VOLUME IX NUMBER 1

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED

JANUARY, APRIL, JULY AND OCTOBER

BY THE

STATE GEOLOGICAL SURVEY

NASHVILLE, TENN.

JANUARY, 1919

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Administrative Report of State Geologist, 1918 .... By Wilbur A. Nelson

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The Coal Pyrite Resources of Tennessee and Tests on Their Availability .... By E. A. Holbrook and Wilbur A. Nelson

List of Publications

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LETTERS OF TRANSMITTAL

NASHVILLE, TENN., January 16, 1919.

To His Excellency, the Governor, and Members of the Geological Commission:

GENTLEMEN—In compliance with the law establishing the State Geological Survey, I have the honor to transmit the report of the State Geologist for the biennial term ending December 19, 1918.

The Survey was under the direction of Dr. A. H. Purdue until his death on December 12, 1917. Dr. L. C. Glenn was acting geologist in charge of the Survey until May 1, 1918, at which time I was appointed State Geologist.

Very respectfully,

WILBUR A. NELSON, *State Geologist.*

January 20, 1919.

To the Members of the Sixty-first General Assembly of Tennessee:

In accordance with the Act creating the State Geological Survey there is submitted for your investigation the administrative report of the State Geologist, covering the period from December 19, 1916, to December 19, 1918. We bespeak your careful consideration of the report, showing the important field occupied by the Survey and the work done by it during the biennial period that has just closed.

Respectfully submitted,

A. H. ROBERTS, *Governor, Chairman of the Commission.*

BROWN AYRES, *Secretary of the Commission.*

Administrative Report of the State Geologist, 1918

DEVELOPING OUR RESOURCES.

In the reconstruction period following the war, the State Geological Survey is as important a factor as it has been during the years of war which have just passed. Many problems have already been brought forward in which the Survey has taken an active part and supplied valuable data and information.

The possibility of oil and gas developments in the state is, at the present time, of great interest. It is one of our national resources with the greatest romance and lure. All the leading oil companies recognize the paramount necessity of having detailed geological work done on the structure of a region where there is a likelihood of oil being found, for it is known that certain types of structure are favorable for oil accumulations, and that if oil or gas is to be found such are the areas where the first drilling should be started.

This was the first work undertaken by the Survey on cessation of hostilities. The United States Geological Survey entered into a co-operative agreement to bear half the cost of this work and sent to Tennessee one of their experts to have charge of the field party which was to work the structure and oil and gas possibilities of a designated area, including portions of Clay, Fentress, Overton and Pickett counties. This area includes the old Spurrier oil eld which produced some oil in the nineties. When this work is completed it is hoped to map other likely areas in the state. Detailed studies and investigations of other mineral resources of the state are being continued by the Survey. A complete list of all reports, whether completed or in preparation, is given on pages 15 and 16.

Soil surveys are being made of the different counties of the state in co-operation with the United States Bureau of Soils, which also bears one-half the expense. In this manner a much larger area has been covered each year than otherwise would be possible if no co-operative agreement was in effect.

Educational work has been carried on throughout the state. In connection with this, an exhibit was prepared and shown at the State Fair, Nashville, Tenn.

A program for preliminary examinations of all water-power possibilities in Middle and East Tennessee has been started. The preliminary examinations already made have shown the presence of large amounts of undeveloped water power. After this investigation is completed a more detailed examination of all possible power sites and reservoirs is urgently needed, so that the state will be in possession of satisfactory information to furnish those interested in such developments. In the last month, an engineer, representing large Canadian interests, visited Tennessee for the purpose of investing in this section; but, although we had the water power, we did not have the detailed information necessary to show outside capital that it would be justified in making further surveys for that special project. With probably over one million undeveloped electrical horsepower in Tennessee, the necessity for this development work is apparent. Gauging stations have been established on many of the important streams and arrangements made whereby the United States Geological Survey pays half of this cost. The information obtained from such stations is essential to all parties that contemplate power developments.

New laws for the development and conservation of the natural resources of the state have been suggested and brought before the people of the state for their consideration. It is hoped that some of these suggestions will be enacted into law by the present legislature. Information has been furnished and reports prepared on cut-over land projects for the returned soldiers and sailors in accordance with the plans of the Reclamation Service of the United States Interior Department. Assistance was given in procuring a large acreage on the Cumberland Plateau on which the options secured were turned over to the government.

War Development.—During 1918, until the close of the war, the entire time and energies of the Survey have been devoted to war work. In war mineral work the Tennessee Survey has the record of being the first State Survey, out of more than a dozen, to publish a report on manganese localities and possibilities of development. This work and the report were made in co-operation with the United States Geological Survey. The value of this work to the people of the state is shown by the following extract from a letter which was written to Washington: "The working (Reece or Taylor Valley Mine) is on the opposite side of the ridge from what was the mine at the time of your visit, at about same elevation, in an ore body twelve feet thick opened for a length of fifty feet and which as a whole runs thirty-three per cent ore averaging forty per cent manganese. . . . The ground was prospected by augers at your suggestion, and the discovery of the deposit is credited directly and in full to your geologic work and its overthrust fault theory by the Southern Manganese Corporation and others, who regard it a big help to the cause." The value of this work to the government is shown by the total tonnage of manganese that was produced by Tennessee during the war period, which amounted to 7,330 tons, while the total tonnage produced in Tennessee previous to the war was approximately 2,680 tons. The total tonnage produced in the United States in 1914 was only 2,635.

Tennessee was fortunate in containing certain minerals which were necessary for the successful carrying on of the war, such minerals having been imported previous to the war.

In addition to manganese, work was done on the ball clay deposits of West Tennessee, on the pyrite deposits of East Tennessee, and the utilization of pyrite from coal.

Mines are operating in West Tennessee on clays suitable for use in making steel crucible pots, glass pots, and high tension electrical insulators, as well as table and sanitary ware. Such materials should be used at home for the manufacture of clay products instead of shipping the raw materials to northern points, where they are now manufactured into the finished articles of commerce.

When the government, at the beginning of the war, called for an increased production of pyrite in this country, the operating mines responded and shipped a greater tonnage. The point was soon reached when all these mines were producing their limit. Then it was necessary to find new supplies. To open new mines, even if they can be found, takes time. The question was, how can the supply of pyrite be increased? So all the occurrences of pyrite were tabulated, and it was shown that the greatest possibility lay in utilizing the waste pyrite from the coal mines of our country. This was a by-product that most of the mines had considered a nuisance and thrown away. There was one mine in Tennessee that was saving its pyrite and shipping it to one of the chemical companies.

Representatives of the Survey visited most of the coal mines in the state, tested their pyrite, showed them how they could separate and save it economically, procured them customers at a good price, and had satisfactory freight rates made on this commodity. By these methods the output of pyrite was increased and more sulphuric acid was made at a time when it was badly needed by the government.

The Survey has continually furnished maps to the United States army officer in charge of the progressive military map of the United States and all mapping recently carried on by the Survey has been where it would be of the most benefit to the War Department. Assistance was especially given in furnishing base maps of certain sections of the government aviation flight area in West Tennessee.

Additional War Duties.—In addition to its regular duties, the Survey has assisted the State Council of Defense in exploration work throughout the state. War mineral agents were appointed in most of the sections of the state and a great impetus given to the development of war minerals.

The State Geologist was designated by the War Department as District Certifying Advisor for the Mining Industry of Tennessee. All applications for indefinite furlough for return to metal mining and metallurgical industries of enlisted men in the United States Army were taken up through the Survey.

With the cessation of hostilities, this work changed to obtaining from all the mining companies a statement of their labor shortage, if any, and assisting them in getting their former employes discharged from the army in order that they might be put to work immediately upon their return. Although this work added greatly to the Survey's duties, it was all taken care of with the voluntary assistance of a former secretary of the Survey.

Advertising Our Resources.—Information is furnished daily by correspondence and in person to those who call at the office, on the minerals and other resources of Tennessee. Localities are given that are susceptible of development. Of course, it is impossible to trace in every case the valuable part that this information plays in the total development that takes place in the industries of Tennessee, but often mines are opened and new industries are developed through the Survey's activities. One instance is mentioned to show the value of a State Geological Survey along these lines. A Georgia mining company wished a deposit of high-grade limestone to be used as a substitute for whiting, and for sale to the paint trade for other purposes. The Survey knew of such a deposit near East Sparta, Tennessee, which was brought to the company's attention, with the result that they acquired the property and opened a quarry during the summer of 1918.

The *Resources of Tennessee,* a quarterly magazine published by the Survey, is devoted to the description, development and conservation of our resources. It shows the outside world that we are "discovering America" in this section of the South and that Tennessee's remarkable minerals, her forests, and undeveloped water powers will eventually make it one of the leading mining and manufacturing states of the Union. It has not yet reached the rank to which it is entitled. The Survey's magazine, as well as its special bulletins, are sent to every state in the Union, as well as to the principal countries of Europe, Asia, Africa, and South America, and it is a common occurrence for requests to be received for additional copies.

GEOLOGICAL WORK OF THE SURVEY.

Barite.—An investigation of the barite deposits in the Sweetwater district, Tennessee, was made by Dr. C. H. Gordon in 1917, and published in the *Resources of Tennessee,* Volume VIII, No. 1, pp. 48-82.

Clay.—Work has been done by Mr. Rolf A. Schroeder on the ball clays suitable for war purposes, in Henry, Carroll, Madison and Henderson counties. Tests of these clays are being made by Prof. C. W. Parmelee of the Ceramic Department of the University of Illinois, under a co-operative agreement with the United States Geological Survey.

Coal.—The coal report, which has been in progress for some time by Dr. L. C. Glenn and the State Geologist, is being revised for publication.

Coal Pyrite.—This Survey co-operated with the United States Bureau of Mines in an investigation of coal pyrite, the work being done by E. A. Holbrook. This report is ready for publication.

General Geology.—In 1915, Mr. Bruce Wade was engaged in the detailed field work necessary to mapping the geological formations in McNairy County. According to the plans of the Survey, this was the beginning of the geological mapping of a belt of country lying mainly west of the Tennessee River and extending northward across the state, known in geology as the Cretaceous area of Tennessee. The average width of this belt is perhaps forty miles. In the southern part of the state, it extends across the Tennessee River into Hardin County. In 1916, Mr. Wade, while a graduate student in geology at Johns Hopkins University, did an aggregate of two months' work, at such times as his studies permitted, on the McNairy County geological report. The latter part of the same year he completed the mapping of the Cretaceous deposits of Hardeman, McNairy, Hardin and Chester counties. Mr. Wade has been in active service in France for the past year or more but is expected to return soon and complete this work.

Dr. J. J. Galloway and Mr. H. N. Coryell were employed in studying the areal, stratigraphic, and economic geology of Rutherford County. This was done under co-operative arrangement between this Survey and the Agricultural Experiment Station, University of Tennessee. In connection with the geological mapping of this county, all of the field work was done for a soil map. Dr. Galloway has prepared the report on this county, which is now ready for publication. The base map of Rutherford County has been published.

Mr. Carl Dunbar completed his manuscript on the Devonian of West Tennessee in 1917 and it is now ready for the press.

The manuscript on the geology and mineral resources of the Crossville area by Mr. Charles Butts is ready for publication. This work was done in co-operation with the United States Geological Survey.

When the state geological map was published, a manuscript on the historic geology of Tennessee was also prepared to accompany the map. The work was done by Mr. Olaf P. Jenkins, and is now ready for the press.

Gravel.—In the work on mapping the Cretaceous formations in West Tennessee, Mr. Bruce Wade gave special attention to the gravel deposits that occur in the vicinity of the Tennessee River. His report on these gravels was published in the *Resources of Tennessee*, Volume VII, No. 2, pp. 55-98.

Limestone.—An investigation of the limestone along railroads in Middle Tennessee for fertilizer purposes was made by Mr. V. W. Blake and Thomas L. Bailey in the summer of 1917. This report is being prepared for publication and will include complete analyses of many of the limestones of this section. These analyses have already been completed by Dr. J. I. D. Hinds.

Manganese—As was true of many other minerals, the European war created a demand for manganese far above the average, and numerous inquiries came into the Survey as to its occurrence in Tennessee. A preliminary investigation of the manganese deposits of East Tennessee was made by the late Dr. A. H. Purdue in the fall of 1917, and an article on the manganese of Bradley County was published in the *Resources of Tennessee*, Volume VIII, No. 2, pp. 46-47.

In the summer and fall of 1918 extensive detailed work was done on manganese in East Tennessee in co-operation with the United States Geological Survey, Messrs. G. W. Stose and F. C. Schrader, representing the government, and Messrs. Arthur C. McFarlan and J. K. Roberts, representing the state. The work was inspected by Messrs. E. O. Ulrich and E. F. Burchard, of the United States Geological Survey. The material collected by these gentlemen was published in two papers in the *Resources of Tennessee*, Volume VIII, Nos. 3 and 4, pp. 153-198 and pp. 235-324, respectively.

The United States Bureau of Mines and the State Survey co-operated in work on the technology of manganese mining, the Bureau of Mines being represented by Messrs. Edmund Newton, W. R. Crane, and E. R. Eaton, one of whom spent most of the summer and fall of 1918 conferring with miners and encouraging the mine owners to increase their output. The report has been written by W. R. Crane and E. R. Eaton and is ready for publication.

Niter.—During the two months from July 15 to September 15, 1917, Mr. Thomas L. Bailey did field work on the caves of the Highland Rim and the Cumberland Mountains, for the purpose of ascertaining the quantity of niter deposits in these caves. The report, together with analyses on this work, was published in the *Resources of Tennessee*, Volume VIII, No. 2, pp. 85-142.

Oil and Gas.—During the last few years oil and gas have been eagerly sought in all parts of the country, and Tennessee has had its share of attention. The Glenmary oil field is still active, as shown in a report by Dr. L. C. Glenn, in 1918, published in the *Resources of Tennessee*, Volume VIII, No. 3, pp. 211-219. Dr. Purdue prepared an interesting report on the oil and gas conditions of the Highland Rim of Tennessee, which appeared in Volume VII, No. 4, pp. 220-228.

An article on the structure of the Waynesboro quadrangle with special reference to oil and gas, by Hugh D. Miser, was published in 1917. The field work for this report was done under a co-operative agreement between the United States Geological Survey and the State Survey, the former bureau being represented by Mr. Miser. A detailed report on this quadrangle was published in the *Resources of Tennessee,* Volume VII, No. 4, pp. 199-219. Dr. A. H. Purdue gives some very interesting facts concerning the Glenmary oil field in the *Resources of Tennessee,* Volume VII, No. 2, pp. 103-108.

Field work on the oil and gas conditions of Overton, Fentress, Clay and Pickett counties is now in progress, under a co-operative agreement between the United States Geological Survey and the Tennessee Survey, Mr. Charles Butts representing the former survey and Messrs. Rolf A. Schroeder and H. E. Hamilton representing the latter. Mr. Butts has charge of the work, Messrs. Schroeder and Hamilton assisting. The result of this work will be published as soon as practicable.

Pyrite.—An investigation of the pyrite in the Ducktown region is in progress. This work is also co-operative and an economical report will be printed later.

Water Power.—Professor J. A. Switzer, hydraulic engineer of this Survey, has made a report on the undeveloped water powers of Tennessee in co-operation with the Knoxville Board of Commerce. This report is now in the press.

Several gauging stations have been and will be established in Middle and East Tennessee to determine the daily run off of the main streams. This work is being done in co-operation with the Water Resource Branch of the United States Geological Survey, who are represented by their district engineer, Mr. C. G. Paulsen.

Zinc.—In 1917, Dr. A. H. Purdue started an investigation of zinc in East Tennessee, but his field notes have not yet been worked up.

County Maps.—In 1917 and early part of 1918, C. R. Watkins, Jr., did field work in preparing the maps of Henderson, Bedford, Carroll, and Maury counties. In March, 1918, Mr. Watkins resigned and in May, Mr. H. E. Hamilton was appointed traverseman, and has been working on Carroll, Overton and Shelby counties. The following table shows the mileage traversed, by counties:

Henderson (complete), all railroads, county roads, and streams.
Bedford (complete), all railroads, county roads, and streams.
Carroll (complete), all railroads, county roads, and streams.
Maury (complete), all railroads, county roads, and streams.

Soil Maps.—In the summer and fall of 1918, John H. Agee, of the United States Bureau of Soils, finished the soil map of Maury County, the work being done in co-operation with the Tennessee Survey. The soil map, with a report, will be published by the above bureau.

A soil map of Meigs County was started by Mr. Agee in the fall of 1918, but was suspended on account of the weather, and this work was transferred to Bedford County. A soil map of Rutherford County has been prepared by N. H. Coryell.

WORK OF THE CHEMIST.

The following is the report of the chemist of the State Geological Survey of work done during the years of 1917 and 1918:

Dr. Paul C. Bowers was chemist of the Survey until the early part of December, 1917, when he resigned to take up war work. Dr. J. I. D. Hinds was appointed to succeed him.

Dr. Bowers' report, including time between November 25, 1916, and December 10, 1917, is as follows:

Determination of Mineral Specimens Sent to the Survey.—Reports made, 220; number of specimens reported, 450; number of mineral contents reported in specimens, 875.

Quantitative Analyses.—Partial chemical analyses, 26 samples; number of determinations, 70.

Dr. Hinds' report follows: Work during the year, including time between December 10, 1917, and December 31, 1918. Nearly all the analyses were partial. A few, especially those of the limestone, were almost complete. Two analyses of water, that from the sulphur well of A. C. Jones and that from Reelfoot Lake, were complete and exhaustive.

Qualitative Analyses.—Number of analyses reported, 209; number of specimens examined, 293; number of constituents determined, 568.

Quantitative Analyses.—Number of analyses, 207; number of determinations, 595.

Cave deposits, nitrates and potassium	69
Limestones	54
Pyrites	25
Manganese ores	19
Phosphate rocks	15
Petroleum	5

Coal	4
Iron ores	3
Waters	3
Miscellaneous	10
Total	207

WORK OF THE FORESTRY DIVISION.

In addition to the regular forestry work, the Forestry Division has devoted a portion of its time during this period to specific war work as requested by the Federal Forest Service.

Educational Work.—(1) Personal visits were made to landowners and persons in Weakley, Carroll, Hardeman, Chester, Williamson, Lincoln, Hamilton, Franklin, Knox, and Sevier counties to inspire reclamation work and for the purpose of studying forest fire conditions. (2) Forty-one articles have been written for publication. (3) Two forestry exhibits were given at the State Fair, Nashville, Tenn. (4) Motion pictures of forestry subjects were given in Nashville. (5) A good deal of time has been spent in effort to organize a much needed forestry association in Tennessee.

Practical Work.—(1) One new gully club was formed in Weakley County. (2) Twenty-four experiments were conducted personally by the Forester, seven of which are new. (3) Ten pounds of black locust seed were secured by the Forester; four farmers planted seed for their spring setting. (4) Thirty-five thousand black locust seedlings were set out by farmers in West Tennessee, 3,000 in Middle Tennessee. (5) Two experiments in dynamiting were conducted. (6) A co-operative plan for gully reclamation and farm forestry has been agreed upon by the Forestry Division of the Tennessee Geological Survey, the United States Department of Agriculture, and the University of Tennessee, Division of Extension. This plan should be of much assistance in extending the work of reclamation, and in helping the farmers to care for and promote the growth of their woodlands.

War Work.—(1) About a half million feet of black walnut was located for the purpose of getting walnut in the hands of the purchaser. (2) One week was spent in the woods of Tennessee estimating black walnut, looking to its use for the government. (3) Owners of black walnut were visited with the view of advising them about selling their black walnut for gunstocks and aeroplanes. (4) The Forester acted as listing officer for the 20th Engineers (Forest) Regiment for Tennessee. (5) Help was given in the publicity campaign for wood fuel, in an effort to get farmers to deliver their wood to town for the relief of the coal situation. (6) The Forester visited Fayetteville and attended a meeting to assist in making effective plans for the working of a fuel company.

It is hoped in the coming year, through a forestry association, to further arouse the people of Tennessee to the absolute necessity of reclamation of Tennessee's waste and gullied lands and for the protection and conservation of her forests. The world is facing a period of reconstruction and the war has brought home the lesson as never before, that the conservation of a nation's natural resources means her prosperity.

GEOLOGICAL CORPS.

During the years 1917 and 1918, the following named persons were employed, most of them for only a part of the time, on this Survey:

Dr. A. H. Purdue was State Geologist until his death on December 12, 1917. Dr. L. C. Glenn was appointed Acting State Geologist and filled the place until May 1, 1918, when Wilbur A. Nelson, who had been elected *State Geologist*, took charge of the Survey.

Bruce Wade, *Assistant Geologist at Work on Cretaceous.*

R. S. Maddox, *Forester.*

J. A. Switzer, *Hydraulic Engineer.*

Paul C. Bowers, *Chemist.*

J. I. D. Hinds, *Chemist.*

C. R. Watkins, Jr., *Traverseman.*

H. E. Hamilton, *Traverseman.*

Rolf A. Schroeder, *Temporary Assistant on Clay Work.*

L. C. Glenn, *Temporary Geologist on Coal and Oil Work.*

C. H. Gordon, *Temporary Geologist on Marble and Barite Work.*

Arthur C. McFarlan, *Temporary Assistant on Manganese Work.*

Thos. E. Bailey, *Temporary Assistant on Cave Work.*

J. K. Roberts, *Temporary Assistant on Manganese Work.*

Carl Dunbar, *Temporary Geologist on Devonian of West Tennessee.*

J. T. Haden, *Temporary Draftsman.*

V. W. Blake, *Temporary Assistant on Limestone.*

Lewis M. Childress, *Secretary.*

Elizabeth C. Ingersoll, *Acting Secretary.*

Ruth C. Hall, *Secretary.*

Ruth Bulla, *Secretary.*

Roscoe Nunn, *Contributed Article on Climate of Tennessee.*

Park Marshall, *Contributed Article on Boundary Lines of Tennessee.*

S. T. Carman, *Temporary Laboratory Assistant.*

Hobart Watson, *Laboratory Helper.*

William Head, *Laboratory Helper.*

Mattie Clendenning, *Laboratory Helper.*

CO-OPERATIVE EMPLOYES.

The following named persons were employed a part of the time in 1917 and 1918, representing organizations that were co-operating with this Survey:

Hugh D. Miser, *representing the U. S. Geological Survey in the Waynesboro Quadrangle.*

Charles Butts, *representing the U. S. Geological Survey in oil and gas work.*

F. C. Schrader, G. W. Stose, E. O. Ulrich and E. F. Burchard, *representing the U. S. Geological Survey in manganese work in East Tennessee.*

Edmund Newton, W. R. Crane and E. R. Eaton, *representing the U. S. Bureau of Mines on manganese investigation.*

H. Ries, *representing the U. S. Geological Survey on Clay Investigations.*

E. A. Holbrook, *representing the U. S. Bureau of Mines on Coal Pyrite Investigations.*

C. W. Parmlee, *in charge of the Ceramic Department of the University of Illinois, and through an agreement with the U. S. Geological Survey tested clays in West Tennessee.*

John A. Agee, *representing the U. S. Bureau of Soils in soil surveys of Maury and Meigs counties.*

C. G. Paulsen, *representing the Water Resource Branch of the U. S. Geological Survey, placing gaging stations in Middle and East Tennessee.*

L. S. Hall, *representing the Water Resources Branch, U. S. Geological Survey, in stream gaging.*

W. D. Sterrett, *representing the U. S. Forestry Service, contributed an article on marketing woodlot products in Tennessee.*

W. R. Mattoon, *forstry specialist, representing the States Relation Service, U. S. Department of Agriculture, on farm forestry.*

PUBLICATIONS.

The following is a list of the publications of the Geological Survey from December, 1917, to December, 1918:

The Resources of Tennessee, Volume VII, Nos. 1, 2, 3, 4.

The Resources of Tennessee, Volume VIII, Nos. 1, 2, 3, 4.

Bulletin 19—Elevations in Tennessee.

Bulletin 20—The Larger Undeveloped Water Powers of Tennessee.

Map of Shelby County, published 1918.

Map of Decatur County, in press.

Map of Chester County, in press.

MANUSCRIPTS AND MAPS.

Some of the following manuscripts and maps are ready for publication and the others are in course of preparation:

The Historic Geology of Tennessee, by Olaf P. Jenkins. (Ready for press.)

The Marbles of Tennessee, by C. H. Gordon, T. N. Dale, and Oliver Bowles. (Ready for press.)

The Geology of Rutherford County (with map), by J. J. Galloway and H. N. Coryell. (Ready for press.)

The Tennessee Coal Fields, by L. C. Glenn and W. A. Nelson. (In preparation.)

Tennessee Phosphates, by J. S. Hook. (In preparation. Delayed on account of Mr. Hook going to war.)

Geology and Mineral Resources of the Crossville Quadrangle (with map), by Charles Butts. (Ready for press.)

Geology of McNairy County, by Bruce Wade. (In preparation.)

The Cretaceous Geology of Decatur County, by Bruce Wade (In preparation.)

The Cretaceous Geology of Hardin County, by Bruce Wade. (All of these papers probably would have been ready for press, but Mr. Wade went in training in 1917, and has been in France in active service for a year or more.)

Forests, Gullies and Reconstruction, by R. S. Maddox. (Ready for press.)

The Coal Pyrite Resources of Tennessee and Tests on Their Availability, by E. A. Holbrook and Wilbur A. Nelson. (Ready for press.)

The Mining and Preparation of Manganese Ores in Tennessee, by W. R. Crane. (Ready for press.)

Preparation of Manganese Ores, by W. R. Crane and E. R. Eaton. (Ready for press.)

Ball Clays of West Tennessee, by Rolf A. Schroeder. (Ready for press.)

Map of Henderson County. (In preparation.)

Map of Carroll County. (In preparation.)

Map of Maury County. (In preparation.)

Map of Bedford County. (Ready for press.)

The total amount expended for geological, soil and forestry work in Tennessee from December 19, 1916, to December 19, 1918, is shown in the following table. With the exception of the first item, this money was expended under co-operative arrangements between this Survey and other organizations:

TOTAL EXPENDITURES.

Expenditures as shown by the preceding Table of Expenditures	$32,885.42
Expended by the U. S. Bureu of Soils, May 1, 1917, to Oct. 1, 1918	2,729.41
Estimated expenses from Oct. 1, 1918, to May 1, 1919, $1,800 00.	
Expended by the U. S. Geological Survey (field expense)	772.03

APPROPRIATION REQUESTED.

The following appropriation is requested of the Sixty-first General Assembly and has been approved by the Geological Commission:

For the purpose of carrying on work of the Survey in accordance with Senate Bill No. 330, Chapter 569, Acts of 1909, from July 1, 1919, to July 1, 1921, salaries and expenses	33,000.00
To be applied toward publishing *Resources of Tennessee*	2,000.00
To be applied toward the publication of bulletins	6,000.00
For the maintenance of the Forestry Division of the Survey, salaries and expenses	10,000.00
Total	$51,000.00

APPROPRIATION FOR TWO MONTHS—MAY AND JUNE—BETWEEN OLD AND NEW APPROPRIATIONS.

For the purpose of carrying on the work of the Survey in accordance with Senate Bill No. 330, Chapter 569, Acts of 1909:

Salaries and expenses, also printing	$3,400.00
Forestry Division	800.00
Total	$4,200.00

TABLE OF EXPENDITURES FROM DECEMBER 19, 1916, TO DECEMBER 19, 1918.

	Office Salary	Field Salary	Field Expenses	Printing and Engraving	Equipment	Supplies	Postage	Freight, Drayage, Telep., Etc.	Miscellaneous	Total
ADMINISTRATION:										
General	$ 3,525.63	$1,199.95	$ 466.02	$ 51.40	$ 423.00	$ 214.77	$ 1.16	$ 187.50	$ 195.11	$ 6,264.54
REPORT AND SURVEY:										
General	....	501.42	156.72	....	314.61	86.75	....	1.30	....	1,060.80
LIBRARY	....	....	....	....	76.57	....	....	....	....	76.57
LABORATORY	3,366.11	....	....	....	2.75	115.03	....	....	....	3,483.89
AREAL GEOLOGY:										
McNairy County	175.00	....	....	....	....	....	....	....	....	175.00
Rutherford County	47.00	....	....	....	....	....	....	....	....	47.00
METALLIC ORES:										
Zinc in East Tennessee	....	243.86	74.81	....	8.40	17.34	....	....	....	344.41
FUELS:										
Coal	....	211.66	....	....	....	....	....	....	....	211.66
Oil and Gas, Special	....	96.66	11.89	....	....	....	....	....	....	108.55
BUILDING STONE:										
Marble	85.00	12.00	29.42	....	....	....	....	....	....	126.42
STRUCTURAL ROCK PRODUCTS:										
West Tennessee Clay (war work)	129.74	412.54	372.85	....	64.34	147.74	4.78	1.20	15.75	1,148.94
CHEMICAL AND ARTS MATERIALS:										
Limestone for Fertilizer	....	139.94	69.45	....	....	....	.49	1.91	....	211.79
Niter	1.62	99.20	82.36	....	1.40	....	.60	....	....	185.18
WATER RESOURCES:										
Undeveloped Water Powers	74.75	35.00	66.20	5.52	....	....	....	....	....	181.47
Gauging Stations	....	....	178.17	....	....	....	....	....	....	178.17
SOIL SURVEY:										
Shelby County	20 00	....	4.50	....	....	....	....	....	....	24.50
Maury County	....	200 00	213.97	....	2.35	....	.25	2.21	....	418.78
Rutherford County	20.00	....	....	....	....	....	....	....	....	20.00
FORESTRY:										
General	2,515.15	2,486.85	696.97	749.82	91.34	46.34	8.58	50.89	16.15	6,662.09

INFORMATION:										
General	2,823.44	276.66	120.25	.50	92.03	130.55	286.08	1.60		3,731.11
Photos					17.85					17.85
STATE EXHIBIT		25.00	44.00		1.30			19.13		89.43
RESOURCES OF TENNESSEE	863.82	120.00	308.15	1.667.52		31.81	58.92	5.04	.40	3,055.66
COUNTY MAP:										
McNairy County				384.16						384.16
Rutherford County			.50							.50
Henderson County		260 00	255.31		.80		.35	1.44		517.90
Bedford County	5.00	311.00	342.19					.50		658.69
Carroll County		1,084.33	825.28	2.85	54.71	15.20	2.11	8.13	4.10	1,996.71
Shelby County			3.10	60 00					18.38	81.48
ELEVATIONS IN TENNESSEE	45.00			413.91						458.91
WAR WORK:										
Manganese	41.76	386.66	424.81	22.50	74.65	8.90	4 00	71.91	3.25	1,038.44
Coal Pyrite	50.00	215.50	160.16					3.59		429.25
Total	$ 13,789.02	$8,318.23	$4,907.08	$3.358.18	$1,226.10	$ 814.43	$ 367.32	$ 356.35	$ 253.14	$ 33,389.85

Due to war conditions there were delays in paying several large bills for work on manuscripts and for printing that has been contracted for but not completed. These accounts will bring the total expenditures up to the amount appropriated.

ACT ESTABLISHING THE GEOLOGICAL SURVEY.

The bill establishing the State Geological Survey was passed by the Fifty-Sixth General Assembly of Tennessee in 1909, and is as follows:

CHAPTER 569.

SENATE BILL NO. 330.

(By Messrs. Greer, Huffaker, and Neal.)

A BILL to be entitled An Act to establish and create the bureau to be known as the State Geological Survey; defining its objects, powers, and duties; providing for the appointment of a State Geologist, and defining his powers and duties; permitting co-operation with Federal and State bureaus in furthering the objects of this Act; providing for the publication of the results of the Survey; providing for the collection of exhibits of the natural resources of the State, and for the final disposition of the equipment and property of the Survey; authorizing entrance upon private lands in the prosecution of the work of the Survey; and making the appropriations for the enforcement of this Act.

SECTION 1. *Be it enacted by the General Assembly of the State of Tennessee*, That there be, and is hereby, created and established a bureau to be known as the "State Geological Survey," which shall be under the direction of a Commission to be known as the "State Geological Commission," composed of the Governor (who shall be ex-officio Chairman of said Commission), the State Commissioner of Agriculture, the State Mine Inspector, the President of the University of Tennessee, the Chancellor of Vanderbilt University, and the Vice Chancellor of the University of the South.

SEC. 2. *Be it further enacted*, That the said Commission shall have general charge of the State Geological Survey and shall appoint as Director a Geologist of established reputation, who shall be known as the "State Geologist," and upon his recommendation such associate geologists, assistants, and employes as may be necessary to carry out successfully and speedily the work of the Survey.

The Director, associates, assistants, and employes appointed under the provisions of this Act shall receive such compensation as shall be determined by the Commission. The said Commissioners shall serve without compensation, but shall be reimbursed for actual expenses incurred in the performance of their official duties.

SEC. 3. *Be it further enacted*, That the said Commissioners shall meet for organization within thirty days after the passage of this Act, and shall appoint a Director as soon thereafter as possible. The regular meetings of the Commission shall be held on the first Wednesday in May and the first Wednesday in November of each year in such place as the Commission shall determine.

SEC. 4. *Be it further enacted*, That it shall be the duty of the State Geologist, subject to the approval of the Commission, to organize and direct the work of the State Geological Survey in field and office; to determine the character, order, and time of publication of the reports of the Survey, and to direct the preparation, printing, and distribution of the same; to arrange for co-operative work with the various Federal and State scientific bureaus where such work shall redound to the interest of the people of the State; to appoint such associates, assistants, and employes as may be necessary to carry out successfully and speedily the work of the Survey; to procure and have charge of the necessary field and office supplies and other equipment, and supervise the acquisition, care and distribution of the collections of the State Geological Survey; and to perform such other work as may be necessary to the successful conduct of the Survey. He shall prepare a report to the General Assembly before each meeting of the same, setting forth the progress and conditions of the Survey, together with such other information as the commission may deem necessary and useful.

SEC. 5. *Be it further enacted,* That the said State Geological Survey shall have for its objects and duties the following:

1. A study of the geological formations of the State, with especial reference to their economic products, including coal, oil, gas, ores, fertilizers, building stones, road-making materials, clays, cement materials, sands, soils, forests, mineral and artesian waters, drainage of swamps, streams, and water powers, and other natural resources.
2. A study of the character, origin, and relations of the soils of the State, with especial reference to their adaptability to particular crops, the maintenance of soil fertility, and the conservation and utilization of supplies of natural fertilizers.
3. A study of the road-making materials of the State, with reference to their character, distribution, and the best methods of utilizing the same.
4. A study of the occurrence and availability of underground water supplies.
5. An investigation of the forests, streams, and water powers of the State, with especial reference to their conservation and development for industrial enterprises.
6. A study of the swamps and other non-tillable lands of the State, with reference to their reclamation for agricultural purposes.
7. A study of the physical features of the State, with reference to their bearing upon the occupations, physical welfare, and intellectual pursuits of the people.
8. The preparation of special reports with necessary illustrations and maps, which shall embrace both general and detailed descriptions of the geology, topography, and natural resources of the State.
9. The preparation of special geologic, topographic, and economic maps to illustrate the structure, relief, and natural resources of the State.
10. The consideration of such other scientific and economic questions as in the judgment of the Commission shall be deemed of value to the people of the State.

SEC. 6. *Be it further enacted,* That the regular and special reports of the State Geological Survey, with proper illustrations and maps, shall be printed and distributed and sold as the Commission shall deem best for the interest of the people of the State and as said Commission may direct, and all moneys obtained by the sale of said reports shall be paid into the State treasury. The said Commission shall cause to be prepared a report to the General Assembly before each meeting of the same, showing the progress and condition of the Survey, together with such other information as they may deem necessary and useful, or as the General Assembly may require: *provided, however,* that the Commission shall have the right to print and distribute said reports.

SEC. 7. *Be it further enacted,* That after having served the purposes of the Survey, all material collected shall be distributed by the Director to the educational institutions of the State in such manner as the Commission may determine to be of advantage to the educational interests of the State; *provided, however,* that if deemed advisable, the Commission may first use such portion as may be necessary to establish a permanent exhibit of the natural resources of the State. On the completion or discontinuance of the State Geological Survey, the Commission shall cause all records, notes, books, reports, charts, maps, manuscripts, instruments, and other equipment and property of the Survey to be placed in charge of a suitable custodian, to be held subject to final disposition by the General Assembly; *provided, however,* that any field or other equipment which the Commission shall deem it undesirable to preserve may be sold as the Commission may direct and the money turned into the State treasury; and, *provided further,* that the copies of the reports of the Survey left on hand for distribution shall be distributed by the custodian in such manner as shall be for the best interest of the people of the State.

SEC. 8. *Be it further enacted,* That the said Commission is hereby authorized to enter into co-operation with the United States Geological Survey and other scientific bureaus of the Federal and State governments for the prosecution at joint expense of such work in the State as shall be deemed of mutual interest and advantage, and under such conditions as said Commission may deem to be for the best interest of the people of the State.

SEC. 9. *Be it further enacted,* That in order to carry out the provisions of this Act, it shall be lawful for any person or persons employed hereunder to enter and cross all lands within the State; *provided,* that in so doing no damage is done to private property.

SEC. 10. *Be it further enacted,* That for the purpose of carrying out the provisions of this Act, fifteen thousand dollars ($15,000) annually for the years 1910 and 1911, or so much thereof as may be necessary, is hereby appropriated out of any money in the State treasury not otherwise appropriated, and the State Treasurer is hereby authorized to pay out the same on the warrants of the Comptroller upon the presentation of the proper vouchers by the Chairman of said State Geological Commission; *provided,* that the appropriation made herein shall not be available until May 1, 1910.

SEC. 11. *Be it further enacted,* That this Act take effect from and after its passage, the public welfare requiring it.

Passed April 30, 1909.

WM. KINNEY,
Speaker of the Senate.

M. HILLSMAN TAYLOR,
Speaker of the House of Representatives.

Approved May 1, 1909.

MALCOLM R. PATTERSON,
Governor.

Forests, Gullies and Reconstruction

By R. S. Maddox.

INTRODUCTION.

The world war is over. We have been shaken by it out of our lethargy and, though a rude awakening, it has revealed to us truths which perhaps we might by no other means have so certainly apprehended. Each country which was engaged in the conflict is now endeavoring to find herself and is taking stock, as it were, so that she may start again upon a firm basis for future prosperity. In this stocktaking certain facts become apparent. Professor J. W. Toumey, director of the Yale School of Forestry, says: "Victory is with the army whose country has the greatest iron mines and smelters, the largest areas of waving grain, and an abundance of wood. . . . If the French had had no forests at the outbreak of the war, France would be devastated today and the nations of Middle Europe feasting in the halls of Paris." It was found during the war that there was no successful substitute for wood—that the soldiers had to be housed in wooden cities instead of tents; that railroad ties, trench supports, roads for transporting artillery, all had to be provided from wood. In addition, our country was scoured for black walnut and black locust to be used for gun stocks, aeroplane stocks, and tree nails for shipbuilding, besides hundreds of millions of board feet of spruce cut from our northeastern and northwestern forests. The fact that our northwestern country alone supplied in one month for aeroplanes three hundred million board feet, may serve to give a small idea of the vast amounts utilized. The paramount importance of food production has been also forcefully brought home to us. Fortunately, our country was not devastated by the war, but the great supply of timber needed from our forests, the enormous quantities of foodstuffs necessary at home and for our allies abroad, should keep us mindful of the incalculable value of our forested and agricultural lands, and make us ever vigilant and active in their conservation.

FORESTED AND FARM LANDS.

Heretofore Tennessee has been noted for the abundance of her hardwood timber and fine agricultural lands. We might say that Tennessee yet has a good acreage of woodlands and an abundance of agricultural lands, but we must at the same time recognize the fact that she has been wasting these resources. Let us consider the forest problem first.

FORESTS.

Forests are the lands which we have in tree growth. Ours in Tennessee have been reduced by constant clearing to thirty or thirty-five per cent of the state's area. Much of this area has already

FIGURE 1. A portion of Tennessee's mountain land where fires have burned without interference. There is no evidence that any timber was ever cut from this area. The young growth has sprung up since the fire three years previously. There should be a heavy stand of good trees.

been cut over, during which process the best trees have been removed. These portions are situated chiefly on the Highland Rim, Cumberland Plateau and the mountains of East Tennessee. These, together with the more scattered woodlands over the state, constitute Tennessee's forests. They contain in sum total an abundance of trees, but not an abundance of timber.

Causes of Forest Conditions.—There are several causes which have contributed to the condition of our forests. The acreage of these woodlands has been reduced too rapidly in proportion to our population, making the forest area comparatively small. In addition, the best trees have been removed from the forests, without any plan for securing new growth and protecting it. Forest fires have been permitted to run unchecked through not only the cut-over areas, but also through those sections yet untouched by the axe. Promiscuous grazing, which has in many cases been closely related to the burning of forest fires, has also helped to diminish the new growth. This comes from permitting stock to graze on burned-over areas, consuming and trampling the remaining young trees.

Importance of Forests.—In the introductory paragraph of this article, it has been shown how important a country's timber supply is to her in an emergency. Vital as forests are for timber production in peace, as well as in war times, they are equally necessary for other uses. Forests are of inestimable value for the protection of our stream flow; without them the rains falling upon our watersheds would have little or no obstruction, thus causing floods down the bare mountain sides, followed by severe drought. In this way, obviously, forests are necessary to agriculture and other industries. The development of water power throughout the state is absolutely dependent upon the forests. Woodlands, too, are the habitat for wild life of all kinds, a part of any state's recognized resources. Fires should be kept out, reforestation should be done, harmful grazing stopped and careful cutting practiced, thus enabling Tennessee to have full stands of valuable forest trees.

GULLIES.

Description.—In considering gullies, we might say lands may be classed as waste when they are badly gullied or sheet washed, so as to be practically useless and a positive source of harm. Without an actual survey and a definite standard of classification, it is impossible to state the acreage of waste lands in Tennessee. From estimates, however, through observation while working in different sections of the state and traveling through others, the writer does not hesitate to say that such lands will most conservatively reach seven hundred and fifty thousand acres. Any man from the car window or public road can easily observe these conditions. Fields of moderate slope and deep soil once cultivated are so badly cut up with gullies that they can no longer be tilled; then being useless they are turned out to waste. Slopes with

FIGURE 2. The type of hill and mountain land that should never be cleared. Such areas should be kept growing timber. The corn rows are noticeable in the picture

FIGURE 3. Mountain land cleared and used for pasture, which should always grow forests. The sloughing off of the surface is very noticeable.

shallow soil have washed until the underlying rocks are so close to the surface that cultivation is practically out of the question. Steep hills and mountain sides cleared and worked for a comparatively short time have been, through erosion, virtually ruined for years to come; lands of this same type also when used for pasture after clearing have sloughed off and eroded to such an extent that they are useless.

Causes of Gullies.—Chief among the causes for these waste and gullied lands are: First, *the character of the soil, i. e.*, the soil constituency. Some soils do not erode rapidly because of the heavier, stiffer clays composing them. Others erode more rapidly because of the admixture of sand with the clay; this is particularly so in West Tennessee. Primarily because of this soil constituency, this section of the state, although comparatively level, is subject to heavy erosion if neglected or abused. Second, *shallow plowing*. This is responsible for a great share of the waste lands all over the state. A thin layer of plowed ground is soon saturated with water; added precipitation then cannot soak rapidly enough into the hard subsoil and therefore runs off over the surface, causing sheet wash or gullies. Third, *constant crop production* (which is not the same as cultivation) *without renewal of fertility*. This lies at the root of much washed land in Tennessee, for land must be renewed in fertility by decayed vegetation in order to render it capable of receiving and retaining necessary moisture. Decayed vegetation itself is a great water container and makes land porous. This can be observed in the mushy decayed remains of an old straw pile. When the vegetable matter, or humus, is quite exhausted the soil becomes less porous and the water runs off more readily over the surface. It is interesting to note that humus changes the color of soil. To cite an example, some clays in the state are very red when lacking in vegetable matter, but with the addition of humus they become a rich chocolate shade. Fourth, *rows running up and down the hill*. This is a very common and harmful practice connected with farming; it causes the surface soil to be carried off down the furrows, exhausting the fertility and causing gullies. Fifth, *clearing of hillsides too steep for cultivation*. Such areas cannot be maintained under the present system of agriculture; even as pasture lands they slough off through the trampling of stock, finally developing into gullies.

Injuries from Gullies.—From an economic standpoint one observes several facts concerning waste lands. Their presence depresses prop-

FIGURE 4. A badly gullied area on the farm of Will Roberson, Dresden, Weakley County, Tennessee, as it appeared before reclamation was started. Work was begun on it August, 1917, by building brush dams and plowing off the gully banks.

FIGURE 5. The same area as Figure 4, showing the black locust and bushes in July, 1918, which were set out in March, 1917. The letters A and B in Figure 4 and 5 show the same places before and after reclamation was begun.

erty values as a caved-in roof affects the value of a house. Also they consume, instead of produce; they eat in upon new land, convey fertility away from the farm and turn good fields into waste by depositing sand, stone and gravel over them. Sometimes they convert bottom lands into swamps, by choking streams with sand, thus causing water to spread over the bottoms. Because of increasing waste lands, new areas of woodlands must be cleared to supply the needed acreage for cultivation and thus forests are sacrificed.

Prevention and Cures.—If there were no harm resulting from waste lands, there would be no practical reason for preventing or reclaiming them, but they are a menace, and the need for restoring them is urgent. There are preventions and cures for these sick areas. Among the preventive measures that might be used are the following: Slopes too steep for cultivation and lands too shallow in soil for tillage should be left uncleared; fertility in cultivated lands should be maintained by supplying regularly the necessary vegetable humus; cover crops should be grown, especially on hillside fields, which should not be allowed to lie bare during the winter; rows should never be run up and down the hills and the ground should be plowed deep. Now for the cures: Practically all, to say the least, of Tennessee's waste lands can be reclaimed, if not for raising agricultural crops, then for raising timber. In stopping erosion, the main object is to catch and hold the escaping dirt. This can be done by making the same agency that washed away the land help build it up again. Thus as the water flows down the channels, carrying the dirt, it must be checked by some obstruction in the bottom of the gullies and forced to deposit its load. These obstructions are merely dams and can ordinarily be built easily and cheaply out of brush. Catching the dirt is but the first step in the reclamation project. It is necessary, next, to secure a permanent growth on the dirt which has been caught by the dams. Usually this can be obtained only by planting, since dams rot out in a few years and voluntary growth by that time rarely is sufficiently strong to hold after the dams are gone. It is often desirable and advisable to plow off the banks, so the dams may more rapidly catch dirt on which to set out growths. Black locust bushes, Bermuda grass and honeysuckle vines have so far proved most successful for this purpose; they have a permanent, strong root system. In addition, they yield a revenue in the form of posts and grazing. Black locust should be cultivated the first year. During this tillage, soy beans and stock peas fre-

FIGURE 6. A very badly eroded area of waste land on the farm of L. C. Brown in the northeastern part of Weakley County, Tenn., near Boydsville, Kentucky. The dams were built in the summer and fall of 1917, the banks plowed off as shown in the picture and the entire area set in black locust in the spring of 1918.

FIGURE 7. The same area as Figure 6, showing the black locust bushes in July, 1918, which were set out in March, 1918. By the time the dams decay the locust trees will have the ground thoroughly bound with their roots.

quently can be planted with them as fall pasture for hogs. No other stock, however, should be permitted in a locust grove, since they injure or kill the young trees by browsing upon them and tramp the ground hard upon the roots. In the spring of 1916 fifty thousand black locust seedlings, in the spring of 1917 sixteen thousand black locust seedlings, and in the spring of 1918 thirty-five thousand black locust seedlings

FIGURE 8. Three-year-old black locust on a once badly gullied area on the farm of Leslie J. Buford, Franklin, Tennessee. The gullies were plowed after dams were built, some dynamiting done, and the area (about two and a half acres) set in black locust in the spring of 1915. Picture taken November, 1918.

were planted in West Tennessee alone. The Forestry Division has a good many areas successfully undergoing reclamation.

The state must keep vigorously working on her forest and waste land problems. Gullies are a menace both to forests and to agricultural lands; forest fires are a menace to woodlands and agricultural lands. He would be a poor fisherman who would go out constantly with his nets full of holes. Waste land on the farm and fires in the woodlands are holes in the net. The holes must be mended.

The Mining and Preparation of Manganese Ores in Tennessee

By W. R. Crane.*

INTRODUCTION.

The character of minerals and their occurrence often have important bearings upon the work of mining and preparing for market; it is therefore considered not only desirable, but necessary in this connection, to discuss briefly the different forms of deposits. Further, the knowledge of the mode of occurrence may be of considerable service in the location of ore deposits and in proving their extent and value.

The minerals found in the manganese districts of East Tennessee are pyrolusite, psilomelane and manganite, the first two occurring in the greatest abundance, although the last mineral is often found in considerable quantities. The manganese oxide mined at the Henley mine in the Greenback district is probably one of the important occurrences of manganite in the state. The carbonate of manganese, rhodochrosite, is found in what promises to be a fair-sized deposit in the East Fork Mine near Sevierville. The other oxides of manganese occur in deposits of varying size and importance in the Johnson, Sweetwater and Cleveland districts, being largely pyrolusite and psilomelane.

TYPES OF DEPOSITS.

General Classes.—There are a number of types of manganese deposits, but most of the occurrences can be grouped under two general types, namely, replacement and cavity filling. In Tennessee, as in most of the manganese districts of the Southern States, there is indisputable evidence that the manganese has been collected from widely scattered sources and has been concentrated from solution in underground waters. A discussion of the source and origin of the ores is not in the province of this paper, but to secure an adequate idea of the

*The field work on this report was done under a co-operative agreement between the State Geological Survey and the U. S. Bureau of Mines. This report is published by permission of the director of the U. S. Bureau of Mines.

character and form of the ore deposits now worked, it is desirable to consider briefly their mode of formation.

The manganese deposits of East Tennessee are associated with iron ores, particularly limonite and hematite, and occur in limestones, dolomite and sandstone. It is also possible that certain deposits may occur in shale beds.

The formations in which the manganese occurs are, in order from below upward, Knox dolomite, Chickamauga limestone (Lenoir of Ulrich), Holston marble, Athens shale, and Tellico sandstone. Probably the larger number of known occurrences of workable deposits are in dolomite, marble and sandstone, but owing to the wide variations in thickness and extent of these formations, also owing to their excessive decay, it is not always possible to determine exactly to which formation a given deposit may be referred.

Replacement Deposits.—By replacement the manganese minerals have taken the place of the various formations and as the immediate source of the manganese was the solutions of the minerals in the underground waters, such replacement naturally took place in fractured areas, in fissures and in bedding and joint planes. Wide variations in thickness and extent of ore bodies would result from such conditions of formation and such are observed in the deposits of this region. The decay of the formations in which replacement took place or where the minerals were deposited, has in the majority of cases freed the minerals, leaving them in the clays, sands and other residual materials. Ample evidence exists, however, to demonstrate that the minerals formerly occurred in the limestones, sandstones and dolomites, as they are still found in these formations, where the decay has not proceeded sufficiently far nor sufficiently deep locally to have separated the mineral from the parent rock.

Manganese occurs in and is a part of the Holston marble or is closely attached to it in the mines in the Sweetwater and Cleveland districts, particularly the McGuire and the Flint Springs mines.

Manganese is also found in the Knox dolomite at the East Fork Mine in the Sevierville district. In the majority of cases the oxides occur in clays and sands, while in the East Fork Mine the carbonate is found in depth in the dolomite, the decay of which has not yet freed the manganese. However, in the upper portions of this deposit the decay of the dolomites has exposed the carbonate to oxygen-bearing waters, which have altered the carbonate to oxides, particularly the mineral psilomelane; in this deposit there are found, therefore, both the unaltered carbonate and the altered product or oxide.

Residual Deposits.—The ores of manganese are in the case of the oxides largely mixtures of mineral and clays or residual products; however, in the case of the carbonate the mineral is still inclosed in the parent rock and is a true ore. The fracture-filling or breccia type of ore is a class intermediate between those above mentioned. The usual occurrence of manganese minerals in clays and sands might more appropriately be spoken of as wash-dirt than ore, as by the simple

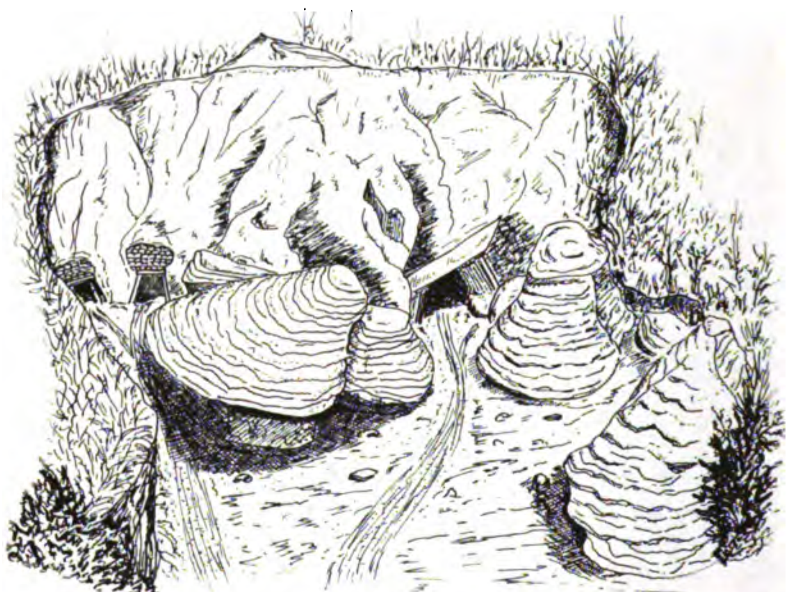


FIGURE 1. Open cut at the McGuire mine, Tennessee, showing effect of limestone pinnacles on method of mining.

process of washing the mineral can be separated from the wastes, while with the rhodochrosite ore preliminary concentration or roasting may be desirable or necessary.

Probably owing to the absence of limestones particularly susceptible to the solvent action of ground waters, the decay of such rocks has not been as excessive as in other localities where the depth of the residual deposits is often one hundred feet or more. That the decay of the limestones and dolomites has been great and is undoubtedly still continuing is evident on examination of the surface and underground workings of the various manganese mines. The decay is also extremely irregular, as is shown by the surface of the bed rock and the presence of large boulders of limestone resting upon it.

It is evident, then, that there are three general kinds of ore mined in this region, namely, the mineral-bearing clays, the breccia ore, and the hard ores of manganese and dolomite, each of which requires a wholly different method of mining and treatment in its preparation as a marketable product.

The two general types of deposits have been brienfly dsicussed particularly with respect to the effect that their occurrence has upon mining and preparation. Aside from the types of deposits there are a number of forms that also have important bearing upon methods of mining and preparation. With the forms as with the types of deposits, a considerable number can be grouped together under a few typical classes, the most important of which are the blanket and irregular forms.

Blanket Deposits.—The blanket form of deposit is probably the most important, both with regard to the quantity and value, the irregular form being a close second. The blanket form is a replacement type of deposit and is found adjacent to and often firmly attached to the Holston marble. Occasionally decay of the marble has proceeded below and beyond the blanket of manganese, consequently freeing it from the marble, upon or close to which it is still found, unless broken up and removed by earth movement and erosion. The blanket of ore conforms in a marked degree with the lay of the bed rock, lying on the flat-lying portions and riding over the irregular masses and boulders, forming a veritable blanket of manganese. In many respects the blanket resembles a bedded deposit, except for its extreme irregularity and lack of conformity with the other and associated formations.

The manganese minerals composing the blanket have a wide range in character and value, and taken as a whole are of greater value than those found in other forms of deposits. In certain localities the grade of the oxides is as high as 55 to 56 per cent metallic manganese. Considerable quantities of iron ore are associated with the blanket form of deposit, occurring in the marble bed rock, in blanket form above, below and interstratified with the manganese. The blanket form of deposit, when broken up and mixed with clays and sands, is considered under the class of mineral-bearing clays or wash-dirt, but owing to its occurrence, such material is difficult to handle and treat systematically in any regular washing or concentration process, being in large and irregular masses.

Irregular Deposits.—The irregular form of deposits is much more varied in its character and mode of occurrence than is the blanket form, and may be subdivided into a number of classes, such as nodular, granular, soft and breccia.

The nodular and granular forms of mineral constitute the most irregular deposits and are therefore the most difficult to locate and determine with respect to their value and extent. The nodular form differs from the granular in that the latter is fragmental, while the former is composed of complete pieces as formed by replacement in the formation from which it came. The occurrence of the two forms is identical within the deposits and has no order at all except as controlled by the extent and dip and strike of the formations in which they are contained. Occasionally the deposits assume a banded form, continuing for some distance with a considerable degree of persistency, then terminating in stringers or enlarged masses. Owing to the thickness of the enclosing formations, it is practically impossible to employ the available information concerning them as a guide in the economic development of the irregular deposits of manganese.

The soft or wad forms of ore are similar in character to the nodular and granular forms, but are, as a rule, more variable as to value, usually being very low in grade. It is probable, also, that the amount of such manganiferous clays is greater than of the other forms mentioned; however, they are of much less consequence economically than the nodular and granular forms.

The last form of irregular deposit considered is the breccia ore, which while very irregular, may prove to be of greater economic importance than the other forms, due to the greater tonnage that such deposits probably contain. The breccia ore in itself is hard, being composed of quartzite, sandstone or chert, which has been extensively fractured by earth movement, and later cemented together again by manganese minerals. Intimately associated with such deposits are other irregular deposits of nodular and granular manganese, which in certain instances may have been derived wholly or in part from the breccia deposits. The combination of clay and manganese with hard ore presents added difficulty to mining and treatment, but is not insurmountable. The grade of the breccia ore is low, probably seldom exceeding 15 per cent and possibly averaging somewhat below that figure; however, owing to the relatively large amounts of such ores, its mining and treatment are worthy of careful consideration. Probably the most extensive deposit of breccia ores so far developed in eastern Tennessee is on the White Oaks property in the Cleveland district, although there are other occurrences, particularly in the Johnson district.

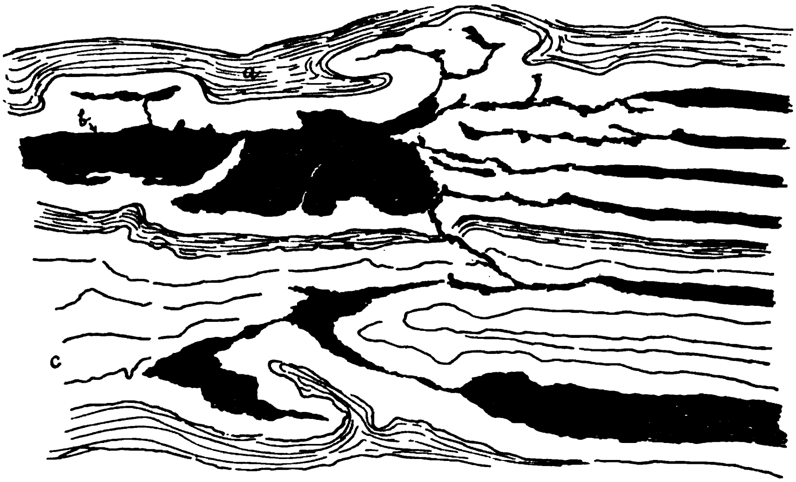


FIGURE 2. Face of open cut showing occurrence of manganese, which is common form assumed by nodular and granular deposits. White Oaks property, Tennessee. *a*, Ferrugenous clay; *b*, manganese; *c*, red and brown clays, banded. This shows occurrence of common form of wash-dirt.

Transported Deposits.—There still remains another form of irregular deposit, which is secondary in its origin, as are certain parts of all deposits of manganese regardless of their origin and form. It is evident from what has been said regarding the blanket form of deposit that there is a certain amount of regularity in its occurrence, both with respect to its position in the bed rock and to its continuity. When, however, a blanket deposit is broken up by decay of the bed rock and the erosion of the residual deposit, the more resistant masses of manganese are transported considerable distances from their point of origin and are often buried in beds of clay. Deposits of high grade manganese are thus formed, but occur in most irregular forms, being scattered indiscriminately throughout extensive beds of clay.

Conclusion.—It is evident from the above discussion of the occurrence of manganese in the various forms of deposits that considerable care must be taken in the various mining operations, such as prospecting, development and mining. The geological sequence of formations once understood is, however, of great assistance in the location of ore deposits, and may in many cases be the determining factor in regard to the possible extent of workable deposits. Deposits that have been located and give promise of having a fair amount of ore, must be developed and mined in such a way as to safeguard the operations against conditions arising from irregularity and uncertainty of occurrence. The character of the ore deposits determines the methods employed in mining, and in a similar manner the character of the ores mined, determine the methods of preparing them for market; the variableness in quality and the uncertainty in quantity being noticeable through the entire work of the mining and preparation of the ores.

METHOD OF MINING.

The methods employed in mining the manganese ores and mineral-bearing clays are somewhat varied, but owing to the limited extent of the deposits and their extreme irregularity, also due to their occurrence in superficial deposits, there are few or no operations that approach a size productive of any considerable tonnage. Most of the operating properties are producing less than fifty tons of finished or clean mineral per month. Aside from the difficulties arising from the uncertainty and irregularity of the deposits, there are other obstacles often encountered, such as scarcity of water and fuel, and long hauls to the railroad. The high price of manganese has, however, stimulated production through the development and operation of numerous deposits that could not otherwise have been worked at a profit.

The various operations necessary to the mining of manganese may be outlined as follows: Prospecting or testing, development, and mining or extraction of the ore or wash-dirt. Ordinarily in mining work these operations are more or less distinct and separate, but with shallow workings and those limited in size there may be and usually is a merging of the work of prospecting, development and mining, which is particularly noticeable in manganese deposits.

Prospecting or Testing.—The prospecting for manganese deposits by test-pits or trenches should not be attempted until a thorough examination of the surface of the property has been made. Surface indications of mineral are desirable although not absolutely essential, as the occurrence of the ore may be such as not necessarily to expose the deposit, or wash from the deposit, on the surface. A careful examination of outcrops often indicates the probable position of a deposit, but such geological relations are only indicative; deposits being the exception rather than the rule, do not always occur where they might and logically should.

When particles and masses of manganese are found on the surface it is evident that they must have resulted from the breaking up of a deposit further up the slope, although it is possible the deposit from which they came may have been completely removed. It is but logical that search should be made directly up the slope upon which the surface indications are found.

The prospecting or testing of manganese properties is probably one of the most important parts of mining, for by prospecting the character and value of a deposit is determined, and upon the information obtained decision is made regarding the advisability of purchase and development. That too great care cannot be taken is shown by the relatively large number of properties that have been purchased, developed to a limited extent, and abandoned through failure to find mineral in workable amounts. The purchase of property and its subsequent proving by testing shows anything but good business sense, but has been done repeatedly and will probably continue to be done regardless of repeated failures.

Prospecting by sinking test-pits is undoubtedly the most satisfactory method owing to the irregularity of the deposits; however, bore holes 5 to 8 inches in diameter have been employed, being drilled by churn drill. The objection to drilling, or in fact testing by small-size holes, is the danger of underestimating or of magnifying the results obtained, for a good body of ore might be passed by with a margin of only a few inches, but no evidence of it obtained; while on the other hand a small mass or stringer of ore drilled through might readily so contaminate the test-hole as to indicate considerable ore throughout several feet of the hole. On the other hand, holes or wells 30 to 36 inches in diameter are of such a size as to readily expose a sufficiently large surface as to show conclusively the presence or absence of workable ore in that immediate locality. It is obvious, however, that test-pits cannot be employed to advantage in other than residual deposits of clay and sand owing to the expense of sinking numerous large openings in hard formations. Test-pits to be effective in testing ground for the irregular forms of deposits should not be spaced farther than fifty feet apart and in deposits lying closer to the surface an even closer spacing is desirable. With considerable depth of overburden the expense of sinking pits close together may be prohibitive and the distance between holes may have to be made seventy-five to one hundred feet. The disadvantage of spacing holes considerable distance apart may be largely overcome by running drifts from the pits, beginning at points where there are more or less pronounced showings of manganese on the walls.

The work of testing by pits is largely done by contract, the usual price being forty to fifty cents per foot; fifteen to twenty feet per day being common. Two men are employed; one at the surface to operate the windlass, the other working in the pit. The equipment, aside from a windlass, is a short-handled pick and shovel, a wooden pail serving as a receptacle for the loosened clay, sand and occasional boulder.

The testing of a deposit depends largely upon the lay of the ground; if of slight slope, test-pits can be employed to advantage, but if on a moderate or high slope, drifts can be used to better advantage. Owing to the irregularity of the deposits, both vertically and horizontally, the direction of the test opening is of little or no importance, either serving equally well in proving a deposit.

Trenches, while being useful in determining the depth of overburden, do little more than indicate the presence of manganese, the extent of the deposit remaining unproven. It is only by pits or drifts placed reasonably close together that even an approximate estimate of a deposit can be arrived at.

Development Work.—The development or opening of a manganese deposit depends largely upon its size, but probably more largely upon the thickness of the overburden and the slope upon which the deposit is situated. Deposits occurring near the surface with but little cover are preferably mined by open-cuts, while those lying at depths must of necessity be worked by underground methods.

Open-cuts are usually developed by making a cut into the bank, beginning at a point determined by requirements of handling the excavated materials, and maintaining a uniform level grade in order to facilitate handling of wheelbarrows or cars, also to permit the escape of water, especially after heavy rains. All excavated materials are handled through the cut; the waste going to the waste bank, the wash-dirt to the screening yard if dry mining is done, or to the washer if the ore is to be washed. Occasionally open cuts are developed by drifts and inclines or slopes, where considerable barren ground has to be traversed before mining can be done. The advantages of open cut work are naturally such as result from having plenty of light, fresh air and greater facilities in handling excavated material; however, there are serious drawbacks to surface work, as excessive heat in summer and cold in winter, and loss of time due to bad weather. The

FIGURE 3. Open cut at the Hambright mine, showing massive body of ore in residual clay.

capacity of open cuts is large, as ample room may be had for developing the working face at the bank.

The development of underground deposits depends largely upon the form of the deposit, but also upon the lay of the ground. On slopes, drifts are most convenient and economical both with respect to forming and operating. Deposits lying on hillsides of moderate inclination can often be opened to advantage by shafts, but shafts should be employed only where drifts are impracticable, owing to distance that they would have to be driven, as the expense of operating shafts especially by hand is rather high; further, the capacity of shafts is small.

Shafts for the development of manganese deposits are small in size, seldom exceeding four by five feet inside dimensions, a more usual size being three and a half by four feet, or four by four feet. Shafts are occasionally lined with a crib-work of timber and less frequently sawed timber and plank are employed, but probably in the majority of cases the clay walls are sufficiently firm and permanent to stand until the deposit is exhausted.

The sinking of shafts is usually done by day labor rather than by contract. Three men are usually employed, two operating the windlass and one loosening the dirt and filling the bucket. The cost of shaft sinking varies somewhat according to locality, but probably ranges from $1.50 to $2.50 per foot; when the shaft must be lined and timber can be had on the property the combined cost varies between $1.75 and $3.00 per foot.

Ordinarily in mining work the development of an ore body or mineral deposit is divided into two distinct operations, namely, connecting the deposit with the surface and providing passages within the deposit for the movement of men, the handling of supplies and ore, and for ventilation. While all of these operations are necessary in mining manganese, yet the restrictions and limitations previously noted in connection with other operations and arising from the irregularity of deposits, also affect the development work. The opening drifts often constitute both outside and inside development work, and at the same time merge into the strictly mining operation or the extraction of the ore or wash-dirt.

Mining.—Mining proper or breaking down of the ore is accomplished at the face of a bank in the open-cut, and at the face of a drift in underground work.

Open-cut work may be done by hand or by mechanical excavation, as steam shovels and drag-line scrapers. Hand work is largely limited to small-scale operations, also to moderate height of bank and amount of overburden that must be handled. Steam shovels, on the other hand, are adapted to large-scale operations, can excavate much higher banks than can be operated by hand work, and can economically strip with ease considerable depth of overburden.

Trucks for steam shovel work in manganese mining are usually provided with broad-faced wheels which operate on a bed or bulkhead of heavy timbers rather than the flanged wheels that must be provided with sectional track. The advantage in this equipment is that the shovel can be handled much more readily on soft ground than if it operated on sectional rail track.

It is rarely ever necessary to employ powder in breaking down banks in open-cuts, as the clays and sands are usually sufficiently soft to be readily excavated by shovels. High banks are seldom carried in steam shovel work, although occasionally heights of 35 to 55 feet have been observed.

The drag-line scraper has been employed in a number of localities in the southern manganese fields, particularly in the Crimora Mine in Virginia and the Flint Springs property in the Cleveland district, Tennessee. In the former locality it was discarded as a failure, but is being used fairly successful in the latter locality. It is probable that the location of the drag-line with respect to the deposit is a determining factor in the success or failure of the equipment; a deep pit imposes rather severe conditions on the drag-line and at the same time limits its range of usefulness.

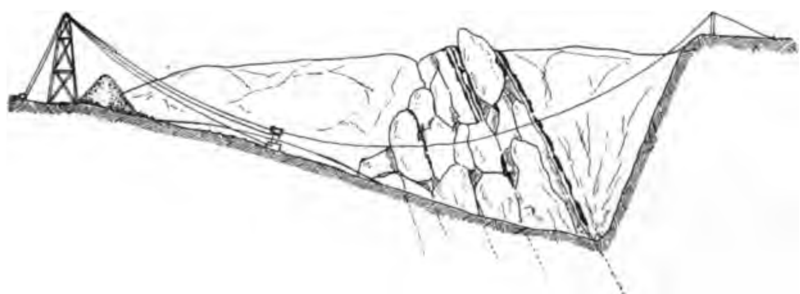


FIGURE 4. Use of drag-line scraper at Flint Springs mine, Tennessee.

A drag-line consists of a large drag scraper operated by cables. The scraper is attached to a two-wheeled trolley that travels upon a cable supported by towers at either end of the cut being excavated. Both carrying and traction cables are connected directly with the drums of hoisting engines; the former being raised and lowered by winding it up or unwinding it, thus permitting the trolley to be placed in any desired point in the pit and in line with the towers; the latter drawing the scraper forward and filling it, whereupon it is raised by tightening the carrying cable and transferred to the point of delivery through the medium of the traction cable. While the ground covered by the operation of the drag-line is limited to an area of a few feet in width between the towers, the range in depth is great and by shifting the end of the carrying cable considerable ground can be covered laterally. There is no doubt but that in certain localities the drag-line can be operated to advantage and can excavate ground even more economically than a steam shovel.

Underground mining operations are much more limited in extent than are the surface workings or open-cuts, as the least amount of work possible is done in order to secure the available ore. All work done by means of drifts is directed toward the one object of removing ore or wash-dirt, and as soon as the ore deposit is exhausted at one point, work is begun at another point where there is promise of ore occurring or where ore already exists. The work of mining ore is carried on entirely at the face of the drifts and is, therefore, what is commonly called breast stopping. In small irregular deposits it is possible to remove all of the ore to the height of a drift by drifting, but in wider deposits it is necessary to widen the face by skirting along the sides of the first drift driven. When it is found necessary to employ supports for the drifts, as is the usual practice, the sides of the skirting drifts are in turn supported by jam-sets, which are ordinary sets jammed up against the sets of the opening drift. An ore body equal in width to six or eight sets can readily be mined by the employment of jam-sets.

When an ore body is found to extend above the level of the opening drift, a second drift can be run, removing the ore to the height of another set; the sets of the second set being placed above and stand directly upon the caps or lagging of the sets below. Sets to the number of five to seven can be superimposed one upon the other, permitting a similar number of drifts to be driven and an ore body removed to a height equal to that number of sets, or from 35 to 50 feet.

In the case of a deposit extending below the level of the opening drift, the most satisfactory method of procedure would be to run a drift directly beneath the drift exposing the ore, placing the posts of the sets of the undercutting drift directly under the sills of the drift above.

It is evident that in the use of over- and under-cutting drifts, also in skirting operations, especially in such unstable formations as clays and sands, that great care must be taken, otherwise too extensive operations would subject the workings to danger of serious falls of ground. Loss of considerable portions of the workable deposits as well as danger to miners would result from such collapse of working places.

Large deposits with fairly solid and firm walls of inclosing clay could undoubtedly be worked to advantage by means of special methods that have found extended application in the mining of soft and broken formations. The milling method could be employed in large deposits and especially in deposits situated on hill and mountain slopes of considerable inclination, where drifts and tunnels could be employed in developing them. From the line of the opening drift, passages or raises are driven, connecting with the top of the deposit or the surface, all excavated material passing through the raises to the drift below, where it is loaded into cars and disposed of according to its value. Such a method could be employed to advantage where there is little or no overburden, although considerable thickness of cover could be readily handled through the raises; with considerable depth of cover, the raises should extend to the top of the deposit only and provision be made for supporting the cover by the employment of specially constructed supports.

Mining the blanket deposits varies considerably from similar work in irregular deposits and resembles more closely work in bedded deposits such as coal and iron ore. Drifts run on such deposits must of necessity be very irregular, which renders the mining and handling of the ore very difficult. For workings of several hundred feet in extent, shafts could probably be employed to greater advantage than drifts and slopes; however, slopes are occasionally employed. Further, mining the blanket deposits entails handling of much waste and probably considerable more than in similar work with the irregular form of deposits, as the ore is more compact and consequently the volume is proportionately smaller.

The rhodochrosite ore at the East Fork Mine has been mined up to the present time by drifts, driven on the mineralized zone. While fairly satisfactory work can be done by drifts in the preliminary work of opening such a deposit, the milling method would be much more applicable for more extensive operations and large outputs.

Other operations incident to mining work, such as drainage, ventilation, lighting, etc., are simple and ordinarily present no serious nor complicated problems. The looseness of the deposits of residual materials readily permits of the escape of water that usually causes much trouble in mining operations. Rarely ever is any trouble experienced due to the accumulation of water in underground workings, but in open-cut work the bottoms of the pits often become puddled by working upon them, especially during wet weather, in which case water may collect, and, unless the pit is self-draining, must be pumped out. Candles and aceytelene lamps are commonly employed in underground work; in open-cut work no lighting is necessary except when work is done at night. Aceytelene flare-lights may furnish ample illumination under such circumstances. Ventilation is usually a matter of small concern owing to the limited scale of the operations, but with more extended work some positive means of forcing air into the workings must be adopted; for shaft work "sails" can be used to advantage, furnaces are quite satisfactory for moderate length of drifts, but rotary blowers must be employed for workings of con-

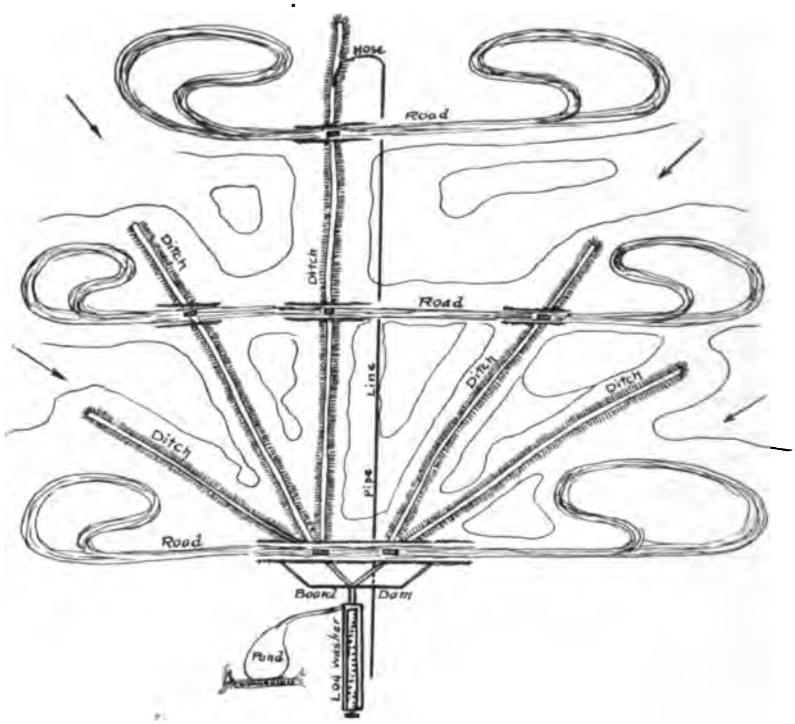


FIGURE 5. Sluicing method used at Unaka Minerals Company mine, near Louisville, Tennessee.

siderable extent. Small blowers, driven by a hoist and acting only while hoisting is being done, may prove satisfactory, otherwise a small gasoline engine may have to be employed.

Handling the ore or wash-dirt and waste from underground workings and strip pits, is an important part of the mining operations and varies largely with the methods of mining employed. In open-cut work the excavated materials are largely handled in wheelbarrows operating on plank tracks or run-ways. All small scale operations employ wheelbarrows, and occasionally they are handled on fairly steep grades by two men, one pulling by rope, the other pushing. It is needless to say that such a method of procedure is both inefficient and expensive. Cars are employed in connection with steam shovels, being moved by hand and mules and occasionally by dinky locomotives. Owing to the practice of following deposits downward within the pit, considerable depth of pits often results, thus requiring the waste and wash-dirt to be hauled up grades of varying degrees of steepness. Locations of deposit may render it impossible to maintain a level or outward sloping approach and entrance to the pits, but where possible such arrangement should be employed. Dragline scrapers have an advantage over steam shovels in that they have the combined ability to excavate and transport, and do not have the disadvantage of maintaining tracks within the pits, which is often a difficult task.

Sluicing methods may be employed very satisfactorily where the slope is sufficient to move the dirt readily, and where an ample supply of water is available. Large tonnage of wash-dirt can be handled economically by sluicing and there is an added advantage in that clayey ore can readily be broken up and largely freed from adhering clay by passing through a sluice, of moderate length. The sluices are either wooden boxes or ditches formed in the clay bed, and are fed by dirt brought in wheelbarrows or by scrapers, and dumped into the sluices by hand or through a hole in a bridge.

Preparation of Manganese Ores

By W. R. Crane and E. R. Eaton.*

The methods employed in cleaning and concentrating manganese ores and the scale of the operations depend largely upon the size and character of the deposit worked. The forms of deposits previously outlined give some idea of the difficulties that may be experienced in their treatment. The irregular forms of deposits are commonly worked and produce the bulk of the material that is washed and otherwise treated. The other forms of deposits, while often large and of fair grade, have been largely ignored up to the present time, owing to the fact that certain more or less difficult problems are presented.

The principal difficulty arising from the treatment of ore or wash-dirt obtained from the irregular forms of deposits, is the uncertainty of a regular and uniform supply. Next in importance to the supply is the character of the manganese occurring in the wash-dirt and the relative proportion of mineral to waste. The forms of ore best adapted to washing and concentration is the nodular and pebble ore of small size, following which is the granular form, both of which are usually of convenient size for log washer and subsequent jig work. The kidney and dornick forms require reduction before they can be successfully handled by logs and on the picking belt, but owing to size and purity it is often possible to make a high percentage extraction prior to treatment in the logs and on the jigs of a standard washing plant.

Owing to the variable conditions mentioned there is a tendency to reduce the equipment employed in treating manganese to a minimum both with regard to kind and number of parts employed, which is frequently done irrespective of the desirability of limiting the necsary equipment. Poor and imperfect cleaning of ores and excessive losses usually result from the curtailment of equipment. It is, therefore, the object of this paper to give the layout of a standard washing plant, to describe the construction of the apparatus or machines, and to explain the operation and adjustment of the various parts.

*The field work on this report was done under a co-operative agreement between the State Geological Survey and the U. S. Bureau of Mines. The report is published by permission of the director of the U. S. Bureau of Mines.

The preparation of manganese ores may be divided into two separate and distinct methods, namely: dry-mining and washing or concentration.

Dry-mining.—Dry-mining does not refer to mining, but rather to the cleaning of the ore, and consists of screening the ore as it is mined. Not all ore or wash-dirt is adapted to dry-mining or cleaning by screens, as certain clays are wet and sticky or plastic, or may occur in large masses, rendering the separation from the ore by screens practically impossible. Dirt most suitable for dry-mining methods is dry and granular, breaking up readily and separating from the mineral with little or no effort.

With certain forms of deposits as the blanket and bedded forms, especially when the deposits have been broken up and distributed throughout beds of clay, hand work with or without screening may be profitably done, but even where the bulk of the ore is of fair size, considerable loss occurs.

The amount of manganese in the dirt is, however, the controlling factor in dry-mining; dirt having less than 15 per cent of mineral cannot be successfully separated by screening, unless the bulk of the mineral is fairly large size.

Washing and Concentration.—The principal considerations affecting the employment of washing and concentrating methods in the treatment of manganese ores are: quantity of wash-dirt available; percentage of manganese in the dirt; and the water supply. While ore may be profitably mined and hand-picked under certain conditions of occurrence even where the proportion of mineral to clay is 1 to 50, that is 2 per cent, yet that is practically impossible where log washers and jigs are employed. Under ordinary conditions of occurrence of manganese in a deposit of clay and sand, it is doubtful whether successful work can be done where the proportion is lower than 1 to 35, while 1 to 10, or 10 per cent, is a fair average of wash-dirt treated.

The cleaning of manganese ores as practiced in the Cartersville district, Georgia, is considered standard, owing to long use, and is largely followed in other districts. Rarely, however, are plants constructed and fully equipped with the apparatus that has proven useful and satisfactory in their operation; the practice cannot, therefore, properly be considered standard. Few plants have a full installation of essential apparatus, many have only a partial equipment, while a number are operating with the irreducible minimum of equipment, namely: a log washer.

In order that an idea may be had regarding a proper method of treatment for the usual run of manganese-bearing dirt and clay, the following outline or flow-sheet is given:

WASH-DIRT TO 1.

1. Grizzly, 2 to 4 in. spaces between bars; oversize to 2; undersize to 3.
2. Rock dump.
3. Log washer, double logs, 20 to 30 ft. long; discharge to 4; overflow to 5.
4. Revolving screen, cylindrical or conical, perforations or meshes 1-2 and 3-16 in.; oversize, everything above 1-2 in. to 6; undersize, 1-2 to 3-16 in. to 7, 3-16 to 0 in. to 8.
5. Mud or settling pond.
6. Picking belt; rock to 2; manganese to 9.
7. Rougher jig (4 cells); grate discharges to 9; hutches, 1st to 9, 2d, 3d and 4th to 10; overflow to 5.
8. Sand jig (3 cells); gate discharges to 9; hutches to 9 or 10.
9. Finished ore bin.
10. Cleaner jig (3 cells); gate discharges to 9; hutches to 9 or 11; overflow to 5.
11. Shaking table; finished product to 9; overflow to 5.

There are seldom more than two jigs employed in the washing plants for manganese-bearing clays and sands, while in many plants only one jig is used. Revolving screens or trommels are commonly used, but many flat screens are employed; in either case it is the exception rather than the rule to find more than one size of opening, which ranges from 3/4 to 1 in. The widest range of sizes fed to the jigs from such screens renders good separation next to impossible. Few of the products of the jigs are clean and require extensive hand picking to complete the preparation, while by simply running the hutches of the rougher jig, fairly clean products can be made on the second or cleaner jig. When only one jig is employed few of the products are suitable for market. Fairly close sizing as indicated in the flow-sheet would make a great improvement in the work done by jigs and reduce the expense of preparation of ore by eliminating hand picking.

A standard washing plant as given in the above flow-sheet is what may be called a single washer or unit, and has a capacity of 40 to 50 tons of clean ore per 10 hours. An increase in capacity of such a plant aside from a small increase gained through crowding, would mean a doubling, trebling or quadrupling of the equipment, with corresponding increase in volume of wash-dirt treated. By single washer is not meant a single log, but a single plant with a double log; while single logs do good work, yet in the plant as outlined a double log should be employed.

Details of the construction of the various forms of apparatus or equipment as employed in a standard plant are given, in order that those unfamiliar with such apparatus may be able to understand them.

The rough sizing apparatus or grizzly situated at the level of the open-cut or mine, receives the wash-dirt by cars, scrapers, sluices or wheelbarrows and delivers it to the log washer, largely freed from large masses of rock. The size of the grizzly depends upon the means employed in handling the dirt; if fed by cars loaded by steam shovels the size must be considerably larger than when fed by hand or other means.

Grizzlies are made in a number of ways but differ mainly in kind of bar used. The most common form is made of railroad rails, laid flange up and parallel with the logs below. There are usually five rails spaced 4 inches apart, making 4 spaces; the length of the grizzly is 3½ to 6 feet. The rails are supported by heavy cross-timbers and are spaced by wooden or iron blocks, or are set into notches cut in the supporting timbers; they are usually held securely in place by timber bolted down upon their ends. The wash-dirt is sorted upon the grizzly, the clay and sand falling through together with all small pieces of manganese and rock; the larger pieces of rock are removed and sent to the rock dump, while the larger pieces of manganese are broken up and forced through the grizzly. Enclosing the grizzly is a wooden box or hopper made of plank, which receives and holds the wash-dirt until fed through the bars.

Logs are undoubtedly the most important part of a washing plant, as they handle large quantities of wash-dirt of a wide range in character and do very efficient work in removing the clay and sand. A double log washer consists of a long strongly built box or trough standing at a slight inclination longitudinally, in which are mounted two long timbers or logs. The logs are provided with gudgeons at the ends, which consist of journals and flanges, the flanges being bolted to flanged octagonal sockets fitting over and fastened to the ends of the logs. The logs are connected by gears at the upper ends, being driven by a train of beveled gears, which in turn are driven by belt.

The trough is constructed of 2-inch plank placed longitudinally, being firmly held in place by frames of heavy timber. The ends of the trough may be made of plank or cast iron plates, the latter having flanges to which are bolted the side planks. The lower plate is called the back gate, the upper the front plate, both of which contain the bearings or pillow blocks. The front plate also has an outlet or discharge opening for the washed mineral, being placed centrally in the plate. The slope of the logs ranges from 3/4 to 1½ inches per foot.

The logs are octagonal in section and range from 16 to 18 inches in diameter between parallel faces, which are protected by straps of iron 2 by ¼ inches and serve as supports for the blades. The blades are 4½ inches wide, 1 inch thick and about 8 inches long. They are put on in two rows in the form of screw-threads, eight blades to the circumference of the log. If the pitch of the threads is 5 feet, which is common, it is necessary to advance each blade 7½ inches for each one-eighth turn or for each side of the octagon. The ends of the blades are of chilled cast iron and are set at angles of 30° to 45° depending upon the character of the material treated; for tough clays the angle should be small, for clays that are easily broken up the angle should be greater.

The logs are set so that the blades of one pass between those of the other, which can readily be secured by setting the log so that when geared together the two oppositely placed blades at the upper end of one log stand vertically, while those on the second log lie horizontally. The action of the blades is such that when the logs revolve the lower blades at the bottom of the trough approach one another, the sloping faces of the blades pushing forward any hard material as rock and ore that they come in contact with. The lifting and pushing action of the blades forcing the ore and clay up the sloping bottom of the trough, together with the thorough agitation in a stream of wash water flowing against the upward moving material, is responsible for the thorough washing done by logs.

The number of revolutions of logs varies from 12 to 15 per minute; the amount of water required varying from 50 to 75 gallons per minute; the capacity is 40 to 50 tons clean ore per ten hours; and the horse power required to drive double log ranges from 20 to 25.

The revolving screen is next in order after the logs and is intermediate between logs and jigs as washing and cleaning apparatus. It consists of a cylindrical or conical surface of woven wire or perforated metal mounted on suitable supports to maintain the shape of the screening surface, the whole being supported on and rotated by a shaft. The screening surface should have at least two sizes of openings, each occupying about one-half the length of the screen. The sizes best adapted to manganese washing are probably 3/16 inch for the smaller and 1/2 inch for the larger openings or mesh.

The screening surface is either bolted or rigidly fastened to cast iron wheels by hoops that are tightened by bolts. The wheels are keyed to the driving shaft and spaced at frequent intervals in order to properly support the screen, preventing sagging and reducing vibration. An inclination of 10° to 15° should be given the screening surface in order to cause the material to pass promptly through the screen.

Revolving screens are driven by gearing, chain and sprocket, and occasionally by belts, direct from the logs or log gearing. The usual number of revolutions for screen of 36 to 48 inches in diameter is 15 to 20 per minute. The capacity of screens of the sizes given ranges between 45 to 55 tons per 10 hours for the smaller and 50 to 75 tons for the larger. The proper length of screens is 60 to 72 inches.

The over-size material from the revolving screen passes to a picking belt, where the coarser material, passing through the logs, is finally separated, the ore going to the finished ore bin while the rock goes to the rock dump. While there are a number of different kinds of picking devices, the most satisfactory is the rubber belt, which serves both as a conveyor and a picking belt.

The sizes of picking belts commonly employed in manganese plants that have proven satisfactory for the usual range of work done are: 30 feet long by 18 inches wide to 50 feet long by 30 inches wide. The capacity of picking belts is limited by the character of the work done; if the material sorted is largely ore and the waste rock is fairly coarse, the capacity is large; similarly where the percentage of ore is small and the individual prices are large, but where the ore and waste are about equal in amount and there is a wide range in sizes, the capacity may be small.

Jigs are employed in handling and treating the undersizes from the screens. There should be at least two sizes, one for the coarser and two of the finer work. The first or coarse jig is called the rougher, the next treating the smaller of the undersize material is known as the sand jig, while the third of the same size as the second, and treating products from both the rougher and sand jig, is the cleaner jig.

The type largely used in manganese cleaning is the Harz jig, being commonly known as the Joplin and stepped jig. The jigs should have at least three working compartments, while the rougher would operate to better advántage with four compartments. The jig box is built in a number of ways, but probably the most satisfactory is to use 2 by 4-inch lumber, which while being easy to put together may also do away with the heavy enclosing frames required by other methods of construction. Compartments are formed in the jig box by building partitions transversely, thus dividing the box into portions of equal dimensions. The compartments all in turn partly subdivided by partitions extending downward from the top of the jig box to a point about one-half the height of the box. Each compartment is thus formed into a U-shaped passage, one part or arm of the passage being of greater height than the other mainly to provide support for the drive shaft, also to furnish a higher head of water in that part of the passage than in the other; the compartment of greater height is known as the plunger cell, the other the screen or sieve cell.

In ordinary practice the plunger and sieve cells are of the same size, although variations are found; however, in the construction of the jig box it is preferable to make them of equal size and to reduce the cross-sectional dimensions, if desired, by placing lining boards on the walls of the plunger cells. The size of compartments may be the same for all three jigs and varies from 20 to 24 inches wide by 30 to 38 inches long for sieve cells, to 18 to 22 inches wide by 30 to 38 inches long for plunger cells.

The sieve cells or the front compartments of a jig have considerably less height than the plunger or back cells; the tops are also placed at lower levels, beginning at the head or feed end of the jig box and proceeding toward the opposite or tail end. The object of this systematic reduction in level is to permit a flow of water and feed from one compartment or cell to the adjacent and lower one. Screens are placed in the cells, the level of each conforming with the height of the various cells.

The plunger cells are provided with plungers supported and operated by heavy iron rods passing through the center and clamped in between heavy cast-iron washers by nuts. The plungers are held closely in position and are positive in action. The upper ends of the

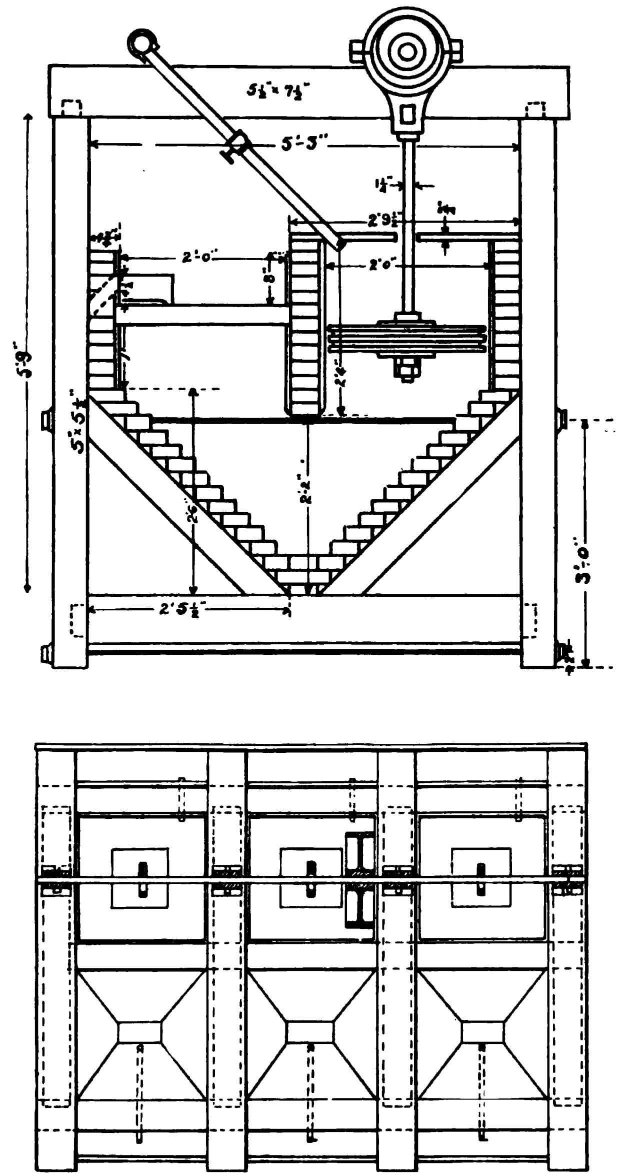


FIGURE 1. Top and side view of Harz jig, which is commonly used in manganese cleaning.

plunger rods are screwed into the shanks of cast-iron eccentrics, which are in turn keyed rigidly to the driving shaft. The eccentrics should be of the adjustable form and with sufficient range in adjustment to permit proper setting to do good work. The usual and desirable range of adjustment is from ¾ to 2 inches, but if larger sizes are treated than given for work in a standard plant, a greater length of stroke should be provided for in the eccentrics.

The speed of drive shafts should be 150 r. p. m. for the rougher jig, and 200 for the sand and cleaner jigs. The length of strokes for rougher jig is 1½ inches for the first two plungers and 1¼ inches the last two, while 1 inch and ⅞ inch are suitable for the first two and last two cells of the sand and cleaner jigs.

Screens or sieves for the front cells are of two kinds, namely: cast-iron and wire cloth. Cast-iron screens are largely used in jigs treating coarse sizes and have the advantage that they are rigid, self-supporting and easily replaced when broken or worn. There is, however, greater variation in size of openings in cast-iron than other screens owing to difficulty in casting. Wire screens are widely used particularly with the smaller sizes of mineral treated, but are flexible and must be supported, which is accomplished by placing wooden supports in the sieve compartments and fastening the screens to them. The wooden support consists of strips of soft wood set on edge and extending longitudinally in the cell, or when fine mesh cloth is employed cross-pieces may be employed forming a cell-work of wooden strips, thus giving support in all directions. The size of mesh of screens for the different cells should be varied somewhat to suit the size of material fed to the jigs, but when jigs with only a few cells are employed there is less need of a change in size. The following sizes of openings or mesh of screens should be employed in the three jigs of the standard plant: rougher jig ¼, ¼, 3/16 and 3/16 inch for the four cells; sand jigs, 3/16, 3/16, ⅛ and ⅛ inch for the four cells; cleaner jigs same as sand jig.

The bottoms of the jig box between the transverse partitions are formed into hoppers by sloping bottom boards, the apexes of the inverted pyrimidal spaces being at the front of the jig or in the middle of the compartment, depending on how the material collected in the bottom of the jig boxes is handled; if drawn off from the front, the former arrangement would be employed, if from the back of the jig, the latter arrangement is preferable. Openings made in the walls of the jig box and connecting with the several compartments are provided with gates, usually of the sliding or rotating types, which are operated by a long-handled lever, permitting both quick and positive action in opening and closing the passages. When materials are drawn from the rear of the jigs, the bottoms of the hoppers are often provided with pipes that extent from under the jigs to some convenient position and are equipped with gates or valves to control the flow. The gates or valves are called spigots and the products discharged are known as hutches.

Mineral accumulating on the sieves consists of two parts, namely: the heavy manganiferous portion not readily moved except downward by gravity, and the lighter portion made up largely of quartz. The latter is displaced in the bed by the former and as soon as it reaches the height of the enclosing walls of the sieve cells is washed off by the flow of water from one cell to the next lower and thence over and off the jig. The former must be removed either by scraping aside the lighter minerals lying above them, or by drawing it off through the walls of the jig. Each sieve cell has, therefore, an opening cut through the front wall, which is provided with a gate and dam to control the discharge of the coarse concentrates accumulating on the sieves. The gate is a strip of sheet iron placed on the inside of the front wall of the jig and adjustable by vertical movement so as to regulate the size of opening. The dam consists of a half-cylinder of sheet metal also placed on the inside of the front wall of the jig and adjustable; further the dam encloses the gate. The dam is set at the desired height above the sieve and determines the character of the mineral reaching the gate. The lower edge of the dam must stand in the material to be discharged and as clean manganese is discharged the height should be from 1½ to 2½ inches.

The water entering with the mineral is called feed or carrying water and should be sufficient in amount and clear, in order that the action of the jig may be observed, therefore it is the usual practice to add fresh water to the feed just before it enters the jig or at least in the feed launder. Often this additional water is ample in amount to supply the jig and at the same time to provide for wastage. However, when the hutch is being discharged from the bottom of the jig, it may be necessary to add to the water in the jig by introducing water into the body of the jig either above or below the plungers. A pipe may be run above the jig and longitudinally with the jig, or back of the jig box, connection being made by branch pipes to the plunger cells. The water fed to the jig in this matter is called hydraulic water. The size of the main hydraulic water pipe should be 2 inches, the branches 1 inch. The amount of water used by four cell jigs is about 350 to 400 gallons per minute, for three cell jigs proportionately less.

Height of dams or tail boards between sieve cells should be 3½ to 4½ inches, which determines depth of bed; increased depth of bed means a corresponding increase in length of stroke plunger. The drop between adjacent cells should be about 1 inch.

Briefly stated the movement of wash-dirt through a standard plant or washer is as follows:

Dirt from the mine is thrown upon the grizzly where all coarse material is separated out and sorted according to its value, the rock going to waste pile, the coarse manganese being broken up so that it can pass through the grizzly and go to logs with all fine material. Water is frequently used to facilitate the movement of dirt through the grizzly, but is applied particularly to the finer material that has passed the grizzly.

The grizzly being placed above the logs feeds directly on or between them, falling into the water filling the log box or trough. The rotation of the logs causes the dirt to be thoroughly stirred and rubbed, and at the same time forces it up the sloping bottom of the trough to the discharge opening at the upper end; the blades acting both as agitators and propellers. The coarser material, including sands, gravel, nodules and fragments of manganese, and cobble stones, is discharged by the logs at the upper end, while clay and the finer particles of sand and waste leave the trough by way of the overflow at the lower end of the trough. Care must be taken with regard to slope of trough, speed of rotation of the logs, position and height of overflow, and amount of wash-water employed, which must be suited to condition and character of wash-dirt if satisfactory work is done.

The material discharged by the logs enters the revolving screen where it is still further washed and freed from adhering clay, and separated into three sizes; the oversize going to picking belt, the undersize to the jigs. The oversize is composed of all sizes above ½ inch. which can be readily sorted by hand. The undersize is divided into two portions: 0 to 3/16 inch and 3/16 to ½ inch, the former going to the sand jig, the latter to the rougher. The screen should be so operated that distinct grades of material are made, according to sizes given.

Care in the design and operation of the screen has much to do in the subsequent work of cleaning manganese, particularly in jigging.

Ample room should be provided for the handpickers working at the picking belt; good light and shelter from sun, rain and wind are important; further, facilities for disposal of sorted products is important, no accumulations of waste or mineral should be allowed. Width and length and slope of belt are important, but are determined largely by conditions existing at the plant, such as slope of ground and disposal of waste and mineral.

The undersizes from revolving screens go direct to the rougher and sand jigs where the final cleaning of the finer material is accomplished. The rougher jig should produce coarse concentrates above the sieves, also the first hutch product should be clean; the remaining hutch products should be retreated. The sand jig should also produce coarse concentrates above the gate discharges and probably clean products from the first two hutches, the remaining hutches being re-run with similar products from the rougher jig. The cleaner jig should produce coarse concentrates and clean hutches, but with ores containing considerable sand and iron it would be advisable to employ a shaking table in order to produce a high grade product.

It is also possible to effect a small saving from the overflow of the logs by screening out the coarser sizes and settling the finer size in classifiers, the coarse size going to the revolving screen, while the settled product is retreated on the shaking table.

No satisfactory nor economical treatment of soft or wad ore has been found as yet and it is doubtful whether such ores can be worked on a permanent basis, owing to high silica content.

Treatment of the breccia ores that are found in considerable quantities in portions of the manganese fields of Tennessee can be freed from their silica and other impurities by graded crushing and jigging, shaking tables being employed where the jig products still retain considerable silica.

The Coal Pyrite Resources of Tennessee and Tests on Their Availability*

BY E. A. HOLBROOK AND WILBUR A. NELSON.

INTRODUCTION.

The brassy yellow colored mineral pyrite (FeS_2), a combination of iron and sulphur often known as fools' gold, is of common occurrence in many kinds of rocks. Commercially it is important only as the basis for the manufacture of sulphuric acid, an acid essential in the manufacture of explosives, fertilizers and other chemical products. On roasting, the pyrite gives up its sulphur to form the gas, sulphur dioxide, which in turn is converted into sulphuric acid in large chambers, chiefly by the use of steam.

Formerly most of the pyrite used in the United States came from Spain, although some sulphuric acid was manufactured by burning or roasting pure native sulphur mined in Louisiana. At the beginning of the present war the Spanish supplies were cut off and it seemed essential, in view of the increased demand for sulphuric acid, to develop every available source of supply in this country. Many pyrite mines were opened in the Appalachian Mountains, especially in Northern Georgia; and increased attention was given to the sulphur deposits in Louisiana and Texas.

It is well known to those engaged in coal mining that frequently balls and bands of pyrite occur with the coal, and this impurity must be removed from the coal before it is placed on the market. Because the coal in a mine contains pyrite balls or bands, however, does not mean that the coal from this mine is high in sulphur, or inferior in quality, for often the contrary is true; that is, the sulphur, having concentrated into definite balls and bands, leaves the true coal comparatively free from sulphur.

Knowing that there were possible pyrite resources in certain of the coal mines in Tennessee, the State Geological Survey effected a co-operation with the United States Bureau of Mines, by which a

*This report was made in co-operation with the U. S. Bureau of Mines, through their Middle West Station, Urbana, Ill., Mr. E. A. Holbrook representing the government.

survey of the pyrite in Tennessee coal mines has been made, and favorable material has been tested in the laboratory used by the Bureau of Mines at Urbana, Illinois.

At the present time, October, 1918, it appears the great demand for pyrite has been met, partly by an unexpectedly favorable development of new sulphur resources in Louisiana and Texas, and partly by development of pyrite mines in the Appalachian Region and in

FIGURE 1. Coal pyrite from the Bon Air district.

Canada. Also it has not been considered opportune to interfere in any way with the production of coal. For these reasons the demand for coal pyrite has not been as great as was expected earlier in the year. However, the supply known to be available constitutes a great reserve in time of need, and calls attention to a potential resource for the future.

This report outlines the known coal pyrite resources of Tennessee and details tests made at Urbana, Illinois, on crude pyrite from the mines of the Bon Air Coal and Iron Corporation, to learn if the material could be mechanically treated to produce a pyrite of commercial purity.

Coal Pyrite Resources in Tennessee.*

Outside of the large deposits of pyrite and pyrrhotite in East Tennessee in the Ducktown region, Tennessee has an additional source of pyrite from certain of the coal seams of the Cumberland Plateau.

The mines in the Bon Air-Clifty district all contain pyrite in the form of bands, nodules and kidneys, which are easily separated from the coal and can be recovered as a by-product. It is estimated that the daily tonnage of pyrite, if all is recovered, from the mines in this district when operating at full capacity will be at least fifty tons daily. This estimate was made to include all the mines operating on the Bon Air branch of the Nashville, Chattanooga and St. Louis Railway.

Clean samples of pyrite from some of these mines gave the following analyses:[1]

Carola Shaft, Bon Air, Tenn.	47.0 per cent sulphur
Braeburn Mine, Eastland, Tenn.	47.6 per cent sulphur
Ravenscroft Mine, Ravenscroft, Tenn.	46.4 per cent sulphur

The mines on the Monterey branch of the Tennessee Central contain pyrite in a recoverable form. This pyrite is similar to that from the Bon Air district, on which tests were made. It is estimated that probably forty tons of pyrite a day could be recovered from this district. Clean samples of pyrite were taken from some of these mines, which gave the following analyses:[2]

Fentress Coal Co., Wilder, Tenn.	46.4 per cent sulphur
Peacock Mine, Big Mountain Coal Co., Obey City, Tenn., Weathered surface pyrite	46.1 per cent sulphur

Hand cobbed samples of pyrite were also taken from these mines, so as to show the approximate percentage of sulphur in carload lots of unwashed pyrite as it would be shipped from the mines if no

*The paragraphs under this subheading were prepared by Wilbur A. Nelson.
[1]Collected by E. A. Holbrook, analyzed by U. S. Bureau of Mines.
[2]Collected by E. A. Holbrook, analyzed by U. S. Bureau of Mines.

plant for treating the pyrite was installed. The following analyses show these results[3]

Carola Shaft, Bon Air, Tenn.	43.88 per cent sulphur
Braeburn Mine, Eastland, Tenn.	46.40 per cent sulphur
Ravenscroft Mine, Ravenscroft, Tenn.	43.72 per cent sulphur
Clifty Mines, Clifty, Tenn.	42.72 per cent sulphur
Fentress Coal Co., Wilder, Tenn.	45.08 per cent sulphur
Peacock Mine, Big Mountain Coal Co., Obey City, Tenn.	40.36 per cent sulphur
Brier Hill Collieries, Crawford, Tenn.	36.08 per cent sulphur

The pyrite from the Fentress Coal Company has been shipped to an acid manufacturer for some time, with satisfactory results to both the mine owners and the acid makers. The pyrite from all these mines, with the probable exception of the Brier Hill Collieries, would be satisfactory for acid making after having been crushed and cleaned.

Pyrite is also found in a few of the mines in the Tracy City-Coalmont district, but not in sufficient quantities to justify saving and shipping.

In the northeastern Tennessee coal field some pyrite occurs, but no detailed investigation was made of this area.

TESTS MADE AT URBANA, ILLINOIS.

About September 1, 1918, two shipments of crude coal pyrite were received at the laboratory of the U. S. Bureau of Mines, University of Illinois, Urbana, Illinois, from the Eastland and Ravenscroft mines of the Bon Air Coal and Iron Corporation, of Bon Air, Tennessee. The possibilities of utilization of coal pyrite on a large scale for the manufacture of sulphuric acid made it desirable to conduct tests on this material to learn if mechanical crushing and washing would produce a high grade commercial pyrite free from coal and other impurities and with possibly clean coal as a by-product. The report following gives an outline of the final tests, together with a flow-sheet outlining a possible method of mechanically treating these materials.

MATERIAL FROM THE EASTLAND MINE.

This lot, about 500 pounds of crude coal pyrite marked from the Eastland mine, consisted of lenses of pyrite up to 10 inches in width and 4 inches in thickness, together with considerable adhering

[3]Collected by Wilbur A. Nelson, analyzed by the Chemist, State Geological Survey.

coal. To the eye, about 50 per cent of the lumps by volume was pyrite and the remainder was adhering coal.

Preliminary tests showed that the clean pyrite in the material was high grade, and that crushing to about 1-inch size would produce a clean pyrite concentrate, and consequently fairly clean coal as a by-product. During crushing, a comparatively small amount of pyrite fines were produced, and therefore the largest sizes were the richest in pyrite. In other words, this coal pyrite, unlike the usual pyrite mineral, is stony and amorphous in structure and does not slime on crushing. This very important point made it possible to recover most of the pyrite by* jigging alone, and the* concentrating table was necessary only in treating the recrushed middlings. Even this product might be fed into the jig and saved as a hutch product, providing the capacity of the jig was ample.

The accompanying quantity flow sheet (page 6) shows the results of the final test run on the pyrite from the Eastland mine. Four hundred and twenty-two pounds were crushed to ¾-inch size in a gyratory crusher followed by rolls. This was jigged in a 2-compartment Harz jig with ¼-inch screen beds. The coarse concentrates were saved as a screen bed product and the fine concentrates were saved as a hutch product. The second screen bed product contained some coal adhering to the pyrite and was a true middling product. It was therefore crushed through a ¼-inch screen and treated on a Butchart concentrating table. The table cleaned this product and produced a high grade concentrate.

*The jig and concentrating table are simple machines in common use in the preparation of minerals.

Flow Sheet of Coal Pyrite Concentration Material From Eastland Mine of the Bon Air Coal and Iron Corporation, Bon Air, Tenn.

Original Material 422 lbs. 32.68% Sulphur
Trial Test.

Crushed to ¾-inch Maximum Size.

Jigged Without Sizing on a 2-compartment Jig.

1st Screen Bed Concentrates.	1st Hutch Concentrates.	2nd Bed Middlings.	2nd Hutch Concentrates.	Tailings (Coal).	Loss 34 pounds.
156 lbs.	24 lbs.	119 lbs.	26.0 lbs.	63.0 lbs.	8.1%
37.0%	5.7%	28.2%	6.1%	14.9%	....
43.1%S.	44.0%S.	36.7%S.	36.1%S.	5.3%S.	....
				19.8% Ash	

Recrushed to ¼-inch size.

Butchart Concentrating Table.

Concentrates.	Middlings.	Tailings.	Loss.
85 lbs.	8 lbs.	19 lbs.	7 lbs.
71.4%	6.7%	16.0%	5.9%
41.6%S.	30.1%S.	12.3%S.	
		32.1%Ash	

NOTES.—1st Screen Bed Concentrated means the coarse concentrates saved on the 1st bed of the jig.

2nd Hutch Concentrates means the fine concentrates passing through this screen and saved at the bottom of the jig.

Middlings means a product of pieces containing part coal and part pyrite which have to be crushed finer before any separation of clean pyrite can be made.

The Resume Sheet (page 66) shows the details of the run.

TESTS ON CRUDE PYRITE FROM THE RAVENSCROFT MINE OF THE BON AIR COAL AND IRON CORPORATION.

The crude coal pyrite from the Ravenscroft mine was of about the same physical appearance as the material from the Eastland mine.* Some of the lenses, however, were of rather light weight and had a peculiar gray color. To the eye it appeared about 75 per cent pyrite by volume and the remainder was adhering coal. This material was tested in a preliminary way and the tests indicated that the same treatment could be used as with the material from the Eastland mine.

*The pyrite which occurs in the mines on the Monterey branch of the Tennessee Central Railroad has the same physical appearance, and it is thought could be prepared for market in a similar way to the pyrite tested.—Wilbur A. Nelson.

This is a point of importance, because in any concentrating plant it would allow indiscriminate mixing of the material from the various mines before treatment. On crushing, the crude pyrite produced only a small percentage of fines, and it appeared that in regular practice, crushing to 1-inch round hole size would be sufficient before attempting concentration.

Resume of Run of Eastland Mine, Bon Air Coal and Iron Corporation.

Total, 422 lbs., 32.7% Sulphur.

Product	Concentrates		Middlings		Tailings		Loss
	Weight	Analysis Sulphur	Weight	Analysis Sulphur	Weight	Coal Analysis	
1st Bed Concentrates	156	43.1%	......	......	......	......	......
1st Hutch Concentrates	24	44.0%	......	......	......	......	......
2nd Bed Middlings (see Table Products)	......	......	......	......	......	......	......
2nd Hutch	......	......	26	36.1%	......	......	......
Jig Tailings	......	......	......	......	63	5.3%S. 19.8%A.	......
Table Concentrates	85	41.6%	......	......	......	......	......
Table Middling	......	......	8	30.1%	......	......	......
Table Tailings	......	......	......	......	19	12.3%S. 32.1%A.	......
Jig Loss	......	......	......	......	......	......	34 lbs.
Table Loss	......	......	......	......	......	......	7 lbs.
Totals	265	42.7%	34	34.7%	82	6.9%S. 22.6%A.	41 lbs.

Practically 265 lbs. of commercial pyrite were recovered, or 62.8 per cent of the total material treated. On further treatment, the 34 lbs. of middlings could be expected to yield 25 lbs. of commercial pyrite, making a total recovery of 290 lbs. of pyrite or 68.7 per cent. The coal tailings were 82 lbs., or 19.4 per cent. The treatment loss was 41 lbs., or 9.7 per cent.

The accompanying flow sheet (page 67) shows the final test treatment of the crude pyrite, together with the products, their quantity and analysis. The resume sheet (page 68 shows the various products and gives an idea of what might be accomplished in percentage of recovery, etc., in a commercial plant.

Conclusions.

The material from both the Eastland and Ravenscroft mines is high grade pyrite with only a small percentage of attached coal. There is no technical difficulty in crushing it to about 1 inch size and, by jigging alone, to save nearly all the contained pyrite in a pure form. While the coal can be recovered in a size and purity such that it can be used as ordinary coal of screening size, yet if most of the pyrite contained as little coal as that sent for testing, it is not commercially important to save and clean the small amount of coal produced.

The concentrating table is recommended only as an auxiliary machine to clean the middling products. For a small plant the recrushed middlings could be fed back to the jig and a concentrating table dispensed with. However, this plan lessens the capacity of the jig.

Bon Air Coal and Iron Corporation, Mine Refuse From Ravenscroft, Tenn.

Original Material, 809 lbs. Sulphur Analysis, 40.5%.

Crush to ¾-inch size.

1st Bed Pyrite.	1st Hutch Pyrite.	2nd Bed Middlings.	2nd Hutch Middlings.	Waste Tailings.	Loss
214 lbs.	38 lbs.	268 lbs.	58 lbs.	173 lbs.	57 lbs.
*26.5%	4.7%	33.2%	7.2%	21.4%	7.0%
45.2%S.	44.0%S.	43.9%S.	43.4%S.	26.3%S.	
				45.3%A.	

Crush to ¼-inch size

308 lbs.

Treat on a Concentrating Table.

Clean Pyrite.	Middlings.	Tailings.	Loss.
244 lbs.	25 lbs.	37 lbs.	2.0 lbs.
75.0%.	7.7%	11.3%	6.0%
44.9%S.	40.5%S.	38.1%S.	
		52.0%A.	

*26.5% means that 26.5 per cent by weight of the original material was saved here.

Resume of Test on Pyrite From Bon Air Coal and Iron Corporation, Ravenscroft, Tenn.

Weight, Less Sample, 790 lbs.

Product	Pyrite Recovered		Middlings		Coal Tailings or Refuse		Losses
	Weight	Sulphur Analysis	Weight	Sulphur Analysis	Weight	Analysis	
1st Bed Pyrite	214	45.2%					
1st Hutch Pyrite	38	44.0%					
2nd Bed Middlings (see Table Products)							
2nd Hutch Middlings (see Table Products)							
Jig Coal Tailings					173	26.3%S. 45.3%A.	
Table Pyrite	244	44.9%					
Table Middlings	25	40.5%					
Table Coal Tailings					37	38.1%S. 52.0%A.	
Jig Loss							57
Table Loss							2
Totals	521	44.7%			210	28.4%S. 46.5%A.	59

From 790 lbs. treated, 521 lbs. of pyrite were recovered, analyzing 44.7 per cent sulphur. This is a recovery of 66 per cent. The middlings were fine enough to be included in this pyrite column.

The coal tailings were 210 lbs., or 26.6 per cent of the original material. They analyzed 28.4 per cent sulphur and 45.6 per cent ash. This material is useless for coal on account of its high sulphur and ash content. Technically, there would be no difficulty in crushing this material finer and in extracting some of the remaining pyrite.

The treatment losses were 59 lbs., or 7.4 per cent.

On page 69 is a flow sheet of a proposed concentrating plant for the crude pyrite from these mines based on an estimated treatment capacity of 50 tons per 8-hour day. It should be remembered that on account of the low value per ton of the pyrite it is necessary to keep a treatment plant as simple as possible, and that while better recoveries might be made with a more complicated plant, yet from the tests it does not seem advisable to install expensive apparatus necessary if the small sizes were to receive special treatment. Moreover, the coal pyrite slimes very little on crushing, and the small sizes are the lowest in pyrite content.

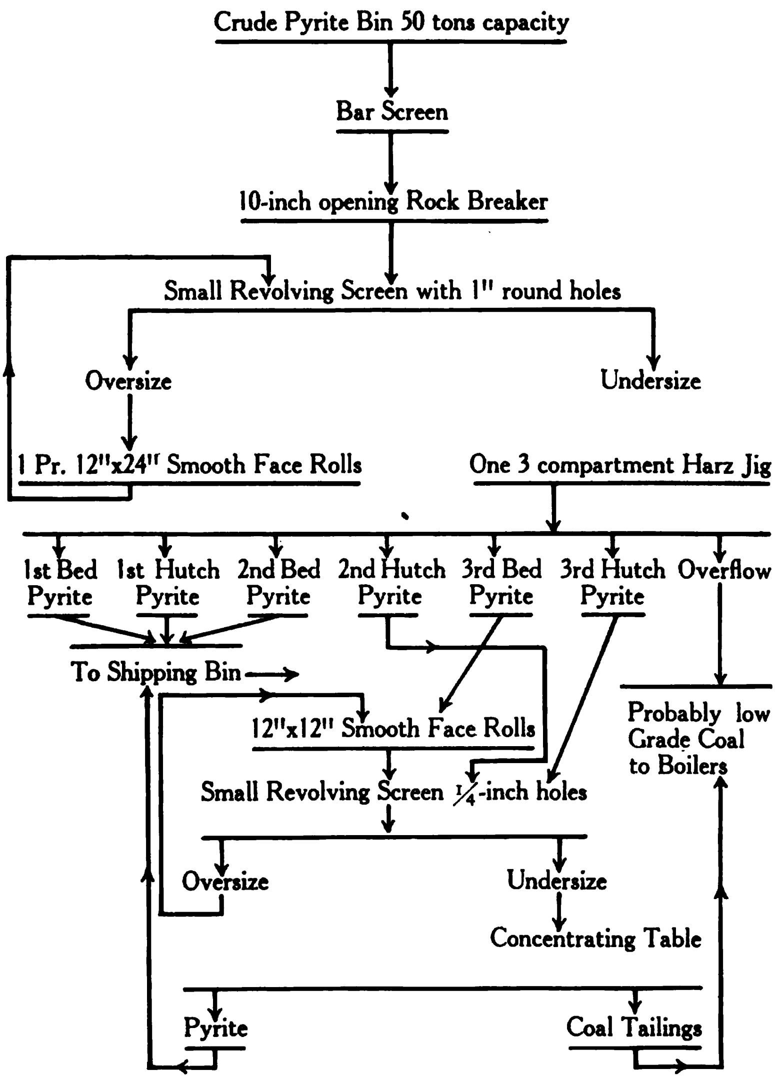
As a preliminary estimate, a plant to treat 50 tons per 8-hour day of crude pyrite should have crushing machinery consisting of a

FLOW SHEET

50-TON COAL PYRITE CONCENTRATING PLANT

FOR

BON AIR—CLIFTY DISTRICT



common Blake or gyratory rock crusher, followed by a pair of smooth rolls. This should be followed by a 3-compartment plunger jig having compartments about 2 feet square. Following this jig should be a pair of small rolls for recrushing the partly cleaned middling products from the jigs, and following these rolls should be a concentrating table for saving pyrite from the crushed material.

The necessary power, building, water supply and bins should probably bring the total cost of a pyrite concentrating plant up to about $14,000 at the present time. For a 100-ton plant per 8-hour day the total cost would be about $20,000.

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.*

BULLETIN No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

BULLETIN No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

BULLETIN No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

BULLETIN No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

BULLETIN No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

BULLETIN No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen; issued May, 1911; postage, 4 cents.

BULLETIN No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

BULLETIN No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

BULLETIN No. 14—The Zinc Deposits of Notheastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations; postage, 3 cents a number.

BULLETIN No. 15—Administrative Report of State Geologist, 1912.

BULLETIN No. 16—The Red Iron Ores of East Tennessee, E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

BULLETIN No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

BULLETIN No. 18—Administrative Report of the State Geologist, 1914.

BULLETIN No. 19—Elevation in Tennessee, by Elizabeth Cockrill; issued 1917, 80 pages; postage, 3 cents.

MAPS—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 15 cents.
Map of Rutherford County, 1916; postage, 2 cents.
Map of McNairy County, 1916; postage, 2 cents.

"THE RESOURCES OF TENNESSEE"—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number. The following are the volumes and numbers issued, with the title of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley. (Out of print).

No. 2—The Camden chert—an ideal road material, by Geo. H. Ashley. (Out of print.)
The Fernvale iron ore deposit of Davidson County, by Wilbud A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.
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No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

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No. 5—The Growth of Our Knowledge of Tennessee Geology, by L. C. Glenn.

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Spring Creek Oil Field, by M. J. Munn. (Out of print.)

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
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No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Heneger.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
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No. 4—Manganese Deposits of East Tennessee (Part II), by G. W. Stose and F. C. Schrader.

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With Laboratory Tests Made at the Ceramic Laboratories, University of Illinois and Notes by Cullen W. Parmelee

Characteristic Properties of Ball and Plastic Refractory Bond Clays ______ By Cullen W. Parmelee

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Ball Clays of West Tennessee

By Rolf A. Schroeder

With laboratory tests made at the Ceramic Laboratories, University of Illinois, and notes by Cullen W. Parmelee.

Introduction.

This report deals primarily with ball clays, which are in great demand at the present time, but occur very sparingly in our country, the majority of deposits being in West Tennessee and just across the line in Kentucky. Such high grade clays are used in the manufacture of porcelain, glass-pots, crucibles, enamel ware, etc. Many firms complain that the supply does not meet the demand and that they have to import from Europe. Moreover, ball clay is a "war mineral," and consequently its exploitation and development are matters of importance. Most of the clay mined here is shipped to other states, where it is manufactured into high-grade porcelain, electric and enamel ware, crucibles, etc. It would be a great boon to Tennessee if a ceramic industry were established here where the clay is found. This report and the accompanying tests will give an impetus, it is hoped, to prospecting and development of clay manufacturing in the South.

[1]"The principal recent concern of the American manufacturers has been to find a substitute for the high grade clays formerly imported from Germany and used in the manufacture of glasshouse supplies, crucibles, lead pencils, emery wheels, etc. At the beginning of the war the users of these clays were apparently well supplied with them. As stocks became depleted, with no prospect for a resumption of imports, the manufacturers of high grade refractory products turned to the United States Geological Survey for information as to sources of domestic clays suitable for these uses."

Bleininger and Schurecht[2] of the Bureau of Standards, have shown the feasibility of substituting domestic for foreign clays and com-

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[1]From U. S. Geol. Survey Bull. 666-T, by Jefferson Middleton, 1917.

[2]Bleininger, A. V, and Schurecht, H. G. Properties of some European plastic fire clays: Bur. Stand. Tech. Paper 79, 1916.

ment as follows on the situation: "The question of replacing the plastic clays imported from Europe in considerable quantities up to the outbreak of the European war has been of importance to the industries concerned. The materials which are chiefly concerned are the Gross Almerode clay for the glass, and the Klingerberg clay for the graphite-crucible and allied industries. Some of the users of these clays have sought to replace them by individual American clays. There is no reason to believe that such clays cannot be found in the United States; in fact, materials have been tested in this laboratory which approach the foreign clays in quality. It would be far better, however, to depend upon a mixture of two or more clays, representing both clays of the open and more refractory and of the dense and vitrifying variety, to secure the desired condition. Since such clays as those from the St. Louis, Mo., district have been used for years

FIGURE 1—Key map of Tennessee showing location of Henry and Carroll Counties.

with good success in glass-pot mixtures, in conjunction with the European clays, it would not be difficult to supplement their qualities by means of materials vitrifying at lower temperatures and not subject to overburning within a considerable range of temperature. Such clays, it is true, are not common, but may be found among the ball clays, or semi-ball clays, of Tennessee and Kentucky * * *."

The field studies which form the basis of this report were made by the writer during the summer and fall of 1918 under the direction of the State Geologist, and in co-operation with the United States Geological Survey.

The writer wishes to acknowledge the valuable advice of Wilbur A. Nelson, State Geologist, and the assistance rendered by operators, owners and numerous persons interested in the deposits concerned.

The area surveyed comprises about 3,500 square miles, including most of that part of the State west of the Tennessee River. (See Fig. 1.)

The object of the investigation was to obtain full information concerning the location, geological relations and economic importance of the ball clays of West Tennessee and to obtain thorough tests on these clays by an expert ceramist.

Among those who have made previous investigations in this region are J. M. Safford,[1] L. C. Glenn,[2] Wilbur A. Nelson,[3] Bruce Wade,[4] Stephenson[5] and Berry.[6]

The Method Pursued in Field Investigation.—The most important towns of the region were visited for a period ranging from one day to several weeks, depending upon their proximity to important clay deposits. Posters, advertising the object of the work and requesting clay property owners to communicate with the field geologist, were placed in conspicuous places, and the work was otherwise made known to the public by means of newspaper accounts and personal interviews with leading men of the various towns. Where the clay deposit looked promising a geological examination was made and a fair sample of clay collected and forwarded to Cullen W. Parmelee, Professor of Ceramic Engineering at the University of Illinois, where preliminary, and in some cases complete, tests were made, the results of which are incorporated in this report under the local descriptions of pits and prospects. The methods of making these tests are discussed in a separate chapter by Mr. Parmelee. In some places auger holes were bored to determine the thickness of the clay stratum or to procure a fresh sample.

Field Method for Distinguishing Ball Clays.—Ball clays should possess a high degree of plasticity, that is, they should cohere like putty. A good test is to whittle off some thin shavings from a fresh sample with a pocket knife. It is quite impossible to obtain long, thin pieces which will not break or crumble unless

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[1]Safford, J. M., Geology of Tennessee. Nashville, 1869.

[2]Glenn, L. C., Underground waters of Tennesse and Kentucky, etc., U. S. Geol. Survey Water-Supply Paper 164.

[3]Nelson, Wilbur A., The clays of West Tennessee. Tenn. Geol. Survey Bull. 5.

[4]Wade, Bruce, Geologic map of McNairy County (in preparation).

[5]Stephenson, Lloyd William. Cretaceous deposits of the eastern Gulf region and species of exogyra from the eastern Gulf region and the Carolinas. U. S. Geo. Survey Prof. Paper 81.

[6]Berry, Edward W. The lower Eocene floras of southeastern North America. U. S. Geol. Survey Prof. Paper 91.

the specimen is ball clay. In boring through ball clay with an auger, the borings should come up in long coils, which do not break, and retain the shape given them by the convolusions of the instrument. A peculiar snapping sound, like the discharge of an electric spark, is commonly heard while boring through fat ball clays and the instrument is pulled down into the clay rapidly, no pressure being necessary, but in gritty, non-plastic clays it is sometimes impossible to bore faster than a foot an hour, employing the utmost downward pressure. Ball clays can be bored several feet in as many minutes. They should have a greasy feel like soap. No sand, mica or grit of any sort should be present. Usually these impurities can be felt with the finger, but a good test is to place a small particle between the teeth and the finest grit will be easily perceptible.

Red, rusty, bright yellow, or black clays will not burn white and hence are not ball clays. White, pale pink, grey, bluish, or brown colors may burn out and these colors may be present in ball clays.

Lastly, ball clay should be homogeneous, having no parting planes such as bedding or close jointing.

SUMMARY.

The economically important clays of West Tennessee occur, with few exceptions, in Henry and Carroll counties. The geologic horizons in which the clay lenses are found are the upper portions of the Ripley (Upper Cretaceous), and the lower Lagrange (Eocene), both consisting of unconsolidated quartz sands. Although clay strata are abundant south of these counties they are for the most part less "pure" and not suitable for ball clay. The common adulterants are quartz, mica and iron compounds. The best ball clays of Henry and Carroll counties seem to be associated with lignite. Very high grade clays are found in these counties, ranking favorably with imported European clays. In all, fifty-nine samples were collected and given preliminary tests. Nineteen were given complete tests. Thirty-four samples represent unworked deposits, of which about 90 per cent are of economic value and the deposits from which they were taken should be developed.

At the present time four or five concerns are mining most of the high grade clay produced in the State. Many good deposits are idle, due to lack of prospecting and initiative on the part of the owners. Another obstacle to further development of new deposits is the reticence on the part of consumers, especially potters, to use a clay they are unaccustomed to, preferring the clay they know to one that may be better and lower priced. Without full tests, often expensive, the prospective producer cannot tell for which purpose his particular clay is best suited and consequently does not cater to the proper industry.

Geographic Distribution.

In Tennessee ball clays are abundant in Henry County, occur to a lesser degree in Carroll County, and sparingly in Haywood and madison counties. In Kentucky[1] they are found in Ballard, Calloway and Hickman counties, mostly in the northern extension of the same formations in which the Tennessee ball clays occur. They are also mined at Edgar, Fla., Woodbridge, N. J., and in Missouri. Foreign localities are England, Austria and Germany.

Topography.

The surface of Tennessee west of the Tennessee River, varies from a very flat flood plain, along the main rivers and tributaries, to a gently rolling or hilly surface in the interstream areas. Generally the surface is moderately hilly and is cut into bolder hills near the valleys of the larger streams. Several different types of topography are characteristic features of the ball clay areas.

Hills of Erosion.—These constitute an unusually hilly belt in the eastern part of the Lagrange exposure. Here gullies and ravines erode the loose sands rapidly, forming a very rough country.

Flatwoods.—The surface underlain by the Porter's Creek clay, especially near the Kentucky line, is of more than average flatness, which is due to the resistance offered by these clays to erosion and to their nearly horizontal attitude.

Geology.

GENERAL STATEMENT.

The rocks in the region under consideration comprise sands, clays and gravels that range in age from Cretaceous to Recent, though the record is not one of continuous deposition. The sands are generally unconsolidated, though locally thin bands of ferruginous sandstone and conglomerate have been formed by cementation. These, however, nowhere exceed several feet in thickness.

[1]Gardner, James H., Some Kentucky clays, Kentucky Geol. Survey Bull. 6.

GEOLOGIC FORMATIONS.

The oldest rocks represented are Paleozoic limestones, exposed just east of the area surveyed, which form the floor of deposition for all subsequent deposits. The Eutaw Sands and the Selma Clay (Lower Cretaceous) rest unconformably upon this floor. These sands also crop out just east of the area under discussion. Over these lie the Ripley and the McNairy Sand Member of the Ripley (of the Cretaceous); the Porters Creek and the Lagrange of the Eocene; the Lafayette of the Pliocene (considered by Berry[1] to be Pleistocene); and the Columbia of the Pliestocene (considered by Berry[1] to be Recent).

FIGURE 3—Cross-bedding in the Ripley sands north of Buena Vista.

STRATIGRAPHY.

Cretaceous System.

Selma Clay.—The Selma clay is exposed in a narrow belt in the southeast part of McNairy County. It is leaden grey or greenish when dry but blue or black when wet. Fossils are abundant and in certain parts the clay is glauconitic. *Exogyra* (a form related to the oyster) and *Ostrea* (an oyster) are characteristic, while reptile bones are

[1]Berry, Edward W., The lower Eocene floras of southeastern North America, U. S. Geol. Survey, Prof. Paper 91.

occasionally found. The formation is about 100 feet thick at Lexington, but thickens southward.

Ripley and the McNairy Sand Member.—These beds are exposed in a band six to fifteen miles wide which extends north and south entirely across the State through Selmer, Lexington and Hollow Rock. This formation is composed of red, brown, yellow, pink and purple sands, cross-bedded (see Fig. 3) and inter-stratified with clay and lignitic material. Concretionary ironstone is abundant. In places the sand includes clay lenses and some of these are being worked in Henry and Carroll counties. This deposit is very similar in appearance to the Lagrange, and considerable difficulty is encountered in discriminating between the two. The following criteria, however, are at times useful: as a rule the Ripley sands are somewhat more orange in color and more micaceous than those of the Lagrange. The thickness of this formation is about 500 feet. It is very liable to erosion and makes exceedingly rough country. Roads built in these sands are often transformed into gullies unless well cared for.

Eocene Series.

The Porters Creek Formation.—This formation rests unconformably upon the McNairy Sand Member of the Cretaceous and outcrops immediately west of the latter in a band averaging four miles in width and traversing the State from north to south.

It is composed mainly of dark, fine-grained, micaceous, sandy clay, which is pale grey when dry but black when wet, and is locally known as "soapstone." On weathered surfaces it possesses a peculiar concentric fracture, giving it a ball-like appearance. Locally, it is penetrated by thin, sandstone dikes. The lower part of this formation also contains interbedded, fine, micaceous, silty sands and greensand. The latter may contain enough calcareous matter to cement certain layers into impure limestone.

The thickness of this formation averages 175 feet. It's surface exposure is unusually flat and the country underlain by it is generally termed "the Flatwoods."

Lagrange Formation.—This formation is of Wilcox age and outcrops immediately west of the foregoing one in a band of variable width. It underlies all of the area under consideration in this report west of the Porters Creek exposure. A thin capping of Lafayette and Columbia loess and loam conceals it in the western portions.

It is composed of cross-bedded and interbedded. sands, clays, lignitic matter and thin gravel beds. Clay conglomerates (see Fig. 4) and breccia occur locally. Much the larger part is sand, which is mostly fine-grained, and is composed of semi-rounded particles of transparent, colorless quartz, chert and muscovite flakes. The color of the sand is usually a cream or light orange, though brown, red, pink and purple is common. A thin veneering of iron compounds upon the sand grains generally causes the coloration.

The clays of this formation are the best in West Tennessee, grading from the best ball clays down to common brick clay. The clav lenses occur in its upper horizons and are generally associated with

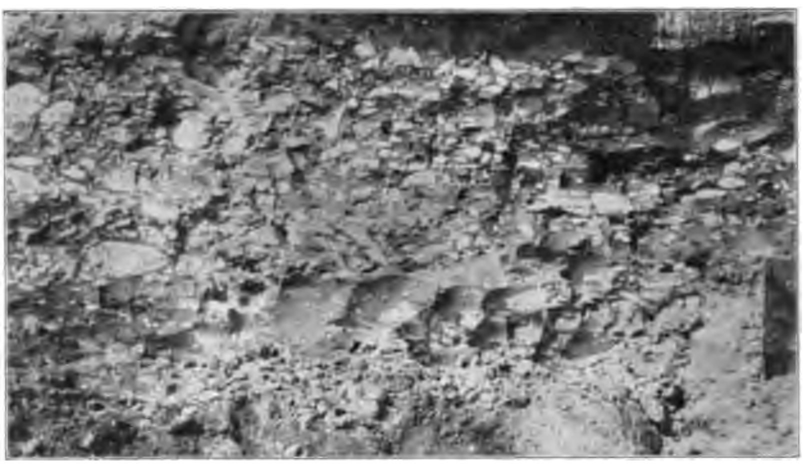

FIGURE 4—Clay conglomerate near Pinson. Scale, 1 inch=10 inches.

lignitic beds. These lenses as a rule cover several acres and are elliptical in plan, their long axes trending several degrees west of north, in Henry and Carroll counties, while in the southern counties they extend east of north. In short there is a tendency towards an alignment parallel to the ancient shore line.

The thickness of this formation varies from 148 feet at Jackson to 936 feet at Memphis.

Pliocene Series.

Lafayette Formation.—Over all the formations just described and extending eastward over the adjoining Paleozoic rocks, there is a thin blanket of brick red sand, clay and gravel, having an average thickness of twenty feet. The sands are characteristically case-hardened and massive, and frequently stand up in vertical walls or "knife-edges" where subjected to erosion. The sands are often accompanied by gravel, which usually forms the basal part. They are especially prominent in the region about Puryear in Henry County, and are composed of novaculite, quartzite and chert. These gravels are considered by Wade[1] to be stream terrace deposits, laid down by the Tennessee River, the detritus being derived from its headwaters in northern Alabama.

Pleistocene Series.

*Columbia Formation.**—This is a thin blanket of loose, brown sand, loess and loam which rests upon the Lafayette sands in this region. It varies in thickness from zero to five feet.

STRUCTURAL GEOLOGY.

These sands and clays lie in the eastern half of an embayment of the ancient seas, which projected northward from the Gulf region and ended in southern Illinois. They were laid down on the floor of this embayment in broad, successive superimposed sheets. At the northern end of this trough in Illinois, the formations rise to the surface like the tip of a spoon. The western half lies in southwestern Missouri and eastern Arkansas. The eastern part crops in parallel zones, trending north and south across the State, the strata dipping gently (thirty feet per mile) towards the west. They have not been subjected to any extensive folding or faulting, the folds being limited to minor crenulations and slight warpings, which have in some cases given rise to symmetrical, dome-shaped hills of low elevation (see Fig. 2). The New Madrid earthquake, which formed Reelfoot Lake,[2] was accompanied by faulting. At this time small sandstone dikes[3] were intruded in the Porters Creek clay.

HISTORICAL GEOLOGY.

The oldest and deepest rocks in this region are the Paleozoic limestones, whose eroded surface formed the sea floor upon which were

*Considered to be Pleistocene by Berry.

[1]Gravels of West Tenn. Bruce Wade, *The Resources of Tenn.*, Vol. VII, No. 2, p. 67.

[2]Fuller, Myron F., The New Madrid earthquake. U. S. Geol. Survey Bull. 494.

[3]Fossiliferous sandstone dikes in the Eocene of Tennessee and Kentucky: abstract from Science, new Ser. Vol. 19, 1904, p. 522.

deposited the Cretaceous and Eocene rocks already described. Towards the end of the Upper Cretaceous the waters were shallow and brackish as indicated by well developed cross-bedding, the presence of leaves and other organic matter in the clay. This period was followed by uplift and subsequent depression, allowing the deposition of the Porters Creek clays in deeper water. The region was again elevated and the Lagrange sands and clays were deposited in brackish, shallow water. (See "Origin of Clay Lenses," p. 92.) During the Oligocene and Miocene the region was lifted out of the sea and remained land until it again subsided in Pliocene time enabling the deposition of the Lafayette sands and the Columbia loam. Then followed another elevation and consequent withdrawal of the seas, exposing the land to erosion, bringing about the major features of the

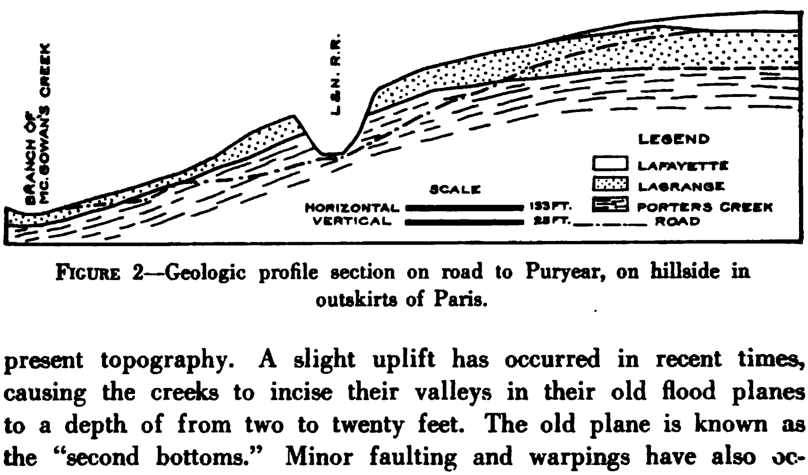

FIGURE 2—Geologic profile section on road to Puryear, on hillside in outskirts of Paris.

present topography. A slight uplift has occurred in recent times, causing the creeks to incise their valleys in their old flood planes to a depth of from two to twenty feet. The old plane is known as the "second bottoms." Minor faulting and warpings have also occurred in recent times.

ECONOMIC GEOLOGY.

Clay, sand and gravel are the only substances of any economic importance contained in these rocks.[1]

The McNairy Sand Member of the Ripley and the Lagrange formations contain ball, sagger and pottery clays; and the Lafayette

[1]The possible occurrence of oil and gas in West Tennessee has recently been arousing some interest. Although none has been found up to the present time, the possibility exists of finding an oil sand here. It is a difficult matter to work out the structure because the contacts are for the most part concealed by the overlying Lafayette sands.

sands are argillaceous enough in places to afford good brick clay.

Sand is mined, especially in the region around Grand Junction, and is used to make plate glass and concrete.

Uses of Ball Clay.

Ball clays are extensively used as a necessary ingredient of white ware mixtures in order to give the body sufficient plasticity and bonding power. The following list enumerates some of the more important ues of ball clay:

1. *Electric Porcelain Ware and Insulators.*—Ball clay, china clay, feldspar and quartz are used in the manufacture of these articles. The function of the ball clay is to increase the plasticity of the mixture so that the many intricate designs which are required can be readily pressed or formed.

2. *Porcelain or China.*—This is made of ball clay, kaolinite, quartz and calcium phosphate or feldspar, depending upon whether a soft or hard ware is desired.

3. *Plate Glass Industry.*—Ball clay is used in making pots in which optical glass is melted. These pots are used but once and are made out of high grade kaolinite with 20 to 30 per cent of ball clay to bind the kaolinite. It also has the effect of increasing the density of the pot when burned.

4. *Sanitary Ware and Enamel Ware.*—This ware is made at extremely high temperature. Hence, a very refractory clay is desirable. The white ball clay from the Dalton Mine, near McKenzie, is used for this purpose.

5. Ball clay is also used in making graphite crucibles, as a binder in abrasive wheels, in the pottery industry, in making greenhouse ware, tiling, lead pencils, chemical ware and cosmetics.

Production and Prices.

In Tennessee, according to reports from operators, the total output of high grade clay for the last fiscal year approximated 65,000 tons. Production was somewhat impeded by freight embargoes and scarcity of labor. The leading producers are the Mandle Clay Mining Co., of St. Louis; Johnson-Porter Clay Co., of Paris, Tenn.; H. C. Spinks Clay Co., of Newport, Ky.; Cooley Ball and Sagger Clay Co., of Hazel, Ky., and A. Nunnelly, Hollow Rock, Tenn.

The average price commanded by sagger clay is $3.00 per ton f.o.b. mines, and of ball clay about $6.00, although the price is governed somewhat by market conditions, some clays varying considerably from these figures. [1]"While the importation of the Gross-Almerode, Vallendar, and other German clays was entirely cut off during the war, that of English clays was not seriously interfered with. The agitation in this country over the possible curtailment of imports brought the English clay miners to the realization, heretofore not evident, of the extent of our dependence upon their clay, with the result that within about a year their price has risen nearly 100 per cent. This development has aroused consumers to redouble their efforts to find suitable domestic substitutes. That their search has been at least partly successful is shown by the fact that clay imports have been steadily decreasing and that at the present rate the 1919 total will be only about 50 per cent of that of a normal pre-war year." War conditions have caused considerable fluctuations in the price of ball clay, but no doubt when normal conditions return the equilibrium of the clay market will be restored. Normally a haul of more than six miles to the nearest railway is prohibitive even if the clay is high grade.

Origin of the West Tennessee Clay Lenses.*

Clays are invariably of secondary origin, and are the result of decomposition of pre-existing rocks or minerals. They may remain in place as residual clays or may suffer transportation and redeposition as sedimentary clays. This latter is the type we are dealing with in West Tennessee. Nevertheless, a few words regarding the formation of the primary clay may be in place. Residuary clays (kaolinite, halloysite and allied species) are largely derived from the decomposition of feldspar or feldspathic rocks. This may be effected by pure water (hydrolysis) with the development of colloidal gels, but is hastened by the action of carbon dioxide and sulphuric acid. Rain water and carbon dioxide from the air react upon feldspar and change it to kaolinite. Sericite and other minerals are also known to yield kaolinite.

The kaolinite (or allied species) thus formed remains as a residual mantel over the parent rock until attacked by erosion, when it be-

[1]Excerpt from monthly report on mineral investigations by the Bureau of Mines, Department of the Interior, March, 1919.

*The writer has made no attempt to make an exhaustive study of this subject. There was no time available for careful investigation, and, moreover, the purpose of this paper is primarily economic and hence it is treated only in a general way.

comes liable to transportation. The assorting and transporting power of running waters rarely allows such residual clays to remain in the place of their origin. The minute size and shape of the constituent particles are such as to render them easily transported by rains and running streams, to be redeposited in stratified beds when the carrying power is lost by the checking of the current, when they flow into lakes and seas. Thus it is evident that clay particles are originally derived from igneous rocks.

The nearest igneous rocks to the embayment deposits will be found in the Appalachian region.

In a discussion of the origin of West Tennessee clays, the following considerations are significant:

1. The Ripley and Lagrange formations in West Tennessee are composed essentially of transparent colorless grains of quartz, muscovite mica and clay (in places micaceous)—the three important decomposition products of a granite.

2. The general configuration of the Cretaceous and Eocene shore line would suggest a source of supply situated in central Tennessee and Kentucky, northeastern Alabama and northern Georgia.

It will be seen that this is the locus of existing or pre-existing argillaceous shales, sandstones and conglomerates of Carboniferous age whose original home was in the granite rocks of the Appalachians

Glenn[1] attributes the primary origin of the clay substance embodied in these deposits to the disintegration of chert and the weathering of limestone in nearby Paleozoic rocks, but he does not account for the presence of white mica in the clay and overburden. Watkins[2] says: "Though this area seems far removed from the crystalline area of the southern Appalachian region, it should be remembered that the waters of Tennessee River, which must have once deposited their burden along this coast line, have their origin far into the crystalline area. Besides this, beds of white clay similar to the West Tennessee clays occur almost continuously in the Cretaceous from Tennessee through Mississippi and Alabama to Georgia. It would seem that a part of the clay may have had its origin in the residual clays of the crystalline rocks."

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[1]Glenn, L. C., Underground waters of Tenn. and Ky. west of Tenn. River, W. S., 164, p 34.

[2]Watkins, Joel H., White-burning clays of the Southern Appalachian States: Am. Inst. Min. Eng., Bull. No. 98, p. 407.

The following theory seems tenable:

(1) That these sands are in part derived from the erosion and redeposition of Carboniferous strata, and in part represent original residual matter from granitic rocks to the east.

(2) That the clay, once incorporated in these rocks has been transported, resorted and redeposited in brackish or fresh water, very near shore or in lagoons, under conditions of comparative tranquility.

(3) That the ball clays in particular, which are confined to northern portions of West Tennessee and southern Kentucky, were deposited at a time of subsidence of the old land surface, the streams being excessively sluggish and of low gradient, with correspondingly decreased transporting power. The clay was probably deposited in lagoons close to shore or in the irregularities of a low, flat land surface, such as ponds or swampy depressions. The presence of numerous leaf impressions in a perfect state of preservation, fossil wood and nuts, corroborates this idea.

The following is an excerpt from Berry's[1] description of a section about one-fourth of a mile south of the depot at Puryear, immediately west of the N., C. & St. L. Railway, in a clay pit (Mandle Clay Mining Co., now abandoned):

"This is the most remarkable leaf-bearing clay that I have ever seen at any geologic horizon. The fossiliferous layers are practically without sand and must have been deposited in very quiet waters. They are crowded with leaves that lie horizontally, but not in matted layers. There is no evidence of seasonal accumulations. * * * The plants must have grown near at hand, for they could not have withstood much transportation. Indeed, most of the forms are evidently coastal types."

"I picture the Wilcox conditions here as an area at the mouth of a Wilcox stream of low gradient, carrying only the finest sediments, that emptied into a lagoon lined on the landward side by a sand beach supporting a typical subtropical strand vegetation and separated by a considerable barrier beach from the main body of embayment waters. That it was not an estuary or bayou seems to be indicated by the lack of carbonaceous muds and the presence of a few gypsum crystals."

[1]Berry, Edward W., The lower Eocene floras of southeastern North America, U. S. Geol. Survey, Prof. Paper 91, p. 48.

The local occurrence of chert, quartzite and novaculite gravels does not disprove the theory just presented. Cherts are common in the Paleozoic rocks not only as concretions but as well-rounded gravel, and we would naturally expect to see their waterworn remains in the younger strata. They form a very small percentage of the total detritus.

Wade[1] has the following to say regarding the origin of these quartzite pebbles: "There are no quartizite or quartz country rocks in the vicinity of West Tennessee, so these gravels were probably derived from the conglomerate horizons in the Pennsylvania series occurring in northern Alabama and East Tennessee. * * * The similarity between these terrace pebbles and the Lee conglomerate of the Cumberland Mountains is striking."

ORIGIN OF THE IRONSTONE CONCRETIONS.

When waters, saturated with iron compounds, descend through unconsolidated sands, they are liable to encounter obstructions on

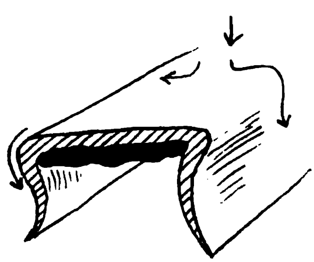

FIGURE 5—Sketch to illustrate origin of ironstone concretions. Arrows indicate direction taken by descending waters. Black portions represent a clay pellet and cross-hatched portions represent the concretion in section.

their downward path and precipitate iron oxide or hydroxide upon these. The obstruction is usually a clay pellet but may be a fossil or merely a coarse stratum of sand. The depositing solutions follow this horizontally and trickle down over the edges, forming, in some cases, stalactitic, curtain-like appendages. (See Fig. 5.) This accounts for the frequent occurrence of iron hard-pan beds immediately above clay deposits, and also for the very white and pure quartz sands immediately below. Saturated chalybeate solutions will precipitate upon the

[1]Wade, Bruce, Gravels of West Tennessee, Resources of Tenn., Vol. VII, No. 2.

slightest particles which may impede their downward progress, such as rootlets, fossils, unusually coarse grains or zones of sand, small clay pellets, etc. A concretion found by the writer at Pit No. 9 of the Cooley Ball and Sagger Clay Co., had the shape of a perfect spherical shell, which enclosed a little loose sand and a yellow clay pellet.

Definitions of Clays.

Clay is a term applied to those earthy materials occurring in nature whose prominent property is that of plasticity when wet and induration when dry. Clays are composed of many different minerals in a fine state of division, of which kaolinite is the most characteristic. Following is a list of minerals found in West Tennessee clays by means of the polarizing microscope:

*Minerals in Tennessee Clays.**

	Quartz	Hydromica	Kaolinite	Rutile	Zircon	Tourmaline	Epidote	Titanite
Clays from the Ripley Formation.								
Sagger clay, Hollow Rock	C	A	C	C		S		
Sagger clay, Hollow Rock	C	A	A	A	S			
Lignitic clay, India	S	A	C	S				
Brown sandy clay, Currier Pit, Paris	C	A	A	A		S		S
Dark clay, Currier Pit, Paris	C	A	C	S				
Clays from the Lagrange Formation.								
Clay lens in Dale's Sand Pit, Lagrange	A	S	A	M	S	S		S
McNanee Pit, Lagrange	C	A	A	A	S			
No. 10 Ball clay, Johnson-Porter Clay Co., McKenzie	S	A	A	S		S		
No. 11 Ball clay, Johnson-Porter Clay Co., McKenzie	S	A	A	S				
Sparks Pit, McKenzie	S	A	A	M		S	S	
Sagger clay, Chrisman-Reynolds Pit, Henry	A	A	C	C	S	S		
No. 1 S. G. P., Mandle Clay Mining Co., Whitlock	S	A	C	C		S		
No. 5 Ball clay, Mandle Clay Mining Co., Whitlock	S	A	C	S				
No. 7 Ball clay, Mandle Clay Mining Co., Whitlock	S	A	C	S		S		
No. 4 Ball, white, Mandle Clay Mining Co., Whitlock	S	A	C	A		S		

*The petrographic data given in this table were obtained from Dr. R. E. Somers of the U. S. Geol. Survey.

	Quartz	Hydromica	Kaolinite	Rutile	Zircon	Tourmaline	Epidote	Titanite
No. 4 Ball, dark, Mandle Clay Mining Co., Whitlock	S	A	C	S				
Wad clay, Cooley Ball & Sagger Clay Co., near Hazel, Ky.	C	C	A	C		S		
Dark Ball clay, Cooley Ball & Sagger Clay Co., near Hazel, Ky.	S	A	C	A	S			
Dixie Brick & Tile Co., Puryear	C	C	VA	S	S	S		S

Note. A—Abundant M—Moderate amounts
VA—Very abundant S—Scarce
C—Common

The foregoing table shows us that in these clays quartz is always present in variable amounts, that mica is, as a rule, abundant, and kaolinite is common to abundant. The presence of quartz and mica is a suggestive fact in a consideration of the genesis of these clay beds. Moreover it will be seen that rutile is common and that zircon, tourmaline, epidote and titanite also occur, which immediately suggests an igneous rock origin for these clays. Doubtless they were derived, in part at least, directly from the granitics of the Appalachian region.

Another important constituent of clay is colloid gel, concerning which Ashley[1] says: "It forms an enveloping coating upon most of the mineral grains, and consists of non-crystalline, hydrated gelatinous aluminum silicates, organic colloids, gelatinous silicic acid and hydrated ferric oxide. Quartz and mica grains which are usually present, do not have the colloid coating, or have it in a much less degree. If this granular matter is in excess the clay is called sandy, weak or *non-plastic*, but if the colloid matter is in excess the clay is considered *very plastic*, fat or sticky."

It will be seen from the foregoing that clay is an aggregate of minerals and consequently is not a mineral but a rock. Chemically, clay consists of hydrous and anhydrous aluminum silicates, free silica and varying amounts of iron and other oxides, carbonates, silicates, etc., in short of stable compounds generally having low specific gravities.

[1]Ashley, H. E., The colloid matter of clay and its measurement, U. S. Geol. Survey Bull. 388, p. 8.

Ball clays are highly plastic, refractory, white or nearly white-burning clays of sedimentary origin, possessing high tensile strength and homogeneity. Consequently they should contain no iron compounds, free silica, mica or grit and should possess no tendency to part along bedding planes. Probably so-called from their striking property of "balling up" or cohering.

Sagger clays are tough, plastic, refractory clays having low shrinkage and are commonly rather siliceous and may be well stratified; in short they are impure ball clays. They are so called from their use in making receptacles known as "saggers," in which the better grades of ware are enclosed during burning.

Wad Clays are low grade, siliceous clays, not necessarily tough or plastic, which are used for grouting or filling up the joints between the saggers, when they are piled one upon another in the kilns.

PROPERTIES OF CLAY.

*Plasticity**—Plasticity[1] is the property which many bodies possess of changing form under pressure, without rupturing, which form they retain when the pressure is removed.

The causes for plasticity are discussed under the definition for clay on page 95. Plasticity is closely related to the amount and kind of colloid matter present and the degree of comminution of the mineral particles. The most highly plastic clays are those that have been subjected to the action of water for long periods. The longer the mineral particles remain in suspension in water the more liable they become to corrasion resulting in still finer division and the more complete is the sorting action. Davis[2] says the following regarding suspension:

"Clay particles suspended in water take on negative electric charges and continually repel one another. Consequently this tends to keep them in suspension. The presence of organic and emulsion colloids greatly increases the stability of suspension and are known as protective colloids. To test the effect of organic matter on suspension,

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*As plasticity is the most prominent property of ball clay, it is discussed rather fully in this report. This subject is also taken up in the accompanying paper by Cullen W. Parmelee.

[1]Ries, H., Clays, occurrence, properties and uses, 2nd ed., 1908, p. 119.

[2]Davis, N. B., The plasticity of clay and its relation to mode of origin: Am. Inst. Min. Eng., Bull. No. 98, pp. 301-330.

a couple of pounds of Delaware washed kaolin, water, and an ounce of peat were placed in a ball mill. After ten hours' mixing the slip was drawn and allowed to dry. It was then mixed with water to a plastic mass. Comparing the resultant plasticity with that in a portion of untreated kaolin, it was found to have increased. Samples of the treated and untreated material were then suspended in water and allowed to settle. After ten hours it was observed that the untreated kaolin had settler clear, while the treated portion showed considerable matter in suspension."

That plasticity is closely related to organic content is evidenced by the common occurrence of lignite in the best clay beds of West Tennessee.

Ashley[1] says that it has been the custom for many years to add various gelatinous substances to clay to improve its working qualities. Some of these are gelatin, glue, starch, gum arabic, dextrine, milk, sodium silicate, cow and horse dung and rotten paper. Acheson,[2] Auclair[3] and Keppler[4] have patented certain methods for improving plasticity by means of colloidal chemical processes.

Ashley[1] has shown that it is possible to measure plasticity by observing the power a given clay has for adsorbing malachite green dye. He has made interesting and extensive tests on many clays, among which are certain important Tennessee clays. The results are shown in the following table. The figures are very instructive, for they give us a numerical conception of relative plasticities.

Plasticity of Tennessee Clays.

Mandle Clay Mining Company, "Special Sagger"	9.09	?
Mandle Clay Mining Company, "Tenn. Ball No. 3"	5.96	
Johnson-Porter Clay Company, "Tenn. Ball No. 9"	5.76	
Potter's Supply Company, "Tenn. No. 3"	4.62	
Potter's Supply Company, "Tenn. No. 4"	4.52	
Johnson-Porter Clay Company, "Tenn. No. 10"	3.45	
Johnson-Porter Clay Company, "X Wad"	1.867	?
Johnson-Porter Clay Company, "UX Wad"	1.824	

(*Table continued on following page.*)

[1]Ashley, H. E., The colloid matter of clay and its measurement, U. S. Geol. Survey Bull. 388.

[2]British Patent No. 7776, Apr. 3, 1907.

[3]French Patent No. 372858, Dec. 22, 1906.

[4]German Patent No. 201987, Aug. 4, 1906.

Potter's Supply Company, "Wad"	1.775
Mandle Clay Mining Company, "Wad"	1.530 ?
Mandle Clay Mining Company, "Tenn. No. 9"	1.473
Johnson-Porter Clay Company, "No. 1 Ball"	1.378

Note.—? indicates values probably too high, due to experimental errors.

*Fusion point** is the temperateure at which a substance melts or fuses, and is measured by means of Seger or pyrometric cones. These are test pieces consisting of a series of mixtures of clays and fluxes, so graded that they represent a complete series of fusion points, each but a few degrees higher than the next one to it. Following is a list[1] showing the fusion points of a few of these cones:

Fusion Points of Seger Cones.

Cone No.	F.°	C.°
.022	1,094	590
.07	1,850	1,010
1.	2,102	1,150
2.	2,138	1,170
5.	2,246	1,230
9.	2,390	1,310
10.	2,426	1,330
12.	2,498	1,370
13.	2,534	1,390
20.	2,786	1,530
27.	3,038	1,670
28.	3,074	1,690
29.	3,110	1,710
30.	3,146	1,730
31.	3,182	1,750
32.	3,128	1,770
33.	3,254	1,790
39.	3,470	1,940

*Porosity** is the state of being porous, or having pores. Pores are the spaces existing between the particles which constitute the porous substance. The porosity of clay is measured by the difference in weight of the burned ware before and after being soaked in water. Generally low porosity is desirable in clay ware, as this increases its resistance to weathering.

*For a further discussion of this subject see companion paper by Cullen W. Parmelee.

[1]Ries, H., Clays, occurrence, properties, and uses, 2nd ed., 1908, p. 181.

*Shrinkage** is the contraction which takes place when clays are dried or heated. This reduction in volume is caused by the escape of moisture and other volatile constituents and amounts to twelve per cent in some clays. Therefore, this loss must be allowed for in molding. Shrinkage varies with the temperature.

*Tensile strength** of clay is the resistance which it offers to rupture when air dried. The force required to pull apart certain Tennessee clays varies between 50 and 112 pounds per square inch.

*Vitrification** of clay occurs when its grains become sufficiently softened by heat to coalesce and render the mass impervious. Complete vitrification takes place at the point of maximum shrinkage.

Adsorption is the property possessed by colloids (and necessarily by clays) of taking other substances out of solution or suspension. This property is closely related to plasticity, which latter can be measured by observing the amount of dye (malachite green) that a given clay will take from such a solution. (See *plasticity*.)

*Color** in clay is very variable. The two chief coloring agents are iron compounds and organic matter. Manganese occurs more rarely. A clay free from these is generally white. Carbonaceous matter colors clay blue, grey, brown, black, or even purplish. Three per cent is probably sufficient to produce a pure black. Iron oxide colors clay yellow, brown or red. Greenish color may be due to iron silicate or glauconite. Dry clays are usually lighter in color than wet ones.

When clays are burned their color generally changes. White clays, of course, burn white and red clays burn red, but pale pink clays burn white; deep yellow ones burn buff or red; grey or black ones may burn red, buff, or white; green ones usually burn red; and those whose coloring matter is wholly of an organic nature, not in excessive quantities, burn white.

METHODS USED IN MAKING THE TESTS.[1]

PREPARATION OF THE CLAY.

The clay was carefully inspected and its color, degree of uniformity and the presence or absence of fragments of minerals (not clay) and organic matter noted.

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*For a further discussion of this topic see companion paper by Cullen W. Parmelee.

[1]The paragraphs under this heading were written by Cullen W. Parmelee.

A sufficient quantity of the clay was then crushed between rolls or in a laboratory mortar. In this operation, care was taken to avoid grinding the material. The purpose was to reduce the clay to particles of sufficiently small size to permit a thorough mixing of the sample. When this crushing was completed, the clay was passed through a twenty-mesh sieve and then moistened with a sufficient quantity of water to bring it to a suitable consistency, after which it was thoroughly worked by hand until the whole mass was of a uniform consistency and freed from air blebs.

MAKING THE TEST PIECES.

When the quantity of clay was sufficient, which ordinarily was the case, the plastic mass was formed into a roll which was slightly smaller in size than the inside diameter of the barrel of a piston press. This press consists of a barrel about fourteen inches long and three inches diameter. At one end is a metal die with an opening one inch square. Fitting snugly in the barrel is a piston head mounted at the end of a long screw. By turning the handle of the crank attached to the other end of the screw, the piston may be made to move in the barrel, forcing the clay out through the die in the form of a long bar having a cross-section of a square inch. This bar was cut into peices four inches long.

When the quantity of clay was insufficient for the method described, the plastic mass was formed into rolls somewhat larger than the brass mold into which they were tamped by hand. This gave trial pieces of dimensions similar to those previously described.

Each piece was marked for identification and also two marks eight cm. (3⅛ inches) apart were made for shrinkage measurements. These test pieces were carefully transferred to suitable drying pallettes before marking.

DRYING AND LINEAR SHRINKAGE.

The test pieces were allowed to dry at room temperature, then transferred to a steam heated drier where they remained at a temperature of about 100° F. for several hours, and finally the drying was completed at 212° F. After cooling, the loss in length due to shrinkage was determined by measuring the distance between the two marks previously made. The linear shrinkage is expressed in terms of the length of the wet piece.

WATER OF PLASTICITY.

This was determined by weighing the wet test pieces immediately after forming and after the drying operation was completed, the plasticity is expressed in terms of the percentage of the weight of difference in weight representing the loss of water. The water of the wet piece.

FINENESS.

One hundred grams of the crushed sample and 800 c.c. of water were thoroughly agitated by shaking in a suitable apparatus for two hours. The mixture of clay and water was passed through sieves of 20, 40, 60, 80, 120, 150, 200-mesh in the order named.

The residue left in the sieve was washed freely and soft lumps were crushed by gentle pressure of the fingers. The residues were then dried and weighed. The results are calculated in terms of the total weight of dry clay used.

SLAKING.

Test pieces in the form of cubes were made from intimate mixtures of equal parts of dry clay and potter's flint. These cubes were cut from bars formed in brass molds in the manner previously described. The dimensions of the freshly made cubes were one inch on the edge.

The cubes were dried first at room temperature, then at a temperature of 160°-170° F., finally at a temperature of 212° F.

When cooled to room temperature these cubes were supported on wire mesh trays (four meshes to the inch) and completely submerged in water at room temperature. Care was taken to avoid agitating the water during the test.

The time required for the cubes to slake or crumble through the wire mesh support was noted.

TRANSVERSE TEST.

The test pieces were formed as bars in the manner already described. They were six inches long and had a cross-section in the plastic state of one square inch. They were first dried at the room temperature, then at a temperature of 140°-150° F. for twenty-four hours and finally at 212°-220° F. for twenty-four hours.

After removal from the oven and cooling to room temperature these bars were supported upon knife edges five inches apart. A load was applied at a point midway between the supports by suspending a pail from a yoke having a knife edge which rested upon the bar at that point. Into this bucket a stream of sand was permitted to flow until the weight of the pail and sand was sufficient to break the bar.

The result of the test was expressed as the Modulus of Rupture, which was calculated as follows:

$$\text{Modulus of rupture} = \frac{3 \times \text{weight in lbs.} \times \text{distance between supports}}{2 \times \text{Breadth} \times \text{Depth}^2}$$

The breadth and depth of the bars were determined by measuring the bars before breaking.

Ordinarily ten bars were tested, and the average of eight or nine taken.

BONDING TEST.

The test pieces are made of equal parts of clay and standard sand that passes a twenty mesh (0.0328 inch hole, 0.0172 inch wire) and is retained on a twenty-eight mesh (0.0232 inch hole, 0.0125 inch wire) standard sieve. This mixture was wet with water and thoroughly worked until brought to a suitable consistency.

The preparation of the test pieces, the conditions of drying and the method of breaking were similar to the methods described under "Transverse Tests."

BURNING TESTS.

The test pieces prepared in the form of bars for drying shrinkage were burned in a laboratory kiln and studied with reference to the changes in shrinkage, porosity, color and hardness brought about at various temperatures.

The laboratory kiln used was of the down-draft type with a chamber capacity of approximately twenty-seven cubic feet. It was coal fired and the normal rate of firing was:

Room temperature to 750° F. in 4 hours.
750° F. to 1,290° F. in 6 hours.
1,290° F. to 1,370° F. in 3 hours.
1,370° F. to 1,850° F. in 2 hours.
1,850° F. up at rate of 35° F. per hour.

The trial pieces were placed in closed saggers (*i. e.*, fireclay boxes) in order to protect them from contact with the flames, and flying ashes.

A separate burn was made to each of four different temperatures, namely, those corresponding to pyrometric cones 2, 5, 9, 12, or approximately 2138° F., 2246° F., 2390° F., 2498° F.

After burning, the shrinkage was determined by measuring the distance between the marks previously made on the piece for the drying shrinkage. The porosity was determined by measuring the volume of water absorbed under a vacuum and comparing this with the total volume of the piece. The procedure was to weigh the cooled test piece, place it in a closed receptacle filled with distilled water and connected with a vacuum pump which could maintain a vacuum of twenty-nine inches. The piece was left in the vacuum for three hours. At the end of that time it was removed, the surface of the test piece wiped dry and weighed. The amount of increase of weight due to the absorption of water represented the open pore space. The total volume of the piece was measured in a volumenometer. This apparatus consists of a large size glass bottle with a wide neck ground so that a glass cap fits it securely. A side tube connects the bottle with a burette or graduated glass tube. The apparatus is filled to a certain point with water and the displacement due to the introduction of the test piece may be measured directly upon the burette which gives the volume of displacement or, in other words, the volume of the test piece. The calculation of porosity becomes

Saturated weight — dry weight = weight of water absorbed.

Weight of water absorbed = volume of water absorbed.

Volume of water absorbed = volume of pores.

$$\frac{\text{Volume of pores}}{\text{Volume of whole piece}} \times 100 = \text{per cent porosity.}$$

Color changes are described for each test piece at each temperature.

Hardness was determined by noting the ease or difficulty experienced in scratching the trial pieces with the point of the knife.

Fusion or deformation tests were made by molding the clay into the form of a standard cone—that is, a three-sided pyramid or tetrahedron 0.23 inches along the edges of the base and 1.2 inches high. These were set in a support of refractory material so that the bases of the cones were only slightly imbedded. With these trial pieces were placed standard pyrometric cones and the whole was burned in a furnace to a high temperature. Two furnaces were used. One was the ordinary Fletcher furnace, which was used for temperatures up to 3038° F. This furnace uses gas with compressed air to generate the temperature. For higher temperatures, a Deville furnace was used. This furnace is operated by the combustion of coke by means of a low pressure air blast. No difficulty was experienced in

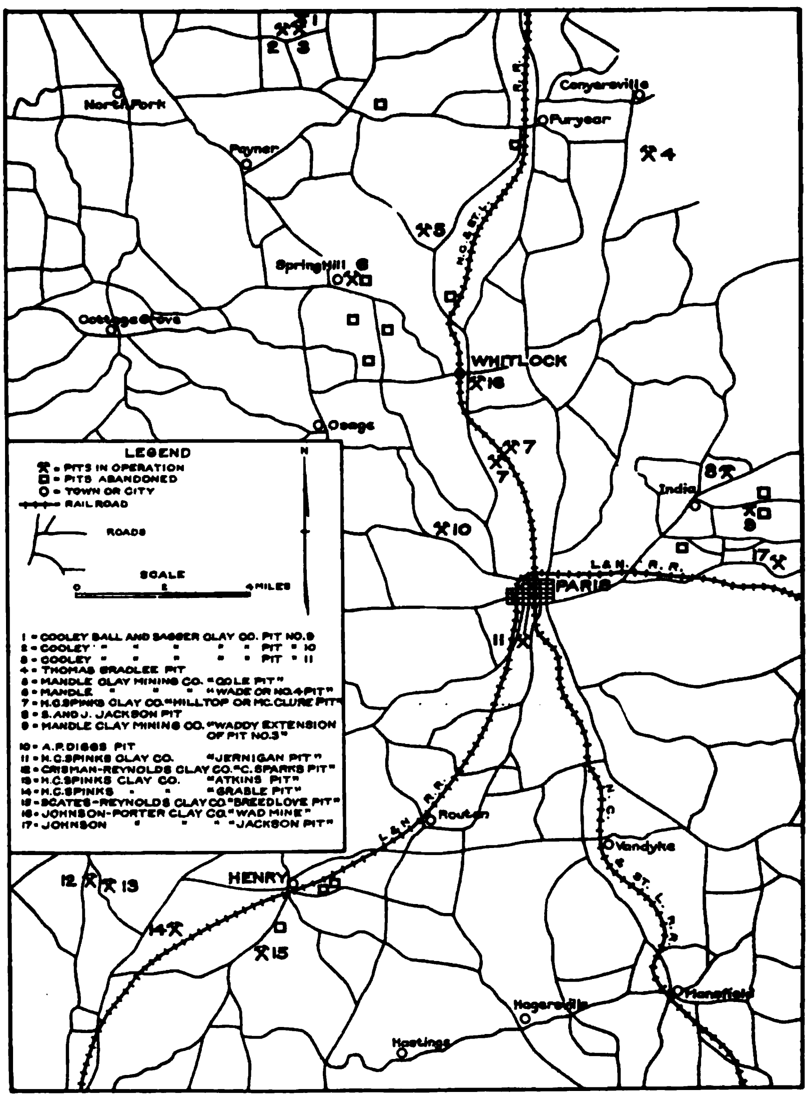

FIGURE 6—Map of Henry County, showing distribution of clay pits.

bringing about the fusion of cone thirty-two, which corresponds to a temperature of about 3218° F.

A test piece is considered fused when it has softened sufficiently to bend over so that the tip touches the base on which the cone is supported. A similar condition of one of the standard pyrometric cones would indicate the temperature at which this had taken place.

Local Descriptions and Results of Tests.

HENRY COUNTY.

Topography.—This county has an area of 625 square miles. The Tennessee-Mississippi River divide crosses the middle of the county in a direction somewhat east of north. The surface along this divide

Figure 7—Grable Pit, near Henry, H. C. Spinks Clay Company.

is rough and broken. On the east it has a relatively steep slope characterized by numerous large and deep gullies, which are eroded headward very rapidly and often make it necessary for roads and houses to be moved to prevent their complete destruction. Stream activity on this side of the divide is more marked than on the other side. West of the divide the general surface has a considerable slope, but soon flattens out into a nearly level plain that stretches westward to the Mississippi bluffs. The greatest elevation is about 600 feet in the northwestern part of the county, and the least 300 feet at the point where the Tennessee River leaves the State. The average elevation is about 500 feet.

HENRY COUNTY PITS.

The H. C. Spinks Clay Co., of Newport, Ky., operates four pits in this county.

Grable Pit.—This pit is situated on the Louisville & Nashville Railroad, two miles west of Henry. It is forty-five feet deep and occupies about two acres. (See Fig. 7.) It is reached by means of an inclined railway 250 feet long, which connects with the Louisville & Nashville Railroad. The angle of slope is about 15° and the clay is hauled up from the pit in dump cars to the sheds at the surface.

Wad, sagger and ball clays are mined here. The clay underlies a hill of ten acres area, the top surface of the clay body dipping with the slope of the hill. The following section was exposed in the pit:

Section at Grable Pit.

Red, clayey sand	10 feet
Grey, sandy clay (wad clay)	30 inches
Brown to dark grey, plastic clay (sagger clay), containing leaf impressions. This clay was sampled (No. 38 S)	20 feet
Pale yellow to pink, very plastic clay, free from grit. This clay was sampled (No. 39 S)	3 feet
Dark, sandy clay (wad clay)	5 feet
Red sand	Exposed to bottom of pit

The dark clays in this pit are rich in beautiful fossil leaf impressions. Some specimens retain the carbonaceous remains of the leaf itself. This, when dry, curls up, powders and vanishes unless protected with a thin coat of shellac. The estimated tonnage in the bank of the twenty feet stratum of sagger clay is 459,700; of the ball clay stratum, 72,600.

Result of Tests.

No. 38 S.—This clay is not deformed at cone twenty-eight, slakes in six and one-half minutes and burns dark cream.

No. 39 S.—This clay is not deformed at cone twenty-eight, slakes in six minutes and burns dark buff.

A preliminary test only was made on these clays, complete tests having been made only on clays that seemed promising as *highly refractory bond clays,* such as are used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on these samples.

Hilltop Mine or McClure Pit.—This pit is operated by H. C. Spinks Clay Co., of Newport, Ky. It is situated four miles north of Paris on the Nashville, Chattanooga & St. Louis Railway. The pit is on the east side of the track, but the clay extends under the track, and

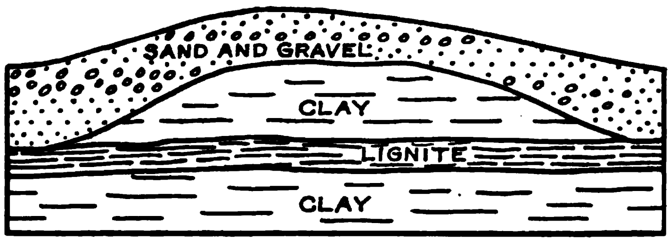

FIGURE 8—Geologic profile section in Hilltop Mine, south of Whitlock, showing unconformable relations of clay and overburden.

preparations were being made to open an extension on the west side at the time this pit was visited. The following section was noted:

Section at Hilltop Mine.

Orange and red, case-hardened sands with cherty gravel and ironstone concretions, containing small clay pellets	10-12 feet
Local unconformity.	
Hard-pan stratum	2 inches
Clay, white with pink blotches and streaks, slightly sandy (sagger clay)	6 feet
Clay, brown, lignitic, sandy (sagger clay)	4 feet
Lignitic clay	1½ feet
Ball clay, greyish-blue and pale brown (sample No. 40 S)	2 feet
Lignitic clay	1 foot
Ball clay, grey (sample No. 40 S)	3 feet
Ball clay, dark brown to greenish black, is said to burn pale greenish color (sample No. 46 S)	3-5 feet
Clay, pale yellow-brown, very plastic, not much grit (sample No. 47 S)	4 feet
White sand	2+ feet

The clay is mined by hand and hauled up a steep incline by mule teams and loaded at a switch at the surface. Several acres of clay are available. Figure 8 shows the unconformable relations between the clay deposit and the overburden.

Result of Tests.

No. 40 S.—This clay is not deformed at cone twenty-eight, slakes in five minutes and burns to a dark cream color.

No. 47 S.—This clay is not deformed at cone twenty-eight and slakes in five minutes.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

No. 46 S.—This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee:

Sample No. 46 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—H. C. Spinks Clay Co. Hill Top Mine on Whitlock-Paris Road. Below grey ball clay and above yellow clay stratum.

Kind of Material—A brown-colored clay of fairly uniform character excepting for slight light brown stains. A small amount of mica is present.

Working property—Good.

Water necessary to develop plasticity—44.2 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 230.9 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 93 pounds per square inch.

Slaking test—70 minutes.

Fineness test:

20-mesh sieve	0.14% residue
40-mesh sieve	0.11% residue
60-mesh sieve	0.19% residue
80-mesh sieve	0.12% residue
120-mesh sieve	0.42% residue
200-mesh sieve	0.82% residue

Drying shrinkage, linear = 5.4 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Not steel hard	11.0%	38.2
Cone 5	Light cream	Steel hard	16.2%	17.4
Cone 9	Light grey	Steel hard	15.6%	14.6
Cone 12	Light grey	Steel hard	17.2%	4.7

Fusion test: Deforms at Cone 32.

This clay burns to a good color at cone nine; its strength when unburned is good. It burns rather open at cone nine, but it will find some use as a ball clay. It has a rather high fusion test and probably will serve where a refractory plastic clay is required, in the manufacture of certain wares. It will serve in the manufacture of sanitary wares, chemical stoneware, stoneware saggers and abrasives.

Jernigan Pit.—This pit is operated by the H. C. Spinks Clay Co., of Newport, Ky. It is leased from T. P. Jernigan and is situated one mile south of Paris. It was opened in June, 1918, and the overburden was being stripped at the time the pit was visited. The pit lies on the west side of a rather steep, wooded hill and is nicely drained by several deep gullies. The clay is hauled by team to Paris. The equipment comprises six wheelers, three scoops, eleven mule teams and a crew of twenty men.

The following section was noted:

Section at Jernigan Pit.

Sand, brown and clayey	0-20 feet
Unconformity	
Clay, white, very sandy, not used	4 feet
Clay, white, plastic and free from sand, containing limonitic spots	1 foot
Clay, brown, plastic, slightly sandy, with occasional yellow stains. It is poorly stratified, containing fossil leaf impressions, and is traversed by vertical joint planes. Thickens towards the northwest. Sample No. 53 S	4-20 feet
Clay, dark olive green, plastic, free from grit. It is traversed by a system of vertical joint planes, along which the clay has weathered to a pinkish brown to a depth of 2 to 3 inches. Contains small amounts of limonite in places. It is said that this clay bleaches white after mining. It is sold as ball clay and is known as No. 9. This clay stratum pinches out toward the west. Sample No. 54 S	3-9 feet
Clay, pinkish grey, very plastic. The upper part of this bed is sold as ball clay. It contains thin strata of yellow, limonitic sand towards the base. Pinches out towards the west, but is said to thicken to nine feet 300 yards towards the northeast. Sample No. 55 S	4 feet
White sand	

Result of Tests.

Sample No. 53.—This clay is not deformed at cone twenty-eight and slakes in five minutes.

Sample No. 54.—This clay is not deformed at cone twenty-eight and slakes in six minutes.

Sample No. 55.—This clay is not deformed at cone twenty-seven and slakes in nine minutes.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests of these samples.

Atkins Pit.—This pit is operated by H. C. Spinks Clay Co., of Newport, Ky., and is situated two miles northwest of the Grable Pit, to which point the clay is hauled by teams. It is a small pit in the early stages of development. The clay underlies a hill of about three acres area. The top surface of the clay body dips with the slope of the hill and a spring emerges from it at the pit. The following section was noted:

Section at Atkins Pit.

Sand, pale orange and brown	10-20 feet
Ball clay, rose, exceedingly tough and plastic; too sticky to be worked	8 inches
Lignitic clay (contains marcasite concretions) not present towards north, 4 feet thick towards south	1 foot
Ball clay, dark greenish grey, contains fossil leaves and nuts (Sample No. 52 S)	9 feet
Clay, white, very tough	1 foot
Clay, white, sandy (wad clay)	2 feet
White sand (depth not ascertained)	

Fossil leaves are found here in great abundance and perfection and of large size (up to one foot long). Two fossil nuts were found here by Mr. Spinks and presented to the writer. They were submitted to Edward W. Berry of Johns-Hopkins University for identification. He has the following to say regarding them: "The fossils proved of exceptional interest. While somewhat unlike in appearance, they appear to represent the results of compression in different planes, and as they are alike under the microscope I take them to represent the same species. It is unique and I have never seen anything like it in the South. It belongs to a genus known as *Monocarpellites* (one-celled, several-seeded nuts of not certainly determined botanical affinity), and is apparently a new species. The only other known occurrence of the genus is in the lignites at Brandon, Vermont, usually regarded as Miocene, but for whose Eocene age I have argued on several occasions. I assume they came from your Lagrange formation and are of Wilcox (Eocene) age."

The specimens will be placed in the U. S. National Museum. As Mr. Berry's assumption is correct, they may prove of value in correlating the Brandon lignites with the Lagrange of West Tennessee.*

Result of Tests.

No. 52 S.—This clay is not deformed at cone twenty-eight and slakes in five minutes.

A preliminary test only was made on this sample, complete tests having been made only on clays that seemed promising as *highly refractory bond clays,* such as are used in the manufacture of glass-

FIGURE 9—Wade, or No. 4, Pit near Whitlock, Mandle Clay Mining Co.

pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

Wade or No. 4 Pit.—This pit is leased from P. A. Wade by the Mandle Clay Mining Co., of St. Louis. It is situated three and one-half miles northwest of Whitlock and is connected with the Nashville, Chattanooga & St. Louis Railway at that place by means of a dinky line. The pit is one of the largest in the State, covering four acres. (See Fig. 9.) It is located on the north side of a low prominence under which the clay lies. Borings show twenty acres of clay available. The overburden is forty-five feet thick and is removed by steam shovel. The equipment comprises three fifteen-ton locomotives, thirty

*See Berry, Edward W., Age of the Brandon Lignite and Flora, Am. Jour. of Science, Vol. XLVII, art. 13, March, 1919.

cars, one steam shovel and a crew of fifty-five men. The sands and clay are removed by blasting with dynamite and the use of picks and shovels. The clay deposit occupies a large bowl-shaped depression

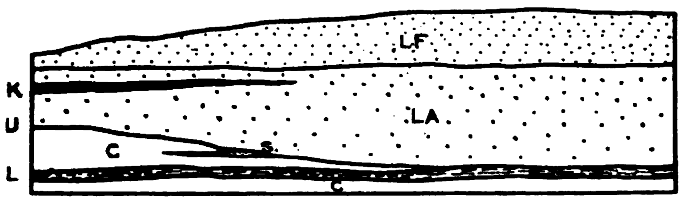

FIGURE 10—Geologic profile section in Wade Pit near Whitlock, showing unconformable relations of clay and overburden.

and is unconformable with the overburden. (See Fig. 10.) The following section was noted:

Section at Wade Pit.

Lafayette—Massive, red and red-brown sands, case-hardened. In removing this stratum with steam shovel it is undermined and slumps off in huge blocks	10-15 feet
Lagrange—Sand, pale brown and cream, streaked with pink, yellow and purple. Contains large ironstone concretions with cores of pyrite (in various stages of decomposition), quartz grains with green iron coating and clay pellets. Also contains a two-foot stratum of hard, indurated kaolinite (pink in color and impure). This stratum is thickest at the south end of pit and pinches out towards north. The kaolinite burns to a pale grey color but is siliceous and non-plastic. Thickness of Lagrange over clay is	30 feet
Disconformity.	
Clay, white and sandy; present at extreme north and south ends of pit; has been eroded in intervening space	0-12 feet
Lignitic clay	4-5 feet
Clay—Tennessee Ball Clay No. 5. Chocolate brown to grey, exceedingly free from iron and grit. Somewhat lignitic especially near top. The organic matter burns out. It is massive and has a greasy feel. The overlying lignite grades into this clay. The color of the clay is lighter towards the base. (See test A)	4½ feet
Lignitic clay, very dark in color	8 inches
Clay—Tennessee Ball Clay No. 4, dark grey and brown, not very plastic unless moist, massive, greasy and somewhat woody. Contains occasional rootlets. Is used for glass-pots. Stands cone No. 36. (See test B)	30 inches
Lignitic clay	8 inches

Clay, known as "pink No. 1 W. W. C.," putty grey with claret streaks and blotches, very plastic at top. The bottom is not so plastic and is discolored by iron and is graded as "No. 4 B. G." This stratum pinches out towards the south. The top is locally known as "gumbo." (See test D)	7½ feet
Clay, known as "No. 1 S. G. P. Ball Clay," simply another phase of the same stratum. It is grey, plastic and free from sand. It becomes pink towards the north, where it is graded as "No. 1 W. W. C." (See above.) (See test C.)	5½ feet
Clay, known as "A No. 2," light grey, stained rose, slightly sandy. (See test E.)	2½ feet
Clay, known as "Sagger No. 2," pale grey, thickest at center of pit. (See test F.)	0-10 feet
Sand, white and sugary	

The accompanying tests were kindly submitted by the Mandle Clay Mining Co., of St. Louis:

Test A—Tennessee Ball Clay No. 5.[1]

Unwashed sample. Volatile matter records free and combined water as well as impurities in the form of lignite.

Analysis.

Volatile	16.45
Silica	46.85
Alumina	33.15
Iron oxide	2.04
Calcium	.35
Magnesium	.40
Potassium	.61
Sodium	.10
Sulphur	.03

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	35.48
1,075 C.	26.55
1,100 C.	19.03
1,125 C.	16.50
1,150 C.	13.90
1,175 C.	9.00
1,200 C.	3.77
1,230 C.	2.29
1,260 C.	2.28
1,290 C.	1.17
1,320 C.	2.15
1,350 C.	1.14
1,375 C.	1.80
1,400 C.	0.82
1,425 C.	1.39
1,450 C.	2.85
1,475 C.	3.80
1,500 C.	5.18

[1]This test was made by the Bureau of Standards, Pittsburgh.

	F.°	C.°	Cone
Fusing point	3,272	1,800	32½
Vitrifies	2,147	1,200	3¼

The average cross-breaking modulus in pounds per square inch determined from tests made on 12 bars in dried condition 387
Time of slaking in water, ⅞-inch dried cube .... 27 minutes
Water of plasticity 44.73%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.57% to 110 degrees C.
14.57% maximum in fire

20.14% total shrinkage
Maximum shrinkage is reached at 1,210 degrees C.

In fire after drying to 110 degrees C.

Degrees	
1,050 C.	2.60%
1,125 C.	7.63%
1,200 C.	10.75%
1,320 C.	14.57%

Test B—Tennessee Ball Clay No. 4.[1]

Analysis No. 1 made in 1915. Unwashed sample.

Volatile	15.30
Silica	44.50
Alumina	35.43
Iron oxide	3.25
Calcium	.34
Magnesium	.42
Potassium	.62
Sodium	.10
Sulphur	.04
	100.00

Analysis No. 2 made in 1917. Unwashed sample.

Volatile	17.30
Silica	42.50
Alumina	35.40
Iron oxide	3.22
Calcium	.34
Magnesium	.43
Potassium	.65
Sodium	.12
Sulphur	.04
	100.00

	F.°	C.°	Cone
Fusing point	3,327	1,830	35½
Vitrifying point	2,147	1,175	2¼

(Bureau of Standards test.)

The average cross-breaking modulus in pounds per square inch determined from test made on 12 bars in dried condition 344
Time of slaking in water, ½-inch dried cube .... 12½ minutes
Water of plasticity 42.90%

[1]This test was made by the Bureau of Standards, Pittsburgh.

Linear Shrinkage.

From room temperature and leather hard to 110° C.:
5.57%
14.57% Max. shrinkage in fire

20.14 Total shrinkage
Maximum shrinkage reached at 1,210° C.

Degrees	
1,050 C.	2.60%
1,125 C.	7.63%
1,200 C.	10.75%
1,320 C.	14.57%

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	42.80
1,075 C.	41.85
1,100 C.	38.75
1,125 C.	36.00
1,150 C.	18.83
1,175 C.	14.65
1,200 C.	14.17
1,230 C.	9.38
1,260 C.	3.79
1,290 C.	.33
1,320 C.	.32
1,350 C.	1.52
1,375 C.	1.81
1,400 C.	1.45
1,425 C.	1.31
1,450 C.	.82
1,475 C.	1.49
1,500 C.	5.27

No. 4 Ball is similar to the No. 5 Ball Clay in a good many respects, but it is not as strong in the green state, nor is its color nearly as good after burning. The difference of the iron content indicates this. However, the refractory properties of the No. 4 is abnormally high, as is also the alumina content.

Test C—Tennessee Ball Clay No. 1 S. G. P.

Analysis made in 1910. Unwashed sample.

Volatile	10.92
Silica	33.13
Alumina	32.32
Iron oxide	1.31
Calcium	.62
Magnesium	.38
Potassium	.59
Sodium	.21
Sulphur	.02
	100.00

	F.°	C.°	Cone
Fusing point	3,238	1,770	32
Vitrifying point	2,246	1,230	5

The average cross-breaking modulus in pounds per square inch determined from tests made on 12 bars in dried condition........ 303
Time of slaking in water ½-inch dried cube........ 12.6 minutes
Water of plasticity 44%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.50%
12.00% Maximum in fire reached at 1,230 degrees C.

17.50 Total shrinkage

In fire after drying to 110 degrees C.
1,230° C. 12.00%

Tennessee Ball Clay No. 1 S. G. P. is for the most part a dark grey clay, though it varies somewhat in color. It is sold by the Mandle Clay Mining Co. to white ware, tile and electric porcelain makers.

Test D—Tennessee Ball Clay No. 1 W. W. C.

Analysis made in 1910. Unwashed sample.

Volatile	13.43
Silica	47.26
Alumina	35.85
Iron oxide	1.01
Calcium	.58
Magnesium	.68
Potassium	.74
Sodium	.45
Sulphur	.00

	F.°	C.°	Cone
Fusing point	3,254	1,790	33
Vitrifying point	2,282	1,250	6

The average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition 279
Time of slaking in water, ½-inch dried cube .... 14 minutes
Water of plasticity 45%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.50%
11.56% Maximum shrinkage in fire, reached at 1,250 degrees C.

17.06% Total shrinkage

In fire after drying to 110 degrees C.:
1,250° C. 11.58%

The Tennessee Ball No. 1 W. W. C. is the choicest of the light clays mined by us. It has a very light gray and pinkish color.

Test E—Tennessee Ball Clay A No. 2.

A No. 2 Ball clay is a uniform smooth-whittling and plastic refractory clay, and is used extensively where clay of this nature is required, principally in the manufacture of potters' supplies, such as stilts and pins, and also in magnesia ware, such as gas mantles, plates on burners for electric stoves, etc. When fired this clay is very strong and of a splendid color.

Test F—Tennessee Sagger Clay No. 2.

No. 2 Sagger clay comes from the bottom of Mine No. 4, and is a very clean and uniform clay of pinkish and white color. It stands a very high heat and makes an excellent Sagger for the higher heats, such as cone ten and twelve. While this clay is very strong after being fired, its semi-open nature prevents cracking both in the drying and in the firing. An important feature of this and our other Sagger clays is their uniformity and cleanliness and low iron content.

Cole Pit.—This pit is operated by the Mandle Clay Mining Co., of St. Louis, and is situated two and one-half miles southwest of Puryear. The clay in this pit is all sold as wad. It is very plastic, sandy and stratified. It is mined by hand and carted three-fourths of a mile to a spur on the Nashville, Chattanooga & St. Louis Railway situated midway between Whitlock and Puryear. The pit is small but the clay deposit is said to underly twelve acres. The dark clays in this deposit bear fossil leaf prints. A spring emerges from the surface of the clay. The following section was observed:

Section at Cole Pit.

Lafayette—Red, massive sands, very rich in gravel towards base	12 feet
Lagrange—Yellow, cream and brown sands containing a pink mass of sandy clay near base	8-12 feet
Hard-pan	1 inch
Clay, grey, plastic and sandy, with yellow stains near top (see test A)	6-8 feet
Clay, dark grey, plastic and sandy in lower portions. This is the best clay in the pit and is said to merge into a ball clay towards the north. Pinches out towards south (see test B)	6-10 feet
Clay, pale grey, very plastic, sandy	3-4 feet
Clay, cream to pinkish, sandy, fibrous fracture	3 feet
Clay, rusty and sandy	2 feet
White sand	

The accompanying tests were kindly submitted by the Mandle Clay Mining Co., of St. Louis, Mo. This test was made by the Bureau of Standards, Pittsburg.

Test A—Special Selected Light Clay.

Analysis made in 1908. Unwashed sample.

Volatile	8.00
Silica	64.30
Alumina	24.60
Iron oxide	1.56
Calcium	.43
Magnesium	.55
Potassium	.42
Sodium	.10
Sulphur	.04
	100.00

	F.°	C.°	Cone
Fusing point	3,182	1,750	31

Open burning clay. Lowest porosity 0.65%, reached at 1,475° C.

Average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition 285

Time of slaking in water, ½-inch dried cube .... 8.6 minutes

Water of plasticity 30.27%

Linear Shrinkage.

From room temperature, and leather hard to 110° C.:

5.46%
4.74% Maximum shrinkage in fire

10.20% Total shrinkage

In fire after drying to 110 degrees C.:

Degrees	Per cent
1,050 C.	0.27
1,125 C.	3.18
1,200 C.	4.12
1,320 C.	4.74

The Special Selected Light Clay behaves very similar to the Special Selected Black Clay in the fire, except that it overburns more gradually. Both clays have practically reached fusing point before overburning begins. The light clay is the stronger of the two in the fired state. Hence it may be advantageous to use a combination of the two clays. The Special Selected Light Clay is a very clean and uniform clay.

Test B—Special Selected Black Clay.

Analysis No. 1, made in 1908. Unwashed sample.		Analysis No. 2, made in 1917. Unwashed sample.	
Volatile	8.80	Volatile	8.00
Silica	61.02	Silica	65.43
Alumina	26.32	Alumina	22.65
Iron oxide	1.38	Iron oxide	2.00
Calcium	.69	Calcium	.50
Magnesium	.72	Magnesium	.70
Potassium	.65	Potassium	.55
Sodium	.18	Sodium	.14
Sulphur	.04	Sulphur	.03
	100.00		100.00

	F.°	C.°	Cone
Fusing point	3,182	1,750	31

Open burning clay. Lowest porosity 0.66%, reached at 1,475° C.

Average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition........ 466

Time of slaking in water, ½-inch dried cubes .... 12½ minutes

Water of plasticity 30.75%

Linear Shrinkage.

From room temperature, and leather hard to 110 degrees C.:	In fire after drying to 110 degrees C.: Degrees	
5.93%	1,050 C.	0.25%
4.63% Maximum shrinkage in fire	1,125 C.	2.21%
	1,200 C.	2.08%
10.56% Total shrinkage.	1,320 C.	4.63%

The Special Selected Black Clay has great strength in the green state and unusually fine plastic properties and is a good bonding clay even though silicious.

Pit No. 3 or Waddy Extension.—This is operated by the Mandle Clay Mining Co., of St. Louis., and is an extension of the exhausted Claxton Pit. It is situated one mile northeast of India. The pit is about one acre in area and is being worked towards the north under a hill which separates it from the old Claxton (No. 3) Pit.

Section.

Sand, red and massive	3 feet
Sand, brown, red and cream, well bedded	8 feet
Lignitic clay thickest at east end of pit, not present south end	1 foot

Sand and clay bed, showing contemporaneous erosion of the clay. The sand is grey, coarse and micaceous and contains intraformational fragments of a similar colored clay. At one end of the pit this clay underlies the sand *in situ* with an unconformable upper surface but thickens to the north, finally replacing the sand entirely and is said to develop into an eight-foot stratum of sagger clay under the hill. (Commercially known as "Special Sagger Clay" and "Tennessee Glass Pot Clay")	5 feet
Lignitic clay, containing pyrite (or marcasite) nodules, thickest on north side	2 feet
Ball clay, dark brown and blue-grey, known as "Tenn. Ball Clay No. 3," contains rootlets and lignitic matter in upper parts	5-6 feet
Clay,* lignitic	18 inches
Clay,* black, contains organic matter	2 feet
Clay,* blue-grey, wet and sandy in places, known as Tenn. Ball No. 6	2 feet

The following tests were kindly submitted by the Mandle Clay Mining Co.:

Special Sagger Clay.

This clay is in many respects like the glass pot clay, such as fusibility, tensile strength, etc. However, it is not so uniform and more siliceous.

Tennessee Glass Pot Clay.[1]

Analysis No. 1, made in 1908. Unwashed sample.		Analysis No. 2, made in 1917. Unwashed sample.	
Volatile	8.38	Volatile	12.00
Silica	63.54	Silica	63.45
Alumina	24.42	Alumina	20.45
Iron oxide	1.22	Iron oxide	1.85
Calcium	.60	Calcium	.50
Magnesium	.63	Magnesium	.55
Potassium	1.00	Potassium	.70
Sodium	.15	Sodium	.14
Sulphur	.06	Sulphur	.06
	100.00		100.00

	F.°	C.°	Cone
Fusing point	3,113	1,729	30

Open burning clays. Lowest porosity 1.23%, reached at 1,425° C.

Cross-breaking modulus average in pounds per square inch, determined from tests made on 12 bars in dried condition....407 lbs.

Tensile strength, direct pull test, fired to cone 8 ....1,055 lbs.

*These beds were concealed by water at the time the pit was visited and hence were not measured. The description was furnished by Mr. Mandle.

[1]This test was made by the Bureau of Standards, Pittsburgh.

Time of slaking in water, ½-inch dried cube .... 12 minutes
Water of plasticity 29.02%

Linear Shrinkage.

From room temperature, and leather hard to 110 degrees C.:
5.48%
4.82% Max. shrinkage in fire
10.30% Total shrinkage

In fire after drying to 110 degrees C.:

Degrees	
1,050 C.	0.50%
1,125 C.	2.87%
1,200 C.	4.09%
1,320 C.	4.82%

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	33.86
1,075 C.	32.55
1,100 C.	29.84
1,125 C.	27.88
1,150 C.	24.67
1,175 C.	22.60
1,200 C.	20.13
1,230 C.	19.07
1,260 C.	18.10
1,290 C.	17.92
1,320 C.	15.09
1,350 C.	10.72
1,375 C.	4.92
1,400 C.	3.10
1,425 C.	1.23
1,450 C.	17.40
1,475 C.	17.72
1,500 C.	22.21

It will be noted that Tenn. Glass-Pot Clay is a siliceous clay, but has splendid strength in the green and fired state, and while it is an open burning clay, it nevertheless has a fairly high fusing point and does not begin to overburn much below same.

Tennessee Ball Clay No. 3.[1]

Analysis made from unwashed sample.

Volatile	14.50
Silica	48.15
Aluminum	32.35
Iron oxide	2.25
Calcium	.60
Magnesium	.54
Potassium	.92
Sodium	.12
Sulphur	.17

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	37.50
1,075 C.	28.70
1,100 C.	20.75
1,125 C.	16.95
1,150 C.	16.48
1,175 C.	13.90
1,200 C.	3.46
1,230 C.	3.46
1,260 C.	2.45
1,290 C.	0.98
1,320 C.	2.34
1,350 C.	1.99
1,375 C.	1.89
1,400 C.	3.02
1,425 C.	3.22
1,450 C.	4.45
1,475 C.	4.67
1,500 C.	5.80

Fusing point, cone 32 plus.
Vitrifying point, 1,230 degrees C.

[1]This test was made by the Bureau of Standards, Pittsburgh.

The average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars, dried........ 326
Time of slaking in water, ⅞-inch dried cube........18½ minutes
Water of plasticity 46.10%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:	In fire after drying to 110 degrees C.:	
	Degrees	
55%	1,050 C.	2.50%
Total shrinkage, 19.05%	1,125 C.	6.65%
	1,200 C.	9.75%
	1,320 C.	13.50

Tennessee Ball Clay No. 6 (Refractory).

Analysis made in 1908. Unwashed sample.

Volatile	13.16
Silica	51.57
Alumina	30.40
Iron oxide	2.10
Calcium	.60
Magnesium	1.25
Potassium	.68
Sodium	.14
Sulphur	.10
	100.00

	F.°	C.°	Cone
Fusing point	3,218	1,770	32

Overburning clay. Lowest porosity 0.35, reached at 1,370 degrees C.
The average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition........ 360
Time of slaking in water, ½-inch dried cube........ 12½ minutes
Water of plasticity, 40%.

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:	In fire after drying to 110 degrees C.:
5.55%	1,370° C. 13.50%
13.50% Maximum shrinkage in fire reached at 1,370 degrees C.	
19.05% Total shrinkage	

Tennessee Ball Clay No. 6 is a smooth, oily clay of beautiful appearance in the green state, and but for its open-burning would be a splendid ball clay. However, its refractoriness and plasticity make it a splendid clay for many purposes.

Pit No. 9 of the Cooley Ball & Sagger Clay Co., of Hazel, Ky.—This pit is situated five and one-half miles west of Hazel, Ky., just south of the Kentucky-Tennessee line.

The following section was seen at the pit:

Section at Pit. No. 9.

Red, clayey sand and gravel with occasional strata of hard-pan	12 feet
Yellow sand	4 feet
Hard-pan conglomerate, with cherty pebbles up to two inches diameter	1-14 inches
Ball clay, grey with pink blotches (the discoloration especially marked in upper portions) with a few red iron concretions near top (sampled for testing as No. 9, White ball)	7-14 feet
Sagger clay, grey	2 feet
Sand, pale grey and coarse	

The accompanying tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee:

Sample No. —, White ball clay, Mine No. 9.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Light, cream-colored, plastic clay, uniform in character.

Working Property—Good.

Water necessary to develop plasticity = 38.1 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 229.8 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 176 pounds per square inch.

Slaking test = 12 minutes.

Fineness test:

20-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	.01
200-mesh sieve	.01

Drying shrinkage, linear = 6.5.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	11.2	26.7
Cone 5	Grayish-white	Steel hard	14.2	16.3
Cone 9	Grayish-white	Steel hard	14.4	12.7
Cone 12	Grayish-white	Steel hard	15.9	2.5

Fusion test: Deforms at cone 33.

This clay burns to a good color, has good strength in the unburned state, and is quite refractory. It is rather open burning at cone nine and is a typical ball clay. It is suggested that it may be useful for the many purposes for which ball clay is used, and also in the manufacture of special refractories, chemical stoneware, terra cotta, face brick, abrasives, and saggers.

The ball clay is employed by insulator and porcelain manufacturers. Two hundred yards southwest of the pit this clay grades into a pale pink to white wad clay, finally merging into a fine, quartz sand, well stratified. This indicates that the transporting waters, at the time of deposition of these sediments, came from a southwesterly direction.

Upon closer examination of the claret discolorations already alluded to we find they have a nucleus of concretionary ironstone. Some of these are hollow and contain a limonitic clay pellet in their interior. It is said that the red color in the clay bleaches in the sunlight.

Occasional fossil-leaf impressions are found in the bedded clay. The whole clay deposit is traversed by several systems of joint planes, the most conspicuous of which has the following attitude: Strike: south 42° west; dip 28° NW.

The clay is carried by auto trucks and wagons to Hazel, Ky., five and one-half miles distant, to be loaded there for shipment. One hundred and twenty-five cars of clay a year are shipped from these mines.

Pit No. 11.—This pit is owned and operated by the same company. It is situated one-half mile south of Pit No. 9 on the east side of the hill. This pit was opened in September, 1917. About two acres of clay are available, or 22,500 tons.

Section.

Dark, earthy sand	2 feet
Gravel, poorly stratified, pebbles up to 1 inch diameter interbedded with red sand	12-25 feet
Local unconformity	
Sand, yellow, well-bedded, dips towards east	0-4 feet
Hard-pan	2 inches
Ball clay, upper half of stratum is white and pink; lower half is dark brown (thickness of each, 3½ feet)	7 feet
This stratum was sampled as "Light Ball No. 11" (upper part), and "Dark Ball No. 11" (lower part).	
Lignitic clay, pinches out towards northwest	5 feet
Clay, pale yellow, very plastic and free from grit	2 feet
Sand, yellow, merges into a brown, micaceous, sandy clay with depth	

The accompanying tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Result of Tests.

Light Ball Mine No. 11.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Light grey, plastic clay, somewhat stained.

Working Property—Good.

Water necessary to develop plasticity—41 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 167.3.

Bonding strength with equal parts of standard sand. Modulus of rupture = 61.4.

Slaking test—8 minutes.

Fineness test:

20 M.	No residue
60 M.	No residue
80 M.	No residue
120 M.	No residue
200 M.	0.09 white sand

Drying shrinkage, linear = 7.5 per cent.

Burning conduct:

	Color	Hardness	Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	11.4	28.9
Cone 5	Grayish-white	Steel hard	15.7	19.2
Cone 9	Grayish-white	Steel hard	16.3	11.1
Cone 12	Grayish-white	Steel hard	17.5	.86

Fusion test: Deforms at cone 33.

This clay burns to a good color, has good strength in the unburned state and is quite refractory. It is rather open burning at cone nine. It is suggested that it will be useful for the many purposes to which ball clay is put and also for the manufacture of special refractories, terra-cotta, chemical stoneware, face brick, abrasives and saggers.

Dark Ball Mine No. 11.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Light cream-colored plastic clay, uniform in character, of medium hardness.

Working Property—Good, slightly sticky.

Water necessary to develop plasticity—41.8 per cent.

Strength of unburned clay—Cross breaking test. Modulus of rupture = 199 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 232 pounds.

Slaking test = 7 minutes.

Fineness test:

40 M.	No residue
20 M	No residue
60 M.	Trace residue
80 M.	Trace residue
120 M. (chiefly white sand)	.03
200 M.	.11

Drying shrinkage, linear = 6.3 per cent.

Burning conduct:

	Color	Hardness	Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	10.3	33.7
Cone 5	Grayish-white	Steel hard	14.1	18.5
Cone 9	Grayish-white	Steel hard	14.7	16.0
Cone 12	Grayish-white	Steel hard	16.6	4.0

Fusion test: Deforms at cone 32.

This clay burns to a good color and has good strength in the unburned state. It is rather open burning at cone nine, has good refractoriness and will be useful for the many purposes to which ball clay is put. It may be used in the manufacture of special refractories, chemical stoneware, terra cotta, face brick, abrasives and saggers.

Pit No. 10.—This pit is owned and operated by the same company and is 200 yards west, and across the hill, from Pit No. 11. It is probable that these two pits are being worked in opposite directions in the same clay stratum. The hill which separates the two pits is about sixty feet high. A well bored in the summit to a depth of fifty feet did not encounter the clay. Its log is as follows:

Log of Well.

Red, earthy sand	14 feet
Red sand and gravel with occasional clay pellets	34 feet

The clay mined at this pit is inferior in quality to that obtained in Pits No. 9 and 11. Altogether, 100 cars of clay have been shipped from this pit. Lignite fragments occur in the clay.

Section.

Red, clayey sand	4 feet
Red and yellow sands, thickening greatly towards north	4+ feet
Local unconformity.	
Hard pan (east end of pit)	1-2 inches

Ball clay, grey merging into pink at east end (sampled as "Grey Ball No. 10")	4-5 feet
Sand, yellow and red	

Result of Tests.

Sample No. —, Grey Ball Mine No. 10.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Plastic clay, fairly uniform in character of a grey color, with slight stains.

Working Property—Good.

Water necessary to develop plasticity—35 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 225 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 164.6 pounds.

Slaking test—7 minutes.

Fineness test:

20 M.	No residue
60 M.	No residue
80 M.	No residue
120 M.	(white sand) .01
200 M.	(white sand) .04

Drying shrinkage, linear = 5.7 per cent.

Burning conduct:

	Color	Hardness	Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	11.0	25.4
Cone 5	Grayish-white	Steel hard	12.6	10.4
Cone 9	Grayish-white	Steel hard	13.1	2.2
Cone 12	Grayish-white	Steel hard	14.0	.26

Fusion test: Deforms at cone 31.

This clay burns to a good color, has good strength in the unburned state. It has a good degree of vitrification at cone nine and is refractory. It may be used as a ball clay or in the manufacture of special refractories, chemical stoneware, terra cotta, face brick, abrasives and saggers.

Johnson and Porter's Wad Mine.—This pit is situated about one-quarter of a mile from Whitlock and is operated by the Johnson-Porter Clay Co., of Paris. Its area is about one acre and there are ten acres of clay available. Some sagger clay has been shipped from this pit and it is claimed that there is a two-foot bed of dark ball clay on the north side. At the time this pit was visited part of the clay deposit was concealed by slump material. The following section was noted:

Section at Pit.

Red, clayey sand, yellow towards base	12-20 feet
Clay, white, plastic, sandy, especially on north side of pit, merging into pink locally; thickest at south end of pit	10-14 feet

The clay is carted to Whitlock for shipment.

Jackson or Porter's Pit.—This pit is owned and operated by the Johnson-Porter Clay Co., of Paris. It is situated five and one-half miles east of Paris near the Louisville & Nashville Railroad. It is about two acres in area and was not being worked at the time it was visited. The body of the clay underlies a low prominence, and the upper surface of the clay dips gently with the slope of the hill, as is so frequently the case. According to Mr. Walter C. Johnson there are ten acres of clay still available and the annual production has been 6,000 tons. Shortage of cars due to embargoes and scarcity of labor have hindered operations somewhat. The clay is carted to Porter's Switch on the Louisville & Nashville Railroad, where it is loaded for shipment.

The following section was noted:

Section at Jackson Pit.

Overburden—Yellow-brown and red sands, poorly bedded and case-hardened, containing thin beds of iron hard-pan	5-8 feet
Clay, brown to black, lignitic, massive, not much sand	0-10 inches
Clay, light grey and bluish grey, plastic when wet, only slightly sandy, known as "J-1 stone fracture." (Sample Tennessee No. 6)	4-6 feet
Bed of quartz sand, coarse, containing muscovite	½ inch
Clay, ball, very dark brown and lignitic in upper portions, merges into grey at depth of one foot. Contains little pockets of yellow limonitic sand in places. This bed pinches out between the overlying beds, known as "No. 1 Ball Clay, glass fracture." (Sample Tennessee No. 7)	1½-4 feet
Clay, cream color, no sand, not quite as good quality as overlying beds	2-6 feet

Result of Tests.

These tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample—Tennessee No. 6.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Jackson Pit, five miles east of Paris, Tenn. (Upper White, "J-1 stone fracture.")

Kind of Material—Plastic clay. Light color, mottled with dark brown, red and yellow; some lumps are brown. It is medium hard.

Working Property—Good.

Water of plasticity = 33 per cent.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 190.5 pounds per square inch.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 179.2 pounds per square inch.

Slaking test = 12 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	0.27%
80-mesh sieve	No residue
120-mesh sieve	0.42%
150-mesh sieve	0.09%
200-mesh sieve	0.24%

Drying shrinkage, linear, 7.5 per cent.

Burning conduct:

	Color	Hardness	Total Linear Shrinkage	Porosity
Cone 2	Cream	Steel hard	13.50%	20.0
Cone 5	Cream	Steel hard	13.60%	16.8
Cone 9	Gray	Steel hard	13.8 %	3.9
Cone 12	Light brown	Steel hard	14.0 %	1.1
Cone 13		Steel hard	13.7 %	3.6

Fusion test: Deforms at cone 31.

The color of this clay when burned at cone nine is rather dark, due probably to reducing conditions in the kiln. Vitrification at this temperature is good. The strength of the unburned clay is good. It is a ball clay type and will be found of value for such uses as ball clays are commonly put to, with a possibility of some service in the manufacture of refractories of certain sorts where a plastic refractory clay is needed.

Test on Sample No. 7.

Received from Tennessee Geological Survey.

Collected by Wilbur A. Nelson.

Locality—Jackson Pit, five miles east of Paris, Tenn. (Middle black, 4 feet thick.)

Kind of Material—A dark gray plastic clay mottled with red and brown. It is of a medium hardness.

Working Property—Good, slightly sticky.

Water necessary for plasticity = 33.7 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 165 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 225 pounds per square inch.

Slaking test = 10 minutes.

Fineness test:

40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	(mica and sand) 0.4%
150-mesh sieve	(mica and sand) 0.4%
200-mesh sieve	(mica and sand) 0.5%

Drying shrinkage, linear, 8.1 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Cream	Steel hard		17.9%
Cone 5		Steel hard	16.0	15.7%
Cone 9	Light tan	Steel hard	18.2	9.5%
Cone 12	Tan	Steel hard	18.0	3.6%
Cone 13		Steel hard	18.7	6.5%

Fusion test: Deforms at cone 30.

The color of this clay when burned at cone nine is rather dark for a ball clay, which possibly may be due to a slight reduction in the kiln. The strength of the unburned clay is good. Vitrification at cone nine is fairly good. It is a ball clay, is fairly refractory and may find some use as bond clay in special refractories; it may also be used for chemical stoneware, stoneware, abrasives, terra cotta, face brick and saggers.

Williams and Dalton Mines.—These two pits are situated close together, four miles east of McKenzie, and are owned and operated by the Johnson-Porter Clay Co., of Paris, Tenn. Mr. M. W. Younkin of McKenzie is manager. The pits are connected by narrow gauge track with the Johnson-Porter spur from McKenzie. The clay body here is large and is overlain by a heavy overburden of typical Lagrange sand, which is moved by a contractor by means of steam shovel and mule teams. The pits are large, each one covering several acres. The clay is shipped to potteries, porcelain, enamel and electric ware manufacturers. Some is also used by glass-pot makers.

Section at Williams Pit.

Sand, yellow, brown and red, with clay pellets and ironstone concretions	36-40 feet
Clay (Tenn. Ball No. 10), white, streaked with pink, exceedingly plastic. Used for porcelain. (No. 27 S.)	5 feet
Clay, lignitic	3 inches
Clay (Tenn. Ball No. 9), dark grey to brown, very plastic and free from grit. This is the best clay in the pit, and is used by glass-pot makers. Grades into a light brown clay known as Tenn. Ball No. 11. Ball No. 9 sampled. (No. 28 S.)	4 feet
Clay, black and lignitic	Depth not tested

Result of Tests.

Tennessee Ball, No. 9.—A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

Sample No. 27 S—Upper stratum.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Received from Tennessee Geological Survey.

Locality—Four miles from McKenzie, Tenn. Williams Mine, Johnson-Porter Clay Co.

Kind of Material—Plastic clay.

Color—Light cream with pinkish tinge. Uniform in appearance.

Hardness—Medium.

Working Property—Very sticky.

Water of plasticity = 35.5 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 240 pounds per square inch.

Bonding strength = modulus of rupture, 138.9 pounds per square inch.

Slaking test = 12 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	(residue white sand) 0.08%
200-mesh sieve	(residue white sand) 0.67%

Drying shrinkage, linear, 8.82 per cent.

Drying conduct—poor.

Burning conduct:

	Hardness	Color	Porosity	Total Shrinkage
Cone 2	Steel hard	Dark tan	0.78	6.0%
Cone 5	Steel hard			16.2%
Cone 9	Steel hard	Light brown	1.8	13.3%
Cone 12	Steel hard	Light brown	6.2	11.7%
Cone 13	Steel hard	Light brown	15.0	13.0%

Fusion test: Deforms at cones 32-33.

The color of this clay when burned is dark and hence will not rank with the best ball clays. It is strong and is quite refractory and will serve for purposes where a plastic refractory clay is required as a bond clay. It may be used in the manufacture of chemical stoneware, stoneware, face brick and saggers, and possibly in the manufacture of abrasives. This clay will have to be burned carefully because of the apparent tendency to overburn at cone thirteen.

Tests on Tennessee Ball Clay No. 11.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Williams Pit, Johnson-Porter Clay Co., McKenzie, Tenn.

Kind of Material—Plastic clay, a mixture of cream-colored and brownish-colored material, the latter predominating. It is moderately hard.

Working Property—Good, sticky.

Water of plasticity = 42.5 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 95.3 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 118.6 pounds per square inch.

Slaking test = 9 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	Trace
150-mesh sieve	Trace
200-mesh sieve	Trace

Drying shrinkage, linear, 5.75 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	21.5	21.15%
Cone 5	White	Steel hard	16.3	19.6%
Cone 9	Grey-white	Steel hard	17.2	7.7%
Cone 12	Grey	Steel hard	17.8	2.2%
Cone 13		Steel hard	17.5	3.4%

Fusion test: Deformed at cone 32-33.

The strength of this clay appears to be rather low. The color is very good and it is fairly well vitrified at cone nine. It is a clay which is fairly representative of the ball clay type and will find use as such, also will be of service for the manufacture of sanitary ware, chemical stoneware, stoneware, face brick, terra cotta and saggers. Its rather high fusion point is likely to make it of service in the manufacture of certain types of refractories, where a plastic clay of good strength is desired.

Section at Dalton Mine.

Lafayette—Sand and clay, red and case-hardened	10 feet
Lagrange—Sand, clayey, brown, containing clay pellets and ironstone concretions and layers, also a clay breccia towards the base	12 feet
Clay, white, sandy in places and not so plastic as Williams Mine clays, but has higher specific gravity. The ball clay is intimately intergrown with sagger and has to be separated by hand. The ball clay is used by enamelware makers on account of its vitrification point. It was sampled as No. 29 S. The saggar clay is known as XX Sagger and was sampled as No. 30 S. Thickness of whole stratum	12 feet

Tests.

These tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 29 S.—This clay is not deformed at cone twenty-seven, slakes in thirteen minutes and burns white. Transverse test—184.3 pounds per square inch.

Sample No. 30 S.—This clay is not deformed at cone twenty-eight, slakes in thirteen minutes, and the transverse test showed a modulus of rupture of ninety-six pounds per square inch.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon these samples.

Diggs' Pit.—This pit is the property of A. P. Diggs and is operated only intermittently. It is situated two and a half miles west of Paris on the New Boston Road. The clay has been removed over a circular area of about an acre and has been sold as ball clay. Borings show it to underlie six acres and outcrops may be seen along a small gully for a distance of 200 feet towards the west. Several springs emerge from the upper surface of the clay deposit. Drainage is good, being accomplished by a gully to the west. The clay underlies a low prominence and is easily removed.

The following section was noted:

Section at Diggs Pit.

Sand, pale brown, containing ironstone concretions and intraformational clay and lignite fragments. Contains thin beds of white and pink clay near base. The sand is colored orange and red and is case-hardened around the ironstone concretions	5-15 feet
Unconformity	
Lignitic clay, with well-preserved pieces of wood, resembling hickory. Some of the fragments are two feet long. Lignite pinches out to the west	1-2 feet
Clay, grey, not very plastic, contains fossil leaf impressions. Pinches out towards the west. Sample No. 59 S	5 feet
Clay, dark greyish green, non-plastic and contains leaf impressions. Sample No. 56 S	1½ feet
Clay, pink, similar to above, becoming sandier with depth and bedded. This bed may thicken towards the east and should be prospected	5 feet

Result of Tests.

No. 56 S.—This clay is deformed at cone thirty-two (very refractory), is slow in slaking and has a high modulus of rupture, 262 pounds per square inch, as shown by the transverse strength test.

No. 59 S.—This clay is deformed at cone thirty-one (refractory), and slakes in seven and one-half minutes.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon these samples.

S. and J. Jackson's Pit.—This is a small pit situated one-quarter mile east of India. The clay is a low grade sagger underlain by a thin bed of ball clay. Sagger clay is mined and carted to Porter's Switch on the Louisville & Nashville Railroad, three and one-half miles distant.

Section.

Sand, brown, with cherty gravel	5 feet
Clay, grey, micaceous	8 feet
Clay, chocolate brown. very plastic, contains occasional specks of limonite (sample No. 41 S)	1-3 feet
Clay, grey-blue sagger	2½ feet
Sand, white	

Result of Tests.

This test was made at the Ceramic Laboratory, University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 41-S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—S. J. Jackson's Pit, one-fourth mile east of India. Lower stratum.

Kind of Material—Borings; a dark gray-colored clay, stained slightly with yellow. It contains some mica.

Working Property—Good, slightly sticky.

Water necessary for plasticity = 39.5 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 262.3 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test Modulus of rupture = 142 pounds per square inch.

Slaking test = 20 minutes.

Fineness test:

20-mesh sieve, residue	0.27%
40-mesh sieve, residue	None
60-mesh sieve, sand residue	0.08%
80-mesh sieve, residue	0.01%
120-mesh sieve, residue sand and mica	0.07%
200-mesh sieve, residue sand and mica	0.18%

Drying shrinkage, linear = 6.25 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	11.80%	34.7%
Cone 5	Light grey	Steel hard	17.1%	10.8%
Cone 9	Light grey	Steel hard	17.2%	13.4%
Cone 12	Light grey	Steel hard	18.8%	1.7%

Fusion test: Deformed at cones 32-33.

This clay burns to a good color at cone nine and it has good strength in the unburned state, but it is rather more open burning than the typical ball clay; however, it will find some use for such purposes as these clays serve. It is suitable for the manufacture of sanitary ware, chemical stoneware, stoneware, face brick, terra cotta, saggers and abrasives. It will probably be useful in the manufacture of refractories requiring a strong plastic clay.

The Mill Pit.—This pit was formerly worked by the Mandel interests but has been abandoned. It is now controlled by H. C. Spinks Clay Co. and W. Allison. It is situated three and a half miles west of Puryear and reached by a very poor road. The old pit is about one acre in area and is well drained by gullies. The clay is said to underlie eight to possibly twenty-five acres. A spring emerges from the surface of the clay.

Section.

Lafayette—Brick red, massive, case-hardened sands with cherty gravel	4 feet
Lagrange—Sand, brown and yellow, with thin beds of white; contains ironstone concretions near base and is strongly cross-bedded........	10 feet
Clay, putty color, very plastic, especially the top portion, occasional pale yellow and pink discoloration. (Sample No. 58 S.)	5 feet
Clay, same properties, only color brown. Is said to merge into lignite towards east	1 foot
Clay, putty grey, not so plastic, gets sandier with depth............	6 feet
Sand, white (iron has been leached out by descending waters)	

Result of Tests.

No. 58 S.—This clay is deformed at cone twenty-eight and slakes in eight minutes.

A preliminary test only was made, complete tests having been made only on those clays which seemed promising as *highly refractory bond clays*, such as are used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make further tests.

Sparks' Pit.—This pit is about five miles west of Henry, and directly north of McKenzie, on the road to Como. It is leased by the Chrisman-Reynolds Clay Co., of Henry.

The pit is located on the east side of the road on a steeply sloping hillside, and has been dug back into the hill about 100 feet, with a width of fifty feet. At present the pit is filled with water, which could be siphoned off. The overburden has been dumped to interfere with the natural drainage into the nearby ravine. The following section was made by Wilbur A. Nelson, State Geologist:

Section of C. Sparks' Pit.

Lafayette—Sand, light orange, darker at base and case-hardened, with a sprinkling of gravel	5-15 feet
Lagrange—Clay, white with pink streaks, flinty fracture with slight incrustation of a white crystalline substance along the cracks. Clay turns to dark brown at 12 feet and then back to white at base	15 feet

This fifteen-foot stratum of clay was sampled and tested as No. 4.

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample Tennessee No. 4, second sampling.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Sparks Pit, near McKenzie, Henry County.

Kind of Material--Plastic clay of a cream color with some pinkish spots. It is of medium hardness.

Working Property—Good.

Water of plasticity, 31.8 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 101.2 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 108 pounds per square inch.

Slaking test = 5 minutes.

Fineness test:

40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	Trace white sand
150-mesh sieve	Trace white sand
200-mesh sieve	Trace white sand

Drying shrinkage, linear, 5.2 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Cream	Steel hard	11.2	2.1
Cone 5	Tan	Steel hard	12.1	21.0
Cone 9	Gray	Steel hard	14.3	1.6
Cone 12	Gray	Steel hard	14.0	1.5
Cone 13		Steel hard	11.9	4.5

Fusion test: Deformed at cone 28.

The color of the burned sample is not quite satisfactory, possibly due to reducing conditions in the kiln, and it seems doubtful that the clay will be available for use in the manufacture of white wares, because of the evidently high iron content. The strength of the clay is fair. It fuses at too low a temperature to permit its use in the manufacture of refractories which are to withstand high temperatures. It is likely that this clay will be more serviceable in the manufacture of chemical stoneware, stoneware, face brick and terra cotta.

Breedlove Pit.—This pit is leased by the Scates-Reynolds Clay Co., of Henry, and is situated about one and a fourth miles southwest of Henry Station. It is circular in shape and about 150 feet in diameter. (See Fig. 11.) The overburden, which ranges from ten to eighteen

Photo by H. Ries.

FIGURE 11—Breedlove Pit, near Henry, Scates-Reynolds Clay Co.

feet in thickness, is dumped a short distance away down a hillside. The clay underlies an area of about ten acres and would amount to 290,385 tons (using twelve feet as the average thickness). Fifty carloads of clay were mined and shipped from here in June, 1918.

Section.

Sandy clay, brown and white	5 feet
Sand, yellow and red-brown, cross-bedded with ironstone concretions and crusts near base	12 feet
Clay,* white, plastic sagger	5 feet
Clay,* very tough, white and plastic	3½ feet
Clay,* white sagger, merges into a white wad clay with pink streaks towards south	5 feet
Ironstone concretions overlying a short, white wad clay	6 feet
Sand, coarse and grey	

* (This bed was sampled as No. 5.)

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 5. Our No. 115.

Received from Tennessee Geological Survey.

Collected by Wilbur A. Nelson.

Locality—Breedlove Pit, near McKenzie.

Kind of Material—Light cream-colored plastic clay, uniform in character and moderately hard.

Working property—Good.

Water necessary for plasticity = 27.2 per cent of weight of dry clay.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 69.3 pounds per square inch.

Bonding strength of a mixture of equal parts sand. Modulus of rupture = 112 pounds per square inch.

Slaking test = 8 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	No residue
150-mesh sieve	No residue
200-mesh sieve	No residue

Drying shrinkage, linear, 5.6 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Light cream	Steel hard		24.8
Cone 5	Light cream	Steel hard	10.3	25.3
Cone 9	Light cream	Steel hard	13.2	8.8
Cone 12	Light grey		14.0	4.8
Cone 13			10.	5.5

Fusion test: Deforms at cone 28.

This clay has a good color when burned. It shows a fair vitrification at cone nine. The strength of the unburned clay is low. It is not sufficiently refractory to be considered as a plastic refractory bond clay. It is likely to be of service in the manufacture of sanitary ware, chemical stoneware, stoneware, face brick and saggers.

Bradlee Pit.—This is a small pit, about thirty feet across, on the land of Thomas Bradlee about three miles southeast of Puryear. It is leased by H. I. Nealy and M. T. Sanders. The clay is a moderately plastic sagger clay and underlies four acres, amounting to

77,000 tons in the bank. It is carted three miles to Puryear for shipment.

Section.

Gravel	3-5 feet
Clay, brown, moderately plastic, stratified and somewhat sandy, contains fossil leaf impressions near base. Sample No. 43 S.	8 feet

A thin bed of sand in the pit shows faulting on a small scale. The displacement is about ten inches, the down-throw block being towards the east. Slight folding or crenulation has also affected these beds.

Result of Tests.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 43 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—Thomas Bradlee farm, leased to M. T. Sanders and H. C. Nealy, three miles southeast of Puryear.

Kind of Material—A clay of a dark gray color with occasional brown stains. It is of uniform texture and contains a small amount of carbonaceous material in the form of fossil leaves. A small amount of mica is present.

Working property—Good.

Water necessary to develop plasticity = 37.3 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 182.7 pounds per square inch.

Bonding strength with equal parts of standard sand, cross-breaking test. Modulus of rupture = 83.2 pounds per square inch.

Slaking test = 20½ minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	0.06% residue
200-mesh sieve	0.14% residue

Drying shrinkage, linear = 5.7%.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	10.0	38.2
Cone 5	Greyish-white	Steel hard	15.7	15.4
Cone 9	Greyish-white	Steel hard	13.2	10.9
Cone 12	Greyish-white	Steel hard	17.4	2.1

Fusion test: Deforms at cone 31.

This clay burns to a good color at cone nine. Its strength when unburned is good; it will find use as a ball clay. It has rather high fusion test and probably will serve where a refractory plastic clay is required, in the manufacture of certain wares. It will serve also in the manufacture of sanitary wares, chemical stoneware, stoneware, saggers and abrasives.

Abandoned Pits in Henry County.

Mandle Clay Mining Co., Pits No. 9, No. 7 and Monroe Pit.
Johnson-Porter Clay Co., Pits No. 9 and No. 11.
"Old Currier Pottery Pit."

HENRY COUNTY PROSPECTS.

Cooley Ball and Sagger Clay Co. Prospect.—Clay is exposed in a gully adjacent to a hill, about 300 yards east of Pit No. 9 of the same company. There are about twelve feet of good clay in a stratum which underlies a fifty-foot hill. Although the overburden increases to forty feet at the summit the clay could be worked around the hill. A creek just below the clay bed would easily drain a pit opened here. Timber is abundant.

Section.

Sand	0-40 feet
Clay, sandy, white	4 feet
Clay, brown, plastic, no grit; contains leaf impressions. (Sample No. 50 S)	8 feet
Clay, similar in character, slightly sandy	Several inches
Clay, pale yellowish brown, very plastic and free from impurities	3½ feet

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 50 S (borings).

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—From gully exposure 300 yards east of Pit No. 9 of the Cooley Ball & Sagger Clay Co. property, five and one-half miles west of Hazel, Ky.

Kind of Material—A dark grey clay with brown mottling. A few mica particles are present.

Working property—Good.

Water necessary to develop plasticity = 37 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 231.9 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 118 pounds per square inch.

Slaking test = 20 minutes.

Fineness test:

20-mesh sieve	Trace of residue
40-mesh sieve	No residue
60-mesh sieve	Trace of residue
80-mesh sieve	No residue
120-mesh sieve	0.02%
200-mesh sieve	Trace of residue

Drying shrinkage, linear = 6.1 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Not steel hard	9.75	37.1
Cone 5	Light cream	Steel hard	14.2	31.2
Cone 9	Light grey	Steel hard	15.3	7.8
Cone 12	Light grey	Steel hard	16.5	1.0

Fusion test: Deforms at cone 31.

This clay burns to a good color. It has a fair degree of vitrification at cone nine. The strength of the unburned clay is good and it would seem that this clay would find use as a ball clay. Because of its rather high fusion test will probably give service as a ball clay in the manufacture of certain refractories. It may be used for the manufacture of sanitary ware, chemical stoneware, face brick and saggers.

S. J. Moore's Prospect.—This prospect is on the farm of E. Stevens, one mile northwest of Puryear on Route 3. The clay outcrops in front of his house on the road. Although there are no other exposures in sight, the clay underlies several acres of cultivated land as has been shown by numerous test holes bored by Mr. Stevens. A strong spring emerges within twenty feet of the outcrop. The overburden ranges between zero and fifteen feet and consists of brown, earthy, loose sand. An auger hole bored at the outcrop shows the following section:

Clay, white and rusty, sandy	8½ feet
Clay, pale brown to putty grey, slightly sandy. (Sample No. 57 S)	4 feet
Clay, same only sandier	Depth not ascertained

The tests show that this clay is not deformed at cone twenty-eight and slakes in seven minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

C. M. Kennerly Prospect.—This deposit is situated four miles east of Puryear. The clay outcrops in several gullies but the quantity and quality do not warrant further investigation. The clay is white and sandy and nowhere over two feet thick. Prospecting may reveal the presence of larger clay bodies.

S. and J. Jackson Prospect.—This prospect is situated about 500 feet south of their clay pit, near India. The clay outcrops in a slight depression in a pasture. An auger hole revealed the following section:

Brown sand and siliceous gravel, with pebbles up to 2½ inches diameter	5-10 feet
Clay, chocolate color, with occasional pockets of rust and mica, somewhat sandy (Sample No. 42 S)	16 feet

Further prospecting holes should be bored to ascertain the quality of the clay in different locations. The sample was not tested.

Cottage Grove.—Just north of this town is a four-foot exposure of ball clay, which occurs in the bottom of a gully on the land of Mr. E. Brizentine. It has an overburden of fifteen or twenty feet.

Result of Test.

This clay is somewhat sticky when wet. Its natural color is grey, which turns very dark on adding water, remaining so until dry, when it becomes dark cream. About two-thirds of the discs and briquettes warped somewhat on drying but not badly. Five of the tensile strength briquettes out of twenty-two broke in the head and were not taken into account.

			Per cent
Water of plasticity of discs and briquettes			25.5
Water of plasticity of tensile strength briquettes			24.5
Tensile strength in pounds per square inch			115.6
Average per cent variation tensile strength briquettes			10.5
Drying shrinkage			5.3
Burning shrinkage;	cone 4	5.0	
	cone 6	9.5	
	cone 8	7.5	
Porosity of burned clay;	cone 4	22.5	

*Resources of Tennnessee, Vol. 2, No. 11.

	cone 6	7.4
	cone 8	10.3
Color of burned pieces;	cone 4	(Cream)
	cone 6	(Dark cream)
	cone 8	(Dark cream)

The chief objection to this clay is its variability. Its character changes in some cases within a horizontal distance of fifteen or twenty feet, with a strong tendency towards sandy clay. The color of the burned clay is too dark for standard ball clay.

The Church and Mill Property.—This prospect is in the rear of the blacksmith's shop, on the outskirts of Cottage Grove. A large gully reveals the presence of clay for a horizontal distance of several hundred feet. Probably this deposit is simply another phase of the large clay body which underlies the whole town and outcrops on the Brizentine land to the north.

Auger Hole Section.

Pale brown, clayey sand	5-10 feet
Lignitic clay	2-3 feet
Clay, dark greenish grey, with leaf impressions. (Sample No. 51)	6 feet
Sand, white	½ inch
Clay, grey, becoming yellow and sandy	3½ feet
Clay, brick red	2 inches
Sand, white	

Result of Test.

Sample No. 51 S was deformed at cone twenty-eight and slaked in four minutes. Hence it is not a very refractory clay.

G. C. Dolan's Prospect.—This clay outcrops in a number of large gullies, over an area of ten acres, on the farm of G. C. Dolan, five miles southeast of Mansfield and two miles over a poor road to the Nashville, Chattanooga & St. Louis Railway. The overburden consists of orange, red and yellow sands, case-hardened and containing beds of gravel, with pebbles up to one-half inch diameter. The sand grains are white, transparent quartz, coated with varicolored iron oxides. Ironstone concretions are abundant. The thickness of the overburden varies from six to twenty feet with an average of ten. The clay surface dips with the slope of the hill. A thin bed of ironstone rests immediately above it.

Auger Hole Section.

Hard-pan	1-3 inches
Clay, white and plastic	4 feet
Clay, yellowish and pink	1 foot

Clay, chocolate brown, occasional yellow streaks, plastic with little sand. (Sample No. 44 S)	10 feet
Clay, grey and sandy	4 feet
Sand, clayey and grey	

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only on those clays which seemed promising as *highly refractory bond clays*, such as are used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make further tests on this sample.

This clay was not deformed at cone twenty-eight and slaked in ten minutes. Transverse test — modulus of rupture = 163 pounds per square inch (strong enough for ball clay).

M. H. R. Wright's Prospect.—This is situated on the Hico and Shilo Church Road, just east of Wright's Mill, in the fourth district. The clay is exposed in the roadbed and nowhere else. The overburden is light and should not exceed ten feet. The clay is chocolate brown, moderately plastic, and slightly sandy. It weathers white. An auger hole was bored to a depth of twelve feet without passing through the clay. Sample collected—No. 20 S.

The tests show that this clay burns to a cream color, slakes in seven minutes and is not deformed at cone twenty-eight.

Only a preliminary test was made, complete tests having been made only on *highly refractory bond clays*, such as are used in making glass-pots and crucibles. The Survey hopes to make additional tests on this clay.

C. W. Fulgham and J. W. Tucker's Prospect.—This deposit is situated four miles northwest of McKenzie and two miles northeast of the Nashville, Chattanooga & St. Louis Railway. The clay deposit is very large and underlies at least six acres and is fifteen to twenty-five feet in thickness, which would give a minimum of 260,000 tons in the bank. It underlies a hill about forty-five feet high on whose slopes it outcrops in numerous gullies. The clay weathers white, but is dark brown when fresh. Many prospecting holes have been bored showing that the thickness persists over a large area. An auger hole bored in the presence of the writer gave the following section:

Auger Hole Section

Clay, grey, impure and sandy	1½ feet
Clay, dark brown, moderately plastic and free from grit. (Sample No. 31 S)	15 feet
Clay, similar in character but somewhat sandy	3½ feet

The overburden varies from zero to twelve feet with an average of eight feet, and would be easy to remove as there is lower land on all sides where it could be dumped. There is a wooded slope towards the north under which the same clay is said to exist.

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois under the direction of Prof. Cullen W. Parmelee.

Sample No. 31 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—C. W. Fulgham and J. W. Tucker's property, four miles northwest of McKenzie, two miles to N., C. & St. L. Ry.

Kind of Material—A dark grey-colored clay of fairly uniform character. It appears to be slightly sandy.

Working property—Good, slightly sticky.

Water necessary to develop plasticity = 35.7 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 878 pounds per square inch.

Bonding strength with equal parts of standard sand. Cross-breaking test. Modulus of rupture = 345 pounds per square inch.

Slaking test = 120 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	0.03% sand
80-mesh sieve	0.04% sand
120-mesh sieve	0.17% sand, mica
200-mesh sieve	0.11% sand, mica

Drying shrinkage, linear = 7.7 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Cream	Steel hard	10.5%	3.8 %
Cone 5	Grey	Steel hard	12.7%	1.19%
Cone 9	Grey	Steel hard	11.6%	1.43%
Cone 12	Grey	Steel hard	12.2%	2.1 %

Oxidation conduct = slow.

Fusion test: Deforms at cone 29.

This clay burns to a fair color at cone nine. It is well vitrified at cone five and has a very high strength in the unburned state. It is probably not quite as white as may be desired for a ball clay. In view of its rather high fusion test and its high strength, it seems probable that this will be of value in the manufacture of crucibles and similar wares. It may be used in the manufacture of chemical stoneware, stoneware, terra cotta, face brick, saggers and abrasives.

J. D. Lee's Prospect.—This clay outcrops in a spring hole on Mr. Lee's farm four miles north of Henry, which is the nearest railway town. The clay is exposed at only one point but appears to underlie a wooded hill of several acres area. The clay seems to be on the edge of a clay deposit and hence the sample taken may not be altogether representative, but it would be necessary to penetrate at least ten feet of overburden to procure a sample elsewhere. The following section was obtained by means of an auger hole:

Red and brown sand	10 feet
Clay, pink and plastic, only slightly sandy. (Sample No. 37 S.)	3 feet
Sand, pink	

Result of Test.

This clay was deformed at cone thirty (high) and slaked in nine minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

John E. Edwards' Prospect.—This promising looking clay stratum outcrops on the Paris-Como Road, about three miles west of Paris. Only the top of the clay is exposed in the road ditch, over a distance of 252 feet. The body of the clay appears to dip gently towards the east and to have its maximum extension towards the south under a hill. Auger holes bored by Mr. Edwards showed the clay to be twelve feet thick at the eastern extremity of the outcrop and six feet thick at the western end. The overburden is twenty-seven feet thick. The following is a complete section:

Clayey sand, pale brown	6 feet
Sand, red, massive with thin ironstone strata	20 feet
Sand, white, with bright yellow and red stains in places	1 foot

Clay, white, with pink blotches, very plastic and free from grit. (Sample No. 48 S.)	4½ feet
Clay, white, somewhat less plastic. (Sample No. 49 S.)	6½ feet
Clay, white, sandy	

Result of Tests.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon these samples.

No. 48 S.—This clay is not deformed at cone twenty-eight and slaked in six and one-half minutes.

No. 49 S.—This clay is deformed at cone thirty (high) and slakes in seven minutes. The transverse test shows a modulus of rupture of 154 pounds per square inch. (Ball clays generally have a strength of 150 pounds or better.)

Railway Exposure Near Routon.—A clay lens outcrops in a railway cut on the Louisville & Nashville Railroad three and a half miles south of Paris. It is under a low hill and its upper surface dips with the topography, the clay being thickest under the summit. This is a very common phenomenon in these clay beds. The clay is folded* locally into small anticlinal folds whose limbs dip 30° north. It is also jointed, the joint planes having the attitude—Dip 90°, strike S 60° E. The clay outcrops over a horizontal distance of 280 feet along the track. It was not sampled.

Section.

Sand, brown and red, case-hardened, containing small ironstone concretions	0-15 feet
Local unconformity.	
Clay, white and pink, sandy, well stratified with many well-preserved fossil leaf impressions	15 feet

Prospecting holes may reveal the presence of better grades of clay underneath.

SECTIONS IN HENRY COUNTY.

Section in gully six miles north of Paris on road to Conyersville.

Lafayette—Brick red, massive sand	8 feet
Coarse, siliceous gravel with pebbles up to two inches in diameter	4 feet

*The inclination of these beds may be caused by slumping.

Lagrange—Sand, pale yellow, orange and red, cross-bedded. Interstratified with grey and pinkish, micaceous clays and thick beds of ironstone. Contains clay pellets	35 feet

Section in gully, three and a half miles west of Paris on Como Road.

Columbia—Brown, clayey sand	3 feet
Lafayette—Sand, brick-red, massive and case-hardened	2-10 feet
Unconformity.	
Lagrange—Well-stratified, thin beds of orange sands, alternating with white to pink clay. The clay resists erosion better than the sand and projects in shelf fashion. This formation is rich in ironstone concretions and layers	10-12 feet
Strongly cross-bedded, white, cream and orange colored sands with clay beds towards the base	5-8 feet

WEAKLEY COUNTY PROSPECTS.

F. H. Skates Prospect.—This clay outcrops in a cut on the Nashville, Chattanooga & St. Louis Railway, two and a half miles northwest of McKenzie. It was thoroughly tested and found to exist in too small quantity to warrant analysis. An auger hole showed the following section:

Sand, pale brown	12 feet
Ball clay, grey	3 feet
Sand	1 inch
Ball clay, rose	1 foot
Sand	¼ inch
Ball clay, rose	9 inches
Sand, yellow	1 inch
Sand, grey.	

Another auger hole only forty feet to the east, five feet deep, showed no clay. Another, thirty feet to the west, showed one and a half feet of ball clay underlain by sand. Mr. John Gardner, former owner, says he bored a hole on the summit of the hill, one hundred yards east of the railway, which showed twenty-two feet of sand underlain by eight feet of good clay. Another hole fifty yards from the track showed no clay at all. From the foregoing it would appear that the deposit, which outcrops on the track, is small and of no consequence but that there is a possibility of finding a separate clay lens one hundred yards back from the track towards the northeast.

William R. Bobo Prospect.—This is a large clay deposit which underlies the hill on which Mr. Bobo's residence is situated, one and a half miles northeast of Christmasville. The clay outcrops are very white and chalky. There is apparently a large quantity of it available, for it outcrops one hundred yards along the road and a well near Mr. Bilbo's house encountered a thickness of twenty-two feet of clay at a depth of ten feet. The clay is in the Lagrange formation of Eocene age. The nearest railway is five miles distant.

Auger Hole Section.

Overburden, loose sand	10 feet
Clay, white, plastic (Sample No. 34 S)	5 feet
Clay, white, very sandy	3 feet

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 34 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—Will R. Bobo, road exposure two miles north of Hinkledale.

Kind of material—A light-colored clay of a uniform character. It contains much sand.

Working property—Good, slightly sticky.

Water necessary to develop plasticity = 33.8 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 251.6 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 174 pounds per square inch.

Slaking test = 17 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve, residue white sand and mica	0.4%
200-mesh sieve, residue white sand and mica	1.9%

Drying shrinkage, linear = 7.4 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	11.7%	27.9%
Cone 5	Light grey	Steel hard	15.1%	14.8%
Cone 9	Light grey	Steel hard	15.0%	10.3%
Cone 12	Light grey	Steel hard	16.7%	0.9%

Fusion test: Deforms at cone 31.

This clay burns to a very good color, but is rather open burning at cone nine for a ball clay. It has good strength in the unburned state and the rather high fusion test indicates that it may be of value as a ball clay in the manufacture of certain types of refractory wares. It may be used for the manufacture of such wares as terra cotta, sanitary ware, chemical stoneware, stoneware, face brick and saggers.

CARROLL COUNTY.

Topography.—Carroll County is situated in the northeastern part of West Tennessee. Its area is 624 square miles.

The Mississippi and Tennessee River divide crosses the county in a direction somewhat east of north, separating it into an eastern

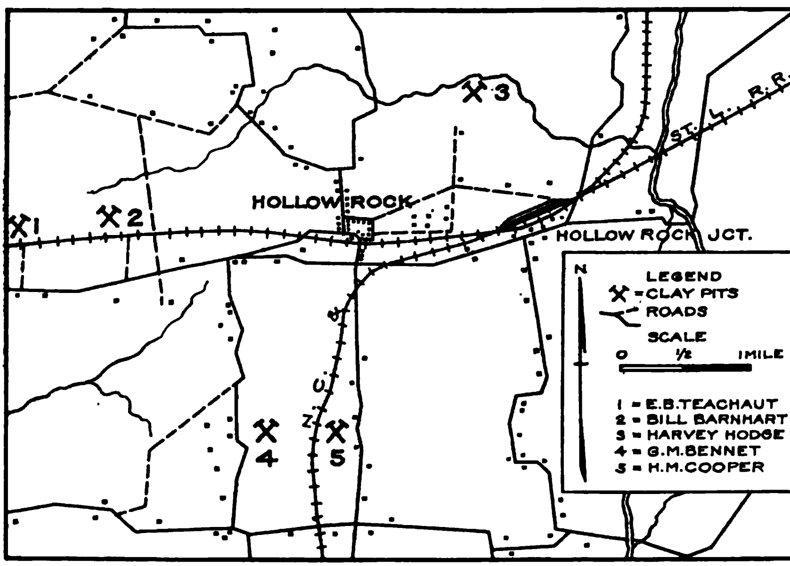

FIGURE 12—Map of Hollow Rock and vicinity, showing distribution of clay pits.

slope, which drains into Big Sandy and Tennessee Rivers, and a larger western slope, which drains into the Mississippi. The divide has an average elevation of 475 feet. The lowest elevation is 350 feet, at the points where the Big Sandy and South Fork of the Obion leave the county. The surface along the watershed is hilly and broken, for headwater erosion is active. The northern and western parts of the county are more level and the main streams here, as a rule, have broad, level flood plains and second bottoms.

CARROLL COUNTY PITS.

H. N. Cooper's Sagger Clay Pit.—This pit is situated on the Buena Vista Road, two miles south of Hollow Rock, on Mr. Cooper's farm. (See Fig. 12.) The clay is in the McNairy Sand Member, of the Ripley Formation (Upper Cretaceous), and has a light overburden consisting of pale brown unconsolidated sand. It underlies a low hill having an area of at least five acres; 121,000 tons of clay are estimated in the bank. The clay body is lens shaped, varying from five to fifteen feet in thickness. The clay is mined by hand and

Photo by H. Ries.

FIGURE 13—Mud cracks, fossil and recent, in clay at Cooper's Pit, near Hollow rock.

carted to Hollow Rock for shipment. It is brown in color, being darkest in its lower portions, where it is somewhat lignitic in character and contains an abundance of fossil leaf impressions. The clay is slightly sandy and stratified throughout and is sold as sagger clay. Well preserved limonitic fossil mud-cracks of remarkable size occur in the upper horizons of the clay deposit on the south side of the pit. It is necessary to separate these from the clay before shipping. (See Fig. 13.) This clay was sampled as No. 2.

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 118. Tennessee Geological Survey No. 2.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Cooper Pit, Hollow Rock, Tenn.

Kind of Material—Plastic clay of a dark grey color, fairly hard, contains mica particles, feels sandy.

Working property—Good.

Water of plasticity = 33.9 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 138 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 86.2 pounds per square inch.

Slaking test = 6 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	Trace, chiefly mica
150-mesh sieve	0.04 per cent

Drying shrinkage, linear = 5.8 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Pinkish	Steel hard	10.0%	29.1%
Cone 5	Pinkish	Steel hard	11.5%	25.0%
Cone 9	Dark grey	Steel hard	13.5%	6.1%
Cone 12	Dark grey	Steel hard	13.7%	5.7%
Cone 13		Steel hard		11.4%

Fusion test: Deforms at cone 30.

This clay shows a good vitrification at cone nine. The color is fair, the strength is also fairly good. It wil probably be of service in the manufacture of terra cotta, sanitary ware, face brick and saggers. It is doubtful that the color will be entirely satisfactory for use as a ball clay.

G. M. Bennet's Pit.—This pit is situated one-half mile northwest of the Nashville, Chattanooga & St. Louis Railway and about two miles southwest of Hollow Rock. The pit is worked intermittently. It is elliptical in shape, 180 feet long and sixty-five feet wide, and is now filled with water which could easily be siphoned off. The clay underlies a low hill, as usual, and has an area of at least one acre, which would give 29,000 tons of clay available in the bank. The overburden is light, measuring from three to eight feet in thickness. The clay lies in the McNairy Member of the Ripley formation (Upper Cretaceous).

There are two strata in the clay body, an upper pale grey, plastic clay, which was sampled (No. 13 S) and a lower dark colored clay, which was not seen on account of the water in the pit. The upper bed is six feet thick and the lower is said to be the same.

Result of Test.

No. 13 S.—This clay was not deformed at cone twenty-seven and slakes in twelve minutes. It cannot be ranked with the highly refractory crucible clays. The transverse test showed a modulus of rupture of 265.2 pounds per square inch, which is high.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Mrs. E. B. Teachaut's Pit.—This pit is situated two miles west of Hollow Rock on the Nashville, Chattanooga & St. Louis Railway and is the property of Mrs. E. B. Teachaut of Huntingdon. It is not now in operation and has been partly filled with slump material. It is circular in shape and measures 150 by 180 feet. The overburden is about twenty feet thick and consists of red, clayey sands, case-hardened, with clay pellets, ironstone concretions and a sprinkling of gravel. Mr. Henderson Hill, who is familiar with this pit, states that a well hole bored fifty yards north of the pit (in the direction of operation) encountered a thirteen-foot stratum of black clay at a depth of thirty-five feet, and another 150 yards to the north encountered the clay at a depth of 70 feet. He also says that black clay was found eighteen feet deep at a point fifty yards west of the pit. Accepting these figures we can estimate the total tonnage of unmined clay (up to the line where the overburden is 35 feet) to be 24,000 tons.

An auger hole showed the following section:

Ironstone hard-pan	1 inch
Clay,* white and plastic	1½ feet
Clay,* grey, becoming very dark and lignitic with depth	5½ feet

*These beds were sampled as No. 26 S.

Tests.

The tests show that this clay burns a dark cream color at ordinary potters' heat, which is too dark for a ball clay. It was not deformed at cone twenty-eight and slakes in three minutes. Hence it is not a refractory bond clay. This clay may prove to be of value mixed with some other type of clay.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Bill Barnhart's Pit.—This pit is not now in operation. It has been described by Wilbur A. Nelson.[1] The following is an excerpt from his report:

"The pit is situated two miles west of Hollow Rock on the north side of the Nashville, Chattanooga & St. Louis Railway. (See map of Hollow Rock and vicinity.) The pit is owned by Bill Barnhart, of Hollow Rock. It is not now worked. The pit is about 100 feet wide, and extends into the hill for nearly 100 yards, and the bed has a thickness of seven feet. The clay extends back under the rest of the hill, which covered about ten acres.

The following is a detailed section of pit:

Section at Barnhart Pit, near Hollow Rock.

A sand, dark red, hardened at top which grades to a lighter color and finally into a yellow sand above the clay	20-25 feet
Clay greyish yellow, slightly gritty, no nodules	7 feet
Sand, fine yellowish white, extends down under clay.	

The clay is colored grey by the presence of a slight amount of organic matter. Very little iron is present, only enough to give it a slight yellow tinge. The clay is of a fairly uniform color, which gets darker toward the bottom of the deposit. It has a conchoidal fracture. No analysis has been made of this clay. Leaf impressions are found in certain layers, and the whole bed is slightly gritty, but no nodules of iron or any other mineral are present. The bed is massive, without joints, or thin sand layers to break up, and clay breaks in lumps of irregular size.

[1]Nelson, Wilbur A., The clays of West Tennessee, Tenn. Geol. Survey Bull. 5, p. 44.

This clay as well as all the others around Hollow Rock is in the upper part of the Ripley formation. The overlying sands are of the Lafayette formation of the Pliocene age, and in all these pits forms the overburden.

The overburden at the pit face is about twenty-five feet, and becomes heavier further back, the maximum being about thirty-five feet. The upper fifteen feet is very hard and difficult to remove, while lower down it is very easily removed, being a loose sand.

This pit is very accessible, as it is right on the Nashville, Chattanooga & St. Louis Railway, and only one-fourth mile from a switch where it can be loaded and shipped. The soil on top of the clay lens is covered with a light second growth timber, most of it still small."

This clay was sampled as No. 19 S. It was once mined and shipped to potteries and stoneware makers.

Tests.

Sample No. 19 S.—This clay is not deformed at cone twenty-seven and slakes in ten minutes. Transverse test—192.7 pounds per square inch.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Harvey Hodge Pit.—This pit is situated about one and one-half miles northeast of Hollow Rock. It is leased and operated by A. Nunnely of Hollow Rock. The clay stratum is fourteen feet thick and underlies a low hill of two acres area. The overburden consists of unconsolidated sand, of Ripley age, zero to fifteen feet thick. On the present face of the pit it measures six feet thick and is easily removed by blasting and scrapers. The pit is elliptical in shape, 160 feet long by 100 feet wide, and is drained towards the northeast by a small gully. It is estimated that 68,000 tons of unworked clay remain in the bank.

Section.

Sand, unconsolidated	0-15 feet
Clay, white, plastic, massive (Sample No. 11)	7 feet
Clay, dark grey, stratified, with fossil leaf prints (Sample No. 1)	7 feet

The clay is hauled over a bad road to Hollow Rock, from which point it is shipped to West Virginia, Pennsylvania and Trenton, N. J., as sagger clay, under the commercial name "291."

Result of Tests.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 1, Tenn. Our Lab. No. 117.

Received from Tennessee Geological Survey.

Collected by Wilbur A. Nelson.

Locality—From 12-foot stratum of black clay of Nunnelly Pit on Harvey Hodge property, Hollow Rock.

Kind of Material—A dark grey, moderately hard clay.

Working property—Good, somewhat sticky.

Water necessary for plasticity = 31.6 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 112 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 112 pounds per square inch.

Slaking test = 5 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	Trace of residue
80-mesh sieve	Trace of residue
120-mesh sieve, residue mica and sand	0.46%
150-mesh sieve, residue mica and sand	0.50%
200-mesh sieve, residue mica and sand	0.60%

Drying shrinkage, linear = 6.8%.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	16.5%	28.0%
Cone 5	White	Steel hard	13.7%	28.0%
Cone 9	Light cream	Steel hard	14.7%	22.1%
Cone 12	Light cream	Steel hard	15.8%	8.5%
Cone 13		Steel hard	16.2%	11.4%

Fusion test: Deforms at cone 31.

This clay burns to a good color at the various temperatures. It is a rather open burning for a ball clay and the strength of the unburned clay is only fair. It is more of a semi-ball clay in nature than a ball clay. It will doubtless be of service in the manufacture of certain grades of chemical stoneware, sanitary ware, terra cotta, face brick, saggers and possibly find some use as a bonding material in the manufacture of certain refractories which are not expected to stand too high temperatures.

CARROLL COUNTY PROSPECTS.

Thompson and Barkdale Prospect.—Clay is exposed in gullies over a distance of a quarter mile on J. M. Barkdale's farm, two miles south of McKenzie. The nearest railway is only a half mile distant. The overburden consists of pale brown, unconsolidated sand having an average thickness of fifteen feet, but varies between zero and thirty feet. The clay deposit is large, underlying at least five acres (and possibly twenty-five, according to Mr. Porter of McKenzie, who has bored a number of test holes). A strong spring emerges from the upper surface of the clay bed. Mr. Thompson says that he encountered a thirty-foot stratum of clay at a depth of thirty-eight feet while sinking a well near his house nearby.

Auger Hole Section.

Sand, light brown, loose	12 feet
Clay, white, very plastic, not much grit (Sample No. 32 S)	9 feet
Clay, white and sandy (Sample No. 33 S)	9 feet

It is estimated that the upper stratum of clay contains 108,500 tons in the bank and the same for the lower.

Sample No. 33 S was considered too sandy to test.

The result of testing No. 32 S shows that the clay burns to a dark cream color which makes it unfit for a ball clay. Its slaking time was 120 minutes, which is very long. It is not deformed at cone twenty-seven, and hence is not to be included among highly refractory clays.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Road Exposure.—Clay is exposed in a gully two and one-half miles north of Huntingdon on the east side of the road to Paris. The deposit is apparently a small one, this being the only outcrop visible. It consists of a lens shaped body underlying a wooded hill and dips 5° to 10° NW with the slope of the hill. The clay is unconformable with the overlying Lagrange sands and contains in its upper part an old stream channel now filled with sand and clay. The clay itself is a poorly-bedded, plastic clay with a delicate pink color. A sample was collected and tested (No. 10 S). The clay lens pinches out towards the west but may underlie an acre or two towards the south.

Section.

Loess and sand, pale brown	4 feet
Sand, red and clayey, with clay pellets near the base	8 feet
Unconformity.	
Clay, pink and white, bedded	4-6 feet
Sand, dark orange and red, case-hardened, with concretions	10+ feet

Result of Test.

This clay was not deformed at cone twenty-five* and slakes in seven minutes. Hence it is not a refractory bond clay. It burns to a cream color at ordinary potter's heat, this being too dark for a good ball clay.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Road Exposure.—A clay "blossom" was found in a ditch on the Huntingdon-McLemoresville Road, in front of Thomas Orman's house, about three miles west of Huntingdon. The clay dips slightly with the slope of the hill and has an overburden of three to eight feet of loose brown sand. The clay bed is at least three feet thick and is exposed for one hundred feet along the road. It is dark grey when fresh and very plastic. A sample (No. 16 S) was collected for testing, but the entire thickness of the stratum was not ascertained. There is a good natural drainage and plenty of opportunity for dumping overburden in case this deposit is ever exploited.

Result of Test.

This clay is deformed at cone twenty-seven and slakes in eighteen minutes, and is therefore not a refractory (ball) clay.

Bonding strength, 182.7 pounds per square inch.

Transverse strength test—654.8 pounds per square inch. These two tests show that this clay is uncommonly strong.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of

*To be confirmed.

glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Road Exposure.—A clay bed outcrops at the base of a hill just beyond the point where the Christmasville Road joins the McLemoresville Road, three and one-half miles west of Huntingdon, on Stanley Hall's land. The clay is six feet thick, but appears to thin out up the hill. It seems to hold its thickness in a direction at right angles to the road. The overburden varies in thickness from four to fifteen feet, and could be easily removed down the hillside. The clay weathers white and is deeply dissected by sun-cracks on exposed surfaces. The fresh clay is dark grey, plastic and free from grit. It was sampled and tested (No. 17 S). The nearest railway is at Huntingdon, three and one-half miles distant. The available tonnage in the bank cannot be estimated without further prospecting (boring).

Result of Tests.

This clay is not deformed at cone twenty-seven and slakes in forty-five minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

L. L. Wilson Prospect.—A clay blossom is exposed in an old railway cut, four miles west of Huntingdon on L. L. Wilson's land. The following section was noted at the road:

Clay, sandy, brown	5-20 feet
Clay, pink and rusty, much sand	5 feet
Clay, white, with pink and yellow stains, fibrous fracture, some rusty portions; appears to improve with depth. (Sample No. 100 S)	5+ feet

This stratum turns to a ferruginous clayey sand thirty-five to forty feet towards the northeast and appears to underlie a hill of several acres area on which Mr. Wilson's house is situated. Prospecting holes should be bored in a northwesterly direction on the summit of the hill. Many springs emerge on all sides from the base of the hill.

Road Exposure.—A good outcrop of white clay was seen on the Huntingdon-McLemoresville road, near Robert Bryant's house, about four miles west of Huntingdon.

The clay is exposed up a hill along the road for a distance of 220 feet, and appears to underlie a large area on Mr. Bryant's farm. It is six feet thick and was sampled for preliminary testing (sample No. 15 S). The clay is white with pink streaks and moderately plastic.

Result of Tests.

This clay deforms at cone twenty-seven and slakes in eight minutes. Hence it cannot be considered a refractory (ball) clay. Moreover it burns to a cream color at ordinary potter's heat, which is too dark for ball clay.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Gully Exposure.—A good exposure of clay was found in a gully on the road to Hodge's Pit, behind a church, one-half mile from Hollow Rock. It is delicate pink in color, plastic and free from grit. A sample was collected for testing (No. 14 S). The stratum is four feet thick and carries an overburden of five to fifteen feet. The clay is exposed over a horizontal distance of fifty feet. It underlies at least one acre. The estimated tonnage of clay in the bank is 10,000.

Result of Tests.

This clay is not deformed at cone twenty-five* and slakes in six minutes. Hence it is not refractory. It burns to a cream color at ordinary potter's heat, and cannot be considered a ball clay. (Ball clays should burn white.)

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Bedwell's Prospect.—A good exposure of clay was found in a gully on Elbert P. Bedwell's farm, five miles south of McLemoresville. The clay is five feet thick and underlies a hill of several acres area. The overburden varies between twelve and fifteen feet in thickness and could be easily removed. It consists of loose brown sand.

*To be confirmed.

The clay is plastic, smooth and has a beautiful pink color with occasional yellowish blotches. It is underlain by a white sugary quartz sand. A sample (No. 21 S) was collected for testing. Unfortunately this deposit is very remote from a railway, the haul under present conditions being eight miles. Timber is abundant and the drainage is good. The estimated tonnage of clay in the bank is 24,000. The tests show that this clay burns to a light buff color at ordinary potter's heat and therefore should be of value to potters so far as color is concerned. It is not deformed at cone twenty-seven and slakes in eight minutes. It is not very refractory.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

S. W. Williamson Prospect.—Several hundred yards from the deposit just described we find a thick bed of white sandy clay. A sample was collected for testing (No. 22 S), but was considered too sandy to warrant further investigation.

Hayward Priest Prospect.—A small bed of clay is exposed on the middle road to Paris, about one and one-half miles north of Huntingdon, near Anthony Coleman's (col.) house. The clay body extends towards the north under Mr. Priest's land. It is at least three feet thick and is exposed along the road for a distance of 225 feet. The clay is pale grey but weathers white. The overburden is not heavy and will nowhere exceed ten feet. An auger hole was bored to procure a sample for testing. (Sample No. 23 S.)

Result of Tests.

This clay deforms at cone twenty-eight and slakes in eight minutes. It is therefore not very refractory, but burns to a light buff color at ordinary potter's heat, and hence may be of interest to this industry.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

The "Huckleberry Schoolhouse" Prospect.—A large deposit of clay outcrops in a gully system east of the schoolhouse, three miles south of McLemoresville. The clay underlies an area of about eight acres. The estimated tonnage available in the bank is 240,000.

Section.

Sand, red-brown	10 feet
Clay, grey-brown, plastic, stratified (Sample No. 18 S)	12 feet
Ironstone layer	1 inch
Clay, sandy and ferruginous	Depth not ascertained

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 18 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—Road and gully exposure, three miles south of McLemoresville near T. A. Younger's farm.

Kind of Material—A greyish-cream colored clay of a uniform character. It is moderately hard and contains mica particles and fine sand.

Working property—Good, not sticky.

Water necessary to develop plasticity = 46.7 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 597.6 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 156 pounds per square inch.

Slaking test = 21 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
120-mesh sieve, residue white sand	0.01%
200-mesh sieve, residue white sand	0.33%

Drying shrinkage, linear = 10.83 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Light buff	Steel hard	13.7%	22.5%
Cone 5	Light buff	Steel hard	17.1%	14.2%
Cone 9	Dark grey	Steel hard	18.7%	9.2%
Cone 12	Dark grey	Steel hard	19.5%	3.3%

Fusion test: Deformed at cone 27.

The color of this clay burned at cone nine is fair. The strength is very high. It is not sufficiently refractory for use as a refractory bond clay. The clay may be used in the manufacture of terra cotta, chemical stoneware, stoneware, face brick and saggers and abrasives.

The Murray Gilchrist Prospect.—A large deposit of promising looking pink clay is exposed in several large gullies, three-fourths of a mile from John Smith's house, west of Gilchrist Lane, and four miles south of Trezevant. This place was formerly known as the William Watkins place. This deposit has been examined by Mr. Wilbur Nelson, State Geologist. The following is an excerpt from his report:[1]

"In the gully farthest south just before the road goes down the hill, the following section was viewed:

Section near Trezevant.

Lafayette—Light orange sandy clay, no gravel	6 feet
Lagrange—Darker orange case-hardened, cross-bedded sand, very little clay	5—7 feet
A very good white clay, exposed to bottom gully	12 feet

In another gully 100 feet north of the former and back from the road, another good exposure was found, as follows:

Section West of Trezevant.

Lafayette—Clay, light orange sandy	5 feet
Lagrange—Sand clay, cross-bedded, dark orange, case-hardened whitish clay pellets scattered through it	12 feet
Clay, white, exposed to bottom of gully	3 feet

The lower bed of white clay, of which only the top is exposed, is one of the best plastic clays, which was found outside of Henry County. This clay undoubtedly extends down at least four or five feet below the bottom of the gully, and should change into a better quality. In places a slight pink mottling is visible, but there is not an injurious amount of iron present. The clay has a fine conchoidal fracture. There is no grit or sand present, and no concretions or nodules of any kind were found.

This clay lens lies in the middle part of the Lagrange formation. The unconformity between that bed and the Lafayette lies between the soft light orange sandy clay, and the hard cross-bedded dark orange sand, which overlay the clay. The clay appears to extend northward from the exposure, and probably covers only three or four acres.

Outcrops can be found in most of the gullies around this locality on all sides of the hills, which will aid materially in determining the extent of the clay lenses. Any pit here could be easily drained.

The overburden, which will vary from seventeen feet at the outcrop to about twenty-five feet under the hill, is at the top a loose sandy

*Nelson, Wilbur A., Clays of West Tennessee, Tenn. Geol. Survey Bull. 5, p. 54.

clay, easily removed. Below this is a bed of sand, case-hardened, which could be removed without much difficulty. This outcrop is four miles by road to Trezevant and two and three-fourths miles by nearest road to the railroad, four miles south of Trezevant.

No clay has been dug at this point and no other good exposures were seen, but prospecting done in this locality would undoubtedly uncover some good ball clay deposits."

The clay in the first gully, nearest the road, underlies about one acre of land and should yield 29,038 tons. It was sampled for testing (No. 24 S). The clay in the other gully, 100 feet towards the north, underlies about two acres and should yield 24,000 tons in the bank. (No. 25 S.)

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Clay No. 24 S.—This clay burns to a light cream color at ordinary potter's heat. It is not deformed at cone twenty-eight and slakes in seven minutes. It should make a good ball clay although it is not highly refractory.

Clay No. 25 S.—This clay also burns to a light cream color. It is not deformed at cone twenty-eight and slakes in nine minutes. Thus it is very similar to No. 24 S and should find a market in the pottery industry.

Hoffman Deposit.—There is an exposure of white clay in a small gully about one-fourth of a mile from Hico, on Mr. Hoffman's farm. The overburden is light, being less than fifteen feet thick, and is composed of orange colored, case-hardened sand. The clay is weathered to a white, chalky color and consistency. An auger hole was bored and gave the following section:

Sand, orange, extremely hard	12 inches
Clay, pale grey, sandy	6 inches
Ball clay, grey	8 inches
Ball clay, yellow-brown	4 inches
Sandy clay	

No sample was collected. The Johnson-Porter Clay Company of Paris, has recently bored a number of prospecting holes and discovered a considerable deposit of their No. 10 and No. 11 ball clay. They have acquired the property and have begun to develop it.

Gully Exposure.—Clay is exposed in numerous large gullies one quarter of a mile west of Buena Vista. The clay underlies about five acres, is very dark and micaceous in character, and was not sampled. It is in the McNairy Sand Member of the Ripley formation (Upper Cretaceous).

Section.

Sand, pale orange and brown, containing hard-pan beds	0 to 20 feet
Clay, black, greasy and micaceous, containing marcasite nodules	12+ feet

"Pyrite Mine."—A small abandoned mine exists on a hillside on Taylor Bennet's land, two and three-fourths miles north of Huntingdon on the Paris road. It is in the Porters Creek formation of Eocene age. The excavation is about thirty feet long by ten feet wide and three feet deep, and is now filled with water. Several wagon loads of marcasite nodules (iron disulphide) have been mined by Mr. Hayden B. Gunter and piled up near by. None has ever been shipped. It would hardly pay to mine these nodules, for the quantity is too limited.

Marcasite Nodules.—Another deposit, very similar to the foregoing, is situated on Mr. Spencer Clark's farm, three and a half miles northwest of Huntingdon. The black Porters Creek clays outcrop in a ravine at the base of a fifty-foot hill. The quantity of marcasite here is also too small to be of any economic importance.

Section on a hillside two miles north of Huntingdon on the Paris road.

Lagrange—Brown, case- hardened sands, containing thin ironstone strata and a small sandy bed of white clay	7 feet
Porters Creek—Red, clayey, micaceous sand, containing large nodular ironstone concretions, up to four feet in diameter and occasional crystals of gypsum of minute size. This stratum probably represents reworked Porters Creek material and might possibly be called basal Lagrange	4 feet
Typical, micaceous Porters Creek clay showing concentric fracture, etc. Exposed over a horizontal distance of 175 feet	30 feet

MADISON COUNTY PROSPECTS.

Road Exposure.—There is a promising looking clay blossom five miles northeast of Jackson on the Brown's Church Road. The clay stratum underlies a hill towards the southwest and may cover four or five acres. There is about a foot and a half of ball clay which may thicken under the summit of the hill, as is usually the case. Since the overburden nowhere exceeds twenty feet it would be well to bore prospecting holes on the top of the hill. The overburden consists of unconsolidated sands, pale orange in color, and measures from five to twenty feet in thickness. The nearest railway is at Jackson, five miles distant over an excellent road. The clay is in the Lagrange formation of Eocene age.

Auger Hole Section.

Clay, grey and rusty, very sandy	1 foot
Clay, chocolate brown and lignitic	½ foot
Clay, same color, less lignitic in character, very plastic and free from grit; poorly bedded	1½ feet
Clay, grey, sandy and stratified	1 foot

Road Exposure.—One-half mile beyond the outcrop just described there is a small bed of rose and yellow colored sandy clay. It is merely a clay blossom and of no economic importance.

Road Exposure.—Two clay deposits outcrop on the Milan Road, two and three-fourths miles north of Jackson. They are similar in character and one section will answer for both.

Section.

Sand, red, case-hardened and strongly cross-bedded, containing clay pellets	0-12 feet
Unconformity	
Clay, grey and rusty, very sandy, weathers to a chalky white. This clay would hardly be worth mining except for whitewash	5-12 feet

Gully Exposure.—A twelve-foot stratum of clay outcrops near the Denmark-Bells Road, about three and a half miles northwest of Denmark. This stratum consists of white, chalky clay interstratified with cream-colored, strongly cross-bedded sands, upon whose projecting edges the clay has formed small stalactites. No clay of any value was found here.

Road Exposure.—A small bed of pink, fossil-leaf bearing clay was found on the Huntersville-Denmark Road, three miles north of Denmark. The clay alternates with beds of white sand and is of no commercial value. It is in the Lagrange formation of Eocene age.

Sam Reid Prospect.—One-quarter mile south of Denmark on the land of Sam Reid (colored) a large deposit of clay may be seen outcropping in numerous gullies.

Auger Hole Section.

Sand, pale brown, with occasional beds of pure transparent quartz sand	0-5 feet
Clay, white with red and yellow discolorations, sandy	15 feet
Clay, white and claret red, plastic and less sand than above	5 feet
Sand.	

This lower stratum may possibly be used for sagger clay, but would not be suitable for ball clay.

L. Marks Prospect.—The following section was noted in a railroad cut, one-half mile south of Oakfield on the Illinois Central Railroad, on property of L. Marks of Jackson.

Lafayette—Red, case-hardened sand	10 feet
Lagrange—Sand, orange, cream and white, with a scattering of clay pellets and ironstone concretions. There are several very thin beds of white clay, interstratified with the sand but of no value	15 feet

Gully Exposure.—Clay outcrops in a large gully on the Deep Gap Road, five miles southeast of Jackson.

Section.

Columbia—Pale brown, earthy sand	3-5 feet
Lafayette—Sand, red, case-hardened, cross-bedded with clay pellets	0-20 feet
Lagrange—Clay, well stratified, white and sandy, stained yellow in places and traversed by a vertical joint system	10 feet

The bulk of the clay lies to the northeast of this exposure. It might be used for a fire brick clay if it occurs in large quantities. Prospecting holes should be bored to determine its extent.

Sternberger Prospect.—An extensive deposit of clay may be seen outcropping in a gully system, two miles south of Neely Station, on the old Williamson place. About five acres of sand and clay have been eroded and transported, leaving a good exposure. At least ten acres of clay remain in place, for it appears to extend to the old Utley place, one-half mile towards the northwest.

Section.

Sand, brown and red, containing ironstone concretions up to one foot in diameter and hardpan layers	7 feet
Unconformity.	
Clay, white with rusty discolorations, well stratified and very sandy. Surface abounds with "miniature hoodoos" (see below)	0-5 feet
Local unconformity.	

Clay, flesh red to pale pink and grey-pink, occasional yellow streaks, bedded. The clay is moderately plastic and free from sand, the bedding planes containing a thin film of dust. It has a greasy feel. Was sampled as No. 62 S. The stratum is very irregular, pinching out entirely here, widening to six feet there. Average thickness	3 feet
Hardpan	1 inch
Sand, white and brown	4+ feet

The chief objection to this clay is its very un-uniform character and the presence of stratification.

A curious erosion feature may be seen on the surface of this clay bed, as well as on many others in West Tennessee. Rapid erosion, accomplished by torrential rains, has carved out little cylindrical clay columns, tapering upwards, and capped by a protective leaf, fragment of hardpan, stick, or most any little piece of flat material. These are generally under six inches in height and make an interesting spectacle when crowded together in large numbers, like so many soldiers. The writer has referred to them as "miniature hoodoos."

Result of Test.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Transverse test—252 pounds per square inch (high). This clay is deformed at cone thirty-one and slakes in ten minutes.

Dr. A. B. Dancy Prospect.—Two thin beds of white ball clay outcrop in gullies on Dr. Dancy's land, two miles east of Jackson on the Lexington Road. The clay should be suited for ball clay, for it is said to burn white. It may thicken under the hill to the south, in which case it would be well worth mining. The railway is only two miles distant over an excellent road. The following section was noted:

Section.

Columbia—Brown clay and sand	1½ feet
Lafayette—Red, case-hardened sand	5½ feet
Lagrange—Orange and cream-colored sands, strongly cross-bedded. with clay pellets	10 feet
Clay, white and pink, very plastic and very little sand, occasional streaks of yellow	2 feet

Road Exposure.—A five-foot stratum of white, sandy, stratified micaceous clay was seen in the Lagrange sands, two miles south of Medon, on the Jackson-Pine Top Road.

Road Exposure.—Two small white, sandy clay blossoms were seen at a point three miles north of Beachbluff and one mile west of Bear Creek.

W. J. Cathey Prospect (R. F. D. 7).—Mr. Cathey submitted a sample of white clay which was very sandy. The deposit was not visited.

W. M. Kelley Prospect.—Mr. Kelley claimed to have a fine grade of clay, twelve miles from Jackson on the Clay Brook Road. A long search was made for this deposit but no clay was found.

Gully Exposure.—Clay is exposed in a large gully on the east side of the Bemis-Denmark Road, eight miles southwest of Jackson. The clay is six to eight feet thick and is white in color. It is too sandy to be of any use except possibly for fire clay or whitewash. It has washed down upon the subjacent sand strata, covering the latter with a thin white crust and hanging from projecting points in stalactites. The overburden is red sand, ten to fifteen feet thick.

MADISON COUNTY SECTIONS.

Section in gully, on west side of road about two hundred yards north of the outcrop just described.

Columbia—Pale brown, earthy sand	3 feet
Lafayette—Dark red, case-hardened sands, standing up in knife-edge fashion, vertical-walled	10-15 feet
Hardpan	3 inches
Lagrange—Sand, yellow, brown and cream-colored, containing clay pellets up to one foot in diameter and thin beds of white, sugary quartz sand	20 feet
Clay, small lens of grey and pink, sandy	1 foot

Section on Pinson Hill.

One mile northeast of Pinson.

Lafayette—Red sand	4 feet
Lagrange—Yellow and cream sands	2 feet
Porters Creek—Typical micaceous, sandy clay, with three-inch sandstone dikes and a dike-like mass of sandstone fifteen feet wide (exposed near the summit)	50 feet

Section Near Bear Creek.

Two and a half miles southwest of Pinson.

Lafayette—Brilliant red and vermillion-colored, case-hardened sands	12 feet
Lagrange—Sand, orange and brown, containing ironstone concretions [illegible] and clay pellets	4-8 feet
Clay conglomerate (see Fig. 4). White clay pellets in a matrix of orange sand. In places the sand has washed out leaving the clay standing in the form of miniature hoodoos	8-18 feet

Section Two Miles South of Medon on Bolivar Road.

Lafayette—Red, hard, clayey sand	10 feet
Lagrange—Brown, cream and white beds of sand, alternating; clayey	10 feet
Clay, white, with yellow stains, sandy, micaceous and well-bedded	6 feet
Local unconformity.	
Clay, grey, well-bedded, rich in mica and sand, containing fossil mud cracks	6 feet

It is said that this white clay was once used in Jackson as pottery clay.

HAYWOOD COUNTY.

W. S. Lea Prospect.—Clay outcrops in a railway cut of the Louisville & Nashville Railway five miles northeast of Brownsville, on W. S. Lea's property.

The clay underlies a hill of ten acres and Mr. Lea has bored several test holes and finds it persistent. It occurs in two strata. The upper stratum is white, with red and yellow discolorations, slightly sandy and not very plastic. (Sample No. 60 S.) It is six feet thick. The lower bed is ball clay, but is only one and a half feet thick. It is brown, lignitic and plastic, resembling Mandle's Tennessee Ball Clay No. 5 in places. (Sample No. 61 S.)

The overburden is light (average ten feet). If the upper bed proves to be suitable for mining, the lower bed could probably be sold as ball clay. As the railway is right there the expense of hauling would be obviated. The brown clay was one of the best and most plastic found outside of Henry County.

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

No. 60 S.—This clay is deformed a tcone thirty-three (high) and slakes in nine and one-half minutes. It burns a light tan color. Transverse test—371.8 pounds per square inch (this is high, 150 pounds being high enough for ball clays).

No. 61 S.—This clay is deformed at cone thirty-three and slakes in twenty-two and one-half minutes.

HARDEMAN COUNTY.

Western Hospital Prospect, Bolivar.—A good exposure of plastic clay occurs in some gullies about one-half of a mile southwest of the Insane Asylum on the State's land. The following section was noted:

Sand, pale orange, clayey, soft at top, hardened at base, a little gravel at top	10-20 feet
Gravel, pebbles are quartzite, up to one inch in diameter	1½ feet
Clay, white, stained yellow in places, sandy and nonplastic	6 inches
Clay, rose, plastic, not very sandy, some mica and poorly bedded, conchoidal fracture (Sample No. 63 S)	3 feet
Clay, somewhat inferior in quality	2 feet

The clay lens underlies a hill towards the east, which extends 20° west of north. Test holes should be bored towards the east near the summit of the hill.

The clay is only two and a half miles distant from the nearest railway. Thus the expense of hauling would not be great.

Result of Tests.

This clay deforms at cone thirty-one and slakes in four and one-half minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Section Five Miles East of Bolivar on the Bolivar-Purdy Road.

Columbia—Pale brown clay and sand	2 feet
Lafayette—Brown and red, case-hardened sands with thin bed of hardpan	10 feet
Lagrange—Reddish-brown and brown sand, containing strata of clay conglomerate towards base. The pebbles are dark grey clay up to two feet in diameter, and somewhat resemble the subjacent Porters Creek clay	38 feet
Unconformity.	
Porters Creek—Typical micaceous clays exposed to creek bottom	15 feet

FAYETTE COUNTY.

McNanee Pit.—This pit is situated one-half mile west of Lagrange near the Southern Railroad and is the property of Miss Anna McNanee of Memphis. It is not now working. The pit covers about five acres and is not exhausted, about five acres of clay remaining unworked. The clay was mined in 1916 and shipped to potteries. The overburden consists of red and brown loess and sands of Lafayette age and measures eight to ten feet in thickness. The clay is pink and grey, with yellow limonitic discolorations. It is sandy and moderately plastic when wet. Ten to twelve feet are exposed but its entire thickness was not ascertained. The clay was not sampled.

J. B. Sims Prospect.—A good clay deposit was found two and a half miles west of Lagrange on the Moscow Road alongside the Southern Railroad. The clay is exposed for 100 feet along the road and appears to underlie a hill to the south. The overburden is composed of brick red sand and averages ten feet in thickness.

Auger Hole Section.

Clay, white to grey, with pale pink and yellow discolorations, sandy	5 feet
Clay, same, not so sandy and moderately plastic (Sample No. 64 S)......	5 feet
Clay, sandy, inferior quality	5+ feet

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Transverse test high (312.4 pounds per square inch). Fusion test—deformed at cone twenty-nine (refractory).

J. F. Dale Sand Pit.—This pit is situated about one mile southwest of Lagrange and reached by a narrow gauge railroad. The sand is shipped to plate glass and concrete manufacturers. The pit is nearly 100 feet deep, the sand being hauled up an incline in tram cars by means of a steam-hoist. It covers several acres.

Section.

Loess	3 feet
Sand, red-brown, somewhat clayey, known commercially as No. 2....	15 feet
Unconformity.	

Clay, white, sandy, micaceous and plastic	4-7 feet
Unconformity.	
Sand, much lighter than the upper stratum, white, cream and pink, with occasional streaks of orange and purple, unconsolidated and cross-bedded. (The white sands are known as No. 1.)	65 feet
Sand, dark red, with clay pellets up to one foot long, composed of white, very plastic and pure clay	2 feet

The clay stratum is discarded but ought to find a market, for the clay has to be mined anyway.

McNAIRY COUNTY.

P. H. Thrasher Prospect.—Mr. Thrasher reports an occurrence of white, plastic clay near his fish pond one-half mile northwest of Selmer. This clay stratum was encountered in digging an outlet for the pond. It is not now visible. Several auger holes were bored but no good clay could be found.

Hole No. 1.—Twenty yards east of the pond and twenty yards south of the outlet:

White sand, slightly argillaceous	5 feet
Sand, saturated with water	5+ feet

Hole No. 2.—Twenty yards southwest of Hole No. 1, directly adjacent to dam:

Dark-colored sand	1 foot
Clay, white to grey, very sandy	8 feet
Sand, brown and reddish	1 foot

Purdy Prospects.—A fine grade of clay is supposed to exist near Purdy, but no clay of superior quality was seen in and about the town. Only several thin strata of white sandy clay could be found and a peculiar grey clay was exposed in a gully 200 yards east of Purdy store.

Section Near Store.

Lafayette—Dark red, clayey sand	6 feet
Ripley—(McNairy sand member) brown and red sand	4 feet
Clay, pale grey, with yellow and red, ferruginous discolorations, rich in sand and muscovite	3-10 feet
Hardpan (said to underlie whole town)	4 feet
Sand, light brown, exposed to bottom of gully	4 feet

The formations dip gently eastward with the slope of the hill.

Falcon Exposures.—Clay outcrops over a large area in a gully system three-fourths of a mile east of Falcon. It underlies a hill of about twenty acres, but is of inferior quality.

Section.

Columbia—Pale brown sand and loam	½-2 feet
Lafayette—Liver-red sands, with occasional white quartzite pebbles up to ½-inch in diameter	5-20 feet
Unconformity.	
Ripley (McNairy sand member)—Clay, grey, very sandy, containing mud cracks and red, sandy streaks	5-8 feet

Section one and one-fourth miles west of Picket's Store (five miles east of Finger).

Unconformity.	
Sand, red, case-hardened	15 feet
Sand, white, alternating with thin beds of poor, white clay. The clay is stained red and yellow by iron and contains muscovite mica	2 feet
Sand, white, pink and cream, cross-bedded, containing thin hardpan layers	20 feet

A. Plunk Prospect.—Clay is exposed in gullies in the rear of Mr. Plunk's house, four miles east of Finger. It is too sandy to be of value.

Section.

Pale brown, case-hardened sands, containing thin hardpan layers	15 feet
Clay, grey and rose, stained yellow, very sandy, and micaceous	3 feet
Sand, brown	10 feet

A similar occurrence was found one-fourth of a mile south of here on E. H. Jones' farm. A three-inch stratum of hardpan underlies the clay.

HENDERSON COUNTY.

J. A. Threadgill Prospect.—Clay is exposed in the roadbed, twelve miles west of Lexington on the Jackson Road on Mr. Threadgill's land. The clay has been mined and used in the manufacture of jugs.

Section.

Columbia—Brown, loamy sand	2 feet
Lafayette—Red, hard sand	5 feet
Lagrange—Clay, white, sandy and stratified	6+ feet

E. L. Fesmire Prospect.—There are several outcrops of clay on Mr. Fesmire's land, five and a half miles northwest of Lexington, and three miles west of Timberlake.

Section Near Road.

Sand, orange and red, micaceous, well cross-bedded	10 feet
Unconformity.	
Sand, yellow, pink and purple, alternating with thin beds of grey clay	12 feet
Black clay	3 feet

Lignite interbedded with white quartz sand, rich in muscovite and containing marcasite nodules	4+ feet

At a point 300 yards northwest of here clay is exposed on a hillside. This clay was once mined for pottery purposes.

Auger Hole Section.

Sand, clayey, brown	4-10 feet
Clay, grey with yellow and red discolorations, sandy, stratified	6 feet
Clay, dark brown to grey, contains finely disseminated mica and sand and occasionally a thin bed of white and yellow sand	8 feet
Clay, same only sandier and more rust	1 foot

The eight-foot stratum should make a sagger clay. The overburden is light and the distance to the nearest railroad is only three miles. (Timberlake, on the Nashville, Chattanooga & St. Louis Railway.)

A. M. Power's Prospect.—A considerable deposit of clay occurs at a point one-half mile northwest of Reagan on Mr. Power's land.

Section.

Sand, brown, unconsolidated	5 feet
Sand, dark red and purple, partly case-hardened, containing small elongated clay pellets and large fluted bodies of ironstone	2-5 feet
Unconformity.	
Clay, grey and sandy, weathers white	2-5 feet
Sand, cream, orange and white, unconsolidated, exposed to bottom of gully	6 feet

The clay underlies a hill to the southeast and appears to thicken as it goes under. The axis of the hill trends N 40° E. The nearest railway is twelve miles distant, which fact, added to the rather inferior quality of the clay, would make its development unadvisable.

Road Exposure, one-half mile west of Lexington on Jackson Road.

Sand, red and brown	10-25 feet
Clay, white and grey, very sandy and micaceous, stratified	8-10 feet

Porters Creek and Selma Clay Outcrops.

Porters Creek.—At "Pyrite Mine," two and three-quarter miles north of Huntingdon on Taylor Bannet's land.

At base of hill on Spencer Clark's land, three and one-half miles northwest of Huntingdon.

On Mr. Wimpel's land, on Deep Gap and Mason Well Cross roads, east of Jackson.

On M. G. Hodges' land, on the Jackson-Heart Bridge Road, nine miles southeast of Jackson.

At the seven-mile post on the Jackson-Miflin Road (not seen).

In front of J. H. Treadgill's house, ten miles west of Lexington on Jackson Road.

On Mrs. H. Roark's place, nine miles west of Henderson, on Bolivar Road.

At Garret's Divide, in cut on new roadbed of the M. & B. O. Railroad.

Selma Clay.—At Hurricane Creek, three miles west of Sardis.

On the Reagan Road, one and a half miles north of Sardis.

On the Selmer-Pleasant Site Road, one mile north of Pleasant Site.

Bibliography.

Ashley, H. E., The colloid matter of clay and its measurement: U. S. Geol. Survey Bull. 388.

Berry, Edward W., (1) The lower Eocene floras of southeastern North America: U. S. Geol. Survey, Prof. Paper 91.

(2) The age of the Brandon lignite and flora: Am. Jour. of Science, vol. xlvii, art. 13, March, 1919.

Branner, J. C., The clays of Arkansas: U. S. Geol. Survey Bull. 351.

Crider, A. F., Clays of western Kentucky and Tennessee, U. S. Geol. Survey Bull. 2851, p. 417.

Davis, N. B., The plasticity of clay and its relation to mode of origin: Am. Inst. Min. Eng. Bull. 98, p. 301.

Eckel, E. C., Stoneware and brick clays of western Tennessee and northwestern Mississippi: U. S. Geol. Survey Bull. 213, p. 382.

Gardner, James H., Some Kentucky clays: Kentucky Geol. Survey Bull. 6.

Glenn, L. C., (1) Underground waters of Tennessee and Kentucky, etc.: U. S. Geol. Survey Water-Supply Paper 164.

(2) Fossiliferous sandstone dikes in the Eocene of Tennessee and Kentucky: abstract in Science, new ser. vol. 19, 1904, p. 522.

Kirkpatrick, F. A., Tests on the clays of Henry Co.: Resources of Tenn. Vol. II, No. 11.

Matson, G. C., Louisiana clays, including the results of tests made in the laboratory of the Bureau of Standards at Pittsburgh: U. S. Geol. Survey Bull. 660e.

Middleton, J., Clay: U. S. Geol. Survey Bull. 666t.

Nelson, Wilbur A., The clays of West Tennessee: Tenn. Geol. Survey Bull. 5.

Ries, H., (1) Clays, occurrence, properties and uses: 2nd ed. 1908.

(2) The clays of the United States east of the Mississippi River: U. S. Geol. Survey Prof. Paper 11.

Safford, J. M., Geol. of Tenn., Nashville, 1869.

Stephenson, Lloyd William, Cretaceous deposits of the eastern Gulf region and species of Exogyra from the eastern Gulg region and the Carolinas: U. S. Geol. Survey Prof. Paper 81.

Wade, Bruce, (1) Geological Map of McNairy Co. (in preparation).

(2) Gravels of West Tennessee: Resources of Tenn. Vol. VII, No. 2.

Watkins, Joel H., White-burning clays of the southern Appalachian States: Am. Inst. Min. Eng. Bull. 98.

Characteristic Properties of Ball and Plastic Refractory Bond Clays

By Cullen W. Parmelee.

Two of the important purposes served by testing clays are the saving of time and of money. Through the neglect of this elementary precaution many mistakes have been made which could easily have been avoided. Good material has been wasted and inferior material has been sold for purposes for which it was entirely unsuited. Perhaps, an even more important reason for the testing of clays is the great advantage and the necessity for knowing more about our national resources in order to be able to furnish native materials for our domestic industries. The cessation of importations of certain clays due to the war has shown very clearly that our former dependence upon them was unnecessary and highly undesirable. The necessity for finding native clays suitable as substitutes has been a valuable experience for the country.

The testing of clays affords a means of classifying them according to their probable usefulness in the various industries. The potter requires white burning clays for the manufacture of wares. Therefore a clay which burns white may be considered as of possible value for such a purpose. Ability to resist high temperatures without fusion is the chief characteristic of the refractory clays used in the manufacture of fire brick, glass-pots, graphite crucibles and other similar wares. Numerous other examples may be cited to illustrate the general scheme of classification. Any real systematic classification becomes much more complicated than these simple examples owing to the very complex character of clay. No two clays are exactly alike, and a proper understanding of the difference is essential in the choice and use of them in the manufacture of all important clay products.

The purpose of clay testing is to obtain as complete knowledge as possible regarding the peculiarities and special usefulness of each clay. To this end, methods of testing have been devised and adopted by leading technical societies, such as The American Ceramic Society and the American Society of Testing Materials.

As an introduction to our discussion of the properties of the clays of West Tennessee it is necessary to define the terms Ball Clay and Refractory Bond Clay to which we will frequently refer. They are both alike in being clays of high plasticity, they have very considerable strength when dry, and burn dense at 2300° F. or at a lower temperature. The ball clay should burn to a light cream or nearly white color. The bond clay should have even greater strength when dry than the ball clay. Its color when burned is immaterial, but it must be sufficiently refractory to resist fusion at temperatures below 3038° F. Some ball clays are available for use as refractory bond clays. Ball clay is indispensable for the potter and bond clay is indispensable for the maker of graphite crucibles and glass pots.

Among the many important characteristics of clay, there are two of especial interest, namely, its workability or plasticity when tempered with a sufficient amount of water and its conduct when burned. The usefulness of a clay for any specific purpose will depend upon these properties as they exist or may be modified.

PLASTICITY.

Plasticity is that property of a moistened mass of clay which permits the molding into a desired shape. It is a property which is very characteristic of clay but for which thus far we have failed to devise a satisfactory means of measuring. Experienced persons are able to recognize different degrees of plasticity but they are not able to express these different degrees in terms which ar intlligible and satisfactory.

Clay consists of mineral particles of widely varying sizes. Some of these are microscopic and even submicroscopic. These very fine particles less than 0.0002 inch in diameter constitute what is known as the colloidal content, which is regarded as the chief cause of plasticity. The separation of these colloidal bodies would be of interest, but the determination of the quantity would not furnish a measure of plasticity since the property is also dependent upon the amounts of each of many sizes of grains of mineral matter present.

Besides the mineral matter there is present also, especially in these types of clays, a small but probably a very important content of organic matter. It is characteristic of clays which contain lignite particles, or are associated with coal formations, that they are of good or even high plasticity. Not only is organic matter present in this easily recognizable form but it is possible that the very "fatty" character of some clays may be due to organic matter of an entirely different sort. In fact, differences in plasticity may be due in part to the varying character as well as amounts of organic matter present. The dark color of most ball clay is due to organic matter. The presence of organic matter is not objectionable in the manufacture of most types of wares, since the portion which is not removed in the preparation of the body is destroyed during burning operation.

WATER OF PLASTICITY.

In order to render clay plastic, it is always necessary to add a certain amount of water which will vary with the character of the material. In general, the more plastic the clay the greater the quantity of water that will be required in order to develop the most favorable condition. It is also true that the amount required is not a fixed amount for any clay but varies between maximum and minimum limits. For example, the average variation for a typical American ball clay is 29 per cent for the least amount of water necessary, and 35 per cent the greatest amount of water permissible in developing this property. In general, it is true that the greater the difference in the amounts of water necessary, the greater the plasticity. Some clays show an excessive elasticity which is accompanied by an abnormally high water content. This is quite as objectionable as a low plasticity, since it is commonly accompanied by a loss of strength in drying and burning.

The colloids already referred to as chiefly responsible for the plasticity are in part, at least, glue-like in character and when brought into contact with water take it into its sponge-like structure which swells like gelatin. The granular material constituting the bulk of the clay is coated with this colloidal material. The water which is present in a plastic mass of clay consists of the portion taken up by the colloidal sponge and the portion filling the capillaries between the grains. Since the very plastic clays, such as ball and bond clays, are made up of exceedingly fine grains, the capillary system is very extensive and the amount of water which is present in the plastic mass is very high. In fact the amount of water necessary to develop plasticity may be regarded in a sort as a measure of the degree of plasticity of a clay.

The following table shows the water of plasticity content of some clays:[1]

English Ball clay	44.9% of the weight of dry clay
English Ball clay	40.3% of the weight of dry clay
Tennessee Ball clay	46.1% of the weight of dry clay
Tennessee Ball clay	44.7% of the weight of dry clay
Tennessee Ball clay	37.6% of the weight of dry clay
Kentucky Ball clay	45.2% of the weight of dry clay
Kentucky Ball clay	50.8% of the weight of dry clay
Mississippi Bond clay	31.3% of the weight of dry clay

DRYING AND SHRINKAGE.

The process of drying is the evaporation from the surface of the moisture brought from the interior through the capillaries. The rate of flow will depend upon the temperature and the humidity of the air and upon the structure of the capillary system of the clay. As water is lost, the mineral grains of the clay mass are gradually brought closer together because of the disappearance of the film of moisture separating them.

As the capillaries decrease in size, the movement of the water becomes slower and unequal rates of shrinkage of the center of the mass as compared with the surface may develop, resulting in checking or cracking. When the grains come in contact with each other in the drying process, shrinkage ceases. Some water will still be retained in the voids between the grains. This slowly moves to the surface as the drying continues. The small portion of water in the colloidal sponge is retained very tenaciously and not driven off until the temperature is raised well above the boiling point of water.

If we compare two clays of different degrees of plasticity, we find that the more plastic requires more water to make it workable and that the loss of water in the drying operation takes place more gradually because of the very extensive capillary system. Also we find that there is greater likelihood of cracking and a greater shrinkage.

Excessive drying shrinkage is objectionable in ball clays, since it is apt to be accompanied by a greater tendency to warping and cracking. Further, the plaster molds used in the potteries are made with an allowance for a certain shrinkage. Any variations in the pottery mixtures due to changes in the character of the materials will

[1]Transactions Am. Ceramic Society, XIX, p. 626.

necessitate discarding old molds and replacement with new, which is a costly matter.

The linear drying shrinkages of some typical ball clays are as follows:

Tennessee Ball Clay No. 3, Whitlock, Tenn.	5.5%
Kentucky Ball clay	6.0%
Kentucky Ball clay	7.3%
English Ball clay	5.5 to 6.0%

FINENESS.

Reference has already been made to the varying degrees of fineness of the particles of a clay mass. It is easily possible to separate those of the larger sizes by means of sieves. The smaller particles may be separated by some method of elutriation; that is, the sorting of the particles by means of a gently flowing current of water. By regulating the velocity of flow, these fine grains may be classified into several groups, according to their diameters. The following table[1] shows the results which have been obtained in the examination of some ball clays by this method:

Per Cent of Residue.

	Separated by Sieves. Coarser than 120 mesh	Separated by Elutriation Average Diameter of Particles 0.0577 mm. (0.0022 in.)	0.0354 mm. (0.00139 in.)	0.0167 mm. (0.0006 in.)
Tennessee Ball Clay No. 3	None	0.02	0.24	0.43
Pikes (English) Ball Clay No. 20	None	......	......	......

Smaller than 0.005 mm. (0.000196 in.):

Tennessee Ball Clay No. 3	99.31
Pikes (English) Ball Clay No. 20	99.00

The exceedingly high percentage content of fine particles is characteristic of very plastic clays, and has a direct relationship to their working properties. The finest portion, that is, those particles having diameters of 0.000196 inch and less, contains the clay suspensoids or colloids which are responsible for the plasticity. The greater part of this fine material consists of granular matter, while the colloids are really only a very small amount. A high content of the so-called clay substance is sometimes accompanied by an excessive degree of plasticity which renders a clay sticky and difficult to work. Other

[1]Bureau of Standards, Technologic Paper No. 1, p. 24.

very important factors in plasticity are the amount, size, relative proportion of sizes, shape and character of the granular material and the amount and character of the soluble salts, *i. e.*, electrolytes present.

Our interest in the fineness of grain of a clay is not limited solely to its relation to the property of plasticity, but extends to other properties, namely, drying conduct, drying shrinkage, warping, tensile or transverse strength and bonding strength.

The processes of drying and shrinkage have already been described. For the reasons which were therein stated, namely, the retention of the water of plasticity in the capillaries and by the spongy collodial material, it becomes evident that the nature and extent of these two factors must have a profound influence upon the drying operation. We may say that the greater the proportion of the fine material the slower the rate of drying, the greater the shrinkage and the greater the tendency to cracking during this stage of the operation. It is the usual practice to mix these clays with coarser materials which overcome these difficulties.

The examination of some standard foreign clays formerly used almost exclusively in this country by crucible manufacturers shows the following content of particles smaller than 0.01 mm. or 0.00039 in diameter.[1]

	Finer Than 0.00039 in Diameter
Gross Almerode clay	61.2%
Klingenberg clay	54.6%
Kaschkau clay	61.3%
St. Loupe clay	86.1%
Breitscheid clay	90.8%

Mere fineness, however, does not determine the relative plasticity of a clay, although there is undoubtedly a close relationship.

TRANSVERSE STRENGTH.

A high degree of plasticity and high strength of the burned clay are usually associated, hence we find the ball and bond clays show high strength tests. This is measured by determining the force required to break a bar of dried clay by supporting it at both ends and applying the load at the center.

[1]Bureau of Standards, Technologic Paper No. 79, p. 22.

BONDING STRENGTH.

Owing to the tendency of very plastic clays to check and air crack in drying a trial piece may be weakened and give too low a test. To obviate this difficulty and to measure the bonding power of a clay it is the practice to make a mixture of equal parts of clay and sand of a standard size and to test it by the same method as employed for the transverse test.

The following table[1] gives a comparison of some foreign and domestic ball and bond clays:

Modulus of Rupture per Square Inch.

	Without Sand	With Sand
English Ball Clay	376	323
English Ball Clay	366	389
Klingenberg A. T.	345	381
Kentucky Ball Clay	239	234
Kentucky Ball Clay	359	362
Tennessee Ball Clay	187	199
Tennessee Ball Clay	326	228
Tennessee Ball Clay	387	282
Southern Illinois	338	262
Northern Illinois	442	240
Mississippi	645	326

$$\text{Modulus of Rupture} = \frac{3\ Pl}{2\ bd^2}$$

P = weight required to break the piece. l = length of piece between supports. b = breadth of test piece. d = depth of piece.

In general we may state that the ball clays range between 150 and 500 pounds per square inch modulus of rupture. The tensile strength test varies between 125 and 250 pounds per square inch.

The bond clays have been classified by the Bureau of Standards[2] in two groups as follows: Group A, those which show a bonding strength of 325 pounds per square inch or more; and group B, those which have a modulus of rupture between 225 and 325 pounds per square inch.

The practical value of this test is found in the fact that the mixtures used by the potter, crucible and glass pot makers contain from

[1]Transactions of the American Ceramic Society, XIX, p. 626.

[2]Transactions American Ceramic Society, XIX, p. 605.

40 to 70 per cent nonplastic material and a large part of the clay content may be of a sort, for important reasons, which is relatively low in strength. Therefore, it becomes necessary for the user to select the ball or bond clays which will give the maximum strength with the quantity which it is permissible to use.

SLAKING TEST.

This test, which is made as described on a previous page, has been proposed as useful for distinguishing between clays of high and low bonding strength. The strong clays require a longer time for disintegration.

EFFECT OF HEAT.

In considering the changes brought about in a clay by heat, we have the following items of particular interest to consider: The color changes, the shrinkages, the rate of vitrification, the heat range and the fusibility. The relative importance of these varies according to the character and the possible usefulness of the clay.

COLOR.

For the potter, the color of the burned clay is an item of much importance. Other things being equal, he will select for use those clays which, when burned, are the most nearly white in color. Ball clays do not burn white at the temperatures commonly used, but vary in shades of cream. Many of our domestic ball clays from Tennessee and Kentucky are superior to the English in this respect. Color cannot be the only criterion of these clays since their plasticity, etc., are of equally great importance.

Color is not an item of importance in the consideration of the plastic bond clays used in the manufacture of crucibles, glass pots, etc.

PROCESS OF VITRIFICATION.

When clays of any kind are burned, we find that two of the important phenomena are a decrease in the linear and the volume dimensions and an accompanying decrease of the pore space of the material as the temperature is raised providing that we do not pass certain temperature limits. The changes of porosity which the clays pass through are so characteristic and well defined that we may use this data as a means of classification of clays for different uses, providing that other essential properties are present.

Clays may be roughly classified as refractory and nonrefractory, depending upon whether they fuse or do not fuse at a temperature of about 2,975° F.

The glass pot and crucible clays must be refractory, while the ball clays may or may not be, but both kinds of clay must burn dense, *i. e.*, have little or no porosity at a temperature not higher than 2,300° F.

The practical importance of this lies in the fact that the potter uses ball clay not only for its plasticity and strength but also for the greater strength and denser structure which it imparts to the ware. Density at a low temperature is a necessary property of refractory bond clays, since thereby the wares become more resistant to the corrosive action of glass and molten metal.

An essential difference between domestic and English ball clays is shown in the following table[1] namely, the fact that the English ball clays burn dense or to a low porosity at a lower temperature than the American clays.

Percentage Porosity at Temperature.

	2,010°	2,100°	2,190°	2,300°
English Ball clay	1.99	0.19	0.68	0.5
English Ball clay	3.4	1.28	0.90	0.9
Tennessee Ball clay	27.5	19.1	8.1	0.7
Tennessee Ball clay	22.3	16.4	8.4	2.4
Tennessee Ball clay	20.7	13.9	3.7	2.3
Kentucky Ball clay	19.0	12.7	1.3	1.3

The decrease in porosity which accompanies an increasing temperature is due chiefly to the influence of the fluxes, such as soda, potash, lime, magnesia and iron. These are present in mineral combinations of various sorts which soften as the temperature rises and bind the more refractory particles in a matrix. This softening of the mass results in a gradual closing of the pores, and when the mass has little or no porosity, it is vitrified. The term vitrified, as used, does not mean that the mass becomes glassy.

The rate at which vitrification proceeds may be learned by determining the changes in porosity at various temperatures.

[1]Trans. Am. Cer. Soc., XIX, p. 628.

Fusion occurs when the quantity of softened material becomes so great that the mass is unable to retain its shape and deforms.

Before that stage is reached the clay passes through a distinct period known as over-burning. This is always shown by the development of a vesicular or sponge-like structure which is indicated by a progressive increase of porosity after passing the minimum point as the temperature steadily increases. The most desirable clays are those which maintain the minimum porosity throughout a wide range of temperature. The vesicular structure indicates a softening of the mass which will be accompanied by a bloating and swelling of the clay and its subsequent collapse. Moreover, the development of the vesicular structure will expose the ware made from the clay to the destructive action of glasses or slags which may be in contact with it.

However, such clays as do not overburn too seriously may be successfully used in mixtures with more refractory clays, and, as is commonly the practice, with coarse-grained calcined refractory clay. This coarse refractory material serves as a skeleton which is bonded by the more fusible clay and permits the gases formed by the fusion to escape, thus reducing or preventing a vesicular structure.

SHRINKAGE.

During the progress of burning the clay test pieces decrease in size due to many chemical and physical changes taking place, such as the decrease in porosity, etc. Naturally the shrinkage varies with the temperature.

A typical ball clay from Tennessee shows the following shrinkages:

1,922° F.	2.5%
2,057° F.	6.65%
2,192° F.	9.75%
2,408° F.	13.50%

FUSION OR DEFORMATION POINT.

This is the approximate temperature at which a test piece of a certain size and shape will soften enough to permit the tip of the piece to bend over and touch the base. The rate of heating and the rate at which the deformation take place are important factors. The temperatures are commonly measured by means of pyrometric cones which are widely known as Seger cones. The highest type of fire clay deforms at cone 35, which corresponds to approximately 3,191° F., and cone 28, or approximately 2,975° F., corresponds to the lowest temperature a clay may deform and be regarded as a good fire clay.

The fusion test is not of importance in the examination of a ball clay for potter's use, but clays which are to be used in the preparation of crucibles, glass pots, etc., should not soften below cone 30 or approximately 3,038° F.[1]

[1]Trans. Am. Cer. Soc., XIX, p. 606.