.	70.	VD	1.66	+	+	+	
12.	78.	M	1.485	+	+	+	
13.	92.8	VD	1.29	-	+	+	
14.	96.5	VD	1.245	+	-	-	
15.	22.5	VD	4.97	-	-	+	

TABLE 95

Acme Black .15-.05u

Reading mm	Intensity	d	Quartz	Halloysite	Illite	NaCl	Montmorillonite
15.1	VVD	7.41	-	+	-	-	-
22.8	VVD	4.97	-	-	+	-	+
25.	M	4.43	+	-	+	-	+
32.0	VVD	3.40	-	-	+	-	-
40.0	VVD	2.81	-	-	-	+	-
44.	D	2.56	-	+	+	-	+
48.	VD	2.36	-	+	+	-	-
51.8	VVD	1.998	-	-	-	+	-
68.5	VD	1.81	+	-	-	-	-
70.	VD	1.66	+	+	+	-	+
78.	M	1.485	+	+	+	-	-
92.8	VVD	1.290	-	+	+	-	+
96.5	VVD	1.245					

TABLE 96

Acme Black .05u

Reading mm	Intensity	d	Quartz	Halloysite	Illite	NaCl	Montmorillonite
11.0	VVD	10.2	-	-	+		+
22.4	VD	4.97	-	-	+		+
25.0	M	4.43	+	-	+		
28.1	D	3.92	-	-	+		
33.4	VD	3.34	+	+	-		
39.2	VD	2.81	-	-	-	+	-
43.5	D	2.58	-	+	+		+
48.1	VVD	2.36	-	+	+	+	+
51.8	VD	2.20		-	-		
57.	VVD	1.98	-	-	-		
60.	VVD	1.90	-	-	-		
68.	VVD	1.81	+	-	-		
70.	VVD	1.66	+	+	+		
77.2	D	1.485	+	+	+		
92.2	VD	1.29	+	+	+		
94.8	VD	1.25	+	-	-		

TABLE 97

Acme Black

Fraction	Quartz	Halloysite	Montmorillonite	Unknown
Plus 325	A			A
2u- 44u	A	C		
1u- 2u	A	B		
.8u- 1u	A	B		
.5u- .8u	B	A		
.25u- .5u	C	A		
.15u- .25u	C	A	C	
.05u- .15u	C	A	C	
Less than .05u	C	A	C	

Brownwood Shale

Tables 98 through 106 give the powder diagrams for the different fractions of Brownwood shale. In the 2 to 44 micron fraction quartz and illite were present. In the 1 to 2 micron and .8 to 1 micron fractions, illite and traces of halloysite were found. In the .5 to .8 micron, .25 to .5 micron, and .15 to .25 micron fractions, illite traces of quartz were found. In the less than .05 micron fraction illite and a very slight trace of quartz were found.

The thermal analysis curve for Brownwood shale in figure is very similar to the illite curve in Figure 11, except Brownwood shale has an endothermic reaction at 750°C. The thermal analysis curve for the .05 to .15u fraction of the Brownwood shale of Figure 12 is very similar to the curve found in Figure 11 for the Brownwood shale sample as a whole.

The approximate mineral analysis of the Brownwood and the relative estimations of the minerals in each fraction are given in Table 106.

Concentric type x-ray powder diffraction pictures of the shale and of the .15 to .25u and less than .05u showed clearly the 001 line of illite and the 002 line of halloysite.

TABLE 98

Brownwood Shale on 325 mesh

	Reading mm	Intensity	d	Quartz	Illite
1.	30.4	D	3.68	-	+
2.	33.4	M	3.34	+	+
3.	40.	VD	2.79	-	+
4.	44.	VVD	2.57	-	+
5.	46.5	VVD	2.44	+	+
6.	50.0	VD	2.26	+	+
7.	51.5	VD	2.19	-	+
8 .	53.3	VD	2.12	+	+
9.	57.)	VD	2.00	-	-
10.	58.)		1.98	+	+
11.	60.	VD	1.97	-	-
12.	63.	VD	1.80	+	-
13.	67.5	VD	1.68	-	-
14.	69.	VD	1.665	+	+
15.	75.3	VD	1.53	+	-
16.	77.3	VD	1.51	-	+
17.	80.6	VD	1.44	+	-
18.	85.5	D	1.37	+	+
19.	95.0	VD	1.26	+	+
20.	100.5	VD	1.198	+	-
21.	102.5	VD	1.180	+	-

TABLE 99

Brownwood Shale 2-44u

	Reading mm	Intensity	d	Quartz	Illite
1.	26.0	VD	4.23	+	-
2.	28.0	VD	3.91	-	+
3.	30.4	D	3.68	-	+
4.	33.4	M	3.34	+	+
5.	40.	VD	2.78	-	+
6.	44.	VD	2.57	-	+
7.	46.5	VD	2.44	+	+
8.	50.0	VD	2.26	+	+
9.	51.5	VD	2.19	-	+
10.	53.3	VD	2.12	+	+
11.	57.)	VD	2.00	+	+
12.	58.)	VD	1.97	-	-
13.	60.	VD	1.89	-	-
14.	63.	VD	1.80	+	-
15.	67.5	VD	1.68	-	-
16.	69	VD	1.66	+	+
17.	75.3	VD	1.531	+	-
18.	77.3	VD	1.51	-	+
19.	80.6	VD	1.44	+	-
20.	85.5	D	1.37	+	+
21.	95.0	VD	1.26	+	+

TABLE 100

Brownwood 1-2u

Reading mm	Intensity	d	Quartz	Illite	Halloysite
11.	VVD	9.99	-	+	-
15.0	VVD	7.41	-	-	+
22.5	VVD	4.97	-	+	-
25.	M	4.44	-	+	+
26.2	D	4.24	+	+	-
28.5	D	3.91	-	+	-
30.	VD	3.70	-	+	-
31.5	VVD	3.56	-	-	-
33.4	H	3.34	+	+	+
39.5	D	2.79	-	-	-
43.8	M	2.58	-	+	+
46.	D	2.46	+	+	
47.5	VD	2.38	-	+	+
49.5	VD	2.28	-	+	-
51.6	VD	2.19	-	+	-
53.5	VD	2.12	-	+	-
57.2	VD	2.00	+	+	-
60.2	VD	1.89	+	-	-
63.0	D	1.80	+	-	-
67.	VD	1.70		-	-
69.	D	1.66	+	+	+
75.2	D	1.53	+	-	-

TABLE 100 (Cont'd)

Reading	Intensity	d	Quartz	Illite	Halloysite
77.2	D	1.51	-	+	-
80.0	VVD	1.44	+	-	+
82.0	VVD	1.42	+	-	-
85.3	M	1.37	+	+	-
91.5	VD	1.28	+	+	+
95.0	VD	1.26	+	+	-
100.	VD	1.191	+	-	-
102.	VD	1.178	+	-	-

Slight trace of Kaolin or Halloysite and slight trace of Salt.

TABLE 101

Brownwood Shale .8-1u

Reading mm	Intensity	d	Quartz	Illite	Halloysite	NaCl
11	VVD	9.99	-	+	+	
15.0	VVD	7.41	-	-	+	
22.5	VVD	4.97	-	+	-	
25	M	4.44	-	+	+	
26.2	D	4.24	+	+	+	
28.5	D	3.91	-	+	-	
30.	VD	3.70	-	+	-	
31.5	VVD	3.56	-	-	-	
33.4	H	3.34	+	+	+	
39.5	D	2.79	-	-	-	+
43.8	M	2.58	-	+	+	
46.	D	2.46	+	+	-	
48.5	VD	2.38	-	+	+	
49.5	VD	2.38	-	+	-	
53.5	VD	2.12	-	+	-	
57.2	VD	2.00	+	+	-	
60.2	VD	1.89	+	-	-	
63.0	D	1.80	+	-	-	
67.	VD	1.70	-	-	-	
69.	D	1.66	+	+	+	
75.2	D	1.53	+	-	-	
77.2	D	1.51	-	+	-	

TABLE 101 (Cont'd)

Reading mm	Intensity	d	Quartz	Illite	Halloysite	NaCl
80.0	VVD	1.44	+	-	+	
82.0	VVD	1.42	+	+	-	
85.3	M	1.37	+	+	+	
91.5	VD	1.28	+	+	+	
95.0	VD	1.26	+	+	-	
100.	VD	1.191	+	-	-	
102.	VD	1.178	+	-		

Very light trace of Halloysite, trace of salt.

TABLE 102

Brownwood Shale .5-.8u

Reading mm	Intensity	d	Quartz	Illite	NaCl
22.5	D	4.97	-	+	-
24.5	M	4.44	-	+	-
33.2	M	3.34	+	+	-
39.	D	2.79	-	-	+
43.5	M	2.58	-	+	-
47.	D	2.38	-	+	-
50.	VVD	2.28	-	+	-
53.	VVD	2.12	-	+	-
57.5	VVD	2.00	+	+	
62.5	VVD	1.80	+	-	-
69.	VVD	1.66	+	+	-
75.	VVD	1.53	+	-	-
77.	M	1.51	-	+	-
81.5	VD	1.44	+	-	-
85.	VD	1.37	+	+	-
90.5	VD	1.28	+	+	-
95.	VD	1.26	+	+	-
100.	VD	1.19	+	-	-

TABLE 103

Brownwood Shale .25-.15u

Reading mm	Intensity	d	Quartz	Illite	NaCl
22.5	D	4.97	-	≠	
24.5	M	4.44	-	≠	
28.	D	3.91	-	≠	
33.2	M	3.34	≠	≠	
39.	D	2.79	-	-	≠
43.5	M	2.58	-	≠	
47.	D	2.38	-	≠	
50.	VVD	2.28	-	≠	
53.	VVD	2.12	-	≠	
57.5	VVD	2.00	≠	≠	
62.5	VVD	1.80	≠	-	
69.0	VVD	1.66	≠	≠	
75.0	VVD	1.53	≠	-	
77.	M	1.51	-	≠	
81.5	VD	1.44	≠	-	
85.	VD	1.37	≠	≠	
90.5	VD	1.28	≠	≠	
95.	VD	1.26	≠	≠	
100.	VD	1.19	≠	-	

TABLE 104

Brownwood Shale .15-.05u

Reading mm	Intensity	d	Quartz	Illite	NaCl
21.	VD	5.26			
23.	VD	4.97	-	+	
25.2	M	4.44	-	+	
28.	M	3.91	-	+	
34.	D	3.34	+	+	
40.	VD	2.79	-	-	+
44.	M	2.58	-	+	
47.	D	2.38	-	+	
52.	D	2.14	+	+	
60.	VD	1.90	+	-	
63.	VD	1.80	+	-	
67.5	VD	1.70	?	-	
69.6	D	1.66	+	+	
75.5	VD	1.53	+	-	
77.6	M	1.51	-	+	
80.0	VVD	1.44	+	-	
85.5	VVD	1.36	+	+	
89.5	VVD	1.290	-	+	
91.5	VD	1.280	+	-	
95.5	VD	1.19	+	-	

TABLE 105

Brownwood Shale <.05u

	Reading mm	Intensity	d	Quartz	Illite	NaCl
1.	23.	VD	4.97	-	+	
2.	25.2	M	4.44	-	+	
3.	28.	M	3.91	-	+	
4.	40.	VD	2.79	-	-	+
5.	44.	M	2.58	-	+	
6.	47.	D	2.38	-	+	
7.	60.	VD	1.90	+	-	
8.	63.	VD	1.80	+	-	
9.	67.5	VD	1.70	?	-	
10.	69.6	D	1.66	+	+	
11.	75.5	VD	1.53	+	-	
12.	77.6	M	1.51	-	+	
13.	80.0	VVD	1.44	+	-	
14.	85.5	VVD	1.36	+	+	
15.	89.5	VVD	1.29	-	+	
16.	91.5	VD	1.280	+	-	
17.	95.5	VD	1.190	+	-	

TABLE 106

Brownwood Shale

Fraction	Quartz	Illite	Halloysite
Plus 325	A	C	
2u-44u	A	B	
1u-2u	A	A	C
.8u-1u	B	A	C
.5u-.8u	B	A	
.25u-.5u	B	A	
.15u-.25u	C	A	
.05u-.15u	?	A	

APPROXIMATE MINERAL ANALYSIS

Mineral	Per Cent Composition
Quartz	36.45
Illite	52.00%
Halloysite	Trace
Fe_2O_3	7.49
Calcite	1.46
Organic	.27
NaCl	.51
Na_2SO_4	Trace
Total	98.18

Seguin Clay

Tables 107 through 114 give the powder diagrams for the Seguin clay. the 1 to 2 micron and .8 to 1 micron fractions contained quartz, illite and a trace of calcite. The .5 to .8 micron fraction contained about an equal mixture of quartz and illite. The .25 to .5 micron and .15 to .25 micron fractions contained illite with traces of quartz. The .05 to .15 micron and less than .05 micron fractions contained preponderately illite. The approximately mineral analysis for the Seguin Clay is as follows: 30% quartz, 45.6% clay minerals, 6.2% ferric oxide, 8.9% calcite, 21% organic material determined by means of hydrogen peroxide, .9% chlorides calculated as sodium chloride, and .22% sulfates calculated as sodium sulfate.

Table 115 gives the estimated relative mineral contents of each fraction of the Seguin clay.

A concentric circle x-ray powder diffraction pattern of a mixture of the .15 to .25u fractions showed the ool line of illite, the 001 line of montmorillonite corresponding to a lattice distance of 15.44° and the 002 line of kaolinite.

TABLE 107

Seguin 2u-44u

Reading mm	Intensity	d	Quartz	Illite	Calcite
25.5	VVD	4.46	+	+	
27.5	VVD	3.90	-	+	+
30.	D	3.71	-	+	
33.2	H	3.34	+	+	-
35.	VD	3.07	-	-	+
36.5	VD	2.81	-	+	-
46.	VVD	2.38	-	+	-
50.	VVD	2.26	-		+
50.8	VVD	2.22	-	+	-
57.	VVD	1.98	+	-	-
59.	VVD	1.85	+	-	+
62.6	M	1.74		-	-
68.8	D	1.66	+	+	+
75.0	VD	1.54	+	-	-
85.1	D	1.36	+	+	+
94.5	VVD	1.26	+	-	+
97.	VD	1.23	+	+	-
100.	VD	1.196	+	-	-
101.5	VD	1.18	+	-	+

TABLE 108

Seguin 1-2u

Reading mm	Intensity	d	Quartz	Illite	Calcite
25.5	M	4.46	-	+	+
28.5	M	3.90	-	+	-
33.1	H	3.34	+ -	+	-
35.2	VD	3.16	-	+	-
36.4	VD	3.07	-	-	+
39.5	VD	2.81	-	+	-
43.6	D	2.58	-	+	-
46.5	VVD	2.38	-	+	-
51.2	VD	2.20	-	+	+
57.	VVD	1.98	+	+	+
60.	VVD	1.90	-	-	+
63.	VVD	1.81	+	-	+
67.	VD	1.72	-	-	-
68.6	D	1.67	+	+	-
75.0	VD	1.54	+	-	-
77.5	VD	1.485	-	-	+
85.3	VD	1.36	+	-	-
91.2	VVD	1.29	-	+	-
97.5	VD	1.23	+	-	+
100.	VVD	1.198	+	-	-
102.0	VVD	1.18	+	-	-

TABLE 109

Seguin .Su-lu

Reading mm	Intensity	d	Quartz	Illite
23.5	D	4.97	-	+
25.2	M	4.44	-	+
29.	VVD	3.90	-	+
30.5	VVD	3.70	-	+
31.5	VVD	3.56	-	-
33.6	VD	3.34	+	+
36.3	VVD	3.11	-	-
38.5	VD	2.70	-	+
44.0	D	2.56	-	+
46.5	VD	2.38	-	+
51.6	D	2.16	-	+
54.	D	2.12	+	+
57.0	VD	2.80	+	+
60.4	VVD	1.90	-	+
63.3	VVD	1.80	-	-
68.	VD	1.68	+	-
69.5	VD	1.65	-	+
71.0	VVD	1.62	-	+
76.1	VD	1.54	+	-
78.0	D	1.50	-	+
83.0	VD	1.40	+	-
86.0	VD	1.36	+	+
89.5	VD	1.32	-	-
91.5	VD	1.28	+	+
100.5	VVD	1.20	+	-

TABLE 110

Seguin .5-.8u

Reading mm	Intensity	d	Quartz	Illite
23.5	D	4.97	-	+
25.2	M	4.44	-	+
29.	VVD	3.90	-	+
30.5	VVD	3.70	-	+
31.5	VVD	3.56	-	-
33.6	VD	3.34	+	+
36.3	VVD	3.11	-	-
38.5	VD	2.80	-	+
44.0	D	2.56	-	+
46.5	VVD	2.38	-	+
51.6	D	2.16	-	+
54.	D	2.12	+	+
57.1	VD	2.00	+	+
60.4	VVD	1.90	-	+
63.3	VVD	1.80	-	-
68.	VD	1.68	+	-
69.5	VD	1.65	-	+
71.0	VVD	1.62	-	+
76.1	VD	1.54	+	-
78.0	D	1.50	-	+
83.0	VD	1.40	+	-
86.0	VD	1.36	+	+
89.5	VD	1.32	-	-
97.5	VD	1.28	+	+
100.5	VVD	1.20	+	-

TABLE 111

Seguin .150-.250u

	Reading mm	Intensity	d	Quartz	Illite
1.	22.5	VD	4.97	-	+
2.	25.0	M	4.44	-	+
3.	28.2	D	3.90	-	+
4.	33.4	VVD	3.34	+	+
5.	39.0	VD	2.80	-	+
6.	43.5	M	2.58	-	+
7.	47.	VD	2.38	-	+
8.	51.5	VVD	2.14	-	+
9.	60.0	VVD	1.90	+	+
10.	67.2	VVD	1.70	+	-
11.	69.2	VD	1.66	+	+
12.	72.6	VD	1.54	+	-
13.	77.2	M	1.51	-	+
14.	81.0	VD	1.43	+	-
15.	91.0	D	1.28	+	+
16.	95.	VD	1.20	+	+
17.					
18.					

TABLE 112

Seguin .250-.55u

	Reading mm	Intensity	d	Quartz	Illite
1.	22.5	VD	4.97	-	+
2.	25.0	M	4.44	-	+
3.	28.2	D	3.90	-	+
4.	33.4	VVD	3.34	+	+
5.	39.0	VD	2.80	-	+
6.	43.5	M	2.58	-	+
7.	47.0	VD	2.38	-	+
8.	51.5	VVD	2.14	-	+
9.	60.0	VVD	1.90	+	+
10.	67.2	VVD	1.70	+	-
11.	69.2	VD	1.66	-	+
12.	72.6	VD	1.54	+	-
13.	77.2	M	1.51	-	+
14.	81.0	VD	1.43	+	-
15.	91.0	D	1.28	+	+
16.	95.	VD	1.20	+	+
17.					
18.					
19.					
20.					
21.					

TABLE 113

Seguin - Less than .05u

	Reading mm		Intensity	d	Quartz	Illite
1.	23.0		VD	4.97		+
2.	25.0		M	4.44		+
3.	28.3		D	3.90		+
4.	39.4		VD	2.80		+
5.	43.6		M	2.58		+
6.	46.5		VD	2.38		+
7.	51.5		D	2.14		+
8.	60.0		D	1.90		+
9.	67.6	BR	VD	1.70	?	-
10.	69.5		VD	1.66		+
11.	77.5		M	1.51		+
12.	80.4		VVD	1.44	?	-
13.	91.2		VD	1.28		+
14.	95.6		VD	1.19		+

Trace of quartz.

TABLE 114

Seguin .05-.150u

	Reading mm	Intensity	d	Quartz	Illite
1.	23.0	VD	4.97		+
2.	25.0	M	4.44		+
3.	28.3	D	3.90		+
4.	39.4	VD	2.80		+
5.	43.4	M	2.58		+
6.	46.5	VD	2.38		+
7.	51.5	D	2.14		+
8.	60.	D	1.90		+
9.	67.6	VD	1.70	?	
10.	69.5	VD	1.66		+
11.	77.5	M	1.51		+
12.	80.4	VD	1.44	?	-
13.	91.2	VD	1.28		+
14.	95.6	VD	1.19		+

Trace of quartz.

TABLE 115

Seguin Clay

Fraction	Quartz	Illite	Calcite
2u-44u	A	C	B
1u-2u	A	B	C
.8u-1u	A	B	?
.5u-.8u	B	B	
.25u-.5u	C	A	
.15u-.25u	C	A	
.05u-.15u		A	
Less than .05u		A	

Approximate Mineral Analysis

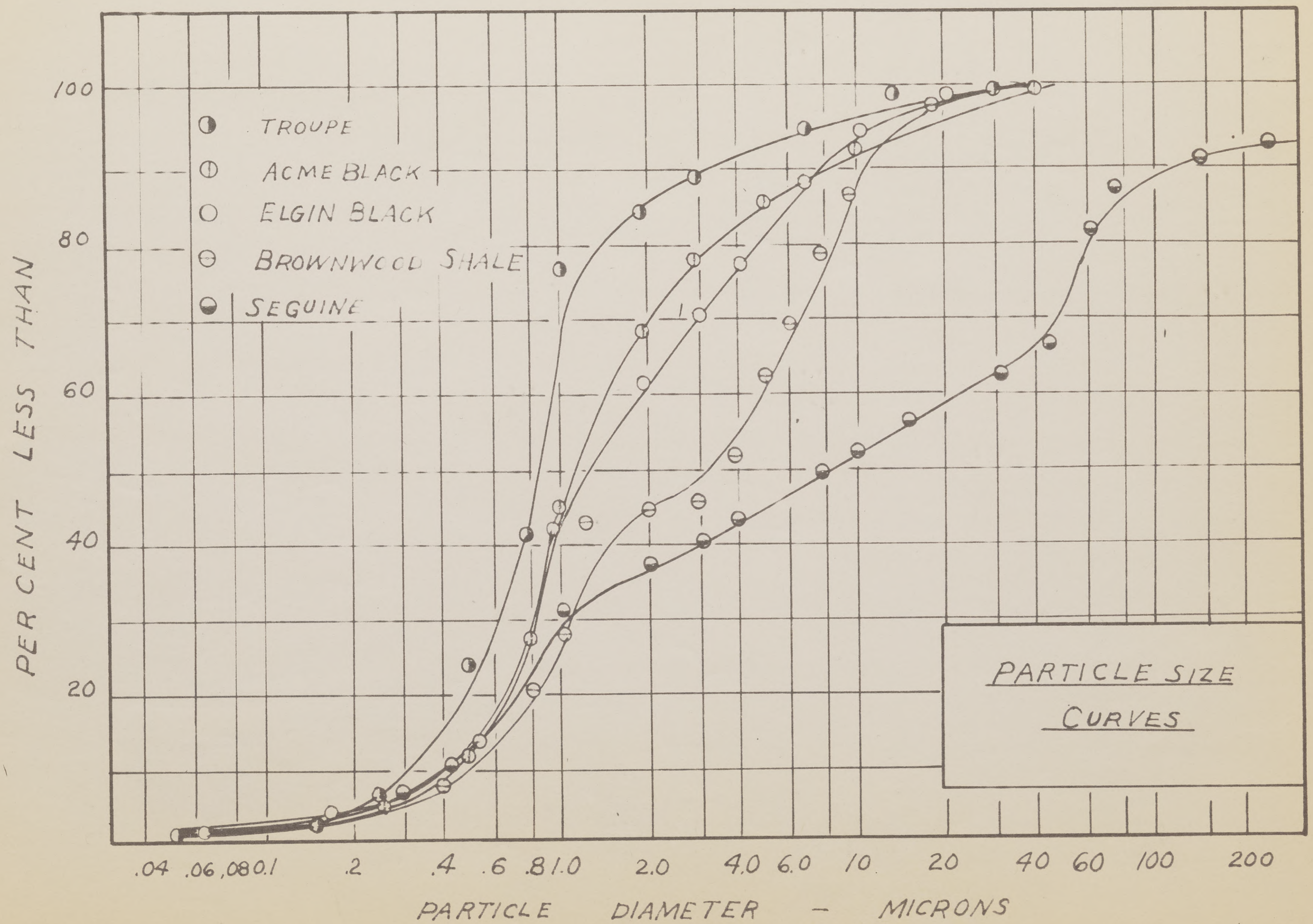
Mineral	Per Cent Composition
Quartz	30.00
Illite	45.60
Fe_2O_3	6.19
Calcite	8.90
Organic	.205
NaCl	.895
Na_2SO_4	.215
Total	91.905%

Particle Size and Plastograph Curves

Tables 74, 75 and 76 give the particle size data, and Figure 13 gives the particle size curves for Troup, Acme black, Elgin black, Seguin and Brownwood clays. Figure 14 gives the plastograph curves for the same.

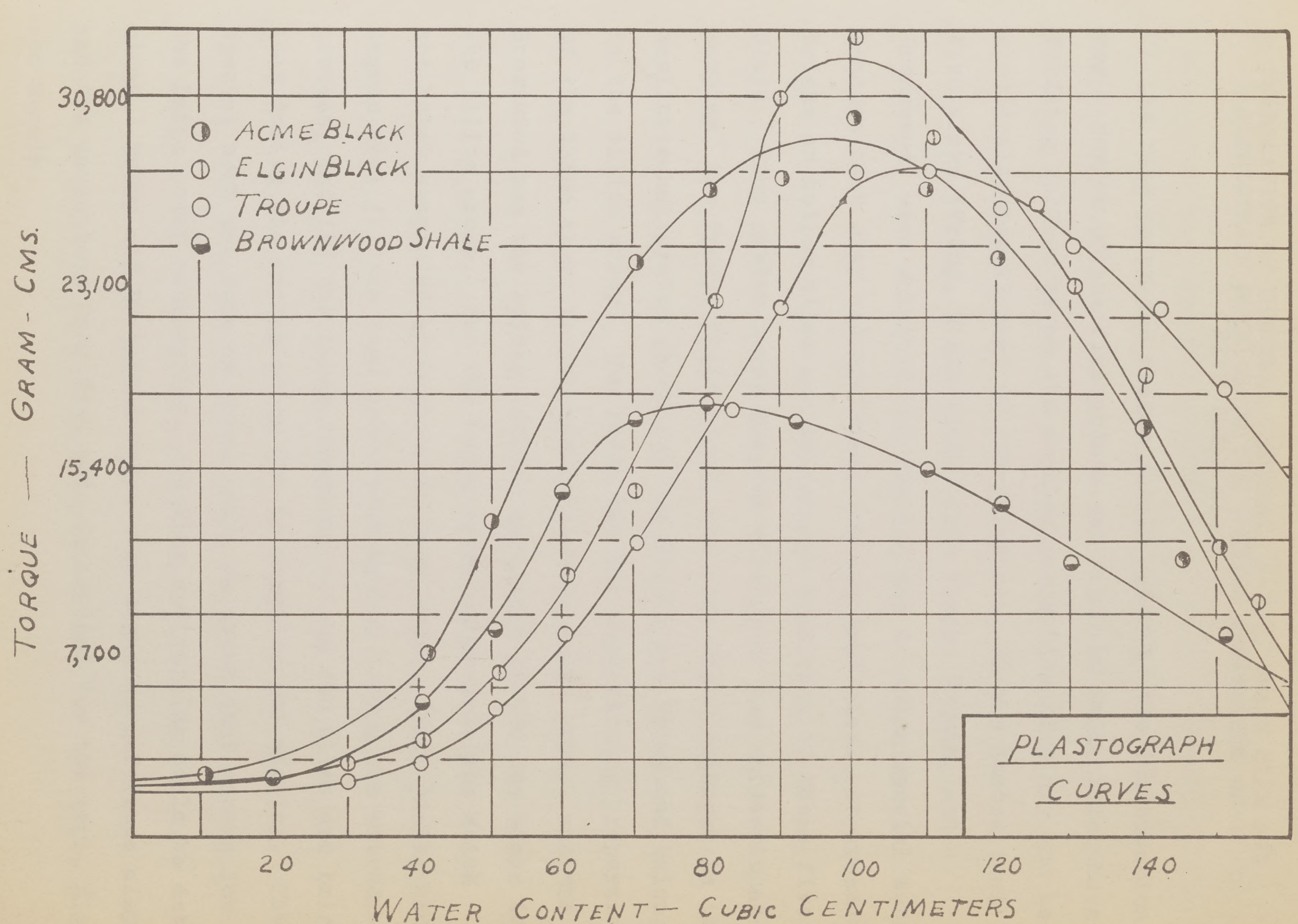
The relative order of increasing surface area is Seguin, Brownwood, Elgin black, Acme black and Troup. The two sets of curves show that the torques produced are not related to the increased surface area because Troup has a larger surface area than either Acme black or Elgin black and its peak torque is less than that of the Acme black or the Elgin black. It must be remembered that the Troup clay contains kaolinite as the preponderate mineral while halloysite is the preponderate mineral in the Acme and Elgin clays. Also the Acme contains traces of montmorillonite and there is a possibility that the Elgin black contains some montmorillonite. The higher torques produced by the Acme black and the Elgin black are probably due to carbon content and adsorbed ions present, for it was shown in the discussion of these two clays that they contained more adsorbed ions than the Troup.

Figure 13



PARTICLE SIZE CURVES
TROUPE
ACME BLACK
ELGIN BLACK
BROWNWOOD SHALE
SEGUINE
PER CENT LESS THAN
100
80
60
40
20
.04
.06
.08
0.1
.2
.4
.6
.8
1.0
2.0
4.0
6.0
10
20
40
60
100
200
PARTICLE DIAMETER - MICRONS

Figure 14


ACME BLACK
ELGIN BLACK
TROUPE
BROWNWOOD SHALE
PLASTOGRAPH CURVES
30,800
23,100
15,400
7,700
TORQUE — GRAM - CMS.
20
40
60
80
100
120
140
WATER CONTENT — CUBIC CENTIMETERS

A CORRELATION OF THERMAL, CHEMICAL, X-RAY, GRAIN SIZE AND PLASTOGRAPH STUDIES TO THE WORKING PROPERTIES OF FIVE TEXAS CLAYS

At this point the reader should refer to the introduction for a review of the five points set forth by Grim, which have deciding influences on the working properties of clays and he should also recall that in the procedure, it was stated that five clays (Troup, Elgin black, Acme black, Seguin, and Brownwood) were selected for the purpose of doing special work, because each clay had different working qualities. At present, bricks or hollow tiles are being made from each of these five clays. From powder x-ray diagram studies of the unfractionated samples, the Troup, Elgin black, and Acme black belonged in the kaolinite-halloysite group and the Seguin and Brownwood belonged in the illite group. The Troup has the best working properties of the three clays in the kaolinite-halloysite group, and the Brownwood has the better working qualities of the two clays in the illite group. The two major troublesome problems which the brick companies have with the Acme black, Elgin black, and Seguin are: (1) the high power consumption during the extruding process, and (2) the large fractions of the raw tiles and bricks lost during the drying stage due to cracking and warping. The special work was done on these clays in order that causes for the large power consumption, cracking and warping could be determined. Troup and Brownwood clays were taken as reference clays and the deviations from them were determined for the Acme, Elgin and Seguin.

The tendency toward gellation when stirred with water in a malt mixer was more pronounced in the case of Seguin, Elgin and Acme clays. The gelatinous nature of the cited clays is probably the cause of the high power consumption during extrusion, and the cracking and warping during drying.

Other factors being equal, i.e., same mineral content, same impurities, same crystal habits, etc., the greater the surface area due to smaller particles the greater the gelling property of a clay. From a study of the five particle size curves of these clays, the Troup curve showed the greatest percentage of smaller particles, which proved that the Troup clay had the largest surface area, but the Troup clay is not a gelatinous clay, and by reasoning from the greater surface area of the Troup clay, the cause of the gelatinous nature of the Acme and Elgin clays is not due to particle size. Also, due to surface tension phenomena, the Troup clay should give a greater maximum torque on the plastograph, but this is not the case, for the Troup's maximum torque was less than that of the Acme and Elgin clays.

The chemical analyses of the three clays (Acme, Elgin, and Troup) and the loss of alkali content during electrodialysis showed that the Acme and Elgin clays have an excess of adsorbed alkali. The excess adsorbed ions on the Acme and Elgin clays were also proved by their viscosity changes during the addition of sodium hydroxide. A slight addition of sodium hydroxide to a Troup slip decreased the viscosity, while a slight addition to the Acme or Elgin slips increased the viscosity to a maximum, and on further additions the viscosity decreased. When ethylene diamine was added to the Troup clay during a plastograph run, there was a decrease in maximum torque, but when the amine was added to the Acme or Elgin, the maximum torque increased. The increased maximum torque produced for the Acme and Elgin black clays may be partially due to the excess adsorbed ions.

In trying to locate the possible causes for the gelatinous clays, the minerals in the clays should be determined, because if the clay contained montmorillonite, its presence would make the clay gelatinous. Mixtures of the fractions .15 - 25u and .05 -15 u of the Acme black and Seguin clays gave the 001 line of montmorillonite on the concentric circle type of x-ray, powder, pictures. The water contents of these two clays for maximum torques on the plastograph did not indicate the presence of very much montmorillonite, because experiments on torsion curves showed that for maximum torque of the air dried Gonzales volcanic ash required over 40% water content. The water contents for maximum torques on the plastograph differed very little for each of the air dried samples of Acme, Elgin or Troup, but on the other hand, the thermal curves of these clays showed that the adsorbed or absorbed waters of the Acme and Elgin clays were greater than for the Troup clay.

Another factor which determines the working properties of a clay is the kind and quantity of organic material present in the clay. As mentioned previously, the hydrogen peroxide method of determining organic material indicated that the Troup had more organic material present than either the Acme Black or the Elgin Black; the thermal curves for the .05 - .15u fractions showed an exothermic reaction for the Acme Black and Elgin Black between 200°C and 500°C which is characteristic of some organic materials when present in clays. The black color of the fractions below .5u of the Acme, Elgin and Seguin was in favor of the organic material. The same fractions of Troup and Brownwood did not have the black appearance, and neither did the .05 - .15u fractions of the Troup or Brownwood give the exothermic reaction between 200°C and 500°C. The black fractions of the Acme, Elgin and Seguin clays became very sticky when mixed with water.

In conclusion, the major cause for the stickiness of the Acme Black, Elgin Black and Seguin clays can be attributed to the presence of organic material, and excess alkali and montmorillonite being secondary contributing factors. It might be worthy of mention here, that the Troup vitrifies at a higher temperature than either the Acme or Elgin, because the percentage of alkali is less in the Troup.

SUMMARY

A summary of the literature on the structures of clay minerals was given. A collection of standard clay mineral powder diagrams was given.

The four clay samples, which had been designated as kaolin, consisted preponderately of kaolinite as the principle mineral, but each contained traces of quartz. However, the white plastic sample from Leakey contained some montmorillonite in addition to kaolinite and quartz, and the pink and white spotted sample from the Davis Mountain contained traces of calcite in addition to kaolinite and traces of quartz. The white Davis Mountain kaolin contained the largest percentage of kaolinite of any of the clays examined; it contained only a slight trace of quartz--probably 2 or 3 % quartz (1% quartz is detectable in clays by means of x-rays).

All the clays except Seguin and Brownwood contained either, halloysite or kaolinite as the preponderate mineral. Illite was the preponderate mineral in the Seguin and Brownwood clays. The Seguin contained traces of montmorillonite, halloysite, calcite, and ferric oxide.

Montmorillonite was the preponderate mineral in each of the two volcanic ashes. The Falls City volcanic ash contained the largest percentage of montmorillonite. The Gonzales ash contained traces of kaolinite, which was identified by the 002 line of kaolinite.

The order of increasing surface area shown by the five particle size curves was Seguin, Brownwood shale, Elgin Black, Acme Black, and Troup. There was no direct relationship between the plastograph and particle size curves for the four clays, Brownwood, Elgin Black, Acme Black, and Troup. The black organic material in the Acme Black and Elgin Black was the cause of the large torques on the plastograph curves for these two clays.

The thermal and chemical analyses confirmed the x-ray results. The thermal analyses and colors of the fractions of Elgin Black, Acme Black, and Seguin indicated the presence of organic material.

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