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BALL CLAY OF THE TROUP DISTRICT, TEXAS

By

H. B. STENZEL

and

CHARACTERISTICS OF TEXAS BALL CLAY NEAR TROUP

By

F. K. PENCE



**Bureau of Economic Geology
Research Laboratory in Ceramics**

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South wall of ball clay in pit of General Refractories Company, near Henry's Chapel, northeastern Cherokee County, Texas. The clay shows the gently inclined slippage planes, the nearly vertical fossilized remains of plant roots, and the lack of bedding. Photograph by John T. Twining, April 1950.

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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BALL CLAY OF THE TROUP DISTRICT, TEXAS

H. B. Stenzel

INTRODUCTION

Ball clay of considerable economic importance has been discovered recently and developed industrially in east Texas in the vicinity of Troup. However, the geologic relationships and stratigraphic position of the ball clay were not known except in a most general way. Hence it was desirable to investigate the deposit so that more reliable geologic information about it might be obtained, which in turn might serve for an evaluation of the extent and economic importance of the deposit. Such data might serve also as a guide to future exploration for such high-grade clays elsewhere.

PURPOSE OF THE REPORT

The purpose of this report then is to present data based on a thorough geologic study and conclusions derived from them concerning the geologic occurrence, extent of the deposit, and its stratigraphic position, to establish a guide or leads to future exploration for such clay deposits, and to give information concerning other deposits that were discovered in the course of the investigation of this area. In addition the purpose of this report is to present such tests, chemical analyses, and technical data as are available at present.

SCOPE OF THE REPORT

For these purposes a great deal of geologic mapping and stratigraphic elucidation had to be undertaken, because conditions of geological surface observation are not at all favorable in the immediate vicinity of the known deposit. This is partly due to the particularly deep mantle of soils, subsoils, weathered rock fragments, and slope wash that cover the vicinity of the clay deposits and partly due to the difficult and obscure stratigraphy of the section involved. In order to recognize and trace a definitive bed that might serve as a key bed for the clearing up of these difficulties, reconnaissance geologic mapping had to be extended as far as the vicinity of the village of Reklaw in Chero-

kee County near the southwest corner of Rusk County, a distance of about 20 miles in S. 15° E. direction from the known ball-clay deposit. It was found that the glauconitic sands, sandstones, and clay-ironstones at the base of the Reklaw formation, forming its Newby member, are the most reliable mappable unit and the least difficult to trace, although considerable changes occur in its composition, thickness, and facies from Reklaw to the ball-clay pits.

The area covered by detailed geologic mapping undertaken specifically for the present report is about 8 miles long in a north-south direction and about 7 miles wide in an east-west direction. This area was mapped on a scale of 8 inches to the mile with aerial photographs as a base. It fits into the northeastern corner of Cherokee County and reaches with its northwestern corner to within 1 mile of Troup. This map is to be published in another report and is not included here.

FIELD WORK

The area was first visited on January 8 and 9, 1946, by Dr. John T. Lonsdale, Director of the Bureau of Economic Geology, accompanied by Mr. F. K. Pence, Director of the Research Laboratory in Ceramics, and Dr. H. B. Stenzel and Mr. H. C. Fountain of the Bureau of Economic Geology. At that time it was agreed that an investigation of the Troup district was both feasible and desirable. The geologic portion of this investigation was handled by H. B. Stenzel. The geologic field work was intermittent from February 1946 to October 1948, as shown by the dates following. During this work Mr. H. C. Fountain assisted the writer during February through June 16, 1946; Dr. Dan E. Feray, Jr., during June 11 to August 31, 1947; Mr. A. L. Lyth, Jr., during September 1947 to January 1948 inclusive; and Mr. C. O. Durham, Jr., for a few days in October 1948.

MAPS

All geologic mapping in northeastern Cherokee County was done on aerial photographic maps obtained from the Eastern Aerial Photographic Laboratory, Field Service Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C. The set of photographs used is of a scale of 8 inches to the mile; the photographs are dated and index numbered as follows:

Sheets CFV-7-28 to CFV-7-36 inclusive, dated 7-16-39; CFV-8-34 to CFV-8-40 inclusive, dated 7-16-39; CFV-13-38 to CFV-13-45 inclusive, dated 9-22-39.

Areas investigated that lie outside of the coverage of these photographs were mapped using as a base the Troupe¹ and Henderson quadrangles, scale 1/48,000,

unedited advance sheets, published by the U. S. Geological Survey. These advance sheets were found to have a more convenient scale than the final editions, which are on the scale of 1/62,500.

Some use was made of land ownership and survey maps, of which the following were available:

Map of Cherokee County, 1879, scale 4,000 varas to 1 inch: General Land Office, State of Texas, Nov. 1879.

Map of Cherokee County [no scale indicated, 1 inch = 2,000 varas]: General Land Office, Austin, Texas, June 1902.

Map of Cherokee County, 1 inch equal 2,000 varas: General Land Office, Austin, Texas, July 1933.

Ownership map of Cherokee County, Texas, 1 inch = 4,000 feet: S. W. Ray, Jacksonville, Texas, January 1931.

GEOLOGICAL DESCRIPTION OF THE TROUP DISTRICT

LOCATION

Troup is a town in southern Smith County (fig. 1), about half a mile north of the Smith-Cherokee County line and 8 miles west of the Smith-Rusk County boundary, and is the site of the plant and kiln of the Troup Works of the General Refractories Company, where most of the ball clay produced in the district is prepared and manufactured into fire brick of various shapes. The ball-clay deposit that is being worked by the General Refractories Company and intermittently by the Thermo Fire Brick Company is about 0.65 mile airline distance S. 85° W. to S. 50° W. of the church at Henry's Chapel, which is a small community in northeastern Cherokee County on Farm Road 13 [Troup-Henderson road] about 5 miles east-southeast of Troup. Other exposures of somewhat similar materials that were discovered during the course of the mapping and are as yet undeveloped are on Mill Creek and Campground Creek or their tributaries, from 1.67 to 5 miles airline distance from the church at Henry's Chapel in a direction of S. 45° E. to S. 24° E., that is, in a generally southeastern direction.

Nearest railroad connections are at Troup on the main line of the Missouri

Pacific Railroad and at Henderson, the county seat of Rusk County, on the same railroad. The area is traversed by numerous well-kept county roads, some of which are hard surfaced, and several hard-surfaced highways such as Farm Road 13 [Troup to Henderson]. There is also a comparatively dense network of electric high-tension lines and gas and oil pipe lines in this region, many of which originate in the great East Texas oil field located about 8 miles east of Troup.

SUMMARY OF PREVIOUS GEOLOGICAL WORK

Geological field work done in eastern Texas prior to 1920 was insufficient to cope with the great geographic extent of the area and with the great extent and complexity of the formations outcropping in the area. Hence prior to that time the beds and their succession were known merely in a very generalized and often insecure or even erroneous way. The geologic map accompanying Dumble's report on east Texas (Dumble, 1920, Pl. 1), for instance, showed the region of the Troup district as the outcrop of only one formation, the "Marine" of the Claiborne group, without any more detailed breakdown of that formation, although a previously published report by Alexander Deussen (1914,

¹Misprint for Troupe.

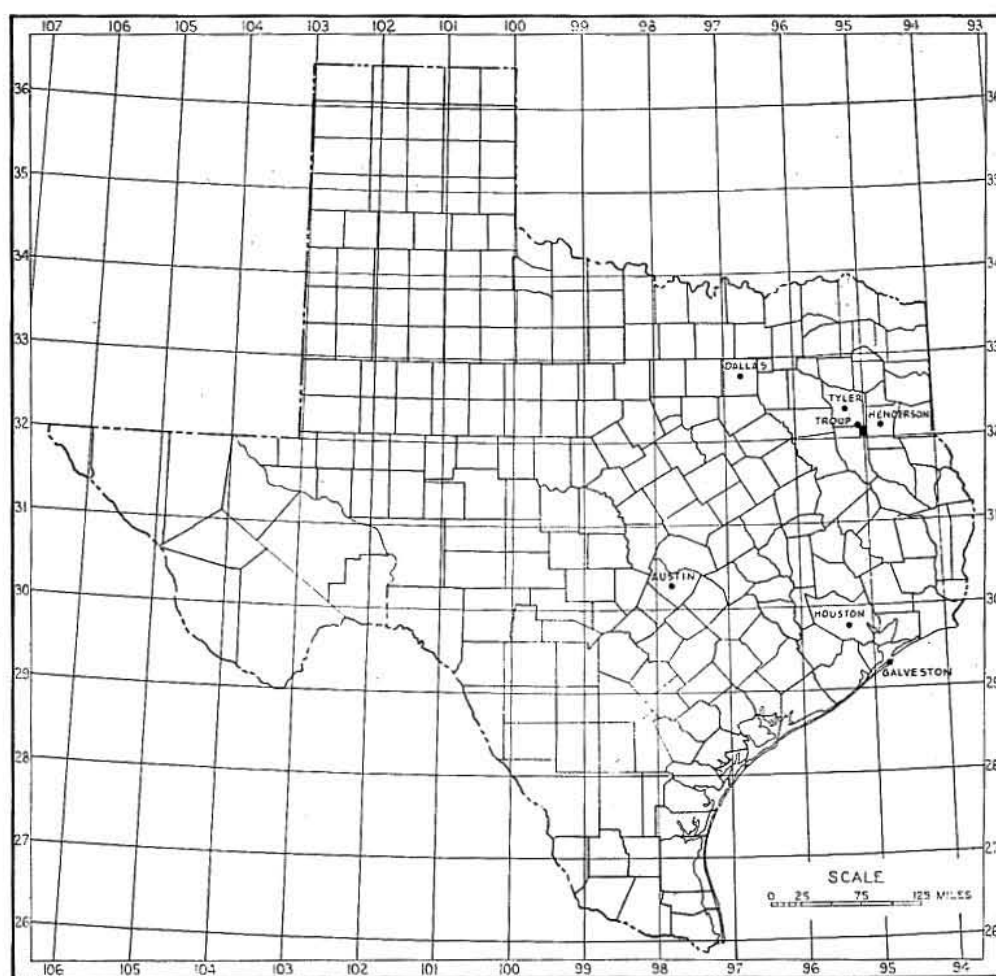


Fig. 1. Location of the Troup district in Texas. The district is indicated by the black rectangle.

Pl. 1) showed the "Wilcox formation" and the Mount Selman formation sharing the outcrops in the same region. In this respect Deussen's map, although it was exceedingly generalized, was more advanced than Dumble's and depicted in a very general way geologic conditions correctly. Deussen's map showed the Wilcox occupying the valleys of the various head-water branches of the Angelina River and the Mount Selman formation occupying the intervening uplands. In retrospect this arrangement was roughly correct only if one included, as Deussen did in this region, the Reklaw and Carrizo formations as they are known today in his "Wilcox formation."

The great increase in geologic field work done in the 1920s by petroleum geologists for the purpose of locating places favorable to exploration for petroleum resulted in the clearing up of most of these uncertainties and old misconceptions of the stratigraphy in eastern Texas. Toward the end of the 1920s a nearly complete, and in all essential major features correct, knowledge of the outcropping beds was attained by these geologists working in eastern Texas. A succession of publications resulting from this work was placed before the public by B. C. Renick (1928), A. C. Ellisor (1929), E. A. Wendlandt and M. G. Knebel (1929), and C. L. Moody (1931). Of these reports the most im-

portant for the present work was the one by Wendlandt and Knebel. The geology of the area was later summarized, chiefly from available published accounts, by F. B. Plummer (1933). These authors elucidated the succession of the beds and described the chief characteristic features of the formations so that a firm foundation for future work in this area became available. Maps submitted by geologists working in Texas were compiled between the years 1924 and 1935 into a geologic map of the State (Darton and others, 1937) on a scale of 1/500,000. This map was a great step forward in the geologic mapping of the area under consideration but had to be rather generalized because of its small scale and the lack of suitable accurate topographic bases. The region around Troup and Henry's Chapel was depicted in a correct but generalized way, and the Queen City, Reklaw, and Carrizo formations and the Wilcox group were shown as outcropping. In retrospective criticism it may be said that the Queen City formation was depicted as occupying too much territory in the region under consideration at the expense of the really much larger Reklaw outcrops and that the Wilcox outcrop in the immediate vicinity of the clay pits was not shown. Similarly the Carrizo formation was omitted in the vicinity of Reklaw.

With the appearance of this Geologic Map of Texas, an era of active geologic mapping and publication of several fundamental reports came to an end. Much less geologic surface mapping is being done now and very little of it is being published. Additional new information concerning finer subdivision of the formations exposed in east Texas and concerning the contacts between successive formations was contributed by H. B. Stenzel (1939).

REGIONAL GEOLOGICAL SETTING

The Gulf of Mexico basin, in which the Troup district lies, is a very extensive depositional and structural province of low topographic relief and slight elevation above sea level, bordering the continent on the south, composed of ordinarily soft or only slightly indurated stratified rocks of Cretaceous and Cenozoic age

that are only slightly disturbed from the original attitudes they achieved at the time they were deposited (fig. 2). In the basin the strata usually dip coastward and at a very low rate of dip, in most regions amounting to less than one degree. Hence, the older of the strata composing the Gulf of Mexico basin, that is, the Cretaceous strata, ordinarily occupy the outer or inland fringe of the basin and disappear coastward under the younger or Cenozoic strata. The various strata form long and narrow outcrop ribbons that are usually parallel to the coast line and in most places form topographic scarps or cuestas with a steeper slope inlandward and a gentler slope coastward.

Natural subdivisions of the Gulf of Mexico basin are twofold. There are those that are approximately parallel and others that are approximately at right angles to the present coast line. Among the latter are the three embayments: the Rio Grande embayment in south Texas separated by the San Marcos arch from the East Texas embayment, which occupies most of eastern Texas and includes the Troup district. The Sabine uplift, which centers on the Sabine River at the Texas-Louisiana boundary, separates the East Texas embayment from the much larger Mississippi embayment, whose axis lies approximately along the Mississippi River.

Among the boundaries of the subdivisions in the Gulf of Mexico basin that are parallel to the present shore line, the one that is of significance here is the boundary between the outer, or inland, and the inner, or shoreward, portion of the basin. Where this boundary crosses the East Texas embayment it is made apparent and even conspicuous by a belt of nearly parallel small faults of post-Eocene age extending from the vicinity of Mt. Enterprise in southeastern Rusk County in a nearly directly western direction to the vicinity of Jacksonville in northern Cherokee County and then in a southwestern direction through Elkhart in southern Anderson County to the vicinity of Buffalo and Centerville in Leon County. The belt is made up of about nine major faults and many more minor ones; some of the faults enclose downdropped blocks or grabens; others are isolated faults. The

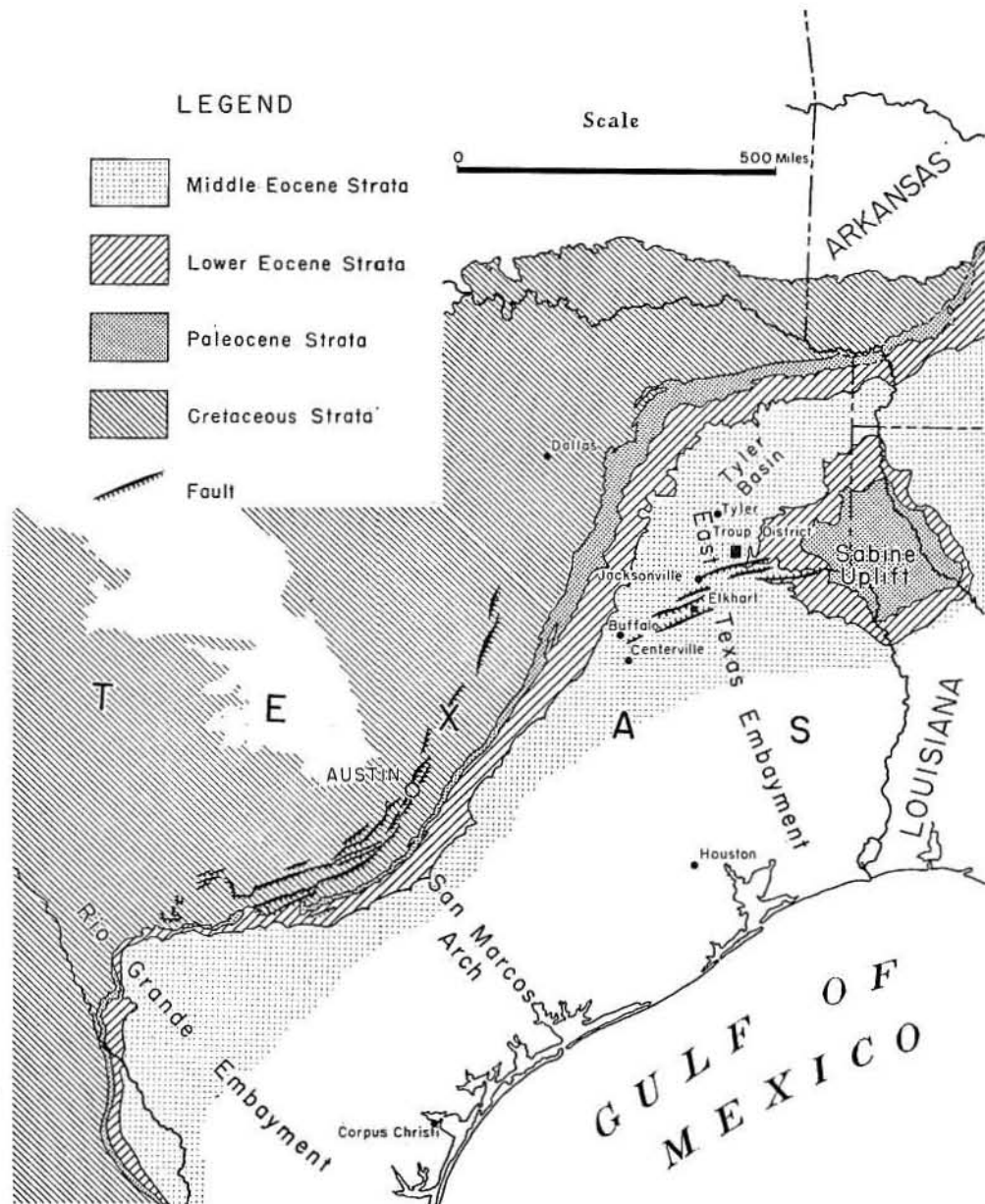


Fig. 2. Regional geological setting of the Tyler basin and the Troup district in the Gulf of Mexico basin. The district is indicated by the black rectangle.

fault belt separates the inland portion or head of the East Texas embayment from the shoreward portion. The head portion is called the Tyler basin from the town of Tyler in Smith County, which lies very nearly at the exact structural center of the basin. Hence the Tyler basin is bounded in the west and north by the inland or

outer margin of the Gulf of Mexico basin, in the east by the west flank of the Sabine uplift, and in the south by the fault belt, which forms the threshold of the basin, so to say, and over this threshold the East Texas embayment extends into the Tyler basin.

The Tyler basin is a syncline that is open in the south, at its threshold, and the strata engaged in the basin-forming at the west, north, and east of the basin dip toward the center, which is occupied by the youngest Cenozoic rocks of the sequence of strata engaged in the basin-forming. The Troup district is part of the basin but lies at its eastern margin not far north of the threshold fault belt. The nearest fault goes through the village of Summerfield, 11 miles south of Troup, and strikes approximately N. 74° E. Owing to the location of the district at the east margin of the basin, the strata of the district strike nearly north-south, to be exact N. 12° W. to S. 12° E., and dip westward (S. 78° W.). Taken over a large distance and averaged, the rate of dip is only 5¼ feet per mile, that is, approximately 1 foot vertically per 1,000 feet horizontally; however, the attitude of the strata is not uniform but changes slightly from place to place so that the rate of dip given above is not directly applicable in many places. How many local deviations from the normal strike and dip there are in this district can be seen from the structure contour lines drawn on the base of the Newby member of the Reklaw formation (fig. 3).

One readily noticeable regional structural feature is the gradual change in strike and dip in the southern part of the district. As the threshold fault near Summerfield is approached the strike turns from its normal north-south direction to a north-west-southeast direction and finally turns into a direction parallel to that fault, that is, nearly west-east, and the dip becomes southward. Simultaneously the rate of dip increases so that in the south part of the district the strata dip southward and toward the threshold fault at an increased rate.

This general attitude of the strata with a westward and southward dip is of profound importance to the distribution of the ball clay at the surface and hence to the chances of finding additional workable deposits. Because of the general westward dip of the strata over much of the district and the southward dip in the southern part, the strata come to lie at greater and greater depth in these two directions, and the older strata, for instance, the upper beds of the Wilcox group, outcrop in the district only in the eastern portion and disappear rapidly under the surface of the ground in westward and southward direction.

TABLE OF FORMATIONS

Cenozoic			GROUP	FORMATION	MEMBER
	Quaternary	Holocene		Alluvium and mantle	
		Pleistocene		Terrace deposits	
	GAP				
Tertiary	Middle Eocene	Claiborne	Queen City	Upper Queen City sand Omen glauconitic sandstone Arp sand	
			Reklaw	Marquez shale Newby glauconitic sand	
			Carrizo	Upper shaly sand and locally indurated sandstone Lower cross-bedded sands	
	Lower Eocene	Wilcox	Undivided	Uppermost beds only, including the ball clay	

Note: Wavy lines indicate disconformities.

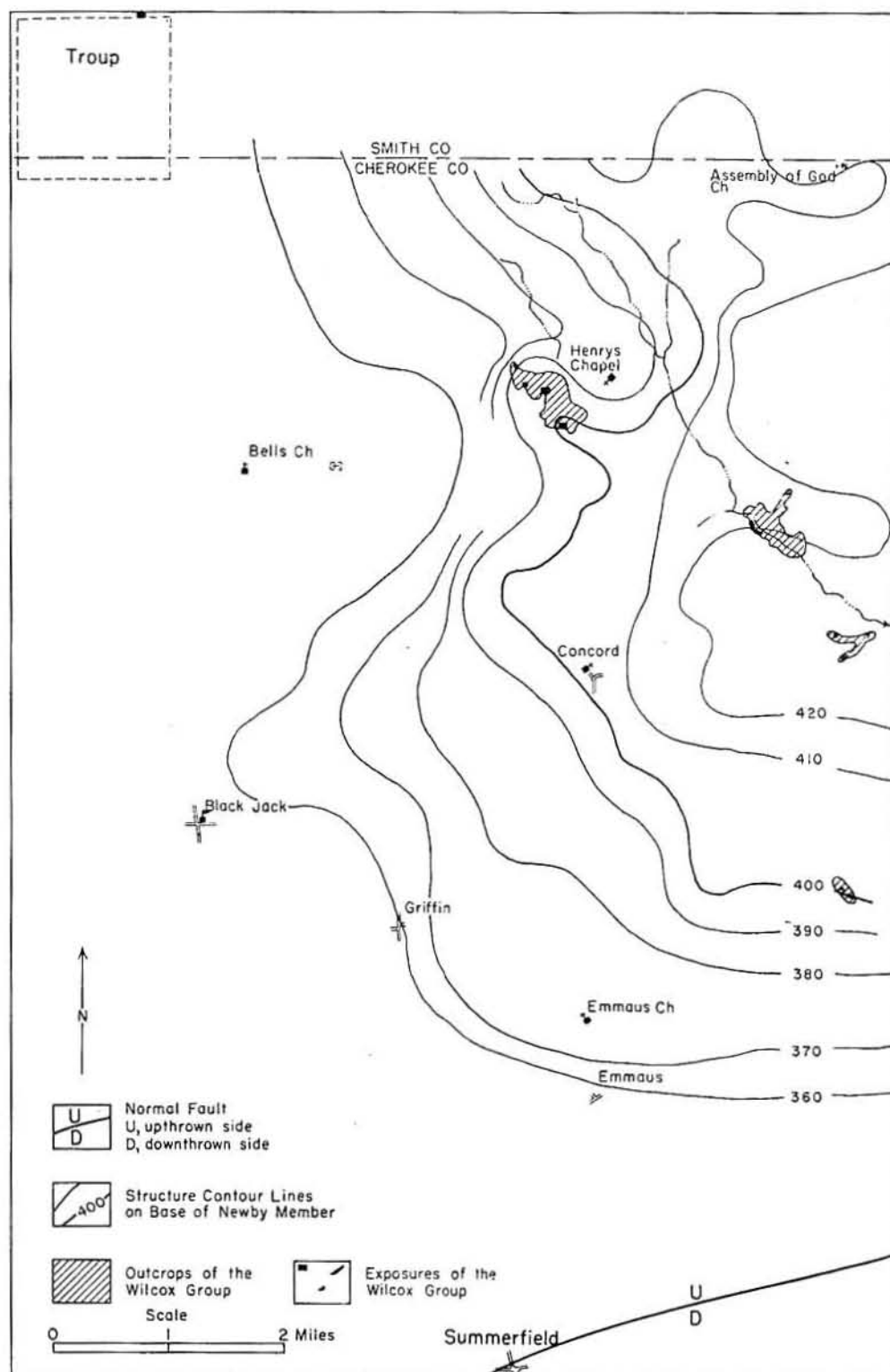


Fig. 3. Structure contour map of the Troup district, Cherokee County, Texas.

STRATIGRAPHY

The strata outcropping in the district naturally fall into two divisions, those that do and those that do not participate in the forming of the Tyler basin. Those that participate are older than those that do not.

The oldest strata that outcrop in the district are the uppermost beds of the Lower Eocene Wilcox group. The youngest strata that participate in the basin-forming are the beds of the Queen City formation in the Middle Eocene Claiborne group that lie stratigraphically above the Omen member of that formation. Hence, only a small part of the Wilcox and Claiborne groups is involved.

In addition there are outcrops of Pleistocene and Holocene deposits, such as creek-terrace, flood-plain, and swamp deposits. These do not participate in the basin-forming and some of them are so young that they are still forming. Also mentioned should be the mantle of soils, subsoils, weathered rock fragments, and slope wash that covers nearly all the district. Some of these mantle deposits are as old as Pleistocene, possibly even Pliocene, and some are forming even today.

For the purpose of this report only the Wilcox group, Carrizo formation, and Newby member of the Reklaw formation are of any importance. Hence the beds younger than the Newby member are not described in the following pages. (Compare the geologic map, Pl. I, and fig. 4).

WILCOX GROUP

In other areas, notably the south flank of the Sabine uplift, the Wilcox group has beds of marine or at least brackish water origin and hence can be divided into formations on that basis. But in the Troup district and immediately east of it, the Wilcox group, as exposed, does not show any trace of brackish or marine origin and is strictly nonmarine. Hence the formations recognizable farther away are not to be segregated in the district and the group remains undivided.

The Wilcox group is several hundred feet thick in this general region and forms extensive outcrops to the east, in the Sabine uplift. However, in the district under con-

sideration only limited and isolated portions of the uppermost 100 feet are visible and need be discussed. Nevertheless, these few feet are of great importance economically for they contain the ball clay of the district. The recognition of the ball clay as part of the Wilcox group is an important result of this study that might lead to the discovery of other deposits.

WILCOX GROUP UNDIVIDED, UPPERMOST BEDS

Surface distribution.—Natural and artificial exposures of the Wilcox group in the district were found only in small isolated places. These are from north to south:

(1) In the bottom of an auger hole, in the woods of a 98-acre tract 20 feet east and 100 feet south of the southeast corner of a 50-acre tract, 1,130 feet west of Sanders Cemetery, 1,200 feet north of the center of location (3), 1,580 feet south of the north line and 6,850 feet west of the east line of the James Hamilton survey (Pl. I).

(2) For a length of 200 feet in the bottom of the channel of that right tributary of Hampton Creek that flows southeastward past the dump heaps of the General Refractories Company clay pit, 2,400 to 2,350 feet airline distance from Sanders Cemetery in S. 80° W. direction, 1,400 to 1,600 feet northwest of the center of location (3), 220 to 450 feet south of the south fence of a 50-acre tract, in James Hamilton survey (Pl. I).

(3) In the clay pit of the Troup Works, General Refractories Company, located 3,275 feet in S. 81° W. direction from the church at Henry's Chapel and 850 feet north of the east-west running county road (Henry's Chapel to Bell's Church), 2,850 feet south of the north line and 7,000 feet west of the east line of the James Hamilton survey (Pl. I).

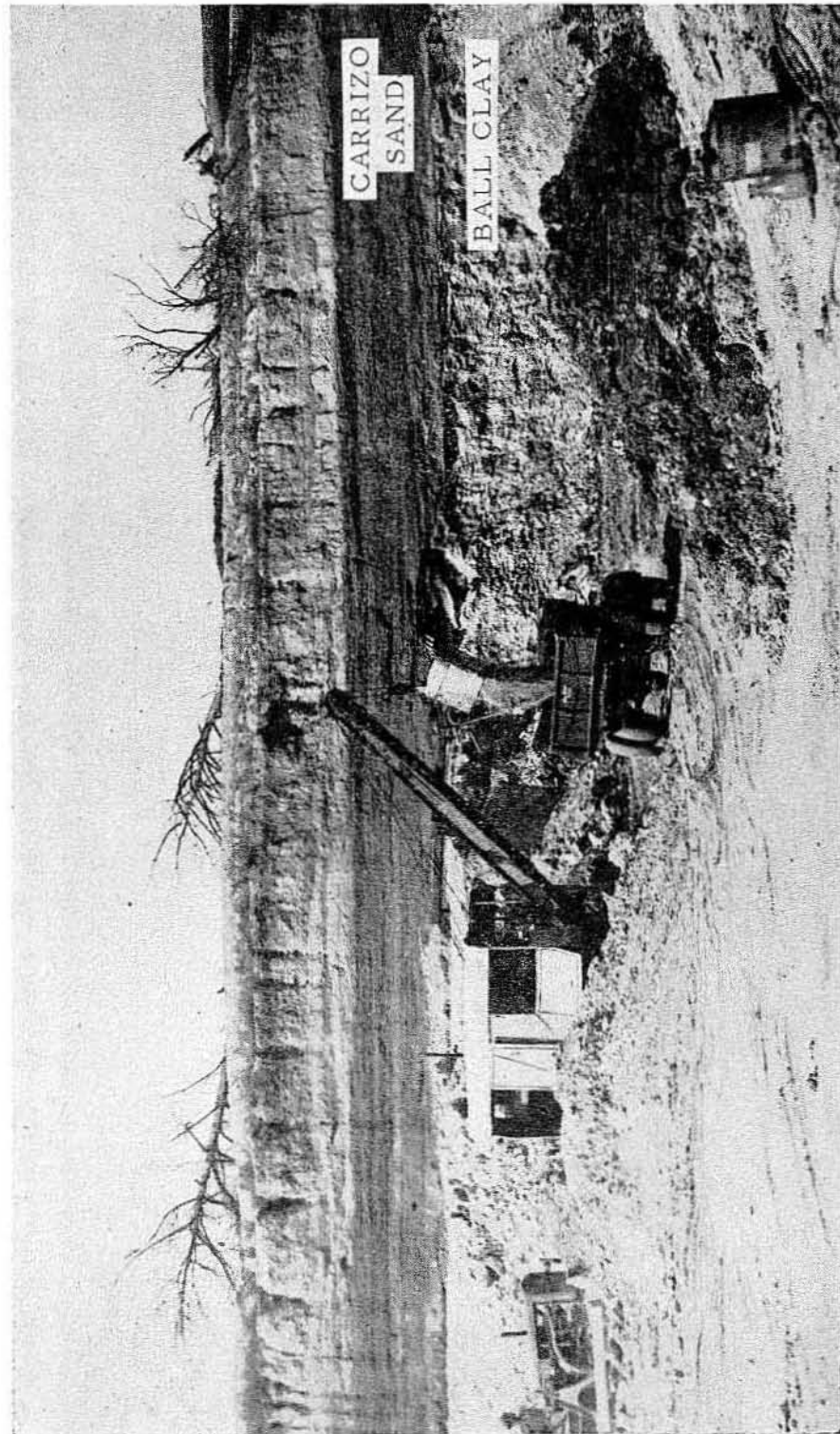
(4) In the bottom of a small abandoned clay pit at the edge of the flood plain, 850 feet due west of location (3) and 950 feet north of the east-west running county road, in James Hamilton survey (Pl. I).

(5) In the bottom of a test well, on the slope leading northward down to the flood plain, about 100 feet north-northeast of a house occupied by a Negro family, 1,000 feet southwest of the center of location (3), and 200 feet north of the east-west running county road (Pl. I).

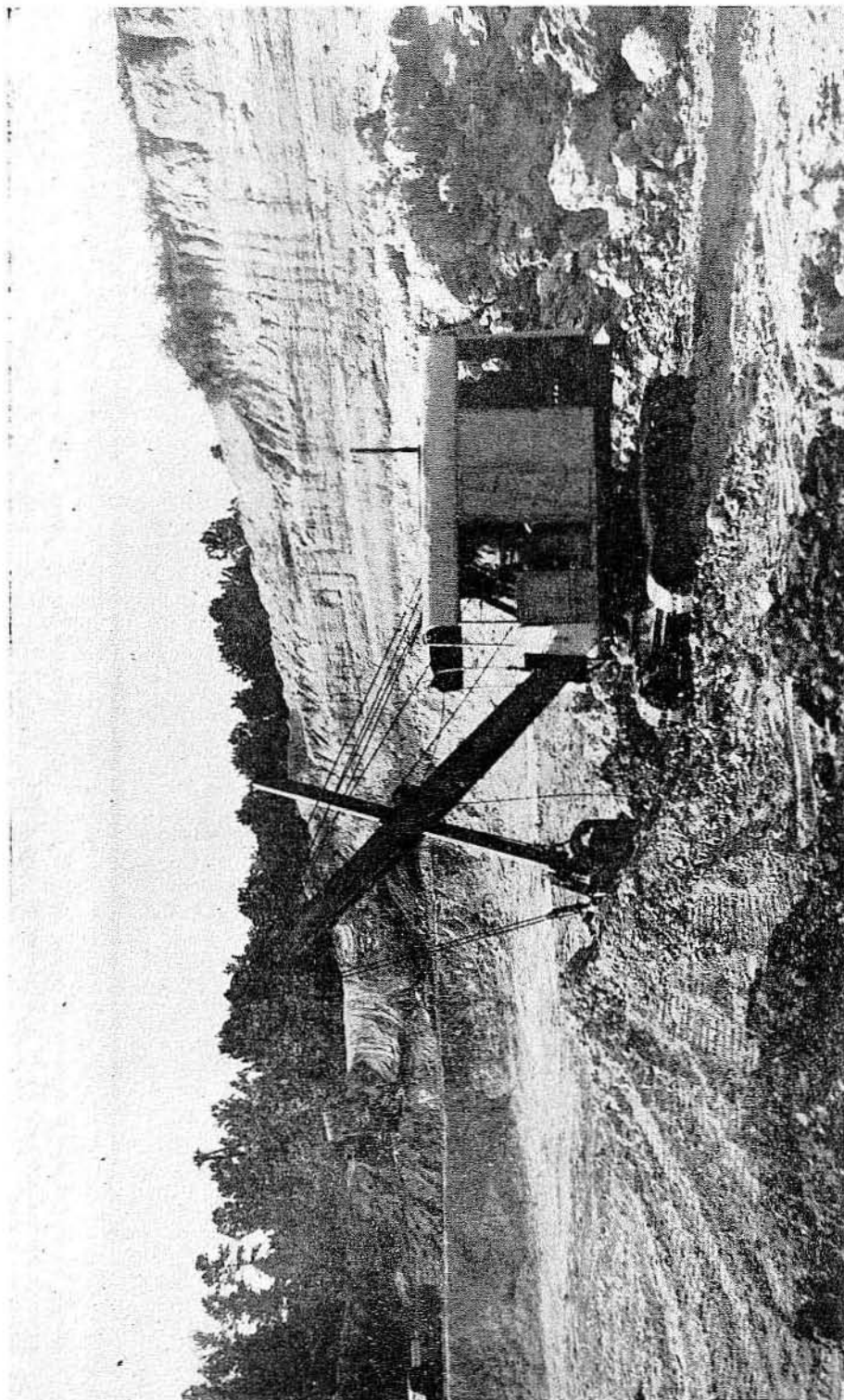
(6) In the clay pit of the Thermo Fire Brick Company, 3,150 feet in S. 50° W. direction from the church at Henry's Chapel, 600 feet south of the east-west running county road, 4,350 feet south of the north line and 6,100 feet west of the east line of the James Hamilton survey (Pl. I).

(7) At a dry waterfall of a small left tributary of Mill Creek, which crosses the east road fork 300 feet east of the county road fork at elevation 356, 300 feet northeast of an abandoned saw mill, and 1,400 feet in N. 64° E. direction from location (8) (fig. 3).

Oversized
page



Ball-clay pit of General Refractories Company, near Henry's Chapel, Cherokee County, Texas. View looking west toward west wall of pit. Drag line and truck loading ball clay are in front of deepest part of pit.



Ball-clay pit of General Refractories Company, near Henry's Chapel, Cherokee County, Texas. View looking toward southwest corner of pit.
Drag line in foreground loading ball clay.

(8) In the west side ditch of the county road, which goes in a general northeast direction from Martin's Chapel, at the bottom of the slope south of the swampy flood plain of Mill Creek, 0.24 to 0.25 mile by road from the road fork at elevation 356, about 1.8 miles southeast of the church at Henry's Chapel, 2,750 feet east of the west line and 7,050 feet north of the south line of the Wesley Dikes survey (fig. 3).

(9) For about 100 feet in the channel of a nearly straight eastward-flowing right tributary of Mill Creek, which rises 0.2 mile northeast of Martin's Chapel, about 1,200 feet upstream (or west) of its confluence with Mill Creek and 750 feet downstream from the pipe-line crossing, 900 feet in N. 22° E. direction from location (11), 500 feet north of the south line and 7,700 feet east of the west line of the Wesley Dikes survey (fig. 3).

(10) At the lower end of the slope just north of the swampy flood plain of the nearly straight eastward-flowing right tributary of Mill Creek, which rises 0.2 mile northeast of Martin's Chapel, where the pipe line crosses this tributary, 1,900 feet upstream from its confluence with Mill Creek, 800 feet in N. 27° W. direction from location (11), 350 feet north of the south line and 7,000 feet east of the west line of the Wesley Dikes survey (fig. 3).

(11) At a place where a north-south fence crosses the channel of a lively, spring-fed, north-flowing right tributary to the nearly straight eastward-flowing branch mentioned under locations (9) and (10), 650 feet south of their confluence and 850 feet in N. 16° W. direction from an abandoned house place, 320 feet south of the north line and 1,550 feet west of the east line of the A. J. Wait survey, 1.71 miles due east of Martin's Chapel (figs. 3 and 5).

(12) In two places, for 100 and 150 feet respectively, in the channel of Campground Creek, where this creek crosses the east-west running boundary between the Daniel Parker and F. J. Vallanova surveys, 3,000 to 3,300 feet east of the west line of the Daniel Parker survey and from 200 feet north to 150 feet south of the east-west running boundary between the two surveys, 2.18 miles directly east of the cross roads that has an elevation of 423 feet and is 1.85 miles south of Concord and 1.17 miles north of Emmaus Church (fig. 3).

It is readily noted from this list that the exposures and outcrops of the Wilcox group in this district are confined to the lowest places in the country, that is, to the creek channels or the flood plains or the immediately adjoining lowermost parts of the valley slopes. This is the effect of the very low dip of the entire Tertiary section here and of the fact that this area is the westernmost end of the Wilcox outcrops, where the Wilcox group through its low dip gradually disappears under the surface of the ground.

The locations listed above readily fall into four groups: one group of exposures (nos. 1 to 6 inclusive) is in the vicinity of the clay pits and is shown in detail on the geologic map, Plate 1; the second group (nos. 7 and 8) is on Mill Creek about 1.8 miles southeast of Henry's Chapel; the third group (nos. 9 to 11 inclusive) is on the nearly straight eastward-flowing branch about 1.7 miles east of Martin's Chapel; and the last group (no. 12) is on Campground Creek 2.75 miles southeast of Martin's Chapel (fig. 3).

This restriction of the exposures in four small areas is in part misleading and it is believed that much more extensive outcrops of the Wilcox group exist in the district but are under thin but effective cover by swamps in the creek bottoms, by thin alluvial silt, sand, and clay deposits in creek flood plains, and by fairly thick slope wash that clothes the base of the adjoining hills. This effective cover is there, because the outcrops of the Wilcox group are restricted to the lowest places in the country, and the lowest places are naturally those that are apt to receive a covering veneer of this kind. This condition is aggravated by the lower sands of the Carrizo formation, which overlies the Wilcox group. These sands are loose and porous and produce a deep, light gray, loose sand soil that washes readily. In addition there is perched ground water in the porous Carrizo where it rests on the impervious Wilcox group. The resulting outflow of the ground water in springs, seeps, and swamps increases the slope wash and gives rise to swamp vegetation, both of which make such an effective cover over the Wilcox strata. The twelve exposures listed above are then only those places at which either vigorous erosion by channel-cutting creeks or excavation by machinery removed this covering veneer so that the bed rock became visible. It is obvious that in many low places a small amount of excavating would expose strata of the Wilcox group, if these places were selected expertly.

Vegetation.—As explained above, the Wilcox group occupies the lowest places in the country. The uppermost beds of the Wilcox group in the district are very

largely impervious to water, but the overlying Carrizo formation, particularly its lower sands, is highly pervious. Hence there is perched ground water above their common boundary. This water issues in many low places as seeps, as swamps, and as springs, some of which boil up strongly. Therefore the usual vegetative cover of the Wilcox group in this district is swamps and bogs. Many of the creek bottoms of the district are impenetrable swamps and bogs with interspersed small lakes extending from one side of the alluvial valley to the other. Such swamps are indicative of the presence of the Wilcox group at shallow depth below the bottom of the swamp. The relationship of the Wilcox group, the perched ground water, and the issuing springs feeding into swamps are particularly clear at location (8). Here innumerable springs and seeps issue near the Carrizo-Wilcox contact at the foot of the hill and slightly above the level of the Mill Creek bottom for more than 1,000 feet. This issuing ground water produces a narrow strip of swamp and morass that hugs the foot of the hill at the edge of the flood plain. A spring, which boils up, and many other less vigorous springs and seeps are in the bed of a short tributary to the north; many swamps and peat bogs exist in the short northern tributaries of Mill Creek for 3,500 feet southeast of the county road bridge. In this area the Wilcox group is visible only in the road ditch (location 8) and at a small waterfall (location 7); the remainder of the Wilcox is effectively hidden by the swamps, bogs, thin alluvial cover, and slope wash of Carrizo sand soil.

Composition.—The composition of the uppermost Wilcox beds in the district is different from place to place; this condition is due to both the lenticular nature of the beds and the erosional effect of the overlying Carrizo sand, which is discussed on page 22. The best exposure, hence the best place to study the composition, is the clay pit of the General Refractories Company, which has been excavated deeply into a hill spur and has uncovered fresh, unweathered beds (Pls. II and III). In the Henry's Chapel area, that is, in the clay pits and their vicinity, the upper-

most Wilcox beds consist of the following sequence (fig. 4):

Top	Thickness Feet
(e) Ball clay	8.2
(d) Ball clay grading into lignitic clay and lignite.....	4.1
(c) Slightly sandy lignitic clay.....	0.2
(b) Fine sandy lignitic clay.....	2.6
(a) Gray argillaceous very fine sand.....	17.0

The ball clay (e) is very tough and harder than the ordinary Eocene clays, fractures usually hackly and irregular and occasionally subconchoidal, has a uniform color of light bluish gray where it is fresh but bleaches to almost white on prolonged exposure to the sun, and is devoid of any bedding or bedding parting planes (frontispiece). In the clay are countless vertical or nearly vertical, dark brown to black, thin but very long, lignitic tubes. On tracing the tubes downward they are found to fork downward at acute angles of divergence, but these forks are rare. The tubes are composed of a central core of ball clay encased by one or several nearly parallel concentric outer walls of lignite. The tubes are slender; their average and common diameter is 2.5 mm, although they vary from 1 to 3 mm in diameter. Individual tubes can be traced downward for several feet; evidently they are at least 8 feet long, because they penetrate the entire 8.2-foot thick stratum, and are more abundant in the upper than in the lower part of the stratum. The tubes are the fossilized remains of roots of ancient plants that grew in Wilcox time upon the ball clay as a soil. Because their cores are filled with the same ball clay that surrounds them, the plants responsible for them must have grown and decayed during the time the ball clay was deposited, and the roots were filled with the ball clay after their decay. The clay is cut and separated into irregular and angular blocks by numerous gently inclined slippage planes. These planes are covered with glossy and finely grooved, wavy slickensides. They dip up to 43° in various directions so that the blocks of clay that they separate have various wedge or lens shapes. The slippage planes branch here and there and occasionally intersect each other. The amount of slippage that each

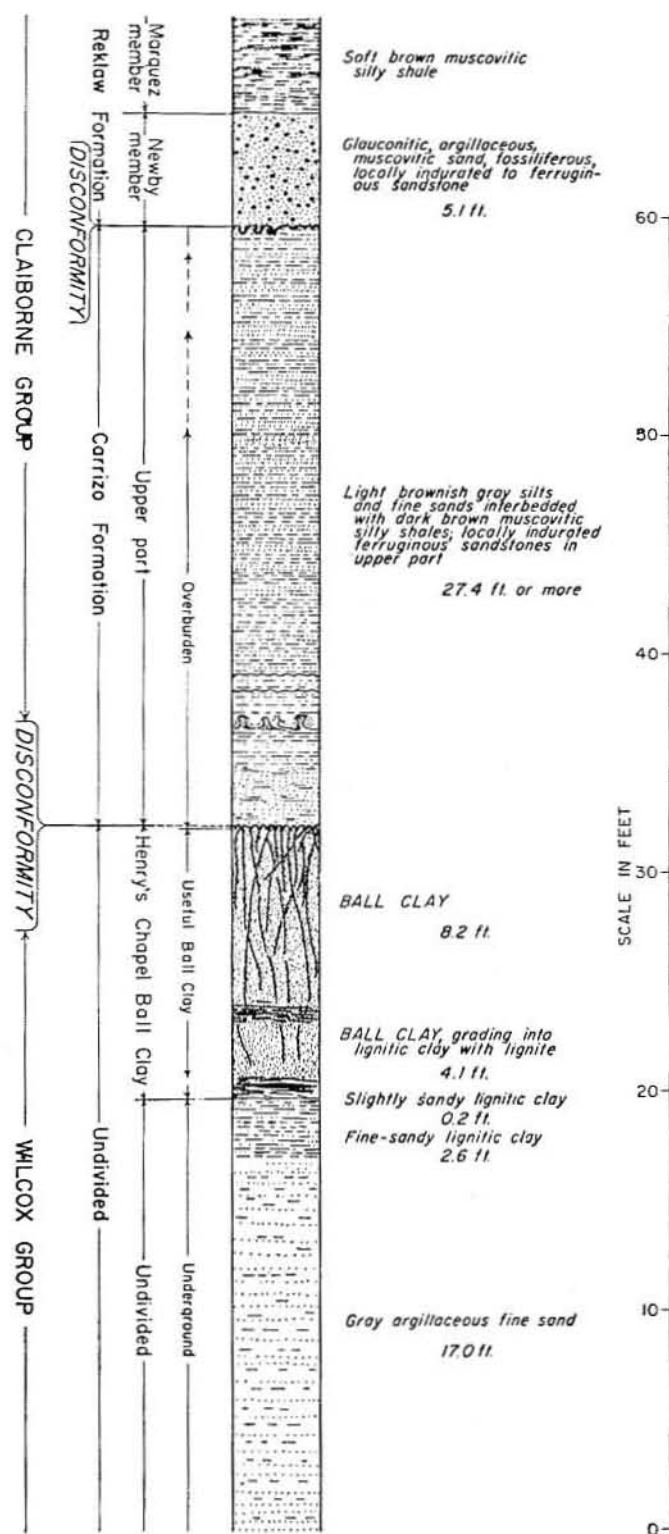


Fig. 4. Stratigraphic section of the ball-clay deposit near Henry's Chapel. Useful portion of ball clay is indicated by stippling.

one has undergone is evidently very small, and in the cases that could be checked by the offset of the vertical fossil roots, it does not exceed 1 or 2 mm.

An occasional impurity of the ball-clay stratum is siderite balls (Pl. IV, A). These balls are heavy and up to 5 inches in diameter. They consist of many small grains of siderite surrounded and held together by ball clay. The grains are 1 to 3 mm in size, roughly spherical in shape; but where they are crowded they have small facets of contact yet are separated by a thin film of clay. Each grain is composed of lamellar and fibrous crystals of siderite radiating from the center of the grain; individual crystals are up to 0.02 mm wide. Under the microscope the freshest of the crystals are colorless to yellowish brown, but most of them are opaque due to alteration products. The refractive index n_a is near 1.63. In the clay matrix of the siderite balls and on the boundary between clay and siderite grains and less commonly in the interior of the grains are small crystals of pyrite and possibly marcasite. The recognizable crystals are pyritohedra. The grains weather readily to a rust-brown opaque color and give the siderite balls a brown-speckled appearance. Most of the grains are weathered.

The second stratum (d of above) is 4.1 feet thick and very similar to the overlying ball clay (e of above) but has no uniform light bluish-gray color. Instead it has on top a layer, 0.8 foot thick, that is nearly black due to a much greater admixture of finely divided lignitic matter. Below is a lighter, grayish layer, 2.5 feet thick, then again a second black layer of 0.8 foot thickness. These layers are ill defined and only roughly horizontal. They fluctuate up or down a little as shown in the General Refractories Company clay pit, but in the Thermo Fire Brick Company clay pit the upper black layer fluctuates considerably, and at one time, when the face of the pit was freshly excavated, it was seen to extend in flame-like tongues irregularly upward into the main body of the ball clay. Aside from these features there are no distinct bedding planes, and the two black layers grade well into those above or below them. Fossil roots are few in

the stratum; so are the slickensides. The lower of the two black layers encloses lenses of xyloid or woody lignite several feet long but only a few inches thick (Pl. IV, B). This lignite is very light and fairly hard, when dry, and splintery; it breaks easily with the grain into horizontal sheets, but the cross-grain break is subconchoidal to splintery; the long-grain vertical break is similar but more splintery. The color is sooty black with a silky sheen, and the grain shows in very fine parallel streaks of silky sheen. Each lignite lens is one piece of lignitized wood flattened by compaction. Associated with the lignite is a great deal of pyrite or marcasite. Hence the lower part of the 4.1-foot thick stratum where the lignite is found cannot be used as a commercial clay.

The third stratum (c of above) and those below it are not visible in the clay pits but have been reached by auger holes. The third and fourth strata are similar to the overlying clay but are sandy and produce a scraping sound during augering. Under them lies a stratum of light gray to faintly brownish, argillaceous very fine sand with a few tiny muscovite flakes (a of above).

Description of individual Wilcox exposures.—The following are local details of the Wilcox strata. The listing is by locations as given on page 12.

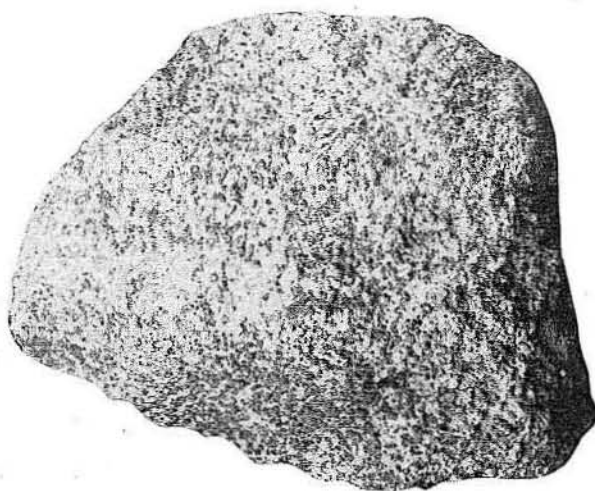
(1) The cuttings dumped near this auger hole indicate that the ball clay was encountered below the Carrizo sand, which crops out at the surface. Depth and thickness data are not available.

(2) The ball clay is exposed in the bottom of the creek channel, which has cut into the clay to a depth of about 2 feet. The fire clay is overlain by Carrizo sand and this in turn by the flood-plain deposit of the creek.

(3) In the General Refractories Company clay pit the Wilcox strata exposed by excavation are (Pls. II and III):

Top	Thickness Feet
(e) Ball clay, uniformly gray.....	8.2
(d) Ball clay, grading into lignitic clay (dark colored, 0.8 foot; gray colored, 2.5 feet; black colored and with lignite lenses, 0.8 foot)	4.1

The section excavated in the pit was extended downward by an auger test hole put down by Mr. H. C. Fountain on May 1, 1946. This auger hole was located at the east edge of the pit 6 feet from the westernmost white oak tree. The log was as follows:

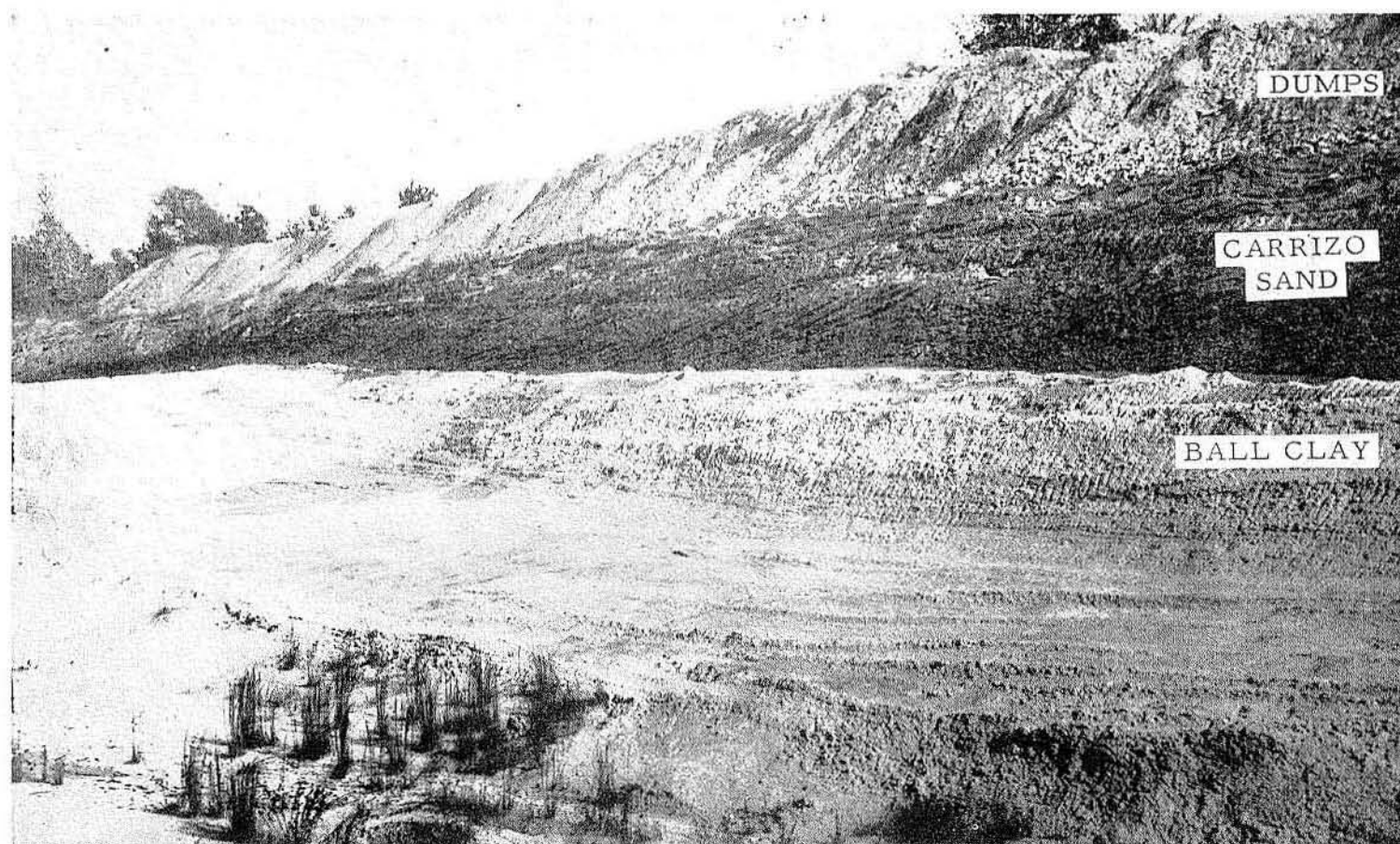


A



B

A, Siderite grains in ball clay from pit of General Refractories Company. B, Lignite pieces from lower part of ball clay at same locality. Natural size.



Ball-clay pit of Thermo Fire Brick Company, near Henry's Chapel, Cherokee County, Texas. View looking toward east end of pit. Cross grooves on Carrizo sand are the tooth marks of the drag line. Water rills and vehicle tracks visible on ball clay.

	Depth Feet
Debris from overburden of clay pit.....	0- 5.5
Ball clay, tough, light gray, dry, rather brittle feeling, made no scraping noise during augering, hence was nearly free of sand. This portion of the log is composed of beds (c) and (d) of above	5.5-15.1
(c) As above, but slightly sandy, made a scraping noise during augering	15.1-15.3
(b) Clay as above, with trace of fine sand	15.3-17.9
(a, upper part) Light gray and buff mottled, argillaceous fine sand ..	17.9-18.2
(a, upper part) Yellow-buff, fine sand ..	18.2-18.3
Total depth	18.3

(4) In the abandoned pit the ball clay is exposed through excavation. The clay lies under alluvial cover.

(5) The dumps of the test well have ball clay. No information is available as to depth or thickness here.

(6) The clay pit of the Thermo Fire Brick Company (Pl. V) furnishes a very similar section of the strata exposed in the excavation. However, this pit is worked only intermittently; hence rain wash has obscured a considerable portion of the working face, and observations are not easily made. The Wilcox strata in this clay pit are as follows:

	Thickness Feet
Wilcox group, uppermost beds: (e) Ball clay, very similar to that of the other clay pit; bedding is absent except for irregular nearly horizontal thick streaks of more carbonaceous, hence darker clay; the bottom layer [upper part of (d)] is very dark brown; at one time when the pit was worked more often, the dark streaks were seen to extend in flame-like tongues irregularly upward into the light gray main body of the clay, but later rain wash obscured these features. The lignitized traces of plant roots are present here too; they extend for 7 feet down from the top of the Wilcox ball clay.....	10.0

The section excavated in the pit was extended downward by an auger test hole put down by Mr. H. C. Fountain in May, 1946. This auger hole was located in the north end of the pit and was logged as

	Depth Feet
[lower part of (d), (c), (b)] Clay....	0.0- 5.0
[upper part of (a)] Soft light gray argillaceous fine sand.....	5.0- 6.0

(a) Firm light gray, spotted with yellow, fine sand with thin argillaceous streaks 6.0-17.1

(7) At this waterfall of an intermittent creek branch, plastic, very light greenish-brown to gray, massive clay with few rusty yellow stain spots, visible for a depth of about 3 feet, lies under alluvial sands and sandy clays. This clay may be the weathered exposure of a fire clay, but this clay is probably not the same stratum as the ball clay of the clay pits.

(8) The exposures in the ditch made by the road-grading machinery are obscure, and a great deal of water is seeping out. Most of the material is a tough, light gray to nearly white, massive or obscurely bedded, argillaceous, fine silt with some tiny muscovite flakes, which has a few rusty yellow-brown stains along porous channels that were made by roots of vegetation growing upon it. Some of the layers are composed of porous, less argillaceous, fine sands and silts. As only 5 feet of section are visible one could not really gain a good concept of the composition of the Wilcox group at this place. Fire clay was not seen but may be present nevertheless; if present it is not the same stratum as the ball clay of the clay pits.

(9) A leached clay, soft, tough and gummy, almost white, is visible here to a depth of about 1 foot.

(10) In the small cut made by the pipe line a 9-foot high exposure shows the following:

	Thickness Feet
(c) Carrizo sand soil: Loose, white to light gray, sandy soil.....	2.0
(b) Weathered Carrizo sand: Firm to coherent, rusty brown, muscovitic, medium-grained sand.....	2.0
(a) Wilcox group: Firm, dark grayish-brown where freshest, light grayish-brown where less fresh, massive, muscovitic, silty clay.....	5.0

(11) The next best section of the uppermost Wilcox beds is visible here (fig. 5). This locality is at a small waterfall, 0.6 foot high, directly

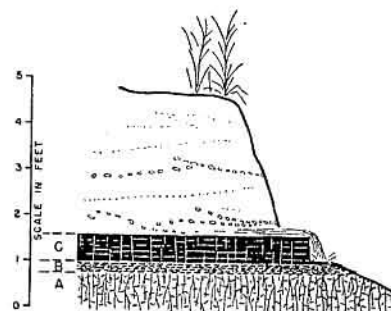


Fig. 5. Wilcox strata exposed at location (11), northeastern Cherokee County, Texas.

under a fence. The waterfall is caused by the superior resistance of the exposed lignite bed. Here the following sequence is exposed for about

20 feet each way from the waterfall in the stream channel and is covered at the sides by various alluvial sands derived from the Carrizo sand, which is exposed farther upstream.

Section in stream channel at location (11).

Top	Thickness Feet
Wilcox group, undivided, uppermost beds.....	
(d) Topmost beds not exposed.....	?
(c) Indurated, brittle, black to brown-black, thinly bedded, shaly, impure, earthy lignite with countless tiny flakes (muscovite?) on bedding planes; cut by sub-parallel, vertical, closely spaced joints	0.6
(b) Firm, black, thinly bedded, muscovitic, very lignitic clay with short slickensided parting planes and pieces of lignite.....	0.3
(a) Soft but very tough, plastic, medium gray-brown when fresh but bleaching to a light gray color, silty underclay with vertical lignitized root imprints. Bottom not visible	0.8

Downstream from this place to the mouth of this branch there are no exposures, except those of coherent, dirty rust-orange, clayey, alluvial sands at the banks of the channel. Upstream there are several steep banks with loose, dark brown when fresh, medium-grained sands with a few chocolate-brown, thin shale partings that are exposures of the Carrizo formation.

(12) Exposed to a depth of about 1 foot is a firm and tough, slightly plastic, whitish-gray with orange-yellow stains, massive, muscovitic, argillaceous silt.

Subsurface distribution.—In June 1947 a geophysical crew drilled 53 shot holes in the region to the north of the clay pits. The area covered by them begins in the south along Farm Road 13 and extends northward to the county line. All holes were drilled rapidly with a fishtail bit. No notes were kept by the drillers during the drilling, but driller's logs were written at the end of the day from memory alone. Hence too much reliance was placed on the memory, and errors were unavoidable particularly because drilling was very rapid. Also the drillers were not trained in the recognition of the strata through which they were drilling nor were they familiar with the area. Therefore the records of these shot holes are not too reliable. However, these shot holes and their driller's logs are the only subsurface information available and are useful to some extent.

A few of the holes were drilled while the writer was present and were recorded reliably at that time. The cuttings of the other holes were inspected and afforded some observations as to the nature of the strata drilled through. All data concerning these shot holes are listed separately on pages 31 to 37.

The shot holes prove the great underground extent of a fire clay or of similar silty clays north of the clay pits. For instance, shot hole 50 located 1.81 miles north of the church at Henry's Chapel encountered an almost white clay with small slippage planes at a depth of 49 feet. It is rather important to know that the ball clay extends that far underground, because this fact indicates that the ball clay or similar clays may have a large distribution and hence may be available elsewhere.

CLAIBORNE GROUP

CARRIZO FORMATION

Surface distribution.—Outcrops of this formation are extensive and occupy the eastern half of the area mapped roughly east of a north-south going line through Henry's Chapel and Concord. East of the area mapped in detail Carrizo outcrops extend for many miles and form large outliers around Henderson in Rusk County. The westernmost exposures of the Carrizo are found in the mapped area in the creek bottoms and their channels and are listed below.

In the channel of Grissom Creek the northwesternmost exposure is in a meander, convex to the north, 1,500 feet south of the Smith-Cherokee County line, 5,550 feet northeast of the nearest place on Farm Road 13, and 6,100 feet due north of the Hampton Creek bridge on that road. Interbedded sands and shales of the upper Carrizo are here exposed in the channel for about 250 feet and are overlain by flood-plain alluvium.

In the channel of Hampton Creek the northwesternmost exposure of Carrizo is on the right bank where the creek swings against the western edge of its valley to form a small bluff, just below a wagon-road ford, 1,100 feet northeast of a farm house, 1,800 feet northeast of the nearest place on Farm Road 13, and 2,850 feet upstream of the bridge of that road over

Hampton Creek. Here the Carrizo formation consists of 3.4 feet of carbonaceous shale with fine silt partings and is overlain by 2.8 to 4.0 feet of glauconitic sands of the Newby member; this in turn is overlain by alluvial gravel and clay.

In the creek which flows past the north end of the General Refractories Company clay pit, the westernmost Carrizo is exposed in the channel and a small bluff on the left side of the creek, 5,050 feet west of the church at Henry's Chapel and 2,150 feet south of the nearest place on Farm Road 13.

In the branch that flows eastward between the two clay pits, the westernmost Carrizo is exposed in two bluffs, one on each side of the branch, 2,250 and 1,950 feet west of bench mark 357.

In Campground Creek the westernmost exposure of the Carrizo formation is in a bluff on the left bank, 3,000 feet southwest of the church at Concord and 2,650 feet west of the road that goes straight south from Concord. Thin-bedded brown sands with shale partings are visible here.

In a right tributary of Campground Creek the westernmost Carrizo is exposed for 500 feet in the deeply cut meandering channel below a waterfall with a deep pool, 5,950 to 5,600 feet south-southwest of the church at Concord and 3,000 to 2,500 feet west of the road that goes straight south from Concord.

Vegetation.—Soils of the Carrizo formation are light gray and sandy; they are podsol soils. The original vegetation was a nearly continuous cover of oak forest with underbrush. The individual trees were widely enough spaced so that the white sandy soil showed between the trees. Remnants of this forest cover are not extensive because most of the land has been cleared for plowing. In the last two decades some of the cleared fields have reverted to pasture. Much of the cleared area has been terraced, and contour plowing is practiced fairly commonly.

Composition.—The Carrizo formation can be divided into two parts for convenience of discussion. The lower part consists of cross-bedded or lenticular sands. These sands are loose and only slightly cemented; their color when fresh is light brownish gray due to an admixture of finely divided carbonaceous matter. On

weathering they assume a pinkish iron-stained color when in the B-zone of weathering or become whitish gray. Soils derived from this lower part are deep, light gray sands with comparatively little admixture of humus. The bedding is water-made cross-bedding. Porosity is high. Because this part of the Carrizo sand is lacking in coherence it washes very readily; hence exposures of it are very rare and do not stand up long.

Toward the top of the Carrizo formation the grain size decreases, and shales make their appearance. This change is, however, very gradual and does not take place at the same stratigraphic level in different localities. Hence there is no sharp demarkation between the upper and the lower part of the formation.

The upper part of the Carrizo formation consists of an interbedded sequence of porous fine sands, clayey or shaly fine sands, and silty shales, all more or less carbonaceous and even bedded. Induration and cementation are variable but owing to the abundance of shale and argillaceous cement the sequence is normally firm; hence it stands up comparatively well under active erosion. This is the reason for the great abundance of excellent exposures of this upper part in ditches and road cuts; such ditches and cuts stand up fairly well and exposures remain visible for a long time. In contrast the lower part of the Carrizo formation is rarely exposed in ditches and road cuts, because in such places the sands wash over too easily and do not remain in place very long after they have been cut into. Coherence of the upper part of the Carrizo in the clay pits is such that chunks and even large blocks of it may fall down from the walls and retain largely their coherence and shape. Locally the sandy beds in the upper Carrizo are cemented by limonite to hard, harsh, black-maroon to rusty brown to variously orange-red, usually massive or irregularly bedded, ferruginous sandstone of variable thickness. Such rock is important as road metal and building stone and as an objectionably hard part of the overburden of the ball clay.

Color is dependent on the amount of carbonaceous or lignitic matter present. The freshest unweathered upper Carrizo has a medium to dark gray color, streaked

according to the bedding. The darker layers may grade even into sooty black if finely divided lignitic matter is abundant. The darker layers are usually the more shaly ones and weather to a chocolate-brown that gradually bleaches on exposure to the sun.

The freshest sandy layers have a grayish color from finely divided lignitic particles; there is also a slight bluish cast to this color perhaps due to finely divided marcasite or pyrite. Weathering is very rapid, and in the freshly excavated walls of the clay pits the sand layers soon become discolored by limonite to a depth of a few millimeters. The weathered colors of the sands vary from dirty rust-yellow-brown, the most common color, to orange-red and light rusty yellow. These colors produced by weathering are usually bright tending toward the yellow part of orange, and due to the interbedding of shales and sands they are banded.

Bedding is even, extensive, and thin in the upper Carrizo. Individual layers no more than 2 inches thick can be traced in the General Refractories Company clay pit nearly through the whole excavation, that is, for at least 400 feet. The base of some of the thicker sand layers shows a

shaly layer visible in the General Refractories pit is penetrated by countless gray, sand-filled boreholes of 3 to 8 mm diameter.

Contorted bedding is present in only one layer, one of the thicker sand layers of the upper Carrizo. The layer is present only in the immediate vicinity of the clay pits where it is visible in the two clay pits (locations (3) and (6)) and in the channel of the creek to the northwest (location (2) of p. 12). The distribution proves that it is traceable for at least 3,500 feet from the northwest to the southeast, although its maximal observed thickness, in the Thermo Fire Brick Company pit, is only 1.5 feet. In all three places it occupies the same stratigraphic position, 4.4 feet above the base of the Carrizo-Wilcox contact (fig. 4). As an average it is only 0.8 foot thick and only the lower part has contorted bedding (fig. 6). Its bedding is turned up in rolls, the heads of which are about 0.9 foot apart. The contorted bedding is apparently caused by subaqueous sliding that took place shortly after deposition of the basal part of the bed but before the upper part of the bed was laid down, because the upper part and all succeeding beds are undisturbed and level.

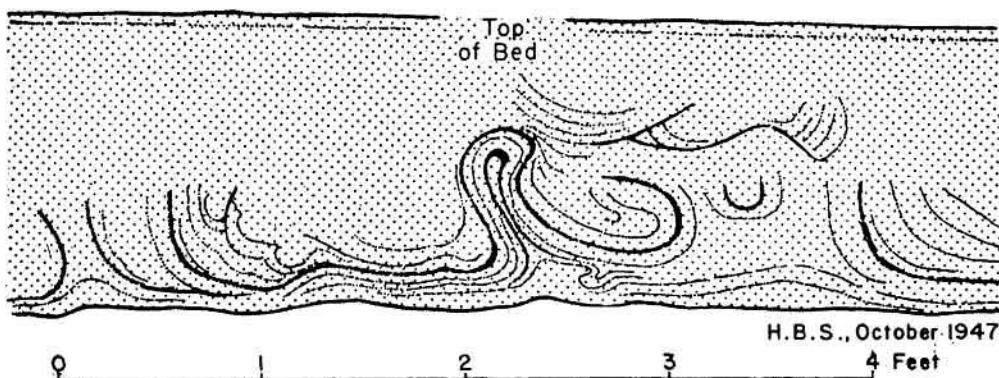


Fig. 6. Contorted bed of sand in the Carrizo formation, General Refractories Company pit near Henry's Chapel, northeastern Cherokee County, Texas.

slight amount of bulging caused by channeling. Ripple-mark bedding is present and can be recognized in vertical section by the small lenses of sand, half an inch thick and $2\frac{1}{2}$ inches long, that are strung in a horizontal continuous layer and are bounded on top and bottom by wavy shale partings. One grayish-black, more lignitic

Massive bedding is rare in the upper Carrizo section; it was found only in two places. One of these is the bottom layer of the Carrizo in the General Refractories Company pit. The layer is 2.5 feet thick, massive to indistinctly bedded; its more argillaceous, darker, and more lignitic parts are discontinuous clouds extending

rarely for more than 1 inch laterally; the more sandy, lighter colored, less lignitic parts have obscure sandy pipes or boreholes (?) that weld the whole into a massive indistinctly bedded unit. The bed is a slightly muscovitic, argillaceous, lignitic silt or fine sand with lenses of xyloid lignite.

In these interbedded sands and silty shales of the upper Carrizo muscovite is fairly abundant—perhaps slightly more abundant than in the overlying Newby member of the Reklaw formation but definitely much less abundant than in the Marquez shale member. Lignitic matter finely divided is present everywhere and may become abundant in some thin layers. The shales have more of it than the sands as a rule. Small pieces of black lignite are not uncommon on bedding planes, and some fossil leaf imprints were seen. Slightly larger lenses of brittle, sooty black, silkily lustrous, xyloid lignite are frequent in the base of the massive, 2.5-foot thick basal layer of the Carrizo in the General Refractories Company pit, where they occur in the basal 0.1 foot right above the Wilcox contact. They are up to 3 mm thick and up to 3 cm long and taper out to very thin ends at their margins. These feathered margins prove that this lignite is syngenetic lignite and not lignite pebbles derived from the underlying Wilcox deposits. Marcasite dust probably is present in all layers, contributes to the bluish cast of the sand layers where they are fresh and unweathered, and is the cause of some of the rapid weathering. Marcasite concretions are the only concretions present but are nonetheless rare. They are silty and up to 2 inches in diameter. They were found only in the contorted bed and in the basal 2.5-foot thick, massive layer of the Carrizo in the General Refractories Company pit.

The more sandy layers of the Carrizo in the Thermo Fire Brick Company pit are cut locally by vertical joints, which stop at the more shaly breaks of the sequence. The joints are of tectonic origin and give a measure of the coherence of the sands which is just strong enough to allow jointing to develop.

Aside from the lignitized plant leaves mentioned above no fossils or imprints

of them are present in the Carrizo sand in this region.

Ferruginous sandstones.—Locally sandy portions of the upper part of the Carrizo formation are highly indurated through infiltration of limonite into the pore spaces between the sand grains. Such ferruginous sandstones are hard and harsh and black-maroon to rusty dark brown to ocher-yellow in color and rarely tend to orange-red or other reddish colors. Bedding is variable from place to place; massive as well as well-bedded sandstones are present. In some of these sandstones are layers of small flat shale pebbles; usually these pebbles have been removed by weathering and the resultant cavities are filled partly or wholly by an earthy ocher-yellow limonite lining. Some layers have abundant muscovite flakes.

These indurated portions of the Carrizo formation are not extensive. One indurated lens that is particularly well exposed is 450 to 1,050 feet north of Farm Road 13 in Wesley Dikes survey just outside of the southwest corner of the T. A. Pratt survey, 2.35 to 2.5 miles east of the church at Henry's Chapel. The size of this lens is 850 by 400 feet, and it may be about 10 feet thick. Such a size is probably about the maximum size attained by the indurated portions of the Carrizo formation. In the General Refractories Company clay pit, at the top of the south face of the pit, a 2.1-foot thick, very hard and harsh, black-maroon to rusty dark brown, massive, ferruginous sandstone ledge was uncovered in October 1948. This ledge was lenticular and wedged out northward; it had not been previously uncovered until the south face of the pit had been moved that far back into the hill spur. In other places the entire indurated portion of the upper Carrizo consists of a few large blocks that have been freed by weathering. Thicknesses of such indurated portions are from 1 to 10 feet only.

Thickness.—Thickness data were obtained from favorable exposures and outcrops by alidade or hand level and from geophysical shot holes. These data demonstrate the formation to be highly variable in thickness. The smallest thickness recorded is 24 feet in geophysical shot hole 50. As this figure is unusually small and

from a geophysical shot hole, some doubt might be entertained as to its reliability were it not that nearly the same figure can be obtained by alidade at the Thermo Fire Brick Company pit, where the smallest thickness measured is 27.4 feet. At a distance of only 1.85 miles from this pit the greatest thickness was measured in this region. It was measured along the county road that connects Henry's Chapel with Martin's Chapel and rises southwestward from the swampy bottom of Grissom or Mill Creek to the top of the upland at 420+ feet above sea level. Along this road, at the edge of the swampy bottom, the Wilcox group is exposed at location (8); higher up, cuts and road ditches expose the lower, cross-bedded part of the Carrizo and the upper, more level-bedded part, which is quite sandy here; at the top of the hill, road ditches expose upper Carrizo sand and some reworked pebbly sands. There is no trace of the Newby member at the top of the road nor at the top of the 440+-foot high sand hill, 1,300 feet east of the right-angle turn of this road; this 440+-foot high hill is only 3,500 feet south of location (8). Measuring by hand level from the top of the Wilcox at location (8) to the top of the upland along the road gave 104 feet as the thickness of the Carrizo here. This is a minimum, but the thickness cannot be much more than 104 feet because Newby outliers are a short distance to the south in the vicinity of Martin's Chapel and lie at 420 to 410 feet above sea level. The following is a tabulation of recorded thickness data in this region:

Location	Thickness Feet
Geophysical shot hole 51.....	50
Geophysical shot hole 50.....	24
Geophysical shot hole 49.....	98.3
Geophysical shot hole 46... approximately	50
General Refractories Company pit,	
northeast corner	29.6
southeast corner	31.5
southwest corner	34.8
northwest corner	35.0
Thermo Fire Brick Company pit,	
center of south wall.....	27.8
west end of south wall.....	27.4
Above location (8)	104.0 +

The reason for the rapid and apparently erratic change in thickness from place to place is to be found in the nature of the

basal contact of the Carrizo formation, which is discussed below.

Wilcox-Carrizo contact.—It is now well known that this contact is disconformable² wherever it is exposed in Texas. In the Troup district observations can be made that prove in more than one way the presence of an erosional disconformity at the Wilcox-Carrizo contact.

Detailed observations of minute features of the contact between the two can be made easily in the two clay pits (locations (3) and (6)) and in the channel of the creek near by (location (2)). As at these three places features of the contact are the same, only observations made in the General Refractories Company pit (location (3)) need be given here. The contact is abrupt without any transition between the Wilcox and the Carrizo. The ball clay is abruptly overlain by shaly sands of the Carrizo. Taken over the entire clay pit, that is, for a maximum distance of about 430 feet, the attitude of the contact is even and nearly level, and maximum differences in elevation of the contact amount to only 5.4 feet. Elevations above sea level of the contact are 359.7 feet in the northwest corner, 359.9 feet in the southwest corner, 365.1 feet in the northeast corner, and 363.2 feet in the southeast corner of the pit. In detail the base of the Carrizo sand is irregular (Pl. VI). Countless small extensions of the Carrizo reach 1 to 2 inches down into the ball clay, and some of the longer extensions have been traced as deep as 4 inches. A few of these Carrizo sand extensions can be demonstrated as fillings of shrinkage cracks in the ball clay; most are fillings of the top part of the slender fossil root tubelets in the ball clay. Aside from these extensions the base of the Carrizo sand is minutely irregular and rises up or down a fraction of an inch over very short distances. There are practically no ball-clay pebbles in the basal Carrizo.

Another proof of the presence of an erosional surface separating the Carrizo from the Wilcox group is the erratic change in thickness of the Carrizo. The Carrizo is particularly thin, averaging only

²Complete discussion of investigations that led to the recognition of this regional disconformity is found in Stenzel, H. B., Buried hill at Wilcox-Carrizo contact in east Texas; MS. at Bureau of Economic Geology.



Wilcox-Carrizo contact from west wall of pit of General Refractories Company, near Henry's Chapel, Cherokee County, Texas. Inch scale at top.

about 30 feet, in the neighborhood of the clay pits and consists there only of the upper shaly part of the formation. Elsewhere the lower cross-bedded sandy part is present in addition to the upper; hence the thickness is much larger and may even rise to 104 feet. If the top of the Carrizo formation, or the base of the Newby member of the Reklaw formation, which is marine or brackish in origin, is taken as a reference level, the base of the Carrizo, or the top of the Wilcox group, is seen to fluctuate as much as 80 feet. In other words, the Wilcox group is cut off on top by an erosional surface of that much relief, and in the neighborhood of the clay pits the Wilcox forms a buried hill under the Carrizo. This hill was in existence in early Carrizo time and was high enough then to rise above the level at which the lower cross-bedded sands of the Carrizo were laid down, but as sediment deposition continued in later Carrizo time, the hill was buried under upper shaly Carrizo (compare fig. 7).

REKLAW FORMATION

The Reklaw formation as a separate mappable unit was first recognized and described by Wendlandt and Knebel (1929, pp. 1352-1355). The type locality of the formation was given by them as the railroad cut in northwestern Nacogdoches County 2 miles southeast of the village of Reklaw in Cherokee County. These authors described the formation as consisting of 20 to 40 feet of brown to dark blue micaceous sandy clay at the base, a 4- to 15-foot thick, rather pure, clayey glauconite containing plentiful fossils in the middle, and a brown clay with streaks of sand and greensand and clay-ironstone concretions up to 100 feet thick at the top. Detailed stratigraphic work done recently by the writer in the vicinity of Reklaw village has shown, however, that the lower division of the Reklaw as described by Wendlandt and Knebel, that is, the 20 to 40 feet of brown to dark blue micaceous sandy clay, does not belong in the Reklaw formation, because it interfingers with and grades laterally into the Carrizo sand and is separated on top from the Reklaw glauconites by a regionally continuous disconformity. This lower division of the

Reklaw of Wendlandt and Knebel is in fact the upper shaly part of the Carrizo as described on preceding pages of this paper. Hence, the restricted Reklaw formation consists of two divisions, a lower glauconite of 4 to 15 feet thickness and an upper brown shale up to 100 feet thick. These two divisions are precisely the two members of the Reklaw which had been described from Leon County (Stenzel, 1939, pp. 65-78). In Leon County the two members, the Newby at the base and the Marquez above, can be segregated and mapped, and their type localities are in that county. Later work has shown these members to be useful divisions recognizable in central Texas and over most of eastern Texas.

Newby Member

Surface distribution.—An outcrop band of this formation continuous except for local alluvial cover extends from north to south through the middle of the mapped area. To the west of this band the member dips and lies under younger formations but to the east it forms numerous outliers that cap some of the high hills of the undulating Carrizo outcrop. Such Newby outliers continue eastward far beyond the mapped area, at least as far as Henderson in Rusk County.

The continuous outcrop band is commonly only 100 to 200 feet wide, is deeply dissected into lobes of various sizes by the numerous creeks originating in the area, and enters the county from the north at a place 1.1 miles west of the Assembly of God church. Going southward it follows roughly a curve that is convex to the west in going past Henry's Chapel and through Concord to a place about 1.5 miles east of Emmaus Church at the south end of the mapped area. This convex curve is a result of the structural attitude of the Eocene beds (fig. 3).

West of the continuous outcrop band only one inlier of the Newby formation is found in the area mapped. This inlier is in the channel of Bridge Creek downstream from the bridge on the county road that goes westward from Griffin to the Troup-Summerfield highway.

Topography.—Weathering oxidizes the glauconitic sands of the Reklaw readily

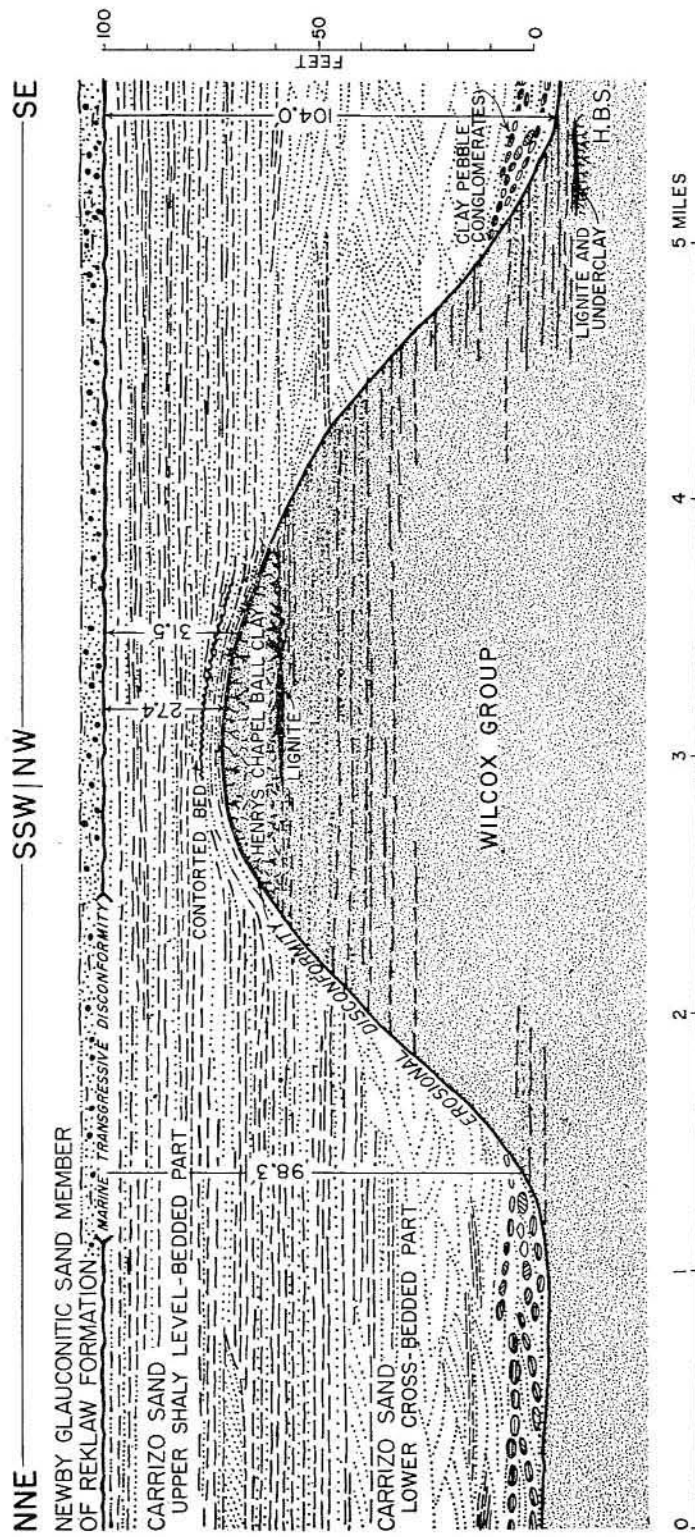


Fig. 7. Cross section of buried hill composed of Wilcox strata and covered by Carrizo sand near Henry's Chapel in northeastern Cherokee County, Texas.

and transforms them into hard ferruginous sandstones. Thus weathering increases their resistance to erosion greatly, at least at first. These ferruginous sandstones form a *cuesta* which commonly faces eastward but is inconspicuous, because the Newby member is thin. In many places the Newby scarp rises only 5 to 10 feet above the general level of the country and is easily overlooked. However, in those places where active erosion by running water has enhanced the general topographic relief the Newby *cuesta* is fairly impressive and steep. It is so along Farm Road 13 near Henry's Chapel where the southeastward-projecting lobe of the Newby *cuesta* is enhanced by the deep valleys of Grissom and Hampton Creeks, and the vertical topographic relief is 65 feet. At the southern end of the mapped area, about 1.5 miles east of Emmaus Church, the Newby *cuesta* is more conspicuous, because there the thickness of the Newby member is three times as large as farther north.

Vegetation.—Like the Carrizo formation the Newby member was originally covered by an oak and pine forest, but this forest probably was denser because the soils of the Newby are more fertile. Where the Newby *cuesta* is low and inconspicuous the land has been cleared but where the *cuesta* is steeper it is still wooded. In such places it is not uncommon that the Newby is wooded, but the Carrizo below and the Marquez above have been cleared, so that a narrow strip of woodland occupies approximately the steep slope of the Newby outcrop.

Soils.—Soils of the Newby are of the podsol type. There is a whitish-gray leached sandy top soil, the zone A, and beneath it is a yellow-orange-colored subsoil with sandstone rock fragments. The ease with which the Newby can be mapped in this area is dependent on the thickness of the sandy top soil. Where it is thick, and it can be 5 feet thick, no rock fragments reach the surface, and mapping becomes very difficult. Where the sandy top soil is thin the sandstone rock fragments reach the surface and may lie on the surface in great numbers and large size. Such rock-strewn slopes are easy to map. The rock-strewn Newby outcrop is usually

steep and commonly occurs at the tip of the various lobes where they project eastward; at the flanks of the lobes there is usually a deep sandy soil cover. Where sandstone rocks are not visible and road ditches do not penetrate deep enough to expose fresher, recognizable Newby materials, a peculiar pale dirty yellow rather than bright orange-colored subsoil indicates to the experienced field geologist the presence of the Newby outcrop. Colors of subsoils are to some extent distinctive of the various mappable units in this area.

Composition.—The fresh, unweathered Newby member cannot be seen in any of the exposures of the area; all the Newby exposures are oxidized, weathered, and thoroughly discolored. Fresh, unweathered material can be had only from excavations and test holes. The fresh material is a coherent, gray-green, massive to poorly bedded, glauconitic, muscovitic, argillaceous, fossiliferous, fine sand. More richly glauconitic parts are better called sandy glauconite rock and are commonly firm. The presence of glauconite, the massive or poorly developed bedding, and the large fossils are diagnostic features serving to segregate the member from the beds below and above. Siderite as interstitial cement is present in some layers and these may pass into impure clay-ironstone layers.

The beds of the weathered Newby member have varying hardness; they range from soft to hard, and induration may be confined to knobby irregular portions of a bed. However, induration is so common in this member that it serves to distinguish it from the commonly very soft immediately overlying section of the Marquez and the commonly merely firm or coherent upper Carrizo shales and sands. Indurated ferruginous sandstone of the upper Carrizo is similar in hardness to the Newby sandstone layers but is distinctly harsher under the hammer.

Colors of the weathered Newby are rusty, ranging from grayish yellow to yellow to orange-red and brown. The harder layers are commonly rust-brown. Maroon-black, so characteristic of the ferruginous sandstone ledges in the upper Carrizo, was not seen. Many of the rust colors of the Newby have a faint olive undertone which

is probably the effect of partly fresh glauconite grains.

Bedding is commonly poor, crude, or even absent; knobby and irregular bedding is common in some layers. Cross bedding is found only in the southern part of the mapped area, in the Newby inlier of Bridge Creek, and 1.5 miles east of Emmaus Church, where it is very well developed in some beds.

Glauconite is rare in some layers and more abundant in others but was found in every bed. It is more abundant in the south. Weathered glauconite grains consisting of limonite can be detected with the hand lens usually; they are rounded, pellet-shaped, and have a shrunken appearance, having pulled away from their enclosing matrix. Tiny flakes of muscovite are present in all beds but are not as common as they are in the Marquez member. All beds seem to be more or less argillaceous and even the loose sands have enough argillaceous matter to make them stick together after drying. Lignite pieces or carbonaceous matter were not found anywhere in this member.

Paleontology.—Fossils are common but are found only as imprints except in the Newby inlier of Bridge Creek where some loose fairly well-preserved *Venericardia* shells have been found. Only two species are abundant; they are the ribbed pelecypod *Venericardia planicosta* Lamarck, which may be up to $2\frac{1}{4}$ inches in size, and the slender conical gastropod *Turritella turneri* Plummer, which may be up to $1\frac{1}{2}$ inches long. Both fossils occur locally in great abundance and are easily detected on account of their size; hardly a layer of the Newby is really free of them. These fossils are the real guides for mapping in this region. *Venericardias* can always be found in the Newby sandstone where blocks of this stone lie around and are diagnostic. This rock is the well-known *Venericardia*-rock of east Texas geologists.

Thickness.—The Newby member is ordinarily only 5 to 10 feet thick in the entire district, and this thickness remains fairly uniform, but at the southern end of the mapped area, about 1.5 miles east of Emmaus Church, at Emmaus, and in

the Newby inlier of Bridge Creek between the former Black Jack brick school house and Emmaus Church, the thickness increases rapidly and rises to 30 feet. This great increase is gained at the top part of the Newby section through the addition of glauconitic sands and sandy glauconites, many of which are cross-bedded. From their field relations it is evident that these added beds are lenses of glauconite-rich beds that have approximately an east-west trend.

Accurately measured thicknesses in the Troup district and surrounding region are as follows:

Cherokee County:

(1) Cut and road ditch on north side of U. S. highway No. 84 (Reklaw-Rusk road) on descent to flood plain of Mud Creek, on the west side of the valley, 1.7 miles southwest of underpass at Reklaw village, east-central Cherokee County [Rusk quadrangle, U. S. Geol. Survey].....13.1 feet

(2) North ditch of east-west going county road, at the settlement of Emmaus, east of the bridge over a left tributary of Sampson Creek and west of the road fork at elevation 377, 0.55 mile south of Emmaus Cemetery, northeastern Cherokee County [Troup quadrangle, U. S. Geol. Survey].....15.4 feet

(3) Waterfall, channel, and banks of Bridge Creek, 850 feet and more downstream from the wooden bridge of an east-west going county road which goes westward from Griffin to State highway No. 110 (Troup-Summerfield road), about half a mile west of Griffin Cemetery, northeastern Cherokee County [Troup quadrangle, U. S. Geol. Survey].....13.5 feet

(4) Cuts on south-going county road, between the two road forks, one of which is at elevation 404, 0.6 mile south of bridge over Boggy Branch, 1.35 miles airline distance east-northeast of Emmaus Cemetery, northeastern Cherokee County [Troup quadrangle, U. S. Geol. Survey].....21.9 feet

(5) Cuts on north-south going county road from road metal pit at top of hill to road fork south of it, 0.3 to 0.46 mile south of Boggy Branch bridge, 1.35 miles east-northeast of Emmaus Cemetery, northeastern Cherokee County [Troup quadrangle, U. S. Geol. Survey].....30.5 feet

(6) West ditch of county road that goes due south from Concord, on north slope of a hill spur leading down to a right tributary of Campground Creek, 1.46 miles south of Concord and 0.39 mile north of the road cross at elevation 423, northeastern Cherokee County [Troup quadrangle, U. S. Geol. Survey] 5.1 feet

Rusk County:

(7) Borrow pit on north side of U. S. highway No. 84 (Rusk-Mt. Enterprise road) on right side of Angelina River, about 300 feet west of the stream, southwestern corner of Rusk County [Cushing quadrangle, U. S. Geol. Survey], Bureau of Economic Geology locality no. 200-T-1.....12.9 feet

(8) Deep cut on a westward slope along north side of U. S. highway No. 84 (Reklaw-Mt. Enterprise road), 0.65 mile east of underpass at Reklaw village, southwestern Rusk County [Cushing quadrangle, U. S. Geol. Survey].....12.9 feet

(9) Cut on Southern Pacific Railroad, 0.85 mile southeast of highway underpass at Reklaw village, in southwest corner of Rusk County [Cushing quadrangle, U. S. Geol. Survey].....12.2 feet

(10) Excavation in west-facing bluff, behind two 10,000-barrel oil storage tanks, overlooking flood plain of Striker Creek, at Gulf Pipe Line pump station, 0.25 mile east of west line of county and 0.75 mile north of U. S. highway No. 79 (Summerfield-Henderson road), west-central Rusk County [Henderson quadrangle, U. S. Geol. Survey], Bureau of Economic Geology locality no. 200-T-2 12.7 feet

(11) Ditches of south-going county road between Alexander Gin and Goldsberry School (Negro), about one-third mile north of school house and 2.5 miles airline distance east of Carlisle, west-central Rusk County [Henderson quadrangle, U. S. Geol. Survey].....9.7 feet

(12) Cut on east side of State highway No. 322 (Henderson-Longview road), 150 feet north of intersection with State highway No. 64 (Henderson-Tyler road), 100 feet east of International-Great Northern Railroad tracks and 150 feet north of highway-railroad crossing, in outskirts of Henderson, just north of city limits, central Rusk County [Henderson quadrangle, U. S. Geol. Survey] 7.4 feet

(13) Cut on New Salem-Glenfawn county road, east of Buford Branch, about 1 mile southeast of New Salem, southwestern Rusk County [Cushing quadrangle, U. S. Geol. Survey].....13.5 feet

Carrizo-Newby contact.—The first definite information concerning this contact was given from a locality in Gonzales County, and simultaneously a disconformity was indicated at the base of the Newby member in Leon County (Stenzel, 1939, footnote 38 on p. 70 and map, Pl. 1). Since then numerous exposures have been seen in Texas at which the base of the member is well exposed and disconformable on the Carrizo formation. Many clear exposures of the contact have been found in Cherokee and Rusk counties, and in every instance a disconformity separates the Newby from the Carrizo. Most of the 13 exposures listed under thickness are good examples of such exposures.

Features of the contact are interesting. At all places the underlying Carrizo and the Newby are parallel as regards their bedding. The only exception to this condition was found at location (1) of page 26; at that place the topmost Carrizo beds differ in attitude from the overlying Newby beds and are beveled by them so

that an angular unconformity is made; over a distance of 20 to 25 feet the 1.5-foot thick top bed of the Carrizo is beveled out completely, and the Newby member comes to rest on the next lower bed of the Carrizo. There seems to have been a slight tectonic movement here that inclined the upper Carrizo after its deposition and before it was beveled by the transgressing Newby sea.

Boreholes filled with Newby sediment and extending down from the base of the Newby into the Carrizo below are common in this region and have been found in all the exposures listed under thickness. At location (6) of page 26 the boreholes were particularly abundant, and the uppermost 5.1 feet of the Carrizo, which here consists of coherent, grayish chocolate-brown, massive to poorly bedded, silty, richly muscovitic, carbonaceous shale with nests of sand, is riddled for 1.7 feet with many boreholes filled with Newby glauconitic sand. These boreholes are three-eighths of an inch thick in the lower part but become up to 2 inches wide in the upper part of the 1.7 feet. In this upper part the boreholes intersect and branch so much that the Carrizo shale is dissected into many small highly irregular pieces. There are also flat pebbles of the Carrizo embedded in the base of the Newby glauconitic sand at this place.

The numerous exposures of the basal disconformity prove conclusively that the disconformity is widespread and continuous. It is particularly important that the disconformity is present in the type area of the Reklaw formation around Reklaw village, where it was seen in all clear exposures of the Newby-Carrizo contact [locations 1, 8, and 9 of pp. 26–27]. This disconformity is one of the reasons for revising the Reklaw section as outlined on page 23.

EXTENT AND GEOLOGICAL RELATIONSHIPS OF THE BALL CLAY

The extent of the ball clay and its availability are severely restricted because of peculiar geological conditions prevailing in the district. From a practical point of view the most important geologic condition limiting the extent of the ball clay

is the basal disconformity of the Carrizo sand.

The only easily traceable marine key bed in the district is the Newby member of the Reklaw formation. The member is a slightly glauconitic, fossiliferous, fine sand with a fauna consisting of many individuals of only two species of mollusks and rests with a very slightly undulating erosion surface on the upper part of the Carrizo formation. Hence it can be deduced that the member is the result of an invasion of the sea. As this sea advanced over quite soft and incoherent sediments of the Carrizo formation it must have had very little difficulty in reducing the top of the Carrizo formation to a nearly even surface. Therefore the base of the Newby member is regarded as a level reference horizon. This conclusion is, of course, important in the interpretation of the relationships of the strata below the reference horizon.

The thickness of the Carrizo formation is quite variable in this region. At the clay pits and in their immediate vicinity the lower cross-bedded sands are absent, and the upper shaly part of the Carrizo formation rests directly on the ball clay of the Wilcox group, separated from the clay by an erosional disconformity. Hence the thickness of the Carrizo is greatly reduced here, amounting to only 24 to 35 feet. But at short distances from the pits, 1.85 miles to the southeast and 1.55 miles to the north-northeast and everywhere to the east of them, the thickness of the Carrizo sand increases to as much as 104+ feet and 98.3 feet, and here both the upper and the lower part of the Carrizo are present (fig. 7). These data demonstrate a buried hill composed of Wilcox strata and buried under the Carrizo formation with its peak near the Thermo Fire Brick Company clay pit, where the Carrizo is the thinnest. The hill is at least 77 feet high; it slopes at least 41 feet per mile to the southeast and 44 feet per mile to the north-northeast. Considering that the buried hill is composed of such soft and non-coherent rocks as loose fine sands, sandy clay-shales and minor lignite seams of the Wilcox group, the slopes of the hill are fairly impressive. The present-day hills in this area are, however, about three

to four times as steep, although they are composed of the same kinds of soft rocks.

The peak of the buried hill is occupied by the 12.3-foot thick ball clay forming the top of the Wilcox group here. The ball clay exposed in the pits is slightly harder than the average Eocene clay-shale and is tough, blocky, and devoid of bedding planes so that it does not break down readily but forms large blocks. It should be somewhat more resistant to erosion than the average Eocene clay and certainly very resistant to chemical weathering because of its composition. The ball-clay cap may have been responsible for resistance to erosion and survival of the hill at the beginning of Carrizo deposition.

As the ball clay is only 12.3 feet thick and occupies the top of the buried hill, its extent is circumscribed by the shape of the top 12 feet of the buried hill. Among the various locations at which Wilcox strata have been found in the district, only locations (1) to (6) inclusive are exposures of this ball clay, and are under thin Carrizo, that is, Carrizo less than 35 feet thick. Hence these locations circumscribe roughly the areal extent of the ball clay. A more exact outline might be obtained by auger holes. The other exposures, locations (7) to (12), are in Wilcox strata other than the Henry's Chapel ball clay and are lower in stratigraphic position within the Wilcox group because they lie under Carrizo sand that is thicker than 35 feet. These exposures (7) to (12) did not disclose a usable ball clay; they all had clays that were too silty or sandy to be useful. Nevertheless the composition of the Wilcox strata in these exposures is remarkably free of iron, lime, and other components that lower the melting point. Hence, it is within the realm of possibility that another ball-clay bed might be hidden in this part of the Wilcox section without being accessible to surface inspection. Only a program of core drilling could prove or disprove this possibility.

To find elsewhere in the vicinity the same bed of ball clay that is quarried at Henry's Chapel, it is necessary to find buried hills such as the one described. Present mapping has not disclosed buried hills of this type. This fact is not necessarily proof that such hills do not exist in the area

mapped in detail. It merely proves that such hills do not exist in those places where valleys of creeks and their branches have cut into the Carrizo formation sufficiently. After all, large areas of the Newby and Carrizo outcrops are not dissected by creeks sufficiently deep, that is, 35 feet or more below the base of the Newby, to disclose what is below the Carrizo. There are large interstream divides under which such buried hills might lie. The fact that the mapping did not disclose any such buried hill does prove, however, that if there be such buried hills in this area they cannot be very large. For if they were very large and wide in extent they would show somewhere in a creek valley.

If the mapping has not disclosed any other buried hills, the drilling of geophysical shot holes has. At shot hole 50 the Carrizo formation appeared to be only 24 feet thick. This is a low figure compared to the thickness of the formation at the clay pits and indicates a buried hill there. Hole 50 was in a field, 5,350 feet west of the east line of the J. M. Procella survey, 950 feet south of the north line of Cherokee County, 1.81 miles nearly north of the church at Henry's Chapel. The log is:

	Depth Feet
Orange-colored clay.....	0-17
Brown shale	25-37
Gray clayey sand	37-39
White gummy clay	49-57
White sandy clay	57-59
Sand	59-60
Total depth	60

Interpretation of the hole: The hole was drilled in June 1947 in the writer's presence. It started in brown shale of the Marquez member of the Reklaw formation; top of Carrizo formation at 25 ft.; top of Wilcox group at 49 ft.; ball clay 49 to 57 ft., that is, 8 feet thick; cuttings of the ball clay from the drilling were almost white and had slippage planes. (Compare geophysical shot-hole data on pp. 31-37.) Although there is a headwaters branch of Grissom Creek only 300 ft. northeast of the shot hole, the valley is not deep enough to disclose the ball clay and only upper Carrizo is found in the channel of the branch beside the usual alluvial fill.

DESCRIPTION OF CLAY PITS

THERMO FIRE BRICK COMPANY

The Thermo Fire Brick Company pit is located 430 feet south of the county road and southwest of Hampton Creek (Pl. I).

The pit is 750 feet long and 150 feet wide. The lowest place in the main part of the pit has an elevation of 365.2 feet and is in the lower part of the ball clay. The section exposed in the south wall of the pit consists of 12 feet of soil, subsoil, and Carrizo formation and 10 feet of ball clay. Because the pit has been inactive for some time the ball clay has been exposed to the weather and is bleached to a grayish-white structureless mass of clay with many desiccation cracks and water rills. At the base of the Carrizo sand a great deal of water seeps out from the ground water perched on the impervious ball clay. During October 1947 even after a dry summer and fall the lower part of the overburden was saturated with water and was seeping constantly. The water drains off into a pond at the west end of the pit; its color is light bluish green, but it is clear.

Elevations of the top of the ball clay from west to east are: 375.6, 375.4, 375.1, 374.3 feet, all at the south side of the pond, and 375.2 feet at the south wall of the main part.

Overburden at the south wall of the pit (Pl. V) consists of about 12 feet of soil, subsoil, and Carrizo shaly sand. Unfortunately dump heaps have been placed on top of this overburden along the entire length of the south wall. About 150 feet from the east end of the pit the overburden consists of orange-red, stratified, rubbly gravel, sand, and clay, which is slope wash from the hill to the south. The material has cut out a small part of the top of the ball clay and cuts deeper to the east. The pit was operated only intermittently and was idle in October 1947, when visited last.

GENERAL REFRACTORIES COMPANY

The General Refractories Company pit is 700 feet north of the county road and southwest of Hampton Creek (Pl. I). The pit is 300 feet long and 390 feet wide (October 1947) in east-west direction. The lowest place in the pit is 345.3 feet above sea level and is in the northwest corner. The section exposed in the south wall where the overburden is thickest is composed of (January 11, 1948) 5 feet of soil, 7 feet of subsoil, 15 feet of Carrizo sand, and 10 feet of ball clay (Pl. III).

The lower part of the Carrizo sand is moist at all times and seeps a small amount of ground water that is perched in the Carrizo sand above the impervious ball clay.

Elevations at the top of the ball clay are 359.7 feet in northwest corner, 359.9 feet in southwest corner, 363.2 feet in southeast corner, and 365.1 feet in northeast corner of pit.

Overburden is about 27 feet thick (January 11, 1948) and will increase gradually as the pit is extended southward into the hill spur. As in the Thermo Fire Brick Company pit, the overburden is loose enough to be removed by bulldozer or drag line. However, at the top of the south face a 2.1-foot thick, very hard and harsh, black-maroon to rusty dark brown, ferruginous sandstone ledge was uncovered in the upper Carrizo sand in October 1948. This ledge had to be blasted. The propor-

tion of overburden to ball clay is roughly 3 to 1, that is, for every cubic yard of ball clay about 3 cubic yards of overburden are removed. The pit is well located on a comparatively low, long, northward-reaching hill spur. Dumps are placed to the north, east, and west of the pit and will not have to be moved again. The pit is worked continuously except during prolonged wet weather in the winter when clay is drawn from a stock pile on the hill spur between pit and county road. The stock pile ensures continuous operation of the company kiln in Troup.

The clay is trucked to Troup, a distance of about 6.5 miles, of which 0.9 mile is over improved county road, a dirt road, and the remainder over the asphalt road of Farm Road 13. The company operates a modern kiln and plant at the north side of Troup on a railroad spur connecting with the Missouri Pacific system.

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APPENDIX

GEOPHYSICAL SHOT HOLES IN NORTHEASTERN CHEROKEE COUNTY

These holes were recorded by the drillers at the end of their working day, not while the drillers were on location. Hence, too much reliance was placed on their memories, and errors of memory were unavoidable. Also the drillers were men not trained in the recognition of the strata through which they were drilling. Therefore many of the records are not too reliable. However, these driller's logs are the only subsurface information available and are useful to some extent.

A few of the holes were drilled while the writer was present and were recorded reliably at that time (see interpretations of holes below). Observations were also made on cuttings of other holes. The holes prove the great underground extent of ball clay north of the clay pits.

Abbreviations used: elev. = elevation; ft. = feet; N = north; S = south; E = east; W = west; TD = total depth.

Hole 1, elev. 399 ft., located in E ditch of N-S going county road, 1,680 ft. W of E-line of J. M. Procetta survey, 4,300 ft. S of N-line of Cherokee County, 1.23 miles N-NE of the church at Henry's Chapel.

	<i>Depth in feet</i>
sandy shale	0- 15
sand	15-130
lignite and shale	130-142
sand	142-162
sandy shale	162-182
TD	182

Interpretation: Hole starts in the uppermost part of the Carrizo formation, about 2 to 3 ft. below the top of the formation; at 130 ft., if not higher, Wilcox was encountered. Driller probably did not record the top of the Wilcox formation early enough.

Hole 2, elev. 373 ft., located in E ditch of N-S going county road, 1,650 ft. W of E-line, 1,900 ft. N of S-line of J. M. Procetta survey, 0.91 mile NE of the church at Henry's Chapel.

	<i>Depth in feet</i>
sand	0- 12
sandy shale	12- 58
sand	58- 88
shale	88-108
lignite	108-113
shale	113-152
TD	152

Interpretation: Hole starts in Carrizo formation, estimated about 17 ft. below top of the Carrizo; at 88 ft., if not higher, the Wilcox group was probably encountered.

Hole 3, elev. 358 ft., located in N ditch of county road at the crossing of Grissom Creek, 2,250 ft. W of E-line, 100 ft. N of S-line of J. M. Procetta survey, 0.55 mile N-NE of the church at Henry's Chapel.

	<i>Depth in feet</i>
sand	0- 4
sandy shale	4- 13
sand and rotten wood	13- 79
sandy shale	79-112
TD	112

Interpretation: Hole starts in alluvium resting on Carrizo formation; Wilcox was probably reached at 79 ft. or higher in hole. Cuttings found at this hole included pieces up to 1 3/4 inches long of brittle, deep black, partly resinous-lustrous partly sooty-dull, woody lignite and grayish chocolate-brown, poorly bedded clay, probably ball clay. These cuttings are from the Wilcox. The lignite apparently is the "rotten wood" of the driller's log.

Hole 4, elev. 398 ft., on W ditch of N-S going county road, 3,550 ft. W of E-line, 600 ft. S of N-line of James Hamilton survey, 0.35 mile N of church at Henry's Chapel.

	<i>Depth in feet</i>
sandy shale	0- 12
shale	12- 48
sand	48- 58
shale	58-102
sandy shale	102-112
TD	112

Interpretation: Hole starts in Newby member; top of Carrizo was at 5 to 7 ft. depth; Wilcox possibly encountered at 58 ft. Light brownish gray, massive clay, probably ball clay, found in cuttings.

Hole 5, elev. 405 ft., in SW ditch of Farm Road 13, 4,400 ft. W of E-line, 1,700 ft. S of N-line of James Hamilton survey, 0.19 mile NW of church at Henry's Chapel.

	<i>Depth in feet</i>
sandy shale	0- 12
shale	12- 60
sandy shale	60-112
TD	112

Interpretation: Hole starts in Marquez shale member; top of Carrizo possibly at 12 ft.; top of Wilcox possibly at 60 ft. depth.

Hole 6, elev. 388 ft., in N ditch of Farm Road 13, 3,450 ft. W of E-line, 2,950 ft. S of N-line of James Hamilton survey, 0.12 mile SE of church at Henry's Chapel.

	<i>Depth in feet</i>
sand	0-112
shale	112
TD	112

Interpretation: Hole starts in Marquez shale; driller's log regarded as wholly unreliable.

Hole 7, elev. 369 ft., located N of Farm Road 13, 2,150 ft. W of E-line, 3,580 ft. S of N-line of James Hamilton survey, 0.38 mile SE of church at Henry's Chapel.

	Depth in feet
sandy shale	0- 22
sand	22- 91
lignite	91- 93
sand	93-100
hard rock	100
lignite	100-102
sandy shale	102-112
TD	112

Interpretation: Hole starts in terrace deposits overlying Carrizo formation; Wilcox reached at 91 ft., if not higher.

Hole 8, elev. 343 ft., located in N ditch of Farm Road 13, 620 ft. W of E-line, 3,900 ft. S of N-line of James Hamilton survey, 220 ft. E of the Grissom Creek bridge.

	Depth in feet
sand	0- 87
lignite	87- 92
sandy shale	92-102
shale	102-112
TD	112

Interpretation: Hole starts in alluvium, near base of Carrizo sand; Wilcox must have been encountered above 87 ft., but was not recorded. Cuttings found at the hole included hunks up to 8 inches long of light gray and light brownish gray, massive to poorly bedded clay.

Hole 9, elev. 350 ft., located in N ditch of Farm Road 13, 620 ft. E of W-line, 4,120 ft. S of N-line of Wesley Dikes survey, 0.9 mile E-SE of church at Henry's Chapel.

	Depth in feet
sandy shale	0- 18
ledge	18
sandy shale	18- 28
sand	28- 62
lignite	62- 67
shale	67-112
hard rock at	82
TD	112

Interpretation: Hole starts near base of Carrizo sand; top of Wilcox probably at 18 ft.

Hole 10, elev. 357 ft., in corner of road fork E of N-going county road and N of Farm Road 13, 1,850 ft. E of W-line, 4,200 ft. S of N-line of Wesley Dikes survey, 1.12 miles E of church at Henry's Chapel.

	Depth in feet
sand	0- 3
sandy shale	3- 8
sand	8- 34
sandy shale	34- 57
sand	57- 72
sandy shale	72-112
TD	112

Interpretation: Hole starts near base of Carrizo sand; Wilcox may have been found at 8 ft. or 34 ft.

Hole 11, elev. 403 ft., on N side of Farm Road 13, 280 ft. W of N-S going county cross road, 3,570 ft. E of W-line, 4,350 ft. S of N-line of Wesley Dikes survey, 1.44 miles E of church at Henry's Chapel.

	Depth in feet
sand	0- 96
lignite	96- 98
shale	98-122
TD	122

Interpretation: Hole starts in Carrizo sand; Wilcox was reached at 96 ft., if not higher.

Hole 12, elev. 412 ft., on E side of N-S going county road, 1,780 ft. E of W-line, 2,770 ft. S of N line of Wesley Dikes survey, 1.06 mile E of church at Henry's Chapel.

	Depth in feet
sand	0- 2
clay	2- 8
sand	8- 72
sandy shale	72- 82
sand	82- 94
sandy shale	94-112
shale	112-122
TD	122

Interpretation: Hole starts in Carrizo sand near its top; top of Wilcox probably at 72 ft.

Hole 13, elev. 407 ft., on W side of N-S going county road, 1,770 ft. E of W line, 1,480 ft. S of N line of Wesley Dikes survey, 1.06 mile E-NE of the church at Henry's Chapel.

	Depth in feet
sandy shale	0- 14
shale	14- 27
sand	27- 92
lignite	92- 94
shale	94-112
TD	112

Interpretation: Hole starts in Carrizo sand, estimated about 18 ft. below top of Carrizo formation; top of Wilcox at 92 ft., if not higher.

Hole 14, elev. 392 ft., location unknown.

Hole 15, elev. 422 ft., on W side of N-S going county road at road fork, 100 ft. N of S line, 1,780 ft. E of W line of M. de los Santos Coy survey, at road corner having an elev. of 422 ft.

First hole	Depth in feet
sandy shale	0- 27
sand	27- 80
"blind"	80-92
TD	92

Second hole	Depth in feet
sandy shale	0- 27
sand	27-126
lignite	126-127
shale	127-142
hard rock at	138
TD	142

<i>Third hole</i>	<i>Depth in feet</i>
sand and gravel.....	0- 3
sandy shale	3- 23
sand	23- 91
lignite	91- 93
shale	93-112
TD	112

Interpretation: Hole starts in Carrizo sand, about 3 ft. below the top of the formation; top of Wilcox possibly at 80 ft. or 91 ft.

Hole 16, elev. 414 ft., on S side of W-E going county road, 20 ft. S of N line, 3,150 ft. E of W line of Wesley Dikes survey, 0.25 mile E of road fork having an elev. of 422 ft.

	<i>Depth in feet</i>
sand	0- 6
sandy shale	6- 63
sand	63- 77
lignite	77- 82
sandy shale	82-112
TD	112

Interpretation: Hole starts in Carrizo sand; top of Wilcox at 77 ft. or higher.

Hole 17, elev. 392 ft., on S side of W-E going county road, 50 ft. S of N line, 4,650 ft. E of W line of Wesley Dikes survey, 0.54 mile E of road fork having an elev. of 422 ft.

<i>First hole</i>	<i>Depth in feet</i>
silt	0- 2
sandy shale	2- 22
sand	22- 63
shale	63- 92
lignite	92- 95
shale	95-112
TD	112

<i>Second hole</i>	<i>Depth in feet</i>
sand	0- 58
shale	58- 69
sand	69- 98
lignite	98-101
shale	101-112
TD	112

Interpretation: Hole starts in Carrizo sand, about 25 ft. below top of formation; top of Wilcox at 58 or 63 ft.

Hole 18, elev. 399 ft., on E side of N-S going county road, 1,920 ft. E of W line, 1,700 ft. N of S line of M. de los Santos Coy survey, 0.33 mile N of road fork having an elev. of 422 ft.

	<i>Depth in feet</i>
sand	0-122
TD	122

Interpretation: Hole starts in Carrizo sand; driller's log is unreliable.

Hole 19, elev. 404 ft., on E side of N-S going county road, 1,920 ft. E of W line, 3,500 ft. N of S line of M. de los Santos Coy survey, 0.67 mile N of road fork having an elev. of 422 ft.

	<i>Depth in feet</i>
sand	0- 8
clay	8- 32
sand	32- 92
lignite	92- 96
sand	96-116
shale	116-122
TD	122

Interpretation: Hole starts in Carrizo sand, a few ft. below its top; top of Wilcox at 92 ft., if not higher. Cuttings found at the hole consisted of small pieces of dark gray-brown, silty, muscovitic, poorly bedded shale, probably Wilcox.

Hole 20, elev. 421 ft., on W side of N-S going county road, 1,770 ft. E of W line of M. de los Santos Coy survey, 2,750 ft. S of N line of Cherokee County, 1.00 mile N of road fork having an elev. of 422 ft.

	<i>Depth in feet</i>
sandy shale	0- 40
sand	40-127
lignite	127-128
sandy shale	128-162
TD	162

Interpretation: Hole starts in Newby member; top of Wilcox probably above 127 ft.

Hole 21, elev. 396 ft., in N ditch of road at right-angle turn of county road, 1,800 ft. E of W line of M. de los Santos Coy survey, 1,050 ft. S of N line of Cherokee County, 1.33 miles N of road fork having an elev. of 422 ft.

	<i>Depth in feet</i>
sand	0- 4
clay	4- 21
shale	21- 37
sand ?	37-128
shale	128-142
TD	142

Interpretation: Hole starts in Carrizo sand, about 4 ft. below its top; top of Wilcox above 128 ft.

Hole 22, elev. 416 ft., in E ditch of N-S going county road, 930 ft. S of N line of Cherokee County on line between M. de los Santos Coy and J. M. Procella surveys, 0.1 mile S of road fork having an elevation of 403 ft.

<i>First hole</i>	<i>Depth in feet</i>
sand	0- 3
sandy shale	3- 13
sand	13- 17
shale	17- 51
sand	51-142
sandy shale	142-148
lignite	148-152
shale	152-182
TD	182

<i>Second hole</i>	<i>Depth in feet</i>
chiefly sand	0- 25
brown shale	25- 56
dark brown, lignitic sandy clay at	56
hunks of dark brown massive clay.....	56- 57
fine loose sand, probably with a hydrostatic head	80-110
sandy clay	110-122
TD	122

Interpretation: The second hole was drilled on June 24, 1947, in the writer's presence. The hole starts in Marquez shale a few feet above the latter's base; top of Wilcox at 56 ft.; Wilcox clay at 56 to 57 ft.

Hole 23, elev. 436 ft., W of NE-SW going county road, 1,070 ft. W of E line of J. M. Procella survey, 1,700 ft. S of N line of Cherokee County, 0.33 mile SW of road fork having an elev. of 403 ft.

	Depth in feet
sand	0- 4
clay	4- 33
sand	33- 39
shale	39- 75
sand	75-159
lignite	159-161
sandy shale	161-172
TD	172

Interpretation: Hole starts in Marquez shale; top of Newby at 33 ft.; top of Carrizo at 39 ft.; top of Wilcox probably above 159 ft.

Hole 24, elev. 415 ft., in E ditch of N-S going county road, 1,830 ft. W of E line of J. M. Procella survey, 2,950 ft. S of N line of Cherokee County, 1.48 miles N-NE of the church at Henry's Chapel.

	Depth in feet
sand	0- 7
clay	7- 13
sand and shale streaks	13- 77
sand	77-123
lignite	123-127
gumbo shale	127-142
TD	142

Interpretation: Hole starts in Marquez shale; top of Newby at 13 ft.; top of Wilcox above 123 ft.

Hole 25, elev. 418 ft., located in Smith County at cross roads, on boundary between J. M. Procella and M. de los Santos Coy surveys, 800 ft. N of county line. Driller's log not available.

Hole 26, elev. 394 ft., located in Smith County on E-W running county road, approximately 1,700 ft. E of W line of M. de los Santos Coy survey and 1,000 ft. N of county line.

	Depth in feet
sandy shale	0- 17
sand	17- 71
blind sand	71-112
lignite	112-114
sandy shale	114-132
TD	132

Interpretation: Top of Wilcox questionably at 112 ft.

Hole 27, elev. 375 ft., located in Smith County on E-W running county road, approximately 3,000 ft. E of W line of M. de los Santos Coy survey and 700 ft. N of county line.

	Depth in feet
sand	0- 82
lignite	82- 84
sandy shale	84-112
TD	112

Interpretation: Hole starts in Carrizo sand; top of Wilcox at 82 ft. possibly.

Hole 28, elev. 397 ft., in N ditch of county-line road, 180 ft. N of N line of Cherokee County, 5,000 ft. E of W line of M. de los Santos Coy survey, 0.39 mile W of Assembly of God church.

	Depth in feet
sand	0- 6
sandy shale	6- 17
shale	17- 47
sand	47-118
lignite	118-121
shale	121-132
TD	132

Interpretation: Hole starts in Carrizo formation very near its top; top of Wilcox at 118 ft. or higher.

Hole 29, elev. 404 ft., located in N ditch of county road at right-angle turn, 2,700 ft. S of N line, 3,850 ft. E of W line of Wesley Dikes survey, 1,700 ft. N of Farm Road 13, 1.45 miles E of church at Henry's Chapel.

	Depth in feet
sand	0-108
lignite	108-111
shale	111-122
TD	122

Interpretation: Hole starts in Carrizo sand, about 15 ft. below its top; top of Wilcox at 108 ft. or higher possibly.

Hole 30, elev. 416 ft., in E ditch of N-S going county road, on top of hill, 1,000 ft. S of N line, 3,850 ft. E of W line of Wesley Dikes survey, 1.47 miles E-NE of church at Henry's Chapel.

	Depth in feet
sand	0-116
shale	116-142
TD	142

Interpretation: Hole starts in Carrizo formation near its top; top of Wilcox at 116 ft. or higher.

Hole 31, elev. 396 ft., in field, 100 ft. from a tank, 4,430 ft. E of W line, 1,470 ft. N of S line of M. de los Santos Coy survey, 0.57 mile E-NE of road fork having an elev. of 422 ft.

First hole	Depth in feet
sand	0- 3
sandy shale	3- 12
sand	12- 27
shale	27- 77
sand	77-105
lignite	105-106
shale	106-132
TD	132

<i>Second hole</i>	<i>Depth in feet</i>
sand	0- 3
clay	3- 17
sand	17- 33
shale	33- 87
sandy shale	87- 92
TD	92

Interpretation: Hole starts in Carrizo formation estimated 24 ft. below its top; top of Wilcox between 33 and 105 ft.

Hole 32, elev. 385 ft., in field on S slope of hill, 4,100 ft. E of W line, 3,200 ft. N of S line of M. de los Santos Coy survey, 0.75 mile NE of road fork having an elevation of 422 ft. Driller's log not available.

Hole 33, elev. 398 ft., exact location not known.

Hole 34, elev. 359 ft., location unknown.

Hole 35, elev. 384 ft., in W ditch of N-S going county road at right-angle turn, 7,000 ft. E of W line of M. de los Santos Coy survey, 3,120 ft. S of N line of Cherokee County, 0.57 mile S of Assembly of God church.

<i>First hole</i>	<i>Depth in feet</i>
quicksand at	78- 89
sand	0-108
lignite	108-112
sandy shale	112-119
lignite	119-121
shale	121-132
TD	132

<i>Second hole</i>	<i>Depth in feet</i>
sand	0-118
lignite	118-122
shale	122-132
TD	132

Interpretation: Hole starts in Carrizo sand, about 26 ft. below its top; top of Wilcox at 89 ft. probably.

Hole 36, elev. 406 ft. in W ditch of N-S going county road, 7,000 ft. E of W line of M. de los Santos Coy survey, 1,600 ft. S of N line of Cherokee County, 0.28 mile S of Assembly of God Church. Driller's log not available.

Hole 37, elev. 403 ft., in N ditch of county-line road at road fork, 7,220 ft. E of W line of M. de los Santos Coy survey, 300 ft. NE of Assembly of God church.

	<i>Depth in feet</i>
sand	0- 6
sandy shale	6- 17
shale	17- 37
sand	37-133
sand and lignite	133-148
sandy shale	148-162
TD	162

Interpretation: Hole starts in Carrizo sand, about 5 to 17 ft. below its top; top of Wilcox above 133 ft.

Hole 38, elev. 387 ft. in N ditch of county-line road, 6,150 ft. E of W line of M. de los Santos Coy survey, 800 ft. W of Assembly of God church.

	<i>Depth in feet</i>
sand	0- 2
sandy shale	2- 13
sand	13- 80
lignite at	80
sand	80-130
lignite	130-133
sandy shale	133-142
shale	142-152
TD	152

Interpretation: Hole starts in Carrizo sand, about 25 ft. below its top; top of Wilcox at 80 ft. probably.

Hole 39, elev. 397 ft., in N ditch of E-W going county road, 8,800 ft. E of W line of M. de los Santos Coy survey, 3,100 ft. S of N line of Cherokee County, 0.66 mile SE of Assembly of God church.

	<i>Depth in feet</i>
sand	0- 7
sandy shale	7- 26
sand	26- 45
sandy shale	45- 63
sand	63-118
lignite	118-121
shale	121-132
TD	132

Interpretation: Hole starts in Carrizo sand, about 25 ft. below its top; top of Wilcox questionably at 45 ft.

Hole 40, elev. 387 ft. in S ditch of E-W going county road at right-angle turn, 10,000 ft. E of W line of M. de los Santos Coy survey, 4,030 ft. S of N line of Cherokee County, 0.93 mile SE of Assembly of God church.

	<i>Depth in feet</i>
clay	0- 22
sand	22- 43
shale	43- 67
sand	67-129
lignite	129-132
shale	132-142
TD	142

Interpretation: Hole starts in Carrizo formation, about 35 ft. below its top; top of Wilcox questionably at 43 ft.

Hole 41, elev. 394 ft., in W ditch of N-S going county road, 10,050 ft. E of W line of M. de los Santos Coy survey, 5,250 ft. S of N line of Cherokee County, 1.13 miles SE of Assembly of God church.

	<i>Depth in feet</i>
sand	0- 7
sandy shale	7- 17
sand	17-128
lignite	128-132
shale	132-142
TD	142

Interpretation: Hole starts in Carrizo formation; top of Wilcox above 128 ft.

Hole 42, elev. 375 ft., in E ditch of county road at right-angle turn, 10,100 ft. E of W line, 1,350 ft. N of S line of M. de los Santos Coy survey, 1.36 miles S-SE of Assembly of God church.

	Depth in feet
clay	0- 18
sandy shale	18- 52
firm sand	52-107
shale	107-109
lignite	109-112
shale	112-122
TD	122

Interpretation: Hole starts in Carrizo sand, about 45 ft. below its top; top of Wilcox questionably at 52 ft.

Hole 43, elev. 355 ft., located on N side of E-W going county road, 9,650 ft. E of W line, 1,320 ft. N of S line of M. de los Santos Coy survey, 1.27 miles S-SE of Assembly of God church.

	Depth in feet
sand	0- 6
sandy shale	6- 17
sand	17- 58
lignite	58- 61
shale	61- 68
lignite coal	68- 71
shale	71- 82
TD	82

Interpretation: Hole starts in Carrizo sand, about 55 to 65 ft. below its top; top of Wilcox at 58 ft. or higher.

Hole 44, elev. 359 ft., located in N ditch of E-W county road, 7,100 ft. E of W line, 1,300 ft. N of S line of M. de los Santos Coy survey, 1.24 miles due S of Assembly of God church.

	Depth in feet
sand	0- 4
sandy shale	4- 17
sand	17- 84
lignite	84- 87
shale	87-112
TD	112

Interpretation: Hole starts in Carrizo sand, about 60 ft., below its top; top of Wilcox questionable, above 84 ft.

Hole 45, elev. 393 ft., located in S ditch of E-W going county road near right-angle turn, 5,550 ft. E of W line, 1,150 ft. N of S line of M. de los Santos Coy survey, 1.3 miles S-SW of Assembly of God church.

	Depth in feet
blind sand	0-112
lignite	112-114
shale	114-125
TD	125

Interpretation: Hole starts in Carrizo sand, about 27 ft. below top of Carrizo; top of Wilcox above 112 ft.

Hole 46, elev. 390 ft., in pasture, 3,550 ft. W of E line of J. M. Procella survey, 4,350 ft. S of N line of Cherokee County, 1.15 miles N of church at Henry's Chapel.

	Depth in feet
orange-colored sand	0- 10
white leached silty clay with orange spots at	10- 19
brown shale in curled shavings	19- 29
sand	29- 30
brown shale in curled shavings	30- 47
massive clay	47- 63
sandy shale and lignite	63- 80
lignite at	80
dark gray to black lignitic shale at	90
TD	92

Interpretation: Hole was drilled in the writer's presence; it started in Carrizo sand; top of Wilcox at 47 ft. exactly; probably ball clay from 47 to 63 ft.

Hole 47, elev. 394 ft., in pasture, 3,580 ft. N of S line, 5,350 ft. W of E line of J. M. Procella survey, 1.18 miles N-NW of church at Henry's Chapel.

	Depth in feet
yellow-brown mottled clay with some ironstone fragments	0- 14
dark gray-brown, muscovitic, silty shale	14- 32
dark brown, muscovitic, silty shale and lignitic shale	32- 33
light gray muscovitic silt and clay	33- 41
dark gray-black, silty, muscovitic shale and lignite	41- 43
dark gray shale and lignite	43- 64
gray-brown, massive clay, probably Wilcox clay	64- 82
TD	82

Interpretation: Hole was drilled in presence of Dan E. Feray, Jr., and starts near top of Carrizo; top of Wilcox at 64 feet exactly.

Hole 48, elev. 431 ft., in field, 3,650 ft. N of S line, 7,050 ft. W of E line of J. M. Procella survey, 1.31 miles NW of church at Henry's Chapel.

	Depth in feet
yellow-brown mottled, gray clay with ironstone fragments	0- 18
dark chocolate-brown, micaceous shale with a concretion ledge at 22 ft. Fossil shells at 42, 45, and 47 ft.	18- 80
sandy shale	80- 82
TD	82

Interpretation: Hole was drilled in presence of Dan E. Feray, Jr., and starts in the Marquez shale member. Top of Newby at 42 ft. or perhaps 5 ft. higher; top of Carrizo at 47 ft. approximately; bottom still in Carrizo. Material blown out of hole through the explosion consisted of large pieces of medium gray, well-bedded clay with subconchoidal fracture, provenance unknown.

Hole 49, elev. 388 ft., in pasture adjoining Grissom Creek, 5,500 ft. W of E line of J. M. Procella survey, 3,600 ft. S of N line of Cherokee County, 1.52 miles N-NW of church at Henry's Chapel.

First hole	Depth in feet
alluvial sands	0- 15
leached white clayey sand	15- 19
sand with brown shale shavings	19- 38
white loose sand	38- 67
lost circulation in porous sand at	67
abandoned in loose sand	75
TD	75
Second hole	Depth in feet
white sandy clay	0- 20
white clayey sand	20- 37
loose sand	37- 93
lignite	93- 97
lignite and sand	97-107
dark brown clay	107-113
hard rock, chips of hard lignite	113-115
TD	115

Interpretation: Holes were drilled in presence of the writer. First hole started 8.3 ft. exactly below top of Carrizo formation. The second hole started 5.3 ft. exactly below the top of the Carrizo formation; top of Wilcox at 93 ft. exactly. Sample from second hole at 109 ft. depth is small chunks of light gray argillaceous silt of the Wilcox.

Hole 50, elev. 391 ft., in field, 5,350 ft. W of E line of J. M. Procella survey, 950 ft. S of N line of Cherokee County, 1.81 miles nearly N of church at Henry's Chapel.

	Depth in feet
orange-colored clay	0- 17
brown shale	25- 37
gray clayey sand	37- 49
white gummy clay	49- 57
white sandy clay	57- 59
sand	59- 60
TD	60

Interpretation: Hole was drilled in June 1947 in the writer's presence. It started in Marquez shale; top of Carrizo at 25 ft.; top of Wilcox at 49 ft. exactly; ball clay 49 to 57 ft. The ball clay was almost white and had slippage planes.

Hole 51, elev. 412 ft., in field, 2,100 ft. N of S line, 6,380 ft. W of E line of J. M. Procella survey, 0.99 mile NW of church at Henry's Chapel.

	Depth in feet
sand soil	0- 7
whitish leached soft clay	7- 18
brownish shale in curled shavings	18- 23
glauconitic shale	23- 27
fossiliferous glauconitic sand and shale at	27- 34
brown shale	34- 43
brown shale	43- 77
fire clay, massive, white to light gray-brown	77- 82
TD	82

Interpretation: Hole was drilled in June 1947 in the writer's presence. It started in Marquez shale; Newby 27 to 34 ft.; Carrizo 34 to 77 ft.; top of Wilcox at 77 ft., with at least 5 ft. of clay.

Hole 52, elev. 401 ft., in field on E side of a N-S going field road, 900 ft. N of S line, 5,750 ft. W of E line of J. M. Procella survey, 0.74 mile NW of church at Henry's Chapel.

	Depth in feet
sand	0- 3
sandy shale	3- 22
shale	22- 82
TD	82

Hole 53, elev. 394 ft., in S ditch of Farm Road 13, 300 ft. S of N line, 5,520 ft. W of E line of James Hamilton survey, 0.53 miles NW of church at Henry's Chapel.

	Depth in feet
sand	0- 5
clay	5- 46
sand	46-108
sandy shale	108-114
lignite	114-117
shale	117-132
TD	132

Interpretation: Hole starts in Marquez shale; top of Wilcox doubtful, above 108 ft.

CHARACTERISTICS OF TEXAS BALL CLAY NEAR TROUP

F. K. Pence

INTRODUCTION

In the middle 1930s, a member of a leading English pottery firm made a visit to Texas for the purpose of investigating the natural resources of the area which would be available for use in the manufacture of fine china. His conclusions were to the effect that the raw material most needed in Texas was the plastic light-firing clay which in ceramic terminology is called ball clay. This type of clay has been imported from England by the dinnerware manufacturers of this country since the founding of the industry in Ohio and other eastern pottery centers. Within the period of the last twenty years domestic ball clay, particularly that mined in western Kentucky and western Tennessee, has been used in increasing quantities, replacing the imported English ball clay.

When the writer began a personal investigation of the Texas raw materials in 1938, he was impressed with the resemblance between the clays of certain counties of east Texas and deposits of western Kentucky and Tennessee. This resemblance was further emphasized by samples taken from two outcrops 6 miles east of Troup, Texas, which the writer examined in 1942, and pronounced to be ball clays of properties comparable to those of the Kentucky-Tennessee area. This appraisal was further confirmed by the fact that physical data showed that the deposits of both areas conform to the band of strata of Tertiary age which was the coastal area of the huge gulf which in time has shrunk to the present Gulf of Mexico. As pointed out by DeBeck,¹ the geologists of both Kentucky and Tennessee have definitely classified the ball-clay areas of those states as belonging to the same group as the plastic light-firing clays of Texas.

It should be stated in this connection that the two deposits east of Troup appear to represent unique outcroppings somewhat isolated from the more obvious band

of strata extending northeasterly across the State and known as the Wilcox group formations. The writer has been greatly interested in locating other outcroppings similar to those of Troup and in 1944 brought to the attention of the Bureau of Economic Geology the valuable ball-clay properties of the Troup clay and the desirability of a detailed geological study of the area. In 1946 the co-operative project was set up, the data of which are reported in this publication. Since the writer has maintained that the properties and characteristics of Troup clay place it in the same classification as the eastern ball clays, it is deemed necessary that this statement should be supported by laboratory data.

The earlier tests were those of the determination of physical properties which are regarded as standard by manufacturers using ball clays. Table I shows these physical tests as made on Troup clay and on standard commercial ball clays. Tests were made in the Ceramic Laboratories of The University of Texas so that the data are entirely comparable.

While the physical tests in the following table may be considered sufficient data upon which to base raw material classification, it is deemed proper to include herewith comparative data obtained by the use of the ultra-advanced mineral examination made possible by equipment more recently acquired at The University of Texas.

It is proper to state that the outstanding quality which takes a plastic clay out of what would otherwise be the ordinary fire-clay class and designates it as a ball clay is that of color. Unless the clay fires sufficiently white to enable it to be incorporated in a white china body in a fairly substantial percentage, it cannot be classified as ball clay. While Table I describes comparative color observations by ordinary visual processes, it is far more accurate to show these comparisons by means of curves obtained by the recording spectrophotometer (fig. 8).

¹DeBeck, H. O., Correlation of Wilcox formation; Bull. Amer. Cer. Soc., vol. 27, p. 377, 1948.

Table 1. Results of physical tests on Troup clay (T) and on typical domestic ball clays (1, 2, 3).

Ball Clays	Water of plasticity	Drying shrinkage	Dry strength	Firing shrinkage	Total shrinkage	Absorption	Color	Firing shrinkage	Total shrinkage	Absorption	Color
	Dry	D.S.	M/R	F.S.	T.S.	Cone 5 Abs.	Color	F.S.	T.S.	Cone 9 Abs.	Color
1	38.3	8.0	375	11.9	19.9	13.0	white	13.0	21.0	7.1	light cream
2	35.1	3.7	210	9.6	13.3	12.0	cream white	12.6	16.3	4.0	cream
3	35.0	4.2	300	11.3	15.5	11.1	light buff	13.3	17.5	5.9	light buff
T	34.0	5.3	380	5.1	13.0	16.3	white	5.5	14.0	8.0	light cream

It will be noted that the curve for the Troup clay lies within the field bounded by the curves for typical commercial ball clays. These curves eliminate any argument as to differences in visual appraisal made by different observers. A comparative study of the mineral characteristics of the Troup ball clay and representative ball clays from the Kentucky-Tennessee area was made with the aid of laboratory instruments as reported in the following paragraphs.

Differential thermal analysis.—The curve on the Troup clay is shown in figure 9, and curve on the Champion-Challenger ball clay is shown in figure 10. The similarity of the curves in these two illustrations is self-evident. Thermal analysis determinations were made by David Harrell, of the Ceramic Research staff, who has developed a thermal analysis apparatus of constant rate of temperature increase and improved sensitivity.

Electron microscope.—The Research Laboratory in Ceramics has conducted extensive studies of the Texas ball clay as well as of representative commercial ball clays by means of micrographs obtained with the assistance of Mr. L. L. Antes in the operation of the electron microscope. A representative micrograph of the Troup ball clay is shown in Plate VII, and a representative micrograph for typical Kentucky-Tennessee ball clay is shown in Plate VIII.

It will be noted that in the preparation of the samples the dispersion of the particles differs in that more crystals are shown in the field of Plate VIII than in Plate VII.

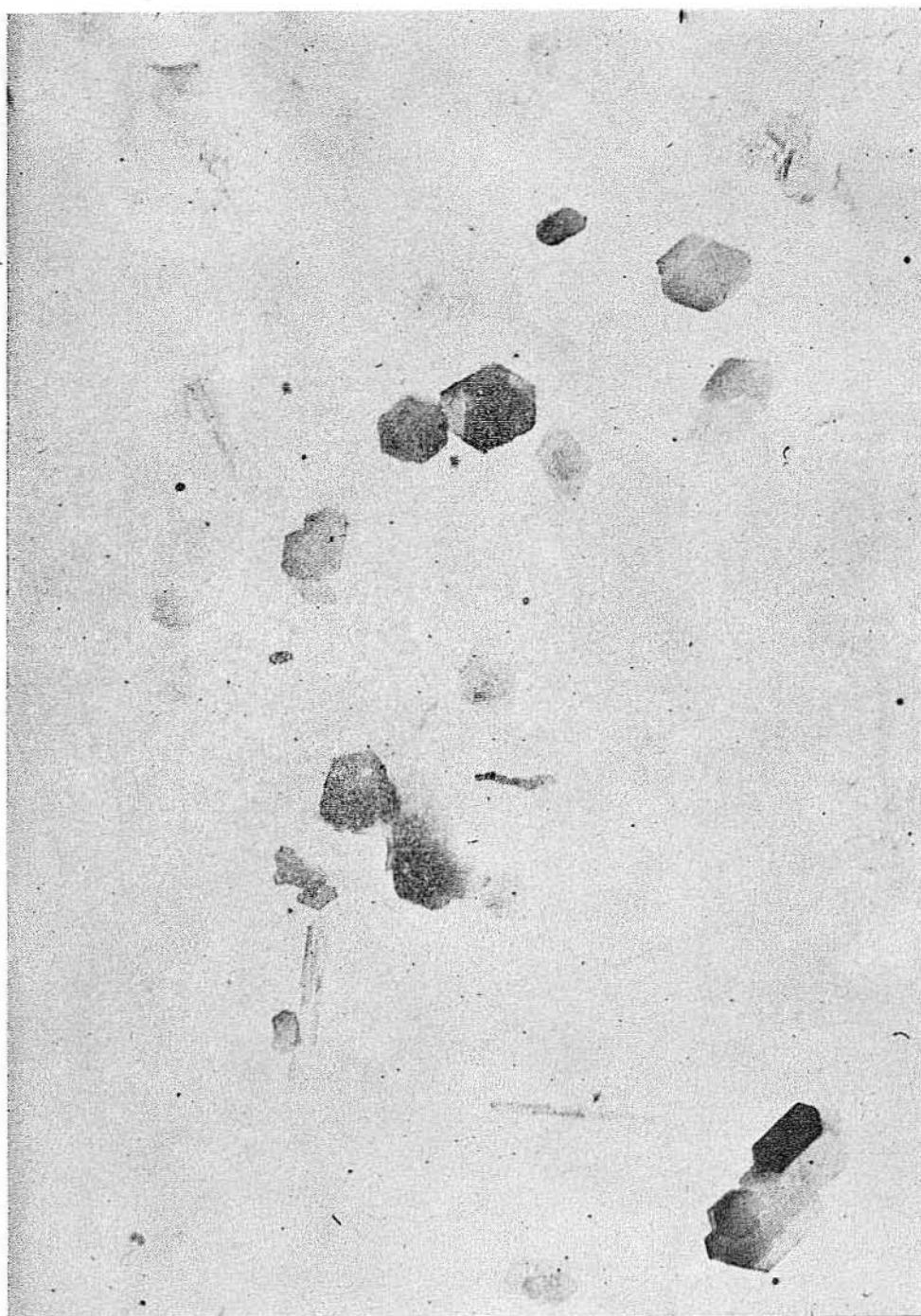
The significant observation is that the crystals in each micrograph show the characteristic outline of kaolinite (characteristic hexagonal outline). This observation demonstrates the kaolinitic composition of a ball clay. Since all ball clays are sedimentary, the property of plasticity and dry strength has been acquired in the process of transportation from the original location of the primary kaolin to the present location of the sedimentary ball clay. A representative micrograph of the primary kaolin from North Carolina is shown in Plate IX.

It will be noted that such complete dispersion was obtained that individual crystals of kaolinite may be clearly observed. They are obviously more definite than those observed in Plates VII and VIII. However, in size and outline they are the same.

X-ray spectrometer.—Of still more significance is the mineral composition revealed by X-ray examination. The X-ray diffraction pattern for Troup clay is shown in figure 11, and that for a typical Tennessee ball clay is shown in figure 12.

The X-ray spectrometer in the Ceramic Laboratory is operated by Mr. R. F. Shurtz, and his interpretation of figures 11 and 12 is as follows:

Referring to the X-ray patterns, a marked similarity between the two clays is immediately noticeable. The first difference which appears between the two charts is seen by comparing the intensity, that is, the height, of the quartz reflections at $\theta = 13.3^\circ$ with the intensities of the kaolinite reflections at $\theta = 12.5^\circ$. Inasmuch as the intensity of a reflection is roughly proportional to the amount of the reflecting mineral present, I have been able to calculate factors based on a



Representative micrograph of Troup ball clay.



Representative micrograph for typical Kentucky-Tennessee ball clay.

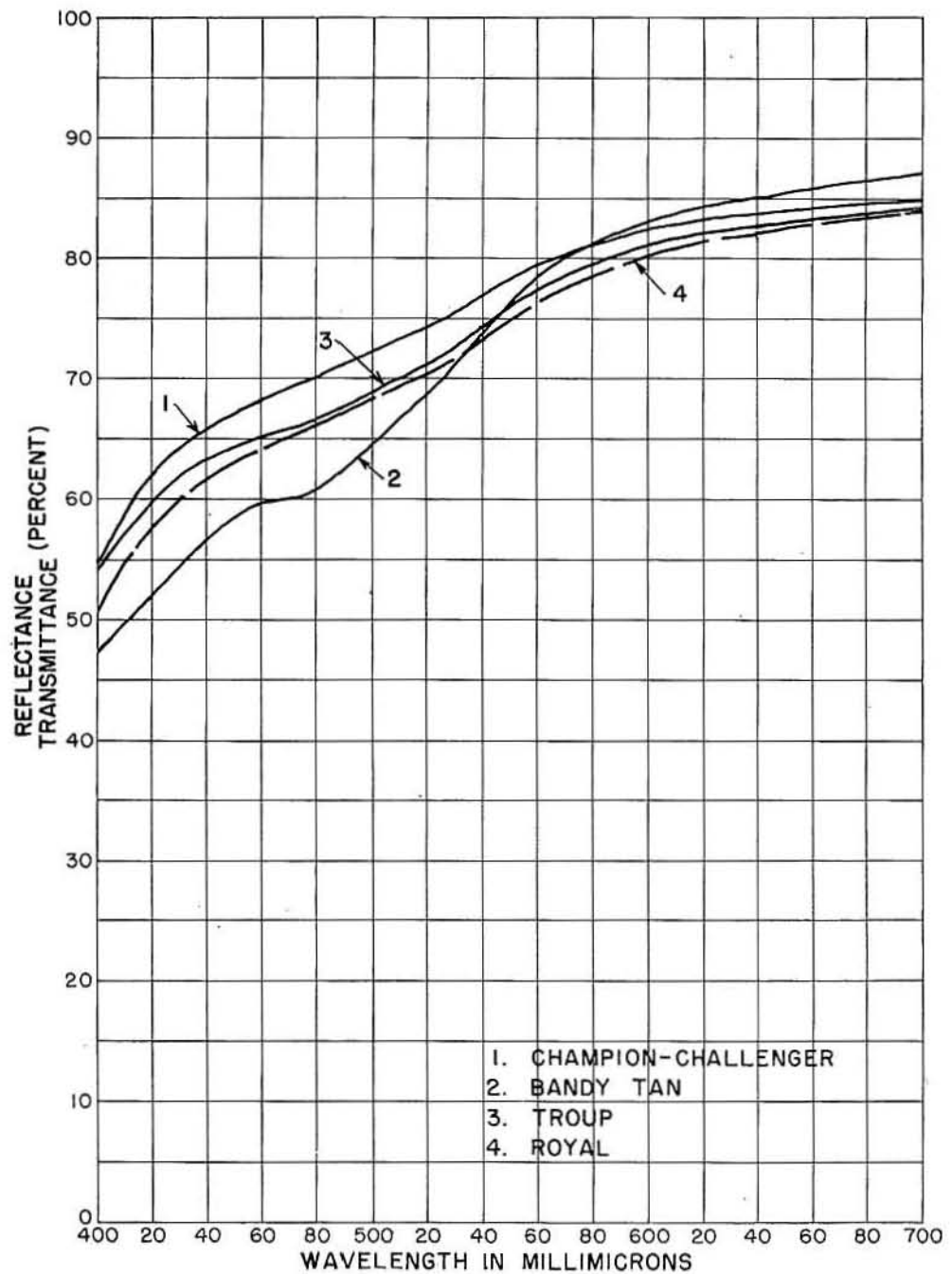


Fig. 8. Comparison of color of Champion-Challenger, Bandy tan, Troup, and Royal ball clays as obtained by recording spectrophotometer.

large number of observations by means of which it is possible to estimate the amount of quartz in these two samples of clay. These estimates are noted on the charts where it is stated that the typical ball clay contains about 20 percent of

quartz while the Troup clay contains about 13 percent of quartz.

It is of interest to discuss comparisons between these patterns and the patterns which are obtained from true kaolins such as those found in North

Carolina and in the Wilcox formation of Texas. These latter are much more perfectly crystallized than the Champion-Challenger or the Troup clay. This is simply another way of stating that the cleavage planes of the better crystallized kaolins are more perfectly developed than they are in the Champion-Challenger and in the Troup. This fact, in the writer's experience, has been found to affect the relative intensities of the X-ray reflections from the kaolinite. In the well-crystallized types of kaolin we find that the reflections at $\theta = 6.12^\circ$ and at $\theta = 12.5^\circ$ are about twice as strong as the reflection at $\theta = 10.1^\circ$. This latter reflection is caused by crystalline planes perpendicular to the cleavage planes of the clay mineral. Inasmuch as the X-ray intensity depends largely on the perfection of the crystal planes causing it, we find that the well-crystallized kaolins show the relative intensities noted above.

In contrast the ball-clay type, such as represented by figures 11 and 12, tends to show about equal intensities for all three of these reflections. This is construed as evidence of crystalline disorder in the ball-clay type of material because the intensities from the cleavage planes have been reduced by imperfections in the orientation of these planes. These imperfections in the crystalline structure are believed to be responsible in at least some measure for the characteristic ceramic behavior of the ball clays.

It will be noted that the foregoing data confirm the similarity of the Troup clay to the typical commercial domestic ball clays. The electron micrographs and the X-ray data demonstrate the basic mineral similarity of the ball clays and kaolin. In

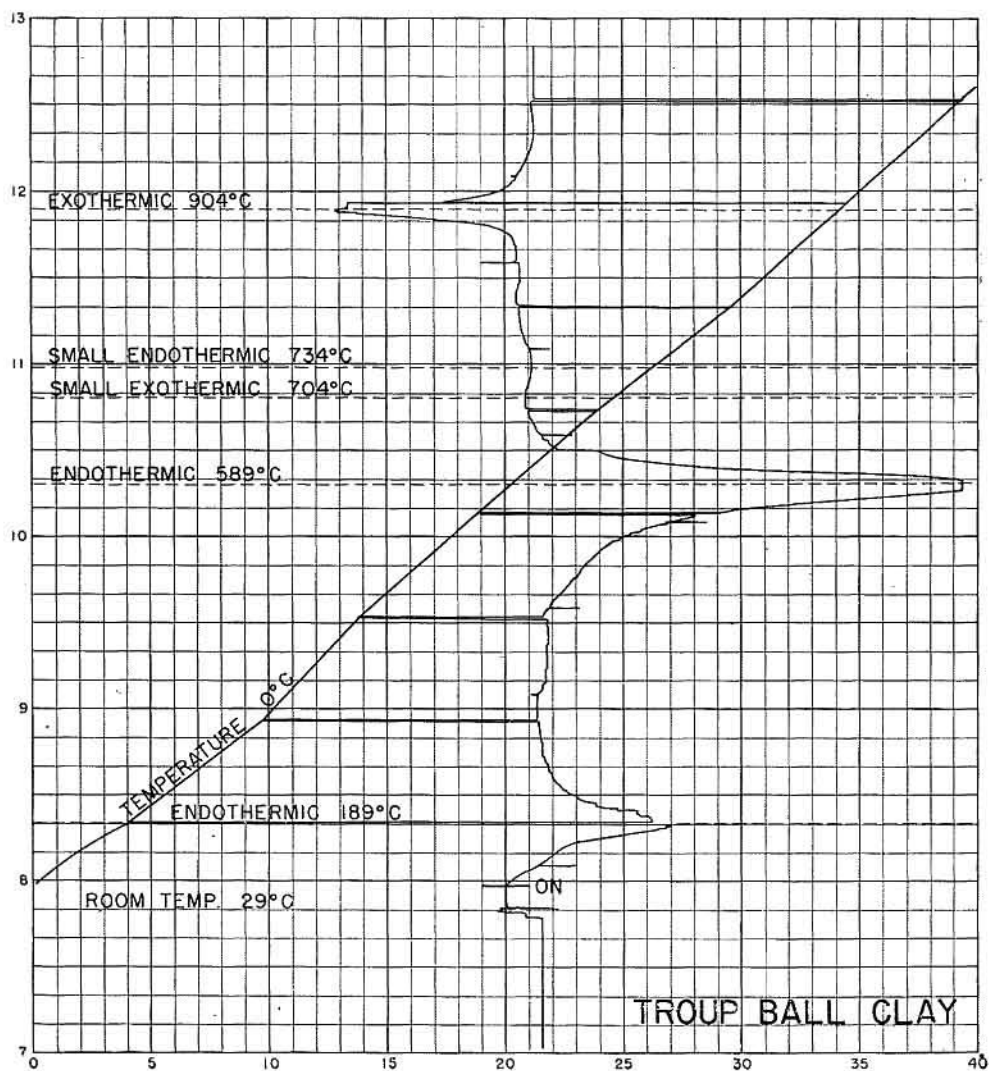
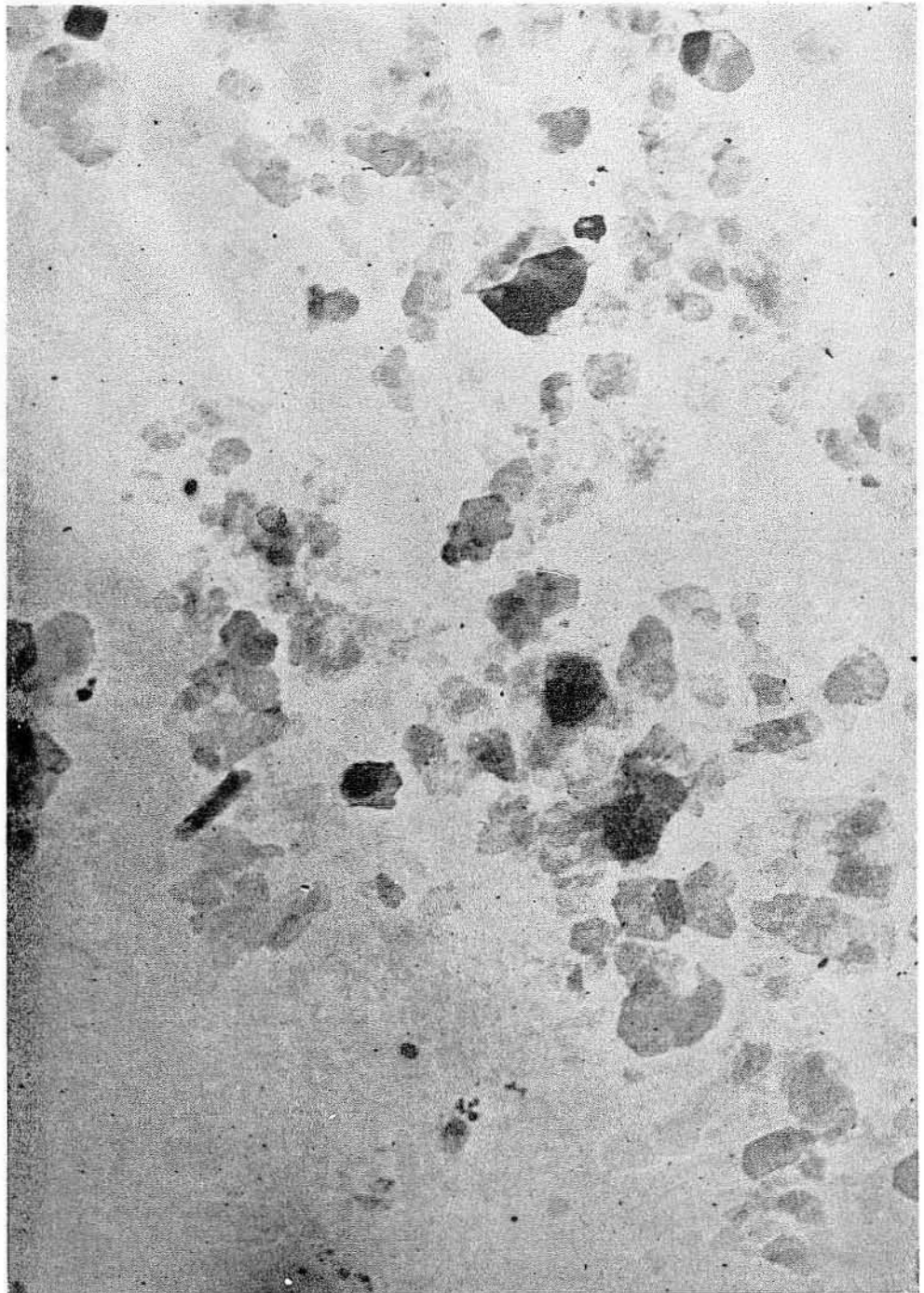


Fig. 9. Differential thermal analysis curve on Troup ball clay.



Representative micrograph of primary kaolin from North Carolina.

fact, a ball clay might be defined as a transported kaolin which acquired plasticity and retained its white firing quality.

A fusion determination on the Troup ball clay showed it to have a P.C.E. of cone 32, placing it in the same refractory class as a good quality kaolin. In fact, both of the outcroppings near Troup are currently being used in the manufacture of high-grade refractory. Chemical analysis of the Troup clay shows the alumina and silica content to correspond with that of pure kaolin plus free silica as follows: Al_2O_3 , 32.69 percent, SiO_2 , 53.73 percent (indicating 15.23 percent free silica). Chemical analysis was made by Daniel A. Schofield of the Research Laboratory staff.

It should be stated in this connection that ball-clay strata may differ in physical properties in slight degrees not indicated by mineral composition. Ball clay is a component of the clay mixtures required by practically all manufacturers of porcelain products, such as electrical, sanitary, chemical, and fine tableware china. The somewhat different procedures followed by various industries result in a difference of requirements or preferences as to ball-clay physical properties. Some ball clays fire whiter than others; some when used as a component when the product is formed by the method of slip casting, give a quicker turnover; some when used as a component of a plastic body for jiggering, develop a smoother surface texture.

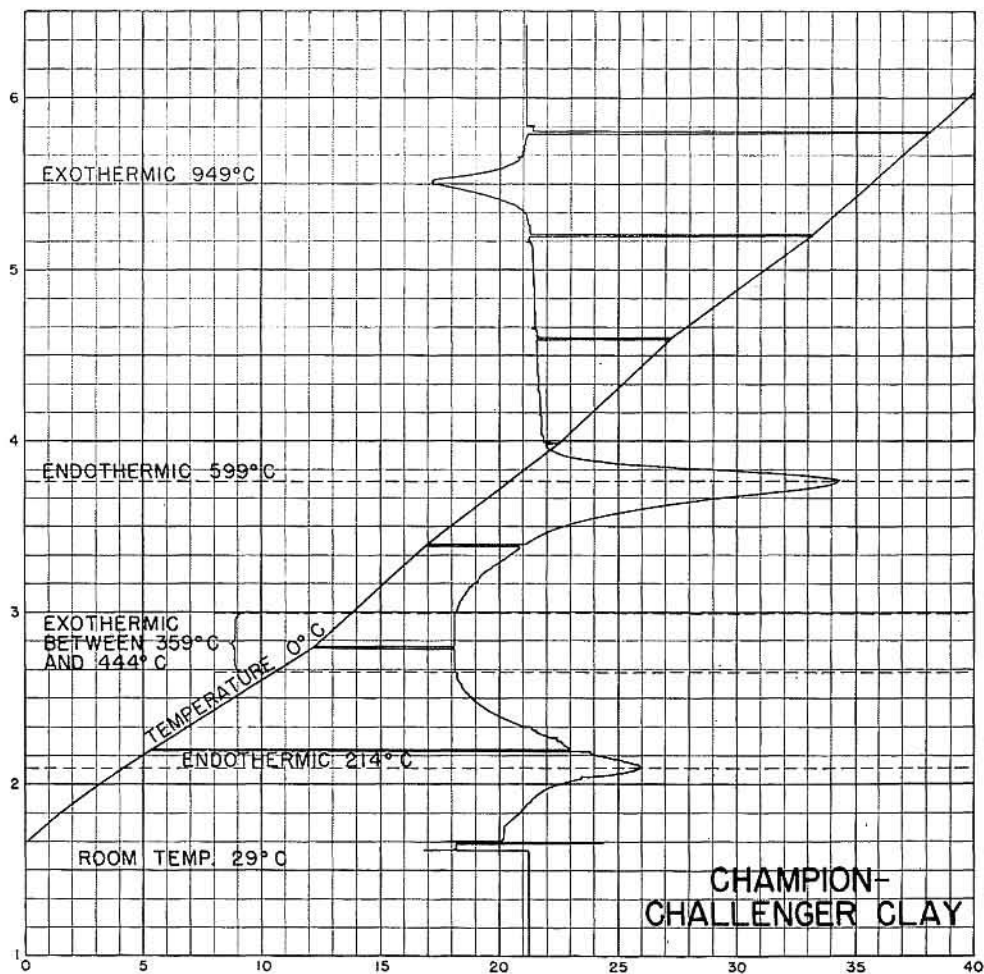


Fig. 10. Differential thermal analysis curve on Champion-Challenger ball clay.

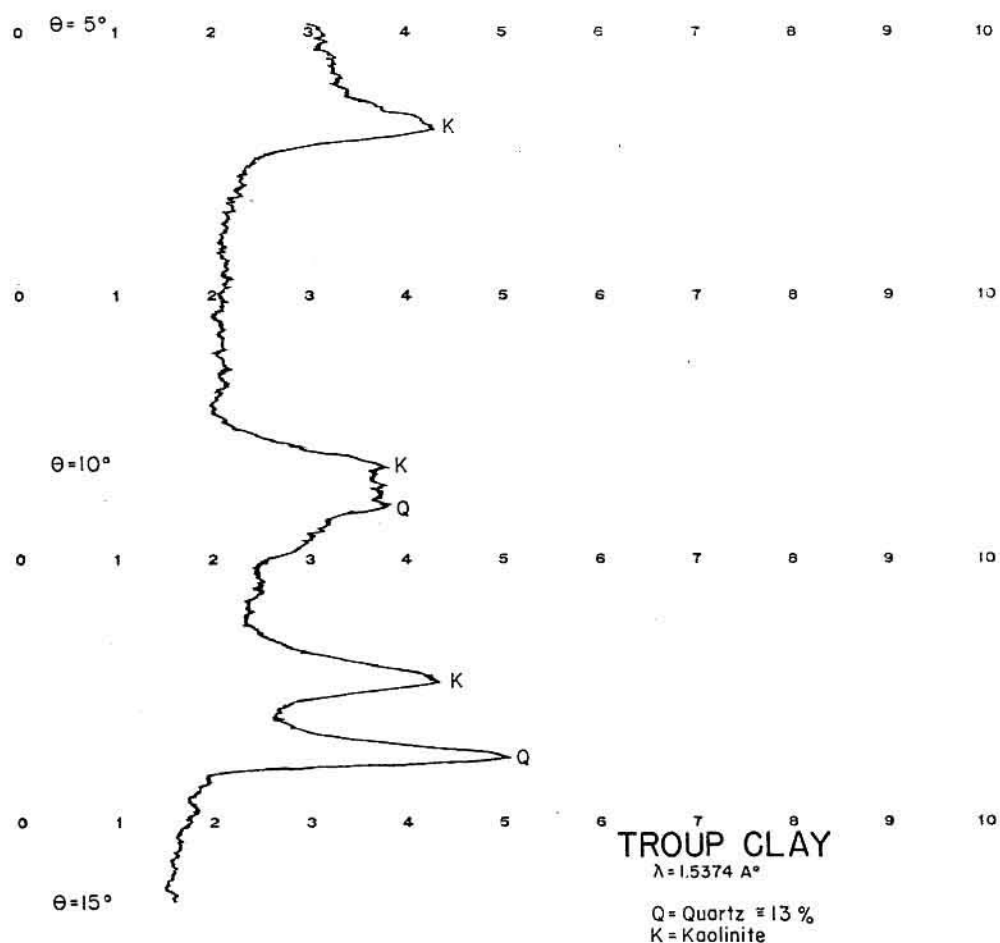


Fig. 11. X-ray diffraction pattern for Troup ball clay.

While the Troup clay with proper ceramic preparation has been shown to meet standard requirements, there is always the possibility that other strata may fulfill a more varied range of requirements. Data obtained by a detailed geological survey of the Troup area (pp. 5-37) are espec-

ially valuable in that they may lead to the location of other ball-clay strata. In the process of such a survey the Bureau of Economic Geology submitted samples to the Research Laboratory in Ceramics for their appraisal. The data on these samples follow.

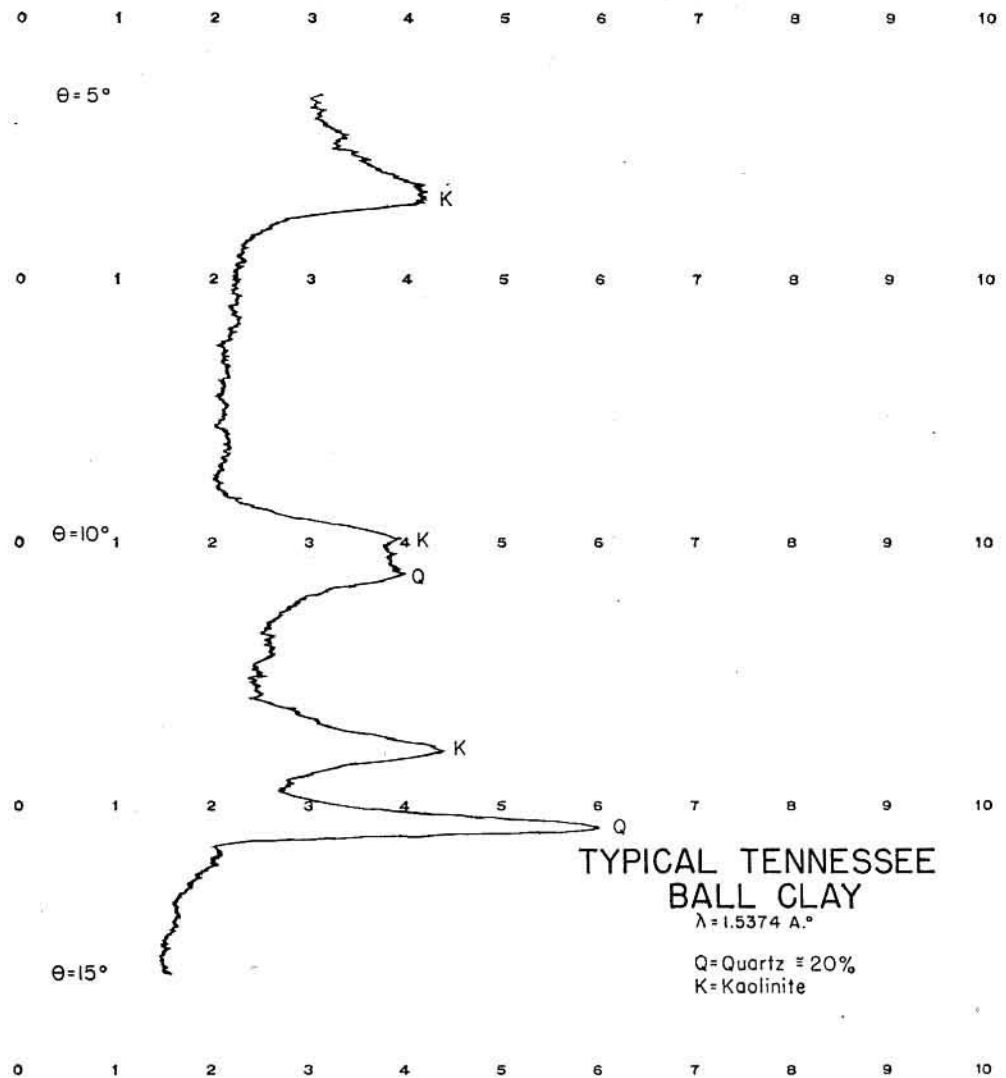


Fig. 12. X-ray diffraction pattern for a typical Tennessee ball clay.

CERAMIC DATA

TROUP CLAY

Location.—From pit being worked by Thermo Fire Brick Company, near Troup, Texas.

Raw color: gray
Plasticity: good
Lime content: none
Drying shrinkage: 6.0%

FIRING DATA (fig. 13)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	light pink	7.0	24.4
04	light pink	7.0	20.7
02	light pink	8.0	19.1
1	light pink	9.0	16.1
5	light cream	13.0	13.0
8	light cream	14.0	8.0

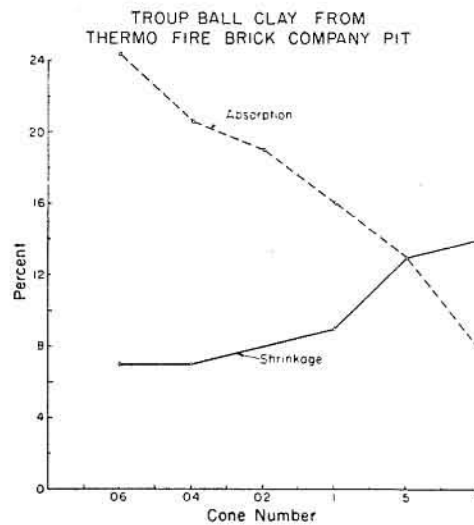


Fig. 13. Absorption and total shrinkage curves of ball clay from Thermo Fire Brick Company pit, Cherokee County, Texas.

SAMPLE S-479

Location.—Test hole 5, augered by Mr. H. C. Fountain, on west side of county road and on southwest side of a northward-flowing right tributary of Mill Creek, on the county road that runs straight south from Henry's Chapel to Concord, 0.25 mile north of 440-foot high hill, on the top of which are three road metal pits, 0.6 mile airline distance northwest of Martin's Chapel, northeastern Cherokee County, Texas. Determined as Carrizo formation by H. B. Stenzel.

Raw color: gray with reddish-brown streaks
Plasticity: good
Lime content: none
Drying shrinkage: 7.6%

FIRING DATA (fig. 14)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	pink	8.0	16.7
04	pink	8.0 +	15.9
02	pink	10.0	14.1
1	pink	10.5	11.3
5	pink	12.0	10.8
8	pink	12.0	8.7

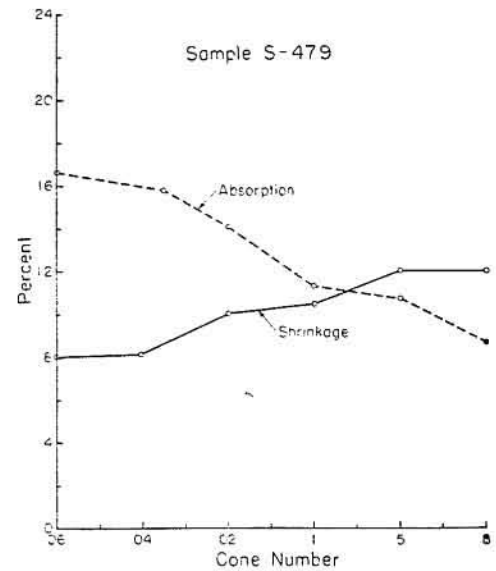


Fig. 14. Absorption and total shrinkage curves of clay (sample S-479) from test hole 5, northeastern Cherokee County, Texas.

SAMPLE S-480

Location.—Shallow auger hole, dug by Mr. H. C. Fountain, in south ditch of Farm Road 13, between Henry's Chapel and Grissom Creek, 0.13 mile west of the bridge over the creek, northeastern Cherokee County, Texas. Determined as Carrizo formation by H. B. Stenzel.

Raw color: gray and reddish-brown mottled
Plasticity: good
Lime content: none
Drying shrinkage: 9.1%

FIRING DATA (fig. 15)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	orange	9.0	14.6
04	orange	10.0	14.4
02	orange	10.5	12.9
1	orange	11.0	12.2
5	red	11.5	10.8
8	red	11.5	8.9

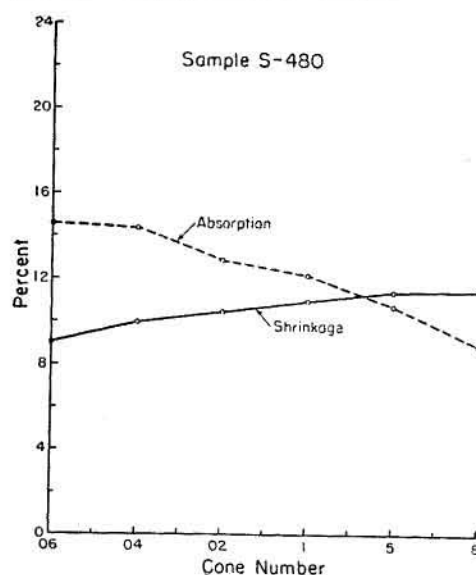


Fig. 15. Absorption and total shrinkage curves of clay (sample S-480) from shallow auger hole, northeastern Cherokee County, Texas.

SAMPLE S-481

Location.—East ditch of abandoned county road, which goes N. 14° E. across Henson Creek, south of Henson Creek and north of B.M.382, about 4 miles northwest of Carlisle, half a mile west of the east line of Smith County, in southeastern Smith County, Texas (compare Henderson quadrangle, U. S. Geol. Survey). Determined as uppermost stratum of Wilcox group by H. B. Stenzel.

Raw color: pink
Plasticity: good
Lime content: none
Drying shrinkage: 7.8%

FIRING DATA (fig. 16)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	pink	8.5	16.0
04	pink	9.0	15.9
02	pink	9.5	14.1
1	gray	10.5	12.0
5	cream	11.5	9.6
8	cream	12.0	7.9

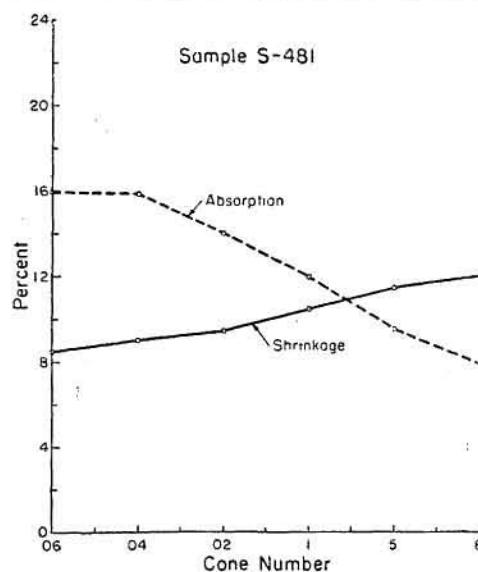


Fig. 16. Absorption and total shrinkage curves of ball clay (sample S-481) from road ditch, southeastern Smith County, Texas.

SAMPLE S-482-1

Location.—Auger hole, dug by Mr. H. C. Fountain, on west side of the curving county road which goes north-northwestward from Concord, on the side of a hill sloping northward to an eastward-flowing right tributary of Mill Creek, 1.11 miles airline distance north of the church at Concord, northeastern Cherokee County, Texas. Determined as Carrizo formation by H. B. Stenzel. Sample from depth 3.7 to 4.4 feet.

Raw color: gray (yellow streaks)
Plasticity: good
Lime content: none
Drying shrinkage: 7.9%

FIRING DATA (fig. 17)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	pink	8.0	14.1
04	pink	9.5	13.6
02	yellow-gray	9.5	11.6
1	yellow-gray	11.0	9.95
5	yellow-buff	12.0	7.2
8	yellow-buff	13.0	5.5

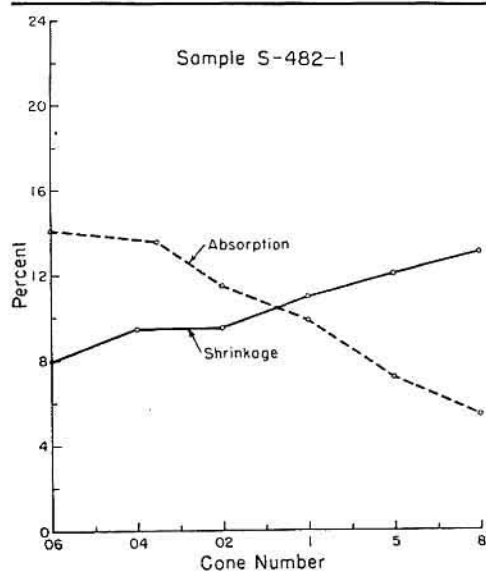


Fig. 17. Absorption and total shrinkage curves of clay (sample S-482-1) from auger hole, northeastern Cherokee County, Texas.

SAMPLE S-482-2

Location.—Same as for sample S-482-1; sample from depth 4.4 to 5.3 feet.

Raw color: yellow-gray
Plasticity: good
Lime content: none
Drying shrinkage: 8.5%

FIRING DATA (fig. 18)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	pink	8.5	14.5
04	pink	9.0	13.8
02	cream	10.5	10.8
1	cream	12.0	10.3
5	cream	12.5	6.3
8	light tan	12.5	5.8

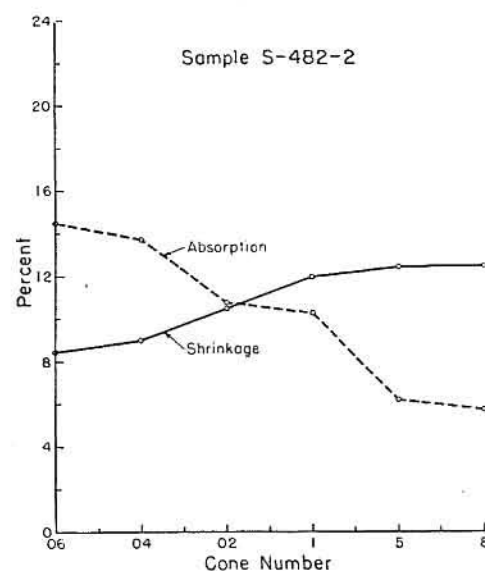


Fig. 18. Absorption and total shrinkage curves of clay (sample S-482-2) from auger hole, northeastern Cherokee County, Texas.

SAMPLE S-482-3

Location.—Same as for sample S-482-1; sample from depth 5.3 to 5.8 feet.

Raw color: yellow-gray
Plasticity: good
Lime content: none
Drying shrinkage: 7.5%

FIRING DATA (fig. 19)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	pink	8.5	14.4
04	pink	8.0	14.2
02	pink	10.0	11.8
1	buff	11.0	9.1
5	buff	12.5	6.6
8	tan	12.5	4.8

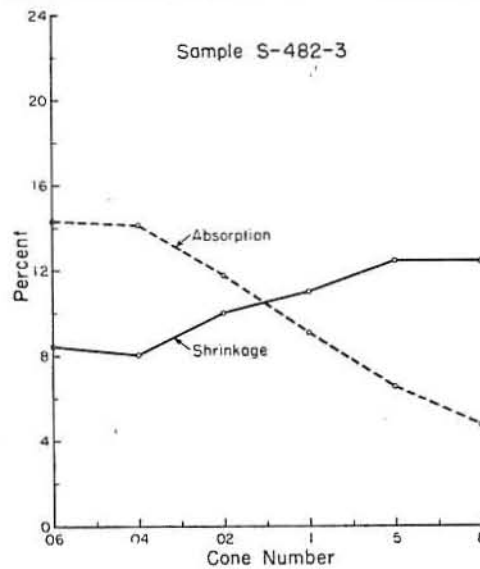


Fig. 19. Absorption and total shrinkage curves of clay (sample S-482-3) from auger hole, north-eastern Cherokee County, Texas.

SAMPLE S-482-4

Location.—Same as for sample S-482-1; sample from depth 5.8 to 6.8 feet.

Raw color: yellow-gray
Plasticity: good
Lime content: none
Drying shrinkage: 8.8%

FIRING DATA (fig. 20)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	light reddish-pink	10.0	14.7
04	light reddish-pink	10.0	14.3
02	light reddish-tan	11.5	11.3
1	light reddish-tan		8.2
5	buff	13.0	4.7
8	tan	15.0	2.4

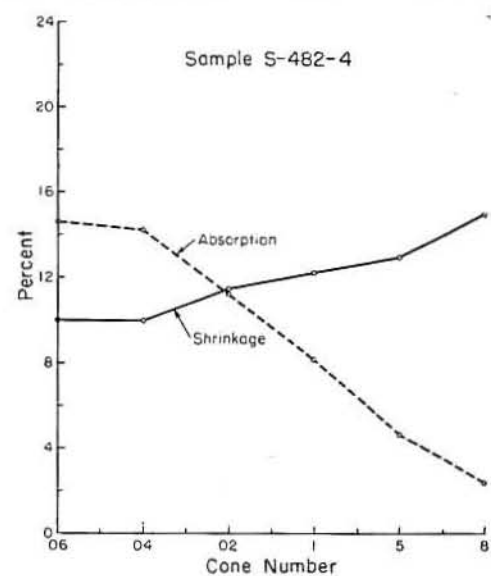


Fig. 20. Absorption and total shrinkage curves of clay (sample S-482-4) from auger hole, north-eastern Cherokee County, Texas.

SAMPLE S-482-5

Location.—Same as for sample S-482-1; sample from depth 6.8 to 7.5 feet.

Raw color: yellow-gray

Plasticity: good

Lime content: none

Drying shrinkage: 9.1%

FIRING DATA (fig. 21)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	light reddish-pink	10.0	15.8
04	light reddish-pink	11.0	14.8
02	light reddish-pink	12.5	10.7
1	light reddish-tan	14.5	8.4
5	buff	15.0	1.1
8	tan	16.5	0.9

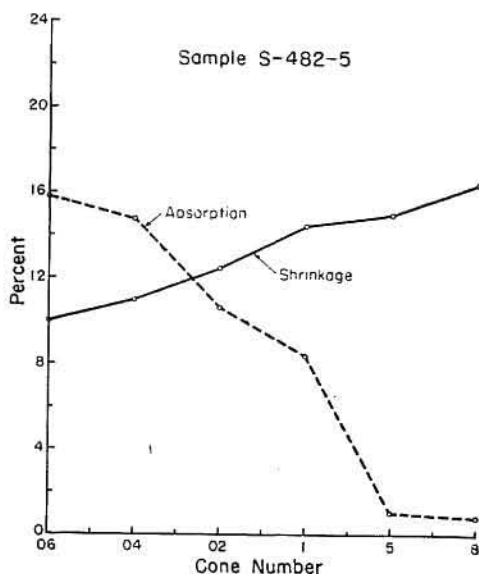


Fig. 21. Absorption and total shrinkage curves of clay (sample S-482-5) from auger hole, north-eastern Cherokee County, Texas.

SAMPLE S-482-6

Location.—Same as for sample S-482-1; sample from depth 7.5 to 8.1 feet.

Raw color: yellow-gray

Plasticity: good

Lime content: none

Drying shrinkage: 8.9%

FIRING DATA (fig. 22)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	light reddish-pink	10.5	15.1
04	light reddish-pink	11.0	15.0
02	light reddish-tan	11.5	11.0
1	light reddish-tan	12.5	6.7
5	tan-buff	13.5	1.4
8	tan	16.5	0.4

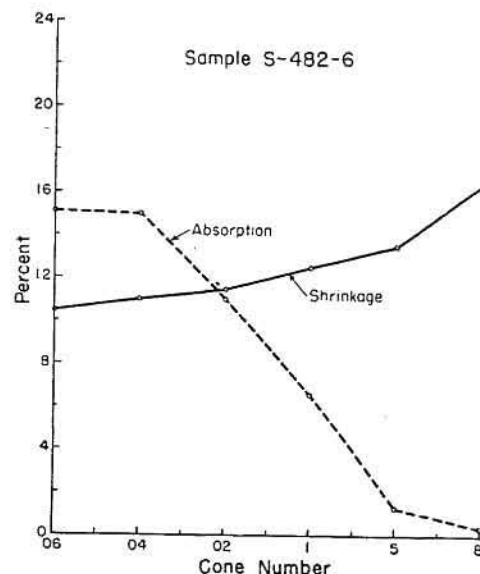


Fig. 22. Absorption and total shrinkage curves of clay (sample S-482-6) from auger hole, north-eastern Cherokee County, Texas.

SAMPLE S-482-7

Location.—Same as for sample S-482-1; sample from depth 10.4 to 10.6 feet.

Raw color: yellow-gray
Plasticity: good
Lime content: none
Drying shrinkage: 11.8%

FIRING DATA (fig. 23)

Cone Number	Color	Percent total shrinkage	Percent absorption
06	light reddish-pink	12.0	17.5
04	light reddish-pink		16.3
02	light reddish-cream	13.5	13.8
1	light reddish-tan	16.0	11.5

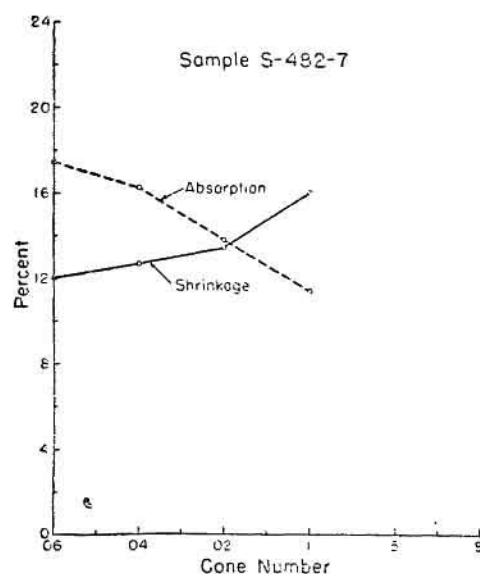


Fig. 23. Absorption and total shrinkage curves of clay (sample S-482-7) from auger hole, north-eastern Cherokee County, Texas.

Since observations of the fired color of all the samples submitted shows that none of them, except the one taken from the Thermo Fire Brick Company pit and sample S-481, could be classified as ball clays, it was not deemed necessary to obtain data beyond the routine physical determinations. The data show the physical properties of strata from the Carrizo formation and of one sample (S-481) from the Wilcox group, and in that respect they will no doubt be of value to geologists.

Parties interested in the purchase of Texas ball clay should communicate with Thermo Fire Brick Company, Sulphur Springs, Texas, or General Refractories Company, Troup, Texas. These companies are currently operating pits 6 miles east of Troup in connection with the manufacture of high-grade refractory products.

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