

**STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES**

BUREAU OF GEOLOGY
Robert O. Vernon, *Chief*

GEOLOGICAL BULLETIN NO. 50

**MINERAL RESOURCE STUDY OF
HOLMES, WALTON AND WASHINGTON COUNTIES**

By
J. William Yon, Jr. and C.W. Hendry, Jr.

Published for
BUREAU OF GEOLOGY

**TALLAHASSEE
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OF
NATURAL RESOURCES**

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LETTER OF TRANSMITTAL



Bureau of Geology
Tallahassee
December 17, 1969

Honorable Claude R. Kirk, *Chairman*
Department of Natural Resources
Tallahassee, Florida

Dear Governor Kirk:

The Bureau of Geology under the Division of Interior Resources of the Department of Natural Resources has as one of its' missions the development of the mineral resources of the State. In particular the Bureau has attempted to find sources of minerals that could be developed in counties of Florida that have been losing population; the so-called deprived counties. Mr. William Yon, Jr. and Mr. Charles Hendry, geologists of this department have completed a thorough survey of Holmes, Walton, and Washington counties in panhandle Florida, and have found new sources of sand and clay which can be developed. The locations of these minerals and the tests performed to prove their value, is being published as Geological Bulletin No. 50.

Respectfully yours,

R. O. Vernon, *Chief*

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The writers are especially indebted to Dr. Robert O. Vernon, Chief of the Bureau of Geology, who added greatly to this report through his many helpful suggestions and encouragement. Appreciation is expressed to the geological staff of the Bureau of Geology for their help in various aspects of the study and to the clerical staff for patience and understanding during the preparation of the manuscript.

Special thanks are expressed to Mrs. Patricia Potter, Executive Secretary to the Walton County Chamber of Commerce for her interest and the many courtesies she extended the writers during the course of the project.

The writers would like to express appreciation to Mr. Lawrence Shirley and Mr. John Sweeney of the U. S. Bureau of Mines for cooperating with the writers in making the reports "Clay and Sand and Gravel Resources Holmes County, Florida" and "Limestone Resources of Washington County, Florida" available for use in this report.

Gratitude is expressed to Mr. M. E. Tyrrell, U. S. Bureau of Mines, who added immeasurably to this study through his advice and especially his untiring efforts in the evaluation of the ceramic raw material submitted from the area of study.

Mr. John Carver, Farmers Home Administration, U. S. Department of Agriculture, was very helpful in securing permission for the writers to use freely the data from the reports by Sweeney and Shirley on the clay, sand, gravel and limestone resources of Holmes and Washington counties, Florida.

The courtesies extended the writers by the County Development Commissions in Holmes, Walton and Washington counties are appreciated.

Appreciation is expressed to the citizens of the counties in the area of this study for their aid during the course of the field work for this report.

MINERAL RESOURCE STUDY OF HOLMES, WALTON AND WASHINGTON COUNTIES

by
J. William Yon, Jr. and C. W. Hendry, Jr.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of this investigation was to study the mineral resources of Holmes, Walton and Washington counties, Florida, providing information on the occurrence of certain minerals, types of tests performed and analyses of samples collected. The information presented is not intended to be an exhaustive investigation leading to immediate commercial development, because in most cases the data only represents information on a single core hole, outcrop or pit. However, the data, where favorable, would certainly indicate that the area might warrant further investigation.

The cut of the intracoastal waterway canal in southern Walton County, stream banks, roadcuts, and core holes were examined, and the samples collected were analyzed for possible economic minerals.

LOCATION OF AREA

The adjoining Holmes, Walton and Washington counties are located in the central part of panhandle Florida, shown in figure 1. Walton County is on the west, Holmes and Washington counties are to the east. Holmes County is north of Washington County. These three counties are bounded to the west by Okaloosa County, to the east by Jackson and Bay counties, to the north by the State of Alabama and to the south by the Gulf of Mexico.

Walton is the largest of the three counties, with a land-surface area of 1046 square miles. Holmes County has a land-surface area of 506 square miles, and Washington County has 625 square miles.

The principal towns are DeFuniak Springs, in Walton County, Chipley, in Washington County, and Bonifay, in Holmes County. These towns are also the county seats.

All of west Florida is completely covered by U. S. Geological Survey topographic maps in either the 7½ or 15 minute series. The topographic map coverage for Holmes, Walton and Washington counties is shown in figure 2.

PREVIOUS INVESTIGATIONS

Bell (1924, p. 53-266), in a preliminary report on the clay resources of Florida, discussed clay deposits in Holmes, Walton and Washington counties.

In a report on the sand and gravel deposits of Florida these deposits in Holmes, Walton and Washington counties were discussed in a general way by Martens (1928, p. 33-123). Vernon (1942, p. 142-143), in his report on Holmes and Washington counties, Florida, discussed the gravel, sand and clay resources.

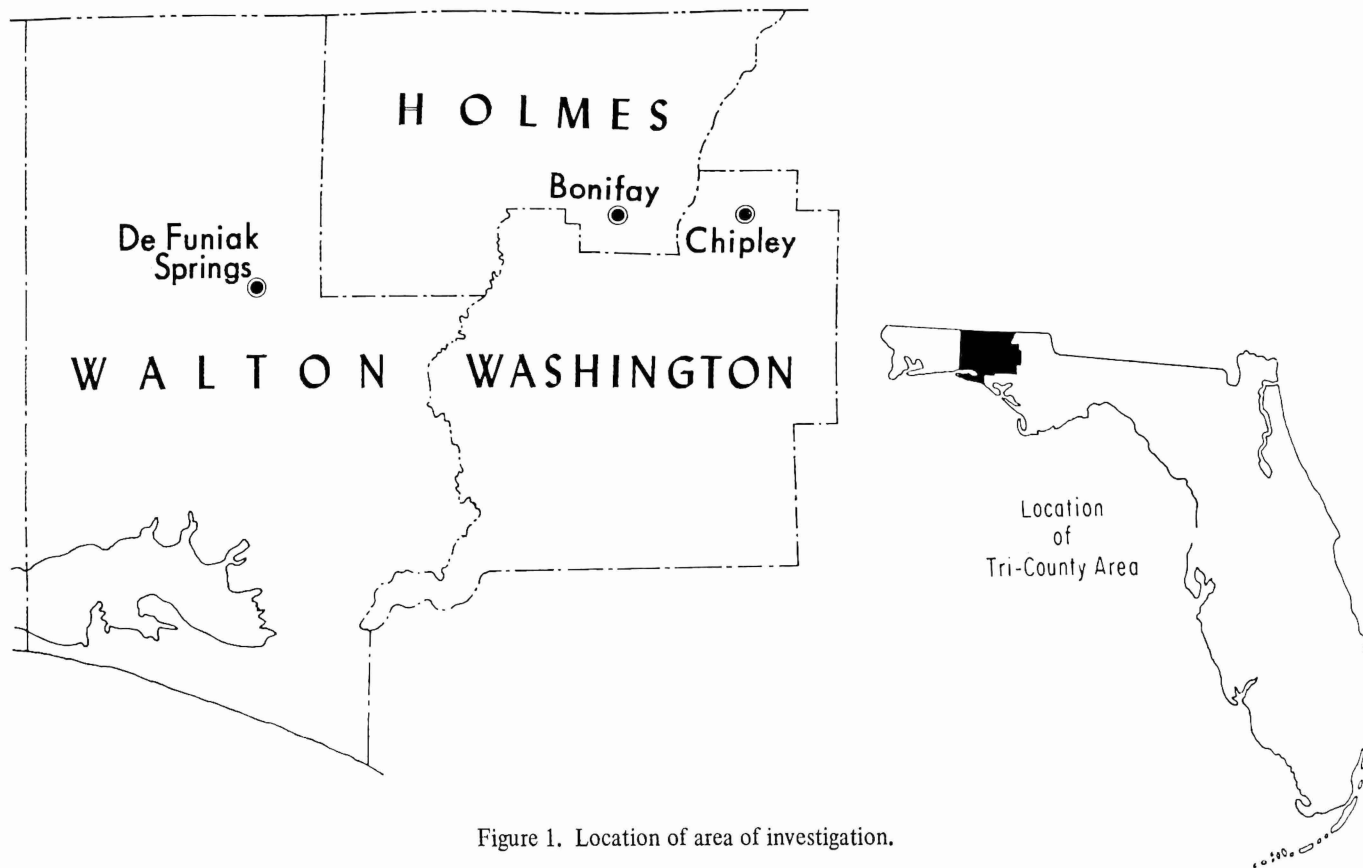


Figure 1. Location of area of investigation.

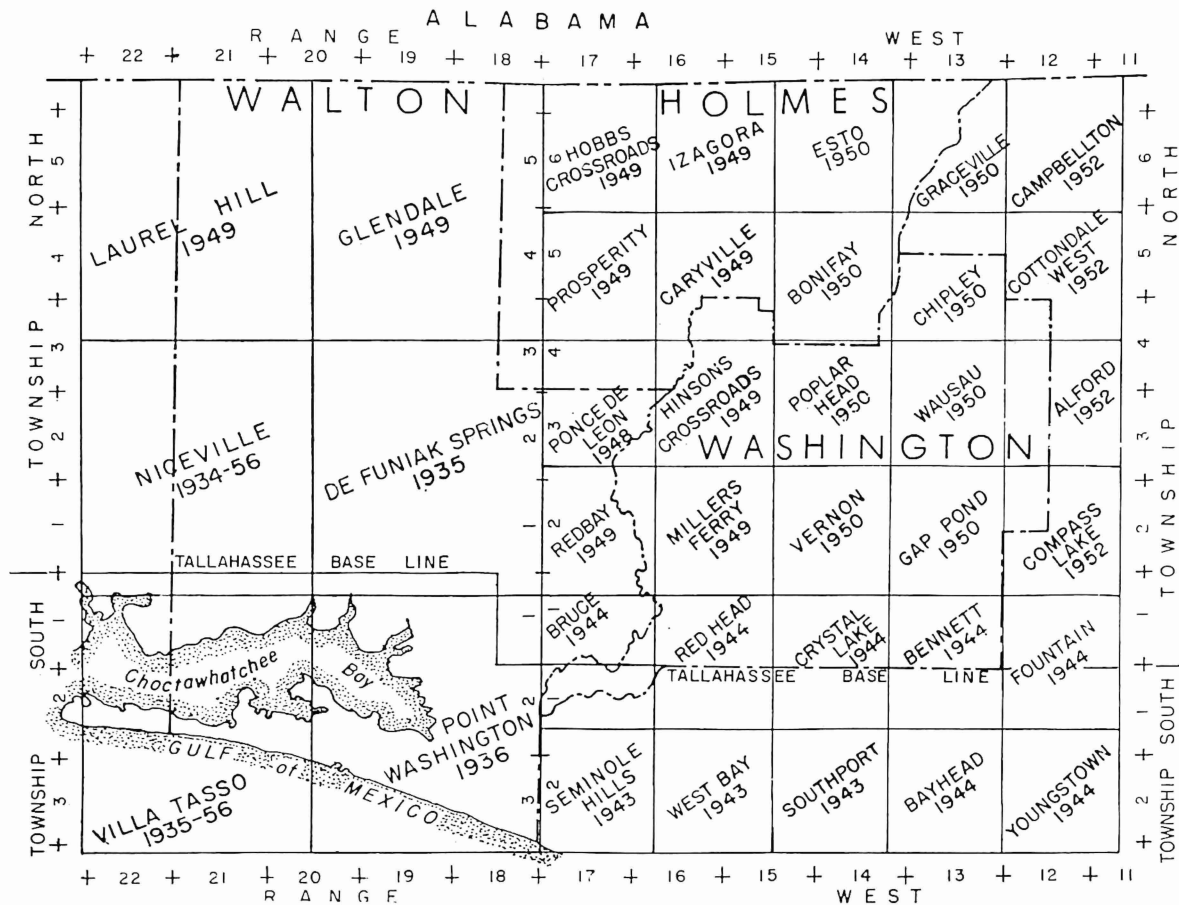


Figure 2. Index to topographic coverage of area of investigation.

The properties of Florida kaolins and clays are reviewed by Calver (1949) in Florida Geological Survey Information Circular No. 2, with specific localities and analyses of clays sampled in Holmes, Walton and Washington counties mentioned on pages 10, 14, 19, 32-33, 43-47, 53, and 58-59.

The most recent and comprehensive report on the gravel, sand and clay deposits of Holmes County is an open-file report prepared for the Farmers Home Administration, U. S. Department of Agriculture by J. W. Sweeney and L. E. Shirley (1965) of the U. S. Bureau of Mines. Sweeney and Shirley investigated the quality of the clay, and the extensiveness and suitability of the gravel and sand for commercial use.

The U. S. Bureau of Mines and the Farmers Home Administration, U. S. Department of Agriculture have given permission to use data from the above report. It will be freely drawn from and discussed in this report.

Florida Geological Survey Bulletin No. 42, by W. D. Reves (1961) is an excellent report on the limestone resources of Holmes and Washington counties. L. E. Shirley and J. W. Sweeney (1965) also investigated the limestone resources of Washington County.

TRANSPORTATION

Holmes, Walton and Washington counties are served by the Louisville and Nashville Railroad. This railroad parallels U. S. Highway 90 and also has a spur across the northwest corner of Walton County and one across the northeast corner of Holmes County. It maintains daily passenger and freight service with connections to the west at New Orleans and to the east at Jacksonville.

U. S. Highway 90 traverses the counties in an east-west direction in the central portion and U. S. Highway 98 is the main east-west coastal route. Numerous State Highways cover the area, generally radiating from the county seats. In addition to the Federal and State network of highways there are abundant secondary county paved and unpaved roads that permit access to almost every portion of the three counties.

Upon construction and completion of Interstate Highway 10, as shown on figure 3, another valuable means of transportation will become available.

The intracoastal waterway passes along the southern part of Walton County and provides a route for an inexpensive form of transportation (fig. 3).

The close proximity of the Choctawhatchee River to all three counties provides a convenient route for shipping mineral products northward to Alabama and southward to the intracoastal waterway.

Natural gas is available from the Houston Texas Gas and Oil Corporation pipe line (fig. 3) that crosses the three counties, and it provides an important source of economic fuel for use in the chemical processing of limestone and the making of structural clay products. Gulf Power Company provides electrical power throughout the area.

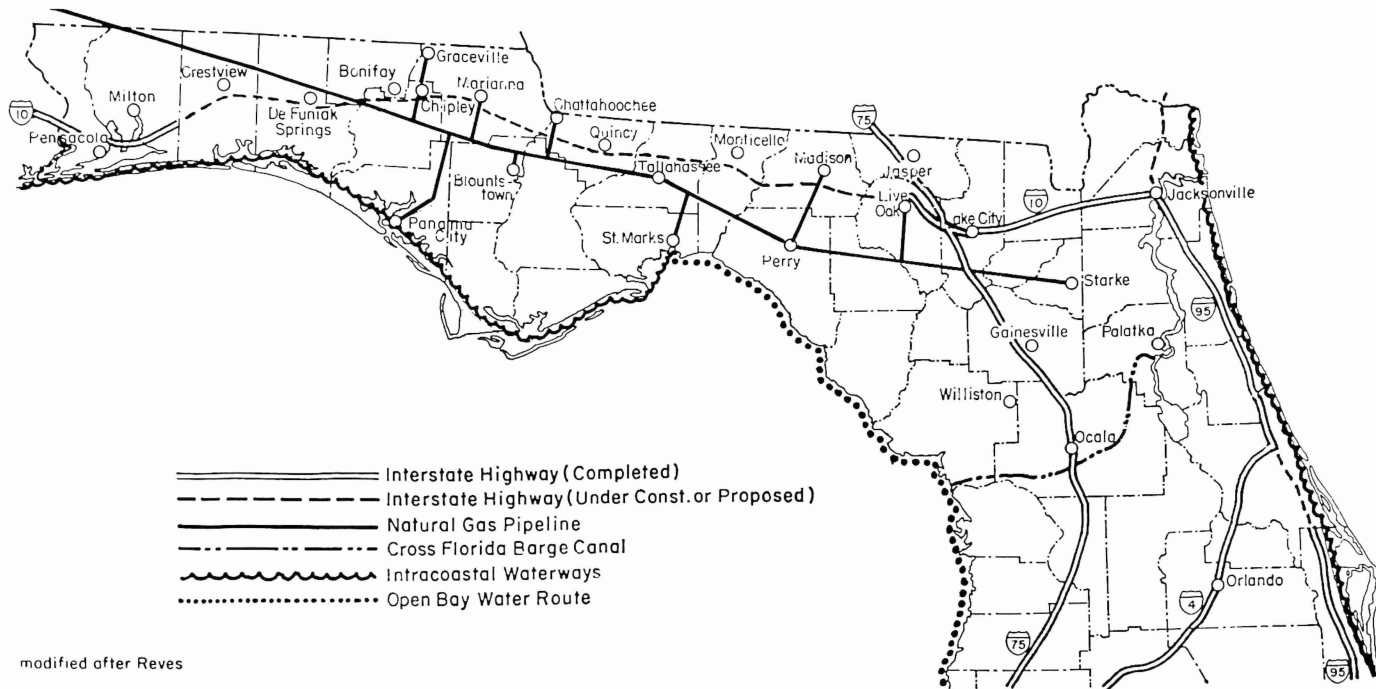


Figure 3. Routes of interstate highways 10, natural gas pipeline, and Intracoastal Canal in the area of investigation.

CLIMATE

Holmes, Walton and Washington counties are in an area of southeast wet continental and north Florida transitional climate. They have an average January temperature of 55-58°F, an average July temperature of 80-84°F, and are 8-10 months frost free. The average annual precipitation is 50-60 inches. Most of the rainfall occurs during the months of June through September.

WELL AND OUTCROP NUMBERING SYSTEM

The well and outcrop numbering system used in this report is based on the location of the well or outcrop and uses the rectangular system of section, township and range for identification. The well or outcrop number consists of six parts: W for well or L for outcrop, county abbreviation, the quarter/quarter location within the section, the section, township, and range.

The basic rectangle is the township which is 6 miles square. It is consecutively numbered by tiers both north and south of the Tallahassee Base Line and is also consecutively numbered east and west of the principal meridian. In the present numbering system the T will be left off the township number and the R off the range number. Each township is divided equally into 36 square miles called sections, which are numbered 1 through 36 as shown on figure 4. The sections are divided into quarters with the quarters being labeled "a" through "d". In turn, each of these quarters is divided into quarters with these quarter/quarter squares labeled "a" through "d".

When there is more than one well or outcrop in a quarter/quarter section they are identified by a sixth number at the end of the fifth unit. The abbreviation used for counties in this report are Ho for Holmes, Wl for Walton, Ws for Washington.

There are some locality or outcrop numbers used in this report that do not conform to the above described system; however, these non-conforming numbers are taken from other publications, and to convert them only would create undue confusion.

GEOLOGY

PHYSIOGRAPHY

The deposits studied in this investigation lie within the East Gulf Coastal Plain, a subdivision of the Coastal Plain Province (Fenneman, 1938, p. 1-83). In Holmes, Walton and Washington counties the major physiographic divisions of Vernon (1951, p. 16), White, Vernon and Puri (Puri and Vernon, 1964, p. 10-15) are recognized, and are as follows: 1) Northern Highlands, 2) Marianna Lowlands, 3) Gulf Coastal Lowlands and 4) River Valley Lowlands, shown in figure 5.

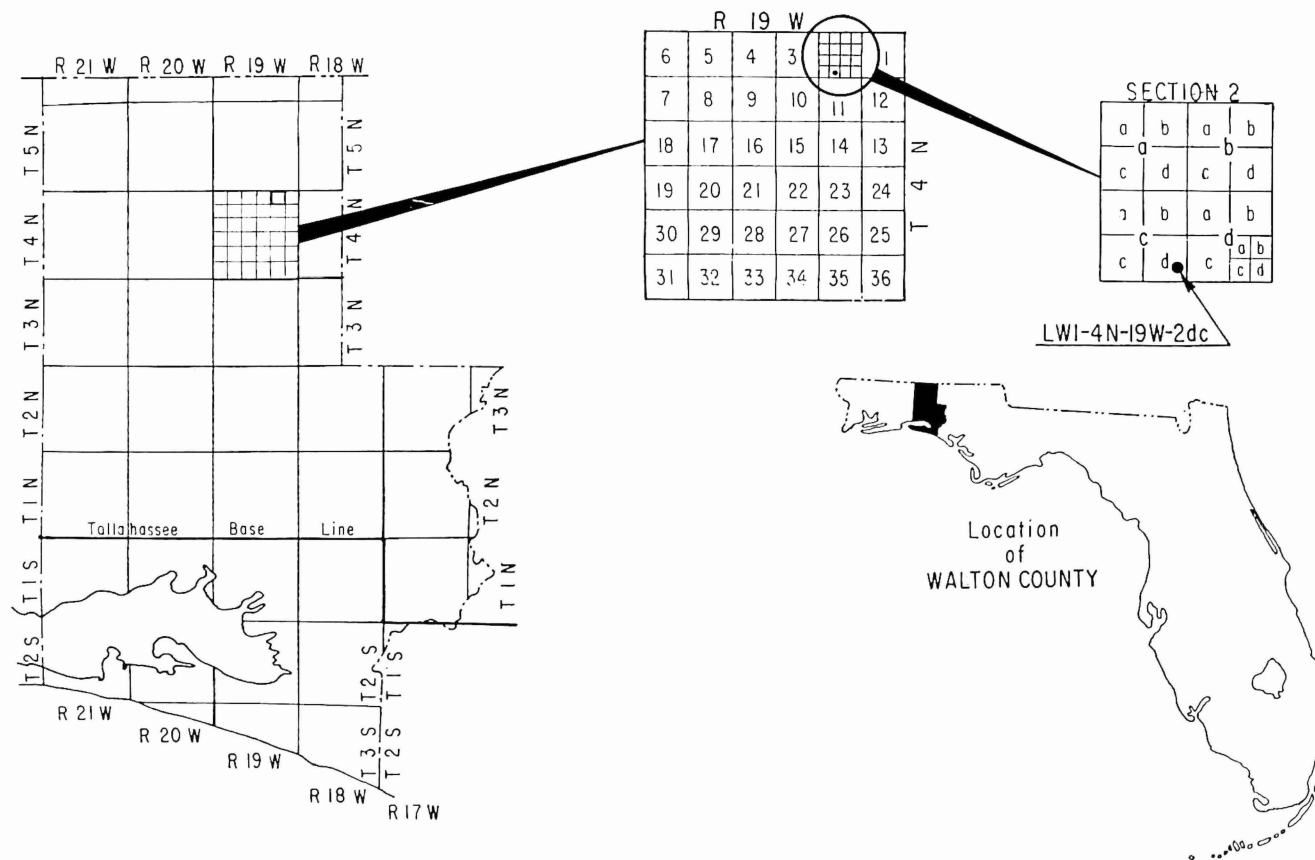


Figure 4. Locality and well-numbering system.

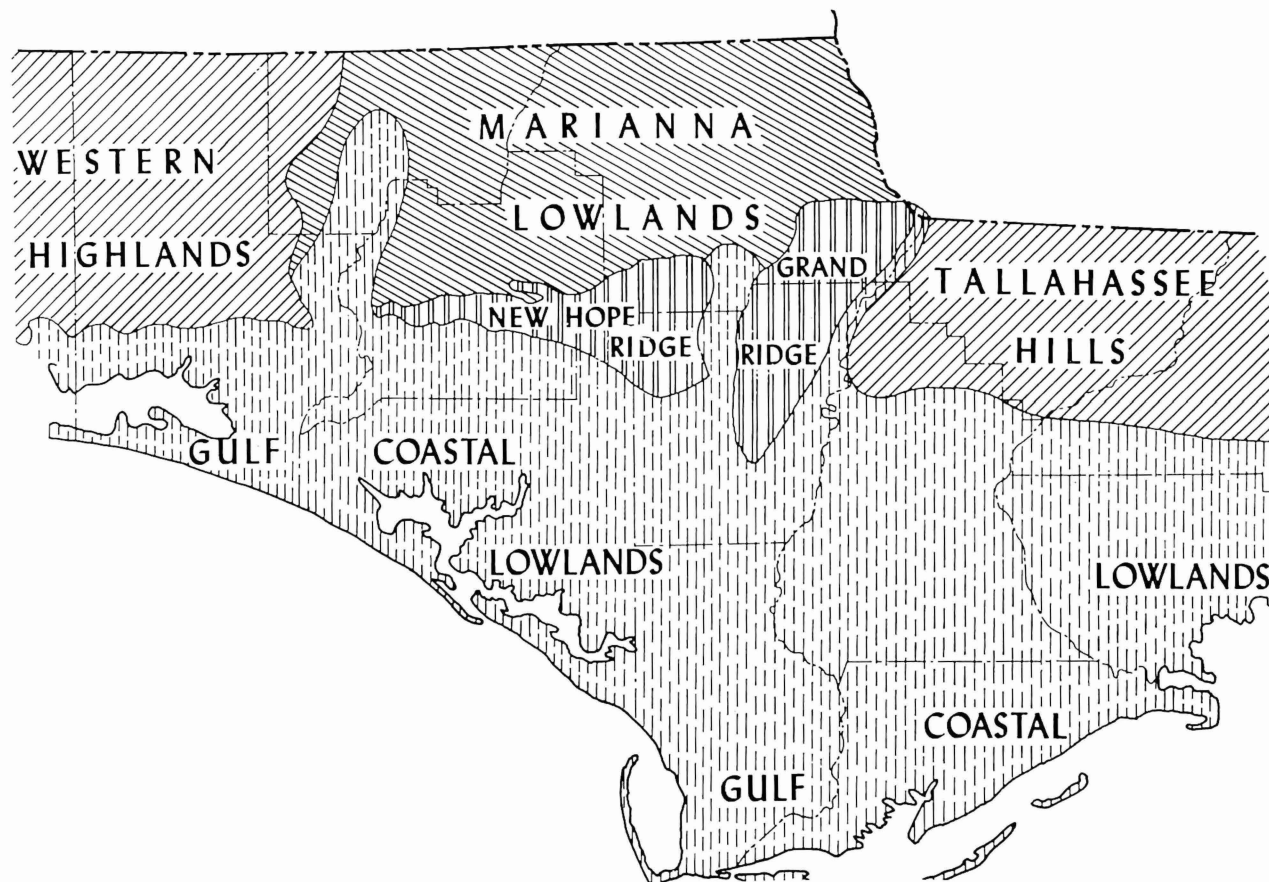


Figure 5. Physiographic map.

NORTHERN HIGHLANDS

The Northern Highlands is an almost continuous section of high land across the northern part of the State. Within the area under discussion the Northern Highlands has been dissected by stream erosion and is separable into lesser continuous higher land masses that are the 1) Western Highlands, 2) The New Hope Ridge, and 3) the Washington County Outliers.

Vernon (1951, p. 15) states that these features are the remnants of a large delta plain made up of smaller coalescing subdelta plains that blanketed older Miocene deposits in late Miocene or early Pleistocene time.

MARIANNA LOWLANDS

The Marianna Lowlands occupy most of central and eastern Holmes County and the northern portion of Washington County. According to Puri, Vernon, and White (Puri and Vernon, 1964, p. 12) the Marianna Lowlands are a result of stream erosion and solution activity. The same agents that formed the Marianna Lowlands also reduced the once continuous remnant hills of Washington County, New Hope Ridge, Western Highlands, Grand Ridge and the Tallahassee Hills. A well developed north-facing scarp (Holmes Valley Scarp) separates the Marianna Lowlands from New Hope Ridge in Washington and Jackson counties.

The lowlands encompass parts of Jackson, Holmes, and Washington counties. They are bounded on the west by the Western Highlands, on the southeast by Grand Ridge and on the south by New Hope Ridge. To the north the lowlands continue into Alabama.

Limestone is near the surface of the ground and consequently, the area is one of karst development with many sinkholes. Many broad shallow basins are present, some of which are filled with water, forming lakes.

GULF COASTAL LOWLANDS

The Gulf Coastal Lowlands are a series of coast-parallel plains or terraces rising from the coast to successively higher levels in a landward direction. These terraces were formed during the Pleistocene Epoch or "Great Ice Age" when world-wide fluctuations of sea level were tied in with the growth and melting of the ice caps. The periods of time when sea level was lowered are referred to as glacial stages. This was accomplished by the storing of large quantities of ocean water as land-glaciers. The interglacial stages were those times when the glaciers receded, thus returning the water to the seas and causing a rise in sea level. During each of the interglacial stages, when sea level rose and remained stationary at one elevation for a long enough interval, a terrace and shoreline was formed.

In the southern part of the area under study Vernon (1942, p. 18) recognized plains lying almost parallel to the present coastline which are bound by erosional scarps. The shorelines of these terraces occur at 220, 150, 105, and 30 feet above the present sea level.

RIVER VALLEY LOWLANDS

The term River Valley Lowlands is applied to all the stream valleys in Holmes, Walton and Washington counties, and especially to those lowland sediments associated with the Choctawhatchee River, the Shoal River and their tributaries.

Vernon (1942, p. 5-15) recognized that four depositional alluvial terraces occur along the Choctawhatchee, separated by escarpments, and are similar in origin to the present flood plain.

STRATIGRAPHY

It is not the purpose nor the intent of this report to discuss fully the stratigraphy of the area under study. Consequently, only that part of the stratigraphy will be discussed which has a direct bearing on the economic geology of the area.

So that the reader will understand the relationship of the formations discussed for economic consideration a stratigraphic chart is included as Table 1.

EOCENE SERIES

JACKSON STAGE

Crystal River Formation

Puri (1953, p. 130) proposed the term Crystal River Formation to replace Vernon's Ocala limestone (restricted). The type locality of the Crystal River Formation is in the Crystal River Rock Company quarry, Citrus County, Florida, where 108 feet of limestone is exposed.

The Crystal River Formation primarily consists of a pale orange, soft to medium hard, good to moderately porous, microfossiliferous, partially recrystallized limestone (calcarenite). In some instances it is a calcirudite because of the large number of *Lepidocyclus* specimens.

The Crystal River Formation in Holmes and Washington counties is a very pure limestone, containing in many places less than 1% impurities (Reves, 1961, p. 5). However, in Holmes County, Florida, near the Alabama State line, the Crystal River becomes sandy and clayey.

OLIGOCENE SERIES

Suwannee Limestone

"Duncan Church Beds"

Cooke and Mansfield (1936) applied the name Suwannee Limestone to the fossiliferous limestones cropping out along the Suwannee River from White Springs to Ellaville. The history of the stratigraphic nomenclature of the Suwannee Limestone has been adequately discussed in Florida Geological Survey Bulletins 21 and 29, which are cited as very good references for historical information.

TABLE 1. STRATIGRAPHIC NOMENCLATURE FOR GEOLOGIC FORMATIONS
IN HOLMES, WALTON, AND WASHINGTON COUNTIES

Era	System	Series	Stage	Formation
Cenozoic	Quaternary	Recent Pleistocene		Stream alluvium Terrace sands
	Tertiary	Plio-Pleistocene		Citronelle
		Miocene	Choctawhatchee	Red Bay Yellow River
			Alum Bluff	"Coarse clastics" Hawthorn, Shoal River, Chipola
			Tampa	St. Marks Chattahoochee
		Oligocene	Vicksburg	Suwannee Limestone (Duncan Church Beds)
				Marianna Limestone
		Eocene	Jackson	Crystal River

The Suwannee Limestone crops out in Holmes and Washington counties, and has been reported on by Vernon (1942), Reves (1961), and Shirley and Sweeney (1965). The west Florida "Suwannee" is a microcoquina, with abundant *Lepidocyclus* and *Operculina* forms in particular, whereas, the type Suwannee is devoid of *Lepidocyclus* and *Operculina* forms but has abundant "cones". It is described generally as a light yellowish orange, abundantly microfossiliferous, partially recrystallized, soft to hard, granular limestone (calcarenite). The term "Duncan Church beds" has been assigned informally to the Suwannee age lithologies in west Florida (Puri and Vernon, 1964, p. 106).

Marianna Limestone

The Marianna Limestone is present both as a surface and subsurface unit in Holmes, Walton and Washington counties. This formation crops out extensively in the vicinity of Marianna, Jackson County, in the northeast corner of Washington County and in west central Holmes County. An historical summary is adequately presented in Florida Geological Survey Bulletin Nos. 21 and 29. The only outcrop of Marianna Limestone in Walton County is at Natural Bridge, section 26, T6N, R20W, but every core hole drilled by the Division of Geology penetrated the Marianna overlying the "Duncan Church beds" in the northern half of Walton County.

This formation is composed of a fine-grained, crystalline to earthy, sparsely fossiliferous, firm massive limestone (calcilutite). It has been quarried for building stone in west Florida as "chimney rock". (Florida State Road Department testing data on the Natural Bridge outcrop is presented on page 80).

MIocene SERIES

TAMPA STAGE

St. Marks and Chattahoochee Formations

The sediments assigned to the Lower Miocene have been subdivided and redefined many times since the name Tampa was first applied to those deposits by L.C. Johnson (1888, p. 235). The latest revision was made by Puri (1953, p. 17). He places all sediments previously called the Tampa Formation in the Tampa Stage. He divided the Tampa Stage into the St. Marks and Chattahoochee Formations. In the present report, the writer will adhere to the nomenclature presented by Puri.

The St. Marks and Chattahoochee formations would include all beds mapped by Vernon (1942) as the Tampa Formation in Holmes and Washington counties. He (Vernon, 1942, p. 68) states that although the Tampa is predominantly a limestone in Washington County it does contain green clayey silts at the base of the section in Holmes County.

ALUM BLUFF STAGE

Miocene Coarse Clastics, Chipola, Shoal River, and Hawthorn Formations

The Alum Bluff Stage encompasses all sediments lying above the Tampa and all deposits below Choctawhatchee age sediments. (Puri and Vernon, 1964, p. 126).

For the purpose of this report the above formations will not be considered individually. However, in a forthcoming report by the Division of Geology on the Geology of Walton County each unit will be discussed in detail.

According to Vernon (1942, p. 76) the sediments of the Alum Bluff are marls, sands, clays, silts, and limestones.

In Holmes County, he (Vernon, 1942, p. 76) reports that carbonaceous clays and silty fine sands are present.

CHOCTAWHATCHEE STAGE

Red Bay and Yellow River Formations

The Red Bay and Yellow River Formations (Puri and Vernon, 1964) include all Miocene sediments that are younger than the Alum Bluff deposits in the area of study.

The Yellow River formation is a sand that is identified only in the subsurface of Walton County, but is absent in Holmes and Washington counties.

The Red Bay Formation is a sand and clay unit that crops out in eastern Walton County and in Washington County.

PLIO-PLEISTOCENE DEPOSITS

(Citronelle Formation)

Overlying the Miocene deposits in Holmes, Walton and Washington counties are younger gravels, sands and clays.

According to Vernon (1942, p. 134) these beds are Plio-Pleistocene in age. These deposits generally lie at elevations above 200 feet, and were deposited on a large delta that covered most of western Florida (Vernon, 1942, p. 134).

Cooke (1945, p. 236-238) relates these deposits to the Citronelle Formation of Pliocene age. However, Puri and Vernon (1964, p. 230) believe the Citronelle sediments are more closely related to the Pleistocene.

RECENT STREAM ALLUVIUM

The Recent deposits occurring along the stream valleys in Walton County consists of sands, clayey sands and sandy clays. They are reworked Pleistocene and Tertiary deposits.

According to Vernon (1942, p. 140) the Recent sediments in Holmes and Washington counties deposited by the streams other than the Choctawhatchee are fine to coarse sands. The Choctawhatchee River carries and deposits sands, silts and clays. Vernon further states that the river deposits are a deep red and

orange color because they are derived from iron-rich beds in Alabama. The deposits of the tributary streams of the Choctawhatchee, however, are light colored because they were eroded from Tertiary and terrace material located within the counties.

ECONOMIC MINERALS

INTRODUCTION

The following is a discussion of minerals that are presently in demand in the industrial-minerals market, and for which little data has been available previously from this area. Most of the treatment in this report is on the clays and sands, although limited discussion is included on heavy minerals, humate, and oyster shells. Gravels are not discussed since they do not occur in commercial quality or quantity.

The location of the coreholes drilled in Holmes and Walton counties by the U. S. Bureau of Mines and the Bureau of Geology, Florida Department of Natural Resources and the outcrop samples are shown on figure 6.

As an appendix to this report there is included a heretofore unpublished report by L.E. Shirley and J.W. Sweeney on the limestones of Washington County.

CLAYS

GENERAL OCCURRENCE

The clays in Holmes, Walton and Washington counties, for the most part, were transported and are both marine and fluvial.

The clays found in the Tampa, Alum Bluff and Choctawhatchee Stage deposits are marine or near shore deposits. Examination by X-ray diffraction indicates that these clays are either kaolinite or montmorillonite. The Miocene clays are generally well bedded and can be seen cropping out in the counties under study. Mapping and correlation of outcrops and core holes indicates that the clays are lenticular in nature.

The Plio-Pleistocene clay deposits are believed to be fluvial and deltaic in origin, and therefore, would be expected to be lenticular in occurrence.

Some of the clays found along the present stream valleys are Pleistocene to Recent in age and are derived from existing deposits within the counties as well as from Alabama.

ECONOMIC CONSIDERATION

Some of the clays in the counties under study, through testing, were found to be useful for making brick, sewer pipe, terra cotta, and several kinds of tile, including glazed tile and lightweight aggregate.

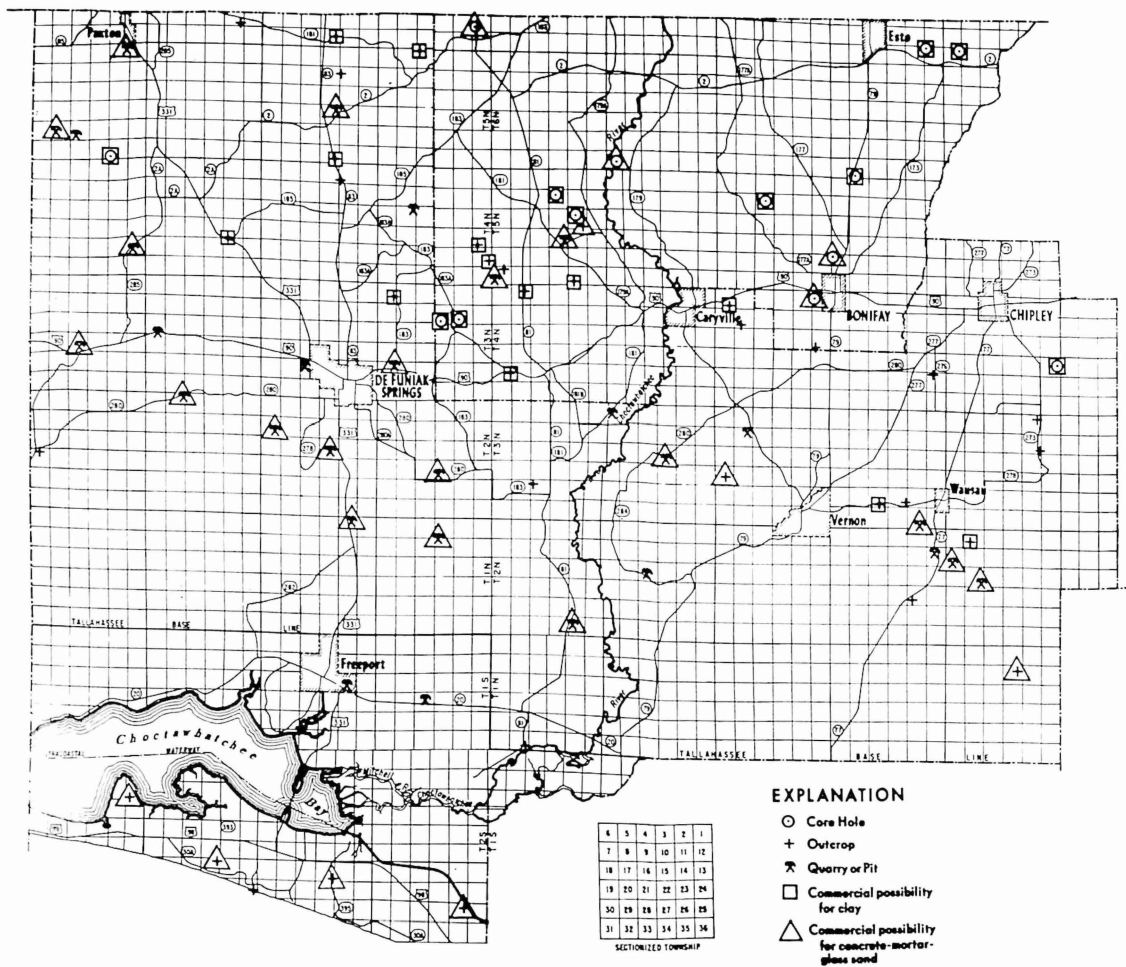


Figure 6. Locations of coreholes and outcrops.

Most of the structural-clay products mentioned above are heavy in their finished form; consequently, in consideration of a plant location, the shipping distance from the plant to the market area is of considerable importance. According to Sweeney and Shirley (1965), the generally accepted distance from plant to market area for structural-clay products is 100 to 300 miles, recognizing of course that this will vary depending on nearness of other producers, quality, demand and price of the products.

So that the reader will more fully understand the basis the writers used for determining an economic clay deposit, the following information is presented. The average brick plant in the U.S. produces 30 million bricks a year. This average includes the old out-moded plants and is, therefore, considered to represent the minimum size for an economic installation. The annual clay requirement for a plant this size would be approximately two cubic yards per 1,000 bricks or 60,000 cubic yards of clay (Aase, 1964).

In order to get a rough estimate of the acreage necessary to support a new clay industry which would require an initial investment of from one-quarter to one-third of a million dollars, the writers computed on the basis of a deposit five feet thick. Since there are 1,613.33 cubic yards per acre foot, such a deposit mined at the rate of 60,000 cubic yards a year would have to cover approximately seven and one-half acres. Therefore, to justify a new plant investment there should be a 30 to 50 year reserve of clay or at least 225 to 375 acres of the deposit averaging five feet in thickness (1.8-3.0 million cubic yards).

The production of structural-clay products in the area of investigation would be in competition with production from the marketing region of Florida, Georgia and Alabama. Aase and Associates (1964, p. 18), in a study on the feasibility of a proposed structural-clay products industry in Redevelopment Area A, Northwest Florida, show the points of present supply for structural-clay products in Florida, Georgia and Alabama, figure 7. As they (Aase, 1964, p. 18) point out, there is a wide distribution of structural-clay products production within the region; however, they believe the following factors would make location of structural-clay products in the northwest Florida area possible.

1. Capture a sufficient market from the area already being served by existing plants.
2. Produce commodities for which there is only limited local competition.
3. Penetrate the relatively unexploited market in the Florida peninsula.

FIELD WORK

During the summers of 1966 and 1967, personnel of the Bureau of Geology were engaged in a field investigation of the mineral resources of Holmes, Walton and Washington counties. In the course of this work 30 clay samples were

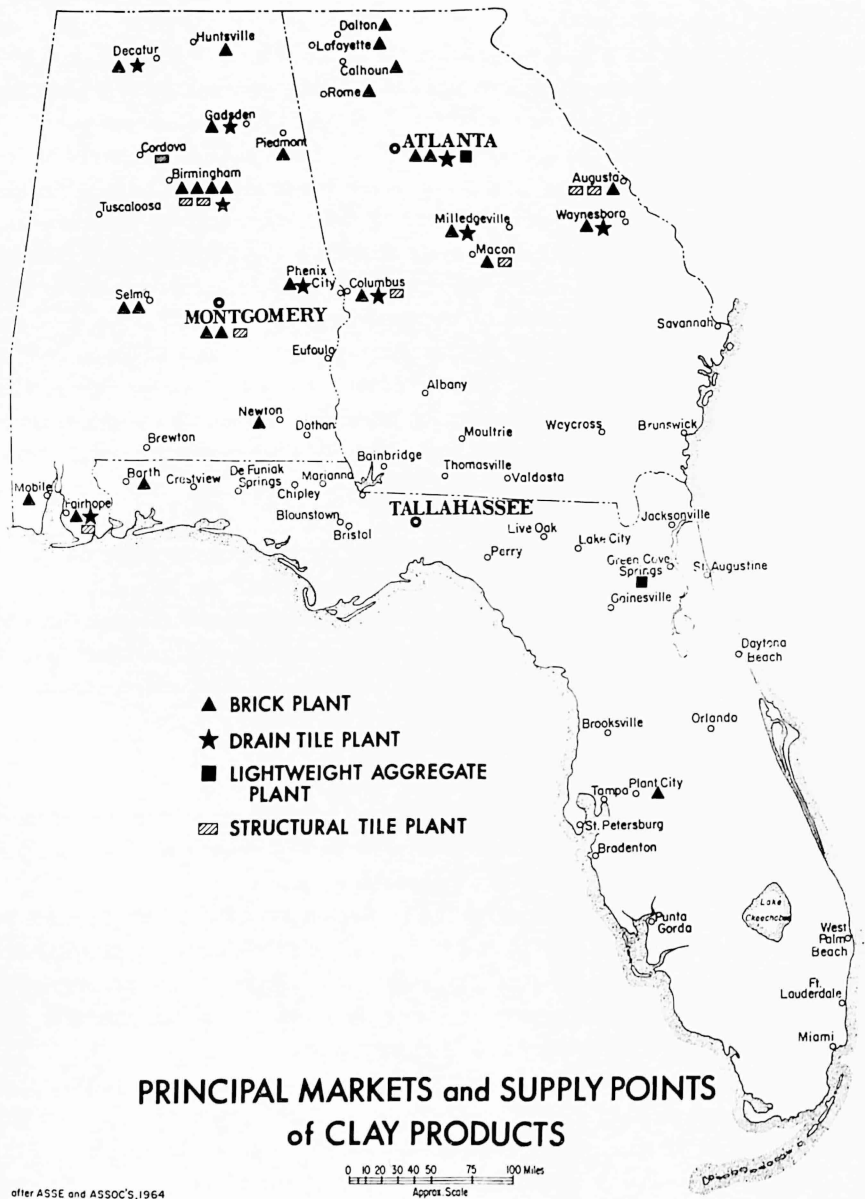


Figure 7. Location of clay products plants.

collected from outcrops and from one core hole (WWI-5N-21W-35-ac) that penetrated 16 feet of clay. The clay samples were collected by channeling down the face of the outcrop from fresh surfaces or as spot samples. Usually the weight of the samples would range from 20 to 25 pounds. From the core hole (WWI-5N-21W-35-ac) the complete interval of clay in the hole (16 feet) was used, and these samples were sent to the U.S. Bureau of Mines for testing.

J. W. Sweeney under the supervision of L. E. Shirley, U. S. Bureau of Mines, did a study on the clay, sand and gravel resources in Holmes County, Florida, during August, September and October, 1964. According to Sweeney and Shirley (1965), "Twenty-three holes were drilled for clays and fourteen for sand and gravel. All drilling was under the supervision of Bureau representatives who logged the holes... The objectives of the program were to locate clays, sand and gravel deposits, to pick the most promising prospects, and to core drill to determine vertical thickness and lateral extent... If an appreciable clay section was penetrated in a deposit, it was usually impossible to pick up the same clay in offset holes drilled a few hundred feet away, due to the rapid lateral facies change. Although 23 holes were drilled only 13 contained clay suitable to warrant testing. "

"In sampling the clays for testing, the whole clay section in a hole was saved but was divided into intervals which corresponded to drill run intervals. In most cases the plastic clay interval was not extensive, due to sand strata interbedded with the clays. Where these interbedded sand strata were over 2 or 3 inches they were discarded, otherwise, the silicious content of the clays would be undesirably high."

CERAMIC PROPERTIES OF CLAYS

Pure clays, that is clays of only one kind of material, in nature are virtually impossible to find. Instead they generally are mixed with substances such as quartz sand, silt and mica as well as iron-bearing minerals.

Heron (1965) made the following observations concerning ceramic properties of clays. The percentages of clay material to non-clay material in a sample has a direct bearing on the use of that particular clay. The larger the percentage of clay minerals present the greater is the increase in the plastic strength, dry strength, water of plasticity, dry and firing shrinkage.

Kaolinite in general has low plastic strength, dry strength, water of plasticity, whereas, montmorillonite has the opposite of these physical characteristics. Montmorillonite is much more complex chemically than kaolinite and will fire to darker colors as well as becoming glassy at low temperatures.

The blending of various clays may make it possible to obtain a useful product. For example, montmorillonite generally has a high plasticity and becomes very useful in blending with other clays that are deficient in this physical characteristic.

Quartz, one of the most common non-clay minerals associated with clay, can have both a good and bad effect on the use of the clay as ceramic material. Too much quartz results in a low plasticity and a poor ceramic bond. However, too little quartz can result in the material being too plastic and having too high shrinkage.

The presence of iron in clay material has a decided effect on the color of the fired-clay products. The final color of the fired-clay product is partially dependent on the compounds of iron produced during the firing of the clay.

LABORATORY TESTING PROCEDURE

To determine the characteristics of clay it must be subjected to standard ceramic testing to see if it as a finished product will meet standard specifications for the various structural-clay products.

Because some clays have both the ideal physical and chemical characteristics they can be used as they come from a deposit. However, if they do not have the right characteristics it may be necessary to develop blends fitted to the manufacturer's process and product.

The following testing procedures were used by the U. S. Bureau of Mines (Hickman and Hamlin, 1964, p. 13):

"A 2-pound representative sample of the material as received is dried at 230°F and ground so that 100 percent passes 20 mesh. One hundred grams of the dried clay is mixed with water (measured) to form a plastic mass. The working properties of the clay are noted, and small test specimens (approximately 1-½" x 2-½" x ¼") are fabricated using a steel mold or die. The test specimens are marked for shrinkage, dried at 150°F for 12 hours and at 230°F for an additional 12 hours. Six of the dried specimens are placed in a laboratory kiln and the temperature raised slowly to prevent disintegration when the mechanically and chemically combined water is released. Approximately 3 hours are required for the kiln to reach 1800°F. Test specimens are removed from the kiln at 1800°, 2000°, 2100°, 2200°, 2300°, and 2400°F, after a 15-minute "soak" at each indicated temperature. About 4 hours are required to cover the range of 1800° to 2400°F, and these temperatures cover the range encountered in most ceramic firing and are adequate for general appraisals.

"The method described for making the test specimen is essentially the "soft mud process" and, in comparison with the "stiff mud process" normally used in commercial production, the quantity of water used for achieving plasticity is higher. Firing shrinkages also are higher since the clay is not de-aired, and the pressure used in forming is much less."

EXTRUSION TESTS

To explain why some of the samples were subjected to extrusion tests the following is quoted from M. E. Tyrrell (personal communication, 1968).

"A laboratory de-airing extrusion machine of the drop-through type is used to test samples found to be promising for heavy clay products in preliminary tests.

"Bulk samples (20-25 pounds) are spread in trays and dried overnight at 160° F. Dried clay samples are crushed to pass a 6-mesh sieve, shales are generally crushed to pass 12-mesh.

"After tempering with water in a dough mixer, the samples are extruded under 28 inches of vacuum. The standard test shape is a 1-inch square bar cut to 8-inch lengths. Shrinkage marks are spaced 6 inches apart on one face of the bar. Bars are dried in air overnight followed by drying 24 hours at 160° F. The bars are fired in an electric box-type kiln on a 24-hour schedule.

"From the extrusion test, the following data are reported: Tempering water, drying shrinkage and dry modulus, characteristics of fired bars including total shrinkage, color, hardness, absorption, apparent porosity, bulk density, and fired modulus of rupture."

In order to more fully understand the testing procedure mentioned above and the laboratory results mentioned later in this report the following terminology is discussed:

Plasticity or Workability

Clays when mixed with water become plastic. Generally clays that are highly plastic when mixed with water are called "fat clays," whereas those that exhibit only slight plasticity when mixed with water are called "lean clay." Clays should be sufficiently plastic to assure good workability and with sufficient strength to flow smoothly in a column during extrusion.

Water of Plasticity

Water of plasticity is the percent of water required to cause a clay to reach a plastic state.

The water of plasticity can be determined by the formula.

$$T = \frac{W_p - W_d}{W_d} \times 100$$

Dry Modulus of Rupture or Dry Strength

Dry modulus of rupture or dry strength is usually determined by either compression or transverse tests performed on the unfired molded or extruded product. The dry strength is sometimes expressed as low, good, etc. However, it is also expressed mathematically in terms of the modulus of rupture in pounds per square inch. Aase (1964, p. 58) states that the dry strength of a brick should exceed 70 pounds per square inch so that it can be handled easily without the danger of breakage.

Fired Modulus Of Rupture

The fired modulus of rupture is the measurement of transverse strength in pounds per square inch of the clay product after firing. According to Aase (1965, p. 58), the fired modulus of rupture for brick should exceed 600 pounds per square inch, 2,000 pounds per square inch for hollow tile or sewer pipe, 1,200 pounds per square inch for drain tile, and 2,700 pounds per square inch for quarry or floor tile.

Drying Shrinkage

Drying shrinkage is the amount of linear shrinkage that takes place in the clay between the time it is shaped into its final form until it is ready for firing.

According to Murray (1960, p. 274), drying shrinkage is dependent on the amount of water in the clay, its character, and its plasticity. That is, some fat clays tend to warp and crack whereas lean clays will dry to form a weak and porous body.

Firing Shrinkage

Firing shrinkage is the amount of linear shrinkage that takes place during firing of the clays.

Total shrinkage which would include drying shrinkage must not exceed 16 percent if the clay is to be suitable for brick and drain tile (Aase, 1964, p. 58).

Percent Absorption

Percent absorption relates to the percent of water absorbed by the finished structural-clay product. In cold climates this factor is important because of freezing and thawing effects. However, Robinson, Buie, and Johnson (1961, p. 7-8) suggest that a better test for absorption is the determination of the saturation coefficient (C/B ratio), which is the ratio of absorption after 24 hours submersion in cold water compared with 5 hours submersion in boiling water.

Firing Temperature

The point at which clays will harden and become brick is a significant factor in the evaluation of clays for structural products. The lower the temperature that the clay will vitrify into brick the better because of the lower amount of fuel that is consumed in the manufacturing process.

The clays sent in by the writers to the Bureau of Mines for testing were fired between 1800° and 2300°F.

Moh's Hardness

Moh's hardness is an empirical scale by which the hardness of an object is determined as compared with a standard. The number increases as the hardness increases.

Bulk Density

Bulk density is in grams (gms) per cubic centimeter (cc), of a specimen expressed as the quotient of its dry weight divided by the total volume.

TEST RESULTS

Thirty outcrop samples were submitted for testing by the writers from Holmes, Walton, and Washington counties. As the test results will indicate there are a number of samples from these counties that will produce structural-clay products. The firing results indicate that some of the clays were unsuited individually for structural-clay products. However, upon blending together the clays from several localities it was determined the composite would make a usable raw material.

Sweeney and Shirley (1965, p. 20), in their study of Holmes County clays, said:

"Clay samples from each of the 13 holes tested were separated into 3 to 7 intervals and ceramic property tests run on each interval. In addition samples from selected intervals from the first three holes were washed to remove sand and fired to determine what effect beneficiation would have on the samples. On evaluation the firing results of each clay interval of the 13 holes, composite samples were prepared for five of the holes that showed potential. Each composite consisted of all the clay intervals of holes, previously tested separately. The composite sample represented the material that would be extracted from a deposit; however, the test results from any one sample interval or composite sample should not be considered conclusive for development of a commercial operation because it only presented the test results of one interval or one site tested, although it is indicative of the possibilities of the material tested. A total of 70 ceramic property tests were made which include 60 tests on individual intervals, five on beneficiated material and five on composites."

They (Sweeney and Shirley, 1965, p. 20) also stated that:

"Chemical analyses were made on selected intervals from six drill holes. A total of nine analyses were made to determine what minerals were present in the clays and to determine if the fluxes, such as Fe_2O_3 , CaO , MgO , were excessive for the manufacture of structural-clay products. The results of these analyses are shown in Table 3." (See Table 2, this report)

SAMPLE DESCRIPTIONS, CHARACTERISTICS, AND EVALUATIONS

The location, field description, unfired characteristics, and the results of the ceramic-property tests of each sample taken are given on the following pages. In the instances where the ceramic-property tests were favorable extrusion tests were conducted and these data are included.

TABLE 2. CHEMICAL ANALYSES IN PERCENT OF SELECTED HOLMES COUNTY CLAYS

U.S.B.M.

Sample #	Location	Interval, feet	LOI ¹ at 140° C	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ ²	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI ¹	Total
HC-1	SW¼ Sec. 11, T3N, R18W	29-33	3.92	68.46	14.44	4.09	.78	—	.50	.07	1.55	.14	9.55	99.58
HC-1		12-22 (washed)	.65	84.50	8.87	1.93	.39	.10	Tr.	.02	.25	.09	3.45	99.60
HC-1		22-30 (washed)	1.39	78.91	10.16	3.65	.65	.09	Tr.	.05	1.15	.28	4.61	99.55
HC-2	SW¼ Sec. 11, T3N, R18W	4-8 (washed)	1.46	75.70	14.24	1.12	1.23	0	Tr.	.04	.30	.11	7.01	99.75
HC-2		8-10 (washed)	2.04	70.58	17.65	1.45	.96	0	Tr.	.08	.47	.13	8.65	99.97
HC-3	SW¼ Sec. 11, T3N, R18W	12-13 (washed)	1.71	82.49	8.40	3.70	.36	.09	Tr.	.01	.30	.08	4.80	100.23
HC-4	S½SW¼ Sec. 10, T3N, R18W	13-17.5	3.31	82.44	8.05	2.00	.55	—	.38	.30	.63	0	6.09	100.49
HC-5	S½SW¼ Sec. 10, T3N, R18W	13.6-18.4	6.90	72.29	12.12	1.90	.40	—	.96	.10	1.30	0	10.56	99.63
HC-6	SE¼ NW¼ Sec. 14, T5N, R17W	1.5-2.9	4.04	67.78	16.52	4.03	.68	—	.37	.08	.47	.16	9.73	99.82

¹ LOI — Loss on ignition.² Total iron.

BUREAU OF GEOLOGY

Holmes County

The data on Sample Nos. 0-137, 0-138, 0-158, 0-197, 0-231 are taken from Florida Geological Survey Information Circular No. 2 (Calver, 1949, p. 32, 33, 53). Though these data are included for reference they are not as complete as test data obtained through present testing procedures of the U. S. Bureau of Mines.

SAMPLE No. 0-137

LOCATION: About four miles east of Argyle and one-quarter mile downstream from Scott's Mill in a bluff on the left bank of Sandy Creek.

FIELD DESCRIPTION: Forty-one foot section containing 5 beds. Collected from 3-foot clay (bed 3).

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Excellent
Water of plasticity	39%
Linear shrinkage	11.2%
Modulus of rupture	1100 psi
Unfired color	Dark gray

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	1.0	15.0	33.7	Reddish orange
1920	0.5	15.4	34.7	Reddish orange
1995	3.0	10.1	28.2	Reddish orange
2100	—	—	—	—
2175	3.0	9.5	27.6	Brick red
2280	—	—	—	—

Potential Use: Not given

SAMPLE No. 0-138

LOCATION: About four miles east of Argyle and one-quarter mile downstream from Scott's Mill in a bluff on the left bank of Sandy Creek.

FIELD DESCRIPTION: Forty-one foot section containing 5 beds. Collected from 3.5-foot clay bed (bed 4).

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Excellent
Water of plasticity	51%
Linear shrinkage	14.1%
Modulus of rupture	820 psi
Unfired color	Grayish yellow

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	1.5	12.2	28.1	Reddish orange
1920	2.0	10.1	23.6	Reddish orange
1995	3.0	5.0	16.0	Reddish orange
2100	—	—	—	—
2175	6.0	2.7	9.5	Light brick red
2280	—	—	—	—

Potential Use: Not given

SAMPLE No. 0-158

LOCATION: Prospect pit near foot of hill 3.3 miles north of Ponce de Leon.

FIELD DESCRIPTION: Collected from 6-foot grayish-yellow clay bed.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	40%
Linear shrinkage	13.2%
Modulus of rupture	720 psi
Unfired color	Medium grayish yellow

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.0	17.3	32.4	Brick red
1920	1.0	14.5	30.8	Brick red
1995	3.0	10.5	25.8	Brick red
2100	4.5	7.5	20.5	Brick red
2175	5.0	4.9	19.5	Brick red
2280	6.0	4.9	17.7	Dark red

Potential Use: Shrinkage high but might be used in the manufacture of brick.

SAMPLE No. 0-197

LOCATION: Just north of milepost 739 on the Louisville and Nashville Railroad, in a gully.

FIELD DESCRIPTION: Sample collected from a 10-foot clayey sand and clay bed.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	46%
Linear shrinkage	9.4%
Modulus of rupture	290 psi
Unfired color	Medium brown

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	1.5	23.8	41.9	Reddish orange
1920	2.5	19.1	38.2	Light red
1995	4.0	14.9	33.3	Light red
2100	7.5	9.8	26.2	Brick red
2175	7.0	8.9	25.4	Brick red
2280	7.5	8.3	24.4	Brick red

Potential Use: The composite sample is suitable for brick.

SAMPLE No. 0-231

LOCATION: About four miles east of Argyle and one-quarter mile downstream from Scott's Mill in a bluff on the left bank of Sandy Creek.

FIELD DESCRIPTION: Forty-one foot section containing 5 beds. A composite of beds 2, 3, and 4 (18.5 feet thick).

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	28%
Linear shrinkage	7%
Modulus of rupture	500 psi
Unfired color	Yellowish gray

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.0	14.7	34.6	Reddish orange
1920	0.0	14.0	34.6	Reddish orange
1995	1.0	13.2	33.9	Reddish orange
2100	1.0	12.7	32.6	Brick red
2175	2.0	11.6	30.9	Brick red
2280	1.5	12.2	32.0	Brick red

Potential Use: Should make brick.

The writers submitted 12 clay samples from Holmes County to the U. S. Bureau of Mines for ceramic property tests, and these data are presented as follows:

SAMPLE No. LHo-5N-17W-31 cbb

LOCATION: SW¼, NE¼, NE¼, section 31, T5N, R17W (Prosperity Quadrangle).

FIELD DESCRIPTION: Collected from clay bed cropping out in ditch on each side of graded road.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	27.1%
Drying shrinkage	10.0%
Dry strength	Good
Color	Yellow

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	15.0	7.3	Orange tan	3	2.03
1900	17.5	5.8	Orange tan	4	2.07
2000	20.0	0.9	Light brown	5	2.33
2100	20.0	0.5	Dark brown	5	2.36
2200	20.0	0.1	Red brown	6	2.38
2300	20.0	0.2	Red brown	6	2.34

Potential Use: Because of excessive shrinkage this clay is not suitable for vitreous clay products.

Remarks: Excessive shrinkage

SAMPLE No. LHO-5N-17W-35 adc

LOCATION: NW¼, SE¼, SW¼, section 35, T5N, R17W (Prosperity Quadrangle)

FIELD DESCRIPTION: Collected on southwest side of roadcut about 7 feet above base of 40- to 50-foot section. Two clay beds exposed, each approximately 15-20 feet thick, and separated by clayey sand beds.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	36.0%
Drying shrinkage	10%
Dry strength	Good
Color	White

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	12.5	24.7	Pink	2	1.61
1900	12.5	24.4	Pink	2	1.61
2000	12.5	22.7	Pink	3	1.67
2100	20.0	13.3	Cream	4	1.97
2200	25.0	0.1	Gray	5	2.52
2300	—	—	—	—	—

Potential Use: Face brick and glazed structural-tile bodies

Remarks: High shrinkage, however, may be used as the plastic fraction in brick and glazed structural-tile mixtures.

SAMPLE No. LHo-4N-18W-25 add

LOCATION: NW¼, SE¼, SE¼, section 25, T4N, R18W (Prosperity Quadrangle)

FIELD DESCRIPTION: Collected from north side of graded road. Clay interbedded with sand.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Low plasticity
 Water of plasticity 28.9%
 Drying shrinkage 2.5%
 Dry strength Fair
 Color Yellow

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	22.1	Light brown	2	1.71
1900	5.0	21.3	Light brown	2	1.72
2000	7.5	17.9	Light brown	3	1.82
2100	12.5	9.7	Brown	4	2.09
2200	15.0	6.7	Dark brown	5	2.20
2300	15.0	4.9	Dark brown	6	2.9

Potential Use: Face brick

Remarks: Should fire to "SW" face brick* specifications at about 2100° F.

*"SW" brick - intended for use where a high degree of resistance to frost action is desired, and the expansion is such that the brick may be frozen when permeated with water.

EXTRUSION TEST

SAMPLE No. LHo-4N-18W-25 add

Body Composition Raw clay through 6-mesh: 100%
 Tempering Water 29% of dry batch weight
 Vacuum On Machine 21 inches of mercury
 Drying 24 hours in air; 24 hours at 140° F.
 Drying Shrinkage 6.3%
 Modulus Of Rupture, Dry Unfired 580 psi

Firing:

Time 24 hours
 Temperature 2100° F
 Cone 4 over

Total shrinkage 12.5%
 Absorption, 5-hour boiled 7.2%
 Absorption, 24-hour soaked 5.8%
 Saturation coefficient 0.81
 Apparent porosity 15.8%
 Bulk density 2.19 gm/cc
 Fired modulus of rupture 3140 psi
 Moh's hardness 7.5
 Color Light brown

Potential Use: Should meet "SW" face brick specifications as processed.

SAMPLE No. LHo-4N-17W-5 ab

LOCATION: Center of S½ of NW¼, NE¼, section 5, T4N, R17W (Prosperity Quadrangle)

FIELD DESCRIPTION: Collected from roadcut on north side of Florida Highway 51. Eight feet of sandy clay interbedded with sand beds. The clay bed is overlain by two feet of overburden. Observations of the clay bed in nearby roadcuts indicate it underlies the entire hill.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Good plasticity
 Water of plasticity 41.1%
 Drying shrinkage 12.0%
 Dry strength Good
 Color Buff

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	12.5	23.9	Salmon	3	1.63
1900	15.0	18.0	Salmon	4	1.74
2000	16.3	14.9	Buff	5	1.81
2100	20.0	5.9	Light brown	6	2.10
2200	20.0	4.3	Brown	6	2.14
2300	21.3	2.0	Dark brown	7	2.21

Potential Use: Common brick; face brick.

Remarks: Should fire to "SW" face brick specifications at 1900°-2000°F. Shrinkage rather high.

SAMPLE Nos. LHo-4N-17W-30 db (5, 6, 16, 46, 56, 156, 1456)

LOCATION: These samples were collected from a roadcut on the south side of U. S. Highway 90 in the E½, SE¼, NE¼, section 30, T4N, R17W (Ponce de Leon Quadrangle).

The following section was measured by Yon, Hendry and Preston.

Bed	Description	Thickness (feet)
10	Soil zone	4
9	Light brown, fine to very coarse, predominantly medium to very coarse, angular to subrounded micaceous, quartz SAND; contains a trace of heavies, up to 2% gravel present; within the bed are zones of kaolinitic clay and blind shrimp tubes. The bed is indurated, toward the east end of the section it becomes more weathered and cut with shear fractures that are filled with clay.	
8	Mottled medium red, yellow orange and yellowish gray, fine to coarse graveliferous, silty, clayey quartz SAND. Bed contains more gravel toward top of bed. Bed is indurated on weathered surface.	10 to 12

- 7

Dark yellow orange and pale greenish yellow, fine to medium, angular to subangular, silty, clayey quartz SAND. The sand contains heavies and pea gravel. Grades into bed 8.

2.5
- 6

Mottled moderate red to reddish brown, dark yellowish orange, light olive gray, very slightly sandy, silty, blocky CLAY. The clay contains arcuate orange color banding. Grades into bed 7.

6 to 8
- 5

Light brown, slightly sandy CLAY. Top 3" of bed is dark brown because of iron enrichment. Grades into bed 6.

1.5
- 4

Mottled dark yellow orange and yellowish gray, very fine to coarse, silty, very clayey quartz SAND. Contains abundant molds and casts of macro-fossils which have been replaced by iron oxide. Bed becomes more clayey toward top. Grades into bed 5.

2.5
- 3

Dark yellow orange, fine to medium quartz SAND. Contains slight amount of clay as matrix and blebs. Molds and casts of macro-fossils replaced by iron oxide. Grades into bed 4.

3.0
- 2

Yellowish to light olive gray, silty to sandy, blocky CLAY. Contains a trace of heavies and a white mineral. Some iron staining along thin bedding. Sharp contact with bed 3.

2.0
- 1

Yellowish gray, fine to medium, quartz SAND. Contains a few coarse grains and a trace of heavy minerals. Specks of light brown limonite staining throughout bed. Grades into bed 2.

6.0

Base of section.

SAMPLE No. LHo-4N-17W-30 db (5)

FIELD DESCRIPTION: Collected from bed 5.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	.Good plasticity
Water of plasticity	45.6%
Drying shrinkage	15%
Dry strength	.Good
Color	Buff

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	15.0	21.4	Salmon	3+	1.66
1900	16.3	17.1	Salmon	5	1.78
2000	20.0	9.9	Light brown	6	1.96

2100	22.5	5.4	Brown	6+	2.09
2200	23.8	4.1	Dark brown	6+	2.12
2300	23.8	4.5	Dark brown	7	2.67

Potential Use: Sewer pipe.

Remarks: Should fire to "SW" face-brick specifications at 1900°-2000°F shrinkage is high.

SAMPLE No. LHo-4N-17W-30 db (6)

FIELD DESCRIPTION: Collected from bed 6.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	High plasticity
Water of plasticity	33.3%
Drying shrinkage	5%
Dry strength	Good
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	7.5	21.6	Tan	3	1.72
1900	7.5	19.6	Tan	4	1.76
2000	10.0	16.8	Tan	4	1.84
2100	12.5	11.7	Light brown	5	1.98
2200	12.5	10.0	Gray brown	6	2.05
2300	12.5	9.9	Gray	6	2.05

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2093°F. Shrinkage a little high.

SAMPLE No. LHo-4N-17W-30 db (16)

FIELD DESCRIPTION: Composite sample of sand and clay from beds 1 and 6.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	27.7%
Drying shrinkage	5.0%
Dry strength	Good
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	20.3	Red tan	3	1.76
1900	5.0	20.1	Red tan	3	1.77
2000	7.5	17.5	Beige	3	1.84
2100	7.5	14.4	Light brown	4	1.91
2200	7.5	13.5	Brown	4	1.94
2300	7.5	13.5	Gray	4	1.95

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2156°F. Mixed by weight: 25% bed 1, 75% bed 6. See Extrusion Test.

EXTRUSION TEST

SAMPLE No. LHo-4N-17W-30 db (16)

Body Composition	Raw clay (bed 6) through 8 mesh: 75% Raw clay (1) through 8 mesh: 25%
Tempering Water	.24% of batch weight.
Vacuum On Machine	26 inches of mercury.
Drying	24 hours in air; 24 hours at 60°C.
Drying Shrinkage	7.3%
Dry Modulus Of Rupture	151 psi.
Firing:	
Time	24 hours
Temperature	2140°F
Cone	5 over
Total shrinkage	10.4%
Absorption, 5-hour	10.4%
Absorption, 24-hour	6.8%
Saturation coefficient	0.65
Apparent porosity	20.5%
Bulk density	1.97 gm/cc
Fired modulus of rupture	1663 psi
Moh's hardness	7.5
Color	Orange-red

Potential Use: Face brick.

SAMPLE No. LHo-4N-17W-30 db (46)

FIELD DESCRIPTION: Composite sample of sand and clay beds 4 to 6 collected from roadcut.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate Plasticity
Water of plasticity	25.9%
Drying shrinkage	2.5%
Dry strength	Good
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	2.5	21.1	Red tan	3	1.75
1900	2.5	20.1	Red tan	3	1.78
2000	5.0	16.7	Beige	4	1.86
2100	7.5	14.4	Light brown	4	1.94
2200	7.5	12.6	Brown	4	2.00
2300	7.5	13.2	Gray	4	1.97

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2156°F. Mixed by weight: 25% bed 4, 75% bed 6.

SAMPLE No. LHo-4N-17W-30 db (56)

FIELD DESCRIPTION: Composite sample of clays from beds 5 and 6.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 30.5%
 Drying shrinkage 2.5%
 Dry strength Good
 Color Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	2.5	22.1	Orange	3	1.72
1900	2.5	20.3	Orange	4	1.81
2000	10.0	14.1	Beige	5	1.94
2100	12.5	9.4	Light brown	6	2.09
2200	12.5	8.4	Brown	6	2.13
2300	12.5	11.7	Gray	6	2.00

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2093°F. Shrinkage slightly high. Mixed by weight: 20% bed 5, 80% bed 6.

SAMPLE No. LHo-4N-17W-30 db (156)

FIELD DESCRIPTION: Composite sample of sand and clays from beds 1, 5, and 6 collected from roadcut.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 29.5
 Drying shrinkage 10.0%
 Dry strength Good
 Color Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	12.5	21.1	Peach	3	1.71
1900	12.5	20.0	Tan	4	1.77
2000	12.5	16.5	Dark tan	4	1.87
2100	12.5	15.9	Light brown	5	1.88
2200	12.5	14.9	Brown	6	1.92
2300	12.5	14.2	Gray	6	1.94

Potential Use: Face brick.

Remarks: Color marginal. Mixes by weight: 25% bed 1, 15% bed 5, 60% bed 6. See Extrusion Test.

EXTRUSION TEST

SAMPLE No. LHo-4N-17W-30 db (156)

Body Composition	Raw clay (bed 1) through 8 mesh: 25%
	Raw clay (bed 5) through 8 mesh: 15%
	Raw clay (bed 6) through 8 mesh: 60%
Tempering Water	.18% of batch weight.
Vacuum On Machine	.26 inches mercury.
Drying	24 hours in air; 24 hours at 60° C.
Drying Shrinkage	3.6%
Dry Modulus Of Rupture	Not determined.
Firing:	
Time	24 hours
Temperature	.2140° F
Cone	5 over
Total shrinkage	11.5%
Absorption, 5-hour	10.0%
Absorption, 24-hour	6.4%
Saturation coefficient	0.64
Apparent porosity	19.3%
Bulk density	2.01 gm/cc
Fired modulus of rupture	1500 psi
Moh's hardness	7.5
Color	Light red.

Potential Use: Face brick.

SAMPLE No. LHo-4N-17W-30 db (1456)

FIELD DESCRIPTION: Composite sample of sands and clays from beds 1, 4, 5 and 6.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Low plasticity
Water of plasticity	21.4%
Drying shrinkage	0.0%
Dry strength	Low
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	0.0	21.0	Orange	2	1.73
1900	0.0	20.1	Orange	3	1.76
2000	0.0	18.1	Tan	4	1.80
2100	2.5	16.8	Light brown	4	1.83
2200	2.5	16.7	Red brown	4	1.83
2300	2.5	17.3	Gray brown	4	1.79

Potential Use: None.

Remarks: This mixture not suitable for use in clay products. Low dry strength; poor ceramic bond; poor color. Mixed by weight: 35% bed 1, 15% bed 4, 10% bed 5, 40% bed 6.

SAMPLE No. LHo-4N-15W-13 cdc

LOCATION: SW¼, SE¼, SW¼, section 13, T4N, R15W (Poplar Head Quadrangle)

FIELD DESCRIPTION: Sample collected from roadcut on north side of east-west road from a 10-foot, massive clay zone. The clay zone is interbedded with sand zones up to six inches thick. The clay zone is overlain by up to two feet of sand. Clay similar to this locality occurs along the entire length of this graded road at the south edge of section 13, T4N, R15W.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 38.4%
 Drying shrinkage 7.5%
 Dry strength Fair
 Color Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	10.0	—	Salmon	Poor bond	—
1900	10.0	—	Salmon	Poor bond	—
2000	10.0	—	Salmon	Poor bond	—
2100	12.5	25.9	Beige	3	1.59
2200	12.5	15.6	Tan	4	1.88
2300	12.5	15.4	Buff	4	1.89

Potential Use: None by itself, however, if blended with clays from LWs-4N-15W-6 bcd (See Extrusion Test) face brick could be manufactured.

Remarks: Poor ceramic bond, however, may be useful as a nonplastic fraction to control shrinkage in brick mixtures. See Sample LWs-4N-15W-6 bcd.

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EXTRUSION TEST

COMPOSITE OF SAMPLE Nos. LWs-4N-15W-6 bcd and LHo-4N-15W-13 cdc

Body Composition	Raw clay LHo-4N-15W-13 cdc through 6 mesh; 50%
	Raw clay LWs-4N-15W-6 bcd through 6 mesh; 50%.
Tempering Water	29% of dry batch weight.
Vacuum On Machine	22 inches of mercury.
Drying	24 hours in air; 24 hours at 140°F.
Drying Shrinkage	4.2%
Modulus Of Rupture, Dry Unfired	380 psi.
Firing:	
Time	24 hours
Temperature	2180°F
Cone	6 over
Total shrinkage	12.5%
Absorption, 5-hour boiled	7.6%
Absorption, 24-hour soaked	5.9%
Saturation coefficient	0.78
Apparent porosity	16.7%
Bulk density	2.20 gm/cc
Fired modulus of rupture	1620 psi
Moh's hardness	6.5
Color	Buff

Potential Use: Should meet "SW" face brick specifications as processed. Attractive color.

The ceramic-property tests on clays from core holes in Holmes County, drilled by the U. S. Bureau of Mines (Sweeney and Shirley, 1965, pp. 38-54) appear in table 3.

Walton County

The following data on Walton County were taken from the Florida Geological Survey Information Circular No. 2 (1949, p. 43, 58).

SAMPLE No. 0-195

LOCATION: One-quarter of a mile south of the railroad at Paxton.

FIELD DESCRIPTION: Collected from silty clay bed 7 feet thick occurring in a ditch.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	28%
Linear shrinkage	5.9%
Modulus of rupture	90 psi
Unfired color	Light pinkish brown

Slow Fired Characteristics

Temp. (°F)	Linear shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.0	19.0	35.7	Reddish orange
1920	0.0	19.1	36.8	Buff
1995	0.5	18.1	35.4	Buff
2100	1.0	17.0	34.6	Buff
2175	1.0	16.7	34.0	Buff
2280	1.5	16.1	31.7	Buff

Potential Use: Suitable for making brick.

SAMPLE No. 0-413

LOCATION: A well on the D. R. Thompson property, 2 miles east of DeFuniak Springs, on U.S. Highway 90, in section 30, T3N, R18W.

FIELD DESCRIPTION: Collected from the bottom six feet of (19-25) well and from an auger hole 20 feet east of well.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	High
Water of plasticity	51.8%
Linear shrinkage	6.0%
Modulus of rupture	190 psi
Unfired color	White

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	10.4	36.8	49.1	White
1920	11.6	35.6	49.9	White
1995	11.6	35.2	49.4	White
2100	18.8	19.5	35.4	White
2175	21.0	15.5	30.0	White
2280	26.2	5.1	13.0	Light purple

Remarks: Steel hard at cone 4 (approximately 2100°F). Pyrometric cone equivalent = 33+ (slightly greater than 3120°F). Clay is 13% of total sample. According to Calver (1949, p. 10) "The kaolin has excellent color, high plasticity, low shrinkage, and moderate strength. It compares, favorably with the Putnam County kaolins." For chemical analysis see Calver (1949, p. 14).

The writers submitted ten samples from outcrops and one sample from a core hole in Walton County to the U.S. Bureau of Mines for ceramic evaluation and the conclusions of these tests are presented on the following pages.

SAMPLE No. LWI-6N-19W-34 cb

LOCATION: SW¼, NE¼, section 34, T6N, R19W (Glendale Quadrangle)

FIELD DESCRIPTION: About 10 feet of mottled gray, red-brown, silty, sandy clay exposed on south side of Florida Highway 181.

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LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	19.2%
Drying shrinkage	10.0%
Dry strength	Good
Color	Yellow

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	12.5	12.2	Orange tan	3	1.94
1900	12.5	10.3	Orange tan	4	2.00
2000	12.5	8.0	Light brown	4	2.08
2100	15.0	7.1	Brown	5	2.12
2200	15.0	7.3	Red brown	6	2.12
2300	Expanded	—	—	—	—

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2000°F. Shrinkage a little high.

SAMPLE No. WW1-5N-21W-35 acc (St. Regis Core hole No. 1)

LOCATION: NW¼, SW¼, SW¼, section 35, T5N, R21W (Laurel Hill Quadrangle)

FIELD DESCRIPTION: Collected from cored interval between 31-52 feet.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Low plasticity
Water of plasticity	16.1%
Drying shrinkage	2.5%
Dry strength	Fair
Color	Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	16.5	Pink	2	1.86
1900	5.0	16.2	Pink	2	1.87
2000	5.0	15.9	Light beige	2	1.88
2100	7.5	15.9	Light beige	3	1.88
2200	7.5	15.6	Light tan	3	1.88
2300	7.5	13.3	Light ivory	4	2.08

Potential Use: Glazed brick and structural tile.

Remarks: The addition of a plasticizer might be required to improve extrusion characteristics.

Table 3. CERAMIC PROPERTY TESTS ON HOLMES COUNTY CLAYS

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-1	SW¼, Sec 11, T3N, R18W	12.9-21.9	5.8	15.0	0.0	1800	Reddish tan	Crumbled	0.0	4.4	2.45
						1900	Reddish tan	Crumply	.0	4.5	2.45
						2000	Tan	Crumply	.0	4.7	2.47
						2100	Tan	Crumbly	.0	4.7	2.49
						2200	Light brown	Fair hard	.0	4.9	2.48
						2300	Purple tan	Fair hard	1.4	5.1	2.50
		21.9-26.0	5.9	25.0	5.5	1800	Red brown	Soft	5.5	4.4	2.49
						1900	Red brown	Soft	5.5	4.0	2.53
						2000	Brown	Fair hard	5.5	4.5	2.51
						2100	Chocolate	Hard	5.5	4.8	2.48
						2200	Dark brown	Hard	6.0	4.9	2.46
						2300	Dark brown	Very hard	6.5	4.8	2.46
		26.0-29.9	5.5	27.6	5.5	1800	Tan	Fair hard	8.0	4.3	2.56
						1900	Tan	Fair hard	9.5	4.5	2.53
						2000	Light brown	Hard	10.0	5.0	2.51
						2100	Chocolate	Very hard	10.0	5.6	2.49
						2200	Brown	Very hard	10.0	6.0	2.44
						2300	Dark gray	Steel hard	10.0	6.8	2.41
		29.9-36.0	5.5	30.6	5.5	1800	Tan	Fair hard	9.0	4.8	2.57
						1900	Tan	Fair hard	10.0	5.1	2.61
						2000	Light brown	Hard	14.0	7.8	2.50

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-1	SW $\frac{1}{4}$, Sec 11, T3N, R18W	29.9-36.0	5.5	30.6	5.5	2100	Chocolate	Very hard	14.0	9.5	2.46
						2200	Chocolate	Steel hard	15.0	10.4	2.43
						2300	Dark gray	Steel hard	15.0	12.7	2.27
HC-1 (Washed)		12.9-21.9	5.8	32.0	5.0	1800	Reddish tan	Fair hard	6.0	4.6	2.60
						1900	Reddish tan	Fair hard	7.0	4.5	2.65
						2000	Tan	Hard	9.0	4.7	2.69
						2100	Tan	Very hard	10.0	5.3	2.69
						2200	Light brown	Very hard	10.0	5.9	2.69
						2300	Brown	Steel hard	10.0	6.2	2.70
		21.9-29.9	5.9	33.0	10.0	1800	Red brown	Fair hard	10.5	4.1	2.68
						1900	Red brown	Hard	11.0	5.3	2.68
						2000	Light brown	Hard	11.5	5.7	2.68
						2100	Brown	Very hard	14.5	6.4	2.65
						2200	Chocolate	Steel hard	14.5	7.2	2.61
						2300	Dark brown	Steel hard	14.5	6.8	2.24
HC-2	SW $\frac{1}{4}$, Sec 11, T3N, R18W	4-8	5.3	16.2	4.5	1800	Pink	Soft	4.5	5.2	2.56
						1900	Pink	Fair hard	4.5	5.5	2.53
						2000	Pale pink	Fair hard	4.5	5.8	2.53
						2100	Off white	Fair hard	4.5	5.9	2.48
						2200	Buff	Fair hard	4.5	5.9	2.48
						2300	Buff	Hard	4.5	6.1	2.46

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-2	SW¼, Sec. 11, T3N, R18W	8-10	5.0	25.0	4.5	1800	Pale pink	Soft	5.0	4.5	2.56
						1900	Pale pink	Soft	5.0	5.0	2.54
						2000	Off white	Fair hard	5.0	4.9	2.53
						2100	Pale buff	Fair hard	9.0	5.2	2.49
						2200	Buff	Hard	9.0	5.7	2.47
						2300	Light gray	Very hard	9.0	5.9	2.46
		10-14	5.1	26.0	5.0	1800	Red tan	Soft	5.0	4.2	2.54
						1900	Red tan	Soft	7.0	4.7	2.50
						2000	Tan	Soft	7.0	4.7	2.54
						2100	Light brown	Fair hard	7.0	5.5	2.47
						2200	Chocolate	Fair hard	7.0	5.8	2.48
						2300	Purple brown	Fair hard	7.0	5.9	2.45
		14-16	5.9	32.2	5.5	1800	Red tan	Fair hard	10.0	4.8	2.69
						1900	Red tan	Fair hard	10.5	5.2	2.69
						2000	Tan	Hard	15.0	7.6	2.61
						2100	Brown	Very hard	15.0	13.2	2.50
						2200	Dark brown	Very hard	15.0	13.9	2.49
						2300	Purple brown	Steel hard	15.0	18.5	2.45
		16-18	5.7	18.8	5.0	1800	Red tan	Fair hard	5.0	4.9	2.44
						1900	Red tan	Fair hard	5.0	5.5	2.40
						2000	Tan	Fair hard	8.0	5.8	2.42
						2100	Light brown	Fair hard	12.0	5.8	2.45

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-2	SW¼, Sec. 11, T3N, R18W	16-18	5.7	18.8	5.0	2200 2300	Gray brown Gray	Hard	12.0	5.6	2.47
								Very hard	15.0	5.2	2.50
		18-23	5.6	3.08	6.5	1800	Red tan	Fair hard	10.0	4.9	2.62
						1900	Red tan	Fair hard	10.0	5.6	2.59
						2000	Light brown	Hard	15.0	8.4	2.48
						2100	Chocolate	Very hard	15.0	11.0	2.45
						2200	Dark brown	Very hard	15.0	12.4	2.41
						2300	Brown black	Steel hard	15.0	13.5	2.37
		4-8	5.3	32.0	5.5 1900	1800	Off white	Fair hard	6.5	4.5	2.60
							Off white	Fair hard	6.5	4.4	2.68
						2000	Pale buff	Hard	6.5	4.5	2.67
						2100	Pale buff	Very hard	11.0	5.0	2.68
						2200	Light gray	Steel hard	11.0	5.7	2.67
						2300	Light gray	Steel hard	11.0	6.3	2.64
HC-2 (Washed)		8-10	5.0	25.0	5.5	1800	Pale flesh	Fair hard	9.0	4.1	2.62
						1900	Pale flesh	Hard	9.0	4.2	2.67
						2000	Pale flesh	Hard	9.0	4.3	2.66
						2100	Buff	Very hard	10.0	5.2	2.70
						2200	Gray buff	Steel hard	14.0	6.2	2.62
						2300	Light gray	Steel hard	14.0	6.6	2.63

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-3	SW¼, Sec. 11, T3N, R18W	12-13	5.7	18.8	5.0	1800	Lt. red-brown	Crumbles	5.0	4.9	2.44
						1900	Lt. red-brown	Soft	5.0	5.5	2.40
						2000	Light brown	Fair hard	8.0	5.8	2.42
						2100	Brown	Fair hard	12.0	5.8	2.45
						2200	Dark brown	Fair hard	12.0	5.6	2.47
						2300	Dark brown	Hard	15.0	5.2	2.50
		13-17.5	5.6	20.4	1.0	1800	Lt. red-brown	Soft	2.5	5.5	2.47
						1900	Lt. red-brown	Soft	2.5	5.8	2.44
						2000	Light brown	Fair hard	2.5	5.9	2.44
						2100	Chocolate	Fair hard	2.5	5.7	2.46
						2200	Dark brown	Hard	2.5	5.5	2.47
		17.5-20	2.1	19.4	1.0	1800	Reddish tan	Soft	1.0	5.3	2.51
						1900	Reddish tan	Fair hard	1.0	5.8	2.42
						2000	Tan	Fair hard	5.0	5.0	2.59
						2100	Light brown	Fair hard	5.0	5.4	2.55
						2200	Chocolate	Fair hard	5.0	5.9	2.47
						2300	Dark brown	Hard	5.0	5.2	2.52
		20-29	5.6	19.2	0.5	1800	Reddish tan	Soft	.5	4.5	2.47
						1900	Reddish tan	Fair hard	1.5	5.3	2.42
						2000	Tan	Fair hard	1.5	5.1	2.44
						2100	Brown	Fair hard	1.5	5.1	2.50
						2200	Chocolate	Fair hard	1.5	5.0	2.50
						2300	Purple brown	Fair hard	1.5	5.2	2.44

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-3	SW¼, Sec. 11, T3N, R18W	38-47	5.0	29.8	5.0	1800	Pink-tan	Fair hard	7.5	4.6	2.60
						1900	Pink-tan	Fair hard	7.5	5.1	2.56
						2000	Light tan	Hard	10.0	5.5	2.55
						2100	Tan	Very hard	11.0	7.1	2.47
						2200	Tan	Very hard	11.0	7.5	2.47
						2300	Light gray	Steel hard	11.0	7.8	2.44
HC-3 (Washed)		13-17.5	2.1	42.8	9.0	1800	Red-brown	Fair hard	13.0	4.7	2.68
						1900	Red-brown	Hard	14.5	5.0	2.75
						2000	Red-brown	Very hard	16.0	6.8	2.73
						2100	Chocolate	Very hard	16.0	6.6	2.69
						2200	Dark brown	Steel hard	19.0	7.5	2.68
						2300	Dark brown	Steel hard	19.0	7.9	2.68
HC-4	S½, SW¼, Sec. 10, T3N, R18W	4-8	5.4	23.2	5.0	1800	Red-brown	Fair hard	5.0	4.6	2.67
						1900	Red-brown	Fair hard	7.5	5.0	2.65
						2000	Brown	Fair hard	7.5	5.4	2.63
						2100	Chocolate	Hard	10.0	5.6	2.58
						2200	Dark brown	Hard	10.0	5.9	2.59
						2300	Dark brown	Very hard	10.0	5.8	2.57
		8-10.5	5.5	24.4	7.5	1800	Red-brown	Fair hard	10.0	6.1	2.55
						1900	Red-brown	Fair hard	10.0	6.1	2.59
						2000	Red-brown	Hard	12.5	6.4	2.58
						2100	Brown	Very hard	12.5	7.5	2.52

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-4	S½, SW¼, Sec. 10, T3N, R18W					2200					
						2300	Dark brown Purple brown	Very hard Steel hard	12.5 12.5	7.6 7.7	2.48 2.42
		10.5-13	5.2	19.0	2.5	1800	Red-tan	Fair hard	4.5	5.7	2.51
						1900	Red-tan	Fair hard	5.0	6.4	2.49
						2000	Tan	Fair hard	5.0	6.4	2.50
						2100	Brown	Fair hard	5.0	6.5	2.50
						2200	Chocolate	Fair hard	5.0	6.2	2.51
						2300	Dark brown	Fair hard	5.0	6.2	2.47
		13-15	5.3	22.6	5.0	1800	Light brown	Fair hard	5.0	5.8	2.46
						1900	Light brown	Fair hard	7.5	6.4	2.47
						2000	Light brown	Fair hard	7.5	4.5	2.47
						2100	Brown	Fair hard	7.5	6.5	2.46
						2200	Dark brown	Fair hard	7.5	6.7	2.45
						2300	Dark brown	Fair hard	7.5	6.3	2.46
		15-17.5	5.1	17.0	5.0	1800	Tan	Soft	5.0	6.1	2.48
						1900	Tan	Soft	5.0	7.5	2.37
						2000	Tan	Soft	5.0	7.6	2.35
						2100	Light brown	Fair hard	5.0	7.3	2.39
						2200	Brown	Fair hard	5.0	7.2	2.39
						2300	Dark brown	Crumbled	—	—	—

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-4	S½, SW¼, Sec. 10, T3N, R18W	17.5-21.5	5.1	16.2	0.5	1800	Tan	Fair hard	.5	9.1	2.32
						1900	Tan	Fair hard	.5	8.8	2.32
						2000	Tan	Fair hard	.5	8.7	2.32
						2100	Light brown	Fair hard	.5	8.5	2.34
						2200	Medium brown	Fair hard	.5	8.7	2.35
						2300	Brown	Crumbled	—	—	—
		25.5-33.0	5.6	22.4	8.0	1800	Light brown	Fair hard	8.5	7.4	2.40
						1900	Light brown	Hard	10.0	7.7	2.39
						2000	Light brown	Hard	10.0	8.1	2.36
						2100	Chocolate	Very hard	13.5	7.7	2.39
						2200	Chocolate	Steel hard	13.5	7.7	2.41
						2300	Dark brown	Steel hard	10.0	8.3	2.36
		36.4-40.8	8.3	31.8	10.0	1800	Red brown	Hard	15.0	10.5	2.22
						1900	Brown	Very hard	17.5	10.0	2.22
						2000	Brown	Steel hard	14.5	9.4	2.19
						2100	Dark brown	Very hard	11.0	9.4	1.80
						2200	Dark brown	Expanded	3.0	33.2	1.20
						2300	—	Melted	—	—	—
HC-5	S½, SW¼, Sec. 10, T3N, R18W	13.6-18.4	5.9	23.0	7.5	1800	Cream	Fair hard	7.5	7.5	2.28
						1900	Buff	Hard	10.0	8.6	2.27
						2000	Buff	Hard	10.0	9.1	2.32
						2100	Cream gray	Very hard	10.0	9.4	2.34
						2200	Light gray	Very hard	10.0	9.5	2.34
						2300	Light gray	Steel hard	10.0	9.7	2.29

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-5	S½, SW¼, Sec. 10, T3N, R18W	18.4	8.4	31.2	12.0	1800	Light brown	Fair hard	14.0	11.9	2.34
						1900	Brown	Hard	14.0	12.2	2.36
						2000	Brown	Hard	14.0	12.5	2.34
						2100	Chocolate	Very hard	14.0	14.4	2.28
						2200	Dark brown	Steel hard	14.0	17.1	1.96
						2300	Dark brown	Steel hard	10.0	19.7	1.91
		20.5-24.0	8.9	19.2	5.0	1800	Light brown	Fair hard	5.5	3.9	2.68
						1900	Light brown	Hard	5.8	5.0	2.46
						2000	Light brown	Hard	5.8	5.9	2.48
						2100	Tan	Very hard	6.0	5.9	2.41
						2200	Dark brown	Steel hard	15.0	21.8	2.41
						2300	Melted	--	--	--	--
		13.6-24.0 Composite	7.3	30.0	10.0	1800	Tan	Fair hard	12.0	6.9	2.33
						1900	Light brown	Fair hard	15.0	6.9	2.33
						2000	Light-brown	Hard	15.0	7.2	2.33
						2100	Gray brown	Very hard	15.0	13.3	2.24
						2200	Dark brown	Steel hard	16.0	24.5	2.21
						2300	Dark brown	Steel hard	16.0	29.1	2.21
HC-6	SE¼, NW¼, Sec. 14, T5N, R17W	1.5-2.9	6.3	16.0	2.0	1800	Red-tan	Fair hard	2.0	6.8	2.52
						1900	Red-tan	Fair hard	4.0	6.9	2.51
						2000	Light brown	Hard	4.0	7.5	2.50
						2100	Brown	Very hard	5.0	7.8	2.48
						2200	Chocolate	Very hard	5.0	7.9	2.44

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-6	SE¼, NW¼, Sec. 14, T5N, R17W	7.3-11.8	5.6	15.4	0.5	1800	Red-tan	Soft	.5	5.6	2.52
						1900	Red-tan	Fair hard	2.5	6.4	2.51
						2000	Tan	Fair hard	2.5	8.1	2.50
						2100	Light brown	Hard	5.0	7.1	2.47
						2200	Chocolate	Hard	5.0	7.3	2.47
						2300	Chocolate	Very hard	5.0	7.2	2.42
		11.8-14.6	6.2	18.0	5.0	1800	Tan	Fair hard	5.0	8.2	2.31
						1900	Tan	Fair hard	5.0	7.7	2.34
						2000	Light brown	Fair hard	5.0	7.7	2.36
						2100	Chocolate	Hard	5.0	7.7	2.37
						2200	Dark brown	Very hard	5.5	7.8	2.33
						2300	Dark brown	Very hard	5.5	6.6	2.30
		21.1-24.2	6.8	17.8	5.0	1800	Light brown	Fair hard	5.5	7.2	2.47
						1900	Light brown	Hard	5.5	8.6	2.43
						2000	Light brown	Very hard	10.0	6.7	2.39
						2100	Chocolate	Very hard	10.0	6.0	2.41
						2200	Dark brown	Steel hard	10.0	11.8	2.40
						2300	Dark brown	Steel hard	10.0	11.1	2.39
HC-10	SE¼, NW¼, Sec. 10 T5N, R17W	27.4-29.7	7.5	25.6	9.0	1800	Tan	Fair hard	10.0	9.6	2.25
						1900	Light brown	Hard	10.5	12.3	2.34
						2000	Brown	Very hard	14.0	14.3	2.31
						2100	Chocolate	Very hard	14.0	16.6	2.37
						2200	Dark brown	Steel hard	14.0	17.0	2.36
						2300	Black brown	Very hard	14.0	22.5	1.76

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-10	SE¼, NW¼, Sec. 10, T5N, R17W	29.7-33.4	8.0	25.4	9.0	1800	Light brown	Hard	10.0	10.7	2.37
						1900	Light brown	Hard	10.0	11.8	2.36
						2000	Brown	Very hard	14.0	14.4	2.35
						2100	Chocolate	Steel hard	14.0	15.3	2.35
						2200	Dark brown	Steel hard	14.0	15.5	2.44
						2300	Black	Very hard	14.0	15.1	2.25
HC-11	N½, NW¼, Sec. 36, T7N, R14W	4.3-8.8	5.8	25.2	5.0	1800	Pink-tan	Fair hard	5.0	5.3	2.64
						1900	Pink-tan	Hard	7.5	5.7	2.62
						2000	Tan	Very hard	10.0	6.9	2.62
						2100	Light brown	Steel hard	14.5	10.8	2.54
						2200	Gray brown	Steel hard	14.5	10.7	2.54
						2300	Gray	Steel hard	14.5	13.7	2.45
		8.8-14.8	5.8	26.4	9.0	1800	Pink-tan	Fair hard	10.0	5.2	2.62
						1900	Tan	Fair hard	10.0	5.8	2.62
						2000	Tan	Hard	10.0	7.9	2.58
						2100	Brown	Very hard	14.5	12.2	2.50
						2200	Dark brown	Steel hard	14.5	14.5	2.50
						2300	Black-brown	Steel hard	15.5	21.8	2.48
		14.8-21.8	5.6	23.4	7.5	1800	Pink-tan	Fair hard	7.5	5.7	2.58
						1900	Pink-tan	Hard	7.5	6.6	2.53
						2000	Tan	Very hard	10.5	9.4	2.45
						2100	Brown	Very hard	10.5	11.3	2.41
						2200	Chocolate	Steel hard	10.5	17.7	2.43
						2300	Brown black	Steel hard	10.5	24.5	2.40

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-11	N½, NW¼, Sec. 36, T7N, R14W	21.8-25.8	5.5	23.2	10.0	1800	Tan	Fair hard	10.0	7.5	2.50
						1900	Tan	Hard	10.0	8.0	2.47
						2000	Light brown	Very hard	10.5	10.1	2.47
						2100	Brown	Very hard	10.5	11.4	2.40
						2200	Chocolate	Steel hard	15.0	14.2	2.39
						2300	Chocolate	Steel hard	15.0	14.4	2.40
		Composite	6.2	25.4	10.0	1800	Light brown	Fair hard	10.0	6.0	2.61
						1900	Light brown	Fair hard	10.0	6.2	2.61
						2000	Light brown	Hard	10.0	5.9	2.74
						2100	Chocolate	Very hard	14.0	12.6	2.49
						2200	Chocolate	Steel hard	14.0	14.7	2.61
						2300	Chocolate	Steel hard	10.0	13.1	2.46
HC-15	NE¼, NE¼, Sec. 31, T7N, R13W	5.1-10.1	6.2	18.2	4.5	1800	Flesh	Fair hard	4.5	6.2	2.70
						1900	Flesh	Fair hard	4.5	5.8	2.73
						2000	Flesh-tan	Hard	4.5	6.4	2.69
						2100	Pale yellow	Hard	4.5	6.3	2.71
						2200	Yellow-tan	Very hard	4.5	6.5	2.70
		31.9-38.8	6.7	16.4	4.5	1800	Tan	Fair hard	5.0	6.8	2.62
						1900	Tan	Hard	5.0	7.0	2.60
						2000	Tan	Hard	5.0	7.1	2.60
						2100	Tan-buff	Very hard	5.0	7.6	2.58
						2200	Buff	Steel hard	15.0	8.2	2.54

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-15	NE¼, NE¼, Sec. 31, T7N, R13W	38.8-43.1	6.7	18.0	5.0	1800	Red-tan	Fair hard	5.0	6.3	2.61
						1900	Red-tan	Fair hard	5.0	6.3	2.62
						2000	Tan	Hard	5.0	6.7	2.60
						2100	Light brown	Very hard	8.0	5.7	2.43
						2200	Light brown	Very hard	8.0	9.0	2.47
		43.1-46.9	6.9	18.1	5.0	1800	Red-tan	Fair hard	5.5	6.3	2.65
						1900	Red-tan	Hard	5.5	6.4	2.64
						2000	Red-tan	Hard	5.5	7.0	2.62
						2100	Brown	Very hard	6.5	10.2	2.49
						2200	Brown	Steel hard	6.5	10.5	2.47
		46.9-50.3	6.5	18.6	5.0	1800	Red brown	Fair hard	6.0	6.3	2.62
						1900	Red brown	Fair hard	6.0	6.3	2.56
						2000	Red brown	Hard	6.0	6.2	2.60
						2100	Chocolate	Very hard	6.0	8.5	2.50
						2200	Dark brown	Very hard	6.0	8.9	2.47
		50.3-52.6	6.6	14.6	5.0	1800	Red brown	Fair hard	5.5	6.2	2.63
						1900	Tan	Hard	5.5	7.5	2.59
						2000	Tan	Hard	5.5	7.2	2.61
						2100	Light brown	Very hard	5.5	9.0	2.53
						2200	Brown	Very hard	5.5	8.8	2.51

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-15	NE¼, NE¼, Sec. 31, T7N, R13W	Composite	6.1	20.6	5.0	1800	Red brown	Fair hard	5.0	6.6	2.62
						1900	Red brown	Fair hard	8.0	6.5	2.65
						2000	Light brown	Hard	8.0	7.1	2.63
						2100	Brown	Very hard	10.0	10.2	2.52
						2200	Brown	Very hard	10.0	10.2	2.50
						2300	Brown	Very hard	10.0	9.6	2.52
HC-17	E¼, SW¼, NE¼, Sec. 9, T5N, R15W	4.6-9.1	5.9	21.0	1.0	1800	Pale flesh	Fair hard	5.0	6.5	2.69
						1900	Pale flesh	Hard	5.0	5.9	2.69
						2000	Pale pink	Hard	6.0	6.1	2.67
						2100	Pale buff	Very hard	7.5	8.1	2.62
						2200	Pale buff	Very hard	7.5	8.6	2.61
						2300	Buff	Steel hard	7.5	9.4	2.56
		9.1-13.6	6.0	19.0	1.0	1800	Pale pink	Fair hard	6.0	6.5	2.66
						1900	Pale pink	Fair hard	6.0	6.5	2.66
						2000	Gray buff	Hard	6.0	6.6	2.62
						2100	Buff	Very hard	6.0	8.2	2.63
						2200	Buff	Very hard	6.0	8.3	2.63
		13.6-18.8	5.6	19.8	1.0	1800	Flesh	Fair hard	5.0	4.9	2.79
						1900	Flesh	Hard	5.0	6.2	2.61
						2000	Pale tan	Very hard	5.0	7.1	2.59
						2100	Buff	Very hard	6.5	9.2	2.50
						2200	Buff	Steel hard	6.5	9.0	2.49
						2300	Gray buff	Steel hard	6.5	11.0	2.44

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-17	E½, SW¼, NE¼, Sec. 9, T5N, R15W	18.8-23.0	6.3	17.6	1.0	1800	Red tan	Fair hard	5.0	6.8	2.47
						1900	Red tan	Fair hard	5.0	7.0	2.44
						2000	Tan	Fair hard	5.0	6.6	2.46
						2100	Tan	Fair hard	5.0	7.1	2.43
						2200	Buff tan	Fair hard	5.0	6.8	2.41
		23.0-27.1	5.9	16.8	1.0	1800	Red tan	Fair hard	5.0	5.7	2.55
						1900	Red tan	Fair hard	5.0	6.2	2.54
						2000	Tan	Hard	6.0	6.8	2.52
						2100	Brown	Very hard	6.5	7.8	2.46
						2200	Brown	Very hard	6.5	7.8	2.45
						2300	Dark brown	Steel hard	6.5	8.3	2.43
		Composite	5.9	20.4	1.0	1800	Red tan	Fair hard	5.0	5.9	2.69
						1900	Red tan	Hard	5.0	6.2	2.66
						2000	Tan	Hard	6.0	6.6	2.65
						2100	Yellow buff	Very hard	10.0	8.8	2.54
						2200	Yellow buff	Very hard	10.0	9.0	2.54
						2300	Gray buff	Steel hard	10.0	8.7	2.52
HC-18	E½, SW¼, NE¼, Sec. 9, T5N, R15W	6.5-9.1	6.1	17.4	1.0	1800	Red tan	Fair hard	6.5	4.7	2.66
						1900	Red tan	Fair hard	6.5	5.0	2.65
						2000	Pink tan	Hard	6.5	5.2	2.64
						2100	Pale tan	Very hard	10.0	7.2	2.56
						2200	Pale tan	Very hard	10.0	7.8	2.55
						2300	Buff	Steel hard	10.0	8.7	2.49

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-18	E½, SW¼, NE¼, Sec. 9, T5N, R15W	9.1-12.3	6.2	23.2	5.0	1800	Red tan	Fair hard	5.5	2.8	2.40
						1900	Red tan	Fair hard	5.5	2.9	2.38
						2000	Pale tan	Fair hard	5.5	3.0	2.35
						2100	Cream	Hard	5.5	3.1	2.28
						2200	Buff	Hard	5.5	3.4	2.36
						2300	Gray buff	Very hard	5.2	5.1	2.73
		12.3-15.8	5.9	24.8	4.5	1800	Red tan	Fair hard	5.0	5.2	2.66
						1900	Red tan	Fair hard	7.0	5.3	2.70
						2000	Tan	Hard	7.0	5.9	2.70
						2100	Cream	Hard	9.0	6.6	2.69
						2200	Buff	Very hard	11.0	9.0	2.66
						2300	Gray buff	Very hard	11.0	10.0	2.65
		15.8-19.8	6.2	29.8	5.0	1800	Pink-white	Fair hard	5.0	2.2	2.66
						1900	Pink-white	Fair hard	6.5	2.2	2.71
						2000	Off white	Fair hard	6.5	2.5	2.70
						2100	Pale buff	Hard	10.0	2.8	2.68
						2200	Buff	Very hard	13.0	3.5	2.65
						2300	Buff	Steel hard	13.0	3.9	2.58
		22.3-32.1	6.2	22.0	5.0	1800	Flesh	Fair hard	5.0	5.2	2.66
						1900	Flesh	Fair hard	5.0	5.3	2.70
						2000	Pale flesh	Fair hard	5.0	5.4	2.69

Table 3. Continued

U.S.B.M. Sample No.	Location	Interval, feet	pH	Unfired Characteristics				Results of ceramic property tests			
				Water for plasticity, percent	Drying shrinkage percent	Firing Temp., °F	Color	Hardness	Shrinkage percent	Absorption percent	Apparent Sp. Gr. percent
HC-18	E½, SW¼, NE¼, Sec. 9, T5N, R15W	36.8-47.8	6.4	24.0	1.0	2100	Pale flesh	Hard	5.0	5.7	2.70
						2200	Pale buff	Hard	5.0	6.4	2.67
						2300	Gray buff	Very hard	6.0	6.6	2.67
						1800	Pink-white	Fair hard	1.0	4.2	2.55
						1900	Pink-white	Fair hard	1.0	4.2	2.59
						2000	Pale buff	Fair hard	1.0	4.2	2.59
						2100	Buff	Hard	1.5	4.3	2.61
						2200	Buff	Very hard	3.5	4.3	2.68
						2300	Buff	Very hard	3.5	4.5	2.59
		Composite	6.1	23.2	5.0	1800	Light tan	Fair hard	5.0	4.7	2.61
						1900	Light tan	Fair hard	5.0	4.6	2.61
						2000	Cream	Hard	5.0	4.8	2.61
						2100	Yellow buff	Hard	9.0	6.3	2.54
						2200	Yellow buff	Very hard	9.0	6.3	2.52
						2300	Yellow buff	Very hard	9.0	5.9	3.15
HC-22	SE¼, SW¼, Sec 32, T6N, R14W	8.0-12.5	6.6	17.4	5.0	1800	Pale flesh	Fair hard	5.0	4.6	2.55
						1900	Pale flesh	Fair hard	5.0	4.6	2.60
						2000	Pink-white	Fair hard	5.0	4.8	2.61
						2100	Gray buff	Hard	6.5	5.2	2.61
						2200	Buff	Hard	6.5	6.3	2.56
						2300	Buff	Very hard	6.5	7.1	2.47

BUREAU OF GEOLOGY

EXTRUSION TEST

SAMPLE No. WW1-5N-21W-35 acc

Body Composition Raw clay through 6-mesh: 100%
 Tempering Water 17.0% of dry batch weight
 Vacuum On Machine 27 inches of mercury
 Drying 24 hours in air; 24 hours at 140°F
 Drying Shrinkage 1.0%
 Modulus Of Rupture, Dry Unfired 270 psi

Firing:

Time 24 hours
 Temperature 2300°F
 Cone 10 over

Total shrinkage 2.1%
 Absorption, 5-hour boiled 13.2%
 Absorption, 24-hour soaked 11.3%
 Saturation coefficient 0.86
 Apparent porosity 25.1%
 Bulk density 118.56 lb/cu ft.
 Fired modulus of rupture 2080 psi
 Moh's hardness 4
 Color Cream

Potential Use: Promising for glazed structural clay products. Some adjustments in the body might be required.

SAMPLE No. LW1-5N-19W-11 aa

LOCATION: NW¼, NW¼, section 11, T5N, R19W (Glendale Quadrangle)

FIELD DESCRIPTION: About 4 feet of mottled gray, red-brown, yellow brown, grayish green, slightly silty clay.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 22.8%
 Drying shrinkage 7.5%
 Dry strength Fair
 Color Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	10.0	23.1	Pink	2	1.62
1900	10.0	17.7	Pink	2	1.76
2000	10.0	16.4	Pink	3	1.78
2100	12.5	15.4	Tan	4	1.84
2200	15.0	14.4	Buff	5	1.90
2300	15.0	13.9	Buff	5	1.91

Potential Use: Face brick mixtures.

Remarks: Might be used to increase the firing range of face brick and structural tile bodies. Good color at 2100°F.

SAMPLE No LWI-5N-19W-34 add

LOCATION: NW¼, SE¼, SE¼, section 34, T5N, R19W (Glendale Quadrangle)

FIELD DESCRIPTION: Collected from 6- to 8-foot mottled gray, red brown clay bed. The bed is exposed in a roadcut on the east side of Florida Highway 83.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 32.4%
 Drying shrinkage 5.0%
 Dry strength Good
 Color Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	20.6	Pink	2	1.72
1900	10.0	19.6	Pink	2	1.75
2000	10.0	16.3	Pink	3	1.86
2100	12.5	9.3	Beige	5	2.10
2200	15.0	3.1	Gray	6	2.32
2300	17.5	2.1	Olive	6	2.35

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2100°F, however, might require addition of grog.

EXTRUSION TEST

SAMPLE No. LWI-5N-19W-34 add

Body Composition Raw clay through 6 mesh: 100%
 Tempering Water 28.0% of dry batch weight.
 Vacuum On Machine 27 inches of mercury.
 Drying 24 hours in air; 24 hours at 140°F.
 Drying Shrinkage 4.2%
 Modulus Of Rupture, Dry Unfired 500 psi.

Firing:

Time 24 hours
 Temperature 2225°F
 Cone 8 over

Total shrinkage 8.3%
 Absorption, 5-hour boiled 11.3%
 Absorption, 24-hour soaked 9.2%
 Saturation coefficient 0.81
 Apparent porosity 22.5%
 Bulk density 1.99 gm/cc
 Fired modulus of rupture 670 psi
 Moh's hardness 3
 Color Tan

Potential Use: None. Poor ceramic bond. Might be used in face brick mixtures.

SAMPLE No. LWI-5N-18W-4 baa

LOCATION: NE¼, NW¼, NW¼, section 4, T5N, R18W (Glendale Quadrangle)
FIELD DESCRIPTION: About 20 to 30 feet of gray sandy, clay exposed in ditch along road.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	23.5%
Drying shrinkage	10.0%
Dry strength	Good
Color	Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	10.0	19.9	Pink	2	1.75
1900	10.0	19.5	Pink	2	1.76
2000	10.0	19.3	Pink	3	1.77
2100	15.0	16.4	Cream	3	1.86
2200	15.0	13.2	Ivory	4	1.97
2300	15.0	11.4	Buff	4	2.02

Potential Use: Artware and glazed structural-tile bodies.
Remarks: Might be used to increase the firing range of face brick mixtures. Good color at 2200°F.

SAMPLE No. LWI-4N-19W-2 decc

LOCATION: SW¼, SW¼, SW¼, section 2, T4N, R19W (Glendale Quadrangle)
FIELD DESCRIPTION: Collected from clay pit formerly used to supply clay for a brick plant located just north of Glendale. The clay bed here is 3 feet thick and is overlain by 8 feet of sand.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Low plasticity
Water of plasticity	25.6%
Drying shrinkage	2.5%
Dry strength	Fair
Color	Red

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	24.9	Light brown	2	1.61
1900	5.0	24.8	Light brown	2	1.61
2000	5.0	23.2	Light brown	3	1.66
2100	7.5	21.1	Brown	4	1.71
2200	10.0	19.4	Brown	5	1.74
2300	10.0	18.5	Gray	6	1.75

Potential Use: Not suitable for use as the principle component in vitreous clay products.
Remarks: Might be used to control shrinkage in a face brick mixture.

SAMPLE No. LWI-4N-20W-26 ba

LOCATION: NE¼, NW¼, section 26, T4N, R20W (Glendale Quadrangle)

FIELD DESCRIPTION: Sample collected from 2- to 3-foot dark gray carbonized clay bed cropping out along Big Swamp Creek near Liberty on U. S. Highway 331.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics High plasticity
 Water of plasticity 24.9%
 Drying shrinkage 12.5%
 Dry strength Good
 Color Gray

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	15.0	22.5	Tan	3	1.63
1900	17.5	16.9	Tan	4	1.76
2000	20.0	12.4	Light brown	4	1.88
2100	20.0	11.1	Brown	5	1.92
2200	Expanded	—	—	—	—
2300	—	—	—	—	—

Potential Use: Lightweight aggregate.

Remarks: High shrinkage, has positive bloating test and abrupt vitrification.

SAMPLE No. LWI-3N-18W-6 bbbd

LOCATION: NE¼, NE¼, NE¼, SE¼, section 6, T3N, R18W (Glendale Quadrangle)

FIELD DESCRIPTION: Sample collected from a 7-foot mottled dark yellowish orange, pale yellowish brown, yellowish gray, silty, sandy clay bed. The bed is exposed in roadcut on Florida Highway 183.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 25.6%
 Drying shrinkage 10.0%
 Dry strength Good
 Color Yellow

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	12.5	16.3	Light red	2	1.84
1900	12.5	14.8	Light red	3	1.88
2000	15.0	10.9	Light red	4	2.00
2100	17.5	8.1	Light brown	5	2.09
2200	20.0	7.4	Brown	6	2.12
2300	20.0	6.8	Dark brown	6	2.13

Potential Use: Flower pots.

Remarks: High shrinkage.

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EXTRUSION TEST

SAMPLE No. LWI-3N-18W-6 bbbd

Body Composition	Raw clay through 6-mesh = 100%
Tempering Water	.25% of dry batch weight
Vacuum On Machine	.21 inches of mercury
Drying	.24 hours in air; 24 hours at 140° F
Drying Shrinkage	.7.3%
Modulus Of Rupture, Dry Unfired	.990 psi
Firing:	
Time	.24 hours
Temperature	.1750° F
Cone	.07 flat
Total shrinkage	.7.3%
Absorption, 5-hour boiled	.16.9%
Absorption, 24-hour soaked	.15.1%
Saturation coefficient	.0.89
Apparent porosity	.30.9
Bulk density	.1.83 gm/cc; 114.2 lb/ cu ft
Fired modulus of rupture	.1750 psi
Moh's hardness	.6
Color	.Salmon

Potential Use: Should be satisfactory for flower pots.

SAMPLE No. LWI-3N-17W-28 a

LOCATION: W½, NW¼, section 28, T3N, R17W (Ponce de Leon Quadrangle)

FIELD DESCRIPTION: Sample collected from a 15-foot clay bed exposed along roadcut of graded road.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	High plasticity
Water of plasticity	.34.1%
Drying shrinkage	.15.0%
Dry strength	.Good
Color	.Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	20.0	11.4	Salmon	3	1.94
1900	20.0	8.0	Salmon	4	2.06
2000	25.0	2.3	Light brown	5	2.27
2100	25.0	1.4	Brown	6	2.34
2200	Expanded	—	—	—	—
2300	—	—	—	—	—

Potential Use: Not suitable for use in vitreous clay products.

Remarks: Excessive shrinkage.

SAMPLE No. LWI-1N-18W-3 a

LOCATION: NW¼, section 3, T1N, R18W (DeFuniak Springs Quadrangle)

FIELD DESCRIPTION: About 40 feet of gray clay exposed in narrow ditch along graded road on both sides of Bruce Creek.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics Moderate plasticity
 Water of plasticity 25.3%
 Drying shrinkage 10.0%
 Dry strength Good
 Color Yellow

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	12.5	14.0	Orange tan	3	1.87
1900	12.5	12.7	Orange tan	4	1.92
2000	17.5	10.0	Light brown	4	2.00
2100	17.5	6.7	Brown	4	2.14
2200	17.5	6.3	Red brown	5	2.16
2300	20.0	4.7	Gray brown	6	2.18

Potential Use: Face brick mixtures.

Remarks: High shrinkage, however, might be used as the plastic fraction in face-brick mixtures.

EXTRUSION TEST

COMPOSITE OF SAMPLE Nos. LWI-1N-18W-3 a and LWI-4N-19W-2 daac

Body Composition Raw clay LWI-1N-18W-3 a through 6-mesh: 50%.
 Raw clay LWI-4N-19W-2 daac through 6-mesh: 50%
 Tempering Water 22.0% of dry batch weight
 Vacuum On Machine26 inches of mercury
 Drying 24 hours in air; 24 hours at 140°F
 Drying Shrinkage 6.3%
 Modulus Of Rupture, Dry Unfired910 psi
 Firing:
 Time 24 hours
 Temperature 2100°F
 Cone 4 over
 Total shrinkage 10.4%
 Absorption, 5-hour boiled 7.3%
 Absorption, 24-hour soaked 5.3%
 Saturation coefficient 0.73
 Apparent porosity 13.3%
 Bulk density 1.83 gm/cc; 114.2 lb/cu ft
 Fired modulus of rupture 2985 psi
 Moh's hardness 6
 Color Light red

Potential Use: Should meet "SW" face brick specifications as processed. Color marginal.

SAMPLE No. LW-1N-17W-32 d

LOCATION: SE¼, section 32, T1N, R17W (Bruce Quadrangle)

FIELD DESCRIPTION: Collected from a 10-foot orange, mottled reddish-brown, silty, sandy clay bed exposed in a drainage ditch on southeast side of Florida Highway 81.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Low plasticity
Water of plasticity	19.0%
Drying shrinkage	2.5%
Dry strength	Low
Color	Yellow

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	—	Orange	2	—
1900	5.0	21.6	Orange	2	1.66
2000	5.0	20.4	Tan	2	1.69
2100	5.0	19.8	Tan	2	1.71
2200	5.0	18.5	Brown	2	1.73
2300	5.0	18.1	Brown	2	1.74

Potential Use: Not suitable for use as the principal component in vitreous clay products.
Remarks: Might be used to control shrinkage in a face-brick mixture.

Washington County

Calver (1949, p. 44-47, 58, 59) presented data on clays collected from Washington County. The following data were taken from his report.

SAMPLE No. 0-124

LOCATION: One mile south of Vernon at site of abandoned Vernon Brick Company.
FIELD DESCRIPTION: Collected from 4- to 5-foot clay bed in pit.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	43%
Linear shrinkage	11.6%
Modulus of rupture	290 psi
Unfired color	Dark red

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	1.0	19.6	37.8	Reddish orange
1920	1.0	17.6	35.9	Reddish orange
1995	4.5	13.5	28.2	Reddish orange
2100	5.0	10.8	27.4	Reddish orange
2175	6.0	10.4	26.8	Reddish orange
2280	10.5	9.2	25.2	Reddish orange

Potential Use: Suitable for use in manufacture of brick.

SAMPLE No. 0-126

LOCATION: Three miles southeast of Vernon on south side of Cravey's Mill Creek.
 FIELD DESCRIPTION: Light gray clay collected from 3-foot section.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Excellent
Water of plasticity	46%
Linear shrinkage	7.6%
Modulus of rupture	70 psi
Unfired color	Light pinkish gray

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	2.0	28.2	44.8	Very light pink
1920	1.0	28.6	44.5	Very light pink
1995	3.0	26.6	43.0	Light pinkish gray
2100	4.5	24.2	40.7	Light pinkish gray
2175	7.0	17.0	34.0	Light pinkish gray
2280	7.5	13.3	30.0	Light pinkish gray

Potential Use: Can be used for making brick.

SAMPLE No. 0-127

LOCATION: At brick plant of Peaden Materials Company (formerly Hall Brick Yard) two miles southwest of Chipley.
 FIELD DESCRIPTION: Sample taken from 3- to 6-foot gray clay bed.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	39%
Linear shrinkage	9.0%
Modulus of rupture	320 psi
Unfired color	Gray

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	2.0	23.0	40.7	Cream
1920	2.5	22.8	40.0	Cream
1995	5.0	16.0	40.0	Cream
2100	7.5	12.0	27.3	Cream
2175	10.5	6.0	17.2	Cream
2280	10.5	5.2	16.1	Cream

Potential Use: Could be used for brick or semi-refractory brick.

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SAMPLE No. 0-128

LOCATION: Borrow clay pit at Wausau, 800 feet west of Wausau Station.

FIELD DESCRIPTION: Collected from 4-foot gray clay bed at top of section.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Excellent
Water of plasticity	48%
Linear shrinkage	7.9%
Modulus of rupture	140 psi
Unfired color	Light pinkish gray

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	2.5	26.9	43.5	Light pinkish gray
1920	3.5	26.6	41.6	Light pinkish gray
1995	5.0	19.3	36.2	Light pinkish gray
2100	6.0	16.5	33.4	Light pinkish gray
2175	11.0	7.9	19.8	Light pinkish gray
2280	11.5	4.9	15.5	Light pinkish gray

Potential Use: Suitable for use in manufacture of brick.

SAMPLE No. 0-129

LOCATION: Borrow clay pit at Wausau, 800 feet west of Wausau Station.

FIELD DESCRIPTION: Collected from 3-foot light gray and pink clay bed near base of section.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Excellent
Water of plasticity	56%
Linear shrinkage	9.8%
Modulus of rupture	170 psi
Unfired color	Light grayish pink

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	2.5	25.0	42.1	Light pink
1920	1.0	26.6	43.0	Light pink
1995	5.0	17.2	34.5	Light pink
2100	6.5	13.8	29.6	Light pink
2175	8.5	10.0	23.3	Light pink
2280	12.0	3.8	13.0	Light pinkish gray

Potential Use: Suitable for use in manufacture of brick.

SAMPLE No. 0-156

LOCATION: Nine miles northeast of Wausau on road to Chipley in roadside ditch on east side of hill.

FIELD DESCRIPTION: Collected from 3-foot clay bed which appears to be interbedded with sands.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Fair
Water of plasticity	40%
Linear shrinkage	10.7%
Modulus of rupture	440 psi
Unfired color	Red

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.5	17.0	35.0	Brick red
1920	1.0	16.2	34.4	Reddish orange
1995	2.0	13.6	32.1	Brick red
2100	3.5	11.9	29.1	Brick red
2175	4.5	10.5	28.1	Dark red
2280	3.5	9.7	27.2	Dark red

Potential Use: Suitable for use in the manufacture of brick.

SAMPLE No. 0-198

LOCATION: Borrow pit near bridge crossing the Choctawhatchee River at Caryville.

FIELD DESCRIPTION: Collected from 4-foot alluvial clay bed exposed in borrow pit.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Fair
Water of plasticity	29%
Linear shrinkage	7.0%
Modulus of rupture	290 psi
Unfired color	Brown

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.5	17.0	35.3	Reddish orange
1920	0.0	17.2	35.8	Reddish orange
1995	0.5	16.4	35.2	Reddish orange
2100	1.5	16.0	33.8	Light brick red
2175	1.5	14.2	32.0	Brick red
2280	1.5	14.7	32.5	Brick red

Potential Use: Suitable for use in making brick.

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SAMPLE No. 0-246

LOCATION: Section located in a roadcut three miles south of Vernon on road to Greenhead.

FIELD DESCRIPTION: A composite 12.5-foot sample of sandy clay, clay, and clayey sand.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Good
Water of plasticity	36%
Linear shrinkage	9.3%
Modulus of rupture	280 psi
Unfired color	Medium orange

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.0	17.1	39.6	Reddish orange
1920	1.5	19.8	39.5	Reddish orange
1995	3.5	15.0	35.8	Light brick red
2100	4.0	12.4	31.2	Brick red
2175	4.5	9.1	28.3	Brick red
2280	5.0	11.1	30.3	Brick red

Potential Use: Suitable for brick.

SAMPLE No. 0-248

LOCATION: Roadside gully 2.7 miles west of Wausau on the Vernon road.

FIELD DESCRIPTION: Collected from 9-foot light gray clay bed in gully.

LABORATORY RESULTS:

Unfired Characteristics

Plasticity	Poor
Water of plasticity	35%
Linear shrinkage	11.1%
Modulus of rupture	320 psi
Unfired color	Yellowish gray

Slow Fired Characteristics

Temp. (°F)	Linear Shk. (%)	Abs. (%)	Porosity (%)	Color
1740	0.0	13.5	31.1	Reddish orange
1920	0.5	12.8	29.6	Reddish orange
1995	1.5	12.4	29.0	Light brick red
2100	1.5	12.6	26.0	Brick red
2175	2.5	10.9	27.2	Brick red
2280	2.5	9.7	26.8	Brick red

Potential Use: Probably suitable for manufacture of common brick.

The writers submitted eight clay samples from Washington County to the U. S. Bureau of Mines for ceramic-property tests and these data are presented with the data from one U. S. Bureau of Mines core hole as follows:

SAMPLE No. LWS-4N-15W-6 bcd

LOCATION: NE¼, SW¼, SE¼, section 6, T4N, R15W (Caryville Quadrangle)

FIELD DESCRIPTION: Collected from shallow borrow pit on east side of graded road. Clay is overlain by less than 5 feet of overburden.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	22.0%
Drying shrinkage	5.0%
Dry strength	Good
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	7.5	18.5	Salmon	4	1.83
1900	7.5	17.2	Salmon	4	1.88
2000	10.0	14.2	Salmon	4	1.99
2100	15.0	6.1	Buff	5	2.35
2200	15.0	4.4	Brown	5	2.42
2300	17.5	3.9	Olive	6	2.45

Potential Use: Face brick.

Remarks: Should fire to "SW" face brick specifications at about 2050°F. Shrinkage a little high. Color marginal. See extrusion tests on Sample Nos. LWS-4N-15W-6 dca and LHo-4N-15W-13 cdc, p. 00.

SAMPLE No. LWS-4N-15W-8 c

LOCATION: Center SW¼, section 8, T4N, R15W (Caryville Quadrangle).

FIELD DESCRIPTION: Collected from approximately 20 feet of massive clay exposed in ditches on both sides of graded road. Clay bed overlain by 5 feet of overburden.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	High plasticity
Water of plasticity	37.0%
Drying shrinkage	10.0%
Dry strength	Good
Color	Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	15.0	22.5	Salmon	3	1.67
1900	15.0	22.2	Pink	4	1.67
2000	15.0	20.4	Pink	4	1.72

2100	17.5	12.0	Pink	5	2.02
2200	20.0	2.3	Gray	6	2.43
2300	20.0	1.6	Green	6	2.48

Potential Use: Face brick mixtures.

Remarks: High shrinkage, however, may be used as the plastic fraction in face brick mixtures. Good color at 2000°F.

SAMPLE No. LWS-4N-14W-25 bba

LOCATION: NE¼, NE¼, NW¼, section 25, T4N, R14W (Wausau Quadrangle).

FIELD DESCRIPTION: Collected from west side of Florida Highway 276.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	20.1%
Drying shrinkage	7.5%
Dry strength	Fair
Color	Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	7.5	20.8	Pink	3	1.72
1900	7.5	19.9	Pink	3	1.74
2000	7.5	19.9	Pink	3	1.74
2100	7.5	18.0	Beige	3	1.80
2200	12.5	15.7	Buff	3	1.84
2300	12.5	15.5	Buff	4	1.85

Potential Use: Face brick mixtures.

Remarks: Might be used to increase the firing range of face brick and structural tile bodies. Good color at 2100°F.

SAMPLE No. WWS-4N-13W-24 db (U. S. Bureau of Mines core hole)

LOCATION: SE¼, NE¼, section 24, T4N, R13W

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Smooth and plastic
Water of plasticity	20.4%
Drying shrinkage	9.0%
Dry strength	Good
Color	Light green

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	9.0	8.9	Tan	Fair hard	2.43
1900	9.0	8.8	Tan	Fair hard	2.42
2000	10.0	9.0	Light brown	Hard	2.40
2100	10.0	10.3	Brown	Hard	2.37

2200	10.0	11.0	Chocolate	Very hard	2.37
2300	10.0	11.3	Chocolate	Steel hard	2.35

Potential Use: Glazed brick and pottery.

Remarks: Fifty nine feet of clay were penetrated. The fired color was fair, the material a little soft, absorption a little high, slight scum and slight effervescence which denotes some carbonate material present.

SAMPLE No. LWS-3N-14W-27 dbd

LOCATION: SE¼, NE¼, SE¼, section 27, T3N, R14W (Wausau Quadrangle)

FIELD DESCRIPTION: Collected along west side of road from 15-foot exposure of light gray, sandy clay. The clay is overlain by less than 5 feet of overburden.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Low plasticity
Water of plasticity	27.1%
Drying shrinkage	Fair
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	2.5	26.5	Pink	2	1.56
1900	2.5	26.0	Pink	2	1.58
2000	2.5	25.7	Pink	3	1.59
2100	5.0	24.0	Pink	3	1.64
2200	10.0	15.9	Gray	4	1.86
2300	10.0	12.6	Gray	5	1.97

Potential Use: Face brick mixtures.

Remarks: Poor ceramic bond. Might be used as a nonplastic fraction to control shrinkage in brick mixtures.

SAMPLE No. LWS-3N-14W-28 bc

LOCATION: SE¼, NE¼, NE¼, section 2, T3N, R13W (Wausau Quadrangle)

FIELD DESCRIPTION: Collected from 6-foot clay bed in north facing roadcut at intersection of Florida Highways 156 and 273.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Low plasticity
Water of plasticity	22.2%
Drying shrinkage	2.5%
Dry strength	Fair
Color	Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	17.1	Beige	2	1.81
1900	5.0	16.8	Beige	3	1.82

2000	5.0	15.7	Beige	4	1.86
2100	7.5	13.2	Buff	4	1.92
2200	10.0	8.3	Yellow	5	2.03
2300	10.0	4.8	Olive	5	2.11

Potential Use: Face brick.
Remarks: Should fire to "SW" face brick specifications at about 2100°F.

EXTRUSION TEST

SAMPLE No. LWs-3N-13W-2 dbbb

Body Composition	.Raw clay through 6 mesh: 100%
Tempering Water	.14.0% of dry batch weight
Vacuum On Machine	.27 inches of mercury
Drying	.24 hours in air; 24 hours at 140°F
Drying Shrinkage	.6.3%
Modulus Of Rupture, Dry Unfired	.610 psi
Firing:	
Time	.24 hours
Temperature	.2100°F
Cone	.4
Total shrinkage	.12.5%
Absorption, 5-hour boiled	.6.3%
Absorption, 24-hour soaked	.5.9%
Saturation coefficient	.0.94
Apparent porosity	.14.0%
Bulk density	.2.22 gm/cc
Fired modulus of rupture	.4310 psi
Moh's hardness	.5
Color	.Light tan

Potential Use: Should meet "SW" face brick specifications as processed. Addition of grog advisable.

SAMPLE No. LWs-3N-13W-11 dd

LOCATION: SE¼, SE¼, section 11, T3N, R13W (Wausau Quadrangle)
FIELD DESCRIPTION: Collected on east side of Florida Highway 273 from 8-foot clay bed exposed in roadcut. The clay bed has 8 feet of overburden.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	.Moderate plasticity
Water of plasticity	.30.6%
Drying shrinkage	.5.0%
Dry strength	.Good
Color	.Pink

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	10.0	13.5	Light brown	2	1.91
1900	12.5	12.4	Light brown	3	1.93

2000	15.0	10.3	Light brown	4	2.00
2100	15.0	8.7	Brown	5	2.06
2200	15.0	7.7	Dark red	6	2.11
2300	15.0	8.0	Dark brown	6	2.09

Potential Use: Might be used as the plastic component in face brick mixtures.

Remarks: High firing shrinkage but fires to good red at 2200°F.

SAMPLE No. LWS-2N-14W-23 dda

LOCATION: SE¼, SE¼, NW¼, section 23, T2N, R14W (Gap Pond Quadrangle)

FIELD DESCRIPTION: Collected from 9-foot clay bed in roadcut of Florida Highway 77 south of Wausau.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	High plasticity
Water of plasticity	27.4%
Drying shrinkage	12.5%
Dry strength	Good
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	15.0	16.6	Orange tan	3	1.82
1900	17.5	12.9	Orange tan	4	1.92
2000	20.0	6.5	Light brown	5	2.15
2100	25.0	1.0	Brown	6	2.44
2200	25.0	1.0	Dark brown	7	2.43
2300	Expanded	—	—	—	—

Potential Use: Not suitable for use in vitreous clay products.

Remarks: Excessive shrinkage.

SAMPLE No. LWS-2N-13W-7 dca

LOCATION: SE¼, SW¼, NW¼, section 7, T2N, R13W (Gap Pond Quadrangle)

FIELD DESCRIPTION: Collected from 40-foot thick mottled red orange and gray clay bed exposed on both sides of graded road.

LABORATORY RESULTS:

Unfired Characteristics

Working characteristics	Moderate plasticity
Water of plasticity	25.4%
Drying shrinkage	5.0%
Dry strength	Good
Color	Tan

Slow Fired Characteristics

Temp. (°F)	Shk. (%)	Abs. (%)	Color	(Moh's) Hardness	Bulk density gm/cc
1800	5.0	18.9	Tan	3	1.75
1900	5.0	17.6	Tan	4	1.78

2000	7.5	14.7	Tan	4	1.79
2100	10.0	9.0	Tan	5	2.05
2200	12.5	5.7	Buff	6	2.15
2300	12.5	5.6	Gray	6	2.13

Potential Use: Face brick or glazed structural tile.

Remarks: Should fire to "SW" face brick specifications at about 2100°F. At this temperature the color is an attractive tan.

EXTRUSION TEST

Body Composition	Raw clay through 6-mesh: 100%
Tempering Water	28% of dry batch weight
Vacuum On Machine	.22 inches of mercury
Drying	24 hours in air; 24 hours at 140°F
Drying Shrinkage	6.3%
Modulus Of Rupture, Dry Unfired	1180 psi
Firing:	
Time	24 hours
Temperature	2050°F
Cone	2 flat
Total shrinkage	12.5%
Absorption, 5-hour boiled	3.7%
Absorption, 24-hour soaked	2.6%
Saturation coefficient	0.70
Apparent porosity	8.2%
Bulk density	2.21 gm/cc
Fired modulus of rupture	6040 psi
Moh's hardness	8
Color	Tan

Potential Use: Might be suitable for face brick or glazed structural tile if blended with a low shrinkage clay or grog.

LIGHTWEIGHT AGGREGATE

Lightweight aggregate is a product of clay and shales that weighs less than aggregates of sand, gravel, and crushed rock. For a clay to be suitable as a lightweight aggregate it must bloat and expand when heated rapidly.

Lightweight aggregates are produced by either the rotary kiln or sinter method. The rotary kiln method is used with clays that dry at a fast rate without major disintegration taking place. The clays also must show good expansion when heated rapidly. Clays subjected to the sintering process may expand only slightly. This process involves a rapid and brief application of heat. Vitrification and glazing of the clay should take place between 2200-2300°F.

The factors related to testing of lightweight aggregate are discussed in Florida Geological Survey Information Circular No. 46 (Hichman and Hamlin, 1965, p. 14 and 15) which states:

"The tests for bloating clays and shales are relatively simple and consist of subjecting the material to heat treatments within the range of commercial working temperatures. Five pounds of the clay are dried overnight at 230°F, crushed with a

roll crusher or jaw crusher (set at $\frac{1}{2}$ inch), and a screen analysis made of the crushed material. With a laboratory kiln heated to 1800°F , 20 grams of the clay ($-\frac{1}{2} + \frac{1}{4}$ inch size) is placed on a refractory slab or boat, inserted in the kiln for 15 minutes, and then removed. This process is repeated at 1900° , 2000° , 2200° , 2300° , and 2400° , or until the clay becomes very sticky and begins to melt.

"The expanded aggregate is tested for weight, percent absorption, and examined for general structure and appearance. During the firing of the clay, the temperature at which sticking or melting occurs is noted."

One sample of clay (LWI-4N-20W-26 ba) collected from a creek bank just north of Liberty, Walton County, Florida, shows promise as a potential source for the manufacture of lightweight aggregate. The following data on this clay is from tests run by the U. S. Bureau of Mines. However, it should be noted that only when extruded did the clay prove suitable for use as lightweight aggregate.

PRELIMINARY BLOATING TESTS

SAMPLE No. LWI-4N-20W-26 ba

Type Material: Clay

Color: Gray

Crushing Characteristics: Angular

Particle Size: $\frac{3}{4}$ "

Retention Time: 15 minutes

Temp. ($^{\circ}\text{F}$)	Bulk density	Lb/ft	Percent abs.	Remarks
2000	1.81	113	2.8	No expansion
2100	1.09	68	14.3	Good pore structure
2200	0.91	57	18.3	Good pore structure
2300	0.51	32	30.9	Over-fired; some large pores

Recommendations: Promising raw material for lightweight aggregate.

ROTARY KILN TEST

EXTRUDED MATERIAL

SAMPLE No. LWI-4N-20W-26 ba

Raw Material

Raw material extruded as 2 inch diameter by 1 inch thick discs, dried, and fed into kiln.

Firing Data:

Pour weight of feed, lbs/ft: 96.9

Bloating temperature $^{\circ}\text{F}$: 2040

Logging temperature, $^{\circ}\text{F}$: 2200

(Nodules sticking together)

Fired Material

(All fired material crushed through roll crushers)

Screen Analysis: (Percentages by weight passing sieves)

$\frac{3}{4}$ "	$\frac{1}{2}$ "	$\frac{3}{8}$ "	No. 4	No. 8
100.0	85.3	73.4	32.8	26.6

Loose pour weights, lbs/ft: Fine, Coarse 39.0

Comments: Appears to be a promising raw material for lightweight aggregate.

ROTARY KILN TEST

SAMPLE No. LWI-4N-20W-26 ba

Raw Material

Screen Analysis: (Crushed through hammermill with 1 1/2" screen)

Through	Retained on	Weight, percent	Cumulative, percent
3/4"	1/2"	15.9	15.9
1/2"	3/8"	18.6	34.5
3/8"	4-mesh	24.6	59.1
4-mesh	8-mesh	13.4	72.5
8-mesh	Pan	27.5	100.0

Fragment shape: Angular

Crushing loss (-4 mesh): 40.9%

Firing Data:

Size range of feed -3/4" + 8 mesh

Pour weight of feed, lbs/ft 96.9

Bloating temperature, °F 2040

Logging temperature, °F 2200

(Nodules sticking together)

Fired Material

(All fired material crushed through roll crusher)

Screen Analysis: (Percentages by weight passing sieves)

	3/4"	1/2"	3/8"	No. 4	No. 8
Coarse	100.0	93.7	81.4	24.7	15.8

Loose pour weights, lbs/ft: Fine, Coarse 31.0

Comments: Popped off in thin flakes. Not suitable for use as lightweight aggregate.

SUMMARY OF CLAY STUDY

The results of the investigation by the authors as well as those of other investigators indicate that resources of clay for use in the manufacture of structural-clay products are available in Holmes, Walton and Washington counties. The tests show that common brick, face brick, tile, pottery and lightweight aggregate can be manufactured from the clays in the area of investigation.

The deposits sampled obviously represent only that particular area from which they were sampled. Although other deposits probably are available the writers made every effort to reconnoiter the area and sampled every clay outcrop that, in the opinion of the writers, had "quantity" possibilities.

The tests indicate that many of the clays sampled can be used in the manufacture of clay products as they come from the ground. However, in others selective mining as well as blending of clays would be necessary. Examples of this are LHo-4N-15W-13 cdc plus LWs-4N-15W-6 cda and LWI-1N-18W-32 plus LWI-4N-19W-2 daac. The data from these test are only departure points and in no way are intended to be sufficient for plant or process design.

The deposition of the clays in Holmes, Walton and Washington counties may be such that they are of a lenticular nature. This is not to say they might not have lateral extent. However, only a drilling program can answer this question.

Table 4 shows the criteria for determining what the clay can be used for in manufacturing clay products. Table 5 shows the classification of those clay localities which proved suitable as potential structural-clay products. It is apparent from Table 5 that the most common product that can be produced from the clays in the counties under study is common brick and face brick.

One of the most significant finds is the clay collected at LWI-4N-20W-26 ba. This clay is important because it is satisfactory for making lightweight aggregate. The U. S. Bureau of Mines testing laboratory ran two rotary kiln tests. The first test was run on a $\frac{3}{4}$ inch clay as kiln feed and the aggregate produced was one consisting of thin plates.

The second test was run using a clay crushed through a 4 mesh screen mixed with about 25 percent tempering water. This material was extruded through a round die 2 inches in diameter. The material coming from the die was then sliced into 1 inch thick discs and fed into the kiln.

The material from the first test proved unsatisfactory for lightweight aggregate because it popped off in thin flakes. The aggregate produced from the extruded material (second test) proved to be satisfactory as an aggregate.

HEAVY MINERALS

The term heavy mineral is applied to those mineral species that have a specific gravity greater than quartz. Minerals within this category, that occur in Florida sediments, are ilmenite, rutile, zircon, and other numerous minerals of less quantity and value. Ilmenite (FeTiO_3) is valuable for its titanium content. Zircon (ZnSiO_4) is valuable for its zirconium content; and rutile (TiO_2) is valuable for its titanium content.

Heavy minerals are present in all of the sediments in Holmes, Walton and Washington counties. However, the surficial deposits along the coastal area of Walton County offer the most potential as a source of heavy minerals. It is not uncommon to find large local concentrations along the present beaches and in the recent sand dunes in the southern part of Walton County. Though only one specific study was made to determine the aggregate percentage of heavies in the sands, the tests performed by the U.S. Bureau of Mines on samples submitted for evaluation as a potential source for glass sand indicate that the titanium content ranges from 0.1 to 0.5 percent. Sample LWI-3S-20W-3 bb was collected from a dune and contained the 0.5 percent titanium. According to the Bureau of Mines analyses most of the titanium was concentrated on the minus 140 screen and could be removed by froth flotation or magnetic separation.

A channel sample was collected from the seaward side of the highest beach dune at Blue Mountain Beach in southern Walton County. This sample (LWI-3S-20W-12 cb) was examined for its heavy mineral content, which amounted to 2.4% by weight of the total sample. Those mineral species identified were ilmenite, rutile, kyanite, zircon, garnet, staurolite, and leucoxene.

TABLE 4. CRITERIA FOR DETERMINING THE USEFULNESS OF CLAYS
FOR CERAMIC CLAY PRODUCTS (after Sweeney, Shirley and others)

	Common brick	Face brick	Decorative brick	Draintile	Chimneytile	Sewerpipe	Lightweight aggregate	
Unfired properties:							Unfired properties:	
Workability	Fairly plastic to plastic	Fairly plastic to plastic	Fairly plastic to plastic	Plastic to very plastic and smooth	Plastic to very plastic and smooth	Plastic to very plastic and smooth	Drying characteristics	Dry readily and show only slightly disintegration when bloating test is made
pH	Basic	Basic	Basic	Basic	Basic	Basic	Dry strength	Strength must be sufficient for proper sizing when crushed for kiln feed
Water for plasticity %	15-40	15-40	15-40	15-40	15-40	0-35		
Drying shrinkage %	0-12	0-12	0-12	0-8	0-8	0-8	Crushing characteristics	-8 mesh material should not exceed 20%
Fired properties:							Fired properties:	
Maturing Temp. °F	1800-2000	1800-2200	1800-2200	1800-2000	1800-2400	1800-2100	Firing range	1800-2200°
Color	Reds, dark reds, red-browns	Red buffs, creams	Mottled, pinks, grays, etc.	Not critical	Not critical	Usually red	Bloating range	Minimum 100°F 200° preferred
Hardness	Very hard to steel hard	Steel hard	Steel hard	Very hard	Very hard	Steel hard	Weight	75-45 lb/ft ³
							Expansion	Gradual weight decrease through bloating range
Shrinkage %	0-10	0-10	0-10	0-8	0-8	0-10		
Absorption %	Up to 20 Depending on climatic conditions	Up to 15 Depending on climatic conditions	Up to 15 Depending on climatic conditions	1-12	0-20	0-8	% Absorption	0-18.0 at best bloating temp.
							Color	Light reds to light grays preferred although color not too critical
							Strength	This must be determined by concrete performance test

TABLE 5. CLASSIFICATION OF CLAY LOCALITIES ACCORDING TO POTENTIAL USE

Common Brick	Face Brick	Dec. Brick	Drain tile	Sewer Pipe	Structural Tile	Chimney Tile	Pottery	Lightweight Aggregate
0-231	Blend of	HC-17	HC-5	LHo-4N-17W-	LHo-5N-17W-35 cda	HC-5	HC-2	LW1-4N-20W-26 ba
0-197	LHo-4N-15W-13 cdc	HC-18	HC-11	30 bdbd(5)		HC-11	HC-5	
	LWs-4N-15W-6 dca		HC-15		WW1-5N-21W-35 acc	HC-15	HC-11	
0-158	LHo-4N-17W-30 bdbd(6)		HC-17		LW1-5N-18W-4 baa	HC-17	HC-15	
HC-2	LHo-4N-17W-30 bdbd(16)		HC-18		LW1-2N-13W-7 dca	HC-18	HC-18	
HC-5	LHo-4N-17W-30 bdbd(46)						LW1-3N-18W-6 bbdd	
HC-11	LHo-4N-17W-30 bdbd(56)							
HC-15	LHo-4N-17W-30 bdbd(156)							
0-195	LHo-4N-17W-5 ba							
0-198	LHo-4N-18W-25 ddad							
0-127	LHo-5N-17W-35 cda							
0-124	HC-17							
0-126	HC-18							
0-246	Blend of							
0-128	LW1-1N-18W-3 a							
0-129	LW1-4N-19W-2 daac							
0-251	LW1-5N-19W-34 add							
0-248								
0-249	LW1-6N-19W-34 cb							
0-156	LWs-2N-13W-7 dca							
	LWs-3N-13W-2 SE corner b							
	LWs-3N-14W-28 bc							
	LWs-4N-15W-6 dca							

HUMATE

The term humate was first used by Swanson and Palacas (1965, p. B1). They reported that "Layers of dune and beach sand along the north coast of the Gulf of Mexico are cemented or impregnated with a conspicuous dark-brown to black water-soluble organic substance herein called humate. The humate-cemented sand, generally 6 inches to 3 feet thick but as much as 15 feet in some places, forms one or several irregular layers in the subsurface of broad land areas at a depth of a few inches to 35 feet. Humate accumulates in subsurface soil layers, in and beneath marsh deposits, in shore and beach sands of bayous and bays, commonly near the mouths of tea-colored streams and near ground-water seepages, and as a type of organic sediment in bodies of brackish or saline water."

Swanson and Palacas (p. B5-B10) list seven varieties of humate-impregnated or humate-cemented sand, several of which are very similar to or the same as the hard-pan of local water-well drillers and carbonaceous sand exposed in banks of canals.

Vernon (1942, p. 136) reported 26.9 feet of "black, cross-bedded, coarse to fine, slightly indurated sand, highly impregnated with stumps, roots and plants, both carbonized and uncarbonized" in the NW $\frac{1}{4}$, NW $\frac{1}{4}$, Section 21, T2N, R15W, Washington County that probably is identifiable as the fifth (p. B8) of the seven varieties of Swanson and Palacas.

The writers noted 3 to 6-inch layers of humate or hard-pan exposed at many localities around Choctawhatchee Bay, and in the banks of the Intracoastal waterway in southeastern Walton County great thicknesses (up to 12–15 feet) of this material are exposed, figure 8. Humate was also observed in samples taken from auger and core holes in southern Walton County.

Swanson and Palacas believe that humate is formed through the leaching of the decaying plant material on the surface then surface and subsurface waters transport this humic substance either to be precipitated in some subsurface sand or transported elsewhere by natural waters and subsequently deposited. The geochemistry of humate is extremely complex (Swanson and Palacas, 1965, p. B1), and this aspect is not to be reviewed here. However, the economic significance of humate is intriguing and a brief statement follows.

The humate cemented sand in the Choctawhatchee Bay area ranges from less than 1 to more than 8 percent organic matter with the average composition of the extracted humate being 55.0 percent carbon, 4.4 percent hydrogen, 38.5 percent oxygen, 1.4 percent nitrogen, and 0.7 percent sulfur (Swanson and Palacas, 1965, p. B18).

"Humate has the capacity to sorb large amounts of metals..." (Swanson and Palacas, 1965, p. B27). Swanson, et al (1966, p. C176) state "...it is suggested

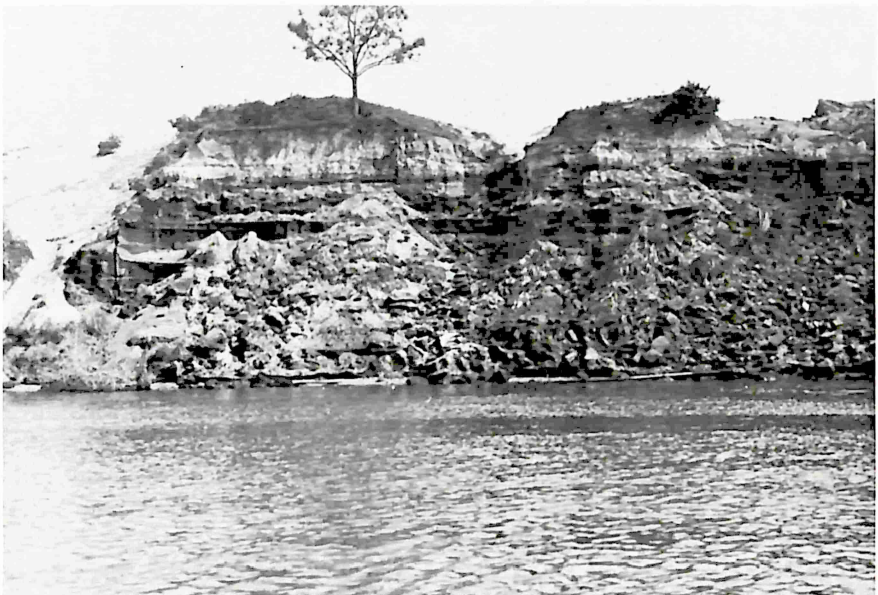


Figure 8. Two views of Humate zones (dark beds) exposed in banks of Intracoastal Waterway in southeastern Walton County.

that the metal-sorption property of the Florida humate maybe of economic use."

The large tonnages available, with the unique characteristic of selectively extracting trace amounts of certain metals, makes humate potentially suitable for use in the chemical and fertilizer industries.

Swanson, et al (p. C176-177) further state:

"Simple drying, light crushing, and sieving of the humate-rich sand produces a powder that is 60 to 75 percent humate. Another seemingly attractive aspect of the humate is its almost instantaneous solubility, for example, in ammonia. Ammonia is widely applied in liquid form to soils as a nitrogen fertilizer. Humate is also soluble in a potassium phosphate (K_3PO_4) solution, and might also provide the other 2 of the 3 major constituents of fertilizers-potassium and phosphorous.

"Other possible, but untested, uses of the physically separated or chemically extracted humate are as a water purifying compound, as an additive in well-drilling fluids, as a wood stain or paint pigment, and as a metal scavenger in a variety of commercial processes."

LIMESTONE

Limestone occurs at or near the surface in Holmes and Washington counties in the Marianna Lowlands area. The surface exposures of this area have been studied in detail by Reves (1961). This comprehensive report should be very helpful to anyone wishing to utilize limerock from these two counties.

Aase (1962) proposed cement and lime industries for Redevelopment Area A, West Florida as possibilities of utilizing the limestone resources of Holmes and Washington counties.

A recent open-file report on the potential limestone resources in Washington County, Florida was prepared by Shirley and Sweeney of the U. S. Bureau of Mines at the request of Farmers Home Administration (F.H.A.), U. S. Department of Agriculture. This open-file report presents data collected from subsurface sources, and the writers feel it is an excellent supplement to the Reves report. The report is an evaluation of both the quantity and quality of limestone available for commercial purposes.

Permission was granted the Bureau of Geology to use any portion of the Shirley and Sweeney (1965) report by the Farmers Home Administration and the U. S. Bureau of Mines. However, the comprehensive nature of their study is such that the writers feel parts of it cannot be extracted without taking away from an excellent report. Consequently, it will be included essentially in its entirety as an appendix to the present study. Only where a discussion of the general geology would create a duplicate is there an omission.

Limestone of Oligocene age crops out near the Alabama-Florida State line in the northern part of Walton County along Bridge Creek at Natural Bridge, as shown in figure 9.

A channel sample of limestone was collected at Natural Bridge, SE¼, SE¼, section 26, T6N, R20W, and submitted to the Florida State Road Department, Division of Materials, Research and Training, for testing. William Wisner, State



Figure 9. View of Natural Bridge in Walton County at locality LWI-6N-20W-26-d.

Road Department, Division of Materials, Gainesville, (personal communication, October 15, 1968), reported that the sample from this locality does not meet the State Road Department specifications for Ocala type limestone because of low carbonate content (90.0%) and high organic content (1.3%), though it did exhibit good load-bearing characteristics.

OYSTER SHELL

Generally, oysters are thought of as a product commercialized for food value. However, in this report the only interest in the oyster is the utilization of the shell itself for commercial purposes. The oyster shell is of commercial value because it is a source of high calcium carbonate.

The oyster shells produced in Florida from areas other than indian mounds or fossil bars found on land are controlled by permit from the Florida Board of Conservation.

In the area of study oyster shells are currently being dredged from Choctawhatchee Bay by Radcliff Materials, Inc. of Shalimar, Florida.

The discussion that follows concerns information supplied to the writers by Radcliff Materials, Inc., (personal communication of October 7, 1968).

Production: Radcliff Materials, Inc. has produced 803,141 tons of shell from 1967 to date in 1968 for a market value of \$2.05 per cubic yard.

Mining Methods: The shell is mined by mobile floating dredge which uses a 12 inch pump. As the shell is pumped from the bay bottom it is washed and loaded on barges for transport.

Reserves: Although the company has surveyed only a portion of Choctawhatchee Bay, they estimate 5 years of reserves at the present rate of production.

Uses: Presently, the primary use of the oyster shell is in road maintenance and for road base. However, the shell is also used by a chemical company for making lime which is used in their process of producing magnesium compounds from sea water.

SAND

Sand is a name applied to an unconsolidated aggregate of minerals or rock particles that range in size from 2 to 0.062 millimeters (0.078 to 0.002 inches). According to the above definition, sand is a size characteristic and does not connote mineralogic composition.

In this report the term sand is used as a size range, but it also has a mineralogic connotation meaning that the sand is predominantly composed of the mineral quartz. The term "high-silica" sand is used to distinguish those sands composed of 98 percent or more silica from sands that are less pure because of either inclusions or iron content.

The grains of sands seen in Holmes, Walton and Washington counties are remnants of rocks that originally occurred in states to the north of Florida,

Georgia, Alabama and the Carolinas. Over a period of thousands of years through various processes of chemical and physical weathering these sand producing rocks were disintegrated and the resulting smaller sand particles were washed into the streams by rains. The streams transported the sand to where some was deposited along the stream-flood plains. That portion of the sand not deposited along the channels finally reached the sea where it too finally came to rest in the area.

This is not to say that this was the final movement of the sand. Even today sands in the area are constantly being shifted around by the present day streams and winds.

The formations exposed at the surface in the counties under study have already been discussed and are shown in table 1 on page 11.

The Plio-Pleistocene (Citronelle) sands are the most important as a commercial-sand source because of their wide-spread nature and because they contain the variation in grain size necessary to meet standard specification for construction sands.

These Plio-Pleistocene deposits are very fine to very coarse grained, iron stained, multicolored, clayey quartz sands that are crossbedded and interbedded with kaolinites. It is not uncommon for the deposits to contain gravel (grain sizes above 4.5 mm or 0.2 inches). However, the gravel is not suitable for economic purposes because it is very fractured and crumbly. Data obtained from core holes drilled in Walton County indicate that in the southwest part of the county these sediments are in excess of 100 feet thick, whereas, in the other parts of the county they average 50 feet in thickness with some of the higher hills capped with 80 feet of Citronelle.

The Recent sands occurring along the stream valleys probably are of economic value but are not considered in this report because of the limited distribution of the deposits when compared to the Plio-Pleistocene sands. Reves (1960), in a report on the mineral resources of Choctawhatchee-Pea River Basin in Florida and Alabama, reports that commercial sand is being mined from the Choctawhatchee River in Alabama.

The sands from the Pleistocene terraces and the recent dunes along the coast of Walton County were found to range in size from very fine to medium. These sands because of their size range were tested for suitability in the manufacture of glass. The results of these tests are discussed on page 93.

USES OF SAND

Vernon (1943, p. 123-127) has shown that Florida sands can be used in a variety of ways to satisfy industrial needs.

The following are generalized criteria for the uses of sand as cited by Vernon (1943) and others (Murphy 1960, A.S.T.M. Florida State Road Department, 1966).

1. Building aggregate (concrete and mortar sand):

Specifications for sand in this category will vary according to local needs. However, the sand is quite often required to meet A.S.T.M. standards or the Florida State Road Department standard specifications for materials for road and bridge construction. In general, if the sand is to meet the specifications it should be hard, strong, durable, free of organic impurities, uncoated quartz (silica) grains.

CONCRETE

The gradation of the sand for concrete shall be as follows:

S.R.D. 1966

Sec. 902.1

& A.S.T.M. (1966)

Seive No.	Total percent retained on seive	Percent passing seive A.S.T.M.
3/4 in.	—	100
No. 4	0-5	95-100
No. 8	0-15	80-100
No. 16	3-35	50-85
No. 30	30-75	25-60
No. 50	65-95	10-30
No. 100	95-100	2-10

The fineness modulus of sand for concrete shall be not less than 2.3 nor greater than 3.1.

MASONRY MORTER

The gradation of sand to be used for masonry mortar is as follows:

A.S.T.M. (1966)

Seive No.	Percent passing seive
No. 4	100
No. 8	95 to 100
No. 100	25 maximum
No. 200	10 maximum

The fineness modulus of the sand shall be 1.6 to 2.5.

The State Road Department (1966) requires that all the material must pass the No. 10 seive and be uniformly graded from coarse to fine.

2. Paving aggregate:

The sand under this category would be used for mixing with asphaltic or bituminous pavements. It must be clean, tough, angular, free from clay or loam and other foreign matter.

State Road Department (1966) grade size requirements are as follows:

Passing sieve	Retained on sieve	% by wt.
No. 4	--	90-100
No. 4	No. 10	0-15
No. 10	No. 40	15-50
No. 40	No. 80	25-60
No. 80	No. 200	8-40
No. 200	--	0-10

3. Molding Sand (refractory sand):

To be useful for molding, according to Vernon (1943) and Murphy (1960), sand must possess the following characteristics:

- Possess a high degree of refractoriness, that is, resist becoming a coherent non-porous mass by heating.
- Be highly permeable so that steam and gases from hot metal can pass through them and thereby not causing bubbles in the metal.
- Possess the ability to retain its molded form at all temperatures to which the sand may be exposed.
- The sand must be durable enough to resist breakdown and deterioration after repeated use.
- Either have a natural bonding agent as clay or organic matter or have the bonding agent added.
- Grain size can vary depending on the needs of the producer.

4. Blasting Sand:

As the name implies the sand is propelled at high velocity by some means. It is very effective in removing paint, renovating stone faces and cleaning metal castings.

Specifications vary according to use (Murphy, 1960, p. 763). Coarse grades range from 4 mesh to 12 mesh, medium grades range from 12 mesh to 30 mesh, finer grades range from 20 mesh to 100 mesh or finer.

5. Glass Sand:

If a sand is to be useful in the manufacture of glass it must be of high-silica quality. That is, the sand must be chemically pure, (SiO_2) and be free of coatings, stains, or mineralogic impurities.

Alumina present in sufficient quantities will cause the glass to be cloudy.

The specifications for grain size of glass sand will vary depending on the manufacture. According to Broadhurst (1954) most manufacturers will accept sands that pass the No. 20 sieve with most of it retained on the No. 100 sieve.

Collection and Presentation of Sand Data

The sediments collected for testing unless otherwise noted in Tables 6, 7, 8 were taken from existing pits, outcrops, and coreholes in the counties under study. Visual inspection of the deposits were made to determine the general uniformity and then a channel sample was made down the complete face of the exposure chosen.

The material was dried and then quartered, using a riffle type sample splitter. After quartering, one quarter was weighed and then screened, using U. S. Standard Sieve Series.

The data obtained from the results of the screening are given by county and are presented in Table 6.

In using the following test results it should be remembered that the data obtained from the sieve analyses represents only one particular set of samples and does not necessarily depict all the material in a given deposit.

Test results of the U. S. Bureau of Mines are also included on Table 7 are designated by the abbreviation U.S.B.M.

The data presented on Tables 6 and 7 represent only that necessary for determining the general usefulness of the deposit for concrete, mortar or abrasives.

Four of the samples collected in the southern part of Walton County were tested for use as glass sands and this data is presented in Table 8.

Production and Mining

Production: The present commercial production of sand in the area under study comes from two mines; Adams Sand Company mine at Mossy Head, Walton County, figure 10 and Miller and Jenkins mine south of Chipley, Washington County, figure 11. The market for the sand from these two mines is local and the use is primarily in construction.

In Washington County, during the year 1966, 13 thousand short tons of sand were produced at a value of \$12,000. In 1967, 8 thousand short tons of sand were produced at a value of \$6,000.

Mining Methods: The excavating of the sand from the two commercial mines in Walton and Washington counties is by pumping from an open water-filled pit. The sand is pumped from the pit to a tower where gravel, clay balls, and vegetable matter are screened out. The sand passing through the screen is either passed directly through hoppers to waiting trucks for transportation to market or to storage piles for later consumption. The sand taken from the borrow pits, the locations of which are shown on figure 6, was mined by dragline or front end loader.

TABLE 6. SCREEN ANALYSES AND GENERAL USES OF SANDS IN HOLMES, WALTON AND WASHINGTON COUNTIES

Deposits				Laboratory Test Data, Screen Analyses Sieve No. and Weight Percent							General Uses	
Sample No.	Location	Source	Method of Sampling	4	8	16	30	50	100	Pan	Fineness Modulus ¹	
HOLMES COUNTY												
LHo-5N-17W-14 dd	SE¼SE¼ Sec 14, T5N, R17W	Outcrop	Channel	1.45	0.75	9.80	33.83	20.29	23.63	9.75	2.2	Concrete Mortar Abrasives
LHo-5N-17W-22 bd	NE¼SE¼ Sec 22, T5N, R17W	Barrow Pit	Channel	3.14	283	8.90	15.35	16.17	32.44	21.15	1.8	Mortar Abrasives
LHo-5N-17W-31 cc	SW¼SW¼ Sec 31, T5N, R17W	Borrow Pit	Channel	—	.34	4.32	28.19	36.38	24.30	6.09	2.0	Mortar Abrasives
WALTON COUNTY												
LWl-5N-19W-22 bb	NE¼NE¼ Sec 22, T5N, R19W	Borrow Pit	Channel	1.20	.20	5.11	30.86	31.86	22.95	8.3	2.0	Mortar Abrasives
LWl-5N-21W-2 bb	NE¼NE¼ Sec 2, T5N, R21W	Borrow Pit	Channel	—	.54	5.30	23.44	22.60	31.14	16.90	1.70	Mortar Abrasives
LWl-5N-21W-28 bc	NE¼SW¼ Sec 28, T5N, R21W	Borrow Pit	Channel	.30	.30	.60	12.65	27.51	44.97	13.65	1.44	

TABLE 6. Continued

Deposits				Laboratory Test Data, Screen Analyses Sieve No. and Weight Percent							General Uses	
Sample No.	Location	Source	Method of Sampling	4	8	16	30	50	100	Pan	Fineness Modulus ¹	
LWI-5N-21W-29 aa	NW¼NW¼ Sec 29, T5N, R21W	Borrow Pit	Channel	0.50	0.80	9.27	32.35	20.16	24.49	12.39	2.05	Mortar Abrasives
LWI-4N-18W-17 bb	NE¼NE¼ Sec 17, T4N, R18W	Borrow Pit	Channel	—	1.01	5.26	24.42	24.31	32.94	12.86	1.81	Mortar Abrasives
LWI-4N-21W-25 ac (1)(Depth, Top to 5 feet)	NW¼SW¼ Sec 25, T4N, R21W	Borrow Pit	Channel	.20	4.00	8.95	16.30	25.30	37.20	6.47	1.94	Mortar Abrasives
LWI-4N-21W-25 ac (2)(Depth, 5 to 8 feet)	NW¼SW¼ Sec 25, T4N, R21W	Borrow Pit	Channel	.40	2.80	13.20	30.20	28.6	22.40	1.80	2.30	Concrete Mortar Abrasives
LWI-3N-18W-30 b	NE¼ Sec 30, T3N, R18W	Borrow Pit	Channel	1.40	3.13	8.19	30.33	30.35	20.36	6.17	2.29	Concrete Mortar
LWI-3N-19W-28 da	SE¼NW¼ Sec 28, T3N, R19W	Borrow Pit	Channel	—	.10	.20	9.11	34.76	48.99	6.81	1.47	
LWI-3N-20W-19 ab	NW¼NE¼ Sec 19, T3N, R20W	Borrow Pit	Channel	—	—	.10	8.5	40.10	47.20	4.10	1.48	

TABLE 6. Continued

Deposits				Laboratory Test Data, Screen Analyses Sieve No. and Weight Percent							General Uses	
Sample No.	Location	Source	Method of Sampling	4	8	16	30	50	100	Pan	Fineness Modulus ¹	
LWL-3N-21W-28 aa	NW¼NW¼ Sec 28, T3N, R21W	Sand Mine	Channel	.70	1.16	12.89	50.65	21.53	10.83	2.05	2.64	Concrete Mortar Abrasives
LWL-3N-16W-6 ac	NW¼SW¼ Sec 6, T3N, R16W	Borrow Pit	Channel	—	—	.78	8.20	17.69	44.79	28.39	1.08	
LWL-2N-18W-22 cc	SW¼SW¼ Sec 22, T2N, R18W	Borrow Pit	Channel	1.78	1.21	6.07	24.13	24.41	34.86	7.12	1.97	Mortar Abrasives
LWL-2N-19W-15 ad	NW¼SE¼ Sec 15 T2N, R19W	Borrow Pit	Channel	—	1.82	3.60	17.31	23.16	50.23	3.56	1.72	Mortar Abrasives
LWL-2N-19W-7 center d	SE¼ Sec 7 T2N, R19W	Borrow Pit	Channel	8.17	5.85	19.57	16.44	21.79	31.07	6.35	2.79	Concrete Mortar Abrasives
LWL-2N-20W-5 bb	NE¼NE¼ Sec 5, T2N, R20W	Borrow Pit	Channel	.60	2.01	9.74	19.09	21.50	38.19	8.84	1.91	Mortar Abrasives
LWL-2N-21W-19 NE corner a	NW¼ Sec 19, T2N, R21W	Railroad Cut	Channel—		—	.10	1.90	19.30	74.20	4.60	1.18	

TABLE 6. Continued

Deposits				Laboratory Test Data, Screen Analyses Sieve No. and Weight Percent							General Uses	
Sample No.	Location	Source	Method of Sampling	4	8	16	30	50	100	Pan	Fineness Modulus ¹	
LWI-1N-18W-10 aa	NW¼NW¼ Sec 10, T1N, R18W	Borrow Pit	Channel	3.53	6.89	13.17	21.31	16.00	29.32	9.56	2.34	Concrete Mortar
LWI-2N-17W-35 ca	SW¼NW¼ Sec 35, T2N, R17W	Borrow Pit	Channel	—	.32	3.39	24.29	26.04	31.96	13.71	1.72	Mortar Abrasives
LWI-1N-19W-2 ad	NW¼NE¼ Sec 2, T1N, R19W	Borrow Pit	Channel	.17	.90	4.95	16.62	21.93	41.35	13.51	1.60	Mortar Abrasives
LWI-1S-18W-21 ad	NW¼SE¼ Sec 21, T1S, R18W	Borrow Pit	Channel	—	.09	.89	13.90	27.10	46.40	11.60	1.46	
LWI-1S-19W-14 ac	NW¼SW¼ Sec 14, T1S, R19W	Borrow Pit	Channel	—	—	.14	2.32	8.44	78.27	10.79	1.03	
WASHINGTON COUNTY												
LWs-3N-14W-35 dc	SE¼SW¼ Sec 35, T3N, R14W	Borrow Pit	Channel	.54	1.15	12.38	47.57	21.45	10.43	5.68	2.54	Concrete Mortar
LWs-3N-15W-8 ab	NW¼NE¼ Sec 35, T3N, R15W	Borrow Pit	Channel	—	.05	.06	4.01	38.99	49.07	7.74	1.40	

TABLE 6. Continued

Deposits				Laboratory Test Data, Screen Analyses Sieve No. and Weight Percent								General Uses
Sample No.	Location	Source	Method of Sampling	4	8	16	30	50	100	Pan	Fineness Modulus ¹	
LWs-3N-15W-19	center of Sec 19, T3N, R15W	Roadcut	Channel	0.54	1.15	12.38	47.57	21.45	10.43	5.68	2.54	Concrete Mortar
LWs-3N-16W-15 bc	SW¼NE¼ Sec 15, T3N, R16W	Borrow Pit	Channel	—	.05	2.15	38.05	44.60	12.19	2.65	2.24	Mortar Abrasives
LWs-3N-13W-7 cc	SW¼SW¼ Sec 7, T2N, R13W	Sand Mine	Channel	1.77	5.14	29.28	45.25	7.07	6.70	4.22	3.09	Concrete Mortar Abrasives
LWs-2N-13W-17 dd	SE¼SE¼ Sec 17, T2N, R13W	Borrow Pit	Channel	.16	1.18	2.69	18.47	25.58	49.20	6.47	1.69	Mortar Abrasives
LWs-2N-14W-12 cb	SW¼NE¼ Sec 12, T2N, R14W	Borrow Pit	Channel	—	.06	.22	8.39	38.09	44.50	8.23	1.47	
LWs-2N-16W-16 da	SE¼NW¼ Sec 16 T2N, R16W	Borrow Pit	Channel	7.18	1.20	3.18	9.68	11.96	35.64	30.57	1.50	
LWs-1N-13W-10 ab	NW¼NE¼ Sec 10, T1N, R13W	Sink Hole	Channel	.64	7.52	20.46	19.66	10.75	36.39	4.56	2.40	Concrete Mortar Abrasives

TABLE 7. SCREEN ANALYSES AND GENERAL USES OF SANDS IN HOLMES COUNTY
(after Sweeney & Shirley)

Deposits				Laboratory Test Data Screen Analyses Sieve No. and Weight Percent							General Uses
Sample No.	Location	Source	Depth in feet	20	-20 +28	-28 +35	-35 +65	-65 +80	-80 +150	-150 (clay)	
HS-1 (USBM)	SW¼ NW¼ Sec. 25 T6N,R18W	Core Hole	Surface	5	12	24	41	8	3	7	Concrete Mortar Abrasives
HS-1	SW¼ NW¼ Sec. 25 T6N,R18W	Core Hole	4.8 -10.2	38	20	17	17	3	1	4	Concrete Mortar Abrasives
HS-2 (USBM)	SW¼ NW¼ Sec. 25 T6N,R18W	Core Hole	Surface	4	6	19	49	12	5	5	Concrete Mortar Abrasives
HS-8 (USBM)	SE¼ Sec. 31 T6N,R16W	Core Hole	13.3 -17.8	7	12	27	35	5	5	9	Concrete Mortar Abrasives
HS-12 (USBM)	NW¼ NW¼ Sec. 30 T5N,R14W	Core Hole	Surface	10	15	26	37	5	3	4	Concrete Mortar Abrasives
HS-13 (USBM)	NW¼ SW¼ Sec. 1 T4N,R15W	Core Hole	Surface	8	10	27	48	5	1	1	Concrete Mortar Abrasives

TABLE 8. ANALYSES OF SAND TESTED FOR USE IN THE MANUFACTURE OF GLASS

Deposits				Laboratory Test Data, Screen Analyses							Chemical Analyses			
				Sieve No. and Weight Percent							Weight Percent			
Sample No.	Location	Source	Method of Sampling	20	30	40	70	100	140	200	Pan	Oxide FeO ₃	Oxide TiO ₂	Insol.
LW1-2S-21W-13 dc	SE¼ SW¼ Sec. 13	Outcrop	Channel	0.90	4.80	15.00	69.40	9.00	0.70	0.10	0.10	0.10	0.10	98.9
LW1-3S-18W-14 bb	T2S,R21W NE¼ NE¼ NE¼ Sec 14	Intracoastal Waterway	Channel	.00	.50	1.50	34.70	45.10	16.20	1.80	.20	.10	.20	99.5
LW1-3S-19W-3 dd	T3S-,R18W SE¼ SE¼ Sec. 3	Roadcut	Channel	.50	4.10	13.50	75.40	5.60	.50	.30	.10	.20	.20	99.1
LW1-3S-20W-3 bb	T3S,R19W NE¼ NE¼ Sec. 3	Dune	Channel	.10	.30	3.10	85.90	8.10	1.80	.30	.40	.20	.50	99.4
	T3S, R20W													

Note: Analyzed by U.S.B.M.

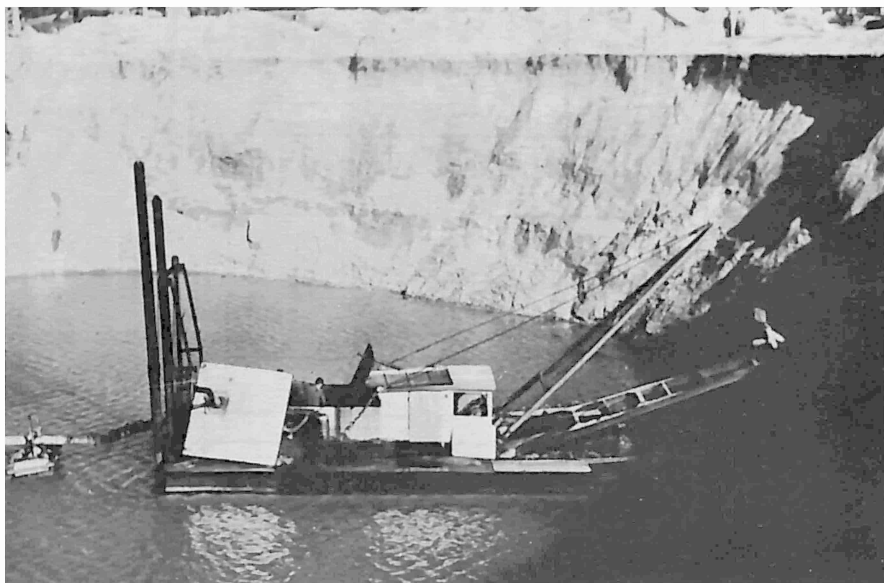


Figure 10. View of Adams Sand Pit in western Walton County at locality LWI-3N-21W-21-cd.

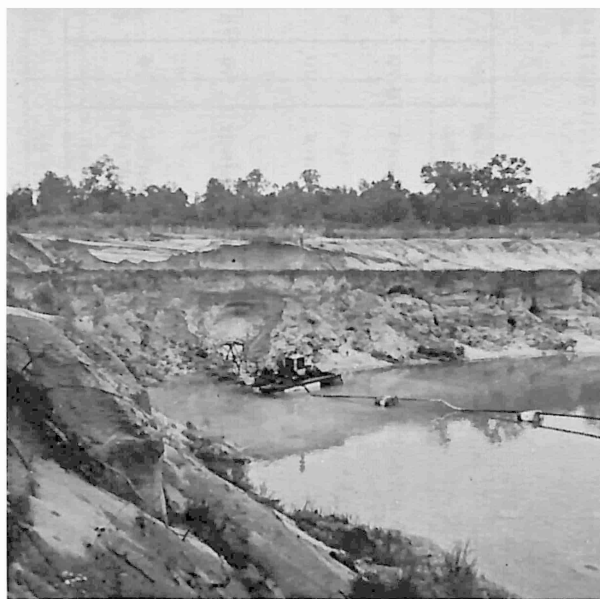


Figure 11. View of Miller and Jerkins sand pit in Washington County at locality LWs-2N-13W-7c.

Conclusions

The tests performed on the sands of Holmes, Walton and Washington counties indicate that they are suitable for use in a variety of industrial products. Though economic factors governing the use of these sands is beyond the scope of this report, the investigation in the area indicate abundant reserves of sand are available.

The following is a discussion, by county, of the sampled localities and the uses for abrasives, concrete, mortar and glass as determined by standard tests. Sands are abundantly available locally for use as fill material and as road stabilizer if it contains up to 10-15% clay.

Holmes County

Sample Nos. LHo-5N-17W-14 dd and LHo-5N-17W-22 bd and LHo-5N-17W-31 cc meet the necessary requirements for mortar sand and abrasives. LHo-5N-17W-14 dd and LHo-5N-17W-31 cc barely meets the necessary required specifications for concrete. However, these samples represent only one particular face of the borrow pit and at other places in the pit the sand fraction in the upper screen sizes (4-8-16) may be present in sufficient quantities to reach the necessary fineness modulus.

Neither of these three sands would be suitable for glass because of iron coatings on the grains.

The test results of the sands taken from the core holes drilled by the U. S. Bureau of Mines in Holmes County are discussed by Sweeney and Shirley (1965) as follows:

"The sand program demonstrated that all of the sands sampled had a potential use for concrete and abrasives. The sands tested were not high quality glass sands due to iron coatings and inclusions, although they may have a potential use for bottle glass. In all but two cases, the sands were found to be surficial with indicated reserves only large enough for small scale operations. Holes HS-7 and HS-8 indicate a sand section ranging from about 41 to 61 feet thick with shallow overburden. This property warrants further exploratory work."

Walton County

As indicated on Table 6 four of the samples are suitable for use in concrete, as they will meet A.S.T.M. and Florida State Road Department specifications. Two samples, LWI-5N-19W-22 bb and LWI-5N-21W-29 aac approach the necessary requirements for concrete and would be satisfactory if sand of a coarser fraction (4-8-16 size screens) was added so that the required fineness modulus could be reached. Sixteen of the samples meet the necessary requirements for use as abrasives and in mortar. Because of iron coatings none of these sands are suitable for use as glass sands.

Tests, as shown in Table 8, conducted by the U.S.B.M. indicate that sands in the southern part of Walton County can be beneficiated to meet specifications for glass sands. According to Shirley (Personal Communication 1968) the sands will have to be beneficiated to remove the iron and titanium content. Shirley further states that the tests show the sands carrying most of the iron and titanium appears to be concentrated on the minus 140 mesh which might suggest the material could be removed by washing, screening and froth flotation or magnetic separation.

Washington County

Concrete sand is available in Washington County as evidenced by the samples tested. Although some of the samples tested fall slightly below required specifications for mortar sand they probably could be used for mortar sands if A.S.T.M. and State Road Department specifications were not a requirement. All of the sands tested should be satisfactory for abrasives. Iron coatings on the grains make these sands unsuitable for use in the manufacture of glass.

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APPENDIX

**LIMESTONE RESOURCES
WASHINGTON COUNTY, FLORIDA**

by
L. E. Shirley and J. W. Sweeney

for
U. S. DEPARTMENT OF AGRICULTURE
Farmers Home Administration

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

Bureau of Mines
Frank C. Memmott, Acting Director

April, 1965

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LIMESTONE RESOURCES WASHINGTON COUNTY, FLORIDA

by
L. E. Shirley¹ and J. W. Sweeney²

INTRODUCTION

The Federal Bureau of Mines at the request of the Farmers Home Administration, United States Department of Agriculture, entered into an agreement for technical assistance in May, 1964 to perform a mineral resource investigation in Washington County. The investigation was to determine the quantity and quality of limestone suitable for various commercial uses, including but not limited to agricultural and road building purposes. Funds were transferred to the Bureau of Mines to cover the costs of the proposed exploration program by core drilling, and the testing and analysis of the limestone core. The Bureau of Mines entered into a contract with Florida Testing Laboratories, Inc., St. Petersburg, for the core drilling, and at a later date into an additional contract for analysis and testing.

The presence of limestone in Washington County has been known for many years. Mossom [7]³ stated that the Marianna-ChIPLEY area contains extensive limestone deposits having enormous tonnages of high grade rock. One of the early wide uses of limestone in the county was for "chimney rock", where the stone was sawed into blocks for use in the construction of chimneys for dwellings. Vernon [11] observed that "there is a sufficient quantity of limestone in these counties (Washington and Holmes) to supply all of Western Florida in road metal and building blocks." He also mentioned that a lime kiln was formerly operated on land now owned by the Alford Lumber Company at the former B. M. Waldon farm. Recent investigations by Reves (1960) [8] and George H. Aase and Associates (1962) [1] [2] recognize the potential of the limestones in Washington County, as well as in contiguous counties. Reves work entailed outcrop sampling of limestone deposits in Washington, Holmes, and Jackson counties and covered many aspects of the limestone industry that might be helpful to potential producers. Aase and Associates made studies that would help lead to the establishment of cement and lime industries in the general area and were concerned with reserves of limestone in Washington County for these industries; detailed plant costs and other factors were also included in the report.

At the present time there are no commercial limestone operations in the county.

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² Geologist, Area II Mineral Resource Office, Bureau of Mines, Knoxville, Tennessee.

³ Bracketed numbers refer to item in the list of references at the end of this report.

ACKNOWLEDGMENTS

Numerous people in the Washington County area assisted in expediting this work. The authors particularly appreciate the assistance of John Carver, Rural Renewal Program Leader, Farmers Home Administration, U. S. Department of Agriculture, Chipley, for his untiring efforts throughout the project. Maurice Scott, Assistant County Agent, U. S. Department of Agriculture, Chipley, worked closely with us in obtaining necessary properties for drilling. Many other officials of the Department of Agriculture, Chipley, assisted in numerous ways to facilitate the work. The assistance and cooperation of local landowners who permitted examination of their properties, some of which were core drilled, is appreciated. E. W. Carswell, Mayor of Chipley, and members of the Washington County Development Commission assisted in some of the physical needs of the study.

LOCATION AND OWNERSHIP

All properties core drilled were within a 32-square mile area, south of Chipley. The area investigated is covered by three 7-½ minute U. S. Geological Survey topographic quadrangle maps, Chipley, Wausau, and Alford, on a scale of 1 inch = 2,000 feet.

Most of the properties drilled were owned by small farmers and businessmen, interested in improving the economy of the county, and agreeable to signing the Bureau of Mines standard form of agreement for mineral exploration. A considerable number of properties were examined but not drilled because of lack of evidence of limestone on the property, legal difficulties in land ownership, or prohibitive company policy. After field examination of the properties, sites to be drilled were selected on the basis of best limestone exposures, continuity of the limestone throughout the area, and the availability of the property for drilling by the Bureau of Mines. Other factors important in selection of drill sites were the proximity to potential markets and economical transportation. One of the largest potential markets for limestone may be as base course material for construction of Interstate 10; most of the properties drilled were within economical hauling distance of this proposed highway. Close proximity to the town of Chipley was also considered to be an asset, because railroad transportation might be an important factor for potential uses other than road construction.

ECONOMIC FACTORS

The successful development of a crushed limestone operation is governed by a variety of factors, economic, topographic and geologic. Some of the economic considerations are market distance, accessibility, quarry and plant locations, power, and land values.

Crushed limestone is a relatively low priced, large volume commodity which produces a small profit margin per unit. Thus a long truck or rail haul to the consumer may result in a prohibitive cost-price balance. Quarry access haulage roads in most instances should not exceed an 8 percent grade. Quarry and plant locations should not be in close proximity to built-up areas; large damage claims have become frequent in some areas because of blasting and dust. Land values must be such that adequate property can be purchased or leased economically for future expansion of the quarry, as well as space for preparation plant, storage, and waste disposal.

Assuming that a limestone deposit suitable for the planned uses is found, favorable topographic factors are very important. The deposit should be located topographically in such a way that gravity drainage is possible to prevent excessive pumping and that enough level ground to locate a plant is available. Adequate water supply is necessary because about 100 gallons of water are needed to wash 1 ton of stone [10].

Physical characteristics of the deposit are very important. The deposit should be as uniform as possible; clay pockets and highly weathered material and other contaminants are undesirable and require selective quarrying, thereby increasing costs.

Low cost electric power is both desirable and important from a cost viewpoint in quarrying and plant operations. When not available, as in the case of most portable plants, diesel engines and diesel-electric generating plants provide a satisfactory substitute.

USES [3]

For many of the uses of crushed limestone, physical properties are of primary importance; for others, chemical composition is the dominant requirement. Many limestones have the physical qualities that render them adaptable to virtually all of the uses for which any crushed stone may be employed, but limestone also has active chemical properties that make it not only useful but essential to many chemical and industrial processes. Limestone has the widest and most diversified uses of all varieties of stone.

The principal uses for which physical properties are of primary importance are shown below:

Concrete Aggregate

A vast tonnage of limestone is used as aggregate for concrete, in which form it is consumed chiefly in highway construction and in the building trades. The crushed limestone should consist of clean, hard, strong, durable, uncoated fragments, free from injurious amounts of soft material. Alkalies and organic matter are undesirable. The stone must meet a variety of tests for acceptability.

Roadstone

The principal uses of limestone in Florida are for concrete, roadstone, and screenings. In 1963 over 25-million tons of limestone was sold or used in the State for these purposes. The requisite qualities of roadstone are similar to those for aggregate. Florida State Road Department specifications are shown in a later section of this report under Chemical Analyses and Tests. The requirements cover both base course material and limerock for stabilized base.

Railroad Ballast

Small quantities of limestone are used by railroad companies in Florida for maintaining road beds. A minimum of $\frac{3}{4}$ inch and a maximum of 2- $\frac{1}{2}$ inches (round openings) for ballast sizes has been widely used, but lately there has been a trend toward the use of smaller sizes. The requirements as to quality are generally the same as for aggregate and roadstone.

Asphalt Filler

Limestone dust, approximately 80 percent of which will pass a 200-mesh screen, is used as a filler in road asphalt surface mixtures. Much of it is classified as a byproduct at crushed stone plants, although the preparation of asphalt filler is a substantial part of the business of some quarrying companies.

Sewage Filter Beds

Crushed limestone is satisfactory for sewage filter beds. Either high-calcium or dolomitic limestone may be so used, and silicious impurities are not objectionable if they are fine grained and evenly distributed. Certain other impurities, notably clay, marcasite, and pyrite, are to be avoided. The stone should be strong and compact, with pore space evenly distributed, and the fragments should be rough to provide anchorage for bacteria. Fines and dirt should be screened out.

Stucco and Terrazzo

Dense, compact limestones of attractive colors may be crushed into small fragments for terrazzo floors, but marble chips that will take a polish are generally preferred.

Poultry Grit

Limestone crushed to granules and screened to uniform sizes is sold for poultry grit. Almost any type of limestone may be so used. The products may be graded by sizes into turkey grit, chicken grit, pigeon grit, and bird grit.

Chalk

Finely ground limestone may be used as a substitute for pulverized chalk in ceramic raw materials and as fillers in numerous products such as rubber, paint, paper, oilcloth, window shades, and linoleum.

Uses for which chemical properties are most important include the following:

Cement Manufacture

Limestone is the chief raw material used in making portland cement. Although pure limestone is not required, constancy in chemical composition is desirable. The general requirements are: (1) The magnesium content should be low enough that the finished product will not contain more than 5 percent magnesia (MgO); (2) The content of iron should be low enough that the ferric oxide content of the cement does not exceed 4 percent; (3) The silica and alumina contents should be in such proportions that they will not interfere with the desired silica-alumina ratio in the finished product; (4) The sulfur content should be low.

Lime Manufacture

Limestone must conform with rather rigid physical and chemical requirements for lime manufacture. Exceptionally pure stone, total carbonates ranging from 97 to more than 99 percent, is generally used because virtually all impurities remain in the lime that results from calcination. For shaft kiln operation the stone should be sound and compact because porous and friable types break down during calcination and the fines retard the draft. For the same reason the fines are screened from the kiln feed. For rotary-kiln operation finer materials may be used. Both high-calcium and high-magnesium stones are used.

Agricultural Uses

The most important uses for limestone in agriculture are as fertilizer, soil conditioner, and corrective for soil acidity. Pure limestone is desirable but not essential, because, although ordinary impurities lessen the percentage of calcium or magnesium available for improving the soil, they are not injurious to plant growth. A local impure limestone may be more economical to use than a high grade material that must bear a relatively heavy transportation charge. There is some difference of opinion regarding the suitability of dolomitic limestone, but most authorities agree that magnesium is of equal value with calcium and that the value of stone for agricultural purposes may be measured by the percentage of total carbonates present. Dolomitic limestone is preferred for magnesium-starved soils. Small quantities of limestone are used in commercial fertilizers as diluting material or filler. Pulverized limestone is also added to stock food as a bone builder.

Chemical and Industrial Uses

Limestone is an important raw material used in metallurgy and in many chemical processes, such as alkali, calcium carbide, sugar, paper, and glass manufacture.

Much of the limestone in Washington County might serve for many of the uses outlined above. Chemical tests indicate that the material is high-calcium limestone, low in silica, iron oxide and alumina. However, extensive physical and chemical tests are advisable for each proposed use, to insure compliance with the requirements of that use.

WORK DONE BY THE BUREAU OF MINES

The purpose of the work was to locate, drill and test limestone deposits in Washington County in an effort to assist in the future industrial development of the county's mineral resources. The quantity and quality of the deposits were to be determined for various commercial uses, including but not limited to agricultural and road building purposes. Drilling began in June, 1964 and with intermittent breaks was completed in September, 1964.

The work was confined to Washington County in an area south of Chipley. Landowners in the area, having potential commercial deposits of limestone, were contacted and requested to sign Bureau of Mines mineral agreement forms permitting access for drilling purposes. Mineral agreement forms were signed by 35 property owners and 13 of these properties, totaling 1,940 acres, were selected for drilling after examination. Many other properties were examined at the request of local landowners or the Farmers Home Administration, but were not selected for drilling because of absence of limestone, or inability to obtain mineral agreements.

The drilling was contracted to Florida Testing Laboratories, Inc., St. Petersburg, Florida, for diamond-core drilling of NX (2-1/8") size. Drilling was accomplished by use of portable Failing "750" and "1500" rotary drill rigs with accessory equipment. Contract drilling was originally estimated to entail 400 feet of overburden drilling and 950 feet of diamond-core drilling in limestone. Twenty-seven holes were drilled on 13 properties in 9 sections; total footage drilled, including overburden, was 1,175 feet. Limestone of commercial significance was penetrated in 19 holes, and the remaining 8 holes were drilled in overburden material consisting of sand and clay or a sand-clay mixture. The drill holes were not cased; drilling mud of the fuller's earth type was used. An arbitrary limit of 20 feet of overburden was set for the project; if limestone had not been encountered at this depth, it was deemed inadvisable to continue drilling. The core as it was recovered from the hole was placed in partitioned core boxes, logged by Bureau personnel, and at the end of each day transferred

to a storage warehouse in Chipley. On completion of the project, core boxes were sealed and shipped to the St. Petersburg laboratory where chemical analyses and tests of the cores were made.

Limestone outcrops, as well as exposures in sinkholes and roadcuts, were features which led to investigations of many of the properties. The limestone was of the massive type and exhibited no bedding; no apparent dip of the bodies could be detected. In most instances, the limestone could be traced on a property without difficulty, by following the strike of the body and by examination of exposures. However, in isolated cases limestone was not penetrated by the drill even when adjacent to good exposures, nor could the body be picked up along the strike. Solution cavities are very common in the limestones of the area and this fact should be of concern in future work.

Recovery of core from the 19 holes penetrating limestone ranged from 47 to 96 percent; low recovery was directly attributable to cavities, clay seams within the limestone, and highly weathered rock. The depth to water level measured by tape in 10 drill holes ranged from 0 to 55 feet and averaged 34 feet.

For testing purposes, and before shipment, the limestone core was divided into intervals exhibiting certain physical characteristics that, it was felt, might have resulted from changes in chemical composition. However, chemical analysis showed the calcium carbonate to be remarkably uniform in most core intervals regardless of physical characteristics. Only two intervals tested less than 97 percent; one interval in Hole W-12, from 37-52 feet, ran 94.08 percent calcium carbonate, and one interval in Hole W-15, from 19-34 feet, ran 92.57 percent combined calcium and magnesium carbonates.

Table 1 is a summary of core drilling data by hole.

CHEMICAL ANALYSES AND TESTS

Chemical analyses were made of the core recovered in the drilling program. The analyses and test work were done by Florida Testing Laboratories, Inc., and were oriented to the requirements of the Florida State Road Department, because it was believed that the greatest possible use of the material would be for base-course material in area and Interstate road construction. The chemical analyses showed the material to be a high-calcium limestone, low in silica, iron oxide and alumina, and a material which might be used for many other industrial and chemical purposes, as well as road construction.

The limerock requirements of the Florida State Road Department for base-course material, stabilized base, and method of chemical analysis of limerock follow:

Florida State Road Specifications [5] Base Course Material

504.2 Limerock — Ocala Formation

This limerock shall show no tendency to air slake or undergo chemical change under exposure to weather. For purposes of geological designation, all limerock

mined above the 28th degree parallel of latitude in the State of Florida shall be considered only under the classification of Limerock-Ocala Formation and shall be treated to meet the following chemical requirements:

Carbonates of Calcium and Magnesium	Min. 95.0
Organic Matter	Max. 0.5
Passing a 3-½-inch Sieve	Min. 97.0

The material shall be graded uniformly from the larger pieces down to dust. All fine material shall consist entirely of dust of fracture.

The material shall have a liquid limit not greater than 35 and a plasticity index not greater than 6.

The material shall be uniform in quality and shall not contain hard or flinty pieces in sufficient quantity to prevent proper bonding or to prevent securing a smooth surface, free from pits and pockets.

The material shall be crushed or broken up to meet the gradation requirements before it is placed on the road.

504.3 Limerock for Stabilized Base

This material shall conform to the requirements of Article 504.2, with the following exceptions:

- (1) Carbonates of calcium and magnesium shall be not less 90 percent.
- (2) The material shall have a plasticity index not greater than 10.
- (3) The material shall be so graded that not less than 97 percent by weight shall pass a 1½-inch sieve and shall be graded uniformly down to dust.

504.4 Method of Chemical Analysis of Limerock

The chemical analysis of limerock shall consist of determining the silica insoluble, iron oxide and alumina by solution of the sample in hydrochloric acid, evaporating, dehydrating and redissolving the residue in hydrochloric acid, and then neutralizing with ammonium hydroxide, and filtering, washing and igniting the residue. The difference between this insoluble matter and 100 percent is reported as carbonates of calcium and magnesium.

Results of chemical analysis by hole interval are shown in Table 2.

Limit tests, set up to rule out excessive plastic material in road construction materials, were made on core from 14 holes. The tests were conducted in accordance with specifications outlined in Section 504.2 and consisted of liquid limit, plastic limit, and plasticity index (P.I.)

P.I.= Liquid limit—Plastic limit.

TABLE 1. SUMMARY OF CORE DRILLING DATA, WASHINGTON COUNTY, FLORIDA

Hole number	Property owner	Location	7½ min. quadrangle	Total depth, feet	Overburden, feet	Rock, feet	Collar elev., feet	Remarks
W-1	C. Bush	E½, SW¼, Sec. 35, T4N, R13W.	Wausau	61.1	16.1	45.0	140	Could find no lateral extent to this deposit.
W-2	N.G. Berry	SW¼, NW¼, Sec. 36, T4N, R13W	Alford	20.0	20.0	—	140	Hole abandoned due to excessive overburden.
W-3	Dunn Heirs	SW¼, NE¼, Sec. 16, T4N, R13W	Chipley	55.0	4.0	51.0	130	Shallow overburden, hole bottomed in limestone.
W-4	Dunn Heirs	SW¼, NE¼, Sec. 16, T4N, R13W	Chipley	21.0	21.0	—	150	Hole abandoned due to excessive overburden.
W-5	E.J. Harrell & Sons	NE¼, Sec. 14, T4N, R13W	Chipley	54.0	4.0	50.0	180	Shallow overburden, hole bottomed in limestone.
W-6	E.J. Harrell & Sons	NE¼, Sec. 14, T4N, R13W	Wausau	54.0	4.0	50.0	165	Shallow overburden, hole bottomed in limestone.
W-7	C. Bush	E½, SW¼, Sec. 35, T4N, R13W	Wausau	20.0	20.0	—	140	Hole abandoned due to excessive overburden.
W-8	Dunn Heirs	SW¼, NE¼, Sec. 16, T4N, R13W	Chipley	52.0	4.0	48.0	145	Shallow overburden, hole bottomed in limestone.
W-9	D. Sasser	SW¼, SW¼, Sec. 15, T4N, R13W	Wausau	49.1	5.0	44.1	145	Shallow overburden, hole bottomed in limestone.

TABLE 1. Continued

Hole number	Property owner	Location	7½ min. quadrangle	Total depth, feet	Overburden, feet	Rock, feet	Collar elev., feet	Remarks
W-10	H. Etheridge	SE¼, NE¼, Sec. 15, T4N, R13W	ChIPLEY	20.0	20.0	—	145	Hole abandoned due to excessive overburden.
W-11	E.G. Rooks	NW¼, NW¼, Sec. 34, T4N, R13W	Wausau	50.0	15.0	35.0	90	Hole bottomed in limestone.
W-12	E.G. Rooks	NW¼, NW¼, Sec. 34, T4N, R13W	Wausau	52.0	5.0	47.0	80	Shallow overburden, hole bottomed in limestone. Deposit may have some lateral extent.
W-13	Hinson & Corcoran	NW¼, SE¼, Sec. 36, T4N, R14W	Wausau	52.0	4.0	48.0	100	Shallow overburden, hole bottomed in limestone.
W-14	Hinson & Corcoran	NW¼, SE¼, Sec. 36, T4N, R14W	Wausau	49.0	4.0	45.0	115	Shallow overburden, hole bottomed in limestone.
W-15	Dunn Heirs	NW¼, SW¼, Sec. 16, T4N, R13W	Wausau	49.0	4.0	45.0	130	Shallow overburden, hole bottomed in limestone.
W-16	Dunn Heirs	NW¼, SW¼, Sec. 16, T4N, R13W	Wausau	52.0	4.0	48.0	120	Shallow overburden, hole bottomed in limestone.
W-17	B.L. Lawrence	NW¼, SW¼, Sec. 14, T4N, R13W	Wausau	77.0	34.0	43.0	170	Penetrated limestone at 27 feet. Excessive overburden probably due to clay pocket.
W-18	F.T. Coleman	SW¼, NW¼, Sec. 14, T4N, R13W	Wausau	57.0	5.0	52.0	160	Shallow overburden, hole bottomed in limestone.

TABLE 1. Continued

Hole number	Property owner	Location	7½ min. quadrangle	Total depth, feet	Overburden, feet	Rock, feet	Collar elev., feet	Remarks
W-19	E.J. Harrell & Sons	SE¼, NE¼, Sec. 24, T4N, R13W	Alford	70.0	60.0	10.0	260	Penetrated 10 feet of rock from surface, then fishtailed through 60 feet of plastic clay.
W-20	E.J. Harrell & Sons	NE¼, SE¼, Sec. 14, T4N, R13W	Wausau	40.0	17.0	23.0	160	Fishtailed 8 feet through overburden, cored 31 feet, fishtailed from 31 to 40 feet through plastic clay.
W-21	E.J. Harrell & Sons	NE¼, SW¼, Sec. 14,	ChIPLEY	59.0	8.8	50.2	175	Shallow overburden, hole bottomed in limestone.
W-22	C. Bush	E½, SW¼, Sec. 35, T4N, R13W	Wausau	45.0	30.0	15.0	150	Penetrated 3 feet of limestone from 17 to 20 feet. Fishtailed last 10 feet through sand and thin limestone lenses.
W-23	C. Bush	E½, SW¼, Sec. 35, T4N, R13W.	Wausau	20.0	20.0	—	140	Hole abandoned due to excessive overburden.
W-24	R.C. Carter	SE¼, SW¼, Sec. 21, T4N, R13W	Wausau	20.0	20.0	—	180	Hole abandoned due to excessive overburden. Hole penetrated marl.
W-25	R.C. Carter	SE¼, SW¼, Sec. 21,	Wausau	37.0	4.0	33.0	140	Hole bottomed in cavity.
W-26	N.G. Berry	SW¼, NW¼, Sec. 36, T4N, R13W	Alford	20.0	20.0	—	140	Hole abandoned due to excessive overburden.
W-27	E.J. Bruner	N½, SW¼, Sec. 36, T4N, R13W	Alford	20.0	20.0	—	155	Hole abandoned due to excessive overburden.

TABLE 2. CHEMICAL ANALYSES

Hole number	Sample interval, feet	Percent					
		CaCO ₃	MgCO ₃	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Total
W-1 ¹	16-61	99.37	—	0.33	0.30	—	100.00
W-3	4-20	97.81	1.10	0.33	0.05	0.16	99.29
	20-45	98.77	0.50	0.55	0.06	0.13	100.01
	45-55	98.53	0.50	0.83	0.05	0.16	100.07
W-5 ¹	4-19	96.52	—	2.72	0.76	—	100.00
	19-43	98.92	—	0.76	0.32	—	100.00
	43-54	99.36	—	0.34	0.32	—	100.02
W-6	4-15	97.42	0.70	1.74	0.05	0.09	99.91
	15-30	98.58	0.60	0.75	0.01	0.06	100.00
	30-54	98.46	0.50	0.86	0.05	0.13	100.00
W-8	4-22	98.61	0.00	1.14	0.08	0.17	100.00
	22-52	99.12	0.50	0.20	0.06	0.12	100.00
W-9	5-15	98.03	0.80	0.99	0.04	0.14	100.00
	15-30	98.98	0.50	0.35	0.06	0.11	100.00
	30-49	98.66	0.80	0.38	0.05	0.11	100.00
W-11	15-35	98.49	0.50	0.80	0.06	0.15	100.00
	35-55	97.89	0.00	1.74	0.13	0.24	100.00
W-12	5-27	99.20	0.50	0.24	0.04	0.02	100.00
	27-37	98.98	0.50	0.43	0.05	0.14	100.10
	37-52	94.08	0.50	5.29	0.03	0.10	100.00
W-13	4-28	97.71	0.50	1.65	0.04	0.10	100.00
	28-52	98.41	0.50	0.91	0.05	0.13	100.00
W-14 ¹	4-24	99.41	—	0.37	0.22	—	99.90
	24-39	99.32	—	0.51	0.17	—	100.00
	39-49	99.42	—	0.19	0.39	—	100.00
W-15 ¹	4-19	98.64	—	1.08	0.28	—	100.00
	19-34	92.57	—	6.60	0.83	—	99.95
	34-49	99.52	—	0.16	0.32	—	100.00
W-16	4-16	98.77	0.50	0.59	0.04	0.10	100.00
	16-52	98.42	0.50	0.77	0.03	0.10	99.82
W-17 ¹	34-44	99.39	—	0.26	0.35	—	100.00
	44-64	98.93	0.50	0.89	0.07	0.11	100.50
	64-77	98.45	0.50	0.90	0.04	0.11	100.00

TABLE 2. Continued

Hole number	Sample Interval, feet	Percent					
		CaCO ₃	MgCO ₃	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	Total
W-18	3-17	98.50	0.50	0.69	0.13	0.18	100.00
	17-37	98.95	0.50	0.27	0.13	0.15	100.00
	37-57	99.14	0.50	0.23	0.03	0.10	100.00
W-20	17-40	99.56	0.00	0.19	0.11	0.14	100.00
W-21	8.8-30	98.16	0.50	1.17	0.06	0.11	100.00
	30-59	98.50	0.50	0.88	0.05	0.07	100.00
W-25	4-12	98.88	0.50	0.23	0.15	0.24	100.00
	12-32	98.03	0.50	1.25	0.07	0.15	100.00

¹Carbonates of calcium and magnesium combined, iron and aluminum oxides combined.

TABLE 3. PHYSICAL PROPERTIES TESTS

Hole number	Liquid limit	Plastic limit	Plasticity Index	Limerock bearing ratio, percent
W-1	N.O. ¹	N.P. ²	N.P. ³	126
W-3	N.O.	N.P.	N.P.	105
W-5	N.O.	N.P.	N.P.	161
W-6	N.O.	N.P.	N.P.	—
W-8	N.O.	N.P.	N.P.	—
W-9	N.O.	N.P.	N.P.	58
W-11	N.O.	N.P.	N.P.	—
W-12	N.O.	N.P.	N.P.	43
W-13	N.O.	N.P.	N.P.	—
W-14	N.O.	N.P.	N.P.	112
W-15	N.O.	N.P.	N.P.	55
W-17	N.O.	N.P.	N.P.	—
W-18	N.O.	N.P.	N.P.	142
W-25	N.O.	N.P.	N.P.	—

¹Not obtainable — Below liquid limit of 35.

²Non plastic.

³Non plastic — Below plasticity index of 6.

Tests were made on the entire core from Holes W-1, 3, 5, 6, 8, 9, 11, 12, 13, 14, 15, 17, 18, 25. Test results indicated an absence of cohesive or excess plastic material in the limestone; the liquid limit falls below 35, and the plasticity index below 6, the standards established by the Florida State Road Department.

In addition to the above tests, one other major test was made of cores from eight of the properties drilled. A relatively recent requirement of the Florida State Road Department and one not shown in the Standard Specifications for Road and Bridge Construction, previously cited, is the Equivalent Limerock Bearing Ratio (L.B.R.) determination. The test is a modification of the California Bearing Ratio (C.B.R.) design method, one of the most widely used for designing flexible pavements. Preliminary studies by the Florida State Road Department revealed that the compactive effort employed in the C.B.R. test procedure would not yield densities comparable to those found in Florida's flexible pavements, so the compactive effort was altered to provide densities equivalent to those required in Florida construction specifications. The C.B.R. method was amended to reflect these changes. Other changes from the C.B.R. method included reduction of two days of time required for capillary soak, omission of swelling tests, and determination of average strength of rocks suitable for base-course material. Standard C.B.R. tests uses, as a basis for evaluation, the average strength of a number of typical crusher-run California materials, including crushed stone, gravel, and disintegrated granite, all of which have strengths considerably in excess of that of Florida limerock. For this reason a number of tests were conducted by the Florida State Highway Department to determine the average strength of limerocks suitable for base material. It was found that this strength was 800 psi, and this value was adopted as a basis for evaluating the strengths of other materials tested. Due to all these modifications, the test being employed could no longer be termed a California Bearing Ratio, so it was renamed the Limerock Bearing Ratio.

The L.B.R. test requires the use of about 80 lbs. of limestone, and is run in accordance with the "Method of Test for Determining the Equivalent Limerock Bearing Ratio of Florida Soils", as outlined in a special publication of the State Highway Department [6]. After completion of the physical requirements of the test, load penetration curves are plotted, and the corrected stress at 0.1 inch penetration determined. The equivalent Limerock Bearing Ratio in percent is then calculated by use of the following formula:

$$\text{L.B.R.}\% = \frac{\text{Corrected Stress} \times 100}{800} = \frac{\text{Corrected Stress}}{8}$$

The L.B.R. determinations were performed on composite cores from the following diamond-drill holes: W-1, W-3, W-5, W-9, W-12, W-14, W-15, and W-18, and deemed representative of the properties drilled. The values obtained range from 43 to 161 percent; three cores tested below 75 percent. The plotted curves and the L.B.R. values expressed in percent are shown in Appendix A of this report. Results of L.B.R. determinations and liquid limit, plastic limit, and plasticity index tests by hole are listed in Table 3.

DISCUSSION OF RESULTS

Drilling, analysis and test results of each hole drilled, by property, are discussed below. Tabulated summary data are shown in Table 1, and the logs of each hole drilled are shown in Appendix B of this report.

Diamond-Drill Holes W-1, W-7, W-22, W-23

Four holes were drilled on the property of Clayton Bush in E½, SW¼, section 35, T4N, R13W. Hole W-1 was drilled on the east side of an open cut which exposed limestone over an area 225 by 165 feet; numerous clay pipes or vertical inclusions were noted in the limestone exposure. The hole was drilled to a total depth of 61.1 feet and bottomed in limestone. Overburden, totaling 16.1 feet consisted of sandy soil, and clay near the limestone contact. Limestone core totaling 45 feet was analyzed as a unit. The limestone, based on analysis and tests, meets Florida State Road Department specifications. Combined calcium and magnesium carbonate was high and is indicative of its potential for uses other than roads. Holes W-7 and W-23 were drilled in overburden only. Hole W-22 cut 3.0 feet of limestone from 17.0 to 20.0 feet and 0.5 feet of limestone at 43.0 feet.

Diamond-Drill Holes W-2, W-26

Two holes were drilled on the property of N. G. Berry in SW¼, NW¼, section 36, T4N, R13W. Both holes bottomed in sandy clay and clayey sand. No limestone was penetrated. Hole locations were adjacent to limestone exposed in a nearby sinkhole. Based on drilling data, overburden thickness on this property was excessive and further drilling unwarranted.

Diamond-Drill Holes W-3, W-4, W-8

Three holes were drilled on the property of Dunn Heirs in SW¼, NE¼, section 16, T4N, R13W. Hole W-3 was drilled near a sinkhole with a vertical exposure of about 12 feet of limestone and in an area of outcropping rock. The hole was drilled to a total depth of 55 feet, and bottomed in limestone; overburden totaled 4 feet, and limestone core 51 feet. For chemical analyses, the core was divided into three intervals. The upper interval from 4-20 feet, ran high in magnesium carbonate compared to analyses from other holes in the same general area. All interval analyses showed high calcium carbonate content, low silica and low iron oxide content. The analyses and tests meet State Road Department specifications. Hole W-4 was drilled in overburden consisting of sand and clay, and bottomed at 21 feet. Hole W-8 was drilled to a total depth of 52 feet. Overburden consisted of 1 foot of sandy clay and 3 feet of limestone; 48 feet of limestone was cored. The core was divided into two intervals for analyses. The

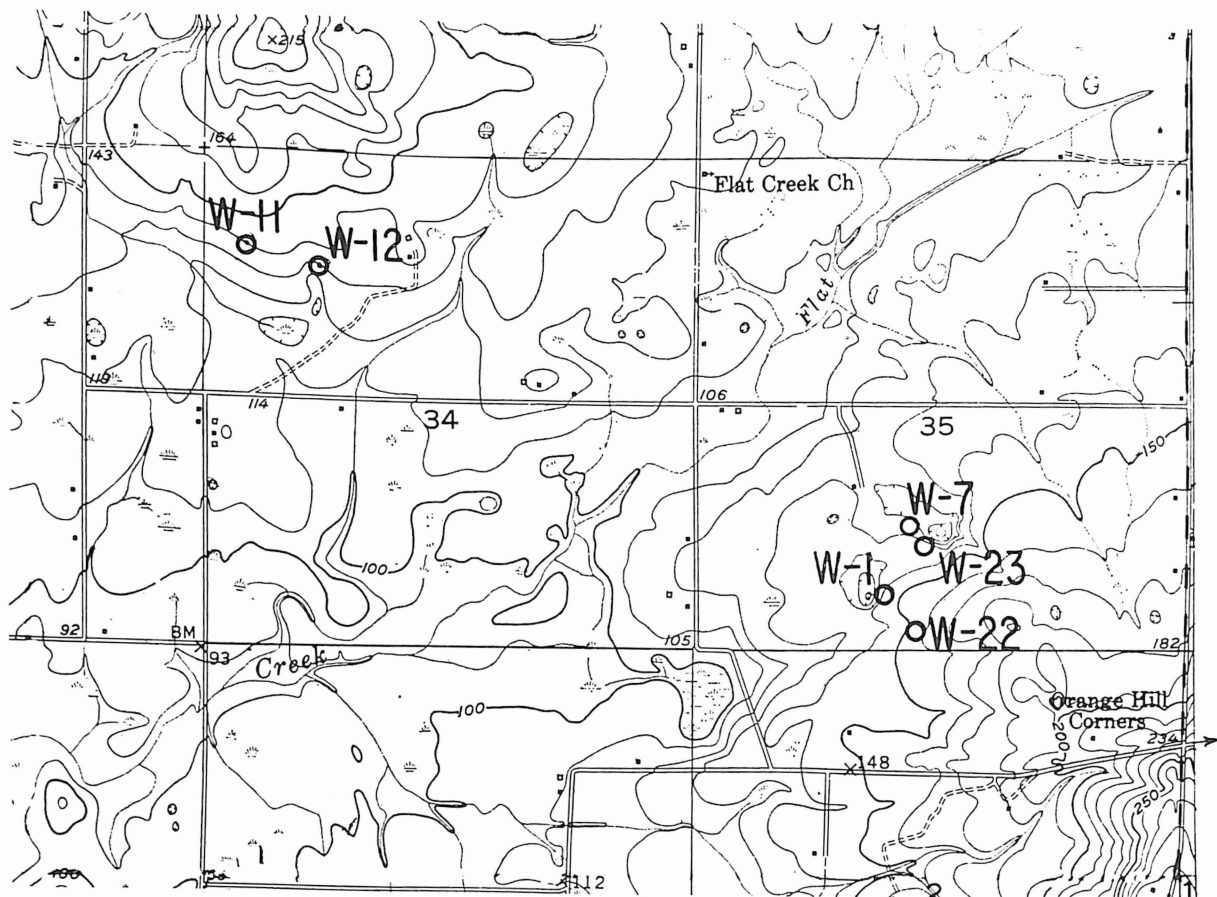


Figure 1. Location map. Holes W-1, 7, 11, 12, 22, 23.

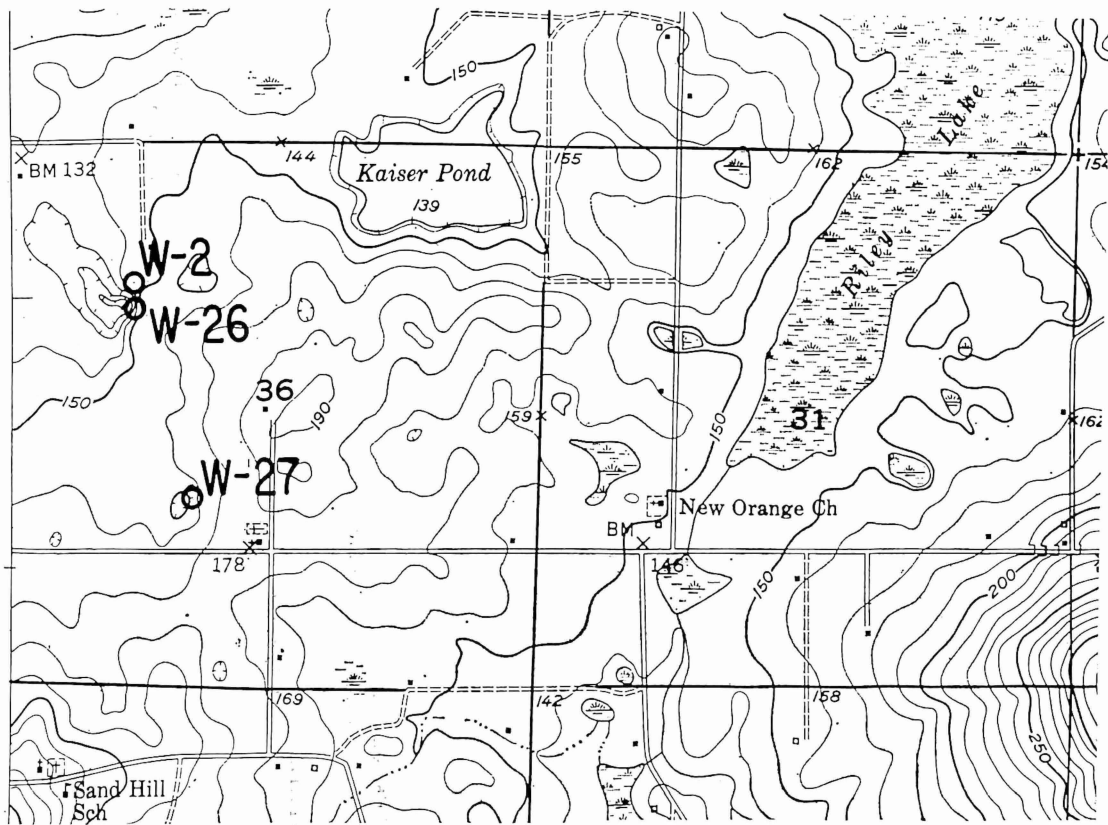


Figure 2. Location map. Holes W-2, 26, 27.

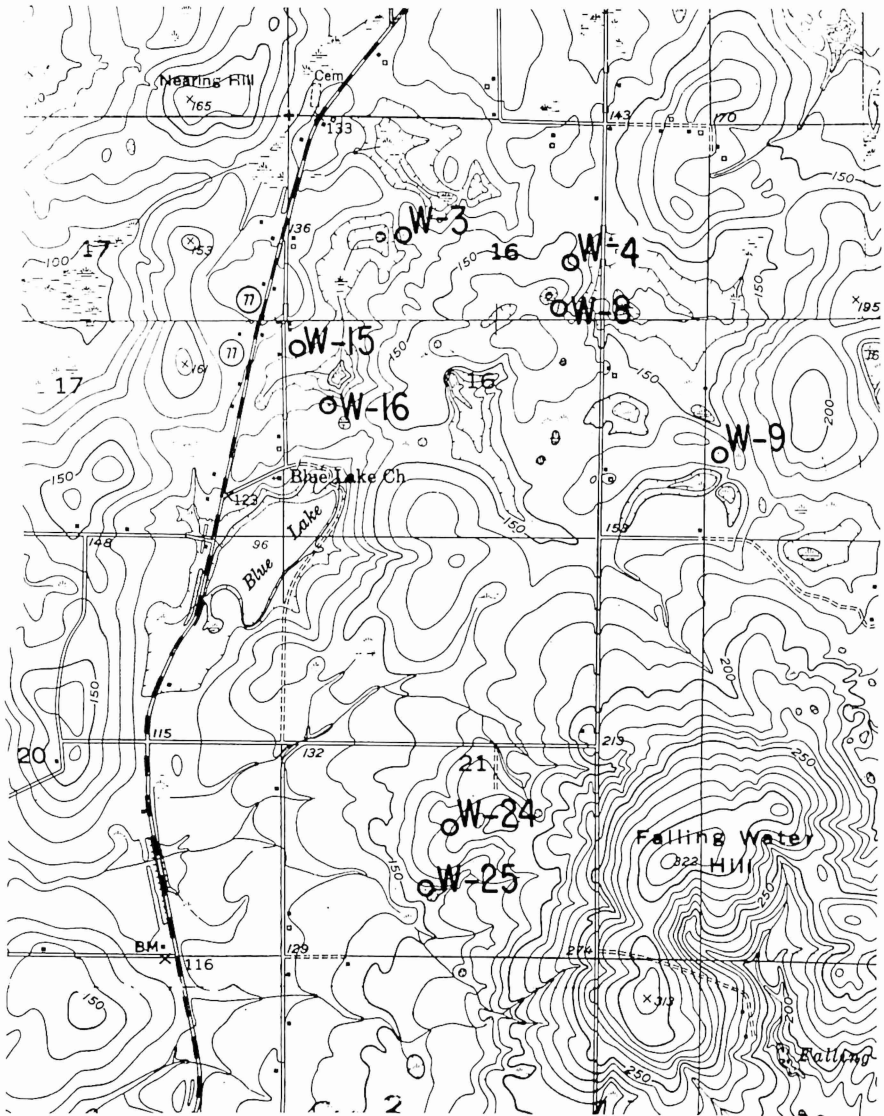


Figure 3. Location map. Holes W-3, 4, 8, 9, 15, 16, 24, 25.

upper interval from 4-22 feet contained no magnesium carbonate; the lower interval from 22-52 was high in calcium carbonate and low in silica, iron oxide, alumina content.

A large deposit of high-calcium limestone is indicated from drilling on this property. Limitation of the material is indicated to the north by Hole W-4, but outcrops on adjoining property to the south show a continuation of the deposit in that direction.

Diamond-Drill Holes W-5, W-6, W-19, W-20, W-21

Five holes were drilled on E. J. Harrell and Sons property in section 14, T4N, R13W, with the exception of W-19. Hole W-5 in the NE¼ was drilled to a total depth of 54 feet and bottomed in limestone. Overburden consisted of 3 feet of sandy clay and soil; limestone cored and cut totaled 51 feet. The material was well indurated and contained some solution cavities throughout the core; a few narrow clay seams were also observed from 14-19 feet. The core was divided into three intervals for analyses; all intervals showed calcium carbonate in excess of 96 percent. The interval from 4-19 feet contained higher silica than the remaining intervals. Liquid limit, plastic limit and plasticity index tests, as well as a Lime Bearing Ratio (L.B.R.) test, were conducted on the composite core from the hole and all were satisfactory. The L.B.R. determination indicated the highest percentage of any core tested. Hole W-6, in NE¼, SW¼, was drilled to a total depth of 54 feet and bottomed in limestone. Overburden consisted of 1 foot of clayey sand; limestone was cored in the remaining 53 feet. Physical characteristics of the limestone were very similar to that in W-5, but more weathering was indicated in this core.

Hole W-19, in SE¼, NE¼, section 24, T4N, R13W, was drilled to a total depth of 70 feet and bottomed in a plastic clay. Overburden was composed of 3.5 feet of sandy soil and weathered limestone. Limestone was penetrated from 3.5 - 10.0 feet and at that point a green plastic clay was encountered. Coring was stopped and the fishtail bit employed from 13.5 to 70 feet. The clay sampled and sent to the Norris Metallurgy Research Laboratory for testing. Test results indicated that the clay was light green in color, had a ph of 7.00, and was long working, smooth and plastic. Its water of plasticity was 20.4 percent, drying shrinkage 9 percent, and dry strength was good. Its drying characteristics were good, but slightly rough and had slight scum. A bloating test was made and was negative. The worked sample was made into briquetts and fired in test kilns. The results were as follows:

Slow Firing Test

Temp. °F	Color	Hardness	%Lin. Shk.	%Abs.	App. Sp. Gr.
1800	Tan	Fair hard	9.0	8.9	2.43
1900	Tan	Fair hard	9.0	8.8	2.42
2000	Light brown	Hard	10.0	9.9	2.40
2100	Brown	Hard	10.0	10.3	2.37
2200	Chocolate	Very hard	10.0	11.0	2.37
2300	Chocolate	Steel hard	10.0	11.0	2.35

Laboratory observations of the fired briquettes indicated that the color was fair, the material a little soft, absorption a little high, slight scum, and slight effervescence, the latter denoting the presence of some carbonate material. The potential uses of the material were given as glazed brick and pottery. This deposit of clay has definite potential and should be investigated further.

Hole W-20, in NE¼, SE¼, section 14, T4N, R13W, was drilled to a total depth of 40 feet and bottomed in clay. Overburden, totaling 8 feet, was composed of clayey sand, sandy clay and limestone fragments. Well indurated limestone was cored from 8 to 26.5 feet; the material contained numerous green clay seams and solutions cavities were noted. Chemical analysis was made of the core as a unit; calcium carbonate was 99.56 percent, the highest of any analysis made. There was no magnesium carbonate, and silica, iron oxide and alumina were very low.

Hole W-21, in SE¼, NE¼, section 14, T4N, R13W, was drilled to a total depth of 59 feet and bottomed in limestone. Overburden totaled 8.8 feet of red clay and weathered limestone. Limestone cored totaled 51.2 feet and consisted of well indurated to soft material, containing solution cavities. For chemical analyses the core was divided into two intervals; both intervals analyzed in excess of 98 percent calcium carbonate and contained 0.05 percent magnesium carbonate. The upper interval from 8.8 to 30 feet contained 1.17 percent silica, 0.06 percent iron oxide and 0.11 percent alumina; the lower interval from 30 to 59 feet contained lower percentages of silica, iron oxide and alumina.

Drilling on this property indicates the presence of a large, massive body of limestone, believed to contain considerable tonnage of indurated limestone suitable for road construction purposes. Close proximity to proposed Interstate 10 is a definite asset.

The clay penetrated in Hole W-19 warrants further exploration to define the extent of the deposit, and additional test work to confirm its commercial possibilities.

Diamond-Drill Hole W-9

One hole was drilled on the property of Dean Sasser in SW¼, SW¼, section 15, T4N, R13W. A large sinkhole and surface outcrops of limestone were exposed on the property. The hole was drilled to a total depth of 49 feet and bottomed in limestone. Overburden consisted of plastic clay containing limestone chips; core consisted of soft, porous, highly weathered limestone. For chemical analyses the core was divided into three intervals; all intervals showed in excess of 98 percent combined carbonates and were low in silica, iron oxide and alumina. Tests conducted consisted of liquid limit and plastic limit for plasticity index and were satisfactory. An L.B.R. determination showed 58 percent, which is probably satisfactory for stabilized base material if it meets other Florida State Road Department criteria.

Based on drilling data from a single hole and surficial information, it is difficult to estimate reserves on this property, but a close spaced drilling program may indicate a large body on this and adjacent properties that might be used for chemical purposes.

Diamond-Drill Hole W-10

One hole was drilled on the property of H. Etheridge in SE¼, NE¼, section 15, T4N, R13W. The hole was drilled to a total depth of 20 feet and abandoned because limestone had not been penetrated. The overburden material consisted of clayey sand.

Diamond-Drill Holes W-11, W-12

Two holes were drilled on the property of E. G. Rooks in NW¼, NW¼, section 34, T4N, R13W. Hole W-11 was drilled to a total depth of 50 feet and bottomed in limestone. Overburden consisted of sandy clay with limestone chips near the rock contact; core consisted of soft, chalky limestone and was highly weathered from 45-50 feet. The core was divided into two intervals for chemical analyses; both intervals analyzed in excess of 97 percent calcium carbonate.

Tests for liquid limit, plastic limit and plasticity index were satisfactory. Hole W-12, 300 feet southeast of W-11, was drilled to a total depth of 52 feet and bottomed in limestone. Overburden consisted of 5 feet of sandy clay containing limestone fragments. Limestone cored totaled 47 feet; the core was hard and porous from 17-27 feet, and soft and chalky from 27 to 52 feet. The core was divided into 3 intervals for chemical analysis and ranged from 99 percent calcium carbonate in the upper interval to 94 percent in the lower interval; all intervals were low in silica, iron and alumina. An L.B.R. determination indicated a value of 43 percent, the lowest percentage of any core submitted for this test.

The high calcium carbonate content from these two holes makes this property attractive for additional drilling to prove the presence of a body large enough for chemical use.

Diamond-Drill Holes W-13, W-14

Two holes were drilled on the Hinson and Corcoran property in NW¼, SE¼, section 36, T4N, R14W. Hole W-13 was drilled to a total depth of 52 feet and bottomed in limestone. Overburden consisted of one foot of sandy soil. Limestone cut by roller bit and core totaled 51 feet. The core indicated dense material with little weathering from 4-33 feet; from 33-52 feet it was weathered and porous. The core was divided into two intervals for chemical analyses; both intervals analyzed in excess of 97 percent calcium carbonate and were low in magnesium carbonate, silica, iron and alumina. All tests on the core including liquid limit, plastic limit, and plasticity index, were satisfactory. Hole W-14, 750 feet east of W-13, was drilled to a total depth of 49 feet and bottomed in

limestone. Overburden consisted of 1 foot of soil and 3 feet of weathered limestone. Core consisted of 45 feet of limestone that was highly porous, weathered and soft. The core was divided into three intervals for chemical analyses, and all intervals analyzed over 99 percent combined calcium and magnesium carbonates, and low silica and iron content. An L.B.R. determination performed on total core from this hole gave a value of 112 percent.

Based on drilling results and outcrops between holes drilled, this property has great potential for a significant body of limestone. Chemical analysis and tests indicate potential use for road construction and chemical uses.

Diamond-Drill Holes W-15, W-16

Two holes were drilled on Dunn Heirs property in NW $\frac{1}{4}$, SW $\frac{1}{4}$, section 16, T4N, R13W. Hole W-15 was drilled to a total depth of 49 feet. Overburden consisted of 4 feet of sandy clay and limestone. Limestone core totaled 45 feet and contained evidence of solution cavities and narrow clay seams from 9-49 feet. Much of the material was weathered and soft. The core was divided into three intervals for chemical analyses and tests were made of the entire core as a composite. The interval from 19-34 feet showed high silica with a reduced calcium carbonate content, but still above limitations of the Florida State Road Department for base course material. An L.B.R. determination conducted on core from this hole showed a value of 55 percent, considered low compared to most of the other determinations. Hole W-16 was drilled to a total depth of 52 feet which included 3 feet of overburden consisting of sandy clay. Limestone core was recovered to 47 feet, where the core barrel stuck in a cavity, and no further attempts to core were made. Physical characteristics of this core were similar to those found in W-15, except the material was more indurated to 22 feet.

Drilling and surface outcrops indicate the probability of a large body of limestone on this property. A closely-spaced drilling program would be necessary to delineate the limestone due to the highly weathered nature of the material and the presence of solution cavities.

Diamond-Drill Hole 17

One hole was drilled on B. L. Lawrence property in NW $\frac{1}{4}$, SW $\frac{1}{4}$, section 14, T4N, R13W. The hole was drilled to a total depth of 77 feet and bottomed in limestone. Hole location was near a sinkhole exposing a limestone face of about 25 feet in thickness. Overburden totaled 34 feet and consisted of soil, clay, and highly weathered limestone. Drilling was continued below the normal 20 foot limit because of occasional penetration of limestone. Total limestone cored was 43 feet most of which was highly weathered, soft and chalky. Tests on core from this hole indicated total carbonates in excess of 99 percent in the upper interval

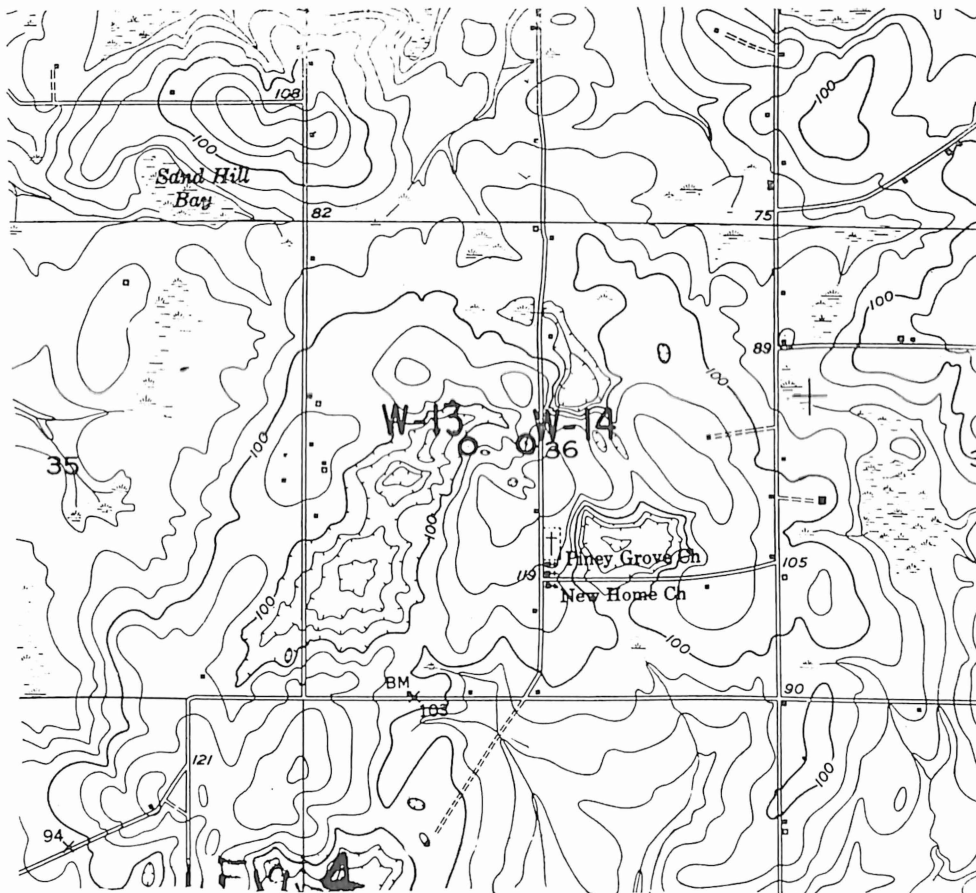


Figure 4. Location map. Holes W-13, 14.

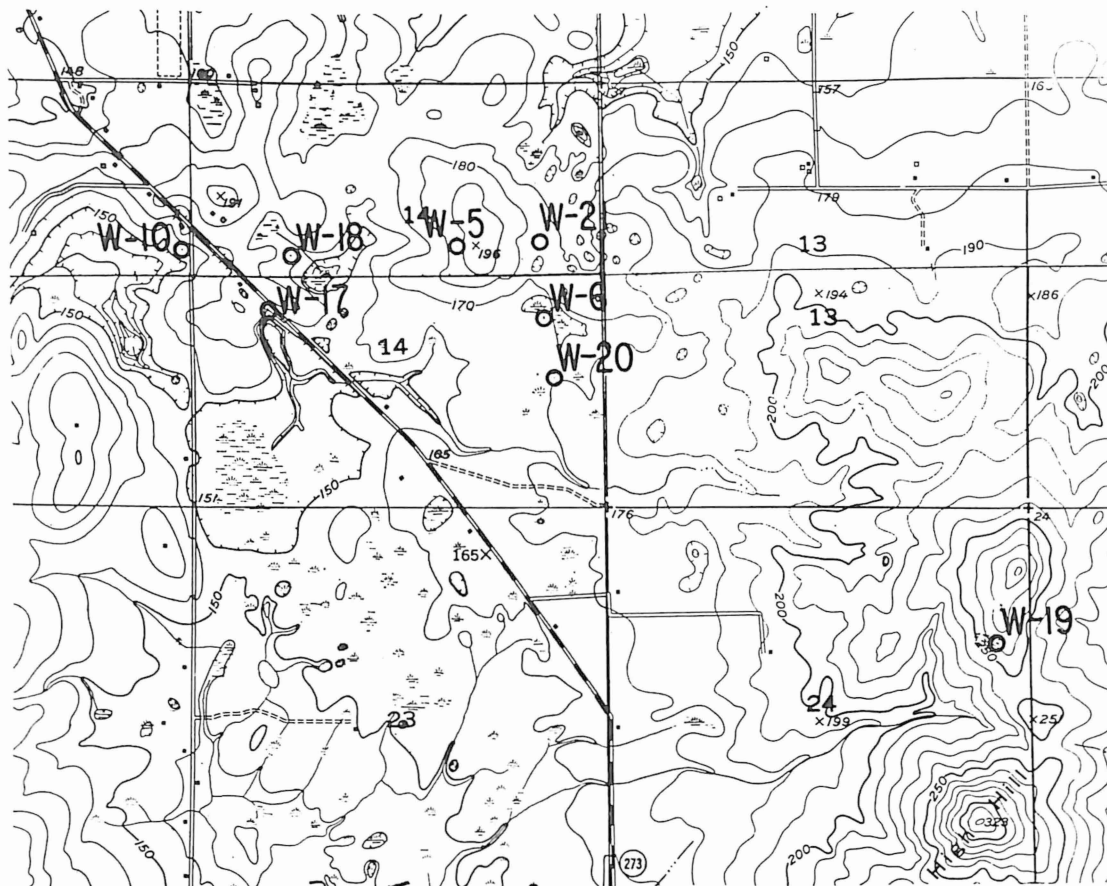


Figure 5. Location map. Holes W-5, 6, 10, 17, 18, 19, 20, 21.

from 34 to 44 feet, and calcium carbonate in the lower intervals in excess of 98 percent. Silica, iron oxide and alumina was low.

Reserve estimates are difficult for this property because of excessive overburden and lack of other holes.

Diamond-Drill Hole W-18

One hole was drilled on the F. T. Coleman property in SW $\frac{1}{4}$, NW $\frac{1}{4}$, section 14, T4N, R13W. The hole was drilled to a total depth of 57 feet and bottomed in limestone. Overburden totaled 5 feet and consisted of soil and clay. Limestone cored totaled 52 feet and consisted of soft, porous material in the upper section from 5-32 feet; the lower section from 32-57 feet was harder, less porous and not as highly weathered as the upper section. The core was divided into 3 intervals for analyses and tests; calcium carbonate in all three intervals was in excess of 98 percent. Silica, iron and alimina were low. Tests consisted of liquid limit and plastic limit to determine plasticity index and were satisfactory. An L.B.R. determination was made which showed 142 percent, indicating its potential use for base course material in road construction. The property is also in close proximity to proposed Interstate 10.

Chemical analyses and tests indicate this material has high potential for road construction as base course material and for chemical use.

Diamond-Drill Holes W-24, W-25

Two holes were drilled on Ralph C. Carter property in NE $\frac{1}{4}$, SW $\frac{1}{4}$, section 21, T4N, R13W. Hole W-24 was drilled 100 feet west of a sinkhole showing a weathered limestone vertical face. The hole was drilled to a total depth of 20 feet in clayey sand and sandy clay containing abundant limestone fragments. Hole W-25 was drilled to a total depth of 37 feet and bottomed in a cavity in the limestone. Overburden totaled 4 feet and consisted of soil and clayey sand. Limestone core was recovered to 32 feet and consisted of indurated material containing some soft, weathered streaks that were highly porous. The core was divided into 2 intervals for chemical analyses; both intervals showed in excess of 98 percent calcium carbonate and 0.5 percent magnesium carbonate. Tests were conducted to determine plasticity index but an L.B.R. determination was not made on the core.

Results of chemical analyses indicate the potential use of this material for chemical purposes. Additional test work is needed to determine its potential for road construction.

Diamond-Drill Hole W-27

One hole was drilled on the property of Earl J. Bruner in N $\frac{1}{2}$, SW $\frac{1}{4}$, section 36, T4N, R13W. The hole was located north of a prominent sinkhole, now caved, exposing limestone along the rims of the sink. The hole was drilled to a total depth of 20 feet in overburden composed of clayey sand and sandy clay; no limestone was penetrated.

RESERVE ESTIMATES

Risks involved in estimating reserves from a widely-spaced drilling program on limestone are both inherent and numerous, and care should be exercised in making estimates for the following reasons: (1) Configuration of the limestone surface can, and frequently does, change rapidly over relatively short distances, as indicated by the drilling, and (2) the extent of solution cavities and weathering within a limestone body cannot be projected with certainty and may be locally more prevalent in some areas than others.

Medium to large tonnages of limestone may be estimated on at least 5 properties investigated; smaller tonnages may be indicated on 4 other properties where limited drilling information exists.

An average weight of 145 lbs. per cu. ft. of limestone, in place, was used to coincide with the average for all Florida limestones, and resultant tonnage was expressed as short tons (2,000 lbs.). The length was determined by measuring distance between holes, and inference beyond holes on exposures of limestone on the property. The width was based on exposures at right angles to the projected strike and as indicated by drill holes. Depths used were actual footages drilled in rock, below overburden, and were not extended below the bottom of the hole; many of the holes bottomed in limestone.

Total estimated tonnage of limestone from the project work was 43-million short tons.

This estimate is believed to be conservative and applies only to those areas drilled; however, many other known properties in the same general area may contain large reserves of limestone and other similar investigations will be necessary to arrive at total reserves in the county.

CONCLUSIONS

Results of drilling, chemical analyses, and tests on several properties in the county indicate the presence of small to large quantities of limestone, suitable for a variety of purposes, including road construction and chemical uses.

Drilling indicated that deposits of limestone, some containing several millions of tons of rock exist in the area. Overburden was shallow in most holes drilled and within economic limits. Limestone was cored to depths in excess of 50 feet and many of the holes bottomed in limestone, indicating economically workable deposits at depth. The deposits have sufficient length, width and depth, as indicated from drilling exposures, to be attractive for further exploration.

Chemical analyses and tests indicated the material to be high-calcium limestone and low in impurities; all analyses showed in excess of 92 percent calcium carbonate. Lime Bearing Ratio determinations and Plasticity Index test results indicate the material may be satisfactory, in these respects, as base course and stabilized base materials for road construction.

In the course of drilling, a clay deposit which may have potential for glazed brick and pottery was found and further exploration and tests on this property appear warranted.

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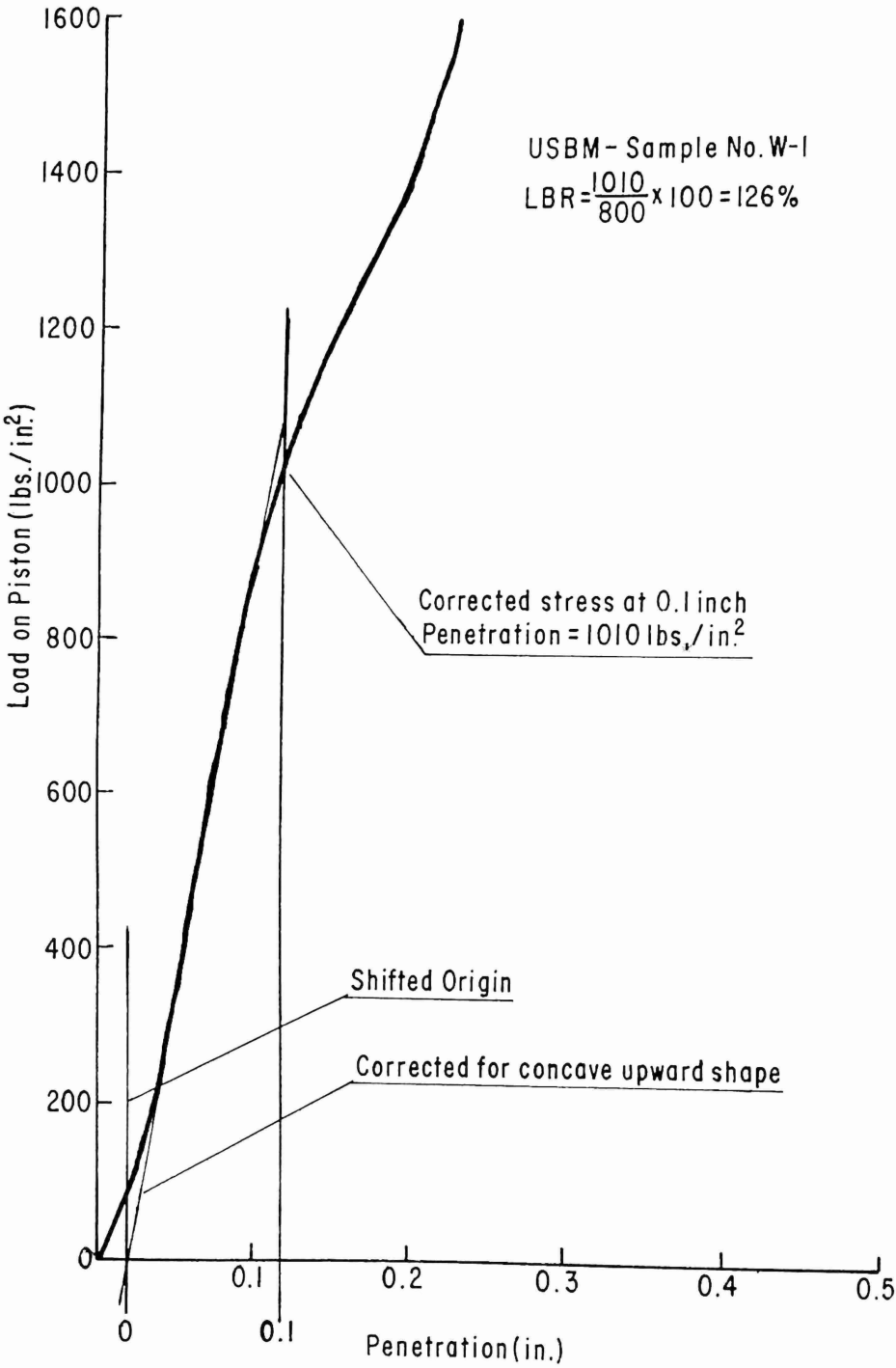
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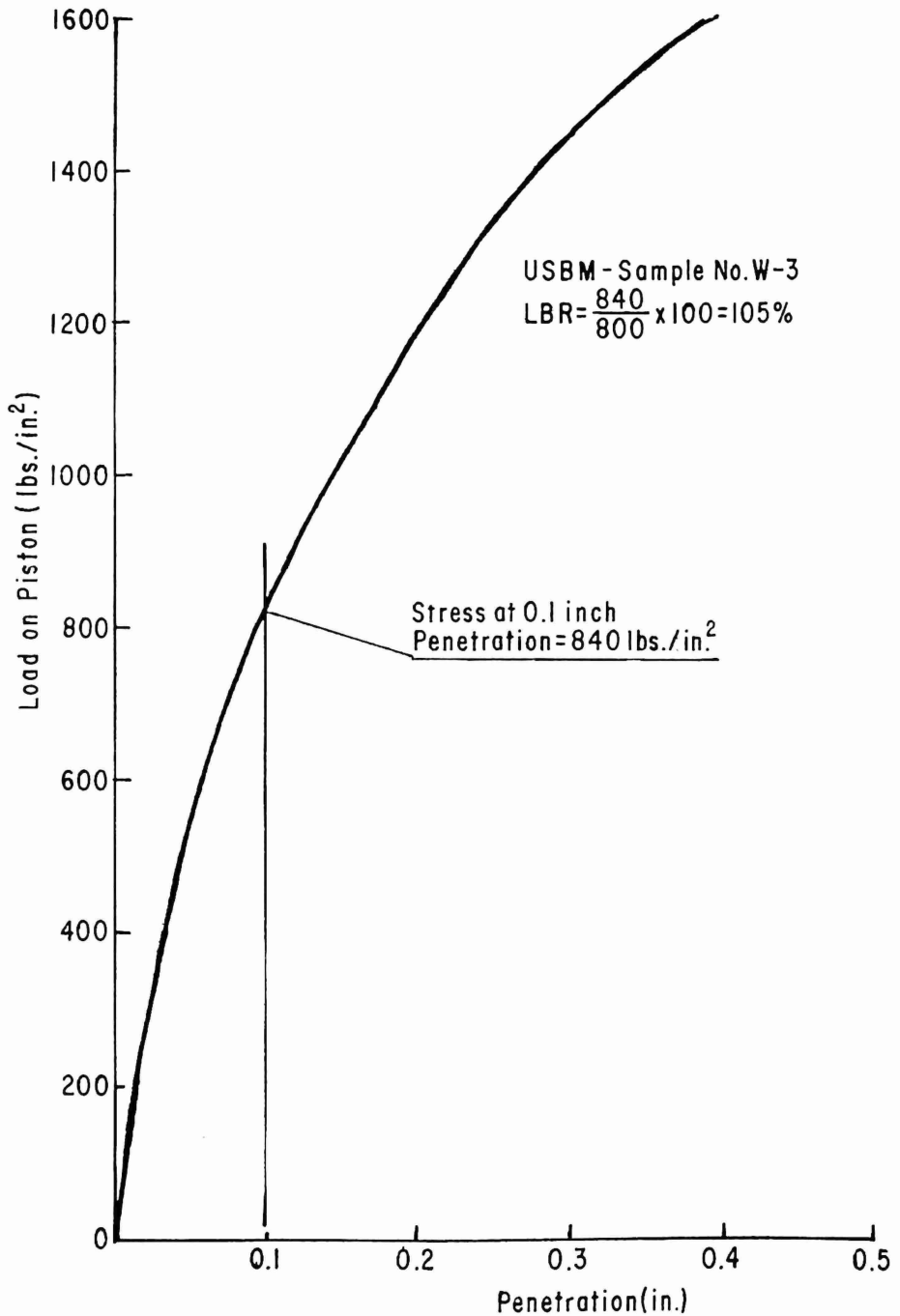
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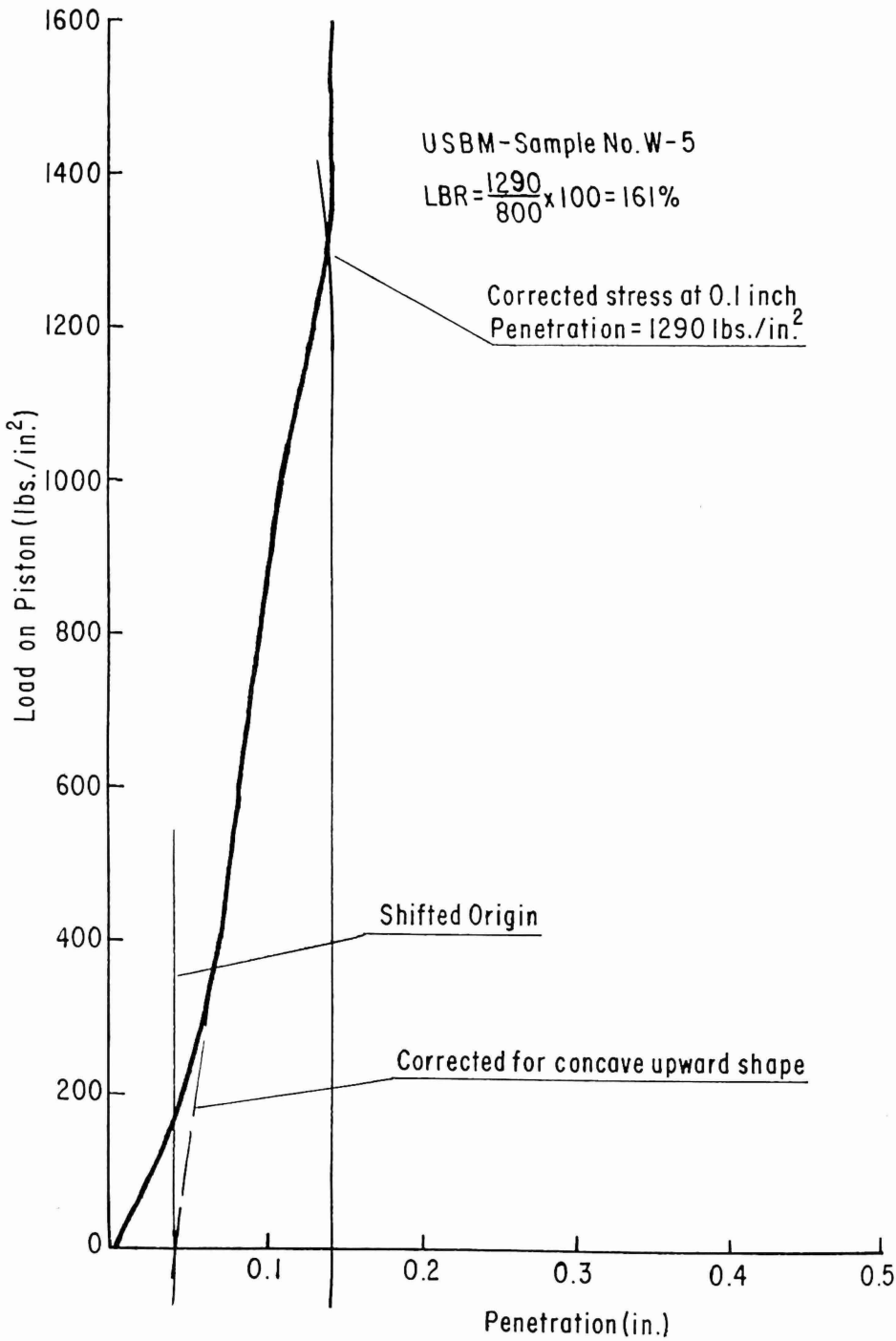
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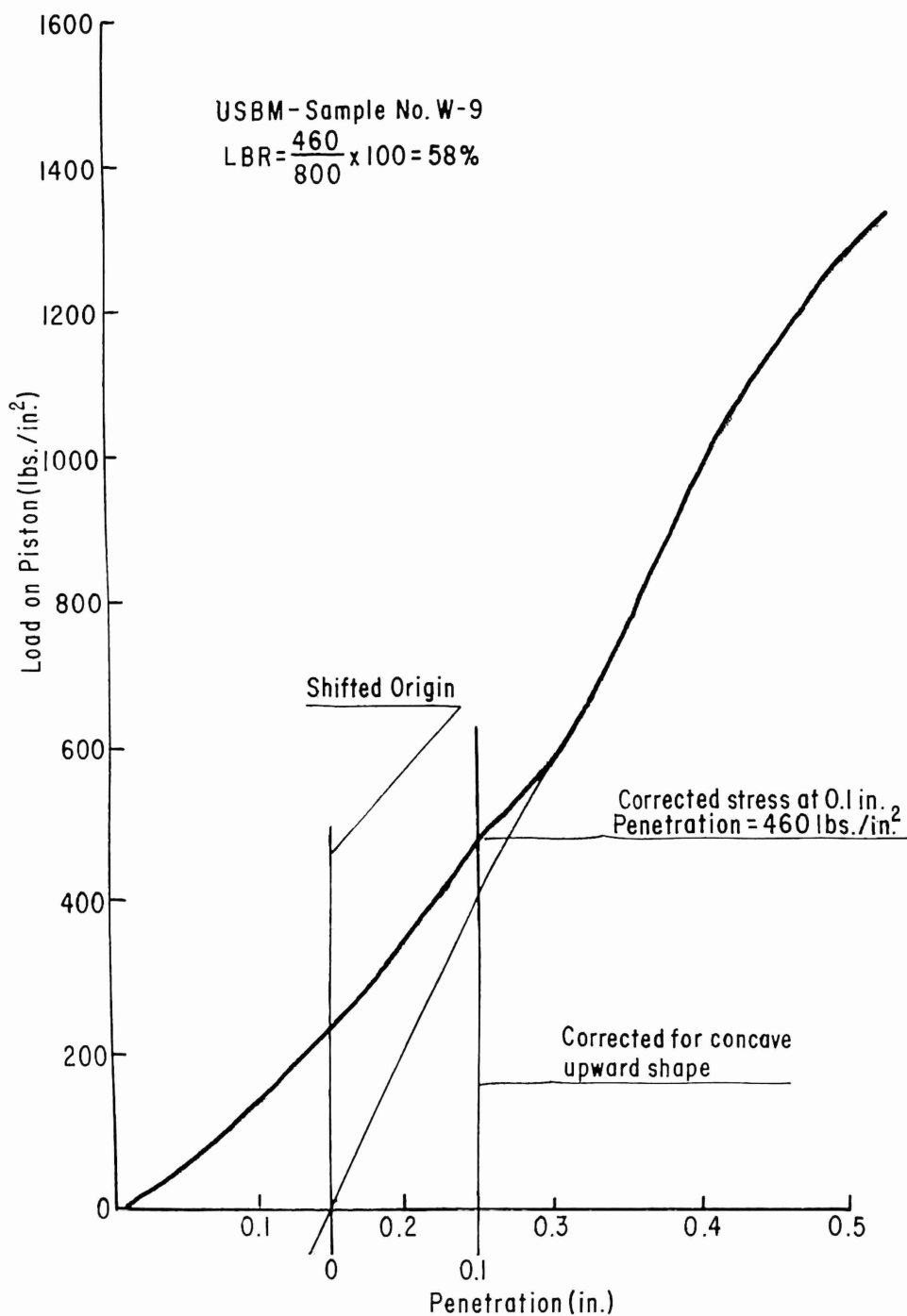
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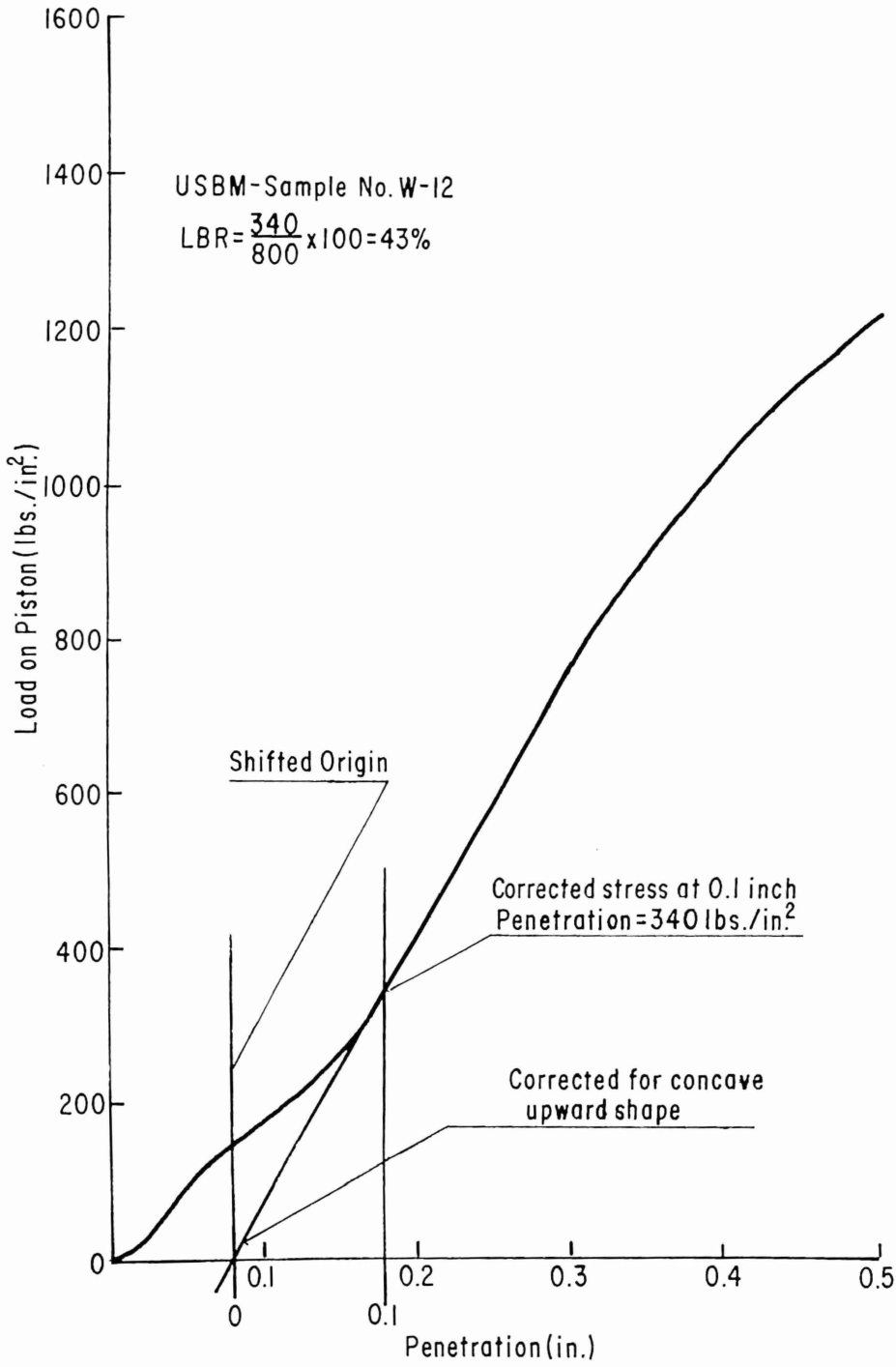
APPENDIX A

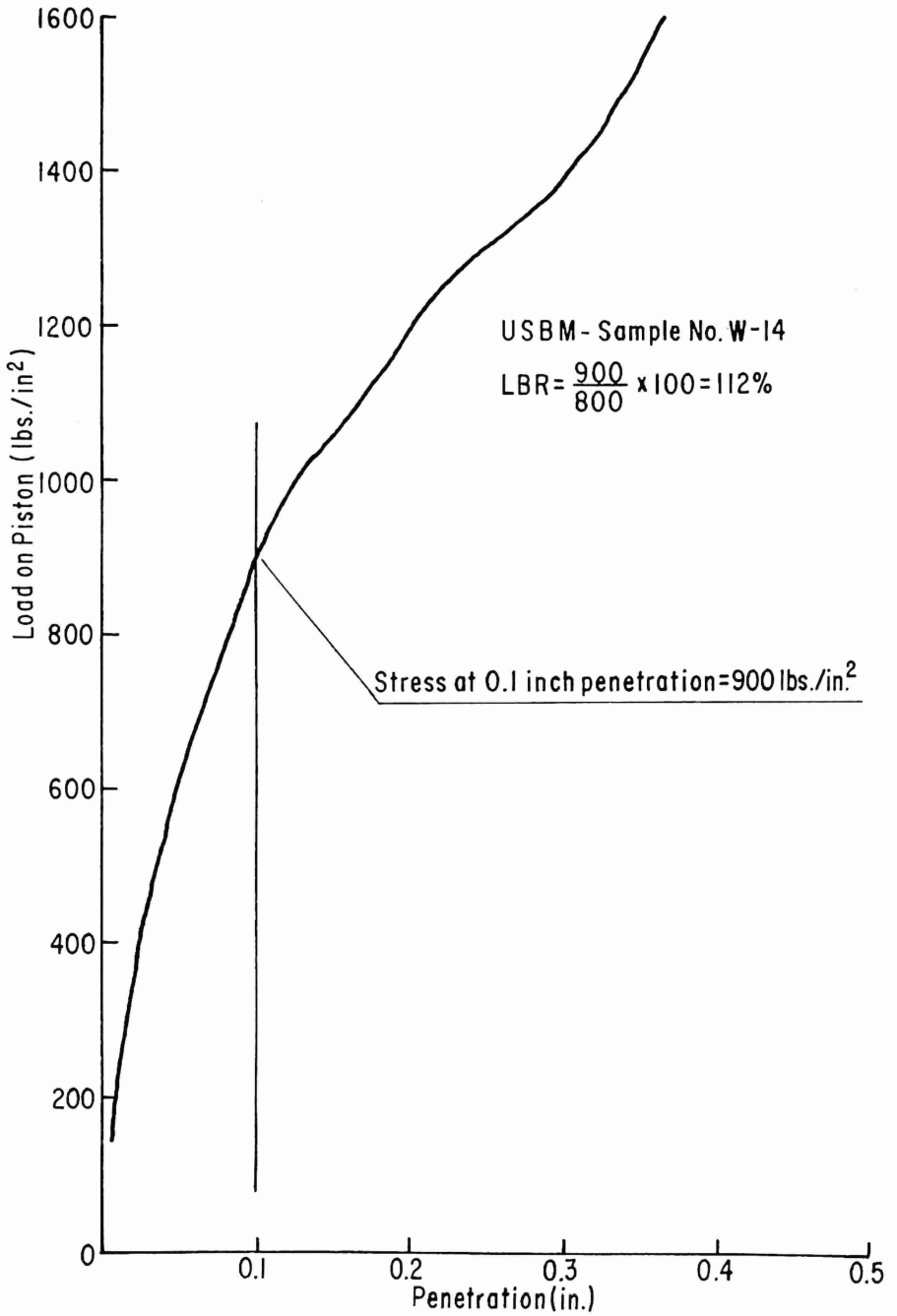


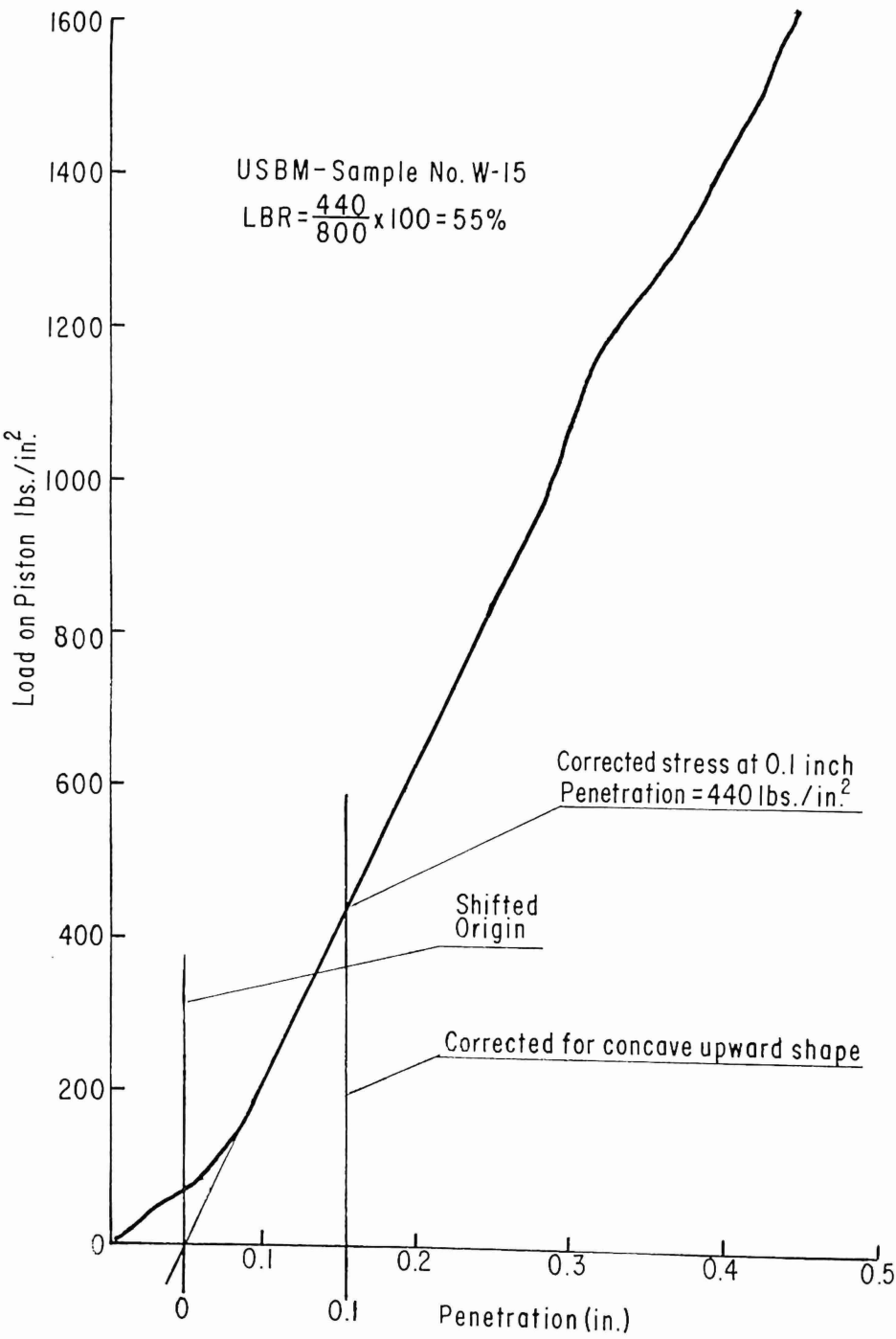


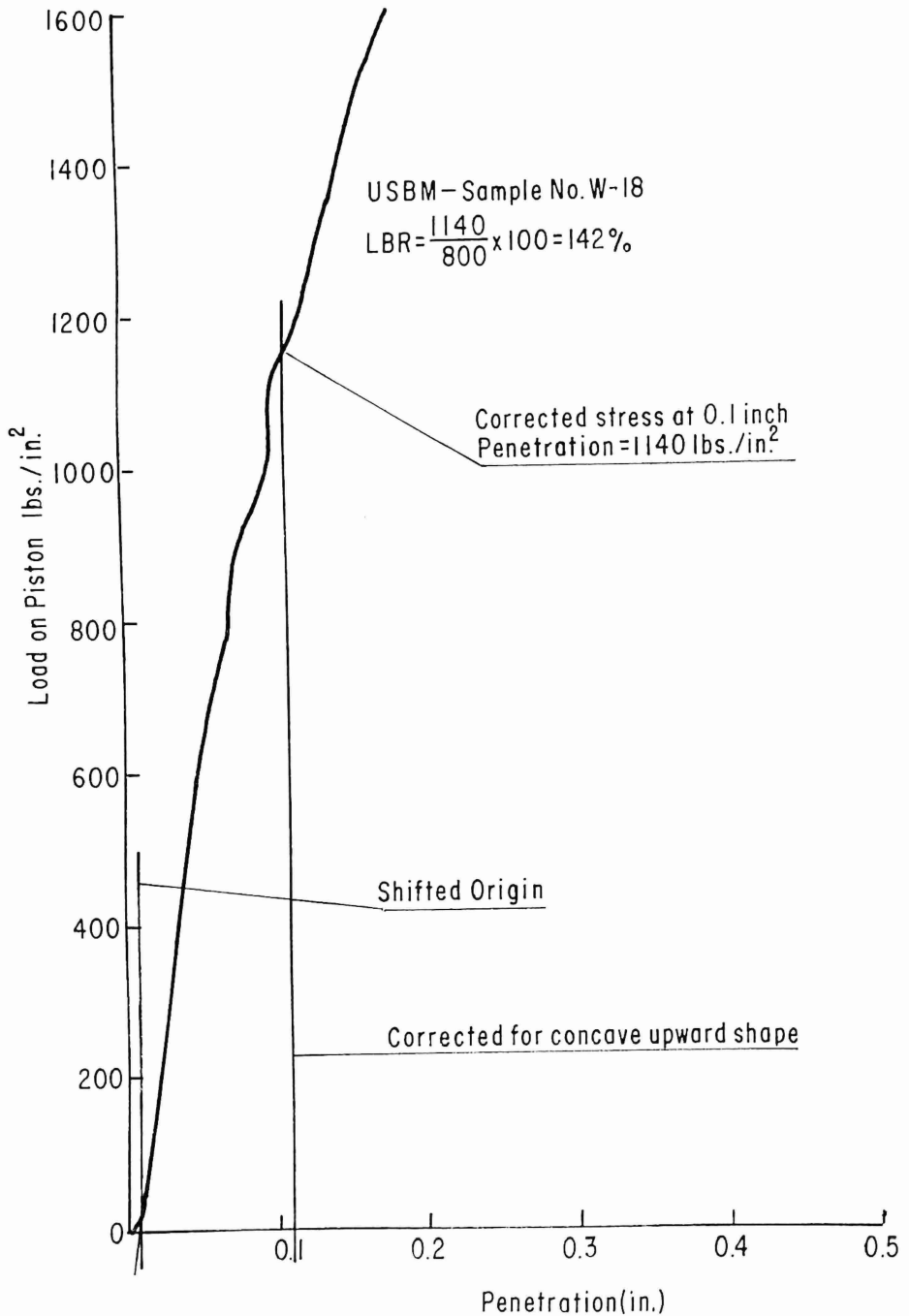












APPENDIX B

Hole No. W-1

PROJECT: Limestone
DRILLER: Bob Huss
TYPE DRILLING: Rotary NX Core
COMMENCED: 6-27-64
COMPLETED: 6-27-64
LOGGED BY: L. E. Shirley

Depth in feet below

land surface

Description

0-16.1	Overburden-brown to red sandy soil in upper 2 feet. Sandy red clay with gray plastic clay at limestone contact.
16.1-21.1	White to cream limestone with iron staining in interstices, soft and chalky. Highly fossiliferous.
21.1-26.1	As above.
26.1-31.1	As above.
31.1-36.1	As above.
36.1-41.1	As above.
41.1-46.1	As above.
46.1-51.1	As above.
51.1-56.1	As above.
56.1-61.1	As above.

Note: Equigranular limestone, microfossils rather than macro in upper section.
Hole bottomed at 61.1 in limestone.

Hole No. W-2

PROJECT: Limestone
DRILLER: Bob Huss
TYPE DRILLING: Rotary NX Core
COMMENCED: 7-28-64
COMPLETED: 7-28-64
LOGGED BY: L. E. Shirley

Depth in feet below

land surface

Description

0-20	Overburden-red clayey sand and red clay, plastic. Hole bottomed at 20 feet because of excessive overburden.
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BUREAU OF GEOLOGY

Hole No. W-3

PROJECT: Limestone
DRILLER: Bob Huss
TYPE DRILLING: Rotary NX Core
COMMENCED: 7-29-64
COMPLETED: 7-29-64
LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Fishtail-overburden-reddish brown, plastic clay.
4-5	Two inches reddish brown clay. Ten inches cream highly fossiliferous limestone weathered, indurated.
5-10	Light cream limestone, well indurated, porous, massive fossiliferous, weathered brown in interstices.
10-15	As above.
15-20	As above.
20-25	As above, less indurated.
25-30	As above.
30-35	As above, softer.
35-40	As above.
40-45	As above.
45-50	As above.
50-55	As above, no change. Hole bottomed at 55 feet in limestone.

Hole No. W-4

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 7-30-64
COMPLETED: 7-30-64
LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-21	Overburden — five feet of reddish-brown sandy clay, sixteen feet of clayey sand, quartz sand medium to coarse. Hole bottomed at 21 feet because of excessive overburden.

Hole No. W-5

PROJECT: limestone
 DRILLER: Jim Shuck
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 7-30-64
 COMPLETED: 7-30-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Overburden — three feet reddish brown sandy clay and soil. One foot limestone cut with roller bit.
4-9	Light cream limestone, well indurated, porous (solution cavities up to ½ inch) highly fossiliferous, massive.
9-14	As above, weathered.
14-19	As above, clay seams, highly porous.
19-24	As above.
24-29	As above.
29-34	As above.
34-38	As above. o38-43
43-48	As above. As above.
48-53	As above.
53-54	As above.
	Hole bottomed at 54 feet in limestone.

Hole No. W-6

PROJECT: Limestone
 DRILLER: Jim Shuck
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 7-30-64
 COMPLETED: 7-31-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	One foot clayey sand. Three feet of limestone (cut with roller bit).
4-9	Light cream limestone, indurated but with thin layers of green (glauconitic?) clay, very porous, massive weathered, fossiliferous.
9-10	As above.
10-15	As above, well indurated, less weathered.
15-20	As above, last 33 inches highly weathered and crumbly.
20-25	As above, indurated with few soft spots.
25-30	As above.
30-35	As above.
35-40	As above.
40-45	As above.
45-50	As above.
50-54	As above, highly fossiliferous.
	Hole bottomed at 54 feet in limestone.

BUREAU OF GEOLOGY

Hole No. W-7

PROJECT: Limestone
 DRILLER: Jim Shuck
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 7-31-64
 COMPLETED: 7-31-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-20	Overburden-reddish-brown sandy clay. Hole bottomed at 20 feet because of excess overburden.

Hole No. W-8

PROJECT: Limestone
 DRILLER: Jim Shuck
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 7-31-64
 COMPLETED: 8-1-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Fishtail. Overburden — one foot reddish brown sandy clay 3 feet of limestone, cut with roller bit.
4-7	Light cream limestone, well indurated with few clay seams (core broken) porous, fossiliferous, weathered, massive.
7-12	As above.
12-17	As above.
17-22	As above, soft, crumbly.
22-27	As above, highly weathered, soft, crumbly.
27-32	As above, highly weathered, soft, crumbly.
32-37	As above, soft, chalky.
37-42	As above, soft, chalky.
42-47	As above, few clay seams.
47-52	As above, highly weathered, soft, chalky. Hole bottomed at 52 feet in limestone.

Hole No. W-9

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 8-1-64
COMPLETED: 8-1-64
LOGGED BY: L. E. Shirley

Depth in feet below

land surface

Description

0-5	Fishtail. Overburden. Red to brown plastic clay containing limestone chips. Sandy in upper 1 foot.
5-10	White to gray limestone. Porous in upper portion, highly fossiliferous. Well indurated sections up to 8 inches thick. Some iron staining in lower 24 inches.
10-15	Porous, highly weathered iron stained, indurated.
15-20	Soft, porous, fossils, crushed. Lower portion.
20-25	Soft, broken and ground limestone.
25-30	Soft, crushed and broken limestone, highly weathered fossiliferous.
30-35	Soft, porous, highly weathered.
35-40	As above.
40-45	As above.
45-49	As above.
	Hole bottomed at 49 feet in limestone.

Hole No. W-10

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 8-3-64
COMPLETED: 8-3-64
LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-20	Overburden — Reddish brown clayey sand.
	Hole bottomed at 20 feet because of excessive overburden.

Hole No. W-11

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 8-4-64
COMPLETED: 8-4-64
LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-15	Overburden. Reddish sandy clay, plastic, limestone chips at 4.5 feet. Highly weathered limestone at 14.5 feet.
15-20	Light cream limestone, porous, highly fossiliferous, soft, chalky.
20-25	As above.
25-30	As above.
30-35	As above.
35-40	As above, 2 inches of plastic clay at 35 feet.
40-45	As above.
45-50	As above, highly weathered, crumbly, soft. Hole bottomed at 50 feet in limestone.

Hole No. W-12

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 8-4-64
COMPLETED: 8-4-64
LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-5	Overburden — Reddish-brown sandy clay with limestone fragments.
5-10	Light cream limestone highly weathered, highly fossiliferous, porous, massive, stained in interstices.
10-12	As above.
12-17	As above.
17-22	As above, hard, porous.
22-27	As above, hard, porous.
27-32	As above, soft, chalky.
32-37	As above, highly fossiliferous, soft.
37-42	As above.
42-47	As above, from 43.5 feet to 44.5 feet hardrock, other soft, crumbly.
47-52	As above. Hole bottomed at 52 feet in limestone.

Hole No. W-13

PROJECT: Limestone
 DRILLER: Jim Shuck
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 8-5-64
 COMPLETED: 8-5-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Overburden — 1 foot soil. 3 feet of limestone cut with roller bit.
4-9	Light cream limestone, fossiliferous, massive bedded, dense, granular and slightly friable, very little weathering.
9-13	As above.
13-18	As above.
18-23	As above.
23-28	As above.
28-33	As above.
33-38	As above, from 33.0 feet to 33.7 feet brown calcareous clayey sand.
38-42	Light cream limestone fossiliferous, massive, granular weathered, friable.
42-47	As above, porous.
47-52	As above.
	Hole bottomed at 52 feet in limestone.

Hole No. W-14

PROJECT: Limestone
 DRILLER: Jim Shuck
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 8-5-64
 COMPLETED: 8-5-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Overburden — Soil — 3 feet saprolitic limestone.
4-9	Light cream limestone, highly porous, solution cavities weathered, highly fossiliferous, soft.
9-14	As above, highly porous.
14-19	As above, weathered.
19-24	As above, equigrained, chalky.
24-29	As above.
29-34	As above.
34-39	As above, porous.
39-44	As above, highly fossiliferous.
44-49	As above.
	Hole bottomed at 49 feet in limestone.

BUREAU OF GEOLOGY

Hole No. W-15

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 8-5-64
COMPLETED: 8-5-64
LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Overburden 2 feet reddish-brown sandy clay 2 feet of limestone.
4-9	Light cream limestone, indurated, fossiliferous, massive, weathered.
9-14	As above, well indurated, large solution cavities.
14-19	As above, highly weathered, few clay seams.
19-24	As above, weathered.
24-29	As above.
29-34	As above.
34-39	As above.
39-44	As above.
44-49	As above, soft, chalky.
	Hole bottomed at 49 feet in limestone.

Hole No. W-16

PROJECT: Limestone
DRILLER: Jim Shuck
TYPE DRILLING: Rotary NX Core
COMMENCED: 8-6-64
COMPLETED: 8-6-64
LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-4	Overburden - 3 feet reddish brown sandy clay 1 foot limestone cut with roller bit.
4-7	Light cream limestone, well indurated, massive fossiliferous, porous.
7-12	As above, well indurated.
12-17	As above, well indurated.
17-22	As above, well indurated, highly porous and weathered.
22-27	As above, soft, fossiliferous, friable.
27-32	As above, soft, chalky, weathered.
32-37	As above, soft, chalky.
37-42	As above, soft, chalky, weathered.
42-47	As above.
47-52	No recovery, cavity, core barrel stuck.
	Hole bottomed at 52 feet in limestone.

Hole No. W-17

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-9-64
 COMPLETED: 9-9-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-34	Overburden cut with fishtail bit, 1 foot black soil — 27 feet red and white mottled clay. 6 feet very highly weathered limestone.
34-39	White limestone, highly weathered, fossiliferous, coquinoïdal, soft and chalky.
39-44	As above.
44-49	White limestone, stained brown in places, highly fossiliferous, soft to marly.
49-54	Cream limestone, fossiliferous, highly weathered, very soft.
54-59	As above.
59-64	As above.
64-69	As above, very soft, at 68.5 feet transition to granular limestone.
69-74	White granular limestone, fossiliferous, soft.
74-77	As above.
	Hole bottomed at 77.0 feet in limestone.

Hole No. W-18

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-9-64
 COMPLETED: 9-10-64
 LOGGED BY: J. W. Sweeney

Depth in feet below land surface	Description
0-5	Fishtail. 0.5 feet black soil, 4.5 feet reddish brown clayey overburden.
5-7	Light cream limestone, highly weathered, fossiliferous, soft, chalky and porous.
7-12	As above.
12-17	As above.
17-22	As above.
22-27	As above.
27-32	Light cream to white limestone, fossiliferous, not weathered as much as above.
32-37	As above.
37-42	As above, less porous.
42-47	As above, some very soft streaks.
47-52	White limestone, soft to chalky, massive, fossiliferous.
52-57	As above.
	Hole bottomed at 57 feet in limestone.

BUREAU OF GEOLOGY

Hole No. W-19

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-10-64
 COMPLETED: 9-10-64
 LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-3.5	Fishtail bit — 0.2 feet gray sandy soil — 3.3 feet gray-green arenaceous limestone with red streaks where limestone breaks, massive, hard but brittle.
3.5-8.5	Gray-green arenaceous limestone, indurated to soft clayey seams, few red spots.
8.5-13.5	2.4 feet gray green arenaceous limestone grading at 15.5 feet to gray green clay with red spots and yellow weathering bands throughout.
13.5-70	Fishtail bit — Gray-green plastic clay slightly arenaceous — few red sandy streaks and yellow weathering stains. Hole bottomed at 70 feet in gray green plastic clay.

Hole No. W-20

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-10-64
 COMPLETED: 9-14-64
 LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-8	Fishtail bit — Overburden 4 feet brown clayey sand, 4 feet brown sandy clay with limestone fragments.
8-10.5	White dolomitic limestone, well indurated, fossiliferous, massive, few packets of greenish clay in limestone, yellowish-brown spots throughout core interval — last 0.5 feet soft and chalky.
10.5-12.5	White well indurated limestone with numerous gray-green clay seams.
12.5-16.5	As above.
16.5-21.5	2.0 feet white limestone well indurated, few green clay seams. 3.0 feet white limestone, well indurated, massive fossiliferous, few solution cavities.
21.5-26.0	White limestone well indurated, fossiliferous, massive, many solution cavities — few reddish weathering spots.
26.0-31.0	0.5 feet white limestone indurated. (Transition to clay) weathered. 0.7 feet red-green mottled plastic clay with limestone fragments. 0.2 feet green-red mottled plastic clay.
31.0-40	Fishtail bit. Cuttings show green-red mottled, clay, plastic. Hole bottomed at 40 feet in clay.

Hole No. W-21

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-14-64
 COMPLETED: 9-14-64
 LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-8.8	Fishtail bit. Red clay with abundant limestone boulders.
8.8-13.8	White limestone, indurated, weathered with abundant green clay seams.
13.8-15.0	As above.
15.0-20.0	White limestone indurated to soft, fossiliferous.
20.0-25.0	White limestone, indurated to soft, abundant solution cavities cause core to be broken, fossiliferous.
25.0-30.0	As above, more dense, less cavities.
30.0-35.0	White limestone, soft and chalky, fossiliferous, massive, weathered.
35.0-40.0	As above.
40.0-45.0	As above.
45.0-49.0	As above.
49.0-54.0	White limestone, well indurated to soft, massive, fossiliferous, highly weathered and solution cavities.
54.0-59.0	White limestone, soft, massive, fossiliferous, weathered.
	Hole bottomed at 59.0 feet in limestone.

Hole No. W-22

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-14-64
 COMPLETED: 9-15-64
 LOGGED BY: J. W. Sweeney

Depth in feet below

land surface

Description

0-20	Fishtail bit - Overburden red sandy clay with limestone fragments, but cut highly weathered limestone from 17 feet to 20 feet.
20-25	Red and gray mottled clayey sand (washed out of core barrel).
25-30	As above.
30-35	0.7 feet red-gray mottled clayey sand. 0.3 feet light gray clay with black specks (organic material).
35-45	At 39 feet about 0.5 feet rock then red and gray sand. At 43 feet about 0.5 feet limestone - red-gray sand.
	Hole bottomed at 45 feet in clayey sand.

BUREAU OF GEOLOGY

Hole No. W-23

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-15-64
 COMPLETED: 9-15-64
 LOGGED BY: J. W. Sweeney

Depth in feet below
 land surface

Description

0-20 Fishtail bit — Dark red-brown sandy soil overburden to 17 feet —
 red-gray mottled plastic clay to 20 feet.
 Hole bottomed at 20 feet in clay, excessive overburden.

Hole No. W-24

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-15-64
 COMPLETED: 9-15-64
 LOGGED BY: J. W. Sweeney

Depth in feet below
 land surface

Description

0-20 Fishtail bit — at 7 feet reddish yellow clay sand overburden 7 feet —
 12 feet gray-red mottled sandy with limestone fragments. 12-20 light
 cream, very plastic clay with abundant limestone fragments (marly).
 Hole bottomed at 20 feet in clay, excessive overburden.

Hole No. W-25

PROJECT: Limestone
 DRILLER: Clayton Davis
 TYPE DRILLING: Rotary NX Core
 COMMENCED: 9-15-64
 COMPLETED: 9-16-64
 LOGGED BY: J. W. Sweeney

Depth in feet below
 land surface

Description

0-4 Fishtail bit — overburden 0-5 feet black soil. 3.0 feet red clayey sand.
 0.5 feet limestone.
 4-5.2 White limestone, indurated, highly weathered with yellowish brown
 streaks where core breaks, fossiliferous.
 5.2-10.2 White limestone well indurated, porous, weathered, highly fossiliferous
 (these zones, friable, with brownish weathering streaks).
 10.2-12.0 As above.
 12.0-17.0 As above.
 17.0-22.0 White limestone, indurated, reddish brown weathered streaks.
 22.0-27.0 As above.
 27.0-30.5 White limestone, soft, weathered, coquinal.
 30.5-32.0 As above.
 32.0-37.0 No cuttings.
 Hole bottomed at 37 feet in cavity.

Hole No. W-26

PROJECT: Limestone
DRILLER: Clayton Davis
TYPE DRILLING: Rotary NX Core
COMMENCED: 9-16-64
COMPLETED: 9-16-64
LOGGED BY: J. W. Sweeney

Depth in feet below
land surface

Description

0-20

Fishtail 1.0 feet red sand overburden 19 feet reddish sandy clay.
Hole bottomed at 20 feet in clay.

Hole No. W-27

PROJECT: Limestone
DRILLER: Clayton Davis
TYPE DRILLING: Rotary NX Core
COMMENCED: 9-16-64
COMPLETED: 9-16-64
LOGGED BY: J. W. Sweeney

Depth in feet below
land surface

Description

0-20

Fishtail bit — 10 feet reddish brown clayey sand. 10-20 feet red-gray
mottled sandy clay.
Hole bottomed at 20 feet in clay.

